Aerial Survey of Seabirds and Marine Mammals at Kaula Island, Hawaii, July 2021

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Executive Summary

An aerial oblique survey of Kaula Island, Hawaii, using a manned, light twin-engine survey aircraft and oblique digital photography was conducted on 20 and 21 July 2021. 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). This survey is the first to capture complete imaging of the island using oblique digital photography rather than a combination of vertical digital photography and oblique digital photography. 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 two days with 100% of the final image mosaic formed from imagery collected on the survey.

In total, 16,514 birds were recorded during the survey with red-footed booby being the most abundant species (n=6,016), followed by brown noddy (n=3,456). Other species recorded include sooty tern, brown booby, great frigatebird, masked booby, booby species, and red-tailed tropicbird.

During the surveys, ten Hawaiian monk seals were recorded, seven resting on a section of coast in the northern region of the western convex side of the island and three were resting on the southwestern coast.

1 Introduction

Normandeau Associates 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 digital aerial imagery.

Kaula Island is a small (0.64 km^2), uninhabited crescent-shaped islet in the western chain of islands making up the Hawaiian Archipelago (Figure 1-1 and Figure 1-2). The islands closest to Kaula are Ni'ihau, which is 37 km 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, while the southern horn extends 914 m from the summit and ends at an elevation of approximately 30 m (Palmer 1936).

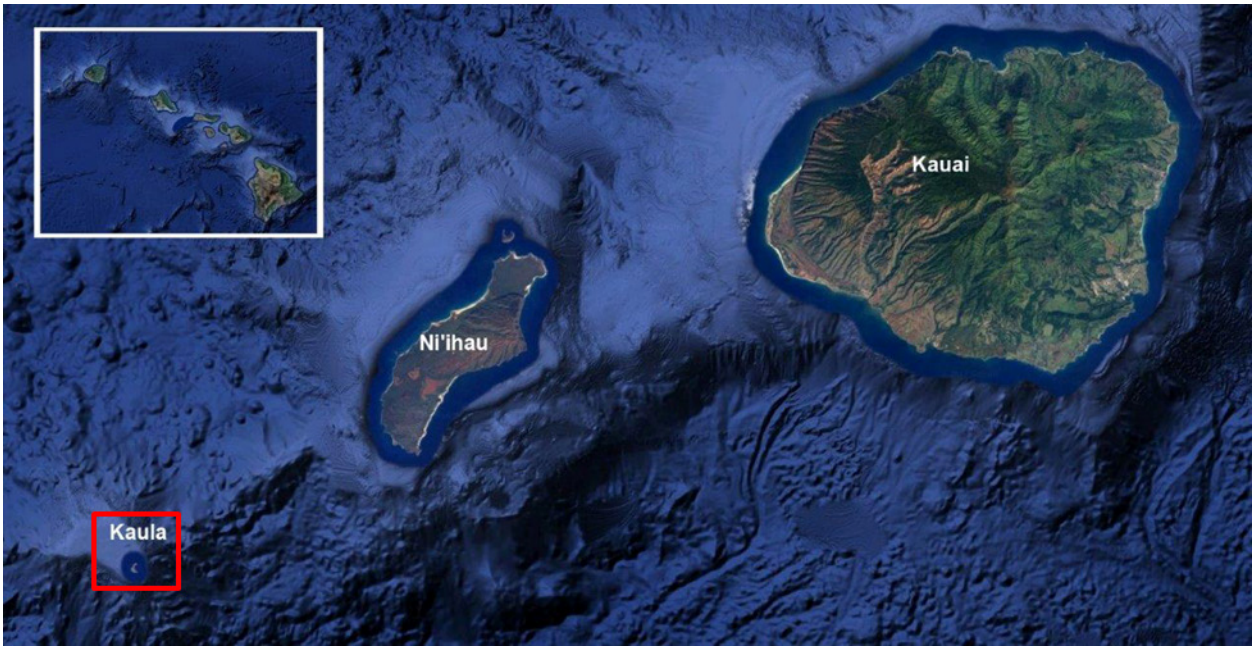

Figure 1-1. Location of Kaula Island relative to the main Hawaiian Islands (inset) and Kauai and Ni'ihau (imagery from ESRI).

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^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. Since 1981, munitions training by the Navy at Kaula has been restricted to inert ordnance delivery and aircraft gunnery (DoN 2008; DoN 2013).

Historically, eleven land-based avian surveys had 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 this report represents the tenth survey conducted over the island. Surveys have been conducted every year since 2013 except for 2020 when COVID-19 restrictions made survey impossible. Two surveys were conducted in 2013 and 2015.

The first survey using this technique was conducted in April 2013. This improved technology 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 20 and 21 July 2021 using oblique imagery capture. Complete oblique imagery was selected because it has become increasingly difficult to

source an aircraft with a floor-based hatch, which is required for capturing vertical imagery. Previous surveys have used vertical digital photography for imaging the top of the island and oblique digital photography for imaging the cliffs. This is the first survey of the Kaula Island to capture imagery across the entire island solely using oblique digital photography.

