Avrainvillea erecta: A new invasive species threat to Hawaiian coral reef communities

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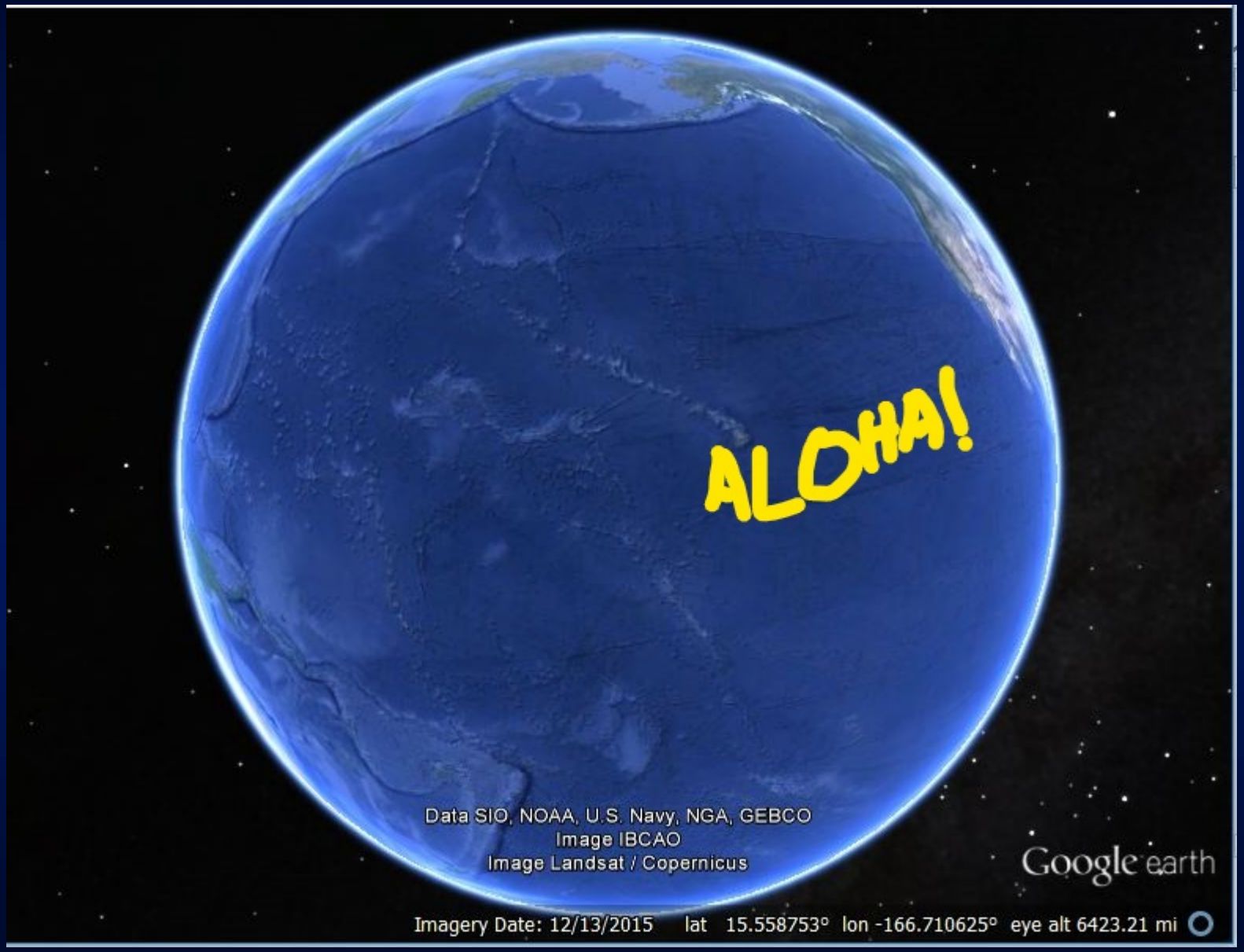
Presentation Objectives

1. Where is Hawaii?
2. Coral Reef Overview
3. Invasive Species Overview in Hawaii
4. Review *Avrainvillea erecta* in Hawaii.
5. Implications for Hawaiian coral reefs
6. Discuss recommendations.

