REPORT

Pilot Project: Development of a Standard Operating Procedure for mapping marine litter on the seafloor using commercial underwater drones

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Pilot Project: Development of a Standard Operating Procedure for mapping marine litter on the seafloor using commercial underwater drones	
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Summary

The objective of this pilot study was to (1) test whether commercial ROVs can be used to collect quantitative data on benthic marine litter, and (2) begin to develop an international standard operating procedure (SOP) for mapping marine litter using commercial ROVs. After repeatedly testing two commercial ROVs (a Blueye Pioneer prototype and a PowerRay by PowerVision) on standardized transects, our preliminary conclusion is that these ROVs are not suitable for collecting quantitative data on marine litter on the sea floor due primarily to the forward-facing angle of their cameras, but also various operational constraints imposed by cable entanglement risks. It is therefore currently not possible to develop and SOP, although one could possibly be made for qualitative sampling given further testing of the ROVs.

Project manager	**Quality control**
Marthe Larsen Haarr	-

PREFACE

The aim of this study was to determine whether commercial ROVs can be used for mapping of marine litter on the sea floor, and if so, to develop and a standard operating procedure (SOP) for their use for this purpose. Salt Lofoten AS (SALT) used two different types of commercial drones (a Blueye Pioneer prototype and a PowerRay by PowerVision) to test the potential for using this class of underwater drones for citizen science. The ROVs were tested for their ability to collect quantitative and qualitative data.

We extend our sincere thanks to Plastreturs Miljøprosjekt for funding the project, and to Nordic Ocean Watch for their collaboration.

Svolvær, 08.03.2019

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Summary

Due to recent advancements in drone technology, relatively simple underwater ROVs (Remotely Operated Vehicles) are becoming more accessible to a greater variety of consumers. This class of ROVs allow for hobby pilots to explore the underwater world without having to invest in high-technology drones or diving certification. The expansion of ROV technology from professional use to the consumer market also opens up opportunities for the use of these underwater drones for research purposes. Commercial ROVs are likely to be attempted used for mapping marine litter underwater, particularly on the sea floor in accessible areas. And while heavy-duty ROVs are routinely used by scientists in underwater research, the potential of the use of commercial, smaller drones for research purposes is yet to be tested.

Our objective was to (1) test whether commercial ROVs can be used to collect quantitative data on benthic marine litter, and (2) begin to develop an international standard operating procedure (SOP) for mapping marine litter using commercial ROVs. To achieve this, we tested two commercial ROVs (a Blueye Pioneer prototype and a PowerRay by PowerVision) repeatedly over standardized transects, as well as general piloting tests to determine their user friendliness.

Our conclusion from this pilot study is that it is not possible to collect quantitative data on litter density on the sea floor with sufficient accuracy or precision to compare densities among surveyed locations. This is due primarily to the forward-facing angle of the ROVs' cameras, but also partially to general operational constraints, such as those imposed by the risk of cable entanglement and thruster blockages. Because of this, it is not possible at this time to establish an SOP for the cuse of commercial ROVs in mapping marine litter on the sea floor. However, commercial ROVs may be suitable for collecting qualitative data to pinpoint certain contaminated areas, and to document substantial changes in the amounts of marine litter in an area.

1. BACKGROUND AND INTRODUCTION

Marine litter is one of the major environmental threats of our time. The current concern over the negative effects that marine litter has on the environment has resulted in the development of national and international strategies to fight the problem. Numerous volunteer beach clean-up organisations and campaigns have also been launched in the last decade, and beach clean-ups are becoming an increasingly popular activity. The fight against marine litter has also expanded to other marine environments, such as people diving and trawling for litter on the seafloor.

Due to recent advancements in drone technology, relatively simple underwater ROVs (Remotely Operated underwater Vehicles) are becoming more accessible for a greater variety of consumers. This class of ROVs allow for hobby pilots to explore the underwater world without having to invest in high-technology drones or diving certification. The expansion of ROV technology from professional use to the consumer market also opens up opportunities for the use of these underwater drones for research purposes. Citizen scientists engage widely in marine litter research, as gathering marine litter data can often be done in a relatively straight forward manner. Marine litter data collection varies from registering litter types and amounts during beach clean-ups, to taking surface samples with a trawl, and geo-tagging marine litter observations. Commercial ROVs are likely to be attempted used for mapping marine litter underwater, particularly on the sea floor (henceforth referred to as benthic marine litter) in accessible areas.

