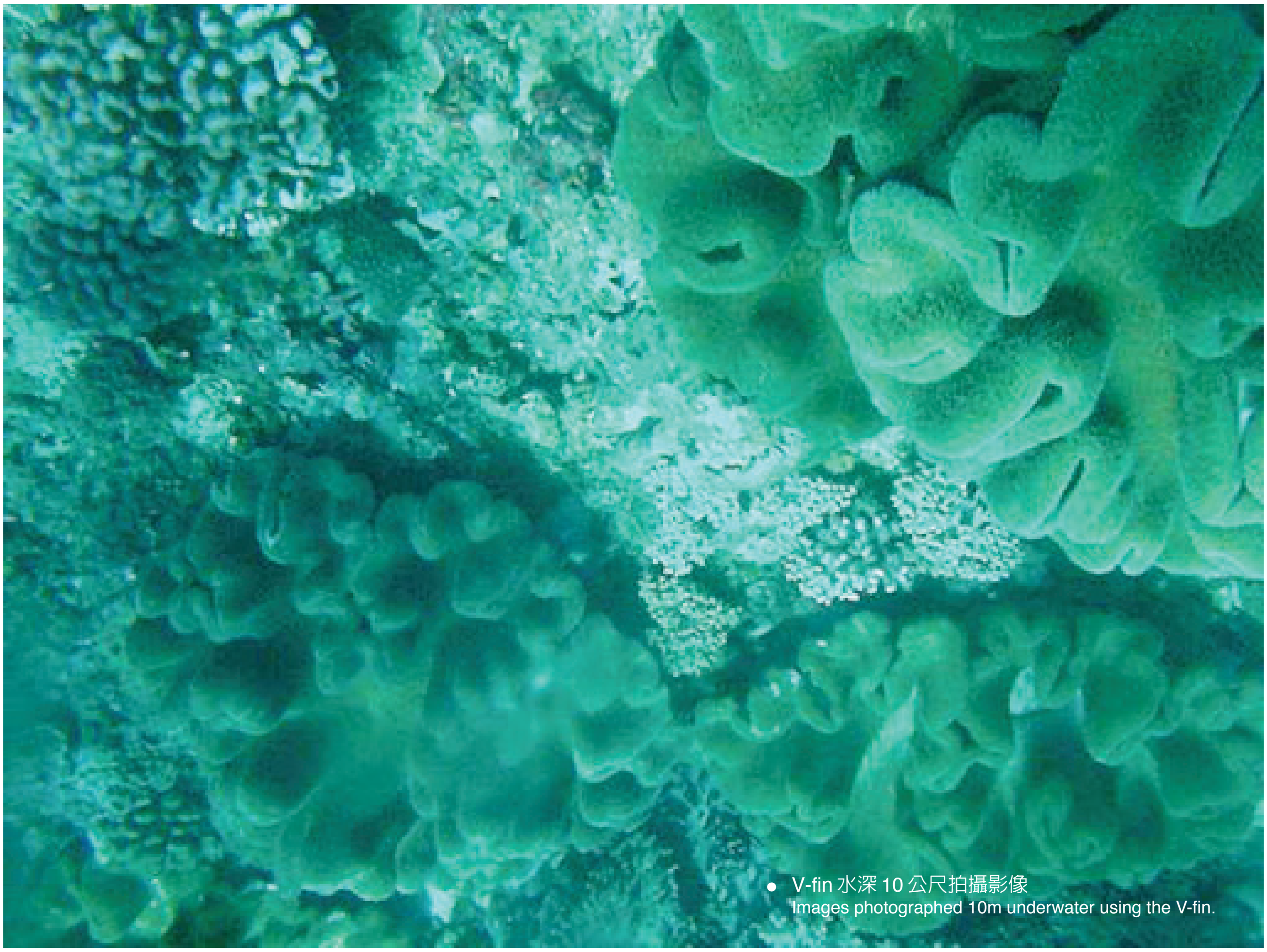
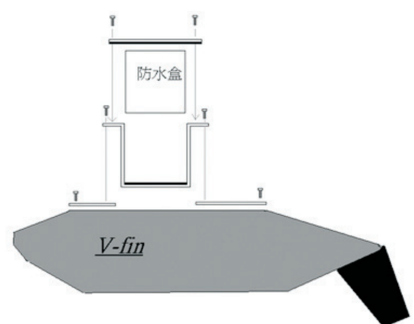


● V-fin 水深 10 公尺拍攝影像
Images photographed 10m underwater using the V-fin.

