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Research Article

Public engagement for the detection of the introduced marine species *Charybdis japonica* in Western Australia

Mathew Hourston*, Justin I. McDonald and Matthew J. Hewitt

Department of Fisheries, Western Australia, PO Box 20, North Beach W.A. 6020, Australia

E-mail: Mathew.Hourston@fish.wa.gov.au (MH), Justin.McDonald@fish.wa.gov.au (JIM), Matthew.Hewitt@fish.wa.gov.au (MJH)

**Corresponding author*

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Abstract

The introduced crab, *Charybdis japonica*, was captured in the Swan River Estuary in Western Australia during October 2012. This constitutes the second documented report of this species in Western Australia after a single specimen was reported in 2010 from a nearby estuary. Given the invasive history of this species in locations such as New Zealand, a rapid-response delimiting survey was conducted to assess the prevalence of this crab within this estuary. A large public engagement campaign was run concurrently with the delimiting survey to inform and enlist the recreational crab fishers that use the Swan River and other nearby estuaries to report any more specimens that they caught. These activities yielded a total of three specimens, all handed in by recreational fishers as a result of the public engagement campaign. All three specimens were caught within a very limited area within the estuary, approximately 8 kilometres from the entrance. The two specimens that were able to be sexed were mature males, with carapace widths of 10.1 and 10.3 mm. The very small number of specimens caught, relative to the abundant native species indicates that *C. japonica* may be relatively scarce in the Swan River Estuary. This result highlights the importance of engaging members of the public to help detect introduced marine pest species in the early stages of incursions.

Key words: marine biosecurity, alien, invasive species, non-indigenous, delimiting survey, citizen science

Introduction

Introduced marine pests are regarded as one of the greatest threats to global marine biodiversity, with the potential to cause considerable economic, ecological, social and cultural impacts (Bax et al. 2003; Charles and Dukes 2007). While prevention is by far the preferred option for managing introduced marine pests, in the event of an incursion, early control measures are often most practical and economically viable and may prevent the population becoming established (Bax et al. 2003). Several introduced marine pest species are identified under Australia's current marine biosecurity regime as having a high potential to have serious impacts on local biodiversity and a high risk of establishment (Hayes and Sliwa 2003). One of which is the Asian paddle crab, *Charybdis japonica* (A. Milne-Edwards, 1867) (Hayes et al. 2005).

Many crabs of the genus *Charybdis* have a documented history of human-mediated dispersal outside of their natural range. *Charybdis hellerii* (A. Milne-Edwards, 1867) is a recorded Lessepsian invader in the Mediterranean Sea and currently is regarded as an invasive species in Brazil (Sant' Anna et al. 2012a) and in the USA (Dineen et al. 2001). *Charybdis longicollis* Leene, 1938, *Charybdis feriata* (Linnaeus, 1758) and *Charybdis lucifera* (Fabricius, 1798), are also species reported in the Mediterranean (Galil et al. 2011; Abelló and Hispano 2006; Mizzan and Vianello 2009, respectively), while *Charybdis variegata* (Fabricius, 1798) has been recently found in Brazil (Sant' Anna et al. 2012b). *Charybdis japonica* is another known introduced marine pest, with the most significant incursion to date detected in New Zealand during 2000 (Smith et al. 2003). Repeat surveys in 2003 and 2009 determined that *C. japonica* is now abundant at several marine and estuarine locations

Table 1. Details of the four confirmed specimens of *Charybdis japonica* caught in Western Australian from the Peel Harvey and Swan River Estuaries. WAM = Western Australian Museum; DOF = Department of Fisheries.

