

## Invasive red king crabs feed on both spawned-out capelin and their eggs

Nina Mikkelsen, Torstein Pedersen\*

\*Corresponding author: torstein.pedersen@uit.no

Marine Ecology Progress Series 563: 139–155 (2017)

### Additional tables and figures

Table S1. *Paralithodes camtschaticus* and *Mallotus villosus*. Data from trawl hauls for red king crabs in study areas at capelin spawning sites in 2005 and 2006. Trawl data by year, stratum and stations for mean depth (m), trawl area (km<sup>2</sup>), ED: egg density at trawl midpoint [ $\text{Log}_{10}(\text{Eggs m}^{-2} + 1)$ ], DIST: distance from centre of capelin spawning area to trawl midpoint (km), RKC: red king crab catch per trawl haul (n), number of stomachs for analysis (n) and abundance (ind. km<sup>-2</sup>), frequency of occurrence of prey (capelin eggs, capelin) in crab stomachs; (FO%). N\_Eggs: mean number of eggs found in stomachs per station. Total numbers of occurrences of eggs and capelin by year are estimated from the number of individuals pooled by year

Year	Stratum	Trawl st.no.	Depth Mean (m)	Trawl swept area (km <sup>2</sup> )	ED ( $\text{Log}_{10}(\text{Eggs m}^{-2} + 1)$ )	DIST (km)	RKC catch (n)	RKC Analysis (n)	RKC abundance (ind.km <sup>-2</sup> )	Egg (FO%)	Cap (FO%)	N_Eggs (Mean)
2005	1	524	38	0.0065	6.94	0.18	4	2	616	50	100	238.5
	1	525	39	0.0071	2.48	1.14	1	1	141	100	100	973.0
	1	527	48	0.0046	5.29	1.06	0	0	0			
	2	517	123	0.0062	2.18	4.73	2	2	323	0	100	0.0
	2	519	110	0.0085	4.58	4.17	0	0	0			
	2	520	62	0.0079	2.30	3.61	50	13	6299	8	92	0.1
	2	526	74	0.0065	0.00	2.33	44	18	6746	0	56	0.0
	2	529	60	0.0096	0.00	2.46	63	17	6542	18	53	0.5
	2	530	61	0.0076	2.30	4.69	2	2	263	0	100	0.0
	2	428*	109		2.00		16	16		88	100	16.4
	2	491*	152		0.00		1	1		0	100	0.0
	2	492*	122		2.18		19	19		32	100	0.8
	3	516	130	0.0084	3.00	7.42	0	0	0			
	3	531	164	0.0266	2.18	6.54	23	10	866	30	70	14
	3	490*	270		0.00		23	23		0	91	0
	4	518	157	0.0040	0.00	6.24	0	0	0			
	4	522	195.9	0.0102	0.00	7.11	0	0	0			
4	523	166	0.0072	1.04	6.30	1	1	140	0	100	0	

Year	Stratum	Trawl st.no.	Depth Mean (m)	Trawl swept area (km <sup>2</sup> )	ED (Log <sub>10</sub> (Eggs m <sup>-2</sup> +1))	DIST (km)	RKC catch (n)	RKC Analysis (n)	RKC abundance (ind.km <sup>-2</sup> )	Egg (FO%)	Cap (FO%)	N_Eggs (Mean)
2006	5	373	60	0.0030	0.00	0.51	10	10	3293	0	0	0
	5	374	90	0.0049	0.00	0.82	4	4	817	0	25	0
	5	387	78	0.0037	0.00	0.62	2	2	539	0	0	0
	5	388	80	0.0046	0.00	0.77	5	5	1078	0	40	0
	5	389	69	0.0044	0.00	0.74	3	3	675	0	0	0
	5	390	58	0.0040	0.00	0.66	6	6	1505	0	0	0
	5	391	58	0.0045	1.71	0.76	1	1	220	0	0	0
	5	419	64	0.0179	0.00	2.98	4	0	224			
	5	420	60	0.0078	0.00	1.30	12	0	1543			
	6	368	42	0.0080	1.04	1.33	0	0	0			
	6	369	44	0.0039	5.69	0.64	1	1	259	100	0	12
	6	370	46	0.0042	5.69	0.69	3	0	720			
	6	371	48	0.0048	1.04	0.79	2	2	421	100	50	2283
	6	372	68	0.0041	0.00	0.69	5	5	1213	0	40	0
	6	376	62	0.0048	0.00	0.80	4	4	831	0	25	0.000
	7	377	74	0.0104	0.00	1.73	5	5	481	20	0	0.400
	7	378	64	0.0046	2.58	0.76	2	2	437	0	0	0.000
	7	379	71	0.0043	0.00	0.72	0	0	0			
	7	380	60	0.0044	0.00	0.73	0	0	0			
	NS**	375	89	0.0040	0.00	0.67	6	6	1482	0	17	0
	NS**	382	104	0.0051	0.00	0.84	2	2	396	50	50	21.5
	NS**	383	150	0.0056	0.00	0.94	0	0	0			
	NS**	384	200	0.0084	0.00	1.40	0	0	0			
	NS**	385	111	0.0053	0.00	0.88	1	1	189	100	100	1
	NS**	386	104	0.0046	0.00	0.77	1	1	216	0	0	0
2005	All							125		23	82	
2006	All							60		10	22	

\*Shrimp trawl data not used in RKC abundance estimates

\*\*NS are non-strata station outside the stratified study area

Table S2. *Paralithodes camtschaticus*. Number of red king crabs (n) used for stomach analysis and their carapace length (CL) in mm (mean  $\pm$  SD). NS Strata outside stratified area.

