Online Resource: Background information and additional foraging/diving behaviours

Prey targeted by lactating Weddell seals (*Leptonychotes weddellii*) in Erebus Bay, Antarctica.

Rose T. N. Foster-Dyer[1], Kimberly T. Goetz[2,3], Takashi Iwata[4,5], Rachel R. Holser[6], Sarah A. Michael[7,8], Craig Pritchard[9,10], Simon Childerhouse[11], Daniel P. Costa[6], David G. Ainley[12], Matthew H. Pinkerton[2], Michelle A. LaRue[1].

Polar Biology (2024)

[1]Gateway Antarctica, University of Canterbury, Christchurch, New Zealand,
[2]National Institute of Water and Atmospheric Research, Wellington, New Zealand,
[3]Marine Mammal Laboratory, Alaska Fisheries Science Centre, National Marine Fisheries Service, NOAA, Seattle, USA,
[4]Atmosphere and Ocean Research Institute, University of Tokyo, Tokyo, Japan,
[5]Graduate School of Maritime Sciences, Kobe University, Kobe, Japan,
[6]Institute of Marine Sciences, University of California Santa Cruz, California, USA,
[7]School of Veterinary Science, Massey University, Palmerston North, New Zealand,
[8]Department of Natural Resources and Environment Tasmania, Hobart, Tasmania, Australia
[9]The Nest Te Kōhanga, Wellington Zoo, Wellington, New Zealand,
[10]Ecovet Consulting, Wellington, New Zealand,
[11]Cawthron Institute, Nelson, New Zealand,
[12] H. T. Harvey & Associates Ecological Consultants, Los Gatos, California, USA.

Corresponding author: rose.foster@pg.canterbury.ac.nz

Table SI1. Demographic and physiological parameters gathered for each lactating Weddell seal instrumented in spring 2018 and 2019 in Erebus Bay. For seals that were unknown age, minimum age was estimated based on the year the seal was flipper-tagged by J. Rotella and B. Garrott (Rotella, 2018), their number of previous pups, and the estimated age of first reproduction for Weddell seals (~7 years in Erebus Bay; Hadley et al. 2006). Duration refers to the length of deployment period the seal had bio-logging devices attached. Fatness ratio (a proxy for body condition) was calculated by dividing axillary girth and straight length. Pup age is the age of the female's pup at the time of instrumentation. Previous pups refers to the number of pups the seal had historically. Data on the maternal age, breeding history and pup age was provided by J. Rotella and B. Garrott (Rotella, 2018).

Seal ID	Location	Date captured	Duration (days)	Mass (kg)	Fatness (girth/ length)	Age (years, est. min.)	Pup age (days)	Previous pups
WS18-01[x]	Tent Island	12/11/2018	4	272	0.67	7	16	Unkn
WS18-02	Tent Island	12/11/2018	5	432	0.72	9	16	2
WS18-03[x]	Tent Island	12/11/2018	4	373	0.72	8	18	1
WS18-04[x]	Big Razorback	13/11/2018	4	304	0.73	11	19	4
WS18-05[x]	Big Razorback	13/11/2018	2	379	0.73	14	19	7
WS18-06	Big Razorback	14/11/2018	4	367	0.78	11	16	3
WS18-08[x]	Tent Island	15/11/2018	5	270	0.82	7	17	Unkn
WS18-09[x]	Hutton Cliffs	16/11/2018	5	450	0.75	9	19	2
WS18-10[x]	Hutton Cliffs	18/11/2018	3	329	0.78	15	21	8
WS18-11[x]	Hutton Cliffs	18/11/2018	3	299	0.73	8*	21	Unkn
WS18-13	Big Razorback	20/11/2018	5	305	0.73	16	24	9
WS18-14[x]	Tent Island	25/11/2018	5	258	0.68	11	31	4
WS18-15	Tent Island	25/11/2018	6	294	0.83	10	33	3
WS18-16	Big Razorback	27/11/2018	4	263	0.69	9	29	2
WS18-17	North Base	28/11/2018	4	287	0.71	16	26	9
WS18-19	North Base	28/11/2018	4	282	0.75	9	30	2
WS18-20	North Base	28/11/2018	4	263	0.87	8	30	1
WS18-21	North Base	29/11/2018	4	307	0.64	7	31	Unkn
WS19-27[x]	Hutton Cliffs	19/11/2019	5	365	0.84	9	26	2
WS19-30	Big Razorback	20/11/2019	5	318	0.71	12	28	5
WS19-36	Big Razorback	28/11/2019	5	242	0.75	10	32	3
WS19-39	Pram Point	2/12/2019	5	290	0.76	9*	29	2
WS19-40	Turks Head	3/12/2019	8	311	0.73	8*	33	0
WS19-41	Pram Point	4/12/2019	5	288	0.68	10*	37	1
WS19-42	Turks Head	5/12/2019	6	314	0.71	9	32	2
WS19-43	Turks Head	7/12/2019	6	252	0.74	8	29	1
		Mean	4.6	312.1	0.74	10.0	25.5	3.3
		SD	1.1	52.1	0.05	2.6	6.3	2.6

