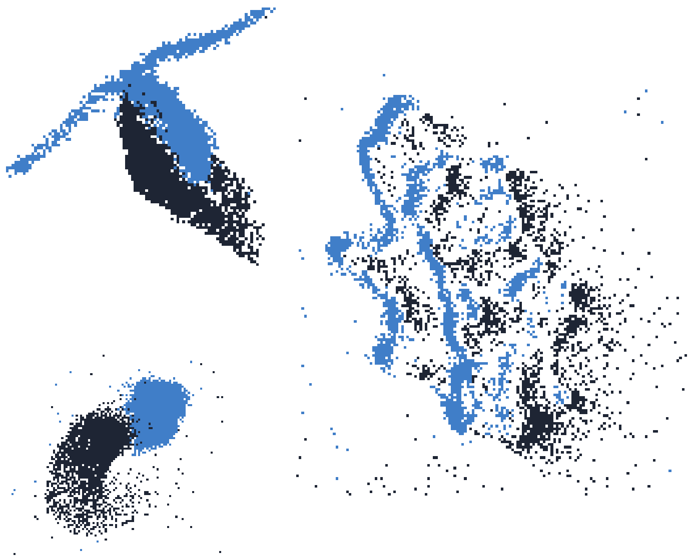
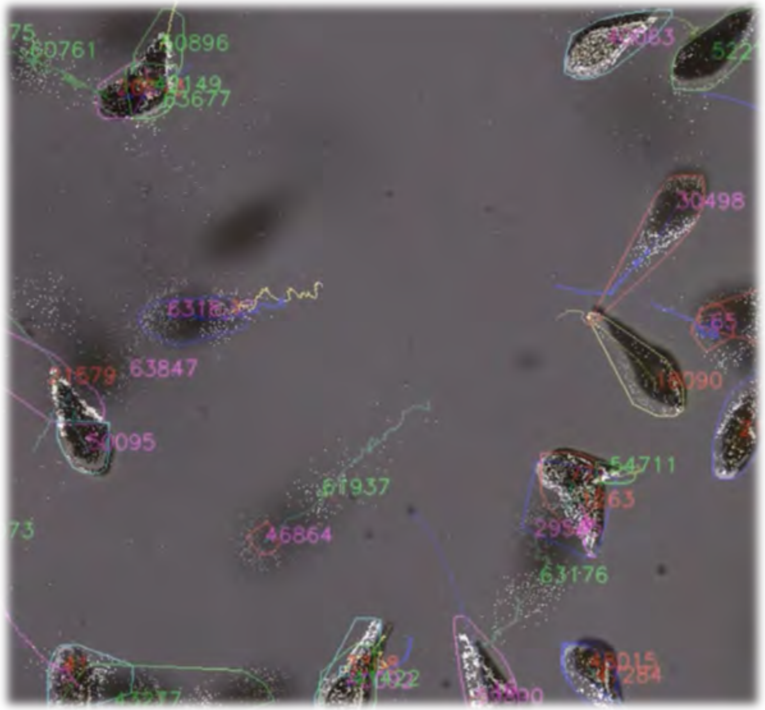
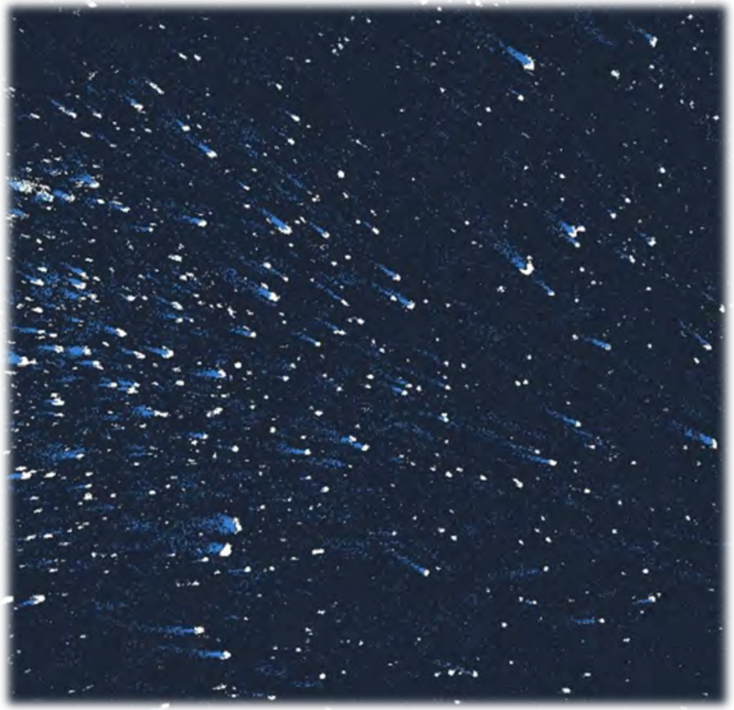
「海洋生物ビッグデータ活用技術高度化」に関する公開シンポジウム 2025年10月31日

「イベントベースビジョンセンサー（EVS）を用いた海洋粒子ビッグデータ生成」

Generation of Marine Particle Big Data Using an Event-based Vision Sensor (EVS)







高塚　進

Susumu Takatsuka

Sony Computer Science Laboratories, Inc： Project Researcher

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)： Visiting Researcher

Agenda

1. The Concept of Frequency Biology
    - A branch of behavioral biology that focuses on the periodicity of life movements

2. Overview and Experimental Results of EVS-Based Marine Particle Measurement Technology

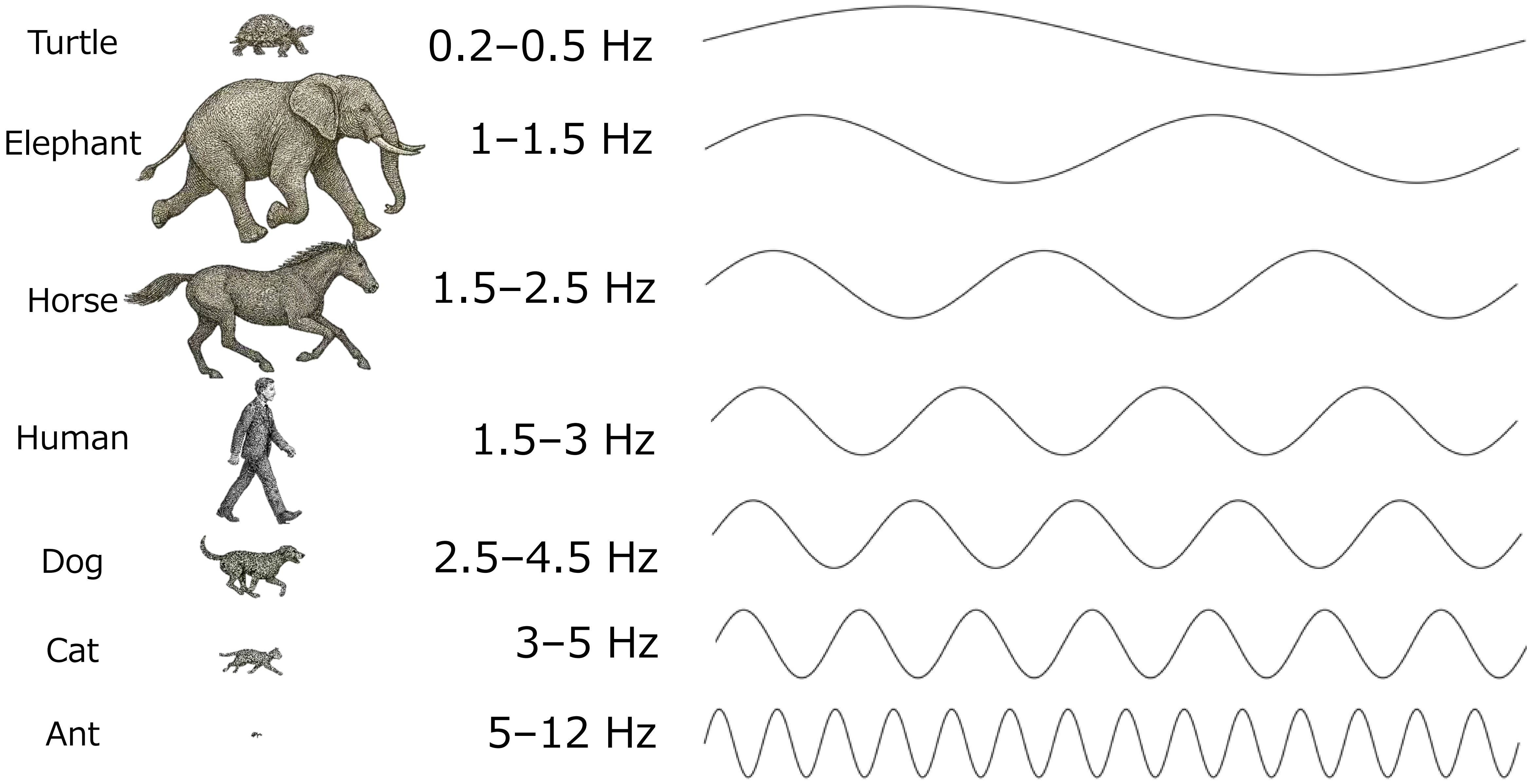
Agenda

1. The Concept of Frequency Biology
    - A branch of behavioral biology that focuses on the periodicity of life movements

2. Overview and Experimental Results of EVS-Based Marine Particle Measurement Technology

We living organisms move by repeating a series of actions

And each living creature has its own characteristic frequency for those repeated movements



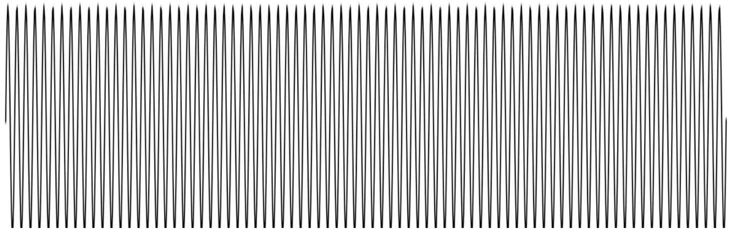
Tiny creatures like insects live in very fast-paced world

Tiny organisms, such as insects, live in a world that moves many times faster than ours.

Insects	Silkworm Moth	8
	Cabbage White Butterfly	10
	Grasshopper	20
	Praying Mantis	25
	Cockroach	30
	Stonefly	33
	Cicada	35
	Rhinoceros Beetle	40
	Green Darner	40
	Bumblebee	150
	Honeybee	200
	Housefly	200
	Large Mosquito	260
	Mosquito	520
	Asian Tiger Mosquito	600
	Black Fly	1,000
	Biting Midge	1,046

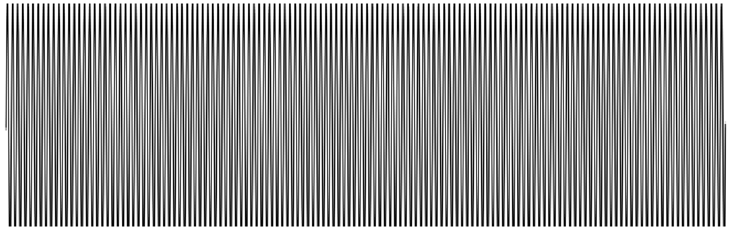
Honeybee

200-250 Hz



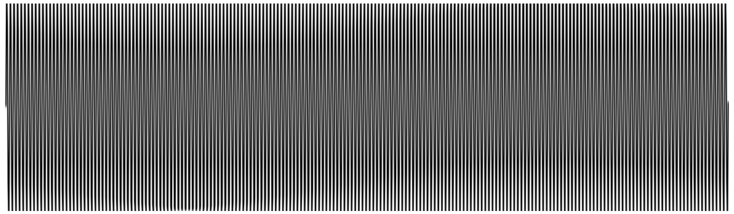
Mosquito

400-520 Hz

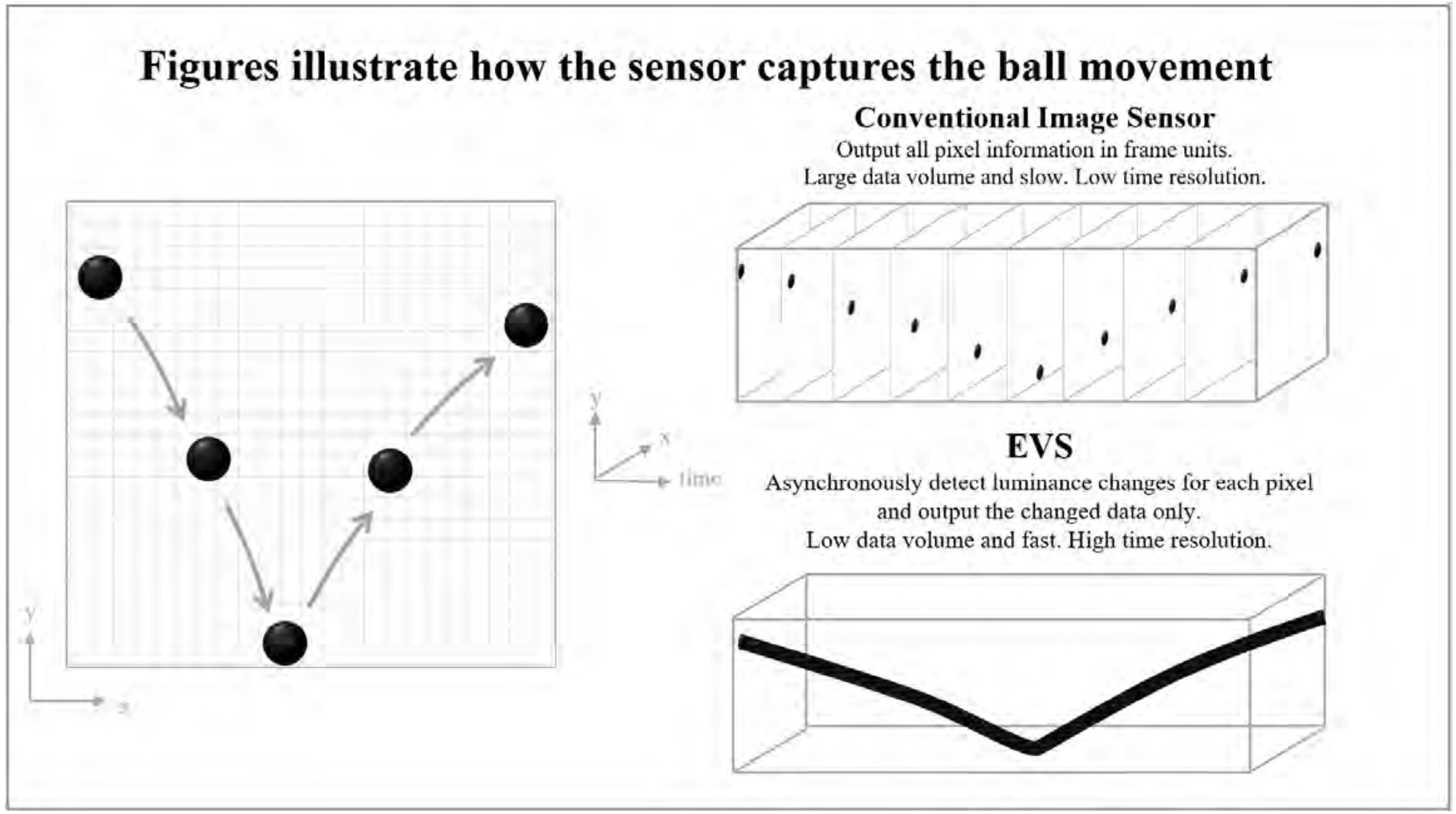


Biting Midge

1000-1046Hz



To capture fast-moving micro-organisms, we decided to use an industrial sensor specialized for motion recognition by AI — the **Event-based Vision Sensor (EVS)** — for biological observation.



