



Research paper

## Indications of parthenogenesis and morphological differentiation in Hawaiian intertidal *Fortuynia* (Acari, Oribatida) populations



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## ABSTRACT

*Fortuynia hawaiiensis* n. sp. represents a new species occurring on the archipelago of Hawaii. The complete absence of males from all Hawaiian samples points to thelytokous parthenogenetic reproduction in this species. This reproductive mode may have evolved in *F. hawaiiensis* n. sp. because it reduces costs of producing males, mate finding and sperm transfer in the extreme conditions of intertidal environments and it facilitates the colonization of new islands. Despite the clonal population structure and the slow evolutionary rate of this species, morphometric analyses demonstrate that populations from different Hawaiian Islands already show slight morphological divergence with the specimens from Maui being by trend the smallest.

A morphometric comparison with other *Fortuynia* species revealed that *F. hawaiiensis* n. sp. and *Fortuynia maledivensis*, both supposed parthenogens, show less intraspecific variability than the sexually reproducing *Fortuynia atlantica*. This may be caused by the narrow and generalized genotypes of the two presumably asexual species. Based on morphometric data and on discrete characters, a close relationship of *F. hawaiiensis* n. sp. with *F. maledivensis* is indicated and hence both species are assumed to be members of a recently evolved Indo-Pacific parthenogenetic lineage.

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### 1. Introduction

The family Fortuyniidae belongs to the mainly marine associated Ameronothroidea and contains three genera, *Alismobates*, *Circellobates* and *Fortuynia*, all together including 18 species. Apart from a single species, namely *Fortuynia smiti* Ermilov, Tolstikov, Mary & Schatz, 2013 which was also found in freshwater habitats of oceanic islands (Ermilov et al., 2013), all other species exclusively inhabit the intertidal zone of marine coasts (Pfingstl, 2015a) and hence are classified as typical thalassobiontic organisms. They show a transoceanic distribution but are confined to subtropical and tropical climate zones (e.g., Pfingstl and Schuster, 2014). The genus *Fortuynia* is the largest taxon of this family with 14 known species. A recent study (Pfingstl, 2015a) demonstrated that all *Fortuynia* species show a homogeneous morphology although they occur on coasts of different oceans of the world as well as on very remote islands. The reason for the lack of morphological diversity is supposed to be the shared ecological preference for similar or even equal niches within intertidal environments (Pfingstl, 2015a). Despite this

morphological and ecological homogeneity, a distinct sexual dimorphism has evolved in some *Fortuynia* species. Males of *Fortuynia yunkerii* Hammen (1963) show modifications on leg IV, males of *Fortuynia atlantica* Krisper and Schuster (2008) possess certain lanceolate notogastral setae, enlarged notogastral porose areas and a pair of obvious lateral protuberances on the notogaster, and *Fortuynia dimorpha* Pfingstl, 2015 males exhibit a completely porose posterior gastronomic region and certain elongated notogastral setae (Pfingstl, 2015b). The reason and function of these different types of sexual dimorphism are yet unknown but some kind of associative mating may be involved allowing rapid mate location and sperm transfer during the short time frame between low and high tide (Pfingstl, 2015b).

Although many *Fortuynia* species occur on remote oceanic islands and archipelagos, little is known about how they have reached these secluded environments and how they have evolved there. A few early studies (e.g., Jacot, 1934; Hammer, 1982) discussed possible ways of dispersal and later investigations (e.g., Coulson et al., 2002; Pfingstl, 2013a) demonstrated that these and other mites are able to survive prolonged periods submerged in seawater and concluded that dispersal via ocean currents is the most likely mode of long distance transport. Studies investigating diversification and speciation processes in intertidal oribatid mites colonizing isolated islands are more or less completely lacking.

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Fortuyniidae were recently recorded from Hawaii (Pfingstl and Schuster, 2014) and this archipelago represents such isolated islands as they lie in the middle of the Pacific Ocean with a distance of more than 4,000 km to the closest continental landmass, namely North America. The geological history of this archipelago is well documented and shows that the single islands have emerged subsequently over a period of approximately 30 Ma years (e.g., Price and Clague, 2002). This geological and geographic setup provides a fertile ground for investigating evolutionary patterns. The specimens from Hawaii were now comprehensively studied and turned out to be members of a new and possibly parthenogenetic species. The aim of the present paper is to give detailed morphological data, investigate morphological differentiation among Hawaiian populations from different islands and discuss their possible parthenogenetic reproduction and biogeographic origin. Additionally, the detected intraspecific variation is compared with that of a single population of *Fortuynia maledivensis* Pfingstl, 2015 another possible parthenogenetic species from the Maldives, and with that of populations of the sexually dimorphic *Fortuynia atlantica* from the archipelago of Bermuda in order to elucidate patterns of variability related to the reproductive mode.