* indicates exact age known animals based on Rotella (2018). All other animals are estimated minimum age.
[x] indicates seals that were identified as a 'non-forager' based on TDR and video data analyses. Remaining seals were classified as a ‘forager’.

Table SI2. Details of each of the bio-logging devices fitted to lactating Weddell seals in Erebus Bay, Antarctica in 2018/2019. We include the make and model of each tag, the size, mass, and position each device was attached to each seal. We used two different types of accelerometers, magnetometers, and three different camera types. The total weight of the equipment attached to each seal weighed no more than 1% of their body mass. Devices were attached using techniques described in Mellish et al. (2010) and Shero et al. (2014, 2018) and used Loctite Quickset Epoxy (25 mL, product code: 1395391).

Device type	Purpose	Description	Size (mm)	Mass (g)	Position
Accelerometer	Detect jaw opening movements	Little Leonardo ORI2000-DG3T/ORI1300-DG3T	20 (dia) x 73	52	Mandible
TDR/magnetometer	3D underwater movement	Little Leonardo ORI1300-3MPD3GT *or* W1000L-3MPD3GT	16.5 (dia) x 90 26 (dia) x 176	42.5 120	Back Back
GPS/accelerometer/TDR	Location of the animal	Techno SmArt Axy-Trek Marine	56 x 24 x 13	26	Head
Camera	Observing foraging behaviours and other interactions between the female and her conspecifics	Little Leonardo DVL1300M130-VD3GT-2R *or* CATS CATS-Cam Wireless CC v7–6.1.x *or* DVLW2000M130-4R	60 x 22 x 22 38 (dia) x 130 60 x 22 x 31	49 280 60	Head or cheek or back
VHF tag	Relocate the animal to remove equipment	ATS MM150 Marine Mammal Backmount	13 (dia) x 58	20	Back

Table SI3. Summary of ethogram used in behavioural analysis software 'BORIS' to analyse footage gathered via seal-mounted camera. A seal could display multiple behaviours simultaneously, e.g., 'swimming' and 'interacting with pup'. 'Key' refers to the keyboard key that logged the behaviour into timeline. 'Type' refers to whether the behaviour was a 'point' event (a singular point in time) or a 'state' event (a period with a start and an end time). 'Modifiers' were optional details added to some behaviours to record further information about an interaction, e.g., the type of behaviour observed or the location at which the behaviour took place.

