

**Aerial Survey of Seabirds and Marine Mammals at Kaula Island, Hawaii,  
November 2019**

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## Executive Summary

An aerial vertical (nadir) survey of Kaula Island, Hawaii, using a manned light twin-engine survey aircraft and ultra-high-resolution digital photography was conducted on 17 November 2019. The vertical aerial survey was complemented with an oblique survey, which was conducted the same day. Carrying out both surveys allows counts to be made of birds on the top of the island and those present on the cliff faces. For 2020, obtaining an aircraft fit for purpose was challenging, and the only aircraft available required oblique imagery to be captured through an aircraft window. The oblique imagery captured was of comparatively low quality and numbers of brown boobies are likely to be under recorded.

This survey was conducted 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.

The survey was completed in one day with 100% of the final image mosaic formed from imagery collected on the high-resolution survey.

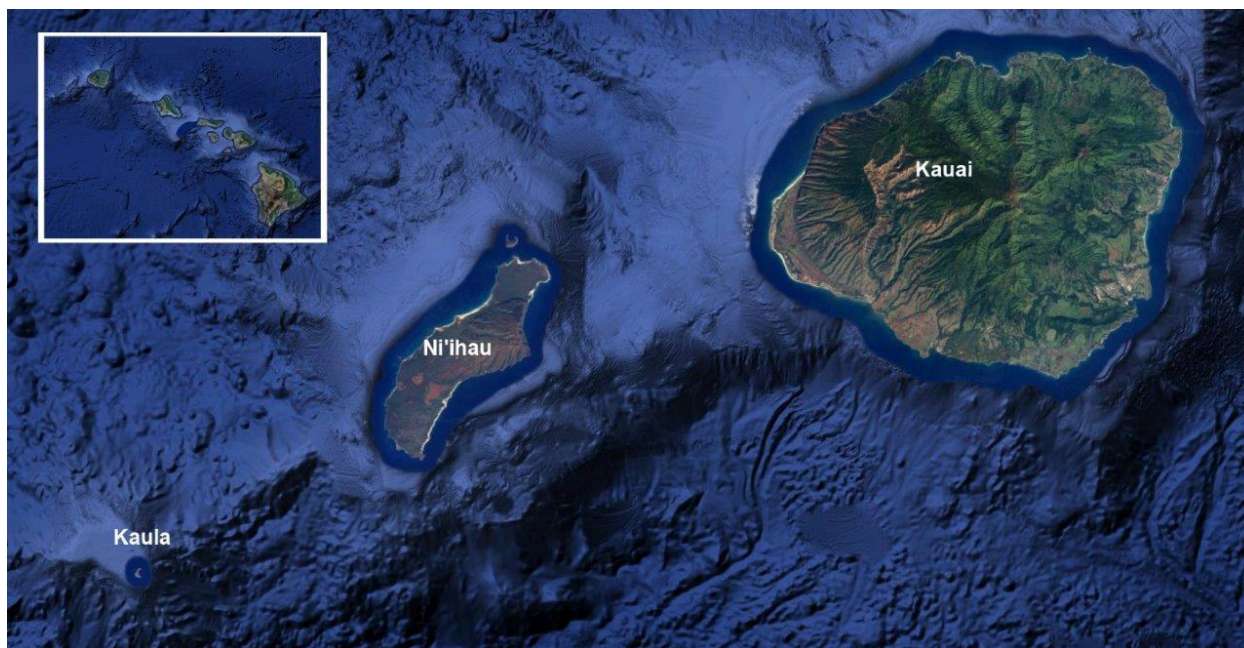
In total, 2,091 birds were recorded during the survey with red-footed booby being the most abundant species (n=1,196) followed by great frigatebird (n=316). Other species recorded included masked booby, brown booby, Laysan albatross, and red-tailed tropicbird.

At the time of the surveys, eight Hawaiian monk seals were recorded: seven resting on a section of coast in the northern region of the eastern convex side of the island and one was swimming off the southern coast.

## 1 Introduction

Normandeau Associates, Inc., and APEM Ltd. were contracted by the U.S. Navy to provide ornithological data for the Pacific island of Kaula, Hawaii, through the capture and analysis of ultra-high-resolution digital aerial imagery.

Kaula Island is a small (0.64 km<sup>2</sup>), uninhabited crescent-shaped islet in the western chain of islands making up the Hawaiian Archipelago (Figures 1–1 and 1–2). The islands closest to Kaula are Ni‘ihau (37 km to the northeast) and Kauai (approximately 111 km to the northeast). A mountain ridge runs along the length of Kaula 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; 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 Kaula Island relative to the main Hawaiian Islands (inset) and Kauai and Ni‘ihau (imagery from ESRI).**



**Figure 1-2. Topography of Kaula Island (photo taken 17 July 2017).**

Since 1952, the U.S. Navy has used the southeastern tip of the island (approximately 0.06 km<sup>2</sup>) 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. Since 1981, the U.S. Navy has restricted munitions training at Kaula Island 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 and aerial observations (2009–2011; Pepi et al. 2009; DoN 2011). Aerial digital surveys commenced in April 2013 and seven surveys have been conducted to date.

The U.S. Navy initially attempted aerial imagery before the finalization of the Seabird Monitoring Plan (DoN 2009) but results were unacceptable. Now with improved technology, the U.S. Navy wanted 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 and has resulted in these 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 Kaula (previously surveyed by boat) because of increased visibility of the higher sections and slopes of the island

## 2 Methods

### 2.1 Survey Design

This digital aerial survey of Kaula was undertaken on 17 November 2019 and included oblique imagery capture.

Ultra-high-resolution digital still images were collected using a manned light twin-engine survey aircraft and a GPS-linked custom flight management camera system (APEM SeeBird01) specifically designed by APEM to target high-resolution surveys for birds and marine mammals.

To prepare for the survey of Kaula, 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 transect was 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 Kaula (see Figure 1–2), two surveys were carried out to ensure that high-quality imagery was achieved over the whole island (100% coverage), including capturing animals on horizontal and vertical ledges.

The collection of oblique images (oblique survey) of birds on steep overhanging cliff faces that may not have been visible from the vertical surveys was undertaken immediately after the second vertical survey on the same day.

The vertical survey was flown between 09:19 and 10:35 in a north-south direction at 1,920 feet. This captured imagery at 2-cm resolution at sea level and 1.4-cm resolution at the higher elevation sections of the island.

The oblique survey was carried out on the same day between 10:39 and 10:50 by flying counterclockwise several times around the island between 500 and 1,800 feet. Although resolution of the oblique imagery varies, the majority is less than 2 cm. However, due to limited aircraft availability, the imagery had to be captured through a closed window.

#### 2.1.1 Vertical Surveys

As it is not technically possible to capture the entire island at 1.33-cm resolution in a single image, several survey transects were flown to gain full coverage of the island. This generated approximately 400 vertical digital photographs collected over an approximate 1.5-hour period. These images were imported as geo-referenced images (WGS 84 projection) into GIS software 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 the most appropriate to minimize the risk of double counting that might have occurred by overlapping areas on single



images. It is acknowledged there is a small chance that movement of birds between transects could cause a bird being double counted. There is 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 because of their longer duration and the disturbance caused, which results in many birds moving around in response to the observers.

The mosaic was split into 296 grid cells ensuring consistency with previous surveys (Figure 2–1) and to aid the identification stage of the analysis.

Specially trained staff recorded the following information from each grid cell of the compiled image covering Kaula 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 that 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 seabirds based on size, shape, and coloration. Two full scans of each grid cell are manually completed to find targets for identification, which are analyzed by the analyst and confirmed by the software. The resolution of the images is extremely high such that the individuals can be identified to species with high certainty.

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

The vertical imagery and GPS information was also loaded into photogrammetry software. This software identified 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 scaled 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 report, APEM/Normandeau would be happy to supply this three-dimensional model to the U.S. Navy. Examples of the vertical imagery can be found in Appendix II.

### **2.1.2 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 ornithologists 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 steep cliffs, small caves, and

overhanging rock ledges. The results were then subjected to the same internal process used in the vertical survey.

## **2.2 Identification and Quality Assurance**

All bird and marine mammal species in the images from Kaula 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 and then checked by APEM's quality assurance manager. The quality assurance manager, an experienced ornithologist, maintains and updates the image library and advises and provides guidance to the image analysis staff.

Known nesting habits of the booby species were used to aid identification of juvenile birds in nests where the physical characters that aid identification were not visible. Masked and brown boobies nest on the ground often near breezy cliff edges or other take-off features. Red-footed boobies usually nest on small trees or shrubs and have a larger nest platform. The nesting substrate/location of nests that contained only juveniles was used to assist identifications.

