Aerial Survey of Seabirds and Marine Mammals at Ka`ula Island, Hawai`i January 2014

GSA # GS-10F-0319M

Delivery Order # N62742-13-F-1872

Prepared For

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March 2014

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Executive Summary

Aerial surveys of Ka`ula Island, Hawai`i, using a manned light twin-engine survey aircraft and very high resolution digital photography were conducted on January 29, 2014. 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, 879 birds of six species were recorded during the survey with great frigatebirds being the most abundant species (n=621) followed by red-footed boobies (n=98). A number of other species were recorded including, Laysan albatrosses, black-footed albatrosses, masked boobies and brown boobies.

At the time of the survey, a total of five Hawai`ian monk seals were resting on ledges in the north-east of the island. Eight humpback whales were sighted by the survey technician, ranging between 200 m and approximately 1 km from the island, though these were not captured in the aerial imagery.

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 Hawai`ian 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° 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).

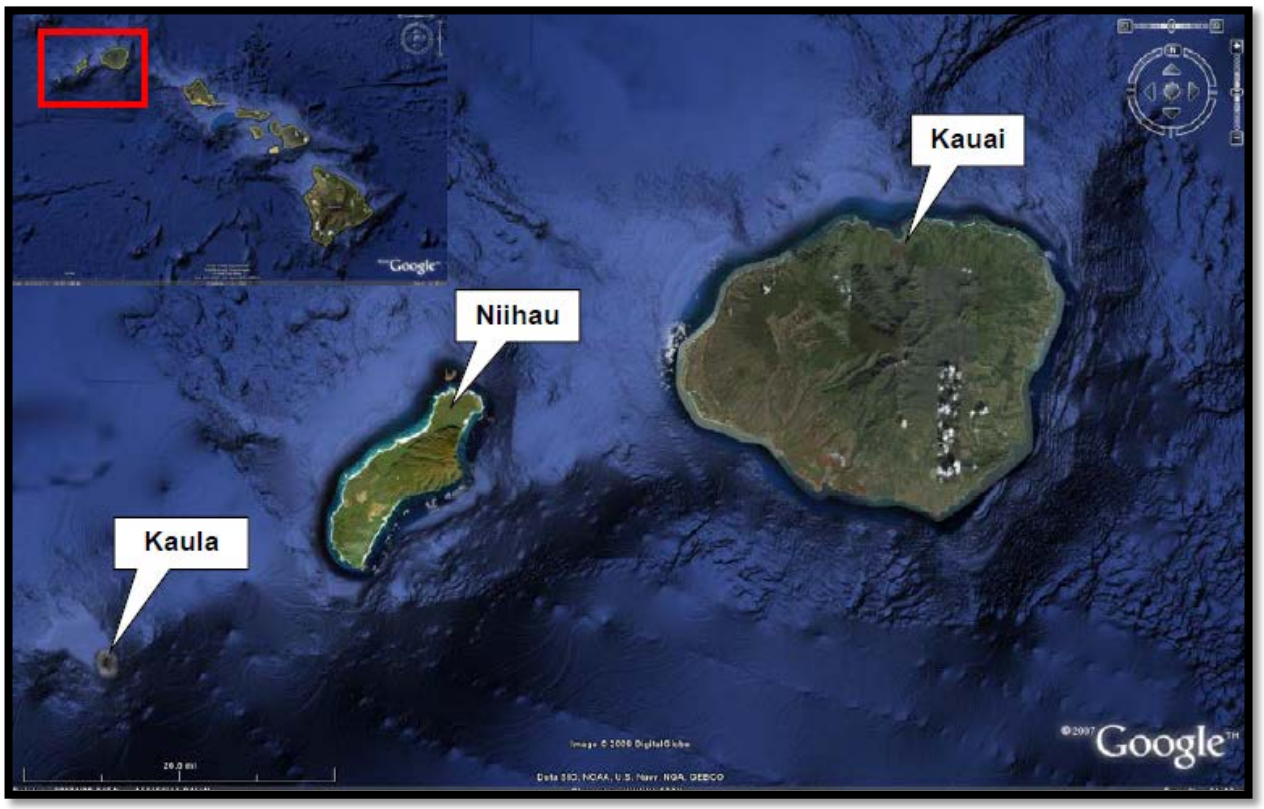

Figure 1-1. Location of Ka`ula Island relative to the main Hawai`ian Islands (inset) and Kauai and Niihau (imagery from Google Earth).

Figure 1-2. Topography of the northern horn 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 present, munitions training by the Navy at Ka`ula has been restricted to inert ordnance delivery and aircraft gunnery (DoN 2008; DoN 2013).