Behaviours	Key	Type	Description	Modifiers
Breath	B	Point	Seal surfaces from underwater to take a breath	
Eating	E	Point	Seal encounters/eats one prey	Prey: Unknown, silverfish, toothfish, shrimp, ice fish, octopus, borch, zoarchid
Bubbles	V	Point	Seal blows bubbles out of nose	Type: Aggressive, at pup, under ice, unknown
Head in sponge	H	Point	Seal pushes head into glass sponge, assumed foraging	Eating: yes, no, unsure
Into water	I	Point	Seal gets into water from on the ice	
Out of water	O	Point	Seal attempts to haul out onto the ice	
Swimming	S	State	Seal is swimming in the water, not resting at surface or on the ice.	
Searching	C	State	Seal is attempting to locate prey. Distinctive from 'swimming' behaviour as seal travels from breathing hole into dark water without her pup and commences foraging dive	Type: successful, unsuccessful (did the seal locate prey)
Aggression	F	State	Seal is attacks or is attacked by another seal nearby	Type: Chasing, biting, general, attacked
Resting	R	State	Seal resting on sea surface or on the ice	Location: On ice, at sea surface, on seafloor
Pup	P	State	Seal is interacting with, or is visibly nearby, her pup	Type: Nursing, playing, swimming, general, aggressive; Location: Underwater, at surface, on ice
Scanning seafloor	A	State	Seal is swimming close to the seafloor	Type: Dark, light, searching.
Vocalising	X	State	Seal is vocalising, inferred from head movement and vibrations	Type: Aggressive, at pup, unknown
Reaming	G	State	Seal reams ice around breathing hole	

Table SI4. Summary of diving behaviour recorded by TDRs attached to lactating Weddell seals in Erebus Bay. Seals that did not dive have been excluded. Dives were classified as any excursion from the surface that reached >10 m and lasted >30 seconds. Foraging bouts were identified as periods of recurring dives that exceed 50 m at least once and occur within 30 minutes of the previous dive. Dive rate per foraging bout (PFB) was the average number of shallow (≤50 m) and deep dives (>50 m) performed within the identified bouts.

Seal ID	All dives (>10m)	Shallow dives (≤50 m)	Deep dives (>50 m)	Max depth (m)	Mean depth (m)	SD (± m)	Max duration (min)	Mean duration (min)	SD (± min)	Foraging bouts	Deep dives PFB	Shallow dives PFB	All dives PFB
WS18-11[x]	6	6	0	15.7	11.9	2.07	0.5	0.5	0.17	NA	NA	NA	NA
WS18-14[x]	1	1	0	18.5	18.5	NA	0.5	0.5	NA	NA	NA	NA	NA
WS18-02	30	6	24	233.7	113.9	71.79	21.5	14.2	7.06	8	3.0	0.5	3.5
WS18-06	13	8	5	343.2	97.0	136.51	24.4	6.3	9.70	1	5.0	8.0	13.0
WS18-13	60	39	21	374.9	91.0	126.94	29.4	5.9	9.06	8	2.6	3.3	5.9
WS18-15	22	8	14	343.0	200.0	142.54	25.1	13.1	9.38	6	2.3	1.0	3.3
WS18-16	169	100	69	428.8	114.5	144.25	26.1	6.6	7.71	8	8.6	10.5	19.1
WS18-17	32	19	13	241.4	76.3	85.41	19.6	4.7	6.97	2	6.5	3.5	10.0
WS18-19	213	89	124	229.0	97.0	74.24	22.6	6.8	6.46	8	15.8	7.8	23.5
WS18-20	159	55	104	337.7	128.7	102.34	18.8	8.4	6.43	5	21.0	6.4	27.4
WS18-21	169	142	27	209.5	40.0	54.43	18.1	2.6	5.12	4	6.8	12.8	19.5
WS19-30	38	24	14	449.3	151.5	183.14	19.3	6.5	6.77	4	3.8	1.5	5.3
WS19-36	25	9	16	296.2	107.0	107.72	19.9	5.7	6.54	4	4.3	5.0	6.5
WS19-39	163	142	21	342.5	39.2	73.72	31.1	3.7	7.07	9	2.8	7.0	9.8
WS19-40	318	246	72	328.0	44.9	66.81	13.9	1.6	2.78	13	5.38	10.0	15.4
WS19-41	680	564	116	325.3	32.0	47.73	26.9	2.9	5.68	10	11.1	11.6	22.7
WS19-42	379	314	65	343.4	38.3	55.37	17.8	1.9	2.95	14	4.7	11.6	16.3
WS19-43	305	107	198	367.2	89.5	69.95	24.8	6.6	5.63	9	20.7	5.7	26.3
Total	**2775**	**1872**	**903**							**113**			
Mean	173.4	117.0	56.4	324.6	91.3		22.4	6.1		7.1	7.8	7.1	14.2
SD	179.2	149.1	54.8	68.6	46.4		4.7	3.6		3.6	6.2	3.6	8.2

