A Combined Benthic Grab and Observation System for Rapid Assessment of Water Column and Seabed

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I. Introduction

A combined benthic grab, acoustic and optical observation system for water column and seabed studies has been developed and deployed in waters off the East Australian Coast during 2009. The system was developed to inform the ecosystem-based spatial management approach being adopted for Australian deepwater environments [1].

The Benthic Optical, Acoustic and Grab System (BOAGS) combines several observational technologies to deliver a platform which maximizes scientific return from a single shipboard instrument deployment. The concept of the system is to provide a tool for rapid assessment of seabed type without the need to deploy multiple independent instruments.

The BOAGS couples sediment grab, cameras, scientific echo-sounder and conductivity/temperature/depth sensor (CTD) to deliver a platform which greatly enhances sampling efficiency and quality of data collected.

A winch and 6000 meter optic fiber tow cable are used to deploy the system from the vessel to a rated working depth of 3000 meters. The tow cable delivers power to the platform with real time data and live video transmitted continuously through the optical fiber from the platform to the surface. The winch has both local and remote control stations. The latter allows the operator to actively control the depth of the BOAGS platform from an operator console within the ship in response to data and video from the system.

II. System Description

A. Platform Design

For several decades researchers have routinely used the 'Smith-McIntyre' spring loaded sediment grab for collecting sediments from the seafloor [3]. Typically this mechanical grab is lowered to the seafloor suspended from a galvanized "hydrographic" wire. Fig. 1 shows the conventional Smith McIntyre grab being deployed with jaws open. A bottom contact trip plate on the base of the grab activates the jaws to collect a sample when it impacts the seafloor. The grab action is twofold in nature. The trip plate initially causes rapid release of spring tension which drives the open jaws into the seabed to a distance of approximately 250mm. The second action takes place as the operator commences recovery from the seabed. As the wire begins to lift the grab from the seabed the wire tension is initially transferred via steel wire rope and pulleys to cause the jaws to close capturing the sediment sample.

Once the jaws are fully closed the grab lifts from the seabed with the weight of the grab (approximately 220kg) maintaining closure of the jaws during recovery to the ship. When on board the grab is lowered onto a mount stand for processing of the sample. The conventional "Smith-McIntyre" grab system has several operational disadvantages particularly when used in deep water.

There is no direct feedback from the sediment grab to the shipboard operator who is effectively "blind" having only inferred information on the depth and status of the grab. For shallow work to depths of around 200 meters (typical of continental shelf studies) the winch wire out reading combined with shipboard echo sounder information is used to lower the grab to an altitude of approximately 5 to 10 meters above the seabed. Once the platform is stable wire is rapidly deployed to cause the grab to impact the bottom. Careful observation of the wire and overboard turning sheave generally provides a skilled operator with confirmation that the grab has impacted the bottom through reduced wire loading. Wire deployment is halted and the recovery phase begins.

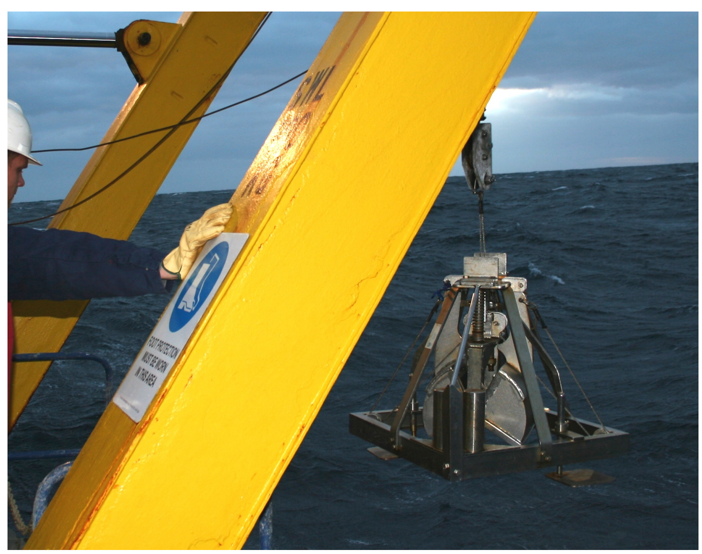

Figure 1. Deployment of a conventional Smith-McIntyre sediment grab

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Figure 2. BOAGS on Mount Stand prior to Deployment (Note: The stainless Steel sediment grab is the central module within the frame)

As water depth increases the effect of ship drift and water currents begin to have a greater effect on the grab and deployment wire. Often large wire angles are observed at the surface and it becomes more difficult to estimate altitude above bottom. For water depths of 1000 meters and beyond the increased weight of wire in water makes it more difficult for bottom impact to be detected. Excessive wire is usually deployed in an attempt to guarantee the grab reaches the seabed but this technique is not always successful. Excess wire will on occasion fall over the grab and cause tilt or tip over of the grab during recovery rather than the closure of the jaws resulting in failure to sample and wire tangle. On other occasions the grab is recovered with jaws still open.

