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Craig Tepper

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Ronald Shaklee

Conference Organizer

Thomas Rothfus

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FIRST RECORD OF *COPULA SIVICKISI* (CNIDARIA: CUBOZOA) IN THE TROPICAL WESTERN ATLANTIC OCEAN: AN ENIGMATIC OCCURRENCE FROM SAN SALVADOR ISLAND, BAHAMAS.

Courtney L. Bennett, Matthew D. Nicholson and Robert B. Erdman
Department of Biological Sciences
Florida Gulf Coast University
10501 FGCU Blvd. South
Ft. Myers, FL 33965

ABSTRACT

Copula sivickisi is a small cubozoan most noted for its sexual dimorphism, courtship behavior, and the presence of adhesive pads on its exumbrellar surface, all of which are unique to the family. This species has only been previously documented from the Indo West-Pacific tropical region. We report the first occurrence of *C. sivickisi* from the tropical Western Atlantic Ocean. Two males were collected by night lighting in near shore waters in Graham's Harbor, adjacent to the Gerace Research Centre on San Salvador Island, Bahamas in June 2010. The presence of this species in the Western Atlantic poses the following questions: Does this occurrence indicate a historically isolated cryptogenic population, a truly circumtropical distribution, or is this a result of a recent anthropogenic introduction?

INTRODUCTION

The class Cubozoa comprises approximately 40 species of box jellyfish including the high profile and dangerous sea wasp *Chironex fleckeri* (WoRMS, 2011). Although recent studies have focused on toxicity, nematocyst structure and the configuration of complex camera-type eyes associated with rhopalia, other studies have examined the sexual dimorphism and complex courtship and mating behavior that are exhibited by some species of this class (Bentlage et al., 2010; Lewis and Long 2005; Lewis et al., 2008). While unique evolutionary features have been recognized in Cubozoans, many species are still poorly described due to the paucity of comprehensive ecological data.

Copula sivickisi (Stiasny, 1926) is a small, sexually dimorphic cubozoan best known for its unique courtship behavior and internal fertilization (Lewis and Long, 2005; Lewis et al., 2008). As with all carybdeids, it is characterized by a single tentacle on each of the interradial pedalia. This species also exhibits four exumbrellar apical adhesive pads used to attach to benthic substrates (i.e. macroalgae and seagrasses) during the day (Figure 1; Figure 2) (Hartwick, 1991). The presence of the adhesive pads appear to be unique to *Copula* and are the criteria used by Bentlage et al (2010) to designate this genus as distinct from all other cubozoan genera.

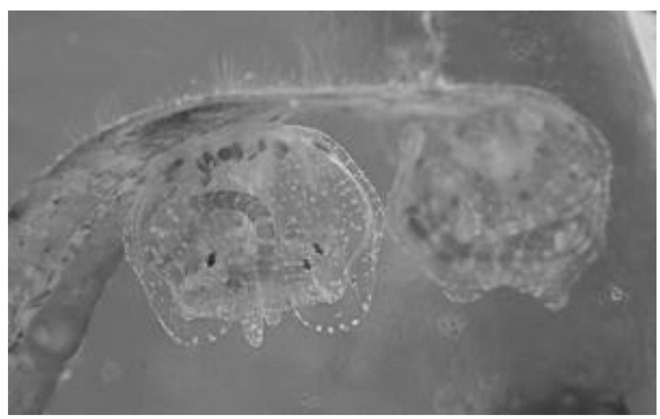

Figure 1. Two male C. sivickisi from San Salvador Island, Bahamas attached to a blade of Thalassia testudinum during the day with tentacles in a "tucked" position - C. Bennett photo.

We report on the first occurrence of *C. sivickisi* from San Salvador Island, Bahamas. Previous records for this species indicate an Indo-West-Pacific (IWP) distribution, which makes this occurrence in the tropical Western Atlantic (WA) somewhat perplexing. We also propose three explanations that may account for this new finding.

