UM4MRM23	CONCEPTS ET PRATIQUES EN OCÉANOGRAPHIE (3) : ÉCOLOGIE ET MÉTHODOLOGIE	
6 ECTS	*Keywords*	mediterranean pelagic and benthic ecology, methodology in oceanography, sampling strategy, fieldwork at sea, data analysis and processing, multivariate analyses, modelling
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Description

Format

Teaching

The course includes 24 hours of lectures, 40 hours of Tutorials / Practical Work, and 8 hours of field trips. The Tutorials/Practical Work consist of:

- Field trips (lagoon ecosystems) and a marine campaign for sampling
- Numerous practical sessions analysing collected samples (pigment measurements, flow cytometry, nutrient analysis, etc.)
- Data analysis (PCA, CA, etc.)
- Time series analysis with Ocean Data View
- Using R to explore spatial interpolation methods and multidimensional exploratory data analysis techniques

Evaluation

- 50% of the final grade will be based on 3 oral presentations (in groups of 3) regarding the data collected during the practical sessions and field trips.
- 50% of the final grade will be based on a 3-hour written exam covering all the practical and theoretical aspects covered during the course unit.

Summary

CPOB-Part 3 is a practical course that combines fieldwork with numerous practical sessions (TP/TD) focused on data processing and analysis. The goal is to illustrate and apply the concepts learned during the first semester and build on the knowledge acquired in CPOB2. Part 3 is dedicated to data acquisition, analysis, and modelling. This course applies to both taxonomic and functional diversities and the methods used to study these aspects in benthic and pelagic environments. The final objective is to integrate theoretical knowledge in biological oceanography and marine ecology with both conceptual and practical skills, providing a comprehensive understanding of the functioning and study methods of marine ecosystems.

Learning objectives

By the end of the course, the student will be able to:

1. Design and apply an ecological field study (benthic and pelagic), including elaborating a sampling strategy, fieldwork, laboratory work, and data analysis.
2. Characterize the diversity of benthic and pelagic organisms and understand their adaptations.
3. Calculate and interpret biotic indices to assess the ecological status of environments.
4. Describe and process data using ordination and clustering methods to implement multidimensional exploratory analysis techniques.
5. Apply spatial interpolation methods and distinguish the limitations of these methods.
6. Analyse temporal variations and trends in oceanographic data

7. Conduct pigment analysis and apply flow cytometry techniques to assess phytoplankton biomass, diversity, and the composition and abundance of planktonic organisms.

Prerequisites

The student should preferably have a background in general ecology.

Bibliography

Manly, B. F., & Alberto, J. A. N. (Eds.). (2014). *Introduction to ecological sampling*. CRC Press.
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S. Frontier, D. Pichod-Viale, A. Leprêtre, Dominique Davoult, Christophe Luczak. Ecosystèmes. Structure, fonctionnement, évolution. Dunod, 4ème édition, Paris., 558p., 2008, 4ème édition. ⟨hal-00481137⟩

Organisation details

The detailed objectives and activities of the course are as follows:

1. Study Design and Sampling Techniques

- Design an ecological field study, from sampling strategy to fieldwork and laboratory work.
- Define a sampling plan that is consistent with the scientific problem posed and list its limitations.
- Master benthic sampling techniques (grab samplers, dredges, etc.) and pelagic sampling techniques (plankton nets, hydrological bottles, CTD profilers).

2. Data Collection and Analysis in Oceanography

- Apply various common analysis techniques in oceanography (measuring photosynthetic pigments, nutrients, cell counting by flow cytometry, etc.).
- Use Ocean Data View software to qualify and visualize a dataset.
- Apply spatial interpolation methods, interpret results, and distinguish the limitations of these methods.

3. Ecological and Biological Studies

- Characterize the diversity of benthic and pelagic ecosystems, the organisms associated with these environments, and understand their adaptations.
- Understand the role of interspecific relationships in community structure and describe the nature of different long-term interactions in the marine environment.
- Understand the Mediterranean lagoon ecosystem: formation, physicochemical characteristics, and lagoon biocoenosis.
- Understand the specificities and implications of life cycle patterns in the sea: reproduction, dispersion, and larval recruitment.
- Conduct growth pattern analysis of the mineralized tissues of organisms. Master the applications of these techniques and their limitations, particularly for studying organism ecology and their applications in fisheries and aquaculture.

4. Long-Term Data Analysis and Interpretation

- Understand and apply the basic tools for studying multi-annual datasets (SOMLIT).
- Compare, explain, and discuss the results of multi-annual series.
- Calculate and interpret biotic indices to assess the ecological status of benthic environments.
- Describe the utility of ordination and clustering methods for reducing data dimensionality and identify the appropriate method.
- Implement and interpret the results of fundamental multidimensional exploratory data analysis methods using R software.

