

# THE WESTERN CHANNEL OBSERVATORY AUTOMATED PLANKTON IMAGING AND CLASSIFICATION SYSTEM

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Marine plankton are an important and diverse group of organisms that make up the lower trophic levels of the marine food web. They play several critical roles in the ocean that have direct or indirect societal benefits, including supporting food security, oxygen production, and carbon sequestration via the biological carbon pump. Plymouth Marine Laboratory (PML) has been making weekly measurements of zooplankton and phytoplankton at Western Channel Observatory (WCO) Station L4 (50°15'N, 4°13'W) since 1988 and 1992, respectively, using traditional ship-based sampling and light microscopy techniques. Thus, Station L4 has become one of the longest-running, continuous plankton time series in the world and a key marine biodiversity reference site for studies into both short- and long-term environmental changes.

Short generation timescales and the potential for rapid changes in community composition make plankton good indicators of environmental change and of the health of the marine environment (McQuatters-Gollop et al., 2024). In the United Kingdom, a *Changes in Phytoplankton and Zooplankton Communities* indicator has been adopted within the UK Marine Monitoring and Assessment Strategy, which holds to account the [UK Marine Strategy](#) for creating a marine protected area (MPA) network and maintaining “clean, healthy, safe, productive and biologically diverse oceans and seas.” The indicator is based on the abundances of distinct planktonic life-forms and their relationships to environmental pressures (Bedford et al., 2020). The same indicator was also used at the regional level in the most recent Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) 2023 Quality Status Report (OSPAR, 2023). Plankton data from the WCO feed directly into both UK and OSPAR reporting. The WCO record is also long enough to support climate change impact assessments. A recent report on long-term changes in plankton communities across the North Atlantic, which included data from the WCO, indicated wide-spread declines in Northeast Atlantic plankton, but more stable levels in the rapidly warming North Sea (Holland et al., 2023).

Traditional plankton sampling techniques include net hauls using standard mesh sizes and water sample collection using Niskin bottles. Samples are preserved