Historically, eleven land based avian surveys have been undertaken on the island (Pepi et al. 2009), but, due to safety reasons, these were replaced with boat based observations through 2011 (Pepi et al. 2009; DoN 2011) and observer based, low altitude aerial surveys (DoN 2011) from 2013 to present.

The U.S. Navy initially 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 looked to improve and build upon the seabird data gathering and marine mammal observation efforts by exploring the use of higher altitude, very high resolution aerial imaging surveys. The first survey using this technique was conducted in April 2013. This improved technology has resulted 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

This digital aerial survey of Ka`ula was undertaken on January 29, 2014. High resolution digital still images were collected using a manned light twin-engine survey aircraft, Twin Piper Navajo PA31 N3949W, 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. All of the required surveys were carried out on the same day (January 29, 2014). This 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). Following on from these, 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.

The first survey carried out (between 10:57 and 12:05 hours) was the vertical high altitude survey conducted at 2,500 feet, which was flown in an east-west direction. This survey captured 2 cm resolution imagery at the higher elevation sections of the island.

Immediately after the first survey (between 12:09 and 13:57 hours), the vertical low altitude survey was flown in an east-west direction at 2,050 feet. 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.

The oblique survey (between 13:59 and 14:20 hours) was conducted on the same day (see Section 2.4) by flying clockwise around the island between 800 and 1,800 feet, and images were taken to capture the sides of the steep cliff faces.

2.2 Data Processing

2.2.1 Vertical Surveys

As it is not technically possible to capture the entire 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 the context of other visual census techniques that 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 was 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) and GIS 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 to species. In addition a manual check of each grid cell was carried out 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.

The vertical imagery and GPS information was also loaded into a specialist piece of photogrammetry software. This software was able to identify points on the island in several overlapping images from which it could triangulate their elevation. Using the GPS information taken from the camera system during the survey it was able to scale and geo-reference the points

and combine their elevations with the imagery product to create a three dimensional model of the island. Although this is not part of the scope of the project, APEM/Normandeau would be happy to supply this three dimensional model to the US Navy.

2.2.2 Oblique Surveys

The oblique images were 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

This section explains some of the survey limitations and weather conditions. Due to the time of the year and expected low solar illumination of the survey area, the survey began before solar noon to maximize solar illumination of the eastern side of the island. This limited as much as possible any shadow from the challenging island terrain. Once the equipment had been installed into the aircraft on the January 26, we waited for a suitable weather window.

Due to some unsettled weather systems to the north of the island, a review of the next day's forecast was undertaken each day. It was decided on the evening of January 28 that the conditions were right to survey the island the following day. The survey was scheduled for ~10:45 hours January 29, departing from and returning to Kalaeloa Airport, Oahu.

Contact with 'Hula Dancer' traffic control was maintained during surveys and the watch supervisor kept informed of survey plans both leading up to the survey and during the flight.

Survey conditions were very good with clouds scattered at 4,000 feet and 12,000 feet with light winds from the northeast at 6 - 16 knots, gusting 23 - 26 knots. Visibility was 7 – 10 km with a slight haze in the area.

