

**To:** Igor Debski, Conservation Services Program  
**From:** Thomas Mattern  
**Project:** Hoiho Population and tracking: POP2018-02  
**Date:** 26 April 2019

## Monthly report for the period 21 Mar 2019 – 20 Apr 2019

### Summary

As penguins all entered the moult phase, no logger deployments occurred in the past month; next deployments are scheduled for the first week of May.

The downtime was used to run comprehensive analyses of the recorded data.

The post-guard stage of the season 2018/19 started already in early December so that no chick-guard data could be obtained when field work commenced. The data outcome was very limited due to the problems with device recovery and damage as outlined in previous reports. GPS data was obtained for two penguins from the Catlins, one each from Te Rere and Penguin Bay. Foraging ranges between Te Rere and Penguin Bay differed (15.3 km vs 31.0 km) as did foraging trip durations (16.6 hrs vs 32.7 hrs). Dive data was recorded for three birds (2x Te Rere, 1x Penguin Bay). One of the Te Rere birds performed short, evening trips and showed high dive rates (no GPS data recorded); dive profiles suggest that foraged pelagically on 8 of its 9 trips. The other penguin fitted with a device at the same time left on one day trips (16.6 hrs) and foraged predominantly at the seafloor (70% of all dives benthic) which correlates with linear foraging observed (see January 2019 report). The Penguin Bay penguin predominantly foraged pelagically (65%) on its first trip while subsequent trips were characterized by benthic foraging again (see graphs on page 2).

During the pre-moult, device deployments occurred at Otapahi, Otago Peninsula (2 birds) and Aramoana (5 birds); except for one of the Aramoana penguins which lost its device package, all loggers were successfully recovered and yielded GPS and dive data. Trip durations differed significantly with Aramoana birds staying at sea for 2-13 days (mean 4.7 days), whereas Otapahi penguins stayed at sea for no longer than three days at a time (mean 1.0 day). This also reflected in foraging ranges (mean foraging range; Aramoana: 33.6 km, Otapahi: 19.2 km).

While the overall data outcome from Otapahi was too limited to draw general conclusions, the data sets of pre-moult movements of hoiho from Aramoana provided valuable, new insights. The combined GPS and dive data were used to model the penguins' habitat use utilizing procedures developed for a comprehensive spatial analysis recently conducted for MPI.

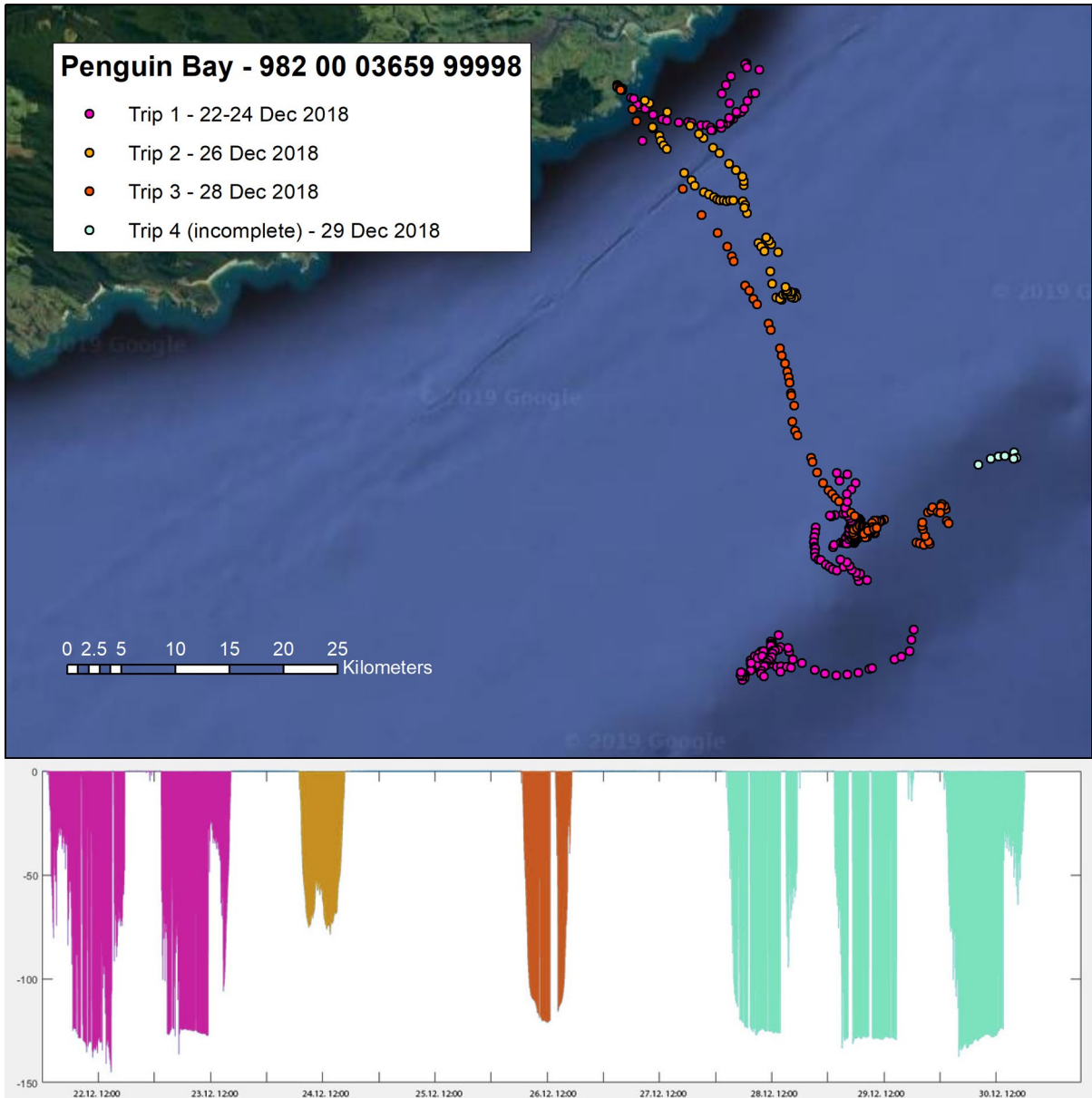
Hoiho from Aramoana foraged predominantly over sandy sediment at water depths of <70m (mean water depth: 35 m) between 5 and 30 km from the coast. A particularly frequent area lay 6-12 km off the coast of Karitane and Waikouaiti. Habitat use modelling indicates an area with a circumference of ca 200 km and an area of 1,750 km<sup>2</sup> ranging from the tip of the Otago Peninsula to the southern end of Barracouta Bay to be particularly suitable for hoiho foraging.

Positions of set net operations between 2009 and 2012 available for this analysis shows a significant overlap with hoiho penguin habitat. Hence, the risk of interactions between fisheries and penguins is substantially higher north of the Otago Peninsula than in South Otago and the northern Catlins and comparable with that of the Foveaux Strait.

## Results

The following section presents graphs of true (i.e. not extrapolated) GPS fixes recorded during separate foraging trips of hoiho from the Catlins, Otapahi and Aramoana. Correspondingly coloured dive profile graphs and summary statistics (individual means) are given below the graph. Full statistics of trip and individual means can be found in the appendix as well as Google sheets for which links are provided.

### Post-guard – Penguin Bay

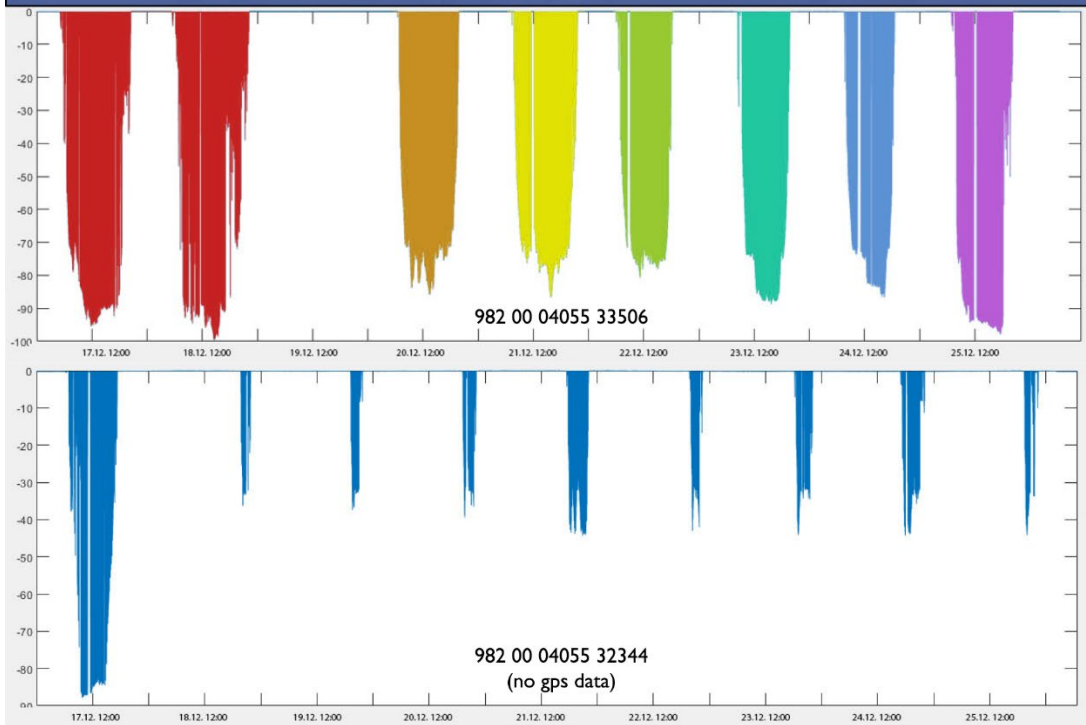
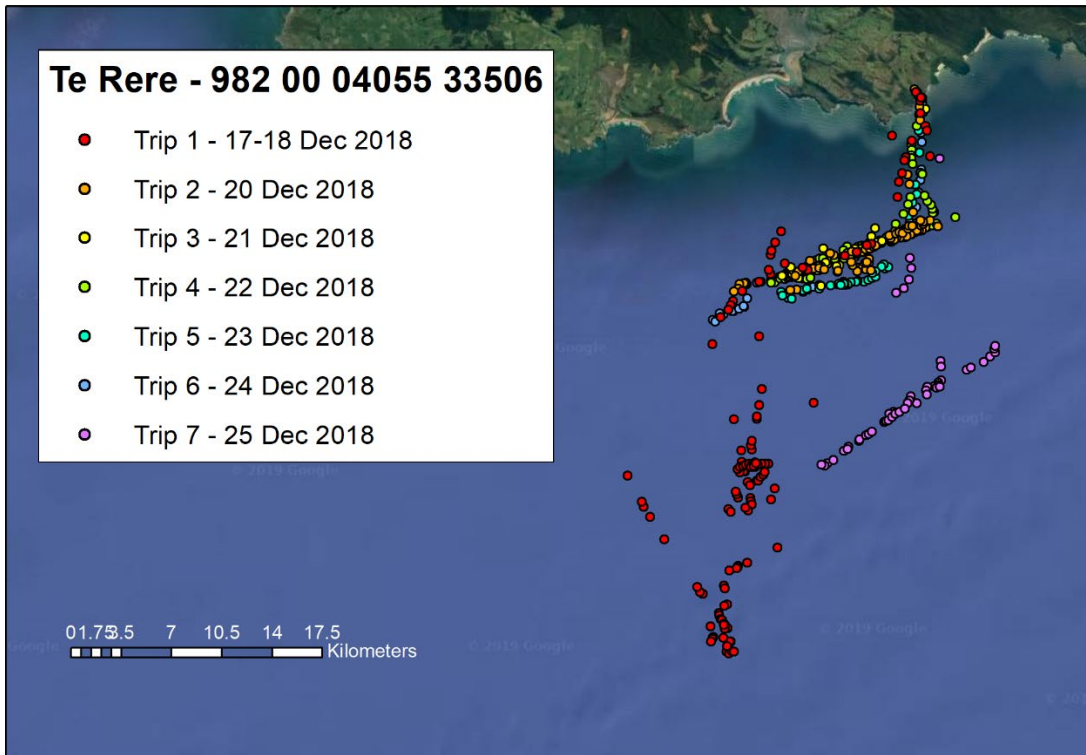


Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive events	Mean dive time	Mean max depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
4	30.9	82.0	4.2	31.9	16.6	395	161	65	54%

Full dive analysis results see appendix or

<https://docs.google.com/spreadsheets/d/1SQ2SU6TKfLQJzKNZmmeoTvebpL4AvOdYTjRnMxo16IE/edit?usp=sharing>

Post-guard – Te Rere

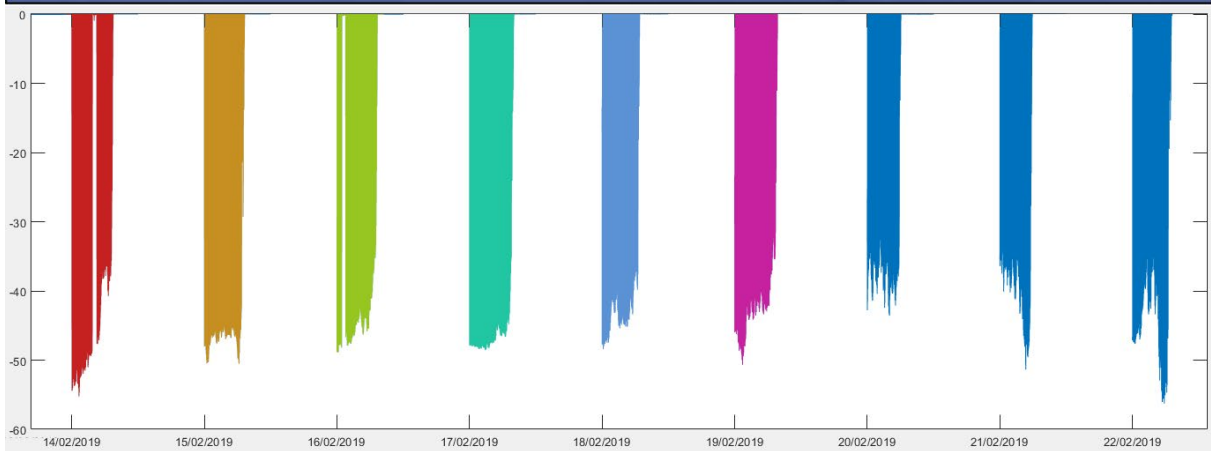
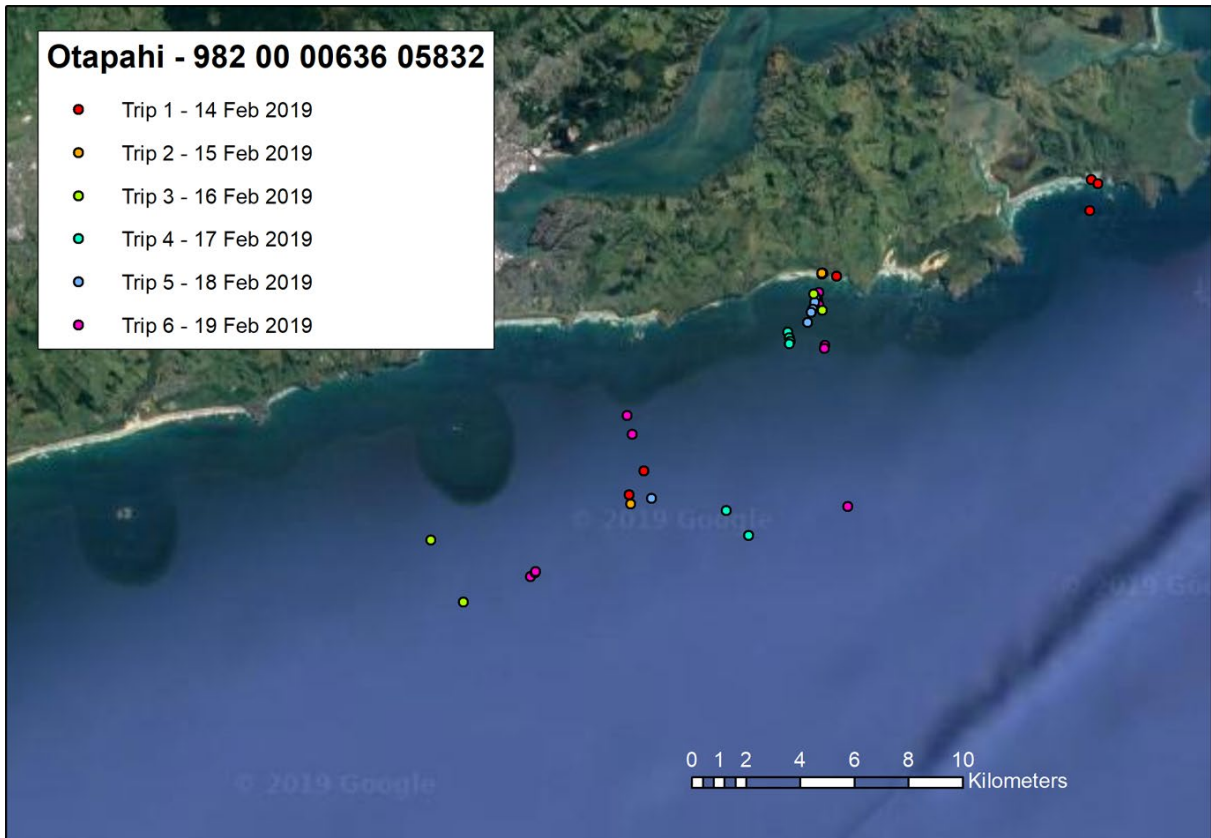


Bird ID	Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean dive events	Mean dive time	Mean max depth	Mean max Depth
	[ n ]	[ days ]	[ km ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
33506	7	16.6	48.9	15.3	8.0	287	122	52	0.70
32344	9	5.4	<i>no gps data</i>	<i>no gps data</i>	<i>no gps data</i>	114	78	23	<i>no gps data</i>

Full dive analysis results see appendix or

<https://docs.google.com/spreadsheets/d/1SQ2SU6TKfLQJzKNZmmeoTvebpL4AvOdYTjRnMxo16IE/edit?usp=sharing>

