

Effects of Ammonia on Corals and Sea Urchins

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Fate & Effects of Contaminants Program Review, Sept 15-17, 2020

Justification

MANAGEMENT ISSUE:

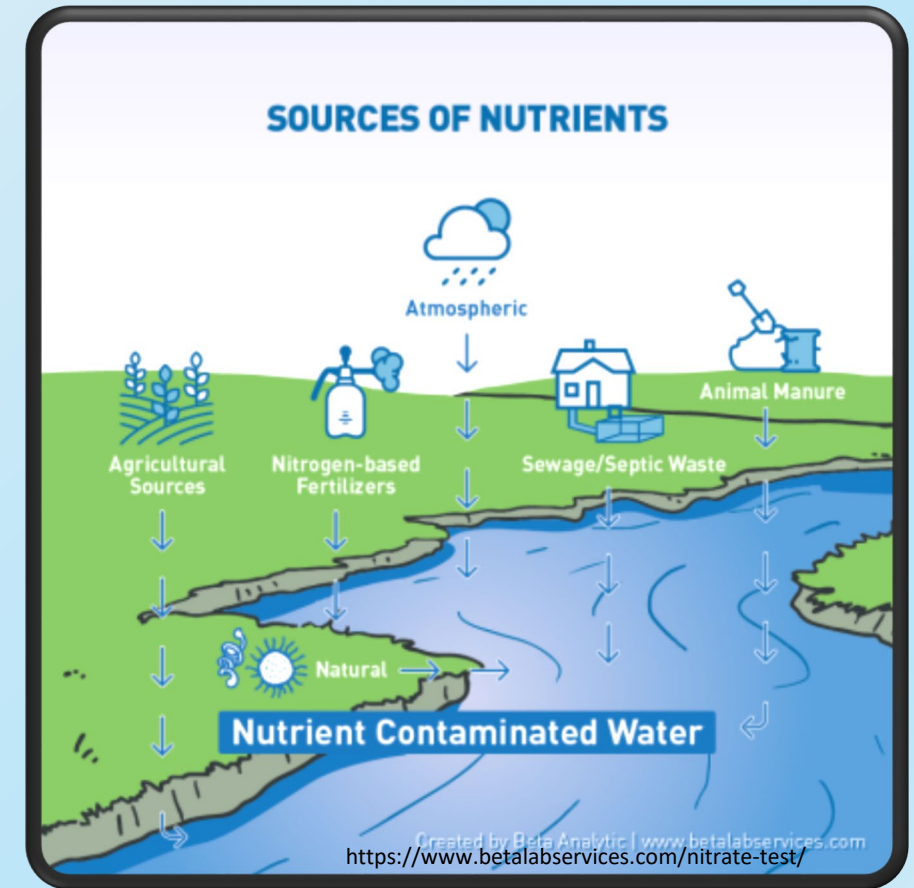
Ammonia toxicity data is insufficient to derive water quality criteria or water quality standards that are protective of coral reef resources.

Purpose

To evaluate whether the EPA water quality criteria (WQC) for ammonia is protective for coral reef organisms.

Objectives

1. Determine the effect concentration range for adult coral nubbins exposed to ammonium chloride.
2. Determine the lethal concentration range for Caribbean ESA coral embryos to ammonium chloride at two temperatures.
3. Determine the effect concentration range for two species of sea urchin embryos exposed to ammonium chloride.



Collaborators:

- **Dr. Margaret Miller - NOAA Fisheries SEFSC**
 - Collaborated on coral larvae experimental design
 - Provided training in coral fertilization and embryology
 - Provided logistical & diver support for gamete collections

- **Dr. Dana Williams – NOAA Fisheries SEFSC**
 - Provided logistical & diver support for gamete collections

- **Mr. Chris Kavanagh NPS FL Bay Interagency Science Center**
 - Laboratory space and lodging during field operations

Clients:

