

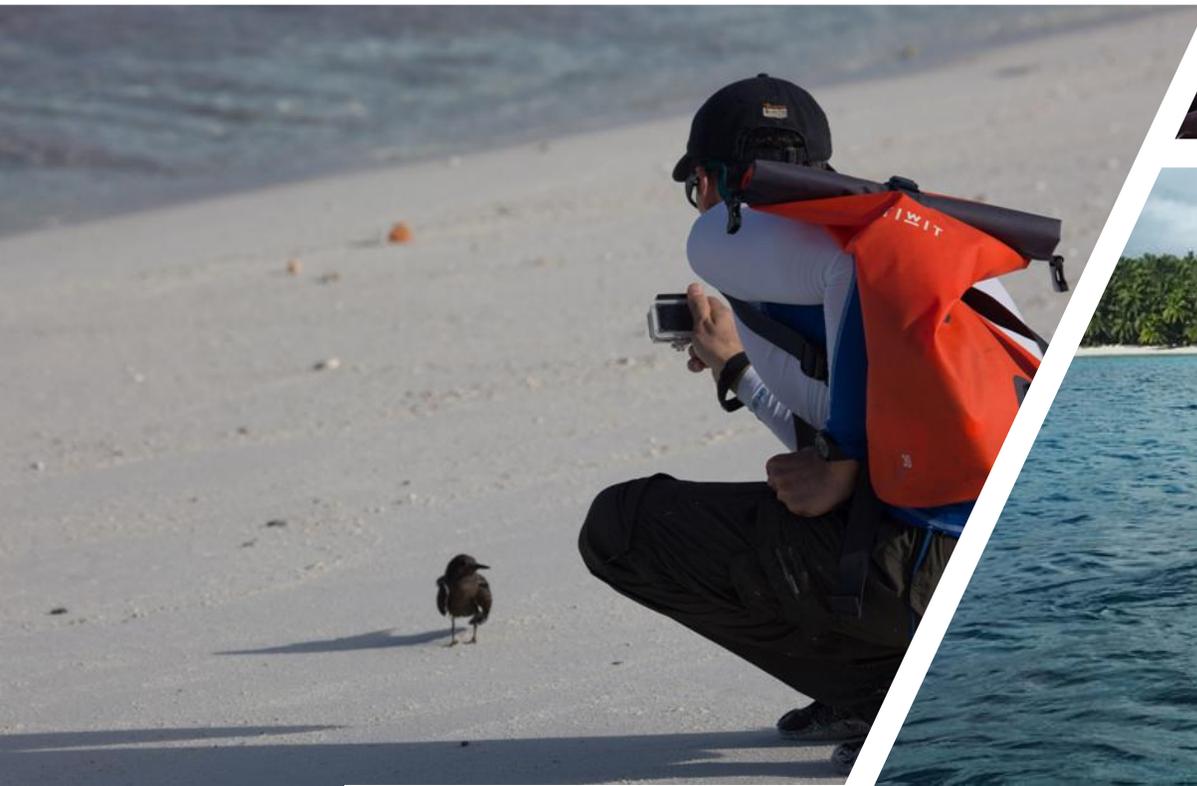
Development and assessment of a fixed-wing amphibious UAV for marine megafauna surveys and enforcement



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OVERVIEW

What's the issue? Why do we think UAVs are the answer?

Where shall we test the UAV?

How can we quantify success?

Aims and Objectives

The UAV design

Flying UAVs in the open ocean. What they don't tell you...

Analysis and Results

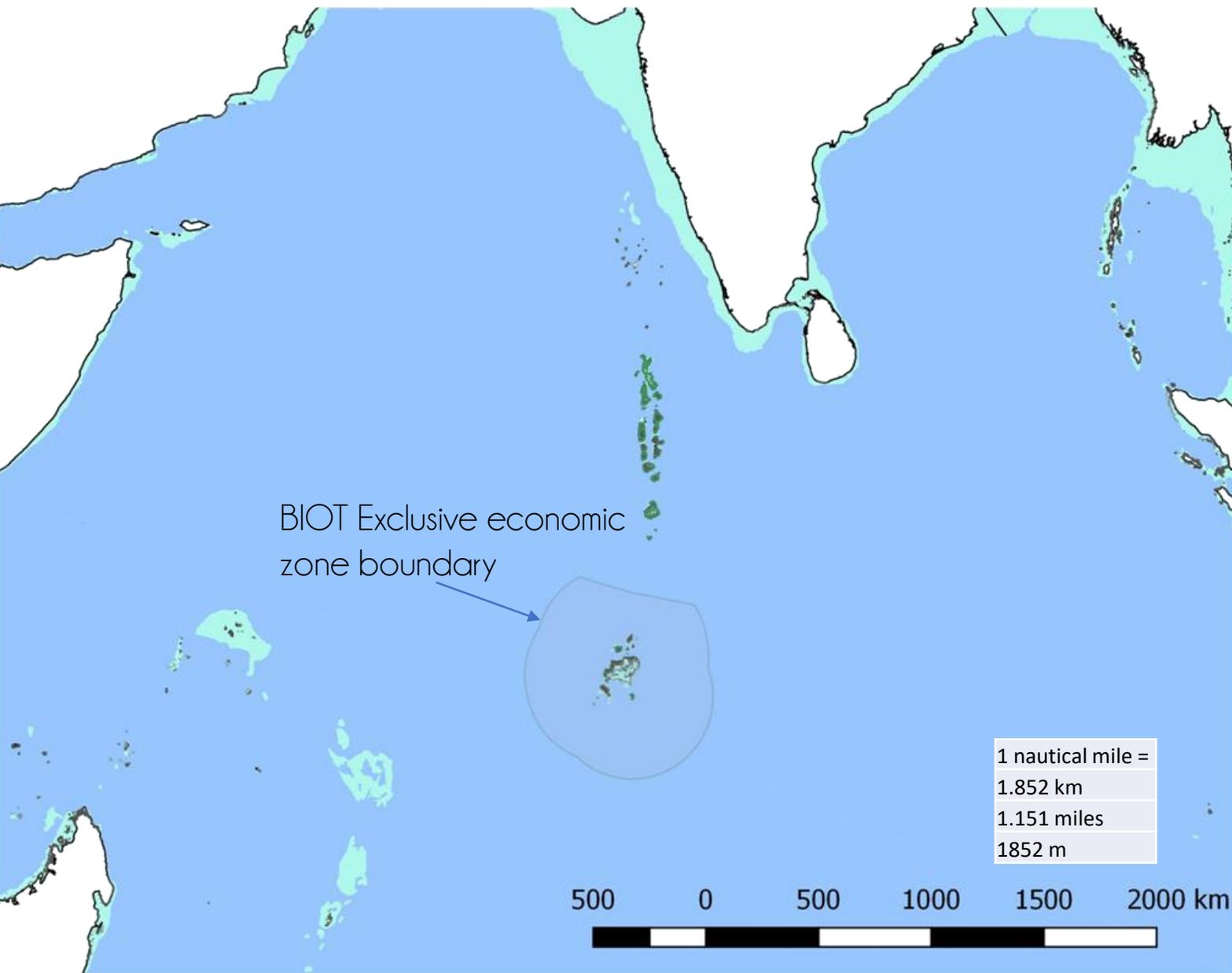
Moving forward



US Dept of State Geographer
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Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Imagery Date: 12/14/2015

