

Update and Revisions of *The Marine Bioinvasions of Hawai‘i: the Introduced and Cryptogenic Marine and Estuarine Animals and Plants of the Hawaiian Archipelago*

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Abstract. This paper provides a revised and updated assessment of the non-native and cryptogenic marine and estuarine biota of the six largest Hawaiian islands from Kaua‘i to Hawai‘i. Carlton & Eldredge (2009) reported 301 introduced and 117 cryptogenic marine and estuarine species in the Hawaiian Islands. We report an additional 32 introduced and 25 cryptogenic species for the Hawaiian marine fauna and flora, along with a Caribbean box jellyfish, whose establishment is uncertain. Four species (the sponge *Tedania ignis*, the hydroid *Eudendrium capillare*, the nematode *Spirocamallanus istiblenni*, and the copepod *Haplostomides hawaiiensis*) previously regarded as cryptogenic are now treated as introduced, while two species (the sponge *Monanchora dianchora* and the copepod *Psammopsyllus* sp.), previously treated as introduced, are now considered cryptogenic. One vector-intercepted species (the ascidian *Symplegma reptans*) incorrectly previously listed as introduced is deleted, and 11 species of green algae (10 cryptogenic and 1 introduced) are also deleted, unsupported by subsequent taxonomic analysis. The net change to the non-native and cryptogenic inventory is thus an additional 32 and 13 introduced and cryptogenic species, respectively, for a total of 463 species (333 introductions and 130 cryptogens) that are either non-native or candidates for such in the Hawaiian marine biota.

Introduction

Carlton & Eldredge (2009), in a study largely completed in 2008, reported 301 introduced and 117 cryptogenic marine and estuarine species in the Hawaiian Islands. We provide here an updated and revised picture of the non-native and cryptogenic marine and estuarine biota of the six largest islands from Kaua‘i to Hawai‘i. Newly added introduced and cryptogenic species are based on published literature, either previously overlooked or published since Carlton & Eldredge (2009). The locations of voucher (museum) material of these additional species are provided in the papers cited. In addition, we clarify, update, or correct some earlier records, and delete from the Hawaiian biota certain species mistakenly interpreted either by us or in the literature as established invasions. We further consider name changes and additional locations as these have come to our attention.

We use the notation “Introduced (addition)” and “Cryptogenic (addition)” to indicate taxa that we now add to the register of non-indigenous and cryptogenic salt-water or maritime species in the Hawaiian Islands. Most of the introduced species were first collected before 2008. Some species were first collected between 2008 and 2010, but were almost certainly present earlier and overlooked. We know of no species that have newly invaded Hawaiian marine ecosystems in the past 5 to 6 years, a phenomenon we comment on in the Discussion.

Systematic Account of Introduced and Cryptogenic Species

FUNGI

A number of species of marine fungi, particularly lignicolous taxa found in the Hawaiian Islands and recorded elsewhere (Gareth-Jones *et al.* 1976), remain to be evaluated for their geographic origin. We add one species to the two mangrove-associated fungi treated by Carlton & Eldredge (2009), but predict that additional species will be found to have been introduced.

Xylomyces rhizophorae Kohlmeyer & Volkmann-Kohlmeyer, 1998 **Introduced (addition)**

Kohlmeyer and Volkmann-Kohlmeyer (1998) first collected this Western Atlantic species “between 1970 and 1992” in the Hawaiian Islands, and described it in part on the basis of material collected in 1992 from He‘eia State Park, Kāne‘ohe Bay, O‘ahu, from the intertidal roots of the red mangrove *Rhizophora mangle*, also introduced from the Atlantic.

CILIOPHORA

(ciliates)

Chonotrichida

Lobochona insularum Matsudo & Mohr, 1964 **Introduced (addition)**

This ectocommensal ciliate was described as a new species living on the pleopods of the introduced Indo-Pacific boring isopod *Paralimnoria andrewsi*. It was first reported from the Hawaiian Islands by Mohr *et al.* (1963) as *Lobochona prorates*, but recognized the next year as a distinct species. Collections were made by Bayard McConnaughey in 1940 in Waikīkī, O‘ahu. It is doubtless still present.

PORIFERA

(sponges)

Recognition of non-native sponges in the fouling communities of Hawaiian harbors and estuaries remains vexing (van Soest *et al.*, 2012), as the systematics and historical biogeography of many taxa throughout the Indo-West Pacific remain obscure. Genetic analyses will be required to resolve many identifications of species and species-groups. This said, it is critical to not default to the assumption that marine sponge distributions are natural throughout the Indian and Pacific Oceans, in the absence of clear evidence of introduction by human activities. Given the many centuries of ship traffic throughout the Indo-Pacific, many species must be viewed as cryptogenic, especially those clearly susceptible to transport by ship fouling, in aquaculture products, or by other vectors (Carlton 2009).

Recent published work has revealed a plethora of additional bay- and harbor-dwelling sponges in the Hawaiian Islands. Several of these have such remarkably disjunct distributions, and have not been reported from intervening locations across the Pacific, that we tentatively consider them as introductions, noting the *caveat* above. One species, the Caribbean *Tedania ignis*, moves from cryptogenic to introduced status as discussed below. All general distributions given below are from van Soest *et al.* (2014) unless otherwise indicated.

Class Demospongiae

Order Hadromerida

Suberitidae

Protosuberites epiphytum (Lamarck, 1815) **Introduced (addition)**

Calcinai *et al.* (2013) reported this Australian species encrusting the introduced octocoral *Carijoa riisei* from shallow water on O‘ahu in 2003, 2006, and 2007 samples. Given how long this species has been recognized in the Australian fauna, and its absence in numerous surveys of sponge faunas across the Pacific, we regard this as an introduction.

Prosuberites oleteira* de Laubenfels, 1957 **Cryptogenic (addition)*

Lim *et al.* (2009) reported *Prosuberites oleteira* in Singapore fouling communities. This suggests that this species, originally described from Pearl Harbor (1948, with an additional record of that date off Diamond Head), must be viewed as cryptogenic in the Islands.

Order Halichondrida**Halichondriidae*****Topsentia halichondrioides* (Dendy, 1905) **Cryptogenic (addition)****

Coles *et al.* (2009) reported this Indo-Pacific species from Pearl Harbor (2007) and Honolulu Harbor (2008).

Scopalinidae***Scopalina* sp.****Cryptogenic (addition)**

Scopalina species occur in both the Atlantic and Pacific Oceans. This unidentified taxon was collected in Honolulu Harbor in 2008 (Coles *et al.* 2009)

Callyspongiidae***Callyspongia (Callyspongia)* sp.****Cryptogenic (addition)**

Calcinai *et al.* (2013) recorded this species from O'ahu at 30 m collected in 2005 and 2007, growing on the octocoral *Carijoa riisei*. Carlton & Eldredge (2009) noted another callyspongiid, but in a different subgenus.

Chalinidae***Cladocroce burapha* Putchakarn, de Weerd, **Cryptogenic (addition)****

Sonchaeng & van Soest, 2004

This Gulf of Thailand species was collected in Pearl Harbor in 2007 (Coles *et al.* 2009) and in Kāne'ohe Bay in 2006 (S. Coles, pers. comm. 2010).

Order Poecilosclerida**Chondropsidae*****Batzella aurantiaca* (Lévi, 1958)****Introduced (addition)**

A Red Sea (Calcinai *et al.* 2013) and Madagascar (Vacelet & Vasseur 1971) species, this sponge was first collected in the Islands in 2007 in Shark's Cove on the north shore of O'ahu in shallow water (Calcinai *et al.* 2013). We tentatively consider it introduced, based on this vast disjunct distribution.

Coelosphaeridae***Lissodendoryx similis* Thiele, 1899****Cryptogenic (addition)**

A widespread Indo-Pacific sponge first collected in Pearl Harbor in 2008 (Coles *et al.* 2009).

