

Zooplankton: ecological role, research lines and study techniques

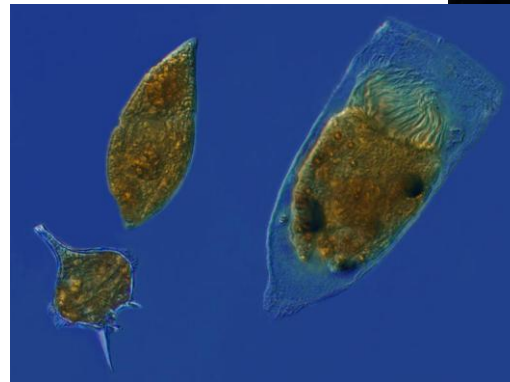
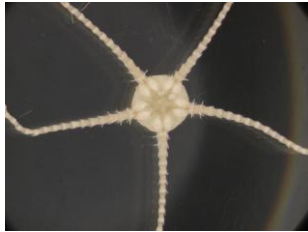
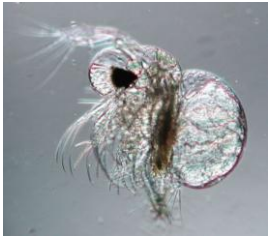
- Elisa Camatti

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
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Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
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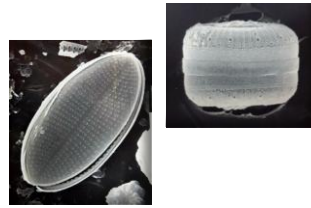
What is the zooplankton

- 🌐 Microscopic or small animal organisms suspended in the water column
- 🌐 Includes: protozoa, copepods, cladocerans, invertebrate larvae, and fish
- 🌐 Excellent biological indicators: they are among the first to respond to environmental changes



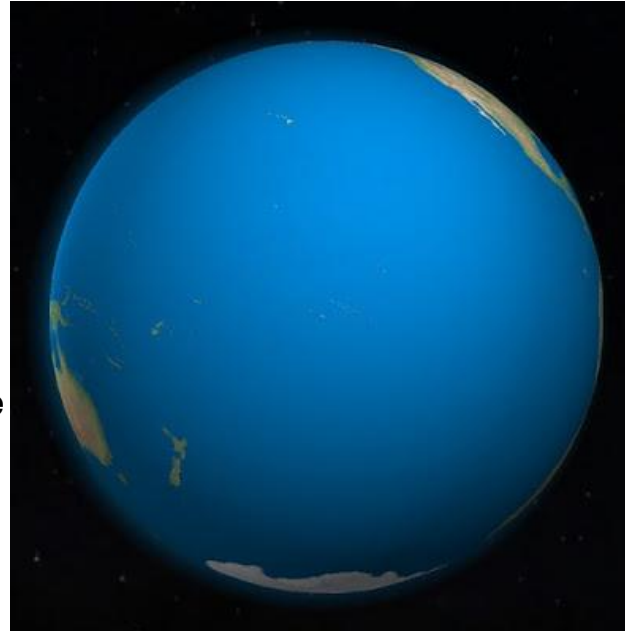
Ecological role of zooplankton

- 🌐 Trophic intermediaries between phytoplankton and fish/marine mammals/humans
- 🌐 Regulate carbon flow (biological pump efficiency)
- 🌐 Mediate the vertical transport of organic matter (diurnal migrations)



