Supplementary Information

Horizon scanning for alien predatory crabs: insights from South Africa
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Supplementary Appendix: Determination of the Environmental Impact Classification of Alien Taxa (EICAT) rating

Following Hawkins et al. (2015)[1], the crab species were classified according to their negative environmental impacts across their global introduced range. As it was not possible to assess current impacts based on the available literature, only the maximum impact (i.e. greatest negative impact recorded) was considered. During classification, the impacts of each alien crab species was categorised under one of the 12 mechanisms by which impact can occur: (i) competition; (ii) predation; (iii) hybridization; (iv) transmission of diseases to native species; (v) parasitism; (vi) poisoning/toxicity; (vii) bio-fouling; (viii) grazing/herbivory/browsing (defined as grazing from this point); (ix) chemical, (x) physical, or (xi) structural impact on the ecosystem; and (xii) interaction with other alien species (denoted here as 'interaction'). For each species, the reported impacts were assigned to one of five categories to obtain the impact rating (hereafter referred to as the EICAT rating). In order of ascending severity of impact, the EICAT ratings are: Minimal Concern (MC), Minor (MN), Moderate (MO), Major (MR), and Massive (MV). Species with known alien populations, but for which no impact information was found, were classified as Data Deficient (DD). A confidence rating (low, medium or high) was assigned to these impact categories to quantify uncertainty. This was based on the availability, type, quality and reliability of the data, the degree of contradiction between data sources, and the spatial scale at which impacts are recorded. For additional details on the assessment process see Hawkins et al. (2015).

Only 9% (i.e. 3 of 34 species) of known predatory crab species could be rated using the EICAT scheme owing to a dearth of information on their environmental impacts. The three species that could be assessed are Chinese mitten crab *Eriocheir sinensis*, Japanese shore crab *Hemigrapsus sanguineus*, and brush-clawed shore crab *H. takanoi* (see Supplementary References, below, for a list publications used in the assessment). The EICAT assessment of the three alien crab species placed on the watch list for South African rocky shores is summarised in Table S1. The somewhat notorious *H. sanguineus* received an EICAT rating of Major, while the other two species were rated as Moderate. See Table S2 for a detailed description of impacts and the rationale behind the assignment of these EICAT ratings.

[1]Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I et al. 2015. Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions* 21: 1360–1363.

Table S1: EICAT assessment results for three alien crab species (family Varunidae) placed on the watch list created in this study, based on maximum reported impacts

Species	EICAT rating	Mechanism	Confidence
Hemigrapsus sanguineus	Major	Competition	Medium
Hemigrapsus takanoi	Moderate	Competition	Low
Eriocheir sinensis	Moderate	Predation	Medium

Table S2: EICAT ratings assigned to three species of alien predatory crabs placed on the watch list in this study, detailed descriptions of the impacts reported per mechanism of impact, and the associated confidence ratings and justifications thereof. The bioregions from which each species has been reported are also listed.

