Development and Sea Trials of a New Camera-Based Assessment Survey System for Reef Fish Stocks Assessment

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***Abstract* — A new towed camera system, known as the Camera-Based Assessment Survey System (C-BASS), is being developed for reef fish stock assessments. This system has the capability of facilitating large-scale quantitative assessments and allows fisheries scientists to enumerate economically important reef fishes in areas such as coral reefs where traditional surveying approaches are not feasible. The system is designed for versatility and simplicity with the goal of being deployable from any vessel equipped with standard oceanographic winches and cables. It is designed to operate in up to 200m depths, and be towed at speeds between 1.5-2 m/s at altitudes of 2-4 m above the sea floor. While being towed, the system stores video from a number of cameras and data from a variety of environmental and system monitoring sensors. The system is powered from the vessel via the cable. A DSL Ethernet based communication link enables the user to view lower resolution video in real time, while full resolution streams are stored on an onboard computer. Coincident environmental data including depth, temperature, salinity, and fluorescence (turbidity and chlorophyll) information as well as tow platform flight characteristics such as altitude above the bottom and tow body attitude are all stored in a MySQL relational database. Presented here is the initial C-BASS research and development phase including sea trial results.**

Keywords— C-BASS, Towed Video, Reef Fish, Fish Stock Assessment

I. Introduction

In recent years, underwater camera-based towed survey systems have become one of the most widespread and effective investigation tools for fisheries and benthic habitat research (Rooper, 2008; Rowland et al.,2006). These systems have varied applications with some used in fish habitat association studies (Cailliet et al., 1999; Rooper et al., 2007), in making fish abundance estimates (Morrison et al., 2006;Shortis et al., 2008;Williams et al., 2010), etc. Considering the different seafloor terrains and various scientific research aims, current efforts can be classified in three ways, bottom contacting, bottom tending, and water column suspended (Rooper, 2008).

Comparisons between camera-based towed systems and the other similar platforms used to capture underwater videos for habitat mapping purpose, such as trawls, ROVs, AUVs, and manned submersibles have been extensively analyzed (Mara et al., 2005;Williams et al., 2010). Currently, there is not a unified system for all of underwater observation works as there is no one system capable of eliminating all sampling biases. The primary consideration when developing a survey system for reef fish assessment is to make clear the study objectives, desired data, analyses that will be conducted, and the specific terrain associated with the study areas (Rooper, 2008).

Reef fish stocks are particularly difficult to assess because of the lack of a single, comprehensive and relatively precise fishery-independent surveying technique (Somerton and Gledhill 2005).Considering the high relief habitats most reef fish species occupy, comprehensively sampling with traditional towed fishing gear such as bottom trawls, bottom contacting and bottom tending towed video survey systems is difficult or impossible. Underwater vehicles such as ROVs, AUVs and manned submersibles are platforms potentially capable, but are generally not as cost effective for comprehensive and synoptic surveys over the large physical areas occupied by a biological fish stock. For example, current red snapper (*Lutjanus campechanus*) assessments in the Gulf of Mexico utilize information from a variety of sampling programs which aids in addressing the biases that each sampling method possesses but none provide region-wide coverage across the range of size classes of fishes assessed (Patterson et al., 2007). The primary motivation for the development of C-BASS is to develop absolute abundance estimates of reef fishes such as red snapper for use in setting fishery total allowable catch quotas.

In accordance with the habitat features of reef fish, and considering the need for comprehensive assessment of reef fish stocks in west Florida shelf (Hine et al., 2008), C-BASS was developed by the Center for Ocean Technology (COT) at the College of Marine Science at the University of South Florida. There have been several previous systems designed for reef fish investigation and research (Robert et al., 2012), enabling efficiencies by utilization of the knowledge gained from other efforts. Our system is equipped with Ethernet-based communications and power for the platform sent though

0.322” 3-conductor cable, found on many research vessels. It is equipped to process and record video from both analog and digital video cameras. Environmental and system data sampled from an altimeter, compass, CTD, and fluorometer are also recorded. This manuscript presents the research and development of C-BASS and its first sea trial off the West Florida Shelf aboard the Florida Institute of Oceanography’s R/V Weatherbird II. These sea trials accomplished trimming and balancing of the platform, confirmation of system and component performance, and over 14 hours of operational testing. The system design and initial performance are discussed herein.