Aircraft used was a Cessna SkyMaster 337H with a two-person crew comprising one pilot and one photographer. A handheld medium format mirrorless camera was operated by the photographer from the copilot seat of the aircraft, shooting through the right-side storm window.

Due to the wide range of topographical features on Kaula (see Figure 1-2), two surveys were carried out to ensure high-quality imagery was achieved over the whole island (100% coverage), including capturing animals on horizontal and vertical ledges.

Aircraft departed and returned to Lihue Airport, coordinating with air traffic control and the military controlled airspace for proper clearance through warning areas W-186 and W-187 in transit, and restricted area R-3107 during survey operations. Contact with 'Hula Dancer' traffic control was maintained during surveys, and the watch supervisor was kept informed of survey plans leading to, during, and after survey flights. Both survey flights were between two and three hours long with one to two hours spent actively collecting imagery.

While collecting imagery the aircraft was flown at a variety of altitudes ranging from 500 to 2,000 ft, horizonal distance ranging from 0.1 to 1 nm (nautical mile), and ground speeds ranging from 100 to 140 kts. Lower altitudes on the first flight were felt to be at an excessive risk of bird strike, and the minimum safe altitude for the second flight was agreed at 1,000 ft by the pilot and photographer. Most imagery was collected at nominal values of 1,500 ft altitude, 0.25 nm horizontal distance, and 100 kts ground speed. Imagery was collected orbiting the island clockwise while banking toward the island for better visibility. These orbits were combined with shorter straight lines passing by the northern and southern points of the islands until sufficient overlapping imagery had been collected. Roughly ten orbits per flight approximate to the nominal values were conducted, combined with shorter passes at closer range and a few orbits at greater ranges and altitudes.

On 20 July, takeoff and landing occurred at 10:43 and 12:31 Hawaiian Standard Time (HST), respectively, with surveying starting at 11:00 and ending at 12:15. On 21 July, takeoff and landing occurred at 08:46 and 11:10 (HST), respectively, with surveying starting at 09:00 and ending at 10:55. The sky was clear of clouds on both flights with a steady easterly wind. Moderate turbulence was encountered on the leeward side of the island for approximately one minute of each orbit with otherwise mostly smooth flying. The camera was focused both manually and aided by the auto-focus. Exposure settings were altered in real time with changing light conditions. The west-facing cliff was partly in shadow and slightly higher exposure settings were used where appropriate. The camera was triggered manually at roughly two shots per second while making each pass, framed with some overlap between successive images. Special attention was paid to cover the entire island by focusing on the bottom third, then middle, then top third of the cliff faces. Image quality was reviewed on the ground after the first flight, and the second flight was conducted closer to the nominal flight conditions listed to improve data quality. Multiple passes were needed to capture the entire area with sufficient resolution and overlap.

2.2 Image Processing and Analysis

All oblique imagery captured on the survey was reviewed and a selection of high-quality images chosen ensuring whole island coverage. Defined boundaries and markers were outlined in the selected images aided by topographical features of the island. This avoided duplicate counts in overlapping areas that appeared in adjacent images. Each of the selected images (non-georeferenced) were loaded into software and birds within the delineated sections were counted. It is acknowledged there is a small chance that movement of birds between image captures could result in a bird being double counted. There is of course an equal chance that a bird could be missed in both images. 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 due to longer duration and disturbance, which results in many birds moving around in response to the observers.

Specially trained staff recorded the following information from each image covering Kaula Island:

- Bird/mammal species by common name (see Appendix I for scientific names)
- Behavior (e.g., sitting or flying)
- Count (number of individuals)

Each image was analyzed using APEM's Graphical User Interface (GUI). 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.

Several full scans of each image were manually completed to find targets for identification and analysis. Image resolution is high, and individuals can be identified to species with a high degree of certainty (Appendix II).

A limitation of using oblique imagery is that no GPS information is generated to determine precise distribution locations for each species from which to create distribution maps unlike previous aerial digital surveys. However, based on visual comparisons with previous years it can be determined that distributions broadly resemble those of previous years. Maps are provided showing an outline of the areas utilized by each species.

2.3 Identification and Quality Assurance

All bird and marine mammal species present in the images from Kaula Island were identified and quality assured using standard internal processes.

The images were processed by image analysts and checked by the Quality Assurance (QA) team. The QA team consists of more experienced ornithologists with significant experience working on data captured during previous surveys of this island carried out by Normandeau/APEM.

Known nesting habits of the booby species were used to aid identification of juvenile birds in nests where the physical characteristics that aid identification were not visible. Masked and

brown boobies nest on the ground often near breezy cliff edges or other takeoff 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.

