Journal of

Fisheries and Aquatic Science

ISSN 1816-4927

Academic Journals Inc.

www.academicjournals.com

Journal of Fisheries and Aquatic Science 5 (5): 377-385, 2010
ISSN 1816-4927

Live Crab Decoys as Luring Method for the Pot Fishery of the Invasive Crab *Charybdis japonica*

M. Vazquez Archdale, I. Hattori and D. Takashima
Fishing Technology Laboratory, Faculty of Fisheries,
Kagoshima University, Shimoarata 4-50-20, Kagoshima 890-0056, Japan

Abstract: The effectiveness of using live crab decoys for capturing the invasive shore swimming crab *Charybdis japonica* was tested during fishing trials. Live male or female crab decoys were placed in pots and their performances were compared to those of fish bait and no bait. Pots were set in a pond from 22 July to 27 August 2002. They were divided into 4 treatments: fish bait, male decoy crab, female decoy crab and no bait. They were subjected to two different soaking times: 1 or 4 days. Catches were recorded according to treatment, species and size. When the soaking time was 1 day fish bait was most effective at luring crabs into pots (0.33 crabs pot^{-1}), while when the soaking time was 4 days female decoys were most effective (0.50 crabs pot^{-1}). Non-target catch was affected by treatment and was highest in fish baited pots, consisting mainly of snails, moray eels and rockfish; but octopus was common in pots containing crab decoys. A modified pot with a protective chamber containing a female decoy was tested during fishing trials in a commercial fishing ground together with fish baited and non-baited pots from 10-14 July 2006. The chamber prevented both decoy escape and octopus predation. Decoy containing pots caught 0.31 crabs pot^{-1} versus 0.25 in fish baited pots and the non-target catch was greatly reduced to 1.23 organisms pot^{-1} compared to 4.95 in baited pots. We conclude that female decoy crabs might be used to attract *C. japonica* conspecifics into pots and might be applied to remove crabs more selectively than using conventional fish bait.

Key words: Crab decoy, pot, eradication, invasive crab, *Charybdis japonica*

INTRODUCTION

Live lures or decoys have been employed successfully only in a few crustacean fisheries, such as that of the spiny lobster *Panulirus argus* in Florida and that of the blue crab *Callinectes sapidus* in the Southern United States. The former employs traps baited with sublegal-sized live lobsters that attract conspecifics, the catch rates reported are three times higher than for any other bait (Heatwole *et al*., 1988). The reason for this effectiveness is not known, but the same researchers propose that decoys emit an aggregative pheromone or an acoustic cue for aggregation that attracts other lobsters in the area. Several studies have reported the presence of sex pheromones carried in crab and lobster urine and the importance of courtship signaling and display prior to mating (Shabani *et al*., 2009; Kamio *et al*., 2008; Hardege *et al*., 2002). Blue crab traps are baited with live mature male crabs to attract premolt

Corresponding Author: Miguel Vazquez Archdale, Fishing Technology Laboratory, Faculty of Fisheries, Kagoshima University, Shimoarata 4-50-20, Kagoshima 890-0056, Japan Tel/Fax: 81-99-286-4272

females. Fishers claimed that females enter the traps looking for the protection they need during molting and a mating partner and thus be caught during the mating season, when the crabs do not feed and are not attracted to baited traps (Van Engel, 1958).

The present study was carried out to test if it is possible to attract the invasive shore swimming crab *Charybdis japonica* into pots using live conspecific decoys and it was conducted as part of a broader study that applies fishing technology to develop better eradication gear and methods for invasive crustaceans (Vazquez Archdale *et al*., 2006a, b, 2007, 2008; Ahmadi *et al*., 2008; Ahmadi and Vazquez Archdale, 2008). This crab was chosen because it supports a small fishery in Japan, Korea, China and Taiwan and because recently it has been introduced as an invasive alien species in New Zealand and research on eradication methods is urgently needed (Smith *et al*., 2003). The advantages of using live decoys are many. They eliminate the need of using fresh or frozen fish bait and minimize the waste of fisheries resources, they can be easily replaced, do not decompose under high water temperatures and most importantly, they are species specific and eliminate non-target catch to a great extent.

