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Short communication

First confirmed records of the non-native amphipod *Caprella mutica* (Schurin 1935) along the coast of British Columbia, Canada, and the potential for secondary spread via hull fouling

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Abstract

Here, we report the first records of the non-native amphipod *Caprella mutica* along the coast of British Columbia, Canada. Between 2006 and 2009, we surveyed marine fouling communities across 81 subtidal sites, and sampled hulls and sea-chests from 18 domestically operated commercial vessels. *Caprella mutica* was present at 33% of the sites and on 22% of the vessels, sometimes at remarkably high densities (>10,000 individuals m^{-2}). Our findings confirm an extensive distribution of *C. mutica* along the coast of the northeast Pacific, and offer additional evidence in support of hull fouling as an important vector for secondary spread.

Key words: caprellid, introduced, northeast Pacific, biofouling, sea-chest, vector, museum records

Since described in its native range of northeast Asia, the marine caprellid amphipod *Caprella mutica* Schurin 1935 (Crustacea: Caprellidae), commonly known as the Japanese skeleton shrimp, has spread extensively, establishing non-native populations on both coasts of North America, western Europe, and New Zealand (reviewed in Ashton et al. 2007). The species was first recorded in California in 1973 (as *Caprella acanthogaster humboldtiensis*, see Marelli 1981). Later reports appeared in Oregon, Washington, and most recently, Alaska (Ashton et al. 2007; Ashton et al. 2008a), suggesting widespread introduction throughout the coastal waters of the northeast Pacific. However, to date, no confirmed accounts of *C. mutica* have been reported from British Columbia, Canada. Moreover, the invasion pathway of *C. mutica* throughout the northeast Pacific remains largely unknown (Ashton et al. 2008b).

Following initial introduction, subsequent invasion across the northeast Pacific may have resulted from multiple, independent trans-oceanic introductions, or alternatively, intra-coastal secondary spread. Because *C. mutica* lacks a planktonic larval phase, the species is characterized by rather limited dispersal potential on the scale of a few kilometers per year (Ashton 2006). As such, other vectors, including ballast water, hull fouling, aquaculture, and rafting on macroalgae, have likely mediated the dispersal of *C. mutica* (Ashton 2006; Ashton et al. 2007). Indeed, hull fouling, which has been proposed as a likely mechanism for long-distance dispersal of *C. mutica* in other introduced regions (Cook et al. 2007), also may partly account for the secondary spread of this species throughout the northeast Pacific.

In this study, we investigated both the presence of *Caprella mutica* in the coastal waters of British Columbia, and the role of hull fouling as a potential vector for secondary spread. As part of a monitoring program for aquatic invasive species, marine fouling communities were surveyed extensively throughout the British Columbian coast (Figure 1). Between 2006 and 2007, we sampled a total of 81 sites that spanned approximately 1,000 km and ranged across commercial ports, recreational marinas, and aquaculture facilities. At each site, an array of settlement plates was deployed across three depths (0.5, 1.5, and 2.5 m). Individual arrays consisted of three round plastic plates, with each plate hanging horizontally (one per depth) and containing four Petri dishes (9 cm diameter) attached to the underside. Settlement arrays were deployed in the early spring, and retrieved the following autumn or early winter, depending on logistical constraints. At eight sites in the Strait of Georgia, the settlement plates were immersed continually from spring 2006 through summer 2007, and Petri dishes were retrieved in sets every four months (see Annex 1).

To assess whether hull fouling serves as a plausible vector for secondary spread, we also examined fouling communities associated with domestically operated commercial vessels. In 2008 and 2009, we sampled 18 vessels, varying in type (barges, ferries, fishing, military, and tugs) and size (~100-10,000 gross registered tonnage), from two drydock facilities on Vancouver Island. We collected organisms along the smooth section of the hull and from the vessel's sea-chests. Sea-chests are recessed areas of the hull that house the intake pipes used for ballast water management and engine cooling. In contrast to the exterior of the hull, sea-chests do not experience constant hydrodynamic flows as the vessel travels through the water, and thus, may serve as a refuge for organisms during transit (Coutts and Dodgshun 2007). To determine the presence and estimate the abundances

