

A World Heritage Site

# Aliens in Papahānaumokuākea Marine National Monument; Some are Green, but None are Friendly

Third Thursday By the Bay Presentation Series at Mokupāpapa Discovery Center

March 18, 2021 • 12 pm Hawai'i / 3 pm Pacific / 6 pm Eastern

<u>Brian Hauk</u><sup>1,2</sup>, Scott Godwin<sup>3</sup>, Holly Bolick<sup>4</sup>, Atsuko Fukunaga<sup>1,2</sup>, Jon Martinez<sup>2</sup>, Randall Kosaki<sup>2</sup>

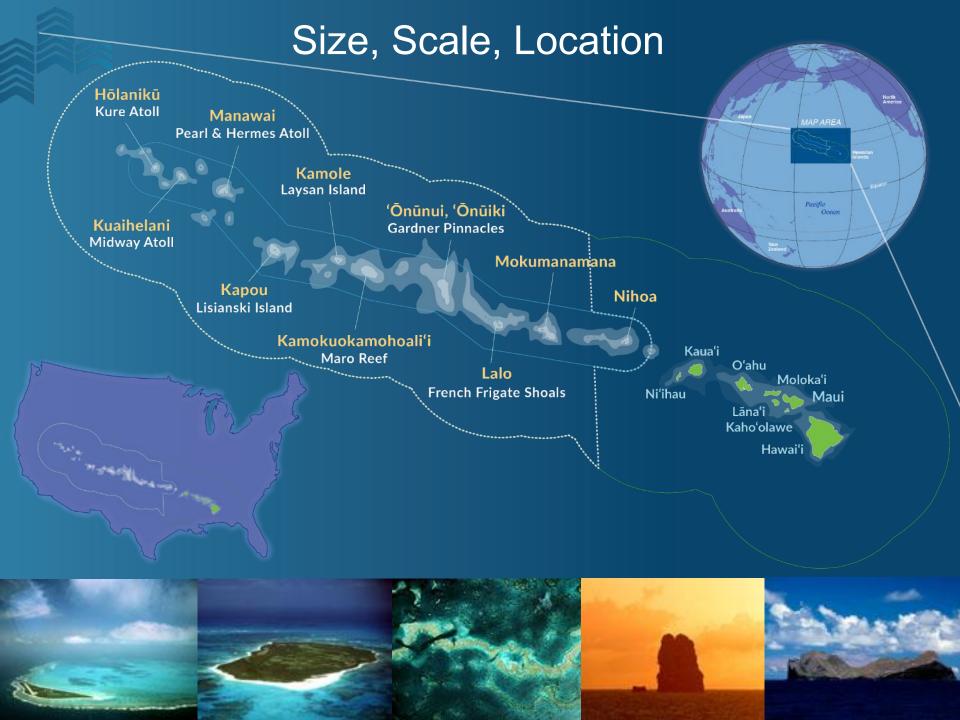
¹Joint Institute for Marine and Atmospheric Research, Honolulu, United States, ²NOAA/NOS/ONMS/PMNM, Honolulu, United States,

³ Self Employed, Honolulu, United States, ⁴Bishop Museum, Honolulu, United States

Presented by: Brian Hauk

JIMAR Resource Protection Manger for PMNM

Brian.hauk@noaa.gov





Source: http://www.davegranlund.com/cartoons/





#### WHAT IS RECREATIONAL BOAT BIOFOULING?

Biofouling refers to organisms attached to or associated with underwater or wetted surfaces of a vessel. Recreational boat biofouling can occur on the hull of your boat and on a variety of recesses and appendages collectively referred to as niche areas (e.g. propellers, rudders, intakes).

#### WHY IS MANAGING RECREATIONAL BOAT BIOFOULING IMPORTANT TO YOU?

Managing biofouling protects your investment, saves fuel, and prevents the spread of aquatic invasive species.

#### DID YOU KNOW? > > > > > > > > > >

BIOFOULING IS A MAJOR CONTRIBUTOR TO THE INTRODUCTION AND SPREAD OF AQUATIC INVASIVE SPECIES.

Aquatic invasive species are non-native species that threaten the diversity or abundance of native species, the ecological stability of infested waters, or any commercial, agricultural, aquacultural, or recreational activities dependent on such waters.



USE BEST PRACTICES DESCR ON THE OTHER SIDE OF THIS HANDOI MANAGE BIOFOULING ON YOUR









Clockwise from left: Large skiff covered in growth; Blue mussels not native to Hawaii; Chiton and limpets not native to Hawaii; Light bulb with Gooseneck barnacles; Gooseneck barnacles which are not a concern.







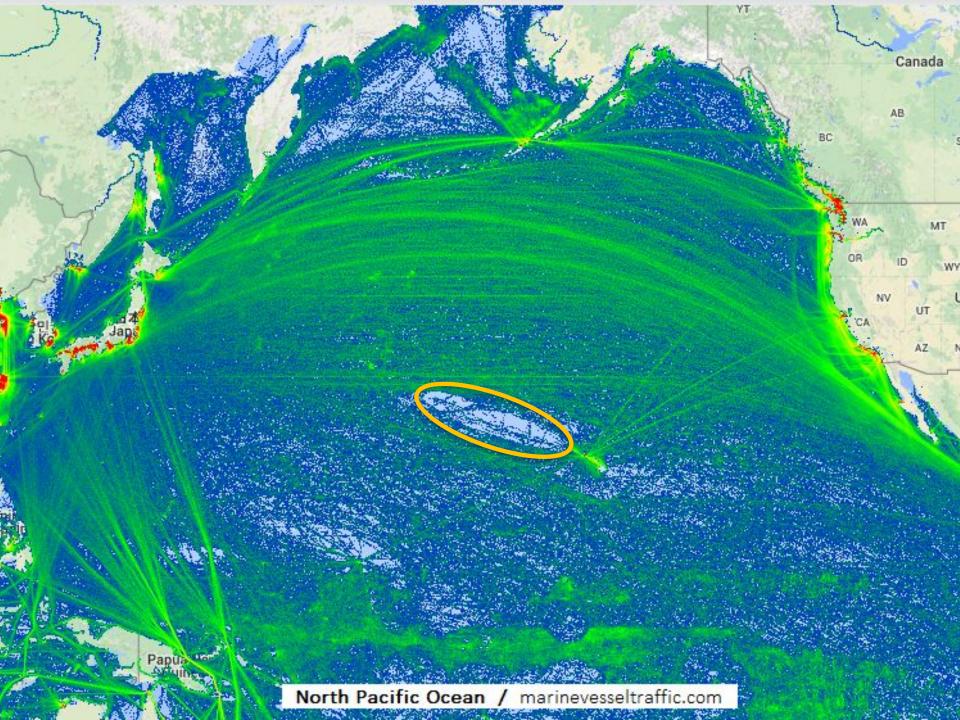
### Hawaii Invasive Species Awareness Month

INVASIVE SPECIES ARE EVERYONE'S KULEANA

https://dlnr.hawaii.gov/hisc/











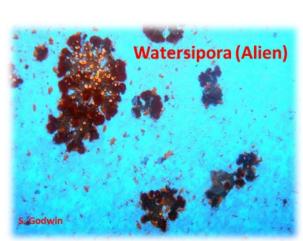
































#### 2020 STATE OF

- RERERER

#### Papahānaumokuākea Marine National Monument

STATUS AND TRENDS 2008-2019



























### 2020 State of the Monument Report:2008-2019

### Marine non-indigenous species:

Status: Fair Trend: Not Changing Evidence Score: Medium

### Aliens species Management Strategies

- 1.Prevent, monitor and control alien species introductions
- 2.Engage Monument users and the public in preventing the introduction and spread of alien species
- 3. Participate in regional efforts by participating in statewide and international initiatives on alien species