[x] indicate non-forager seals (seals that did not dive deeper than 50 m). Total, mean and SD refer to foraging animals only and exclude these data.

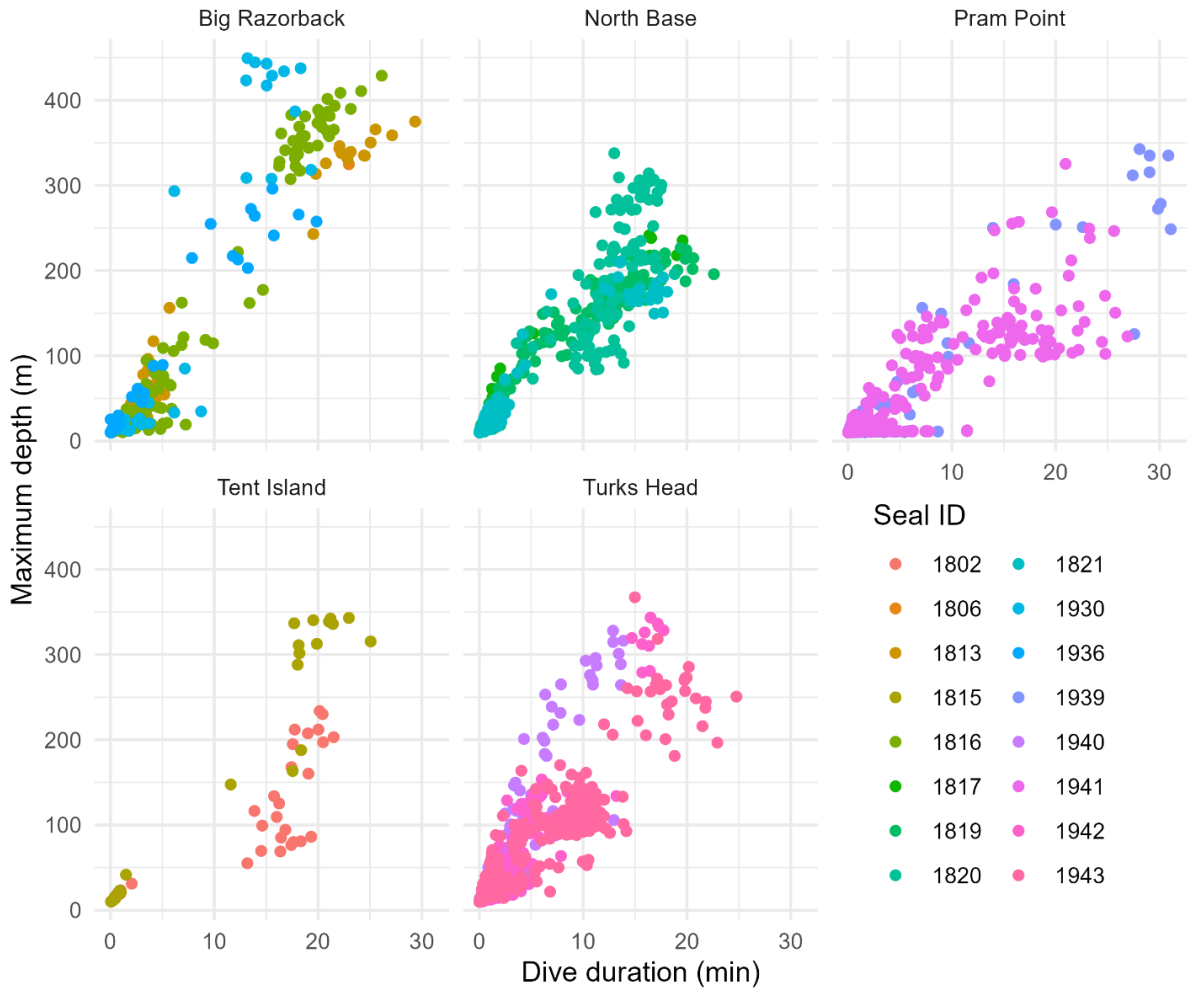

Fig. SI5. Plot of dive depth and dive duration at each of the locations that lactating Weddell seals were studied in Erebus Bay in 2018/2019. No seals tagged at Hutton Cliffs performed any dives. We note is a distinction in depth-duration patterns between some locations. Dives were deepest at Big Razorback and longest at Pram Point, which we suggest may be driven by the different bathymetry and prey availability of each location.

Table SI6. Summary of the dive depth and duration recorded at each of the five locations where lactating Weddell seals performed dives in Erebus Bay. Seals dived the deepest at Big Razorback and the longest at Pram Point. Fewer dives performed were at Tent Island resulting in inflated mean values.

	n		Depth (m)			Duration (min)		
Location	Seals	Dives	Max	Mean	SD (±)	Max	Mean	SD (±)
Big Razorback	5	310	449.3	112.9	142.9	28.6	6.3	7.8
North Base	4	573	337.7	87.8	85.9	22.6	5.9	6.5
Pram Point	2	842	342.5	33.3	53.7	31.1	3.1	6.0
Tent Island	2	51	343.0	149.4	113.8	25.1	13.7	8.0
Turks Head	3	1000	367.2	56.0	67.5	24.8	3.3	4.5