3 Results

3.1 Species Abundance

Ten marine mammals (one species) and 16,514 birds (eight species/groups) were recorded on Kaula Island during July 2021 (Table 3-1; Appendix I). Red-footed booby (n=6,016) was the most abundant bird species, and red-tailed tropicbird (n=125) 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 during July 2021

Species/Group	Scientific Name	Total
Birds		
Booby species	*Sula* spp.	184
Brown Booby	*Sula leucogaster*	1,573
Brown Noddy	*Anous stolidus*	3,456
Great Frigatebird	*Fregata minor*	1,375
Masked Booby	*Sula dactylatra*	1,262
Red-footed Booby	*Sula sula*	6,016
Red-tailed Tropicbird	*Phaethon rubricauda*	125
Sooty Tern	*Onychoprion fuscatus*	2,523
Total birds		***16,514***
Marine Mammals		
Hawaiian Monk Seals	*Neomonachus schauinslandi*	10
Total Birds and Marine Mammals		***16,524***

3.2 Species Distribution

3.2.1 Total Birds and Marine Mammals

A limitation of using oblique imagery is that no GPS information is generated to determine precise distribution locations for each species from which to create distribution maps unlike previous aerial digital surveys. Visual comparisons with previous years enable us to determine that distributions broadly resemble those of previous years. Maps have been generated from previous years' point data that show an outline of the areas utilized by each species.

Birds were widely distributed throughout the whole island, most concentrated in the northern and eastern regions. Brown noddies and sooty terns were almost exclusively found along the western convex section of the island, primarily on the lower slopes and cliffs. Both species were very concentrated to specific areas of the western coast. Great frigatebirds were predominantly

located toward the eastern coast, similarly to the red-tailed tropicbirds mostly seen in the same area. 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 whole island. Hawaiian monk seals were found grouped on the western side of the island.

3.2.2 Brown Noddy

A total of 3,456 adult brown noddies were recorded during the survey (Table 3-1), of which 37 were flying (Table 3-2). These were concentrated toward the southwestern slopes of the island along the cliff edges and scattered along the cliff face on the western coast (Figure 3-1).

3.2.3 Sooty Tern

A total of 2,523 sooty terns were recorded during the survey (Table 3-1), of which 16 were flying (Table 3-2). These were concentrated toward the western slopes of the island in two major flocks (Figure 3-2).

3.2.4 Red-Tailed Tropicbird

A total of 125 red-tailed tropicbird were recorded during the survey (Table 3-1), of which 59 were flying (Table 3-2). One individual in this study was recorded as juvenile while the rest were recorded as adults. These were concentrated in the concave eastern section of the island (Figure 3-3).

3.2.5 Great Frigatebird

A total of 1,375 great frigatebirds were recorded during the survey (Table 3-1), of which 87 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 (Figure 3-4), and very few in the southern half. A total of 120 immature birds were counted, of which 113 were juveniles (Table 3-2).

3.2.6 Masked Booby

A total of 1,262 masked boobies were recorded during the survey (Table 3-1), of which nine were flying (Table 3-2). The majority were present along the central northern ridge running along the island, with only a few toward the southern tip of the island (Figure 3-5). A total of 234 immature birds were counted, of which 205 were juveniles (Table 3-2).

3.2.7 Brown Booby

A total of 1,573 brown boobies were recorded during the survey (Table 3-1), of which 1,466 were adults including 27 flying (Table 3-2). They were widely scattered throughout the island, but with a higher concentration on the concave east side of the island and along the central ridge (Figure 3-6). Of the total recorded, 107 were immature of which 80 were juveniles (Table 3–2).

3.2.8 Red-footed Booby

A total of 6,016 red-footed boobies were recorded during the survey (Table 3-1), of which 70 were captured in flight (Table 3-2). Out of the total birds, 1,002 were immatures including 394 juveniles (Table 3-2). They were present across the whole island with higher densities in the northern region of the island on both sides of the ridge (Figure 3-7).

3.2.9 Booby Species

A total of 184 unidentified boobies were recorded during the survey (Table 3-1), 18 were adults, and 166 were immatures including 82 juveniles (Table 3-2). Nine of these unidentified boobies were recorded in flight and were distributed across the island (Figure 3-8).

3.2.10 Marine Mammals

During the survey, ten Hawaiian monk seals were recorded (Table 3-1). Seven of these were resting on a section of coast in the northern region of the western convex side of the island and three were resting on the southwestern coast (Figure 3-9).

Table 3-2. Species, Age, and Numbers of Sitting and Flying Birds Recorded July 2021

Species/Group	Adult		Immature		Juvenile	Grand Total
	Flying	Sitting	Flying	Sitting	Sitting	
Booby species	3	15	6	78	82	184
Brown Booby	27	1,439	1	26	80	1,573
Brown Noddy	37	3,419	—	—	—	3,456
Great Frigatebird	87	1,168	—	7	113	1,375
Masked Booby	9	1,019	—	29	205	1,262
Red-footed Booby	61	4,953	9	599	394	6,016
Red-tailed Tropicbird	59	65	—	—	1	125
Sooty Tern	16	2,507	—	—	—	2,523
Grand Total	**299**	**14,585**	**16**	**739**	**875**	**16,514**

Figure 3-1. Distribution of brown noddies recorded on Kaula Island.

