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Real-time Monitoring of Fish Activity on an Inshore Coral Reef

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Abstract - **This paper describes an underwater camera and instrumentation system for monitoring fish species activity on an inshore coral reef in a Marine Park in Hong Kong. The system consists of a high-resolution pan, tilt and zoom camera with associated instrumentation package for measuring the local environment, including dissolved oxygen, temperature, pressure, salinity and ambient light conditions. It is connected to the shore base station via a fibre-optic cable with power conductors. The system is designed to be used for long periods of time, continuously. The first period chosen was for 100 days during the coral spawning season from June to August 2004. The system has also been used regularly for 2-3 weeks at a time to monitor changes in fish behaviour in different climatic conditions.**

Results from the initial experiment show that fish species activity is generally markedly different from that recorded by human divers. There is also some correlation between species, time of day, and climatic and environmental conditions - correlations that have not been reported before. The paper will give details of the results of the observations, as well as technical details of the system. It will also refer to an associated project using an ROV for transect measurements on the reef, data from which has a bearing on the subject of the paper.

I. INTRODUCTION

The most common methodology for monitoring fish activity on coral reefs is to use SCUBA divers. Many papers have been published in this area e.g. [1 - 5]. However, any form of human intervention can be damaging to the reef, especially in areas where the habitat is under threat. This is especially the case where inexperienced divers are involved, and Marine Parks set aside for conservation and recreation are concerned.

The work for this project was carried out at the Hoi Ha Wan Marine Park in Hoi Ha, Hong Kong. This is one of the few areas in Hong Kong where the habitat is nominally conserved, and being a sub-tropical area, corals grow in patches instead of the extensive formations elsewhere. City University of Hong Kong has a laboratory attached the WWF Marine Life Centre in Hoi Ha, and this is used for a number of activities related to marine science and engineering.

Hoi Ha Wan was established a as a marine park in 1996, and fishing is still allowed by indigenous residents. At the same time, the area has become a favourite destination for recreational divers, and eco-tourism. This has had a negative effect on the marine environment and extensive monitoring must therefore take place to establish the extent of this constant human intervention.

Three of the authors have published previously on the use of underwater instrumentation, robotics and communications [6 - 9], as well as the use of remote operated vehicles (ROVs) to conduct environmental monitoring on the reefs at Hoi Ha Wan. The other has published on sub-tropical fish activity as well as reef observations [10 - 14].

The authors have also previously reported on the design of a camera for *in situ* recording of fish activity over a period of one month [15 - 16]. Most of the results reported previously on fish behaviour have only considered day-time and good-weather conditions [2 - 5]. Night observations on reef fish by SCUBA divers were much less and these were restricted in terms of number of samplings [17 - 18]. As will be shown, being able to monitor fish behaviour on a 24 hour basis in any weather conditions gives a very powerful tool for more accurate observations. In this paper, we review the design and installation of the underwater camera which achieved this task, as well as some preliminary results of the fish species behaviour. It is also possible to capture on video rare events, such as the spawning of coral, as occurred recently.

As the authors have been involved in taking transect measurements from the coral reef at Hoi Ha Wan using an ROV, we also report a synopsis of our recent findings [20] from a comparative study of using ROVs and SCUBA divers in monitoring the coral reef environment, which has interesting implications for the work reported here.

II. THE CAMERA SYSTEM

High quality imaging is supported by using an optical fibre cable to prevent loss of data and image. The video signal is sent directly over the powered optical cable to the shore station in the Marine Science and Engineering Laboratory in the Marine Park at Hoi Ha Wan, Hong Kong.

This decreases distortion of video signal and at the same time increases the speed of transmission due to fibre optic. A block diagram of the system is shown in Fig. 1.

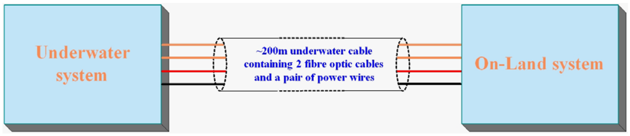

Fig. 1. Block diagram of the camera system

The system also has external connectors that allow a controllable illumination from a single or array of lights, as well as a serial data interface so that external instrumentation can be interfaced to the communications system, thus allowing real time monitoring of the ambient surroundings.