5. Teamwork and Communication

- Organize and work in small groups for fieldwork and prepare for oral presentations.
- Present an oral synthesis of the data acquired during practical sessions.

SYLLABUS

Sampling Strategy (É. GOBERVILLE)

Lecture: 4hs / Practical work: 4hs / Students' presentation: 1h
This chapter is devoted to the sampling strategy, ***from the basics of sampling during lectures to data analysis*** *in the practical work (****with R****), while presenting the most important steps for developing and conducting a relevant sampling and different methods of data analysis. To illustrate this chapter short videos are also available.*

Part. 1. Lecture: Knowing whole from its part…in the most effective way (~2h30)

- Introduction
- Basics of sampling
- The purpose of sampling
- Steps to develop and conduct a sampling strategy
- Choosing sampling methods
- Sampling and monitoring

Part. 2. Lecture: Going on the grid: gridding and spatial interpolation (~1h30)

- What is spatial interpolation and why
- Sample of interpolation
- Interpolation methods (a quick overview)
    - *Thiessen polygon*
    - *Local average*
    - *Inverse distance weighted*
    - *Spline*
    - *Kriging*

Part 3. Students' presentation of their sampling plan (= 1h)

After the theoretical teachings (Part 1 more specifically), students have a dedicated period of personal work aimed at proposing a coherent sampling plan (based on the initial scientific question) that could be implemented during the pelagic cruise day. Students present the result of their reflections as a group, and the proposals are discussed.

Part 4. Practical work (with R) : Sampling strategy and spatial interpolation (= 4hs)

- Converting Coordinates
- Maps of your sampling stations
- Zonation - theoretical example
- Inverse distance weighted (IDW), step-by-step
- Spatial interpolation based on IDW using data from previous years (focus on chlorophyll a and interpretation of spatial patterns)
- Comparison between observations and interpolated values (cross-validation)

Techniques and Applications of Pigment Analysis in Oceanography (F. LANTOINE)

Lecture: 1h30 / Practical work and field trip: 10h / Tutorial work 3h / oral presentation: 2 h

I. Diversity and Molecular Structure of Photosynthetic Pigments

- Chlorophyllous pigments
- Carotenoids
- Phycobiliproteins

II. Importance of Pigment Analysis in Oceanography

- Quantitative aspects: Biomass assessment, primary production estimation
- Qualitative aspects: Taxonomic identification, physiological state of phytoplankton

III. Measurement Methods

- Analytical Techniques: Spectrophotometry / Fluorometry /Chromatography
- Indirect Methods: In vivo fluorescence (CTD profiles) / Remote sensing for large-scale monitoring

Practical Session – Pigment Measurement

- Sampling and preparation: Filtration and preparing samples during a field cruise
- Measurement: Determination of pigment concentrations using spectrofluorometry
- Data Analysis: Interpretation of chlorophyll concentrations and their distribution in relation to environmental characteristics

Learning Objectives/ By the end of this module, students will be able to:

- Understand the interests of pigments in marine ecology
- Learn and apply pigment measurement techniques in oceanography
- Analyze and interpret pigment data in a practical setting

The session includes a scientific cruise to study the impact of coastal nutrient inputs from rivers on the phytoplankton community. Students design a sampling strategy and collect data from 20 stations, analyzing pigments, flow cytometry, and key physico-chemical parameters. After processing the data in the lab, they interpret phytoplankton distribution in relation to environmental conditions and present their findings in an oral presentation

Measuring biological diversity and assessing ecological quality status in the marine environment (J ORIGNAC)

Lecture: 2hs / Practical work and Tutorial work: 11h

1) Assumptions for measuring biodiversity /Spatial scale /Different levels of diversity
2) Examples of diversity indices
3) Methods for plotting species abundance data
4) Assessment of benthic ecological quality using macrobenthic invertebrate communities
5) Macrobenthic succession in relation to organic enrichment (SAB curves)
6) Biotic indices and ecological groups in benthic macrofauna
7) Macrobenthic succession in relation to organic enrichment (SAB curves)
8) Focus on the AMBI index
9) Objective of practical work

How to use AMBI software tutorial

Practical Multivariate Analysis (A PRUSKI)

Lecture: 1h30 / Practical work and Tutorial work: (2 x 3h30) / Students' Presentations (2h)

Objective: This module introduces the use of multivariate analysis for handling complex datasets and performing unconstrained analyses using R software. Students will work with real datasets collected during their field studies, applying methods such as Principal Component Analysis (PCA) and Correspondence Analysis (CA). Step-by-step tutorials and short videos will guide students through the analysis process.

Lecture Outline:

1. **Introduction to Multivariate Analysis**: Understanding variables, dimensionality reduction, and ordination.
2. **Principal Component Analysis (PCA)**: Basic principles and application.
3. **Correspondence Analysis (CA)**: Introduction to the method and its ecological relevance.