Fig.1. *Avrainvillea erecta*, Oahu Island.
Photo Credit: Liv Wheeler, University of Hawaii

Pacific Ocean



Hawaiian Archipelago

Oahu Island


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA
Image Landsat / Copernicus
Google earth
Imagery Date: 12/13/2015 lat 21.448914° lon -157.950695° elev 0 ft eye alt 47.88 mi

Honolulu Harbor

What is a coral reef?

1. Coral reefs are geologic structures comprised of calcium carbonate laid down by a thin veneer of animal tissue, know as a coral polyp.

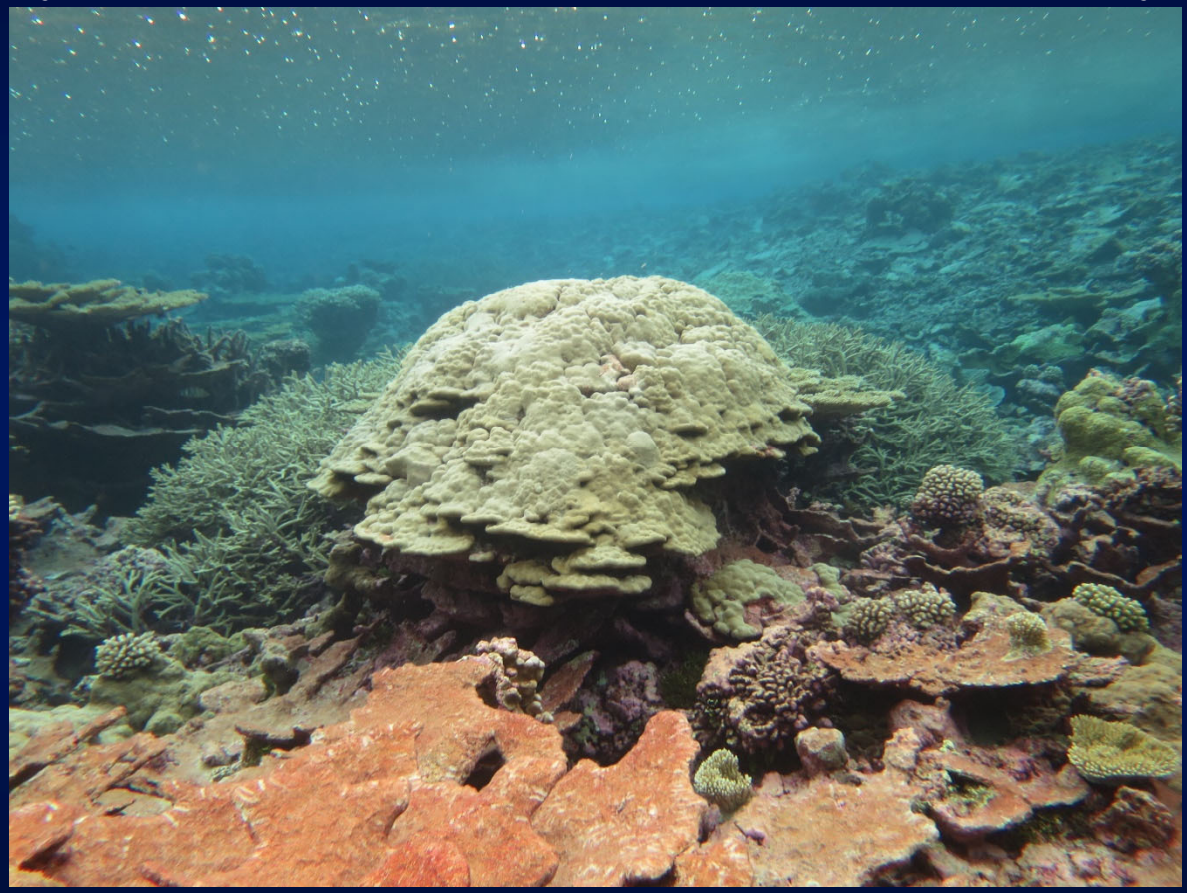


Fig. 2. Coral Reef. Photo Credit: Kevin B. Foster, USFWS.

