Supporting the Florida Shellfish Aquaculture Industry

Review of Past and Current Applied Research and Monitoring Projects in Cedar Key

Leslie N. Sturmer
UF/IFAS Shellfish Aquaculture Extension Program

Welcome to the new and improved Online Resource [...] orida Shellfish Aquaculture.

This site provides, through the University of Florida IFAS Shellfish Aqu [...] sion Program, information about shellfish farming and related activities for the general public, growers, and others involved in the shellfish industry. A "news blog" is featured which provides current information on a timely basis. This site also includes updates on research and extension projects, presentations from industry workshops, suppliers' lists, and pertinent publications. Read More

NEWS & EVENTS

5th Annual Oyster South Symposium
February 9, 2022
The 5th Annual Oyster South Symposium is being held on April 5-7, 2022 in Biloxi, North Mississippi.
Read More »

NOAA Offers Hatcheries Training and Help with Monitoring Harmful Algal Blooms
February 8, 2022
The Aquaculture Phytoplankton Monitoring Network (AQPMN) is currently recruiting shellfish aquaculture farms and organizations along the Gulf Coast to
Read More »

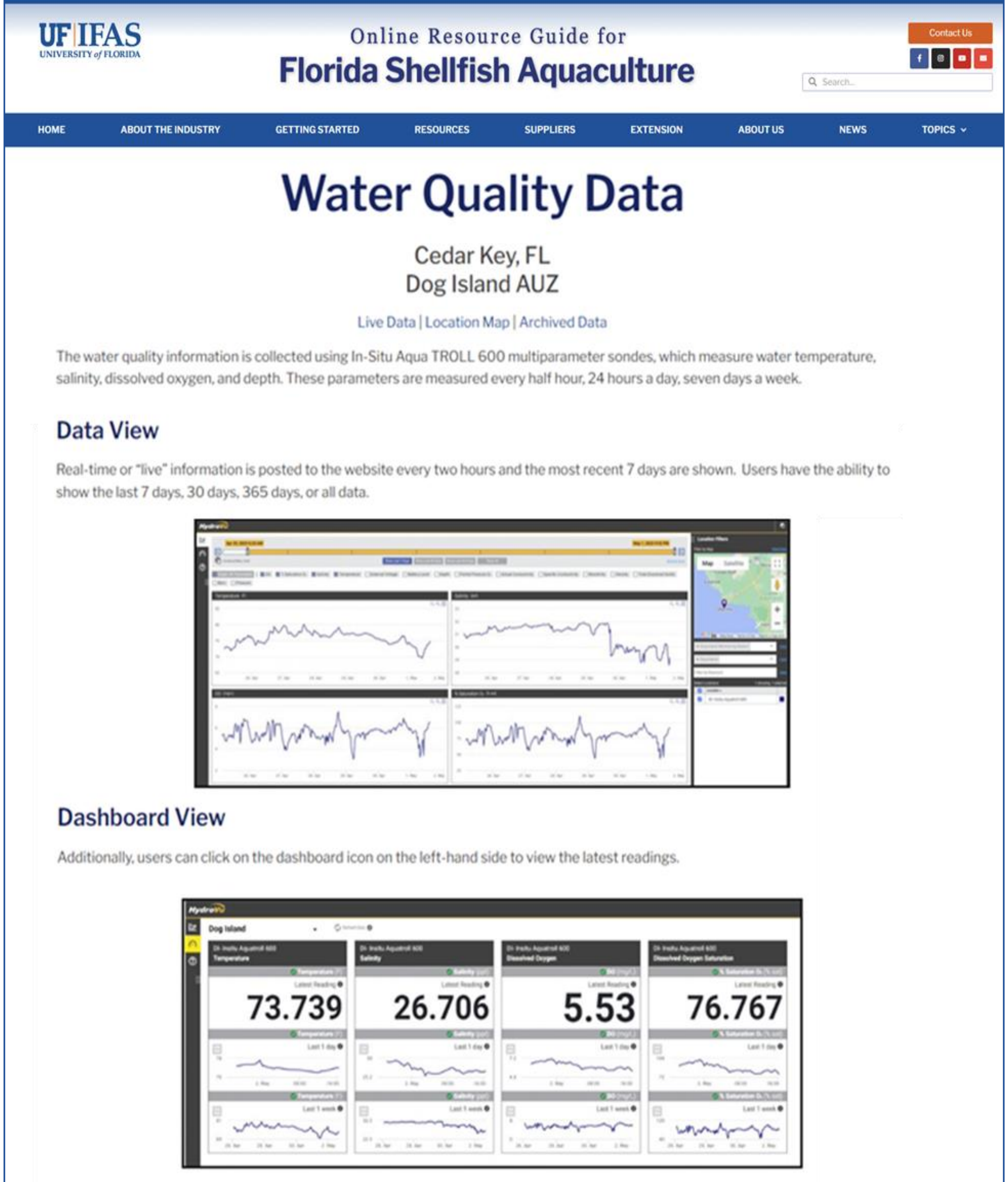
UF/IFAS awarded grant to boost shellfish aquaculture and water quality initiatives
January 6, 2022
Shellfish like clams and oysters can help restore ocean health and support economic development and food
Read More »

Session 4 – Harvesting a Crop of Oysters – is Now Available
November 22, 2021
The fourth session Harvesting a Crop of Oysters of this Online Course is now available. The

Cedar Key Water Quality Monitoring

Provide real-time and archived data at two Aquaculture Use Zones for 20 years

Website:
shellfish.ifas.ufl.edu



Online Resource Guide for
Florida Shellfish Aquaculture

Water Quality Data

Cedar Key, FL
Dog Island AUZ

Live Data | Location Map | Archived Data

The water quality information is collected using In-Situ Aqua TROLL 600 multiparameter sondes, which measure water temperature, salinity, dissolved oxygen, and depth. These parameters are measured every half hour, 24 hours a day, seven days a week.

Data View

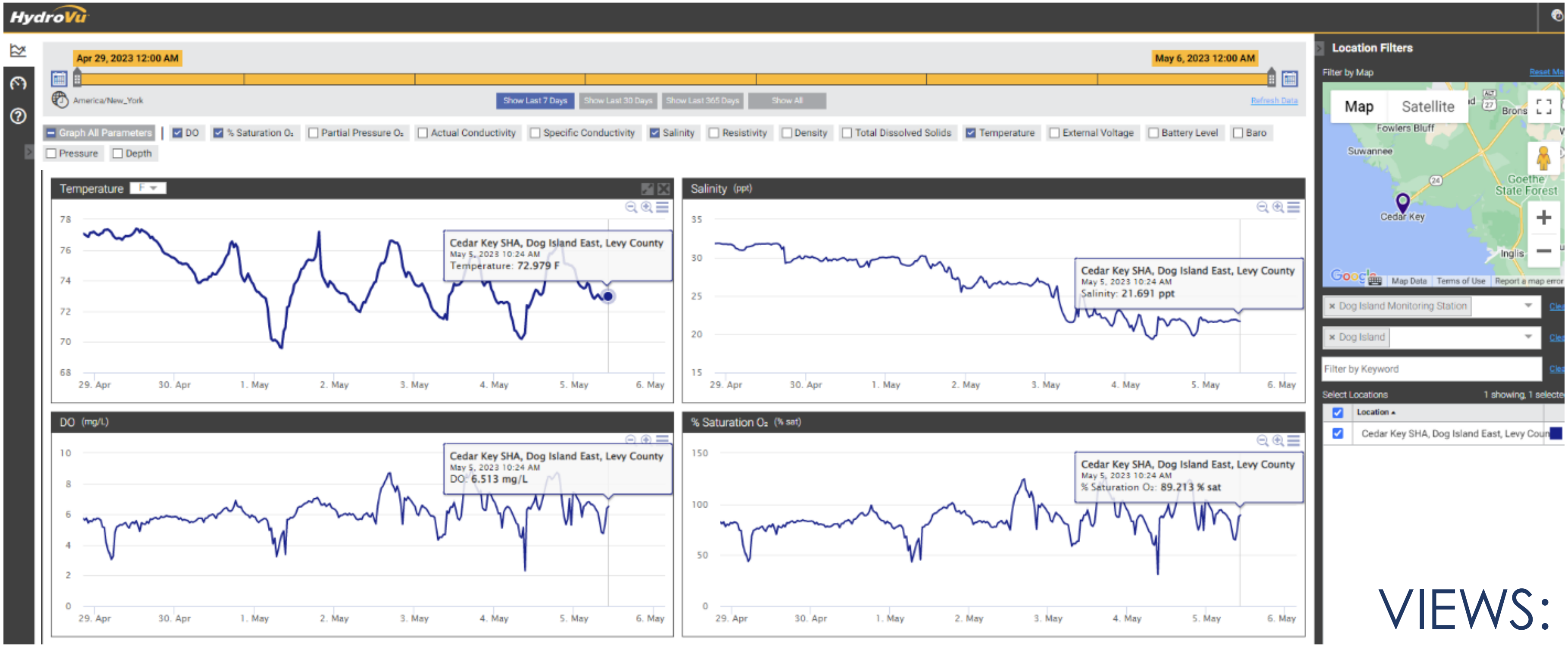
Real-time or "live" information is posted to the website every two hours and the most recent 7 days are shown. Users have the ability to show the last 7 days, 30 days, 365 days, or all data.

Dashboard View

Additionally, users can click on the dashboard icon on the left-hand side to view the latest readings.

