Global biogeochemical provinces of the mesopelagic zone

General information
State: Accepted/In press
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Section for Oceans and Arctic, University of British Columbia, Sorbonne Universités, National Oceanography Centre, Nova Southeastern University, University of Cape Town, CNRS
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Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Biogeography
ISSN (Print): 0305-0270
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.35
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.33
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.58
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.54
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.42
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.95
BFI (2010): BFI-level 2
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Web of Science (2007): Indexed yes
Original language: English
DOIs:
A MSFD complementary approach for the assessment of pressures, knowledge and data gaps in Southern European Seas: The PERSEUS experience

PERSEUS project aims to identify the most relevant pressures exerted on the ecosystems of the Southern European Seas (SES), highlighting knowledge and data gaps that endanger the achievement of SES Good Environmental Status (GES) as mandated by the Marine Strategy Framework Directive (MSFD). A complementary approach has been adopted, by a meta-analysis of existing literature on pressure/impact/knowledge gaps summarized in tables related to the MSFD descriptors, discriminating open waters from coastal areas. A comparative assessment of the Initial Assessments (IAs) for five SES countries has been also independently performed. The comparison between meta-analysis results and IAs shows similarities for coastal areas only. Major knowledge gaps have been detected for the biodiversity, marine food web, marine litter and underwater noise descriptors. The meta-analysis also allowed the identification of additional research themes targeting research topics that are requested to the achievement of GES.

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography

Pages: 28-39
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Marine Pollution Bulletin
Volume: 95
Issue number: 1
ISSN (Print): 0025-326X
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.46 SJR 1.302 SNIP 1.331
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.245 SNIP 1.277 CiteScore 3.23
A new look at ocean carbon remineralization for estimating deepwater sequestration

The "biological carbon pump" causes carbon sequestration in deep waters by downward transfer of organic matter, mostly as particles. This mechanism depends to a great extent on the uptake of CO2 by marine plankton in surface waters and subsequent sinking of particulate organic carbon (POC) through the water column. Most of the sinking POC is remineralized during its downward transit, and modest changes in remineralization have substantial feedback on atmospheric CO2 concentrations, but little is known about global variability in remineralization. Here we assess this variability based on modern underwater particle imaging combined with field POC flux data and discuss the potential sources of variations. We show a significant relationship between remineralization and the size structure of the...
phytoplankton assemblage. We obtain the first regionalized estimates of remineralization in biogeochemical provinces, where these estimates range between -50 and +100% of the commonly used globally uniform remineralization value. We apply the regionalized values to satellite-derived estimates of upper ocean POC export to calculate regionalized and ocean-wide deep carbon fluxes and sequestration. The resulting value of global organic carbon sequestration at 2000m is 0.33PgCyr-1, and 0.72PgCyr-1 at the depth of the top of the permanent pycnocline, which is up to 3 times higher than the value resulting from the commonly used approach based on uniform remineralization and constant sequestration depth. These results stress that variable remineralization and sequestration depth should be used to model ocean carbon sequestration and feedback on the atmosphere.

**General information**

State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, Sorbonne Universités, National Oceanography Centre
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Pages: 1044-1059
Publication date: 2015
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Global Biogeochemical Cycles
Volume: 29
Issue number: 7
ISSN (Print): 0886-6236
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.55 SJR 2.701 SNIP 1.221
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.046 SNIP 1.462 CiteScore 5.03
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.361 SNIP 1.274 CiteScore 4.02
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.204 SNIP 1.551 CiteScore 4.85
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.936 SNIP 1.512 CiteScore 4.55
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 3.478 SNIP 1.605 CiteScore 4.63
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 4.161 SNIP 1.549
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.32 SNIP 1.42
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 3.107 SNIP 1.466
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.169 SNIP 1.575
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.856 SNIP 1.415
Web of Science (2006): Indexed yes
Progressive changes in the Western English Channel foster a reorganization in the plankton food web

Growing evidence has shown a profound modification of plankton communities of the North East Atlantic and adjacent seas over the past decades. This drastic change has been attributed to a modification of the environmental conditions that regulate the dynamics and the spatial distribution of ectothermic species in the ocean. Recently, several studies have highlighted modifications of the regional climate station L4 (50° 15.00'N, 4° 13.02'W) in the Western English Channel. We here focus on the modification of the plankton community by studying the long-term, annual and seasonal changes of five zooplankton groups and eight copepod genera. We detail the main composition and the phenology of the plankton communities during four climatic periods identified at the L4 station: 1988-1994, 1995-2000, 2001-2007 and 2008-2012. Our results show that long-term environmental changes underlined by Molinero et al. (2013) drive a profound restructuration of the plankton community modifying the phenology and the dominance of key planktonic groups including fish larvae. Consequently, the slow but deep modifications detected in the plankton community highlight a climate driven ecosystem shift in the Western English Channel

