

Departamento de Biología Facultad de Ciencias del Mar y Ambientales Universidad de Cádiz

INTEGRATED ASSESSMENT FOR DECISION AND MANAGEMENT SUPPORT WITHIN THE BAHÍA DE CÁDIZ NATURE PARK (SPAIN)

UNA EVALUACIÓN INTEGRADA PARA EL APOYO DE LA TOMA DE DECISION Y EL MANEJO DEL PARQUE NATURAL DE LA BAHÍA DE CÁDIZ (ESPAÑA)

> Sarah Camilleri Cadiz, 2015

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HACEN CONSTAR:

Que esta Memoria, titulada "INTEGRATED ASSESSEMENT FOR DECISION AND MANAGEMENT SUPPORT WITHIN THE BAHÍA DE CÁDIZ NATURE PARK (SPAIN)" presentada por D^a. Sarah Camilleri, resume su trabajo de Tesis Doctoral y, considerando que reúne todos los requisitos legales, autorizan su presentación y defensa para optar al grado de Doctor en Gestión Marina y Costera/Marine and Coastal Management.

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The trees that are slow to grow, bear the best fruit

- Moliere

If it is right, it happens —The main thing is not to hurry. Nothing good gets away.

- John Steinbeck



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Extended Abstract

Tanto los enfoques del pensamiento sistémico como de la investigación integrada son ampliamente aplicados dentro de la gestión ambiental, como métodos que facilitan la organización y la utilización de información proveniente desde diferentes niveles de gobernanza y desde diferentes fuentes científicas. En este estudio estos enfoques se aplican para estudiar el Parque Natural de la Bahía de Cádiz tanto desde un punto de vista general, así como para una exploración detallada de cuestiones específicas. Esta zona protegida se caracteriza por extensas áreas de fangos intermareales y por la marisma supralittoral principalmente compuesta de ambientes artificiales destinados a la producción de sal y la acuicultura. A pesar de su carácter artificial, estos hábitats son ecosistemas ricos en biodiversidad y se conforman como importantes áreas de acogida de poblaciones de aves acuáticas invernantes.

La primera parte de este estudio consta de: (1) una revisión de los instrumentos políticos, legales y de gestión relevantes a la área de estudio y (2) la identificación de los elementos sociales y naturales que caracterizan a la Bahía de Cádiz. El segundo objetivo se cumple por medio de la aplicación del marco conceptual DPSIR (Drivers-Pressures-States-Impacts-Responses). Este marco pretende organizar varios elementos socio-naturales bajo las categorías de Conductores, Presiones, Estados, Impactos y Respuestas.

Los resultados incluyen un primer mapa conceptual que ofrece una visión más amplia del parque, incorporando además elementos que actúan desde fuera de sus fronteras geográficas. Para ello y mediante una consulta con expertos, se destacan en este mapa los elementos que mejor definen los funciones sociales-ambientales y las tendencias más significativas que marcan el área de estudio. Así se destacan los temas prioritarios para la mejora de la gestión del parque. Estos incluyen (i) la definición del estado de conservación actual del parque con respecto a cambios en la legislación, como es el caso del la Ley 2/2013 (anteriormente conocida como la Ley de Costas) (ii) la promoción del desarrollo sostenible, con respecto a los sectores establecidos en el área del parque (i) la conservación de la integridad ecológica del parque (iii) la promoción de la cultura, del uso y la participación del público y (iv) la conservación del sistema hidrológico y de la calidad del agua.

Posteriormente se diseñó un segundo mapa conceptual con objeto de ilustrar con mayor detalle, un tema más específico: conocer cómo los sectores de la sal y de la acuicultura dieron lugar a presiones, definidas en este estudio como cambios de cobertura y de uso del suelo, los cuales a su vez impactan en la integridad ecológica del parque.

Las 'Respuestas' se discuten por separado, a través de una revisión de las recientes acciones que se han originado a varios niveles y las propuestas más recientes de gestión por parte de la administración del parque, para tratar diversos temas que afectan a la zona.

El marco DPSIR resulta ser adecuado para la identificación de elementos tanto relativos a las dimensiones sociales como a las ambientales, aunque se excluyen elementos que operan a una escala más global (presiones como el calentamiento global). Por tanto, el marco espera servir como herramienta de apoyo en todas las futuras iniciativas de investigación y gestión integrada relacionadas con esta zona.

A continuación, el estudio se centra en un enfoque más específico, analizando con métodos cuantitativos, como los cambios del paisaje conectados con la evolución de las industrias extractivas, han influido en la biodiversidad del parque.

En el segundo trabajo presentado en esta tesis se combinan los métodos de teledetección, técnicas de SIG y otros datos auxiliares, con el objetivo de producir un marco metodológico para el seguimiento de los cambios del paisaje. Mediante la aplicación de imágenes de satélite LANDSAT, las áreas de marisma natural y artificial se clasifican de forma independiente y mediante la fusión de los resultados se crean mapas de cobertura del suelo para los años 1985, 2000 y 2011. A continuación, en SIG se superpone, sobre estos mapas, las capas con datos del uso del suelo, generando así, mapas integrados de cobertura y uso, permitiendo considerar de forma simultánea los dos tipos de datos.

Los cambios observados en las áreas naturales son sutiles. Además, debido a que estas zonas son más susceptibles a la variabilidad de factores ambientales, como es el caso de la fluctuación mareal, estos cambios deberían ser estudiados durante espacios

temporales más amplios. Sin embargo, los cambios de cobertura observados en la marisma artificial son notables. Estos incluyen un aumento de 800 ha de área inundada en la zona norte del parque, vinculado a la expansión de la industria salinera. Por otro lado cabe destacar la tendencia de revegetación en otras zonas cubriendo una área superior a 2000 ha. Se observa que estos procesos de sucesión de la vegetación son características de aquellas zonas abandonas y sin uso. Esta proliferación de vegetación densa también se encuentra en aquellas zonas de acuicultura extensiva donde el mantenimiento de las fincas no siempre es continuado en el tiempo.

La metodología desarrollada es aplicable en el seguimiento de los cambios de cobertura y uso de la zona. Así mismo se considera de suma utilidad para el apoyo en la toma de decisiones relacionadas con las tareas de conservación, restauración y la gestión de los sectores extractivos presentes en el parque. Además el método es aplicable y extrapolable a otras zonas con características similares, ofreciendo opciones de monitorización rápidas, económicas y de gran apoyo al trabajo de campo convencional. Se considera especialmente relevante para áreas de marisma donde predomine el carácter artificial. Además la base de datos digitales producida es flexible y adaptable a la integración de ulteriores capas de información procedentes de la investigación en ciencias naturales y sociales Finalmente este estudio propone una investigación más detallada de las tendencias de factores abióticos y bióticos que acompañan a los cambios de paisaje, así como sus efectos sobre los diferentes servicios que ofrece el Parque Natural de la Bahía de Cádiz.

A continuación el estudio evalúa el impacto de los procesos paisajísticos identificados sobre las poblaciones invernantes de aves acuáticas, los cuales se consideran excelentes indicadores de la calidad ambiental de la marisma. Todo ello se conforma como el objetivó general del tercer trabajo presentado en esta tesis.

Inicialmente se revisa la relevancia internacional del parque como hábitat de aves acuáticas según los criterios del convenio Ramsar. Después, para las poblaciones de un grupo de especies indicadoras, se analizan las tendencias temporales desde el 1985 hasta el 2015. Estas tendencias locales se comparan con las tendencias poblacionales a escala nacional y global, para así discernir entre cambios localmente inducidos y otros procedentes de procesos a otras escalas. Posteriormente y a través de la aplicación de métodos de análisis multivariante, se analizan las relaciones entre los cambios del

paisaje anteriormente identificados y los cambios de distribución de las especies seleccionadas.

Los resultados confirman el papel crucial de los humedales artificiales como zona de acogida para las poblaciones invernantes de aves acuáticas cumpliendo los requisitos de zona Ramsar: de hecho la Bahía de Cádiz mantiene poblaciones demás de 20.000 aves de forma constante y numerosas especies superan al 1% de su población global.

Por otro lado, los resultados producidos en este estudio revelan como los cambios en la estructura de la comunidad de aves acuáticas se relacionan con la evolución de los sectores extractivos y las alteraciones del paisaje observadas. Esto incluye un importante descenso de las poblaciones de aves ictiófagas asociadas al receso de la industria de la acuicultura. También se observan disminuciones importantes del chorlitejo patinegro (*Charadrius alexandrinus*) y del correlimos menudo (*Calidris minuta*). El declive de las poblaciones de estas especies de limícolas se asocia a la degradación de zonas supralitorales, con pérdida de comederos y dormideros. Los resultados muestran además una mayor sensibilidad de estas dos especies a los cambios del paisaje en comparación con otras especies de aves.

El estudio de los cambios espacio-temporales revela un mayor uso de las zonas del parque por las especies estudiadas, durante el periodo entre 2000 y 2004, el cual también se caracteriza por un mayor uso extractivo. Esta observación se complementa con un aumento significativo en la diversidad durante este periodo.

Además, las áreas de mayor riqueza y densidad de aves se corresponden con zonas caracterizadas por cuerpos de agua de amplia extensión y con profundidades de 0-50 cm. Estas incluyen tanto zonas de salinas industriales como zonas restauradas y manejadas. Otras áreas con valores significativamente elevados de riqueza y densidad de aves, lo conforman el binomio de zonas intermareales junto a zonas supralitorales cercanas. Por eso se aconseja que se tomen medidas de conservación específicas para estos tipos de áreas. Por ejemplo, dentro de las fincas salineras, de diciembre a marzo los niveles de agua se pueden gestionar para mejorar la disponibilidad de recursos tróficos para las aves acuáticas. Estas acciones no entran en conflicto con las labores salineras ya que la preparación de la finca para la producción de sal no comienza hasta abril / mayo. Además se propone el restablecimiento de fincas salineras artesanales o de

acuicultura extensiva en zonas próximas a los fangos intermareales. Esta medida puede mejorar la disponibilidad de comederos y dormideros durante las mareas altas, a bajos costes energéticos y con bajos riesgos de depredación. Por la misma razón se sugiere la organización temporal y espacial de los despesques en fincas de acuicultura extensiva, permitiendo una continua disponibilidad de sustratos ricos en macroinvertebrados, de alto valor alimenticio para las aves.

Finalmente, se detectan bajos valores de riqueza y abundancia de aves en zonas supralitorales de interior que, por la falta de actividad y de mantenimiento, han sido densamente vegetadas. Debido a que el restablecimiento de la actividad extractiva aquí se considera económicamente inviable, se recomienda que estas áreas se evalúen en términos de otros servicios que pueden ofrecer como: la educación ambiental, el ecoturismo, la investigación, la protección que ofrecen a la franja costera de inundaciones mareales y la regulación de la calidad del agua.

Claramente, todas estas consideraciones se deben tomar como un componente más dentro de la estrategia global de la conservación del parque teniendo en cuenta otras prioridades y factores de valor, tanto desde el ámbito ambiental como social.

Chapter 1.
Justification & Scope

1.1. Theme of the study

The study explores the use of an integrated research approach for management support of a protected coastal zone consisting of natural and artificial wetlands and holding international importance for hosting significant populations of migratory waterbird species.

Throughout the various research stages, this approach is applied at multiple scopes. It is first used to gain an overall understanding of the case study through the identification of priority issues and characteristic natural and social elements. Later, the integrated approach is applied to answer specific research questions concerning the protected area. Such questions concern the effects of sector-driven land-use and land-cover changes on the populations of prioritized migratory waterbirds, these being amongst the park's key biodiversity indicators.

1.2. Relevance to marine and coastal management

Due to their numerous and advantageous values and services, coastal zones worldwide have become a primary habitat for humans, so much that this has attracted approximately half of the global human population to inhabit the 100 km wide strip that make up the world's coasts. With demographic estimates indicating that the world's human population shall rise from 5.8 to 9.3 billion by 2050, populations in coastal regions are also predicted to follow this growth (Olsen 2000). Consequently, the degradation evident in coastal and marine ecosystems, including loss of habitats and associated biodiversity, contamination effecting the quality of coastal waters, sea-level rise, coastal erosion and more (European Environment Agency 2006), should also be expected to rise in parallel.

This increasingly complex scenario, has given rise to regulation frameworks as is the Integrated Coastal Zone Management (ICZM) approach. Such an approach is reflected in the shift from a sectorial to a multi-sectorial structure of coastal governance worldwide. Born around two decades ago and ever since evolved and adapted in various manners to fit specific objectives, this approach sets the idea of integration as the foundation for the desired coastal management (Portman et al. 2012). The integration concept is multi-dimensional (Figure 1) implying one or several of the following: (1) spatial integration across both horizontal and vertical geographical gradients (2)

temporal integration at appropriate scales (days, seasons, decades and more) (3) horizontal integration among different use sectors and vertical integration among different levels of government (4) trans-disciplinary integration considering both natural and social sciences (5) integration between short- and long-term actions and planning (Garra and Losada 2010).

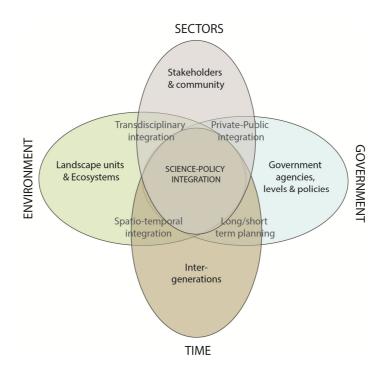


Figure 1 The multiple integration levels to be considered in ICZM as adapted from Portman et al. (2012)

The case presented in this study concerns a coastal region where a 3000 year old interaction between man and his natural environment exists. The outcome of this ancient interaction is a mixed natural and artificial environment which, in spite of its altered state, continues to provide numerous key ecosystem services. These characteristics provide a complex system through which the integration concept and associated tools and methods can be applied at multiple levels. Such tools/methods include conceptual frameworks that provide the organizational backbone required within decision making processes (Brouwer et al. 2003), spatial analysis tools including remote sensing applications and GIS (Geographic Information System) and multivariate statistical analyses.

Following this approach, research findings aim at providing solid advice to be considered within future management actions concerning the area. Further the study is a positive contribution towards the management of similar coastal zones, as well as to

the overall development of the coastal/marine integrated research field.

1.3. Scope of the study

The study area (Figure 2) comprises of the 10, 522 ha encompassed by the Bahía de Cádiz Nature Park, declared a protected area at a national level since 1989 (Junta de Andalucia 2004). It is situated on the south western Atlantic coast of Spain, within the province of Cádiz, between 36° 22' to 36° 37' N and 5° 7' to 6° 16' W (Ramsar Convention Secretariat 2012a). This is a region characterized by a bi-seasonal climatic pattern made up of hot and dry summers and cool and mildly wet winters, with an annual mean temperature of 17.8 °C and mean rainfall of 650 mm. In addition, strong winds and a semi-diurnal tide with a range of 3-4 m are important influences (Lobo et al. 2000).

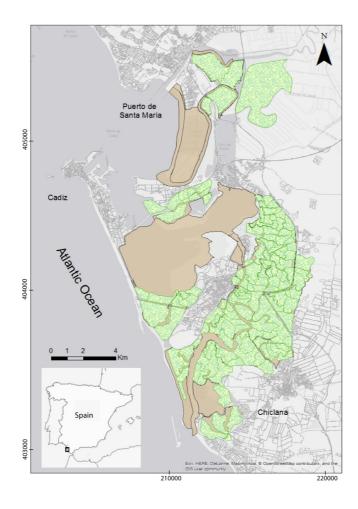


Figure 2 Location and geographical composition of the Bahía de Cádiz Nature Park. Artificial marsh areas (green) and natural marsh areas (brown) are distinguished.

Whilst different ecosystems are present, including sandy beaches, dunes, lagoons and rocky islets, the habitats that best characterize the park are the extensive intertidal sand and mudflats and its supralittoral salt marshes¹. Interestingly, a large proportion of the supralittoral marshes comprise of human-made or artificial marsh i.e. natural marsh transformed to accommodate extractive activities (Figure 2) (Ramsar Convention Secretariat 2012b). This artificial marsh is estimated to make up approximately 60% of the total park area.

Widespread alteration took place in the late 1800s when much of the marshland that nowadays comprises the park territory was transformed into artisanal salt extraction plants (*salinas*²) to accommodate the rapid growth of the sector. As this sector gradually lost its economic viability, further changes followed. Commonly these salinas were adapted into deeper and larger ponds for extensive polyculture (non-selective aquaculture) which takes advantage of fry carried inward by incoming tides. Further, between the late 1900s and the early 2000s, a number of structures suffered stronger transformations accommodating semi-intensive aquaculture and industrial scale salinas. Additionally, following the various crises experienced by these sectors, in a considerable number of salinas all extractive activity was abandoned resulting in structural degradation (Yufera & Arias 2010). Figure 3 depicts the different landscape characteristics linked to these different land-use cases.

Vegetation communities vary along the different marsh types with aquatic vegetation including algas (*Ulva lactuca*, *Enteromorpha linza*, *Codium tomentosum*) and marine spermatophytes (*Cymodocea nodosa*, *Zostera noltii*) inhabiting the mudflats; halophytic species as *Spartina maritima* and *Salicornia ramosissima* characterizing the low marsh areas; *Sarcocornia fruticosa*, *Suaeda vera* and *Halimione portulacoides* being present in low/high marsh transitional zones; and *Sarcocornia perennis*, *Limoniastrum monopetalum* and *Arthrocnemum macrostachyum* inhabiting the higher elevation marsh (Junta de Andalucia 2004).

¹ Both intertidal flats and salt marshes are subclasses of the Marine/Coastal Wetlands class within the Ramsar Classification System for Wetland Types (Ramsar Convention Secretariat 2012)

² A typical artisanal salina consists of a 1.5m deep reservoir pond directly filled by incoming sea-water, and a series of interconnected ponds and channels of a progressively shallow depth, through which seawater flows and evaporates leading to the formation of salt crystals in the final crystallization ponds (Yufera & Arias 2010).

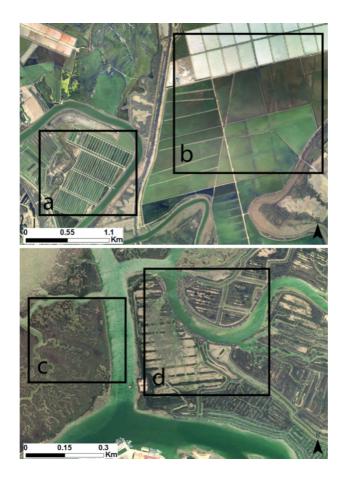


Figure 3 Snapshots of a 2011 aerial orthophoto of the study area demonstrating the different landscape characteristics of (a) semi-intensive aquaculture (b) industrial salt extraction (c) natural low marsh and (d) abandoned salt extraction plants taken over by tidal flooding and succession processes

Although the artificial marsh is built from the same marsh substrate, with the potential of accommodating similar marsh ecosystems, controlled water flow and evaporation processes result in high salinities, consequently changing vegetation distribution and diversity. As in the natural marsh, different species distribute according to their preferred environmental conditions, some species colonizing areas with occasional submergence whilst others preferring drier conditions therefore growing on walls. Vegetation cover also varies according to the intensity of use and maintenance within an installation, tending to be scarce in installations accommodating more rigorous activities. As for inactive salinas, lack of maintenance usually leads to their walls breaking at various points, exposing them to tidal flows and leading to diverse situations ranging from complete flooding, to permanent dryness or to sediment

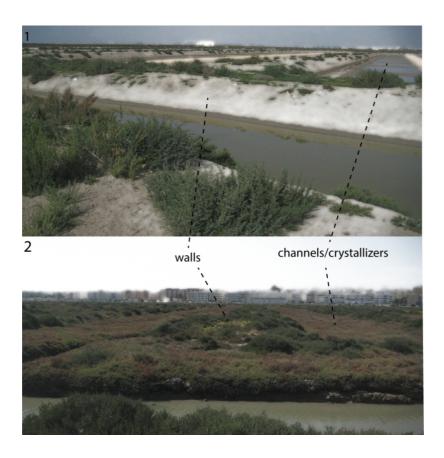


Figure 4 Photos of different salina plots within the park. Photo nr.1 captures the water-filled compartments and fairly vegetated walls of the restored artisanal salina named La Esperanza. Photo nr.2 captures an abandoned salina plot of which both wall and channel areas have been revegetated through succession processes.

accretion and vegetative secondary succession³ (Figure 3d and Figure 4) (Clares Sánchez 2004).

Both natural and artificial habitats are also home to a rich faunal biodiversity. This includes numerous macroinvertabrates including annellids (*Nereis diversicolor*), molluscs (*Cerastoderma edule*, *Hydrobia ulvae*), crustaceans (*Artemia salina*, *Carcinus maenas*), insects (Chironomidae, Ephydridae and Coleoptera) (Arias and Drake 1994) and numerous fish species including *Sparus aurata*, *Liza aurata* and *Dicentrarchus labrax* (Drake and Arias 1991). Most importantly, the park provides important resting, feeding and reproduction grounds for thousands of migrating waterbirds from over 50

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³Secondary succession refers to vegetation colonization processes occurring over barren surfaces which are however sufficiently stable and contain nitrogen, phosphorus and a seed bank from communities that previously occupied the same substrate.

different species, the most numerous being waders (Charadriidae and Scolopacidae) and gulls (Laridae). The presence of these populations has earned the park protection at various levels: it is a designated Special Protection Area as under the European Birds Directive 2009/147/EC. Further, in 2002 the area was declared a Ramsar Site, and hence a Wetland of International Importance, for hosting important numbers of various waterbird species (Junta de Andalucia 2004).

As with vegetation communities, faunal biodiversity is also influenced by the different abiotic conditions present within the numerous artificial marsh scenarios described. Case in point are the spatial and temporal variations in macroinvertebrate populations according to the use, use intensity and the geographical situation attributed to a salina. Macroinvertebrate biomass is found to be superior in extensive aquaculture pools with managed water levels and water/sediment quality in comparison to neglected ponds or intensive aquaculture ponds which are subject to rigorous benthonic cleaning procedures following the end of every fish producing cycle. Also species diversity is found to drop with increasing distance of a salina plot from the tide influenced area. Furthermore, within the two different aquaculture systems the annual variability in fish predator intensity and environmental conditions result in temporal variability in macroinvertebrate populations (Arias Garcia & Drake Moyano 2004). Intensive aquaculture systems are also impoverished in terms of fish species richness, these housing monocultures of sea bream (Sparus aurata) in contrast to the polyculture systems housed by extensive systems (Yufera & Arias 2010). As secondary consumers further up the food chain, waterbirds' abundances and distributions are also influenced by the landscape's abiotic and biotic variability (GEAM 1997; Masero, Perez-Hurtado et al. 2000; Muñoz Arroyo 2004; Pérez-Hurtado 1992).

1.4. Hypothesis and research objectives

Overall hypothesis. An integrated research approach can support the selection of multiple indicators for the analysis of landscape and biodiversity spatio-temporal trends characterizing the Bahía de Cádiz Nature Park, providing adequate data in support of the park's management.

Following, are the specific hypothesis and research objectives linked to the different stages of the study:

<u>Hypothesis 1.</u> An integrated research framework is appropriate for initially scoping the cause-effect relationships underlying the park's priority management issues.

In response to this hypothesis the following objectives were accomplished:

- the identification of political and legislative frameworks, and priority management issues, relative to the study area
- the adaptation of the DPSIR (Driver-Pressure-State-Impact-Response) framework for the scoping of socio-environmental elements operating within the system at overall and specific levels.

<u>Hypothesis 2.</u> Sector developments within the park's geographical boundaries have caused important land-use and land-cover changes (LUCCs) over the past 25 years.

In response to this hypothesis the following objectives were accomplished:

- the analysis of satellite imagery spanning the 1985-2011 period, for the identification of land-cover changes
- the integration of land-cover and land-use data using a GIS work-space
- the development of a methodological framework for continued monitoring of LUCCs within the study area.

<u>Hypothesis 3.</u> Migratory waterbird populations have undergone size and distribution changes as a result of the landscape change dynamics that have taken place within the study area in the past 25 years.

In response to this hypothesis the following objectives were accomplished:

- the area's international importance as waterbird habitat was revised
- long-term wintering waterbird population trends were analyzed against trends at other geographical scales
- spatio-temporal tendencies of the wintering waterbird populations were studied in relation to landscape changes.

Results and conclusions extracted through the accomplishment of these objectives, were intended for supporting management and decision-making within the Bahía de Cádiz Nature Park.

1.5. Thesis structure

This thesis is structured into the following chapters:

This first and current chapter serves as an initial introduction to the study, its relevance to marine and coastal management, the study area, and both general and specific hypothesis and research objectives.

The second chapter includes a review of the state-of-the-art research relevant to the different research stages. This covers the integrated research approach as the underlying concept of this study. Further the specific methodologies applied throughout the study are reviewed, mainly: the DPSIR framework as a scoping tool of priority issues and characterizing elements tied to the study area; land-cover and land-use analysis through the use of remote sensing and GIS technologies and the use of waterbird populations as indicators of landscape changes for evaluating environmental quality.

The third chapter includes results that answer the research questions and objectives relative to Hypothesis 1. These results are documented within an article entitled Multiple D-P-S-I frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain). This article has been published within the Journal of Coastal Conservation: Planning and Management under the Special issue project entitled 'Lessons learned to address new challenges in coastal conservation, planning and management'.

The fourth chapter includes results that answer the research questions and objectives related to Hypothesis 2. These results are documented within an article entitled *Landuse and land-cover change analysis in predominantly artificial coastal wetlands:* proposing a methodological framework. The article was submitted to Wetlands Ecology and Management on the 5th of September 2015.

The fifth chapter includes results that answer the research questions and objectives related to Hypothesis 3. These results are documented within an article entitled Evaluating the influence of land-use changes on waterbird populations in artificial wetlands. The article is intended to be submitted shortly.

The sixth chapter includes a collection of all conclusions and recommendations formulated from each stage of the study. These recommendations are directed towards the study area's administrative body, involved stakeholders and to all future research initiatives. Further, numerous recommendations are transferrable towards other case-studies with similar issues.

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Chapter 2. Introduction

2.1. Fundamental considerations of the integrated research approach

Whilst the discussion of the system approach or the system theory is an old one, its philosophical roots dating back to 1770, its acceptance as a model for organization and management has only occurred over the last 50 years. Over this time, the idea of the system as being an integrated whole composed of interrelated parts or elements, and the resulting development of systems thinking, have become increasingly applicable within all natural and social scientific fields requiring synthesis and analysis of complexity. Whilst this approach is no guarantee for easy solutions, it successfully facilitates comprehension and appropriate action (Guberman 2004; Kast & Rosenzweig 1981).

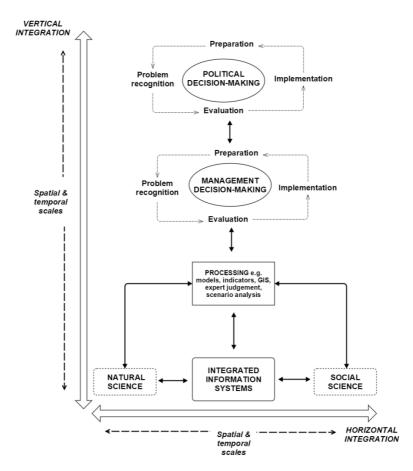


Figure 1 The integrated approach for decision support as adapted from Brouwer et al.(2003). The arrows within the flow-chart illustrate the movement of data/knowledge between science and decision-making at different levels. Arrows outside the flow-chart indicate the directions of vertical and horizontal integration and the consideration of spatial and temporal scales

System thinking has also come to be the basis of all integrated research, this consisting of an interdisciplinary approach, based on drawing knowledge from different fields and sciences, with the aim of providing decision-makers with a more complete

vision of the issue being handled. Brouwer et al. (2003) propose a straightforward framework (Figure 1) describing the components and processes that make up integrated research

Integrated research is also widely advocated in environmental, water and coastal management. At the base of all integrated research frameworks applied within these fields is a common notion of considering information coming from both natural and social scientific fields. With respect to wetland management Brouwer et al. (2003) point out at three levels of integration to be considered: the integration of ecological components, the integration of biogeochemical and physical components and the integration of socio-economic and socio-cultural component. The simultaneous consideration of environmental and social factors is also central within the Millennium Ecosystem Assessment, through its ecosystem services notion - these being the benefits that people obtain from ecosystems including provisioning (e.g. food and water supply), regulating (e.g. climate regulation), cultural (e.g. aesthetic and recreational qualities) and supporting (e.g. primary production) services (Millenium Ecosystem Assessment 2005). Further the European Water Framework Directive (2006/60/EC), aimed at protecting different water body types including coastal waters and wetland systems, also promotes the integration of various disciplines (hydrology, soil science, economics), as well as information on water uses and values for human populations (European Commission 2003).

Besides the horizontal integration across diverse disciplines, the vertical information supply across the various levels of management or political decision-making (local, regional, national and global) is fundamental (Figure 1). This course opens up possibilities of collaborative processes favouring communication between scientists, users, stakeholders and decision-makers, and consequently increases the success rate of objectives (Brouwer et al. 2003; Tscherning et al. 2012).

Finally, as indicated in Figure 1, scaling issues are important considerations within both directions of integration. Appropriate temporal and spatial scales should be identified prior to data collection such that these can correctly reflect the phenomenon being analysed (European Commission 2003): for example impacts as sea-level rise can only manifest themselves through the study of long-term data built from yearly recordings. Scales are also important within research-policy or management-policy integration. Few et al. (2004) draws attention to the discontinuity of the long-term national coastal strategies onto local-based action, pointing out spatial mismatch

between national shoreline protection plans, that are fixed to the shoreline area, and actual local requirements that may involve land-use or settlement pattern changes further inland beyond this line.

2.1.1 The DPSIR framework as an integrated assessment support-tool

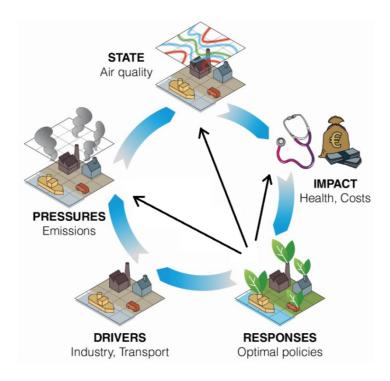


Figure 2 The DPSIR framework in its original form as in Smeets & Weterings (1999)

The first stages of any integrated assessment start by scoping the existing situation of the case being studied, thereby diagnosing potential issues, and defining possible research/management issues and possible solutions (Brouwer et al. 2003). This process is frequently guided by the use of conceptual tools as is the DPSIR (Drivers, Pressures, State, Impact, Responses) framework (Figure 2), applied for the analysis of the causal links between social and natural elements characterizing the system/area/case-study being assessed. A technical report for the European Environmental Agency (EEA) by Smeets & Weterings (1999) documents one of the earliest adoptions of this framework for reporting on environmental issues. In this original form:

• *Drivers* include anthropogenic activities that influence the environment (e.g. industrial development)

- *Pressures* are the effects of the driver in the environment (e.g. increasing contaminating emissions)
- *State* refers to the environmental condition resulting from these changes (e.g. lowered air quality)
- *Impact* refers to the effect of the induced environmental state changes on human health, ecosystems or materials (e.g. lowered ecosystem heath, disease etc.)
- *Responses* refer to the measures taken to improve the environmental situation at stake (e.g. protection of green areas)

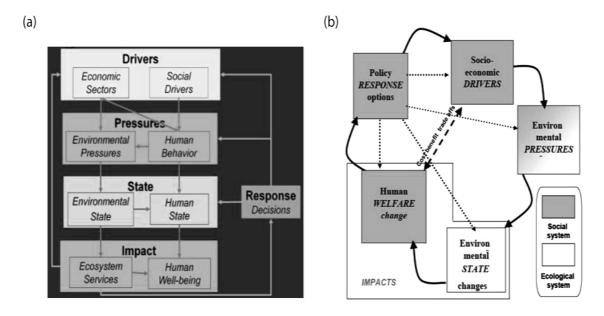


Figure 3 In the adaptations of the DPSIR framework in EPA (2012) and O' Higgins et al. (2011) the social component is emphasized. In (a) a parallel pathway is added to consider human health. In (b) the term *Impact* is replaced by *Welfare*, for a better distinction of environmental and social dimensions.

Despite its popularity, the framework has also been exposed to a fair share of criticism being described as an over-simplistic, linear representation of real situations in which issues tend to extend over multiple scales. For instance, in the study of local situations the framework might exclude issues of global importance as global warming or sea-level rise. These limitations have been met by a diversity of adaptations of the framework: in Ness et al. (2010) a multi-level DPSIR is used to represent the alternative approaches posed at different institutional levels when dealing with a unique issue. Further, in other studies the framework has been adapted to improve its consideration of the social dimension of the issues under study (Figure 3).

Finally, the framework's potential to solve 'real life issues' is found to improve through the integration of knowledge from its end-users, stakeholders and experts into the identification of cause-effect relationships, during its development stage. Its relevance is also found to improve when it is able to provide multiple decision options, rather than rigid conclusions (Tscherning et al. 2012).

Within this study the DPSIR framework was applied for a general overview of the actual socio-environmental context characterizing the study area, as well as for a more detailed investigation of the causal links underlying sector-driven landscape changes and the effects of these on inhabiting waterbird populations. The latter objective aimed at providing a contextual backbone for subsequent quantitative research with respect to these issues. These subsequent research stages are introduced in the following sections.

2.2. Wetland landscape change analysis through the application of remote sensing

Worldwide, wetlands under threat by land reclamation through draining and filling for agriculture or urbanization. This trend is especially accentuated in coastal zones with a long history of human occupation, as is the case of the Mediterranean Basin where approximately 50% of the natural wetland coverage is estimated to have been lost during the 20th century alone (Airoldi & Beck 2007; Perennou et al. 2012). Moreover global influences of change as is climate change and sea-level rise are set to exacerbate these tendencies: up to 20% of the global coastal wetland coverage is expected to disappear by 2080 as a result of sea-level rise alone, with greater losses expected where the inward regression of wetlands is impeded (Webb et al. 2013).

Frequently wetland landscape have also been modified for the establishment of long or short-term productivity systems including rice paddies, aquaculture ponds or salt extraction sites. These human-made habitats are recognized for maintaining a certain degree of wetland functionality and are therefore referred to as artificially-created wetlands (Ramsar Convention Secretariat 2010). As described previously, these habitats make up a great part of the Bahía de Cádiz Nature Park.

Understanding the landscape changes that characterize these habitats is considered a priority issue when working towards their sustainable management. The quantification of such changes can also provide better knowledge of the ecosystem services being compromised. In this respect, remote sensing techniques and resources have become increasingly important in supporting inventorying and monitoring of wetlands, having

been applied within environmental projects of all scales. These methods are also promoted by the Ramsar Convention on Wetlands, to sustain the filling of gaps in the present baseline global wetland database (Rebelo et al. 2009).

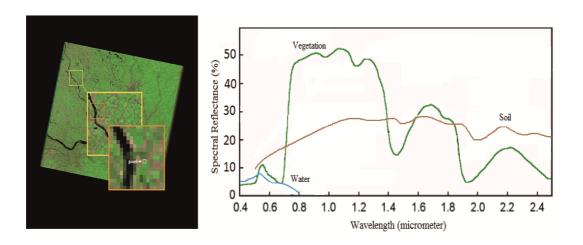


Figure 4 A satellite image is a 2-dimensional array of pixels (left) each of with is characterized by a spectral signature. The spectral signatures of three land-cover types are seen in the graph on the right (PALSIS 2011; USGS 2013a)

Landsat, Satellite Pour l' Observation de la Terre (SPOT), Advanced Very High Resolution Radiometer (AVHRR), Indian Remote Sensing satellites (IRS), radar systems, Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) and Moderate-resolution Imaging Spectro-radiometer (MODIS) are some satellite sensors that have been applied for wetland detection. These sensors provide 2-dimensional imagery composed of an array of pixels, each pixel being characterized by a spectral signature which is the spectral response of the surface captured, in the bands of the remote sensor. Image classification is hence based on this spectral data (Ozesmi & Bauer 2002).