InSitu 600 Multi-parameter Data Sonde

- Temperature
- Salinity
- Dissolved oxygen
- Records every 30 minutes
- Posts every 2 hours



Cedar Key SHA, Dog Island East, Levy County
May 5, 2023 10:24 AM
Temperature: 72.979 F

Cedar Key SHA, Dog Island East, Levy County
May 5, 2023 10:24 AM
Salinity: 21.691 ppt

Cedar Key SHA, Dog Island East, Levy County
May 5, 2023 10:24 AM
DO: 6.513 mg/L

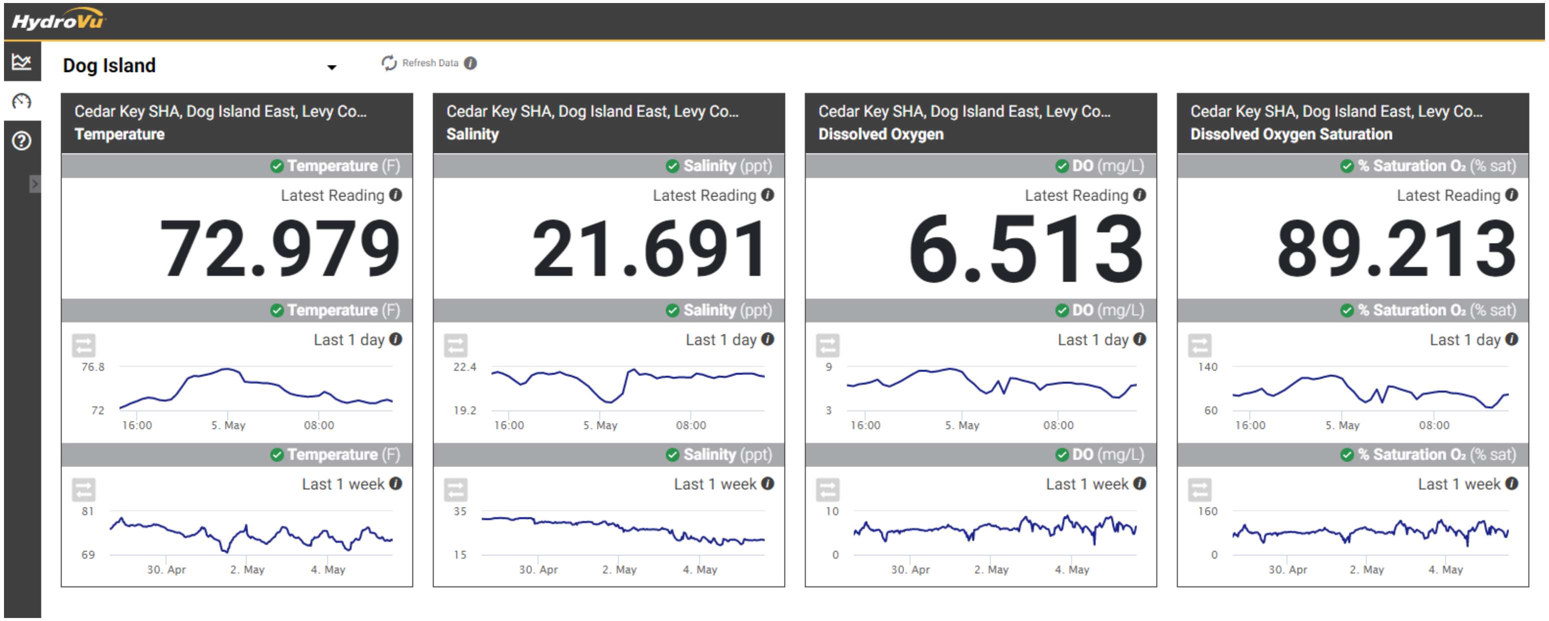
Cedar Key SHA, Dog Island East, Levy County
May 5, 2023 10:24 AM
% Saturation O₂: 89.213 % sat

× Dog Island Monitoring Station

× Dog Island

1 showing, 1 selected

☑ Cedar Key SHA, Dog Island East, Levy County



Cedar Key SHA, Dog Island East, Levy Co... Temperature	Cedar Key SHA, Dog Island East, Levy Co... Salinity	Cedar Key SHA, Dog Island East, Levy Co... Dissolved Oxygen	Cedar Key SHA, Dog Island East, Levy Co... Dissolved Oxygen Saturation
Temperature (F)	Salinity (ppt)	DO (mg/L)	% Saturation O₂ (% sat)
Latest Reading	Latest Reading	Latest Reading	Latest Reading
72.979	21.691	6.513	89.213

VIEWS:

- Data
- Dashboard

Archived Monthly Data

Dog Island, Levy County

2024

- January 2024
- February 2024
- March 2024

2023

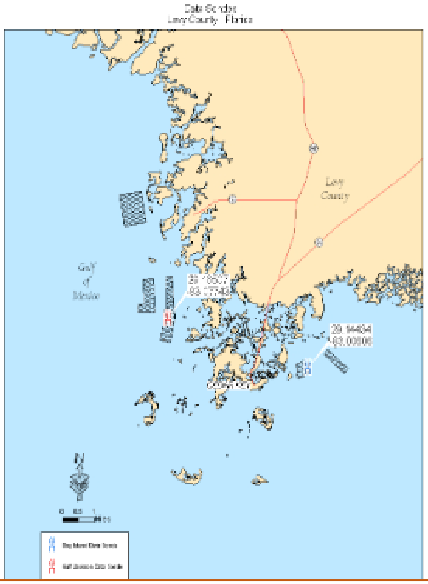
- January 2023
- February 2023
- March 2023
- April 2023
- May 2023
- June 2023
- July 2023
- August 2023
- September 2023
- October 2023
- November 2023
- December 2023

2022

- January 2022
- February 2022
- March 2022
- April 2022
- May 2022
- June 2022
- July 2022
- August 2022
- September 2022
- October 2022
- November 2022
- December 2022

2021

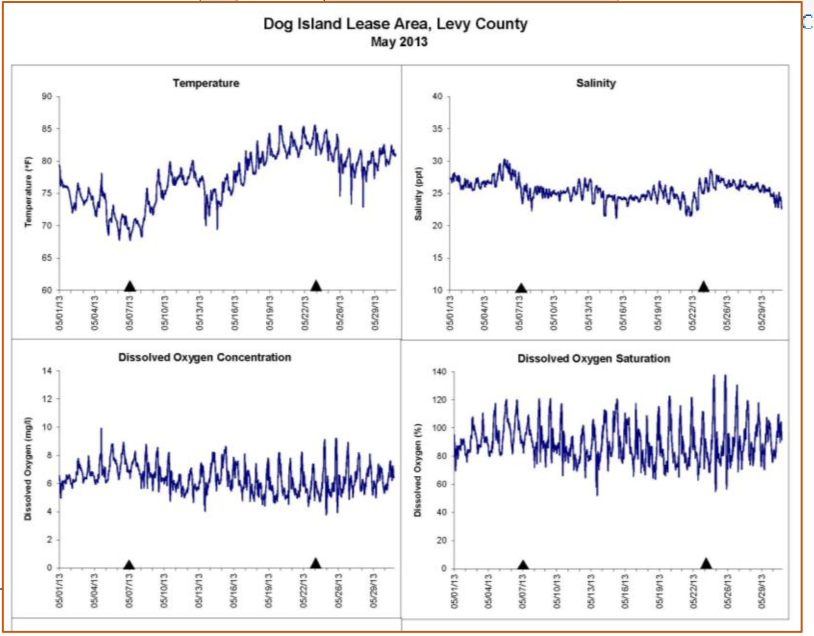
- January 2021
- February 2021



LIVE
Water Quality

ARCHIVED
Water Quality Information

- Alligator Harbor, Franklin County
- Body A, Brevard County
- Body F, Brevard County
- Dog Island, Levy County
- Gulf Jackson, Levy County
- Horseshoe Beach, Dixie County
- Indian River, Indian River County


Dog Island Lease Area, Levy County
May 2013

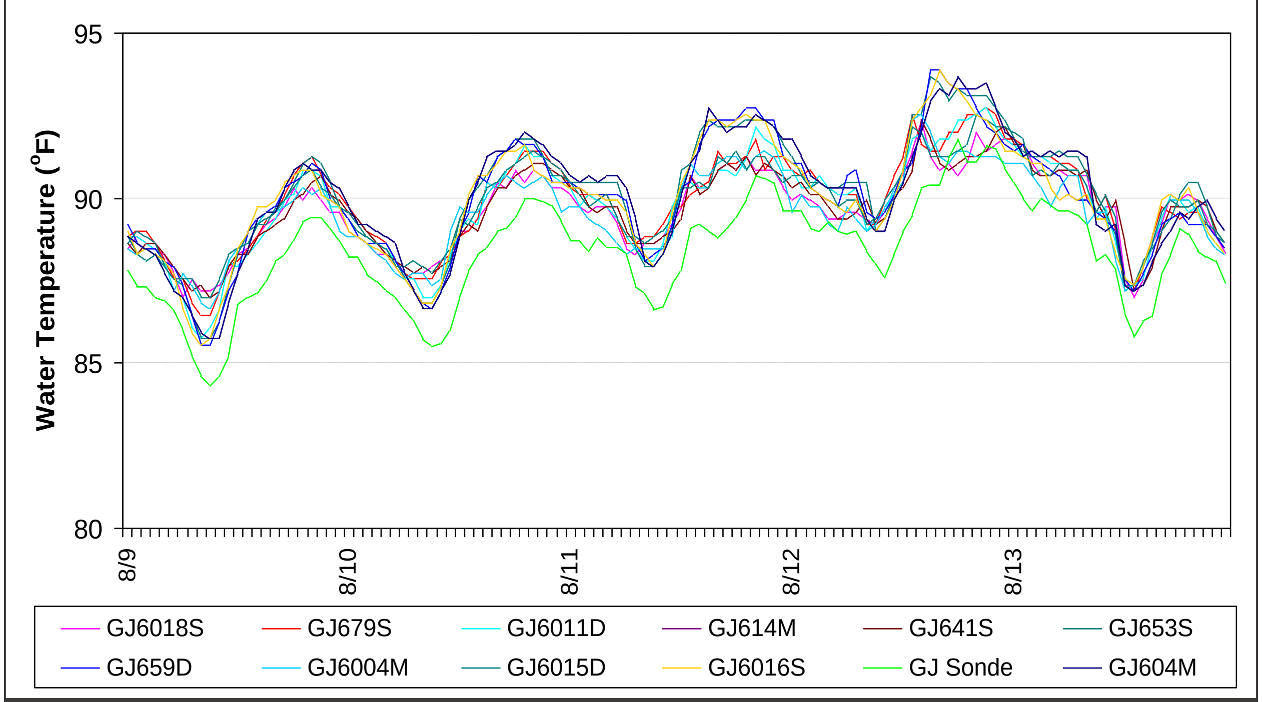
- Initiated in 2002 with USDA funding
- Purchased YSI sondes for 9 lease areas in 7 counties
- UF and DACS maintained stations and data
- By 2012 reduced to 2 stations in Cedar Key – DI and GJ
- Past 2 years evaluated several monitoring systems

