GECOMARS 2020

International workshop on ecosystem based management 4-5 February 2020, Marseille (France)

Book of abstracts Recueil des résumés



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ATURA 200



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GECOMARS 2020

Congrès international sur la gestion écosystémique

Recueil des résumés

International workshop on ecosystembased management

Book of abstracts

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Programme

Talk: 10 min Questions: 5 min

Mardi 4 février 2020 – Tuesday, February 4th, 2020

8:00 – 8:30 A	ccueil des participants /	Reception of participants
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8:30 – 9:00 Ouverture du congrès / Opening of the workshop

- Mots d'accueil / Welcome speech, Directeurs du MIO (Mediterranean Institute of Oceanology)
- Mots d'accueil / Welcome speech, Office Français de la Biodiversité

Session 1: Approche écosystémique dans le suivi des milieux / Ecosystem-based approach to environmental monitoring

- 9:00 9:30 <u>Keynote conference</u>: **"Ecosystem-based quality indices: valuable tools for environment management"** by **Charles-François Boudouresque**, P. Astruch, D. Bănaru, B. Belloni, A. Blanfuné, T. Changeux, P. Chevaldonné, C. Fernandez, J.G. Harmelin, T. Perez, G. Pergent, C. Pergent-Martini, S. Ruitton, T. Thibaut
- 9:30 9:45 **"The Posidonia oceanica matte: a unique coastal carbon sink for climate change mitigation. Implications for management"** by **Briac Monnier**, G. Pergent, C.F. Boudouresque, M.Á. Mateo, C. Pergent-Martini, A. Valette-Sansevin
- 9:45 10:00 **"The use of very high resolution images for mapping of** *Posidonia oceanica* **reef"** by Agostino Tomasello, A. Savona, V. Pampalone, P. Cassetti Federica, G. Signa, M. Pirrotta, C. Andolina, E. Aleo Adele, C.D. Tramati, S. Vizzini, A. Mazzola, S. Calvo, **Anselme Muzirafuti**, S. Lanza, G. Barreca, A. Crupi, F. Gregorio, M. Cascio, M. Fontana, G. Randazzo
- 10:00 10:15 **"Bridging risk assessment of human pressure and the status of ecosystems"** by **Sandrine Ruitton**, P. Astruch, A. Blanfuné, C.F. Boudouresque
- 10:15 10:30 **"What biotic indices tell us about ecosystem change: lessons from the seagrass** *Posidonia oceanica*" by Ilaria Mancini, A. Oprandi, I. Rigo, M. Montefalcone, C. Morri, A. Peirano, P. Vassallo, C. Paoli, C.N. Bianchi
- 10:30 10:45 **"Laying a gas pipeline through a** *Posidonia oceanica* meadow: an example of its effects on plant recovery and epifaunal diversity" by Marcello Cotugno, M. Lorenti, M.B. Scipione, F.P. Patti, M.C. Buia



10:45 – 11:15 Pause / Break

- 11:15 11:30 **"Oil Spill response in mangroves: why a specific Ecosystem-based Management is required?"** by **Philippe Cuny**, R. Jézéquel, E. Michaud, L. Sylvi, C. Chevalier, V. Morel, C. Militon
- 11:30 11:45 **"An ecosystemic approach of an ecological crisis in Berre lagoon"** by Nicolas Mayot, V. Faure, R. Grisel, M. Mahé
- 11:45 12:00 **"Ecosystem based approach in Large Lakes: Monitoring, understanding and management"** by **Orlane Anneville**
- 12:00 12:15 "Six years of monitoring of the fish communities on the shallow bottoms around the Embiez Islands and Cape Sicié" by Sylvain Couvray, R. Simide
- 12:15 12:45 *Discussion*
- 12:45 14:00 Déjeuner / Lunch Session poster / Poster session
- 14:00 14:30 <u>Keynote conference</u>: **"Managing marine ecosystems affected by climate change"** by Jason M. Hall-Spencer
- 14:30 14:45 **"L'approche écosystémique appliquée à la gestion des espèces introduites en** Méditerranée : focus sur les pays du sud de la Méditerranée" by Samir Grimes
- 15:45 15:00 **"Marha, an integrated project using an ecosystem-based approach for the French natural marine habitats conservation and management"** by Juliette Delavenne, M. Labbe, A. Pibot
- 15:00 15:15 "Are terrestrial and marine core areas of Port-Cros National Park (Provence, France) managed on a species or an ecosystem basis?" by Charles-François Boudouresque, F. Médail, P. Ponel, P. Astruch, A. Barcelo, A. Blanfuné, T. Changeux, P. Chevaldonné, G. Cheylan, L. Le Diréach, G. Martin, C. Moussay, M. Peirache, M. Perret-Boudouresque, S. Ruitton, I. Taupier-Letage, T. Thibaut
- 15:15 15:30 "Combining long-term monitoring and research for marine ecosystem conservation: 30 years of research and monitoring in the Catalan MPAs" by Bernat Hereu, E. Aspillaga, P. Capdevila, D. Díaz, A. Garcia-Rubies, C. Linares, G. Rovira, J. Ortega, M. Zabala

15:30 – 16:00 *Pause / Break*



Session 2: Etude des socio-écosystèmes / Study of socio-ecosystems

- 16:00 16:30 <u>Keynote conference</u>: **"Approche écosystémique et réparation du préjudice écologique**" by Gilles J. Martin
- 16:30 16:45 **"An ecosystem-based approach to study the Biguglia lagoon socio-ecosystem** (Mediterranean Sea)" by Vanina Pasqualini, M. Erostate, E. Garel, M. Garrido, F. Huneau, S. Robert
- 16:45 17:00 **"Approche socio-écosystémique pour évaluer la gestion des récifs artificiels"** by **Jessica Salaun**, S. Pioch, J.C. Dauvin
- 17:00 17:15 **"Changes in the ecological status and natural capital of** *Posidonia oceanica* **meadows due to human pressure and extreme events"** by Ilaria Rigo, C. Paoli, G. Dapueto, F. Massa, A. Oprandi, S. Venturini, L. Merotto, G. Fanciulli, V. Cappanera, M. Montefalcone, C.N. Bianchi, C. Morri, C. Pergent-Martini, P. Povero, P. Vassallo
- 17:15 17:30 **"Interdisciplinary study on invasive species: the case of the ctenophore** *Mnemiopsis leidyi* in the Berre Lagoon (Southeast France)" by Guillaume Marchessaux, C. Claeys, D. Thibault
- 17:30 18:00 Discussion
- 20:00 23:00 Dîner / Social Dinner

Mercredi 5 février 2020 – Wednesday, February 5th, 2020

Session 3: Gestion écosystémique des pêches / Ecosystem-based management of fisheries
 8:30 – 9:00 Keynote conference: "Towards the ecosystem approach to fisheries in a global context" by Philippe Cury
 9:00 – 9:15 "Evaluating broad-scale connectivity to improve the management of Hake fishery in the north-western Mediterranean Sea" by Vincent Rossi, M. Hidalgo
 9:15 – 9:30 "Coupling the map of marine habitats and fish accumulation zones: a three-dimensional spatial approach for the management of halieutic resources" by M. Lamouret, P. Boissery, C. Viala, N. Thirion-Moreau, Arnaud Abadie



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- 9:30 9:45 **"European Water Framework Directive and fisheries management of large rivers:** potential contributions from trophic modelling. Example of the Lower Saône" by Thomas Changeux, D. Bănaru, A. Dragotta, E. Franquet, L. Cavalli, J.F. Frujet, J.P. Mallet, N. Stolzenberg
- 9:45 10:00 **"A Spatial Decision Support System for the sustainable management of fishing in Marine Protected Areas"** by **Giulia Dapueto**, C. Paoli, P. Vassallo, M. Pozzi, F. Massa, I. Rigo, G. Fanciulli, S. Venturini, L. Merotto, V. Cappanera, P. Povero
- 10:00 10:30 Pause / Break
- 10:30 10:45"A multidisciplinary analytical framework to delineate spawning areas and quantify
larval dispersal in coastal fish" by Térence Legrand, A. Di Franco, E. Ser-Giacomi,
A. Caló, V. Rossi
- 10:45 11:00 **"Gulf of Lions: the contribution of ecosystem knowledge to the Ecosystem-Based Management of Fisheries"** by **Daniela Bănaru**, F. Diaz, F. Carlotti, M. Harmelin-Vivien, C.F. Boudouresque
- 11:00 11:30 *Discussion*
- Session 4: Evaluation des services écosystémiques / Assessment of ecosystem services
- 11:30 11:45 **"Ecosystem Services Assessment in the Bay of Marseille"** by P. Scemama, Charlène Kermagoret, F. Alban, R. Mongruel
- 11:45 12:00 **"Towards strong sustainability: a framework for economic and ecological management of Marine Protected Areas"** by Chiara Paoli, P. Vassallo, M. Pozzi, F. Massa, I. Rigo, V. Cappanera, L. Merotto, S. Venturini, I. Lavarello, C. Valerani, V. Gazale, A. Zanello, M. Vannini, P. Povero, G. Dapueto
- 12:00 12:15 "Multi-agent modelling, a lab experiment for building ecosystem-based management policies in coastal and marine socio-ecological systems: Results from the SAFRAN project, an exercise in the Natural Marine Park of the Gulf of Lion" by Catherine Boemare, E. Mosseri
- 12:15 12:45 *Discussion*
- 12:45 12:50 Clôture partielle du congrès / Partial closure of the workshop
- 12:50 14:15 Déjeuner / Lunch Session poster / Poster session



Soutiens financiers / Backers :













