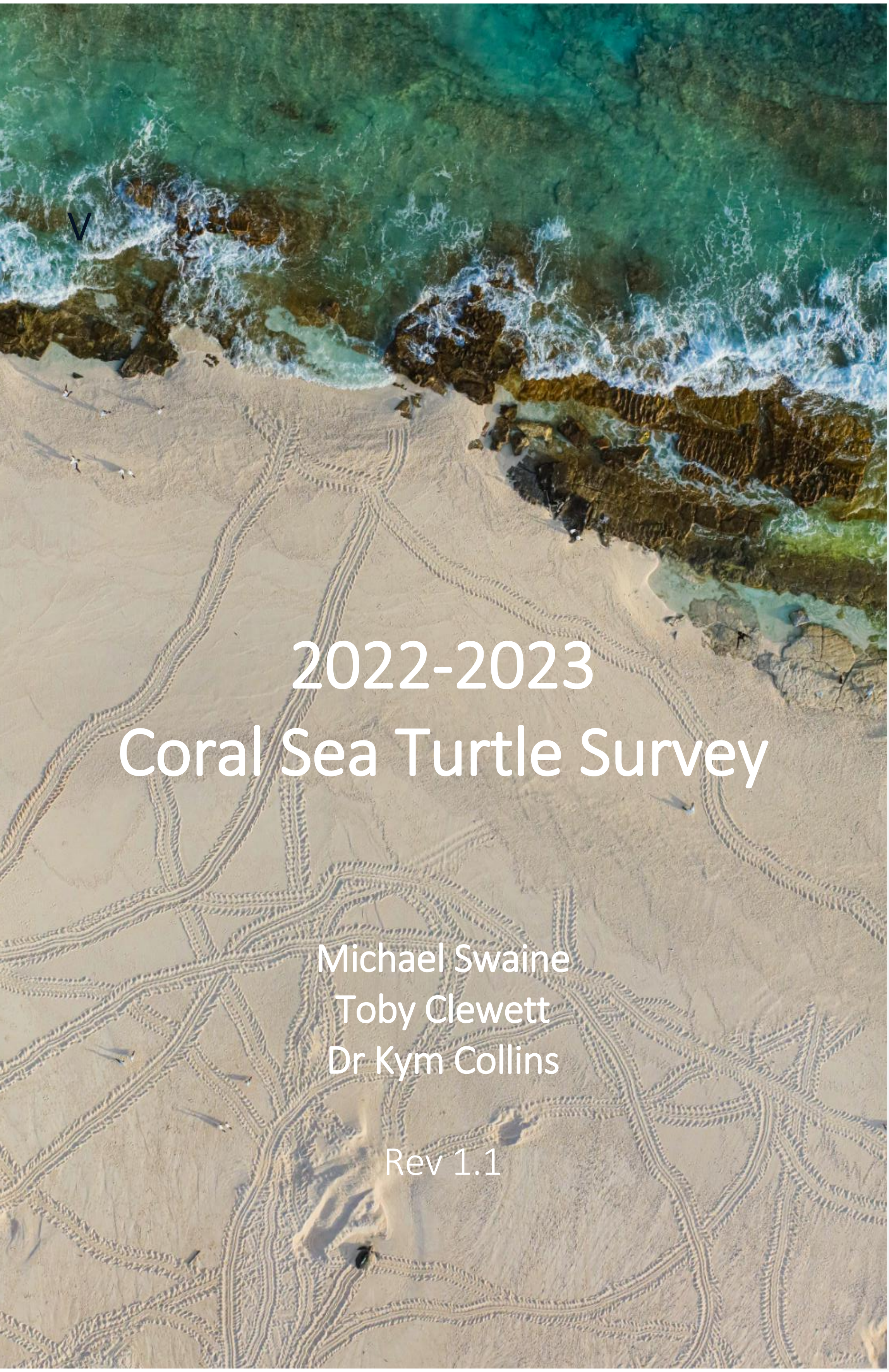

2022-2023 Coral Sea Turtle Survey

Michael Swaine
Toby Clewett
Dr Kym Collins

Rev 1.1

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2) Executive Summary

This report outlines the findings of the 2022-2023 turtle count conducted within the Coral Sea Marine Park. For the purpose of this survey, an aircraft was used as the primary means of observation, and track counting occurred on the low tide the morning after a midnight high tide. The capture window was at the peak of the bell curve for the laying season (based on research by Dr Ian Bell). This capture methodology allowed researchers to conduct an aerial examination of turtle activities spread across 44 islands located within the Coral Sea Marine Park. By implementing a dual capture methodology, the survey team was able to record a total of 66 individual captures.

2021-2022 compared to 2022-2023 season

Based on the previous 2021-2022 season and this 2022-2023 season, Lihou Reef islands and Diamond Islets (Tregrosse Reefs) had the highest volumes of turtles counted in the survey. The southern islands had significantly lower counts on both captures; as such, it can be tentatively inferred that the northern islands have higher volumes of turtle stock compared to the southern islands and represent a higher priority for continued turtle monitoring work. Magdelaine cays are included in this count, however were only captured in the second capture.

Comparing the volumes between 2021-2022 and 2022-2023, where a dual capture method was used for many more islands, we see a much cleaner dataset. There are less statistical outliers (for example south Diamond Islet in 2021-2022) when multiple captures occur, which provides a cleaner and more reliable dataset.

When comparing the data from the previous season, 2021-2022, this year's survey revealed a decrease in the number of observed turtle tracks. A comparison between both seasons can be seen in Figure 2-1 on the next page. The introduction of the GlobalPod V4 system was a notable change in this year's survey methodology. This camera pod was designed for marine survey, equipped with six cameras arranged in an oblique configuration on the aircraft and allowed the crew to quickly capture a broad area of the island in high detail. The ability to cover a larger area quickly was essential, given the remote locations of these islands relative to the mainland. Time spent at the islands was minimal, as most of the time was dedicated to transit out to, and between the various islands. The survey spanned a duration of nine days, with two of those days being dedicated to transit flights, to position the aircraft at the nearest airport to the area being surveyed.

Turtle counts

A total of 849 tracks were counted in total (in comparison to 1684 in the previous season). These were combined up and down tracks. The total adjusted figures were 388 complete tracks to 685 in the last season.

There was a total of 47 deceased turtles counted this year compared to 36 last year. This discrepancy is due to the addition of another island. Total ‘newly observed’ deaths (compared to last season) was 8.

Weather

Weather conditions also played a role in the survey, as many of the islands were captured under full cloud cover. The combination of early morning captures and dense cloud cover led to a higher number of recorded "faded / bad light tracks" when compared to the previous season. Despite these challenging conditions, the new camera array functioned effectively and played a crucial role in compensating for the poor lighting conditions.

Island morphology

There were some notable changes between the islands: some islands had split in two, others had changed shape entirely since the previous capture window. Changes could even be observed between the dual captures, where large rocks would be buried or excavated from sand. This would have been in part due to the bad weather conditions experienced during the survey, resulting in larger than average swell conditions.

Vegetation

Vegetation overall had an average decrease in square metre coverage of 2%, with the largest decrease in vegetation being on Hermit Crab Islet (Lihou Reef) which observed a notable 23% vegetation loss between 21-22 and 22-23 season going from 66,312m² to 50,772m². On the opposite side, Turtle Islet (Lihou Reef) observed a vegetation growth of 11% between seasons, increasing from 17,098m² to 18,991m².

Debris

Sizable debris (human marine debris beyond 100mm) was also digitised and counted within the data of the latest survey. In total 117 items of rubbish were recorded, of which most items were commercial fishing related objects (buoys, drums and rope). The highest amount of rubbish was observed at Magdelaine Cays – North which was almost double the next highest island (Coringa SW Islet). Magdelaine Cay North also had the highest number of deceased turtles, although it cannot be assumed that the two are related given the lack of supporting evidence.

Birds were observed (noted by the flight crew) in the highest volumes at Coringa, Herald and Willis with the second highest being Cato and the Diamonds.

Recommendations

Taking what we have learned in the previous captures for future surveys we have three main recommendations.

1. Boots on the ground

Utilising volunteers from the Bureau weather station at Willis Islet will significantly help in controlling count data. Having a human control methodology serves as a robust form of ground truthing. Recording turtle track data throughout the season will help us better understand at what point the capture window falls within the seasons bell curve of peak laying. It will also help in smoothing statistical anomalies by better understanding how numbers fluctuate during the weeks around the capture window.

2. Reduce the total islands captured

Limiting the capture area to these northern islands only (Lihou, Diamonds, Willis, Magdalene, Herald and Coringa) and introduce a third flight will get a better cost to output ratio.

3. Introduce a bird counting flight

A high-speed single pass down the centre of the island at 600ft with a modified camera array capturing the entire island at 7mm will allow most of the birds on the island to be counted in a single pass before they take flight at a resolution where species identification can occur. Turtle tracks can also be counted in this flight. Structure from motion photogrammetry (SfM) island models will be less robust than the previous days due to the bowling effect, however this can be controlled from the second days capture.

Tri capture methodology flight order

Flight 1: Extreme resolution bird capture 0.7cm.

Flight 2: High resolution track capture 1cm (same capture method as previous captures for species identification, ground control generation and island maps)

Flight 3: Low resolution track capture 3cm (a single pass flown at 1200ft capturing the whole island).

Shooting in a lower resolution on the third flight will reduce costs significantly by lowering processing times. Basic maps can be generated that are enough to count new tracks only, which will significantly aid in eliminating statistical variations. If either of the first two flights are missed, they can be rectified within this third flight at the highest resolution.

Nesting Turtle Comparisons

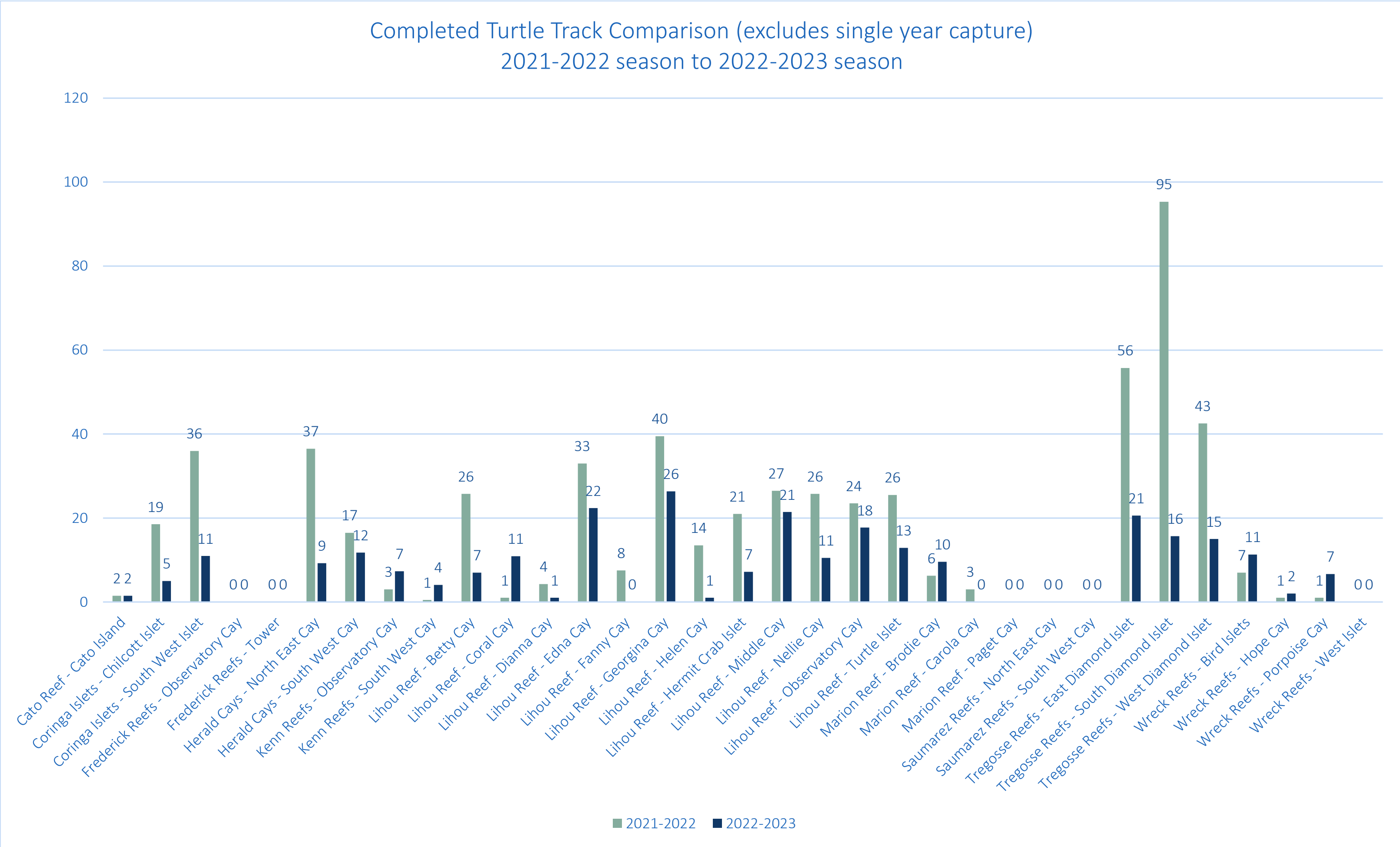


Figure 2-1 A comparison of total indiviual turtles passing the dunal crest for 2021-2022 and 2022-2023

3) Full Statistics

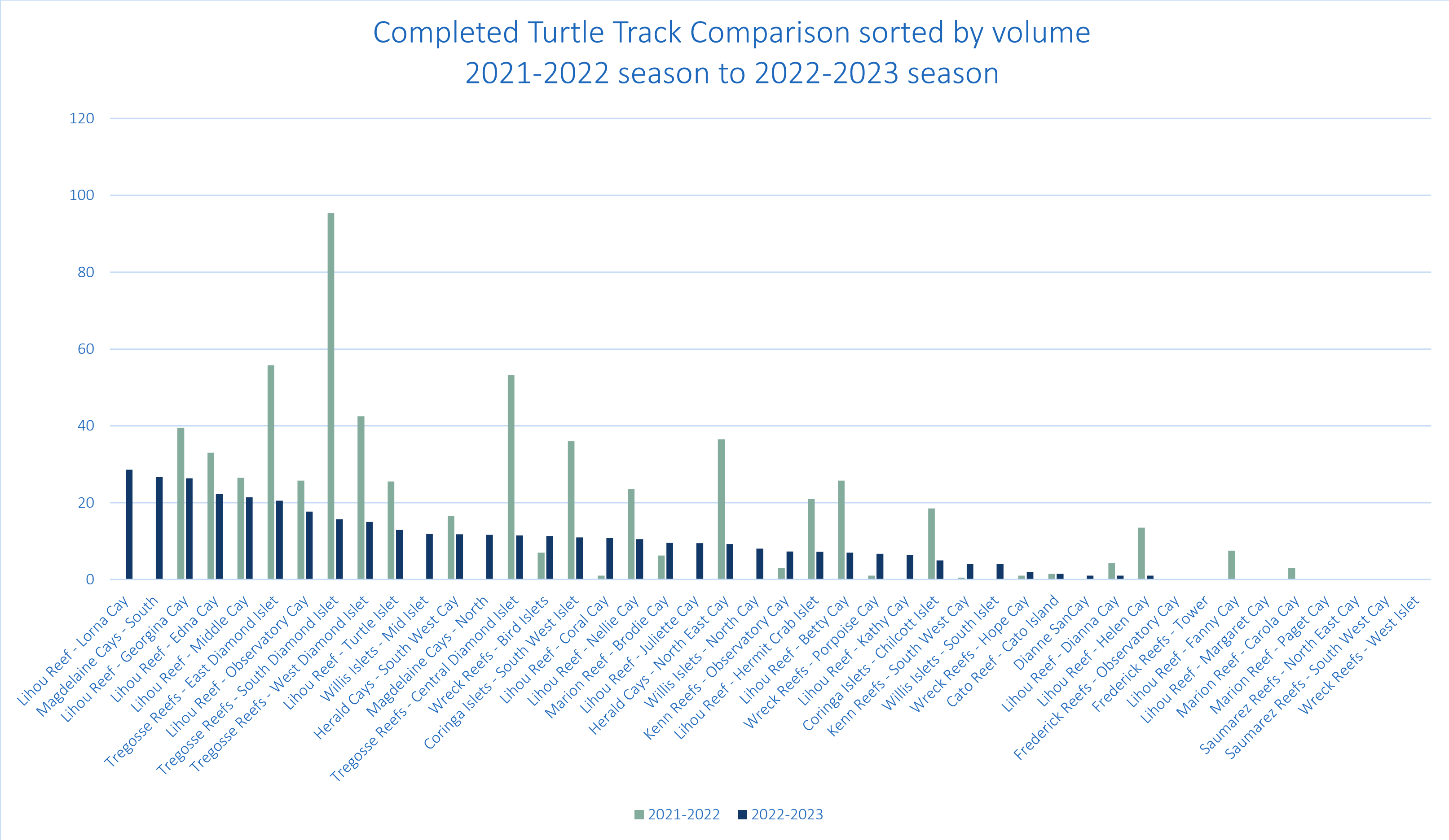


Table 3-1 2021-2022 and 2022-2023 Combined and sorted. Islands missed in 2021-2022 are represented as blank fields

Totals 2021-2022 (previous season)

In total there were 1684 unique tracks counted (up and down) with 685 completed tracks (passing the dunal crest)

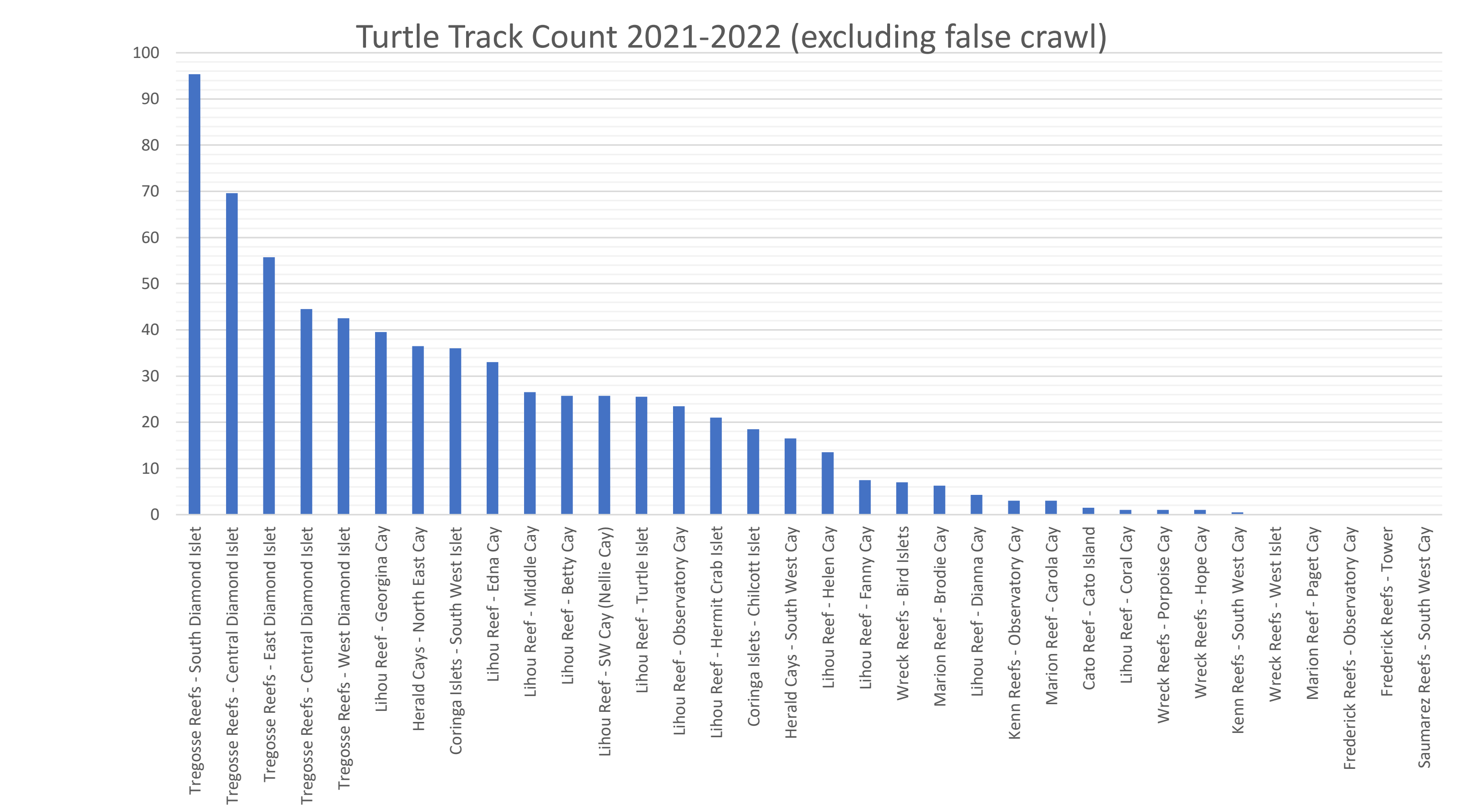


Figure 3-1 Total recorded tracks for the 2021-2022 season

Totals 2022-2023

In total there were 849 unique tracks counted (up and down) with 349 completed tracks (passing the dunal crest)

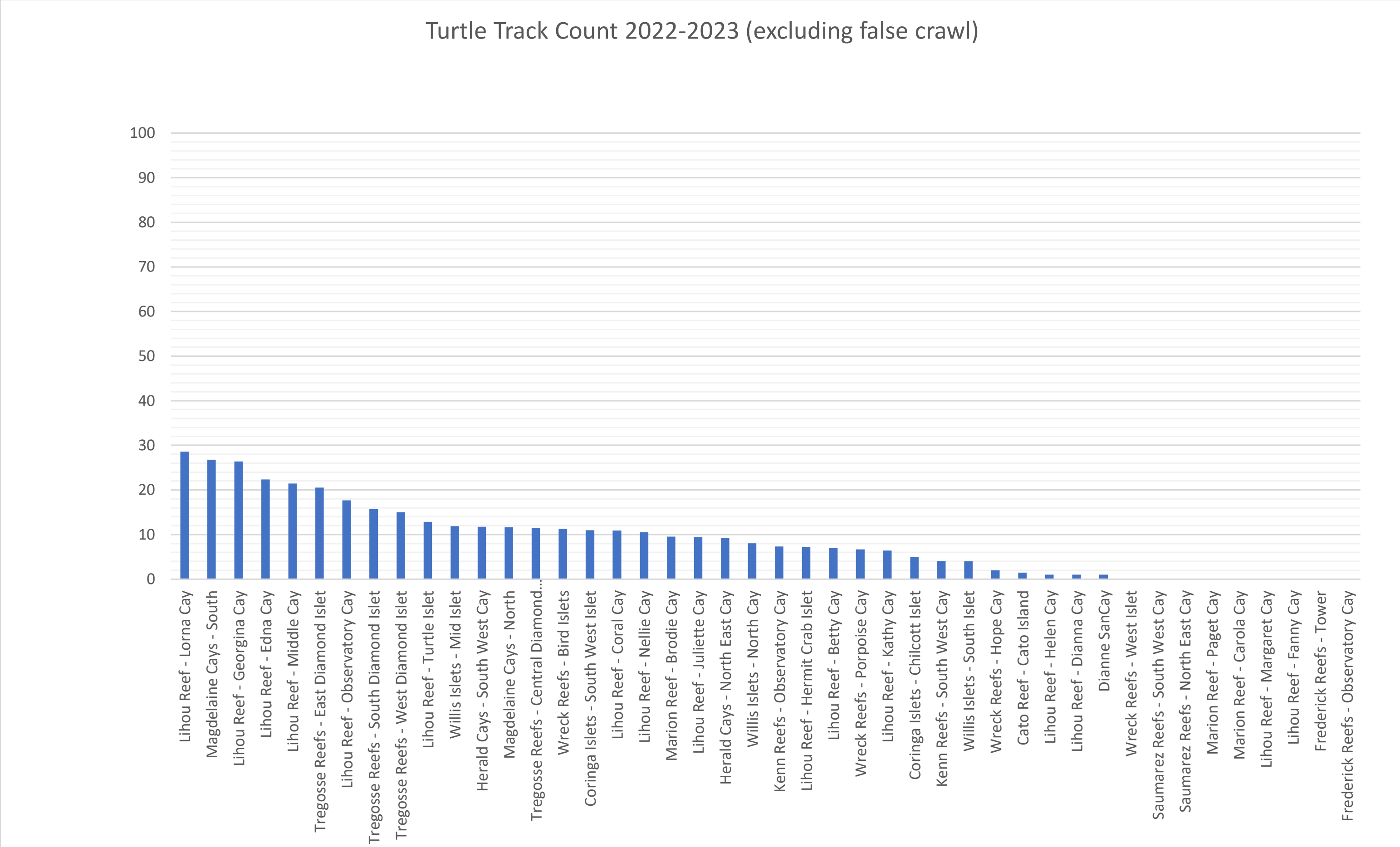


Figure 3-2 Total recorded tracks for the 2022-2023 season

Turtle track classes

The unique characteristics linked to a turtle track, as well as the uncertain aspects of a track were documented throughout the operator's digitisation procedure. Various noteworthy features associated with turtle tracks were observed, including ambiguous aspects of some tracks. To capture this information, the operator recorded the track section and added data from the following categories as needed. In cases where further data from the following categories was required, an appropriate identifier would be attached to provide more context and specificity.

1. Standard Track: These tracks are recorded as single up or down movements.
2. False Crawl: This category includes tracks that indicate the turtle did not pass the dunal crest and are recorded as separate Up and Down movements.
3. Ambiguous Direction: In instances where the operator was unable to determine the direction of the turtle track, this identifier would be used.
4. Likely Previous Day: This label is applied to tracks that are suspected to have been made the day before.
5. Possible Previous Day: Tracks that could potentially be from the previous day are marked with this identifier.
6. Bad Light Faded Track: This category encompasses tracks that have become difficult to discern due to poor lighting conditions or fading over time.
7. Turtle (living): When a living turtle is observed, this identifier is used.
8. Turtle (deceased): In cases where a deceased turtle is encountered, this label is applied.
9. Non-Standard Pattern: This category is reserved for tracks that display strange or abnormal patterns that deviate from the norm.
10. Covered by Another Track: When a track segment is found to be overlapped or obscured by another track, this identifier is used to denote the situation.
11. By employing these classifications, researchers can better understand and analyze the various aspects of turtle tracks encountered during the digitization process. This comprehensive approach to documentation can contribute significantly to the understanding of turtle behavior and patterns, thus enabling more effective conservation efforts in the long run.

This subsequent tables offers a comprehensive summary of the discrepancies observed across all sites.