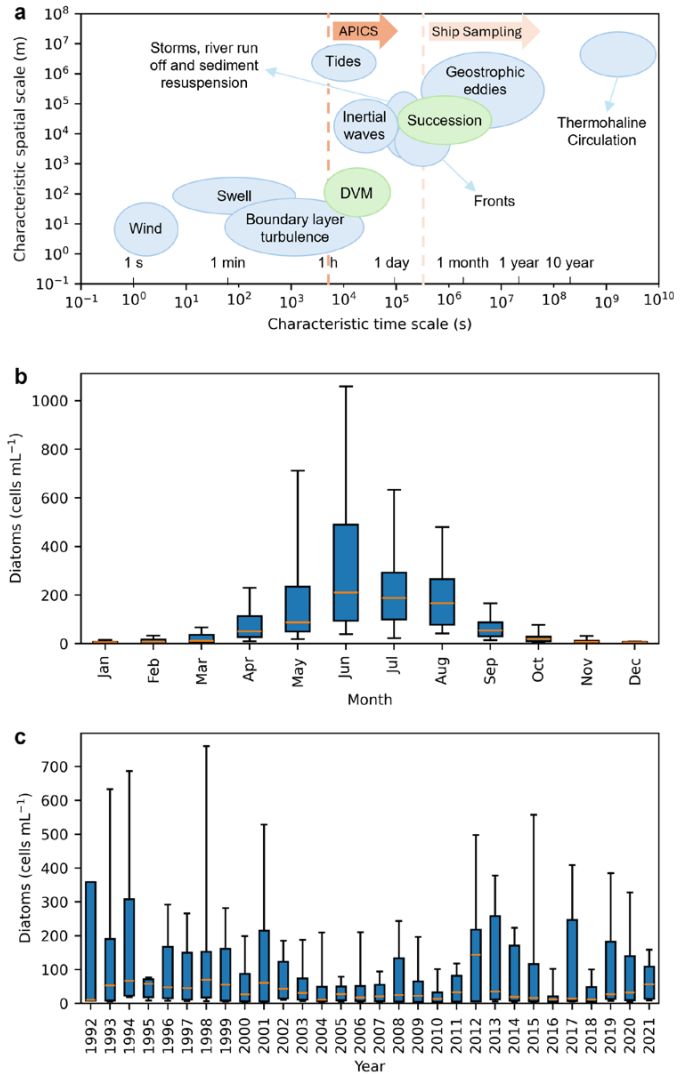


FIGURE 1. Processes impacting plankton communities at various temporal scales. (a) Physical (blue) and biological (green) processes that impact plankton communities are ordered according to their characteristic temporal and spatial scales. The light orange dashed line marks the period (weekly) at which ship-based samples are collected at the WCO's Station L4. The dark orange dashed line marks the period (~ hourly) at which samples can be collected using the Automated in situ Plankton Imaging and Classification System (APICS). *Figure adapted from Cushman-Roisin and Beckers, 2011, Figure 1.7* (b) Box plots show monthly variations in diatom cell concentrations at Station L4 between 1992 and 2021, as derived from traditional weekly ship-based sampling. The orange lines indicate the median concentrations across all years, while the blue boxes give the interquartile ranges. Whiskers (lines extending from the blue boxes) are drawn at 5% and 95%. Fliers (data that extend beyond the whiskers) have been excluded from the plot. (c) Box plots show annual variations in diatom cell concentrations at Station L4. The orange lines indicate median concentrations across all months in that year. The blue box and whiskers are the same as in b.

and taxonomically identified and counted in the laboratory using light microscopy. This process has several drawbacks. For example, standard mesh sizes can be biased toward certain plankton sizes, and fragile or gelatinous organisms can be damaged or fragmented during the sampling and preservation process, making identification difficult. Further, there is no opportunity to observe behavioral interactions among organisms (Remsen et al., 2004; Greer et al., 2021).

Ship-based sampling is also time-consuming and restricted to periods when there is good weather, limiting the frequency at which data can be collected. Historically, plankton samples from Station L4 have been collected once a week (weather permitting), enabling important seasonal and interannual changes to be quantified and studied. However, numerous processes that influence plankton population numbers and community composition have shorter characteristic timescales and thus are either missed or aliased by weekly sampling. These include successional changes in the plankton community that characterize bloom events or the recovery of the community following passage of a storm (Topor et al., 2022), diel vertical migrations (DVMs) that are undertaken by many larger zooplankton (Parra et al., 2019), and changes due to the tide

(Figure 1). Fine-scale spatial heterogeneity, for example, caused by the presence of fronts, can also result in large apparent changes in community composition as water masses hosting different communities are advected over the sampling site. Collectively, these processes complicate the interpretation of weekly time series.

In an attempt to address these issues, several groups around the world have now pioneered the use of underwater cameras to monitor plankton communities (Lombard et al., 2019). Building on these efforts, a new WCO Automated in situ Plankton Imaging and Classification System (APICS) is being operationalized. Distinguishing features of the system include (1) the use of two autonomous submersible camera units—an *Imaging FlowCytobot (IFCB)* and a *Moonpool Plankton Imager (PI-10)*—that provide broad size spectrum imaging capability, and (2) a configuration that facilitates deployment under a remotely operated, moored buoy (Figure 2). The system will image both phytoplankton and zooplankton (size range <10  $\mu\text{m}$ –20 mm) at a depth of 10 m. APICS will enable a ~100-fold improvement in sampling frequency, which allows many of the processes missed by weekly sampling to be resolved (Figure 1a). The cameras sample a known volume of water, with the IFCB imaging a 5 mL sample every 20 minutes and the PI-10