DE TOURISME ICE O ET DES CONGRÈS







Mercredi 5 février 2020 – Wednesday, February 5th, 2020

- SALSA : Les salins d'Hyères : mise en place d'une gestion socio-écosystémique / The saltmarshes of Hyères : implementation of a socio-ecosystembased managment
- 14:15 14:45
 Keynote conference: "Ecosystem-based management of coastal lagoons, regional and local issues" by Rutger De Wit
- 14:45 15:00 "Historique de la gestion des salins d'Hyères" by Frédérique Gimond-Lanteri
- 15:00 15:15 **"Biodiversité, connaissance, communication et gouvernance pour la gestion écosystémique du site des Salins d'Hyères (Var, France)"** by **Matthieu Lascève**, M. Simo, F. Gimond-Lanteri, G. Queffeulou
- 15:15 15:30 **"La lagune des Pesquiers (Hyères) : mise en perspective historique et approche** écosystémique" by Daniel Faget
- 15:30 15:45 **"Mapping of Ruppia spiralis habitat within the saltmarshes of Hyères (Provence,** France): a key species for an ecosystem-based approach" by P. Astruch, Laura Massinelli, M. Lascève, C.F. Boudouresque
- 15:45 16:15 Pause / Break
- 16:15 16:30 "Favouring exchanges between the sea and the lagoons: a necessary support to the restoration of the functional role as fish nursery in the saltmarshes of Hyeres (Provence, France)" by Laurence Le Diréach, P. Astruch, T. Changeux, F Moussy, C. Jehl, N. Brodu, M. Boursault, M. Charpentier, F. Gimond-Lanteri, M. Harmelin-Vivien, M. Lascève, N. Lucchini, A. Lyonnet, M. Roux, T. Schohn
- 16:30 16:45 "Improving the management of Hyères saltmarshes (Provence, France) using an ecosystem-based approach" by Patrick Astruch, C.F. Boudouresque, D. Faget, T. Changeux, M. Lascève, L. Le Diréach, F. Gimond-Lanteri, L. Massinelli, F. Moussy, N. Angles d'Ortoli, G. Marchessaux, F. Carlotti, L. Guilloux, M.C. Gomez, M. Simo
- 16:45 17:45 *Discussion*
- 17:45 17:55 Clôture du congrès / Closure of the workshop











Communications orales / Oral communications



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Session 1 : Approche écosystémique dans le suivi des milieux / Ecosystem-based approach to environmental monitoring



Ecosystem-based quality indices: valuable tools for environment management

Charles-François Boudouresque¹, Patrick Astruch², Daniela Bănaru¹, Bruno Belloni², Aurélie Blanfuné¹, Thomas Changeux¹, Pierre Chevaldonné³, Catherine Fernandez³, Jean-Georges Harmelin², Thierry Perez³, Gérard Pergent⁴, Christine Pergent-Martini⁴, Sandrine Ruitton¹, Thierry Thibaut¹

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Environmental issues have been addressed on the basis of three different approaches. (i) The earliest is the 'Human-centred' approach; it was characterized by the dichotomy between 'useful' species (for Man) and pests (competitors of humans). The concept of ecosystem goods and services can be considered as the modern form of this approach. (ii) The species-centred approach characterized the 20th century and remains the most common approach adopted in many countries and by several international agencies; it is supported by groups of experts working on a given taxon ('taxonomic lobbies'). It is based upon outstanding species (a fuzzy concept, including iconic species), which are designated as deserving appropriate management, in contrast to 'ordinary species'. (iii) Finally, the 21st century ecosystem-based approach, although still rarely used, is the one that can best meet the challenges driven by global change and ensure the proper management of natural habitats. In contrast with indices based upon a species, or a group of species belonging to a given taxon, that may not detect a strong impact on the ecosystem, and even erroneously suggest a 'good ecological status', indices based on the functioning of the entire ecosystem, from primary producers to top predators, such as Ecosystem-Based Quality Indices (EBQIs), provide a realistic assessment of the ecological status. EBQIs have already been established for north-western Mediterranean marine ecosystems: the Posidonia oceanica seagrass meadow, underwater marine caves and infralittoral reef macroalgal forests. They are currently being developed for coralligenous habitats, saltmarshes and circalittoral coastal detrital bottoms. The ecosystem-based approach can be applied to all types of ecosystems and it is important now to extend this approach to infralittoral sandy bottoms, the beach-dune-Posidonia oceanica banquette ecosystem, the deep sea and terrestrial ecosystems, the pelagic ecosystems and their coupling with benthic ecosystems, and an area more extensive than the north-western Mediterranean: eastern, central and southern Mediterranean, and Atlantic coastal areas. Ecosystem-based management and EBQIs are not incompatible with specific management measures based upon certain iconic species, which are also part of an ecosystem. The interest of ecosystem-based management is that it is not limited to the accumulation of specific management measures for iconic species, which can be mutually incompatible when, for example, an iconic species proliferates at the expense of other iconic species in the same habitat.

Keywords: Ecosystem based approach, environment management, index



The *Posidonia oceanica* matte: a unique coastal carbon sink for climate change mitigation. Implications for management

Briac Monnier¹, Gérard Pergent¹, Charles-François Boudouresque², Miguel Ángel Mateo^{3,4}, Christine Pergent-Martini¹, Audrey Valette-Sansevin¹

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Seagrass meadows have long been recognized for their high ecological and economic value (ecosystem services). More recently, a potential role in climate regulation, due to their ability to fix and sequester carbon, has been the focus of intensive study. In the Mediterranean Sea, the matte, a specific structure built by the seagrass Posidonia oceanica, is of particular interest because it keeps buried for thousands of years massive amounts of carbon. Recent studies carried out along Corsican coastline show a mean fixation of 1.61 tonnes C ha⁻¹.year⁻¹, with a sequestration between 27 and 30%, a mean matte thickness of 2.1 m and 6 483 t C_{org} ha⁻¹ of organic carbon trapped in the matte. An extrapolation to the Mediterranean basin (1.0 to 1.5 million hectares covered by *P. oceanica* meadow; mean matte thickness: 1 m) shows that the total stock of organic carbon sequestered in the P.oceanica matte might be as much as 3 087 to 4 632 Gt. The conservation of the P. oceanica meadows thus constitutes an issue of major importance since any degradation of the matte, which has been built up over the past millennia, would be likely to release considerable quantities of carbon. Rather than playing a major role in the attenuation of the impact of climate change (blue carbon sequestration), the *P. oceanica* meadow would then become a source of carbon that would be likely to amplify the greenhouse gas emissions. Management of *P. oceanica* meadows should take into account not only their role in carbon sequestration, but also the whole of their ecosystem services, in the framework of the functioning of the ecosystem.

Keywords: Posidonia oceanica meadow, Carbon sequestration, Climate change mitigation



The use of very high-resolution images for mapping of *Posidonia oceanica* reef.

Agostino Tomasello^{1,4}, Andrea Savona^{1,4}, Vincenzo Pampalone¹, Paola Cassetti Federica^{1,4}, Geraldina Signa^{1,2}, Maria Pirrotta^{1,4}, Cristina Andolina¹, Elisa Aleo Adele^{1,4}, Cecilia Doriana Tramati¹, Salvatrice Vizzini^{1,2}, Antonio Mazzola^{1,2}, Sebastiano Calvo^{1,4}, Anselme Muzirafuti⁴, Stefania Lanza⁴, Giovanni Barreca⁴, Antonio Crupi⁴, Francesco Gregorio⁴, Maria Cascio⁴, Marco Fontana⁴, Giovanni Randazzo^{1,4}.

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Posidonia oceanica is an endemic Mediterranean seagrass that forms wide and dense meadows from the surface up to about 40 m depth. P. oceanica can develop on matte, a typical terraced structure built up by itself, consisting of intertwined rhizomes, roots and sediment, which may allow shoots to reach the sea surface, where may form typical reefs (récif barrière) considered "natural monuments". These structures have received increasing attention for the potential ecosystem services they provide in protecting the coasts from erosion, forming new habitats (coastal lagoons) and contributing to carbon sink. P. oceanica reefs are particularly exposed to the expected increase in temperature and to storm frequency and intensity, which represent a problem in terms of P. oceanica "natural monuments" conservation. Therefore, much more attention must be paid to the implementation of monitoring tools able to detect the early signs of seagrass regression. The main aim of this study was to investigate the distribution of the P. oceanica reefs located in front of 4 pocked beaches (PB) along both the northern and southern coasts of Sicily. A remote sensing approach was used to assess the reef extensions including their associated structures (atolls, and tiger meadows). In particular, very high-resolution drone images (~2cm of pixels size), combined with GPS field data, were used to obtain 2 and 3D-reconstruction of P. oceanica reefs. Generated orthophotos and digital elevation model were imported into geospatial analysis software to quantify their extension and volumes. The 3D-model allowed to estimate bathymetrical distribution of *P. oceanica* reef. This approach may enable to achieve a more detailed and complete understanding of the role of *P. oceanica* reefs in coastal marine dynamics and in PB in particular. This might also contribute to gain a better insight into the ecosystem services they provide.

Keywords: Posidonia oceanica; monitoring; mapping



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Bridging risk assessment of human pressure and the status of ecosystems

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In the frame of the management of natural environment impacted by anthropogenic activities, it is essential to assess and quantify its related pressures, so it can be linked to the status of the ecosystems. However, neither or very few geographical areas have a thorough knowledge of uses and sources of impact to quantify them. For this reason, we propose to rate impact sources based on a risk assessment using semi-quantitative rating grids.

The impact source is defined as the environmental factor responsible for the impact (e.g. sewage, fishing activity or coastal development). Here, we propose an environmental Risk Assessment of Marine Ecosystem (RAME) by considering several rating combined criteria that will allow us to obtain a criticality score. These semi-quantitative criteria are: (1) the sensitivity (S) of the environment, ecosystem or species; (2) the importance (I) of the impact source; (3) the distance (D) from the impact source and (4) the occurrence (O) of the pressure. Hereafter, the index is weighted by a criterion of control that is related to the environmental management. This type of assessment method is already used to consider the environmental risk in the industrial field, genetic modified organisms or even public health. Its adaptation is implemented within the framework of the evaluation of the risk of a natural environment exposed to human activities.

This method can adapt to all types of pressure and is not specific to a particular situation such as the LUSI based on terrestrial uses that are not clearly linked to the environmental status (Gardi et al., 2010), the HAPI bases on few human terrestrial and marine pressures concerning only the subtidal rocky shore (Blanfuné et al., 2017) or the pressure index of Ar Grall et al. (2016) for intertidal communities.

