

Assessing, Quantifying, and Promoting the Value of Ecosystem Services Provided by the Hard Clam Aquaculture Industry in Florida

> Leslie N. Sturmer, Shirley Baker, Sherry Larkin, Kelly Grogan







## Introduction: Ecosystem Services



- Transformation of natural assets supplied by ecosystems into beneficial goods and functions that humans value
- Those generated by bivalves are widely acknowledged, but not well-quantified or valued for most specific populations
  - Values depend on location
  - Requires site-specific studies for validation and use in decision-making

References: Chan et al. 2006, Cloern 1982, Officer et al., 1982, Shumway et al., 2003, Newell 2004

## Introduction: Ecosystem Services (ES)

- Bivalves and shellfish farms are ecosystem service providers
  - Regulating services: Improve water quality / Store carbon
  - Supporting service: Nutrient cycling
  - Provisioning service: Provide food
  - Cultural services: Recreation, ecotourism, and heritage
- ES have not been quantified or valued for the Florida hard clam farming industry
  - Provides over 600 jobs and produces 180 million clams annually
  - Economic impact of \$53 million estimated in 2007 (Adams et al. 2008)









## OBJECTIVES

In the state

**Conduct literature reviews** Identify and address ecosystem services information gaps Determine feasible range of ecosystem values **Disseminate research results** 

## **Conduct Literature Reviews**

- Searched literature for information
  - ES provided by shellfish
    - Clam farming in particular
    - ES related to nitrogen removal and carbon storage
  - ES valuation associated with bivalve culture
- Used search engines:
  - Web of Knowledge
  - Google Scholar
  - Science Direct
  - Springer Link



## Conduct Literature Reviews

- Information on ES summarized and reported include
  - Bivalve species
  - Ecosystem service
  - Unit of analysis
  - Quantitative measure of service
  - Valuation associated with bivalve culture
    - Valuation of ecosystems
    - Valuation of ES from bivalves
    - Studies on carbon storage by timber rotation
    - Nitrogen removal from wastewater
    - Nitrogen abatement costs