II. SYSTEM RESEARCH AND DEVELOPMENT

A. System Overview

The C-BASS platform is a standard tow body with the capability to be deployed from small to mid-sized research vessels equipped with a four conductor winch-controlled cable. This includes vessels equipped with standard 3 conductor CTD hydrowire used on many research vessels, since the shielding can be utilized as a fourth conductor. It is designed to fly 2-4m above the sea floor at speeds of 1-2 m/s for hours at a time. The tow platform system can be explained in terms of its sub-systems: structural hardware; power supply; controls and data storage; communications; cameras and lighting; flight and science sensors. Each of these systems will be described separately below.

B. Structural Hardware

The frame of the tow body (Figure 1) is identical to another tow body designed and built at USF/COT, for the SIPPER III system (Samson et al., 2001).The frame measures 1.2 m wide by 0.7 m tall by 1.7m long, and the system weighs approximately 140 kg. It is equipped with a reconfigurable bridle allowing adjustments which accommodate any changes to the platform’s center of gravity that may occur with changes in system components or configuration. The core of C-BASS encases the onboard computer, communications equipment, microcontroller, transformer, power supply module, compass, and hard drives. The housing is an anodized aluminum cylinder 0.2 m diameter by 1.05 m long and is attached longitudinally to the center of the platform on the main chassis. The altimeter, fluorometer, and CTD are also attached to this frame chassis. Three cameras and two lights are then each independently attached on reconfigurable rails for versatility during testing and experimentation. Eventually, a finalized configuration of at least some of the cameras and lights will be attached in a fixed bracket to allow calibration for stereo video analysis. All vessels have been depth rating confirmed in pressure tank testing, and can be easily mounted on other tow frames of accommodating proportions. Finally moveable weights and flotation are attached to increase the system’s stability and enhance flight performance.

