

## NUMBERS AND SIZES OF THE SHRIMP *RHYNCHOCINETES URITAI* KUBO, 1942 (DECAPODA: CARIDEA) CAUGHT IN BAIT AND REFUGE TRAPS

Yumiko Osawa<sup>1</sup>, Masakazu N. Aoki<sup>2</sup>, Raymond T. Bauer<sup>3</sup>, and Martin Thiel<sup>4,5,6,\*</sup>

<sup>1</sup> Shimoda Marine Research Center, University of Tsukuba, Shimoda 415-0025, Japan

<sup>2</sup> Graduate School of Agricultural Science, Tohoku University, Sendai 981-8555, Japan

<sup>3</sup> Department of Biology, University of Louisiana, Lafayette, LA 70504-2451, USA

<sup>4</sup> Facultad Ciencias del Mar, Universidad Católica del Norte, Larrondo 1281, Coquimbo, Chile

<sup>5</sup> Millennium Nucleus Ecology and Sustainable Management of Oceanic Islands (ESMOI), Coquimbo, Chile

<sup>6</sup> Centro de Estudios Avanzados en Zonas Áridas, Coquimbo, Chile

### ABSTRACT

Catch rates and sizes of hingebeak shrimp *Rhynchocinetes uritai* Kubo, 1942 were studied with two types of traps: bait traps that were exposed for 1-2 days and unbaited “refuge traps” exposed for 2-4 weeks. Shrimp were collected twice a month from June 2010 to May 2012 on rocky substrata in Oura Bay, Shimoda, Japan. Overall the numbers of shrimp caught did not differ between the two trap types, but when adjusted for soak times, the bait traps had substantially higher catch rates than the refuge traps. Addition of light to the bait traps had no significant effect on catch rates. However, shrimp in the baited traps were significantly larger than those in the refuge traps. The results show that size distribution can be greatly affected by trap type. Consequently, using two types of traps simultaneously increases not only the catch efficiency but also ensures that all sizes of the reproductively mature shrimp population are sampled in adequate numbers, which is especially important in protandric hermaphrodites.

KEY WORDS: bait traps, catch efficiency, hingebeak shrimp, refuge traps

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### INTRODUCTION

Caridean shrimp can be very abundant and diverse in coastal habitats, including fragile systems like seagrass beds and coral reefs. Shrimp are also important fisheries resources (Orensanz et al., 1998; Wehrtmann et al., 2012) and they can have strong ecological effects on benthic communities (Dumont et al., 2011). Therefore it is important to determine their population structure and estimate their densities. In open habitats, the principal types of equipment used to sample shrimp are otter and beam trawls (Bauer, 2004; Chiba et al., 2013), but these sampling methods are unsuitable on rocky or uneven bottoms (e.g., coral reefs). Suction samplers are occasionally used (Ory et al., 2012), but these are logistically challenging on heterogeneous hard-bottoms and limited to shallow waters, commonly <25 m depth (Wahle et al., 2013). In these environments, traps and collectors can be more efficient, both for fisheries and ecological studies (Ralston, 1986; Gooding et al., 1988; Arrasate-López et al., 2012; Wahle et al., 2013). However, few studies have evaluated trapping methods suitable to describe shrimp populations and communities on coastal hard bottoms.

Traps are being used for a wide range of crustacean species and purposes (Krouse, 1989; Miller, 1990; Calado and Narciso, 2004). Many studies examined the catch efficiency of different trap types (Beninger et al., 1986; Boutil-

ier and Sloan, 1987), soak time (Miller, 1990; Montgomery and Craig, 2003), bait, conspecifics or light (Bishop et al., 1984; Krouse, 1989; Calado and Narciso, 2004; Michel et al., 2010), habitat and season (Inoue et al., 1977; Pihl and Rosenberg, 1982; Tremblay and Smith, 2001), or deployment position (Arrasate-López et al., 2012). For decapod crustaceans, baited traps (for adults) and settlement collectors (for early benthic stages) are most commonly employed (Orensanz et al., 1998; Wahle et al., 2013).

Baited traps usually have large openings, allowing adult decapods to enter, and fish remains or dead mollusks are mostly used as bait (Ralston, 1986; Miller, 1990). Since bait traps attract actively foraging individuals, catches are often biased towards particular sizes or sex (Miller, 1990; Goñi et al., 2003; Bellchambers and De Lestang, 2005). Bait traps usually catch the larger (more desirable) individuals, thereby not being representative for the entire adult population of a species.

In contrast to bait traps, settlement collectors (also known as “refuge traps”) generally only allow access for smaller, juvenile and small adult individuals, which find refuge in regular or irregular spaces in boxes or bags filled with plates, filaments, seaweeds, rocks, mollusk shells or other structures (Beninger et al., 1986; Tapella and Lovrich, 2006; Wahle et al., 2009). These settlement collectors are often used to estimate settlement rates in lobsters (Booth and Tarring, 1986; Wahle et al., 2013) and crabs (Blau and Byersdorfer,

\* Corresponding author; e-mail: thiel@ucn.cl

1994; Tapella and Lovrich, 2006). While these refuge traps are mostly employed for juvenile lobsters or crabs, they are also effective for sampling other decapod species, including caridean shrimp (Blau and Byersdorfer, 1994; Pan et al., 2011).

