APPENDIX M. Habitat Use and Behavioral Monitoring of Hawaiian Monk Seals in Proximity to the Navy Hawaii Range Complex. Report Period: August 2010-July 2011

Project Annual Report

Primary Investigator: Charles Littnan, Lead Scientist, Hawaiian Monk Seal Research Program, National Marine Fisheries Service

Submitted by: Kenady Wilson, Scientist III, Hawaiian Monk Seal Research Program, Ocean Associates Inc.

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EXECUTIVE SUMMARY

As of August 1, 2011, 21 monk seals were instrumented as part of this NMFS-Navy/DOD collaborative project. In 2010, 11 seals were tagged; however, four seals lost their tags due to a bad batch of epoxy and data were only recovered for 7 animals (1F, 6M). In 2011, eight new animals were tagged, and two seals were tagged that had also been instrumented in 2010. Data were recovered for 6 of these animals (1F, 5M). Dive data for 3 of the 10 seals tagged in 2011 were never downloaded to the server and were therefore not included in the analyses. Additionally, data for one seal tagged on Molokai (RW30) was not visible at all on the server. It is unclear what may have caused these malfunctions, but steps are being taken to remedy these issues in the future.

Data are currently being analyzed to identify monk seal home ranges and core areas of use, and to examine variation in monk seal diving and foraging behavior. These analyses give insight into how monk seals move and utilize their available habitat. During both deployment periods, monk seals tended to stay within the 600 m depth contour surrounding the MHI and neighboring banks, and most dove to depths < 100 m. Their foraging trips typically lasted less than one day, but some seals were observed to take trips lasting 1-3 weeks in duration. Continued monitoring will reveal if these extended trips are more common than previously assumed. Understanding the duration of time spent foraging, the type of foraging occurring, and the amount of time spent foraging in specific areas is an important step in thoroughly understanding monk seal behavior and will provide good baseline data for future comparisons regarding the impact of Navy activities on their behavior.

The next phase of analysis will include a comparison of current home range calculations to home ranges and core areas that are calculated via a mechanistic home range model. These models provide a more detailed understanding of animal movement and habitat use by incorporating stochastic processes into the model. They enable the use of behavior metrics and habitat variables within the model thus allowing these variables to influence the designation of a home range or core area rather than defining home ranges solely on a seals' presence within an area. Additionally, the percent of time seals spent within the HRC will be calculated and a model will be developed to analyze behavior bouts (at varying time-scales) to detect 'significant' changes in behavior. These behavior events will then be compared to periods of HRC activities to look for correlations.

INTRODUCTION

Hawaiian monk seal abundance is falling from a 2007 estimate of 1,146 individuals. Most monk seals reside in the remote Northwestern Hawaiian Islands (NWHI) where the decline is approximately 4% yr^{-1}. A smaller, recently established population in the main Hawaiian Islands (MHI) has greater survival rates and the total number of seals is increasing. The estimated MHI intrinsic rate of population growth is 1.13 compared to a range from 0.89 to 0.98 in the NWHI. While this increasing population in the MHI provides some hope for the species' continued existence, it brings with it a new host of potential management concerns.

There are a variety of natural and anthropogenic threats that exist in the MHI including human-interactions (i.e. fisheries, beach disturbance, boat activities, pollution etc.) and disease exposure (from both domestic and feral sources). The question has also been raised whether or not activities associated with naval operations in the Hawaii Range Complex (HRC) may be impacting monk seals at-sea and currently, no data exists to assess any impact or disturbance of these activities to seals. To address this question it is necessary to quantify and compare monk seal at-sea behaviors both outside and during periods of HRC activities. Very little is currently known about the at-sea behavior and ecology of these MHI seals. Telemetry studies to understand their foraging behaviors and habitat use are one of the first critical steps to help inform management actions for the species.

In 2010, NOAA Fisheries' Hawaiian Monk Seal Research Program (HMSRP) and U.S. Navy Pacific Fleet Environmental TO initiated a collaborative research effort to investigate potential impacts of naval activities in the HRC on monk seals. This multi-year study is ongoing and the intent of this interim report serves as an update on completed field activities and review current results and future analyses.

Tag Capability

The HMSRP uses new technology to better understand the foraging behavior and habitat use of main Hawaiian Island monk seals. The Sea Mammal Research Unit (SMRU) has developed a telemetry tag using global position system (GPS), GSM modem (cellular phone) and standard behavior recording technologies in order to increase the quality and amount of data researchers obtain in marine mammal telemetry studies. This tag contains a hybrid GPS system that is capable of acquiring GPS pseudo-range data within a snapshot window of only 0.2 s. The pseudo-range data is transmitted to researchers and processed with separately downloaded GPS ephemeris data to produce high-quality GPS fixes (with a horizontal error radius of about 55m). In addition, the tag also collects and stores detailed *individual* dive behavior and haul-out information as well as temperature up-cast profiles. To transmit data to researchers, the tag utilizes a GSM modem to relay stored data via existing commercial cell phone networks. While the tag must be within approximately 20 km of a GSM base station for a data call to be established, data can be stored for up to six months in between calls, allowing animals to move large distances from base stations while still collecting detailed behavioral data. Tags are expected to be operational for up to one year or until the animal molts. In the past, monk seals tagged with these instruments have collected data from 0 – 8 months, with most seals retaining their tags for 3 - 6 months. Monk seals forage under rocks and overhangs near the ocean floor, resulting in the rough treatment of tags and data collection periods that are often shorter than the life expectancy of the tag.

Historical Findings

Very few studies have been conducted on MHI movements and habitat use. Due to technological limitations these earlier studies could not determine precise diving locations and were unable to examine complete dive records. These studies have shown that monk seals spend most of their time at sea in nearshore, neritic, marine habitats (Littnan et al. 2006). Land-based observations and volunteer sightings indicate that 35.6% of the MHI seals travel between islands throughout the year. There is high individual variability in monk seal foraging behavior; however, most foraging trips last from less than 1 day to 1-2 weeks and seals tend to remain within the 200 m depth contour surrounding the MHI and nearby banks (Littnan et al. 2006).

Multiple telemetry studies have been conducted in the NWHI to monitor monk seal behavior, diet, and habitat use; however, like in the MHI, these studies used satellite locations of varying accuracy and did not have access to the complete dive record. These studies were able to elucidate the general movements and behavior of monk seals in the NWHI and provide a baseline for future behavior studies. Seals were found to move extensively within the barrier reefs of the atolls, on the leeward slopes of reefs and islands at all NWHI colony sites, and along the Hawaiian Archipelago submarine ridge to nearby seamounts and submerged reefs and banks (Stewart et al. 2006). Most dives were less than 150 m deep, though dives of some seals exceeded 550 m. Movements and home ranges were highly variable between age and sex classes and between the different colonies (Curtice et al. 2011).

Activities and Findings as of August 2011

Figure 1. Photo of R4DF with a cell phone tag attached to the pelage of the seal.

The primary objectives of this cooperative research project were threefold:

1) Deploy cell phone tags on monk seals in the main Hawaiian Islands.
2) Monitor monk seal habitat use and behavior: determine home range sizes, foraging areas, and identify potential foraging hot spots of seals in the MHI.
3) Identify potential changes in monk seal behavior in relation to Navy activities in the MHI.

Objective 1: Cellphone Tag Deployments in MHI

During the first year of deployment, three, week-long trips were made to Kauai where we deployed 4 instruments, two trips were made to Molokai with 4 instruments deployed, and 3 instruments were deployed opportunistically on Oahu (Table 1). As of August 2011, 10 additional tags were deployed as part of the 2nd year of funding. Tags were deployed on Kauai (3), Oahu (2) and Molokai (5). The remaining tags will be deployed opportunistically on Oahu.

Table 1. Hawaiian monk seals captured and instrumented in the Main Hawaiian Islands. Bold font indicates seals used in current analyses.

Seal ID	Tag #	Age	Sex	Deploy Site	Deploy Date	Comments
2010						
R012	**11393**	**Adult**	**M**	**Oahu**	**3.1.2010**	
R018	**11478**	**Adult**	**M**	**Kauai**	**6.9.2010**	
R4DI	**11337**	**SubAdult**	**M**	**Kauai**	**2.9.2010**	**tag fell off**
RE70	**11420**	**Adult**	**M**	**Molokai**	**3.27.2010**	
RI11	**11419**	**Adult**	**M**	**Molokai**	**3.26.2010**	
RI13	11392	Adult	M	Molokai	3.26.2010	tag fell off
RK05	11475	Adult	M	Kauai	2.10.2010	tag fell off
RO28	11423	SubAdult	F	Kauai	2.11.2010	tag fell off
RR70	**11396**	**Adult**	**M**	**Oahu**	**6.29.2010**	
unk	11170	Adult	M	Molokai	3.28.2010	No permanent ID
R4DF	**11476**	**SubAdult**	**F**	**Oahu**		
2011						
RH42	11666	A	M	Molokai	1.21.2011	no dive data
RW30	11626	SubAdult	F	Molokai	1.22.2011	
RB24	**11424**	**SubAdult**	**F**	**Kauai**	**1.25.2011**	
R018	**11668**	**A**	**M**	**Oahu**	**2.18.2011**	
RB02	**11660**	**Adult**	**M**	**Molokai**	**6.12.2011**	
RW02	**11799**	**S3**	**M**	**Kauai**	**7.13.11**	
T21M	**11813**	**A**	**M**	**Oahu**	**7.15.11**	
R4DI	**11805**	**A**	**M**	**Kauai**	**6.15.11**	
R306	11662	A	M	Molokai	5.31.11	no dive data
RO36	11801	A	M	Molokai	5.31.11	no dive data

Objective 2: Determination of Home ranges, foraging trip characteristics, and dive behavior

Data is downloaded periodically using Google Earth to view the current location and recent movements of the instrumented animals. As of 7/31/2011 six tags were still recording data, analyses had been completed for 9 animals (female: n = 2, male: n = 7), and preliminary analyses had begun for 4 animals (male: n = 4). Most of the seals made regular foraging trips out to sea where they traveled, on average, 26.96 km in 0.64 days (Figures 2 & 3). The mean haul-out duration was 0.29 days with seals spending ~ 40% of their time on land (Table 2).

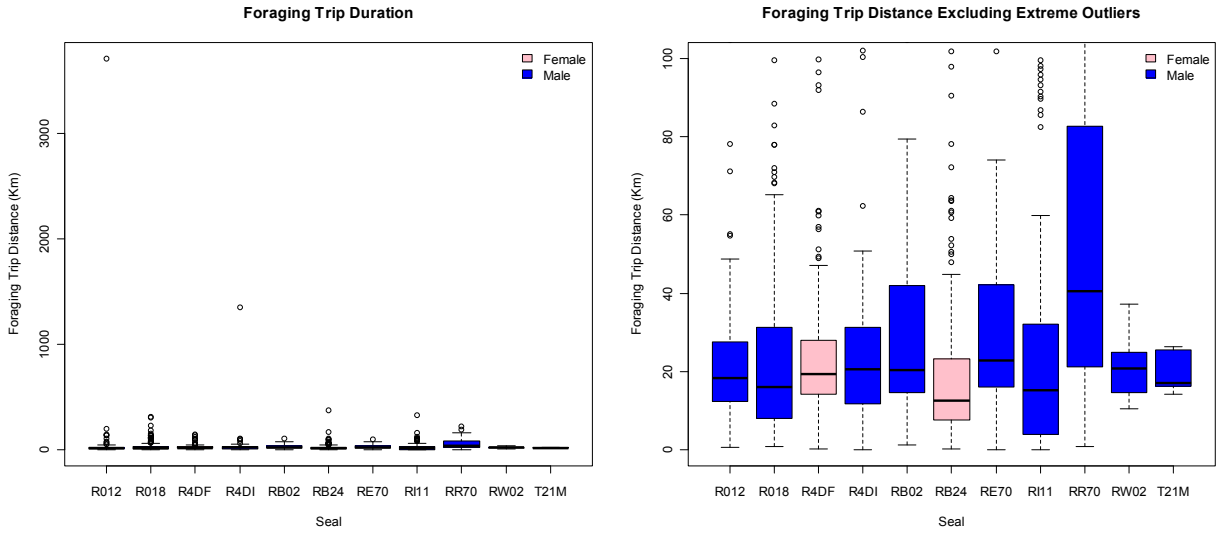

Figure 2: a) Foraging trip distance for monk seals, b) Foraging trip distance for monk seals, excluding extreme outliers.