Desmacellidae***Biemna fistulosa* (Topsent, 1897)****Cryptogenic (species resolution)**

Beginning in 1996, a *Biemna* sp. was reported from a number of locations around O'ahu. Although originally identified as *B. fistulosa*, this identification was subsequently questioned (Carlton & Eldredge 2009). Calcinai *et al.* (2013) restored this identification for O'ahu material of this widespread Indo-Pacific species.

Iotrochotidae***Iotrochota purpurea* (Bowerbank, 1875)****Cryptogenic (addition)*****Iotrochota baculifera* Ridley, 1884****Cryptogenic (addition)**

These Indo-Pacific species were first collected in 2008 in Pearl Harbor (*I. purpurea*) and Honolulu Harbors (both species) (Coles *et al.* 2009).

Mycalidae***Mycale (Carmia) phyllophila* Hentschel, 1911 **Cryptogenic (addition)****

A widespread Indo-Pacific species collected in 2008 in Pearl Harbor (Coles *et al.* 2009).

Mycale (Aegogropila) cf. M. lilianae* **Cryptogenic (addition)*

Carballo & Hajdu, 1998

This Brazilian species was collected in 2003 and 2007 in shallow water on the octocoral *Carijoa riisei* (Calcinai *et al.*, 2013). Calcinai *et al.* (2013), while finding the Brazilian population (including paratypes) and Hawaiian material to be a close match, hesitated to confirm the identification, because of it being “unlikely that the Hawaiian and the Brazilian specimens are conspecific with such a disjunct distribution” (unless, of course, this species was introduced from Brazil).

Mycale (Carmia) cf. M. toxifera* (Dendy, 1896) **Cryptogenic (addition)*

Another species epibiotic on *Carijoa riisei*, this Australian sponge was collected in 2005 and 2007 in shallow water in Shark’s Cove, on the north shore of O’ahu (Calcinai *et al.* 2013). We demur from assigning this species an introduced status because of the tentative nature of the identification, based in part on the poor condition of the Hawaiian material examined by Calcinai *et al.* (2013).

Crambeidae***Monanchora clathrata* Carter, 1883 **Cryptogenic (addition)****

This Indo-Pacific sponge was collected in Pearl Harbor in 2008 (Coles *et al.* 2009).

Monanchora dianchora* de Laubenfels, 1935 **Cryptogenic (previously Introduced, and species resolution)*

Carlton & Eldredge (2009) noted a *Monanchora* sp. in Honolulu Harbor and Ke’ehi Lagoon (collected in 1997, and initially identified as *Neofolitispa unguiculata*). Coles *et al.* (2009) identified this as the Indo-Pacific *M. dianchora* based on 2008 collections.

Monanchora quadrangulata* (Lévi, 1958) **Introduced (addition)*

A Red Sea species collected in 2005 at a popular dive site, a shipwreck (the fuel boat *Yo-257*) off Waikīkī in 30 meters, growing on *Carijoa riisei* (Calcinai *et al.*, 2013). The distribution appears to be too disjunct to be natural.

Tedaniidae***Tedania ignis* (Duchassaing & Michelotti, 1864) **Introduced (previously Cryptogenic, and species resolution)****

Referred to as the Indo-Pacific species *Tedania reticulata* by Carlton & Eldredge (2009), Calcinai *et al.* (2013) returned the identification of this Hawaiian population to the Caribbean *Tedania ignis*, under which name it was earlier treated by de Laubenfels (1950) and Bergquist (1967). It is thus a member of the introduced Caribbean element in the Hawaiian fauna.

Raspailiidae***Raspailia (Clathriodendron) darwinensis* **Introduced (addition)****

Hooper, 1991

An Australian species collected in 2008 in Pearl and Honolulu Harbors (Coles *et al.* 2009). As with the Australian *Protosuberites epiphytum* (above), the lack of reports of this species in intervening localities suggests an introduced status.

CNIDARIA
Class Hydrozoa
 (hydroids)

Oceaniidae***Corydendrium parasiticum* (Linnaeus, 1767) Introduced (addition)**

Coles *et al.* (2009) discovered this species, of unknown origin but now circumglobal in warm waters, in Pearl Harbor fouling communities in 2008. Independently, Calder (2010) reported it from Pearl Harbor based on Bishop Museum collections from a “boat in drydock, 5.iv.1950.” The location, position (drydock) and date (5 April 1950) identify the vessel as the *YON-146*, a fuel barge towed to Pearl Harbor in 1950 from Guam, where *C. parasiticum* is established (Kirkendale & Calder 2003). The first record of this species as present and established in the Hawaiian Islands should thus be 2008.

Turritopsis* sp.*Introduced (name change)**

Calder (2010) noted that the specific name of the *Turritopsis* populations in the Hawaiian Islands [referred to as *T. nutricula* by Carlton & Eldredge (2009)] remains to be determined, although he provisionally retained the name as “*cf. nutricula*.” We revert here to *Turritopsis* sp., given that populations in the Islands differ from those from the type locality of *T. nutricula* in Charleston, South Carolina (Calder 2010). Nevertheless, we still regard it as introduced. Calder (2010) further noted that Miglietta *et al.* (2007) referred Cooke’s first record of *T. nutricula* from Ala Wai Yacht Harbor to the offshore Hawaiian species *T. minor* Nutting, 1905, but argued for direct comparison of the two species “before it can be determined whether or not they are conspecific.” We concur that the habitats of the harbor-dwelling fouling populations and offshore populations are sufficiently distinct that they are unlikely to be the same species.

Bougainvilliidae***Bimeria vestita* Wright, 1859****Introduced (addition)**

It is surprising that this common fouling hydroid was not recorded earlier from the Islands. Calder (2010) collected it in 2009 on bridge pilings in Hawai‘i Kai on O‘ahu. Its type locality in Scotland suggests that more than one species has been captured in the species concept, especially for populations in warmer waters. While described from Europe long ago, it may have been introduced there, and its origin remains unknown.

Bougainvillia muscus* (Allman, 1863)*Introduced (Change of Record [earlier date])**

Many species in Hawaiian fouling communities were doubtless present much earlier than first recorded in the literature, and museum collections can assist in resolving past records. The first record of this species recognized by Carlton & Eldredge (2009) was from 1967 in Kāne‘ohe Bay, its only known location in the Islands. Calder (2010) reported Bishop Museum collections from Honolulu Harbor (1945) and Pearl Harbor (1948), with additional collections (Calder 2010) from both stations in 2009 and 2007, respectively, indicating that it remains established in these harbors. *Bougainvillia muscus* may have been one of many World War II era arrivals.

Halopterididae***Halopteris plagiocampa* (Pictet, 1893)****Introduced (addition)**

Cole *et al.* (2009) reported this species from Honolulu Harbor based on 2008 collections. Schuchert (2003) described a broad Indo-West Pacific distribution, including Japan and northern Australia. Kirkendale & Calder (2003) also recorded it from Guam.

Pandeidae***Amphinema* sp.****Cryptogenic (addition)**

Calder (2010) reported a yet-to-be-identified species of this fouling hydroid from bridge pilings in Hawai‘i Kai, O‘ahu, collected in 2009.

Hydractiniidae***Stylactaria munita*** Calder, 2010**Cryptogenic (addition)**

Described as a new species from bridge pilings in Hawai'i Kai, O'ahu, based on material collected on an oyster shell in 2009, *S. munita* is close to Mediterranean species and to a species of *Stylactaria* from Pacific Mexico (Calder *et al.* 2010), suggesting an allochthonous origin.