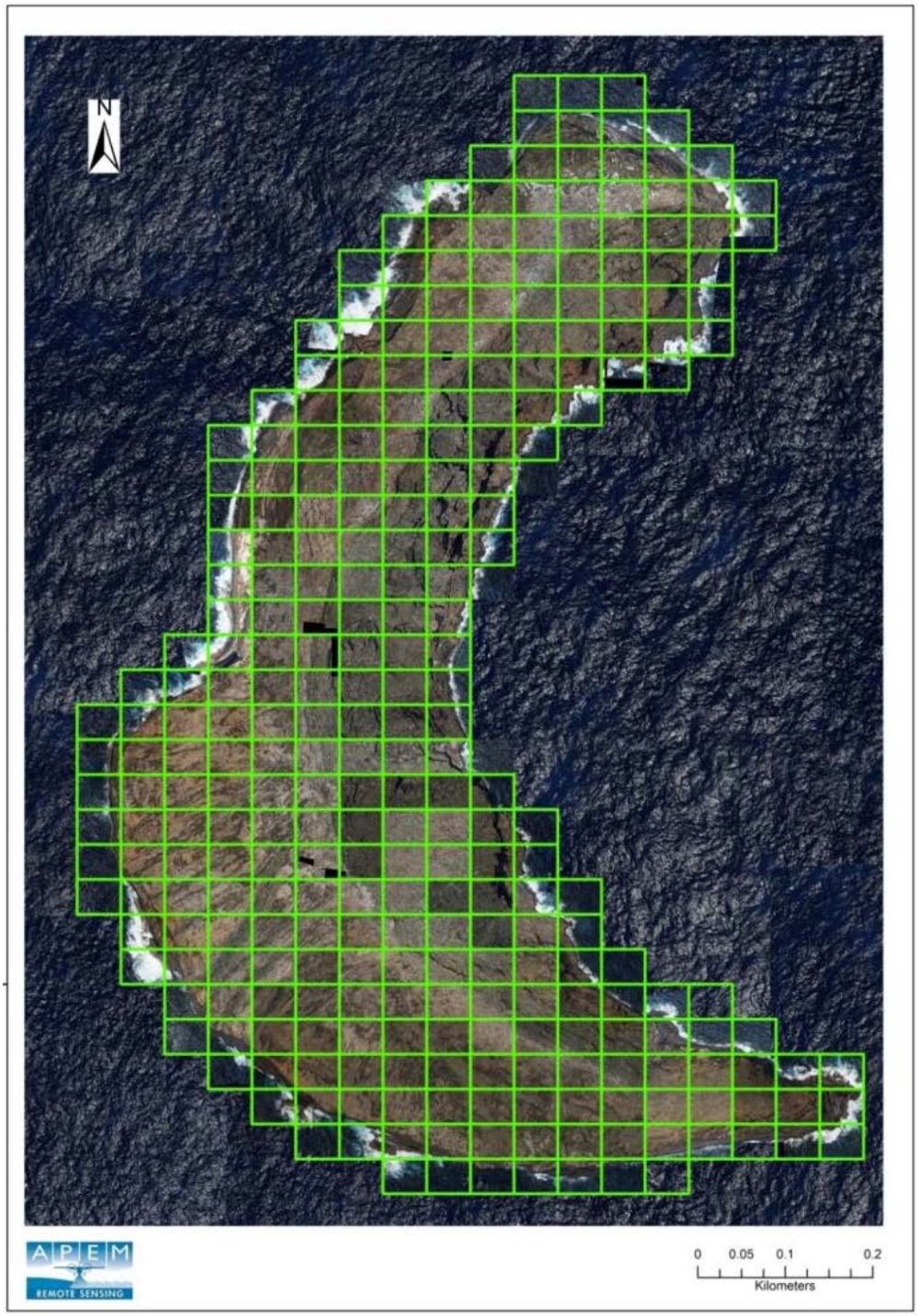

Figure 2-1. Ka`ula Island image analysis grid. Compiled images from the two vertical surveys were joined to cover Ka`ula Island. The compiled image was analyzed in 295 grid cell sections (marked in green).

3 Results

3.1 Species Abundance

A total of 879 birds (6 species) and five marine mammals (2 species) were recorded on Ka`ula Island during January 2014 (Table 3-1). Great frigatebirds (n = 621) were the most abundant bird species, and brown booby (n=3) were the least abundant. Comparison with prior years is provided in Appendix III.

Table 3-1. Total Number of Birds and Marine Mammals Recorded on Ka`ula Island by Vertical and Oblique Surveys during January 2014

		Numbers Recorded		
Species/Group	**Vertical Survey**	**Oblique Survey**	**Visual Observation**	**Total**
Birds				
Black-footed albatross	11	-		11
Laysan albatross	81	-		81
Great frigatebird	596	25		621
Masked booby	65	-		65
Brown booby	3	-		3
Red-footed booby	98	-		98
Total Birds	*854*	*25*		*879*
Hawai`ian monk seal	5	-		5
Humpback whale			8	8
Total Birds and Marine Mammals	**859**	**25**	**8**	**892**

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 January 2014 aerial survey. Generally, birds were distributed across the whole island with higher concentrations along the eastern and western coastlines and in the north of the island. Black-footed albatrosses were present in the far north of the island. Laysan albatrosses were distributed mainly in the northern half and along the central ridge of the island. Great frigatebirds were concentrated on the north east side of the island. Boobies were widely scattered—masked

boobies were recorded along the central higher areas, brown and red-footed boobies were recorded slightly lower down the island. Hawai`ian monk seals were recorded in the northeastern section of the island. Eight humpback whales were recorded by visual observation, which were all within one kilometer of the island itself.

3.2.2 Black-footed albatross

A total of 11 black-footed albatrosses were recorded on Ka`ula Island during the survey (Table 3-1). The majority were single birds sitting on higher ground on the northern horn of the island (Figure 3-2). One pair were sitting amongst the vegetation at the north tip of the island and a single bird was flying east over the northern edge of the island heading out to sea (Figure 6-1).

3.2.3 Laysan albatross

A total of 81 Laysan albatrosses were recorded on Ka`ula Island during the survey (Table 3–1). The majority were present along the highest ridge running through the center of the island, with individuals located in the southeastern and northern sections of the island (Figure 3–3). Birds were mostly recorded sitting on bare areas of ground with 16 pairs of Laysan albatross observed sitting together. A total of four birds were recorded in flight over the center of the island (Figure 6–4).