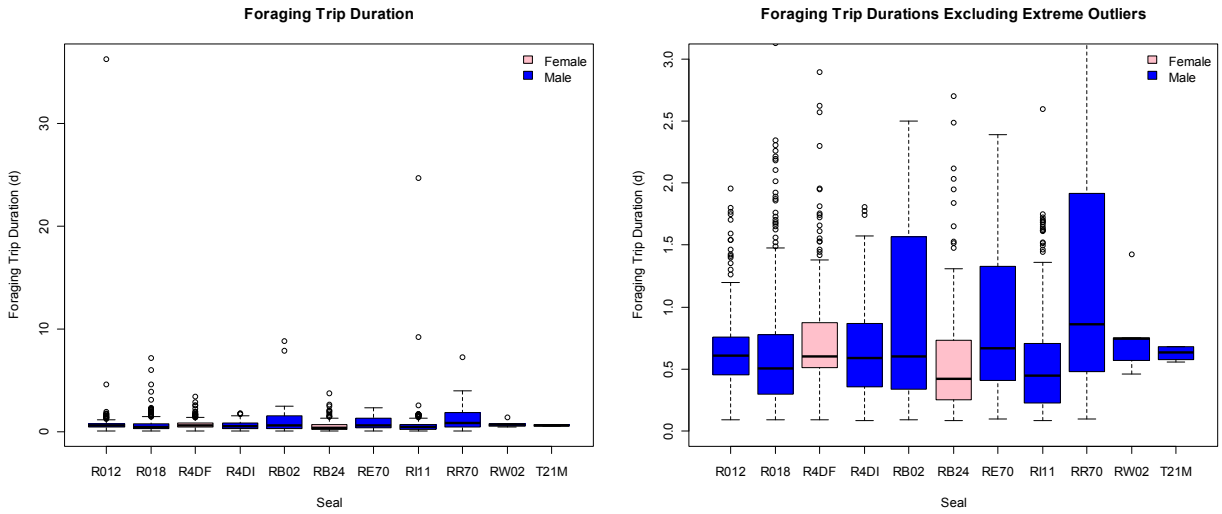

Figure 3: a) Foraging trip durations for monk seals, b) Foraging trip duration for monk seals, excluding extreme outliers.

Table 2. Mean percent of time spent on land for each seal during the tag deployment period.

Seal ID	Age	Sex	Time on Land (%)
R012	A	M	41.00
R018	A	M	38.53
R4DF	A	F	36.68
R4DI	S4	M	40.37
RB02	A	M	40.68
RB24	S4	F	40.54
RE70	A	M	40.15
RI11	A	M	41.15
RR70	A	M	49.01
RW02	S3	M	25.58*
T21M	A	M	38.30*

*These are preliminary numbers for these animals due to only two weeks of data having been collected at the time of writing this report.

Mean foraging trip distance and duration, as well as maximum dive depth are similar between seals (Figures 2, 3, & 4). However, there were multiple outlying data points for all seals which varied by individual (Figures 2 - 5). Excluding R012's extended pelagic foraging trip, none of the seals traveled more than 300 km per trip and most traveled less than 50 km (Figure 2). The mean dive depth was 29.9 m with a maximum of 529 m and a median depth of 12.8 m during the deployment period. The average dive duration was 4.88 min with a median of 4.7 min and 28% of the time spent between dives being spent at the surface. The longest recorded dive was 49.16 min with a maximum depth of 2.4 m indicating that it was likely not a foraging dive.

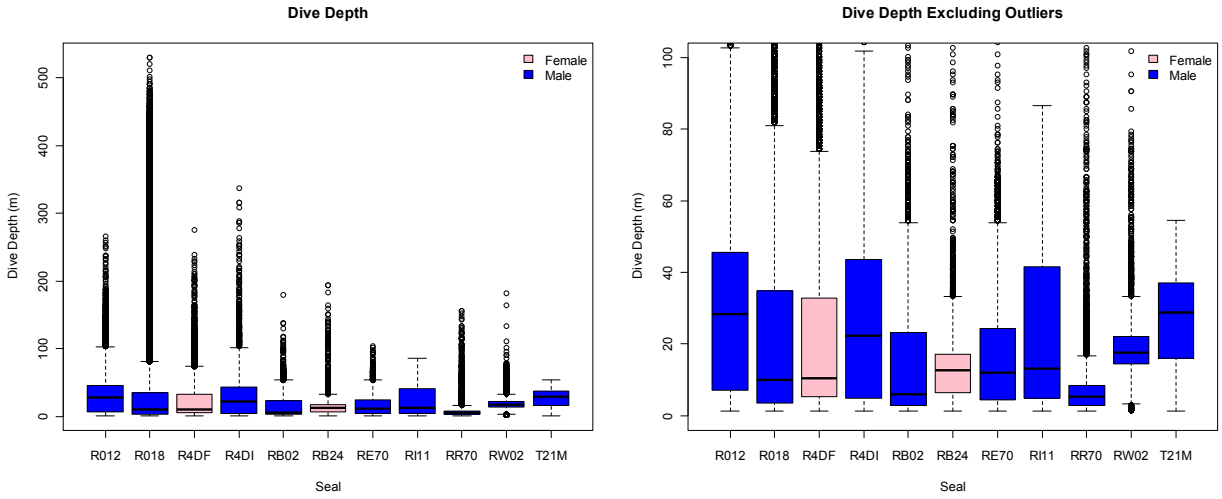

Figure 4: a) Dive depths for monk seals including extreme outliers and b) Monk seal dive depths less than 100 m.

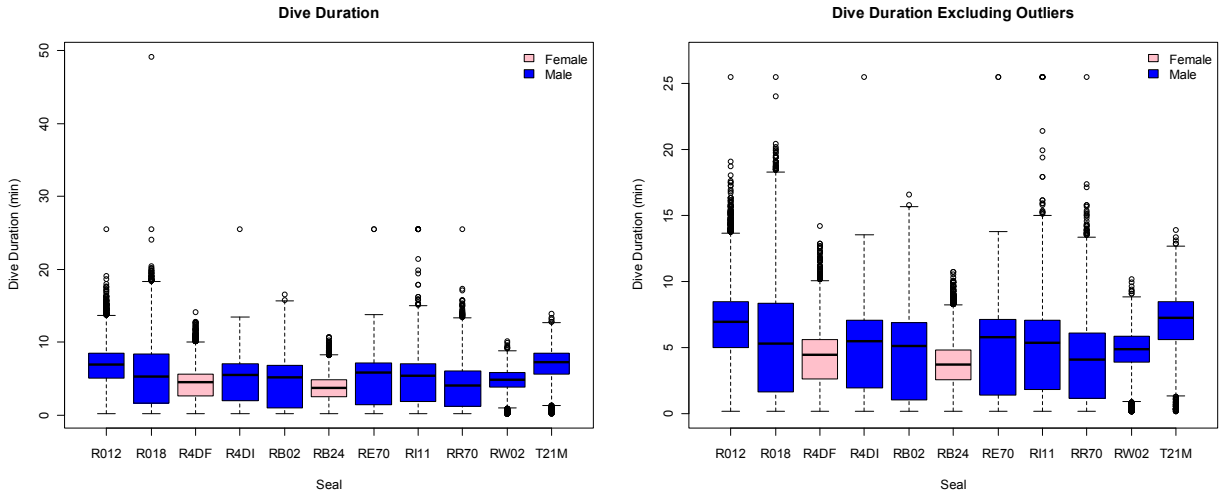

Figure 5. Dive durations for monk seals

The two female seals (R4DF and RB24) had similar dive depths and durations to male seals, but there was less average variation in both the depth and durations of their dives (Figures 4 - 7). Additionally, the maximum depths and durations reached by the females were shallower and shorter than the males (Figures 6 & 7). However, the maximum dive durations for all of the male seals tagged in 2010 were exactly the same (25.5 min), which may indicate some kind of artifact with the data collection or storage within the tag.

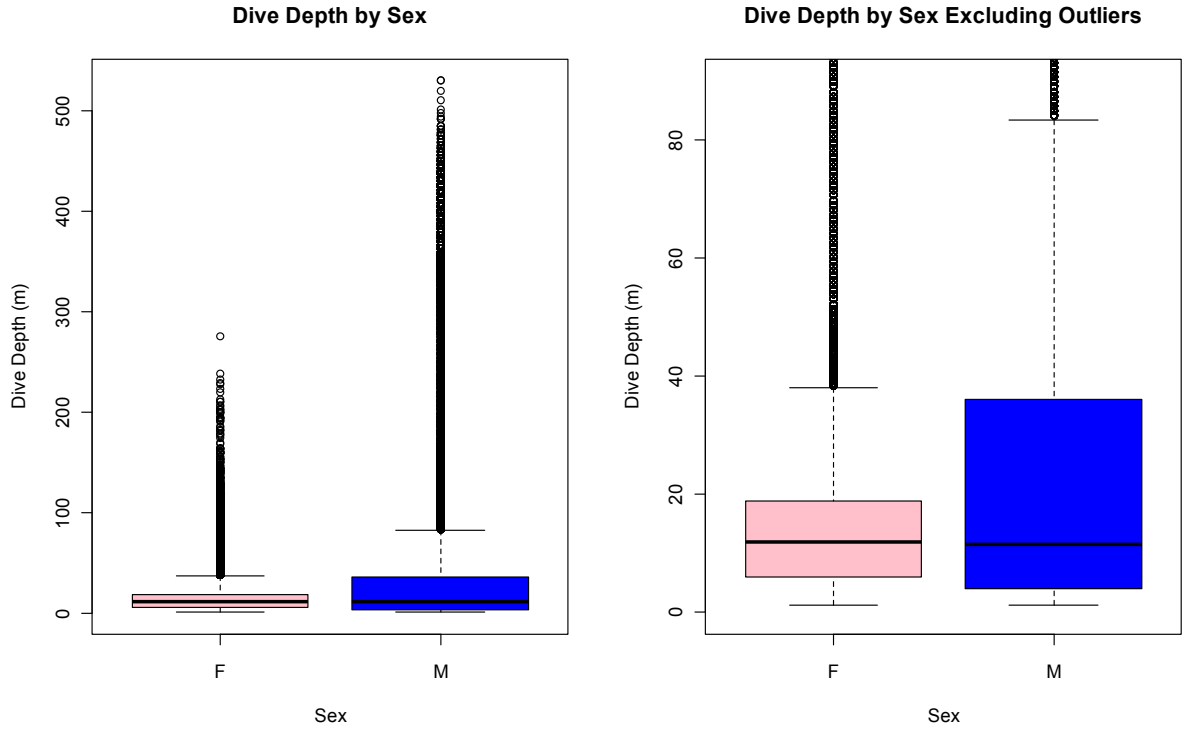

Figure 6. Dive depth relative to sex.