Figure 3-2. Distribution of sooty terns recorded on Kaula Island.

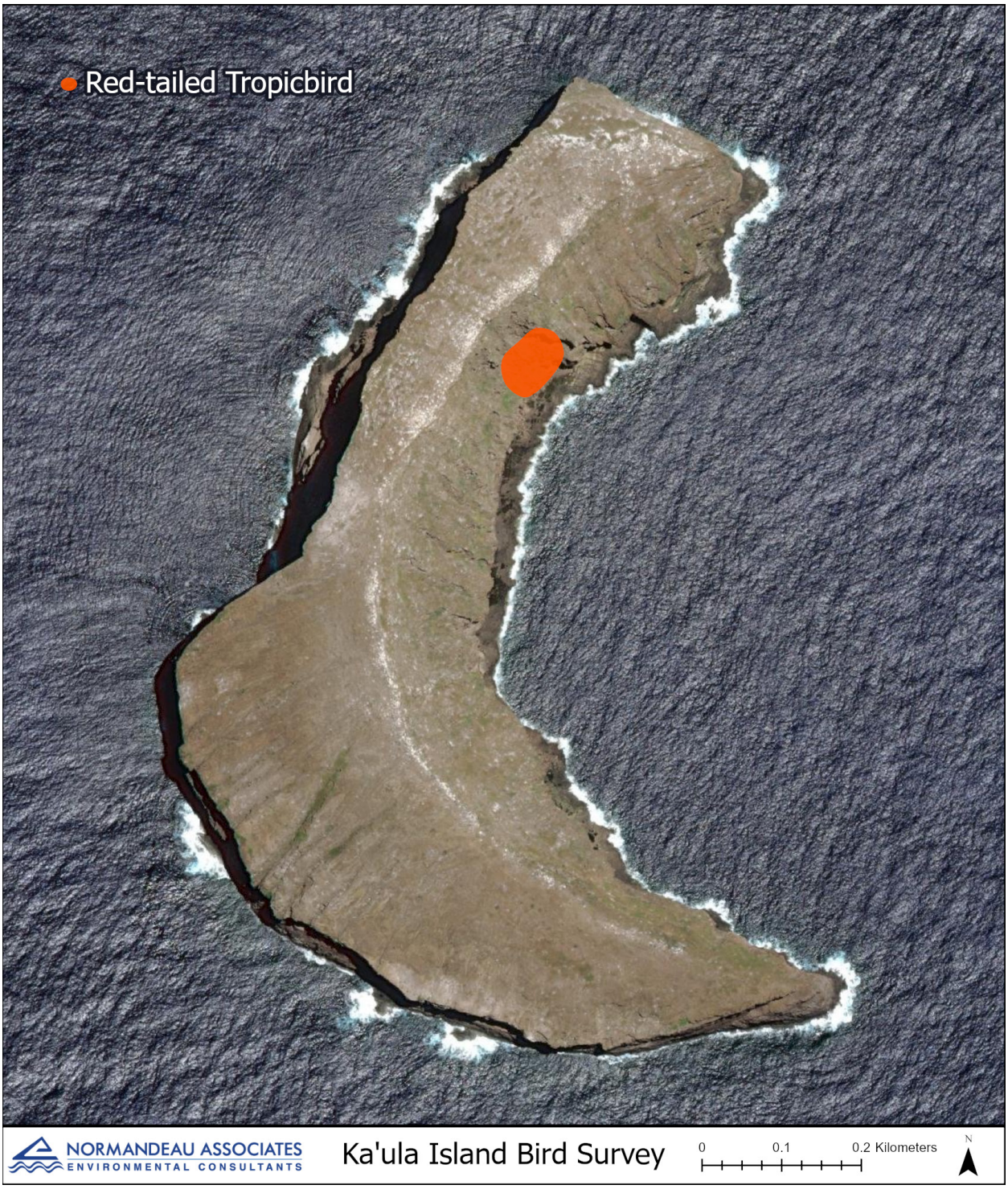

Figure 3-3. Distribution of red-tailed tropicbirds recorded on Kaula Island.

Figure 3-4. Distribution of great frigatebirds recorded on Kaula Island.

Figure 3-5. Distribution of masked boobies recorded on Kaula Island.

Figure 3-6. Distribution of brown boobies recorded on Kaula Island.