There are few studies on the reproductive biology of *C. japonica*. In China it has been reported that they become sexually active after their first year and that their reproductive season occurs twice a year, from April to May and from August to September (Wang *et al*., 1996). In Korea, it has been found that they reach sexual maturity in one year, that the average carapace width sizes at which 50% of the males and females reach sexual maturity are 62.0 and 38.7 mm and that the spawning season lasts from June to August.*Charybdis japonica* probably follows the same pattern of courtship and mating reported for other swimming crabs in which the male crab captures a premolt female and carries her around for several days until she molts (Dunham, 1978). Copulation is briefly restricted to the period after this molt and the male carries the female for a few more days until her exoskeleton hardens and is released or escapes.

Sex pheromones have been documented in several crustaceans, such as the crabs *Carcinus maenas* and *Macropipus holstatus* and the urine from premolt or recently molted female crabs induced searching activity in their male conspecifics (Eales, 1974; Hardege *et al.,* 2002). The same was observed in females of *C. sapidus*, whose urine triggered the male's courtship behavior. It was also determined that males detect such pheromone through their antennules (Gleeson, 1980). This evidence supports the attractiveness of decoys as luring agents for pots.

Theoretically, the ideal decoy should only attract members of the same species, reducing the amount of non-target catch by attracting fewer species into the pots. One study with lobster decoys reported lower rates of by-catch, such as crabs, sea urchins and trunkfish, because they could be avoided by not using attractive edible baits (Heatwole *et al*., 1988). We also expect that a similar reduction in by-catch will result in our study.

This study presents a novel study for using live decoys to attract the invasive *C. japonica* and is the first attempt to find if they can be used as an alternative fishing method. The purpose of this study was to compare the effectiveness of live decoys of the crab *C. japonica* with that of ordinary fish bait during field trials. This was done in the hope of developing a better luring method that does not waste fisheries resources in the form of bait and reduces by-catch of non-target organisms.

MATERIALS AND METHODS

The fishing trials were conducted in a 70 m by 1000 m pond located in Kagoshima City, Japan (Vazquez Archdale and Kuwahara, 2005), which is connected through concrete pipes

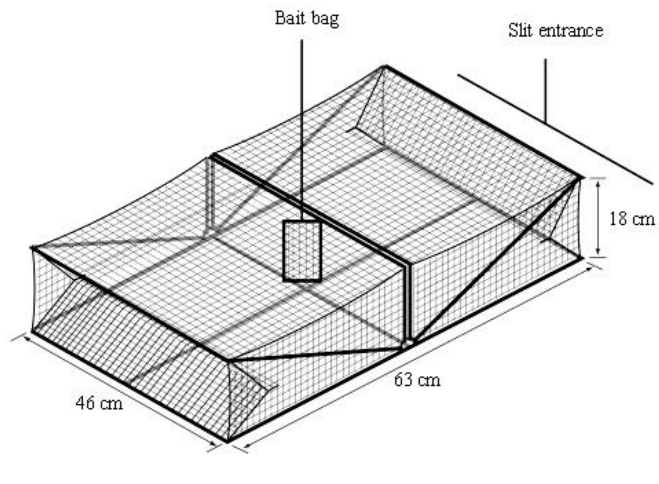

Fig. 1: Shape and dimensions of box-shaped crab pot used during the different luring treatments. Bait bag and slit entrances are indicated

to Kagoshima Bay and permits the entry of the local marine organisms. Trials took place in the summer, from 22 July to 27 August 2002. The pond's depth fluctuated from 2.5 to 4.5 m depending on the tide. *C. japonica* was the predominant crab species found in the pond. Surface water temperature ranged from 26.7 to 31.0°C.

