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First non-native crustacean established in coastal waters of Alaska

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ABSTRACT: Relatively few non-native species are known from coastal ecosystems at high latitudes to date. We examined the fouling community in Alaska for the presence of the marine amphipod *Caprella mutica*, which is native to the northwestern Pacific Ocean and has invaded many different global regions. Between 2000 and 2007, fouling panels were deployed in 6 sheltered, shallow bays in Alaska. *C. mutica* were detected on panels at 4 of these bays, ranging from southeastern Alaska (Ketchikan) to the Aleutian Islands (Dutch Harbor), and have been present in Alaska for at least 6 yr. This appears to be the first reported occurrence of a non-native marine species in the Aleutians and also the first confirmation that a non-native crustacean has established self-sustaining populations in Alaska. These data contribute to growing evidence that coastlines in Alaska are susceptible to biological invasions.

KEY WORDS: Alaska · *Caprella mutica* · Distribution · Introduction · Invasion

INTRODUCTION

In the Northern Hemisphere, the number of recorded marine non-native species apparently declines at high latitudes (Ruiz et al. 2000, Molnar et al. 2007). This pattern is perhaps best described for the Pacific coast of North America, where far fewer non-native species have been reported from Alaska than from California, Oregon, or Washington. A previous analysis of literature revealed only 10 non-indigenous species reported in Prince William Sound, Alaska, compared to 55–157 species from large bays in California to Washington (Ruiz et al. 2000). This phenomenon could be due to sampling bias, with lower search effort occurring in Alaskan waters. However, recent standardized surveys of sessile invertebrates that develop fouling communities on settlement panels indicate non-native species are indeed less common in Alaska compared to estuaries to the south, resulting in a steep latitudinal cline when controlling for search effort and habitat (Hines & Ruiz 2000, Ruiz et al. 2006, G. M. Ruiz unpubl. data).

Non-native species are relatively rare in Alaska. None are known to occur for large geographic regions and major taxonomic groups. It is noteworthy that non-native marine species have not been recorded in the Aleutian Islands and west of Kachemak Bay, with the exception of the kelp *Macrocystis pyrifera* on Kodiak Island (S. Saupe pers. comm.). Even more striking is the apparent lack of established populations of non-native crustaceans, as a dominant taxonomic group for invasions in North America and elsewhere (Ruiz et al. 2000). While 13 non-native species of copepods were found in the ballast water of ships arriving in Prince William Sound, none of these have been found in surrounding waters to date (Hines & Ruiz 2000). Conlan (1990) describes a single sample of the non-native *Jassa marmorata*, from Point Slocum (near Sitka, Alaska), representing the only available record of a non-native crustacean in Alaska, and it is not clear whether this species has become established (Ruiz et al. 2006).

During exploratory examination of Alaskan mobile fouling species collected between 2000 and 2003, we identified several individuals of *Caprella mutica* Schurin, 1935. The native habitat of *C. mutica* is sub-boreal northeastern Asia (Schurin 1935). It has been recorded as an introduced species on Pacific and Atlantic coastlines in the Northern Hemisphere (e.g. Martin 1977 [described as *C. acanthogaster humbold-*

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tiensis], Willis et al. 2004, distribution reviewed by Ashton et al. 2007b) and from New Zealand in the Southern Hemisphere (Inglis et al. 2006). *C. mutica* was absent from Alaskan expedition reports of Mayer (1903) and Rathbun et al. (1910). Neither was it recorded in more recent studies of the fauna of Alaska (Laubitz 1970, Hines & Ruiz 2001). Native caprellid species in Alaska include the fouling species *C. alaskana*, *C. laeviuscula*, and *C. kennerlyi* (Hines & Ruiz 2001).

The first introduction of *Caprella mutica* to the west coast of North America was recorded from Humboldt Bay, California, in 1973 (Marelli 1981). It has since been recorded from Santa Barbara oil platforms in the south to Puget Sound in the north (Ashton et al. 2007b and references therein). Water temperatures of 30°C and salinities <16 are known to cause mortality to *C. mutica* (Ashton et al. 2007a). From its distribution, the species is known to survive temperatures as low as –1.8°C, and it was described to be unlikely that salinity would limit the distribution of *C. mutica* from the open coast; although, low salinities may limit its distribution in brackish waters (Ashton et al. 2007a). In its native habitat, *C. mutica* is found associated with attached macroalgae and drifting seaweeds, including *Sargassum* spp., and on aquaculture structures, such as ropes for *Undaria* culture in Otsuchi Bay (Kawashima et al. 1999). Abundance of *C. mutica* in the native range was found to be (average ± SE) from 25.3 ± 5.2 ind. m^{-2} (April) to 1223.3 ± 89.7 ind. m^{-2} (June) (Fedotov 1991). Abundances in excess of 10 000 ind. m^{-2} have been recorded from its introduced range (Ashton 2006). Fecundity, as number of eggs per brood, can range from 15 to 363 eggs female^{-1} (Fedotov 1991, Ashton 2006), although, the maximum number of recorded hatchlings produced by a single female is 82 (Cook et al. 2007). There is a positive correlation between fecundity and female body length (Vassilenko 1991).

