Land and marine areas used by female New Zealand sea lions/pakake in The Catlins/Te Akau Tai Toka in winter 2022

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EXECUTIVE SUMMARY

A small breeding population of New Zealand sea lions/pakake/whakahao (NZSL) has been recolonising The Catlins/Te Akau Tai Toka since 2007, in a human-modified landscape. Interactions with vehicles (accidents and disturbance) are a known risk. There are also concerns for interactions with fishing gear and recreational boating. Detailed understanding of the land and marine habitat uses of the Catlins female NZSL is needed to manage and mitigate these risks. From June to August 2022, five adult female NZSL were instrumented with fastloc-GPS satellite tags, and one juvenile female with a GPS logger, in The Catlins. This was a follow-up on a previous tracking study in 2019. The tags recorded land and marine locations and dive depths of these animals for up to 80 days each with a high location accuracy (~20 m). This report presents the analyses of the data from the 2022 tracking project and the results most relevant to management, and provides recommendations for achieving the goals of the NZSL Threat Management Plan and for future research.

Adult female NZSL spent on average 48% of their time on land. During periods on land, they used between nine and 18 land sites each between the Clutha River/Mata-au Mouth and Wallace Head, with a concentration of sites from Campbell Point/Taumatakōtare/Ōwaea to Jacks Bay/Ōtemakura. Each female had one site each where they spent more time than any other (29-55% of their time onshore). Surat Bay was overall the most used beach (33% of time on land across all females). Female NZSL spent on average 20% of their time on land within 20 m of a road, primarily along The Nuggets Road. They spent on average 77% of time on land at beaches with vehicle access, notably Surat Bay and Cannibal Bay/Ōrakiutuhia.

Adult female NZSL foraged almost exclusively within 300 m from land on shallow rocky reefs (79% of marine locations). The core foraging range (65% Kernel density) was a small area around the tip of Tokatā/ Nugget Point (known as 'The Nuggets'). The rest of the foraging range was concentrated in discreet areas all along the coast from Campbell Point to Jacks Bay, but did not include estuaries, other than the mouth of the Catlins River/Pounawea Estuary. This estuary was used regularly but for very short periods (overall <2% of their time at sea) by females to travel to and from land sites. The mean dive depth was 10.5 m, with 97% of all dives < 30 m depth; 69% of the dives were benthic. The deeper dives were in the 'offshore area', considered a part of their foraging range but seldom used in winter, at depths of 40-70 m about 4-13 km off Nugget Point.

There were only 3.5 days of data (only land locations and dives) from the juvenile female (1.5 year-old) due to tag malfunction. She used land sites along Kaka Point Road and The Nuggets Road, crossing the road at Campbell Point. Her diving behaviour was very different from any of the adults i.e. exclusively diving at night, continuously and at constant depth (i.e. not on rocky reefs).

Comparisons with the results of a previous 2019 winter tracking of female NZSL in The Catlins were only qualitative due to the difference in accuracy of locations (ARGOS locations vs fastloc-GPS locations). The diving behaviours in 2019 were within the range of the 2022 study. Adult female NZSL used the same general areas for foraging and as land sites but there might be differences in core foraging range between 2019 and 2022. Some land locations are specific to individuals and therefore, there were differences because different females were studied (one adult female was studied in both years and used similar sites in 2019 and 2022).

Recommendations for management included (1) for land sites with risks from vehicles, speed reduction for key coastal roads, 'safe zone' investigation, better signage, education, fences, and warning systems, (2) recreational fisher surveys to determine interactions at sea in coastal areas, and (3) for Catlins River Estuary, assessing boat speed limits, education, set net regulations. Future science needs identified were (1) year-round land habitat use (using existing data, future resights and structured studies), (2) year-round diet (proxy for seasonal changes in foraging range), (3) fishery overlap analyses (recreational and commercial), and (4) marine habitat use outside winter and marine habitat use of yearlings.

CONTENT

1. INTRODUCTION

New Zealand sea lions/pakake/whakahao, *Phocarctos hookeri*, historically bred throughout most of the coastline of New Zealand (Childerhouse & Gales, 1998; Collins et al., 2014). Remnant breeding colonies persisted in the sub-Antarctic islands of New Zealand after extirpation of the species from the rest of New Zealand. Since the 1990s, the species has been recolonising its historical breeding range on Stewart Island/ Rakiura (recently declared a breeding colony; Chilvers, 2018), and on the South Island at sites along the Otago Peninsula/Muaūpoko and, more recently, in The Catlins/Te Akau Tai Toka (Augé, 2011; Frans *et al*., 2022; McConkey *et al*., 2002; Figure 1). The recolonisation of the South Island sites is occurring in a human-modified landscape. This has generated risks for sea lions and a need for management to ensure that these mainland populations successfully grow and become breeding colonies. Facilitating population growth on the South Island/Te Waipounamu is one of the goals of the New Zealand sea lion Threat Management Plan (TMP) 2017-2022[1].

In 2007, the first recorded New Zealand sea lion pup was born in The Catlins since extirpation of the species. Similar to what happened at the Otago Peninsula, an adult female originally tagged at the Auckland Islands/Motu Maha, pupped in The Catlins. Thereafter, she and her female offspring kept breeding there. The return of the sea lions to the Catlins coast creates risks for sea lions interacting with humans on land (e.g. coastal roads, vehicles on beaches) and at sea (e.g. fishing gear and recreational boating in estuaries). In 2019, an initial study satellite-tracked four female New Zealand sea lions in The Catlins (Reed *et a*l., 2023; Reed, 2021). This report presents the results of a follow-up study conducted in 2022 where a different tracking technology was used, with improved location accuracy. The aim of the study was to provide results that could guide management of the Catlins New Zealand sea lion population to mitigate risks from human interactions.

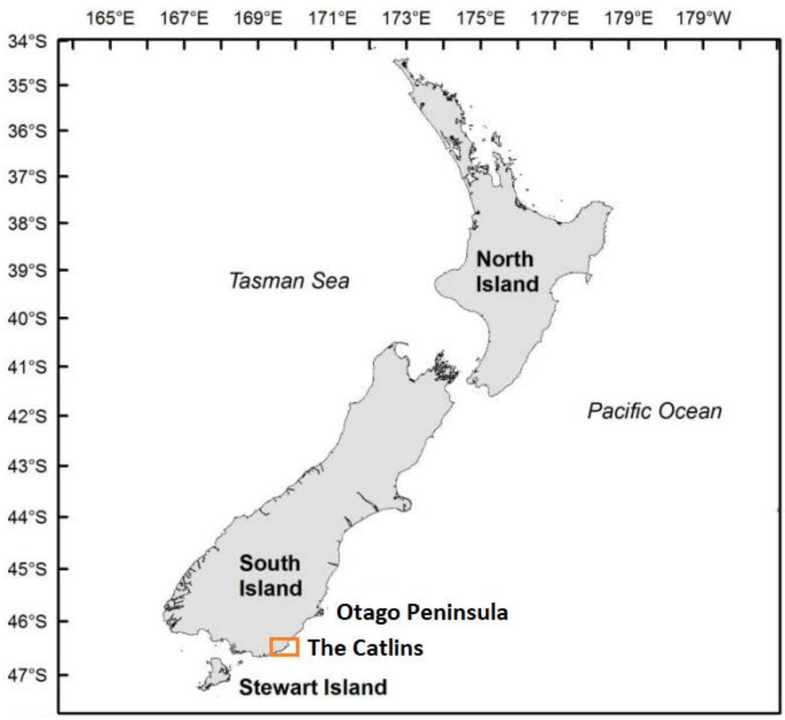

Figure 1. Locations where New Zealand sea lions currently breed on the mainland (Otago Peninsula, Catlins, Stewart Island). Orange: the extent of The Catlins coast covered in this study.

[1] https://www.doc.govt.nz/nature/native-animals/marine-mammals/seals/new-zealand-sea-lion/new-zealand-sea-lion-rapoka-threat-management-plan/

In June 2022, a field team led by Simon Childerhouse (Cawthron Institute) and Micah Jensen (Wild Vet Care) was contracted by the Department of Conservation (DOC) to deploy and recover tracking instruments on female New Zealand sea lions in The Catlins. The instruments were retrieved in August 2022. For the purpose of this report, the data obtained from the instruments were provided in their raw format, along with field reports and records of instrument settings, for analyses as part of the analysis contract. The scope of the analysis contract was to 1) clean, describe and submit the data and metadata from the 2019 and 2022 studies for upload to the DOC Marine Data Portal[2], 2) analyse and interpret the GPS tracking and dive data in the context of the goal of the New Zealand sea lion Threat Management Plan to facilitate growth of the New Zealand sea lion population, and 3) Include recommendations for DOC, Te Rūnanga o Ngāi Tahu, Fisheries New Zealand and local government to manage threats to the animals on land and at sea.

2. METHODOLOGY

2.1 Study area and field work

The Catlins coast is remote and rugged. There are a few small settlements and roads dotted along the coast. Coastal land use is primarily farmland. The coastline is indented and alternates rocky shores, sandy beaches and cliffs, with several large estuaries and numerous headlands (Figure 2). Shallow rocky reefs (<30 m) are common marine habitat along the coastlines. The continental shelf extends out to approximately 30 km. The bathymetry slowly dips from 0 to 30 m in the coastal area within 500 m to 1 km from shore, and to 40-50 m depth within 5 km from shore. There is a large shallow bay (Molyneux Bay) north of Nugget Point/Tokatā where depths remain below 20 m up to 15 km from shore.

The field team captured seven New Zealand sea lions (five adult females, one juvenile female and one pup) in The Catlins in early June 2022 to fit them with tracking instruments (Table 2). The total estimated number of live adult and juvenile New Zealand sea lion females in the Catlins population at the time of the study was 10 and 9, respectively. Captures and instrumentation followed the same well-established protocols and used the same specially-designed catching gear as in previous tracking studies (Augé *et al.*, 2011b; Chilvers *et al*., 2005; Gales & Mattlin, 1998; Reed *et al*., 2023). The fieldwork was undertaken under DOC Animal Ethics Protocol AEC 391 as DOC-led research for management. The fieldwork, captures and gear used were described in full detail in a fieldwork report and a veterinary report prepared by Simon Childerhouse and Micah Jensen[3], respectively.

In summary, team members searched for animals at known sites and a team member observed the animal for a minimum of three hours before capture took place. The animal was caught in a specially-designed hoop net with several team members restraining the animal while the veterinarian placed a mask delivering the anaesthetic (isoflurane). The animal was then restrained on a stretcher for safety and taking measurements. All captures proceeded without incident and animals were anaesthetised for circa 20 minutes (range 19-26 minutes; one animal was kept under anaesthesia for 40 minutes due to an unrelated medical examination) and all recovered fully within 20 minutes. Tags were glued onto patches of 7 mm neoprene prior to the captures. The neoprene patches were glued onto the fur along the ridge of the back of the sea lions using Devcon 5-minute epoxy glue (ITW Performance Polymers, Massachusetts, USA) (Figure 3). All captured females were known to be from the Catlins population (i.e. were born and tagged as pups in The Catlins), with the exception of the female named "Unknown", that was an unmarked female of unknown origin.

[2] https://doc-marine-data-deptconservation.hub.arcgis.com/

[3] These reports are available on request to marinemammals@doc.govt.nz

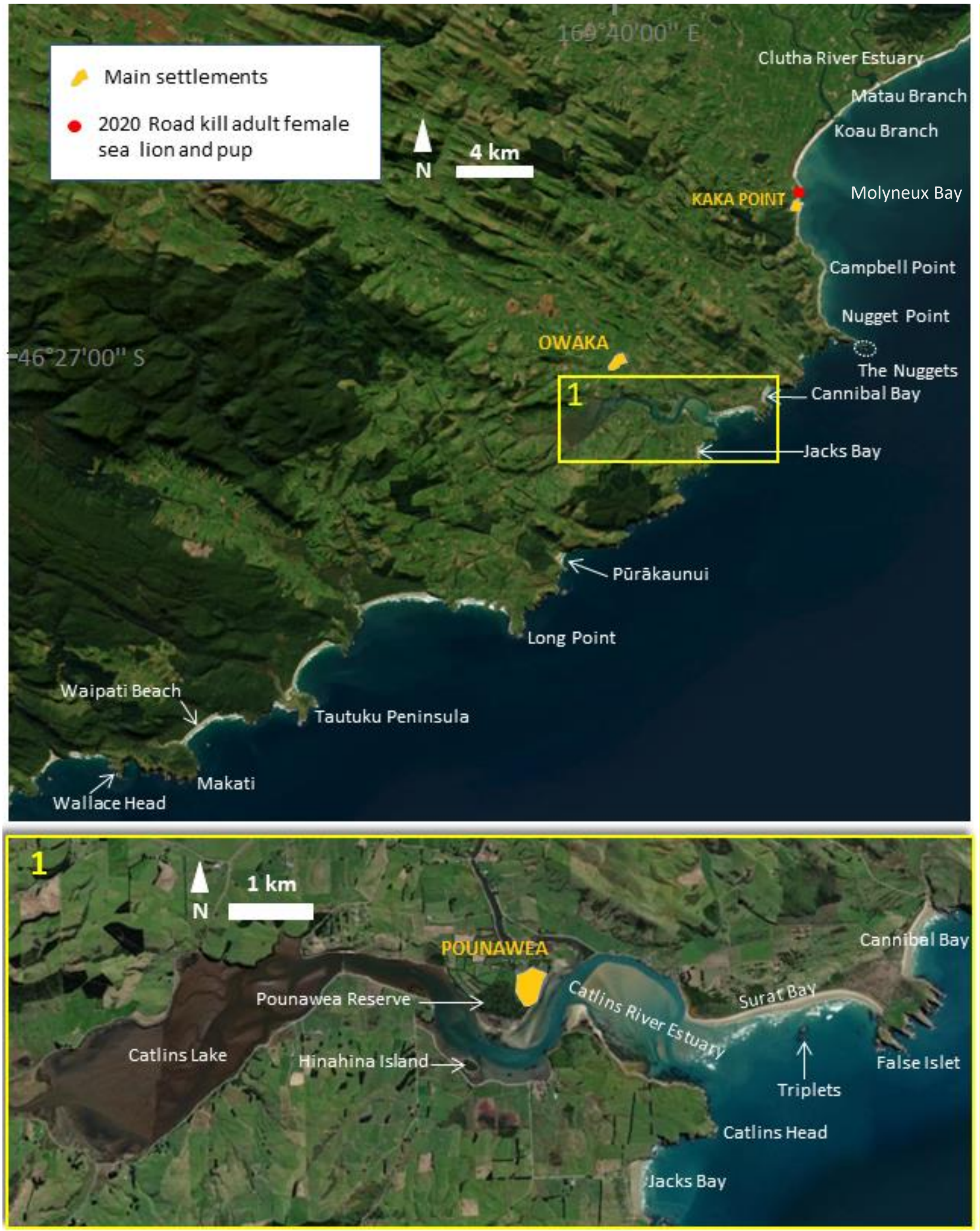

Figure 2. Map of the study area in The Catlins with key sites, main settlements, and location of a road kill of two female New Zealand sea lions (one adult and one pup) in 2020.

Table 2. Summary of New Zealand sea lion captures and tag deployments in this study. For microchips: Jade and P446 are Trovan Unique-ID, all others are Trovan FDX-B ID-162C.

ID Name	Jade	Kiwa	P446	P447	Unknown*	Susie	Jade's pup (male)
Age (years)	6	15	6	6	Not known	1.5	0.5
Flipper tags	P449	3452 (lost)	P446	P447 (lost)	Never had	XGET	VETH
Microchip #	00076900C7	9560000116 58007	0770EA5B	0007710B79	9560000116 52712	9560000115 54037	9560000116 63553
Tracking tag PTT-ID	SPLASH10 21A0049 220948	SPLASH10 21A0284 220953	SPLASH10 21A0289 220952	SPLASH10 21A0286 220950	SPLASH10 21A0074 220949	Axy-Trek KIM1 /	Axy-Trek KIM2 /
Tag on	1/06/22	2/06/22	1/06/22	1/06/22	4/06/22	4/06/22	5/06/22
Location	Hinahina Island	Surat Bay	Cannibal Bay	Hinahina Island	Surat Bay	28 The Nuggets Rd	Pounawea Reserve
Weight (kg)	116.0	134.5	110.0	128.0	106.2	57.0	Not taken
Length (cm)	192	191	Not taken	184	177	139	128
Girth (cm)	118	123	Not taken	122	116	83	83
Tag off	20/08/22	15/08/22	13/07/22	20/08/22	21/08/22	17/07/22	17/07/22
# days	80	74	41	79	77	40	41
Notes	Nursing a pup	Tag fell off but was recovered on land**	Tag fell off and was lost	Nursing a pup	Microchip inserted on 4/6/22	Only 3.5 days of data available (malfunction)	Data not available (malfunction)

** Unknown is a female that was never flipper-tagged (no tag loss, rip or hole) and was not microchipped at time of capture (she was microchipped during the fieldwork); it is not known which population she is from. She travelled between The Catlins and Otago twice during the study and was re-captured on the Otago Peninsula for retrieval of tags.*
***The tag was picked up by a member of the public at Roaring Bay where it had fallen off from the sea lion on land, and later recovered thanks to the location transmitted via ARGOS after 8 days indicating it was at a private residence. The DOC ranger went to enquire at that location and recovered the tag.*

Figure 3: Attachment locations of the SPLASH tag (left) and VHF tag (right). The Axy-Trek tags were placed at a similar location as the SPLASH tags. Photo credit: Field team/Ros Cole.

The instruments deployed on the five adult females were Wildlife Computers SPLASH10-F-296 tags[4] (210 g, 85 x 85 x 27 mm). These tags are data-archiving ARGOS satellite transmitting tags with fastloc-GPS technology and Time-Depth Records (TDR). This tag does not obtain and store GPS locations but a series of information from the satellites that it can pick up quickly when the tag surfaces (called 'snapshots') which are later used to compute the GPS locations during post-processing of the data. The tags acquired fastloc-GPS snapshots that were stored in the tag and regularly transmitted via ARGOS. Any GPS locations that had an accuracy index (number of satellites) of < 4 was not computed by the tag as accuracy was too low (Baylis *et al.*, 2018). The SPLASH tags also recorded ARGOS locations and those were available. However, ARGOS locations were not used for the analyses due to their poor accuracy (approximately 1-3 kms on average at best after filtering) compared to the fastloc-GPS locations that have approximately 20 m accuracy on average.

The settings of the SPLASH tags were set by the field team with guidance from Wildlife Computers (see Appendix 1 for all settings); all tags had the same settings. In summary, the SPLASH tags were set to acquire and store fastloc-GPS snapshots to be able to get a GPS location every hour when the female was at sea and on land (but a location every 8 days if the tag was dry for longer than 48 hours). The TDR was set to record 1 depth reading every 10 seconds.

One male pup and one juvenile female were caught and instrumented with Technosmart Axy-Trek Marine HD tags[5] (45 g, 65 x 40 x 15 mm). These were to be deployed on pups but the yearling female was deemed too small to be instrumented with a SPLASH tag. These tags collect the same information as SPLASH tags, store GPS and TDR data but do not transmit; therefore, they need to be recovered to obtain the data. The two tags were recovered successfully. Settings for these tags were not available.

Each studied sea lion was also instrumented with a VHF tag placed behind the tracking tag on the lower back of the animal (Figure 3). This VHF tag was used to locate individuals for regular checks during instrumentation and for re-capture to remove the tags. The ARGOS-transmitted GPS location information and the VHF transmitters were used to locate and visually check on the tags once a week after the first 3 weeks. Verified locations, observed behaviours and the state of the tag attachment were recorded in field reports. The information in these reports is summarised in Appendix 2. This information was used for the analyses by providing ground-truthing to confirm tracking data (terrestrial habitat use) and, for nursing females, the location of their pups.

2.2 Data preparation – Time-Depth records

The raw dive data from the SPLASH tags was included in the Wildlife Computers files (.wch) provided for each female. The software HexDecode.2.02.0030 (Wildlife Computers) was then used to convert the files into comma-delimited text files (.csv). First, the UTC times were transformed to New Zealand local times. The .csv files were then formatted to the appropriate sequence of columns (local date / local time / depth). The raw data from the Axy-Trek tags were downloaded using XManager and converted to .csv files.

