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# KEYNOTE SPEAKERS

## Science from a historical perspective: 175 years of change in the North Sea

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The world's seas and oceans have been subject to anthropogenic pressures for a very long time – from decades to centuries – and a newly emerged discipline, termed 'marine historical ecology', studies the long-term 'footprint' of human society on the marine environment. This plenary addresses 175 years of change in the North Sea, a shelf sea which is highly productive, but also subject to a particularly broad range of pressures. The talk is partly based on historical datasets, digitised from archives at Cefas and other government institutes in recent years. Already 175 years ago fisheries were extensive with thousands of sailing trawlers, and the North Sea far from 'virgin.' Steam power was introduced, and by the early 1900s the UK fleet alone numbered over 1200 steam trawlers, fishing in the entire North Sea. Fishing pressure increased steadily throughout the twentieth century, apart from temporary reductions during both World Wars, and especially accelerated from the 1960s onwards with developments such as mechanised beam trawling and improved fish finding techniques. It is only since the turn of the millennium that fishing pressure has decreased, aided by the European Union fleet reduction scheme, so that by now, many stocks are exploited sustainably. Meanwhile the North Sea has been a 'hotspot of marine climate change,' warming up more rapidly than surrounding seas; and has also undergone major changes in nutrient inputs from rivers, with associated periods of eutrophication.

This talk shows that climate change, fishing, changing nutrient inputs from rivers, and political events have been, and currently are, major drivers of the North Sea ecosystem. For example, each of these pressures have left a 'mark' on what might be the world's longest time-series on fish size distribution: North Sea plaice, from 1902–present. At different times, either larger or smaller plaice predominated the size distribution, and changes in average sizes of fish can be attributed to prevailing pressures or drivers. A range of North Sea fish species have also shifted their distribution over the past century – often northward and deepening as may be expected with global warming, but sometimes southward and into shallower waters. Not only climate change, but also fishing has acted as driver of distribution shifts; this has been the case in at least cod, sole, and turbot. The North Sea has also seen changes in the elasmobranch (skates and sharks) assemblage over the past century, shifts in the timing of spawning of fish, and a marked range expansion of squid. Combined these changes, which have come to light through analysis of long-term, historical datasets, indicate a fundamental reorganisation of marine communities over time. This demonstrates how 'marine historical ecology' can provide us with a substantially improved, and more holistic perspective of long-term change: not only to help understand what happened long ago, but in support of current and future management of our marine environment.

Keywords: North Sea; marine historical ecology; climate change; fisheries; fishing pressure; nutrients; size distribution; distribution shifts

## The history of marine science in Belgium

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Marine sciences were a largely unexplored scientific area in Belgium until halfway the 19th century. Although some important predecessors were active during the previous centuries, it is Pierre-Joseph Van Beneden (1809-1894) who is considered as the founding father of marine sciences in Belgium. Van Beneden, professor of zoology at the Catholic University of Leuven, was the first researcher to study marine fauna in the North Sea in a systematic manner. He even established his own modest marine laboratory called *Laboratoire des Dunes* (Dune Laboratory) on the east bank of the Ostend harbour. This first marine research station in the world was an ideal base of operations, not only for Van Beneden's own expeditions at sea, but for those of his son as well. Edouard Van Beneden (1846-1910), professor of zoology at the University of Liège, further introduced numerous students to the marine research field from this station at the Belgian coast.

The marine research field gained momentum in the whole of Europe during the 1870s. Marine stations emerged at countless locations along the European coastline, while pioneering scientific ocean expeditions produced a wealth of new data. The era of modern marine research had begun, and many Belgian scientists were involved. Researchers such as father and son Van Beneden, Alphonse Renard (1842-1903), Gustave Gilson (1859-1944), Paul Pelseneer (1863-1945), Auguste Lameere (1864-1942), Julius Mac Leod (1857-1919), Alphonse Meunier (1857-1918), Charles Van Bambeke (1829-1918), Louis Stappers (1883-1916) and Jean Massart (1865-1925) made important contributions. At the turn of the century, marine science in Belgium further led to several important breakthroughs. The Antarctica expedition of the *Belgica* in 1897-1899 made history, while Gustave Gilson initiated a large-scale systematic research project in the North Sea. Between 1898 and 1939 he collected no less than 14,000 marine samples in the Southern Bight of the North Sea, which serve as important reference material for current studies.

The enthusiasm of the Belgian scientific world towards these marine studies during the 2<sup>nd</sup> half of the 19<sup>th</sup> century contrasted sharply with the unwillingness of the Belgian authorities to invest in adequate research infrastructure and to provide appropriate funding. Both the creation of a marine laboratory financed by the State and the construction of a governmental research vessel were major obstacles. The Marine Research Institute (*Zeewetenschappelijk Instituut (ZWI)*) in Ostend, which opened its doors in 1927, eventually became the first marine institute to receive funding from the government. The introduction of the first official Belgian federal oceanographic research vessel took even more time. It was not until 1984 that the *RV A962 Belgica* was launched.

During the second half of the 20<sup>th</sup> century, and especially from the 1970s onwards, the foundation was laid for a more multidisciplinary and interinstitutional approach to the study of the seas and oceans in Belgium. Nowadays, around 1,500 scientists are attached to 115 marine research groups from Belgian universities, graduate schools and scientific institutions. For their studies, they can count on the services of two research vessels: the *RV Belgica* and the Flemish research vessel *RV Simon Stevin* (launched in 2012).

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# SCIENCE FROM A HISTORICAL PERSPECTIVE



## A database of benthos and plankton in Romanian Black Sea waters

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Since 1956 several large benthos and plankton datasets had been collected in Romanian Black Sea waters, but they remained mostly unavailable to the wider research community. The aim of gathering and electronically archiving these historical data sets on marine biodiversity was to save and quality check them and render accessible for future spatial and temporal analyses in Black Sea countries and Europe. We have searched paper archives and scanned the primary protocols and grey literature on marine phytoplankton, zooplankton and macrozoobenthos species from Romanian Black Sea waters for the period 1956 -1999. The datasets were collected covering soft bottoms and the pelagic habitats.

The phytoplankton datasets contain 509 stations located in shallow to shelf waters and over 2129 samples collected from March to November, between 1956 and 1980, with no similar frequency of sampling each year, representing 28054 records of abundance data (cells · L<sup>-1</sup>) and biomass (mg · m<sup>-3</sup>) for individual phytoplankton taxa.

The zooplankton datasets for the period 1956 - 1980 contain 1227 samples collected at 675 stations from different layers, using the Baskakova net. They represent 39518 records of quantitative (density as ind · L<sup>-1</sup> and biomass as mg · m<sup>-3</sup>) and qualitative data (zooplankton species diversity).

The macrozoobenthos datasets for the period 1977 - 1999 include 679 samples collected at different transects of the Romanian Black Sea littoral, between Sulina and Mangalia, from 5m to 55m depths. Van Veen grab with a sampling area of 1/20 m<sup>2</sup> was employed as a macrozoobenthos sampler. The datasets contain 5102 records of abundance data (ind · m<sup>-2</sup>) and biomass (g · m<sup>-2</sup>) of macroinvertebrates identified at species level where possible.

All datasets have been formatted and converted to Darwin Core and submitted to EMODnet Biology. Units and taxonomy have been standardized and checked in WORMS to update the scientific names, with erroneous data being removed and all metadata included. Each delivered dataset was subjected to standard quality control procedures, especially on the level of taxonomy.

Keywords: historical datasets; phytoplankton; zooplankton; macrozoobenthos; Black Sea

## Marked changes in megafauna composition of the North Sea require multidisciplinary collaborations: an historical overview

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The North Sea is a shallow and highly productive sea in which **long-term ecosystem changes** may ultimately be related to changes in climate or nutrients, but the long-term dynamics are influenced by anthropogenic impacts and internal factors such as competition and predation. Its fishing grounds have been exploited for centuries, resulting in stock depletions, a modified species composition, and shifts towards reduced life-expectancies of most commercial fish species. **Seabirds and marine mammals** have been affected, often in unexpected ways. Atlantic whale stocks are slowly recovering from historical overexploitation and sightings within the North Sea have become more frequent as a result. The species composition and overall abundance of dolphins and porpoises have fluctuated over decadal time scales, seemingly in response to climatic variations or variations in prey availability.

Seabirds and marine mammals are charismatic marine species that many people are concerned about. These concerns range from conservation priorities on one end to suggestions to reduce stocks by culling to protect commercial fisheries. Many species at higher trophic levels are characterised by relatively long lifespans, long generation times, complex social structures, and extensive ranges. As top-predators, these species have a structuring role in the ecosystem, which means that understanding their **population dynamics** is indispensable for ecosystem studies. Historical census work conducted by a variety of research institutes around the North Sea since the mid-1980s forms the baseline of our current understanding of the **spatial distribution, habitat requirements** and **species interactions** of seabirds and marine mammals (often under the umbrella of the 'European Seabirds at Sea Database Co-ordinating Group').

Marine ecosystems are sensitive to (natural) fluctuations, but it is far from clear exactly how climate change, human exploitation or environmental modifications interact and affect the functioning, **trophic dynamics** and **biodiversity** within the North Sea. Over the most recent decades, partly as a result of European policy, fishing intensity has declined or has shifted geographically, several forms of marine pollution have decreased while others have emerged. Unfortunately, synoptic surveys of the North Sea have not been continued as a result of which recent data are largely lacking and large parts of the North Sea are currently understudied. Within the context of this historical work, we urgently need a refreshment of **distribution data**, a new series of experiments to assess the impact and importance of current levels of discards provisioning on marine birds, and more attention to ecological interactions between marine mammals, seabirds and their (fish, crustacean, benthic) prey. Proposals for multi-disciplinary collaborations will be put forward.

Keywords: charismatic megafauna; ecosystem changes; species interactions; historical distribution data; trophic dynamics; future collaborations

## Sustainability of Marine Biological Stations, lessons from a historical perspective

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*Scientia potentia est* (knowledge is power) and when governments became aware of the implications of the aphorism the sea became both a medium of transportation to investigate new territories and a depository of resources. The most important trip in Biology, and possibly in other ambits of humanism, was that of the HMS-Beagle, an exploration of the biodiversity of the planet on board of a vessel of the Royal Navy. Soon marine biodiversity became key to understand the origins and evolution of living organisms, and there was an urgent need for easy access to marine biological resources. Then, marine biological stations (MBS) began to sprout, first in Europe and then in USA and other countries, mostly due to the efforts of single scientists or that of reduced groups of people. In many circumstances, marine stations were shelters providing visiting researchers access to the marine coastal bioresources during their teaching summer holidays. In all cases, they became centers allowing consolidating the three pillars of Biology; the evolution, the cell and the heredity theories. Scientific/technological advance found their opportunity in MBS with good biological specimens, model organisms, at hand. Mere descriptive taxonomy became comparative in the light of evolution theory and moved forward through microscopy, comparative anatomy/morphology and comparative embryology. Then research on marine biota became more physiological, to finally drive into the application of biochemical and molecular biology approaches, as perfectly reflected in the work of the Nobel prize winners working as visitors in marine stations. MBS also catalyzed genetic research during the rediscovery of Mendelian laws in the first quarter of the 20<sup>th</sup> century. Cellular processes became focus of research, and for instance a lot of our knowledge on fertilization stems from research on marine coastal organisms accessed in MBS. Now, organizations such as OECD or institutions such as the European Commission are discovering the power of Marine Biotechnology in the development of new products (pharmaceuticals, nutraceuticals, cosmetics, industrial products...) towards a cohesive economic growth worldwide. Much of such biotechnological knowledge is stemming from MBS.

Since P.J. Van Beneden opened the first marine station in Ostend 175 years ago, or in the 145 years of life of the oldest living ones in Roscoff and Naples, MBS have shown capacity to adapt to the changes in scientific-mainstreams, when not being the vanguard in such changes. In the era of "multiomics" and the "open-science-cloud" marine stations are still alive showing through their history adaptability and resilience. It is for this reason that, in times in which some institutions are facing strong cuts and even some are being closed, MBS need to learn from their history to take lessons into their future sustainability. Organization into a pan-European research infrastructure such as EMBRC-ERIC has been the move towards consolidation and progress for some of these stations, and within its long term sustainability assessment EMBRC-ERIC is writing the history of MBS as a coffee table book that should be published in 2019.

Acknowledgements: EU through H2020-INFRAIA-1-2016-2017 project Assemble+

Keywords: marine biological stations; history; evolution; cell theory; heredity; sustainability; marine biological resources; marine biotechnology. EMBRC-ERIC

## Short history of the Adriatic marine science: Croatian naturalists and their contributions

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Written documents on the scientific approach to the Adriatic Sea appeared in the 16th century. Since then several ascents and declines in research activities have been recognized. The middle of the 19th century, the investigations were carried out mostly by individual scientists who have set a firm basis for further research. The second half of the 19<sup>th</sup> century, and the period before the World War I can be qualified as the most fruitful period in the classical research of the Adriatic Sea. By that time, first permanent biological research stations were founded in the North Adriatic, several coastal cruises and offshore expeditions were organized and international collaboration in sea research was conferred. On the contrary, the period between the World War I and II, is considered as a decline in general recognition of the Adriatic Sea in spite of advances in some aspects of marine research. In the period after the World War II, a new boom in the Adriatic marine research occurred. Recent investigations are characterized by a large-scale international collaboration in multidisciplinary and interdisciplinary approaches. Previous research in the Adriatic basin resulted in several events important in the world marine sciences: the creation of a tidal theory, the description of some hundreds species new for science, the concept of marine benthic biocenology, the concept of the relativity of depth zonation, and others. Croatian naturalists have a great contribution in the research of the Adriatic Sea and at the same time had a significant contribution to the world marine science.

Keywords: marine science; Adriatic Sea; history; Croatian naturalists; contributions

## Marine data archeology: A heritage for future science

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Digitization of historical data is crucial to fill spatial and temporal gaps in datasets that are currently available to science. These datasets can give researchers new insights in the underlying processes that control the functioning of our ecosystems. Within the LifeWatch project a data archeology strategy was developed to identify, prioritize, digitize, quality control the data, and eventually to publish the dataset.

Since 2012 more than 100 historic biodiversity datasets created by or in close collaboration with Belgian marine scientists were identified and recovered. Here, we present the results of the digitization of the scientific papers on the Belgian Antarctic expedition (1897-1899) under the command of Adrien de Gerlache with the famous research vessel Belgica. During this two-year expedition more than 1,200 animal species and 500 plants were sampled and the results were published between 1901 and 1949 entitled '*Expédition antarctique belge. Résultats du voyage du S.Y. Belgica en 1897-1898-1899 sous le commandement de A. de Gerlache de Gomery*'. This dataset includes 2,082 records for 235 sampling stations in the Antarctic region. Data were digitized from 31 original expedition reports including 29 zoological and 2 botanical reports. Taxa belonged to 16 different phyla. The Arthropoda were the most abundant with 26.3% of observations (160 species), followed by the Ochrophyta (15.7%, 240 diatom species) and the Bryozoa (14.5%, 95 species). Most chordates belonged to the seals, penguins and other bird species. Within the phylum Arthropoda no less than 47 unique species were identified as insects (which is quite remarkable because researchers did not expect to find them in the cold climate of Antarctica). Also, during this expedition the Antarctic midge, *Belgica Antarctica*, was discovered making it the largest endemic insect of the continent. Six orders of insects were discovered of which the beetle species (Coleoptera) were most represented.

All these data are now assigned with a Digital Object Identifier (DOI) and are made available (open access) to the scientific community through the Integrated Marine Information System (IMIS) in 1 easy-to-access dataset.

Visit <http://www.lifewatch.be/en/marine-data-archeology> to check out more results.

Keywords: data archeology; historical datasets; marine; biodiversity; Belgica; Antarctic; expedition

## Transitional larval type of *Alcyonidium hirsutum* (Bryozoa, Gymnolaemata): From Van Beneden to the era of modern methods

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The XIX century is rightfully considered to be the golden age of natural sciences. That was the time when the major theories on the structure, development and evolution of living organisms appeared and many of them were based on comparative anatomical and embryological works. The earliest reports on bryozoan development date back to the mid-nineteenth century (Farre 1837; Nordmann 1839-1840; Hassall 1841, Reid 1845; Van Beneden 1845; Dalyell 1847, 1848). Major types of bryozoan larvae (cyphonautes, pseudocyphonautes, paracoronate and coronate larva) were described already at that time, although they were often mentioned as eggs, "gemmulae", or embryos.

The ctenostome genus *Alcyonidium* Lamouroux 1813 is unique among Bryozoa being comprised of the species with planktotrophic cyphonautes (*Alcyonidium albidum*, *A. mytili* sensu stricto Dalyell, 1848), species with lecitotrophic pseudocyphonautes (*A. duplex*), and paracoronate larva (*A. gelatinosum*, *A. hirsutum*, *A. mytili*, *A. polyoum*, *A. variegatum*). Thus, it is a valuable model for studying evolution of bryozoan larval types. Paracoronate larvae of *A. hirsutum* (former *Halodactyle vélu* Van Beneden, 1845) first mentioned as "oeufs" (eggs) in the 1845 paper of the famous Belgian zoologist Pierre-Joseph Van Beneden "*Recherches sur l'anatomie, la physiologie et le développement des Bryozoaires qui habitent la côte d'Ostende*". It could be considered as a transitional larval type showing characters of both, cyphonautes and coronate larvae. Van Beneden described the appearance of that larvae and presented several drawings (Pl. V, fig.3-8), showing some "cyphonautes-like" features like a cone-shaped body with convex episphere bordering by the corona on the lower edge and a flattened hyposphere. Later on, the development and larval structure in various oviparous and larviparous species of *Alcyonidium* were studied (Prouho 1892; Barrois 1877; Harmer 1887; Seeliger 1906; Zschiesche 1909; more recently – D'Hondt 1972, 1973, 1975, 1977, 1979, 1983; Cadman & Ryland 1996a,b; Gruhl 2008, 2009) providing data for comparison. Still, although being one of the first described *Alcyonidium* larva, nothing is known about the internal structure of the larva of *A.hirsutum*. To fill this gap we applied TEM, SEM and immunocytochemistry methods to reconstruct its anatomy, that also allowed to support an idea that non-feeding larvae originated many times throughout bryozoan evolution.

This study was performed using facilities the Educational and Research Station "Belomorskaja", White Sea. Financial support was provided by the Russian Science Foundation (grant № 18-14-00086).

Keywords: Zoology in XIX century; Pierre-Joseph van Beneden; Bryozoa; paracoronate larva; anatomy

## New findings on epipelagic copepods of the Colombian Pacific Ocean based on historical data: September 2003

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Based on data of September 2003, recent advances in the understanding of the copepod community in the Colombian Pacific Ocean (CPO) are presented, since these organisms are a key link between lower and higher trophic levels, have an important role in the carbon and nitrogen cycles, and some are bioindicators of changes in environmental conditions. Surface phytoplankton (chlorophyll-*a*) and zooplankton biomasses, as well as some abiotic variables were evaluated in twelve night and twelve daytime stations distributed throughout the CPO. Zooplankton samples were collected with a standard conic net (50 cm-opening, 363  $\mu\text{m}$ -mesh size). CTD data was taken to document thermohaline spatial differences.

Inverse relationships among copepods and phytoplankton and zooplankton biomass in several sampling stations could be explained by trophic relationships, among other causes. Copepod abundance and zooplankton biomass were more representative in intermediate waters (41.8% and 56.7%, respectively), suggesting a transitional area in their spatial distribution. On the contrary, phytoplankton biomass was higher in coastal waters (79.3%), as usually observed in such areas, where upwelling processes are frequent. The higher copepod night abundance (62.6%) could be related to their diel vertical migration, usually in order to avoid predation. Calanoida was the most abundant order (45.1%) with the genera (0.03-4.8%): *Acrocalanus*, *Calocalanus*, *Candacia*, *Canthocalanus*, *Centropages*, *Clausocalanus*, *Cosmocalanus*, *Euchaeta*, *Labidocera*, *Lucicutia*, *Nannocalanus*, *Paracalanus*, *Pleuromamma*, *Pontella*, *Pontellina*, *Rhincalanus*, *Subeucalanus*, *Temora*, and *Undinula*.

Nevertheless, *Oncaea* (Cyclopoida) (42.4%) showed the highest abundance and widest distribution, followed by *Corycaeus* (11.0%), *Sapphirina* 1.1%, *Copilia* 0.2%, and *Farranula* (0.1%) (Poecilostomatoida). *Microsetella* (0.1%) was the only representative of Harpacticoida. This taxonomic composition is analogous of that of September 2001 and 2002. *Oncaea* and *Corycaeus* were the most abundant by night (45.2% and 11.3% respectively). Moon phases influence was also observed, since copepods and zooplankton biomass (65.9%) were more abundant during the first quarter (53.9%), confirming that this phenomenon is produced in the CPO, like in other regions. The spatial distribution of the organisms could be influenced by currents. The effect of salinity was *greater* than temperature, perhaps due to the coastal-oceanic gradient of low to high salinity, inverse to temperature, which is a typical characteristic of normal environmental conditions in the CPO. These findings were supported by significant associations (PCA) among abiotic and biotic variables. Notwithstanding, it is advisable to include samplings in other months due to chronological changes in environmental conditions.

Keywords: *Copepoda*; *Oncaea*; zooplankton; phytoplankton; trophic relationships; light influence

## The deep-sea octocoral collections of the Telegraph Company “Det Store Nordiske” during 1871-1957 from Japanese waters

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The Pacific Ocean and the Far East including Japan were explored since the 18th century and scientists have described several marine organisms from this region. NHMD (previously ZMUC, Zoological Museum University of Copenhagen, Denmark) is known to have the famous deep sea Galathea expedition collection. They also have another well-known marine invertebrate collection, of Dr. Mortensen's Pacific Expedition in 1914 which includes several Japanese deep-sea octocorals. Both expeditions were conducted for scientific purposes. However, there also exist a unique collection donated by Det Store Nordiske before the scientific expeditions.

Det Store Nordiske Telegraf-Selskab A/S (The Great Northern Telegraph Company) was not performed by scientists but the Danish Underwater Telegraph Cable company established in 1869 at Copenhagen, Denmark. Previously described 13 type specimens of octocorals collected by Det Store Nordiske from the North West Pacific are deposited in Museum of Evolution, Uppsala University, Sweden.

To characterize Japanese deep water benthic fauna, we conducted a survey of unidentified Japanese octocorals in the collection of NHMD during 2012-2015 (Matsumoto 2014, 2015). The survey revealed a big contribution by Store Nordisk to the deep sea octocoral fauna around Japanese water during the years 1871 to 1957.

In the database of NHMD before the survey, there was a total of 107 octocoral specimens by the collectors of Det Store Nordiske, 75 from the North West Pacific, 3 tropical West Atlantic, 26 Indo-Pacific, 2 Mediterranean, and 1 unknown locality. According to our survey, total 128 specimens from the North West Pacific were counted and sorted in NHMD. As a result, the new species of Det Store Nordiske collection in NHMD was described and was named after the collector belonging to the company (Matsumoto & Ofwegen, 2015). In this manuscript, we are going to show a second species which was also found in misidentified material of the U.S. Albatross Expedition collection in the Smithsonian Natural History Museum, U.S.

Because of environmental changes, we can never collect again some species which could be collected 100 years. The historical collection in the museum of the university helps us to understand the past environment and fauna for the long term, such as more than 100 years' accumulation of human or natural impact.

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Keywords: deep water coral; Denmark; gorgonian; Octocorallia; North West Pacific



## Fifty-year changes of phytoplankton in the deep-water basin of the Black Sea

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During the period from 1970s to 1980s the Black Sea has been affected by intensive eutrophication, which led to drastic changes and regime shifts in ecosystems on the shelf and in the open waters. They were manifested in elevated values of chlorophyll a, biomass of phytoplankton, primary production, etc. The goal of the current research was to trace the long-term (1968–2017) dynamics of phytoplankton biomass and taxonomic composition in connection with changes of physical and chemical properties of environment.

Prominent changes occurred in the species composition of phytoplankton. During 50-year period the following taxons showed the decreasing trend: dinoflagellates *Protoperdinium spp.*, *Prorocentrum spp.*, *Gyrodinium spp.*, *Gymnodinium spp.*, *Ceratium fusus*, *C. tripos*, *Gonyalax spp.* and diatoms *Chaetoceros spp.*, *Thalassiosira anguste-lineata*, *Coscinodiscus spp.*, *Thalassionema frauenfeldii*. At the same time, coccolithophores *Emiliana huxleyi* and *Acanthoica quattrosipina*, diatoms *Proboscia alata* and *Pseudonitzschia spp.* showed an increasing trend.

The annual (average for warm part of year from May to October) depth integrated biomass has varied over a wide range from 1 to 46 g m<sup>-2</sup>. Eutrophication of the deep-water basin in the 1970-1980s created the favourable conditions for phytoplankton growth. The concentration of inorganic nitrogen in the deep cold intermediate layer (CIL) increased from 1.2 to 3.3 μM during the period from 1970s to mid-1980s. However, most of this nutrient stock was locked in the deep layers due to high stratification of the Black Sea waters. This potential for phytoplankton development was actualized during the cold climatic period from 1984 to 1996. The deep winter convection occurred during this period intensified the upward flow of biogenic elements into the photosynthetic zone. Thus, the cold climatic period acted as the immediate driver of a sharp increase of the total phytoplankton biomass and amount of diatoms and dinoflagellates by a factor of 6. Simultaneously the nitrogen-to-phosphorus ratio (N:P) in the CIL increased from 6:1 to 11:1 mitigating the limitation of the growth of phytoplankton by nitrogen. After 1996 the falling of concentration of inorganic nitrogen by 1.5 times and reduction of N:P to 9:1 led to decrease in the biomass of the both groups by 1.5-2 times. During the 50-year period a fourfold reduction in biomass of silicoflagellates was associated with a 30% decrease of the concentration of silicon. The increase in quantity of coccolithophores by 2 orders of magnitude was caused by 50% increase in concentration of phosphate. As a result, the taxonomic composition of phytoplankton changed. Before 1984, diatoms and dinoflagellates prevailed in the phytoplankton biomass, making 54% and 40%, respectively. After 1996, the corresponding contribution of diatoms, coccolithophores and dinoflagellates was 40%, 23% and 20%.

Keywords: long-term changes; phytoplankton; nutrients; climate change; Black Sea

## Climate-driven shifts of species ranges or just a bias? A case study of newly recorded molluskan species from the Barents Sea

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In recent years, there have been frequent reports of invertebrate species newly recorded from particular areas of the Northeastern Atlantic, and it has often been suggested that these are the result of changes in species ranges due to recent warming. These suggestions make three assumptions: 1) that we have a good knowledge of the fauna of these areas; 2) that new records of "southern" species are more frequent than new records of "northern" species; 3) that climate change is the only factor affecting species range. Publications, suggested climate-driven changes for marine invertebrates, report findings of a single or few species, therefore these suggestions remain unproved until they had not been tested on an unbiased entire dataset. These risks creating a fictional connection between climate change and changing species distribution, as well as risking overlooking other non-climatic processes in ecosystems. I tested these assumptions on published records of more than 30 benthic molluskan species which have been found alive for the first time in the Russian part of the Barents Sea since 2006.

Majority of records were made along the coast of the Kola Peninsula and adjacent waters. Some of the discussed species are warm-water species and may have extended their ranges northward in response to climate change. However, our baseline knowledge of the molluskan fauna of this area before 2006 is limited by the frequent lack of molluskan specialists to study the available material, by the frequent lack of detailed publication and by changes in sampling and processing methods. Also, while the main purpose of both past and present investigations of the Barents Sea has been to describe the general state of the bottom communities and quantitative distribution of benthos, accuracy of the assessment of species composition had almost never been tested. During the special study of the Russian museum collections I also found that almost none of materials collected during the older investigations are persisting now. "Southern" species are in fact not significantly commoner than new records of "northern" species as it was revealed by a series of chi-square tests. Also natural, non-climatic reasons are more likely be suggested as drivers in the case of reliably-observed range shifts.

Similar suggestions of climate-driven changes in distribution have been put forward for other Barents Sea benthic invertebrates; as mollusks have probably been better studied than these other groups, these suggestions should be treated with caution.

Keywords: *Gastropoda*; Mollusca; climate change; arctic; historical collections

## Metchnikovellids as basal microsporidia: Research history and perspectives

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The first metchnikovellid microsporidium was described in 1897 by Caullery and Mesnil as *Metchnikovella spionis*, a hyperparasite of the intestinal eugregarine *Polyrhabdina brasili* from the polychaete *Spio martinensis*. In the later studies of these scientists (Caullery, Mesnil, 1914, 1919), the description of this type species was improved and detailed; more species were discovered and the genera *Metchnikovella*, *Amphiamblys* and *Amphiacantha* were erected. Thus, the history of the metchnikovellid study has begun. Metchnikovellid microsporidia are hyperparasites of intestinal gregarines parasitising marine worms, mainly polychaetes. Based on the morphology of spores believed to be a primitive form of those in higher microsporidia, two types of sporogony and suggested lack of the merogonial proliferation in the life cycle, the metchnikovellids were regarded as a monotypic taxon affiliated with microsporidia (Vivier, 1965; Vivier and Schrével, 1973; Sprague, 1977; Sprague et al., 1992). Recently, the SSU rDNA phylogeny and phylogenomic analyses have confirmed this conclusion and demonstrated the basal position of metchnikovellids in the microsporidian tree (Simdyanov et al., 2009; Nasonova et al., 2015, 2016; Mikhailov et al., 2016). To the present time, about 30 species of metchnikovellids have been described. The genera are distinguished by the morphological characters of the cysts and the number of spores per cyst. Many species are known only from old descriptions and illustrations. Only eight species have been investigated using electron microscopy (Vivier and Schrével, 1973; Hildebrand, 1974; Desportes and Théodoridès, 1979; Ormières et al., 1981; Larsson, 2000; Larsson and Køie, 2006; Sokolova et al., 2013, 2014). The majority of metchnikovellids were found in different bays of the English Channel and the Mediterranean Sea shoreline of France (Caullery, Mesnil, 1914, 1919; Schereshevsky, 1924; Mackinnon, Ray 1931; Hildebrand, Vivier, 1971; Vivier, 1965, 1975; Vivier and Schrével, 1973; Hildebrand, 1974; Ormières et al., 1981). There were several findings of metchnikovellid microsporidia in the North Atlantic, the Hebrides, the North Sea, and the Baltic Sea (Caullery, Mesnil, 1914, 1919; Reichenow, 1932; Desportes, Théodoridès, 1978; Larsson, 2000; Larsson, Køie, 2006). They were also found near California, the Pacific Ocean (Stubblefield, 1955). A few hyperparasites were discovered in the Kola Bay, the Barents Sea (Awerinzew, 1908; Dogiel, 1922). During the last 30 years, several species have been recorded in the Kandalaksha Bay, the White Sea (Sokolova et al., 2013, 2014; Rotari et al., 2015; Paskerova et al., 2016). Such a mosaic distribution is thought to be accounted by technical difficulties in searching and studying these organisms due to their microscopic size, hyperparasitic mode of life and presumable sporadic occurrence in the environment. The natural diversity of metchnikovellids seems to be unrevealed. Long-term monitoring studies of the natural habitats, modern light and electron microscopy, molecular ecological approaches, phylogenetic and phylogenomic analyses are necessary for further revealing the diversity of metchnikovellids and better understanding their evolution and relationships with other microsporidia.

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Keywords: *metchnikovellidae*; microsporidia; hyperparasites; phylogeny; diversity; polychaetes; gregarines

## Quantification of benthic biodiversity and biomass in time, space and changes with season at an Antarctic site

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Climate change is increasingly emerging as one of the major threats to biodiversity, especially in the polar regions. The composition and distributions of marine assemblages are being altered directly and indirectly by rapid recent climate forcing. Of particular importance are those regions of the globe that are changing the fastest such as the polar coasts. Antarctic coastal benthic communities are considered to be especially climate sensitive due to their high regional heterogeneity and uniqueness (endemicity).

This study aims to quantify long term change (1998 -2015) in marine benthic biodiversity at a coastal Antarctic site and describe the first Antarctic seasonal study of shallow water biodiversity and biomass. Repeating and improving a protocol from 1998 all benthic organisms >3mm in size within 0.25m<sup>2</sup> quadrats were collected at 6m, 12m and 20m depths near Rothera Point, Adelaide Island, West Antarctic Peninsula. However, the current study additionally performed this during both the austral summer and winter, (of 2015) and at three different transects to gauge temporal and spatial variability.

Organisms were identified to the lowest possible taxonomic unit and their wet, dry and ash free dry masses obtained. We identified considerable reductions in biodiversity, particularly a loss of sessile organisms. The greatest change occurred at 12m where faunal density, richness and diversity declined significantly. Benthic community structure and biomass (measured as Ash Free Dry Mass) did not vary seasonally. The lack of significant seasonal difference in biodiversity and biomass suggest that benthic fauna are not strongly affected or are able to cope with the winter decrease in primary production. The reduction in shallow water biodiversity over time is likely to be caused by an increased frequency of iceberg disturbance (a knock on effect of fast ice losses). Ongoing climate change in the coming decades is likely to drive more ice scour at the poles, through both reduced fast ice allowing more movement of existing icebergs and retreating glaciers producing more icebergs.