# Question # 1 What is a cryptogenic species?

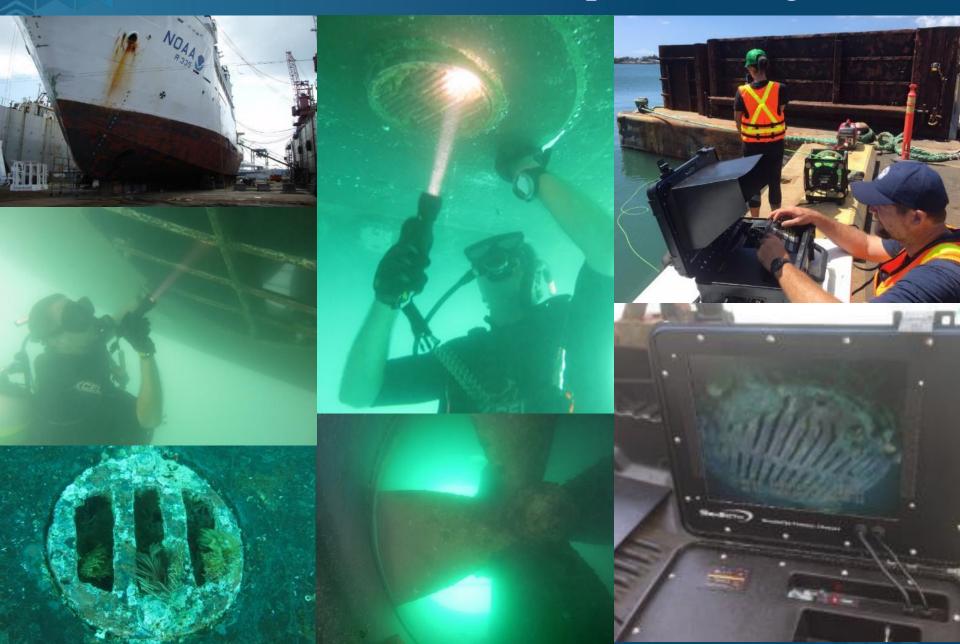
Organisms that are not native to a particular environment and have been accidentally or purposely introduced into new ecosystems

Organisms that are found only in a particular geographical region

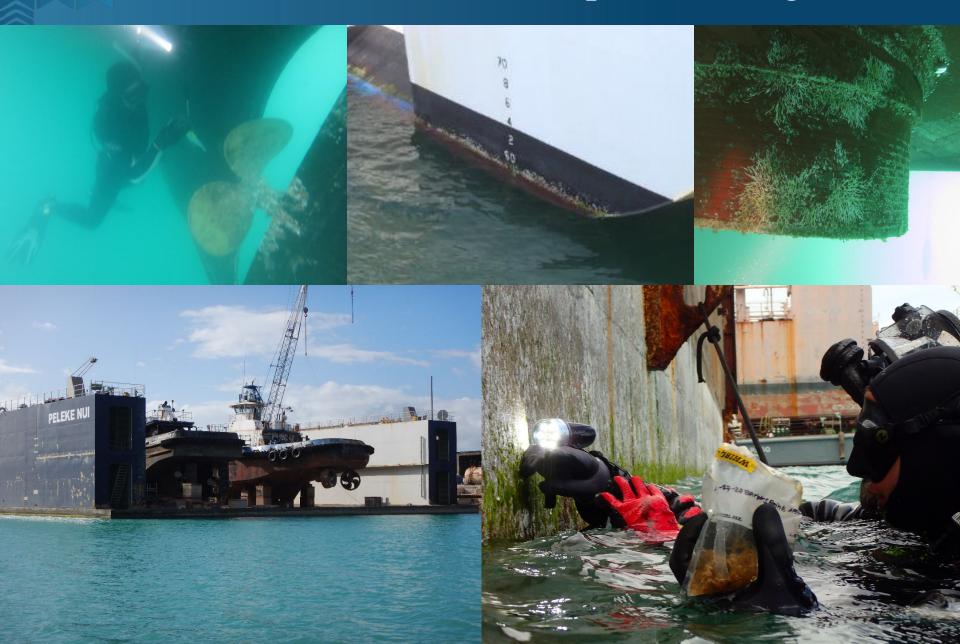
Organisms whose origin is unknown with regards to being native or introduced

Organisms that are naturally found in a certain type of ecosystem

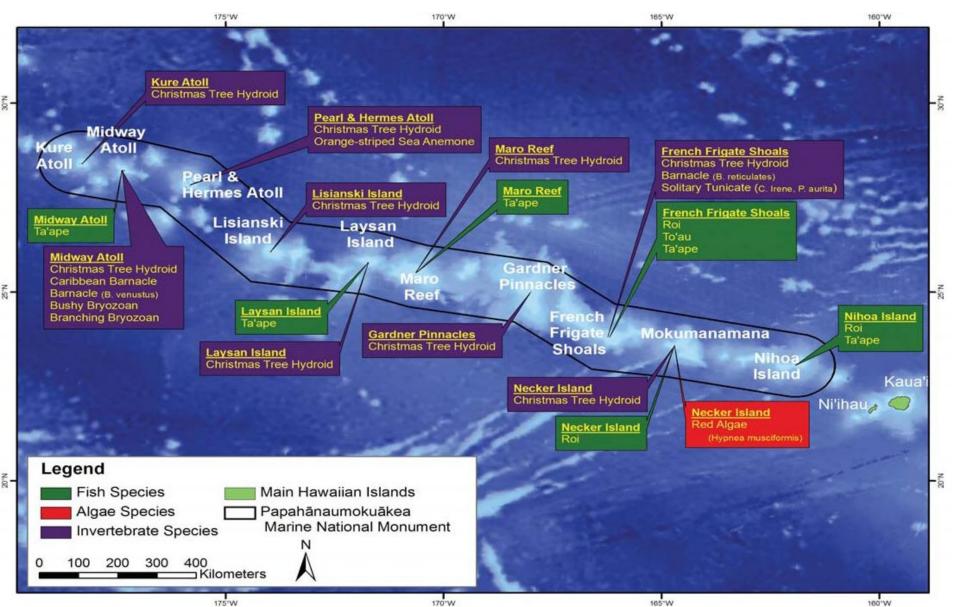
## Vessel Risk Assessment & Inspection Program