PHYTOPLANKTON

**50% (a half)
Of the Oxygen we breathe**



**SALTY WATER
COVERS ABOUT THE 70% OF THE PLANET' SURFACE**



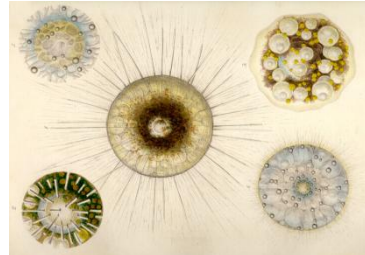
ZOOPLANKTON

The insects of the ocean



Various types of classification: Unicellular/multicellular, Size, Nutrition

- **Micro 20-200 μm**



- **Meso 0,2-20 mm**



- **Macro 2-20 cm**



- **Mega > 20 cm**

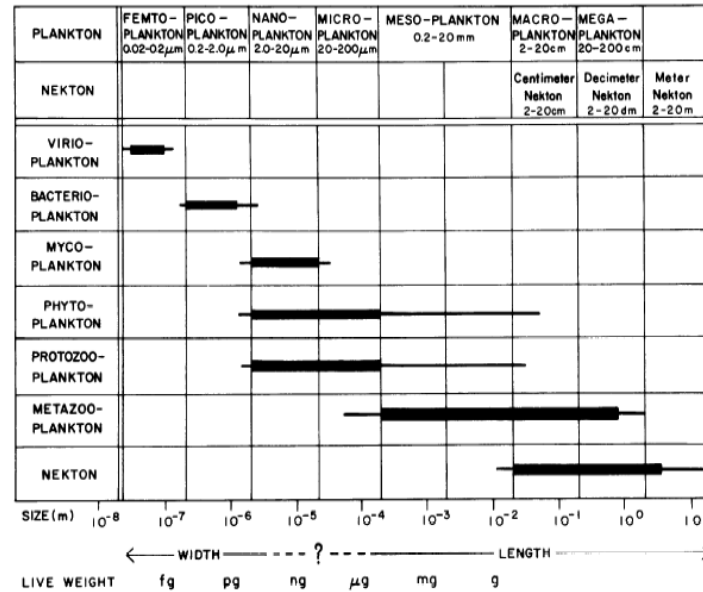
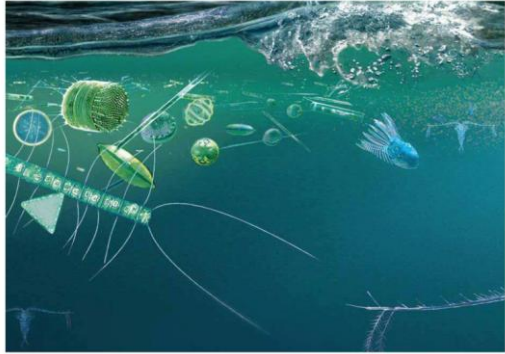


Fig. 1. Distribution of different taxonomic-trophic compartments of plankton in a spectrum of size fractions, with a comparison of size range of nekton.

Why we study it



PHENOLOGY



SEASONAL CALENDAR OF ANNUALLY
RECURRING LIFE CYCLE EVENTS

- PHENOLOGICAL PHASES OF PLANTS AND ANIMALS ARE DRIVED MAINLY BY ENVIRONMENTAL FACTORS
- CHANGES IN PHENOLOGY ARE GOOD INDICATORS OF THE IMPACT OF CLIMATE CHANGE



Main research lines

Biodiversity and Distribution

- Taxonomic and Functional Diversity Study
- Mapping Spatial and Temporal Distribution
- Monitoring Invasive Species and Community Shifts

Ecological Role and Biogeochemical Cycles

- Participation in the Carbon Cycle (Biological Pump)
- Central Position in Marine Food Webs
- Pelagic-Benthic Connections

Climate Change and Human Impacts

- Responses to Warming, Acidification, and Hypoxia
- Impacts of Microplastics and Contaminants
- Phenological Changes and Latitudinal Shifts

Technologies and Advanced Monitoring

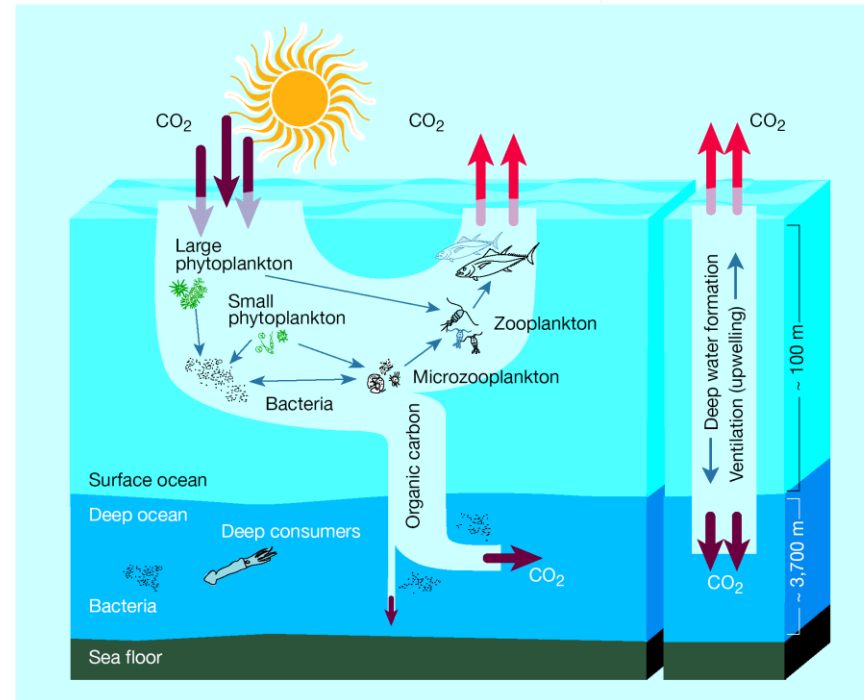
- In Situ Imaging (UVP6, ZooScan, FlowCam)
- eDNA and Metagenomics for Hidden Biodiversity
- AI and Machine Learning for Automatic Classification