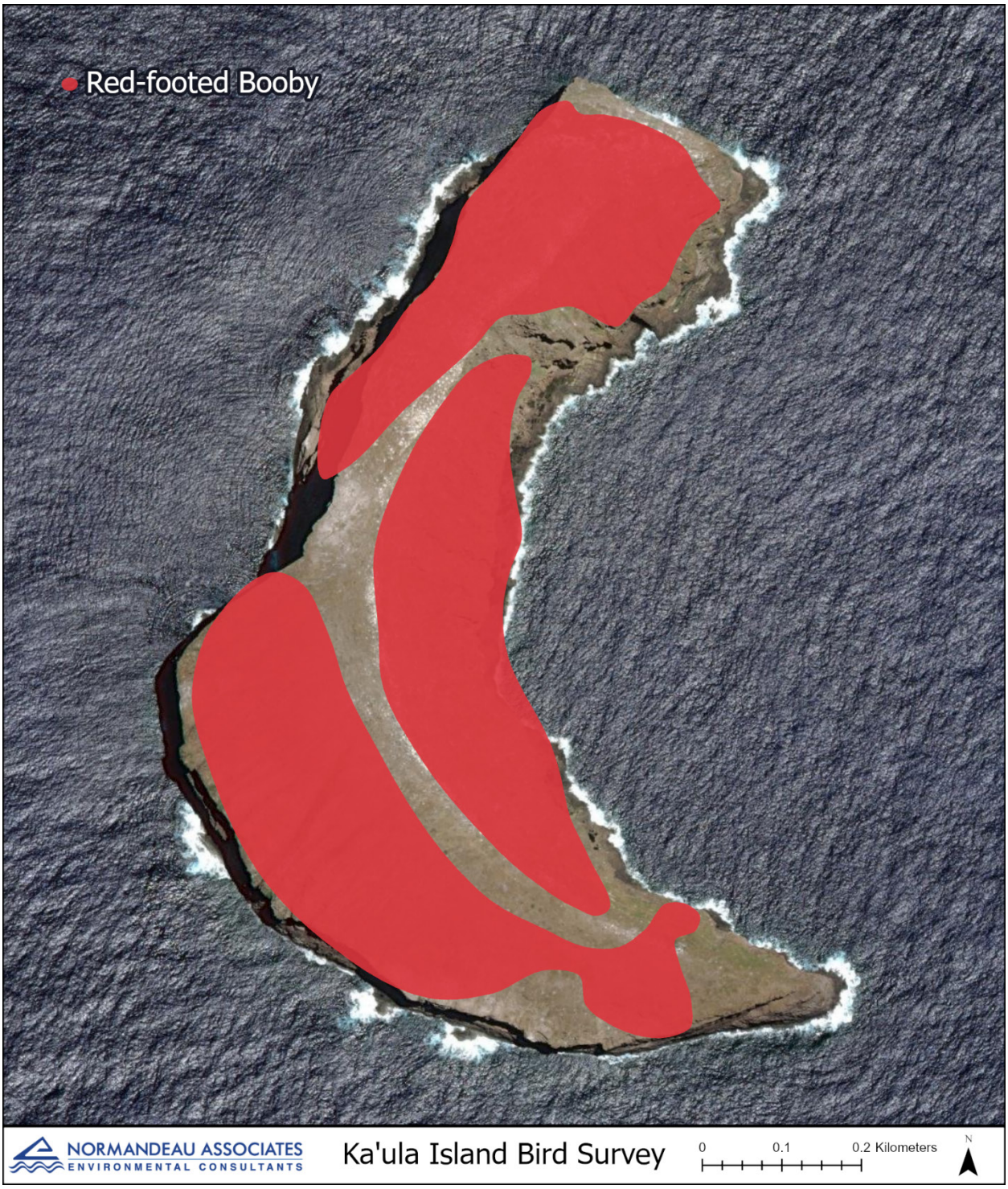

Figure 3-7. Distribution of red-footed boobies recorded on Kaula Island.

Figure 3-8. Distribution of unidentified boobies recorded on Kaula Island.

