The following supplement accompanies the article

Individual variation in seasonal movements and foraging strategies of a land-locked, ice-breeding pinniped

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Table S1. Measurements of 75 Caspian seals tagged in 2009-2012, BMI - Body mass index. BMI=Weight (kg)/(Body length (cm)/100)^2.

Tag ID	Tagging date	Sex	Weight (kg)	Body length (cm)	Girth (cm)	BMI
SPOT 98184	11.11.2009	F	51.5	106	110	45.83
SPOT 98185	11.11.2009	F	61.5	109	110	51.76
SPOT 98186	11.11.2009	F	66.5	108	119	57.01
SPOT 98187	10.11.2009	M	56.5	111	113	45.86
SPOT 98188	11.11.2009	M	66.5	121	118	45.42
SPLASH 57014	18.10.2010	F	59	102	122.5	56.7
SPLASH 57015	19.10.2010	F	70.5	118	124	50.6
SPLASH 57017	18.10.2010	F	77.5	126	124	48.8
SPLASH 57018	18.10.2010	F	64	115	115	48.4
SPLASH 57019	19.10.2010	M	71	127	132	44
SPLASH 57021	18.10.2010	F	75.5	124	119	49.1
SPLASH 57022	18.10.2010	F	61.5	118	118	44.2
SPLASH 57023	19.10.2010	F	73	123	120	48.3
SPLASH 57025	19.10.2010	F	59	119	116	41.7
SPLASH 57026	18.10.2010	F	62	116	115	46.1
SPLASH 57030	19.10.2010	F	76	118	124	54.6
SPOT 57032	28.10.2010	F	76	115	123	57.5
SPOT 57039	28.10.2010	F	60	112	119	47.8
SPOT 57040	20.10.2010	M	67	119	128	47.3
SPOT 57041	23.10.2010	F	58	113	112	45.4
SPOT 57042	28.10.2010	F	56	111	110	45.5
SPOT 57043	28.10.2010	F	78	121	131	53.3
SPOT 57044	20.10.2010	F	60	119	118	42.4
SPOT 57045	28.10.2010	F	76	122	124	51.1
SPOT 57046	20.10.2010	F	78	122	124	52.4
SPOT 57047	23.10.2010	F	55.5	119	119	39.2
SPOT 57048	28.10.2010	F	72	126	125	45.4
SPLASH 57049	20/04/2011	M	46	122	112	30.9
SPLASH 57050	20/04/2011	M	41	126	105	25.8
SPLASH 57051	19/04/2011	M	36	124	98	23.4

Tag ID	Tagging date	Sex	Weight (kg)	Body length (cm)	Girth (cm)	BMI
SPLASH 57052	19/04/2011	M	38	125	97	24.3
SPLASH 57053	17/04/2011	F	48.5	116	104	36.0
SPLASH 57054	19/04/2011	M	50	136	103	27.0
SPLASH 57055	17/04/2011	F	41	114	101	31.5
SPLASH 57057	17/04/2011	M	42	134	102	23.4
SPLASH 57058	17/04/2011	M	37	114	95	28.5
SPLASH 57059	20/04/2011	M	40	132	105	23.0
SPLASH 57060	19/04/2011	M	41	142	106	20.3
SPLASH 57061	21/04/2011	M	40	129	98	24.0
SPLASH 57062	17/04/2011	M	41	119	101	29.0
SPLASH 57063	17/04/2011	F	42	118	99	30.2
SPLASH 57064	21/04/2011	F	43	120	103	29.9
SPOT 57065	20/04/2011	M	41	120	102	28.5
SPOT 57066	21/04/2011	M	49.5	125	104	31.7
SPOT 57069	19/04/2011	M	45	123	100	29.7
SPOT 57070	20/04/2011	M	37	116	104	27.5
SPOT 57071	20/04/2011	M	38	120	104	26.4
SPOT 57073	19/04/2011	M	38.5	115	95	29.1
SPOT 57074	21/04/2011	F	40	111	103	32.5
SPOT 57086	21/04/2011	F	38	117	107	27.8
SPOT 57087	19/04/2011	M	31	121	92	21.2
SPOT 72416	20/04/2011	M	44.5	119	107	31.4
SPOT 72417	19/04/2011	M	36	118	101	25.9
SPOT 72500	20/04/2011	M	35.5	120	92	24.7
SPOT 72554	17/04/2011	M	41	119	93	29.0
SPOT 72558	20/04/2011	F	31.5	120	91	21.9
SPOT 72562	21/04/2011	F	34	113	89	26.6
SPOT 72575	20/04/2011	M	32	123	94	21.2
SPOT 72576	20/04/2011	F	30	112	89	23.9
SPOT 72588	19/04/2011	M	27	114	96	20.8
SPOT 117802	21/10/2012	F	56.5	111	114	45.9
SPLASH 117799	21/10/2012	F	70	115	115	52.9
SPLASH 117794	21/10/2012	F	81	117	128	59.2
SPLASH 117782	21/10/2012	F	71	110	113	58.7
SPLASH 117792	21/10/2012	F	67	112	108	53.4
SPLASH 117793	21/10/2012	F	65.5	112	111	52.2
SPOT 117807	22/10/2012	F	73	122	125	49.0
SPOT 117808	22/10/2012	F	60	117	115	43.8
SPLASH 117788	22/10/2012	M	74	121	121	50.5
SPOT 117815	22/10/2012	F	74	117	125	54.1
SPLASH 117781	22/10/2012	M	81	121	135	55.3
SPOT 117816	22/10/2012	F	84	108	126	72.0
SPO T 117812	23/10/2012	M	86	135	120	47.2
SPOT 117805	23/10/2012	M	83	129	127	49.9
SPOT 117819	23/10/2012	M	78.5	127	124	48.7