Modeling and Future Scenarios

- Ecological and Biogeochemical Models
- Predictive Simulations with Climate Scenarios
- Integration with Observational Data

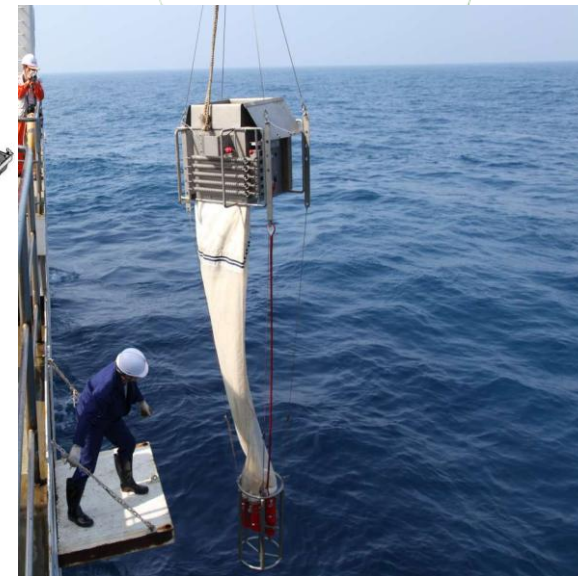
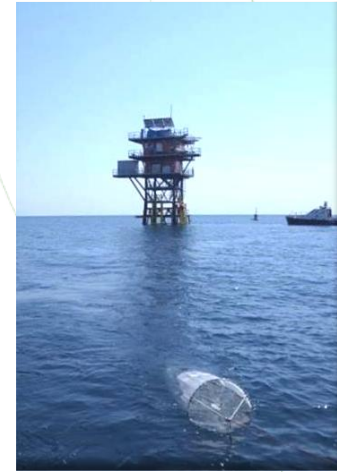
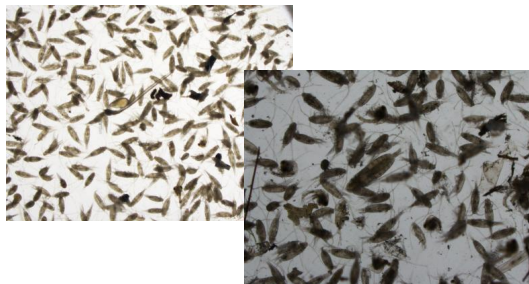
Adaptive Strategies and Life Cycle

- Vertical Migrations, Diapause, and Plasticity
- Adaptations to Extreme Environmental Conditions
- Relationship with Fish Larval Development



Traditional sampling and analysis techniques

- 🌐 Plankton nets (e.g., WP2, Bongo, Multinet)
- 🌐 Niskin bottles
- 🌐 Manual microscopic analysis in the laboratory





To date, a traditional, systematic/morphological approach has been used to analyze zooplankton samples. Image analysis tools are being developed to integrate this approach with artificial intelligence.

WP2 Net

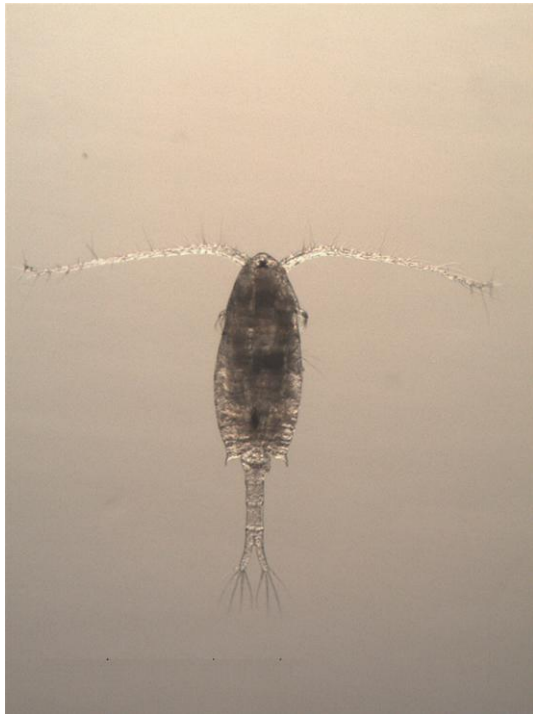
Standard plankton net for vertical sampling; 200 μm mesh