Pre-moult - Otapahi

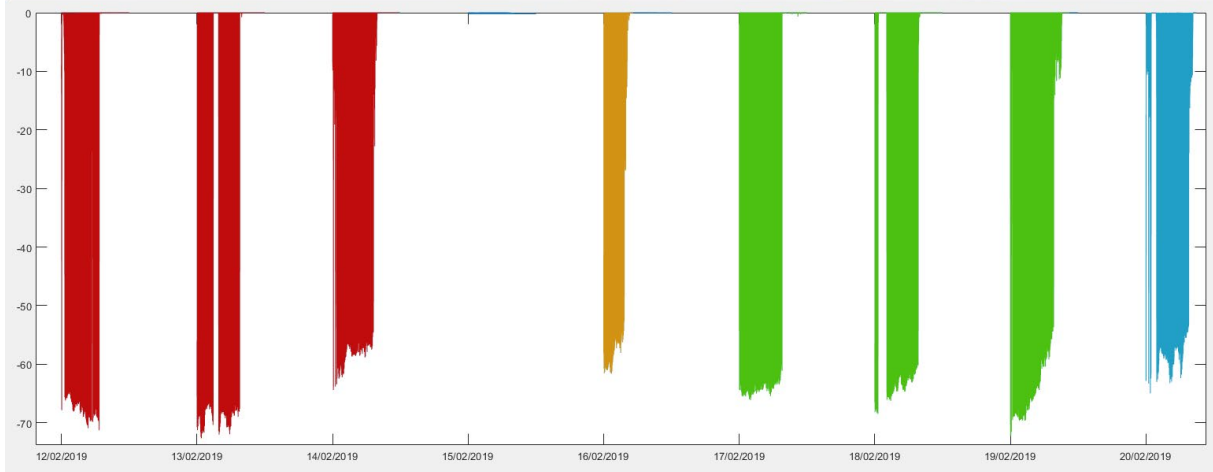
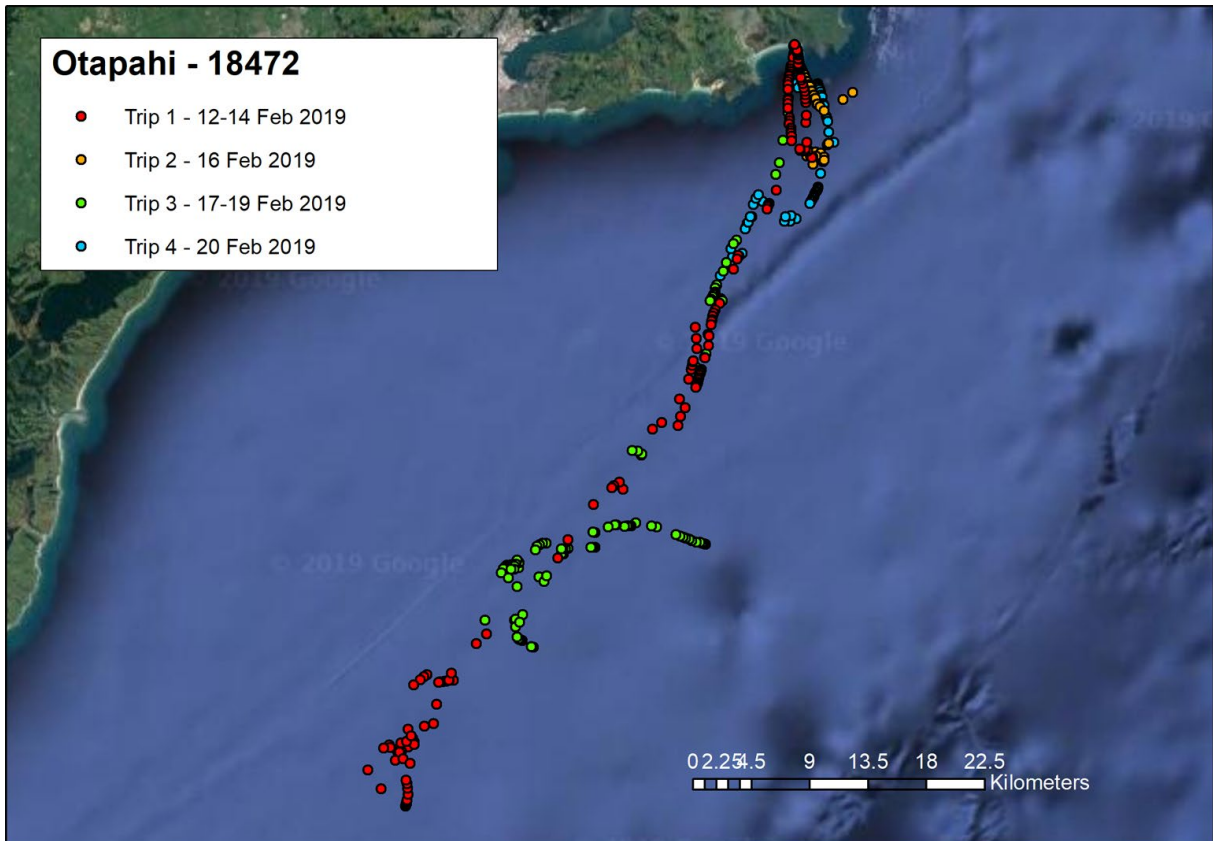


Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive events	Mean dive time	Mean max depth	% benthic dives
<i>[ n ]</i>	<i>[ h ]</i>	<i>[ km ]</i>	<i>[ km/h ]</i>	<i>[ km ]</i>	<i>[ km ]</i>	<i>[ n ]</i>	<i>[ s ]</i>	<i>[ m ]</i>	
9	13.0	15.9	1.24	13.2	9.1	263	131	37	84%

Note: GPS data was of poor coverage so that parameters that are based on spatial data are not likely to reflect actual movement behaviour correctly. These values are given in italic font.

Full dive analysis results see appendix or

[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYVc36jQzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYVc36jQzR8gVe2mvPZHjxuAGs/edit?usp=sharing)

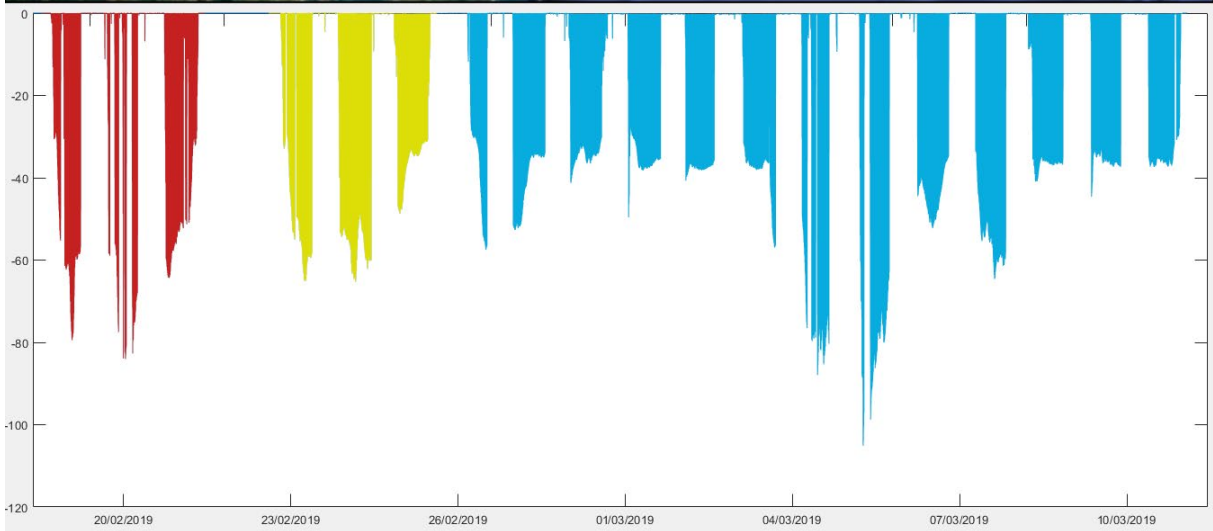
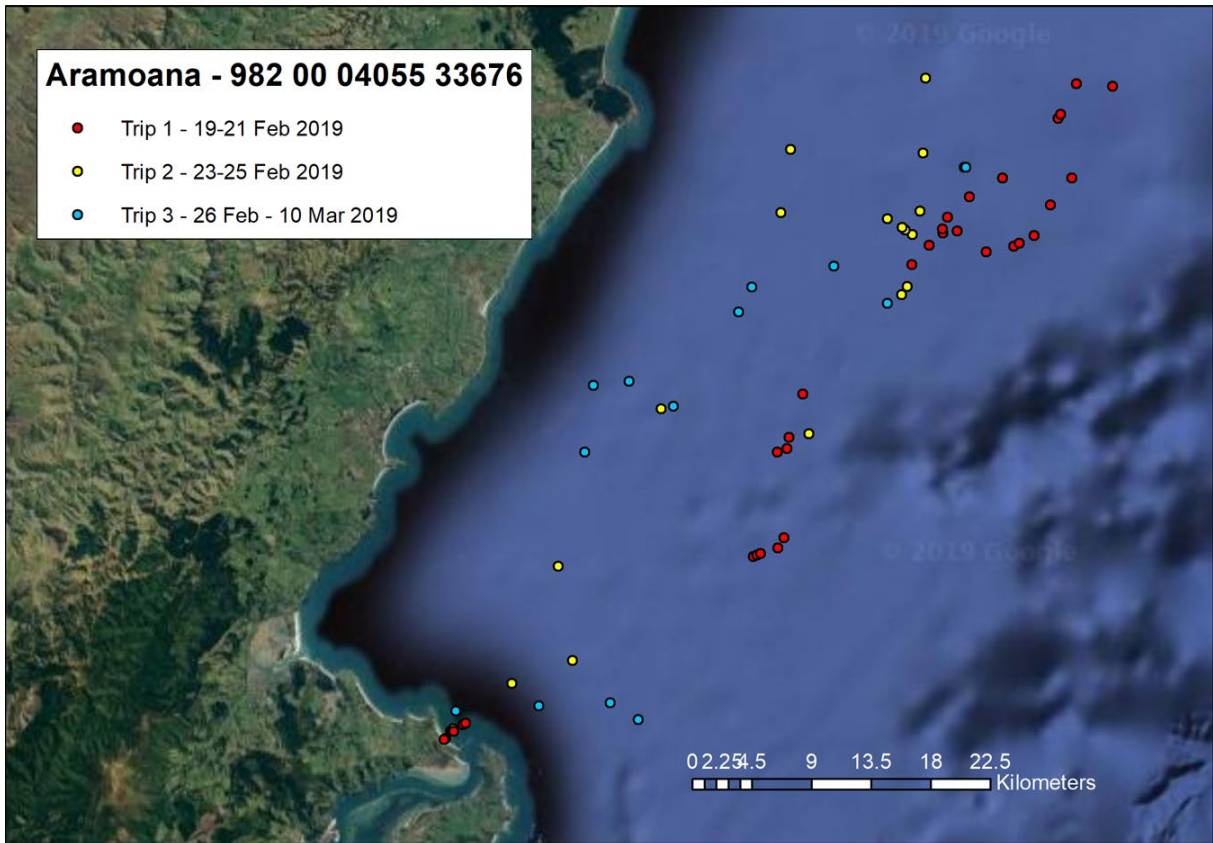


Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive events	Mean dive time	Mean max depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
4	1.5	72.6	2.14	25.2	14.2	464	133	38	84%

Full dive analysis results see appendix or

[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYvc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYvc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing)