3.2.4 Great frigatebird

A total of 621 great frigatebirds were recorded during the survey (Table 3–1). High concentrations were present in the northern section and along the east side in the concave section of the island. Very few birds were present in the southern half of the island (Figure 3–4). There were scattered nesting colonies especially on the slopes and ravines on the eastern side, with many birds on occupied nests. Small clusters of male great frigatebirds could also be seen displaying their red gular pouches (throat area).

3.2.5 Masked booby

A total of 65 masked boobies were recorded during the survey (Table 3–1). The highest concentrations were in the northern section of the island, mainly on the higher ground and along the ridge crest in the center of the island. Smaller numbers were along the central ridge in the southern section of the island and a single bird was flying over the south-west slope (Figure 3–5).

3.2.6 Brown booby

Three brown boobies were recorded on Ka`ula Island during the survey (Table 3–1). Two were sitting on the eastern slope in the center of the island in close proximity to nesting great frigatebirds and small groups of red-footed and masked boobies. A further individual was resting in the south-east of the island towards the central ridge (Figure 3–6).

3.2.7 Red-footed booby

A total of 98 red-footed boobies were recorded during the survey (Table 3–1). They were widely distributed with the majority of birds recorded along the central ridge of the island and on higher ground. A cluster of 40 red-footed boobies were observed alongside a number of great frigatebirds in the north of the island on the eastern slope (Figure 3–7).

3.2.8 Marine mammals

During the course of the survey, five Hawai`ian monk seals were recorded resting on ledges on the island (Table 3–1). All five seals were together in one group in the northeast concave section of the island (Figures 3–8, 6-2). Although not captured in the survey imagery, eight humpback whales were seen from the survey aircraft, ranging between 200 m and approximately 1 km from the island.