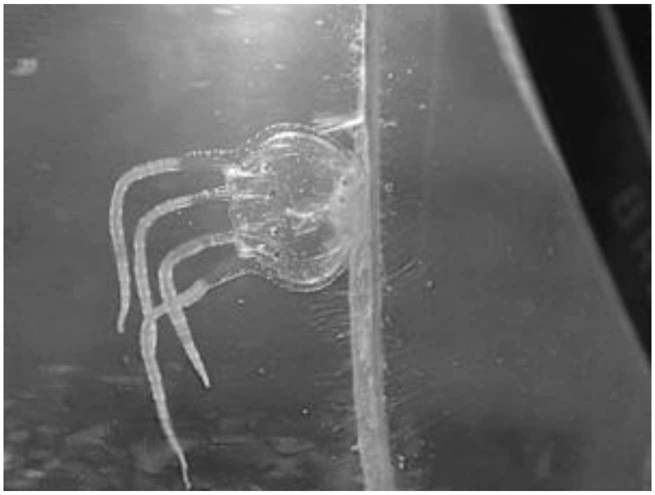

Figure 2. Male C. sivickisi from San Salvador Island, Bahamas attached to a blade of Thalassia testudinum during the day with tentacles in a relaxed position - C. Bennett photo.

MATERIALS AND METHODS

Environmental Setting

San Salvador Island is one of the easternmost islands of the Bahamas and is isolated from the Bahamas Bank by waters up to 4000 m in depth. The island is surrounded by a series of incomplete fringing reefs with numerous near shore patch reefs. Grahams Harbor on the northern tip of the island is protected to the north by a well-developed fringing reef and is open to deeper waters to the west. This large shallow embayment contains scattered patch reefs and extensive sea grass beds (Gerace et al., 1998).

Specimen Collection

Two male *C. sivickisi* were collected while night lighting from near shore waters in Graham's Harbor, directly adjacent to the Gerace Research Centre in June 2010. Specimens were maintained in ambient seawater for laboratory observation and relaxed in 5% ETOH before preservation in 80% ETOH. Samples were shipped to the U.S. National Museum of Natural History for further analysis and curation.

DISCUSSION

Previous records of *C. sivicksi* indicate a broad IWP tropical and subtropical distribution (Figure 3) with the eastern most record from Hawaii (Matsumoto et al., 2002) and the westernmost from the Gulf of Siam (Stiansy, 1922). The occurrence of this species in the tropical WA is enigmatic for which several explanations are plausible. Does this occurrence indicate a truly circumtropical distribution, a historically isolated cryptic population, or is this a result of a recent anthropogenic introduction?

The circumtropical distribution of marine species suggests a long distance dispersal ability of larvae and adults that is unaffected by longitudinal climate restrictions. However, the latitudinal distribution of most shallow water marine tropical species is restricted by large scale temperature barriers that coincide with oceanic gyre patterns. Although broad scale longitudinal patterns of distribution would seem highly probable in the tropics, there is a conspicuous absence of homogenous distributions. The majority of tropical species and genera are concentrated into four longitudinal biogeographical regions: the IWP, Eastern Pacific, WA, and Eastern Atlantic (Briggs, 1974; 2007).

The IWP is generally recognized as the major tropical center of origin with faunal abundance over 2.5 times that of the WA, the region with the second highest level of biodiversity. Within the IWP, the richest region is the East Indies Triangle (Figure 3), proposed to be the origin of species that have undergone successful dispersal westward across the Indian Ocean and into the tropical Atlantic (Briggs, 2007). While it is plausible that *C. sivickisi* may exhibit a broad longitudinal distribution, the absence of additional distribution data hampers the ability to assess this explanation.