All analyses of dive data were conducted using R 4.2.2 (R Core Team, 2022) and R studio (RStudio Team, 2020). Raw dive data were calibrated, corrected and analysed using the R package diveMove version 1.6.1. (Luque, 2007) and functions *createTDR, calibrateDepth, diveStats, plotTDR* and *timeBudget*. For the data from the SPLASH tags, the data from column 'Dry' was used to manually offset any error of surface values (Dry=1 means that the tag was out of the water and, therefore, all

[4] https://wildlifecomputers.com/qr/splash10-f-296/
[5] https://www.technosmart.eu/axy-trek-marine-1000/

depths at corresponding times were set to 0 m). The depth threshold for dive calibration was set to 3 m. Therefore, any dive for which the maximal depth was less than 3 m was not considered as a dive but associated with travelling, resting at sea, or inaccuracy errors. These parameters were the same as used in Augé *et al*. (2011a) and Reed *et al*. (2023).

The *diveStats* function produced a table with summary statistics for each individual dive, including maximum depth reached, dive duration and bottom time. The *timeBudget* function produced a table with start and end times of each dry and wet periods, hereafter called land and marine periods.

2.3 Data preparation – GPS locations

The fastloc-GPS snapshots from the SPLASH tags were post-processed in the Wildlife Computers Portal to obtain fastloc-GPS locations using the processor 'Fastloc GPS Solver'.

The dataset of fastloc-GPS locations (thereafter called locations) was cleaned to remove any outlier marine locations more than 50 km away from any other locations and any outlier land locations more than 10 km away from any other land locations. Manual filtering was then conducted on land locations, and any locations that were deemed unreachable from expert knowledge of the area (e.g. fences, habitat, cliffs etc) were removed.

Each fastloc-GPS location is associated with an accuracy index that is the number of satellites used to compute the location. The average accuracy index of the location dataset was 7.0 (Figure 4). Studies have shown that the median accuracy of fastloc-GPS locations obtained with 7 satellites is 14 m and 8 m with 10 satellites; for GPS locations obtained with 4 satellites, median accuracy decreases to 36 m (Dujon *et al.*, 2014). By assigning the median accuracy values from Dujon *et al.* (2014) to the accuracy indices, the estimated average location accuracy of the dataset was estimated at 17 m.

The limited location data available from the Axy-trek tag was plotted without any grooming or further analysis because it only covered 3.5 days and only land locations were recorded.

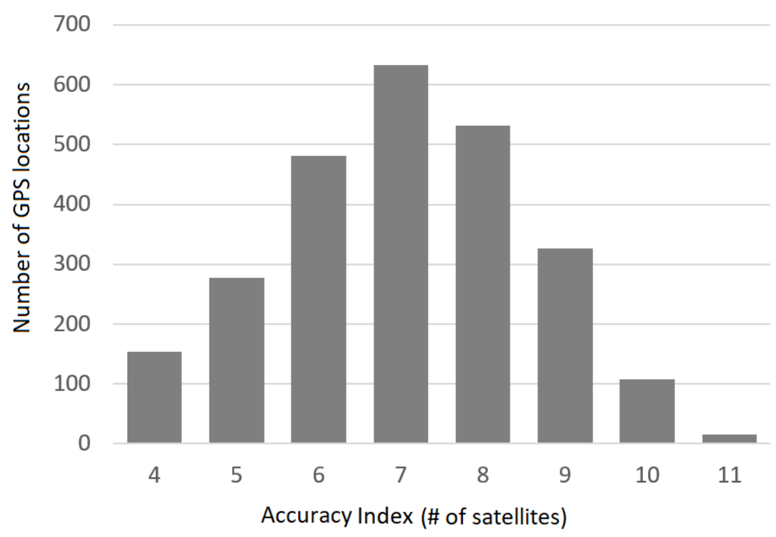

Figure 4*. Accuracy index of fastloc-GPS locations for five female New Zealand sea lions tracked in The Catlins during winter 2022 with SPLASH-10 tags.*

The start and end times of land and marine periods were used to classify each location as a land or a marine location. Locations close to coastlines (< 40 m) that were in the wrong habitat due to accuracy (e.g. a marine location on land) were then identified. This was done by selecting all locations in land area using the NZ Coastlines and Islands Polygons (Topo 1:500k) dataset from the National Topographic Office of LINZ[6] (the coastlines in this dataset were first manually improved for coastline accuracy using Google Earth imagery). If inspection indicated a location was over a marine area when it was a land location, or vice versa, then the location was manually moved to the closest site on land or at sea, or deleted if it was > 40 m from the shoreline.

One of the animals tracked during winter 2022 (microchip #956000011652712, called Unknown in this report) moved to the Otago Peninsula during the study. All locations and corresponding dive data that were part of the route to and from Otago and during the time she spent around the Otago Peninsula were separated from the rest of the dataset and analysed separately. The aim of this report was to look at habitat use in The Catlins. The Otago data were analysed and are reported separately and succinctly in this report, for information and for the purpose of comparison with Catlins data.

2.4 Land use analyses

2.4.1 Sites used

The total land area used by each individual sea lion during the study was calculated by applying a 20 m buffer to the dataset of their land locations. This constituted the land home range. The 20 m buffer allowed to account for accuracy of the locations and minimal movements of the animals. A land home range was mapped, and its area calculated, for the studied population overall and for each of the studied sea lions.

The land locations and the duration of the periods on land associated with those locations were used to calculate where and how long each sea lion spent onshore. The dive data were first analysed with the R package diveMove version 1.6.1. function *timeBudget* (Luque, 2007) to extract the amount of time for each land period. This function processed the dive summary statistics to extract the start and end times of each period onshore. The 'dry threshold' was set to 10 minutes. This means that if the tag was dry for less than 10 minutes, it was not considered as a land period but a short break during a marine period (either on land or at sea). The length of land periods for P446 were estimated from the proportions of land locations only as there was no dive data available. Therefore, the results of land use for P446 were not included in the overall means or the statistical analyses for comparisons.

One key land location was attributed to each period on land. Key land locations were described as the centroid of a discreet agglomeration of land locations within an area of diameter 250 m, across all the studied sea lions. If the agglomeration was larger than 250 m wide, several centroids 250 m apart from each other were created. Total time spent at each key land location was calculated for each and all studied sea lions using the length of land periods, previously calculated. Corresponding percentages of time spent at each key land location compared to the total amount of time spent on land were also calculated. Finally, the amount of time spent by each sea lion at each key land site was mapped, providing a visualisation of where and how much time each sea lion spent on land along the coast.

[6] https://data.linz.govt.nz/layer/51560-nz-coastlines-and-islands-polygons-topo-1500k/

2.4.2 Human interactions

The risk of interactions with vehicles on roads during periods on land was estimated by determining the amount and proportion of time each animal spent at key land sites where the land home range overlapped with a 20 m buffer around a formed road (sealed and unsealed) but excluding any off-road tracks such as tracks across farmland or access beach tracks through the dunes. The risk of interactions with vehicles on beaches was estimated by determining the amount and proportion of time each animal spent at beaches (in dunes and on sand) that are accessible to and known to be used by vehicles.

Road data were obtained from the NZ Road Centrelines (Topo, 1:50k) dataset from the National Topographic Office of LINZ[7]. A buffer of 4 m was applied to estimate the area of each road. The percentage of time that an individual sea lion spent at key land locations that overlapped with roads or were within 20 m of a road was then calculated to assess individual risks of interactions with roads.

The use of vehicles on beaches was assessed from literature search, evidence of vehicle use from satellite imagery and local knowledge from DOC rangers. Vehicles driven on beaches include cars, 4WD trucks, quads, motorbikes and tractors for recreational purposes (e.g. vehicle enthusiasts, dog walking from car) or for launching boats.

The recent Vehicles on Beaches Bylaw[8] of the Clutha District Council (effective since January 2023), prohibits driving in sand dunes, expect to access the beach. Therefore, the proportion of time that each animal spent on sand versus in dunes at each beach was also estimated. All land locations were plotted over satellite imagery (Google Earth) and locations over sand were manually selected. The proportion of time each animal spent on the sand was estimated from the number of locations compared to the total number of locations at the beach over the study. However, this is only an estimate due to the location accuracy and the narrow width of beaches. Therefore, these values are the best available estimates but are given for indicative purpose only.

2.5 Marine use analyses

2.5.1 Dive analyses

Means and standard deviations (±) for diving parameters were calculated for each animal from the statistics summary of individual dives produced with the function *diveStats* of the R package *diveMove* version 1.6.1. (Luque, 2007). These parameters were 'depth' for each dive (the maximum depth reached during that dive), 'duration' for each dive (time spent below 3 m depth) and the 'bottom time' (time spent at depths within 80% of the maximal depth of the dive, e.g. if maximum depth was 60 m, the bottom time was the continuous time spent under 48 m deep). The proportion of bottom time was then calculated and a dive was classified as most likely benthic if the bottom time was > 30% of the total time of the dive.

The timing of diving activity during the day was investigated using the start time of each individual dive for each animal by (1) plotting the depth versus time of day and (2) calculating the proportion of dives during daytime versus nighttime. The daylight hours used to investigate temporal characteristics of diving was set as per 1 July 2022, with approximate daylight from 7.30 am to 5.30 pm.

[7] https://data.linz.govt.nz/layer/50329-nz-road-centrelines-topo-150k/

[8] https://www.cluthadc.govt.nz/recreation/beaches

2.5.2 Location analyses

The dive data were used to calculate the number and duration of marine periods (i.e. foraging trips) using the start and end times of each marine period, previously computed with R package *diveMove* version 1.6.1. function *timeBudget* (Luque 2007). The 'dry threshold' was set to 10 minutes (i.e. if the tag was dry for less than 10 minutes, it was included in the same foraging trip). The 'wet threshold' was set to 2 hours. This means that a period at sea of less than 2 hours was not recorded as a separate foraging trip but integrated with the following trip. The number and duration of foraging trips were then calculated.

Kernel density (KD) estimates were used to identify and classify the marine areas used by the studied animals. The KD estimates were computed for cell size of 50 m and a search radius of 200 m in ArcGIS (ESRI, Redlands, California, USA). The core foraging ranges (the most intensely and repeatedly used areas) were calculated as the 65% KD distribution of all the marine locations, the general foraging range (repeatedly used areas) as the 95% KD and the overall marine home range (all marine areas visited) as the 100% KD. The marine home range not classified as foraging consisted of areas used for travel, exploration, or very low intensity of foraging. The extent of the marine home range is indicative only and does not include all areas used (interpolating tracks and locations would have decreased the robustness of the results). Polygons were created for the three categories and were clipped to the marine extent to remove any land area that would have been included. The final core and general foraging ranges and marine home range were then plotted and their areas computed.

The bathymetry data used to estimate depths within foraging ranges were obtained from the dataset NZ Bathymetry 250m Imagery/Raster layer from NIWA[9], and the displayed contour depths on maps were obtained from the dataset Depth contour polyline (Hydro, 1:90k-1:350k) from the New Zealand Hydrographic Authority of LINZ[10].

2.5.3 Comparisons with other years and mainland populations

The winter 2019 tracking study of female Catlins New Zealand sea lions was used to compare the results of this study with data from three years earlier during the same season. The comparison between the 2019 and 2022 studies could provide an understanding of consistency of behaviours across years, with the potential to guide more effective management actions. The results from Reed (2021) and Reed *et al*. (2023) were used for the comparison, along with the raw data provided by Dr Nathan Reed. In this prior study, four female New Zealand sea lions were satellite-tracked over winter 2019 for 21 to 104 days. The tracking devices provided ARGOS locations. Diving data were restricted to one female for two foraging trips only (813 dives). Only one female was satellite-tracked in both 2019 and 2022 (P446).

A comprehensive foraging study of female New Zealand sea lions took place at the Otago Peninsula over three years during autumns 2008 to 2010. The comparison between the winter Catlins study and the autumn Otago study could provide a better understanding of seasonal changes in behaviour, especially the comparisons of the results of the female Unknown that spent time at Otago during winter 2022. The results from Augé *et al.* (2011a), Augé *et al*. (2011b) and Leung *et al.* (2013) were used for this comparison. Thirteen female New Zealand sea lions were tracked in autumn 2008, 2009

[9] https://data-niwa.opendata.arcgis.com/datasets/nz-bathymetry-250m-imagery-raster-layer/explore

[10] https://data.linz.govt.nz/layer/50448-depth-contour-polyline-hydro-190k-1350k/

and 2010 for 26 to 46 days. The tracking devices provided ARGOS locations. Diving data were available for all individuals (> 80000 dives).

First, an inspection of the older data and their accuracy was undertaken to determine if and how they could be compared with the 2022 data. Based on the outcomes of this inspection and trial analyses, quantitative or qualitative comparisons could be conducted.

It has been well established in previous studies that female New Zealand sea lions in the South Island exhibit significantly less extreme diving and foraging behaviours than females at the Auckland Islands or Stewart Island. In summary, female sea lions at Otago and The Catlins forage in very coastal areas (within a few kilometres from land) and dive on average between 10.5 and 20.2 m (Augé, 2011; Reed, 2021), whereas females at the Auckland Islands forage on average between 45 and 102 km from land and dive on average at 129 m depth (Chilvers *et al*., 2006), and those at Stewart Island > 20 km from land at average depths of 60 m (Chilvers, 2018). Similar differences were demonstrated for juvenile females between Otago and the Auckland Islands (Leung *et al*., 2013). Therefore, there was no further comparison done in this report with the sub-Antarctic populations.

3. RESULTS

3.1 Datasets available

The four SPLASH tags recovered provided full datasets for locations and depth records. The SPLASH tag that was not recovered had transmitted the fastloc-GPS snapshots via ARGOS but only a summary of the depth records in pre-set bins of depth ranges. Therefore, there were five location datasets and four dive datasets of adult female New Zealand sea lions available for the analyses. The dive data in bins were not used further due to the locations of foraging. The two Axy-Trek tags were recovered from one yearling and one pup, but only very limited data for one of the tags were available for this report (3.5 days, land locations and diving records only, no at-sea locations were recorded). The other Axy-Trek tag malfunctioned and no data were collected.

All raw spatial data and the key spatial results presented in the following sections were submitted for publication on the DOC Marine Portal[11] where readers can consult and explore the results, in addition to the maps presented in this report.

Four of the five females studied remained in The Catlins area during the study. The female called Unknown went to the Otago Peninsula from 15 June to 23 July, then travelled back down to The Catlins again. She then went back up to the Otago Peninsula on 7 August where she was re-captured to retrieve the tags (Figure 5). This dataset was split between Catlins and Otago (the Otago results are presented in section 5.4) with the Catlins locations and dive data selected as those that were at the same or below the latitude of all other females' locations (i.e. in The Catlins area).

In total, across the five adult females and one yearling studied, there were 275 foraging trips consisting of 4740 GPS locations (Figure 5) and almost 68000 dives obtained for analyses in The Catlins (Table 3). There were a further 48 trips, 458 GPS locations ad over 16000 dives for analyses at Otago.

[11] https://doc-marine-data-deptconservation.hub.arcgis.com/

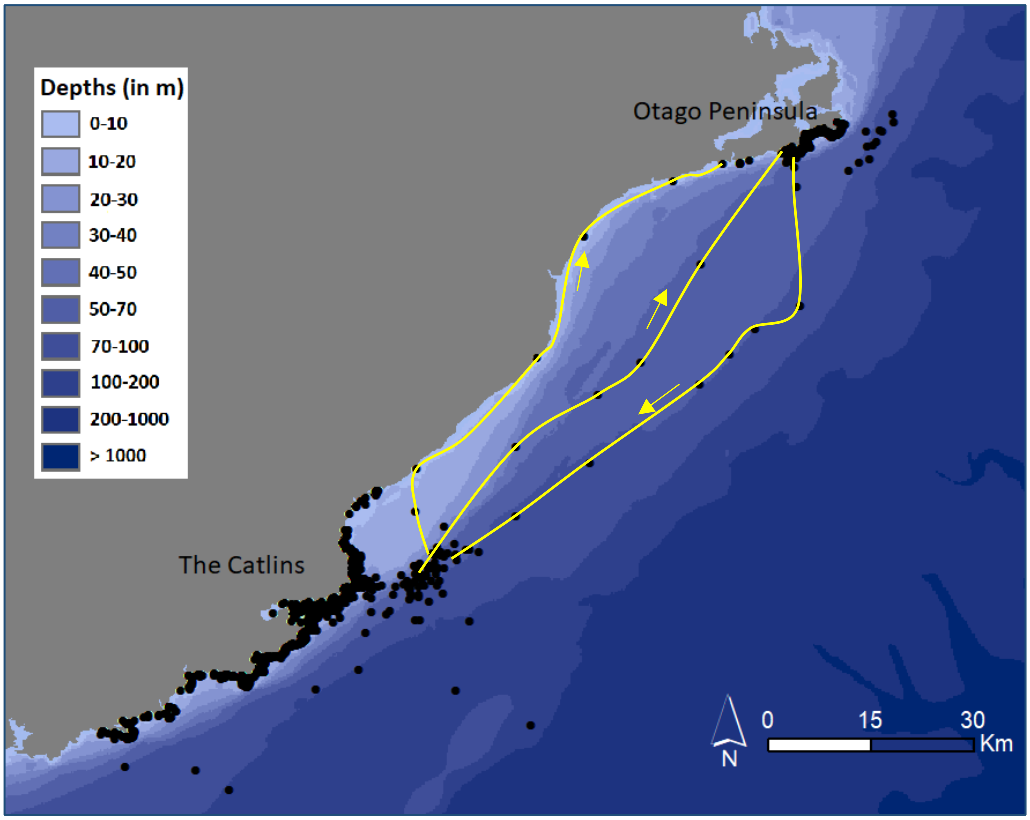

Figure 5. All GPS locations (black dots) of adult female New Zealand sea lions obtained during instrumentation between June and August 2022 (land and marine). Note that the locations north of The Catlins and around the Otago Peninsula are from only one female (Unknown). The routes taken to travel between the two sites are indicated in yellow with arrows indicating the direction of travel.

Table 3. Summary of all data available for analyses of land and marine habitat use of adult female New Zealand sea lions in The Catlins during winter 2022.

ID Name	# Days tracked	# foraging trips	# GPS locations removed during cleaning	# Land GPS locations	# Marine GPS locations	# dives
Jade	80	79	40*	566	690	21865
Kiwa	74	102	26	692	657	15005
P446	41	22#	9	210	189	No data
P447	79	64	38*	443	785	21402
Unknown (Catlins)	24	27	13	197	201	8721
Susie**	3	3	-	110	-	993
Totals (Catlins only)	301	275	120	2218	2522	67986
Unknown (Otago)	53	48	10	458	371	16525

 # Estimated from GPS locations
** Approximately 1/3 of these were from Hinahina Island and Pounawea Reserve where GPS locations are of poorer accuracy due to the forest cover.*
*** The tag malfunctioned and only recorded at the start of deployment. The GPS locations were recorded every 20 minutes compared to every hour for other animals, dive records were obtained every 5 seconds compared to 10 seconds.*

3.2 Terrestrial habitat use in The Catlins

3.2.1 Characteristics of periods on land

The studied adult female sea lions spent on average 48.3% of their time onshore for periods of 11.0 hours on average (Table 4). In total, the land home range of the animals covered an area of land of 0.76 km^2 across multiple sites along the coast. Most of this land home range was sandy beaches or the dune areas behind those beaches, with the exceptions of Pounawea Reserve and Hinahina Island that have rocky shores backed with coastal native forests and the southern point of Pūrākaunui that has rocky shores backed with sward. All studied females remained close to shore during their periods onshore, within approximately 100 m from the water.

Each of the five adult female sea lions had a definite location where they spent more time than at any other locations (Figure 6). These locations were Surat Bay for Jade (55 % of her time) and Kiwa (49% of her time), the beach off the Clutha River Matau Branch for P446 (estimated from number of GPS locations to 29% of her time), Pounawea Reserve for P447 (44% of her time) and Jacks Bay/Ōtemakura for Unknown (39% of her time). All females used numerous other locations apart from these: 17 other locations for Jade, 18 other locations for Kiwa, 12 other locations for P446, 8 other locations for P447 and 11 other locations for Unknown. There was no notable difference in land use between females nursing pups or not, apart from having longer periods onshore and having more regular attendance patterns at the site where their pups were at the time.

3.2.2 Land home range adjacent or on roads

The sites used by the adult females that were on or within 20 m of a road were on: part of Jacks Bay, the coastline along Kaka Point Road and The Nuggets Road. On average, individuals spent 23.5% of their time on land at these sites, but there were large inter-individual differences (Table 4).