	Peel Harvey	Specimen #1	Specimen #2	Specimen #3
Figure		Figure 2A	Figure 2B	Figure 2C
Date of capture	Unknown	19/10/2012	28/10/2012	15/12/2012
Date of report	9/11/2010	19/10/2012	20/11/2012	8/01/2013
Date of identification	9/11/2010	25/12/2012	20/11/2012	11/01/2013
Location	Peel-Harvey	Swan River	Swan River	Swan River
Latitude	Unknown	-32.008334	-32.009116	-32.007053
Longitude	Unknown	115.77307	115.773585	115.772203
Capture method	Unknown	Drop Net	Drop Net	Drop Net
Material received	Frozen specimen	Cooked specimen	Photograph	Frozen specimen
Sex	M	M	Unknown	M
Size (carapace width)	9.5 cm	10.1 cm	Unknown	10.3 cm
Colouration	Light tan with dark pattern on carapace	Dark olive carapace, violet limbs	Dark olive carapace, violet limbs	Dark olive carapace, violet limbs
Stored at	WAM	WAM	Not Kept	DOF
Catalogue number	WAM C46162	WAM C51671		DOF 736
Identified by	A. Hosie / S. Ayong	A. Hosie	A. Hosie	A. Hosie

on New Zealand's North Island, and is reported to have locally displaced native species such as *Ovalipes catharus* (White, 1843) (Gust and Inglis 2006; Fowler et al. 2011; Fowler et al. 2013a, b). An incursion of *C. japonica* in Western Australia has the potential to displace native Western Australian crab species, such as *Portunus armatus* (Lai et al. 2010), a highly important recreational and commercial species to Western Australia (Johnston et al. 2011).

The first occurrence of *C. japonica* in Australia was a single male specimen caught in the Port River, South Australia in 2000 (Hooper 2001). Despite a large delimiting survey ($\approx$5000 trap hours), no further specimens were found and it was concluded that this species did not establish a viable population (Hooper 2001). In late 2010, a single male *C. japonica* was discovered in the Peel-Harvey Estuary (PHE), Western Australia, by a commercial fisherman. A delimiting survey and public awareness campaign were undertaken to determine if more individuals were present, but none were detected. The details of the PHE specimen have been included in Table 1 for the sake of completeness, however details of the PHE delimiting survey are not discussed further. Although no further specimens have been detected from the PHE, the first specimen in the Swan River Estuary (SRE) was detected in 2012 by a recreational fisher in response to that initial public awareness campaign (from the PHE). In response, the Department of Fisheries launched a coordinated delimiting and community engagement campaign involving several government agencies, industry, recreational fishers and the broader community to determine if more *C. japonica* were present in the area. The outcome of those activities were that during that same austral summer, a further two specimens were detected.

The use of citizen science, including public engagement campaigns such as used for this current program, actively engages the public in scientific research (Bonney et al. 2009). While citizen science programs have inherent challenges to overcome, and have received criticism of their scientific integrity (Conrad and Hilchey 2011), the engagement of recreational fishers allows researchers to dramatically increase the effective effort used in the search for introduced marine pests to a level which may be cost prohibitive if performed entirely by funded staff. Various studies have demonstrated the benefits that public engagement can have to introduced marine species studies (e.g. Crall et al. 2010; Dickinson et al. 2010) and their usefulness for crab species in particular (Delaney et al. 2008), which are often conspicuous and a readily identifiable member of the aquatic fauna.

This article provides information on the three specimens of *C. japonica* that were collected from the Swan River Estuary, Western Australia, as well as the details of the delimiting study and public engagement campaigns. It highlights the importance of the public engagement and how lessons learned can benefit future marine biosecurity responses.