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, GEOMAR - Helmholtz Centre for Ocean Research Kiel, Marine Biological Association of the United Kingdom, Université Montpellier
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Pages: 524-532
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Progress in Oceanography
Volume: 137
ISSN (Print): 0079-6611
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.4 SJR 1.922 SNIP 1.278
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.703 SNIP 1.348 CiteScore 3.34
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.909 SNIP 1.461 CiteScore 3.65
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.397 SNIP 1.595 CiteScore 3.87
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.741 SNIP 1.794 CiteScore 4.17
Defining Mediterranean and Black Sea biogeochemical subprovinces and synthetic ocean indicators using mesoscale oceanographic features

The Mediterranean and Black Seas are semi-enclosed basins characterized by high environmental variability and growing anthropogenic pressure. This has led to an increasing need for a bioregionalization of the oceanic environment at local and regional scales that can be used for managerial applications as a geographical reference. We aim to identify biogeochemical subprovinces within this domain, and develop synthetic indices of the key oceanographic dynamics of each subprovince to quantify baselines from which to assess variability and change. To do this, we compile a data set of 101 months (2002-2010) of a variety of both “classical” (i.e., sea surface temperature, surface chlorophyll-a, and bathymetry) and “mesoscale” (i.e., eddy kinetic energy, finite-size Lyapunov exponents, and surface frontal gradients) ocean features that we use to characterize the surface ocean variability. We employ a k-means clustering algorithm to objectively define biogeochemical subprovinces based on classical features, and, for the first time, on mesoscale features, and on a combination of both classical and mesoscale features. Principal components analysis is then performed on the oceanographic variables to define integrative indices to monitor the environmental changes within each resultant subprovince at monthly resolutions. Using both the classical and mesoscale features, we find five biogeochemical subprovinces for the Mediterranean and Black Seas. Interestingly, the use of mesoscale variables contributes highly in the delineation of the open ocean. The first axis of the principal component analysis is explained primarily by classical ocean features and the second axis is explained by mesoscale features. Biogeochemical subprovinces identified by the present study can be useful within the European management framework as an objective geographical framework of the Mediterranean and Black Seas, and the synthetic ocean indicators developed here can be used to monitor variability and long-term change.

General information

State: Published
Organisations: National Institute of Aquatic Resources, Section for Marine Ecology and Oceanography, IFREMER, University of Washington, Universitat de les Illes Balears, IRD, European Commission - Joint Research Center
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DOI: 10.1016/j.pocean.2015.04.025
Publication: Research - peer-review › Journal article – Annual report year: 2015
Centre for Macroeology, Evolution and Climate (CMEC) (38784)

This project investigated large scale patterns and variations of life in the ocean, focusing primarily on fishes. The theme used fishes to investigate how processes associated with climate change and human impacts (e. g., fishing and eutrophication) influence fish life histories, biodiversity and the dynamics of populations and species over large time and space scales. Studies have focussed on key processes affecting life histories and distribution of populations and species, including reproduction, mortality, and migration.

The project had one full-time PhD student, and 5 postdoctoral scientists. The relatively high number of postdocs in a short period was due to their success at finding permanent jobs as tenure-track assistant professors, or as research scientists or managers in either industry or academia.

Key results by DTU Aqua colleagues in the project include the following:
- A pan-Atlantic analysis and discovery of how temperature affects reproductive timing in cod, with evidence for local adaptation of cod thermal physiology and counter-gradient evolution. Our ongoing work is now investigating the consequences of this adaptation for match-mismatch of cod larval production with the timing of the peak production of major zooplankton prey species (e. g. Calanus finmarchicus, Pseudocalanus sp.)
- New estimates of the numbers, locations and volumes of the mesopelagic provinces of the world’s oceans, and based for the first time on the dynamics of ocean primary productivity, C sedimentation and photic zones. These new habitat descriptors of the mesopelagic ocean will provide new contexts for studies of ocean biodiversity, and the distribution and productivity of mesopelagic fishes and other biota.
- New models of fish lifetime reproductive output which demonstrated that a fish’s annual reproductive output was strongly related to maximum body size. Moreover, indeterminate spawners had ca. 10-fold higher reproductive output per unit weight than determinate spawners suggesting possible differences in survival rates among the early life history stages between these two groups of fishes.
- Estimates of how climate change will affect the spawning locations and timing for herring in the North Sea, based on climate change scenarios, lab studies of temperature effects on egg survival rate and substrate requirements for herring egg deposition
- Global patterns in taxonomic and functional descriptors of fish biodiversity and how these are inter-related and affected by ocean conditions (e. g., primary production, ecosystem size). Ongoing work is relating these patterns to biodiversity protection (e. g., MPA coverage).

The project was coordinated by University of Copenhagen, Denmark. The project was funded by the Danish National Research Foundation.

National Institute of Aquatic Resources

Section for Marine Ecology and Oceanography

University of Copenhagen
Period: 01/01/2010 → 31/12/2015
Number of participants: 7
Research areas: Oceanography & Marine Populations and Ecosystem Dynamics

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