The beaches along The Nuggets Road were the most used, with 10 key land locations used by the studied sea lions. The key land locations were all between Campbell Point/Taumatakōtare/Ōwaea and Nugget Point/Tokatā, except for one key land location in the northern part of this road (Figure 7). The sites along The Nuggets Road were used regularly throughout the study but for shorter periods of time than at other sites (mean 6.4 hrs, compared to mean of 11.0 hrs for all key land locations).

Table 4*. Summary of characteristics of periods onshore of female New Zealand sea lions in The Catlins in winter 2022.*

ID Name	Age (in years)	% of time onshore	Mean duration of period onshore (in hrs)	Min (in hrs)	Max (in hrs)	Land home range (in km^2)	% Time spent on	
							Beaches with vehicles	Road or within 20m of a road
Jade	6	49.6%	12.0 ± 7.6	1.2	36.0	0.17	85.9	28.5
Kiwa	15	55.6%	9.6 ± 7.8	0.2	34.1	0.22	85.0	10.4
P446	6	*Not data available*				0.11	54.9*	38.3*
P447	6	45.2%	13.2 ± 7.4	1.3	37.0	0.11	38.4	1.5
Unknown	-	42.5%	9.6 ±4.5	0.5	18.8	0.26	73.7	38.8
Mean	-	48.3%	11.0 ± 7.4	-	-	-	76.6 ± 20.8	23.5 ± 12.4

**Estimated from the % of GPS locations*

Figure 6: Percentages of time each adult female New Zealand sea lion spent at land sites in The Catlins during winter 2022. Note the most used locations of each female (name in white).

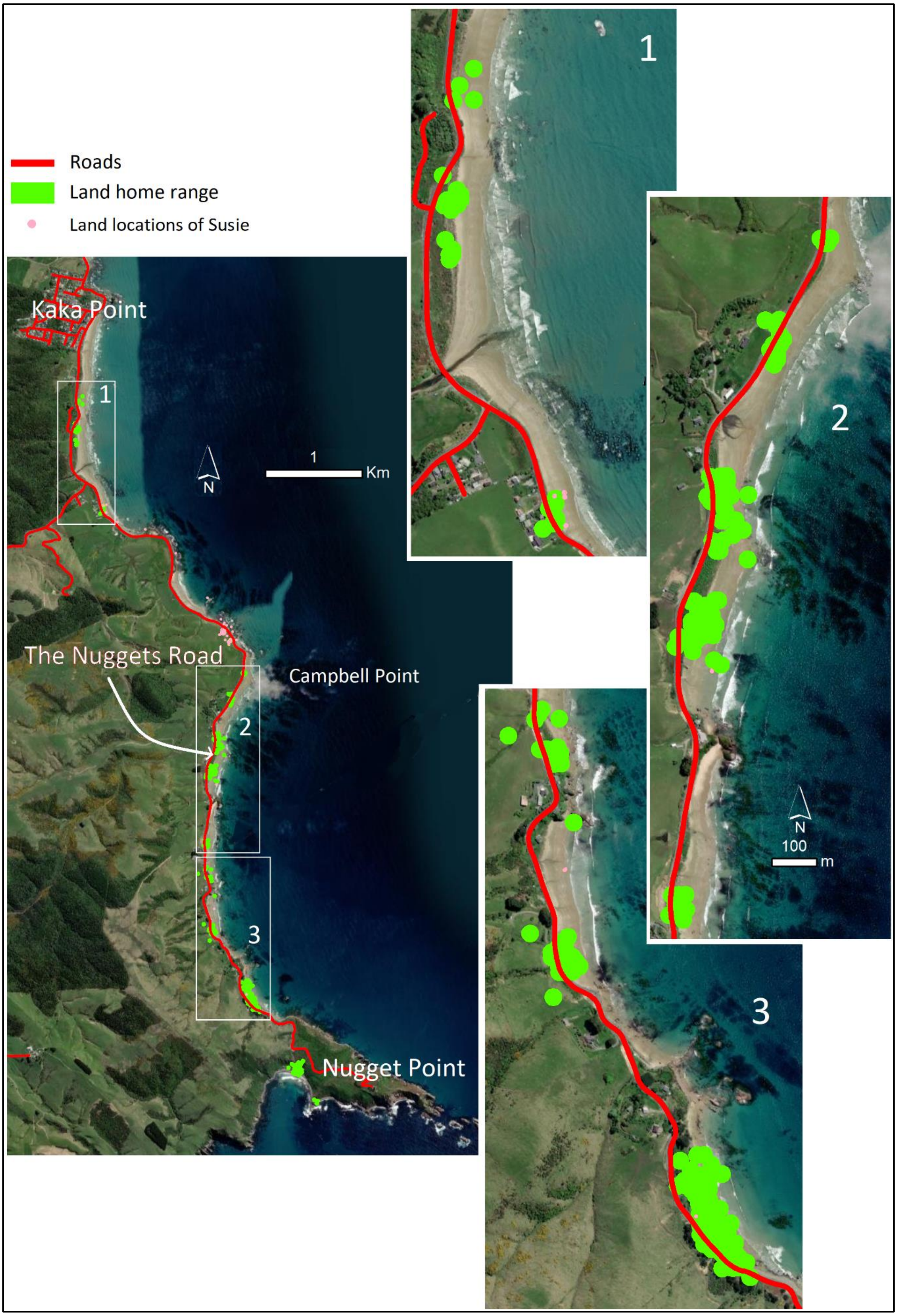

Figure 7: Land home range of adult female New Zealand sea lions during June-August 2022 along the coastline between Kaka Point and Nugget Point in The Catlins. Added in pink: the land locations of Susie (yearling female) during 4-7 June 2022 (most just north of Campbell Point).

Jade spent 265 hrs at land locations along The Nuggets Road during the study (28.5% of her time on land). Kiwa spend 67 hrs there (8.0% of her time onshore). P447 only came onshore three times there and spent < 2 % of her time (13 hrs). Unknown never came onshore along The Nuggets Road. P446 used the area along The Nuggets Road area and it was estimated, from number of GPS locations, that she spent approximately 33.0% of her time onshore at these locations (which equates to approximately 166 hrs, if using the mean percentage of time spent on land for the other studied females).

The beaches along Kaka Point Road were less used during the study with only a total of 29 hrs recorded when adult females were within 20 m of this road (equivalent to 2-3% of individual time on land).

There were three key land locations used by the studied sea lions at Jacks Bay (Figure 8). The northernmost key land location did not fall within 20m of the road and was only used by Kiwa for 2.9% of her time onshore. The two other locations were only used by Unknown. She spent 38.8% of her time there and her land home range overlapped the road.

The Axy-Trek tag that was deployed on Susie (female yearling, 1.5 year-old) contained only 3.5 days of data which was not enough to analyse in more detail. The land locations of Susie during those few days were along The Nuggets Road, some in similar areas used by adult females, but most were in a different area of the road, north of Campbell Point where no studied adult females came ashore during the study (see Figure 7). There, Susie crossed the road multiple times to reach her land sites.

3.2.3 Land home range on beaches with vehicle access

On average, adult female New Zealand sea lions spent 76.6% of their time at beaches accessible to vehicles (Table 5). Beaches that are accessible and regularly used by all types of vehicles and that were used by sea lions during this study were Cannibal Bay/Ōrakiutuhia, Jacks Bay/Ōtemakura, all the beaches along The Nuggets Road and some along Kaka Point Road, Pūrākaunui, the beach north of the Clutha River/Matau Branch and the beach along Tautuku Peninsula.

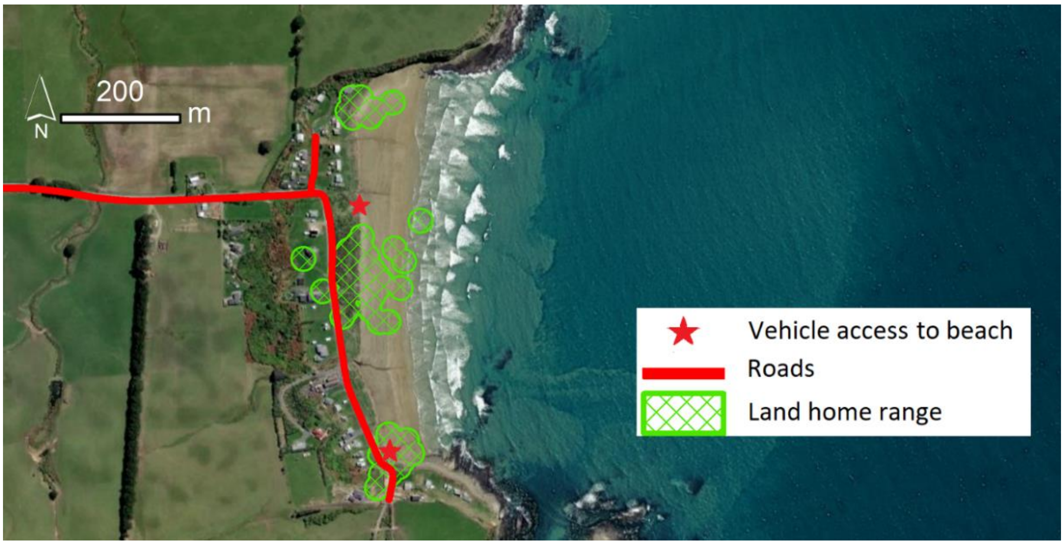

Figure 8: Land home range of adult female New Zealand sea lions tracked during June-August 2022 at Jacks Bay in The Catlins.

Table 5. Percentage of time on land spent at beaches accessible and regularly used by motorised vehicles by adult female New Zealand sea lions during winter 2022.

ID Name	Surat Bay	Cannibal Bay	Jacks Bay	Kaka Point + The Nuggets	Pūrākaunui	East of Matau Branch	Tautuku Peninsula	Total
Jade	54.6	0.0	0.0	30.4	0.9	0.0	0.0	85.9
Kiwa	48.9	3.8	2.9	7.6	21.8	0.0	0.0	85.0
P446	16.5	12.6	5.3	35.0	1.9	28.7	0.0	100.0
P447	4.8	32.1	0.0	1.5	0.0	0.0	0.0	38.4
Unknown	13.8	12.3	38.8	3.2	2.7	0.0	2.9	73.7
Mean	-	-	-	-	-	-	-	76.6 ± 20.8

The studied females spent on average 42.6% of their time on land at those beaches with access for all types of vehicles (Table 5). Surat Bay was the most used beach by female New Zealand sea lions (32.9% of total time onshore, throughout the length of the beach or in the dunes, Figure 9) but is only accessible by motorbikes and quads (and occasionally farm vehicles). There are multiple walking tracks through the dunes at this beach that can also be used by motorbikes and quads. Therefore, the level of risk from the vehicles using Surat Bay beach may differ from those on other beaches. Other beaches in The Catlins are accessible and regularly used by vehicles but they were not visited by the sea lions in this study during winter 2022.

While on land at Cannibal Bay, the adult females spent an estimated 68% of their time on the beach, and the rest of the time in the dunes (Figure 10). This equated to a total of 356 hours over a period of approximately 2.5 months when at least one female sea lion was on the beach at Cannibal Bay, at risk of disturbance or collision with vehicles.

The risks from vehicles on beaches along The Nuggets Road and Kaka Point Road is similar to the risks of vehicles on roads for these two roads (as in previous section) because these roads follow the coastline very closely and back most beaches (see Figure 7). There are vehicle access paths to all the beaches all along these two roads. The females using the beaches adjacent to The Nuggets and Kaka Point Roads spent an estimated 55% of their time on the beaches and the rest of the time was predominantly spent in the small dunes and swards between the beach and the road or on the other side of the road (some locations were on the roads).

Figure 9: Land home range of adult female New Zealand sea lions during June-August 2022 at Surat Bay in The Catlins. Note that vehicle accesses to the beach include both ends of the beach but that there are many other walking tracks through the dunes.

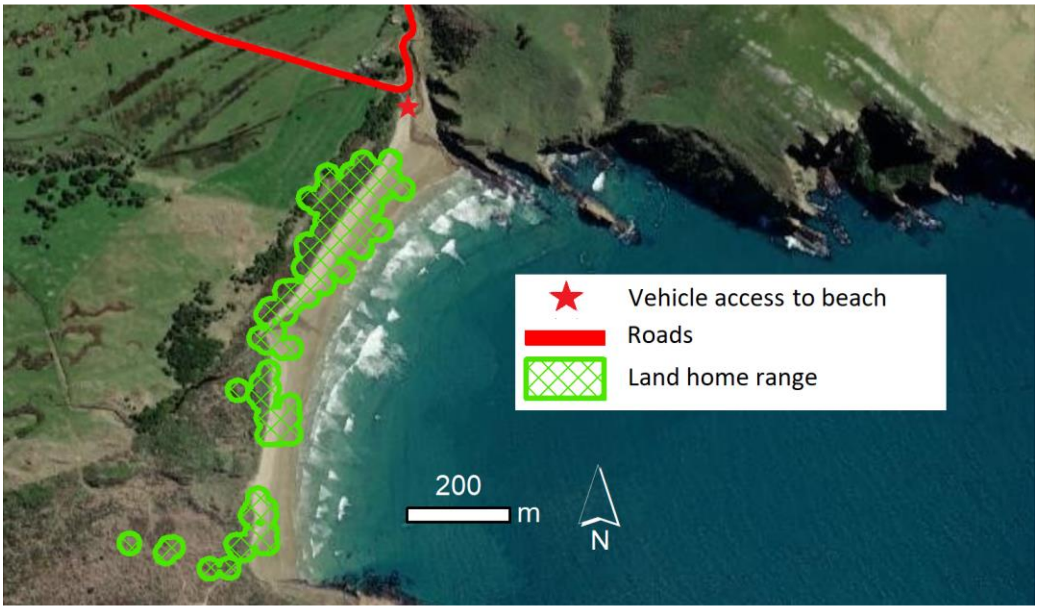

Figure 10: Land home range of adult female New Zealand sea lions at Cannibal Bay in The Catlins during June-August 2022

There were three discrete sites used by the studied females at Jacks Bay spread along the length of the beach (see Figure 8). The two key land locations at the southern end of Jacks Bay were adjacent to the access tracks used by vehicles to access the beach from the road. The two studied females that used this beach spent an estimated 58% of their time on the sandy beach.

While on land at Pūrākaunui, the studied females spent an estimated 53% of their time on the sandy beach, predominantly in the northern part of the beach (Figure 11), away from the campground and vehicle access to the beach.

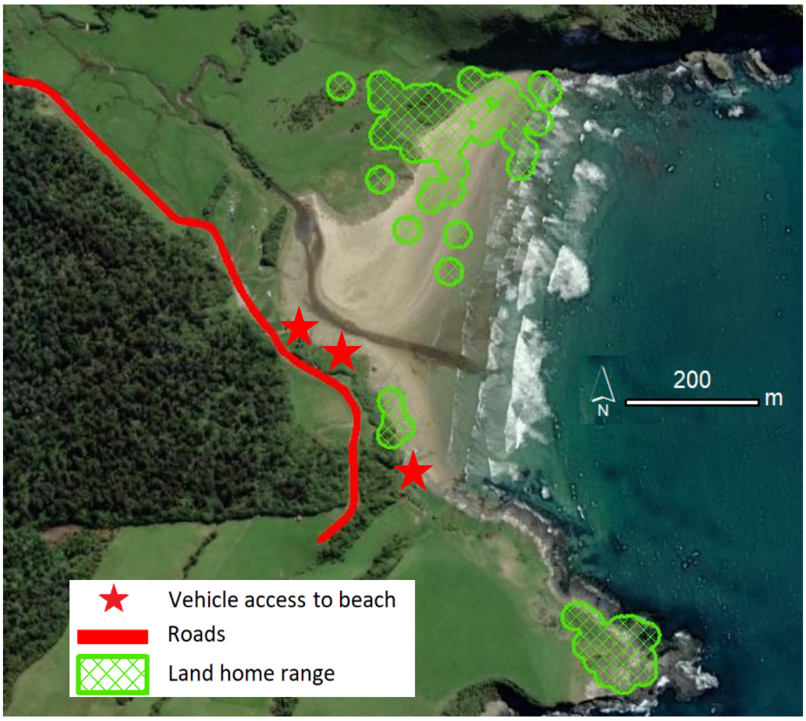

Figure 11: Land home range of adult female New Zealand sea lions during June-August 2022 at Pūrākaunui in The Catlins.

P446 was the only female that used land sites north of Kaka Point/Rakitāmau during the study. The beach on the north side of the mouth of the Clutha River (Figure 12) was her most used land site. Recent satellite imagery showed large numbers of vehicle tracks in the sand and in the dunes in her land home range in this area. P446 spent approximately half her time on the sandy beach when in this area.

The female called Unknown spent one period of 8 hrs on land at Tautuku Peninsula (Figure 13), on the sandy area in front of the main access track used by vehicles to access the cribs from the beach. Tautuku Bay beach (on the other side of the river which vehicles cross to get to the cribs on the peninsula) is regularly used by vehicles to get to the cribs. This beach with vehicle traffic was, however, not used by the sea lions in this study.

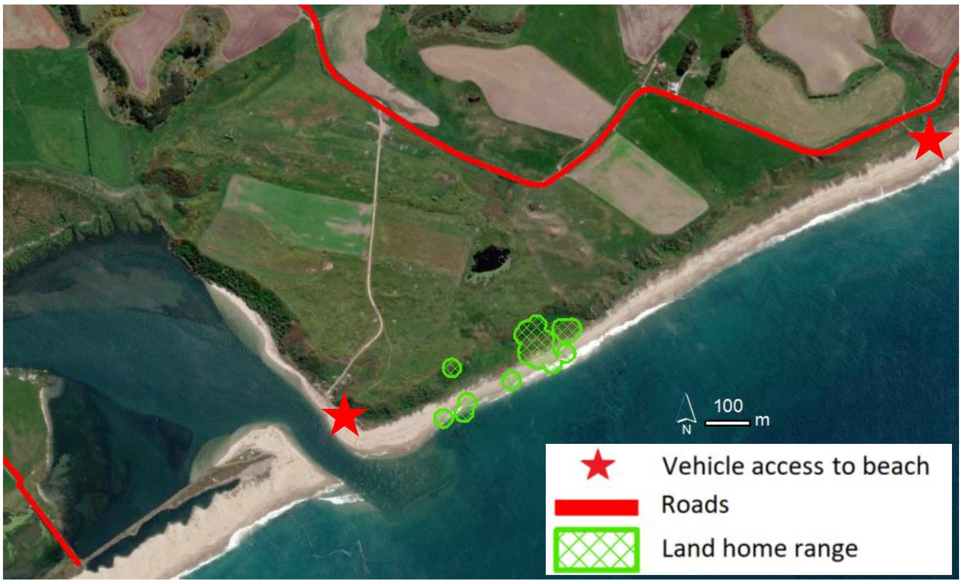

Figure 12*: Land home range of adult female New Zealand sea lion P446 on the beach north of the Clutha River*/Matau Branch during *June-August 2022.*

Figure 13*: Land home range of adult female New Zealand sea lion called Unknown on the beach at the Tautuku Peninsula on 30 July 2022.*

3.2.4 Locations of pups

Jade and P447 were nursing pups during this study. It was difficult to determine where their pups were throughout the study because both females spent large amounts of time at various land sites without their pups. Jade's pup was tracked but no data were available due to malfunction. The locations of pups were estimated based on the amount of time the females spent at the different sites, the patterns of attendance and the records of visual sightings of pups reported in field reports (Appendix 2).

P447's pup was only sighted at Pounawea Reserve during the survey. However, P447 did not come to this site for long periods (i.e. from 14 July to 18 July, from 19 July to 7 August and from 12 August to the end of the study 20 August) and P447 was seen taking her pup to sea during a field visit on 19 July. Based on the attendance pattern of P447 at the different sites, it is most likely that the pup spent time at several other sites, including Surat Bay and Hinahina Island. It is estimated that P447's pup was never at sites on or close to roads. There is no evidence that P447's pup spent time at Cannibal Bay, from the available data, though P447 spent long periods onshore at this site. P447 was also re-captured at Cannibal Bay but the field team did not record a pup there and P447 went to sea after her release. This likely indicates that her pup was not at this site but instead at Surat Bay, where she had spent an equal amount of time during the previous week. The conclusion is that P447's pup was never at Cannibal Bay and, therefore, never spent time at beaches used by vehicles at the time of this study.

