FINAL

Aerial Survey of Seabirds and Marine Mammals at Ka`ula Island, Hawai`i—April 2013

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Executive Summary

Aerial surveys of Ka`ula Island, Hawai`i, using very high resolution digital photography were conducted on 23 and 24 April 2013. A vertical (nadir) aerial survey was complemented by an oblique survey to allow counts to be made both of birds on the top of the island and those present on the cliff faces.

This survey was carried out to meet the aims and objectives of the work required by the U.S. Navy to monitor the status of the seabird populations on the island (DoN 2009). The images collected have been analyzed and quality assured, and the raw counts of animals recorded are presented in this report.

In total, 18,795 birds of 11 species were recorded during the survey with sooty tern being the most abundant species (n=14,635) followed by red-footed booby (n=1,690). A number of other species were recorded including black-footed albatrosses, Laysan albatrosses, red-tailed tropicbirds, masked boobies, brown boobies, great frigatebirds, grey-backed terns, brown noddies, and white terns.

At the time of the survey, a total of 11 Hawai`ian monk seals were resting on ledges on the east side of the island.

1 Introduction

APEM and Normandeau were contracted by the U.S. Navy to provide ornithological data for the Pacific island of Ka`ula, Hawai`i, through the capture and analysis of digital high resolution aerial imagery.

Ka`ula Island is a small (0.640 $km^2$), uninhabited crescent shaped islet in the west of the chain of islands making up the Hawaiian Archipelago (Figures 1–1 and 1–2). The islands closest to Ka`ula are Niihau Island, which is located 37 km to the northeast, and Kauai Island, approximately 111 km to the northeast. A mountain ridge runs along the length of Ka`ula Island (approximately 1,676 m), which at its highest point is 164.6 m above sea level (Palmer 1936). The terrain drops steeply from the ridge crest at a mean slope of 36° (Palmer 1936), and steep V-shaped ravines have been cut by ephemeral streams on the windward slopes such that the island has little level terrain (Elmer and Swedberg 1971). The northern horn of the island extends 762 m from the summit and ends at an elevation of approximately 85 m, while the southern horn extends 914 m from the summit and ends at an elevation of approximately 30 m (Palmer 1936).

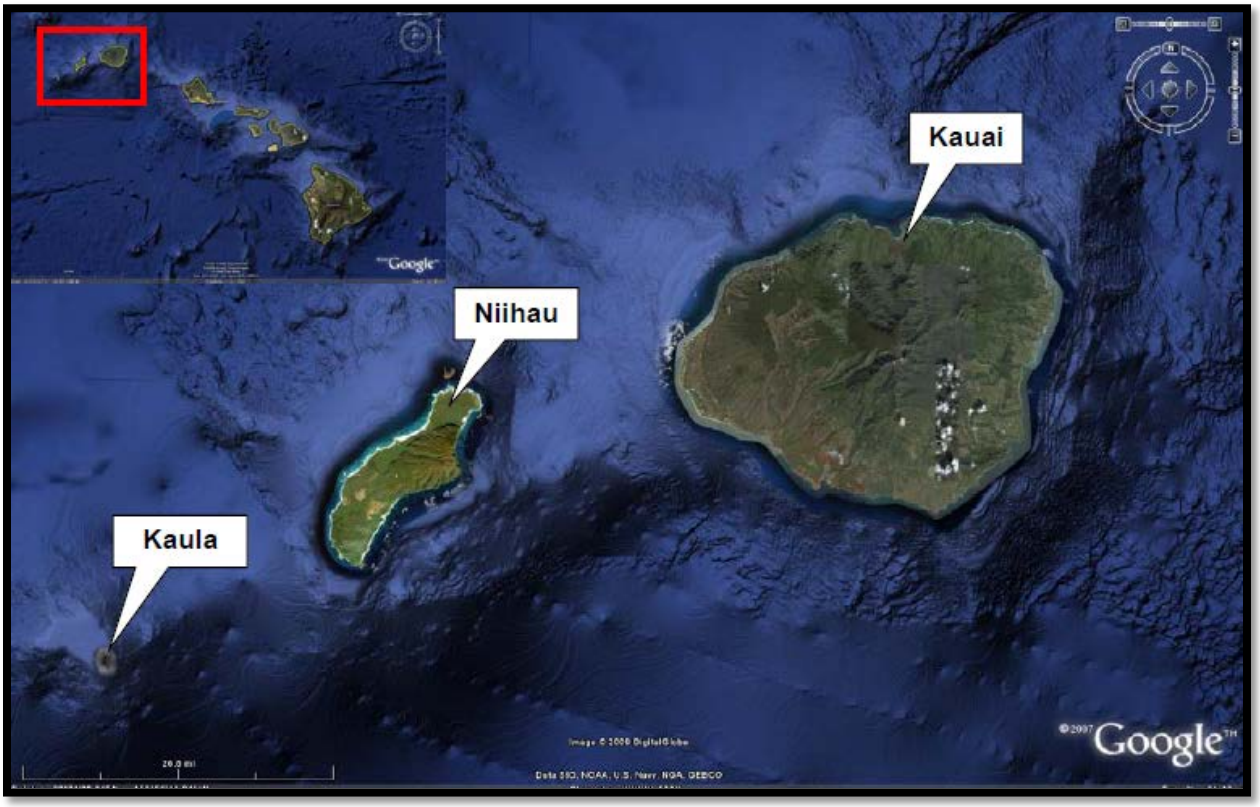

Figure 1–1. Location of Ka`ula Island relative to the main Hawai`ian Islands (inset) and Kauai and Niihau (imagery from Google Earth).

Figure 1–2. Topography of Ka`ula Island.

Since 1952, the U.S. Navy has used the southeastern tip of the island (approximately 0.06 km^2) as a range to train aviators in air-to-surface and surface-to-surface weapons delivery. Both live and inert ordnance were used during training missions through 1980, but from 1981 through 2009, munitions training by the Navy at Ka`ula has been restricted to inert ordnance delivery and aircraft gunnery (Walker 1983, 1984).

Historically, eleven land based avian surveys have been undertaken on the island (Pepi et al. 2009), and, due to safety reasons, these have been replaced with boat based observations (Pepi et al. 2009; DoN 2011) and observer based, low altitude aerial surveys (DoN 2011).

The U.S. Navy attempted aerial imagery prior to the finalization of the Seabird Monitoring Plan (DoN 2009) but results were unacceptable. Now with improved technology available, the Navy seeks to improved and build upon the seabird data gathering efforts by exploring the use of higher altitude, very high resolution aerial imaging surveys. This improved technology is expected to result in the following improvements:

- Increased count accuracy through post-hoc, quantitative analysis of imagery rather than near-instantaneous live counts by observers in the field
- Increased count accuracy through elimination of bird disturbance effects from low-flying helicopters
- Increased count accuracy and bird identification ability on Ka`ula, previously surveyed by boat, because of increased visibility of the top, bottom, and sides of cliffs

2 Methods

2.1 Survey Design

The digital aerial survey of Ka`ula was undertaken on 23 and 24 April 2013. High resolution digital still images were collected using a Piper PA-31 Navajo N3949W twin-engine survey aircraft and a GPS-linked custom flight management camera system, the APEM SeeBird01, specifically designed by APEM to target high resolution surveys for birds and marine mammals.

To prepare for the survey of Ka`ula, flight planning software was used to define the required flying altitude and speed according to the camera, lens, and required pixel resolution. During the survey, each of the survey transects were flown using a GPS guided management system and the image acquisitions were automatically triggered at predefined positions.

Due to the wide range of topographical features on Ka`ula (see Figure 1–2), three surveys were carried out to ensure that high quality imagery was achieved over the whole island (100% coverage), including capturing animals on horizontal as well as vertical ledges. Two of these surveys were carried out on the same day (23 April 2013) and involved vertical surveys of Ka`ula Island including one at high altitude (vertical high altitude survey) and one at lower altitude (vertical low altitude survey) in which the downwards facing camera was at a 90º angle to the aircraft. The first survey carried out on 23 April (between 1230 and 1335 hours) was the vertical high altitude survey conducted at 2,500 feet, which was flown in an east-west direction with transect lines spaced 90 m apart. This survey captured 2 cm resolution imagery at the higher elevation sections of the island.

Immediately after the first survey (between 1341 and 1437 hours), the vertical low altitude survey was flown in an east-west direction at 2,050 feet with transects spaced 90 m apart. This captured imagery at 2 cm resolution at sea level. The combination of the two surveys allowed the whole island to be captured at a minimum of 2.5 cm resolution.

On 24 April, the third survey involved collecting oblique images (oblique survey) of birds on steep, overhanging cliff faces that would not have been visible from the vertical surveys. Weather delays and airspace restrictions prevented this third survey from being conducted on the same day (see Section 2.4). The oblique survey was carried out by flying clockwise around the island between 1,400 and 1,800 feet, and images were taken to capture the sides of the steep cliff faces. The camera was operated manually at a range of angles to the aircraft.

2.2 Data Processing

2.2.1 Vertical Surveys

As it is not technically possible to capture the whole of the island at 2 cm resolution in one single image, several survey transects were undertaken to gain full coverage of the island. This generated approximately 1,500 vertical digital photographs collected over a ~two hour period. These images were imported as geo-referenced images (WGS 84 projection) into ArcView (version 9.2) and spatially joined to create one large image mosaic covering the whole island. Images with the highest resolution for each location on the island were used to compile the mosaic, and any overlapping image sections were removed. This method was considered to be

the most appropriate to minimize the risk of double counting that might have otherwise occurred by treating each individual image in isolation (due to overlapping areas). It is acknowledged that there is a small chance that movement of birds between transects could result in a bird being double counted. There is of course an equally small chance that a bird could be missed in both transects. On this basis, it is reasonable to assume that the risk of double counting is equal to the risk of undercounting, and the effect on the population count is negligible.

This small chance of error should be viewed in context against other visual census techniques which carry a greater risk of error as a result of their longer duration.

The mosaic was split into 295 grid cells (Figure 2–1) to aid the identification stage of the analysis.

Specially trained APEM staff were responsible for recording the following information from each grid cell of the compiled image covering Ka`ula Island:

- Bird / mammal species by common name (see Appendix I for scientific names)
- Behavior (e.g. sitting, flying, diving or on occupied nest)
- Count (number of individuals)
- Position (easting, northing) of individuals
- Date and time stamp of image collection

Each grid cell was analyzed using APEM's Graphical User Interface (GUI) software. The software contains a detection algorithm which picks out all the objects which are presented to the image processing staff. As part of the identification process, the software contains an automated species separation tool used for identifying regularly encountered European seabirds, based on size, shape and coloration. As the software function has not yet been developed for species likely to be encountered in the Pacific, each analyst themselves identified the species detected in each grid cell. This identification is based upon the size, shape and visible characteristics present in the images. The resolution of the images is extremely high, such that the individuals can be identified with a high degree of certainty. In addition they carried out a manual check of each grid cell to ensure that all birds and mammals were captured.

Survey data were analyzed to produce maps showing bird and marine mammal distribution in a GIS format. For each map, bird and mammal observations were comprised of individual points geo-referenced to actual spatial location at the time of sighting.

2.2.2 Oblique Surveys

A selection of the manually collected images was spatially correlated against features in the vertical dataset to ensure correct spatial placement of each image. These images were then passed on to trained staff to identify and enumerate the number of birds and marine mammals in each image that could not have been seen from the vertical imagery due to the presence of steep cliffs and overhanging rock ledges. The results of these counts were then subjected to the same internal process used in the vertical survey.