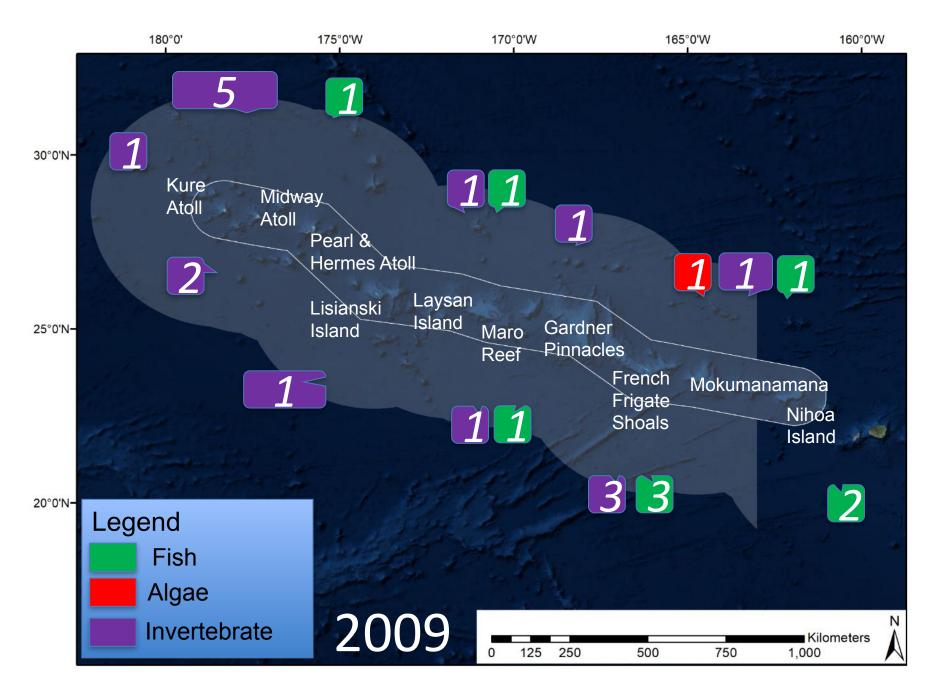
## Vessel Risk Assessment & Inspection Program

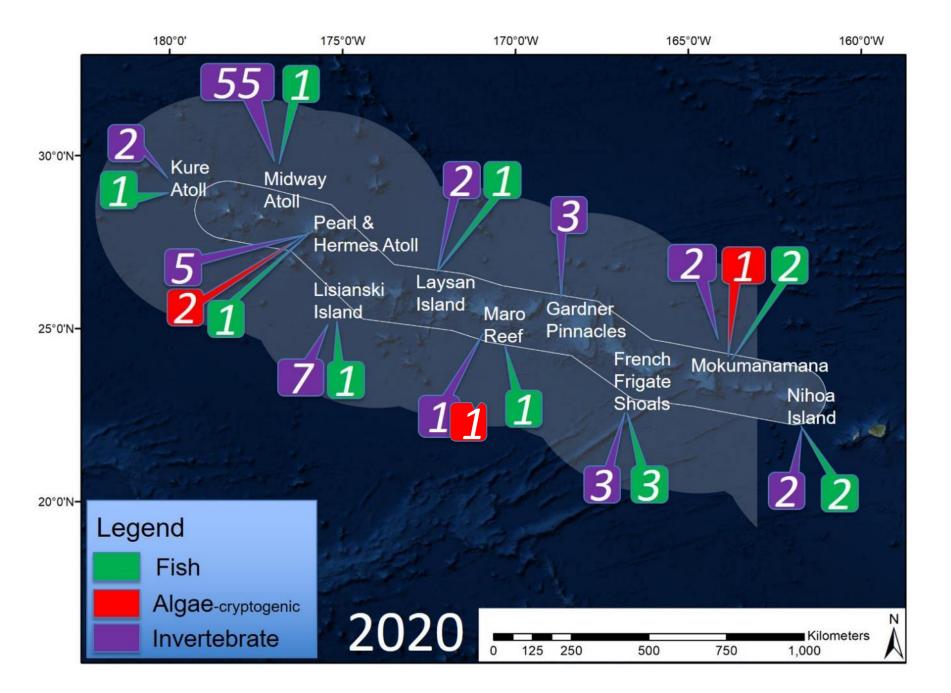






Friedlander, A., K. Keller, L. Wedding, A. Clarke, M. Monaco (eds.). 2009. A Marine Biogeographic Assessment of the Northwestern Hawaiian Islands. NOAA Technical Memorandum NOS NCCOS 84. Prepared by NCCOS's Biogeography Branch in cooperation with the Office of National Marine Sanctuaries Papahanaumokuakea Marine National Monument. Silver Spring, MD. 363 pp. Sources: Abbott, pers comm; DeFelice et al., 1998; DeFelice et al., 2002; Godwin et al., 2004; Godwin, 2008; Godwin, pers comm; Waddell et al., 2008; Zabin et al., 2004.









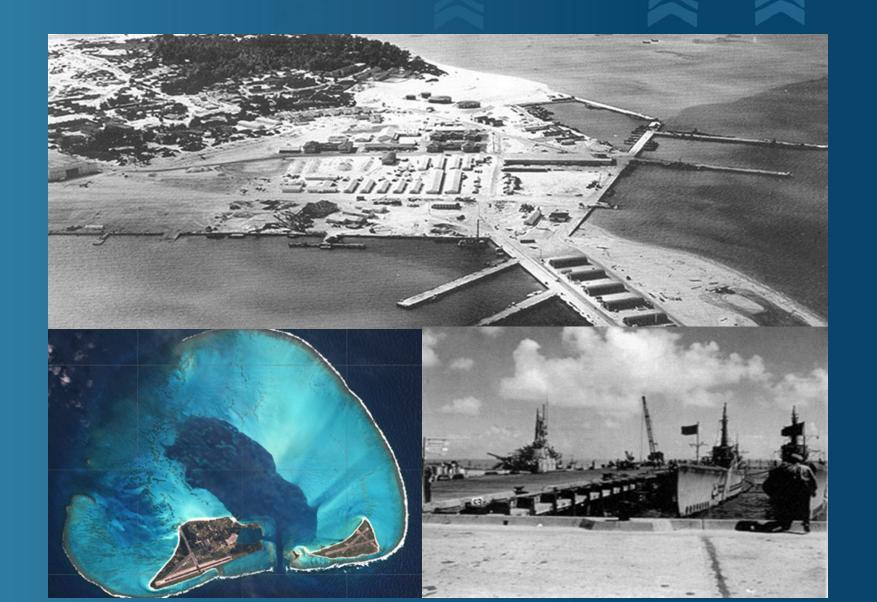


## Question # 2

What Atoll and/or Island has the highest number of alien species recorded within PMNM?

- Manawai (Pearl & Hermes Atoll)
- Lalo (French Frigate Shoals)
- Pihemanu (Midway Atoll)
- Kapou (Lisianski Island)