Based on these considerations, we hypothesize that bait traps and refuge traps will capture different population segments of a species. Growing and reproductively mature individuals (especially females) might have requirements for high energy food, and thus will be attracted to bait traps. In contrast, smaller individuals require suitable shelters (Wahle and Steneck, 1991; Palma et al., 1998) and will thus be more common in refuge traps. For a thorough evaluation of the population dynamics, catching the small individuals of the adult population will be especially important in sequential hermaphrodites. A number of shrimp species are protandric hermaphrodites and the small males are often not efficiently caught with baited traps (Koeller, 2000; Dunham et al., 2005). Employing different types of sampling gear (including refuge traps) might thus ensure that all parts of the adult population can be sampled representatively.

*Rhynchocinetes uritai* Kubo, 1942 (Decapoda: Caridea) is common on shallow subtidal hard bottoms of SE Japan (Maihara, 2002). It is a sequential protandric hermaphrodite, with males changing to females with increasing size and age (Bauer and Thiel, 2011; Osawa et al., 2015). Because *R. uritai* occurs in heterogeneous groups in crevices or under rocks, a combined use of bait and refuge traps might be expected to be efficient in sampling all population segments of these shrimp. In this study, catch efficiency was compared between bait traps and refuge traps. We hypothesized that large, reproductive females would be caught primarily in the bait traps, while small, subadult individuals and possibly males would predominate in the refuge traps.

## MATERIALS AND METHODS

### Study Area

The study was conducted between June 2010 and May 2012 in a subtidal rocky area of Oura Bay near the University of Tsukuba's Shimoda Marine Research Center (SMRC), Shimoda, Japan (34°39'52"N; 138°56'19"E). The study area is characterized by rocks and boulders extending over water depths of 1-6 m, and is delimited by a rocky intertidal shore at the upper edge and by sandy substrata below 7 m. All traps were deployed at water depths of 3-6 m. *Eisenia bicyclis* and *Sargassum ringgoldianum* are the major seaweeds in shallow water (1-3 m depth), and *Ecklonia cava* and *S. giganteifolium* dominate at 3-6 m water depth. Some species of red turf algae, such as *Gelidium elegans* and *Pterocladia tenuis*, are known as the major under-story algae. Most seaweeds in the study area develop during the summer and fall months (Baba, 2011), but some of the larger kelps also show intense growth during the winter months (Haroun et al., 1989). Several fish species (*Gymnothorax kidako*, *Chromis notata*, and several species of wrasses) are commonly observed at the study site, including the predatory fish *Sebastes marmoratus* as well as several species of *Sebastes*. Remains of *R. uritai* were found in the stomach of one individual of *Sebastes marmoratus* (personal observation, YO), suggesting that this species is an important predator of *R. uritai* in the study area.

Temperatures in the study area fluctuate between 14.2° and 24.8°C and salinities usually vary between 34 and 35 psu (Osawa et al., 2015). Yamaguchi et al. (2006) reported an annual average wave height of approx. 1.2 m and a wave period of 6.9 seconds at Irouzaki, at the entrance of Oura Bay. The main storm season in the study area is during the typhoon period, between July and September (Kumagai, 2006).

### Sampling

Hingebeak shrimp, *Rhynchocinetes uritai*, were collected at about biweekly intervals on subtidal rocky substrata at 4-6 m water depth. Two types of traps were used, bait and refuge traps. For bait traps we furthermore examined whether light affects catch efficiency (see below).

Bait traps (Fig. 1A) were modified from extra-large black-color plastic eel traps made by Abe Industries. They were similar in shape and dimension to other cylindrical traps commonly used to capture shrimp (Harrison et al., 1986; Calado and Narciso, 2004). The cylindrical bait traps used herein were 80 cm long and had an internal diameter of 15 cm. Removable caps, shaped as the entrance of a minnow trap, were placed on both sides of the openings. The openings were adjusted to 2.5-3 cm wide entrance holes through which the shrimp entered the traps. Traps were made of plastic with several small holes to allow water flow, were dark in color and impenetrable to light. Three dead sardines were used for bait in each trap. All bait traps were collected after 22-48 hours, because previous studies had shown that capture efficiency of baited traps for decapod crustaceans is highest after soak times of 1-2 days (Miller, 1990; Calado and Narciso, 2004; Montgomery, 2005); in brachyuran crabs saturation of bait traps may even be reached within the first 24 hours (Robertson, 1989; Castro and DeAlteris, 1990).