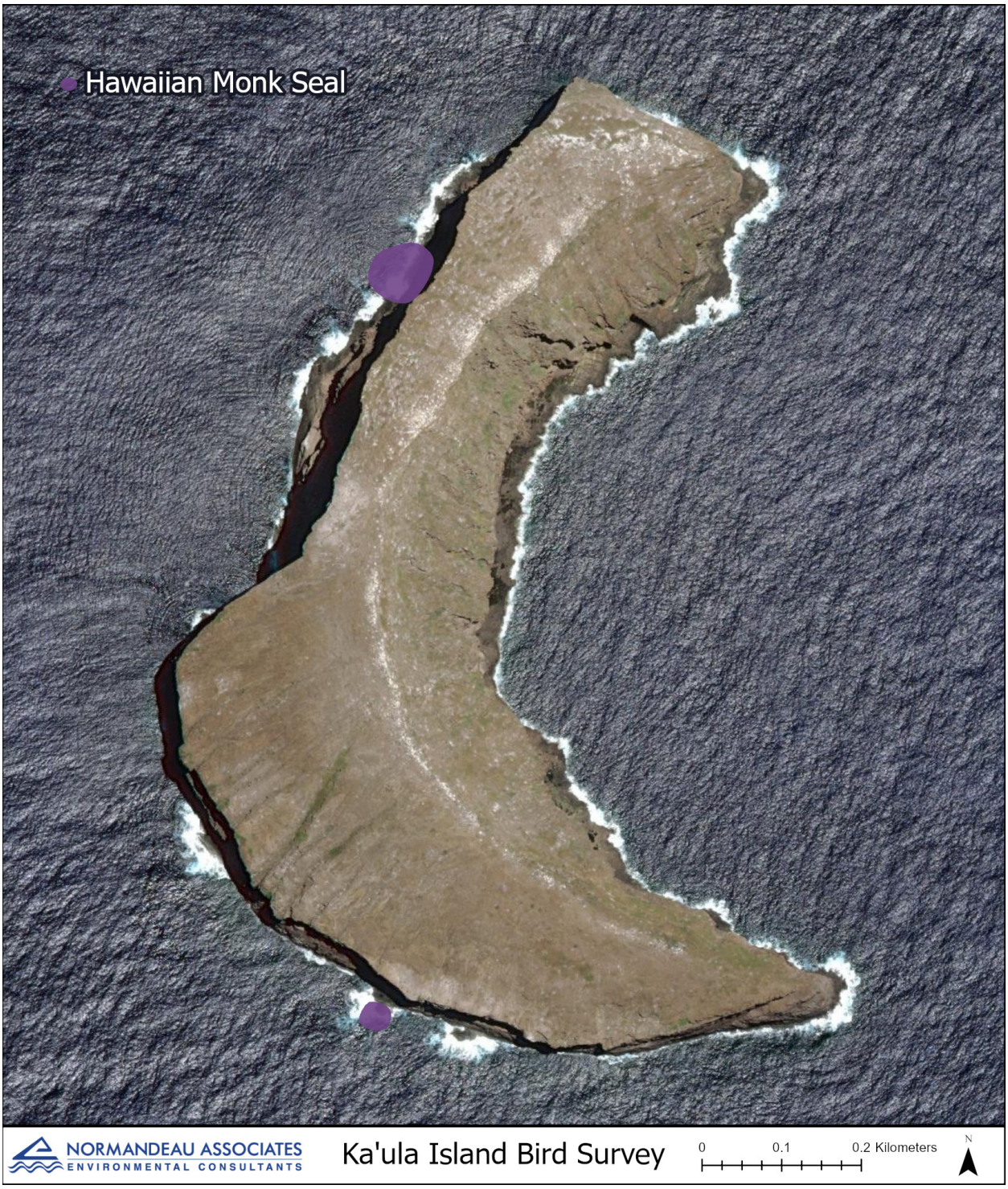

Figure 3-9. Distribution of Hawaiian monk seals recorded on Kaula Island.

4 Discussion

During the July 2021 survey, 16,514 birds and ten Hawaiian monk seals were recorded at Kaula Island (Table 3-1). The seven bird species were red-footed booby, brown noddy, sooty tern, brown booby, great frigatebird, masked booby, and red-tailed tropicbird. Red-footed booby accounted for 36% (n=6,016) of all seabirds recorded. The next most abundant species was brown noddy (n=3,456) and sooty tern (n=2,523) (Table 3-1). Brown booby (n=1,573), great frigatebird (n=1,375), masked booby (1,262), and red-tailed tropicbird (n=125) were the least abundant species recorded. A total of 184 boobies could not be recorded to species level (Table 3-2).

The most abundant species during this survey was red-footed booby. They were present across the whole island with higher numbers in the northern region on both sides of the ridge. Lower numbers of both masked and brown booby were recorded (Table 3-1). The count of 6,016 red-footed boobies during this survey is the highest recorded through Normandeau/APEM aerial digital surveys. Recent surveys seem to suggest the bulk of breeding occurs during July and August (Appendix IV; Appendix V).

Of the 6,016 red-footed boobies found, 5,014 were adult birds of which 256 were within pairs, so conceivably there could have been up to 9,772 adults (Table 3-2) (Appendix IV). The remaining 1,002 red-footed boobies were aged as immature or juvenile birds. Of the 184 unidentified boobies recorded in this survey, most were likely to be immature red-footed.

Most of the masked boobies were present along the central northern ridge running along the island with the distribution similar to those of previous aerial digital surveys with very few in the southwestern section. Of the 1,262 recorded, 1,028 were adults and 234 were immatures including 205 juveniles (Table 3-2). Of the adult birds recorded in July 2021, 308 were within pairs, with 720 recorded as single birds; therefore, it can be assumed there could have been up to 874 pairs present on the island during the July survey. Recent surveys seem to suggest the bulk of breeding occurs during July and August (Appendix IV; Appendix V).

Brown boobies were scattered throughout the island but with a higher concentration on the concave side of the island and along the central ridge. Of the 1,573 recorded, 107 were immatures including 80 juveniles (Table 3-2). Of the 1,466 adult brown boobies recorded, 272 were within pairs and 1,194 as single birds, which allows an estimation of 1,330 pairs to be calculated. The highest count of brown booby from aerial based methods was recorded in this survey, the highest count since the land-based survey in September 1971 (n=1,700) (Appendix III).