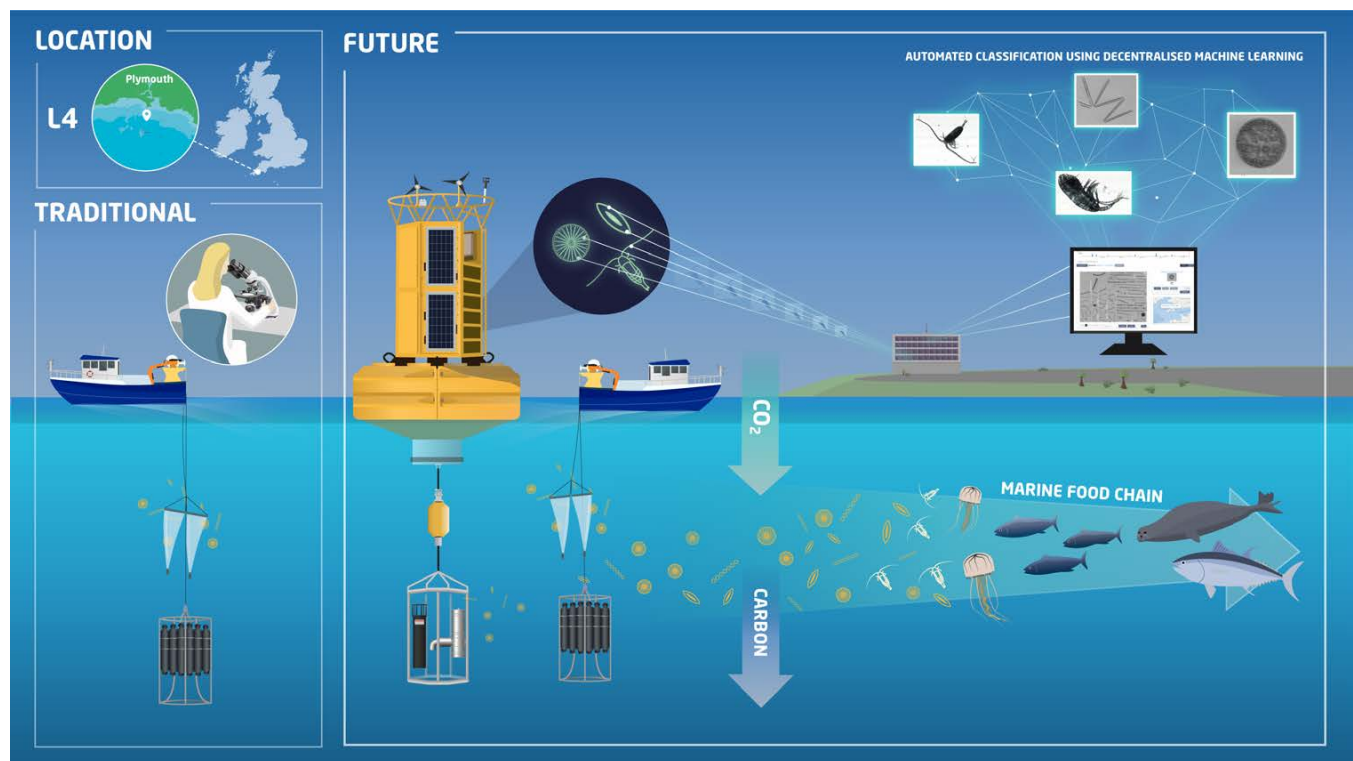


FIGURE 2. Traditional ship-based plankton sampling methods that have been deployed at Station L4 in the Western Channel Observatory. They are contrasted with future methods that include the addition of APICS and the automated, high-frequency imaging of plankton. With APICS, images are automatically transmitted back to the laboratory. The laboratory operates a node within a decentralized network that allows the team to collaborate with external partners on the automated classification of data using machine learning techniques.

actively pumping water through the camera unit at a rate of 34 L min<sup>-1</sup> to ensure organisms present at lower concentrations (~100 individuals per m<sup>3</sup>) can be accurately enumerated. Real-time data processing will be facilitated using swarm learning (Warnat-Herresthal et al., 2021)—a machine learning methodology that allows multiple owners of biological image data to participate in decentralized, collaborative networks where they can leverage the data and expertise of external partners to obtain better, higher efficacy classification results (Figure 2).

The WCO's APICS and similar systems offer advantages over traditional sampling methods for both assessing candidate MPAs and monitoring existing ones. Cameras deployed in situ facilitate the collection of high frequency data over an extended time period, allowing a more detailed picture of the environment to be assembled. In general, it is financially and logistically impossible to collect a similar volume of data using traditional, ship-based sampling methods. Further, the real-time processing of data from autonomous camera systems directly facilitates operational monitoring, including for harmful algal blooms and invasive species, which in turn facilitates more rapid decision-making by marine managers.