What is a coral reef?

1. Corals gain their nutrition, in part, through filter feeding and also from nutrients provided by microscopic plants/dinoflagellates, called *Zooxanthellae*, that they host in a mutual symbiotic relationship.

Fig. 3. *Monitopra flabellata*. 4. Coral. Photo Credit: Kevin B. Foster, USFWS.

What is a coral reef?

1. Requirements for corals to flourish and reproduce:
   a) Clean water quality conditions, free of sediments, contaminants and excess nutrients
   b) Coral planula (larval) require clean substrates to successfully attain settlement. (Chemical cues from crustose coralline algae)

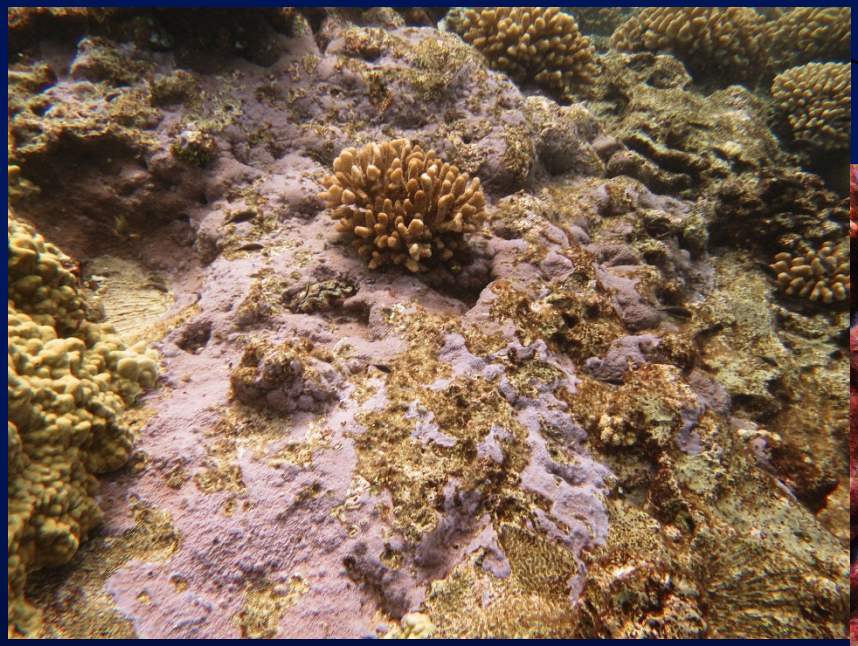


Fig. 5. Crustose Coralline Algae. 6. CCR. Photo Credit: Kevin B. Foster, USFWS.

What is a coral reef?

1. Coral reefs support thousands of species of plants and animals

Fig. 7 Parrot Fish (*Scarus*). 8. Soft and Harbor Coral. Photo Credit: Kevin B. Foster, USFWS.

What is a coral reef?

1. Coral reefs support habitat for functions that include species reproduction, forage, resting and shelter from predators…

Fig. 9. Gray Reef Shark.
Photo Credit: Kevin B.
Foster, USFWS.

Coral Reefs

1. Hawaii is the endangered species capital of the world!! Coral reefs also support habitat for federally listed species such as the threatened Hawaiian Green sea turtle (*Chelonia mydas*) or Honu and the endangered Hawksbill sea turtle (*Eretmochelys imbricata*).
2. Coral Reefs also support endemic species: up to 1/3 of all marine mollusks in Hawaiian waters are only found in Hawaii. Of the 7,000 Hawaiian aquatic species, over 1,250 are only known to occur in Hawaii.

Fig. 10. Hawksbill Sea Turtle 11. Green Sea Turtle and 12. Octopus (He'e) Photo Credit: Kevin B. Foster, USFWS.

Coral Reefs

1. Coral reefs also support resting and forage habitat for migratory birds, including federally protected sea birds.
2. Coral reefs function as buffers between large oceanic swells and coastal lands, diffusing wave energy and reducing the risk of erosion.

Fig. 13. Fairy Tern, Sea bird. Photo Credit: Kevin B. Foster, USFWS.