2.3 Quality Assurance

All bird and marine mammal species present in the images from Ka`ula Island were identified and quality assured using a standard internal APEM process.

All images containing birds and marine mammals were processed in each grid cell (see Section 2.2) and then checked by APEM's quality assurance manager. The quality assurance manager, an experienced ornithologist, is responsible for maintaining and updating the image library and also provides advice and guidance to the image processing staff.

2.4 Weather Conditions and Survey Limitations

Airspace restrictions and unsuitable weather conditions left only a short time frame available for surveys. This section explains some of the survey limitations and weather conditions experienced.

The APEM survey team arrived in Honolulu on 19 April and installed camera systems in the aircraft on 20 April. This was followed by a local test flight on the southern part of Oahu. The team was on standby for survey for 21 through 24 April, after which the airspace over the islet was unavailable for survey (U.S. Navy imposed restrictions). The weather on 20 and 21 April was unsuitable due to a large weather system over the survey area. On 23 April, conditions improved throughout the day and became suitable for survey in the early afternoon. Airspace clearance for survey closed at 1600 hours local time on 23 April and was available between 0700 and 1100 hours on 24 April. As such, only a short time frame was available for surveys.

The survey flight transited from Kalaeloa Airport on Oahu Island. During all three surveys (i.e., vertical high altitude survey, vertical low altitude survey, and oblique survey), weather conditions were good with a few (20%) high scattered clouds at 4,000 feet, light wind from the northeast, and visibility > 10 km throughout.

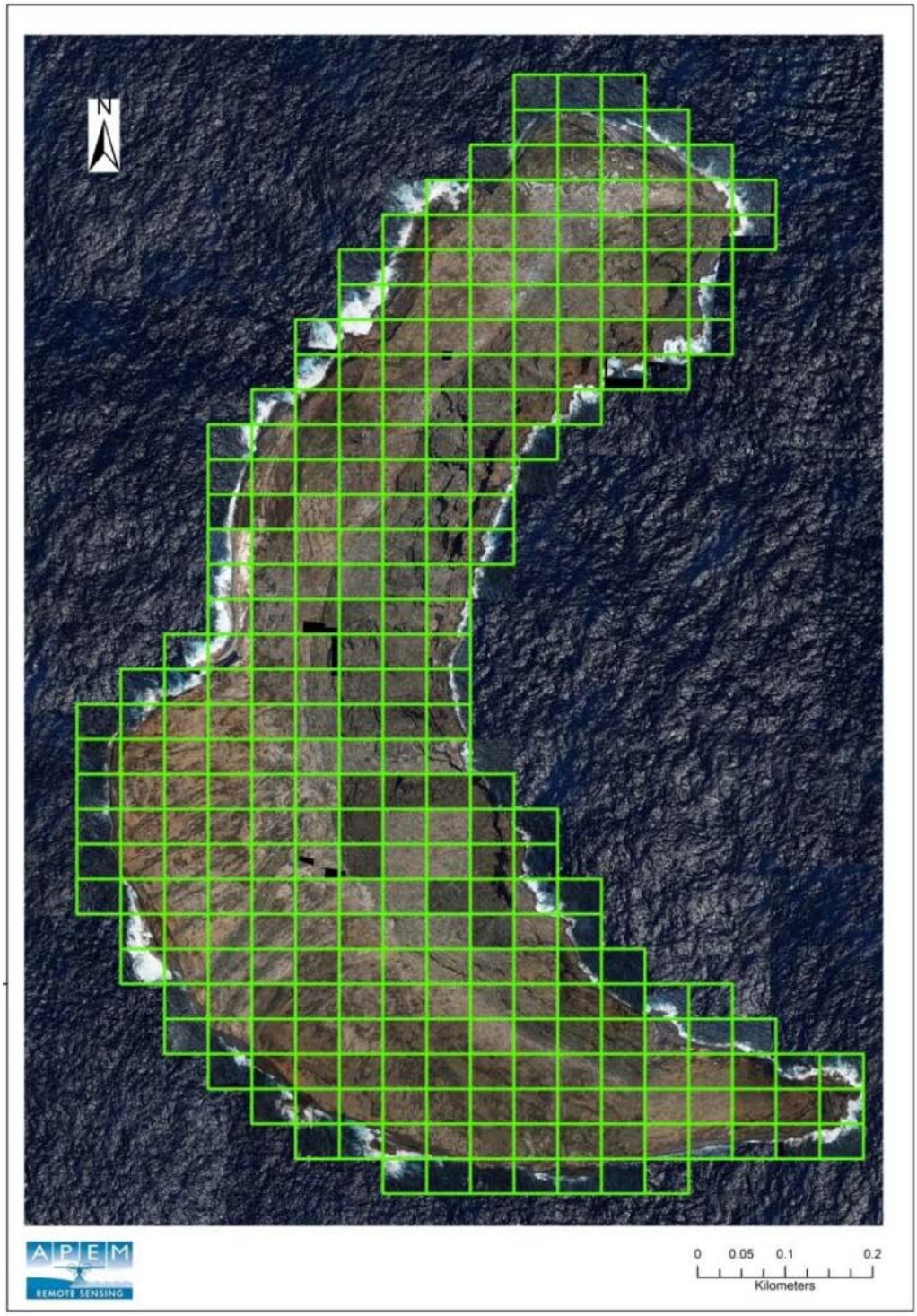

Figure 2–1. Ka`ula Island image analysis grid. Compiled images from the two vertical surveys were joined to cover Ka`ula Island. The compiled image was analyzed in 295 grid cell sections (marked in green).

3 Results

3.1 Species Abundance

A total of 18,795 birds (11 species) and 11 marine mammals (1 species) were recorded on Ka`ula Island during April 2013 (Tables 3–1 and 3–2). Sooty terns (n = 14,635) were the most abundant bird species, and black-footed albatross (n=3) were the least abundant.

Table 3–1. Total Number of Birds and Marine Mammals Recorded on Ka`ula Island during the April 2013 Survey

Species/Group	Number of Birds Sitting	Number of Birds in Flight	Total Number Recorded
Birds			
Black-footed albatross	3	-	3
Laysan albatross	16	4	20
Red-tailed tropicbird	90	224	314
Great frigatebird	1,290	125	1,415
Masked booby	548	2	550
Brown booby	95	6	101
Red-footed booby	1,666	24	1,690
Brown noddy	57	-	57
White tern	6	-	6
Sooty tern	14,223	412	14,635
Grey-backed tern	4	-	4
Total Birds	17,998	797	18,795
Marine Mammals			
Hawai`ian monk seal	-	-	11
Total Birds and Marine Mammals	17,998	797	18,806

Table 3–2. Total Number of Birds and Marine Mammals Recorded in the Vertical and Oblique Surveys on Ka`ula Island during April 2013

Species/Group	Number Recorded in Vertical Survey	Number Recorded in Oblique Survey
Birds		
Black-footed albatross	3	-
Laysan albatross	20	-
Red-tailed tropicbird	261	53
Great frigatebird	1,414	1
Masked booby	550	-
Brown booby	101	-
Red-footed booby	1,688	2
Brown noddy	-	57
White tern	6	-
Sooty tern	14,635	-
Grey-backed tern	4	-
Total Birds	18,682	113
Marine Mammals		
Hawai`ian monk seal	11	-
Total Birds and Marine Mammals	18,693	113

3.2 Species Distribution

3.2.1 Total Birds and Marine Mammals

Figure 3–1 shows the location of all birds and marine mammals recorded on Ka`ula Island during the April 2013 aerial survey. Generally, birds were fairly evenly distributed across the whole island with higher concentrations in the southeast and northern sections and a sparse distribution in the southeast corner. Great frigatebirds were widely distributed with higher concentrations on the east side of the island. Boobies were also widely scattered—masked boobies were recorded along the central higher areas, and brown and red-footed boobies were recorded slightly lower down and in most sections of the island. Terns were recorded mainly on the slopes on the northwest and southwest sections of the island. Red-tailed tropicbirds were grouped together on the east side of the island. Hawai'ian monk seals were recorded on the east side of the island.

3.2.2 Black-footed Albatross

Three black-footed albatrosses were recorded sitting close together at the very northern end of the island close to the cliff top (Figure 3–2).

3.2.3 Laysan Albatross

A total of 20 Laysan albatross were recorded during the surveys; four of these were recorded in flight low over the island and 16 were sitting (Table 3–1). The majority were present along the highest ridge of the island, with a small group of four birds present towards the northern end, a cluster in the center of the island, and a single bird in the southeast end (Figure 3–3). All appeared to be adults sitting mostly on bare areas of ground however one appeared to be sitting on vegetation that could possibly be a nest.

3.2.4 Red-tailed Tropicbird

A total of 314 red-tailed tropicbirds were recorded. Of these, 224 were flying and 90 were sitting (Table 3–1). They were mostly found on the east side of the island mainly in the concave section with relatively few present in the southeast and northern parts (Figure 3–4). During the oblique survey, birds were recorded under overhangs on the eastern side of the island; these birds would not have been detected from the vertical surveys.

3.2.5 Great Frigatebird

A total of 1,415 great frigatebirds were recorded during the survey. Of these, 125 were flying and 1,290 were sitting (Table 3–1). There was a higher concentration on the east side of the island with only a few birds present in the southwest section (Figure 3–5). There were scattered nesting colonies especially on the slopes and ravines on the eastern side. Thirty-seven juveniles were observed in nests similar to the one captured in Figure 3–15 and 296 of the 1,290 sitting birds were on occupied nests.

3.2.6 Masked Booby

A total of 550 masked boobies were recorded during the survey; two of these were flying and 548 were sitting (Table 3–1). The highest concentrations were recorded in the northern section of the island mainly along the higher ground and along the ridge crest in the center of the island (Figure 3–6). A large number of birds could be seen occupying nests, and six juvenile birds were recorded in nests.

3.2.7 Brown Booby

A total of 101 brown boobies were recorded during the survey; six of these were flying low over the island and 95 were sitting (Table 3–1). They were widely distributed across the whole island with no significant concentrations (Figure 3–7). Virtually all of the sitting birds appeared to be on nests.

3.2.8 Red-footed Booby

A total of 1,690 red-footed boobies were recorded during the survey. Of these, 24 were in flight and 1,666 were sitting (Table 3–1). They were widely distributed across most of the island with the highest concentrations in the north and northwestern sections along with a cluster in the east concave section (Figure 3–8). Thirty-two juvenile birds could be seen in nests, and many of the sitting adult birds also appeared to be on nests.

3.2.9 Brown Noddy

From the oblique imagery, a total of 57 brown noddies were recorded sitting on the northwestern cliffs (Table 3–1; Figure 3–9).

3.2.10 White Tern

Six white terns were recorded during the survey and these were all sitting (Table 3–1). Four were located in the southwest section of the island and two were in the northwest section (Figure 3–10).

3.2.11 Sooty Tern

A total of 14,635 sooty terns were recorded during the survey of which 412 were flying and 14,223 were sitting (Table 3–1). They were present in high concentrations both in the southwest and northwest sections with relatively few birds recorded in the east side other than birds mainly in flight (Figure 3–11).