Cubic refuge traps were 32 cm long, 32 cm wide and 14 cm high, composed of 5 black wavy plastic boards placed on top of each other, leaving approx. 2 cm space between them (Fig. 1B). This type of refuge trap is similar to commonly used settlement collectors, which have several layers of sheets (in this case made from plastic) placed on top of each other to form crevices that are suitable for small invertebrates (see, e.g., Booth and Tarring, 1986; Kiyomoto et al., 2006). Refuge traps were placed above 5 mm mesh bags (100 cm long and 120 cm high) which were left open; at the day of retrieval, the mesh bag was quickly pulled over the trap and closed before bringing the trap up to the boat. Traps were left in the field for 24 hours in February 2011. From March 2011 to May 2012, traps were collected after 11-41 days, because previous studies had shown that soak times of several weeks are most efficient for settlement or refuge traps (Montgomery and Craig, 2003). Soak times of refuge traps (for details see Table S1 in the online edition of this journal, which can be accessed via <http://booksandjournals.brillonline.com/content/journals/1937240x>) varied due to logistical reasons, e.g., weather conditions which interfered with or prevented sampling.

Four bait traps were used during the entire study period from June 2010 until May 2012. Between June 2010 and December 2011, all bait traps were left without lights, but from January 2012 until May 2012 LED lights were added to two of the bait traps to examine whether light might further enhance the catch efficiency of this trap type. Each LED light consisted of three bulbs powered by AAA size batteries. The lights produced approx. 138 lux and maximum continuous lighting time was up to 40 hours on land. Just before the traps were placed in the field, the LED lights were turned on and covered with five clear ziploc bags to keep them dry. Two refuge traps were deployed on each sampling occasion from February 2011 to May 2012 to examine the seasonal differences in capture rate.

All traps were carefully deployed by two SCUBA divers at the sites where shrimp were commonly found. Rocks were placed close to the entrances of bait traps and the surroundings of refuge traps to better integrate the traps in the substratum matrix. Bait traps were collected with two 0.5 mm mesh bags (60 cm × 35 cm) covering both entrances. Refuge traps were retrieved within the 5 mm mesh bags. At each sampling date, on the first day the bait traps were put out and the refuge traps were retrieved. The refuge traps were brought to the laboratory, all shrimp carefully collected and the traps were cleaned. On the next day, the bait traps were retrieved and the refuge traps were put out to be left until the next sampling date, two weeks later.

### Preservation and Measurements of Shrimp

The collected shrimp were placed in a cooler box (88 cm long, 42 cm wide, 44 cm high) with seawater and immediately transported to the laboratory of SMRC. All specimens were preserved with 10% neutralized formalin seawater as soon as possible after the sampling.

Carapace length (CL) was measured from the base of the supraorbital spine to the posteromedial end of the carapace using a digital caliper under the binocular microscope. Specimens <4.0 mm CL were measured using a stereomicroscope with a video micrometer (Olympus VM-60). The sexual condition of each individual was determined based on several sexual characteristics. Males were identified based on the presence of