Heavy-duty ROVs are routinely used by scientists in underwater research, but the potential of the use of commercial, smaller drones for research purposes has yet to be tested. Mapping of marine litter underwater is a demanding task, both because of the vast areas to be covered and very heterogeneous accumulation patters (Buhl-Mortensen & Buhl-Mortensen 2017). In addition, poor visibility, difficult weather conditions, and depth increases the difficulty of mapping benthic marine litter or verifying theoretical density models. The commercial drones used in this project have 70 m long cables, although commercial ROVs can come with cables up to 150 m. This restricts their mapping activities to areas of relatively shallow waters, and presumably their potential lies mainly in mapping coastal areas, which are easily accessible by boat or even directly from land. While a practical limitation of commercial drone use, mapping nearshore areas is also highly useful as most sea floor clean-up actions take place in shallow waters accessible to divers. ROV mapping of coastal areas may be used to pinpoint diver clean-up locations and the litter found there, thus making actions safer and more efficient.

Our objective was to (1) test whether commercial ROVs can be used to collect quantitative data on benthic marine litter so as to compare pollution levels among locations, and (2) begin to develop an international standard operating procedure (SOP) for mapping marine litter using commercial ROVs. The ability to collect quantitative data indicating the density of benthic marine litter using comparatively inexpensive commercial ROVs would be a highly useful research tool and could enable the establishment of an international citizen science database to both compare pollution levels among different regions and locations, and to prioritize clean-up efforts. Commercial ROVs may not be suitable for collecting quantitative data, however. In which case data collection will be limited to qualitative data indicating the presence/absence of litter, possibly with some categorical grading of the pollution level, as well as information on the types of litter. Qualitative data may be used to pinpoint certain contaminated areas, and document large changes in the amounts of marine litter in an area (for example after a shock event, such as a storm or industrial leakage). An SOP would describe how the ROVs can be used to collect data on marine litter, along with suggested guidelines of operation to ensure as standardized results as possible to enable comparisons among locations and users. The idea is that, by following the SOP, anyone with an ROV can contribute to the marine litter research and become citizen scientists.

2. METHOD DEVELOPMENT AND IMPLEMENTATION

2.1 ROVs tested

The ROVs used in this project were chosen due to their affordability, availability and reported functionality. The goal was not to buy the best drone on the market, but to buy drones that are affordable for a variety of consumers, and which fulfill the relatively simple requirements of being able to film and photograph underwater. In addition, the drones had to be used-friendly and controllable through a smart phone. We tested two ROVs: PowerRay by PowerVision and Blueye Pioneer prototype.

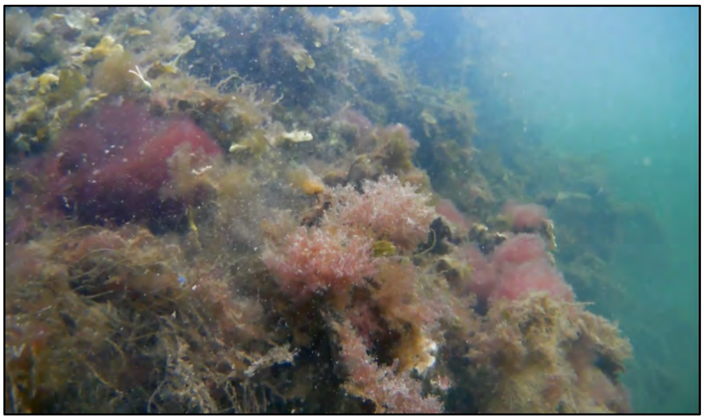

Image 1: Underwater still picture taken with a BluEye prototype (Photo: SALT).

The PowerRay was chosen due to being widely recommended as a good tool for filming underwater, and because it was one of the only commercial underwater ROVs already available for sale (and not only as a pre-order). In addition, the PowerRay was among the lowest priced drones with good user ratings[1]. The PowerRay was used during the summer months of 2018. Unfortunately, it became damaged by water leaking inside its plastic shell before the full range of testing could be completed.