Track Classes (2021-2022)

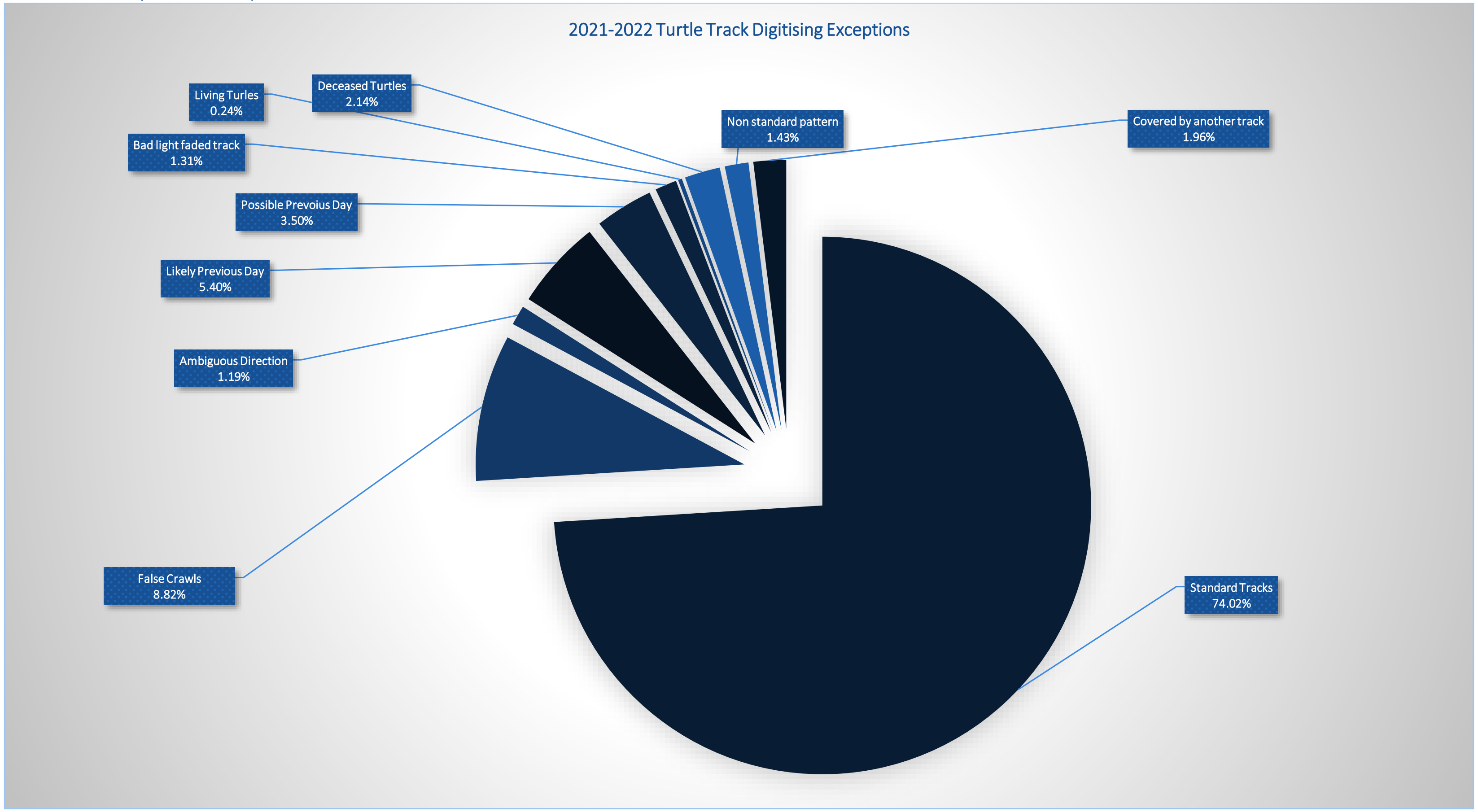


Figure 3-3 Turtle Track Classes 2021-2022

Track Classes (2022-2023)

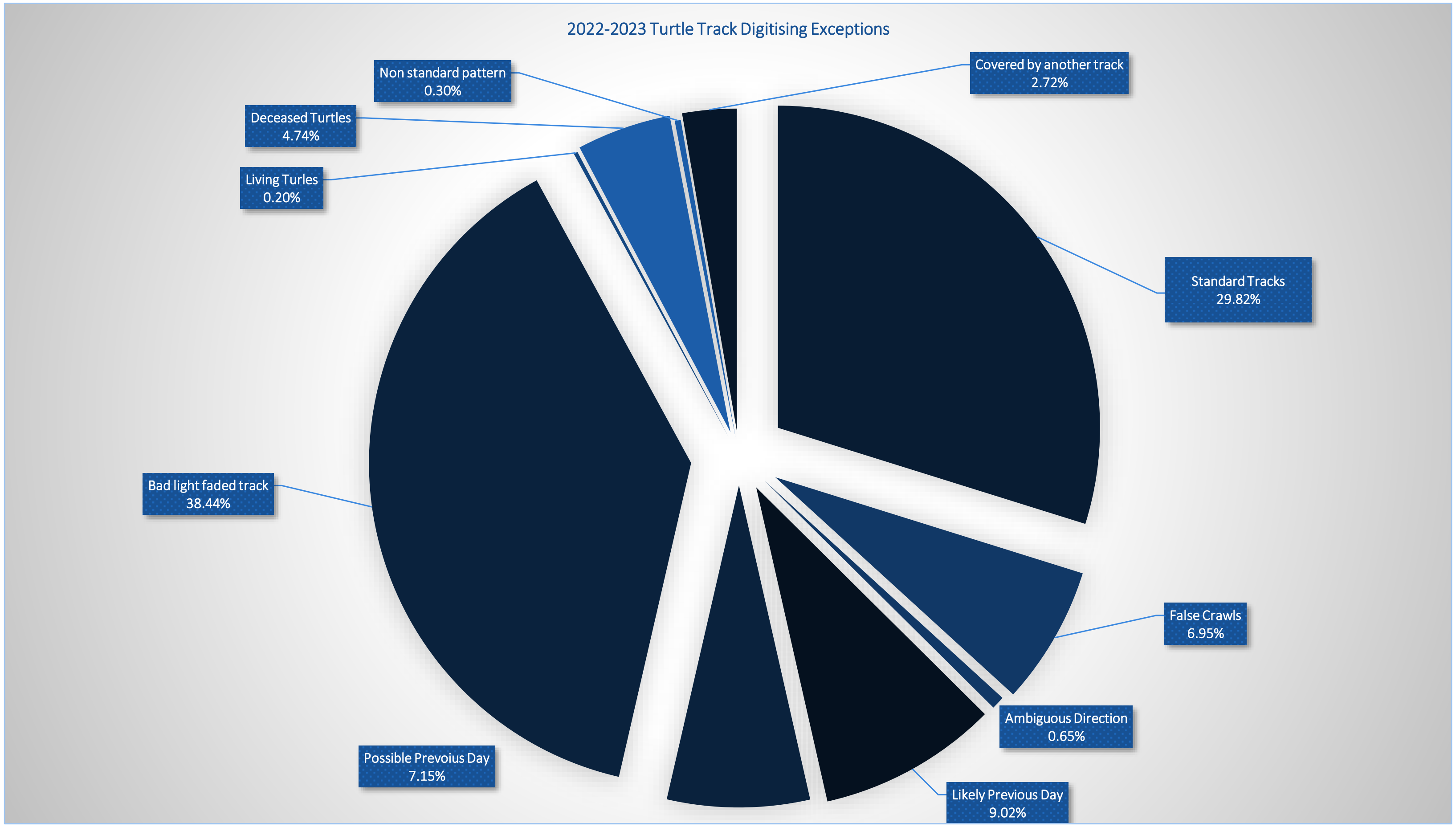


Figure 3-4 Turtle Track Classes 2022-2023

Complete track count (2021-2022)

Date	Island Name	Total Counted	Standard Tracks	False Crawls	Ambiguous Direction	Likely Previous Day	Possible Prevoius Day	Bad light faded track	Living Turles	Deceased Turtles	Non standard pattern	Covered by another track	Adjusted Total	Adjusted Total less false crawl
Treg_SDiIslet_220202	Tregosse Reefs - South Diamond Islet	195	163		6	2	10	2			2	10	95	95
Treg_CDiIslet_220202	Tregosse Reefs - Central Diamond Islet	154	115	5	1	23	4					6	72	70
Treg_EDiIslet_220202_03	Tregosse Reefs - East Diamond Islet	126	103	13	1	4	1	4	0	0	1	3	62	56
Treg_CDiIslet_220203	Tregosse Reefs - Central Diamond Islet	101	86	12							1	2	51	45
Treg_WDiIslet_220202_03	Tregosse Reefs - West Diamond Islet	87	75	3	7	2	4	3	0	0	1	0	44	43
Liho_GeoCay_220202_03	Lihou Reef - Georgina Cay	109	73	25	3	6	4	2	0	0	0	1	52	40
Hera_NECay_220202	Herald Cays - North East Cay	73	70								3		37	37
Cori_SWIslet_220202	Coringa Islets - South West Islet	78	66	5		1					6		39	36
Liho_EdnCay_220202_03	Lihou Reef - Edna Cay	74	62	7	0	1	3	1	0	0	1	2	36	33
Liho_MidCay_220203	Lihou Reef - Middle Cay	89	53	17		3				16			35	27
Liho_BetCay_220202_03	Lihou Reef - Betty Cay	69	51	8	0	21	7	0	0	0	0	1	30	26
Liho_SWCay_220202_03	Lihou Reef - SW Cay (Nellie Cay)	62	42	17	0	0	4	5	1	0	0	5	34	26
Liho_TurIslet_220203	Lihou Reef - Turtle Islet	61	48	4	2		6					1	28	26
Liho_ObsCay_220203	Lihou Reef - Observatory Cay	86	47	14		4	1			20			31	24
Liho_HerIslet_220202_03	Lihou Reef - Hermit Crab Islet	50	38	6	0	4	5	2	0	0	2	0	24	21
Cori_ChiIslet_220202	Coringa Islets - Chilcott Islet	37	30					2			5		19	19
Hera_SWCay_220202	Herald Cays - South West Cay	35	29	2				2			1	1	18	17
Liho_HelCay_220203	Lihou Reef - Helen Cay	27	27										14	14
Liho_FanCay_220203	Lihou Reef - Fanny Cay	19	15	4									10	8
Wrec_BirIslet_220222	Wreck Reefs - Bird Islets	22	14			7	1						7	7
Mari_BroCay_220221_22	Marion Reef - Brodie Cay	18	13	2	0	6	0	0	2	0	0	0	7	6
Liho_DiaCay_220202_03	Lihou Reef - Dianna Cay	13	8	5	0	0	0	0	0	0	1	0	7	4
Kenn_ObsCay_220222	Kenn Reefs - Observatory Cay	8	5				2					1	3	3
Mari_CarCay_220221	Marion Reef - Carola Cay	7	6			1							3	3
Cato_CatIsld_220222	Cato Reef - Cato Island	4	3				1						2	2
Liho_CorCay_220202_03	Lihou Reef - Coral Cay	4	2	0	0	0	3	0	0	0	0	0	1	1
Wrec_PorCay_230112	Wreck Reefs - Porpoise Cay	4	2				2						1	1
Wrec_HopCay_230114	Wreck Reefs - Hope Cay	9	2			5	2						1	1
Kenn_SWCay_220222	Kenn Reefs - South West Cay	4	1			2			1				1	1
Wrec_WesIslet_230112	Wreck Reefs - West Islet	0	0										0	0
Mari_PagCay_230113	Marion Reef - Paget Cay	0	0										0	0
Fred_ObCay_230112	Frederick Reefs - Observatory Cay	0	0										0	0
Fred_Tower_230112	Frederick Reefs - Tower	0	0										0	0
Saum_SWCay_230112	Saumarez Reefs - South West Cay	0	0										0	0
	Totals	1684	1247	149	20	91	59	22	4	36	24	33	759	685

Figure 3-5 Complete turtle track count and digitisation class features 2021-2022

Complete count (2022-2023)

Date	Island Name	Total Counted	Standard Tracks	False Crawls	Ambiguous Direction	Likely Previous Day	Possible Prevoius Day	Bad light faded track	Living Turles	Deceased Turtles	Non standard pattern	Covered by another track	Adjusted Total	Adjusted Total less false crawl
Liho_LorCay_221230	**Lihou Reef - Lorna Cay**	53	11			12	8	33				6	29	29
Magd_SouCay_221228	**Magdelaine Cays - South**	46	3		1		6	43				2	27	27
Liho_GeoCay_221230	**Lihou Reef - Georgina Cay**	56	23	6	1	15	7	21	1			1	29	26
Liho_EdnCay_221230	**Lihou Reef - Edna Cay**	43	13	4		2	2	26				4	24	22
Liho_MidCay_221230	**Lihou Reef - Middle Cay**	66	32	6		6	7			12	3	2	24	21
Treg_EDiIslet_221229-30	**Tregosse Reefs - East Diamond Islet**	40	18	1		6		22				2	21	21
Liho_ObsCay_221230	**Lihou Reef - Observatory Cay**	54	18	2		4	4	14		19			19	18
Treg_SDiIslet_221229-30	**Tregosse Reefs - South Diamond Islet**	33	15	3	1		1	15				1	17	16
Treg_WDiIslet_221230	**Tregosse Reefs - West Diamond Islet**	33	29									1	15	15
Liho_TurIslet_221230	**Lihou Reef - Turtle Islet**	25	12				1	10		1		3	13	13
Will_MidIslet_221227-28	**Willis Islets - Mid Islet**	30	9	7		1	4	12				1	15	12
Hera_SWCay_221227-28	**Herald Cays - South West Cay**	22	5	3	1	2	3	15				1	13	12
Magd_NorCay_221228	**Magdelaine Cays - North**	38	9			2		14		15			12	12
Treg_CDiIslet_Average	**Tregosse Reefs - Central Diamond Islet**	26	10	4		5		13				1	13	11
Wrec_BirIslet_230112-14	**Wreck Reefs - Bird Islets**	23	8	3		4	3	13					13	11
Cori_SWIsle_221227-28	**Coringa Islets - South West Islet**	22	7	2	1	3	2	13					12	11
Liho_CarCay_221230	**Lihou Reef - Coral Cay**	20	4			8		15				2	11	11
Liho_NelCay_221230	**Lihou Reef - Nellie Cay**	17	5	2		3	9	9					12	11
Mari_BroCay_230113	**Marion Reef - Brodie Cay**	23	16	2		1	4						11	10
Liho_JulCay_221230	**Lihou Reef - Juliette Cay**	19	8	2		1	5	7					10	9
Hera_NECay_221227-28	**Herald Cays - North East Cay**	20	2	3	1			15				1	11	9
Will_NorCay_221227-28	**Willis Islets - North Cay**	30	5	13		6		11					14	8
Kenn_ObsCay_230112-14	**Kenn Reefs - Observatory Cay**	12	2			3	3	10				1	7	7
Liho_HerIslet_221230	**Lihou Reef - Hermit Crab Islet**	16	3			4		11					7	7
Liho_BetCay_221230	**Lihou Reef - Betty Cay**	16	10	2				4					8	7
Wrec_PorCay_230112-14	**Wreck Reefs - Porpoise Cay**	14	1	1			3	11	1				7	7
Liho_KatCay_221230	**Lihou Reef - Kathy Cay**	12	4			3	2	7					6	6
Cori_ChiIslet_221227-28	**Coringa Islets - Chilcott Islet**	9		1	2			8					5	5
Kenn_SWCa_230112-14	**Kenn Reefs - South West Cay**	8	5			1		3					4	4
Will_SouIslet_221227-28	**Willis Islets - South Islet**	8	3					6					4	4
Wrec_HopCay_230112-14	**Wreck Reefs - Hope Cay**	4	2					2					2	2
Cato_CatIsld_230112-14	**Cato Reef - Cato Island**	4	2	1				1					2	2
Liho_HelCay_221230	**Lihou Reef - Helen Cay**	2	2										1	1
Liho_DiaCay_221230	**Lihou Reef - Dianna Cay**	2	2										1	1
Dian_SanCay_221227	**Dianne SanCay**	4	1	2				1					2	1
Wrec_WesIslet_230112-14	**Wreck Reefs - West Islet**												0	0
Saum_SWCay_230112-13	**Saumarez Reefs - South West Cay**												0	0
Saum_NECay_230112-13	**Saumarez Reefs - North East Cay**												0	0
Mari_PagCay_230113	**Marion Reef - Paget Cay**												0	0
Mari_CarCay_230113	**Marion Reef - Carola Cay**												0	0
Liho_MarCay_221230	**Lihou Reef - Margaret Cay**												0	0
Liho_FanCay_221230	**Lihou Reef - Fanny Cay**	2		2									1	0
Fred_Tower_230112-13	**Frederick Reefs - Tower**												0	0
Fred_ObCay_230112	**Frederick Reefs - Observatory Cay**												0	0
	Totals	**849**	**296**	**69**	**7**	**90**	**71**	**382**	**2**	**47**	**3**	**27**	**423**	**388**

Figure 3-6 Complete turtle track count and digitisation class features 2022-2023

Vegetation change

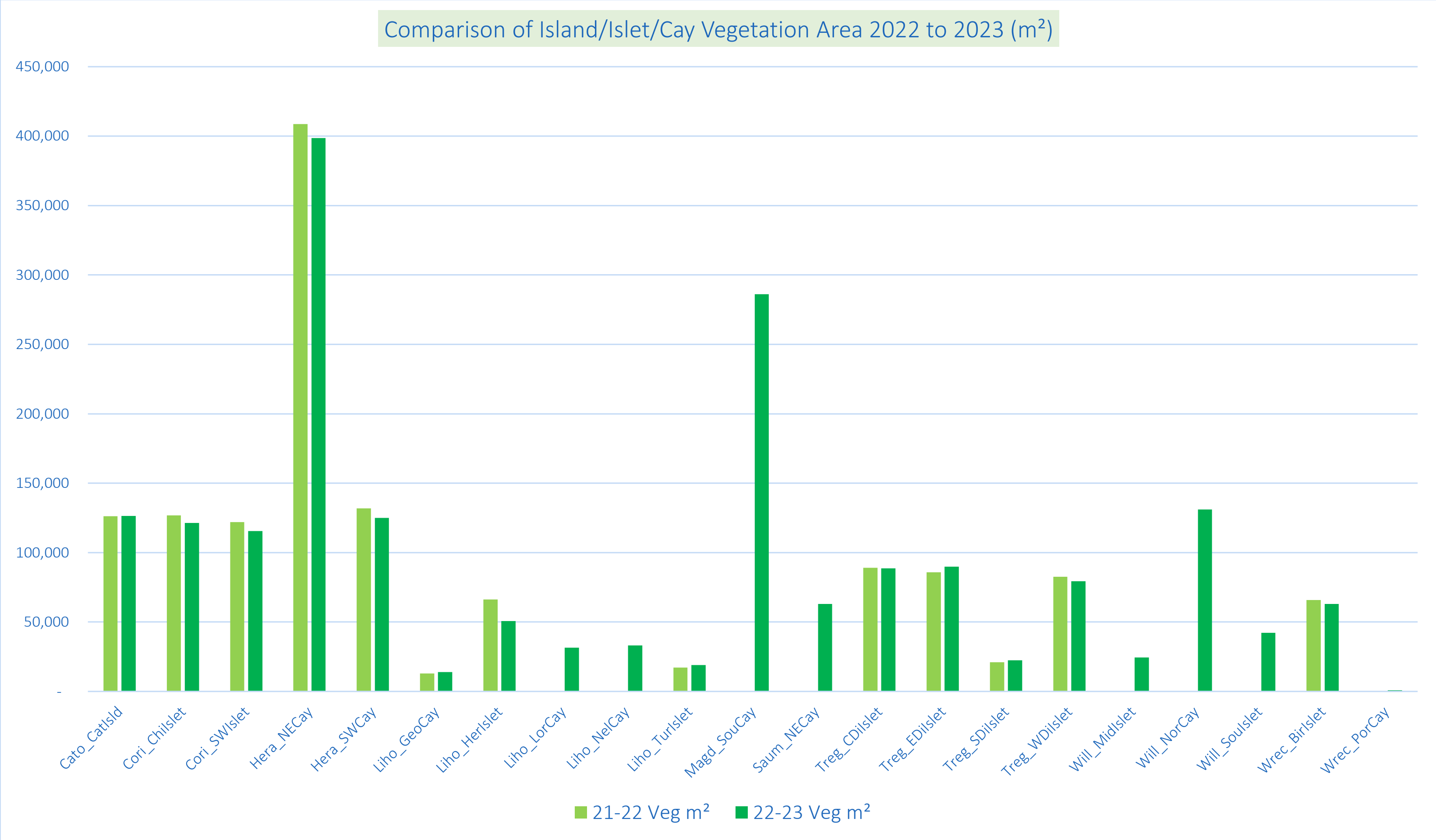


Figure 3-6 Comparison of vegetation changed between two seasons

Vegetation change complete table

Name	21-22 Veg m²	Capture Qty 21-22	22-23 Veg m²	Capture Qty 22-23	Veg Change %
Cato Reef - Cato Island	126,168	1	126,354	2	0%
Coringa Islets - Chilcott Islet	126,835	1	121,309	2	-4%
Coringa Islets - South West Islet	122,025	1	115,425	2	-5%
Herald Cays - North East Cay	408,696	1	398,604	2	-2%
Herald Cays - South West Cay	131,828	1	124,998	2	-5%
Lihou Reef - Georgina Cay	12,917	2	13,845	1	7%
Lihou Reef - Hermit Crab Islet	66,312	2	50,772	1	-23%
Lihou Reef - Lorna Cay			31,559	1	
Lihou Reef - Nellie Cay			33,184	1	
Lihou Reef - Turtle Islet	17,098	1	18,991	1	11%
Magdelaine Cays - South			286,047	1	
Saumarez Reefs - North East Cay			62,969	1	
Tregosse Reefs - Central Diamond Islet	89,008	2	88,603	2	0%
Tregosse Reefs - East Diamond Islet	85,799	2	89,885	2	5%
Tregosse Reefs - South Diamond Islet	21,061	1	22,348	2	6%
Tregosse Reefs - West Diamond Islet	82,642	2	79,354	1	-4%
Willis Islets - Mid Islet			24,405	2	
Willis Islets - North Cay			131,148	2	
Willis Islets - South Islet			42,118	2	
Wreck Reefs - Bird Islets	65,805	1	62,969	1	-4%
Wreck Reefs - Porpoise Cay			758	2	
				Average	-2%

Table 3-7 full figures of vegetation change between seasons

4) Mapping Summary

In the structure from motion photogrammetry process the three-dimensional structure of the photograph is recreated. For coastal environments the high resolution three-dimensional information can be used to understand the environment from various perspectives including the beach profile, the terrain ruggedness such as sand and rock, the shape of the intertidal, beach and inland areas of an island, the locations of features such as body pits created by nesting turtles, and the shape and form of vegetation on the island including differentiation between groundcover and more mature trees.

Mapping

For each island, islet or cay feature captured during aerial survey, a mapping summary is provided as an PNG/Geo-PDF file (see 'Maps' attachment). Each of these maps lists key summary statistics for the feature, including its location, capture date, number of fresh turtle tracks, island area and perimeter, potential nesting area, vegetation area, beach length per turtle, and nesting area per turtle. Digitised features include the dunal crest, the extent of the turtle nesting area (termed 'Potential Nesting Area'), the extent of vegetation (if present), turtles, turtle tracks and marine debris. These features are displayed thematically on each map.

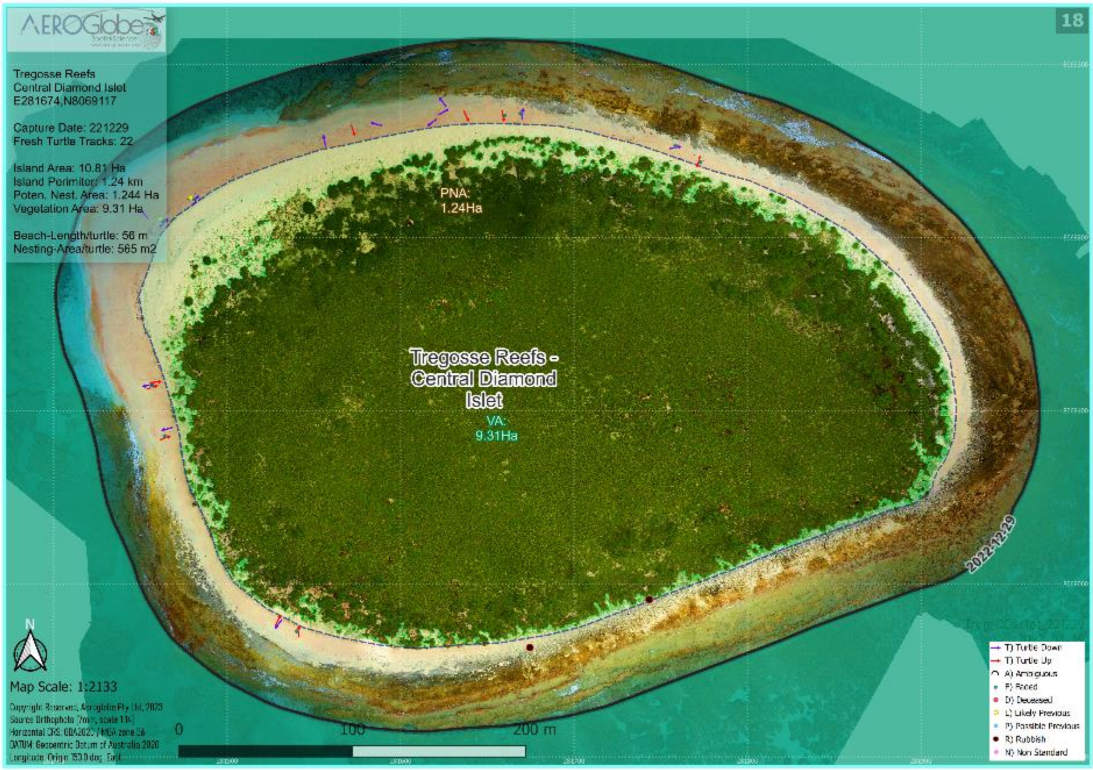


Figure 4-1 Individual map for the 2022-12-27 to 2023-01-14 campaign, available as Location aware Geo-PDF.

Berm Crest

Extraction of the berm crest (see in figure here) using a combination of the orthophoto, the Digital Surface Model ('DSM'), and contour data increased operator ability to accurately determine the location of geomorphic zones and slope change within, and in proximity to the intertidal zone. The area inside the berm crest, or dune crest was used to define the potential turtle nesting areas.

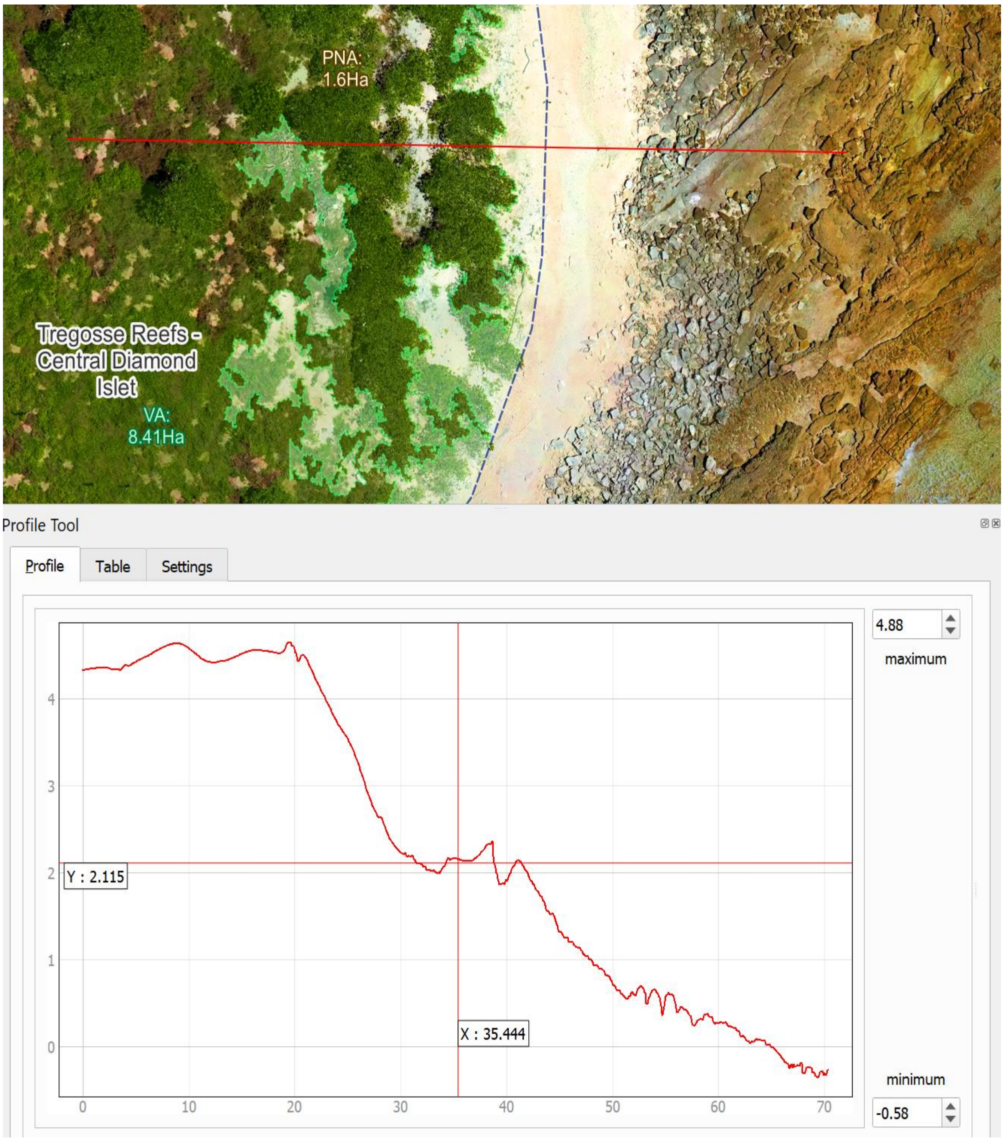


Figure 4-2 **top image:** Aerial photo with berm crest delineated as dotted line **bottom image:** Elevation Profile of the Digital Surface Model (DSM)

Vegetation Delineation

Vegetation on the islands, islets and cays may play an important role in turtle nesting behaviour. The flora of barrier islands can act as a barrier for turtles traversing the sand. Woody vegetation may also provide a habitat for nesting sea turtles by influencing sand temperature and moisture, or providing shelter from light and wind (Santos 2016, Varela-Acevedo 2009). Below in Table 4-1 shows the calculation of RGBVI values from image data, by using the reflectance values of Red, Green and Blue image bands, which is subsequently used to determine the presence or absence of vegetation.

