

Distribution of Fiddler Crabs in East Asia, With a Note on the Effect of the Kuroshio Current

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Abstract

Fiddler crabs (Crustacea: Ocypodidae: genus *Uca*) are the dominant brachyuran crabs in many tropical and subtropical coastal areas. Their distribution is known to be influenced by larvae transported by ocean currents. Seventeen species are recorded from East Asia (Japan, Korea, China and Taiwan), with seven species exclusively found from Penghu in the center of the Taiwan Strait, southwestern and eastern Taiwan, and the Ryukyus. In the region of the East Asian islands, the main current is the Kuroshio Current which flows from the east side of Luzon, via eastern Taiwan and the Ryukyus, to southern Korea and the southern main islands of Japan. The distributional pattern of fiddler crabs around Taiwan apparently is a result of the larval dispersal influenced by the Kuroshio Current and the small intruding Kuroshio Branch into the Taiwan Strait. To determine whether the Kuroshio Branch can transport *Uca* larvae into the South China Sea (and Taiwan Strait) during the breeding season in summer, further studies can focus on the genetic differentiation between populations affected by the Kuroshio Current and Kuroshio Branch, respectively.

Key words: fiddler crabs, larvae, distribution, Taiwan, Kuroshio Current, South China Sea

1. Introduction

Fiddler crabs of the genus *Uca* (Crustacea: Ocypodidae) are common and conspicuous crabs in tropical and subtropical intertidal mudflats and mangroves (Crane, 1975). They are highly diverse with about 100 species having been described (Crane, 1975; Beinlich & Hagen, 2006; Ng et al., 2008; Shih et al., 2009, 2010a, 2012; Landstorfer & Schubart, 2010; Naderloo et al., 2010). Regarding the *Uca* fauna of East Asia (China, Taiwan, Japan and Korea), although it appears less abundant than that of Southeast Asia (Crane, 1975), more species have been recognized since 1975 and 17 different species have now been reported (Sakai, 1976; Dai et al., 1986; Dai & Yang, 1991; Shih, 1994; Ng et al., 2001; Yoshigou, 2001; Shih et al., 2010a,b, 2012).

In the East Asian islands (Taiwan, the Ryukyus and the main islands of Japan), 13 species of *Uca*

have been recorded. Among them, one (*U. formosensis*) is endemic to Taiwan (including Penghu), four (*U. arcuata*, *U. borealis*, *U. lactea* and *U. splendida*) are also distributed in continental Asia, and eight (*U. coarctata*, *U. crassipes*, *U. dussumieri*, *U. jocelynae*, *U. perplexa*, *U. tetragonon*, *U. triangularis* and *U. vocans*) are found exclusively in islands (including Hainan) (cf. Shih, 1994; Yoshigou, 2001, Shih et al., 2010b). The eight insular species are not distributed on the continent and this is probably related to the currents around the various islands, as the distribution of *Uca* is known to be influenced by the planktonic larval dispersal transported by ocean currents (Barnwell & Thurman, 1984; Hopkins & Thurman, 2010; López Duarte et al., 2011). For example, the currents in the West Atlantic (including the Caribbean Sea) affect the fiddler crab dispersal during summer when they spawn (reproduce) (Hopkins & Thurman, 2010).

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In East Asia, the main current is the Kuroshio Current, which flows from the east side of Luzon, via eastern Taiwan and the Ryukyus, to southern Korea and the southern main islands of Japan (Hsueh, 2000). A branch of the Kuroshio Current (= Kuroshio Branch) intrudes into the northern South China Sea (= SCS) and Taiwan Strait during winter, but it is open to debate whether the branch intrudes during summer too (Jan et al., 2002, 2010; Liang, 2003, 2008).

The aim of this study is to see if the distribution of fiddler crabs in East Asia can be explained by the effect of the Kuroshio Current. The records of fiddler crabs from China (including Hainan), Taiwan (including Penghu Islands and Dongsha Island) and Japan (including the Ryukyus) based on references (Yoshigou, 2001; Shih et al., 2010b, 2012; Shih, 2012) were plotted on maps of East Asia.

Among the 17 species of *Uca* from East Asia, *U. annulipes* and *U. typhoni* were only recorded from Hainan and are not included in analyses because they do not have a direct relationship with the Kuroshio Current. The remaining 15 species could be separated into two categories, the continental and insular groups (cf. Shih et al., 2010b). The distribution of the insular group is clearly highly related to the larval dispersal caused by the Kuroshio Current, which will be discussed in detail later.

