Neural Network for Automated Identification of Lobster Traps from Aerial Surveys

Global Ghost Gear Initiative

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Index

Glossary & Acronyms

MPA- Marine Protected Area

UAV- Unoccupied Aerial Vehicle

NN- Neural Network

IoU- Intercept of Union

mAP- Mean Average Precision

1. Project Goal

Develop a neural network (NN) to detect lobster traps in images captured by Unoccupied Aerial Vehicles (UAVs). Lobster trapping for Spiny Lobster (*Panulirus argus*) together with Queen Conch (*Strombus gigas*) are the most commercially valuable fisheries within the Turneffe Atoll, each with a specific time frame for legal fishing activity [1].

However, these traps can continue ghost-fishing or ensnaring fish that enter, resulting in damage to the marine ecosystem by directly reducing the numbers of reef fish & in time affecting economic value of fishing areas. Shallow water habitats are most used for lobster fisheries in the Turneffe Atoll, therefore these are the areas of focus in this study [2].

Additionally, active fishing traps can be difficult to locate and are often deployed in known protected areas, this tool would allow for more effective management of Marine Protected Areas (MPAs) in order to prevent the use of illegal fishing activity.

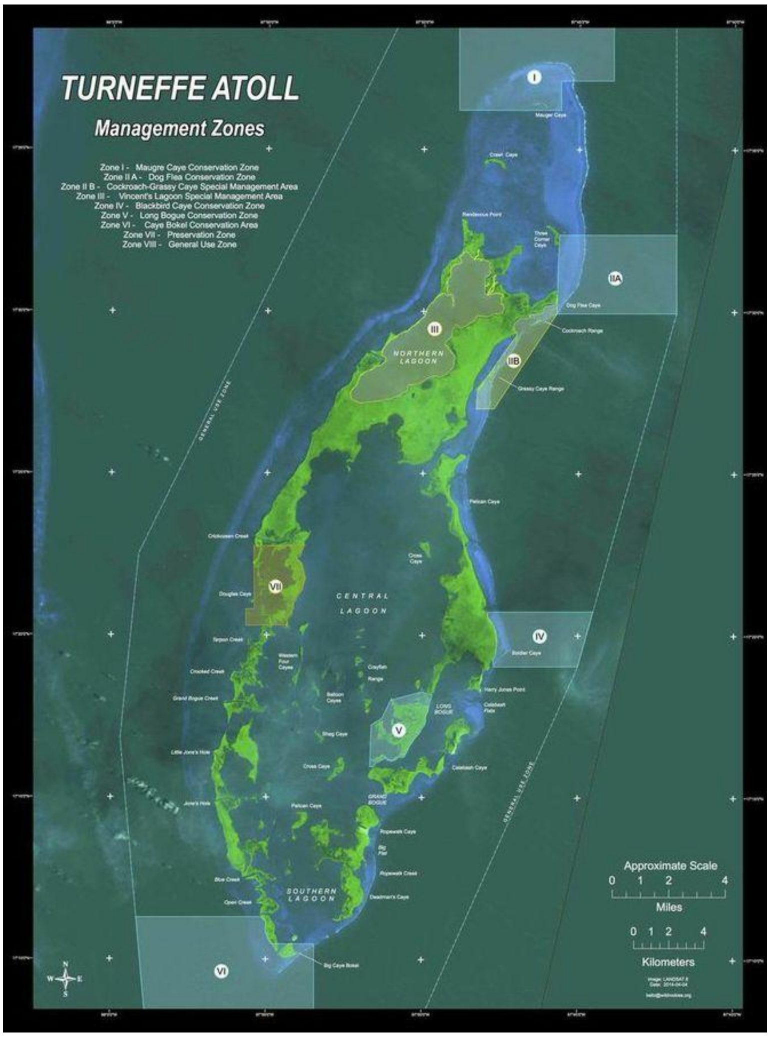

Figure 1- management zones Turneffe Atoll Marine Reserve (TAMR), broken down into zones for Conservation, Special Management, Preservation and General Use.

