Homing behaviour of rock pool blenny *Parablennius parvicornis* (Pisces: Blenniidae)

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The homing ability of the rock pool blenny *Parablennius parvicornis* was studied at a rocky shore on Gran Canaria (Canary Islands, Spain). A total of 140 fish was tagged in five different rock pools and 100 of these were displaced from their original site, during low tide. This blenny species shows great site fidelity and is able to return home from 400 m away. Results show that homing success mainly depends on the displacement distance and it increases when fish return against the current, whereas sex and fish size have no influence.

Keywords: homing behaviour; fish; tidal rock pools; blenny

Introduction

Homing behaviour has been studied in several freshwater and marine fish species (Gibson 1967; Thompson 1983; Quinn and Brodeur 1991; Mitamura et al. 2009; among others). However, it is possible to distinguish two types of homing in fish: (1) seasonal migrations from their feeding habitat to the spawning site, where conditions are optimal for egg and larval development – this occurs in migratory species like tuna, salmon, herring, cod and capelin (Hansen et al. 1993; Dittman and Quinn 1996); or (2) diel short-distance movements between the feeding and residential sites (home range) showing strong fidelity to their habitat (Lindholm et al. 2006; Lowe et al. 2007). In both cases, displacements will have consequences for population processes such as recruitment and mortality (Sale 1978; Helfman 1993).

In the intertidal zone, many species are permanent residents, which means that they complete their entire life cycle there (White and Brown 2013). Knowing the home range of intertidal species is important to implement faunal conservation strategies, particularly on islands where human pressure is high in coastal areas. Homing in intertidal zones is studied in the field with displacement experiments (Griffiths et al. 2003; White and Brown 2013), or in a completely artificial environment (Jorge et al. 2011). Generally, displacement experiments consist of tagging fish, relocating them at distances varying from 1 to several hundred metres and observing their position at low tide to record movement patterns of identifiable individuals (Santos and Almada 1988; Matthews 1990; Montero et al. 2004; Mitamura et al. 2009). Alternatively, mechanisms prevalent in fish orientation can be studied in artificial environments, to highlight the cues relevant to homing (Jorge et al. 2011).

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As have many rocky intertidal fish, several blenny species have been shown to have good homing abilities (Santos et al. 1989; Jorge et al. 2011), and our aim is to determine whether *P. parvicornis* also has this ability. This blenny is an intertidal fish living in rock pools during low tide (Bath 1990). It occurs in subtropical areas along the east African coast, from Senegal to the Democratic Republic of the Congo, including the archipelagos of Azores, Madeira, Canaries and Cape Verde (Zander 1986; Domingues et al. 2008).

Parablennius parvicornis is a relatively long-lived species (Ros et al. 2006). Younger males of 1 year have a body length of approximately 10 cm, while older males can reach 16 cm (Santos et al. 1995). Like many other intertidal blenny species, males spend a lot of time in shelters under rocks guarding their nests during the breeding season (Cody 1993; Almada and Santos 1995). Both sexes have different home ranges and this seems to be connected with morphological differences in brain areas related to orientation (Costa et al. 2011). Their homing abilities could also be modulated by age because of breeding motivation or familiarity with the release site as has been demonstrated in other blennies (Jorge et al. 2011). In this paper we studied the homing abilities of the rock pool blenny according to its sex and length.

Material and methods

The study was carried out on the northeast coast of Gran Canaria Island (Canary Islands; 28°09'30.16" N, 15°26'05.51" W; central east Atlantic), in an area that has been recently proposed as part of a marine reserve. This rocky coast is about 700 m long and is oriented northwest–southeast. It is characterized by a large tidal zone made up of hundreds of rock pools of volcanic origin (Figure 1). The winds on this shore generally come from the northwest, north or northeast. Sea waves generated by these winds determine the current direction along the shore (Pacheco-Martínez 2003). The direction of the shore current was checked using a Davis drifter (20 × 15 cm) several times along the studied period.

Five rock pools (named I, II, IIIa, IIIb, IV) with approximately the same tidal elevation (they oscillated between 1.4 and 10.8 m² in surface, between 0.4 and 0.7 m depth, and between 1.9 and 4.4 m³ in volume), at the end of the middle tidal zone, were studied between 3 February and 2 June, 2010. The distance between pools I and II, and between II and III (a and b) was 100 m; rock pools IIIa and IIIb were separated by only 10 cm, and the distance between pools IIIa and IIIb and pool IV was 200 m. The pools were selected according to the following criteria: (1) sufficient number of fish in the pool; (2) a reduced size that facilitated fish observation and capture; (3) a lack of connection with other rock pools; and (4) a similar distance from the lower level of tide.