Ms. Jennifer Moore

Dr. Pat Shaw-Allen

Dr. Andy Bruckner

Dr. C. Anna Toline

Ms. Joanna Walczak

Mr. Ken Weaver

Ms. Hilary Lohmann

NOAA Fisheries SERO Protected Resources

NOAA Fisheries Office-Protected Resources

Florida Keys National Marine Sanctuary

NPS Region 2 South Atlantic Gulf

Florida Dept. Environmental Protection

Florida Dept. Environmental Protection

USVI Dept. Planning & Natural Resources

International:

Sustainable Grenadines

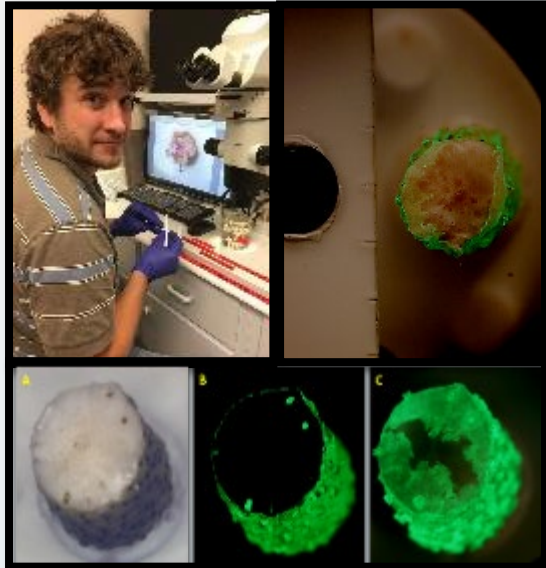
Tobago Cays Marine Park

Parques Nacionales Naturales de Colombia

Oceanario Islas del Rosario Colombia



1. Tissue Regeneration Assay (wound healing)



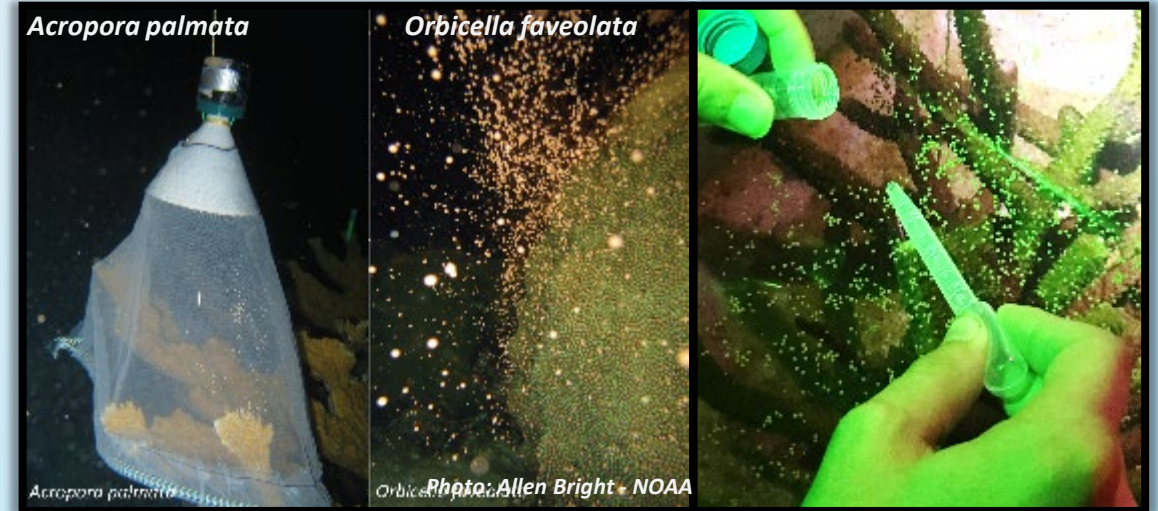
Acropora formosa nubbins



Dosing system

- Replicated NH_4Cl doses: 0.13—2.6 mg/L TAN
- Fragments imaged daily
- Daily static treatment renewal - 10 d exposure
- Water quality measurements daily: salinity, pH, temp., ammonia
- Image analysis for growth rate or % healing