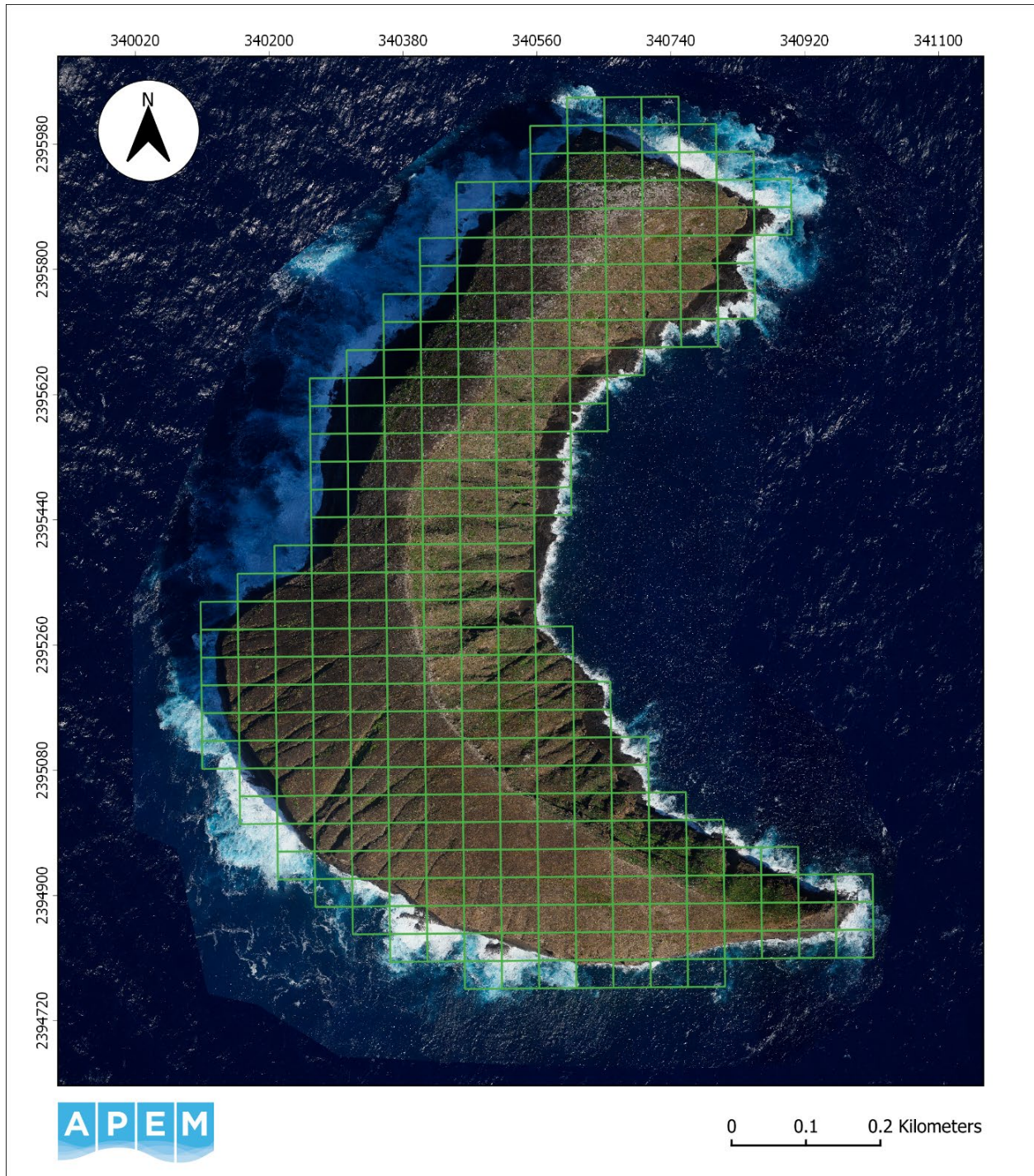
## **2.3 Weather Conditions and Survey Limitations**

This section explains some of the survey limitations and weather conditions. Once the equipment had been installed into the aircraft on 15 November 2019, a short test flight was conducted in the afternoon. Some system issues were then resolved, and another test flight was carried out on the morning of 16 November 2019. After this, we transited up to Lihue in preparation to carry out the survey.

On the morning of 17 November 2019 weather forecasts and radar imagery predicted very promising conditions with little to no cloud over the survey area. After a discussion with the pilot, a decision was made to carry out the survey.

Survey conditions were good with no cloud cover over the island and a mean wind speed of 22 knots from the north. Visibility was greater than 10 km during all surveys.

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



**Figure 2-1. Kaula Island image analysis grid.**

Compiled images from the two vertical surveys were joined to cover Kaula Island. The compiled image was analyzed in 296 grid cell sections (marked in green).

### 3 Results

#### 3.1 Species Abundance

Eight marine mammals (1 species) and 2,091 birds (6 species) were recorded on Kaula Island during November 2019 (Table 3–1). Red-footed booby (n=1,196) was the most abundant bird species, and red-tailed tropicbird (n=1) was the least abundant species. Comparison with prior years is provided in Appendix III.

**Table 3–1. Total Number of Birds and Marine Mammals Recorded on Kaula Island by Vertical and Oblique Surveys during November 2019**

Species/Group	Number Recorded	Visual Observation	Total
<b>Birds</b>			
Laysan albatross	17	-	17
Red-tailed tropicbird	1	-	1
Great frigatebird	316	-	316
Masked booby	217	-	217
Brown booby	185	-	185
Red-footed booby	1,196	-	1,196
Booby species	159	-	159
<b>Total Birds</b>	<b>2,091</b>	-	<b>2,091</b>
<b>Marine Mammals</b>			
Hawaiian monk seal	8	-	8
<b>Total Birds and Marine Mammals</b>	<b>2,099</b>	-	<b>2,099</b>

#### 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 Kaula Island during the November 2019 aerial survey. Birds were widely distributed throughout the island, mostly concentrated in the northern and eastern regions. Laysan albatross, great frigatebirds, and one red-tailed tropicbird were almost exclusively found along the eastern concave section of the island with frigatebirds particularly concentrated towards the north. Boobies were widely scattered. Masked boobies were mainly recorded along the central ridge, while brown and red-footed boobies were more widely distributed around the island. Hawaiian monk seals were found grouped on the eastern side of the island with one observed swimming off the southern coast.

##### 3.2.2 Laysan Albatross

A total of 17 Laysan albatross were recorded during the survey (Table 3–1), all found on the eastern concave section of the island (Figure 3–2) with a single bird at the northern end and no

birds at the southern end. Of the total recorded, all were adults, and two were in flight (Table 3–2).

### **3.2.3 Red-Tailed Tropicbird**

A single red-tailed tropicbird was recorded during the survey (Table 3–1), which was a flying adult (Table 3–2) found in the northern region of the concave eastern section of the island (Figure 3–3).

### **3.2.4 Great Frigatebird**

A total of 316 great frigatebirds were recorded during the survey (Table 3–1), of which 83 were flying (Table 3–2). The majority were present in the northern half of the eastern concave section of the island, with some flying just off the northern edge of the island, some distributed along the central ridge, and very few in the southern half (Figure 3–4). Two immature birds were counted, both of which were juveniles (Table 3–2).

### **3.2.5 Masked Boobies**

A total of 217 masked boobies were recorded during the survey (Table 3–1), one of which was flying (Table 3–2). The majority were present along the central northern ridge running along the island with only a few towards the southern tip of the island (Figure 3-5). Six immature birds were counted, one of which was a juvenile (Table 3–2).

### **3.2.6 Brown Boobies**

A total of 185 brown boobies were recorded during the survey (Table 3–1), of which 34 were flying (Table 3–2). They were widely scattered throughout the island, but with a higher concentration on the concave east side of the island. Several flying birds were present just off the coast along the western convex edge of the island (Figure 3-6). Of the total recorded, one was a juvenile (Table 3–2).

### **3.2.7 Red-footed Boobies**

A total of 1,196 red-footed boobies were recorded during the survey (Table 3–1), of which 24 were captured in flight (Table 3–2). Of the total, 92 were immature, one of which was a juvenile (Table 3–2). They were present across the island with higher densities in the northern region on both sides of the ridge (Figure 3–7).

### **3.2.8 Booby Species**

A total of 159 unidentified boobies were recorded during the survey (Table 3–1), all of which were immature; four were flying (Table 3–8). Individuals were mostly recorded towards the northern end of the island and were sitting in groups amongst the grasses.