This analytical tool would allow for the assessment of trap-use at large scale throughout areas of interest, in order to monitor the extent of lobster trapping both within and outside the fishing season. This technique can also be used to reduce the resources allocated to surveying this and other marine protected areas (MPAs) by tackling this widespread issue on a more targeted and efficient basis.

Figure 2- lobster traps (on the left) for Caribbean Spiny Lobster (*Panulirus argus*) in storage on land while the season is closed, and Queen Conch (*Strombus gigas*) being butchered post capture (on the right).

2. Origin of Images

Melissa Schiele, at the time, Research Associate , Dr Tom Letessier, Research Fellow, from the Zoological Society of London (ZSL), and Sarah Keynes from the Marine Management Organisation (MMO), a UK government department, were invited by the Turneffe Sustainability Association (TASA) to conduct aerial surveys as part of a wider project addressing illegal fishing in the area in the Turneffe Atoll Marine Reserve (TAMR). Survey flights were conducted using a water landing fixed-wing drone, built by Aeromao, a Canadian-based UAV company [1].

In total, twenty-four transects were flown over three weeks. Primarily, this project focussed on surveying for illegal fishing activity and training of TASA staff to conduct UAV surveys. Subsequent output included land use change within the marine reserve, assessing boat movement in restricted areas and detection of rubbish and discarded fishing gear, which included lobster traps [1].

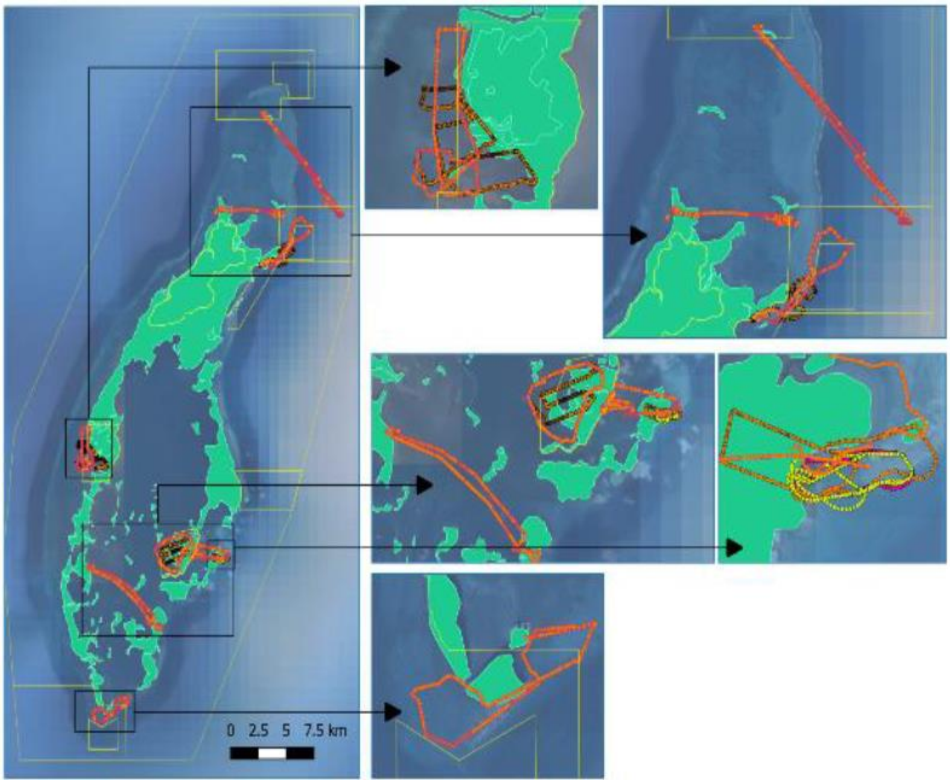

Figure 3- Locations of survey areas across the Turneffe Atoll Marine Reserve (TAMR), indicating the twenty-four transects flown during the course of the study [1].