Impact caused by the species and the mechanism of impact	Confidence rating and justification
Hemigrapsus sanguineus EICAT rating: Major Bioregions: Mediterranean, Northeast Atlantic, Northwest Atlantic	
Competition – A census of crab populations from 1998 to 2005 at Edith Read Wildlife Sanctuary in Rye, NY, revealed a 95% decrease in the abundance of the flatback mud crab *Eurypanopeus depressus*, an 80% decrease in the lower intertidal density of the periwinkle *Littorina littorea*, and declines in populations of the Atlantic rock crab *Cancer irroratus*, shore crab *Carcinus maenas*, and spider crab *Libinia emarginata* which coincided with the expansion of the Japanese shore crab *Hemigrapsus sanguineus.* In 1998 and 1999, Atlantic rock crab and shore crab were uncommon, and in 2000 large areas were devoid of shore crab and Atlantic rock crab, and with few flatback mud crabs (Kraemer et al. 2007).	Medium – The impacts are based on observations in the field over long periods of time (1998–2005) and on inferred data. From the fact that the area was devoid of some species, one could assume that *H. sanguineus* caused local population extinction of these species. Studies and evidence are scarce. Impacts are recorded at a spatial scale that may not be relevant to the scale over which original native communities can be characterised, but extrapolation or downscaling of the data to relevant scales is considered reliable or to have little uncertainty.
Hemigrapsus takanoi EICAT rating: Moderate Bioregions: Northwest Atlantic, Baltic	
Competition – In 2008, alien populations of the brush-clawed shore crab *Hemigrapsus takanoi* and Japanese shore crab *H. sanguineus*, which is present along the Opal coast on the French side of the Dover Strait, were found to inhabit similar habitats to that of the native shore crab *Carcinus maenas.* Where *H. takanoi* was present in high densities (Dunkirk harbour) it was found to significantly dominate *C. maenas* which showed extreme declines in abundance. In contrast, in areas with low abundance of *H. takanoi* (Boulogne-sur-mer), *C. maenas* dominated (Dauvin et al. 2009).	Low – It is inferred from the observational evidence that *H. takanoi* caused the reduction in population densities of *C. maenas*. The study states that *C. maenas* was not dominant in areas where *H. takanoi* was dominant, but not that the densities declined. The interpretation of data/information is difficult and not direct or clear, and the evidence is thus not of good quality.
Eriocheir sinensis EICAT rating: Moderate Bioregions: Arctic, Mediterranean, Northeast Atlantic, Northwest Atlantic, Baltic, Arabian Seas, Northeast Pacific, Northwest Pacific	
Predation – Laboratory feeding trials revealed that the Chinese mitten crab *Eriocheir sinensis* is a predator of chironomids, isopods, eggs of two fish species and the freshwater shrimp *Gammarus pulex.* Juvenile *E. sinensis* predated on *G. pulex* more than the native Atlantic stream crayfish *Austropotamobius pallipes*. Outdoor mesocosms experiments, in 2012, at a meadow at the University of Leeds Field Research Unit, UK, further revealed declines in the abundance of amphipods, isopods, chironomids and gastropods when *E. sinensis* was present. Together with the feeding experiments this infers that predation by *E. sinensis* is responsible for declines (Rosewarne et al. 2016).	Medium – Laboratory experiments were conducted for four weeks to determine the diet of *E. sinensis*. Outdoor mesocosm experiments revealed a decline in abundance of invertebrates in the presence of *E. sinensis*. These data were then used to infer that these changes occur in natural communities. Impacts are recorded at a spatial scale that may not be relevant to the scale over which original native communities can be characterised, but extrapolation or downscaling of the data to relevant scales is considered reliable or to have little uncertainty. The data are thus reliable and not contradictory to any other studies.

Supplementary References: List of publications documenting the environmental impacts of the three EICAT-rated crab species placed on the watch list produced by this study. An asterisk (*) denotes publications providing evidence of the highest recorded impact used to allocate the EICAT rating.

Eriocheir sinensis

Czerniejewski P, Rybczyk A, Wawrzyniak W. 2010. Diet of the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1853, and potential effects of the crab on the aquatic community in the river Odra/Oder Estuary (N.-W. Poland). *Crustaceana* 83: 195–205.

Gilbey V, Attrill MJ, Coleman RA. 2008. Juvenile Chinese mitten crabs (*Eriocheir sinensis*) in the Thames estuary: distribution, movement and possible interactions with the native crab *Carcinus maenas. Biological Invasions* 10: 67–77.

*Rosewarne PJ, Mortimer RJ, Newton RJ, Grocock C, Wing CD, Dunn AM. 2016. Feeding behaviour, predatory functional responses and trophic interactions of the invasive Chinese mitten crab (*Eriocheir sinensis*) and signal crayfish (*Pacifastacus leniusculus*). *Freshwater Biology* 61: 426–443.

Rudnick DA, Chan V, Resh VH. 2005. Morphology and impacts of the burrows of the Chinese mitten crab, *Eriocheir sinens*is H. Milne Edwards (Decapoda, Grapsoidea), in south San Francisco Bay, California, USA. *Crustaceana* 78: 787–807.

Hemigrapsus sanguineus

Bourdeau PE, O'Connor NJ. 2003. Predation by the nonindigenous Asian shore crab *Hemigrapsus sanguineus* on macroalgae and molluscs. *Northeastern Naturalist* 10: 319–334.

