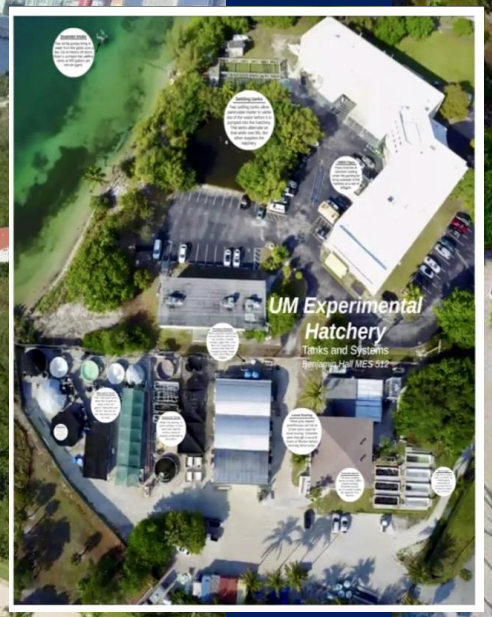
Sustainable Offshore Aquaculture: Environmental Considerations

Daniel Benetti, PhD, and Aaron Welch, J.D., PhD.
University of Miami - RSMAS
Marine Aquaculture Program

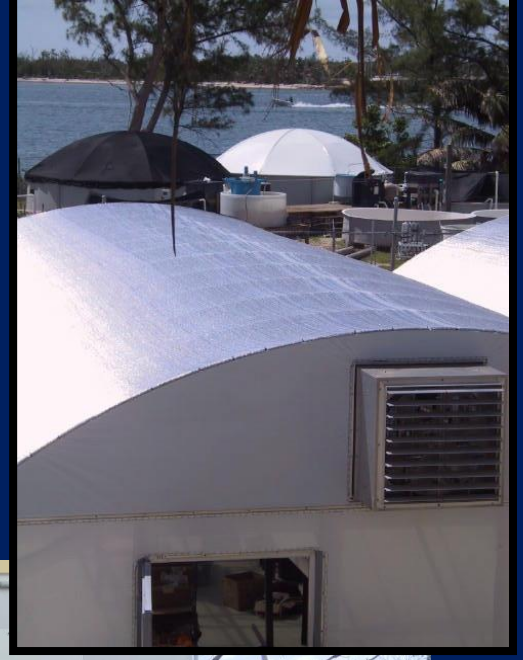
UNIVERSITY OF MIAMI EXPERIMENTAL HATCHERY
An Incubator of Technology



U AQUACULTURE

GLOBALG.A.P.

HATCHERY FACILITIES
OUR BEST ASSET IS OUR PEOPLE



GLOBALG.A.P.

Sea Grant
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

LARVAL REARING TECHNOLOGIES PRODUCING HIGH QUALITY OFFSPRING OF A NUMBER OF HIGH-VALUE MARINE FISH SPECIES

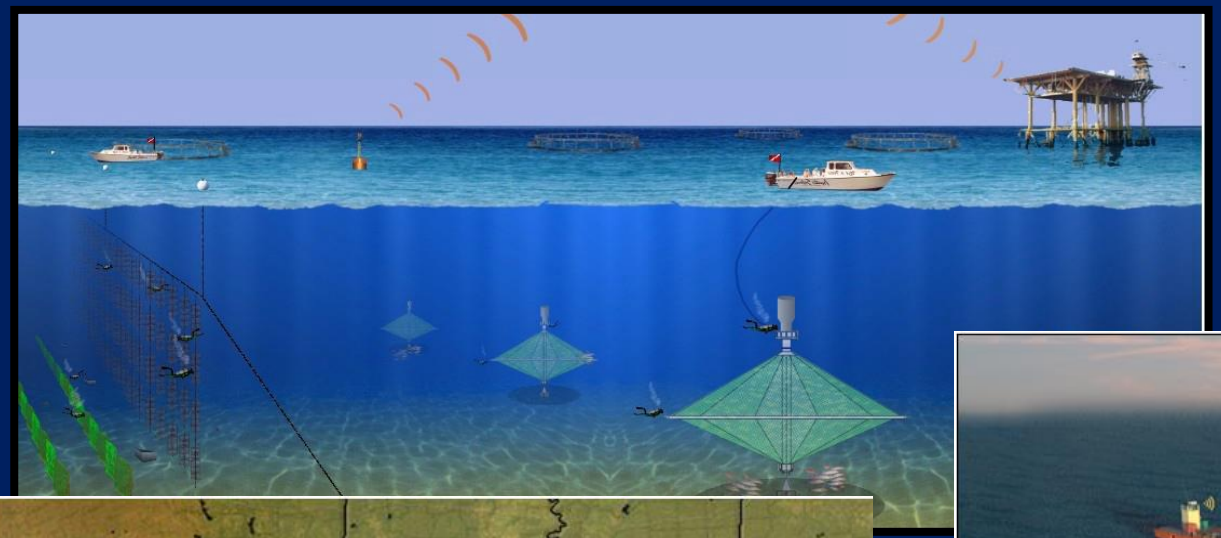
PROACTIVE HEALTH MANAGEMENT STRATEGY USING PROPHYLAXIS, ADEQUATE NUTRITION, PROBIOTICS, PROTEASES, ADDITIVES, ORGANIC ACIDS, ESSENTIAL OILS, BACTERIOPHAGES, ETC