Imagery was collected during the course of this study, using a Sony RX0 nadir camera with 20mp, with the UAVs nadir camera set to a 10-degree angle of inclination, in order to reduce glare from water surface reflectance [1].

3. Economic and ecological impacts of lobster trapping in TAMR

3.1 Economic implications of lobster trapping within TAMR

The use of lobster traps has numerous impacts on the local environment and long term implications for fisheries management in the TAMR. There is therefore a strong economic and environmental imperative to manage the use of lobster traps, within this MPA.

Firstly, the TAMR is the second most economically valuable lobster trapping area in Belize, after the Central Region of the country, valued at $BZ 16.4 M nationally in 2016 [3]. In order to protect this resource, patrols are carried out within the TAMR, and the trapping season is closed between 14th February and 13th of June for recovery of local stocks. Trapping activity within this season carries the risk of reducing yields the following year. Considering that Between 2004 and 2009, lobster fisheries fell from 20.4% of national deliveries to 6.2% and has continued to fall since, conserving existing lobster stocks are vital for the continued use of this resource, and the economic viability of the industry [2].

Based on a questionnaire survey of lobster fishers operating within the TAMR, there was consensus among participants that the catching of undersized lobsters is a serious threat to this industry [2]. The monitoring of this activity is vital to limiting reductions in the yield regionally, and the Belize Coast

Guard is working with TASA to actively enforce these limits regionally. As recently as June 2021, a fishing camp operating within the TAMR during the closed season was searched, to reveal one hundred and eighty-nine lobster tail, thirty-four of which were revealed to be under-sized and soft-shelled [7]. This enforcement activity is indicative of the value of the fisheries locally, and the need for fine-scale management of this resource to protect fishing the fishing industry within the TAMR.

Figure 4 - one hundred and eighty-nine lobster tails, seized by Belize Coast Guard and the TASA in 2021, including from thirty-four juveniles [7].

3.2 Ecological implications of lobster trapping within TAMR

The reduction of lobster populations results in a decrease in ecological services provided by this species locally. Lobsters function as mid-trophic level consumers, transferring energy from primary producers and primary consumers to apex predators [4]. In the seagrass-dominated areas within the TAMR where lobsters are targeted, these species play a vital role in transferring energy further up trophic levels. Steep reductions in these species can therefore have a strong negative impact on ecological functioning within this ecosystem, by reducing nutrient availability to predators responsible for keeping larger fish populations in check [4].

In addition to reductions of *Panulirus argus* directly, bycatch from traps can have an additional impact on this species within this ecosystem. No literature could be found on bycatch rates within lobster traps deployed in the Turneffe Atoll. However, a study of 4940 lobster traps in the similar climatic region of the Gulf of California showed that 15% of trap contents were discard species, covering a wide variety of taxa, including Octopus, sea snails, elasmobranchs, finfish and cormorants [5]. This indicates that excessive use of lobster traps within the TAMR may contribute to biodiversity loss within the MPA and is worthy of continual monitoring to reduce these knock-on effects. Ghost fishing by derelict traps may also have an impact on local fish and lobster populations, as once animals are caught inside, their bodies serve as bait to attract new animals, in a process known as self-baiting, the removal of abandoned traps is therefore highly important [6].

As well the direct impact of trapping, movement of traps on the seafloor can also have negative impacts on the benthic habitat, as movement by dragging was shown to cause damage to soft coral species, when studied in the Gulf of California [5]. The impact of this movement can also be seen in figures 5 and 6. Finally regional declines in lobster catch numbers have been attributed to illegal dredging, mangrove clearance and construction activities as the primary causes [2].