## Pihemanu (Midway Atoll)



# Maritime Heritage & Alien Species Project

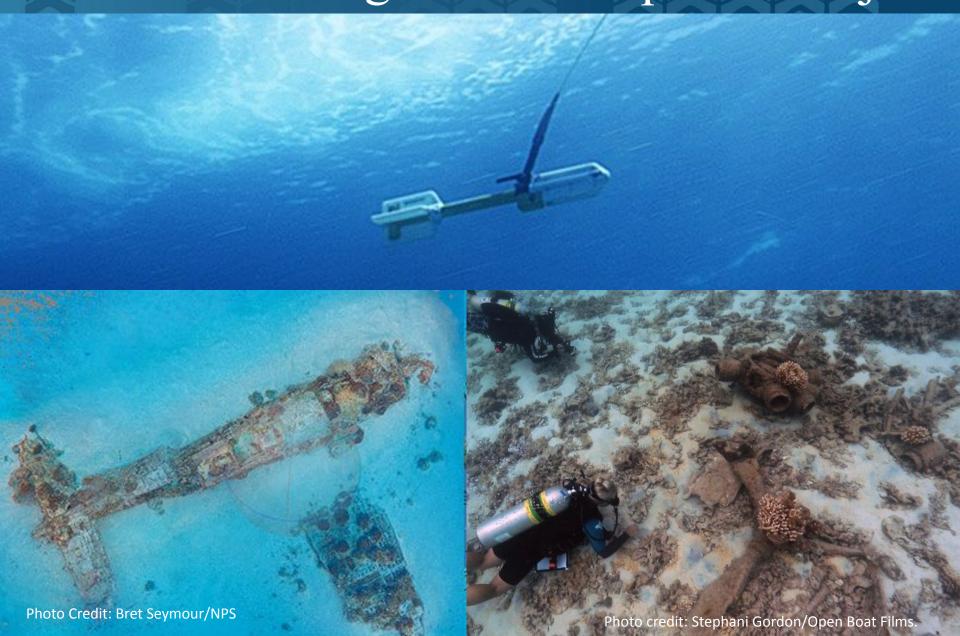




Photo # 80-G-701852 Diorama of Japanese air raid on Midway, 4 June 1942





**Marine National Monument** 

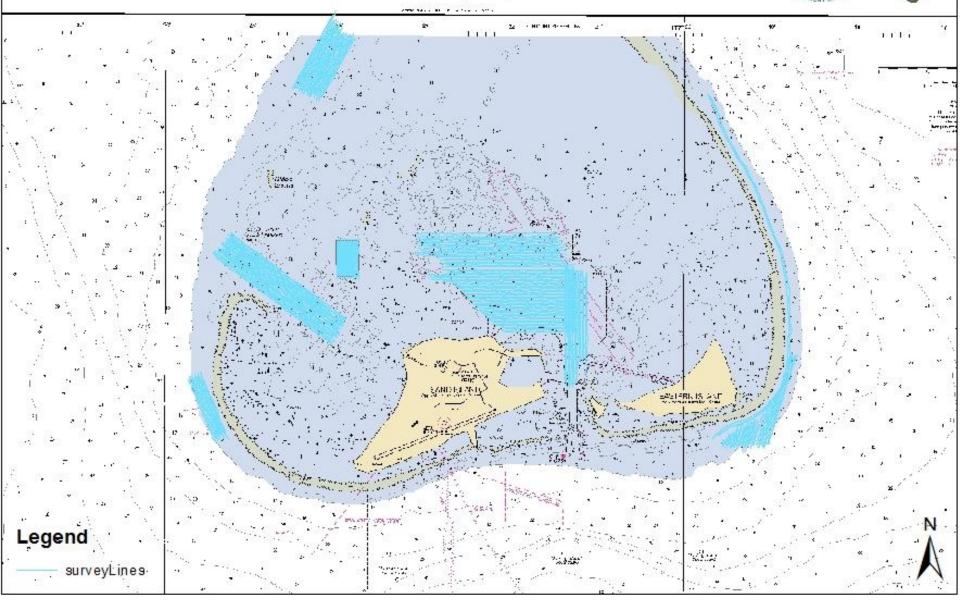
Exploring the Sunken Heritage of Midway Atoll:

Honoring the Legacy of the 75th Anniversary of the Battle of Midway





Magnetometer Survey Coverage Map May 3-16, 2017



# Midway Survey Results

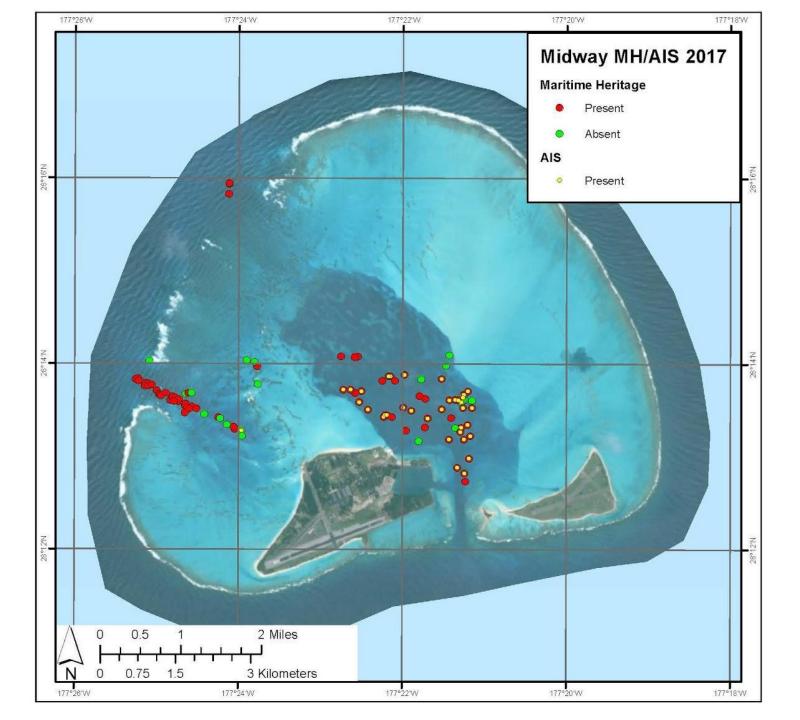
| Data Type                        | Quantity | Positive Findings |
|----------------------------------|----------|-------------------|
| Magnetometer Detections          | 137      |                   |
| Anomalies Investigated           | 102      | 82                |
| Alien Species Surveys            | 107      | 36                |
| Photo cradit: Scott Godwin /NOAA |          |                   |

1) Pennaria disticha 2) Crella (Yvesia) spinulata 3) Amathia verticillata 4) Sabellastarte spectabilis



















# Question # 3 What is a magnetometer?

- An automated DNA barcoding device
- A machine that detects the presence of alien species
- A device that measures magnetic fields or anomalies
- A scientific instrument used to determine benthic habitat types