The Blueye Pioneer was chosen as it was designed in Norway and, in the beginning of its production, fairly affordable. The close physical proximity to the Blueye engineers gave the project team an extra cushion in case the drone would need repairs during the project. The Blueye Pioneer was pre-ordered, but due continued postponement of delivery, the project team did not receive their drone. However, we were able to borrow a Pioneer prototype in September 2018.

Image 2: Blueye pioneer (left) and PowerRay (right). Source: Blueyerobotics.com, powervision.me/eu.

1 See for example: http://www.top10drone.com/best-underwater-drones/, https://www.bhphotovideo.com/explora/video/hands-on-review/in-the-field-with-the-power-vision-powerray, and https://www.bhphotovideo.com/explora/video/hands-on-review/in-the-field-with-the-power-vision-powerray for reviews of the PowerRay.

2.2 Quantitative assessment

We assessed each ROV's potential for quantitative data collection through a simple experiment. We prepared a transect consisting of 5 drink bottles of varying sizes, emptied and re-filled with pebbles and/or sand, and tied at 2m intervals along a rope with buoys on each end for easy deployment and retrieval. The objective was to create a standardized 10m long transect with litter items of known size along it on which to test the ROVs.

The transects were deployed in shallow water (1.5-3m) on relatively homogeneous substrate (silt or sand) in locations accessible from land. The ROVs were piloted over the transect at set depths repeatedly to test their reliability, accuracy and precision. The objective of these tests was to determine whether these commercial ROVs can be used to scan transects of known size for litter, thus allowing the density of litter (e.g., # items m^{-2}) to be estimated.

Videos recorded of the transects were analyzed using the free image analysis software ImageJ (https://imagej.nih.gov/ij/index.html). Still images were saved of each bottle along the transect, and the known size of each bottle used to set the scale to determine the field of view (Figure). This process was repeated for five videos of each transect with both ROVs, with minimum two images of each bottle in a transect analyzed. Each image was also processed five times. This was done to determine the precision in the field of view whilst piloting the drone, which is critical to determining whether reliable estimates of area can be made, and which in turn are paramount to quantitative estimates of litter density.

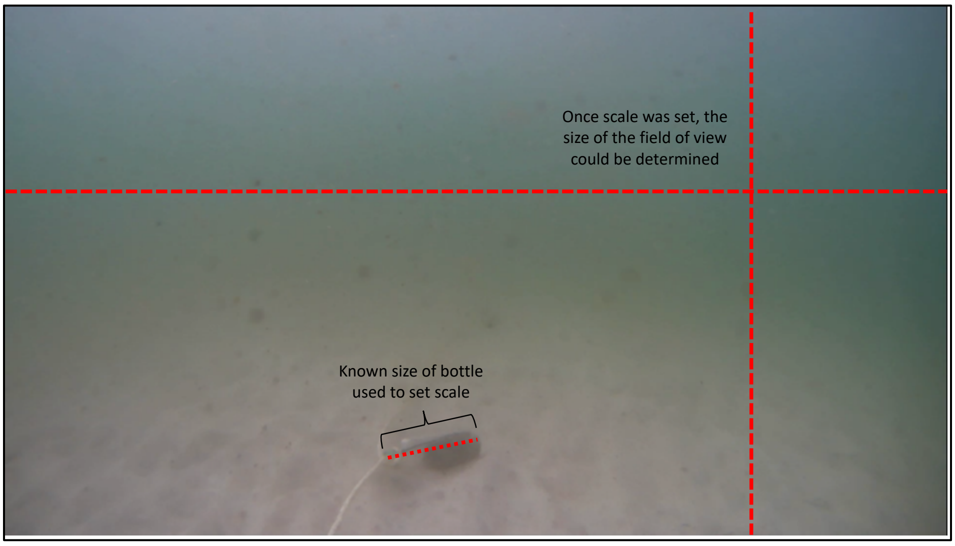

Figure 1: Sample still image from ROV videos showing one of the bottles on the rope transect used to set the scale (i.e. pixels per cm), and subsequently to determine the field of view (area shown in the image, calculated as width x height and given in m^2.