LARGE MARINE PROTECTED AREA MANAGEMENT



- The British Indian ocean territories (BIOT) marine protected area (640,000 km²) is an example of a very large marine protected area set up in 2010 by the British government and is a 'no-take' zone, where no fishing is allowed
- Current visual ecological monitoring include intermittent dive transects and beach based surveys
- Current enforcement methods involve the patrolling of the BIOT vessel
- Active science research influencing management

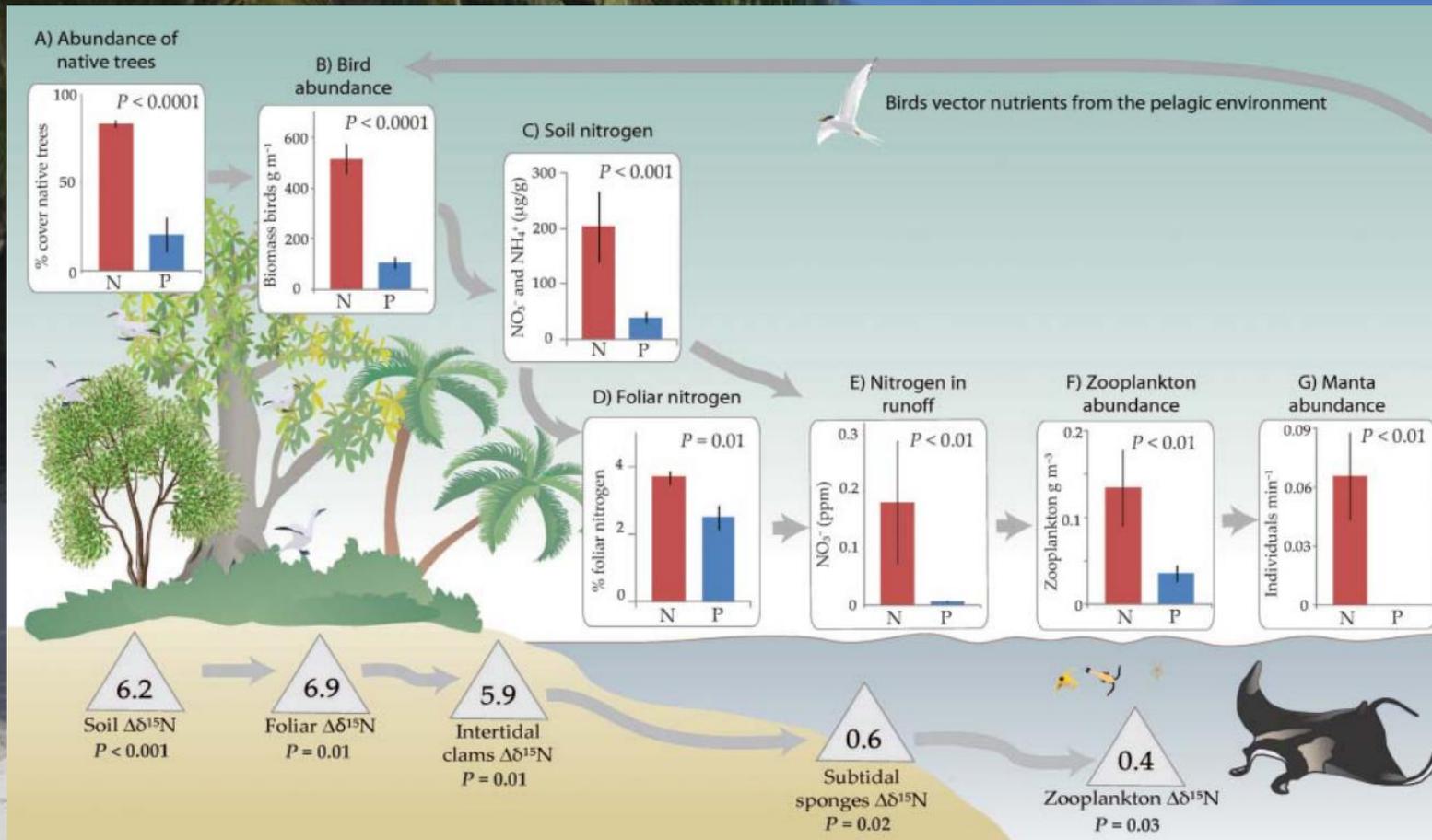




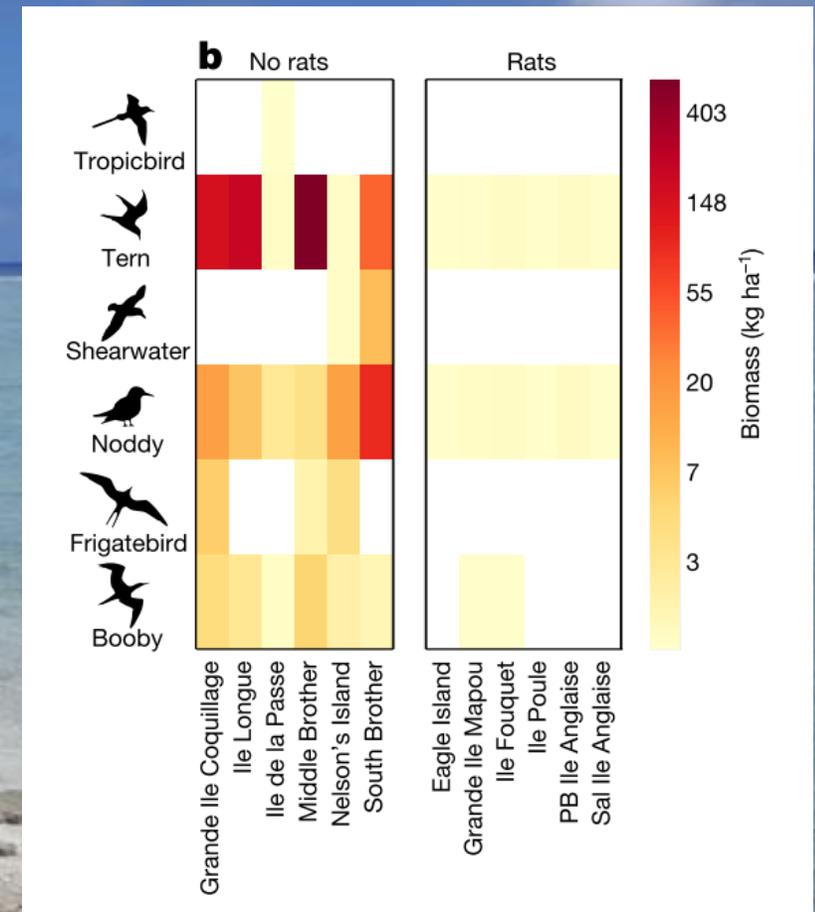
Photo credit Jude Brown SFPO



BIRDS, NUTRIENT FLOW AND RATS



(McCauley et al., 2012)



(Graham et al., 2018)