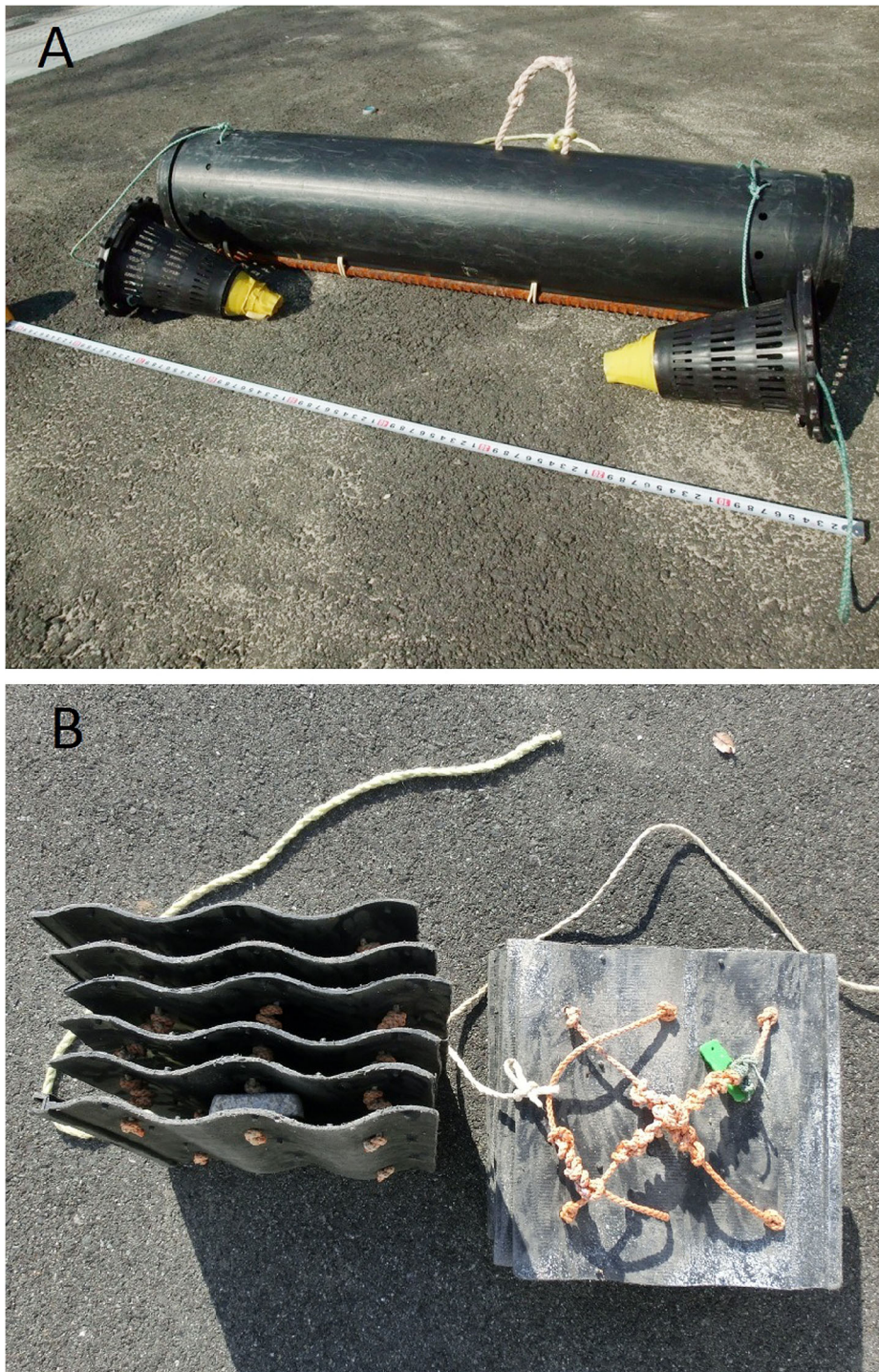


Fig. 1. A, bait trap; B, refuge trap used to capture shrimp *Rhynchocinetes uritai*. This figure is published in colour in the online edition of this journal, which can be accessed via <http://booksandjournals.brillonline.com/content/journals/1937240x>.

prominent lateral lobes on the endopods of the first pleopods and an appendix masculina (AM) next to the appendix interna on the endopods of the second pleopods. Females were recognized by the absence of these male characteristics and the presence of vitellogenic ovaries and breeding dress (BD), i.e., expanded flanges on the basipods of the first to third pleopods, an adaptation for incubating embryos (Bauer, 2004). Individuals that had appendices masculinae and larger flanges were identified as “transitionals” according to the previous study by Bauer and Thiel (2011). Shrimp without external male and female characteristics (prominent lateral lobes on the

endopods of the first pleopods, AM and BD) were considered juveniles. All individuals <4.0 mm CL were classified as juveniles.

#### Comparisons Between Trap Types

To examine for differences in numbers of shrimp caught in the two trap types used herein (bait and refuge traps), the mean number of shrimps/trap was compared for the time period February 2011 to May 2012 when refuge traps and the bait traps without lights were deployed simultaneously. Since the environmental conditions and the seasonal cycle of the shrimp affected



all traps equally at each sampling date, there is dependency between trap types within each sampling date. However, as only few traps were used and deployed over a relatively extensive sampling area, there is no sample dependency between sampling dates, which can be considered independent from each other. Consequently, paired *t*-tests (pairing mean catches of the two trap types for each sampling date) were utilized to test the null hypotheses of no difference in shrimp catches between trap types. Similarly, the mean CL of shrimp in refuge traps and the bait traps without lights were compared with paired *t*-tests. For the time period when two of the bait traps were deployed with LED lights (January to May 2012), we compared whether the mean number of shrimp trap<sup>-1</sup> differed between bait traps with and without light with a paired *t*-test. Sampling dates for which no paired data were available for the respective comparisons (due to loss of traps) were not considered for these analyses.

The numbers of males and females in bait traps without light and refuge traps were counted to compare the sex ratio. Sex ratios were calculated as the number of males divided by the total number of males and females (transitionals were excluded). Values >0.5 indicate that the sex ratio is skewed towards males and <0.5 indicate that it is skewed towards females. For each trap type, a binomial test was used to test whether the male:female ratio differed significantly from a 1:1 sex ratio. The overall sex ratio, the proportion of transitionals, and the proportion of ovigerous females in each trap type (bait traps without light and refuge traps) were compared using Pearson's chi-squared test.