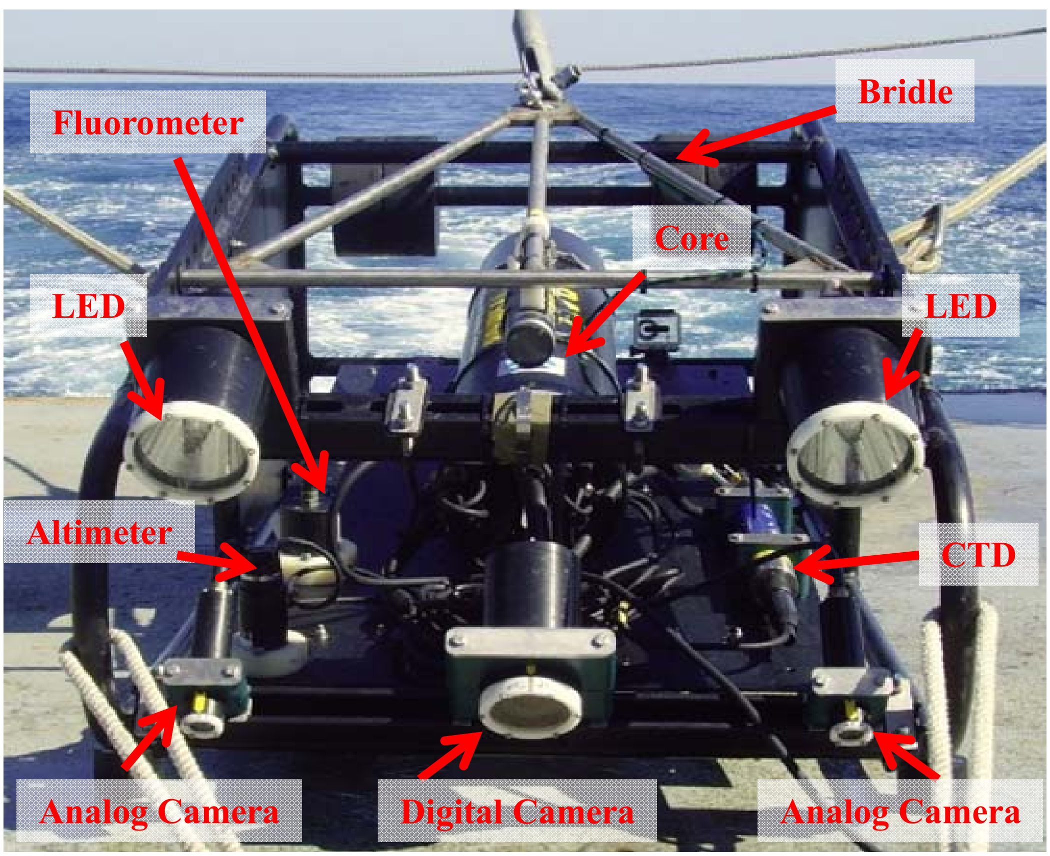

Figure 1: C-BASS System and Components

C. Power

A preliminary power budget estimation of total component usage and hydrowire losses was completed to ascertain the power needs of the components selected. Based on these estimations and the desire to utilize the commonly available hydrowire cable, it was determined that to power C-BASS from the vessel a series of voltage transformations was needed to achieve the needed power supply. This type of cable is limited to 1000 V and 1 A, so based on previous experience, it was decided that a system set up for 700 KVA would provide enough power with adequate safety factor. Voltage provided from the vessel is 220VAC 60Hz and it is converted to 750VAC through a transformer. The topside transformer is located in a custom made, portable, weatherproof deck box equipped with fuses and breakers as well as a manual emergency kill switch for safety. The 750VAC is then conducted through the slip ring of the winch to two of the internal conductors of the winch wire. Another transformer in the C-BASS tow body's core vessel converts the voltage back to 220 VAC before going to three AC-DC switches providing the 5VDC, 12VDC, and 30VDC used within the system. With this voltage, a total power budget of ~700 KVA is achieved using the cable described above. Power supply diagram is shown in Figure 2. For the first set of deployments, the average power consumption with the entire system operating and logging data was less than 400 Watts.

