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Population dynamics of *Maja squinado* in the Ría de A Coruña (Galicia, NW Spain), using mark-recapture experiments

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INTRODUCTION: The spider crab, *Maja squinado*, has a complex life history and population dynamics, being their main feature the planktonic larval phase, ontogenetic changes in habitat use in postlarval phases, small-scale aggregations, large-scale migrations, and a metapopulation structure comprising a chain of local coastal populations connected by larval dispersal and adult migrations (Freire *et al.*, 2002; González-Gurriarán *et al.*, 2002; Sampedro et al. 1999; unpublished data). The objective of the present study is to estimate the main parameters driving dynamics (growth-at-moult, mortality and recapture rates and local population size) in shallow-water local populations of *Maja* using mark-recapture experiments. Connectivity among local shallow-water populations and between these and deep-water mating ground populations is also described.

Figure 1. Experimental traps used in the study.

SAMPLING: Monthly samplings were carried out between December 1997 and November 1999 using experimental traps (Fig. 1). The sampling area was the Ría de A Coruña (NW Spain) (Fig. 2). Three shallow water (5-15 m) sampling stations were selected along the ría. Another station was selected in deeper water (25-30 m) in the central channel of the ría, that constitutes the migration corridor for postpubertal adults. In the inner area of the ría (Bastiagueiro), where the abundance is higher, sampling was performed along a transect in the longitudinal axis of the ría where seven tows were carried out disposing the traps parallel to the coast. Each tow was separated approx. 180 m from each other.

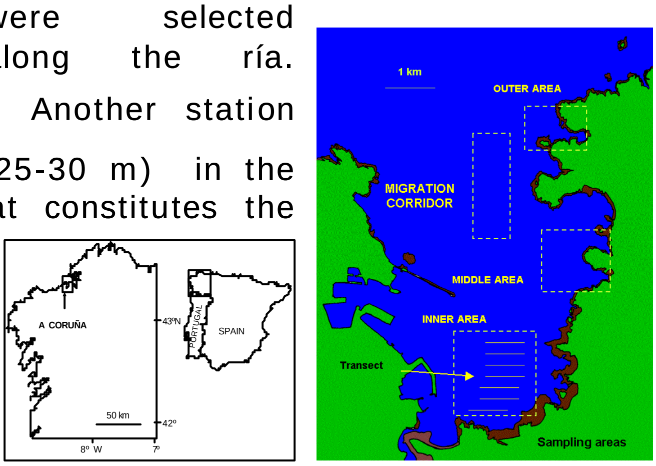

Figure 2. Location and sampling areas in the Ría de A Coruña.

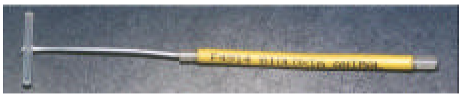

Figure 3. T bar anchor tags used in the experiment.

Mark-recapture experiments: Crabs were captured, marked and released in the same area. T-bar anchor tags FD 89-SL (Fig. 3), from Floy Tag® (Seattle, Washington, USA), with individual codes were used. The tag was inserted in the base line of the fifth leg, between the cephalothorax and the abdomen. Recaptures were obtained during monthly sampling. Additional recapture data coming from commercial fisheries were used only for the analysis of movements among local populations. During the sampling period a total of 12606 crabs were captured. From these, 9093 were marked and 670 recaptured, what shows a recapture rate of 7.4%.

Growth at moult: 38 of the recaptured crabs had grown. Average growth at moult was 32.4% of the preecdysial size, ranging from 22.9 and 45.7% (table 1). No significative differences were found between sexes or type of moult (prepubertal vs. terminal) (ANCOVA, p>0.05 in both cases).

Table 1. Growth at moult of *Maja squinado* in the Ría de A Coruña. Percentage of moult increment (PMI) by sex and type of moult.

		Prepubertal moult			Terminal moult			
		Males	Females	Total	Males	Females	Total	Total
PIM	Mean	32.65	31.95	32.30	32.86	32.27	32.43	32.38
	SD	2.66	5.97	4.43	6.88	3.94	4.70	4.54
	Min	29.88	23.49	23.49	25.95	22.88	22.88	22.88
	Max	37.49	39.42	39.42	45.71	38.99	45.71	45.71
CL min		73.1	76.1		93.7	97.2		
CL max		112.8	94.3		119.5	130.0		
	N	6	6	12	6	17	23	35

Conectivity: Two local juvenile populations were found in shallow waters along the ría. The first one, with higher crab abundance, in the inner part (Bastiagueiro), and the second one in the middle part (Canide). No exchange of crabs was observed between both populations (more than 95% were recaptured in the same area were they were marked).

Some adult crabs marked in shallow areas were recaptured in the central channel (migration corridor). Two thirds of these were coming from the inner part (Bastiagueiro).