The present study describes the occurrence of *Caprella mutica* in Alaska, representing a large northward extension of its known range along western North America.

MATERIALS AND METHODS

Between 2000 and 2003, marine fouling communities were surveyed at 6 bays on the Pacific coast of Alaska (Fig. 1). A standard fouling panel method was used to collect the samples of the sublittoral invertebrate community for identification of resident species. Within each bay, 3 sites of human activity, including marina and harbor pontoons, private and public docks, and shipping terminals were surveyed once between 2000 and 2003. At each site, 3 PVC panels (14 × 14 cm) were deployed horizontally, surface-down at 1 m water depth. The panels were left for 3 summer months prior to retrieval and sample preservation in formalin (10%) or ethanol (75%). A similar study, but deploying 10 plates at each bay (various numbers of sites per bay, and 10 plates at 4 sites in Kachemak Bay), was repeated at 6 bays in 2007 (Fig. 1, Table 1). During the latter study, organisms fouling the floating pontoons (algae and hydrozoans) were also opportunistically inspected for the presence of *Caprella mutica*.

In 2007, the mobile component (organisms not firmly attached to the panels) of the fouling samples taken over all years was inspected for the presence of *Caprella mutica*. All caprellids were examined from the resulting material, and *C. mutica* were identified using the following characteristics: setation on Pereonites 1 and 2 and Gnathopod II; numerous dorsal tubercles on Pereonites 3 to 7, including >3 pairs on Pereonite 5; numerous lateral tubercles on Pereonites 3 to 5, in particular, multiple tubercles around the base of each gill (adapted from Arimoto 1976). These characteristics are most obvious in large male individuals. It should be noted that female and juvenile stages of this species are not easily identifiable and can be confused with the native *C. alaskana* and *C. kennerlyi* (Riedlecker et al. in press). Thus, the presence of *C. mutica* was only confirmed when male specimens >15 mm length were found.

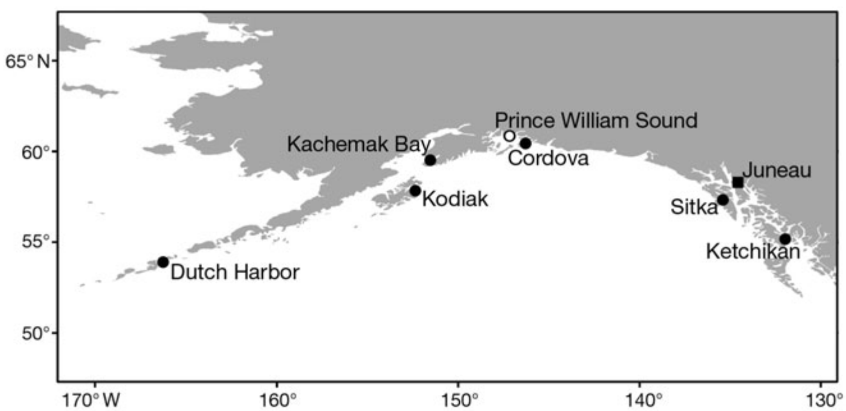

Fig. 1. Location of bays sampled for *Caprella mutica* in Alaska between 2000 and 2003 (○); in 2007 (■); both occasions (●)

RESULTS

In samples collected between 2000 and 2003, *Caprella mutica* individuals were found at a total of 7 sites in 3 differ-

Table 1. *Caprella mutica.* Presence/absence records from samples collected from 2000 to 2003 and in 2007. Bays are listed from west to east (top to bottom). Temp.: approximate annual temperature range (°C taken from www.nodc.noaa.gov); ticks: presence (p: panel collection; o: opportunistic collection); crosses: absence