A total of 125 red-tailed tropicbirds were found in July 2021, mostly concentrated in the concave eastern region of the island. Only one breeding pair was recorded on the island with 122 recorded as single birds, which could be assumed to be half of a pair with the other half potentially foraging at sea. A maximum estimate of 247 individuals is assumed (Appendix IV).

Most 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. A total of 1,375 great frigatebirds were recorded

during the survey (Table 3-1) of which 87 were flying (Table 3-2) and 24 were in pairs. A total of 120 immature birds were counted, 113 of which were juveniles (Table 3-2). This count represents the highest record of the species since April 2013 (n=1,415) (Appendix V).

Unlike the last survey in November 2019, brown noddies were recorded in the July 2021 survey and were mostly concentrated on the cliff edges on the western side of the island. All 3,456 brown noddies were recorded as adults, 37 of which were flying (Table 3-2). Of these 3,456 birds, 22 were within pairs with 3,434 recorded as single birds; therefore, it can be assumed there may have been up to 3,445 pairs present, or a maximum of 6,890 individuals (Appendix IV). This survey represents a relatively lower count compared to the July surveys of 2015 and 2017 and August 2018 where 7,000–8,000 brown noddies were recorded (Appendix V).

In this survey, two main colonies of sooty terns were recorded amounting to 2,523 individuals. Of these birds, 2,507 were sitting and 16 were flying concentrated toward the western slopes of the island. Sooty terns were not recorded in the previous survey in November 2019, but this is likely due to November lying outside of the peak breeding season. The results of this survey are considerably lower compared to the peak count of 40,814 recorded in March 2016 (Appendix V).

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

Hawaiian monk seals are highly endangered, 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. Ten Hawaiian monk seals were recorded, seven of which were on the northern region of the western convex side of the island and three on the southwestern coast. Numbers have remained fairly consistent throughout the ten aerial digital surveys between 2013 and 2021 (Appendix V).

Overall, the aerial oblique survey method demonstrates that complete counts of seabirds can still be obtained when compared to data captured using combined oblique and vertical digital photography, including the ability to accurately assess the number of birds on apparently occupied nests almost impossible to record from boat surveys. The distributions of birds generally recorded were broadly similar to other July/August aerial 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 observed and survey type).

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6 Appendices

Appendix I. Scientific Names of Relevant Bird and Mammal Species

Common Name	Scientific Name
Brown noddy	*Anous stolidus*
Sooty tern	*Onychoprion fuscatus*
Red-tailed tropicbird	*Phaethon rubricauda*
Great frigatebird	*Fregata minor*
Masked booby	*Sula dactylatra*
Brown booby	*Sula leucogaster*
Red-footed booby	*Sula sula*
Hawaiian monk seal	*Neomonachus schauinslandi*

Appendix II. Survey Imagery Examples

Appendix III. Results of Bird Surveys Conducted on Kaula Island, Hawaii (1932–2021)*

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	July 2021
Laysan albatross *Phoebastria immutabilis*	-	1 old egg	150	-	100	-	100	9	33	44	60	-	-	-	-	20	11	81	100	-	21	-	-	17	-
Black-footed albatross *Phoebastria nigripes*	1 old egg	-	100	-	75	-	75	-	2	4	10	-	-	-	-	3	-	11	3	-	4	-	-	-	-
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	-	1	100	23	502	245	1	125
Great frigatebird *Fregata minor*	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	1,375
Booby species *Sula species*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	713	159	184
Masked booby *Sula dactylatra*	common	1,000	300	1,200	125	200	400	236	202	567	350	-	-	-	-	550	219	65	84	526	183	514	1,312	217	1,262
Brown booby *Sula leucogaster*	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	1,573
Red-footed booby *Sula sula*	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	6,016
Masked/red-footed booby *Sula dactylatra / S. sula*	-	-	-	-	-	-	-	-	-	-	-	820	850	1,859	912	-	-	-	-	27	-	24	-	-	-
Masked/brown booby *Sula dactylatra / S. leucogaster*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	51	-	-
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	-	-	7,137	4,115	7,871	7,612	-	3,456
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	-	-	-	-	-	-	-	-	-	-	-	-

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	July 2021
White tern *Gygis alba*	uncommon	10	10	200	40	10	-	9	12	9	-	10	9	9	12	6	-	-	-	1	-	-	-	-	-
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	-	-	147	40,814	768	6,535	-	2,523
Grey-backed tern *Onychoprion lunatus*	uncommon	2,800	-	250	1,250	50	300	4,110	1,467	35	-	1	3	-	-	4	-	-	-	-	1	-	5	-	-
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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
House finch *Haemorhous mexicanus*	-	6	15	40	-	20	6	-	1	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nutmeg manikin *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**	**1,145**	**13,576**	**47,664**	**14,075**	**23,187**	**2,091**	**16,514**
Total Number of Species	**16**	**19**	**16**	**24**	**12**	**19**	**17**	**15**	**19**	**19**	**15**	**11**	**11**	**8**	**8**	**11**	**9**	**6**	**7**	**8**	**10**	**7**	**8**	**7**	**8**

*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.