4. Detectability of lobster traps in aerial imagery

In aerial surveys, lobster traps were detectable form their outlines in shallow water, based on the distinctive straight edges of the trap. The key difficulty in identifying traps was distinguishing between the devices themselves and the clear sandy patches where they had been placed previously. Constructed from palm timber, the pale colour of the traps creates a contrast between the seafloor and the seagrass which dominates the surrounding area, allowing us to identify the traps against the sea floor. Once a trap is moved, for inspection of contents, or dragged by the fisher to ensure more precise placement [5] the sandy bottom of the seafloor is exposed, creating a patch of similar dimensions to the original trap. Distinguishing between these patches and actual lobster traps was vital for the functioning of the NN. However, the presence of these distinctive patches provides evidence of past trapping activity, which may be useful for monitoring purposes within the TAMR, especially if the time taken for disturbed patches to be re-colonised by seagrass can be quantified.

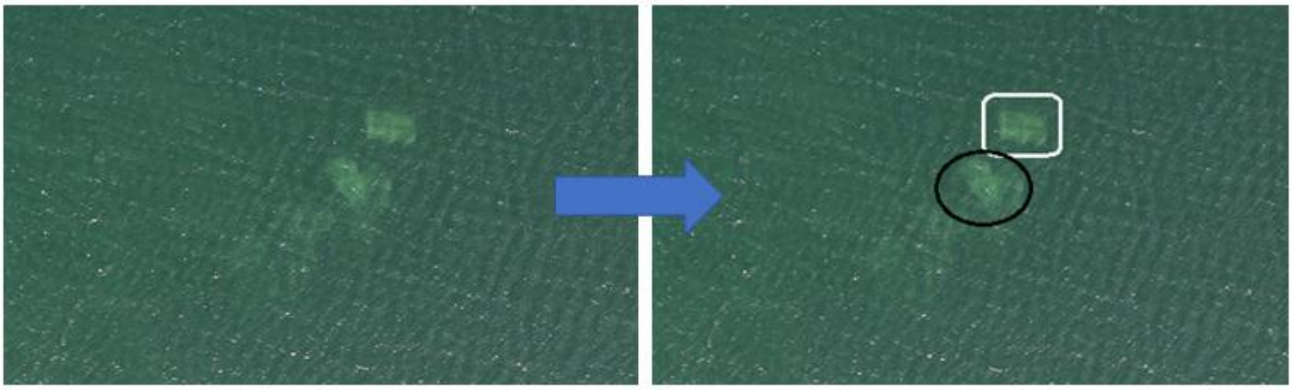

Figure 5- shows a lobster trap, in the white rectangle, in contrast with the patch of seafloor exposed by the movement of a trap previously.

5. Neural network training process

The model was trained using RGB images derived from the aerial survey of sites within the Turneffe Atoll Marine Reserve. In total 4,900 RGB images were analysed for the presence of traps, from which 133 images were found to contain lobster traps.

Once images had been selected from the dataset, they were uploaded to our account on Darwin V7 Labs, where areas of the images containing objects of specific interest can be isolated and used as training data for the algorithm. Once all images were reviewed, the image data was extracted from pixels within the outlines of the objects used in the training of an NN.

Contrast & lighting was reduced in each image to produce a secondary training set of data, in order to simulate traps found at greater depths, with less distinguishable outlines due to low light and higher turbidity. This way, the network was trained using images in which the traps were progressively more difficult to identify. As a result, the algorithm was developed using image sets is capable of identifying lobster traps in low light conditions or deeper water.

6. Neural network model performance

Model 'Belize-ZSL-GGG-LT-2-Inst-Seg-24-03-22was trained using 219 images.

The model has a Loss of 0.69. The Loss function is a metric used to define how far off the model is from the targeted output, or the error between the target value and the output from the model.

This model generated a 92.57% mean average precision (mAP) for a 50% Intercept of Union (IoU) & 59.35% mAP for a 75% IoU.