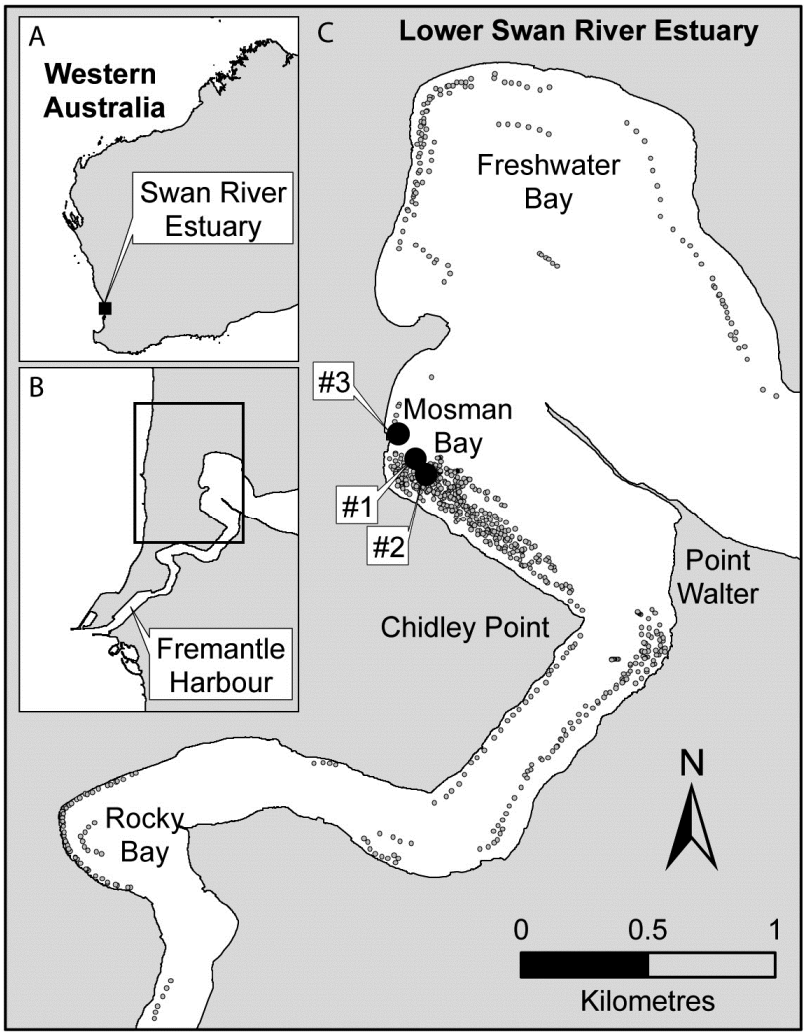

Figure 1. A: The location of the Swan River Estuary within Western Australia. B: The location of Fremantle Harbour in relation to the survey area. C: Map of the Swan River Estuary showing the location of the three *Charybdis japonica* captures (labeled #1, #2 and #3 to correspond with Table 1 and Figures 2 and 3), as well as the locations of the traps (irrespective of trap type) set during the 2012/13 delimiting survey (grey circles).

Methods

Estuary habitats

The Swan River Estuary (SRE) is a microtidal system in the temperate south-west of Western Australia (Figure 1A). It is composed of three distinct regions: the entrance channel, the shallow basins and the riverine reaches. *C. japonica* was detected in the upstream part of the entrance channel, where it joins the basins. This is the deepest section of the estuary (*ca.* 20 m) and experiences marine conditions for most of the year. This area contains many man-made, high-complexity habitats such as moorings, wharf and jetty piles and breakwaters, which provide suitable habitat for crab species. The estuary contains a variety of natural substrates but it is predominately unconsolidated sediments such as mud and sand, with significant areas of submerged macrophytes including seagrass and macroalgal stands. Localised areas of bare limestone rock are also present, predominantly in the entrance channel and lower basin (Valesini et al. 2010). The commercial port of Fremantle is located at the estuary mouth, approximately 6 km downstream from the *C. japonica* capture location. The port also contains high complexity structures and is a hub for international shipping movements (Figure 1B).

Trap types

Three trap types were used throughout the response activities, operahouse (dome) traps, commercial hourglass traps and drop nets.

