Surveying marine debris in the Great Pacific Garbage Patch utilizing ship-launched drones and beyond-visual-line-of-sight operations

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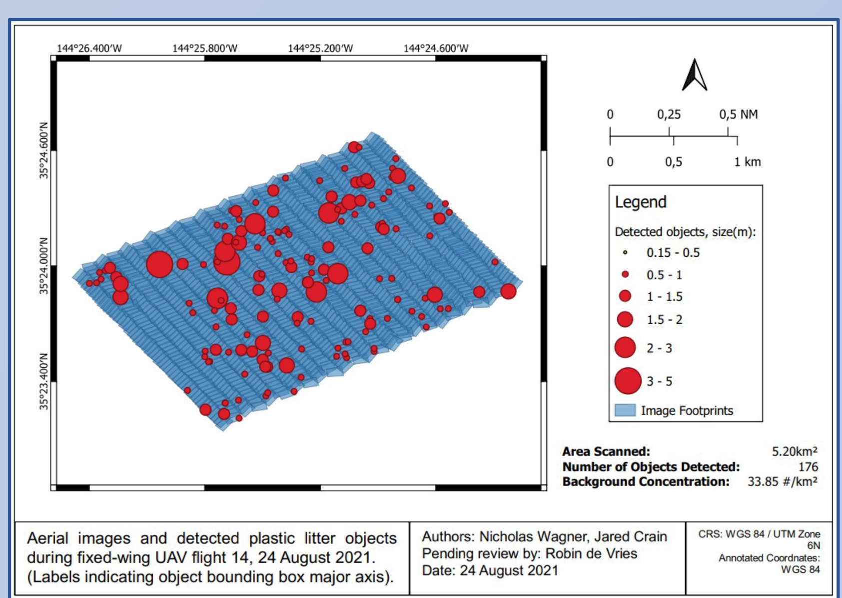
Introduction

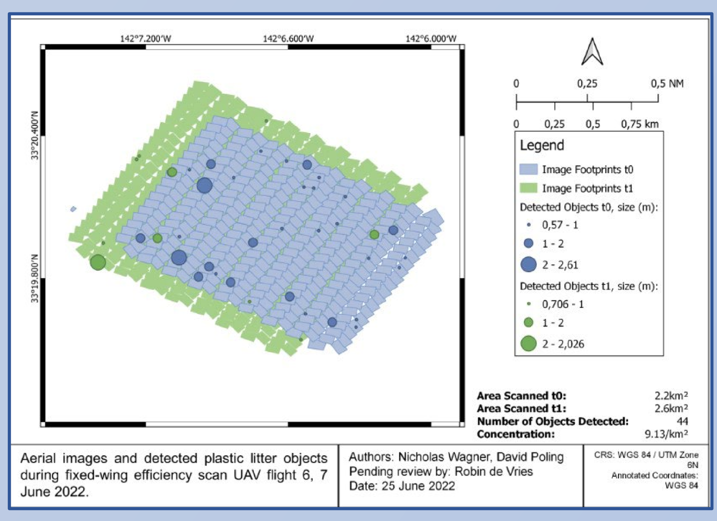
Detecting and recovering at-sea marine debris presents a multitude of engineering and operational challenges, however it is critical for both protecting the open ocean environment and vulnerable coastal and shallow water habitats. For this project we tested, evaluated, and developed systems and procedures to operationalize a fixed-wing drone launched and recovered from an in-situ ship collecting marine debris in the Great Pacific Garbage Patch (GPGP). In August 2021 and June 2022, Oceans Unmanned deployed to the GPGP as part of The Ocean Cleanup (TOC) trial of their System 002 ocean cleanup system to collect real time aerial data to both direct response efforts and to measure system effectiveness. As a follow-on to previous remote detection of plastic debris using manned aircraft and small quad-copter style UAS, a fixed-wing UAS was employed for enhanced endurance, resolution, range, and coverage area. The collected imagery was analyzed by a machine-learning algorithm developed by TOC to automatically detect mega-plastic debris.