Brousseau DJ, Filipowicz A, Baglivo JA. 2001. Laboratory investigations of the effects of predator sex and size on prey selection by the Asian crab *Hemigrapsus sanguineus*. *Journal of Experimental Marine Biology and Ecology* 262: 199–210.

Brousseau DJ, Goldberg R, Garza C. 2014. Impact of predation by the invasive crab *Hemigrapsus sanguineus* on survival of juvenile blue mussels in western Long Island Sound. *Northeastern Naturalist* 21: 119–133.

Dauvin JC, Rius AT, Ruellet T. 2009. Recent expansion of two invasive crabs species *Hemigrapsus sanguineus* (de Haan, 1835) and *H. takanoi* Asakura and Watanabe 2005 along the Opal Coast, France. *Aquatic Invasions* 4: 451–465.

DeGraaf JD, Tyrrell MC. 2004. Comparison of the feeding rates of two introduced crab species, *Carcinus maenas* and *Hemigrapsus sanguineus*, on the blue mussel, *Mytilus edulis*. *Northeastern Naturalist* 11: 163–167.

Freeman AS, Byers JE. 2006. Divergent induced responses to an invasive predator in marine mussel populations. *Science* 313: 831–833.

Gerard VA, Cerrator RM, Larson AA. 1999. Potential impacts of a western Pacific grapsid crab on intertidal communities of the northwestern Atlantic Ocean. *Biological Invasions* 1: 353–361.

Griffen BD, Byers JE. 2009. Community impacts of two invasive crabs: the interactive roles of density, prey recruitment, and indirect effects. *Biological Invasions* 11: 927–940.

Griffen BD, Williamson T. 2008. Influence of predator density on non-independent effects of multiple predator species. *Oecologia* 155: 151–159.

Jungblut S, Beermann J, Boos K, Saborowski R, Hagen W. 2017. Population development of the invasive crab *Hemigrapsus sanguineus* (De Haan, 1853) and its potential native competitor *Carcinus maenas* (Linnaeus, 1758) at Helgoland (North Sea) between 2009 and 2014. *Aquatic Invasions* 12: 85–96.

*Kraemer GP, Sellberg M, Gordon A, Main J. 2007. Eight-year record of *Hemigrapsus sanguineus* (Asian shore crab) invasion in western Long Island Sound estuary. *Northeastern Naturalist* 14: 207–224.

Lohrer AM, Whitlatch RB. 2002a. Interactions among aliens: apparent replacement of one exotic species by another. *Ecology* 83: 719–732.

Lohrer AM, Whitlach RB. 2002b. Relative impacts of two exotic brachyuran species on blue mussel populations in Long Island Sound. *Marine Ecology Progress Series* 227: 135–144.

MacDonald JA, Roudez R, Glover T, Weis JS. 2007. The invasive green crab and Japanese shore crab: behavioral interactions with a native crab species, the blue crab. *Biological Invasions* 9: 837–848.

Peterson BJ, Fournier AM, Furman BT, Carroll JM. 2014. *Hemigrapsus sanguineus* in Long Island salt marshes: experimental evaluation of the interactions between an invasive crab and resident ecosystem engineers. *PeerJ* 2: e472.

Tyrrell M, Guarino PA, Harris LG. 2006. Predatory impacts of two introduced crab species: inferences from microcosms. *Northeastern Naturalist* 13: 375–390.

Hemigrapsus takanoi

*Dauvin JC, Rius AT, Ruellet T. 2009. Recent expansion of two invasive crabs species *Hemigrapsus sanguineus* (de Haan, 1835) and *H. takanoi* Asakura and Watanabe 2005 along the Opal Coast, France. *Aquatic Invasions* 4: 451–465.

Landschoff J, Lackschewitz D, Kesy K, Reise K. 2013. Globalization pressure and habitat change: Pacific rocky shore crabs invade armored shorelines in the Atlantic Wadden Sea. *Aquatic Invasions* 8: 77–87.

Van den Brink AM, McLay CL, Hosie AM, Dunnington MJ. 2012. The effect of temperature on brood duration in three *Halicarcinus* species (Crustacea: Brachyura: Hymenosomatidae). *Journal of the Marine Biological Association of the United Kingdom* 92: 515–520.