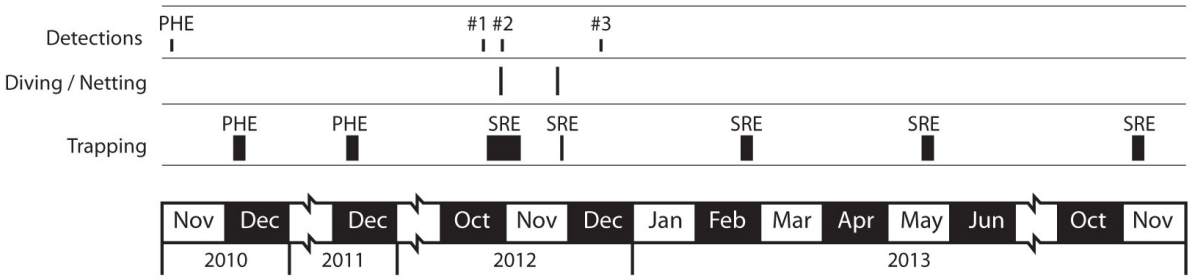

Figure 2. Timeline of events for *Charybdis japonica* detections and response activities in Western Australia between November 2010 and November 2013. PHE = Peel Harvey Estuary, SRE = Swan River Estuary. #1, #2 and #3 denote specimens captured in the Swan River Estuary and correspond with specimen notation in Table 1 as well as Figures 1 and 3.

Operahouse traps were the most common trap type used, as they are reported to be most effective for the target species (Vazquez Archdale et al. 2003). Hourglass traps are used by commercial crab fishers in the region. Drop nets are the most common recreational crabbing gear type in Western Australia and were the method of capture for all three individuals captured in the SRE. The number of trap drops and trapping dates are presented in Table 2. Pilchards (*Sardinops neopilchardus*) were the most commonly used bait, however other types were trialed including mullet (*Mugil cephalis*) and chicken carcasses as well as the addition of palm sugar to the other baits as sugars have been shown to increase catch per unit effort in their native habitats (*sensu* Kawamura et al. 1995; Hooper 2001). All non-target organisms caught during the delimiting survey were immediately returned to the water alive.

Delimiting survey

A single male *C. japonica* was reported from the SRE in October 2012, initiating the delimiting survey in that estuary. Delimiting trapping was conducted by the Department of Fisheries in the SRE exclusively between October 2012 and November 2013 and was centred on the location of the initial SRE *C. japonica* capture and expanded outwards from that known point of occurrence. The delimiting survey comprised four separate trapping periods (Table 2, Figure 2), the first immediately followed the initial SRE detection (Specimen #1) while the remaining three trapping periods were conducted 3, 6 and 12 months after that initial detection. The activity of the native portunid crabs in the SRE is very seasonal, with the greatest activity occurring in the summer months. Trapping periods and intensity was temporally targeted to apply the greatest effort when the crabs were most active. As the two subsequent public captures were in very close proximity to that initial location (within 100 m) intensive trapping was maintained there throughout all trapping periods. In addition, trapping was extended several kilometres up and down stream (Figure 1C), primarily targeting substrates similar to that at the initial capture site but also capturing areas with high complexity substrates and areas of presumed suitable habitat. In total, 935 traps were placed over the four sampling periods, in the immediate area and surrounds of the original captures. The different gear and bait types were deployed randomly. While natural substrates were sampled over the four trapping periods, the majority of traps were deployed on soft substrates near to man-made habitats such as moorings, jetties, rock walls, boat pens, yacht clubs and wharves. These sites were targeted as firstly, this is where the individuals caught in the SRE were captured, and secondly, the majority of *C. japonica* specimens caught in New Zealand were associated with man-made structures and hard substrates (Jones and Browne 2006). Locations were based on the best available data known for invasive *C. japonica*, environmental parameters and from regions in the SRE where the *C. japonica* specimens had been captured.

Trap soak times were approximately 24 hours for operahouse and hourglass traps, as this period was determined to be most effective for the practicality of the survey as well as the trap type used (Vazquez Archdale et al. 2007). While the effects of soak time, trap type efficacy and trap saturation could not be evaluated using the current study design, workers observed very little evidence of in-net predation. Drop nets were deployed for 1–2 hours based on similar times used by recreational fishers.

Table 2. Details of the sampling effort employed during the delimiting survey for *Charybdis japonica* in the Swan River Estuary. The effort for traps and nets is measured in trap hours, tangle net in set hours and visual searches in dive hours.