2. Early Life Stage Fertilization & Survival Assays



Acropora palmata

Orbicella faveolata

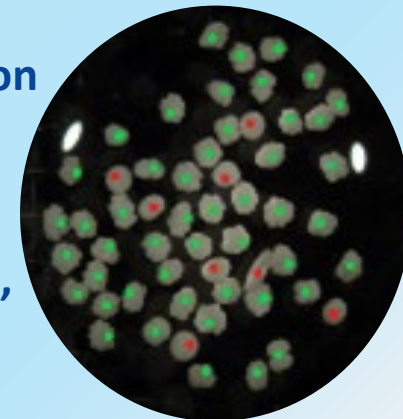
Acropora palmata

Orbicella faveolata Photo: Allen Bright - NOAA

In situ gamete collections

Ex situ gamete collections

- Gametes collected, processed and fertilization efficiency determined
- Replicated NH_4Cl doses: 0.26—2.6 mg/L TAN
- Water quality measured 24 & 48h pH, temp., salinity, ammonia
- Treatments refreshed @ 24h
- Embryos enumerated microscopically @ 24-48 h



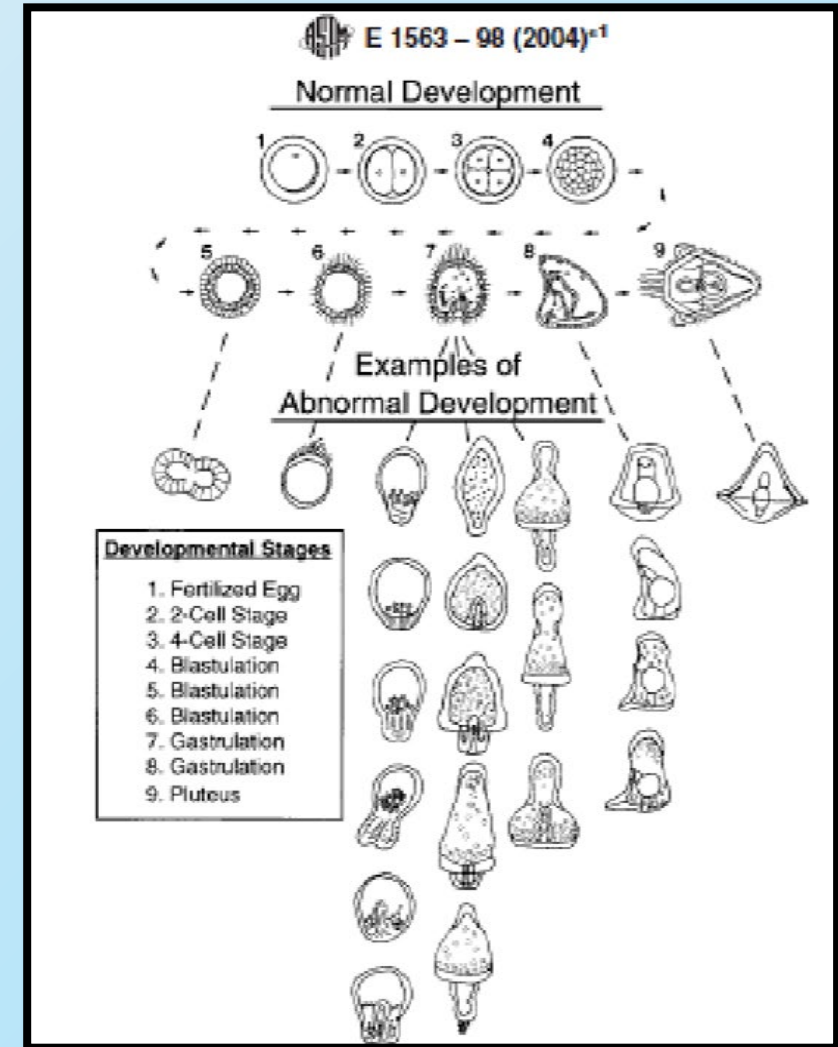
Acropora palmata embryos