Keywords: Antarctica; benthic; biodiversity; biomass; coastal shallows; depth; seasonality; Western Antarctic Peninsula

## Reconstructing Mediterranean historical seascapes through the analysis of archives of underwater photographs

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The assessment of historical shifts in marine ecosystems' structure and functioning needs recognition and inclusion of how anthropogenic activities altered marine biodiversity in the past (Manez et al. 2014). In particular, identification of effective management and restoration strategies requires a knowledge of historical trends of change (*historical marine ecology*; Lotze and Worm 2009), which, however, is limited. Time-series are often either too short to adequately cover long-term variations (Jackson 2001) or spatially fragmented and temporally scattered. To overcome this, a possible approach consists in the selection of sites of investigation for which historical data can be mined from archives of underwater photography. Such approach appears particularly suitable for the Mediterranean Sea, where either scientific or artistic underwater photography has a long tradition, dating back to the infancy of underwater photography at the end of the 1950s.

We investigated changes occurred in the composition of hard-bottom epibenthic communities in the Marine Protected Area (MPA) of Portofino (NW Mediterranean Sea) using underwater photographs dating back to the 1980s and stored in private archives or published in the grey literature, as well as new pictures taken *ad hoc* in the same localities of the historical sites. Since the original pictures were not taken for scientific purposes, a guideline was developed to standardize the extrapolation of semi-quantitative data. Based on their persistence, disappearance or temporal invariance, the different considered taxa were assigned to one of the three following categories: "winners" (e.g. invasive algae *Caulerpa cylindracea* and *Womersleyella setacea*; encrusting and massive sponges; octocorals *Paramuricea clavata* and *Corallium rubrum*), "losers" (e.g. erect algae; gorgonian *Eunicella cavolini*) and "changeless" (e.g. seagrass *Posidonia oceanica*; gorgonian *E. singularis*) (Baskin 1998).

The qualitative nature of our data did not allow the establishment of cause-effect relationships. However, our approach allowed us to interpret changes in the epibenthic community structure considering multiple co-occurring stress factors including fishing (and its restriction after marine protected area establishment), the occurrence of heatwaves and related mass-mortality events, biological invasions, eutrophication, sedimentation and turbidity produced by coastal activities, and diving impacts. We propose this approach as a reliable semi-quantitative method for reconstructing historical baselines and describing long-term change of marine benthic communities.

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Keywords: historical ecology; marine benthos; coralligenous; Mediterranean Sea

# SCIENCE IN THE NORTH SEA

## Predictive value of trait-based measures for benthic secondary production in the German North Sea

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Understanding the role of biodiversity for ecosystem functioning has become a central research theme in marine ecology. Benthic communities with a higher diversity have been suggested to operate more effectively, which could be quantifiable as a higher secondary production. However, there is no general ecological relationship between diversity and production, not only due to environmental influences, but also because of species-specific effects.

Functional diversity has been identified as the key to understanding the link between biodiversity and ecosystem functioning. We are taking a trait-based and large-scale observational approach to relate patterns in macrofaunal secondary production to functional diversity in the southern North Sea, where benthic macrofauna is confronted with many natural and anthropogenic stressors. Functional diversity is expressed in indices based on dissimilarities of species traits such as feeding type, environmental position, and larval development. Production is calculated with taxon-specific empirical productivity models.

Patterns of functional diversity were spatially more homogeneous than taxonomic diversity. A handful of species provided the majority of the secondary production. Spatially implicit regressions are used to analyze how secondary production is related to environmental factors and trait diversity. We explore further whether models are improved by including specific key traits potentially contributing to energy flow.

Knowledge on the explanatory value of trait composition for maintaining productivity in our system is needed to explore scenarios of anticipated changes in diversity.

Keywords: biodiversity; ecosystem functioning; functional diversity; macrozoobenthos; productivity map

## The molecular basis for positive health effects of sea spray on human lung cells

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The positive health effects of living in coastal areas have generally been attributed to psychological mechanisms. Recently, it has been suggested that sea spray aerosols cause beneficial health effects through interaction with the mTOR signaling pathway. Here, we provide molecular evidence to support this hypothesis. Using in-vitro experiments, we exposed human epithelial lung cells to extracts of natural sea spray aerosols sampled at the sea shore, sea spray aerosols generated in the laboratory, pure homoyessotoxin and a chemical mTOR inhibitor. We observed significant effects on the mTOR pathway in all exposed samples. Similar to the chemical mTOR inhibitor, we observed a downregulation of genes involved in the mTOR pathway for natural sea spray aerosols. Downregulation and inhibition of the mTOR pathway have been associated with positive health effects in numerous studies. Furthermore, we observed significant regulation of genes and pathways that are closely linked with mTOR most likely caused by the effects on the mTOR pathway. These genes and pathways include the new potential pharmaceutical target PCSK9 and the steroid biosynthesis. For all genes and pathways, the effects of the natural sea spray aerosol and the chemical mTOR pathway were highly similar. This suggests that natural sea spray aerosols contain molecules similar to the chemical mTOR inhibitor, at least in terms of effects, and highlight the potential of sea spray aerosols as new potential pharmaceutical leads. Overall, these results provide a substantial molecular evidence base for positive health effects of sea spray aerosols through the mTOR pathway in human long cell lines.

Keywords: sea spray; human health; RNA



## The development of the wrasse fishery along the Skagerrak coast

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During the last decade, the Skagerrak coast of Norway and Sweden has seen the development of a new fishery for cleaner wrasses. In contrast to most fisheries, wild caught wrasses are transported and released into salmon net pens for the biological control of salmon lice infestation. Catch for wrasses has increased dramatically in recent years; however, our knowledge on their biology and ecology is still limited. A major concern relies on the fact that the environmental conditions along the Skagerrak coast differ significantly from those experienced in the northern coast of Norway, where salmon farms for translocated wrasses are located. Moreover, recent studies have revealed differences in phenotypic traits as well as genetic structuring in the two main cleaner wrasses caught in Norway. Here, I will provide a general overview of the development of the wrasse fishery in the Skagerrak coast of Norway. I will also present recent findings on corkwing wrasse *Symphodus melops*, one of the main species used by the salmon industry, and discuss these advances in relation to adaptation of translocated fish to climate change.

Keywords: fishery; cleaner fish; translocations; corkwing wrasse; *Symphodus melops*

## Noise in the North Sea: How man-made underwater sound playbacks impact Norway lobster development

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Low-frequency sound levels (10 – 500Hz) in the oceans have increased by at least 100-fold globally over the last century, predominantly caused by increased commercial shipping. This has led to concern over potential impacts on marine fauna and international legislation e.g. Marine Strategy Framework Directive; requiring EU member states to ensure that anthropogenic (man-made) noise levels in the oceans do not adversely affect the environment.

Tolerance to stressors such as underwater noise in early life history may be particularly important to an individual's fitness; planktonic larval phases such as the zoeal stages I, II and III (ZI, ZII and ZIII) of the commercially important Norwegian Lobster *Nephrops norvegicus* (L.) have been suggested to be a bottleneck for reproductive success and recruitment to the adult population.

We conducted a controlled laboratory experiment to investigate whether and how ship noise, played back throughout the early life stages of *N. norvegicus* affects larval development. Three sound treatment groups, emulating different levels of shipping activity were compared:

- 'Busy' treatment consisting of frequent ship noise with regular timings.
- 'Occasional' treatment consisting of less frequent ship noise at randomized intervals.
- 'Ambient' treatment consisting of constant ambient noise (Control).

At ZI, neither treatment affected development time to the next stage in comparison to the control. However, the duration of ZII was significantly longer in the 'Busy' treatment than the other two treatments. The duration of ZIII was significantly longer in the 'Occasional' group than the other two treatments. Both 'Busy' and 'Occasional' groups also showed significant (33% and 46% respectively) reductions in escape response stamina compared to the control.

Our results are the first to our knowledge to demonstrate that anthropogenic noise has the potential to prolong the larval phase *and* reduce anti-predator escape response stamina of decapod crustaceans. In the wild this would likely increase the risk of predation, leading to reduced recruitment to the adult population. The fact that ship noise playbacks only affected the duration of the later larval stages of *N. norvegicus* suggests that longer-term cumulative exposure is required before developmental delays occur. Alternatively, the later larval stages could be particularly sensitive to ship noise playbacks. The significantly longer duration of larval ZIII in the 'Occasional' treatment compared to the 'Busy' treatment suggests that the regular timing of the ship noise exposure allowed the larvae to develop tolerance to these conditions, whereas the random timings of the noise exposure in the 'Occasional' group did not allow tolerance buildup to the same degree. This has implications for methods used in future noise experiments and may highlight a potential for studies to underestimate the likely effects of noise if they utilize a regular exposure regime.

Our findings underline the need to investigate the responses of invertebrate larvae, including crustaceans, to noise. It is not clear (and rather unlikely) that results can be reliably extrapolated between species, so a wider range of ecologically/commercially important invertebrate species deserve further study.

### Acknowledgements

Work was conducted at St Abbs Marine Station, Scotland. Thanks to Sam Freeman for practical assistance.

Keywords: marine; stressor; noise; sound; anthropogenic; development; nephrops; crustacean; larvae; invertebrate

## Antibiotic resistance of *Vibrio* spp. isolated from German North and Baltic Sea coastal waters and sediments

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*Vibrio* spp. are ubiquitous bacteria in estuarine and sea water environments. Within this genus 12 species appeared to be **human pathogenic**, in particular *V. parahaemolyticus*, *V. vulnificus* and *V. cholerae*. They can cause gastroenteritis or wound infections (sometimes followed by septicemia). In the case of gastroenteritis, when antibiotic treatment is clinically indicated, means of choice are Doxycyclin (class of antibiotics: Tetracycline) or Ciprofloxacin (class of antibiotics: Quinolone). *V. vulnificus*-infections, although rather rarely seen, but when often with severe outcomes, are treated with Cephalosporine (class of antibiotics:  $\beta$ -Lactamases) or Doxycyclin (Alter et al. 2011).

Today a variety of different classes of antibiotics based on their mechanisms of action are known (van Hoek et al. 2011). But the extensive application of antibiotics in human and veterinary medicine as well as in agriculture have impacted bacterial communities and resulted in various resistances to the antibiotics (which are genetically controlled by **antibiotic resistance genes** (ARG)). Thus the emerging of ARGs, inter alia in aquatic environments, is becoming an increasing worldwide concern (Zhang et al. 2009).

In Germany severe ***Vibrio*-related human infections** after contact with sea water are known since 1994. Ever since, outbreaks of *Vibrio*-infections have been reported for the Baltic Sea coast following summer heat waves. For the more saline waters of the North Sea, only single cases of *Vibrio*-infections have been reported in the recent past. Concern is growing that *Vibrio* infections may become an emerging disease in Northern European coastal waters particularly with regard to **climate change** (Baker-Austin et al. 2013). Consequently, it is of utmost interest to find out whether environmental isolates of *Vibrio* spp. exhibit antibiotic resistances in order to provide optimal targeted treatment of *Vibrio*-infections.

The occurrence of antibiotic resistance in human pathogenic *Vibrio* spp. (in particular *V. parahaemolyticus*, *V. vulnificus*, *V. cholerae*) with regard to clinical isolates is already known (e.g. through the formation of  **$\beta$ -Lactamases**) (Obaidat et al. 2017). Our current study examines if *Vibrio* spp. strains of environmental samples from the German North and Baltic Sea coastline also exhibit antibiotic resistances against commonly used antibiotics like **Penicilline, Cephalosporine and Carbapeneme**. In order to investigate the spatial and seasonal pattern of ARGs of *V. parahaemolyticus*, *V. vulnificus* and *V. cholerae* a monitoring study was carried out at bathing sites along the German North and Baltic Sea coast. Thereby water and sediment samples were taken monthly at 7 sites in total over a 1-year period. Samples were analysed with culture-dependent and molecular methods for potentially pathogenic *Vibrio* spp. ARGs were determined by **multiplex real-time PCR** for all isolates.

Using the data provided in this study, conclusions may be drawn concerning the occurrence and the distribution of already existing antibiotic resistances in the aquatic environment and the **bathing sites** of North and Baltic Sea, respectively.

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Keywords: *V. parahaemolyticus*; *V. vulnificus*; *V. cholerae*; antibiotic resistant genes; human infections;  $\beta$ -lactamases; multiplex real-time PCR; bathing sites

## A meta-analysis of isotopic compositions of North Sea marine mammals

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For over a decade, the North Sea has been undergoing significant changes due to global changes, global warming and fishing. We conducted meta-analyses on marine mammals sampled in the North Sea to test the potential antropogenic impact on feeding behaviour of grey seals, harbour seals and harbour porpoises. Data included  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values measured in blood cells and muscles from the three species. SIBER, an isotopic niche quantification approach, is used to highlight potential dietary similarity and thus competition between marine mammal species. Harbour seals sampled in Germany showed the highest  $\delta^{15}\text{N}$  values, reflecting a trophic position at the top of the food web, alongside grey seals. In contrast, harbour porpoises sampled from Germany displayed the lowest trophic position. The ellipse overlapping between German harbour and grey seals was very important, showing similarity in, and therefore potential competition for, food sources. On the other hand, the harbour seal and the harbour porpoise of Germany displayed extended ellipse size compared to the grey seal. This may be due to a more diverse diet and, perhaps, a more opportunistic foraging behaviour than grey seals. Surprisingly, another group of grey seals sampled at Isle of May, Scotland displayed lower  $\delta^{15}\text{N}$  values and a very small ellipse size compared to grey seals from Germany, presumably being even more selective in their prey choice. Nevertheless, comparing the trophic position of the groups of grey seals requires caution as the isotopic baseline differed between the two sampling areas. This study allowed the determination of the competition, the spatial variations and the trophic niches of marine mammals in the North Sea and will, at the end, evaluate the effects of the changes in the North Sea on the ecology of marine mammals.

Keywords: marine mammals; North Sea; stable isotopes

## Benthic production and energy export from man-made structures to softbottoms: Does it matter?

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Over the last decade, the installation and operation of extensive offshore wind farms led to a substantial increase in artificial substrates in the North Sea. Man-made structures (MMS) such as wind turbines, oil and gas rigs represent additional hard-substrate habitats in the areas of the North Sea that are predominantly characterized by soft sediments.

Research on large offshore structures has identified a suite of unique effects ranging from biodiversity changes with repercussions on local ecosystem functioning to the provision of habitat for fouling communities, acting as stepping stones also for non-native species. Consequently, MMS might induce structural, functional and process-driven changes over various spatial and temporal scales, that are different from those expected for natural soft-bottom benthic systems. However, our current understanding of how ecological functioning might be modified by the addition of these MMSs is still scarce.

Many ecosystem goods and services of the North Sea such as long-term carbon storage and natural resources (e.g. for fish, birds, mammals and finally humans) are intimately linked to the benthic system. Benthic invertebrates form the major food source for many commercially exploited fish species and thus the production (i.e. species energy that is turned into biomass) of benthic communities is of direct relevance for the food provisioning ecosystem service.

In this study, production was calculated based on species populations as a quantification of energy flow and trophic interactions. The obtained results may thus provide clear signals for status and possible responses of populations and entire ecosystems to the introduction of MMS. The analysis included different datasets from various monitoring programmes of offshore wind farms and oil and gas rigs (i.e. the production and biomass of fouling communities and of natural soft-bottom community) from the Southern North Sea over several years. We analysed production changes due to environmental parameters and the presence of the structures in a meta-analysis. The analysis revealed clear modifications in the upper parts of MMSs, where the highest production values and potential biomass export to soft bottoms were detected. The outcome may thus represent a first step to disentangle the potential effects of additional biomass discharge from MMS on the ecological functioning of benthic systems.

Keywords: macrobenthos; man-made structures-MMS; offshore wind farms; ecological functioning; secondary production; energy flow changes

## Monitoring phytoplankton dynamics in the Belgian continental zone using a Cytosense flowcytometer

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Phytoplankton are responsible for roughly 50% of global primary production. Some species are capable of forming harmful algal blooms (HABs), with important ecological and human health impacts. Flow cytometry (FCM) allows studying phytoplankton dynamics at high spatial and temporal resolution and can be an important tool for the early detection of harmful species. Since 2016, a Cytosense FCM is used onboard RV Simon Stevin to measure phytoplankton size, shape and fluorescence characteristics in the Belgian Continental Zone (BCZ), in an automated and semi-continuous way (30-60 minutes between samples). Here, we report on data generated in 2016 within LifeWatch, a European infrastructure for biodiversity and ecosystem research. FCM phytoplankton size, shape and fluorescence characteristics were recorded at multiple stations along a west-east and onshore-offshore gradient. Based on a total of 55 FCM parameters, phytoplankton functional groups were defined using Easyclus software (Thomas Rutten projects) and their biomass was calculated. Bayesian network models (BNM) were used to analyse *Phaeocystis* bloom intensity, phytoplankton size class distribution, biomass and diversity data, and examine the relationship with different abiotic and biotic environmental parameters. We found that nanophytoplankton was highest throughout the year in both number and biomass for all stations. Picophytoplankton were more abundant in western stations and stations associated with low turbidity. The time series data, also revealed an intense *Phaeocystis* bloom in spring (March) and a second small bloom at the end of summer (September) near the outflow of the Scheldt estuary, a feature not yet reported from the BCZ. BNM revealed an inverse correlation between total dissolved nitrogen and bloom magnitude. There was a negative association between the sum of nitrate and nitrite and phytoplankton diversity. Overall, phytoplankton diversity, biomass and total zooplankton were higher near the outflow of the Scheldt estuary. This FCM dataset of the BCZ provides the opportunity to study short and long term trends in phytoplankton community structure and abundance, with high spatial and temporal resolution, which enables the detection of small, local changes in the phytoplankton community (e.g. a second *Phaeocystis* bloom). This data will be valuable for studying the effects of pollution, eutrophication and climate change over time.

Keywords: Cytosense; phytoplankton; time series; Bayesian network models; Belgian continental zone

## Habitat impacts by beam and pulse trawling in the southern North Sea

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The passage of a bottom trawl causes incision into the seabed sediments. This trawl penetration is followed by sediment reworking, mixing and mobilisation. Trawl penetration depth has also been associated with benthic mortality rates, and is suggested as a cost-effective alternative to estimate benthic habitat impacts. We will present two field experiments to study the seabed disturbance caused by commercial tickler-chain trawls and commercial pulse trawls using a combination of observational and modelling approaches. Both experiments compared flatfish-directed bottom trawls where mechanical disturbance using tickler chains was replaced by electrical disturbance using electrodes. One field trial took place in a shallow coastal-zone area (Voordelta) using a 4 m beam with trawl shoes to open net (Depestele *et al.*, 2016). The second field trial was located in the deeper offshore area of the Frisian Front, and compared 12 m trawls which were kept open by a wing-shaped foil instead of the conventional cylindrical beam with two trawl shoes ('SumWing' trawl versus 'PulseWing' trawl).

Numerical modelling has shown in both studies that the gear components of tickler-chain trawls penetrated deeper into the seabed in contrast to pulse trawls, whereas there was no difference in the quantity of sediment mobilised in the wake of these two gears. Bathymetrical measurements using a multi-beam echo sounder (MBES) confirmed that the relic tickler-chain trawl tracks were consistently deeper than after the passage of a pulse trawl. In addition, the Sediment Profile Imaging (SPI) analysis in the Frisian Front study has shown that beam trawls homogenised the sediment deeper, flattened the seabed topography more and removed the oxidised layer more than pulse trawls do. Particle size analysis using box corer samples suggested that pulse trawling only caused coarsening of the top layers (winnowing effect), while tickler-chain trawls also injected finer particles into the deeper sediment layers. SPI analysis showed that the reduced pulse trawling impacts allowed a faster re-establishment of the oxidised layer and micro-topography in contrast to tickler-chain trawling. The lower impact of the pulse trawl is mainly due to the replacement of tickler chains by electrodes. Since the mortality rate imposed by a bottom trawl is proportional to the penetration depth of the gear, we infer that the mortality rate imposed by mechanical disturbance of the pulse trawl is reduced by a similar proportion.

Further work comparing the mechanical, electrical, chemical and biological effects of gears on varying substrates, habitats and hydrographic conditions and associated effects on seabed status and functions will build a more integrated view of gear effects on the seabed overall.

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Keywords: benthic habitat; demersal fisheries; ecosystem effects; fishing impacts; mechanical disturbance; seabed sediments; trawling

## Response of zooplankton dynamics to multiple stressors in the North Sea

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Marine ecosystems are increasingly experiencing multiple disturbances as climatic change leads to changes in sea water temperature, salinity, and pH, while increased nutrient concentration and pollutants are important chemical stressors resulting from human activities. There is still a lack of quantitative data and understanding on how these chemical stressors and stressors resulting from climate change interact in marine ecosystems. In particular, it should be taken into account that physical stressors resulting from climate change can affect contaminant exposure and toxic effects and vice versa. Our study investigated the relative contribution of various environmental drivers, including nutrients and pollutants, to density and diversity dynamics of the zooplankton community in the Belgian part of the North Sea (BPNS).

We applied multimodel inference on generalized additive models to quantify the relative contribution of chlorophyll a, temperature, nutrients, salinity and anthropogenic chemicals (i.e. polychlorinated biphenyls and polycyclic aromatic hydrocarbons) to the dynamics of calanoid copepod species (Copepoda, Calanoida) in the Belgian part of the North Sea. Six calanoid copepod species reaching high abundances in the BPNS were selected, namely *Temora longicornis*, *Acartia clausi*, *Centropages hamatus*, *Paracalanus parvus*, *Pseudocalanus elongatus* and *Pseudodiaptomus marinus*. Temperature was the only predictor consistently showing a high importance in all models predicting the abundances of the selected copepod species. The relative contribution of other predictors was species-dependent. Anthropogenic chemicals were important predictors for three out of six species (*T. longicornis*, *A. clausi* and *P. marinus*) indicating that chemical mixtures at low concentrations should not be left unattended when performing risk assessments in a natural environment.

Keywords: multiple stressors; anthropogenic chemicals; North Sea; zooplankton; multimodel inference



## Are squid embryos affected by man-made underwater sound?

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Anthropogenic noise has become a pervasive pollutant in today's oceans and there is now clear evidence that such noise can adversely affect the physiology, morphology, behaviour and survival of marine species. To allow the evaluation of ecosystemic responses to this marine stressor, the type of responses and their magnitudes need to be understood for a wide range of species from different trophic levels. Squids are important components in marine food webs and transfer substantial biomass between pelagic and coastal ecosystems. The effects of noise on squid embryos and potential carry-over effects onto the paralarvae are unknown, to the best of our knowledge, for any cephalopod species. Squids attach their egg strands to physical structures and the embryos are thus unable to move away from stressors during their development. Early life stages are more vulnerable to stressors than the more robust adults of most sessile and mobile species, presenting critical population bottlenecks. It is therefore imperative to consider these stages in marine stressor studies, including noise, if the consequences are to be understood on a population (and ecosystem) level. Our study aims to address the above gap of knowledge, and to generate scientific evidence for informing policy for Scottish/UK and EU environmental legislation.

We tested the hypotheses that chronic exposure of squid embryos (*Loligo* spp.) to ship noise playbacks causes (i) prolonged development time, delayed organogenesis, reduced size of egg strands, egg capsules- and dorsal larval mantle length, (ii) embryonal and larval morphological abnormalities, premature hatching, and reduced survival, (iii) metabolic suppression (D-Glucose, total protein and total phospholipid content of eggs) and (iv) structural damage of sensory epithelia and statolith malformation of freshly hatched larvae. Recently-spawned egg clusters laid onto fishers' ropes (water depth 15-35m) from St Abbs and Eyemouth Voluntary Reserve (North Sea) were transferred to St Abbs Marine Station. Individual egg strands were kept in 8 acoustically transparent 25L plastic bags with constant UV sterilised seawater supply, from a temperature controlled, aerated sump tank. Water parameters in each bag were kept constant ( $T=14\pm 0.5^{\circ}\text{C}$ , salinity  $34\pm 0.20$ ,  $\text{DO}>90\%$ ). Bags in each treatment were held in 1000L water baths and exposed to either 6 hrs of ship noise playback (2 x 3hrs with 2 hrs silence in-between), or to a silent control over 8 hrs, throughout embryonic development (30 days) until the last day of hatching (day 44). Bags were checked hourly, and paralarvae were removed from the experimental bags immediately. Exposure to ship noise playbacks significantly affected squid embryo development, resulting in altered physiology, both premature and delayed hatching, reduced survival, and morphological deformities, compared to the control. The results highlight the importance of considering marine invertebrates when evaluating the effects of anthropogenic noise on marine fauna and their early life history stages. A follow-up field-study is underway.

**Acknowledgements:** Work was conducted at St Abbs Marine Station, a private charity on the Scottish East coast. Funding was received from the Marine Alliance for Science and Technology for Scotland. The help of numerous volunteers is greatly acknowledged.

Keywords: marine; stressor; noise; invertebrate; loligo; anthropogenic; development; larvae

## Deep-sea bivalve robust to long-term experimental ocean acidification combined to particle availability

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**Background:** The ocean is acidifying and coastal systems such as the Norwegian fjords are under strong local human pressure. For instance, the discharge of mine tailings and aquaculture in fjords could result in particle overload, which may affect the life of filter-feeders. Deep-sea coral reefs are present in some fjords at depths ranging from 40 to 6000m. These ecosystems are emblematic of the richness of cold and North Atlantic waters but are facing possible under-saturation with respect to aragonite by the end of the century. *Acesta excavata* is a bivalve inhabiting the reefs and one of the three species building the reef. Like for most deep-sea organisms, the literature on its physiology is scarce, and the abilities of such animals - living in environments harboring little variation - to cope with future environmental changes is supposedly low. Ocean acidification on bivalve has mostly been shown to induce metabolic suppression, with a potential to recover control metabolic performances when the food sources are increased (e.g. Thomsen et al. 2013 in *Global Change Biology* 19(4)).

**Methods:** In this crossed design, we looked at the effect of 1) seawater acidification (-0.4 pH units) combined to 2) decreased (-P) and increased (+P) particle load (>40µm). The animals were exposed to the six crossed treatments (Control and Low pH x Control particles, +P and -P) for five months. The seawater used was from natural habitats. It was filtered out of >40µm particles in the decreased treatment, and filters were re-suspended in the increased particle load treatment.

We expected the seawater acidification to impact the animal physiology negatively and hence, a decreased particle load to be limiting to the animal abilities to cope with seawater acidification, contrary to an increase in particle load.

**Results:** We however could not validate our hypothesis, since we observed no significant effect of pH on the ecophysiology of the mussel (mortality, calcified growth, respiration, acid-base balance). The diet had a slight effect with decreasing the lysosome integrity from 80% of the cells in the control to 50% in the +P treatment. The +P treatment also yielded a difference in the buffering capacity of the coelomic fluid. From these results, we can conclude *Acesta excavata* is apparently quite robust to the changes of pH it experienced on the time-scale of this experiment, even with limited potential food particles. However, an increase in particle load seemed to be a potential stressor to this animal and solicits further investigation. The diet of these mussels is only partially described (filtration rates on artificial feeds) and more information on its natural diet is needed in order to understand how this bivalve is able to not display the expected signs of metabolic suppression/compensation in facing ocean acidification.

Analyses of tissue for gonad index, fatty acid composition, total lipids as well as stress markers are ongoing.

**Keywords:** Coral ecosystems; Ecophysiology; Global change; bivalves; ocean acidification

## Environmental changes and the condition of Downs herring in Belgian marine waters: New insights based on historical data

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Atlantic herring (*Clupea harengus*) are found in the northern part of the Atlantic Ocean and have been one of the most important fish species on European markets since the middle ages. Based on the location of their spawning grounds different spatial components were identified in the North Sea herring population. In this research, we focused on the Downs herring that migrate to the area of the Flemish Banks in the Southern Bight of the North Sea for spawning in the beginning of November. After spawning, these herring stay a few months in Belgian waters before heading back to the foraging grounds in central parts of the North Sea (Lescauwaet et al. 2013). Gustave Gilson and Charles Gilis collected data about individual fish characteristics (length, weight, vertebrae number, age...) of a subset of the landings in Belgium from 1942 until 1950. This unique set of data, containing information of more than 6000 individual herring, was digitized by VLIZ (Lescauwaet et al. 2018). The aim of this study was to infer trends of individual fish characteristics between 1942 and 1950 and to assess whether these trends could be related to environmental drivers such as long-term climatic oscillations and temperature anomalies. To do so, we made use of regression-based techniques as described in Zuur et al. (2009). These models were assessed based on their model fit and residual diagnostics. We found that long-term climatic oscillations such as the Atlantic Multidecadal Oscillation ( $p < 0.001$ ) and monthly temperature anomalies ( $p < 0.001$ ) explained patterns in the condition of the herring. We found that herring caught between 1945 and 1948 were in better condition ( $p < 0.001$ ) than in other years, but did not differ in the amount of vertebrae. Our results add new knowledge about the variability in the Downs herring as well as the environmental drivers influencing this variability in the Southern Bight of the North Sea. This is of vital importance in the context of sustainable fisheries management.

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Keywords: data science; fish characteristics; environment

## Filling gaps in knowledge of North Sea benthic biodiversity: Identifying priority areas for conservation

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The North Sea is one of the best-studied marine areas in the world, yet serious gaps remain in the knowledge – and therefore also the protection – of its benthic biodiversity. Although the current network of marine protected areas (MPAs) covers roughly 22% of the North Sea, most of these MPAs are designed to target only pelagic species and birds, and benthic protection is particularly lacking in offshore areas. We carried out two research cruises, in 2016 and 2017, with the aim of helping to fill those information gaps, by documenting benthic habitats and communities in areas that had previously been identified as being of ecological importance, but from which data on benthos were lacking. Over a total of 16 weeks, we surveyed 25 areas in the waters of five countries (Denmark, Germany, Netherlands, Norway, and the United Kingdom), using a combination of: visual sampling via a remotely operated vehicle (ROV) and filming by professional SCUBA divers; acoustic seafloor mapping with a multibeam echosounder; and benthic grab sampling. Roughly 1400 taxa were identified (with more than 900 to species level), from depths ranging from 8 to 460 m. We present the main findings of these surveys, with an emphasis of the distribution and abundance of key community types of ecological interest, including biogenic reefs, gorgonian gardens, deep-sea sponge aggregations, sea pen and burrowing megafauna communities, pockmarks and worm aggregations. We also highlight areas of particular importance for threatened species and habitats (such as *Arctica islandica* and *Sabellaria spinulosa*), vulnerable marine ecosystem (VME) indicator species (such as *Virgularia mirabilis* and *Isidella lofotensis*), and commercial species. These results are used as the basis for specific management and conservation proposals for outstanding areas, based on the occurrence of features that have been prioritised for protection under national and European legislation, and/or relevant international conventions.

Keywords: benthic communities; biodiversity; conservation; management; MPAs; North Sea; threatened species; threatened habitats; VMEs

## Benthic functional diversity along small scale natural sediment gradients: Do functional aspects vary synchronously with species composition?

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Benthic macrofauna in the North Sea is subjected to a wide variety of anthropogenic stressors, which have a significant impact on community composition. In order to understand how these communities react to anthropogenic influences, the effect of natural environmental variation, such as temperature, salinity, or sediment characteristics, must first be understood. It is generally known that natural variation causes differences in the classical biological measures, such as the species diversity of benthic communities, however there is a paucity of studies regarding the response of functional diversity. Due to the tight linkage of functional diversity to ecosystem processes, it is important to understand these functional aspects of community diversity for understanding changes in ecological processes as a whole, and ultimately the effects on vital ecosystem services and goods.

This study determined changes in functional diversity of benthic macrofaunal communities along natural sediment gradients on small spatial scales (i.e. ~5 km). Soft-bottom assemblages including infauna and epifauna in the Sylt outer reef area of the North Sea were examined, with functional diversity being based on functional traits. Changes in functional diversity are compared to species diversity and relationships present are discussed. For the first time, this study examines if there are functional changes along sediment gradients on such a small scale. The results thus deliver valuable insight on the potential effects of community changes on ecosystem functioning and process-driven changes in assemblages. Further, the outcomes provide an important framework for ecological monitoring and impact assessments for future North Sea projects.