To break this down, the mAP refers to the Mean Average Precision of the model, calculated by calculating the average between the 'Precision,' consisting of the true positive predictions + false positive predictions and the 'Recall,' consisting of the true positive predictions + false negative predictions derived from the model.

The IoU refers to the amount of area on the image taken up by the target in question (in this case the Z trap), that is covered, or intercepted by the target identified by the algorithm. The 59.35% mAP for a 75% IoU is an encouraging result, as this means in 59.35% of cases where lobster traps were identified in the images, the area identified by the algorithm covered a total of 75% of the lobster trap. When the IoU was reduced to only 50% of the Z trap area, the algorithm performed at 92.57% mAP- meaning that the algorithm covered at least 50% of the traps every single time.

The NN was also capable of distinguishing between traps and areas of cleared seafloor, adjacent to the traps, at least in the dataset used for training.

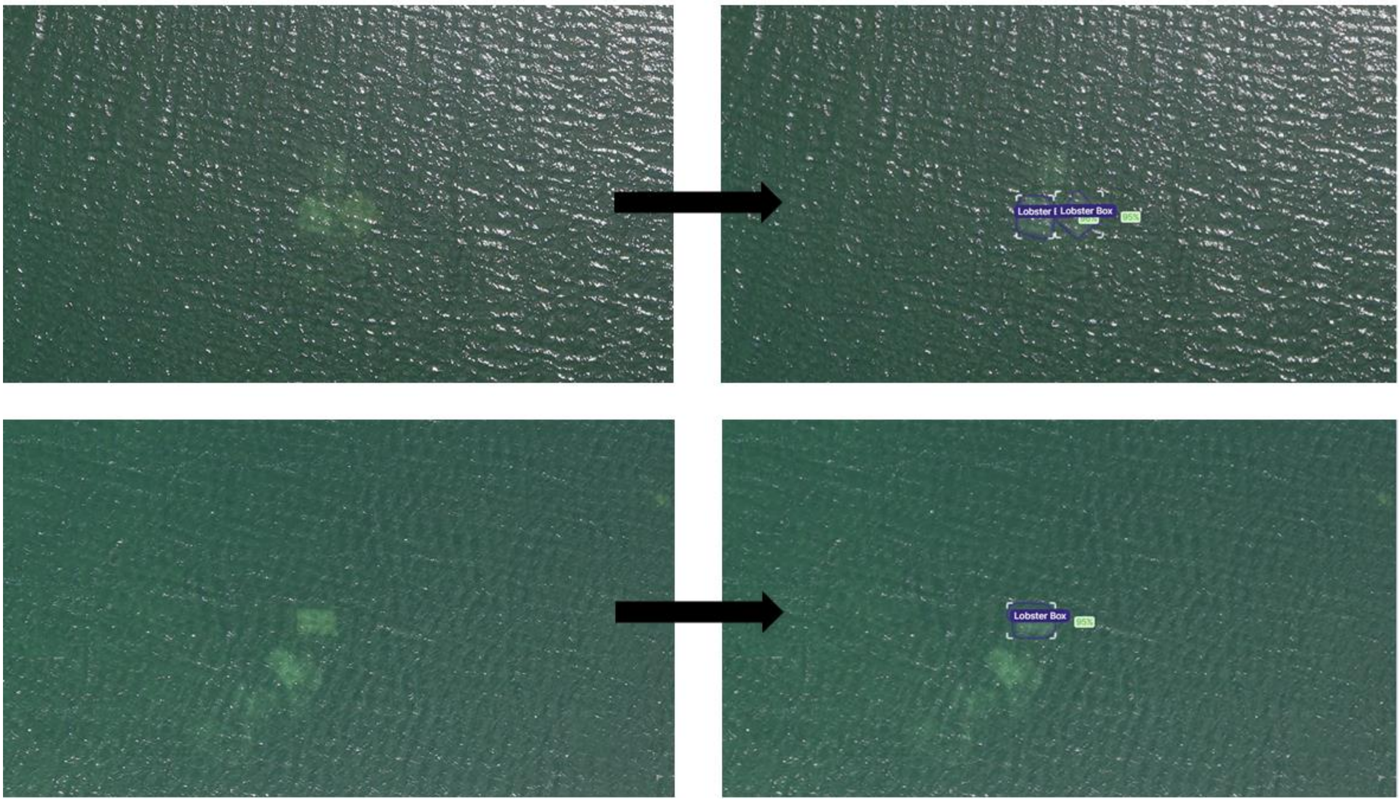

Figure 6- an image containing a lobster trap, identified by the NN produced in this study. The neural network has detected two different sections of the trap and provides a 'bounding box' with coordinates for the location of the net within the image. Note the cleared areas of seafloor outside of the bounding box that were not identified as traps, due to differences in outline resolution.

7. Use of neural network in future lobster trap surveys

The NNs developed in this project can be accessed using the API provided in the Darwin V7 labs, which we can provide in numerous formats (CLI, Python, Javascript, Shell and Elixir).

The NN can be used to directly identify Antillean Traps in aerial images of areas being studied for the presence of this fishing gear. Once the API from the NN is set up for the end user, images from aerial surveys can be fed in and those that contain traps will be flagged, with areas containing traps annotated on the image. When a trap is identified, the bounding box will identify the location within the photograph, which in combination with flight data from the drone, can be used to derive the coordinates of the traps for removal.

8. Implications for use of neural network in MPA management

The use of this tool to identify lobster traps in aerial surveys can be applied directly as a management tool for the TAMR, in order to monitor the deployment of traps throughout the MPA. Here are a few important implications that can be derived from the use of this tool.