2. The continental group of *Uca* species

Seven species of *Uca* are limited to areas near the continent, including China, Penghu and western Taiwan, but absent or rare in eastern Taiwan or the Ryukyus. The continental group includes *U. acuta*, *U. borealis*, *U. arcuata*, *U. formosensis*, *U. lactea*, *U. paradussumieri* and *U. splendida* (Fig. 1A-G).

Uca acuta and *U. paradussumieri* range along the coast of continental China and Vietnam (Fig. 1A-B) (Dai et al., 1986; Dai & Yang, 1991; Kosuge et al., 1997; Shih et al., 2010b). *Uca formosensis* is endemic in western Taiwan and Penghu (Fig. 1G) (Shih et al., 1999). The other species - *U. arcuata*, *U. borealis*, *U. lactea* and *U. splendida* - have similar wider distribution, i.e. continental China, western Taiwan, Penghu and Vietnam. In addition, *U. arcuata* and *U. lactea* can be found from Korea

to the main islands of Japan; *U. arcuata* is further recorded from the Ryukyus; *U. borealis* can be found in the main islands of Japan; and *U. splendida* is rare in Dongsha (Fig. 1C-F) (Crane, 1975; Shih, 1994; Yoshigou, 2001; Shih et al., 2010a,b, 2012). According to Aoki et al. (2008), the population of *U. arcuata* in Okinawa has a different genetic structure from others, which may be caused by the founder effect instead of the dispersal caused by the Kuroshio Current.

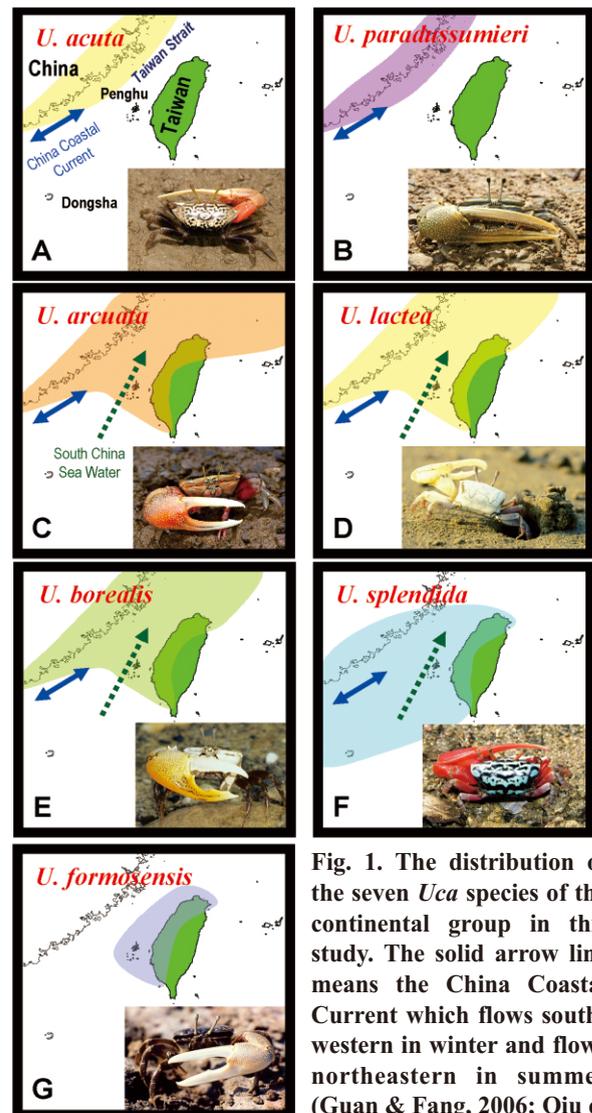


Fig. 1. The distribution of the seven *Uca* species of the continental group in this study. The solid arrow line means the China Coastal Current which flows southwestern in winter and flows northeastern in summer (Guan & Fang, 2006; Qiu et

al., 2011). The dotted arrow line means the South China Current from the South China Sea (Huang et al., 1992; Jan et al., 2002, 2010).

The seven continental species are not found in eastern Taiwan (Fig. 1), Dongsha (except *U. splendida*; Fig. 1F) or the Ryukyus (except *U. arcuata*; cf. Fig. 1C), which may not be related to the Kuroshio Current. Except for *U. formosensis*,

the distribution of the other six *Uca* species (Fig. 1A-F) may be affected by the China Coastal Current which flows southwestern in winter and flows northeastern in summer (Guan & Fang, 2006; Qiu et al., 2011), as well as the South China Sea water from SCS (Huang et al., 1992; Jan et al., 2002, 2010). Additional crustacean examples for the distribution influenced by the China Coastal Current include copepods and barnacles (Hwang & Wong, 2005; Chan et al., 2007).