Twelve collapsible box-shaped pots (Kagotoku Shiroyama Kenmousha, Ise, Japan; iron rod frame 46×63×18 cm and black polyethylene netting, 2.3 cm mesh size) with narrow slit entrances on both ends were employed (Fig. 1). The local fishers use these pots to capture octopus and various crab species. Four treatments were assigned to test the effectiveness of the decoys to standard bait, which consisted of one Japanese mackerel *Trachurus japonicus* (average fork length 13.1 cm). This bait was placed inside a small meshed bag that hung inside the pot in front of the entrances. Other treatments consisted of male and female decoy crabs, because male decoys are an effective lure in the fisheries of *C. sapidus* and females of various crabs have been documented to attract conspecific males with a pheromone contained in their urine. The decoy crabs were trapped using baited pots from the pond, placed individually inside the pots and allowed to move freely. No attempt was made to enclose them in any type of cage or container since, it was considered that the pot's narrow slit entrances would prevent escape (Vazquez Archdale *et al*., 2007). The decoys were considered to be mature by their size, since they are reported to be sexually active after one year of age and the crabs captured where bigger than the sizes reported for 50% sexual maturity: 6.2 cm carapace width for males and 3.9 cm for females. Their mean sizes were 8.37 cm (SD 1.42, n = 9) carapace width for the male decoys and 7.18 cm (SD 2.08, n = 13) for the females. Decoy crabs could be distinguished from other caught crabs later because record was kept of their individual information, such as sex and carapace width measurement and this information could be used to identify them; for this reason marking was not necessary. The last treatment was non-baited pots, which served as control.

Pots were placed in a row running along the length of the pond and their locations were randomly assigned for each day's treatment to eliminate the effect of geographical distribution of the organisms in the pond. The distance separating the pots was about 15 m, which is preferred by commercial fishers. Pots were individually tied to a 6 m line, which was attached to a float and lowered to the seafloor by skin-divers around 15:00 on each day. To evaluate the effectiveness of the treatments in relation to time, two soaking times were employed during the experiments: 1 day (24 h) during weekdays from Monday to Thursday and 4 day (96 h) from Thursday to Monday. The former was based on the usual 1 day soaking time of pots operated with fish bait and *C. sapidus* decoys (Bishop *et al*., 1984) and the latter because a longer soaking time (1-2 weeks) is reported for lobster decoys (Heatwole *et al*., 1988). Divers retrieved the pots; the catch was identified, measured and released back into the pond in order not to deplete populations.

Decoys were used continuously until the end of the experiment or replaced by crabs from the catch when they disappeared or fell victim to octopus predation. If there were not enough crabs in the catch, the pot would be reset with fish bait. This resulted in the difference in pot numbers for each treatment.

Statistical analysis was done by testing for the differences between two proportions. Where, the probability of pots caching crabs was determined for each treatment using the ratio of pots catching crabs from the total number of pots deployed. Comparisons were done between two treatments and the null hypothesis was that the probabilities of catching crabs between both luring treatments were equal. Depending on the calculated standard normal random variable Z values, the null hypothesis was accepted ($-1.960 < Z < 1.960$ for 5% significance levels, or$-2.576 < Z < 2.576$ for 1% significance levels) or rejected.

Additional fishing trials were conducted in a commercial fishing ground in Nagashima island, Northern Kagoshima from 10-14 July 2006 to test the effectiveness of female *C. japonica* decoys against fish bait following commercial fishing practices. The luring treatments used were fish baited pots, female decoy pots and non-baited pots as control. To prevent decoy predation by octopus, the pots used for this treatment were slightly modified by adding a net partition from one slit entrance to the other and dividing them into two floors. The decoy was put on the top floor and the catch would fall into the bottom floor after entering through the slits. The rigging of the gear followed local fishing practices; pots were fastened to a bottom longline at 15 m intervals in a sequence that alternated the different treatment types (5 pots treatment^{-1}). The line was tied to chain anchors and marker buoys at each end. Depth ranged from 18-25 m. Because, female decoys were not available and had to be obtained, the pots for this treatment were baited with fish in the first trial. For the remaining trials, decoy pots were set depending on female crab availability and this resulted in the difference in pot numbers for each treatment. The pots were set for 1 day and retrieved the next day from a small boat powered by an outboard engine; the organisms in the catch were identified, measured and released. Following this, fresh bait was placed in baited pots and all pots were reset for the next trial.

RESULTS

During the underwater operations, it was observed that some *C. japonica* were attracted to the pots containing live crab decoys. They were seen outside the pots, resting against the netting of the walls, in the entrances, or on the top of the pots. No such behavior was observed in pots under the other treatments.