Eudendriidae***Eudendrium capillare*** Alder, 1856**Introduced (previously Cryptogenic)**

Calder (2010) has assigned Cooke's 1972 collections (Carlton & Eldredge 2009) of *Eudendrium* from Honolulu Harbor and Kāne'ohe Bay to *E. capillare*. We treated it as *Eudendrium* sp. and as cryptogenic. Calder collected further material in 2009 in fouling communities on a bridge piling in Hawai'i Kai. This species is thus known only from O'ahu. As with *Bimeria vestita*, the origin of this species is unknown, and it may comprise a group of cryptic species.

Eudendrium carneum Clarke, 1882**Introduced (addition)**

Reproductive material of this widespread fouling species collected in 1976 in Pearl Harbor and in 1997 in Honolulu Harbor (Calder 2010) indicate that this hydroid is established in the Islands. While Calder (2010) concluded that "*Eudendrium carneum* has been established in waters of the state for more than 50 years based on previously unidentified material," these earliest specimens were collected (as with *Corydendrium parasiticum*, above) from a visiting fuel barge, the *YON-146*, brought to Pearl Harbor in 1950 from Guam. *Eudendrium carneum* may have occurred in Guam at that time, but was not present in collections there from 1997 to 2000 (Kirkendale & Calder 2003). This said, the *YON-146* may have picked up this hydroid somewhere else in the Pacific, prior to Guam.

Tubulariidae***Ectopleura* sp. cf. *E. viridis*** (Pictet, 1893)**Cryptogenic (addition)**

Material in the Bishop Museum collected in 1978 from anchor cables at 3 m depth in Kāne'ohe Bay was provisionally assigned to this Indo-West Pacific species by Calder (2010), constituting the first report from the Islands.

Corynidae***Coryne* sp.****Introduced (addition)**

[= *Syncoryne mirabilis* of Chu & Cutress (1955), *nec* L. Agassiz, 1849]

Carlton & Eldredge (2009) noted the report of *Syncoryne mirabilis* (Agassiz, 1862) by Chu & Cutress (1955) as found in 1954 in Hilo Harbor, Hawai'i, but set it aside as a probable misidentification and because of the lack of any subsequent report of a similar corynid. Calder (2010) recovered colonies of this small and inconspicuous *Coryne* in 2009 on O'ahu that he believed are conspecific with the species of Chu & Cutress's (1955) report. *Coryne* sp. was found by Calder on algae in fouling communities on bridge pilings in Hawai'i Kai. Despite the lack of species-level identification, we feel confident in assessing this species as introduced.

Class Anthozoa

(sea anemones)

Order Actiniaria**Haliplanellidae*****Diadumene lineata*** (Verrill, 1869)**Introduced (Change of Record [earlier date])**

[= *Haliplanella luciae* (Verrill, 1898)]

Daphne Fautin collected *D. lineata* on Coconut Island in Kāne'ohe Bay, Oahu, in November 1972 (California Academy of Sciences collections, CAS-IZ 9974.00, Accession Number 24280; record accessed August 2014; name shown as *Haliplanella luciae* and collector shown as D[aphne]. F. Dunn), extending the first record of this well-known Asian anemone to more than 40 years ago, rather than 1999 as reported by Zabin *et al.* (2004). It remains unreported from other Islands.

Class Scyphozoa
(jellyfish)

Magistiidae

***Mastigias* sp.**

Introduced (addition)

In October 1974, a *Mastigias* species was observed and photographed in Kāneʻohe Bay, off the Heʻeia pier (Devaney & Eldredge 1977). Tentatively identified by Devaney and Eldredge as the native species *Thysanostoma flagellatum* (Haeckel, 1880), Cooke (1984) recognized it as *Mastigias* near *M. papua* (Lesson, 1830), a non-native species. DeFelice *et al.* [2001; cited as “Eldredge and Smith, 2001” by Bayha & Graham (2011)] then noted it in passing with a brief entry (a “... smaller species of jellyfish, *Mastigias* sp. ... is also thought to be an alien”), accompanied by a photo by “T. Kelly” of two *Mastigias* of unknown provenance. The *Mastigias papua* reported and photographed by Reed (1971, p. 50, fig. 14) as “particularly abundant” in Kāneʻohe Bay is, however, *Phyllorhiza punctata* (Cooke, 1984).

Bayha & Graham (2011), in reporting the jellyfish *Mastigias* from Florida, noted that the Hawaiian record constituted the first occurrence of this jellyfish outside its native western and central Indo-Pacific range. *Mastigias “papua”* consists of a complex of Indonesian species (Dawson 2005, Bayha & Graham 2011). It is not known to which member of this complex the Hawaiian population belongs. While apparently unreported since 1974, Hawaiian jellyfish are poorly studied, and *Mastigias* may well still be present, mistaken for *Phyllorhiza punctata*, another introduced jellyfish in the Islands.

Class Cubozoa
(cubomedusae, box jellyfish)

Tripedaliidae

***Copula sivickisi* (Stiasny, 1926)**

Introduced (name change)

[= *Carybdea sivickisi*]

Bentlage *et al.* (2010) transferred this species to the new genus *Copula*. Crow *et al.* (2015, this volume) review the occurrence of *C. sivickisi* in the Islands.

***Tripedalia cystophora* Conant, 1897**

Introduced (Establishment Unknown)

Crow *et al.* (2015, this volume) report the discovery of a single specimen (a mature ovigerous female) of this Caribbean species in August 2011 “at a boat dock near mangroves in the Kaʻelepulu Canal, Enchanted Lakes, Oʻahu.” The location (near Kailua, on the windward coast) is distant from Oʻahu’s major ports, and would suggest that a population had become established and dispersed around the island. That said, we await further records to confirm its continued presence. *Tripedalia cystophora* was described from Jamaica and subsequently reported from Florida to Brazil, with further isolated records from Indonesia and the Seychelles (Crow *et al.* 2015). We suggest that the tropical western Atlantic Ocean is its native region, and that transport of polyps or medusae by ships have introduced it to the Indo-Pacific theater. It would not be surprising to find that it is much more widespread than now reported.

NEMATODA
(nematodes)

Order Secernentea

Camallanidae

***Spirocamallanus istiblenni* Noble, 1966**

Introduced (previously Cryptogenic)

Regarded as possibly native by previous workers, and first described from native fish in the Islands, Gaither *et al.* (2013) have shown that this parasitic nematode was introduced with the bluestriped snapper, *Lutjanus kasmira*, from French Polynesia (Marquesas and Society Islands) between 1958 and 1961. Native host acquisition was rapid: by 1962 it had been found in the endemic *Istiblennius zebra* (zebra blennies; *paoʻo*) (Noble 1966). Historical, biogeographic, molecular, and ecological evidence confirm that this parasite is non-native.

PLATYHELMINTHES

(flat worms)

Class Monogenea

(flukes)

<i>Euryhaliotrema anguiforme</i> (Zhang, 2001) Kritsky, 2012	Introduced (addition)
<i>Euryhaliotrema chrysotaeniae</i> (Young, 1968) Kritsky & Boeger, 2002	Introduced (addition)
<i>Euryhaliotrema spirotubiform</i> (Zhang, 2001) Wu, Zhu, Xie & Li, 2006	Introduced (addition)
<i>Haliotrematoides patellacirrus</i> (Bychowsky & Nagibina, 1971) Kritsky, Yang & Sun, 2009	Introduced (addition)
[= <i>Haliotrema patellacirrus</i>] <i>Haliotrematoides longitubocirrus</i> (Bychowsky & Nagibina, 1971) Kritsky, Yang & Sun, 2009	Introduced (addition)
[= <i>Haliotrema longitubocirrus</i>] <i>Haliotrema</i> sp. 1	Introduced (addition)
<i>Haliotrema</i> sp. 2	Introduced (addition)
<i>Lutianicola</i> sp.	Cryptogenic (addition)
<i>Polylabris</i> sp.	Cryptogenic (addition)

At least 7 monogene parasites of two introduced French Polynesian fish, the bluestriped snapper *Lutjanus kasmira* and the blacktail snapper *L. fulvus*, were imported to the Islands in the late 1950s and early 1960s, although not discovered until these fish were sampled in O'ahu for parasites in 2006 and 2007 (Vignon *et al.* 2009). Vignon *et al.* (2009) noted that two additional monogenes, *Lutianicola* sp. and *Polylabris* sp., were "likely" non-indigenous, but preferred to assign these a cryptogenic status. Kritsky (2012) noted that Vignon *et al.*'s *E. spirotubiform* may be *E. paululum* Kritsky & Justine in Kritsky, 2012. Kritsky further assigned Vignon *et al.*'s (2009) *Euryhaliotrema cf. E. anguiforme* to *E. anguiforme*.