The attendance pattern of Jade indicated that Jade's pup was also moved between Hinahina Island and Surat Bay several times during the study, with visual confirmation of the pup sighted at Hinahina Island and Surat Bay as per the field reports. While Jade spent large amount of time on the beaches along The Nuggets Road and at Cannibal Bay, there is no evidence that her pup was at those sites, from the available data. Therefore, it is most likely that Jade's pup never spent time at sites near or close to a road or on a beach regularly used by vehicles at the time of this study.

The data available for the female yearling Susie, the sightings reported during field visits and the location of her capture and re-capture all indicated that she used the beaches along The Nuggets Road significantly. She was first caught along The Nuggets Road and her re-capture took place at Wilsher Bay, along The Nuggets Road. She was also sighted at Wilsher Bay on 11 July. Her land locations and field observations indicated that she crossed the road regularly at Campbell Point. Despite having limited data, it is possible to infer that Susie regularly used sites that are on or within 20 m of a road and beaches used by vehicles.

3.3 Marine habitat use in The Catlins

3.3.1 Diving behaviours

The studied adult female New Zealand sea lions all exhibited shallow dives, with overall 97.3% of dives < 30 m deep and an average dive depth of 10.5 m (Table 6 and Figure 14). Dives were also short, with a mean duration of 1.5 minutes.

A large proportion of dives (68.8%) were classified as benthic and this number is likely underestimated due to the way bottom time is calculated when depths during their shallow diving varied constantly, when most likely following a rough topography.

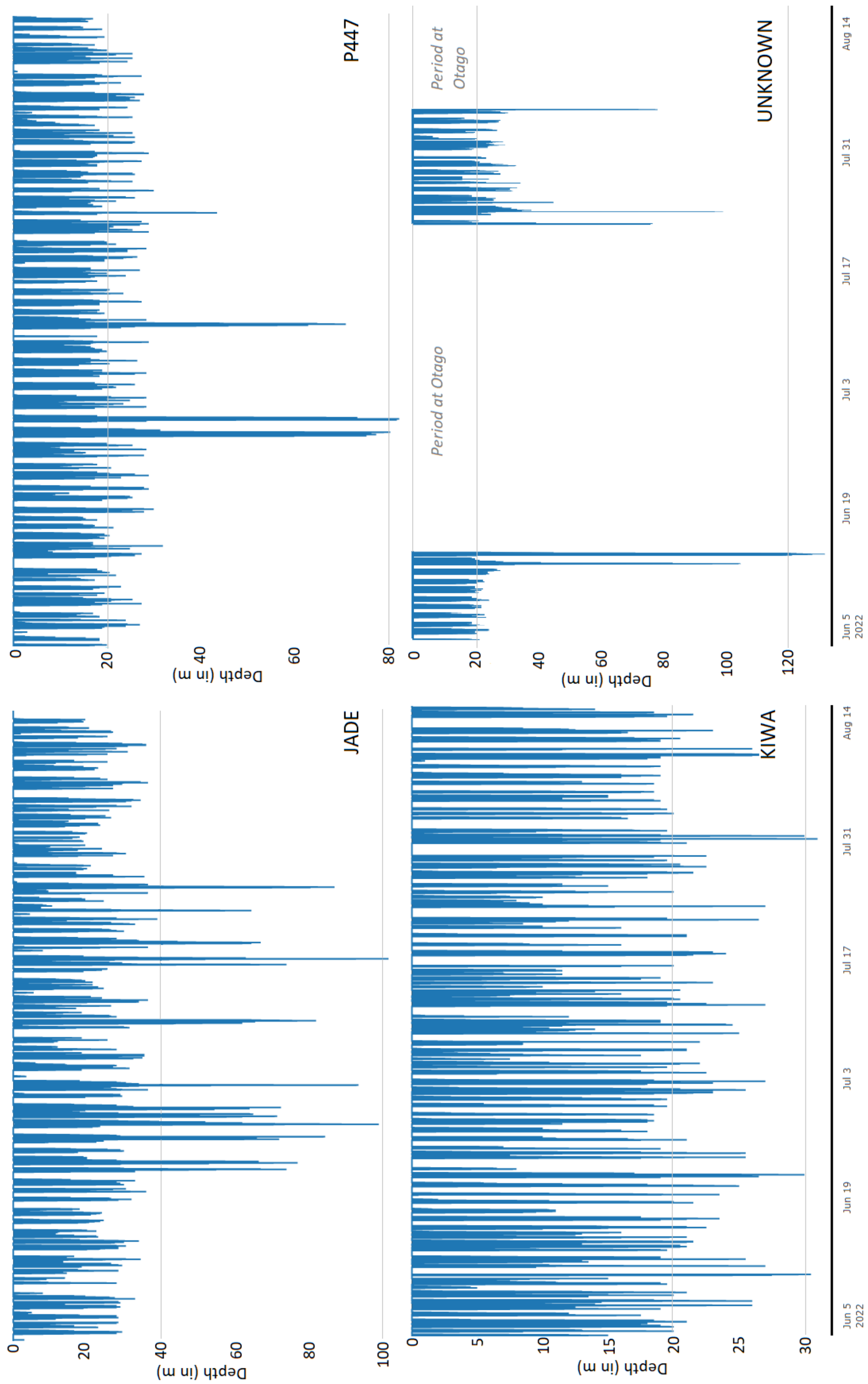

***Figure 14**. Full dive profiles of four adult female New Zealand sea lions during the winter 2022. Note the different maximum depth in each plot.*

Table 6. Summary of diving behaviours of female New Zealand sea lions in winter 2022

ID Name	Age (in years)	Average depth (in m)	Median depth (in m)	Maximal depth (in min)	% dive <30m deep	Average duration (in min)	Maximal duration (in min)	% benthic dives
Jade	6	12.3 ± 12.2	8.0	102.0	93.7%	1.4 ± 1.0	6.8	68%
Kiwa	15	7.5 ± 4.5	6.0	31.0	99.9%	1.5 ± 1.3	8.2	74%
P446	6	*No data*						
P447	6	10.1 ± 7.3	8.5	82.5	98.5%	1.6 ± 1.0	6.3	64%
Unknown	/	12.8 ± 13.2	10.0	131.5	97.2%	1.3 ± 1.1	7.3	67%
Susie	1	13.7 ± 5.2	14.6	53.0	98.5%	1.3 ± 0.6	3.4	94%
Overall adult means*	-	10.5 ± 9.4	8.0	-	97.3%	1.5 ± 1.1	-	68.8%
*Excludes results for Susie (yearling)								

Therefore, the main diving behaviour was benthic. For dives > 30 m deep, the proportion of benthic dives declined for all three females to 63% for Jade, 49% for P447 and 48% for Unknown (noting that Kiwa only had 4 dives > 30 m so there was no value for this individual). Therefore, adult females exhibited more pelagic dives when diving deeper but remained predominantly benthic as well.

All females dived throughout the day and night, with an overall higher percentage of shallower dives during daytime. The females that dived at depths greater than 30 m (Jade and P447) exhibited those deeper dives during nighttime only (Figure 15) (Unknown only dived deeper before and after her travel to and from Otago Peninsula at various times of the day).

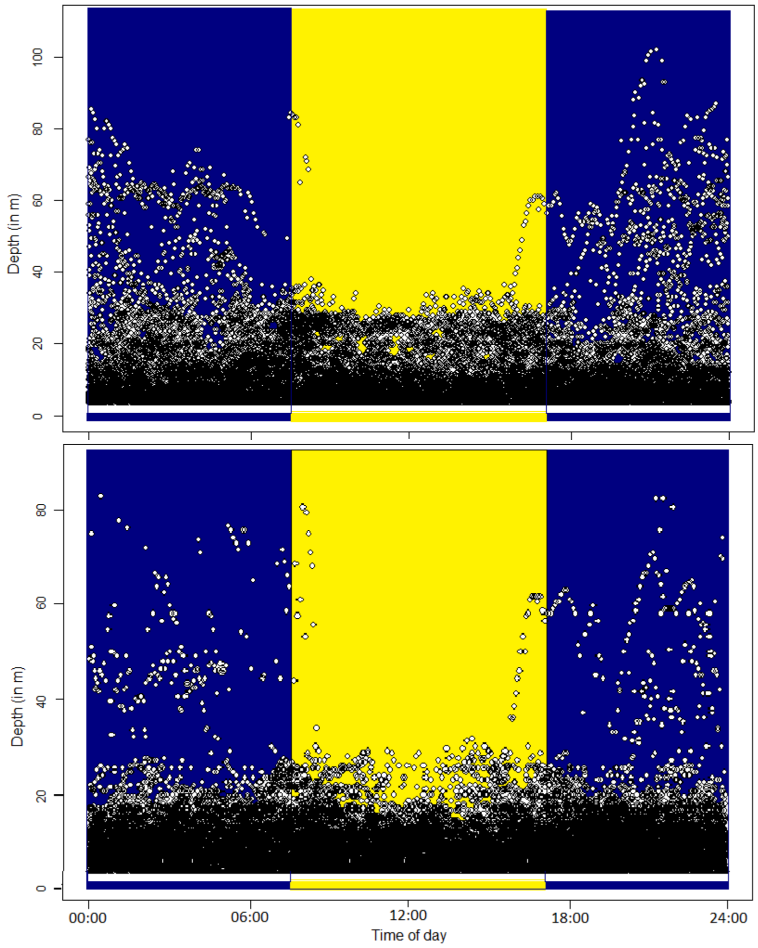

Figure 15. Maximum depths reached during dives per time of day for adult female New Zealand sea lions Jade (top) and P447 (bottom) in The Catlins in winter.Yellow = approximate daytime, blue = approximate nighttime, noting small changes in sunrise and sunset times across the study period 1 June-20 August).

The Axy-Trek tag that was deployed on Susie (female yearling, 1.5 year-old) contained only 3.5 days of data. Mel Young (DOC) extracted the dive data available from the file downloaded from the tag and provided dive summaries and the dive profile (Figure 16). Susie's dive depth was deeper than that of the adults, but dive duration was shorter than the adults (see Table 6). The standard deviations of Susie's dive data were smaller than for adults indicating a much more consistent diving depth and duration. The proportion of benthic dives was significantly higher than adults. This yearling also exclusively foraged at night, leaving to sea at sunset and returning to land before sunrise, with continuous diving for 12 hrs at almost the same depth, apart from a short period of deeper diving (Figure 16).

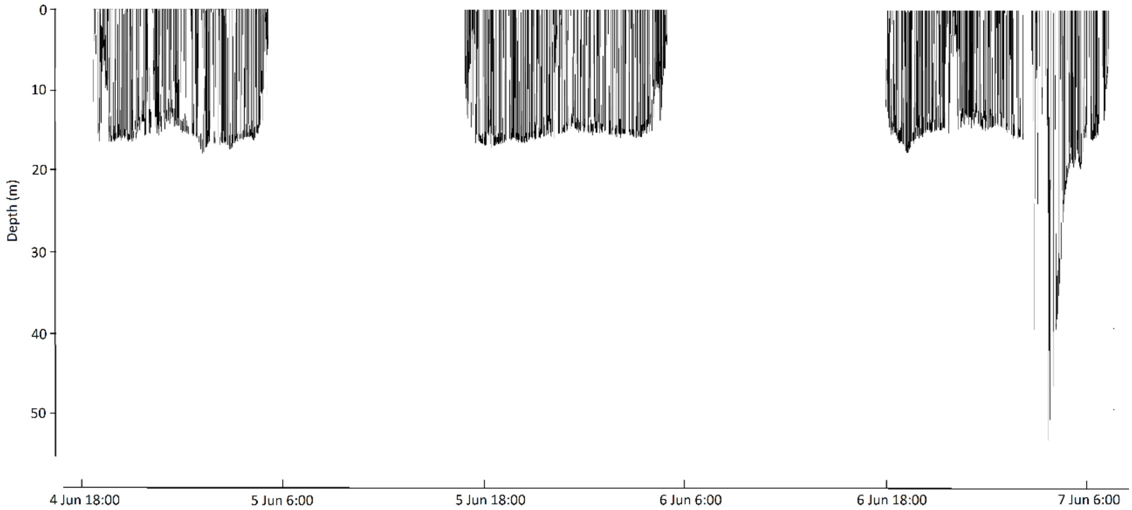

Figure 16: *Dive profile of female yearling New Zealand sea lion Susie (1.5 year-old) during 4-7 June 2022 (provided by Mel Young, DOC)*

3.3.2 Foraging areas

The studied adult female New Zealand sea lions at The Catlins predominantly exhibited short foraging trips (mean 12.5 hrs) and the maximum recorded foraging trip was 39.8 hrs (Table 7). The studied adult female New Zealand sea lions foraged almost exclusively in very coastal areas during the study period, with 86.7% of all marine locations within 300 m from shore.

Table 7. *Summary of foraging trip duration and areas of the core foraging range (65% Kernel density estimate, KD) and overall foraging range (95% KD) of adult female New Zealand sea lions off The Catlins coast in winter 2022.*

ID Name	Age (in years)	Mean trip duration (in hrs)	Median trip duration (in hrs)	Minimum trip duration (in hrs)	Maximum trip duration (in hrs)	Core foraging (in km^2)	General foraging (in km^2)
Jade	6	12.2 ± 5.7	12.3	2.2	28.8	0.08	1.10
Kiwa	15	7.8 ± 3.7	7.1	2.1	19.6	0.34	6.51
P446	6	0.43	6.11	-	-	0.43	6.11
P447	6	16.2 ± 7.7	15.6	2.2	39.8	0.26	3.11
Unknown	-	12.5 ± 6.2	12.7	2.2	26.8	0.14	3.50
Overall means	-	11.6 ± 6.5	10.7 ± 3.6	-	-	0.25 ± 0.14	4.07 ± 2.25

The area around the islets at the tip of Nugget Point/Tokatā (locally known as 'The Nuggets', an area of 0.19 km^2) constituted the core foraging range (65% Kernel density) of the studied adult female New Zealand sea lions in The Catlins in winter (Figure 17).

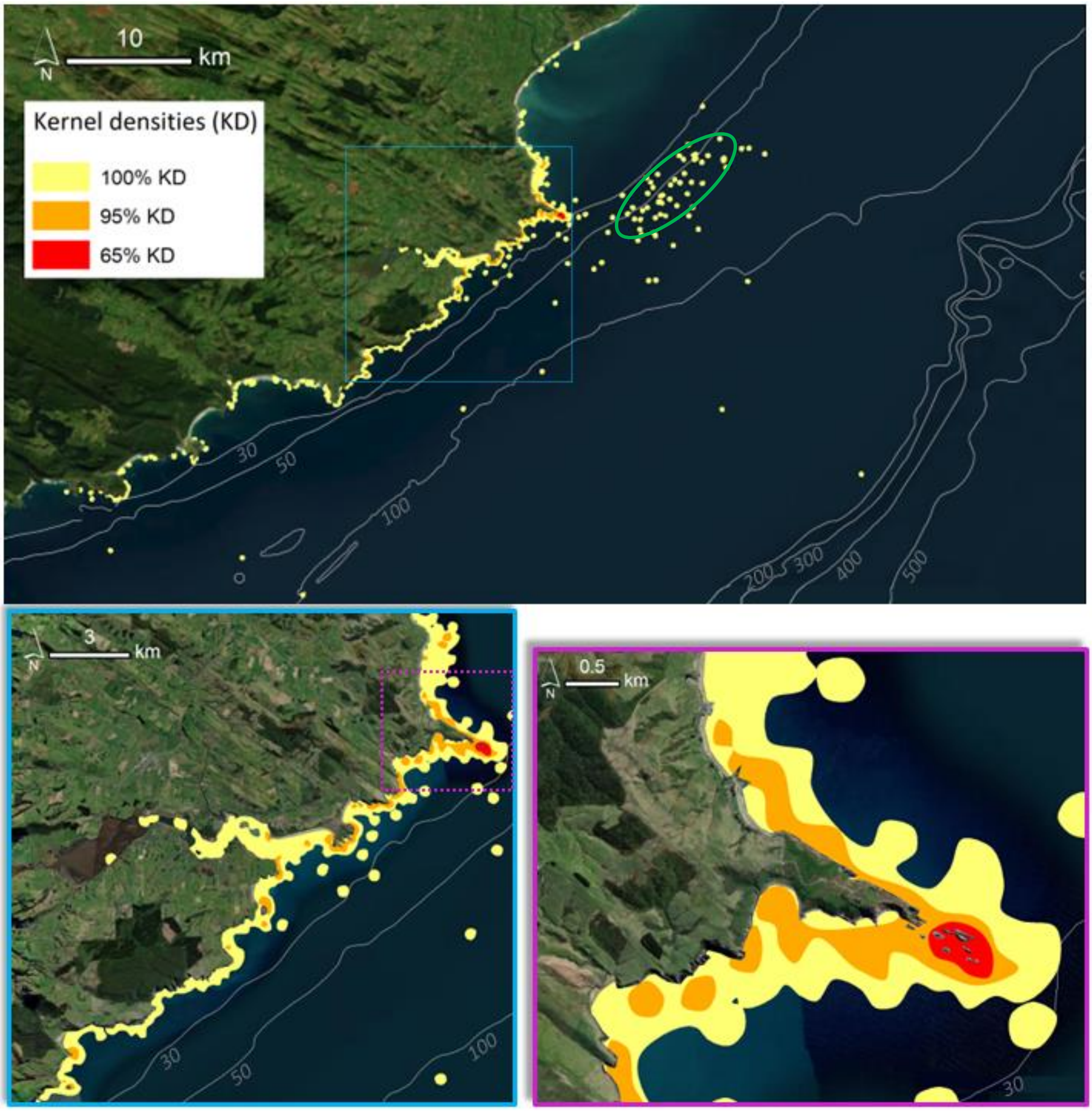

Figure 17: Area of the core foraging range (65% kernel density estimate, KD), general foraging range (95% KD) and marine home range (100% KD) of all adult female New Zealand sea lions combined in The Catlins in winter 2022. The bottom right panel is zoomed on Nugget Point/Tokatā. Note that the area of 'The Nuggets' was the only core foraging range used by this group at the time of this study. The area contained in the green oval indicates an area used for foraging but that was not classified as such due to the low density of locations in this 'offshore' area compared to areas along the coast.

The area of The Nuggets (within 150 m of all the islets) contained 21.4% of all marine locations recorded during the study. Marine locations around Nugget Point/Tokatā overall (including the Nuggets and the entire point from Kaimataitai to Roaring Bay, up to 400 m from shore) represented 33.4% of all marine locations recorded during the study. All studied females foraged around Nugget Point and The Nuggets during the study.

The general foraging range (95% kernel density) of marine locations covered in total 3.22 km^2 and was made of a series of discreet areas of near-shore habitats concentrated from Campbell Point to False Islet/Ōtara, the mouth of the Catlins River/Pounawea Estuary, and south of The Catlins River along Catlins Head, Tuhawaiki Island/ Pīhautakohia and four small scattered areas further south down to Cosgrove Island/Puke-māukuuku.

Jade, P447 and Unknown were the only females to forage further from land than 700 m. They mostly foraged over a distinct area of more concentrated locations between 4 and 13 km from land off Nugget Point, in water of depths between approximately 40 and 70 m (see Figure 17). Jade spent time in this 'offshore' area during five foraging trips, P447 during three trips (at the same time and in the same area as Jade) and Unknown during two trips. This 'offshore' area was not classified as general foraging range. However, the Kernel analysis settings used did not allow for a low density of locations where foraging was not as concentrated as in the coastal area to be classified as foraging. Inshore and offshore locations were not separated because there were too few locations in the 'offshore' area for an analysis to be meaningful. However, the 'offshore' area (circled in green in Figure 17) represents a foraging area with very low intensity of use during winter. In total, 2.8% of time at sea across all females were spent in this 'offshore' area. Jade spent more time there than any other females and spent 6.5% of her time at sea foraging in the 'offshore' area.

There was a level of inter-individual difference in foraging ranges (Figures 18a and 18b). Three of the five adult females only had The Nuggets as their core foraging range. The core foraging range of another female included The Nuggets, along with other areas along Nugget Point, False Islet and Catlins Head. Kiwa's core foraging range did not include The Nuggets although she foraged there but included several other areas from Campbell Point to Cosgrove Island. The females nursing pups (Jade and P447) were the females that had the most concentrated foraging range (Table 7), both around The Nuggets with areas in proximity of the coast between the Catlins River and just North of Nugget Point. P446 was the only studied female that foraged further north than Campbell Point (apart from Unknown, that foraged at Kaka Point during a short period of time). Unknown was the only female that foraged further South than Long Point/Irihuka. The core foraging range varied between individual females but were all < 0.5 km^2 in size (Table 7).

