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Conservation notes

Live seafood trade as a pathway for the introduction of invasive species in Hong Kong

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ABSTRACT

Invasive marine species pose ecological threats to native biodiversity and economic losses to local mariculture sectors. The present case study in Hong Kong illustrates how live seafood trade can unintentionally introduce invasive species worldwide. Our observations focused on invasive slipper limpets, with implications extending to other invasive species. These findings underscore the need to incorporate marine sustainability principles into seafood industries amidst expanding global trade.

1. Introduction

Hong Kong's seafood consumption rate is more than three times the global average, at 70.75 kg per capita. Over 70 % of its seafood, amounting to 385,000 tonnes, is imported from around the world, with a preference for live shipments (Lu, 2022). However, the trade in live seafood raises ecological concerns, notably the potential introduction of invasive species. In this context, we draw attention to two unintentionally introduced species often found alongside imported seafood as hitchhikers: the Atlantic slipper limpet *Crepidula fornicata* and the onyx slipper limpet *Crepidula onyx*. Both species are widely recognised as invasive and have successfully established populations beyond their native ranges (Fig. 1). Using Hong Kong as a case study, we illustrate how the live seafood trade can serve as a pathway for the global introduction of these limpets.

2. Unexpected observations of *C. fornicata* in Hong Kong

In our recent surveys at seafood wet markets in Hong Kong, we observed *C. fornicata* attached to the imported channelled whelk *Busycotypus canaliculatus* (Fig. 2a, b). These whelks were imported live from the northeastern coast of the United States, which is also the native region of *C. fornicata* (Fig. 1). The observed limpets included both males and females (21 ± 7 mm shell lengths). They attached to the whelks either individually or in stacks, with the smaller males positioned atop the larger females, indicating possible copulation (Fig. 2c, d). These observations are particularly concerning as the limpets were sexually mature, indicating high invasion potential given the species' documented reproductive viability (Richard et al., 2006; Pechenik et al., 2017), extended pelagic larval

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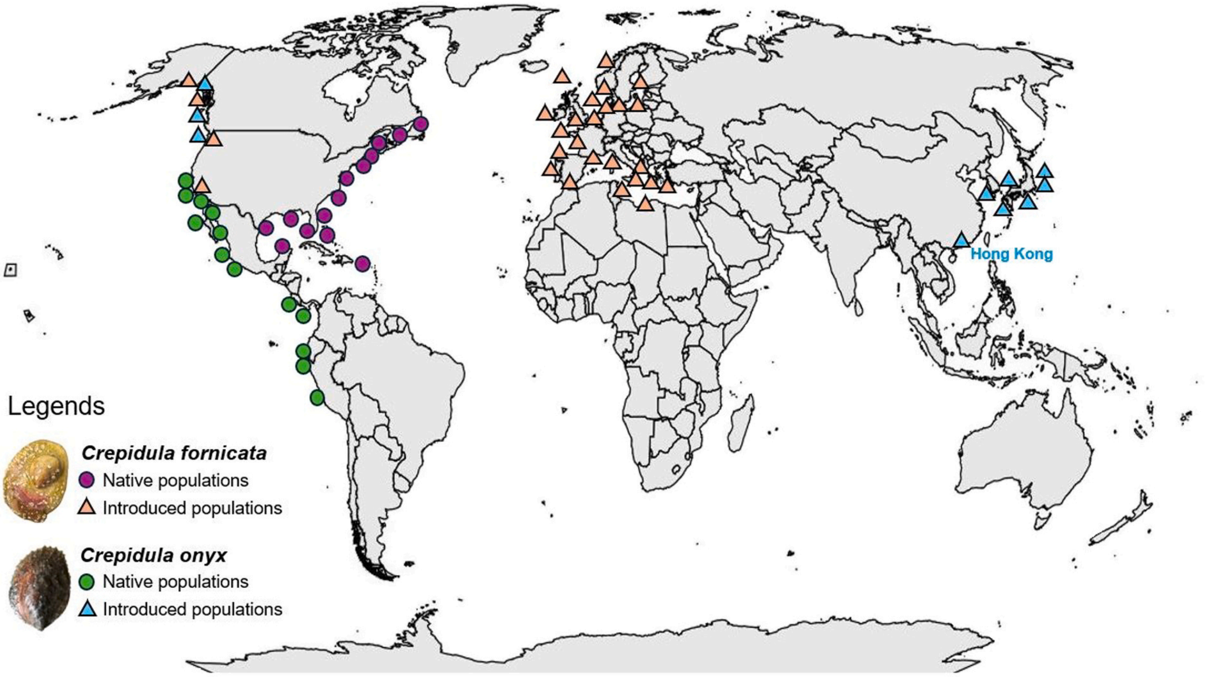