The on-shore system consists of the following:

a) Data controlling Unit;
b) WDM filter;
c) Fibre-to-video converter;
d) Isolating transformer;
e) Video capturing hardware to PC

The whole system uses a bidirectional communication via the two optical fibre cables. Control commands in RS-232 format are sent from one of the PCs through PC's 'com port' to the underwater system. Those commands can be for camera control, lighting control or sensor control. The RS-232 command signals are converted to optical signals and sent down one of the fibre optic cables to the underwater system. The optical signal sent back from underwater system is combination of both video (with wavelength 820nm) and sensor data (with wavelength 1300nm), a WDM filter is applied to split the signals. After the optical signals separated, the two signals of different wavelengths are converted to a video signal and a data signal by the fibre-to video converter and the fibre-to-RS232 converter respectively. The data signal can then be sent back to the PC and the video is processed through video-capturing hardware and then displayed on the screens of two PCs. The main power to the underwater system is 110Vac stepped down from an isolation transformer from 220Vac electric source. A specially designed cable was constructed or this project. It contained two multi-mode optical fibres and two twisted copper power cables. The cable was coated with a PVC waterproof covering, with aramid yarn to prevent water leakage along the cable. Its diameter was 14mm, and the length 210m.

The Underwater system contains the following:

a) Toroidal transformer 115/230 a.c.;
b) Power supply board;
c) Light;
d) Controlling board;
e) Video-to-fibre converter;
f) Sea-Bird interface board;
g) Optical coupler;

Once the optical signal is received by the underwater system, the control board converts it into different signal formats for the different components, e.g. RS232 for lighting brightness control, RS422 for camera movement control and RS232 for sensor control. As the video image is needed for real-time, the video signal is converted to optical one continuously. When the retrieving of sensor data from PC on-land is requested through correct command, the Seabird sends the data in RS232 format to the RS232-to fibre converter.

The communications system was designed to control the camera pan, tilt and zoom, as well as sending command data to the LED light that was fixed externally to the camera. It was also decided to design the system such that any external sensors connected to the camera via the serial data port on the casing could be controlled, such as requesting data stored on the internal flash memory of the sensor unit, or to acquire data in real time. The camera was based around a SpeedDome III unit. This has a resolution of 480 lines and the output was composite video 1Vpp NTSC format. The SpeedDome was chosen as it had the ability to track objects using built in software.

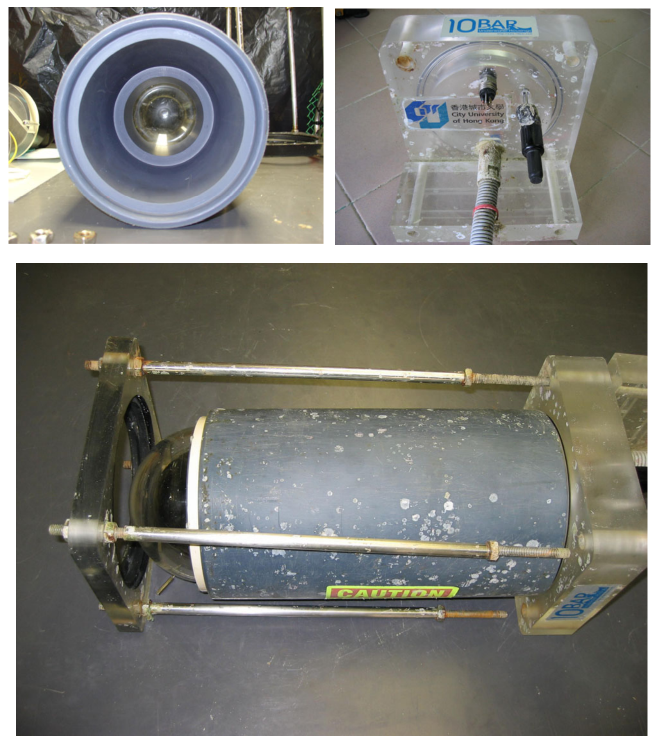

Fig. 2. Camera housing

The housing is built to protect the camera and all electronics being put underwater. The underwater housing for this project includes an acrylic dome acting as a window of the camera, a main body to house the electronics and a sealed cover with the attached underwater cables. The acrylic dome is screwed on the top of main body with an O-ring seal. Acrylic and Nylon were used as the casing construction materials. The camera housing can be seen in Fig. 2, with the associated electronics in Fig. 3.