## RESULTS

Individuals of *R. uritai* were found in all traps, and only on one sampling date (9 February 2011) there were no shrimp in the refuge traps (Fig. 2). Other crustaceans (*R. conspiciocellus*, *Heptacarpus futilirostris*, *Thalamita pelsarti*) and benthic animals (*Nassarius sufflatus*, *Ophioplocus* sp., *Anthocidaris crassispina*) were also found in the traps, but *R. uritai* dominated the catches at all sampling dates. The maximum catches of shrimp on particular days (70 shrimp in one bait trap in March 2011, and 66 shrimp in one refuge trap in September 2011) suggest that during most of the study period both trap types were not saturated.

The mean number of shrimp captured (individuals/trap) with the refuge traps was greater (19.6 individuals/trap) than the bait traps without light (13.4 individuals/trap), but differences were not significant (paired *t*-test,  $t = -1.61$ ,  $df = 20$ ,  $P = 0.12$ ) (Fig. 3A). Sex ratios in the catches of the two types of traps were significantly different (Pearson's chi-square test,  $\chi^2 = 107.52$ ,  $df = 1$ ,  $P < 0.01$ ) (Fig. 3B); the mean sex ratio of refuge traps was significantly biased towards males (0.72;  $P < 0.01$ ) while the mean sex ratio of the bait traps without light was significantly biased towards females (0.44;  $P < 0.01$ ) (see also Table 1). The proportion of ovigerous females differed significantly between the two trap types (Pearson's chi-square test,  $\chi^2 = 7.34$ ,  $df = 1$ ,  $P < 0.01$ ). Refuge traps captured more ovigerous females than non-ovigerous females (0.64), while in bait traps without light approximately equal numbers of ovigerous and non-ovigerous females were caught (0.51) (Fig. 3C). Many of the ovigerous females in the refuge traps had oocytes in advanced developmental stages in their ovaries, indicating that they were close to produce a subsequent brood. The proportion of transitionals in the catches of refuge traps was significantly lower (0.08) than in bait traps without light (0.21) (Pearson's chi-square test,  $\chi^2 = 53.2$ ,  $df = 1$ ,  $P < 0.01$ ) (Fig. 3D).

The mean CL of captured shrimp was significantly smaller in the refuge traps compared to the bait traps (paired *t*-test,  $t = 7.52$ ,  $df = 19$ ,  $P < 0.01$ ). Shrimp ranging in size from

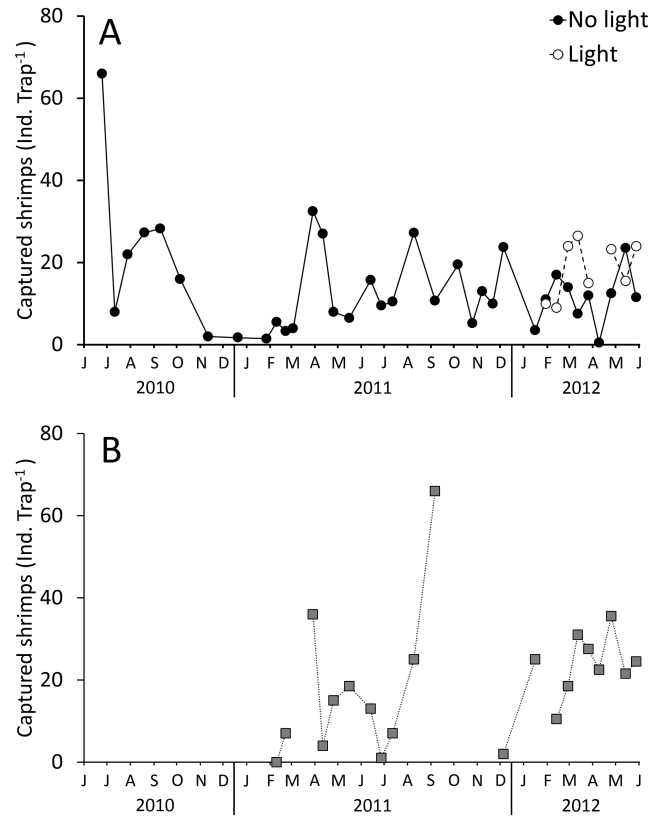


Fig. 2. Average number of shrimp *Rhynchocinetes uritai* captured with (A) bait traps, and (B) refuge traps during the entire study period (June 2010-May 2012). Soak times differed between bait traps (1-2 days) and refuge traps (11-41 days); for details see Table S1 in the online edition of this journal, which can be accessed via <http://booksandjournals.brillonline.com/content/journals/1937240x>.

1-7 mm CL were more common in the refuge traps, while large shrimp from 7-13 mm CL were proportionally more abundant in the bait traps (Fig. 4).

During the time period when the effect of lights was tested with the bait traps (January to May 2012), the highest catch without light was 29 shrimp in one trap in February and 55 shrimp in another trap with light in April (Fig. 5). In general, the bait traps with light attracted more shrimp (21.3 individuals/trap) than bait traps without light (13.6 individuals/trap), but due to the high variability in catches between individual traps, these differences were not statistically significant (paired *t*-test,  $t = 1.52$ ,  $df = 7$ ,  $P = 0.17$ ).