| Marine Non-Indigenous Invertebrate Species throughout PMNM |   |          |                              |          |     |     |     |     |     |     |                |     |  |
|--|---|----------|------------------------------|----------|-----|-----|-----|-----|-----|-----|----------------|-----|--|
|  |   |          | Distribution by Island/Atoll |          |     |     |     |     |     |     |                |     |  |
|  | Taxon   | Status   | Z<br>H                       | MOK      | FFS | GAR | MAR | LAY | LIS | P&H | MID            | KUR |  |
|  | PHYLUM ANNELIDA                                   |          |                              |          |     |     |     |     |     |     |                |     |  |
| Class Polychaeta<br>Family Chaetopteridae                  |   |          |                              |          |     |     |     |     |     |     | V              |     |  |
| Order Eunicida<br>Family Lumbrineridae                     | Chaetopterus variopedatus                         | A        |                              |          |     |     |     |     |     |     | X              |     |  |
|  | Kuwaita (Lumbrineris) heteropoda                  | С        |                              |          |     |     |     |     |     |     | Х              |     |  |
| Order Sabellida<br>Family Sabellidae                       |   |          |                              |          |     |     |     |     |     |     |                |     |  |
|  | Branchiomma cingulatum                            | A        |                              |          |     |     |     |     |     |     | X              |     |  |
|  | Potamethus elongatus<br>Sabellastarte spectabilis | C        | Х                            | X        | -   | X   |     | Х   | Х   |     | X              |     |  |
|  | Potamilla sp.                                     | Ü        |                              | <u> </u> |     | _^_ |     | _^_ |     |     | Î              |     |  |
| Family Serpulidae  | 4.  |          |                              |          |     |     |     |     |     |     |                |     |  |
|  | Hydroides brachyacantha                           | Α        |                              |          |     |     |     |     |     |     | Х              |     |  |
|  | Hydroides elegans                                 | A        |                              |          |     |     |     |     |     |     | Х              |     |  |
|  | Hydroides exaltata                                | A        |                              |          |     |     |     |     |     |     | X              |     |  |
|  | Pseudovermilia pacifica                           | A        |                              |          |     |     |     |     |     |     | X              |     |  |
|  | Salmacina tribranchiata                           | A<br>C   |                              | -        |     |     |     |     |     |     | X              |     |  |
|  | Protula cf. atypha<br>Vermiliopsis sp.            | C        |                              |          |     |     |     |     |     |     | <del>l</del> x |     |  |
| Order Terebellida  | v вттираю ф.                                      | F        |                              |          |     |     |     |     |     |     |                |     |  |
| Family Terebellidae  |   |          |                              |          |     |     |     |     |     |     |                |     |  |
| ,  | Lanice conchilega                                 | Α        |                              |          |     |     |     |     |     |     | Х              |     |  |
| PI   | HYLUM ARTHROPODĂ                                  |          |                              |          |     |     |     |     |     |     |                |     |  |
| Class Hexanauplia  |   |          |                              |          |     |     |     |     |     |     |                |     |  |
| Order Sessilia   |   |          |                              |          |     |     |     |     |     |     |                |     |  |
| Family Chthamalidae  |   |          |                              |          |     |     |     |     |     |     | ļ              |     |  |
| L  | Chth ama lus proteus                              | Α        |                              |          |     |     |     |     |     |     | Х              |     |  |
| Class Malacostraca   |   |          |                              | -        |     |     |     |     |     |     |                |     |  |
| Order Amphipoda  |   | $\vdash$ |                              |          |     |     |     |     |     |     |                |     |  |
| Family Caprellidae   | Convolla cocura                                   | A        |                              | -        |     |     |     |     | X   |     |                |     |  |
| Order Isopoda  | Caprella scaura                                   | <u>^</u> |                              |          |     |     |     |     |     |     |                |     |  |
| Family Ligiidae  |   |          |                              |          |     |     | -   |     | -   |     |                |     |  |
| . s.iii.j Eigilado   | Ligia (Megaligia) exotica                         | Α        |                              |          |     |     |     |     |     |     | X              |     |  |

| Marine Non-Indigenous Invertebrate Species throughout PMNM |                         |   |                              |     |     |     |     |     |     |     |     |   |
|--|-------------------------|---|------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|---|
|  |                         |   | Distribution by Island/Atoll |     |     |     |     |     |     |     |     |   |
| Taxon  |                         | Z | MOK                          | FFS | GAR | MAR | LAY | LIS | P&H | MID | KUR |   |
|  | PHYLUM Bry ozoa         |   |                              |     |     |     |     |     |     |     |     |   |
| Class Gymnolaemata   |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Order Ctenostomatida                                       |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Family Vesiculariidae                                      |                         |   |                              |     |     |     |     |     |     |     |     |   |
|  | Amathia distans         | Α |                              |     |     |     |     |     |     |     | Х   |   |
|  | Amathia verticillata    | Α |                              |     |     |     |     |     | Х   |     | Х   |   |
| Order Cheliostom atida                                     |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Family Schizoporellidae                                    |                         |   |                              |     |     |     |     |     |     |     |     |   |
|  | Schizoporella cf errata | Α |                              |     |     |     |     |     |     |     | Х   |   |
| Family Bugulidae   | Bugula sp.              | Α |                              |     |     |     |     |     |     |     | Х   |   |
| Ph   | IYLUM CHORDATA          |   |                              |     |     |     |     |     |     |     |     |   |
| SUBPHYLUM UROCHORDA  | TA                      |   |                              |     |     |     |     |     |     |     |     |   |
| Class Ascidiacea   |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Order Aplousobranchia                                      |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Family Didemnidae  |                         |   |                              |     |     |     |     |     |     |     |     |   |
|  | Diplosoma listerianum   | Α |                              |     |     |     |     |     |     |     | Х   |   |
|  | Didemnum perlucidum     | Α |                              |     |     |     |     |     |     |     | Х   |   |
|  | Didemnum sp.            | Α |                              |     |     |     |     |     |     |     | Х   |   |
|  | Lissoclinum fragile     | Α |                              |     |     |     |     |     |     |     | Х   |   |
| Family Polyclinidae  | -                       |   |                              |     |     |     |     |     |     |     |     |   |
|  | Polyclinum constellatum | Α |                              |     |     |     |     |     |     |     | Х   |   |
| Order Phlebobranchia                                       |                         |   |                              |     |     |     |     |     |     |     |     |   |
| Family Ascidiidae  |                         |   |                              |     |     |     |     |     |     |     |     |   |
|  | Ascidia archaia         | Α |                              |     |     |     |     |     |     |     | Х   |   |
|  | Ascidia sydneiensis     | А |                              |     |     | Х   |     |     |     |     | Х   |   |
|  | Phallusia nigra         | А |                              |     |     |     |     |     |     |     | Х   |   |
|  | Ascidia sp. A           | Α |                              |     |     |     |     |     |     |     | Х   |   |
| Order Stolidobranchia                                      | •                       |   |                              |     |     |     |     |     |     |     |     |   |
| Family Pyuridae  |                         |   |                              |     |     |     |     |     |     |     |     |   |
|  | Microcosmus exasperatus | А |                              |     |     |     |     |     | Х   | Х   | Х   | Х |
|  | Herdmania pallida       | А |                              |     |     |     |     |     |     |     | Х   |   |
|  | ·                       |   |                              |     |     |     |     |     |     |     |     |   |

| Marine Non-Indigenous Invertebrate Species throughout PMNM |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|--|--------------------------|--------|------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
|  |                          |        | Distribution by Island/Atoll |     |     |     |     |     |     |     |     |     |  |
|  | Taxon                    | Status | NH                           | MOK | FFS | GAR | MAR | LAY | LIS | P&H | MID | KUR |  |
| Family Styelidae   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Cnemidocarpa irene       | Α      |                              |     | Х   |     |     |     | Х   |     | Х   |     |  |
|  | Polycarpa aurita         | C      |                              |     | Х   |     |     |     | Х   | Х   | Х   |     |  |
|  | Styela canopus           | Α      |                              |     |     |     |     |     |     |     | Х   |     |  |
|  | Symplegma brakenhlelmi   | Α      |                              |     |     |     |     |     |     | ?   | Х   |     |  |
|  | Botrylloides sp          | Α      |                              |     |     |     |     |     |     |     | Х   |     |  |
|  | Botryllus sp.            | Α      |                              |     |     |     |     |     |     |     | Х   |     |  |
| SUBPHYLUM VERTEBRATA                                       | <b>\</b>                 |        |                              |     |     |     |     |     |     |     |     |     |  |
| Class Osteichthyes   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Family Lutjanidae  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Lutjanus fulvus          | Α      |                              |     | Х   |     |     |     |     |     |     |     |  |
|  | Lutjanus kasmira         | Α      | Х                            | Х   | Х   |     | Х   | Х   | Х   | Х   | Х   | Х   |  |
| Family Serranidae  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Cephalopholis argus      | Α      | Х                            | Х   | Х   |     |     |     |     |     |     |     |  |
|  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| P  | HYLUM CNIDARIA           |        |                              |     |     |     |     |     |     |     |     |     |  |
| Class Hydrozoa   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Oreder Anthoathecata                                       |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Family Pennariidae   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Pennaria disticha        | Α      | Х                            | Х   | Х   | Х   | Х   | Х   | Х   | Х   | Х   | Х   |  |
| Class Anthozoa   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Family Diadumenidae  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Diadumene lineata *      | AN     |                              |     |     |     |     |     |     | ?   |     |     |  |
| Pi   | HYLUM PORIFERA           |        |                              |     |     |     |     |     |     |     |     |     |  |
| Class Calcarea   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Order Leucosolenida  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Family Heteropiidae  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Heteropia glomerosa      | A      |                              |     |     |     |     |     |     |     | Х   |     |  |
| Class Demospongiae   |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Order Dendroceratida                                       |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
| Family Darwinellidae                                       |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Chelonaplysilla violacea | С      |                              |     |     |     |     |     |     |     | Х   |     |  |
|  | Darwinella australiensis | С      |                              |     |     |     |     |     |     |     | Х   |     |  |
| Family Dictyodendrillidae                                  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |
|  | Dictyodendrilla dendyi   | С      |                              |     |     |     |     |     |     |     | Х   |     |  |
|  |                          |        |                              |     |     |     |     |     |     |     |     |     |  |