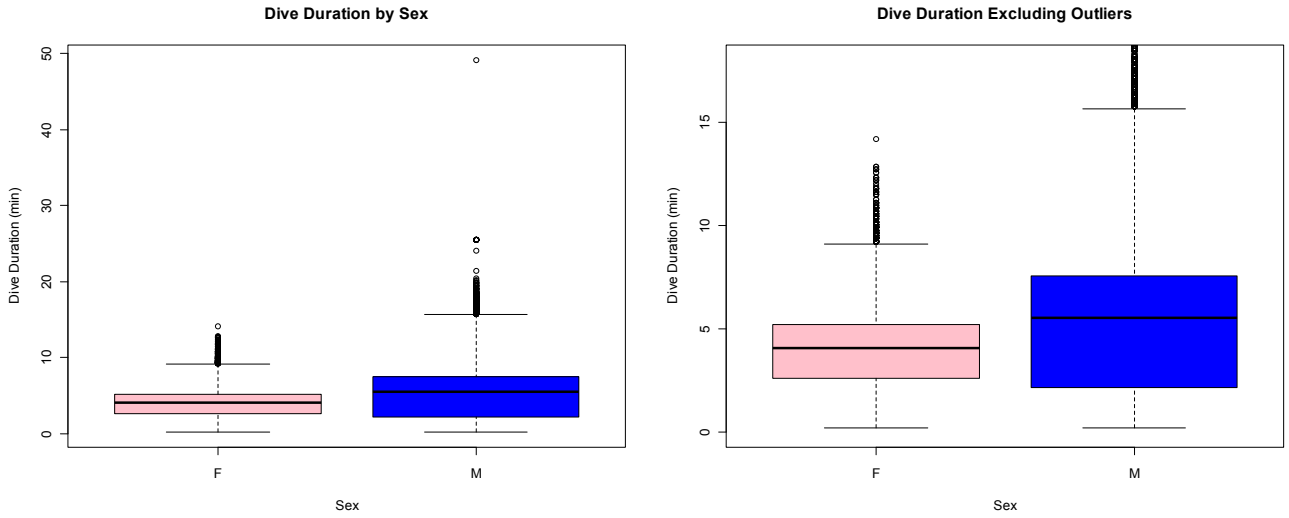

Figure 7. Dive duration relative to sex.

Although foraging trip distances and durations were similar between seals, there was high variability in the space utilized by individuals (Figures 8 – 18). For example, R4DF, a seal tagged on Oahu, traveled from Oahu to Hawaii and spent time foraging near all the islands in between (Figure 8). Conversely, most of the seals tagged on Molokai tended to stay near that island or on Penguin Bank for the duration of tag deployment (Figures 12 & 13). Six of the seals (54%) made regular trips between two or more of the islands, while the remainder showed fidelity to one island. Two seals made at least one long pelagic foraging trip during the deployment period. R012, an adult male tagged on Oahu, traveled over 3,000 km on one trip which lasted 36 days (Figure 8); and RB24, a sub-adult female tagged on Kauai, traveled over 300 km on one trip that lasted almost 4 days (Figure 15). Most of the seals remained within the 600 m depth contour surrounding the MHI and surrounding banks (Figures 8 – 18).

Fixed kernel density home range and core area estimates (utilization density estimates) were calculated for all 11 seals (Table 3). This type of analysis gives the probability of finding an animal in a particular location and also creates contour isolines encompassing areas of equivalent probability. The 95th percentile contour is considered the animal's home range, where there is a 95% probability of finding the animal in that area at any given time; the 50th percentile contour is considered the core area of use, where there is a 50% probability of finding the animal. Utilization densities for monk seals were broken down farther by including a 75th percentile contour, a mid-level between the home range and core area (Figures 8 – 18). Most seals had core areas on one island regardless of their inter-island travels; however, two animals that spent considerable time on multiple islands had segmented core areas that spanned multiple islands (Figures 8 & 11).

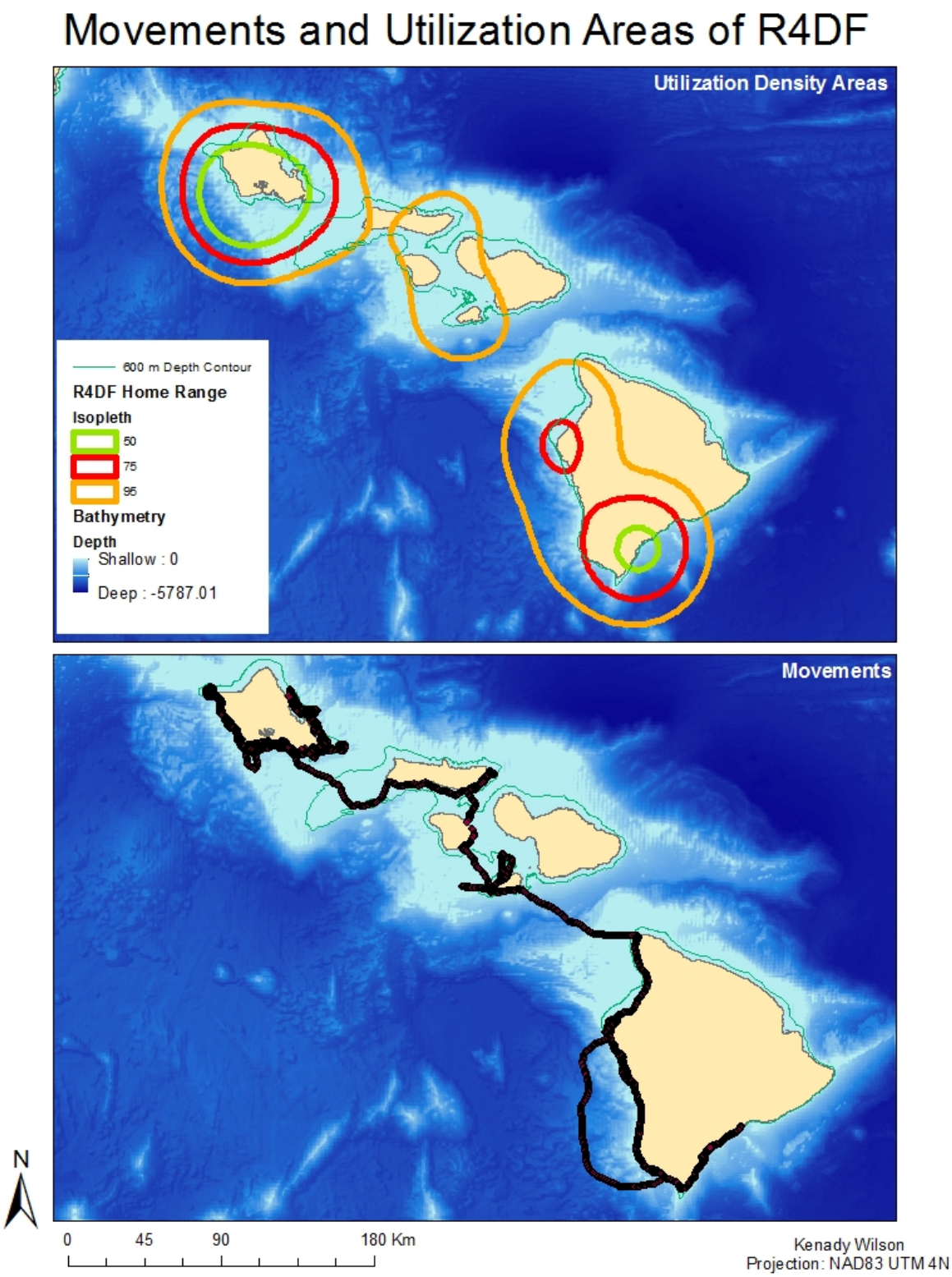

Figure 8. Map of R4DF overall movements and home range areas from July – November 2010

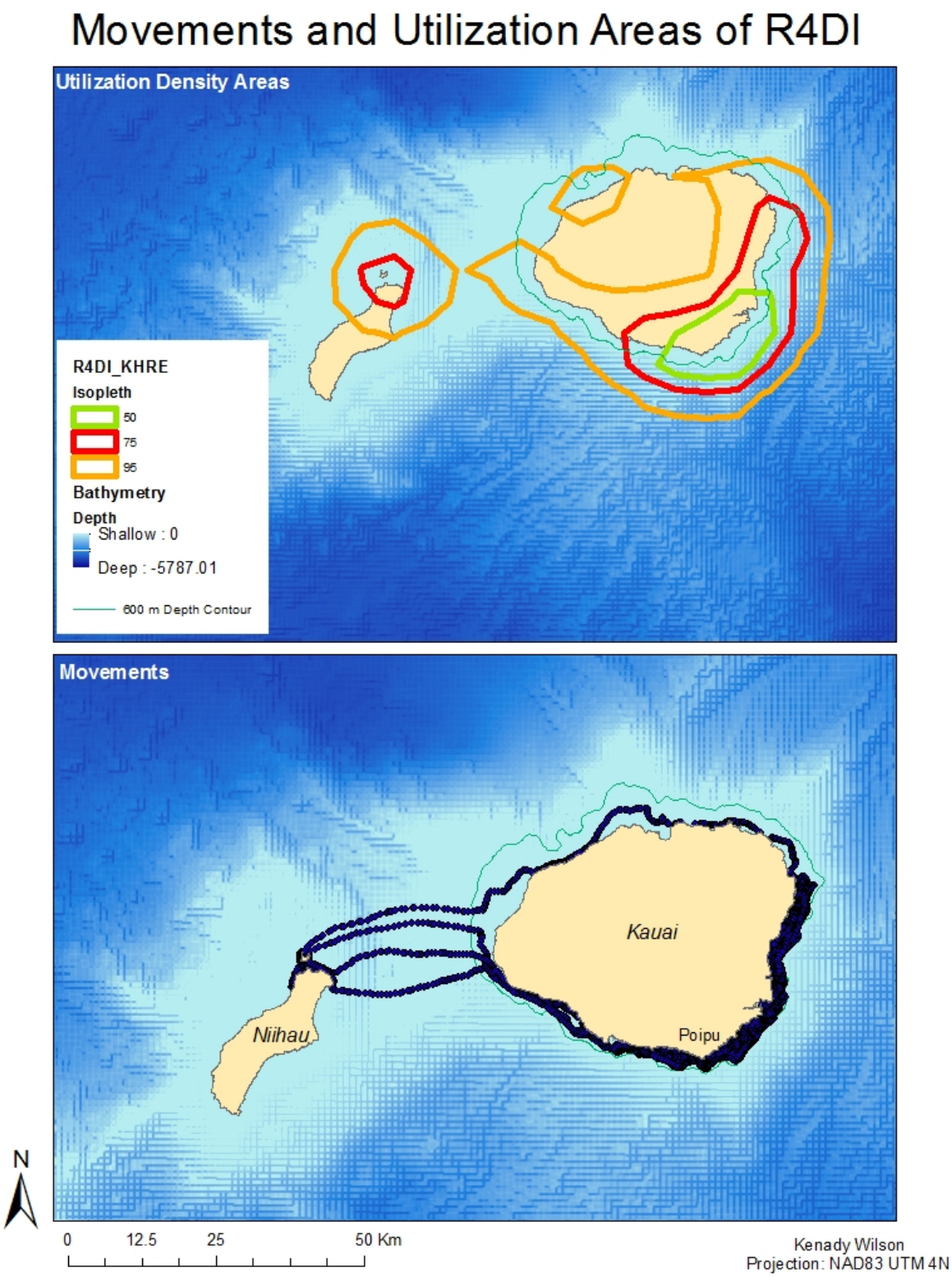

Figure 9. Map of R4DI overall movements and home range areas in February 2010 and June-July 2011.