Since, the total number of pots set varied depending on treatment, the values were also expressed as catch efficiency pot^{-1}. The number of pots catching crabs from the total of pots set is also indicated inside the parenthesis. From Table 1, the most effective treatment for catching *C. japonica* was the fish bait, while both decoy crabs and no bait treatment where not effective. Statistical analysis showed significant differences in the probabilities of a pot catching crabs baited with fish when compared with male decoy pots (Z = 2.919,

Table 1: No. of trapped *C. japonica* after 1-day soaking time by sex and luring treatment

		Crab catch (No. of pots catching)			Catch efficiency pot^{-1}		
Luring treatment	No. of pots	Male	Female	Sum	Male	Female	Sum
Fish bait	73	9(9)	15(14)	24 (20)a,b	0.12	0.21	0.33
Male decoy crab	33	1(1)	0	1 (1)b**	0.03	0	0.03
Female decoy crab	22	1(1)	0	1 (1)a*	0.05	0	0.05
No bait	37	1(1)	0	1 (1)b**	0.03	0	0.03

a* indicates significant ($p<0.05$) difference between fish bait and female decoy treatments; b** indicates highly significant ($p<0.01$) difference between fish bait and male decoy and no bait treatments

Table 2: Number of trapped *C. japonica* after 4-day soaking time according to luring treatment

		Crab catch (No. of pots catching)			Catch efficiency pot^{-1}		
Luring treatment	No. of pots	Male	Female	Sum	Male	Female	Sum
Fish bait	15	1(1)	0	1(1)a	0.07	0	0.07
Male decoy crab	12	0	2(2)	2(2)	0	0.17	0.17
Female decoy crab	12	3(3)	3(3)	6(6)a*	0.25	0.25	0.50
No bait	13	0	0	0	0.00	0.00	0.00

a* indicates significant ($p<0.05$) difference between fish bait and female decoy treatments

$p<0.01$), female decoy pots ($Z = 2.270$, $p<0.05$) and non-baited pots ($Z = 3.114$, $p<0.01$). No significant differences were found when decoy crab and non-baited pots were compared between themselves. The crab catch for the 4-day soaking time is shown in Table 2, where the most effective treatment was the female decoy followed by male decoy crabs. Here, statistical analysis showed a significant difference between fish bait and female decoy crab pots ($Z = 2.552$, $p = 0.0108$), while there were no differences between fish bait and male decoy pots and female decoy pots and male decoy pots. The only treatment having a significant difference with non-baited pots was female decoy ($Z = 2.828$, $p<0.01$). Crab catches in the fish bait treatment were greatly reduced when, compared with those obtained in the 1-day soaking time; but the exact causes of this could not be determined because no observations took place during the days between setting and retrieval of the pots 4 days later. Catches showed that decoys sometimes attracted conspecifics of the same sex.

Regarding soaking time, no significant differences were found between 1 and 4-day fish bait pots; but 1 and 4-day female decoy pots were significantly different ($Z = 3.130$, $p<0.01$). When, comparing 1-day soaking time, fish baited pots and 4-day female decoy crab pots, there was no statistical difference between their probabilities of catching crabs.

Fish baits had to be replaced every day and a total of 88 fish had to be used during both 1 and 4 days soaking experiments. On the other hand, only 9 male and 13 female decoys were employed during the trials. Live decoys could be used for many days until they escaped, were eaten by octopus in the catch and some lasted until the end of the trials. Table 3 shows the results of the effectiveness of individual lures (fish bait or crab decoy), which was calculated by dividing the total catch of economically important species by the number of fish baits (88), male decoys (9) and female decoys (13). Because, the same decoys were used in the 1 and 4-day soaking times, the catches of both treatments are combined. The most effective luring treatment for catching crabs was the female decoy, catching almost twice as many crabs as male decoys and fish bait. Octopus was also attracted to decoy containing pots, while moray eels and rockfish were predominant in baited pots.

The results of the fishing trials conducted in the commercial fishing ground are presented in Table 4, which again support the previous evidence of the attractiveness of female decoys. Decoys had larger catch efficiencies than fish bait and they were 0.31 and 0.25 crabs pot^{-1}, respectively.