Stratum	Measurements	Female	Male	All
S1	n	1	2	3
	CL mm (mean $\pm$ SD)	116	117 $\pm$ 1	117 $\pm$ 1
	CL mm (range)		(116, 118)	(116, 118)
S2	n	39	49	88
	CL mm (mean $\pm$ SD)	115 $\pm$ 15	117 $\pm$ 17	116 $\pm$ 16
	CL mm (range)	(77, 148)	(86, 156)	(77, 156)
S3	n	13	20	33
	CL mm (mean $\pm$ SD)	103 $\pm$ 4	137 $\pm$ 37	123 $\pm$ 33
	CL mm (range)	(96, 108)	(98, 190)	(96, 190)
S4	n	1	0	1
	CL mm (mean $\pm$ SD)	116		116
	CL mm (range)			
S5	n	7	24	31
	CL mm (mean $\pm$ SD)	140 $\pm$ 12	152 $\pm$ 28	149 $\pm$ 25
	CL mm (range)	(128, 162)	(54, 193)	(54, 193)
S6	n	2	10	12
	CL mm (mean $\pm$ SD)	140 $\pm$ 16	158 $\pm$ 12	154 $\pm$ 14
	CL mm (range)	(129, 151)	(141, 179)	(129, 179)
S7	n	1	6	7
	CL mm (mean $\pm$ SD)	136	163 $\pm$ 12	159 $\pm$ 15
	CL mm (range)		(147, 178)	(136, 178)
NS	n	2	8	10
	CL mm (mean $\pm$ SD)	152 $\pm$ 17	153 $\pm$ 16	153 $\pm$ 17
	CL mm (range)	(140, 164)	(135, 178)	(135, 178)
2005	n	54	71	125
	CL mm (mean $\pm$ SD)	112 $\pm$ 23	122 $\pm$ 26	125 $\pm$ 118
	CL mm (range)	(77, 148)	(86, 190)	(77, 190)
2006	n	12	48	60
	CL mm (mean $\pm$ SD)	142 $\pm$ 12	154 $\pm$ 22	152 $\pm$ 21
	CL mm (range)	(128, 164)	(54, 193)	(54, 193)

Table S3. *Paralithodes camtschaticus* and *Mallotus villosus*. Overview of treatment of crabs and egg prey in the stomach evacuation experiment. Design of study by time schedule, collection, storage and transportation of experimental animals. Tanks used at research facilities are described by shape, volume (l), water flow (l min<sup>-1</sup>) and ambient temperature (°C)

Experimental design of stomach evacuation experiment of capelin in red king crab stomachs, carried out in 2011		
<b>Predator: Red king crab</b>	Batch I	Batch II
Numbers	21	15
Catch	March 16	March 23
Transport to Tromsø	March 17, 17 h by car	March 23, 7 h by plane
Storage in Tromsø	March 18 - March 25	March 23 - March 25
Feed	Outdoor seapool with flow through UV filtered ambient sea water in Tromsø	
Transport to Research Station	Capelin eggs and dead capelin	
	March 25, 1 h by car, three crabs died during transport and storage in Tromsø	
<b>Prey: Capelin eggs</b>		
Catch	March 15, caught by purse seine outside Honningsvåg	
Production of egg clumps	March 16, ~200 g eggs, 4 ml sperm, ~ 50-100 ml seawater at 2.7°C. One hour incubation ensuring eggs adhered to each other and formed egg clumps. Placed in 50 l plastic boxes filled with natural sea water at 2.7°C	
Transport to Tromsø	March 17, 17 h by car, no water exchange, temperature rose from 2.7°C to 6°C	
Arrival in Tromsø	March 18. Water was exchanged with UV treated seawater at 2.9°C	
Storage in Tromsø	~ 200 g egg clumps were cut into bar-shaped pieces (~ 10 x 2.5 x 1.5 cm) with wet weight at approximately 15 g	
Transport to Research Station	March 18 - March 25, in 50 l plastic boxes in dark fridge at 2°C with daily UV filtered water exchange	
Arrival at Research Station	March 25, 1 h by car	
	Buffodine disinfection treatment	
<b>Stomach evacuation experiment</b>		
Crab storage tanks	March 26 - April 6, rectangular tanks, volume 1350 l, water flow 15 l min <sup>-1</sup> , temperature 2.9°C	
Egg incubation tanks	March 26 - April 6, circular tanks, volume 40 l, water flow 1.5 l min <sup>-1</sup> , temperature 2.9°C	
Crab experimental tanks	March 26 - April 6, rectangular tanks, volume 300 l, water flow 2 l min <sup>-1</sup> , temperature 2.9°C	