文、圖 | 蕭憲隆、黃冠穎
Article, Photos | Shiao Hsien-lung and Huang Guan-yen

淺談水下光學攝影 - 恆春南灣之行



● 防水盒置於 V-fin 底部之示意圖
An illustrated drawing of the waterproof box placed at the bottom of the V-fin.

Introducing underwater optical photography - An excursion to Hengtsuen's South Bay

壹、前言

一、水下環境是一個極為複雜與危險的處所，中山大學海洋環境工程研究所田文敏教授曾指出，水下環境的物理特徵包括：

（一）絕氣：水體無法提供人類呼吸所需的氧氣。

（二）低溫：水溫較低且比熱較高，易造成人體的失溫現象。

（三）透光性及能見度差：光線可穿透的範圍受水體混濁度影響，約為數公尺，在混濁水體或底泥被攪動的情況下，能見度僅達數公分或甚至為零。

（四）異常環境壓力：水壓隨水深而增加，每深10公尺增加一大氣壓，異常的環境壓力易引起血管栓塞。

（五）流動性：海水流動的作用增加作業的困難度。

二、因此上述特徵顯示水下攝影具有一定的難度。以攝影原理觀之，水下攝影與一般陸地上攝影並沒有特別的差異，最大的差異即是光線通過的介質不同，一者是空氣，一者為水。除此之外，水下攝影要克服隨水深增加的水壓所可能造成的滲水現象，因此「水密」的要求是最重

Part I Foreword

I. As underwater environment remains a rather complex and hazard-pone place, Prof. Tien Wen-min of Chung Shan University Oceanic environmental engineering research institute has pointed out that underwater environment's physical characteristics include,

(I) Inertia: The water body is unable to provide oxygen that humans need.

(II) Low temperature: the water temperature is relatively lower and with a higher relative heat, which tends to cause the human body to suffer from hypothermia.

(III) Poor visibility and light penetration: the range of light penetration is determined by the clarity of the water body, which is approximately several meters; in opaque water body or when the bottom silt is disturbed, the visibility often reduces to a few centimeters or even down to zero.

(IV) Abnormal setting pressure: the hydraulic pressure tends to increase as one goes deeper, one barometric pressure for every 10 meters down, and abnormal setting pressure tends to cause thrombosis.

(V) Fluidity: the fluidity of the seawater tends to hinder the operation.

II. As a result, the foresaid characteristics also suggest there are certain difficulties in underwater photography. To gauge from the photography theory, underwater photography does not differ from land photography that much, yet the major distinction lie in that light passes through a different medium, one being the air, and the other being the water. Besides that, underwater photography needs to take into account the hydraulic pressure before percolation sets in. As a result, the watertight demand becomes a critical issue, and the quality of watertight gadgets can hinder the life cycle of the equipment, and the quality of filming.

III. Underwater photography is generally conducted via the following means,

(I) Direct photography by divers

As curtailed by physical constraints, coupled with the foresaid underwater setting characteristic, humans' activities in the sea are greatly limited, and are often dangerous and time sensitive.

(II) By underwater remotely operated carriers

Which can be divided into remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV), and a major advantage of both lies in that the controller can control the vehicle by using a control box or a control lever aboard a ship or at the shore; it offers simple navi-

● 相機及 V-fin 之合成
The makeup of the camera and the V-fin.