3.2.12 Grey-backed Tern

Four grey-backed terns were recorded during the survey, and all of them were sitting (Table 3–1). All were recorded in the southwest or northwest section amongst sooty terns (Figure 3–12).

3.2.13 Marine Mammals

During the course of the survey, 11 Hawai`ian monk seals were recorded on ledges on the eastern side of the island (Table 3–1). Two were in the northeastern section and nine were resting on the larger ledges towards the southeastern section (Figure 3–13).

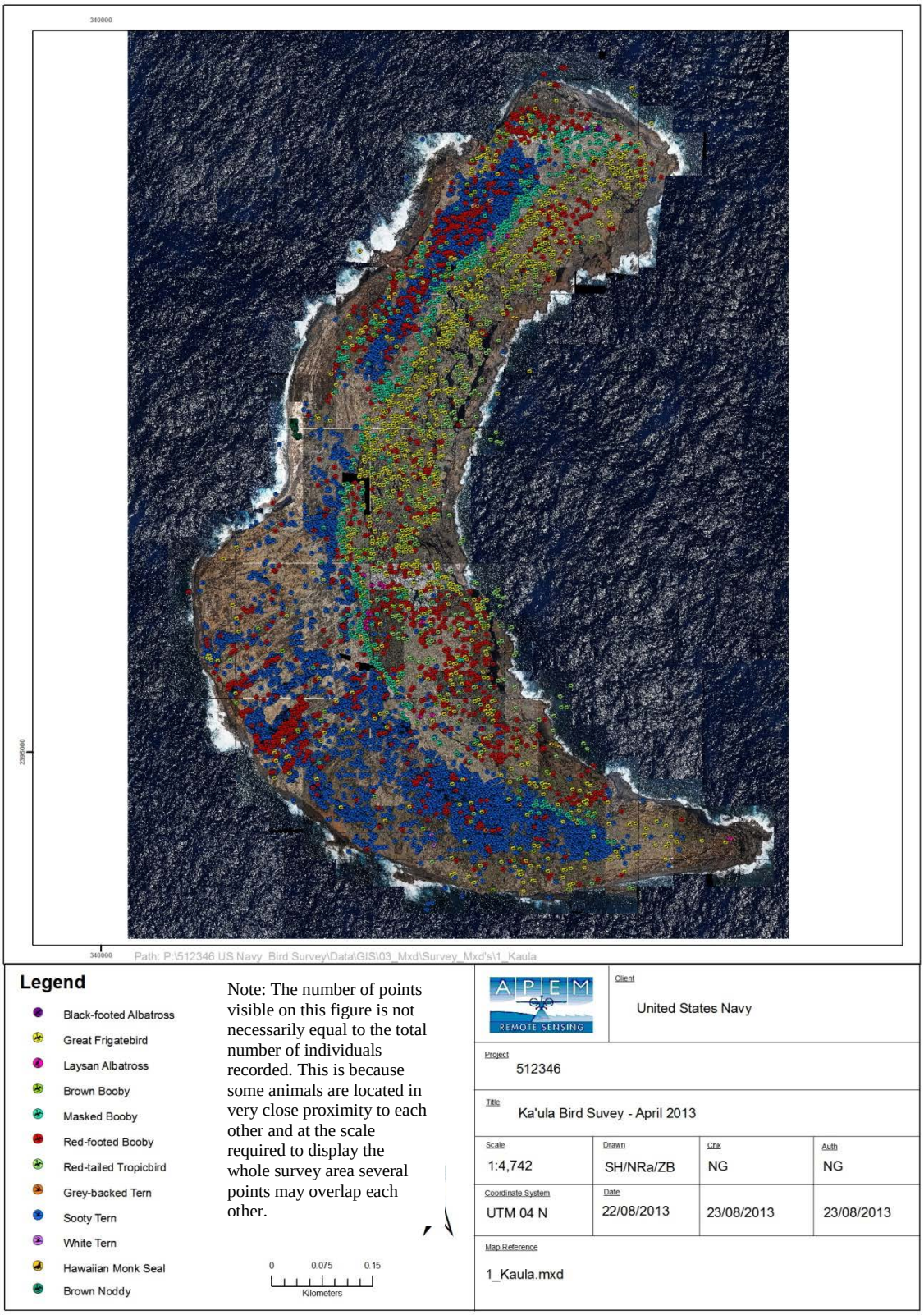

Figure 3–1. Distribution of the total bird species and marine mammals recorded on Ka`ula Island during the April 2013 survey.

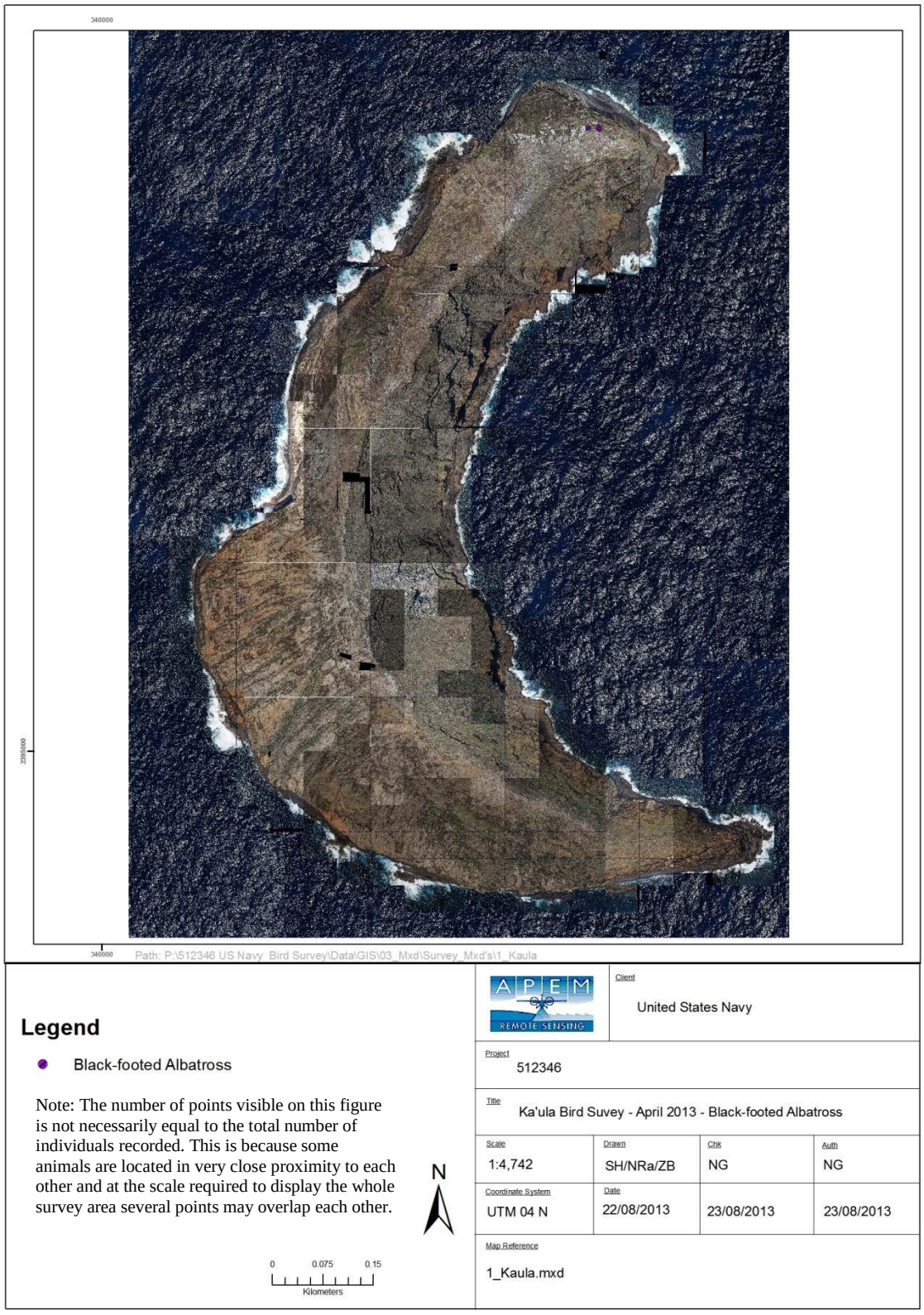

Figure 3–2. Distribution of black-footed albatrosses recorded on Ka`ula Island during the April 2013 survey.

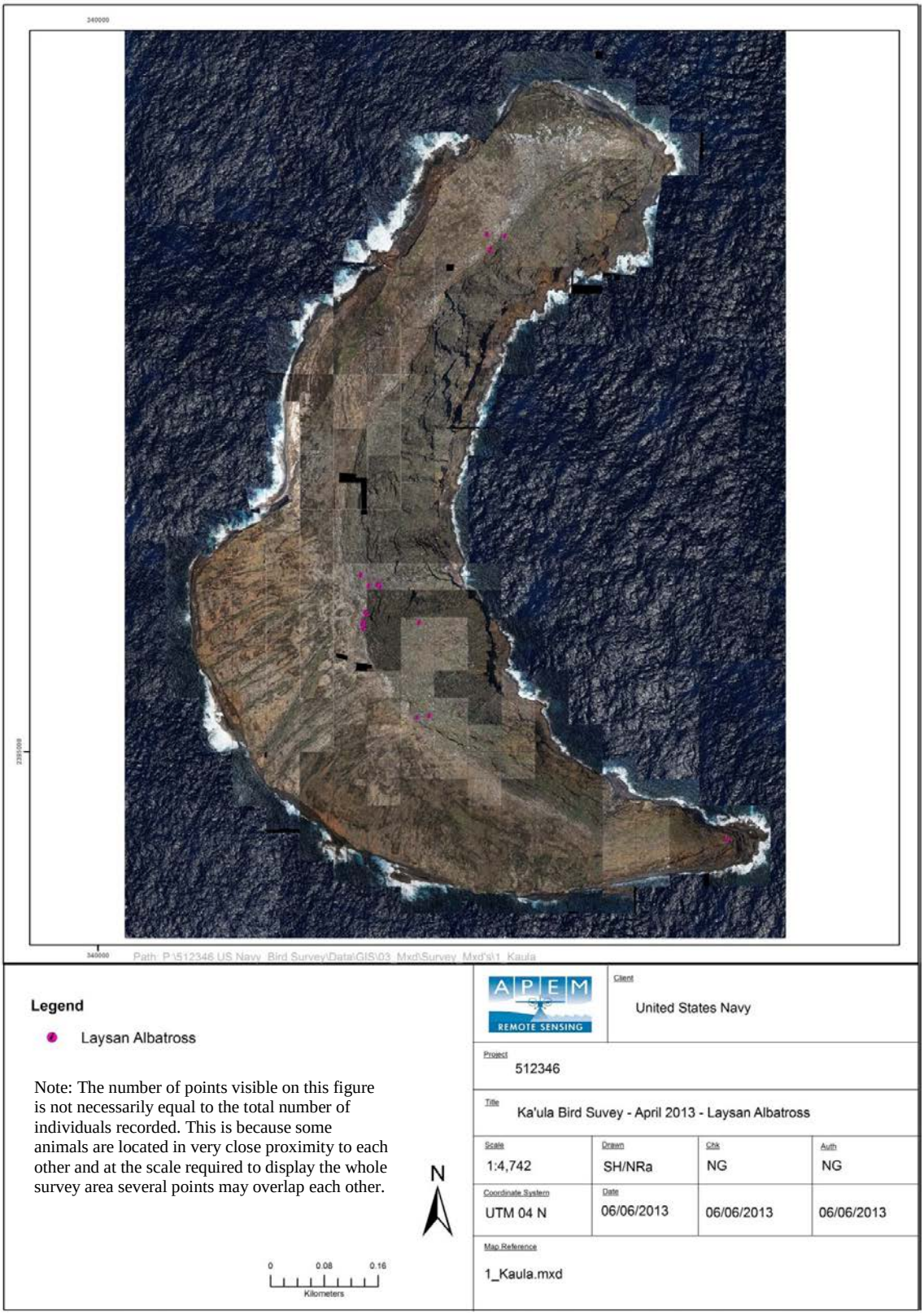

Figure 3–3. Distribution of Laysan albatrosses recorded on Ka`ula Island during the April 2013 survey.