## DISCUSSION

The numbers of shrimp *R. uritai* caught by the two trap types did not differ but it is important to keep in mind that soak times of the traps differed substantially. Bait traps were exposed for 1-2 days while refuge traps were left in the field for >10 days (up to 41 days during the winter 2011/12). Consequently, per unit time the bait traps without light caught more shrimp (13.1 individuals/trap per day) than refuge traps (1.4 individuals/trap per day). Herein we did not test for the optimum soak times, which were assumed: (1) to be short (1-2 days) for bait traps accounting for decay and/or consumption of bait, and (2) comparatively long

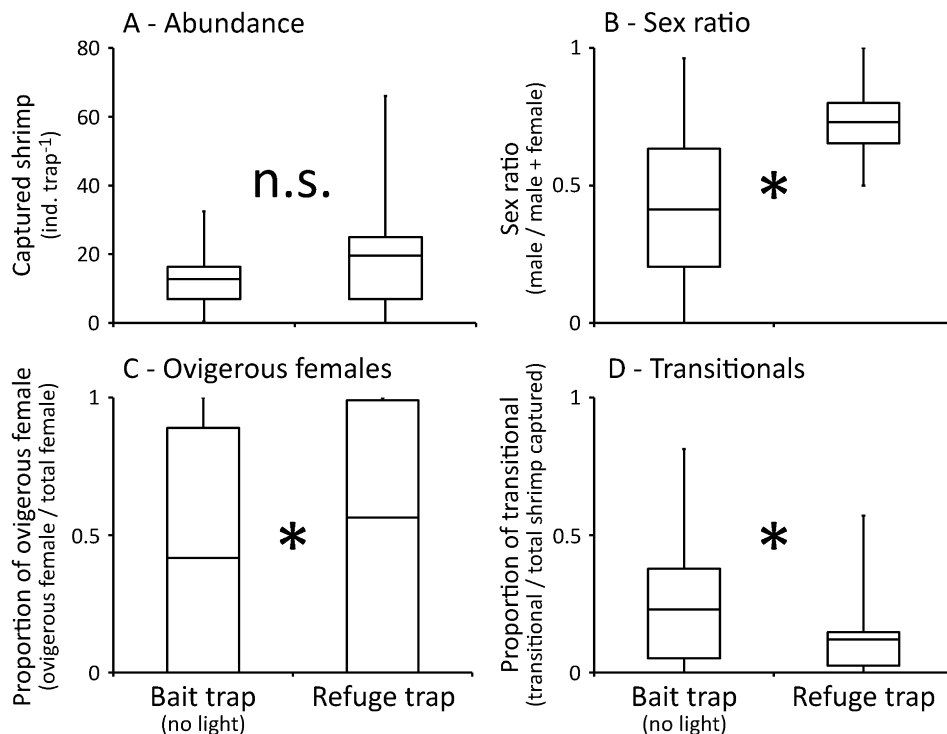


Fig. 3. *Rhynchocinetes uritai* captured in the two types of traps (refuge traps and bait traps without lights) between February 2011 and May 2012. A, mean number of shrimp; B, sex ratio; C, proportion of ovigerous females; D, proportion of transitionals. Boxes show the 75%, mean, and 25% interval and upper and lower whiskers show the range of the sex ratio; \*  $P < 0.05$ ; n.s., not significant.

(>10 days) for refuge traps in order to permit incorporation of the traps into the natural benthos matrix. Bait traps caught larger individuals (transitionals and females) than the refuge traps, which underscores the different function that both trap types provide for shrimp, high energy food in bait traps, and shelter in the case of refuge traps.

Nickell and Moore (1992) found that benthic animals were strongly attracted to bait, with their movements being significantly different from random. In this study, bait traps soaked for 1-2 days captured large numbers of shrimp, showing that these traps were attractive for shrimp. Catch rates for *R. uritai* were in the same range as those for shrimp in other studies with similar-sized bait traps (Calado and Narciso, 2004). Somers and Stechey (1986) reported that four types of bait attracted similar numbers of crayfish but meat was more effective for larger individuals. Bait is generally perceived via chemical cues, and the spatial range of attraction depends on local current regimes and the type and amounts of bait being used (Krouse, 1989; Miller, 1990). These factors are likely to play a role in the capture of *R. uritai*, and future studies should examine the efficiency of

different types of bait and also the distances over which shrimp are attracted to the traps.

Attraction toward light has been reported for a variety of marine vertebrates and many invertebrates (Holmes and O'Connor, 1988; Øresland, 2007; Michel et al., 2010). Light traps are commonly used for planktonic larval stages (Doherty, 1987; Øresland, 2007) or for epibenthic organisms (Muntz, 1994), but they have rarely been used to capture benthic crustaceans. Indeed, many benthic crustaceans are nocturnal and avoid light (Smith et al., 1998; De Grave et al., 2006). On the other hand, bioluminescence of carrion (mediated by bacteria) might attract scavengers (Muntz, 1994). This could be responsible for the large numbers of *R. uritai* in some bait traps with light, even though numbers were not significantly different from the bait traps without light. A recent study by Hannah et al. (2015) also showed no attraction of *Pandalus jordani* Rathbun, 1902 to lights on (unbaited) fishing lines. Additional studies are needed to examine whether light affects how crustaceans are attracted to bait.