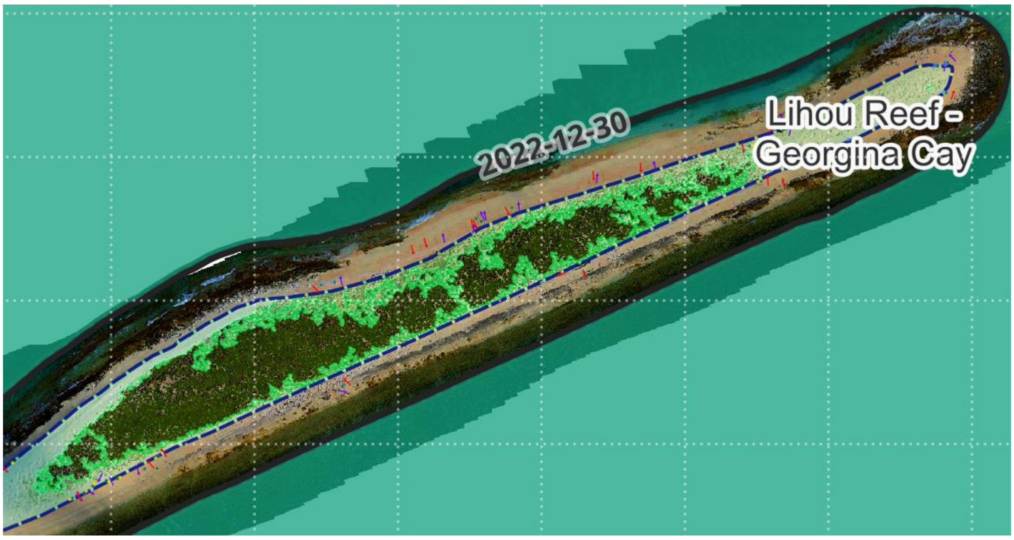


Figure 4-1 – *Vegetation areas for Georgina Cay shown with green outline top)*

To classify vegetation these works used image band math to automate the delineation of vegetation areas, based upon the 'Red Green Blue Vegetation Index' ('RGBVI') proposed by (Juliane Bendig a, 2015)

Table 2

Visible band vegetation indices (VI_{RGB}) used in this study where R = reflectance (%), R_R = red, R_G = green, R_B = blue. Red Green and Blue are the DN values in the respective channels extracted from the orthophotos.

VI	Name	Formula	References
GRVI	Green Red Vegetation Index	$\frac{R_G - R_R}{R_G + R_R}$	(Tucker, 1979)
MGRVI	Modified Green Red Vegetation Index	$\frac{(R_G)^2 - (R_R)^2}{(R_G)^2 + (R_R)^2}$	Introduced here
RGBVI	Red Green Blue Vegetation Index	$\frac{(R_G)^2 - (R_B * R_R)}{(R_G)^2 + (R_B * R_R)}$	Introduced here

Table 4-2 showing extract of Table 2 from Bendig shows the mathematical equation used to define the index value that is used to determine the presence of vegetation.

[A] Santos, Armando José Barsante, et al. "Individual nest site selection in hawksbill turtles within and between nesting seasons." Chelonian Conservation and Biology 15.1 (2016): 109-114.
[B] Varela-Acevedo, Elda, et al. "Sea turtle nesting beach characterization manual." Examining the Effects of Changing Coastline Processes on Hawksbilll Sea Turtle (Eretmochelys imbricata) Nesting Habitat (2009): 46-97

SANTOS ET AL. — Nest Site Selection in Hawksbill Turtles 111

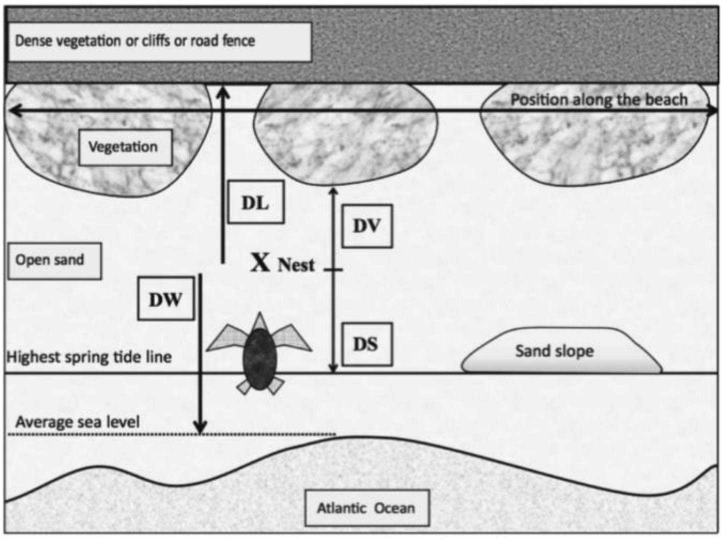


Figure 2. Schematic of the nest site distances. Distance from current waterline (DW), distance from highest spring tide line (DS), distance from vegetation line (DV), distance from the maximum upper limit (DL), and position along the beach (PB). The microhabitats vegetation, sand slope, and open sand are also indicated.

Figure 4-3 shows an extract from Santos, Armando José Barsante, et al. "Individual nest site selection in hawksbill turtles within and between nesting seasons." Chelonian Conservation and Biology 15.1 (2016): 109-114, figure 2.

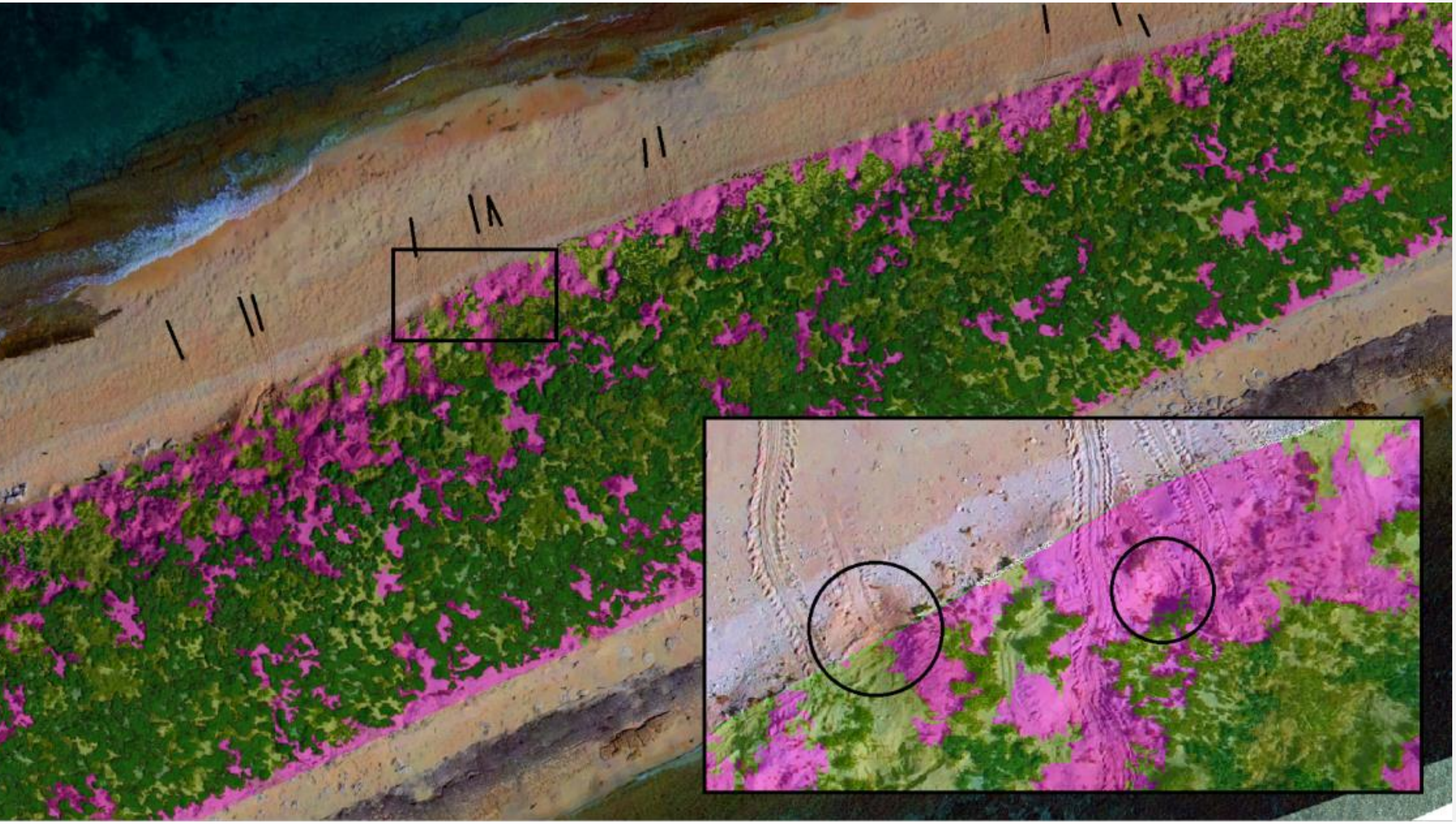


Figure 4-4 *(and inset) showing turtle nesting (pink) and vegetation areas in close proximity to turtle nest site (right).*

A Mean Shift Segmentation algorithm was applied to the RGBVI image to create polygons, and zonal summary statistics were used to classify resultant polygons as vegetation. Zonal statistics calculated for each polygon included mean, mode and standard deviation. Distance (in metres) to the dunal crest from each segmented polygon was calculated, and the combination of these RGBVI reflectance and geo-statistics provided opportunity to refine the semi-vegetated areas as contributing to the potential nesting area for an island feature.

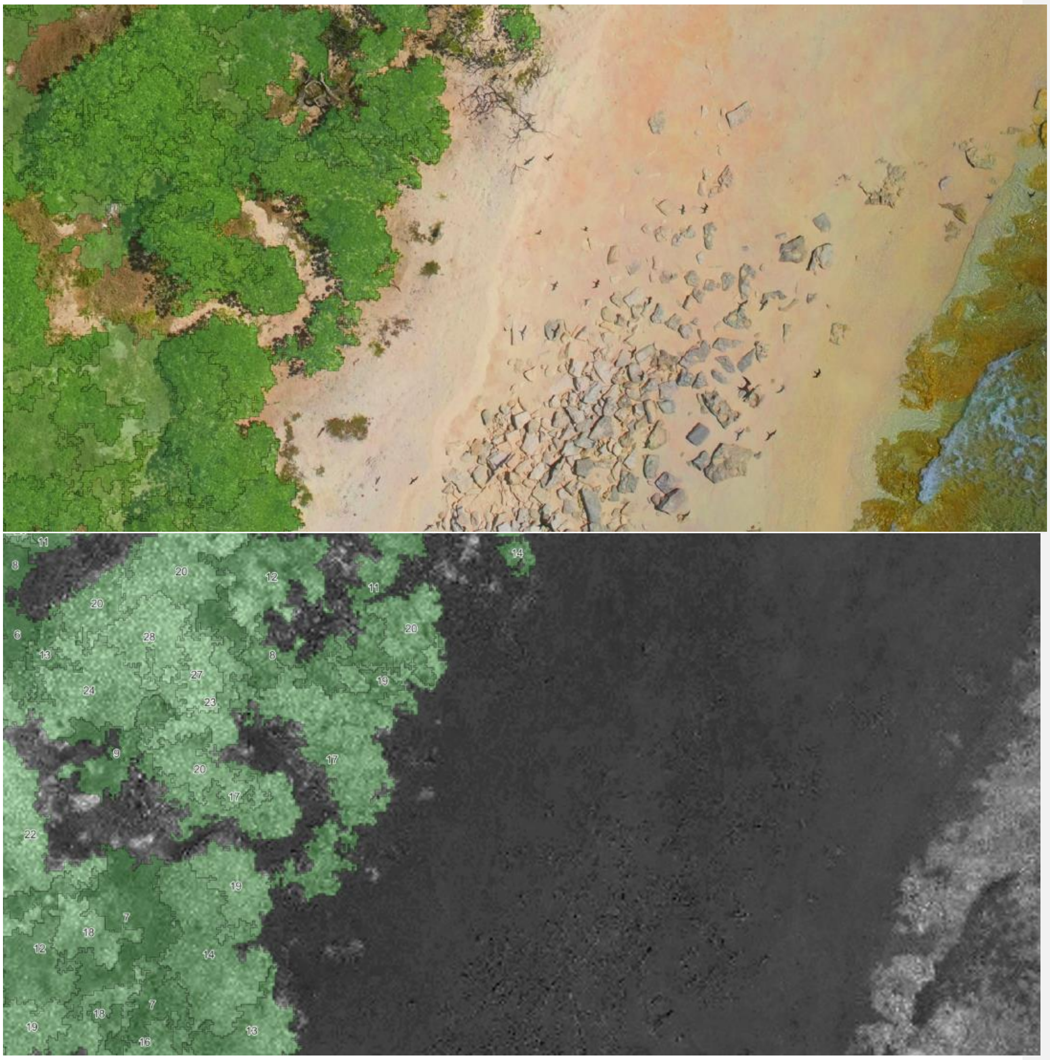


Figure 4-5– *"RGVI colour photo (top) and RGBVI greyscale image (bottom).*

Track Sections

Extraction of turtle track sections, marine debris and deceased turtles from orthophoto imagery was coordinated with the feature attributes attached to each feature. A set of 1337 individual photos are available as a file set, and are also displayed in the report appendix. To aid interpretation, each extracted section has been rotated to orient upwards. The example provided here shows coding and extraction of a common turtle 'up' track on Georgina Cay when captured via survey on Dec 30th 2023. Coded information for the jpg filename 'Liho_GeoCay_221230_Id668_T_Rot317_UP.jpg' includes feature date (221230), identifier to link back to a spatial dataset record (668), class (T), bearing (317 degrees to North), and direction Up/Down (UP).