3. The insular group of *Uca* species

Eight species of *Uca*, viz. *U. coarctata*, *U. crassipes*, *U. dussumieri*, *U. jocelynae*, *U. perplexa*, *U. tetragonon*, *U. triangularis* and *U. vocans* (Fig. 2A-H), can be categorized as the insular group, because they are not found in the area near the continent.

Except for *U. vocans*, the distribution of the eight species is similar because all can be found in

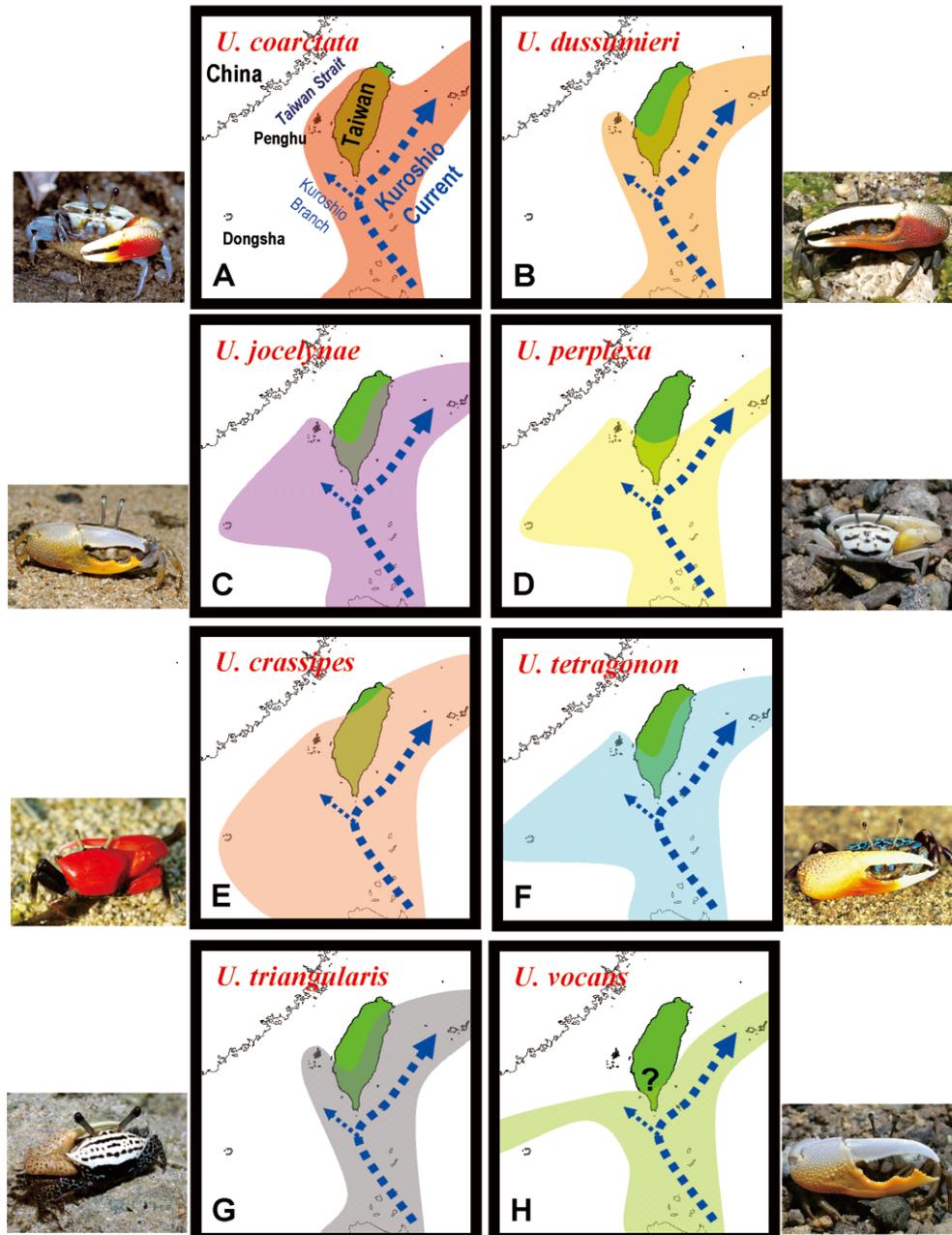


Fig. 2. The distribution of the eight *Uca* species of the insular group in this study. The thick dotted arrow line means the Kuroshio Current and the thin dotted arrow line means the Kuroshio Branch. The "?" in Fig. 2H means the distribution of *U. vocans* in Taiwan is not clear.