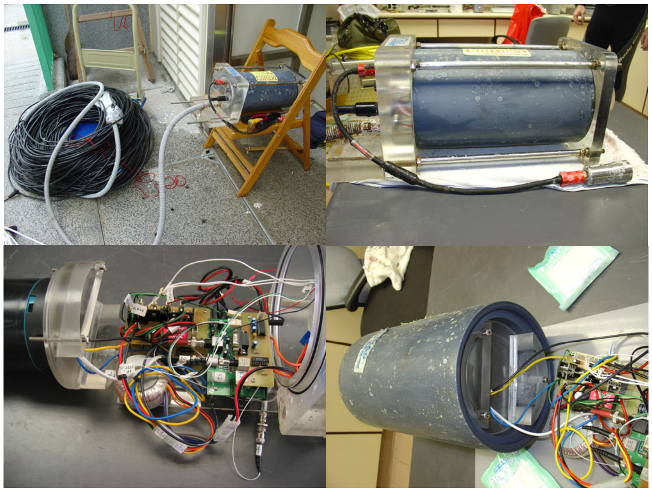

Fig. 3. Assembling the camera electronics in the housing

Once the video is received by the PCs in the laboratory, they can be stored, either as a compressed file in real time on the HDD, or recorded directly onto DVD using an attached DVD recorder. This can be programmed so that the recording can be timed. The burned DVDs can then be examined for analysis. The video data on the PCs will be used as source material for an automated fish species identification and counting system currently under development.

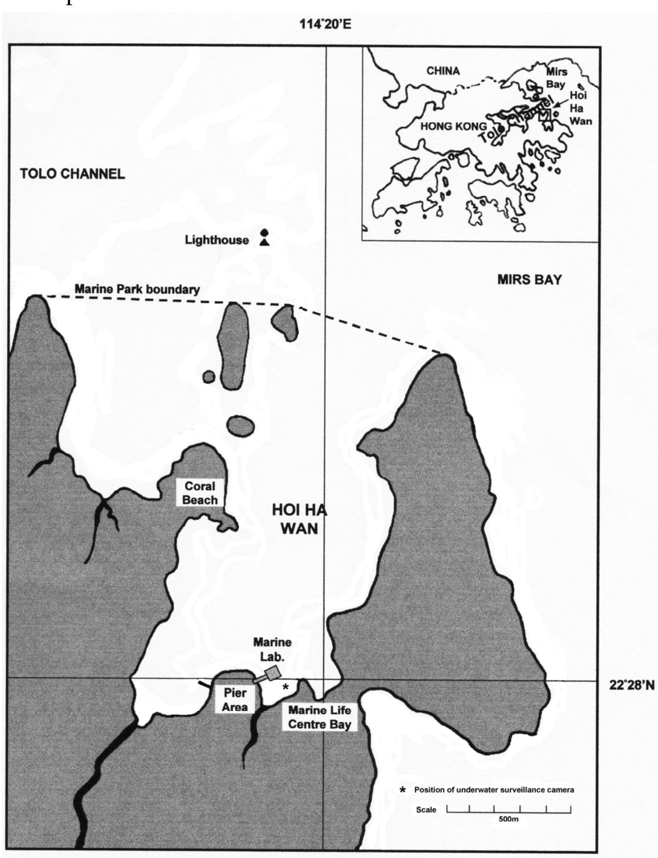

Fig. 4. A map of Hoi Ha Wan Marine Park, showing the deployment site of the underwater camera at the Marine Life Centre Bay

III. METHODOLOGY OF THE OBSERVATIONS AND RESULTS

The video camera was deployed on a hard coral community (~5 m in depth) at the Marine Life Centre Bay of the Hoi Ha Wan Marine Park (Fig. 4).

Ten-minute video footage for each hour was taken round the clock in July 2004. The dataset of fish assemblage representing fine days were collected for 5 days, i.e., on 4th, 7th, 8th, 10th, 15th of July. Another dataset representing days of storm and heavy rainfall, which occurred between 16th and 18th (n = 3), were also obtained. The visibility of the water is approximately 2 m. The camera recorded video footage of a water volume of ~ 2m^3. Species occurring were identified and their number in each footage was recorded. The number of fish was quantified as the number of fish occurring in each 10-minute video footage. Density of fish was obtained by dividing the number of fish by the volume of water, i.e., 2 m^3.