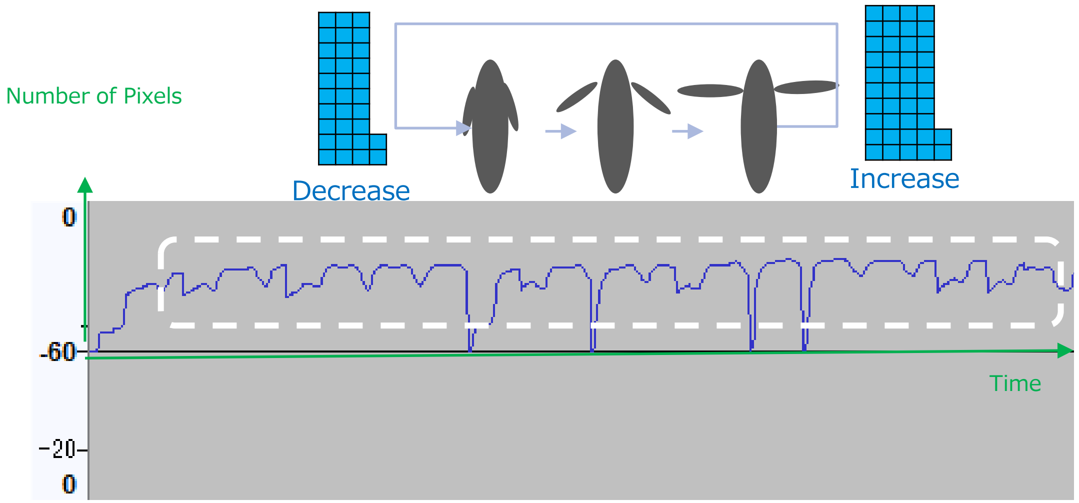
Features of EVS

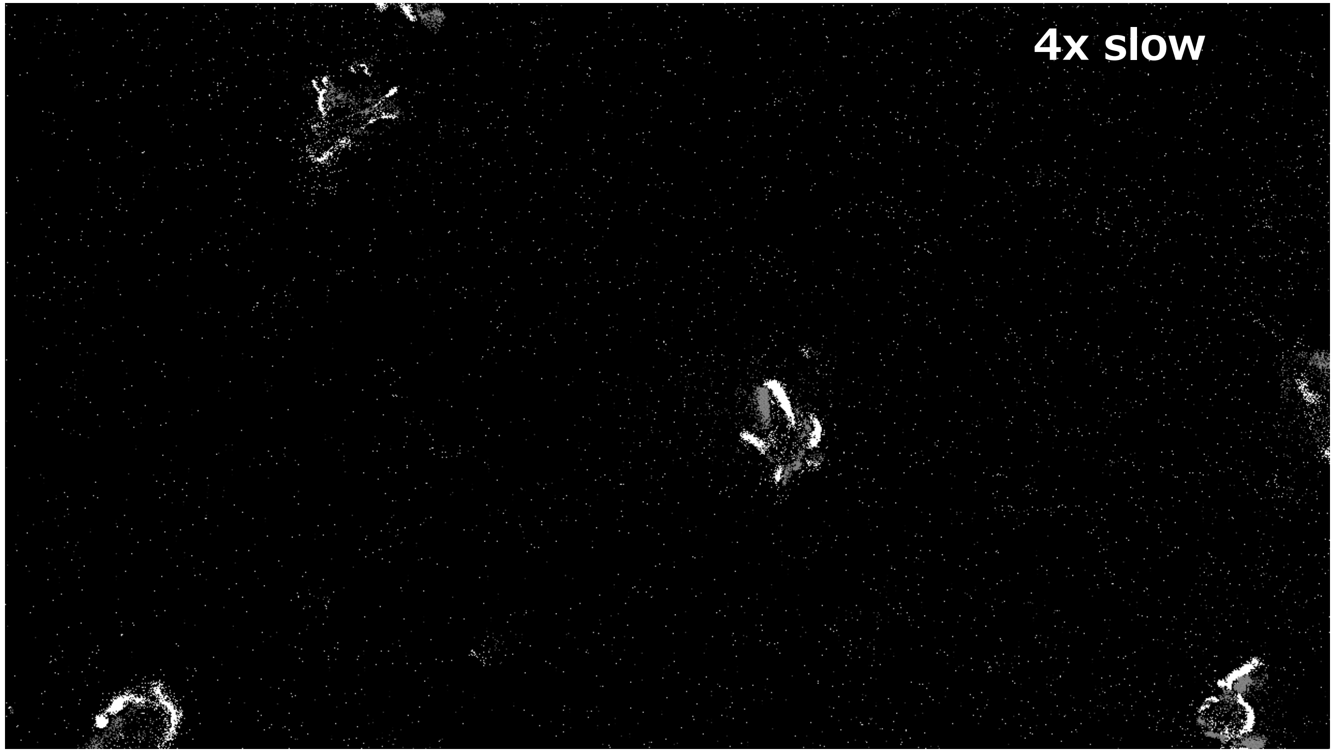
- A sensor optimized not for humans, but for AI.
- It only detects areas that become brighter or darker; it does not recognize color. Instead, it performs ultra-high-speed sensing at 10,000 times per second.

Attribute	Computational Load	Color Information	Frame Rate	Motion Blur	Data Size	Power Consumption
Conventional Image Sensors	High	RGB	30–1000 fps	Frequent	Large	High
EVS	Low	Binary. Only polarity of lightened or darkened.	10,000 fps	Minimal	Small	Low

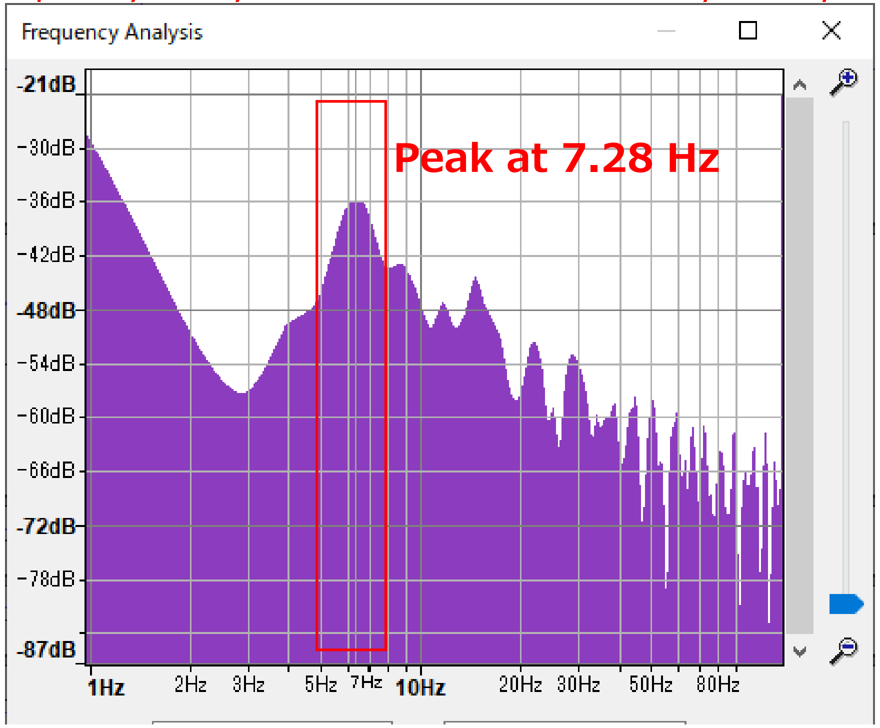
Estimate the flapping motion from the frequency of pixel count variations per individual

- The video below left shows Artemias measured by EVS played back at 4x slow speed.
- The top right graph shows the temporal change in the increase and decrease in the number of pixels for a single individual with the measurement of artemia.
- The comb-like pattern in the graph, representing temporal changes in pixel count, is thought to be caused by the flapping motion of the plankton's swimming appendages.
- Frequency analysis of increase/decrease cycles by FFT, it has peak at 7.28Hz.
- Counted artemia's flapping time on slow video, it was flapping its wings 7 times per second.



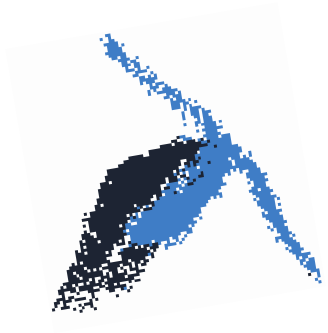


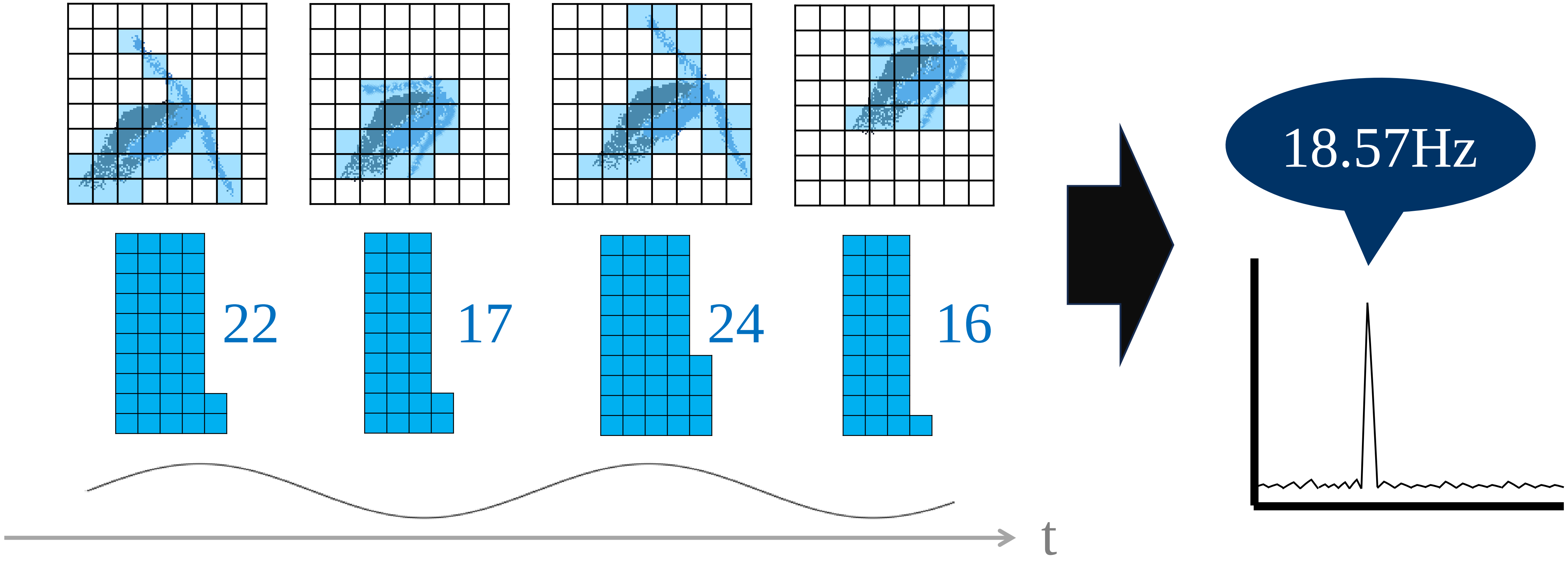
Frequency analysis of increase/decrease cycles by FFT



Focusing on the frequency of temporal changes in the number of pixels of an individual.

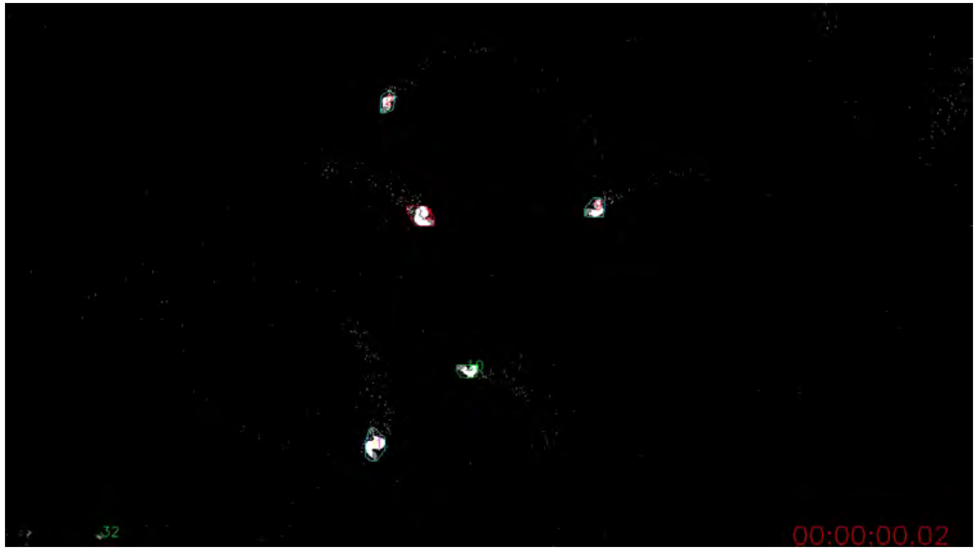
- Even if to focus only on the increase or decrease of number of pixels rather than the color or shape, it is possible to calculate the frequency from the repetitive motion.
- Frequency analysis of the temporal increase or decrease in the number of pixels of a single individual may be a feature to estimate species.





Conducting an accuracy validation experiment with a high-speed camera

As a result of verifying whether the frequency of changes in the number of pixels in EVS aligns with the number of flagellar movements of ascidian sperm per second measured using a high-speed camera as the ground truth, they were found to be almost identical.



Before sperm activation

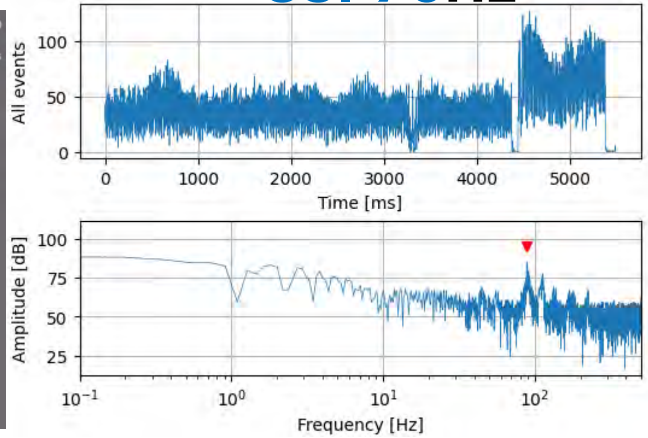
High -speed camera count

88times

≒

EVS frequency

88. 76Hz



After sperm activation: chemoattractant (SAAF 500 nM)