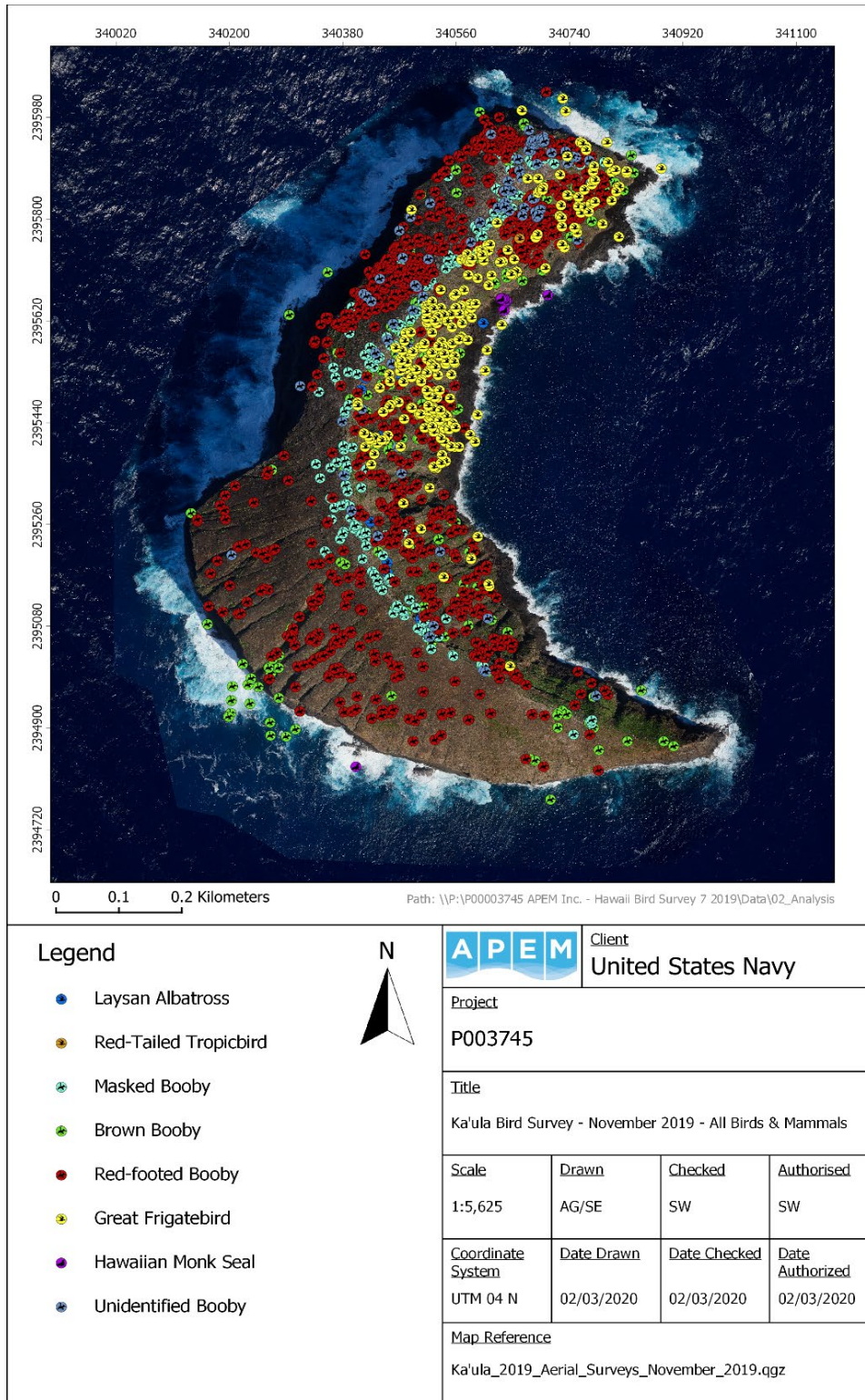
### **3.2.9 Marine Mammals**

During the survey, eight Hawaiian monk seals were recorded. Seven of these were resting on a section of coast in the northern region of the eastern convex side of the island; one was swimming off the southern coast (Table 3–1, Figure 3–9).

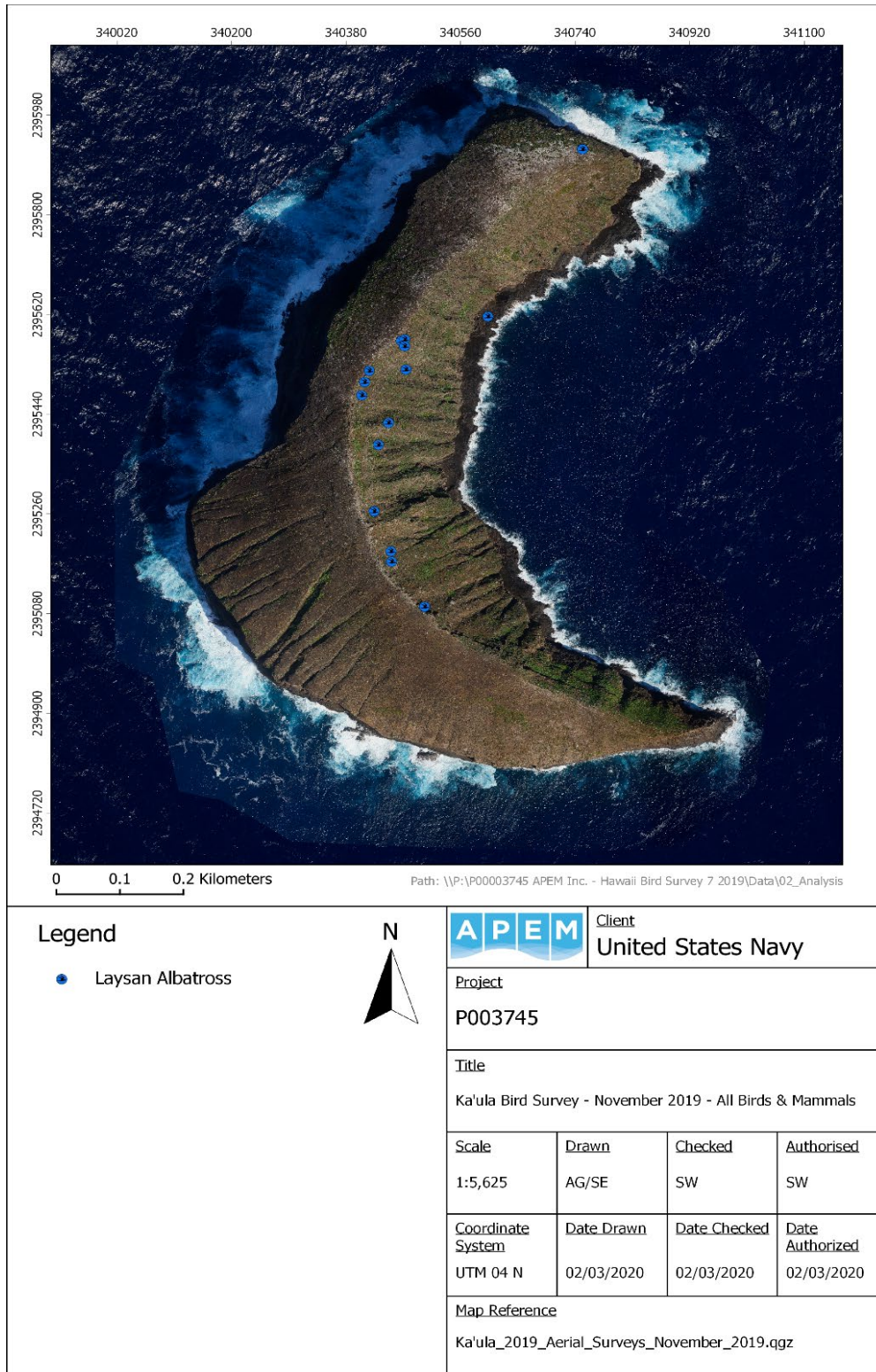
General note: the number of points visible on each figure is not necessarily equal to the total recorded as some animals are in close proximity and may overlap at the scale used to display the entire island.

**Table 3–2. The Species, Age, and Numbers of Sitting and Flying Birds Recorded in the November 2019 Aerial Survey**

Species	Adult		Immature		Juvenile	Total
	Flying	Sitting	Flying	Sitting	Sitting	
Laysan albatross	2	15	-	-	-	17
Red-tailed tropicbird	1	-	-	-	-	1
Great frigatebird	83	231	-	-	2	316
Masked booby	1	210	-	5	1	217
Brown booby	34	150	-	-	1	185
Red-footed booby	24	1,080	-	91	1	1,196
Booby species	-	-	4	155	-	159
<b>Total</b>	<b>145</b>	<b>1,686</b>	<b>4</b>	<b>251</b>	<b>5</b>	<b>2,091</b>