A further limitation with conventional grab samplers is that there is no real-time fine-scale information about the seabed characteristics to guide the operator or to give context to a successful grab. For example recovery of an empty grab could indicate a wider area of hard seafloor but could also be due to an accidental tripping during deployment or an encounter with a rock or small hard area in amongst a larger area of soft sediment. In these situations repeat deployments are usually necessary but in deep-water these will take a significant amount of time.

The structural frame of BOAGS has been designed with the Smith-McIntyre sediment grab as the core of the platform along with the infrastructure for the other observational sensors that constitute the system. This has required special adaptation of the grab to allow integration with the larger BOAGS platform. Fig. 2 shows the sediment grab as a modular component of the platform. The jaws of the grab and the bottom contact trip plates protrude beyond the base of the BOAGS platform so that they are first to impact the seabed during the sampling phase. The shape of the base minimizes the likelihood that other structural elements of the platform will impact the seabed before the grab which is particularly important on sloping or uneven seabed. At the top of the platform where the deployment cable connects to the structure is a sliding bar which is linked to the jaws of the grab. Once the grab has triggered, the sliding bar is released and is free to move upwards as the cable tension returns. This causes the jaws to close capturing the sample. The full weight of the BOAGS platform maintains closure of the jaws during recovery to the surface (Fig. 5).

An additional feature of the BOAGS sediment grab is the inclusion of an arming motor. Locking pins are fitted to the trip plate mechanism to prevent accidental activation of the grab until they are removed. This firstly eliminates grab activations that sometimes occur in rough sea conditions where waves slap against the trip plates as the grab enters the water. Secondly the BOAGS system is designed to be an observational tool which is used in close proximity to the seabed to capture video and stills images prior to collection of the grab sample. Typical height above seafloor for this observation work is between 1 and 3 meters. In moderate to rough sea conditions ship heave will cause the BOAGS platform to move up and down close to the seafloor with potential for accidental contact. Grab closure is prevented until the arming motor is activated by the operator which extracts the locking pins just prior to collection of the sample.

The modified Smith-McIntyre grab within the BOAGS systems is modularized and can be removed from the frame as a complete assembly. This provides the possibility to design and fit other sampling modules to the system such a water sampling carousels or alternate sediment sampling instruments.

B. *Video and Digital Stills Cameras*

The BOAGS platform is fitted with two video cameras which provide the operator with live video. This allows careful selection of sample site and precise control of the grab operation maximizing likelihood of success. The first camera is a high sensitivity PAL color camera, Hitachi HV-D30P. This camera has very good low light capability and good resolution and is used as the principal survey camera for bottom characterization. Illumination is provided by two LED Multi-Sealites manufactured by Deep Sea Power and Light each providing around 2500 lumens in water. The composite video signal from this camera is transmitted continuously to the surface for display. It is used by the system operator as a visual cue for control of winch wire-out and thus maintains position of the BOAGS platform just above the seabed. The second camera works at close range solely to observe the status of the grab. The camera is a relatively inexpensive color camera which is coupled with a small custom made 5W LED light. The composite video signal from this camera is also transmitted continuously to the surface and is used during the grab sampling phase to visually verify that the grab has closed after recovery from the seabed.

The system is also fitted with a paired digital stills camera system and strobe for high resolution imagery of the seabed and the water column. The mechanical mounts for the cameras are carefully designed to ensure the alignment and position of the cameras is accurately maintained. The complete paired digital camera assembly can be removed as a sub-module from the platform without disturbance of the camera housings. This aspect is critical in ensuring that the calibration of the system is not altered. In-water calibration is conducted in a large tank or pool using a reference frame which is photographed at different orientations [2]. Custom software is then applied to the images to characterize the system and produce a calibration model. This enables sizing of any biota captured in the frame of both cameras during a survey using image analysis software.

The cameras used in the system are Canon 5DMkII which are coupled with a Canon 580EXII strobe. Full ETTL exposure capability is maintained in the system. A custom camera synchronization circuit accepts signals from the operator console to allow photographs on demand. The system can also be configured to take photographs at regular time intervals or in response to the detection of acoustic signatures by the Simrad echo-sounder system. In this way the digital stills subsystem provides the ability to capture very high resolution images of the seafloor and to capture water column images of biota.