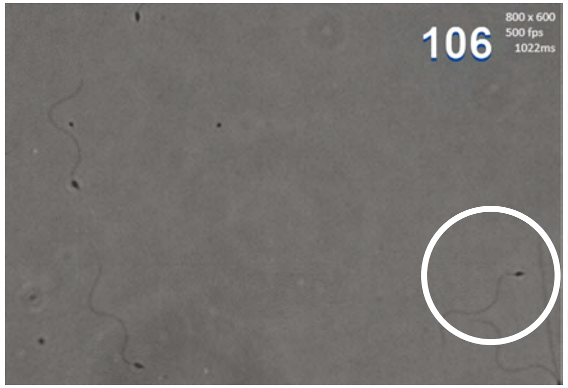
High -speed camera count

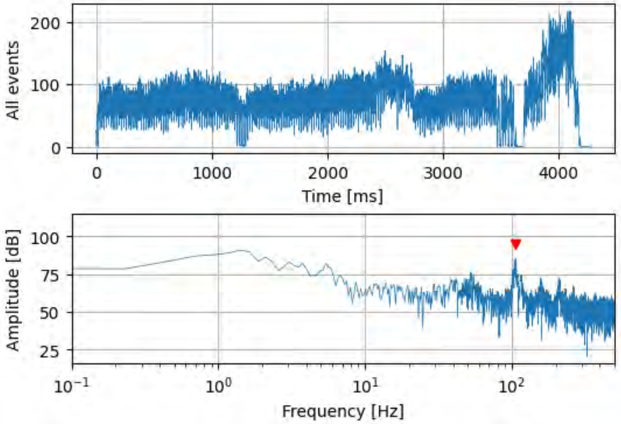
106times

≒

EVS frequency

106. 66Hz





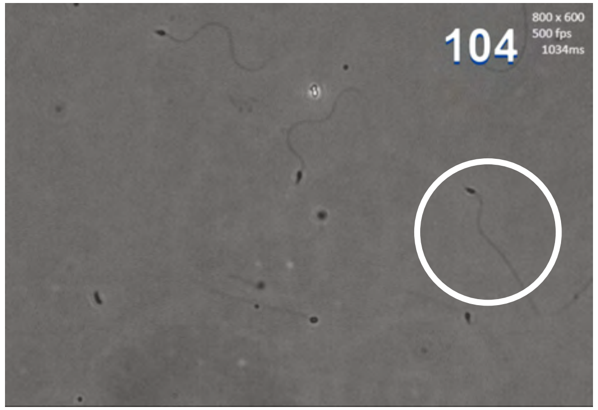
High -speed camera count

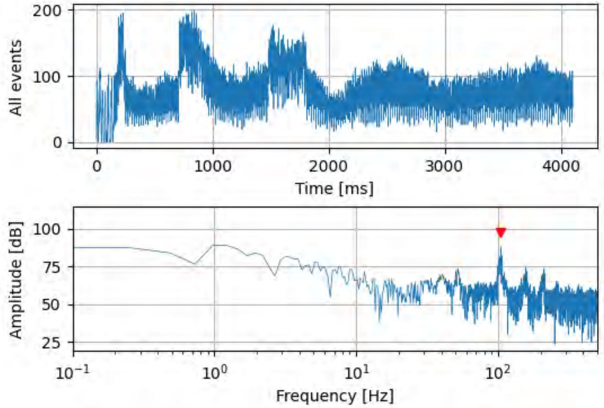
104times

≒

EVS frequency

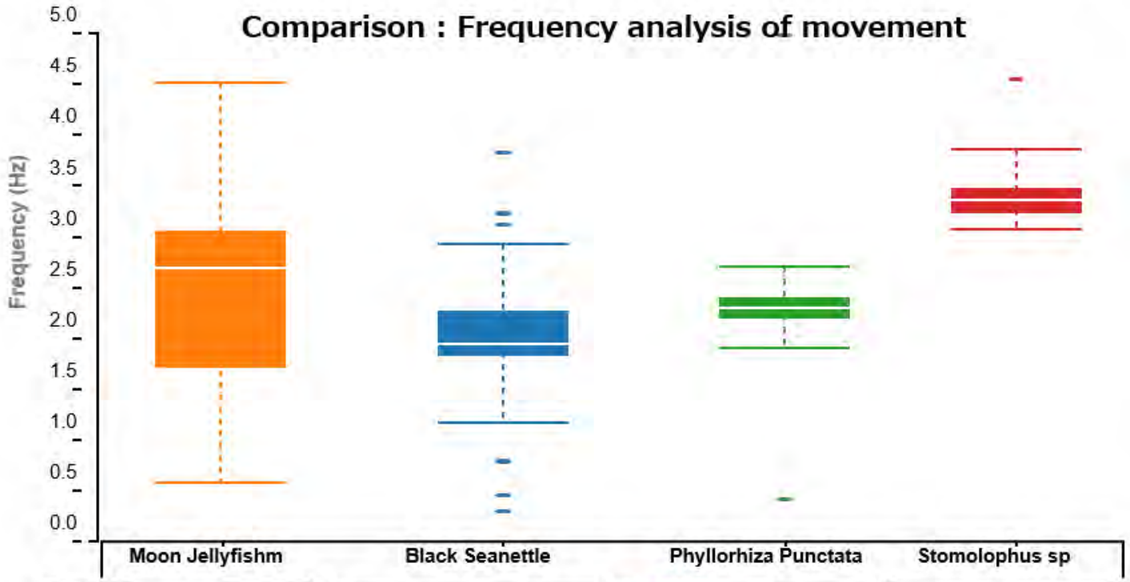
104. 99Hz

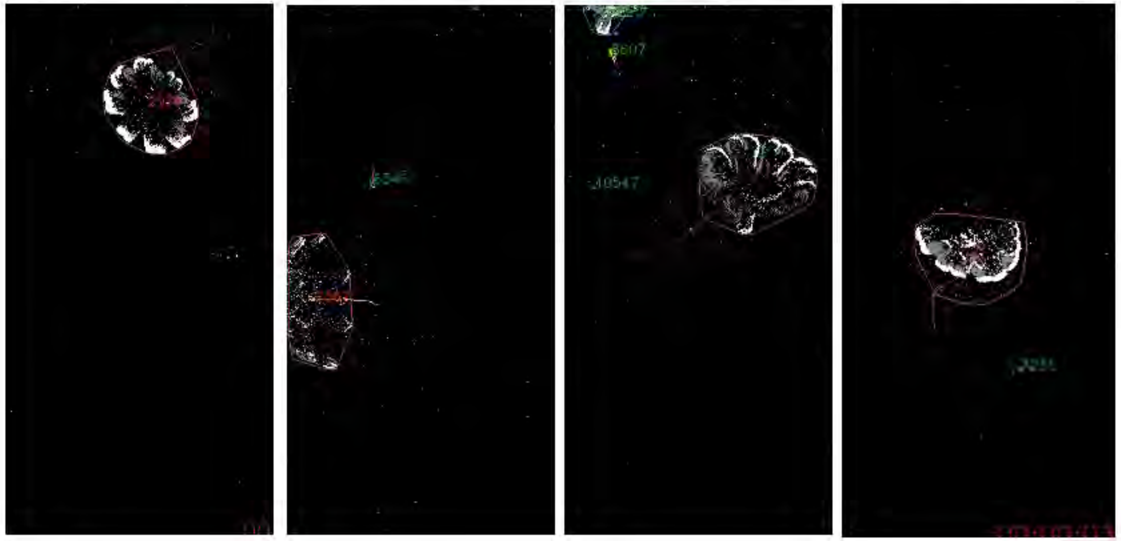




A comparison of jellyfish larvae showing different locomotion frequencies among species within the same order, *Semaeostomeae.*

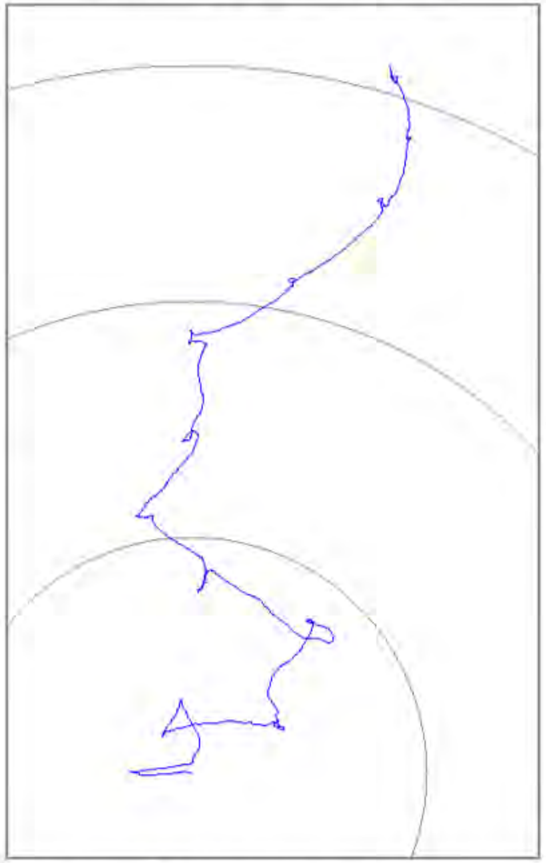
Using frequency analysis, we examined whether different species exhibit distinct behavioral signatures.
The larvae of four closely related jellyfish species each show unique frequency patterns. With the EVS, we can also capture their trajectories, as shown on the right.
By analyzing these data, we aim to better characterize and understand species-specific behavioral features.





Phyllorhiza Punctata

Trajectory of movement

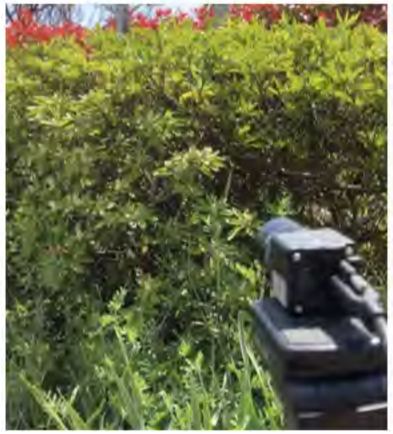


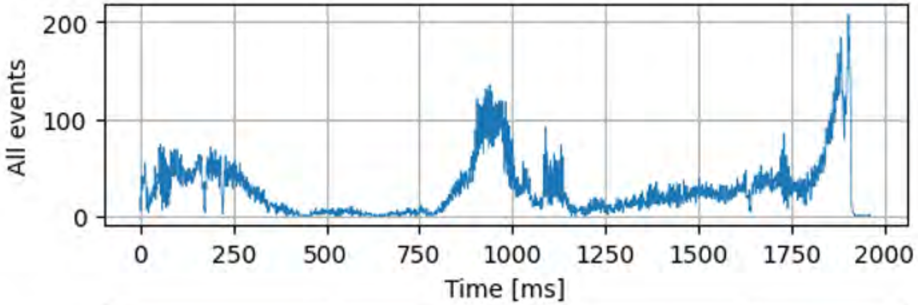
Y-axis of the transition of the coordinates of the center of gravity

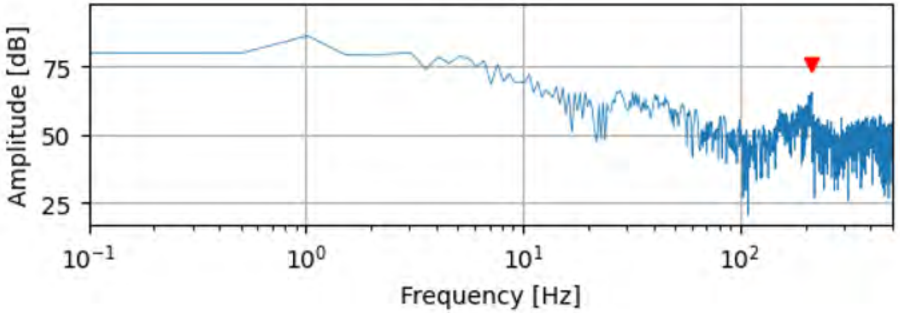
Analysis Video

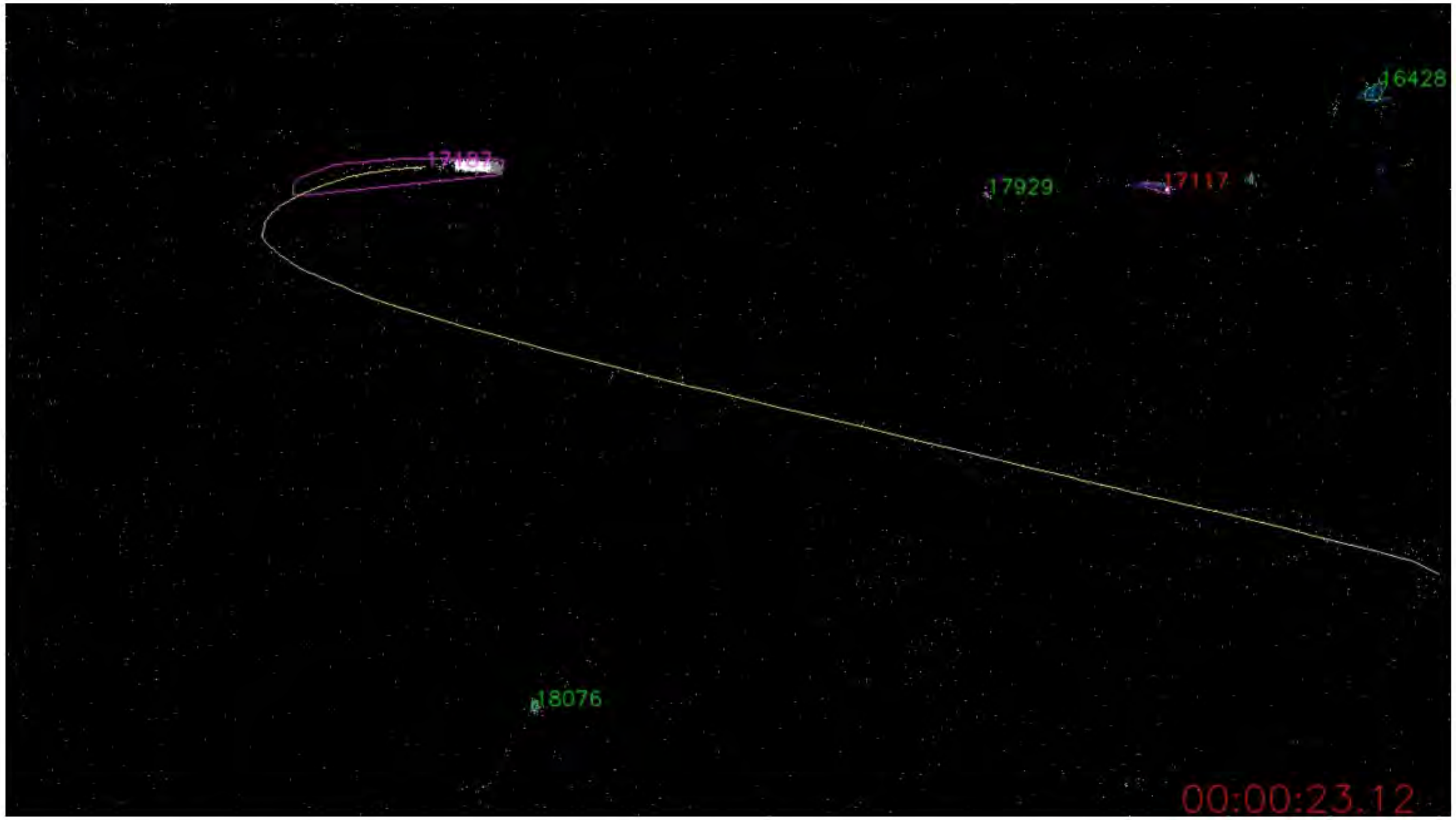
Frequency analysis @ **2.25 Hz**

Experiments measuring honeybees with EVS









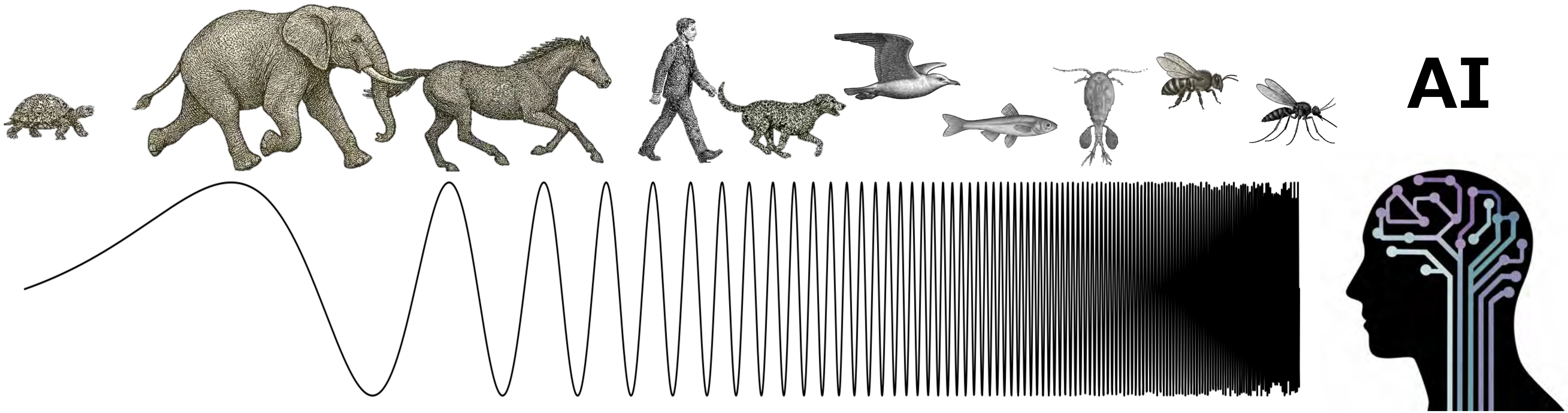
FFT was calculated from EVS data, showing a peak at 213.45 Hz.

Past studies have shown that the speed of the honeybee's wing flap is about 200～250 times per second
http://youchoose.camelstudio.jp/choosers/t_nishimura/3341.html

Through AI sensing, humans can now perceive the ultra-fast behaviors of living organisms that are far beyond the limits of human vision. We believe this could potentially open up an entirely new field within behavioral biology.

We have defined **Frequency Biology** as a branch of behavioral biology that focuses on the periodicity of life movements, utilizing advanced sensing technologies to investigate the dynamics of living organisms.