These resources provide numerous advantages for inventorying and monitoring of wetlands. Repeated coverage by the satellites allows for seasonal or yearly monitoring of wetland coverage, as well as the investigation of land-uses within or around wetland areas. Also, the digital format of satellite data allows for easy integration within GIS (geographic information systems) environments. Further, a considerable amount of satellite imagery is available free of charge from online resources. For example for this study, Landsat imagery was ordered free of charge via the US Geological Survey (USGS) Centre for Earth Resources Observation and Science (EROS) (USGS 2013b).

Hence, in comparison to the use of conventional ground/aerial photography or field surveys, automated classification processes using satellite imagery are more affordable in terms of both time and money, thereby providing monitoring opportunities where funds or other resources are limited (Ozesmi and Bauer 2002; Teferi et al. 2010).

The general objective of the use of this imagery for these landscape studies, is usually that of classifying the different land-use or land-cover classes present, providing information on their extent, condition and distribution (Akumu et al. 2010). Whilst land-use denotes man's utilization of the land, land-cover refers to its physical and biotic characteristics. Because of their close relation and interchangeability, the terms land-use and cover (LUC) and land-use and cover change (LUCC) are usually applied (De Mûelenaere et al. 2012).

Classification methods fall under either unsupervised or supervised methodologies. In unsupervised methods, pixels are automatically classified based on spectral similarity. In supervised methods, pixel samples from known land-cover types are used to train the classification algorithm, which is then used to map the rest of the image (Jensen 1996). With respect to wetland classifications, no standard classification method exists (Teferi et al. 2010). However, in a review of remote sensing applications for wetland studies, Ozesmi and Bauer (2002) found unsupervised classification or clustering to be the most commonly used method, with Maximum-likelihood being the most common algorithm when it comes to supervised classification.

The use of satellite imagery for LUCC studies also entails a range of difficulties. When using medium resolution datasets (20-30 m) small or narrow wetland patches may be difficult to identify. Also, spectral confusion between different wetland classes or between wetland classes and other land types may occur (Figure 5). Also, images may not always capture wetland environments at optimum water conditions for their detection, and cloud cover may limit selection.

Some recommended ways of improving classification results include the use of multi-temporal images covering different seasons for instance, or the use of ancillary data (Ozesmi and Bauer 2002). Ancillary data includes any type of spatial or non-spatial information that may support classification. It may consist of field observations, interview data, aerial or terrestrial photography, Digital Elevation Models (DEMs) and maps of all kinds: land-cover, land-use, geology, hydrology, transportation networks, political boundaries and vegetation. The choice of use may depend on the aim of the study, as well as on availability and reliability (De Mûelenaere et al. 2012; Jensen 1996;

Rebelo et al. 2009). Using these data sources, layered or rule-based classification methods, as opposed to traditional classification methods, can be applied to improve results. For example, in Jensen (1996), ancillary elevation data was used to stratify a scene into two files distinguishing lower and higher elevation ranges accommodating different vegetation types, to then classify the different layers independently.

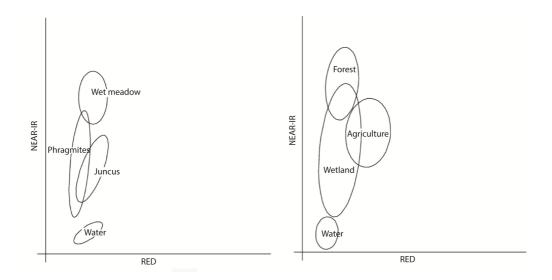


Figure 5 Variability of spectral signatures plotted for the near infrared and red band. The graph on the left shows the degree of overlap of signatures of different wetland types. On the right, the signature for the generic wetland class is shown with respect to other cover types.

More importantly, classification efforts using satellite imagery are usually tied to specific management objectives. In Lymburner et al. (2007) classification provided knowledge on the clarity of wetland water bodies, a criteria that is used to identify wetlands that are switching between two states and may therefore be more responsive to management intervention. In Amiri et al. (2014) change analysis based on Landsat imagery was used to study habitat availability for surface feeding and diving birds. Similarly, within this study, LUCCs shall be analysed with the aim of acquiring knowledge on the evolution of intertidal and supratidal marsh habitats that are important migratory bird habitats for serving as feeding, resting and breeding sites.

Studies involving the use of remote sensing imagery for the study area are limited. Guillemot (1984) documented the analysis of the area using Landsat MSS imagery spanning the 1975-1984 period. However the limited resolution of these images (79 x 79 m) gave results of limited precision and the same author pointed out at the use of the next-generation higher resolution Landsat TM images as a plausible solution. More

recently, Hernández Carrero et al. (2010) also provided a classification of a Quickbird image highlighting the distribution of marine angiosperms in the intertidal/low marsh area of the park. The innovation of this study lies in the attempt to classify the entire park area through the use of multi-temporal imagery providing novel visual and quantitative data on wetland coverage and change dynamics in the study area.

2.3. Waterbirds as indicators of landscape change in wetland habitats

Waterbirds are defined by the Ramsar Convention as being ecologically dependant on wetlands and are thus well recognized indicators of the value and health of wetland ecosystems (Wetlands International 2015) Their populations respond to environmental factors functioning at different scales, exhibiting variability in occurrence, abundance and breeding success. Further their visibility and vocalizations, present advantages with respect to monitoring and counting (Carignan and Villard 2002).

On a global scale waterbird populations have depreciated at faster rates than bird populations linked to other habitats, and of the 964 wetland dependant bird species, 203 are extinct or globally threatened (Millennium Ecosystem Assessment 2005). Interestingly, more of these globally threatened species depend on coastal systems than on inland wetlands (Figure 6).

Various reasons for these declines can be pointed out ranging from local pressures as habitat loss or degradation which compromise the intactness of stopover sites to global phenomena such as climate change, which result in direct impacts effecting breeding performance or indirect impacts caused by changes in habitat conditions (Bellio et al. 2009; Bortels et al. 2011; Sutherland et al. 2012). As a consequence of reduced natural wetland availability, waterbird populations worldwide are ever more dependent on artificial wetland areas - rice paddies, salt extraction plants and aquaculture ponds - which they use as alternative feeding, roosting and breeding habitat (Bellio et al. 2009; Birtsas et al. 2011; Dias et al. 2014; Tourenq et al. 2001). Generally, although these artificial wetlands cannot entirely substitute the functions of natural ones, when appropriately managed as waterbird habitat, they do mitigate the effects of natural habitat loss on these populations (Ma et al. 2010).

Habitat suitability of artificial wetlands is a function of the combination of environmental variables including water depth, water level fluctuation, vegetation, salinity and pH, topography, food type, food availability and accessibility, wetland size,

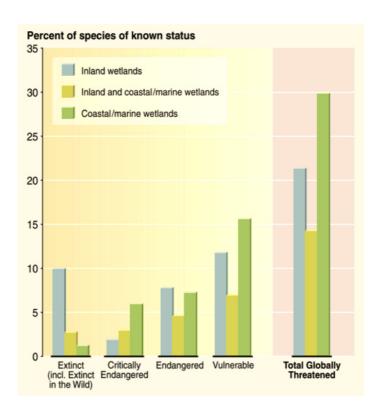


Figure 6 Percentages of waterbirds associated to inland and coastal wetlands according to the designated threat category (Millennium Ecosystem Assessment 2005).

and wetland connectivity (Bellio et al. 2009; Dias et al. 2014; Ma et al. 2010; Sripanomyom et al. 2011), as well as bird biometrics (e.g. foot and beak length) and habits. Figure 7 illustrates the variable adaptation of different bird types to the different water depths. Furthermore, some bird species may present different degrees of adaptability to these human-managed landscapes e.g. long-distance migrants to be more susceptible to decline in these scenarios (Rendón et al. 2008).

In sight of these complex bird-habitat relations, the appropriate management of artificial wetlands in favour of their adequacy as complementary waterbird habitats should be supported by the integrated knowledge of region-specific ecosystem variables, the consideration of their spatial and temporal variability, as well as knowledge of the habitat requirements of the inhabiting waterbirds. Furthermore such objectives need to consider the priorities/trade-offs amongst different species, whilst fitting into local social and economic constraints (Ma et al. 2010).

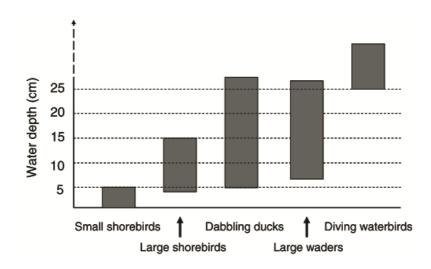


Figure 7 Variation of preferred water depths for foraging amongst different waterbirds (Ma et al. 2010).

The Bahía de Cádiz Nature Park's complex of natural and artificial marshlands are a recognized waterbird stopover site and since 2002 the area is a declared Wetland of International Importance according to the Ramsar convention, for hosting over 20,000 waterbirds yearly and over 1% of the flyway populations of numerous (mainly wader) species (Junta de Andalucia 2004).

The variability of use of this predominantly artificial site by different waterbirds has been thoroughly studied in Masero et al. (2000), Perez-Hurtado et al. (1993) and Pérez-During wintering periods, different species distribute along the Hurtado (1992). different environmental gradients present over the intertidal flat and salina areas, these offering diverse roosting and foraging opportunities, the latter being mainly based on macroinvertabrate or fish densities. Short-beaked and short-legged species (Calidris and Charadrius sp) will mainly feed within shallower environments, the former detecting prey visually and thus feeding from the water column, and the latter feeding from the benthos through tactile facilities. Meanwhile, other longer legged waders will feed in from the surface water lamina (e.g. Himantopus deeper areas: some feeding himantopus), whilst others search for benthonic species (e.g. Limosa sp.). As for Recurvirostra avosetta, this species uses its unique beak shape to sweep over exposed mud and the flamingo (Phoenicopterus roseus) is frequently observed in deep and extensive waters of industrial salinas where it can filter-feed on brine shrimp and bluegreen algae (Castro & Marín Estrella 2004). Meanwhile fish-eating species as the cormorant (*Phalacrocorax carbo*) are mainly associated to aquaculture sites. Infact these species are known to have exhibited important population booms mainly tied to the intensification of aquaculture activities, so much that they are considered as problematic predators for the sector (Arias García & Drake Moyano 2004; GEAM 1997).

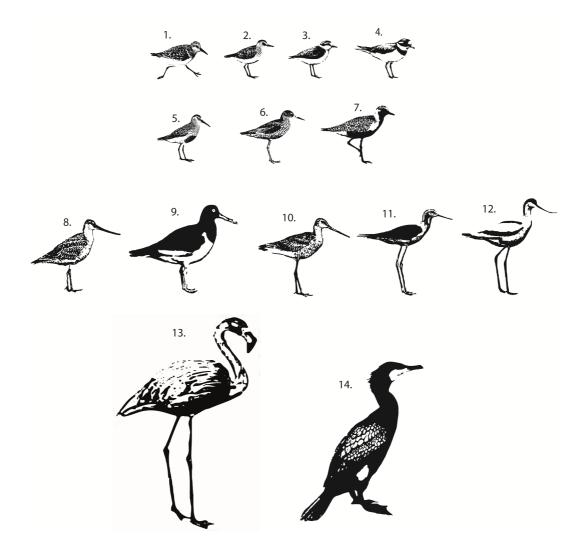


Figure 8 Waterbird species of the study area that are normally linked to specific landscape characteristics (1) Calidris alba (2) Calidris minuta (3) Charadrius alexandrinus (4) Charadrius hiaticula (5) Calidris alpina (6) Tringa totanus (7) Pluvialis squatarola (8) Limosa lapponica (9) Haematopus ostralegus (10) Limosa limosa (11) Himantopus himantopus (12) Recurvirostra avosetta (13) Phoenicopterus roseus (14) Phalacrocorax carbo

On the basis of all the known waterbird-habitat interrelations, this study covers the most extensive spatio-temporal analysis of wintering waterbird populations to be

accomplished for the study area. Following Pérez-Hurtado (1992), it is the only study in this field that accounts for census data covering the complete park area. Furthermore, the study considers the full 1985-2015 dataset available for wintering populations. Throughout this process it offers a most updated analysis of the effects of the LUCCs underwent during the past decades on inhabiting waterbird trends and distributions.

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Chapter 3. The DPSIR framework as a support tool for integrated research

This chapter documents the work carried out to answer Hypothesis 1, whereby an integrated research approach was applied with the aim of analysing the cause-effect relationships characterizing the studied system (the Bahía de Cádiz Nature Park) at multiple focus levels. The work is presented in the form of an article entitled:

'Multiple D-P-S-I frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain)'

This article was published online on the 10th of October 2014, within a special edition of the *Journal of Coastal Conservation: Planning and Management*. It is available through the following link:

http://link.springer.com/article/10.1007%2Fs11852-014-0347-7

This work includes a review of the national laws, European directives and international agreements relative to the study area. Further, it outlines priority management objectives of relevance. Following it sets forth the DPSIR framework as an integrated research support tool for the identification of social and environmental elements that characterize the study area, including a review of the framework's applications, setbacks and possibilities for improvement.

Combining literature review and expert consultation, two DPSI frameworks were designed: (i) a wider-scoped framework aimed at capturing all natural and social elements of influence within the area (ii) a second framework zooming into the causal relations underlying one of the priority management issues of the area, namely, the effects of land-use and land-cover changes on the park's ecological integrity. Following a review of ongoing and proposed response (R) actions was given.

The designed frameworks provide a graphical tool through which the socioenvironmental issues representative of the park can be analysed and communicated. These frameworks are available in digital format and may be adapted for use within future integrated research and management efforts relative to the area. Selected elements can be prioritized over others and new frameworks may be designed, in accordance to study objectives. Further these frameworks can support the development of analytical tools such as indicators or models.

Multiple DPSI frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain)

Sarah Camilleri · Alejandro Pérez-Hurtado de Mendoza · Giovanni Gabbianelli

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Abstract System thinking and integrated research are widely applied approaches in environmental management, often facilitating the organization of information from different levels and sources. They are here applied to support the review of (1)political and management instruments and (2) elements that characterize the Bahia de Cádiz Nature Park (Spain). The latter objective is sustained by the DPSIR (Driver-Pressure-State-Impact-Response) framework. A first DPSI conceptual map offers a broader view of the park capturing a range of elements that act at global, national and regional levels. Next, through expert consultation, prioritized DPSI issues describing the current situation of Bahia de Cádiz Nature Park are highlighted. A second DPSI map is designed to explore specific land-use and land-cover changes and their effects on the park's ecological integrity, offering a greater level of detail. 'Responses' are discussed separately, through a review of most recent response actions that have originated at various levels, and future ones proposed by the park's management. The framework proves to be appropriate to identify elements from both social and environmental dimensions, but excludes global-scale elements that do not fit the scope of this analysis. The review hopes to support future integrated research initiatives, involving in-depth analysis though the use of tools as are indicators or models.

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Introduction

System thinking for integrated assessment

System thinking is one problem-solving approach that has gained considerable recognition within different scientific areas. Its success is based on its aptitude to organize complex systems and create a structured working set-up, prior to delve into deeper research. In this way, it has supported poorly formalized scientific areas and thus is essentially of a revolutionary nature (Guberman 2004; Tett et al. 2011). This approach is also widely applied within environmental management tools as is the Millennium Ecosystem Assessment's (MEA) framework which focuses on linkages between ecosystem services and human well-being; thus aiming at offering decision makers a systematic way of dealing with sustainability goals, understanding trade-offs across sectors and affectively aligning responses with the correct level of governance (Millennium Ecosystem 2005).

The system approach is also of great value within integrated research, which considers data from different components and levels. The concept of integration is gaining in recognition, as reflected by governance shifting from methods that approach sectors as independent entities towards the involvement of cross-scale institutions and institutional diversity (Berkes 2002; Ostrom et al. 1999). As Mitchell (cited in Brouwer et al. 2003) affirms; such integration methods encompass a multitude of dimensions of the case /system to be managed, thus supporting decision-making in a more holistic manner and reducing the chances of problems arising from uncertainties and incomplete information. As shown in Fig. 1,



political decisions at all levels (international, national, regional, local) are linked to management planning, which in turn determines the kind of information that should be fed into an integrated knowledge database. Within environmental management, such a database may involve information from different natural or social sciences. For example, in wetland management this may include data concerning the different ecological components (e.g. birdlife, macro-invertebrate communities), various biogeochemical and physical systems (e.g. hydrologic features, nutrient cycles) as well as the socio-economic and sociocultural context (e.g. the value of food resources and flood control for the neighboring populations). This information can then be integrated using the variety of available tools including models, indicators, GIS (Geographical Information Systems), expert judgment and scenario analysis (Brouwer et al. 2003). As shown by the arrows in the flow diagram in Fig. 1, information exchange is always bi-directional. Decision makers provide the queries for which science must provide solutions. Next, decision makers choose solutions, test their success and this experience translates into further input for research. Importantly, all relevant scale issues must also be considered within:

- (i) vertical integration of data from science into the management and political decision making contexts e.g. longer-term climate change impacts vs. short-term coastal zone planning (Few et al. 2004),
- (ii) vertical integration of data amongst different decisionmaking levels e.g. broad geographical scale of strategic plans *versus* narrower spatial scale of coastal management plans in the UK (Few et al. 2004)
- (iii) horizontal integration of data generated from research under the different natural or social scientific disciplines. Within these disciplines, further scale considerations must be made:
- horizontal geographical gradients, exchanges and fluxes e.g. dunes, wetlands and marine ecosystems lying across the same horizontal plane),
- vertical geographical gradients spanning atmosphere, soil and groundwater,
- temporal gradients e.g. tides, climatic patterns and fisheries production and sea-level rise vary across days, seasons, years, decades or larger glacial/interglacial scales respectively (Crossland and Kremer 2001).

The system approach is here used to review the Bahía de Cádiz Nature Park with the objective of gaining a better understanding of (i) relevant political and management issues and (ii) characteristic natural and social elements. As a result, it aims at providing a strong base to following integrated research efforts.

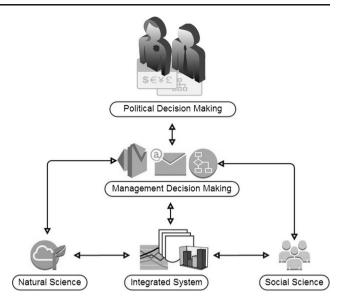


Fig. 1 Framework linking political and managerial decision-making levels to an integrated information system. (Designed in www.gliffy.com)

The Bahía de Cádiz nature park

The Bahía de Cádiz Nature Park (N.P.) (Fig. 2) is found on the Atlantic coast of the province of Cádiz, situated on the western coast of the region of Andalucía (Spain), between 36° 22′ to 36° 37′ N and 5° 7′ to 6° 16′ W, occupying an area of 10,522 ha (Ramsar 2012; Junta de Andalucía 2004b). The landscape is a clear reflection of the historical interaction between man and the surrounding natural environment. Apart from the close proximity of five municipalities, much of the tidal wetland area that makes up a big proportion of the park area, has been modified from its natural state, originally to be used as salt extraction ponds, locally known as *salinas* (Pérez-Hurtado 1992).

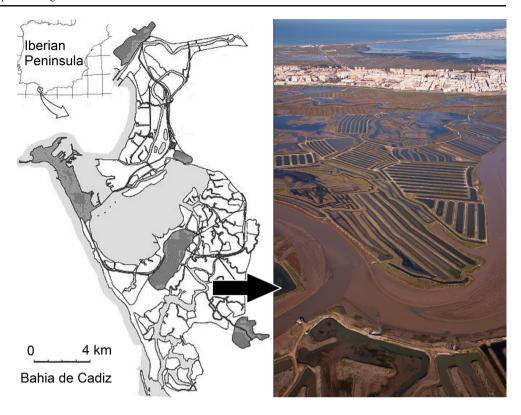
The bay is also noteworthy for its physico-chemical parameters; these being linked to its transitory position, between two continents (Europe and Africa) and two bodies of water (the Mediterranean Sea and the Atlantic Ocean). It is characterized by a Mediterranean climate with temperate winters and hot summers, a strong marine influence with a mean tidal range of 2.4 m and ecosystems including sandy beaches, dunes, lagoons and rocky islets With respect to its biodiversity, the area is especially important as a resting, feeding and breeding site for thousands of aquatic birds that migrate through the East Atlantic and the Mediterranean flyways (Pérez-Hurtado and Hortas 1994; Hortas Rodríguez et al. 2004).

Legal frameworks and management objectives

The familiarization with the political and legal character of the studied system is a fundamental step within environmental research, offering a more rooted understanding of existing



Fig. 2 Location and graphical representation of the Bahía de Cádiz N.P. and aerial shot showing a section of modified wetland and a proximate urban centre (Adapted from Muñoz Arroyo 2000, Photo: Luis Guijo (pers.comm))



issues and management. The Spanish legal system is a hierarchical one, meaning that legal instruments at a lower jurisdiction level cannot conflict those at a higher one. Its elements, ranked from higher to lower jurisdictional power, include: laws, decree-laws, legislative decrees and regulations. Meanwhile international treaties and European Union (EU) legislation; must be signed, ratified and published in the Official State Gazette in order to obtain national legislative importance (Cabrero 2002).

In Andalucía, the management of natural spaces is regulated by two national laws. The first is that of Natural Heritage and Biodiversity¹ which encompasses two fundamental management tools: the Natural Resource Management Plan (PORN: *Plan de Ordenación de los Recursos Naturales*) and the Master Plan for Use and Management (PRUG: *Plan Rector de Uso y Gestión*). The second of these laws is concerned with the Inventory of Natural Protected Spaces in Andalucía.² It is tied to both the PORN and PRUG, and additionally sets a framework for the elaboration of the Sustainable Development Plan (PDS; *Plan Desarollo Sostenible*). This is also the law through which the Bahía de Cádiz N.P. (encompassing two other nature reserves in its territory-*Isla del Trocadero* and *Marismas de Sancti Petri*) was first declared a protected space in 1989. Its current PORN, PRUG

and the PDS, have also been approved through two different decrees³ (Junta de Andalucía 2013a).

In addition, other laws and frameworks with stronger relations to regional development and urban planning are also highly relevant. Important examples includes the Law for the Conservation and the Sustainable Use of the Littoral Zone⁴ and the Spatial Plan for the Bahía de Cádiz.⁵ The former is a law of great influence on all littoral systems/activities and replaces the old Spanish Coastal Law (discussed in later sections). The latter is sub-regional plan that considers all territory-related legal aspects. Amongst other challenges, these frameworks struggle to incorporate their integrated approach and the necessary attention to environmental aspects within other established laws, as is the Land Act⁶ (Barragán Muñoz et al. 1996; Barragán Muñoz and Macías Bedoya 2004; Barragán Muñoz et al. 2004; Junta de Andalucia 2006; Macías Bedoya 2000).

Further, EU and international agreements are also tightly intertwined into management plans and objectives. As a protected coastal wetland area, the management of the Bahía de Cádiz N.P. falls within the overlapping domains of three

⁵ This is tied to Spatial Plans in Andalucía (according to the Spatial Planning Law 1/1994) approved by Decree 462/2004 of the 27th of July ⁶ Land Act 2/2008 of the 20th of June



¹ Law 42/2007 of the 13th of December for Natural Heritage and Biodiversity

² Law 2/1989 of the 18th of July for the Inventory of Natural Protected Spaces in Andalucía

³ Decree 79/2004 of the 24th of February for the PORN and PRUG and Decree 117/2006 of the 10th of October for the PDS of the Bahía de Cádiz ⁴ Law 2/2013 of the 29th of May for the Conservation and the Sustainable use of the Littoral zone, that replaces the old Spanish Coastal Law 22/1988 of the 28th of July

European directives. This first one is the Water Framework Directive (WFD)⁷ which aims at the provision of a framework for the protection of inland surface waters, transitional waters, coastal water and groundwater. Further the park is part of the Natura 2000 network (an EU wide network of nature protection areas) established to assure the long-term survival of Europe's most valuable and threatened species, composed of Special Areas of Conservation (SACs) designated under the Habitats Directive⁸ and Special Protection Areas (SPAs) designated under the Birds Directive.9

Article 6 of the WFD ties the three directives together by establishing the requirement of a register of areas protected by other specific EU legislation e.g. Natura 2000 areas. Meanwhile Article 4.1.c. requires all areas within this register to comply with ground water and surface water standards by 2015. Further, Article 4.2 specifies that when integrating WFD objectives and pre-established protected area regulations, as those specified by the Birds and Habitats Directives, the most stringent of options should be opted for (Water Framework 2000). This idea is represented in Fig. 3. Meanwhile, there is also a considerable overlap of tasks within river basin management plans under the WFD and protected spaces under the Habitats and Birds Directives. This overlap could suppose an opportunity for advances in the conservation of such spaces, improved collaboration and integration of disciplines, but also greater technical/legal/administrative complexity (Howell and González García 2010).

Finally the park's international significance is a further noteworthy fact. In 2002, the Bahía de Cádiz N.P. was included in the list of Wetlands of International Importance according to the Ramsar convention, for regularly hosting at least 1 % of the population of different aquatic bird species. The Ramsar convention remains the only international convention which centres its efforts on a singular ecosystem type with its objectives targeting (i) the prevention of loss of further wetland area (ii) their conservation and that of the biodiversity they host through the harmonization of national policies and the implementation of 'rational use' concept and (iii) the contribution to global sustainable development. Its policies stand as landmarks for a great number of international bodies including the EU initiative MedWet, coordinated by the Committee for Mediterranean Wetlands set up during the COP7 (Conference of the Contracting Parties 7) Ramsar Conference (Junta de Andalucia 2004a, b).

Rounding up, all the political and legal frameworks discussed above are important cornerstones for the design of appropriate local conservation and management objectives. For the Bahía de Cádiz N.P., the harmonious coexistence of sustainability within socio-economic activities: salt extraction, aquaculture and fishing/shell fishing

proximate human settlements and the natural environment is

targeted through the overall objectives of:

- the conservation of environmental elements: the aquatic
- system; habitats, flora and fauna of interest
- the provision of services with links to culture, education research and public use.

Integrated research aiming at supporting these objectives, must be based on knowledge of the interplay of natural and anthropogenic elements characterizing this protected area. In the following section the DPSIR (Driver-Pressure-State-Impact-Response) framework is set forth as a tool for the definition of these elements and their inter-relations.

Materials and methods

An introduction to DPSIR framework: a support tool for integrated research

The DPSIR is a conceptual framework applied for system analysis, through the definition of cause-effect relationships between sectors of human activity and the environment (Agyemang et al. 2007; Chung and Lee 2009). The framework's integration of both human and environmental factors make it fitting for coastal areas as that of the Bahía de Cádiz N.P., marked by a 3,000 year human occupation. Its origins date back to the late 90s, being first proposed by the Organization of Economic Co-operation and Development (OECD) as a tool for the support of indicator use, to be later adopted by the European Environmental Agency (EEA) (Tscherning et al. 2012). According to this original DPSIR view: social and economic development (e.g. population growth) act as Drivers which exert Pressure on the environment (e.g. discharge of waste). This alters the State of the environment (e.g. the water quality), and leads to *Impacts* on human health, ecosystems and materials (e.g. disease, decline of resource quality and availability). This chain reaction finally leads to a societal Response (e.g. policies) that feeds back on the Drivers, Pressures, States and Impacts (Smeets and Weterings 1999).

A critical approach to DPSIR

The DPSIR framework has been applied in a wide range of projects, dealing with different types of systems and through different methodological approaches. Its most fundamental function, as defined in Smeets and Weterings (1999), is the organization of all elements that characterize a system, under

Birds Directive 2009/147/EC of the 30th of November 2009, on the conservation of wild birds (this being the codified version of Directive 79/ 409/EC)



Water Framework Directive 2000/60/EC of the 23rd of October

⁸ Habitats Directive 92/43/EC of 21st May 1992, on the conservation of natural habitats and of wild fauna and flora

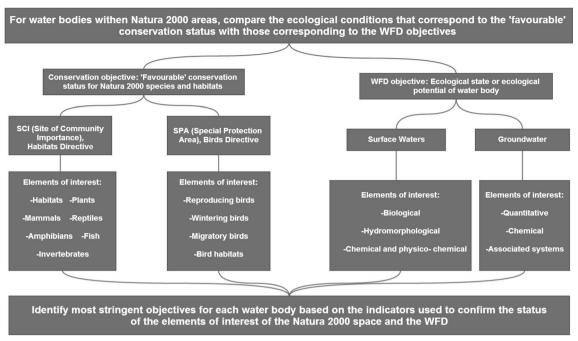


Fig. 3 Scheme for guidance through the selection of the most rigid of objectives for the management of water bodies located in Natura 2000 protected areas (adapted from Howell and González García 2010, designed in www.gliffy.com)

one of its five categories. Next, the framework may support the use of indicators, as well as the development of new ones. It has also been used in combination with other evaluation tools and methods. Examples of such evaluations include that by Kristensen (2003) where the framework supports the selection of system-specific indicators for integrated analysis at later stages; that by Karageorgis et al. (2006) where it is used as a starting point for scenario development; and that by Agyemang et al. (2007) where it is combined with participatory approaches, GIS and remote sensing techniques. Finally, the framework is also a valid communication tool of research results, its structure providing accessibility and meaningfulness to decision makers, whilst providing sets of decision options rather than one definite solution (Tscherning et al. 2012).

However, the framework has also been subject to plenty of criticism, as a result of which it has been adapted in various ways, with the purpose of overcoming its setbacks. One main limitation, that is frequently pointed out at is its over simplification and its unrealistic linear representation. For example a marine fishery DPSIR might fail to indicate how the workings of this sector lie embedded within those of other sectors, as aquaculture e.g. the response to overfishing such as curtailing fisheries will impact on aquaculture too. Therefore, the realization of finding one DPSIR embedded within another is a frequent one (Atkins et al. 2011). Further, a singular framework alone may fail to represent the real multi-level situation of problems that extend throughout different policy, stakeholder, geographical or temporal levels. Ness et al. (2010) approaches this problem by the unison of the DPSIR and the

Hägerstrand framework, proposed to facilitate gaining macro and microscopic insights for better understanding of system related issues. This adaptation of the DPSIR framework is used to explore the different European, national, regional and local approaches; to treat Baltic Sea eutrophication caused by Swedish agriculture. In the same way a multi-scale approach is proposed within the MEA framework, to better reflect the multi-scale nature of decision-making, include *Drivers* that are external to the region, and provide a means of examining the different sub-regions/sub-groups that make up a system (Millennium Ecosystem 2005).

Meanwhile Tscherning et al. (2012) states that DPSIR's ability to represent the 'real world' may be improved through trans-disciplinary research involving academic researchers from different disciplines as well as non-academic participants such as land-managers, user-groups and the general public. This may counteract one of DPSIR's drawbacks i.e. that of being biased and of excluding perspectives of certain user groups as well as improve project success. For instance, participation of end-users during model\tool design has been shown to be important for enhancing its use and acceptance after the design stage (Tscherning et al. 2012). Another problem is the confusion linked to the classification of some system elements. A non-native species may be considered as a State element, however with a considerable increase in population dimensions such species become a real *Pressure*. Also, threats as climate change and sea-level rise, whilst being real pressures, have stronger links to global issues than to local ones and their consideration within the study of local-scale systems may be disputable.



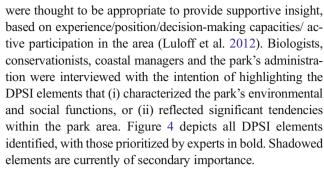
Further, the consideration of social elements (e.g. human disease or death rate) is not consistent from study to study. This idea can be demonstrated by comparing two different wavs in which the framework has been applied by two different research groups. In the DPSWR (Driver-Pressure-State-Welfare-Response) framework adapted by the KnowSeas project in O'Higgins et al. (2011) the term *Impact* is replaced with the term Welfare, to avoid confusion between environmental and economic impacts. Environmental and social elements are therefore held separate, and are combined only in the Pressure group. On the other hand, the integrated framework proposed in EPA (2012) counteracts the dissociation of environmental and human dimensions within the 'traditional' DPSIR, by adding a parallel pathway to more explicitly consider human health. On a positive note, this comparison points out at the variable adaptations of the DPSIR framework making it a flexible tool that may be fit the users' research objectives.

Two DPSI frameworks for the Bahía de Cádiz nature park

The design of two DPSI conceptual maps was considered necessary in order to analyze the system encompassed by the park at multiple levels, whilst counteracting the aforementioned limitations of the framework. Specific responses were thought worth formulating following future in-depth qualitative and quantitative studies of chosen DPSI elements and their interrelations. For this reason, and also for a clearer representation of results, they are not included in the DPSI maps designed at this stage. However a later section describes past, on-going and possible future response actions.

The first of the DPSI frameworks proposed hereunder is wider in scope, capturing elements that are geographically located within the park; as well as those linked to global, national, regional and local tendencies. The park's official documentation and other supporting literature sources was 'scoped' for the identification these elements. The EEA's definitions of Drivers, Pressures, States and Impacts, from Smeets and Weterings (1999), were used as reference during classification. Further, following the integrated framework concept from EPA (2012); Social Drivers, Social Pressures, Social States and Social Impacts were also classified. As for environmental impacts these were organized according to four groups of ecosystem services as classified by the Millennium Ecosystem Assessment: provisioning (products obtained directly from the ecosystems), regulating (benefits obtained from the regulation of ecosystem processes), cultural (nonmaterial benefits people obtain from ecosystems through cognitive development and aesthetic experiences) and supporting (benefits necessary for the production of all other ecosystem services) services (Pinto et al. 2013).

The DPSI elements identified were discussed with key informants selected through a purposive sampling approach (Trochim and Donnelly 2007). These were individuals who



Next a second DPSI map (Fig. 5) was designed to explore one of the priority issues for the park's management, offering a greater level of detail. This concerns the effects of the Land-Use and Land-Cover Changes (LUCCs) linked to the salt extraction and aquaculture sectors; on the ecological integrity of the area (Junta de Andalucia 2004c, 2006; Masero Osorio 2004; Muñoz Arroyo 2000; Pérez-Hurtado 1992; Pérez-Hurtado and Hortas 1993).

Discussion

A birds-eye view of the park system

The first, wider-scope DPSI (Fig. 4) is composed of numerous elements attempting to capture aspects that, to a higher or a smaller degree, make up the park system. Its acts as an inventory that may function as the starting point for more focused research efforts. Priority elements, highlighted through expert consultation, are represented in bold. These elements are related to priority issues that characterize the current situation of the park and that need to be dealt with through appropriate action. These priority issues include:

- (i) The definition of the current conservation status of the park with respect to modified legislation
- (ii) The promotion of sustainable development with respect to sectors based within the park area
- (iii) The conservation of the park's ecological integrity
- (iv) The promotion of culture, public use and participation
- (v) The conservation of the hydrological system and water quality

In the following subsections each of these issues are discussed in greater detail. Continuous reference is made to DPSI elements (*in italics*) from the conceptual map in Fig. 4.