Penghu, Taiwan and the Ryukyus. *Uca vocans* is widely distributed in the West Pacific and eastern Indian Ocean, including the Philippines and the Ryukyus (Crane, 1975; Yoshigou, 2001). It is expected that this species can be found around Taiwan, but needs further sampling and identification (as "?" in Fig. 2H). Additional distribution includes *U. tetragonon* and *U. vocans* from Hainan (Shih et al., 2010b); and *U. crassipes*, *U. jocelynae*, *U. perplexa* and *U. tetragonon* are further recorded from Dongsha (Fig. 2C-F) (Shih, 2012).

The larval dispersal of crabs is thought to be assisted by the currents (Barnwell & Thurman, 1984; Hopkins & Thurman, 2010; López Duarte et al., 2011). The distribution of the insular group in this study is best explained by the Kuroshio Current and the Kuroshio Branch (Hsueh, 2000). The distribution of the crustacean barnacles and copepods around the East Asian islands were reported to be affected both by the Kuroshio Current and the Kuroshio Branch (Chan et al., 2007; Hwang et al., 2007).

Although some *Uca* species are widely distributed across the Indo-West Pacific, e.g. *U. coarctata*, *U. crassipes*, *U. dussumieri*, *U. jocelynae* and *U. tetragonon*, they are absent or only rarely recorded from the areas around the SCS (especially Borneo) (Crane, 1975; Shih et al., 2010a,b). Apparently there are some marine barriers preventing the larvae from entering the SCS. The above species can only be found in the eastern and northeastern parts of the SCS, including Luzon, Penghu and Taiwan, which is apparently influenced by the Kuroshio Current.

The further distribution of the insular group in Penghu and western Taiwan of Taiwan Strait can be explained by the Kuroshio Branch. The distribution generally does not include the northwestern Taiwan where the Kuroshio Branch barely extends (Jan et al., 2010) and it is reflected in the fact that nearly no insular group can be found in northwestern Taiwan (Fig. 2).

Exceptions include *U. coarctata* from the estuary of Danshuei River in northwestern Taiwan (Fig. 2A) (Ho, 1996a) and *U. crassipes* from Homei in northern Taiwan (Fig. 2E) (Ho et al., 1993; Ho, 1996b; Shih et al., 2012). The individuals collected might be from larvae transported from northeastern Taiwan (e.g. Ilan(=Yilan) County) occasionally (e.g.

typhoons) or a small branch of the Kuroshio Current as proposed by Qiu et al. (2011). There has been no additional collection recently (personal observation).

The records of the insular *U. crassipes*, *U. jocelynae*, *U. perplexa* and *U. tetragonon* from Dongsha at the northern opening of the SCS (Shih, 2012) may be related to the Kuroshio Branch (Fig. 2). However, it may also be related to the larval behavior of these species or the different requirements of the habitat of this island, because only four insular species can be found on this island. The recent finding of the continental *U. splendida* on Dongsha (Shih et al., 2012) shows the influence from the coastal current, similar to the conditions in Penghu and western Taiwan (Fig. 1).

4. Suggestion for future studies

Most geologists agree that the Kuroshio Branch enters the SCS (and Taiwan Strait) during winter, but it is open to debate as to whether the branch intrudes during summer too (Jan et al., 2002, 2010; Liang, 2003, 2008). One hypothesis being considered is that the Kuroshio Branch intrudes into Taiwan Strait directly from the Luzon Strait in summer (Jan et al., 2002, 2010). Another hypothesis supports the view that the Kuroshio Current Kuroshio loops west of Luzon Strait, with a small intruding branch confined to the northern SCS during summer; and a large intruding branch of Kuroshio extending west and into the interior of the SCS during winter (Liang, 2003, 2008).

As summer is generally the breeding season for most marine organisms, including fiddler crabs (Hopkins & Thurman, 2010), the genetic structure from the populations in the SCS (and the Taiwan Strait) may be slightly different from others, if the Kuroshio Branch cannot transport the larvae during the summer breeding season. Further studies may focus on the population genetics of the fiddler crabs on both the west and east sides of Taiwan by using high-resolution DNA markers which include the mitochondrial cytochrome oxidase subunit 1 (COI) and control region (D-loop) (Oliveira-Neto et al., 2008; Cho et al., 2009; Guo et al., 2012), as well as the nuclear internal transcribed spacer (ITS) (Chu et al., 2001, 2003; Tang et al., 2003). The

degree of genetic differentiation may reflect the effects of the Kuroshio Branch on the larval dispersal of *Uca*.

Further mechanisms for the different distribution of *Uca* species may be explained by different behavior of larvae in adaptation to the waves and the currents (Young, 1995). The behavior of larvae at different stages (zoea I to V and megalopa) are important to reveal additional clues for the detailed distribution of different *Uca* species.

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