Bay	Temp. (°C)	Sites	Latitude, longitude	Presence/ absence
2000–2003 sites				
Dutch Harbor[a]	1 to 12	City Spit Dock	53.91°N, 166.51°W	✘
		Port of Dutch Harbor	53.90°N, 166.53°W	✓ (p)
		East Point Dock	53.88°N, 166.54°W	✓ (p)
Kodiak[b]	2 to 14	Container Dock	57.78°N, 152.40°W	✘
		St. Paul Harbor Marina	57.79°N, 152.41°W	✘
		Ouzinkie Pier	57.92°N, 152.50°W	✘
Kachemak Bay[c]	0 to 13	Peterson Bay	59.57°N, 151.28°W	✘
		Homer Spit	59.44°N, 151.71°W	✘
		Port Graham Hatchery	59.60°N, 151.24°W	✘
Prince William Sound[d]	4 to 14	Chenega Bay Marina	60.65°N, 148.12°W	✘
		Main Bay Hatchery	60.53°N, 145.76°W	✘ (p)
		Small Boat Harbor (Cordova)	60.32°N, 148.15°W	✘
Sitka[b]	4 to 16	Cove Marina	57.12°N, 135.39°W	✓ (p)
		Thomsen Harbor	57.05°N, 135.35°W	✓ (p)
		Crescent Harbor	57.05°N, 135.32°W	✘
Ketchikan[d]	5 to 16	Homestead Skiff	55.39°N, 131.74°W	✓ (p)
		Promech Air	55.35°N, 131.66°W	✓ (p)
		Cruise Dock	55.34°N, 131.65°W	✓ (p)
2007 sites				
Dutch Harbour	1 to 12	Small Boat Harbor	53.88°N, 166.55°W	✘
Kachemak Bay	0 to 13	Peterson Bay	59.57°N, 151.28°W	✘
		Homer Spit (Harbor)	59.44°N, 151.71°W	✘
		Halibut Cove	59.60°N, 151.24°W	✘
		Jakalof Bay	59.47°N, 151.54°W	✘
		Seldovia Harbor	59.61°N, 151.41°W	✓ (p)
Prince William Sound	2 to 13	Small Boat Harbor (Cordova)	60.53°N, 145.76°W	✘
		Small Boat Harbor (new)	60.53°N, 145.76°W	✘
Sitka	3 to 16	Cove Marina	57.12°N,135.39°W	✘
		Thomsen Harbor	57.05°N, 135.35°W	✓ (o)
		Crescent Harbor	57.05°N, 135.32°W	✓ (o)
		ANB Dock	57.05°N, 135.32°W	✓ (o)
		Sawmill Cove	57.05°N, 135.23°W	✘
		Sealing Cove	57.05°N, 135.35°W	✘
Juneau	2 to 13	Harris Harbor	57.0°N, 135.3°W	✘
		Yacht Dock	57.0°N, 135.3°W	✘
		People's Wharf	57.0°N, 135.3°W	✘
		Lightering Float	57.0°N, 135.3°W	✘
		Aurora Harbor	58.31°N, 134.44°W	✘
		Douglas Harbor	58.28°N, 134.39°W	✘
		Fritz Cove Road	58.35°N, 134.65°W	✘
		Auke Bay Boat Harbor	58.38°N, 134.65°W	✘
		Tee Harbor	58.41°N, 134.76°W	✘
		Amalga Harbor	58.49°N, 134.79°W	✘
Ketchikan	5 to 17	Homestead Skiffs	55.39°N, 131.74°W	✘
		Carlin Air Float	55.35°N, 131.66°W	✓ (o)
		Bar Harbor	55.35°N, 131.68°W	✓ (o)
		Knudsen Cove Marina	55.47°N, 131.80°W	✘
		Refuge Cove Marina	55.40°N, 131.74°W	✘
		Hole in the Wall	55.32°N, 131.52°W	✘
		Thomas Basin	55.34vN, 131.64°W	✘

[a]2002, [b]2001, [c]2000, [d]2003

ent bays in Alaska (of 18 sites in 6 bays examined; Table 1). Two of the bays were in southeast Alaska (Ketchikan and Sitka), and 1 was in the Aleutian Islands (Dutch Harbor). Where present, abundance of *C. mutica* was <10 ind. panel^{-1}. During 2007, *C. mutica* individuals were collected at 6 sites in 3 bays: Ketchikan, Sitka, and Kachemak Bay (of 31 sites in 6 bays; Table 1). From Kachemak Bay, *C. mutica* were only found in 2007 from a single panel at Seldovia Harbor (5 ind.), whereas they were found amongst fouling communities of red branching algae at Sitka and Ketchikan (50 to 100 ind. on an approximately 5 cm^3 clump of algae at each site; opportunistic collections).