(New technologies have often created new academic fields — as was the case with DNA sequencers)



Agenda

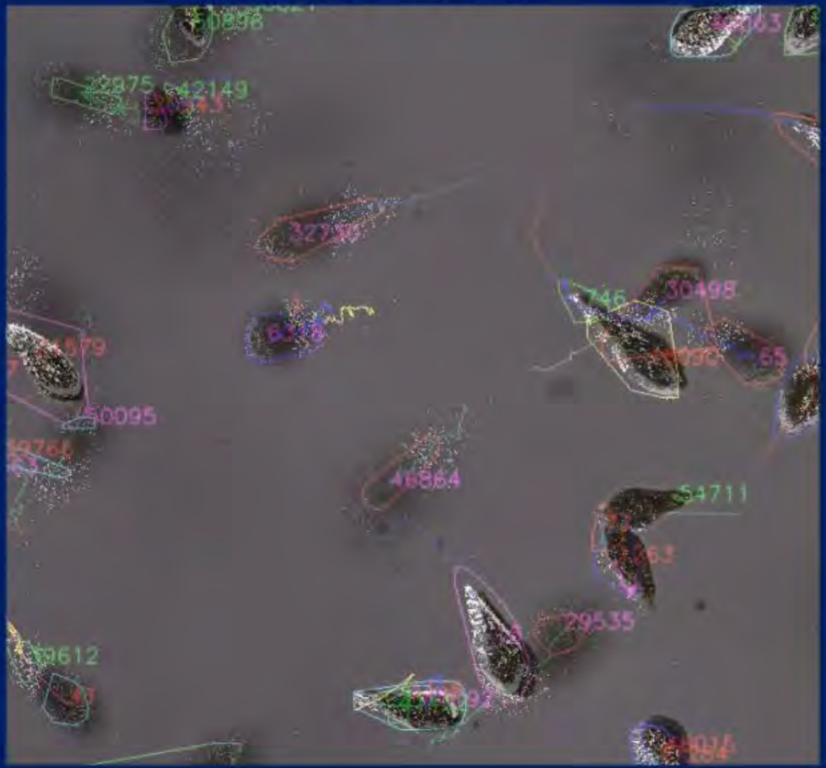
1. The Concept of Frequency Biology
   - A branch of behavioral biology that focuses on the periodicity of life movements

2. Overview and Experimental Results of EVS-Based Marine Particle Measurement Technology

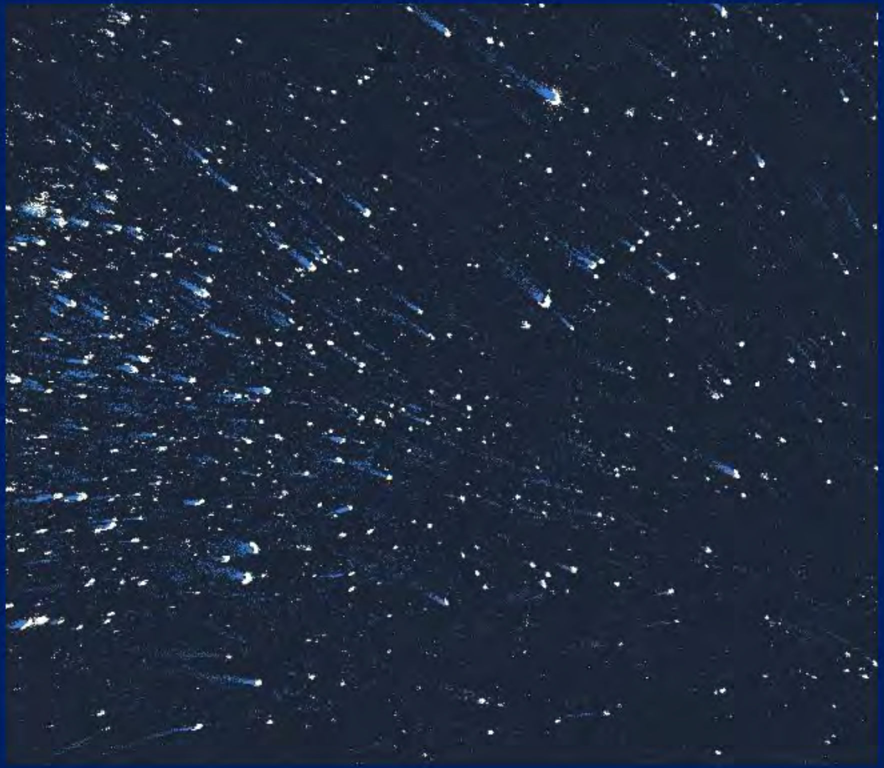
Purpose of This Study

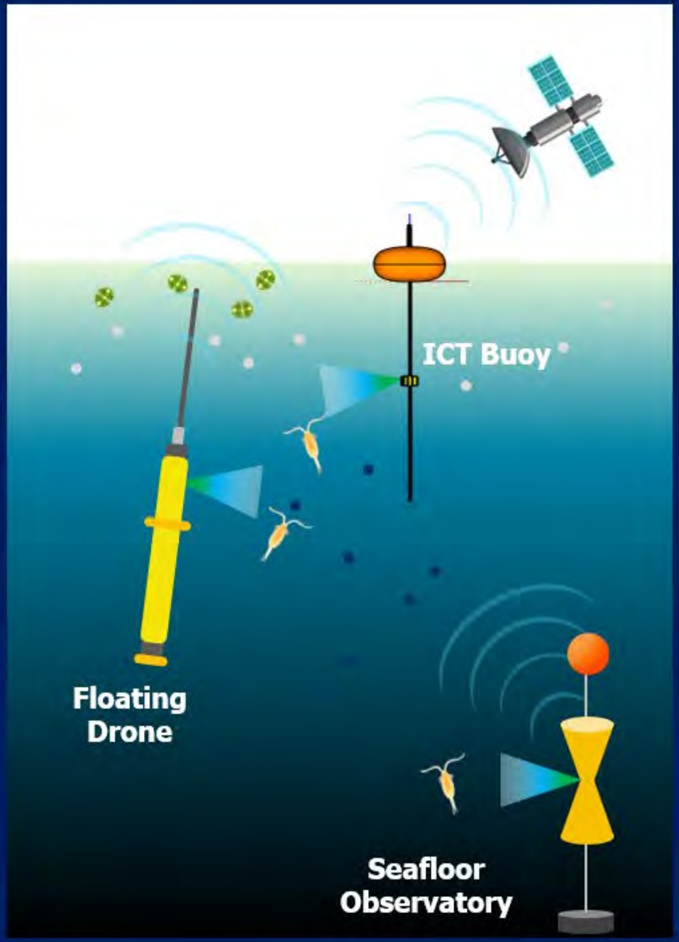
- Using event-based vision sensors (EVS) developed for industrial applications, we aim to directly observe 'marine particles' — the fundamental components of marine ecosystems — including biological particles such as plankton and non-biological particles such as sinking aggregates and sand, in the water column.
- It is intended to be mounted on ICT buoys and profiling floats in the future.

The phytoplankton Chattonella, a causative species of red tides



Direct observation of marine snow using an EVS mounted on the ROV





Comparison with conventional high-speed cameras

	FASTCAM Nova S6 Conventional high-speed cameras	EVS prototype Camera
number of pixels	1024x768	1280x720
Frame rate	9000fps	10000fps
Data size per minute	594 GB	200MB～1 GB
Camera power consumption	138W	10.2～12.5W
Lighting power consumption	120W	1～7.2W

EVS has a significantly smaller data size as well as much lower power consumption for the camera and lighting.

The EVS strength can meet requirements for the ocean particle shooting

Required performance of ocean particle shooting		EVS strengths
High speed imaging is necessary to accurately measure the number and movement of particles	→	**Ultra high-speed shooting at 10,000 fps**
Most of the underwater spaces are dark (Requires very bright illumination)	→	**Capture even the slightest change in brightness** (No need bright illumination)
Radio waves do not transmit well underwater, so recorded **data must be saved in memory**	→	**The data size is very small** because only pixel information with changes in brightness is recorded in binary form.
Long-time shooting is desired even with a limited battery capacity	→	**Low power consumption** can be contributed to long time shooting

Application areas where EVS-based marine particle measurement can be applied

- There are various applications for particle measurement technology using EVS.
- Currently, we are focusing on collaborative research in the following three areas.

Environmental impact assessment of offshore development

Stable fisheries resources and biodiversity

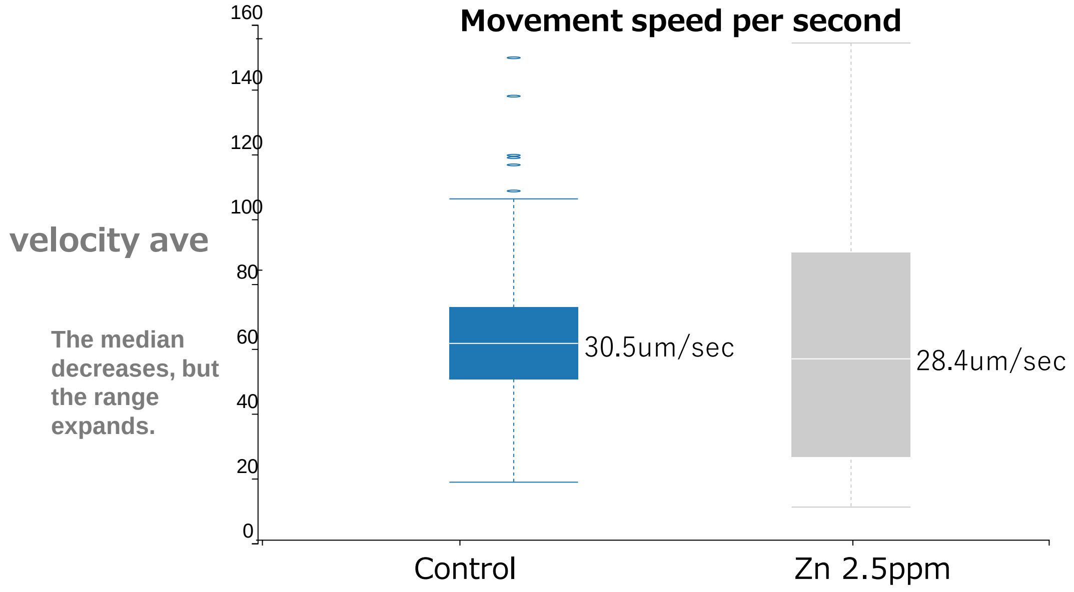
Climate change and ocean carbon fixation evaluation

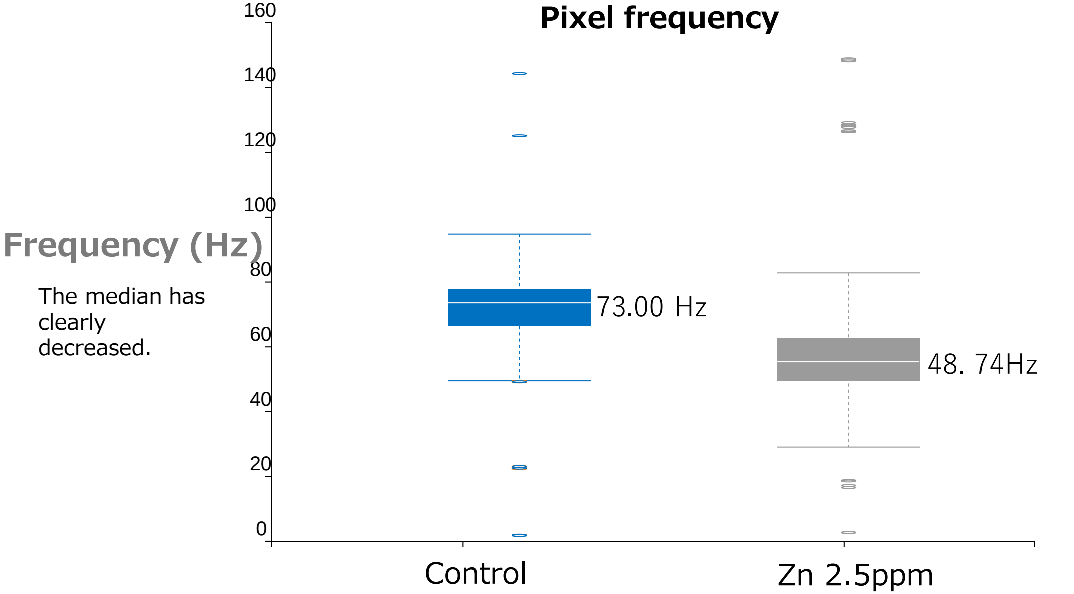
Toxicity laboratory experiments on plankton

Environmental impact assessment of offshore development

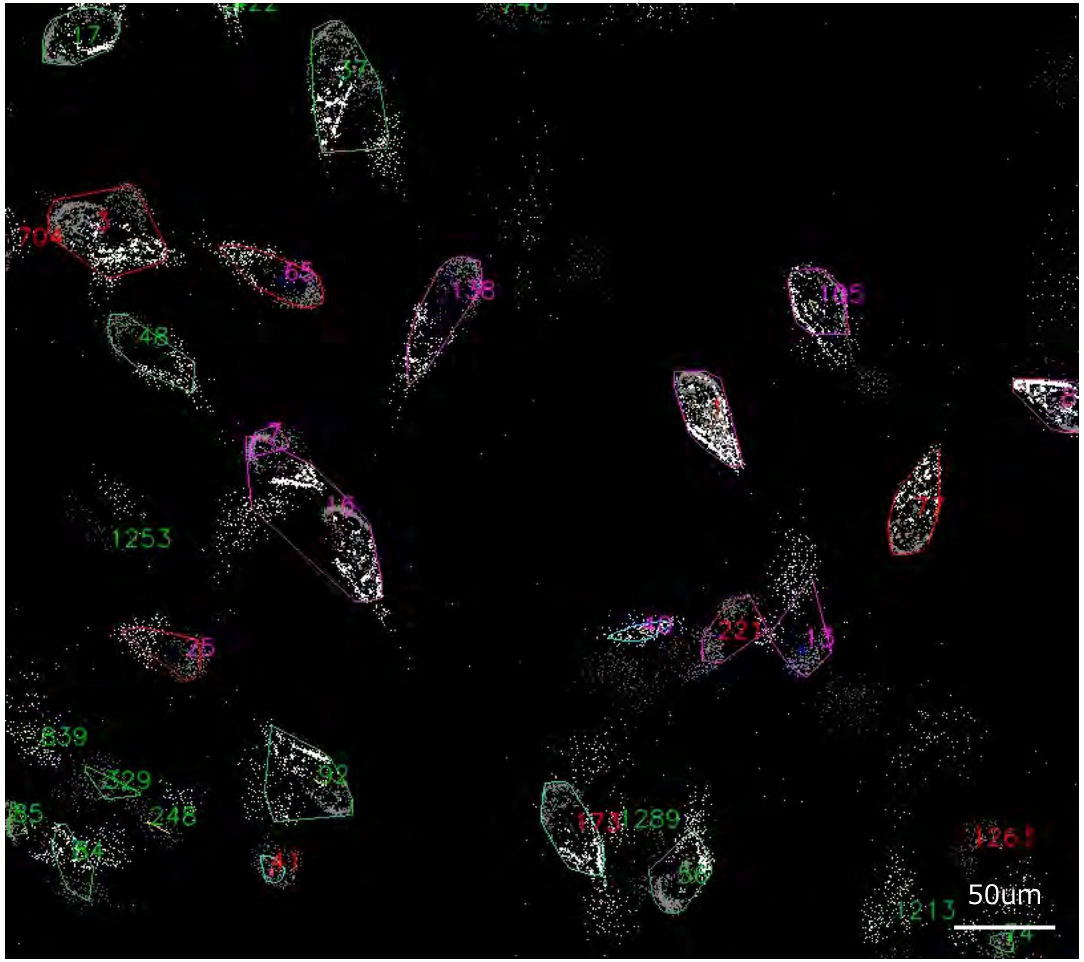
An experiment observing the effects of metal leaching during the process of seabed ore extraction and offshore recovery on the behavior of phytoplankton, using EVS. The study targets species commonly found in the ocean, with metals such as Zinc being incrementally added to analyze their behavior. Comparison is possible using the quantitative data output by EVS.

The EVS captures subtle changes that are not visible to the human eye





Chattonella marina

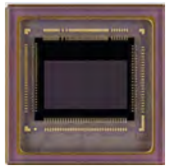


Collaborative Research

Masanobu Kawachi, Specially Appointed Researcher Biodiversity Division (Office for Biodiversity Resource Conservation Research Promotion), National Institute for Environmental Studies (NIES)

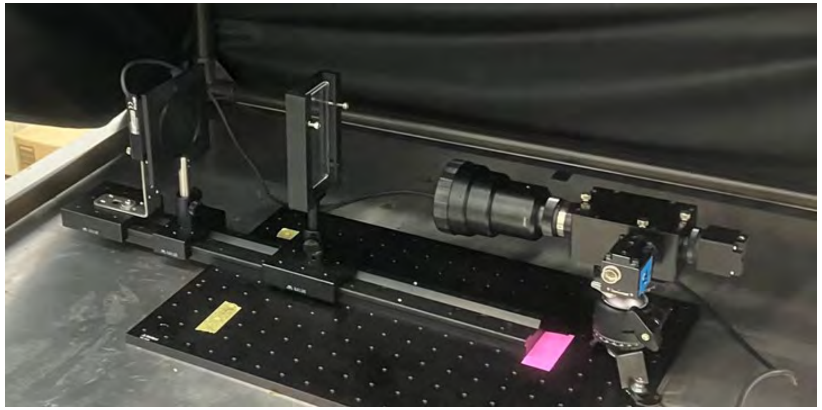
Prototype of a marine particle sensing device equipped with an EVS sensor

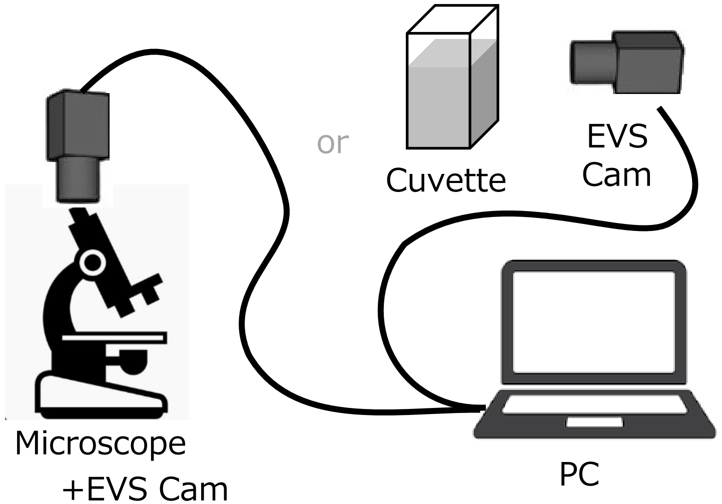
- Sensor is IMX636 (Sony Semiconductor Solutions)
- EVS cameras are available from several companies. e.g., Prophesee, Century Arcs.
- 30x30x36mm, weighing 40g
- In vittlo, measurements are made using a Cuvette or microscope; in situ measurements are made in a pressure-resistant container, submerged or placed in an ROV.



