Developing the SeaBED AUV as a Tool for Conducting Routine Surveys of Fish and their Habitat in the Pacific

M. Elizabeth Clarke
Northwest Fisheries Science Center, NOAA, Seattle, WA 98112 USA
Curt Whitmire and Erica Fruh
Northwest Fisheries Science Center, NOAA, Newport, OR 97365 USA
Jeff Anderson, Jeremy Taylor, John Rooney and Scott Ferguson
Pacific Islands Fisheries Science Center, NOAA, Honolulu, HI 96882 USA
Hanumant Singh
Woods Hole Oceanographic Institution, Woods Hole, 02543 MAUSA

***Abstract*- The Northwest Fisheries Science Center (NWFSC) and the Pacific Islands Fisheries Science Center (PIFSC) are collaborating with researchers at Woods Hole Oceanographic Institution (WHOI) to develop the SeaBED autonomous underwater vehicles (AUV) to overcome the challenges in surveying fish in inaccessible habitats. Traditional survey techniques such as bottom trawls are of limited applicability in such areas due to the rocky, rugose terrain. Fish in marine protected areas must also be surveyed using non-lethal methods. Furthermore, monitoring deeper coral reefs are difficult since many important habitats are below depths that can be surveyed by divers. Hover-capable bottom-tracking AUVs offer a unique tool that is appropriate for work in such areas. We present preliminary results from two surveys: one of deep water corals on a mesophotic coral reef near Guam and another of demersal fishes on rocky reefs off southern California. We discuss some developments needed to utilize this tool for future routine surveys and assessments.**

I. INTRODUCTION

The Northwest Fisheries Science Center (NWFSC) and the Pacific Islands Fisheries Science Center (PIFSC) are collaborating with researchers at Woods Hole Oceanographic Institution (WHOI) to develop the SeaBED autonomous underwater vehicles (AUV) to overcome the challenges in surveying fish in inaccessible habitats. Traditional survey techniques such as bottom trawls are of limited applicability in such areas due to the rocky, rugose terrain. Fish in marine protected areas must also be surveyed using non-lethal methods. Furthermore, monitoring deeper coral reefs are difficult since many important habitats are below depths that can be surveyed by divers. Hover-capable bottom-tracking AUVs offer a unique tool that is appropriate for work in such areas. We present results of initial surveys and discuss the development needed to utilize this tool for future routine surveys and assessments.

The SeaBED AUV [1] [2] is a multi-hull, hover-capable vehicle that, unlike traditional torpedo shaped AUVs, is capable of working close to the seafloor while maintaining precise altitude and navigation control (Figure 1). Its 2,000 m depth rating makes it an ideal tool for conducting surveys of reef, shelf and deep slope habitats and its small footprint allows it to be operated from platforms ranging from global-class oceanographic research ships to small vessels of opportunity.

A modular suite of sensors, including digital cameras, multibeam sonar and CTD allows the SeaBED AUV to be used for non-extractive surveys of groundfish, reef fish and other benthic communities in previously unassessed habitats. The SeaBED AUV can provide significant improvements in the positional accuracy and resolution of the optical data, which when combined with detailed oceanographic data will result in increased areal coverage and more efficient fishery-independent surveys.

II. THE PROBLEM

Rocky areas and deep depths present challenging survey areas, often within heavily utilized habitats. It is often necessary to monitor these areas, but they are not amenable to traditional techniques such as diver surveys, bottom trawls, and surface-borne acoustics. The SeaBED AUV design enables it to accommodate a wide variety of sensor types and configurations. Cameras and lighting for both still and video imaging are common sensors that have been configured to produce orthogonal images of the seafloor. Such imagery provides invaluable small-scale, high-resolution data for studies of seafloor geology and sessile invertebrate communities. However, using orthogonal imagery to census

the diversity of mobile fauna has limitations caused by avoidance.

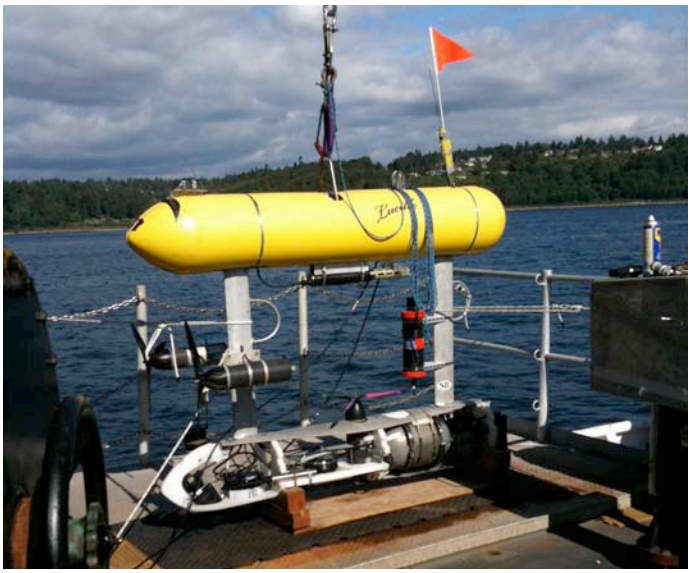

Figure 1. The SeaBED AUV on the deck of the NOAA Ship McArthur II.