Keywords: functional diversity; biodiversity; benthic assemblages; environmental gradient; sediment

## The walrus (*Odobenus rosmarus*): A distinctive member of the Pleistocene megafauna in Belgium

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The southern North Sea is one of the most productive Pleistocene fossil-bearing localities worldwide, including megafauna such as woolly mammoth, steppe bison and giant deer. Historically, the majority of the bone material has been collected accidentally by bottom trawlers who sold or donated it to museums and private collectors. In 2017 and 2018, three scientific campaigns were conducted to the Scheur, a site in a navigation channel off the coast of the Zeebrugge harbor (Belgium). The collected fossils could be assigned to glacial and interglacial stages and to both marine and terrestrial Late Pleistocene faunas. In particular, a high amount of bones and bone fragments of juvenile and adult walrus (the modern *Odobenus rosmarus*) were recovered. The exceptionally good preservation of these fossils suggests lack of secondary transport, indicating an on-shore colony where walrus remains could accumulate over a longer period. Since these fossils were collected by beam trawling, the finds lack a precise stratigraphic context and no age determination has been performed on the bones yet. However, previous studies on similar findings of Late Pleistocene walrus in the Netherlands offshore area revealed age estimates of < 50 ka. This young age seems implausible since because at that time, terrestrial conditions prevailed in the southern North Sea. As the modern walrus is a cold-adapted species occurring in arctic and sub-arctic climate regions, an occupation of the Belgian palaeo-shoreline, which only occurs during interglacials, seems unlikely. Recently however, palaeo-landscape reconstructions of the Belgian Continental Shelf demonstrated that a regional lag in sea level high-stand occurred during the Last Interglacial (Eemian). This lag appears to be caused by post-glacial subsidence of a glacio-isostatic forebulge between East Anglia and Belgium. As such, the land masses might have continued to 'sink' simultaneously with the Last Glacial sea level fall (Weichselian Early Glacial), enabling prolonged marine to near-coastal conditions on the Belgian Continental Shelf while temperatures already deteriorated towards glacial values. This could have resulted in favorable conditions for walrus colonies along the Belgian palaeo-shoreline. Investigations of deep sediment cores that will be taken near the Scheur site in the summer of 2018 will reveal further information about the landscape in this period and whether this would indeed have been a suitable habitat for Pleistocene walruses.

Keywords: southern North Sea; palaeontology; palaeolandscape; marine mammal

## Prevalence of *Vibrio parahaemolyticus*, *V. cholerae* and *V. vulnificus* in the German North and Baltic Sea coastal waters

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*Vibrio* is a genus of facultative anaerobe Gram negative bacilli, which are medium to highly halophile and occur naturally in **marine environments**. Several species of *Vibrio* are **pathogens** and associated with gastroenteritis, wound infections and septicemia. For the Baltic Sea outbreaks of *Vibrio*-related wound infections have been reported following hot summer months whereas for the more saline waters of the North Sea, only single cases of *Vibrio*-related wound infections have been reported up to now (Huehn et al. 2014; Breidenbach & Frank 2012). Despite growing concern that ***Vibrio* infections** may increase in Northern European coastal waters due to rising sea surface temperatures in the course of climate change, there is only insufficient knowledge of the ecology of *Vibrio* and their **health risk** potential in these regions, however.

Therefore, a monitoring study was carried out at bathing sites along the **German North and Baltic Sea** coast and within the Ems estuary. Thereby water and sediment samples were taken monthly at 7 sites in total over a 1-year period. Because vibrios seem to be highly variable in habitat preference (Schmidt et al., 2014) sampling sites were further chosen in various water body types according to the European Water Framework Directive to be able to compare *Vibrio* prevalence in different habitats.

Samples were analysed with culture-dependent as well as with molecular methods like **qPCR** for potentially pathogenic *Vibrio spp.* in the context of biotic and physico-chemical parameters in order to determine the driving factors governing their occurrence and distribution.

Thus, the present study aims to give a contribute of knowledge on the prevalence of ***V. parahaemolyticus*, *V. cholerae* and *V. vulnificus*** in different areas of the German North and Baltic Sea coastal waters in relation to **driving factors** governing their occurrence and **distribution**.

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Keywords: marine environments; pathogens; vibrio infections; health risk; German North & Baltic Sea; qPCR; *V. parahaemolyticus*; *V. cholerae*; *V. vulnificus*; distribution

## Measuring the ‘shadow’ effect of an artificial structure on benthic communities in the Southern North Sea

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Artificial structures in the North Sea, such as oil and gas extraction platforms, provide a solid substrate for sessile epifauna in areas which are characterized by soft sediment habitats. This epifauna mainly consist of filter-feeders and may reach up to 500-fold the biomass found in the surrounding environment. These filter-feeders can alter the nutrient composition in the overlying water column by depleting organic matter and enriching it by producing faeces and nutrients. In addition, hydrodynamics in the wake of the platform are altered by the structure itself causing a change in sedimentological characteristics. So far it is unknown to which extent both the biogeochemical as physical effects influence the surrounding benthic community composition in the long-term. Epifauna communities on artificial structures have been shown to change in composition even after a long time span, nevertheless, the effects of this epifauna on the environment were only investigated for short-term periods.

This study assesses the effects of an >40 years old offshore gas platform on the species composition in the wake of the platform. The species composition and a set of biotic factors of the sediment were assessed up to 600m from the platform along four transects in perpendicular directions. The benthic species were identified by both morphological and molecular approaches. The molecular approach was able to recover on average three times more taxonomic families compared to the morphological approach. Whereas the morphological approach was restricted to macrofauna solely, the molecular approach was able to detect many meiofaunal families. Both approaches revealed small differences in species composition closer to the platform. These differences were mainly due to sedimentological changes, and in particular changes in organic matter contents. This study found no evidence for far reaching effects on the surrounding benthic community composition.

Keywords: artificial structures; metabarcoding; benthic ecology; epifauna; North Sea; decommissioning



## Blue carbon of shellfish beds: Understanding the vaults of biogenic reefs

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Shellfish beds provide ecosystem services, from habitat provision for benthic organisms to benthopelagic coupling to commercially important extractive resources. However, shellfish beds are also some of the most threatened marine habitats, historically having been targeted by fisheries, subject to disease spread and at risk from changing marine environments and marine development. The Blue Carbon in the NE Atlantic MPA network is poorly known<sup>1</sup> but shellfish beds within them have the potential to be substantial carbon stores<sup>2,3</sup> on a par with mangroves, seagrasses and saltmarshes<sup>4</sup>. The present study aims to quantify the carbon storage potential of a number of native shellfish species; European flat oysters (*O. edulis*), horse mussels (*Modiolus modiolus*) and blue mussels (*M. edulis*). *O. edulis*, is the focus of emerging restoration projects throughout Europe, therefore quantifying the potential carbon storage which restored reefs can provide is important grounds to justify such work. Seasonal depositional rates of native shellfish will be studied under realistic environmental settings of flow rate and seston availability, using facilities at the St Abbs Marine Station. This study will also be replicated in-situ at a potential restoration site in the Dornoch Firth. Further experiments are planned to quantify carbon stored in horse mussel beds and to quantify the carbon budgets of native shellfish, assessing carbon input and output and quantifying net carbon sequestration.

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Keywords: blue carbon; *Ostrea edulis*; *Modiolus modiolus*; biogenic reef; shellfish beds; nature's capital

## Optimizing survey data for ecological niche modelling of rare species: A case study with starry ray from the North Sea

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Ecosystems in the higher latitudes are usually inhabited by a small number of highly abundant and a high number of rare species. Particularly rare species may be of high conservation concern, but based on their rarity, knowledge gaps frequently exist about their biology, ecology and population status. Regarding marine fishes, extensive monitoring data are available for some parts of the world such as the North Sea, which is a major advantage compared to most other taxa. Nevertheless, the corresponding surveys have typically developed over time and are not optimized for monitoring rare species, which often leads to non-representative sampling and reduced data quality. Chondrichthyans are an important example of rare species with data limitations. A high number of species have declined worldwide and this is also apparent for the North Sea, where several species are supposed to be threatened.

Ecological niche modelling is an approach to estimate the fundamental niche of a species. It requires only little species information (at least presence records) that is readily available by North Sea monitoring data. However, the low prevalence of rare species could negatively affect predictive performance of estimated models. Thus, this study aims for optimizing available monitoring data from the North Sea to develop ecological niche models of rare species. This is done by filtering techniques and adjustments of the spatial sampling units. Here, we focus on starry ray *Amblyraja radiata*, which nowadays is the most abundant of the rare skates in the North Sea. If significant models can be obtained from the developed optimization techniques, this method could be applied to other even rarer species.

Keywords: North Sea; chondrichthyan species; ecological niche models; data optimization

## Functional characteristics of the food web of artificial hard substrates of offshore wind farms along a depth gradient

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The establishment of man-made structures, such as offshore wind farms, provides hard substrates to naturally soft-bottom areas. Hard substrate fauna rapidly colonizes this new habitat, altering the natural biodiversity and thus affecting both ecosystem structure and functioning, e.g. food web interactions. The aim of the present study is to investigate the structural and functional food web characteristics along a depth gradient on a wind turbine in the Belgian part of the North Sea. For this purpose, macrofaunal organisms were collected at six different ecological zones along a depth gradient on a gravity-based wind turbine: (a) the intertidal zone, (b) the *Mytilus edulis* zone (~ 5 m water depth), (c) the *Jassa herdmani* zone (8-9 m water depth), (d) the *Metridium dianthus* zone (15-25 m water depth), (e) the erosion protection layer (EPL) and (f) the nearby soft substrate. All organisms were identified at the lowest possible taxonomic level and processed for stable isotope analysis ( $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ ). Based on stable isotope signals, the organisms from the seven zones were classified into eight functional groups.  $\delta^{15}\text{N}$  values showed that the variation in trophic position ranges was high between different ecological depth zones, with the EPL community showing the highest range (2.36 - 6.59), whereas the narrowest range was observed by the intertidal community (1.89 - 3.33). The high range for the EPL community suggests a possible relation between trophic position and mobility of the organisms. Overall, the structural difference in the fouling communities was partly reflected in other food-web characteristics (Layman indices) of the fouling communities: the intertidal food web is clearly different from the more homogeneous deeper parts which changed gradually with depth. This can be partly explained by the trophic plasticity of particular species, such as the anemone *Metridium dianthus* and the brittle star *Ophiothrix fragilis* which shift food sources and trophic positions depending on the zone they inhabit. This study corroborates the hypothesis that there is structural and isotopic variation of the food web along the depth gradient at a wind turbine; however, this is not reflected in the functional characteristics of the communities, indicating a more complex utilization of food sources and trophic level occupation.

Keywords: stable isotope analysis; artificial hard substrates; trophic interactions

## Are benthic food webs different on small spatial scales?

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Benthic food webs are very important as they provide food for higher trophic levels. However, during the last century North Sea benthos has been affected by different types of increasing anthropogenic pressures, such as fishing, windfarms and sand extraction. Studies concerning human activity consequences, especially the trawling effects on benthos, have shown changes in its abundance, biomass and production over various spatial and temporal scales. For fish, a decline in trophic level due to overfishing has been underlined both worldwide and for the North Sea. In general, the effects of human pressures on benthic communities are well understood and some studies have already highlighted that benthic trophic interactions can be regarded as being resilient by opportunistic feeding, i.e. most species being generalists, and trophic redundancy. However, there is still little detailed knowledge on benthic food web structure and trophic interactions of different habitats and communities.

In this study, we investigated the trophic levels and food webs of the macroinvertebrates and demersal fish in two different North Sea benthic communities based on stable isotope analysis ( $^{13}\text{C}/^{12}\text{C}$  and  $^{15}\text{N}/^{14}\text{N}$  ratios). The samples were collected from the *Bathyporeia-Tellina* and Central North Sea communities in the German Bight. For the first time, the food webs of these two communities were analyzed, by comparing trophic parameters, such as carbon sources, trophic levels and feeding types. Similarities and differences in the trophic structure between the two communities are discussed against the background of natural conditions and anthropogenic disturbances. Thus our results provide valuable knowledge and a sound scientific baseline for understanding trophic functioning in the context of marine management and sustainable use of marine resources.

Keywords: stable isotopes; benthic assemblages; trophic levels; food webs

## UK Marine Protected Areas monitoring: The North Sea and beyond

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The UK has an obligation to monitor the status of the marine environment in accordance with a number of international and domestic policies. A key tool in achieving our obligations, in relation to marine biodiversity targets, is the implementation of a 'Blue Belt' of Marine Protected Areas (MPAs) around the UK coast. This network, which comprises both European sites (designated under Natura 2000) and also nationally designated MPAs, is intended to contribute to an Ecologically Coherent Network (ECN) of MPAs in the North East Atlantic, agreed under the Oslo Paris (OSPAR) Convention and other international and domestic commitments. Following the designation of this network, Defra has tasked Cefas, JNCC, Natural England, the Environment Agency, and Inshore Fisheries and Conservation Authorities (IFCAs), in collaboration with other statutory nature conservation bodies and academic partners, with delivery of a programme of MPA monitoring in Secretary of State (SoS) waters. The remit of this programme is to provide evidence against which the condition of designated habitat and species features within MPAs may be assessed, relationships between pressures and feature condition can be investigated, and the efficacy of adaptive management measures may be evaluated.

At the time of submission, the SoS programme has conducted dedicated monitoring surveys or highly detailed verification surveys at 40 inshore and offshore MPAs since 2013, ten of which are located in the North Sea. Further research and development surveys and international collaborative activities have also been conducted to improve our understanding of the MPAs and their designated features in the context of the wider North Sea ecosystem, and explore applications for the MPA monitoring programme. This presentation gives an overview of the achievements of the programme to date, using R&D case studies from the North Sea and wider SoS waters; including innovation in monitoring approaches and sampling designs, testing and development of indicators, technical and operational advances, achievements in inter-agency collaboration, and progress towards ecosystem-based MPA monitoring.

Keywords: Marine Protected Areas; marine monitoring, marine management; marine survey; benthic habitats; collaborative working

## The impact of decades of environmental change on phytoplankton communities in the Belgian part of the North Sea

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Long-term time series are crucial for identifying trends and changes in the biomass and structure of marine communities in the context of environmental and climate change resulting from natural and anthropogenic causes (e.g. eutrophication and modified nutrient cycles). In Belgium phytoplankton research has been conducted since the 1970s in the framework of several independent research projects. In the course of the Belspo BRAIN-be project 4DEMON (4 DEcades of Belgian marine MONitoring), an initiative to recover and integrate (historical) marine biodiversity and environmental data in the Belgian part of the North Sea (BPNS), phytoplankton diversity and biomass data from the 1970s to the 2000s were compiled, standardized and analyzed, with a focus on diatoms and dinoflagellates.

Comparison of diatom and dinoflagellate communities between the 1970s and the 2000s revealed significant changes, including a marked increase in both diatom and dinoflagellate abundance and shifts in phenology, with an earlier start of the diatom spring bloom and the emergence of a pronounced dinoflagellate summer bloom. In addition, the annual phytoplankton community composition has become more similar the whole year round. The observed changes are probably a result of complex bottom-up and top-down interactions. On the basis of environmental datasets, such as historical abiotic data measured in the BPNS (4DEMON), EU LifeWatch ERIC data series, and Dutch long-term monitoring (Rijkswaterstaat) programs, we hypothesize that the observed changes may be partly related to a combination of increasing (winter) water temperatures, clearer water conditions and changing nutrient ratios.

Keywords: diatoms; dinoflagellates; time series; Belgian part of the North Sea

## Improving restoration of a keystone species: Understanding the settlement behaviour of the European oyster *Ostrea edulis*

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The European native oyster *Ostrea edulis* once formed extensive beds that constituted a central resource. Ecologically, they were biodiversity hotspots that mediated effective coastal ecosystem functioning, while harvesting of *O. edulis* contributed to food security and spurred local economies. Yet, intense overfishing in the 19<sup>th</sup> century, combined with more recent stressors such as coastal development and disease outbreaks, led to these beds being functionally extinct<sup>1</sup>. Today, several European countries are trying to restore *O. edulis* to recover the ecological functions which, as a keystone species, it once provided in our marine environment. Its beds have therefore become the focus of conservation and restoration efforts in the North Sea.

To maximise the success of current restoration efforts it is crucial to understand the settlement behaviour of *O. edulis* larvae. This can inform selection of settlement substrates that will maximise recruitment of young *O. edulis* spat from newly restored oyster beds. In addition, it enables fine-tuning of larval dispersal models, aimed at designing networks of restoration sites which can promote larval recruitment and connectivity between restored beds. This is because larvae can prolong their planktonic duration, and thus influence their overall dispersal, if suitable settlement sites are absent<sup>2</sup>. Although there have been several studies in the past investigating settlement of *O. edulis* larvae, their prime aim was to improve settlement in hatchery conditions, i.e. producing individually settled oysters sold for commercial consumption. Yet, to inform restoration efforts, there is a need to further our understanding of the settlement behaviour of this species under natural scenarios.

In the present study, mature *O. edulis* larvae were presented with a range of settlement substrates which could be either expected under natural scenarios or laid into the sea to encourage larval settlement if adequate substrate is missing. The hypothesis was that these substrates would differ in their potential to induce settlement. Larval behaviour was subsequently monitored over a 74h time period. We show marked differences in the proportion of larvae settling, but crucially also in the time it took larvae to start metamorphosing. We discuss the implications of these results for planned restoration efforts and propose future research directions that settlement experiments could take to further our understanding of the settlement inducers and preferences in this species, therefore improving the prospective success of *O. edulis* restoration efforts in the North Sea.

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Keywords: *Ostrea edulis*; oyster; settlement; restoration

## Understanding the effects of electromagnetic field emissions from Marine Renewable Energy Devices (MREDs) on the commercially important edible crab, *Cancer pagurus* (L.)

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With the rapid increase in Marine Renewable Energy Devices (MREDs) worldwide, there is a clear need for the implications to be properly assessed with regards to current ecological status and potential future consequences. Proposed sites and developments are based on current knowledge and assessments of the local environment, despite relatively little being known about the ecological effects of such developments on marine benthic organisms. Electromagnetic fields (EMF) originate from both anthropogenic (telecommunication cables, power cables, MREDs) and natural (Earth's natural geomagnetic field) sources. Several decapod crustaceans are known to be magneto sensitive, yet information available on the effects of electromagnetic fields emitted from MREDs is scarce<sup>1,2</sup>.

The effects of simulated electromagnetic fields (EMF), emitted from sub-sea power cables, on the commercially important decapod, edible crab (*Cancer pagurus*), were assessed. Crabs were obtained from the St Abbs and Eyemouth Voluntary Marine Reserve (North Sea), and transported to St Abbs Marine Station. Crabs were exposed for 24-hours to static EMFs at strengths of 2.8mT and 40mT. Stress related parameters were measured (L-Lactate, D-Glucose, Haemocyanin and respiration rate) along with behavioural and response parameters (antennular flicking, activity level, attraction/avoidance, shelter preference and time spent resting/roaming).

Exposure to electromagnetic fields, of the strength predicted around sub-sea cables, had significant physiological effects on *Cancer pagurus* and changed their behaviour. Crabs showed a clear attraction to EMF exposed shelter (69%) compared to control shelter (9%) and significantly reduced their time spent roaming by 21%. These results predict that in benthic areas surrounding MREDs, where there is increased EMFs, there will be an increase in the abundance of *Cancer pagurus* present due to altered behaviour resulting in an attraction to the source of the EMF emissions. EMF disrupted the circadian rhythm of haemolymph L-Lactate and D-Glucose levels. Melatonin levels in several species have been found to be affected by EMF exposure<sup>3,4</sup>. This suggests that EMF exposure could affect crustaceans on a hormonal level. This potential aggregation of crabs around benthic cables and the subsequent physiological changes brought about by EMF exposure, is a cause for concern. This study shows that the impact of EMF on crustaceans must be considered when planning MREDs.

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Keywords: *Cancer pagurus*; edible crab; electromagnetic field; environmental stressor; marine renewable energy



## Fish or garbage: Do diet and foraging choices of an avian scavenger impact on its breeding performance?

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Human activities induce behavioural and population changes in animal species affected by them. For instance, opportunistic scavengers may benefit from the exploitation of human-mediated food subsidies. Such is the case of the Lesser Black-backed Gull (*Larus fuscus*), an originally marine forager whose breeding population has expanded, from the mid-20th century onwards, throughout the coasts of the Southern North Sea and further inland, by relying on the exploitation of fishery discards, garbage and soil organisms as food resources. 5 years of GPS tracking data of adult *L. fuscus* breeding at the Outer Port of Zeebrugge (Belgium) have provided evidence of widespread foraging on both fishery discards and terrestrial food sources by this population, with a marked variation between sexes and furthermore between individuals. On the other hand, stable isotope data from feathers of fledglings show that the food provided by adults to their chicks is here predominantly of marine origin. Cost-benefit analyses of a marine versus terrestrial diet in chicks, as well as of a terrestrial or marine foraging behaviour of adults, shed light on the consequences of diet and foraging choices, and how these might be affected by changes in human activities, such as a decrease in the production of fishery discards.

Keywords: gulls; discards; garbage; foraging niche; scavengers; breeding performance; gps; stable isotopes

## Response of different estuarine zooplankton taxa to instantaneous salinity reductions

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Salinity variation is a key factor influencing the distribution of estuarine biota and constitute a considerable stress on the living organisms. In the ocean and estuarine systems, zooplankton can experience rapid salinity changes due to heavy precipitation, ice and snow melting, storms or its own vertical migration in a stratified waters. However, this rapid natural salinity change has a smoother character, rather than instantaneous changes in salinity of anthropogenic nature, such as periodic discharges of water from dams separating seas and freshwater lakes. A novel cause of anthropogenic salinity variation is a Blue Energy production.

In the Blue Energy production, energy is generated from the mixing of waters with different salinities in a process called Reverse Electrodialysis (RED). The world's first Blue Energy power plant is currently being tested in the Netherlands. Organisms passing through a RED plant are subjected to multiple stressors, including salinity shock that zooplankters experience when sea water and freshwater merge. Rapid salinity reductions may have a negative consequence for planktonic organisms such as mortality, decrease in growth rates and impaired feeding ability, but knowledge on this is currently limited.

We study the possible impact of Blue Energy generation on zooplankton by reviewing available work on the impact of salinity reductions on zooplankton. In a series of controlled experiments using natural zooplankton assemblages collected in the western Wadden Sea we investigate the impact of instantaneous salinity changes on survival of different estuarine mesozooplankton taxa.

Keywords: zooplankton; salinity shock; mortality; blue energy

## Tracking wild cod in a wild ocean: Investigating the effects of man-made sound on Atlantic cod (*Gadus morhua*)

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The distribution and movement of all marine aquatic life structures the marine ecosystem from deep ocean canyons to the shallower North Sea. Understanding the movement and behaviour of marine animals can provide us with information on the wellbeing of the species as well as a tool to predict how the increasing human activities at sea may influence marine life. However, tracking marine animals like fish, is challenging in a harsh environment like the North Sea. Over the past decade, technological advances in telemetry have transformed our ability to observe aquatic animal behaviour and movement. Smaller sized tags with longer battery life have given us the opportunity to tag smaller animals and track them over a prolonged period of time. Furthermore, acoustic tags including a pressure and acceleration sensor are now available, leading to additional detailed data on fish behaviour and physiology.

Since 2010 Atlantic cod (*Gadus morhua*) have been tagged with acoustic tags in the North Sea. Over the past eight year this has provided us with a rich data set of over 150 tagged cod moving through the area. This telemetry data on cod has given indications of the migration paths these fish follow every year: from coastal zones in winter to more offshore areas in summer. The data has furthermore shown how cod use offshore man-made structures like wind turbines. However, little is known about the effects of sounds that accompany human activities, like pile driving and seismic exploration. The Population Consequences of Acoustic Disturbance on Cod project (PCAD4Cod) looks into the effects of seismic sound on Atlantic cod movement behaviour. This project, funded by the Joint Industry Program (JIP), uses an integrated set of techniques to study the impacts of this high intensity sound on cod. One of the goals of this project is to expose free-ranging cod to a real seismic survey and study the effects. To accomplish this, acoustic telemetry is used to track the movement and behaviour of the cod before, during and after the survey.

The tags can detect both pressure and acceleration which will add detailed information on position and behaviour on top of the detection data. The full seismic survey will take place during the coming field season (2018) and will provide new insights into how man-made seismic noise can affect wild cod movement and behaviour in the North Sea. Here, we will present first results from the field.

Keywords: acoustic telemetry; Atlantic cod; PCAD4Cod; seismic sound; North Sea

## How several pressures influence the benthic ecosystem status in the Southern Bight of the North Sea

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The marine ecosystem is influenced by several pressures, but at what pace do they impact it? An ongoing debate urging for uniform assessments. The Marine Strategy Framework provide a good base for scientifically sound assessments. The approach for evaluating the sea-floor integrity allows to objective compare and integrate the impact degree and the areal extent of degradation caused by human activities on the seafloor. In this study, we applied a harmonized and uniform set of indicators with respect to the benthic ecosystem in the Belgian North Sea. We assessed the impact of dredge disposal and aggregate extraction, two activities only allowed in dedicated zones, and compared this to the impact of the more widespread fishery activity. At certain pressure thresholds (e.g. volume disposed, volume and frequency of extraction, number of trawls), all activities caused a decrease in benthic habitat quality. However, for each activity the thresholds and the areal extent of degradation were quite different and dependent on the benthic habitat type in which the activity took place. Such detailed insights on pressure footprints are necessary, to allow for an integrated evaluation of the impact on the sea-floor status across multiple activities.

Keywords: benthic ecosystem; pressure footprint; indicators; harmonized assessment

## Life cycle closure of jellyfish in the North Sea area

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Most scyphozoan jellyfish and hydromedusae have benthic polyp stages which can reproduce asexually. Triggered by environmental conditions, they release medusae and can thus be the driving force behind gelatinous zooplankton blooms, which have been increasingly causing problems in many areas worldwide. Knowledge of the distribution and habitat preference of these polyps could be important for predicting future blooms of jellyfish. For most jellyfish species in the North Sea area, the location of the benthic polyps is unknown and only polyps of the moon jellyfish *Aurelia aurita* are regularly found in coastal areas. We summarise information on the distribution and population structure of benthic and early pelagic stages of jellyfish in the North Sea area obtained on sampling cruises in Dutch coastal waters and the North Sea in 2012-2018, discuss possible locations and habitats where the missing polyps of species might be found, and methods that can be used to find them.

Keywords: jellyfish; North Sea; polyps; life cycle closure; zooplankton

## Interactions between biological and physical effects modify local biogeochemical cycling processes in offshore wind farms

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In order to meet the increasing demand for renewable energy production, many European countries have installed offshore wind farms (OWFs), thereby introducing large surfaces of artificial hard substrates in marine areas often exclusively consisting of sandy sediments. Near the sea surface, these artificial communities are dominated by the blue mussel (*Mytilus edulis*: 18-38 kg m<sup>-2</sup>). Below this mussel belt, the amphipod *Jassa herdmani* is the dominant organism (minimum 10 000 ind. m<sup>-2</sup>). In order to investigate the functional importance of these new communities, we performed clearance rates experiments and found that both *M. edulis* (0.27 l gDWT<sup>-1</sup> h<sup>-1</sup>) and female *J. herdmani* (0.12 l gDWT<sup>-1</sup> h<sup>-1</sup>) act as important filter feeders. Given their high densities on the turbines, this results in the filtering of more than 500 000 l of seawater by the OWF fouling fauna of 1 gravity-based foundation each day. The subsequent production of detritus and (pseudo)faeces by the fouling fauna creates a continuous additional source of organic matter to the often permeable sediments. Our detailed study in the vicinity of a wind turbine in the North Sea revealed an increase in organic matter, a fining of the sediments and a change from a species-poor to a species-rich benthic community dominated by the ecosystem engineer *Lanice conchilega*. Our experiments on the effects of the physical fining of the sediments revealed a decreased penetration depth of advective water currents, a reduced trapping of diatoms and a decreased mineralization efficiency. Large densities of *L. conchilega* further result in an increased trapping of fines, accelerating the physical changes in the sediment matrix caused by increased deposition rates. As such, benthic degradation of organic matter will then no longer be governed by physical processes, but mediated by biological processes (bioturbation, bio-irrigation). As a consequence, the introduction of fouling communities on artificial hard substrates in the water column will be reflected in the sea-floor functioning through a shift from permeable sediments with very efficient mineralization processes towards sediments where organic matter can be accumulated for longer periods.

Keywords: North Sea; offshore wind farms, ecosystem functioning

## BeRMS 2020 – Innovative census of Belgian marine biodiversity

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The Belgian Part of the North Sea (BPNS) harbours a rich biodiversity. A large number of these species has been listed in the Belgian Register for Marine Species (BeRMS), which was published in 2010 by the VLIZ Belgian Marine Species Consortium. However, a significant number of taxonomic groups are not or only insufficiently included in this register. For most of these groups, species identification remains an important bottleneck for ecological research and biodiversity policy. In 2018, the Flanders Marine Institute (VLIZ) initiated a project to update BeRMS and boost the Belgian marine biodiversity research.

With new scientific expertise and possibilities since the first edition of BeRMS, more taxonomic groups can be included in 2018. Another important addition is a time stamp for species records and, where possible, a habitat description. The goal is to establish a current species register for the period 2010-2020 that can be compared with historic observations of the Belgian marine biodiversity and serve as a baseline for future reference. This is highly relevant for descriptor 1 of Good Environmental Status according to the Marine Strategy Framework Directive.

Different activities will feed into the project. A systematic query of data systems such as EurOBIS and the VLIZ Open Marine Archive for species observations in the BPNS will yield information on recent observations. Citizen scientists will contribute to current observations of species and will allow for the observation of rare species. Marine Research Groups will be asked for unpublished species records. The LifeWatch Observatory is a continuous source of species observations and the LifeWatch Taxonomic Backbone will be the backbone of BeRMS. Targeted field campaigns will be undertaken to document poorly known species assemblages.

Novel species identification methods will be applied or developed, such as meta-barcoding or metagenomics approaches and automated image recognition. We will evaluate which types of images (light microscopy, scanning electron microscopy, micro-CT scans) can be made of collected Belgian marine species and document these in a related image bank. Where relevant and useful, we aim to make DNA barcodes available and provide reference to available specimens. Research activities testing conceptual hypotheses on changes in ecosystems or on assessing ecosystem functions related to certain taxonomic groups or habitats will contribute to the update of BeRMS by documenting all sampled species occurrences. As many as possible relevant Belgian Marine Research Groups will be involved in the project via various ways of collaboration.

Keywords: biodiversity; species identification; species observations

## Alien species in Belgian marine waters: An information platform and checklist for science and policy support

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Since 2006, data and information on alien species in the Belgian marine and brackish habitats were collected. The work is a collaborative effort of the 'VLIZ Alien Species Consortium', consisting of a network of experts, supported by a secretariat hosted by the Flanders Marine Institute (VLIZ). So far (April 2018), 81 alien species from different taxonomic groups, mainly arthropods, seaweed and molluscs, have been reported to have established populations in the area of interest. Scientific information on the species' origin, pathways of introduction, factors influencing spreading, potential socioeconomic or ecological effects, eradication measures, species' morphology, etc. have been gathered from distributed scientific publications and are collected in species factsheets. A first collection of factsheets has been published in a Dutch book in 2012 (Vandepitte et al. 2012) and an updated version is planned to be out early 2019. The update includes a revision of the existing fact sheets, the writing of new species fact sheets and an English translation. A two-way information exchange with the World Register for Marine Species (WRIMS) has been put in place and acts as an important data source for the marine component of the TriAS project (Tracking Invasive Alien Species - BELSPO). Furthermore, the effort aims to tackle the general lack of accessible local/regional alien species data. The alien species list and the factsheets are also online available via the VLIZ Coastal Wiki portal ([www.vliz.be/wiki](http://www.vliz.be/wiki)), including full-text references.

### Reference

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Keywords: alien species; species factsheets; information platform; Belgium



## Macrobenthos-mediated nutrient cycling in offshore windmill farm environments under future ocean climate settings

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The installation of offshore wind farms (OWFs) in the Belgian part of the North Sea (BPNS) introduces large surfaces of artificial hard substrates (AHSs). These AHSs are expected to modify the physico-chemistry and ecology of the adjacent seabed due to, among others, altered hydrodynamics and organic enrichment originating from the fouling OWF fauna and proposed aquaculture activities in the OWF concession area. In addition to local habitat changes associated with the AHSs, global climate change stressors such as ocean warming and acidification also challenge coastal ecosystems. They can, for example, influence the benthic communities and the way in which the (affected) biodiversity contributes to ecosystem services such as biogeochemical cycling. Through bioturbation and bio-irrigation macrofauna reworks the sediment and alters both physical structure and chemical composition, often facilitating microbial activity and removal of nitrogen via coupled nitrification-denitrification processes. A consequence of this process is however the production of the potent greenhouse gas nitrous oxide (N<sub>2</sub>O), produced during nitrification and denitrification. Hence there is need for knowledge on the cumulative effect of local anthropogenic impacts associated with OWFs and global climate change on the coastal ecosystem and its effect on the production of the greenhouse gas N<sub>2</sub>O.

The project PERSUADE (EXPERIMENTAL approaches towards Future Sustainable Use of North Sea Artificial HarD SubstratEs) aims to investigate ecosystem-wide responses to combined global and local stressors and the effect on the production of N<sub>2</sub>O in a future climate setting, by quantifying the interactions between the biotic and abiotic compartments in an OWF environment. We therefore consider both the fouling and soft substrate fauna and their effect on nitrogen cycling. A four-step approach is envisaged to provide an empirically based mechanistic understanding of the biogeochemical response of the benthic environment to the installation of OWF. First the behavioural activities that are relevant for mediation of biogeochemical cycling (i.e. particle mixing, burrow ventilation, feeding) will be investigated by recording hydraulic porewater signatures in the polychaete *Lanice conchilega* and the bivalves *Ensis directus* and *Abra alba*. These species are expected to represent dominant members of the benthic community in the OWF environment in the BPNS. Secondly, the effect of density and allometry of these species on the N<sub>2</sub>O production will be studied. The developed techniques and insights gained in the first two parts of the project will then be used to study the benthos-mediated biogeochemical cycling under future ocean conditions. Organisms will be incubated under different climatic conditions (higher temperatures and lower pH) and their behavioural responses will be observed. To determine the effect on nutrient cycling, oxygen consumption rates will be determined and the solutes exchanges across the sediment-water interface will be measured. Finally, the acquired results will be incorporated in the development of a model to investigate and predict the long-term production of the greenhouse gas N<sub>2</sub>O in OWF environments under future climate scenarios.