Fig. 14. Reef Pavement Zone. Photo Credit: Nadiera McCarthy, USFWS.

Coral Reefs

1. Coral reefs also support multi-million dollar recreational industries such as boating, surfing, fishing, spear fishing and scuba diving...

Fig. 15. Coral Reef (*Turbinaria reniformis*).
16. Acropora sp and diver
Photo Credit: Kevin Foster, USFWS, 2017.

Coral Reefs

1. Coral reefs serve as a source of food for millions of subsistence fishers throughout the Indo-Pacific.

Fig. 17. Fishers. Photo Credit: Kevin Foster, USFWS.

Questions?

Species Dispersal and Invasives

1. Drifting organisms began colonizing the Hawaiian islands soon after they were formed and this process has been on-going for millions of years, leading to the evolution of many endemic marine, freshwater, and terrestrial organisms in the Hawaiian Archipelago.
2. As the most isolated islands in the world, a great many species failed to naturally colonize and assisted passage was required to bridge the vast expanse of the Pacific Ocean.
3. Most introduced species arrived from international shipping (as fouling and in ballast), some were intentionally introduced and most species hail from the Indo-West Pacific, Eastern Pacific and North Atlantic.
4. According to Carlton and Eldgredge (2009), over 300 aquatic species have been introduced to Hawaii and an additional 100 species are considered cryptogenic.

Invasive algae and their effects on Hawaiian coral reef communities

1. *Avrainvillea lacerata (*formerly, *A. amadelpha), Gracilaria salicornia, Hypnea musciformis, Acanthophora spicifera* and Kappaphycus spp.

Fig.18. *Avrainvillea lacerata*, Oahu Island.
Photo Credit: Dr. Kim Peyton, State of Hawaii, Department of Aquatic Resources

Invasive Green Alga: *Avrainvillea lacerata*

1. Discovered in nearshore environment on leeward Oahu Island in 1981, suspect Honolulu Commercial Harbor as point of origin.
2. Currently observed from the upper intertidal, splash zone, to depths of at least 130 feet in both sediment (e.g., sand/mud) and hard substrate (e.g., calcium carbonate) on eastern, southern and western Oahu and Port Allen, Kauai.
3. Plant consists of 1 to 4 blades with compact basal holdfast that forms tight clusters on the reef.
4. Outcompetes native algae/seagrass and alters habitats by trapping sediments.
5. Acts as a secondary substrate for other algae.

Fig.19. *Avrainvillea lacerata*, Oahu Island.
Photo Credit: Kevin Foster, USFWS 2010

Invasive Red Alga: *Gracilaria salicornia*

1. Successful in calm, protected waters, dispersal through fragmentation, first introduced in 1978 by Dr. Max Doty, HIMB, for aquaculture purposes.
2. Found on reef flats and eroded limestone, from the mid-intertidal tidepools to shallow subtidal, to about 12 feet deep.
3. Comprised of solid, cylindrical branches, 1-2 mm in diameter, with short, pointed tips. May arise from one to several branches that become dense, small bushes with a rounded profile.
4. Competes with native algae, e.g., *G. coronopilofia* for reef substrate by forming large, intricate mats that cover the substrate and inhibit settle of other algae species. *G. coronopilofia is a* native limu that is harvested and consumed by Hawaiians.

Fig.20. *Gracilaria salicornia*, Oahu Island.
Photo Credit: University of Hawaii

Invasive Red Alga: *Hypnea musciformis*

1. Rapid growth rate, ability to epiphytize other algae and easy fragmentation facilitates distribution from Kauai to Oahu, Molokia and Maui Islands and was originally introduced in Kaneohe Bay in 1974 for aquaculture purposes.
2. Common on calm intertidal and shallow subtidal reef flats, tidepools and rocky intertidal beaches and as epiphytic on Sargassum. During bloom stage, may be found free-floating.
3. Firm, highly branched and twists around axes of other algae. The ends of branches are flattened with broad hooks (tendril-like).
4. Found in large, nearly uni-algal mats, during the winter can represent 2/3 of biomass of drift algae on windward and leeward beaches on Maui. Thousands of pounds form windrows on Maui beaches and decay, with a strong foul odor.