Keywords: Ecosystem based management; MPAs; Ecosystem services; multi; agent-based modelling; marine habitats



What biotic indices tell us about ecosystem change: lessons from the seagrass *Posidonia oceanica*

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The increasing anthropogenic pressure on marine ecosystems is causing a progressive decline of water quality and seafloor integrity. The meadows of the endemic Mediterranean seagrass *Posidonia oceanica* (L.) Delile are considered a priority habitat under the European Directive 92/43/CEE, because of their ecological and economic importance, and constitute an elective indicator of environmental status. Historical data on three meadows along the Ligurian coast allowed assessing change in meadow status over time. A number of indicators were calculated at different levels of ecological complexity (i.e., plant, meadow, associate community, and seascape), including the aggregate index PREI (Posidonia Rapid Easy Index), currently adopted by the environmental agencies. The aims of the present paper are a) to define the current health status of the *P. oceanica* meadows; b) to assess their changes through time by comparison with historical information; c) to evaluate the consistency. Meadow status displayed improvement, worsening or no change over time according to the specific index that was considered. suggesting that the use of a set of indices is highly recommended to define the health status of *P. oceanica* meadows and to follow their time evolution.

Keywords: Seagrass; Ligurian Sea; Ecological indices; historical data



Laying a gas pipeline through a *Posidonia oceanica* meadow: an example of its effects on plant recovery and epifaunal diversity.

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Marine areas are facing significant increasing threats, which include biological, physical, chemical pollutions and habitat destruction, all causing loss of biodiversity. In order to mitigate environmental changes, different restoration tools have been elaborated in order to assist recovery of a disturbed ecosystem. Here we report on the spontaneous *Posidonia oceanica* recovery in front of the harbour of Ischia (Punta San Pietro, Gulf of Naples, Italy) after its partial destruction due to the laying of a submarine gas pipeline between the Ischia island and the mainland (Torregaveta, Monte di Procida, Italy). The trench, 300m long and dredged between 7.5 and 5.5m depth, was filled with rubbles after the deployment of the pipeline. The continuous flux of ramets from the adjacent stands favoured a natural recolonization. Ten years later (2009-2019), the spontaneous *Posidonia* recovery was mapped, combining the use of underwater photogrammetry technique and GIS. In order to assess the ecosystem function of the new Posidonia patches, the diversity of the associated epifaunal community was evaluated by analysing major elements of the motile invertebrate fauna (amphipods, isopods and molluscs) and comparing their structure and composition with those of populations from established meadows around the island.

Keywords: Natural recovery, dredging, epifauna, Posidonia oceanica,





Oil Spill response in mangroves: why a specific Ecosystem-based Management is required?

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Mangroves are formed by mangrove trees and shrubs that grow in the intertidal zone at the seacontinent interface. They constitute major ecosystems of tropical to temperate muddy coasts and estuaries that perform several ecological functions, including: mitigation of coastal erosion and flooding hazards associated with storm waves, extreme tides and tsunami, providing nurseries for some estuarine and coastal species (e.g. shrimps, fishes), production and recycling of organic matter, carbon storage, functioning as long-term sinks for several contaminants. World mangroves face a number of threats with increasing habitat destruction caused by direct and indirect anthropogenic pressures coupled with global climate change. They are known to be extremely vulnerable to oil spills. Even if the fate and impact of oil spills in such ecosystems have been partially monitored and experimentally studied (e.g. 30-year TROPICS field experiment in Panama islands, replicated field trials conducted in central Queensland, Australia) significant gaps in knowledge remain. The dynamic of oil in such ecosystem is complex and depend of the interlink of abiotic as well as of biotic processes. Understanding the fate and impact of the oil spill thus require an integrated understanding of the functioning of the whole mangrove system facing the pollution. The case of the mangroves of French Guiana, subjected to intense hydro-morphosedimentary dynamics under the direct influence of the massive discharge of suspended sediments from the Amazon River, will serve as conceptual model to highlight the importance of the need of a specific Ecosystem-based Management response in case of oil spill.

Keywords: Mangrove; oil spill; French Guiana; Biocomplexity



An ecosystemic approach of an ecological crisis in Berre lagoon

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Berre lagoon is a Mediterranean lagoon deeply impacted by industry and urbanization. Since 1966, a hydroelectric power plant discharges an important quantity of freshwater and nutrient into the lagoon inducing large ecosystemic change. The lagoon ecosystem drops into an eutrophic state with loss of Zostera meadow and marine macrofauna. In 1994, an important monitoring network of Berre lagoon was set up. Different compartments of the ecosystem were measured: water quality, sediment quality, macrophytes (including Magnoliophyta), benthic macrofauna, fisheries and ichtyofauna. Results show ecosystem evolution linked to the different phases of eutrophication reduction. However, in 2018, an important ecologic crisis occurred, inducing anoxia in more than 90% of the lagoon surface. The data analysis of the monitoring network during and after this crisis, with environmental and climatic factor, allowed to understand the degradation along the different ecosystem's compartments and their reliance one year after. The origin of this crisis is due to a "cocktail effect" of high spring nutrient input, high water temperature, important water stratification, lack of wind, lack of Zostera meadow and an important benthic biomass. This crisis displays the extreme fragility of Berre lagoon ecosystem. This analysis of different regime shift of Berre lagoon ecosystem show the importance of an ecosystemic approach for monitoring network.

Keywords: Ecosystem, long term analysis, eutrophication, regime shift



Ecosystem-based approach in Large Lakes: Monitoring, understanding and management

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Decades of research in limnology have provided evidence of lake resource degradation as a result of cumulative perturbation through time by long-term human impacts. Multiple anthropogenic pressures operating at a local scale combine with ongoing global climate change to alter physical and biological characteristics of lakes. In the context of increased anthropogenic pressures, large lakes require adapted management practices to maintain good water quality that have important implication on their ability to provide for a variety of services including fisheries, safe drinking water and recreational opportunities. Ecosystem based management has gained increasing popularity around the world. When this approach applies for lake monitoring, it allows researchers to describe trophic structures and to perform quantitative analyses that enable a better understanding of lake sensitivity to multiple stressors. Advances in the understanding of processes regulating ecosystems are essential and have become a major challenge to provide adapted management advices that ensure the delivery of multiple ecosystem services. This presentation will focus on Lake Geneva to illustrate how bottom-up and top-down controls combine to drive water quality and fish abundances. Finally, this study highlights the value of environmental monitoring and the relevance of an ecosystem-based approach to advice management strategies that meet current and future needs.

Keywords: Lake Geneva, fisheries, water quality, climate change, eutrophication



Six years of monitoring of the fish communities on the shallow bottoms around the Embiez Islands and Cape Sicié.

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Located between the Port-Cros National Park and the Calanques National Park, the Embiez Islands and the Cape Sicié massif have important natural heritage conservation issues highlighted by the establishment of three Natura 2000 sites. Coastal ecosystems and associated fish communities are subject to various anthropogenic pressures. The fish assemblages of shallow bottoms have been surveyed over the 2012-2017 period by visual censuses in 8 sites, twice a year, in order to assess their structure and temporal changes. The results obtained during these 6 years of monitoring show that the fish communities of this area are diversified and abundant but dominated by a few species of herbivores, mesocarnivorous and planktivorous. Fish species belonging to higher trophic levels are rare and individual fish sizes are generally small. The fish community of this area differs from those observed in marine protected areas, where appropriate management measures of fishing activities are applied. Fish monitoring following an ecosystemic approach allows to discuss the efficiency of MPA management measures to sustain functional ecosystem services.

Keywords: fish assemblages, management, fisheries, Natura 2000



Managing marine ecosystems affected by climate change

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Overfishing, destructive fishing practices, eutrophication/pollution and the spread of invasive species are the main impacts caused by human activities in coastal marine habitats. Rising CO₂ levels pose several threats to marine life which interact with other anthropogenic pressures. The most obvious of these is warming, which is causing artic ice loss, marine heat waves, mass mortalities of habitat-forming organisms, coastal squeeze, increased storminess and is making eutrophic areas more eutrophic whilst making oligotrophic areas more oligotrophic. Rising atmospheric CO₂ levels are also causing deoxygenation and ocean acidification and these global ocean stressors are acting synergistically. The talk will round off with the reasoning behind strategic management of human activities to rebuild coastal ecosystem resilience at the same time as avoiding wasting money on lost causes. The aim is to use examples from all over the world to illustrate these points and to present the ecosystem service benefits to mankind that can be gained from sticking to global initiatives such as the Paris Agreement and the Convention on Biodiversity (Hall-Spencer & Harvey 2019).

Keywords: Marine Ecosystem Services, Pressures on Coastal Habitats, Smarter Coastal Management



L'approche écosystémique appliquée à la gestion des espèces introduites en Méditerranée : focus sur les pays du sud de la Méditerranée

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Les espèces introduites en mer Méditerranée ne sont plus appréhendées uniquement comme un sujet de recherche scientifique pour la compréhension du phénomène d'introduction en Méditerranée de ces espèces non indigènes, ou pour la compréhension de leurs effets sur la structure, l'organisation et le fonctionnement de la biodiversité marine méditerranéenne et plus globalement de l'écosystème méditerranéen. Elles sont aujourd'hui au centre des questions socioéconomiques et à celles liées à la gouvernance maritime et côtière. Les implications sanitaires et biotechnologiques de ces espèces sont également devenues une question d'intérêt scientifique de premier ordre.

Les effets déjà perceptibles, certes à petite échelle, sur l'économie locale de plusieurs régions au sud de la Méditerranée et les perspectives d'activités que la prolifération et l'extension de l'aire de distribution de ces espèces ouvrent interpellent sur l'approche développée à ce jour pour le traitement de cette question importante. En effet, la compréhension des «drivers» de ces proliférations d'espèces non indigènes contribue à la compréhension de l'évolution des processus environnementaux, y compris les changements climatiques, qui touche le bassin méditerranéen.