The use of towed sleds, AUVs and submersibles for either characterizing sampling areas, or as a primary observation tool, is increasing. There are several conditions that must be considered when developing a survey that can be used for management purposes. Not only must the necessary data be acquired but it must also be determined if these data can be intercalibrated with information acquired from other more traditional surveys. Furthermore, a determination must also be made whether the sampling error and bias due to variability in the detectability of target species or avoidance or attraction of target species can be estimated. Finally it is important that the surveys can be standardized such that the design of the survey is consistent from year to year [3].

The SeaBED AUV has already demonstrated some advantages over other submersibles and AUVs. When surveys are conducted using photography or videography as the primary observing tool, measurement of the sampling unit (i.e.image frame) size is necessary. This may be difficult when using towed vehicles or ROVs since maintaining constant altitude is challenging for these types of vehicles. The SeaBED AUV's altitude control allows it to remain at a fixed depth, or fixed altitude off the seafloor and thus allows the size of the sampling unit to be easily determined (Figure 2). In addition to the bottom tracking capability, the relatively small size and modular sensor suite make the vehicle ideal for our applications.

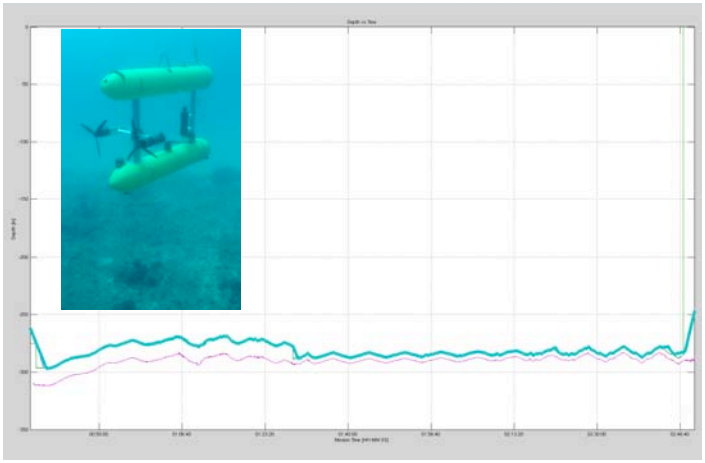

Figure 2. Plot of depth of seafloor and altitude of SeaBED AUV above bottom during typical mission and SeaBED AUV conducting survey near bottom (inset).

We have modified the sensor suite to make this AUV more appropriate for fisheries applications. Typically the camera and lighting on the SeaBED have been configured to produce orthogonal images of the seafloor. These images are particularly useful when studying sessile invertebrate communities. Initial surveys conducted with the SeaBED AUV also showed that some motile animals such as demersal rockfish species could be easily detected and that analysis of the digital photographs can give information on the general distribution and abundance of rockfish that reside on the west coast of the U.S. [4]. While orthogonal cameras have advantages when considering such things as hydrodynamics and lighting, the overhead views from orthogonal cameras can make it difficult to identify some motile fauna. Also when these cameras are used to census motile fauna, issues such as fish avoidance may become a problem [5]. In order to assess the issue of avoidance and improve detection of motile fauna as well as to provide imagery that will aid in identifying fish species, both a downward-looking and an oblique-looking camera were installed on the SeaBED AUV. The oblique view provides a better perspective for examining morphological characteristics used for identifying fish; both the oblique and orthogonal cameras still provide a good overhead view of fish and their associated habitat (Figure 3).

Figure 3. Photograph of rockfish in vase sponge from oblique camera (top) and orthogonal camera (bottom).