(i) The definition of the current conservation status of the park with respect to modified legislation

Governance, management and administration (D) is one factor of great influence on the quality of services offered by



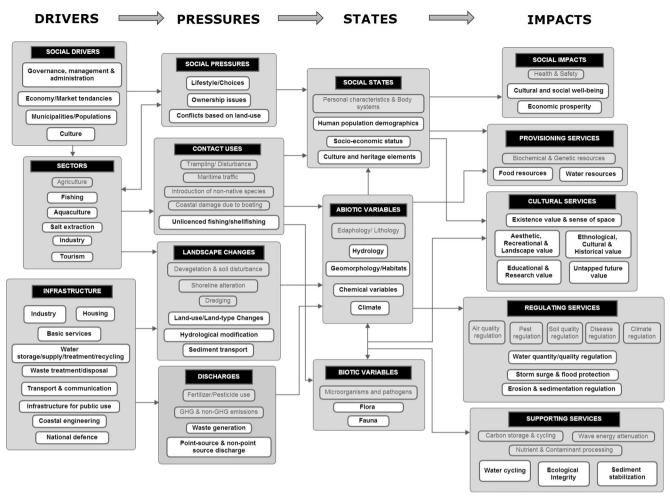


Fig. 4 DPSI map indicating *Drivers*, *Pressures*, *States* and *Impacts* characterizing the Bahía de Cádiz N.P., and the links between them. Elements prioritized through expert consultation are in bold. Elements of minor importance are shadowed (Designed in www.gliffy.com)

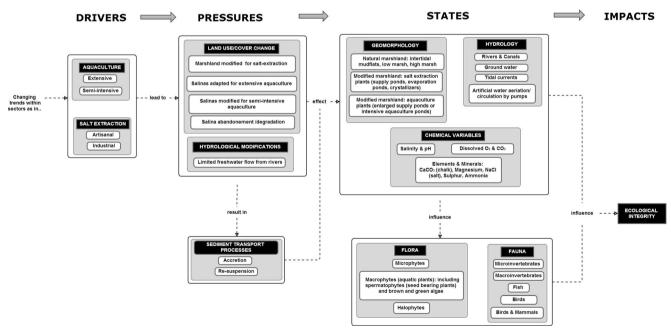


Fig. 5 DPSI map describing the dynamics of LUCCs resulting from the salt extraction and aquaculture sectors in the Bahía de Cádiz N.P. and their effects on ecological components (Designed in www.gliffy.com)

the protected area. On a positive note, the legislative context that backs governance/management/administration here, is an extensive one composed of numerous norms. Landmark frameworks from various levels have already been presented in detail in the Introduction section. These have led to the implementation of legislation that has been fundamental for the area's conservation. Of further important mention is: Decree 79/2004 of the 24th of February according to which all activities permitted within the park are regulated following the determined zonation (Zones A,B1-4 and C1-4), Decree 14/ 1996 of the 16th of January for the Regulation of the Quality of Littoral waters, and Law 7/2007 of the 9th of July for the Integrated Management of the Environmental Quality Further, other activity-specific norms support their administration by responsible bodies. Some examples include Law 1/2002 of the 4th of April which offers important guidelines in the regulation of aquaculture activities; and on behalf of the regional Ministry of Agriculture and Fishing the Order of the 15th of October 2007 provides technical norms for ecological aquaculture production.

In other cases, lack of technical clarity within legislation, may also complicate governance and administrative chores. The aforementioned Law 2/2013 (the older Spanish Coast Law), is exemplary of this. On one hand, this law has claimed areas 'naturally inundated by tides, but where the inundation cycles are controlled artificially by walls, gates or similar systems' to be part of the maritime-terrestrial public domain. Following the hypothetical inclusion within this public domain, the salinas might benefit the conservation easement offered by this law for public territory, whereabouts protection measures would be implemented whilst allowing owners to retain private property rights. This might also serve for the creation of buffer zones for the park, still unaccounted for by current environmental legislation. However, in reality, there fails to be a clear interpretation and implementation of this law, as a result of which the salinas' status in this respect remains ambiguous (Barragán Muñoz et al. 1996, 2004; Junta de Andalucia 2006; Macías Bedoya 2000) with social, economic and ecological repercussions.

As a result of this ambiguity, the area is thus suffering the consequences of social pressures as are *Ownership issues* (*P*) and *Conflicts based on land-use* (*P*). A great number of salinas are nowadays owned by multinational companies or inheritors with little interest in the park's conservation efforts or in activities characterized by limited profitability and significant investment risks. As a result of lack of implementation of the Coastal Law, there has been limited collaboration by these private owners, with the park's conservation initiatives. There is instead a tendency to maintain the salina plots unproductive, whilst speculating their possible future sale and urbanization. This is a hypothetical situation that would secure higher and faster profit-making for their owners. Moreover this situation is encouraged because of the proximity of the

nearby municipalities (El Puerto de Santa Maria, Puerto Real, Chiclana de la Frontera, San Fernando and Cádiz) to the park and their high demand for land (Antonio Gómez Ferrer pers.comm). Further, the most recent modifications to Law 2/2013 reinforce possibilities of such a situation. These modifications include a reduction of the no-construction area from 100 to 20 meters from the coastline, with building to be allowed in exceptional cases in the remaining 80 meters (Viudez 2013). The real implications of the modified law, with respect to the park area, are however still to be determined and published (Antonio Gómez Ferrer pers.comm).

(ii) The promotion of sustainable development with respect to sectors based within the park area

Despite being the main economic activity based within the park's limits, the Aquaculture (D) sector takes up less than 1 % of the working population of the area. In addition to the legal and economic issues faced by the sector, theft and predation of fish stock by birds, are other issues of detriment to profitability, especially in the case of smallerscale enterprises. As a consequence, many activities within aquaculture installations are nowadays of secondary importance or have ceased. These activities are based on marshland, previously modified for Salt extraction (D). This is another industry of considerable influence within the park, but which has lost its importance with the times, leaving very few installations in activity (less than 10 %). The timeline in Fig. 6 briefly describes the rise and fall of the Salt extraction industry and the concurrent development of Aquaculture since the 1970s.

The fall of these sectors is in part linked to the unclear faith of the territory and the ownership/conflict issues described above. However in addition to these local pressures, there are other pressures that act from other levels. These include global Economy/Market tendencies (P) such as competition, varying product value and limited profitability of artisanal methods with respect to industrial ones (Barragán Muñoz et al. 1996, 2004; Junta de Andalucia 2006; Macías Bedoya 2000). As a result of all the described drivers and pressures; these extractive activities have been marginalized, related business and association initiatives jeopardized and sustainable production and marketing strategies have failed to develop. Local produce is therefore limited within the local population's Lifestyle/Choices (P), a situation that is unfavourable with respect to the area's Socio-economic status (S), already characterized by unemployment figures which overcome the regional and national averages, with provincial records hitting highs of 40 % in 2013 (Espinosa 2013). Impacted services include: Food resources (I) and the Economic prosperity (1) in the area (Antonio Gómez Ferrer pers.comm).



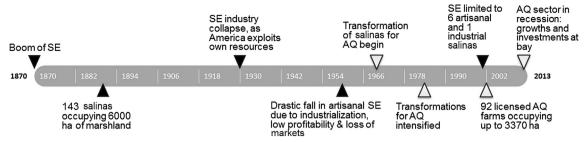


Fig. 6 Time line showing the evolution of the salt extraction (SE, black markers) and the aquaculture (AQ, grey markers) industries in the park area (Designed using OfficeTimeline)

As a result of this situation, the revival of these sectors under sustainable measures, is being viewed as a possible solution to this multifaceted issue.

(iii) The conservation of the park's ecological integrity

The quality of the park's natural components (including biotic and abiotic elements) is strongly linked to the rise and fall of the sectors that it is home to.

Fishing (S), especially shell fishing activities in the case of the park, is a traditional economic activity which comes with its own share of problems. The biggest threat here is all the *Unlicensed fishing/shell fishing (P)* that takes place from beaches, intertidal zones, and from fishing vessels within the bay. Despite the unknown magnitude of this problem, it is considered to be of detriment on fish/shellfish populations and habitats.

More importantly, the *Aquaculture (D)* and *Salt extraction (D)* sectors are tightly linked to events that have altered the park's landscape resulting in strong *Landscape changes (P)*. As a result of complicated ownership dynamics described above, the lack of use and maintenance of the salinas, and their eventual abandonment has led to the degradation of their physical structure and consequently the reduction of the ecological niches and biodiversity they accommodate.

Meanwhile, other sectors that have experiences growth in the recent years e.g. Industry (D) and Tourism (D). These have also contributed to other pressures suffered by the park's natural elements. *Industry (D)* is what now generates most employment in the area. This sector is however subject to global fluctuations too, as shown by the 1990s crisis of the shipbuilding industry, following harsh completion from Asiatic countries and privatization trends. Manufacturing, aviation and dredging are currently active industries in the area. Tourism (D) has shown upward trends too, although the kind offered is strongly linked to the 'sun and sea' offer, with limited efforts to promote the park area (Junta de Andalucia 2006). Their developments has mostly contributed to the spread of all forms of *Infrastructure (D)*. In this sense, modifications during the last 30 years have been considerable, including new highway sections, new rail and tram lines, new industrial polygons and new port infrastructure; and have contributed to other kinds of *Landscape changes (P)* as are the draining and filling of salinas/marshland and urban sprawl.

These pressures are suffered by all *Geomorphology/Habitats (S)*, *Flora (S)* and *Fauna (S)* in the park, as a result of which the following changes and impacts are experienced:

- loss of biodiversity and habitat fragmentation threatening
 Ecological integrity (I)
- the alteration of physical processes due to land-use changes or infrastructural development effecting regulating services as are Sediment stabilization (I), Erosion and sedimentation regulation (I) and Storm surge & flood protection (I)
- habitat degradation, or modification for intensified activities compromising Water quantity/quality regulation (I).
- (iv) The promotion of culture, public use and participation

Landscape changes (P) above mentioned may also be of detriment to Culture and Heritage elements (S) as are the casas salineras. These are one-floor buildings found within the salina areas that served as homes, shelter and storage for owners and laborers. As reported in Suárez Japón (2004), only around a quarter of the total number of houses are presently in good state. The same can be said of 26 tide mills, previously used to ground wheat or salt, of which only 6 are conserved, whist others lie in ruins or have completely disappeared (Molina Font 2001). Other Culture and Heritage elements (S) include traditional knowledge and language linked to the traditional sectors aforementioned. Their conservation is not only linked to the functioning the sectors and the well-being of the landscape on which they are found, but also to the perception of the local populations, this being linked to Culture (D) and related Lifestyle/Choices (P). A consideration of these links can be important to improve Cultural and social wellbeing (I) and Cultural Services (I) as are Existence value and sense of space (I), Education and research value (I) and Untapped future value (I).

 (v) The conservation of the hydrological system and water quality



There have also been considerable efforts in improving Water storage/supply/treatment/recycling (D) and Waste treatment/disposal (D) in the last decades, dealing with pressures as Waste generation (P) and Point source and non-Point Source discharge (P) (Junta de Andalucía 2006). As for regulation by the WFD, it is the Guadalete-Barbate Water Plan that takes account of the Hydrology (S) units within the park area, establishing zonation and monitoring programs for them to reach a 'good' status based on ecological, chemical and quantity related criteria. The first round of monitoring results summarized in Junta de Andalucía (2010) encompasses:

- five rivers/watercourses, draining into the park, all of which are in 'bad' state according to WFD criteria;
- six transitional water units, found within the park area of which two are in 'good' state, according to WFD criteria;
- five groundwater units, outside the park boundaries, of which one is in 'good' state according to WFD criteria;
- four coastal units, surrounding the park's coastline, of which all are in 'good' state according to WFD criteria.

Following such results the WFD deadline for 'bad' status bodies has been extended from 2015 to 2027. Efforts dealing with this issue hope to improve services as are the provision of *Water resources (I), Water quantity/quality regulation (I)* and Water *cycling (I)*.

The consideration of LUCCs and their ecological consequences on the park's ecological integrity

The design of the second framework (Fig. 5) focuses on the salt extraction and aquaculture related landscape changes that have for long characterized a considerable area of the park, and the ecological consequences of these changes. Whilst this point has already been given mention under DPSI issue Nr. 3, the framework and the discussion hereunder, provide a more detailed picture.

The most meticulous studies that aimed at quantifying the landscape transformation linked to Salt extraction (D) and Aquaculture (D) was that by Barragán Muñoz et al. (1996), in which more than half of the marshland area found within the present park boundaries was claimed to have undergone some form of modification. The first modifications took place to accommodate Artisanal (D) salt extraction. Such activity takes place in traditional salinas. A singular exemplary covers an approximate area of 50 ha and is separated from the rest of the marshland by a bordering wall, made of earth and rubble from the marsh area itself. Throughout the wet season, gates placed at certain points of the wall are left open and the salinas are subject to natural tidal patterns. Around April/May, when temperatures rise and precipitation decreases, the gates are closed and seawater that enters at high tides is trapped into the supply pond to then travel through a labyrinthic

evaporation area and finally arrive to the crystallizers where salt is manually collected in September/October. Salt production, is also present at an *Industrial (D)* scale. Although there are fewer examples of this kind, industrial production is now responsible for 80 % of the total salt produce. Apart from occupying a much larger surface area (e.g. 440 ha), mechanical methods are employed here and profitability is superior (Pérez-Hurtado 1992, Muñoz Arroyo 2000).

As for aquaculture, this has developed into various forms which have contributed to different kinds of modifications of the pre-existing salinas. In the case of Extensive (D) polyculture, the supply pond areas of the old salinas are either reused in their original state or adapted (deepened and enlarged) to improve production rates. As with salt extraction, these ponds are subject to the tidal influence during the winter months and are almost permanently closed around February/ March, trapping inside large volumes of water and fry. The fry feeds on other trapped natural life-forms and grows to become fish of a marketable size, to be fished out between October and December. In improved forms of extensive aquaculture, the vegetation growing within these ponds is fertilized to increase food availability or additional industrially-bred fry is added to the natural stock. For the other kind of aquaculture, the Semiintensive (D) kind, the original salina structure is completely replaced by ponds for monoculture. Further the production system is supplied with fodder and equipped with pumps for oxygenation and aeration (Yúfera and Arias Garcia 2010). In additional to structural and technical difference, production rates vary from about 0.1 kg/m² by the extensive methods, to 4 kg/m² through industrial ones (Arias García and Santaella Sánchez 2004).

The crisis by which both sectors were hit at different times, as well as the social drivers and pressures described above have led to an important trend: *Salina abandonment/degradation (P)*. In Muñoz Arroyo (2000) more than 1,300 ha (22 %) of the entire salina area is claimed to be characterized by this trend. This is evident by the breaking of the salina gates and walls, and their progressive inundation or increase in vegetation cover. These changes also lead to other physical pressures e.g. *Limited freshwater flow from rivers (P)*. Meanwhile, different *Sediment transport processes (P)*, spur as a result of degradation and abandonment. These pressures in turn alter the dynamics of *Hydrology (S)* and *Geomorphology (S)* elements followed by considerable shifts within the abiotic gradients and biotic distributions present within the salina areas.

Salinity & pH (S) are two important abiotic factors that strongly determine ecological patterns here. Within an active salina, biodiversity drops as the salinity rises, closer towards the production areas. Therefore the deeper supply ponds at one end, with a salinity of 60 g/L, host a richer diversity of planktonic or benthonic *Macrophytes* (S), *Macroinvertebrates* (S) and Fish (S) species. Meanwhile the environment within



the shallow crystallizers at another end, holds salinity levels of up to 300 g/L and a slight acidic pH, exclusively endured by some *Microphytes* (S) (e.g. *Dunaliella salina*) and *Micronvertebrates* (S) (e.g. *Artemia salina*).

As for Salinas modified for semi-intensive aquaculture (P), this also accounts for some significant changes; specifically an overall reduction in environmental heterogeneity and a resulting impoverishment in biodiversity richness (Pérez-Hurtado pers. comm). Apart from a more rigid control of physio-chemical conditions, the uniform depth of the ponds, and the sea-bream monoculture; the surface sediments of the ponds bottoms are completely removed during cleaning routines, following every 14 month production cycle, thus disrupting the benthonic Macroinvertebrate (S) population (Arias García and Drake Moyano 2004).

As for higher vegetation forms, different zones of Natural marshland: intertidal mudflats, low marsh and high marsh (S) are marked by different frequency of inundation, salinity levels, soil structure and inhabiting Halophytes (S). The same plant preferences are noticeable in active or abandoned salinas, with different plants growing over the wetter or dryer wall sections. Of great interest is the unpredictability linked to the kind of succession observed in abandoned patches. This varies according to factors as; distance from the tide-influenced area, altitude, water drainage, salinity levels, and the presence of vegetation propagules from vegetation previously found on salina walls. Therefore an abandoned salina located nearby the intertidal zone would suffer frequent submergence, this favoring the growth of vegetation forms linked to primary succession (Salicornia ramosissima, Spartina maritima or Sarcocornia perennis). One with a medium waterline, with occasional inundation and efficient drainage would most probably be succeeded by species usually present in low/high marsh transitional zones (Sarcocornia fruticosa, Suaeda vera and Halimione portulacoides). In spots with poorer drainage and less frequent flooding, the invasive Spartina densiflora would be a more common colonizer. In higher altitude zones, with little or no inundation; high marsh species as Arthrocnemum macrostachyum and Limoniastrum monopetalum, would be more common. As for pools that remain in a permanently inundated state, these provide perfect environments for aquatic microphytes and macrophytes (e.g. Althemia spp. and Ruppia spp.) (Castellanos et al. 2004).

These sector-related transformations and the resulting habitat evolution are claimed to be strong determinants of ecological change. In the case of the P.N. de la Bahia de Cádiz this is interesting with respect to the presence and distribution patterns of bird species. This is because, alongside the remnant areas of natural marshland, the salina areas are considered as very important alternative resting, feeding and reproduction sites for the 58

species of migrating and/or reproducing aquatic Birds (S)¹⁰ that can be found within the park area. Their controlled and repeated annual water management patterns provide predictability for these habitants, as well as a range of environmental conditions. The different water depths, for instance, accommodate aquatic bird species that exhibit different food preferences and feeding habits, this depending on their biometrics: leg length and beak length/shape. Smaller birds which shorter beaks and legs (e.g. Charadrius alexandrinus) are more likely to feed within shallow pools, those with longer legs and a shorter beak (e.g. Himantopus himantopus) will wonder in deeper pools mainly feeding from the surface water lamina, whereas long-legged and longbeaked birds (e.g. Limosa limosa) are able to feed on benthonic species. Reproducing species are also selective with respect to their nesting sites. Different avocet species may prefer areas with scarce vegetation to better detect the presence of predators or vegetated zones for shelter and camouflage, whereas flamencos and spoonbills generally look out for isolated zones with plenty of material for building their elaborate nests. Finally, amongst the threats encountered within these anthropized environments; is the presence of certain Reptiles and Mammals (S), including rats and dogs, presenting greater predation risks for the protected bird populations (Hortas Rodríguez et al. 2004)

To round up, the identification of the above drivers, pressures and state elements provides a good knowledge base for research efforts that aim at gaining insight of the *Ecological integrity (I)* of the park area. Unnasch et al. (2008) describe this as a characteristic of a system with its dominant ecological features (e.g., elements of composition, structure, function, and ecological processes) occurring within their natural ranges of variation and which is resistant and resilient to most perturbations imposed by natural dynamics or human disruptions. According to the 'Ecological Integrity Assessment Framework' (EIAF), proposed by the same authors:

(i) it is first important to identify the coarse filter/fine filter¹¹ biological/ecological resources that need to be conserved (e.g. the different natural marshland habitat types and

tems, only secondarily on species. Coarse-filter focal ecological resources are identified first, typically including all of the major ecosystem types within the planning landscape. Next, the 'fine filter' is applied, i.e. species that are not adequately addressed through the ecosystem-scale point of view, are included as additional foci for planning and conservation



¹⁰ The park area hosts 58 different species belonging to 15 different families: ducks, grebes, swallows, seagulls and terns, cormorants, fish eagles; and a number of waders, including oyster catchers, avocets, plovers, calidrids, phalaropes, herons, storks, spoonbills and flamencos ¹¹ The "coarse filter/fine filter" approach focuses primarily on ecosystems, only secondarily on species. Coarse-filter focal ecological resources

- inhabiting bird species), as well as the stressors that may affect these resources
- (ii) for each resource; attributes and associated indicators must be found in order to measure the system's integrity (e.g. land cover fragmentation and species abundance and distribution) and
- (iii) finally management can work on shifting the system to reach desired conditions for the identified biological/ ecological resources.

Responses

Responses as defined by the Millennium Ecosystem Assessment, include all kinds of actions that work for the prevention/compensation/amelioration of, or the adaption to, changes in the ecosystem's provided services or their perceived value. Such action may include interventions of a legal, technical, institutional, economic, and behavioral nature and may operate at various levels: from local to international (EPA 2012).

Responses that have originated in the recent years do not deal with each of the park's priority issues to the same extent. For example, there are still advances to be made with respect to the conservation status of the park in connection to recently modified laws. This remains one of the most serious issues that is yet to be resolved, and a vital step for the creation of a more favourable legislative and administrative environment for the park. Water quality remains another complex matter in which plenty of space for improvement remains. Some punctual examples of improvement exist. The park management has worked on improving authorization procedures for water disposal from aquaculture installations, so as to reduce the frequency of unreported activity. Further, different aquaculture installation types are dealt with separately, according to the intensity of their activity, through specific controls and regulations (Junta de Andalucía 2004b). However, as pointed out before, a number of water bodies within/surrounding the area are still in a 'bad' condition according to WFD standards, and deadlines for meeting requirements have been extended.

Other issues have been counteracted by numerous actions, of which the longer-term effect is still to be evaluated. The sustainable development of the park's sectors has been met by interest from small groups that have recognized the unexploited potential of the park. In 2011, an important step was made in this direction when a group of entrepreneurs launched the SPINVERDE project, with the aim of activating and supporting business ventures based within the park. Supported projects are meant to be connected to university research and should fall under Green Economy standards as defined by the OECD and Eurostat. Meanwhile advances have already been made on the commercial side. New regulations such as Decree 352/2011 of the 29th of November, that regulates the artisanal

food industry in Andalucía now allows the branded commercialization of salt and aquaculture products, certifying and guaranteeing their origin, as well as their natural, controlled and artisanal production. Fairs promoting these products are also being organized within the park grounds.

Action also originates at local levels, from within specific salina plots. The privately owned San Vicente salina in San Fernando, is one ancient plot in which traditional methods of extraction are practiced and branded gourmet salt products (e.g. flower salt, sea foam salt) sold. Additionally educational and gastronomical visits, are organized within its grounds, with the aim of promoting local culture and knowledge. In additional the Esperanza Chica, Esperanza Grande and San Jose del Palmar salinas in Puerto Real, are already synonymous with an appreciable environmental quality and are being used for research and educational purposes. Activities are coordinated through collaborative efforts of the local university and the original salineros (individuals who have worked in the sector) and fall under the implementation of the European INTERREG-SAL project for the revaluation of Atlantic artisanal salinas. Although extraction is currently on hold here, the plots are intended for younger entrepreneurs who are interested in reactivating the production cycle under sustainability principles, and for the commercialization of salt, fish, microalgas etc.

The valuation of these plots for commercial purposes, and responses that act towards their regeneration also contribute to the park's ecological components. Assuming that active salina plots offer suitable feeding habitats for various protected bird species, the restoration efforts by regional authorities in at least 18 salina plot should be a positive contribution towards the park's ecological integrity. Conservation measures are also implemented in industrial scale salinas as is *La Tapa* in el Puerto de Santa Maria (e.g. control of water levels to accommodate flamingo colonies).

Meanwhile culture, public use and participation have been a favorite subject counteracted by numerous initiatives. This includes the recent rise of alternative forms of tourism; another emergent sector that aims at valuing the park's potential cultural services. Different examples include: sustainable nautical tourism, cultural tourism, active tourism and ornithological tourism. Various efforts from different levels, aiming at supporting these sectors, can be reported. The municipalities around the park have collaborated with tourism related regional administrative bodies, to improve, in terms of possibilities and quality, the offer of nautical activities to new visitors of the area. New private companies are also starting to offer novel cultural activities within the park area: guided educational visits, archeological workshops, site-specific theatre and more. Active tourism is another sub-sector of high potential. In this respect, in the last years regional administrative bodies have reformed numerous pathways within the park; facilitating access and providing basic infrastructure:



signposts, information boards and bird-watching towers. Here too, small private groups are starting to offer activities as are organized bicycle or boat trips. Sustainability is frequently enlisted amongst the characteristics of these activities. Care must be taken to avoid the abuse of the term 'sustainable' solely for promotion purposes and appropriate controls must be implemented to ensure its real practice (Ruiz Navarro and Bueno Corpas 2012). In this respect, the park has also joined the European Charter for Sustainable Tourism in Protected Areas: an initiative of the EUROPARC federation, that promotes the development of sustainable tourism within protected areas, offering guidance to managers of such spaces and companies wishing to invest funds and efforts into such initiatives (Junta de Andalucia 2006).

Meanwhile most recent response actions proposed by the park administration may be found within the 2013/4 Work Plan. These responses are the results of a SWOT (Strengths, Weaknesses, Opportunities, Threats) and an MCEA (Maintenance, Correction, Exploration and Adaptation) analysis and are linked to one of four main objectives: (i) guaranteeing an adequate administrative and technical backbone (ii) conservation of habitats and populations of special interest (iii) development of sustainable economic activities, and (iv) public use and participation. Clearly these objectives are a good match to the DPSI issue discussed above.

At the administrative level, the park aims at achieving better integration of its efforts with those of other governing and managing bodies with links to the fishing, aquaculture and coastal management. Further it aims at working in favour of the implementation of integrative legislation as is the Law 7/2007 of the 9th of July Integrated Management of the Environmental Quality, as well as a more defined interpretation of Law 2/2013 by concerned authorities so as to clarify ownership issues with respect to privately owned areas that overlap footpaths and recreational areas within the park. Further some areas where different land-uses co-exist require a revised Land-use Management Plan. In technical terms, advances within the park's GIS are required.

With respect to conservation, the structural and functional restoration of more of the park's salinas remains a priority. Other important targets that require attention include: the socio-economic evaluation of the park's services, the creation of buffer zones around the protected areas and the study of natural dynamics of the territory to support the efficient planning of restoration work, thus avoiding futile work. With respect to water systems, some expected initiatives that should be implemented include: systemic reporting of illegal polluting discharge sources, exploration of innovative water management mechanisms with the involvement of more public/private bodies and preventive measures taken during land works in the territory to minimize effects on sedimentary processes (Junta de Andalucia 2013b).

As for the creation of sustainable economic opportunities, existing traditional sectors require improved regulation and control measures. Such is the case for clandestine shell fishing activities. Further, the acceptance of such measures by local inhabitants should be supported through public participation and education. Meanwhile, support of emerging sectors is encouraged. Examples include that of a currently developing project based in a sewage plant in Chiclana de la Frontera, sponsored by a international consortium of business companies, which is targeting the use of nutrients from waste water to grow algal biomass destined for biodiesel and biogas production (Ruiz Navarro and Bueno Corpas 2012).

Conclusions and future considerations

The two conceptual maps presented above, along with their reviews, fulfill our intention of gaining insight into the system studied, by generating a graphical and comprehensible representation of a real life situation. The multi-level perspective provided demonstrates the adaptability of the original DPSIR framework, allowing the user to obtain both a general outlook as well as a deeper comprehension of a more specific issue. Additionally, the inclusion of expert opinion, proves to be an effective approach for filtering out less significant elements, and is a positive step during the initial stages of any research project.

The conceptual frameworks designed are highly descriptive but focus on representing elements that are targetable through smaller-scale and shorter-term plans. Global-scale pressures such as climate change and sea-level rise are still considered of great importance but are unrepresented here as they fall outside the scope of the study, and fall under competences of larger-scale, longer-term, international initiatives.

The review presented in this paper hopes to serve as a base for future initiates involving in-depth assessments through the use of environmental, social and economic indicators used to supply qualitative and quantitative information. Indicator use can range from; the use of one indicator to indirectly indicate another phenomenon (e.g. biological disruption as indicator of land degradation), to the use of multiple indicators as in multicriteria decision making, or the creation of composite indicators (Brouwer et al. 2003). As for models, another proposed assessment tool, there is also variability. Activity models relate socio-economic drivers to nutrient, toxin and sediment fluxes (pressures); natural systems models provide insight into the dose-response relationship by linking flux (pressure) information to habitats, ecosystem and human well-being (state, impacts and responses); and valuation models look into costs, benefits and trade-offs information through the use of monetary (or other) value linked to system elements and processes (Turner 2000).

Finally these frameworks also hope to support the search for data resources; as well as identify data gaps. With respect



to the Bahía de Cádiz N.P. available longer-term data sets include birdlife census records going back to 1985/6, as well as freely accessible aerial photography and satellite imagery dating backwards to up to 1956.

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Chapter 4. Land-cover and land-use analysis using remote sensing and GIS technologies

Whilst aiming at answering Hypothesis 2, this chapter provides results that document the land-use and land-cover changes (LUCCs) that have characterized the study area over the past 25 years. The work is presented in article format entitled:

'Land-use and land-cover change analysis in predominantly artificial coastal wetlands: proposing a methodological framework'

This article has been submitted to the journal Wetlands Ecology and Management.

As explained in previous chapters the landscape changes tied to salt extraction and aquaculture developments within the park area are important influences on the area's ecological integrity. The work presented in the following article provides a qualitative and quantitative examination of these changes.

LUCC analysis for the entire park area was performed through the combination of remote sensing and GIS technologies. Through the classification of freely available Landsat imagery, land-cover maps for the 1985-2011 period were produced. Subsequently, these maps were overlain by land-use data in a GIS environment resulting in combined land-use and cover data. These processes permitted the quantification of LUCCs.

Further this study resulted in the following outputs:

- On the basis of the designed methodology, a work-scheme for routine monitoring of the landscape changes of the study area, was proposed. The method's applicability is also extendable to landscape studies of all wetland/marsh areas of a predominant artificial nature. Moreover its low attributed costs facilitates its accessibility.
- The resulting GIS database also allows for integration and analysis of all types of spatial datasets tied to the area, hence opening numerous future research possibilities.
- The resulting digital maps are also intended for upload onto the online Andalucian environmental information network, REDIAM (Red de Información Ambiental de Andalucía):

http://www.juntadeandalucia.es/medioambiente/site/rediam.

This network would provide free visualization and download possibilities of these maps.

Wetlands Ecology and Management

Land-use and land-cover change analysis in predominantly artificial coastal wetlands: proposing a methodological framework --Manuscript Draft--

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Land-use and land-cover change analysis in predominantly artificial coastal

wetlands: proposing a methodological framework

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Abstract

In areas with a long history of human occupation, coastal wetlands have undergone extensive modification to accommodate extractive activities as salt extraction and aquaculture. These habitats, know as artificial wetlands, maintain some of the ecological functions of natural wetlands in spite of their artificial character. Their suitability as complimentary waterbird habitat is one of their best documented functions. As we found limited information on the applicability of remote sensing and GIS techniques for the study of land-use and land-cover changes in such habitats, we aimed at filling this gap by testing these methods on the mixed natural and artificial salt marsh complex within the Bahía de Cádiz Nature Park (Spain). Using Landsat imagery spanning the 1985-2011 period, natural and artificial marsh areas were classified separately and results merged to produce land-cover classification maps. Different change dynamics were observed for the natural and artificial areas, the latter exhibiting prominent changes, including widespread vegetative succession. Further, through the overlay of ancillary land-use data for 2011, an integrated land-use and cover map was produced for this year. Different scenarios arising from the abandonment of extractive activity and structural negligence were highlighted. Furthermore, a methodological framework for the classification of wetlands of considerable artificial coverage was designed. The method is cost-effective and open for integration of additional datasets, considered a beneficial resource for conservation and land-use management. Its applicability for monitoring of landscape change not only pertains to the study area, but also extends to other coastal wetland areas of a similar combined natural-artificial nature.

Keywords

Artificial wetlands, Land-use and land-cover; Change detection; Landsat; GIS; methodological framework

1. Introduction

Wetlands stand amongst the most threatened natural habitats, with global coverage losses estimated at 50% during the last century (Perennou et al. 2012). These trends are expected to be highly accentuated in coastal zones which accommodate close to half of the global population (Olsen 2000) and where anthropogenic pressures, including landreclamation or water abstraction, are more intense. Such is the case of the Mediterranean Basin, where a long-history of human occupation has lead to extensive loss and degradation of natural ecosystems. Approximately 50% of natural wetland coverage is estimated to have been lost in this region throughout the 20th century, in parallel to global trends (Airolodi and Beck 2007; Perennou et al. 2012). Interestingly Perennou et al. (2012) suggest that of the remaining wetlands in this region, circa 23 % are classified as artificial wetlands, these consisting of human-made structures built out of the natural wetlands to accommodate extractive activities. These include saltpans, aquaculture ponds, rice fields and water storage ponds (EEA 2013; Ramsar Convention Secretariat 2012). In spite of their artificial nature, these structures maintain physiochemical, biological and landscape attributes by which they preserve, to a lesser or greater degree, some of the ecological functions of natural wetlands. One of the best documented of these functions is that as waterbird habitat for feeding, breeding and roosting purposes (Ma et al. 2010; Sadoul et al. 1998; Tourenq et al. 2001). In sight of this, adequate management fit for these specific habitats is needed in the sphere of wetland conservation.

The quantification of surface area occupied by different wetland classes and the measure of change undergone by these classes provides fundamental information in the process of gaining in-depth understanding of the effects of loss, degradation or modification on wetland ecosystem services (Perennou et al. 2012). Remote sensing tools and resources have become increasingly important in supporting this purpose, being applied in projects of all scales to support monitoring, planning, assessments and decision-making (Rebelo et al. 2009). Further in wetland studies these methods offer information on water body depth and optical quality (Lymburner et al. 2007), as well as on the extent and the qualities of different vegetation classes (Adam et al. 2010); these being important indicators in the environmental assessment of these habitats. The popularity of use of these methods is based on their applicability over large geographic areas and considerable time-scales, offering cost-effective and time-saving support to

conventional field surveys. Further, their digital outputs make results easy to integrate into GIS (Geographical Information Systems) for advanced analysis (Adam et al. 2010; Bortels et al. 2011; Hurd et al. 2006; Jensen 1996; Ozesmi and Bauer 2002; Teferi et al. 2010). Generally, such studies are also supported by ancillary data which includes any type of spatial or non-spatial information that supports the classification process, including: field observations, interview data, aerial or terrestrial photography, Digital Elevation Models (DEMs) and maps of all kinds (De Mûelenaere et al. 2012; Jensen 1996; Rebelo et al. 2009).

In spite of the vast amount of landscape related research supported by remote sensing methodologies (Bortels et al. 2011; De Mûelenaere et al. 2012; Ozesmi & Bauer 2002; Sripanomyom et al. 2011) we found limited information on their specific applicability to artificial wetlands. Through this study we aimed at filling this gap by testing these methods for the analysis of landscape changes in wetlands that have undergone extensive modification to accommodate human activities. In doing so landcover (physical and biotic character of the land) and land-use (human employment of the land) were considered as interacting components of landscape change (De Mûelenaere et al. 2012). In support of this objective, the salt marsh complex within the Bahía de Cádiz Nature Park (BCNP) was considered an adequate study site for a number of reasons. This protected area consists of mixed natural and artificial marshland, the latter accommodating traditional salt extraction and aquaculture activities. The land-use and land-cover changes (LUCCs) marking these artificial marshes have been frequently observed (Camilleri et al. 2014; Castellanos et al. 2004; Yufera & Arias, 2010) but never mapped or analyzed through the integration of remote sensing and GIS methods as is being considered here. Routine monitoring of LUCC patterns would benefit the park's management through the provision of valuable landscape data. Additionally this data would contribute to conservation of the park's inhabiting waterbird populations, for which it holds international importance and is a declared Ramsar site (Junta de Andalucia 2004). All considered, the specific objectives undertaken here included: (i) the integration of multi-temporal remote sensing data analysis and GIS methods, for land-cover and land-use classification and change detection (ii) designing an methodological framework appropriate for routine monitoring of the study area, and also applicable to other wetland areas of a similar highly artificial nature.

2. The study site: the Bahía de Cádiz Nature Park

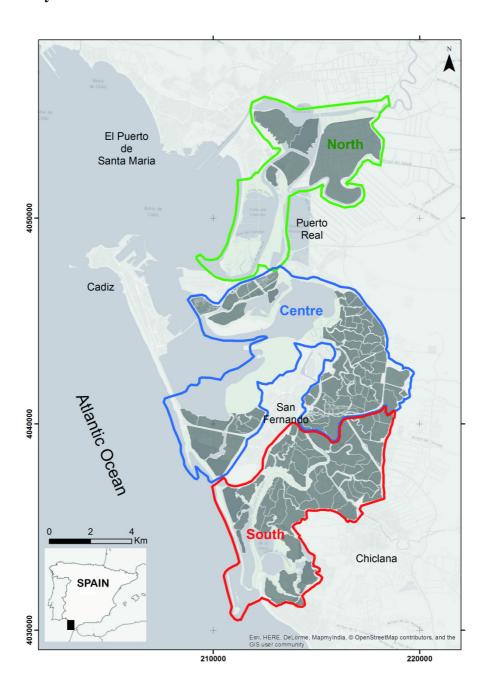


Fig 1 Location of the BCNP. Park boundaries are marked by the three sections (North, Centre, South) created here to facilitate result interpretation in later sections. Darker grey sections within these boundaries represent artificial marsh areas.