Results

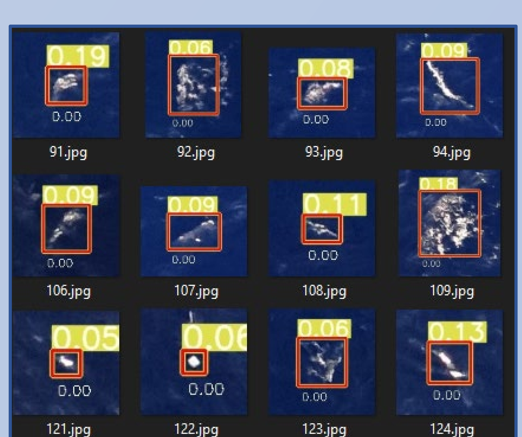
Over the course of both campaigns, 34 total flights were conducted with 30 of the flights conducted as zonal scans and 4 efficiency scan flights. Flights were conducted with a maximum range of 4 km from the GCS and a maximum duration of eighty-six minutes of flight time. Telemetry connection was generally strong and no loss-of-link events occurred. The longest flight duration was 86 mins and surveyed an area of 6.8 square kilometers with 1495 images. Over 127 square kilometers total were surveyed and over 27,000 images were collected for analysis. The average calculated debris density was 27 pieces of large marine debris per square kilometer.

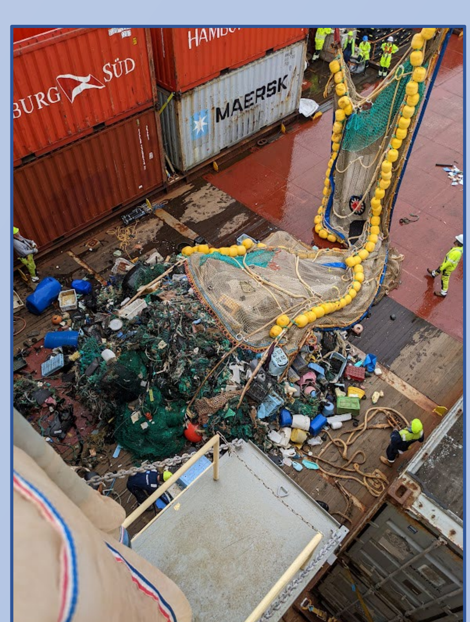


Following automatic debris detection and validation, data from zonal background scan flights was imported into QGIS for mapping and reporting. Reports were created showing image footprints and detections classified by size (see figure).



Flight No	Area covered (km2)		Raw "Detections" (#)		Validated Detections (#)		Ratio of Raw to Validated		Concentration (#/km2)	
1		1.44		443		12		36.92		8.33
2		2.49		773		33		23.42		13.25
3		2.50		535		26		20.58		10.40
4		4.09		726		183		3.97		44.74
5		3.30		7275		63		115.48		19.09
6		3.14		2396		47		50.98		14.97
7		4.33		2769		34		81.44		7.85
8		5.52		1096		19		57.68		3.44
9		4.04		13429		70		191.84		17.33
10		4.69		5141		40		128.53		8.53
11		4.23		2491		61		40.84		14.42
12		4.41		3853		342		11.27		77.55
13		4.00		8556		101		84.71		25.25
14		5.20		3055		176		17.36		33.85
15		6.13		5246		175		29.98		28.55
16		6.22		930		229		4.06		36.82
17		6.12		1959		371		5.28		60.62
18		4.84		3068		87		35.26		17.98
19		5.50		1709		45		37.98		8.18
20		4.36		993		14		70.93		3.21
21		5.50		11041		175		63.09		31.82
22		3.72		3454		113		30.57		30.38
	Total	95.77	Total	80938	Total	2416	Overall	33.50	Overall	25.23





Methodology

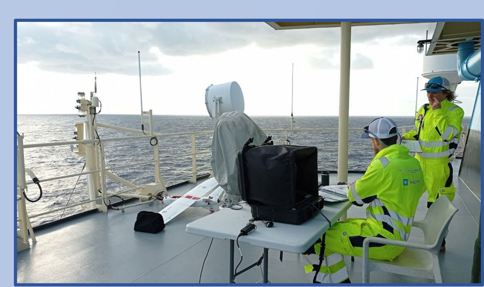
The Aeromao Talon Amphibious fixed-wing Unmanned Aircraft System (UAS) was selected for its long-range capabilities and endurance, as well as water-proofing required for landing on the water. All Talon UAS operations were conducted from the vessel Maersk Tender. The Tender was accompanied by a sister-ship, Maersk Trader, as part of the System 002 operations. The vessels courses and positions were driven by the System 002 operations, and all aerial surveys were conducted based on the positions of the vessels and System 002. The Talon was hand-launched from a deck directly above the bridge deck. For recovery, the UAS was belly-landed on the water alongside the ship and retrieved using the on-board workboat.