Keywords: macrobenthos; ocean acidification; ocean warming; offshore-windfarms; aquaculture; biogeochemical cycling

## Investigating the combined effects of climate change on ecophysiological response of offshore wind farm fouling fauna

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In the past decades, the Belgian part of the North Sea (BPNS) has been affected by a mixture of local and global pressures. Locally, an increasing trend to install offshore wind farms results in the introduction of artificial hard substrates and an increase in potentially non-indigenous fouling fauna. Plans to use these concession areas for aquacultural activities will further affect the food web structure and aggravate the emission of nitrous oxide (N<sub>2</sub>O), a potent greenhouse gas. On a global scale, the International Panel for Climate Change (IPCC) 'business-as-usual' climate change scenario predicts a rise of ocean temperature by 3°C and a drop in oceanic pH of 0.3 by the end of this century.

The overall objective of the PERSUADE project (Experimental approaches towards future sustainable use of North Sea artificial hard substrates) is to investigate the impact of these combined pressures on food web interactions and nutrient cycling of coastal ecosystems and integrate the dynamics of the water column and the sediment while doing so.

This presentation reports on the experiments done with blue mussel (*Mytilus edulis*), the dominant species of the intertidal fouling community on the artificial hard substrate structures of the Belgian offshore wind farms. Additionally, blue mussel is also the target species for the aquaculture industry. To gain insight into respiration, nutrient exchange and survival of this species under current environmental conditions and the aforementioned future climate settings, a fully crossed laboratory experiment was set up. Incubations ran for six weeks in four different environmental treatments: 'CTRL' (control settings – ambient temperature of 12°C and current pH), 'pH' (ambient temperature of 12°C and pH lowered by 0.3), 'TEMP' (elevated temperature of 15°C and current pH) and 'CC' (climate change scenario – elevated temperature of 15°C and pH lowered by 0.3).

Under each of these environmental settings, different ecophysiological parameters were tested in the third and sixth week of incubation. Survival of blue mussels was significantly lower in the climate change scenario ( $p = 0.044$ ) compared to the control settings, while the differences in condition index between the environmental treatments were not significant. Mixed effects modelling reported highly significant effects of time (week 3 and 6 of incubation), pH (current or lowered) and temperature (ambient or elevated) on both respiration rate and clearance rate, which were higher in the 'PH' and 'TEMP' treatments and showed a synergistic response in the 'CC' treatment.

These changes in ecophysiological response across the environmental treatments suggest that climate change will affect both the survival of blue mussel and the physiology of the survival individuals, which in turn will affect the local offshore wind farm ecosystem.

Keywords: climate change; ocean acidification; fouling fauna, ecophysiology; *Mytilus edulis*

# SCIENCE IN A MODERN ERA

## Long-term plankton measurements using semi-automatic image classification techniques

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Long-term biodiversity measurements are necessary to understand changes and pressures on an ecosystem. To support scientific research on biodiversity and ecosystem functioning, the Flanders Marine Institute (VLIZ) established a marine observatory as part of LifeWatch Belgium within the European Strategy Forum on Research Infrastructures (ESFRI). This observatory carries out sampling campaigns in the Belgian part of the North Sea (BPNS) onboard the RV Simon Stevin, visiting in total 17 stations on a monthly or seasonal basis. During these campaigns, various seawater and seabed characteristics are measured, as well as biological samples including phytoplankton, zooplankton, and macrobenthos.

Large amounts of biological samples are generated, and processing these using traditional methodologies is labor-intensive and time-consuming. Thus, innovative techniques that generate high-resolution data in a time-efficient process are favored.

As an accepted technique to carry out taxonomic classification of plankton samples, image analysis is applied within LifeWatch with two different methodologies. For zooplankton, samples are collected with a vertical 200 µm WP2 plankton net and fixed in formaldehyde. Zooplankton samples are scanned with the ZooScan (Hydroptic) and the images are processed with ZooProcess and Plankton Identifier. On the other hand, Phytoplankton samples are collected by filtering surface water in a 50 µm Planktonnet Apstein net and fixed in Lugol. The samples are processed with the FlowCam using the VisualSpreadsheet software. Both techniques generate pictures of the particles in the water sample that can be classified on the basis of the imaged particle's properties. After the automatic classification, the annotation by software is manually validated.

In total, we have measured the abundance of plankton from January 2014 onwards for zooplankton, and from May 2017 onwards for phytoplankton. Zooplankton is processed only at a higher taxonomic level: 18 taxa over 900.000 observations are currently validated. Phytoplankton is processed mostly at genus level, and 45 taxa over 120.000 observations are currently validated. In both cases, the use of software allows experts to work on the samples and enhance taxonomic resolution.

In addition, the datasets generated are freely available through the LifeWatch Data Explorer (<http://www.lifewatch.be/en/lifewatch-data-explorer>), on the condition that the dataset is cited. The improvement of classification algorithms and camera resolution would result in even more accurate classifications, and require less human effort. Nonetheless, we have succeeded in implementing image analysis methodologies to process large amounts of plankton samples. By distributing these data to the wider scientific community, we hope to enable researchers to gain quick access to biodiversity parameters in the BPNS.

Keywords: biodiversity; plankton; image analysis; zooplankton; phytoplankton; Belgian Part of the North Sea

## OBIS 2.0: Towards real-time integration, quality control, and analysis of rich marine data streams

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Millions of marine species observations as well as measurements of abundance and biomass can be accessed through the Ocean Biogeographic Information System (OBIS). In recent years, OBIS developed a RESTful Application Programming Interface (API) to help drive a new portal interface and an R package for analytical use, which is proven to be attractive to users and now drives multiple third-party applications. However, the system for harvesting new data was experiencing major delays due to aging and out of date processes and software infrastructure. The process of quarterly data loads through a process that involves a fair bit of manual labor in addition to long processing times to rebuild database indexes and other aspects of the system was problematic in getting new data online and meeting user expectations - from both data providers and data consumers.

Here we present our new OBIS infrastructure and technology stack which aims to achieve the following high-level objectives:

1. Near real-time data integration from OBIS Nodes - as soon as OBIS Nodes advertise the availability of new or updated data, the OBIS system begins automated processing to ingest data and completes integration routines in a timely manner.
2. The ability to scale the system to hundreds or thousands of new datasets and millions of new records while providing timely results for queries, data access (download and streaming), and products (analytics and indexes).
3. The ability to integrate environmental variables in addition to biological observations and to fully leverage this new type of data in queries, data access, and products.
4. Improve on the real-time analytics capability of OBIS to directly inform biodiversity indices, essential ocean variables and biodiversity indicators, starting at the API level to support science end users (e.g., via R/Python packages) and custom apps/portals along with a flexible and ever evolving set of reports through the OBIS portal.
5. Improve the full visibility of the OBIS Network by persistently linking OBIS Nodes, data provider institutions, and individual contributors (data providers, authors, etc.) together such that each entity is cited and their full contribution to OBIS easily accessible.

Future plans include an online data entry and editing tool including the capability to manage both open, public data as well as data that are under limited embargo due to research project constraints and the ability to provide and share annotations on the quality of the published data.

Keywords: OBIS; biodiversity data; software infrastructure; quality control; FAIR principles

## Fishing for advantages with on-board electronic monitoring and digital image analysis techniques

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The relevance of electronic monitoring (EM) in turning data-poor into data-rich situations and cutting costs will become more and more important as a tool for sustainable fisheries management under an ecosystem approach. In this study we evaluate the utility of using cameras to a) identify beam-trawled rays passing on a sorting conveyor and b) digitally analyze the extent of bleeding on the undersides of beam-trawled flatfish. For a), video footage was collected onboard a commercial Belgian beam trawler; and for b), photographs were taken from 66 fish of six species sourced from the R/V Simon Stevin while beam-trawling in the Belgian coastal zone of the Southern North Sea. A trained reviewer was able to correctly identify thornback, undulate and spotted rays, among others, when comparing review record counts with on-board observations. For the second part of this study, injuries of interest were visible multifocal cutaneous petechiae (termed 'point bleeding'), and suffusion or haemorrhaging (termed 'bruising'). A series of algorithms was developed by students of the University of Ghent to 1) separate the fish from the background, 2) align each image and identify the species by raytracing; 3) segment the fish into fin, body and head regions (e.g. based on K-means clustering, frequency domain, Gabor filter and superpixel techniques); and 4) quantify the surface area of bleeding injury of each region by using species-specific thresholding techniques (i.e. hsv hue). For validation, results from the algorithmically obtained surface area % were compared to three rater's average % estimates. By accurately recording catches on-board and recording the coverage of externally visible bleeding injury, a device could be developed to combine and automate both camera-based techniques to sort any commercial catch and at the same time measure quality of whole fish or fillets. Such technological advancements will facilitate the transition towards a more sustainable fishery and the implementation of the European landing obligation.

Keywords: CCTV camera monitoring; commercial fisheries catches, digital image analysis

## Research Infrastructures and their collaborative potential to address scientific questions at global scale

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Research Infrastructures (RIs) are facilities, resources and services used by scientists to carry out research and develop innovation. A number of EU research infrastructures (e.g. LifeWatch ERIC, ELIXIR, EMBRC ERIC, EuroBioImaging ERIC) have been developing various virtual research environments (VREs), which include many virtual laboratories (vLabs) offering, one stop-over point access, high computational capacity and collaborative research platforms that supporting the needs of digital biodiversity science. This presentation provides examples on the use of the vLabs initially developed by LifeWatch ERIC but then taken up as examples by other RIs.

The RvLab operating on a high-performance computer cluster, has been used in order to address the global question on the taxa equality. The taxonomic research community has developed a system for describing, classifying and naming taxa across multiple categories. This taxonomic information on marine biota is organized and made publicly available through the World Register of Marine Species (WoRMS) that delivers more than 250,000 described valid species names. Although scientists consider an equal status (in terms of contribution to overall diversity) to each taxon used in taxonomy, biogeography, ecology and biodiversity, the question “*are all taxa equal?*” has never been tested at a global scale. We present evidence that this question can be addressed by applying relatedness indices (Taxonomic Distinctness) over the entire WoRMS metazoan tree.

The virtual micro-CT laboratory (Micro-CT vLab), which can be used by the members of the scientific community interested in the digitisation methods and biological collections, makes the micro-CT data exploration of natural history specimens freely available over the internet. Therefore, Micro-CT vLab makes it possible the online exploration and dissemination of micro-CT datasets, which are only rarely made available to the public due to their large size and a lack of dedicated online platforms for the interactive manipulation of 3D data.





## Migratory routes and stopover sites of the Lesser Black-backed Gull: Where to go if your options are endless?

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Long-distance migration has evolved in many genera of birds to cope with spatio-temporal fluctuations in the environment (1). This allows them to complete their annual cycle under favourable conditions, for example by taking advantage of seasonal peaks in food availability (2). Within species, populations have typically well-defined migration routes, stopover sites and wintering areas (3). However, in individuals may still differ in their choice of wintering areas in relation to age, size or sex, which is referred to as differential migration (4).

Lesser Black-backed Gulls (*Larus fuscus*) show pronounced individual variation in migration strategies with some birds wintering as close as Northern France or Southern England, while others migrate as far south as Senegal (5–7). In addition, Lesser Black-backed Gulls have in the past century progressively adapted to anthropogenic food sources, taking advantage of new feeding opportunities in agricultural and urban habitats, next to their historic marine habitat (8). Hence, their options to select winter and stopover sites are nowadays almost endless.

In this study we used 5 years of GPS tracking data of adult Lesser Black-backed Gulls breeding in the southern bight of the North Sea to investigate the movements and temporal dynamics in habitat selection outside the breeding season. We did not find differences in migration routes and wintering areas between sexes. However, males and females differed significantly in their timing and use of stopover sites. Differential migration hence occurred during autumn migration. It took females on average 15 days longer to reach their wintering sites than males. During autumn migration, females made more extensive use of stopover sites, in particular in North France and the UK where they almost exclusively foraged in agricultural areas. Males, in contrast, did not significantly alter their diet during autumn migration. This shift in habitat use and protracted autumn migration coincided with the timing of moult, which overlaps with chick rearing and migration in the Lesser Black-backed Gull. Our results suggest that this overlap between energy-demanding activities may cause females to perform a more prolonged autumn migration and select different foraging habitats during autumn migration.

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Keywords: gulls; migration; gps; tracking; timing; habitat

## Coevolutionary dynamics of cymothoid isopods and their fish hosts

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The study of co-evolution between parasites and their hosts is a powerful approach for investigating a range of fundamental evolutionary patterns and processes, including diversification, specialisation, and whether particular evolutionary changes are irreversible. One of the single most extraordinary examples of host-parasite co-evolution is shown by cymothoid isopods, a highly diverse family (~400 species) which are all obligate parasites of fish - including many commercially important species. Superficially at least, within the suborder Cymothoidea, cymothoids represent the extreme of a continuum of 'trophic dependency' from free-living scavengers and predators, through temporary to obligatory parasitism. As parasites on highly labile hosts, Cymothoids have evolved striking parasitic strategies. Some species, for example, gruesomely supplant their host's tongues; the only natural example of functional, anatomical replacement by another organism. Other parasitic modes include external attachment to the dermis, within the opercular cavity, invagination within the body.

Due to their bizarre life-histories, large size relative to their hosts, and their economic impacts in fisheries and aquaculture, cymothoids have been studied for over a century and mostly using traditional taxonomical approaches. However, compared with their free-living relatives, evolution of morphological innovation in cymothoids has been largely constrained by their parasitic lifestyle. Early taxonomic work, for example, prioritised variable or inconsistent features with an emphasis on body shape - a convergent character influenced by location on the host: *Mothocya ihi* resembles other buccal-inhabiting species but is actually placed within a genus of mainly gill attaching species. Host species have also been important for classification of cymothoids due their seemingly high specificity but host range for most species remains unknown. Thus, intraspecific morphological variation in cymothoids is easily confounded with interspecific differences which obfuscate evolutionary relationships, makes identification problematic, and species boundaries unclear. Without a clear phylogenetic

The objective for this project is to establish the relationships within Cymothoidea and to apply this phylogenetic framework to answer whether cymothoids and their hosts have cospeciated, whether different parasitic modes have evolved 'progressively', and examine host specificity. Our approach sits at the interface between the historical and modern themes of this symposium, where we have used high-throughput DNA sequencing of museum specimens up to 100 years old, using novel ancient DNA techniques. This has allowed us to sample more broadly than traditional methods both taxonomically and biogeographically. We have recovered full, or nearly-complete mitogenomes, and high copy number loci for over forty cymothoid species from across the world, representing the different parasitic strategies and range of habitats including deep sea and riverine. Furthermore, for some species, we have also recovered the mitogenomes of the cymothoid host - some previously not sequenced - allowing us to confirm host identities. Additionally, geometric morphometrics have allowed us to quantify patterns of shape variation in important morphological traits and show that both ecology and phylogeny are influential. These data are important for understanding the evolutionary dynamics marine host-parasite systems, and identify novel hosts as climate induced range shifts introduce cymothoids to new environments.

Keywords: coevolution; ancient DNA; parasites

## A transcriptomic approach to unravel fatty acid pathways of harpacticoid copepods in a changing environment

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Global climate change is threatening coastal marine ecosystems by causing changes in oceanographic conditions such as temperature and pH. These shifts affect the physiological performance and productivity of organisms in marine food webs and thus the overall functioning of the ecosystem. A better understanding of the physiological response and adaptive capacity of coastal marine organisms is critical to assess their fate in a rapidly changing ocean.

Harpacticoid copepods are a dominant component of estuarine benthic meiofauna, efficient grazers on diatoms, and a major food source for juvenile fish. They are known to contain high levels of polyunsaturated fatty acids (PUFAs), which are essential dietary constituents for fish and humans as they can't produce these fatty acids themselves. Harpacticoid copepods on the other hand are able to bioconvert PUFAs that originate from primary producers, a process known as 'trophic upgrading'. This capacity for PUFA bioconversion might be an essential strategy for harpacticoid copepods to respond quickly to environmental changes. However, the underlying molecular mechanism and its activation are still unknown for these organisms. Therefore, we aim to uncover the genetic pathways of PUFA bioconversion and to which extent warming and acidification will affect this process.

Within our project, we are generating transcriptomic data from the estuarine harpacticoid copepod *Platychelipus littoralis* subjected to different diet, temperature and pH treatments. RNA sequencing and novel bioinformatic tools are used for *de novo* transcriptome assembly, and subsequent annotation and differential expression analysis of PUFA metabolism-related genes.

Keywords: transcriptomics; global change; harpacticoid copepods; fatty acid metabolism

## Eavesdropping in the wild: What are porpoises and bats up to

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Echolocating animals use sound to scan their environment for information, to navigate and to forage. In the framework of the Lifewatch Observatory at the Flanders Marine Institute, two passive acoustic sensor networks are installed to detect echolocation calls as a proxy for presence. These sensor networks continuously monitor harbour porpoise (*Phocoena phocoena*, C-PODS) in the Belgian Part of the North Sea and bats (batcorder) along the Belgian coast line. Whilst the C-PODs are spaced across a coastal, midshore and offshore gradient, the batcorders are installed in IJzermonding and Zwin, and one in Oostende. Both systems listen to the sound in the environment, yet only record the sound (batcorder) or sound characteristics (C-PODs) when the device is triggered for an echolocation call. Besides revealing an animal's presence, the features of a recorded echolocation call can also disclose the species and/or the behaviour types. Harbour porpoises produce very distinctive series of narrow band high frequency clicks (120-140 kHz, mode 132 kHz), called click trains. A very short interclick interval (< 10 ms) for example, indicates foraging behaviour. For bats, we can distinguish social, transit and foraging calls and sweeps. Depending on the distinctiveness of echolocation calls, taxonomic identification can go as far as the species level. After preprocessing with the sensor manufacturer's software, the data is transferred to the in house developed database and made available for all registered users through the LifeWatch data explorer. For both sensor networks, a collaboration with OD nature expands the network and facilitates the exchange of data and expertise. This collaboration enabled two Master thesis projects, investigating the seasonal distribution and feeding behaviour of harbour porpoises, as well as the correlation between aerial survey data and passive acoustic detections. The batcorder's preliminary results show the presence of at least eight species of which the common and Nathusius' pipistrelle (*Pipistrellus pipistrellus* and *Pipistrellus nathusii*) are the most abundant along the Belgian coast. Primarily of interest is the ecological role of estuaries and wetlands during the spring and autumn bat migrations. In conclusion, the aim of these passive acoustic sensor networks within the LifeWatch Observatory is to collect long term data series which provide high resolution information on presence/absence and secondly, observe the species' behaviour in specific habitats.

Keywords: passive acoustics; bats; harbour porpoise; echolocation

## LifeWatch marine data services supporting marine biodiversity and ecosystem research

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LifeWatch, a landmark research infrastructure on the ESFRI roadmap, is a cross-domain e-science infrastructure supporting biodiversity and ecosystem research. In the marine domain LifeWatch provides data services for a large and broad user community dealing with a variety of data types. Activities include provision of data tools and services for taxonomic, ecological, omics, biogeographic, environmental and various types of biological observation data. Specific data systems have been developed to serve the European and international marine research communities, in this context acting both as data providers and data users.

The tools for data archiving, access, quality control, standardization and harmonization, analysis and publication are integrated in a Marine Virtual Research Environment (Marine VRE). The Marine VRE provides a framework for service provision towards and co-development with the user community both within and outside the LifeWatch network (EMODNet, EMBRC, OTN, DISSCO, LTER, WoRMS (Eur)OBIS, IODE, iMarine, SeaDataNet, etc.).

Scientific use cases of the LifeWatch marine services that can be demonstrated include marine species distribution modelling, visualization of introduction of non-indigenous species and species migration, species traits based ecosystem indicators, etc. Various associated user stories evidence the crucial importance of e-science infrastructure like the LifeWatch taxonomic backbone and related reference data systems in the framework of contemporary large scale European marine biological research.

Keywords: -science; marine biodiversity; virtual research environment; data systems; species distribution modelling; non-indigenous species; species traits

## Paving the way for macrobenthic diversity assessment in impacted areas of the Belgian part of the North Sea using metabarcoding

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Human activities such as marine aggregate dredging, construction of wind turbines and dredge disposal induce habitat changes which alter species composition and structure of the seafloor. Macrobenthos is used as an indicator for environmental quality, where species are identified using morphological characteristics. DNA based approaches such as metabarcoding may complement, and speed up the characterisation of these communities. However, the taxonomic resolution of the method is currently hampered by a lack of reliable reference sequence data to which the metabarcode sequences can be compared. In addition, methodological issues such as homogenization of bulk specimens versus eDNA present in the ethanol preservative and the choice of primers for amplification may influence the resulting diversity estimates.

We compiled long-term monitoring data from soft sediment macrobenthic communities in the Belgian part of the North Sea to determine the taxa that are expected to be found in this area. Taxon names were cross validated against the WoRMS database. Next, ethanol preserved specimens were identified, morphologically diagnostic characters photographed and specimens stored as reference material for DNA sequencing. Partial or whole specimens were subjected to DNA extraction and COI Sanger sequences have been generated. In total, 334 species belonging to nine phyla were identified in soft sediments of the BPNS over the last 15 years. The classes Polychaeta, Malacostraca and Bivalvia are the most species rich and harbour 40%, 37% and 13% of all species, respectively. At present, 90 species are in the reference database, which reflect the expected phyla and classes. Collection of additional species is an ongoing effort. The reference specimens provide a taxonomic link of metabarcode sequence data which is indispensable when using metabarcoding for the assessment of environmental quality and health.

In addition to the generation of the reference database, we collected three replicate grab samples from three impacted and one control area in the Belgian part of the North Sea. Species composition in these areas is well known. Specimens from one replicate per area were morphologically identified before homogenization and DNA extraction. We optimized the amplicon library preparation for both the ethanol fixative and the bulk specimens using two primersets for the mitochondrial COI gene and one primer set for the ribosomal 18S rRNA gene. Metabarcoding data of mock communities, field samples and the ethanol fixative will be compared with morphological identification of the communities to verify the applicability of the method for monitoring.

Keywords: reference database; macrobenthos; voucher specimens; DNA barcoding; metabarcoding

## What moves European sea bass?

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Studying movement behaviour is imperative to understand how and why a species uses its habitat. In the North East Atlantic, the highly mobile European sea bass (*Dicentrarchus labrax*) is known to move from shallow, inshore feeding grounds in summer to deeper waters offshore in search of warmer temperatures in winter for spawning. Knowledge on these spatiotemporal changes in movement behaviour and distribution is critically limited for bass in the Southern North Sea. The species is currently being exploited at unsustainable levels, with previous management failures being largely attributed to data deficiency. The cutting-edge technology of the acoustic data storage tag (ADST) enables the observation of individual fish movements in the wild. The transmitted acoustic signal of ADSTs can be detected by receiving hydrophones, whenever the tagged fish roams within its detection range. Moreover, tag recovery allows to access the data-storage part and reconstruct individual depth and temperature records stored on the tag itself. In 2018 and 2019, 120 sea bass, caught by hand-line fishing in the Belgian Part of the North Sea and Western Scheldt, will be tagged with ADSTs, to fill the knowledge gap on spatiotemporal habitat use of the species. After tagging, the fish acoustic receiver network of the Belgian LifeWatch Observatory will be able to pick up the signals of the transmitter tags. This PhD research project aims to describe and explain spatiotemporal patterns in distribution and movement behaviour of *D. labrax*. Firstly, this study will describe how these temporal shifts in habitat preference and use in the Southern North Sea are driven by temperature changes. Next, we will investigate whether the migrated distance is influenced by body length and sea temperature. As a final objective, recommendations will be made for an adaptive fisheries management, needed now more than ever, in the light of global change and the current overexploitation of European sea bass.

Keywords: European sea bass; telemetry; LifeWatch; movement behaviour; spatial ecology

## Where to go during winter? Habitat use does not shape variation in migratory strategies in lesser black-backed gulls

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Optimal foraging theory predicts that individuals strive to minimise their foraging effort, while at the same time maximising their foraging success. Seabirds evolved life histories that involve travelling long distances during their annual cycle, and a large extent of intra-specific variation in migration distance is assumed to be related to spatio-temporal distribution patterns of their food resources. If so, potential costs of migrating over longer distances (e.g. higher energy expenditure and mortality risk, or delayed arrival at the breeding sites) can be expected to be offset by reduced competition, fewer predators or pathogens, or energetically-favourable foraging conditions. We applied long-term GPS tracking data of lesser black-backed gulls breeding in the southern part of the North Sea, to quantify variation in foraging effort between wintering sites. We thereby predicted lower foraging effort with increasing distance from the breeding colony, possibly mediated by differential habitat use. Contrary to our expectations, however, neither habitat use nor foraging effort differed between wintering regions, and individuals that migrated further covered a significantly larger cumulative distance year-round. We hence conclude that migration distance is not offset by a lower daily effort during winter, and that migration strategies in this species are likely shaped by other cost-benefit trade-offs.

Keywords: habitat use; foraging effort; GPS trackers; *Larus fuscus*; lesser black-backed gull



## Occurrence and ingestion of microplastics by zooplankton in Kenya's marine environment: First documented evidence

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Microplastics can be ingested by marine organisms and may lead to negative impacts at the base of marine food chain. This study investigated the occurrence and composition of surface water microplastics and to provide evidence of ingestion by zooplankton. Surface seawater was collected using a stainless steel bucket and sieved directly through a 250µm mesh size stainless steel sieve, while 500 µm mesh size net was horizontally towed to collect zooplankton at eleven georeferenced stations off the Kenyan coast in February 2017 on board RV Mtafiti National Research Vessel. Microplastic particles were sorted and characterized using Optika dissecting microscope. Polymer types were identified using ALPHA Platinum Attenuated Total Reflectance - Fourier Transform Infrared (ATR-FTIR) spectroscopy. A total of 149 microplastics particles, with an average abundance of 110 particles m<sup>-3</sup> were found in the surface water. One twenty-nine (129) particles were found ingested by the zooplankton groups, in which *Chaetognatha*, *Copepoda*, *Amphipoda* and fish larvae ingested 0.46, 0.33, 0.22 and 0.16 particles individual<sup>-1</sup> respectively. Filaments dominated the surface water and ingested microplastics with 76% and 97% composition respectively. White particles were prevalent in water (51%), whereas black was the preferred colour (42%) by all the zooplankton groups. Water particles were in the range of 0.25 - 2.4 mm, while those ingested ranged between 0.01 to 1.6mm. Polypropylene (PP) was predominant in water, with low density polyethylene (LDPE) being the most ingested polymer type. The results of this study provide the first documented evidence on the occurrence, composition and ingestion of microplastics by zooplankton in Kenya's marine environment indicating that microplastics have a potential of entering the pelagic food webs and causing pollution in the study area.

Keywords: microplastics; zooplankton; Kenya; marine environment; polymer; ingestion

## Current initiatives supporting dynamic evolvement and long term sustainability of Genomic Observatories in a European and international context

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Are seas and oceans changing faster than current science allows us to grasp their state? How quickly can new knowledge be communicated to societies and policy makers in meaningful ways? How can the need for long-term observations be reconciled with the ever changing research-funding priorities?

To respond to the above questions and address the respective challenges, there is need for long-term financial support and evolution of Genomic Observatories. Such evolution requires participatory processes to integrate new technologies, methods and additional levels of information into a standardized and globally coordinated assessment of marine ecosystems dynamics. The project ASSEMBLE PLUS aims at the implementation of Genomic Observatories (GOs) into the European ESFRI Research Infrastructure -EMBRC-ERIC for its long-term support. The ASSEMBLE PLUS GOs community has close links with the Genomic Standard Consortium (GSC), Tara Oceans, MicroB3-OSD, other ESFRI infrastructures (ELIXIR, LifeWatch, Bioimaging, OpenScreen), as well as non-molecular monitoring networks of global oceans. The actual network is supported by the biggest and most historical marine Institutes and comprises stations across the European coasts from south (Greece) to north (Norway) as well as stations from the Red Sea, Arctic and Antarctic. As an important part of its activities, it will support the continuation of the emblematic Ocean Sampling Day (OSD) event developed within the MicroB3-FP7 project, optimize protocols and address standardization of observations in different types of marine ecosystems and adopt the FAIR data principles.

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Keywords: Genomics Observatories; Gos; Ocean Sampling Day; OSD; Assemble Plus; EMBRC ERIC; participatory; standards

## Discovering a resident family of Risso's dolphins off São Miguel with a newly developed Photo-ID app

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We developed a photo ID program to classify marks in the dorsal fin of Risso's dolphins and put together a catalogue containing 569 individuals and 1124 photos. We discovered, based on the number of resightings, that in the south coast of São Miguel Island there exists two kinds of pods: transients and residents.

Analysing the temporal distribution of the resident pod from 2010 to 2018, there are no encounters with the family in 2012 and 2013. Since 2014 the family remained in the area and 2 new individuals were added to the group. Nowadays, this pod is formed by 9 adult females and 2 calves.

Keywords: Risso's dolphins; photo-ID; Azores

## The viability of *Gracilaria salicornia* seaweed farming at Kibuyuni in Kwale County, South coast Kenya, for commercial extraction of agar

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Seaweed farming is an alternative livelihood venture that was initiated in southern coast of Kenya in the recent past with a purpose of raising the socioeconomic status of the local coastal communities. Seaweeds refer to several species of macroscopic multicellular marine algae and comprise of certain species that can be cultured in the sea. Two seaweed species; *Kappaphycus alvarezii* and *Eucheuma denticulatum* were introduced for farming in southern coast of Kenya. Though the production of *E. denticulatum* has been satisfactory, that of *K. alvarezii* which has greater commercial benefit has remained insignificant. This study aims to bridge the gap so created, by testing the suitability of an alternative commercially viable seaweed species for cultivation.

This study will be carried out at Kibuyuni in southern coast of Kenya for a period of six months in order to assess the suitability of the coastal site for cultivation of *Gracilaria salicornia* by the local coastal community for commercial gain. *G. gracilis* is a cultivatable seaweed species popularly known for use in production of agar which has commercial benefits and widely used in industry. The gracilarioid will be grown in three replicated sites using suspended polyethylene ropes (off-bottom method). Daily growth rate and the agar yield of *G. salicornia* harvested from the three sites will be determined and compared. Daily growth rate (DGR = % day<sup>-1</sup>) will be calculated using the formula described by Dawes *et al.* 1993, while the native agar yield (NAY = % dry weight) will be determined using the procedure adapted from Wakibia *et al.* 2001. One way Anova statistical analysis test will be used to test significant differences in the mean growth rate and yield values between sites. All data obtained will be processed and analyzed using Microsoft® Excel and Minitab® software. All statistical tests of significance will be determined at  $\alpha = 0.05$ .

Keywords: *Gracilaria Salicornia*; off-bottom

## A new compact cost-efficient concept for underwater range-gated imaging: The UTOFIA camera

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Underwater Time of Flight Image Acquisition system (UTOFIA) is a H2020 project launched in 2015 (H2020- 633098) to develop a compact and cost-effective underwater imaging system especially suited for observation in turbid environments.

The UTOFIA project targets technology that can overcome the limitations created by scattering, one of the most common problems for imaging in water, by introducing cost-efficient range-gated imaging for underwater applications. This technology relies on an image acquisition principle that can extend the imaging range of the cameras 2-3 times in respect to other cameras. Moreover, the system will simultaneously capture 3D information of the observed objects. Today range-gated imaging is not widely used, as it relies on specialised optical components making systems large and costly. Recent technology developments have made it possible a significant (2-3 times) reduction in size, complexity and cost of underwater imaging systems, whilst addressing the scattering issues at the same time.

By acquiring simultaneous 3D data, the system allows to accurately measure the absolute size of marine life and their spatial relationship to their habitat, enhancing the precision of fish stock monitoring and ecology assessment, hence supporting proper management of marine resources. Additionally, the larger observed volume and the improved image quality make the system suitable for cost-effective underwater surveillance operations in e.g. fish farms, underwater infrastructures. The system can be integrated into existing ocean observatories for real time acquisition and can greatly advance present efforts in developing species recognition algorithms, given the additional features provided, the improved image quality and the independent illumination source based on laser.

First applications of the most recent prototype of the imaging system will be provided including inspection of underwater infrastructures and observations of marine life under different environmental conditions and its comparison with conventional cameras.