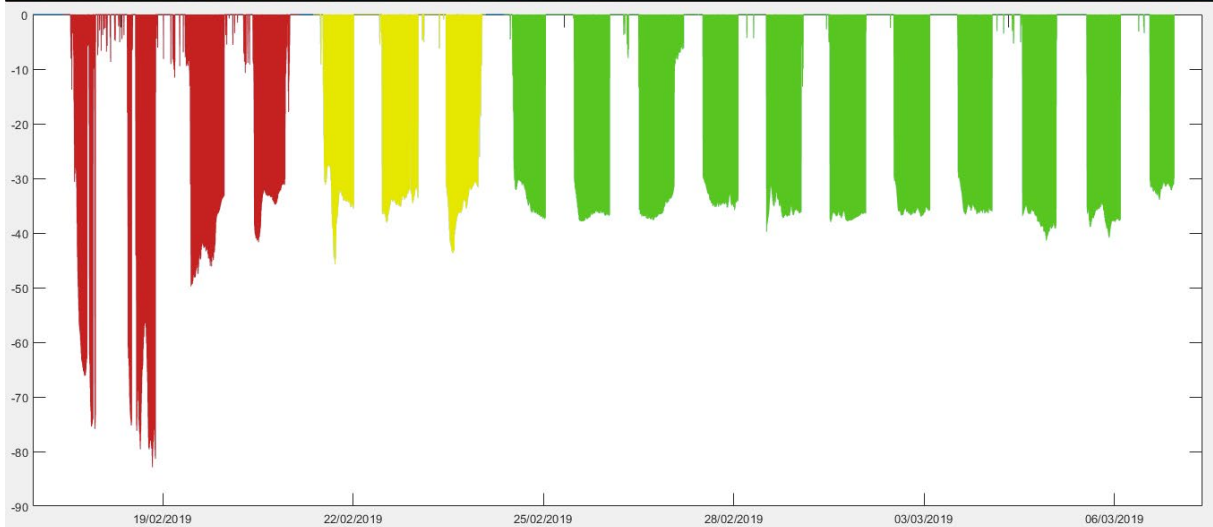
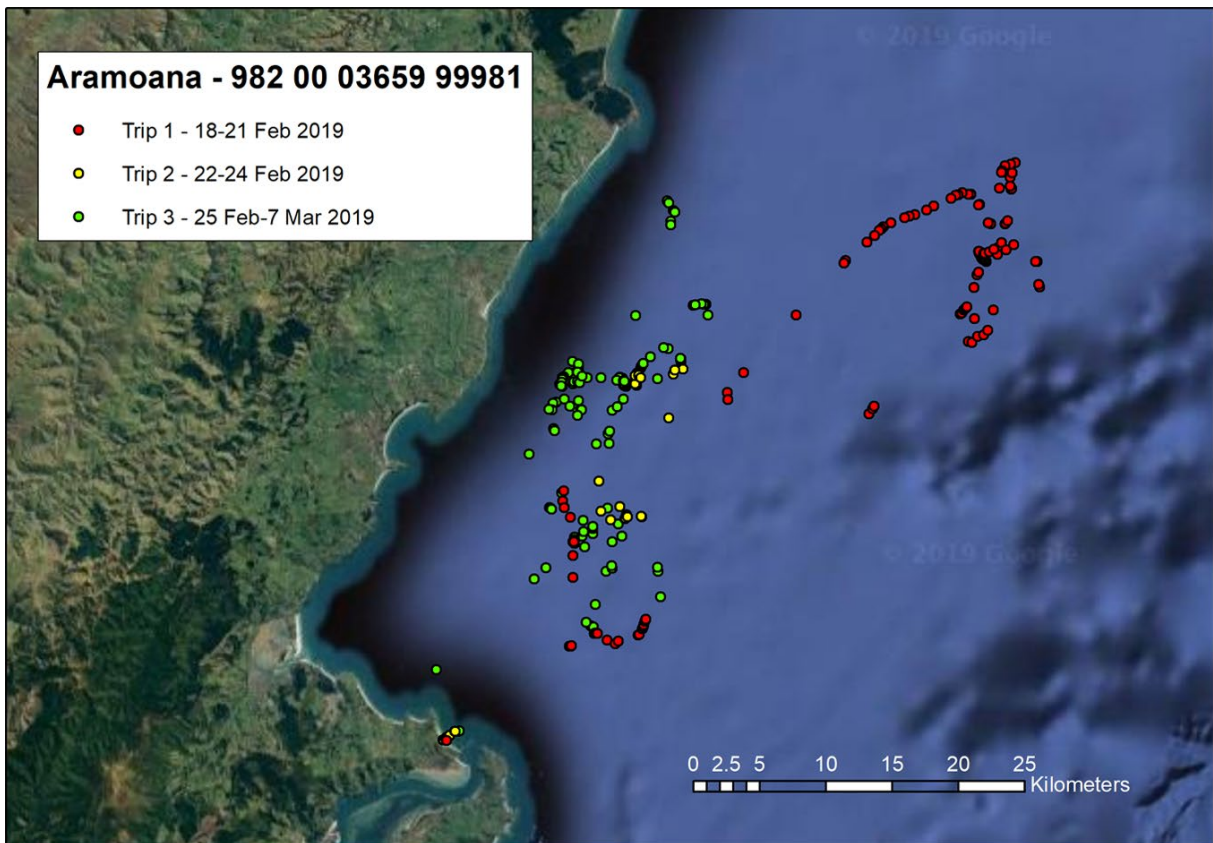
Pre-moult – Aramoana



Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive events	Mean dive time	Mean max depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
3	5.8	123.7	1.30	45.2	22.0	263	147	38	67

Full dive analysis results see appendix or

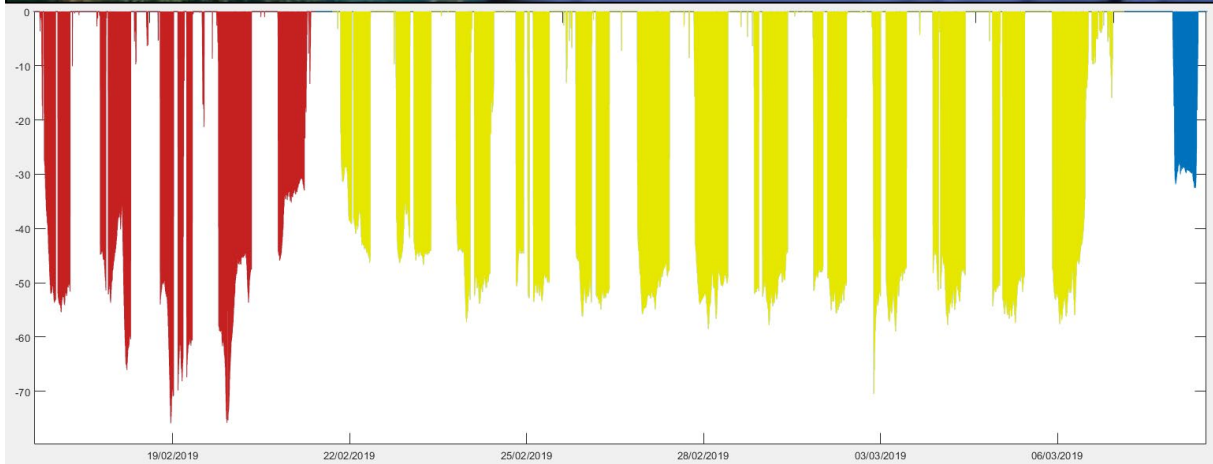
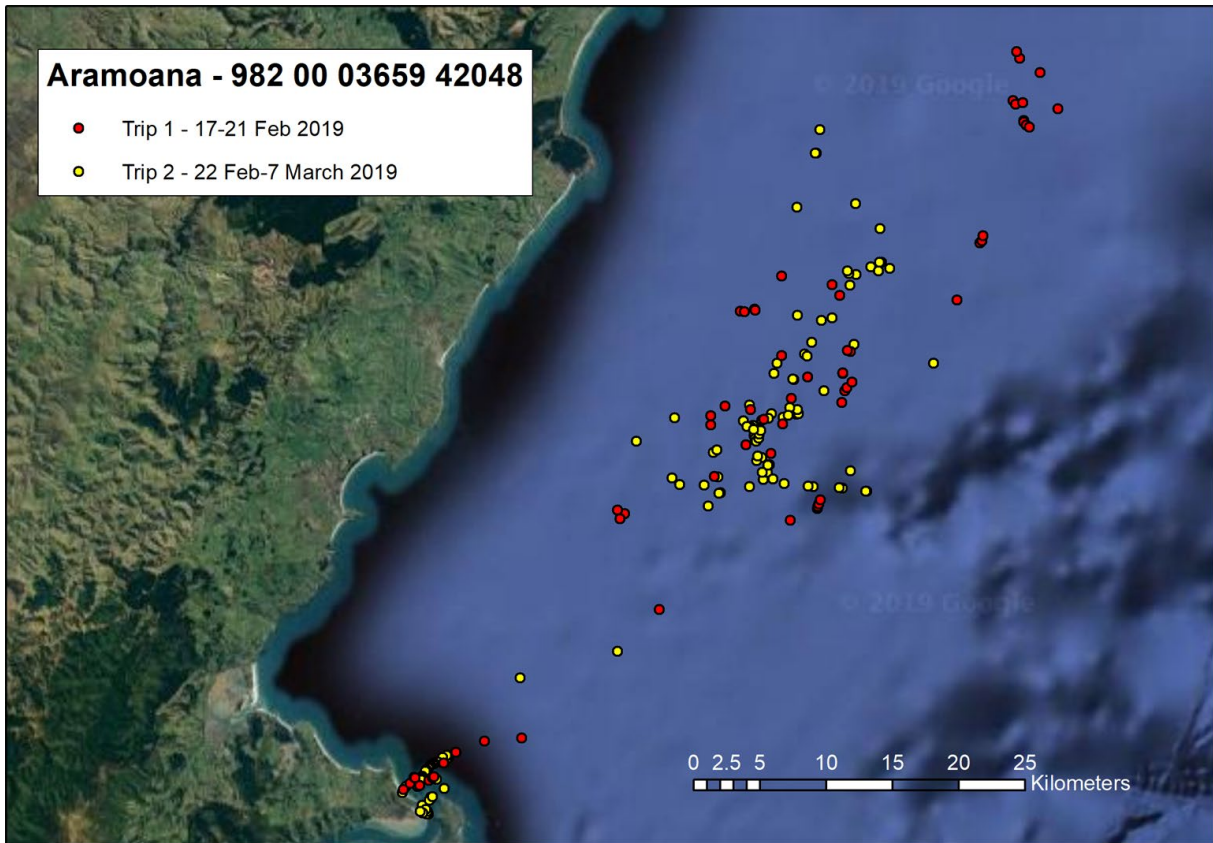
[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYVc36iJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYVc36iJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing)



Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive Events	Mean dive Time	Mean max Depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
3	5.4	118.3	0.91	32.3	15.9	1588	133	31	73

Full dive analysis results see appendix or

[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing)