Photo credit Claire Collins

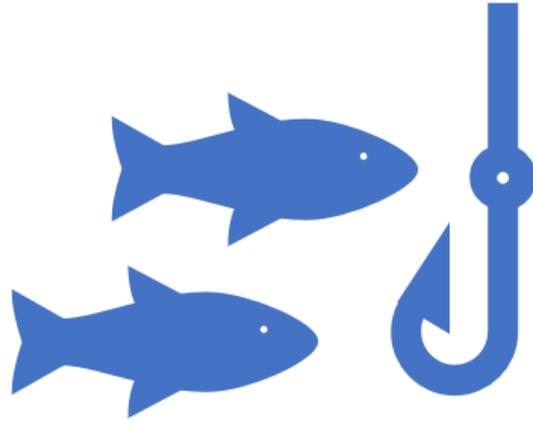
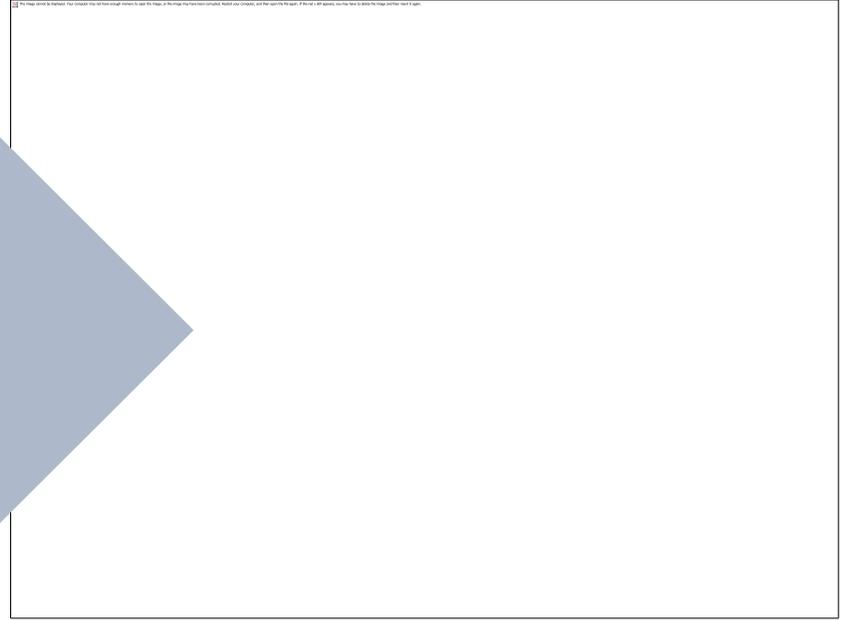


Photo credit Claire Collins



IUU (ILLEGAL, UNREPORTED AND UNREGULATED) FISHING AND ENFORCEMENT OF THE RULES

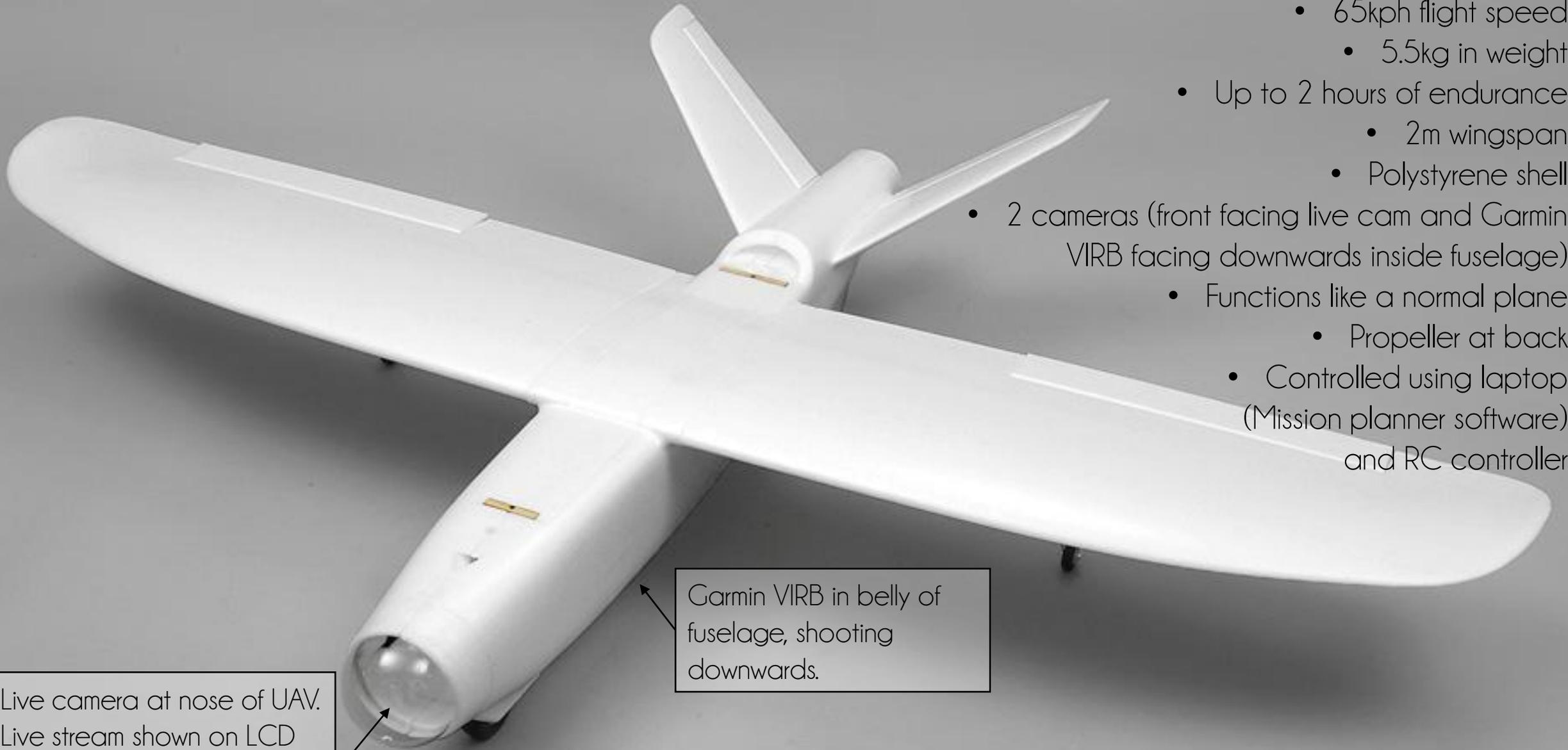


AMPHIBIOUS UAVS - OBJECTIVES

- Conduct the first megafauna survey using UAV within the BIOT MPA.
- As a demonstration of the UAV's suitability for megafauna surveys, test whether there is a difference between relative abundances of megafauna between islands with rats on them and islands with nesting birds.
- To assess the application of this UAV as a surveillance tool and to highlight future recommendations for its use.

Fixed-wing Amphibious UAV

- 65kph flight speed
 - 5.5kg in weight
- Up to 2 hours of endurance
 - 2m wingspan
 - Polystyrene shell
- 2 cameras (front facing live cam and Garmin VIRB facing downwards inside fuselage)
- Functions like a normal plane
 - Propeller at back
- Controlled using laptop (Mission planner software) and RC controller



Live camera at nose of UAV.
Live stream shown on LCD
screen with pilot.

Garmin VIRB in belly of
fuselage, shooting
downwards.