3. Sea Urchin Embryo Development Toxicity Assay



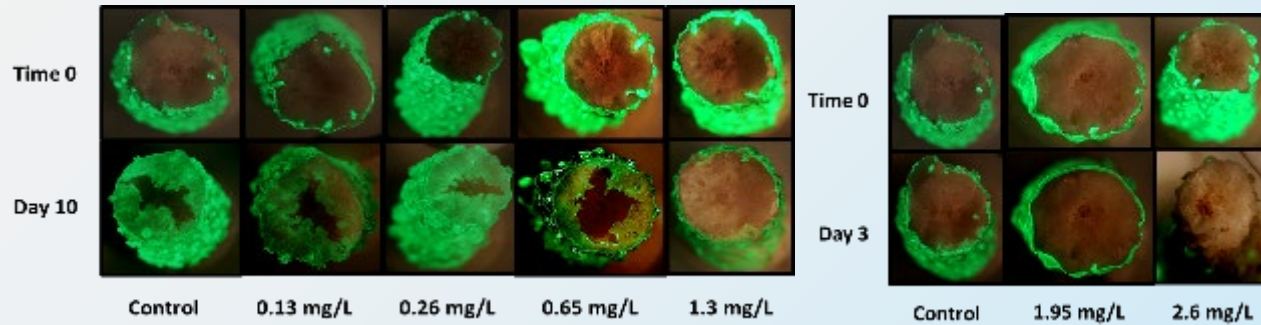
- Sea urchin gametes are collected, washed and counted.
- Ova are fertilized ($\geq 95\%$ fertilization efficiency needed).
- Water quality measurements initial and 48 h
- Embryos incubated 48 h to pluteus stage and formalin fixed.
- Embryos scored for % normal development microscopically

Fertilization

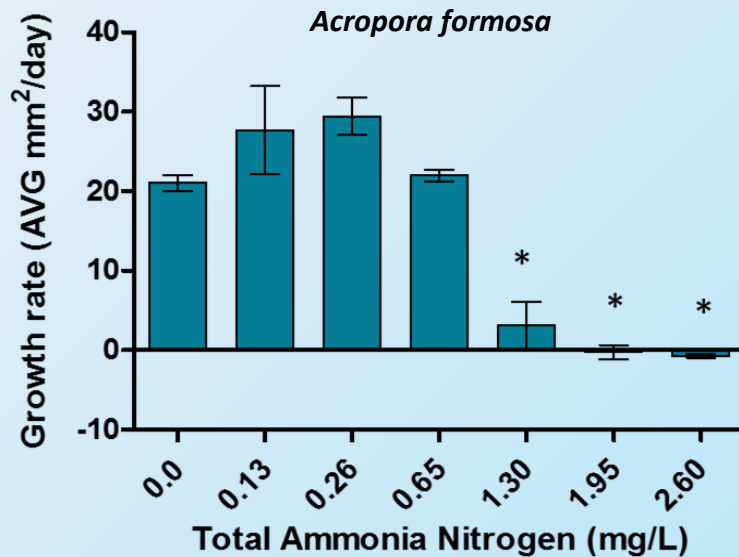


ASTM <https://www.astm.org/Standards/E1563.htm>

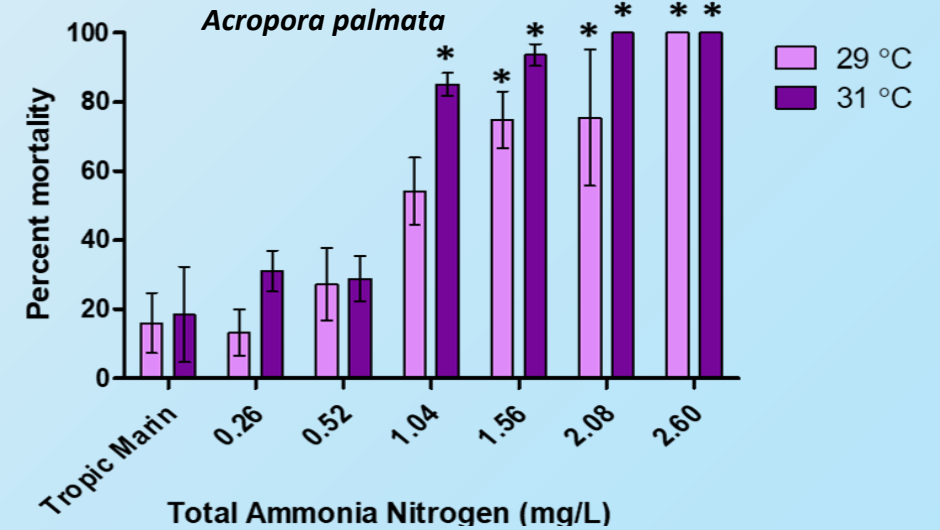
1. Laceration Regeneration Assay (wound healing)