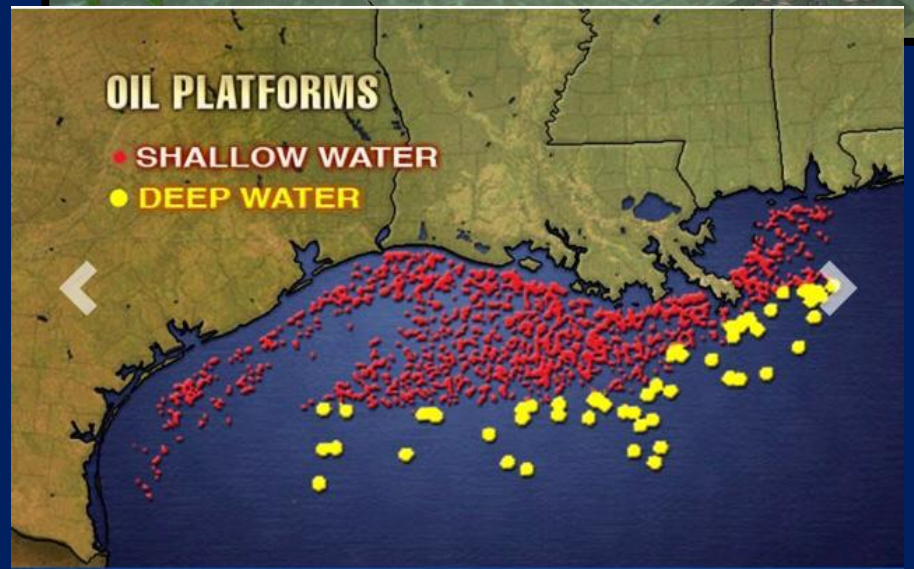
CANDIDATE SPECIES FOR OFFSHORE AQUACULTURE DEVELOPMENT IN THE GULF OF MEXICO AT DIFFERENT LEVELS OF FEASIBILITY