3. RESULTS

3.1 Qualitative experiences

Some teething problems were to be expected as the ROVs tested were first-generation technology and prototypes. The ROV technology is developing at a fast pace, and therefore the conclusions of this study should be considered accordingly.

The project team experienced very few dives where the drones worked seamlessly. Troubles experienced included entanglement of the propellers/thrusters, low battery life, delays of the live streaming (often resulting in crashes), entanglement of the cable on underwater constructions, failure to start the propellers, and problems controlling the propellers. Operations in kelp forests or close to the sea floor proved demanding as both drones had fairly exposed propellers which drew loose objects into them, causing them to jam. Poor visibility and ocean currents made the testing of the drones even more demanding, as it was challenging to control the dive direction and avoid entanglement.

Ability to dive in areas with poor visibility, currents and vegetation is crucial if ROVs are to be used for marine litter mapping. Having to restrict the dives to marine environments with no vegetation and little current negatively affect the ability to compare litter density between locations, as well the ability to map many ecologically valuable areas. It should also be recognized, however, that more extensive testing is required before final conclusions regarding the potential to use ROVs in marine litter research can be made.

Image 3. Testing the PowerRay (top) and the Blueye Pioneer prototype (bottom) in Lofoten (Photos by Marthe Larsen Haarr and Christian Lysvåg).

3.2 Quantitative results

The field of view proved very variable, and it was not possible to consistently maintain a similar field of view during filming. The average field of view calculated with the help of bottles of known size along the transect differed greatly among different still frames from the videos. The coefficient of variation (CV), which shows the standard deviation as a percentage of the mean, gives an indication of the precision, or consistency, of estimates. Typically, when engaging in scientific work, one seeks to keep precision to where the CV is approximately 5% or less. The CV for the field of view estimated for different still images during a transect video, varied from approximately 20% to 80% (Figure 2).

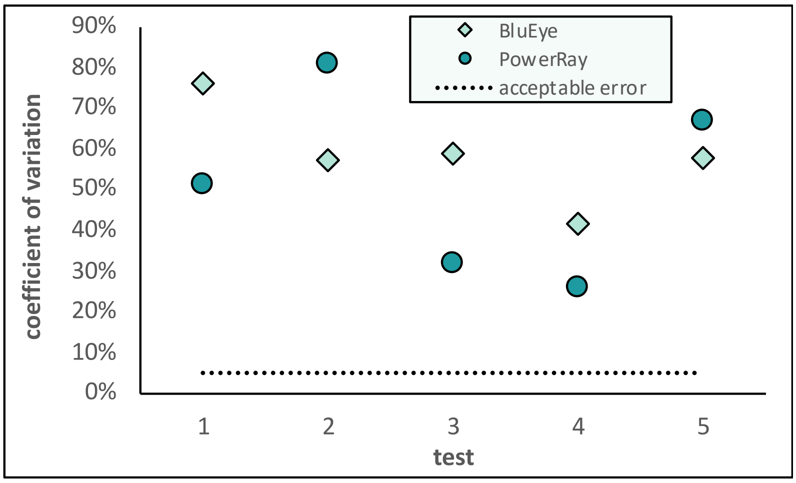

Figure 2: The coefficient of variation (i.e., the standard deviation divided by the mean, expressed as per cent) of the estimated field of view calculated from different still images of each test video (pass over transect). Results are shown for both drones. The stippled line shows what is typically the maximum variation allowed in scientific work.

A large portion of this variation is likely due to the fact that the drones' cameras do not point directly down as they are located on the front of the drones, not underneath. This camera placement gives a forward – down view of the sea floor, rather than a pure top – down view. Combined with wide angle lenses, this results in a considerably larger field of view towards the top of the image, compared to the bottom. When a bottle is visible towards the middle of the frame, the estimated field of view is 3-4 times greater than when the bottle is visible towards the bottom of the frame (Figure 3). Consequently, the seafloor can only be reliably, and clearly, viewed in the bottom third of the image.

