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Ecology and management implications of an invasive soft coral species, *Carijoa riisei* in Hawaii

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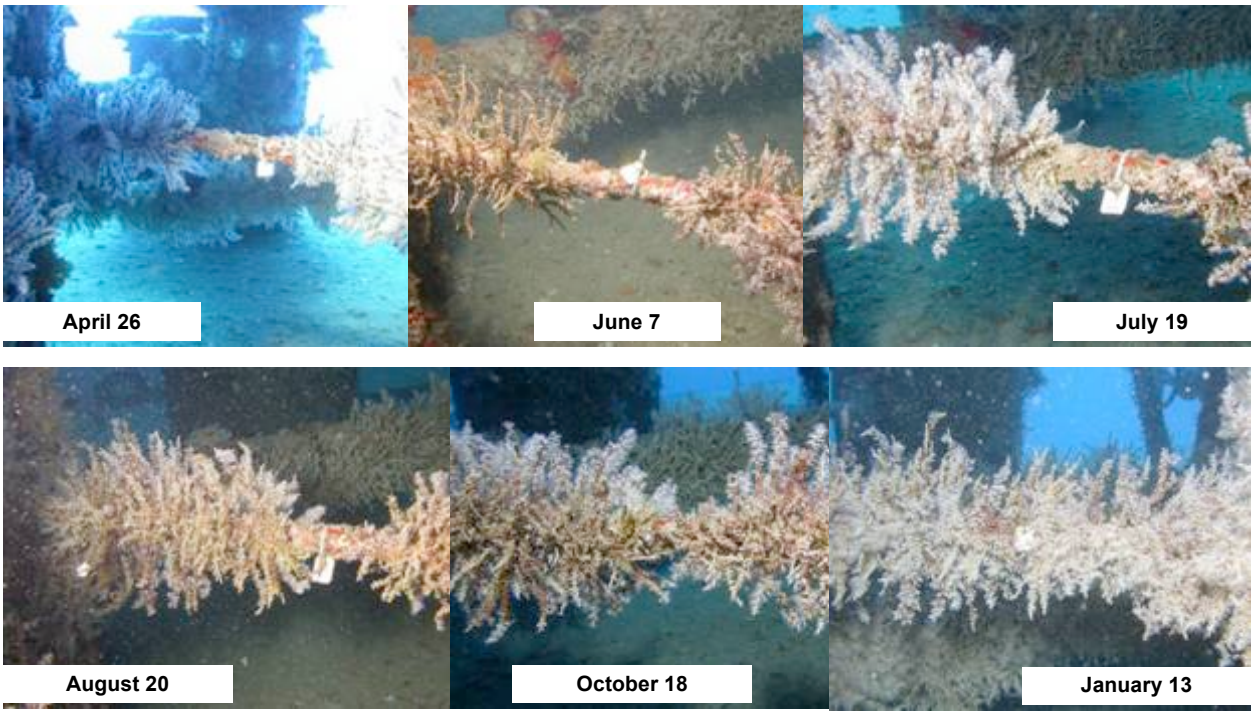

Overview

The objectives of this research project center around answering the following two research questions: (1) How effective is mechanical removal *C. riisei*? (2) From where did the population of *Carijoa riisei* in Hawaii originate? Field manipulations and measurements using SCUBA have been employed to address the former, and molecular techniques have been applied to address the later.

Accomplishments of this research

How effective is mechanical removal *C. riisei*?

- To explore the use of fresh water as a potential tool for *C. riisei* eradication, preliminary experiments were performed to assess the tolerance of *C. riisei* to low salinities. Polyps were exposed to salinities between 0-25 PSU in 5 PSU increments. The time of exposure to kill 50% of *C. riisei* polyps was 1.5 minutes for 0 PSU, 2 minutes for 5 PSU, 20 minutes for 10 PSU, 90 minutes for 15 PSU, >6hours for 20 PSU and 2 days for 25 PSU. Prolonged exposure to low salinity is clearly an effective means of eradication for *C. riisei*, although the technical difficulties in reducing the salinity in the field for prolonged periods remain to be explored. One obvious potential would be for fresh water to be introduced into the plastic shrouds which are being used to wrap pier pilings in Kauai.
- A research paper detailing these experiments is currently being written, and will be provided to the Department of Land and Natural Resources when completed.

From where did the population of *Carijoa riisei* in Hawaii originate?