Table 3: Effectiveness of fish bait and decoys at catching commercially valuable species

			No. of organisms caught/No. lures (total catch)			
Luring treatment	No. of lures	No. of pots	Crab	Octopus	Moray eel	Rockfish
Fish bait	88	88	0.28 (25)	0	0.09 (8)	0.05 (4)
Male decoy crab	9	45	0.33 (3)	0.56 (5)	0.11 (1)	0
Female decoy crab	13	34	0.54 (7)	0.23 (3)	0	0

Table 4: No. of trapped *C. japonica* after 1-day soaking in commercial fishing ground

Luring treatment	No. of pots	Total crab catch	Catch efficiency pot^{-1}
Fish bait	20	5	0.25
Female decoy crab	13	4	0.31
No bait	20	0	0.00

Table 5: No. of captured organisms after 1-day soaking in pond

	Luring treatment			
Catch organism	Fish bait	Male decoy crab	Female decoy crab	No bait
Shore swimming crab	24	1	1	1
Xanthid crab	1		1	
Goby	5	2	2	2
Moray eel	5			
Catfish		2		1
Rockfish	3			
Mojarra	1			
Snail	190	12		2
Octopus		4	2	
Sea hare		1		
Total by-catch	205	21	5	5
Total no. of pots	73	33	22	37
By-catch/pot	2.81	0.64	0.23	0.14

Table 6: No. of captured organisms after 4 day soaking in pond

	Luring treatment			
Catch organism	Fish bait	Male decoy crab	Female decoy crab	No bait
Shore swimming crab	1	2	6	
Xanthid crab	1			
Goby		1	2	1
Moray eel	3	1		
Catfish				3
Rockfish	1			
Snail	23	15	4	1
Octopus		1	1	
Sea hare		1		
Sea cucumber			1	1
Total by-catch	28	19	8	6
Total no. of pots	15	12	12	13
By-catch/pot	1.87	1.58	0.67	0.46

Regarding the catch of non-target organisms in the pond trials (Table 5, 6), it was found that fish bait had the largest catch. The catch was predominant in snails *Batillaria cumingii*, moray eels *Echidna nebulosa* and rockfish *Sebasticus marmoratus*. Decoy crabs attracted snails and octopus *Octopus vulgaris*, their natural prey. Non-baited traps caught the fewest organisms of all. Non-target catches ranged from 2.81-1.87 organisms pot^{-1} in fish baited pots, 1.58-0.64 in male decoy pots, 0.67-0.23 in female decoy pots and 0.46-0.14 in non-baited pots, respectively. The non-target catch in the fishing trials showed a similar trend (Table 7) and catches of non-target organisms were 4.95 organisms pot^{-1} in fish baited pots, 1.23 in female decoy pots and 2.30 in non-baited pots, respectively.

Table 7: No. of captured organisms after 1 day soaking in commercial fishing ground

	Luring treatment		
Catch organism	Fish bait	Female decoy crab	No bait
Shore swimming crab	5	4	
Four-lobed swimming crab	11		1
Catfish	5		18
Scorpion fish	11	1	4
Goby	1	1	3
Blenny	13		
Rockfish		4	
Velvet fish		4	
Puffer fish	2		
Rainbow fish	1		
Ivory shell	2		
Snail	44	1	1
Octopus	1	1	1
Sea hare	8	4	16
Starfish			2
Total by-catch	99	16	46
Total no. of pots	20	13	20
By-catch pot^{-1}	4.95	1.23	2.30

DISCUSSION

Present study suggests that employing female crab decoys as lures in pots targeting the invasive shore swimming crab *C. japonica* has potential. We attribute the effectiveness of the female decoys to a sex pheromone probably contained in their urine that attracts males towards them, since the same has been documented among various crabs. Water from tanks containing female *Portunus sanguinolentus*, *C. maenas* and *M. holstatus* elicited searching and courtship responses in their male conspecifics (Dunham, 1978; Gleeson, 1980). A male *C. japonica* kept in captivity at the time of the trials was observed removing a perforated plastic partition separating it from a female crab found in the same aquarium. The pair started mating shortly after coming together. This provides some evidence on the possible attracting power of the female *C. japonica* decoy. Nevertheless, it was also observed that female crabs were just as common in the catch of female decoy pots, so we suspect that other factors are involved, such as an aggregation pheromone or visual stimuli. Reports have shown that female *C. sapidus* will congregate if many are placed in a tank and that they seek contact with each other (Gleeson, 1980). Females of *C. sapidus* showed that both visual and chemical stimuli are required to trigger the courting and mating behavior of males (Teytaud, 1971; Kamio *et al*., 2008). Field experiments also show different ratios of female and male crabs entering pots with male decoys of *C. sapidus*, which were 1:1.7 and 2.7:1 (Bishop *et al*., 1983, 1984). All of this indicates that besides mating there are other reasons for crabs entering pots with decoys of their same sex and further research must clarify this point.