Keywords: Time of Flight camera; ToF; 3D vision; aquaculture biomass estimation; vision in turbid environments

## Enabling discovery of ocean science data in the modern era using geospatial and information science

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Applying science to decision making in the modern era depends on the ability to readily discover relevant scientific information and data. In recent years, the U.S. government has made significant efforts to improve the discovery and access of ocean science information. One example of such efforts is Bureau of Ocean Energy Management's (BOEM's) Environmental Studies Program Information system (ESPIS). For more than 40 years the U.S. Department of the Interior's Environmental Studies Program (ESP) has conducted ocean research specifically to inform offshore ocean energy and mineral resources management decisions. Historically, the results of this research have been communicated and preserved through study reports. Other sources of scientific data and information included archival repositories such as the National Centers for Environmental Information (NCEI), and a variety of peer reviewed scientific publications. The distributed nature of this information made it challenging to locate, access and discern how it was related to ESP research. In an effort to streamline the search, discovery and retrieval of BOEM ocean science data and information, the agency has re-invented its information management system utilizing the latest geospatial and database technology. A comprehensive database of studies research metadata was built along with a web based user interface. The new system utilizes Angular JS technology to support a sophisticated front-end user interface, Leaflet - an open source JavaScript library - to support a mapping interface that allows users to search for information by geography, and Microsoft SQL Server to enable in-depth searches of thousands of documents and publications. This architecture allows unprecedented discoverability of archived and current research using keyword searches, full text search, and map and geographic name index based spatial queries. Relevant research results are linked to sources across the Internet, such as conference proceedings, online datasets, and scientific journals articles. The result is a text and map based geospatial interface that is robust and user friendly way for scientists and the public to access results of BOEM's ocean research results.

Keywords: information management; data management; GIS

## The European Tracking Network: Connecting biotelemetry users in Europe

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Aquatic biotelemetry techniques have proven to be valuable tools to generate knowledge on species behaviour, gather oceanographic data and help in assessing effects from anthropogenic disturbances. These observations support international policies and directives, needed for species and habitat conservation. As aquatic systems are highly interconnected and cross administrative borders, optimal data collection and integration should be organized on a large scale. This need, triggered the development of regional, national and international aquatic animal tracking network initiatives around the globe.

Despite the large and growing number of researchers using biotelemetry in Europe, no formal collaborative network structure existed. To meet the demand for a Pan-European aquatic telemetry network, the European Tracking Network (ETN) was launched in 2017 in the framework of the European projects AtlantOS (<https://www.atlantos-h2020.eu/>) and LifeWatch (<http://www.lifewatch.be/etn>) (Abecasis et al. under review).

The overarching objective of ETN is to ensure a transition from a loosely-coordinated set of existing regional telemetry initiatives to a sustainable, efficient and integrated Pan-European biotelemetry network embedded in the related European and global initiatives. This will be achieved through: 1) the implementation of a centralised European database, with requirements and policy mapped to the data standards of existing international biotelemetry data systems, 2) improving the usefulness and inter-applicability of currently available technology and foster technological advancements, 3) promoting the establishment of key telemetry infrastructure and research on key species and 4) providing technical training and disseminate knowledge to (early career) researchers.

With ETN, Europe will be positioned in the global arena of aquatic telemetry network initiatives.

Keywords: European Tracking Network

## Time investment and territorial behaviour of lesser black-backed gulls (*Larus fuscus*) during the pre-laying period

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Like many seabird species, lesser black-backed gulls arrive in their breeding colonies long before the onset of breeding (del Hoyo et al., 1996). This early arrival is likely related to the necessity of an early territory establishment in the colonies. Intriguingly, within a colony, there is a large variation in breeding densities. Typically, central parts with high concentrations of nests are surrounded by more scattered or isolated nesting territories. The highest concentrations of nests often reflect the most productive positions within a colony, characterized by a higher breeding success (Savoca et al., 2011). Such increased breeding success of central breeders likely result from lower predation rates on eggs or chicks. This suggests a high level of competition to get and maintain these high-quality territories - if territory quality or the social environment contributes to the enhanced reproductive success. If so, individuals of higher quality are predicted to relegate lower quality individuals to peripheral sites within a colony.

Using lesser black-backed gulls as a model species, the present work investigates arrival dates, time-budgets and territorial behaviour during the pre-laying period in function of breeding density and sex, given potential differences in competitiveness due to the sexual size dimorphism (Olsen & Larson, 2003). While accurate assessment of territorial behaviour in free-ranging gulls has long been hampered by their highly unpredictable nest presence, latest advances in miniaturized remote-sensing devices now allow to monitor individuals at unprecedented spatio-temporal resolution (for a review see Kays et al., 2015).

Since 2013, per year about 20 lesser black-backed gulls breeding in Zeebrugge (Belgium) and Vlissingen (The Netherlands) have been tagged with UvA-BiTS solar-powered GPS-ACC loggers as part of the LifeWatch GPS bird tracking network. In this project, we will combine information on time-budgets as derived from the GPS data, and the number of aggressive interactions as derived from the three-axial accelerometer, and relate these to extrinsic (breeding density, weather conditions, social context) and intrinsic (sex, body condition) factors. Next, we will relate these factors to individual reproductive success. We will present the first results of these currently ongoing analyses.

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Keywords: satellite-tracking; movement ecology; territorial behaviour; time-budgets; pre-laying period; lesser black-backed gulls



## Ocean currents predict fine scale genetic structure and source-sink dynamics in a marine invertebrate coastal fishery

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Estimates of connectivity are vital for understanding population dynamics and for the delimitation of spatial management areas. However, understanding connectivity in the marine environment is still a major challenge because the relative contributions of environmental factors influencing the exchange of individuals amongst subpopulations are difficult to assess. This study combined population genetics with hydrodynamic modelling (Regional Oceanographic Modelling System - ROMS) to assess the spatial and temporal exchange of individuals amongst subpopulations of the endemic New Zealand scallop, *Pecten novaezelandiae*, within the commercial Coromandel fishery area. Small but significant genetic differentiation was revealed amongst subpopulations, suggesting that the Coromandel fishery does not form a single panmictic unit, but that it supports a model of source-sink population dynamics. Highly variable levels of self-recruitment were observed in the different subpopulations and variability in ocean currents estimated from ROMS strongly reflected the genetic structure of populations. Connectivity as assessed by ROMS was a significant explanatory variable of genetic differentiation when accounting for the spatial dependency between locations. Results imply that exploitation strategies should be spatially and temporally adjusted to ensure sustainable scallop fisheries in the future, for example by setting annual catch limits for each subpopulation in relation to its likely role in supporting recruitment. This study highlights the importance of combining different methods for a better prediction of spatial dynamics of populations, and the role that such an approach may play in the management of marine resources.

Keywords: marine connectivity; gene flow; source-sink dynamics; regional ocean modelling system; scallop; New Zealand; fisheries management

## The Continuous Plankton Recorder Survey: 60 years of data and counting

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2018 is a milestone year for the CPR Survey, marking 60 years of continuous monitoring in the North Atlantic. Although the Survey has been operating since 1931, standardised methods of sample collection and analysis were brought in to start in 1958, and have remained unchanged since then, resulting in a globally important and unique source of information on the health of the ocean.

In the marine environment, long-term datasets are rare, and those that do occur typically collect samples in coastal environments. In contrast, the CPR Survey operates in the open ocean, towing transects every month over thousands of nautical miles. By using the same methods over 6 decades, CPR data have helped progress our understanding of the marine environment, providing a form of “yard-stick” against which new measurements can be compared. Such baseline information is essential in identifying if, when and where changes have occurred, and help support the development of appropriate management of our seas.

CPR data are used by the scientific community, and can be applied to societal issues, such as climate change and healthy ecosystems, through inclusion in policy work. The CPR dataset continues to evolve, as new research topics appear, new data and instruments are continually added to keep pace with current scientific thinking. Originally designed to describe the marine environment, the CPR Survey today provides unrivalled information on multi-decadal changes in marine biodiversity, spread and abundance of pollution (e.g. marine plastics) and informs understanding of our oceans to support ecosystem-based management.

This presentation will highlight both the value of long-term time-series and the necessity for the continuous evolution of such monitoring programmes, in order for them to respond to new challenges, and remain at the forefront of ocean science.

Keywords: time-series; long-term; CPR; evolution; ocean monitoring

## BIO-Tide: An international collaboration to tackle the complexity of marine tidal flats

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Coastal tidal sediments drive the nutrient and carbon fluxes across the sediment-water interface and thus provide a pivotal role in the coastal filter function. To a large extent, they mediate coastal eutrophication and support water quality improvements. The presence of biofilms stabilizes sediments and is an important agent against coastal erosion.

Understanding the impact of anthropogenic effects such as climate change and pollution on the coastal areas requires us to know how biotic and abiotic factors affect the coastal tidal sediments. This necessitates an interdisciplinary approach in which the contribution of organisms, ranging from microorganisms up to macrofauna, and environmental factors, such as sediment grain size, on the sediment fluxes can be quantified. The BIO-Tide project (EU Horizon 2020 ERA-Net COFUND BiodivERsA, [www.bio-tide.eu](http://www.bio-tide.eu)) brings together experts from different marine fields to do just that. The integrated use of novel techniques and high-tech equipment applied directly in the field allows for a realistic fine-scale spatial and temporal recording of the sedimentary processes. The incorporation of information obtained allows us to model the (a)biotic effects on sediment fluxes and productivity.

Keywords: tidal sediments; BiodivERsA; microphytobenthos; microbial community; macrofauna; isotope labelling; ecological modelling; metagenomics; metatranscriptomics; RN

## Direct mapping of *Undaria pinnatifida* habitat range in the nearshore ocean with satellite remote sensing

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*Undaria pinnatifida*, wakame in trade name, is among the list of “100 of the World’s Worst Invasive Alien Species” [1]. This seaweed native to Asia settled in Europe from 1970s by ballast water [2], spread all over the world. Field survey and remote sensing have been performed to identify the habitat of *Undaria pinnatifida*. The former has high costs and limited study area, while the conventional latter utilizes the sea temperature to outline its blurry range [3]. Based on in-situ spectral measurement this study proposes a new remote sensing method to obtain the range of *Undaria pinnatifida* directly. The spectra of *Undaria pinnatifida* in seawater were observed at 380-1050nm with our homemade small spectrometer. The reflectance of *Undaria pinnatifida* is almost vanished below 680 nm, sudden rising from 680nm to 750nm, which enables us to establish new index for Sentinel-2 satellite bands to specify brown range: (Red band – Red-Edge band)/ (Red band + Red-Edge band). Here visible red and red-edge band has the centre wavelength 665 and 705 nm, respectively. Our in-situ measurement achieved to specify *Undaria pinnatifida* up to 3 m in depth. *Undaria pinnatifida* is annual plants, in spring growing most whereas other blown algae in the nearshore ocean are perennial. By using this difference, we can distinguish the *Undaria pinnatifida* from others. Our new method will be applied to South French coast [4] as well as to Funakoshi-bey in Japan.

The authors appreciate the experimental cooperation with Enoshima Aquarium as well as the financial support from Super Scientist Program (SSP) in Hokkaido University under Global Science Campus project in Japan Science and Technology Agency (JST).

Keywords: *Undaria pinnatifida*; wakame; remote sensing; habitat

## Bioerosion: Seeing the invisible and touching the untouchable

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Have you ever thought to 'hold' your underwater study site in your hands or to 'touch' a hole made by a boring sponge? By combining acoustic and electromagnetic technologies, such as Computed Tomography (CT), sophisticated image analysis, three-dimensional (3D) modelling software, and the versatility of 3D printers, it is possible to have your site at the tip of your fingers. All these new technologies are easily combined with each other thanks to the high performance computer, files format standardization, and interoperability among software, offering new perspectives and approaches in the analysis, understanding and representation of ecological processes. This is especially valuable for ecological processes the less evident due to the spatio-temporal scales or the places where they occur.

Bioconstruction and bioerosion are key processes in mesophotic biogenic temperate reefs. They occur in difficult to access places and act at many spatial and temporal scales. Investigation of bioerosion processes requires sampling species and analysing the shape of holes and cavities hidden inside the substrates, and the identification of the signs left by organisms, which often vanish after they are dead. High-resolution X-ray CT is a technology widely used in medical, archaeological, geological and industrial applications. CT combines the use of X-rays and computerised analysis of the images allowing 3D volume reconstruction of an object. This non-destructive imaging technique allows 3D stereo-visualization of the inner structure of biogenic substrates at a very fine scale and to investigate how the different species compete for the inner space. Three-dimensional printing technology allows physical reconstruction of the negative volumes dug into the substrate.

In this study, CT has been used to analyse short and long-term (i.e., 3 and 12 years) bioconstruction and bioerosion processes occurring in experiment travertine tiles deployed on different typologies of mesophotic biogenic reefs in the northern Adriatic Sea. The most important borers were sponges from the genus *Cliona* and the bivalve species *Rocellaria dubia*. Boring organisms leave recognisable traces inside the substrates allowing us to compute the eroded volume and estimate the net balance between construction and destruction processes. The bioeroding pattern of different species was then 3D printed in order to better visualize the shape of holes produced by different species growing and spreading inside the substrate. The 'augmented' poster presentation of the findings of this study testifies the utility of combining these different new technologies in marine ecological studies, as well as a new way to represent and communicate science.

Keywords: image analysis; 3D printer; coralligenous outcrops; ecological processes; mesophotic habitat; Mediterranean Sea

## The Census of Antarctic Marine Life, and its legacy 10 years on

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The Census of Antarctic Marine Life (CAML 2005-2010) was a component of the Census of Marine Life (2000-2010) that brought together a community of Southern Ocean researchers and helped them exchange expertise and coordinate at various levels. The International Polar Year was a pivotal component of CAML, and included 18 major research voyages to Antarctica and the Southern Ocean. This formed a new benchmark for the assessment of Southern Ocean biodiversity. While previously thought to be low in species diversity, the Southern Ocean has an unexpected richness of life.

At the end of five years of extensive biodiversity exploration and assessment by CAML, a new initiative, the multi-authored "CAML Biogeographic Atlas of the Southern Ocean", was established under the aegis of the Scientific Committee on Antarctic Research (SCAR) to provide an up-to-date synthesis of Antarctic and sub-Antarctic biogeographic knowledge. In an unprecedented international collaboration 147 scientists from 91 institutions across 22 countries (Australia, Belgium, Brazil, Canada, Chile, Denmark, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Russia, South Africa, Spain, Switzerland, the UK and the USA) combined their expertise and knowledge and published the Atlas in 2014.

Data gathered during CAML was preserved in the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (SCAR-MarBIN), which is now part of the Antarctic Biodiversity Portal ([biodiversity.aq](http://biodiversity.aq)) which is part of the EU Lifewatch Infrastructure. Biodiversity.aq is a SCAR product, currently supported as one of the Belgian contribution to the European Lifewatch-ERIC (European Research Infrastructure Consortium). *The goal of lifewatch is to provide access to: Distributed observatories/sensor networks; Interoperable databases, existing (data-)networks, using accepted standards; High Performance Computing (HPC) and Grid power, including the use of the start-of-art of the so-called Cloud and Big Data paradigms technologies; Software and tools for visualization, analysis and modeling.*

The knowledge and data gathered as a result of CAML will continue to help inform conservation policy, including the debate over whether or not to establish marine protected areas in the open ocean. Sophisticated environmental models coupled with existing species distribution data provide a valuable outlook on the possible future distribution of key species as they adapt to climate change.

Keywords: Southern Ocean; biodiversity

## The World Register of Marine Species – A decade of taxonomy and experience

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The World Register of Marine Species (WoRMS) celebrated its 10th anniversary in 2017. WoRMS is a unique database: there is no comparable global database for marine species. The World Register of Marine Species (WoRMS) provides an authoritative and comprehensive list of names of marine organisms, including information on synonymy. While highest priority goes to valid names, other names in use are included so that this register can serve as a guide to interpret taxonomic literature.

The content of WoRMS is controlled by taxonomic experts, not by database managers. WoRMS has an editorial management system where each taxonomic group is represented by an expert who has the authority over the content, and is responsible for controlling the quality of the information. Each of these main taxonomic editors can invite several specialists of smaller groups within their area of responsibility to join them.

Over the past ten years, the content of WoRMS has grown steadily, and the system currently contains more than 243,000 accepted marine species (1). WoRMS has not yet reached completeness: approximately 2,000 newly described species per year are added, and editors also enter the remaining missing older names, an effort amounting to approximately 20,000 taxon name additions per year. WoRMS is used extensively and is accepted as an international standard for marine taxonomic information.

An actively collaborating editor community and Data Management Team are indispensable in keeping a database like WoRMS alive, and mean that WoRMS is now regarded as the standard marine species taxonomic backbone for numerous other initiatives. It is imbedded in a lot of European and international initiatives such as e.g. LifeWatch, EMODnet, (Eur)OBIS, Catalogue of Life, Encyclopedia of Life and GBIF. WoRMS is also a key component of the LifeWatch Taxonomic Backbone, which aims to (virtually) bring together different component databases and data systems, all of them related to taxonomy, biogeography, ecology, genetics and literature. By doing so, the LW-TaxBB standardises species data and integrates biodiversity data from different repositories and operating facilities and is the driving force behind the species information services of the Belgian LifeWatch.be e-Lab and the Marine Virtual Research Environment (Marine-VRE) that are being developed.

Keywords: taxonomy; World Register of Marine Species

## DNA barcodes for fish identification: To believe or not to believe

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A popular FISH-BOL-program is actively developing as a global effort to coordinate an assembly of a standardized reference sequence library for all fish species, one that is derived from voucher specimens with authoritative taxonomic identifications ([www.fishbol.org](http://www.fishbol.org)). As a result, many authors conclude that the identifications of specimens that remain problematic for the researcher or observer after consulting the photographic guide and descriptive accounts will in most cases be enabled by DNA barcoding (Mecklenburg et al. 2016). However, there are known cases of controversial results obtained by DNA barcoding and other genetic markers, for example for the taxonomy of cods *Gadus macrocephalus* and *G. ogac* (Stroganov et al. 2011; Mecklenburg, Steinke 2015). Other types of problems are situations where barcode sequences from samples of morphologically different species exhibit little variability (0-hypothesis is not rejected), for example, in cases of Arctic cods *Arctogadus borisovi* and *A. glacialis* (Møller et al. 2002; Jordan et al. 2003) or flatfishes *Hippoglossoides robustus* and *H. elassodon* (Kartavtsev et al. 2007) and *Pseudopleuronectes yokohamae* and *P. schrenki* (Kartavtsev et al. 2007). In turn, when the 0-hypothesis is rejected and polyphyletic origins of genera are revealed, the problem of the levels of taxonomic division arises: to separate numerous independent genera/species or to unite branches in the same genus/species and accept them as subgenera (groups of related species)/subspecies. The first way, for example, is accepted for minnows of *Abramis* – *Ballerus* – *Blicca* – *Vimba* species group, and the second one for *Alburnus* – *Chalcalburnus* (Eschmeyer et al. 2018). And in the case of *Huso* and *Acipenser* (family Acipenseridae) even the third unique way to ignore both polyphyletic origins of these nominal genera and morphological evidence (Vasil'eva et al. 2009) is accepted (Eschmeyer et al. 2018).

Our common studies on genetic variation and differentiation within Ponto-Caspian shads (*Alosa*) based on a single mtDNA gene and 11 microsatellite loci suggest the lack of support for most of previously described and morphologically diverged taxa (Sotelo et al. 2012). And only more complex sequencing analyses of both mitochondrial and nuclear markers succeeded in detecting various Eurasian phylogenetic lineages in spirlins (*Alburnoides*) and gudgeons (*Gobio*) (Mendel et al. 2008; Stierandová et al. 2016). Our recent studies are related with some taxonomic problems in Ponto-Caspian gobies (family Gobiidae) and spined loaches (fam. Cobitidae). We are trying to select the most appropriate genetic markers and out-groups, and in some cases we are faced with the need to check voucher specimens for samples from GenBank dataset, but for samples that are devoid of a voucher fund it is completely impossible. And so we should collect new materials for DNA researches with voucher samples available for any verification.

Keywords: molecular genetic studies; taxonomic problems; limited resolution; voucher specimens



## Heading South or North: Novel insights on European silver eel (*Anguilla anguilla* L.) migration in the North Sea

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The European eel (*Anguilla anguilla* L.) is a catadromous fish species which migrates from coastal and freshwater habitats to the Sargasso Sea to spawn. During the last decades, recruitment of the European eel has declined by as much as 90 to 99 %, making it a critically endangered species according to the IUCN Red List. Various causes likely contribute to this decline, such as migration barriers, habitat deterioration, pollution, human-introduced parasites, fisheries and changes in ocean climate. To aid conservation and recovery of European eel stocks, the European Union adopted a Council Regulation (European Eel Regulation; EC no. 1100/2007) which imposes a management system that ensures 40 % escapement of the spawning stock biomass, defined as the best estimate of the theoretical escapement rate if the stock were completely free of anthropogenic influences. Consequently, unraveling the migration routes and determining the number of eels reaching the North Sea aids in evaluation of the regulation. However, exact migration routes and destination of European eel are still unknown. We explored European silver eel migration by acoustic telemetry in the North Sea. Within the LifeWatch observatory, a network of 163 permanently installed acoustic receivers is present since 2014 in Belgian rivers, canals, Schelde Estuary and the Belgian part of the North Sea. Cooperation between separate projects in Belgium, Germany and The Netherlands allowed us to cover a wide geographical range of this species. Eels were tagged with acoustic transmitters in four different river catchments in Western Europe and swam to the Dutch-Belgian coastal zone during their spawning migration. We are the first to observe southward migrating silver eels in the North Sea.

Therefore, we conclude that at least part of the Western European eels migrate towards the English Channel, in contrast with the Nordic migration route hypothesis (i.e. eels migrate over Scotland to reach the Atlantic Ocean). Different migration routes may have different bio-energetic implications: some routes may be energetically more demanding, leaving less energy for spawning. As such, management may need to focus more on areas where eels take an energetically favourable route and contribute more to spawning. Therefore, increasing our knowledge on marine eel migration contributes to achieving a sustainable eel stock management. The results also emphasize the importance of international cooperation in order to address these large-scale fish migration issues, and the efficacy of acoustic telemetry as a technique to track fish over large distances, including in coastal marine environments.

Keywords: European eel; marine migration; telemetry; conservation; LifeWatch

## Seascape-mediated patterns and processes of population differentiation in European seabass

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Identifying biologically relevant levels of population structure and demographically independent populations is imperative for sustainable fisheries management, but challenging because of high levels of gene flow and large population sizes leading to weak genetic structure. However, increasingly good access to genome-wide variation and architecture have facilitated accurate determination of fine scale genetic population structure. Here, we studied the population structure of European seabass (*Dicentrarchus labrax* L.), a commercially exploited and farmed fish with high dispersal capacity. In addition, we examined the influence of geographic distance and abiotic environmental variables on the observed genetic structure with a seascape genomics approach. Seabass showed a largely panmictic pattern within the Atlantic Ocean, whereas several genetic clusters were distinguished within the Mediterranean Sea based on 2,549 SNP markers genotyped using ddRAD sequencing. Introgression of Atlantic alleles was detected throughout the western Mediterranean Sea, but introgression of Mediterranean alleles was only found in a restricted area in the Atlantic Ocean off the Strait of Gibraltar. Seascape analysis suggested that genetic population structure is mediated by both dispersal limitation and environmental gradients, pointing to local adaptation. As such the study provides key information for fisheries and conservation management of European seabass.

Keywords: Atlantic Ocean; Mediterranean Sea; population genetics; seabass; seascape; SNP

## Composition of macro-infauna and their distribution across Northern Benguela upwelling system - Namibia

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Macro-infauna are among the most abundant organisms in marine ecosystems where they play a critical role in nutrient cycling, organic matter turnover, provision of nourishment to the higher organisms in the food web and maintenance of soil physical and biogeochemical structure through bioturbation. Despite their significance in marine realms, there is inadequate scientific understanding of macro-infauna diversity in Benguela Upwelling Systems (BUS) specifically across Oxygen Minimum Zones (OMZ). Three transects were chosen; Cape Frio (20°S), Walvis Bay (23°S) and Luderitz (26°S) for sampling. Sediments were systematically collected at 20°S (2nm, 20nm, 40nm), 23°S (2nm, 20nm, 70nm) and 26°S (90nm) using multi-corer where macrofauna were sub sampled using plastic corers (diameter=3.5cm; length=10cm). The samples were preserved using 5% buffered formaldehyde solution, stained with Rose Bengal (to aid in sorting) and observed under a dissecting microscope. Nematodes were the dominated organisms in macrofauna samples whose percentage ranged from 21-84.5% in all sampling stations. 20°S 40nm had the highest taxa of nematodes (751000ind-m<sup>2</sup>) an indicator of their ability to survive in hypoxic environments (0.41ml-l). 23°S 40nm sampling site was anoxic (0.148ml-l) with no recorded nematodes and annelids indicating failure of macrofauna to adapt in extremely low oxygen. Annelids (polychaetas and oligochaetas) had lower percentage than nematodes in all sampling sites showing limited ability to adapt in extreme environments. The results highlighted the adaptability of nematodes in hypoxic conditions which could have been enhanced by symbiotic relationship with sulphur reducing bacteria, *Theomargarita*. Further analysis is underway to identify nematodes to genus level (macrofauna and meiofauna samples) hence providing baseline data and adaptive mechanisms of nematodes in OMZ.

Keywords: oxygen minimum zones; macrofauna; Benguela upwelling system; nematodes

# CITIZEN SCIENCE

## New opportunities from citizen science for conservation assessments of the Mediterranean shark populations

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Sharks are among the most endangered group of animals in the world, and in the Mediterranean Sea they have shown steep declines both in coastal and pelagic ecosystems. Of the 40 species of sharks occurring in the Mediterranean Sea, 57% are classified by the IUCN as threatened (vulnerable, endangered and critically endangered), of which 30% are critically endangered. This regional status is higher than the global figure where only 16% of the species are threatened and 2% are critically endangered.

Because of their low population density, contemporary records of Mediterranean sharks are often so scattered in space and time to make these species under detectable with conventional survey records. Hence developing tools to obtain and interpret data from alternative data sources such as citizen scientist programs involving fishermen, scuba divers, sailors, surfers and other ocean users represent important opportunities for detecting increasingly rare shark species. This is the aim of the sharkPulse project, a Stanford global initiative with the scope of filling the data gap characterizing global shark abundance and distribution from sightings supported by photographic evidence. Currently, sharkPulse has worldwide aggregated over 5000 sighting records of 268 species. Here we illustrate this program for the Mediterranean Sea. We will show how this program is organized in the region and how its data can be used for conservation.

These data may update most of the IUCN sharks' assessments for rare species in the Mediterranean Sea, including up-listing 13 species from data deficient to assessed. Furthermore, old photos, like ones found in historical public or private archives, matched with historical ecology reports and museums evidence are helping us to characterize the historical occurrence of many shark populations in the region. The angel shark (*Squatina* sp.), for example, is now listed as critically endangered in the Mediterranean Sea as it has strongly declined, and in some cases disappeared from most of its historical range in the last century. Our data suggest angel sharks have still geographic strongholds in the Mediterranean and NE Atlantic. These sites could represent important conservation opportunities for preserving the last individuals of these species and planning recovery programs.

Finally, creating sighting record networks for detecting the presence and inferring the conservation status of sharks is extremely important to accelerate the conservation of this important group of marine animals both in the Mediterranean Sea and worldwide. SharkPulse is moving in this direction by building an integrated system with local national focal points and collaborating with other monitoring programs assembling shark occurrence records like the GFCM's MEDLEM (General Fisheries Commission for the Mediterranean Sea, MEDiterranean Large Elasmobranch Monitoring) project. We will illustrate an example of this integration work by showing the case of the great white shark (*Carcharodon carcharias*) currently considered critically endangered in the Mediterranean and Europe. We observe that sharkPulse is able to detect records in areas in which MEDLEM has low sampling effort and, because of its smart conception, can quickly provide updated data to the latest sightings.

Keywords: shark sightings; sharkPulse; endangered shark species; shark baselines project

## Mary, Joseph, alien species... Guess who's on the beach today? “The guardians of the coast” are back again.

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Students of the catering school “E. Cornaro”, in the framework of a project of citizen science, named “*Guardians of the coast*”, promoted by Costa Crociere foundation, in collaboration with the Robotic School, the Ligurian Fisheries and Environment Observatory (OLPA) and TLC Web Solutions S.R.L. of Genoa, have “adopted a stretch of coast” of Jesolo, near Venice, on the Adriatic Sea, to carry out monitoring and surveys. The project, allowed to collect data about fauna occurrent (*Chamelea gallina*, *Callista chione*, *Mitilus galloprovincialis*, *Donax trunculus*, *Donax vittatus*, *Ensis minor*, *Cerastoderma spp.*, *Mytilus galloprovincialis*, etc.) flora, waste (plastic), alien species; moreover it also aimed to raise awareness among students and citizens on the coastal marine environment, on pollution related problems, on the sustainable use of marine resources, because everything has repercussions on our table and on our food. In addition, attention was also focused on the sustainable consumption of fish, to limit the exploitation of the usual species, valorizing in the recipes the “poor fish” and species with low commercial value. Investigations have also highlighted social and economic aspects, related to a building development and improper exploitation of the coastal strip. The information, data and images have been collected, useful digital tools, including an application for iOS and Android devices that allowed georeferencing and the creation of maps; these data are loaded to a nationally shared open database, with students and citizens who have operated along other parts of the Italian coast. These data collected by amateur and non-professional scientists could be useful to assist professionals, in collecting information, with significant results to protect the marine environment.

Keywords: citizen science, Cornaro, guardians of the coast, Jesolo, Venice, monitoring, investigations

## Synergy between citizen science and artificial intelligence: The case study of *Grampus griseus* in the Northern Ionian Sea

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The Jonian Dolphin Conservation (JDC) is an association involved in scientific research aiming to study Cetaceans populations in the Gulf of Taranto (Northern Ionian Sea, Central-eastern Mediterranean Sea). JDC has started its scientific activities with a broad project of Citizen Science (CS), promoting since 2009 collaborative initiatives between scientists (Department of Biology, University of Bari and Institute of Intelligent System for Automation (National Research Council ISSIA- CNR) and volunteers (i.e students and citizens) on board of two 40ft catamarans specifically designed as observation platforms for monitoring dolphins and whales. Both catamarans are equipped with HD video imaging systems devoted for photo-identification study and hydrophones for bioacoustics studies. The number of boarded volunteers is about 10.000 per year and the survey effort is of about 200 days per years, with 6-7 hours per day. When an enormous amount of information was collected the organization and analysis of data request a key role by Statistics and Artificial Intelligence. In particular, as consequence of CS activities, sighting data and geo-referred photos of the Risso's dolphin *Grampus griseus* (Cuvier, 1812) have been collected in the Gulf of Taranto from 2013 to 2016 allowing to define its spatial distribution and site fidelity in the basin. Remarkably, although the Risso's dolphin is widely distributed from the tropics through the temperate regions in both hemispheres, the species is ranked as Data Deficient by IUCN Red List in the Mediterranean Sea. Thus, the need of a more comprehensive understanding of its spatial and temporal distribution and habitat use is very urgent mostly considering the requirements under the UE Habitat Directive, Marine Strategy Framework Directive (MSFD) and Maritime Spatial Planning Directive (MSPD). Citizen Science provides an opportunity to enhance long-term research, with unprecedented insights into the spatial distribution of *G. griseus* in the Northern Ionian Sea (Central-eastern Mediterranean Sea). An automated identification tool within a novel photo-identification method was applied on the Risso's dolphins, which show white scars of their dorsal fins as possible fingerprints. The tool requires no user's interaction and the system can process multiple images in a single run, overcoming the constraints of the state-of-the-art photo-identification tools. A total of 60 Risso's dolphins were identified and univocally catalogued. This result corroborates the hypothesis of a resident population of *G. griseus* showing site fidelity in a relatively restricted area of the Gulf of Taranto. The availability of this promising identification tool make possible the challenge of understanding the migration pattern and residency of the Risso's dolphins within the Mediterranean Sea and on global scale. As a result, the citizen science is a cost-effective means of carrying out broad scale cetaceans monitoring and represent an essential milestone to raise awareness on the marine biodiversity in terms of ecosystem services and socio-cultural heritage provided.

Keywords: citizen science; artificial intelligence; photo-identification; Risso's dolphin

## Web Ecological Knowledge (WEK) – A still neglected scientific opportunity

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Besides people who voluntarily participate in marine conservation or monitoring programs (i. e., *citizen scientists*), there are millions of internauts who unintentionally publish information about the distribution of marine species in the World Wide Web (WWW). These data are scattered among websites or social network pages of dive centres, underwater photographers and scuba divers. This information could be gathered to integrate or cross-validate scientific data, to support scientific analyses and to inform decision makers for management purposes. All the ecological information contained in the WWW and exploitable for scientific purposes will be here termed as Web Ecological Knowledge (WEK).

The WEK is constantly fueled by internauts, representing a free, refreshable, long-term exploitable reservoir of information.

Particular attention should be given to underwater videos published on the WWW, which can provide additional information allowing i) to extract abundance and distribution data of target species at local scale, ii) to detect temporal changes of seascapes in the most popular dive sites, iii) to find unexpected interactions between conspicuous species, iv) to locate particularly vulnerable sites, v) to detect the presence of lost fishing lines and damaged organisms, all this without the costs of a true field expedition. Videos are useful to establish which areas should be monitored by scientists due to their richness in species biodiversity and vulnerability. Since videos may provide additional information compared to photographs and visual observations, simple protocol standards for video recording should be included in marine *Citizen Science* programs (CS) to train non-professional underwater video operators. Moreover, crowdsourcing initiatives could be promoted to invite scuba divers to add date, coordinates and depth to their videos. Videos by trained amateurs should be shared on the WWW to be freely available to scientists. A georeferenced archive linking of underwater videos potentially useful for scientific purposes may help in finding information on species distribution.