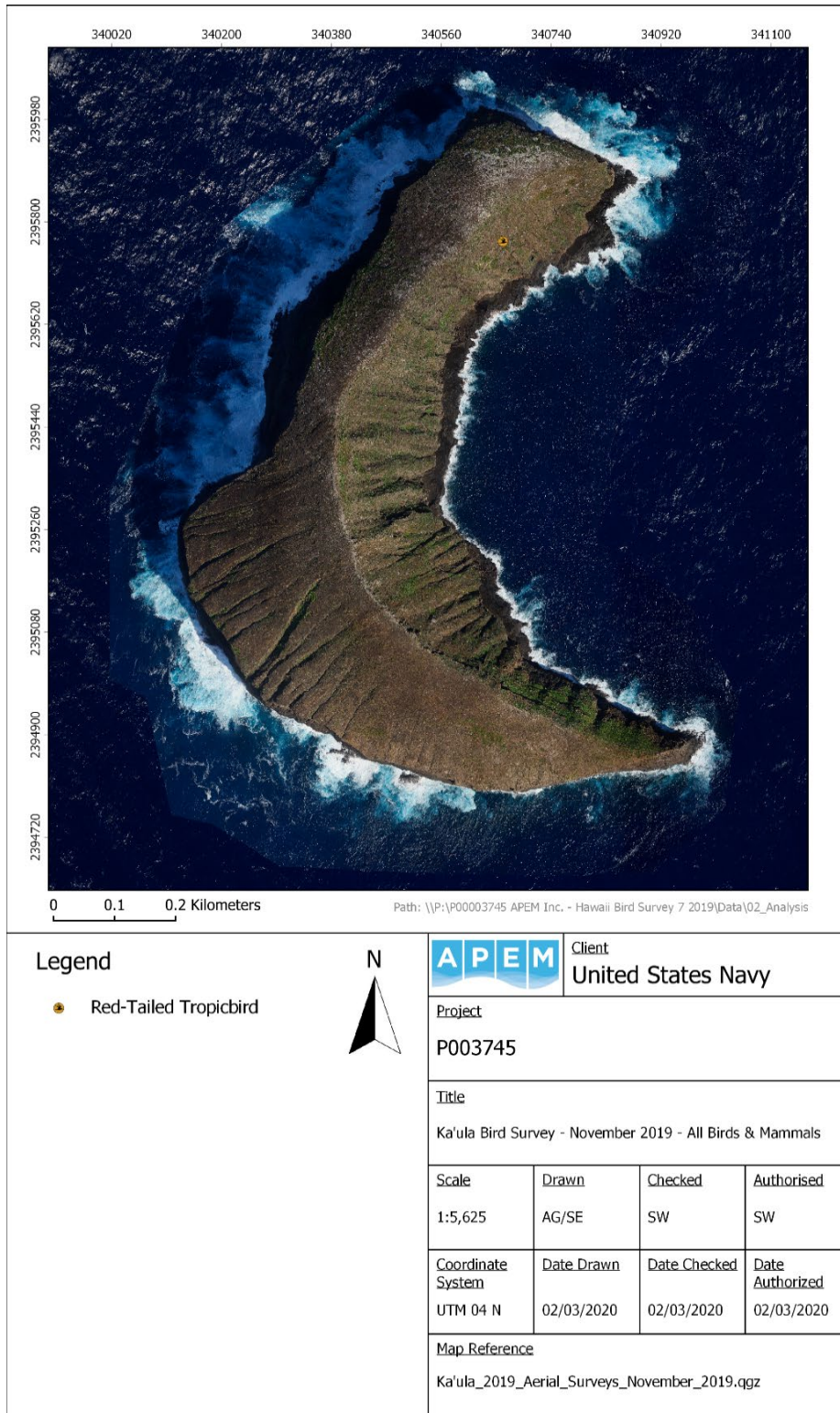
**Figure 3-1. Distribution of all birds and marine mammals recorded on Kaula Island during November 2019.**  
 The number of points visible on this figure is not necessarily equal to the total recorded.



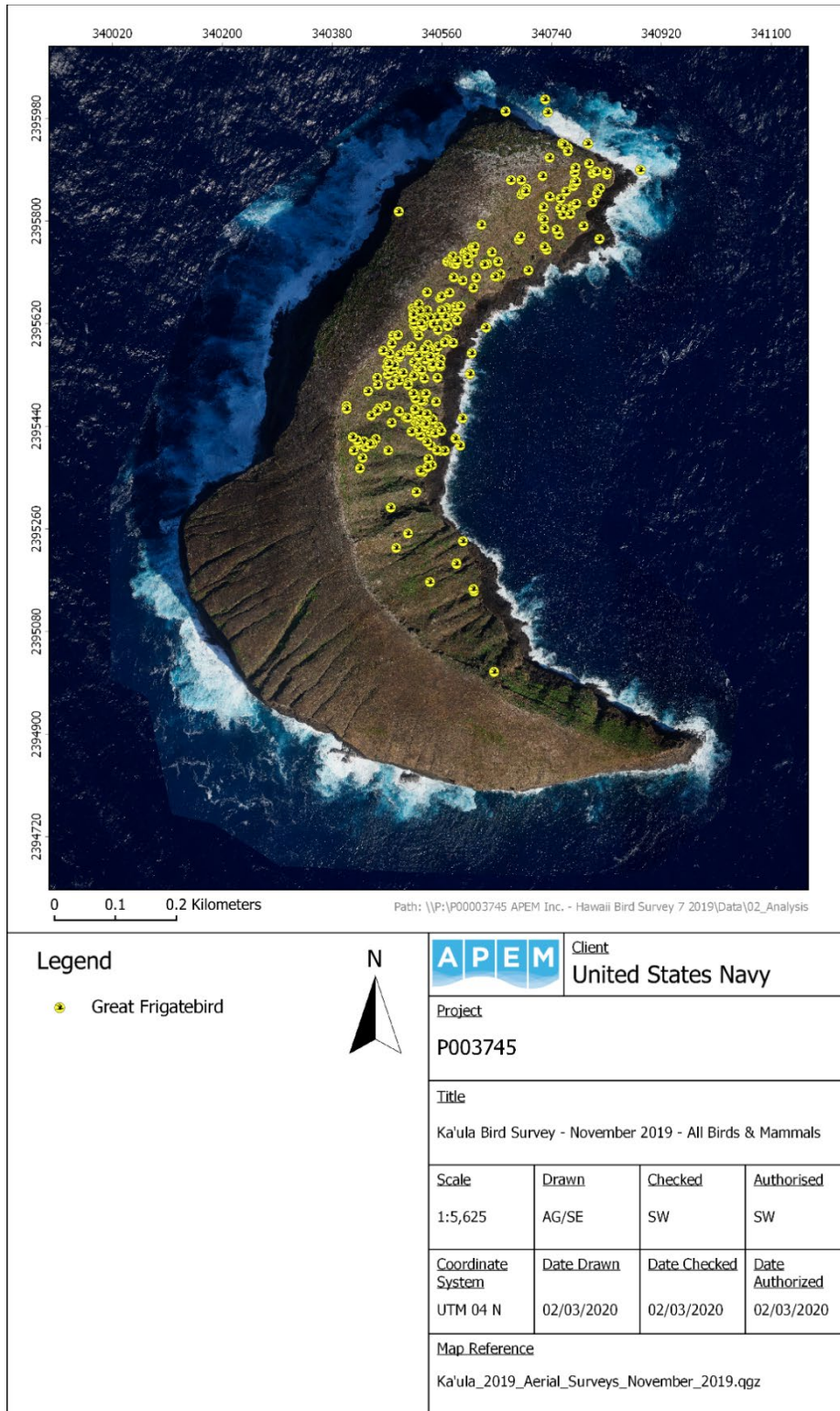
**Figure 3-2. Distribution of Laysan albatross recorded on Kaula Island during November 2019.**

The number of points visible on this figure is not necessarily equal to the total recorded.