Monitoring Water Temperatures during Summer, 2007-2013

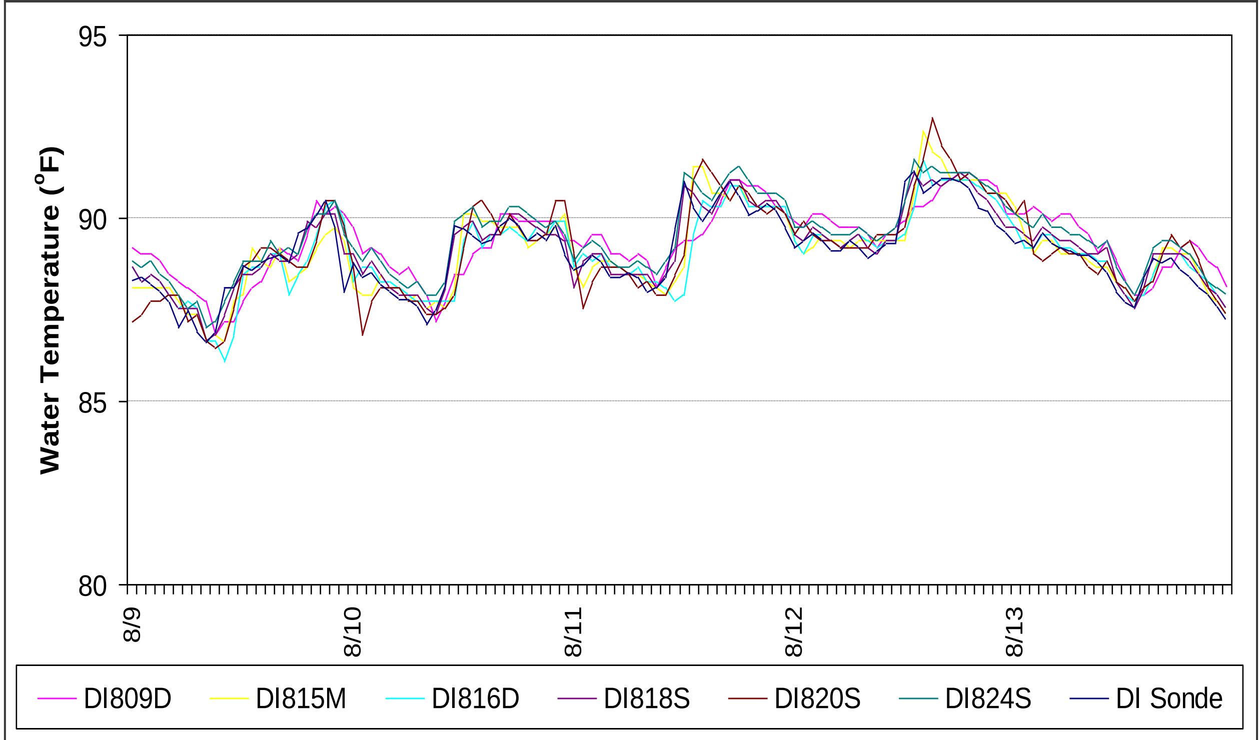
- Loggers provided to clam growers to deploy inside bags at Cedar Key leases
  - 17 leases in 2007 (8% coverage)
  - 33-39 leases in 2008-10 (16-20%)

- Describe temperature variability within and among lease areas
  - Diurnal and annual
  - Water depth
  - Substrate characteristics
  - Tidal and wind currents
  - Moon phases

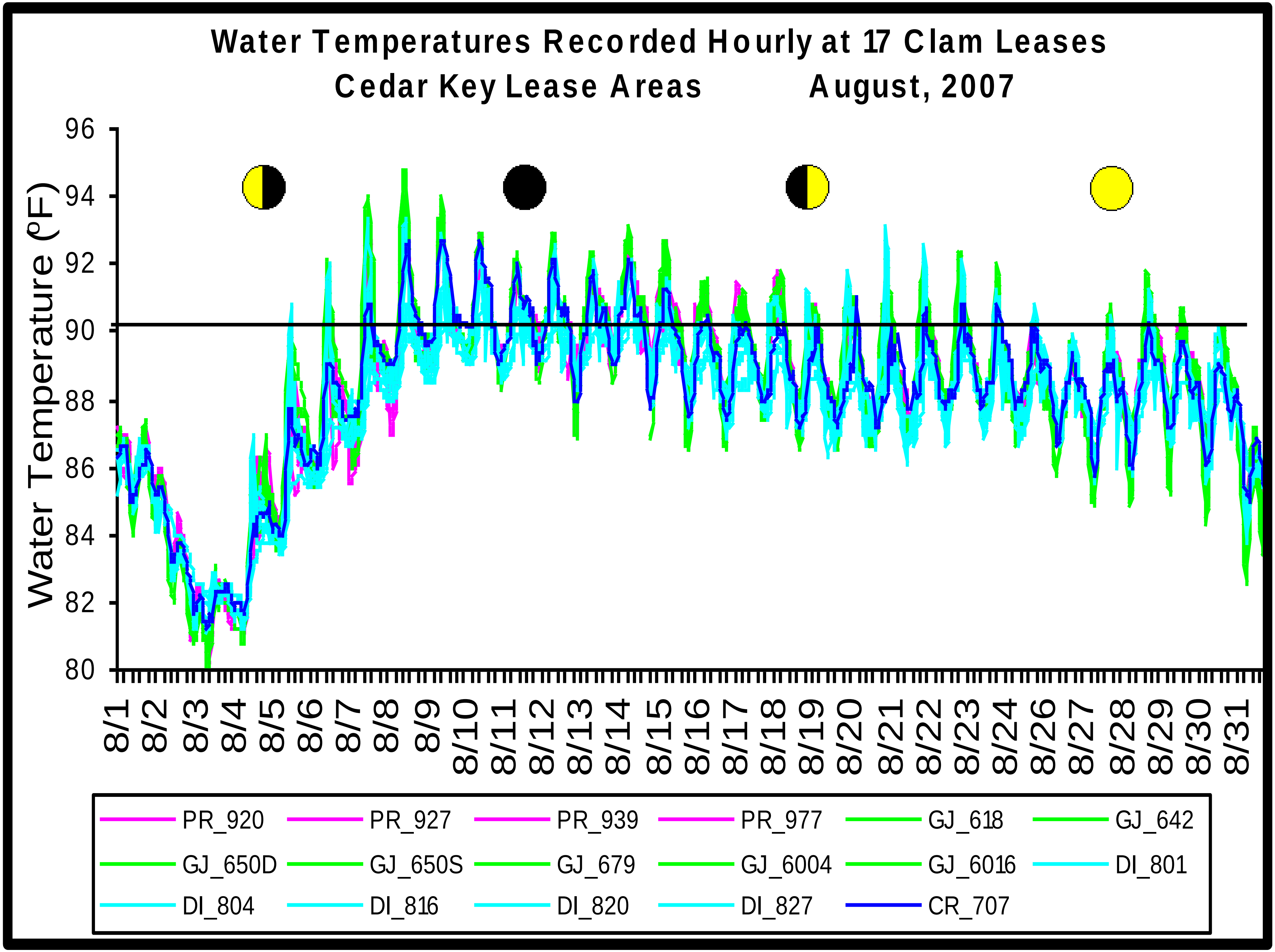
HOBO® Pendant Temperature Data Logger (2.3 x 1.3 x 0.9 inches)



Gulf Jackson AUZ Leases (n=12) August 9-13, 2009



Dog Island AUZ Leases (n=7) August 9-13, 2009


Water Temperatures Recorded Hourly at 17 Clam Leases
Cedar Key Lease Areas August, 2007
Water Temperature (°F)
96
94
92
90
88
86
84
82
80
8/1
8/2
8/3
8/4
8/5
8/6
8/7
8/8
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
8/17
8/18
8/19
8/20
8/21
8/22
8/23
8/24
8/26
8/27
8/28
8/29
8/30
8/31
PR_920
PR_927
PR_939
PR_977
GJ_618
GJ_642
GJ_650D
GJ_650S
GJ_679
GJ_6004
GJ_6016
DI_801
DI_804
DI_816
DI_820
DI_827
CR_707

Evaluating Abiotic And Biotic Factors Influencing Hard Clam Production In Florida

2020-2023

Determine relationships between water quality, phytoplankton, and seed health 8 hatcheries and 7 nurseries in three geographic locations

HARBOR BRANCH
FLORIDA ATLANTIC UNIVERSITY

Sea Grant

UF|IFAS
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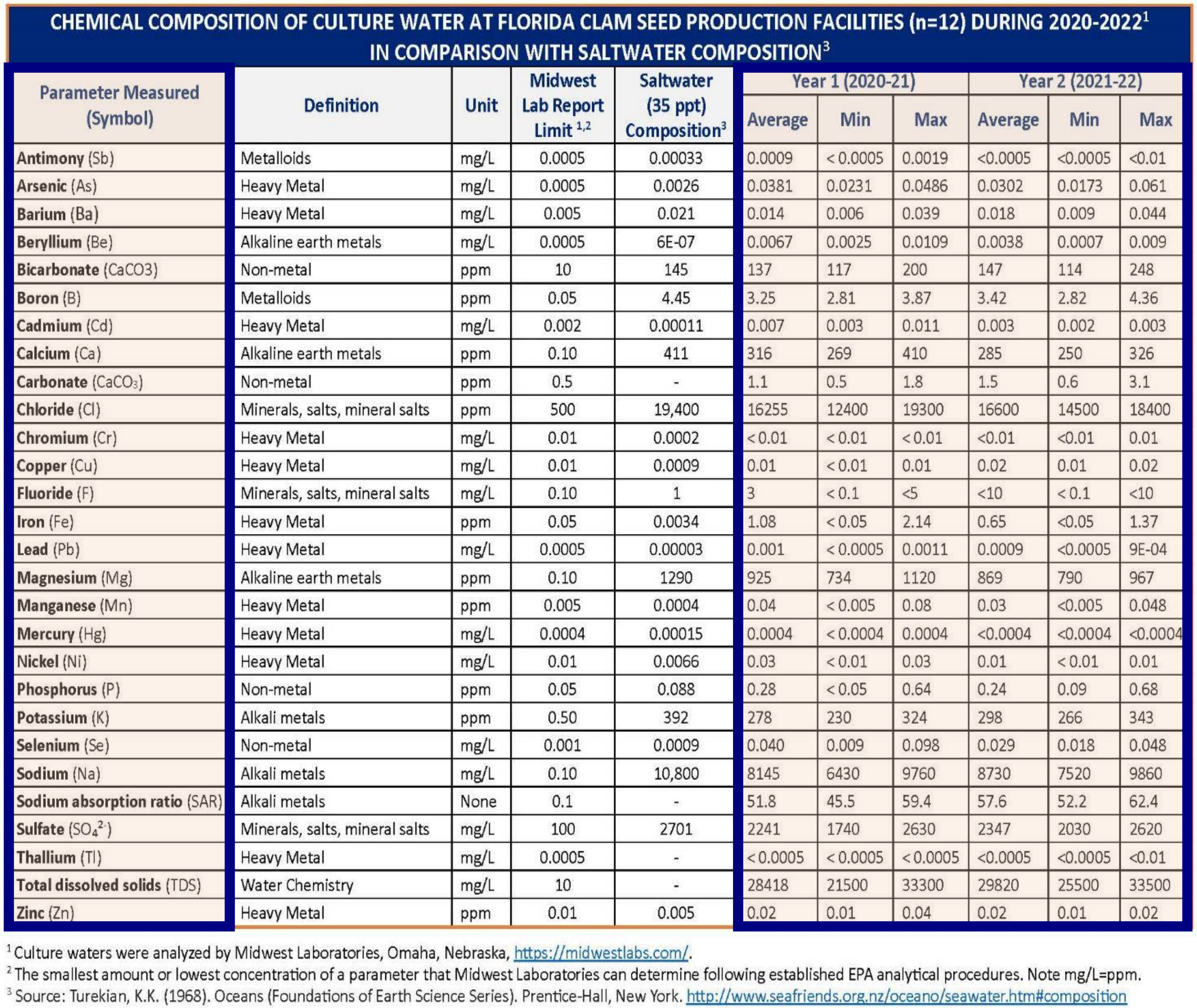
Chemical Composition