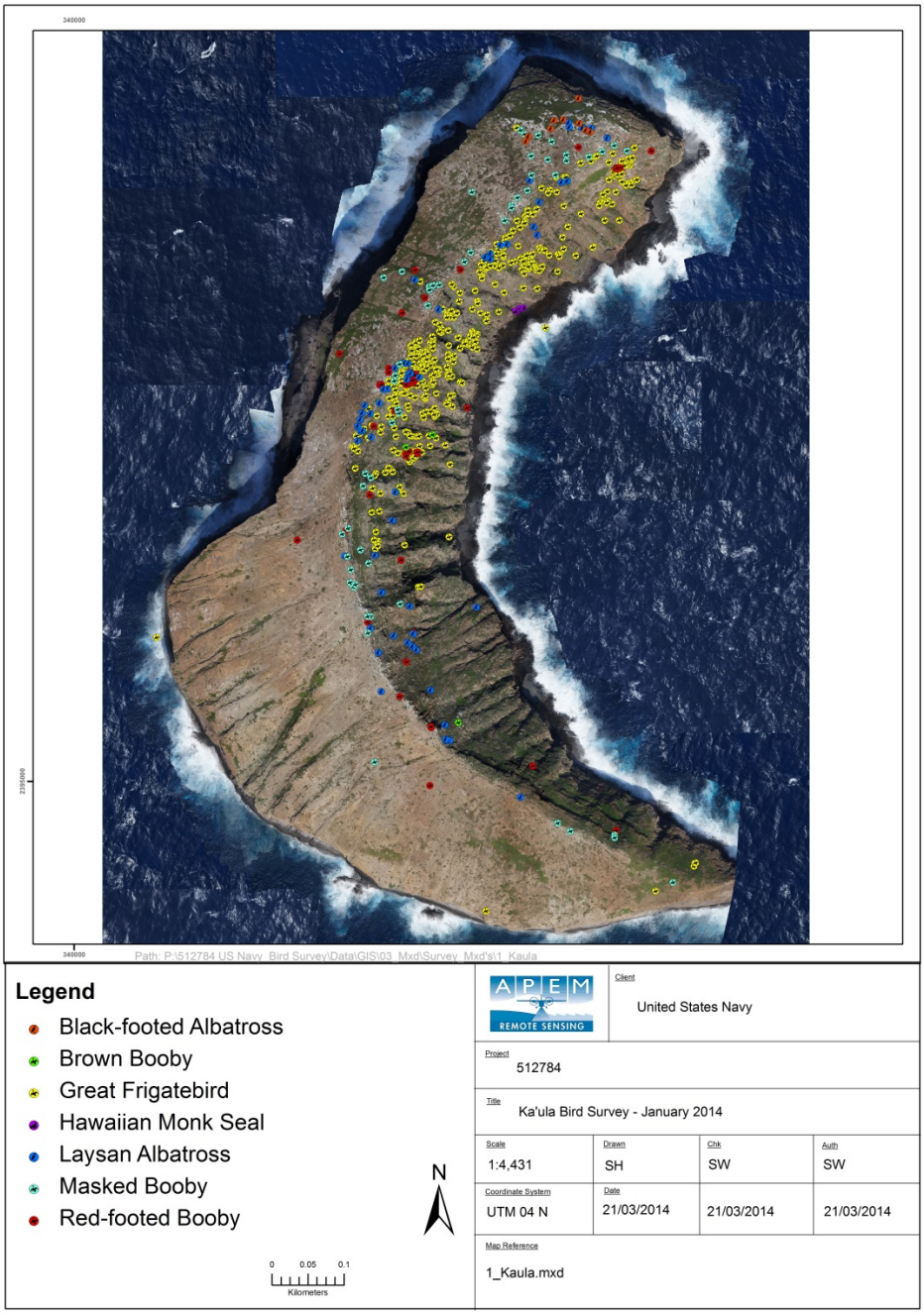

Figure 3-1. Distribution of all birds and marine mammals recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

Figure 3-2. Distribution of black-footed albatrosses recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

Figure 3-3. Distribution of Laysan albatrosses recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

Figure 3-4. Distribution of great frigatebirds recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

Figure 3-5. Distribution of masked boobies recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

Figure 3-6. Distribution of brown boobies recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

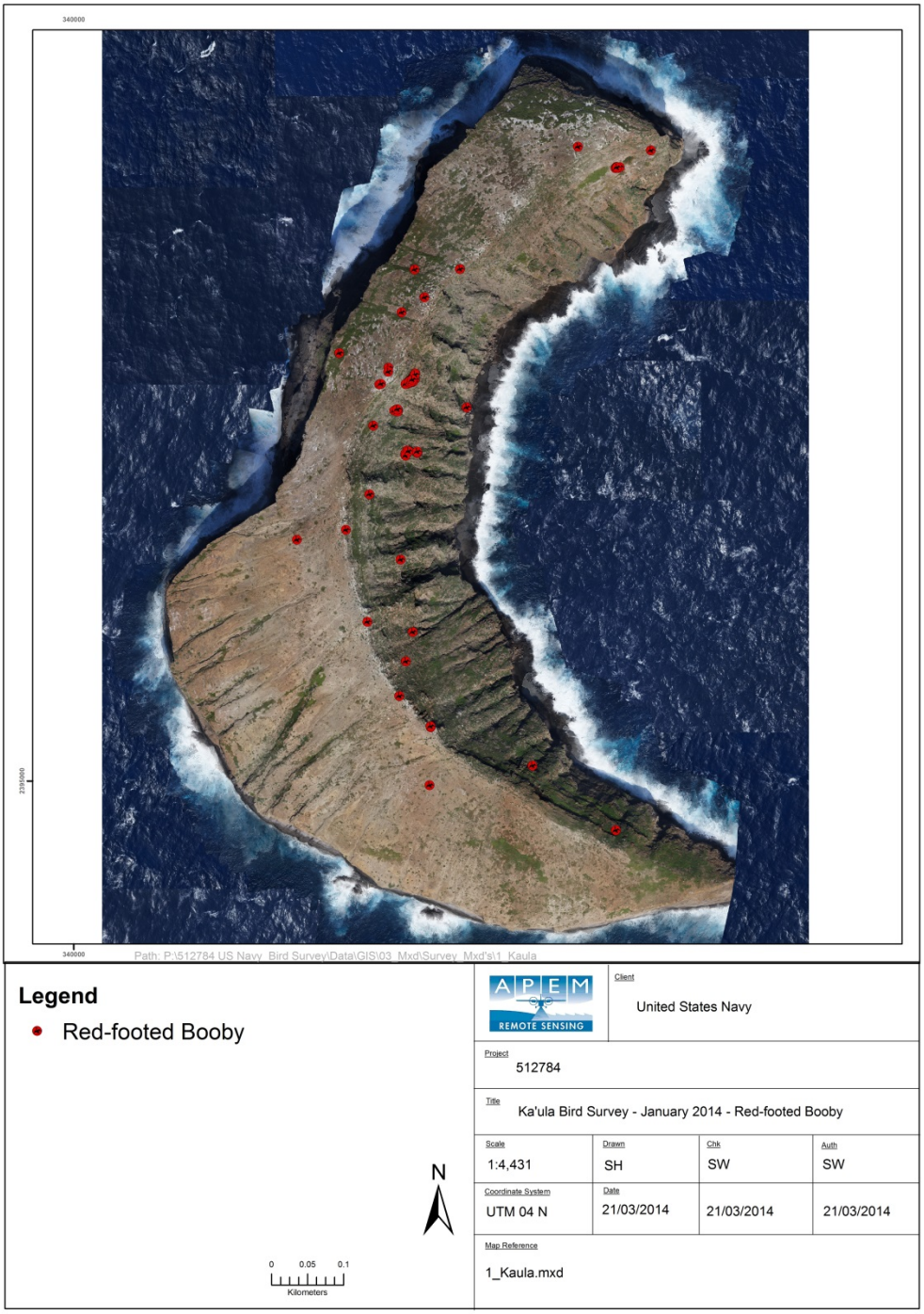

Figure 3-7. Distribution of red-footed boobies recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