Here, we want to highlight the huge potential of data shared on the WWW to integrate marine sciences even in case of little funding for fieldwork. Since many dive spots are mostly frequented by recreational divers rather than academics, it is more likely that non-scientific divers were in the right place at the right time to unintentionally record species, peculiar behaviours or responses to unpredictable disturbance events. This is an opportunity already exploited through different initiatives on land. For this reason, the diving system could address specific commercial strategies focused on the potential of CS projects.

Keywords: Web Ecological Knowledge; WEK; occurrence records; social media; WWW; crowdsourcing; data sharing; open access



## Citizen science and local ecological knowledge in fishery and ichthyological research in the eastern Adriatic Sea

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In the last decades, we are witnessing a broad array of biodiversity changes occurring in the Adriatic Sea. These changes are a consequence of a variety of factors, but climate change and various anthropogenic activities are the greatest threat to biodiversity of the Adriatic Sea. Changes are diverse and are happening on a broad temporal and spatial scale. Researchers are few and are sometimes unable to adequately investigate these issues using traditional data collection methods. In the world of fishes, we are witnessing phenomena such as bio-invasion, tropicalization, meridionalization, overfishing and others. To enhance our data collection capacities, we are using all possible means to expand the pool of data collectors. In the last decade we have tried to raise awareness of the issue of invasive and alien fish species; we have engaged citizens to help us in the effort to detect occurrences of certain species; through various projects we have had the opportunity to approach fishermen directly and to encourage them to bring to our attention occurrences of unknown and rare species; we have used various media channels to pass on the important information about toxic species etc. For the last two years, we have been engaged in large-scale survey of local ecological knowledge (LEK) through which we have gathered precious information on the current status of Adriatic ichthyofauna and fishery related information and changes they are subjected to. The data, along with other data gathered through various scientific surveys, is helping us to form a more complete picture of changes occurring in the Adriatic Sea. Here we present the most notable efforts in citizen science and local ecological knowledge as tools in biodiversity research in the Adriatic Sea.

Keywords: local ecological knowledge; citizen science; fisheries; invasive fishes

## Can data collected in the Citizen Science project EduMar be used to monitor coastal marine biodiversity in Portugal?

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In a climate change scenario, it is important to aware society for the need to protect marine species biodiversity and to ensure its sustainability. Therefore, the project EduMar/EduSea (Educate for the Sea) is being developed in Portugal aiming to educate students (elementary and middle school) for the preservation of the sea and its resources through citizen science. More than 300 students are participating in a set of interdisciplinary science activities focusing on learning the causes and consequences of climate change in ecosystems of the intertidal rocky shores and acquiring skills to identify and report on site a set of bio-indicator and common rocky shores species. At Avenças Beach, Portugal, using the iNaturalist app, students are mapping those species, gathering data to help researchers better monitoring the coastal marine biodiversity and understanding how climate change may affect that biodiversity. We will present data collected by these students analysing its quality for research purposes. We will also share our experience with such young citizen scientists and the best practices learned for future design of similar projects.

Keywords: citizen science; education; marine biodiversity; climate change

## BLUE SMART: Blue education for sustainable management of aquatic resources

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The development of sustainable fisheries and aquaculture is one of the strategic guidelines of the development of fisheries sector in the Republic of Croatia. In the Operational Programme for support of the European Maritime and Fisheries Fund in Croatia there is an estimation of roughly 25 000 people employed in this sector in Croatia. More specifically, around 30% of these employees work in the fisheries sector in Zadar County. Being a strategic sector of the County's development, fisheries and aquaculture are very often marked in the relevant local and national strategies as an emerging sector with a very high potential for growth and jobs. This brings the urgent need to create new workforce on the labor market, capable of supporting the further development of the blue sector in Zadar County and Croatia in general. Hence, the project "Blue Education for Sustainable Management of Aquatic Resources - BLUE SMART" was applied and positively evaluated through the call: Blue Careers in Europe, within European Maritime and Fisheries Fund- EMFF (Executive Agency for Small and Medium-sized Enterprises- EASME). BLUE SMART project started on 1<sup>st</sup> January 2017 and will finish on 31<sup>st</sup> of December 2018.

The general objective of the BLUE SMART project was to create new skills and competences in blue economy sector and increase the employability of current and future sectors' workers in the County of Zadar. First specific objective was to create conditions for training of a new generation of students and professionals equipped with the appropriate skills to match the needs of the industry. This specific objective has been achieved by creating conditions for the establishment of a new graduate (Master) study "Sustainable Management of Aquatic Ecosystems". The idea for such graduate study in sustainable management of water ecosystems was greeted both from the local companies and undergraduate students. Second specific objective was to provide people already working in the field with the new skills required, which will be achieved by design of a Training Course for the Vocational Education and Training in "Introduction to sustainable fisheries practice". The Training Course will retrain and upskill workers employed in blue economy or other sectors and/or people currently unemployed for a job in the blue economy, as well as diversify and expand the skills of people currently employed in the blue economy to progress in their career and/or to facilitate their mobility to other maritime jobs.

Keywords: fisheries; aquaculture; Zadar county; sustainable management; aquatic ecosystems

## A century of marine citizen science

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In November 2015, whilst walking along a beach in Germany, a retired postal worker became part of a 108-year-old citizen science initiative launched by George Park Bidder of the Marine Biological Association (MBA). She found what transpired to be the world's oldest message in a bottle. Released by Bidder into the North Sea in 1906 to help map ocean currents and predict the natural dispersal of fish larvae.

Established in 1884 the MBA is one of the world's longest-running societies dedicated to promoting and undertaking research into our oceans and the life they support. Throughout its history, the MBA has involved the community in its research, and carried out what is now commonly called citizen science.

Initiatives such as the Shore Thing Project, BioBlitz, Crab Watch, Sealife Survey and others continue to engage the public in collecting data to support scientific study and the management of marine activities. We present the journey from early MBA 'citizen science' initiatives to recent and current projects. Focusing on scientific outputs and how approaches have responded to a rapidly changing world.

Keywords: citizen science; fish stocks; invasive species

## What can we do for you? A citizen science project around the world aboard a 10m sailing boat

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A modern Beagle does not need to be very big. It's aboard a 10m classic sailing boat that Anaïs and Marco, an evolutionary biologist and a professional sailor, will set out in 2020 to sail around the world. Sadly, Starnakel is too small for you to embark with us... but perhaps your research project can?

In this poster we'll introduce you to who we are, to our boat, our itinerary, and to the opportunities and constraints such a voyage presents for conducting scientific research and sampling.

In return we hope you'll introduce us to your research topic, your needs, and how we could maybe collect some useful data for you.

The poster will also present what Citizen Science projects and punctual research collaborations we have identified or participated in so far.

Keywords: benthic habitat; demersal fisheries; ecosystem effects; fishing impacts; mechanical disturbance; seabed sediments; trawling

## From collecting data to the development of marine environmental status monitoring tools: The new level of Citizen Science

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In recent years the involvement of citizens in environmental monitoring has increased worldwide. Citizen science (CS) projects on marine environment have spread up from tropical coral reefs to temperate habitats. Besides its relevant role in environmental education and increase people awareness, the advantages of CS approach lie in expanding our ability to collect information and data in space and time, in the face of limited investments.

Since 2006, trained scuba diver volunteers are collecting data on the distribution and abundance of 43 easily identifiable selected key marine species along the coasts of the Mediterranean Sea, by applying the Reef Check Mediterranean Underwater Coastal Environment Monitoring (U-CEM) protocol ([www.reefcheckedmed.org](http://www.reefcheckedmed.org)). The growing need to assess the environmental status of Mediterranean habitats and the large availability of data collected by Reef Check Mediterranean volunteers along subtidal rocky habitats suggest the possibility to develop innovative and reliable biotic indices that may support decision makers in applying conservation strategies, especially in Marine Protected Areas (MPAs). The proposed Reef Check Mediterranean Species Sensitivity (**MedSens**) index is based on U-CEM data and on the sensitivities of the selected species toward the disturb agents indicated by the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Species sensitivities were assessed following the Marine Evidence based Sensitivity Assessment (MarESA; [www.marlin.ac.uk](http://www.marlin.ac.uk)) approach, developed by the Marine Life Information Network of the Marine Biological Association of the UK. This approach takes into account both the resistance and resilience of the selected species against each considered pressure, which are defined according to benchmark levels and detailed literature review.

**MedSens** index provides the mean sensitivity of the surveyed assemblages towards three main categories of human (physical, chemical and biological) pressures. The greater the average sensitivity of the assemblages, the lower is the extent of the disturbances to which they are subjected. Coastal marine assemblages rich in sensitive species provide evidences of a good environmental status, as required by the MSFD. This index may help not only to assess the environment quality status but also to identify the most likely sources of disturb acting in the study area.

**MedSens** index can be easily calculated by scientists and managers in each area and period of interest by using the open access U-CEM data and a plugin developed for the QGIS platform, a free and open-source desktop geographic information system. This allows a large amount of biological information, gathered by volunteers, to be synthesized and made available for scientific and management purposes. Thanks to **MedSens**, the Reef Check Mediterranean project can provide a real contribution to marine biodiversity conservation, a new step forward for the citizen science.

Keywords: coralligenous habitats; rocky bottoms; biotic indices; anthropogenic impacts; geographic information system; Mediterranean Sea

## Capturing our Coast – Communications and key messaging to engage and retain citizen scientists over a three-year project

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One of the biggest challenges of citizen science programmes once participants are recruited, is keeping them motivated to collect data and stay involved for the duration of the project. A strategic, innovative and integrated communications strategy that adapts as barriers and successes are identified, is vital in achieving this.

Capturing our Coast (CoCoast) is a three year UK-wide project furthering understanding of intertidal marine life around the coastline by working with citizen scientists to collect biological data. CoCoast has successfully created a skilled and passionate community, training 3,000 people in intertidal survey techniques and engaging hundreds more through simple activities open to all. Delivered through a national collaboration of eight key partners (universities, NGOs and research institutes), the project is underpinned by a multi-level volunteer engagement strategy and key messaging designed to maximise and standardise the participant experience. The strategy is responsive to change as the project develops and becomes more informed about what works and what does not. At a regional level, communications and events are tailored to fit local community demographics and interests, whilst nationally, incentives campaigns encourage participation by targeting specific groups.

Components include a strong training and support programme, website, regional and national communications, social media and regional social events. The website (~300 user logins per month) provides everything a volunteer needs in one place, including resources, a data entry portal, event information, national campaigns and project updates. Similar information can also be accessed through Facebook pages (>2,650 followers) and Twitter (>3,600 followers), which are open to everyone. Once signed up and allocated to a hub, participants receive frequent and personalised communications from them, as well as centralised national newsletters and, in the final year, feedback on research results.

In addition to core project activities, a suite of 'lite' national survey campaigns which require no training, such as "Spermwatch" and "Marine Invaders", have provided a range of entry points for engagement. Many are packaged as fun search activities with a focus on discovery and enjoyment whilst still producing valuable data. Novel naming and targeted regional promotion of campaigns has captured media attention and raised the public profile of the whole project.

This integrated communications and engagement strategy, responding to the needs and motivations of our participants, generates both a feeling of belonging to a local project through close connection to a hub and plenty of face to face opportunities with the scientists, whilst still being part of a bigger picture.

This framework provides a multitude of opportunities to motivate participants, from gamification and competition incentives, to enabling them to recognise their share in the overall successes of the wider project.

The communications strategy as a key element in the success of CoCoast will be discussed, alongside lessons learnt, legacy and the future. Furthermore, the talk will discuss how, through an external evaluation process, detailed data is being gathered to evaluate project success and identify ways to increase the overall impact with regards to participation levels, participant enjoyment and for the benefit of marine science.

Keywords: citizen science; coast; intertidal; rocky shore; communications; engagement; motivation; public participation; volunteer



# GENERAL SESSION

## Do moonsnails shape the population dynamics of Baltic clam at subarctic White Sea?

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It is generally recognized that abiotic factors predominates in shaping community structure and dynamics in harsh conditions of high-latitude marine habitats. Thus system productivity seems to be of first importance in community regulation. Nevertheless, a little is known about keystone predator species in subpolar regions, so a bias may occur in evaluating the role of top-down processes in communities. A survey of traceable predation is extremely useful to fill such a gap of knowledge since the effect could be directly observed in natural conditions. A 15-year long-term study of population structure and dynamics of Iceland moonsnail *Amauropsis islandica* (predator) and Baltic clam *Limecola* (*Macoma*) *balthica* (prey) populations at two intertidal locations in the subarctic White Sea (Russia) as well as caging experiment were performed to define predator-prey interactions. Analysis of both data sets showed that *Amauropsis* performs size-selective and ontogeny-shifted predation upon *Macoma* on the White Sea sandflats. By applying the additive modeling (GAMM), we found the strong relationship between the mean size of *Macoma* on the tidal flat and the shape of *A. islandica*'s shell size frequency distribution observed in previous year. Therefore, a certain effect of predator upon otherwise quite unpredictable clam dynamics was considered.

The project was partly supported by the RFBR grant 18-34-00405 and by the ongoing Program of the Russian Academy of Sciences "Functioning and dynamics of subarctic and Arctic marine ecosystems" (AAAA-A17-117021300220-3).

Keywords: top-down regulation; predator-prey interaction; traceable predation; *Amauropsis islandica*; *Limecola balthica*; *Macoma balthica*; intertidal; White Sea; resources

## Space-time distribution of microplastics in the neuston around the Salento peninsula (Central Mediterranean Sea)

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Due to the difficulty to carry out repetitive investigations in the open sea, biological studies are commonly limited to few or single dates in sample collections.

This is particularly true for studies on neuston that historically have never relied upon repetitive sample collections. Two oceanographic cruises (2013, and 2015) in the central Mediterranean Sea represented the occasion to compare situations at different seasons and years. Successively (2017), also programmed collections have been carried out in selected sites around the Salento Peninsula (South East Italy, Central Mediterranean Sea) with the aim to obtain a more reliable indication on the distribution of the neustonic microplastics in time and space. Timely repeated collections of neuston in one site (station: Arpa 1) for a solar year, and spatially repeated collections in another site (station: Otranto) on a single date, together with data coming from preceding collections in the same area, allowed to establish that the presence of microplastics is constant in all the samples, although extremely variable in abundance and typology. Types of plastic materials were dominated by Poly Ethanol PE polymers on a total of 9 categories. The Salento peninsula has not rivers, thus it is not responsible of important litter outflow into the sea around. Most of plastics, consequently, have to come from elsewhere. Microplastics appear more abundant in neuston during summer-autumn than in winter (station Arpa 1, 4 collections). At the site Otranto (3 samples collection, at 1, 3, and 6 miles offshore), the concentration of microplastics grows with the distance from the coast. The lacking of important local sources suggests that the sampling effort must be enhanced and/or prolonged before to discuss these indications with the complex frame of environmental parameters, surface currents, wind regimes, and degradation processes.

Keywords: microplastics; neuston; Mediterranean Sea

## European Marine Board expert working group's recommendations to strengthen Europe's capability in biological ocean observations

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Biological ocean observations, in addition to current physical and chemical observations, are necessary to help understand the structure and functioning of marine ecosystems, to determine patterns and trends of biodiversity and to be able to inform the sustainable use of the ocean's living resources. Only by integrating sustained biological observations within monitoring programs, it will be possible to understand our changing oceans and to implement flexible management strategies that will adapt to evolving scenarios of societal and environmental change. The biological Essential Ocean Variables (EOVs) of the Global Ocean Observing System (GOOS), and the marine Essential Biodiversity Variables (EBVs) of the Group on Earth Observations Biodiversity Observation Network (GEO BON), are welcomed initiatives towards this integration.

Enhanced biological ocean observing capacity is needed to strengthen the European vision of marine biodiversity conservation and to fulfil the European Union goal of "Good Environmental Status" for all its marine waters, as stated in the Marine Strategy Framework Directive and other legislative initiatives seeking a healthy and sustainable managed marine environment. As most of the observing requirements in Europe have regional scale characteristics, observing networks must be sustained and adjustable to the observing requirements. Technological progress will allow for flexible approaches, improving existing observing methodologies and broadening the scope and range of variables that can be measured.

A long-term, large-scale integrative biological observing system spanning over both oceanic and coastal systems is of fundamental value in expanding knowledge of the world in which we live and in the context of current shorter term fluctuations. Observation networks will also fulfil a critical strategic need for predictions and a more informed basis for environmental policy to safeguard our natural heritage and to guarantee the sustainable use of ocean living resources by multiple users and stakeholders, bringing benefits now and for future generations.

Keywords: biology, observations, monitoring, EOOS, EOVs, EBVs

## Contrasting adaptations in shallow and deep-sea bivalves from East Atlantic: transcriptome-wide analysis

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Bivalve molluscs play a significant role in nearshore reef ecosystems and constitute one of the dominant groups of macrofauna in the deep sea. In European waters, several intertidal bivalves including *Limecola (Macoma) balthica*, *Mya arenaria* and *Mytilus edulis* are widely presented in upper sublittoral communities. Typical subtidal species, particularly *Arctica islandica*, *Hiatella arctica* and *Mya truncata* occur from low tide level mark down to bathyal zone. Next-generation sequencing has recently catalyzed studies of local adaptations by obtaining a large number of co-dominant genetic markers, even when no reference genome is available. We used whole body transcriptomes of common bivalves inhabiting contrasting environmental conditions, available from GenBank SRA database. Comparison of transcriptomes of phylogenetically close taxa showing contrasting adaptations, or phylogenetically distant taxa with similar adaptive traits allows to reveal convergence and parallelisms at the molecular level. This approach allows to test the hypothesis of the origin of mutations that lead to similar phenotype effects, and reveal the velocity at which mutation in the DNA may cause a phenotypic effect. Transcriptome-wide scans for common genes under selection were implemented by using the standard pipeline with estimation of dN/dS ratio in ortholog genes of studied species and computation of GO terms (Gene Ontology terms) enrichment. Ortholog genes were identified with protheintho program and dN/dS values were determined in PAML codeml program for each orthogroup. GO enrichment analysis was performed with Webgestalt software. The results of comparative transcriptome analysis led to the identification of candidate genes responsible for intertidal, upper sublittoral and shelf habitat adaptations in common European marine bivalves. The research was supported by the RFBR 18-34-00572, RAS research projects AAAA-A17-117042410167-2 and AAAA-A17-117030310207-3, Programs of Presidium RAS "Dynamics of gene pools in natural populations" and "Development of vital and biosphere processes".

Keywords: bivalvia; subtidal; adaptation; RNA-seq

## Diet and feeding behavior of the sand sole (*Solea lascaris*, Risso 1810) in Central Atlantic coast of Morocco

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During winter 2016, 124 fish of the sand sole (*Solea lascaris*) were sampled in four different area of the Central Atlantic coast of Morocco. The diet behavior was studied by the evaluation of the percentage of numerical (Cn) and gravimetric (Cp) abundance of preys for both age (length ranges) and sex. The result shows a high diversity of benthic preys. The relative importance composition of preys notice high abundance of three Major taxa, Decapoda (Cn:25.63%, Cp:32.10%) Polychaeta (Cn:12.81%, Cp:21.20%) and Bivalvia (Cn:22.28%, Cp:22.61%). Moreover, we observe the effect of sex and age in the diet behavior of the sand sole.

Keywords: diet; sand sole; *Pegusa lascaris*; Central Atlantic; Morocco

## Is the French Mediterranean European pilchard crisis related to their diet?

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During the last decade there has been a decrease in landings, biomass and body condition of planktivorous fish in the north-western Mediterranean Sea. This induced major fisheries crisis related to commercial European pilchard (*Sardina pilchardus*). A merging hypothesis is that this may be related to changes in their diet (Le Bourg et al., 2015). Moreover, these planktivorous species play a key role in the food web channeling the organic matter from plankton to higher predators also targeted by fisheries.

The aim of our research was to study the temporal variability of the European pilchard's diet in term of species composition, size and energetic quality (proteins, carbohydrates, lipids) related to plankton composition.

The analyzed individuals were collected in the Bay of Marseille by local fishermen from October 2016 to July 2017. The stomach contents were compared to the plankton collected by 80 µm mesh size nets. Main prey were copepods: *Clauso/Paracalanus* spp., *Microsetella* spp., Corycaeidae and Oncaeidae. Our results showed a particularly selective feeding behavior for the European pilchard mainly for the most energetic **plankton groups** (and **sizes**) with **the highest** percentages of proteins.

However, European pilchard continues to consume small prey and their condition remains low compared to recent studies (Le Bourg et al., 2015). Why is European pilchard consuming small prey? Are large size copepods that they used to eat actually missing from the plankton community? Does this diet change have to do with the monthly variations of environmental parameters?

This preliminary work will be continued over time and completed by the study of other species of planktivorous fish, as well as by the analysis of stable isotopes. This will lead to hypotheses about the role of fluctuations in plankton composition and abundance as well as its nutritional quality on diet and body condition of planktivorous fish.

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Keywords: French Mediterranean; European pilchard; plankton composition; biochemical analyses of plankton; monthly variation; trophic interactions; stomach contents

## Phytoplankton response to anomalous physical-chemical conditions in the Gulf of Trieste (Northern Adriatic Sea)

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We studied the influence of anomalous meteorological and hydrological conditions that occurred in the Gulf of Trieste from March 2006 to February 2007 on phytoplankton structure and function. We computed monthly mean (or median) air temperature, total precipitation, wind speed, river discharge, seawater temperature, salinity, photosynthetic available radiation (PAR), cyanobacteria, nano- and microphytoplankton abundances during the study year and compared them to climatological (1999-2014 for PAR; 1999-2007 for nanophytoplankton; 1998-2015 for the other variables) mean/median data. We then related the cyanobacteria (0.2-2  $\mu\text{m}$ ), nano- (2-20  $\mu\text{m}$ ) and microphytoplankton (20-200  $\mu\text{m}$ ) of the study year to inorganic nutrient concentrations. Median river inputs in October and November were 9- and 15-fold lower, respectively, than the time series medians, with consequent high salinity from May to November (up to +1.26 compared to the climatological data). Monthly mean seawater temperatures were lower than the climatological values (-2.95 °C at the surface) from March to August 2006 and higher (+2.15 °C at the surface) from September to February 2007. Reductions in freshwater input and nutrient depletion were likely responsible for a decrease in microphytoplankton (median annual abundance over 60% lower than the climatologic median) and cyanobacteria (up to 47% lower than the climatology). Significant seasonal differences in cyanobacteria and microphytoplankton abundances ( $R_{\text{ANOSIM}} = 0.52$ ;  $p < 0.05$ ), as well as in seawater temperature and salinity ( $R_{\text{ANOSIM}} = 0.73$ ;  $p < 0.05$ ) between the study period and the climatology were highlighted. The late spring diatom bloom was not reflected in high photosynthetic rates whereas an unusually high primary production was estimated in November ( $7.11 \pm 1.01 \mu\text{gC L}^{-1} \text{h}^{-1}$ ), when a mucilage event occurred due to very stable atmospheric and oceanographic conditions. The typical seasonal succession of pelagic phototrophs (micro-, nanophytoplankton and cyanobacteria) was altered since an exceptional cyanobacteria bloom first developed in April, followed by a delayed diatom bloom in May. The reduced availability of phytoplankton biomass had several repercussions on both the pelagic and benthic trophic webs.

The Gulf of Trieste may be considered a natural megacosm due to its peculiar geomorphologic characteristics and we believe that the structural and functional response of phytoplankton to anomalous physical-chemical conditions observed in this area may have broader implications and could be extended beyond the geographical limits of this particular ecosystem.

Keywords: microphytoplankton; nanophytoplankton; cyanobacteria; primary production; river discharge; extreme meteorological event



## Trophic subsidy through ecosystems: role and dynamics of nearshore subtidal detrital accumulations of *Laminaria hyperborea*

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Kelps are major foundation species that support one of the most productive habitats in coastal environments (1-2 kgC.m<sup>2</sup>.yr<sup>-1</sup>). Despite kelp forests being extensively studied in term of biodiversity and ecological functioning; the area of influence of such productive ecosystem is largely underestimated and remains little-understood. In Europe, the dominant kelp species, *Laminaria hyperborea*, is not hardly influenced by grazing and a major part of the biomass is exported via erosion, old-frond detachment or dislodgment. Kelp accumulations are observed on the coast as beach wracks but also offshore in benthic habitats where debris settle depending on topography (depressions, canyons) or current. Kelps supply adjacent habitats in organic matter and constitute a source for external food webs. “Hotspots” of secondary benthic production arise when detritus accumulates. To describe the degradation dynamics of *L. hyperborea* accumulations and to investigate the role played by the debris in structuring adjacent habitats and benthic communities, two six-month litter-bag experiments have been deployed *in-situ*. We used a multidisciplinary approach combining community ecology, trophic ecology (stable isotopes), biochemistry (chemical defenses), physiology (PAM and respiration proxy) and microbiology. According to the experimental depth, *L. hyperborea* degradation is a slow process leading to an average biomass loss of 15%.month<sup>-1</sup>. The large fragments remain visually fresh and respond to light stimuli (PAM) after 5-6 months of degradation. These results suggest that *L. hyperborea*, even dislodged and exported could still fulfil the primary-producer function after several months. At the same time, kelp tissues are rapidly colonized by macrofauna and a relatively complex multitrophic ecological succession develops after 3-4 months. Kelp forests are important habitat modifiers and through the process of export and accumulation can impact a variety of subtidal ecosystems.

Keywords: kelp beds; degradation; production; connectivity; stable isotopes

## Photoacclimation of Prymnesiales (Haptophyta) species to different light quality conditions

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Light conditions under water vary considerably in terms of both quality and quantity due to the depth with the wavelength-dependent extinction coefficients, the weather with clouds passing over, the day length and other factors. The photoacclimation response aims to balance the light-harvesting and the photoprotective capacities together. Therefore, it participates in the competitive ability of a species through the growth and the survival and plays a substantial role in the presence or absence of a species in a determined habitat. This process involves different chemical and or biological modifications depending on the timescale. In fact, photoacclimation processes are sorted into two categories depending on their short- or long-term dynamics. For example, at long term occur changes in the structure and the composition of both photosystems I and II and particularly at the pigment level, whereas the xanthophyll cycle is activated at short term with the associated non-photochemical fluorescence quenching. Haptophyte algae are interesting as they present a huge variety of pigments with light-harvesting or photoprotective properties. The light-harvesting pigments consist of chlorophyll a, different chlorophylls c such as Chl *c1* and MV-Chl *c3* as well as fucoxanthin pigments such as 19'-hexanoyloxyfucoxanthin and fucoxanthin. The xanthophyll cycle in haptophytes has a photoprotective role and is based on a one-step enzymatic de-epoxidation/epoxidation reaction between two molecules called diadinoxanthin and diatoxanthin. In the nature, the pigment set of a cell changes to cope with the environmental constraints such as the available light in order to maximize its activities, including photosynthesis. This project aims to determine the adjustment of the pigment pool in Prymnesiales to different light quality conditions and observed changes could be related to the light environment in coastal and open-ocean waters, which usually display spectra richer respectively in green and blue wavelengths. In order to study this subject, a range of Prymnesiales species representing different pigment types were grown under different light spectra through white fluorescent light as well as white, red, blue and green LED lights. Subsequently, HPLC analyses were performed to determine the presence as well as the amount of extracted pigments from the algae harvested at the end of the exponential phase.

Keywords: Haptophyta; Prymnesiales; pigments; light quality

## *Cymodocea nodosa* performance under stress from fish-farming in the Aegean

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Seagrasses are highly important species in coastal ecosystems, providing a raft of services which include carbon storage, sediment stabilisation and habitat creation for other organisms. This work investigates the sometimes fragile relationship between marine environmental health, and commercial scale aquaculture. Fish farming is an important industry in Greece, where fish are produced both for export and local consumption. However, nutrient enrichment from fish farms has been associated with deteriorating environmental conditions.

This research set out to determine the nutrient enrichment effects from fish farm effluents on the growth dynamics and metabolism of the seagrass *Cymodocea nodosa*. As part of the TAPAS Horizon 2020 EU funded project, our sampling location was in the Argolikos bay, Eastern-Peloponnese. We sampled patches of *C. nodosa* close and far from a fish farm, and carried out seasonal sampling in June 2017 (summer) and March 2018 (winter). Samples were collected by scuba diving, where at each seasonal campaign we collected above and below ground seagrass biomass. Later in the lab we applied reconstruction techniques to determine growth dynamics over time. Water column, pore water and sediment samples were also collected and filtered in the field for nutrient analyses. Finally, we also immediately processed the youngest *C. nodosa* leaves, rhizomes and roots (frozen in N<sub>2</sub> (liq) and later freeze dried) for analysis on nutrients and key metabolites.

We measured the structural variables of *C. nodosa* patches (density, growth dynamics), the physiological characteristics of *C. nodosa* (nutrient content, metabolites) and finally biogeochemical variables of the water column and sediment. Metabolomics analyses allowed us to detect if *C. nodosa* patches were stressed by fish farm effluents and allowed us to determine the level of strain on the immediate environment. Analysis of growth enabled us to see if *C. nodosa* growth was deteriorated close to the farm, or alternatively whether it proliferated due to high availability of nutrients.

Keywords: seagrass; fish farming impacts; environmental impact; omics

## JPI Oceans - The Joint Programming Initiative Healthy and Productive Seas and Oceans

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The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) is an intergovernmental initiative launched by the Council of the European Union in 2011 to provide a strategic policy platform for a long-term European approach to marine and maritime research and technology developments. JPI Oceans currently brings together 21 European countries (representatives from ministries and research funding agencies), who invest in marine and maritime research and covers all European sea basins.

JPI Oceans adds to the value and impact of national R&D and innovation investments by:

- aligning national policy priorities, strategies, policies, competences and programmes;
- driving scientific excellence through mission oriented joint actions;
- building trust and encouraging new forms of collaboration and partnership between local, regional, national and European policymakers, research funding agencies, research performing organizations, international initiatives and other stakeholders;
- fostering and testing new cooperative tools and innovative approaches and science-policy cooperation with stakeholder involvement to translate science into policy.

JPI Oceans has launched a number of actions, above and beyond joint calls for proposals, testing different approaches and new collaborative tools that are fit for purpose and working towards the alignment of national programmes. In each action, one or two countries take the lead, driving the process in partnership with the other participating countries.

Current actions include:

- **Ecological aspects of microplastics:** JPI Oceans has mobilized funding of €7.7M from 10 countries for a joint call to address this emerging issue.
- **Technology and Sensor Developments MarTERA ERA-Net Cofund:** JPI Oceans has supported a new ERA-Net Cofund on maritime and marine technologies and Blue Growth, which launched its first call (€30M) in December 2016.
- **Blue Bioeconomy ERA-Net Cofund:** through JPI Oceans, and in collaboration with ERA-Nets COFASP and MarineBiotech, 22 funding agencies from 17 member countries have announced the ambition to commit around €30M to fund research and innovation that will support the development of a sustainable and climate-friendly blue Bioeconomy.
- **Ecological aspects of Deep Sea Mining:** for the second phase of the action, 5 JPI Oceans member countries launched on 1st August 2017, a joint call (€6M) on Impacts of Deep-Sea Nodule Mining with possible in-kind contributions from other countries.
- **Munitions in the Sea:** providing scientific support to agencies addressing these risks, assessing available and new detection technologies and exchanging knowledge and practices.
- **Intercalibration for the EU Water Framework Directive:** proving comparability of assessment methods in different countries, by engaging experts, increasing experience with joint data collection and analyses and providing cost-efficient scientific support to policy.
- **European Marine Sensor Calibration:** pursuing metrological sound ocean measurements and instruments capable of continuous operation within known parameters during prolonged deployment in harsh conditions.
- **Food and Nutrition Security:** JPI Oceans cooperates with JPI FACCE and JPI HDHL towards the launch of a Knowledge Hub.

Keywords: JPI Oceans; alignment national programmes; joint actions

## The European Ocean Biogeographic Information System (EurOBIS) and its relation with international data systems

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The European Ocean Biogeographic Information System – EurOBIS – is an online marine biogeographic data system compiling data on all living marine species. The main aims are to centralize the largely scattered biogeographic data on marine species collected by European institutions and to make these data freely available and easily accessible. EurOBIS continues to grow through voluntary data contributions from the marine scientific world. Currently, EurOBIS consists of more than 850 datasets, representing over 20 million distribution records.

All data in EurOBIS are subject to a number of quality control procedures before they are made available online, assuring a minimum level of quality necessary to put the data to good use. These quality control steps are embedded in online web services available through LifeWatch and encompass a taxonomic, geographic, outlier and data format check. Several data systems developed and maintained at the Flanders Marine Institute (VLIZ) are involved in these checks, such as the World Register of Marine Species and Marine Regions.

On a European level, EurOBIS intensively collaborates with the Biological Lot of the European Marine Observation and Data Network (EMODnet). While EurOBIS is the data engine for EMODnet Biology and is investing in the development of relevant analysis tools and applications, EMODnet Biology is developing new data products illustrating the temporal and geographic variability of European marine species having high environmental relevance based on EurOBIS data.