Table SI7. The percentage of time each foraging seal spent benthic foraging (with the seafloor visible) on video.

Seal ID	Video length (hrs)	Searching time (min)	Seafloor time (min)	Percentage seafloor (%)
WS18-13	3.2	36.9	29.5	79.9
WS18-16	2.2	19.9	6.2	31.3
WS18-17	0.8	14.7	9.0	61.4
WS18-19	2.0	57.1	4.8	8.4
WS19-30	4.3	127.7	1.0	0.8
WS19-36	4.0	14.6	4.6	31.3
WS19-39	3.8	90.7	15.2	16.7
WS19-40	3.8	148.3	24.5	16.5
WS19-41	4.2	174.4	22.5	12.9
WS19-42	0.4	22.5	0.0	0.0
WS19-43	0.3	16.5	7.5	45.3
Total	**29**	**723.3**	**124.8**	**17.3**
Mean	2.6	65.8	11.3	27.7
SD (±)	1.5	56.9	9.6	24.4

Table SI8. Summary of results of the binomial logistic regression used to identify demographic and physiological parameters that effect whether a female Weddell seal (*Leptonychotes weddellii*) forages during lactation. We analysed only seals tagged in 2018 (*n* = 18) and assessed the inclusion of location as a random effect to account for the potential different foraging access at each location. We scaled and centred all predictor variables to ensure they were comparable. We excluded number of previous pups due to the number of unknown individuals. *P*-values indicate whether the model was significantly different than the null. Akaike weights (wts) and relative likelihood (rel.LL) calculated using *qpcR* package (v. 1.4-1).