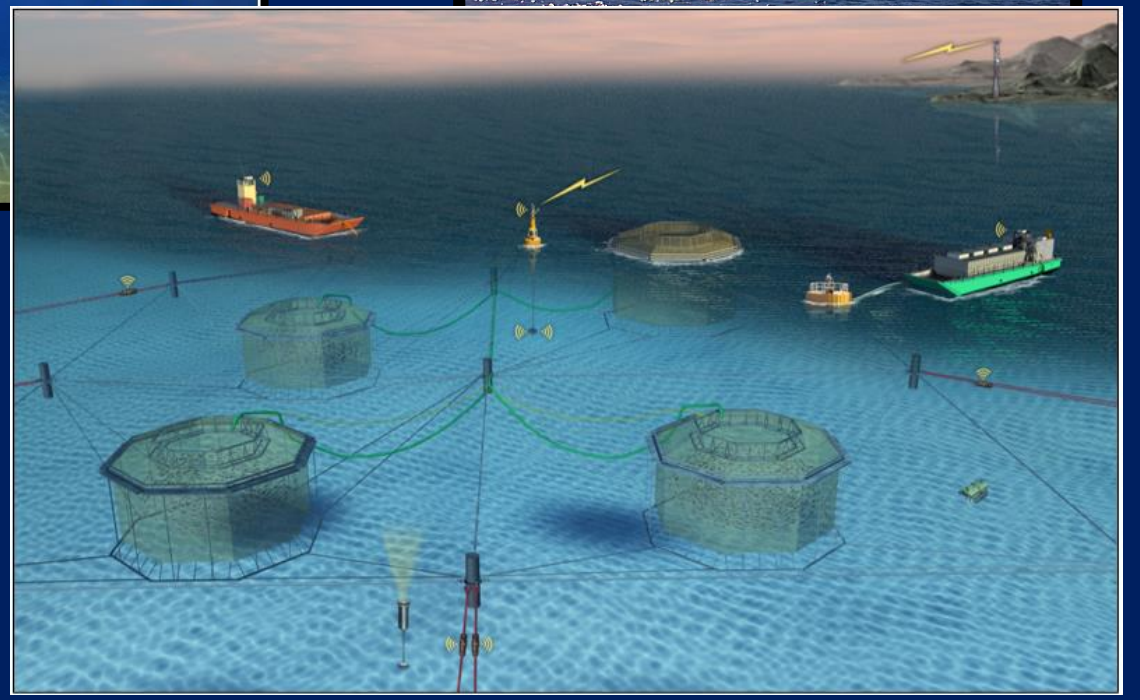
AQUACULTURE

CURRENT STATUS

- Technology still limits move towards fully automated, farms offshore
- Challenges/limitations: Permits, distance/depth, circulation/currents
- Oil/gas platforms hold promise but legislation/cost/liability still prohibitive







The environmental argument against offshore aquaculture:

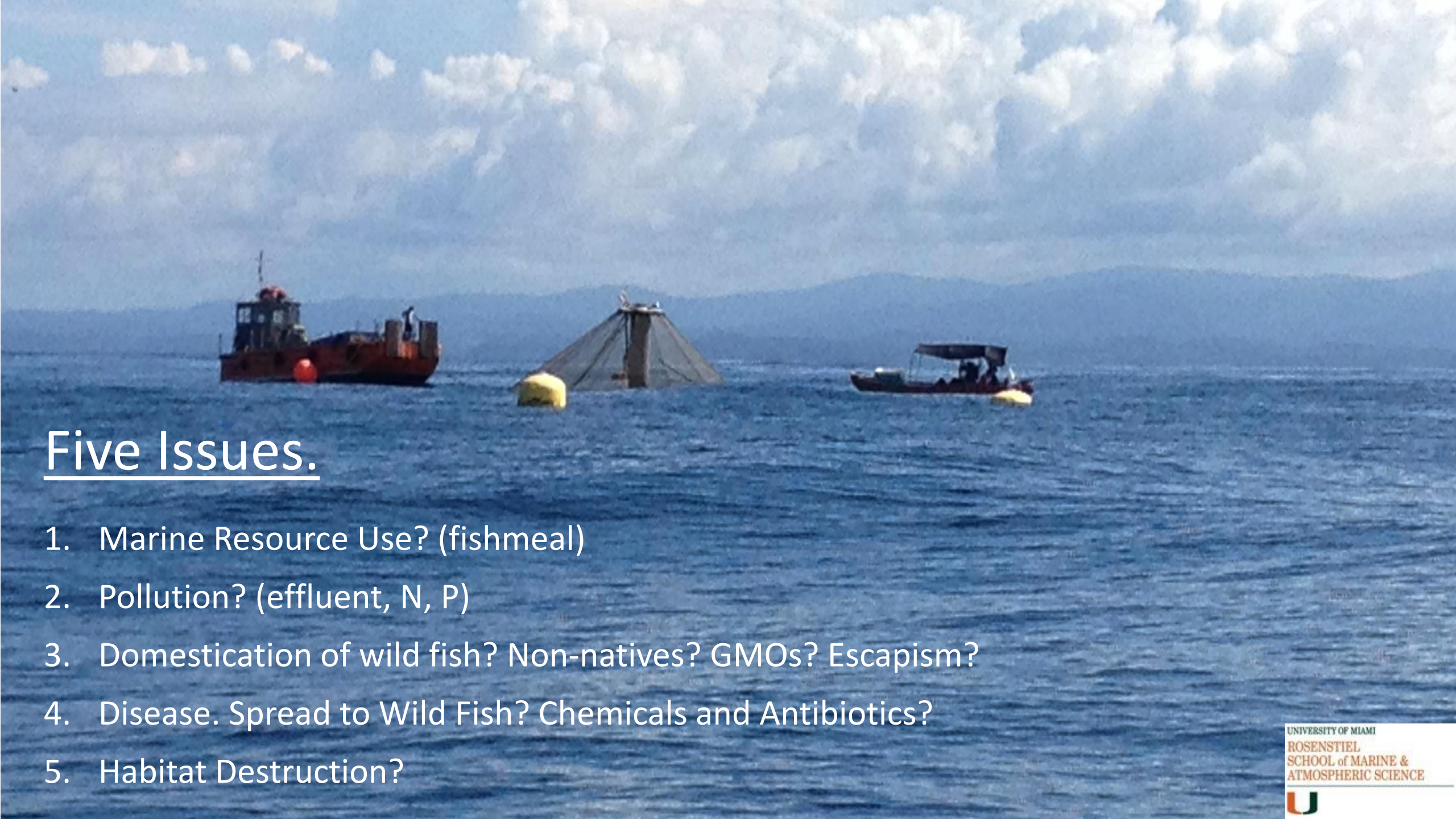
- Industrial aquaculture in open waters, such as the ones proposed, are associated with many serious environmental and health concerns, including: the ***escape of farmed fish*** into the wild; ***outcompeting wild fish for habitat***; food and mates or intermixing with wild fish and altering their genetics and behaviors; ***the spread of diseases and parasites from farmed fish to wild fish*** and other marine life; and ***pollution from excess feed, wastes and any antibiotics or other chemicals*** used flowing through the open pens into natural waters.