要的關鍵，水密措施完善與否，將影響儀器整體壽命與拍攝品質。

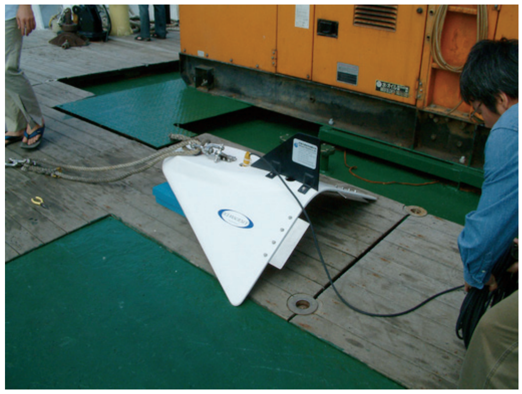
三、水下光學攝影一般可分爲下列幾種方式進行：

（一）潛水人員直接拍攝：
由於人類生理上的限制，加上前述之水下環境特徵，使得人類在海洋下的活動受到極大的限制，不但具有高度危險性，且不易持久。

（二）水下無人遙控載具：
可分爲線控(Remotely Operated Vehicle,簡稱ROV)與無線(Autonomous Underwater Vehicle, 簡稱AUV)兩大類，兩者共同的優點是操控者可以在船舶或岸上利用控制盒或控制室內的搖桿等設備來操控，具簡易之航行能力，並藉著載具上之攝影機獲得影像。然而其缺點是價格昂貴，均需仰賴國外進口，維修與保養不易。

（三）改良之拖曳式載具（V-fin）
V-fin之外觀類似太空梭的拖曳式設備，其流線外型可減少阻力，使其在水中可以穩定的移動。V-fin之底部挖空，可安裝儀器，原本係安裝聲學式都普勒流速儀(Acoustic Doppler Current Profiler, 簡稱ADCP)來測量海流，後經由中央警察大學與台灣大學共同改良，可使V-fin改裝不同之儀器，並亦設計出可自然浮於水面(浮性)以及可下沈至水中(沉性)的V-fin，使其應用更爲廣泛。

四、本次實驗即是應用防水數位相機與V-fin結合，實地至海上進行水下攝影，期能同時兼顧安全性、實用性及環境特殊性，以最



● V-fin之照片
The V-fin films

gability and is able to capture images through the camera that the vehicle carries. The only setback is the expensive cost, and the imported units make repair and maintenance difficult.

(III)By improved V-fin carrier
The appearance of a V-fin carrier resembles a space shuttle's carrier device, where the streamlined design serves to reduce the drag force, making it easier to glide through in the water. The bottom of the V-fin has a hollow chamber, which can be used to contain the equipment, and is once used to house an acoustic Doppler current profiler (ADCP) for measuring ocean currents. The device is later jointly modified by Central Police University and National Taiwan University, refitting the V-fin with varied instrument, and has been designed to be surface buoyant and submersible V-fins, making it more widely adaptable.

IV. The experiment pertains to utilizing the combination of the waterproof digital camera and the V-fin for conducting field underwater photography in anticipation of creating a maximum yield under limited budget, addressing to safety, practicality and environmental characteristics. In light that the seas around the southern Taiwan's Kenting area are home to the most precious marine ecology - the coral reefs ecosystem, which also falls under the Coast Guard Administrations' marine environment protection and conservation work as required by law, a written document has been made with the Maritime Patrol Directorate General for the Hengtsuen Maritime Patrol Corps to dispatch a 20T near-coast patrol boat to render assistance for the experiment expedition.

Part II Experiment design

I. Given that V-fin has an empty cavity at the bottom, this has led to the concept of having a waterproof box mounted to the cavity, and the water-resistant camera can then be placed within, which pertains to a waterproof box made of clear sheet acrylic, with a cover fashioned out of think sheet silicon with emulsified grease (waterproof grease) for waterproofing, uti-

少的經費產生最大的效益。因台灣南部墾丁海域擁有海洋中最珍貴之環境生態 - 珊瑚礁生態系，亦為本署依法執行之海洋環境保護與保育事項，故經函請海洋巡防總局同意後，由恆春海巡隊派遣 20 噸近岸巡邏艇協助此項實驗之進行。