Fig.21. *Hypnea musciformis*, Oahu Island. Photo Credit: Dr. Jennifer Smith UH

Invasive Red Alga: *Acanthophora spicifera*

1. Entered Oahu Island on a barge from Guam in the 1950s, is now widespread throughout all 8 main Hawaiian Islands.
2. Abundant in calm, shallow reef flats, tide pools, and rocky intertidal benches. Attaches to hard substrates, (e.g., rocks, basalt ledges and dead corals). Also free floating, brittle and distribution by fragmentation.
3. Has short (4-10 cm), compact and very dense thalli in high water motion areas; in low areas, thalli are tall, up (10-25 cm), openly branched and occur in scattered clumps. Grows from a large, irregularly shaped holdfast.
4. Competes with native algae species such as Laurencia spp. or Hypnea spp.

Fig.22. *Acanthophora spicifera*, Oahu Island. Photo Credit: Keoki Stender, UH-Dive Prg.

Invasive Red Alga: *Kappaphycus alvarezii*

1. Some of the largest tropical red algae, with hi growth rates that double plant size in 15-30 days. Introduced to Kaneohe Bay in 1974 for aqualculture purposes.
2. Observed at depths from 1-50 feet. Loosely attached to broken coral, or unattached fragments floating in shallow and deep waters and form large moving mats.
3. Thalli coarse with branches 1-2 cm diameter; irregularly brittle branches up to six feet tall with primary and secondary branches.
4. Reproduces vegetatively and successfully outcompetes native algae througout Kaneohe Bay.

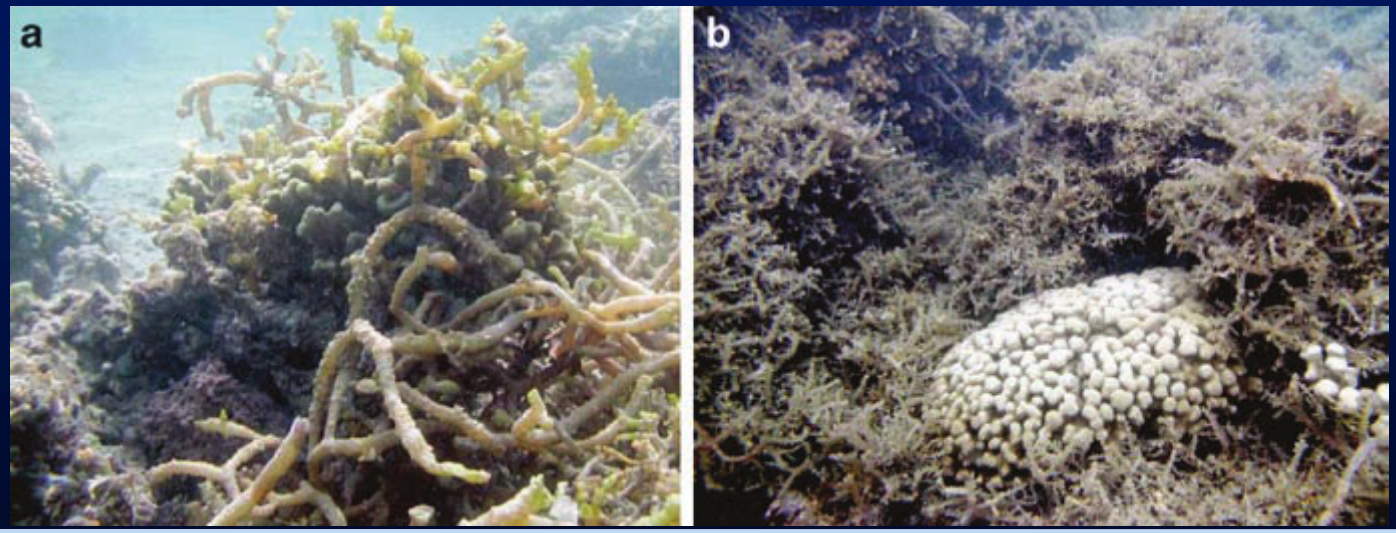


Fig. 23 and 24. *Kappaphycus alvarezii*, Oahu Island.
Photo Credit: Dr. Jennifer Smith.