ANNELIDA

Class Clitellata

(oligochaetes)

Marionina coatesae Erséus, 1990 **Introduced (addition)**
Demopoulos *et al.* (2007) and Demopoulos & Smith (2010) reported this marine oligochaete from Kāne'ohe Bay, O'ahu, based on 2001 collections. Described from Hong Kong and China, it was subsequently reported from Bermuda (Healy & Coates 1999) and Australia and Japan (Torii 2012). Given its widespread distribution through the western North and South Pacific, we regard it as a probable introduction (perhaps by ballast water) to both the Hawaiian Islands and Bermuda.

Class Polychaeta

(polychaetes)

Capitellidae

Magalhães & Bailey-Brock (2012) revised the Hawaiian capitellid polychaetes, a notoriously difficult group, based on morphology. Molecular work may change the identification of some of the following species, but regardless it is probable that the species considered as introduced do indeed represent non-native taxa; several others are cryptogenic.

Capitella giardi (Mesnil, 1897)**Introduced (species resolution)**

Bailey-Brock (1990) reported “*Capitella capitata*” [quotation marks added] co-occurring with the introduced polychaete *Polydora nuchalis* in oyster aquaculture ponds on O‘ahu. This capitellid has now been identified (Magalhães & Bailey-Brock 2012) as the European species *Capitella giardi*. It has also been reported from Florida (Warren 1976), to where it would appear to be introduced if the identification is correct. Warren (1976) suggested that a record of *Capitella capitata* from Point Barrow, Alaska was “probably *C. giardi*,” but she did not examine the material on which that record was based, and this record should be set aside. *Capitella giardi* was collected again in 1988 and 1989 at Kahuku, O‘ahu, in 1990 on the Kona coast of the Big Island in an oyster farm, and in 2004 in Waikoloa at the Anchialine Pond Preservation site.

Magalhães & Bailey-Brock (2012) noted that *C. giardi* “was collected from oyster farms and may have been introduced to the Hawaiian Islands together with *Polydora nuchalis* and *Boccardia proboscidea*.” However, the vector for bringing this European species to the Islands is unclear. The *Polydora* and *Boccardia* were introduced with commercial oysters from the Pacific coast of the United States, where *C. giardi* is unknown (but may have been overlooked, as capitellids are often misidentified or remain unidentified in collections). Shipping directly from Europe remains a possibility, although presumably this would involve transport of warmer-water stocks of *C. giardi*, such as from the Mediterranean.

Capitella jonesi (Hartman, 1959)**Introduced (addition)**

Magalhães & Bailey-Brock (2012) identified capitellid populations collected in 1992 from Maunaloa Bay, Kawaiui Beach Park near Niu Valley, O‘ahu as this Western Atlantic species, previously known from Massachusetts and Florida. Aquaculture products from the Atlantic coast or shipping may have brought this species to the Islands.

Mediomastus californiensis Hartman, 1944**Introduced (addition)**

No *Mediomastus* species had been previously reported in Hawaiian waters until Magalhães & Bailey-Brock (2012) identified specimens from O‘ahu as this Eastern Pacific species, which ranges from Alaska to southern California. Locations include Paikō Lagoon, Maunaloa Bay (1980), Honolulu Harbor (1997), Pearl Harbor and adjacent Mamala Bay (2002 and 2001 respectively) and Kāne‘ohe Bay (1993). Magalhães & Bailey-Brock (2012) noted that *M. californiensis* “may have been introduced to O‘ahu, as it is found mainly at Honolulu and Pearl harbors.” There are a number of undescribed species of *Mediomastus* in California (Leslie Harris, pers. comm. 2013), and the Hawaiian specimens are larger than Californian *M. californiensis*. We admit this species as an introduction to the Islands, while noting that it may prove to be a species other than *M. californiensis*. Ballast water appears to be the most likely mechanism of transport.

Capitella singularis (Fauvel, 1932)**Cryptogenic (addition)**

Previously known from the Indian Ocean and Indonesia, this species was first collected in the Hawaiian Islands in 2004 from Mamala Bay, O‘ahu, under threadfin mariculture cages at 40 m depth.

Capitella* sp.*Cryptogenic (addition)**

An unidentified *Capitella*, part of the “*Capitella capitata*” complex, was collected in 2002 in Moanalua Stream on O‘ahu (Magalhães & Bailey-Brock 2012).

Heteromastus* sp.*Cryptogenic (addition)**

Magalhães & Bailey-Brock (2012) noted that Hawaiian material resembles *H. filiformis* (Claparède, 1864), a name applied to what is almost certainly a number of similar-looking species from the Atlantic (including Mediterranean) and Pacific Oceans. Specimens were collected in 2010 in Maunaloa Bay, O‘ahu, intertidally on the introduced alga *Avrainvillea amadelpha*.

Scyphoproctus edmondsoni Magalhães & Bailey-Brock, 2012 **Cryptogenic (addition)**

Described as a new species from Nu‘upia Pond, O‘ahu (where the introduced polychaete *Polydora websteri* was also recorded) based on 2002 material, this worm appears to be related to species from the Indian Ocean (Magalhães & Bailey-Brock 2012). Additional specimens were collected on the hull of the *USS Machinist* floating dry dock in 1996 in Pearl Harbor, the *Machinist* having been towed to Pearl Harbor from the Philippines in 1992 (whether the population on the drydock was reproducing, or the worms were four years old, is unknown, although the latter seems unlikely). Based on the habitat and locations, we regard this as a cryptogenic species.

Spirorbidae

Protolaeospira capensis (Day, 1961) **Cryptogenic**

[= *Protolaeospira* sp. A of Vine *et al.*, 1972]

[= *Protolaeospira translucens* (Bailey & Harris, 1968) in Bailey-Brock, 1976]

Vine *et al.* (1972) reported *Protolaeospira* sp. A, collected in 1970, from Coconut Island, O‘ahu, on a fouling settlement panel, noting that “It appears to be closely related to, or perhaps the same as, *S[pirorbis] translucens* ... from the Galapagos Islands.” Bailey-Brock (1976) recorded additional specimens from O‘ahu, Maui, and Hawai‘i, and confirmed the identification as *P. translucens*, a species then synonymized with the South African *P. capensis* by Knight-Jones *et al.* (1979). This highly disjunct distribution suggests ship-mediated distribution from an unknown origin, and we thus consider it cryptogenic in the Islands.

Serpulidae

Pomatoleios kraussii (Baird, 1865) **Introduced (Retention of Status)**

Salmacina tribranchiata (Moore, 1923)

Serpula watsoni Wiley, 1905

Zabin *et al.* (2013), in a paper comparing intertidal species richness and composition between central California and O‘ahu, treated three species of Hawaiian serpulid polychaetes, *Salmacina tribranchiata* (as “*Salmacina dysteri*”), *Serpula watsoni* (as “*Serpula vermicularis*”), and *Pomatoleios kraussii* as cryptogenic, cryptogenic, and status unknown, respectively. These three species were treated as introductions by Carlton & Eldredge (2009). However, these re-assignments were in error (C. Zabin, pers. comm., 2013).

