Complex patterns of habitat use by spider crabs *Maja squinado* revealed by stable isotope analyses

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INTRODUCTION: Juveniles of the spider crab *Maja squinado* inhabit shallow waters (up to 10-15m deep) using both rocky and sandy bottoms and carrying out slow, small-scale and non-directional movements. Recent evidences suggest that juveniles settle in very shallow rocky areas where they spend their first year and afterwards disperse to deeper areas (10-20m) where they spend another 1.5 years up to the terminal moult. After maturity, adults migrate to deep waters (>50m) where they mate. The present study will characterize patterns of habitat use by juveniles contrasting two hypotheses about juvenile habitat use: 1) ontogenetic changes, with small juveniles settling and living in rocky areas (<10 m deep) and large (>1 year old) living in deeper (10-20 m) sandy or rocky bottoms (in exposed and sheltered zones respectively), 2) continuous habitat changes switching between rocky and sandy areas during the juvenile phase without any ontogenetic trend.

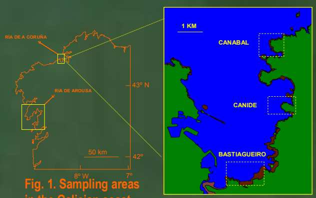

Fig. 1. Sampling areas in the Galician coast

METHODOLOGY: Two geographical areas along the Galician coast (NW Spain) were sampled (Fig. 1). The Ría de A Coruña, an exposed area where large juveniles use mainly soft-bottoms, and the Ría de Arousa, a sheltered zone where the juveniles use mainly rocky bottoms during the complete period. Analyses of stable isotopes of carbon and nitrogen (^{12}C and ^{13}C; ^{14}N and ^{15}N) were used as indicators of the sources of organic matter and diet composition (trophic levels) for crabs from different geographical areas, habitats (rocky and sandy bottoms) or body colour ("red" and "white" crabs, the most abundant colourations in rocky and sandy bottoms respectively). Relative proportions of isotopes were estimated:

$$\delta^{15}N‰ = [(^{15}N/^{14}N)\ sample / (^{15}N/^{14}N)\ standard - 1] \times 1000$$

$$\delta^{13}C‰ = [(^{13}C/^{12}C)\ sample / (^{13}C/^{12}C)\ standard - 1] \times 1000$$

Atmospheric nitrogen and VPDB (Pee Dee Belemnite) were used as standards for the nitrogen and carbon analysis respectively.

δN in the tissues of consumers are enriched approx. 3‰ respect to their prey (Owens, 1987) and allow to estimate the position (trophic level) of an organism in the food web. Values of δC change only slightly with trophic level but are strongly dependent on the origins of the organic matter (different types of primary producers or detritus) (Fry & Sherr, 1984; Peterson *et al*., 1985, Wainwright *et al*., 1993; Fry, 2002), allowing in our case to discriminate plankton based vs. benthic (seaweed or detritus based) food webs.

Isotope analyses were carried out in two tissues for spider crabs: hepatopancreas (with a high metabolic turnover) and muscle, to estimate trophic relationships in the short and medium term (weeks vs. months or years). Complementary isotope analyses were carried out for representative components of coastal food webs (invertebrates, seaweeds, sedimentary organic matter and plankton).

RESULTS:

Geographical variability:

The results indicate the existence of geographical differences in feeding or in biochemical composition of the hepatopancreas, which could modify the tissue's isotopic signature (Fig. 2a and 2b, Table 1). Differences in δN and δC values of juveniles of *Maja squinado* inhabiting rocky habitats of the Ria de Arousa and Ria de A Coruña were significant for hepatopancreas (ANOVA, p<0.005) and non-significant for muscle (ANOVA, p=0.6587 y p=0.3262).

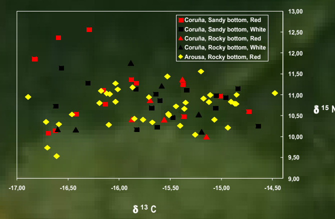

Fig. 2a. Carbon and nitrogen stable isotope ratios (‰) in muscle of *Maja squinado* juveniles.