C. Sensors and Acoustics

The BOAGS platform is equipped with a Seabird 37SI CTD. This instrument provides measurement of water temperature, conductivity and depth at a rate of 2 Hz. Serial data from sensor is transmitted continuously during a deployment to the surface for display and archive.

An altimeter on the system provides information on the height of the platform above the seabed. This is particularly useful in those situations where the bottom is sloping or the topography is unknown. The altimeter is a Kongsberg Simrad model 1007 with a typical range of 200 meters.

A Simrad EK60 scientific echo-sounder is also integrated with the BOAGS system. The sounder at operates at a frequency of 120kHz and is coupled with a Simrad split beam 120kHz deep water transducer. The echo-sounder enhances the capability of the BOAGS system by allowing the collection of acoustic data from the surface to the seabed. At a frequency of 120 kHz the useful range for the sounder is approximately 300 meters. The BOAGS system has been designed to allow addition of extra acoustic frequencies. In the case of lower frequencies where the size of transducer becomes significantly larger the option exists to replace the sediment grab module with an echo-sounder module. This integration is relatively seamless.

D. Winch and Cable

A custom designed winch to CSIRO specification was built for deployment of the BOAGS system (Fig. 3). The winch is all electric and uses a variable speed drive to power the winch drum. This provides good speed control across the required operational range of the winch which spans rapid deployment and recovery at speeds up to 100 metres per minute to slow raising and lowering of the BOAGS platform into and out of its storage cradle on deck. The winch requires a three phase 415V volt supply rated at 64 amps.

Figure 3. BOAGS winch with 6000 meters of cable

The winch is fitted with 6000 meters of electro optical tow cable manufactured by Tyco-Rochester. The cable is part number A305382 with outer diameter of 9.98 mm and a breaking strength of 71 kN. The cable contains two Rochester Electro-Light elements each combining copper conductor and 9/125/245um single mode optical fibers and an additional two smaller copper conductors. Rated working voltage for the Electro-Lights is 1200 Volts.

The winch is fitted with a MOOG-Focal slip ring comprising two single mode optical passes and 12 electrical passes. The winch has two joystick controls, one local and one remote. The remote joystick allows the operator to take control of the winch after the platform has entered the water.

E. Power and Data Transmission

A 600V AC power supply derived from a step up isolation transformer on board the vessel delivers power to the cable for the BOAGS platform. The main electronics housing (Fig. 4) on the platform contains a step down transformer with a nominal voltage output of 28 VAC.

The output voltage of this transformer will vary due to IR loss on the cable as the load changes but this variation is relatively small. The 28VAC supply is rectified and feeds two independent wide input range DC/DC switch mode modules which generate regulated 12V and 24V DC buses which power the system.

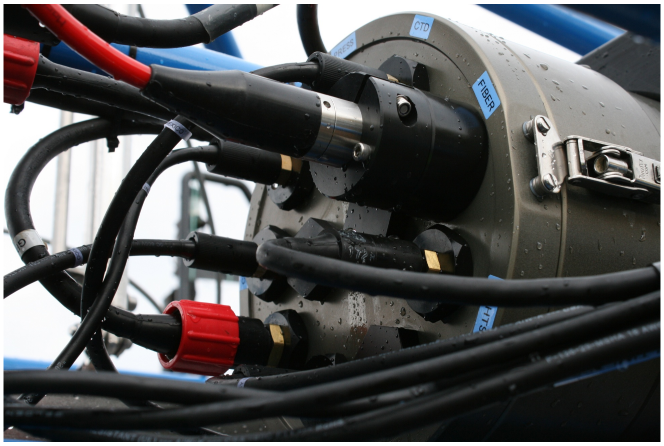

Figure 4. BOAGS main electronics pressure housing

Two composite PAL video channels and 10 Mbit Ethernet data channel are transmitted over the fibers within the cable. Focal model 914 fiber optic multiplexers carry these signals. A serial terminal server within the main electronics pressure housing provides input for four serial data channels. The terminal server is connected into the 10 Mbit Ethernet link on the fiber. Platform sensors connected to the terminal server are the Altimeter, CTD, Orientation sensor and the microprocessor switch board. These sensors appear as standard COM ports on the control and acquisition PC on board the ship.

The EK60 echo-sounder on the BOAGS platform is also connected into the 10 Mbit Ethernet channel on the fiber. Proprietary Simrad ER60 software running on the system console PC on board the vessel acquires data continuously from the echo-sounder during a deployment.