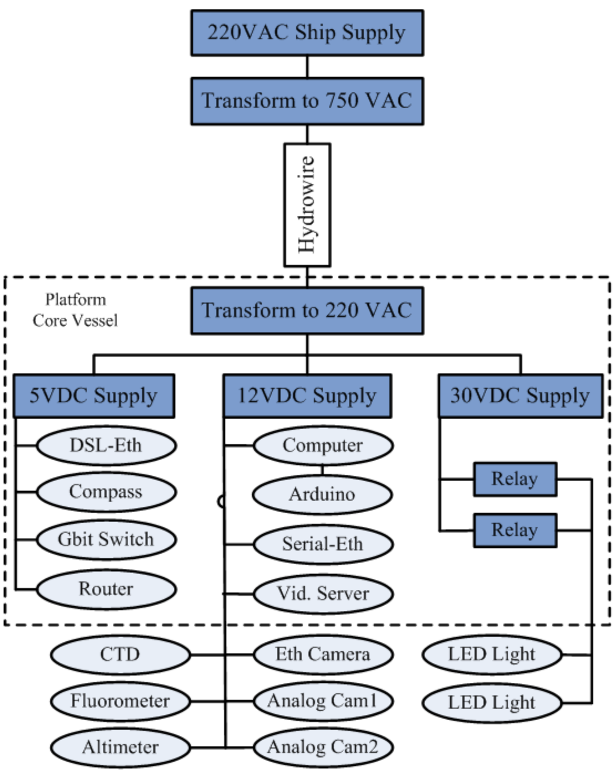

Figure 2: C-BASS Power Supply and Distribution

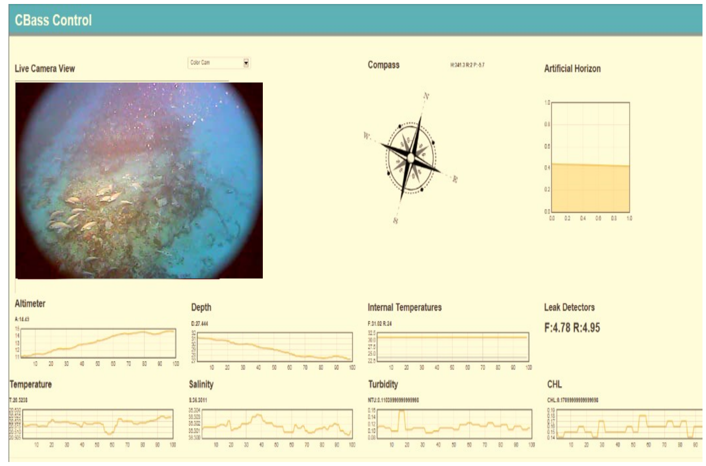

Figure 3: User Interface for Control and Monitoring

D. Controls and Data Storage

The embedded system in the core vessel is a Xi3 X5A computer equipped with an Ubuntu Server Linux operating system and an Athlon dual core 3400E 22W processor. Two solid state hard disks with total 960GB storage capacity are used for data and video storage. The XI3 performs two functions: a.) recording and data basing of the video and data streams, and b.) web service to the top side client for real time low resolution video, data viewing, and system control. For the first task, the XI3 primarily uses the Python language to read the sensor values and monitor new video files written to disk and MySql to database the information. The second function provides information to the topside user in a custom interface.

The interface developed for C-BASS is a Pyramid Web application using the XI3 as a server and Internet Explorer on the top side computer as the viewing client (Fig.3). In the live view, the user can choose to display low resolution video from any one of the cameras sent via real time streaming protocol (rtsp). The video is shown along with the most recent sensor values, a compass rose based on the compass's heading, and an artificial horizon based on the pitch and roll of the tow body. Time series plots of the other sensor values show a rolling 100 value plot for ease of monitoring. Lastly, the interface provides controls to Start/Stop recording of each camera, light controls, a mechanism to output data as a csv file, and overall system status. From this interface, the user can monitor videos, coincident environmental data, and flight parameters that help to pilot C-BASS.

E. Communications

The C-BASS system is set up to balance functionality with available bandwidth, by giving the user enough information to ensure proper functionality yet store all of the data on board the platform. This eliminates the need for a custom winch which could limit the platform's versatility. The use of a Blackbox SDSL 2000 Network Extender modem set topside and onboard the platform allows a modest 784 kb data stream including one low resolution camera of the user's choice and all of the serial sensor data. To achieve the DSL link, one of the internal conductors of the cable is used along with the cable wire jacketing. This may result in bandwidth variability from vessel

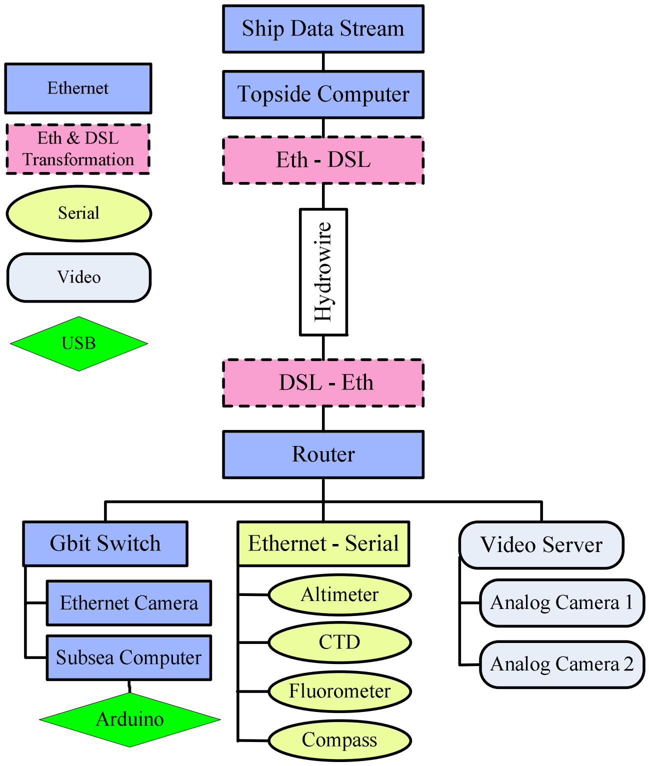

Figure 4: C-BASS Communications Network

to vessel depending on cable length and environmental variables which may impact the signal to noise ratio.