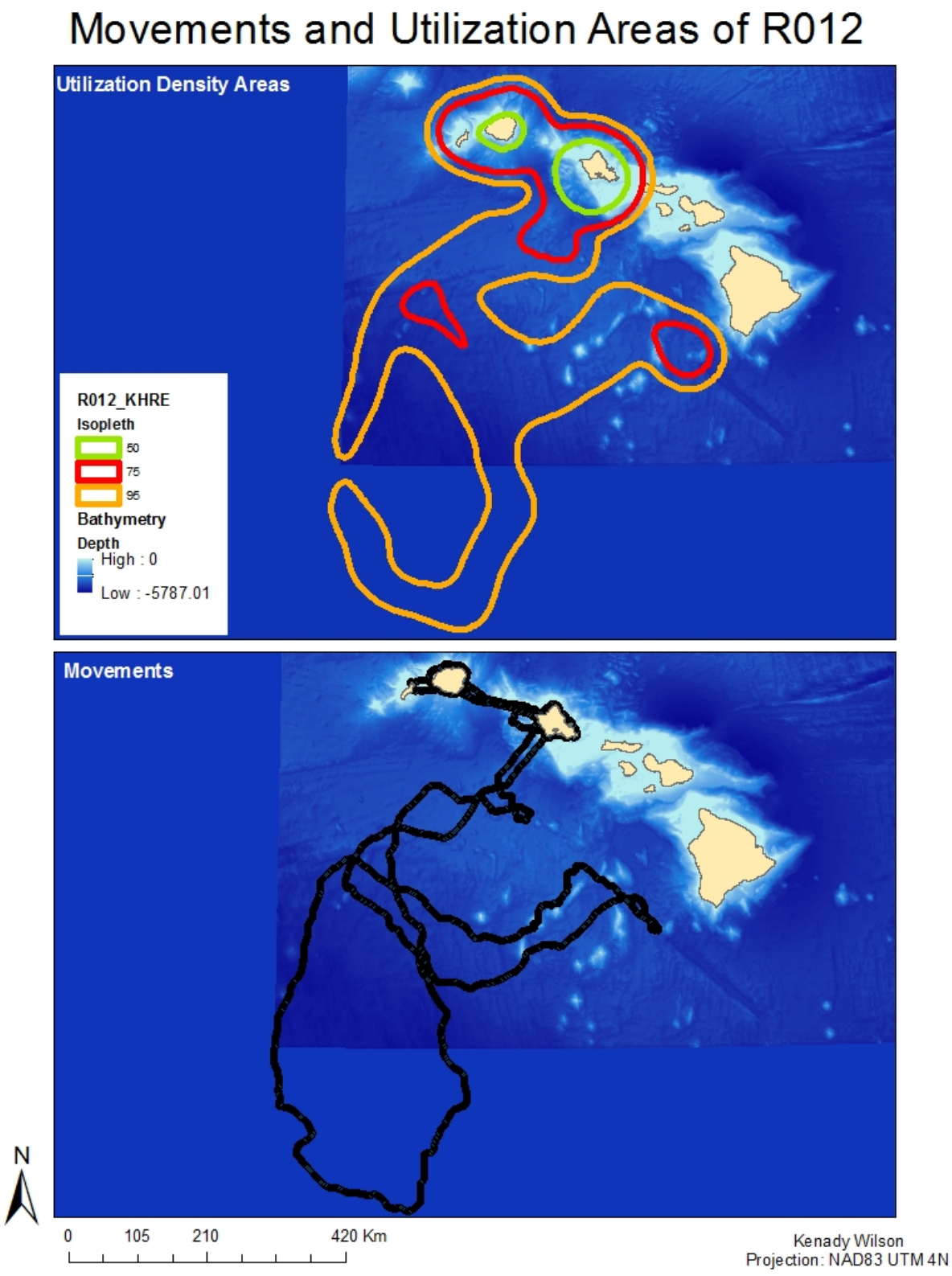

Figure 10. Map of R012 overall movements and home range areas from March – August 2010.

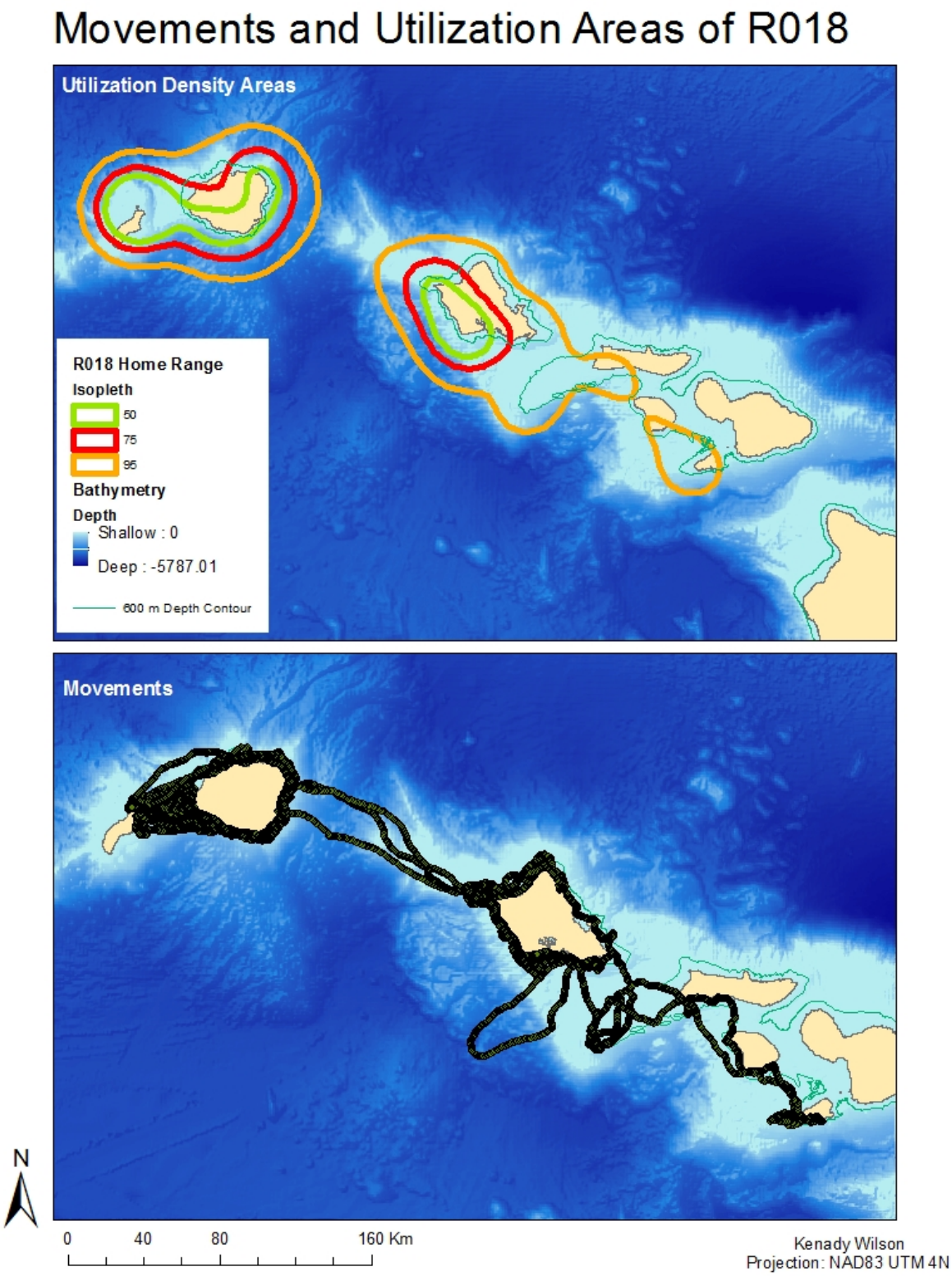

Figure 11. Map of R018 overall movements and home range areas from June – December 2010 and February – June 2011.

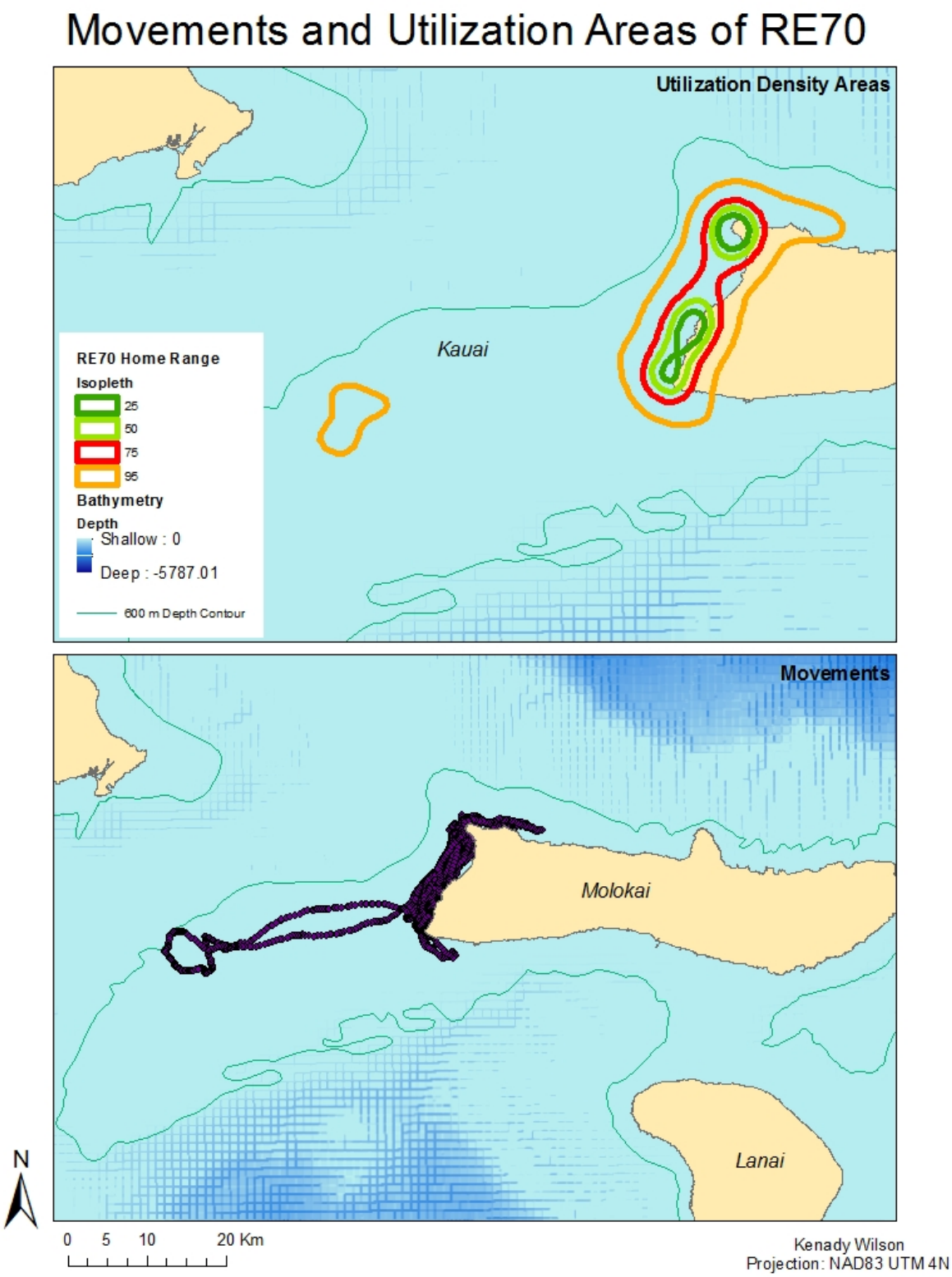

Figure 12. Map of RE70 overall movements and home range areas from March - May 2010.