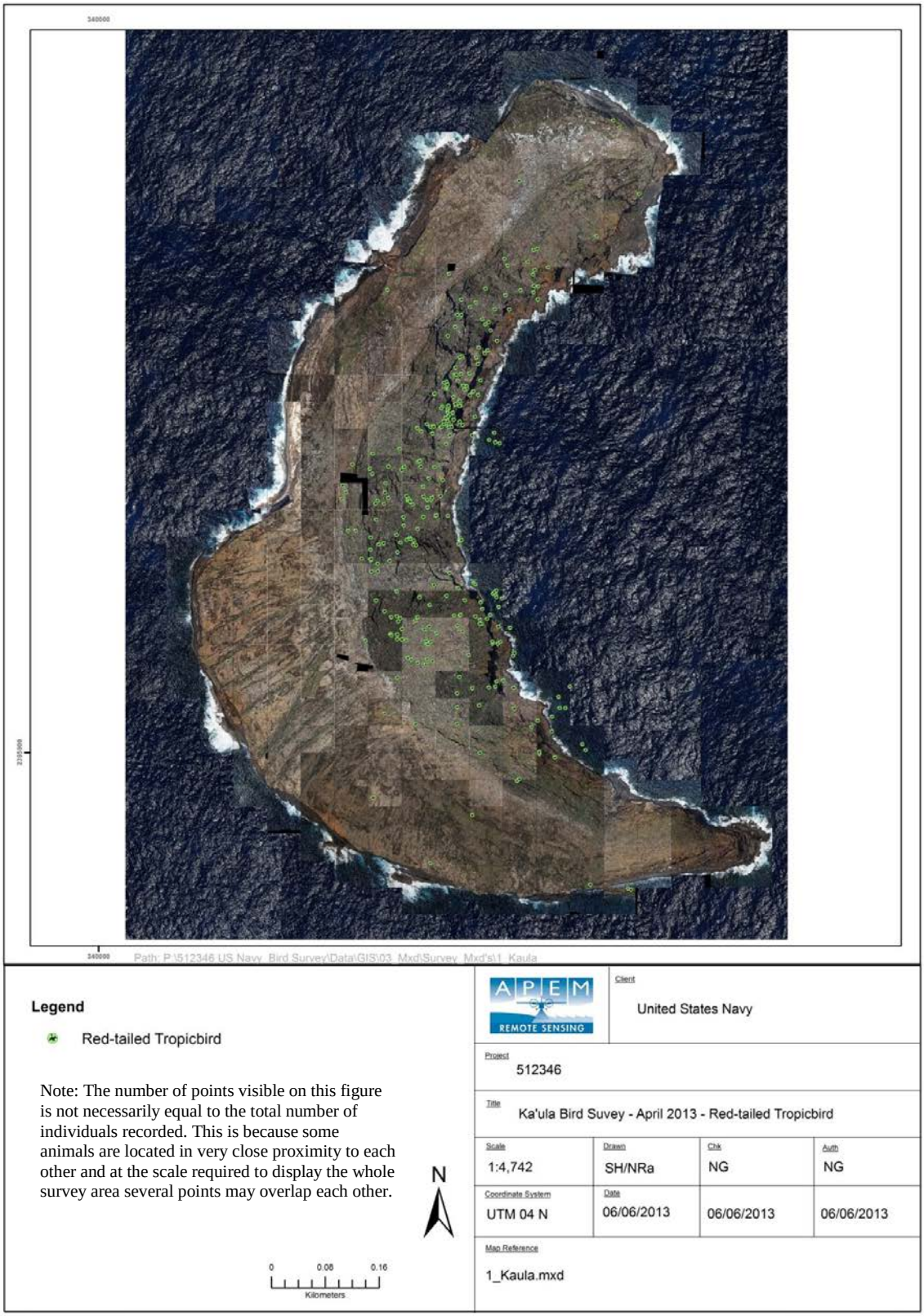

Figure 3–4. Distribution of red-tailed tropicbirds recorded on Ka`ula Island during the April 2013 survey.

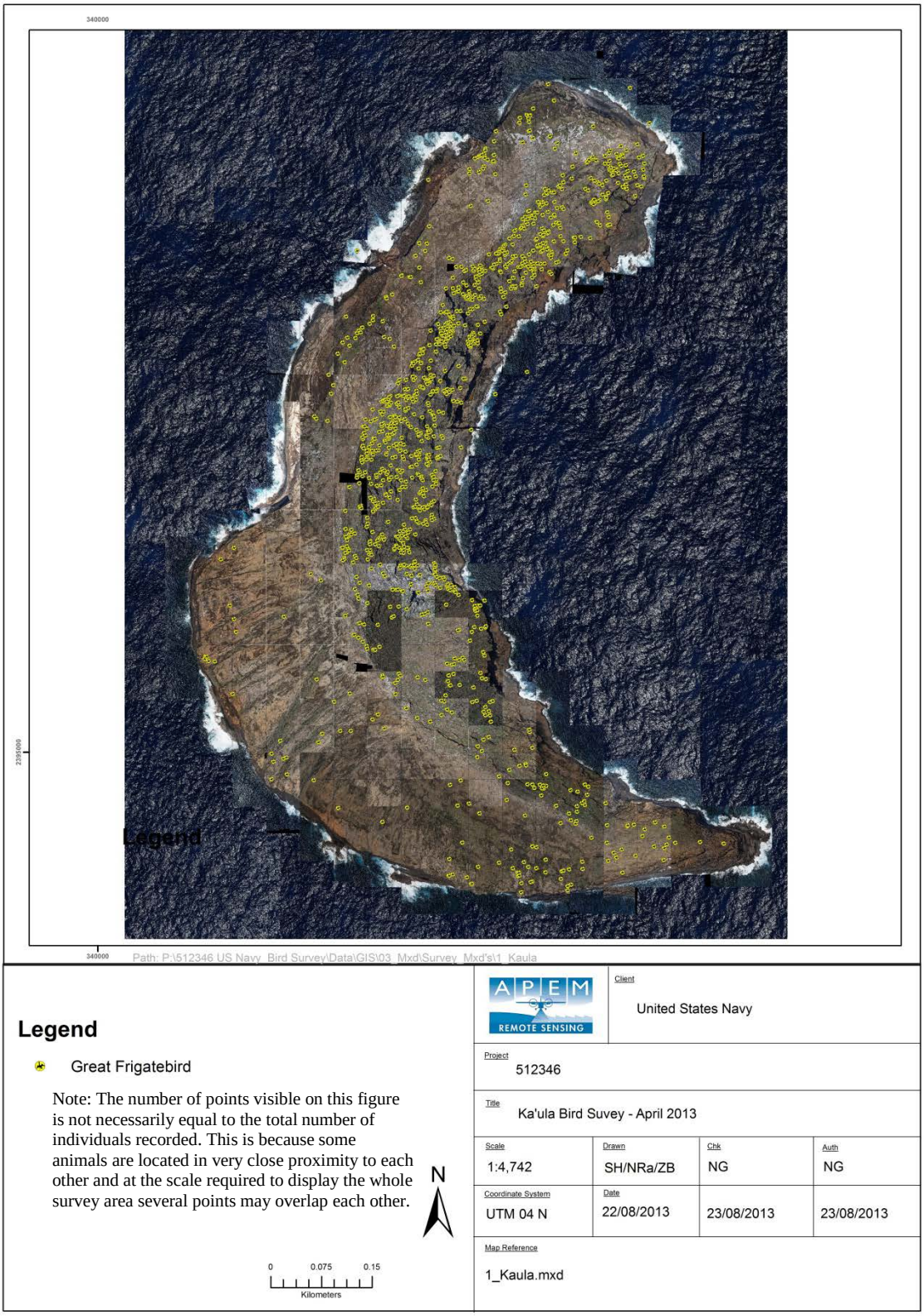

Figure 3–5. Distribution of great frigatebirds recorded on Ka`ula Island during the April 2013 survey.

Figure 3–6. Distribution of masked boobies recorded on Ka`ula Island during the April 2013 survey.

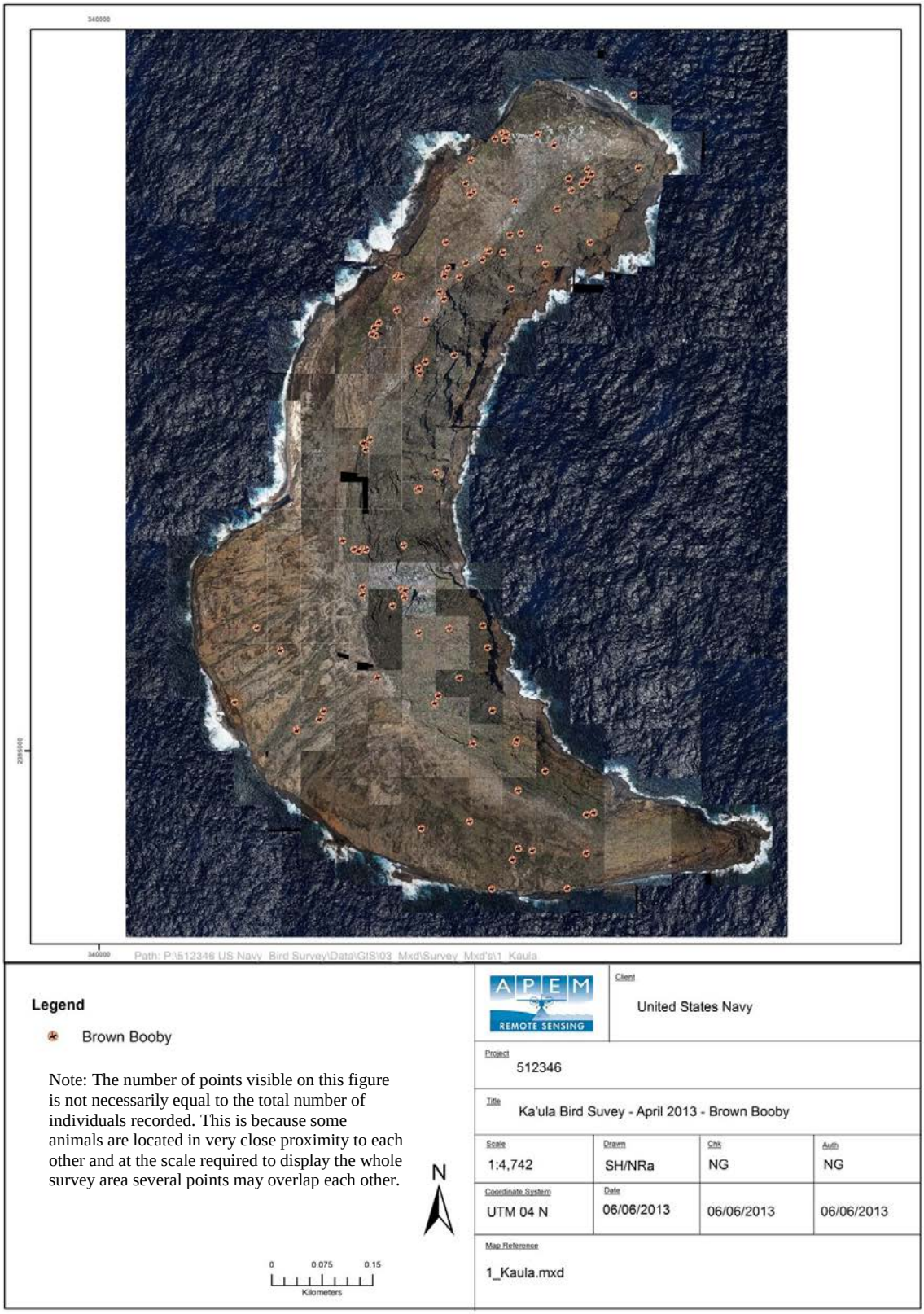

Figure 3–7 Distribution of brown boobies recorded on Ka`ula Island during the April 2013 survey.