Large females and transitionals of *R. uritai* were significantly more common in bait traps than in the refuge traps.

Table 1. Proportions of the different life history stages of *Rhynchocinetes uritai* in the different trap types from January to May 2012.

	Juveniles	Males	Transitionals	Females	Total
Refuge traps (%)	1.4	66.5	6.9	25.2	433
Bait traps (no light) (%)	0	28.2	18.8	53.0	234
Bait traps (with light) (%)	0.3	36.7	12.9	50.1	341

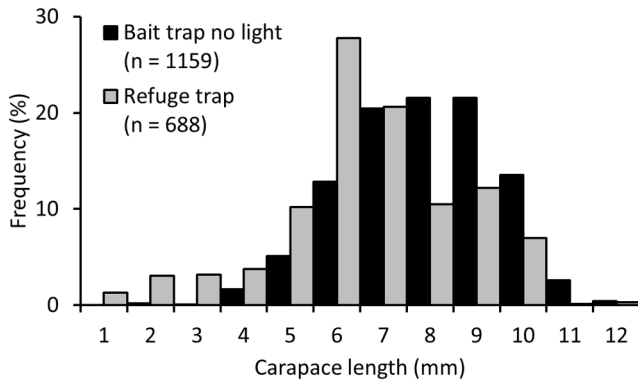


Fig. 4. Size frequency distribution of *Rhynchocinetes uritai* captured in bait traps without lights (black bars) and refuge traps (gray bars) between February 2011 and May 2012.

The unequal vulnerability of individual shrimp to trap capture is often explained by behavioral differences between the sexes (Krouse, 1989; Dunham et al., 2005). For example, Bellchambers and De Lestang (2005) found that swimming crabs *Portunus pelagicus* (Linnaeus, 1758) captured with bait traps had a narrow size range, and the catch was heavily biased toward large males, similar to that observed in many other crabs and lobsters (Miller, 1990). The tendency of bait traps to catch more males than females in those studies might be related to the greater activity of males, and to the lower appetite of incubating females (Miller, 1990). In *R. uritai*, the males were also expected to be more active than females, because their mating system is thought to be pure searching where small agile males actively search for females (Bauer and Thiel, 2011). However, our results showed that males were less attracted to bait traps than females and transitionals, which were highly attracted toward such traps. The high proportion of transitionals might be explained by energetic requirements due to organ transformation and intense growth. The high proportions of females in bait traps, also reported for other shrimp species (Dunham

et al., 2005; Tuset et al., 2009), could be due to various reasons. Goñi et al. (2003) mentioned that *A. MacDiarmid* (personal communication) observed dramatic increases in feeding activity and trap catchability of female *Jasus edwardsii* (Hutton, 1875) after larval release. Females of the clown shrimp *Hymenocera picta* Dana, 1852 are slightly larger than males and it has been suggested that they need more food for the production of eggs (Seibt and Wickler, 1979). Similarly in *R. uritai*, the females are larger than males and since eggs require more energy than sperm, females may be more strongly attracted to bait than males. Large females in the protandric hermaphrodite *Pandalus hypsinotus* Brandt, 1851 might even actively chase the smaller males out of the traps, thereby causing the observed female-biased sex ratio, as discussed by Dunham et al. (2005). Yamane and Fujiishi (1992) showed the number of individuals that escape was affected by the diameter of the opening of prawn pots (see also Gooding et al., 1988). It could also be that fewer males were captured by bait traps because the smaller (and presumably more active) males might readily escape through the relatively wide trap entrance holes.

While overall there were fewer females in refuge traps than in bait traps, the proportion of ovigerous females was higher in the refuge traps. The avoidance of bait traps by ovigerous females has also been reported for other crustaceans (Howard, 1982). The reasons for this are unknown at present, but it might be possible that ovigerous females about to release their larvae (and molt shortly thereafter, see Bauer and Thiel, 2011) avoid actively foraging conspecifics that aggregate in the bait traps. Furthermore, many of the ovigerous females in the refuge traps had ovaries in advanced developmental stages, suggesting that they might actively seek out the aggregations of males in the refuge traps, similar as proposed for female *R. typus* approaching sites with preferred dominant males (Díaz and Thiel, 2004).