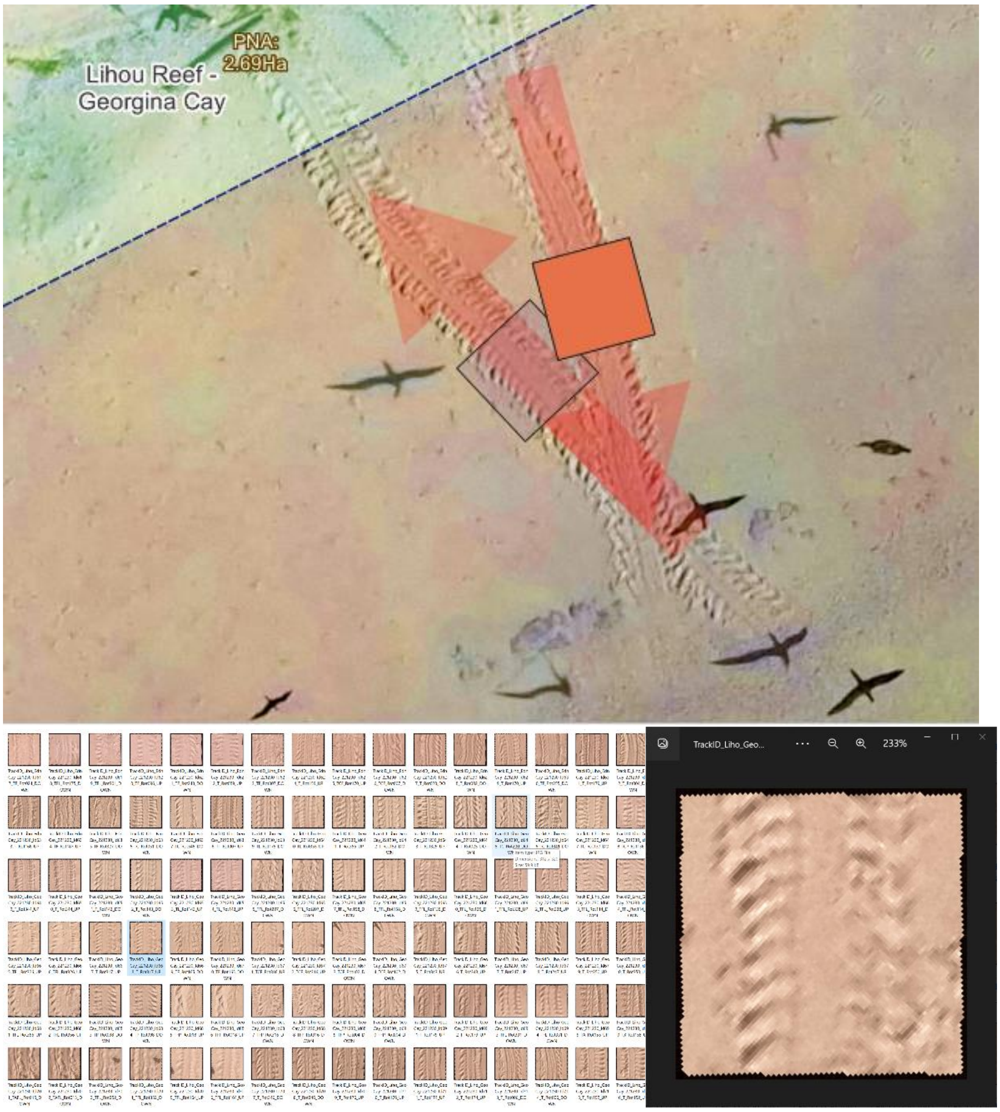


Figure 4-6 examples of track sections and how they were digitised

Results of potential nesting areas

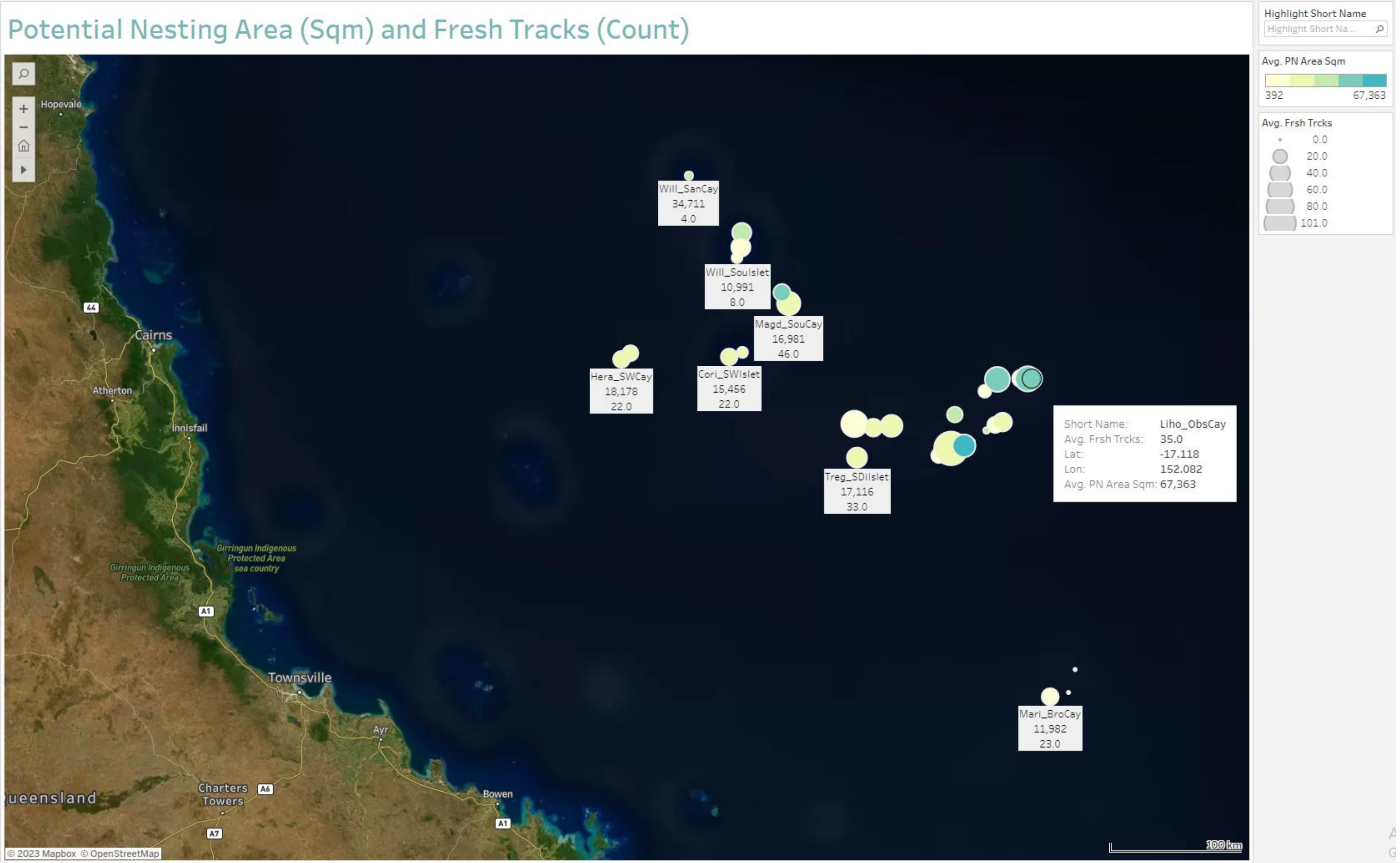


Figure 4-7 Potential nesting areas in the northern section of the capture area

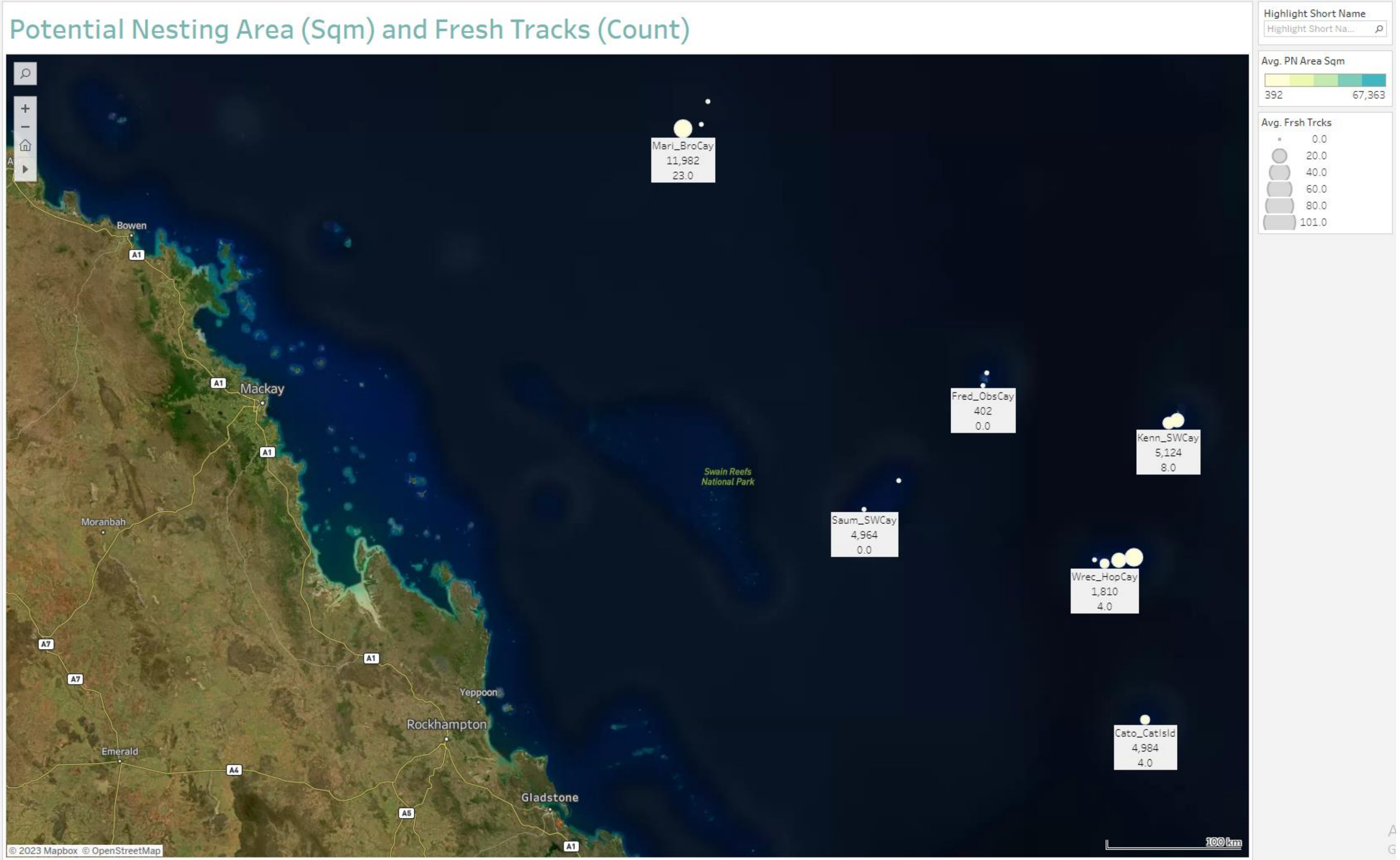


Figure 4-8 Potential nesting areas in the southern section of the capture area

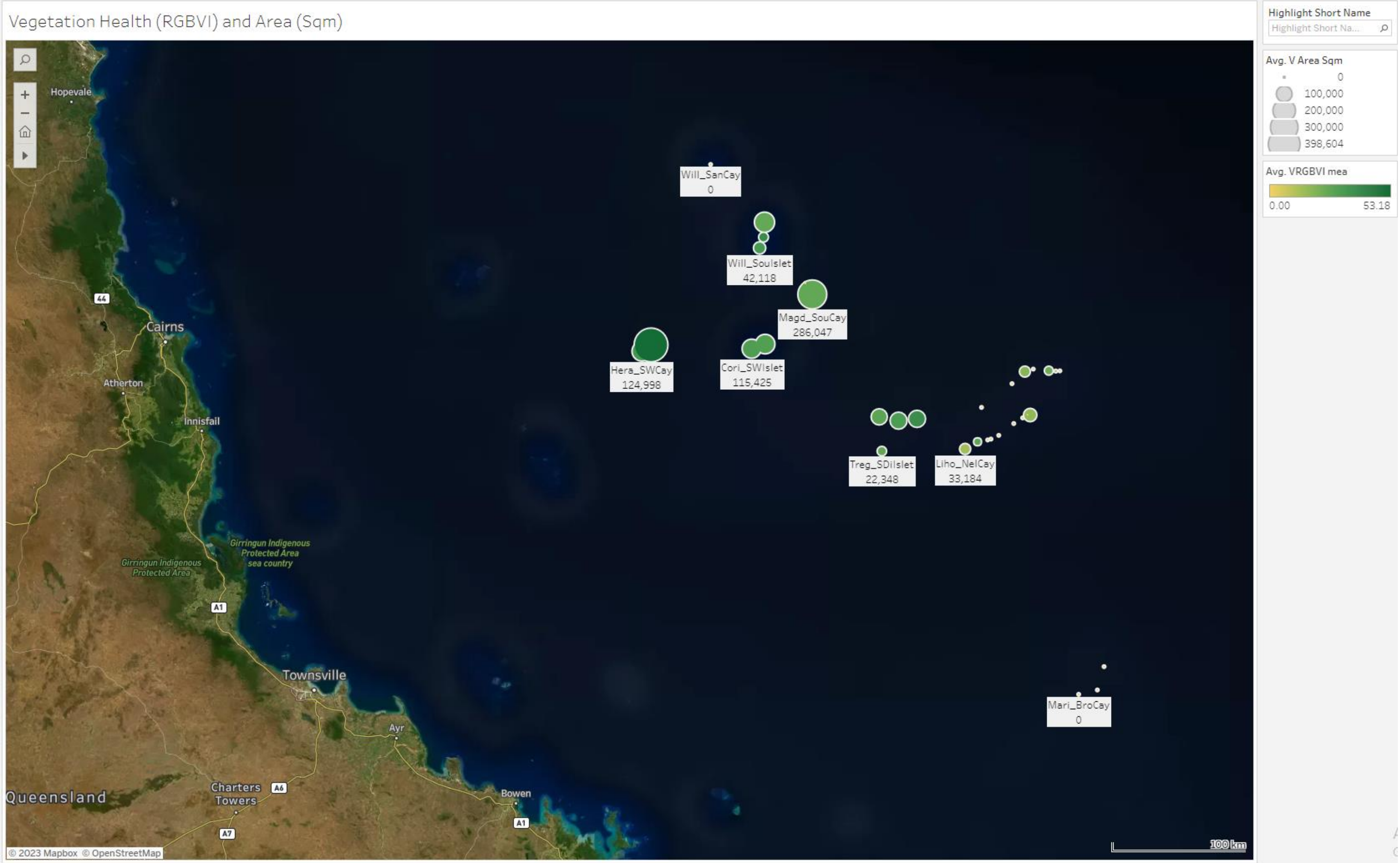


Figure 4-9 Vegetation totals in the northern section of the capture area

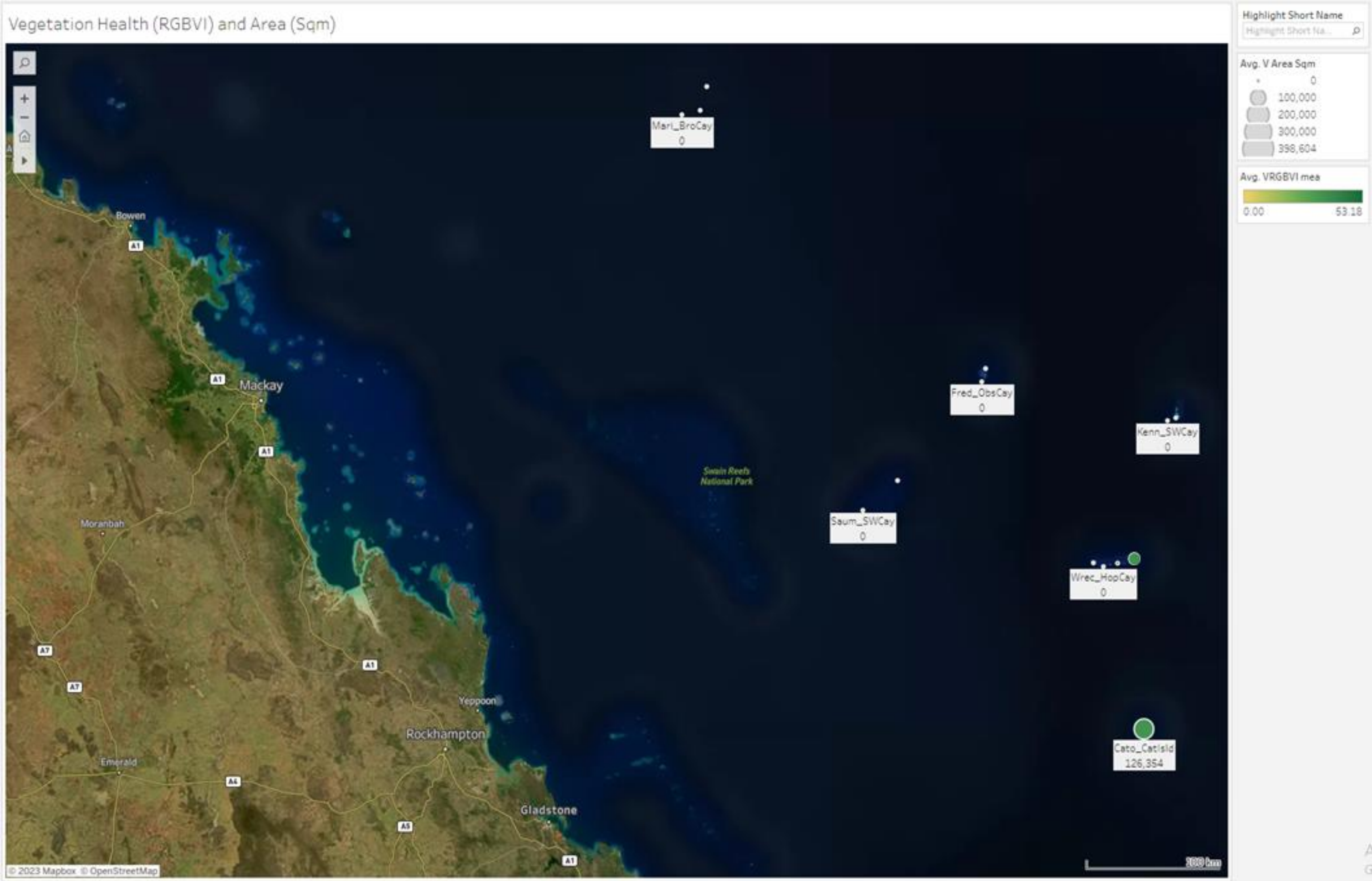


Figure 4-10 Vegetation totals in the southern section of the capture area

5) Adjusted totals

Due to the counting methodology statistical multipliers needed to be applied. Statistical multipliers are a crucial aspect of aerial surveys of turtle tracks as they allow us to estimate the number of turtle crawls on a beach accurately. During the surveys, we counted the tracks left by turtles overnight and removed any false crawls that do not cross the dunal crest. To account for potential double counts we ran a dual capture. From here a statistical multiplier was created based on the statistics tabulated (refer table 1), and we reduced the count of likely previous night crawls by 90% of their original value. Similarly, we reduced the count of possibly previous night crawls by 25% of their original value, as there is a chance they could have been counted in the previous night's survey.

By using statistical multipliers, we can estimate the actual number of turtle crawls on the beach, which provides valuable information for conservation efforts and helps to inform policies that protect these endangered species.

We also count every single track, and label accordingly as an UP or a DOWN track. As a result, the total number is then divided in half to account for the same turtle going up and then down the beach.

Site Name	Capture	Possbile Previous Day	% Correct	Likely Previous Day	% Correct
Kenn Reefs - Observatory Cay	230114	4	0	4	4
Kenn Reefs - South West Cay	230114	4	0	1	1
Tregosse Reefs - Central Diamond Islet	221230	0	N/A	7	7
Tregosse Reefs - East Diamond Islet	221230	2	1	11	11
Tregosse Reefs - South Diamond Islet	221230	4	0	0	N/A
Willis Islets - Mid Islet	221228	0	N/A	0	N/A
Willis Islets - North Cay	221228	0	N/A	0	N/A
Willis Islets - South Islet	221228	0	N/A	0	N/A
Wreck Reefs - Bird Islets	230114	2	0	7	2
Wreck Reefs - Hope Cay	230114	2	0	4	4
Wreck Reefs - Porpoise Cay	230114	0	N/A	1	1
Wreck Reefs - West Islet	230114	0	N/A	0	N/A
Cato Reef - Cato Island	230114	0	N/A	0	N/A
Coringa Islets - Chilcott Islet	221228	1	0		
Coringa Islets - South West Islet	221228	0	N/A	6	6
Herald Cays - North East Cay	221228	0	N/A	0	N/A

Table 5-1

Statistical Formular used.

The following items were used in the statistical adjustment of the total count:

- False Crawls
- Accidently counting the previous day (likely and possibly categories)
- Counting all tracks (both up and down)
- Counting deceased turtles

Formula for error and statistical results is as follows:

$$\frac{(\text{Standard Tracks} + \text{Ambiguous Direction} + \text{Covered by another track} + \text{Non standard pattern}) + (\text{Likely previous day} * 0.1) + (\text{Possibly previous day} * 0.75)}{2}$$

Potential errors

The broad area captured gives us a snapshot of the entire region and is an excellent indication of the turtle activity around the islands. The ability to project this captured activity into population numbers however is limited, as these snapshots do not give us the full picture of actual turtle numbers nesting on these islands. Were there more turtles nesting a fortnight or a month after the capture? Were there more turtles nesting the night before the capture? And did each track counted in the capture represent a successful nesting by an individual female?

Based on the data gathered, there were the occasional statistical outliers. For example, on Willis Islets - North Cay we counted 47 total tracks on December 27th and 12 tracks on December 28th. Of these, the number of "likely previous day" tracks were 15 and 0, respectively, while the number of false crawls were 19 compared to 6. After applying the statistical multipliers, the adjusted total track counts were 13 on the 27th and 3 on the 28th, which is still over a 4:1 ratio between nights. To account for this potential large variation in track numbers counted between dual captures the final data supplied in our counts was an average of the two nights.

Although we completed the capture during the peak of the nesting season, to attain a more robust count it would be extremely beneficial to capture higher density islands over three-four nights. Moreover, to be better able to relate track counts to nesting success a ground truthing method on some of the larger count islands is also recommended. Willis Island could possibly be used for this purpose, as there are people on the island that may be able to do morning track counts and nesting success numbers over a longer period.

6) Quality Assessment

Quality assessment generates essential metadata that enables data-driven decision-making with confidence. By examining raw data, opportunities for re-processing survey inputs are identified (Fig. 6-1), ensuring reliability in measurements and values obtained from the aerial survey data model. Crucially, these outputs offer clients guidance on the certainty of their conclusions, particularly when comparing different aerial survey campaigns and changes in turtle nesting areas.

Various factors contribute to data quality measurements, including Orthophoto horizontal (XY) positional accuracy (Fig. 6-1), Digital Surface Model vertical (Z) accuracy, model confidence (e.g., the number of raw photo projections), model scale and shape, and the consistency and extent of model coverage. To establish confidence in vegetation height changes between campaigns, a ground extraction (non-vegetation) methodology has been reviewed and developed. Berm Crest Extraction Using Orthophoto, DSM, and Contours Significant advancements in analytics have been made regarding the quality assessment and assurance of aerial survey areas. Additional efforts have been dedicated to determining the robustness of conclusions drawn about sand and vegetation changes. The extraction of the berm crest using Orthophoto, Digital Surface Model (DSM) and contour data has revealed numerous substantial alterations in island geomorphology.

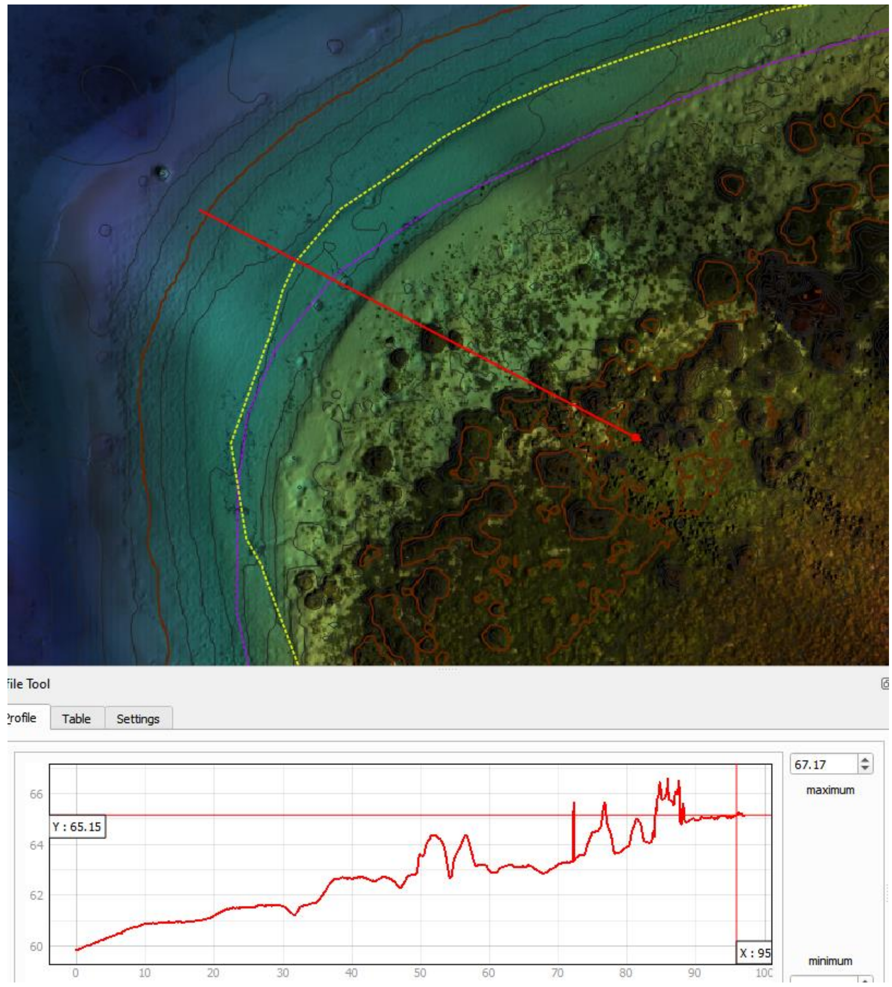


Figure 6-1

Comparing turtle stock estimates with consecutive day tracks

As confirmed in our previous seasons report, capturing the same site on two consecutive days significantly improved the fresh track identification process, providing increased confidence in the second days' fresh count. This dual capture methodology was again used for 20 of the 44 islands currently surveyed. During the digitisation of these dual capture islands the second capture was initially processed, followed by the first. The marked tracks from both dates were then compared, with any required changes to track category on the second capture noted (Figure 6-2) and subsequently amended. This process enabled us to calculate correction factors (i.e., statistical multipliers) for track categories that could then be applied to the single capture islands surveyed.

Figure 6-2

Figure 6-2. Second capture image of Kenn Reefs - Observatory Cay showing turtle track categories that needed updating (in red circles) after direct comparison to tracks marked on the initial capture day.

7) Accuracy Statement

We have broken the accuracy into six levels of absolute accuracy (Table 6-1), from Level 1 which is the gold standard of aerial survey with a high level of accuracy to Level 5 which has low absolute accuracy.

	PCM GCP	RTK GCP	RTK Drone	Satellite	Polynomial transformation	Aircraft IMU Only
Robust GCP network	1	2	NA	NA	NA	NA
Robust features (large unmoving rocks ect)	2	2	NA	NA	NA	NA
Limited GCP network	3	3	3	4	5	6
Limited features or no features (half of island sand)	3	3	3.5	4	5	6
No features (submerged reef or rocks only)	3	3	4	5	6	6
No features (sand cay no submerged objects)	3	3	5	5	6	6

Table 6-1.

Data Quality: Levels of Accuracy, Precision or Confidence

Level 1

Generated from placement of control, projected from registered permanent control marks, and has the highest level of accuracy. The registered permanent control marks provide a precise reference for the orthorectification of the aerial photograph, resulting in little error. Aerial imagery controlled from a network of points will have <2cm of XY error <10cm Z error provided the control is within an acceptable distance and evenly spread.

The use of registered permanent control marks ensures that the aerial photograph has the highest possible level for geospatial analysis, mapping and other applications that require high levels of precision and the highest level of accuracy achievable for aerial photography.

Level 2

Generated from placement of control from using RTK survey equipment. Aerial imagery controlled from a network of points will have <2cm of XY error <10cm Z error relative to these control points provided the control is within an acceptable distance and evenly spread.

The use of registered permanent control marks ensures that the aerial photograph has the highest possible accuracy for geospatial analysis, mapping and other applications that require high levels of precision.

It is important to note that the accuracy statement may vary based on the specific method used to generate the control marks that affects the accuracy of the control mark itself. It is limited to the accuracy of the point on the ground.

Level 3

Control obtained using existing SfM (Structure-from-Motion) photogrammetry generated from a drone.

In this case, the control points are generated using SfM data captured from an RTK (Real-Time Kinematic) drone, which is a type of surveying equipment that uses GPS signals to achieve high-precision positioning. However, it should be noted that the accuracy of the RTK data may be impacted by the distance between the drone and the base station. The RTK data may also be influenced by other factors such as atmospheric conditions or electromagnetic interference.

Despite these limitations, the use of RTK drone data as control points ensures that the aerial photograph has a relatively high level of accuracy, despite some bowling effects. It is estimated accuracy in the XY plane is +/- 10 cm (Kalacska, et al., 2020). This level of accuracy is suitable for many geospatial analysis, mapping and other applications that require high levels of precision.

It is important to exercise caution when using aerial photographs for applications that require high levels of accuracy and to consider any limitations or sources of error such as atmospheric conditions, camera calibration, or the quality of the control points (in this case none). In addition, the accuracy of the RTK data should be carefully evaluated in the context of the specific location and conditions of the aerial photograph, as these islands have no base stations to get correction data from.

Level 4

Obtained from using non-rigid transformation controls generated with satellite imagery and has an accuracy of +/- 15 meters. This means that any location or object depicted in the photograph may be up to 15 meters off from its absolute location on the ground. This data is suitable for many geospatial analysis, mapping and other applications; however, it is important to note that caution should still be exercised when using this photograph for applications that require higher precision and should be used for reference purposes only and not for navigation, safety, or any other purpose that requires real-time or precise location information.

In addition, it is important to note that control on these islands was limited. Non-rigid transformation controls were generated using Sentinel-2_L2A satellite imagery as a reference, which improves the accuracy of the aerial photograph relative to these existing satellite maps.

Sentinel-2_L2A has an accuracy statement that reads as follows:

"The imagery in Sentinel-2_L2A is acquired by the Sentinel-2 satellites operated by the European Space Agency, and its accuracy may vary from location to location. We make every effort to ensure that the imagery is as accurate and up to date as possible, but we cannot guarantee its accuracy or timeliness. Therefore, the imagery should be used for reference purposes only, and not for navigation, safety, or any other purpose that requires real-time or precise location information."

Bing Maps has an accuracy statement that reads as follows:

"The imagery in Bing Maps is provided to Microsoft by third-party providers, and its accuracy may vary from location to location. We make every effort to ensure that the imagery is as accurate and up to date as possible, but we cannot guarantee its accuracy or timeliness. Therefore, the imagery should be used for reference purposes only, and not for navigation, safety, or any other purpose that requires real-time or precise location information."

By using satellite imagery as a reference to generate non-rigid transformation controls, we have improved the accuracy of the aerial photograph. However, it is important to keep in mind the limitations of the reference imagery, and exercise caution when using the photograph for applications that require high levels of accuracy.

Level 5

Control obtained using polynomial transformation controls and has an accuracy of +/- 20 meters, Z data unusable. It is important to note that the polynomial transformation method used to orthorectify the images can contain transformation errors in the shape. This means that any location or object depicted in the photograph may be off from its actual location on the ground. While this level of accuracy is suitable for many geospatial analysis, mapping and other applications, it is important to exercise caution when using this photograph for applications that require higher precision.

In addition to the accuracy statement, it is important to note that control on these islands was limited. The polynomial transformation controls were generated using satellite imagery as a reference, which improves the accuracy of the aerial photograph relative to these existing satellite maps.

The satellite imagery used to control this data was Sentinel-2_L2A.

Sentinel-2_L2A has an accuracy statement that reads as follows:

"The imagery in Sentinel-2_L2A is acquired by the Sentinel-2 satellites operated by the European Space Agency, and its accuracy may vary from location to location. We make every effort to ensure that the imagery is as accurate and up to date as possible, but we cannot guarantee its accuracy or timeliness. Therefore, the imagery should be used for reference purposes only, and not for navigation, safety, or any other purpose that requires real-time or precise location information."

Level 6

The data in question suffers from a lack of proper control and relies heavily on aircraft instruments, resulting in poor accuracy with a margin of error of around +/- 50 meters. This significant level of imprecision could have severe implications, particularly in the realm of geomorphology, as it may lead to erroneous conclusions.

Furthermore, it is worth mentioning that the absence of Z data compounds the issue when the accuracy is already so compromised. The inclusion of Z data is of utmost importance in comprehending the field of geomorphology. Given the circumstances, it is only appropriate to utilize this data classification for animal counts, as the accuracy is too poor, and the Z data is unusable.

Absolute / Relative accuracy

Whilst absolute accuracy is poor due to limited RTK reception at the islands, relative accuracy in most instances will be an order of magnitude better in accuracy. This can be further improved with post processing and manual calibration, particularly in areas of high amounts of unchanging features (rocks).

8) Capture methodology.

Flights

The peak sea turtle nesting time in the Coral Sea Marine Park (CSMP) is during the two-week period covering the last week of December and the first week of January. The requirement of this survey was the provision of aerial photogrammetry to be conducted during this two-week period, followed by a comprehensive analysis and reporting of nesting turtles, turtle tracks and offshore turtle scrums in the CSMP during this time. The works included the survey of 44 islands within the CSMP (Figure 4-1).

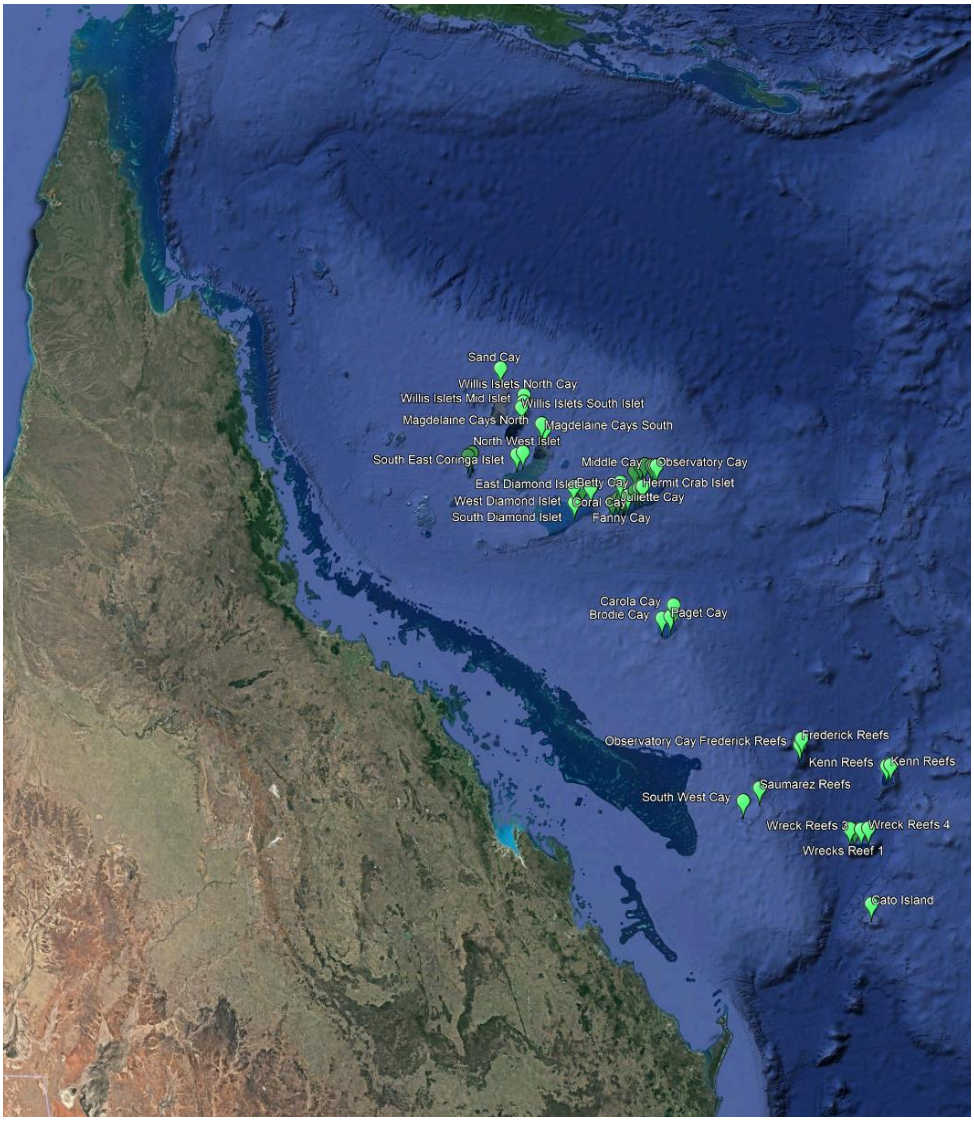


Figure 9-8-1

Camera Array

We captured aerial imagery using our Global Pod 4 (Figure 9-1-1). This is the fourth generation of our airborne SfM camera platform. It incorporated six independent sensors, four orientated in an oblique setup and two as Nadir, one as a primary and one as a backup sensor (Figure 9-1-2). This allows for banking turns whilst still maintaining Nadir and is optimised for island corridor surveys.

Figure 9-1-1 The P68 with all six cameras attached.

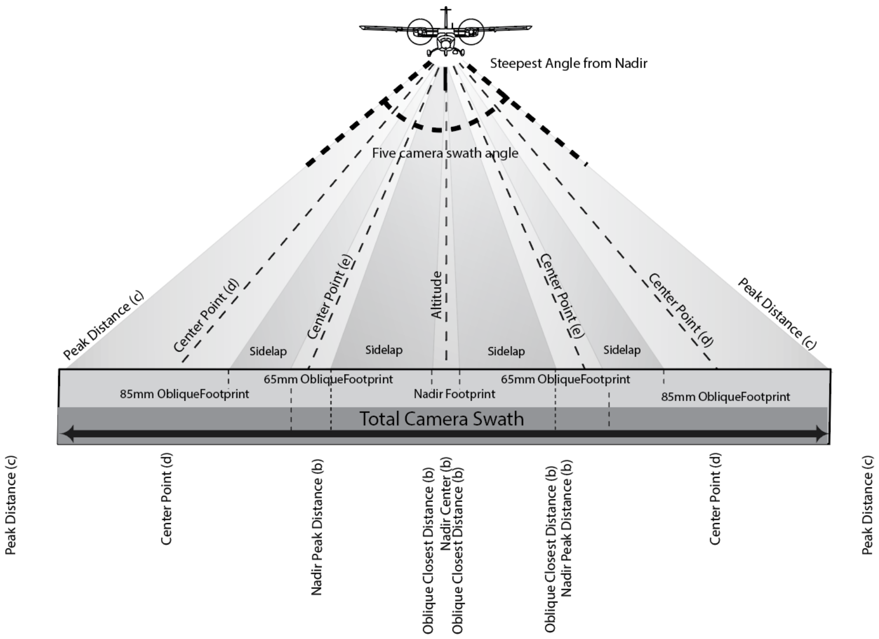


Figure 9-1-2 Diagram detailing the layout of the five -camera array and the swath captured

Survey Patterns

Unlike our previous Parks Australia survey, we conducted a dual survey of the islands which included a (1) standard semi-grid-based survey as well as a (2) corridor-based survey. We believe that this expansion of the methodology to include both survey methods will significantly benefit the client and the survey results.

Planned standard Grid-Based Survey

Based on feedback from previous captures, where inner vegetation was missing, and to create better SfM modelling of volumetric and vegetation analysis, we opted to approach with twin methodologies. Initial passes were conducted at a higher altitude of 1100-900ft (depending on island size), and islands were shot as a standardised grid, with 5% sidelap for NADIR sensors and 100% sidelap for Oblique sensors. The initial pass will allow the capture of birds prior to their flight to assist in fauna analysis, as well as capture the inner vegetative parts of the island that were missed in the last seasons capture. The passes were calculated based on island width and the grid survey will follow straight transects (Figure 9-1-3). As a result of this altered methodology, this will be a lower resolution survey, compared to the previous season, between 1 and 2.5cm (depending on island size).