貳、實驗設計

一、因 V-fin 底部為一空槽，故構思用一個防水盒固定於該處，再把防水的數位相機放入防水盒中，包括用透明壓克力板製成的防水盒、蓋子則使用薄矽膠板加上膏狀矽油(防水油膏)，利用壓力使之密合，達成防水之目的。最後將相機置入防水盒內，再將防水盒固定於 V-fin 底部，即可開始進行水下攝影。

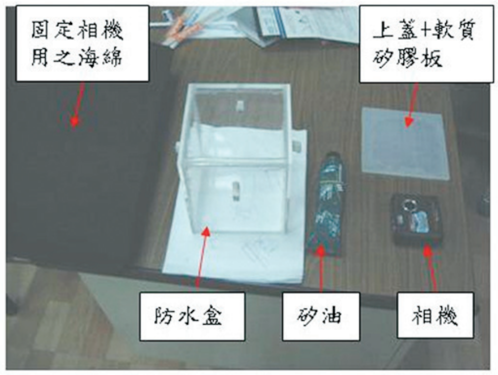
二、本次實驗用的相機為 Pantax Optio 43RW的數位相機，其防水性佳，相機設定之拍攝模式為 640 x 480 之動畫模式，每秒拍攝張數(films per second,簡稱fps)可高達15張，因使用容量 1 Gigabyte 之 SD 記憶卡，搭配使用 2400mAh 之電池，將 fps 設為 3，可連續拍攝 155 分鐘。

參、實驗經過與成果

在與恆春海巡隊聯繫過後，此次實驗於 94 年 5 月 23 日進行，中央警察大學與台灣大學研究團隊共 10 人於當日8時抵達恆春海巡隊，在拜會副隊長徐光榮及向巡邏艇上同仁說明過整個研究流程後，8時30分準時開船出發，於8點50分抵達拍攝地點，研究人員立即組裝儀器設備，老師並不時的在旁指導，艇上同仁亦是熱心協助，在組裝完畢後，實驗分成下列幾個階段進行：

一、相機及防水盒之水密測試：

9時18分進行測試，該處水深10公尺，進行約五分鐘，測試結果，防水盒未滲水，相機已可拍到水中珊



● 實驗所用之相關材料
Relevant materials used in the experiment.

lizing hydraulic pressure to achieve a waterproof purpose. At last, the camera is placed into the waterproof box, and the waterproof box is then mounted onto the V-fin's bottom to begin the underwater photography.

II. The experiment utilizes a Pantex Optio 43RW digital camera, which offers an excellent waterproofing capability, with the camera set to a filming mode of 640x480 animated mode, where the films per second (fps) is at 15 frames. By using a 1 Gigabyte SD memory card, coordinated with a 2400mAh battery, the fps is tune to 3, and the camera is capable of filming 155 minutes continuously.

Part III Experiment process and findings

Upon contacting the Hengtsuen Maritime Patrol Corps, the experiment is slated for May 23, 2005, as a 10-member Central Police University and National Taiwan University research team arrives on the scene at the Hengtsuen Maritime Patrol Corps at 8:00AM of the scheduled date, and upon meeting with deputy Corps commander Hsu Kuang-rong and patrol boat crew presenting the research flow of the entire expedition, the boat sets sail at 8:30AM, and arrives at the filming site at 8:50, where the researchers begin to load the gears, with the curriculum instructor providing guidance on the side. The crew help out enthusiastically, and upon loading the gears, the experiment proceeds with the following stages,

I. Watertight testing of the camera and waterproof box

At 9:18, as the test proceeds, the site measures 10m in water depth, where a test filming of five minutes has been conducted, and the result indicates that the waterproof box has not seeped, and the camera is capable of capturing the coral images underwater.