- Ions
- Heavy and alkali metals
- Inorganic chemicals

n=28



CHEMICAL COMPOSITION OF CULTURE WATER AT FLORIDA CLAM SEED PRODUCTION FACILITIES (n=12) DURING 2020-2022[1] IN COMPARISON WITH SALTWATER COMPOSITION[3]

Parameter Measured (Symbol)	Definition	Unit	Midwest Lab Report Limit [1,2]	Saltwater (35 ppt) Composition[3]	Year 1 (2020-21)			Year 2 (2021-22)		
					Average	Min	Max	Average	Min	Max
Antimony (Sb)	Metalloids	mg/L	0.0005	0.00033	0.0009	< 0.0005	0.0019	<0.0005	<0.0005	<0.01
Arsenic (As)	Heavy Metal	mg/L	0.0005	0.0026	0.0381	0.0231	0.0486	0.0302	0.0173	0.061
Barium (Ba)	Heavy Metal	mg/L	0.005	0.021	0.014	0.006	0.039	0.018	0.009	0.044
Beryllium (Be)	Alkaline earth metals	mg/L	0.0005	6E-07	0.0067	0.0025	0.0109	0.0038	0.0007	0.009
Bicarbonate (CaCO3)	Non-metal	ppm	10	145	137	117	200	147	114	248
Boron (B)	Metalloids	ppm	0.05	4.45	3.25	2.81	3.87	3.42	2.82	4.36
Cadmium (Cd)	Heavy Metal	mg/L	0.002	0.00011	0.007	0.003	0.011	0.003	0.002	0.003
Calcium (Ca)	Alkaline earth metals	ppm	0.10	411	316	269	410	285	250	326
Carbonate ($CaCO_3$)	Non-metal	ppm	0.5	-	1.1	0.5	1.8	1.5	0.6	3.1
Chloride (Cl)	Minerals, salts, mineral salts	ppm	500	19,400	16255	12400	19300	16600	14500	18400
Chromium (Cr)	Heavy Metal	mg/L	0.01	0.0002	< 0.01	< 0.01	< 0.01	<0.01	<0.01	0.01
Copper (Cu)	Heavy Metal	mg/L	0.01	0.0009	0.01	< 0.01	0.01	0.02	0.01	0.02
Fluoride (F)	Minerals, salts, mineral salts	mg/L	0.10	1	3	< 0.1	<5	<10	< 0.1	<10
Iron (Fe)	Heavy Metal	ppm	0.05	0.0034	1.08	< 0.05	2.14	0.65	<0.05	1.37
Lead (Pb)	Heavy Metal	mg/L	0.0005	0.00003	0.001	< 0.0005	0.0011	0.0009	<0.0005	9E-04
Magnesium (Mg)	Alkaline earth metals	ppm	0.10	1290	925	734	1120	869	790	967
Manganese (Mn)	Heavy Metal	ppm	0.005	0.0004	0.04	< 0.005	0.08	0.03	<0.005	0.048
Mercury (Hg)	Heavy Metal	mg/L	0.0004	0.00015	0.0004	< 0.0004	0.0004	<0.0004	<0.0004	<0.0004
Nickel (Ni)	Heavy Metal	mg/L	0.01	0.0066	0.03	< 0.01	0.03	0.01	< 0.01	0.01
Phosphorus (P)	Non-metal	ppm	0.05	0.088	0.28	< 0.05	0.64	0.24	0.09	0.68
Potassium (K)	Alkali metals	ppm	0.50	392	278	230	324	298	266	343
Selenium (Se)	Non-metal	mg/L	0.001	0.0009	0.040	0.009	0.098	0.029	0.018	0.048
Sodium (Na)	Alkali metals	mg/L	0.10	10,800	8145	6430	9760	8730	7520	9860
Sodium absorption ratio (SAR)	Alkali metals	None	0.1	-	51.8	45.5	59.4	57.6	52.2	62.4
Sulfate (SO_4^{2-})	Minerals, salts, mineral salts	mg/L	100	2701	2241	1740	2630	2347	2030	2620
Thallium (Tl)	Heavy Metal	mg/L	0.0005	-	< 0.0005	< 0.0005	< 0.0005	<0.0005	<0.0005	<0.01
Total dissolved solids (TDS)	Water Chemistry	mg/L	10	-	28418	21500	33300	29820	25500	33500
Zinc (Zn)	Heavy Metal	ppm	0.01	0.005	0.02	0.01	0.04	0.02	0.01	0.02

[1] Culture waters were analyzed by Midwest Laboratories, Omaha, Nebraska, https://midwestlabs.com/.

[2] The smallest amount or lowest concentration of a parameter that Midwest Laboratories can determine following established EPA analytical procedures. Note mg/L=ppm.

[3] Source: Turekian, K.K. (1968). Oceans (Foundations of Earth Science Series). Prentice-Hall, New York. http://www.seafriends.org.nz/oceano/seawater.htm#composition

Scan to download

- Annual (2020-22) analyses of source (surface, ground) waters
- All values were in range of those defined for seawater composition

Volatile Organics (VOC)

n=80

- High vapor pressure
- Low water solubility
- Man-made chemicals
  - Paints
  - Pharmaceutical
  - Refrigerants

EPA 8260 WATER

- 1,1,1,2-Tetrachloroethane
- 1,1,1-Trichloroethane
- 1,1,2,2-Tetrachloroethane
- 1,1,2-Trichloro-1,1,2-trifluoroethane
- 1,1,2-Trichloroethane
- 1,1-Dichloroethane
- 1,1-Dichloroethene
- 1,1-Dichloropropene
- 1,2,3-Trichlorobenzene
- 1,2,3-Trichloropropane
- 1,2,4-Trichlorobenzene
- 1,2,4-Trimethylbenzene
- 1,2-Dibromo-3-Chloropropane
- 1,2-Dibromoethane
- 1,2-Dichlorobenzene
- 1,2-Dichloroethane
- 1,2-Dichloropropane
- 1,3,5-Trimethylbenzene
- 1,3-Dichlorobenzene
- 1,3-Dichloropropane
- 1,4-Dichlorobenzene
- 2,2-Dichloropropane
- 2-Butanone
- 2-Chlorotoluene
- 2-Hexanone
- 4-Chlorotoluene
- 4-Methyl-2-pentanone
- Acetone
- Acrylonitrile
- Allyl Chloride
- Benzene
- Bromobenzene
- Bromochloromethane
- Bromodichloromethane
- Bromoform
- Bromomethane
- Carbon disulfide
- Carbon Tetrachloride
- Chlorobenzene
- Chloroethane
- Chloroform
- Chloromethane
- Chloroprene
- cis-1,2-Dichloroethene
- cis-1,3-Dichloropropene
- cis-1,4-Dichloro-2-butene
- Dibromochloromethane
- Dibromomethane
- Dichlorodifluoromethane
- Ethyl Ether
- Ethyl Methacrylate
- Ethylbenzene
- Hexachlorobutadiene
- Iodomethane
- Isopropylbenzene
- m,p-Xylenes
- Methyl Acrylate
- Methyl Methacrylate
- Methyl tert-Butyl Ether
- Methylene Chloride
- Naphthalene
- n-Butyl Benzene
- n-Propyl Benzene
- o-Xylene
- p-Isopropyltoluene
- sec-Butylbenzene
- Styrene
- tert-Butylbenzene
- Tetrachloroethene
- Tetrahydrofuran
- Toluene
- Total Trihalomethanes
- Total Xylenes
- trans-1,2-Dichloroethene
- trans-1,3-Dichloropropene
- trans-1,4-Dichloro-2-butene
- Trichloroethene
- Trichlorofluoromethane
- Vinyl acetate
- Vinyl chloride

- Annual (2020-22) analyses of source (surface, ground) waters
- All values below those of reporting values following EPA analytical procedures

Herbicides

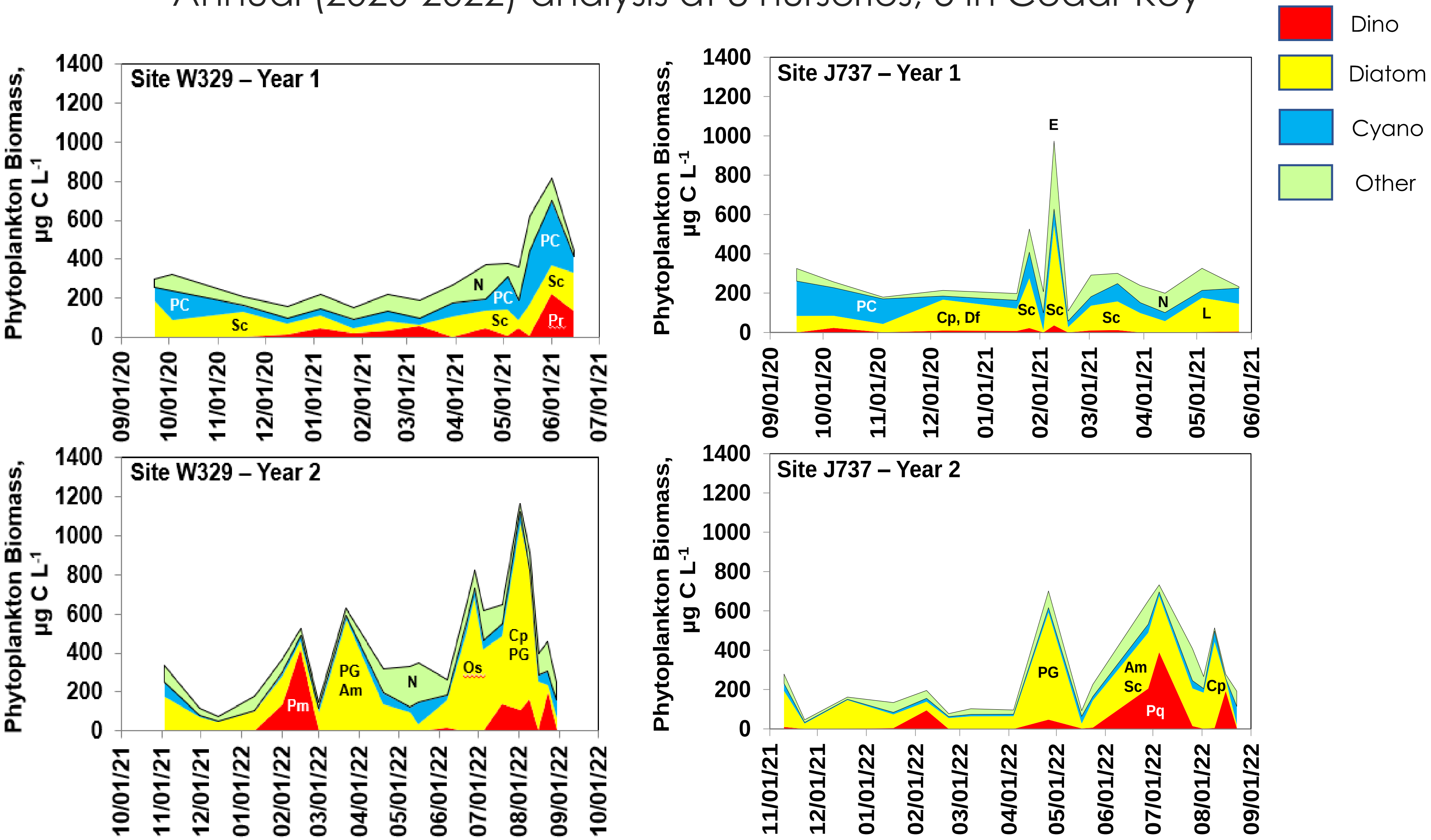
- 2020-22
- Contacted local road department
- **Glyphosate**
  - Kills certain weeds and grasses.
  - Blocks enzyme essential for plant growth
  - Used locally alongside roads
- Values less than reporting limit of 10 ppb in both years