MOLLUSCA

Class Gastropoda

(snails)

Littorinidae

Littoraria scabra (Linnaeus, 1758) **Cryptogenic (addition)**

Reid (1986) commented that this Indo-West Pacific snail, largely restricted to mangrove communities, was “Rare in [the] Hawaiian Islands where mangroves were only established this century.” Whether *L. scabra* was introduced inadvertently with mangroves imported from the Philippines in the early 20th century thus bears consideration.

The presence of *Littoraria scabra* in the Islands was overlooked by the long-term misidentification of the native periwinkle *Littoraria intermedia* (Philippi, 1846) as *L. scabra*. Thus, in the most widely used identification guide to Hawaiian mollusks (Kay 1979, page 72, fig. 24G) *L. intermedia* is mis-identified as *L. scabra* (Reid 1986, p. 125). Jeannette Whipple Struhsaker’s work on *L. scabra* is also based on *L. intermedia* (Whipple 1965, Struhsaker 1966, Reid 1986), and *L. intermedia* is still omitted from monographic treatments of Hawaiian mollusks [e.g., Severns (2011)].

True *L. scabra* occur on at least three islands: O‘ahu, Moloka‘i, and Hawai‘i (Table 1). One specimen was collected in 1916 on *hau* (*Hibiscus tiliaceus*) in Kāne‘ohe Bay, but *L. scabra* was not found again in the Islands until the 1960s, when it was collected from mangroves, *hau*, *kiawe* (*Prosopis pallida*), and on mud near mangroves (Table 1). The O‘ahu population of *L. scabra* took a dip *circa*

Table 1. Records of the gastropod *Littoraria scabra* in the Hawaiian Islands

1916	O'ahu	Kāne'ōhe Bay: Mokuolo'e [= Coconut Island]	D.B. Langford	1 (mixed with <i>L. intermedia</i> , <i>fide</i> D. G. Reid)	"on branches of Hawtrees overhanging the shore + at high water dipping into the water. The 2 largest shells were a couple of feet above high water level." (BPBM catalogue entry) [Hawtree = hautee or hau = <i>Hibiscus tiliaceus</i>]	BPBM 228537	Reid, 1986, p. 103; D.G. Reid, pers. comm., February 2011
1961 (July)	Hawai'i	Puako	Carl C. Christensen	3		BPBM 205244	Reid, 1986, p. 103
1979	Hawai'i	North end of Puako Reef	M. Severns	2 (mixed with <i>L. intermedia</i>)	"From Keawe tree" [kiawe, <i>Prosopis pallida</i>]	E.A. Kay Collection	D.G. Reid, pers. comm., February 2011
1982 (May)	Moloka'i	One Ali'i Fishpond	Ann Fielding	1	"living in mud near mangroves"; 27 o'oo (BPBM catalogue entry)	BPBM 207349	Reid, 1986, p. 103
1982	O'ahu	Kāne'ōhe Bay: Coconut Island	D.G. Reid	—	On <i>Rhizophora</i> and <i>Hibiscus</i> trees	BM	D.G. Reid, pers. comm., February 2011
2004 (31 August)	O'ahu	Kāne'ōhe Bay: Coconut Island	Chela Zabin	—	From mangroves and on dead wood on shore, in 2003–2004.	BM (wet collection, unregistered)	Chela Zabin and D.G. Reid, pers. comm., May–June 2011
2006 (February)	O'ahu	"channel to Pearl Harbor" at Hickam Air Force Base	David Lum	—	"... collected some giants (up to) 36.7mm) until about two years ago from mangroves lining the channel to Pearl Harbor. They were quite common up until that point in time, but they suddenly disappeared."	Lum Collection	David Lum, pers. comm., February–March 2011
2006	O'ahu	Hickam AFB (Ft Kam reef area)	John Jacobs	"a number of live specimens"	"In 2010, I couldn't find a single shell"	Jacobs Collection	John Jacobs, pers. comm., 15 March 2011
2000s	O'ahu	Pearl Harbor	Chris Takahashi		"... from a mangrove tree in the middle of a sand bar off Pearl Harbor. They tend to be under leaves and in the center of the mangrove patches Recently they seem to have totally disappeared."	Takahashi Collection	Chris Takahashi, pers. comm., 28 March 2011
2011 (June)	O'ahu	Pearl Harbor	David Lum and J.T. Carlton	Common	On <i>Rhizophora mangle</i>	—	Herein

BPBM = Bernice P. Bishop Museum, Honolulu
 BM = British Museum (Natural History), London

2009–2010 (Table 1), but the snail is now common on red mangroves (*Rhizophora mangle*) in Pearl Harbor at Hickam Air Force Base, O‘ahu (J.T. Carlton & D. Lum, field observations, June 2011).

The presence of *L. scabra* in 1916 in Kāne‘ohe Bay is difficult to explain. Oceanic rafting of mangrove-associated *Littoraria* species has been invoked (Reid 1986) but remains speculative, although it may explain this early record. More probable as a vector are unrecorded attempts to introduce mangroves from the Philippines to the Hawaiian Islands prior to the officially recognized records commencing in 1922 (reviewed by Carlton & Eldredge 2009). Cooke (in MacCaughy 1917) mentioned in passing, for example, an attempted introduction from the Philippines in 1908, and it is unlikely that this casual note records the sole such attempt. Exactly how mangrove seeds or seedlings were transported in these early years is not known and we have not found detailed descriptions of such shipments, so we cannot ascertain with certainty the potential for additional species to be carried with them. Nevertheless there seems to be significant potential for associated biota to be transported in crates containing plants, root masses, soil, leaves, and so forth. Regardless, it may be that the O‘ahu population (if there was a reproducing population prior to the 1920s) went extinct, given the lack of collections for much of the rest of the century in a region well-known for an intensive continuous history of shell collecting.

Alternatively, D.G. Reid (pers. comm. 2011) has suggested that *L. scabra* may have been naturally present prehistorically on the Islands, but maintained low-density populations in the absence of mangroves. As the mangrove populations grew in size, sparse populations of a species such as *L. scabra* that thrives best on mangroves may have increased. It would be interesting to learn if populations of other mangrove-obligate species, such as insects or other arthropods, thought to be native to the Islands, increased through the 20th century.

If, however, *L. scabra* successfully colonized the Islands in the last half of the 20th century, mechanisms of introduction also remain unclear. The gap between importations of mangroves in the 1920s and the 1960s collections of *L. scabra* suggests that mangrove introductions were not the vector. As noted above, rafting to the Islands remains speculative, the more so since mangroves themselves did not manage to colonize the Islands naturally.

Finally, we note that whether *Hibiscus tiliaceus* is native to the Islands remains uncertain (J. Price 2006, at HEAR: http://www.hear.org/species/hibiscus_tiliaceus; last accessed May 2014), leaving open the possibility of its introduction by the Polynesians. *L. scabra* does occur with *H. tiliaceus* (D.G. Reid, pers. comm. 2011, and Table 1) although not abundantly so, and may thus be transportable with *H. tiliaceus*. This said, *H. tiliaceus* does not appear to show a founder effect in the Islands (Takayama *et al.* 2006), which, however, could be the result of multiple synanthropic introductions over centuries. As *Prosopis pallida* is also introduced, it is thus possible that all the host plants that support *L. scabra* are themselves not native.

Phylogeographic studies of *Littoraria scabra* in the Hawaiian Islands and the Indo-Pacific would permit determining to which populations the Hawaiian *L. scabra* are most closely related.

Class Bivalvia

(mussels, oysters, clams, shipworms)

Mytilidae

Mytilus galloprovincialis Lamarck, 1819 **Deleted**

Severns (2011, p. 436 and facing pl. 199) reported this mussel from the Hawaiian Islands with the notation, “Intertidal. Between rocks in tidal areas with high water flow.” The provenance of the photographed specimen is not given, nor are any locations for this species in the Hawaiian Islands. Other than being intercepted in vessel fouling in Pearl Harbor in 1998 (Carlton & Eldredge 2009), we know of no populations of this cold- to warm-temperate species in the Islands, and do not treat it as a member of the non-indigenous fauna.