II. Testing the filming performance of the submersible V-fin

At 9:34, the camera and waterproof box are mounted to the submersible V-fin; the V-fin is launched into the water, with the boat speed tugging at 0 to 4 knots, sailing at a water depth of approx. 10m. The underweight belly has made the V-fin gliding on water surface with the belly up. 9:41, the V-fin is retrieved and re-

瑚影像。

二、測試沉性 V-fin 之拍攝表現：

9 時 34 分將相機及防水盒裝入沉性V-fin，9時33分入水，船速控制在 0~4 節，水深約 10 公尺。腹部過輕無法平衡導致V-fin以腹部朝上姿勢在水面滑行；9 時 41 分，將V-fin收回，加掛浮球，再次施放，此次V-fin以穩定姿態行進約 50 秒，船速達 4 節，可攝得連續海底影像，受海水影響，顏色幾乎都爲藍色，水深愈淺影響愈小，於 9 時 47 分回收。

三、測試浮性 V-fin 之拍攝表現：

10 時 20 分改以浮性 V-fin 進行拍攝，水深 5~10 公尺，船速 0~4 節，拖曳時以低速漂浮(約 1 節)可保持平衡不致翻倒，若加速拖曳 V-fin ，結果導致其翻轉成底部朝上，推測是頭部太輕。 10 時 30 分，回收V-fin於前方置放鉛塊以增加重量；10 時 45 分，再次施放，先以低速拖曳兩分鐘，正常平穩，再加速至 4 節， V-fin 以穩定姿勢前進，水深約 10 公尺；近距離所拍攝之珊瑚影像非常清楚， 11 時 04 分回收 V-fin ，返回隊部碼頭，中午休息。

四、使用浮性V-fin做長時間連續拍攝：

下午 1 時進行短暫研討與修正，1 時40分改採鋼索拖曳V-fin，水深 10~25 公尺左右，船速 4 節，鋼索長約 5 公尺，於水深 20 公尺處，因V-fin與目標距離約有17公尺，故只能勉強分辨出輪廓，當水愈來愈淺時，則影像清晰度與色彩表現也愈來愈好；此次拖曳約6分鐘，狀況良好，於 1 時 47 分回收 V-fin 。

肆、結論與心得

一、結論

（一）拖曳速度爲 0~4 節時，速度

launched with buoy; this time the V-fin glides in a steadfast manner for approx. 50 seconds at a boat speed of 4 knots, making it feasible to film the undersea image, where as affected by the ocean, the images are nearly in blue, and the impact is lessened when buoyed near the water surface; the V-fin is retrieved once again at 9:47.

III. Testing the filing performance of the buoyant V-fin

At 10:20, the filming switches to the buoyant V-fin, working on a 5 - 10m water depth, at a boat speed of 0 - 4 knots, tugging with a low-speed buoy of approx. 1 knot to keep the V-fin balanced without toppling. When tugging the V-fin at an accelerated speed, it tends to lead to the V-fin's flipping with its belly side up, which is deduced to be a light head-load. 10:30, the V-fin is retrieved and weighed down with a lead block in front. 10:45, the V-fin is re-launched, first tugging at a low speed for 2 minutes for steadiness before the speed picks up to 4 knots, where the V-fin is seen traversing steadily at a water depth of 10m. All coral images captured in near distance have been very clear. 11:04, the V-fin is retrieved and the ship returns to the dock, followed by a lunch break.

IV. The use of buoyant V-fin for extended continuous filming:

At 1:00PM following a short session of discussion and revision, a decision is made to tug the V-fin using steel cable at 1:40, working at a water depth of 10-25m, at a boat speed of 0 - 4 knots, with 5m cable trailing. At a water depth of 20m, with the V-fin only 17m from the target, only vague contours could be made out. As the water gets shallower, the image clarity and resolution become better and better. Upon tugging it for around six minutes, the conditions get better; at 1:47, the V-fin is recalled.

Part IV Conclusion and reflection

I. Conclusion

(I) Tugged at a speed of 0 to 4 knots, the faster the angle be tween the rope and the water surface would become larger. It appears to be near a 45-degree angle when sailing at a four nautical mile speed, and near a 30-degree angle when sailing at a 7 nautical mile speed as the angle becomes smaller as the V-fin speed picks up. The V-fin is however able to sail smoothly at a low speed when the boat is navigating at a one nautical mile, but tends to lose balance and capsize as swayed by the waves sailing at a 2 nautical mile speed, while the V-fin is able to move forward smoothly underwater sailing at a 3 nautical speed or faster.