Within the WCO, APICS will complement the traditional sampling methods that support the current multiyear time series by allowing short-period processes and controls on biodiversity to be studied and understood. In addition, the continuation and expansion of long-term observations based on traditional methods will remain paramount for studying the long-term impacts of climate change.

## REFERENCES

- Bedford, J., C. Ostle, D.G. Jones, A. Atkinson, M. Best, E. Bresnan, M. Machairopoulou, C.A. Graves, M. Devline, A. Milligen, and others. 2020. Lifeform indicators reveal large-scale shifts in plankton across the North-West European shelf. *Global Change Biology* 26:3,482-3,497, <https://doi.org/10.1111/gcb.15066>.
- Cushman-Roisin, B., and J.-M. Beckers, eds. 2011. *Introduction to Geophysical Fluid Dynamics: Physical and Numerical Aspects*. International Geophysics book series, vol. 101, Elsevier, 828 pp.
- Greer, A.T., L.M. Chiaverano, L.M. Treible, C. Briseño-Avena, and F.J. Hernandez. 2021. From spatial pattern to ecological process through imaging zooplankton interactions. *ICES Journal of Marine Science* 78:2,664-2,674, <https://doi.org/10.1093/icesjms/fsab149>.
- Holland, M.M., A. Louchart, L.F. Artigas, C. Ostle, A. Atkinson, I. Rombouts, C.A. Graves, M. Devlin, B. Heyden, M. Machairopoulou, and others. 2023. Major declines in NE Atlantic plankton contrast with more stable populations in the rapidly warming North Sea. *Science of the Total Environment* 898:165505, <https://doi.org/10.1016/j.scitotenv.2023.165505>.
- Lombard, F., E. Boss, A.M. Waite, M. Vogt, J. Uitz, L. Stemmann, H.M. Sosik, J. Schulz, J.-B. Romagnan, M. Picheral, and others. 2019. Globally consistent quantitative observations of planktonic ecosystems. *Frontiers in Marine Science* 6:196, <https://doi.org/10.3389/fmars.2019.00196>.

- McQuatters-Gollop, A., R.F. Stern, A. Atkinson, M. Best, E. Bresnan, V. Creach, M. Devlin, M. Holland, C. Ostle, K. Schmidt, and others. 2024. The silent majority: Pico- and nanoplankton as ecosystem health indicators for marine policy. *Ecological Indicators* 159:111650, <https://doi.org/10.1016/j.ecolind.2024.111650>.
- OSPAR. 2023. Pelagic habitats thematic assessment. In *Quality Status Report 2023*, OSPAR Commission, London, <https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/pelagic-habitats/>.
- Parra, S.M., A.T. Greer, J.W. Book, A.L. Deary, I.M. Soto, C. Culpepper, F.J. Hernandez, and T.N. Miles. 2019. Acoustic detection of zooplankton diel vertical migration behaviors on the northern Gulf of Mexico shelf. *Limnology and Oceanography* 64:2,092-2,113, <https://doi.org/10.1002/lno.11171>.
- Rensen, A., T.L. Hopkins, and S. Samson. 2004. What you see is not what you catch: A comparison of concurrently collected net, Optical Plankton Counter, and Shadowed Image Particle Profiling Evaluation Recorder data from the northeast Gulf of Mexico. *Deep Sea Research Part I* 51(1):129-151, <https://doi.org/10.1016/j.dsr.2003.09.008>.
- Topor, Z.M., A.M. Genung, and K.L. Robinson. 2022. Multi-storm analysis reveals distinct zooplankton communities following freshening of the Gulf of Mexico shelf by Hurricane Harvey. *Scientific Reports* 12:8721, <https://doi.org/10.1038/s41598-022-12573-y>.
- Warnat-Herresthal, H. Schultze, K.L. Shastry, S. Manamohan, S. Mukherjee, V. Garg, R. Sarveswara, K. Händler, P. Pickkers, N.A. Aziz, and others. 2021. Swarm learning for decentralized and confidential clinical machine learning. *Nature* 594:265-270, <https://doi.org/10.1038/s41586-021-03583-3>.

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