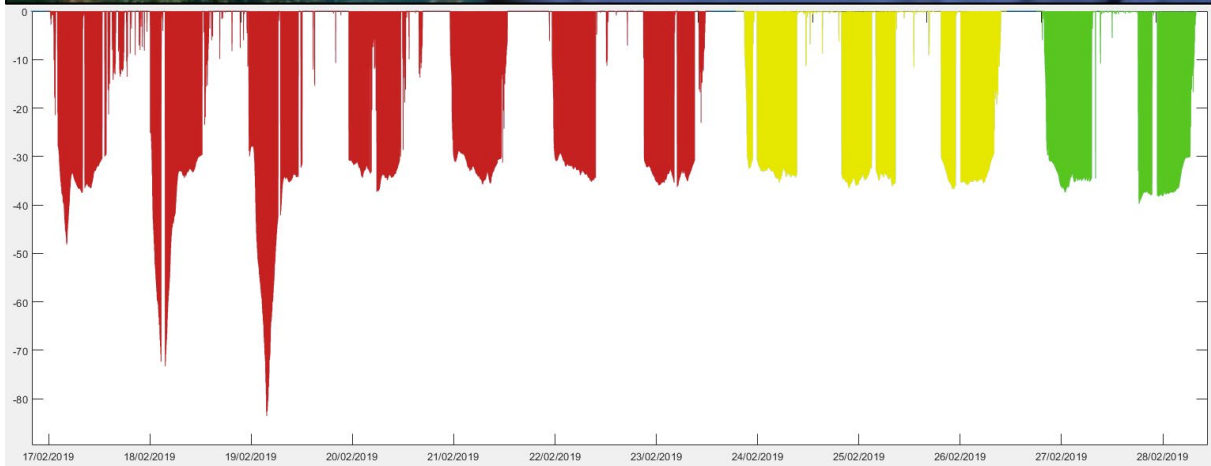
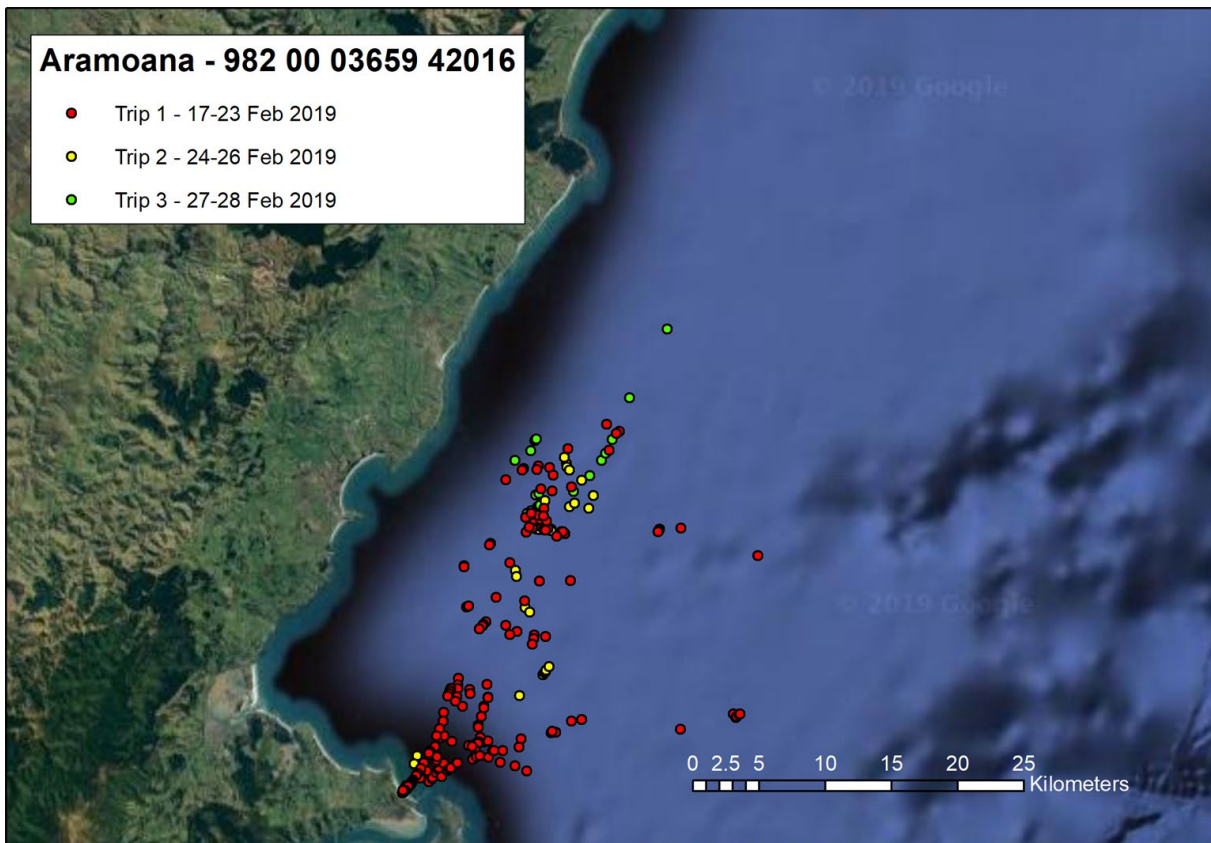


Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive Events	Mean dive Time	Mean max Depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
3	6.0	147.9	1.03	34.0	18.7	1588	15.5	35	73

Full dive analysis results see appendix or

[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing)





Trip number	Mean trip duration	Mean distance travelled	Mean travel speed	Mean maximum range	Mean range	Mean dive Events	Mean dive Time	Mean max Depth	% benthic dives
[ n ]	[ days ]	[ km ]	[ km/h ]	[ km ]	[ km ]	[ n ]	[ s ]	[ m ]	
3	2.6	100.8	1.60	23.0	12.8	895	116	28	76

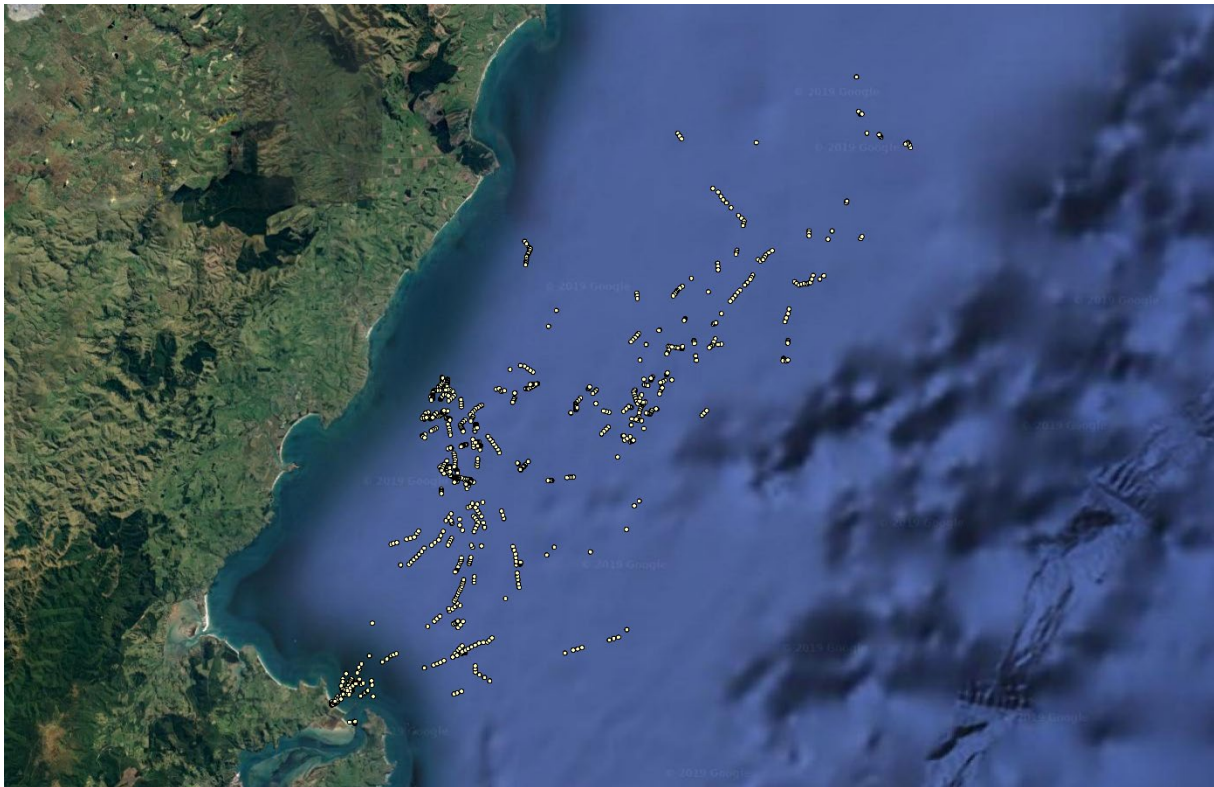
Full dive analysis results see appendix or

[https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob\\_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Tm262UJQ6Sgpob_FEYVc36jJqzR8gVe2mvPZHjxuAGs/edit?usp=sharing)

### Pre-moult – Use of the marine habitat of hoiho from Aramoana

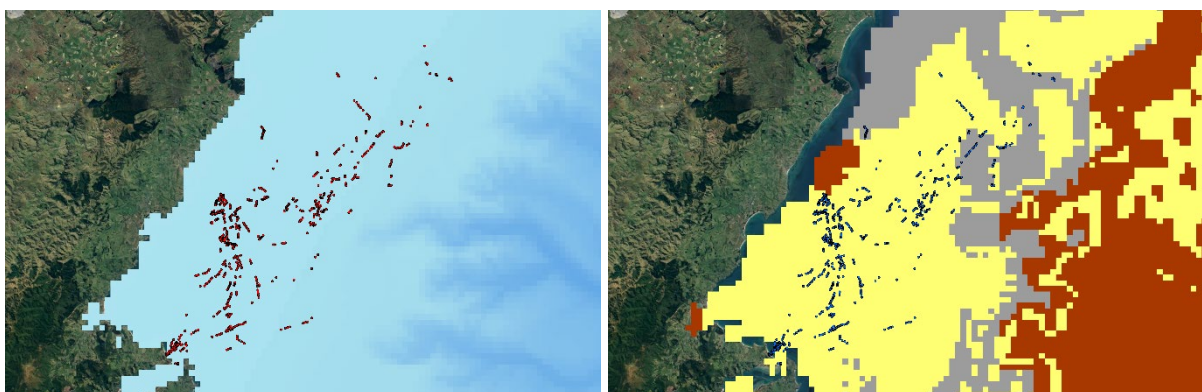
To determine habitat characteristics that determined the foraging movements of hoiho during the pre-moult phase, GPS data recorded on penguins from Aramoana was used in models developed for MPI (“PRO2017-06 Characterization of yellow-eyed penguin / fishery interaction”). These models assess habitat suitability using a probabilistic presence approach.