Table S2. Prior distributions used for SSM parameters. Highly informed prior was placed on the first location (place of tagging: Kendirli in 2009, 2010 and 2012, and Komsomoletz bay in 2011. γ_{for} and γ_{trv} are mean autocorrelations, θ_{for} and θ_{trv} are the mean turn angles (in degrees) for the foraging and travel behavioural states, respectively. α_1 – probability of remaining in foraging state at time *t* given foraging state at time *t-1*. α_2 – probability of switching to the foraging state at time *t* given the travel state at time *t-1*. Σ represents the covariance matrix and τ a scaling parameter. For more details see Breed et al. 2009.

Parameter	Prior distribution
γ_{for}	beta (1,1)
γ_{trv}	beta (1,1)
θ_{for}	beta (5,5)*2π
θ_{trv}	beta (5,5)*2π -π
α_1	beta (10,1)
α_2	beta (1,10)
Σ	Wishart ($\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$, 2)
τ	beta (1,1)*1000
Lat 1st loc (2009, 2010, 2012)	t(42.75,100000,100)
Lon 1st loc (2009, 2010, 2012)	t(52.55,100000,100)
Lat 1st loc 2011	t(45.51,100000,100)
Lon 1st loc 2011	t(52.63,100000,100)

Table S3. Location and transmission summary for each tag.

Tag ID	Number of filtered locations	Length of track (km)	Start transmission	End transmission	Number of days	km/day	Average positions/day
98184	326	2835	11/11/2009	02/03/2010	111	25.54	2.9
98185	367	2403	11/11/2009	02/03/2010	111	21.65	3.3
98186	99	852	11/11/2009	05/12/2009	114	7.47	0.9
98187	495	3651	10/11/2009	28/03/2010	138	26.46	3.6
98188	290	1972	11/11/2009	12/03/2010	121	16.30	2.4
57014	623	5200	18/10/2010	05/03/2011	138	37.68	4.5
57015	511	3041	19/10/2010	26/02/2011	130	23.39	3.9
57017	700	5602	18/10/2010	13/03/2011	146	38.37	4.8
57018	660	2488	18/10/2010	12/03/2011	145	17.16	4.6
57019	524	4846	19/10/2010	22/03/2011	154	31.47	3.4
57021	129	1190	18/10/2010	14/11/2010	27	44.09	4.8
57022	709	3919	18/10/2010	26/03/2011	159	24.65	4.5
57023	620	6779	19/10/2010	15/03/2011	147	46.11	4.2
57025	570	3391	19/10/2010	08/01/2011	81	41.86	7.0
57026	685	4282	18/10/2010	20/02/2011	125	34.26	5.5
57030	458	4018	19/10/2010	24/03/2011	156	25.76	2.9
57032	233	1636	28/10/2010	10/03/2011	133	12.30	1.8
57039	195	1869	28/10/2010	18/04/2011	172	10.87	1.1
57040	116	2092	20/10/2010	14/03/2011	145	14.43	0.8
57041	190	3569	23/10/2010	01/04/2011	160	22.31	1.2
57042	193	1906	28/10/2010	01/01/2011	65	29.32	3.0
57043	197	2287	28/10/2010	12/03/2011	135	16.94	1.5
57044	290	3345	20/10/2010	09/03/2011	140	23.90	2.1
57045	161	2674	28/10/2010	17/02/2011	112	23.87	1.4