Shallow rocky reefs represented the predominant foraging habitat of all adult females during winter, with overall 78.7 % of marine locations being within the area mapped as 'rocky reef' in the DOC national rocky reef layer[12] (Figure 19). The general foraging range was almost fully contained within the area of the mapped 'rocky reef'. Satellite imagery in selected areas where very shallow reefs were visible highlighted the clear association between the marine locations of adult female New Zealand sea lions and shallow rocky reefs (Figure 20).

[12] To access this dataset, contact marine@doc.govt.nz

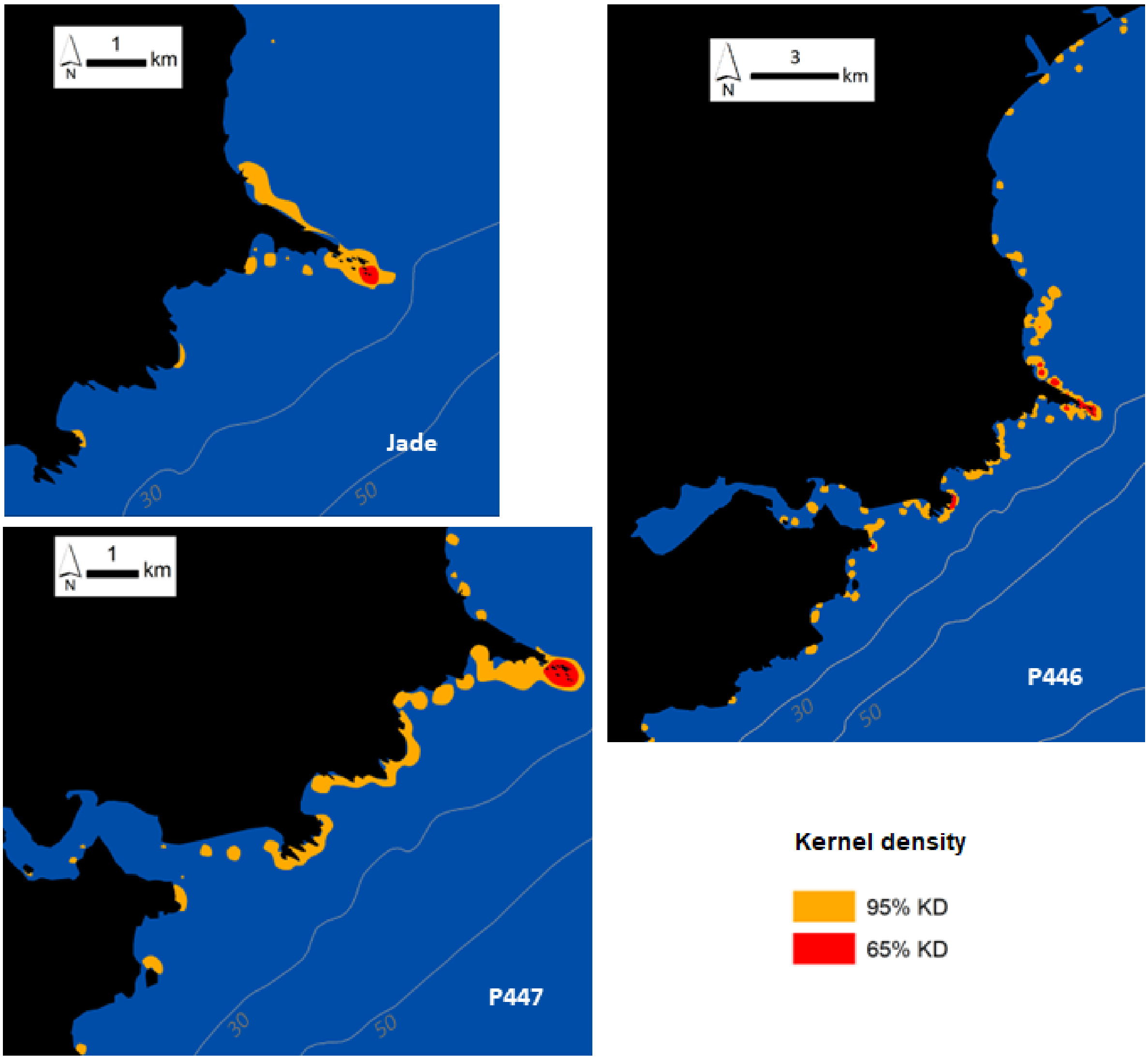

Figure 18(a). Areas of the core foraging range (65% Kernel density estimate, KD) and overall foraging range (95% KD) of individual adult female New Zealand sea lions in The Catlins in winter 2022 (Jade, P446 and P447).

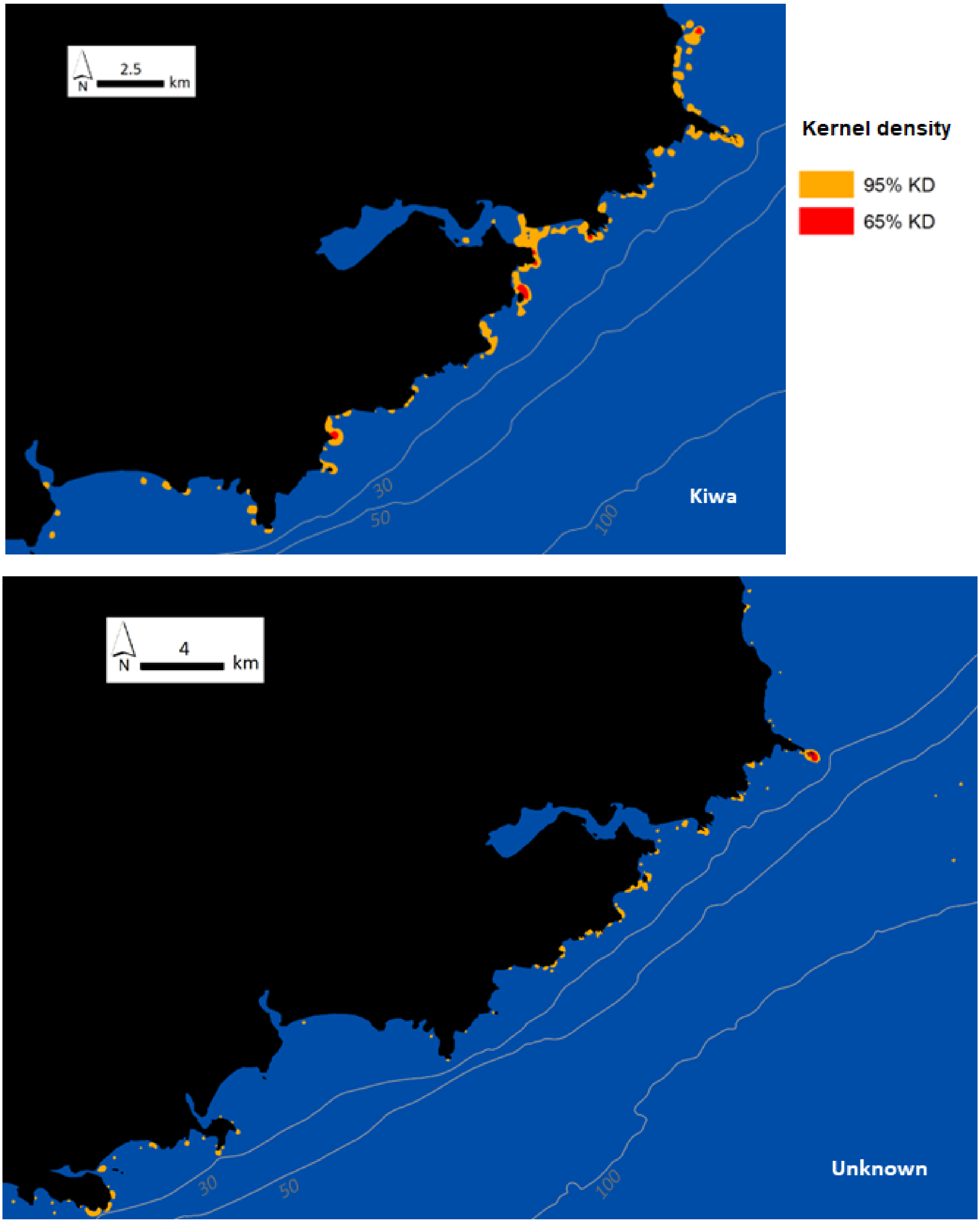

Figure 18(b). Areas of the core foraging range (65% Kernel density estimate, KD) and general foraging range (95% KD) of individual adult female New Zealand sea lions in The Catlins in winter 2022 (Kiwa and Unknown).

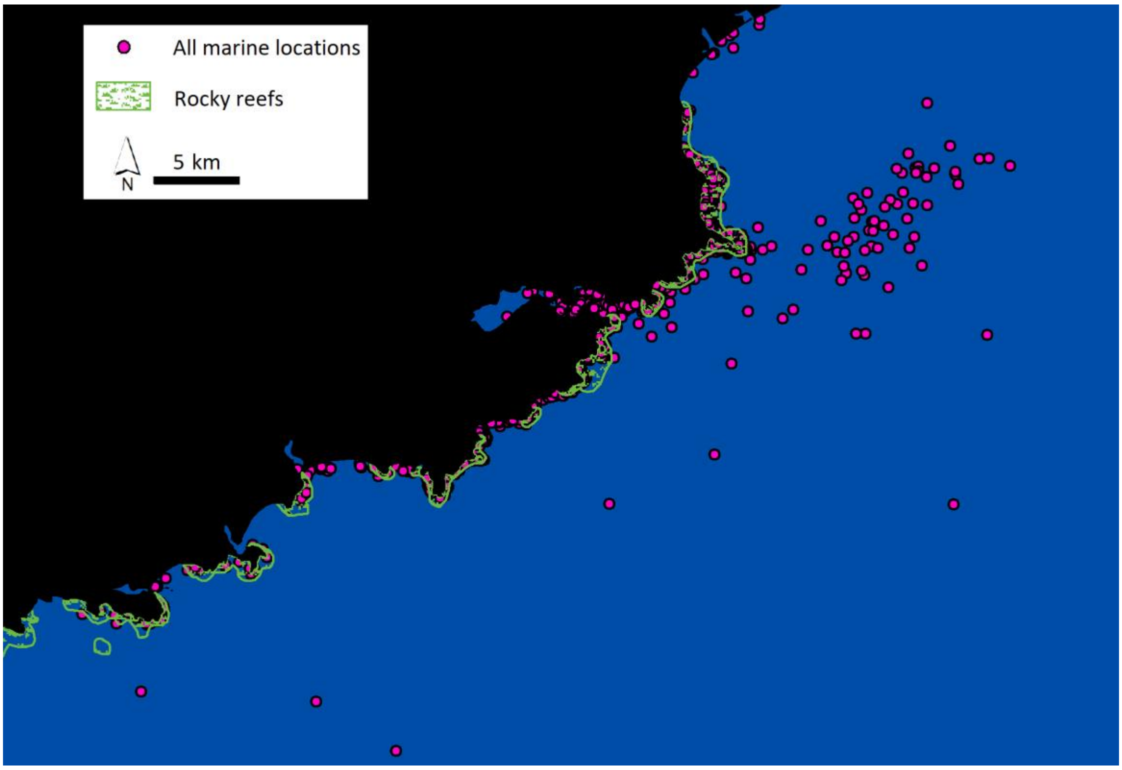

Figure 19: Marine locations of all studied adult female New Zealand sea lions in The Catlins during winter 2022 with the areas of shallow rocky reefs as per the DOC national rocky reef layer.

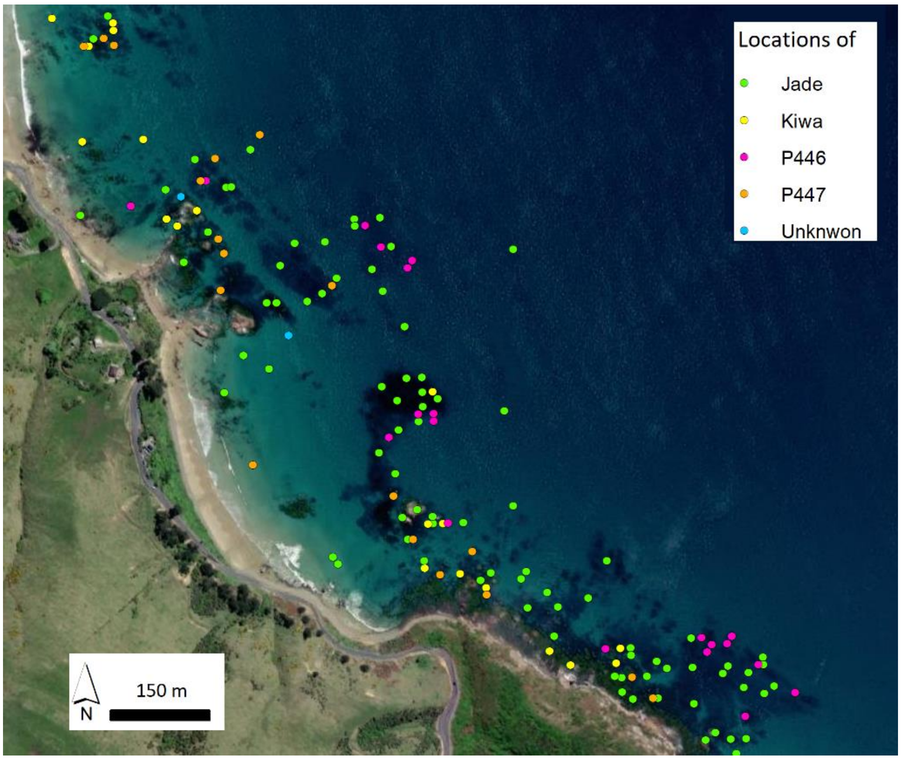

Figure 20: Marine locations of all studied adult female New Zealand sea lions during winter 2022 around Kaimataitai at Nugget Point. The shallow rocky reefs are visible on the satellite imagery as darker areas (source: ESRI, Maxar, Earthstar Geographics).

3.3.3 Use of estuaries

The Catlins River Estuary was not included in the core foraging range of any of the studied adult female sea lions. Unknown did not enter this estuary during the study other than along Surat Bay to reach her land sites. Across all four other females, they spent only 5.5% of their total time at sea in the estuary (< 2% of each individual's time). However, they had to travel to several land sites within the estuary (Hinahina Island and Pounawea Reserve), and hence a large proportion of that time was travelling to and from a land site. During the study, Kiwa travelled through the estuary at least once during 50% of the day, P447 during 42%, Jade during 21% and P446 during 12%. Only the lower part of the estuary (area east of Pounawea Reserve) was used, except for Jade and Kiwa that entered Catlins Lake/Kuramea once for < 3 hrs each. There did not appear to be a temporal pattern of use of the estuary as GPS locations in the estuary were spread equally across daylight and nighttime.

Across all studied females, only the mouth of the estuary was used as a general foraging area during the study (a small area delineated adjacent to the western end of Surat Bay can be described as a 'travel corridor' to reach the land sites there with a wide beach area that is tidal) (Figure 21-A). At the individual level, there were some small discreet areas classified as general foraging areas inside the Catlins River Estuary and a larger one covering its mouth (Figure 21-B). Analysis of the timing of the locations within the larger foraging area covering the mouth of the estuary showed typical foraging patterns, with consecutive locations within the area. However, analyses of timing of locations showed that all locations further up the estuary could not be matched with consecutive locations.

Figure 21: Marine use of The Catlins River Estuary by five adult female New Zealand sea lions during winter 2022, with A: Core foraging range (65% kernel density (KD), general foraging range (95% KD), and marine home range (100% KD) for all females combined, and B: for each female individually displayed together (note that the 100% KD is similar to A and that the 95% KD within the estuary are travel corridors, not foraging range).

Hence, this indicated that they were most likely related to travel, but with the possibility of incidental foraging on the way (i.e. if the females did not using land sites inside the estuary, they did not enter e.g. Unknown). Therefore, it is most likely that some foraging took place at the mouth of the Catlins River Estuary but that foraging did not regularly occur within the estuary.

The other estuaries were not used by any of the studied adult females, expect for Kiwa that visited and foraged at the mouth of the Tahakopa River Estuary once for 3.5 hrs and for Unknown that foraged just outside Waipati River Estuary on three occasions of < 2 hrs each during the period when she used the adjacent land site at the end of Waipati Beach.

3.3.4 Otago Peninsula habitat use

Unknown spent 67 % (52 days) of the study at the Otago Peninsula. She travelled twice from The Catlins to the Otago Peninsula and once the other way. It took her between approximately 7 and 13 hrs to travel between the two areas (see Figure 5). She used different routes every time and dived throughout the trips. She never came onshore despite being very close to shore during one trip.

At the Otago Peninsula, Unknown spent 45.3 % of her time onshore (compared to 42.5% in The Catlins) and periods onshore lasted on average 12.3 ± 6.7 hrs with a maximum of 30.3 hrs (compared to 9.6 ± 4.5 hrs with a maximum of 18.8 hrs in The Catlins). The mean foraging trip duration was 14.6 ± 6.9 hrs (compared to 12.5 ± 6.2 hrs in The Catlins). There was no significant difference between duration of foraging trips (Welch Two Sample t-test; $t = -1.36$, $df = 54.94$, p-value = 0.18) or duration of periods on shore ($t = -2.04$, $df = 63.46$, p-value = 0.05) between the data of Unknown at the Otago Peninsula and in The Catlins.

The average dive depth of Unknown at the Otago Peninsula was 17.0 ± 13.3 m, with a maximum of 87.5 m and 88.2 % of her dives were less than 30 m depth (Figure 22). In The Catlins, her average dive depth was 12.8 ± 13.2 m and 97.2% of her dives were less than 30 m depth. The average dive duration was 1.6 ± 1.3 min with a maximum of 7.3 min. In The Catlins, her dive duration was 1.3 ± 1.1 min. Unknown dived significantly deeper at the Otago Peninsula than in The Catlins ($t = -28.43$, $df = 21$, p-value < 0.01). The duration of her dives was also significantly greater at the Otago Peninsula than in The Catlins ($t = -18.85$, $df = 21$, p-value < 0.01).

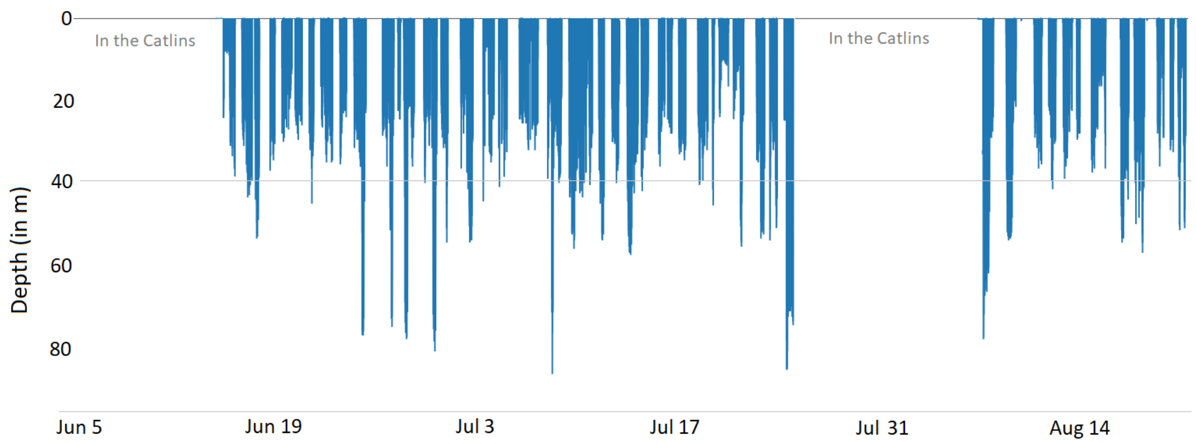

Figure 22: Dive profile of adult female New Zealand sea lion Unknown off the Otago Peninsula during winter 2022.

The land sites used by Unknown were all on the Otago Peninsula and were all sandy beaches. She spent time at Sandfly Bay, the entrance of Hoopers Inlet, Allans Beach, Cicily Beach, Wharekakahu Beach (both are small beaches found just East of Allans Beach) and Papanui Beach (Figure 23). She foraged primarily on the coastal rocky reefs and 91% of all marine locations were < 300 m from land. She only foraged offshore (5-7 km from land) during parts of five foraging trips when she exclusively foraged in the area of the bryozoan thickets (see Augé *et al*., 2012b). Marine locations within 50 m of the rocks that constitute Gull Rocks and Tow Rock and on the shallow rocky reefs between them accounted for 31% of all her marine locations.