Caprella mutica were not found in our collections from Kodiak, Prince William Sound (including Cordova), or Juneau. Specimen vouchers were deposited in collections at the National Museum of Natural History, Washington, DC (USNM 1110028), and at the University of Alaska Fairbanks' Museum (UAM Marine Arthropod 376).

DISCUSSION

The discovery of *Caprella mutica* in Alaska increases its known range in the North Pacific and raises interesting questions about its arrival here. The species has not previously been recorded from Alaska, but the number of individuals collected at 2 sites (>50 ind. on a small clump of algae at Ketchikan and Sitka) over a 6 yr period suggests that it has successfully established in southeastern Alaska. It is noteworthy that the species also occurred in Kachemak Bay and, especially, in Dutch Harbor, the western-most extents of our sampling. For these latter 2 bays, where specimens were found in only 1 yr, we suspect *C. mutica* has established self-sustaining populations, but persistent populations remain to be confirmed. Because population fluctuations have been noted in their native habitat and Scotland (Fedotov 1991, Ashton 2006), the absence of *C. mutica* from the Dutch Harbor site sampled in 2007, especially considering the limited extent of sampling, does not allow evaluation of population status. In a similar fashion, individuals in Kachemak Bay may be a recent introduction, or a population may have been established but not sampled during the 2000 survey.

The time of arrival or geographic distribution of *Caprella mutica* in Alaska is currently not known. Our survey data suggest it may be very widespread, since our occurrence records now span ~35° of longitude and annual seawater temperatures of 0 to 16°C. Anecdotally, Prince William Sound and Juneau, where *C. mutica* was not found, experience a strong glacial freshwater influence, which may be limiting the establishment of *C. mutica* here.

To our knowledge, this is the first record of a non-native marine species found in the Aleutian Island chain (Dutch Harbor), and *Caprella mutica* appears to be the first non-native marine crustacean species established in Alaska. It is interesting to consider whether the populations in Alaska are part of a northwards extension along the Pacific coast of North America or a trans-Aleutian range extension from their native habitat in northeastern Asia. Assuming that the population in Dutch Harbor is established (but not captured during this survey), the range of *C. mutica* now extends along the Aleutian chain. In either case, it must be questioned why *C. mutica* has not been previously recorded from Alaska. Several possibilities cannot be excluded: (1) following introduction to the south of Alaska, *C. mutica* has continued to spread (independently or anthropogenically), its range has now expanded to include Alaska; (2) climate change has contributed to the success of *C. mutica* in Alaska (Stachowicz et al. 2002); or (3) increased anthropogenic activity in Alaska (Schumacher & Kruse 2005) has led to its spread here. Mechanisms for the introduction of *C. mutica* include shipping, recreational vessels, floating algae, and in association with aquaculture movements (Ashton 2006). Any or all of these mechanisms may have been responsible for its introduction to Alaska, although shipping (attached to vessel hulls) is considered most likely.

Characteristics contributing to the wide geographic range of *Caprella mutica* include wide environmental tolerance (Ashton et al. 2007a), production of multiple large broods (Cook et al. 2007), and its association with human activity in coastal habitats (Ashton 2006). The impacts of the introduction of *C. mutica* on ecosystems are unknown; however, there is the potential for significant ecological impacts, due to their competitive nature (displacing European native congeners from artificial substrates; Shucksmith 2007) and ability to achieve high abundances (>300 000 m^{-2}; Ashton 2006).

The present study contributes to evidence based on other taxa (e.g. tunicates, bryozoans, and hydroids; Ruiz et al. 2006) that Alaska is at risk of invasions by non-native marine species. Such invasions may result especially from the northward spread of the many non-native species established from California to Canada, due to either natural dispersal or anthropogenic transfers (Cohen & Carlton 1995, Ruiz et al. 2000, Hines et al. 2004). To date, there is little evidence that environmental conditions in Alaska limit the colonization of these or other non-native species, even in the absence of climate change (deRivera et al. 2007). The identification of *Caprella mutica* in Alaska can be considered an indicator of the susceptibility of the area to marine introductions. The continued and increased monitoring for the spread of other non-native marine species in Alaska is encouraged.

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