Tag ID	Number of filtered locations	Length of track (km)	Start transmission	End transmission	Number of days	km/day	Average positions/day
57046	403	4434	20/10/2010	13/04/2011	175	25.34	2.3
57047	275	2597	23/10/2010	24/03/2011	152	17.08	1.8
57048	187	2666	28/10/2010	11/02/2011	106	25.15	1.8
57049	1227	3624	20/04/2011	04/08/2011	106	34.19	11.6
57050	2441	7666	20/04/2011	11/11/2011	205	37.39	11.9
57051	1501	3317	19/04/2011	16/08/2011	119	27.87	12.6
57052	3249	11142	19/04/2011	15/12/2011	240	46.43	13.5
57053	3497	8711	17/04/2011	11/01/2012	269	32.38	13.0
57054	1005	2831	19/04/2011	17/07/2011	89	31.81	11.3
57055	1283	5258	17/04/2011	18/08/2011	123	42.75	10.4
57057	1326	3213	17/04/2011	15/08/2011	120	26.77	11.1
57058	3194	12405	17/04/2011	06/12/2011	233	53.24	13.7
57059	646	1523	20/04/2011	21/06/2011	62	24.56	10.4
57060	1402	4638	19/04/2011	21/08/2011	124	37.40	11.3
57061	2256	8846	21/04/2011	09/10/2011	171	51.73	13.2
57062	2895	12718	17/04/2011	13/12/2011	240	52.99	12.1
57063	2414	11110	17/04/2011	25/10/2011	191	58.17	12.6
57064	2816	8156	21/04/2011	23/11/2011	216	37.76	13.0
57065	2174	10637	20/04/2011	08/03/2012	323	32.93	6.7
57066	1351	3854	21/04/2011	03/09/2011	135	28.55	10.0
57069	1948	9056	19/04/2011	27/10/2011	191	47.41	10.2
57070	1995	9744	20/04/2011	29/11/2011	223	43.70	8.9
57071	1462	8119	20/04/2011	04/10/2011	167	48.62	8.8
57073	2582	9637	19/04/2011	28/01/2012	284	33.93	9.1
57074	884	2831	21/04/2011	28/07/2011	98	28.88	9.0
57086	1021	2363	21/04/2011	14/08/2011	115	20.55	8.9
57087	2624	13515	19/04/2011	01/03/2012	317	42.63	8.3
72416	2363	8356	20/04/2011	26/11/2011	220	37.98	10.7
72417	723	2875	19/04/2011	11/07/2011	83	34.64	8.7
72500	3294	13998	20/04/2011	05/04/2012	351	39.88	9.4
72554	1856	9735	17/04/2011	27/03/2012	345	28.22	5.4
72558	1359	3795	20/04/2011	25/09/2011	158	24.02	8.6
72562	2787	14419	21/04/2011	02/04/2012	347	41.55	8.0
72575	2479	12383	20/04/2011	27/02/2012	313	39.56	7.9
72576	1177	5510	20/04/2011	10/09/2011	143	38.53	8.2
72588	1381	6329	19/04/2011	07/09/2011	141	44.89	9.8
117781	1495	5496	22/10/2012	20/03/2013	150	36.64	10.0
117782	1290	5480	21/10/2012	04/03/2013	135	40.59	9.6
117788	1465	4919	22/10/2012	20/03/2013	150	32.79	9.8
117792	1395	4711	21/10/2012	01/03/2013	132	35.69	10.6
117793	675	2289	21/10/2012	08/01/2013	79	28.97	8.5
117794	1478	5214	21/10/2012	17/03/2013	147	35.47	10.1
117799	1203	4456	21/10/2012	09/03/2013	139	32.06	8.7
117802	1146	3985	21/10/2012	25/02/2013	125	31.88	9.2
117805	1228	5453	23/10/2012	23/03/2013	151	36.11	8.1
117807	1099	4102	22/10/2012	04/03/2013	133	30.84	8.3

Tag ID	Number of filtered locations	Length of track (km)	Start transmission	End transmission	Number of days	km/day	Average positions/day
117808	1039	4341	22/10/2012	25/02/2013	126	34.45	8.2
117812	1415	4987	23/10/2012	22/03/2013	151	33.03	9.4
117815	997	4138	22/10/2012	15/02/2013	117	35.37	8.5
117816	1265	4542	22/10/2012	13/03/2013	142	31.99	8.9
117819	1130	4629	23/10/2012	06/03/2013	134	34.54	8.4

Table S4. Comparison of average movement speeds of 75 Caspian seals between two behavioural states (SD – standard deviation).

	Mean (km/h)	Median	Range	SD
Foraging moves	0.66	0.53	0.2 – 2.3	0.45
Travelling moves	2.37	2.21	1.6 – 4.0	0.56
Wilcoxon rank sum test	W = 139, p<0.001			

Table S5. Estimated parameter means for 15 groups of modelled satellite tracks. γ_{for} and γ_{trv} are mean autocorrelations, θ_{for} and θ_{trv} are the mean turn angles (in degrees) for the foraging and travel behavioural states, respectively. α_1 – probability of remaining in foraging state at time *t* given foraging state at time *t-1*. α_2 – probability of switching to the foraging state at time *t* given the travel state at time *t-1*.

Group	No of individuals	γ_{for}	γ_{trv}	θ_{for}	θ_{trv}	α_1	α_2
All 2009	5	0.49	0.77	179.9	0.9	0.95	0.09
2010 Kendirli	7	0.63	0.79	182.1	0.5	0.98	0.05
2010 Slow	7	0.46	0.71	179.5	1.5	0.98	0.04
2010 Others	8	0.44	0.73	180.8	2.0	0.96	0.04
2011 Females1	5	0.37	0.84	178.7	-0.8	0.99	0.04
2011 Females2	4	0.41	0.77	175.6	-0.6	0.99	0.06
2011 Males mid1	4	0.17	0.72	170.0	-2.6	0.99	0.05
2011 Males mid2	4	0.18	0.81	175.9	-1.0	0.97	0.11
2011 Males n1	5	0.33	0.78	184.7	-2.2	0.99	0.08
2011 Males n2	4	0.30	0.80	189.2	0.0	0.97	0.11
2011 Males s1	4	0.11	0.77	183.6	0.2	0.98	0.05
2011 Males s2	3	0.28	0.72	168.2	0.6	0.99	0.04
2012 Females SPLASH	5	0.56	0.82	180.4	1.9	0.95	0.07
2012 Females SPOT	5	0.35	0.78	175.1	2.1	0.96	0.05
2012 Males	5	0.40	0.82	182.4	1.5	0.96	0.06

Table S6. Comparison of estimated parameter means for 15 groups of modelled satellite tracks. γ_{for} and γ_{trv} are mean autocorrelations, θ_{for} and θ_{trv} are the mean turn angles (in degrees) for the foraging and travel behavioural states, respectively. α_1 – probability of remaining in foraging state at time *t* given foraging state at time *t-1*. α_2 – probability of switching to the foraging state at time *t* given the travel state at time *t-1*, SD – standard deviation.