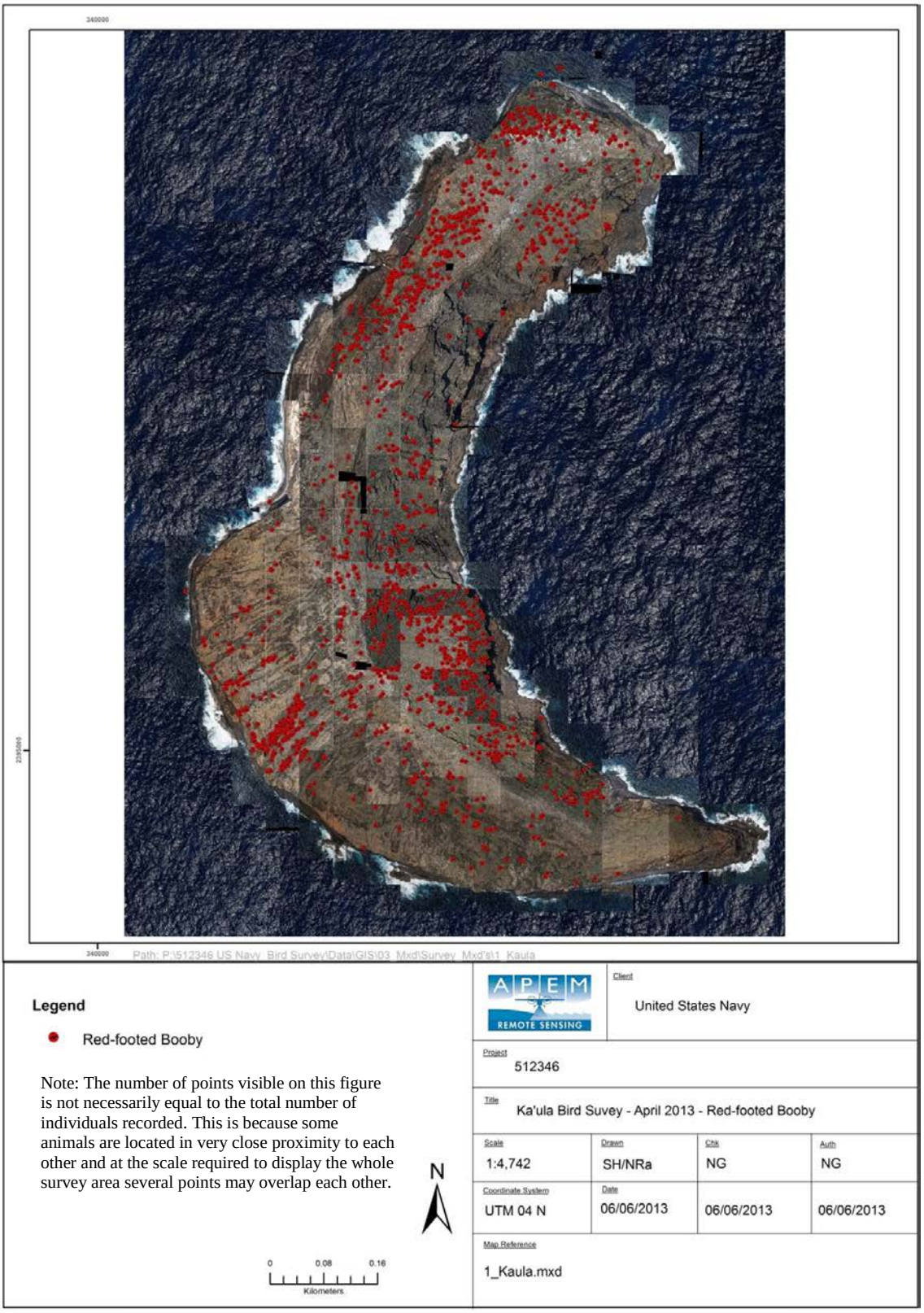

Figure 3–8. Distribution of red-footed boobies recorded on Ka`ula Island during the April 2013 survey.

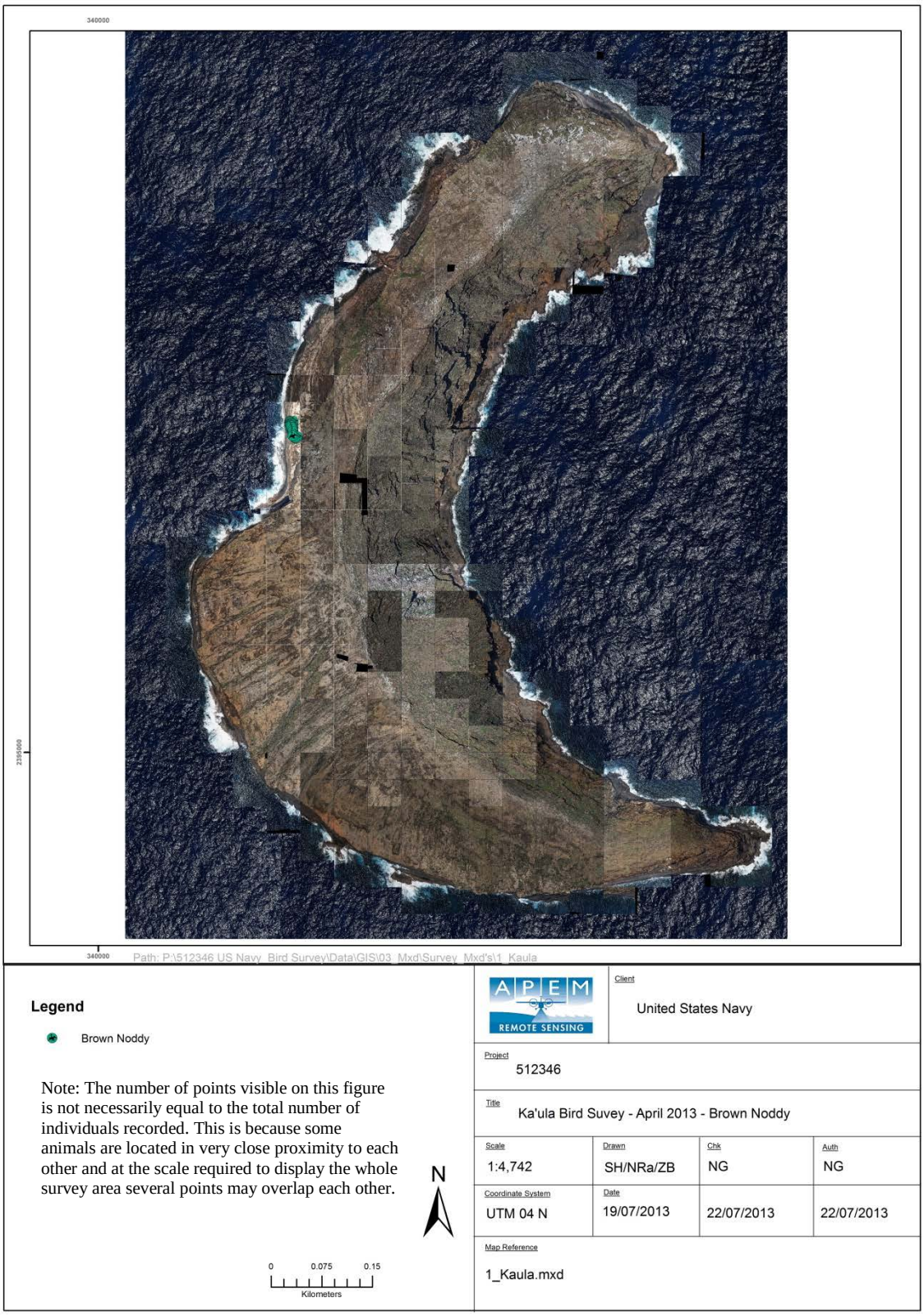

Figure 3–9. Distribution of brown noddies recorded on Ka`ula Island during the April 2013 survey.