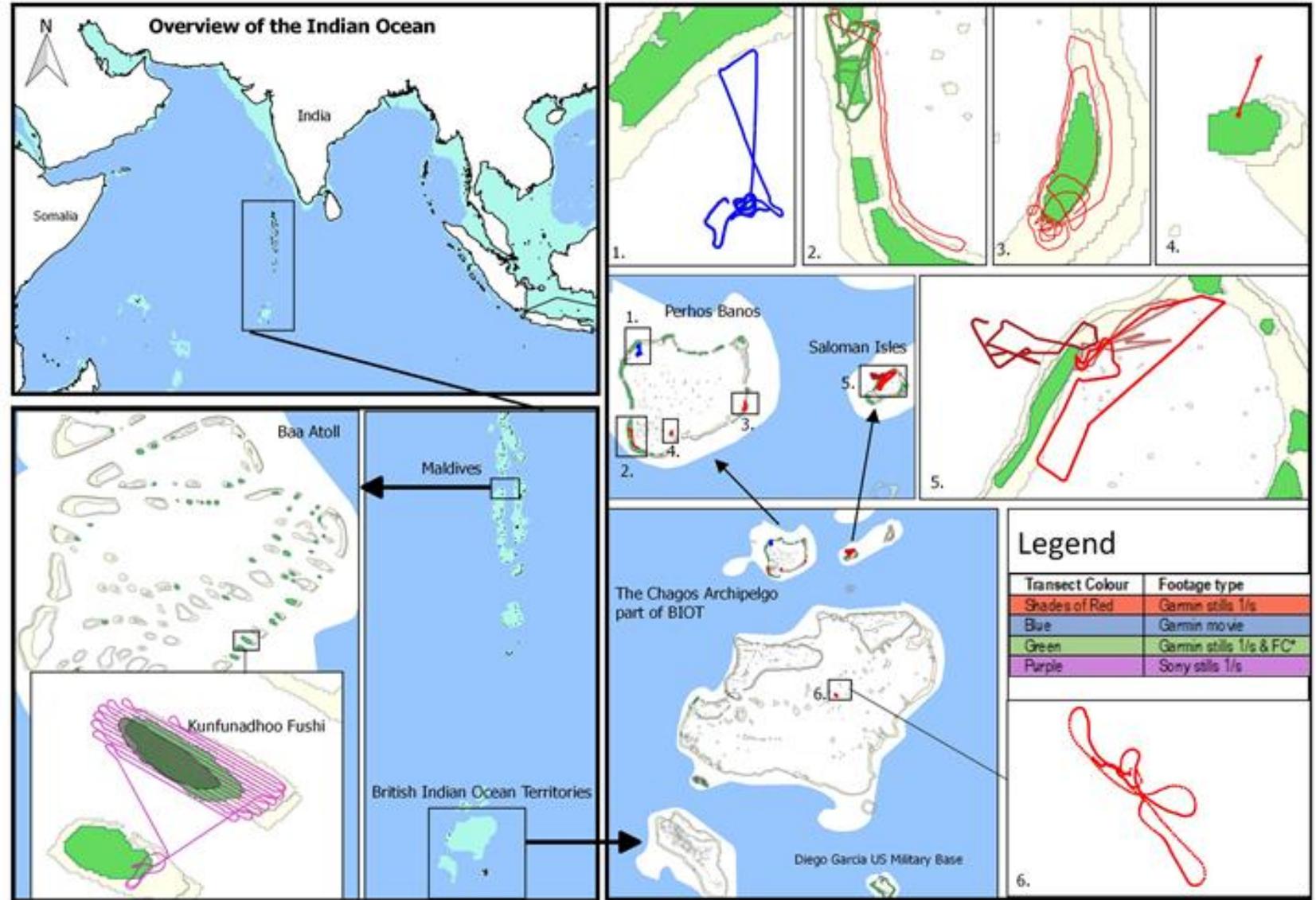




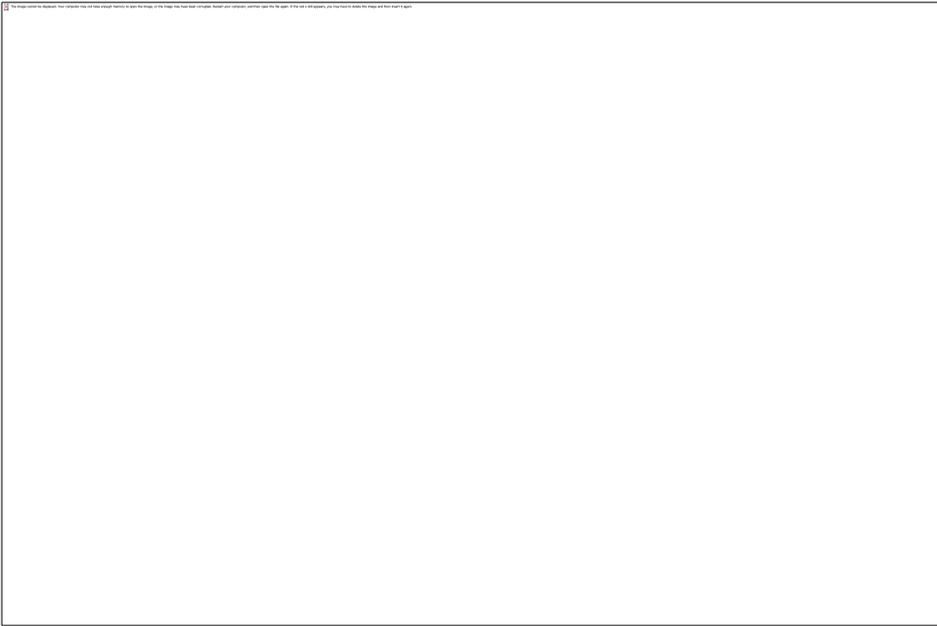


METHODS

- In the BIOT, two atolls of Perhos Banos and Saloman were targeted as part of a dedicated marine research expedition exploring connectivity between bird populations and coral reefs, in May 2018
- Sampling on the Great Chagos Banks were conducted as part of UAV enforcement trial (June 11th-23rd)
- In the Maldives, the survey was conducted as part of an island mapping project on behalf of a resort.



Transects flown in the Maldives and the British Indian Ocean Territories. Flights are presented as coloured transect lines. *FC refers to the Front camera system which records film. Map made using QGIS v 2.8.1





YOU CAN NOT CONTROL THE WEATHER

1. Winds exceeding 20 knots which can bring the UAV down as batteries fully drain mid-air and the motor overheats
2. Logistical constraints, meaning the crew were not always available for UAV retrieval
3. The location of the vessel in proximity to islands due to the Captains ability to anchor safely
4. Mechanical and/or electrical failure of the UAV which needed constant fixing

ANALYSIS

IMAGE ANALYSIS

All images were individually inspected by the principle investigator (12,000+ images).

Images were visually enhanced to aid in animal detection.

Metadata was extracted and mapped in QGIS v2.8.

STATISTICAL ANALYSIS

Double counting was accounted for by retaining every 5th image.