During low tide, 20 to 40 rock pool blennies were caught in each of these pools using a hand net (140 fish caught in total), and subsequently marked and displaced at the same time. Forty additional fish were also captured, marked and not displaced in pools IIIa and IV (20 fish each). Specimens were maintained in a bucket during the manipulations. One by one, fish were measured to the nearest millimetre and tagged with a visible implant fluorescent elastomer tag, without the use of anaesthetic because of its added effect on mortality (see Munday and Wilson 1997). This implant is an effective tagging system for identifying small rock pool fish in the field (Griffiths 2002). The retention rate after tagging is high and mortality attributable to tagging is

Figure 1. Geographical location and spatial distribution of pools where individual of *Parablennius parvicornis* were caught (home pools) and displaced.

low (0–7%), even in small fish and crabs (Willis and Babcock 1998; Malone et al. 1999; Griffiths 2002, 2003; Claverie and Smith 2007; NMT 2008). Although blennies are resistant to drying, we attempted to operate as quickly as possible. Four colours (red, green, orange, yellow) were used for fish tagging. Combinations of colours were used in each pool to differentiate their respective fish populations. Then, within a pool, individuals were differentiated by the location of tags (on each body side, near the dorsal fin and/or on the tail). For each individual within a rock pool we assigned a number from 1 to 40.

After tagging, fish were displaced from their home pool to another selected pool, as soon as possible, in the two directions parallel to the coast (northwest/southeast). Displacement distances were 200, 300 and 400 m. The recipient rock pools were chosen keeping in mind only the distance from origin and the absence of bigger fish to reduce potential risk of predation.

The five sampled pools were identified using fixed landmarks on the shore. They were visited randomly, at low tide, each day during the first week and once every 2 weeks during the rest of the experiment (14 visits per rock pool). For a better fish census, observations were made after nightfall, using a UV light (Griffiths 2002). To facilitate the census and because fish try to stay in their refuges (under stones or in crevices), individuals were attracted to the recorder using pieces of bread. Stones and rocks in the pools were not moved during the census to avoid frightening fish and potentially encouraging them to leave the pool.

Among the fish that successfully homed, a random sample of 24 individuals was obtained to determine their sex in the laboratory (nine dominant males, two satellite

males and 13 females) by visual identification of internal reproductive structures, after fish were anaesthetized with metacaine (MS-222) and killed using percussive stunning.

Non-parametric analysis of data obtained was conducted with Statistica12.0 software (StatSoft Inc., Tulsa, OK, USA). Moreover, a logistic regression model was fitted to predict the probability of returning to the home pool taking distance and current direction into account simultaneously. This model was of the form:

$$\text{logit}(p_{SH}) = b_0 + (b_1 + b_2 I_F) \text{ distance} + \xi;$$

where p_{SH} is the probability of a successful homing, I_F is an indicator variable that takes the value 1 if fish homed in favour of the current and 0 otherwise, and distance is the distance between the release and the home pools. The odds of homing are defined as the ratio of the probability of homing over the probability of not returning [$p_{SH}/(1 - p_{SH})$], the logit function being $\text{logit}(p_{SH}) = \log[p_{SH}/(1 - p_{SH})]$. The intercept (b_0) from this model is then the estimated log odds of homing for the whole population of interest. The coefficient b_1 is the effect of distance when a fish homes against current, and b_2 is the additional effect of homing in favour of the current. ξ is the residual term which is supposed to follow a normal distribution.

Results

A total of 140 fish (average length 10.10 ± 1.52 cm) were captured and displaced in four field visits (another 40 fish were captured and not displaced; average length 10.28 ± 1.33 cm). After being displaced, 94 fish (67.1%) were sighted in the home rock pool at least once, and 82 of them (58.6%) were re-sighted more than once in the same pool. Some individuals were also seen resting in other rock pools (35%) next to their original pool. We found, after the first week, that 87.5% of the fish not displaced remained in the same pools (72.5, 67.5, 62.5 and 57.5% after the first, second, third and fourth months, respectively).