Ostreidae

Saccostrea sp. **Introduced (taxonomic status)**

Carlton & Eldredge (2009) treated the *Saccostrea* established on O‘ahu as a member of the species group *S. “cucullata,”* pending genetic analyses of the Hawaiian population. Severns (2011, p. 464,

pl. 212) identified the Hawaiian *Saccostrea* as *S. scyphophilla*, a widespread Indo-West Pacific species (Huber 2010). We await genetic confirmation of the O‘ahu material of this difficult group for species-level identification, which work may also assist with resolving the origin of the Hawaiian *Saccostrea*. Severns attributed the source of his illustrated specimen to the collections of the Florida Museum of Natural History, but the specimens are at the Field Museum (Chicago) (Janeen Jones, pers. comm. June 2014). The illustrated specimens (FM 203516), originally identified as *Saccostrea glomerata*, are not from the Islands, but were collected in 1955 from New South Wales, Australia.

Anomiidae

Monia nobilis (Reeve, 1859)

Introduced (retention of status; name change)

Huber (2010) argued for placing this species in the genus *Monia*, with which assignment we agree. Kay (1979) noted that this jingle shell was “widely distributed in the Indo-West Pacific,” which distribution Huber (but repeating Kay’s statement as “West Pacific”) felt could not be verified; he therefore concluded that “*nobilis* is endemic Hawaiian.” However, Huber (2010) also noted that *Anomia caelata* Reeve, 1859 (= *Monia caelata*) is a junior synonym of *Anomia nobilis* Reeve, and that the former occurs in the Red Sea. Tan & Woo (2010) further recorded the former (as *Pododesmus caelata*) from Singapore. Following Carlton & Eldredge (2009), we retain *Monia nobilis* as introduced to the Islands.

Chamidae

Chama pacifica Broderip, 1835

Introduced (new location)

Severns (2011, p. 466) illustrated a specimen of this species collected at 10 m depth attached to dead coral in Kihei, Maui. It was previously known only from 1996 collections in Pearl Harbor (Carlton & Eldredge, 2009).

Chama lazarus Linnaeus, 1758

Introduced (new location)

Severns (2011, p. 466, pl. 213 on facing page) illustrated a specimen of this species from 50 m depth, “growing within a wreck off Lahaina, Maui.” It was previously known only from Pearl and Honolulu harbors, O‘ahu, based on 1996 collections (Carlton & Eldredge, 2009).

Teredinidae

Teredo parksi Bartsch, 1921

Introduced (addition)

Bartsch (1921) described the shipworm *Teredo parksi* from Pearl Harbor, based on specimens collected in 1920. Carlton & Eldredge (2009) remarked that Bartsch (1921) did not provide the date of collection, but we have since found that Walcott (1922) reported the date of Bartsch’s activities and collections in the Islands. Turner (1966) considered *T. parksi* to be juvenile *Teredo furcifera* von Martens, 1894, and thus a junior synonym of that species, which is how Carlton & Eldredge (2009) treated it. However, we overlooked the fact that Turner (in Santhakumaran, 1986) resurrected *T. parksi* as a distinct species, based on its reproductive biology. *Teredo parksi* is widely distributed throughout the Indo-West Pacific, and we regard it as introduced to the Islands.

CRUSTACEA

Class Copepoda

Leptopontiidae

Psammopsyllus sp.

Cryptogenic (previously Introduced)

Karaytug & Sak (2005) suggested that Kunz’s (1993) report of the Atlantic interstitial sand-dwelling copepod *Psammopsyllus stri* Mielke, 1983 (from Kaua‘i and O‘ahu) be reconsidered, pending a redescription of the Hawaiian material. They noted that the Hawaiian population does not match Mielke’s description in several regards. Although this copepod may have been introduced to the Islands in ships’ sand ballast, and while it seems probable that it has strong affinities to Atlantic clades and is thus allochthonous, we revert to a cryptogenic status for it pending further study.

Botryllophilidae***Haplostomides hawaiiensis* Ooishi, 1994 Introduced (previously Cryptogenic)**

Carlton & Eldredge (2009) considered this species cryptogenic pending further data on its host ascidian specificity. The discovery of *H. hawaiiensis* with its host ascidian *Polyclinum constellatum* in Mazatlan harbor, southern Gulf of California, Mexico, in 2008 supports “the notion of a high host specificity of *H. hawaiiensis*” (Tovar-Hernández *et al.* 2010). We suggest that this copepod co-evolved with *Polyclinum constellatum* in its native range, which is probably in the Indo-West Pacific or Australian theaters, the centers of diversity of the genus *Polyclinum*.

Class Ostracoda

We omitted ostracods from our previous work, lacking any clear evidence of either introduced or cryptogenic species. Kornicker *et al.* (2010) reported on collections of several species from ports and harbors on Kaua‘i, Moloka‘i, Maui, and Hawai‘i. The ostracod fauna of bays and estuaries in the Pacific theater is poorly known, and little attention has been paid to the question of which, if any, species may have been distributed anthropogenically. We here assess just one example.

Cypridinidae***Paravargula trifax* Kornicker, 1991 Cryptogenic (addition)**

Of the species treated by Kornicker *et al.* (2010), only one occurs elsewhere: *Paravargula trifax*, which was described from Enewetak Lagoon, and also occurs in American Samoa. It was collected in 1996 and 2003 in shallow water in boat harbors and around docks on Kaua‘i and Maui.

Class Isopoda**Philosciidae*****Littorophiloscia culebrae* (Moore, 1901) Introduced (new location)**

Howarth *et al.* (2012) reported this maritime isopod on Maui, based on 2006 collections near Hobron Point on a rocky beach strand.

INSECTA**Class Diptera (flies)****Chironomidae*****Kiefferulus longilobus* (Kieffer, 1916) Introduced (addition)**

[= *Chironomus* sp. near *C. hawaiiensis* of Howarth *et al.* (2012); nec Grimshaw, 1901]

This Indo-Pacific marine midge was first collected in 2006 on Maui in wetlands at the Kanahā Pond State Wildlife Sanctuary (Howarth *et al.* 2012), and again in 2012 on Sand Island, O‘ahu, where it was found to be “breeding in large numbers in [sea urchin] rearing tanks containing seawater” (Howarth & Oishi 2013). Howarth and Oishi speculated that adults could have arrived in the Islands as stowaways via airplanes or ships, or that larvae could be transported in ballast water or in crevices in ships’ hulls.

BRYOZOA

(bryozoans)

Class Gymnolaemata**Schizoporellidae*****Schizoporella errata* (Waters, 1878) Introduced (species resolution)**

Carlton & Eldredge (2009) noted that “one or more” species of *Schizoporella*, a genus of bryozoans well-known to include a number of species associated with ship fouling, were present in the Hawaiian Islands, with possible candidate taxa including *S. errata* and *S. japonica*. McCann *et al.* (2007) reported the Hawaiian populations under the Atlantic-based name *Schizoporella pungens* (Canu and Bassler, 1928), but this designation was meant to be preliminary (L. McCann, pers.comm).

May 2011). Collections made in Pearl Harbor in 1996 and 2011 have now been identified as *Schizoporella errata*, a warm-water Mediterranean species that has also been introduced to California (Ryland *et al.* 2014).

Lepraliellidae

Celleporaria brunnea (Hincks, 1884)

Deleted

Koçak (2007) remarked that this Eastern Pacific species “was also recorded from Hawai‘i, where it may have been transported via hull fouling,” citing Godwin (2003). The record is based on finding this bryozoan on a barge towed from southern California to Pearl Harbor in 1999; it was not found in the wild. We do not consider it to be a member of the Hawaiian fauna.