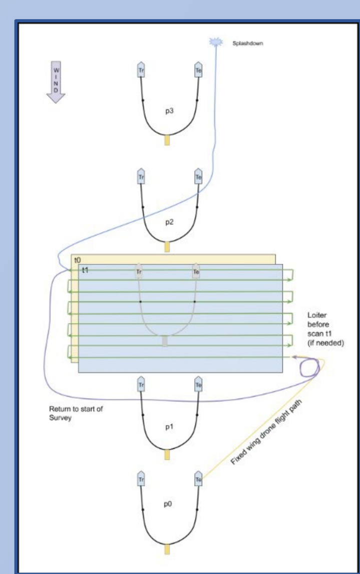
Two types of flight operations were conducted, zonal background scans and efficiency scans. Zonal scans were conducted to contribute to the understanding of background mega-plastics concentration and distribution while efficiency scans were designed to collect aerial imagery prior to System 002 passing through an area, and then scan the same area post-collection to measure the system efficiency.

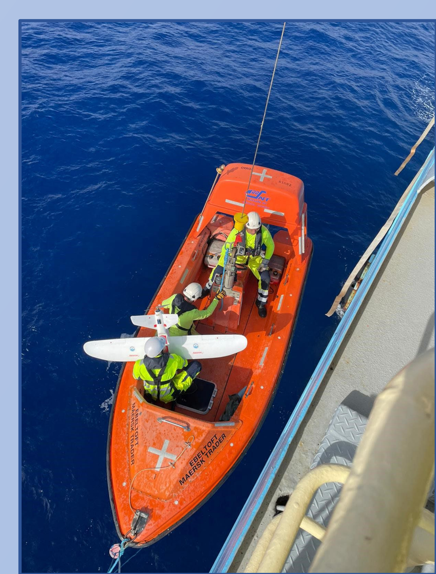
For efficiency scans, the Talon was flown at 43m Above Ground Level (AGL) producing a 2.00cm/pixel Ground Sample Distance (GSD). For zonal background scans, the Talon was flown at 80m AGL producing a 2.50cm/pixel GSD. A gridded flight plan was used with 0% sidelap and 0% frontlap. Mission Planner software suite was used for the Ground Control Station. All flights were conducted prior to 1030 or after 1700 local time to maintain a solar elevation angle less than 45° to minimize sun glint. Flights were conducted both morning and evening as conditions and vessel operations allowed.

All collected raw imagery paired with a location and attitude metadata CVS file were fed into TOC's machine-learning debris detection flow and suspected debris detections were validated manually.

Beyond Visual Line of Sight (BVLOS) flights were pre-approved through coordination with Oakland Oceanic Controlled Airspace/ Flight Information Region (OCA/FIR).







Conclusion

The success of these unique missions has demonstrated the capability of ship-based UAS operations to survey larger ocean and coastal areas for at-sea floating marine debris to monitor distribution and abundance or direct and evaluate in-situ response and cleanup efforts.

Building on the successful proof-of-concept of zonal background scans in 2021, the 2022 campaign advanced the application of at-sea UAS for marine debris detection to include the successful collection of efficiency scan data which will inform the design of future marine debris collection systems. This type of data is critical to assist in increasing "harvest efficiency" at sea and reducing "dollars per kilo" of recovered debris.

There are several areas for further improvements to this concept of operations to increase efficiency and reduce costs. Next generation Vertical Takeoff and Landing (VTOL) systems should be tested and evaluated to eliminate the need for landing in the ocean requiring the launch of a recovery vessel and repeatedly exposing the system to salt water. In addition, higher resolution cameras would allow for higher survey altitudes leading to larger areas surveyed per flight.

The biggest potential improvement might be our current work on the development of Artificial Intelligence (AI) onboard the UAS to provide real-time heatmaps of plastic concentrations. Having AI integrated to the camera onboard the UAS (at-the-edge AI) allows critical density information to be delivered via the onboard telemetry system to the ship to allow real-time navigational adjustments to focus collection efforts on the areas of highest concentrations.

Additional work in this space has the potential to take these materials and methods beyond the research phase and into full-scale global operations collecting more data to map and characterize the marine debris of the GPGP and other oceanic marine debris hotspots. Such information is crucial to increase efficiency and decrease costs for the monitoring and cleanup efforts of these areas.