Les preuves scientifiques, apportées en particulier par les travaux de Zenetos et Galil (2010-2019), quant à l'accélération du rythme des introductions laissent à penser que la tendance va s'amplifier à l'avenir, notamment compte tenu des scénarios climatiques récents du GIEC mais également par l'intensification et la diversification des facteurs et des vecteurs d'introductions d'espèces non indigènes en Méditerranée.

La gestion de ces introductions et les stratégies d'adaptation vis-à-vis de leurs effets, notamment non désirables sur l'écosystème méditerranéen exige la mise en œuvre d'une approche écosystémique à toutes les échelles pertinentes de la connaissance, de la planification et de l'action.

L'objectifs de la présente contribution est d'analyser les approches de gestion mises en œuvre à ce jour au niveau régional, sous régional et nationale avec un focus sur les pays du sud de la Méditerranée en tenant compte du transect Canal de Suez-Détroit de Gibraltar.

Keywords: Espèces non indigènes ; approche écosystémique ; Méditerranée.



Marha, an integrated project using an ecosystem-based approach for the French natural marine habitats conservation and management

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Ecosystem-based management is a concept which was first applied to fisheries management and is now accepted as a valid and efficient way of proceeding. The concept is now increasingly used for Protected Area management and marine environment management in general. In France, most of marine habitats do not reach a good conservation status. Their last assessment under the Habitat directive has shown a critical situation. The Life integrated project Marha (Marine habitats) pursues the objective of restoring and maintaining the good conservation status of natural marine habitats by supporting all stakeholders implicated in the management of the 162 Natura 2000 protected sites around France. The actions engaged in the project Marha lie within the broad context of ecosystem-based management. Knowledge enhancement on habitats functioning, ecosystem services and the anthropic pressures the habitats deal with, will lead to actual actions to improve governance and mitigate the pressures. Conservation and management actions will be adjusted to the site, the identified habitats and pressures and the people involved. Actions can be awareness rising for some well-targeted audience, adapting ongoing practices and support spatial planning approaches.

Keywords: Marine Habitats; Habitat directive; MPA; Life integrated project



Are terrestrial and marine core areas of Port-Cros National Park (Provence, France) managed on a species or an ecosystem basis?

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The Port-Cros National Park (PCNP, France, Mediterranean) was established in 1963. The core area of the PCNP is constituted by the archipelagos of Port-Cros and Porquerolles. For almost 60 years, the management policy of the PCNP has steadily progressed, in phase with (i) changes in doctrines and goals in the field of nature conservation; (ii) what was socially acceptable at a given time; (iii) a very active Scientific Council; and (iv) a gradual shift from species-centred to ecosystem-based management. On the basis of several examples, we illustrate earlier and recent problems faced by the PCNP, together with responses or practices that are suited, or not, to an ecosystem-based approach: the introduction of *Posidonia oceanica* seagrass strains, the proliferation of rats, feral cats, the appearance of wild boar, the decline of the Tyrrhenian painted frog, the construction of an artificial reef, etc. The Park's doctrine has been to explain (i) that the abundance of species fluctuates naturally, and that we must not be too hasty to intervene as soon as a species declines or another species proliferates; ecosystems are in constant evolution; (ii) that nature sometimes does things better than humans; (iii) that a national park is neither a zoo nor a botanical garden, and the purpose is not to artificially increase the species diversity (an approach based on an erroneous understanding of the biodiversity concept). The management approach of the PCNP is still far from being ecosystem-based. However, it has been marked by remarkable successes, such as the progress achieved in the fight against invasive species and the management of beaches (driftwood, dead leaves of P. oceanica).

Keywords: Biological invasions, Control of invasive species, Ecosystem-based approach, Management, Mediterranean, National Park



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Combining long-term monitoring and research for marine ecosystem conservation: 30 years of research and monitoring in the Catalan MPAs

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Biological communities are affected by several ecological processes that act at different temporal and spatial scales, making them difficult to study in an integrative way. Long-term monitoring programs combined with experimental studies give us a more complete understanding about the processes and the impacts that shape marine benthic communities. Moreover, long-term monitoring can find out unexpected results that can lead to new research perspectives. This combination is especially useful when conservation measures integrate different approaches such as spatial and fisheries management. The monitoring program of the Catalan MPAs started in 1990 and has been performed yearly until the present to assess the effectiveness of management on marine ecosystems. This monitoring included a variety of organisms with important ecological and economic roles and showed a high diversity of responses to protection due to their different life strategies, dynamics, or behaviour. Parallel studies on community ecology and species dynamics and demography provided us complementary knowledge to better understand their responses to punctual or recurrent impacts, allowing us to design predictive models and conservation and restoration tools. Moreover, the discovery of unexpected results, gave us new insights on the functioning of this system, as well as the key to design new descriptors and management tools for the conservation of marine ecosystems. New research and management perspectives have emerged from this experience, such as the need to integrate spatial and fisheries management, increasing the spatial scales of monitoring, standardize protocols and methodologies with other MPAs, and find measures to promote the connectivity between MPAs at a regional scale.

Keywords: Long-term monitoring, research, management, Marine Protected Areas



GECOMARS 2020 - International workshop on ecosystem-based management, 4-5 February 2020, Marseille



GECOMARS 2020 - International workshop on ecosystem-based management, 4-5 February 2020, Marseille


Session 2 : Etude des socio-écosystèmes /

Study of Socio-ecosystems



Approche écosystémique et réparation du préjudice écologique

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La loi n°2016-1087 sur la reconquête de la biodiversité, de la nature et des paysages a fait entrer le principe de la réparation du préjudice écologique dans le Code civil (art. 1246). Elle définit ce préjudice comme étant constitué par « *une atteinte non négligeable aux éléments ou aux fonctions des écosystèmes ou aux bénéfices collectifs tirés par l'homme de l'environnement* » (art.1247). L'une des questions essentielles posée par cette innovation est relative aux modalités de la réparation du préjudice écologique. Elle est réglée par l'article 1249 du Code civil qui dispose dans ses deux premiers alinéas :

« La réparation du préjudice écologique s'effectue par priorité en nature.

En cas d'impossibilité de droit ou de fait ou d'insuffisance des mesures de réparation, le juge condamne le responsable à verser des dommages et intérêts, affectés à la réparation de l'environnement (...).

Cette disposition interroge. La réparation du préjudice écologique « *en nature* » est-elle toujours compatible avec une approche écosystémique? Ne risque-t-elle pas d'ouvrir la voie à des manipulations dangereuses pour les écosystèmes ?

Lorsque la réparation en nature est impossible, le texte prévoit la condamnation à des dommages et intérêts. Dans ce cas, l'évaluation du préjudice écologique s'impose. Quels sont les divers modes d'évaluation aujourd'hui retenus par les tribunaux et en quoi sont-ils en contradiction ou en harmonie avec une approche écosystémique? Quelles sont les recommandations que la communauté scientifique peut adresser aux autorités judiciaires pour éviter que des erreurs soient commises sur ce point ?

Keywords: Préjudice écologique, Réparation, Evaluation, Approche écosystémique



An ecosystem-based approach to study the Biguglia lagoon socio-ecosystem (Mediterranean Sea)

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The Biguglia lagoon, located in the north-western Mediterranean (Corsica), is a natural reserve which has been affected by a tremendous territorial change since last decades. An ecosystembased approach should enable to understand the functioning of an ecosystem which can be considered as a socio-ecosystem in order to provide decision support for its conservation and restoration. The objective of this work is to present the research approach carried out on the Biguglia lagoon. The decreasing of the water quality is reflected by a shift from a dominance of aquatic magnoliophytes in the 1970s to varying dominance of phytoplankton and opportunistic macroalgae in the early 2000s. At the same time, it has been observed an ongoing deterioration of the quality of groundwater partly providing the lagoon with fresh water, which can be attributed to the uncontrolled urbanization development all over the alluvial plain surrounding the lagoon. Efforts undertaken to improve the hydraulic management and the reduction of nutrient inputs in the watershed allowed to observe signs of ecological restoration. In addition, the socio-ecosystem functioning study requires a multidisciplinary approach where the natural and social scientists must work together as it is conducted within the framework of the Human-Environment Observatory of the Mediterranean coast (OHM-LM).

Keywords: Mediterranean lagoon; ecosystem-based approach; ecosystem functioning; groundwater; restoration



Approche socio-écosystémique pour évaluer la gestion des récifs artificiels

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L'approche écosystémique est depuis quelques années de plus en plus utilisée pour décrire les interactions entre les espèces et prendre en considération l'ensemble de l'écosystème et du sociosystème, dans les évaluations environnementales. Elle est employée par exemple dans les aires marines protégées ou les parcs d'éoliennes offshores. Cette démarche systémique pourrait être appliquée à l'évaluation de l'intérêt d'outils d'ingénierie écologique comme les récifs artificiels (Pioch, 2008). Ceux-ci sont immergés depuis une cinquantaine d'années, comme réponse à la diminution des stocks halieutiques, sur l'ensemble des façades maritimes avec une prépondérance en Méditerranée (Tessier, 2013). Cependant, en Méditerranée, sur 26 sites répertoriés (Tessier et al., 2015), une dizaine n'ont fait l'objet d'aucun rapports de suivis écologique ou socio-économique publiés connus ni de nouvelle implantation sur les cinq dernières années. Le manque de données sur l'évaluation de ces structures pose donc des questions sur leur efficacité, tant d'un point de vue écologique que social. L'objectif de cette présentation et de développer les bases d'une approche socio-écosystémique originale destinée à répondre à ce besoin d'évaluation, notamment pour les gestionnaires. Nous proposerons, en effet, un cadre d'analyse pour vérifier l'adéquation entre un réseau socio-écologique « récifs artificiels » d'étude et les objectifs initialement attendus par les acteurs, notamment les décideurs et financeurs. Nous discuterons également des limites posées par ces approches pour améliorer les connaissances systémiques liées à l'évaluation d'outils d'ingénierie écologique, comme les récifs artificiels.