Date	Method	Effort (hrs)
22/10/12 - 8/11/12	341 operahouse traps	8184
	95 drop nets	95
30/10/2012	2 day dives, 3 night dives	3.3
22/11/12 - 23/11/12	20 hourglass traps	480
26/11/12 - 28/11/12	tangle netting	48
18/02/13 - 22/02/13	103 operahouse traps	2472
	12 hourglass traps	288
6/05/13 - 10/05/13	164 operahouse traps	3936
11/11/13 – 15/11/13	180 operahouse traps	4320
	20 hourglass traps	480

A single round of day and night diver surveys were also undertaken as part of the delimiting survey, which was conducted in the immediate vicinity of the reported *C. japonica* captures. Surveys comprised of pairs of divers conducting a search pattern across the study area examining all portunids encountered. All divers had been trained and were competent in distinguishing *C. japonica* from native species. Six diver pairs conducted the day surveys, while only three pairs conducted the night surveys. Dive duration was up to one hour.

The decision to conclude the delimiting survey after 12 months was a pragmatic one, based on the absence of specimens in the survey traps. An internal informal benefit/cost analysis also indicated that based on the limited numbers of detections in relation to the trapping and public engagement hours invested, the species was either not established or the population was not currently at invasive marine pest levels and would require extensive resources to detect at such a small level.

Public engagement campaign

The public engagement campaign comprised a broad spectrum of activities including the statewide distribution of almost 10,000 Asian Paddle Crab pest alert flyers (DoF 2014, Appendix 1), inclusion in the WA pestwatch smart phone app as well as multiple media releases, which generated considerable media interest and resulted in four radio interviews and 34 news stories published in print and online media.

The pest alert flyer was available through the Department's website and physical offices, and was actively disseminated through an array of avenues, including directly to the fishers by Fisheries and staff from other agencies on the water, at boat ramps and at a further 20 community events around the state. It was also disseminated indirectly to the public through stakeholder groups and bodies such as commercial fishermen, vessel operators, dive, fishing and tackle businesses, port authorities, local government, environmental groups, marinas and yacht clubs, marine industry groups, media outlets, universities, and other relevant state government bodies.

The flyer included several colour photographs of the target species, *C. japonica,* as well as native Portunid crabs such as *Portunus armatus, Thalamita sima* H. Milne Edwards, 1834, *C. feriata* and *Scylla serrata* (Forsskål, 1775) that were similar to the target species and likely to be caught in the same area. Annotation and diagnostic characters were added to the images to help the recreational fishers to distinguish the introduced from native species. Contact details, options for reporting and procedures for specimen collection were provided to allow efficient reporting by members of the public to the Western Australian Department of Fisheries. Fishers were urged to keep and report any crabs that they had caught and suspected of being *C. japonica* for collection by the Department. An amnesty on number and size limits was offered for any crabs kept on suspicion of being the target species. The public awareness and community engagement campaign has been ongoing since the first detection in the Swan River in 2012, varying in intensity according to season (and reactional fisher activity) and as of 2015 the flyer continues to be disseminated through targeted outlets.

Results

A total of three specimens of *C. japonica* have been confirmed from the Swan River Estuary, all of which were collected by recreational fishers targeting the native crab, *P. armatus*, using drop nets. All three reports were made in direct response to the public awareness campaigns regarding this species. Two of the captures resulted in specimens being handed into the department, while one report was via photograph only. The two specimens received were both mature males with carapace widths of 10.1 and 10.3 mm. The details of all captures and the current location of specimens are summarised in Table 1. Images of all individuals from SRE are presented in Figure 3.