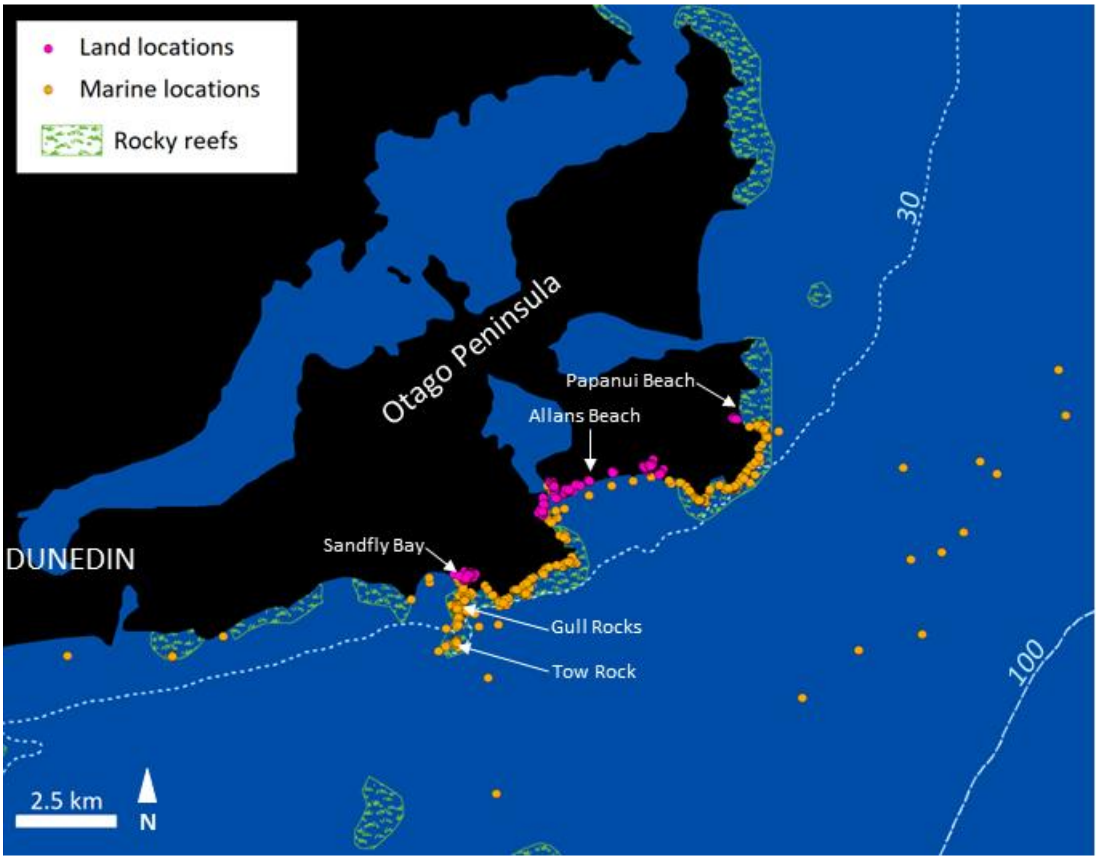

Figure 23: *Land and marine locations for adult female New Zealand sea lion Unknown during her two periods at the Otago Peninsula in winter 2022 (she was instrumented in The Catlins and tag recovery took place at Sandfly Bay, Otago Peninsula).*

3.4 Comparison with 2019 Catlins study and 2008-10 Otago study

3.4.1 Behaviours in The Catlins 3 years apart

Due to the difference in accuracy of the data between the 2019 study (ARGOS locations) and this study (fastloc-GPS locations), direct quantitative comparisons of results of foraging areas and foraging trips between years were not possible. An illustration of this difference in accuracy is shown in Figure 24. ARGOS locations are known to have a large error (often remaining to 1 to 3 km after best cleaning and filtering of the data, in particular for marine locations) whereas fastloc-GPS locations can have accuracy of up to 20 m after post-processing.

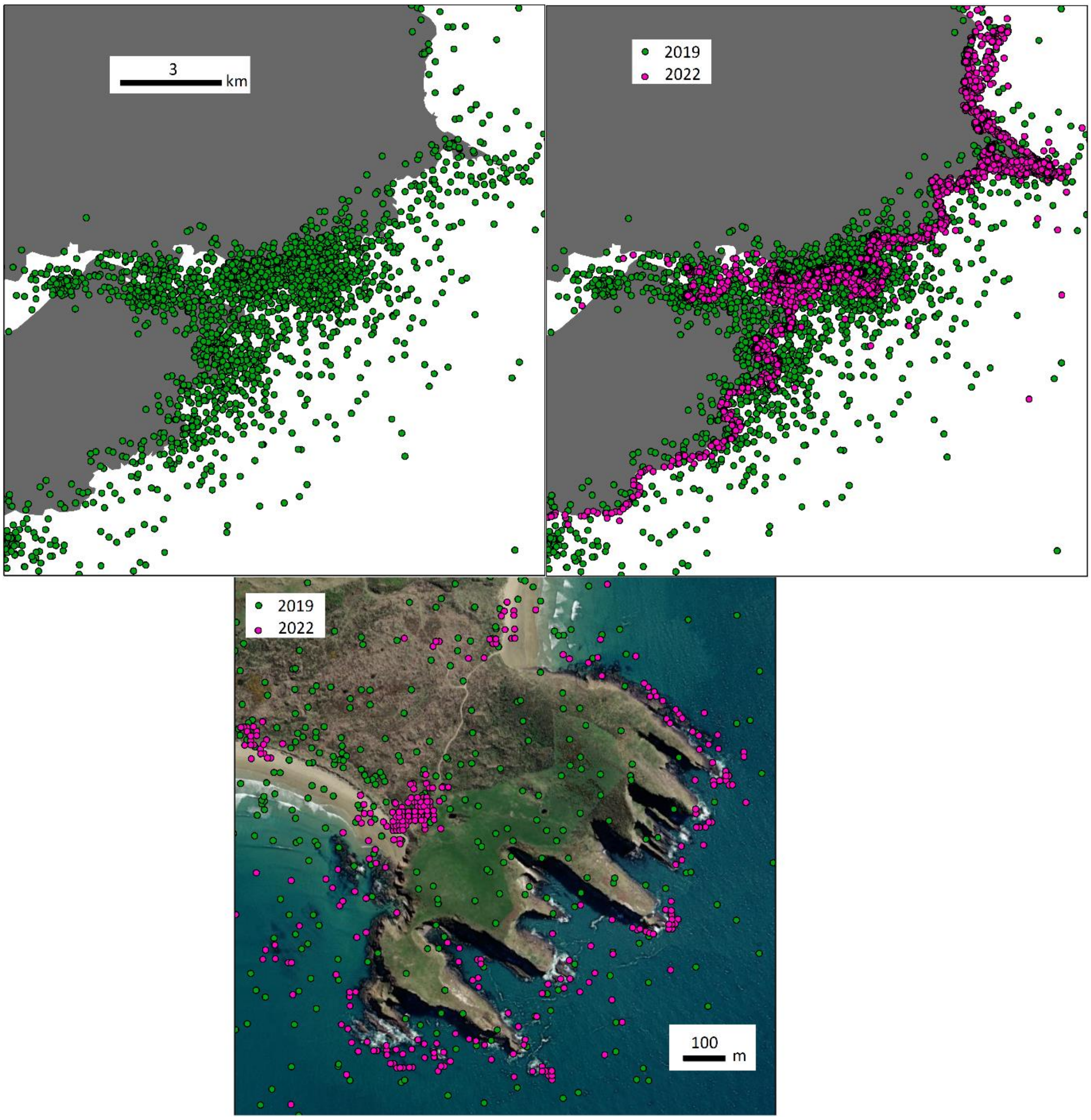

Figure 24: Comparison of the accuracy of all ARGOS locations (from 2019 study; Reed *et al.,* 2023*) and all (land and marine) fastloc-GPS locations (this study).*

As illustrated, filtered ARGOS locations were still widely spread across land and sea and did not allow for separating locations on land to those at sea without dive data that were not recorded during the 2019 study. Therefore, the low ARGOS location accuracy prevented the ability to remove land locations which would have significantly inflated the estimation of use of the area around land sites.

Qualitative comparisons were conducted between the 2019 and 2022 datasets. The latitudes north and south reached in The Catlins area (i.e. excluding Unknown's trip to Otago Peninsula) were consistent between the two years (Figure 25). Approximate maximum distance from land (excluding Unknown's extreme trip) and extent of offshore and inshore areas used were relatively similar between the two years. A notable exception was Catlins Lake that was only visited twice during the 2022 study whereas one of the females studied in 2019 regularly entered Catlins Lake as she had a regular land location there. Another noticeable difference in the data was the small number of locations around Nugget Point and up along the coast of The Nuggets Road during 2019 compared to 2022.

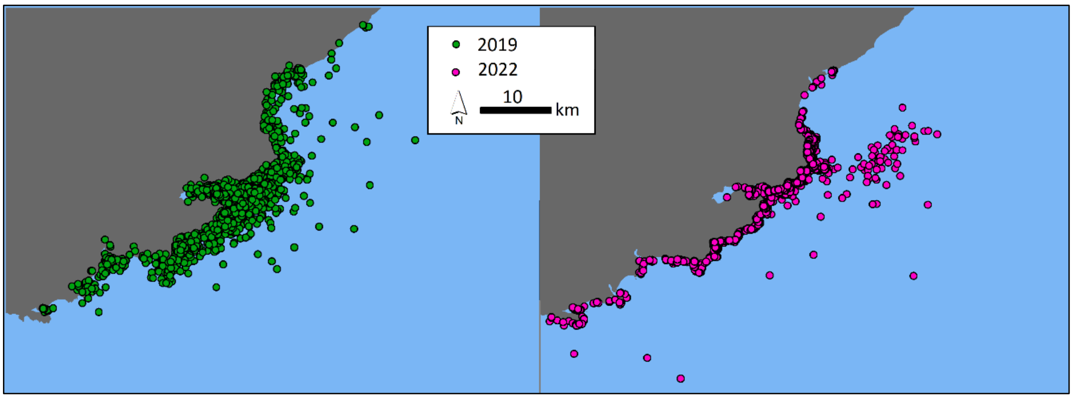

Figure 25: Comparison of the 2019 locations and 2022 locations (land and marine) of all studied female New Zealand sea lions. Note that 2019 was ARGOS accuracy and 2022 was fastloc-GPS accuracy.

However, most of locations in the 2019 datasets around the Catlins River Estuary and nearby would have most likely been land locations as more land fixes are generated than at sea with ARGOS. Therefore, the proportion of locations in the other areas may, in fact, be higher for marine locations and may have been highlighted in the 65% KD in 2019 if land locations could have all been removed (though in a much coarser output than with the 2022 data).

P446 was the only individual studied during both 2019 and 2022. She was not nursing a pup in either year. P446's marine home ranges were bounded by approximately the same latitudes during each year (Figure 26) and she seemed to have used the same land sites, but maybe for different proportion of her time. Similar to the comparison amongst all females between both years, there was an apparent lack of marine locations around Nugget Point in 2019 compared to 2022 (with the same possible caveat than explained above).

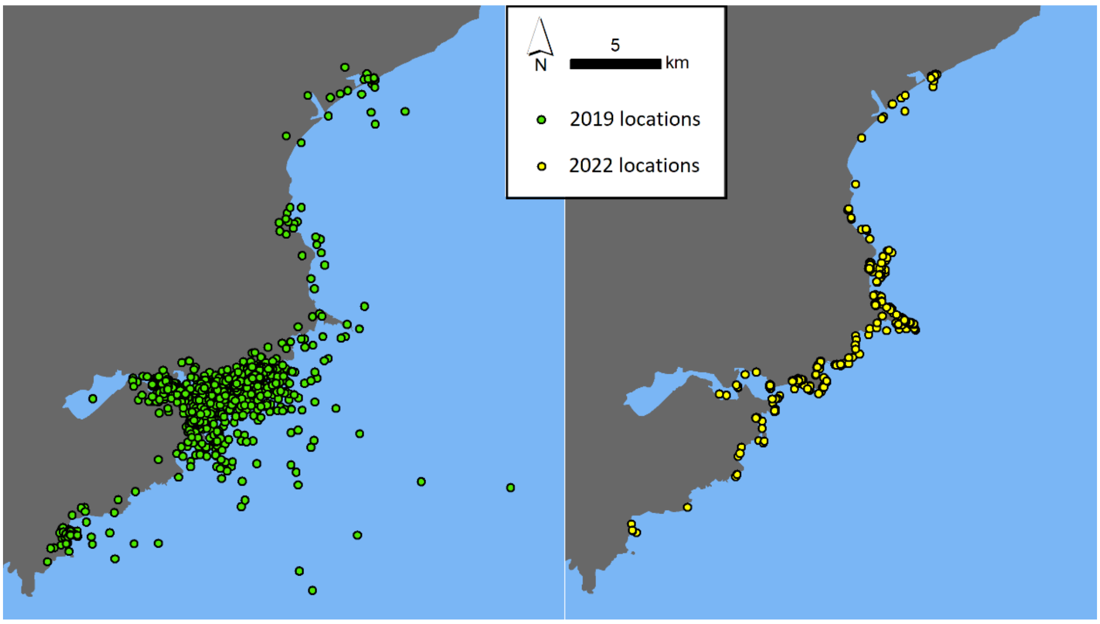

Figure 26: Comparison of the winter 2019 locations and winter 2022 locations (land and marine) of female New Zealand sea lion P446 (aged 3 in 2019). Note that 2019 was ARGOS accuracy and 2022 was fastloc-GPS accuracy.

In terms of diving, the only data from 2019 were from two foraging trips of one female, not studied in 2022 (Reed *et al*., 2023). Therefore, quantitative comparison would not be meaningful due to the low number of dives and inter-individual differences. The data from 2019 gave a mean dive depth of 8.9 m ± 5.2 m and all dives were <30 m, and the mean dive duration was 1.4 ± 1.1 min. Therefore, the 2019 means fall within the 2022 range of means for both depth and duration. This indicates that the diving behaviour of female New Zealand sea lions in The Catlins as described here is likely typical of winter. Similar to the 2022 study, diving took place during daytime and nighttime with a higher proportion of dives during daytime (71% of dives took place between sunrise and sunset).

3.4.2 Comparison with autumn behaviours at the Otago Peninsula

In the 2008-2010 tracking study of New Zealand sea lions at the Otago Peninsula, adult and juvenile females were included but there was no effect of age on characteristics of land use or foraging behaviours. Therefore, comparison included all individuals. The 2008-10 study took place during autumn (March-May) whereas the 2022 Catlins study took place in winter (June-August).

There were significant differences in dive duration between Otago Peninsula in autumn (1.8 mins) and Catlins in winter from this study (1.5 mins) ($t = -50.15$, $df = 143182$, $p\text{-value} < 0.01$) and in dive depth with a mean of 20.2 ± 24.5 m in autumn at Otago Peninsula and 10.5 m in winter in The Catlins. Areas of foraging ranges could not be quantitatively compared due to the differences in location accuracy, so a qualitative comparison was conducted.

The land use and foraging characteristics of Unknown during the time she spent at the Otago Peninsula in 2022 were very similar to those of Otago Peninsula females during autumn 14 years earlier. Unknown used land sites and foraging areas that were some of the core areas used by Otago Peninsula females in autumns 2008-2010, notably the bryozoan thickets. While the fastloc-GPS accuracy provided much better resolution of exact foraging areas on the shallow coastal rocky reefs, the general pattern of foraging was similar to Otago Peninsula females in autumns 2008-2010.

4. DISCUSSION

4.1 Land and marine use of The Catlins sea lions

In winter, adult female New Zealand sea lions in The Catlins exhibited very coastal foraging, with most foraging taking place within 300 m from shore. Shallow rocky reefs between Campbell Point in the north and Pūrākaunui in the south were the almost exclusive foraging habitat and the near-shore area of The Nuggets was the only core foraging range across all studied females. Their diving behaviours and general foraging areas were mostly consistent between years but the core foraging range might vary between years. There were also differences in areas used amongst individuals between years, in particular in the northernmost and southernmost areas of the marine home range.

Land sites used by adult female New Zealand sea lions in The Catlins in winter spanned the same coastline as their marine home range but each adult female had a specific land location where she spent more time on land than at any other sites. These individually-specific sites varied amongst females. Therefore, the adult female New Zealand sea lions that were not part of the study may have used other land sites. For instance, the local DOC ranger reported that two of the other known Catlins females used land sites at Long Point during the same period covered by the study and that another female is known to use land sites further north than the studied females. To have a more complete picture of the most important land sites for the whole population, the results of this tracking study should be combined with existing sightings available and local expert knowledge spanning the same period.

The three days of data for the female yearling Susie indicated that she used the same general land sites as adults but her diving behaviour was significantly different from adult behaviours in this study, and adult or juvenile (two-year-old) behaviours observed at the Otago Peninsula (Augé, 2010). It appears that Susie's dive profile was very similar to profiles of yellow-eyed penguins/hoiho that forage in Molyneux Bay, the large bay to the north of Nugget Point (Mel Young, personal communication). None of the studied adult females foraged in this bay other than on the coastal rocky reefs. From Susie's dive profile, it is apparent that she did not forage on shallow rocky reefs. Due to the very short duration that that the available data cover, confident conclusions cannot be made. Further study of this age group (yearlings) will be needed to determine if yearlings forage in entirely different habitats to adults.

In winter, the estuaries did not constitute foraging habitats for adult female New Zealand sea lions in this study in The Catlins. Only the mouth of the Catlins River estuary was part of the general foraging range of three out of the five studied adult females. Four adult females used land sites inside the estuary and, therefore, they had to swim through the estuary regularly to reach those land sites but did not forage during those travels. This result differs significantly from the results of the 2019 study that concluded that the Catlins River estuary constituted part of the main 'core range' for all four females studied (Reed *et al.*, 2023). However, during the 2019 study, the land and marine locations could not be separated and this is why Reed *et al*. (2023) used the term 'core range', and not the term foraging range. This 2022 study showed that several land areas within the Catlins River estuary and Surat Bay, at its mouth, are extensively used as land sites by female New Zealand sea lions. Therefore, Reed *et al*. (2023) was able to identify areas of the estuary as core range but could not identify the type of range that it represented or the detailed sites within the estuary where the females were (on land or at sea). This 2022 study with its finer accuracy of locations showed that female New Zealand sea lions used the Catlins River estuary extensively for travelling to land sites but not for foraging, during winter.

The 'offshore' area used by adult female New Zealand sea lions at The Catlins was a defined area in water depths of 40 to 70 m. Due to the density of marine locations in the coastal area and the Kernel density parameters used, this area was not identified as part of the foraging range. However, it was clearly part of the foraging range even though it was only used with very low intensity during this study. The pattern of use of this offshore area interestingly matches the pattern of foraging areas observed off the Otago Peninsula where the core foraging ranges of Otago Peninsula female New Zealand sea lions, in autumn, consistently included a defined offshore area of depth 60-70 m off the peninsula (Augé, 2011). This offshore area corresponded to the known extent of bryozoan thickets there. It is possible that bryozoan thickets occur in the offshore area defined by the locations of the Catlins female sea lions but there was no information available to confirm this. There is very little information of the benthic community in the mirroring area off Nugget Point. The Otago Peninsula female sea lions are known to use these bryozoan thickets significantly during autumn. Based on the results from the tracking off the Otago Peninsula in winter 2022, it appears that the bryozoan thickets are also used in winter, but perhaps, with a lower intensity. Several prey species in the diet of the Otago Peninsula female sea lions are migratory and this may lead to a seasonal change in marine habitat use (Augé *et al.*, 2012a). Interestingly, sea lion foraging patterns may indicate the presence of bryozoan thickets or other similar deep biogenic habitats that would provide special foraging grounds. It is possible that female sea lions in The Catlins may use the offshore area more prominently in autumn or other seasons than in winter.

4.2 Data accuracy and other limitations

4.2.1 Accuracy of tracking locations

The spatial accuracy of the fastloc-GPS data allowed for detailed land and marine use analsyes that ARGOS data could not provide. Due to the very coastal foraging behaviour of mainland female New Zealand sea lions and their overall restricted range, accurate data is needed to understand patterns of distribution. Therefore, future tracking studies of New Zealand sea lions on the mainland must use tracking devices that can provide location data with GPS accuracy. Using a lower accuracy will not provide meaningful data for management.