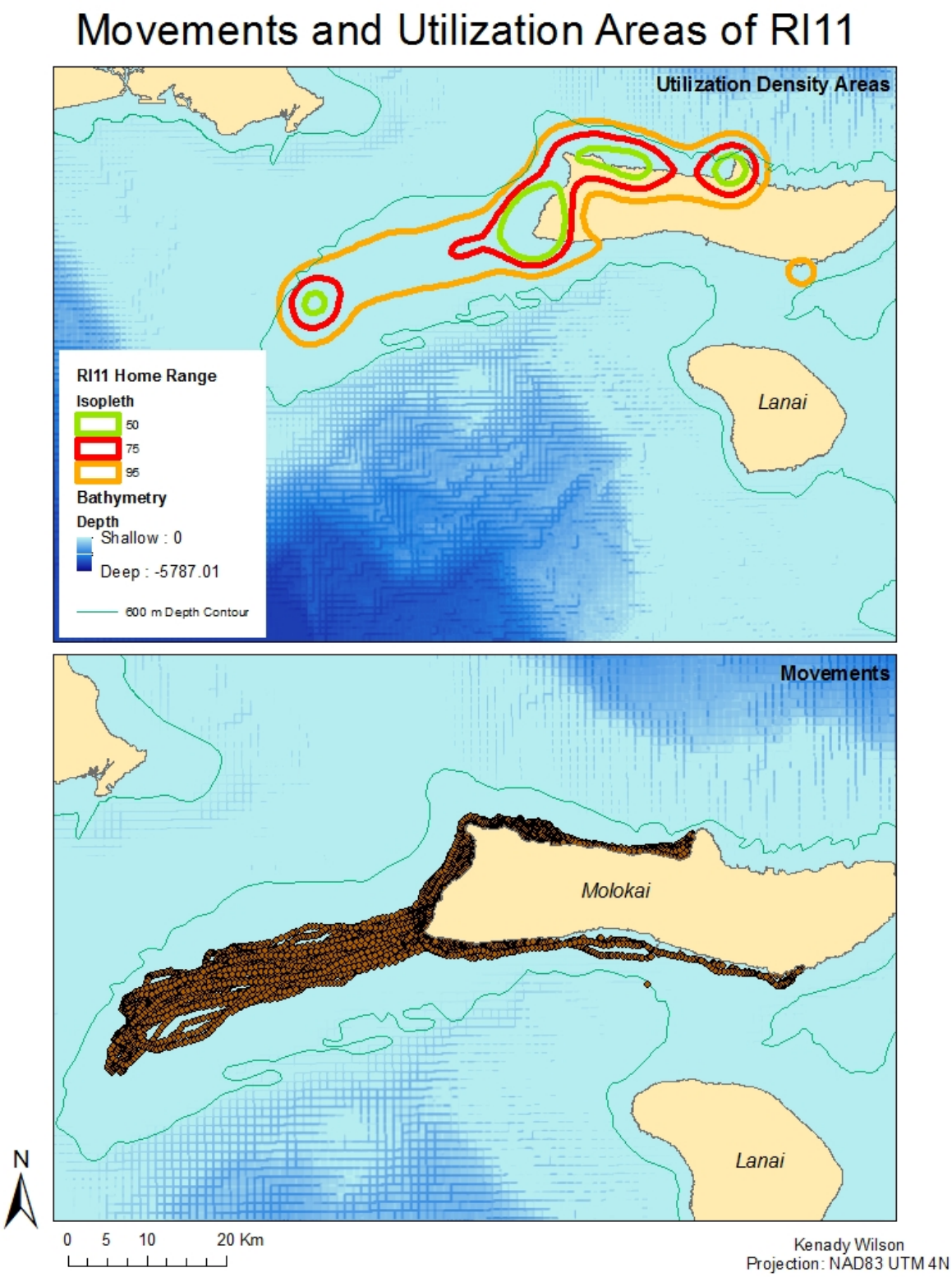

Figure 13. Map of RI11 overall movements and home range areas from March - October 2010.

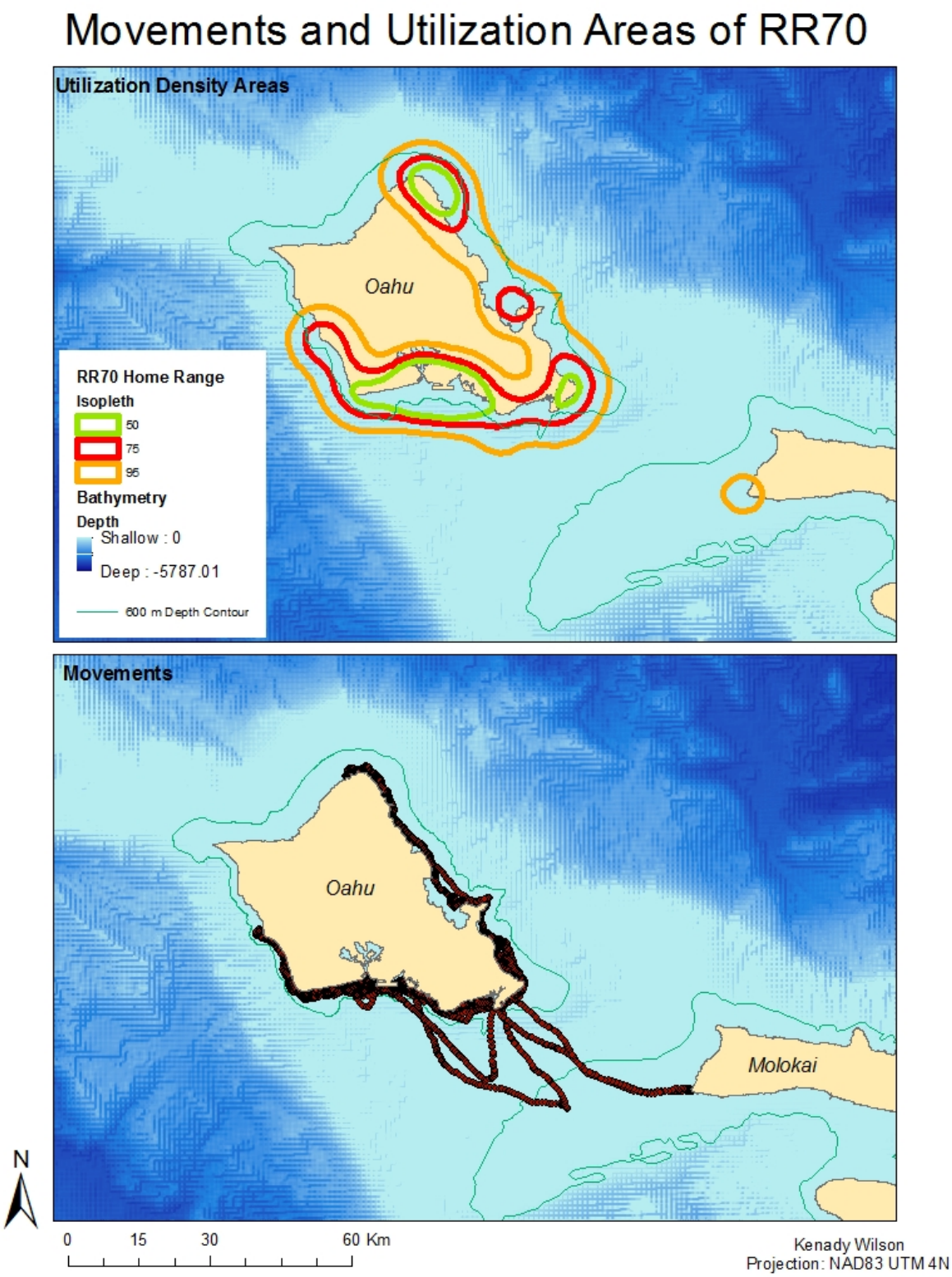

Figure 14. Map of RR70 overall movements and home range areas from June - August 2010.