Aims:

- Introduce basic exploratory multivariate analyses.
- Demonstrate how ordination methods help manage multivariate datasets.
- Use PCA and CA to interpret ecological data and explain their practical applications.
- Assess the number of principal components to retain, interpret scores, and apply them in further analyses.

Skills Acquired: By the end of the module, students will:

- Understand PCA and CA principles and identify when to apply them.
- Perform PCA and CA in R and interpret results.
- Evaluate the pros and cons of these methods.
- Analyze real datasets, including those from previous practicals, and integrate findings into ecological research.

Learning Objectives (Bloom's Taxonomy):

1. **Remember**: Define key concepts like PCA, CA, ordination, and types of data used.
2. **Understand**: Explain dimensionality reduction and the principles of PCA and CA.
3. **Apply**: Choose and conduct PCA/CA in R based on dataset characteristics.
4. **Analyze**: Evaluate eigenvalues, variable contributions, and the number of components to retain.
5. **Evaluate**: Compare matrices for PCA suitability and analyze the strengths/limitations of PCA/CA.
6. **Create**: Apply PCA/CA to a chosen dataset, interpret results, and present findings.

Keywords: Multivariate analyses, ordination, unconstrained analysis, R software

Introduction to Ocean Data View (ODV)

Lecture: 1h30 / Practical work - Tutorial work 3h

Objective: The goal of this session is to familiarize participants with the ODV software, its functionalities, and how to process and visualize oceanographic data mainly using data collected during student' cruise.

1. Introduction to ODV

- Overview of ODV: capabilities, supported data formats, and use cases.
- Key features: data import/export, interactive maps, and visualization tools.

2. Data Import and Setup

- Guide participants through installing ODV and importing data.
- Explore metadata and dataset consistency.

3. Data Visualization

- Create basic visualizations (vertical profiles, map plots).
- Use advanced visualizations (horizontal sections, overlays).

4. Data Analysis and Export

- Introduce statistical tools and data quality control.
- Demonstrate exporting data for further analysis.

Practical /tutorial Work

This section applies directly to the data collected during the students' cruise, which aimed to study the effect of continental nutrient input on phytoplankton communities. Students will use all the data acquired during their sampling cruise to create maps and figures.

1. Guided Exercise: Data Import and Visualization (20 minutes)

Objective: Import the students' own cruise data into ODV. Create basic visualizations for key parameters (e.g., phytoplankton abundance, salinity, temperature) and display them as vertical profiles or map plots. Students will visualize how phytoplankton abundance varies in relation to environmental parameters and river input.

2. Advanced Visualizations

Objective: Create horizontal section plots and interpret spatial distribution.

3. Data Analysis and Export

Objective: Perform basic data analysis on the collected data.

Studying Temporal Variation and Trends in Oceanographic Data

Lecture: 1h30 / Practical work - Tutorial work 3h

Objective: Students will learn how to analyze temporal variations in oceanographic data, detect trends, and interpret changes using their own cruise data and data from the **SOMLIT** (French National Survey of Coastal Environment).

1. Introduction to Temporal Variation and Trends

- **Overview of Temporal Variation:** Definition, significance, and types (short-term and long-term trends).
- **Trend Detection:** Identifying patterns in seasonal cycles, climate change, and other environmental changes.

2. Tools for Analyzing Temporal Trends

- **Using ODV:** How to visualize time series data and create plots for temporal changes.
- **Trend Detection Methods:** Linear regression, moving averages, and other statistical tools.

3. Interpreting Temporal Trends

- **Analyzing Temporal Data:** Walkthrough of cruise data (phytoplankton abundance) and its variations.
- **Using SOMLIT Data:** Accessing and comparing long-term trends in phytoplankton and environmental factors from SOMLIT.
- **Impact on Ecosystem Dynamics:** Relating temporal trends to ecological processes like phytoplankton blooms.

4. Practical Application

- **Hands-On Exercise:** Students analyze time series from their cruise data and SOMLIT data, focusing on trends in phytoplankton and environmental parameters.
- **Discussion:** Interpretation of results and comparison of short-term cruise data with long-term SOMLIT trends.