EurOBIS also plays an important international role. As a regional OBIS node, it shares all its data with OBIS. EurOBIS is also a key component of the LifeWatch Taxonomic Backbone, which aims to (virtually) bring together different component databases and data systems, all of them related to taxonomy, biogeography, ecology, genetics and literature. By doing so, the LW-TaxBB standardises species data and integrates biodiversity data from different repositories and operating facilities and is the driving force behind the species information services of the Belgian LifeWatch.be e-Lab and the Marine Virtual Research Environment that are being developed.

Data collected for biological studies however often include more than just the biological parameters such as presence or abundance. Data collected at the same time can include physical and chemical measurements, which can provide insights into the environmental conditions the species live in. Details on the nature of the sampling methods, equipment used and effort can also be of major importance. The EurOBIS database is fully compatible with the newly established OBIS-ENV data format, allowing easy capture of such related data.

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Keywords: biogeography; LW-TaxBB; species distributions; environmental data

## Statistical properties of alternative methods of fish abundance assessment in baited, remote, underwater video

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Baited Remote Underwater Video (BRUV) is an emerging modern technique for non-destructive monitoring of fish populations for stock assessment and basic ecological research, and has been shown to have greater statistical power than commonly used destructive methods for detection of moderate changes in fish population density in time or space. However, for many fish species the variance in abundance can be volatile, making estimates of mean abundance for some economically important species uncertain, and changes in mean abundance difficult to distinguish from changes in its variance. This problem is compounded by the method for estimating abundance in BRUVs: namely finding the quantity MaxN, which is the maximum number of fish visible in the field of view in a single frame of video. This quantity may be biased downward in some species caused by the limited field of view, and is expected to have a higher sampling variance than the true number of individuals near the bait since there is an additional methodological variance caused by subsampling of those present individuals within the viewfinder of the camera. An alternative method of estimating BRUV species abundance is to model the time of arrival of any number of individuals of a given species to the camera. Time of first arrival is expected to be negatively correlated with abundance within a random-walk model of fish movement, and the variance properties of this measure can be adjusted by choice of the number of arrivals used in the calculation of arrival time. This method has the advantage of easier and faster video analysis, and potentially lower sampling variance than MaxN due to greater flexibility. Based on a sample of BRUV deployments in central Croatia using processed sardine bait and a stereo GoPro camera system, we calculate sampling variance of time of first appearance and its covariance with MaxN for common species *Chromis chromis*, *Coris julis*, *Serranus scriba*, *Diplodus annularis*, *Diplodus vulgaris*, *Diplodus sargus* and *Sparus aurata*. We find that sampling variance for time of first appearance (T1) can be lower than that for MaxN, resulting in higher statistical power in detecting differences in mean abundance, and T1 is significantly correlated with MaxN in the studied species, with correlation coefficients in the range of -0.2 to -0.28. Using T1 as a proxy for population density in a baited camera system can solve longstanding problems in abundance estimation with these methods.

Keywords: baited remote underwater video; statistical power; abundance estimates

## Predator nonconsumptive effects on prey demography: Field experimental evidence from the Atlantic coast of Canada

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Predator nonconsumptive effects (NCEs) on prey are ubiquitous in nature. In aquatic systems, such NCEs are often triggered by predator-released waterborne cues that are detected by prey. To minimize predation risk, prey exhibit immediate behavioural responses (e.g., cessation of feeding or moving away). However, the consequences of such responses for prey demography remain poorly understood. This knowledge gap is important to address because, ultimately, demography influences the impact of a species on its community. Therefore, we investigated predator NCEs on two key demographic variables for prey, recruitment and reproduction, through manipulative field experiments in rocky intertidal habitats from Nova Scotia, Canada. As model predator-prey systems, we used dogwhelks (*Nucella lapillus*) and their main prey, barnacles (*Semibalanus balanoides*) and blue mussels (*Mytilus* spp.).

We found that dogwhelk NCEs limited barnacle recruitment by limiting barnacle settlement, as barnacle larvae settled elsewhere when detecting dogwhelk cues, likely to reduce future predation risk as settled organisms grow to adults. The observed nonconsumptive limitation intensified with dogwhelk density but disappeared under high barnacle recruit density (favoured by phytoplanktonic food supply) or in the presence of adult barnacles, seemingly because chemical cues by barnacle recruits and adults are known to attract conspecific larvae seeking settlement. High water motion in wave-exposed environments also eliminated dogwhelk NCEs on barnacle recruitment, apparently through dogwhelk cue dilution. Furthermore, the months-long exposure of barnacle recruits to dogwhelk cues limited reproductive output once the recruits developed into adults. This was probably a result of a reduction of recruit feeding under dogwhelk cue exposure, as found previously in the lab. Our field experiments also showed that dogwhelk cues can also limit recruitment in blue mussels. However, this limitation was less intense than for barnacles, which may be explained by the fact that mussels remain mobile to some extent throughout their benthic life and can, thus, avoid predation more often than barnacles, which are fully sessile after settlement. Overall, our research shows that predator NCEs can affect prey demography by limiting prey recruitment and reproduction and that biotic and abiotic factors can modulate such NCEs.

Keywords: predator nonconsumptive effects; prey demography; recruitment; reproduction; manipulative field experiment; rocky intertidal; dogwhelks; barnacles; mussels

## Mediterranean aquaculture impact on the infralittoral rocky shore: a study case from the Aegean Sea

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The nutrient enrichment from fish cage culture in the Mediterranean has been associated with negative impacts in environmental conditions and surrounding habitats in several occasions. However, these studies have been usually directed to the benthonic habitat in the close vicinity of the fish farms neglecting other sensitive habitats. Thus, for the first time ever, the effect of nutrient loading from multiple fish farm facilities on infralittoral rocky shore macroalgae community using ecological and metabolomics analysis is here evaluated. To achieve this Vourlias Bay, a semi-enclosed bay with intermediate hydrodynamics in the Peloponnese region on the Aegean (Greece) was chosen as the study site. This bay has sea bream aquaculture facilities and there is recorded evidence of nutrient enrichment made by farm discharges in the past. At the site, seasonal sampling was done in two campaigns during June 2017 and March 2018, two sites were chosen in an impact gradient from the fish farm, one close to the aquaculture site and one far from it as a control. In each site a transect of 50m along the shore was done, every 10m the macroalgae was scraped on 40cm<sup>2</sup> quadrats and all the material collected, along this quadrat photography was performed for digital analysis and macroalgae and associated fauna was collected and frozen in liquid nitrogen for metabolic analysis. As a result, seasonal patterns in composition and structure of both macro-algae and its associated epifauna were found, sea urchin cover, in particular, was higher during the summer than in winter evidencing the effect of temperature on grazing pressure. The metabolomics analysis allowed to describe pathways involved in the tolerance or degradation of key species in relation to nutrient enrichment from fish farm discharges. And the multiparametric analysis relating macroalgae community with the ecological and biogeochemical water quality evidenced the effect of both seasonality and fish farm effluents.

Keywords: macroalgae; aquaculture effect; omics; rocky shore; Mediterranean



## On the relationships between macrobenthos activities and sediment oxygen dynamics - A case study in the Scheldt estuary

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The aim of this work was to propose an empirical scaling framework of bioturbation effect in sediment oxygen dynamics, by building population density - benthic functioning relationships in the estuarine ecosystem. Density-dependent microcosm experiments were carried out in three dominant bioturbators and bio-irrigators in the Schelde estuary: *Corophium volutator*, *Limecola balthica*, and *Hediste diversicolor*. Their contrasting feeding, burrowing, and irrigation methods represent a broad range of taxonomic groups, functional effects and functional responses within benthic communities. The body size allometry scaling law was tested, and robust macrobenthos-mediated sediment oxygen consumption models were constructed. Population density contributed to 47%-98% of total oxygen consumption variation, and accounted for 26%-88% of bio-irrigation variation. For the combined dataset, metabolic rate contributed significantly (56.2%) to the overall stimulatory effect and predictive power increased to 76% with the inclusion of geographical variability. Eventually we linked the model functions to bioturbators/bio-irrigators population maps in the Schelde Estuary, to extrapolate benthos-mediation effects to sediment geochemistry at landscape scales. Our results revealed that the effect of bioturbators on sediment oxygen dynamics can be described simply in terms of bioturbators' population metabolic rate, and the same rule are shared cross-taxa and cross-abiotic gradients.

Keywords: sediment oxygen consumption; bio-irrigation; population density; metabolic theory; allometric laws

## What do free-living nematodes tell us about the benthic ecosystem functioning? Insights from the northern Adriatic Sea

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Between July 2010 and July 2012, free-living nematodes were seasonally investigated at a time-series shallow site of the northern Adriatic Sea, synoptically to the estimates of several biological processes (e.g. microbial exoenzymatic activities, prokaryotic C production, primary production and benthic oxygen consumption) and the study of microphytobenthos (i.e. benthic diatoms). This effort allowed to insert nematodes within an overall evaluation of the benthic ecosystem functioning, as it is described in Franco et al. (2016), in order to investigate the interactions between nematofauna and the other components of the ecosystem. Overall, 72 genera of free-living nematodes, belonging to 24 families, were identified indicating the presence of a well-structured assemblage both in terms of taxonomic composition and functional diversity (the latter synthetically expressed by the Maturity Index and Index of Trophic Diversity). Over the 2-year study, nematofauna showed significantly higher abundances in summer samplings. The concomitance of such peaks with those of microphytobenthos suggested a noticeable role exerted by benthic diatoms in supporting nematodes numbers. This link was additionally supported by the fact that nematodes' higher abundances during summer were mainly ascribable to epistrate feeders, i.e. nematodes that forage preferably on microalgae. The distance-based linear model (DISTLM) routine further confirmed the interactions between microphytobenthos and nematofauna since the outputs indicated Chl *a*, i.e. a proxy of microalgal abundance, as the only environmental variable that predicted the variation of nematode genera assemblage ( $F = 1.9624$ ,  $p < 0.001$ ).

Among epistrate-feeders that proliferated in summer samplings, *Ptycholaimellus* was the dominant genus. This result shed light on the interactions of nematofauna with the microbial heterotrophic component of the benthic ecosystem since *Ptycholaimellus*, an agglutinating nematode, builds complex networks of tubes that stimulate the interaction with heterotrophic microbes for the cleavage of polysaccharides with consequent repercussions for the overall degradation of the organic matter. An indication of the link between *Ptycholaimellus* and benthic prokaryotes was suggested by the significant relationship between the abundance of this genus and  $\beta$ -glucosidase rates, the latter ascribable to prokaryotic exoenzymes ( $r^2 = 0.715$ ;  $p < 0.01$ ).

Our results indicate that free-living nematodes interact with both the autotrophic and the heterotrophic microbial components of the benthic ecosystem, by exploiting microalgal proliferation during summer and by influencing prokaryotic degradation of the organic matter. Notwithstanding, since at the investigated time-series site nematofauna showed to be prone to inter-annual changes of challenging explanation, the study of this assemblage deserves to prosecute in a forthcoming time-series of data.

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Keywords: free-living nematodes; *Ptycholaimellus*; microphytobenthos; benthic ecosystem functioning; shallow coastal sediments; Northern Adriatic Sea

## Linear growth and shell shape variation in *Macoma calcaria* (Gmelin, 1791) (Bivalvia: Tellinidae) from the White Sea

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Arcto-boreal bivalve *Macoma calcaria* (Gmelin, 1791) is a common species in the White Sea, where it occurs in soft bottom communities at depths from 1 to 250 m. The vertical distribution of *M. calcaria* in the White Sea is bimodal with local maximums at 10 and 50 meter depths with highest abundance in shallow water populations, particularly at 10-15 m (Naumov, 2006). In this study we investigated morphometrical and growth characteristics of *M. calcaria* from contrasting subtidal habitats - shallow-water localities with pronounced seasonal variation in water salinity and temperature, and deep-water sites located below the thermo- and halocline where clams live in more stable conditions. For this analysis, *M. calcaria* sampled from 10-180 m depth during the decade between 1964 and 1974 and later stored in the Collection of Zoological Institute were used. Shell length (L), height (H), width (W) and the width of the external growth rings were measured with Vernier calipers to the nearest 0.1 mm. For morphometric analysis, standart indices (H/L, W/L and W/H ratios) were used. H/L ratio varied for molluscs from different depths (range was from 0.709 to 0.761; Kruskal-Wallis test:  $\chi^2 = 9.57$ ,  $p = 0.02$ ), but without a linear pattern. Comparison of samples by two other morphometric ratios did not show significant differences between molluscs from different depths ( $W/L = 0.304 + 0.007$ ,  $W/H = 0.418 + 0.009$ ).

Mean values of morphometrical indices calculated for the combined dataset when all individuals have been taken into account, was not significantly different from described earlier (Naumov et al., 1987). According to our analysis, growth rates in *M. calcaria* vary with depth, but also without a clear linear pattern. Nevertheless, clams from the most deep populations (180 m) had slower growth rates. The research was supported by the RFBR 18-34-00572, RAS research projects AAAA-A17-117042410167-2 and AAAA-A17-117030310207-3, Programs of Presidium RAS "Dynamics of gene pools in natural populations" and "Development of vital and biosphere processes".

Keywords: *Macoma calcaria*; the White Sea; linear growth; morphometrics

## Salt marsh foraminifera from the subarctic White Sea

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Foraminiferans are meiofaunal protists that occupy marine habitats from deepest part of the ocean to intertidal deposits including salt marshes. These nearly terrestrial vegetated biotopes at the interface of the land and the sea evolve at the upper intertidal in temperate and high latitudes. Being a part of the intertidal zone, salt marshes are largely influenced by tidal cycles that create a vertical zonation in a salt marsh. Tidewater supplies nutrients and oxygen which allow halophytic plants and marine organisms to inhabit these nearly terrestrial biotopes. The fauna of salt marsh foraminifera of mid-latitudes has been scrutinized, whereas in high latitudes they have not received much attention. Here, we report on species composition, abundances and vertical distribution of living salt marsh foraminifera from the subarctic White Sea. In total, we found 9 species. Most of them occur worldwide, except *Elphidium albiumbilicatum*, which is known to be a high latitude species. This is the most northern location, where *Balticamina pseudomacrescens* and *Trochammina inflata* were encountered. Foraminiferal fauna of the subarctic White Sea salt marshes was surprisingly abundant (up to 3000 living specimens per 10cm<sup>3</sup>). Applying the method of non-metric multidimensional scaling, we visualized the changes in foraminiferal assemblage composition from high marsh to tidal flat. Two distinct assemblages of high and low marsh of foraminifera were found in the White Sea salt marshes, each confined to certain vegetation belt. High marsh assemblages are represented by agglutinated species of *Jadammina macrescens*, *B. pseudomacrescens* and *T. inflata*, low marsh – by calcareous species of *E. williamsoni* and *E. albiumbilicatum* and agglutinated *Miliammina fusca* as well. The abundances of salt marsh foraminifera of the subarctic White Sea are higher than on other studied subarctic locations, but are comparable to temperate salt marshes due to relatively warm summer in the White Sea region.

Keywords: salt marsh; foraminifera; subarctic; the White Sea

## Benthic size spectra, biomass and production along the bathymetric gradient in the Arctic Ocean (Fram Strait, 79°N).

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We present bathymetric patterns in benthic community structure and functioning at the LTER (Long-term Ecological Research) observatory HAUSGARTEN in the Fram Strait. Meiofauna, macrofauna and sediments were sampled at 15 stations along a bathymetric gradient from Spitsbergen coastal waters (100-300m) across the Vestnesa Ridge (1000m) down to the Molloy Hole (5561m). Benthic organisms were identified, enumerated and measured to obtain individual dimensions, biovolume and biomass. Secondary production, respiration and carbon demand were estimated based on individual biomass data. Benthic size spectra were constructed by plotting the biomass or production against the log<sub>2</sub>-transformed size classes.

Benthic standing stocks, production and carbon demand declined with depth alongside with the decline in food quantity and quality (as indicated by POC and chlorophyll *a* content in sediments). Compared to those for the meiofauna, bathymetric declines were stronger for macrofauna and a transition towards a system dominated by smaller organisms in deeper ocean zones could be documented. Meiofauna:macrofauna biomass and production ratios increased from 0.1 and 0.6, respectively, in coastal waters to 0.3 and 1.9 on the rise (4042-5102m). The benthic biomass size spectra were bimodal in shape, the width of size spectra declined with increasing depth (from 32 to 23 classes). A reduction of the number of size classes was stronger in macrofaunal part of the spectra. The largest and the smallest size classes as well as the peak in biomass for macrofauna were shifted towards smaller sizes in deeper zones. Fragmented size spectra observed at the two stations (including the Molloy Hole) could be interpreted as effects of physical sediment disturbance (by currents or bioturbation) and resulted in dramatic increase in meiofauna:macrofauna ratio in biomass (0.8) and production (6.5) in the Molloy Hole. The presented patterns are likely to be modified by on-going regional changes in ice coverage and productivity, and the food supply to the deep sea in the course of the climate warming.

Keywords: size spectra; benthic biomass; Arctic Ocean; deep-sea; benthic secondary production

## EMBRC-ERIC: A global reference research infrastructure for fundamental and applied marine biology and ecology research

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The European Marine Biological Research Centre (EMBRC-ERIC) is a supra-national distributed Research Infrastructure (RI) designed to further fundamental and applied marine biology and ecology research in renowned marine biological stations and institutes across Europe and associated European Union countries.

EMBRC-ERIC's mission aims at promoting the development of blue biotechnologies by supporting fundamental and applied research activities in medicine, nutrition, aquaculture, biotechnology, and fisheries, among others, thus ensuring long-term sustainability of marine stations.

Europe played a key-role in the creation of marine stations in the second half of the XIX century. These undertakings, which happened within a short period of ca. 30 years, were prompted by the necessity to study in detail the evolution of life, which originated and developed in the oceans, and to understand the diversity, sustainability and exploitation of marine life. The study and sustainable exploitation of the marine biological potential is only tractable with the integration of existing knowledge and capacities, through a world-class research infrastructure, such as EMBRC-ERIC, also in association with other relevant RIs.

EMBRC-ERIC thus provides a single access point to a unique portfolio of services, resources and knowledge. In particular, EMBRC-ERIC provides access to marine biological resources and ecosystems, state of the art experimental facilities and technology platforms to users from all sectors, for either precompetitive studies or commercial applications, and for education and training activities.

For that purpose, Joint Development Activities (JDAs) will continuously improve the existing services as well as enable the development of new services adjusted to the scientific and biotechnological research priorities of academic, governmental and industrial users and in response to emerging societal challenges. EMBRC-ERIC will provide the environment, facilities and expertise for the education and training of students and professionals in the life sciences.

Finally, Research Infrastructures (RIs) play an increasingly important role for the advancement of knowledge and technology in Europe and worldwide. Referring to facilities, services and resources, which are open to the scientific community to conduct top-level research, RIs bring together the suitable conditions and critical mass to enable cutting edge, large-scale research. The advancement of knowledge and technology towards Europe requires RIs to open up to the scientific community. EMBRC-ERIC is thus embedded in a strategic landscape of 48 RIs covering all research areas from biology to social sciences and physics to comply the long term needs of the European Research community.

EMBRC-ERIC is a vehicle for long-term programmatic planning, including acquisition or development of novel technologies, and coordinating information collection for open-access, interoperable data repositories, supporting excellent science pursuits and the establishment of new enabling technologies.

Keywords: blue bioeconomy; biodiversity; services; ERIC; ecosystems; resources

## Effects of fish farm effluents on epiphytic algae and faunal community associated with *Laminaria hyperborea*

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Production of fin-fish is a major industry in Norway, with more than 1.3 million tons produced in 2017, a 3-fold increase over the last 15 years. This rapid expansion has resulted in a significant restructuring of the industry, including increased farm sizes (from 3-5000 tons up to 14 000 tons) and relocation of farms from quiescent fjords to dynamic and exposed areas along the coast. It is well known that discharges (i.e. particulate and dissolved effluents) from intensive fish farming in net cages alters the structure and functioning of benthic communities, although this knowledge is restricted to soft bottom habitats. Impacts to other habitats (i.e. hard-bottom habitats) along the Norwegian coast have been poorly studied.

*Laminaria hyperborea* is the dominating kelp species at exposed hard-bottom sites along the Norwegian coast, forming forests that are estimated to cover an area larger than 10 000 km<sup>2</sup>. Kelp forests are biodiversity hotspots much due to their structural complexity, and serve key functions in the ecosystem by providing refuge, habitat, nursery grounds and feeding grounds for more than a hundred marine faunal species, including seabirds and economically important fish such as Atlantic cod (*Gadus morhua*) and saithe (*Pollachius virens*).

It is hypothesized that increased loading of available nutrients could stimulate the growth of fast-growing epiphytic macroalgae and bryozoans on the lamina, which could negatively influence the kelp through decreasing total surface area available for nutrient uptake and light interception necessary to conduct photosynthesis. Stimulation of fast-growing macroalgae species on the stipe may lead to changes in the epiphytic community structure and reduce the habitat complexity. The holdfasts of *L. hyperborea* have been proposed as a eutrophication-indicator, as excess nutrients may motivate the presence of opportunistic species, and alter the faunal composition.

To assess the potential effects of fish farm effluents on *L. hyperborea* forests, 6 different fish farms were chosen: 3 at the beginning of the production cycle (had a low fish biomass and therefore low effluent load), and 3 at the end of the production cycle (high fish biomass and high effluent load), in addition to 6 reference locations. Lamina and stipe data were collected from 10 individual plants from each location, while holdfast data was collected from 3 individual plants from each location. Total epiphytic biomass of algae and % cover of bryozoans were assessed for the lamina, while epiphytic algae growing on the stipe were identified and weighed to assess changes in community structure. Holdfast macrofauna (>500 µm) was identified and counted to assess shifts in community composition and to evaluate the potential as an indicator-unit. Several parameters were modelled or sampled, and used to explain observed patterns, including wave exposure, current velocity, plant age, kelp density along transect, amount of fish feed used at fish farm sites and distance to nearest farm.

Keywords: kelp; aquaculture; *Laminaria hyperborea*; epiphytes; macroalgae

## How does seascape structure affect seagrass fish assemblages? A seasonal case study from the Baltic Sea and Skagerrak

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Investigating distribution patterns among organisms through large-scale (km) approaches became common in terrestrial environments with the introduction of landscape ecology in the 1980s. This has contributed to increased understanding of the importance of spatial heterogeneity among landscapes and how pattern-process relationships vary with scale. In marine environments, however, studies using similar scale-dependent methods are relatively uncommon, especially in temperate waters, such as Skagerrak and the Baltic Sea in Sweden. In this study, we explore how seascape structure (i.e. composition and configuration of benthic habitat patches) influences fish assemblage compositions during summer - and autumn seasons in 20 eelgrass (*Zostera marina*) meadows on the Swedish east (Baltic Sea) -and west coasts (Skagerrak). In general, seascape structure had a larger influence on fish assemblage variables in the summer season compared to the autumn. Surprisingly, seascape structure also had more and stronger influence on fish assemblage variables in the Baltic Sea compared to Skagerrak. For instance, juvenile fish abundance in the Baltic was positively influenced by seascape heterogeneity. Interestingly, this is in contrast to previous findings from the Swedish Skagerrak coast, where juvenile abundance was shown negatively correlated to complexity (heterogeneity) of seascapes. In fact, most of the fish assemblage variables from the Baltic Sea (e.g. total abundance, juvenile abundance, low-level carnivores and mid-level carnivores) were positively influenced by more complex seascapes, indicating the importance of spatial heterogeneity among seascapes in the Baltic Sea. This research offers new insights into habitat patch dynamics in relation to mobile organisms in temperate coastal areas, particularly in the Baltic Sea region.

Keywords: seascape; landscape ecology; eelgrass; fish; baltic sea; skagerrak



## Morphological and genetic studies on *Raphidascaris acus* from the Caspian Sea

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Using exact morphologic and genetic studies, it has been recently shown that many nematode species are in fact species complex. In this case, there are not such studies related to the Genus *Raphidascaris* Railliet & Henry, 1915. Herein, the morphologic and genetic variations among the Iranian population of the species *Raphidascaris acus* (Bloch, 1779) Railliet & Henry, 1915 and the other allopatric populations with morphologic and genetic information were compared to show whether this species can be considered as a species complex. A total of 20 specimens of *R. acus* were collected from *Esox lucius* Linnaeus from the Caspian Sea and the morphology of the Caspian population of this species was surveyed for the first time using both light and scanning electron microscopy. Meanwhile, some parts of rDNA including ITS1, 5.8s and ITS2 were sequenced and presented as the genetic marker for this species. To understand whether *R. acus* can be considered as a species complex, the Caspian population of this species was compared morphologically with the allopatric populations of Czech and Canada and genetically with the allopatric population of Poland (Vistula lagoon). Morphologically, there was no difference between the Caspian and Czech populations but the Caspian and Canadian populations differed in the length of ejaculatory duct and the presence of the small triangular elevation between bases of subventral lips. The nucleotide difference between the Caspian and Polish populations was 4.48%. In comparison with the interspecific genetic distances in the genus *Raphidascaris*, this value is notable since among the congeners, the genetic distances between *R. acus* and three other species sequenced earlier namely *Raphidascaris lophii* (Wu, 1949), *Raphidascaris trichiuri* (Yin & Zhang, 1983) and *Raphidascaris longispicula* Li, Liu, Liu & Zhang, 2012, were 25.41%, 24.84% and 24.41%, respectively. In conclusion, based on morphological and genetic differences among the allopatric populations of *Raphidascaris acus*, this species is probably a species complex. Nonetheless, the definitive taxonomic decision in recognizing *R. acus* as a species complex and description of its sibling species depend on surveying the other allopatric populations.

Keywords: *Raphidascaris acus*; Caspian Sea; species complex

## Of natural predation and gastronomy: Who's eating the invasive lionfish (*Pterois miles*) in Cyprus (Levantine Sea)

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Since its appearance in western Atlantic and Caribbean waters, the Indo-Pacific lionfish (*Pterois miles* and *Pterois volitans*) are an invasive species of celebrity status. Their populations have impacted local marine ecology within their invaded areas by exhibiting biological and ecological traits that facilitate their dispersion and successful establishment. Since 2012, *P. miles* is one among recent invasive species that has already overtaken the eastern Mediterranean Levantine Sea while rapidly expanding westwards. A factor that may be contributing to lionfish success is the prey and predator so-called naïveté. Lionfish is consuming naïve prey while experiencing low to none predation from native naïve predators (i.e. enemy release). Natural predation and human exploitation are considered as necessary structuring forces for controlling lionfish populations. In consequence, information of when and where predation by native mesopredators and consumption by humans begin is important for management strategies of this invasive species in the Mediterranean and elsewhere. Here we present a chronology (2012 to date) and spatial distribution of this process in Cyprus. One mesopredator fish species seemingly begun to prey on lionfish as early as two years after the onset of the lionfish expansion in Cyprus and another fish species was first observed by accident in 2017 ingesting a lionfish. Predation of lionfish is occurring at different depths and throughout the year. Humans lost their naïveté during the early stages of the lionfish invasion (2014/2015) when a few persons (all with access to information in the web) showed an experimental gastronomical interest on the lionfish. Since then, the frequency of the consumption of lionfish and its acceptance (not anymore considered a preposterous idea to consume this species), increased in a temporal pattern that closely matches dissemination of information about the lionfish by different sources and types of media (e.g. TV, newspapers, web), as well as the increase in the abundance of the lionfish around the island. There is an incipient trade for this species in the artisanal market where the lionfish in the bycatch is transported inland to villages for its consumption. For management purposes is important to perform comparative studies on the social and natural consumption of the lionfish in other affected areas of the Mediterranean.

Keywords: invasive species; Pterois; lionfish; opportunistic predation; mesopredator; human consumption

## Allometry of mitochondrial respiration in mussels

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Allometric decline of mass-specific metabolic rate with increasing body size in organisms is a long-known and well-documented phenomenon. The patterns observed at the organismal level indicate fundamental allometric changes in the rate of cellular metabolism and mitochondrial functioning; however, the mechanistic causes of these differences remain under debate. The aerobic metabolic rate is performed through the mitochondrial pathway of oxidative phosphorylation. Therefore, it is meaningful to predict that allometric pattern for mitochondrial functioning would reflect the pattern of aerobic metabolism. Surprisingly, there have been relatively few studies that have assessed the possible link between mitochondrial respiration and body size in invertebrates. We studied body size dependence of mitochondrial respiration of blue mussels *Mytilus edulis* L. Mussels were of the same age (3 years), but differed in size. In order to test functional capacities of mitochondria from mussels of different sizes respiration was determined at normal (15°C) and elevated (27°C) exposure temperatures. Mitochondria were isolated from hepatopancreas and respiration rate was measured using high-resolution respirometry method (by Oxygraph-2k, Oroboros Instruments). Substrates, inhibitors and uncoupling agents for oxidative phosphorylation (OXPHOS) and electron transport system (ETS) were added step-by-step in order to assess maximal respiration rates, respiratory control ratio, proton leak, activity and impact of all complexes of ETC. Temperature significantly accelerated state 3 (ADP-stimulated) mitochondrial respiration, maximal respiration with uncoupled ETS, and caused an increase of Respiratory Control Ratios. On the contrary, state 4 respiration (indicative of the proton leak) as well as respiration related to electron flux through complexes of ETC did not show an increase at stress temperature (27°C). Body size of mussels had a strong effect on most studied parameters. ADP-stimulated respiration, electron flux through complex IV, proton leak and uncoupled respiration showed a pronounced increase with body mass of mussels with power coefficients of 1.8, 1.2, 0.2 and 0.8, respectively. The obtained results showed that larger mussels had higher OXPHOS rates than smaller ones. Since all mussels were of the same age, larger ones obviously were characterized by rapid growth. It is possible that elevated growth abilities in some specimens compared to the others result from more efficient metabolic regulation which in turn is related to higher mitochondrial capacities.

Keywords: metabolic allometry; high-resolution respirometry; mussels; mitochondrial respiration

## On the use of Crustacea as a surrogate taxon for the environmental quality assessment in the Hellenic coastal waters (WFD)

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Coastal waters are usually exposed to anthropogenic pressure, such as aquaculture, sewage, or maritime traffic, which can cause a significant decrease of the water quality. Benthic invertebrate biodiversity is often used as an indicator for the water quality, since these organisms are susceptible to environmental changes. Thus, monitoring of the macrobenthos status is very important, as it can lead to an early detection of environmental disturbance, and -consequently- to immediate measures of restoration.

Scientific knowledge plays a pivotal role in informing policy makers and stakeholders, in order to take proper action in water management, regarding human pressures and environmental recovery processes. Therefore, every piece of information allowing to understand the complexity of coastal environments is urgently needed for the future conservation planning.

Crustacea is one of the most important macrobenthic taxa. As a matter of fact, they are used by many scientists as an indicator or surrogate of the total macrobenthic assemblage composition and diversity. In our study, carried out within the context of the Water Framework Directive (WFD) implementation for the Hellenic coastal waters, over a period of four consecutive years, Crustacea was the second group after Polychaeta, in terms of species richness and abundance.

From a dataset of 80 stations around Greek coasts, 28,631 individuals belonging to 931 species were identified, in total, whereas the number of Crustacea found was 3,653, belonging to 265 species.

The present work examines the potential use of Crustacea as a surrogate for the estimation of the water body quality, comparing their multivariate patterns of abundance and species richness with the values of the BENTIX (Simboura and Zenetos, 2002) index, as calculated by the entire macrobenthic fauna datasets in order to provide indication on the ecological quality of the respective stations sampled.

Keywords: crustacean; macrobenthos; coastal waters; bio-indicators

## Interannual (2016–2017) variability of winter-spring microzooplankton in the open South Adriatic Sea: Effects of deep convection

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The South Adriatic is an entry point for water masses originating from the Ionian Sea and a place of dense water formation for the eastern Mediterranean deep circulation cell. Water masses, entering the South Adriatic in larger amount during the winter, show decadal variability explained by different circulating regimes (cyclonic and anticyclonic) in the Ionian Sea. This study has drawn attention to an aspect of the winter ecology of the open South Adriatic that heretofore has not been incorporated into explanations of the distribution and production of its planktonic communities. Four sampling stations (P-100, P-150, P-300 and P-1200) were situated along the central transect of the South Adriatic. Zooplankton were sampled with vertical hauls of Nansen opening-closing net in the winter and spring months for two years (2016–2017). Total microzooplankton abundances, community structure, spatial and temporal variability of microzooplanktonic groups, hydrography and biological properties are presented. In 2016 the highest microzooplankton abundance was in January at the 0–50 m layer of all stations. The maximum, 22575 ind m<sup>-3</sup> was at the nearshore station P-100. Copepod nauplii were the dominant with high contributed tintinnids (*Undella claparedei*, *Eutintinnus lusus-undae*, *Epiplocylis undella* and *Dictyocysta mitra*). Abundance then generally decreased both offshore and with depth. In 2017 microzooplankton provides strong evidence of convective events. Exceptionally high abundances of tintinnid, copepod nauplii and adult copepods were recorded in April with maximum 46234 ind m<sup>-3</sup> in the surface layer station P-1200. The largest part of the population was made of adult copepods with nauplii and copepodites and also tintinnids (*U. claparedei*, *E. lusus-undae*, *Salpingella acuminata*, *Codonella aspera* and *Codonella amphorella*). However, even though tintinnids and copepods declined with increasing depth, their abundance during 2017 was several times higher in some layers below 200 m than in 2016 and previous winter investigations in the deep South Adriatic. Therefore, year-to-year variability in the intensity of winter convection may have an important impact on the biogeo-chemical cycle and carbon storage in the Deep South Adriatic.