(1440)     (1440)	<ul> <li>evidence induit avanue of the existing and avanuable induiting sequences and avanues of the redededire and calculate storage and, in the schopter of marship or school storage and available. Farther academing along provides available.</li> </ul>
	400.4400           51.050m           51.050m <t< td=""></t<>
Statem	4146.01/mil 50.25/min 51.25/m
a)         54.4465           d)         55.2305           south         55.2467           south         55.2467           south         53.4467           south         south           south         south      <	312.05/mm           313.05/mm           314.05/mm           314.05/mm <td< td=""></td<>
	50.11/mm           51.24/mm           51.44/mm           51.44/mm           53.45/mm           54.55/mm           54.56/mm           54.56/mm           54.56/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm           55.45/mm <t< td=""></t<>
orbit 514403 S14423 224424 10 22444 10 224444 10 22444 10 224444 10 224444 10 224444 10 224444 10 224444 10 224444 10 2244444 10 224444 10 224444 10 224444 10 224444 10 224	5118.97/bm           5218.87/bm           528.07/bm           <
orbit 514403 S14423 224424 10 22444 10 224444 10 22444 10 224444 10 224444 10 224444 10 224444 10 224444 10 224444 10 2244444 10 224444 10 224444 10 224444 10 224444 10 224	92 (Arylen)           123 (Arylen)           124 (Arylen)           125 (Arylen)           126 (Arylen)           127 (Arylen)           128 (Arylen)           129 (Arylen)
stri di angio Lia 23 angio se 23 angio di di angio di an	1318/07/m0           13
Lis 27 2016 25 2220 26 25 2200 20 25 2400 20 40 25 4400 20 400 20 400 2	123.000m         123.000m           133.000m         133.000m           133.000m         133.000m           133.000m         133.000m           133.000m         130.000m           133.000m         100.000m           133.0000m         100.000m           133.0000m         100.0000m           133.0000m         100.0000m           133.0000m         100.0000m           133.0000m         100.0000m           133.0000m         100.0000m           133.0000m         100.0000m           133.00000m         100.0000m           133.00000m         100.00000m           133.00000m         100.00000m           133.00000m         100.00000m           133.00000000000000000000000000000000000
-52 2016 -54 2006 -54 2006 -54 2006 -54 2006 -54 2006 -54 2006 -54 20	4.52.44/km           5.53.80/km           5.53.80/km           5.31.20/km           5.
4 20 02/16 200 53 442/6 2010/0 2010	358 Big/sch           353 Big/sch           354 Big/sch           355 Big
pp 53 44/b pitel or med onese, "tob server med onese," Tob source and composite the composite of the composite of resource of the server of the composite of the composite of the composite of the server of the composite of the composite of the composite of the server of the composite of the composite of the composite of the server of the composite of the composite of the composite of the server of the composite of the	433.24/km 533.05/km bits try fixing male areas of blo sociations. Tain reduction and active accessor and active accessor and reduction and active accessor activity at any areas and active accessor activity at any access and active accessor activity at any access any activity and activity accessor activity at any accessor and activity accessor activity at any accessor any activity accessor activity at any accessor any activity accessor activity accessor any accessor activity accessor activity accessor any accessor accessor accessor accessor any accessor
alishi estitik ore etted ostanty. Taki s oranis and scorpskar test of the destant Spatiaces of absorbing the source of the sourc	632 Go/km bio the facing analy, assess of the senaround some of the facing and assess of the senaround in the senaround of the senaround in the senaround in the senaround in the senaro
entrifice one steal netware. Table a constant and scoression there are a constant and scoression there are a constant and scoression appoints of some are and and scores are and and score are and score are and and score are and an	bits or discipling stack aware of the sen around reduction and assistent series or all reduction and assistent series or all shall a distribute sendific. Further sendifing clam process and
the interview of the in	<ul> <li>evidence induit avanue of the existing and avanuable induiting sequences and avanues of the redededire and calculate storage and, in the adopted marshic or solutions autoregan available. Familier according allangements and in a solution of the solution of the solutions.</li> </ul>
angen sikal tern, skure by gerrikes (100) visit er expensi wisken in onervation. entities of the site of the site of the site	
	Adams, C.M. L. Starmas, and T. Marcons. 201 Proceeding the Concentra Database Concentration (Concentration Conference on Neuropean Database) Doublin 19:55 Technolog Data Intermation Search (EDG), 7 pp. 2010.
	enter 120% Association Frankry & Aurily
	a province of the second secon