Pesticides

- 2021-22
- Contacted local mosquito control department
- **Naled -** active ingredient sprayed near Cedar Key nursery facilities
- Values less than the reporting limit of 1.0 ug/L for pesticides

Phytoplankton Composition and Biomass

Annual (2020-2022) analysis at 8 nurseries, 3 in Cedar Key

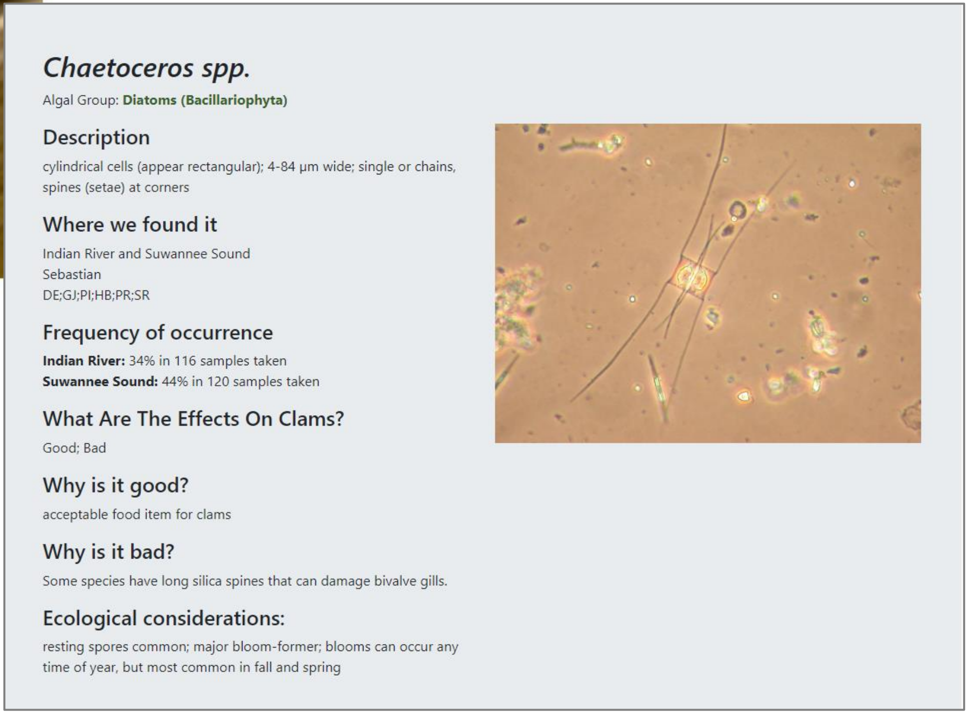


- Diatoms major algal group, considered positive in food webs
- Dinoflagellate biomass below values associated with HAB events

What Do Clam Eat?

A web-based pictorial guide to food sources for clams – spatial and seasonal distribution of marine phytoplankton in Suwannee Sound and Indian River

- Chlorophyll a and biomass patterns
- Major groups and common species (n=43)
- Description of each algal species
  - What leases found
  - Frequency of occurrence
  - Effects on clams
  - Ecological considerations



Chaetoceros spp.

Algal Group: **Diatoms (Bacillariophyta)**

Description

cylindrical cells (appear rectangular); 4-84 μm wide; single or chains, spines (setae) at corners

Where we found it

Indian River and Suwannee Sound
Sebastian
DE;GJ;PI;HB;PR;SR

Frequency of occurrence

Indian River: 34% in 116 samples taken
Suwannee Sound: 44% in 120 samples taken

What Are The Effects On Clams?

Good; Bad

Why is it good?

acceptable food item for clams

Why is it bad?

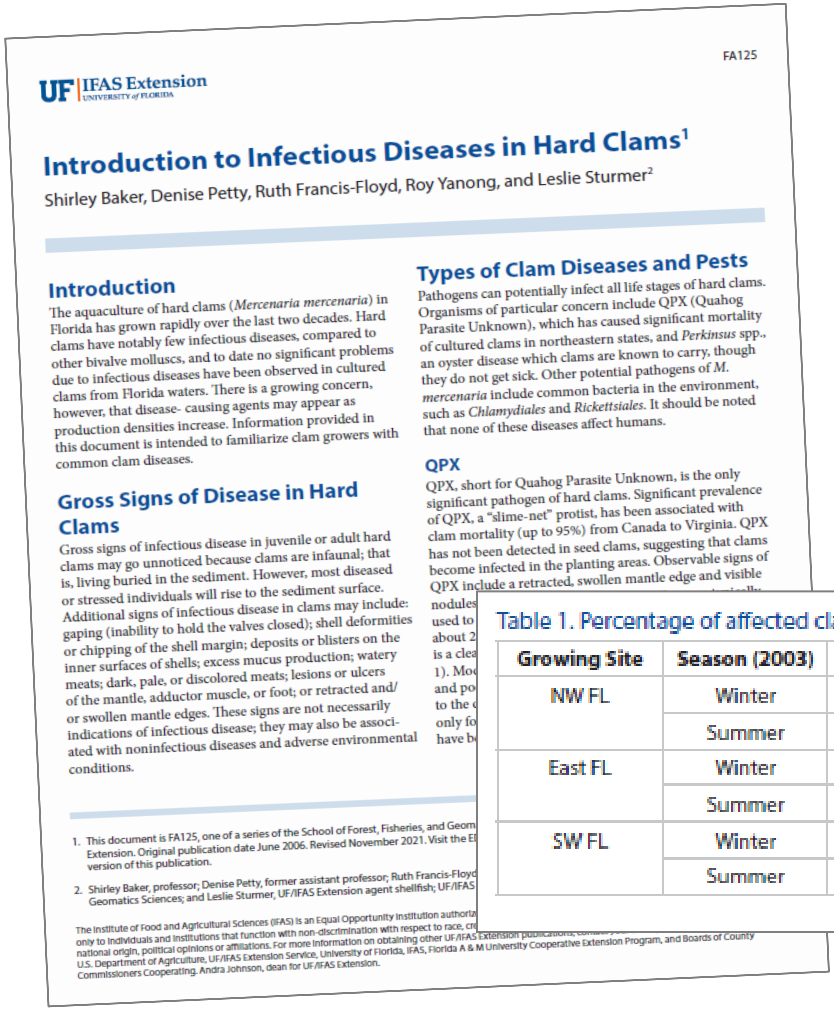
Some species have long silica spines that can damage bivalve gills.

Ecological considerations:

resting spores common; major bloom-former; blooms can occur any time of year, but most common in fall and spring

Developed by:
Nikki Dix, Edward Phlips, Shirley Baker, and Susan Badylak
UF/IFAS Fisheries and Aquatic Sciences Program
Leslie Sturmer, UF/ IFAS Extension

Clam Health



FA125

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Introduction to Infectious Diseases in Hard Clams[1]

Shirley Baker, Denise Petty, Ruth Francis-Floyd, Roy Yanong, and Leslie Sturmer[2]

Introduction

The aquaculture of hard clams (*Mercenaria mercenaria*) in Florida has grown rapidly over the last two decades. Hard clams have notably few infectious diseases, compared to other bivalve molluscs, and to date no significant problems due to infectious diseases have been observed in cultured clams from Florida waters. There is a growing concern, however, that disease- causing agents may appear as production densities increase. Information provided in this document is intended to familiarize clam growers with common clam diseases.

Gross Signs of Disease in Hard Clams

Gross signs of infectious disease in juvenile or adult hard clams may go unnoticed because clams are infaunal; that is, living buried in the sediment. However, most diseased or stressed individuals will rise to the sediment surface. Additional signs of infectious disease in clams may include: gaping (inability to hold the valves closed); shell deformities or chipping of the shell margin; deposits or blisters on the inner surfaces of shells; excess mucus production; watery meats; dark, pale, or discolored meats; lesions or ulcers of the mantle, adductor muscle, or foot; or retracted and/or swollen mantle edges. These signs are not necessarily indications of infectious disease; they may also be associated with noninfectious diseases and adverse environmental conditions.

Types of Clam Diseases and Pests

Pathogens can potentially infect all life stages of hard clams. Organisms of particular concern include QPX (Quahog Parasite Unknown), which has caused significant mortality of cultured clams in northeastern states, and *Perkinsus* spp., an oyster disease which clams are known to carry, though they do not get sick. Other potential pathogens of *M. mercenaria* include common bacteria in the environment, such as *Chlamydiales* and *Rickettsiales*. It should be noted that none of these diseases affect humans.

QPX

QPX, short for Quahog Parasite Unknown, is the only significant pathogen of hard clams. Significant prevalence of QPX, a "slime-net" protist, has been associated with clam mortality (up to 95%) from Canada to Virginia. QPX has not been detected in seed clams, suggesting that clams become infected in the planting areas. Observable signs of QPX include a retracted, swollen mantle edge and visible
nodules
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1. This document is FA125, one of a series of the School of Forest, Fisheries, and Geom
Extension. Original publication date June 2006. Revised November 2021. Visit the E
version of this publication.