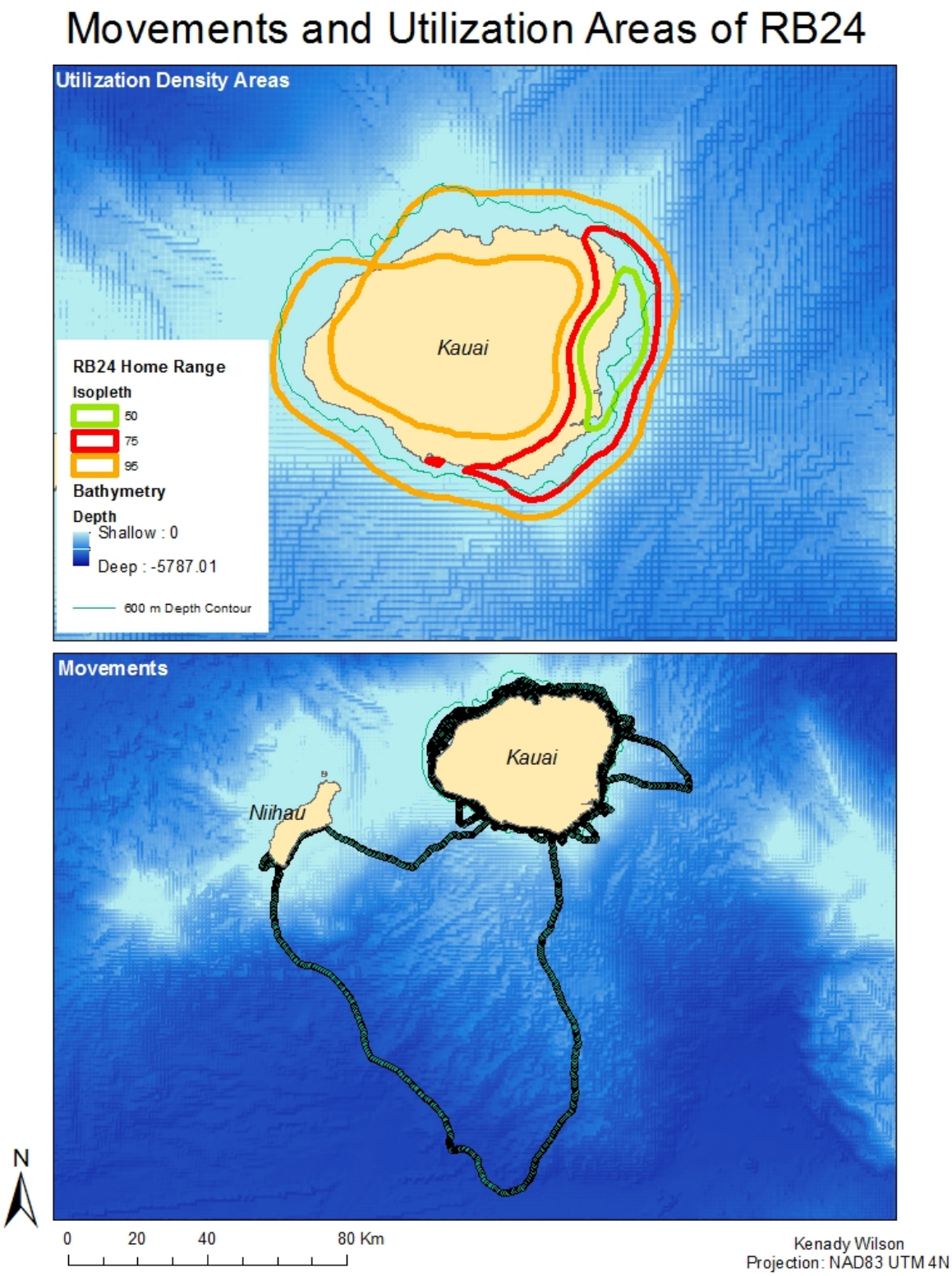

Figure 15. Map of RB24 overall movements and home range areas from January - July 2011.

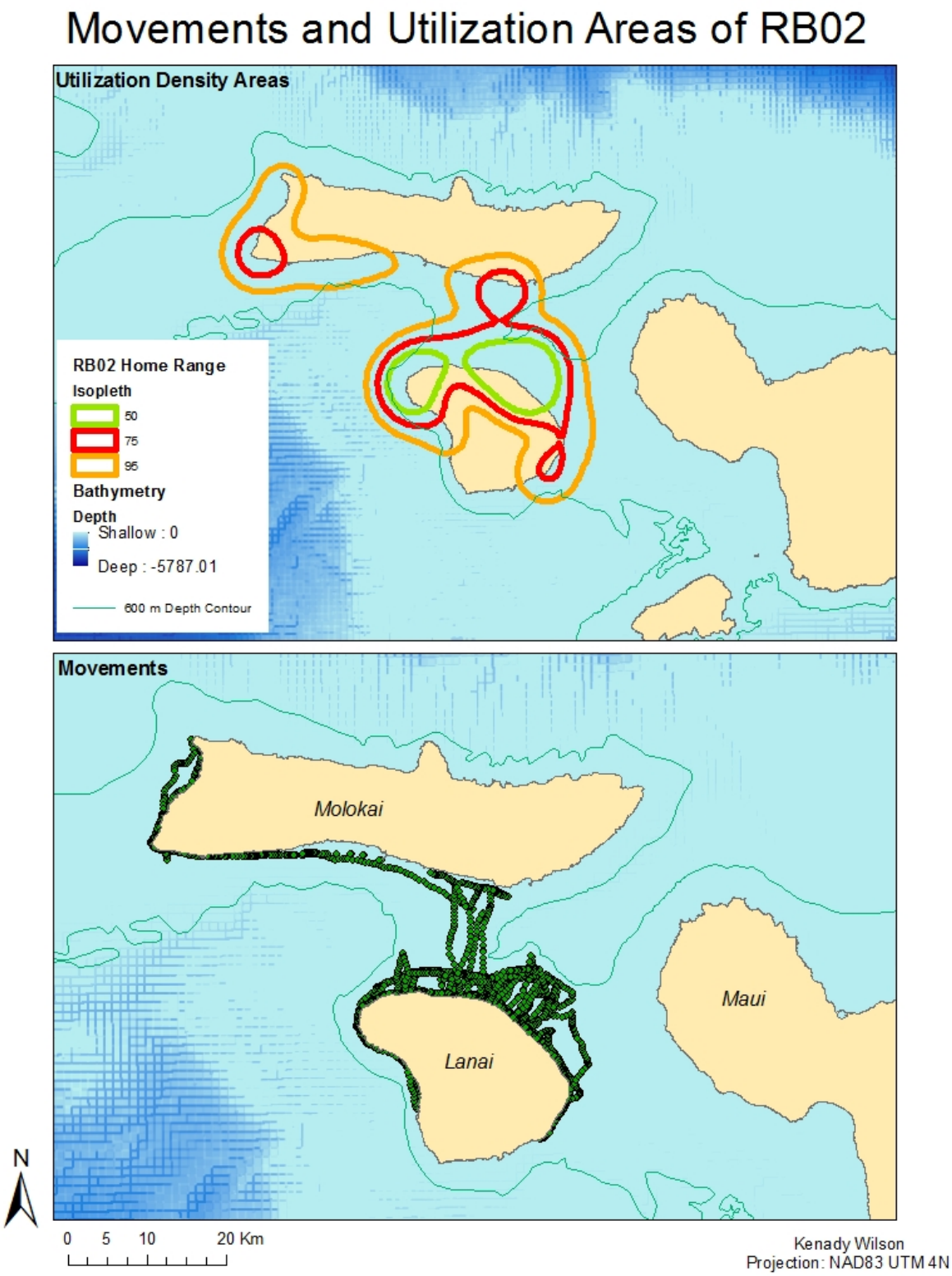

Figure 16. Map of RB02 overall movements and home range areas from June – July 2011.

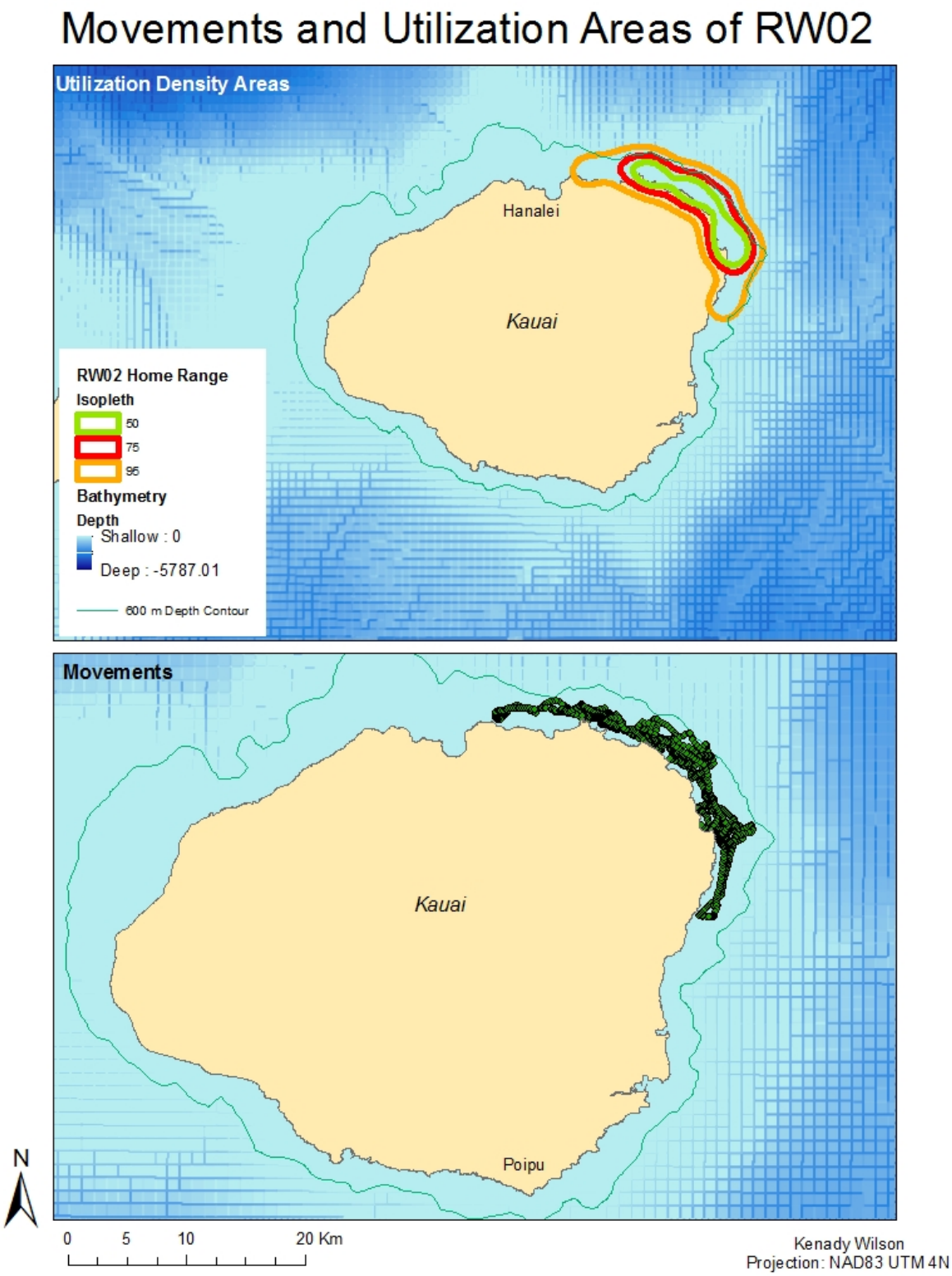

Figure 17. Preliminary map of RW02 movements and home range areas in July 2011.