The tidal marsh complex encompassed by the BCNP is found on the southwest Atlantic coast of the province of Cádiz (Spain), between 36° 22′ to 36° 37′ N and 5° 7′ to 6° 16′ W, with an extension of 10,522 ha (Ramsar 2012) (Figure 1). The climate here is Mediterranean with an annual mean temperature of 17.8 °C and mean rainfall of 650 mm. It is also predominantly bi-seasonal: hot summers and temperate winters. Further,

the area is influenced by strong winds, a semi-diurnal mesotidal regime with a range of 3-4 m and a high average annual sunshine rate (Lobo et al. 2000).

Although it consists of a diverse range of habitat types (beach, dunes, temporal lagoons etc.), the park is strongly characterized by its extensive intertidal mudflats and its supratidal natural and artificial salt marshes. By the late 1800s more than half of the original natural low/high marsh, had been transformed into salt extraction ponds and canals (*salinas*¹), these making up the so-called artificial marsh (Camilleri et al. 2014). As the salt extraction sector lost its economic viability these structures were adapted for other uses. Mainly, ponds were dug deeper and larger to be used for extensive aquaculture, taking advantage of fry carried inward by incoming tides. Later on (late 1900s/early 2000s) some areas underwent stronger transformations into semi-intensive aquaculture ponds and industrial-scale salinas (Yufera & Arias 2010). In other sections of the park, a considerable number of salinas were abandoned and as result of inactivity and poor maintenance, wall rupture and exposure to tidal flooding followed, resulting in a range of scenarios ranging from permanent dryness to sediment accretion and vegetative secondary succession (Clares Sánchez 2004).

Despite these transformations, these artificial structures are still classified under the park's protected marshland, and having been created from the same marsh substrate, containing water bodies at controlled levels and being periodically exposed to tidal regimes, they are still able, to some degree, to accommodate marsh ecosystems/communities (vegetation, macrophytes, fish and waterbirds) thereby contributing to the area's ecological integrity (Camilleri et al. 2014; Junta de Andalucia 2004; Pérez-Hurtado & Hortas 1992).

3. Materials and Methods

3.1. Data

Landsat images were ordered free of charge via the US Geological Survey (USGS)

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¹ A typical salina is made up of a series of interconnected ponds, of decreasing depths, through which seawater flows. As water evaporates, aided by sun and wind forces, salinity increases until salt crystals result in the final compartments.

Centre for Earth Resources Observation and Science (EROS) (USGS 2013). Available imagery was first reviewed according to the following criteria:

- i. Good quality: images selected had low cloud cover and were free of noise and distortion e.g. striping
- ii. Representation of distinct moments of the area's phenological cycle characterized by (i) biophysical characteristics of vegetation, soils and water ecosystems; (ii) salt and aquaculture production cycles. Images were selected to represent the *wet* and the *dry* seasons, during which both natural elements as well as production cycles were at distinct phases. For inter-annual comparability, an attempt was made to select images from proximate dates.
- iii. Representation of low tide moments with a major exposure of land surface area as suggested in Hurd et al. (2006) and Jensen (1996). The predicted tide level corresponding to the images' acquisition time, was extracted using the WXTide32 tide calculator (WXTide32 2007). An attempt was made to select images with as much of a comparable tide level as possible.

The final selection of six images were acquired from remote sensor systems with bands of equivalent temporal (16 day revisiting time), spatial (30m x 30m), spectral (0.45 - $12.5 \,\mu m$) and radiometric (8-bit) resolutions (EOPortal 2014). PAN and TIR bands with differing characteristics were not utilized. Metadata and tide levels for these images are summarized in Table 1.

		1985	2000	2011
-	Satellite & Sensor	Landsat 5 TM	Landsat 7 ETM+	Landsat 5 TM
Wet Season	Acquisition	March 5 10:33 a.m.	Feb 3 10:55 a.m.	Feb 9 th 10:52 a.m.
	Tide level	-0.45m	-0.25m	-0.52m
	Satellite & Sensor	Landsat 5 TM	Landsat 7 ETM+	Landsat 5 TM
Dry Season	Acquisition	August 12 th 10:32 a.m.	July 12 10:54 a.m.	Sept 5 10:51 a.m.
	Tide level	+0.1m	+0.1m	+0.5m

Table 1 Metadata for the selected satellite images and predicted tide levels at acquisition time

Additionally, the following ancillary data was acquired:

- A Web Map Service Panchromatic Orthophoto of 1984/5 accessed from REDIAM (2013)
- ii. Aerial orthophotos from November 1956, July 1998, August 2001, June 2004, July 2007, August 2009 and June 2010, from Junta de Andalucia (2013)
- iii. Historical imagery from Google (2013)
- iv. Chartaceous and digital land-use maps, plus other related land-use information obtained through expert interviews with the park's administrative body and other stakeholders from regional agencies
- v. Zonation and geomorphologic maps of the park from Junta de Andalucia (2004)
- vi. Ground truth data
- vii. Local temperature and precipitation data, corresponding to the years of the images, obtained from the national meteorological agency AEMET (2013) and Hernández Armenteros (2002) (synthesized in Annex I).

3.2. Method

The following steps describe the method developed, further illustrated in a step-by-step workflow in Figure 2. All processing and analysis was carried out within ENVI 4.7. and ESRI ArcGis v. 10.1.

3.2.1. Pre-processing considerations

The comparable acquisition times for the six images signified a reduced possibility of anomalies in reflectance values caused by sun angle effects. Additionally, all the acquired images came with an L1T correction level which includes radiometric, geometric and precision correction. In these images, the WGS84 ellipsoid had been employed as the Earth model for the Universal Transverse Mercator (UTM-29N) coordinate transformation.

Atmospheric correction was therefore the only pre-processing required, for minimizing the influence of dispersion and absorption by atmospheric molecules, aerosols and reflective objects. The FLAASH tool (ENVI) was used for this purpose. This tool applies algorithms extracted from the MODTRAN model (ITT Visual Information Solutions 2009). Initially the conversion of the digital numbers (DNs) into

radiance was required. This conversion, repeated for all the single band files, is a very important step for eventual analysis as is the calculation of vegetation indices (Teferi et al. 2010). The atmospheric correction was then performed using the Sub-Artic Summer Atmospheric Model and the Maritime Aerosol Model. Output images provided reflectance values.

3.2.2. Classification and accuracy assessment

Trial classifications were performed applying a variety of unsupervised and supervised classification algorithms. Different parameters were tested (spectral subset, spatial subset and number of classes). For supervised classifications, training ROIs (Regions of Interest) for classification and reference ROIs for subsequent accuracy testing, were selected from classes identified through the park's geomorphological map. Because of the unpredictability of the state of artificial areas, these ROIs, were selected from natural areas with a recognized stable state. The CORINE² (Coordination of information on the environment) land-cover classification system was also used as a reference (EEA 2013).

Resulting classification maps were evaluated visually through comparison with available aerial orthophotos and Google Earth imagery. The best classifications were obtained with the maximum-likelihood classification algorithm (Naumann 2008) using the blue band (band 1, 0.45- $0.52\mu m$) for water-body penetration; the green band (band 2, 0.52- $0.56\mu m$), the red band (band 3, 0.63- $0.69\ \mu m$) and the near-infrared (IR) band (band 4, 0.76- $0.9\mu m$) all of which are important with respect to vegetation discrimination and vegetation biomass; and the short-wave IR band (band 5, 1.55- $1.75\mu m$) due to its ability to discriminate vegetation and soil moisture, and its ability to distinguish between wetland types (Jensen 1996). Further, the masking of non-marsh areas (mainly agricultural and urban areas) external to the park boundaries was found to reduce confusion within results. The resulting classes were: (1) *Seawater* (2) *Intertidal flat* (3) *Low marsh* (4) *High marsh* and (5) *Beach / Sand plain*.

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²The CORINE program is a European Union initiative for the coordination of environmental information. One of its initiatives includes the production of an inventory of land-cover in 44 classes, presented as a cartographic product at a scale of 1:100 000 and operationally available for most areas of Europe.

Following, accuracy assessment was performed for each classification map, resulting in an error matrix which compares the classification result with reference ROIs for each class. Other accuracy assessment results included the producer's accuracy which refers to the probability that a reference pixel belonging to a certain land-cover class on the ground is classified as such, and the user's accuracy which refers to the probability that a pixel labelled as a certain land-cover class in the map really belongs to that class (Jensen 1996; Liu et al. 2007). The overall accuracy and kappa (K) coefficient analysis values were also calculated. The K-coefficient is sometimes preferred as a standard measure of classification accuracy due to its compensation for chance agreement (Foody 2002). K-coefficient values can range from -1 to +1, with positive values showing positive correlation between classification results and reference data. Landis and Koch K-value groupings consider values greater than 0.80 as representing strong agreement, values between 0.40 and 0.80 as representing moderate agreement and values below 0.40 as representing poor agreement (Teferi et al. 2010).

3.2.3. Reclassification of artificial marshland

Some important considerations were made at this stage. Firstly, only wet season images were considered for all subsequent analytical stages as it was seen that these gave better representations of certain land-cover types. Further, it was noted that maximum-likelihood classification results were most reliable for natural areas, and further treatment was required to classify the artificial areas separately. In order to gain more insight into the relation of classification results to remaining artificial areas, a ground truth survey was organized during March 2014. A total of 25 artificial areas were visited. Collected photographic material and written observations were then contrasted to image analysis results. This confirmed that artificial marsh areas needed to be reconsidered through a separate classification.

During subsequent analysis, an ancillary land-use vector polygon marking the border of all the salina properties was used to stratify the total park area into two sets: natural areas and artificial areas. Natural areas were masked and trial classifications were once again applied to remaining artificial marshland, evaluating results against available aerial photography. The ISODATA unsupervised classification (Memarsadeghi et al. 2007) was found most suitable this time. The same spectral subset

as in maximum-likelihood classification was utilized. Classification results were then analysed against available aerial photography.

Further, to facilitate the characterization of these artificial classes, false colour imagery using the 4,3,2 and the 4,5,3 band combinations were produced. The first is the standard false colour composite that is frequently used for vegetation studies and by which vegetation appears in shades of red which varies according to factors as is density. As for the 4,5,3 combination; this offers added definition to land-water boundaries with wetter areas acquiring darker hues because of the IR absorption of water (Quinn 2001). In addition, the Normalized Difference Vegetation Index (NDVI) was calculated using the standard formula:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$
 (Tucker 1979)

where NIR and RED stand for the spectral reflectance measurements acquired in the near-IR and visible red regions respectively. In particular the index makes use of the IR band as it provides sensitivity to variations in vegetation biomass and moisture content in vegetation and soil (Jensen 1996). In the corresponding images each pixel represented an NDVI value ranging from -1 to +1. Pixels with values below 0.1 and of a lighter colour are known to represented areas with no vegetation, moderate values (0.2-0.3) are typical of grass covered surfaces and intense colour pixels with 0.6 - 0.9 values are indicative of high density vegetation (Weier and Herring 2000).

Following an analysis of these results, five new classes were identified: (1) Water body (2) Inundation/Small water bodies (3) Vegetation Type 1 (4) Vegetation Type 2 and (5) Bare and dry surface.

Ground truth observations, orthophotos, false-colour and NDVI images, were used to select reference ROIs for each of these new classes, against which the accuracy of the classification was tested. Although, the selection of reference data using mixed methods and materials is sometimes considered as a less accurate method when compared to a 100% ground truthing based procedure, this method is a very practical option when working with classifications of past imagery (Rozenstein and Karnieli 2011).

3.2.4. Post-classification change detection

Post classification change detection analyses were run for classification results in both natural and artificial areas. This is the most commonly used method for change detection, involving a pixel-by-pixel comparison of two classification maps, resulting in maps and matrices that summarize the changes (Jensen 1996).

3.2.5. Creation of land-cover maps

The separate classification results for the natural and artificial areas were vectorized for use in ArcGis. The pixel set relative to each class was converted into a singular polygon feature class. A total of ten polygon feature classes resulted. Following, the Merge (Data Management) tool was used to combine all ten natural and artificial classes (and their attributed data) into a single polygon feature layer. This step was necessary to facilitate the quantitative analysis of class attributes. Further, a manually drawn polygon representing roads and urbanization within the park area was added. This kind of combination of auto-classification and manual labeling is recognized by Song et al. (2012) as often being, a most accurate approach in the generation of land-cover and land-use maps. Next, the PAEK (Polynomial Approximation with Exponential Kernel) smoothing algorithm within the Smooth Polygon (Cartography) tool was used to reduce the pixilated effect, thus improving the aesthetic quality of the maps. The outcomes were checked and corrected for topology. This gave the final land-cover maps for 1985, 2000 and 2011 (wet season).

3.2.6. Land-use and cover integration

Three land-use polygon feature classes for the three studied years were updated with land-use information as corresponding to each salina plot. Land-use categories included: (1) Artisanal salt extraction (2) Industrial salt extraction (3) Shellfish culture (4) Extensive aquaculture (5) Semi-intensive aquaculture (6) Urban and (7) No activity.

Using the Union (Analysis) tool from the Overlay toolset, a geometric union of the land-cover and land-use class features for each respective year, was computed. All the land-cover and land-use attributes were written to the output feature class. Once more this step was required to facilitate the quantitative analysis of class attributes. Further land-use and cover maps were generated.

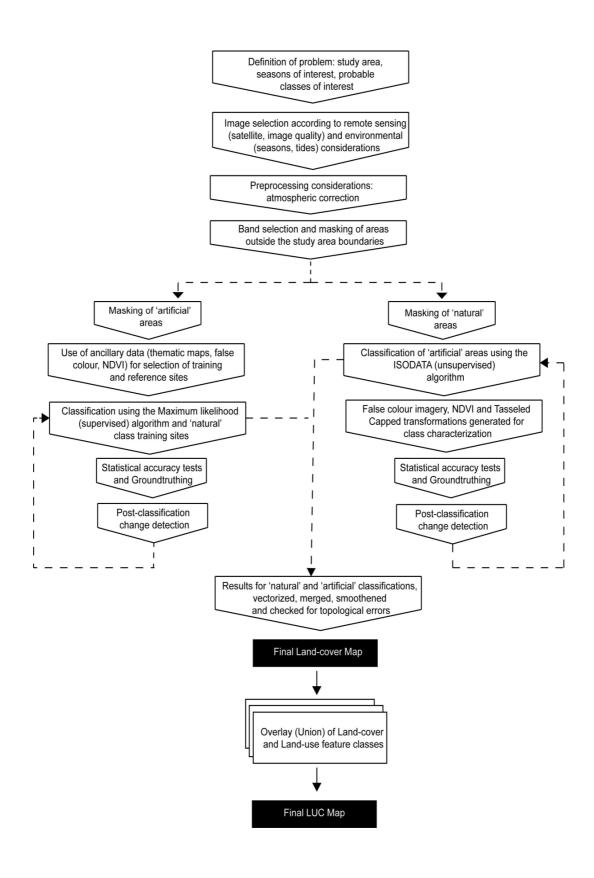


Fig 2 Workflow describing the developed methodology

4. Results and Discussion

4.1. Land-cover results

The merged results for the maximum-likelihood classifications for natural areas and ISODATA classifications for artificial areas are presented in Figure 3.

In the North area, two significant trends were observed with respect to the natural areas. Firstly, a change of proportion of *Low marsh* to *High marsh* was noted in the Los Toruños area when contrasting the situation in 2011 with that of previous years. This change was attributed to the re-opening of channels (previously obstructed by a constructed footpath) meant to restore the natural hydrodynamics of the natural marshland. As for the increased size of the sand spit (*Beach/Sand plain*) south of this same area, this was attributed to the restored river flow and increased sediment transport, following the re-opening of a lost upstream connection. Both restoration measures took place in 2004 (Pérez-Hurtado pers. comm), and therefore were evident in the 2011 map. In both cases the -27cm tide difference between the 2000 and the 2011 image, was considered a possible contributor to the observed changes.

With respect to the artificial areas in the North, the most evident change was observed between 1985 and 2000 in the top-right area of Los Toruños, where vegetated and dry patches of land (*Vegetation Type 1*, *Vegetation Type 2*, *Bare and dry surface/Urban*) changed towards the cover classes *Inundation/Small water bodies*, and to a larger extend to *Water body*. Comparison of the classification results with aerial photography confirmed that the *Inundation/Small water bodies* class was a mixed one composed of mixed surfaces typical of semi-intensive aquaculture made up of a surface of alternating canals and walls. It was also typical of areas with scarce to no vegetation cover (as confirmed by NDVI values of 0.25-0.35 - See Annex II) and shallow inundation. In both cases the water/land mixed surface falling within the satellite's instantaneous field of view resulted in mixed pixels (Ozesmi and Bauer 2002). As for the *Water body* class, it corresponded to more extensive water laminas, giving rise to pixel signatures representative of a 'purer' class.

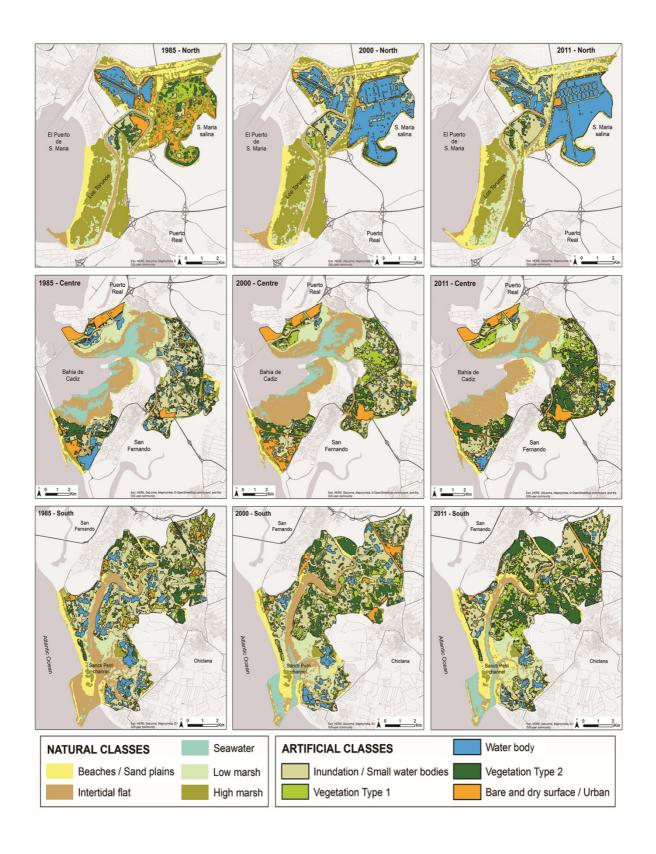


Fig 3 Land-cover classification maps for 1985, 2000 and 2011 divided into North, Centre and South sections to aid interpretation.

As for the Centre, the natural areas in this zone were dominated by *Intertidal flats*. A progressive increase in the size of these flats was noted through the years of the study. This tendency was also present between 1985 and 2000 despite the +0.25m tide difference, whereby the increased waterline would be expected to give a reduced coverage of the flat. This trend was also supported by the reported accumulated sedimentation of 0.2 cm/ year in this area (Ligero et al. 2002).

Meanwhile, artificial inundated environments in the centre section were largely replaced by vegetation (*Vegetation Type 1* and *Vegetation Type 2*) throughout the study period. Aerial photography confirmed that the inundated state of 1985 represented water-filled compartments of active ponds. Meanwhile the densely vegetated state of 2011 corresponded to structures where little to no extractive activity and poor maintenance, have led to wall rupture, continued exposure to tidal fluctuation, sediment accretion and vegetative secondary succession³ (Castellanos et al. 2004). The mean NDVI values for these two vegetation classes provided further detail about their characteristics⁴. In all three images *Vegetation Type 1* was characterized by lower NDVI values (0.36-0.58) than *Vegetation Type 2* (0.60-0.64), the higher values referring to greater vegetation densities. NDVI values are given in Annex II.

Of particular interest was the case of a salina situated at the southernmost tip of the 'Centre' section which was inundated in 1985 possibly due to ongoing extractive activity, dried up in 2000 - a probable result of inactivity, and re-inundated in 2011. The 2000 to 2011 re-inundation scenario was found to reflect conservation works carried out in 2004, whereby this salina's hydrodynamic regime was restored with the aim of providing new habitats for waterbirds (Pérez-Hurtado pers. comm).

For the natural areas in the South section, situated along the right bank of the Sancti Petri channel, the proliferation of *Low marsh* vegetation was considered plausible. This area classifies as Zone A i.e. areas with the highest protection level, where no human activity is permitted. The observed trend was considered a possible sign of the improved health of this marsh patch, as a result of conservation measures. Further, the

³Secondary succession refers to vegetation colonization processes occurring over barren surfaces which are however sufficiently stable and contain nitrogen, phosphorus and a seed bank from communities that previously occupied the same substrate.

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⁴ Given the atmospheric correction applied to the three images, the index values extracted for each image may be considered comparable, although the different sensor corresponding to the year 2000 might introduce variability.

sedimentation rates of 0.7-1.1 cm/year along this channel reported in Ligero et al. (2010) supported this trend of increasing marsh vegetation. Meanwhile, a progressive sprawl of *Vegetation Type 1* and *Vegetation Type 2* (previously noted for the artificial marshes in the Centre section) was also observed over the artificial marsh in the South (as noted previously for the Centre zone).

Aerial photography confirmed that the *Bare and dry surface* class had to be interpreted with care as this class represented saline or barren grounds within the park, but also urban elements that that have grown around the park boundaries: new roads, rail and tram lines, water treatment plants, industrial polygons and port infrastructure. Both surfaces gave rise to similar spectral signatures and were not distinguishable through the land-cover maps.

Accuracy test results for maximum-likelihood and ISODATA classifications for the three wet season images come in the six confusion matrices shown in Table 2. The overall accuracies for the six classifications ranged from 75 to 98 %, whereas K-coefficient values ranged from 0.69 to 0.98. Following guidelines in Teferi et al. (2010), these values indicated moderate to strong classification-reference agreement.

Overall, maximum-likelihood classifications gave the best accuracy results. In these cases, minimal error (7-12%) was generated by misclassification of *Seawater* or *Low Marsh* pixels under *Intertidal flat*, or vice versa. Most of this error was expected to be generated from confusion at boundary areas, as the separation of these three classes tends to be subtle and undefined, especially due to tidal fluctuations.

A greater degree of confusion resulted from the ISODATA classifications. The misclassification of *Vegetation Type 1* pixels under the *Vegetation Type 2* class was recurring for the three years. For these classes, producer accuracies fell to the lowest levels (13.24% for *Vegetation Type 1* in 1985 and 35.29% for *Vegetation Type 2* in 2000), indicating that the error was highly effected by the inappropriate selection of reference sites. For 1985, confusion during reference site selection for *Vegetation Type 1* was related to the low representation of this class during this year. This assumption was also supported by the observed patchiness and low area coverage of the class (Figure 3), as well as by its corresponding NDVI value (0.36) which was relatively lower than it is for the other years.

Table 2 Confusion matrix for the maximum-likelihood classifications for Natural areas and for the ISODATA classifications for Artificial areas in which reference samples (REF) for each class were compared to classification results (CLASS.). Various accuracy (Acc.) measures were also calculated.

Maximum likelihood classification for Natural areas

	1985					2000					2011							
REF. CLASS.	Seawater	Intertidal flat	Low Marsh	High Marsh	Beach/ Sand plain	User Acc.	Seawater	Intertidal flat	Low Marsh	High Marsh	Beach/ Sand plain	User Acc.	Seawater	Intertidal flat	Low Marsh	High Marsh	Beach/ Sand plain	User Acc.
Seawater	90.73	0.44	0	0	0	96.48	88.31	2.22	0	0	0	77.27	98.5	3.42	0	0	0	73.51
Intertidal flat	8.61	97.86	1.54	0.67	0	97.35	11.69	97.72	7.05	0	0	95.86	1.5	86.61	7.94	1.62	2.22	95.13
Low Marsh	0.66	0.98	98.24	0.45	0	98.46	0	0.06	83.72	0.32	0	99.71	0	9.73	87.38	1.08	0	78.41
High Marsh	0	0	0.11	98.22	0	99.77	0	0	2.92	99.68	0	92.79	0	0.14	2.22	96.5	0	94.21
Beach/Sandplain	0	0.71	0.11	0.67	100	96.9	0	0	6.32	0	100	87.96	0	0.1	2.45	0.81	97.78	96.22
Total	100	100	100	100	100		100	100	100	100	100		100	100	100	100	100	
Producer Acc.	90.73	97.86	98.24	98.22	100		88.31	97.72	83.72	99.68	100		98.5	86.61	87.38	96.5	97.78	
	Overall Accu	racy: 97.9402	2% K	K-coefficier	nt: 0.9717		Overall Accuracy: 94.4028 % K-coefficient: 0.9144				Overall Accuracy: 90.0239% K-coefficient: 0.8556				56			

ISODATA classification for Artificial areas

	1985					2000					2011							
REF.	Water body	Inund./ Small water bodies	Veg. Type 1	Veg. Type 2	Bare/dry surface	User Acc.	Water body	Inund./ Small water bodies	Veg. Type 1	Veg. Type 2	Bare/ dry surface	User Acc.	Water body	Inund./ Small water bodies	Veg. Type 1	Veg. Type 2	Bare/dry surface	User Acc.
Water body	98.01	0.59	0	0	0	99.49	100	0	0	0	0	100	99.68	1.16	0	0	0	98.74
Inund./Small water bodies	1.99	99.41	29.41	0	0	79.34	0	72.11	8.26	0.98	0	91.38	0.32	90.46	2.37	0	0	97.81
Veg. Type 1	0	0	13.24	6.27	0	52.94	0	5.44	70.64	63.73	0	51.33	0	8.38	62.45	2.35	0	81.03
Veg. Type 2	0	0	57.35	93.73	0	75.39	0	0	21.1	35.29	0	61.02	0	0	35.18	97.65	0	78.91
Bare/dry surface	0	0	0	0	100	100	0	22.45	0	0	100	73.39	0	0	0	0	100	100
Total	100	100	100	100	100		100	100	100	100	100		100	100	100	100	100	
Producer Acc.	98.01	99.41	13.24	93.73	100		100	72.11	70.64	35.29	100		99.68	90.46	62.45	97.65	100	
	Overall Accuracy: 85.3066% K-coefficient: 0.812				Overall Accuracy: 75.27% K-coefficient: 0.6905				Overall Accuracy: 89.6760% K-coefficient: 0.8655									

As land-cover maps pointed out at sharper changes in the artificial marsh areas, the results of the change detection analysis (1985 to 2011) for these areas were considered most important. These results are synthesized in Table 3. The area in hectares corresponding to two important change types have been highlighted: (i) inundation of extensive areas (changes to the *Water body* class) with an 809 ha coverage (ii) vegetation spread and succession (changes towards *Vegetation Type 1* and *Vegetation Type 2*) in 2394 ha of the park. The change detection map in Figure 4 is a complementary spatial output. This map indicated how the first change was concentrated in the North area, whereas the second change was widespread throughout the Centre and South sections.

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		Water body	Inundation/ Small water bodies	Vegetation Type 1	Vegetation Type 2	Bare and dry surface	Class Total
	Water body	349	132	312	119	246	1158
	Inundation/ Small water bodies	428	943	390	235	197	2192
-	Vegetation Type 1	290	1241	170	285	34	2020
2011	Vegetation Type 2	83	611	169	457	23	1344
	Bare and dry surface	5	38	68	34	65	210
	Class Total	1155	2965	1110	1129	566	
	Class Changes	806	2023	939	672	501	

Table 3 Results (area in hectares) from the 1985 vs. 2011 change detection analysis for artificial areas. Values highlighted in grey represent no-change areas. Values enclosed by a dashed line represent vegetative succession. Values enclosed by a zigzagged line represent inundation.

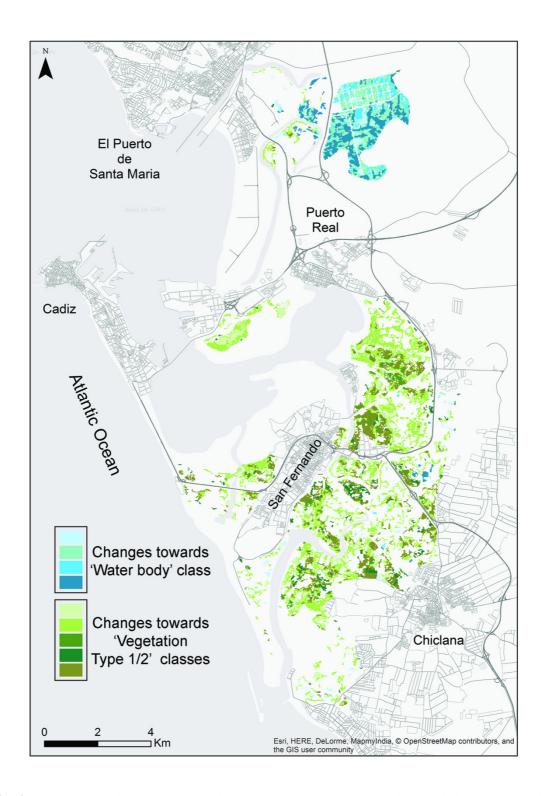


Fig 4 Change detection map illustrating two main change types (i) inundation by extensive water bodies, illustrated by all the changes towards the *Water body* class (ii) vegetation succession, illustrated by all the changes towards the *Vegetation Type 1/2* classes

4.2. Land-use and cover (LUC) map

Because of space limitations, the result of land-cover and land-use data integration was depicted solely for 2011 (Figure 5). Where no active land-use was declared, only land-cover was indicated. As for the overlaying land-use layer, this was depicted by grids and patterns to allow the reader to visualize both information layers contemporarily, revealing a diversity of LUC scenarios.

The widespread inundation in the North area was found to be linked to the development of *Industrial salt extraction*.

Meanwhile, dominant coverage by *Vegetation Type 1* and *Vegetation Type 2* was found to be common for inactive areas, as well as in *Extensive aquaculture* plots (Figure 5a). This observation indicated that vegetation spread is not exclusively linked to abandoned salinas, and is also present in areas where extractive activities are declared. The latter case threw light on a well-known issue whereby plots are frequently declared as productive hence justifying their ownership, but in reality little or no use is given to them. Consequently the lack of maintenance results in structural negligence followed by vegetation sprawl. Other salinas used for *Artisanal salt extraction* and *Extensive aquaculture*, had a mixed *Vegetation Type 1* and *Inundation/Small water bodies* cover, evident of proper maintenance.

We also found different land-cover scenarios in different inactive areas (Fig 5b). For these cases, the land-cover status was considered indicative of the time span a salina plot was abandoned for. Plots covered by a dense *Vegetation Type 2* cover are probably those in which activity has ceased since many decades. In other no-activity areas, classified under *Inundation/Smaller water bodies*, the abandoned state is probably younger and the original pond structure is still intact.

Further, Figure 5c contrasts active and inactive areas all of which are characterized by considerable inundation. In the former case inundation was found to reflect aquaculture activities. On the other hand, inactive and inundated areas corresponded to sites where low maintenance had probably resulted in the breaking of walls and continuous flooding, due to proximity to the opening of the Sancti Petri channel.

In this map *Urban* components, including roads and industrial polygons, were differentiated from the *Bare and dry surface* cover type.

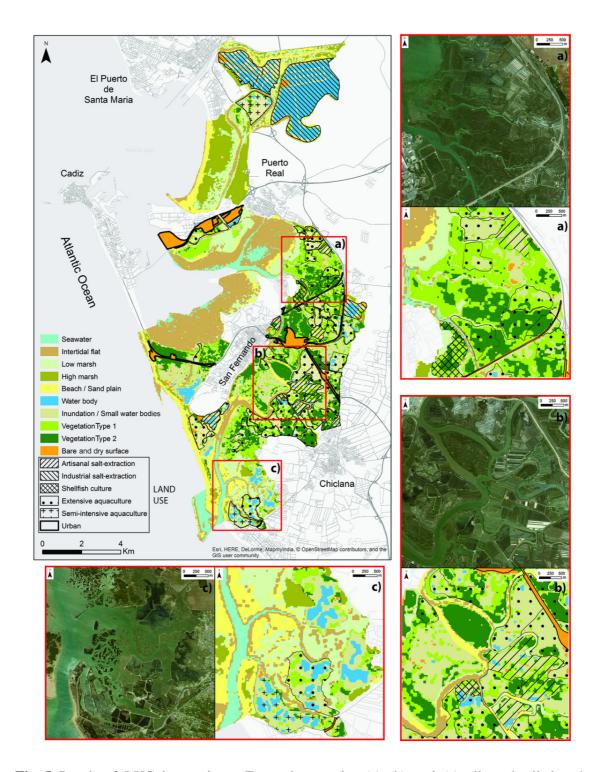


Fig 5 Result of LUC integration. Zoomed examples (a) (b) and (c) allow detailed and simultaneous examination of both land-cover and land-use layers. For each example, the corresponding area from a high resolution 2010 orthophoto is shown to aid interpretation.

4.3. Land-cover and LUC area coverage

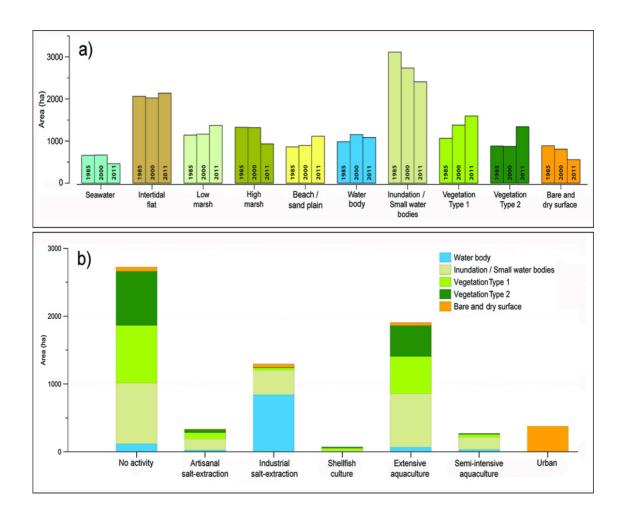


Fig 6 Areas (ha) relative to land-cover classification and LUC maps in Figures 3 and 5. The histogram in (a) indicates the surface area relative to each land-cover class for 1985, 2000 and 2011. The stacked column histogram in (b) shows the area of each land-cover type pertaining to each land-use class for 2011.

The histogram in Figure 6a was indicative of how much of the park's surface area classified under each of the 10 land-cover classes during each of years studied, partially supporting the interpretation of the land-cover maps in Figure 3. Importantly, the *Inundation/Small water bodies* class underwent a decreased coverage of 700 ha, whereas each of *Vegetation Type 1* and *Vegetation Type 2* gained 500 ha of coverage. These trends link to the previously described vegetation succession resulting from decreased extractive activity and maintenance.

The LUC histogram for 2011 (Figure 6b) communicated two important pieces of information. Firstly, it illustrated the division of the park's area under each land-use class. A total of 2700 ha of the park area was out of activity in the 2011 scenario.

Following Extensive aquaculture (1900 ha) and Industrial salt extraction (1300 ha) were the next most dominant classes in terms of area. This histogram was also indicative of the proportions of each land-cover type relative to each land-use class. It is clear that No activity areas and low maintenance Extensive aquaculture areas have comparable proportions of the all five land-cover classes, in-line with previous observations made from Figure 5a.

5. Conclusions

This study was successful in providing adequate quantitative and qualitative LUCC data pertinent to the study area. The results presented drew attention to the different landscape change processes occurring within natural and artificial wetlands. The changes observed in natural areas were subtle, making these zones more stable in nature. These areas are generally more exposed to natural cycles. Hence there is a higher probability of changes recorded here being linked to environmental variability (e.g. tidal fluctuations) As an example, tidal fluctuations play an important role in altering habitat environmental conditions, accentuating the uncertainty related to interpreting the changes in these areas, allowing us to extract hypothesis rather than definite conclusions. Even when comparing moments with equal predicted tide levels (as used here), real tide levels can still differ by up to 30 cm, resulting in significant changes in low-elevation zones as is that of the BCNP (Benavente and Morris, pers.comm).