Fig. 1. Worldwide documented distribution of the Atlantic slipper limpet *Crepidula fornicata* and the onyx slipper limpet *Crepidula onyx*: *C. fornicata* is native to the Atlantic coast of North and Central America but has been introduced to Europe and other regions. *C. onyx* originates from the Pacific coast of Central and South America, but has spread to North America and East Asia, including Hong Kong (Woodruff et al., 1986; Morton, 1987; Blanchard, 1997; Son, 2003; Fofonoff et al., 2018). Although not depicted on the map, we anticipate the potential future presence of *C. fornicata* in Hong Kong waters due to its introduction through seafood imports (see Fig. 2).

Fig. 2. Recent observations of the Atlantic slipper limpet *Crepidula fornicata* attached to the imported channelled whelk *Busycotypus canaliculatus* in seafood wet markets in Hong Kong: **(a)** Display of *B. canaliculatus*, which is gaining popularity and becoming more expensive among local seafood consumers; **(b)** Discovery of *C. fornicata* on *B. canaliculatus* in May 2024. The Chinese words on the label translate to "Whelks imported from the United States, priced at HK$148 each (approximately US$19)"; **(c)** More instances of *C. fornicata* attached to *B. canaliculatus*, observed individually (white-arrowed) and in stacks with the smaller males on top of the larger females (pink-arrowed), during visits in December 2023 and **(d)** in January 2024. The shell lengths of *B. canaliculatus* ranged from 120 to 210 mm in the photographs.

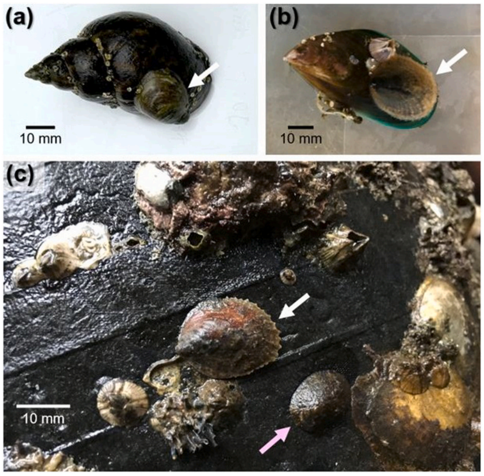

Fig. 3. Photographs taken in 2018–2023 illustrating the widespread presence of the introduced onyx slipper limpet *Crepidula onyx* in Hong Kong's environments: **(a)** Attachment of *C. onyx* (white-arrowed) on the Japanese ivory shell *Babylonia japonica*, a seafood species imported from Japan and purchased from a local wet market; **(b)** *C. onyx* observed on the green-lipped mussel *Perna viridis*, a native species collected from a rocky shore in Hong Kong; **(c)** *C. onyx* also found on manmade structures like steel and concrete piles beneath piers, coexisting with local intertidal communities, including the common limpet *Patella vulgate* native to Hong Kong (pink-arrowed).

duration (Pechenik, 1984; Blanchard, 1997), and broad environmental tolerance to variables including salinity, temperature and acidification (Blanchard, 1997; Diederich and Pechenik, 2013; Reyes-Giler et al., 2021). The subtropical climate of Hong Kong, with a mean temperature of 24 °C ranging from 12 °C in winter to 34 °C in summer (Fang et al., 2010; Pecquet et al., 2017), falls within the tolerance range of *C. fornicata*. The projected warming trends may further enhance the reproductive output of *C. fornicata* (Valdizan et al., 2011). To the best of our knowledge, and based on records in the Hong Kong Register of Marine Species (Astudillo et al., 2025), this species has never been reported locally and our observations signify the first documented presence of *C. fornicata* in Hong Kong. This situation raises concerns about the potential invasion of *C. fornicata* into Hong Kong through live seafood imports.