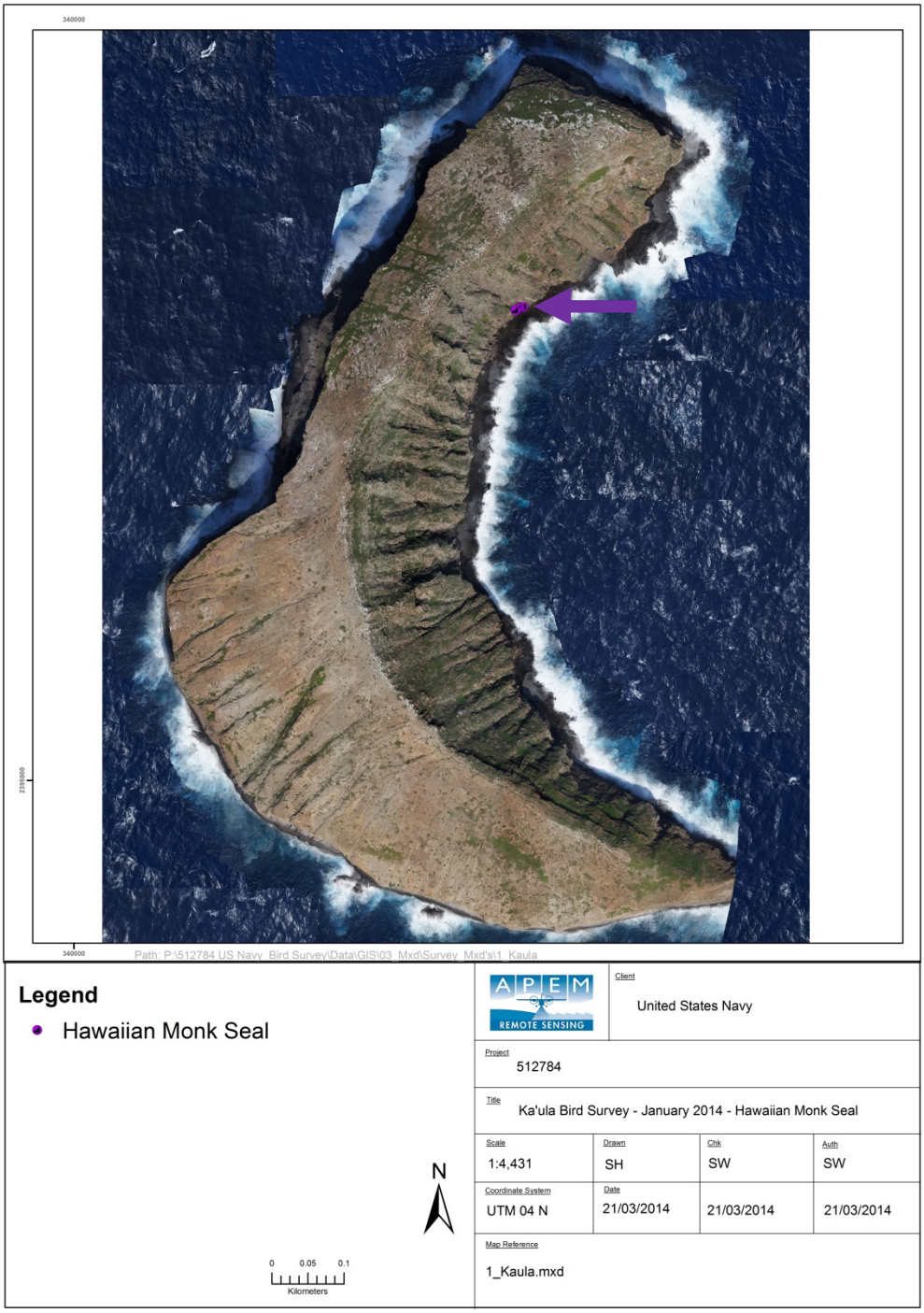

Figure 3-8. Distribution of Hawai`ian monk seals recorded on Ka`ula Island during the January 2014 survey. Note: The number of points visible on this figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several points may overlap each other.