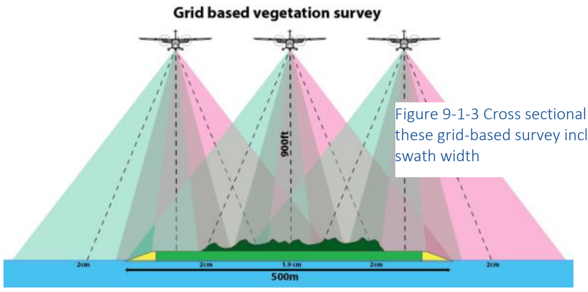


Figure 9-1-3 Cross sectional view of these grid-based survey including swath width

Corridor Survey / orbit methodology

As per our previous capture for Parks Australia, we planned on conducting an orbit-based corridor survey, with our primary system as well as with our Ver 5. system, simultaneously. With the additional camera system, we can conduct >30° banking turns and still be able to capture Nadir images. This allows us to orbit islands whilst conducting Nadir photogrammetry and builds on systems we have developed from earlier corridor-based surveys. This method also allows for fast and extremely high-resolution corridors of the beach area to be captured to enable accurate turtle track counting.

Figure 9-1-4. Orbital flight patterns utilising experimental camera array with the swath spreading across the island during a single pass and a dual pass in Figure 9-15.

During the capture experiments we also tested dual corridor passes to determine whether this methodology would result in full island coverage utilising extreme oblique cameras (Figure 9-1-6). This was aimed at validating software to further reduce aircraft time during capture.

Figure 9-1-6. Diagram of two corridor passes to provide full island coverage.

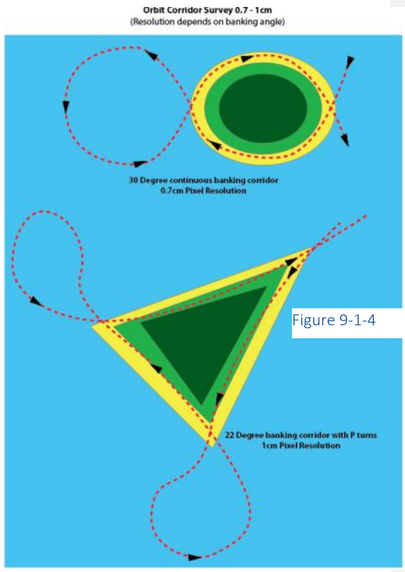


Figure 9-1-4

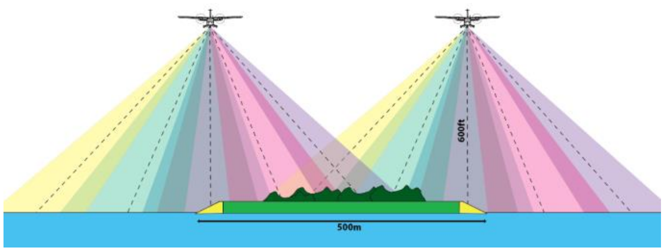


Figure 9-1-6 dual corridor swath

9) Flight Summary

Weather conditions for this capture were poor to fair (refer to section Weather / Safety) with partial cloud making conditions tricky for SfM processing, with bright and dark areas on the same island (refer Weather for SfM) (Figure 10-1). This weather resulted in wet cameras on a few occasions which needs to be considered for future captures of this kind.

Figure 9-1 A sample of the conditions experiences

Poor weather was expected at this time of year therefore decision trees were put into place to ensure safe operation. Liddle's Air Service performed all tasks well, and daily flight checks of the aircraft and equipment were made. Additionally, safety briefings were conducted before, during and after each flight, in the form of a debrief. There were no issues with the aircraft from a safety perspective. A life raft was placed between the camera operator and pilot, and the front passenger seat was removed for easy movement through the aircraft in the event of a water landing (Figure 10-2).

Figure 9-2 on transit to the capture location

Cameras performed satisfactorily overall, however some issues with the Port 65mm camera resulted in modified survey patterns. In addition, the Nadir 65mm camera failed on the first flight resulting in the backup camera being utilised for islands captured on December 27th. The Nadir camera was subsequently repaired the same evening.

Flight 1

Flight Date: 27 December 2022
Flight Number: 221227 Flight Route: YBTL-YSHR
Start Time: 04:05 Finish Time: 11:30
Distance Covered: 603 Nautical Miles Total time: 7.4 (Figure 10-3)

Islands captured

Figure 10-3. Map of Flight 1

- Coringa Islets - Chilcott Islet
- Coringa Islets - South West Islet
- Herald Cays - North East Cay
- Herald Cays - South West Cay
- Grounding
- Willis Islets - Mid Islet
- Willis Islets - North Cay
- Willis Islets - South Islet

Figure 9-3

Flight notes

Flight departed Townsville one hour before first light.

We attempted the initial passes for the bird survey over the first two targets (Herald Cays), however the methodology resulted in the birds taking flight. Subsequently, our descent to the lower survey altitude gave the birds just enough time to obtain the same altitude as the aircraft. As a result of this danger, it was decided to discontinue with these initial passes. This change to our methodology, due to safety concerns, will be further discussed later in the report (Section 12). Shooting the lower altitude component of the survey first and then climbing would avoid this safety issue, however it would also void the bird count due to scattering.

Figure 9-4 flying towards the capture area above a layer of thick cloud. The cloud proved to be problematic for early morning photogrammetry

Flight 2

Flight Date: 28 December 2022
Flight Number: 221228 Flight Route: YSHR-YSHR
Start Time: 04:25 Finish Time: 10:55
Distance Covered: 609 Nautical Miles Total time: 7.1 (Figure 10-4)

Islands captured

Figure 10-5. Map of Flight 2

- Coringa Islets - Chilcott Islet
- Coringa Islets - South West Islet
- Herald Cays - North East Cay
- Herald Cays - South West Cay
- Willis Islets - Mid Islet
- Willis Islets - North Cay
- Willis Islets - South Islet
- Magdelaine Cays - North
- Magdelaine Cays - South

Figure 9-5

Flight notes

Issues with the Port 65mm Camera resulted in the flight pattern being modified to compensate. We believe moisture got into the camera on the first day of capture to cause these issues. There was still bad weather during this capture with some islands covered in showers of rain. Weather was marginal over many islands (Figure 10-6).

Figure 9-6 Better weather then previous day, still isolated clouds and showers

Flight 3

Flight Date: 29 December 2022
Flight Number: 221229 Flight Route: YSHR-YSHR
Start Time: 04:45 Finish Time: 10:25
Distance Covered: 520 Nautical Miles Total time: 5.7 (Figure 10-6)

Islands captured

Figure 10-6. Map of Flight 3

- Tregrosse Reefs - Central Diamond Islet
- Tregrosse Reefs - East Diamond Islet
- Tregrosse Reefs – South Diamond Islet

Figure 9-7

Flight notes

We had some very ordinary weather for this flight despite a much more optimistic forecast. The weather was perfect at the point of departure, however about half-way out to sea there were multiple walls of bad weather. We worked our way through and captured the Diamonds, apart from West Diamond as it was raining over the island (we cannot get the cameras wet during capture).

After East Diamond, conditions continued to deteriorate during our transit to Lihou. We diverted away from the system towards the southern area of Lihou hoping the weather would break and allow us to shoot in reverse. There was a small gap and we managed to capture part of Nelly Cay, however the rain started again followed by another wall of weather. We then turned south for Marion Reefs - Carola Cay before encountering more weather that we could not get through (Figure 10-7). We therefore made the call to return to Shute Harbour, as the risk of flying into a storm cell was a probability. This scenario highlights the advantages of the dual capture methodology from a safety perspective. Knowing that we had the opportunity to gather data of all targets on a second day relieved the pressure during the decision-making process when discussing potential risks in the cockpit. During these captures the need to finish the task at hand can lead to tunnel vision, increasing the likelihood of taking risks.


Figure 9-8 flying towards heavy rain. We cancelled the flight early as a safety precaution

Flight 4

Flight Date: 30 December 2022
Flight Number: 221230 Flight Route: YSHR-YIGM
Start Time: 04:30 Finish Time: 11:30
Distance Covered: 710 Nautical Miles Total time: 7.0 (Figure 10-8)

Islands captured

Figure 10-8. Map of Flight 4

- Lihou Reef - Betty Cay
- Lihou Reef - Coral Cay
- Lihou Reef - Dianna Cay
- Lihou Reef - Edna Cay
- Lihou Reef - Fanny Cay
- Lihou Reef - Georgina Cay
- Lihou Reef - Helen Cay
- Lihou Reef - Hermit Crab Islet
- Lihou Reef - Juliette Cay
- Lihou Reef - Nellie Cay
- Lihou Reef - Kathy Cay
- Lihou Reef - Lorna Cay
- Lihou Reef - Margaret Cay
- Lihou Reef - Middle Cay
- Lihou Reef - Observatory Cay
- Lihou Reef - South West Cay
- Lihou Reef - Turtle Islet
- Tregrosse Reefs - Central Diamond Islet
- Tregrosse Reefs - West Diamond Islet
- Tregrosse Reefs - East Diamond Islet
- Tregrosse Reefs - South Diamond Islet

Figure 9-9

Flight notes

Weather started out poor so the initial take off was delayed (Figure 10-10). Once airborne, conditions were the best weather of the entire capture survey, about 50% cloud cover. We managed to successfully survey twenty sites within the capture window.

Figure 9-10 on the tarmac before tack off waiting for weather to clear prior to take off

Flight 5

Flight Date: 12 January 2023
Flight Number: 230112 Flight Route: YHBA-YGLA
Start Time: 03:50 Finish Time: 10:56
Distance Covered: 699 Nautical Miles Total time: 7.1 (Figure 10-10)

Islands captured

Figure 10-10. Map of Flight 5

- Cato Reef - Cato Island
- Frederick Reefs - Observatory Cay
- Frederick Reefs - Unnamed
- Kenn Reefs - Observatory Cay
- Kenn Reefs - South West Cay
- Saumarez Reefs - North East Cay
- Saumarez Reefs - South West Cay
- Wreck Reefs - Bird Islets
- Wreck Reefs - Hope Cay
- Wreck Reefs - Porpoise Cay
- Wreck Reefs - West Islet
- Frederick Reefs - Observatory Cay
- Frederick Reefs - Unnamed
- Saumarez Reefs - North East Cay
- Saumarez Reefs - South West

Figure 9-11

Flight notes

Weather was conducive for safe flight; however, some clouds were encountered around the target area (Figure 10-12).

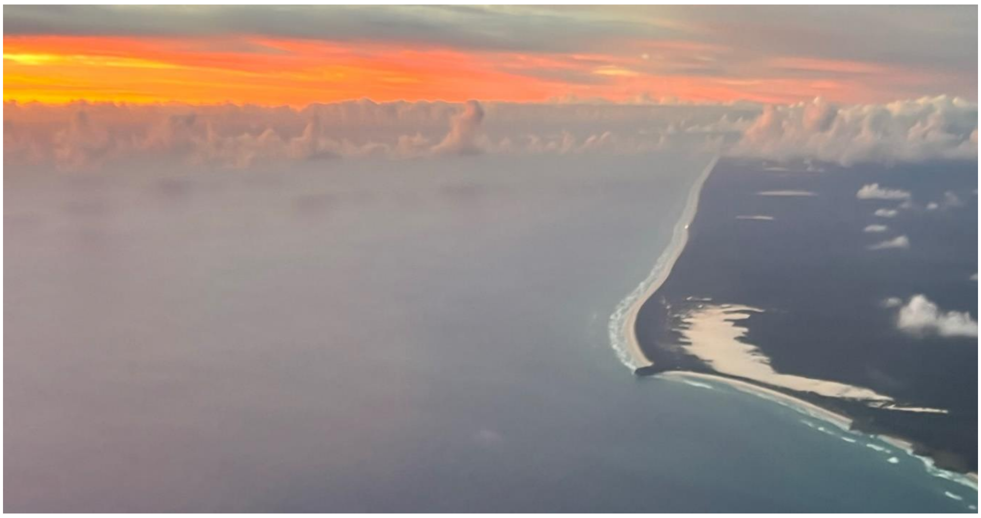


Figure 9-12 layers of stratus cloud and scattered cumulus cloud as we transited past Fraser island towards Cato Island

Flight 6

Flight Date: 12 January 2023
Flight Number: 230112 Flight Route: YHBA-YGLA
Start Time: 04:00 Finish Time: 10:56
Distance Covered: 700 Nautical Miles Total time: 6.9 (Figure 10-12)

Islands captured

Figure 10-12. Map of Flight 6

- Frederick Reefs - Observatory Cay
- Frederick Reefs - Unnamed
- Marion Reef - Brodie Cay
- Marion Reef - Carola Cay
- Marion Reef - Paget Cay
- Marion Reef - Unnamed
- Marion Reef - Unnamed
- Saumarez Reefs - North East Cay
- Saumarez Reefs - South West Cay

Figure 9-13

Flight notes

This flight was always going to be the hardest flight. There was a tropical depression to the north that was feeding moisture in a band stretching along the reef to the Swains (Figure 10-13). The track was flown clockwise, with Marion Reef being the first captured. During the initial transit north, you can see the deviations left and right of track required to move around bad weather. Nonetheless, the weather was satisfactory at the islands for SfM capture.

Figure 9-14 We departed IFR due rain. Weather improved as we tracked offshore. The lights are the ships lined up off the coast of Gladstone

Flight 7

Flight Date: 14 January 2023
Flight Number: 230114 Flight Route: YGLA-YHBA
Start Time: 04:30 Finish Time: 11:45
Distance Covered: 678 Nautical Miles Total time: 6.3 (Figure 10-14)

Islands captured

Figure 10-14. Map of Flight 7

- Cato Reef - Cato Island
- Kenn Reefs - Observatory Cay
- Kenn Reefs - South West Cay
- Wreck Reefs - Bird Islets
- Wreck Reefs - Hope Cay
- Wreck Reefs - Porpoise Cay
- Wreck Reefs - West Islet

Figure 9-14

Flight notes

Departed IFR from Gladstone in-between rain showers, yet the weather significantly improved offshore. The 35mm camera fogged during transit and remained foggy for Kenn Reefs, however the camera was clear by Wreck Reef.

Flight 8 and 9

Transit flights.
Flight Date: 26 December 2022 and 14 January 2023

10) Weather Analysis and Insights

A comprehensive understanding of weather conditions is essential when studying turtle nesting patterns and determining optimal conditions for aerial photography of turtle tracks. The summarised graphs provided below facilitate an overall understanding of the weather conditions experienced within the designated capture regions. These conditions include cloudy, rainy, sunny, and windy days. By examining the interplay between these weather patterns and turtle nesting behaviours, we can glean valuable insights to better comprehend the factors influencing nesting activities. Moreover, this information enables the identification of ideal weather conditions for capturing high-quality aerial photographs of turtle tracks, thus improving our ability to monitor and protect these essential habitats.

Capture Area One: East Diamond Islet

A weather analysis of East Diamond Islet, the central most point within the northern section, was used to represent the weather patterns encountered in the northern CSMP survey area (Figure 11-1). The timeframe for this data collection extended from December 17th to December 30th, 2022.

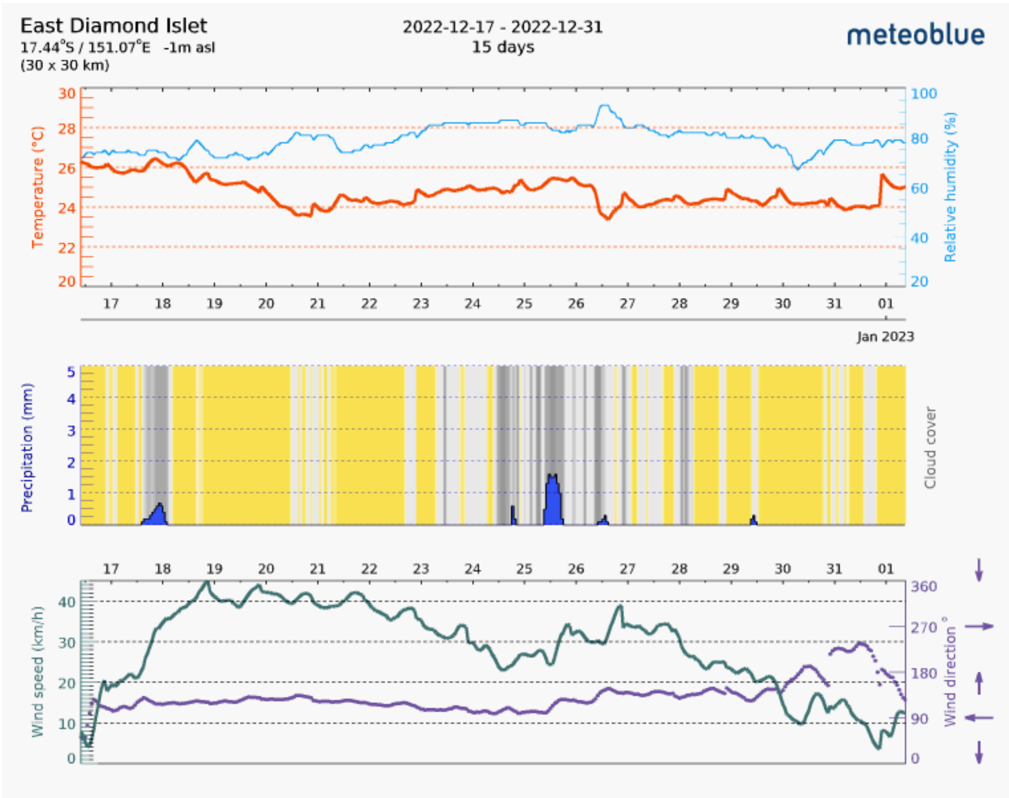


Figure 10-1 weather graph for capture area 1

Capture Area Two: Cato Island

Similarly, the weather patterns experienced at Cato Island, the southernmost point within the southern section, were utilised to describe the weather patterns experienced in this lower section of the survey area during the capture period (Figure 11-2). The data collected for this analysis spans from January 1st to January 30th, 2023, offering a comprehensive view of the area's weather during this period.

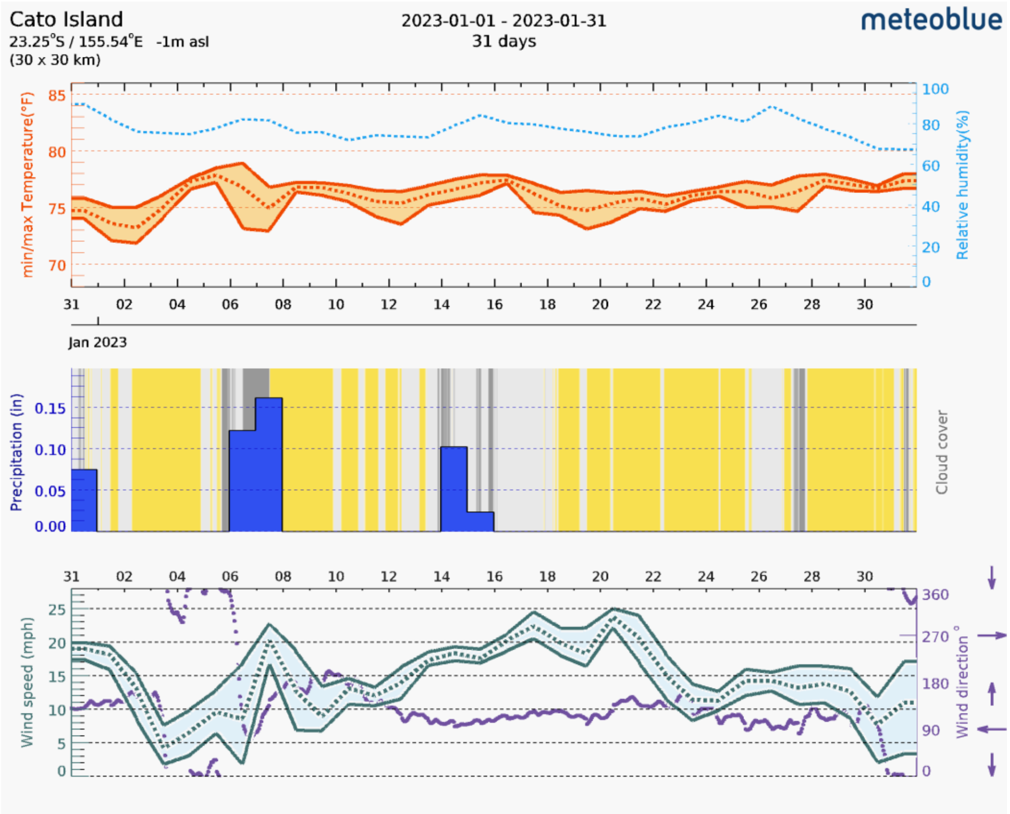


Figure 10-2 Weather graphs for capture area 2

Safety / Weather

Prior to departure all crew were required to undertake Helicopter Underwater Escape Training (Figure 11-3). This course is aimed at increasing the crew's experience and, in turn, their chances of successfully evacuating the aircraft and subsequently surviving at sea in the case of a water ditching.

At the time of the capture survey, a low pressure system was creating instability around the target islands resulting in thick cloud bands and winds up to 30 knots in areas, as well as sections of thick, turbulent cloud.

Figure 10-3

Prior to each flight, a series of checkpoints were created to assess for deteriorating weather conditions during the capture. To do this we used a decision tree as a tool to help us assess the risks and make an informed choice. To follow this decision matrix, we first identified all the relevant factors that could affect the safety of the flight such as the severity and location of the weather, location of the island relative to weather, how weather would impact the resulting capture, airborne hazards, and the distance and duration of the remaining flight including aircraft endurance.

As mentioned in Flight 3's notes earlier, weather continued to deteriorate during this flight (Figure 11-4), beyond just compromised data collection and as a result, the decision tree dictated that we abort the flight and return to Shute Harbour.

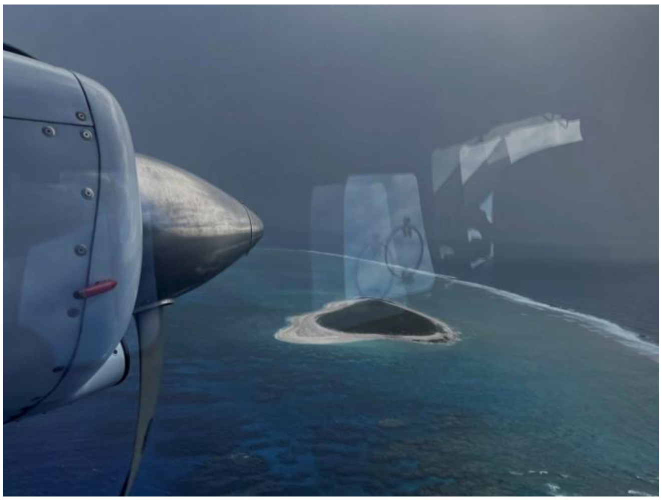


Figure 10-4 flying into bad weather near the Diamond Islands

In addition to using the decision tree, we also followed a series of safety procedures prior to each flight. These procedures included assessing the condition of the aircraft and ensuring that all safety equipment was in working order. We also conducted a pre-flight briefing to discuss the flight plan and identify any potential hazards or risks.

During the flight, we followed established procedures for communication and navigation, including monitoring weather conditions and updating the flight plan as necessary. We also maintained regular contact with ground support teams to ensure that they were aware of our location and status at all times. This was via the use of an Iridium go GPS phone.

By following these safety procedures, as well as using the decision tree to assess the risks associated with deteriorating weather conditions, we were able to conduct our flights safely and efficiently, whilst successfully capturing all islands at least once.

Weather for SfM Photogrammetry

Weather condtions made aerial photogrammetry difficult during the capture period.

Contrast between sun and cloud.

As the clouds were moving fast during the capture, some intitial passes had full sun while the second pass was under thick cloud offering minimal light. This lighting contrast between images resulted in challenges when generating necessary tie points to aid in merging datasets together.

An example of this bright / dark comparison can be seen in Figure 11-5. Similarly, this lighting contrast could also be seen within a single photograph from one camera within which part of the image is in sun while the other part is in shade from cloud (Figure 11-6).

When merging datasets together, the resulting overall island image would subsequently show a tiger stripe pattern (Image below), where the oblique cameras covered the same area as the nadir cameras from the previous run causing the lighting to shift from a dark pass to a bright pass. This required a greater effort to rectify and effected the quality of the SfM model.

Figure 10-5

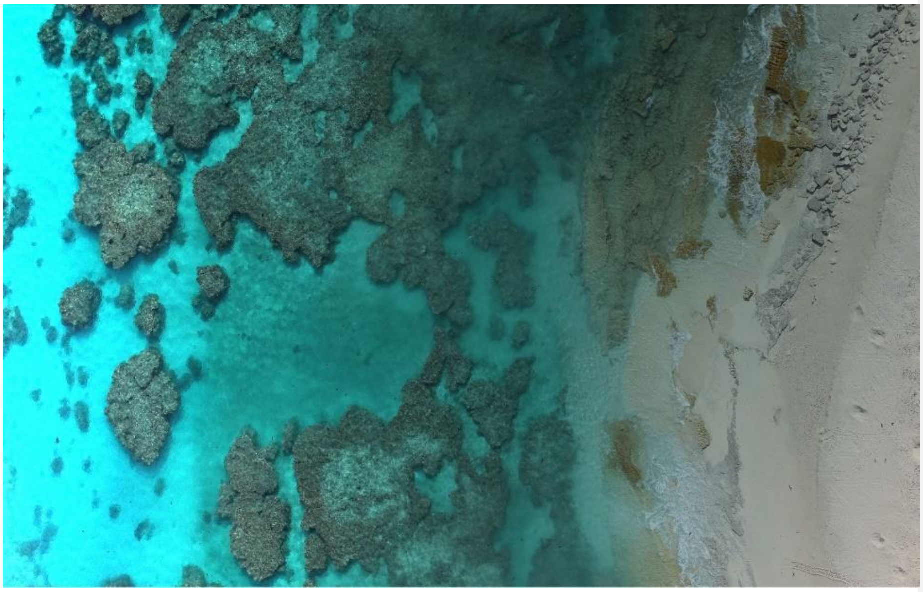


Figure 10-6

Challenges We faced

Images of sand have limited tie points and can create high contrast areas within these images (Figure 11-7). As a result, they can cause false positives when generating tie points and leave noise in the point cloud. This occurs because birds, especially those with dark feathers, create high contrast regions that can be mistakenly identified as unique features in the SfM process. This can cause the software to generate false tie points, leading to inaccuracies in the 3D models and point clouds.

Moreover, birds can also create shadows that can make it difficult to capture accurate details and texture on the smooth sand surface. These shadows can also cause the software to generate incorrect tie points or miss important details, leading to incomplete or inaccurate 3D models. This is especially problematic on islands with high bird densities.

Figure 10-5 birds flying over the sand cause issues with generation of tie points in SfM processing

11) Counting Birds

Counting bird populations on these remote islands can be challenging. Large bird populations, vegetation and remoteness are some of the issues that limit the accuracy of such counts. To address these challenges, we proposed capturing aerial photography of the populations, alongside the turtle captures, to collect accurate bird population data.

For the most accurate count, all birds need to be captured in a single pass over the island. It is common knowledge, however, that aircraft, including drones, disturb birds. Moreover, the sensor resolution and speed of drones are too low resulting in unreliable capture counts due to bird movement during passes. Conversely, we theorised that an aircraft could capture the island in a single fast pass at a resolution sufficient for bird species identification.

Methodology

We flew a single pass over the islands using an experimental array of six cameras setup in an orientation to capture the entire island at a high enough resolution to accurately determine the quantity of birds (Figure 12-1). This pass was done prior to descending to complete the lower altitude turtle track beach surveys as per the original scope or works.