Ria	Habitat	Colour	MUSCLE					HEPATOPANCREAS				
				δ 15 N		δ 13 C			δ 15 N		δ 13 C	
			N	Mean	S E	Mean	S E	N	Mean	S E	Mean	S E
Coruña	S	W	16	10.84	0.1	-15.57	0.15	16	8.93	0.09	-19.17	0.23
Coruña	S	R	15	11.08	0.19	-16.06	0.18	15	8.63	0.22	-19.25	0.3
Coruña	R	W	6	10.66	0.28	-15.82	0.24	6	9.24	0.16	-19.44	0.4
Coruña	R	R	5	10.61	0.23	-15.53	0.13	5	9.1	0.2	-19.44	0.45
Arousa	S	R	39	10.71	0.07	-15.64	0.1	38	8.72	0.07	-20.3	0.1
All Groups	S	R	81	10.8	0.06	-15.71	0.07	80	8.81	0.06	-19.78	0.11

Table 1. $\delta^{15}N$ and $\delta^{13}C$ in muscle and hepatopancreas of spider crab juveniles from different habitats (sandy, S, and rocky, R, bottoms) and body colour (red, R, and white, W)

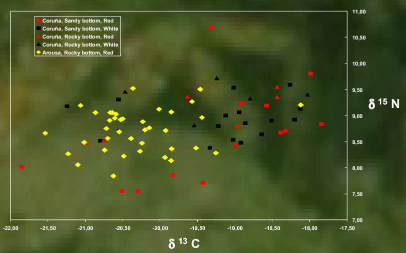

Fig. 2b. Carbon and nitrogen stable isotope ratios (‰) in hepatopancreas of *Maja squinado* juveniles.

Habitat and body colour variability:

Habitat shifts within the Ria de A Coruña are more frequent than suggested by previous studies. There are no significant differences in isotopic ratios for muscle and hepatopancreas between red and white spider crabs nor between individuals from sandy and rocky bottoms (Table 2). However, a high variability for both tissues was shown among individuals from the same habitat and with the same colour (e.g. δN values in muscle ranged between 10.08 and 12.56 for red crabs from sandy bottoms). This suggests the existence of a wide variability in diet composition among crabs, ranging almost one trophic level.

	MUSCLE				HEPATOPANCREAS			
	δ 15 N		δ 13 C		δ 15 N		δ 13 C	
	$F_{(1,38)}$	p	$F_{(1,38)}$	p	$F_{(1,38)}$	p	$F_{(1,38)}$	p
Habitat	2.44	0.1268	0.44	0.5099	3.3	0.077	0.24	0.6267
Colour	0.22	0.6411	0.25	0.6212	0.98	0.3275	0.06	0.8127
Interaction	0.51	0.481	3.39	0.0735	0.13	0.717	0.06	0.8077

Table 2. Results of ANOVAs carried ou to compare isotope ratios in muscle and hepatopancreas among crabs living in different habitats and with different body colours.

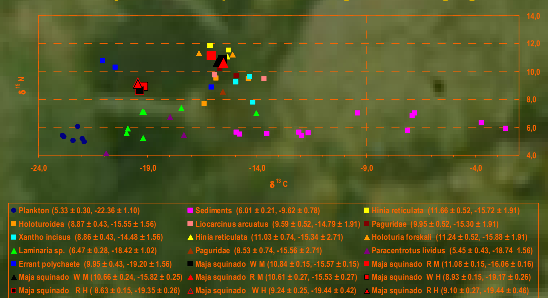

Fig. 3. Food web in the Ria de A Coruña. $\delta^{15}N$ and $\delta^{13}C$ values for samples from rocky and sandy bottoms are indicated by triangles and squares respectively.
For *Maja squinado*: R=red, W=white, M=muscle and H=hepatopancreas

Food webs and diet:

Two separate compartments were found in the coastal benthic food web in the Ria de A Coruña, according to the source of organic matter: a plankton based one, corresponding mostly to the rocky habitat, and one of sedimentary origin, which corresponds to sandy bottoms. Average values for $\delta^{15}N$ (approx. 10.8) of muscle tissue of *Maja squinado* are higher than those corresponding to typical herbivorous invertebrates such as the sea urchin *Paracentrotus lividus* (mean $\delta^{15}N$= 5.45) and similar to values for carnivorous invertebrates, e.g. errant polychaetes (mean $\delta^{15}N$= 9.95) and the gastropod *Hinia reticulata* (mean $\delta^{15}N$= 11.35) (Fig. 3). $\delta^{13}C$ for spider crab juveniles shows an intermediate value between the components of the pelagic and benthic compartments, indicating that juveniles consume preys from both rocky and sandy habitats in almost similar proportions.

Isotopic ratios for C and N in hepatopancreas are lower than in muscle. In the case of C, this could be due to the higher lipid content. The effect of biochemical composition on isotopic values is currently being analysed.

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