What we know about the newly discovered *Avrainvillea erecta*

1. First observed October 14, 2014 during a USFWS marine biological survey of Honolulu Commercial Harbor Entrance Channel, FNP(Foster, USFWS, Petyon and Murakawa, DAR) in sand habitat at depths between 36 to 45 feet amongst seagrass (*Halophila descipiens*) meadow and patches of calcareous green algae (*Halimeda kanaloana*).
2. The second observation occurred during a research dive by the University of Hawaii on April 22, 2017 at Keehi Lagoon (Wade, UH) at depths between 75 and 120 feet in sand habitat with seagrass (*Halophila descipiens*) and calcareous green algae (*Halimeda kanaloana*).

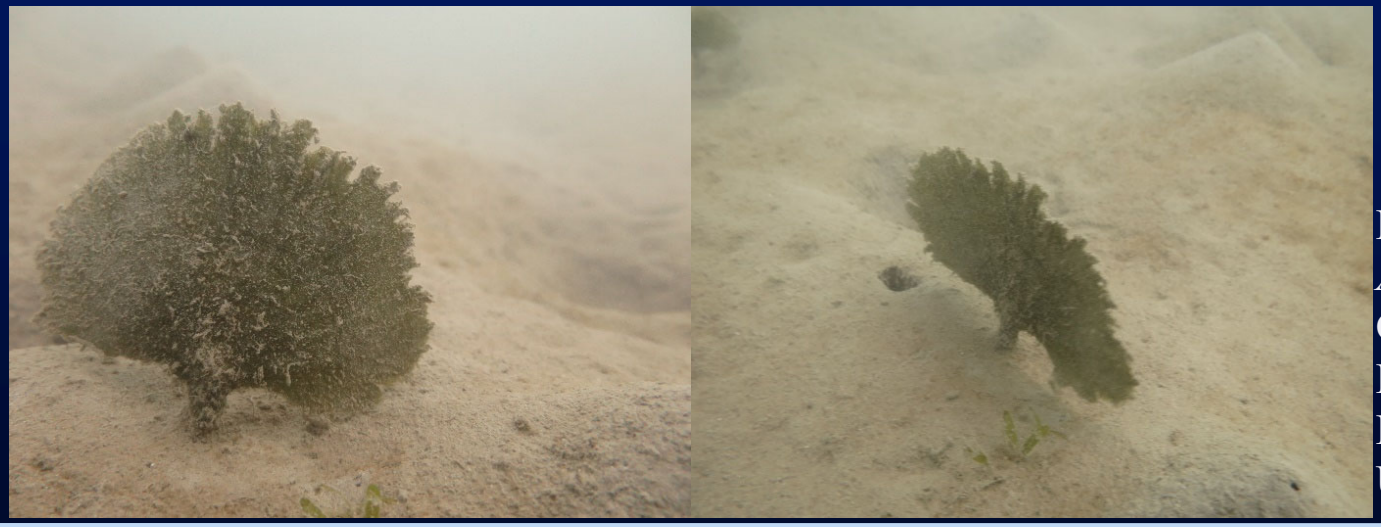


Fig.25 and 26. *Avrainvillea erecta*, Oahu Island. Photo Credit: Kevin B. Foster, USFWS.

What we know about the newly discovered *Avrainvillea erecta*

1. Two morphologies were observed, blade-like and loose siphons due to water flow exposure. Individuals with completely formed blades were fully exposed while individuals with loose assemblage of siphons were in depressions.
2. Observed as single individuals or in patches (10 - 20 individuals per square meter).
3. Individuals with spherical assemblages of loose siphons were consistently much smaller in thallus size than the well-formed blade morphology.
4. Holdfasts of larger, more mature individuals protruded from the sediment by approximately 1-5 cm, creating a conical mound at the base of the alga.

Fig.27 and 28. *Avrainvillea erecta*, Oahu Island. Photo Credit: Kevin B. Foster, USFWS.