Firstly, filtered GPS positions of foraging dives (i.e. benthic dives) are plotted in ArcGIS. Filtered positions consist of true GPS fixes, i.e. fixes recorded by the device prior to a dive event, and extrapolated locations of dives that occurred within 10 minutes of a true GPS fix.



*Filtered GPS positions used for habitat utilization model*

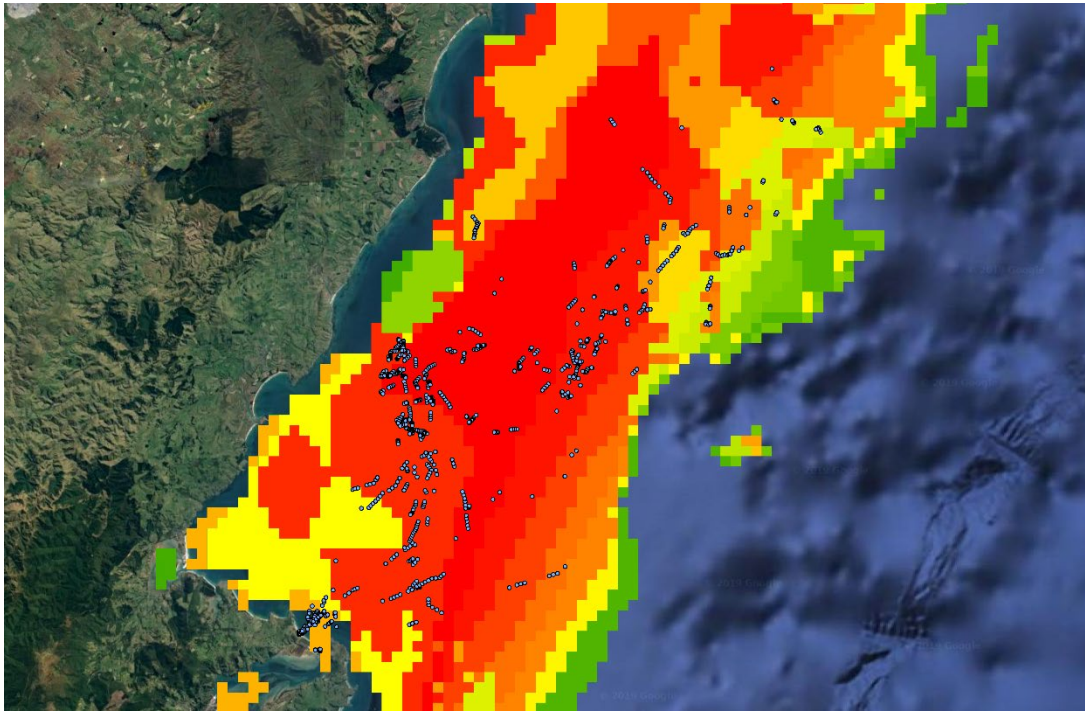
Secondly, gridded (1x1km) habitat data are added as background layers to the plot.



*Hoiho GPS positions in relation to bathymetry (left) and seafloor sediment grids (right; yellow: sand, grey: gravel, brown: mud)*

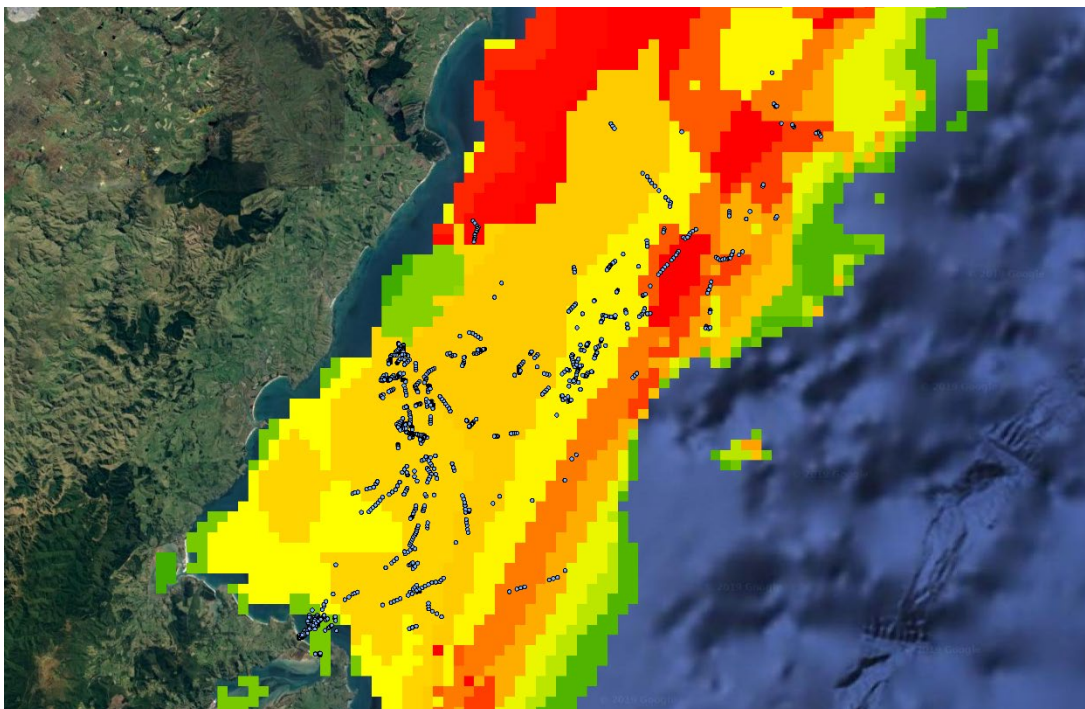
Other variables tested were distance from origin (i.e. colony) and freshwater source (i.e. river mouths) but both variables had minor to no effects on the penguins’ spatial distribution. Main factors were water depth (<70m) and sandy and, to a lesser, extent gravel sediments.

Counting of hoiho GPS positions within each grid cell allowed it to determine relative importance of factor values. Subsequently a grid analysis was performed where all cells (i.e. including those not visited by hoiho during this study) were assessed on their suitability for penguins based on their factor values.



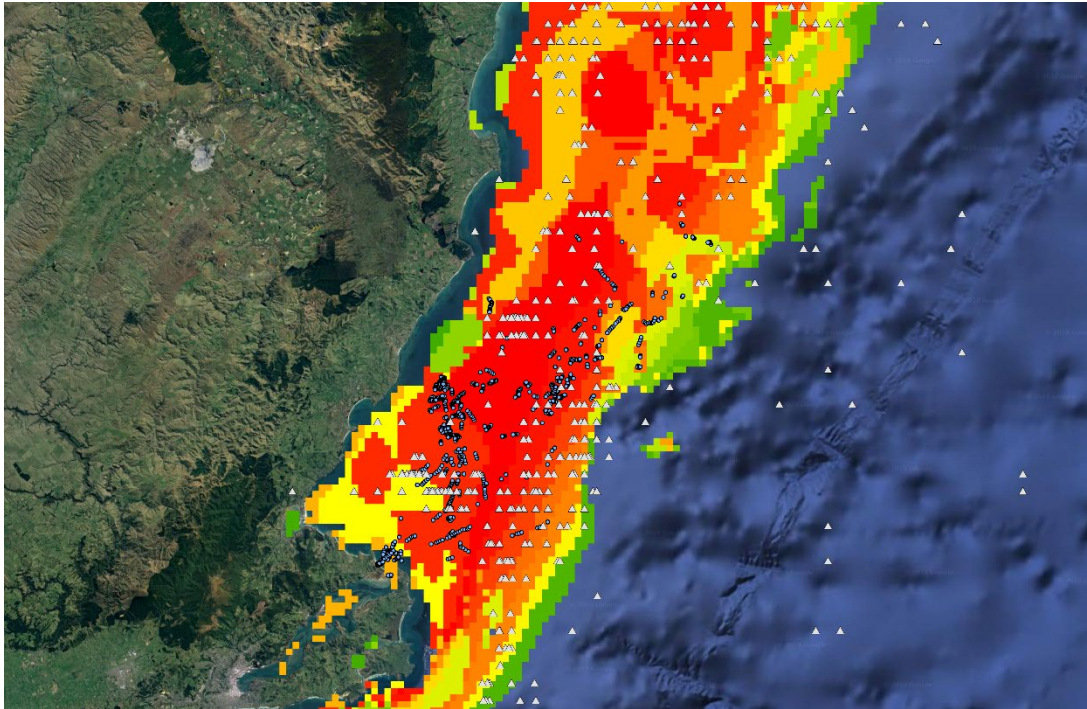
*Modelled habitat suitability for hoiho from Aramoana. Orange and red areas represent grid cells where penguins are most likely to forage at the seafloor (20-100% occurrence probability based on water depth and sediment type). Yellow, green and empty cells are of lesser to no interest for the penguins.*

This is a considerably improved model output compared to that based on foraging data available during the original modelling exercise, where foraging preferences of penguins from Oamaru were used to assess habitat utilization:



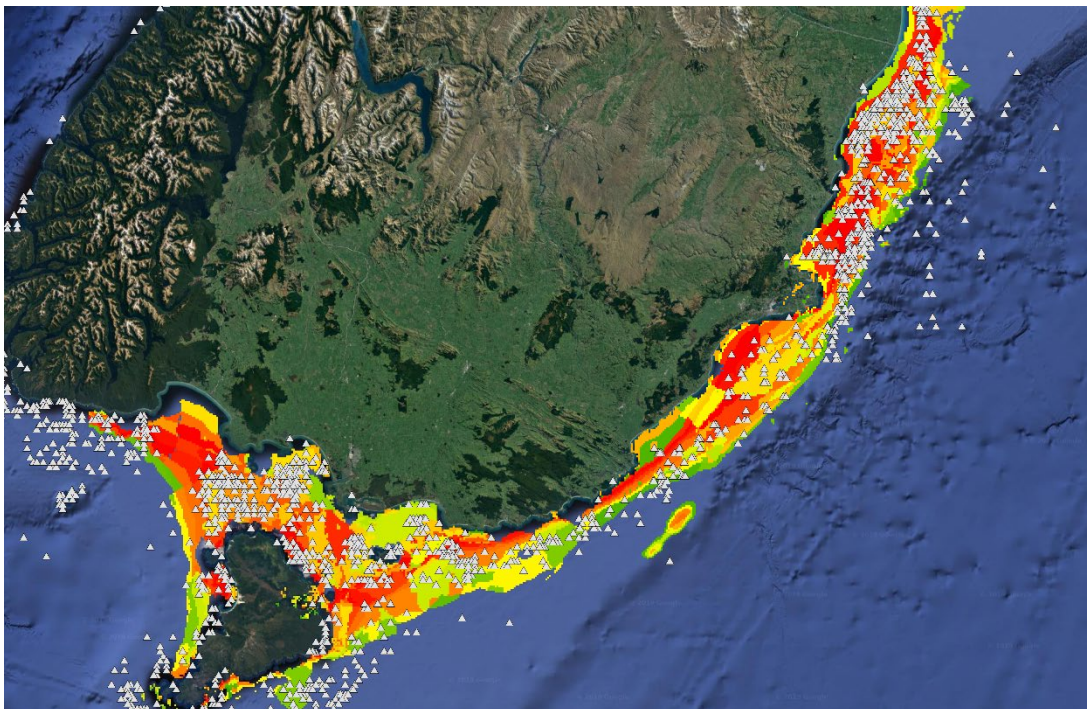
*Modelled habitat suitability using foraging data of hoiho from Oamaru.*

Clearly, extrapolating habitat preference from different regions misrepresents actual habitat suitability for the Blueskin Bay to Shag Point region. Moreover, these revised habitat models highlight substantial overlap of hoiho foraging activity with set netting activities.



*Habitat utilization of hoiho from Aramoana in relation to set netting operations (fisheries data from 2009 to 2012).*

Clearly, both penguins and set net fisheries target similar habitats so it can be assumed that birds from the region are considerably more susceptible to set netting when compared to hoiho from the southern Otago Peninsula or northern Catlins. The level of likely interaction with set netting operations is comparable to that of hoiho in Foveaux Strait.



*Habitat utilization of hoiho in relation to set netting operations (fisheries data from 2009 to 2012).*

### Next steps

Monitoring of hoiho foraging movements and behaviour will resume in the first week of May in the Catlins. These activities will be continued throughout the winter and into the pre-breeding and incubation stages of this year. The range of operation is planned to be extended to sites in North Otago and Stewart Island from October onwards.

# Hoiho dive analysis - post-guard 2018 [trip means]

Site	BirdID	Trip number	Trip number	Start Time	End Time	Trip duration	Distance travelled	Mean travel speed	Maximum range	Mean range	Dive Events	Dive rate	Surface Time	Surface Distance	Surface Velocity	Dive Time	Max Depth	Water Depth *	Descent Duration	Descent Velocity	Bottom Time	Maximum Wiggle Amplitude	Mean Wiggle Amplitude	Ascent Duration	Ascent Velocity	Foraging Effort	Diving Efficiency	Ratio of benthic dives	
		[n]	[n]			[h]	[km]	[km/h]	[km]	[km]	[n]	[dives/h]	[s]	[m]	[m/s]	[s]	[m]	[m]	[s]	[m/s]	[s]	[m]	[m]	[m]	[s]	[m/s]	**	***	
Te Rere	982.00.04055.33506	1	12/17/18.5:07	12/18/18.22:10	41.0	121.0	2.95	28.0	13.8	13.8	519	12.6	39	23.0	0.02	92	46.3	68.2	26	0.99	38	4.3	0.005	30	0.91	0.26	0.67	0.42	
Te Rere	982.00.04055.33506	2	12/20/18.6:31	12/20/18.19:47	13.2	40.7	3.08	12.8	6.8	6.8	244	18.5	48	68.7	0.01	147	61.7	60.0	30	1.68	86	6.7	0.004	33	1.58	0.42	0.74	0.85	
Te Rere	982.00.04055.33506	3	12/21/18.7:20	12/21/18.21:55	14.2	33.5	2.37	10.7	6.8	6.8	284	20.1	52	46.2	0.01	127	53.0	54.7	27	1.45	73	5.8	0.006	29	1.39	0.38	0.72	0.82	
Te Rere	982.00.04055.33506	4	12/22/18.6:01	12/22/18.18:11	12.2	31.8	2.60	11.3	5.9	5.9	232	19.0	64	30.5	0.01	124	48.8	54.2	28	1.31	68	5.5	0.013	30	1.27	0.35	0.70	0.77	
Te Rere	982.00.04055.33506	5	12/23/18.8:25	12/23/18.19:47	11.3	35.0	3.10	11.5	6.6	6.6	232	20.6	52	26.2	0.02	124	54.7	61.6	29	1.36	64	6.0	0.008	32	1.27	0.34	0.72	0.72	
Te Rere	982.00.04055.33506	6	12/24/18.7:39	12/24/18.18:34	10.8	34.7	3.21	14.5	7.3	7.3	209	19.4	64	51.8	0.02	123	53.5	56.6	30	1.35	63	5.8	0.005	32	1.26	0.33	0.71	0.79	
Te Rere	982.00.04055.33506	7	12/25/18.6:55	12/25/18.20:17	13.4	45.4	3.38	18.1	8.9	8.9	290	21.6	49	56.7	0.03	116	53.2	71.2	31	1.22	52	5.7	0.007	35	1.13	0.31	0.75	0.52	
Te Rere	982.00.04055.32344	1	12/16/18.19:10	12/17/18.17:16	22.1						247	11.2	42			97	34.5	no gps data	28	0.96	38	3.8	0.005	33	0.82	0.29	0.77	no gps data	
Te Rere	982.00.04055.32344	2	12/18/18.19:43	12/18/18.21:46	2.2						72	33.3	35			68	18.6	no gps data	16	1.01	35	2.1	0.018	19	0.84	0.36	0.76	no gps data	
Te Rere	982.00.04055.32344	3	12/19/18.19:15	12/19/18.21:46	2.4						89	37.1	35			66	18.5	no gps data	14	1.09	38	2.1	0.012	17	0.93	0.37	0.72	no gps data	
Te Rere	982.00.04055.32344	4	12/20/18.19:14	12/20/18.22:05	2.9						86	29.9	40			79	21.5	no gps data	17	1.12	43	2.2	0.013	22	0.91	0.38	0.77	no gps data	
Te Rere	982.00.04055.32344	5	12/21/18.17:28	12/21/18.22:08	4.6						124	27.2	38			97	31.8	no gps data	19	1.41	55	3.2	0.007	25	1.12	0.40	0.75	no gps data	
Te Rere	982.00.04055.32344	6	12/22/18.19:47	12/22/18.22:30	2.6						85	32.2	46			69	20.4	no gps data	15	1.03	37	2.2	0.004	19	0.86	0.33	0.69	no gps data	
Te Rere	982.00.04055.32344	7	12/23/18.18:14	12/23/18.22:05	3.8						111	28.9	49			76	20.6	no gps data	17	1.02	40	2.1	0.008	21	0.82	0.33	0.72	no gps data	
Te Rere	982.00.04055.32344	8	12/24/18.16:57	12/24/18.22:04	5.0						137	27.2	57			76	20.6	no gps data	19	0.94	35	2.1	0.016	24	0.72	0.30	0.70	no gps data	
Penguin Bay	982.00.04055.99998	1	12/22/18.5:21	12/23/18.20:33	39.2	156.90	4.00	40.3	20.5	20.5	527	13.4	104	21.5	0.05	163	67.5	129.7	48	1.13	58	7.0	0.001	59	0.96	0.27	0.78	0.35	
Penguin Bay	982.00.03659.99998	2	12/24/18.11:08	12/24/18.20:55	9.8	38.80	3.97	17.5	9.3	9.3	172	17.6	42	85.0	0.00	162	50.9	57.2	29	1.41	102	5.3	0.005	32	1.28	0.48	0.79	0.65	
Penguin Bay	982.00.03659.99998	3	12/26/18.10:38	12/26/18.21:28	10.8	50.20	4.63	35.1	23.2	23.2	167	15.4	73	178.2	0.12	161	68.8	81.2	45	1.22	64	7.2	0.007	54	1.04	0.30	0.79	0.69	
Penguin Bay	982.00.03659.99998	4	12/28/18.6:28	12/30/18.22:17	63.8			34.5	13.6	13.6	712	11.2	125	171.6	0.12	159	72.7	104.1	49	1.15	55	7.6	0.007	57	1.04	0.25	0.75	0.54	

\* Water depth was derived by associating actual and extrapolated dive locations with bathymetry data published by NIWA (2006, 250m grid bathymetry data)

\*\* dive time / (surface time + dive time)

\*\*\* bottom time / (surface time + dive time)

## Hoiho dive analysis - post-guard 2018 [individual means]

Site	BirdID	Trip number	Trip duration [h]	Distance travelled [km]	Mean travel speed [km/h]	Maximum range [km]	Mean range [km]	Dive Events	Dive rate [dives/h]	Surface Time [s]	Dive Time [s]	Max Depth [m]	Water Depth * [m]	Descent Velocity [m/s]	Bottom Time [s]	Ascent Velocity [m/s]	Foraging Effort	Diving Efficiency	Ratio of benthic dives
Te Rere	982.00.04055.33506	7	16.6	48.9	2.95	15.3	8.0	287	18.8	53	122	52	61	1.34	64	1.26	0.34	0.72	0.70
Te Rere	982.00.04055.32344	9	5.4			no gps data			28.2	45	78	23	no gps data	1.05	39	0.85	0.34	0.73	no gps data
Penguin Bay	982.00.03659.99998	4	30.9	82.0	4.20	31.9	16.6	395	14.4	86	161	65	93	1.15	55	1.04	0.25	0.75	0.54

