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BICOLOR (HUTTON, 1834) (GASTROPODA:
STREPTAXIDAE) FROM THE SOCIETY ISLANDS,
FRENCH POLYNESIA

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First Records of the Invasive Predatory Land Snail *Gulella (Huttonella) bicolor* (Hutton, 1834) (Gastropoda: Streptaxidae) from the Society Islands, French Polynesia¹

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Abstract. *Gulella (Huttonella) bicolor* (Hutton, 1834), an invasive streptaxid land snail now circumtropical in distribution, is recorded for the first time from the Society Islands of French Polynesia, on the islands of Maupiti and Mo'orea, and its distribution in the islands of the Pacific is reviewed. Although its origin has been in question, previously overlooked paleontological studies indicate that *G. bicolor* is native to India. *Gulella bicolor* preys on terrestrial mollusks and its presence increases the threat of the extinction of what remains of the Society Islands' rich fauna of endemic land snails, already at risk because of anthropogenic habitat modification and the earlier introduction of other alien molluscivores.

INTRODUCTION

Gulella (Huttonella) bicolor (Hutton, 1834) is a molluscivorous land snail belonging to the family Streptaxidae native to India but is now of circumtropical distribution as a result of human commerce and that has been introduced to many of the islands of the Pacific (Naggs 1989; Solem 1989; Cowie 2002; Rowson & Herbert 2016). We report the first records of the species in the Society Islands of French Polynesia, on the islands of Maupiti and Mo'orea.

The earliest records of *G. bicolor* in the islands of the Pacific are those of Semper (1870–1894) for the Philippines, Tryon (1885) for New Caledonia, and Moellendorff (1900) for the Mariana Islands (all as *Ennea bicolor*). Subsequently, in the western Pacific it has been reported from the Ryukyu Islands (Clench 1964), Taiwan (Pilsbry & Hirase 1905), Indonesia (Bentham Jutting 1950, 1964; Vermeulen & Whitten 1998; Vermeulen 2007), Papua New Guinea (Rensch 1937; Wiktor 2003), Malaysia (Bentham Jutting 1961; Berry 1965; Vermeulen 2007; Foon *et al.* 2017; Phung *et al.* 2017); Singapore (Bentham Jutting 1961); Australia (Stanisic 1981; Solem 1989; Smith & Stanisic 1998), and the Solomon Islands (Solem 1960; Delsaerd 2016). In Micronesia it has been reported from the Republic of Palau (Smith 1993; Cowie *et al.* 1996; Rundell 2005), and the Federated

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States of Micronesia (Clench 1964; Harry 1966); recent records for the Mariana Islands are those of Clench (1964), Harry (1966), Kurozumi (1994), Bourquin (2002), Brook (2010), and Kerr & Bauman (2013). It has also been reported from Fiji (Clench 1964; Brook 2010; Brodie & Barker 2011, 2012; Brodie *et al.* 2013). In Polynesia, *G. bicolor* has previously been reported from Atafu Atoll, Tokelau (Thompson 2010), American Samoa (Cowie 1998b, 2001b; Cowie & Cook 1999; Cowie & Rundell 2002; Brook 2010), [Western] Samoa, Fanning Island (Tabuaeran) in the nation of Kiribati, Wallis Island (Uvea), and the Cook Islands (Brook 2010), the Kingdom of Tonga (Brook 2014), as well as the Austral Islands (Gargominy & Fontaine 2003, 2014) and Marquesas Islands (Clench 1964) in French Polynesia. *Gulella bicolor* was among the species intentionally introduced to the Hawaiian Islands as part of biological control efforts targeting the Giant African Snail *Lissachatina fulica* (Bowdich, 1822) (Davis & Butler 1964; Krauss 1964) and contrary to an earlier report (Cowie 1997) still survives there in small numbers (Cowie *et al.* 2008).

