Development and Field Testing a Satellite-linked Fluorometer for Marine Mammals:

Shedding Light on the Unknown

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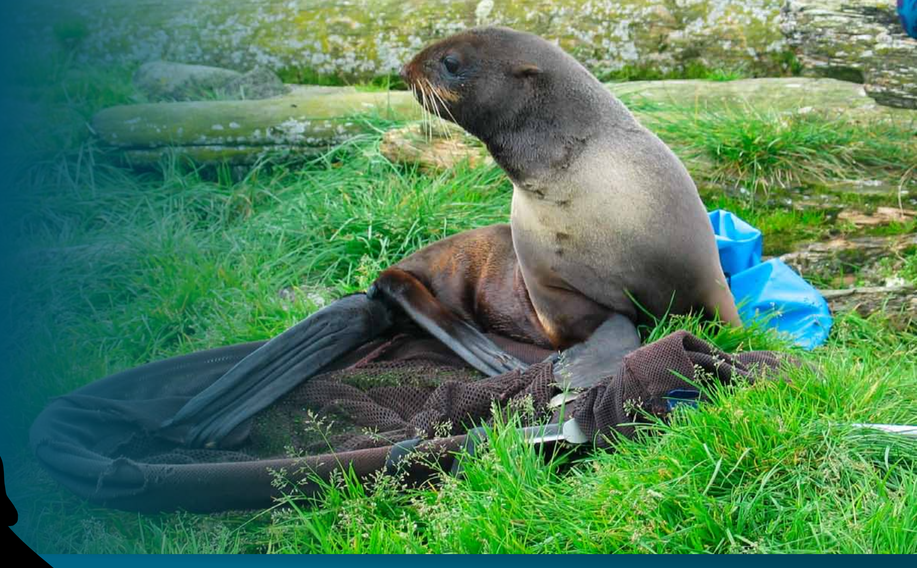


Abstract

Understanding the responses of marine mammals and other apex predators to spatial and temporal variability of primary productivity is fundamental for their conservation and for predicting how they will be affected by future climate change. Attaining this goal is often hampered by paucity of oceanographic data, but the use of animal-borne platforms as environmental sensors has quickly emerged to complement conventional oceanographic data collection methods, sample inaccessible locations, and provide real-time data of animal behavior corresponding to the abiotic vertical structure of the water column. Despite recent advances in biotelemetry, fluorometers have only recently been incorporated into transmitting systems. **The purpose of this project was to incorporate a miniature fluorometer into a satellite-linked transmitter to provide measures of in situ phytoplankton fluorescence, which were used to calculate chlorophyll-*a* (chl-*a*), a proxy for primary productivity.** After evaluating the suitability (i.e. size, power consumption, and electronic interface) of commercially available fluorometers, the ECO Puck™ (WET Labs, Inc., Philomath, OR), which measures chl-*a* (0-75 µg Chl/l), was interfaced with an archival instrument (i.e. SPLASH10), manufactured by Wildlife Computers, Redmond, WA. Laboratory trials and simulated deployments in the field (i.e. manual casts in Puget Sound, WA) indicated the interfaced prototype functioned properly relative to another calibrated instrument of similar configuration (Figs. 1 and 2). Additionally, trials on trained, open water Steller sea lions (*Eumetopias jubatus*) allowed us to address concerns regarding the orientation and fragility of the optics (Fig. 3). To determine the best approach for collecting, summarizing, and compressing data for transmission through the Argos satellite system, the prototype was deployed on an adult female northern fur seal (*Callorhinus ursinus*) captured on St. Paul Island, Alaska. The archived data (i.e. fluorescence, temperature, depth, and conductivity) collected at 4 Hz for all dives exceeding 10 m depth (range=10-120 m) during an eight day trip at sea were used to examine anomalous data, determine if the data reduction routines established for the Argos system were a sufficient summary of the data, and verify functionality of the Argos message generation by the transmitting unit (Fig. 4). The final phase of this project will entail deploying a satellite-linked fluorometer (Fig. 5) on free-ranging Steller sea lions.