| Marine N                 | ine Non-Indigenous Invertebrate Species throughout PMNM |          |                              |          |  |     |  |     |  |  |  |     |
|--------------------------|---|----------|------------------------------|----------|--|-----|--|-----|--|--|--|-----|
|                          | J   |          | Distribution by Island/Atoll |          |  |     |  |     |  |  |  |     |
|                          | Taxon   | Status   | Z                            | MOK      | FFS  | GAR | MAR  | LAY | LIS  | P&H  | MID  | KUR |
| PI                       | HYLUM PORIFERA  |          |                              |          |  |     |  |     |  |  |  |     |
| Order Dictyoceratida     |   |          |                              |          |  |     |  |     |  |  |  |     |
| Family Dysideidae        |   |          |                              |          |  |     |  |     |  |  |  |     |
|                          | Dysidea arenaria  | С        |                              |          |  |     |  |     |  |  | Х  |     |
| Order Haplosclerida      |   |          |                              |          |  |     |  |     |  |  |  |     |
| Family Chalinidae        |   |          |                              |          |  |     |  |     |  |  |  |     |
|                          | Cladocroce burapha                                      | С        |                              |          |  |     |  |     |  |  | Х  |     |
|                          | Haliclona sp.   | С        |                              |          |  |     |  |     |  |  | Х  |     |
| Family Callyspongiidae   | Callyspongia sp.  | С        |                              |          |  |     |  |     |  |  | Х  |     |
| Order Hadromerida        |   |          |                              |          |  |     |  |     |  |  |  |     |
| Order Poecilosclerida    |   |          |                              |          |  |     |  |     |  |  |  |     |
| Family Coelosphaeridae   |   |          |                              |          |  |     |  |     |  |  |  |     |
|                          | Lissodendoryx (Lissodendoryx) similis                   | С        |                              |          |  |     |  |     |  |  | Х  |     |
| Family Crambeidae        |   |          |                              |          |  |     |  |     |  |  |  |     |
| -                        | Monanchora cf. unguiculata                              | Α        |                              |          |  |     |  |     |  |  | Х  |     |
|                          | Monanchora guadrangulata                                | Α        |                              |          |  |     |  |     |  |  | Х  |     |
| Family Crellidae         |   |          |                              |          |  |     |  |     |  |  |  |     |
| •                        | Crella (Yvesia) spinulata                               | C        |                              |          |  |     |  |     |  |  | Х  |     |
| Family Hymedesmiidae     | (   |          |                              | 1        |  |     |  |     |  |  |  |     |
| , ,                      | Phorbas burtoni   | С        |                              |          |  |     |  |     |  |  | Х  |     |
| Family Tedaniidae        | , no but building                                       |          |                              |          |  |     |  |     |  |  |  |     |
|                          | Strongylamma wilsoni                                    | C        |                              |          |  |     |  |     |  |  | Х  |     |
|                          | Tedania (Tedania) strongylostyla                        | Ċ        |                              |          |  |     |  |     |  |  | X  |     |
| Order Tethyida           | r oddina (r oddina) oliongyrootyra                      |          |                              |          |  |     |  |     |  |  |  |     |
| Family Tethyidae         |   |          |                              |          |  |     |  |     |  |  |  |     |
| ,                        | Tethya deformis   | C        |                              |          |  |     |  |     |  |  | Х  |     |
| PHY                      | LUM RHODOPHYTA  |          |                              |          |  |     |  |     |  |  |  |     |
| Class Florideophyceae    |   | 1        |                              |          |  |     |  |     |  |  |  |     |
| Order Gigartinales       |   | $\vdash$ |                              |          |  |     |  |     |  |  |  |     |
| Family Cystocloniaceae   |   | H        |                              |          |  |     |  |     |  |  |  |     |
| ,                        | Hypnea sp.  | С        |                              | Х        |  |     | Х  |     |  | Х  |  |     |
| Order Ceramiales         | riganiou op.  | $\vdash$ |                              | <u> </u> |  |     | <del></del>                                      |     |  | <del>-                                    </del> |  |     |
| Family Rhodomelaceae     |   | $\vdash$ |                              |          | <del>                                     </del> |     | <del>                                     </del> |     | <del>                                     </del> | <del>                                     </del> | <del>                                     </del> |     |
| . withy ich was melaveae | Chondria tumulosa                                       | С        |                              |          | <del>                                     </del> |     | <del>                                     </del> |     | <del>                                     </del> | Х  | <del>                                     </del> |     |
|                          | Total Species   | 61       | 4                            | 5        | 6  | 3   | 3  | 3   | 8  | 6  | 55   | 3   |
|                          | A = Alien Established                                   | 39       |                              | . •      |  |     |  | •   |  |  |  |     |
|                          | C = Cryptogenic   | 21       |                              |          |  |     |  |     |  |  |  |     |
|                          | AN = *Alien (not established)                           | 1        |                              |          |  |     |  |     |  |  |  |     |
|                          | Aut = Auton (not established)                           |          |                              |          |  |     |  |     |  |  |  |     |

## DISEASE AND INTRODUCED SPECIES PREVENTION PROTOCOL FOR PERMITTED ACTIVITIES IN THE MARINE ENVIRONMENT (PMNM BMP #011)



#### 1. Equipment and Dive Gear Disinfection

- Level One: Equipment in direct contact with diseased coral tissue, other diseased organisms or alien species.
- Level Two: Equipment not used to sample diseased coral tissue, other diseased organisms or alien species
- Level Three: All dive gear used in the Monument
- Level Four: Conditions for accessing intertidal zones within the Monument