The further the fish were displaced the longer they took to return. The return of the first blennies was recorded 48 hours after the fish release (fourth low tide): four fish returned to their pools from 200 m along the surface current and five from 200 m against it after 62 hours fish were recorded that were displaced 300 m to the north-west (they came back in favour of the current), and subsequently (after 103 hours) some were observed that had been displaced 300 m against the current. Finally, the last to return after 134 hours were those displaced 400 m (they came back against the current) (Table 1). The time taken for fish to return was estimated from a daily census and was therefore usually overestimated.

Body length of the successfully homed fish (returned to the home range) varied from 6.5 to 14.5 cm, which represents the complete size range of the fish initially caught (Table 1). The mean length of successfully homed fish was not significantly different from that of non-successfully homed fish (Mann–Whitney U -test: $Z = -1.43$; $P = 0.15$; $N_{\text{not-homed}} = 46$; $N_{\text{homed}} = 94$).

The proportion of fish that successfully homed differed with current direction (Fisher test, $p = 0.024$). In this way, the logistic regression model indicates that the probability of returning home decreases with increased release distance ($b_1 = -0.002$, $p = 0.002$; Figure 2). A significant effect of the surface current on the homing success of fish ($b_2 = -0.001$, $p = 0.04$) was also noticed (Table 2). On average, more than half

Table 1. Proportion of fish that successfully homed from different distances swimming against or with the current.

Current	No. of fish displaced	Distance		Returned fish		Non-returned fish		Time for homing (h)	% Fish homed
		(m)	Length (cm)	n	Length (cm)	n	Length (cm)		
			Mean SD		Mean SD		Mean SD		
Non-displaced	40	0	10.28 1.33						57.5*
Displaced to the northwest (with current)	40	200	10.52 1.38	30	10.53 1.24	10	10.44 1.82	48	75.0
	20	300	8.67 1.63	10	8.86 1.87	10	8.48 1.41	62	50.0
	20	400	9.91 1.55	9	10.01 1.96	11	9.81 1.22	120	45.0
Displaced to the southwest (against current)	20	200	10.56 1.41	18	10.44 1.23	2	11.65 3.04	48	90.0
	20	300	9.74 1.09	13	9.67 1.13	7	9.87 1.10	103	65.0
	20	400	10.81 1.08	14	10.79 1.28	6	10.87 1.07	134	70.0
Total	180		10.11 1.52	94	9.85 1.54	46	9.89 1.63		67.1

Note: *% of resident fish 4 months after tagging.

Figure 2. Logistic model for the probability of returning to the home pool [$Prob(return\ home)$] as a function of distance and current direction. Note that for all distances the probability of returning against the current (A) is higher than when the current is favourable (F).

Table 2. Summary of the logistic regression model estimation.

Coefficients	Estimate	Standard error	Z value	p
b ₀	2.45832	0.69355	3.54	0.00039
b ₁	−0.00713	0.00240	−2.97	0.00293
b ₂	−0.00245	0.00123	1.99	0.04641

(67.1%) of displaced fish were able to home (Table 1), but this percentage increased to 75% when fish returned home against the current (61.2% when returned along the current).

Discussion

Homing has been demonstrated in a variety of small site-attached fish (Griffith 2003; Lowe et al. 2007, among others). This ability seems to be related to the complexity of the habitat where they live, so that fish species with strong affinity for complex substrata, like intertidal pools, have smaller home ranges and exhibit higher site

fidelity than species with lower affinity for complex substrata (Lowe and Bray 2006). In this context, *P. parvicornis* has higher than expected homing abilities (Gibson 1988; Griffiths et al. 2003; Olding-Smee and Braithwaite 2003). This blenny species is able to return home from at least 400 m (we cannot be sure that 400 m is the critical distance from where the rock pool blenny can return because this was the largest distance tried in our experiment).

Despite a high proportion of displaced fish successfully homing to their original pool, they do not spend their whole life in one pool. During the days following their return, many fish were observed resting in other pools close to their original pool. Visiting other pools is probably a way of exploiting food resources, avoiding competitors (in some pools the density of blennies was relatively high) or eluding momentary environmental stress due to variations in tide level (White and Brown 2013).

A lot of studies suggest that homing abilities result from intertidal fish learning the topographic characteristics of their home area (Dodson 1988; Gibson 1988; Olding-Smee and Braithwaite 2003; Braithwaite and Burt de Perera 2006; Burt de Perera and Guilford 2008), or by using a sense of spatial orientation (Jorge et al. 2011). Despite the small home range, some species are able to find their way back from relatively distant and unfamiliar areas (i.e. *Lipophrys pholis*; Jorge et al. 2011).