Male *C. japonica* decoys were not effective in our trials, but this may be due to several factors. In the decoy fishery of *C. sapidus*, the male crab decoys are effective early in the mating season (April-May), when the females outnumber the males and seek desperately for mating partners (Bishop *et al*., 1983, 1984). If pots containing male decoys of *C. japonica* are placed during those months, we may obtain more encouraging results. Also, the single male decoy we employed may not have been powerful enough to lure females into the pots. Decoy pots for *C. sapidus* employ 2-6 male decoys pot^{-1}, so an increase in our number of male decoys may increase effectiveness (Bishop *et al*., 1983, 1984).

Regarding the catch of non-target organisms, pots containing decoys showed results comparable to non-baited pots and they did not attract many unwanted species. Decoys were very selective towards their own species, with the exception of octopus, their natural predator. During the fishing trials, the partition installed in the pots prevented decoy damage by octopus. Protective measures, such as a container for the decoy, are essential in areas where octopus is abundant. Pots targeting *C. sapidus* have a chamber in the center of the pot where, the decoy crabs are housed; the same method could be applied to our pots (Bishop *et al*., 1984; Christian *et al*., 1987). Low non-target organism catch has been reported in pots containing lobster decoys, where lower rates of crabs, sea urchins and trunkfish in the catch were obtained because they did not contain edible baits (Heatwole *et al*., 1988).

Many fisheries rely on the attractive nature of baits to lure animals into pots. This practice is not selective and attracts many undersized and unwanted organisms. Furthermore, high quality fish bait is suitable for human consumption, wastes valuable fisheries resources, needs frozen storage and consumes time during thawing and handling. In contrast, live crab decoys are easy to obtain and maintain by the fishers and because they are alive they do not spoil nor need to be replaced daily. Decoy crabs can be used for days, weeks and even months. Fishers catching *C. sapidus* use decoy male crabs for over a month. In our trials, the fish bait rapidly deteriorated due to the high water temperature in summer, which did not last for more than one day. Decoys survived for many days at those temperatures.

Crab decoy pots might be applied to remove invasive crabs from geographical areas where, they have been introduced. *C. japonica* is currently spreading in New Zealand, competing with local animals for food and habitat and is a potential carrier of crustacean viral diseases that can destroy many valuable fisheries resources (Maeda *et al*., 1988). Trapping these crabs with conventional methods is unrealistic, but using decoys that are species specific might be applied.

Finally, we encourage further research on the applications of decoys for crustacean pot fisheries. Present study with *C. japonica* tried to develop a new method for attracting this crab into pots that is species specific, reduces non-target catch and can be utilized to remove it from geographical areas were it has been introduced as an invasive alien species. Further research on the development of decoy fisheries should center on determining the ideal season of the year when they are effective, finding the optimum soaking time and developing a protective enclosure within the pot that prevents decoy escape and protects them from octopus predation.

ACKNOWLEDGMENTS

We are grateful to Dr. Gunzo Kawamura for his constant support and to Dr. Greg N. Nishihara (Nagasaki University) for critically reading and improving the manuscript.

REFERENCES

Ahmadi, G.K. and M. Vazquez Archdale, 2008. Mechanisms of phototaxis in American crayfish, *Procambarus clarkii* (Girard, 1852) following different methods of trapping. J. Fish. Aquatyic Sci., 3: 340-352.

Ahmadi, G.K., M.V. Archdale and K. Anraku, 2008. True electrotaxis threshold voltage in the American crayfish *Procambarus clarkii*. J. Fish. Aquatic Sci., 3: 228-239.

Bishop, J.M., E.J. Olmi, J.D. Whitaker and G.M. Yianopoulos, 1983. Capture of blue crab peelers in South Carolina: An analysis of techniques. Trans. Am. Fish. Soc., 112: 60-70.

Bishop, J.M., E.J. Olmi and G.M. Yianopoulos, 1984. Efficacy of peeler pots and experimental habitat pots for capture of premolt blue crabs. Trans. Am. Fish. Soc., 113: 642-654.