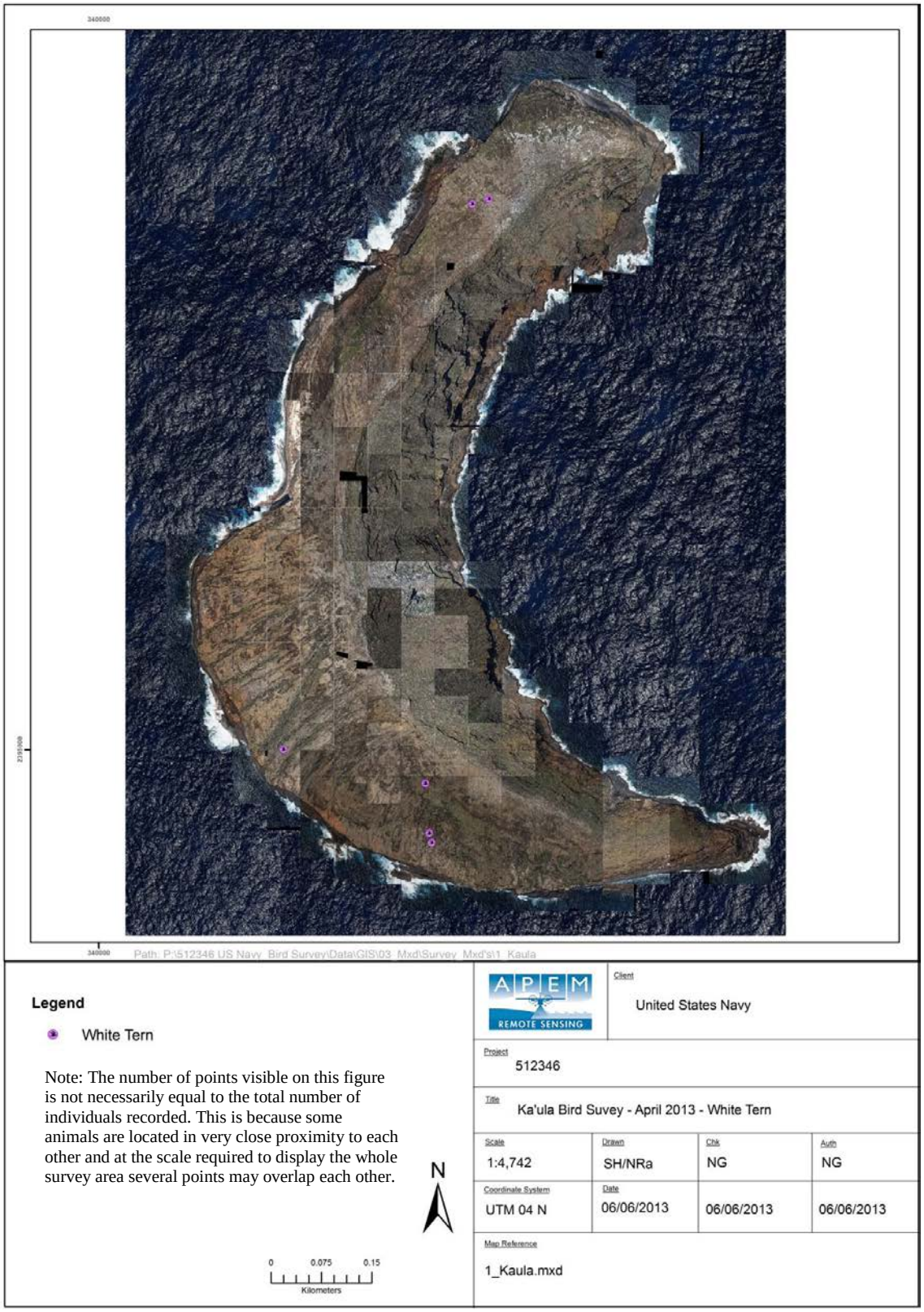

Figure 3–10. Distribution of white terns recorded on Ka`ula Island during the April 2013 survey.

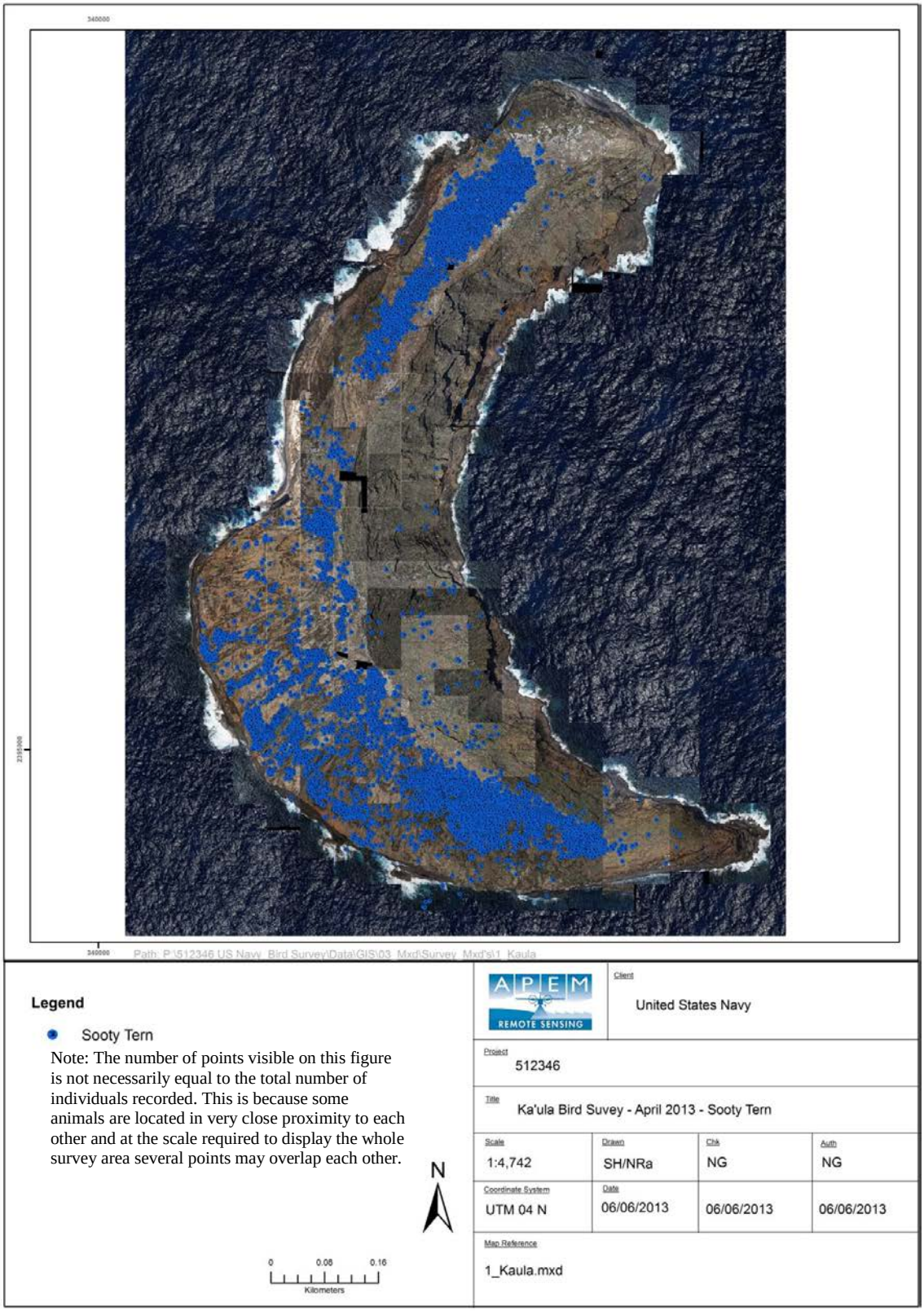

Figure 3–11. Distribution of sooty terns recorded on Ka`ula Island during the April 2013 survey.

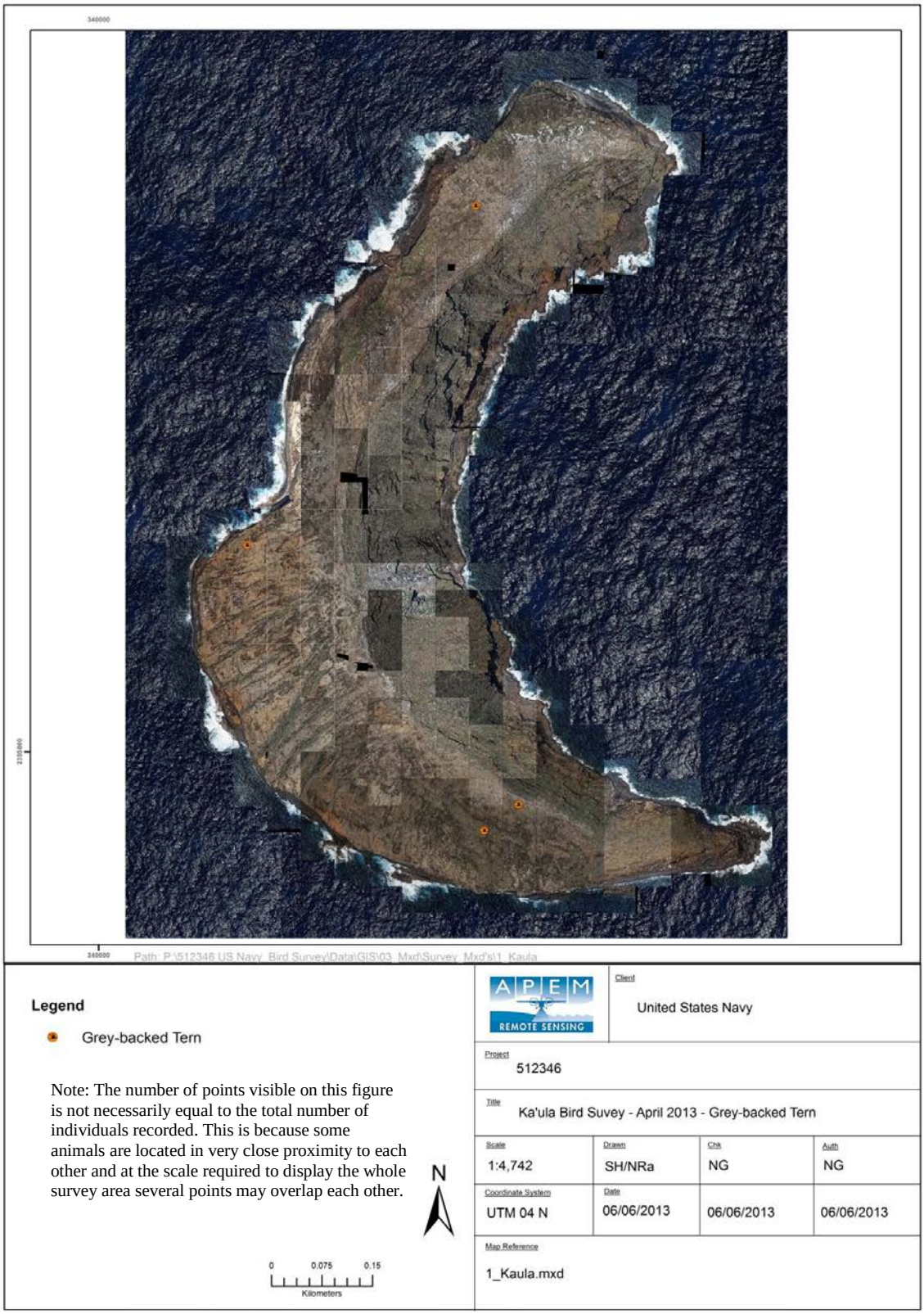

Figure 3–12. Distribution of grey-backed terns recorded on Ka`ula Island during the April 2013 survey.