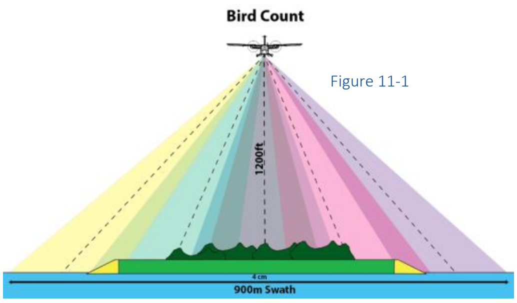


Figure 11-1

Results

We believe this general method has a great deal of merit. Unfortunately, only two island captures were attempted before the decision was made to cancel the bird passes due to safety concerns. The disturbance caused and additional time taken by these initial bird passes meant that the birds reached flight altitudes during the subsequent 600ft beach (turtle track count) survey passes. As such they posed potential conflict with the aircraft. Based on our two attempts we estimate we only have about 5 minutes of capture time before the birds reach the aircraft altitude.

Unfortunately, we didn't gather enough data to accurately determine the feasibility of such a method. Of the data we did gather, identification of bird species was difficult. They were the first two islands surveyed and light was limited due to thick cloud and, as a result, the quality of the photos was diminished (Figure 12-2). The need for good light conditions is a factor that is tricky to ensure given the remote location of the islands.

Figure 12-2. sample of birds taken at the 3cm pixel resolution.

SfM maps for bird counts

The challenge with using Structure from Motion (SfM) maps for counts is that birds often move during the pass, which can lead to inaccurate results. Subsequently, software will filter this movement as noise and remove the birds from the image. Birds that were moving would cause distortion in the orthophoto and often disappear. This issue is highlighted by the comparison of the original photo and the orthophoto shown in Figure 12-3. The effects of cloudy or rainy weather on image quality can also be noted, as can the degradation of image quality from the original to the projected image; however, this can mostly be overcome with higher resolution processing.

By leveraging our knowledge and expertise, we hope to improve the accuracy and usefulness of these aerial surveys in understanding and managing bird populations and their habitats. Ultimately, our goal is to support the broader scientific community in addressing critical questions and challenges in marine science and conservation.

It is our recommendation that all individual images be reprojected from their original source via the Pitch Yaw and Roll values obtained from the IMU (inertial measurement system) into a GIS Software. Furthermore, forward lap between images should be limited as IMU accuracy is lower in forward lap. Additionally, this method can remove relative error by not having the same images counted twice.

Our team has explored various software programs for asset counting using aerial photography in other GIS domains. We are more than willing to share our experiences and offer recommendations and contribute to building a method to count birds and species types in this and other marine science projects.

Figure 11-2 comparison of original data and process SfM

Counting systems infrastructure

Due to the volume of birds encountered in some areas, it is important to use AI / deep learning algorithms and image processing techniques to detect and identify birds in the images and produce accurate population estimates (Figure 12-4). These types of counts could most likely be automated with existing AI models, combined with human oversite.

Figure 11-5 an example of the sheer volume of birds

Counting birds that cannot be seen Utilising SfM volumetric calculations.

To account for birds that cannot be seen in the images, an alternative counting method based on delineating the area of tree cover as separate to vegetated ground cover, and then combining this with vegetation height to calculate the tree volume. A realistic ratio of tree volume to bird stock can also be calculated by counting the quantity of birds nested in several existing trees.

Due to the three dimensional (3D) information contained within the Structure From Motion (SFM) data products, vegetation volume can be calculated as the difference (or subtraction) between the ground surface and the tops of all objects in the 3D model. The two datasets required to achieve this are the ground or Digital Elevation Model (DEM), and the top surface or Digital Surface Model (DSM). The calculation of the DSM minus the DEM results in a new dataset referred to as the Digital Height Model (DHM). The result of this calculation can be seen in the figure below.

Table 11-1 (above) Comparing trees with nested birds and the size between seasons

Using image processing techniques, the vegetation areas on islands have been delineated at a fine-scale using the image based Vegetation Index (RGBVI) followed by segmentation and thresholding. By using a combination of the Digital Height Model (DHM) with the island vegetation, a Canopy Height Model (CHM) can be produced. The classification of vegetation on the island into woody vegetation (WV) and ground cover (GC) is derived by using a height value as a threshold. This threshold is determined based on the specific characteristics of the island's flora and can vary depending on the region and the types of vegetation present.

Once the classification has been completed, the woody vegetation and ground cover areas are calculated separately. The woody vegetation areas are used to estimate the number of trees, while the ground cover areas provide a baseline for understanding the overall vegetative cover on the island. A tree volume estimation can be derived by multiplying the area of woody vegetation by the average height of trees, as determined by the Canopy Height Model (CHM).

In order to obtain a more accurate estimate of bird populations, researchers can conduct field surveys to count the number of birds nesting in selected trees within the study area. This information, combined with the calculated tree volume, allows for the development of a realistic ratio of tree volume to bird stock. This ratio can then be applied to the entire island, providing a more comprehensive understanding of the bird population that accounts for those individuals not visible in the images. Furthermore, this approach can be refined by taking into consideration various factors that may influence bird populations on the island, such as seasonal variations, habitat preferences, and species-specific nesting behaviours. By incorporating these factors into the analysis, researchers can better understand the dynamics of bird populations and their relationship with the island's vegetation.

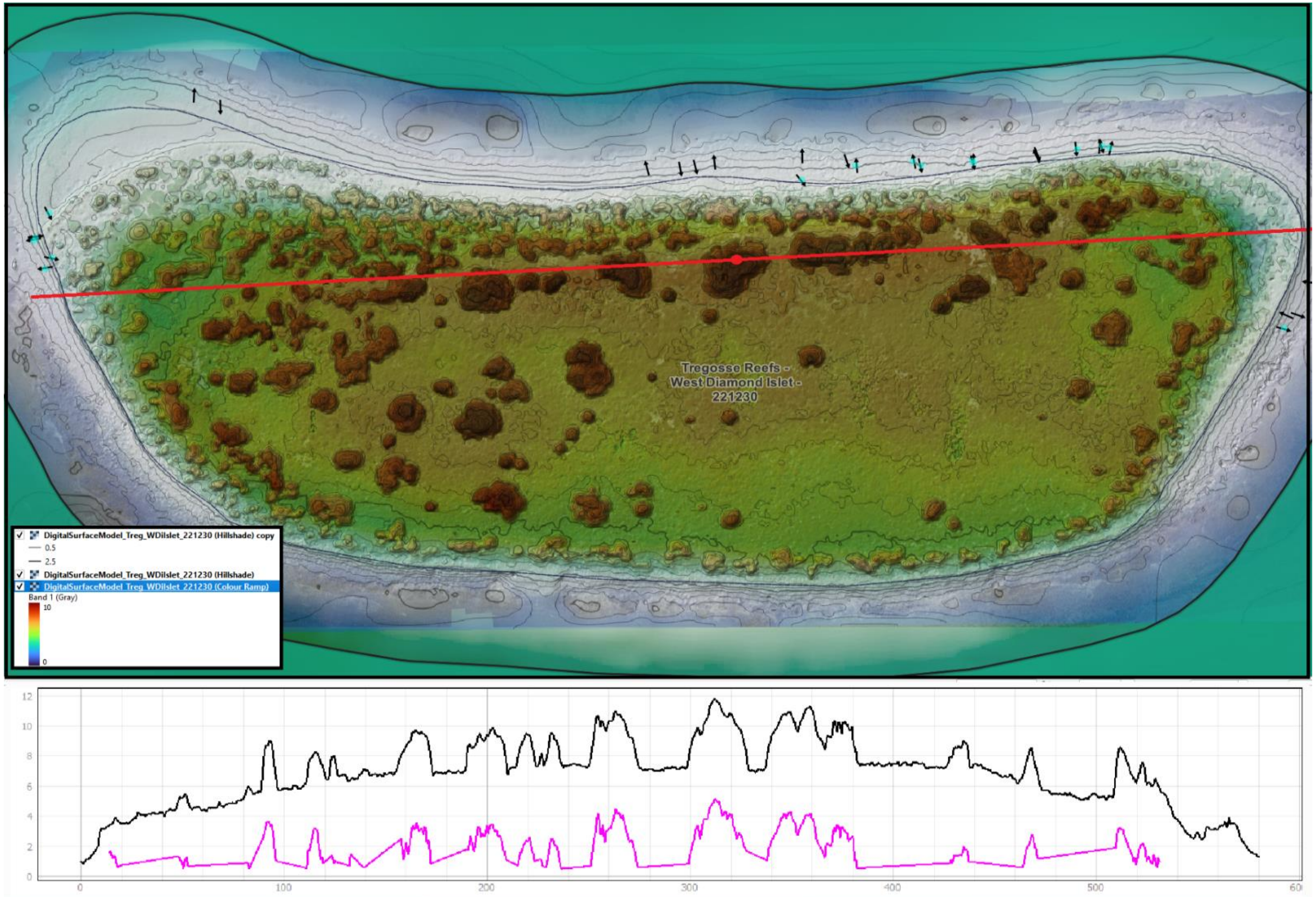


Figure 11-6 MAIN: west Diamond Islet on 30th Dec 2022, colour ramp for Digital Elevation Model (DHM) and 0.25m contours as black lines overlaid using transparency onto a black and white orthophoto. X-Section RED LINE: cutting across the centre line of the island is the position of a cross-section. Graph below shows cross-section lines for the BLACK-Digital Surface Model (DSM) and PINK-Digital Height Model (DHM).

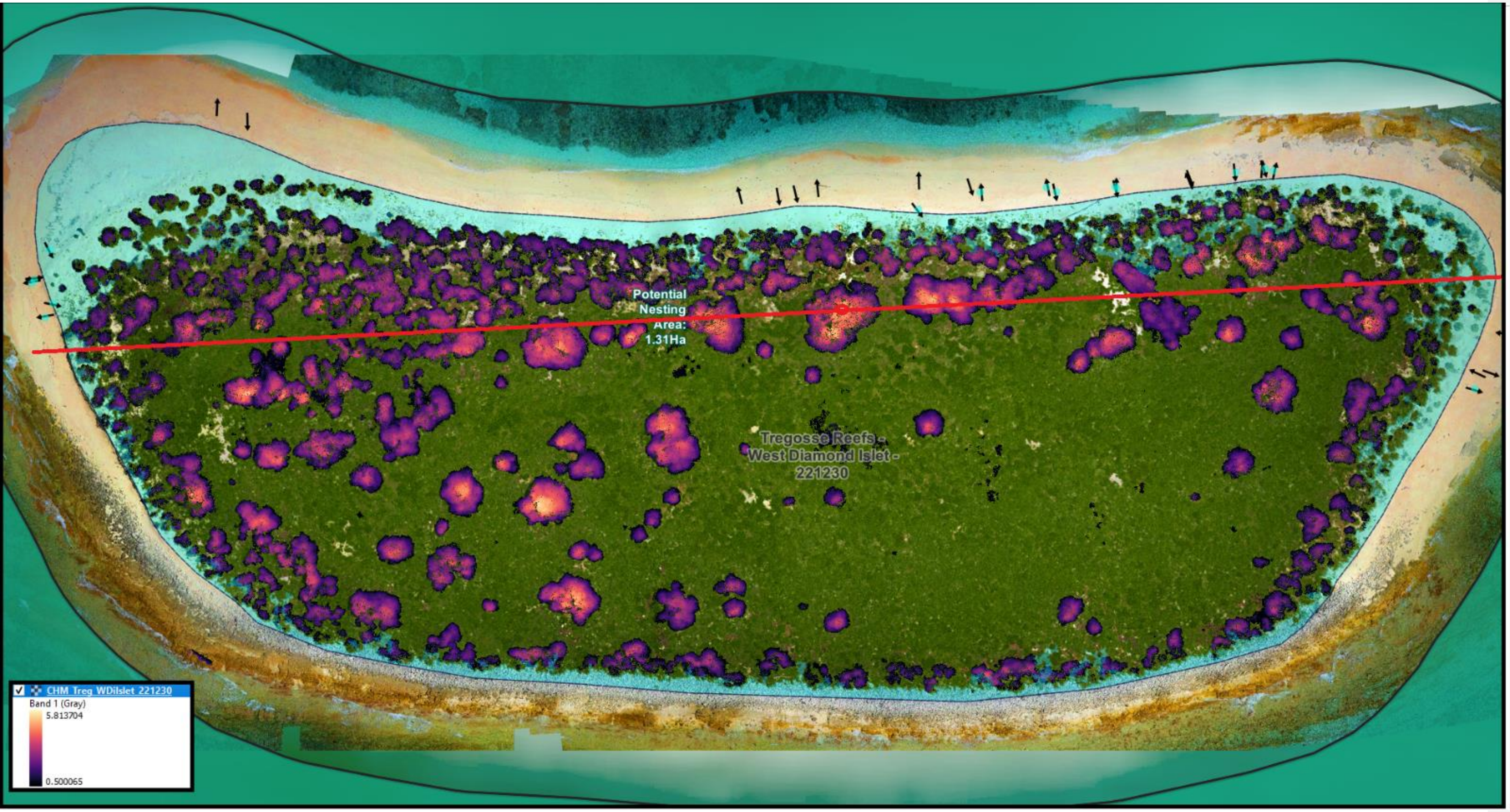


Figure 11-7 shows a heat map that visualises tree height on West Diamond Island. Digital Height Model (DHM) for West Diamond Islet on 30th Dec 2022 for values greater than 0.5 metres. Height values start at 0.5 metres in Dark Blue and are shown in a continuous colour ramp through to 5.8 metres above ground level. Larger trees appear with large yellow centres (tree crown) with a dark blue ring. The combination of vegetation areas (classified using RGBVI) and height (by the Digital Height Model) result in a clear delineation between vegetative 'Ground Cover' and trees or 'Woody Vegetation'.

Future Survey Requirement

To achieve the resolution shown in Figure 12-8, an approximate resolution of 7mm would be required. We took this image from the zoomed oblique camera, while in a turn, as a sample for later testing to determine the resolution requirements for bird identification. Based on this resolution, we would need to incorporate another two cameras into our existing six camera array (increasing the system to 8 x 100mp medium format sensors) to achieve the entire swath of all islands in a single pass (Figure 12-9). These cameras would have a closer focal length of 80mm and achieve a 900m wide swath at sub centimetre resolution. This resolution would allow biologists to identify each species of bird and could also be utilised as training data for AI systems for future autonomous counting of species types.

Figure 11-8 A 7mm resolution photograph demonstrates the detail that can be seen with a higher resolution capture methodology.

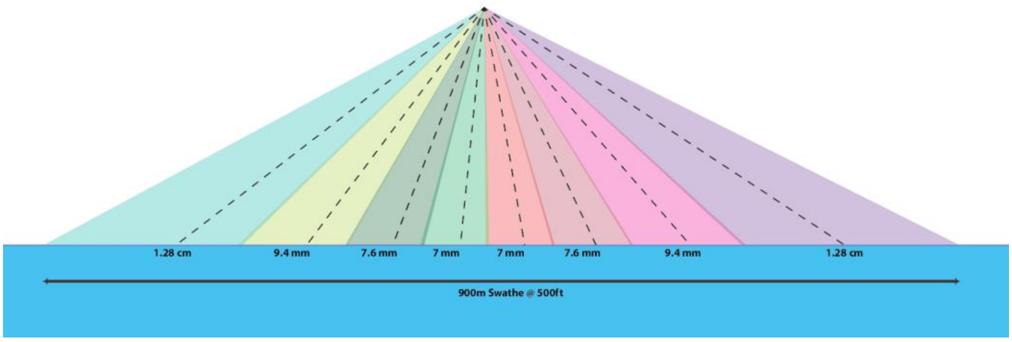


Figure 11-911-8 the camera array required to be able to capture an entire island (2400 megapixel a second).

12) Deceased Turtles

During this survey, we documented 47 deceased turtles across various stages of decomposition. While the previous season's count was only 36, it did not include Magdelaine Cays - North which accounted for 15 of this season's total. This island displayed a significantly higher presence of fishing debris, compared to the others—although correlation does not suggest a cause. The island's topography featured numerous exposed rocks that may have caused the turtles to become trapped or disoriented (Figure 13-1).

The sand cays with no vegetation as a guide for turtles as to where the sea might be (generally in the opposite direction) and possessing generally featureless, lunar landscape interiors that can have significant depressions below the dunal crest, thereby blocking any sight of the sea, can lead some turtles, with their eyes basically just above ground level, to get disoriented, exhausted and expire. Middle Cay, depicted in Figure 13.2 is one such 'death trap', with the rocky depression at least 4 metres below the surrounding dunal crests.

Figure 13-1 A few dead turtles on Magdelaine Cays around rocks

Excluding the data from Magdelaine Cays - North, the observed ratio of dead turtles was marginally lower than the previous season (Figure 13-2). However, this minimal difference between the two seasons is not statistically significant.

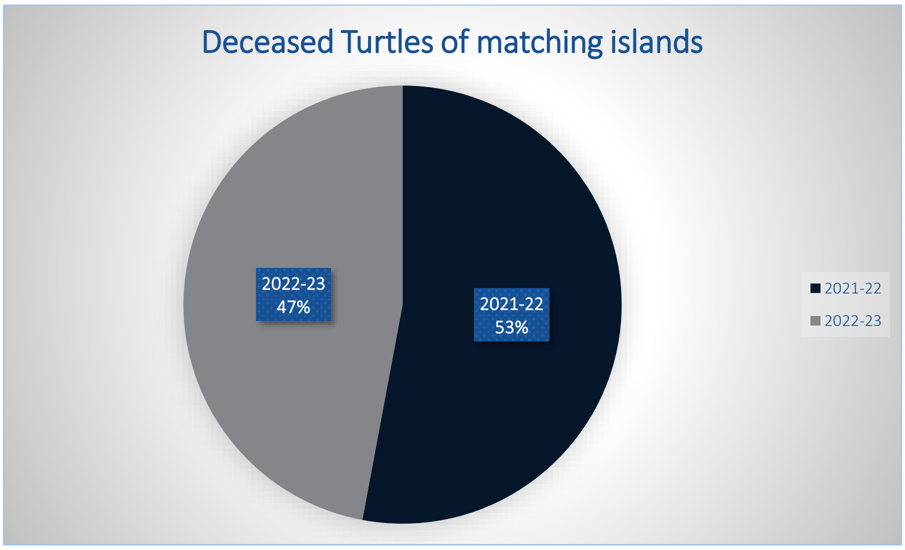
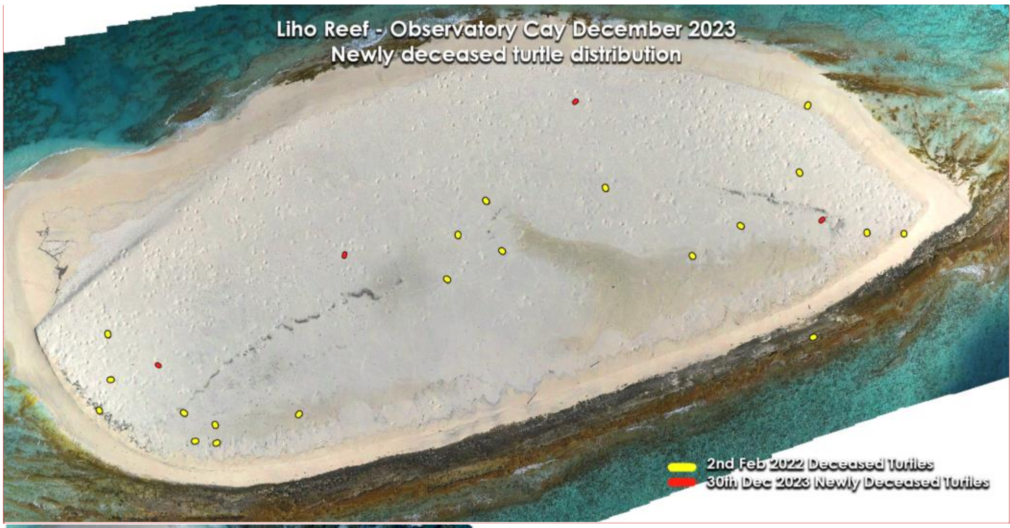


Figure 12-1 comparing two years of turtle counts on islands with a known data point.

Comparing Death counts

A comparative analysis was conducted between last seasons expired turtle count and this seasons data. This enabled us to obtain a precise count of the turtles that have perished within the eleven-month timeframe between the two captures. The pertinent statistics are presented below:

- Four new deaths counted on Lihou Reef - Observatory Cay (Figure 13-3)
- Four new deaths counted on Lihou Reef – Middle Cay (Figure 13-4)



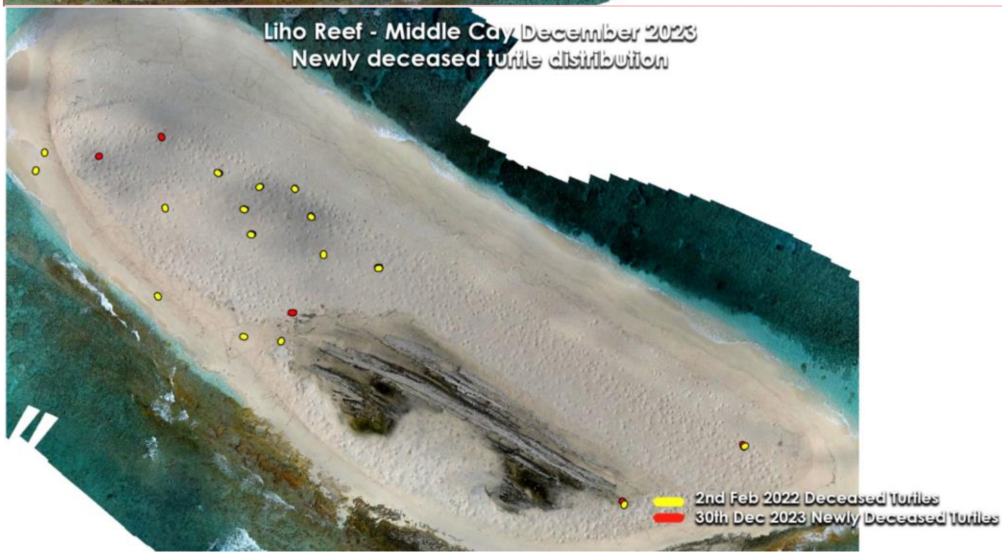


Figure 12-2 Lihou Reef – Observatory Cay and Middle Cay December 2023 Deaths. Yellow = old deaths, red = new deaths

Commented [HF1]: Lihou

Commented [HF2]: Note spelling: Lihou Reef

Waltzing to the End: Marathon Matilda's Final Journey

Last season we encountered a turtle that left a lasting impression on our team. We named her "Marathon Matilda," in recognition of her determination and resilience. Marathon Matilda's journey was an impressive one, as she crawled an extraordinary 706 meters, digging numerous body pits and drawing large circles on the sand (Figure 13-5). We first recorded her presence on February 3rd, 2022, and included her in our living turtle count with great enthusiasm.

Figure 12-3 Marathon Matilda captured on Lihou Reef – Middle Cay Feb 2022 after a 700m journey

Unfortunately, while conducting our second track count this season, we came across a deceased turtle in the exact location (to the centimetre) that we had photographed Marathon Matilda (Figure 13-6). The image captured last season must have been taken either on the day of or the day following Matilda's passing. This image now serves as a sombre reminder of her final journey.

The story of Marathon Matilda, like the character in the famous "Waltzing Matilda" song, ends with a poignant conclusion. Matilda's remarkable voyage came to an end, but the distance she travelled was truly remarkable and makes one appreciate the perseverance and strength of these amazing creatures. As we remember Marathon Matilda, we are reminded of the importance of understanding and protecting the fragile lives of these incredible animals.

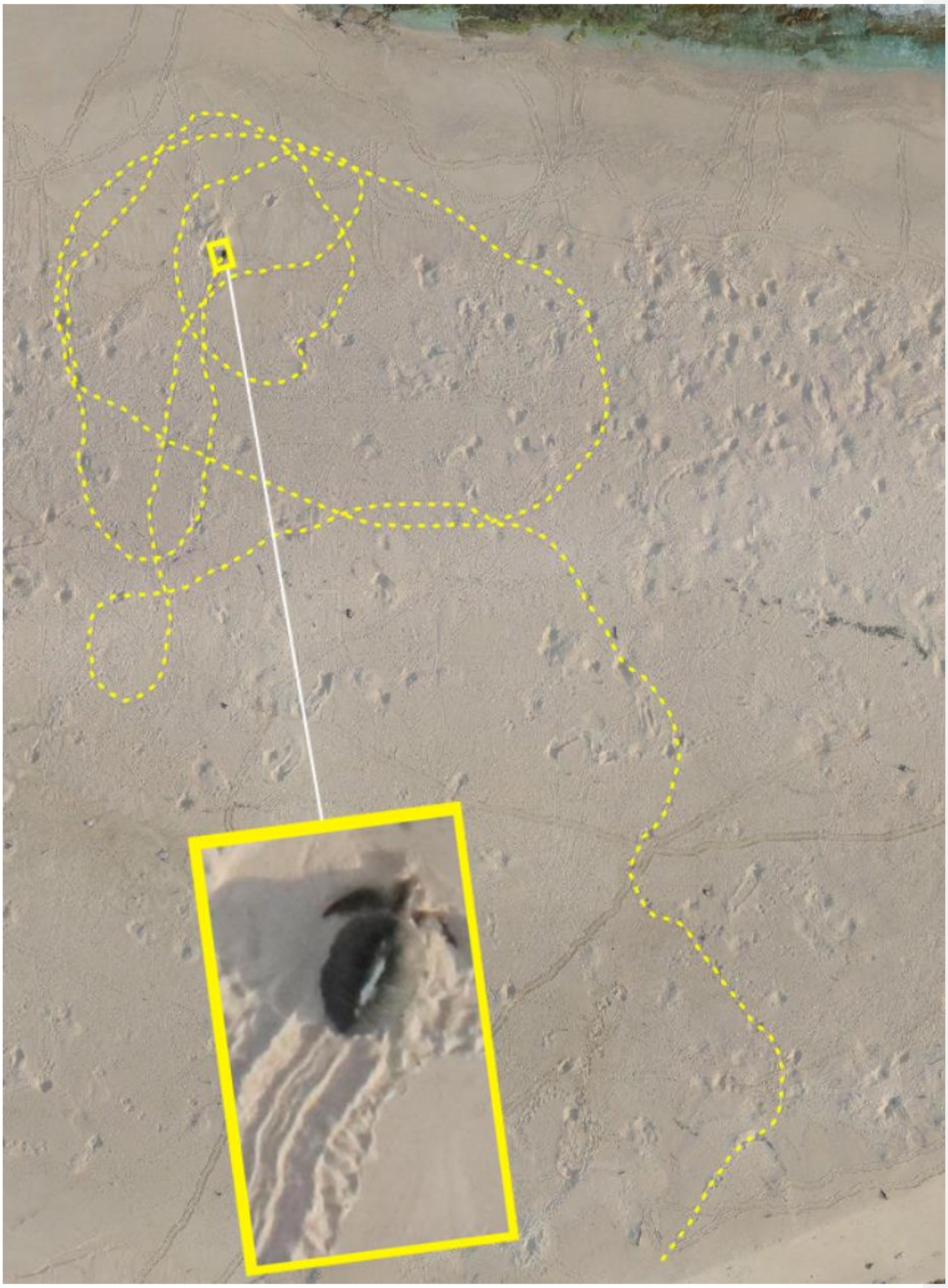


Figure 12-4 The entire track parth of Marathon Matilda

Figure 12-5 Marathon Matilda’s corpse in the same location as her photo the previous year. Unfortunately she perished from exhaustion.

State of decay and counting new deaths

Marathon Matilda's corpse seems to be more eroded than other turtles when we compare between seasons. This is possibly due to her distance from the water's edge, providing easy access by hermit crabs, as well as being located within the busy dunal crest area where turtles frequently dig body pits.

Out of interest we have selected six corpses (Figure 13-7) to show various states of decay.

Figure 12-7 We have observed that the turtles in the middle of the islands tend to decay much slower than those closer to the waters edge.

13) Geomorphological change

Although not a requirement in the current scope of works, the survey was structured to enable data to be repurposed to map geomorphic change of islands should this be a requirement in the future.