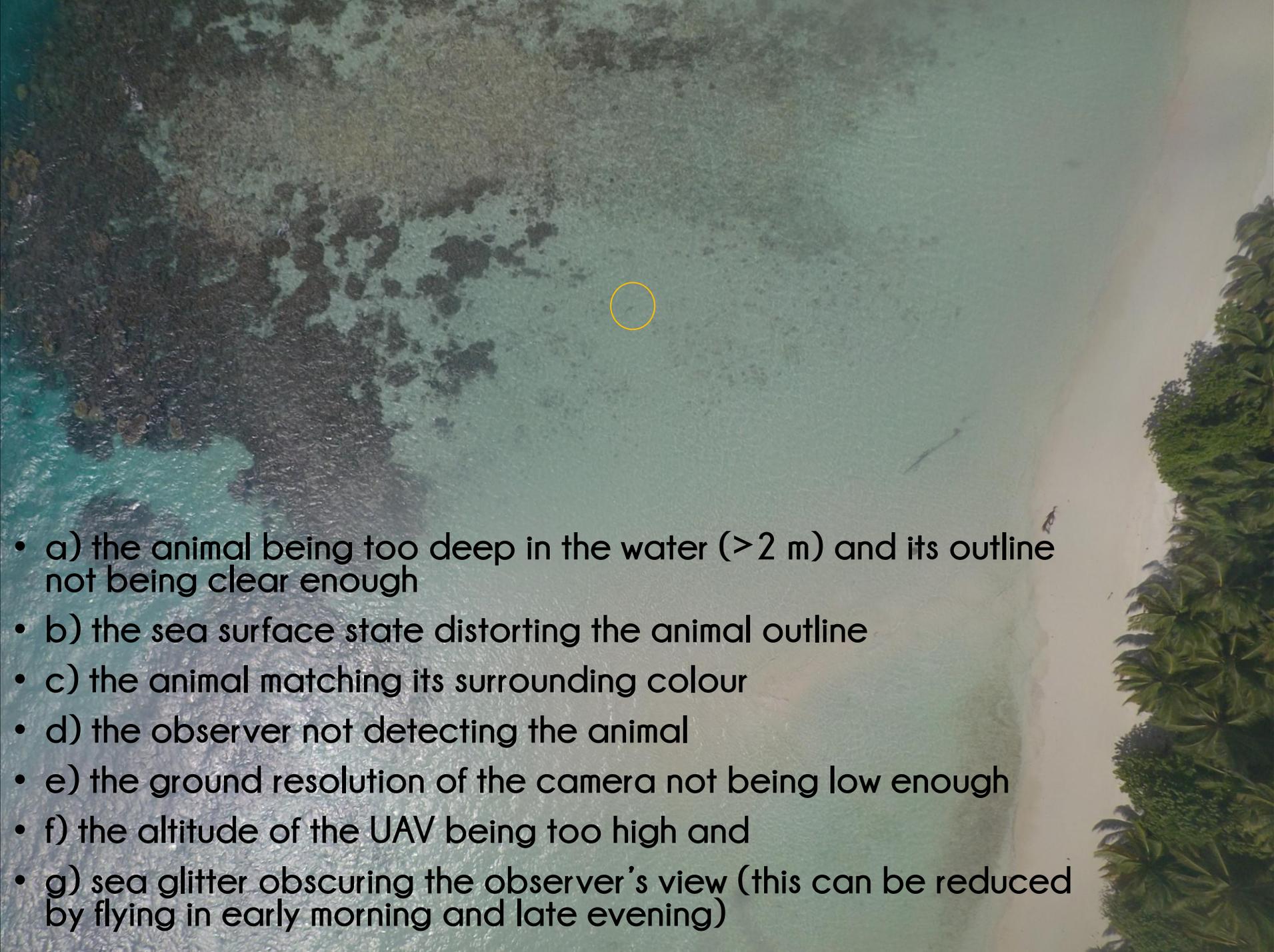
GLMMs (generalised linear mixed models) were used to see what the effects of rats or non rat islands were on response variables (e.g. Individual species or grouped relative abundance or occurrence)

IUU DATA ANALYSIS

The MMO produced a set of technical and operational criteria (amended by us at ZSL) in order to ascertain the UAV's effectiveness as a tool for enforcement.