Meanwhile bolder changes were recorded in the artificial wetland zones. These could be interpreted with greater confidence allowing us to point out a series of new research questions. With respect to observed vegetation succession, further field studies are suggested to uncover the related dynamics at play. For instance, more research is needed to uncover the species composition and the community structure characterizing the *Vegetation Type 1* and *Vegetation Type 2* classes. Other studies point out at the dominance of late-succession, species-poor plant communities with low structural diversity (Rupprecht et al. 2015), or the presence of invasive species (e.g. *Spartina densiflora*), in artificial salt marshes. Such trends are reported to modify energy turnover rates, alter natural decomposition rates and lead to changes in the normal import/export of detritus, which may in turn effect the sedimentation/erosion regime of a system whilst pushing native species to more stressful environments with long

submergence periods or higher salinities (Benito & Onaindia 1991; Castellanos et al. 2004; Castillo et al. 2008; Rupprecht et al. 2015). In this respect, this study has provided valuable geographical and historical land-use and cover data, based on which such trends in the revegetated areas of the park, can be investigated in greater detail.

Further the integration of land-cover and land-use data provided important information pertinent to the identification and the understanding of different scenarios resulting from the abandonment of artificial marsh zones. Firstly, it exposed cases where, despite the declaration of use, no real use or maintenance occurs. It also provided an understanding on the 'age' of inactivity of a plot, distinguishing abandoned zones disconnected from the tidal flow that undergo sedimentation and vegetation sprawl, from other areas that are found closer to the water-line and are hence more susceptible to flooding. The time-span of inactivity and the distance of the installation from the tidal zone are amongst the determinant variables of landscape change scenarios following the cessation of extractive activities (Castellanos et al. 2004).

The occurrence of the identified land-use and cover trends are also expected to influence the park's ecosystem at other biotic levels: macroinvertebrate and fish abundance and richness is found to vary on the basis of different land-use practices (Arias Garcia & Drake Moyano 2004; Yufera & Arias 2010). Consequently, these variations in biodiversity are also influential on foraging, roosting and breeding opportunities for the inhabiting waterbird populations (Masero et al. 2000; Muñoz Arroyo 2004; Pérez-Hurtado 1992). We encourage the use of the digital maps and resources provided by this study, for the longer-term study of the LUCC-birdlife spatio-temporal relationships, thereby making use of annually compiled census datasets that cover the entire park area. This issue should be prioritized as these populations are the basis of the site's international importance in terms of conservation.

Meanwhile a wider perspective into the compromised ecosystem services is especially important. For example areas marked by succession, whilst being species-poor might still be valuable for the provision of other services as are carbon trapping and export of silica for intake by arthropods (Rupprecht et al. 2015). Services as flood protection and recreation must also be considered.

Finally the method developed was successful in providing a monitoring framework for routine analysis of landscape changes. The potential information provided by the application of this framework may facilitate decision-making with respect to land-use licence granting, water-level management in favour of the supported biodiversity, the protection of zones for the regeneration towards natural conditions, and the identification of areas which would benefit from restoration works. Also, the method is exportable to other case-studies with similar characteristics, as are the various artificial wetland areas situated along the Mediterranean Basin (Perennou et al. 2012). Generally, it is considered especially appropriate for areas where natural and artificial environments are similar in terms of spectral signatures, hence requiring separate treatment in order to be distinguished. Further the availability of medium resolution imagery available for free download and the availability of open-source image processing and GIS software may also support the analytical stages at minimal costs, increase the framework's accessibility to both public/private entities with limited funding. Alternatively, higher resolution or hyperspectral imagery (Adam et al. 2010) can also be applied within the designed framework. These resources would resolve issues of poor discrimination and low accuracies for certain classes whilst compromising cost-effectiveness. In addition the resultant GIS database is a potential workspace with the capacity for integration of other information layers generated from natural or social science fields. Finally the method may also support the development of landscape-related prediction models which may hypothesize future scenarios, based on historical LUCC evolution and different management approaches.

Acknowledgements

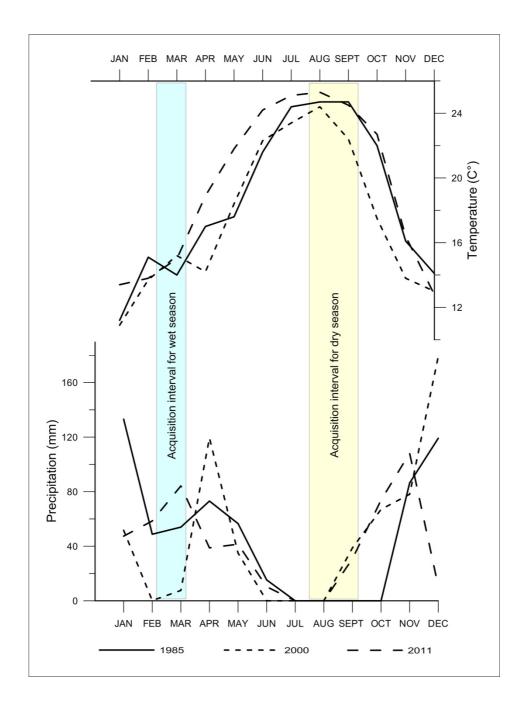
All research work was carried at the University of Bologna (UNIBO) (Italy) and the University of Cádiz (UCA) (Spain). Acknowledgements also go to the administrative board of the Bahía de Cádiz Nature Park, especially the park manager Antonio Gómez Ferrer for providing expertise and administrative support. All stakeholders who assisted in data collection must also be thanked. Of important mention are also other researchers who have advised me during the study; namely Dr. Nicolas Greggio, Dr. Beatrice M.Sole Giambastiani, Dr. Gonzalo Muñoz Arroyo, Dr. Javier Benavente and Dr. Edward P. Morris.

Disclosure of potential conflict of interest

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Annex I

Local temperature and precipitation trends for 1985, 2000 and 2011. Image acquisition intervals corresponding to the wet and dry periods are indicated.



Annex II

Mean and standard deviation values for the NDVI for classes relative to artificial areas. The mean values are averages of the index values for all the pixels classified under each respective class. These indexes were calculated for the 1985, 2000 and 2011 images representing the park under wet season environmental conditions

		NDVI	
	1985	2000	2011
Water body	-0.02	-0.32	-0.51
	±0.66	±3.15	±0.31
Inundation/Small water bodies	0.34	0.35	0.25
	±0.16	±0.23	±0.17
Vegetation Type 1	0.36	0.58	0.45
	±0.18	±0.15	±0.13
Vegetation Type 2	0.60	0.64	0.61
	±0.10	±0.11	±0.08
Bare and dry surface	0.22	0.24	0.23
	±0.06	±0.13	±0.13

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Chapter 5.

An analysis of the influence of sector-related landscape change on waterbird populations

This chapter documents the final research stage of this project linked to objectives posed in relation to Hypothesis 3. It is presented in article format and is entitled:

'Evaluating the influence of land-use changes on waterbird populations in artificial wetlands'

This article is ready to be submitted to the journal *Biological Conservation*.

At this stage land-use and land-cover datasets for 1985, 2000 and 2011, produced through the work discussed in Chapter 4, were integrated with long-term wintering waterbird population data covering the 1985 to 2015 period. The study encompassed the following targets:

- a. a revision of the park's 'Ramsar site' status by which it is considered an internationally important stopover site for migratory waterbirds
- b. local population temporal trends for a selected group of indicator species were compared to national and flyway trends, so as to discern locally influenced changes from others operating at a larger scale
- c. the spatio-temporal tendencies for some of these indicator species were studied in relation to previously identified landscape changes.

Through the completion of this stage, the formulation of guidelines for the support of land-use and restoration planning aimed at enhancing the park's value as waterbird habitat, was possible. These guidelines should be considered in the context of an integrated management approach whereby the area should be evaluated for its other ecosystem services alongside its potential for waterbirds.

Evaluating the influence of land-use changes on waterbird populations in artificial wetlands

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Abstract

Artificial wetlands including salt extraction or aquaculture ponds are well known for their potential as complimentary waterbird habitat, mitigating adverse effects of natural habitat loss and degradation. However, such habitats are subject to changes in land-use management including the intensification of activities (e.g. the creation of intensive aquaculture systems) or long-term neglect giving way to vegetation succession processes. This study analyses the influences of such land-use and cover processes on waterbird populations in the Bahía de Cádiz Nature Park (Spain) including (i) a revision of the park's international relevance as waterbird habitat (ii) a comparative temporal trend analysis with the aim of discerning locally-induced changes from those linked to dynamics operating at larger geographical scales (iii) the application of multivariate ordination techniques for an understanding of species distribution in relation to landscape transformations. Detected changes in waterbird community structure included a drop in fish-eating bird populations parallel to the aquaculture crisis, and in Kentish plover and little stint populations associated with reduced accessibility to supralittoral ponds. A major coverage of active areas or managed water bodies, was found to enhance zone accessibility to waterbirds throughout the park area, contributing to overall diversity. Further, higher waterbird richness and abundance values were found to be a function of extensive inundation, as well as proximity of intertidal zones and accessible supratidal zones. Advised waterbird conservation measures include the temporal staggering of water management to accommodate wintering waterbirds and production cycles; rotational drawdowns in extensive aquaculture areas and the re-establishment of extractive activities to facilitate waterlevel management. Inland densely vegetated zones should be valued for other services including coastal protection and recreation.

Keywords

Land-use and land-cover; Artificial wetlands; salt extraction; aquaculture; waterbirds

1. Introduction

Worldwide, natural coastal wetlands are extensively effected by habitat loss and degradation resulting from anthropogenic developments. These trends compromise the numerous services offered by these habitats, including their accessibility as stopover sites for migratory waterbirds. Moreover, global pressures - mainly climate change and sea-level rise - exacerbate the effects of these losses (Bortels et al. 2011; Catry et al. 2011; Navedo et al. 2007; Sutherland et al. 2012). Consequently, numerous waterbird populations worldwide are suffering declining trends: such is the case for 37% of the wader populations of the East Atlantic Flyway (Catry et al. 2011; The International Wader Study Group 2003; Navedo et al. 2007)

Nonetheless some of the extensive transformations undergone by wetlands have also led to the creation of artificial systems which maintain physicochemical and landscape properties suiting waterbird requirements. These systems include rice paddies, salt and aquaculture ponds and water reservoirs. Numerous studies have investigated the role of these sites in replacing or complimenting their natural counterparts as waterbird habitats. Often, different waterbird communities or species exhibit a variable preference to different types of artificial habitats. This variability is found to highly depend on the physical and chemical character of these environments, as determined by implemented use and management patterns. Further this preference may vary from site to site, according to the availability of natural areas as opposed to artificial ones, and different species may redistribute differently during the different wintering/pre-migrations stages. (Bellio et al. 2009; Kloskowski et al. 2009; Masero 2003; Tourenq et al. 2001).

Salt extraction plants comprise one well-studied artificial waterbird habitat. These systems provide shallow inundated areas harbouring dense populations of high salinity tolerant invertebrates and are thus valuable feeding habitats. Further they serve as important roosting areas supporting populations feeding in adjacent intertidal mudflats (Dias et al. 2006; Dias et al. 2014; Masero et al. 2000; Masero 2003; Pérez-Hurtado & Hortas 1992; Sripanomyom et al. 2011). However, as a consequence of the global economic constraints met by the salt producing industry, these habitats have been majorly transformed into aquaculture systems, or abandoned (Camilleri et al. 2014; Dias 2009). In Sadoul et al. (1998) of 168 known salt extraction sites in the Mediterranean Basin, 45% were found to follow these trends.

With respect to aquaculture, there is a tendency for such systems to impoverish areas in terms of habitat diversity and waterbird richness. This is especially notable in modern intensive systems where the higher degree of disturbance and steep-sided deep ponds remain exclusively accessible to large fish eaters, whilst excluding smaller waders (Hortas 2004; Sripanomyom et al. 2011) As for the abandonment of extraction structures this may give way to natural dynamics resulting in wall breaking, tidal flooding, sedimentation and vegetation succession (Birtsas et al. 2011; Castellanos et al. 2004; Camilleri et al. 2014; Camilleri et al. in prep). Whilst the reestablishment of marsh vegetation possibly restores the ecosystem food-web base, at very high densities it may also obstruct waterbird foraging and movement (Ma et al. 2010). The influence of such trends on waterbird populations are less known and the benefits of the reestablishment of natural wetland dynamics versus the restoration of functional extraction ponds remains an ongoing debate (Takekawa et al. 2006).

This study aimed at analyzing the consequences of such landscape transformations on wintering waterbird populations at the Bahía de Cádiz Nature Park (hereafter BCNP) situated in the south of Spain. The park encompasses an extensive area of coastal wetland located along the East Atlantic flyway and is a declared Ramsar site for regularly accommodating important populations of numerous migrating waterbird species (Junta de Andalucia 2004; Ramsar Convention 2003). The specific targets underlying this analysis included (i) an update of the waterbird status of the park with respect to relevant Ramsar criteria (ii) a study of the long-term waterbird population trends through the comparison with trends at larger spatial scales to distinguish local from global scale influences (iii) an analysis of the spatio-temporal changes of waterbird populations in response to landscape change.

2. Methods

2.1. Study area

The BCNP is found on the Atlantic coast of the province of Cádiz (southwest Spain), between 36° 22′ to 36° 37′ N and 5° 7′ to 6° 16′ W, occupying an extension of 10, 522 ha (Figure 1). This region is marked by a bi-seasonal climate of dry/hot summers and cool/fairly wet winters. It is also characterized by a considerable tidal range of 3-4 m (Lobo et al. 2000) that distinguishes intertidal from supratidal habitats.

The park is characterized by extensive mud/sandflats and supralittoral marshland most of which consists of artificial habitats: mainly salt extraction and aquaculture ponds (Ramsar 2012). Figure 1 delineates these different environments (the park area is here divided in 22 zones, corresponding to the bird census zonation plan referred to throughout the study).

The strongest landscape transformations took place between the 1800s and the mid-1900s to accommodate the growth of the artisanal salt extraction sector. A typical salt extraction plant covers an maximum area of 100 ha and consists of a 1.5 m deep

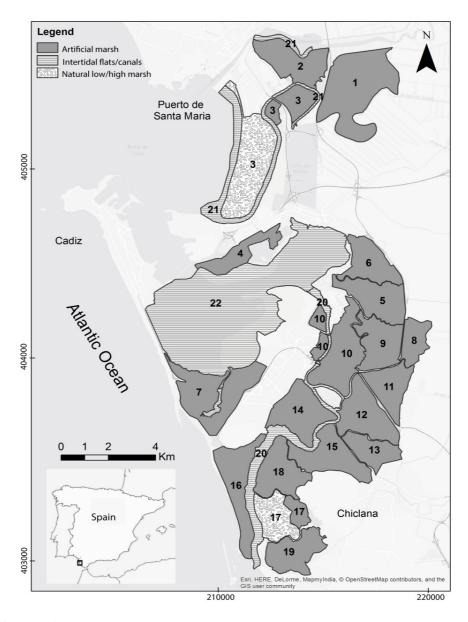


Figure 1 Map of the BCNP (south Spain). Numbered zones (1-22) correspond to the censused zones cited throughout the reading. A major part of the park area comprises of artificial marsh. Remaining unmodified areas include intertidal flats and canals and natural marsh areas.

reservoir pond, and a series of interconnected ponds through which water column depth progressively decreases to just a few cm (Yufera & Arias 2010). Very few artisanal plants operate nowadays, and in some areas larger industrial scale plants have appeared.

As for aquaculture developments, these commenced during the 1970's, starting with extensive aquaculture systems wherein sections of the original salinas were deepened to take advantage of fry carried inward by incoming tides. In these, the original salina structure was partially maintained. It was only later that numerous structures underwent stronger transformations into semi-intensive monoculture ponds of a uniform depth of approximately 2 m (Hortas Rodríguez, 2004; Muñoz Arroyo 2004).

Following the various crises that effected both sectors, many plots have been neglected or are poorly maintained. Some installations have also been restored for conservation purposes (Camilleri et al. in prep).

2.2. Land-cover and land-use data acquisition

A set of 3 Landsat satellite images capturing the site during the bird wintering period (March 1985, February 2000 and February 2011) and at low tide moments, were analyzed using ENVI 4.7. The methodology developed in Camilleri et al. (in prep) was followed.

For each image, atmospheric correction was first applied. Next, each image was stratified into artificial and natural areas which were classified separately using the ISODATA (unsupervised) and the Maximum-Likelihood (supervised) classifications respectively. Land-cover classes included 5 natural classes (*Seawater, Intertidal flat, Low marsh, High marsh, Beaches/Sand plains*) and 5 artificial classes (*Water body, Inundation/Small water bodies, Sparse vegetation, Dense vegetation* and *Bare and dry surface*). Classification results were checked for statistical accuracy and were vectorized for use within ArcGis 10.1. Within this workspace, artificial and natural classification results were merged to give the final land-cover maps. Smoothing and topology operations were performed to improve the map quality and post-classification change analysis was performed. Following, using the Intersect tool, for each of the 22 census zones as in Figure 1, the area (ha) corresponding to each land-cover class was calculated. Furthermore, land-cover maps were overlain by corresponding land-use feature class for each studied year, allowing contemporary visualization of both datasets.

2.3. Reviewing international importance

The site's international importance for waterbirds was first proposed in Pérez-Hurtado & Hortas (1992). However official status was not acquired until 2002 (Junta de Andalucia 2004). Within this study this status was reviewed in line with Ramsar waterbird criteria according to which the area must regularly support (i) over 20,000 waterbirds (Ramsar criterion Nr. 5) and (ii) 1% of the flyway population of at least one waterbird species (Ramsar criterion Nr. 6) (Ramsar Convention 2014). With respect to criterion Nr. 6, the 1 % flyway population threshold values were cited from the WPE5 (Waterbird Population Estimates 5th Edition) report in Wetlands International (2012).

2.4. Waterbird dataset preparation for spatio temporal statistical analysis

Wintering bird census data was available for the following years: 1985/6 and 1990/1 (data from Pérez-Hurtado 1992); 1996 and 2002 (data from GEAM 1996 and 2002) and annually for the 2004-2015 period (data from Junta De Andalucia 2013). Some of these datasets were adjusted to reflect waterbird populations corresponding to the park's subdivision into 3 intertidal and 19 supratidal zones as shown in Figure 1. This zone division corresponds to the bird counting methodology plan applied by the park's administration since 2004 and its use favoured optimal use of available data.

All waterbird species recorded within the park throughout the census period were reviewed for (i) suitability as indicators of landscape change according to their foraging behaviour-habitat relationships (ii) constancy of representation throughout the dataset. A total of 16 species were selected for the study including: the sanderling (*Calidris alba*) and the oystercatcher (*Haematopus ostralegus*) typical of sandy habitats; other small waders associated to 0-5 cm water depths including the little stint (*Calidris minuta*), the dunlin (*Calidris alpina*), the ringed plover (*Charadrius hiaticula*), the Kentish plover (*Charadrius alexandrinus*) and the grey plover (*Pluvialis squatarola*); others preferring 5-10 cm waters including the common redshank (*Tringa totanus*), the bar-tailed godwit (*Limosa lapponica*) and the black-tailed godwit (*Limosa limosa*); bigger waders foraging in 5-25 cm deep waters as the black-winged stilt (*Himantopus himantopus*) and the pied avocet (*Recurvirostra avosetta*); the greater flamingo (*Phoenicopterus roseus*) preferring spacious pools with 15-50 cm depths and fish-eating species including the little egret (*Egretta garzetta*), the grey heron (*Ardea cinerea*) and

the great cormorant (*Phalacrocorax carbo*) (GEAM 2002; Arias García & Drake Moyano, 2004).

2.5. Statistical analysis

2.5.1. Temporal trends analysis

Wintering population trends for each waterbird species were calculated using the TRIM (Trends and Indices for Monitoring Data) software (Pannekoek & van Strien 2001), which allows for missing counts in the time series and produces unbiased yearly indices and standard errors using Poisson regression. The time effects model with imputed indices, considering serial correlation and over-dispersion was used.

Trends for other coastal wetlands including the Doñana National Park (south Spain) and the Tagus estuary (Portugal), cited from Rendón et al. (2008) and Catry et al. (2011) respectively, were used for comparison with nearby local situations. National trends were cited from SEO/Birdlife (2012) and global flyway trends were cited from WPE5 data in Wetlands International (2015).

2.5.2. Spatio-temporal data analysis

From the available waterbird dataset, the data representing three representative periods for the study area was utilized. Datasets from 1985-1991-1996 represented Period 1, datasets from 2002-2004-2005 represented Period 2 and datasets from 2009-2010-2011 represented Period 3. For each of the 22 zones, mean densities of the studied waterbird species were calculated considering these datasets. Little egret (*Egretta garzetta*) and Grey heron (*Ardea cinerea*) numbers were excluded from all following analysis.

MDS (non-metric multidimensional scaling) analysis based on the Bray-Curtis similarity index was performed to analyze period/zone similarities based on the square-root transformed species densities. Ordination validity was verified using the Kruskal stress coefficient. For between-period comparison of zone ordination, Relative dispersion and the Index of Multivariate Dispersion (IMD) (Clarke & Warwick 2001) were calculated. For within-period analysis, Percentage of Similarity Analysis (SIMPER) (Clarke, 1993) was used to study the contribution of each species to grouped

zones with over 60% similarity. Further, period and zone Shannon diversity Index values were extracted using neperian logarithms. All the described analyses were performed using the statistical software package PRIMER v.6.

Following, in SPSS v.21 richness, abundance (using density values) and diversity differences amongst periods and zones were analyzed by one-way ANOVA tests. Normality and homogeneity of variances were verified using the Kolmogorov-Smirnov and Levene test respectively. Homogenous groups were separated by a Student-Newman Keuls (SNK) test set at the 5% significance level.

Land-cover and waterbird density relationships were studied using the canonical correspondence analysis (CCA), a unimodal response model in which ordination axes are linear combinations of the environmental variables that maximize the dispersion of species scores (Ter Braak 1986, 1990). Significance of land-cover classes was measured by Monte-Carlo permutation tests. CCA was performed using the BiodiversityR package (Kindt & Coe 2005) in RStudio v.0.98.953.

3. Results

3.1. Land-cover and land-use change

A comparative analysis of land-cover change results revealed that the major changes occurred within artificial areas (Figure 2). Changes in natural areas (zones 3, 17, 20, 21, 22) were less defined. Further natural zones were more likely to be influenced by environmental variables as is tide level.

The north was marked by increased inundation with a coverage of around 800 ha¹ mainly due to the conversion of an extensive plot of drained marsh into an industrial salina (zone 1) (Land-use information is synthesized in Annex I). In the rest of the park, several inundated zones were gradually replaced by vegetation, this trend reaching its climax in 2011 and representing a total coverage of over 2000 ha² (See zones 5, 6, 9, 10, 13, 14, 15 and 18).

Non-linear change patterns were found to reflect implemented water management

.

^{1, 2} Values cited from change detection analysis results (Camilleri et al. in prep)



Figure 2 Land-cover maps of the study area for 1985, 2000 and 2011 (adapted from Camilleri et al. in prep)

measures or land-use changes. As an example, within zone 7, inundation from 2000 to 2011 was found to correspond to the conservation works implemented in 2004 aimed at restoring suitable hydrological conditions for the regeneration of birdlife habitats (Pérez-Hurtado, pers. comm). Also in zones 9, 12 and 14 vegetation succession trends were halted as a result of land-conversion for semi-intensive aquaculture implying intense maintenance measures including the clearing of vegetated surfaces.

Figure 3 synthesizes the temporal evolution of different land-uses and offers a breakdown of their respective land-cover changes. This result indicated an increase in the extent of active area within the park during the 2000 period, majorly as a result of extended coverage corresponding to industrial salt extraction and semi-intensive aquaculture. These uses contributed to an increased inundated surface during this period. Meanwhile, taking into account the overall study period, inactive and extensive aquaculture areas contributed to a reduction in inundated area and a rise in vegetation cover.

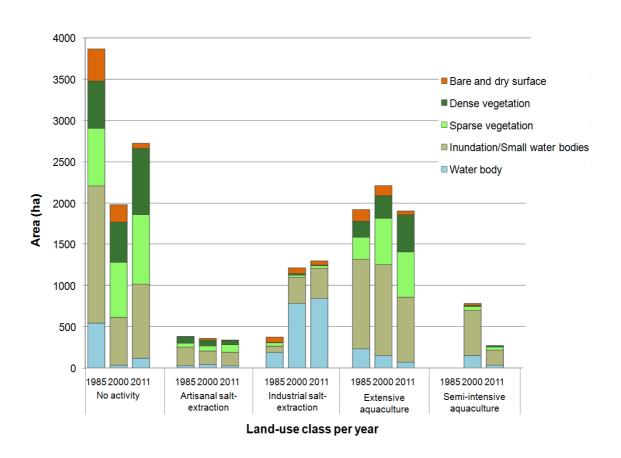


Figure 3 Evolution of coverage dedicated to the different extractive activities. Corresponding land-cover is also indicated.

3.2. International status

The BCNP was shown to invariably function as waterbird stopover site during the study period, annually hosting over 20,000 bird individuals majorly represented by gulls (Laridae) and wader families, Charadriidae and Scolopacidae, (Figure 4). Further the 11 species were found at numbers greater than 1% of the flyway population (Table 1), including 7 wader species (*C. alpina, L. lapponica, H. himantopus, C. hiaticula, R. avosetta, C. alexandrinus* and *L. limosa*); 1 gull (*L. michahellis*), the fish-eating *P. leucorodia* and *C. nigra* (Eurasion Spoon bill and Black Stork)

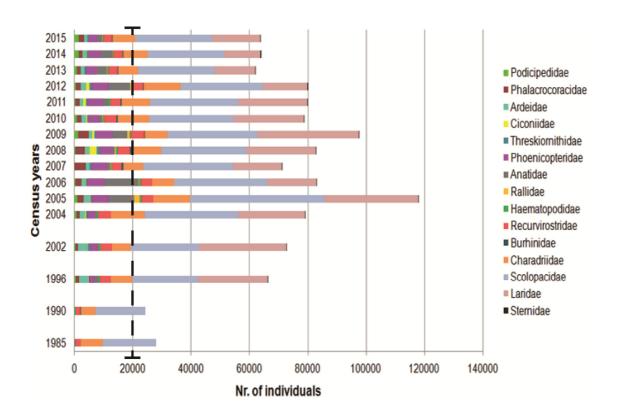


Figure 4 Waterbird population abundances over the censused years with respect to the 20, 000 limit set by Ramsar criterion Nr.5. A breakdown of family composition is included. For 1985 and 1990 only wader species were censused.

		1% of	Mean
		flyway	abundance
		population	2010-2015
1	Calidris alpina	13300	19379
2	Larus michahellis	7000	8571
3	Larus fuscus*	5500	5062
4	Pluvialis squatarola*	2500	2118
5	Tringa totanus*	2400	1962
6	Phoenicopterus roseus	1300	4216
7	Limosa lapponica	1200	2208
8	Himantopus himantopus	760	969
9	Charadrius hiaticula	730	5440
10	Recurvirostra avosetta	730	2471
11	Charadrius alexandrinus	660	1467
12	Limosa limosa	610	1138
13	Platalea leucorodia	110	645
14	Ciconia nigra	15	25 [†]

Table 1 Species with 2010-2015 mean abundances greater than the 1 % flyway population threshold as in the WPE5 report in Wetlands International (2012). The mean abundance for *Ciconia nigra* (†) is based on 2012-2015 data. Species marked with an (*) come close to the 1% threshold.

3.3. Temporal trends at local, national and flyways scales

Computed temporal trend results for the BCNP, and reported trends for neighbouring wetland areas, national trends and flyway trends are resumed in Table 2. A majority of the trends for Spain corresponded to the 1990-2010 period, whereas most flyway trends corresponded to the 1997-2007 decade.

Local rising trends for waders as *C.alpina*, *C.alba*, *C.hiaticula* and *L. lapponica* were parallel to trends at a national and global scale. *R.avosetta* populations also exhibited a moderate increase, as in the neighbouring Doñana wetlands, despite decreasing trends at a national level.

For other species, local drops in population size were recorded despite increases at other scales, pointing out at possible habitat issues at a local level. This tendency was observed for the small sized wader *C.alexandrinus* and larger fish-eaters including *E.garzetta* and *A.cinarea*.

		Overall	slope					
Species	Codes	Additive	Multiplicative	P	BCNP	Donana	Spain	Flyway
Calidris alpina (Dunlin)	CLP	0.02 ± 0.00	1.02 ± 0.00	< 0.05	Mod. increase	-	Increase	Stable
Calidris alba (Sanderling)	CLB	0.04 ± 0.02	1.04 ± 0.02	< 0.05	Mod. increase	-	Increase	Increase
Calidris minuta (Little stint)	CAM	±0.09	1.01 ± 0.1	-	Uncertain	-	Indefinite	Increase
Charadrius hiaticula (Ringed plover)	СНН	0.35 ± 0.01	1.04 ± 0.02	< 0.01	Mod. increase	-	Increase	Fluctuating
Charadrius alexandrinus (Kentish plover)	CHA	-0.03 ± 0.00	0.97 ± 0.00	< 0.01	Mod. decline	-	Increase	Unknown
Pluvialis squatarola (Grey Plover)	PLS	± 0.01	1.01 ± 0.01	-	Stable	-	Increase	Decreasing
Tringa totanus (Common redshank)	TRT	0.003 ±0.009	1.003 ± 0.009	-	Stable	-	Mod. decrease	Stable
Limosa lapponica (Bar-tailed godwit)	LLA	0.075 ± 0.023	1.078 ± 0.025	< 0.01	Mod. increase	-	Stable	Increase
Limosa limosa (Black-tailed godwit)	LLI	-0.032 ± 0.018	0.968 ± 0.018	-	Uncertain	Increase	Decrease	Decrease
Haematopus ostralegus (Oystercatcher)	НАО	0.020 ± 0.011	1.020 ± 0.011	< 0.05	Mod. increase	No data	Increase	Decrease
Himantopus himantopus (Black winged stilt)	HIH	0.023 ± 0.016	1.023 ± 0.016	-	Uncertain	Increase	Increase	Stable
Recurvirostra avosetta (Pied avocet)	REA	0.016 ± 0.008	1.016 ± 0.008	< 0.05	Mod. increase	Increase	Decrease	Stable
Phoenicopterus roseus* (Greater flamingo)	PHR	0.030 ± 0.025	1.031 ± 0.027	-	Uncertain	Increase	Increase	Increase
Egretta garzetta* (Little egret)		-0.054 ± 0.010	0.947 ± 0.009	< 0.01	Mod. decline	No data	Increase	Increase
Ardea cinerea* (Grey heron)		-0.070 ± 0.013	0.932 ± 0.012	< 0.01	Mod. decline	Increase	Increase	Increase
Phalacrocorax carbo* (Great Cormorant)	PHC	0.027 ± 0.042	1.027 ± 0.043	-	Uncertain	Increase	Increase	No data

Table 2 Temporal trends for the BCNP, nearby coastal wetlands (Doñana wetlands and Tagus estuary), Spain and relevant flyways. For the BCNP TRIM slopes (± SE) were based on wintering waterbird data for the 1985-2015 period, or for the 1996-2015 for asterisked species (*). Trend classes include strong increase (significantly greater than 5% per year); moderate increase (significant but less than 5% per year); uncertain (not possible to assert any population trend); stable (trends without significant increases or decreases); moderate decline (significant but less than 5% per year); steep decline (significantly greater than 5% per year). Species codes used in posterior result sections are also enlisted.

Species with uncertain trends were found to exhibit random or highly uneven changes throughout the study period. Supplementary trend charts are given in Annex II providing additional information for these cases. For *C.minuta*, uncertainty was based on a divided trend: an increase from 1985 to 2005, in parallel with the increasing flyway trend, and a steep drop thereafter. *P. roseus* populations doubled from 2004 to 2005 and fluctuated ever since. This observation was also in line with 1997-2007 flyway trend result. Finally, *P.carbo* populations four-folded from 1996 to 2007, dropping back after. A similar increase was recorded in Doñana and at a national level.

3.4. Spatio-temporal analysis

3.4.1. Between-period analysis

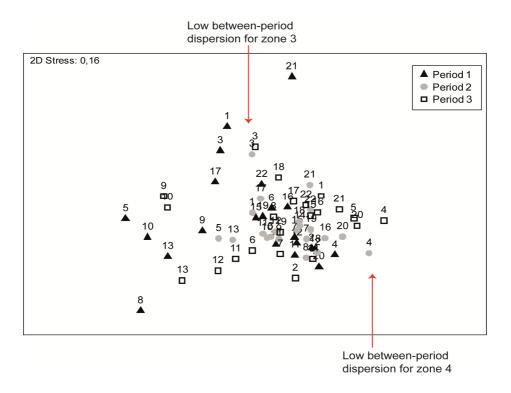


Figure 5 MDS ordination analysis results for the three periods studied indicating S17 Bray-Curtis similarities amongst the zones with respect to the square-root transformed mean densities of the 14 indicator species

Relativ	e dispersion	Multivariate Dispersion (MD)								
Period	Dispersion Index	Period comparison	Index of MD							
1	1.228	1 vs. 2	0.549							
2	0.647	2 vs. 3	-0.513							
3	1.126	1 vs. 3	0.135							

Table 3 Relative dispersion and Multivariate dispersion for the 3-period similarity analysis

The MDS ordination for the three studied periods (Figure 5) indicated closer grouping of zones during Period 2, in comparison with Periods 1 and 3. This observation was also confirmed by a lower Dispersion Index value for Period 2 (0.647) as well as by the Multivariate Dispersion Index values (Table 4).

This result was also indicative of variations of individual zones throughout the three periods, with the majority of zones exhibiting considerable between-period separation in terms of waterbird composition, with some exceptions (e.g. zone 3 - a natural zone- and zone 4 - a restored area).

Additionally one-way ANOVA results pointed out at a significantly higher Shannon diversity index for Period 2 (F= 4.48, p= 0.015) whereas no significant differences (SNK test, p<0.05) in diversity values resulted between Periods 1 and 3. Waterbird density values exhibited no significant differences among periods (F=1.57, p>0.05).

3.4.2. Within-period analysis

Within-period similarities were interpreted through separate MDS ordinations (Figure 7) accompanied by SIMPER results (Table 4).

Period 1 MDS ordination (Stress 0.13) resulted in three clusters. Group A consisted of the largest number of zones majorly consisting of natural intertidal habitats (zones 22, 21) and proximate supralittoral zones (zones 2, 4,6,7,12,14,15,16,18,19) marked by deep or shallow inundation mainly tied to artisanal salt extraction and extensive aquaculture activities. This was also the cluster with most typifying species and highest average abundances, marked by dominant presence of shallow water (0-10cm) species that feed in both intertidal flats and supratidal artificial marsh areas (*C. alpina, Charadrius spp., P.squatarola* and *T.totanus*). Deeper water species *L.limosa, R. avosetta* and *P. carbo* were also present but lower Sim/SD (1.20, 1.28 and 1.09) and % Contribution values indicated higher zone selectivity amongst

these species. In Group B zones (zones 3, 17- both being partly natural and partly artificial) a similar combination of species as in Group A was found, although average abundances were generally lower here. Group C zones were also characterized by inundation and the presence of salt extraction and extensive aquaculture installations. However these zones were predominantly situated inland with poor connection to intertidal areas. In this group zones performed lowest in terms of both typifying species and abundances and alongside *C. alpina*, the grouping were solely based on species known for their preference to supratidal habitats with up to 10-25 cm depths (*T.totanus*, *H. himantopus* and *L.limosa*).

The Period 2 MDS (Stress 0.12) reiterated the previously observed homogeneity amongst zones with respect to waterbird density, with 18 out of 22 zones clustering within Group A at the 60% similarity level. These 18 zones were found to be diverse in terms of geographical location (including intertidal zones, nearby supratidal zones and zones positioned further inland), land-cover and characteristic land-uses. The typifying species of this group were also highly diverse.