- We have used the mitochondrial NADH-dehydrogenase subunit 2 gene (ND2) because it is among the most variable of genetic markers reported for octocorals to date, and there is existing octocoral sequence data from over 100 genera (McFadden et al. 2006) with which to compare our findings. In addition, we have developed a new set of primers that amplify a hypervariable intron in the 54 kDa subunit of the signal recognition particle (SRP54). This is the first hypervariable, single-copy sequence marker ever developed for octocorals, and a manuscript outlining the development of this marker is almost ready for submission, and will be provided to the Department of Land and Natural Resources when it is completed.

- To date, we have obtained 249 mitochondrial DNA sequences from over 320 samples world-wide. Among these samples, we have found a total of 32 haplotypes (unique sequence variants) across all locations around the globe.
    - Of the 32 haplotypes identified, 7 occur in Hawaii and they are not closely related to other locations. Two of the haplotypes are dominant and account for roughly 90% of all Hawaii samples (Fig. 1). Although haplotypes are shared between Hawaii and other locations, there are no obvious patterns.
    - Combined mitochondrial and nuclear data show both higher and considerable unique genetic diversity in the Indo-Pacific compared to samples from throughout the tropical Atlantic, indicating that *Carijoa* is native to Pacific with a long history of continuous residence, and not a recent introduction from the Caribbean-Atlantic. Ecological data on obligate predators exclusive to the Indo-Pacific support this finding.

- Samples of *C. riisei* from the Atlantic have similar genetic variants from Brazil to Florida to Africa, suggesting that sampling was sufficient to detect the source population if *C. riisei* in Hawaii were recently introduced from the Caribbean. However, none of the *Carijoa* sampled from throughout Hawaii (n=96) share any of the Caribbean ND2 haplotypes and only a single SRP54 allele (of 29), indicating that the Hawaiian populations almost certainly derive from Indo-Pacific rather than Caribbean origins.

- Our data clearly support an Indo-Pacific origin - not a Caribbean-Atlantic origin - for *C. riisei* in Hawaii. Although our sampling of Indo-Pacific sites is far from comprehensive, the most likely sources from which the Hawaiian Archipelago was colonized include the locations that share the specific ND2 haplotypes found in Hawaii: Australia, Bali, Palau, and Fiji/Tonga (Fig. 2). Based data we have compiled from the International Comprehensive Ocean-Atmosphere Dataset (ICOADS) of Pacific Ocean vessel traffic from the years 1940-1979, additional areas of likely origin (i.e., harbors and high density shipping lanes) ought to be sampled to resolve this issue. Given the number of cryptogenic and exotic marine taxa in Hawaiian harbors, such a survey may reveal patterns of likely invasion and perhaps suggest the vectors and sources of greatest risk.

- Our results also suggest that there is a cryptic species of *Carijoa* in Hawaii. One of the ND2 haplotypes and one of the SRP54 alleles are exclusively associated with a distinct transparent color morph of *Carijoa* found at Port Allen, Kauai. This non-random sorting of genetic variants among transparent and white morphs (despite close physical proximity) suggests reproductive isolation that may be indicative of a distinct species. This transparent morph, and the sequences amplified from it, is found only on Kauai, and nowhere else in our current dataset that includes samples from around the globe. However, we did not sample any other dark locations which mimic the conditions in Port Allen, and we are currently unable to infer if this putative species is widely distributed but unsampled, or restricted to Hawaii. Again, additional surveys of harbors on the high density shipping lanes identified in Fig. 2 should shed some light on this question.

Dissemination of results.

- An oral presentation of the origins of *Carijoa* in Hawaii was given at the International Society for Reef Science (ISRS) in Bremen, Germany on September 20th 2006. The results were also presented in oral presentations at the 2006 Hawaii Conservation Conference on June 28th 2006, the Annual Albert L. Tester Memorial Symposium on March 23rd 2007 at the University of Hawaii, and will again be presented during the 2007 Ocean Day festivities on June 6th 2007.
- Environment Hawaii published an article on the contents of the oral presentation given at the 2006 Hawaii Conservation conference in October 2006 (Volume 17, number 4).
- There are currently 3 manuscripts in preparation for submission outlining the results of this study, and each will be provided to the Department of Land and Natural Resources when they are ready for submission. The first outlines the development of the novel nuclear marker, and the evidence for a putative cryptic species of *Carijoa* in Hawaii, and will be submitted to Coral Reefs in May of 2007. The second manuscript outlines the global sampling of *Carijoa* populations, and refutes the Caribbean source for a modern introduction of *C. riisei* into Hawaii. This second manuscript will likely be submitted to Molecular Ecology in June of 2007. The final manuscript outlines the use of low salinity exposure to eradicate *Carijoa* colonies in tank experiments, and that manuscript is expected to be completed by the end of the summer.

