

Imaging Plankton at 5 Knots

Biological Oceanography and near Real Time Processing

by Charles Cousin & Cedric Guigand

In 2005, Bellamare, LLC and the Rosenstiel School for Marine and Atmospheric Science of the University of Miami started collaborating on the development of a new plankton imaging instrument for fisheries research. Dr. R. Cowen and C. Guigand originated an optical scanning system, based on machine vision technology and back lighting techniques (shadowgraphy). Bellamare was in charge of integrating the instrument, by packaging the precision optical and electronic components of the system into pressure rated enclosures, and designing a robust and reliable oceanic towed vehicle for field demonstration. The instrument is dubbed ISIIS for "In Situ Ichthyoplankton Imaging System."

ISIIS was developed to fulfill a demand for better sampling techniques. Current larval fish sampling studies are typically carried out with towed net systems, which offer limited versatility and data analysis. Nets collect organisms over the sampling distance/depth profile(s) and hence do not provide a fine scale resolution of organism population. Net tows also require massive sums of time to perform data analysis — approximately one man-year of post-processing work for every two days at sea. These limitations have spurred many attempts to develop in situ imaging systems and a number of systems already exist - each having their particular focus. While successful, these systems often are limited in the volume of water sampled or imaging capabilities, making it difficult to study relatively rare organisms (i.e. fish larvae).

ISIIS technology presents a notable advancement which allows for a wide spread of application, as the vehicle and its imaging system are configurable and give the versatility needed for studying a range of organisms - from small, abundant plankton, to larger and more rare specimens. The first prototype, as described in an article in the journal of *Limnology and Oceanography: Methods* 6, 2008 126-132 by Dr. R. Cowen and C. Guigand, has already demonstrated, sampling close to 10% of the volume fil-

tered by net systems, which was an improvement over previous in situ imaging systems, by more than an order of magnitude. The ISIIS prototype also quantified densities of fish larvae equal to, or better than 1 sq. m. and 4 sq. m. MOCNESS net samples, taken in the same location and at the same time of year.

Moreover ISIIS allows for:

- Categorization of fish larvae and other meso-zooplankters
- Identification of the organism taxonomy as the larvae are see-through and their features can be easily recognized
- Observation of their In Situ orientation
- Analysis of aggregation and their relation to the environmental conditions
- Studies of behavioral/orientation relevant to feeding, floating, diurnal rhythm and vertical migration.
- The gathering of data pertaining to spawning and stock assessment via the measurement of egg abundance over large areas.

To enhance ISIIS's sampling and data analysis capabilities in real-time mode, an image recognition software is being developed by Dr. Gavriil Tsechpenakis of the Department of Electrical and Computer Engineering at the University of Miami.

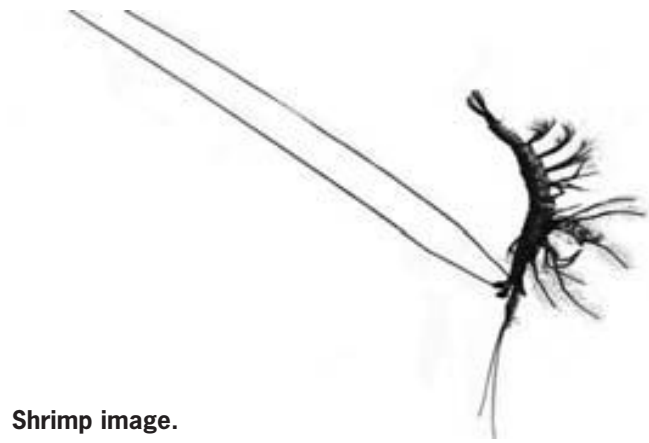
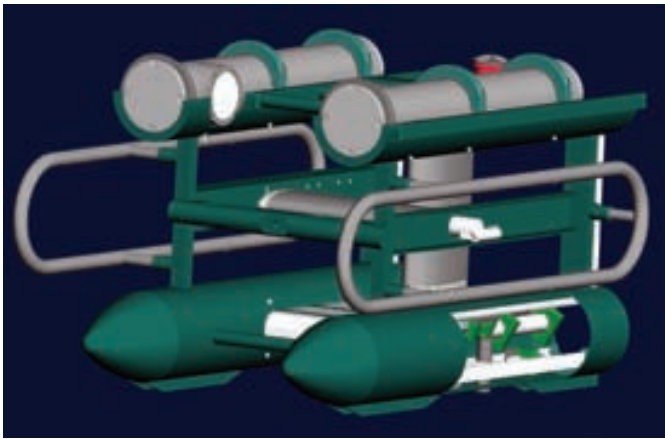
Since the completion and testing of the first prototype, a variety of system optimizations have been incorporated, including RSMAS's success in generating an enhanced depth of field for ISIIS's camera equipment and Bellamare's successes in improving the vehicle's configuration, thereby reducing the equipment's environmental disturbance, and most importantly, developing capabilities for pre-programmed undulation.

Bellamare's engineering efforts have focused on adding undulation capabilities to ISIIS, so that it could map a preset section of the water column and provide a fine scale resolution of the distribution of organisms at different depths. The vehicle's 200 m depth-rated design mini-



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Shrimp image.

mizes vibrations affecting image resolution and allows a near-completely undisturbed view of larval organisms, due to both the frame's advanced hydrodynamic features, and towing the platform from the side of a ship rather than from the stern, thereby moving the tether out of the path of ISIIS's sensitive camera equipment.

The vehicle frame is divided into four compartmentalized enclosures with imaging and optical equipment seamlessly integrated into ISIIS's ventral housings and environmental sensors and electronics in the dorsal housings. The sensitive instrument equipment is isolated from the aluminum frame by using separating suspension and vibration absorbing materials, and the vehicle's tether is secured to the frame with shock absorbing component.

The vehicle navigates with the use of a controlling elevator wing, that receives feedback from a position sensor, capable of performing water depth soundings. A second wing serves as a rudder and provides towing ability from a side of the supporting ship.

At the normal operating towing speed of 5 knots, the Matlab simulations predict a required tether length of 700 m, in order to reach 200m operational depth. A LabView based interface allows ISIIS's undulating depth profiles to be pre-programmed before deployment.

In order to optimize the ISIIS configuration and operational profile, Bellamare has performed extensive computational fluid dynamics simulations. The results have demonstrated that the vehicle generates enough lift to reach target water depths. Similar simulations have confirmed the preliminary drag estimates, used to structurally engineer the vehicle, while under hydrodynamic loading. Additionally, the CFD simulations have proven that virtually entirely undisturbed water flows through the imaging volume of the vehicle, providing a near-completely natural view of the target organisms.

The structural analysis of the ISIIS includes static and dynamic evaluations and was performed using ANSYS. The integrity of the pressure enclosures and the optical glass view-port design have also been validated for the operational conditions.

RSMAS and Bellamare view ISIIS as a truly modern solution for the scientific fisheries research community. Capable of real time data analysis and the opportunity to re-analyze data at will, ISIIS brings thoroughly desired speed to ichthyoplankton research and the field of biological oceanography in general.

Bellamare has created a survey to help define the needs of the scientific community for the successful application of this instrument and invites all interested parties to participate in order to ensure that ISIIS will be available to everyone in need.

www.bellamare-us.com

About the Authors

Charles Cousin is the president and co-founder of Bellamare LLC. Since completion of his MSE in Naval Architecture and Marine Engineering at the University of Michigan, Ann Arbor 1999, he has been leading the design and manufacturing of oceanographic instruments, towed vehicles and manned acrylic submersible. Charles can be contacted at charles@bellamare-us.com.

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