The WP2 net is a standard instrument used for zooplankton sampling, consisting of a conical-cylindrical net with a fine mesh (generally 200 μm) and a circular opening of 57 cm in diameter, ideal for vertical collections in the water column up to several hundred metres deep.



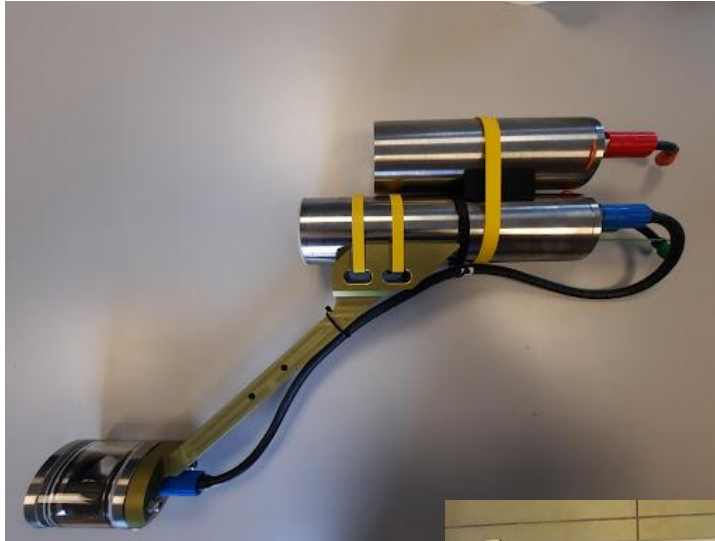
Innovative technologies

- In situ imaging: direct observation in the water column
- UVP6 (Underwater Vision Profiler 6): vertical profiles, particles, and zooplankton >100 μm
- ZooScan and FlowCam: automated imaging in the laboratory



Underwater Vision Profiler 6 (UVP6)

In situ imaging system for the characterization and counting of particulate matter and zooplankton >100 μm



UVP6 stands for Underwater Vision Profiler 6 and is an advanced instrument for in situ observation of marine particulate matter, including planktonic organisms, debris aggregates, and mineral particles, throughout the water column.

Main features:

It acquires sequential images of a known volume of water, allowing for automatic analysis of particulate matter.

It provides data on:

- Particle abundance and size
- Vertical distribution of organic matter
- "Visible" zooplankton communities

It also includes auxiliary sensors (e.g. pressure, temperature).

ZooScan

Automated system for high-resolution imaging and identification of zooplankton in the laboratory



ZooScan is a high-resolution scanner (typically 2,400 dpi) used to digitize fixed zooplankton samples. The resulting images are then processed using dedicated software (ZooProcess, Plankton Identifier) to automatically quantify, measure, and classify the organisms.

Main features:

It uses flat scanning in a transparent-bottom cuvette.

It provides detailed images of planktonic organisms and marine detritus.

Calculates morphometric metrics (area, length, transparency, shape, etc.).

It allows semi-automatic or automatic classification with AI and reference libraries.



FlowCam

Automated system for the morphological and dimensional analysis of microscopic particles in suspension



FlowCam - Flow Cytometer and Microscope, is an imaging-in-flow analysis system that combines the advantages of digital imaging, flow cytometry, and digital microscopy to analyze particles and organisms suspended in liquid, such as phytoplankton and small microzooplankton.

Main features:

- Acquires real-time images of particles as they pass through a flow cell.

- Measures morphological and optical parameters (size, shape, transparency, etc.).

- Allows semi-automatic identification of organisms with analysis software and AI.

- Used in both marine and freshwater, for live or fixed samples.