Communications within the core vessel are managed via Ethernet through a router and a gigabit switch. An Ethernet to serial port transformation module is used for data collection from the scientific sensors, which currently includes an altimeter, CTD, fluorometer and compass. A video server is used to convert the content from the two analog cameras' into an Ethernet capable digital stream. All Images and videos captured from the cameras are processed by the sub-sea computer and saved to the internal hard disk storage for download and analysis following platform retrieval. Lastly, an Arduino Micro controller is onboard and controlled by the Xi3 via a USB link.

F. Cameras and Lighting

The CBASS system is equipped for both digital and analog cameras. Two analog Sony CCDs cameras and one Arecont Vision digital camera are currently used. One analog color camera delivers 550 lines of standard resolution video with a 0.2 lux rating while the other analog camera is black and white with 600 line resolution for low light (0.0003 lux). An AXIS 241Q Video Server enables analog cameras to be integrated into IP-based, high quality, de-interlaced, digital video streams that are sent over the Ethernet network. The Arecont Vision AV10005 digital camera is equipped with a 10 megapixel CMOS image sensor configured for 1080p, 30fps binned video optimized for low light applications. For the initial deployment, the Arecont camera was outputting H264 video, a motion compensated modern scheme able to achieve high compression ratios. Two custom manufactured Bridgelux 85 watt array LED lights provide illumination for the video cameras during low light deployments. The lights can be turned on and off using USB relays controlled by the onboard computer. Each camera and light is separately mounted in its own housings with the intent of eventually configuring them for stereo recording to allow the capability of target sizing.

G. Performance and Science Sensors

Scientific sensors, including a WETLabs FLNTU fluorometer and a Falmouth Scientific 2" Micro-CTD are installed on the frame in order to better understand the environmental aspects of the assessment. An altimeter is also mounted to the frame to ensure proper platform height above the seabed. Internal to the core vessel is a Honeywell HMR3400 compass for tracking vehicle attitude. Fore and aft leak detection sensors and thermistors for monitoring the temperature within the core vessel are all connected to and read by an Arduino Micro Controller. All sensors are logged independently and at varying frequencies. There are currently unused interfaces to facilitate future scientific sensor expansion.

III. SEA TRIAL RESULTS

A. Sea Trial Description

The first sea trial for C-BASS was conducted on the West Florida Shelf WNW of the mouth of Tampa Bay between the 25 and 50m isobaths. This excursion was broken into two short cruises due to weather constraints the first trip began on February 28, 2013 and ended on March 2nd, the second started two days later and lasted through March 6th. The majority of this cruise was obtaining imagery along the Gulfstream Natural Gas Pipeline (Fig.5), a location which ensured a reasonably consistent bottom habitat for video sampling. During each mini-cruise, a total of six tows of varying lengths were conducted. The primary objectives included trimming and balancing the platform, with particular attention to its dynamic pitch, roll, and yaw characteristics. Basic functionality of the platform's communications, power, video, computing, and sensor systems in static and dynamic tests were also tested.

C-BASS was deployed using a Dynacon winch via the aft U-frame onboard the R/V Weatherbird II. The tow speed averaged approximately 1.75 m/s and the pilot communicated via radio with the winch operator to "fly" the platform 2-4 meters above the bottom so the cameras could view the sea floor obliquely. This is further accomplished with consistent vessel speed and frequent communications with the winch operator to pay-out or reel-in tow cable. An EK-60 sonar is part of the R/V Weatherbird II's science package and was used to assist in piloting the C-BASS as well as for comparative biological data sets.

TABLE I. **SEA TRIAL DEPLOYMENT STATISTICS**

Tow #	Sea State	Time in Water (min)	Time Near Bottom (min)	% Time Near Bottom	Average Altitude (m)	Average Pitch (deg)	Pitch Std Dev (deg)
1	3	7	0	0%	NA	~20	NA
2	3	6	0	0%	NA	~12.5	NA
3	3	12	2	17%	5.74	9.63	9.69
4	3	15	2	13%	5.97	2.92	9.13
5	4	83	79	95%	5.95	0.12	5.66
6	4	102	96	94%	4.67	1.55	6.62
7	3	30	27	90%	3.64	3.77	5.45
8	2	97	94	97%	5.25	4.31	7.65
9	2	15	7	47%	3.9	2.41	5.3
10	2	78	66	85%	3.16	5.88	5.44
11	3	209	197	94%	2.59	5.55	4.94
12	3	211	205	97%	2.13	2.13	4.47

B. Sea Trial Results

During the sea trial, a total of 12 deployments were carried out with underwater times ranging from 12 minutes to 211 minutes (Table 1).