UFIFAS

Authors	Species and Sundy Area	Sample	Meas	are of the service										
Ferriana at al 2009	Precific operations (Constanting opport), blue moverin (Myridier volatio), Varnah clarme macandy (Kyridier gabb, provinsionally) in Portugal, France, Slovenia, Italy and Spatharia	Collaction from 5 de Tarent systems: Lacit Cheran, Partai: Stoto Characteridal bay). The Bay of Piran (shellow basis), Chicegai (Adriatic pose), The Bio Portugia (hyperbaling burner)	Net N construit (tour N ye <sup>2</sup> ) 0.7 in phytophrakter mei 8 1 m driftug, cet 120s tequitation apervalents (PCU) ner year, by syster autrus (f.esc) (crearity, 309 and 353, se que 20000 (PC) yok ner of Konkinement nicosta (Peruia Bereza and Cherggiar, 285 by chaos (Ear Fourieta).			Memore of the service/Methods opt practices that sequenter carbon including. Recessition, bridge forces and treated fallow	Cost. \$11.17 to \$22.084 C							
Prr 30/8	Manale and Actific oysers	island lagoon system) 2010 data from 3 meaned and 2 syster factor representing 23% of mussel and 37% of	Cachon seq. rate: 218 kg C $C_0$ per ton of inuiseds hervasted and 441 kg COs system bareceted, from barrented she'll and			Carbon seq. rate: 218 kg C C <sub>0</sub> per ten of inutsels harvested and 441 kg CO <sub>0</sub> overters harvested, from harvested she'll and		and 441 ke COs overers harvested, from harvested shell and		and 441 ke COs overers harvested, from harvested shell and		ord and	al Sector Model used to determine cerbon ion costs under different agricultural subsidy	\$15 76 to 51 30 per 10 <sup>4</sup> short ton/year
in Scotlaria		oyater production in Netiliard	dend on thirming pruding			syment necessary to induce additional	\$6 52 to \$7.39 A of COsper							
Higgins of	Eastern orsters in		Removal rate (lig): 152 total nikogen (TN), 19 total		ion of carbon through lengthened rotations	year								
al 2011	Chraspeake Bay	Oyster Instant and shell	phosphorone (L2), and 3823 total embore (TC) for 10 <sup>o</sup> harvest-areed systems, 378 TN ha <sup>1</sup> , 54 TP ha <sup>-1</sup> , and 10,234 TC ha <sup>-1</sup> for 286 systems m <sup>2</sup>			questering cerbor in forests, assuming that opriate species and timber practices used in	\$5 to \$43.334 C							
Mitri and	multimors philippisonini in 20 ciam fat.		ded CO2 seq. mean rare (and CO in <sup>2</sup> yr <sup>13</sup> ); 3.18 from shells and 5.56 from eachitestion			operate species and innoer prilonoes used in	62 (0 6-0-03A 1.							
Munari 2012	the Lagron of the Portbella River, Indy	monthly for a year, total 401,545 kg (1148,6 g pr. )	Some 55, proteins menn role (nod 33, m <sup>2</sup> yr. ): 32.7 from respitation N removal me (contarms 2,500,000 havested inflemecks), 500 kg cf (			ty cost of conversion of agricultural land to number planting and maintenance-	\$18.43/MT with timber harvest, \$58.1/MT without							
Reitons and Myuphy: n d	Hard clause in coartal MA	24 harvested and 24 wild classe of 1-1.5 inclusion thickness				and without timber harvest revenue r model used to determine cost of converting al land to forests, assuming that the landowner allowates had to timber and versionitoro	\$76.13 to 220,240 (?							
Rice, 206)	Northern quebog@in the Providence River section of Namig much Day	9.1 clause e <sup>42</sup> (abisa 25 <sub>9</sub> 400 MT)	Filtering rate approximately 1.0 $\times$ 105 m $^{2}\delta$ $^{-}$ of water			forestation projects determined through as enlibrated by econometric estimation of hind as a function of socioeconomic and	\$45 - \$1203 of C							
Rilegerd and Scenip 3503	Soil clurus (Mycaresarriz) in Dighavit al Eyra Hoved, Funes, Deamark	Sample colline ed in October 2000 and August 2001, fr-e clanas of 27,8+1.5 ant.	Effecting rate: autocaus and total respected of solids up to 0–13 $m^2 {\rm diam}^2 {\rm d}^2$ for our		1.13	hio lisclors	10201							
				AUTOMOTION CONTRACTOR		forestation projects, assuming that the enoptimally allocates agricultural land to forest	\$8/x (Delta states), \$704 U.S							
			10000	and the second s	1		Average of \$1381 C at							
			Strengers et al. 2008	Giebal	Use of Integrated Model to Assess Global Environment (IMACE) to construct carbon abatement supply curves		buseline values							

Reviews can be accessed at website: <u>http://shellfish.ifas.ufl.edu/</u> <u>environmental-benefits/</u>



- · Examined three environmenttally beneficial ES provided by clam farming
  - Water filtration
  - Carbon (C) storage
  - Nitrogen (N) removal
- Identified key ES knowledge gaps in literature
- Measurements not available for harvest-sized clams at water temperatures found in Florida

Water filtration video, N and C cycle illustrations can be accessed at website: http://shellfish.ifas.ufl.edu/environmental-benefits/



(Inorganic N)