The temporal accuracy of the GPS locations was, at the maximum, one GPS location every hour as the SPLASH tags were set to obtain one location every hour but this varied depending on satellites available. While this dataset was adequate for analyses of marine habitat use, a finer temporal accuracy could provide more details on foraging locations, in particular for areas with known interactions with human activities (e.g. estuaries). In some foraging studies using fastloc-GPS technology on other species of sea lions, the temporal accuracy was set to 5-15 mins (Baylis *et al.*, 2018; Blakeway *et al*., 2021). For detailed analyses and management recommendations on land, the one-hour temporal accuracy limited the understanding of sea lion movements in this study, particularly in areas close to roads. In these areas, having finer-detailed data in time could provide more certainty of risk. It is recommended that temporal accuracy be set at 5 or 10 minutes in future studies to gain better detail of movements of sea lions. This would use more battery but would provide more useful data and, for < 70 days of tracking, can be supported by the battery (tags can start falling after > 40 days so long studies are not possible unless losing tags is not an issue).

There was poor spatial and temporal accuracy of the GPS locations when sea lions came onshore in forested areas (Hinahina Island and Pounawea Reserve). In these areas, few locations were obtained and the location accuracy was below that of non-forested and marine areas. The detailed habitat use was therefore coarser than in other areas. Hinahina Island and Pounawea Reserve are not directly adjacent to roads and are not used by vehicles, therefore, the lower accuracy did not impact on the results of this study. There is, however, a road across the water in close proximity to Hinahina Island. While it does not appear that the studied sea lions came onshore there, it is not possible to be fully confident in this result due to the low temporal and spatial accuracy of the GPS locations at this site. Within an hour, a sea lion could have moved on the road and then back on the island, for instance, and the difference between this behaviour and spatial inaccuracy cannot be confidently determined. For this site and other known forested areas that have a road nearby or are used by vehicles, a solution should be implemented in future studies to ensure habitat use at those sites are well monitored during the tracking study. Satellite-based tracking devices for marine animals cannot obtain locations accurately under canopy. There may be future development for marine tags with the 'SWIFT fix' GPS system (Forrest *et al*., 2022) but it does not appear that a marine tag with this functionality is currently available (the combination of the requirements for marine resistance and satellite connection and forest accuracy is rarely needed in the same tag). One potential solution could be to set up an automated VHF radio telemetry with a multi-antennae array at the same time as the tracking period at to determine locations in forested areas (Hinahina Island would be a candidate for such a set up). If the VHF tags are left on the animals, then attendance patterns at those sites could be gathered until the tag falls off.

Any interpretation of the land use data in this study must be made in the context that the duration between two consecutive land locations was at the minimum one hour. Female sea lions can move significant distances during an hour. Moreover, any land locations indicated that the females would have crossed the area between the sea and her location as well. It is not possible to confirm where and how long a sea lion would be staying but it needs to be kept in mind when using the results of this study for management, in particular for the risks from roads and vehicles on beaches. Therefore, the results presented for the sites on or close to roads or beach with vehicle access, need to be considered as a minimum amount of time these animals were exposed to risk from vehicles. Finer temporal accuracy of the GPS locations could reduce this uncertainty in future studies.

The post-processing of the fastloc-GPS snapshots to compute GPS locations allows to add user-entered GPS locations (exact date, time, latitude, longitude) which increases the accuracy of the output as the algorithm includes those to calibrate the overall dataset. Therefore, when using fastloc-GPS tracking device, it is important to record GPS locations of where the tag was deployed and removed and of any sightings of the animal during deployment (like it was done in the field reports during deployment). It is recommended that a clear plan to record these locations is implemented for future studies (from DOC staff and members of the public).

The SPLASH 10 tags used in this study had a setting feature called "Enable haulout location, duration, and post haul-out movement". This was not enabled during the 2022 deployment. Enabling of this feature may have given a more accurate picture of land habitat use (for example, more GPS locations around areas where they came ashore), and may have reduced the analytical effort. It is recommended that for future deployment of these same tags on mainland New Zealand sea lions, and if one of the aims of the study is to look at land habitat use, this be enabled and set prior to deployment. As explained in regards to temporal accuracy, this would be useful to gain a better understanding of the exact use of areas of or near roads and beaches with vehicle access.

In conclusion, the recommendations for ensuring suitable accuracy for future studies are to:

- Use only tracking devices with GPS accuracy for any future study of mainland New Zealand sea lions
- Set the devices to obtain a GPS location every 5 or 10 minutes (on land and at sea, with no switch off when onshore)
- Record GPS locations of captures and re-captures and during any encounters of tracked sea lions
- Plan to survey any forested areas known to be used by sea lions with a complementary local monitoring system

4.2.2 Seasonal limitations

This study in The Catlins and the previous study conducted in 2019 took place during winter only. Therefore, the data do not directly provide information on whether their behaviours, on land and at sea, remain the same during the rest of the year. However, the female New Zealand sea lions based around the Otago Peninsula showed foraging site fidelity across a three-year study during autumn (2008-2010), and they also consistently used the same area of coastline (reaching the same lowest and highest latitudes as their foraging areas) during the entire year over those three years (Augé *et al.*, 2014). The patterns observed in winter in The Catlins were similar. Therefore, it is unlikely that the female New Zealand sea lions based in The Catlins migrate or use completely different land or marine areas during other seasons. However, there may be some seasonal changes in proportion of time spent foraging between inshore and offshore, while most likely remaining coastal. There are also likely changes in the proportion of time they spent at different land sites during different seasons as observed at the Otago Peninsula.

As reported in Reed *et al*. (2023) and confirmed in this 2022 study, female New Zealand sea lions in The Catlins in winter exhibit even shallower and more coastal foraging behaviour than the females based at the Otago Peninsula in autumn. Having one female spending time both in The Catlins and at the Otago Peninsula during 2022 allowed comparison of foraging behaviours of the same individual in The Catlins and at Otago Peninsula during the same season. This female exhibited deeper and longer dives at the Otago Peninsula but remained as coastal at both sites. This confirmed that the small difference in dive depths is most likely not due to seasonal changes but rather due to habitat configuration (shallow rocky reefs slightly deeper at the Otago Peninsula). Overall, the marine habitat use of Catlins female New Zealand sea lions is closely related to the habitat use that was exhibited by the Otago Peninsula female sea lions. While we cannot exclude that there would be some differences in foraging behaviours in summer and spring, these would most likely be minimal and the general foraging areas used would unlikely drastically change.

In conclusion, there may be some seasonal changes in land and marine uses of the Catlins female New Zealand sea lions. However, it is most likely that these changes would not result in drastic differences in general areas used compared to those during winter. The results from the winter studies provided a suitable basis to implement some management measures. Studying the land and habitat use during other seasons would provide a more detailed understanding of their behaviours, in particular around known areas of risk from human interactions and for analysing overlap with fishing activities.

4.3 Recommendations for land-based management

4.3.1 Managing risks from roads

The Catlins has several roads that closely follow the coastline, often adjacent to sandy beaches. Many of these roads were recently sealed in the last decade, increasing the average speed of vehicles. There are concerns about risks from collisions between vehicles and sea lions, in particularly following the deaths of Matariki and her pup on the coastal road just north of Kaka Point in 2020 (see Figure 2). The results of this study indicated a significant spatial overlap between female sea lions and cars on Kaka Point Road and The Nuggets Road as most females considerably used areas within 20 m of these roads, including crossing the road to reach a land site. This creates high risks of collision.

The Nuggets Road and Kaka Point Road are sealed and have 100 km/h speed limits. They receive low to medium levels of vehicle traffic, with a seasonal pattern from tourists visiting Nugget Point in summer. While there are some discrete sites along these roads that were predominantly used by female New Zealand sea lions during this study and where management of traffic could be implemented specifically, sea lions can come ashore anywhere along these roads. Moreover, collisions may be more likely to occur at sites where females come onshore for shorter periods or less often (for instance local drivers may already be more prudent in areas they already know are regularly used by sea lions). Therefore, it is recommended that management should be applied to most roads where they follow the coastline.

Road traffic controls at key identified sites (roads and beaches) should be part of the NZ sea lion Threat Management Plan because there have been examples of road kills in recent years and regular witnessed occurrences of vehicles disturbing sea lions on beaches. Reductions in speed limits, speed reducers (e.g. speed bumps), additional signage, fences to direct sea lions crossing roads at only a few dedicated spots, education of local road users and visitors, or an innovative technological warning system when sea lions are present on roads, could all reduce risks of collision on roads between sea lions and vehicles. Underpasses might also be an option to encourage sea lions off roadways.

4.3.2 Managing risks from vehicles on beaches

New Zealand beaches are legal roads unless bylaws prevent vehicle usage. In 2022, the Clutha District Council consulted on a proposal to ban vehicles from eight beaches in The Catlins at Taieri Mouth, Kaka Point, Cannibal Bay, Surat Bay, Jacks Bay, Pūrākaunui, Tahakopa and Tautuku, and reduce the speed limit to 30 km/h on all other beaches. After consultation, the vehicle bans were dropped from the proposal and, instead, replaced with several rules (e.g. no driving in sand dunes except to access the beach or above the high-water mark). The Vehicles on Beaches Bylaw (Clutha District Council, 2023) became effective on 1 January 2023. It allows for the creation of 'safe zones' (vehicle prohibited areas) if there are appropriate data and consultation to support the need for them.

This study described land habitat use of female New Zealand sea lions over a single winter for a sample of the population. While these data can be used to promote the need for 'safe zones' at the sites identified, there may be a need to demonstrate the consistency in sea lion behaviour over winter, and the use of these sites during other seasons. It would be interesting to compare land locations as per the results of this 2022 study with sightings of other female New Zealand sea lions during the same period. It would indicate whether there are key land locations that were not included in those from the 2022 studied females but that would be important for the population (e.g. the site in Catlins Lake used in 2019 by one female that was not used during 2022). Analysing all available sightings of females over the last 3 to 4 years may also provide enough data to demonstrate the use of the sites during other seasons and the consistency in use.

Overall, management actions would be more effectively informed by incorporating year-round data on how sea lions use critical sites such as known areas around roads or beaches with vehicle access. Studies could involve more satellite tracking outside of winter, but this would always be for shorter periods due to the restrictions of the attachment of the tags and their battery life, and for a sample of animals. Year-long resight monitoring could, instead, use automated VHF telemetry, or automated camera or video surveillance, or a combination of both at critical sites. This would give a better year-round understanding of land habitat use by sea lions and vehicles to develop the most effective management actions at these sites.

4.4 Recommendations for marine-based management

This study provided a detailed understanding of marine use and foraging areas of a sample of adult female New Zealand sea lions in The Catlins in winter. However, it is not possible to determine confidently if there are seasonal changes in these patterns, particularly in summer and spring. Further tracking studies will be needed to determine potential seasonal differences. A year-round diet study may also provide a proxy to determine whether it is likely that female New Zealand sea lions change their foraging areas between seasons.

Based on the results of this study, in winter, the Catlins River estuary is not used for foraging by female New Zealand sea lions. However, the animals in this study regularly travelled through the estuary to access land sites. During this study, the two females with pups kept their pups at land sites within the estuary. Both females moved their pups between sites several times and the pups also swam within the estuary. Pups also likely regularly swam on their own in the estuary near the land sites where their mothers left them (this was witnessed once by the field team around Hinahina Island), so this is critical habitat for part of the population that were not tracked in this study. There are risks to females and pups from interactions with fishing gear and boats in the estuaries, even though these animals are not foraging regularly in this area.

Commercial and recreational set nets are prohibited off The Catlins from shore to 4 nm as part of the Southland set net prohibited areas[13] enforced by MPI. However, the restriction does not apply to rivers, river mouth entrances or river estuaries. Almost all the general foraging range identified in this study falls within the set net prohibition area, but set netting can take place in the Catlins River estuary where females and pups swim through. There is already evidence of sea lion interactions with set nets e.g. flipper tags were found stuck in a net, in this instance the sea lion was later sighted alive (Ros Cole, personal communication).

The shallow rocky reefs predominantly used by female sea lions are most likely where most recreational fishing takes place, and some commercial fishing. There are limited data on current distribution of recreational fishing, but commercial fishing data would be available for overlap analyses. A recreational fishing survey in The Catlins, would provide a better understanding of spatial distribution of this activity and target species. Surveys of recreational fishers could concurrently indicate if they have had interactions with sea lions. Analyses of spatial and species overlaps could indicate potential future issues and the need to take some precautionary measures to ensure the Catlins population grows without creating substantial negative interactions.

In conclusion, as the population of sea lions in The Catlins increases, management issues arising from sea lions with human activities will likely increase if management is not implemented (e.g. in Otago; Augé *et al*., 2012b). In order to prevent issues from arising, actions must be proactive. The issues encountered in The Catlins are generally similar to those at the Otago Peninsula. Therefore, it is recommended that the approach to management be coordinated between the two areas, in particular in trialling management options and monitoring. Several management actions can be looked at being implemented now to limit risks of death or disturbance from vehicles, notably working with Clutha District Council to reduce collision risk on Kaka Point Road and The Nuggets Road, and at several beaches, principally Cannibal Bay. Starting discussions with Fisheries New Zealand for addressing the risk of entanglement in set nets in the Catlins River Estuary could also be an action that can be taken.

4.5 Future science needs for Threat Management Plan

The New Zealand sea lion Threat Management Plan's aims for the South Island are: "facilitate population growth". This can be done by increasing the annual number of pups born in The Catlins and by trying to encourage any adult or juvenile females that immigrate from southern populations to remain in The Catlins to breed by limiting disturbance and providing suitable habitats. The risks of deaths or disturbance of female New Zealand sea lions in The Catlins is therefore a key element that will implement the success of population growth.

Recommended future science needs to better understand these risks are, in suggested order of priority:

[13] https://www.mpi.govt.nz/dmsdocument/929-Southland-Recreational-Fishing-Rules-

- **Year-round land habitat use**. The detailed data of land habitat use from this study in winter needs to be combined with data from other seasons and future years to be comprehensive and ensure any management put in place is and remains effective for protection. This can be done by analysing resighting data from previous years and monitoring the population more consistently in future.

- **Year-round diet**. Determining the current diet of female New Zealand sea lions during all seasons and, thereafter, monitoring the diet of females regularly (e.g. every 5 years) would provide proxy information to detect potential changes in foraging areas using a less invasive method than tracking animals.

- **Fishery overlap analyses**. An analysis of recreational and commercial fishing distribution in relation to the results of this study would lend insight into the potential risks for sea lions in the marine environment from boat strike and fishing gear entanglement, and inform a proactive approach to mitigating these risks.

- **Foraging behaviours of yearlings**. The small amount of data available from the juvenile female (1.5 year-old) tracked in this study indicated that this age group may forage in different habitats than adults where risks of vessel strike or fishing gear entanglement may differ. Therefore, it would be useful to determine the marine habitat use of this age group (yearlings) in The Catlins but also at Otago Peninsula as only older juveniles were studied there in 2008-10.

- **Determining the use of the 'offshore area' outside winter**. The 'offshore area' identified in this study may be used more intensively as foraging area in other seasons. Considering that this area might be where most interactions between sea lions and commercial fishing occur, it would be useful to understand sea lion use of this area outside the winter months.