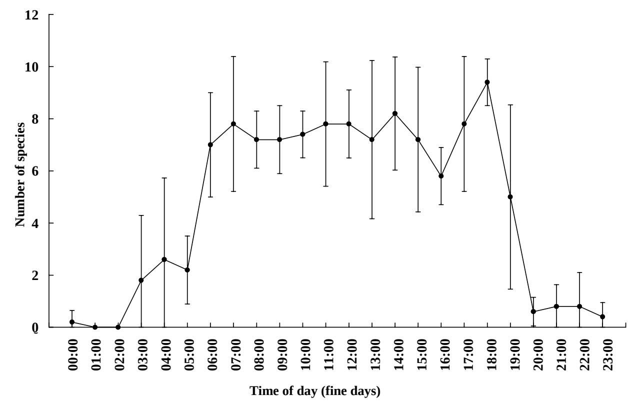

Fig. 5. Mean number of species.

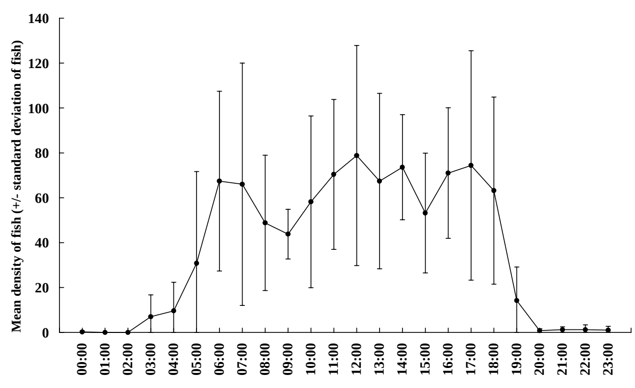

Fig. 6. Mean density of fish (Number of fish · m^{-3})

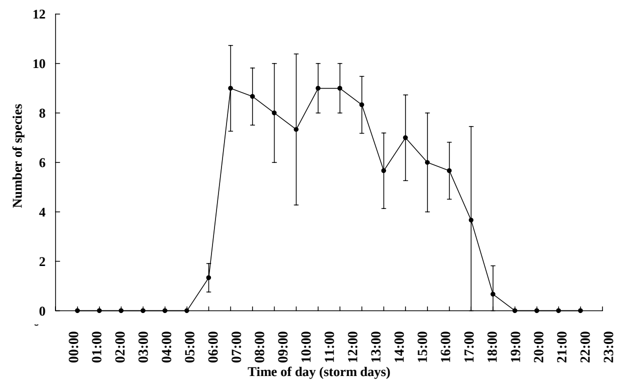

Fig. 7. Mean number of species

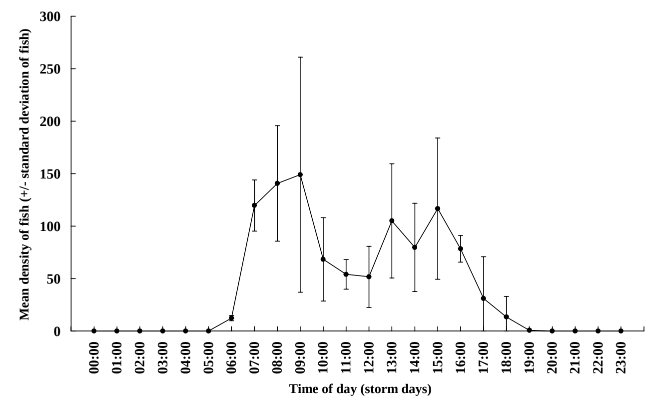

Fig. 8. Mean density of fish (Number of fish · m^{-3})

Abundance and species of fish were identified from this footage and results were shown in Fig. 5 and Fig. 6 for fine weather days. Fig. 7 shows the number of fish species and Fig. 8 the density for stormy and rainy days. The number of fish species and levels of fish density generally increase during daylight and decrease to almost zero at night. These two parameters were also the highest during dawn and dusk. These figures show that the coral fishes are most active during dawn and dusk in fine days. During the night, they tend to hide in crevices among the coral colonies for shelter. There is also an increase in fish density in the morning of stormy days, this indicate the fishes tend to be active feeding within a brief period only.