What we know about the newly discovered *Avrainvillea erecta*

1. Individuals were generally clean and not heavily epiphytized.
2. Several individuals were observed with feeding scars (large bite marks), giving some thalli a U-shaped appearance.
3. Specimens collected from Honolulu Harbor and Keehi lagoon occurred in sand habitat, amongst seagrass meadows (*Halophilpha descipiens*) and patches of calcareous green algae, (*Halimeda kanaloana*)

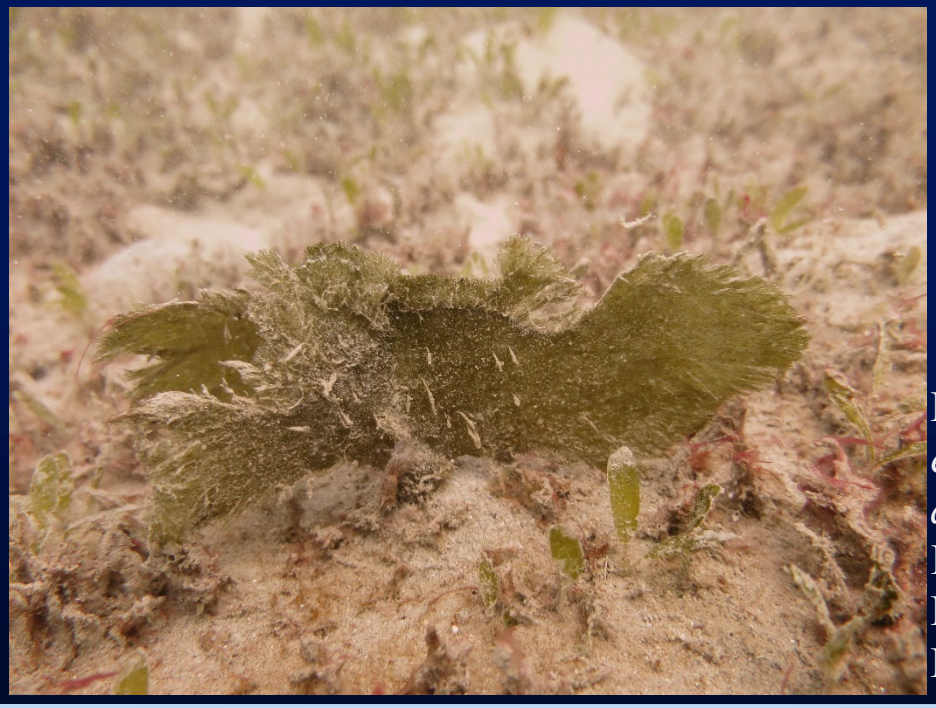


Fig.29. *Avrainvillea erecta* & *Halophila descipiens*, Oahu Island.
Photo Credit: Kevin Foster, USFWS.

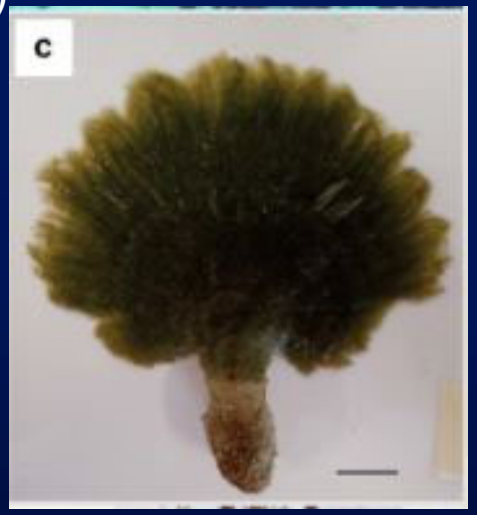


Fig.30. *Avrainvillea erecta*, Oahu Island.
Photo Credit: Rachael Wade, UH.

What we know about the newly discovered *Avrainvillea erecta*

1. Specimens were olive green when collected and dried to darker green when collected. Adult individuals ranged in height from 6.7 to 15.8 cm. Frond length ranged from 3.6 to 10.8 cm.
2. Adult thallus was comprised of a blade, stipe and holdfast, and holdfasts comprised up to 46% of the overall thallus length.
3. Juveniles consisted only of a holdfast and a spherical assemblage of loose siphons and appeared to be in the beginning stages of forming a blade.
4. Morphologically identified as A. cf. erecta
5. DNA sequencing indicated samples collected from Honolulu Harbor and Keehi Lagoon to be identical.

