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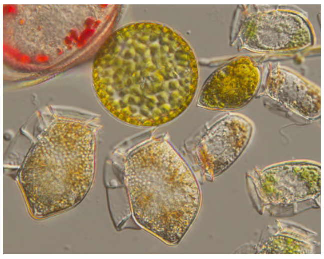
UK PELAGIC HABITATS EXPERT GROUP

NCEA Natural Capital and Ecosystem Assessment

Mixoplankton in the context of Natural Capital and Policy

HIGHLIGHTS



- Traditional monitoring and management tools for oceans, seas, and coasts rely on outdated conceptual frameworks.
- Many phytoplankton and up to half of protist-zooplankton combine plant-like photosynthesis with animal-like consumption within a single cell.
- These dual-function organisms, called **mixoplankton**, challenge marine ecological classifications and require nuanced approaches in studies and management.
- Research over the past two decades has revealed mixoplankton's vital role in structuring and supporting marine food webs.
- The emerging **mixoplankton paradigm** underscores the need for modernized ecological frameworks and management approaches.

Mixoplankton are fundamental to the health of marine food webs in UK waters, and understanding their natural capital value offers new insights into ecosystem resilience and sustainability

A new paradigm in marine ecology

Our monitoring and management tools relating to fisheries production and global change, operate within a paradigm that builds on a simple division between 'plant-like' phytoplankton and their consumers, the 'animal-like' zooplankton at the base of the marine food web.

It is now recognised that most phytoplankton and as much as half the protist-zooplankton combine both plant-like photosynthesis and animal-like consumer activity synergistically within the same single-cell. These are the mixoplankton.

Mixoplankton are not hybrids of phytoplankton or zooplankton, neither did they originate from phytoplankton. Rather, phytoplankton evolved from mixoplankton. The recently published Mixoplankton Database reveals that various marine mixoplankton were previously mislabelled as phytoplankton or zooplankton.

Mixoplankton play an important role in structuring, functioning, and provisioning of food webs in coastal and marine waters. This has led to the emergence of a new paradigm in marine ecology — the mixoplankton paradigm, which sees a restructuring of the plankton food web.

In UK coastal and marine waters, records from the Ocean Biogeographic Information System (OBIS) database reveal the occurrence of 126 species of mixoplankton.

These exhibit a size range over many orders of magnitude (akin to that of mouse to elephant) and express diverse prey preferences (e.g., virus, bacteria, cyanobacteria, diatoms, multicellular animals such as copepods, shrimps, snail larvae etc.). Mixoplankton thus defy attempts to pigeonhole them into a one-size fits all scenario configuration.

A healthy marine ecosystem, particularly in shelf-coastal regions, depends greatly on the proliferation of diverse populations of mixoplankton. However, under certain environmental conditions, the proliferation of noxious mixoplankton can lead to harmful algal blooms, diminishing the value of this ecosystem asset to both ecological health and people.

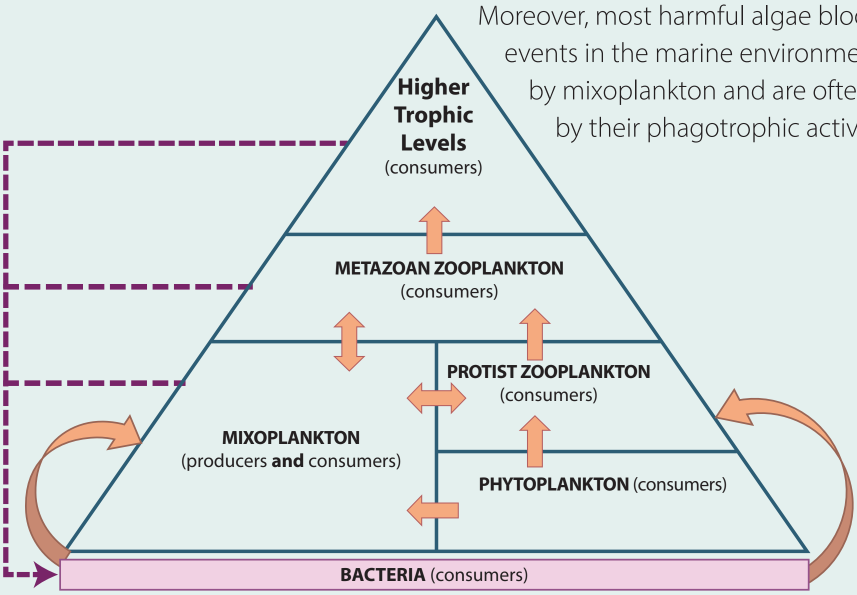
Mixoplankton are more than mixotrophs

All phytoplankton are able to photosynthesize and use some form of dissolved or particulate inorganic nutrients.

Mixoplankton are chlorophyll-containing protist microbes capable of predation. As mixotrophs, they combine photosynthesis, the ability to use dissolved organic nutrients (e.g., amino acids, sugars), and grazing, The dissolved inorganic nitrogen (DIN) excreted from prey digestion within a mixoplankton cell is recycled internally to drive photosynthesis.

Mixoplankton have very different consequences for food web structure as they can convert a wide range of nutrient forms into plankton abundance and directly influence trophic dynamics by consuming other organisms, including competitors and even their own predators. This complexity impacts many marine ecosystem services such as harvestable fish biomass, climate regulation, and water quality maintenance, which are heavily influenced by plankton species that are now defined as mixoplankton.

Moreover, most harmful algae bloom (HAB) events in the marine environment are caused by mixoplankton and are often triggered by their phagotrophic activity.



Mixoplankton paradigm where the base of the food web comprises phytoplankton and mixoplankton.

Mixoplankton paradigm

The ***mixoplankton paradigm*** is the third major shift in marine ecology, following the *microbial loop* — a trophic pathway where dissolved organic carbon (DOC) is returned to higher trophic levels via its incorporation into bacterial biomass, and then coupled with the 'classic food chain' formed by phytoplankton to zooplankton to nekton; and the *viral shunt* — a mechanism that prevents marine microbial particulate organic matter from migrating up trophic levels by recycling them into dissolved organic matter, which can be readily taken up by microorganisms.

The mixoplankton paradigm compliments the microbial loop and viral shunt while adding complexity and stability to biological communities and food web.

Mixoplankton types

Mixoplankton span size ranges of many orders of magnitude and express diverse prey preferences. Mixoplankton thus defy attempts to pigeonhole them into a one-size fits all scenario configuration.

Constitutive Mixoplankton (CM): innate ability to photosynthesise and consume contributing to primary production, carbon drawdown and nutrient recycling	**Specialist Non-Constitutive Mixoplankton (NCM):** gained photosynthetic ability from specific prey taxonomic groups
Non-Constitutive Mixoplankton (NCM): acquires phototrophic ability from prey, contributing to primary production temporarily	**plastidic Specialist Non-Constitutive Mixoplankton (NCM):** gained ability to photosynthesise by keeping chloroplasts from specific prey
Generalist Non-Constitutive Mixoplankton (NCM): gained ability to photosynthesise by keeping chloroplasts from diverse prey	**endosymbiotic Specialist Non-Constitutive Mixoplankton (NCM):** gained ability to photosynthesise by keeping specific prey as symbionts

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This newsletter has been jointly produced by the Cardiff University, ARK dynamics and the Environment Agency as part of the NCEA Programme. It reflects the collaborative efforts of these organisations in advancing the understanding and management of mixoplankton in UK waters.