2. Shirley Baker, professor; Denise Petty, former assistant professor; Ruth Francis-Floyd
Geomatics Sciences; and Leslie Sturmer, UF/IFAS Extension agent shellfish; UF/IFAS

UF/IFAS EDIS Publication, FA125
https://edis.ifas.ufl.edu/

- Baseline established in 2003
- Seasonal sampling of clams from three clam farming locations in state - SWFL, IRL, CK
- Examined for disease using histology and RFTM
- No evidence of QPX
- Granulomas most frequently observed abnormality, followed by Rickettsiales-like organisms, metazoans, and inflammation

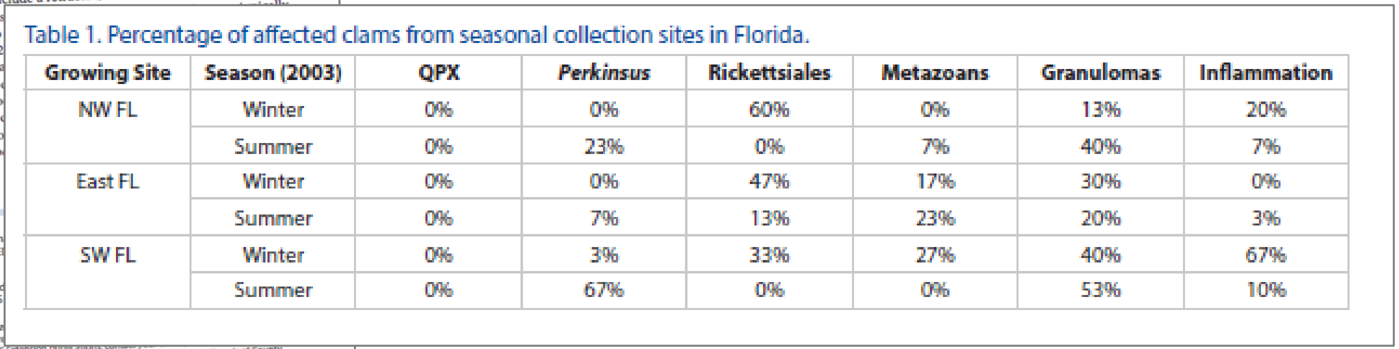
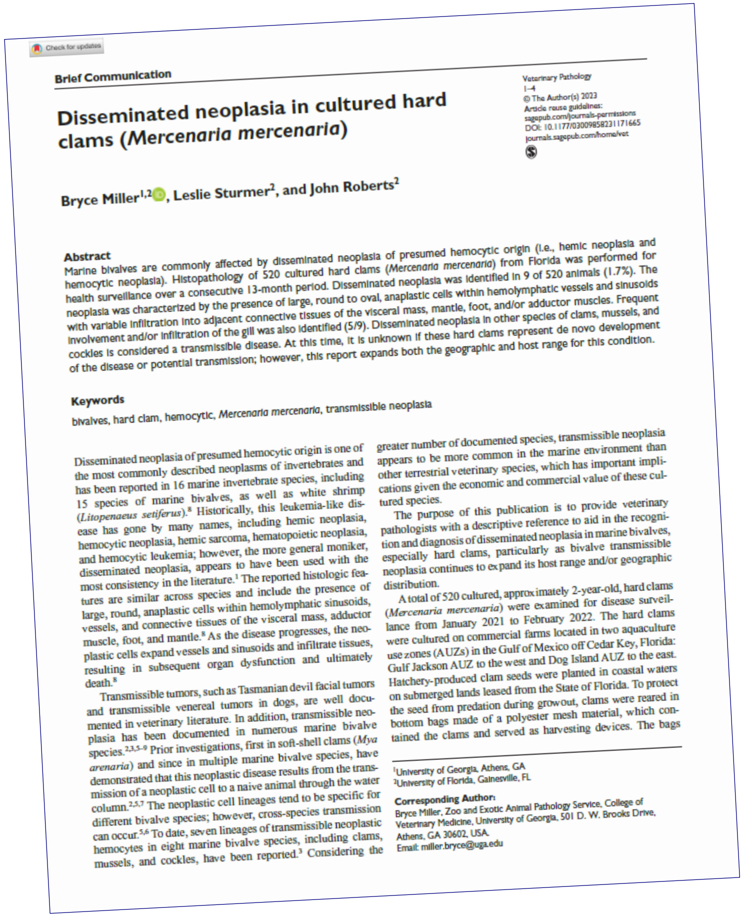


Table 1. Percentage of affected clams from seasonal collection sites in Florida.

Growing Site	Season (2003)	QPX	*Perkinsus*	Rickettsiales	Metazoans	Granulomas	Inflammation
NW FL	Winter	0%	0%	60%	0%	13%	20%
	Summer	0%	23%	0%	7%	40%	7%
East FL	Winter	0%	0%	47%	17%	30%	0%
	Summer	0%	7%	13%	23%	20%	3%
SW FL	Winter	0%	3%	33%	27%	40%	67%
	Summer	0%	67%	0%	0%	53%	10%

- Extension publication to create awareness of potential shellfish disease

Clam Health



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Brief Communication

Veterinary Pathology
1–4
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Disseminated neoplasia in cultured hard clams (*Mercenaria mercenaria*)

Bryce Miller[1,2], Leslie Sturmer[2], and John Roberts[2]

Abstract

Marine bivalves are commonly affected by disseminated neoplasia of presumed hemocytic origin (i.e., hemic neoplasia and hemocytic neoplasia). Histopathology of 520 cultured hard clams (*Mercenaria mercenaria*) from Florida was performed for health surveillance over a consecutive 13-month period. Disseminated neoplasia was identified in 9 of 520 animals (1.7%). The neoplasia was characterized by the presence of large, round to oval, anaplastic cells within hemolymphatic vessels and sinusoids with variable infiltration into adjacent connective tissues of the visceral mass, mantle, foot, and/or adductor muscles. Frequent involvement and/or infiltration of the gill was also identified (5/9). Disseminated neoplasia in other species of clams, mussels, and cockles is considered a transmissible disease. At this time, it is unknown if these hard clams represent de novo development of the disease or potential transmission; however, this report expands both the geographic and host range for this condition.

Keywords

bivalves, hard clam, hemocytic, *Mercenaria mercenaria*, transmissible neoplasia

Disseminated neoplasia of presumed hemocytic origin is one of the most commonly described neoplasms of invertebrates and has been reported in 16 marine invertebrate species, including 15 species of marine bivalves, as well as white shrimp (*Litopenaeus setiferus*).[8] Historically, this leukemia-like disease has gone by many names, including hemic neoplasia, hemocytic neoplasia, hemic sarcoma, hematopoietic neoplasia, and hemocytic leukemia; however, the more general moniker, disseminated neoplasia, appears to have been used with the most consistency in the literature.[1] The reported histologic features are similar across species and include the presence of large, round, anaplastic cells within hemolymphatic sinusoids, vessels, and connective tissues of the visceral mass, adductor muscle, foot, and mantle.[8] As the disease progresses, the neoplastic cells expand vessels and sinusoids and infiltrate tissues, resulting in subsequent organ dysfunction and ultimately death.[8]

Transmissible tumors, such as Tasmanian devil facial tumors and transmissible venereal tumors in dogs, are well documented in veterinary literature. In addition, transmissible neoplasia has been documented in numerous marine bivalve species.[2,3,5–9] Prior investigations, first in soft-shell clams (*Mya arenaria*) and since in multiple marine bivalve species, have demonstrated that this neoplastic disease results from the transmission of a neoplastic cell to a naive animal through the water column.[2,5,7] The neoplastic cell lineages tend to be specific for different bivalve species; however, cross-species transmission can occur.[5,6] To date, seven lineages of transmissible neoplastic hemocytes in eight marine bivalve species, including clams, mussels, and cockles, have been reported.[3] Considering the greater number of documented species, transmissible neoplasia appears to be more common in the marine environment than other terrestrial veterinary species, which has important implications given the economic and commercial value of these cultured species.

The purpose of this publication is to provide veterinary pathologists with a descriptive reference to aid in the recognition and diagnosis of disseminated neoplasia in marine bivalves, especially hard clams, particularly as bivalve transmissible neoplasia continues to expand its host range and/or geographic distribution.

A total of 520 cultured, approximately 2-year-old, hard clams (*Mercenaria mercenaria*) were examined for disease surveillance from January 2021 to February 2022. The hard clams were cultured on commercial farms located in two aquaculture use zones (AUZs) in the Gulf of Mexico off Cedar Key, Florida: Gulf Jackson AUZ to the west and Dog Island AUZ to the east. Hatchery-produced clam seeds were planted in coastal waters on submerged lands leased from the State of Florida. To protect the seed from predation during growout, clams were reared in bottom bags made of a polyester mesh material, which contained the clams and served as harvesting devices. The bags

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- In 2007-8, health of market-size clams from 12 Cedar Key growers assessed during summer
- Clam samples submitted for pathology during mortality events (VIMS)
- In all cases, no diseases of concern found

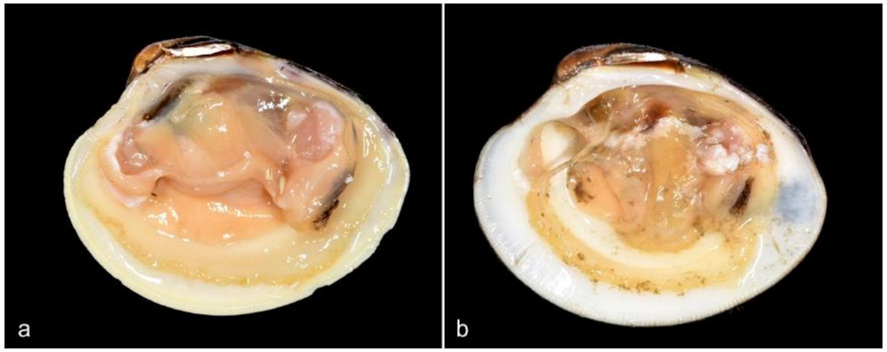

Figure 1. Images of normal and affected hard clams with the umbo (anterior) oriented to the left. (a) Unaffected male with expected visceral mass size. (b) Diseased male with disseminated neoplasia exhibits a markedly decreased visceral mass size and recession of the mantle.