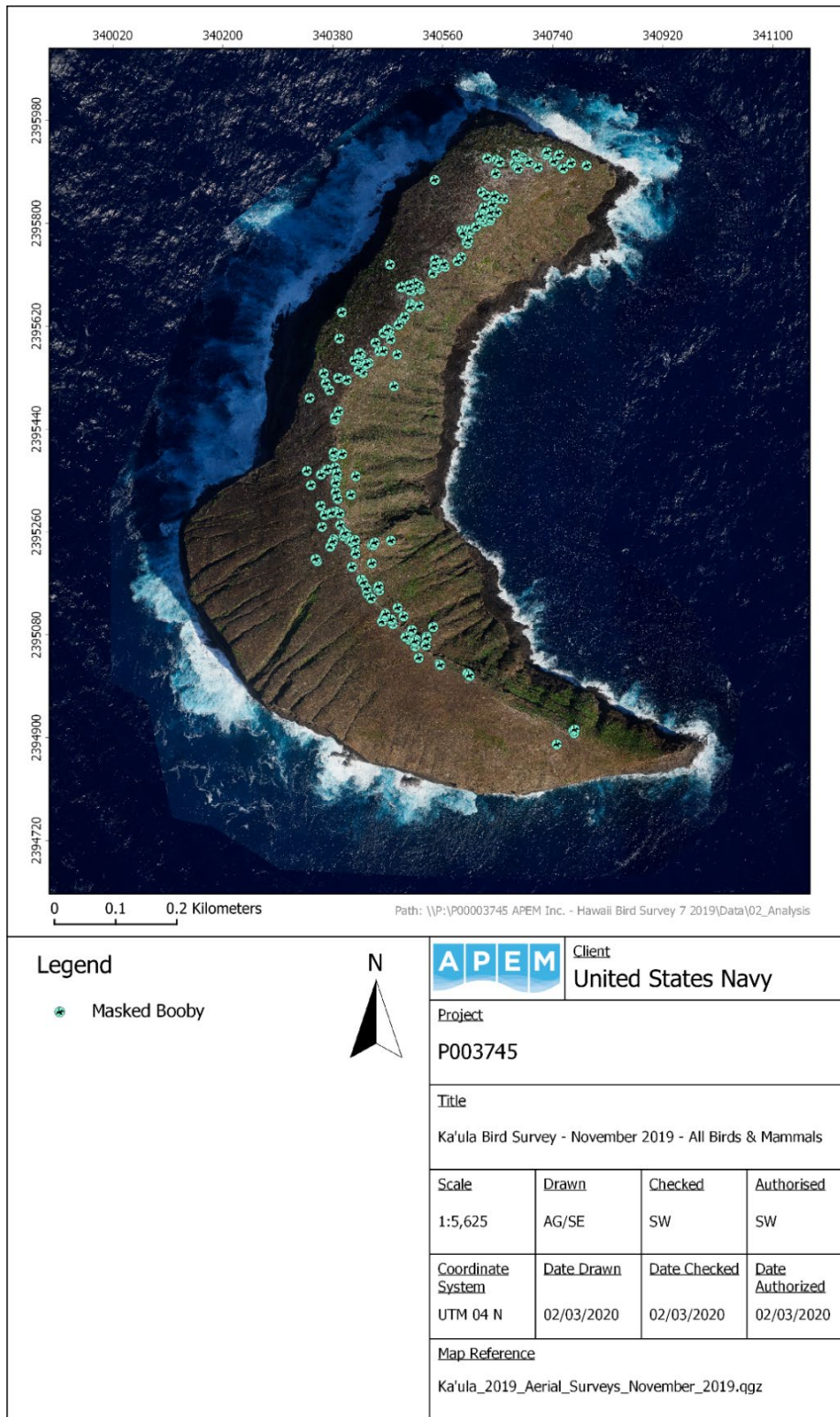


**Figure 3-3. Distribution of red-tailed tropicbirds recorded on Kaula Island during the November 2019 survey.**  
The number of points visible on this figure is not necessarily equal to the total recorded.



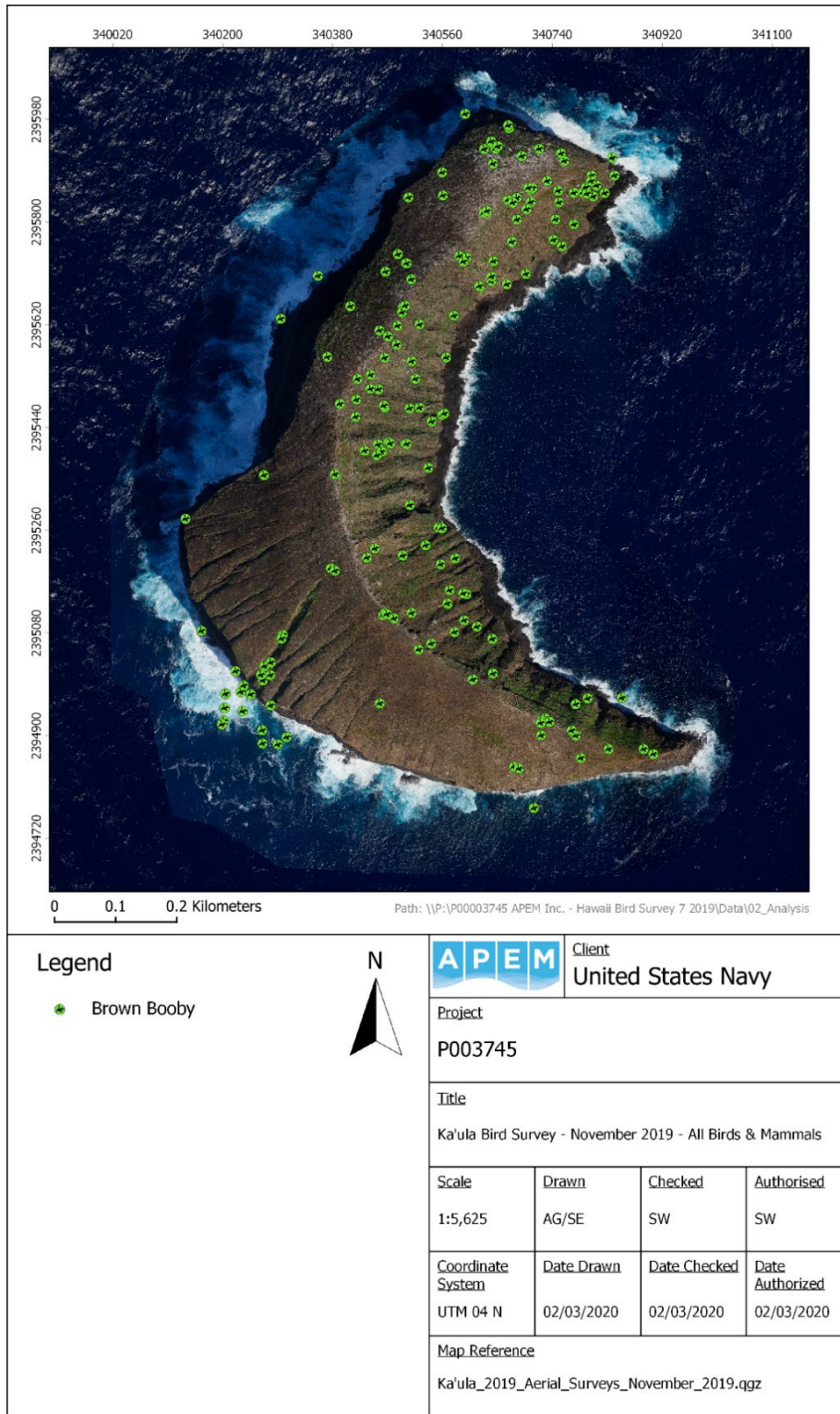
**Figure 3-4. Distribution of great frigatebirds recorded on Kaula Island during November 2019.**

The number of points visible on this figure is not necessarily equal to the total recorded.

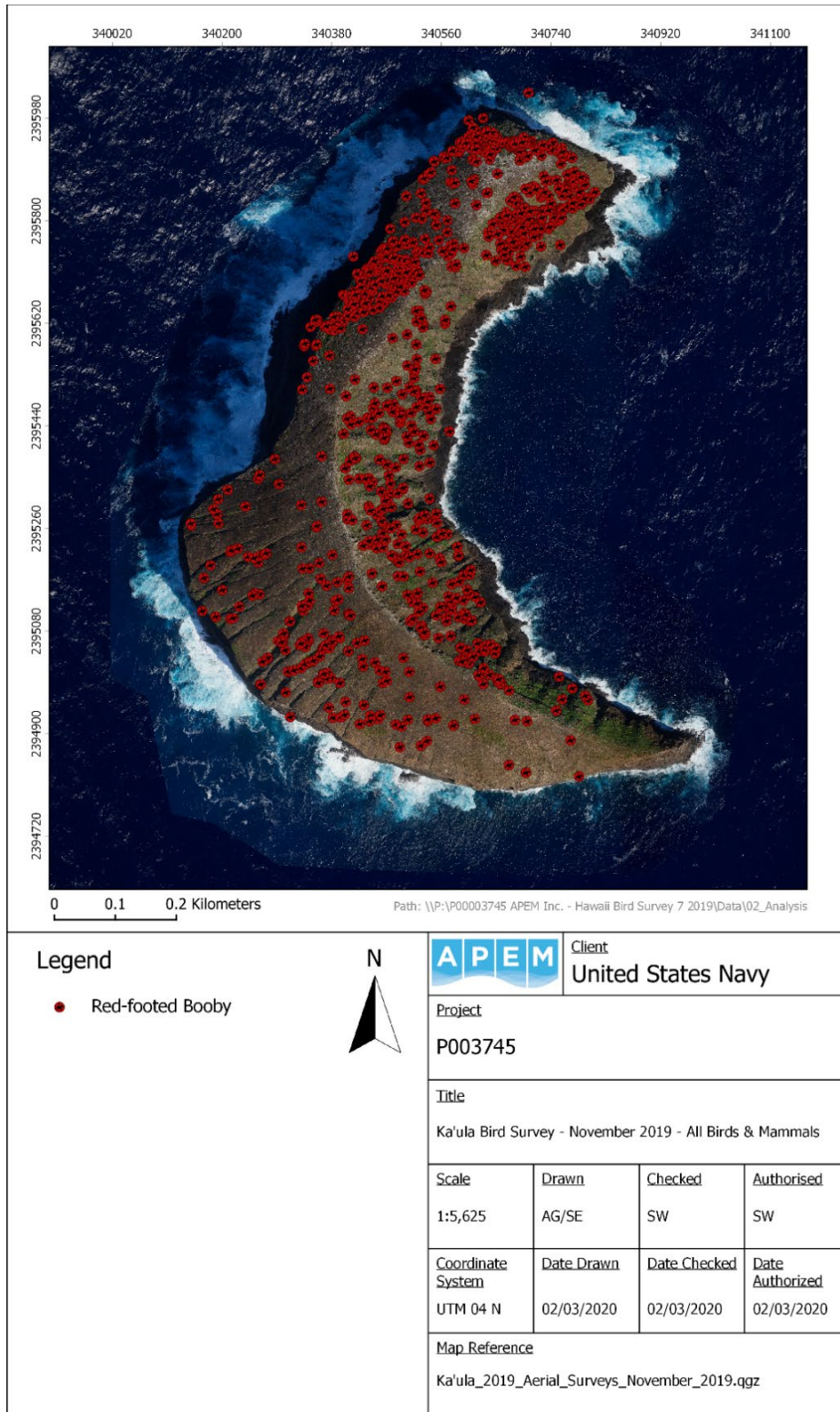


**Figure 3-5. Distribution of masked boobies recorded on Kaula Island during November 2019.**

The number of points visible on this figure is not necessarily equal to the total recorded.