III. Deep Water Coral Survey at Galvez Bank, Guam

Deep water corals are not the only understudied components of coral reef ecosystems. Not much attention has been focused on scleractinian coral reefs and other associated benthic organisms below depths of ca. 30 m [6] [7] [8] [9]. The term "mesophotic coral ecosystem" (MCE) has been coined to describe light-dependant communities of corals and other organisms found at these depths [10]. The scarcity of studies of MCEs relative to those focused on shallow reefs is particularly acute in areas outside the Caribbean region, including the insular Pacific [11]. As part of a systematic effort to address this data gap the SeaBED AUV was deployed on 5 dives at Galvez Bank in Guam (Figure 4). Repetitive dives over the same tracks were made to analyze temporal changes in demersal reef fish communities. Benthic substrates and sessile communities are being analyzed (Figure 5). Initial results using a simple random point count method [12] and benthic classification scheme developed for towed aquatic assessment device (TOAD) camera sleds [13] are noticeably different from those obtained from TOAD imagery, due to the higher resolution and consistently better quality of the AUV's imagery. Based on these preliminary results, the SeaBED likely will provide more accurate and detailed characterization of benthic communities and habitats than previously used methods.

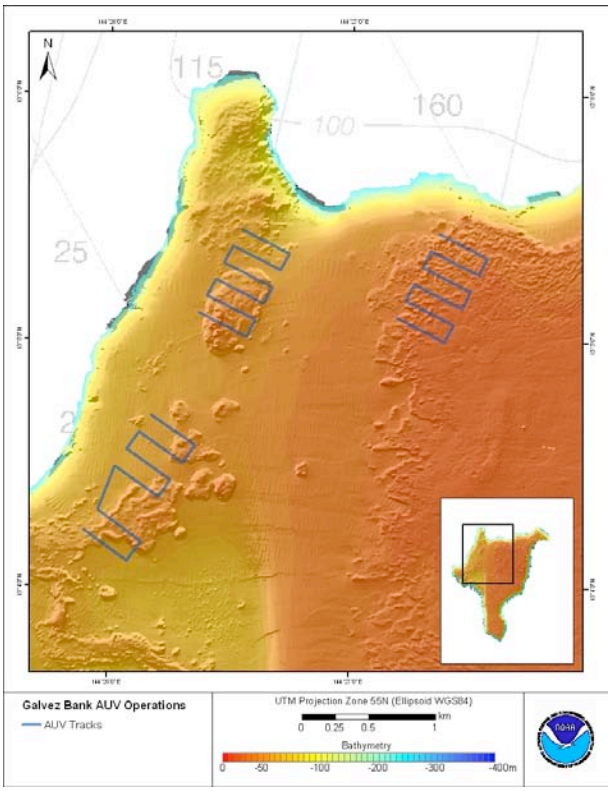

Figure 4. Location of SeaBED AUV Dives at Galvez Bank, Guam.

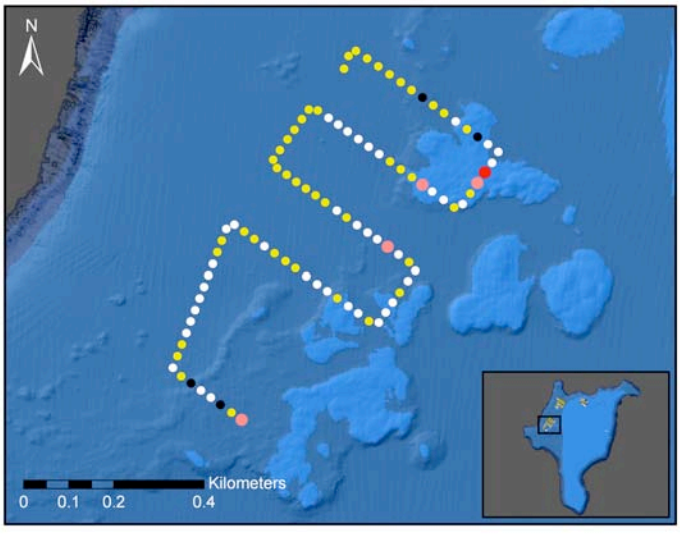

Figure 5. Results from classifying orthogonal camera imagery from one of the AUV dives on Galvez Bank. Red/pink dots show the location of corals, with higher percentages of coral cover having darker shades. Yellow, black and white dots indicate sandy, rocky, and a mix of sandy and rocky substrates

IV. Groundfish Surveys in the Channel Islands, California

In the area of the Channel Islands the SeaBED AUV was used to conduct pilot surveys of fish and their habitat (Figure 6) as well as to map cultural heritage sites in the area. During these surveys it was evident that rockfish are the primary species seen (99% of all fish seen). While some rockfish could be specifically identified (Figure 7) based on distinctive color patterns, many fishes can still only be categorized into distinctive groups. Work is still underway with rockfish taxonomists to assign specific species identifications to many of these rockfish. Many of these fish are juveniles for which specific identifications can be difficult. Furthermore, 5.6% of the rockfish could not be categorized into any distinct group.