A list of fish species identified from the footage recorded by the underwater surveillance camera is shown below.

Class Actinopterygii
- Family Pomacentridae (Damselfishes)
  - *Neopomacentrus bankieri* (Chinese demoiselle)
  - *Abudefduf bengalensis* (Bengal sergeant)
- Family Labridae (Wrasses)
  - *Halichoeres nigrescens* (Bubblefin wrasse, Diamond wrasse)
  - *Stethojulis interrupta* (Cut-ribbon wrasse)
  - *Thalassoma lunare* (Moon wrasse)
- Family Gobiidae (Gobies)
- *Amblygobius phalaena* (Banded goby)
- Family Siganidae (Rabbitfishes)
  - *Siganus canaliculatus* (Seagrass rabbitsfish, Pearl-spot or White-spotted spinefoot)
- Family Apogonidae (Cardinalfishes)
  - *Apogon pseudotaeniatus* (Doublebar or Two-banded cardinalfish)
- Family Mullidae (Goatfishes)
  - *Parupeneus biaculeatus* (Pointed goatfish)
  - *Upeneus tragula* (Freckled goatfish)
- Family Gerridae (Mojarras)
  - *Gerres macrosoma* (Bulky mojarra)
- Family Scaridae (Parrotfishes)
  - *Scarus ghobban* (Blue-barred parrotfish, Blue-striped parrotfish)
- Family Blenniidae (Blennies)
  - *Aspidontus dussumieri* (Lance blenny)
  - Family Serranidae (Groupers)
  - *Cephalopholis boenak* (Chocolate hind, brown coral-cod)
  - *Epinephelus quoyanus* (Longfin grouper)
- Family Tetraodontidae (Pufferfishes)
  - *Takifugu alboplumbeus* (Hong Kong pufferfish)
- Family Scorpaenidae (Scorpionfishes)
  - *Sebasticus marmoratus* (Marbled rockfish, Common rockfish)
- Family Syngnathidae (Seahorses and Pipefish)
  - *Hippocampus kuda* (Spotted seahorse, yellow seahorse)
  - *Syngnathus schlegeli* (Seaweed pipefish)

Diurnal activity patterns of some common species have been identified and shown below in Fig. 9. This indicates different species were active at different period of time of the day. Most common species, such as Chinese demoiselle, Bengal sergeant, Bubblefin wrasse, Moon wrasse and Seagrass rabbitsfish were active during dawn and dusk. Pointed goatfish was active only during dusk. All these common species are generally active during daylight and inactive at night.

The camera has been deployed in similar fashion from the middle of June 2005. Preliminary results show results for slightly different weather conditions. However, on night on 30th June, at ~2000, egg masses were observed ejected from coral colonies (*Family Faviidae*) in front of the camera - Fig. 10. Ejection of sperms occurred subsequently and caused the translucent nature of the water column at ~2100. - Fig 11.

Visual data from the video footage of this spawning event is currently being cross-correlated with data from the attached instrumentation package, which measures salinity, dissolved oxygen, light intensity, water pressure and temperature.