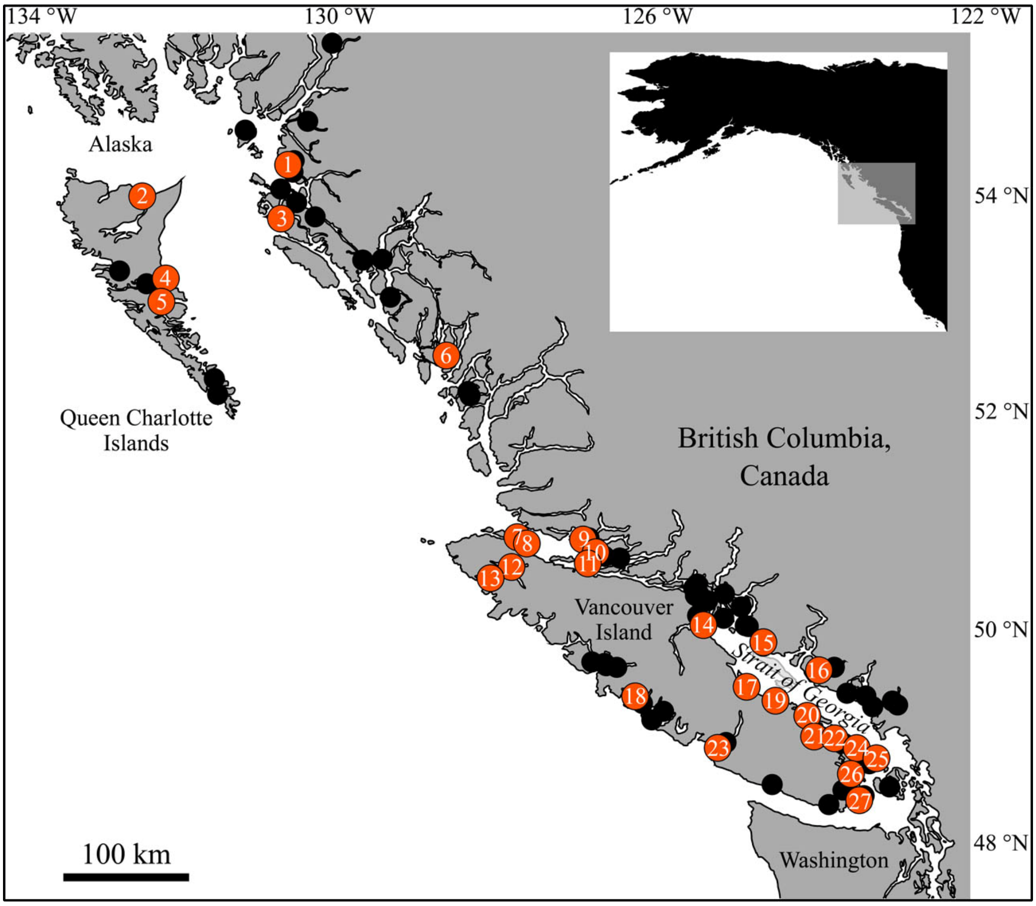

Figure 1. Site locations (circles) of fouling communities sampled along the coast of British Columbia, Canada between 2006 and 2007. Numbered orange circles designate locales at which *Caprella mutica* was present, as referenced in Annex 1

of organisms on the hull and in sea-chests, we collected samples opportunistically from the most heavily fouled sections, or when possible, using 0.1 m^2 quadrats.

Upon collection, all specimens were preserved in either formalin (10%) or ethanol (>70%), and transported to the laboratory for further identification. *C. mutica* was identified by its characteristic dorsal and lateral tubercles present along pereonites 3-7 and at the base of the gills (in adult females, tubercles often extend to the cephalon). Adult males were further distinguished from morphologically similar congeners by the presence of dense setae on elongated pereonites 1-2 and gnathopod 2, and a prominent middle projection on the propodus of gnathopod 2 (as described in Riedlecker et al. 2009). Voucher specimens (Figure 2), subsequently collected from Victoria, have been deposited at the Royal British Columbia Museum (RBCM 009-00048-001).

Based on our surveys, *Caprella mutica* is broadly distributed along the coast of British Columbia (Figure 1). The species was discovered at 33% (27 of 81) of the locations surveyed, extending from southern Vancouver Island and the Strait of Georgia northward to the Queen Charlotte Islands and Prince Rupert (Annex 1). Additionally, in at least 7 of 8 sites sampled in successive years, *C. mutica* was found each year (Annex 1), suggesting the presence of established populations. Estimated densities ranged from 157.2 to 16,159 individuals m^{-2} (average ±SE: 1,994.3±218.8), which correspond to densities reported for populations in other invaded regions (Buschbaum and Gutow 2005; Ashton 2006). To our knowledge, these records represent the first published reports of *C. mutica* in British Columbia, and thereby complete a relatively continuous distribution throughout the coastal waters of the northeast Pacific, ranging from southern California to southwest Alaska (Ashton et al. 2007).

The precise arrival date of *C. mutica* to British Columbia remains unknown; however, a subsequent examination of museum voucher material (RBCM) revealed that the species was present in southern Vancouver Island at least a decade prior to our surveys. We examined 57 lots of Caprellidae, collected between 1927 and 2004 from various locations, ranging from southern Vancouver Island to just south of the Alaska border. Two adult females of *C. mutica*, labeled previously as *Caprella* sp., were discovered in a voucher collected from Victoria in 1995 (RBCM 995-00006-008). This record coincides roughly with the first report of *C. mutica* from Puget Sound, Washington in 1998 (Cohen 2004). Although we cannot rule out the possibility that the species was present along the coast of British Columbia before this time, museum collections dated prior to 1990 (55 of the 57 lots) failed to yield *C. mutica*, suggesting that the species may have been either absent or uncommon.