(II) There is a need to redesign the waterproof box, for the higher hydraulic pressure in deeper water could led to fracturing the waterproof box, leaving it to reply on the camera's waterproofing function. Yet during the last time of the extended filming, the camera has eventually given out due to exceeding the range of waterproofing capability, and the battery also exhibits signs of charred burns, and the files stored on

愈快則繩索與水平面的夾角就愈大。4節時接近45度，但超過4節時，速度愈快則夾角愈小，在7節時約呈30度。V-fin在船速1節時可以平衡地慢速前進，若是2節左右則易被浪打到失去平衡而翻覆，3節以上V-fin下沉至水中則可平衡前進。

（二）需重新設計防水盒，因較深水域之水壓過大，導致防水盒破裂後，只靠相機本身的防水功能，但在最後一次的長時間拍攝時超出相機之負荷進水而損毀，電池負極有燒焦痕跡，SD記憶卡之檔案也因此受損，殊爲可惜。未來應採用更好的防水相機或直接用相機防水盒以改善防水性。

1. 愈接近珊瑚拍攝表現愈好，但過近影像卻反而模糊(因相對角度變化太快)且有撞擊海底之危險，太遠則無法分辨顏色，此次的實驗結果顯示，理想的實驗深度約在5~15公尺左右。

2.施放時V-fin時要隨時注意水深變化及繩索的施放，以免發生意外。

二、心得

（一）本次實驗非常成功，成果亦十分豐碩，無法一一在本文呈現，若日後持續改良，應可作爲高效率大範圍之機動水下攝影工作載台，若能應用於本署巡防艦艇，應可大幅提昇水下偵搜能力，對達成海上救難、海洋災害救護、漁業資源維護、海洋環境保護及保育的任務助益甚多。

（二）從此次的實驗設計、規劃到最後的執行，我們在指導教授陳先文

the SD memory chips have been damaged as well, to pose certain regrets. In the future, better waterproof camera should be adopted, or perhaps deploy a camera waterproof case to improve the waterproofing.

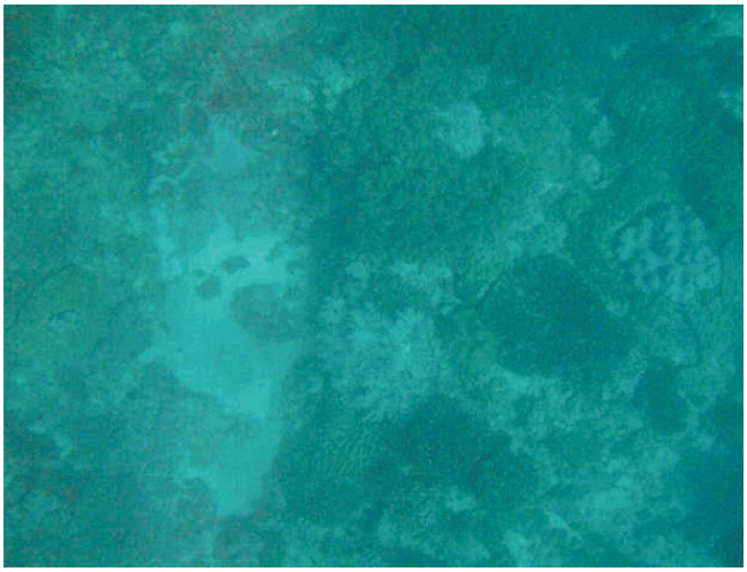
1. The closer to the coral clusters the better the filming results would become; however, when too close, the images inadvertently become blurry, most probably from swift angular changes, and at risk of impacting objects at seabed. Whereas the colors become indistinguishable when the camera is operated in long-range shots. The experiment findings show an ideal experiment depth to be at around 5 to 15m.
2. When launching the V-fin, it is prudent to keep watch the changes in water depth and the release of the rope to avoid creating hazard.