Parameter	Mean	Median	Range	SD
γ_{for}	0.36	0.37	0.1 – 0.6	0.14
γ_{trv}	0.77	0.78	0.7 – 0.8	0.04
t test	t=10.59, p<0.001			
θ_{for}	179.07	179.9	168.2 – 189.2	5.47
θ_{trv}	0.27	0.50	-2.6 – 2.1	1.48
t test	t=122.19, p<0.001			
α_2	0.06	0.05	0.04 – 0.11	0.271
α_1	0.97	0.98	0.95 – 0.99	0.134
t test	W=123.4, p<0.001			

Table S7. Maximum depth of dives for all 33 seals with SPLASH tags, SD – standard deviation.

Tag ID	Mean	Minimum	Maximum	SD	Number of records
57014	16.387789	6.5	87.5	16.54036	303
57015	9.658436	1.5	42.5	8.683996	243
57017	13.858268	6.5	62.5	13.81647	254
57018	11.49513	6.5	42.5	5.385692	308
57019	17.210909	6.5	125	19.83534	275
57021	15.103448	6.5	62.5	12.4558	58
57022	17.641768	6.5	42.5	12.31228	328
57023	29.582677	1.5	125	29.03074	254
57025	14.505464	6.5	62.5	11.63537	183
57026	16.268018	1.5	30	8.87579	222
57030	9.138112	6.5	42.5	7.457551	286
57049	7.750804	6.5	30	3.301973	311
57050	13.001751	6.5	30	4.439357	571
57051	6.5	6.5	6.5	0	49
57052	121.847473	1.5	200	78.34912	554
57053	10.875887	1.5	17.5	2.824253	705
57054	6.561798	6.5	17.5	0.824485	178
57055	41.070605	6.5	200	43.8421	347
57057	6.5	6.5	6.5	0	188
57058	83.974016	6.5	200	69.79171	635
57059	6.5	6.5	6.5	0	31
57060	6.572835	1.5	30	1.508739	254
57061	29.80642	6.5	62.5	11.26125	514
57062	117.525528	6.5	200	69.58584	568
57063	61.553611	6.5	200	42.89994	457
57064	40.682982	6.5	200	46.74629	664
117781	13.469697	1.5	127.8	18.88283	396
117782	20.762058	1.5	70	12.83572	311
117788	11.374088	1.5	70	8.156928	411
117792	14.914508	1.5	42.5	9.286081	386
117793	12.783333	1.5	25	4.927647	180
117794	15.497423	1.5	58	11.40461	388
117799	13.987736	1.5	66	12.50536	265

Table S8. Maximum depth dives for all seals for each month. SE - standard error, SD – standard deviation (Note in this summary analysis dives of 200 m and exceeding 200 m are lumped as the actual max depth is not returned). Number of individuals is shown in brackets for each mean estimate. Number of males = 14, number of females = 19.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max of Max depth	127.8	87.5	42.5	200.0	200.0	200.0	200.0	200.0	200.0	200.0	125.0	62.5
Min of Max depth	6.4	4.2	3.1	6.5	6.5	6.5	6.5	6.2	12.3	9.0	6.5	6.0
Mean of Max depth	17.9	10.2	11.4	20.6	35.4	49.2	49.7	48.3	63.2	25.7	13.0	10.3
	(17)	(15)	(12)	(15)	(15)	(15)	(14)	(13)	(8)	(26)	(24)	(20)
SE	2.1	1.9	1.3	7.5	10.7	14.6	15.1	15.9	21.4	3.1	1.4	1.0
SD	8.8	7.2	4.6	29.2	41.5	56.4	56.6	57.3	60.6	15.9	6.7	4.4
Female max	87.5	87.5	42.5	112.5	200	200	200	175	87.5	125	125	62.5
Female	17.2	10.9	12.4	23.3	49.8	56.4	45.5	28.7	22.2	24.1	13.7	11.2
mean of Max depth	(14)	(12)	(9)	(4)	(4)	(4)	(4)	(4)	(3)	(18)	(17)	(15)
SE	2.3	2.3	1.6	10.5	21.1	20.2	17.7	12.6	7.2	3.5	1.6	1.2
SD	8.8	7.9	4.8	20.9	42.2	40.3	35.4	25.1	12.5	14.9	6.8	4.6
Males max	127.8	12.5	19	200	200	200	200	200	200	200	125	58
Males	21.2	7.4	8.3	19.6	30.2	46.6	51.3	57.0	87.8	29.1	11.4	7.8
mean from means	(3)	(3)	(3)	(11)	(11)	(11)	(10)	(9)	(5)	(8)	(7)	(5)
SE	5.6	0.6	1.3	9.8	12.7	18.9	20.5	22.1	29.4	6.6	2.5	1.3
SD	9.7	1.1	2.2	32.5	42.0	62.8	64.8	66.4	65.7	18.5	6.7	2.9