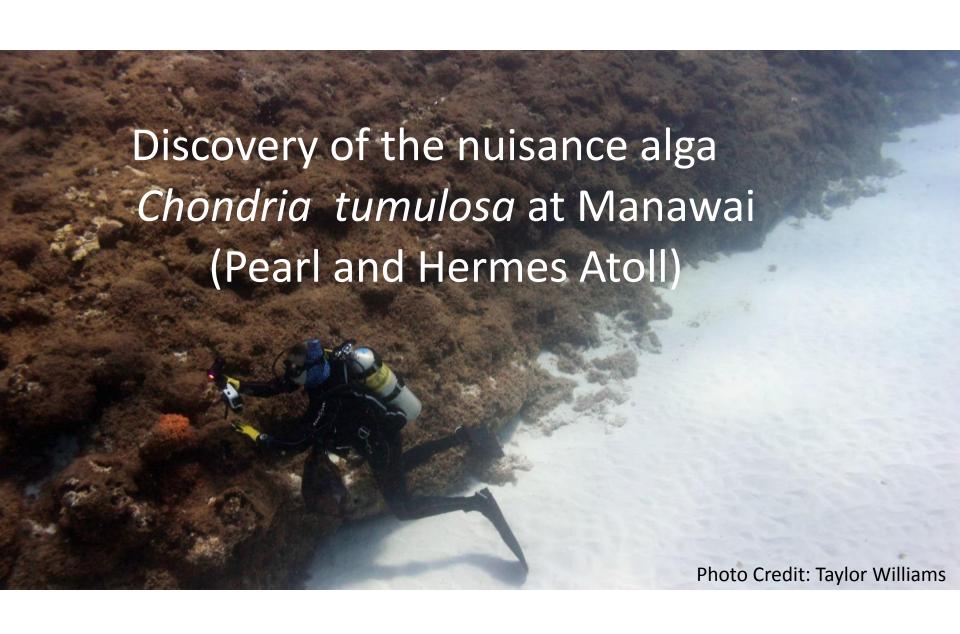


#### II. Cleaning Tender Vessels

III. Disinfection of Shipboard Wet Laboratories







### Credit (team effort!)

- Field work: H. Spalding, T. Williams, K. Pascoe, and B. Craig
- Surveys: H. Spalding, K. Pascoe, T. Williams, B. Craig, and A. Fukunaga
- 3-D Photogrammetry: K. Pascoe and B. Craig
- Algal Fragment Experiments: H. Spalding, T. Williams and B. Hauk
- Invasive Algal Advisement: A. Sherwood and C. Smith
- Molecular and Morphological ID: A. Sherwood and lab
- Mesophotic surveys: R. Kosaki, B. Hauk, S. Matadobra, K. Lopes, J. Leonard
- Boat support: Crew of the R/V Rainier and NOAA boat crew
- PI and mesophotic video: R. Pyle



RESEARCH ARTICLE

Taxonomic determination of the cryptogenic red alga, *Chondria tumulosa* sp. nov., (Rhodomelaceae, Rhodophyta) from Papahānaumokuākea Marine National Monument, Hawai'i, USA: A new species displaying invasive characteristics

Alison R. Sherwood 1\*, John M. Huisman2, Monica O. Paiano1, Taylor M. Williams3, Randall K. Kosaki 4, Celia M. Smith1, Louise Giuseffi5, Heather L. Spalding3

1 School of Life Sciences, University of Hawai'i, Honolulu, HI, United States of America, 2 Department of Biodiversity, Western Australian Herbarium, Conservation and Attractions, Kensington, WA, Australia, 3 Department of Biology, College of Charleston, Charleston, SC, United States of America, 4 NOAA, Papahānaumokuākea Marine National Monument, Honolulu, HI, United States of America, 5 NOAA, Pacific Islands Fisheries Science Center, Honolulu, HI, United States of America

\* asherwoo@hawaii.edu

#### **Abstract**

Survey cruises by the National Oceanic and Atmospheric Administration (NOAA) in 2016 and 2019 yielded specimens of an undetermined red alga that rapidly attained alarming levels of benthic coverage at Pearl and Hermes Atoll, Papahānaumokuākea Marine National Monument, Hawai'i. By 2019 the seaweed had covered large expanses on the northeast side of the atoll with mat-like, extensive growth of entangled thalli. Specimens were analyzed using light microscopy and molecular analysis, and were compared to morphological descriptions in the literature for closely related taxa. Light microscopy demonstrated that the specimens likely belonged to the rhodomelacean genus Chondria, yet comparisons to taxonomic literature revealed no morphological match. DNA sequence analyses of the mitochondrial COI barcode marker, the plastidial rbcL gene, and the nuclear SSU gene confirmed its genus-level placement and demonstrated that this alga was unique compared to all other available sequences. Based on these data, this cryptogenic seaweed is here proposed as a new species: Chondria tumulosa A.R.Sherwood & J.M.Huisman sp. nov. Chondria tumulosa is distinct from all other species of Chondria based on its large, robust thalli, a mat-forming tendency, large axial diameter in mature branches (which decreases in diameter with subsequent orders of branching), terete axes, and bluntly rounded apices. Although C. tumulosa does not meet the criteria for the definition of an invasive species given that it has not been confirmed as introduced to Pearl and Hermes Atoll, this seaweed is not closely related to any known Hawaiian native species and is of particular concern given its sudden appearance and rapid increase in abundance in the Papahānaumokuākea Marine National Monument; an uninhabited, remote, and pristine island chain to the northwest of the Main Hawaiian Islands.

G OPEN ACCESS

Citation: Sherwood AR, Huisman JM, Paiano MO, Williams TM, Kosaki RK, Smith CM, et al. (2020) Taxonomic determination of the cryptogenic red alga, Chondria tumulosa sp. nov., (Rhodomelaceae, Rhodophyta) from Papahanaumokuakea Marine National Monument, Hawai'i, USA: A new species displaying invasive characteristics. PLoS ONE 15(7): e0234358. https://doi.org/10.1371/journal.pone.0234358

Editor: Marcos Rubal García, CIIMAR Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, PORTUGAL

Received: March 3, 2020 Accepted: May 22, 2020

Published: July 7, 2020

Copyright: This is an open access article, free of all copyright, and may be freely reproduced, distributed, transmitted, modified, built upon, or otherwise used by anyone for any lawful purpose. The work is made available under the <u>Creative</u> Commons CCO public domain dedication.

Data Availability Statement: All newly generated DNA sequence data have been submitted to GenBank and are available under the following accession numbers: (COI: MT039621 - MT039626; rbcL: MT039601 - MT039620; SSU: MT039627 - MT039630).