Celleporaria pilaefera (Canu & Bassler, 1929) **Introduced (addition)**

The Indo-Pacific bryozoan *Celleporaria pilaefera* was first collected in 1997 on O‘ahu (Honolulu Harbor and Ke‘ehi Lagoon), and subsequently in Kāne‘ohe Bay and Waikīkī (Coles *et al.* 1999, 2002a, 2002b), but inadvertently omitted by Carlton & Eldredge (2009). It was found in 2002 in Florida (McCann *et al.* 2007). It is probable that it has been introduced via ship fouling much more widely around the world than reported.

CHORDATA

Class Ascidiacea (sea squirts)

Didemnidae

Diplosoma sp. cf. *D. spongiforme* Giard, 1872 **Introduced (addition)**

A species similar to this European (Turon & Becerro 1992) ascidian has apparently been spreading in recent years, but the identification remains unresolved. In 2002 it was reported from Florida (McCann *et al.*, 2007, and NEMESIS data base: <http://invasions.si.edu/nemesis/browseDB/SpeciesSummary.jsp?TSN=-457>; last accessed May 2014), in 2002–2003 it was reported from Brazil (Rocha & Faria 2005), and in 2007 from Puerto Rico (NEMESIS data base, *op. cit.*). In 2008 Coles *et al.* (2009) collected it in Pearl Harbor and Ke‘ehi Lagoon on O‘ahu.

Asciidiidae

Phallusia philippinensis Millar, 1975

Introduced (name correction)

An introduced *Phallusia* present in the Islands since the 1930s was previously identified as the Indian Ocean–Red Sea species *P. nigra* (Carlton & Eldredge 2009). Based on genetic and morphological evidence, the Indo-Pacific fouling ascidian *P. philippinensis* and not *P. nigra* is present in the Hawaiian Islands (Vandepas *et al.* 2015).

Styelidae

Polycarpa cryptocarpa (Sluiter, 1885)

Introduced (addition)

A new addition to the Hawaiian ascidian fouling fauna is *Polycarpa cryptocarpa*, previously known from the Western Pacific Ocean and the tropical Indian Ocean (Monniot & Monniot 2001). It was collected in 2008 in both Pearl Harbor and Honolulu Harbor (Coles *et al.* 2009).

Symplegma reptans (Oka, 1927)

Deleted (previously Introduced)

We inadvertently included this species as an established introduction in our earlier work. However, specimens were collected in 1996 in O‘ahu only on the *USS Machinist*, which had been towed from the Philippines to Pearl Harbor in 1992. While the ascidians may have been reproducing on the dry-dock (rather than being four years old), the *Machinist* was then towed to Guam in 1999. As *S. reptans* has not otherwise been reported from O‘ahu (Coles *et al.* 2009), we delete it from the record.

Botryllus sp. and *Botrylloides* sp.

Introduced (Change of Record [earlier date])

Carlton & Eldredge (2009) reported that the first record of botryllids in the genera *Botryllus* and *Botrylloides* was 1973. One of us (LGE) conducted fouling plate surveys on O‘ahu between May

1961 and January 1962. The original laboratory analysis notes of these plate surveys have now been located, and we note that *Botryllus* “*schlosseri*” and *Botrylloides* sp. were present in 1961. As with many other fouling species, these common harbor and ship fouling taxa may have been introduced even earlier, perhaps associated with the extensive shipping traffic of World War II.

***Symplegma brakenhielmi* (Michaelson, 1904) Introduced (Change of Record [earlier date])**

We note an earlier record of this fouling ascidian than the one (1967) previously reported (Carlton & Eldredge 2009): in September 1961, the fouling community on the Hawaiian Marine Laboratory (now the Hawai‘i Institute of Marine Biology) research vessel *Salpa* was sampled by one of us (LGE) and found to include this species (recorded as *S. connectans*).

Class Aves

(birds)

Anatidae

***Anas platyrhynchos* Linnaeus, 1758**

Introduced (addition)

While occasional apparently migratory Northern Hemisphere mallards have long been recorded in the Hawaiian Islands, *Anas platyrhynchos* owes its modern-day established populations in the Islands to introductions that commenced in the 1800s (Pyle & Pyle 2009). Mallards are a member of the brackish-water fauna of the Islands, and, as such, function as consumers in these communities. Mallards can be observed, for example, feeding in the brackish water Manoa-Palolo Channel (a stream leading to the Ala Wai Canal) and at Ala Moana Park (JTC, field observations, June 2011).

ALGAE

(seaweeds)

Chlorophyta

(green algae)

Ulvaceae

***Ulva* spp.**

Deleted (previously 10 Cryptogenic and 1 Introduced)

Carlton & Eldredge (2009) treated 11 species of the sea lettuce *Ulva* as cryptogenic and one species, *Ulva expansa*, as introduced, based on older morphological concepts of species differentiation and biogeography, as reflected, for example, by Abbott & Huisman (2004). However, based on molecular re-assessments beginning in the 20th century, algal species concepts have changed dramatically. One result of this is the resolution (long known or suspected by many phycologists) that the application of species names based on cold-water European or American populations to tropical and sub-tropical seaweeds was not supportable.

O’Kelly *et al.* (2010), applying a molecular approach to the *Ulva* species in the Hawaiian Islands, found that only one of the previous 12 named species in the Islands, *Ulva fasciata*, was substantiated by molecular analysis. Rather, of 11 resolved OTUs, 6 were “not previously reported from anywhere in the world” (but could represent named species not yet characterized genetically), 3 matched named species (but 2 of these prove to be synonyms), and 2 others match “unnamed species from Japan and New Zealand.” We thus delete from further consideration 10 species previously treated as cryptogenic (*Ulva clathrata*, *U. compressa*, *U. flexuosa*, *U. intestinalis*, *U. linza*, *U. paradoxa*, *U. prolifera*, *U. reticulata*, *U. rigida*, and *U. taeniata*) and 1 species previously treated as introduced (*Ulva expansa*). None of these taxa are now recognized by these names in the Hawaiian flora. We retain *Ulva fasciata* (now known by its senior synonym *Ulva lactuca*) as cryptogenic (see below), and newly recognize *Ulva ohnoi* as cryptogenic (see below).

***Ulva* “*lactuca* Linnaeus, 1753”**

[= *Ulva fasciata* Delile, 1813]

Cryptogenic (name change)

While this alga is traditionally considered native, ulvoid algae are one of the most common groups of plants on ships’ hulls (e.g., Mineur *et al.* 2007, 2008), making it difficult to distinguish natural

occurrences from human-mediated transport and introduction. O’Kelly *et al.* (2010) noted that what was long treated in the Hawaiian literature as *Ulva fasciata* is now considered a synonym of *Ulva lactuca*, a species said to occur on almost every coast of the world from polar to tropical waters. Not surprisingly, the species concept *lactuca* remains unclear (Kirkendale *et al.* 2013), and we therefore place the name in quotation marks.

Ulva ohnoi Hiraoka & Shimada, 2004

Cryptogenic (addition)

The native range of this bloom-forming alga, recently described from Japan, is not known. It has been recognized from both the Hawaiian Islands (O’Kelly *et al.* 2010) and Australia (Kirkendale *et al.* 2013). There has been speculation that *U. ohnoi* was not native to Japan (Hiraoka *et al.* 2004). It has been found in ballast water samples intercepted in Italy (Flagella *et al.* 2010).

The material analyzed by O’Kelly *et al.* (2010) was collected in 2007 on both O’ahu and Maui (GenBank accession numbers 02907, 03282, and 03276, *vide* O’Kelly *et al.* 2010, fig. 3, p. 7, with locations and date from <http://algae.manoa.hawaii.edu/hadb/database/index.php?action=search&srhm=gnus&q=Ulva+ohnoi&x=42&y=17>; last accessed May 2014).