Response	Predictors	*n*	AICc	BIC	Log-lik	ΔAICc	Akaike wts	Rel.LL	*p*-value
Forager_01 ~	**age_pup**	**18**	**24.82**	**25.80**	**-10.01**	**0**	**0.370**	**1**	**0.026**
	age_pup + (1 | location)	18	26.27	28.69	-10.01	1.45	0.179	0.484	0.085
	age_pup + mass_kg	18	26.84	27.79	-9.56	2.01	0.135	0.365	0.054
	1	18	27.20	27.84	-12.48	2.38	0.112	0.304	
	fatness + age_pup	18	27.41	28.37	-9.85	2.59	0.101	0.274	0.072
	mass_kg	18	29.44	30.42	-12.32	4.62	0.037	0.099	0.574
	fatness	18	29.54	30.52	-12.37	4.72	0.035	0.094	0.647
	fatness + mass_kg + age_pup	18	29.75	30.24	-9.34	4.93	0.031	0.085	0.099
	fatness + mass_kg + age_pup + (1 | location)	18	33.35	32.80	-9.17	8.52	0.005	0.014	0.158

Table SI9. Summary of percentage of prey encountered by lactating Weddell seals in Erebus Bay above and below 50 m for all seals that encountered prey on video captured by seal-mounted camera. We also report the total percentage of prey taken above 50 m at each location.

Seal ID	Prey >50 m	Prey ≤50 m	Percentage prey >50 m (%)	Percentage prey ≤50 m (%)	Location	Total prey ≤50 m by location (%)
WS18-13	6	0	100.0	0	Big Razorback	0.3
WS18-17	3	0	100.0	0	North Base	0
WS18-19	134	0	100.0	0	North Base	0
WS19-30	310	1	99.7	0.3	Big Razorback	0.3
WS19-39	14	0	100.0	0	Pram Point	29.4
WS19-40	165	71	69.9	30.1	Turks Head	44.2
WS19-41	37	15	67.3	32.7	Pram Point	29.4
WS19-42	31	25	55.4	44.6	Turks Head	44.2
WS19-43	30	4	86.7	13.3	Turks Head	44.2
Total	**730**	**116**	**84.1**	**15.9**		
Mean	81.1	12.8	86.6	13.4		
SD (±)	103.4	23.5	17.7	17.7		

Table SI10. Summary of the depths of each prey encountered by each lactating Weddell seal that was observed capturing prey on video recorded using seal-mounted camera. All seals except WS19-42 had an average depth of prey encounters deeper than 50 m.

Seal ID	*n*	Mean depth (m)	SD (± m)	Min depth (m)	Max depth (m)
WS18-13	6	345.2	52.1	239.2	373.4
WS18-17	3	178.8	4.7	173.7	183.0
WS18-19	134	152.7	22.4	91.8	187.8
WS19-30	311	404.6	56.8	5.2	449.0
WS19-39	14	203.1	34.6	155.0	272.5
WS19-40	236	195.8	122.0	1.0	310.5
WS19-41	52	152.6	97.4	7.3	254.8
WS19-42	56	48.6	19.8	14.8	82.8
WS19-43	33	94.6	41.6	33.7	209.2

Table SI11. Summary of prey encounters observed in video footage. Seals that did not encounter prey on camera have been excluded. Prey was grouped by nearest possible taxonomic class. Crustaceans included various mysids, decapods, and amphipod species. Unknown prey included all prey that were unable to be identified or not visible in the video footage.