The first four tows were short in duration with adjustments to the platform's weight distribution needed in between each. Tows 1 and 2 were performed while still debugging the data logging controller debugging and as a result, data wasn't recorded. Tows 5 and 6 were the first bottom following tows. During the second trip (tows 7-12), all tows except tow 9 were extended bottom following operational deployments. In general, as tows progressed, a larger percentage of time was spent near the bottom and the average altitude flown decreased as confidence in the system grew.

During these tows, the system's functionality was confirmed. As mentioned, in the first two tows, the system level recording was not functional, but this was repaired by the third tow and remained functional for the duration of the cruises. The power supply and transformations worked as planned. The communications with the DSL modems required some adjustment of speed, lowering the bandwidth from 1.5 Mb to 784 kb to increase reliability during operational tows. Occasional losses of connectivity occurred when the towbody entered the water, made contact with the seafloor, and when the winch was paying out and reeling in. These dropouts were eliminated by the third tow. Performance of the video recording and storage, along with the serial sensor data, all performed as expected.

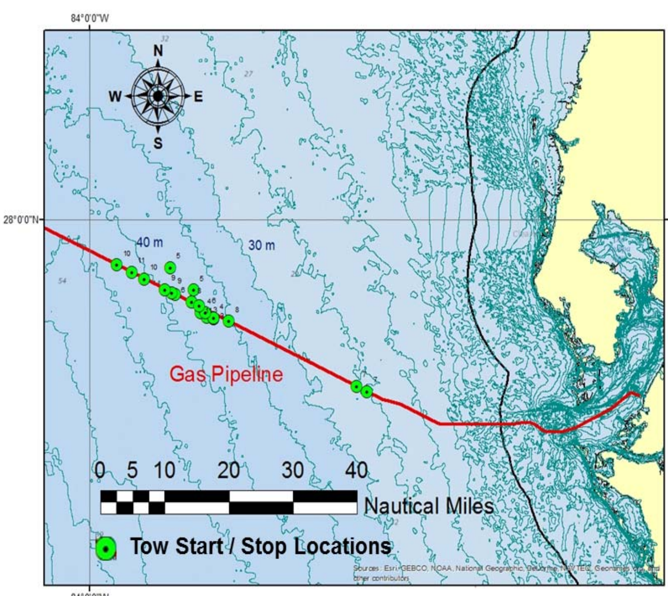

Figure 5: Sea Trials Tow Locations

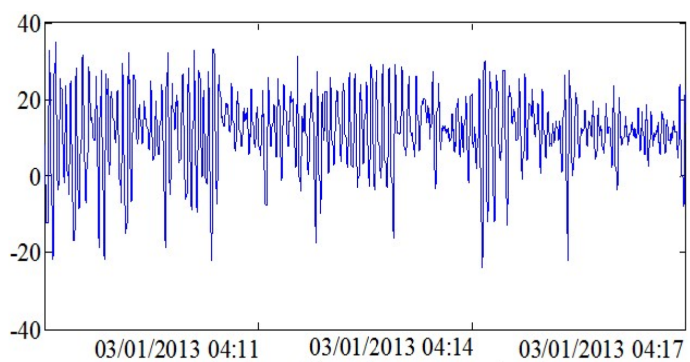

Figure 6: Pitch Data Before Center of Gravity Adjustments (Tow 3)

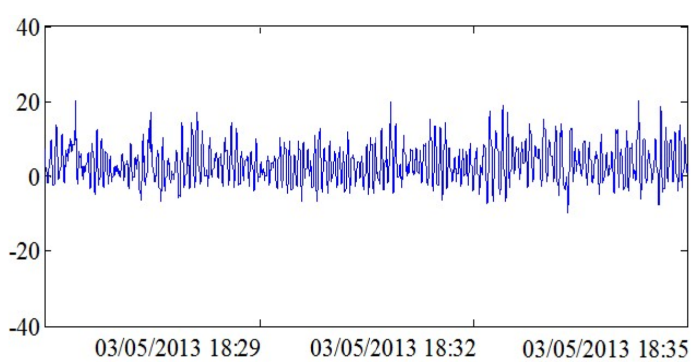

Figure 7: Pitch Data After Center of Gravity Adjustments (Tow 12)