Keywords: Socio- écosystème ; Récifs artificiels ; réseau d'acteurs ; réseau trophique



Changes in the ecological status and natural capital of *Posidonia oceanica* meadows due to human pressure and extreme events

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Littorals represent highly dynamic and complex systems which undergo changes imposed by several environmental factors and human-induced disturbances. Some coastal habitats, like Posidonia oceanica meadows, are considered as biological indicators thanks to their susceptibility to pressures and changes, according to the European Water Framework Directive. In this work, several P. oceanica meadows in the Portofino Marine Protected Area (North-western Italy) are analysed to evaluate potential effects of impacts on coastal ecosystems. The aims of this study are: 1) to analyse the ecological status of *P. oceanica* by means of the Conservation Index (CI), able to get information about how the meadows react to disturbance events and about their potential recovery ability; 2) to quantify the Natural Capital (NC) value of *P. oceanica* through emergy analysis, a biophysical approach able to quantify resources directly or indirectly used up to generate or maintain an ecological system; it represents a measure of overall functioning; 3) to assess changes in NC value and ecological status due to anthropogenic impacts and extreme meteorological disturbances (e.g. anchoring and sea-storms, respectively); 4) to estimate the effects of anchoring restriction measures. Results obtained for CI and NC revealed similar trends: meadows with high ecological status showed the highest NC values alike, thus proving the existence of a link between the ability of ecosystems to store NC and develop a complex functioning and the meadows state of health. Moreover, both measures highlighted how natural or anthropogenic impacts affect conditions of the ecosystem, showing changes when the system is exposed to disturbance.

Keywords: Seagrass meadows; emergy analysis; Marine Protected Areas; Disturbances; Liguria (Italy)



Interdisciplinary study on invasive species: the case of the ctenophore *Mnemiopsis leidyi* in the Berre Lagoon (Southeast France)

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The ctenophore *Mnemiopsis leidyi* is a very invasive species in Mediterranean coasts. Ctenophores invasion's impact is strong: decline of biodiversity, competition for resources with endemic species and socio-economic consequences. Mnemiopsis leidyi was observed for the first time in 2005 in the Berre Lagoon which is an ecosystem historically disturbed by strong industrial discharges and significant freshwaters inputs from both natural and anthropogenic (EDF hydroelectric power station) origins. Between 2015-2019 an interdisciplinary study has been carried out associating a sociological qualitative survey and an oceanography monitoring. The originality of this study is to associate oceanography and sociology in order to estimate the impact of Mnemiopsis on the functioning of this socio-ecosystem. We were able to show that the population of *Mnemiopsis* is maintained within a large range of temperatures (3°C-28°C) and salinities (10-30), with a quantity of carbon available ~3 mg C L⁻¹. In the laboratory, spawning by adults was observed at temperatures as low as 8°C, while transition larvae can spawn at 10°C. The strong proliferation of ctenophores in the Berre lagoon mainly affects professional fishermen. The clogging of nets, the mutilation of catches, the accelerated degradation of the material and the increase in the strenuousness induce an annual economic loss estimated at 50 %. Swimming is not affected except in case of large blooms during which beaches of the lagoon might be avoided; likewise, boating activities are impacted only in case of strong blooms when the organisms clog the cooling systems of the engine.

Keywords: Invasive species, Mediterranean lagoon, Mnemiopsis leidyi, interdisciplinarity



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Session 3 : Gestion écosystémique des pêches / Ecosystem-based management of fisheries



Evaluating broad-scale connectivity to improve the management of Hake fishery in the north-western Mediterranean Sea

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Assessing the spatial structures and dynamics of marine populations is still a major challenge due to the interlocked scales of oceanic variability and the highly dispersive early-life stages of most marine species. Indeed, larval dispersal and connectivity control several key evolutionary and ecological processes that are fundamental pre-requisites for the effective protection and management of marine ecosystems. Our modelling framework, the Lagrangian Flow Networks, provides a systematic characterization of connectivity by evaluating the dispersal of the most dispersive phases of marine populations. Focusing on the European Hake, a commercially and ecologically important demersal species, we investigate the impacts of broad-scale connectivity processes on the long-term variations of hake's recruitment in the north-west Mediterranean (e.g. the Gulf of Lion, the Spanish mainland and the Balearic archipelago). We show that the observed inter-annual variability of recruitment in contiguous management units is well reproduced by an hydroclimatic index and our synthetic connectivity estimates. Larval Self-Recruitment is the most powerful metric as it integrates both local and remote influences, capturing recurrent circulation patterns that affect recruitment success of each stock in different manners. We also reveal that the climatic impact on recruitment is spatially structured at regional scale due to complex biophysical processes not related to dispersal but to larvae's survival. These results suggest the need to incorporate connectivity processes into stocks assessment procedures. Under constant development, our modelling framework helps characterizing population connectivity and provides relevant information to fishery managers.

Keywords: Connectivity; modelling; larval dispersal; recruitment; hake; fishery spatialized unit



Coupling the map of marine habitats and fish accumulation zones: a three dimensional spatial approach for the management of halieutic resources

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The spatialization of halieutic data is an essential element to define and create efficient protected and managed areas. Moreover, the distribution of fish schools is not homogeneous in the water column and is strongly linked with marine habitats. It is thus necessary to develop techniques allowing a spatial evaluation of halieutic resources. Multibeam echo sounders (MBES) allow to obtain acoustic data of the seafloor and the water column with a centimetre positioning accuracy and a decimetre resolution. A single acquisition provides the bathymetry, a backscatter mosaic of the sea bottom (similar to sonar images) and an acoustic imagery of the water column. The treatment of bathymetric data with different algorithms specifically developed for marine environment highlight the seafloor rugosity using several metric indices. A supervised classification including the depth, the rugosity indices and the backscatter value provides maps of marine habitats which is finally validated with ground truth. Data from the water column are analysed using an algorithm that detects acoustic targets corresponding to fishes. A georeferenced point cloud of fish schools is thus automatically created. The 3D model of the seafloor obtained from the bathymetry is textured with the map of marine habitats. Points corresponding to fish detection are then added on the 3D model to provide a complete map. Through this process managers have the use of a clear visualization of fish accumulation and the key marine habitats within their areas of interest. This approach provides spatial information on several functional compartments of key Mediterranean ecosystems such as Posidonia oceanica meadows, coralligenous communities and algae-dominated rock reefs.

Keywords: Mapping; marine habitats; 3D; multibeam echo sounder; water column; halieutic



Directive cadre européenne sur l'eau et gestion de la pêche des grands cours d'eau : apports potentiels de la modélisation trophique. Exemple de la Saône aval.

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The publication of the Water Framework Directive (WFD) in 2000 orientated research towards the development of scientific methods for qualifying the ecological status of water bodies. By fractioning the diagnosis of the ecological quality of running water bodies into different biological compartments (phytoplankton, macrophytes, phytobenthos, invertebrate benthic fauna and ichthyofauna), the WFD was at odds with the ecosystem approach.

After 20 years of implementation of the WFD, the improvements observed in certain water bodies, and concerning particular water quality elements, particularly physicochemical ones, make it possible to reconsider the role rivers play as a production support for fishing. This is the case of the Lower Saône, a large low-flow floodplain river, traditionally exploited by professional and amateur fishers.

Prior to the redeployment of fishing exploitation, there is a need for a quantitative study of the living resources biomass available in rivers. To this end, food web modelling, using ECOPATH software, proposes a quantitative approach that considers the river ecosystem as a whole. The final goal is to estimate the impact of biomass removal by fishing under different scenarios. In the case of the Lower Saône, these scenarios are based more particularly on the arrival and progressive expansion of the wels catfish, and also on the arrival of the mollusc *Corbicula fluminea* over the last 30 years. As a first step, we identify the main trophic groups to be retained, using the few available examples in the literature of application of the ECOPATH model in freshwaters, and we consult with various hydrobiologists specializing in large rivers. In a second step, it will be possible to specify the trophic flows that link these groups as part of a new ecosystem approach to these hydrosystems.

Keywords: Fisheries; Large rivers; Trophic models; ECOPATH



A Spatial Decision Support System for the sustainable management of fishing in Marine Protected Areas

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Fishing is a worldwide activity impacting on limited stocks, that can recover, but it's necessary to avoid over-exploitation and permanent damages to ecosystems. The aim of this work is to provide a Spatial Decision Support System (SDSS) for develop sustainable management strategies for fishing in marine protected areas (MPAs). The system, based on a generalized and iterable procedure and tested on Portofino MPA (Italy), can be applied to any area. Starting from the assessment of the natural capital, the SDSS allows an ecosystem-based evaluation of fishing impact based on information (namely the harvest per species) gathered during the authorisation procedure, mandatory for fishermen in MPA. Subtracting the fishing annual harvest flow from the fish biomass production flow, it is possible, for each species, to assess if the MPA system is able to support fishing or if there is an over-fishing condition. Being fishing spatially distributed, the SDSS generates results (e.g. values, maps) at different spatial level: MPA, protection zones and even smaller. The models implementation in a computerized system as SDSS allows simplifying and quickly updating results and carrying out simulations of alternative management scenarios responding to manager needs in real time so to establish *ad hoc* actions.

Keywords: Environmental impact; Emergy analysis; Strong sustainability; GIS; Spatial distribution



A multidisciplinary analytical framework to delineate spawning areas and quantify larval dispersal in coastal fish.

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In a context of anthropogenic and environmental perturbations, scientists and managers should focus on spawning areas in all oceanic systems to achieve a sound spatial management and protection of coastal fishes. Yet, the precise locations where eggs are spawned are actually one of the main unknowns of the fish life cycle. Here, we propose an analytical framework which combines Lagrangian modelling, network theory, otolith analyses and biogeographical information to pinpoint and characterize larval sources which are then grouped into discrete spawning areas. Such well-delineated larval sources allow improving the quantitative evaluations of both dispersal scales and connectivity patterns. To illustrate its added value, our approach is applied to two case-studies focusing on Diplodus sargus and Diplodus vulgaris in the Adriatic Sea. We evidence robust correlations between otolith geochemistry and modelled spawning areas to assess their relative importance for the larval replenishment of the Apulian coast. Our results show that, contrary to D. sargus, D. vulgaris larvae originate from both eastern and western Adriatic shorelines, suggesting the need of a tight international collaboration between adjacent countries to ensure efficient fishery spatial management. Furthermore, 31% of D. sargus larvae and 24% of D. vulgaris larvae of the Apulian populations originate from Marine protected areas (MPAs), exemplifying larval export from MPAs to surrounding unprotected areas. This flexible multidisciplinary framework, which can be adjusted to any coastal fish and oceanic system, exploits the explanatory power of a dispersal model, fine-tuned and backed-up by observations, to provide more reliable scientific basis for the management and conservation of marine ecosystems.