- In 2021-22, histology of adult clams sampled monthly from Gulf Jackson and Dog Island AUZs over 13-month period
- Neoplasia found in 1.7% of samples
- Common parasites found included metazoan larvae (43%) and Chlamydiales-like organisms (<1%)

Clam Genetic Diversity

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ASSESSMENT OF GENETIC DIVERSITY IN WILD AND AQUACULTURE STOCKS OF *MERCENARIA MERCENARIA* IN FLORIDA

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ABSTRACT The northern hard clam *Mercenaria mercenaria* is one of the most commercially important bivalve species produced via aquaculture in the eastern United States. Breeding practices associated with large-scale hatchery production of hard clam seed may result in unintended, potentially negative consequences including inbreeding and reduced levels of genetic diversity. Seven microsatellite markers were used to compare levels of genetic diversity in six hatchery stocks and four wild stocks from the state of Florida. Wild stocks of *M. mercenaria* had slightly higher levels of allelic richness and similar observed heterozygosity (wild = $A_r = 3.61$, $H_o = 0.448$; hatchery = $A_r = 3.46$, $H_o = 0.452$); however, these differences were not statistically significant (A_r: $P = 0.145$; H_o: $P = 0.931$). Differentiation was highest between hatchery stocks ($G_{ST} = 0.03$, SD = 0.007; $P < 0.001$) but minimal among hatchery-by-wild comparisons. In contrast, wild stocks were not differentiated ($G_{ST} = -0.002$, SD = 0.004; $P \approx 0.58$) and Bayesian comparisons of competing gene flow models (panmixia, stepping stone, and full-migration) suggested that wild stocks were effectively panmictic at this scale. Together, these results indicate that some genetic drift has occurred within hatchery populations, possibly as a result of broodstock selection and spawning practices. The genetic divergence between wild and hatchery stocks observed in this study are not as pronounced as seen in other aquaculture bivalve species. Given the large scale of hard clam production in Florida we argue that hatchery practices should incorporate long-term genetic goals (i.e., avoidance of inbreeding) to maintain the integrity of hatchery stocks. A secondary objective of this study was to amplify a congeneric species, *Mercenaria campechiensis*, using the same suite of microsatellite markers to assess their utility for detecting interspecific hybridization. Amplification success was poor and failed for four of the seven loci. The identification of microsatellite loci for different species of *Mercenaria* should be identified *de novo* in the future.

KEY WORDS: *Mercenaria mercenaria*, aquaculture, population genetics, microsatellites, panmixia, clam, northern quahog

INTRODUCTION

The hard clam *Mercenaria mercenaria* (Linnaeus, 1758), is a marine bivalve native to the eastern seaboard of the United States in coastal waters from the Gulf of St. Lawrence to Florida (Harte 2001). Populations of *M. mercenaria* have been commercially exploited for over 100 y (MacKenzie et al. 2001); declines in harvests and fluctuations in abundance, however, prompted the development of aquaculture technology to procure seed for large-scale clam production (Arnold et al. 2009). Propagation of *M. mercenaria* has increased substantially in the last 35 y (Castagna 2001) in part due to advances in culture techniques made during the 1950s (Manzi & Castagna 1989). Most notably, the state of Florida has seen dramatic increases in *M. mercenaria* production, which has largely been attributed to job retraining programs for underemployed fishermen, increased availability of aquaculture leases, and refined production techniques (Colson & Sturmer 2000).

The commercial hard clam industry in Florida is comprised of more than 300 shellfish growers who farm submerged land leases totaling over 2,100 acres (Adams & Sturmer 2012). Hatchery production of *Mercenaria mercenaria* is typically accomplished via a five-stage process including broodstock selection and maintenance, spawning, larval culture, postset culture, and nursery culture in raceways or upwellers (Hadley & Whetstone 2007). Because the production of wild seed varies annually as a function of environmental conditions, clam aquaculture is almost entirely dependent upon hatcheries for seed (FAO 2013). Given the reliance on hatcheries for the mass production of offspring, resource managers would benefit from considering the genetic consequences of current breeding practices. For example, large-scale seed production accomplished using small numbers of broodstock may result in a significant reduction in genetic diversity and an increased likelihood of inbreeding relative to wild populations (Lutz 2001). Such outcomes may have potential negative consequences for survival and growth. The application of genetic techniques to inform aquaculture production has resulted in increased yields (Langdon et al. 2003), disease resistance (Ford & Haskin 1987), and growth rates in a variety of shellfish species through selective breeding practices (see Guo 2009 for review). Baseline information on hatchery stock diversity remains an important goal in aquaculture given the potential consequences, both positive and negative, associated with broodstock selection and management techniques.

Culture of *Mercenaria mercenaria* in Florida occurs primarily in the Gulf of Mexico, where the natural occurrence of this species is controversial. Palmer (1927) listed the species distribution as occurring in waters along the Texas coast; Harte (2001), however, contends that these were mostly likely mistaken identifications. Sources of *M. mercenaria* introductions

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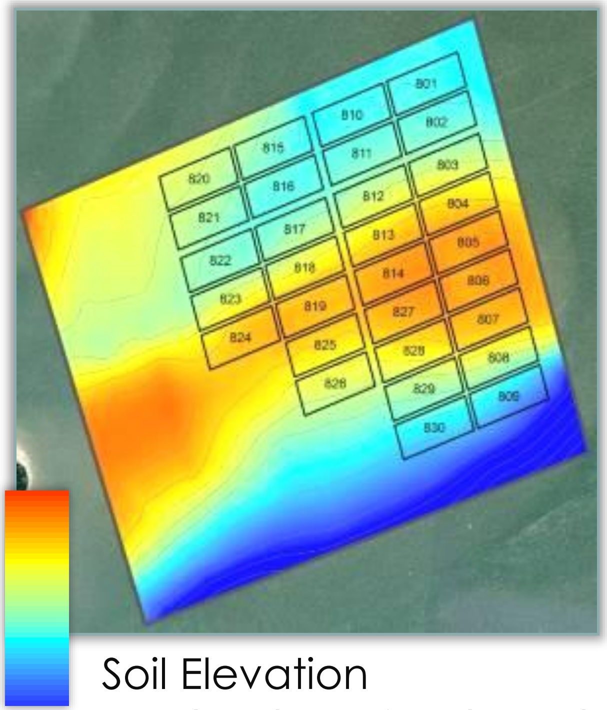
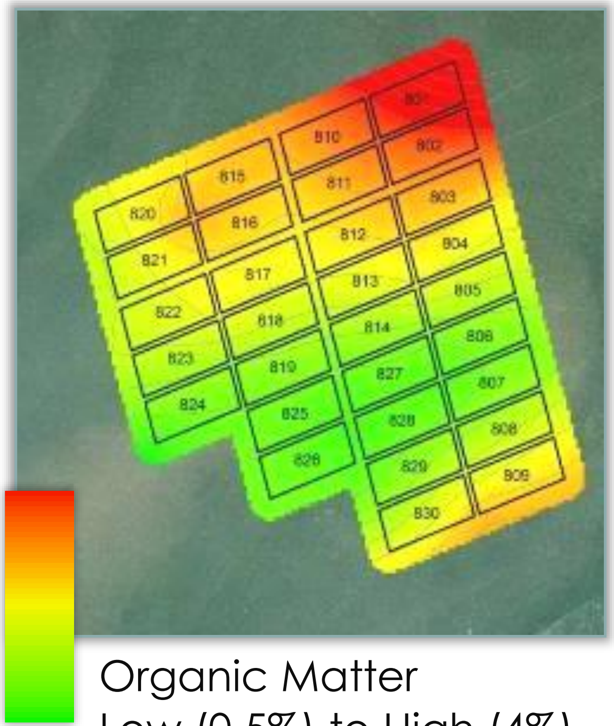
- In 2003, mitochondrial DNA used to quantify diversity in 6 FL hatchery stocks and wild stocks from FL, GA, NY
- Haplotype diversity (range of 0-1) was high in wild stocks (0.80-.89), lower in cultured stocks (0.63-82)

- In 2014, microsatellite markers used to compare levels of diversity in 6 hatchery and 4 FL wild stocks
- Differentiation in allelic richness and heterozygosity was highest between hatchery stocks
- Some genetic drift within hatchery stocks, possibly as a result of broodstock selection
- Divergence between wild and hatchery stocks not as pronounced as in other cultured bivalves

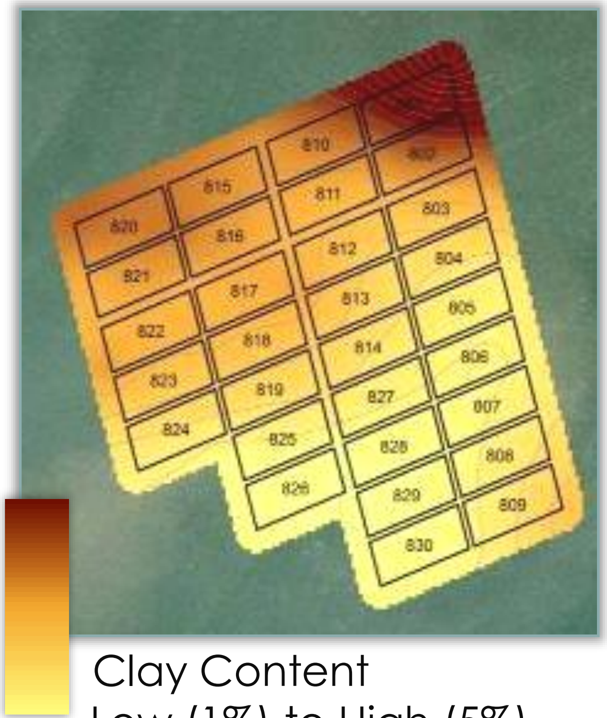
Soil Characterization Study, 2009-10



Soil Elevation
Low (-6.5) to High (+1.5")



Organic Matter
Low (0.5%) to High (4%)



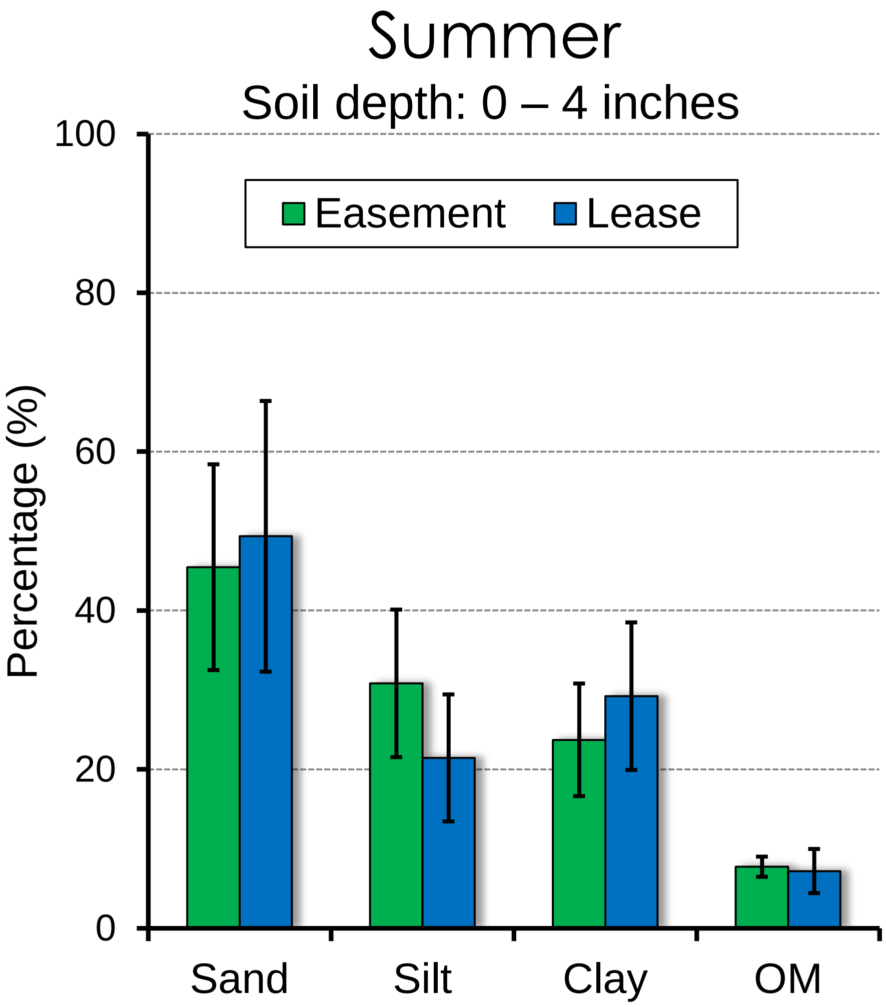
Clay Content
Low (1%) to High (5%)