RESULTS

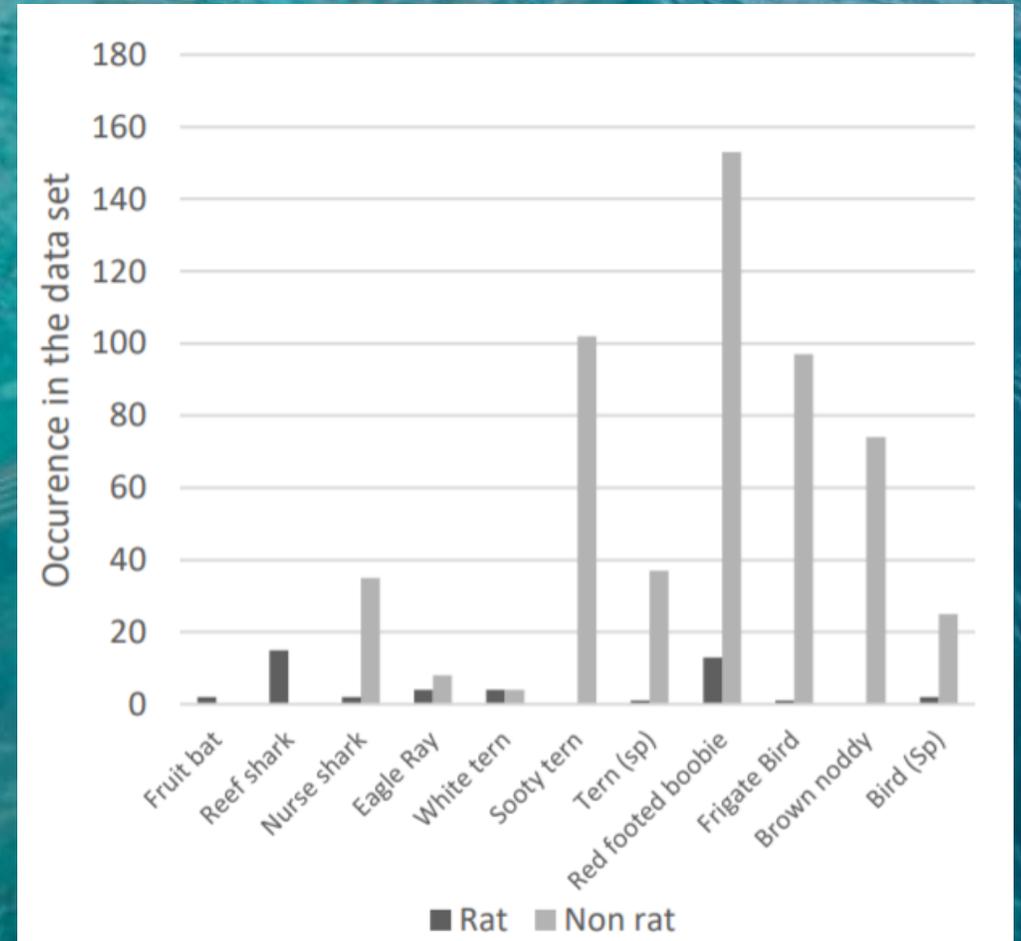
RESULTS



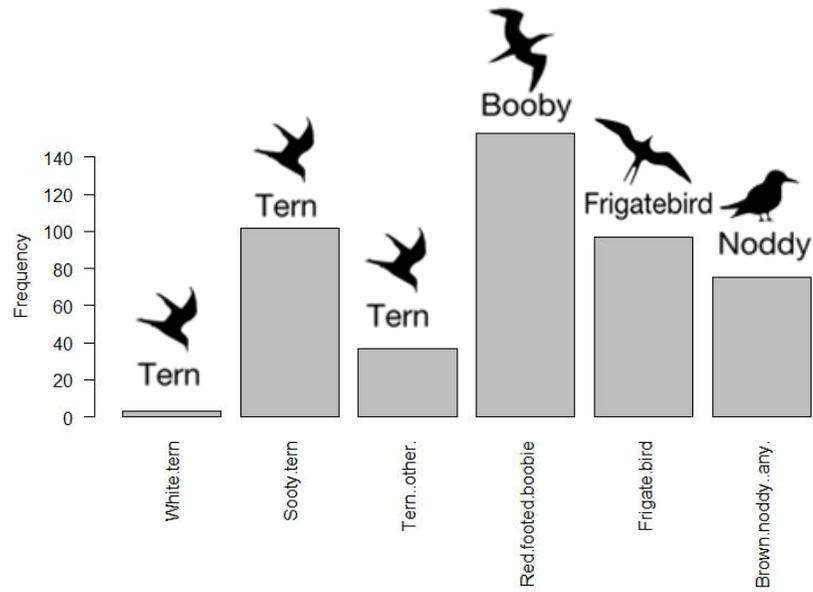
- a) the animal being too deep in the water (> 2 m) and its outline not being clear enough
- b) the sea surface state distorting the animal outline
- c) the animal matching its surrounding colour
- d) the observer not detecting the animal
- e) the ground resolution of the camera not being low enough
- f) the altitude of the UAV being too high and
- g) sea glitter obscuring the observer's view (this can be reduced by flying in early morning and late evening)

ECOLOGICAL RESULTS SUMMARY

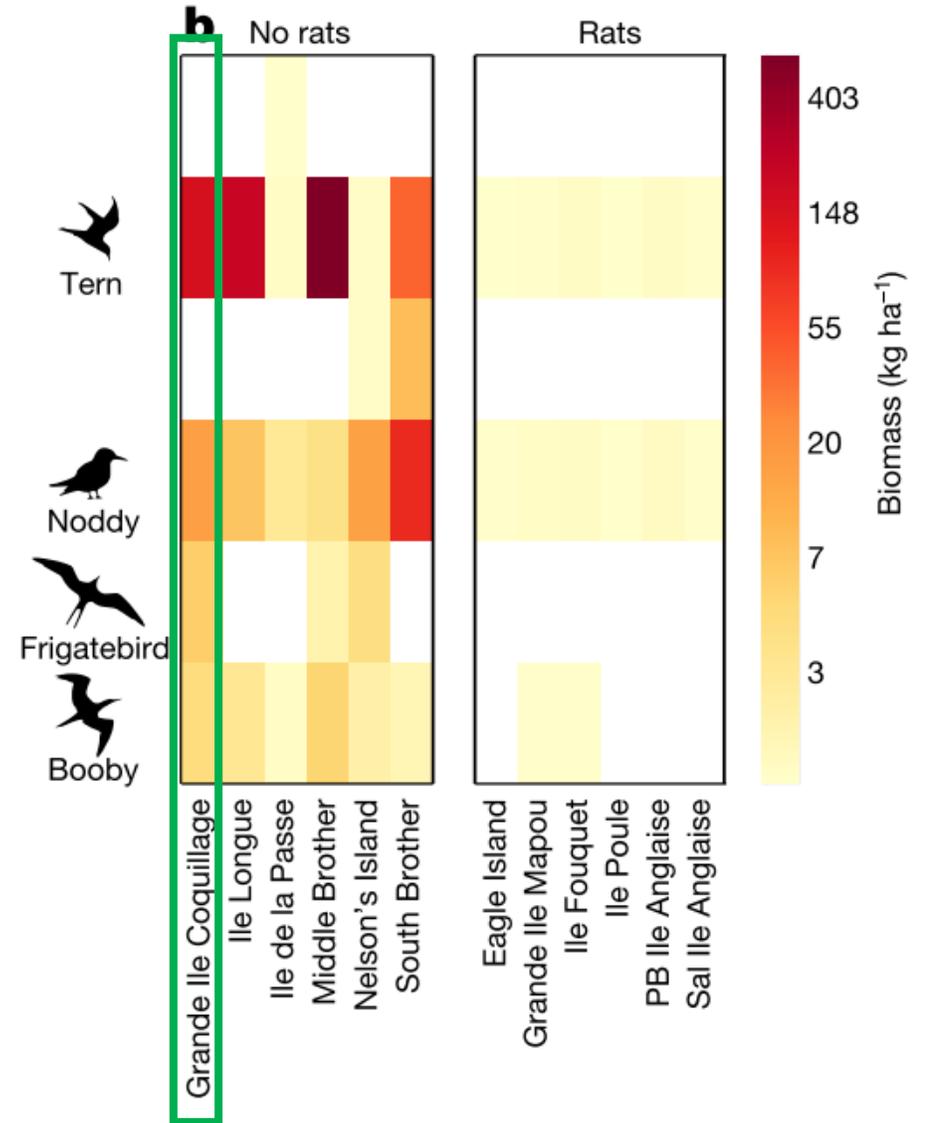
- 12,000 images over 12 flights, resulting in 2365 after retaining every 5th
- Red footed boobies appear in most of the images (binary occurrence i.e. is it in an image, or not)
- Sooty terns relative abundance was the highest
- Using $N \sim RNR + LC + (I)$
 - For total abundance as a response, the effect of rat or non-rat islands was significant ($\text{Pr}(\text{Chi}) = 0.03281$) as it was for total richness, ($\text{Pr}(\text{Chi}) = 0.01631$)



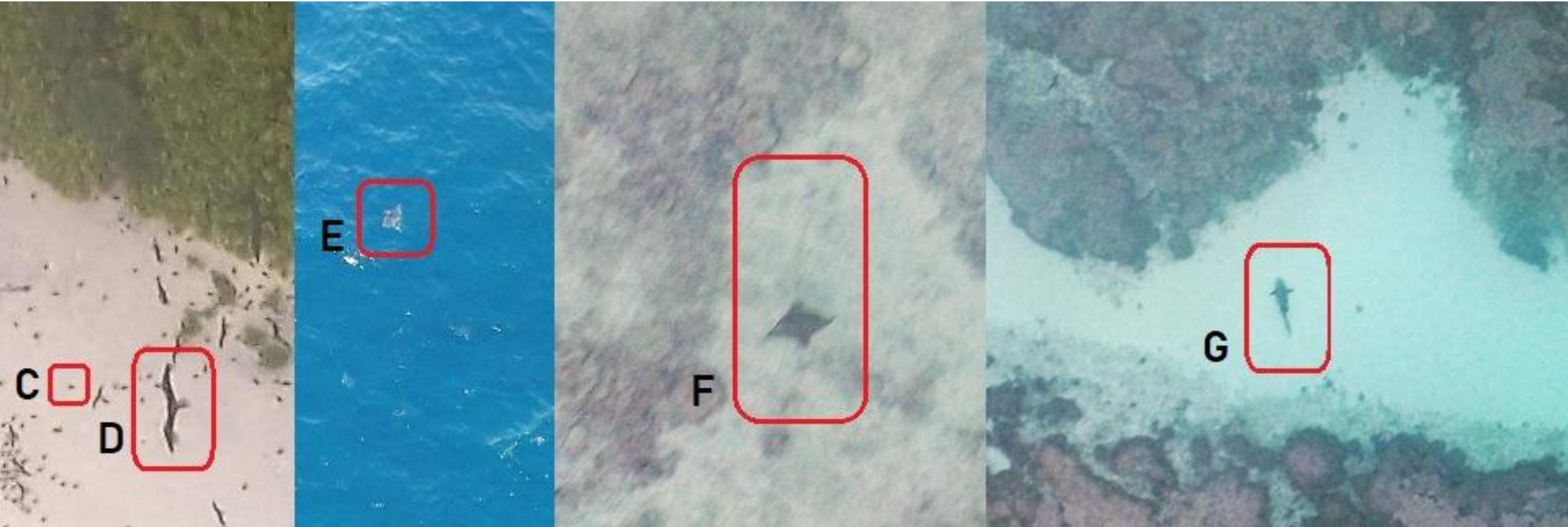
UAV detected *species richness* for Grand Ile Coquillage