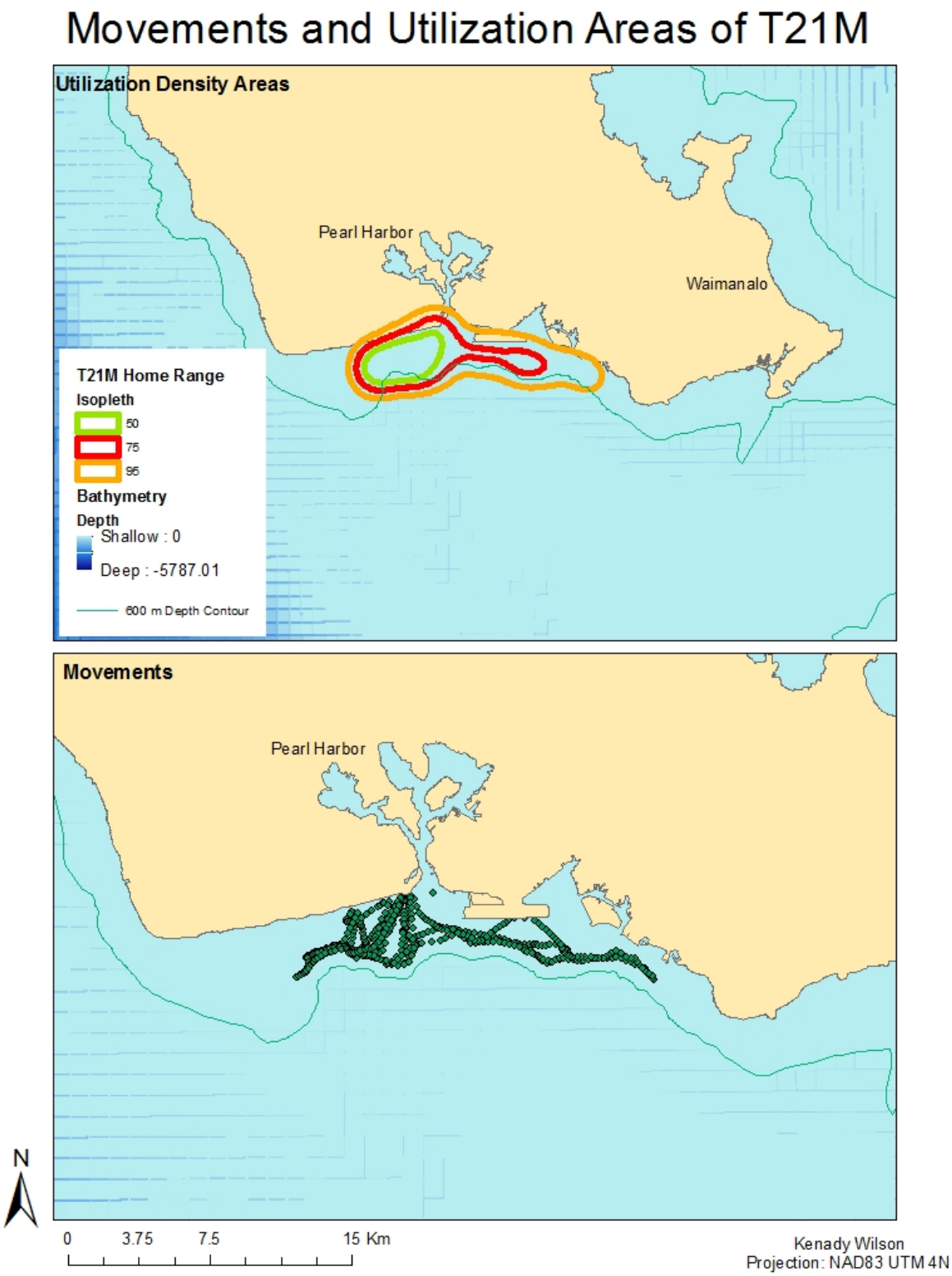

Figure 18. Preliminary map of T21M movements and home range areas in July 2011.

Core area sizes were similar between seals, while home range sizes were more variable (Table 3, Figure 19). The variable home range sizes are likely due to the increased area traveled by some animals (R4DF & RO18) and the pelagic foraging trip of R012.

Table 3. Utilization density estimates of home range (95%), core area (50%), and mid-level area (75%) sizes.

SealID	Age	Sex	# Locations Used	50% UD (km^2)	75% Area (km^2)	95% Area (km^2)
R012	A	M	19827	13708.65	60304.19	222038.5
R018	A	M	36945	4109.261	8782.538	22708.37
R4DF	A	F	23849	7572.84	20486.52	62814.71
R4DI	S4	M	7711	303.7034	780.9517	2516.4
RB02	A	M	4797	206.0989	525.2296	1240.893
RB24	S4	F	30903	153.4154	468.8894	1540.636
RE70	A	M	6892	31.6168	67.35753	190.8463
RI11	A	M	25244	167.665	439.6378	1061.621
RR70	A	M	12052	328.2178	806.9396	1923.39
RW02	S3	M	1711	43.28034	87.26405	186.0164
T21M	A	M	831	18.05877	44.63046	97.45327

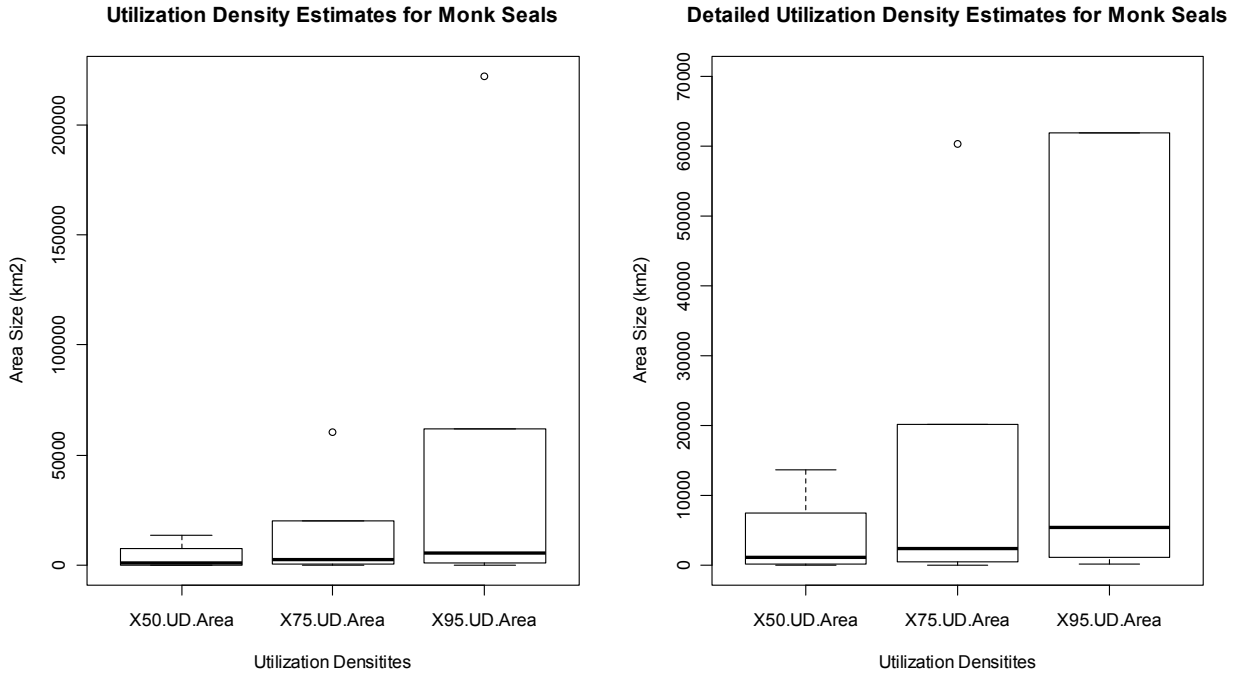

Figure 19. Fixed kernel density estimates for monk seal home ranges and core areas

In the future these home range calculations will be compared to the home ranges and core areas that are calculated via mechanistic home range models, which provide a more detailed understanding of animal movement and habitat use, by incorporating stochastic processes into the model.

Objective 3: Identify potential changes in monk seal behavior

Analyses to correlate monk seal behavior and Navy training activities in the MHI will begin once all tags have ceased transmission or been recovered. These analyses will include calculating the amount of time each seal spent within the HRC during tag deployment, and incorporating Navy activities into a mechanistic home range model of monk seal movement behavior and habitat use.

A meeting between researchers and Navy personnel to discuss data and analysis techniques is tentatively scheduled to occur in 2011.

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Appendix 1. Highlights of select foraging trips for seals tagged in 2010

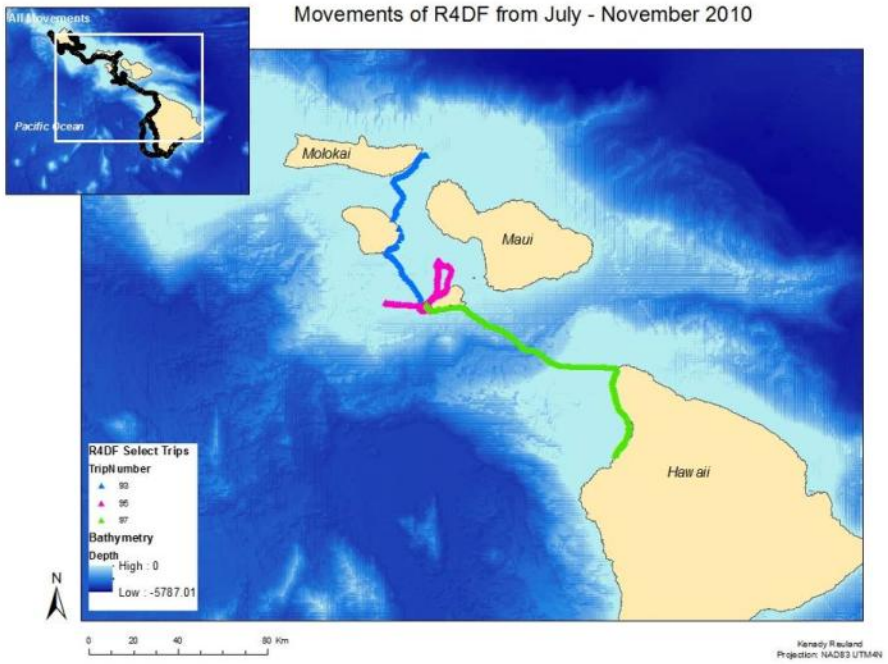

Figure 1. Map of R4DF overall movements with tracks highlighted for select foraging trips

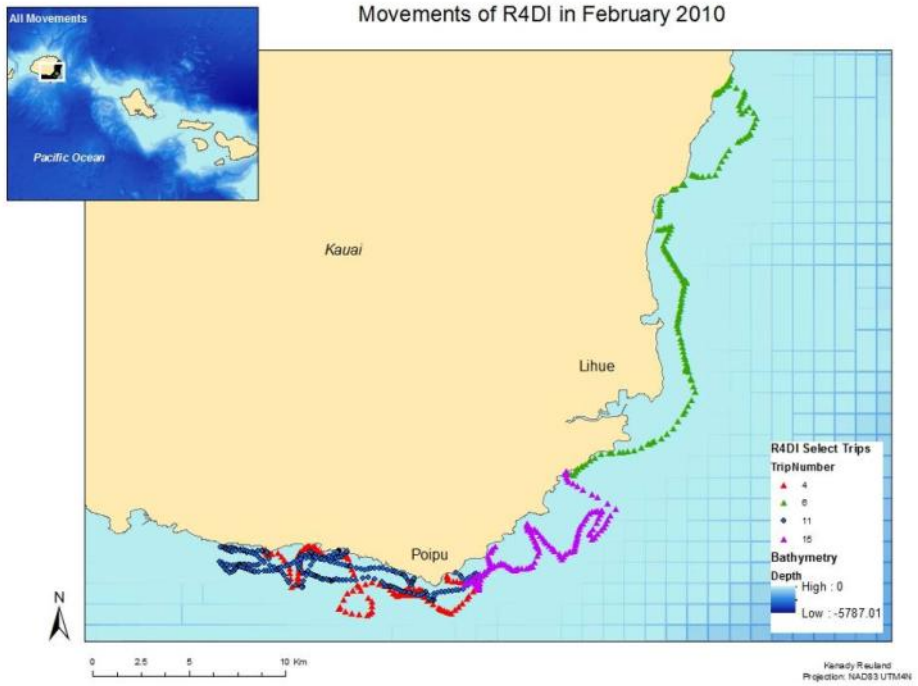

Figure 2. Map of R4DI overall movements with tracks highlighted for select foraging trips