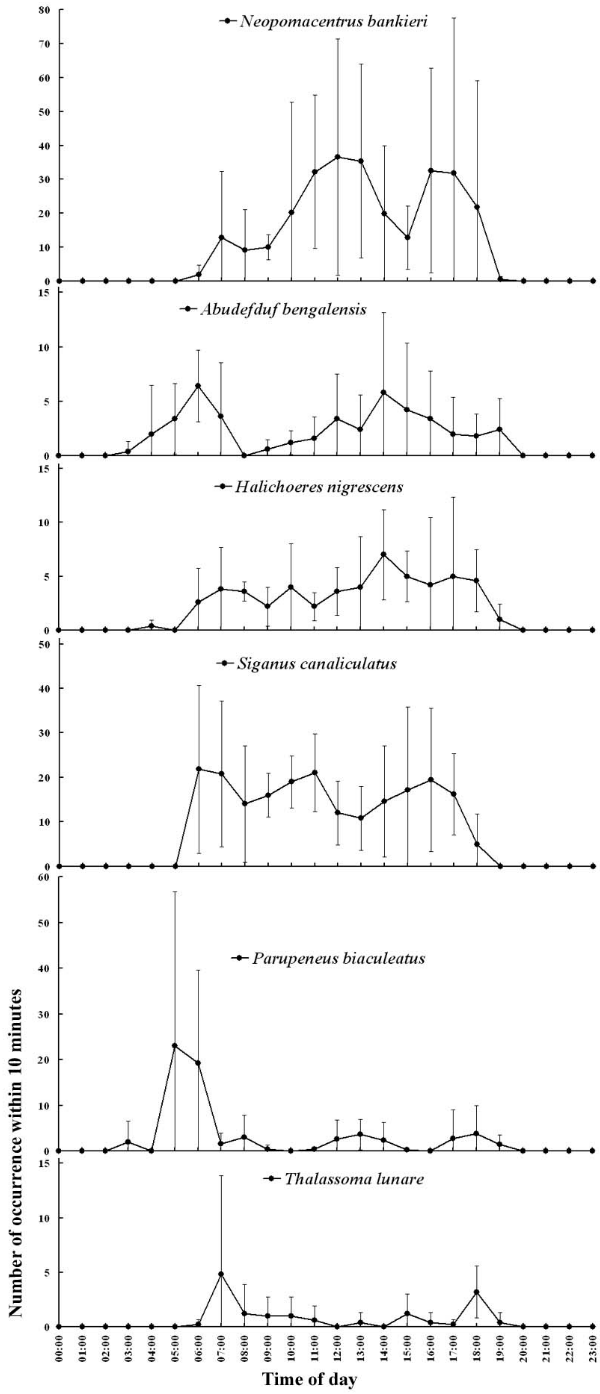

Fig. 9. Number of occurrence of fish in 10-minute video footage of six common fish species.

IV. COMPARISON WITH FISH CENSUS BY SCUBA DIVER METHOD

The fish census dataset collected at 10.00 am through the five days was used to compare with that collected by SCUBA diving method. The SCUBA diving method was conducted on a 100 m transect line at the same coral site of the underwater surveillance camera on 5th July. The fish census method followed that suggested by the Reef Check manual, i.e., the diver swam slowly along four 20 m-long 5 m-wide segment or belt transect along the 100 m transect line (each belt transect had a 5 m gap between each other) and count the number of fish seen in each belt transect [16]. In order to obtain a comparable dataset, the diver stayed in the belt transect for 10 minutes for fish observation. Fig. 12 show a decrease in number of fish counted using the SCUBA diver method. This decrease is significant and pronounced

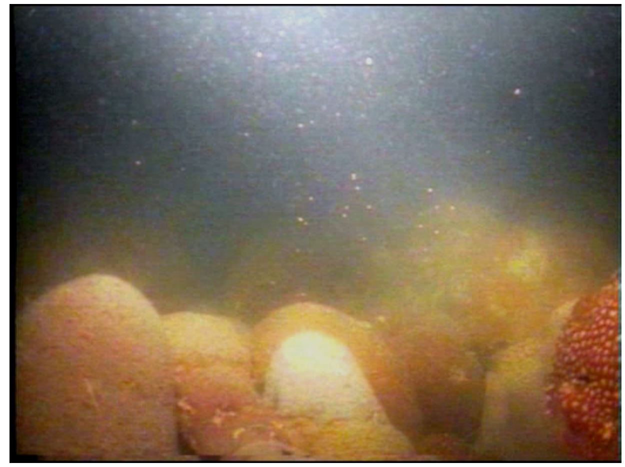

Fig. 10. Coral spawning - egg release, 20:00 30 June 2005

Fig. 11. Coral spawning - sperm cloud, 21:00 30 June 2005

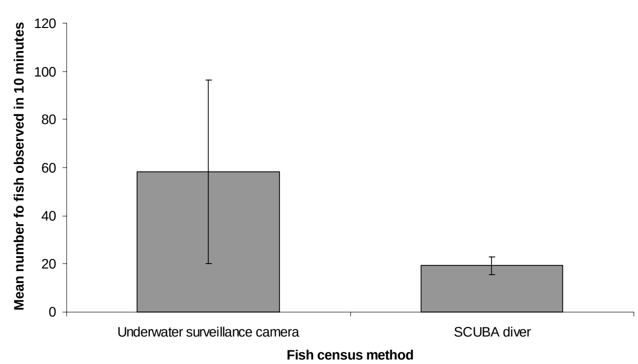

Fig. 12. Mean (± standard deviations) number of fish observed by underwater surveillance camera (n=5, data collected at 1000 for five days) and SCUBA diver (n=4, data collected in four belt transect) for 10 minutes.