3. Lessons learnt from the invasion of *C. onyx*

A similar scenario can be seen with *C. onyx*, an invasive species which has already established a stable population in Hong Kong. *C. onyx* likely arrived in Hong Kong through ballast water or ship hull fouling originating from California (Woodruff et al., 1986; Morton, 1987). Live seafood imports represent another possible pathway for the introduction of *C. onyx*, as evidenced by the attachment of *C. onyx* on seafood imported to Hong Kong, such as the Japanese ivory shell *Babylonia japonica* (Fig. 3a). Apart from attaching themselves to imported seafood, alternative mechanism for this species introduction involves the presence of limpet larvae in the transport seawater, given their extended planktonic stage, plasticity to environmental changes, and high survivability under conditions of limited food availability (Maboloc and Chan, 2021; Reyes-Giler et al., 2021). This transport seawater is typically discarded after use, leading to the discharge of surviving larvae into the sea. Currently, the introduced *C. onyx* is widely distributed in Hong Kong waters, coexisting with native species and readily found on both natural and artificial substrates (Fig. 3b, c). Drawing parallels with *C. onyx*, its closely related species, *C. fornicata*, have followed similar introduction pathways that allowed them to spread in Europe (Blanchard, 1997). Given its high stress tolerance across life stages and the lack of effective interventions, there is a possibility that *C. fornicata* could also be unintentionally introduced into Hong Kong waters in the near future.

4. Ecological risks of *C. fornicata* invasion

The invasion of *C. fornicata* can be ecologically harmful due to its high proliferation rate and competitiveness against native species. For instance, *C. fornicata* often attach to and grow on other shellfish, increasing their burden and disrupting their feeding behaviour. In Europe, the attachment of *C. fornicata* has been shown to reduce the growth and survival rates of the blue mussel *Mytilus edulis* (Thieltges, 2005). Likewise, the introduction of *C. fornicata* into Hong Kong might lead to comparable impacts on the native green-lipped mussel *Perna viridis* (Fig. 3b). Moreover, *C. fornicata* filter-feeds on plankton and detritus, with such efficiency that it can diminish food availability for other local filter-feeders like mussels and oysters (Blanchard, 1997). The efficient feeding nature of *C. fornicata* is associated with a high deposition rate of faeces and pseudofaeces, contributing to nitrogen loading in the water column (Thieltges et al., 2006). This process could also enhance sedimentation and modify the habitats of benthic fauna (Goulletquer et al., 2002; Grasso et al., 2023). Moreover, invasive *C. fornicata* could carry parasites that might infect native species (Quinn et al., 2022). These ecological implications observed from *C. fornicata* in Europe offer insights into the potential outcomes of its invasion in Hong Kong, also suggesting negative impacts on local mariculture industries, particularly concerning bivalve shellfish such as oysters.

Overall, the increasing international seafood trade is likely to facilitate the spread of slipper limpets and other invasive species into

Hong Kong and beyond, posing threats to marine ecosystems and mariculture sectors and causing economic losses. To minimise the introduction of slipper limpets, a robust biosecurity management plan is strongly recommended. This should include strict regulations on the importation of shellfish from areas known to harbour slipper limpets and thorough inspections of all consignments prior to release, with measures to remove any hitchhikers from imported seafood products. Striking a balance between meeting the rising demand for seafood and safeguarding marine ecological health is crucial to mitigate these risks. Maintaining this delicate balance is key to ensuring marine sustainability and the long-term viability of seafood industries amidst expanding global trade.

CRediT authorship contribution statement

Elizaldy Acebu Maboloc: Writing – original draft, Visualization, Investigation, Conceptualization. **James Kar-Hei Fang:** Writing – review & editing, Visualization, Supervision.

Ethical declaration

The authors confirm that this study was conducted in accordance with Elsevier's ethical guidelines. No further ethical concerns are to be declared.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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