C. C-BASS Stability

A primary concern prior to the sea trials was the system's dynamic performance, and the first tows, under 1-2 m sea conditions, the system's stability was unacceptable. As can be seen from Fig.6, C-BASS is tilted upwards, and oscillation for pitch angle is large with amplitudes ranging between -22 degrees and 35 degrees. During subsequent tows, adjustments to the center of gravity, modifications to the tow point, and the addition of more weight allowed the platform to be towed at a reasonable pitch, while slightly tail heavy at 2-5 degrees, which is preferable in the event of inevitable bottom impacts. While the oscillations were still heavily dependent on sea state, comparing tows 3 and 12 demonstrates significant reduction in the average pitch standard deviation by over 50% (Table 1, Figures 6 & 7). Similarly, the platform's roll and yaw are considered stable with standard deviations of less than one degree and less than 5 degrees respectively during tows.

D. Video Results

The ultimate test of a system's performance is the usability and quality of the data collected, and in this case that is the video from the three cameras. During these sea trials, over 700 minutes of bottom video were collected by each camera. These were each analyzed for content, resulting in counts of numerous species. Through the sea trial, several fishes including red grouper (*Epinephelus morio*), lionfish (*Pterois volitans*), and gray snapper (*Lutjanus griseus*) were captured on camera. Figure 8 offers examples of the quality of video/images that were obtained during this sea trial. As expected, some issues with the lighting positioning, water clarity, and camera limitations affected the quality of the video collected. Due to the size and forward facing footprint of the towbody, the spacing between the cameras and the lighting is limited, which causes some extreme variations when flying too close to the seafloor. In addition, inexperience in operating and set-up of the system's digital camera resulted in some poor quality video tows for that particular camera. However, the analog cameras performed well and consistently for each and every tow.

E. Lessons Learned

a) We were pleasantly surprised by the stability of the platform during these first tows. We attribute this to vertical and horizontal panels which help the towbody resist fluctuations in pitch, roll, and yaw. The addition of floatation to the top of the platform and weight to the bottom also helped by creating separation between the centers of buoyancy and gravity.