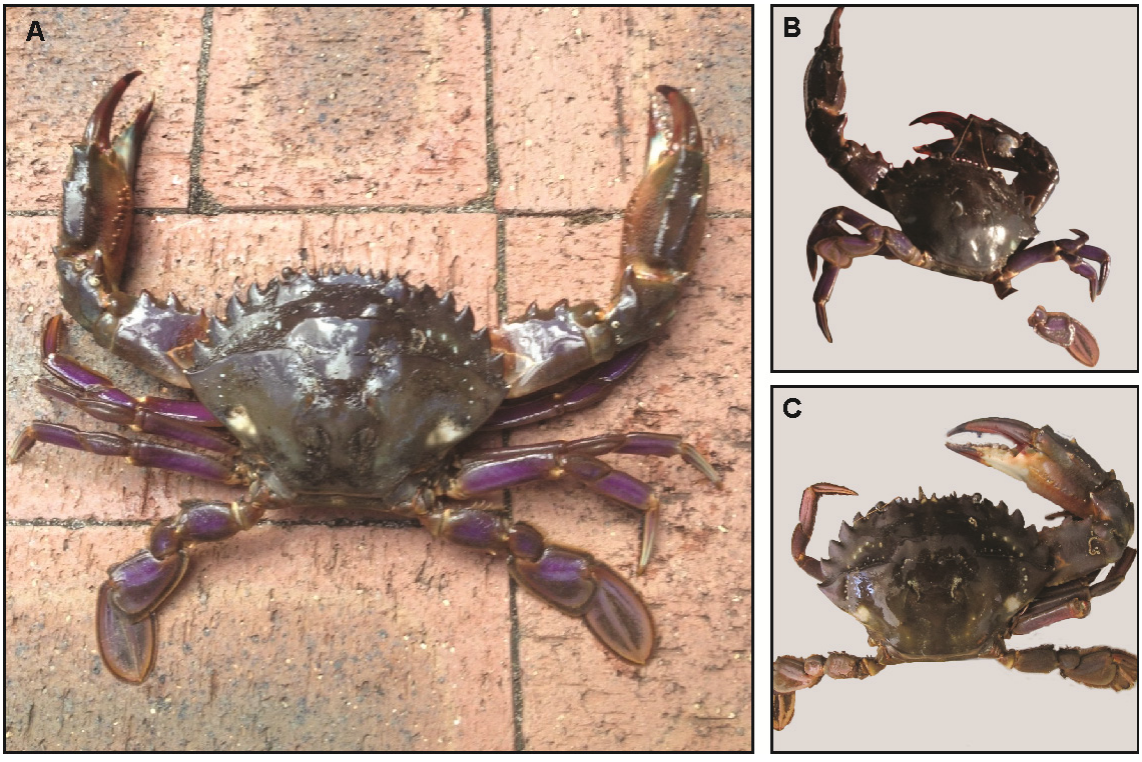

Figure 3. Three specimens of *Charybdis japonica* collected from the Swan River Estuary, Western Australia. A: Specimen # 1, B: Specimen # 2 and C: Specimen # 3. Specimens #1, #2 and #3 correspond to the equivalent notation in Table 1. Photographs A, B and C by B. Laroux, P. Shaw and M. Hewitt, respectively.

Delimiting survey

In total, more than 20,000 trap hours were logged over the course of the delimiting surveys in the SRE, however no further specimens of *C. japonica* were caught or observed (Table 2). Catches typically included the common native blue manna or blue swimmer crab (*P. armatus*) and the four-lobed swimming crab (*T. sima*) at a rate of approximately three individuals per trap. Single specimens of the native species *C. feriata* and *Portunus sanguinolentus* (Herbst, 1783) were also caught. Since the end of the delimiting surveys (November 2013), there were no further reports of *C. japonica* through either the public awareness campaign or commercial fishers. However, there have been a number of other, typically more tropical, Portunid species reported that have been mistaken for *C. japonica* by members of the public (i.e. *Charybdis natator*, *Charybdis granulata* (De Haan, 1833), *C. feriata*, *Charybdis annulata*, *Thalamita danae* Stimpson, 1858 and *S. serrata*).

Public Awareness Campaign

Since the beginning of the public awareness campaign in October 2012 over 400 public reports have been received and followed up by the Department of Fisheries, resulting in the two further confirmed reports of *C. japonica* in the Swan River Estuary within three months of the initial specimen.

As all three *C. japonica* specimens were collected by recreational fishers and reported in response to the public engagement campaign, the recreational fishing effort targeting crabs, which includes *C. japonica*, was estimated. Although contemporaneous data were not available, a broad recreational fisher survey completed in the preceding year (March 2011-February 2012) had sufficient resolution to estimate the recreational crabbing effort. We have assumed that similar amounts of effort were expended during the subsequent years, including the year of capture. The Department's survey of recreational fishers estimated that approximately 8,874 fisher days

(se = 1,352) were spent in the SRE specifically targeting crabs during the recreational fisher survey period. This equates to approximately one *C. japonica* caught for every 3,000 crab fisher days.