Table S4. *Paralithodes camtschaticus* and *Mallotus villosus*. Data for stomach evacuation rate experiment on red king crab fed with capelin egg meals in 2011. Crabs and egg meals are listed by wet weights. Individual egg weight was calculated for each meal offered. Meal size is also given as both a percentage of crab body weight (BW) and as numbers of eggs. Spilling rate (%) is the percentage of eggs offered but not eaten

Experimental animals and prey	Range	Mean $\pm$ SD
<b>Red king crab (n = 18)</b>		
Weight (g)	837 - 2 416	1 422 $\pm$ 348
<b>Offered clump of capelin eggs</b>		
Individual egg weight (g)	$8.9 \times 10^{-4}$ - $1.8 \times 10^{-3}$	$1.2 \times 10^{-3} \pm 2.19 \times 10^{-4}$
Weight (g)	9.00 - 19.52	13.41 $\pm$ 2.97
Weight (% BW)	0.50 - 1.9	1.00 $\pm$ 0.35
Number of eggs	7 050 - 18 921	11 222 $\pm$ 3 051
<b>Consumed clump of capelin eggs</b>		
Weight (g)	3.86 - 12.28	7.27 $\pm$ 2.94
Weight (%BW)	0.22 - 1.13	0.53 $\pm$ 0.24
Number of eggs	2 492 -10 748	6 061 $\pm$ 2 508
Proportion unconsumed (% of offered)	6.0 -66.7	45.5 $\pm$ 19.6

Table S5. Prediction success table for the logistic regression model for presence of capelin eggs (g(x)). (Response) or absence of capelin eggs (reference) in a total of 185 crab stomachs is given by observed and predicted values.

Observed egg occurrence	Predicted by model	
	Presence	Absence
Presence (response)	10.9 (31%*)	24.1
Absence (reference)	24.1	125.9 (84%**)
Predicted total	35	150

\*) Successfully predicted presence

\*\*\*) Successfully predicted absence

Table S6. *Mallotus villosus* and *Paralithodes camtschaticus*. Parameter estimates and 95% confidence interval for input data used in Monte Carlo estimation of consumption of capelin eggs by red king crabs: mean stomach number of eggs in stomach (W), average stomach evacuation time (A), egg incubation time (T) and number of red king in stratum (P) and by abundance (ind. km<sup>2</sup>)

Stratum	W (n)			A (h)			T (d)			P (n)			P (abundance) (ind. km <sup>-2</sup> )
	( mean ± SD)	Confidence interval		( mean ± SD)	Confidence interval		( mean ± SD)	Confidence interval		Total number ( mean ± SD)	Confidence interval		
		Low	High		Low	High		Low	High		Low	High	
S1	605.2 ± 285.6	0.0	973.0	5.34 ± 0.47	4.4	6.22	40 ± 2	36	44	1 907 ± 1 191	0	4.670	252
S2	2.2 ± 2.2	0.0	7.5	5.36 ± 0.45	4.49	6.22	40 ± 2	36	44	205 657 ± 78 923	72.088	338.207	3389
S3	10.4 ± 9.4	0.0	30.3	5.38 ± 0.47	4.52	6.29	40 ± 2	36	44	6 753 ± 4 745	0	13.139	445
S4	0			5.39 ± 0.46	4.49	6.27	40 ± 2	36	44	2 472 ± 2 000	0	7.408	47
S5	0			5.38 ± 0.45	4.48	6.24	37 ± 2	34	40	7 809 ± 2 049	4.083	11.977	1098
S6	608.2 ± 648.8	0	2048	5.38 ± 0.46	4.5	6.29	37 ± 2	34	40	4 713 ± 1 577	1.680	7.942	590
S7	0.2 ± 0.2	0	0.6	5.39 ± 0.45	4.46	6.3	37 ± 2	34	40	1 847 ± 930	0	3.679	231
2005	9 ± 8.6	0.3	24.6	5.37 ± 0.44	4.57	6.22	40 ± 2	36	44	216 994 ± 78 194	77.769	351.763	1590
2006	171.7 ± 217.1	0	744.9	5.38 ± 0.45	4.48	6.28	37 ± 2	34	40	14 157 ± 2 849	8.888	19.918	613



Fig. S1. *Mallotus villosus*. Plastic boxes (50 l) with letter files made of rigid perforated PVC and fertilized capelin eggs-clumps in natural seawater. Boxes were used for the transportation of eggs to the experimental facilities



Fig. S2. *Paralithodes camtschaticus*. Storage tanks for red king crabs used in the stomach evacuation experiment



Fig. S3. *Mallotus villosus* and *Paralithodes camtschaticus*. Red king crab in an experimental tank feeding on capelin eggs