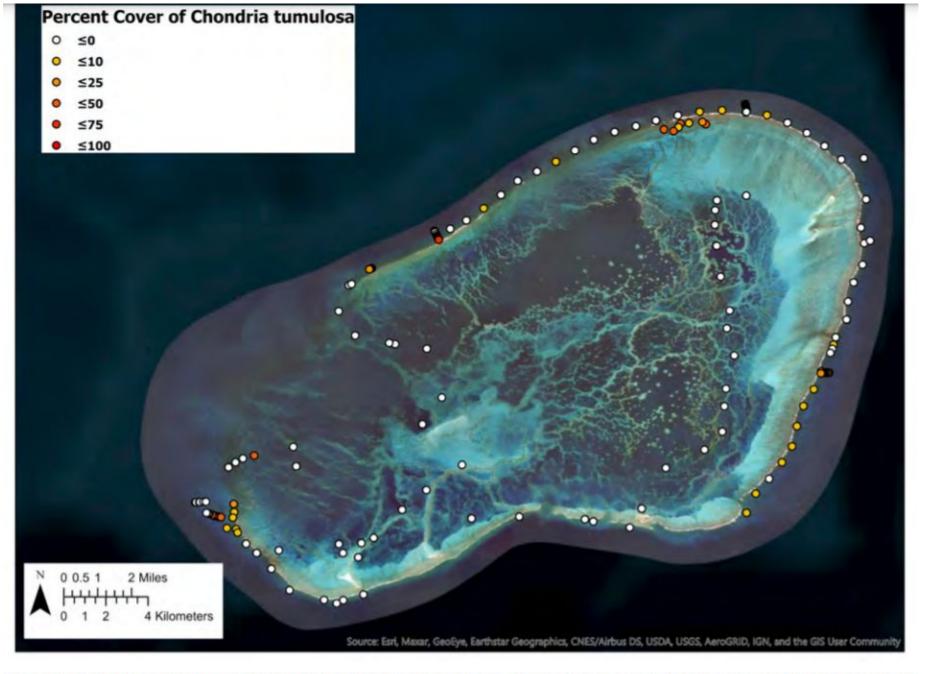


Figure S.LR.7.11. Observations of invasive red alga *Chondria tumulosa* at Pearl and Hermes Atoll at both shallow and mesophotic depths in 2019. Image: PMNM



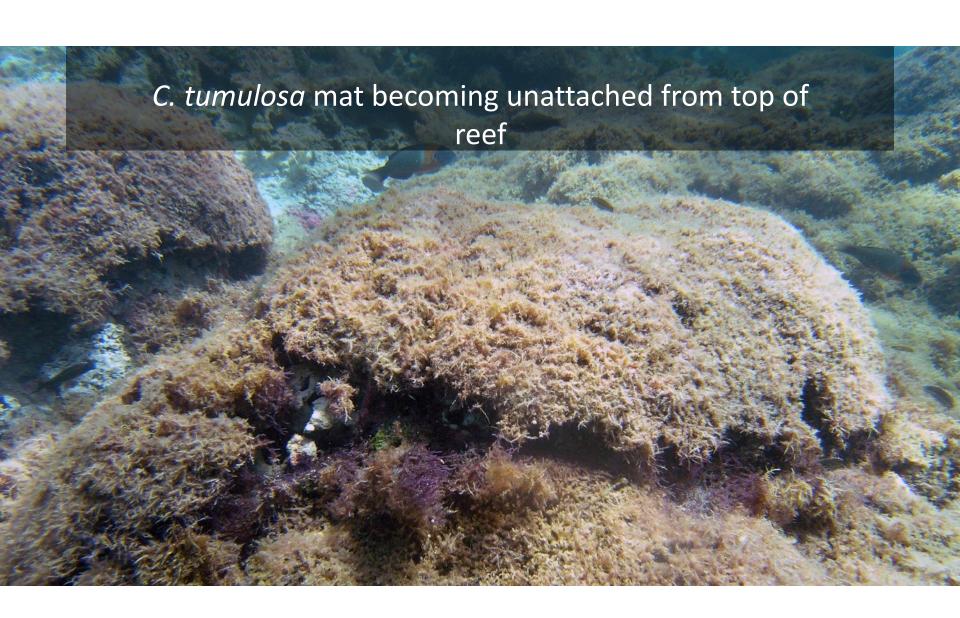




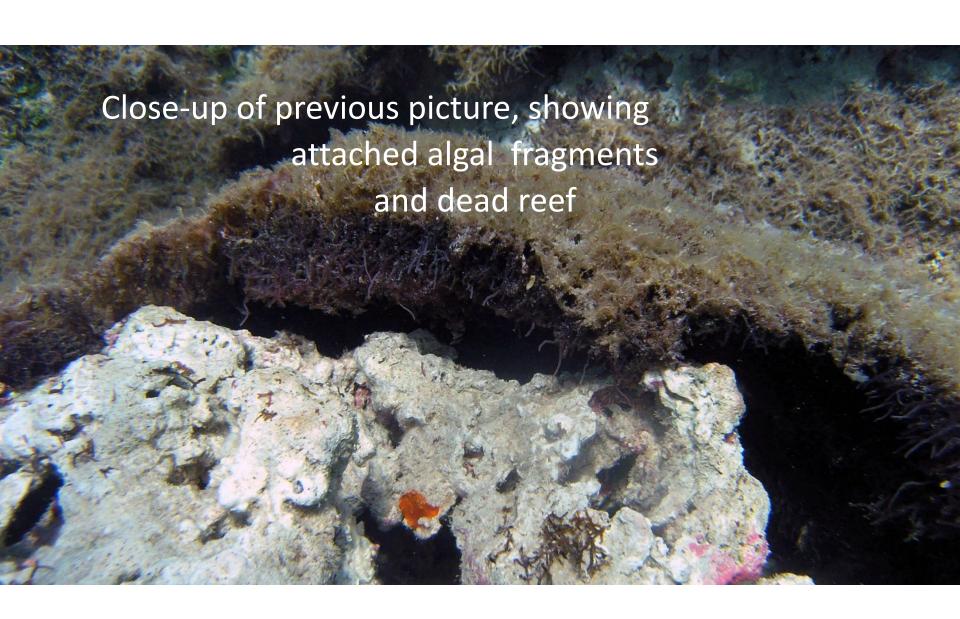
### Question #4

What ecological category is Chondria tumulosa currently placed in?

- An endemic species
- An alien species
- A native species
- A cryptogenic species













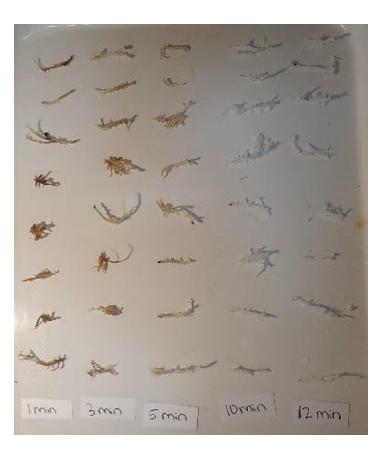
### Algal fragment experiments to determine concentration and duration of bleach needed for *Chondria* mortality







#### C. tumulosa fragment experiments (many trials)



 Algal fragments soaked in a 6% commercial bleach solution turns fragments white after 10 minutes.

• Weaker concentrations or less soaking time are not effective at causing fragment mortality



#### **Current Recommendations**

- 1. Remove all fragments via a visual inspection in daylight of all dive gear
- Soak gear/equipment in 6% commercial-grade bleach for 10 minutes followed by a freshwater rinse
- 3. Fully dry dive gear/equipment before use in a different island or atoll.

NOTE: Particular caution should be paid to dive gear containing mesh, such as goody bags, or Velcro that easily catch and retain algal fragments.

https://sanctuaries.noaa.gov/news/jul20/newly-named-nuisance-alga-chondria-tumulosa.html







### Question # 5

What was utilized in trial studies to kill *Chondria* tumulosa?

- Soda Pop
- Bleach
- Gasoline
- Beer

### Take Home Messages

- 1. 61 alien species found in PMNM as of 2020 compared to the 13 known from 2009. Roughly 10% of the 400+ species in the MHI
- 2. Once established, marine alien species may used human introduced substrates to move from harbors to surrounding areas
- 3. Hull inspections and BMP's are our best strategy for preventing new introductions into PMNM at this time





# Thank You QUESTIONS?

Brian.hauk@noaa.gov