The integration of remote sensing technology and geospatial analysis tools has enabled the study of geomorphic change in island environments with exceptional detail. By harnessing the power of high-resolution aerial imagery and three-dimensional models, we can now observe and quantify changes in the landscape over time. Examining the colour, texture and form derived from photogrammetric data captured between campaigns provides the opportunity to track changes in coastal geomorphology and terrestrial habitats (Figure 14-1). In the context of climate change, this quantifiable information is a useful tool to manage these fragile ecosystems, that are vulnerable to rising sea levels and other environmental stressors. By monitoring and examining geomorphic and habitat changes, resource managers and researchers can improve their understanding of underlying processes and take steps to protect these valuable habitats.

Figure 14-1.

In addition to its scientific value, this volumetric survey data can also have practical applications in land management and conservation planning. For example, by identifying changes in turtle nesting areas, researchers can establish protected zones and implement strategies to reduce human impacts on these important habitats. The data can also be used to inform decisions about resource allocation, such as prioritising areas for habitat restoration or erosion control. By providing detailed, accurate information about the state of island ecosystems, the survey can help guide effective conservation and management practices that promote long-term sustainability and resilience.

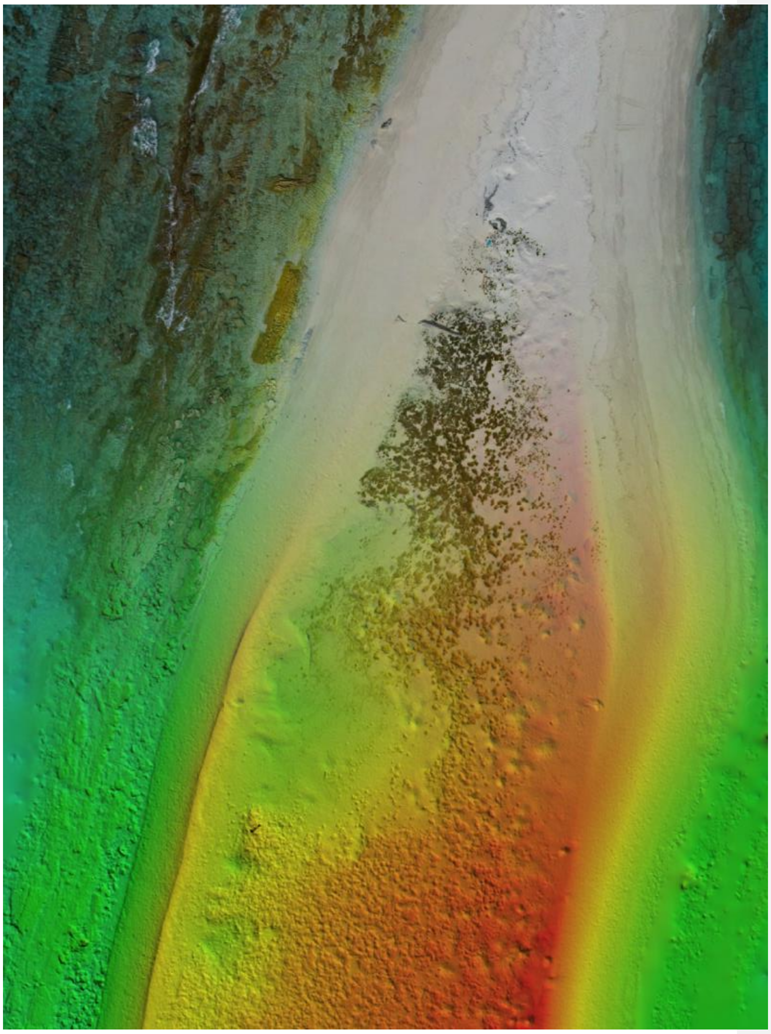


Figure 13-1 A combination of a volumetric model and a photogrammetry model. The Colours denote altitude with warmer colours being higher. Body pits can be seen on the eastern edge above the berm crest.

Geomorphic change of berm crest between seasons

Figure 14-2 shows the location of the dunal crest at Liho Reef – Middle Cay of Feb-02-2022 (pink) to Dec-30-2022 (yellow)

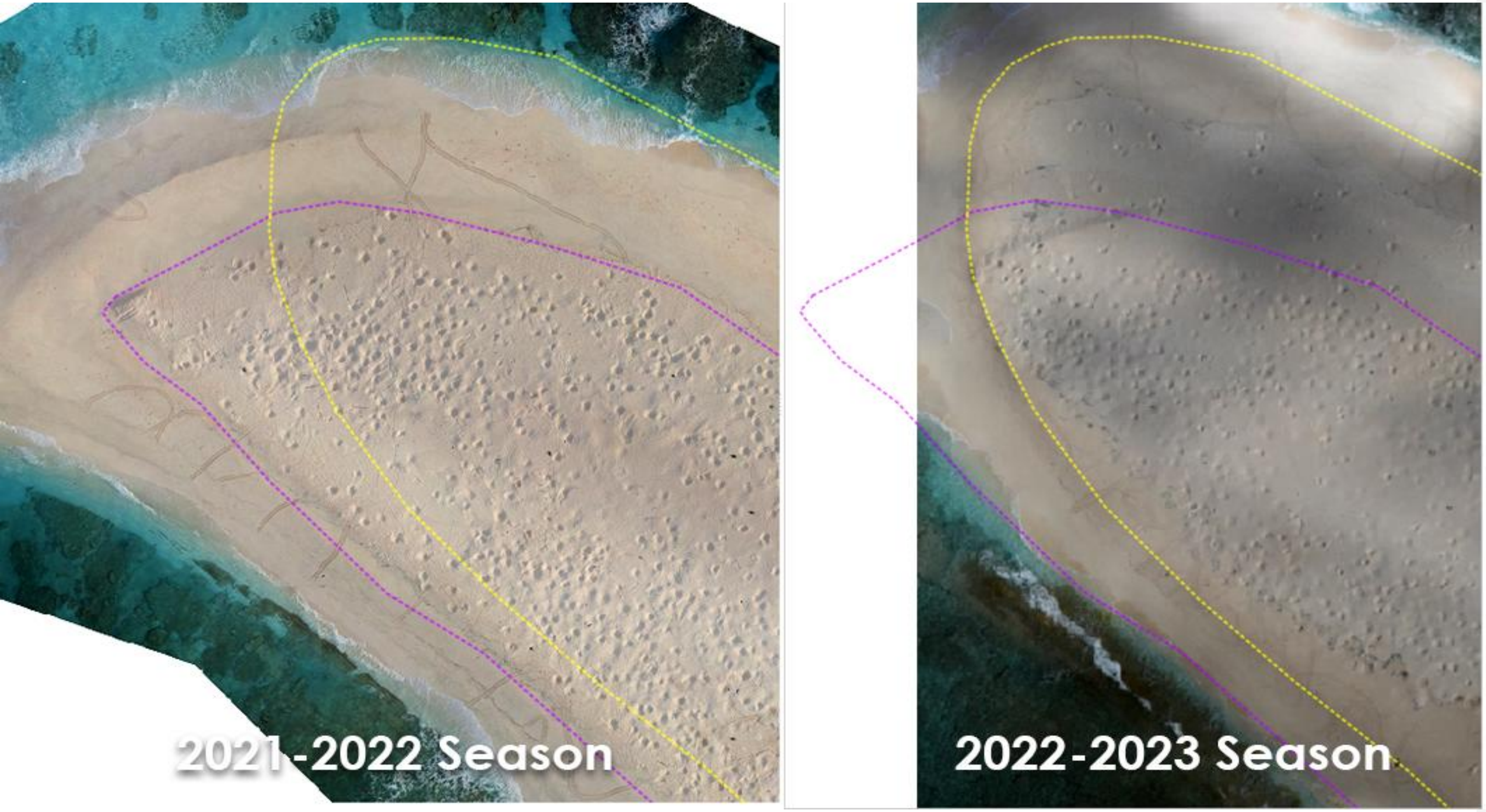


Figure 14-132 The extent of change between Middle Cay.

Change in turtle nesting area

Figure 14-3 – Change in Turtle Nesting Area

Figure 14-3 showing the change in nesting areas

Figure 13-4 Two images that compare Lorna Cay in Lihou Reef split into two separate islands. The sand on the south western corner has also shifted significantly northwards. The image on the left was supplied by Parks Australia.

Weather for SfM of Geomorphology

The thickness of clouds impacted the quality of the data captured during SfM photogrammetry for some of the islands, which in turn impacted our ability to accurately utlise the data for volumetric geomorphology capture. As the islands surrounding beaches are white sand, they are ideal for everything but SfM. While SfM photogrammetry is a powerful tool for capturing detailed data of coastal environments to understand geomorphology, it is not without its challenges. Thick clouds can limit the amount of available light and create a diffused, soft light that can make it difficult to capture accurate details and texture. Conversly bright sun can cause glare and a resulting noise in the capture that needs to be cleaned out. Cleaning of this data for geomorphic measurement will take time beyond the scope of the turtle nesting surveys. That said, we believe the tool would provide invaluable information.

We have gone ahead and done this post-processing on a few of the islands to aid as proof of concept. The biggest challenge is generating quality tie point data. Light plays a large part in being able to capture this accurate data and record quality tie points.

XY Area change is easy to get relatively accurate results, should volumetric (Z) change be required this would take more processing.

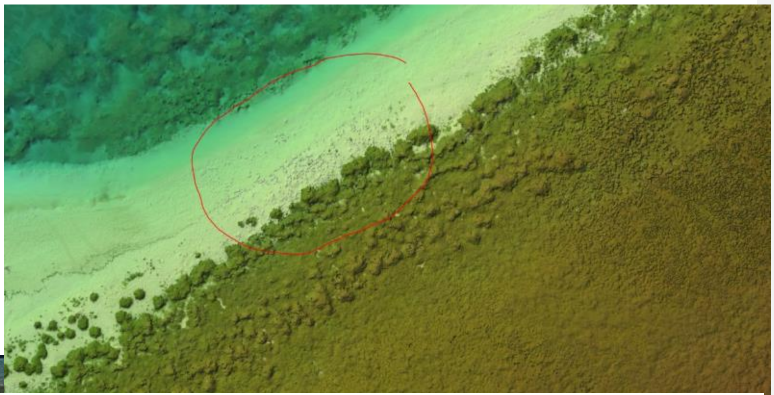


Figure 13-2

Figure 13-3

14) Marine Debris Observations

Marine debris was counted at all islands. Magdelaine Cays – North had the highest number of marine debris related items counted (34) as can be seen in Table 15-2 (next page). Below is a sample of 100 images. The islands at Saumarez Reefs weren't recorded due to lack of turtle tracks, however there was quite a large amount of debris relative to island size sighted.

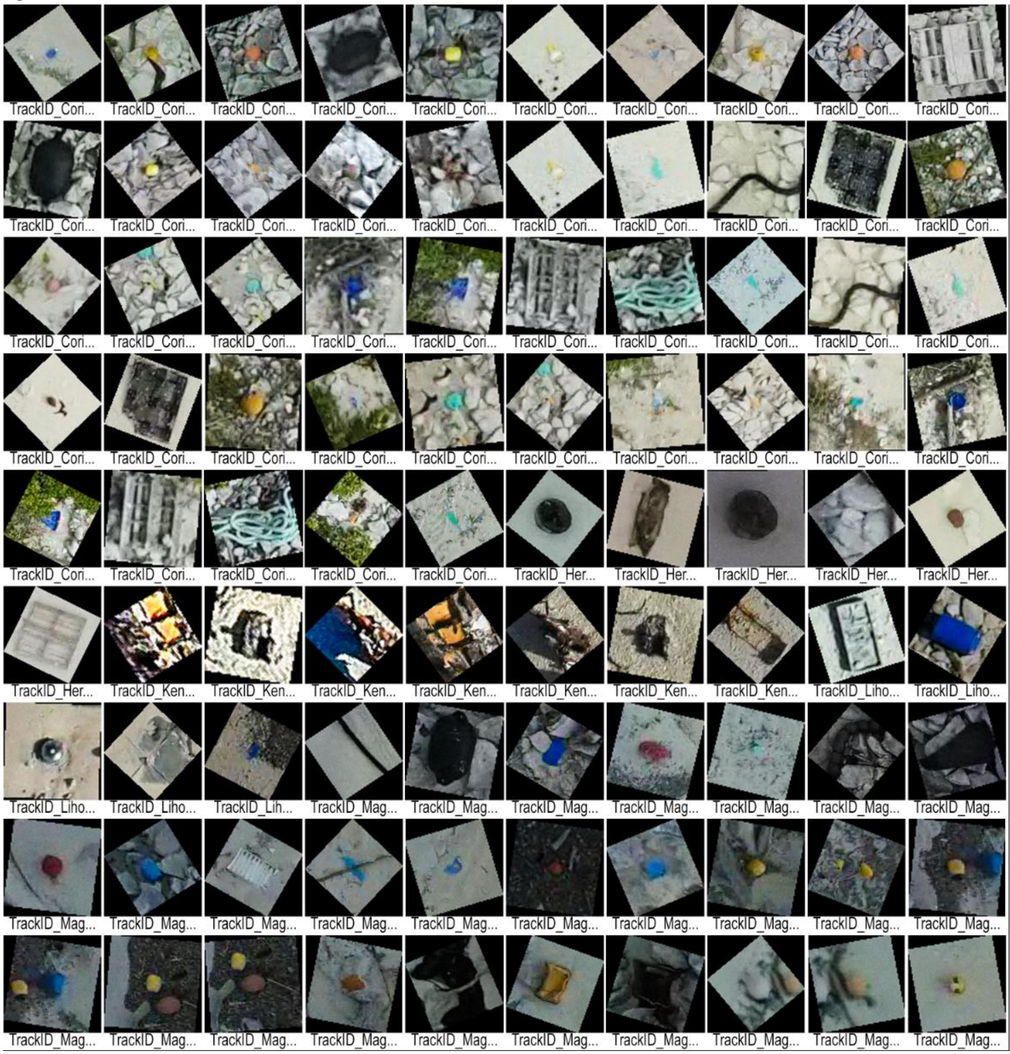


Figure 14-1 a photo list of observed marine debris

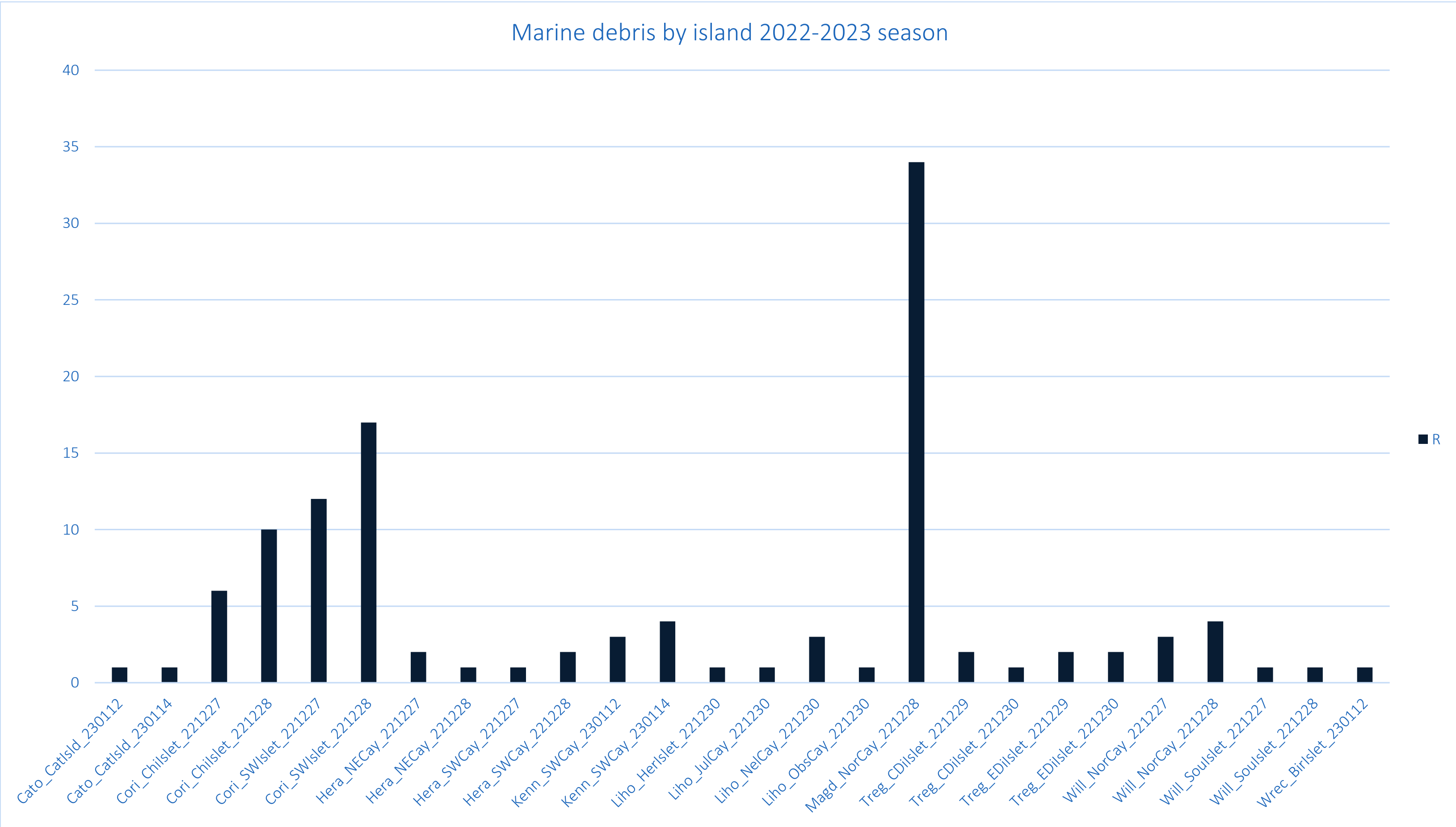
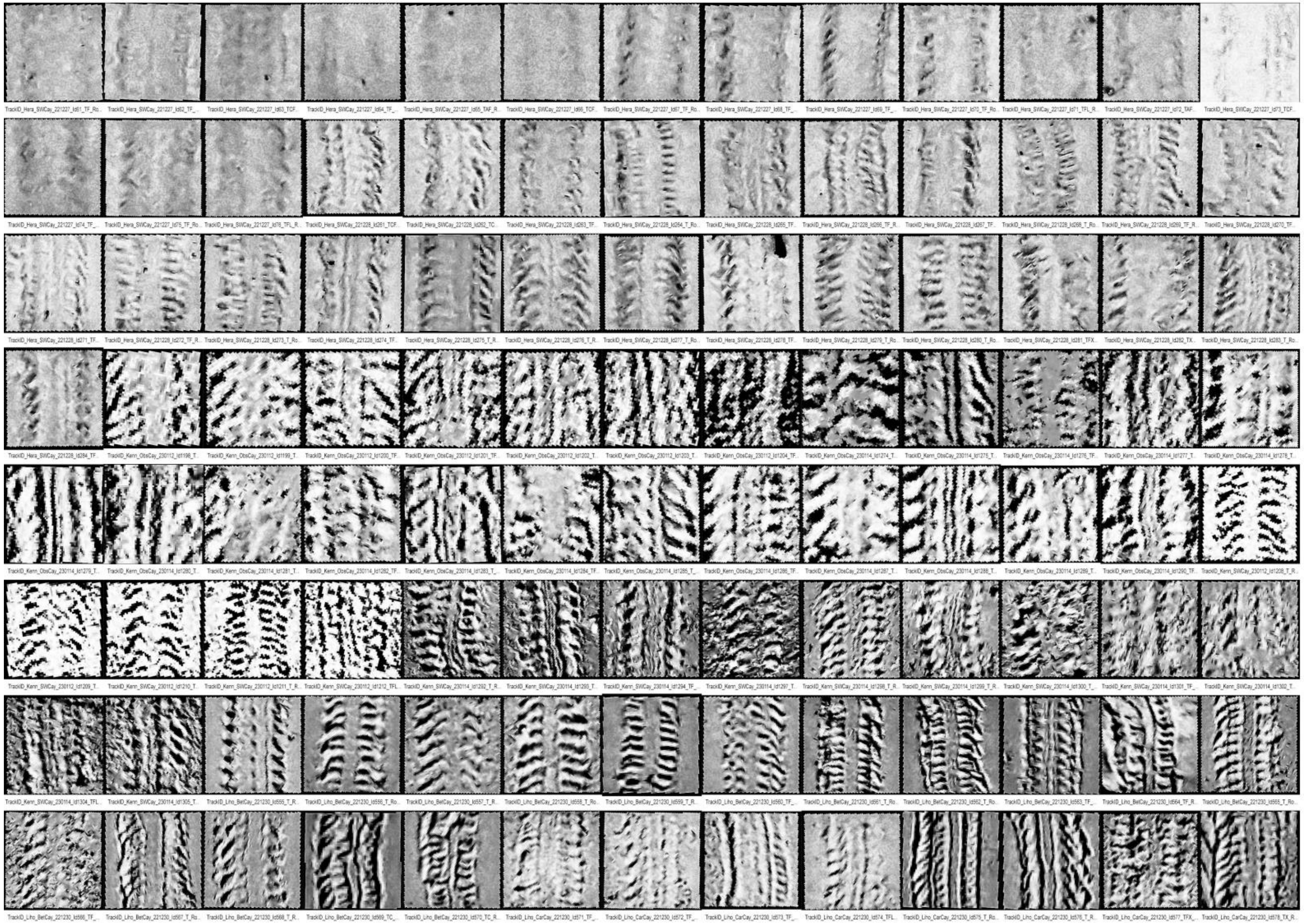
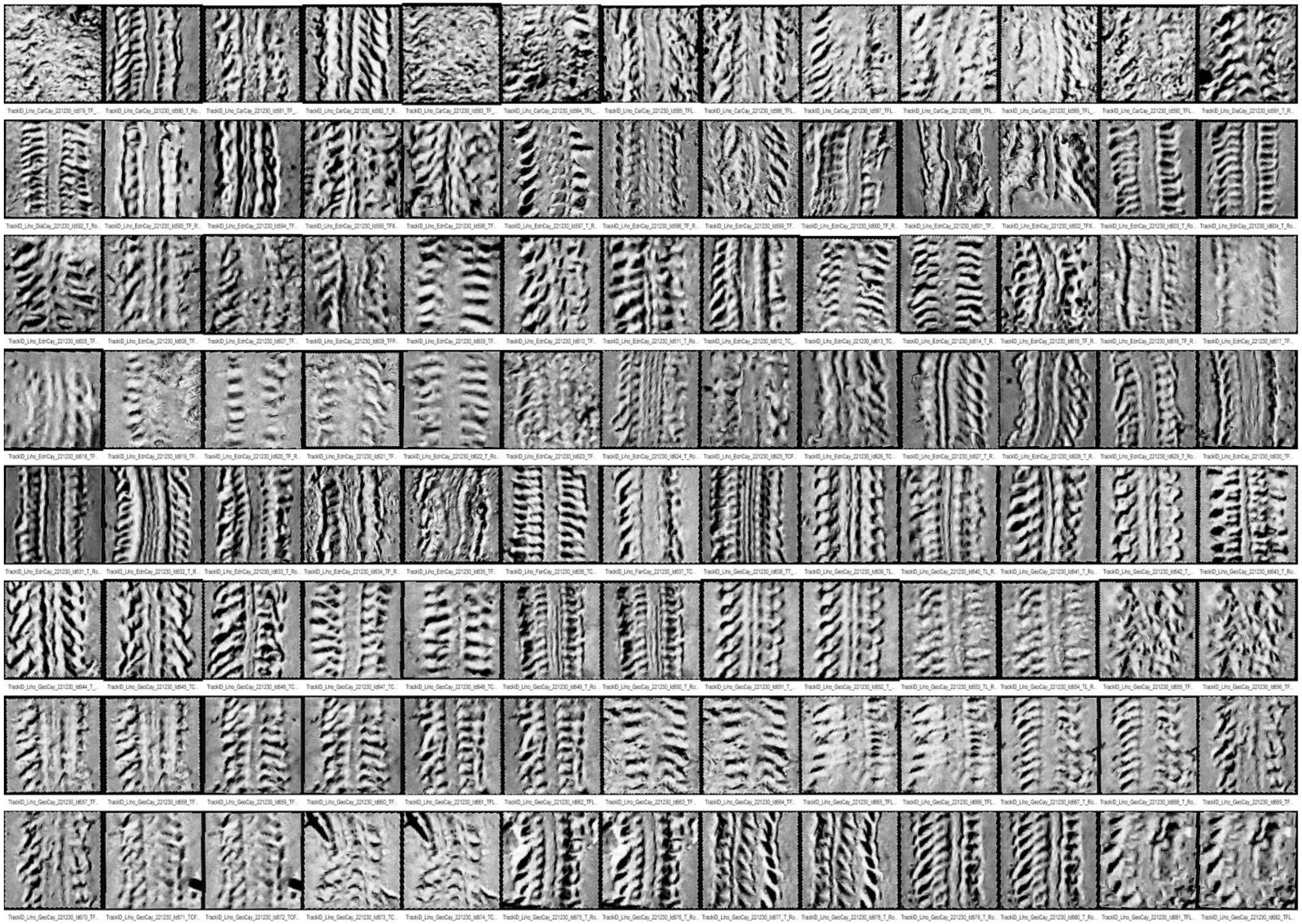


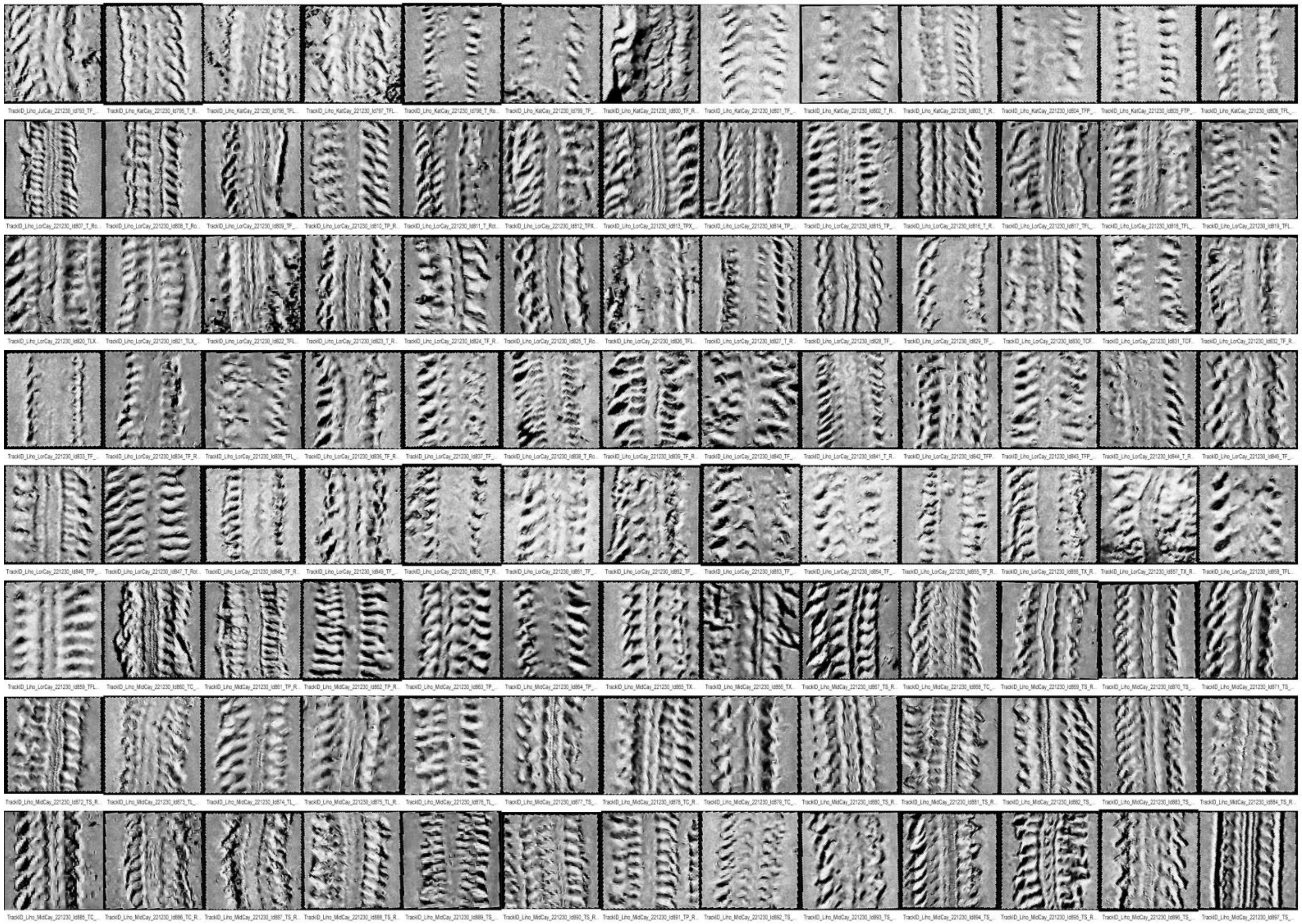
Table 15-1 - Rubbish observed in 2022-2023 season