III. SYSTEM OPERATION

The BOAGS platform is typically deployed from a research vessel using a stern “A” frame. Once the platform has been deployed to a depth greater than 10 meters the operation of the winch is transferred to the remote joystick at the operators console. Lights, sensors, cameras and acoustics are switched on and the deployment begins. Logging of data from all sources is controlled by custom software applications. Video is recorded to hard disk using a nNovia QCR Deck. Video clips are stored in Quicktime format.

When the platform reaches the seabed the operator controls height above bottom using the winch joystick and visual cues form the survey camera. During this time video and digital stills images are captured to characterize the habitat. Once a suitable sampling location has been determined the grab arming motor is activated to remove the trigger locking pins. The system is lowered to make contact with the bottom causing the grab to trigger and collect a sample. Recovery of the platform from the seabed is performed as quickly as possible to avoid the chance of slack wire developing a loop due to residual cable torque. The system is then hauled back on deck with collection of data continuing throughout the recovery phase. Fig. 5 shows the system returning to deck.

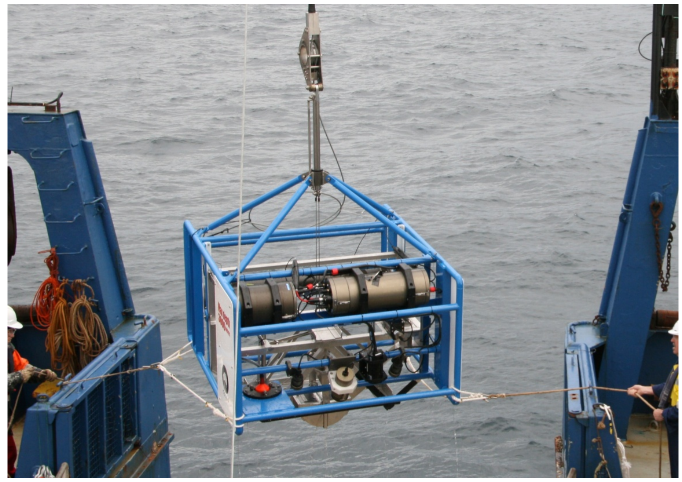
Figure 5. BOAGS system recovery with sediment grab jaws closed and the sliding shaft attached to the tow cable termination extended.

Once on deck the platform is returned to its mount stand and sediment samples are recovered from the grab (Fig. 6).

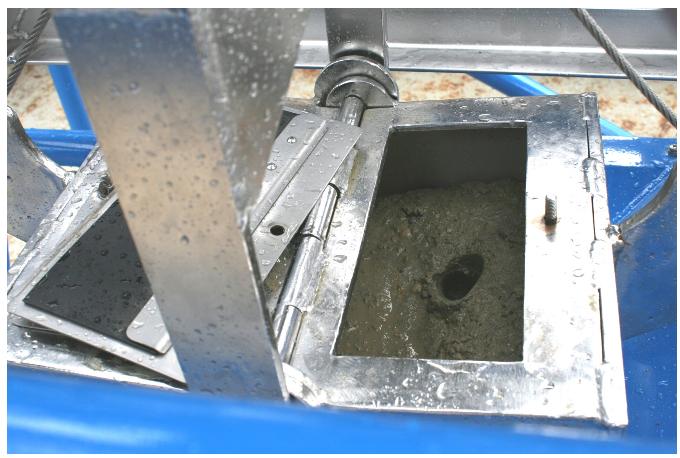
Figure 6. Sediment sample from 1560 meters depth

IV. CONCLUSION

The BOAGS platform provides a highly flexible sampling tool which not only improves the efficiency and reliability of collecting sediment samples but greatly enhances understanding of the seabed habitat through provision of context at the sample site. In addition the CTD and acoustics sensors on the platform significantly “value-add” by providing physical and biological measurement of the water column during each deployment.

The BOAGS system achieves its design goal as a rapid assessment tool for ocean observation.

Acknowledgment

We would like to acknowledge the contribution of colleagues who assisted in the manufacture and testing of the system. Jeff Cordell who assisted in the implementation and at sea testing of the winch and BOAGS system. David Kube and the CSIRO Engineering Technical Services team who constructed the system. Mr Ian Helmond for mechanical design of the BOAGS platform and for meeting the challenging task of integrating the Smith-McIntyre sediment grab to allow it to work in the BOAGS system. Dr Robin Wilson from the Museum of Victoria for advice on grab designs and sample collection methods.

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