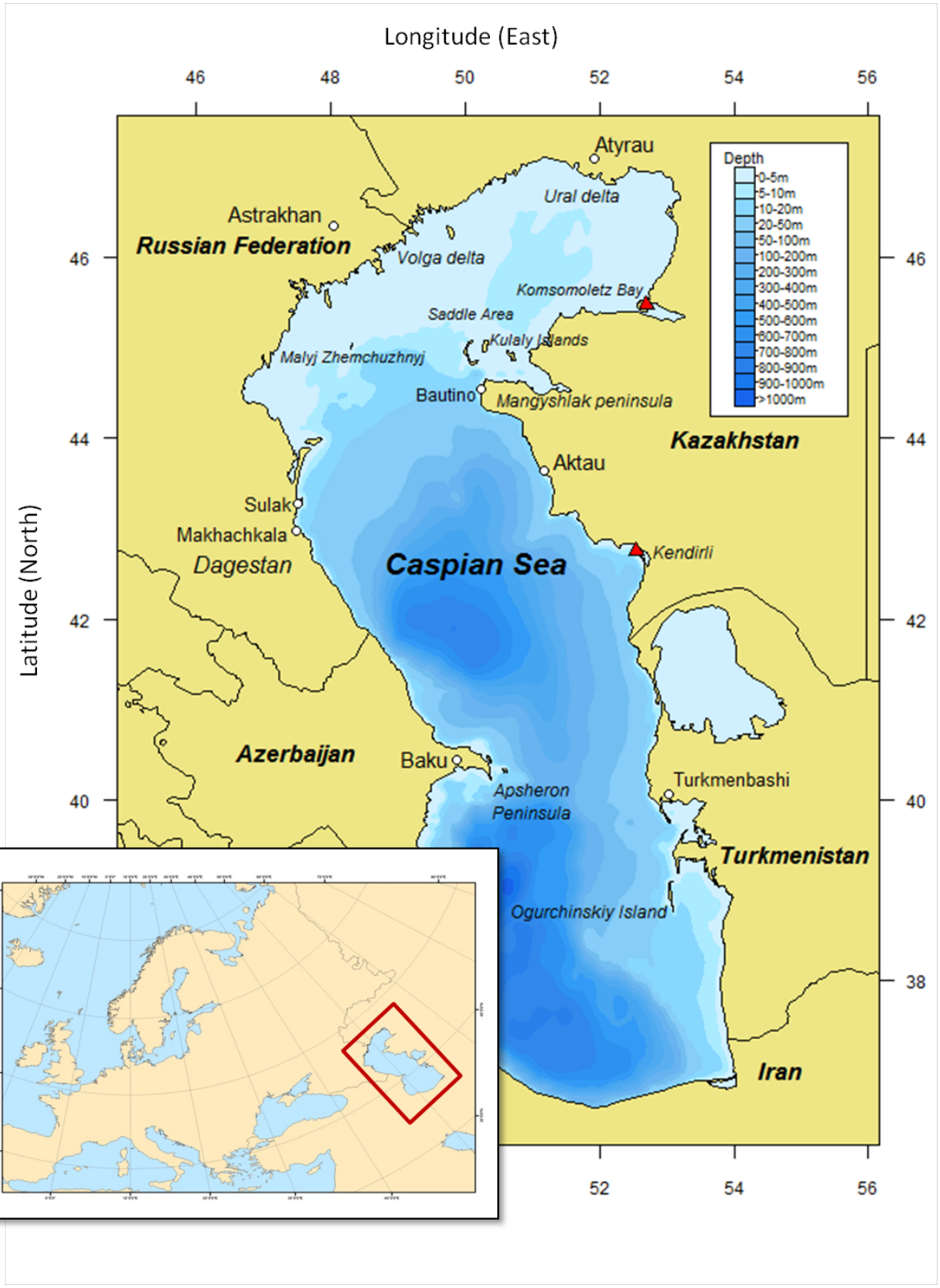


Figure S1. Map of the Caspian Sea. Tagging locations are shown by red triangles.

Figure S2. Moulting aggregations of Caspian seals in Komsomolets Bay, April 2011. Authors' photographs – credit: Lilia Dmitrieva (upper), Simon Goodman (lower).