Towards automation and AI

- Machine learning for automatic identification (EcoTaxa)
- Creation of interoperable databases
- Integration into ocean digital twins

Integration with policies and monitoring

- Contribution to ecological status (Marine Strategy Framework Directive - MSFD)
- Marine biodiversity assessment
- Long-term monitoring programs (LTER, LifeWatch, Euro-BiolImaging)



eDNA

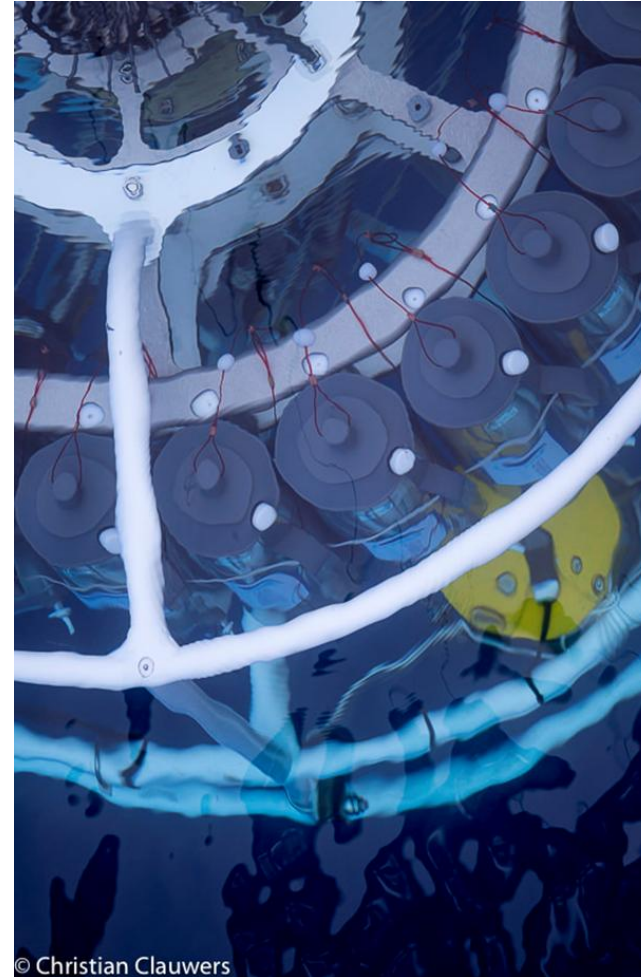
What is eDNA?

- eDNA = environmental DNA, genetic material released by organisms into the environment (e.g., mucous membranes, skin, excrement).
- It is found in water, sediments, biofilms, and air/aerosols.



Why use eDNA at sea

- Non-invasive method
- Detects even rare or cryptic organisms
- High sensitivity, resolution, and taxonomic coverage
- Complementary to traditional methods