V. DISCUSSION

Traditional diver-based fish census has to be carried out in fine and warm days. The camera described in this paper, however, can run continuously non-stop during fine and stormy days. The collected footage expands our knowledge on fish activities during bad weather such as days with storm and heavy rain or low sea water temperatures, which always happens in subtropical coral areas such as Hong Kong.

Using underwater camera for fish census has the advantage of increasing sampling size in terms of time but it is restricted to the spatial sampling area. The diver method is the reverse, i.e, temporal sampling size is restricted but sampling area can be increased due to the mobility of the diver. In this study, the camera observed fish only over an area of ~ $5m^3$ of coral area whereas the diver observed over an area of ~$400m^3$, i.e., four segments x 20 m long x 5 m wide.

When the camera is used in coral area with high sediment load, the dome is subjected to be masked by the sediment and ‘marine snow’. These ‘marine snow’ is tiny lump of fine silt and sediment stick together by plankton or mucous secreted by the marine organisms. After the camera has been deployed for a few days, a biofilm consist of bacteria and algae is also form on the dome. This biofilm is the first stage of fouling and attract settlement of more larvae of fouling organisms. The settled sediment and silt and fouling has to be cleaned regularly by diver by using cotton cloth so as to obtain a clear image.

The results obtained in the preliminary analysis of the data collected from this project mirror the results of a similar and related study carried out by the authors into the effectiveness of using remote operated vehicles for monitoring the subtropical coral communities, also in Hoi Ha Wan [17].

This study evaluated the use of remote control vehicle (ROV) in monitoring subtropical coral communities. Comparisons were made between the datasets obtained by the ROV and SCUBA diver video transect (‘Diver’) and between that obtained by ROV and point intercept transect (PIT) method on three nearby coral sites with different hydrography, scleractinian composition, dominant species and percentage cover. There was no significant difference between the dataset between the ROV and ‘Diver’ dataset whereas the PIT method over-estimated coral percentage cover at sites with low to medium coral cover. Power analysis shows that the minimum detectable change in coral percentage cover, δ, had low mean values between 0.39% and 1.65% for the ROV dataset, 0.66% for the 'Diver' dataset, and 12.11% for the PIT dataset. This implied that the ROV and SCUBA survey methods can produce higher precision in terms of detecting temporal changes in coral communities and are thus suitable for scientific research purposes; whereas data collected by PIT methods are useful for monitoring the general state of coral community and for habitat management in which less precision on temporal changes is required.

As with the preliminary data presented here on the *in situ* camera measurements, the main advantage of using ROV, or permanent camera, over SCUBA diver in obtaining video transects and fish species behaviour data is that there is no time limitation for how long the equipment can stay submerged. Thus, for example, the ROV can go for a wider horizontal range for video taking. The fixed camera and ROV are also useful in unfavourable diving conditions such as limited visibility, adverse weather, and unpredictable rapid water current which is dangerous for divers.

VI. CONCLUSIONS

It is clear from the results presented in this paper that monitoring fish behaviour and identifying specific fish species data is more sensitive using a fixed, permanent video camera compared to the more usual SCUBA diver methods. This is similar to the results obtained using an ROV to monitor coral communities. The permanent video camera can also provide data for bad weather conditions as well as at night.

The design of the camera allowed for pan, tilt and zoom, as well as using a powered fibre optic cable to allow control at long distance. Although the results presented are for a camera observing a coral reef approximately 200m from the on-shore laboratory, future plans involve measurements at two more reefs at Hoi Ha Wan Marine Park, one 600m from the laboratory, the other over 1 km away. The system is capable of working at a distance of approximately 5 km from the shore station.

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