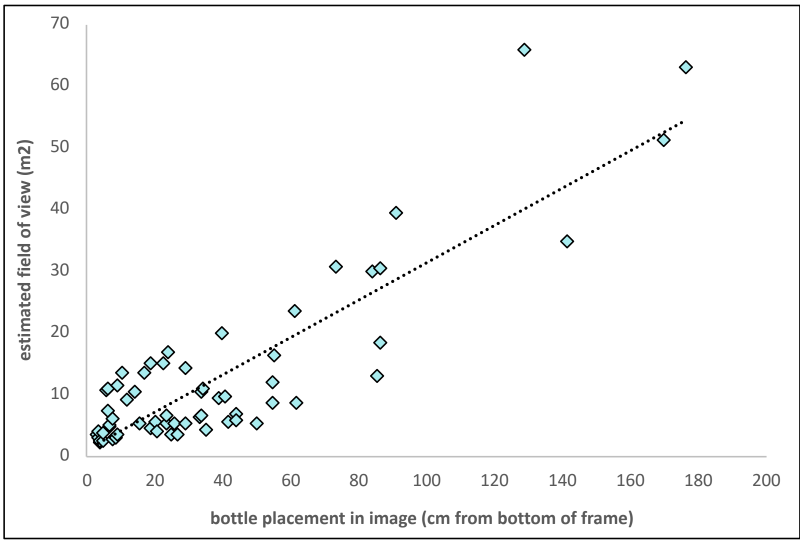

Figure 3: estimated field of view vs. the placement in the image of the bottle used to set the scale.

The angle of the cameras in combination with wide angle lens also means the drones must be quite close to the seafloor to film it in any detail, meaning only relatively small areas can be covered at a time. We sought to compare the estimated field of view between transects filmed from different heights above the seafloor. However, this proved impossible as the bottles along the transect were not sufficiently visible to use to set a scale when piloting the drone much more than half a meter above the sea floor. This also means that most litter items will not be reliably visible when the drone is piloted higher above the seafloor than this.

To estimate the full area surveyed, which would be necessary to calculate density of litter on the seafloor, we need not only the field of view, but also the duration of the survey; or more specifically the speed of travel. Given the angle of the ROVs' cameras, however, it was extremely challenging to accurately determine the length of time taken to cover the 10 m long transects. The drones' direction of travel was frequently also somewhat erratic, increasing the variability in time taken to cover the transects. Combined with the significant error associated with calculating the field of view, this resulted in considerable uncertainty regarding the size of the area surveyed. Consequently, we did not attempt to calculate this area and do not show these results.

4. DISCUSSION

The forward angle of the drones' cameras in combination with their wide-angle lenses is a challenge when wanting to map marine litter as the drone must be piloted very close to the sea floor to accurately see objects and only the bottom third of the image gives a good view of the sea floor. Consequently, one can only cover very small areas at a time, and it is not possible to quantitatively assess litter density as the field of view cannot be standardized with sufficient precision. These challenges are only likely to increase if areas with more complex bottoms are sought out. We tested this only over fairly homogeneous areas with silt or sand bottoms. As the drones can only assess depth, and not height above the sea floor, the field of view will be even more variable if the bottom is sloped or uneven, such as over rocky bottom.

The operation of the drones was not always as straight-forward as hoped, and we encountered several technical issues during the field work. Especially delays in streaming of the underwater footage caused difficulties when trying to maneuver the drone close to the sea floor and in complex environments where the drone could easily get stuck. In addition, the battery life of the drones seemed to suffer from the cold conditions in our area. In addition, we also had multiple technical difficulties with the PowerRay and the motor would not always power up.

Combined, these challenges mean that the tested commercial drones are currently unsuitable for quantitative assessments of marine litter densities on the sea floor, even in nearshore coastal waters. These constraints likely apply to any commercial drone with cameras mounted on the front. The drones may, however, be useful for qualitative assessments where the presence/absence of litter and the relative amounts (low, medium, high) identified in relatively small, targeted locations without physical obstacles for safe operation (e.g., kelp or other drone entanglement risks). Such areas may include small harbors. Because of the numerous constraints to their operation, it is our assessment that it is currently not possible to produce an SOP for even qualitative mapping of benthic marine litter. However, this may change as commercial ROVs continue to develop and further testing for mapping purposes is carried out.

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