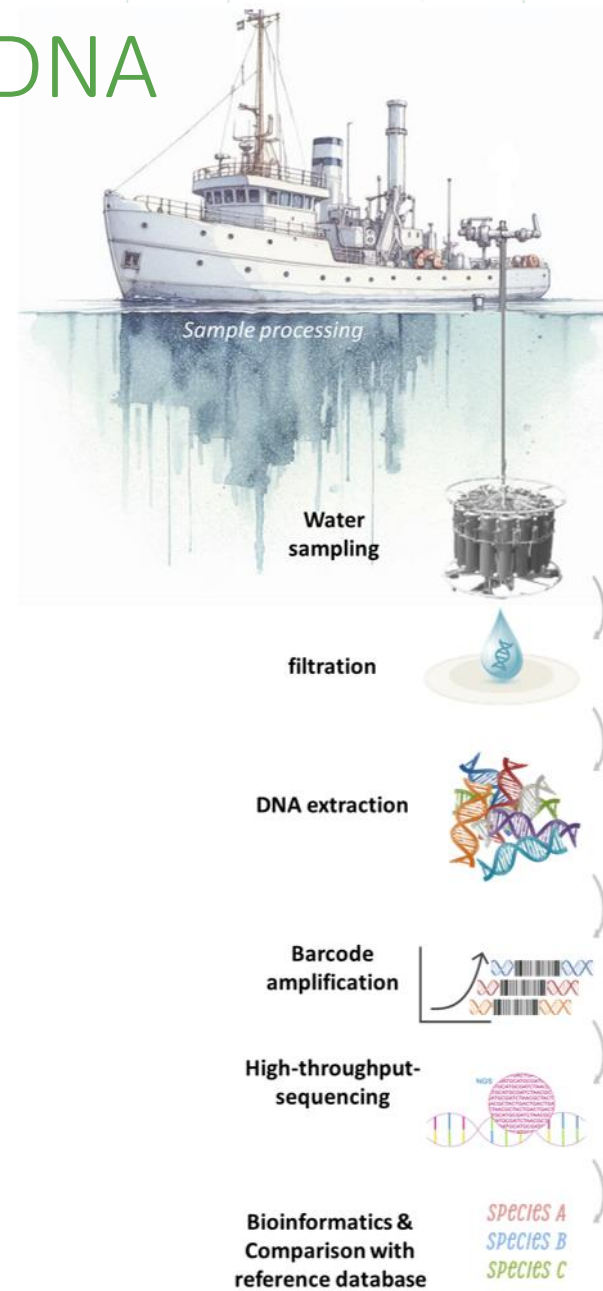
Meccanismi di dispersione e persistenza

- eDNA is dispersed by currents.
- Its persistence depends on: light, temperature, salinity, and microorganisms.
- Variable decay (from hours to days).



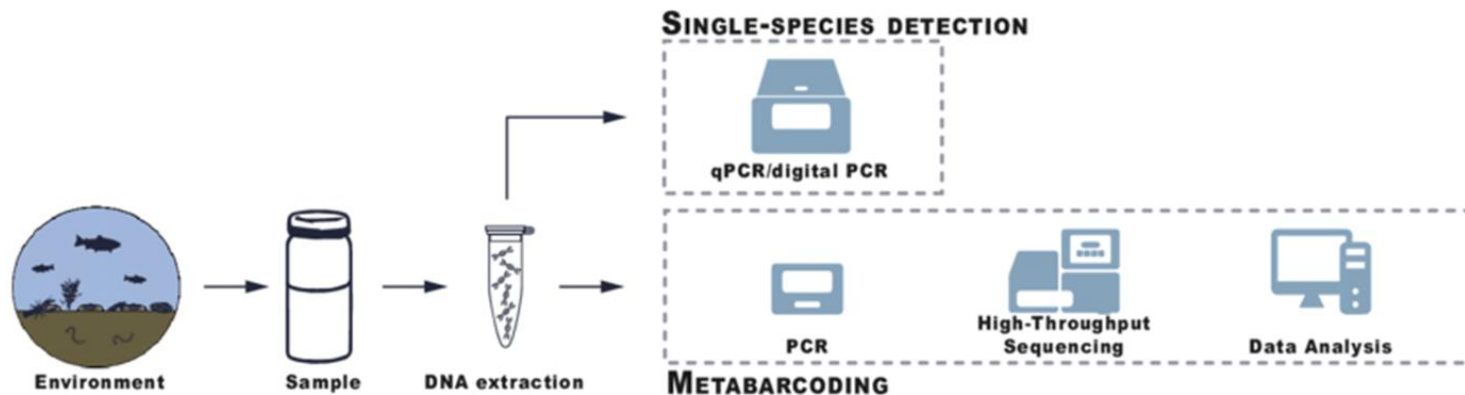
Tecniche di campionamento dell'eDNA

- Water sampling (e.g., Niskin bottles)
- Filtration in situ or in the laboratory
- Storage: cold, ethanol, or specific buffers



Analytical Pipeline

- DNA Extraction
- Amplification (qPCR/metabarcoding)
- Sequencing (e.g., Illumina)
- Bioinformatics: Taxonomic assignment and ecological analysis



Applications in marine ecology

- Biodiversity monitoring
- Early-detection of alien or invasive species
- Food web studies
- Conservation and management of sensitive habitats



Examples and case studies

- Mediterranean Sea: Monitoring of pelagic species
- Arctic and remote regions: Marine mammal surveys
- Tropical reefs: Fish diversity assessment

NEW EDNA METHOD FOR IDENTIFYING ENDANGERED FISH IN HONG KONG MARKETS



Using environmental DNA (eDNA) present in the drain runoff water of fish markets, researchers were able to extract and sequence enough DNA to identify over 100 species of fish that had passed through the market.