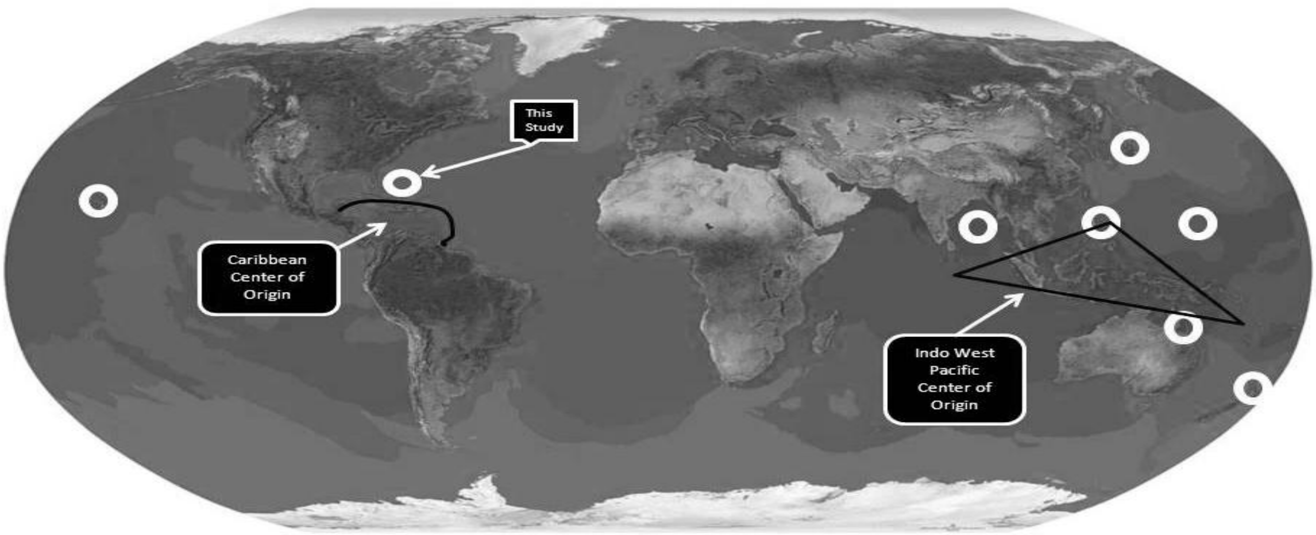

Figure 3. Geographical representation of previous occurrences of C. sivickisi in the IWP and the first occurrence in the WA along with approximate boundaries of the Indo West Pacific and Caribbean centers of origin (Briggs, 2007).

Cryptic marine species, otherwise known as sister species, are characterized as morphologically indistinguishable from each other, with divergent molecular patterns that prevent reproduction of fertile, viable offspring (Knowlton, 1993; 2000). The idea of the cryptic marine invertebrate has been rapidly gaining attention as more scientists are recognizing the possibility of different speciation pressures in the sea as opposed to terrestrial environments (Knowlton, 1993).

The existence of cryptic populations of marine invertebrates is a common phenomenon in geographically isolated populations as small population size and lack of gene flow across ocean basins and through land masses promote the beginnings of speciation. Similarly, this occurrence of *C. sivickisi* is separated from all other documented populations by both great distances and geographical obstacles (Figure 3). While Bentlage et al. (2010) presents evidence for at least one oceanic cubozoan species, life cycle restrictions relieve most cubozoans of the ability to traverse ocean basins. Based on these premises, it is unlikely that gene flow naturally occurs between the IWP and WA populations of *C. sivickisi*, and further increases the likelihood of a cryptic WA population. However, at this time it is impossible to tell how long this population has been separated and what genetic divergences may have taken place (Bentlage et al., 2010).

Most cubozoans inhabit near shore environments and, with the exception of the Alatinidae, are unlikely to cross open ocean habitats (Bentlage et al., 2010). However, due to anthropogenic influences, once insurmountable obstacles (i.e. open oceans) have been overcome. Since 1790, there have been 298 recorded marine invasions in North America, with 51% linked to the shipping industry (Ruiz et al., 2000). Over 30% of reported North American introduced species are native to the IWP, and the rate of invasions has steadily increased (Ruiz et al., 2000). With exception to this most recent record, all other documented occurrences of *C. sivicksi* are from the IWP (Figure 3), an area that is home to many major shipping ports.

The most common mechanism of transport for pelagic marine species is the release of ships ballast water collected from the export site, yet an organism's entry into the ballast water of a ship or equally viable vector does not ensure a successful invasion; there are multiple factors that could lead to failure of establishment (Briggs, 2007). Carlton (1996) suggests six scenarios that could have major effects on the potential for a successful invasion: changes in donor regions (the area from which the organisms came from before being transplanted), new donor regions, changes in recipient regions (endpoint of the invasion), invasion windows, stochastic inoculation events, and changes in dispersal vectors. Fluctuations in any or all of the previously mentioned factors could have a major impact on whether a successful invasion occurs. Although the mechanism of introduction of *C. sivickisi* into the WA may never be clear, anthropogenic influences cannot be ruled out.

With the addition of *C. sivickisi*, the number of cubozoans reported from the tropical WA is increased to 7 species including: *Alatina alata*, *Carybdea marsupialis*, *Chiropsalmus quadrumanus*, *Tamoya haplonema*, *Tamoya ohboya*, and *Tripedalia cystophora*. (Bentlage et al., 2010; WoRMS 2011). Based on current distribution records, five of the seven species are endemic to the WA with a report of *Tripedalia cystophora* from one locale in the Indian Ocean and a wider sub-tropical and tropical Pacific distribution of *C. sivickisi* (Bentlage et al., 2010). Although the material collected in this study is currently undergoing morphological and genetic analysis, the details that facilitated the presence of this species in the WA are yet to be determined.

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