Population dynamics: To obtain population dynamics data, the MARK program (White & Burnham, 1999) with the Cormack-Jolly-Seber model (recaptures only), was used. From the recapture history, monthly survival (f) and recapture (p) probabilities were estimated. Sexes were

Table 2. Mark-recapture models for adults in Bastiagueiro

ADULT MALES

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(.)}	576.24	0.00	0.685	1.00	24	62.03
{Phi(.) p(.)}	577.83	1.59	0.309	0.45	2	96.43
{Phi(t) p(t)}	586.03	9.79	0.005	0.01	46	48.51
{Phi(.) p(t)}	588.88	12.64	0.001	0.00	24	62.03

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(.)}	576.24	0.00	0.999	1.00	24	62.03
Seasonal model	590.95	14.71	0.001	0.00	31	49.13

ADULT FEMALES

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(t)}	330.11	0.00	0.998	1.00	46	18.76
{Phi(t) p(.)}	342.73	12.62	0.002	0.00	24	43.77
{Phi(.) p(t)}	357.59	27.48	0.000	0.00	24	44.16
{Phi(.) p(.)}	366.14	36.03	0.000	0.00	2	85.46

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(t)}	330.11	0.00	1.000	1.00	46	18.76
Seasonal model	366.20	36.10	0.000	0.00	18	52.77

analyzed separately in adults due to differences in growth and terminal moult and migration timing. Different models were run (Table 2) and classified under the “Akaike Information Criterion” AIC. In Bastiagueiro, in the case of adults, the best fit was obtained for the model including a variable f and a constant p for males, and variable f and p for females. Both sexes were analyzed together for the juveniles, being the best fit for the model with f and p variable in time, with independence of sex (Table 3).

Table 3. Mark-recapture models for juveniles in Bastiagueiro and Canide.

JUVENILES INNER AREA (Bastiagueiro)

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(t)}	3023.00	0	0.99402	1	46	239.04
{Phi(.) p(t)}	3034.75	11.75	0.00279	0.0028	24	293.26
{Phi(t) p(g*t)}	3035.40	12.391	0.00203	0.002	68	204.59
{Phi(g) p(t)}	3036.60	13.6	0.00111	0.0011	25	293.10
{Phi(g*t) p(t)}	3043.81	20.808	0.00003	0	69	213.01
{Phi(g) p(g*t)}	3044.68	21.678	0.00002	0	48	254.63
{Phi(.) p(g*t)}	3046.74	23.739	0.00001	0	47	258.72
{Phi(g*t) p(g*t)}	3055.17	32.166	0	0	92	183.35
{Phi(t) p(.)}	3081.05	58.047	0	0	24	339.56
{Phi(t) p(g)}	3082.34	59.34	0	0	25	338.84
{Phi(g*t) p(g)}	3098.13	75.128	0	0	48	308.08
{Phi(g*t) p(.)}	3100.91	77.903	0	0	47	312.88
{Phi(g) p(g)}	3245.32	222.32	0	0	4	544.01
{Phi(.) p(.)}	3246.99	223.99	0	0	2	549.69
{Phi(.) p(g)}	3247.65	224.65	0	0	3	548.35
{Phi(g) p(.)}	3248.88	225.88	0	0	3	549.58

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(t)}	3023.00	0.00	1.000	1.000	46	139.25
Seasonal model	3111.72	88.72	0.000	0.000	16	286.55

JUVENILES MIDDLE AREA (Canide)

Model	AICc	? AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(t) p(.)}	418.94	0.00	0.224	1.00	24	47.54
{Phi(.) p(.)}	419.54	0.61	0.165	0.74	2	84.65
{Phi(t) p(g)}	419.79	0.85	0.146	0.65	25	46.34
{Phi(g) p(.)}	419.90	0.96	0.138	0.62	3	83.00
{Phi(t) p(t)}	419.92	0.98	0.137	0.61	46	36.17
{Phi(.) p(g)}	420.05	1.11	0.128	0.57	3	83.16
{Phi(g) p(g)}	421.85	2.91	0.052	0.23	4	82.95
{Phi(t) p(g*t)}	427.20	8.26	0.004	0.02	69	22.66
{Phi(.) p(t)}	427.64	8.70	0.003	0.01	24	48.02
{Phi(g) p(t)}	428.49	9.56	0.002	0.01	25	46.81
{Phi(g*t) p(t)}	430.05	11.11	0.001	0.00	69	17.12
{Phi(g*t) p(.)}	433.27	14.33	0.000	0.00	47	28.73
{Phi(g*t) p(g)}	434.84	15.90	0.000	0.00	48	28.21
{Phi(g*t) p(g*t)}	441.79	22.85	0.000	0.00	92	16.19
{Phi(.) p(g*t)}	461.40	42.46	0.000	0.00	47	33.69
{Phi(g) p(g*t)}	463.52	44.58	0.000	0.00	48	33.69

For the middle-part population (Canide), just juveniles were analyzed due to very low adult captures. In this case, the best fitting model was a f variable and constant p one, with independence of sex.