Udoteaceae

Udotea argentea Zanardini, 1858

Introduced (addition)

An unusual addition to the non-native marine flora of the Islands (a group of species which in general is characterized by shallow-water, hard-bottom species) is this deeper-water green alga, typically found growing in sand in 20 to 60 m depth (Bailey-Brock & Magalhães, 2010). Bailey-Brock & Magalhães (2010) reported it as discovered in 2007 in south-west O’ahu. Widely found throughout the Indo-Pacific, it appears to be a ballast-water introduction to the Hawaiian Islands.

Rhodophyta

(red algae)

Sherwood & Carlile (2012) reported that the Atlantic alga *Schimmelmania* sp., *cf. S. elegans* Baardseth, 1941, was found in 2010 in a closed tank in an abalone aquaculture facility on the Big Island; the tank and the algae were subsequently destroyed after this discovery. While the Islands appear to be too warm for this cool- to warm-temperate seaweed, its transportation with aquaculture products highlights concerns that these operations can serve as viable vectors for non-native species.

Spyrideae

Spyridia “filamentosa” (Wulfen, 1803)
Harvey, 1833” Clade A

Introduced (addition)

Spyridia “filamentosa” (Wulfen, 1803)
Harvey, 1833” Clade B

Introduced (addition)

Conklin & Sherwood (2012) demonstrated that this red seaweed consists of five distinct clades in the Hawaiian Islands. Whereas Clades A and B are of wide occurrence in the Pacific Ocean, they are restricted to around O’ahu (with the majority of samples collected on the south shore – that is, close to the two principal harbors), with additional samples from the Maui Nui complex (i.e., Moloka’i, Lāna’i, and Maui). The earliest sample of Clade A is from Moloka’i in 1991 and of Clade B is from Magic Island, O’ahu in 1978, but both clades were probably present in the Islands much earlier. Conklin & Sherwood (2012) suggested that these clades are possible introductions with shipping traffic.

Rhodomelaceae

Polysiphonia sp.

Introduced (addition)

Hollenberg (1968) recorded a *Polysiphonia* from the Hawaiian Islands under the name *Polysiphonia tepida* Hollenberg, 1958, originally described from Beaufort, North Carolina. Locations and habitats included Kāne’ohe Bay (1952), on a boat hull in Ala Wai Yacht Harbor, Honolulu (1951), a fish rearing facility aquarium in Waikīkī (1962), and Keawanui Pond on Moloka’i (1944). Abbott (1999) repeated Hollenberg’s record, but had no new collections. *Polysiphonia “tepida”* is now reported

from a broad suite of locations from the Atlantic Ocean and throughout the Indo-West Pacific (http://www.algaebase.org/search/species/detail/?species_id=11318; last accessed May 2014), and thus doubtless involves a number of similar-looking species. We thus demur from using a species name for this *Polysiphonia*, but predict that it will be found to be non-native once genetic studies are done.

Gracilariaceae

Hydropuntia perplexa (Byrne et Zuccarello, 2002) **Introduced (addition)**

Conklin, O'Doherty et A.R.Sherwood, 2014

Conklin *et al.* (2014) reported the cryptic invasion of the red alga *Hydropuntia perplexa*, possibly of Micronesian origin, which had been previously confused with the native alga *Gracilaria coronopifolia* (*limu manauaea*). Populations are established on Maui, Kaua'i and O'ahu. Herbarium material dates from 2007 (Conklin *et al.* 2014), but the introduction may have occurred much earlier.

Phaeophyta

(brown algae)

Sargassaceae

Sargassum muticum (Yendo, 1907) Fensholt, 1955 **Deleted**

We re-emphasize that this Asian species is not established in the Hawaiian Islands. It was treated by Abbott & Huisman (2004) as a "new record" for the Islands, on which basis it has now appeared as a distributional record in Algae Base (http://www.algaebase.org/search/species/detail/?species_id=90; last accessed May 2014). This alga was collected as a fouling species from a barge towed to Pearl Harbor from California. We have no record of its establishment.

Results and Discussion

We report an additional 32 introduced and 25 cryptogenic species for the Hawaiian marine fauna and flora, along with one additional species, the Caribbean box jellyfish *Tripedalia cystophora*, whose establishment is uncertain. Four species previously regarded as cryptogenic (Carlton & Eldredge, 2009) are now treated as introduced (*Tedania ignis*, *Eudendrium capillare*, *Spirocamallanus istiblenni*, and *Haplostomides hawaiiensis*), while two species previously treated as introduced are now considered cryptogenic (*Monanchora dianchora* and *Psammopsyllus* sp.). One vector-intercepted species (*Symplegma reptans*) incorrectly listed as introduced is deleted, and 11 species of green algae (10 cryptogenic and 1 introduced) are also deleted, unsupported by subsequent taxonomic analysis. The net change to the non-native and cryptogenic inventory is thus an additional 32 and 13 introduced and cryptogenic species, respectively.

From our 2009 assessment of 301 introduced and 117 cryptogenic species, we thus now recognize 333 introductions and 130 cryptogens, for a total of 463 species that are either non-native or candidates for such in the Hawaiian marine biota. Given the limited understanding of the historical biogeography and systematics of a vast number of marine invertebrates and algae in the Hawaiian Islands – including protozoans, sponges, hydroids, flatworms, nemerteans, nematodes, gastrotrichs, kinorhynchs, gnathostomulids, rotifers, kamptozoans, tardigrades, oligochaetes, polychaetes, ostracodes, copepods, isopods, tanaids, amphipods, pycnogonids, mites, littoral insects, bryozoans, ascidians, and filamentous algae, among other groups—the actual number of non-native and cryptogenic marine species in the Archipelago is, without doubt, considerably greater.

We emphasize that collections of species associated only with transport vectors should not be recorded as new members of the Hawaiian flora or fauna. If there is no evidence that these species have escaped into the wild (from, for example, aquaculture facilities or ships' hulls) or are reproducing in the wild, then these species would not be considered as established and therefore not members of the Hawaiian biota. As noted above, then, the alga *Sargassum muticum* and the bryozoan *Celleporaria brunnea* (both found in 1999 on a barge towed from California), as well as the alga *Schimmelmania elegans* (found in 2010 in an aquaculture facility on the Big Island) are deleted from the Hawaiian inventory. Similarly, earlier interceptions, such as the hydroid *Corydendrium para-*

siticum (found in 1950 on a barge from Guam) would not constitute first records of the species in the Islands, although they provide robust evidence for (rather than speculation about) specific vector transport.

Finally, as we noted in the Introduction, no species are known to have arrived and become established in the Hawaiian Islands since 2009. While this may reflect the efficacy of increased control of certain vectors, such as ballast water or aquaculture imports, it is more likely that species have continued to arrive (such as in hull fouling) but remain undetected. Species arriving and becoming established may remain below the level of detection for some years due to lag times in building up populations that would be found in casual encounters, while at the same time systematic surveys of Hawaiian marine fouling communities in ports and harbors have not been conducted since the summary by Carlton & Eldredge (2009).

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The first author notes, with great sadness, that Lucius Eldredge, my co-author on this paper and our earlier monograph, is no longer with us to continue to explore and expand our understanding of the marine fauna and flora of the Hawaiian Archipelago. Introduced species were a deep and abiding interest of Lu, and he had a genetic ability to ferret out on the one hand the most obscure records in the grayest of literature, while, on the other, to spot a new mention of an alien marine species in the Hawaiian Islands buried in the midst of a 300-page taxonomic monograph dealing with some element of the Indo-West Pacific biota. This paper reflects Lu’s extraordinary lifetime of meticulous and painstaking scholarship which, while it can be well-remembered, cannot be surpassed.

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