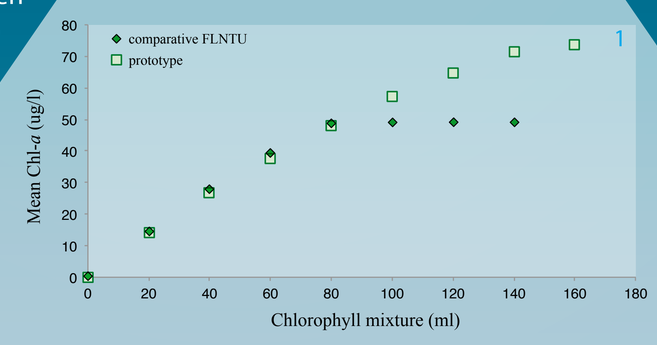


Figure 1. To verify functionality of the prototype described above, measurement trials were conducted under controlled conditions in the lab. The prototype and another calibrated instrument (Fluorometer-Turbidity Unit; FLNTU) were suspended in a black bucket of water, which was diluted (20 ml increments) with a chlorophyll mixture extracted from frozen spinach. Results indicated measurements of chlorophyll concentration (µg/l) were linear (as they should be) and saturated at the programmed maximum value (i.e. 73.9 µg Chl/l). Results of the prototype also were comparable to the other FLNTU, with a programmed maximum value of 50 µg Chl/l. Between the two instruments, standard deviations of measurements (n ~ 480 samples per dilution) ranged from 0.008 to 0.390 µg/l.

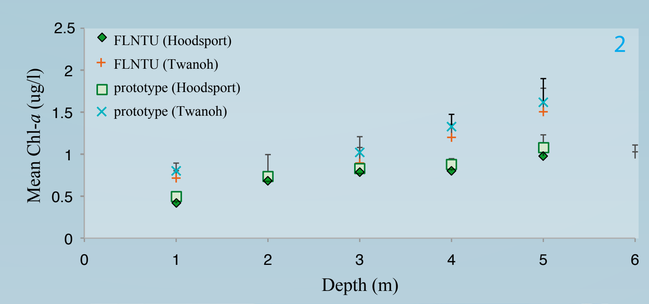


Figure 2. To simulate deployments in the field, manual casts of the same two instruments were conducted in Hood Canal, Puget Sound, Washington. Deployments were conducted from a skiff adjacent to the Hoodsport and Twanoh buoys (http://orca.ocean.washington.edu/). As expected in a dynamic environment, values differed slightly between the two instruments, but overall trends were similar. Error bars equal standard deviation.

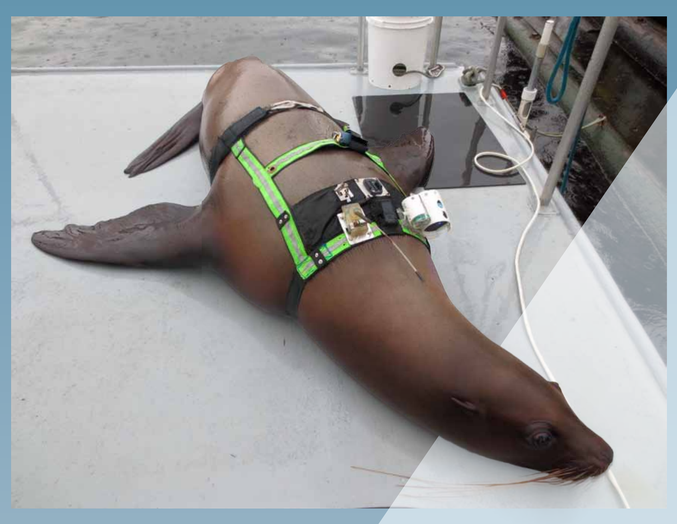


Figure 3. To determine if sensor orientation associated with animal behavior affected measurements while in the environment, the prototype was deployed on three trained, open-water Steller sea lions during filmed, routine experiments at the Open Water Research Facility, University of British Columbia. These trials indicated the prototype was robust to various behaviors we were concerned about (e.g. pitch/roll, rapid speeds and surfacings, reaction to the light, etc.).