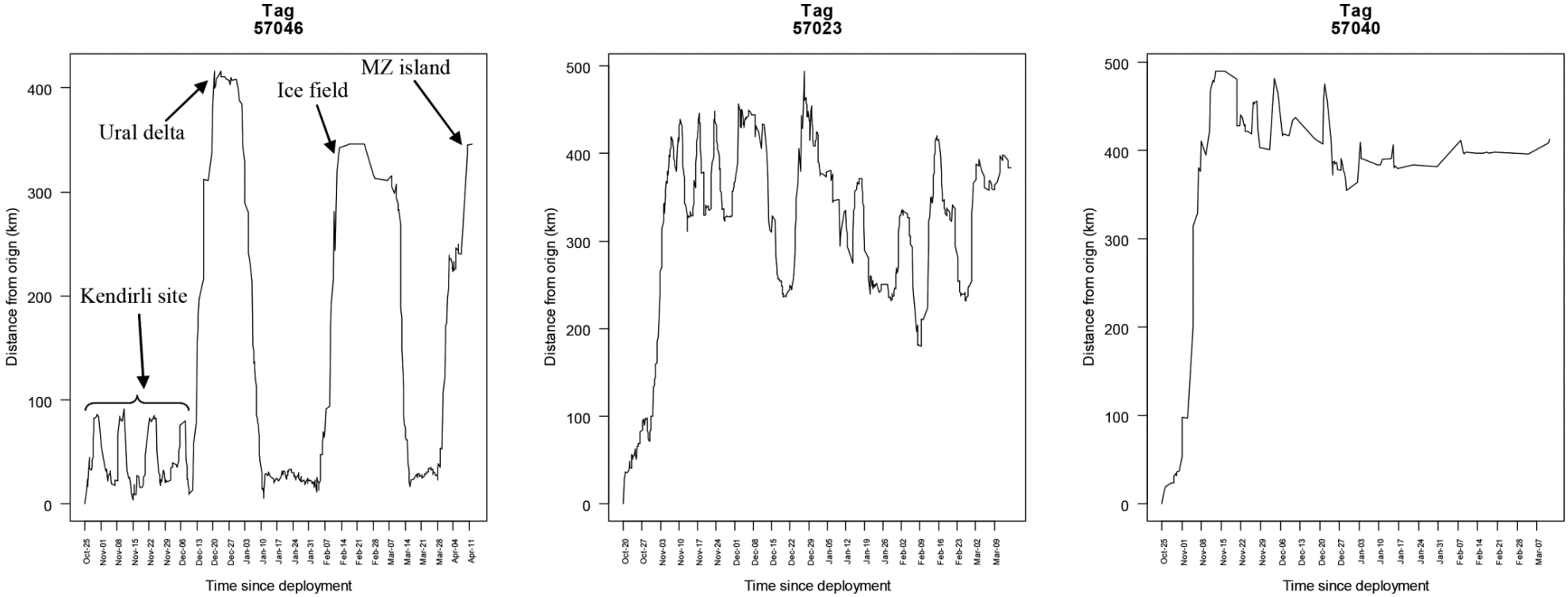


Figure S3. Plots of distance from tagging site versus time over the deployment period for seals 57046, 57023 and 57040. The plots give an indication of the temporal variation of the movement behaviour highlighting periods of consistent movement and more sedentary behaviour.

a) Seal 57046 initially made 4 foraging trips to a location ~90 km northwest of Kendirli, and moved to the Ural delta in mid-December. At the time of extensive ice formation in early January it returned to Kendirli. It made a trip to the ice field in early-February before once again returning to waters close to Kendirli by mid-March. At the end of March it travelled to Malyj Zhemchuzhnyj Island (MZ), where it may have moulted.

b) Seal 57023 showed a consistent movement rate of around 46 km per day over the deployment period. After release it initially moved south from Kenderli into waters around 100-200 m deep before swimming into the shallow north eastern basin where it spent most of November. It appears to have spent most of the ice season shuttling between the ice edge and deeper water southwest of Bautino.

c) Seal 57040 initially moved south before swimming into the shallow north eastern basin at the start of November. During the ice season it was relatively stationary after approximately January 3rd when it appears to have been trapped in area of consolidated ice with no access to open water.