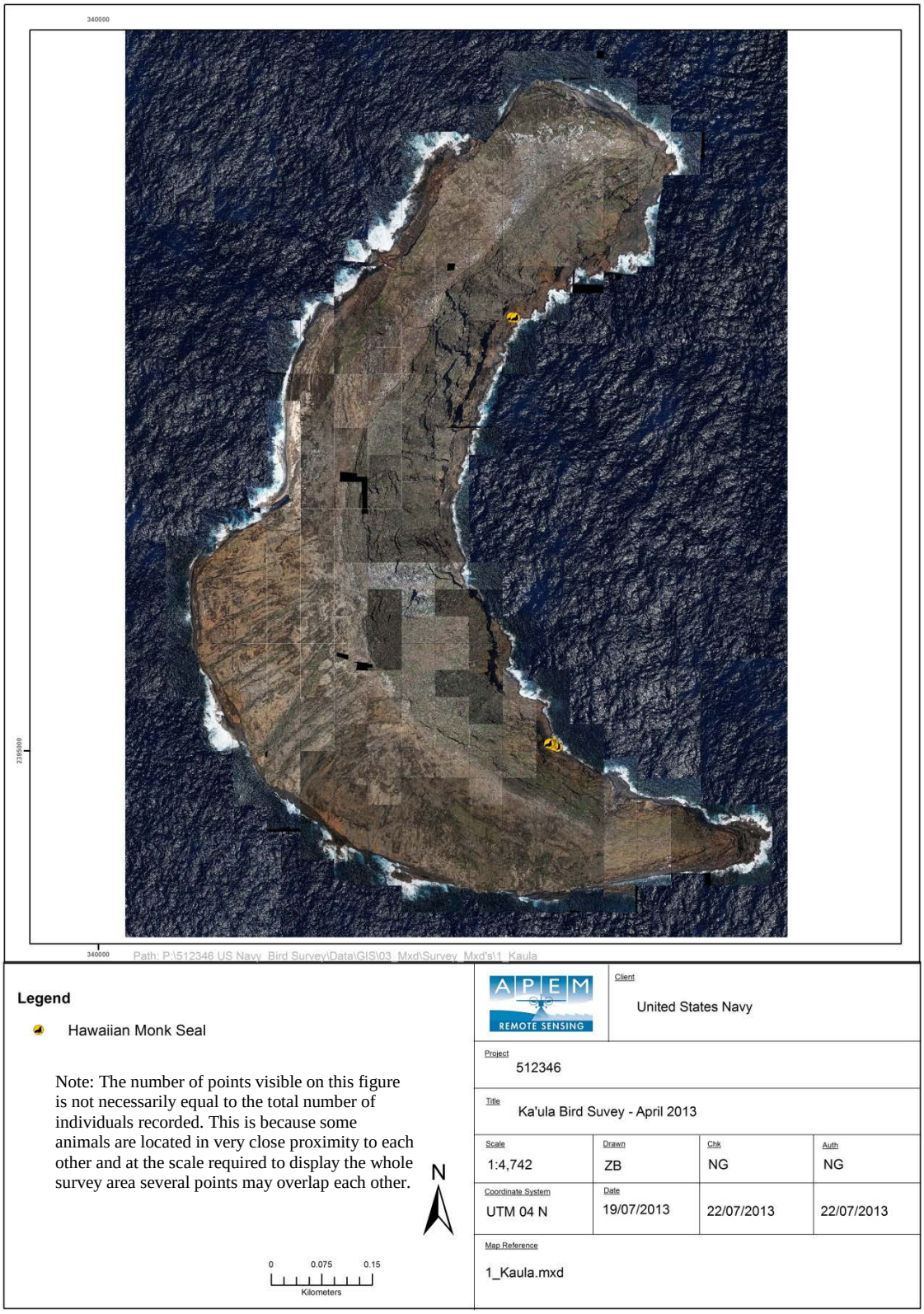

Figure 3–13. Distribution of Hawai`ian monk seals recorded on Ka`ula Island during the April 2013 survey.

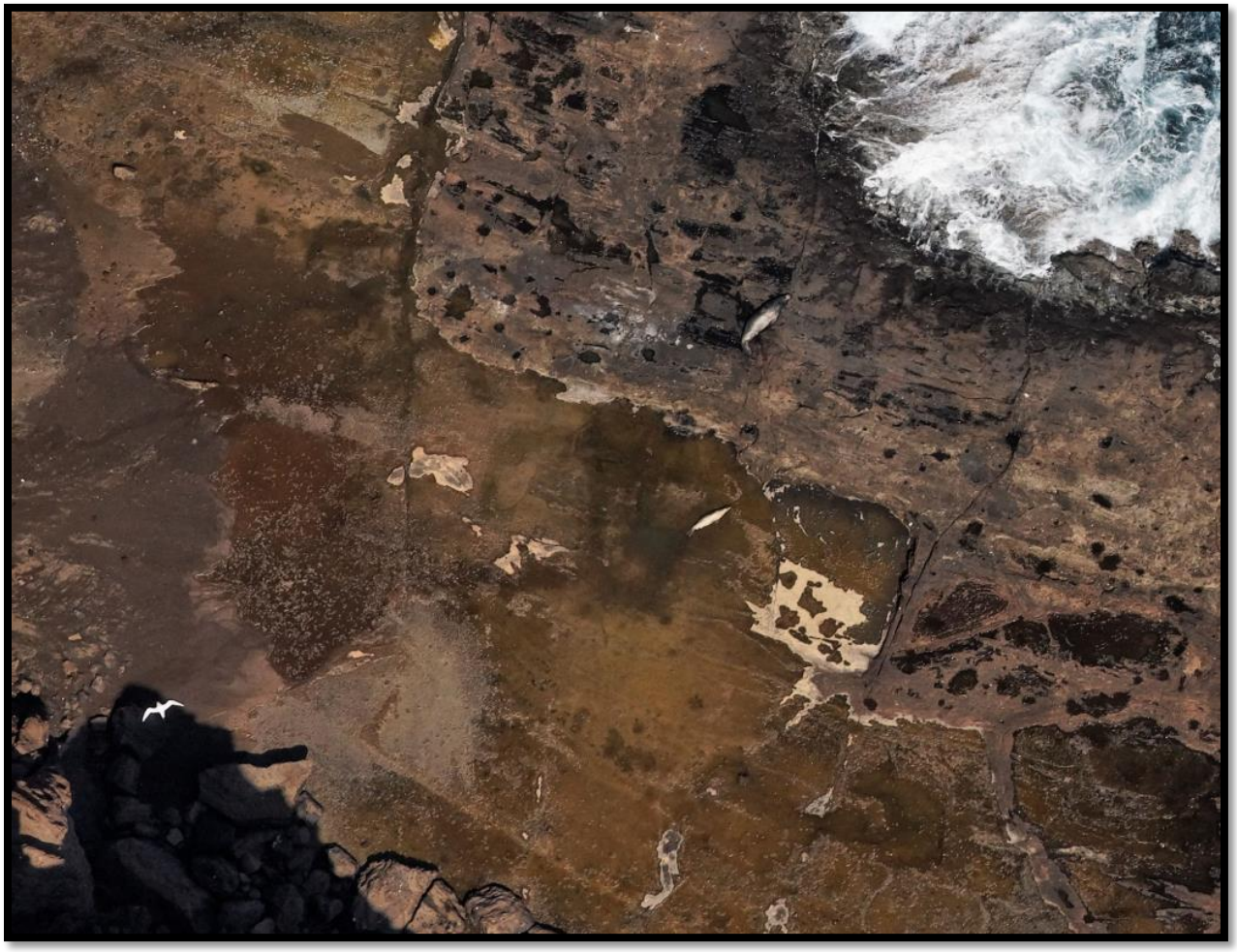

Figure 3–14. Hawai`ian monk seals resting on ledges and a red-tailed tropicbird towards the northeast end of Ka`ula Island during the April 2013 survey.

Figure 3–15. Laysan albatrosses and brown boobies along the ridge towards the northern end of Ka`ula Island during the April 2013 survey.

Figure 3–16. Great frigatebirds, including a single chick (circled), on the east side of Ka`ula Island during the April 2013 survey.

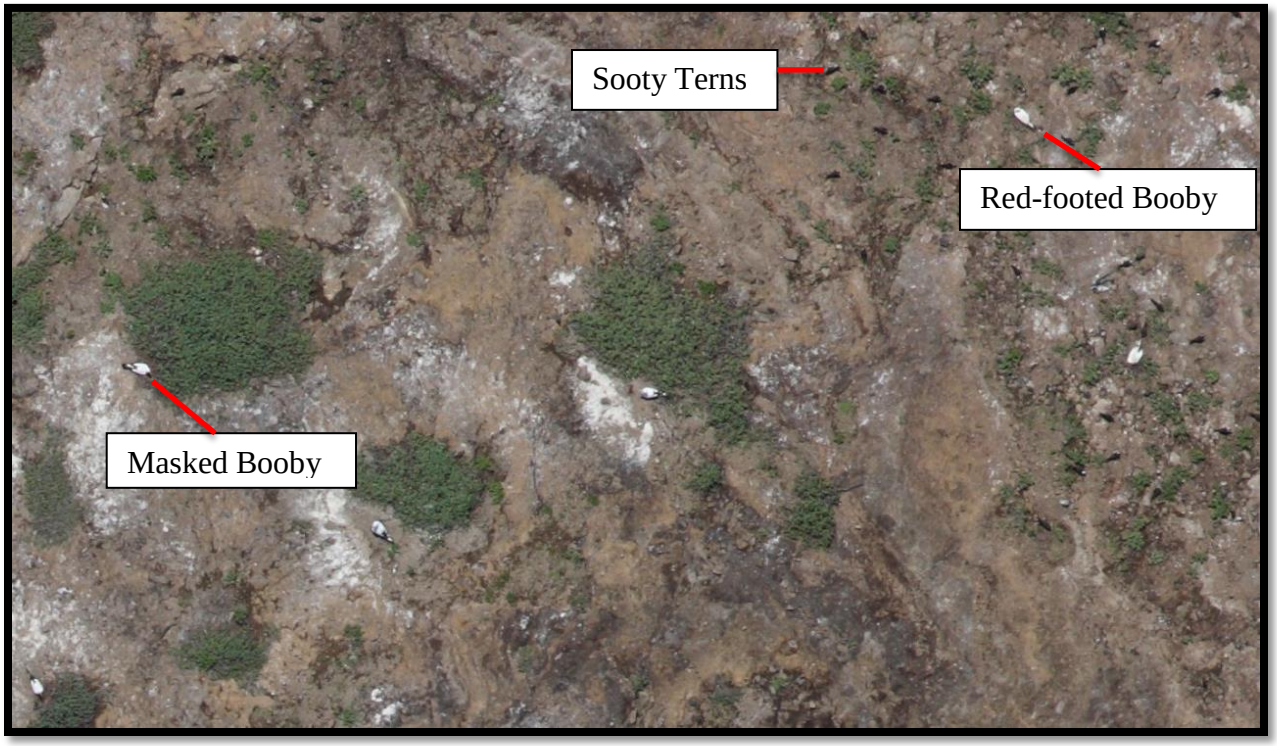

Figure 3–17. Masked boobies, red-footed boobies, and sooty terns on the northwest side of Ka`ula Island during the April 2013 survey.

Figure 3–18. Black-footed albatrosses (center) at the northern end of Ka`ula Island during the April 2013 survey.

4 Discussion

Overall, during the vertical and oblique surveys, a total of 18,795 birds and 11 Hawai`ian monk seals were recorded on Ka`ula Island during April 2013 (Table 3–1). The 11 bird species present were black-footed albatross, Laysan albatross, red-tailed tropicbird, great frigatebird, masked booby, brown booby, red-footed booby, brown noddy, sooty tern, white tern, and grey-backed tern. The most abundant species was sooty tern, accounting for 78% of all seabirds recorded, compared to 74% in 2012. Since 2009, sooty terns have accounted for between 63%-81% of all seabirds observed during summer surveys at Ka`ula (Fujimoto and Juola 2012). The next most abundant species were red-footed booby, great frigatebird, masked booby, and red-tailed tropicbird (see Table 3–1). Grey-backed tern (n=4) and black-footed albatross (n=3) were the least abundant species recorded.

Three black-footed albatrosses were recorded at the very northern end of the island in close proximity to the cliff top (see Figure 3–18). This species hasn't been recorded since 1998 when ten were observed during a land-based survey (Appendix II).

Laysan albatross were present on the higher ground scattered along the central ridge (see Figures 3–3 and 3–14). Numbers recorded in this survey were comparable to previous counts made from land based surveys (Appendix II) and higher than those estimated from all boat based surveys conducted since 2009, which have failed to find any Laysan albatross.

Red-tailed tropicbirds were mainly present on the east side of the island with the vast majority flying near the cliff edge. Numbers recorded in this survey (n=314) were similar to previous land based surveys in 1980 (n=276) and 1984 (n=209).