\* Water depth was derived by associating actual and extrapolated dive locations with bathymetry data published by NIWA (2006, 250m grid bathymetry data)

\*\* dive time / (surface time + dive time)

\*\*\* bottom time / (surface time + dive time)

# Hoiho dive analysis - pre-moult 2019

Site	BirdID	Trip number	Start Time	End Time	Trip duration	Distance travelled	Mean travel speed	Maximum range	Mean range	Dive Events	Dive rate	Surface Time	Surface Distance	Surface Velocity	Dive Time	Max Depth	Water Depth*	Descent Duration	Descent Velocity	Bottom Time	Maximum Wiggle Amplitude	Mean Wiggle Amplitude	Ascent Duration	Ascent Velocity	Foraging Effort	Diving Efficiency	Ratio of benthic dives
		[n]			[days]	[km]	[km/h]	[km]	[km]	[n]	[dives/h]	[s]	[m]	[m/s]	[s]	[m]	[m]	[s]	[m/s]	[s]	[m]	[m]	[s]	[m/s]	**	***	
Otapahi	982.00.00636.05833	1	14/02/19 10:54	14/02/19 20:27	0.4	21.7	2.26	13.9	7.7	180	19	57	230.9	0.32	134	39.9	30.1	24	1.43	83	4.3	0.004	30	1.21	0.76	0.46	0.77
Otapahi	982.00.00636.05833	2	15/02/19 07:22	15/02/19 20:15	0.5	15.0	1.15	14.1	10.0	261	20	195	1041.4	0.28	132	39.7	31.6	25	1.35	78	4.5	0.010	31	1.15	0.79	0.45	0.89
Otapahi	982.00.00636.05833	3	16/02/19 06:23	16/02/19 20:19	0.6	25.7	1.84	19.4	12.8	286	21	170	591.7	0.37	132	39.1	32.5	23	1.37	82	4.5	0.006	29	1.16	0.79	0.47	0.95
Otapahi	982.00.00636.05833	4	17/02/19 06:21	17/02/19 21:00	0.6	14.1	0.96	12.7	9.4	316	22	153	606.4	0.51	127	36.6	32.7	24	1.22	74	4.1	0.008	31	1.01	0.79	0.42	0.84
Otapahi	982.00.00636.05833	5	18/02/19 06:11	18/02/19 19:47	0.6	15.2	1.11	14.4	10.2	262	19	177	394.6	0.24	135	37.6	29.7	24	1.36	85	4.2	0.004	28	1.18	0.78	0.47	0.84
Otapahi	982.00.00636.05833	6	19/02/19 06:38	19/02/19 20:45	0.6	25.6	1.81	17.7	11.6	291	21	176	217.4	0.17	132	37.6	33.9	24	1.34	81	4.1	0.007	30	1.11	0.77	0.45	0.74
Otapahi	982.00.00636.05833	7	20/02/19 06:41	20/02/19 19:05	0.5	3.4	0.27	7.7	7.3	273	22	173	548.0	0.32	120	36.2	20.3	22	1.37	73	3.7	0.008	27	1.15	0.75	0.44	0.95
Otapahi	982.00.00636.05833	8	21/02/19 06:29	21/02/19 18:51	0.5	10.8	0.86	10.8	8.3	230	18	241	906.3	0.35	130	35.8	30.2	23	1.37	82	3.6	0.003	28	1.16	0.76	0.47	0.69
Otapahi	982.00.00636.05833	9	22/02/19 06:48	22/02/19 20:03	0.6	11.6	0.88	8.1	4.2	267	20	202	278.2	0.13	136	34.4	9.9	25	1.16	81	3.6	0.006	32	0.89	0.78	0.44	0.93
Otapahi	18472	1	12/02/19 06:49	14/02/19 20:52	2.6	124.8	2.01	46.0	25.8	720	12	163	301.2	0.24	146	44.1	59.4	31	1.12	82	4.7	0.003	36	1.01	0.75	0.37	0.65
Otapahi	18472	2	16/02/19 06:57	16/02/19 17:33	0.4	18.6	1.76	6.4	3.7	200	19	247	1427.9	0.30	124	35.4	43.1	26	1.01	71	4.0	0.008	30	0.91	0.71	0.35	0.65
Otapahi	18472	3	17/02/19 07:11	19/02/19 22:05	2.6	114.4	1.82	35.5	20.7	704	11	250	635.4	0.20	141	43.0	55.4	30	1.13	79	4.6	0.001	34	1.04	0.75	0.37	0.64
Otapahi	18472	4	20/02/19 10:09	20/02/19 21:19	0.5	32.7	2.96	13.0	6.5	231	21	54	411.4	0.20	119	29.5	46.7	27	0.85	61	3.3	0.017	33	0.75	0.79	0.33	0.47
Aramoana	982.00.03659.95988	1	18/02/19 09:52	21/02/19 20:13	3.4	125.4	1.52	42.8	19.2	1034	13	159	727.3	0.35	127	32.8	40.5	27	1.01	70	3.4	0.004	32	0.92	0.72	0.38	0.62
Aramoana	982.00.03659.95988	2	22/02/19 07:41	24/02/19 20:14	2.5	52.8	0.87	23.2	11.0	834	14	179	2665.2	0.34	131	29.2	26.5	21	1.22	89	3.1	-0.003	23	1.20	0.77	0.50	0.75
Aramoana	982.00.03659.95988	3	25/02/19 06:53	07/03/19 16:06	10.4	176.6	0.71	30.9	17.4	2897	12	181	1943.4	0.26	141	31.7	32.8	21	1.32	99	3.3	-0.005	23	1.33	0.77	0.52	0.81
Aramoana	982.00.03659.42044	1	17/02/19 06:50	21/02/19 20:05	4.6	152.9	1.40	51.6	25.5	1211	11	189	1829.9	0.45	135	39.1	44.6	27	1.21	82	4.2	0.002	29	1.16	0.75	0.43	0.65
Aramoana	982.00.03659.42044	2	22/02/19 06:58	07/03/19 07:26	13.0	272.5	0.87	41.2	26.3	3295	11	216	2840.0	0.36	137	41.7	44.6	26	1.35	85	4.5	-0.002	27	1.35	0.75	0.44	0.77
Aramoana	982.00.03659.42044	3	08/03/19 07:41	08/03/19 17:53	0.4	18.3	1.77	9.1	4.2	258	25	374	192.9	0.00	106	24.9	21.3	18	1.23	71	2.8	-0.003	19	1.18	0.74	0.48	0.78
Aramoana	982.00.03659.42011	1	17/02/19 06:50	23/02/19 21:50	6.6	171.2	1.08	22.4	12.4	2193	14	146	641.6	0.30	114	26.8	29.7	20	1.15	71	3.0	0.004	24	1.01	0.73	0.43	0.67
Aramoana	982.00.03659.42011	2	24/02/19 07:23	26/02/19 21:36	2.6	65.0	1.05	19.5	13.9	816	13	193	1460.1	0.34	123	29.8	29.8	20	1.37	83	3.5	0.004	22	1.25	0.74	0.48	0.84
Aramoana	982.00.03659.42011	3	27/02/19 07:40	28/02/19 21:00	1.6	65.5	1.75	28.1	12.7	569	15	184	1270.9	0.46	115	28.9	27.8	20	1.28	74	3.3	0.002	23	1.16	0.72	0.44	0.83
Aramoana	982.00.04055.33671	1	19/02/19 07:23	21/02/19 20:30	2.6	118.9	1.94	49.3	24.1	624	10	211	1047.1	0.17	141	39.2	47.1	30	1.08	72	4.2	0.002	41	0.84	0.78	0.37	0.64
Aramoana	982.00.04055.33671	2	23/02/19 06:48	25/02/19 20:46	2.6	87.4	1.41	43.1	27.0	803	13	286	1999.4	0.29	145	37.4	40.0	27	1.24	88	4.1	0.001	33	1.05	0.80	0.45	0.66
Aramoana	982.00.04055.33671	3	26/02/19 12:25	10/03/19 20:31	12.3	164.9	0.56	43.1	15.6	3019	10	216	6310.7	0.45	155	37.8	30.5	26	1.31	98	4.1	-0.002	32	1.13	0.80	0.50	0.72

\* Water depth was derived by associating actual and extrapolated dive locations with bathymetry data published by NIWA (2006, 250m grid bathymetry data)

\*\* dive time / (surface time + dive time)

\*\*\* bottom time / (surface time + dive time)



## Hoiho dive analysis - pre-moult 2019 [individual means]

Site	BirdID	Trip number [n]	Trip duration [days]	Distance travelled [km]	Mean travel speed [km/h]	Maximum range [km]	Mean range [km]	Dive Events [n]	Dive rate [dives/h]	Surface Time [s]	Dive Time [s]	Max Depth [m]	Water Depth * [m]	Descent Velocity [m/s]	Bottom Time [s]	Ascent Velocity [m/s]	Foraging Effort [m/s]	Diving Efficiency [m/s]	Ratio of benthic dives
Aramoana	Axytrek 13	3	5.4	118	0.91	32.3	15.9	1588	12.7	173	133	31	33	1.18	86	1.15	0.75	0.47	0.73
Aramoana	Axytrek 17	3	6.0	148	1.03	34.0	18.7	1588	15.5	259	126	35	37	1.26	79	1.23	0.75	0.45	0.73
Aramoana	Axytrek 18	3	2.6	101	1.60	23.0	12.8	895	14.3	168	116	28	29	1.24	75	1.11	0.73	0.44	0.76
Aramoana	iGotU 17022	3	5.8	124	1.30	45.2	22.0	556	11.1	237	147	38	39	1.21	86	1.01	0.79	0.44	0.67
Otapahi	Axytrek 16	9	0.5	16	1.24	13.2	9.1	263	20.1	172	131	37	28	1.33	80	1.11	0.78	0.45	0.84
Otapahi	Axytrek 23	4	1.5	73	2.14	25.2	14.2	464	15.7	179	133	38	51	1.03	73	0.93	0.75	0.36	0.60

\* Water depth was derived by associating actual and extrapolated dive locations with bathymetry data published by NIWA (2006, 250m grid bathymetry data)

\*\* dive time / (surface time + dive time)

\*\*\* bottom time / (surface time + dive time)