In every case, except for Canide, monthly models were compared with seasonal ones, but the last show worse fit in every case. Juvenile survival rates in Bastiaguiero are the highest, confirming this area as an adult production (“source”) area, while in Canide, with a high mortality rate, adult production is almost zero (“sink population”) (Fig.4)

Population size: A first approximation to population size was performed using the Petersen method modified by Seber (1982) to reduce bias in small samples: N=[(M+1)(C+1)/(R+1)]-1, where M is the number of crabs marked in month 1, C the total number of captured crabs in month 2, and R number of marked crabs captured in month 2. N estimates population size at the beggining of the experience. This is a valid method for closed populations, so just consecutive months with no migration, no recruitment and no terminal moult were used to estimate population size.

Table 4. Estimated population size (N) and 95% Poisson confidence interval of juveniles (left) and adults (right) of Maja squinado in the Ría de A Coruña. M, number of individuals marked in the first sample; C, total number of individuals captured in the second sample; R, number of marked individuals in the second sample.

	Inner area (Bastiagueiro)			Middle area (Canide)		
Juveniles	Oct 98	Nov 98	Oct 99	Nov 98	Dec 99	Oct 99
M	195	407	359	185	168	174
C	498	354	595	180	127	200
R	7	5	10	5	3	3
N	12,225	24,139	19,504	5,610	5,407	8,793
IC 95% -	6,623	48,767	33,932	11,334	11,898	19,347
IC 95% +	22,824	11,894	11,514	2,764	2,376	3,864

	Males		Females	
Adults	Jul 98	Jul 99	Aug 98	Aug 99
M	137	91	155	54
C	213	155	258	383
R	13	9	6	7
N	2,108	1,434	5,771	2,639
IC 95% -	1,320	807	2,924	1,429
IC 95% +	3,841	2,628	11,182	4,928

Adult males and females were separately analyzed. As seen in table 4, juvenile population size is remarkably larger than adult, and also the inner part larger than the middle one (Canide) that correlates with the higher mortality rates occurring in Canide.

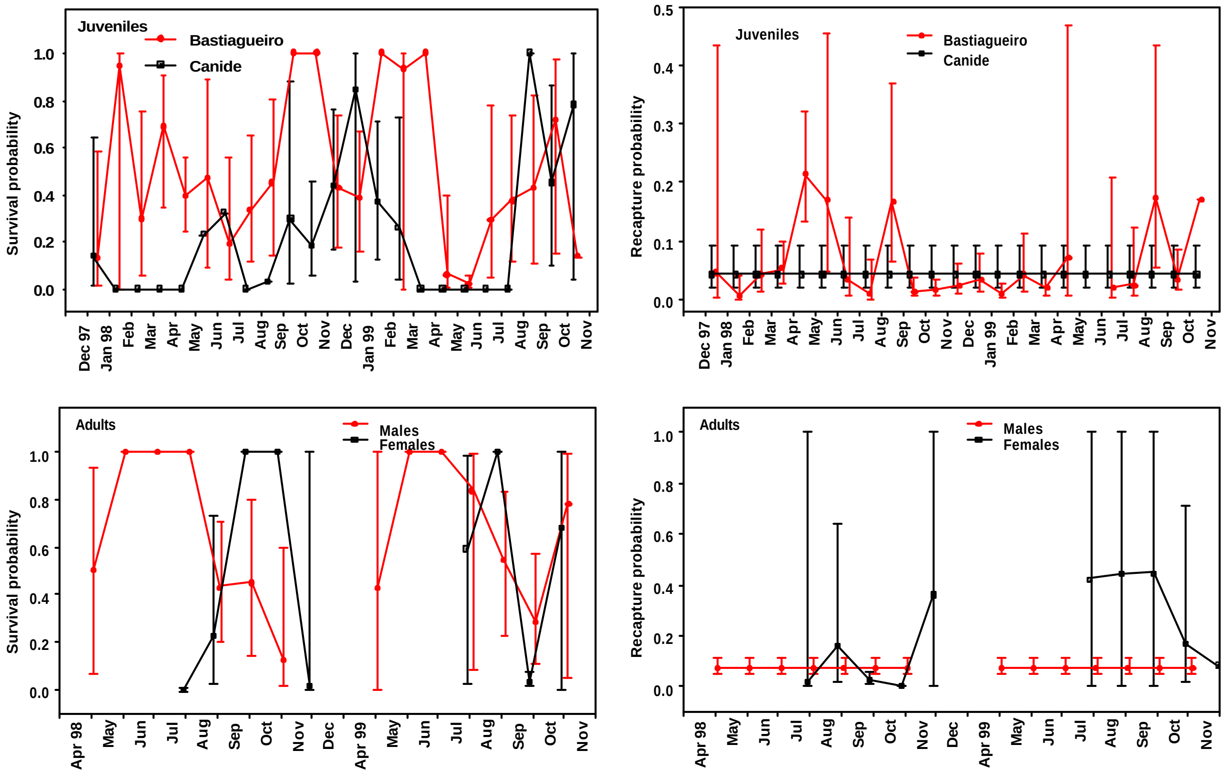

Figure 4. Parameter estimates of survival rate (f) and probability of recapture (p) for the best fitted models of Maja squinado in the Ría de A Coruña.

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