Keywords: Marine connectivity; Marine protected area; Coastal fishes; Fish natal origins; Population dynamics



Gulf of Lions: the contribution of ecosystem knowledge to the Ecosystem-Based Management of Fisheries

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The Gulf of Lions (GOL) is a highly productive system due to nutrient concentrations mainly related to river inputs and upwelling activity and represents a feeding area for many marine species. Many species have been intensively exploited on the GOL continental shelf for decades, and most fish stocks are currently fully exploited or overexploited. The achievement of effective marine ecosystem-based management implies the regulation of the use of the living resources based on the understanding of the structure and dynamics of the ecosystem to which they belong. Ecosystem modelling facilitates the analysis of the ecosystem functioning and has been proposed as a tool to inform management decision-making for fisheries. Two different ecosystem models: Ecopath with Ecosim (EwE), and end-to-end coupled SYMPHONIE-Eco3MS-OSMOSE (SEO), parametrized, calibrated and validated with field data, have recently been used to analyse the structure and dynamics of the GOL ecosystem in relation to fisheries pressure. The EwE model links the benthos and the pelagos compartments and includes benthic groups such as Posidonia oceanica. However pelagic primary producers sustain the high production of the GoL food web. Multiple controls (bottom-up, wasp-waist, top-down) interact in marine ecosystems and only an ecosystem approach can highlight their respective effects. Such complex interactions have recently been shown between climate variations and fisheries using the SEO model, and this has provided a basis for proposing a set of potential mechanisms that may explain the observed changes in the GOL ecosystem. These mechanisms may aggravate the current fisheries crisis in the French Mediterranean.

Keywords: Ecosystem modelling; fisheries; climate; Ecopath with Ecosim; SYMPHONIE; Eco3MS; OSMOSE coupled model



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Session 4: Evaluation des services écosystémiques / Assessment of ecosystem services



Ecosystem Services Assessment in the Bay of Marseille

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Life IPE Marha (2018-2025) aims to restore and sustain a favourable conservation status of marine natural habitats in Natura 2000 sites. In this context, ecosystem service assessments (ESA) are carried out in various French sites including the Bay of Marseille. First, we applied the TRIAGE methodology: a strategic assessment of the issues with experts of the site (local managers and scientists). TRIAGE puts forward two main concerns: (1) the intensification of recreational uses (both by residents and visitors) and (2) the conservation of *Posidonia oceanica* meadows. In order to address both issues, we selected two adapted methodologies based on the strategic assessment: Respectively, (1) a study oriented toward understanding the demand for ecosystem services (concentrated on recreational activities) and (2) a study of the capacity of the P. oceanica meadows to deliver ecosystem services using state-and-transition model. The objective of this communication is to present the ESA process, from the strategic assessment to the results of the analysis. Considering the progress of the project, we will focus on the study regarding capacity of P. oceanica meadows to provide ecosystem services. State and transition models consist in the definition of alternative states of the habitat based on ecological indicators, the identification of the bundle of services associated to each state and the identification of transition vectors that can explain the shifts between each state. State-and-transition models can be very powerful frameworks to integrate multiple functions and services delivered by ecosystems while accounting for their temporal dynamics.

Keywords: TRIAGE; Ecosystem services bundles; Posidonia meadows



Towards strong sustainability: a framework for economic and ecological management of Marine Protected Areas

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This study represents a progress of results obtained in the context of EAMPA (Environmental Accounting in Marine Protected Areas) Italian project. EAMPA project, launched by Italian environmental Ministry in 2014 and ended in 2018, aimed at providing to Marine Protected Areas (MPA) managers an operational tool for environmental accounting. At this purpose a specific framework to assess natural capital values and to obtain a budget considering ecosystem services has been applied in several national MPAs. Here, an upgraded version of the framework, developed in the context of GIREPAM EU Interreg Project, is proposed. The formulated approach implements some additional and key feature, that can represent a significant improvement to the model. First, two budgets are proposed and then compared, the environmental and the economic ones, aiming at achieving sustainability of both domains. Moreover, as far as the ecological part is considered: 1) the final result, initially represented by modified the budget, is replaced with a strong sustainability assessment; 2) impacts directly exerted on MPA natural capital, and associated with ecosystem services fruition by MPA's customers, are taken into account and included in the budget; 3) sustainability maps are generated; 4) a Spatial Decision Support System for MPA managers is obtained. The upgraded framework represents a practical tool to operationalise the sustainability assessment and to monitor sustainability level. Moreover, the framework puts in practice the so-called "ecosystem services cascade", since it includes the assessment of the natural capital and the ES and the benefits it generates.

Keywords: Ecological economics; emergy analysis; sustainable development; spatial decision support system; costs; benefits analysis



Multi-agent modelling, a lab experiment for building ecosystem-based management policies in coastal and marine socio-ecological systems: Results from the SAFRAN project, a prospective exercise in the Natural Marine Park of the Gulf of Lion.

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Coastal areas are a multiple-use space. They host many activities related to the exploitation of natural resources that are sources of market ecosystem services: food provision through artisanal and industrial fisheries, recreational services through blue tourism (snorkelling, diving, etc.). They also offer a variety of non-market ecosystem services (nurseries, spawning grounds or shelters for exploited species, CO₂ sequestration, filtration and recycling of toxic substances, erosion control through the dune belts). Increasing multiple human impacts on coastal areas threatens the sustainable provision of all these services. In this context of multiple pressures, uni-functional artificial structures are submerged to address specific challenges one by one (e.g. targeting coastal erosion, sea level rise, or depletion of fish stocks). The sustainable development of coastal and marine areas requires that land-use planning, including marine infrastructures (dikes, artificial reefs, floating wind turbines) are now seen as integrated policies.

Keywords: Ecosystem based management; MPAs; Ecosystem services; multi-agent-based modelling; marine habitats



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SALSA

Les salins d'Hyères : mise en place d'une gestion socio-écosystémique / The saltmarshes of Hyères: implementation of a socio-ecosystem based management



Biodiversité, connaissance, communication et gouvernance pour la gestion écosystémique du site des Salins d'Hyères (Var, France).

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Les Salins d'Hyères (950 ha), propriété du Conservatoire du Littoral sont gérés par la Métropole Toulon Provence Méditerranée suivant un nouveau plan de gestion qui repose sur :

- La préservation des patrimoines naturels et paysagers.
- La connaissance de la biodiversité, la préservation de la mémoire salinière et l'accueil du public.
- La gouvernance et la gestion.

Ces espaces remarquables ont bénéficié de nombreux suivis naturalistes, notamment l'avifaune via un protocole standardisé depuis 2001. On y a dénombré 324 espèces dont 56 nicheuses, 138 hivernantes, 304 migratrices.

A l'instar des reptiles, des chiroptères ou de la flore terrestre qui font l'objet d'inventaires et de suivis, les milieux aquatiques n'ont pas été en reste : cartographie des herbiers aquatiques dès 2003 avec une réactualisation en 2013 démontrant une augmentation du taux de recouvrement des macrophytes et la découverte de characées patrimoniales. Puis les inventaires de la piscifaune ont révélé 9 espèces en 2002 puis 16 en 2010.

La démarche écosystémique du programme SALSA propose la mise en œuvre d'actions concrètes de gestion en faveur de l'ichtyofaune en les conciliant avec les autres espèces patrimoniales ainsi que l'optimisation du rôle des salins comme nurserie.

Paysages de l'entre terre et mer, richesses biologiques, trame historique et culturelle, les salins d'Hyères sont indéniablement des espaces complexes en constante mutation. L'approche écosystémique ici initiée permettra d'affiner les protocoles de gestion de ces zones humides si singulières, et apparaitra de fait comme un nouvel outil de compréhension de leurs milieux au service des gestionnaires.

Keywords: Salins d'Hyères, biodiversité, gestion, approche écosystémique.



La lagune des Pesquiers (Hyères) : mise en perspective historique et approche écosystémique

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Formation remarquable élaborée il y plus de 6000 ans, le double tombolo de Giens enserre un espace lagunaire relié à la pleine mer par un grau. A l'exemple de tous les systèmes lagunaires, la lagune des Pesquiers a longtemps été mobile, dotée d'une vie propre, conditionnée par les tempêtes d'ouest et par l'apport des fleuves côtiers. Son histoire est marquée par la rupture répétée de ses lidos. La stabilisation contemporaine du cordon dunaire ouest, motivée par le développement des salines au milieu du XIX^e s., a installé l'idée que cet ensemble géomorphologique pouvait être durablement fixé. L'abandon de ces activités industrielles au cours du XX^e s., et les effets du changement global, forcent aujourd'hui les communautés littorales à s'interroger sur l'avenir de ce site artificialisé. Face à l'alourdissement des opérations de maintenance des cordons dunaires, et aux effets annoncés de la montée du niveau de la mer, le temps est peut-être venu de rendre à la lagune sa liberté, en la laissant trouver un nouvel équilibre avec son milieu. La lagune des Pesquiers, renouant avec sa toponymie, pourrait représenter dans un proche avenir un véritable atout pour la gestion des richesses halieutiques de cette partie du littoral provençal. Elle jouerait alors le rôle d'une pépinière ichtyque, favorisant le maintien des activités locales de la pêche artisanale.