- Began working with UF soil scientists (Todd Osborne, Rex Ellis, Mark Clark) in 2008
- Aqueous soil samples collected used to produce bathymetric and soil (OM, clay, sand) property maps of Dog Island AUZ
- Spatial relationships and lease specific trends were evident

Soils-Based Approach to Clam Farming, 2011-12

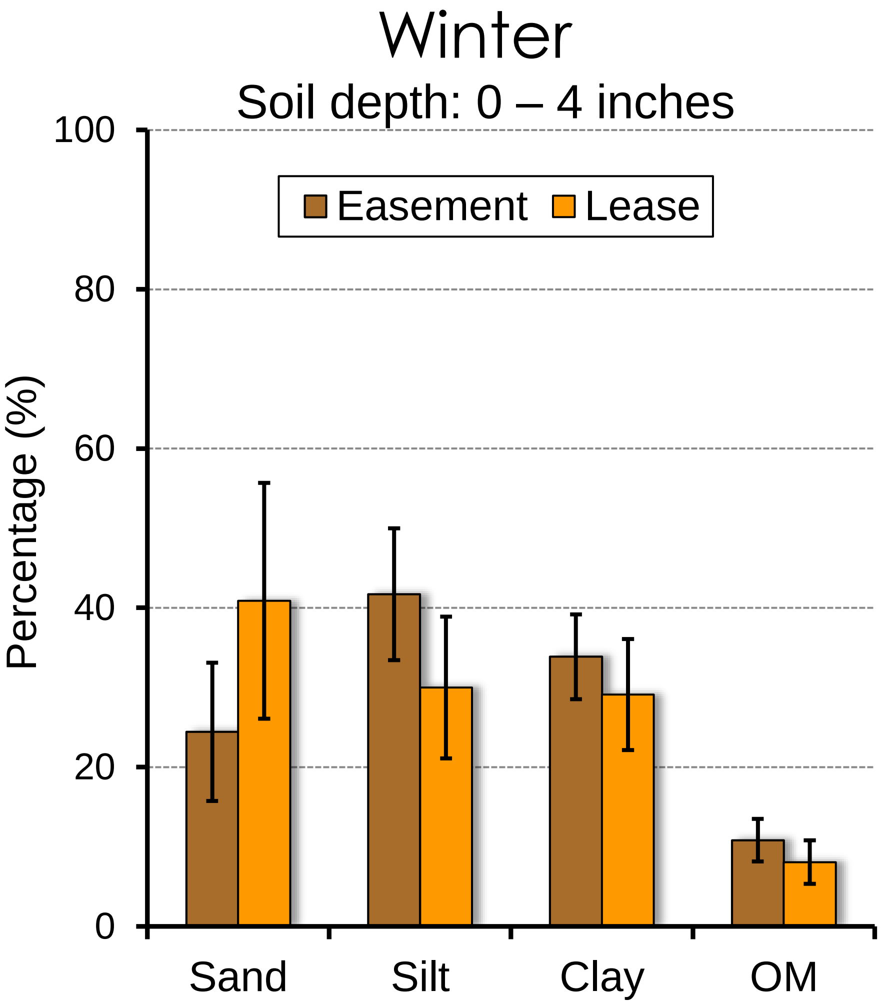
- Findings from soil characterizations at Dog Island AUZ led to the following questions:
  - Do soil properties differ in areas of intensively farmed leases versus adjacent unfarmed areas (e.g., easements, navigational corridors)?
  - Do relationships exist between hard clam aquaculture harvesting methods and soil properties? If so, what is the recovery time of the soil properties?

Clam Farm Soil Properties – Dog Island AUZ, L816



Summer

Soil depth: 0 – 4 inches

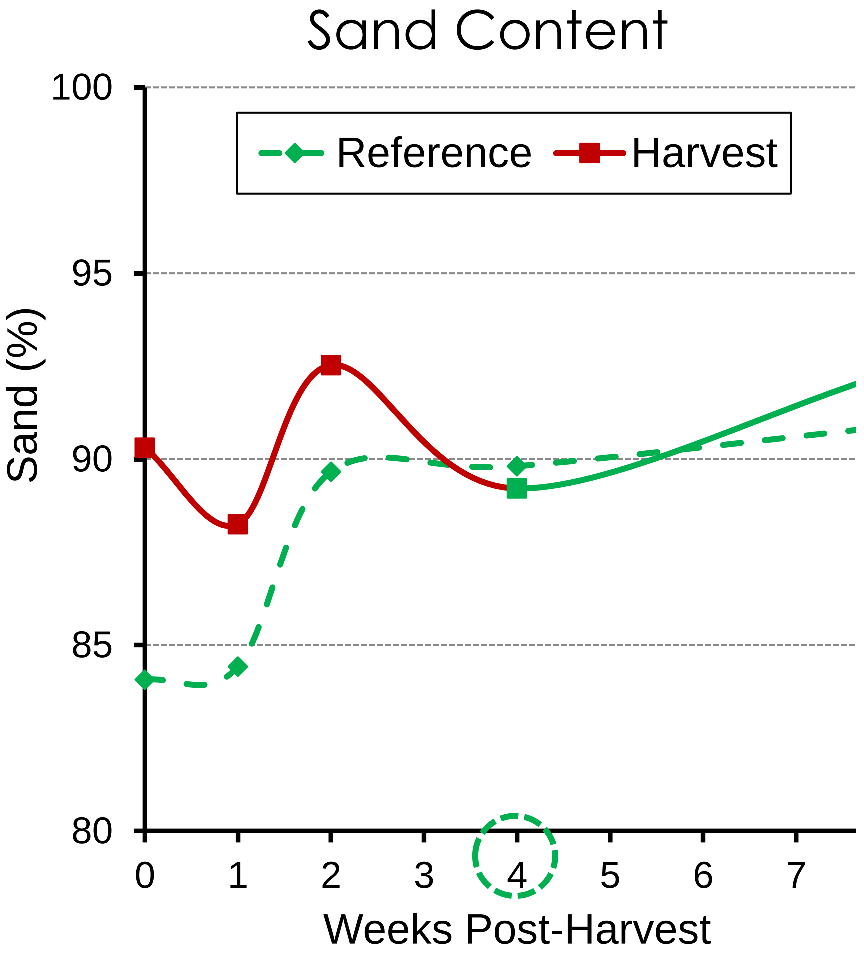


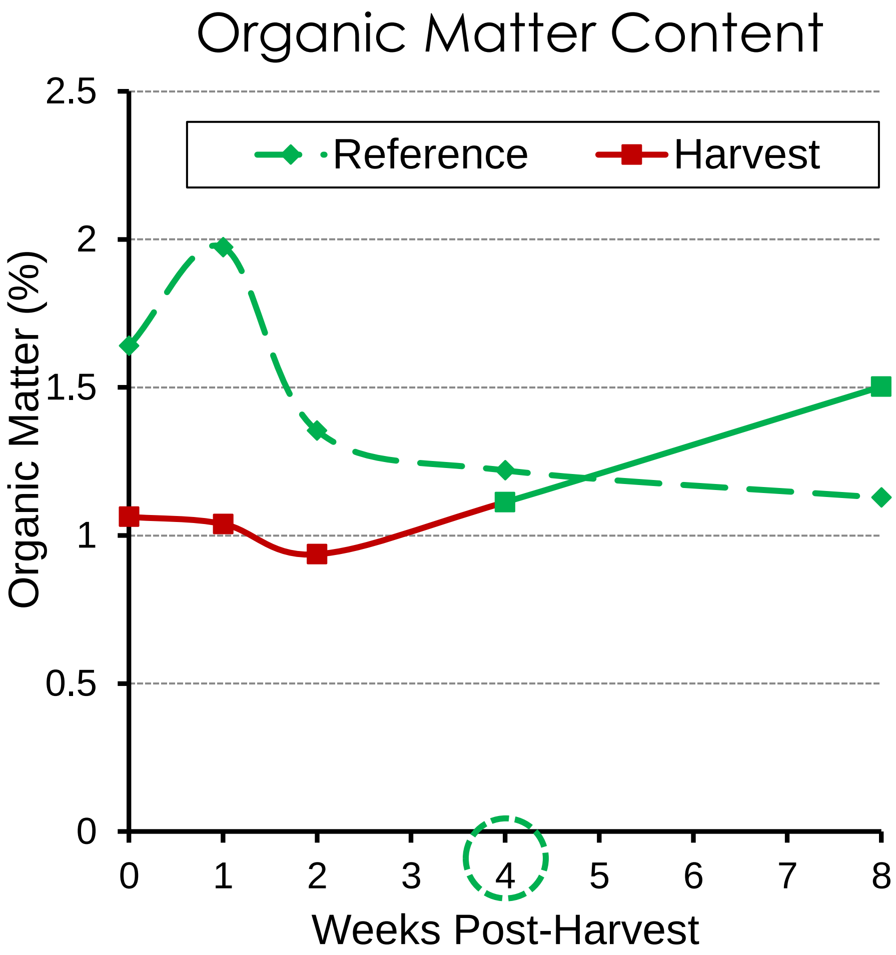
Winter

Soil depth: 0 – 4 inches

- Soil properties (0-4" and 4-8") of 15 leases at Dog Island and Gulf Jackson AUZs were compared with adjacent (unfarmed) areas in summer and winter
- Soil properties did not differ significantly from unfarmed soils at majority of leases

Soil Properties after Harvest – Dog Island AUZ, L803





- Soils within tracks of harvested cultured bags and at adjacent (reference) sites were sampled for sand, OM, clay, and silt content at harvest and 1,2,4,and 8 weeks post-harvest at 7 leases
- Soil properties converged with reference values in 2-4 weeks at the Dog Island leases and 2-8 weeks at the Gulf Jackson leases