Biodepos (Organic I

NO Nitrification



Legend

Nitrogen in

tissues

## Address ES Info Gaps

- Conducted laboratory measures to address information gaps
  - Clearance (filtering) rates measured as decrease in light absorbance of algal and detrital suspensions using fiber-optic colorimeter
  - C and N amounts determined by measuring contents of clam tissue and shell using stable isotope mass spectrometry
- Other measures determined
  - Nitrogen excretion
  - Oxygen uptake / respiration



References: Baker and Hornbach 1997, 2001, 2008; Dame 1996; Engleman et al. 1985; Hornbach et al. 1991; Verardo et al. 1990

## Address ES Info Gaps

- Clams incorporate N from their food
   (phytoplankton) into tissues and shell
- Clams also store C in shells and tissues, but also process CaCO<sub>3</sub> while they grow



- At harvest, accumulated N and C is removed from the water
- N and C extraction values determined and used in valuation

Clam Grade	Shell Width (inches)	Shell Length (inches)	Water Filtration (gal/day)	N Removed (grams)	C Stored (grams)
Littleneck	1.03	1.88	4.5	0.09	2.76
Button	0.92	1.67	3.5	0.07	1.97
Pasta	0.80	1.49	2.7	0.06	1.37

## Valuation of ES provided by Clams



- ES provided automatically as a result of natural functions
  - "Free goods" that society does not have to pay for
  - Un-priced and at risk of being lost when ecosystems are lost or degraded
- Accepted methods used for estimating monetary value of ES
- Replacement cost method uses market information to obtain a conservative estimate of a feasible alternative
  - Quantity of ES is determined; then cost of providing service with humanmade alternatives is estimated (e.g., wwt plant, planting new trees)

## Valuation of ES provided by Clams

- Calculated costs that would be incurred to replace the industry's services with the next best alternative
- For N removal, values based on costs of wastewater treatment plants in Florida cities
  - Values per pound of N removed, ranged from \$3.44 for Clearwater to \$5.22 for Fort Myers
  - Based on land values and cost of living, factors that affect the cost of treatment plants



## Valuation of ES provided by Clams

- For C storage, creation and maintenance of pine tree plantations used as a possible alternative to clam production
- Costs included pine production, as well as land value in an alternative use
- In counties with high urban, agricultural, or commercial land values, opportunity cost high
  - Highest values (\$119.01 per ton) for Collier County
  - Lowest values (\$0.71 per ton) in rural Franklin County





#### **SEAWATER FILTERING**

544 million gallons of seawater were filtered per day by the statewide production of 136 million clams\*.

# FERTILIZER

#### NITROGEN REMOVAL

25.4 thousand pounds of nitrogen were removed from the coastal waters.

### **CARBON STORAGE**

760.6 thousand pounds of carbon were sequestered from the coastal environment.

# (\$)

### ECONOMIC VALUE

Value of these benefits was estimated at \$99,680, which represents the public good value provided to Florida citizens at no cost.

## Disseminate Research Results

- Florida hard clam aquaculture provides economic values for ecosystem services generated by the industry
- These values based on production results from 2012 FL Aquaculture Survey
- Infographics poster developed by UF IFAS Dept. Agricultural Education and Communication



Home in Environmental Senetrice

#### **Environmental Benefits**

"Green" Clams: Estimating the Value of Environmental Benefits (Ecosystem Services) Generated by the Hard Clam Aquaculture Industry in Florida

Introduction | Water Flitration | Nitrogen Removal | Carbon Storage | Value of Benefits | More Info

Shellfish (oysters, clams, mussels, etc.) provide a favorable environment for the coastal and estuarine waters in which they are grown. In turn, shellfish farming can provide local communities with a variety of ecceystern services, whose value can be quantified. The results of a University of Florida (UF) study conducted in 2015 demonstrate the unique sustainability of Florida hard clam aquacuture. Three environmentally-beneficial ecceystern services (water filtration, nitrogen removal and carbon storage) provided by clam farming were examined. Efforts focused on assembling values for ecceystern services specific to clam culture. Measurements, particularly for harves-lsized clams at water temperatures found in Florida, are not available through the literature. To address these information gaps, pertinent laboratory measures were determined. Read further for a description of these ecceystern services, their value estimates, and how they relate to Florida's "green" clam culture industry.