Keywords: Lagune des Pesquiers ; double tombolo ; artificialisation



Mapping of *Ruppia spiralis* habitat within the saltmarshes of Hyères (Provence, France): a key species for an ecosystem-based approach

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Hyères saltmarshes (Pesquiers and Vieux-Salins; Provence, France) are Mediterranean lagoons deeply altered since antiquity; they are an example of a socio-ecosystem characterized by industrial activities since 1848 for salt production and artisanal fishing (Pesquiers saltmarsh). After the end of industrial exploitation in 1995, Hyères saltmarshes became property of the Conservatoire du Littoral (Coastal Protection Agency) in 2001 and managed by the Toulon Provence Méditerranée (TPM) metropolitan area. Since then, access to the sites is restricted in order to preserve the historical heritage of the site and biodiversity of birds. The present work aims to localize and map Magnoliophyta aquatic meadow habitats and related macroalgal communities in order to : (i) better understand the water management of the saltmarshes, inducing the presence or absence of Magnoliophyta and (ii) assess the health status of macrophytes community (dry biomass, seeds and flower mean density). The main observed Magnoliophyta was Ruppia spiralis, Linnaeus ex Dumortier a halophilous species considered as an ecosystem engineer; its presence in such brackish waters can be considered as an indicator of good conservation status. Our results show a relatively high abundance of *R. spiralis*, with a distribution and abundance strongly related with environmental conditions and water management. This study is the first step of an ecosystem-based approach; R. spiralis, as a primary producer, belongs to a major functional compartment of the ecosystem which constitute the saltmarshes. Understanding the functioning of Hyères saltmarshes ecosystem will improve its management in a concerted way according to the current priorities defined by the newly established local management plan and at a larger scale, in the framework of the European Union's Marine Strategy Framework Directive (MSFD).

Keywords: Ruppia spiralis, saltmarshes, mapping, ecosystem-based approach



Favouring exchanges between the sea and the lagoons: a necessary support to the restoration of the functional role as fish nursery in the saltmarshes of Hyeres (Provence, France)

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Since millennium, Mediterranean lagoons and wetlands have been strongly modified by Man for different purposes. The salt exploitation of saltmarshes of Hyères (*Salin des Pesquiers* and *Vieux Salins* sites) has led to the isolation of the lagoon from the sea to control evaporation. Whether or not their ecological functioning is currently altered regarding fish population, was one of the aspects of their ecosystemic study.

During 2018-2019, 4 samplings with 4 mm-mesh size fyke nets (24h fishing duration) have confirmed that the two saltmarshes still have a relict nursery role. If juvenile fishes were numerously dominant in the catches, adults were also present. A few euryhalin and permanent small-sized taxa (Atherinidae, Gobiidae, Syngnathidae) contributed to 90% of the total abundance in the catches. The amphihalin migrator *Anguilla Anguilla* (mainly adult stages) was the main contributor to the biomass of catches. Juveniles from commercial species such as *Dicentrarchus labrax, Sparus aurata,* Mugilidae and Soleidae were caught in spring and autumn when entering from the sea. Their tolerance to a wide range of salinity allows them to benefit temporarily from good environmental conditions for their growth. However, considering the low connectivity and the high salinity we measured, most of those marine fish juveniles are probably trapped inside the lagoon. In the *Salin des Pesquiers* and in the *Vieux Salins* as well, the closer were the sampling sites from the open sea, the higher were the species richness and the juveniles' density, suggesting that a part of the lagoons works as an ecological sink.

The diversity of fish assemblages of the saltmarshes of Hyères is directly dependent from the effectiveness of the connection with the open sea. Among the different actions emerging from the SALSA project, a sluice gate between the North pound (*Salin des Pesquiers*) and the alimentation channel could significantly enhance exchanges and potentially support fish resources at sea.

Keywords: Saltmarshes, experimental fishing, fish nursery



Improving the management of Hyères saltmarshes (Provence, France) using an ecosystem-based approach

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The management of saltmarshes and coastal wetlands is often centred on the so-called 'heritage species' (rare, threatened and charismatic species). In addition, managers, stakeholders and the public at large generally favour certain visible higher-level taxa, such as birds and Magnoliophyta, rather than e.g. invertebrates and the 'ordinary biodiversity'. This 'species-centred' or 'taxoncentred' approach, a legacy from the 20th century, is fully understandable in a number of areas where definitely and critically endangered species occur. However, in many areas, an ecosystembased approach, of course including species and higher taxa, but based upon the whole functioning of the ecosystem, from primary producers to e.g. detritus feeders and top predators, would present advantages of paramount importance. The ecosystem-based approach involves the management of the interactions between functional compartments, and the search for an equilibrium according to the supposed baseline, ecosystem services and management goals. This approach offers a basis for considering the current global change. A conceptual model of the whole salt marsh ecosystem, including lagoon bottoms, water body and terrestrial adjacent habitats, has been established. Taking into account the high diversity of salt marsh environments physically and biologically as well, this model is a frame that should be adapted to each case study. Here, the authors focus on two case studies in Provence (Vieux Salins and Salin des Pesquiers), north-western Mediterranean. Historical data running over several centuries (opening and closure of connexions with the sea, fisheries, salt production), the management during the last decades mainly based upon waterfowl conservation and enhancement, the weaknesses of the traditional speciescentred approach and the advantages of an ecosystem-based approach are highlighted through novel applications.

Keywords: Saltmarshes, ecosystem-based approach, management, conservation, Mediterranean



SALSA – The saltmarshes of Hyères: implementation of a socio-ecosystem based management, 5th of February 2020, Marseille







Poster



Distribution of manila clam, *Ruditapes philippinarum* (Adams et Reeve, 1850), into Berre lagoon according to the environmental condition

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The Manila clam *Ruditapes philippinarum* (Adams et Reeve, 1850) is one of the most commercially exploited bivalve molluscs in the world (Dang *et al.* 2010). Since 2013, *R. philippinarum* expands into Berre lagoon. In 2017, the density was between 41 and 1 264 clams/m², that is exceeding densities of other French sites (Sanchez *et al.*, 2014; Mahé, 2017). In February 2018, clam's professional fishery has been opened into Berre lagoon. During the summer and autumn 2018, an ecological crisis occurred in the lagoon and clam stock has been decimated. Consequently, fishery was closed in September 2018.

Clam stock study was conducted between March and July 2019 into Berre lagoon. 238 stations were sampled. During this fieldwork, the number and the size of clams, the number of other bivalves and the grain size were evaluated for each station. The grain size was assessed for 50 stations. Hydrological parameter was recorded monthly since 1994 in 10 stations into Berre lagoon (chlorophyll a, salinity, temperature and oxygen).

The goal is to explain the clam distribution into Berre lagoon using environmental parameter: other bivalves' distribution, grain size and hydrological data (chlorophyll a, salinity, temperature and oxygen). The long-term goal is to try to assess the clam recolonization and to evaluate the time needed for the fishery to reopen.

Key words: Manila clam, Berre lagoon, Fishery, Stock



Toxic algal blooms at the urban coast: a citizen's point of view

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The complex nature of sea pollution in urban areas due to anthropic activities prevents traditional monitoring techniques from obtaining measurements representative of true human exposure and the real health status of an urban context.

A respiratory syndrome has been repeatedly observed in humans concomitantly with *Ostreopsis* spp blooms in the Mediterranean area. In this study, volunteers of a local Citizens Observatory named Osservatorio del Mare a Molfetta (OMM) have monitored the proliferation of the toxic microalga *Ostreopsis ovata* along the coast of Molfetta, a city on the Southern Adriatic Sea, where the occurrence of *O. ovata*-blooms has been officially reported since summer 2009. The traditional *O. ovata*-monitoring, -alert and -provisional protocols, based on single sampling station per city every 15 days between June and September need improvements.

With the aim of establishing a low cost and more effective monitoring protocol, since June 2016 trained OMM volunteers sampled sea water at two stations distant from each other 5 Km along the urban coast. Planktonic cells were numbered under the light microscope. We found that: a) *O. ovata* distribution was not identical in the two sampling stations; b) the dinoflagellata proliferation always started during summer at the station closer to the urban centre c) *O. ovata* was detected beyond the end of September up to January of the following year and d) the non-toxic diatoms *Coscinodiscus sp.* were also detected in summer season along with *O. ovata* and were predominant in the phytoplankton community.

We conclude that the weekly sampling of seawater in at least two stations along the urban coast from June to January is an effective method to predict toxic algal blooms in our hometown.

Furthermore, there is a possible correlation between the proximity to the urban centre and the rate of proliferation of the dinoflagellata *O. ovata* and the diatoms *Coscinodiscus* sp. suggesting that the whole urban coast ecosystem may be impacted by the city-caused pollution. Future studies will have to confirm this hypothesis.

Keywords: Ostreopsis ovata, Toxic Algal Bloom, Plankton, Citizens Observatory.





A citizen science approach in the monitoring of a *Posidonia oceanica* meadow in the Italian Southern Adriatic Sea.

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A model of citizens' observatory, named Osservatorio del Mare a Molfetta (OMM), has been translated into practice to observe and monitor the health status of the marine and coastal environment of the city. For this reason, we examined the local *Posidonia oceanica* meadow named San Vito-Barletta, extending along the coast of Apulia region in the Italian Southern Adriatic Sea. In fact, *P. oceanica* meadows are considered good bioindicators revealing the health status of the annexed marine-coastal ecosystems.

This meadow has been lately graded as "disturbed".

With the goal of gathering information necessary for the preservation of the urban seagrass meadow, volunteers of OMM conducted underwater visual census of the epiphytes on *P. oceanica* leaves. Two campaigns of investigations in three different stations, namely Molfetta, Giovinazzo and Mola di Bari, revealed that the distribution of the epiphytic communities was not uniform among the meadow. In Molfetta station, the leaf-epiphytes biomass was visibly more abundant with increased filamentous epiphytes.