Refuge traps caught primarily small shrimp, as was expected. The proportion of shrimp <5 mm CL was relatively high in the refuge traps despite the fact that the mesh bags used to retrieve the refuge traps had mesh openings of 5 mm. While some small shrimp might have escaped through the mesh bags during sampling, a substantial number remained in the traps. The distance between the boards of refuge traps is also likely to affect the catch rate and in particular the size spectrum of the shrimp. The importance of the relationship between shelter size and the size of crustaceans able to find protection in these substrata has been documented by numerous studies (Wahle, 1992, 2003). Future studies should identify the relationship between shelter size in the refuge traps and the size and stage of captured shrimp.

No clear seasonality was observed in the catch efficiency of the refuge traps used herein. In other studies from similar latitudes, settlement collectors comparable to our refuge traps had higher catch efficiencies during specific seasons related to the main settlement period (Booth and Tarring, 1986; Pan et al., 2011). Strong temporal variation in catches of shrimp with traps can also be enhanced by seasonal migrations between habitats (Pihl and Rosenberg, 1982). The lack of a clear seasonal peak in the refuge traps could be due to the fact that: (1) settlement of *R. uritai* is continuous, (2) traps were soaked for relatively long time periods (11-

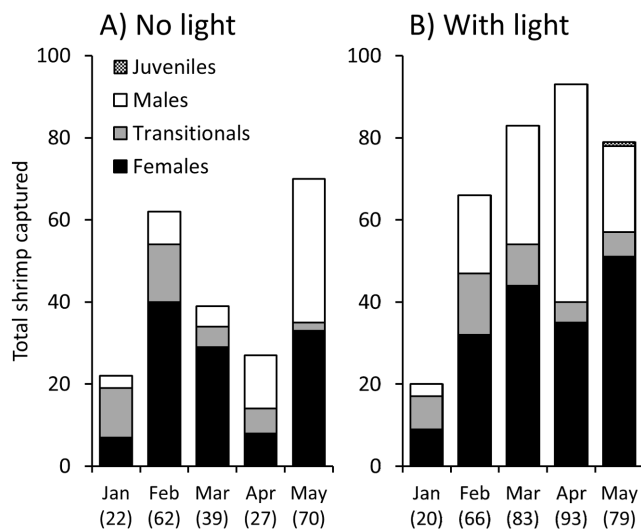


Fig. 5. Total number of captured individuals with bait trap without light (A) and bait trap with light (B) from January to May 2012. The number in parentheses below the months shows the total number of captured individuals in each month.

41 days), or (3) not only settlers, but also a wide size spectrum from the benthic population was caught in the refuge traps. Initial settlers may also molt and grow while living in the refuge traps, similar as observed for crabs captured in settlement collectors (Beninger et al., 1986). In laboratory rearing experiments of *R. uritai*, the intermolt interval was 12-14 days for adult females (Bauer and Thiel, 2011), and since the soak interval was longer than that, juvenile individuals are indeed likely to grow in the refuge traps. Other organisms growing and material accumulating in collectors provide food for juvenile decapods during their first phase of benthic life (Blau and Byersdorfer, 1994; Tapella and Lovrich, 2006). Consequently refuge traps with moderate overgrowth might be most efficient because they would allow small crustaceans to find food in shelter without the need to forage outside of the traps (Wahle, 1992). Conditioning these refuge traps might further enhance their catch efficiency as also seen for lobsters (Mills and Crear, 2004).

In this study, immatures, adult males, transitionals and adult females of *R. uritai* were captured with the combination of bait and refuge traps, which allowed determining the life history of this species (Osawa et al., 2015). The refuge traps mainly captured the smaller males, while the bait traps captured the transitional individuals and females, confirming that the combination of refuge and bait traps is a good strategy for obtaining representative samples of the reproductively mature population. Based on these results, we recommend that other studies on the population structure of benthic crustaceans from hard bottom substrata should also utilize a combination of different trap types, thereby ensuring that all segments of the population will be sampled representatively.

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Table S1. Soak times (days in water) and retrieval day for bait traps and refuge traps between June 2010 and May 2012.

Retrieval day	Bait trap, no light	Bait trap with light	Refuge trap
24-06-2010	1		
11-07-2010	1		
28-07-2010	1		
19-08-2010	1		
09-09-2010	1		
05-10-2010	1		
11-11-2010	1		
19-12-2010	1		
20-12-2010	1		
27-01-2011	1		
09-02-2011	1		1
21-02-2011	2		1
03-03-2011	1		
29-03-2011	1		25
11-04-2011	1		11
25-04-2011	1		13
16-05-2011	1		20
13-06-2011	1		22
27-06-2011	1		13
12-07-2011	1		14
09-08-2011	1		28
06-09-2011	1		26
06-10-2011	1		
25-10-2011	1		
07-11-2011	1		
21-11-2011	1		
05-12-2011	1		13
16-01-2012	1		41
30-01-2012	1	1	
13-02-2012	1	1	13
28-02-2012	1	1	15
12-03-2012	1	1	12
26-03-2012	1	1	13
09-04-2012	1		13
25-04-2012	2	2	15
14-05-2012	1	1	17
28-05-2012	1	1	13