Although it has been suggested that the origin of *G. bicolor* lies in Africa and its outlying islands (Kobelt 1903–1905; Benthem Jutting 1961; Dundee 1974; Solem 1989; Delannoye *et al.* 2015), reports of its presence in the Pleistocene of India (Bhatia & Mathur 1973; Kotlia & Joshi 2006, 2008) confirm the conclusion of Naggs (1989), Vermeulen & Whitten (1998), and Barker & Efford (2004) that it is instead native to India. Kerr & Bauman (2013) suggested that it was introduced to the Pacific Islands prehistorically but, although a dozen or so species of terrestrial snails have been translocated into and around the islands of Micronesia, Polynesia, and New Caledonia, Vanuatu, and Fiji in eastern Melanesia (Remote Oceania in the sense of Green 1991) by Pacific islanders prior to European contact (Christensen & Weisler 2013), there is no archaeological or other evidence to support such a claim for *G. bicolor*.

METHODS

Since 2011 JGK has been conducting a series of multidisciplinary studies of human impact on the island of Mo'orea and Maupiti in the Society Islands (e.g., Dotte & Kahn 2017; Kahn *et al.* 2015a, 2015b; Stevenson *et al.*, in press). One of the techniques used is the analysis of nonmarine mollusks recovered by flotation or wet-screening of soil samples obtained during the archaeological excavations (Christensen *et al.*, in press). Land snails so obtained were identified by reference to the malacological collection of the Bernice P. Bishop Museum in Honolulu, Hawaii (BPBM), and voucher specimens of the species discussed here will be deposited in that collection and in that of the Muséum National d'Histoire Naturelle, Paris, France (MNHN).

RESULTS

The following specimens of *G. bicolor* were obtained: **Maupiti Island:** Teahutapu, S16.450°, W152.275°, archaeological site MAU-1, TP1 A2, obj. 4, J.G. Kahn, 2012 (BPBM 279625, 1 spm.); same, TP1 C1, obj. 4, J.G. Kahn, 2012 (BPBM 279647, 1 spm.); same, TP1 C2, obj. 3, J. G. Kahn, 2012 (BPBM 279651, 2 spms.); **Mo'orea Island:** Haumi Beach, S17.575°, W149.791°, archaeological site ScMo-350, N95E 116 A2, obj. 6, J.G. Kahn, 18 July 2014 (BPBM 277198, 1 spm.). Detailed archaeological reports of both sites have been published elsewhere (Kahn 2012a, 2014a, 2016).

DISCUSSION

In light of the numerous prior records of *G. bicolor* from Pacific islands its appearance in the Society Islands is not unexpected and would perhaps occasion little comment were it not for the potential threat that its establishment poses to the survival of the islands' unique native land snail fauna. Like most of the volcanic high islands of Polynesia, the Society Islands originally hosted a remarkably diverse fauna of native land snails (Garrett 1884). The tree snails of the family Partulidae are best-known because of their significance in genetic research (e.g., Crampton 1916, 1932; Clarke & Murray 1969; Murray & Clarke 1980; Goodacre 2001), but other families, especially the Achatinellidae, Vertiginidae, Endodontidae, Charopidae, Helicarionidae, and Zonitidae, contain numerous endemic species (Baker 1938, 1940, 1941; Cooke & Kondo 1961; Solem 1976, 1983; Gargominy 2008). Unfortunately, many of these have become extinct since initial settlement of these islands some 1,000 years ago (Allen 2014; Kahn 2012b, 2014b, Kahn & Sinoto 2017, Stevenson *et al.*, in press) as a result of anthropogenic landscape change (Orliac 1997; Christensen *et al.*, in press) and the introduction of alien predators.

Gulella bicolor is a predator of land snails that attacks by extending its elongate body into the aperture of the shell of its prey (Wada & Chiba 2013). It feeds on small land snails such as subulinids and pupillids (Mead 1961; Barker & Efford 2004), and accordingly its use as a biocontrol agent has been suggested (Krauss 1964; Srivastava 1968; Mead 1979; Naggs 1989). *Gulella bicolor* will also prey on the young of larger species such as *Lissachatina fulica* (Williams 1951; Mead 1961), although because of its small size (shell height ca. 6 mm) it is not regarded as a threat to the survival of larger snail species such as *Partula* (United States Department of the Interior, Fish and Wildlife Service [USFWS] 2016). Nevertheless, although *G. bicolor* has not yet been shown to adversely affect the native land snails of the islands to which it has been introduced (USFWS 2016) numerous authorities have expressed concern that its establishment in the Pacific could adversely impact native land snail species (Solem 1989; Smith & Stanisic 1998; Brook 2010; Brodie & Barker 2011, 2012).