- LOEC = 1.3 mg/L TAN
- Loss of tissue and auto-fluorescence observed at 72 h in 2.6 mg/L TAN
- Tissue regeneration arrested at 72 h in 1.95 mg/L TAN
- EC₅₀ = 0.86 mg/L TAN



2. Early Life Stage Fertilization & Survival Assays

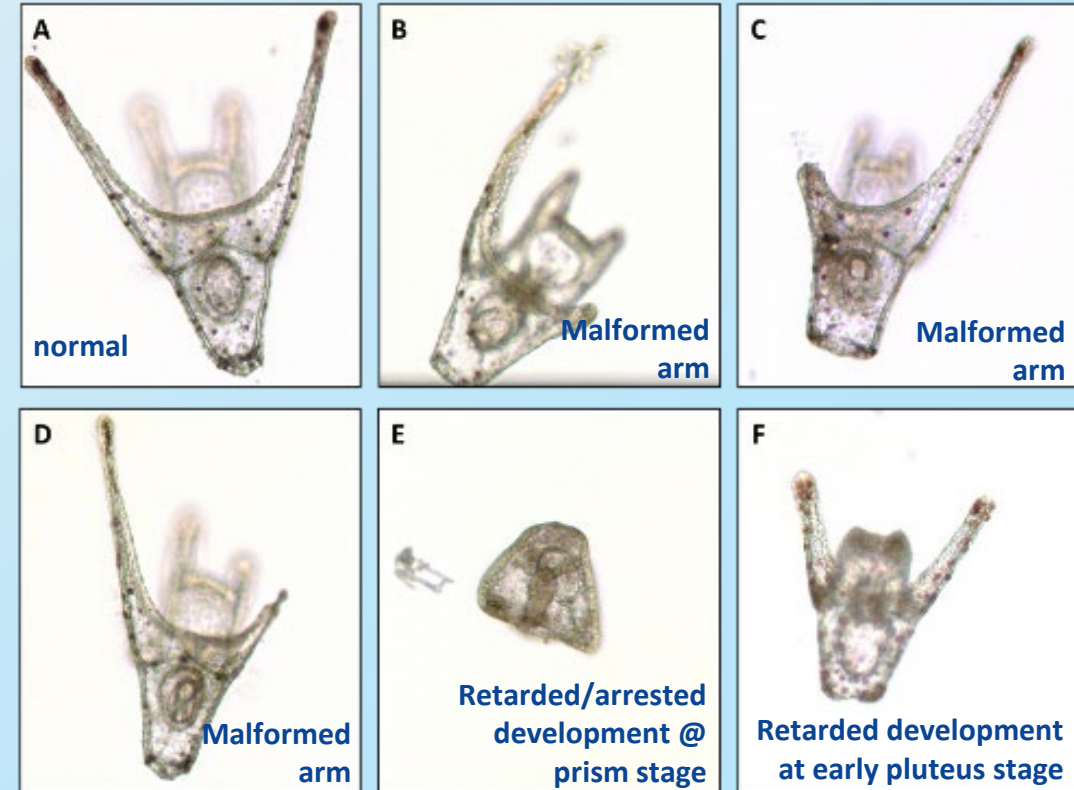
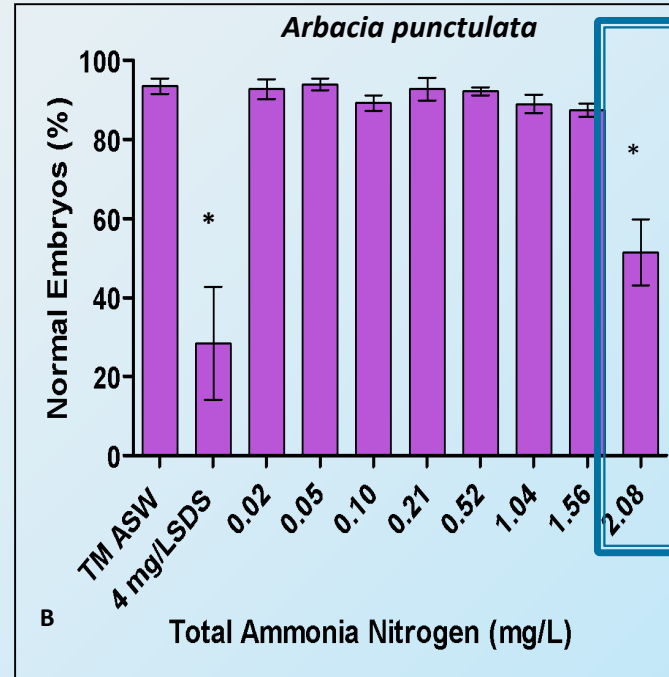
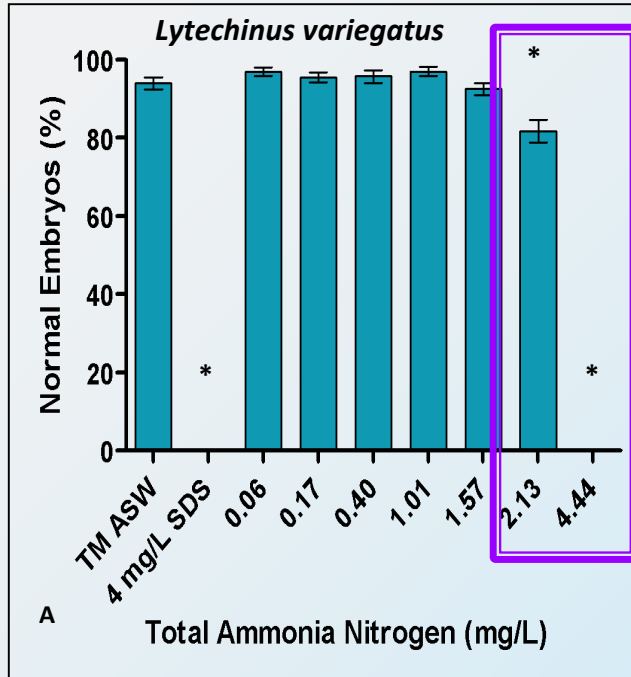