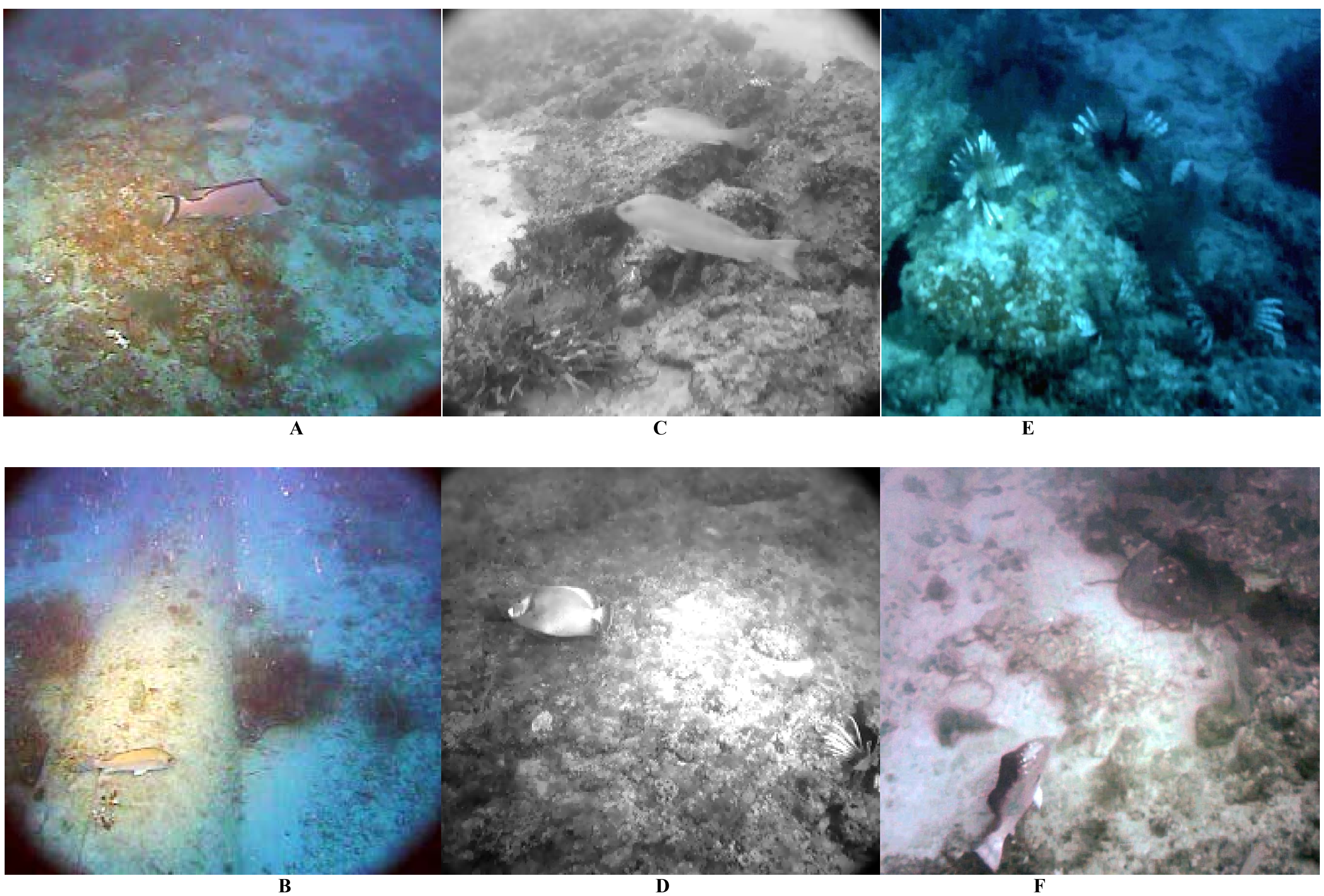

Figure 8: Examples of the imagery collected from the color (A, B) and b/w (C,D) analog cameras and the digital camera (E, F)

b) Sea conditions affect C-BASS stability performance, but even in what may be the upper limit of sea states for deployment, the video collected was still acceptable.

c) Although it is a much more modern compression scheme providing higher compression ratios, the H264 compression of the digital camera contained several artifacts, and did not cope well with the large displacement of our objects of interest (fishes, corals, etc.) between frames. This displacement is due to ship speed sled attitude change, and fish movements. For future deployments we will be switching to a motion jpeg scheme, which compresses each frame independently.

d) Coordination with the ship's captain and winch operator is essential to maintain a constant cruising speed and towbody altitude, otherwise system collisions with the seabed are inevitable. The addition of a video feed to the bridge, including the system's flight dashboard, was useful in later tows.

e) Proper set-up and separation of the system's lighting and cameras is needed to ensure quality video. This is a challenge for the current prototype due to space limitations.

f) "Flying" the system involves continuous monitoring of the altitude of the vehicle, assessment of bottom threats in the two path, and evaluation of visibility. These require diligence on the part of the operator to avoid colisions while producing adequate data. Risk of collision will always be problematic so design for the impacts of collisions with bottom features is imperative.

IV. CONCLUSION

The development and sea trials of the new towed Camera-Based Assessment Survey System, C-BASS, have been described here in detail. This system can be used for assessing reef fish stocks, as well as the other benthic video based surveys, such as underwater archeology, habitat evaluations, etc. The system's hardware and software configurations have been introduced. Its dynamic performance, specifically pitch, roll, and yaw results from sea trials, have validated the system stability performance. The DSL Ethernet based communication the user to achieve near real-time monitoring of low resolution video and coincident environmental data. In addition, the uutilization of the DSL communications and power supply through standard hydrowire was demonstrated to be effective for this objective, thereby providing a versatile method for powering and controlling a towed platform using cable that is commonly available on research platforms. The video images obtained have demonstrated the system's survey performance, and further analysis of said videos validates its usefulness.

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