To gain further insight relevant to direct future conservation actions, citizens of OMM engaged with a scientific research centre to conduct a population genetics study on the local marine plants using highly variable microsatellites markers. The study revealed that the meadow San Vito-Barletta shows an excess of heterozygosity and demonstrated the existence of at least two subpopulations. Since the sampling areas are situated along the coasts of different urban centres, this situation may reflect the diverse anthropogenic pressures that vary among cities .Therefore, as local citizens' observatory, we now have to undertake the necessary actions to raise general public awareness on the need to promote good conservation practices to preserve San Vito Barletta meadow and the annexed coastal-marine ecosystem

Keywords: Posidonia oceanica, *seagrass, underwater visual census, micro satellite genotyping, citizen science, epiphyte.*





A unique feature of lagoon along French Mediterranean coast

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Posidonia (Posidonia oceanica) has the ability to build original vertical structures which can lead to seagrass reef formations. One of the last remaining large Posidonia barrier reefs along the French Mediterranean coast is located on the Natura 2000 area around the Embiez Island (Provence). The Brusc coast, the Gaou Islands and the Embiez Island shape a bay which communicates with the sea on the southern side through three small channels. On the north side, the barrier reef limits the communication between the sea and the bay forming an original lagoon whose morphology, functioning and dynamics will be presented here. This lagoon is home to a mosaic of habitats with 3 different types of seagrass meadows including 2 Posidonia barriers reefs and patches of Zostera (Zostera noltei) and Cymodocea (Cymodocea nodosa), sandy and rocky bottoms and anthropogenic structures. 37 coastal fish species including 19 at juvenile stage were observed by underwater visual census in this lagoon between March 2018 and March 2019. Large variations of species richness, density and biodiversity indices were found between these habitats. Despite its rich magnoliophyte collection, fish community and patrimonial heritage, the Brusc lagoon has suffered in the past and still suffers today from many direct and indirect anthropic pressures. Among others, a cartographic analysis shows the significant loss of lagoon surface including the barrier reef structure due to shore artificialization. In addition, the artificial nourishment of proximate beaches outside the lagoon area is the main cause for the loss in the 2000s of 99,9 % of the Cymodocea meadow which historically covered the majority of the lagoon bed. Twice less fish species, a density 40 times less important and also no inhabitant fish species at juvenile stage were found in the sand bed compared to in the regrown *Cymodocea* patches. This sand bed, covering in 2018 more than 70 % of the whole area, induces a massive decrease in productivity and a loss of ecosystem functions in the lagoon. Here, we compile data on morphology, ecological dynamic and functions, and on the impacts of anthropic pressures to gain knowledge to help us implement a sustainable management of the Brusc lagoon.

Keywords: Lagoon, Barrier reef, Seagrass, anthropic pressure



Study of the *Posidonia oceanica* meadow's upper limit with georeferenced photogrammetry

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Photogrammetry allows to generate maps based on a high number of photographs and the tie points between them. Commonly used in terrestrial mapping with drones, georeferenced photogrammetry is rarely used in underwater studies. In order to obtain a centimetre positioning accuracy through direct georeferencing, we developed a floating platform encompassing two submerged cameras synchronised with a Real Time Kinetic Global Navigation Satellite System at the surface. This device can be used from 1 m to 10 m depth in clear waters and the photographic views of the seafloor, with a millimetre resolution, allows us to map shallow habitats previously impossible to detect with classic methods such as acoustic sounding and aerial photographs. With this in mind, we used the platform to shoot more than 3 400 photos on a distance of about 500 m along the upper limit of the shallow Posidonia oceanica meadows of the Mugel, a creek in La Ciotat (Provence, France) located in the National Park of Calanques. The underwater photographs and the position data from the GNSS were synchronised using the ViewMap software developed by Seaviews to provide each picture with geographic coordinates. All the photos were then processed in the Metashape software developed by Agisoft in order to build an ortho-mosaic of the meadow's limit. Thanks to its high resolution, the orthophotographs allowed the mapping of various features of the seascape such as the position of the limit with a centimetre accuracy, bare matte patches, litters of dead leaves, artificial objects (moorings, wrecks) and marine organisms living on the seafloor. Thus, underwater photogrammetry has the potential to provide spatial information on several functional compartments of the *P. oceanica* ecosystem.

Keywords: Mapping; photogrammetry; seagrass; georeferencing; underwater



Orthomosaic of the upper limit of the P. oceanica meadow in the Mugel Creek with a zoom on a mooring system.


Towards the development of ecosystem-based indicators of mangrove functioning state as part of the EU water framework directive

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The Water Framework Directive (WFD, 2000/60/EC) enjoins European Union members to reach the "good status" objectives for their water bodies by the end of the second and third management cycles, which extend from 2015, end of first management cycle, to 2021 and 2021 to 2027 respectively. The two elements used to define a "good status" for a water body are the "good chemical status" and the "good ecological status" which are defined in terms of compliance with all the guality standards established for chemical substances at European level and in term of the quality of the biological community, the hydrological characteristics and chemicals characteristics, respectively. In metropolitan France, several bioindicators are used to monitor the quality of coastal waters: phytoplankton, angiosperms or benthic invertebrates. As well as no absolute standards for biological quality can be apply across the European Community, there are no bioindicators that can be used for both mainland France and its overseas territories. In French tropical areas, the coastline is often occupied by an iconic ecosystem, the mangrove forest. Due to their localization in the intertidal zone, their functioning is influenced both by the quality of oceanic and continental waters, making mangroves an interesting sentinel ecosystem. Therefore, mangrove forests are considered to define functional indicators to support the management mission of the WFD in tropical and subtropical zones. For that purpose, a research group (MIO, LEMAR, MNHN, EcoLab, Ifremer) with complementary areas of expertise (mangrove ecology, microbiology, botanic, zoology), was mandated in 2016 by the French Agency for Biodiversity. An ecosystem-based approach is used on mangroves located in four overseas territories: French Guiana, Martinique, Mayotte, and Guadeloupe islands. This approach should enable us (i) to understand and assess the functioning of mangroves subjected to various anthropogenic pressures and (ii) to identify valuable tools to assess the "ecological status" of the overseas coastal waters as part of WFD.

Keywords: Water Framework Directive; ecological status; bioindicator; mangrove forest



Lagrangian Flow Network: a powerful and flexible modelling framework to study the multi-scale connectivity of marine populations.

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The "ecosystem-based" management and protection of marine living resources advocate strategies that embrace several disciplines across various spatio-temporal scales. Indeed, our growing understanding of larval dispersal and of its impacts on marine populations (e.g. spatial structure, temporal dynamics, long-term persistence) call for an urgent need to incorporate multiscale connectivity processes in the evaluation and design of conservation plans. However, the large seascape with fragmented habitats and chaotic ocean circulation as well as the large variability of biological traits among marine species impede our ability to properly appraise connectivity. Inspired from Network Theory, we present a novel modelling framework (Lagrangian Flow Network) which fully characterizes the connectivity of pelagic early-life stages (i.e. eggs, larvae, propagules). The network is built by sub-dividing the region of interest into several boxes (subareas of the ocean, equivalent to habitat patches) which are then interconnected through the transport of larvae by ocean currents. We build connectivity matrices from millions of virtual trajectories computed using data of ocean currents originating from high-resolution hydrodynamical model or satellite products. Additional factors, such as reproductive output and habitat suitability, can be parameterized to modulate larval production and settlement success, respectively, in each box. Post-processing of matrices permits the identification of hydrodynamic provinces, the computation of various connectivity proxies measuring retention (Self-Recruitment, Local Retention) and exchange (Source-Sink) of larvae. Future developments include the implementation of realistic larval traits and the effects of abiotic factors (e.g. temperature, planktonic food...) on larval survival. The model can be tuned for any species whose ecological traits are well known or it can be used in a generic manner, following an "ecosystem-approach" to connectivity, thanks to efficient computing and the analysis of large ensemble of matrices. It provides synthetic diagnostics of connectivity which help conservation stakeholders and managers to evaluate population dynamics and to design a well-connected network of Marine Protected Areas.

Keywords: Connectivity; model; larval dispersal; marine protected areas; habitat patchiness



Compétition interspécifique et capacité invasive d'*Holothuria (Roweothuria) arguinensis* : Son régime alimentaire représente-t-il un danger pour les espèces autochtones méditerranéennes ?

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Ce travail porte sur le régime alimentaire de l'espèce invasive *Holothuria arguinensis* et la possibilité d'entrer en compétition dans l'acquisition de l'aliment, avec les espèces d'holothuries autochtones du site de Salamandre (Algérie).

Les holothuries étudiées sont omnivores et se nourrissent à la fois de végétaux (diatomées, macroalgues, cyanophycées, feuilles vivantes et mortes de *Posidonia oceanica*) et d'animaux (spicules d'éponge, crustacés, coquilles de bivalves, foraminifères et nématodes). Les crustacés sont très consommés par l'ensemble des espèces autochtones (21.33%, 16%, 10% et 9.06%, chez *H. forskali, H. sanctori, H. tubulosa* et *H. poli* respectivement), tandis que les foraminifères sont la ressource la plus consommée par *H. poli* et *H. tubulosa* (17.33% et 29.33% respectivement). La fraction végétale est très appréciée par *H. forskali* (diatomées et algues avec 28.66% et 20.66% respectivement) et *H. sanctori* (algues et diatomées avec 31.33% et 21.33% respectivement). *Holothuria arguinensis* se démarque par une consommation importante de coquilles de bivalves, de spicules d'éponges et de nématodes, avec 24.80%, 11.6% et 6.80% respectivement). Les macroalgues (avec 27.80%), sont également très consommées par *H. arguinensis*, contrairement aux cyanophycées qui ne sont pas consommées. L'analyse statistique (Permanova) montre une différence de régime alimentaire très hautement significative (P < 0.001) entre *Holothuria arguinensis* et les quatre espèces d'holothuries autochtones. *H. arguinensis* est une espèce qui peut être qualifiée de "spécialiste".

Holothuria arguinensis, ne montre aucune compétition avec les holothuries autochtones étudiées. Cette espèce invasive préfère des ressources alimentaires, qui ne sont que peu consommer par les autres holothuries.

Keywords: Holothuria arguinensis ; espèce invasive ; régime alimentaire ; compétition ; Côte ouest algérienne.