Zones in the Period 3 MDS (Stress 0.12) clustered within 4 groups. Group A zones consisted of artificial marsh areas found at distinct points of the park, all holding extensive water bodies as a result of industrial salt extraction (zones 1,2 and 8), aquaculture activity (zone 19), or restoration works (zones 7). This group was represented by the greatest number of typifying species, including species with diverse habitat preferences as C. alpina and P.roseus. Group B zones consisted of intertidal flats/canals and adjacent supralittoral artificial marsh with a combination of inactive and active plots. As in Group A a diverse range of species typified this group. Some appreciable differences were however notable: first *P.roseus* was not a typifying species in this group, further *L.limosa* was typical to Group A zones whereas L.lapponica was typical to Group B zones. Zones in Groups C and D corresponded to interior regions of the park with zones in Group C marked by a major active surface area in contrast to Group D zones. These groups were marked by lower average abundances in comparison to the other groups, as well as a notable contribution to grouping by deeper water species (T.totanus, P.carbo, H.himantopus and R. avosetta). Furthermore the number of typifying species was lowest in Group D. ANOVA tests also confirmed significant reductions (p < 0.0001) in richness (S) and abundance (N) values amongst zones pertaining to the different Period 3 groupings (Figure 7). Richness and abundance values were highest in intertidal areas and were found to drop in supratidal areas as a function of reduced management/extractive activity and increased distance from the intertidal area.

Figure 6 MDS ordination analysis results for Period 1, Period 2 and Period 3 indicating S17 Bray-Curtis similarities amongst the 22 zones for the square-root transformed mean densities of the 14 indicator species. Dashed circles group zones of at least 60% similarity. Land-cover and use annotations have been added.

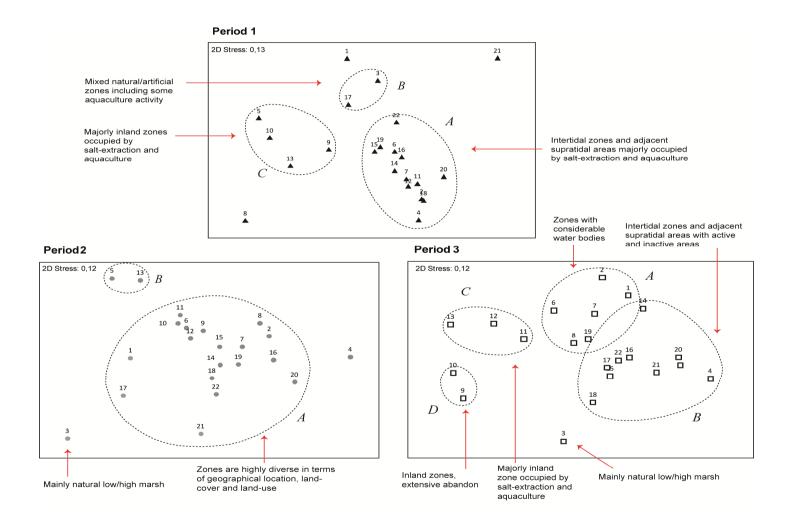


Table 4 SIMPER results for Period 1, Period 2 and Period 3 for zones grouped in the MDS ordinations in Figure 6. For each group, Average abundances, Average similarities, Similarity to Standard deviation ratio (Sim/SD) and %Contribution values relative to each species were calculated..

Period	1														
Group A: Average similarity: 67.29					Group I	3: Average si	milarity: 6	1.07		Group C: Average similarity: 66.73					
Av. Av.						Av.	Av.				Av.	Av.			
Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib%	
CLP	1,50	19,54	5,00	29,04	CLP	0,70	21,84	-	35,76	CLP	0,39	16,77	3,67	25,13	
CHA	0,72	8,78	3,68	13,05	TRT	0,24	9,26	-	15,16	TRT	0,44	14,64	1,63	21,94	
CHH	0,59	7,68	5,00	11,41	PHC	0,26	7,75	-	12,69	HIH	0,33	14,23	3,87	21,32	
PLS	0,58	7,19	3,74	10,69	PLS	0,17	6,40	-	10,48	LLI	0,46	13,04	2,24	19,54	
TRT	0,55	6,35	3,40	9,43	CHA	0,22	6,21	-	10,17	PLS	0,12	4,45	6,38	6,67	
LLI	0,61	4,53	1,20	6,73	CHH	0,15	5,74	-	9,39						
REA	0,51	4,00	1,28	5,95											
PHC	0.53	3.39	1.09	5.04											

Period Group	2 A: Average	similarity:	71,47		Group	B: Average	similarity	: 76,62	
	Av.	Av.				Av.	Av.		
Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib
CLP	1,62	18,41	4,65	25,76	TRT	0,66	16,77	-	21,89
CHH	0,78	8,44	3,40	11,80	HIH	0,50	12,98	-	16,95
TRT	0,57	6,90	3,82	9,65	PLS	0,45	11,98	-	15,64

CLP	1,62	18,41	4,65	25,76	TRT	0,66	16,77	-	21,89
CHH	0,78	8,44	3,40	11,80	HIH	0,50	12,98	-	16,95
TRT	0,57	6,90	3,82	9,65	PLS	0,45	11,98	-	15,64
CHA	0,51	5,74	3,01	8,03	LLI	0,50	11,86	-	15,48
PLS	0,51	5,38	2,59	7,53	CHA	0,38	7,44	-	9,71
CAM	0,44	5,35	4,14	7,48	CLP	0,37	6,98	-	9,12
PHR	0,54	4,71	1,42	6,60	CHH	0,30	5,26	-	6,87
REA	0,52	4,23	1,73	5,92					
PHC	0,40	4,22	2,26	5,90					
HIH	0,36	3,30	1,34	4,62					

Period	Period 3																		
Group A: Average similarity: 65.30					Group	B: Average	e similari	ty: 65.34		Group	C: Averag	e similari	ity: 66.31		Group D: Average similarity: 69.10				
	Av.	Av.				Av.	Av.				Av.	Av.				Av.	Av.		
Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib%	Sp.	Abund	Sim	Sim/SD	Contrib%
CLP	1,20	15,63	5,64	23,94	CLP	2,33	23,22	5,28	35,54	TRT	0,71	19,02	8,57	28,69	TRT	0,53	18,85	-	27,27
PHR	0,93	6,99	1,06	10,70	CHH	0,96	9,18	4,84	14,04	REA	0,50	10,78	2,54	16,25	PLS	0,26	12,36	-	17,89
CHH	0,66	6,75	2,24	10,33	PLS	0,72	7,56	2,13	11,58	PHC	0,31	8,07	3,38	12,17	PHC	0,51	12,15	-	17,58
TRT	0,53	5,94	1,54	9,09	TRT	0,50	5,61	4,15	8,59	PLS	0,25	5,74	4,47	8,65	HIH	0,24	9,90	-	14,33
HIH	0,47	5,34	3,15	8,17	LLA	0,74	5,02	1,13	7,68	HIH	0,39	5,67	0,88	8,54	CHH	0,17	5,72	-	8,27
PLS	0,40	5,25	5,39	8,03	PHC	0,44	4,65	3,24	7,12	CHH	0,31	5,26	11,26	7,93	PHR	0,10	3,96	-	5,73
CHA	0,44	4,82	2,20	7,38	CHA	0,46	3,08	1,38	4,72	LLI	0,23	4,46	2,11	6,73					
REA	0,58	4,08	1,05	6,25	REA	0,44	2,27	0,70	3,48	PHR	0,38	3,85	0,58	5,81					
LLI	0,50	3,96	0,76	6,07															
PHC	0,50	3,74	1,72	5,72															

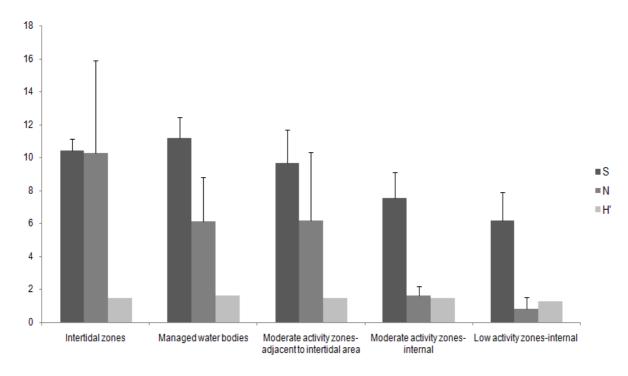


Figure 7 Variation in richness (S), abundance in individuals/ha (N) and diversity (H') for Period 3 zones grouped according to ordination results

For all 3 Periods, Zone 3 was singular in terms of waterbird populations. This area was also unique in terms of habitat, consisting of an extensive natural area encompassing natural low and high marshland and a long beach. Additional analysis (not presented in this study) pointed at *C.alba* and *H. ostralegus* as being the most characteristic species here.

3.5. Habitat-waterbird relations

Previous landscape studies confirmed the presence of distinctive land-cover states (mainly extensive inundation and vegetation succession), best distinguished during the last period. The habitat-waterbird relations for this period were analyzed though CCA ordination (Figure 8). The ordination was significant according to the Monte Carlo test (F = 1.873, p = 0.016). From all constrained components, CCA1 and CCA2 accounted for 62.52% and 26.14% of variance respectively. The *Water body* and *Inundation/Small water bodies* classes were the most explicative environmental variables along CCA1. *Sparse vegetation, Dense vegetation* and *Inundation/Small water bodies* were the most explicative environmental variables along CCA2. Zone 3 was removed from the analysis due to its singularity.

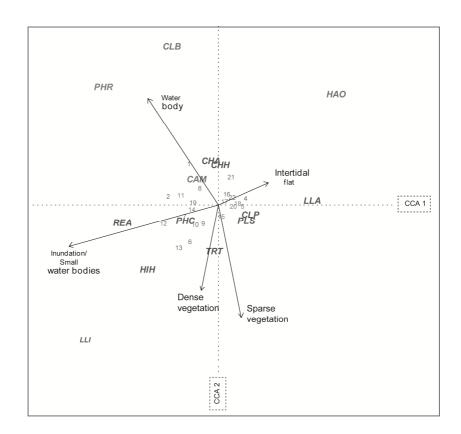


Figure 8 CCA ordination summarizing the preferred distribution of the 14 indicator species in Period 3, along intertidal habitats (*Intertidal flat* variable) and artificial marsh habitats (*Water body*, *Inundation/Small water bodies*, *Sparse vegetation*, *Dense vegetation* variables).

Whilst *H. ostralegus* and *L.lapponica* were found to exhibit stricter relations to intertidal habitats, others placed between intertidal environments and supratidal zones marked by inundation (e.g. *Charadrius spp*), or sparsely vegetated areas (e.g. *C. alpina* and *P. squatarola*). Extensive water bodies were found to attract shallow depth feeders as *C.minuta*, and deeper water feeders as *P. roseus*. On the other hand, *T.totanus*, *L. limosa*, *H.himantopus* and *R.avosetta* distributed in areas with more restricted inundation and sparse to dense vegetation, with *T.totanus* occurring even in densely vegetated areas.

4. Discussion

The study showed that the mosaic of natural and artificial habitats of the BCNP have made it possible for the area to maintain its international importance as a wintering site for waterbirds in the Western Paleartic ecozone. The park has incessantly accommodated total wintering populations of over 20,000 birds and supported numerous species at numbers superior to the 1% flyway threshold; thereby satisfying waterbird Ramsar criteria. Hence, as

reported in other sites worldwide (Bellio et al. 2009; Kloskowski et al. 2009; Ma et al. 2010; Márquez-Ferrando et al. 2014; Masero et al. 2000; Pérez-Hurtado & Hortas 1991), the artificially managed wetlands here play a crucial role as complementary waterbird habitat.

However, how artificial habitats function as waterbird habitat highly depends on the way they are used or managed (Tourenq et al. 2001). Results here drew attention to changes in waterbird community structure parallel to sector developments and consequential landscape alterations. Trends tied to the growth of the aquaculture industry from 1985 to 2000 were a case in point. In a review of population numbers by the park's administration in 2002 (Ramsar Convention 2003) egrets (E.garzetta) and cormorants (P.carbo) were amongst the species whose numbers rose above the 1 % flyway population threshold. These trends are strongly associated to an increase in extensive aquaculture and the appearance of semiintensive aquaculture ponds of a character exclusive to larger fish-eaters. In the latter case, the deep ponds, higher levels of human and mechanical disturbance and between-production cleaning procedures that are highly detrimental to marcoinvertebrate populations make these areas inaccessible to smaller birds (Arias Garcia & Drake Moyano 2004; Sripanomyom et al. 2011). Yet, during the end of the 21st century, low profitability brought about the progressive abandoning of ponds (Hortas 2004; Yufera & Arias 2010) leading to important declines in the abundances of egrets and cormorants, and consequently the review of the 2011-2015 mean populations given in this study (Table 1) indicated that they no longer satisfy the 1% limit. Further, rising trends for the little egret, the grey heron (A. cinarea) and the cormorant at national and/or global scales (Table 2) confirmed that these declines were strongly correlated to the local reduction in local foraging opportunities.

Sectorial development has also been a determining factor behind trends of flamingo (*P. roseus*) populations. Alongside rising trends at a national and a flyway level, local populations doubled from 3000 to 6000 individuals in 2004. This observation is simultaneous to the creation of the 800 ha Santa Maria industrial salt extraction plant (zone 1). These birds are known to exhibit preference to this zone due to its spacious and deeper (15-50cm) waters rich in brine shrimp prey (Castro & Marín Estrella 2004).

On the other hand, the park maintained its potential as a wintering site for waders although numbers fluctuated differently for different species. The black-winged stilt (*H. himantopus*), the pied avocet (*R. avosetta*), the ringed plover (*C. hiaticula*) and the Kentish plover (*C. alexandrinus*) were found to rise above the 1% population limit, whereas the

dunlin (*C. alpina*) and the two godwit species (*Limosa spp.*) were new additions ³. Further, dunlin and bar-tailed godwit numbers were on a moderate increase, paralleled by increases at larger spatial scales too (Table 2). These species are evidently well accommodated by the park's habitats. In contrast, local trend results for the Kentish plover pointed out at a moderate decline with numbers having dropped from 4000 to 1500 individuals in the past 30 years, going against national increasing trends of up to 100% from 1991 to 2009. However these rises are more bound to be due to population redistributions rather than global positive growth (SEO/Birdlife 2012). The little stint (*C. minuta*) is another wader with exhibited declines in local populations despite registered increases in flyway trends. These local population drops are most likely tied to a major sensitivity of these species to site-specific issues.

Land-use and cover changes in the supralittoral zones of the park were also found to influence the spatial distribution of waterbird populations. Ordination results pointed towards a more widespread use of the park area by a major number of bird species during the 2002-2005 period (Period 2). Overall species diversity was also found to be significantly higher at this time (See Figure 5 and Figure 6 (Period 2, Group A)). Landscape studies also confirmed that the area dedicated to aquaculture or salt production reached its maximum in this moment. Evidently, the higher degree and variability of use resulted in the extended presence of a major number of managed ponds with conserved walls and controlled water levels, thereby enhancing accessibility for a higher diversity of waterbirds in a greater number of zones.

However not all land-use types serve as waterbird habitat in the same manner and the relative land-cover traits play a crucial role in determining this. During the 2009-2011 period (Period 3) highest waterbird richness and abundances were recorded in managed zones having extensively inundated areas, providing open space and also a range of depths (See Figure 6 (Period 3, Group A), Table 4 and Figure 7). These zones included two industrial salinas, an aquaculture site with unusually extensive pools and a restored area. These zones accommodated considerable abundances of smaller birds as the dunlin and the Kentish plover wading in 0-5 cm depths, as well as larger flamingos preferring 50 cm deep waters. This is indicative of the availability of a range of depths and related environmental conditions - pH and salinity, availability of exposed mud, ecosystem production rates and prey concentration - providing optimal foraging conditions for a major diversity of species (Ma et al. 2010;

³ Results from this study are contrasted to population review results in Ramsar Convention (2003)

Sripanomyom et al. 2011). Further the clear or sparsely vegetated walls in these sites provide adequate roosting conditions.

Further, in the 1985-96 and 2009-11 periods (Periods 1 and 3), the function of intertidal flats and adjacent areas as coupled habitats was apparent (See Group A of Period 1 and Group B of Period 3 in Figure 6). Zones here included intertidal flats/canals and adjacent supralittoral zones. During both periods these supralittoral zones were composed of inactive plots, as well and numerous extensive aquaculture areas. This intertidal/supratidal combination was found to have significantly high waterbird richness and abundances (Figure 7) being populated by numerous waders: the dunlin, plovers, godwits, the common redshank (T. totanus) and the pied avocet (Table 5). The dependence of these birds on both intertidal and supratidal habitats is also confirmed in CCA ordination results for Period 3. Intertidal areas are highly productive feeding sites, whereas associated supralittoral zones are valid as both supplementary feeding and roosting habitats. Further, extensive aquaculture plants are structurally similar to the original artisanal salt pans offering ponds with gently sloping sides and waters with mean depths of 0.7 m and their potential lies in the fact that following episodes of water drawdown and fish harvesting their exposed marcoinvertebrate-rich sediment provides excellent feeding opportunities for waterbirds (Arias Garcia & Drake Moyano 2004; Bellio et al. 2009). The proximity of intertidal zones and accessible adjacent supratidal translates in lower commuting energy costs for birds (Dias et al. 2006; Sripanomyom et al. 2011), and possibilities feeding activity to continue for longer periods of time. Further predation risks are lower in comparison to more internal zones. In sight of this, the aforementioned recorded drops in Kentish plover and little stint populations may have been a consequent result of the reduced availability of suitable roosts, as these species are known for spending substantial time feeding at high tide in order to compliment low-tide feeding (Masero et al. 2000; Rosa et al. 2006).

Results also brought to light the influence of the abandonment and negligence of numerous plots in the park on waterbird distribution. For the BCNP region other authors (Masero 2003; Perez-Hurtado et al. 1993) have suggested a causal link between abandonment and the decline and redistribution of some species. This study confirmed that zones effected by these processes are impoverished in terms of richness and abundances. This trend was further pronounced in internal areas that, following long-term inactivity and negligence, were disconnected from intertidal areas and ceased to be reached by tidal waters, giving way to sedimentation and dense vegetation sprawl (Figure 7). Such trends are associated with completely abandoned plots or extensive aquaculture areas that are poorly maintained and

where use is sporadic. As the landscape studies pointed out, such scenarios climaxed in the last period studied (Figure 2, 2011 map). Smaller *Calidris* and *Charadrius spp*. were most affected by these processes failing to access these zones for foraging or roosting (See Figure 6 and Table 5 (Period 3, Group D) whereas species known to have a greater trophic plasticity such as the common redshank and the black-winged stilt could still access these areas. Whether these species forage or roost in these areas is however uncertain as censuses did not report the state of activity of counted birds.

5. Management recommendations

The artificial wetlands of the BCNP are vital in sustaining the wintering waterbird populations in the park. However in addition to its protection, adequate management and restoration plans are required to maintain and enhance its potential as waterbird habitat. Through an ecosystem-based conservation approach, different areas can be managed to meet the needs of multiple bird species (Ma et al. 2010). Spatio-temporal analysis results have given light to aspects that favour this objective.

The presence of extensively inundated areas with gradually increasing depths ranging from 0 to 50 cm and clear (or sparsely vegetated) walls, were found to serve as optimal sites for accommodating a higher variety of waterbirds of different sizes. It is fundamental that the best use as waterbird habitat is made in these areas, through appropriate conservation measures. The two industrial salinas situated in the north sector are such areas. Here, the temporal staggering of water level management is advised to accommodate waterbird populations during periods of increased energy demand, as well as salt production cycles later on. The December-March period coincides with the wintering and the pre-migration period of migratory birds. During these months water depths can be managed to enhance food resource availability. Following, around April/May water management can be better directed towards salt production (Masero et al. 2000; Masero 2003; Muñoz Arroyo 2004; Pérez-Hurtado 1992).

Further, the combination of intertidal and adjacent supratidal zones was found to present high efficiency foraging and roosting opportunities for waterbirds. The potential of neglected areas of relative proximity to the tidal zone can be enhanced by supporting the reestablishment of salt or aquaculture extractive activity, which would facilitate the regulation of floodgates to control the periodic exchange of tidewater so as to maintain optimal water conditions to enhance food availability for waterbirds. In extensive aquaculture sites

surrounding intertidal areas, the sequential rotation of drawdowns is another important consideration that would ensure a constant provision of supratidal feeding sites. Vegetation cover in these areas should also be controlled to offer accessible roosting sites. A sparse vegetation cover composed of native plant species may provide an optimal food web base without creating physical obstruction (Ma et al. 2010).

With respect to neglected and densely vegetated inland zones, the reestablishment of extractive activity here may be an expensive option. Instead in depth research of vegetation community structure is recommended here and restoration measures in favour of natural marsh communities should be considered. These sites must also be evaluated in terms of other services they may provide (e.g. CO₂ trapping, coastal protection, water quality regulation, recreation and more) thereby ensuring a truly integrated management approach (Camilleri et al. 2014).

With respect to currently restored zones, these are considered to be very dynamic environments with some aspects taking decades to stabilize after construction (Ma et al. 2010). Close monitoring is suggested so that knowledge from previous experiences can feedback future projects.

Finally, legal and management tools must facilitate collaboration efforts between research teams, governmental and non-governmental agencies and local salt and fish pond owners. This is crucial in determining the success of the implemented management actions.

Acknowledgements

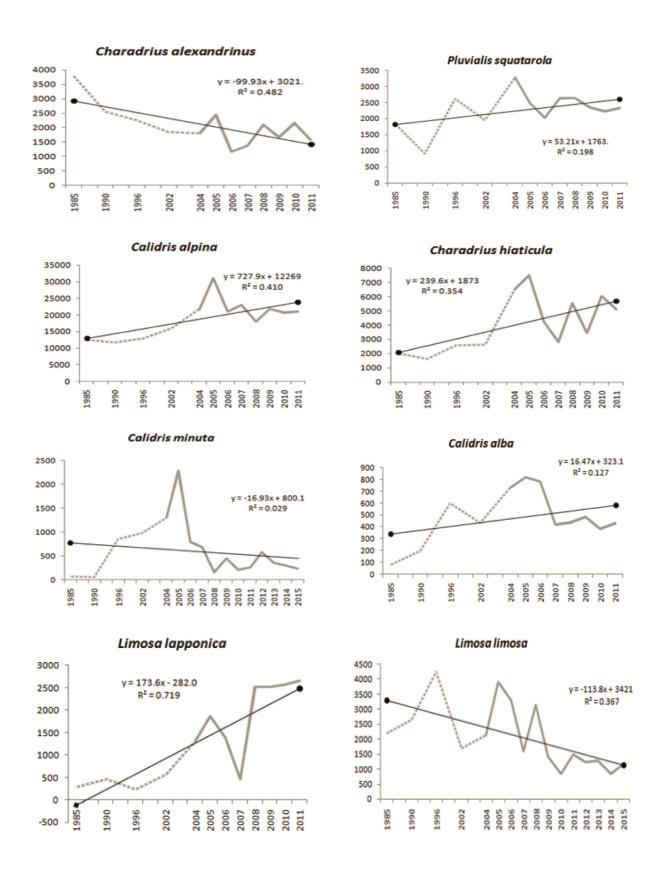
All research work was carried at the University of Bologna (UNIBO) (Italy) and the University of Cádiz (UCA) (Spain). Financial support was provided by the Education Audiovisual and Culture Executive Agency through the Erasmus Mundus Joint Doctorate Program in Marine and Coastal Management (MACOMA) (2011-2014) [specific grant agreement number 2011-1614/001-001 EMJD]. Authors wish to extend their appreciation to the agency. Acknowledgements also go to Antonio Gómez Ferrer (the park manager), and staff from the Andalucian Environmental and Water Agency for facilitating data access.

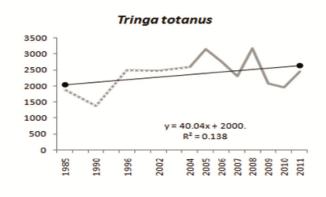
DM (drained marsh), NoA (No Activity), AS (artisanal salt extraction), IS (industrial salt extraction), EA (extensive aquaculture), SIA (semi-intensive aquaculture), R (restored zones)

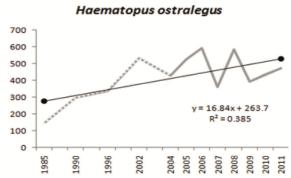
Zone	1985	2000	2011
1	DM	IS	IS
2	IS	IS	IS
3	EA	SIA	SIA
4	NoA +EA	NoA +EA	NoA +EA+R
5	NoA + EA + AS	NoA +EA+AS	NoA +EA
6	EA+AS	EA	NoA +EA+AS
7	NoA	NoA	NoA + R
8	NoA	NoA +AS	IS + EA
9	EA+AS	EA+AS+SIA	EA + AS
10	NoA	NoA +EA	NoA
11	NoA +EA	EA	NoA + EA
12	EA+AS	EA+SIA	EA + AS
13	NoA +AS	EA+AS	EA + AS
14	NoA +EA	NoA+SIA	NoA
15	NoA +EA+AS	EA	EA
16	EA+AS	EA+AS+SIA	NoA + EA + AS
17	NoA	EA	NoA
18	NoA	NoA	NoA + EA
19	NoA +EA	EA+ SIA	NoA + EA + SIA

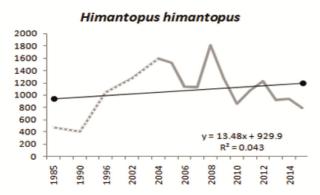
Annex II

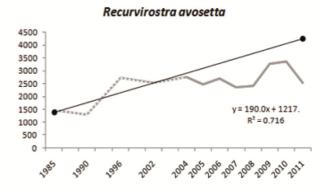
Annual variations in abundance of wintering waterbirds

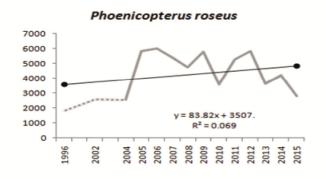


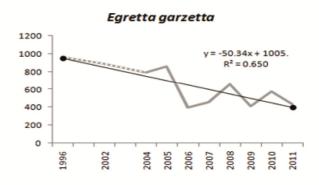


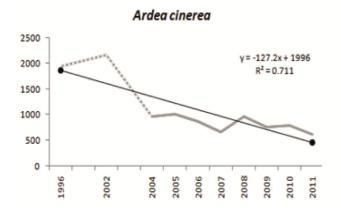


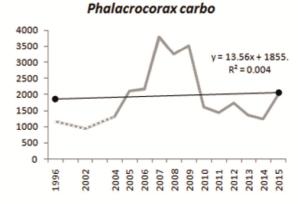












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Chapter 6. Conclusions

The study documented was successful in analysing characteristic spatio-temporal trends pertaining to the Bahía de Cádiz Nature Park, using indicators selected through an integrated management approach. As a result the following list of conclusions and recommendations were formulated. They are meant to benefit the park's administrative body, involved stakeholders and decision-makers and future research initiatives concerning the area.

- I. Through the conceptual framework applied in Chapter 3 the socio-environmental scenario characterizing the park area was studied at both general and specific levels, leading to the following conclusions:
- 1. The priority issues to be considered within the park's management plans include:
 - i. The definition of the current conservation status of the park with respect to modified legislation
 - ii. The promotion of sustainable development with respect to sectors based within the park area
- iii. The conservation of the park's ecological integrity
- iv. The promotion of culture, public use and participation
- v. The conservation of the hydrological system and water quality
- 2. With respect to issue 1.i., the implications of the recent modifications to Law 2/2013 (old Coast Law) on ownership issues should be clarified. Negotiations should be made in favour of conservation easement whereby environmental preservation measures would be implemented whilst allowing salina owners to retain private property rights.
- 3. With respect to issue 1.v., we found that 13 out of a total of 21 water units linked to the park area are currently in a bad state according to the Water Framework Directive. These comprise of rivers/watercourses, transitional waters and groundwater units; the state of which may highly depend on systems (e.g. municipalities) external to the park boundaries. The implications of this situation on the hydrological system within park area should be reviewed and corrective action should involve collaboration with neighbouring urban/agricultural centres.
- 4. With respect to the DPSIR framework:

- i. It supports an integrated research approach by supporting the identification of social and environmental elements/indicators (and important links between them) characterizing the park's priority issues.
- ii. The framework's adaptability makes it a practical tool applicable within research or management efforts directed towards any of the identified priority issues (1.i-v).
- iii. Further, the integrated nature of the framework is in line with current integrative management and legislation tendencies (e.g. Law 7/2007 of the 9th of July for the Integrated Management of the Environmental Quality).
- iv. It supports the identification of all provisioning, regulating, cultural and supporting services as described by the Millennium Ecosystem Assessment.
- v. Despite its primary focus on local-scale issues targetable through shorter-term plans, pressures such as climate change and sea-level rise, better targeted through larger-scale and long-term plans, should not be overlooked.

The framework is therefore a recommendable support tool in all future integrated management and research initiatives.

II. Following the identification of sector-related land-use and land-cover changes that have occurred within the park area over the past 25 years, in Chapter 4, the following conclusions and recommendations were formulated:

- 1. Some degree of land-cover change was recorded in the natural areas of the park, including:
 - a change in the ratio of low to high marsh in the Los Toruños area, possibly related to restoration efforts in 2004, aimed at re-establishing the natural hydrodynamics of the area
 - ii. growth of the sandspit of the Playa de Levante (Los Toruños area), possibly linked to increased sediment transport following the upstream re-opening of the Rio San Pedro in 2004.
- iii. a progressive increase in the size of the intertidal flat area
- iv. proliferation of low marsh vegetation in the Sancti Petri channel

With respect to these changes we recommend longer-term evaluations through a combination of remote sensing, GIS techniques and field-based methods, in order to exclude possible variability based on environmental factors (as tide level or climate patterns).

- 2. The most important land-cover and land-use changes identified in the artificial marsh areas include:
 - i. extensive inundation over 800 ha, linked to the expansion of industrial salt extraction in the north of the park, replacing a drained marsh area
 - ii. vegetation succession over 2394 ha spread throughout the remaining park area, replacing inundation/pond areas linked to artisanal salt extraction and aquaculture activities. Succession processes were found to be present over abandoned areas and plots declared for extensive aquaculture uses. In the latter case, despite declared extractive activities, the actual use and maintenance is probably sporadic or none at all, thereby allowing succession processes to take over.
- 3. With respect to the located vegetation succession dynamics, further research exploring the following points is suggested:
 - i. the relation amongst underlying factors of succession dynamics including: the distance of the area from the tidal area, time since activity has ceased within an area, altitude, water drainage, salinity levels, and the presence of vegetation propagules.
- ii. the characterization of the plant communities within areas marked by succession, as well as related energy turnover rates, decomposition rates, detritus import/export, sedimentation/erosion rates and influences on faunal communities (most importantly macroinvertebrates).
- 4. An integrated approach towards the management of succession-marked areas is advised accounting for all their potential values including: ecological integrity, water quality regulation, flood protection, erosion/sedimentation regulation, carbon storage.

- 5. The classification methodology developed is suggested for use in future monitoring efforts of the park's landscape changes. It's advantages include:
 - i. low attributed costs due to the possibilities of using freely downloadable satellite imagery and open-source analytical software
 - ii. a resulting digital GIS database with the capacity of integration with other information layers
- 6. The land-cover and land-use data generated is an optimal resource in landscape management facilitating decision-making related to land-use planning (e.g. the identification of real vs. declared uses, land-use licensing) and conservation and restoration planning.
- III. Following the analysis of the spatio-temporal relations between the identified landscape changes and migratory waterbird populations in Chapter 5, the value of the park's natural-artificial wetland complex in sustaining wintering waterbird populations was confirmed. The following are conclusions and recommendations formulated as a result of this study:
- 1. The park maintains its international importance as waterbird habitat by supporting wintering populations of over 20,000 birds and by annually supporting numerous species at numbers superior to the 1% flyway threshold; thereby satisfying relevant Ramsar waterbird criteria.
- 2. The evolution of the salt extraction and aquaculture sectors and their consequent landscape changes have been highly influential on the overall waterbird community structure. Two major episodes have been identified: (i) a period of increasing extractive activity approximately between 1985 and 2000 and a consequent overall increase in the management of water levels (ii) a period of decline in the proportion of actively managed area between 2000 and 2011, accompanied by increased negligence of pond structures. The influence of this reduction in land-use was reflected in:
 - i. the declines in fish-eating species the little egret (*Egretta garzetta*), the grey heron (*Ardea cinarea*) and the great cormorant (*Phalacrocorax carbo*) parallel to the crisis effecting the aquaculture sector

- ii. declines in populations of small waders the little stint (*Calidris minuta*) and the Kentish plover (*Charadrius alexandrinus*) pointing out at a major sensitivity of these species to local pressures.
- 3. During periods of major coverage of active/managed areas and water bodies, we found a more widespread use of the park area by waterbirds, as well as significant increases in overall species diversity. Hence in order to enhance the area's potential for waterbirds, conservation measures must include adequate land-use management and landscape restoration plans. In line with this target, the following recommendations have been formulated:
 - i. Areas with extensively inundated areas of 0-50 cm water depths including industrial salinas (La Tapa and Santa Maria), the restored area in the Rio Arillo zone and the Esteros de Sancti Pectri ponds were found to accommodate waterbird populations at high richness and density values. The potential of these sites as waterbird habitat should be maintained and even enhanced thorough the consideration of the multiple environmental factors favouring foraging and roosting opportunities. Alongside water depth, other variables including salinity, pH, prey density, vegetation cover must be controlled.
 - ii. In areas with ongoing extractive activity, it is possible to manage water levels to favour of the accommodation of waterbird populations, without compromising production cycles. Within:
 - salt extraction ponds, water levels can be managed to enhance food resource availability during the wintering and pre-migration phases of waterbirds from December to March. This does not interfere with the salt production cycle which usually runs from April to October.
 - extensive aquaculture sites, the sequential rotation of drawdowns in different ponds is recommended. This system would regularly provide macroinvertebrate-rich exposed substrates for high-intake feeding during high-tide moments.
- iii. Adjacent intertidal flats and supratidal artificial marshes were found to act as a habitat compound that accommodates waterbirds at significantly high richness

and abundance values. Intertidal areas are highly productive feeding sites, and proximate marshes present foraging and roosting opportunities at low commuting and predation costs. For this reason, appropriate water-level management in supralittoral areas of relative proximity to intertidal flats or canals is recommended. The re-establishment of salt extraction or aquaculture activity in these areas should therefore be prioritized. Such measures would facilitate the regulation of water levels through the control of flood gates permitting periodic exchange of tidewater.

- iv. Abandoned and densely revegetated zones situated in the internal sections of the parks were found to accommodate low waterbird richness and abundances. As the reestablishment of extractive activity here is considered economically unviable, it is recommended that these areas are evaluated in terms of other services they may provide, other than their use as waterbird habitat. Relevant services to be considered include recreational/educational/research values, storm surge/flood protection, water quality regulation and more.
- v. Existing restored sites must be closely monitored and experience feedbacked into future plans.
- 4. The applied analysis can be replicated for breeding waterbird population data.

Annex I

Material related with attendance to the MEDCOAST CONGRESS 2013 (Marmaris, Turkey) is attached her, including:

- ✓ Letter of acceptance of submitted manuscript
- ✓ Record of attendance
- ✓ Poster presented
- ✓ Manuscript published within the EMECS 10 MEDCOAST 2013 Proceedings and Book of Extended Abstracts of the Global Congress on ICM

SARAH CAMILLERI University of Cadiz,

11510 Puerto Real, Spain

02 April 2013

Dear Colleague,

The Abstract Review Committee of the "Global Congress on Integrated Coastal Management: Lessons Learned to Address New Challenges" has finally completed the selection process. I am pleased to inform you that your paper entitled:

DPSIR Framework for Support of Integrated Assessment

is accepted for **poster** presentation. We had a remarkable response to the call and received over 400 abstracts from authors residing in 50 countries. Several good quality abstracts had to be declined due to space limitations in the technical program of the Congress, which will include about 150 oral and 160 to 180 poster presentations. The decision on the mode of presentation (poster or oral) of accepted abstracts is made solely on the size of the expected audience that would be interested to follow the subject dealt by the presentation, **definitely not** on the scientific / professional quality of the abstract. Abstracts of very high scientific quality are chosen for poster presentation due to the specificity of the subject matter. Manuscripts of all presentations, oral or poster, will be included in the conference proceedings without an indication. The poster presentations constitute a very important part of the Global Congress. There will be a contest among poster presentations and the best three posters chosen by a jury will be awarded in the Closing Session.