The introduction of alien terrestrial mollusks to the islands of Remote Oceania began during the prehistoric period (Christensen & Weisler 2013), and its pace has accelerated since the initiation of Western contact in the 18th century AD (Cowie 2000; Régnier *et al.* 2015). Because of human-induced habitat destruction and the effects of non-native predators, native land snail faunas throughout tropical Polynesia are rapidly being replaced by an assemblage dominated by alien snails and slugs (Cowie 1997, 2000, 2001a, 2001b, 2002), some of which, like *G. bicolor*, are predators that pose a direct threat to native taxa. Most prominent among these is the land snail generally known as *Euglandina rosea* (Férussac, 1821), although a recent study (Meyer *et al.* 2017) indicates that more than a single species may be involved. *Euglandina rosea*, a North American spiraxid, is a large snail with a shell length often in excess of 60 mm (Pilsbry 1946) which was intentionally introduced to the Hawaiian Islands in the mid-1950s in an ill-advised biocontrol program targeting the Giant African Snail *Lissachatina fulica* (Bowdich, 1822) (Mead 1961, 1979; Schalie 1969), formerly known as *Achatina fulica*. One or more species of *Euglandina* were subsequently introduced to the Society Islands and numerous other locations in the Pacific and beyond (Meyer *et al.* 2017). These highly efficient predators have been a major factor in the extinction of the region's partulids and other native land snail species (Tillier & Clarke 1983; Clarke *et al.* 1984; Coote & Loève 2003; USFWS 2016). Because of its impact on non-target organisms and its ineffectiveness against its intended target

(Christensen 1984; Civeyrel & Simberloff 1996; Cowie 2001a; Meyer *et al.* 2017), the introduction of *Euglandina* to the Pacific islands is perhaps the world's best-documented case of a modern biocontrol program gone horribly wrong.

Another major predator on the native snails of the Society Islands, probably second in importance only to *Euglandina*, is the flatworm *Platydemus manokwari* De Beauchamp, 1963, which has been reported from Mo'orea (Lovenburg 2009) and Tahiti (Justine *et al.* 2015) and probably occurs throughout the archipelago. *Platydemus manokwari* has been implicated in the extinction of native land snail species elsewhere in the Pacific (Hopper & Smith 1992; Ohbayashi *et al.* 2007; USFWS 2016). Like *E. rosea*, *P. manokwari* has become established on a number of Pacific islands (Justine *et al.* 2015), sometimes being introduced intentionally as an agent for the biological control of the Giant African Snail (Muniappan *et al.* 1986; Muniappan 1990; Cowie & Cook 1999; Winsor *et al.* 2004; USFWS 2016) notwithstanding the clear threat its introduction poses to the region's native land snail fauna.

Several other molluscivorous land snail species have also become established in Remote Oceania, either as inadvertently transported species [the streptaxid *Streptostele musaecola* (Morelet, 1860) and the zonitid *Oxychilus alliarius* (Miller, 1822)] or as intentionally introduced biocontrol agents [streptaxids *Gonaxis kibweziensis* (Smith, 1894) and *G. quadrilateralis* (Preston, 1910)]. *Streptostele musaecola* has been reported from Tahiti (Solem 1989) and undoubtedly occurs elsewhere in the Society Islands. Similar in size to *G. bicolor*, it is probably of less concern than *Euglandina* spp. and *P. manokwari*, but like *G. bicolor* must be recognized as potential threats to the native land snails of the Society Islands. Thus far the range of *O. alliarius* in tropical Oceania is limited to the Hawaiian Islands (Meyer & Cowie 2010; Curry & Yeung 2013; Curry *et al.* 2016). *Gonaxis kibweziensis* and *G. quadrilateralis* have been introduced to a number of Pacific islands as part of biocontrol efforts targeting the Giant African Snail (Mead 1979; Cowie 2000) but have not become established in the Society Islands or other Pacific islands where they have not been intentionally introduced.

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