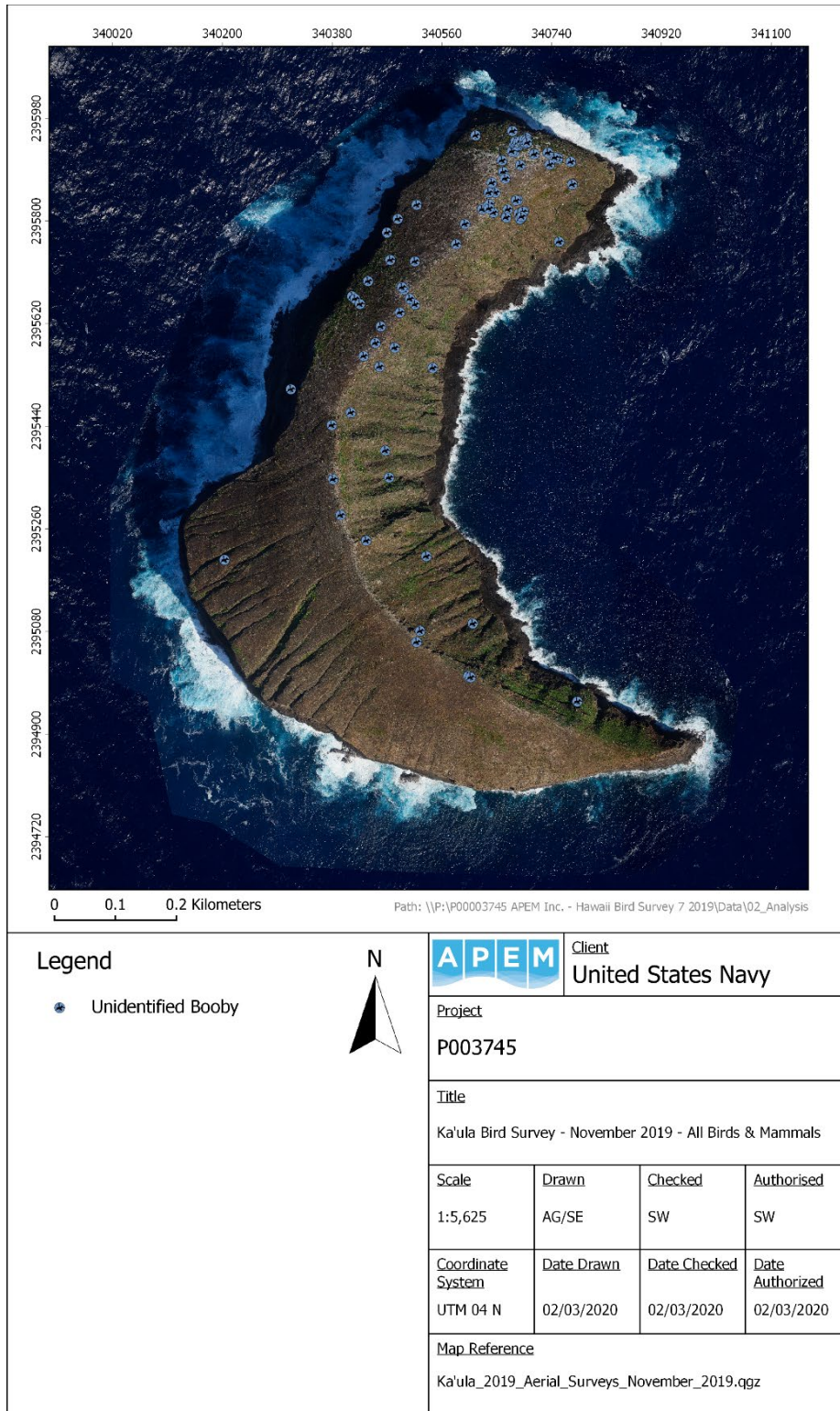


**Figure 3-6. Distribution of brown boobies recorded on Kaula Island during November 2019.**  
 The number of points visible on this figure is not necessarily equal to the total recorded.

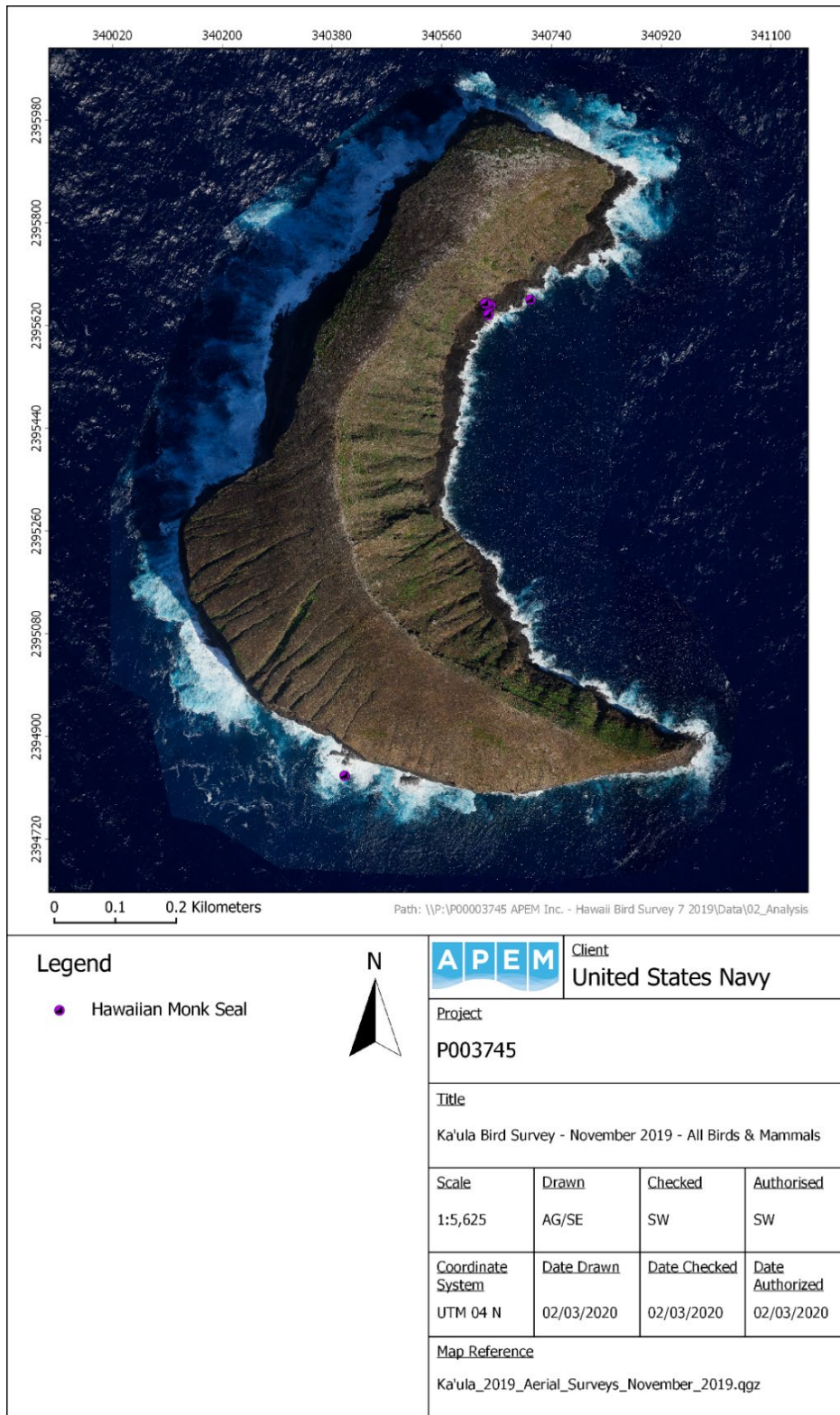


**Figure 3-7. Distribution of red-footed boobies recorded on Kaula Island during November 2019.**

The number of points visible on this figure is not necessarily equal to the total recorded.



**Figure 3-8. Distribution of unidentified boobies recorded on Kaula Island during November 2019.**  
 The number of points visible on this figure is not necessarily equal to the total recorded.