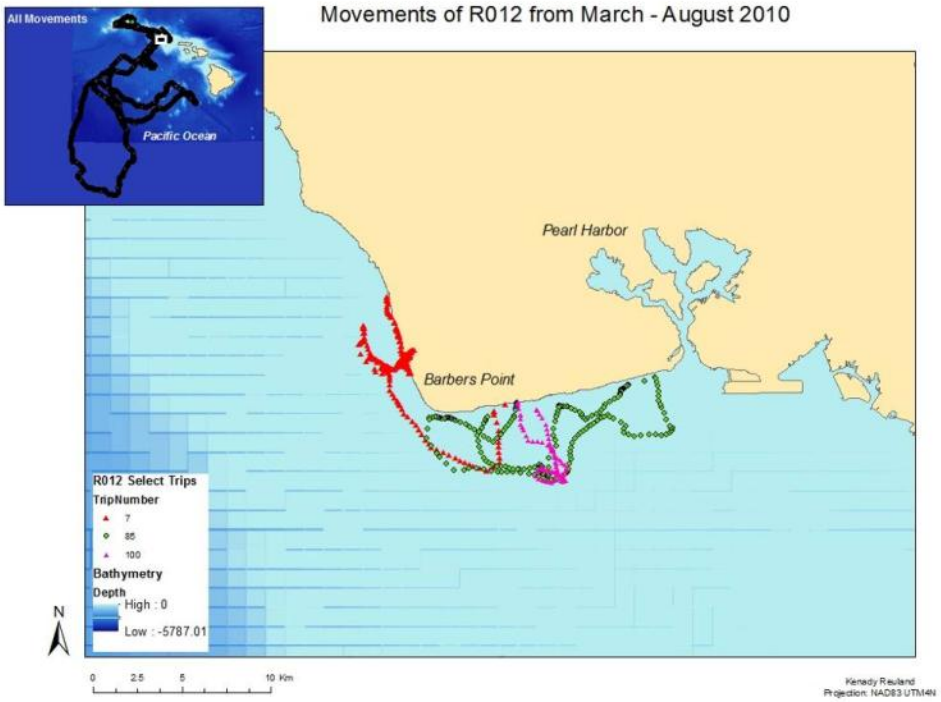

Figure 3. Map of R012 overall movements with tracks highlighted for select foraging trips

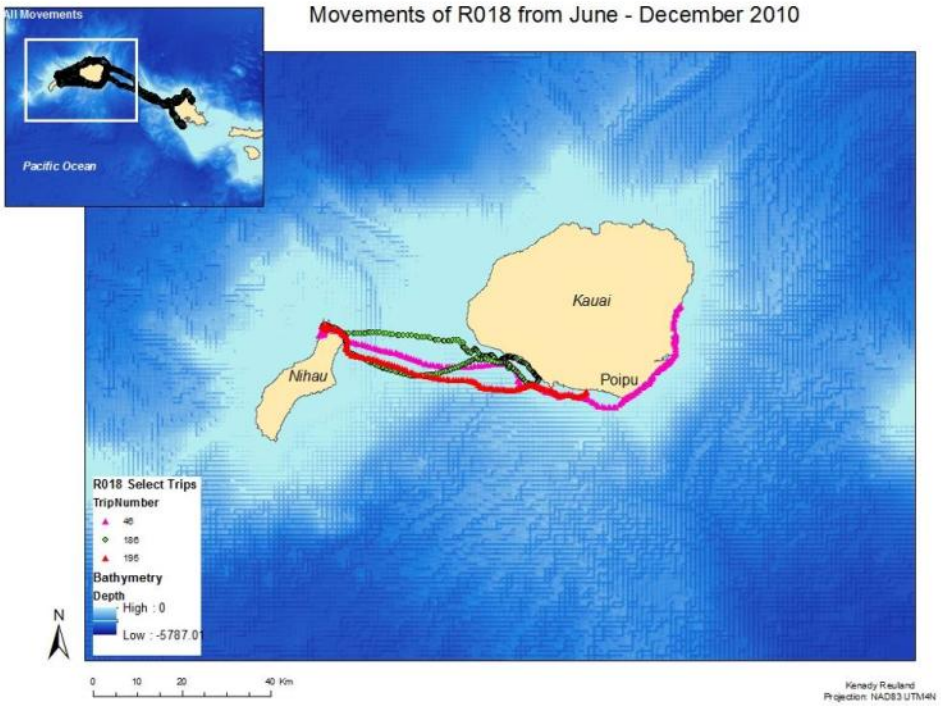

Figure 4. Map of R018 overall movements with tracks highlighted for select foraging trips

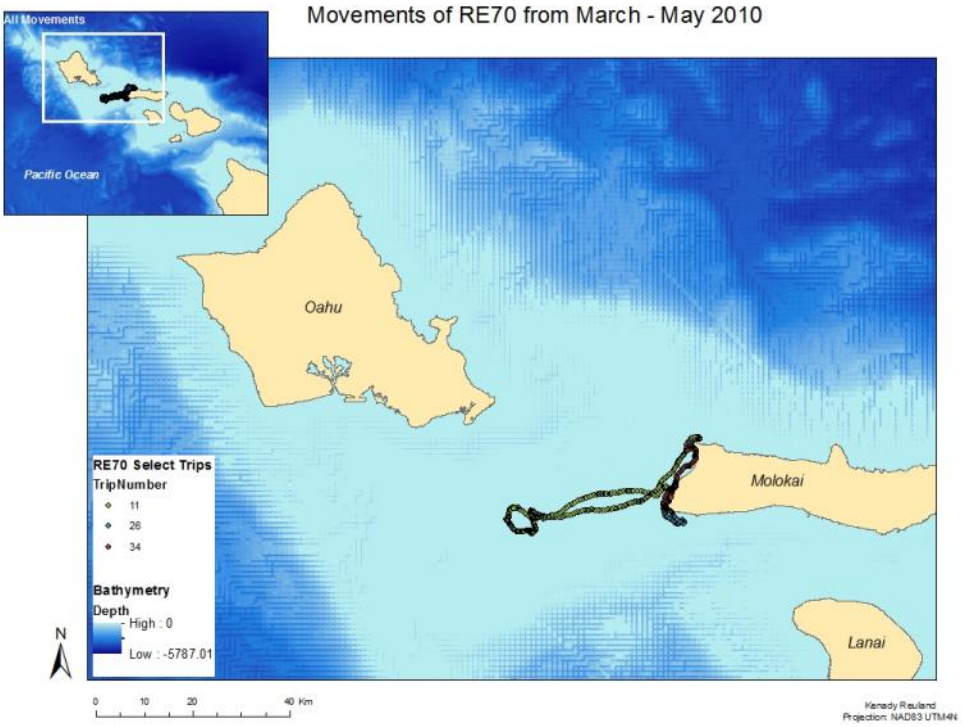

Figure 5. Map of RE70 overall movements with tracks highlighted for select foraging trips

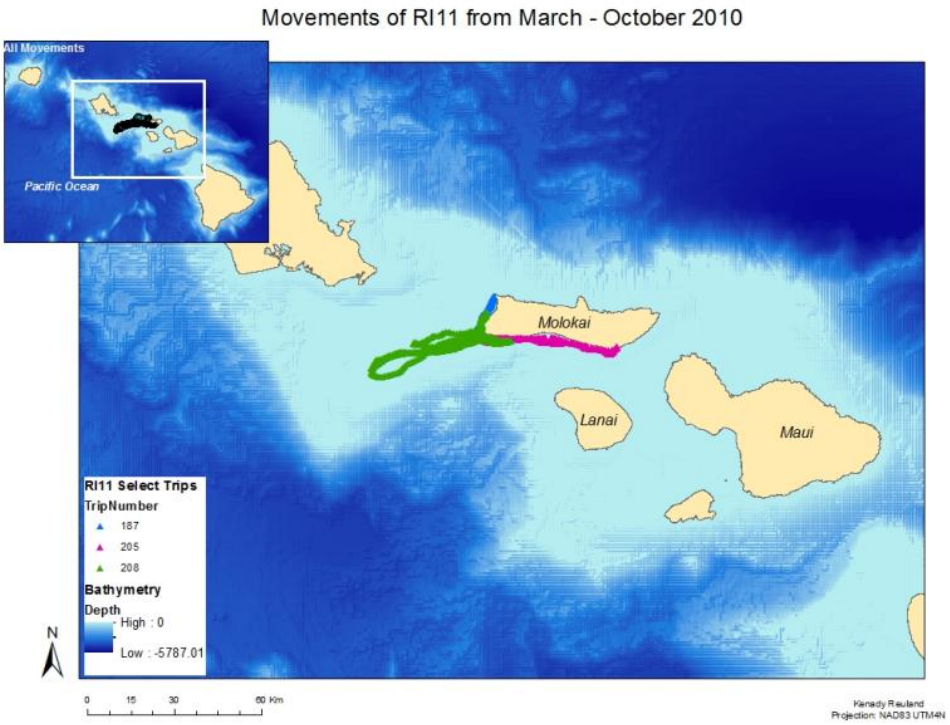

Figure 6. Map of RI11 overall movements with tracks highlighted for select foraging trips

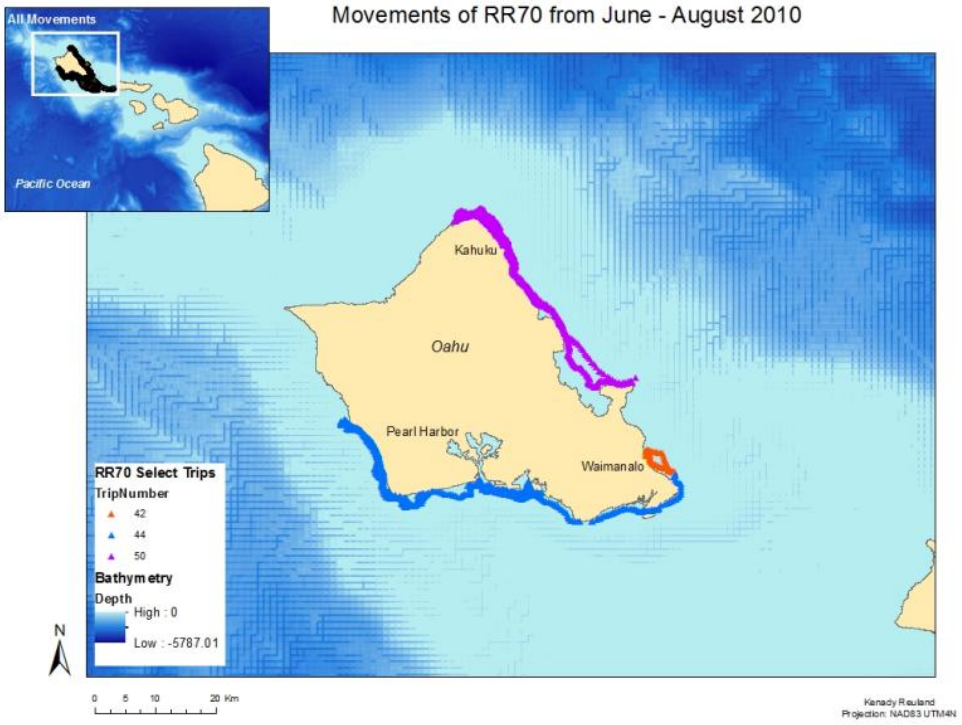

Figure 7. Map of RR70 overall movements with tracks highlighted for select foraging trips