IMX636

In vitro

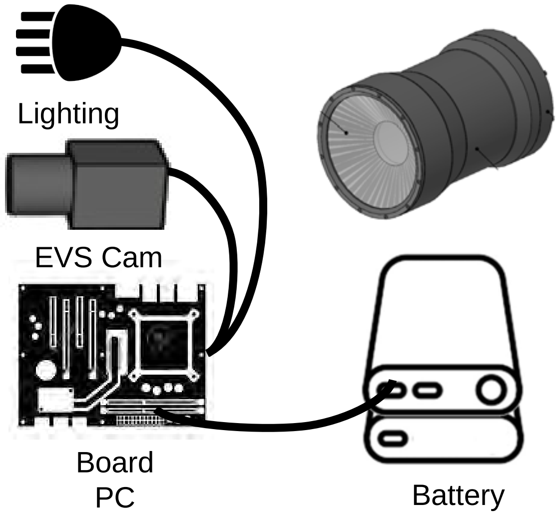


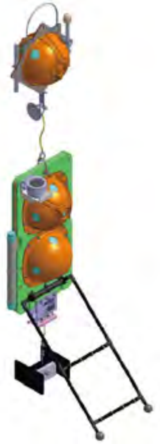


In situ

Pressure vessel

Installed ROV

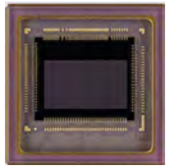




Pressure-resistant glass sphere

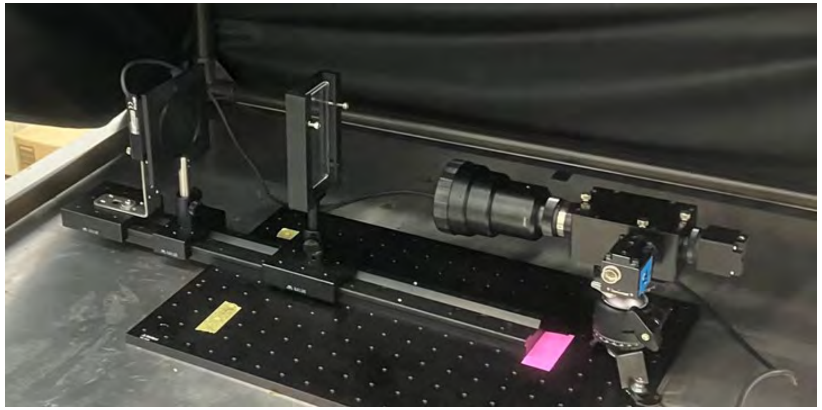
Prototype of a marine particle sensing device equipped with an EVS sensor

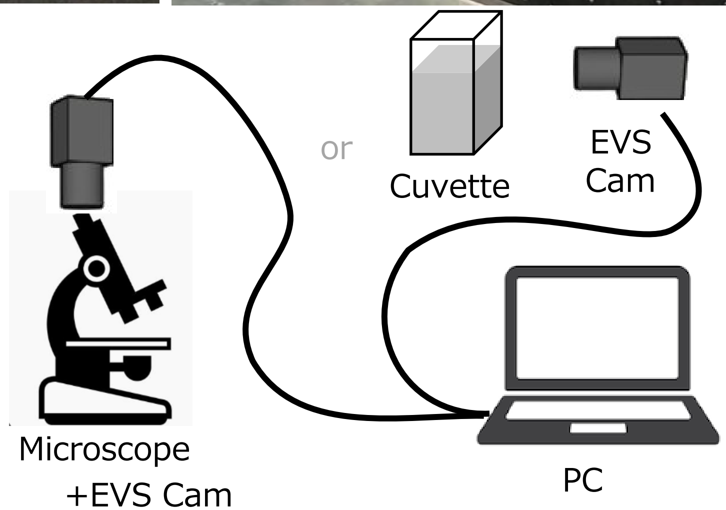
- Sensor is IMX636 (Sony Semiconductor Solutions)
- EVS cameras are available from several companies. e.g., Prophesee, Century Arcs.
- 30x30x36mm, weighing 40g
- In vittlo, measurements are made using a Cuvette or microscope; in situ measurements are made in a pressure-resistant container, submerged or placed in an ROV.



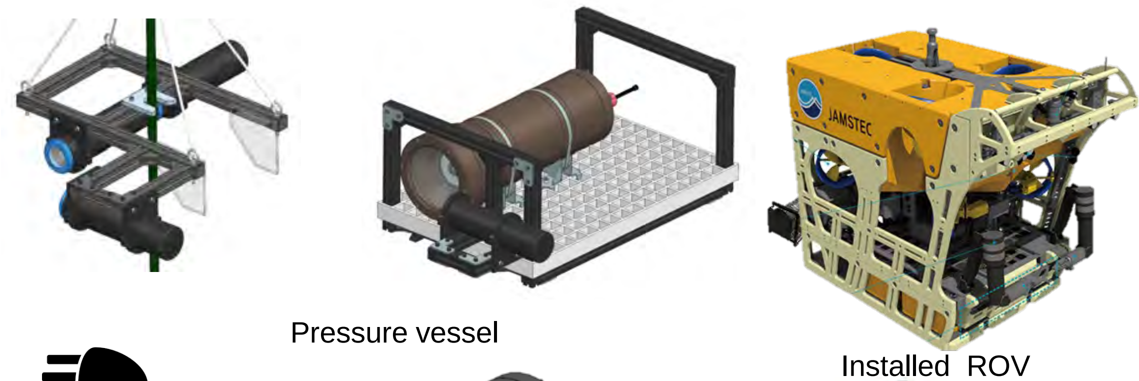
IMX636

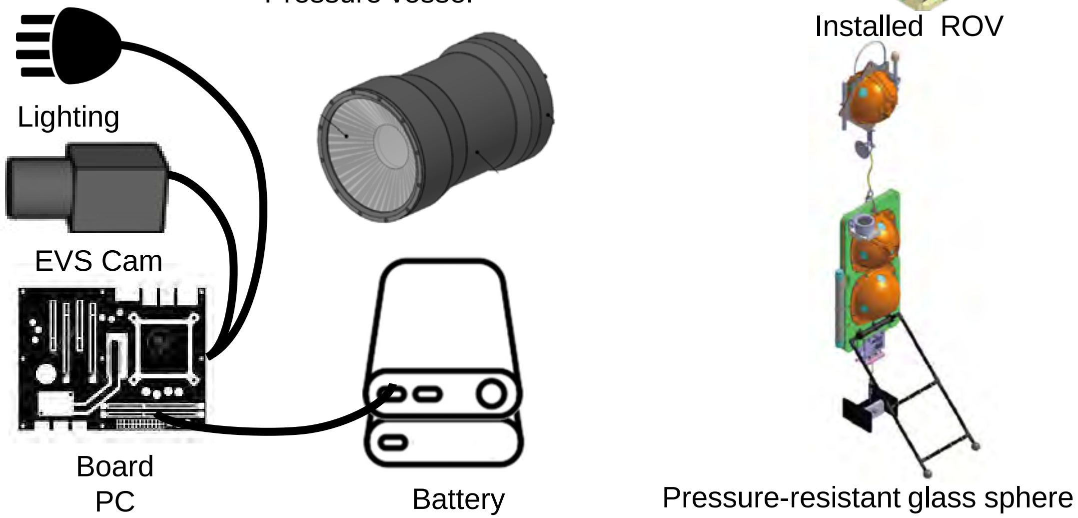
In vitro





In situ





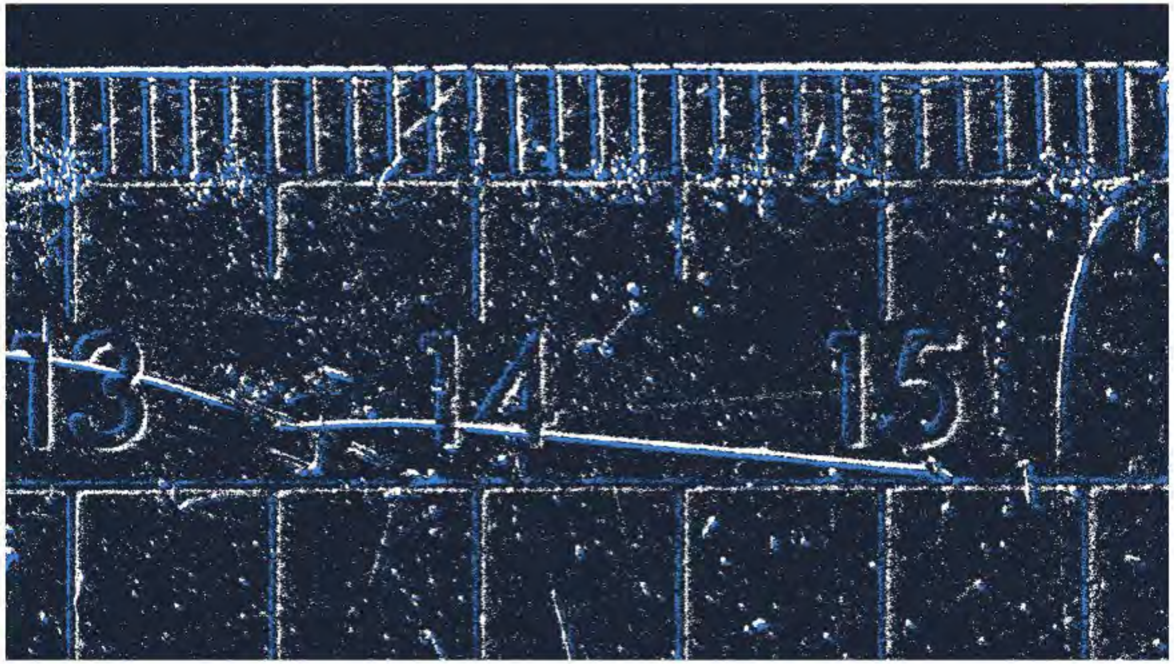
Aggregates, plankton, and jellyfish larvae were placed in a glass case.

The inner dimensions of 50 × 100 × 2 mm for imaging.

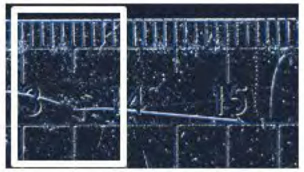
28.3mm
1280 pixels

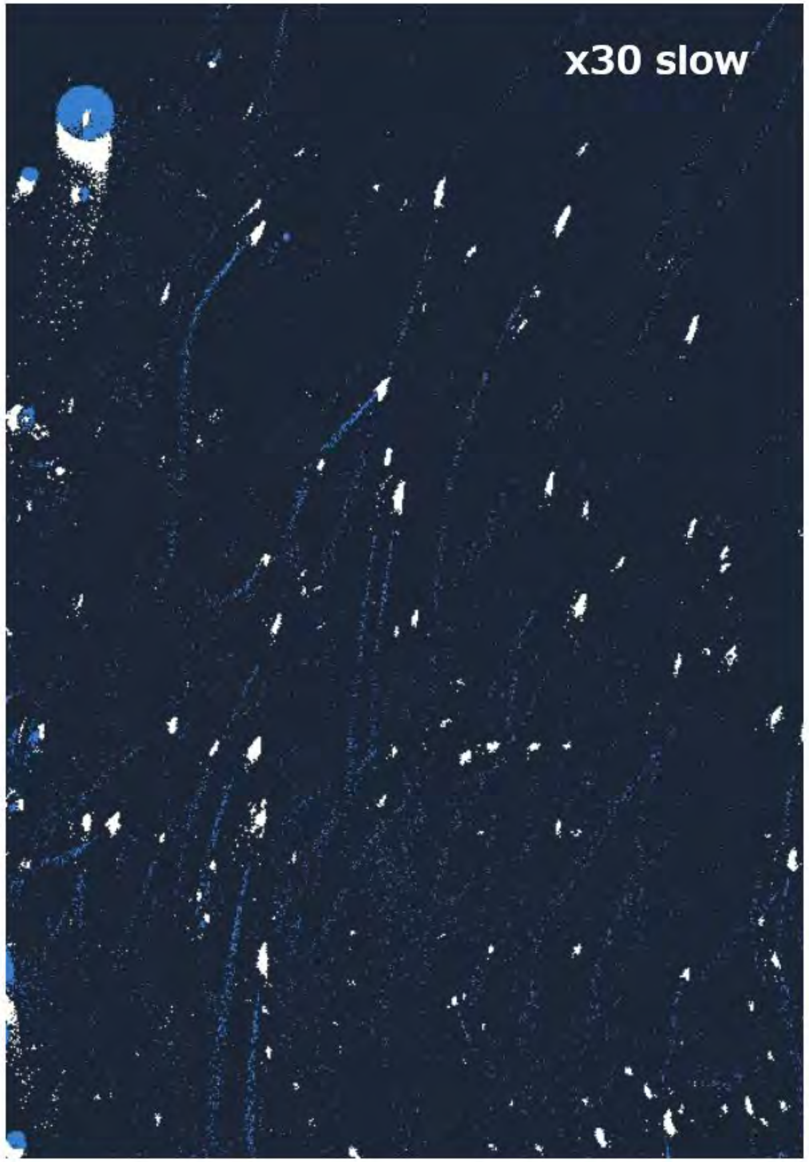
28.3/1280=0.022
1pixel=0.022mm=22um

720 pixel

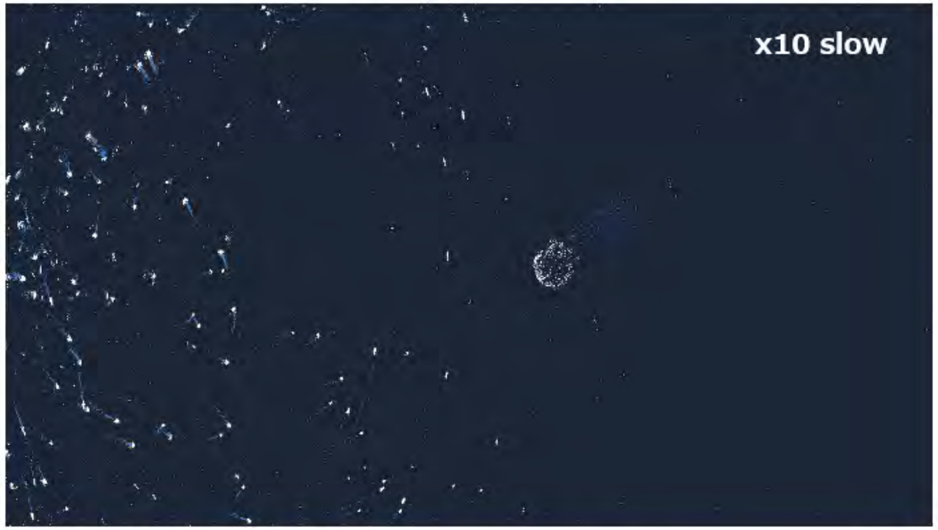


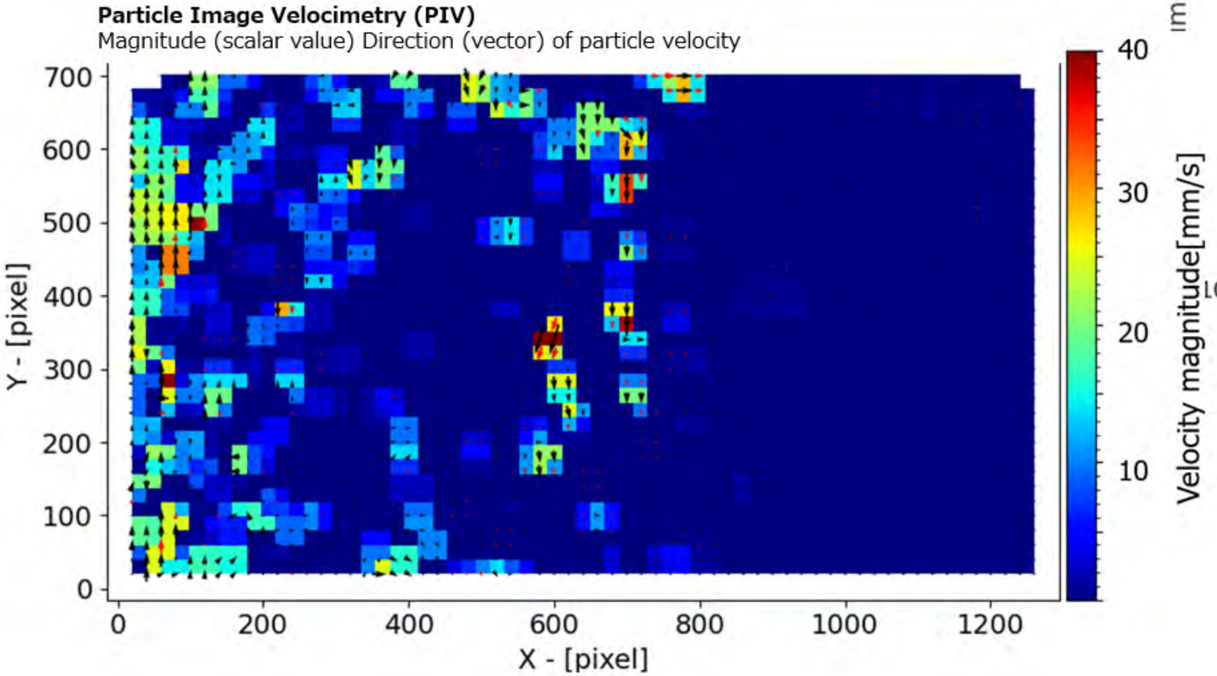
The high-speed imaging of the EVS enables measurements with sufficient temporal resolution to analyze the motion of individual particles in detail.
The playback speeds from left to right are 1×, 10×, and 30×. Since the EVS has a time resolution equivalent to 10,000 fps, it is possible to slow down and examine the same data at these speeds..