This letter is sent to the first author (or to the communicating author) only. You should coordinate with your co-authors for ensuring the timely preparation of your final manuscript, which must be submitted online by 30 June 2013 together with 5 to 10 keywords by using the link: "http://conference.medcoast.net/modul/index/menu/Online-submission/18"), after uploading the signed https://conference.medcoast.net/modul/index/menu/Online-submission/18"), after uploading the signed https://conference.medcoast.net/modul/index/menu/Online-submission/18) at the Congress web page. https://conference.medcoast.net/modul/index/menu/Online-submission/18) at the congress web page. https://conference.medcoast.net/modul/index/menu/Online-submission/18) at the congress web page. https://conference.medcoast.net/modul/i

Inquiries on any matters should be directed by e-mail to the Congress Secretariat (medcoast@medcoast.net). You may follow further development of the Congress by visiting our web page (https://conference.medcoast.net).

MED Mediterranean Coastal Foundation

Printing of your paper in the proceedings and inclusion in the conference program will be assured after the review of the submitted manuscript by the Abstract Review Committee in relation to the quality and originality of the contents, the quality of the English language used and the compliance of all rules described in the Manual for Preparation of Manuscripts, which can be downloaded from the Congress web page. Please note that, if there is a remark of the Abstract Selection Committee about your abstract, it is printed at the bottom of this letter.

The Global Congress, which resulted from joint organization of the Tenth International Conference on Environmental Management of Enclosed Coastal Seas (EMECS 10) and the Eleventh International Conference on the Mediterranean Coastal Environment (MEDCOAST 2013) will, no doubt, be a world event on Integrated Coastal Management. With your contributions, we look forward to a rewarding scientific meeting during 30 Oct - 03 Nov 2013 at the highly attractive premises of Grand Yazıcı Club Turban Hotel, in the charming resort Town of Marmaris, Turkey.

I look forward to meeting you during the Congress.

Sincerely yours,

Prof.Dr. Erdal Özhan

President,

MEDCOAST Foundation



Mediterranean Coastal Foundation

Global Congress on Integrated Coastal Management: Lessons Learned to Address New Challenges 30 October – 03 November 2013, Marmaris, Turkey

25 July 2013

SARAH CAMILLERI

University of Cadiz, 11510 Puerto Real, Spain

Dear Sarah Camilleri,

I am pleased to inform you that your manuscript entitled:

DPSIR Framework as the basis of Integrated Assessment

which you submitted to *Global Congress on Integrated Coastal Management: Lessons Learned to Address New Challenges* (30 October – 03 November 2013, Marmaris, Turkey) is accepted for inclusion in the Congress Proceedings. Your presentation will be scheduled to an appropriate session of the Congress Program, which will be circulated in September.

Please kindly note that registration to the conference is carried out through the Congress web page at the address: http://conference.medcoast.net. At least one author of your paper must be pre-register by 31 July 2013 for starting the process of editing of your manuscript. Information on this issue is also available at the Congress web page.

If you need entry visa for Turkey, you may use this letter for indicating the reason for travel when you apply for visa.

I look forward to a successful and enjoyable scientific event and to meeting you in Marmaris.

Prof.Dr. Erdal Özhan

Chair, Global Congress on ICM

President, Mediterranean Coastal Foundation





Record of Attendance and Presentation

This is to certify that: Sarah Camilleri

Organisation: Integrated GeoScience Research Group,

University of Bologna

Attended: Global Congress on ICM: Lessons Learned to

Address New Challenges. EMECS 10 MEDCOAST 2013 Joint Conference, 30 October – 03 November 2013

Venue: Grand Yazıcı Club Turban Hotel

Presented the A Conceptual Framework for Integrated

paper entitled: Assessment

Prof.Dr. Erdal Özhan

President,

Mediterranean Coastal Foundation

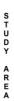


A Conceptual Framework for Integrated Assessement of the Bahia de Cadiz Nature Park (Spain)

-Sarah Camilleri, MACOMA Erasmus Mundus Doctoral Candidate-

Supervisors:
Profs. Alejandro Perez Hurtado (Coastal Wetlands Research Group, University of Cadiz)
Profs. Giovanni Gabbianelli (Integrated Geoscience Reasearch Group, University of Bologna)





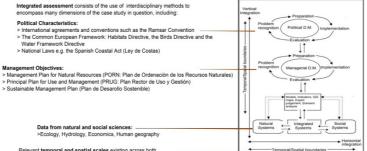
NTRODUCTION



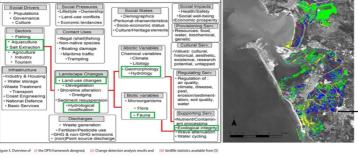
The Bahia de Cadiz Nature Park (N.P.), found on the central part of the Allantic coast of the Cadiz province, consists of 10.522 hectares of lanscape that well reflects the historical interaction between man and the surrounding natural environment. Apart from the proximity of the five municipalities, ports and indudustrial polygons that surround it, much of the tidal welland area reveals how it has been transformed for salt extraction or aquaculture [4].

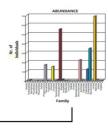












The DPSIR conceptual framework is applied to gain a better understanding of how elements from natural and social systems interact. The framework supports: > scoping, through literature review and expert consultation, to identify elements and causal links that characterize the area > selection of appropriate research tools and methods > identification of available data as well as data gaps [8] Knowledge gained at this stage shall be used to support later data integration...

Aerial photography and LANDSAT satellite images are being used to study land use/land cover change since 1985 until the present day ENVI 4.7 is the software supporting this stage. Results shall be integrated with...

...birdlife census records for wintering and breeding populations. Such data has been collected since 1985/6 until nowadays, covering different zones of the park with the possibility of looking into the spatio-temporal distribution of different bird families and species. NatureServe Vista (ESRI ArcGIS™ extension that uses Spatial Analyst and Microsoft Access) is the software being considered at this stage.

Conclusions from this kind of integration hope to provide support to management and decision-making linked to the park area!

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A Conceptual Framework for Integrated Assessment

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Abstract

Interdisciplinarity and knowledge integration are widely applied concepts for decisionsupport within environmental management. The choice of an appropriate framework to support integrated assessment is an important step for the definition of the system being studied. The DPSIR (Driver-Pressure-State-Impact-Response) framework is one such tool which functions by addressing the cause-effect relationships between human activity and the environment, thus being ideal for anthropogenized natural environments as is the Bahia de Cádiz Nature Park. The paper describes how, supported by input from literature review and expert consultation, the framework may be used as an entry point for the definition of the significant D-P-S-I elements that characterize the study area, playing at different spatial and temporal ranges. Human health concepts are included, emphasizing its 'integrated' nature. Results demonstrate an interest in uncovering dynamics amongst drivers within the 'Sectors' and 'Infrastructure' groups; resulting changes within land-use patterns and hydrological modifications (pressures); their effects on the different land-types, geological and hydrological characteristics, vegetation and birdlife (states) and the effects of these on the different services (impacts) the park environment offers. Remote sensing, GIS technology and indicators are postulated as efficient analysis tools for applying to available aerial photos, satellite imagery and birdlife census data. Ultimately the framework hopes to serve as a conceptual base for future investigation, within the scope of this project and beyond.

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Introduction

There is a growing interest in interdisciplinary concepts and integrated assessment within environmental management (Brouwer *et al.*, 2003) as seen within governance methods shifting from approaches which treat sectors of decision making as independent entities towards cross-scale institutions and institutional diversity.

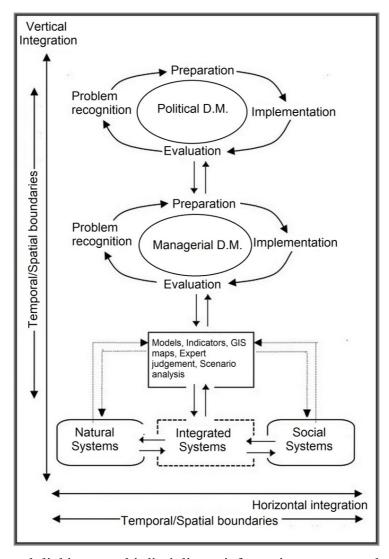


Fig 1. Framework linking a multi-disciplinary information system to decision making at managerial and political levels (D.M. = decision making) (adapted from Brouwer *et al.*, 2003).

Through integrated assessment, decisions are supported in a more holistic manner reducing the chances of problems arising from uncertainties and incomplete information (Brouwer *et al.*, 2003). Knowledge integration may involve information from different spheres. In wetland management this may include: different ecological components (birdlife, macro invertebrate communities), various biogeochemical and physical systems (hydrologic features, nutrient cycles) and the socio-economic/socio-cultural context. Figure 1 describes a decision-making cycle depicting the horizontal

integration across different knowledge systems and the vertical integration of information as decision-making contexts become more complex.

It also depicts the important consideration of varying temporal and spatial boundaries to be considered. In the coastal zone spatial scale is to be considered across horizontal geographical gradients, exchanges and fluxes; but also across vertical ones with atmosphere, soil and groundwater. Temporal variation is also varied. Tides, climatic patterns, fisheries production, the El Nino phenomenon and sea-level rise are just some examples of how natural cycles and human activities may vary across days, seasons, years, decades or larger glacial/interglacial scales respectively. Further the same issue may extend across different geographical and time scales from a natural scientific perspective, a social scientific perspective and a political perspective (Boesch cited in Brouwer *et al.*, 2003).

Primarily this report aims at fixing the scope of any possible integrated assessment of the study area: problems to be addressed, identification of system boundaries and recognition of policy objectives and the ways in which they can be evaluated. The best starting point is to generate a baseline description of the coastal system being studied (Turner, 2000). The DPSIR (Driver-Pressure-State-Impact-Response) framework is one appropriate tool that can serve this purpose. Visually depicted as a conceptual map, it is used for system analysis of the environment studied, through the definition of cause-effect relationships between sectors of human activity and the environment (Agyemang et al., 2007; Chung and Lee, 2007). According to this systems analysis view: social and economic development (e.g. population growth) act as DRIVERS towards the exertion of PRESSURE on the environment (e.g. land-use change), the STATE of the environment changes (e.g. degradation of natural habitat), and lead to IMPACTS on human health, ecosystems and materials (e.g. loss of natural shoreline protection) that may bring forth a societal RESPONSE (e.g. zoning and management) that feeds back on the driving forces, pressures, state and/or impacts (Smeets and Weterings, 1999). The framework's integration of both human and environmental factors make it fitting for coastal areas as that of the Bahia de Cádiz Nature Park, marked by a 3000 year human occupation.

The first and most fundamental function of the DPSIR Framework, as defined in Smeets and Weterings (1999), is the classification of all elements that characterize the system or area being studied under one of its five classes (Drivers, Pressures, State, Impacts, Responses). Second is the identification of existing, or formulation of new, indicators as tools for the evaluation of these elements and the relationships between them as in Kristensen (2003) where, in combination with management questions and with input from literature review, the framework supported the selection of system-specific indicators for integrated analysis at later stages. Although indicators are the 'tool' originally supported by DPSIR, the framework has also been used as a starting point for scenario development, participatory approaches and modelling. Finally, the framework is also a valid communication tool of research results, its structure providing accessibility and meaningfulness to decision makers, whilst providing sets of decision options rather than one definite solution (Tscherning *et al.* 2012).

Tscherning *et al.* (2012) includes a thorough review of a number of studies using the DPSIR framework in order to determine under which conditions its application may be a real support to decision making. Out of 21 studies analysed, 18 defined their DPSIR elements through literature review. Such an example is the historical

environmental assessment of the coastal zone of the inner Thermaikos Gulf in Greece by Karageorgis *et al.* (2006). Meanwhile in 8 out of the 21 studies, stakeholders where involved during the definition of the DPSIR elements either through expert consultation as in Borja *et al.* (2006) or through participatory methods as in Agyemang *et al.*, (2007). This approach, was found to allow the conceptual model to be a better representation of the 'real world' especially when this knowledge integration is of a trans-disciplinary nature involving academic researchers from different disciplines as well as non-academic participants such as land-managers, user-groups and the general public. The basing of research on a range of perspectives counteracts one of DPSIR's possible drawbacks: that of being biased and of excluding perspectives of certain groups. This approach is relevant during all research activities and stages of a project, and should be considered for realistic assessment. An example is the participation of end-users during model\tool design for enhancing its use and acceptance after the design stage (Tscherning *et al.*, 2012).

Considering the above functions and best-practice related to the DPSIR framework, the overall objective was to identify the most significant Drivers, Pressures, States and Impacts characterizing the Bahia de Cádiz Nature Park, through literature review and expert consultation; and thereby propose tools and methods for their analysis. 'Responses' were thought worth considering during later evaluation stages.

Study Area

The Bahia de Cádiz Nature Park has been declared a protected natural space at a regional level since 1989. It is found on the western Atlantic coast of the province of Cádiz between 36° 22' to 36° 37' N and 5° 7' to 6° 16' W (RAMSAR, 2012) occupying an area of 10,522 ha and being surrounded by five municipalities (Junta de Andalucia, 2004). The landscape reflects the historical interaction between man and the surrounding natural environment. Much of the natural tidal wetland area has been transformed into salt pans (referred to as 'salinas') after a boom in the artisanal saltextraction industry, occupying 8,000 ha of the nowadays-park area by 1894 (Villalobos, 2004). Nowadays, very little artisanal salt production remains and much of the salinas (salt pans) are either inactive or have been transformed for aquaculture, an activity present since the 1970s (Arias García and Santaella Sánchez, 2004). Industrial scale salt extraction can also be found. The bay is also significant for its biodiversity, hosting various migrating and wintering bird species, including certain breeding populations. Of great importance is its RAMSAR status, acquired in 2002, designating the area with the title of 'Wetland of International Importance especially as Waterfowl Habitat' (Junta de Andalucia, 2004). It is also crucial for spawning, nursery and foraging of various fish species (RAMSAR, 2012).

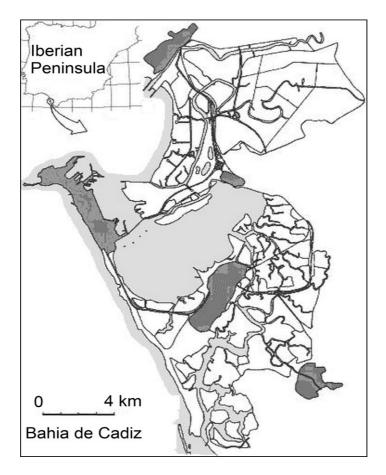


Fig 1. Location and boundaries of the park. The light grey areas indicate coastal waters and the internal hydrological system. The dark grey patches mark the surrounding urban centres (adapted from Muñoz Arroyo, 2003)

Methodological Approach

All the available park documents were 'scoped' for the compilation of the D-P-S-I classes that would support horizontal integration as well as for the identification of priority political and management objectives that would support vertical integration. The EEA's (Smeets and Weterings, 1999) definitions of Drivers, Pressures, States and Impacts were used as a reference for correct classification. Further, a 'DPSIR Words List' available at EPA (2012) fulfilled a dictionary/checklist function at this stage. Further the integrated framework concept from EPA (2012) was applied by including a parallel 'human health' pathway through which social drivers, human behaviour (pressures), human state and human well-being (impacts) were considered. In addition to Social Impacts, other Impacts were organized within the four groups of ecosystem services as classified by the Millennium Ecosystem Assessment: provisioning (products obtained directly from the ecosystems), regulating (benefits obtained from the regulation of ecosystem processes), cultural (non-material benefits people obtain from ecosystems through cognitive development and aesthetic experiences) and supporting (benefits necessary for the production of all other ecosystem services) (Pinto et al. 2013).

Next, the framework assumed the role of a communication tool during interviews with key informants (Hay, 2004). A purposive sampling approach (Trochim and Donnelly, 2007) was applied to select key informants, these being individuals who; based on their experiences, positions, decision-making capacities, and/or active participation in the area; were thought to have the right knowledge to be able to provide supportive insight (Luloff et al., 2012). Further the selected participants satisfied another condition: that of least bias by personal interests based on economic (or other) activities taking place within the park. This criterion is in line with the fact that a holistic vision of the park area is considered fundamental at this stage of the project and in line with the open vision of DPSIR. Bias based on personal research/career interests is harder to avoid. Based on a visual presentation of the draft framework, open-ended discussions with four interviewed experts; a biologist/conservationist, the park's managing director and two coastal managers; aimed at acquiring qualitative information to highlight the priority elements that best (a) support maintenance of the park's environmental and social functions or (b) reflect significant tendencies within the park area. Further, tools and methods that could be used to quantify these elements and links or monitor such changes were discussed.

Results

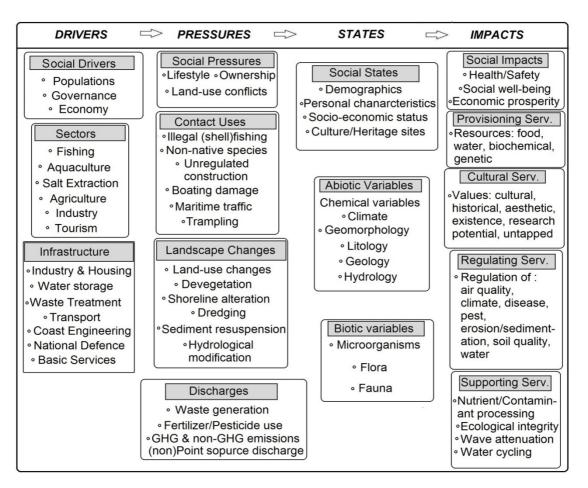


Fig 3. D-P-S-I framework of the Bahia de Cadiz Nature Park (Serv. = services)

Figure 3 represents the D-P-S-I elements characterizing the Bahia de Cádiz Nature Park as identified from literature review. This was the schematic representation that served as a discussion tool during expert consultation aimed at prioritizing elements (and links between them) and identifying appropriate analysis tools, methods and models.

Conclusions

Integrated assessment should be tailor made to fit management objectives identified at different levels. Primarily, the park's local-scale management objectives are enlisted within the 'Management Plan for Natural Resources' (PORN: Plan de Ordenación de los Recursos Naturales) and the 'Principal Plan for Use and Management' (PRUG: Plan Rector de Uso y Gestión) created through decree 79/2004, and on which the Program for Public Use (Programa de Uso Publico) is based. Other goals are outlined within the Sustainable Management Plan (Plan de Desarollo Sostenible) for the park created through decree 177/2006. All three plans target a combination of socio-economic activities and natural elements with the aim being a harmonious coexistence (Junta de Andalucia, 2004; Junta de Andalucia, 2006a; Junta de Andalucia, 2006b).

Karageorgis *et al.* (2006) explain how the fulfilment of these objectives should always be supported by regulations and guidelines of direct or indirect relevance to land, natural resource and water management and originating from three levels:

- (i) International agreements and conventions such as the Ramsar Convention (Ramsar Convention Secretariat, 2010) with its Wise Use Handbooks and the Millennium Ecosystem Assessment for Wetland and Water (Millennium Ecosystem Assessment, 2005).
- (ii) The Common European Framework, made up of directives which set out goals that all EU countries must achieve, such as the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC) which set out objectives for the conservation and enhancement of wetlands and their flora and fauna, and the Water Framework Directive within which the specific role of wetlands is elaborated in the CIS Guidance Document no. 12. (Coops and van Geest, 2007).
- (iii) National Frameworks (national laws, ministerial decisions) underlining formulated binding legislative acts. Of great relevance is the Spanish Coastal Act (Ley de Costas) which, since its approval in 1988, has been the base of discussion regarding the classification of salina areas under Maritime-Terrestrial Public Domain (Barragán Muñoz *et al.*, 2004).

The DPSIR conceptual framework and expert consultation have served for the identification of the priority system elements (Drivers-Pressures-States-Impacts) and interactions to be considered when working out ways (Responses) for reaching current and future management goals. Drivers as 'Economic tendencies', 'Governance' and 'Management and Administration' are considered highly influential with respect to all the natural and social dynamics characterizing the area. This is a clear example of how local scale dynamics (e.g. ownership issues) are unavoidably conditioned by decisions at other temporal and spatial scales. There is also great interest in understanding how and to what extent the variable activity intensity of sectors as 'Aquaculture', 'Salt extraction' and 'Infrastructure' related drivers (e.g. expansion of industrial zones) have lead to pressures involving landscape changes (land-use, hydrological and sediment

related modifications). With the decline of artisanal salt industry, fish poly-culture remained as a residual activity for the owners of these ponds. Many ponds were partially adapted to extensive fish farming reutilising the evaporation areas by digging the ponds to increase depth and by opening more floodgates whilst others were completely transformed for semi-intensive or intensive fish monoculture. And finally, many others remain abandoned. This being an artificial system, without proper maintenance, unused areas may be destined to disappear: unused ponds may be either swallowed by the sea while other ponds may completely and permanently dry (Yufera and Arias, 2010). Changes in land-cover and land-use influence the abiotic state (habitat types, hydrological features and chemical variables) and the biotic state (habitant flora and fauna). Of important mention are the 58 non-passerine bird species including a reproductive population composed of waders, shorebirds, seagulls and terns; as has been demonstrated by many studies carried out in the area (Pérez-Hurtado, 1992 and Muñoz Arroyo et al., 1997). Finally, alterations within the social and environmental state that characterizes a system results in impacts on resources and services of different kinds including food, education, recreation, water quality regulation and ecological integrity.

Brouwer et al. (2003) propose indicators and models as two important ways of assessing these kinds of chain interactions through the provision of both qualitative and A combination of environmental, social and economic quantitative information. indicators is usually proposed in order to capture a whole range of impacts on natural and social systems under different management scenarios. Further three possible indicator approaches are proposed. Firstly a phenomenon can be indicated with the help of a phenomenon in another area e.g. biological disruption can be an indicator of polluting discharge. Next, different indicators can be linked in a multi-criteria kind of framework as applied in Chung and Lee (2009) for the prioritization of water management. Finally, integration can be interpreted as the integration of values of different indicators into one value, as in Benini et al. (2010), where a composite indicator composed of air quality, water consumption and waste production data is used to study the environmental performance of a municipality. Although the ability of a single indicator to reflect an entire ecosystem is questionable, in many cases to consider studying variations of single elements or relationships may be more of a realistic and reachable aim. This is so in the Baltic drainage basin case study described in Turner (2000) where, due to limited detailed data, the social benefits (impacts) of eutrophication (pressure) reduction are studied through a single system function: provision of beach recreation and amenity. Models, the other proposed assessment tool, may be organized into three activity models, natural systems models and models with a valuation dimension. Activity models relate socio-economic drivers to nutrient, toxin and sediment fluxes (pressures). Natural systems models provide insight into the doseresponse relationship by linking flux (pressure) information to habitats, ecosystem and human wellbeing (state, impacts and responses) e.g. food supply/demand models, fisheries stock models. Finally valuation models look into costs, benefits and trade-offs information through the use of monetary (or other) value linked to system elements and processes. Finally indicator and model data will then provide input for evaluation methods of possible management scenarios, the choice of which is dependent on the spatial scale of the project. The application of economic valuation methods is favoured despite the difficulty of representing everything with a monetary value (Turner, 2000).

On one hand, policy relevant research shall demand data required of the different disciplines and this will help identify date inconsistencies, limitations or real gaps

(Turner, 2000). On the other hand the choice of assessment methods should adapt to whatever data is made available or is easily accessible. Environmental research in the area has been active at many levels, also supported by the fact that part of the University of Cádiz installations are located in the park area and is home to the environmental and marine sciences faculties and other research centres. The above review and the presented DPSIR framework hope to serve as a conceptual base for any future projects or assessments. Within this project it targets the integration of longer-term data sets as: (i) birdlife census records going back to 1985/6 and (ii) free aerial photography dating back to 1956 and satellite imagery from international and regional sources which, through remote sensing and GIS methods can be used for studying spatio-temporal variations of land types and vegetation groups.

Novel data sets include those within the 2012 assessment plans for different river basins in Andalucía including the Guadalete-Barbate of which the park makes part. Of relevance within this plan are assessment results of transition and coastal water bodies through a combination of ecological and chemical indicators in compliance with the Water Framework Directive (Junta de Andalucia, 2012). Updated socio-economic data should also be provided by local and regional administrations. Further, in addition to interviews with experts, future assessments based on this framework may also consider stakeholder input, into the prioritization of D-P-S-I elements and linkages and further research stages, as an interesting way of looking at variations between the public's and experts' perception of environmental issues.

Acknowledgements

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Key words: Integrated Assessment, Tidal wetland, DPSIR, Expert consultation, Bahia de Cádiz Nature Park

Annex II

The two attached posters were presented during different events held during the mobility research period in Ravenna. The events were:

- ✓ Ravenna2012 Fare i conti con l'ambiente organized within public spaces of the municipality of Ravenna
- ✓ Io studio l Ambiente 2013 organized within University grounds





ERASMUS MUNDUS JOINT PhD IN MARINE AND COASTAL MANAGEMENT (MACOMA)



Integrated Assessement for Decision and Management Support within the Bahia de Cadiz Nature Park (Spain) Sarah Camilleri-





Supervised by: Prots. Alejandro Pesez Huttado (Coastal Wetlands Research Group, University of Cadia) Prots. Glovanni Gabbianelli (Integrated Geomience Research Group, University of Rollogua)

BACKGROUND:

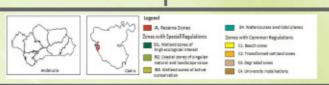
The very complexity of coastal systems has lead to a continuing development and interest in inter-disciplinary concepts and methods and integrated assessement. Such approaches help:

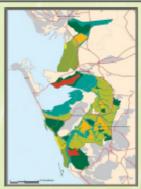
although uncertainties and uncomplete information are inevitable [2].

STUDY AREA:

The park is found centered on a large area of wetland in the central part of the Atlantic coast of the Cadiz province, with a total area of 10.522 hectares.

It received the 'Nature Park' status in 1983 and was also declared a RAMSAR site in 2002 for its International importance as Waterbird habitat [4]





Pigure : Zonation Map-of the Bahia de Cadix Nature Park: [4]

RESULTS FROM LITERATURE REVIEW

The study area is characterised by a dymanic character linked to processes occurring at different temporal and spatial scales.

At indefinitely large time-scales, sca-level rise and geo-morhological change are important.

In terms of a century, the landscape has been shaped by the salt-extraction industry (8,000 hectares by 1894) [6], aquaculture in the 70s [1], shell-fishing, urbanization and industrialization [4].



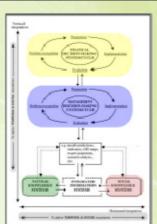


Figure 3: Premework linking information from multi-fladp science with decision-making systems. The two-ways arrows this a cyclical system where information can be supplied to demanded from any component. Adapted from [3]

- > relevant temporal (which are the relevant processes?) and spatial scales (are areas outside the park relevant?)
- > political characteristics of the system e.g. EU Directives: Birds Directive, Habitat Directive, Water Framework Directive

> nature of electisions and management objectives: dependance on current priorities, past failures, possible future issues

Integration shall involve information from different spheres:

- > ecological components (e.g. birdlife, macro-invertabrates) > biogeochemical and physical system (e.g. hydrology, nutrient cycles)
- > socio-economic and socio-cultural context e.g. lack of economic viability of artisanal salt extraction, modernization

[2, 3]

WORK IN PROGRESS

- Literature review and collection of data
 Application of D-P-S-I-R framework for system conceptualization
 Spatio-temporal analysis for 1956-2012 period using GIS

FURTHER FUTURE AIMS ...

- Development of indicators for the system evaluation
 Result integration for the formulation of recommendations simed at decisions and management support







Contact: Sarah Camilleri, Scienze Ambientali, via S. Alberto, 163, 48123; Ravenna. Tel +390544937311 Email: sarahcam84@yahoo.co.uk







Erasmus Mundus PhD in Water and **Coastal Management**



Integrated Assessement for Decision and Management Support of the Bahia de Cadiz Nature Park (Spain) - MSc. Sarah Camilleri

Supervised by:

Profs. Alejandro Perez Hurtado (Coastal Wetlands Research Group, University of Cadiz)

Profs. Giovanni Gabbianelli (Integrated Geoscience Reasearch Group, University of Bologna)

BACKGROUND:

Integrated assessement consists of the use of interdisciplinary concepts/methods which reflect the very complexity of coastal systems, by encompassing as many dimensions of the case study in question.

An integrated system shall be defined by relevant temporal and spatial scales political characteristics and the nature of management objectives; and shall involve data from ecological components, biogeochemical and physical systems and socio-economic and socio-cultural context [1].

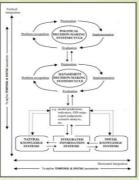


Figure 1:This framework (adapted from [1]) links information from multi-disciplinary science with decision-making systems. The two-way arrows make this a cyclical system where information can be supplied to and demanded from any component.

STUDY AREA:



The park, found on the central part of the Atlantic coast of the Cadiz province consists of a large area of wetland with a total area of 10.522 hectares, surrounded by 5 municipalities.

It recieved the 'Nature Park' status in 1983 and was declared a RAMSAR site in 2002 for its International Importance as Waterbird habitat [4]



Figure 2: Zonation Map of the Bahia de Cadiz Nature Park [4]

RESEARCH CONDUCTED:

The DPSIR conceptual framework is being applied:

> as a **scoping tool, supporting literature review**, to identify elements and causal links that characterize the area

> as a communication tool, supporting expert consultation, with the aim of including a more real perspective into the framework

The final result is a database composed of visual and quantative data that may be integrated to understand how the different DPSI elements interact. This knowledge is oriented towards decision and management support of the park.



Figure 4. Satellite images (LANDSAT) of the area are classified using ENVI 4.7 prior to be utilized within quantitative change detection analysis (Image from own rest

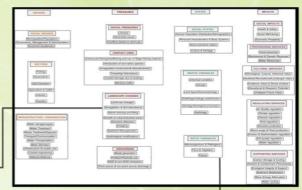


Figure 3: D-P-S-I elements for the Bahia de Cadiz Nature



Figure 5. GIS extensions such as NatureServ Vista are to be applied to assess the spatio-temporal distribution of species of greatest conservation concern (Image adapted from [2] and [5])

FERENCES.

7. A Boronico, S. A. Turner, R. K. (2003). Integrated Assessment and Sustainable Water and Westand Tocover, R. A. Boronic of Concepts and Memoria. Imaginated Assessment, 4(3), 172–184. doi:10.170/fileig.4.5.172.2377.

8. A Boronic of Concepts and Memoria. Integrated Assessment, 4(3), 172–184. doi:10.170/fileig.4.5.172.2377.

8. A Boronic of Concepts and Memoria. Integration of Concepts Inframework and a spatial analysis both HABITAT support the indementation of river basin management plans. Intl. Journal River Basin Management Vol. 7, No. 4 (2009), 209–311.

[4] Junta de Andalucia (2004). Decreto 78(2004, de 24 de febrero, por el que se aprueba el Plan de Ordenación de los Recursos Naturales y el Plan Rector de Uso y Gestión del Prague Natural Bahia de Cáda; (20) qui nº 71, de 13 de abril, refereired ori. 12(20) de . 8. Plane Hundero de Mendoza, A Quod A, El Chrellago Planego Proportiona (de la bestión de la Cardia de Mandoza, A Quod A). El Chrellago Planego Proportiona (de 2227), el Salinas en la Conservación de sura Especie en Peligin in. Junta de Andalucia (2004) Salinas de Andalucia (pp. 226-227). Elffrachering K. Hoffene, El Salinas, en la Conservación de sura Especie en Peligin in. Junta de Andalucia (2004) Salinas de Andalucia (pp. 226-227). Elffrachering K. Hoffene, El Saches C., 8 APateus, S. O. Y. (2012) Does research applying the decida (10) 1076 (Salinasco 2011 (5.00))

Annex III

The following is a report of activities carried out during the 3-month mobility program at FURG (Federal University of Rio Grande) in Brazil.







Identification of candidate:

Sarah Camilleri, PhD candidate in the ERASMUS MUNDUS Ph.D. program in Marine and Coastal Management (MACOMA) (2011-2014). Throughout this 3-year program, the candidate has been carrying out her research activities with the Group of Coastal Wetland Conservation at the University of Cadiz (UCA) (Spain) under the supervision of Profs. Alejandro Perez-Hurtado, and with the Integrated Geoscience Research Group at the University of Bologna (UNIBO) (Italy) under the supervision of Profs Giovanni Gabbianelli. The project investigated is entitled 'Integrated Assessment for Decision and Management Support within the Bahia de Cadiz Nature Park (Spain)'.

Title:

Report of the mobility phase at the Institute of Oceanography of the Federal University of Rio Grande (FURG) (Brazil)

Purpose of visit:

This report aims at documenting the general characteristics, objectives and activities of the 3-month mobility visit undergone by the candidate during the 3rd year of the aforementioned Ph.D. program, at the Institute of Oceanography of FURG (Brazil). Profs. Milton L. Asmus acted as supervising tutor during the visit. In terms of funding and coordination, the MACOMA consortium supported this mobility.

Objective:

Generally, the mobility phase aimed at offering the candidate an opportunity to extend and support her research work through participation and collaboration activities at a third (non-EU) country university. Further, it intended to serve as additional experience in terms of work and travel.

Description of activities:

- The candidate was offered workspace and material in the premises of the Laboratory of Coastal Management (Laboratório de Gerenciamento Costeiro, LABGERCO) of the Institute of Oceanography in FURG, in order to pursue her research duties including data analysis and writing. The technical support offered by experts in Geographical Information Systems (GIS) was of great value at this stage.
- The candidate was also involved in group meetings/discussions held by the research team working on
 the project entitled 'Risk, perception and vulnerability to Climate Change in wetland-dependent coastal
 communities in the Southern Cone of Latin America'. The value of this involvement was tied to the
 similarity of the research lines of the candidate's project and this South American exemplary, both
 studies focussing on coastal wetland systems and the ecosystem services they provide.
- The candidate offered two presentations to LABGERCO members and candidates from associated
 courses. The first presentation aimed at introducing the candidate's research work. The second
 presentation aimed at proving information with respect to Ph.D. and Masters programs, MACOMA and
 WACOMA (Water and Coastal Management). Both, written material and oral presentation, were
 prepared in Portuguese, additionally serving as a language exercise.
- Whilst at FURG, the candidate attended seminars, classes and masters/doctoral thesis presentations of
 interest. These sessions covered subjects related to the Brazilian experience in coastal management,
 environmental education at FURG and various local coastal management projects based in the Rio
 Grande area where FURG is situated.
- The candidate also joined an educational visit, organized by LABGERCO, to Taim Ecological Station (Rio Grande do Sul, Brazil). The visit served as an excellent introduction to some of the natural habitats that characterize this area of Brazil including vast lagoon systems, marshland, beaches and dunes. The station is also home to many migratory bird species and mammals as is the capybara.

- The candidate visited the UDELAR (Universidad de la República, Uruguay) premises in Maldonado, this being one of the partners of the aforementioned project 'Risk, perception and vulnerability to Climate Change in wetland-dependent coastal communities in the Southern Cone of Latin America'.
 This trip included a visit to Laguna de Rocha, which is the second largest coastal lagoon in Uruguay, as well as one of the study areas within the same project.
- Finally, the candidate visited the Federal University of Santa Catarina (Florianópolis, Brazil), where
 the supervising tutor Profs. Milton L. Asmus was acting as visiting professor at the Department of
 Geography. Here the candidate repeated the two aforementioned presentations. Further, this visit
 included a boat trip along a stretch of the south coast of the Santa Catarina Island, with the aim of
 reporting observed ecosystems of importance, and associated services.

Conclusion:

Overall, the mobility phase proved to be a positive experience at a professional, cultural and personal level. All the universities/departments visited offered good quality infrastructure and expertise. Further, all their members were exceptionally supportive and helped in any way possible to make the visit proceed smoothly. Great appreciation goes to the supervising tutor, Profs. Milton L. Asmus, whose availability and flexibility was fundamental whilst planning the various stages of the visit. Finally, of important mention is Prof. Camilo Dias Seabra Pereira from the University of Santa Cecilia (UNISANTA)(Brazil), for initially authorizing my mobility to FURG.

Suggestions:

I would recommend LABGERCO to any present and future MACOMA and WACOMA candidates interested in undergoing a mobility period at a third country university. Candidates shall be able to gain knowledge and carry out research in a variety of coastal management related fields (policy, oceanography, GIS, protected areas and more). Finally I also recommend LABGERCO for its friendly and supportive environment, as well as for its professionalism.

Sarah Camilleri

Quell.