- 2°C temperature increase, reduced toxicity threshold ~35 %
- 29°C
 - LC₅₀ = 0.89 mg/L TAN
 - LOEC = 1.56 mg/L TAN
- 31°C
 - LC₅₀ = 0.58 mg/L TAN
 - LOEC = 1.04 mg/L TAN



Acropora palmata embryos

3. Sea Urchin Embryo Development Toxicity Bioassay

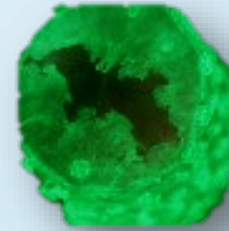


- *Lytechinus variegatus* development LOEC = 2.13 mg/L TAN
- *Arbacia punctulata* development LOEC = 2.08 mg/L TAN
- *Arbacia punctulata* fertilization LOEC > 2.08 mg/L TAN

Discussion/Conclusions

Comparisons with existing National Water Quality Criteria (US EPA 1989):

Acute WQC 0.223 mg/L UAN
 Chronic WQC 0.035 mg/L UAN



- Coral nubbins: *Acropora formosa* $EC_{50} = 0.095$
 - **Acute** **unlikely** protective
 - **Chronic** **likely** protective
- 29 °C Coral embryos: *Acropora palmata* $LC_{50} = 0.074$
 - **Acute** **unlikely** protective
 - **Chronic** **likely** protective
- 31 °C Coral embryos: *Acropora palmata* $LC_{50} = 0.055$
 - **Acute** **unlikely** protective
 - **Chronic** **possibly** protective
- Sea urchin embryo development
 - **Acute** **unlikely** protective
 - **Chronic** **likely** protective
 - *Arbacia punctulata* LOEC = 0.174 mg/L
 - *Lytechinus variegatus* LOEC = 0.149 mg/L

Summary: Lethal and Effect Conc. of Unionized Ammonia Toxicity

Species	Time	Endpoint	Temp (°C)	UAN exposure range (mg/L)	UAN EC50 LC50 (mg/L)	UAN NOEC (mg/L)	UAN LOEC (mg/L)
<i>Acropora formosa</i>	10 d	tissue regeneration	26	0.008-0.302	0.095	0.152	0.231
<i>Acropora palmata</i>	48 h	larvae mortality	29	0.021-0.217	0.074	0.087	0.133
<i>Acropora palmata</i>	48 h	larvae mortality	31	0.024-0.249	0.055	0.049	0.100
<i>Arbacia punctulata</i>	0.5 h	fertilization	20	0.007-0.121	ND	0.121	>0.121
<i>Arbacia punctulata</i>	48 h	embryo development	20	0.0-0.267	0.174	0.103	0.137
<i>Lytechinus variegatus</i>	48 h	embryo development	23	0.005-0.149	ND	0.124	0.149

- 2 °C increase in temperature decreases the toxicity threshold by 35 % for *A. palmata* embryo survival.
- Considering ESA listed *A. palmata* larvae LC_{50} are not protective, when setting Water Quality Standards.
- Results demonstrate a need to review current National Water Quality Criteria to protect vulnerable coral reef resources.

Applications and/or Products

How data/results/technologies are shared:

Briefings & Data Sharing

- NMFS Protected Resources on findings for use in consultations
- EPA Office of Water to contribute to water quality standards that include coral
- National Park Service to assist in management decisions
- Florida DEP, Ken Weaver, for their Triennial Review of Florida's Water Quality Standards. Current standards do not consider coral species impacts.
- USVI Dept. of Planning & Natural Resources, Hilary Lohmann, to inform their water quality standards review. Current standards do not consider coral species impacts.

Training

- Training workshop conducted for toxicity bioassay tests with user groups i.e., citizen scientists, resource managers, students
- "How-to" videos for visualizing techniques and assays created and made available on the www.cdhc.noaa.gov website.

Public accessibility

- NOAA's Institutional Repository - data, metadata, reports & publications
- NOAA's Coral Reef Conservation Program's CoRIS system - Reports and manuscripts
- CDHC Website – cdhc.noaa.gov



Future Directions

Study Specific

- Complete exposure studies for branching and mounding morphologies of ESA coral species
- Determine species sensitivity distributions
- Conduct multi-stressor experiments

Methods & Techniques

- Continually innovate to improve measurements, precision, accuracy, and insights
 - Exploratory proteomics (elucidating modes of action and diagnostic bioindicators)
 - Endocrine disruption
 - Genotoxicity
- Environmental chemistry
 - Increased in-house capacity needed
 - Instrumentation
 - Staffing needs

Strategic Research

- Ensure our work is mission oriented and issue driven
- Ensure our clients are active partners in our research



Lisa May



Cheryl Woodley



Laura Webster



Carl Miller

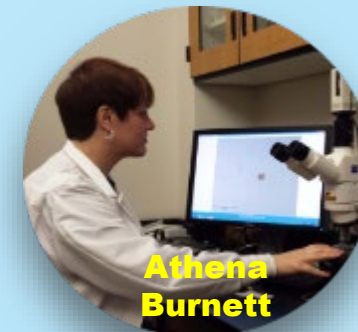
Coral Health & Disease Program



Zac Moffitt



Ron Kothera



Athena Burnett



Elizabeth Duselis

Questions?