It is acknowledged that uncertainties exist in this estimation, including what proportion of those fishers actually received the awareness materials, whether all of the fishers that caught a *C. japonica* correctly identified it and whether all specimens caught were reported. Nevertheless, even given these uncertainties, the relative scarcity of reported specimens compared to amount of recreational fishing effort and the number of reports is a good indication that this species is relatively scarce in the SRE.

Discussion

The delimiting activities for *Charybdis japonica* in South-western Australia were substantial and included an intensive trapping regime and public engagement campaign. Three specimens of *C. japonica* have been recorded as a result of the public engagement campaign. The fact that not a single specimen was collected in more than 20,000 trap hours of the delimiting survey indicates that if there is a population of this species in the SRE it is likely to be very small in the areas sampled. This inference is supported by the results of the public engagement campaign for recreational fishers in which only three individuals were reported despite almost 9,000 boat days of recreational crab fishing being spent in the Swan River Estuary during the study period.

This campaign has allowed the Department of Fisheries to gather data, crucial to the detection and further management of this species. In the case of these operations it is highly unlikely that the agencies responsible for aquatic biosecurity could have matched the amount of combined fishing effort engaged in by the recreational fishers. We believe that tapping this resource for detecting the presence of an introduced marine pest species, in parallel with the delimiting survey, has significantly improved the detection power of the activity. In many cases, public engagement has been vital for the early detection of introduced marine species and crucial for their management (Delaney et al. 2008). For example, at least two other introduced pest crab species have been first detected by members of the public. The Asian shore crab, *Hemigrapsus sanguineus* (de Haan, 1835) in North America was discovered by a college student (Williams and McDermott 1990), and *C. japonica* was first detected in New Zealand by a commercial fisherman (Jones and Browne 2006). This study further highlights the usefulness of incorporating an effective public engagement campaign to detect introduced species in aquatic environments.

The recent incursions of *C. japonica* in Western Australian waters are important from a biosecurity perspective as they are only the second (PHE) and third (SRE) confirmed from Australia, and the most recent is the largest so far. The fact that two separate incursions have been detected in the past three years indicates that there has potentially been an increase in 1) the inoculation pressure, 2) the survivability of these crabs in south-western Australia, or 3) of the detection rates of incursions.

An increase in inoculation pressure cannot be quantified without knowing the exact vector that supplied the organisms, however it is generally considered that international vessels are a primary vector for the transfer of non-indigenous marine species (Hewitt et al. 2010) and is the supposed method of introduction of *C. japonica* in New Zealand (Gust and Inglis 2001). As the international port of Fremantle is located in the lower reaches of the Swan River Estuary, it is plausible that the propagules originated in the port. Trade statistics for Fremantle port indicate a progressive increase in the number of international vessels visiting the port annually with a 700% increase between 2002 and 2012. Furthermore, the proportion of those ships originating in the native range of *C. japonica* (south-eastern and eastern Asia) has steadily increased (FPA 2013), and the number of ships originating in New Zealand has quadrupled. Additionally, there are 11 recreational yachting clubs and marinas in the saline reaches of the SRE, capable of hosting international recreational vessels.

Comparison of the reported environmental tolerances for *C. japonica*, with the conditions found in the PHE and SRE indicate that this species is capable of surviving at these locations (NIMPIS 2014). However, the minimum water temperatures are at the lower limits of this species' known tolerance, particularly in their larval phase (Fowler et al. 2011). Between 2010 and 2012, Western Australia experienced a marine heatwave event that raised local water temperatures by up to 3 ºC (Pearce and Feng 2013). It is plausible that the elevated temperatures in the region allowed larval *C. japonica* to successfully settle where they may not have previously. This is supported by the capture of the six other

Portunid species detailed above, during the same year, which are also atypical to the region and normally inhabit warmer, lower latitude waters.