C Fujimoto, J. & Juola, F. (2012). *Kaula 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 Kaula Island, Hawaii. Prepared for Commander, Pacific Fleet through a contract with NAVFAC Pacific.

Appendix IV. Estimates of Seabird Numbers during the July 2021 Aerial Digital Survey of Kaula Island, Hawaii

Species	ADULTS			Immature/Juvenile			Total Birds	Number of Pairs*	Max Individuals*
	Birds in Pairs	Singles	Total	IM	J	Total			
Brown Noddy	22	3,434	3,456	—	—	—	3,456	3,445	6,890
Sooty Tern	—	2,523	2,523	—	—	—	2,523	2,523	5,046
Red-tailed Tropicbird	2	122	124	—	1	1	125	123	247
Great Frigatebird	24	1,231	1,255	7	113	120	1,375	1,243	2,606
Masked Booby	308	720	1,028	29	205	234	1,262	874	1,982
Brown Booby	272	1,194	1,466	27	80	107	1,573	1,330	2,767
Red-footed Booby	256	4,758	5,014	608	394	1002	6,016	4,886	10,774
Booby species	—	18	18	84	82	166	184	18	202
Total Estimated Number of Birds							**16,514**		**30,514**

*A pair is assumed to be two birds, all singles (including single flying birds and excluding immatures and 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 (2013–2021)*

Common Name	Scientific Name	Global Population	Regional Population[2] (Hawaii) Breeding Pairs	Apr 2013	Aug 2013	Jan 2014	Jan 2015	July 2015	Mar 2016	July 2017	Aug 2018	Nov 2019	July 2021
Black-footed albatross	*Phoebastria nigripes*	64,500 breeding pairs[4]	55,000	3	-	11	3	-	4	-	-	-	-
Laysan albatross	*Phoebastria immutabilis*	1,180,000 mature individuals[4]	590,000	20	11	81	100	-	21	-	-	17	-
Red-tailed tropicbird	*Phaethon rubricauda*	> c.32,000 individuals[1]	9,000-12,000	314	85	-	1	100	23	502	245	1	125
Great frigatebird	*Fregata minor*	500,000-1,000,000[2]	10,000	1,415	1,369	621	748	1,078	1,005	777	719	316	1,375
Booby species	*Sula species*	-	-	-	-	-	-	-	-	-	713	159	184
Masked booby	*Sula dactylatra*	Unquantified. Described as 'fairly common'[3]	2,500	550	219	65	84	526	183	514	1,312	217	1,262
Brown booby	*Sula leucogaster*	> c.200,000 individuals[1]	1,400	101	109	3	2	867	179	969	1,231	185	1,573
Red-footed booby	*Sula sula*	> c.1,000,000 individuals[1]	7,000-10,500	1,690	191	98	209	3,693	1,319	2,650	4,764	1,196	6,016
Masked/red-footed booby	*Sula species*	-	-	-	-	-	-	27	-	24	-	-	-
Masked/brown booby	*Sula species*	-	-	-	-	-	-	-	-	-	51	-	-
Brown noddy	*Anous stolidus*	500,000-1,000,000 breeding pairs[2]	112,000	57	3,713	-	-	7,137	4,115	7,871	7,612	-	3,456
Black noddy	*Anous minutus*	1-1.5 million breeding pairs[2]	12,000	-	22	-	-	-	-	-	-	-	-
White tern	*Gygis alba*	Likely exceeds 100,000 breeding pairs[2]	15,000	6	-	-	-	1	-	-	-	-	-
Sooty tern	*Onychoprion fuscatus*	60-80 million breeding pairs[2]	>1,000,000	14,635	7	-	-	147	40,814	768	6,535	-	2,523
Grey-backed tern	*Onychoprion lunatus*	Likely 70,000 breeding pairs[2]	44,000	4	-	-	-	-	1	-	5	-	-

Common Name	Scientific Name	Global Population	Regional Population[2] (Hawaii) Breeding Pairs	Apr 2013	Aug 2013	Jan 2014	Jan 2015	July 2015	Mar 2016	July 2017	Aug 2018	Nov 2019	July 2021
Hawaiian monk seal	*Neomonachus schauinslandi*	1,209 individuals of all age classes[5]	632 sexually mature seals[5]	11	7	5	7	9	10	8	7	8	10
Total Estimated Number of Birds				**18,795**	**5,733**	**879**	**1,147**	**13,576**	**47,664**	**14,075**	**23,187**	**2,091**	**16,514**
Total Number of Species				**11**	**9**	**6**	**7**	**8**	**10**	**8**	**9**	**7**	**9**

[1] del Hoyo et al. 1992

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

[3] Stotz et al. 1996

[4]Birdlife International http://www.birdlife.org/datazone/

[5]IUCN Red List http://www.iucnredlist.org/details/13654/0