#### WHAT ARE ECOSYSTEM SERVICES?

The transformation of a set of natural resources supplied by ecosystems into beneficial goods and functions that humans value. An ecosystem is a complex system of plant, animal, fungal, and microorganism communities and their associated non-living environment interacting as an ecological unit. Disseminate Research Results

 All project results posted to new topic page on website,
 Online Resource
 Guide for Florida
 Shellfish
 Aquaculture

Go to http://shellfish.ifas.ufl.edu/environmental-benefits

## Disseminate Research Results

- Clam Farm Benefits

   Calculator allows growers to
   inform buyers, consumers,
   and resource managers that
   shellfish aquaculture is a
   sustainable "green" industry
- With inputs of farm location and # clams harvested per year by grade size, the *Calculator* provides an estimate of the economic value of ES a grower's crop provides on an annual basis

## Florida Clam Farm Environmental Benefits Calculator

Inter	county	where	your	clam	farm	is	located:	

#### Understanding this tool:

Enter your annual clam farm production:

625,000	Number of littleneck (1" or greater) clams harvested
218,000	Number of buttons (7/8") clams harvested
5,000	Pounds of pasta (5/8") clams harvested (calculator will convert to numbers)

Calculate

Brevard

The Clam Farm Benefit Calculator allows Florida growers to make a simple estimation of the environmental benefits their farms provide to the coastal waters in which their clams are grown. These benefits include nitrogen removal and carbon sequestration (storage). With inputs of farm location and the number of clams harvested per year by grade size, this tool will provide an estimate of the economic value of the benefits that a clam grower's crop provides on an annual basis.

The Clam Farm Benefit Calculator is intended to be simple and accessible. As such, this tool should be considered as a starting point for understanding the value of molluscan shellfish in the environment, rather than a scientific accounting of precise values.



While some environmental benefits of clams can be easily documented, such as nutrient (for example, nitrogen) extraction associated with removing the product at harvest; others, such as denitrification, are not. The benefits in this calculator are based only on the clams harvested in a year, not on the entire standing crop of the farm (for example, seed, juveniles). This makes precise calculations of the economic value of these benefits difficult. The results presented here should be considered approximations of the benefits produced by clams. These benefits do not account for sales value of the clams harvested or costs (seed, gear, labor) associated with arowing them.





**Florida Clams** Produced Naturally in Florida, USA





ndar of Event



About our Industry ing powies keathy food daan down de wild seath of costs down de seath of the costs i vasa in with our costs ar grean About now.

About our Farms & Farmers Clam familie supports analiguativeses in 11 Paras social counties. You can find out more about our clam graving areas and meet some of our clam families new.

e one estand Ist in strin of our dam growing areas and of our dam fameto nex.



About our clams in igny the conversity production of clams in igny equited Learn southe recional and state registric place so ensure public health and table and early recipe using our days and to prevent the environment.



**Clam Farming O** By the Numbers

Disseminate Research Results

- Florida Clams website designed and produced to showcase the industry
- Working platform to promote cultured clams as environmentally friendly and benign

Go to http://www.flaclams.com

## ACKNOWLEDGEMENTS

- University of Florida graduate students
  - Angelo (Jason) Spadora, SFRC Fisheries & Aquatic Sciences
  - Jorge Avila, Food and Resource Economics
- Motionbuzz Multimedia developed Environmental Benefits
   webpages
- Dacing Tree, Inc. developed web-based *Clam Farm Calculator* which was inspired by the National Tree Benefit Calculator
- Ada Lang developed the *Florida Clams* website
- Nitrogen and carbon cycles illustrated by Anna Hinkelday
- Clam filtration video created by UF IFAS Communications
- Funding
  - FDACS 2014-15 Florida Aquaculture Project, Contract # 00094300