1. Within and outside of protected areas, traps can be identified through aerial surveys. Considering that lobster traps in the TAMR are mostly deployed in shallow water, in or near to seagrass meadows, a higher proportion of traps will be visible than if they were deployed in areas dominated by coral reef.
2. Traps identified during the lobster trapping season can provide useful information as it pertains to the level of fishing activity with the TAMR. When the season is closed, this tool can be used to highlight illegal lobster fishing activity, and to locate lost or abandoned traps that may still pose a threat to wildlife through self-baiting [6].
3. By providing spatially-explicit data on lobster trapping activity via the identification of individual traps, the fisheries department can verify information provided by fishing camps operating within the TAMR. This would be to the benefit of TASA, TAMR and the Belize Coast Guard, as the provision of information regarding sustainable fishing practices within the region would lead to more efficient use of resources in regard to law enforcement and increase transparency between fishers and regulatory government bodies.
4. Given continued decline in yield from lobster fisheries within the Turneffe Atoll, information that can used to calculate fishing activity within the region may be useful to the fisheries department, in terms of comparing the numbers of traps deployed, to the number of licenses issued within the season. If trap numbers within the season are considered to be higher than expected, then information necessary to re-evaluate the number of licenses issues is available to necessary bodies.
5. Within the closed season, numbers of lost or abandoned traps can be evaluated, by cross-referencing locations with information from the Fisheries Department and Belize Coast Guard regarding illegal trapping activity. Once it can be safely assumed that no illegal fishing activity is not taking place within a given area, a correction factor for aerial surveys can be derived, based on the number of lost or abandoned traps within randomly selected areas across TAMR.
6. This correction factor can be used to determine whether lost traps are contributing to the decline in lobster yields regionally. This will have important implications for the management of trapping activity within the TAMR and may contribute to a more actively monitored and sustainable ecosystem for fishers.

7. Finally, large scale aerial surveys by UAV will yield more imagery data on the diversity of ALDFG present within the TAMR, which can be applied to make more complex recognition algorithms, increasing the accuracy of detection of gear that may cause harm to the marine environment.

9. Acknowledgements

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