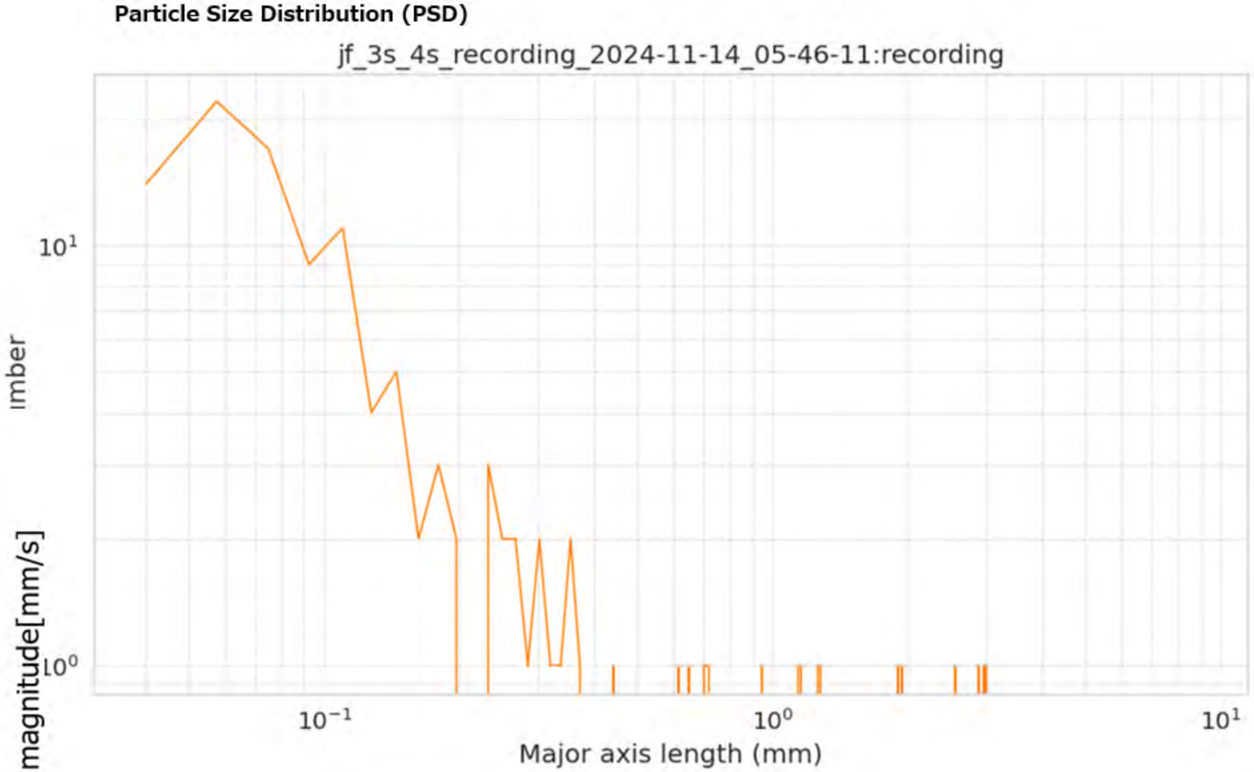




With these ultra-high-speed measurement capabilities of the EVS, it is possible to calculate the particle size distribution, as well as their velocity and direction.

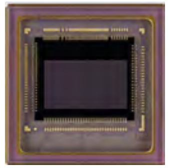






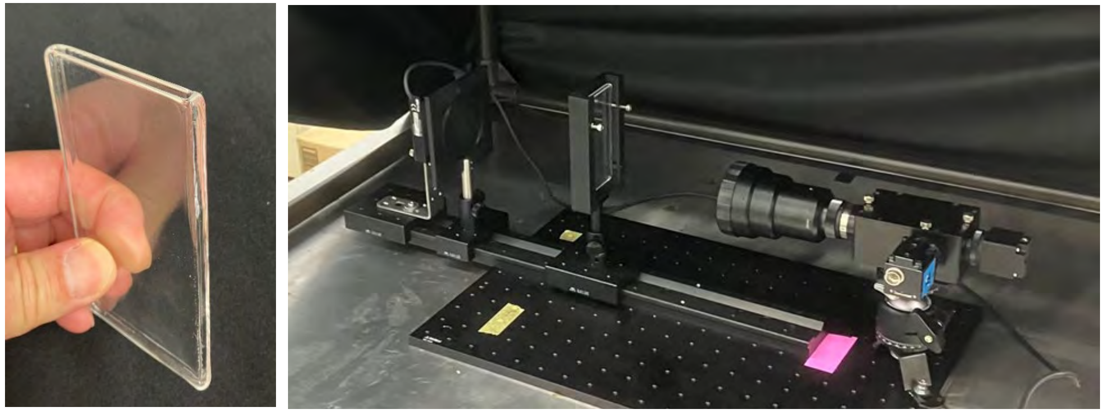
Prototype of a marine particle sensing device equipped with an EVS sensor

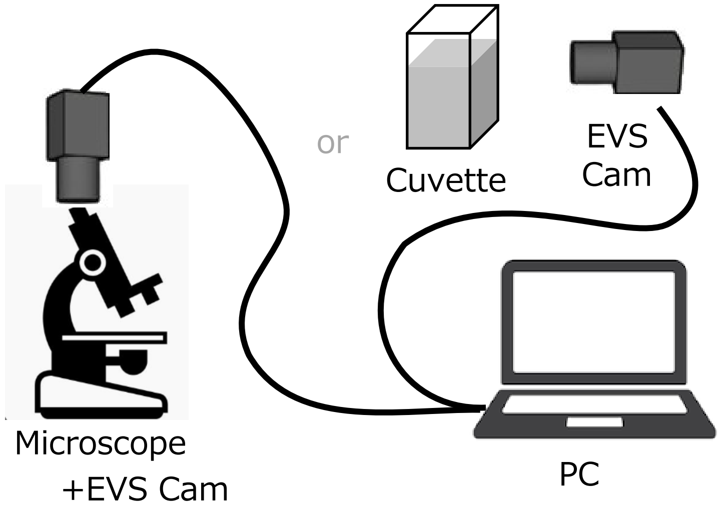
- Sensor is IMX636 (Sony Semiconductor Solutions)
- EVS cameras are available from several companies. e.g., Prophesee, Century Arcs.
- 30x30x36mm, weighing 40g
- In vittlo, measurements are made using a Cuvette or microscope; in situ measurements are made in a pressure-resistant container, submerged or placed in an ROV.



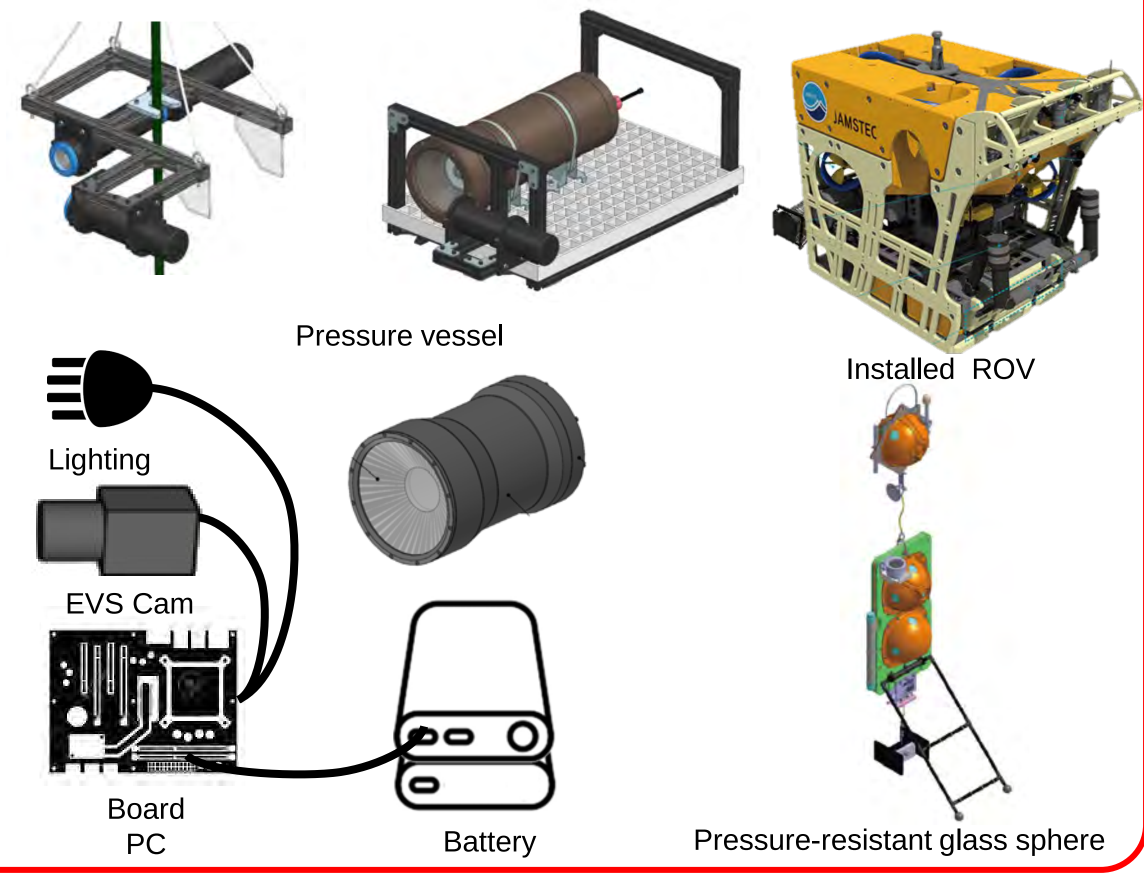
IMX636

In vitro



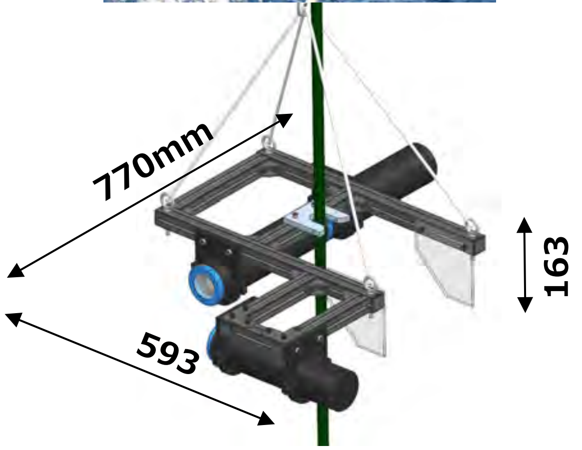


In situ



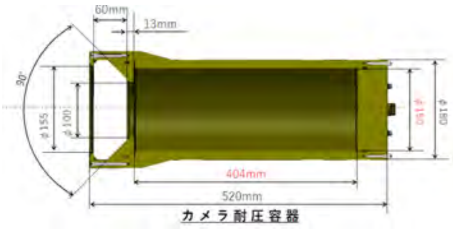
Device sizes depending on depth and measurement duration

Compact device for mooring
Φ80mm
depth of 1750m (5,700ft)

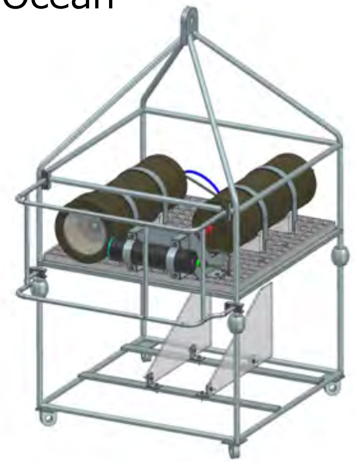


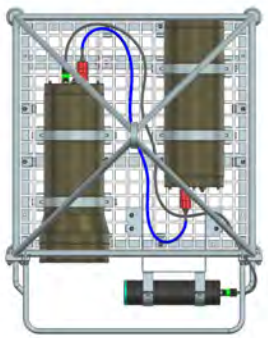
For deep sea
Φ180mm
depth of 3000m (11,482ft)

Mounted on the ROV



One-Year Long-Term Deployment in the Antarctic Ocean

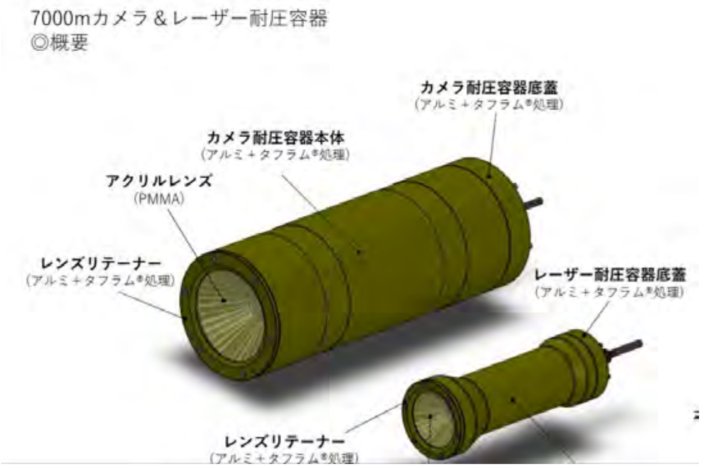




It records for 30 seconds every 2 hours for over a year.

For deep sea
Φ180mm
depth of 7000m (22,966ft)

a, Pressure-resistant housing for the camera and battery
b. Pressure-resistant housing for the lighting
The two housings are connected by a deep-sea pressure-resistant cable.