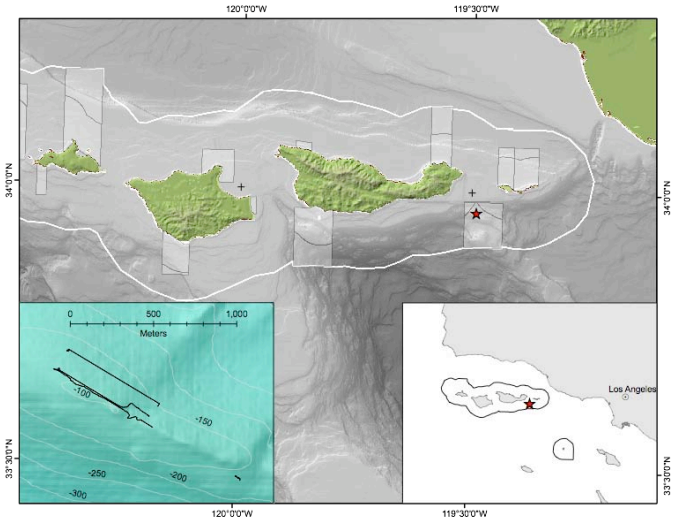

Figure 6. Location of three AUV transects used to survey fish in area of the Channel Islands, California

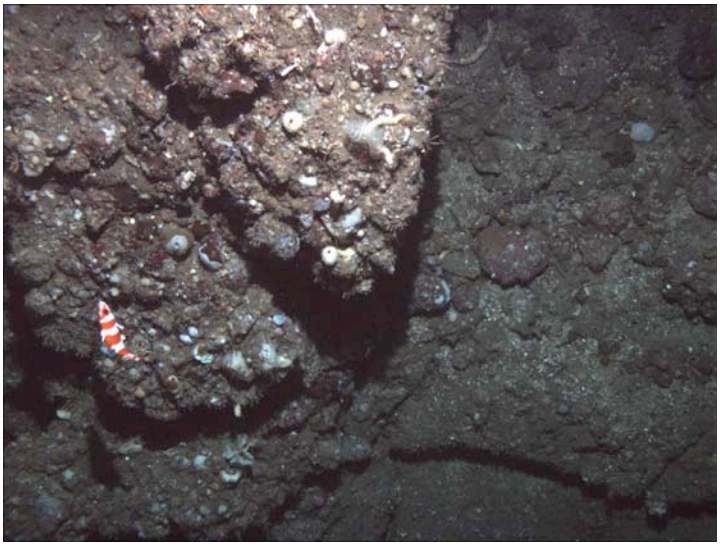

Figure 7. Photo of a flag rockfish near Channel Islands, California, taken from orthogonal camera on SeaBED AUV

During surveys in the Channel Islands we also mapped cultural heritage sites. The site of a plane crash was mapped and a detailed photomosaic was produced (Figure 8.) This photomosaic not only shows the details of the plane but also shows associated fauna.

Figure 8. Photomosaic of 1940's era plane crash.

V. Future Development Needs

We have made significant progress in developing the SeaBED AUV as a tool that's suitable for surveys of fish and their habitat but other developments are needed before the SeaBED can be used to routinely survey motile animals. As with any routine survey, understanding the biases caused by variability in detectability of some species is a top priority.

Many studies have focused on standardizing trawl survey catch data so that abundance can be estimated. However, few studies e.g. [14] [15] have been undertaken to understand the biases associated with surveys from manned and unmanned vehicles. Avoidance or attraction of species due to light and noise are known but the discontinuous lighting and minimal noise produced by the SeaBED AUV may make avoidance or attraction minimal. There is evidence from [14] [15] [16] [17] that some sedentary species of rockfish, especially those

that do not undergo diurnal changes in behavior, can be surveyed using visual methods with minimal bias. No matter how minimal these biases they must be better understood if AUV surveys are to be accepted as a method to produce routine estimates of fish abundance. Because the current camera configuration is not ideal for viewing and understanding fish avoidance, we are developing a forward-looking video camera to examine behavioral responses of fish to this AUV.

Finally, still more experience is needed to routinely assign specific names to many of the species that are seen in the photographs. As we move forward utilizing this tool, standardized survey protocols are being developed. Factors such as time of day, light levels, altitude off the seafloor must be standardized [5] and intercalibrations with existing independent surveys are needed so these data can be integrated into routine assessments of fish.

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