Great frigatebird was the third most abundant species (n=1,415), and these were widely distributed with higher concentrations on the east side of the island. Numbers recorded were higher than those from previous surveys. This could be due to the aerial imagery allowing for accurate counts to be made of relatively tight clustered groups of birds on ledges and small plateaus that may not have been visible or may have been disturbed during previous surveys.

Of the booby species, red-footed booby was the most abundant during the survey followed by masked booby and brown booby (see Table 3–1). The count of red-footed boobies during the April 2013 survey (n=1,690) was higher than most of the previous surveys undertaken. This could have been due to the seasonal timing of the survey, as they are known to lay eggs during the winter months (DoN 2011), which could explain why large numbers appeared to be sitting on nests with guano visible (see Figure 3–16). Numbers of masked booby (n=550) were similar to those recorded in previous surveys and higher than the more recent boat based surveys which had highest numbers in 2011 (red-footed/masked booby n=1,859) and 2012 (red-footed/masked booby n=912). Brown booby numbers were very similar to those recorded from boat based surveys in July 2009 (n=112), and higher than subsequent boat based surveys.

Sooty terns were present mainly on the southwestern and northwestern slopes of the island, both on bare ground and in amongst areas of grass. Many could be seen nesting amongst ordnance. In terms of complete counts, numbers recorded were greater in April 2013 (n=14,635; see Table 3–1) than that estimated from all boat based surveys since July 2009 (range n=9,745 to n=3,382). This is likely to be as a result of the survey technique because aerial imagery is able to accurately count birds sitting on the higher ground and may not be a result of any actual change in population. Numbers of grey-backed tern and white tern were comparable with previous boat based surveys of the island. Relatively low numbers of brown noddy were recorded from the oblique survey during April 2013 compared to previous land based surveys carried out in the summer months. This is possibly due to the time of year that the birds are breeding.

The absence of any wedge-tailed shearwaters or petrels was not unexpected as they were likely to be inside burrows and are also mainly nocturnal in the breeding season. Locating these species would be difficult with any survey method other than land-based surveys.

Overall the aerial survey method demonstrates that complete counts of seabirds can be obtained including assessing accurately the number of birds on apparently occupied nests (AONs) that would be almost impossible to record from boat surveys. Capturing aerial imagery also creates a permanent record / snapshot of the area at a specific time, allowing users to revisit the imagery / data as often as required. One slight limitation is that birds such as tropicbirds could be hidden under vegetation or ledges that could not be picked up on all the vertical or oblique imagery, so

locating nests was difficult. It is also important to note that survey techniques have differed historically on the island and may not all be directly comparable (see Appendix II for a list of all bird species previously observed and survey type).

5 References

DoN (1976a). *Environmental Impact Assessment, Ka`ula Island Target, Hawai`i*, 1 February 1976. NASBP.

DoN (2009). Kaula Island Seabird Monitoring Plan. Department of Navy. 13 pp.

DoN. (2011). Ka`ula / Kaua`i field report, HRC marine species monitoring, February 15–20, 2011. Prepared for Commander Pacific Fleet by NAVFAC Pacific.

Elmer, J. S., and G. Swedberg. (1971). Assessment of environmental impact, Ka`ula Island target. DoN, Commander Fleet Air Hawai`i.

Fujimoto, J., and F. Juola. (2012). *Ka`ula Island ship-based seabird survey, 6 July 2012*. Prepared for Commander Pacific Fleet by NAVFAC Pacific.

Palmer, H. S. (1936). Geology of Lehua and Ka`ula islands. Bernice P. Bishop Museum Occasional. Papers 12(13). 11 pp.

Pepi, V. E., A. Kumar, M. E. Laut, J. Hallman, J. Kim, and A. D. Anders. (2009). *Ka`ula Island ship-based seabird and marine mammal surveys, 21–22 July 2009*. Prepared for Commander, Pacific Fleet by NAVFAC Pacific. 29 pp.

Walker, R. R. (1983). Report on trip to Ka`ula Island, June 19–20, 1980.

Walker, R. R. (1984). Ka`ula trip report, April 16–18, 1984.

Appendix I. Scientific Names of Relevant Bird and Mammal Species

Common Name	Scientific Name
Black-footed albatross	*Phoebastria nigripes*
Laysan albatross	*Phoebastria immutabilis*
Wedge-tailed shearwater	*Puffinus pacificus*
Red-tailed tropicbird	*Phaethon rubricauda*
Great frigatebird	*Fregata minor*
Masked booby	*Sula dactylatra*
Brown booby	*Sula leucogaster*
Red-footed booby	*Sula sula*
Brown noddy	*Anous stolidus*
White tern	*Gygis alba*
Sooty tern	*Onychoprion fuscatus*
Grey-backed tern	*Onychoprion lunatus*
Hawai`ian monk seal	*Monachus schauinslandi*

Appendix II. Results of Bird Surveys Conducted on Ka`ula Island, Hawai`i, 1932–2013*

Common Name	Scientific Name	Aug 1932 Land based survey (A)	Aug 1971 Land based survey (A)	Jan 1976 Land based survey (A)	Sep 1976 Land based survey (A)	Mar 1978 Land based survey (A)	Aug 1978 Land based survey (A)	Mar 1979 Land based survey (A)	Jun 1980 Land based survey (A)	Apr 1984 Land based survey (A)	Jun 1993 Land based survey (A)	Nov 1998 Land based survey (A)	Jul 2009 Boat based survey (B)	Jun 2010 Boat based survey (A)	Jun 2011 Boat based survey (C)	July 2012 Boat based survey (C)	Apr 2013 Aerial digital survey (D)
Laysan albatross	*Phoebastria immutabilis*	-	1 old egg	150	-	100	-	100	9	33	44	60	-	-	-	-	20
Black-footed albatross	*Phoebastria nigripes*	1 old egg	-	100	-	75	-	75	-	2	4	10	-	-	-	-	3
Bonin petrel	*Pterodroma hypoleuca*	1 chick	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bulwer's petrel	*Bulweria bulwerii*	several	100	-	100	-	50	-	100	580	100	-	1	1		-	-
Wedge-tailed shearwater	*Puffinus pacificus*	many burrows	4,100	-	4,000	-	800	-	1,415	980	400	200	16	-	-	-	-
Christmas shearwater	*Puffinus nativitatis*	-	450	-	250	-	100	25	20	60	18	-	-	-	-	-	-
White-tailed tropicbird	*Phaethon lepturus*	-	3	1	1	-	1	2	-	-	-	1	-	-	-	-	-
Red-tailed tropicbird	*Phaethon rubricauda*	common	950	-	450	60	100	40	276	209	146	15	31	3	5	1	314
Great frigatebird	*Fregata minor*	common	950	250	800	400	250	250	134	155	701	650	131	430	105	26	1,415
Masked booby	*Sula dactylatra*	common	1,000	300	1,200	125	200	400	236	202	567	350	-	-	-	-	550
Brown booby	*Sula leucogaster*	common	1,700	50	1,000	75	60	200	212	169	397	60	112	1	6	40	101
Red-footed booby	*Sula sula*	uncommon	1,300	100	150	85	200	400	344	222	1,375	1,200	-	-	-	-	1,690
Masked/red-footed booby	*Sula* species	-	-	-	-	-	-	-	-	-	-	-	820	850	1,859	912	-
Pacific golden plover	*Pluvialis fulva*	several	-	10	14	-	1	2	-	21	-	15	-	-	-	-	-
Wandering tattler	*Heteroscelus incanus*	-	-	5	1	-	1	1	-	-	-	-	-	-	-	-	-
Ruddy turnstone	*Arenaria interpres*	-	50	5	20	-	4	24	1	7	1	12	-	-	-	-	-
Brown noddy	*Anous stolidus*	most numerous	67,700	-	7,000	7,000	10,000	1,000	10,560	3,950	5,778	-	-	-	-	-	57
Black noddy	*Anous minutus*	-	100	20	100	75	200	-	-	207	6	-	-	-	-	-	-
Brown/black noddy	*Anous species*	-	-	-	-	-	-	-	-	-	-	-	711	705	306	597	-
Blue-grey noddy	*Procelsterna cerulea*	small colony	-	-	200	-	-	-	-	-	-	1	-	1	-	-	-
White tern	*Gygis alba*	uncommon	10	10	200	40	10	-	9	12	9	-	10	9	9	12	6
Sooty tern	*Onychoprion fuscatus*	common	16,800	2,500	1,000	130,000	2,500	50,000	28,850	83,680	27,255	200	6,169	3,382	9,745	4,509	14,635
Grey-backed tern	*Onychoprion lunatus*	uncommon	2,800	-	250	1,250	50	300	4,110	1,467	35	-	1	3	-	-	4
Barn owl	*Tyto alba*	-	1	3	3	-	1	6	4	2	7	3	-	-	-	-	-
Japanese white-eye	*Zosterops japonicus*	-	-	2	3	-	-	-	-	-	3	-	-	-	-	-	-
Northern mockingbird	*Mimus polyglottos*	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Northern cardinal	*Cardinalis cardinalis*	-	2	-	7	-	-	-	-	-	-	-	-	-	-	-	-

Common Name	Scientific Name	Aug 1932 Land based survey (A)	Aug 1971 Land based survey (A)	Jan 1976 Land based survey (A)	Sep 1976 Land based survey (A)	Mar 1978 Land based survey (A)	Aug 1978 Land based survey (A)	Mar 1979 Land based survey (A)	Jun 1980 Land based survey (A)	Apr 1984 Land based survey (A)	Jun 1993 Land based survey (A)	Nov 1998 Land based survey (A)	Jul 2009 Boat based survey (B)	Jun 2010 Boat based survey (A)	Jun 2011 Boat based survey (C)	July 2012 Boat based survey (C)	Apr 2013 Aerial digital survey (D)
House finch	*Haemorhous mexicanus*	-	6	15	40	-	20	6	-	1	1	8	-	-	-	-	-
Nutmeg mannikin	*Lonchura punctulata*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-
Total Estimated Number of Birds		-	**98,022**	**3,521**	**16,811**	**139,285**	**14,548**	**52,831**	**46,280**	**91,959**	**36,847**	**2,785**	**8,001**	**5,385**	**12,035**	**6,097**	**18,795**
Total Number of Species		**16**	**19**	**16**	**24**	**12**	**19**	**17**	**15**	**19**	**19**	**15**	**11**	**11**	**8**	**8**	**11**

*Data sourced from:

A – DoN. (2011. Ka`ula / Kaua`i field report, HRC marine species monitoring, February 15–20, 2011. Prepared for Commander Pacific Fleet by NAVFAC Pacific.

B – Pepi, V. E., A. Kumar, M. E. Laut, J. Hallman, J. Kim, and A. D. Anders. 2009. *Ka`ula Island ship-based seabird and marine mammal surveys, 21-22 July 2009*. Prepared for Commander, Pacific Fleet by NAVFAC Pacific. 29 pp.

C – Fujimoto, J., and F. Juola. 2012. *Ka`ula Island ship-based seabird survey, 6 July 2012*. Prepared for Commander, Pacific Fleet by NAVFAC Pacific.

D – Normandeau Associates, Inc. and APEM, Ltd. Joint Venture. 2013. Aerial Survey of Seabirds and Marine Mammals at Ka`ula Island, Hawai`i. Prepared for Commander, Pacific Fleet through a contract with NAVFAC Pacific.