Parablennius parvicornis has a small home range, particularly among territorial males (Cody 1993; Miranda et al. 2003), due to its relatively small body length (normally about 10 cm) (Santos et al. 1995), its great site fidelity, and because it is an intermittent swimmer. Therefore, it is doubtful that topographic memory is the only mechanism in homing when these blennies are released hundreds of metres from their home pool, as has been suggested for other fish species (Almada et al. 1983; Jorge et al. 2011). Despite the fact that the homing abilities of blennies seem to be independent of current direction, as observed in *Lipophrys pholis* (Jorge et al. 2011), in *P. parvicornis* the homing success increased when fish swam against the current. This could indicate that fish can also use other possible landmarks, such as olfactory cues, to return home, as has been widely documented in other fish species (Harden-Jones 1968; Hasler and Scholz 1983, among many others).

Atema et al. (2002) and Gerlach et al. (2007) described ebb tide plumes of lagoon water that extend many kilometres from reefs, and suggested that such plumes could provide chemosensory cues for dispersal and settlement stages of reef fish as they develop swimming efficiency. In this way, the characteristic odour clues provided by the composition of each pool community, acting much like a fingerprint, could act as long-distance landmarks (*sensu* Braithwaite and Burt de Perera 2006) that the rock pool blenny could use to orient swimming against the current (we are not able to discount the possibility that fish that homed along the current could also occasionally detect these odours because of water recirculation due to periodic tidal currents). This does not exclude the possibility that the rock pool blenny, once into its home range, uses other spatial landmarks or geometric relationships between landmarks to orient itself, as has been observed in rock pool gobies (Aronso 1971).

Homing success varies widely within and between species (Braithwaite and Burt de Perera 2006; White and Brown 2013) although any detailed comparison is hampered by differences in the methods and criteria of success employed by studies. We observed neither an increase in homing success with increased length (or age) of *P. parvicornis*, as reported in other blennies (Jorge et al. 2011), nor any difference between sexes. Furthermore, this failure of sex to impact the homing success is

particularly relevant because it casts doubt on the role of sexually dependent brain dimorphism in determining the spatial cognitive capacity of both sexes. This has been suggested in mammals, birds and other fish species to explain differences in male and female home ranges (Sherry 1998; Park and Bell 2010; Costa et al. 2011). Males of *P. parvicornis* establish and guard nests and almost never leave their nest area during the breeding season (Cody 1993). However, females with a larger dorsolateral telencephalon, which could be involved in spatial abilities (Costa et al. 2011), do not show parental care and move relatively long distances to spawn into nests defended by different males (Cody 1993; Ros et al. 2006).

According to Gibson (1999), the stability of pool topography seems to be an important regulator of residence time of fish. We observed that fish from pools situated in areas frequently visited by swimmers, children, etc. showed the weakest rate of homing (in pools I and II, closer to the bathing area, the proportions of non-returned fish were 50% and 22.5%, respectively). This is probably because of visitors moving the pebble assemblages and causing disturbances in the environment and pool communities (*sensu* Griffiths et al. 2006). Although this does not seem to frighten off the breeding fish (Cody 1993), it probably modifies the characteristics of the pools' odour (even by accidentally adding substances like sunscreen).

Intertidal areas on rocky shores can provide persistent high-quality habitats (Almada and Santos 1995), and rock pool blennies experimentally displaced can find the new habitat less suitable than the former, particularly as a result of competition with resident fish that have the advantage of better knowing the available resources (food and refuge), and by uncertainty about predatory risk in this new site. For intertidal rocky fish, staying in a well-known area may be important in terms of quick access to shelter from predators and strong water movements (Aronso 1971; Almada et al. 1983; Santos et al. 1989; Markel 1994). Therefore, it is important for a fish to have a good knowledge of its rock pool, and its surrounding, to avoid predation. Homing may also be important to avoid becoming stranded in pools whose conditions may become inadequate for survival in a way that is not immediately predictable (White and Brown 2013). For instance, a pool whose physical and chemical conditions are momentarily favourable may become stagnant, too hot, or even dry out. Another benefit of searching for the home pool, is that this vicinity provides sufficient resources. Finally, the occurrence of agonistic behaviour in both sexes could be an important factor of homing (Santos et al. 1989). A fish that accidentally enters a pool where residents occupy shelters may suffer more intense and frequent aggression than if it stays in a stable familiar pool and group.

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