Keywords: microzooplankton; tintinnids; copepod nauplii; deep winter convection; South Adriatic

## The role of Marine Protected Areas in influencing the invasion success of the alien crab *Percnon gibbesi*

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The biotic resistance hypothesis states that pristine communities, with high species richness and functional diversity, are less prone to biological invasions than species-poor areas either this is natural or it is a result of human activities. Complex communities with high levels of biodiversity, such as those hosted by Marine Protected Areas, should offer fewer niche opportunities (e.g. resources and space) to invasive species thereby reducing both their establishment possibilities and success (i.e. settlement and/or expansion).

The present study aimed to evaluate the capacity of marine protected communities to provide a buffer against the establishment of one of the most invasive species in the Mediterranean Sea: the Percnidae crab *Percnon gibbesi* (H. Milne Edwards, 1853). Here, it was tested if predation provides a higher resistance to the invasion by *P. gibbesi* in protected native communities than in exploited ones. Specifically, this study aimed to compare (a) the abundance and diversity of predator assemblages of *P. gibbesi*, (b) the predation pressure on *P. gibbesi* and (c) the density of this species in protected and unprotected areas in the Mediterranean Sea. Tethering experiments were conducted in the field to assess the relative predation rate on two size classes of *P. gibbesi*, using long and short tethers, at two protected and two unprotected sites randomly chosen on the northern coast of Sicily (Southern Tyrrhenian Sea).

The abundance and diversity of predators of *P. gibbesi* and the relative predation rate on tethered crabs were higher at protected than unprotected sites, independent of crab size and tether length; the density of *P. gibbesi* was significantly lower in protected than unprotected areas.

The findings of this study, although restricted to a small spatial scale, support the existence of mechanisms for biotic resistance in Mediterranean protected native communities and provide experimental evidence that the restoration of predator assemblages confers better invasion resistance to marine protected areas against *P. gibbesi* invasion. More generally, the present study confirms that marine protected areas are an effective tool for ameliorating the impact of some biological invasions in the Mediterranean Sea.

Keywords: alien invasion; biotic resistance; Marine Protected Areas; Mediterranean Sea, *Percnon gibbesi*; predation

## The impact of temperature rise on viruses of the picoplankton community in the Adriatic Sea

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Viruses are an important and dynamic component of the marine microbial community. They are shaping microbial populations by lysing the host cells and thus are changing the biogeochemical nutrient cycling. The rise of sea surface temperature caused by the global warming could have a significant effect on viral population and their interaction with the marine microbial community. This could affect the way carbon is exported through the microbial food network. Modified laboratory dilution experiments that allow estimates of viral lysis on marine picoplankton (bacteria, *Prochlorococcus*, *Synechococcus*, picoeukaryotes) under *in situ* and 3°C above *in situ* temperatures were performed at seasonal scale. Viral lysis removed 14-94% day<sup>-1</sup> of bacterial standing stock, 3-135% day<sup>-1</sup> of *Prochlorococcus* standing stock, 0.9-30% day<sup>-1</sup> of *Synechococcus* standing stock, and 0.2-17% day<sup>-1</sup> of picoeukaryote standing stock. Rates of viral lysis on picoplankton were more pronounced in the warmer months (July and November), particularly for the autotrophic picoplankton groups (especially *Synechococcus* and picoeukaryotes) that were significant hosts for viral infection. However, the largest part of the total picoplankton biomass loss through the viral lysis was related to bacteria (48-98%). A rise in temperature of 3°C increased the both, picoplankton biomass production and the amount of lysed picoplankton biomass, especially autotrophic hosts. These results suggest that the global warming could increase the virus-mediated flux of picoplankton carbon toward the pool of dissolved organic matter.

Keywords: marine viruses; viral lysis; picoplankton; global warming

## In the eye of the holopelagic annelid *Tomopteris helgolandica*

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Light is the basis of many photo-dependant mechanisms in organisms; perceive light is therefore essential to numerous species depending on it. In this way, light has been one of the foundations to evolution: the organisms have developed, among others, a specific organ – the eye. The opsins are the main molecules involved in the mechanism of light perception, also present in extraocular structures. It is then interesting to study such proteins in order to better understand the light detection process. Based on molecular phylogeny, opsins can be classified in four families: ciliary opsins, rhabdomeric opsins, cnidopsins and the group four opsins. The expression of these proteins is one of the most conserved characteristics of photoreceptor cells (PRCs), involved in light sensitivity - one PRC usually express only one opsin. These proteins are thus used to identify PRC present in an organism.

Annelids possess many sensory organs, which the photoreceptor-like sense organs taking part in the annelid vision are the best-investigated. Therefore, one can take advantage of annelids to gain insights in the knowledge of light detection process.

Transcriptome data analysis in *Tomopteris helgolandica*, a bioluminescent and holopelagic polychaete, reveal that at least nine different opsins are expressed. These molecules are differently distributed between the cephalic and the body regions, questioning the respective role of the organs expressing them. The results of the project showed different expression patterns for four cephalic opsins, which can be related to each other and lead to the assumption of opsin co-expression. They also showed unexpected sensory structures into the brain tissue for which the nature remains unknown. Moreover, we observed similarities between annelid species, in the structure and the formation of the eyes.

In conclusion, the results obtained during this project are added to previous researches and provide new information about *Tomopteris helgolandica* and more specifically about its visual system. In addition to provide new insights into the understanding of visual systems and photoreceptor cells, they open new red lines into the bioluminescence process and to the possibility of its relation with light perception in numerous bioluminescent species.

Keywords: *Tomopteris helgolandica*; visual system; opsin; photoreceptor cells; bioluminescence



## Higher ecosystem biodiversity helps the single species coping with ocean acidification

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Ocean acidification is known to severely affect a wide variety of marine organisms, including key species of the Mediterranean coralligenous assemblages as the red coral *Corallium rubrum* and coralline algae. However, most of current evidences are based on the response of single organisms experimentally treated in isolation from their natural coralligenous habitat. Thus, it remains unknown if the presence of the original coralligenous assemblages might mitigate the observed impacts of ocean acidification on the single species inhabiting these complex systems. The new multispecies mesocosm experiments we conducted demonstrate that, despite the presence of the coralligenous in the mesocosms cannot significantly buffer the high-pCO<sub>2</sub> induced changes on seawater chemistry, the impacts on the dominant organisms (including *C. rubrum*, coralline algae and encrusting sponges) are progressively reduced with increasing biodiversity level of the natural coralligenous assemblage. Our results suggest that the complex networks of biological interactions occurring in this highly diversified natural ecosystem can increase the resistance of the single biotic components to ocean acidification. We conclude that the risk of extinction imposed by ocean acidification on key biotic components of the coralligenous habitat, fundamental in the overall Mediterranean ecosystem functioning, could be mitigated by adopting conservation strategies safeguarding its biodiversity.

Keywords: biodiversity; ecosystem functioning; calcification; conservation; red coral; coralline algae; sponge; coralligenous assemblages

## Seasonal trend of the macrofauna inhabiting two Mediterranean species of *Sarcotragus* (Porifera, Demospongiae)

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Sponges are important component of several benthic habitats and represent important “micro-hotel” (Pearse, 1932) where organisms, belonging to different *taxa*, can find refuges, additional sources of feeding, nursery areas and establish also symbiotic relationships (Cerrano et al., 2006). In the recent years, Mediterranean keratose sponges (e.g. *Ircinia variabilis*, *Sarcotragus spinosulus*, *Spongia officinalis*) were subjected to mortality events principally due to anomalies of the water temperature (Cerrano et al., 2000; Di Camillo et al., 2013), likely leading to local extinction or variation also of their associate fauna.

For this study, five samples of two species of the genus *Sarcotragus* (Irciniidae: Demospongiae), living in two different areas, were collected bimonthly by scuba divers along an annual cycle. In particular, we investigated the species *S. spinosulus* (Schimdt, 1864), living on the mussel beds of the Conero Promontory (North Adriatic Sea) at 8 m depth, and *S. foetidus* (Schimdt, 1864), living around 20 m depth on the rocky cliff of the Portofino Promontory (Ligurian Sea). More than one hundred *taxa* were identified and most of them resulted common in the two associated sponge species, as the species *Caratonereis (Composetia) costae* (Annelida: Nereididae). Both the species of sponges supported high values of density and diversity especially of Annelida, Crustacea and Mollusca. Although the size of the sponges and the internal volume of the aquiferous system are the main factors that influence the symbiotic fauna (Gherardi et al., 2001), *S. foetidus*, characterized by greater dimensions of the channels, hosted lower values of the associated zoobenthos compared to *S. spinosulus*. Indeed, *S. spinosulus* can host and sustain a high number of symbionts on its surface and inside its canals. This result suggests that the variation of the water temperature, the higher trophic inputs and productivity of the Adriatic Sea in comparison with the Ligurian Sea, and probably also the neighboring habitat, can be the principal causes that contribute to diversify and modify the macrofaunal communities associated with *Sarcotragus* spp. One again, sponges can be considerate as “habitat-forming species” so with functional role as ecosystem engineers capable to provide habitat for many species.

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## Environmental concerns of LIFE-SEACAN project: Spatiotemporal analysis of the impact of wastewater from a canning industry on benthic ecosystem

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The Galician Rías Baixas are a group of bays of tectonic origin located in the NW coast of the Iberian Peninsula. They host 80 % of the fish canning industries in Spain, which produce 4300 million cans every year. These industries are characterized by high water consumption and the subsequent emission of large quantities of wastewater. This is a major environmental concern, as Galician Rías Baixas host both a great marine biodiversity and intense fishing and aquaculture activities. The project LIFE-SEACAN (LIFE14 ENV/ES/000852) aims to demonstrate the potential of two innovative biofilm-based technologies (aerobic granular sludge and hybrid bioreactors) to decrease the impact of canning industries on marine ecosystems. The project includes an analysis of the impact of the wastewater from a canning industry on benthic ecosystem. Here we present the results of an initial assessment of the wastewater impact. With that purpose, samples were taken at 6 sites at each of the 4 sampling stations (2 potentially impacted by wastewater and 2 controls). Sampling at each site included taking 6 samples with a Van-Veen grab, 5 for the study of the fauna and 1 for the study of the sediment, plus water samples for the study of its physical-chemical characteristics. Furthermore, sediment traps were installed at each sampling station to measure matter fluxes towards the sediment. Sampling was carried out quarterly during a year. One of the control stations was discarded from this study because of its major differences with the 3 remaining stations regarding sediment type. Significant seasonal variations in the characteristics of the assemblages were found at each site. Differences between sites were also found to be significant and persistent through the year. The results, though not significantly conclusive, suggest the existence of a moderate impact in the area under the influence of the wastewater discharge.

Keywords: impact; canning; benthic ecosystem

## Latitudinal and bathymetrical species richness patterns in the NW Pacific and adjacent Arctic Ocean

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To better understand the species latitudinal and depth gradients in the NW Pacific and its adjacent Arctic Ocean, distribution records of all marine species were extracted from the Ocean Biogeographic Information System (OBIS) and Global Biodiversity Information Facility (GBIF), merged, cleaned, and taxonomically cross-matched with the World Register of Marine Species (WoRMS). We analysed 324,916 distribution records of 17,414 species from 0 to 10,900 m depth, latitude 0 to +90 degrees, and longitude +100 to +180 degrees. Species richness per c. 50 000 km<sup>2</sup> hexagonal cells were used to calculate alpha (average), gamma (total) and ES50 (estimated species for 50 records) per latitudinal band and depth zone.

ES50, gamma, and alpha species richness decreased significantly with latitude and depth. The highest number of records (73%) was of shallow water species (0 to 500 m). The Philippines and Palau Islands had the highest species richness (more than 13,000 per hexagon). Gamma species richness and mean sea surface temperature (SST) per each 5-degree latitudinal bands were significantly correlated with Ocean Area (km<sup>2</sup>) ( $r = 0.89$ ) and SST ( $r = 0.52$ ). The latitudinal gamma and alpha diversity increased from the equator towards the mid-latitudes (5-10° N), with a sharp increase in latitude 10° N, then further decreased at higher latitudes. The latitudes 60-70° N had the lowest gamma and alpha diversity where there is almost no ocean area available.

Keywords: latitudinal; bathymetrical; species richness; NW Pacific; Arctic Ocean

## Fish monitoring in the Mediterranean Sea: Statistical power of baited, remote, underwater video is higher than traditional trammel net sampling for fish stock assessment

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Sentinel monitoring of fish populations is an indispensable component of sustainable management, yet most current methods of fish monitoring are either destructive or have questionable or unknown statistical power to detect change. Evaluating the power of alternative methods is difficult because fish population densities rarely follow anything resembling a normal distribution, and spatio-temporal variance itself is highly variable, making changes in mean abundance difficult to separate from changes in variance, regardless of sample size. It is currently unclear if there are any methods of fish stock assessment that are capable of reliably demonstrating population declines before they result in serious ecological and economic losses. We evaluated the suitability and statistical power of two alternative methods in the Mediterranean Sea: traditional but destructive trammel net sampling, and non-destructive BRUV (baited remote underwater video). Based on 20 and 90 deployments of trammel and BRUV sampling equipment near Kornati NP in Croatia in 2016 and 2017, we found that abundance of most fish species were indistinguishable from either quasi-Poisson or negative binomial distributions, often zero inflated, for which there are no simple methods for calculating statistical power. We used numerical simulation to precisely estimate power in confirmatory tests using generalized linear models that assume a quasi-Poisson distribution of residuals with a log link function for the nonzero component of abundance, and a binomial distribution with logit function for the presence/absence component of abundance. We found that the dispersion parameter varied among species from 0.1 to over 60 for BRUV sampling, and up to 300 for schooling species in the trammel method. Because of higher dispersion and lower mean abundances, the trammel method is incapable of detecting less than a 60% loss in abundance in any species at a power of 80%, while the BRUV method can detect less than a 50% loss in a total of 10 species. For 72% of species, the BRUV method can detect a loss of 50% at less than half the field effort of the trammel method. Because of high dispersions in both methods, logistic regression on presence/absence generally has greater statistical power than testing for differences in mean nonzero abundance. Presence/absence can be measured with BRUV for nearly every species (but not in trammel) based on time of its first appearance. Our results indicate that for the Mediterranean Sea, the non-destructive BRUV method has higher statistical power for detection of loss in most species. However, several species have volatile abundance distributions and there remains a great need for the further refinement of non-destructive methods for detecting moderate fluctuations in mean population density of economically/ecologically important fish species.

Keywords: stock assessment; BRUV; trammel; statistical power; generalized linear models

## Possible marine picoplankton response to future warming

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Climatic models predict surface water temperatures increase by 2-4oC over the next few decades. Global warming is assumed to alter the trophic interactions and carbon flow patterns of aquatic food webs, especially in the areas that are highly reactive to external forces, such as the Adriatic Sea. A major role in the global carbon cycle and regulation of the world's climate is played by marine microorganisms. Temperature is an extremely influencing factor on microbial processes such as production, growth rate and growth efficiency, as well as on bacterial grazing and viral lysis. To address the importance of microbial processes in global climate change, we performed laboratory grazing dilution experiments on the growth and mortality rates of the picoplankton community of the Adriatic Sea in four different seasons under *in situ* and 3°C above *in situ* temperature. Experimental temperature increase had different impact on the growth and mortality rates of different picoplankton groups in different seasons. The highest growth and mortality rates for heterotrophic bacteria were recorded in February, for *Prochlorococcus* and *Synechococcus* in July and November, and for picoeukaryotes in April. Mortality of all picoplankton groups was mainly caused by protistan grazing. 89-91% of total picoplankton biomass was channelled to grazers in the cold months compared to 75-84% in the warm months. The experimental temperature increase also resulted in greater enhancement of bacterial respiration than bacterial production. Consequently, bacterial growth efficiency was negatively related to temperature in all months. These results point to important changes in the future carbon cycle related to the role of microorganisms in the Adriatic Sea further increasing the importance of microbial food web in biomass transfer towards higher trophic levels.

Keywords: Adriatic Sea; picoplankton community; grazing dilution experiments; global warming

## Growth performance and physiological traits of *Posidonia Oceanica* exposed to a hypersaline environment

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The endemic seagrass *Posidonia oceanica*, widely distributed along the coasts of the Mediterranean Sea, is a seagrass species which form dense meadows between the surface and depths of 30–40 m, constituting the *climax* stage of infralittoral zones. *P. oceanica* is generally considered a highly sensitive species to salinity increments; however, in a particular case, natural populations can grow under salinity levels above its normal threshold of tolerance.

One such case is a population of *P. oceanica* in the Stagnone of Marsala, a semi-enclosed lagoon, situated on the western coast of Sicily. This environment is characterized by extreme temperature and salinity variations, with seasonal periods of hypersalinity in summer, that potentially representing a stress for plants, which are able to survive under this natural hydrodynamic gradient. In this study, growth performance and physiological traits variations of *P. oceanica* population growing inside the Stagnone of Marsala, were analysed in order to assess if the shoots coming from such gradient are able to differentially response, adapt and tolerate this kind of stress. *P. oceanica* collected along such gradient, from the semi-enclosed lagoon towards open sea, was exposed to a controlled hypersaline short term stress in a mesocosm environment, with the aim of separating effects of salinity from other potentially deleterious stressors, like temperature. It examined effects of salinity stress compared with seawater controls over 4 weeks at 46 PSU on *P. oceanica* growing in mesocosms.

An interesting aspect to highlight is the gradient of adaptation to hypersaline stress from the open sea towards the Stagnone of Marsala with an increasing for these population in the content of proline and respiratory rates, reduction of growth and photosynthetic rates, of leaf water potential ( $\Psi_w$ ) and osmotic potential ( $\Psi_\pi$ ) (i.e. more negative), while turgor pressure ( $\Psi_p$ ) was unaffected.

These responses suggest that *P. oceanica* plants growing in the center of the Stagnone of Marsala under the fluctuating influence of hypersaline waters (up to 46 PSU) for decades evolved an osmo-acclimation strategy that differs from the plants growing under natural salinity levels (37–38 PSU) and at longer time have been able to develop physiological and/or structural to support this particular strategy.

Keywords: *Posidonia oceanica*; hypersaline stress; hypersaline lagoon; water relations; photosynthesis; osmolytes

## A multiscale seascape approach to assess animal communities in Baltic Sea seagrass meadows

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Seagrass meadows are important habitats for commercially important fish species, as they constitute nursery-, hiding- and foraging grounds. Though, a worldwide decrease of seagrass coverage by c. 29% has occurred during the last century, and along the Swedish west coast has a reduction of 60% during the past 30 years been documented. On the Swedish east coast (western Baltic Sea), however, little is known about seagrass distribution and quality; therefore, it is imperative to understand the role of seagrass meadows in relation to faunal and floral communities at different scales, in this region. This study aims to investigate epifaunal communities in Baltic Sea eelgrass (*Zostera marina*) meadows using a multiscale seascape approach. Twenty sites (each composed of a focal seagrass meadow) were sampled for epifauna and seagrass habitat metrics. A further ten sites were mapped (at a 600 m diameter scale) to quantify benthic habitat spatial patterning, and to assess the potential effects of larger spatial scale variables. Fish data were also collected to gain an indication of the fish assemblage that utilise these seagrass meadows. Seagrass structural complexity (i.e. seagrass shoot height and density) played a minor part in explaining the variation in epifaunal communities, whereas the presence of other flora and amount of filamentous algae explained a major part of the variation and were both positively related to epifaunal abundance. Furthermore, seascape variables, such as total vegetation coverage, explained some of the variation of epifaunal abundance, though negatively, as did the presence of fish. As many epifauna groups recruit through larvae carried with water currents, an increased vegetation coverage assessed at the seascape level can be expected to have a negative effect on epifauna abundance, whereas an increased structural complexity of the meadow increases the enticement of the habitat, thus potentially increasing the abundance and diversity of epifaunal groups. This study fills an important knowledge gap of the function of eelgrass meadows and their associated flora and fauna communities in the western Baltic Sea and gives insight into the importance of different scale variables that affect these underwater ecosystems.

Keywords: Baltic Sea; eelgrass; epifauna; seascape



## Combined effects of nutrients from aquaculture and agriculture on macroalgal growth: A bioassay study

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A sustainable expansion of marine aquaculture is only possible if farms are managed according to the resilience and carrying capacity of their respective environments. Until now, many fish farms are operated as open-systems, releasing immense amounts of dissolved nutrients into surrounding waters. Increased nutrient levels around fish farms cause higher macroalgal growth in the direct vicinity. However, it is still unknown how nutrient pollution from fish farms interacts with other coastal nutrient sources such as agricultural run-off from land. Thus, the aim of this study was to assess effects from two different nutrient sources alone and in combination on different macroalgal species.

In a bioassay experiment, we measured the effects of nutrient release from aquaculture (varying distance to a fish farm) and agriculture (addition of fertiliser) on the growth and nutrient up-take of four different macroalgae: bladder wrack (*Fucus vesiculosus*), dulse (*Palmaria palmata*), sea lettuces species (*Ulva* spec.) and the common green branched weed (*Cladophora rupestris*). The experiment was running over a course of 4 weeks in a northern Norwegian fjord. Both nutrient sources alone increased growth rates of most algal species. However, combination of both nutrients had strong species-specific effects on growth rates. Specifically, growth rate of *Cladophora* strongly increased. Our preliminary results highlight the importance of interactive effects of several human-induced impacts on ecosystem properties.

Keywords: ecosystem effect; marine aquaculture; bioassay; macroalgae; eutrophication; nutrient pollution

## Rates and patterns of missing appendages in snow crab (*Chionoecetes opilio*) population in the southern Gulf of Saint Lawrence and its possible causes

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Crustaceans may lose their pereopods (chelipeds and walking legs) due to predation, intra- and inter-specific competition, through moulting process or during the commercial fishing activity (Abello et al., 1994). Missing pereopod patterns in a snow crab (*Chionoecetes opilio*) population were analyzed based on annual bottom survey data conducted since 2000 in the southern Gulf of Saint Lawrence, northwestern Atlantic. Pereopods loss rates were regressed over sex, maturity stage and size, as well as the moulting phase. Spatio-temporal variation of appendage loss and relationship between appendage loss and crab abundance were also considered.

Preliminary results showed that a significant difference between the sexes, maturity phases and size. The rates for immature crab were generally low and constant over all sizes, whereas the rate was two to three times higher in sexually mature than immature crab. In addition, these rates were twice as high in smaller mature males as for larger ones. This pattern is even apparent in recently moulted males. Older shelled (terminally moulted) males showed only a moderate increase in appendage loss over a mating period compared to recently moulted one that are the first participant to the mating competition. The loss rates were twice as high in smaller mature males as for larger ones. The rates for females were about half of the rates observed in males and were more or less constant with crab size. In males the 2<sup>nd</sup> pereopods had the highest loss rates whereas the chelipeds and 5<sup>th</sup> pereopods had the lowest. In females, the 2<sup>nd</sup> and 5<sup>th</sup> pereopods had the highest rates whereas the chelipeds had a rate less than half that of any other pereopods. Pereopod loss rates in females were about 60% those observed in males. Mature females similarly showed higher rates than immature ones with newly moulted females having a moderate increase in pereopod loss rates than older mature females. This may be a function of the longer life expectancy of mature female versus male snow crab. Annual changes in the pereopod rates showed some correlation with underlying population dynamics, most notably high abundance levels in large males.

Such results strongly suggest that the main cause for pereopod loss may occur at intra-specific (mating) competition (Conan and Comeau, 1986) rather than commercial fishing induced loss.

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Keywords: snow crab; crustacea; decapoda; northwestern Atlantic; appendage loss; mating competition

## Human exposure to algal toxins via sea spray aerosols

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Airborne exposure of man to marine natural substances via sea spray aerosols (SSAs) is recently receiving more and more attention. The inhalation of low concentrations of biogenics has been hypothesized as one of the human health promoting mechanisms<sup>[1]</sup> that causes the epidemiologically observed beneficial coastal health effect<sup>[2]</sup>. Algal toxins or phycotoxins, such as okadaic acid (OA) and yessotoxin (YTX), are proposed as possible key effect chemicals within this so called biogenics hypothesis. However, no observations have ever confirmed the presence of these specific phycotoxins in SSAs, nor was aerosolisation ever suggested. The only phycotoxins which have been measured within an (natural) aerosol phase, are brevetoxin (PbTx) and ovatoxin (OVTX), and this under favorable sea spray aerosolisation conditions during severe blooms of *Karenia brevis* and *Ostreopsis ovata*, respectively. During these events, when high air concentrations of PbTx ( $\leq 180 \text{ ng m}^{-3}$ )<sup>[3]</sup> and OVTX ( $\leq 2 \text{ ng m}^{-3}$ )<sup>[4]</sup> are generated, exposed coastal populations may experience respiratory syndromes. These elevated air concentrations are the exception. Background concentrations are usually much lower, certainly for toxins (e.g. YTX) which are produced by non-severe blooming species. The quantification of these low concentrations is not that straightforward. Only in exceptional cases environmental samples contain quantities that exceed the analytical limits of detection and quantification.

This study aimed at the development of new methods to simultaneously quantify multiple phycotoxins in SSAs, in both direct and indirect ways. SSA phycotoxin concentrations were analysed by combining two analytical techniques: ultra-high performance liquid chromatography coupled to high-resolution Orbitrap mass spectrometry (UHPLC-HRMS), and inductively coupled plasma optical emission spectrometry (ICP-OES). With these analytical techniques and the artificial production of SSAs using a marine aerosol reference tank<sup>[5]</sup>, specific phycotoxins were not only detected and quantified for the first time in an (natural) aerosol phase, but also the aerosolisation process itself was studied. Using these newly developed methods in the field, the first data are being generated to assess the environmental air concentrations of phycotoxins which are suggested as potential health-promoting chemicals within the biogenics hypothesis.

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Keywords: sea spray aerosols; biogenics hypothesis; phycotoxins; UHPLC-HRMS

## Spatial and temporal distribution and community structure of macro-infauna in seagrass biotope – Shimoni, Kenya

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Macrobenthic infauna organisms provide an important role in ecosystem processes such as nutrient cycling, pollutant metabolism, dispersion and acting as food source for larger organisms. Despite their importance and significance in marine ecosystems, there is inadequate scientific understanding of macro-infauna species distribution and interactions with both biotic and abiotic factors. This study determined the macro-infauna abundance and community diversity in seagrass habitats in three sampling sites in the Kenyan south coast (Wasini, Kibuyuni and Sii Island) for a period of three years (December 2012, March 2014 and December 2014). Three replicates of sediments samples were systematically collected from three transects of 50m length and 5m width after every 10m at each station using plastic corers (length= 10cm, diameter= 6.4cm). The samples were preserved using 5% buffered formalin solution, stained with Rose Bengal (to aid in sorting of macro-infauna) and observed under dissecting microscope. Abundance in the three monitoring sites was averagely relatively high (26 789 individuals/m<sup>2</sup>) dominated mostly by *Amphipoda*, *Polychaeta*, *Nematoda*, *Oligochaeta*, *Tanaidacea* and *Ostracoda* classes. Diversity indices in the three monitoring sites were relatively low ranging from 1.609 to 2.144. The results showed that the three sampling stations had similar macro-infauna distribution and community structure whereas abundance varied temporally with seagrass cover. This suggests that temporal changes in seagrass cover influences macrofaunal abundance hence the need to maintain healthy seagrass cover.

Keywords: seagrass; macro-infauna diversity; macro-infauna density

## Analysis of plant growth regulators in two of green seaweeds using high-performance liquid chromatography with electrospray ionization tandem mass spectrometry

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Seaweed extracts and seaweed based products have been recently used as biofertilizer and biostimulant in agriculture due to the presence of a number of plant growth regulators and many other micro/ macro-element nutrients. Although marine algae are widely utilized in the world as biofertilizers in agriculture and horticulture, there are only a few investigations of micro algae usage on development of organic farming in our country. In order to fill this gap, the primary focus of the present work is to reveal main plant growth regulators (indole-3-acetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA<sub>3</sub>), zeatin(Z), and kinetin) of two feasible seaweeds which are *Penicillus capitatus* and *Flabella petiolata* from green seaweed groups available in on seashores of Turkey as a source of potential biofertilizer. To develop an efficient, specific and validated analytical method suitable for the extraction and quantification of plant growth regulators (indole-3-acetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA<sub>3</sub>), zeatin(Z), and kinetin) of the seaweeds, a specific extraction procedure (75 % methanol/water, v/v) was implemented into an analytical protocol using an appropriate buffer solution followed by solid-phase extraction (SPE). Final analyses were performed by high performance liquid chromatography with a photodiode array (PDA) detector in accompanied with tandem mass spectrometry.

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Keywords: plant growth regulators; LC-MS/MS; *Penicillus capitatus*; *Flabella petiolata*

## The latest updates from 9°50' N East Pacific rise hydrothermal vent communities: Beginning of the end is starting

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Hydrothermal vents provide important habitats for deep sea life by chemical energy gradient created by hydrothermal fluid flux. Free living or symbiotic chemoautotrophic microorganisms utilize redox potential in these fluxes and produce organic matter which is the starting point of an unexpectedly productive food web. Features and composition of hydrothermal fluids affect community structure directly due to different adaptation levels of species to the conditions, and energy requirements of the organisms. Because of high tectonic and volcanic activity in hydrothermal vent areas; physical and chemical properties of hydrothermal fluids changes in short time periods, especially in fast spreading areas. These changes cause change in community structure. Cycles of successions observed in fast spreading centers which start by volcanic eruption, species adapted to hot and H<sub>2</sub>S rich fluid flux start to invade new hydrothermal sources. Subsequently, because of cooling and decrease in H<sub>2</sub>S concentrations, dominant species in communities' change, in the end of cycle fluxes stop due to increasing distance to magma, and food web collapse due to lack of driving chemical energy.

9°50' East Pacific Rise is a fast spreading ridge center with high hydrothermal activity. Geological, chemical and biological properties of the region attract scientists' attention since the 1980s. Biogeochemistry and ecosystem of the region has been monitored repeatedly for long time. Our team went to the site on April 2017, 12 years after last volcanic eruption. We conducted survey on vent communities by evaluation of camera records and taking environmental DNA samples. Physical and chemical properties of hydrothermal flux measured *in situ* by using electrochemical sensors. Our observations show that while free living chemoautotrophic microorganism and *Alvinella Pompejana* involving communities observed around hot and H<sub>2</sub>S rich fluxes, *Riftia pachyptila* dominated communities are thriving around the moderate level fluid fluxes; low H<sub>2</sub>S concentration and lower temperature favors *Bathymodiolus thermophilus* dominated communities. Comparison of community structure with previous observations of previous years shows the presence of succession in community clearly, and our findings show that after 12 years from the last eruption succession cycle comes to the end phase.

Keywords: hydrothermal vents; community; succession; electrochemistry

## The RELIONMED EU-LIFE project: public and stakeholder awareness of invasive lionfish in Europe

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The recent invasive spread of *Pterois miles* (Bennett, 1828) has raised concerns due to its potential ecological and socioeconomic impacts. The species is now established in several eastern parts of the basin and is expanding rapidly. The coastal ecosystems of Cyprus, near the Suez Canal, are amongst the first Mediterranean waters to be affected by the lionfish invasion. Sightings from scientists, fishermen and divers confirm that the lionfish are becoming abundant around the island of Cyprus.

The RELIONMED project (Preventing a LIONfish invasion in the MEDiterranean through early response and targeted REmoval) aims to tackle the invasion and mitigate its impacts in biodiversity hotspots and priority habitats off Cyprus. The project aims to make Cyprus the first line of defence against the invasion of lionfish in the Mediterranean. RELIONMED's main objectives are a) to develop the capacity to ensure that Cyprus can tackle the lionfish invasion, b) to assess the effectiveness of a range of lionfish invasion prevention measures such as the development and implementation of an early detection and removal system driven by motivated citizens and c) to develop tools that can be transferred and replicated in other countries of the region.

An Atlantic lionfish invasion has shown that management is most effective when the public and stakeholders are engaged. Therefore, the RELIONMED project aims involve citizens in tackling the invasive lionfish off the coasts of Cyprus. In October and November 2017, surveys were conducted to assess baseline knowledge and perceptions of the general public and primary stakeholders of lionfish in Cyprus. A telephone survey was used to assess the perceptions and knowledge of a representative cross section of adults while questionnaire surveys with marine stakeholders (members of the public who make use of the marine environment as a resource, e.g. anglers, divers, and decision-makers) were conducted alongside meetings held in five districts across the country.

The results revealed differences between public and marine stakeholders' knowledge and perceptions; with the latter being significantly more informed. There was a divergence in opinion regarding the consumption of lionfish and the purchase of products made from lionfish (e.g. jewellery). The public was more opposed to such statements than the stakeholders. However, both the public and stakeholders agreed that it is necessary to undertake research to understand the potential effects of lionfish on the local environment, economy and human-health as well as to develop a management strategy to limit the spread of lionfish.

Keywords: Lessepsian immigrants; invasive species; *Pterois miles*; socioeconomics; Mediterranean