## 2. Material and methods

### 2.1. Sample collection

Samples of intertidal algae were scraped off with a knife from intertidal rocks during low tide and afterwards put in a Berlese–Tullgren apparatus on-site in order to extract the mites.

(a) *Fortuynia hawaiiensis* n. sp., six populations from different islands (Fig. 1): (1) RS-2000 Oahu, north coast, Turtle bay, July 1994; (2) RS-2001 Hawaii/Big Island, west coast, near Kona Reef Hotel, July 1994; RS-2002, Hawaii/Big Island, west coast, south of National Historical Park “Pu’uhonua o Hōnaunau”, July 1994; (3) RS-2003 Kauai, north coast, near Kilauea Lighthouse, August 1994; (4) RS-2004 Kauai, west coast, north of Kealia, August 1994; (5) RS-2005 Maui, northwest coast, close to Honolua, August 1994 and (6) RS-2006 Maui, west coast, near Kaanpali, August 1994; all Hawaiian samples leg. R. Schuster. Only female specimens were found on the above listed Hawaiian Islands.

(b) *Fortuynia maledivensis*: Maldives, Malé atoll, Island of Villingili, 8 Feb. 1983, coll. W. Fiala, leg. R. Schuster.  
(c) *F. atlantica*: Bermuda, Concrete Beach, Devonshire Bay and Gunner Bay; collected on various occasions in the years 2011 and 2012; leg. T. Pfingstl.

### 2.2. Microscopic preparation

For detailed morphological observations and drawings, animals stored in ethanol (70%) were embedded in Berlese mountant. In order to perform morphometric measurements specimens were heated in lactic acid (approx. 60 °C for about 24 h) and then put into temporary slides. Drawings and measurements were made with an Olympus BH-2 Microscope equipped with a drawing attachment and an ocular micrometre. Labeling of drawings was done according to Grandjean (1966, 1968).

### 2.3. Morphometric analyses

For the investigation of intraspecific variation of the new species *F. hawaiiensis* n. sp., samples pooled in four different island populations were analyzed: (1) population “Oahu” (RS-2000,  $n = 15$ ), (2) population “Hawaii” (RS-2001 and RS-2002,  $n = 28$ ), (3) population “Kauai” (RS-2003 and RS-2004,  $n = 15$ ), (4) population “Maui” (RS-2005 and RS-2006,  $n = 10$ ) (see Fig. 1). For the investigation of species distinctness as well as morphological variation between supposed parthenogenetic and sexually reproducing *Fortuynia* species we further analyzed a population of the supposed parthenogenetic *F. maledivensis* ( $n = 37$ ) and populations of the sexually dimorphic *F. atlantica* ( $n = 14$ , only females were used in order to exclude variation caused by sexual dimorphism). The four Hawaiian populations were pooled for this comparison.

Fourteen continuous variables were measured (Fig. 2). Mean, standard deviation and coefficient of variation (CV) were calculated, and Kruskal–Wallis and Mann–Whitney  $U$  test were used for comparing the means of variables between all groups and for pairwise comparisons, respectively. Multivariate analyses were performed on  $\log_{10}$ -transformed raw and size-corrected data. Size correction was done by dividing each variable through the geometric mean of the respective specimen as described for example in Jagersbacher-Baumann (2014). Principal Components

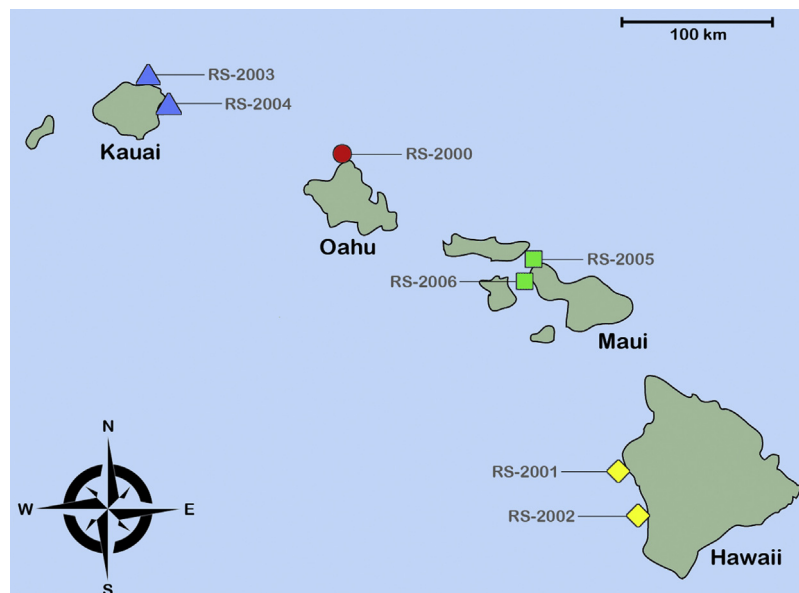


Fig. 1. Distribution of sampled *Fortuynia hawaiiensis* n. sp. populations on the Hawaiian archipelago.

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