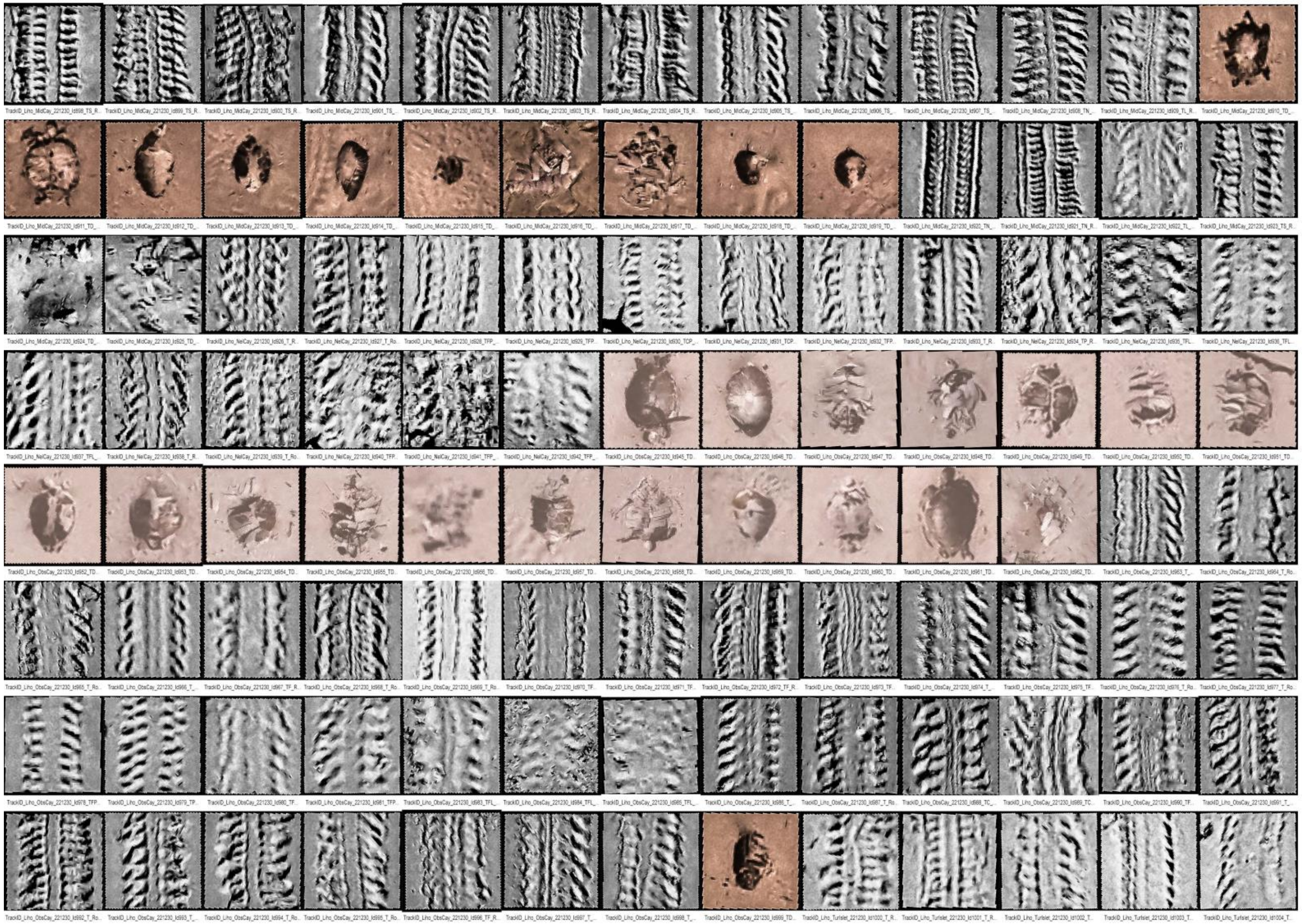
Addendum I - Turtle Tracks

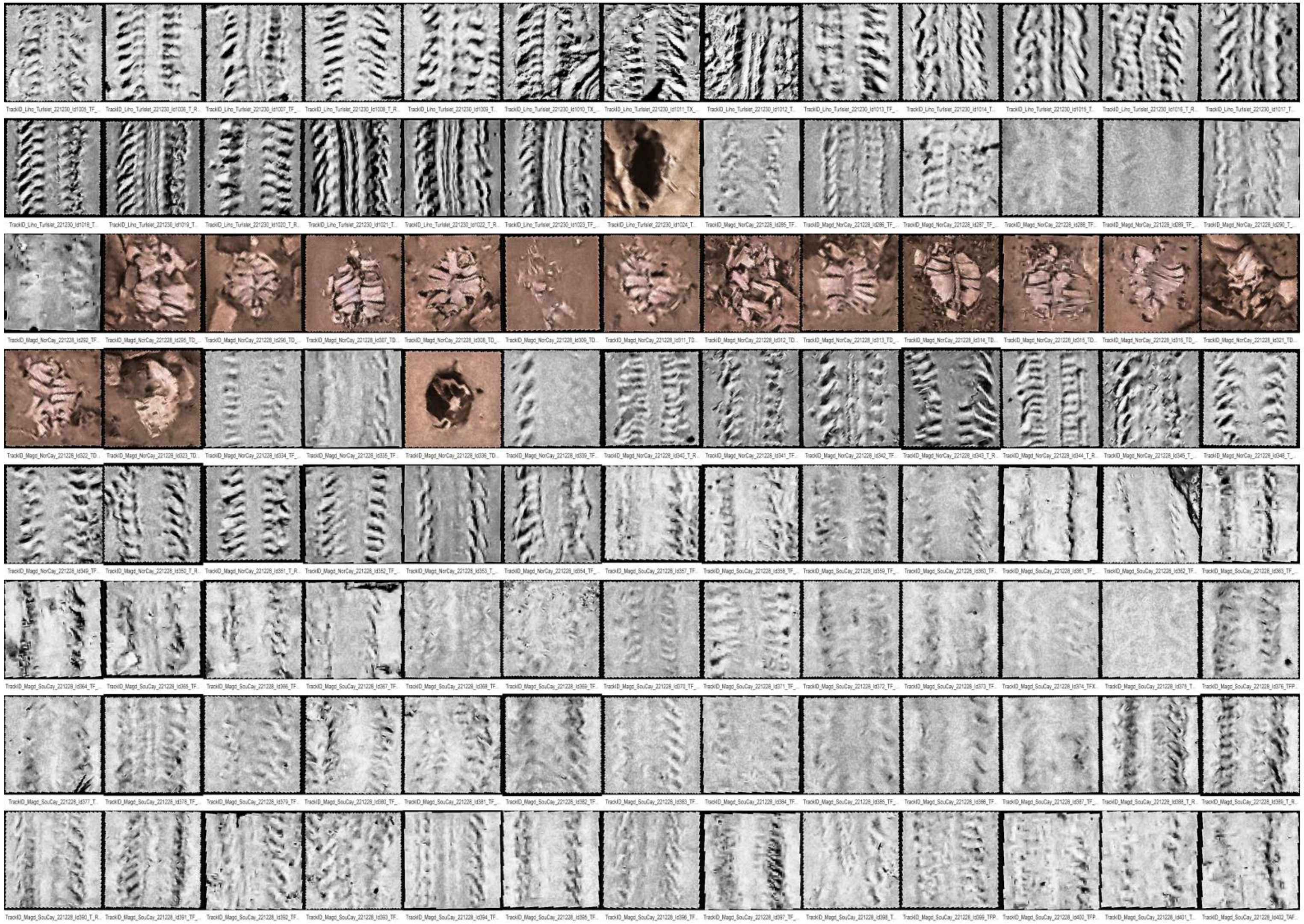


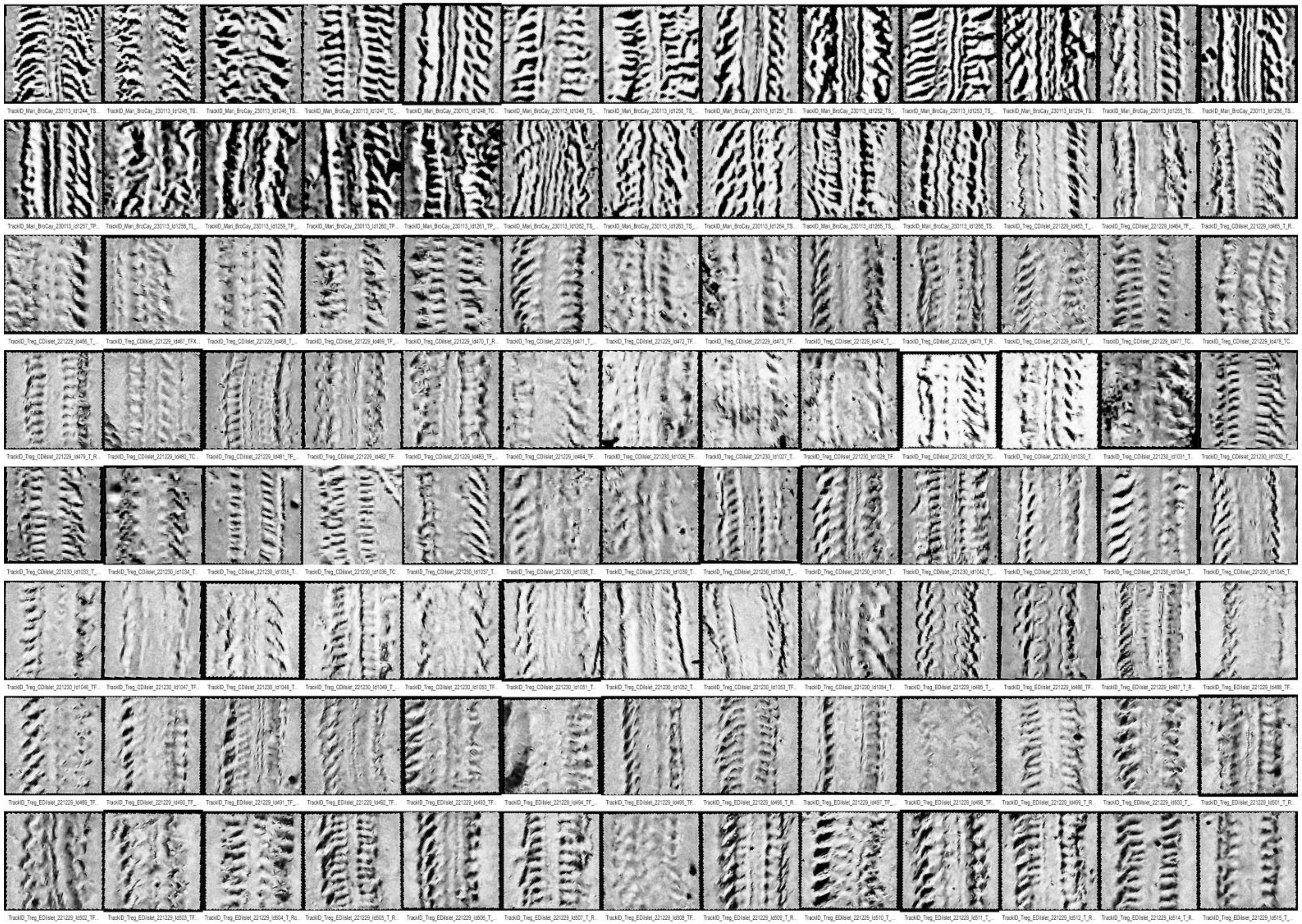
AeroGlobe Spatial Science

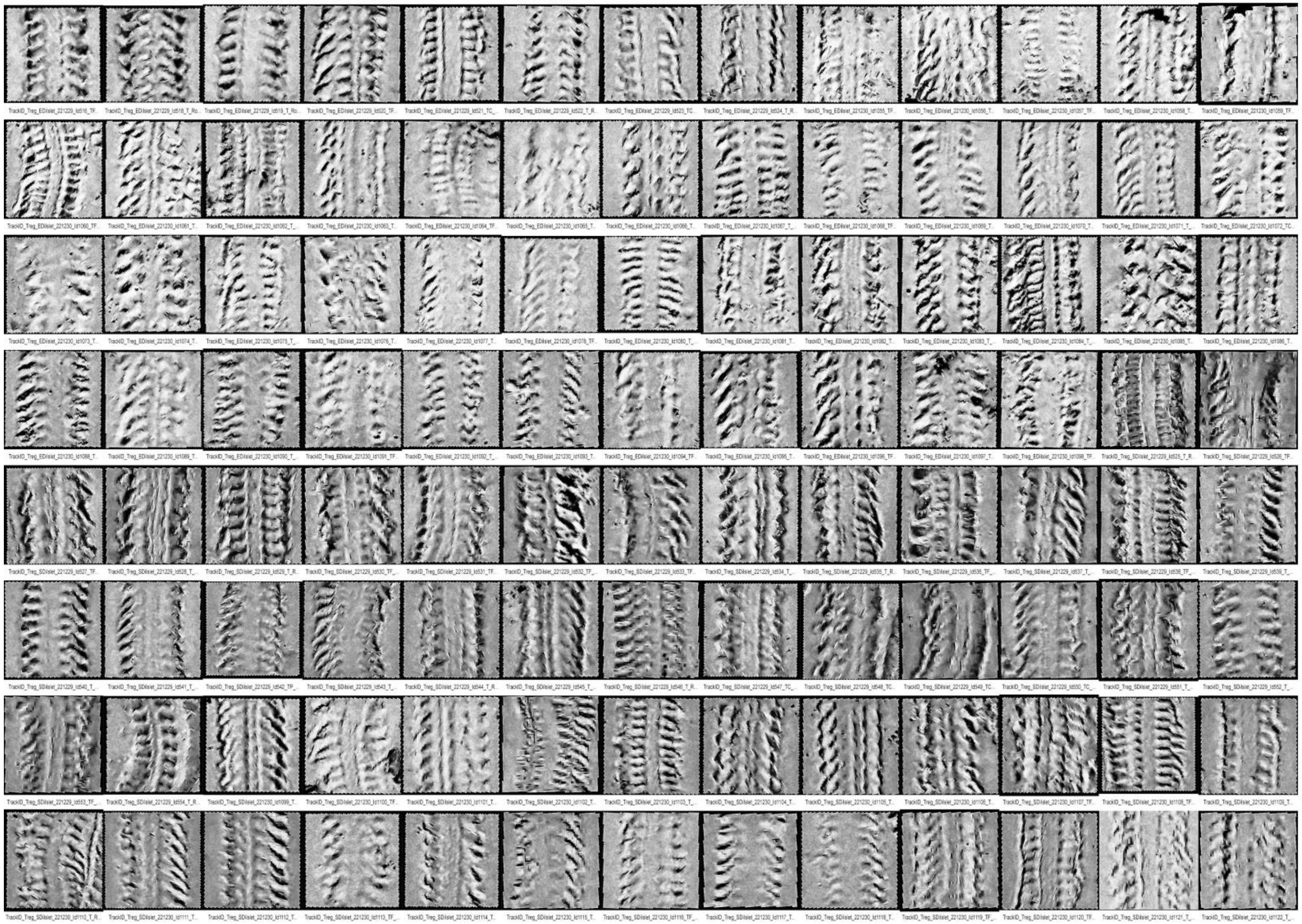


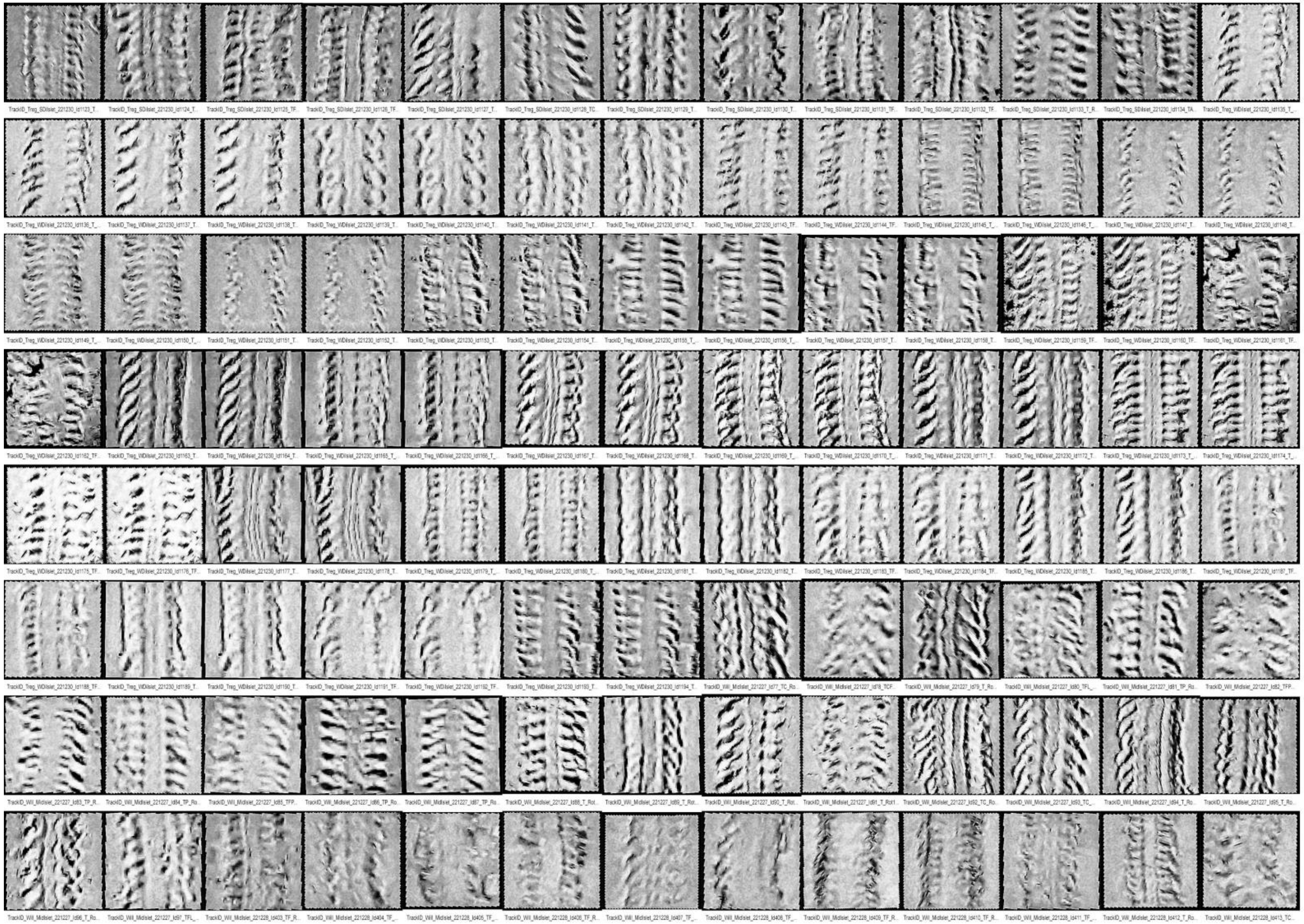


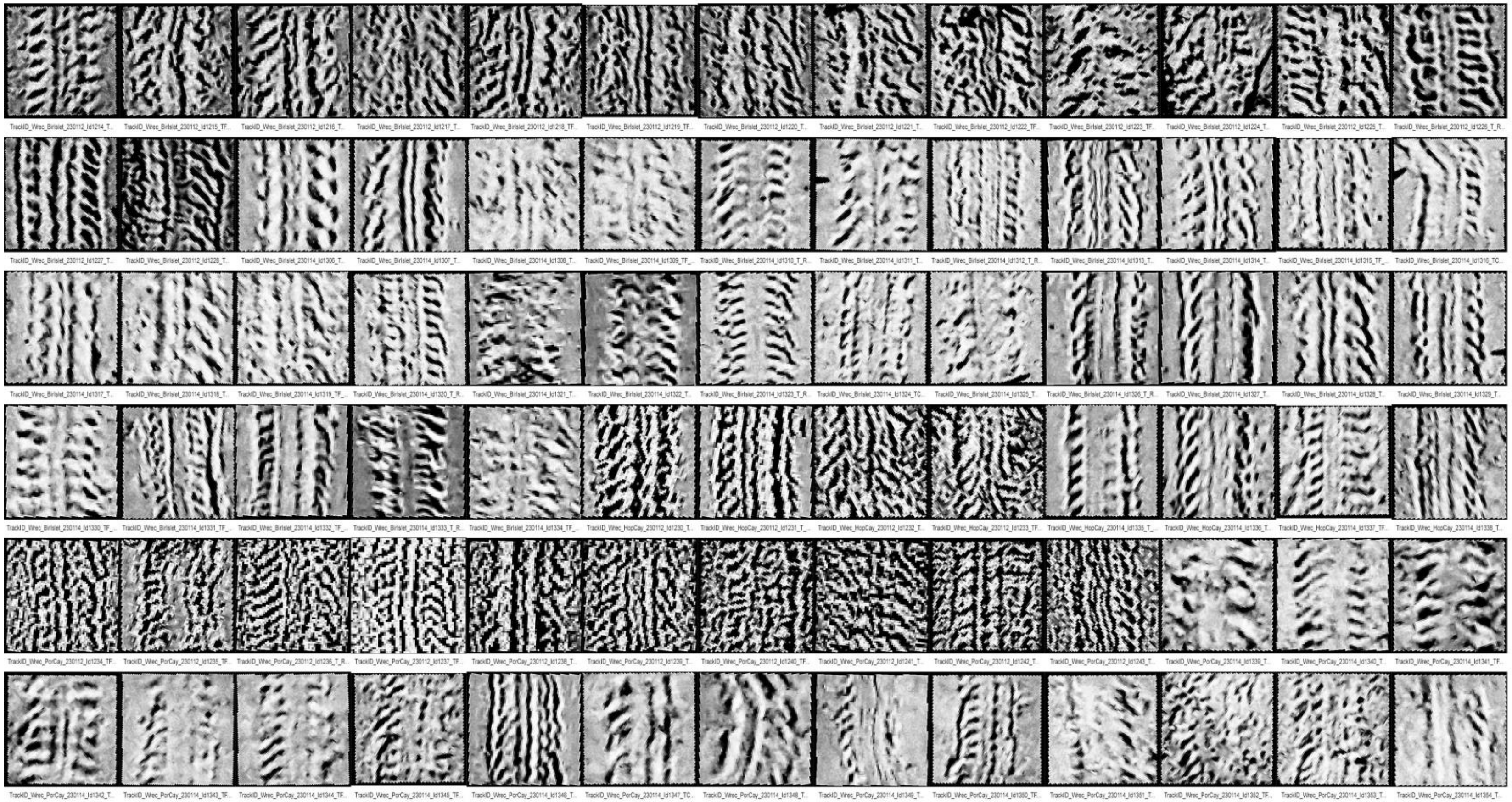












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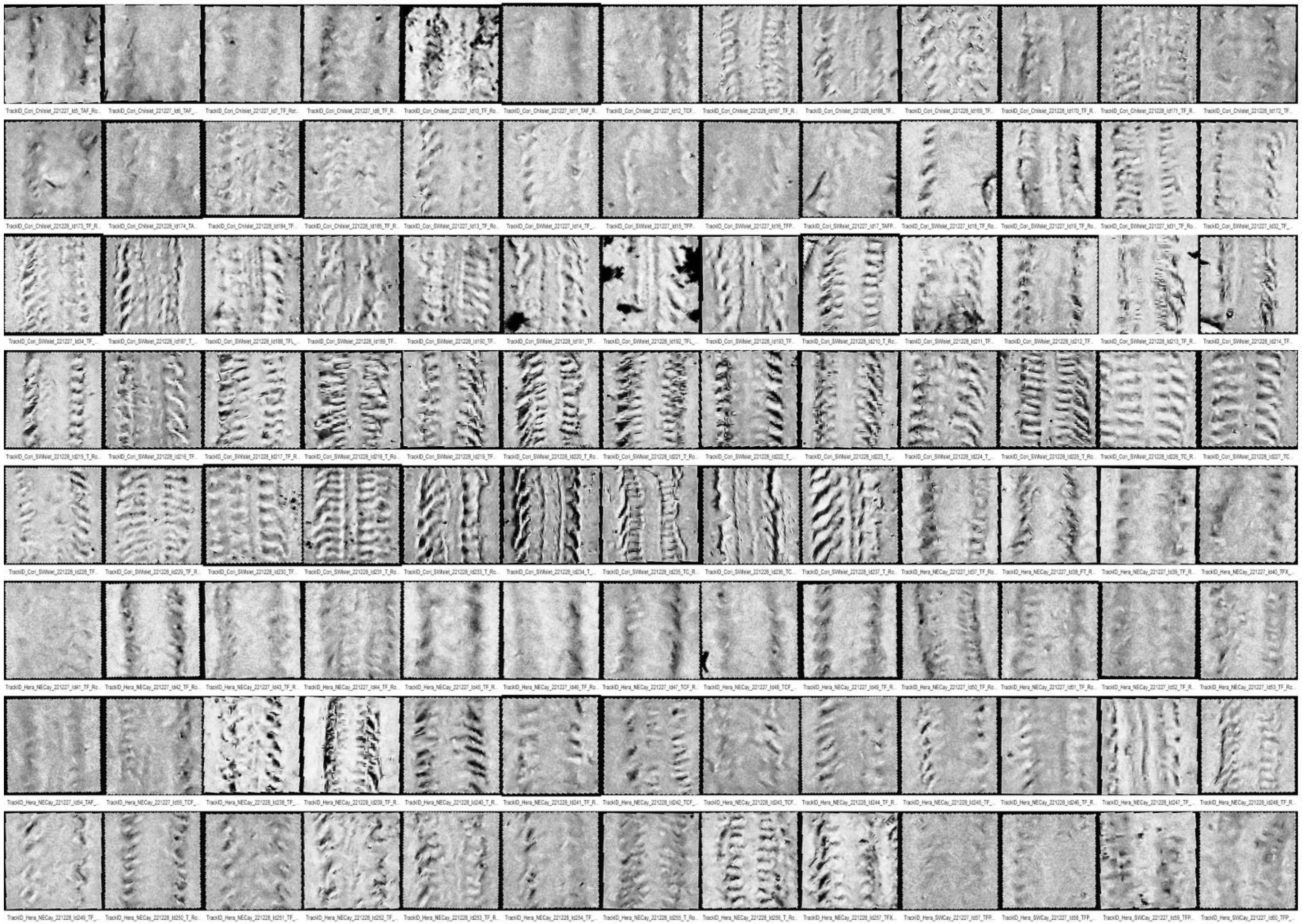

Addendum II - Aerial Maps

15) References

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The findings and conclusions presented in this report are based solely on the analysis of aerial photography data.

While every effort has been made to ensure the accuracy and reliability of the data, the authors acknowledge that there may be limitations and uncertainties. The authors do not claim that the findings presented in this report are conclusive or definitive on complete turtle stock, and they caution readers against drawing overly broad or definitive conclusions based solely on this study without the use of ground truth control. We recommend ground truth exercises where possible to help eliminate statistical outliers.