**Figure 3-9. Distribution of Hawaiian monk seals recorded on Kaula Island during November 2019.**

The number of points visible on this figure is not necessarily equal to the total recorded.

## 4 Discussion

During the November 2019 vertical survey, 2,091 birds and eight Hawaiian monk seals were recorded at Kaula Island (Table 3–1). The six bird species present were red-footed booby, great frigatebird, masked booby, brown booby, Laysan albatross, and red-tailed tropicbird. The most abundant species was red-footed booby, accounting for 57% (n=1,196) of all the seabirds recorded. The next most abundant species were great frigatebird (n=316) and masked booby (n=217) (see Table 3–1). Brown booby (n=185), Laysan albatross (n=17), and red-tailed tropicbird (n=1) were the least abundant species recorded. A total of 159 unidentified immature boobies were also recorded (Table 3–2).

Laysan albatross were mainly found along the eastern side of the island (Figure 3-2). Numbers recorded in this survey (n=17) were less than those recorded in the January 2015 aerial digital survey (n=100). Out of the 17 adult Laysan albatrosses found in November 2019, there were two pairs and 13 single birds, so conceivably there could have been up to 15 breeding pairs present (Appendix IV) at the time of the survey. No Laysan albatross were found during the August 2018 or July 2017 surveys, but 21 were found in March 2016. Laysan albatross breed between November and February in this region. Experiments looking at impacts of nest disturbance on Laysan albatross suggests the birds are highly sensitive to disturbance (Rice and Keyon 1962) so increased activity on the island in any one year may cause reduced populations on the island.

One red-tailed tropicbird was found in the November 2019 survey flying in the northeastern region of the island. Red-tailed tropicbirds nest inside caverns or crevasses on the island; therefore, analysis of both vertical and oblique imagery is necessary to detect the amount present. However, the oblique imagery from November 2019 was of poor quality and any birds on or within the steep cliffs went undetected, possibly explaining the low count of the red-tailed tropicbird. Although red-tailed tropicbirds have been found to breed year-round in the tropics, the peak nesting activity is recorded between March and August (Vanderwerf and Young 2014), which could also explain the low number of birds found within this survey and other winter surveys.

The majority of great frigatebirds were present in the northern half of the eastern concave section of the island with some flying just off the northern edge of the island, some distributed along the central ridge, and very few in the southern half (Figure 3–4). Two immature birds were counted and both were juveniles (Table 3–2). A total of 316 great frigatebirds were recorded during the survey (Table 3–1), of which 83 were flying (Table 3–2). This is considerably lower than the 748 birds recorded in January 2015 and August 2018 surveys (n= 719). The highest record of the species was 1,414 individuals in April 2013. Previous surveys suggest that the peak breeding season for the great frigatebird on Kaula Island is between March and August. The two juveniles recorded in this November survey compared to recent surveys in July 2017 (n= 215) and August 2018 (n= 86) support this seasonal timing.

The most abundant species during this survey was red-footed booby. These were present across the island with higher numbers in the northern region on both sides of the ridge (Figure 3–7). Lower numbers of masked and brown booby were recorded (see Table 3–1). The 1,196 red-footed boobies recorded during this survey is higher than in January 2015 (n= 209). Recent



surveys seem to suggest the bulk of breeding occurs during June to August, and the August 2018 survey recording a peak count from aerial digital surveys of 4,764.

Of the 1,196 red-footed boobies found, 1,104 were adult birds, of which 60 were visible as apparent pairs, so conceivably there could have been up to 1,074 breeding pairs present (Appendix IV). The remaining 92 red-footed boobies were aged as immature or juvenile birds. Large groups of boobies were gathered at the northern tip of the island amongst the grass and vegetation. Though most of these were likely to be red-footed, 159 were immature and could not be confidently identified (Figure 3-4).

Most of the masked boobies were present along the central northern ridge running along the island (Figure 3-5). Distribution is similar to that of previous aerial digital surveys having very few in the southwestern section (Figure 3-5). Of the total recorded, one was a juvenile bird (Table 3-2). Of the 217 recorded, 211 were adults and six were immature including a single juvenile. Of the adult birds recorded in November 2019, 46 were visible as apparent pairs and 165 recorded as single birds. This suggests there could have been up to 188 pairs present on the island during the November survey. The species is known to lay eggs from February to April but this can be earlier or later (Richardson 1957). This could explain why the abundance of this species in November 2019 (n=217) is much lower than found in the previous survey in August 2018 (n= 1,312). The three largest counts have now occurred in either August or September on Kaula (Appendix III).

Brown boobies were scattered throughout the island but with a higher concentration on the concave side of the island. Several flying birds were present just off the coast along the western convex edge (Figure 3-6). Of the 185 recorded, one was a juvenile bird (Table 3-2). Of the 184 adult brown boobies recorded, 10 were visible as apparent pairs and 174 as single birds, which allows an estimation of 179 pairs to be calculated. The highest count of brown booby from aerial based methods was recorded in August 2018 (n=1,231) and before that in the land-based survey in August 1971 (n=1,700) (Appendix III).

Seabirds can spend long periods of time out at sea so single birds recorded during this survey may be half of a pair. Appendix V 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 single birds being one half of a pair. However, because the breeding season of seabirds in Hawaii is spread throughout the year, not all birds may be paired up in November.

Hawaiian monk seals are highly endangered and protected under the U.S. Endangered Species Act, the U.S. Marine Mammal Protection Act, Hawaii State Senate Bill 2441, and classed by IUCN as category C1. Seven Hawaiian monk seals were recorded on the east side of the island and one was swimming off the southern coast (Figure 3-9). Numbers have remained fairly consistent throughout the eight aerial digital surveys between 2013 and 2019 (Appendix III).

Overall, the aerial survey method demonstrates that complete counts of seabirds can be obtained, including the ability to accurately assess the number of birds on apparently occupied nests 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. 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 observed and survey type and Appendix V for results by year of all aerial digital surveys completed).

## 5 References

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## 6 Appendices

### Appendix I. Scientific Names of Relevant Bird and Mammal Species

Common Name	Scientific Name
Laysan albatross	<i>Phoebastria immutabilis</i>
Red-tailed tropicbird	<i>Phaethon rubricauda</i>
Great frigatebird	<i>Fregata minor</i>
Masked booby	<i>Sula dactylatra</i>
Brown booby	<i>Sula leucogaster</i>
Red-footed booby	<i>Sula sula</i>
Hawaiian monk seal	<i>Neomonachus schauinslandi</i>

## Appendix II. Survey Imagery: Vertical Image Examples



**Figure 6-1. Laysan albatrosses (circled) just below the ridge of Kaula Island during the November 2019 survey.**



**Figure 6-2. Flying brown booby (top), red-footed booby, and Laysan albatross on the west side of Kaula Island during the November 2019 survey.**



**Figure 6-3. Hawaiian monk seals resting on ledge on the eastern side of Kaula Island during the November 2019 survey.**



**Figure 6-4. Mixed group of roosting boobies of different ages on the northern tip of Kaula Island during the November 2019 survey.**