Examples and case studies



MiFish

SURFACE

Sardina pilchardus (European pilchard) *Trachurus* (jack macrel)

Tursiops aduncus *Tursiops truncatus* *Pseudorca crassidens*

Trisopterus luscus (cods) *Pteroplatytrygon violacea* *Stenella*

Thunnus alalunga (Albacore) and others

75M

Istiophoriformes

Mauroliscus muelleri *Vinciguerra poweriae* **Lantern fishes** *Notoscopelus elongatus* *Myxophum punctatum* *Hygophum benoiti* *Ceratoscopelus maderensis*

Cyclothone braueri (Garrick)

BOTTOM

Mesoplodon *Dipturus* *Balaenoptera physalus* (Fin whale)

Chauliodus sloani (viperfish) *Etmopterus spinax* (velvet belly lanternshark) *Lampanyctus pusillus*

Cataetx rubrirostris (Rubynose brotula) *Polyacanthonotus rissoanus* (Smallmouth spiny eel)

Arctozenus risso (spotted baracuda) *Stomias*

Limitations and challenges

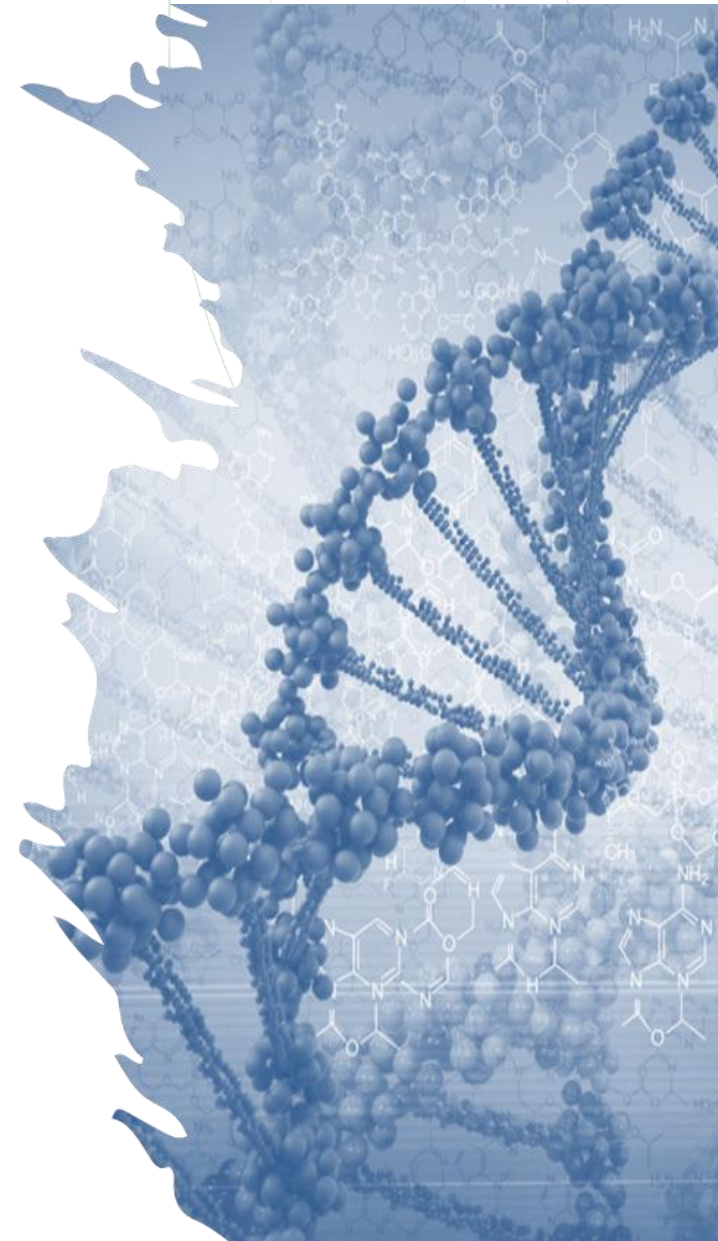
- 🌐 Relative, if not qualitative, quantification
- 🌐 Possible contamination
- 🌐 Difficulty in standardization
- 🌐 Complexity in bioinformatics

eDNA vs Traditional methods

eDNA	Traditional methods
Water, sediment	Whole organisms
Non-invasive	Invasive (nets, dredges)
High sensitivity (even rare species)	Limited by catch
Identification: Molecular	Morphological
Medium-long analysis times	Variable (often very long)
Standardization still under development	Heavily dependent on individual expertise

Conclusions and future perspectives

- eDNA is a promising and expanding technology
- Towards automated, real-time monitoring
- Integration with other technologies and environmental policies





THANKS!

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