Christian, P.A., M.V. Rawson and T.D. Shierling, 1987. Effectiveness of six trap types and other factors for harvesting premolt blue crabs (*Callinectes sapidus*) in a Georgia tidal creek. N. Am. J. Fish. Manage., 7: 63-70.

Dunham, P.J., 1978. Sex pheromones in crustacea. Biol. Rev., 53: 555-583.

Eales, A.J., 1974. Sex pheromone in the shore crab *Carcinus maenas* and the site of its release from females. Mar. Behav. Physiol., 2: 345-355.

Gleeson, R.A., 1980. Pheromone communication in the reproductive behavior of the blue crab *Callinectes sapidus*. Mar. Behav. Physiol., 7: 119-134.

Hardege, J.D., A. Jennings, D. Hayden, C.T. Müller, D. Pascoe, M.G. Bentley and A.S. Clare, 2002. Novel behavioral assay and partial purification of a female-derived sex pheromone in *Carcinus maenas*. Mar. Ecol. Prog. Ser. MEPS, 244: 179-189.

Heatwole, D.W., J.H. Hunt and F.S. Kennedy, 1988. Catch efficiencies of live lobster decoys and other attractants in the Florida (USA) spiny lobster fishery. Fla. Mar. Res. Publ., 44: 1-15.

Kamio, M., M.A. Reidenbach and C.D. Derby, 2008. To paddle or not: Context dependent courtship display by male blue crabs, *Callinectes sapidus*. J. Exp. Biol., 211: 1243-1248.

Maeda, M., T. Itami, A. Fukumoto, O. Hennig and T. Imamura *et al*., 1988. Detection of penaeid rod-shaped DNA virus (PRDV) in wild-caught shrimp and other crustaceans. Fish. Pathol., 33: 381-387.

Shabani, S., M. Kamio and C.D. Derby, 2009. Spiny lobster use urine-borne olfactory signaling and physical aggressive behaviors to influence social status of conspecifics. J. Exp. Biol., 212: 2464-2474.

Smith, P.J., W.R. Webber, S.M. McVeagh, G.J. Inglis and N. Gust, 2003. DNA and morphological identification of an invasive swimming crab *Charybdis japonica* (A. Milne-Edwards, 1891) in New Zealand waters. N. Z. J. Mar. Freshwater, 37: 753-762.

Teytaud, A.R., 1971. The laboratory studies of sex recognition in the blue crab *Callinectes sapidus* Rathbun. Sea Grant Technical Bulletin No. 15. University of Miami Sea Grant Prog., pp: 62.

Van Engel, W.A., 1958. The blue crab and its fishery in Chesapeake Bay. Part 2. Types of gear for hard crab fishing. Virginia Inst. Mar. Sci., 79: 43-55.

Vazquez Archdale, M. and O. Kuwahara, 2005. Comparative fishing trials for *Charybdis japonica* using collapsible box-shaped and dome-shaped pots. Fish. Sci., 71: 1229-1235.

Vazquez Archdale, M., L. Kariyazono and C.P. Añasco, 2006a. The effect of two pot types on entrance rate and entrance behavior of the invasive Japanese swimming crab *Charybdis japonica*. Fish. Res., 77: 271-274.

Vazquez Archdale, M., C.P. Añasco and S. Hiromori, 2006b. Comparative fishing trials for invasive crabs *Charybdis japonica* and *Portunus pelagicus* using collapsible pots. Fish. Res., 82: 50-55.

Vazquez Archdale, M., C.P. Añasco, Y. Kawamura and S. Tomiki, 2007. Effect of two collapsible pot designs on escape rate and behavior of the invasive swimming crabs *Charybdis japonica* and *Portunus pelagicus*. Fish. Res., 85: 202-209.

Vazquez Archdale, M., C.P. Añasco and Y. Tahara, 2008. Catches of swimming crabs using fish mince in teabags compared to conventional fish baits in collapsible pots. Fish. Res., 91: 291-298.

Wang, C., L. Xue, F. Liu and J. Pan, 1996. The preliminary study on reproductive biology of *Charybdis japonica* (A. Milne-Edwards). J. Zhejiang Coll. Fish., 15: 261-266.