4 Discussion

Overall, during the vertical and oblique surveys, a total of 879 birds and five Hawai`ian monk seals were recorded on Ka`ula Island on January 29, 2014 (Table 3–1). The six bird species present were black-footed albatross, Laysan albatross, great frigatebird, masked booby, brown booby and red-footed booby. The most abundant species was great frigatebird, accounting for 71% (n=621) of all the seabirds recorded. The next most abundant species were red-footed booby (n=98), Laysan albatross (n=81) and masked booby (n=65) (see Table 3–1). Black-footed albatross (n=11) and brown booby (n=3) were the least abundant species recorded.

Black-footed albatross were mainly sitting on higher ground on the northern horn of the island (see Figure 3-2), and a single bird was recorded flying east over the northern edge of the island (Figure 6-1). Higher numbers of black-footed albatross were recorded during land based survey in January 1976 (n=100; Appendix III) and lower numbers were recorded during land based surveys in November 1998 (n=10; Appendix III). The number of black-footed albatross recorded during January 2014 (n=11) is the highest recorded since June 1980 (Appendix III).

Laysan albatross were mainly present on the higher ground scattered along the central ridge (see Figure 3–4). Numbers recorded in this survey (n=81) were lower than previous counts made from land based surveys in January 1976 (n=150; Appendix III) and higher than counts from land based surveys in November 1998 (n= 60). Counts were higher than those made in August 2013 by aerial digital survey (n=11). Generally numbers were similar to those recorded during various land-based surveys during the 1970's and 1980's. As Laysan albatrosses are known to incubate their eggs between November and February it is possible that many of the sitting birds present at the time of the survey could have been on occupied nests. Of the 81 recorded all appeared to be adults, of which 77 were sitting and four were flying. Of the sitting birds there were 16 paired (32 individuals) and a further 35 single birds sat on grassy ledges or sandy areas that could have been suitable for nesting. A further 10 sat in two larger groups. If our interpretation of behavior is correct, one could assume up to 51 pairs (16 pairs plus 35 pairs) were present at the time of the survey.

Great frigatebird was the most abundant species recorded in January 2014 (n=621). These were widely distributed across the east side and in the north of the island. Numbers recorded were higher than those from previous land based surveys of January 1976 (n=250; Appendix III). 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. However, numbers were less than those of the last two digital aerial surveys conducted in April 2013 (n=1,415; Appendix III) and August 2013 (n=1,369; Appendix III).

Of the booby species recorded, red-footed booby was the most abundant during the 2014 survey followed by masked booby and brown booby (see Table 3–1). The count of red-footed booby during the January 2014 survey (n=98) was comparable to that made during the land based January 1976 survey (n=100; Appendix III). Numbers had decreased compared to the August 2013 aerial digital survey (n=191; Appendix III).

Numbers of masked booby decreased during the 2014 survey (n=65) compared to the previous land based survey conducted in January 1976 (n=300; Appendix III) with the highest

concentrations observed on the higher ground and along the ridge crest in the center of the island (see Figure 6-4). Numbers had also decreased compared to the previous survey in August 2013 (n=219; Appendix III). The species is known to lay eggs from February through to April but this can be earlier or later (Richardson, 1957). The higher numbers recorded during August 2013 suggest that breeding on Ka`ula could occur mainly through the summer months.

Low numbers of brown booby were recorded during the January 2014 survey (n=3). Numbers had decreased compared to those recorded from land based January 1976 survey (n=50) and the August 2013 aerial digital survey (n=109).

Seabirds can spend long periods of time out at sea so single birds recorded during this survey may be half of a pair. Appendix IV shows the minimum estimated number of birds present based on the actual individuals recorded in the imagery and a maximum estimated number of birds based on relevant single birds being one half of a pair. However, please note that as the breeding season of seabirds in Hawai`i is spread throughout the year not all birds may be paired up in January.

The observer in the aircraft observed seven adult humpback whales and a single calf close to the island during the survey. Four adults and a calf were recorded travelling together approximately 1 km off the northwestern coast of the island (Figure 6-3). A further two adults were recorded approximately 200 m off the southwestern coastline with a single adult whale less than 500 m off the southern horn of the island. Humpback whales undertake seasonal migrations from high latitude feeding grounds in spring and summer to tropical breeding grounds where they mate and calve during winter (Mobley, 2001).

Overall the aerial survey method demonstrates that complete counts of seabirds can be obtained including ability to accurately assess the number of birds on apparently occupied nests (AON’s) that would be almost impossible to record from boat surveys. 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. It is also important to note that survey techniques have differed historically on the island and may not all be directly comparable (see Appendix III for a list of all bird species previously observed and survey type).