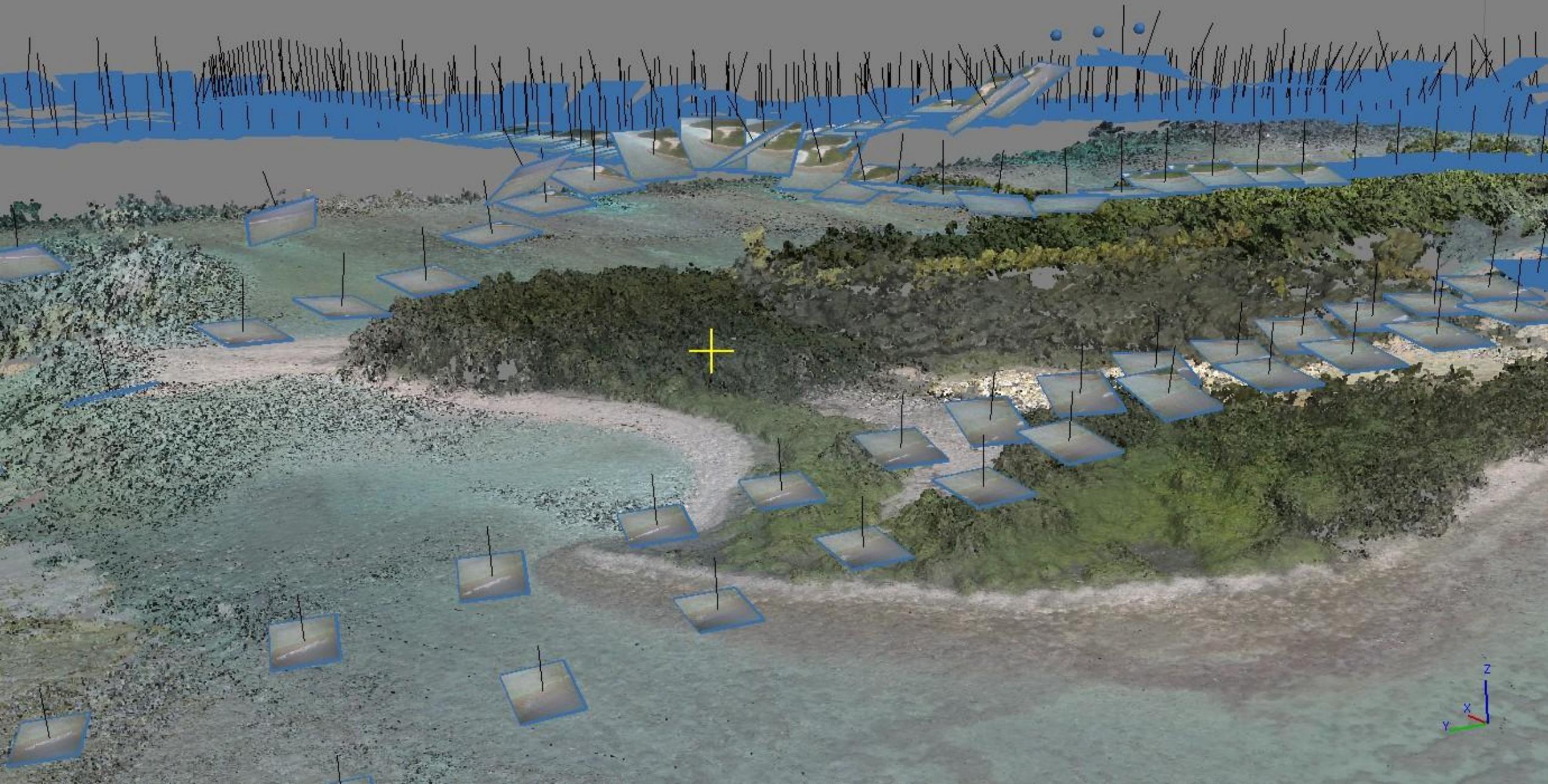
Definition; Species Richness: How many different species there are, in a specific area. It does not take into account numbers of individuals (i.e.. number of sooty terns).