II. Reflection

(I) The experiment has been a huge success, with impressive results as well that might not have been fully covered in this writing; given continued improvement, the device can serve as a large-area, mobile underwater photography working platform, which when applied to frigates of Coast Guard Administration could greatly enhance the vessel's underwater reconnaissance capability, presenting innumerable yield to maritime rescue, ocean disaster rescue, fishery resource planning, oceanic environment conservation and preservation among others.

(II) Starting from the initial experiment planning at the drawing board to the final field execution, our study team, led by our curriculum professor Chen Shien-wen, has had several brainstorming sessions with Taiwan University postgraduate students in various discussions and simulations, where they have encouraged us to test out our ideas, making us more aware of treasuring the sweet research fruit despite all the hardship.

(III) Having studied at the Central Police University for close to a year, I am keenly aware of the scare resources in the local marine study filed, given that there are only three marine study vessels in Taiwan at the present time, and the demand over supply scenario does leave the researchers very little time to launch their annual field studies. As bound by circumstantial restricts, many researchers turn to outfitting less equipped fishing boats using rental equipment to conduct scientific study and ocean environment survey. On the other, by assessing how the Coast Guard Administration operates over 100 boats and ships, given that they be open to collaborate with the academic sector, the potential yield not only promises a chance for Coast Guard associates to partake oceanographic and marine studies to excel their knowledge in the ocean environment, but also a greatly yield in relevant academic study, warranting the feasibility to be a probable cause in the Coast Guard Administration's future operational



老師的帶領下，與台灣大學研究生歷經多次的腦力激盪，進行各式討論與模擬，只要一有新的想法，他都鼓勵我們不斷嘗試，讓我們更會珍惜這一切辛苦但卻甜美的研究成果。

（三）在中央警察大學已進修了將近一年之時間，深深感受到國內海洋科學界「巧婦難爲無米之炊」之難處，因國內目前僅有3艘海洋研究船，僧多粥少，每年每位學者可使用的時間極爲有限，往往不得已只能租用設備與生活環境甚差的漁船進行科學研究與海洋環境調查，反觀本署擁有艦艇百餘艘，若能適當與學術界合作，除了可擴大本署同仁參與海洋科學研究，促進對於海洋環境之瞭解外，更可將相關學術研究成果，當成本署相關施政之參考。

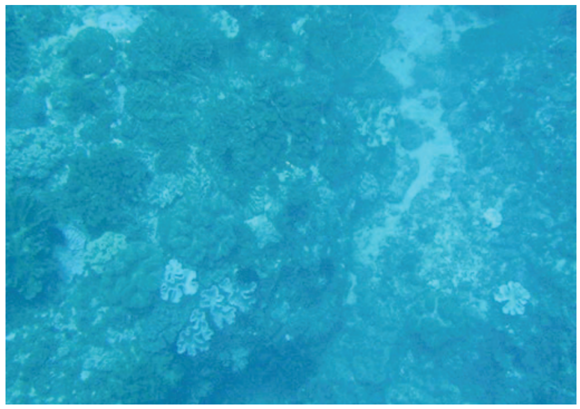
三、謝誌

感謝中央警察大學水上警察研究所陳先文助理教授與台灣大學海洋研究所劉倬騰教授之指導，以及對於此次實驗經費與設備之補助。此外，更要感謝本署海洋巡防總局的支持，以及恆春海巡隊全體同仁及PP2026艦艇上同仁的全力協助與配合，使本次研究能圓滿成功，特此致謝。

（本文作者任職於第一海巡隊）

● 以防水盒及相機置於水中拍攝珊瑚，以測試水密情形
The camera contained in waterproof box is placed underwater for photographing the corals, intended to test the state of watertight sealing.

● 沉性 V-fin 水深 10 公尺拍攝之影像
Images photographed at a 10m depth underwater using submersible V-fin.



● 浮性 V-fin 水深 10 公尺，拍攝距離約 7 公尺
The buoyant V-fin dives to 10m underwater and takes photos at a 7m range.

consideration.

III. Acknowledgement

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