Life Cycles in Marine Ecosystems: Reproductive and Dissemination Strategies (L BESSEAU)

Lecture: 1h30 / Practical work – 1h30

This lesson focuses on reproduction and dissemination in the marine environment. The introduction covers the environmental constraints faced by marine organisms in relation to reproduction and population dynamics.
The first part of the course addresses the diversity of reproductive strategies in the sea, including:

- Sex expression
- Reproductive strategies
- Reproductive rhythmicity
- Reproductive ecophysiology
- Environmental threats to reproduction

The second part examines the early stages of marine organism life cycles from both an ecophysiological and ecological perspective, focusing on:

- Developmental ecophysiology and metamorphosis
- Larval dispersal and recruitment

During the practical, students will:

- Observe different types of larvae from various phyla in local zooplankton samples
- Conduct in vitro fertilization experiments using sea urchins and ascidians, and observe the first stages of embryonic development

Use of Molecular Tools in Marine Microbiology (R. LAMI)

Lecture: 3hs / Practical work: 1hs

1. Diversity of Techniques in Marine Microbiology

- Importance of molecular tools compared to traditional methods like culture and microscopy.
- Molecular tools are crucial for studying marine microorganisms that are often difficult to culture.

2. Fundamentals of Molecular Tools in Marine Microbiology

- Taxonomic Markers: Understanding the advantages and limitations of markers like 16S (for bacteria) and 18S (for eukaryotes).
- Techniques: DNA extraction, amplification, sequencing, and analysis. Other molecular techniques are also discussed.

3. Benefits of Molecular Approaches in Marine Microbiology

- Concrete examples of molecular research:
    - Fundamental Research Example: Tara Oceans project, which studies microbial diversity in the world's oceans.
    - Applied Research Example: Discovery of bioactive molecules from marine sponges by studying the holobiont (the host and its microbial community).

Practical Session (TP)

- Marine Bacteria Culturing: Culturing marine bacteria.

- Microscopy Observation: Using epifluorescence microscopy with DAPI staining to observe bacteria from seawater. This demonstrates the need for molecular tools to identify the 99% of bacteria that are unculturable.
- Students will calculate the percentage of culturable bacteria in the Banyuls Bay.

This course highlights the importance of molecular tools in studying marine microbiology, offering both theoretical knowledge and practical experience.

Biological Archives (F LARTAUD)

Lecture: 1h30 / Practical work: 3hs

CM – Use of Biological Archives in Marine Sciences (1h30)

- Biomineralization: The process by which organisms form minerals.
- Biomaterials: Materials produced by living organisms.
- Archive Time in the Skeleton of Organisms – Sclerochronology: The study of growth patterns in the skeletons of organisms such as fish, bivalves, and corals.
- Application of Sclerochronology:
    - Age Estimation in Aquaculture Fisheries: Using sclerochronology to determine the age of organisms, particularly in aquaculture.
    - Paleoclimate Archives: Using biological archives to study past climate conditions.
    - Geochemical Proxies in Biological Archives: Analyzing chemical signatures within biological materials to gain insights into environmental conditions.

TP – Sclerochronology (3h)

- Focus on analysing growth patterns using ImageJ software. The session includes examples of data acquisition and growth profile analysis.
- Growth and Age:
    - Otoliths (fish ear bones) for assessing growth rates and age.
    - Labelling Techniques for calibrating growth patterns, with examples from bivalve shells (cockles, oysters).

Skills

- Analysing growth patterns in mineralized tissues of organisms.
- Understanding the advantages and limitations of these techniques, especially for studying the ecology of organisms, as well as in fisheries and aquaculture.

Ecology of Coastal Mediterranean Lagoons (S. SANCHEZ-BROSSEAU)

Lecture: 2h / field/practical's: 4h

Lecture Plan

1. **Definition and Description of the Biotope**
    1.1. Overview of the coastal Mediterranean lagoon ecosystem
    1.2. Key characteristics and environmental factors
2. **Description of the Associated Biocoenosis**
    2.1. Species and communities living within the lagoon
    2.2. Interactions between organisms in the ecosystem
3. **Natural and Anthropogenic Disturbances**
    3.1. Impact of natural events (e.g., storms, sea level changes)
    3.2. Human-induced changes (e.g., pollution, urbanization, overfishing)

Fieldwork in Canet Lagoon

1. **Measurement of Abiotic Parameters**
    1.1. Temperature (T°C) / Salinity levels
2. **Sampling Techniques in the Water Column**
    2.1. Use of sieves, landing nets, and other equipment for sampling
3. **On-site Observation and Identification**
    3.1. Field identification of species using taxonomic keys
    3.2. Target species: molluscs, arthropods, cnidarians, fish, and more

Adaptation to Lagoon Ecosystems

This short course (1 hour) explores aspects of animal communities living in Mediterranean lagoons and their ecophysiological traits. The course begins with a review of the trophic richness of these environments. Key topics include:

- Resident vs. migratory species in lagoon ecosystems
- Adaptive traits of these species
- Aquaculture of lagoon species, based on their ecophysiological traits

These concepts will be demonstrated during a field trip to the Canet Lagoon (66), where students will observe these traits in the field.

Note: This document is for informational purposes. The details of the content and format of the courses and evaluations may change from year to year.