Identification to species level is possible

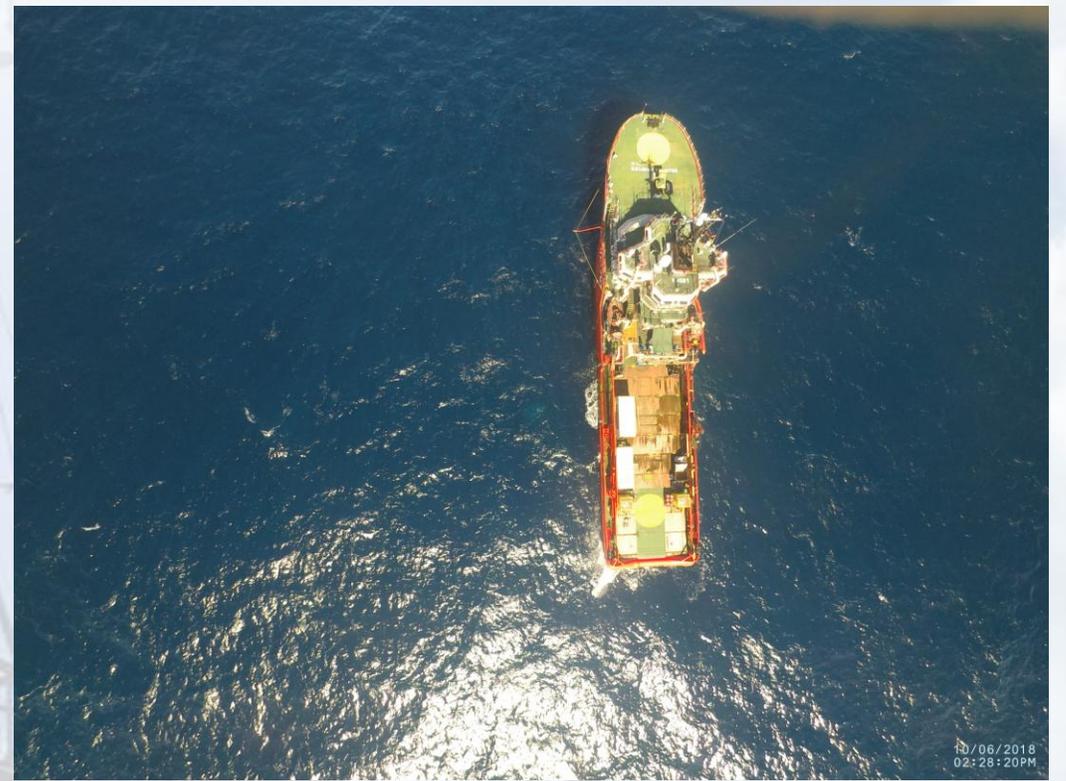


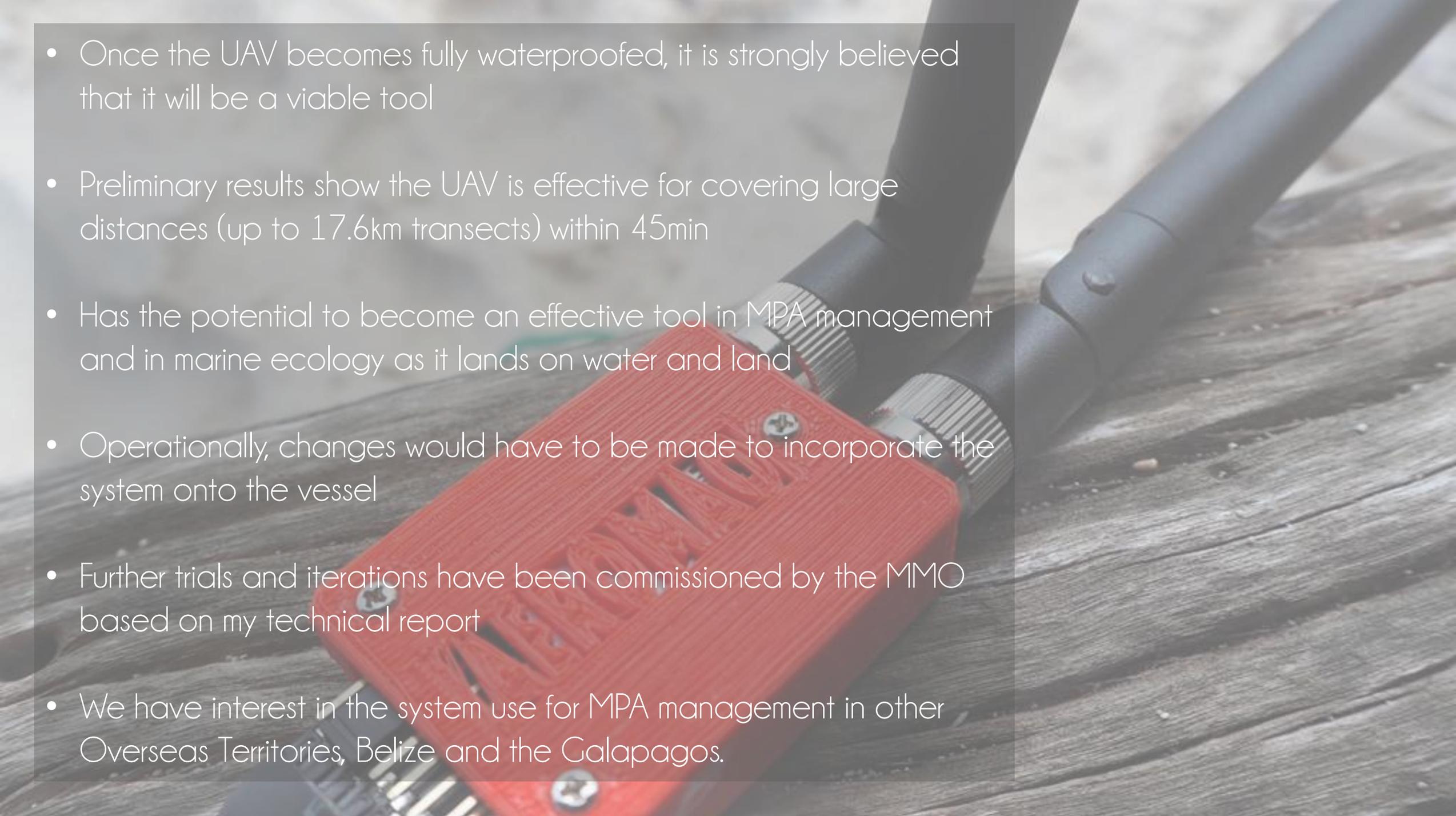
C Sooty tern, **D** Frigate bird, **E** Reef manta ray, **F** Spotted eagle ray, **G** Tawny nurse shark



ENFORCEMENT RESULTS SUMMARY

- 8 flights were flown
- Unable to fly further than required 12 nautical miles in FBWB mode
- Garmin VIRB camera unable to detect the lettering on the sides of the boats
- Was able to clearly detect fishing line and buoys behind a small 8 m vessel, at 65 m altitude which is essential for the enforcement in prosecution procedures



- 
- A close-up photograph of a red, textured electronic device, possibly a sensor or data logger, with a black cable attached. The device is resting on a wooden surface. The background is blurred, showing more of the wooden surface and some green foliage.
- Once the UAV becomes fully waterproofed, it is strongly believed that it will be a viable tool
 - Preliminary results show the UAV is effective for covering large distances (up to 17.6km transects) within 45min
 - Has the potential to become an effective tool in MPA management and in marine ecology as it lands on water and land
 - Operationally, changes would have to be made to incorporate the system onto the vessel
 - Further trials and iterations have been commissioned by the MMO based on my technical report
 - We have interest in the system use for MPA management in other Overseas Territories, Belize and the Galapagos.

BELIZE

TURNEFFE ATOLL MARINE RESERVE

Belize is situated in central America on the Caribbean coast.

In November, 2012, the Turneffe Atoll Marine Reserve was officially declared.

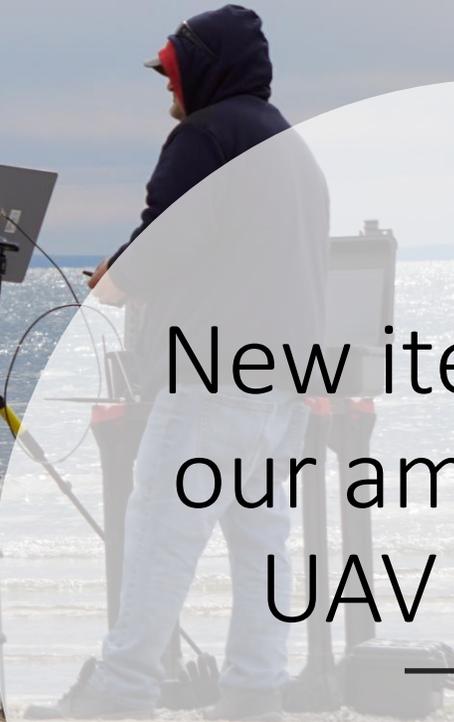
The management team of the reserve want to explore using our fixed-wing amphibious UAV in the fight against illegal fishing vessels.



- Improved cameras
- Fully waterproofed fuselage has already been repeatedly tested in Canada
- Fully salt waterproof servo plugs
- Still lightweight and easy to assemble



New iteration of
our amphibious
UAV is born





Thank you for your attention

With special thanks to Tom and Marcus, the crew of the Grampian Frontier, US Navy, the Royal Marines, BIOT FCO and the Bertarelli Foundation for funding everything.

For more information or any questions, please contact

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McCauley, D. J. et al. (2012) 'From wing to wing: The persistence of long ecological interaction chains in less disturbed ecosystems', Scientific Reports, 2.



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