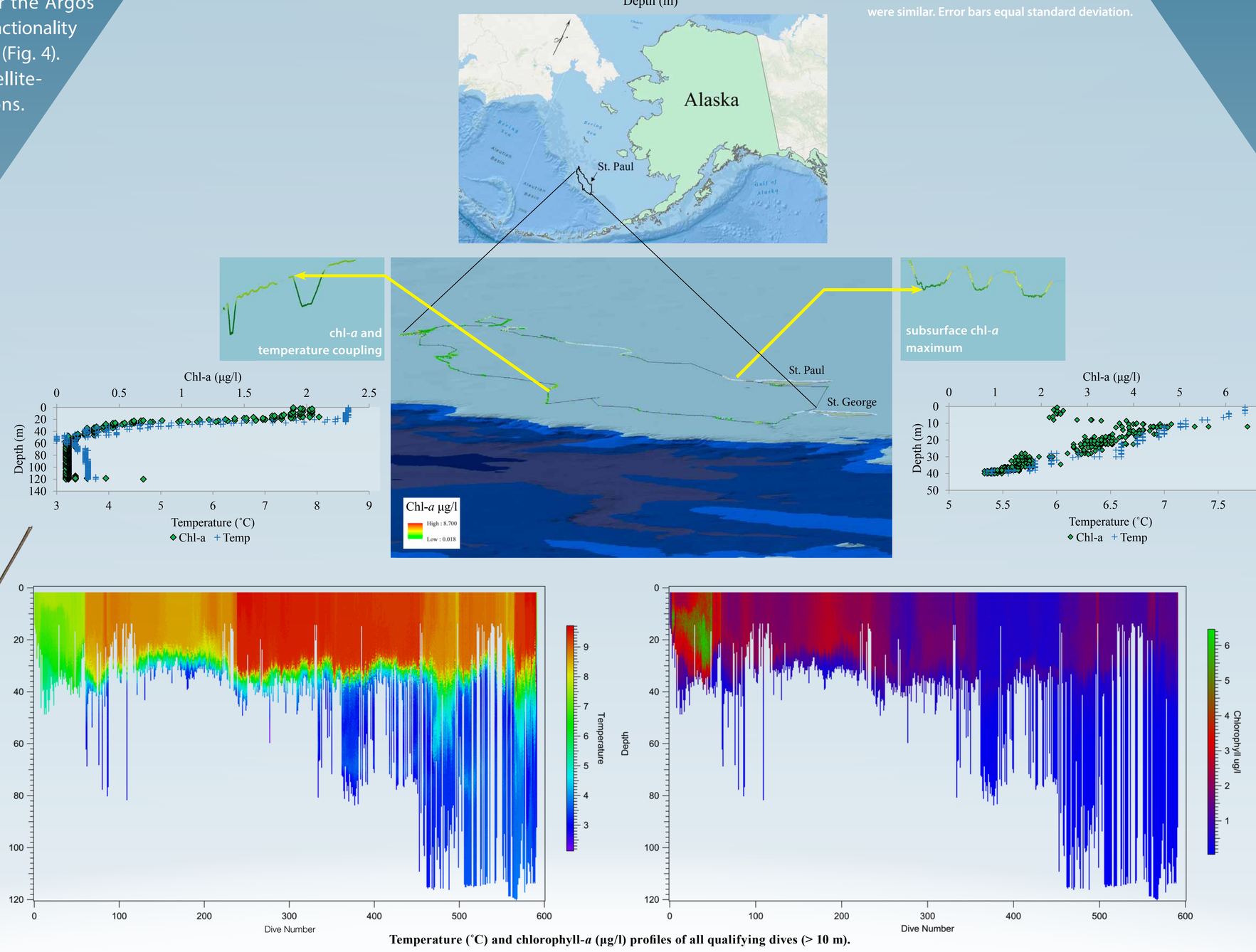


Figure 4. Illustration of an eight day trip conducted by an adult female northern fur seal (*Callorhinus ursinus*) captured on St. Paul Island and tagged with the prototype, which archived temperature and fluorescence at 4 Hz. These data were used to determine the best approach for collecting, summarizing, and compressing data for transmission through the Argos satellite system, which has bandwidth restrictions of 256 bits per message.

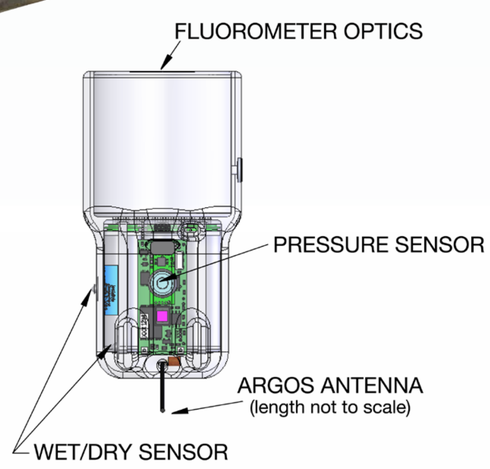
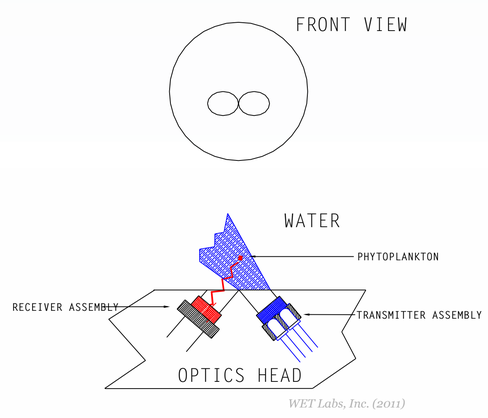


Figure 5. Illustration of the AM-A320A-AU Fluorometer (including specs), which was cast in a fashion to support the SPLASH10 archival tag with the ECO Puck™ fluorometer and Wildlife Computer's "Cricket" Argos transmitter. The final testing phase of this project will entail deploying the units on free-ranging Steller sea lions. At a user-defined rate the tag will collect chlorophyll data on the ascent of a user-defined qualifying dive. Although messages are 100% customizable, transmitted data will be reported to the nearest hour and include:

1) the chlorophyll value at 3 m depth (for future comparisons with satellite remote sensing data),
2) the maximum chlorophyll value and the depth at which it occurs,
3) the chlorophyll value at the maximum dive depth (including the depth value),
4) the sum of all chlorophyll values from the surface to the maximum depth of the dive.



Optics schematic: a transmitter emits a high energy shortwave of light (470 nm for chlorophyll) at 1 Hz, which in turn is absorbed by phytoplankton in the water column. Voltage readings of fluoresced light detected by a receiving assembly with an interference filter are then archived by the SPLASH10.

Summary

- Although configured for larger pinnipeds, the framework of the AM-A320A-AU Fluorometer is fairly modular, allowing for additional designs.
- Fluorescence quenching, bio-fouling, additional calibration, and behavior based processing of sensor data will be investigated further for the AM-A320A-AU Fluorometer.
- This technology will be a cost-effective means for providing surface and subsurface data of animal ecology relative to the dynamic physical and biological ocean.

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References

WET Labs, Inc. 2011. ECO Fluorometer User's Guide. Philomath, OR. 30 p. Available at *http://www.wetlabs.com/sites/default/files/documents/ECO-FL-Rev-AM-Manual.pdf*

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