Seal ID	Prey encounters	Crustacea	*Pleuragramma antarcticum*	*Dissostichus mawsoni*	*Trematomus borchgrevinki*	Channich-thyidae	Octopoda	Zoarci-dae	Within sponge	Unknown
WS18-13	6	0	4	0	0	0	0	0	1	1
WS18-17	3	0	0	0	0	0	0	0	3	0
WS18-19	134	1	132	0	0	0	0	0	0	1
WS19-30	311	257	10	0	0	1	0	0	0	43
WS19-39	14	2	0	0	0	1	0	0	1	10
WS19-40	236	130	0	0	0	1	2	1	0	102
WS19-41	55	1	5	2	8	5	0	0	0	34
WS19-42	56	0	1	0	0	0	0	0	0	55
WS19-43	33	0	9	0	0	0	0	0	0	24
Total	**848**	**391**	**161**	**2**	**8**	**8**	**2**	**1**	**5**	**269**
Mean	94.2	43.4	18.0	0.2	0.9	0.9	0.2	0.1	0.6	29.9
SD (±)	110.7	90.8	42.9	0.7	2.7	1.6	0.7	0.3	1.0	33.5

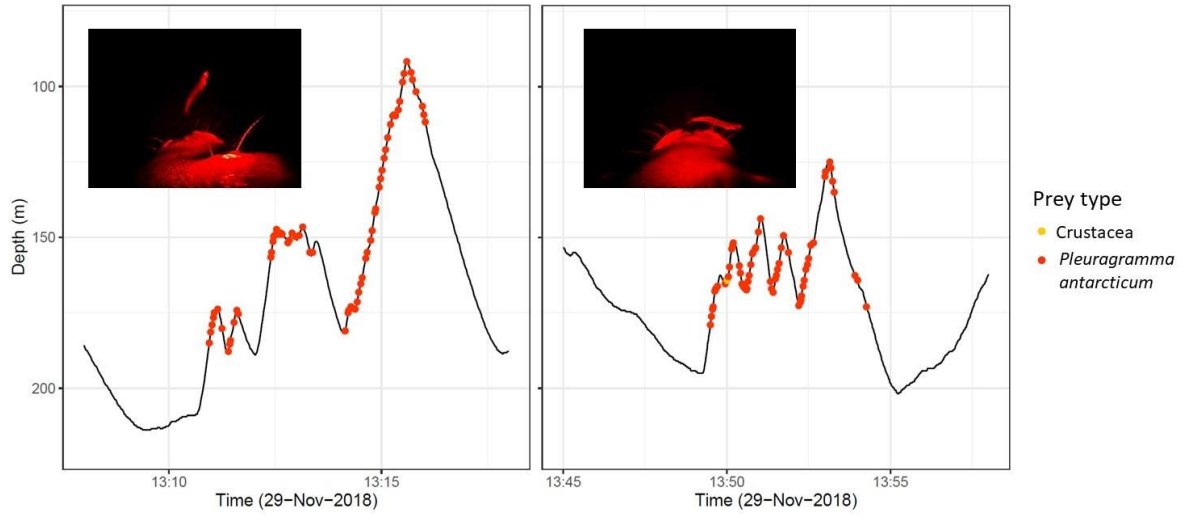

Fig. SI12. Periods of foraging extracted from the dive record for seal WS18-19 showing the two dives in which the seal encountered Antarctic silverfish *(Pleuragramma antarcticum)*. Black lines represent route travelled by seal, circles represent points in time that the seal encountered one prey, and colour of circle represents different prey types. By overlaying TDR and prey encounter data, it became visible that the seal was capturing many of the silverfish while ascending in the water column, potentially using the surface backlighting to locate the prey. Inset images are two examples of the prey identified to be Antarctic silverfish (*P. antarcticum*) during the dives, the seals snout is visible at the bottom of the image.

Online Resource 2: Video SI13. Video captured by seal-mounted camera of lactating Weddell seal WS18-15 encountering a *Trematomus borchgrevinki* shortly after entering the water. The seal captures the fish quickly and chews on it a few times. The seal then releases the fish, recaptures and then releases the fish once more. The seal then blows bubbles out of her nose and does not pursue the fish further. The interaction is reminiscent of the way a cat may play with a mouse. It is unclear why the seal did not consume the fish. The camera on WS18-15 was attached to the seal's cheek in an attempt to more accurately identify prey species.