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6 Appendices

Appendix I. Survey Imagery

Figure 6-1. Black-footed albatross flying east off the northern edge of Ka`ula Island during the January 2014 survey.

Figure 6-2. Five Hawai`ian monk seals resting on a ledge in the northeast of Ka`ula Island during the January 2014 survey.

Figure 6-3. Four adult humpback whales and a calf close to the northern end of Ka`ula Island during the January 2014 survey.

Figure 6-4. Flying and sitting Laysan albatrosses (top center) and flying and sitting masked boobies along the central ridge of Ka`ula Island during the January 2014 survey.

Figure 6-5. Sitting Laysan albatrosses (one bottom left and two bottom middle) and black-footed albatross (circled) on the northern end of Ka`ula Island during the January 2014 survey.

Appendix II. Scientific Names of Relevant Bird and Mammal Species

Common Name	Scientific Name
Black-footed albatross	*Phoebastria nigripes*
Laysan albatross	*Phoebastria immutabilis*
Great frigatebird	*Fregata minor*
Masked booby	*Sula dactylatra*
Brown booby	*Sula leucogaster*
Red-footed booby	*Sula sula*
Hawai`ian monk seal	*Neomonachus schauinslandi*
Humpback whale	*Megaptera novaeangliae*

Appendix III. Results of Bird Surveys Conducted on Ka`ula Island, Hawai`i, 1932–2014*

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)	Aug 2013 Aerial digital survey (D)	Jan 2014 Aerial digital survey (D)
Laysan albatross	*Phoebastria immutabilis*	-	1 old egg	150	-	100	-	100	9	33	44	60	-	-	-	-	20	11	81
Black-footed albatross	*Phoebastria nigripes*	1 old egg	-	100	-	75	-	75	-	2	4	10	-	-	-	-	3	-	11
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	85	-
Great frigatebird	*Fregata minor*	common	950	250	800	400	250	250	134	155	701	650	131	430	105	26	1,415	1,369	621
Masked booby	*Sula dactylatra*	common	1,000	300	1,200	125	200	400	236	202	567	350	-	-	-	-	550	219	65
Brown booby	*Sula leucogaster*	common	1,700	50	1,000	75	60	200	212	169	397	60	112	1	6	40	101	109	3
Red-footed booby	*Sula sula*	uncommon	1,300	100	150	85	200	400	344	222	1,375	1,200	-	-	-	-	1,690	191	98
Masked/red-footed booby	*Sula dactylatra / S. sula*	-	-	-	-	-	-	-	-	-	-	-	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	3,713	-
Black noddy	*Anous minutus*	-	100	20	100	75	200	-	-	207	6	-	-	-	-	-	-	22	-
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	7	-
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*	-	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)	Aug 2013 Aerial digital survey (D)	Jan 2014 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**	**5,733**	**879**
Total Number of Species		**16**	**19**	**16**	**24**	**12**	**19**	**17**	**15**	**19**	**19**	**15**	**11**	**11**	**8**	**8**	**11**	**9**	**6**

*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.

C – Fujimoto, J & Juola, F. (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.

Appendix IV. Estimates of Seabird Numbers during the January 2014 Aerial Digital Survey of Ka`ula Island, Hawai`i.

Species/Group	Minimum estimate of birds numbers	Maximum estimate of birds numbers*
Birds		
Black-footed albatross	11	20
Laysan albatross	81	130
Great frigatebird	621	1,222
Masked booby	65	120
Brown booby	3	6
Red-footed booby	98	196
Total Estimated Number of Birds	**879**	**1,694**

*A pair is assumed to be two birds, all singles are assumed to be one of a pair and are doubled up to obtain maximum estimate.

Appendix V. Results of Aerial Digital Surveys conducted by Normandeau/APEM of Ka`ula Island, Hawai`i, 2013-2014*

Common Name	Scientific Name	Apr 2013	Aug 2013	Jan 2014
Black-footed albatross	*Phoebastria nigripes*	3	-	11
Laysan albatross	*Phoebastria immutabilis*	20	11	81
Red-tailed tropicbird	*Phaethon rubricauda*	314	85	-
Great frigatebird	*Fregata minor*	1,415	1,369	621
Masked booby	*Sula dactylatra*	550	219	65
Brown booby	*Sula leucogaster*	101	109	3
Red-footed booby	*Sula sula*	1,690	191	98
Brown noddy	*Anous stolidus*	57	3,713	-
Black noddy	*Anous minutus*	-	22	-
White tern	*Gygis alba*	6	-	-
Sooty tern	*Onychoprion fuscatus*	14,635	7	-
Grey-backed tern	*Onychoprion lunatus*	4	-	-
Total Estimated Number of Birds		**18,795**	**5,733**	**879**
Total Number of Species		**11**	**9**	**6**