2023 Annual Report of WG48: Towards Best Practices Using Imaging Systems for Monitoring Plankton

The fourth business meeting of Working Group 48 (WG 48) on 'Towards Best Practices Using Imaging Systems for Monitoring Plankton' took place virtually on October 17, 2023. A total of 11 members attended the meeting. This session focused on presenting recent developments and discussing the next steps for WG48's Terms of Reference (ToR). The meeting's agenda can be found in WG 48 *Endnote 2*.

AGENDA ITEM 1

Updates on memberships

Junbai Yue, an early career scientist (Ph.D. student) from Tsinghua University, joined the working group to increase early career scientist participation.

AGENDA ITEM 2

Updates on the review paper of underwater imaging systems for plankton monitoring

- Developed a full outline (WG 48 *Endnote 3*) for the review manuscript “A primer for underwater plankton imaging systems”.
- Finished sections on background, the impact of underwater environment on optical plankton imaging, the introduction section on underwater plankton imaging systems, and the selection of imaging systems.
- We are now working on the case studies and future developments with a completion date by March 2024.

AGENDA ITEM 3

Special issue of “Deep learning in marine science” in *Frontiers in Marine Science*

Working Group members Zheng, Bi, Cheng, and Benfield successfully completed a special issue titled “Deep Learning in Marine Science” for *Frontiers in Marine Science* (see *Endnote 4*). The issue received over 60 manuscript submissions, 38 of which have been published.

AGENDA ITEM 4

Meetings and meeting proposal

- WG 48 members Bi, Kimmel, and Zheng sponsored a session on the application of deep learning in marine science for the 2023 PICES annual meeting.
- WG 48 members Bi and Kimmel proposed a session on the rapid plankton assessment for the 2024 PICES annual meeting (refer to *Endnote 5*).
- Members Kimmel, Bi, Keister, and Campbell of Working Group 48 proposed a session focused on ecosystem monitoring through underwater plankton imaging systems. This session has since been integrated with other sessions covering similar topics as part of the 7th Zooplankton Production Symposium (refer to *Endnote 6*).

WG48 Endnote 1

WG 48 participation list

Members	Country	October 17 attendance
Hongsheng Bi (Co-chair)	USA	☑
Xuemin Cheng (Co-chair)	China	☑
David Kimmel (Co-chair)	USA	☑
Julie Keister	USA	☑
Robert Campbell	USA	☑
Mark Benfield	USA	☑
Akash Sastri (PICES Bio)	Canada	☒
Paul Covert	Canada	☒
Haiyong Zheng	China	☒
Haifeng Gu	China	☒
Satoshi Kitjima	Japan	☑
Lindsay Dhugal	Japan	☑
Kazutaka Takahashi	Japan	☑
Park Wongyu	Korea	☒
Pitor Margoński	Ex officio member ICES	☒
Klas Ove Moeller	Observer	☒
Junbai Yue	Student, Observer	☑
Bri Groves	Student, Observer	☑

WG 48 Endnote 2

WG 48 October 17, 2023 meeting agenda

20:00 – 2100 EST, October 17, 2023

1. Opening remarks (Bi)
2. ECOP Membership Discussion (All)
3. PICES Annual Meeting Overview (All)
    1. Focus: Seattle event scheduled for October 23rd-27th
    2. Special Emphasis: "Applications of Deep Learning Systems in Marine Science" session
4. 7th Zooplankton Production Symposium Review
    1. Highlight: Plankton imaging systems session in Hobart, “Get it from the image: In situ imaging and spatially detailed observations of zooplankton for ecosystem studies.”
5. Special Issue Collaboration Initiative
    1. Subject: Partnership with "Remote Sensing" (MDPI journal, Impact Factor: 5.0)
6. Review Paper Development
    1. Topic: Drafting the outline for “A Primer for Underwater Plankton Imaging Systems”
7. Open Forum for Additional Matters
    1. Discussion of any other pertinent topics or agenda items.

WG 48 Endnote 3

Title: A primer on underwater plankton imaging system

1. Background:
2. Impact of underwater environment on optical plankton imaging
3. Introduction to underwater plankton imaging systems
    1) Illumination component
        a) Simple backlighting:
        b) Focused shadowgraph imaging:
        c) Bright-field imaging
        d) Dark-field imaging
        e) Light-sheet illumination or Laminar illumination
    2) Imaging unit
        a) Telecentric imaging
        b) Fluorescence imaging
        c) Holography
4. Selection of imaging systems
    1) What needs to be considered?
    2) Considerations regarding targets
        a) Understanding targets
        b) Knowing environments
        c) Comprehending objectives
    3) Considerations regarding imaging systems
        a) Open area versus closed imaging
        b) Imaging volume
        c) Image frequency
        d) Suitable image sensor
        e) Exposure time
    4) Deployment platform
5. Examples: Imaging systems for monitoring work
    1) Time series
    2) Spatial distribution
    3) Species composition
6. Future development
    1) Inter-calibration among different systems
    2) Rapid/real time plankton assessment
    3) Multi-mode imaging
    4) Combine with other tools such as acoustic and environmental e-DNA
7. Summary

WG 48 Endnote 4

Proposal for special topic in *Frontiers in Marine Science*

Deep learning (DL), mainly composed of deep and complex neural networks such as recurrent networks and convolutional networks, is an emerging research branch in the field of artificial intelligence and machine learning. The DL revolution continues to have a far-reaching impact on all scientific disciplines and every corner of our lives. With continuing technological advances, marine science is entering into the big data era with the exponential growth of information. DL is an effective means of harnessing the power of big data. Combined with unprecedented data from cameras, acoustic recorders, satellite remote sensing, and large model outputs, DL enables scientists to solve complex problems in biology, ecosystems, climate, energy, as well as physical and chemical interactions. Although DL has made great strides, it is still only beginning to emerge in many fields of marine science, especially towards representative applications and best practices for the automatic analysis of marine organisms and marine environments.