**Appendix III. Results of Bird Surveys Conducted on Kaula Island, Hawaii (1932–2019)\***

Common Name Scientific Name	Land-Based Survey (A)											Boat-Based Survey (A, B, C)				Aerial Digital Survey (D)									
	Aug 1932	Aug 1971	Jan 1976	Sep 1976	Mar 1978	Aug 1978	Mar 1979	Jun 1980	Apr 1984	Jun 1993	Nov 1998	Jul 2009 (B)	Jun 2010 (A)	Jun 2011 (C)	Jul 2012 (C)	Apr 2013	Aug 2013	Jan 2014	Jan 2015	Jul 2015	Mar 2016	Jul 2017	Aug 2018	Nov 2019	
<b>Laysan albatross</b> <i>Phoebastria immutabilis</i>	-	1 old egg	150	-	100	-	100	9	33	44	60	-	-	-	-	20	11	81	100	-	21	-	-	17	
<b>Black-footed albatross</b> <i>Phoebastria nigripes</i>	1 old egg	-	100	-	75	-	75	-	2	4	10	-	-	-	-	3	-	11	3	-	4	-	-	-	
<b>Bonin petrel</b> <i>Pterodroma hypoleuca</i>	1 chick	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Bulwer's petrel</b> <i>Bulweria bulwerii</i>	several	100	-	100	-	50	-	100	580	100	-	1	1	-	-	-	-	-	-	-	-	-	-	-	
<b>Wedge-tailed shearwater</b> <i>Puffinus pacificus</i>	Many burrows	4,100	-	4,000	-	800	-	1,415	980	400	200	16	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Christmas shearwater</b> <i>Puffinus nativitatis</i>	-	450	-	250	-	100	25	20	60	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>White-tailed tropicbird</b> <i>Phaethon lepturus</i>	-	3	1	1	-	1	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Red-tailed tropicbird</b> <i>Phaethon rubricauda</i>	common	950	-	450	60	100	40	276	209	146	15	31	3	5	1	314	85	-	1	100	23	502	245	1	
<b>Great frigatebird</b> <i>Fregata minor</i>	common	950	250	800	400	250	250	134	155	701	650	131	430	105	26	1,415	1,369	621	748	1,078	1,005	777	719	316	
<b>Booby species</b> <i>Sula species</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	713	159	
<b>Masked booby</b> <i>Sula dactylatra</i>	common	1,000	300	1,200	125	200	400	236	202	567	350	-	-	-	-	550	219	65	84	526	183	514	1,312	217	
<b>Brown booby</b> <i>Sula leucogaster</i>	common	1,700	50	1,000	75	60	200	212	169	397	60	112	1	6	40	101	109	3	2	867	179	969	1,231	185	
<b>Red-footed booby</b> <i>Sula sula</i>	uncommon	1,300	100	150	85	200	400	344	222	1,375	1,200	-	-	-	-	1,690	191	98	209	3,693	1,319	2,650	4,764	1,196	
<b>Masked/red-footed booby</b> <i>Sula dactylatra / S. sula</i>	-	-	-	-	-	-	-	-	-	-	-	820	850	1,859	912	-	-	-	-	27	-	24	-	-	
<b>Masked/brown booby</b> <i>Sula dactylatra / S. leucogaster</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	51	-	
<b>Pacific golden plover</b> <i>Pluvialis fulva</i>	several	-	10	14	-	1	2	-	21	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Wandering tattler</b> <i>Heteroscelus incanus</i>	-	-	5	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Ruddy turnstone</b> <i>Arenaria interpres</i>	-	50	5	20	-	4	24	1	7	1	12	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Brown noddy</b> <i>Anous stolidus</i>	most numerous	67,700	-	7,000	7,000	10,000	1,000	10,560	3,950	5,778	-	-	-	-	-	57	3,713	-	-	7,137	4,115	7,871	7,612	-	
<b>Black noddy</b> <i>Anous minutus</i>	-	100	20	100	75	200	-	-	207	6	-	-	-	-	-	22	-	-	-	-	-	-	-	-	
<b>Brown/black noddy</b> <i>Anous species</i>	-	-	-	-	-	-	-	-	-	-	-	711	705	306	597	-	-	-	-	-	-	-	-	-	
<b>Blue-grey noddy</b> <i>Procelsterna cerulea</i>	small colony	-	-	200	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	

Common Name Scientific Name	Land-Based Survey (A)											Boat-Based Survey (A, B, C)				Aerial Digital Survey (D)									
	Aug 1932	Aug 1971	Jan 1976	Sep 1976	Mar 1978	Aug 1978	Mar 1979	Jun 1980	Apr 1984	Jun 1993	Nov 1998	Jul 2009 (B)	Jun 2010 (A)	Jun 2011 (C)	Jul 2012 (C)	Apr 2013	Aug 2013	Jan 2014	Jan 2015	Jul 2015	Mar 2016	Jul 2017	Aug 2018	Nov 2019	
<b>White tern</b> <i>Gygis alba</i>	uncommon	10	10	200	40	10	-	9	12	9	-	10	9	9	12	6	-	-	-	1	-	-	-	-	
<b>Sooty tern</b> <i>Onychoprion fuscatus</i>	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	-	-	147	40,814	768	6,535	-	
<b>Grey-backed tern</b> <i>Onychoprion lunatus</i>	uncommon	2,800	-	250	1,250	50	300	4,110	1,467	35	-	1	3	-	-	4	-	-	-	-	1	-	5	-	
<b>Barn owl</b> <i>Tyto alba</i>	-	1	3	3	-	1	6	4	2	7	3	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Japanese white-eye</b> <i>Zosterops japonicus</i>	-	-	2	3	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Northern mockingbird</b> <i>Mimus polyglottos</i>	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Northern cardinal</b> <i>Cardinalis cardinalis</i>	-	2	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>House finch</b> <i>Haemorhous mexicanus</i>	-	6	15	40	-	20	6	-	1	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Nutmeg manikin</b> <i>Lonchura punctulata</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Total Estimated Number of Birds</b>	-	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	1,145	13,576	47,664	14,075	23,187	2,091	
<b>Total Number of Species</b>	16	19	16	24	12	19	17	15	19	19	15	11	11	8	8	11	9	6	7	8	10	7	8	7	

\*Data sourced from:

- A DON (2011). Kaula / 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). *Kaula Island ship-based seabird and marine mammal surveys, 21-22 July 2009*. Prepared for Commander, Pacific Fleet by NAVFAC Pacific.
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## Appendix IV. Estimates of Seabird Numbers during the November 2019 Aerial Digital Survey of Kaula Island, Hawaii

Species/Group	Minimum Estimate	Maximum Estimate*
Laysan albatross	17	30
Red-tailed tropicbird	1	2
Great frigatebird	316	622
Masked booby	217	376
Brown booby	185	358
Red-footed booby	1,196	2,148
Booby species	159	-
<b>Total Estimated Number of Birds</b>	<b>2,091</b>	<b>3,536</b>

\*A pair is assumed to be two birds, all singles (including single flying birds and excluding juveniles) 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 Kaula Island, Hawaii (2013–2019)\***

Common Name	Scientific Name	Global Population	Regional Population <sup>2</sup> (Hawaii) Breeding Pairs	Apr 2013	Aug 2013	Jan 2014	Jan 2015	July 2015	Mar 2016	July 2017	Aug 2018	Nov 2019
Black-footed albatross	<i>Phoebastria nigripes</i>	64,500 breeding pairs <sup>4</sup>	55,000	3	-	11	3	-	4	-	-	-
Laysan albatross	<i>Phoebastria immutabilis</i>	1,180,000 mature individuals <sup>4</sup>	590,000	20	11	81	100	-	21	-	-	17
Red-tailed tropicbird	<i>Phaethon rubricauda</i>	> c.32,000 individuals <sup>1</sup>	9,000-12,000	314	85	-	1	100	23	502	245	1
Great frigatebird	<i>Fregata minor</i>	500,000-1,000,000 <sup>2</sup>	10,000	1,415	1,369	621	748	1,078	1,005	777	719	316
Booby species	<i>Sula speceis</i>	-	-	-	-	-	-	-	-	-	713	159
Masked booby	<i>Sula dactylatra</i>	Unquantified. Described as 'fairly common' <sup>3</sup>	2,500	550	219	65	84	526	183	514	1,312	217
Brown booby	<i>Sula leucogaster</i>	> c.200,000 individuals <sup>1</sup>	1,400	101	109	3	2	867	179	969	1,231	185
Red-footed booby	<i>Sula sula</i>	> c.1,000,000 individuals <sup>1</sup>	7,000-10,500	1,690	191	98	209	3,693	1,319	2,650	4,764	1,196
Masked/red-footed booby	<i>Sula species</i>	-	-	-	-	-	-	27	-	24	-	-
Masked/brown booby	<i>Sula species</i>	-	-	-	-	-	-	-	-	-	51	-
Brown noddy	<i>Anous stolidus</i>	500,000-1,000,000 breeding pairs <sup>2</sup>	112,000	57	3,713	-	-	7,137	4,115	7,871	7,612	-
Black noddy	<i>Anous minutus</i>	1-1.5 million breeding pairs <sup>2</sup>	12,000	-	22	-	-	-	-	-	-	-
White tern	<i>Gygis alba</i>	Likely exceeds 100,000 breeding pairs <sup>2</sup>	15,000	6	-	-	-	1	-	-	-	-
Sooty tern	<i>Onychoprion fuscatus</i>	60-80 million breeding pairs <sup>2</sup>	>1,000,000	14,635	7	-	-	147	40,814	768	6,535	-
Grey-backed tern	<i>Onychoprion lunatus</i>	Likely 70,000 breeding pairs <sup>2</sup>	44,000	4	-	-	-	-	1	-	5	-
Hawaiian monk seal	<i>Neomonachus schauinslandi</i>	1,351 (95% confidence interval 1,294-1,442) individuals of all age classes <sup>5</sup>	632 sexually mature seals <sup>5</sup>	11	7	5	7	9	10	8	7	8
<b>Total Estimated Number of Birds</b>				<b>18,795</b>	<b>5,733</b>	<b>879</b>	<b>1,147</b>	<b>13,576</b>	<b>47,664</b>	<b>14,075</b>	<b>23,187</b>	<b>2,091</b>
<b>Total Number of Species</b>				<b>11</b>	<b>9</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>10</b>	<b>8</b>	<b>9</b>	<b>7</b>

<sup>1</sup> del Hoyo et al. 1992

<sup>2</sup> Hawaii Department of Land and Natural Resources (<http://dlnr.hawaii.gov/wildlife/cwcs/hawaii/species/fact-sheets/>)

<sup>3</sup> Stotz et al. 1996

<sup>4</sup> Birdlife International <http://www.birdlife.org/datazone/>

<sup>5</sup> NOAA Fisheries stock assessment report 2019 <https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock><http://www.iucnredlist.org/details/13654/0>