Profs. Milton L. Asmus

Annex IV

This Annex includes:

- ✓ the attendance certificate for the Seminar entitled 'Gestion Integrada de Areas
 Litorales' held in Cadiz on the 10th of November 2011
- \checkmark the certificate for the theoretical and practical course of 'Recreational Skipper' acquired on the 21^{st} of September 2012





CERTIFICADO ASISTENCIA

Se certifica que:

D. / DŘO. SARAH CAMILLERI,

con DNI X-9281540-M,

Ha asistido al Seminario "Gestión Integrada de Áreas Litorales", celebrado el día 10 de noviembre de 2011, organizado dentro del Proyecto JUNTOS por UPTA Andalucía e impartido por Bureau Ingenio S.L.

En Cádiz, a 10 de noviembre de 2011

Dpto/de Formación Bureau Ingenio S.L.

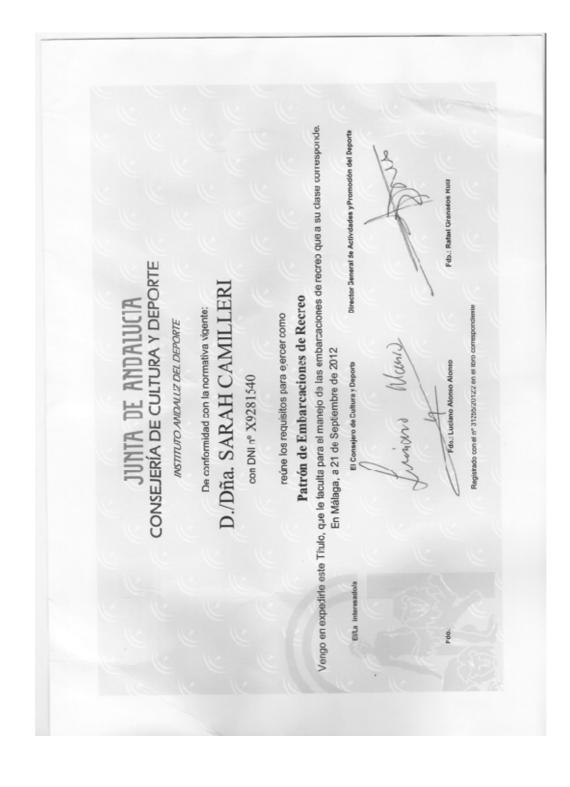








El interesado



Annex V

This annex includes:

- ✓ Curriculum vitae
- ✓ Mobility passport

PERSONAL INFORMATION

Sarah Camilleri



- 8, HoneyBee, Lorenzo Gatt str, BKR 4031 Ta`Paris, Birkirkara (Malta)
- 00356 21495903 00356 99879257(Malta), 0034 697292466 (Spain)
- x sarahcam84@yahoo.co.uk

Sex Female | Date of birth 24/03/1984 | Nationality Maltese

PREFERRED JOB

Environmental/Resource Management, Education, Conservation and Research

WORK EXPERIENCE

01/06/2003-30/09/2006

English Teacher

EC and EF Language Schools, (Malta)

Teaching English as a Foreign Language (Writing, Listening, Speaking, Reading) (Seasonal)

Business or sector Education

01/10/2006-01/08/2007

Quality Control Laboratory Analyst

Medichem

HF 61- Hal Far Industrial Estate BBG 3000., HalFar (Malta)

Chemical Analysis of Raw Materials, Intermediate and Final Products in a Pharmaceutical Company. This included a short training course on HPLC and GC (Liquid and Gas Chromatography) in Girona, Spain.

Business or sector Pharmaceutical

01/01/2007-30/07/2007

English Teacher

EADI Escuela de Idiomas

61-63, Carrer Enric Borras, Badalona, Barcelona (Spain)

Teaching English at various levels to children and youths. Also adult one-to-one classes.

Business or sector Education

01/10/2009-30/04/2010

Translator

University of Cadiz, Cadiz (Spain)

Spanish to English translation of University Website, daily news and agenda, etc.

Business or sector Translation Services/University Media

01/07/2010-31/08/2010

Accomodation Coordinator and Administrative Assistant within a Language Education Program

Chamber College

Edgar Bernard street, GZR 06, GZR 06 Gzira (Malta)

Assistance in organisation and coordination of student accommodation and activities for a school offering language courses in Malta.

Liaising between College, Hotel Staff and Students.

Dealing with travel, medical or education related claims by students.





Business or sector Education

01/08/2010-01/03/2011 Freelance Translator

Global Translation Soutions Ltd. St. Lucia Street, VLT 07 Valletta (Malta)

Translation of text documents from Spanish and English to Maltese

Business or sector Translation Services

15/03/2011-15/09/2011 **Environmental Officer**

STMicroelectronics

Industry Rd, ZRQ 10 Kirkop (Malta)

Running of Environment Management, Waste Management and Chemicals/Materials Management Systems. Liaising with all involved parties. Organisation of related activities and preparation of required reports.

Business or sector Manufacturing

23/10/2011 Marine and Coastal Management PhD Candidate

FUECA Fundación Universidad-Empresa de la provincia de Cádiz

Edificio Consorcio Tecnológico de Cádiz (CTC), C/Benito Pérez Galdós,, s/n 11002 (Spain)

Research-University of Cadiz, University of Bologna.

Business or sector Professional, scientific and technical activities

EDUCATION AND TRAINING

MATSEC and London O'Levels 01/10/1989-30/06/2000

MATSEC: ranging from 1-4, London: B

St Catherines High School, Pembroke (Malta)

MATSEC (Local examination board): Maltese, Religious studies, Italian, Engish Language and

Literature, Maths, Physics, French, Biology, Chemistry and Art;

LONDON: Chemistry, English Language and Physics

01/10/2000-30/06/2002 A Levels Overall Grade: B

Gan Frangisk Abela Junior College, Msida (Malta)

A'level: Biology and Chemistry; Intermediate Level: Physics, English and Philosophy.

24/10/2002-19/12/2002 **TEFL** С

EC Language School, (Malta)

Training as Teacher of English as a Foreign Language

Bachelor of Science 01/10/2002-30/06/2006

Second Class Upper (Honours)

University of Malta Chemistry and Biology

01/10/2008-30/04/2010 Masters in Water and Coastal Management

University of Plymouth (UK) and University of Cadiz (Spain)

Water and Coastal related themes, with a specialization in Fisheries Management and Marine

Α



Curriculum vitae Sarah Camilleri

Protected Areas.

01/01/2012-31/03/2012

Recreational Skipper

Escuela Nautica Taboga, Cadiz (Spain)

PERSONAL SKILLS

Mother tongue(s)

Maltese and English

Other language(s)

Italiar
Spanish
Portuguese

UNDERSTANDING		SPEAKING		WRITING
Listening	Reading	Spoken interaction	Spoken production	
C1	C1	C1	C1	C1
C1	C1	C1	C1	C1
A1	A1	A1	A1	

Levels: A1 and A2: Basic user - B1 and B2: Independent user - C1 and C2: Proficient user Common European Framework of Reference for Languages

•

Communication skills

Communicative and social. Ability to work with different age groups. Positive team-worker and participative.

Organisational / managerial skills

Good Level of Organization

Computer skills

Word, Excel, Power-point, Internet, SPSS, ArcGIS, Adobe Illustrator

Other skills

- Extensive travel experience around Europe, India, Thailand, Morocco, Brazil and Uruguay
- Various manual skills in creative arts

Driving licence

В

ADDITIONAL INFORMATION

Project details:

Degree: During the last year I chose to carry out my thesis research in Biology. This involved a spatiotemporal vegetation survey at White Tower Bay, which supported the best sand dune ecosystem in Malta. The aims of the study were to record all the plant species present (including alien species, as an indication of the degree of invasion due to anthropogenic actions), observe any spatial or temporal variations and record observed anthropogenic influences. The study included research on past and present conservation actions. As a result a biological spectrum of the dunes was compiled and maps of the area, highlighting the different zones of the dunes, were plotted for each season. The Belt Transect Method was used to sample the area. Shore Profiling was used as part of the Mapping process. Results were generated through various statistical tests like Species Richness, Evenness-Dominance and Cluster Analysis. SPSS was utilized.

Masters: This masters course consisted of a 1-year general theoretical/practical period, half of which was spent at the University of Plymouth (UK) and the other half at the University of Cadiz (Spain). This was followed by a 9-month research period during which I wrote my thesis entitled -Considerations during the Proposal Stages of a Marine Fisheries Reserve in Conil de la Frontera. This study focussed on bottom-up management actions held with respect to the creation of a Marine Fisheries Reserve in an Andalucian fishing village. Through this study I considered already existing examples of locally managed reserves as ones in Galicia (North Spain), undertook a stakeholder analysis and explored further themes linked to the zone studied, as illegal fishing, product certification, the Tuna Fish







Industry, offshore wind-farming, aquaculture, fishing tourism etc.

Additional Voluntary Experience during Masters thesis period:

- 1) Work with Spanish NGO 'Ecologistas en Accion' including; administrative chores, report reviews, meeting participation
- 2) Collaborations with Spanish and Maltese Fishing Cooperatives (bridging contact person, research support)

Voluntary Work: 1) Member of SharkLab Malta, an international NGO (www.sharklab.tk) with the main objective of the global study of elasmobranch species through locally based research teams. Activities include: snorkelling, egg-case searches and visits at local fish markets for the recording of captured elasmobranchs.2) Participation in Operation Delphis, locally organized by the marine conservation team of Nature Trust Malta in collaboration with Rimmo (Réserve Internationale Maritime en Méditerranée Occidentale)

MACOMA PASSPORT OF RESEARCH MOBILITY



Joint Ph.D. Programme in Marine and Coastal Management

1. This MACOMA Passport of Research Mobility is awarded to



1.Surname(s): **Camilleri** 2. First name(s):**Sarah**

3. Address(house number, street name, postcode, city, country):

56, Via Armando Diaz, 48121, Ravenna, Italy.

4.Date of birth: 24/03/1984 5.Nationality: Maltese

6. Signature of the holder:

2. This MACOMA Passport of ResearchMobility is issued by

- 7. Name of the issuing organization: University of Cadiz, Spain
- 8. Sending Partner (organization initiating the research mobility experience): **MACOMA Consortium**
- 9. Name, type and address:

Joint Ph.D. Programme in Marine and Coastal Management (MACOMA)

Erasmus Mundus Joint Doctoral Programme

Address: Faculty of Marine and Environmental Sciences Campus Puerto Real. 11519. Puerto Real. Cádiz. Spain

10. Surname(s) and first names of person

11.Title/position

- T. Angel del VallsCasillasProgramme Coordinator
- 12.Telephone: +34 956016794; +34 95601676413.e-mail:<u>angel.valls@uca.es</u>; <u>agua.mundus@uca.es</u>,
- 14.Issuing data (dd.mm.yyyy):
- 15. Signature and stamp, main coordinator: Prof. Angel del Valls



3. The Partner Organization of the MACOMA Research Mobility Experience No 1. First Academic year 2011-12

13. Host partner (organization receiving the holder of the MACONA Passport of research mobility):

University of Cadiz, Spain

Academic Year: Core and optional modules = 60 ECTS

14. Name, type and address of host partner:

University of Cadiz, Spain

Address: Faculty of Marine and Environmental Sciences Campus Puerto Real. 11519. Puerto Real. Cádiz. Spain

15. Surname(s) and first names of coordinator:

T. Angel del Valls Casillas

16. Title/position

Full professor

17.Telephone:

+34 956016794

18.e-mail:

angel.valls@uca.es;

Duration of the MACOMA Research Mobility:

19. From: **26.09.2011** 20. To: **30.09.2012**

21. Score of the MACOMA Research Mobility (ECTS scale): 60 ECTS

22. Additional requirement or conditions (special equipment, field work, observation data etc): or22. Grade (please use ECTS scale: A –F):

-Attendance of Seminar 'Integrated Management of Littoral Zones' (10th November 2011)

-Attendance to a 3-month course and examination, for the achievement of the Certification of Recreational Craft Skipper (PER: Patrón de embarcaciones de recreo) (certificates attached)

23. Any comments from host partner:

24. Signature of the host coordinator:

T. Ångel del Valls Casillas



25. Date of issue:30/09/2012

Explanatory note

MACOMA Passport of Research mobility is Ph.D. programme standard document, which records detail of the contents and the results – in terms of skills and competences or of academic achievements –of period that a Ph.D. student has spent in Institutions another that host University (other University, Enterprises, Research Center and others) for learning and research purpose. MACOMA Passport of Research Mobility designed on the base of ideas of EUROPASS facility.

3.a Description of the MACOMA Research Mobility experience N°2a 1st Semester. (6 months). Second Academic Year 2012-13. Research Period

26. Host partner (organization receiving the holder of the MACOMA Passport of research mobility):

University of Bologna

27. Name, type and address of host partner:

Lab IGRG, CIRSA,

Via San Alberto,

163, 48123,

Ravenna, Italia

28. Surname(s) and first names of coordinator:

Profs. Giovanni Gabbianelli

29. Title/position: University Professor/Head of Earth Biology, Geology and Environmental

Science (University of Bologna)

30.Telephone: +39 051 20 9 4924

31.e-mail: **giovanni.gabbianelli@unibo.it**

Duration of the MACOMA Research Mobility:

32. From: **01.10.2012**

33. To: **31.03.2013**

34. Score of the MACOMA Research Mobility (ECTS scale): 30 ECTS

35. Additional requirement or conditions (special equipment, field work, observation data etc): or 36. Grade (please use ECTS scale: A –F):

37. Any comments from host partner:

38. Signature of the host coordinator:

38.a. Signature of the Ph.D. candidate's supervisor:

7 Settierell

39. Date of issue: **08/11/2013**

Elmafa

(Stamp)

Objective(s) of the MACOMA Research Mobility:

-Review of integrated assessment methods and conceptual frameworks (as DPSIR) and their adaptability to the study of the Bahia de Cadiz Nature Park

40. Activities/research carried out during MACOMA Research Mobility:

- theoretical review of integrated assessment and conceptual frameworks applied for environmental research and assessment
- expert consultation
- identification and acquisition of available data sets to support integrated assessment as well as identification of data gaps.
- 41. Study visits (if possible, where): Visit to University of Cadiz/Bahia de Cadiz Nature Park for expert consultation

- 42. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration):
- 43. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: oral or poster; others):
- 44. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others):

DPSIR framework for support of integrated assessment of the Bahia de Cadiz Nature Park (Spain) (in process) to be sent to Environmental Management (Springer)

45. Other information:

3.bDescription of skills and Competences Acquired During the MACOMA Research Mobility experience N^o 2a

1st Semester. (6 months). Second Academic Year 2012-13. Research Period

- 46. Research/job related skills and competences acquired:
- -Knowledge of relevant international, European and national legislation as well as regional and local scale regulation of the nature park under study
- -Knowledge of integrated assessment
- -Knowledge of the background and applications of frameworks used to support environmental research and assessment with a special focus on DPSIR for its application to the system studied
- 47. Organization skills and competences acquired (if not included under' point 30):
- Organization of various meetings with experts including the park's manager, two coastal managers and one ecologist
- -Organization and normalization of various data sets
- 48. Computer skills and competences acquired (if not included under' point 30):
- Use of 'framework design' software and online programs
- 49. Language skills and competences acquired (if not included under' point 30):
- -Improvement of Italian speaking skills
- 50. Social skills and competences acquired (if not included under' point 30):
- -Expert consultation served as a useful exercise through which I learned to formulate effective questions for straight-forward communication so as to obtain the information needed
- Communication with the nature park manager and Spanish entities whilst researching for available datasets, introduced me to formal procedures of data acquisition
- 51. Other skills and competences acquired (if not included under' point 30):

52.Date: 08.11.2013

53. Signature of the supervisor(s)

54. Signature of the holder

9 Settievell

55. Position of supervisor: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

3.c Description of the MACOMA Research Mobility experience N° 2b 2ndSemester. (6 months). Second Academic Year 2012-13. Research Period

56. Host partner (organization receiving the holder of the MACOMA Passport of research mobility):

University of Bologna

57. Name, type and address of host partner:

Lab IGRG, CIRSA, Via San Alberto,

163, 48123,

Ravenna, Italia

58. Surname(s) and first names of coordinator: Profs Giovanni Gabbianelli

59. Title/position: University Professor/Head of Earth Biology, Geology and Environmental

Science (University of Bologna) 60.Telephone: +39 051 20 9 4924

61.e-mail: giovanni.gabbianelli@unibo.it

62. Duration of the MACOMA Research Mobility:

From: **01.04.2013** To: **30.09. 2013**

63. Score of the MACOMA Research Mobility (ECTS scale): **30 ECTS**

64. Additional requirement or conditions (special equipment, field work, observation data etc): or 65. Grade (please use ECTS scale: A –F):

66. Any comments from host partner:

67. Signature of the host coordinator:

67.a. Signature of the Ph.D. candidate's supervisor:

68. Date of issue: **08.11.2013**

Elmarfa

Objective(s) of the MACOMA Research Mobility:

Analysis of tempo-spatial land-use and land-type patterns characterizing the Bahia de Cadiz Nature Park throughout the last 30 years

- 69. Activities/research carried out during MACOMA Research Mobility:
- -theoretical research of remote sensing and analysis of images acquired by remote sensing
- software training for data analysis
- Course
- 70. Study visits (if possible, where):
- 71. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration): Attendance of course on 'Remote Sensing and its Applications' as well as final presentation (in Italian) at the Department of Environmental Engineering (University of Bologna)
- 72. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: oral or poster; others):
- 73. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others):

First article at an advanced stage:-

Title (subject to change): DPSIR framework for support of integrated assessment of the

Bahia de Cadiz Nature Park (Spain)

Targeted journal category: Environmental Management

74. Other information:

3.dDescription of skills and Competences Acquired During the MACOMA Research Mobility experience N^{o} 2b

2ndSemester. (6 months). Second Academic Year 2012-13. Research Period

- 75. Research/job related skills and competences acquired:
- Strengthening of knowledge of remote sensing and its applications especially for the study of wetland areas as found in the Bahia de Cadiz Nature Park.
- Strengthening of knowledge of satellite image online sources (e.g. USGS)
- Training on required software for the analysis of images acquired.
- 76. Organization skills and competences acquired (if not included under' point 30):
- Improved skills for the organization of meetings with researchers having different backgrounds, effectively managing and integrating the diverse inputs.
- 77. Computer skills and competences acquired (if not included under' point 30):
- Training on software for the analysis of satellite imagery (ENVI 4.7.). Applications explored included: atmospheric correction, classification (supervised/non-supervised) and change detection analysis.
- Training on ArcGIS
- 78. Language skills and competences acquired (if not included under' point 30):
- Improved Italian speaking skills
- Improved academic writing skills
- 79. Social skills and competences acquired (if not included under' point 30):
- Improved presentation skills
- 80. Other skills and competences acquired (if not included under' point 30):
- Familiarization with methods of online satellite image acquisition
- 81.Date: 08.11.2013
- 82. Signature of the supervisor(s)

83. Signature of the holder

84. Position of supervisor: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

3.e Description of the MACOMA Research Mobility experience N° 3a 1st Semester. (6 months). Third Academic Year 2013-14. Research Period

- 85. Host partner (organization receiving the holder of the MACOMA Passport of research mobility): **University of Bologna**
- 86. Name, type and address of host partner: Lab IGRG, CIRSA, Via San Alberto, 163, 48123, Ravenna, Italia
- 87. Surname(s) and first names of coordinator: Profs Giovanni Gabbianelli
- 88. Title/position: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

89.Telephone: +39 051 20 9 4924

90.e-mail: **giovanni.gabbianelli@unibo.it**

91. Duration of the MACOMA Research Mobility:

From: **01.10.2013** To: **31.03.2014**

- 92. Score of the MACOMA Research Mobility (ECTS scale): 30 ECTS
- 93. Additional requirement or conditions (special equipment, field work, observation data etc): or
- 94. Grade (please use ECTS scale: A –F):
- 95. Any comments from host partner:

96. Signature of the host coordinator: 96.a. Signatur

96.a. Signature of the Ph.D. candidate's supervisor:

97. Date of issue: 05.05.2014

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Objective(s) of the MACOMA Research Mobility:

Chapter 1: Completion of the first article for publishing within a peer reviewed journal. Chapter 2:

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- -Testing the correctness of results obtained from classification of satellite imagery and change detection analysis, through ground-truthing.
- -Compilation of land-use data to support the interpretation of land-cover results obtained through satellite imagery classification and change detection analysis.

Chapter 3:

Organization of birdlife datasets for treatment and integration with land-use and land-cover results.

98. Activities/research carried out during MACOMA Research Mobility:

- Participation in Congress
- Participation in Educational Fair
- Presentation/Discussion of overall project work and results within the Biology

Department at the University of Cadiz

- Ground-truthing fieldwork
- Completion of 1st Article/Chapter

- Treatment of land-cover and compilation of land-use data using ArcGIS 10.0
- Review of literature linked to the study of environmental quality of protected areas using/integrating birdlife data.
- Organization/Selection of birdlife datasets.
- 99. Study visits (if possible, where):

Two visits to the University of Cadiz for presentation of results and ground-truthing fieldwork

- 100. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration):
- 101. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: oral or poster; others):
- -Participation in GeoDay 2014 (Bologna) to promote the different projects and initiatives of the IGRG Lab and MACOMA projects
- -Participation at MEDCOAST CONGRESS 2013 (Marmaris, Turkey) with the presentation of the manuscript 'A Framework for Integrated Assessment: the Bahia de Cadiz Nature Park' and a poster with the same name.
- 102. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others) :

Publication of 'A Framework for Integrated Assessment: the Bahia de Cadiz Nature Park' within the EMECS 10 – MEDCOAST 2013 - Proceedings and Book of Extended Abstracts of the Global Congress on ICM

Completion of the article 'Multiple D-P-S-I frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain)' for publication within a special edition of the Journal of Coastal Conservation: Planning and Management (JCCPM). Currently waiting to be informed about an official deadline for sending in the article for peer reviewing.

103. Other information:

3.fDescription of skills and Competences Acquired During the MACOMA Research Mobility experience N° 3a

1st Semester. (6 months). Third Academic Year 2013-14. Research Period

- 104. Research/job related skills and competences acquired:
- Congress related experience: poster presentation, debate participation, networking etc.
- -Improved knowledge/skills with respect to ArcGIS applications
- Improved knowledge with respect to the pros and cons of ground-truthing.
- 105. Organization skills and competences acquired (if not included under' point 30):
- -Organization of field trip in Cadiz with the aim of ground-truthing i.e. comparing results from the analysis of satellite imagery and 'real' ground observations.
- 106. Computer skills and competences acquired (if not included under' point 30):
- -Familiarization and use of online software for poster design: Inskcape
- -Use of open-source programs for framework and timeline design: Gliffy, Office Timeline
- -Use of more ArcGIS applications for the study of land-use in the area and the integration of birdlife datasets.
- 107. Language skills and competences acquired (if not included under' point 30):
- -Presentation done in Cadiz were in Spanish. This was useful for refreshing my Spanish.

108. Social skills and competences acquired (if not included under' point 30):

- Experience with regards to participation in debates during a variety of presentation sessions touching a variety of Integrated Coastal Zone Management issues
- Skills related to the bridging communication between two different research groups (IGRG, UNIBO and Biology Dept., UCA)
- Networking with experts working in different departments of the Spanish public sector for the consolidation of information and available data sets.

109. Other skills and competences acquired (if not included under' point 30):

110.Date: **01.05.2014**

111. Signature of the supervisor(s)

112. Signature of the holder

113. Position of supervisor: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

3.g Description of the MACOMA Research Mobility experience No 3b 2nd Semester. (6 months). Third Academic Year 2013-14. Research Period

114. Host partner (organization receiving the holder of the MACONA Passport of research mobility):

University of Bologna

115. Name, type and address of host partner:

Lab IGRG, CIRSA, Via San Alberto, 163, 48123, Ravenna, Italia

116. Surname(s) and first names of coordinator: Profs Giovanni Gabbianelli

117. Title/position: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

118.Telephone: +39 051 20 9 4924

119.e-mail: giovanni.gabbianelli@unibo.it

120. Duration of the MACOMA Research Mobility:

From: **01.04.2014** To: **26.09.2014**

121. Score of the MACOMA Research Mobility (ECTS scale): *30 ECTS*

122. Additional requirement or conditions (special equipment, field work, observation data etc): or

123. Grade (please use ECTS scale: A –F):

124. Any comments from host partner:

125. Signature of the host coordinator: 125.a. Signature of the Ph.D. candidate's supervisor:

126. Date of issue: **09.02.2015**

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Objective(s) of the MACOMA Research Mobility:

- Completion of result analysis and writing relative to Chapter 2
- Preparation of work plan, bibliographical material and datasets for Chapter 3
- Mobility to a third country university: Federal University of Rio Grande (FURG) (Brazil) authorized by University of Santa Cecilia (UNISANTA (Brazil)
- 127. Activities/research carried out during MACOMA Research Mobility:

Chapter 2:

- Interpretation of land-cover results and integration of land-cover and land-use data in ArcGIS 10.0
- Preparation of written material, figures and tables for the publication of results within a scientific journal

Chapter 3:

- Bibliographical research
- Final organization of bird census datasets for treatment and integration with results from Chapter 2.
- -Definition of objectives and organization of tasks relative to the participating researchers/authors from both UNIBO and UCA.

Three-month mobility to a 3rd country university; Laboratory of Coastal Management (LABGERCO) at FURG (Brazil). The following activities correspond to the phase:

- Continuation of research duties including data analysis and writing.
- Involvement in group meetings/discussions regarding projects regarding wetland areas
- Power point guided oral presentations, delivering information regarding my research project and the MACOMA/WACOMA programs, to LABGERCO members. All material was prepared in Portuguese.
- Attendance of seminars, classes and masters/doctoral thesis presentations related to the Brazilian experience in coastal management, environmental education at FURG and local coastal management projects.
- University visits to UDELAR (Universidad de la República, Uruguay) premises in Maldonado and Federal University of Santa Catarina (Florianópolis, Brazil).
- Field trips: educational visit to Taim Ecological Station (Rio Grande do Sul, Brazil), trek to Laguna de Rocha (second largest coastal lagoon in Uruguay), boat trip along a stretch of the south coast of the Santa Catarina Island
- 128. Study visits (if possible, where): Federal University of Rio Grande (FURG) (Brazil), UDELAR (Universidad de la República, Uruguay), Federal University of Santa Catarina (Florianópolis, Brazil).
- 129. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration):
- 130. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: *oral or poster; others):
- 131. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others) :
- Article Nr 1: 'Multiple D-P-S-I frameworks for support of integrated research: a case study of the Bahía de Cádiz Nature Park (Spain)'

ACCEPTED for publication, on 03/10/2014 within the *Journal of Coastal Conservation:* Planning and Management under the Special issue project provisionally entitled 'Lessons learned to address new challenges in coastal conservation, planning and management'

Article Nr. 2: 'A study of land-use and land-cover in the coastal wetlands of the Bahia de Cádiz Nature Park (Spain) combining remote sensing and GIS methods', submitted to the Journal of Environmental Management on 31/01/2015.

On 12/02/2015 the authors received a communication from the journal claiming that despite the interesting work covered by the article, it appeared to have a regional rather than an international focus, as preferred by the editorial board. Other journals are currently being investigated, for almost immediate submission

132. Other information:

3.hDescription of skills and Competences Acquired During the MACOMA Research Mobility experience N^o 3b

2nd Semester. (6 months). Third Academic Year 2013-14. Research Period

133. Research/job related skills and competences acquired:

- Improved skills with respect to the procedures behind the publishing procedures in academic journals
- 134. Organization skills and competences acquired (if not included under' point 30):
- Improved skills when working in a multi-disciplinary team
- Improved skills when working in a new university, using a new linguistic/cultural language
- Improved skills for organizing work trips between different universities.
- 135. Computer skills and competences acquired (if not included under' point 30):
- Improved skills for working in a GIS and Excel environment
- Improved skills using Adobe Illustrator v. CC 2014 for image design
- 136. Language skills and competences acquired (if not included under' point 30):
- Improved level of written and spoken Portuguese during the mobility period in Brazil
- 137. Social skills and competences acquired (if not included under' point 30):
- Interaction with a new research group within a novel cultural context
- Presentation skills in a new language and context
- 138. Other skills and competences acquired (if not included under' point 30):

139.Date: 09.02.2015

140. Signature of the supervisor(s)

141. Signature of the holder

122. Position of supervisor: University Professor/Head of Earth Biology, Geology and Environmental Science (University of Bologna)

3.i Description of the MACOMA Research Mobility experience No 4a 1st Semester. (6 months). Fourth Academic Year 2014-15. Research Period

143. Host partner (organization receiving the holder of the MACOMA Passport of research mobility): University of Cadiz

144 Name, type and address of host partner: Biology Department, Faculty of Environmental and Marine Sciences, University of Cádiz, Avenida Saharahui, 11510, Puerto Real, Cádiz, Spain

145. Surname(s) and first names of coordinator: Profs Alejandro Perez Hurtado de Mendoza

146. Title/position: University Professor (University of Cadiz)

147.Telephone: +34 956 016011

148.e-mail: alejandro.perez@uca.es

149. Duration of the MACOMA Research Mobility:

From: **27.09.2014** To: **31.03.2015**

150. Score of the MACOMA Research Mobility (ECTS scale): 30 ECTS

151. Additional requirement or conditions (special equipment, field work, observation data etc): or

152. Grade (please use ECTS scale: A –F):

153. Any comments from host partner:

154. Signature of the host coordinator: 154.a. Signature of the Ph.D. candidate's supervisor:



155. Date of issue: 22.06.2015

Objective(s) of the MACOMA Research Mobility:

Chapter 2:

-Revision of article for re-submission

Chapter 3:

- -Statistical treatment of birdlife datasets for the study of spatio-temporal trends
- 156. Activities/research carried out during MACOMA Research Mobility:
- Meetings with research team at the University of Cadiz and collaborating researchers from the University of Sevilla and the University of Extremadura, for the design of the methodology relative to Chapter 3
- 157. Study visits (if possible, where):

University of Sevilla for meetings with research team

- 158. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration):
- 159. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: oral or poster; others):
- 160. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others)

Publication relative to Chapter 2 entitled 'Monitoring land-use and land-cover change in a mixed natural and artificial marsh: a case of the Bahia de Cadiz Nature Park (Spain)' for potential submission to: Environmental Monitoring and Assessment, Environmental Conservation, Journal of Coastal Research, Wetlands Ecology and Management, Journal of Environmental Planning and Management

161. Other information:

3.j. Description of skills and Competences Acquired During the MACOMA Research Mobility experience Nº 4a 1st Semester. (6 months). Third Academic Year 2014-15. Research Period 162. Research/job related skills and competences acquired: - Improved knowledge/skills with respect to ArcGIS applications - Improved knowledge with respect to the spatio-temporal analysis with respect to bird population datasets 163. Organization skills and competences acquired: - Organization of meetings and team work between researchers participating in the work relative to Chapter 3. 164. Computer skills and competences acquired: - Use of new ArcGIS applications - Use of Adobe illustrator for image design and editing 165. Language skills and competences acquired: - Spanish was the main working language during this stage 166. Social skills and competences acquired: - Networking with collaborators from different Spanish universities 167. Other skills and competences acquired: 168. .Date: 169. Signature of the supervisor(s) 170. Signature of the holder

171. Position of supervisor: University Professor (University of Cadiz)

22.06.2015

3.k. Description of the MACOMA Research Mobility experience No 4b 2nd Semester. (6 months). Third Academic Year 2014-15. Research Period

172. Host partner (organization receiving the holder of the MACOMA Passport of research mobility):

University of Cadiz

173. Name, type and address of host partner:

Biology Department, Faculty of Environmental and Marine Sciences, University of Cádiz, Avenida Saharahui, 11510, Puerto Real, Cádiz, Spain

174. Surname(s) and first names of coordinator: Profs Alejandro Perez Hurtado de Mendoza

175. Title/position: University Professor (University of Cadiz)

176. Telephone: +34 956 016011

177. e-mail: alejandro.perez@uca.es

178. Duration of the MACOMA Research Mobility:

From: **01.04.2015** To: **31.10.2015**

179. Score of the MACOMA Research Mobility (ECTS scale): 30 ECTS

180. Additional requirement or conditions (special equipment, field work, observation data etc): or

181. Grade (please use ECTS scale: A –F):

182. Any comments from host partner:

183. Signature of the host coordinator: 183.a. Signature of the Ph.D. candidate's supervisor:



184. Date of issue: 22.06.2015

Objective(s) of the MACOMA Research Mobility:

- Completion of result analysis, result interpretation/discussion and writing relative to Chapter 3
- Writing of Doctoral Thesis
- 185. Activities/research carried out during MACOMA Research Mobility:
- -Interpretation of statistical results as generated from R Statistical Computing Program
- Compilation of all results gathered and written during the 4 research years into Thesis format
- 186. Study visits (if possible, where):
- 187. Participation in Conferences, workshops, seminars without presentation (please indicate title, host institutions, duration):
- 188. Participation in Conferences, workshops, seminars with presentation(s) (please indicate title; host institutions; title of presentation(s); indicate: *oral or poster; others):
- 189. Publications preparing during MACOMA Research Mobility (please indicate title; where and when publication is planning to be published; others):
- Article Nr. 3: 'Reviewing international importance, temporal trends and spatial tendencies for wintering waterbirds in a Ramsar site' for submission to *Biological Conservation*
- -Doctoral Thesis

190. Other information:

3.1. Description of skills and Competences Acquired During the MACOMA Research Mobility experience Nº 4b 2nd Semester. (6 months). Third Academic Year 2014-15. Research Period 191. Research/job related skills and competences acquired: - Improved knowledge with respect to the spatio-temporal analysis and result interpretation with respect to bird population datasets 192. Organization skills and competences acquired: - Improved skills when working with an extensive team of researchers 193. Computer skills and competences acquired: -Improved skills using Adobe Illustrator v. CC 2014 for image design 194. Language skills and competences acquired: - Spanish was the main working language during this stage 195. Social skills and competences acquired: - Collaboration with an extensive team of researchers 196. Other skills and competences acquired: 197.Date: 198. Signature of the supervisor(s) 199. Signature of the holder 22.06.2015

200. Position of supervisor: University Professor (University of Cadiz)

- 5. The Partner Organization of the MACOMA Research Mobility experience. (To be provided by the Host Institution)
- a. (Annex: Certificate of stay for the mobility N° 1). Transcript of records for the 1st Academic year. Core Modules
- b. (Annex: Certificate of stay for the 1st semester of the mobility No 2a)
- c. (Annex: Certificate of stay for the 2nd semester of the mobility No 2b)
- d. (Annex: Certificate of stay for the 1^{st} semester of the mobility N^o 3a)
- e. (Annex: Certificate of stay for the 2nd semester of the mobility No 3b)

5.a Description of the MACOMA Research Mobility experience

My mobility experience consisted of:

- 4 semesters at the University of Cadiz
- 4 semesters at IGRG Laboratory (University of Bologna).
- A further 3 months were spent at FURG university (Brazil) (Report in Annex).

5.b Description of skills and competences acquired during the MACOMA Research Mobility experience.

Knowledge on the following themes was acquired: Environmental legislation related to the study area, Integrated assessment, DPSIR framework, Remote sensing, GIS applications, Migratory waterbird populations, Ramsar sites

Technical skills:

Use of the following software: Gliffy (online) for the building of conceptual frameworks, Office Timeline, ENVI 4.7. for satellite imagery analysis, ArcGIS 10.1 for analysis of spatial data, Inkscape for poster design, Excel, Adobe Illustrator v. CC 2014 for image design Interpretation of results generated through R-Statistical Computing Program

Languages:

Improvement of Spanish and Italian writing, reading, speaking and listening skills Introduction to Portuguese

Others:

dataset organization, meeting organization, expert consultation, academic writing, oral and poster presentation skills, fieldwork organization, knowledge of publishing procedures.

6. Total assessment of MACOMA Research Mobility experience								
Total number of MACOMA Research Mobility experiences:								
Total score of MACOMA Research Mobility(ECTS scale):	180 ECTS							
Grades, received: (A, B, C)								
General quality assessment:								
Main Coordinator: T. Angel del Valls Casillas								
Position: Programme Coordinator								
Signature:	(Stamp)							
	(Stamp)							
Issuing data (dd.mm.yyyy):								