It is quite probable that there has been an increase in detection rates for *C. japonica* as a result of increased public awareness. The initial detection of this species in 2010 was by a commercial fisherman that submitted a specimen of a crab to the Department not because he suspected it was *C. japonica*, but simply because he did not recognize it. This resulted in a small awareness campaign that introduced this species in the minds of the public. The first report from the SRE was from a recreational fisher who remembered the flyers from the original 2010 campaign and recognized the specimen as an introduced species. This new report instigated a reinvigorated publicity campaign, further raising the profile of the species. The reports of the final two specimens were both made in direct response to this increased public engagement campaign. The detections of this species by the public have been made, not necessarily because the species is now inherently more detectable, but because there is a greater awareness of this pest by the effective survey workforce, *i.e.* recreational fishers. This is particularly relevant now that it is more than 12 months since the last specimen was caught and there have been no further reports to date, despite a continuing public engagement activities and an ongoing awareness of this species, evidenced by the continuing reports of suspected individuals from the public.

The possibility of an ongoing presence of *C. japonica* is of concern due to the species' proven invasive capabilities elsewhere. However, with the current information, the number of individuals in Western Australia is likely small, evident in the small number of specimens caught during the delimiting and public engagement activities. The trapping regime described for the delimiting survey was designed to oversample the immediate region of the original *C. japonica* captures from the SRE. This is an appropriate technique for the detection of scarce species such as *C. japonica* was thought to be, particularly given that the oversampling occurred in an area where the species was confirmed as being present *i.e.* its realised niche in the SRE. The concession for this localised oversampling was that the intensity of the survey was somewhat less in other areas. Nevertheless, the survey design spatially and temporally accounted for the potential habitat niche of this species, particularly in regards to salinity tolerance, and focused effort the areas of the SRE it was capable of inhabiting. One area in which the delimiting survey could be improved would be to diversify the methods used to detect *C. japonica*. Although different trap and bait types were used, these are still effectively trap-based sampling devices, targeting adult crabs. A more holistic approach may be appropriate, targeting different life-stages such as juveniles or larvae, and may give a better indication of the presence and prevalence of this species.

One of the primary lessons learned during the course of these activities is the importance of providing simple and readily interpretable identification material to members of the public who have had little to no taxonomic training. The cornerstone the public engagement activities was the provision of the pest alert flyer which had to be refined from its original form created in 2010 of the PHE awareness campaign, to its current state. The biggest improvement to the flyer was the provision of photographs and clear distinguishing characteristics of the four most common native species for which it could be easily mistaken. The inclusion of this information dramatically decreased the misidentification rate of the recreational fishers, evidenced by the fact that these four species became less prevalent in the reports while species other than those four became relatively more common. This increased the efficiency of the public engagement campaign by not having to deal with as many erroneously reported crabs. It also reduced the impact of the fishers on those native species, as the fishers were able to return the native crabs immediately to the water without having to keep them for formal identification.

These are the first reports of *C. japonica* captured in Western Australian waters and the first time multiple specimens have been caught at the same location in Australia. The usefulness of the public engagement campaign was indicated by the capture of three specimens of *C. japonica* by the public in response to that campaign, compared to none being caught by the delimiting survey, despite the investment of more than four times the sampling effort of the most comparable study (Hooper 2001). Although the delimiting survey has concluded in the SRE, the public awareness campaign will be continued at a lower level to maintain the vigilance of the recreational crab fishers. If any more specimens are collected and reported, another survey may need to be conducted.

Clearly, the public awareness campaign used to detect *C. japonica* through recreational fishers was highly successful in this case and similar

approaches are recommended as a very useful tool for the detection of introduced marine pest species. The increased effective workforce may have the ability to amplify the detectability of introduced marine pests at a stage when populations are still small and manageable. As the detection and management of introduced marine pests early in the invasion process is crucial, the use of public awareness campaigns provides vital data to managers at a critical stage of invasion process.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Western Australian Department of Fisheries Asian Paddle Crab pest alert flyer.

This material is available as part of online article from:
http://www.reabic.net/journals/mbi/2015/Supplements/MBI_2015_Hourston_etal_Appendix1.pdf