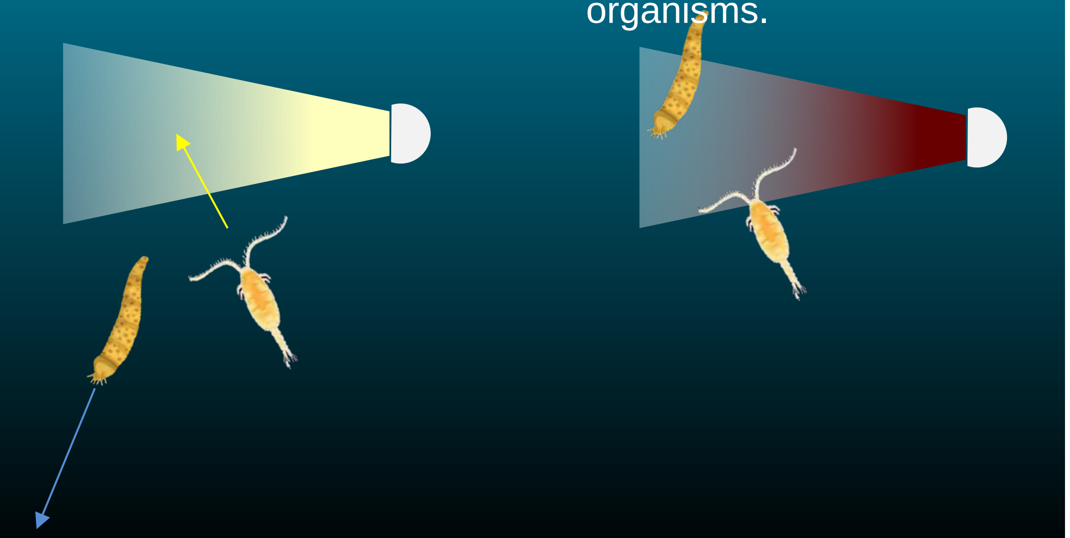
We have developed various devices according to depth and operating time requirements.
These include small units that can be attached to sediment traps, devices mounted on ROVs, and systems designed for year-long moored observations

Lighting : Near-infrared illumination that does not induce phototaxis

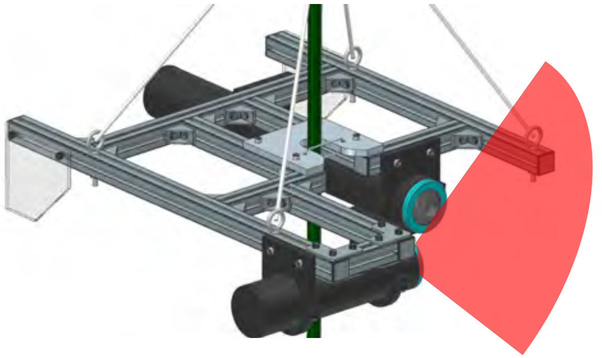
White light is conventionally used to brightly illuminate the space being video-recorded underwater. Plankton and larvae are known to have phototaxis, which is the tendency of plankton to be attracted to light. Therefore, we were not able to measure the organisms naturally and correctly. EVS can capture even the slightest changes in near-infrared light . We used illumination with a wavelength of 770 nm, which does not affect most organisms. In this way we achieved non-invasive measurements.

Normal illumination (white light)
Wavelengths that can be sensed by living organisms. Induces phototaxis and prevents observation in its natural state.

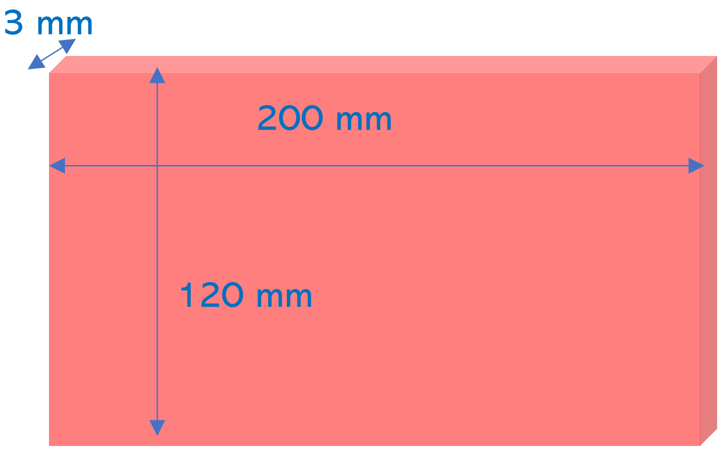
Non-invasive illumination
Wavelength of 770 nm, which is unrecognizable to common organisms. Realizes observation without affecting living organisms.



Measurement using sheet-like laser irradiation. Improved accuracy in particle size measurement. Positioned perpendicular to the direction of the camera lens.



In case of using macro lens (VS-LDA4)



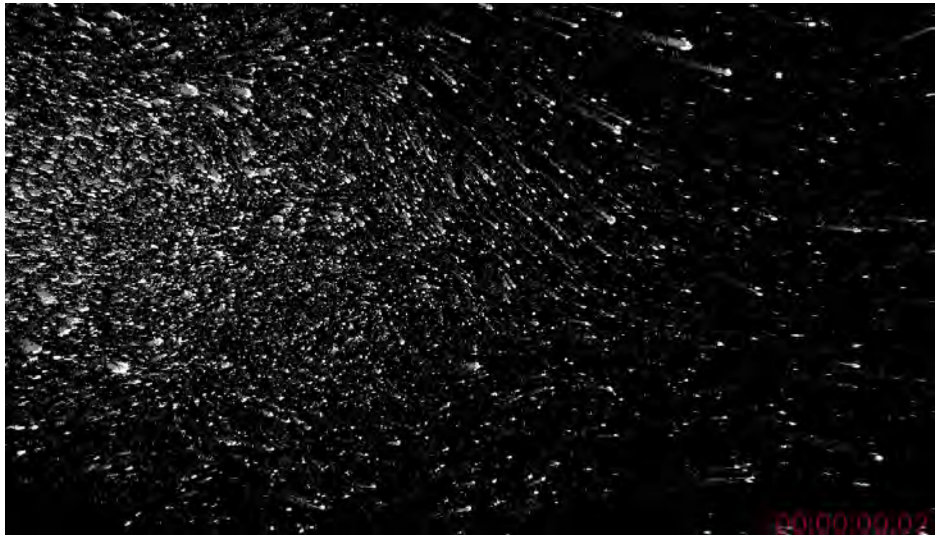
Imaging volume
200x120x6(±3)mm

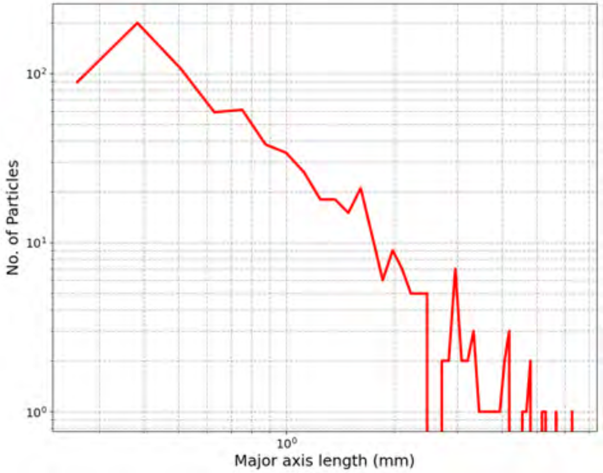
1 pixel recognition size
≒ 0.15625mm/pixel

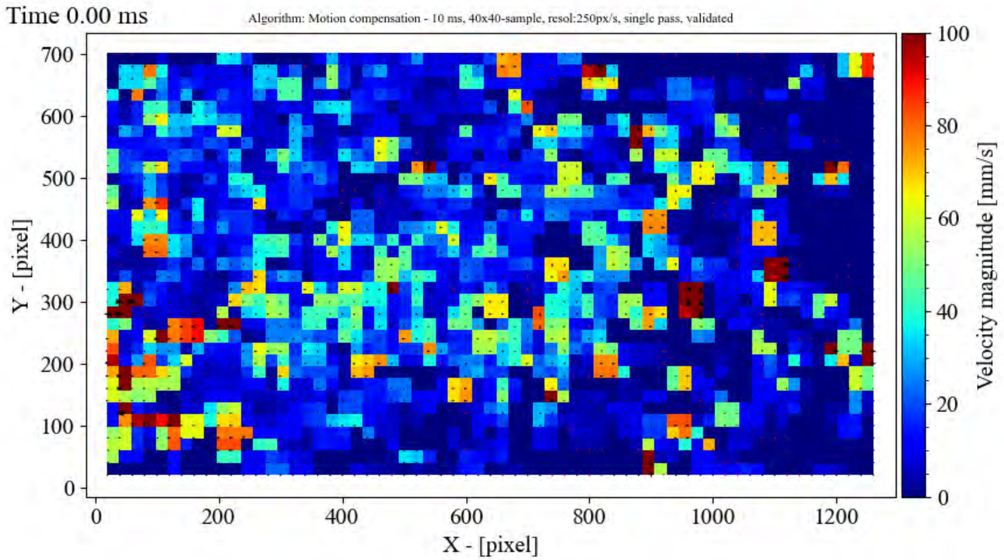
size error rate ±1.9%
VS-LDA4 macro lens

An experiment using the EVS mounted on an ROV for deep-sea measurements

High-speed imaging of suspended particles was conducted, and analyses were performed on particle size distribution, as well as flow velocity and direction.

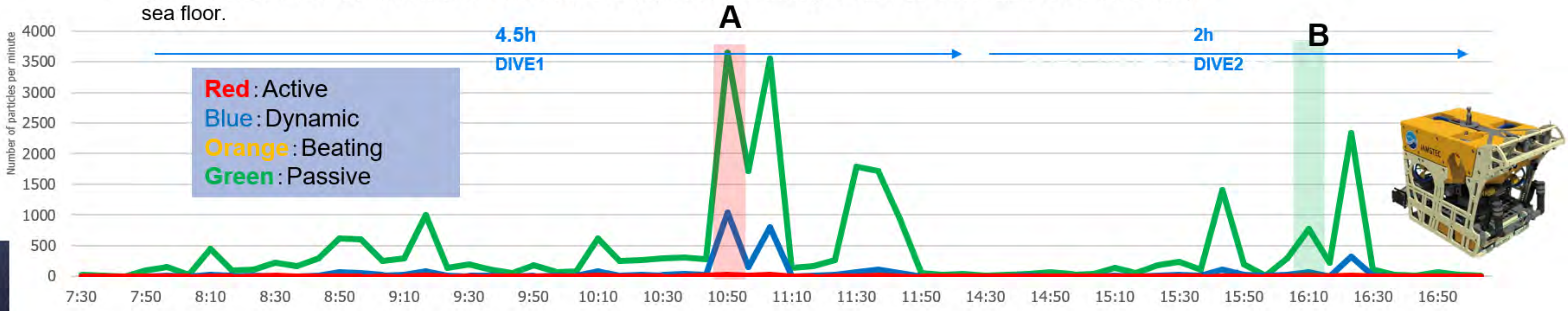






ROV observations at hydrothermal deposits and biomass estimation based on particle analysis

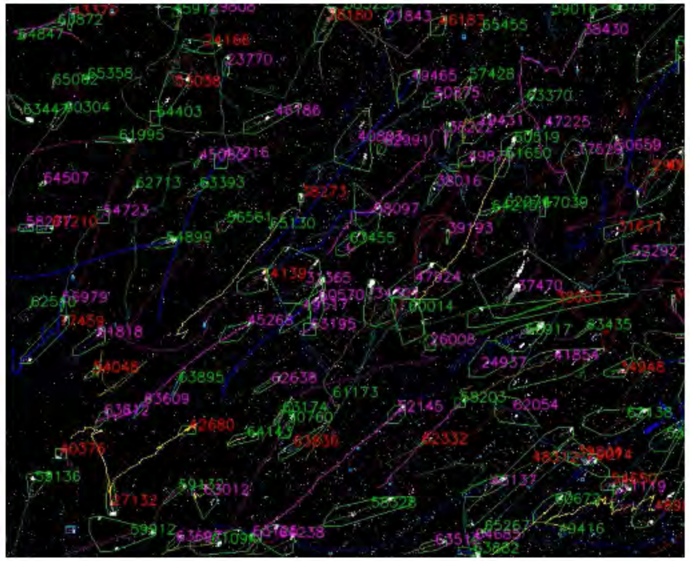
- EVS was installed behind the ROV and recorded during the 6.5 hours dive.
- The horizontal axis is time and the vertical axis is the number of particles observed.
- There are several events that increase the number of particles. For example, when the ROV lands on or takes off the sea floor.



Observation point-A. Chimney collection

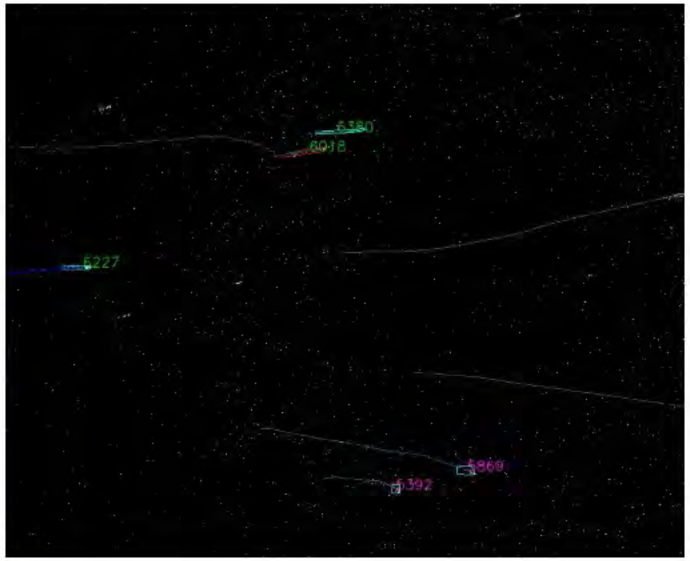
Chimney sample collection at a hydrothermal vent

A chimney is a chimney-shaped structure formed when minerals in hot water coming out from the seafloor.



Observation point-B. Recovery of equipment

Recovery of measuring equipment at the bottom of the ocean



The particles observed during this dive were classified into four groups

Environmental impact assessment of offshore development

Were the clusters (point clouds) recognized?

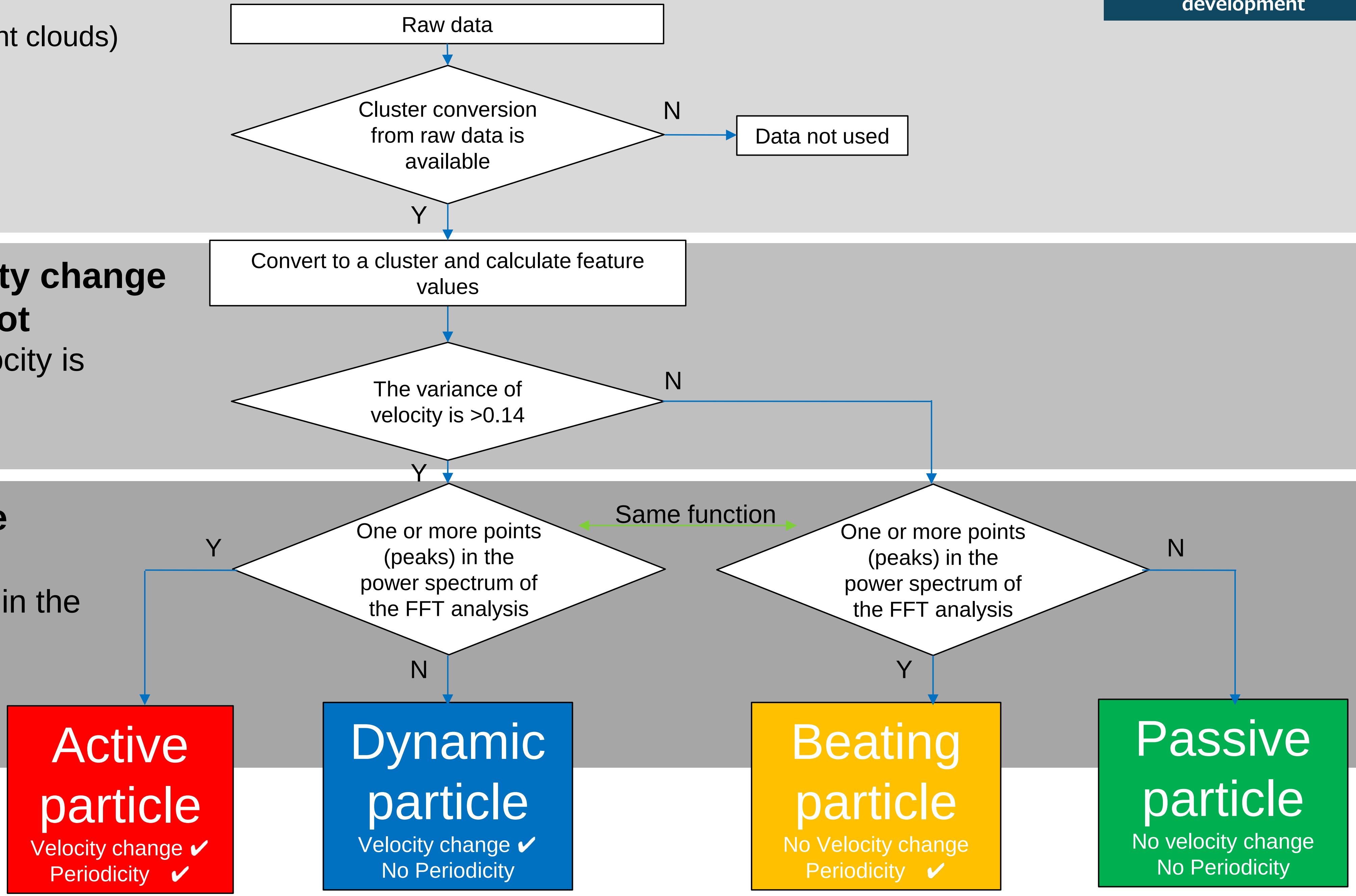
Cluster recognition

Whether a velocity change is occurring or not

The variance of velocity is greater than 0.14.