Currently, DL in marine science mainly leverages cutting-edge techniques to analyze data collected by in-situ optical or acoustic imaging sensors for underwater applications, such as plankton classification and coral reef detection. This research topic aims to expand the applications of marine science to cover all aspects of detection, classification, segmentation, localization, and density estimation of marine objects, organisms, and phenomena.

Topics of interest include, but are not limited to:

- Best practices for the application of deep learning in marine/underwater object detection/classification of marine organisms (plankton, fish, and coral reef, etc.) and marine environments (trash and debris, etc.).
- Deep learning for optical/acoustic image enhancement in ocean observation/exploration (marine organism, seafloor, etc.).
- Deep learning for detection, classification, localization, and density estimation of marine organisms (fish and marine mammals) with underwater optical/acoustic data acquisition technology.
- Deep learning for detection, classification, and segmentation of objects and phenomena in the ocean from the data of remote sensing and drone surveys.
- Research on new datasets for underwater/marine optical/acoustic data analysis.

WG 48 Endnote 5

Title: Rapid Plankton Assessment for Ecosystem Assessment
Duration: 1 day
Convenors: Hongsheng Bi and David Kimmel
Corresponding convenor: Hongsheng Bi
Description: The objective of this session is to explore the importance of rapid plankton assessment in comprehending and managing the ocean carbon cycle, highlighting the crucial role of plankton in ecosystem management. We will concentrate on underwater imaging techniques

and leverage deep learning technologies for efficient plankton assessment and subsequent application of this information to address ecosystem management in the face of a changing climate. This session aims to unite experts in underwater imaging and deep learning systems, focusing on the applications of these techniques to facilitate rapid plankton assessment. Our aspiration is that this session will drive progress in plankton assessment methodologies, allowing us to develop a framework that integrates real-time or near real time plankton data with information from other sensors. This integration will be instrumental in examining and forecasting ecosystem status.
PICES Expert group: WG 48, WGISMP: Towards best practices using Imaging Systems for Monitoring Plankton

WG 48 Endnote 6

7th ZPS Session 8: Get it from the image: In situ imaging and spatially detailed observations of zooplankton for ecosystem studies

Convenors:
Klas Ove Möller (Helmholtz-Zentrum Hereon, Germany) (corresponding)
Mark C. Benfield (Louisiana State University, USA)
Hongsheng Bi (University of Maryland, USA)
Rob Campbell (Prince William Sound Science Center, USA)
Elaine Fileman (Plymouth Marine Laboratory, UK)
Adam Greer (Skidaway Institute of Oceanography, University of Georgia, USA)
Russell Hopcroft (University of Alaska Fairbanks, USA)
Jules Jaffe (University of California, San Diego, USA)
Julie Keister (University of Washington, NOAA Fisheries, USA)
David Kimmel (NOAA, USA)
Jianping Li (Shenzhen Institutes of Advanced Technology, CAS, China)
Dhugal Lindsay (JAMSTEC, Japan)
Jens Nejstgaard (Leibniz Institute of Freshwater Ecology and Inland, Germany)
Sophie Pitois (Cefas)

Invited Speaker:
Lars Stemmann
(Sorbonne Université, France)

Zooplankton serve as critical links in aquatic food webs and influence biogeochemical cycling. Because of this key trophic role, their spatial and temporal distribution, abundance, and behavior are used as indicators of ecosystem structure and function. Traditional net sampling of zooplankton, along with data processing, is labor intensive and requires significant taxonomic expertise. While imaging has a long history of application in zooplankton ecology, recent developments in in-situ optical imaging technologies and artificial intelligence/machine learning

(AI/ML) are poised to revolutionize zooplankton ecology. New imaging systems are becoming more energy efficient and versatile, allowing for deployments on various observation platforms such as AUVs, Argo floats, and moorings. The rapid rise of AI/ML and significant advances in computing have led to an increased taxonomic resolution and specificity in zooplankton image processing. Furthermore, in situ observation of zooplankton allows distribution and abundance to be combined with information on organism traits, such as lipid reserves, egg clutch size, and body size, and datasets can be integrated with complementary high-resolution data streams, such as acoustics and eDNA, to reveal drivers of zooplankton population changes. In addition to this tremendous potential, technological developments also bring significant new challenges, such as ensuring quality control of massive image datasets, data storage and sharing, intercalibration of instruments, developing processing and classification algorithms, and extending observations through time by comparing with traditional sampling. We welcome contributions on all aspects of zooplankton imaging, including imaging system development, AI/ML data processing, comparisons to traditional net sampling, as well as efforts to integrate imaging with other high-resolution observational technologies. Presentations focusing on new emerging technologies should extend beyond the purely technical and aim to provide insights into ecological and biogeochemical processes. We aim to foster discussion on the advantages, shortcomings, and future needs that must be considered in order to apply imaging technology to zooplankton ecology.