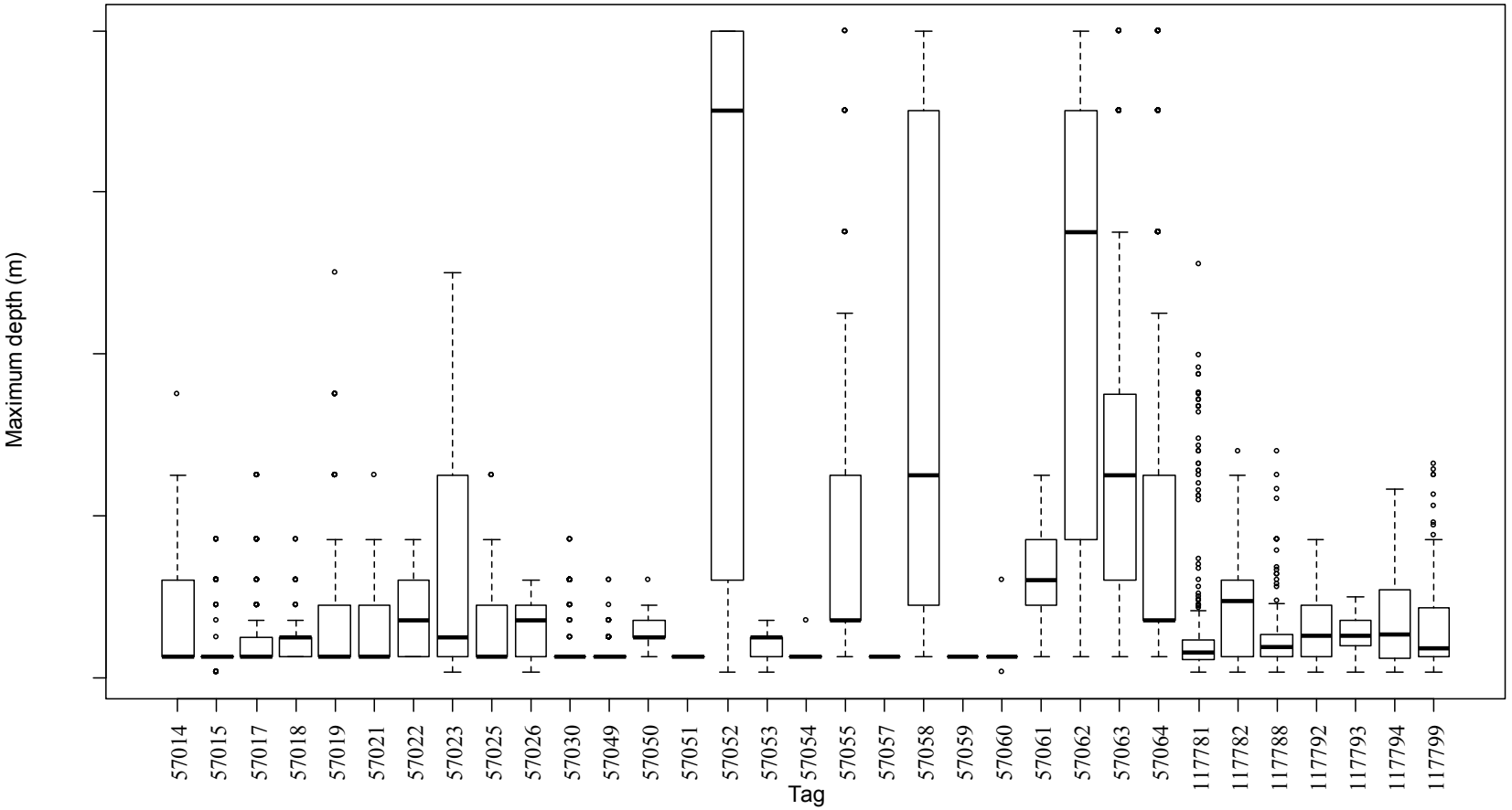
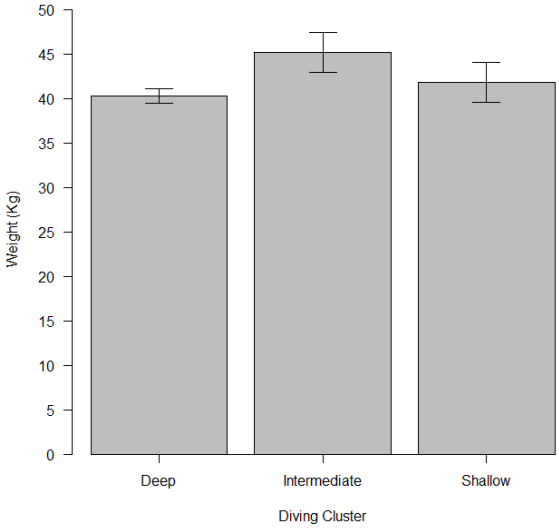
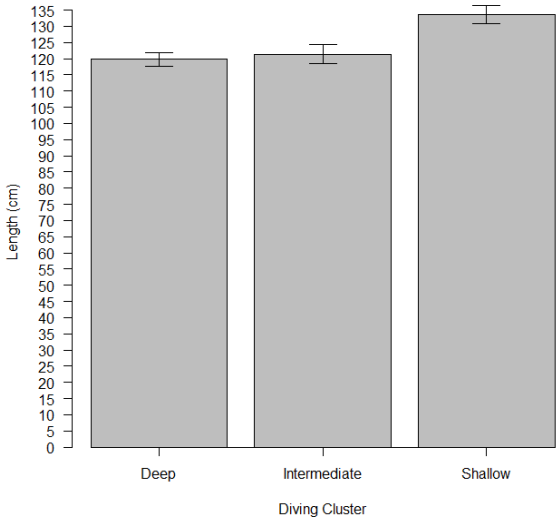


Figure S4. Variation in maximum dive depths recorded per 6 hour window for 33 SPLASH tags deployed 2009-2012. Note in this summary analysis dives of 200m and exceeding 200 m are grouped as the actual max depth is not returned.

a)



b)



c)

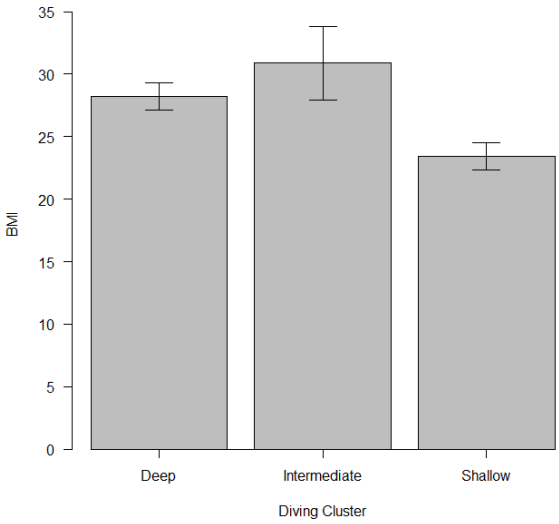


Figure S5. Variation in body size parameters (Weight, Standard body length, and BMI; mean and standard errors) for 15 seals tagged with SPLASH tags in spring 2011, in relation to membership of dive behaviour cluster (Deep, n=7; Intermediate, n=3; Shallow, n=5) identified by Hierarchical Cluster Analysis.