Figure 2. *Caprella mutica* adult male (above) and female (below) collected from Victoria, British Columbia. Scale bar = 5mm (Photograph by M.A. Frey)

Given this species' limited dispersal potential, the current distribution of *C. mutica* throughout the northeast Pacific has likely been achieved, at least in part, by human-mediated transport. Indeed, our vessel surveys revealed that the hulls of commercial vessels may serve as a common transport mechanism for *C. mutica* along the coast of British Columbia, with additional connections to Alaska and Washington State. The species was present on 22% (4 of 18) of the vessels sampled at densities ranging from 10 to 430 individuals m^{-2}. On three of the vessels, *C. mutica* was collected from the smooth surfaces of the hull in association with other fouling organisms (e.g., *Mytilus* sp.), and in two of the vessels, the species was found in the sea-chests living among large colonies of hydroids (*Obelia* spp.), suggesting that these individuals were not recruited from adjacent waters just prior to drydocking, but rather represent established hitchhikers.

Collectively, these results highlight the potential role of hull fouling in the dispersal of *C. mutica*. The expansion of *C. mutica* throughout the northeast Pacific and particularly to northern sites in British Columbia (e.g., locales 1-6) and Alaska (Ashton et al. 2008a) over the past 30-40 years appears to exceed the natural dispersal capabilities of the species, suggesting that alternative explanations likely account for its widespread distribution. Various human-mediated vectors, including aquaculture transfers, oil platforms, timber floating, and hull fouling of service and recreational vessels, may operate as potential modes of dispersal for *Caprella* (e.g., Cook et al. 2007; Page et al. 2006; Willis et al. 2004). Similar to other studies (Buschbaum and Gutow 2005; Ashton 2006; Coutts and Dodgshun 2007), our findings reveal that hulls and sea-chests of commercial vessels also serve as effective vectors for *C. mutica*. Indeed, coupled with intra-coastal vessel movements and stepping-stone dispersal (Cook et al. 2007), hull fouling may have contributed significantly to the secondary spread of this species. Future research that assesses the survivorship of *C. mutica* on vessel hulls under realistic flow conditions (e.g., en route) may further clarify the importance of this vector to the species' dispersal throughout its introduced range.

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Annex 1
Locales and dates from which *Caprella mutica* collected in British Columbia

Map Reference	Geographic Locale	Geographic coordinates		Collection Date(s)
		Latitude, °N	Longitude,°W	
1	Prince Rupert	54.29	130.35	Oct 2007
2	Masset	54.01	132.14	Oct 2007
3	Kitkatla	53.80	130.44	Oct 2007
4	Sandspit	53.24	131.86	Sep 2007
5	Cumshewa Inlet	53.02	131.91	Sep 2007
6	Klemtu	52.54	128.40	Oct 2007
7	Queen Charlotte Strait	50.83	127.52	Oct 2007
8	Queen Charlotte Strait	50.81	127.48	Oct 2007
9	Broughton Archipelago	50.79	126.69	Oct 2007
10	Broughton Archipelago	50.71	126.66	Oct 2007
11	Broughton Archipelago	50.62	126.71	Oct 2007
12	Quatsino Sound	50.58	127.61	Oct 2007
13	Quatsino Sound	50.46	127.89	Oct 2007
14	Campbell River*	50.03	125.24	Sep 2006, May 2007, Oct 2007
15	Powell River*	49.84	124.53	Sep 2006, May 2007, Oct 2007
16	Sunshine Coast	49.61	123.83	Oct 2007
17	Deep Bay*	49.47	124.73	Sep 2006, Jan 2007
18	Clayoquot Sound	49.38	126.09	Oct 2007
19	French Creek*	49.35	124.36	Sep 2006, Jan 2007, May 2007
20	Nanaimo*	49.21	123.96	Sep 2006, May 2007
21	Ladysmith*	49.00	123.82	Sep 2006, May 2007, Dec 2007
22	Thetis Island	48.98	123.67	Oct 2007
23	Barkley Sound	48.90	125.08	Jan 2008
24	Galiano Island	48.90	123.40	Nov 2007
25	South Pender Island	48.75	123.23	Nov 2007
26	West Saanich*	48.65	123.45	Sep 2006, Jan 2007
27	Victoria	48.43	123.37	Oct 2007
NA	Victoria †	48.42	123.37	Oct 2008
NA	Esquimalt †	48.43	123.42	Sep 2008, Oct 2008

*locales sampled in successive years; †collected from vessels at drydock facilities