Figure 1: Frequency of mitochondrial ND2 haplotypes and SRP54 alleles in samples of *Carijoa riisei* included in this study. A) Frequency of genetic variants by ocean basin in comparison to the samples in Hawaii. Note that none of the Atlantic types are represented among the Hawaii samples. B) Frequency of mtDNA haplotypes and nDNA alleles by island throughout the Main Hawaiian Islands, with SRP54 allele frequencies (left pie chart) and ND2 frequencies (right pie chart) at each island location.

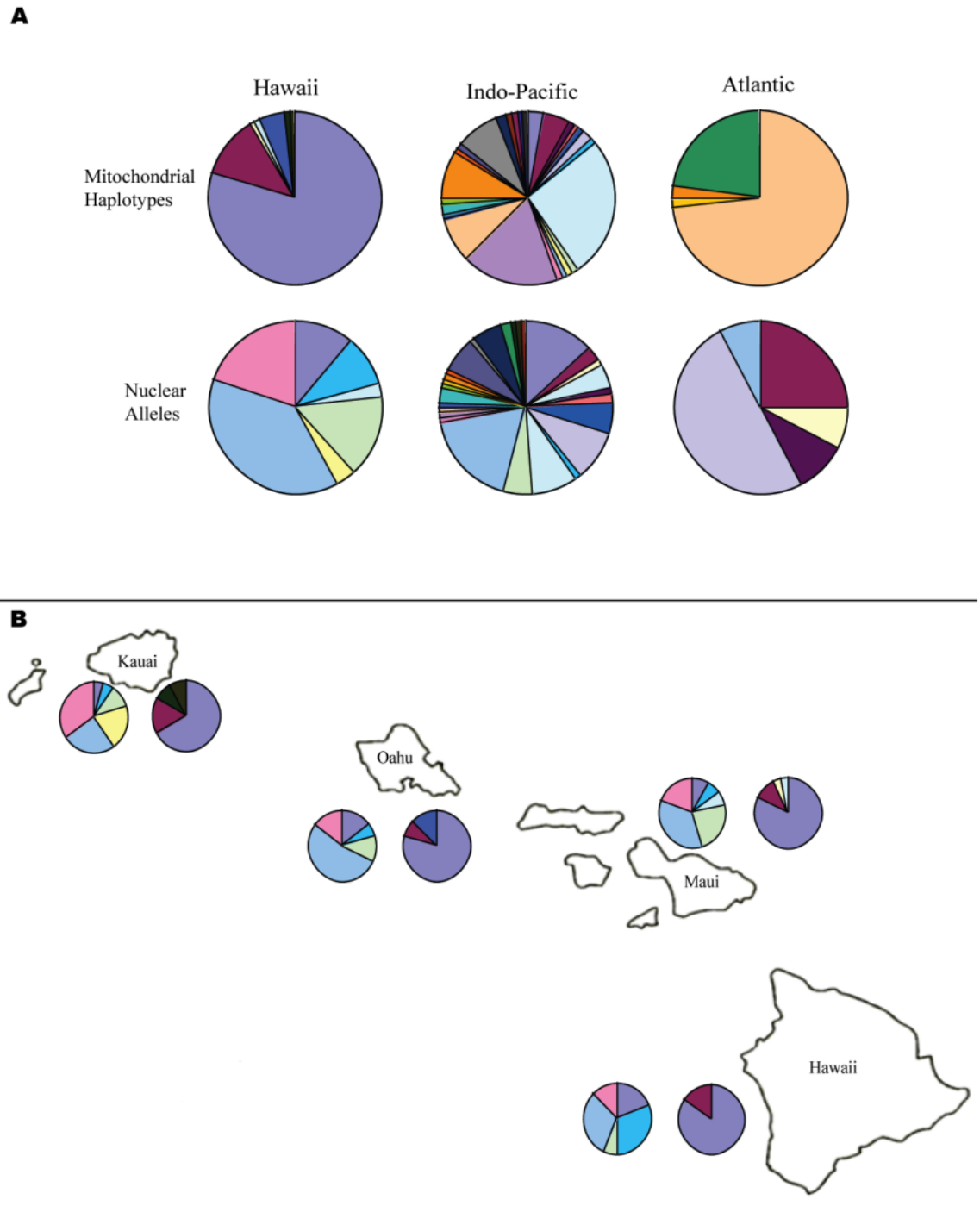

Figure 2: Pacific vessel traffic patterns compiled from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). Locations which share identical ND2 haplotypes with Hawaii are indicated with the haplotype number that is shared. Note that none of the haplotypes are shared with Panama or any location in the Atlantic/Caribbean.