Figure S6.

In order to evaluate the extent to which Caspian seal diving is benthic versus pelagic, we calculated the proportion of dives in 6 hour summary windows where the maximum depth bin corresponded with the maximum bathymetry at the inferred location for the specified period. On this basis the frequency of benthic diving was highest in the north Caspian, with proportions of benthic dives exceeding 90% for the majority of locations (Fig. S6 b). The frequency of benthic diving rarely exceeded 20% in the middle and southern Caspian for deep and intermediate clusters defined by HCA (Fig. S6b). However these dive classifications should be treated cautiously since there was a significant error rate, where the maximum depth bin recorded exceeded the bathymetry at the inferred location (Fig. S6a). This emphasises the large degree of uncertainty arising from data (including both foraging and transit dives) summarised into 6 hour windows, and constrained to 14 depth bins, meaning both dive location and depth are not quantified precisely.

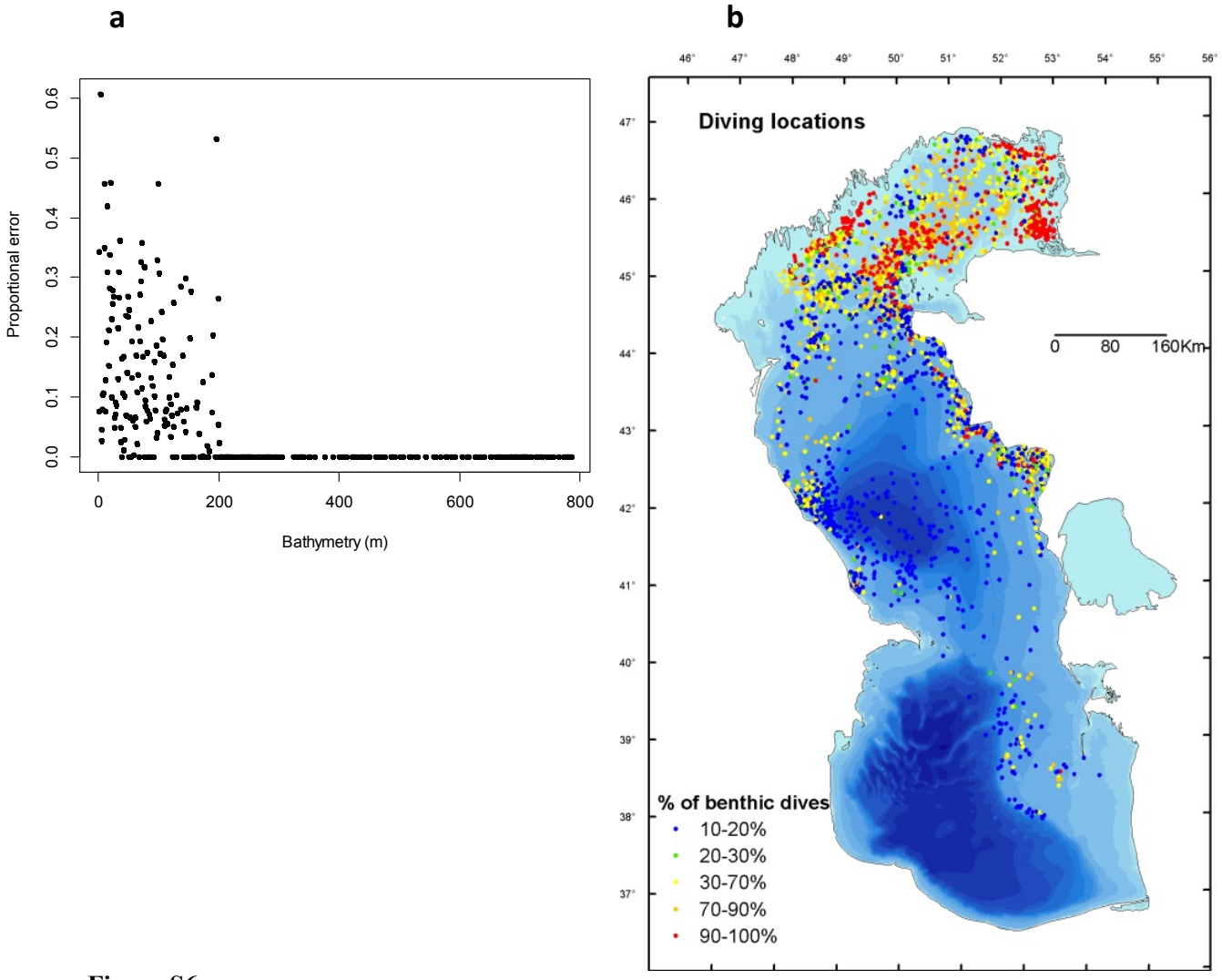


Figure S6.

a) Scatterplot of proportion of errors in relation to the chartered water depth. Y-axis shows mean proportion of dives recorded at depth intervals deeper than charted water depth (X-axis) at the location.

b) Spatial distribution of percentage of assumed "benthic" dives (defined as percentage of dives at the depth intervals matching the charted water depth at location).