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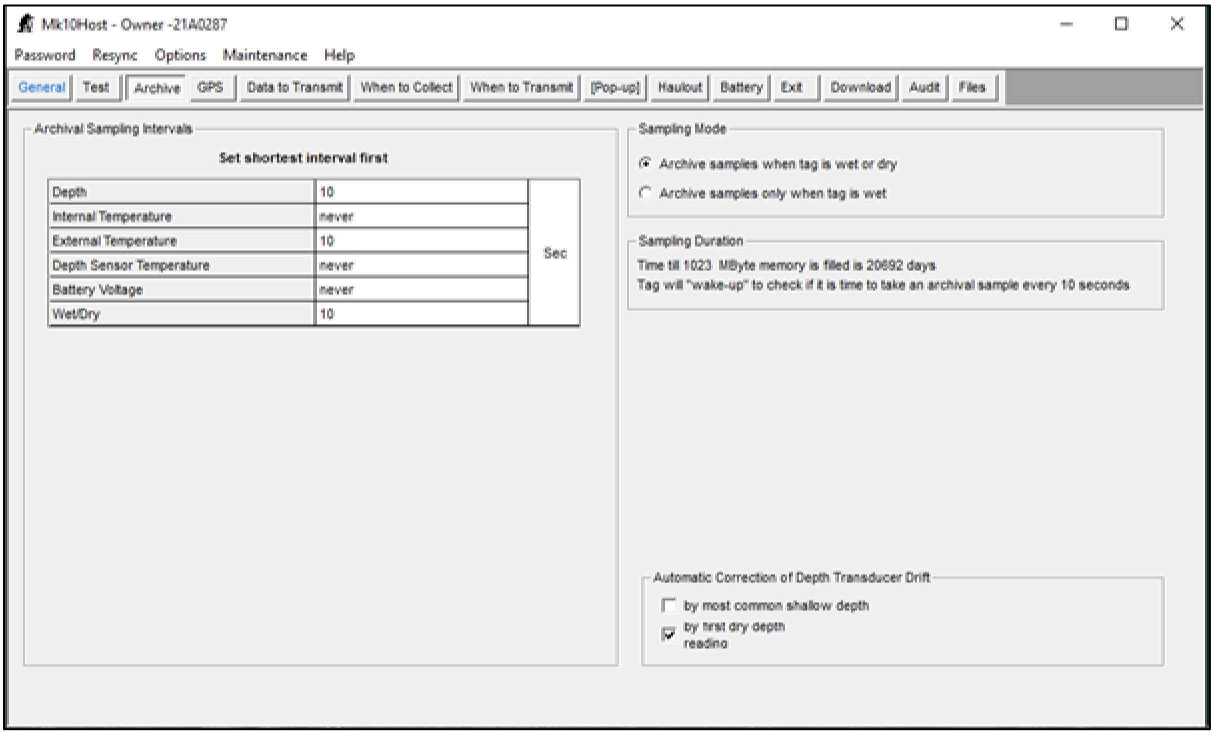
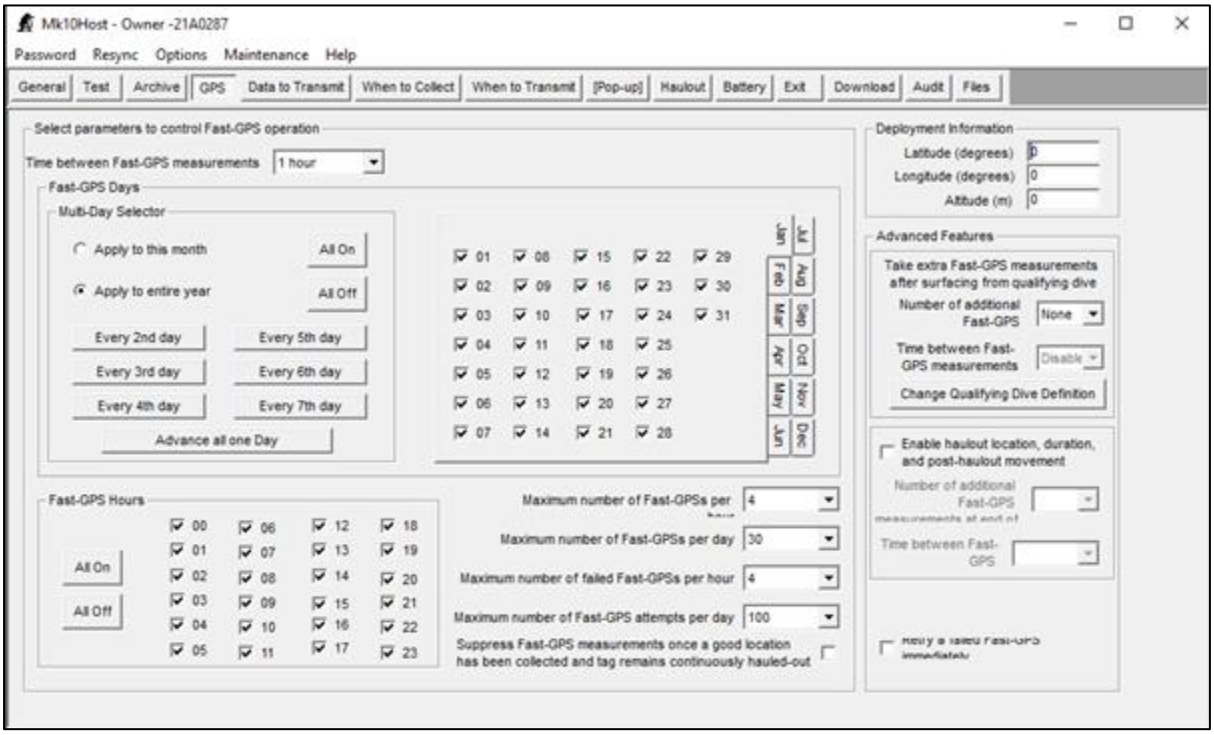
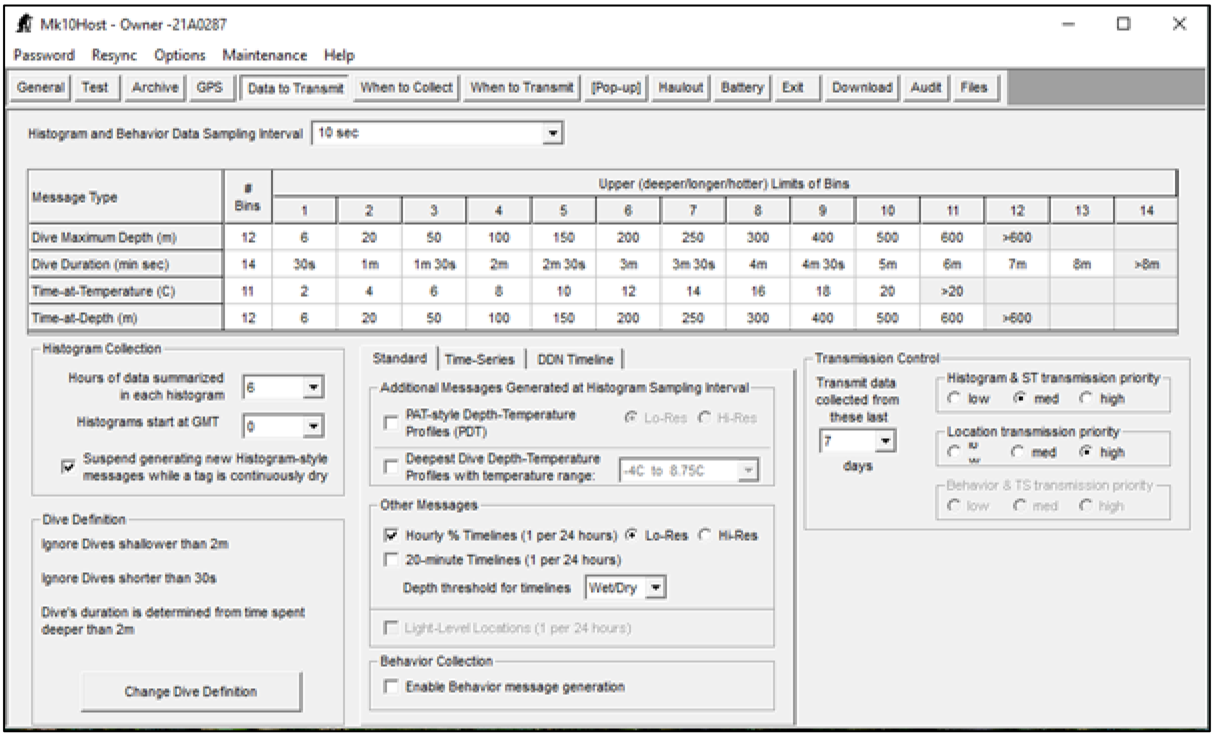
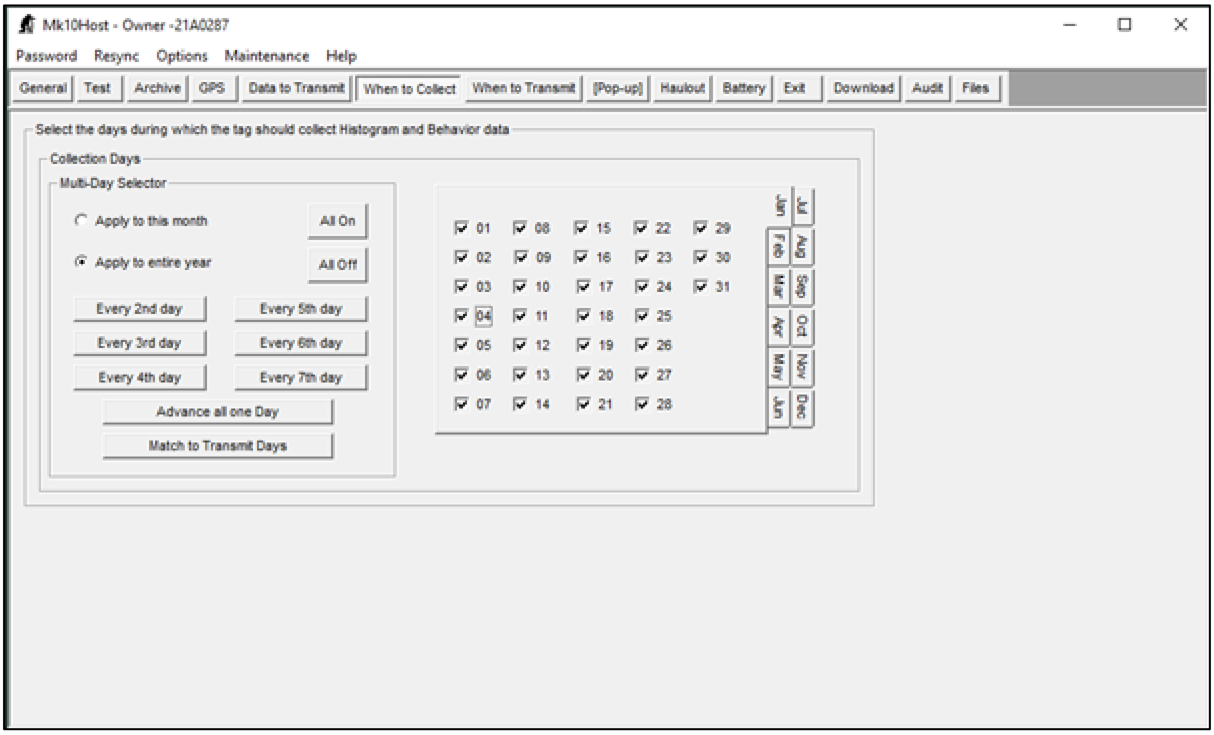
APPENDICES

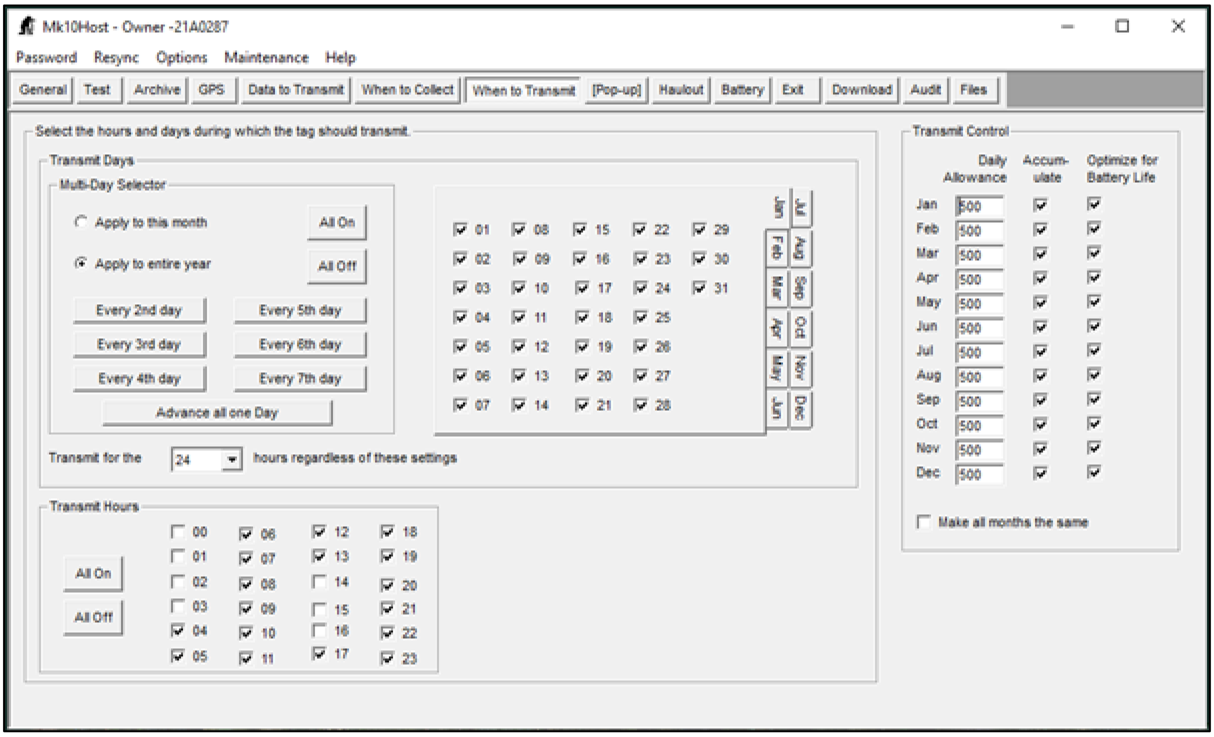
Appendix 1. Tag settings – Example for Kiwa's tag (all tags were set the same)

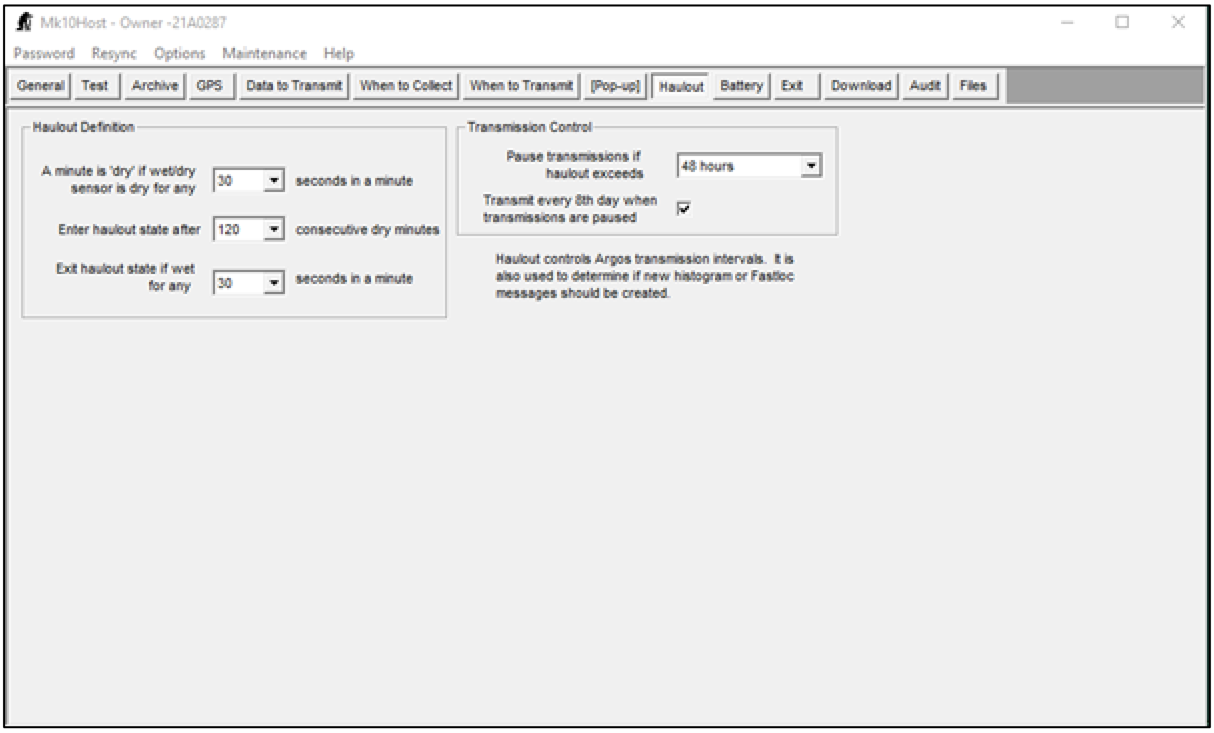





Mk10Host - Owner -21A0287
Password Resync Options Maintenance Help
General Test Archive GPS Data to Transmit When to Collect When to Transmit [Pop-up] Haulout Battery Exit Download Audit Files
Histogram and Behavior Data Sampling Interval 10 sec
Message Type
Bins
Upper (deeper/longer/hotter) Limits of Bins
Dive Maximum Depth (m) 12 6 20 50 100 150 200 250 300 400 500 600 >600
Dive Duration (min sec) 14 30s 1m 1m 30s 2m 2m 30s 3m 3m 30s 4m 4m 30s 5m 6m 7m 8m >8m
Time-at-Temperature (C) 11 2 4 6 8 10 12 14 16 18 20 >20
Time-at-Depth (m) 12 6 20 50 100 150 200 250 300 400 500 600 >600
Histogram Collection
Hours of data summarized in each histogram 6
Histograms start at GMT 0
Suspend generating new Histogram-style messages while a tag is continuously dry
Dive Definition
Ignore Dives shallower than 2m
Ignore Dives shorter than 30s
Dive's duration is determined from time spent deeper than 2m
Change Dive Definition
Standard Time-Series DDN Timeline
Additional Messages Generated at Histogram Sampling Interval
PAT-style Depth-Temperature Profiles (PDT) Lo-Res Hi-Res
Deepest Dive Depth-Temperature Profiles with temperature range: -4C to 8.75C
Other Messages
Hourly % Timelines (1 per 24 hours) Lo-Res Hi-Res
20-minute Timelines (1 per 24 hours)
Depth threshold for timelines Wet/Dry
Light-Level Locations (1 per 24 hours)
Behavior Collection
Enable Behavior message generation
Transmission Control
Transmit data collected from these last 7 days
Histogram & ST transmission priority low med high
Location transmission priority low med high
Behavior & TS transmission priority low med high


Mk10Host - Owner -21A0287
Password Resync Options Maintenance Help
General Test Archive GPS Data to Transmit When to Collect When to Transmit [Pop-up] Haulout Battery Exit Download Audit Files
Select the days during which the tag should collect Histogram and Behavior data
Collection Days
Multi-Day Selector
Apply to this month
All On
Apply to entire year
All Off
Every 2nd day
Every 5th day
Every 3rd day
Every 6th day
Every 4th day
Every 7th day
Advance all one Day
Match to Transmit Days
01 08 15 22 29
02 09 16 23 30
03 10 17 24 31
04 11 18 25
05 12 19 26
06 13 20 27
07 14 21 28
Jan Feb Mar Apr May Jun
Jul Aug Sep Oct Nov Dec


Mk10Host - Owner -21A0287
Password Resync Options Maintenance Help
General Test Archive GPS Data to Transmit When to Collect When to Transmit [Pop-up] Haulout Battery Exit Download Audit Files
Select the hours and days during which the tag should transmit.
Transmit Days
Multi-Day Selector
Apply to this month
All On
Apply to entire year
All Off
Every 2nd day
Every 5th day
Every 3rd day
Every 6th day
Every 4th day
Every 7th day
Advance all one Day
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Transmit for the 24 hours regardless of these settings
Transmit Hours
All On
All Off
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Transmit Control
Daily Allowance
Accum-ulate
Optimize for Battery Life
Jan 500
Feb 500
Mar 500
Apr 500
May 500
Jun 500
Jul 500
Aug 500
Sep 500
Oct 500
Nov 500
Dec 500
Make all months the same


Mk10Host - Owner -21A0287
Password Resync Options Maintenance Help
General Test Archive GPS Data to Transmit When to Collect When to Transmit [Pop-up] Haulout Battery Exit Download Audit Files
Haulout Definition
A minute is 'dry' if wet/dry sensor is dry for any 30 seconds in a minute
Enter haulout state after 120 consecutive dry minutes
Exit haulout state if wet for any 30 seconds in a minute
Transmission Control
Pause transmissions if haulout exceeds 48 hours
Transmit every 8th day when transmissions are paused
Haulout controls Argos transmission intervals. It is also used to determine if new histogram or Fastloc messages should be created.

Appendix 2. Field reports – Summaries of weekly field reports from Charlie Barnett, DOC ranger.

- Tag check 30/06/2022

Kiwa at Pounawea Reserve at 11:00 at Western end of Surat Bay in the dunes. Tags firmly attached, no sign of lifting, maybe some fur pulling.
P446 along The Nuggets Road near Karoro Creek at 11:55. Tags had no sign of lifting.
Jade at Eastern end of Surat Bay at 14:26. With pup (tag VETH). Maybe some fur pulling on VHF tag of Jade. All other tags no showing any lifting.
P447 at Pounawea Reserve at 15:39. With pup, suckling. No sign of lifting of the tags.
Susie (XGET)'s VHF tag was found in grass across The Nuggets Road between Short Bay and Campbell Point. The VHF tag was presumably pulled off by the fence line she had to go under to get to the spot (cut through the neoprene). Susie seemed to have crossed the road regularly to reach this spot based on the track (the tagging team had also seen her crossing the road there on 5 June).

- Tag check 6/07/2022

Kiwa at Pūrākaunui at 12:45 (VHF signal, no visual as she was in the small bay on the side – Cheryl Pullar indicated she had seen here there in the flax bush before).
P447 at Cannibal Bay at 13:45. Tags appeared fine but no good visual due to sand. No pup sighted (but did not search for it).
Jade on the beach before Nugget Point at 14:45. No pup seen. No sign of lifting of the tags.

- Tag check 11-16/07/22

Susie (XGET) in Wilsher Bay on 11/07 under a tree by The Nuggets Road. She was found by chance from visible tracks as no VHF tag. Other tag showed no sign of lifting.
Jade and her pup (VETH) at Hinahina Island on 13/07 at 10:00. Pup was suckling. No sign of tags lifting.
P447 on 15/07 at Eastern end of Surat Bay at 10:19. Tucked in the dunes under flax bush. SPLASH tag seemed to have a bit of lifting on one side, no other sign of lifting. No pup seen.
P446 on 16/07 at Cannibal Bay at 17:00. Her SPLASH tag had fallen, pulling the fur.
On 17/07, XGET was captured at 8:45 at Wilsher Bay to remove her GPS tag. Jade's pup (VETH) was captured at about 13:00 at Hinahina Island to remove his GPS tag (the GPS tag was lifting and was attached only by about 25% of its surface). Jade was seen on Hinahina Island during her pup's tag removal and tags looked well attached.

- Tag check 19-20 /07/22

Kiwa at Pūrākaunui at 9:50 on 19/07. No sign of lifting of the tags.
P447 at Pounawea Reserve on 19/07 at 12:35. Left to sea at that time with her pup. Tags showed no lifting.
Unknown sighted by Jim Fyfe at the entrance of Hoopers Inlet on the Otago Peninsula (date approx. 20 July). Tags looked well attached but some lifting on one side of the SAPLSH tag (looked like fur pulled).

- Tag check 26-29/07/2022

Jade by The Nuggets Road second beach from Nugget Point on 26/07 at 11:10. Tags looked in good condition with no lifting. No pup.
P447 at Hinahina Island 29/07 at 9:25. No sign of tag lifting. No pup.

- Tag check 1-5/08/22

Kiwa at Western end of Surat Bay on 1/08 at 12:00. No lifting of tags.

P447 at Cannibal on 1/08 at 13:50. She came ashore recently. No sign of lifting of tags. No pup.
Jade in the middle of Surat Bay on 4/08 at 10:57. No sign of tags lifting. No pup.
Kiwa at Western end of Surat Bay on 4/08 at 10:15. Tags looked good but other sea lions were poking them. May be a small lift on the GPS tag on one side.
Unknown at Cannibal Bay on 5/08 at 10:00.

- Tag check 10-11/08/22

P447 at Pounawea Reserve (no date/time). Pup suckling. No visual on tags.
Kiwa at Roaring Bay (no date/time). Tags seem all good but "flattened fur" (wet?) around the SPLASH tag.
Jade on the last beach before Nugget Point (no date/time). Tags looked good.


Kiwa's tag on 10/11 August (4 days before it fell off at Roaring Bay)

WildCoast