Whether they are periodic or not

One or more peaks in the FFT analysis.



Estimation from analysis results

Environmental impact assessment of offshore development

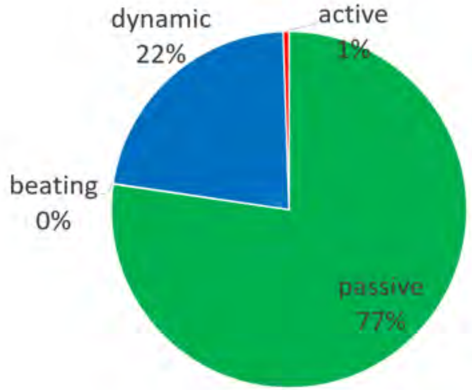
- During the chimney collection in point-A, 4721 particles were counted per minute; in point-B, 846 particles were counted.
- “Dynamic particles” group (Velocity change , No Periodicity) was 22% for A, compared to 8% for B. Point-A had the highest number of particles in the Acitve group with both velocity change and periodicity in all shooting time.
- Based on these results, we considered that the suspended particles observed in A could be estimated to have a higher percentage of organisms in the observed particles than those in B.
- Our hypothesis was that A was the result of the effect of the roll-up of larvae and zooplankton from the hydrothermal community living in the chimney.
- **This technology enables the estimation of both the number of particles and the biomass they contain.**

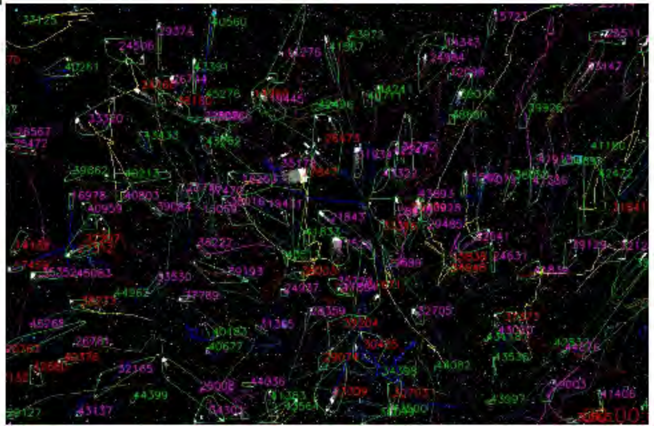
Possibility of bio-particles	High	Mid		Low
Group	Active	Dynamic	Beating	Passive
Velocity change	✓	✓	none	none
Periodicity	✓	none	✓	none

During observations at both points A and B, the ROV thrusters were kept inactive to prevent the generation of turbulence. In addition, the EVS was mounted at the rear of the ROV so as to minimize potential disturbances from hydrothermal discharge at the vent site as well as turbulence induced by manipulator arm operations.

Observation point-A. **Chimney collection**

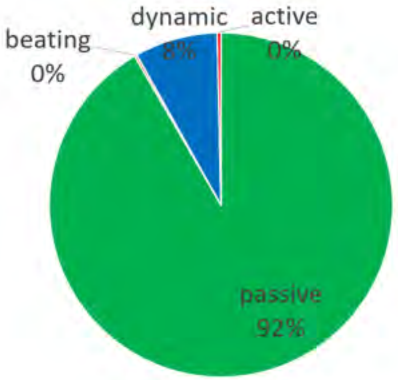
Total 4721/min			
Active	Dynamic	Beating	Passive
25	1045	2	3649

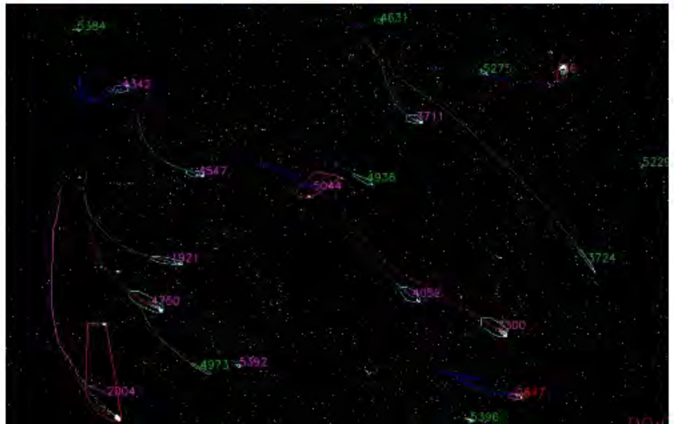




Observation point-B. **Recovery of equipment**

Total 846/min			
Active	Dynamic	Beating	Passive
3	66	2	775





Publication

Millisecond-scale behaviours of plankton quantified in vitro and in situ using the Event-based Vision Sensor (2024-08-28)

doi: https://doi.org/10.1002/ece3.70150


Ecology and Evolution

Forward Series

RESEARCH ARTICLE Open Access

Millisecond-scale behaviours of plankton quantified in vitro and in situ using the Event-based Vision Sensor

Susumu Takatsuka, Norio Miyamoto, Hidehito Sato, Yoshiaki Morino, Yoshihisa Kurita, Akinori Yabuki, Chong Chen, Shinsuke Kawagucci

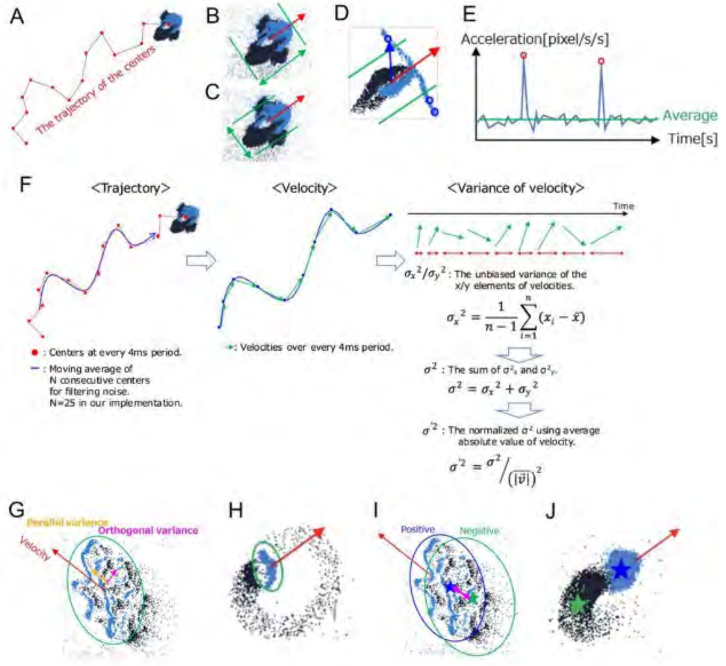
First published: 27 August 2024 | https://doi.org/10.1002/ece3.70150

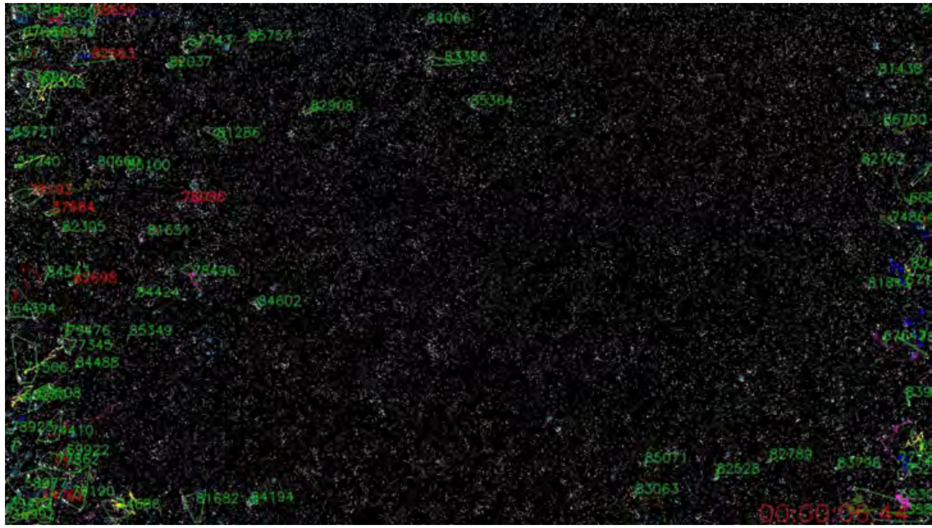
Susumu Takatsuka and Norio Miyamoto contributed equally to this work.

SECTIONS PDF TOOLS SHARE

Abstract

The Event-based Vision Sensor (EVS) is a bio-inspired sensor that captures detailed motions of objects, aiming to become the 'eyes' of machines like self-driving cars. Compared to conventional frame-based image sensors, the EVS has an extremely fast motion capture equivalent to 10,000-fps even with standard optical settings, plus high dynamic ranges for brightness and also lower consumption of memory and energy. Here, we developed 22 characteristic features for analysing the motions of aquatic particles





EVS analysis video taken at Lake Biwa (Takatsuka et al., 2023)

Conference and Symposium Presentations

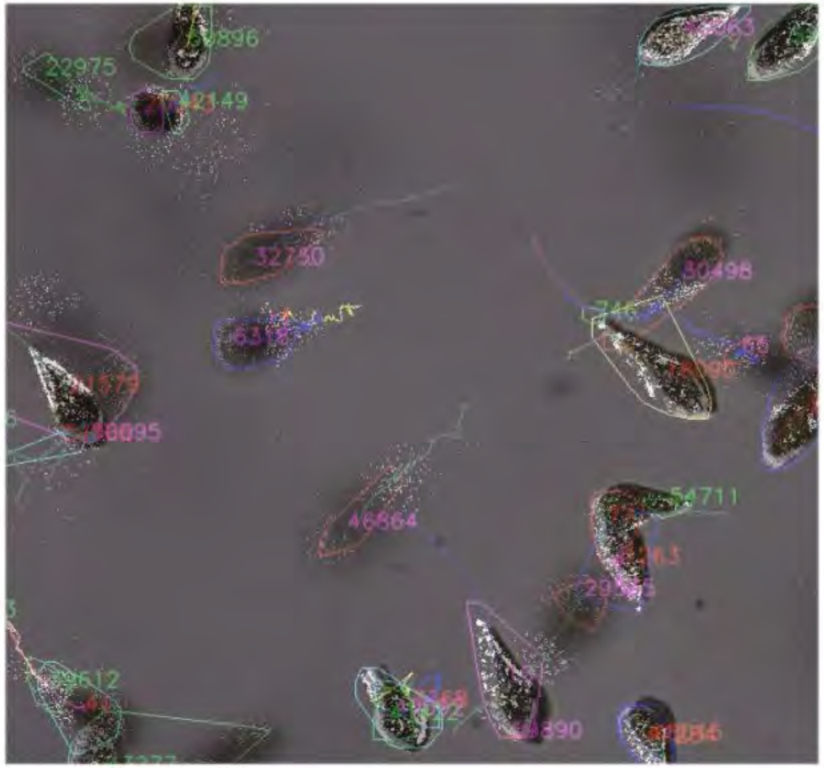
Since 2024, numerous conference presentations have been actively delivered, resulting in an increasing number of lecture invitations and collaboration inquiries.

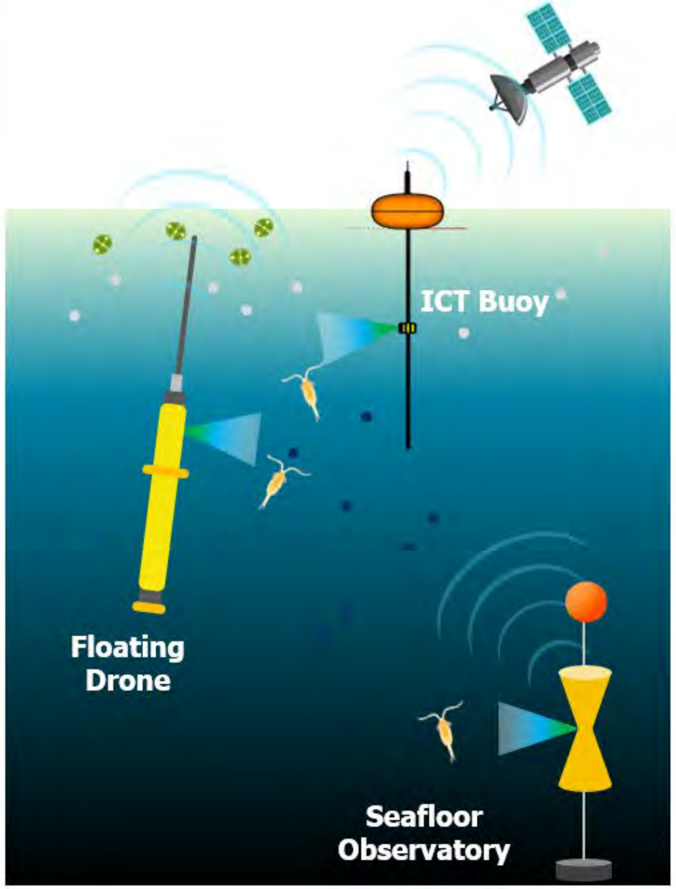
- **Feb 19, 2024:** *Ocean Sciences Meeting 2024*, New Orleans
- **May 13, 2024:** *The 30th Food Production Technology Research Meeting*, University of Tokyo, Institute of Industrial Science (Oki Laboratory)
- **Sep 16, 2024:** *Joint Meeting of the Japanese Plankton Society and the Japanese Benthos Society*
- **Oct 10, 2024:** *Ocean Optics Conference*, Las Palmas
- **Jan 7, 2025:** *Joint Meeting on Biomechanics and Biolocomotion 2025*, Kyoto
- **Jan 28, 2025:** *Lecture at Monterey Bay Aquarium Research Institute (MBARI)*, California
- **Feb 2, 2025:** *Lecture at Harbor Branch Oceanographic Institute (HBOI)*, Florida
- **Apr 28, 2025:** *European Geosciences Union (EGU) General Assembly*, Vienna
- **Jun 10, 2025:** *International Seabed Authority (ISA) Expert Scoping Workshop*, Kobe University
- **Jul 17, 2025:** *EISESiV Consortium*, Tokyo Institute of Science, Ookayama Campus
- **Oct 6, 2025:** *Cabinet Office, Headquarters for Ocean Policy – Study Group on Emerging Marine Technologies*
- **Oct 29, 2025:** *GloBIAS Bioimage Analysis Symposium*, RIKEN Kobe
- **Oct 31, 2025:** *Symposium on Advanced Technologies for Marine Life Big Data Utilization*
- **Nov 9, 2025:** *Underwater Minerals Conference (UMC 2025)*, Florida
- **Dec 18, 2025:** *Optical Communication Systems Symposium*, Chunichi Hall & Conference
- **Jan 28, 2026:** *Offshore Tech Japan 2026 – Marine Robotics Seminar*
- **Feb 26, 2026:** *Ocean Sciences Meeting 2026*, Glasgow

Proposal for collaboration

- This project is supported by research funding from (The Ministry of Education, Culture, Sports, Science and Technology).
- We also offer equipment rental, data analysis services, and technical consulting.
- **If you are interested, please feel free to contact us.**

Contact mail
susumu.takatsuka@sony.com





This research is being developed by a joint team from JAMSTEC and Sony.

国立研究開発法人海洋研究開発機構
JAMSTEC
JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

Sony CSL

Yasuhito Hayashi
Biological Oceanography Researcher Ph.D
Software & Hardware Engineer
JAMSTEC

Norio Miyamoto
Evolutionary Biology Researcher Ph.D
JAMSTEC

Shinsuke Kawagucci
Geology Environmental Dynamics Analysis Researcher Ph.D
JAMSTEC

Susumu Takatsuka
Principal Investigator
Sensor Researcher
Sony CSL
Visiting researcher
JAMSTEC

Hitoshi Azumi
Hardware & Electrical Engineer
Researcher
Sony CSL

Tomohiro Kawahara
Hardware & Sensor Engineer Ph.D
Researcher
Sony CSL

Hiroshi Ueno
Software and Network Engineer
Researcher
Sony CSL

MEXT's "Advancement of Technologies for Utilizing Big Data of Marine Life" Grant Number JPMXD1521473834, JSPS KAKENHI Grant Number 20K06754
Grant-in-Aid for Specially Promoted Research "Response of biogeochemical cycle and lower trophic ecosystem to the environmental change in the Southern Ocean, East Antarctica" Grant Number 23H05411