Fig.31. *Avrainvillea erecta*, Oahu Island. Photo Credit: Kevin B. Foster, USFWS.

Implications for Hawaiian Coral Reefs

1. Invasive species threaten coral reef communities by outcompeting native seagrass and algae. In Hawaii, an endemic gastropod, *Smaragda bryanaie*, forages on seagrass exclusively.

2. Invasive plants grow in dense patches that support epiphytes of other algal species, creating a flocculent canopy. Without clean, hard substrates, coral larvae settlement is compromised and establishment of new corals is problematic.

3. Invasive species threaten endemic species, such as the endemic corals..e.g., *Montipora capitata* and *Leptoserus hawaiiensis.*

4. Invasive species also threaten marine species biodiversity and degrade ecological functions such as species reproduction, forage, resting and shelter.

Implications for Hawaiian Coral Reefs

1. As healthy intact native reefs loose their resiliency, functions such as wave energy reduction will also be degraded and coastal erosion will escalate, threatening residential homes, coastal roads and infrastructure, military installations and commercial industries.

Fig. 32. Coral community in transition dominated by *A. lacerata* and epiphytic canopy. Photo Credit: Kevin Foster, USFWS.

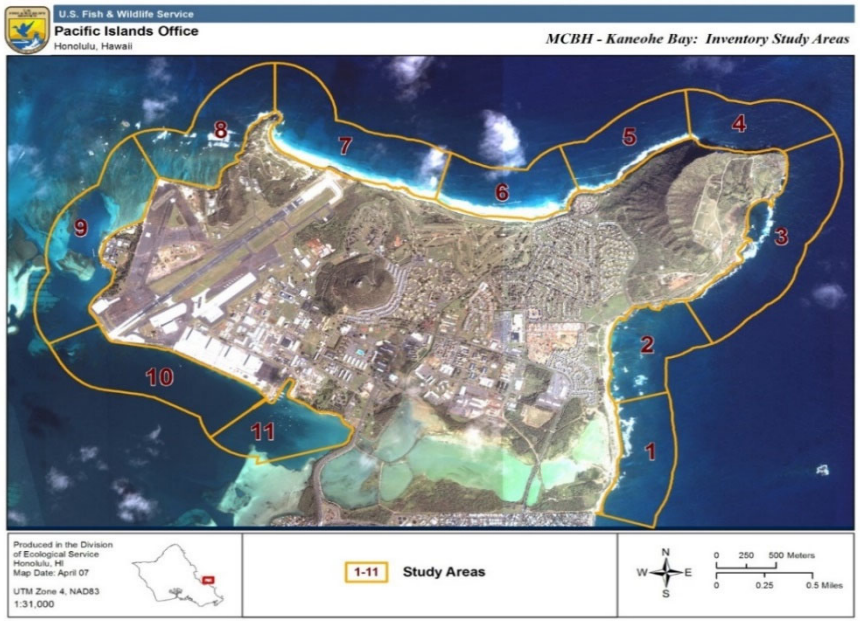


Fig. 33. Marine Corps Base Hawaii (Mokapu Penninsula): Ulupau Crater (east), Runway (West).

Measures to protect Hawaiian marine biodiversity and the State's economy

1. Inspect "hotspots" within Honolulu Harbor annually to identify the presence of newly established species.

2. Deploy a rapid response dive team to eradicate incipient populations of invasive species.

3. 80% of all materials that come to Hawaii pass through Honolulu Harbor, some of which are barged to neighbor islands.
    1. Periodically inspect inter-island barge vessel hulls for invasive species.
    2. Inspect neighbor island harbors (e.g., Kawaiihae, Kahului, Hilo or Nawiliwili Harbors) for invasive species.

Measures to protect Hawaiian marine biodiversity and the State's economy

1. Inspect trans-Pacific barges for hull fouling prior to arrival into Hawaiian harbors.

2. Establish effective laws that hold "dirty" barge owners (or anyone) responsible for introducing invasive marine species to Hawaiian waters.

Questions/Comments?

Dr. Kim Peyton, Paul Murakawa and Kevin Foster