The Center for Food Safety: September 25, 2018.

The environmental argument against offshore aquaculture:

- Contrary to claims that farmed fish production will alleviate pressure on wild fish stocks, industrial aquaculture has actually exacerbated the population declines of wild fish. This will be especially true in offshore aquaculture facilities that farm carnivorous fish, which require a diet often derived from wild-caught fish such as menhaden, mackerel, herring, and anchovies. ***The industry's ever-growing demand for fish in feed jeopardizes the survival of wild fish and disrupts the balance of the marine ecosystem.***

The Center for Food Safety: September 25, 2018.



Five Issues.

1. Marine Resource Use? (fishmeal)
2. Pollution? (effluent, N, P)
3. Domestication of wild fish? Non-natives? GMOs? Escapism?
4. Disease. Spread to Wild Fish? Chemicals and Antibiotics?
5. Habitat Destruction?

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

The Problem with Nutrients.

- Nutrient pollution a considerable concern surrounding aquaculture development in the U.S.
- Has been a large problem at aquaculture installations around the world (e.g. Islam 2005).
- Politics: Numerous groups have objected to the development of aquaculture citing effluent concerns.
- Legal implications: CWA NPDES Permits, CAFO regulations, Ocean Discharge Criteria, etc...

Our Work

- Environmental monitoring at the world's first commercially scaled offshore aquaculture facility.
- 16 to 21 cages. 6,400 m^3 per cage.
- Located in the Costa Arriba Region of Panama, on the Caribbean/Atlantic coast.
- 8 miles offshore. ~ 60 m depth. Strong alongshore currents (~ 0.3 to 0.5 m s^{-1}). Relatively oligotrophic.
- Culturing Cobia (*Rachycentron canadum*)

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Monitored Parameters

PELAGIC ENVIRONMENT

- NO_3+NO_2, NH_4, TDN, PN,
- PC.
- Chl-a
- CTD Profiles
  - D.O.
  - Temp
  - Salinity
- C6 Profiles
  - Chl-a.
  - Turbidity
  - Rhodamine
  - CDOM

BENTHOS

- PN
- PC
- Chl-a
- TOC

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Received: 25 July 2018 | Revised and accepted: 10 January 2019

DOI: 10.1111/jwas.12593

WILEY

Journal of the World Aquaculture Society

APPLIED STUDIES

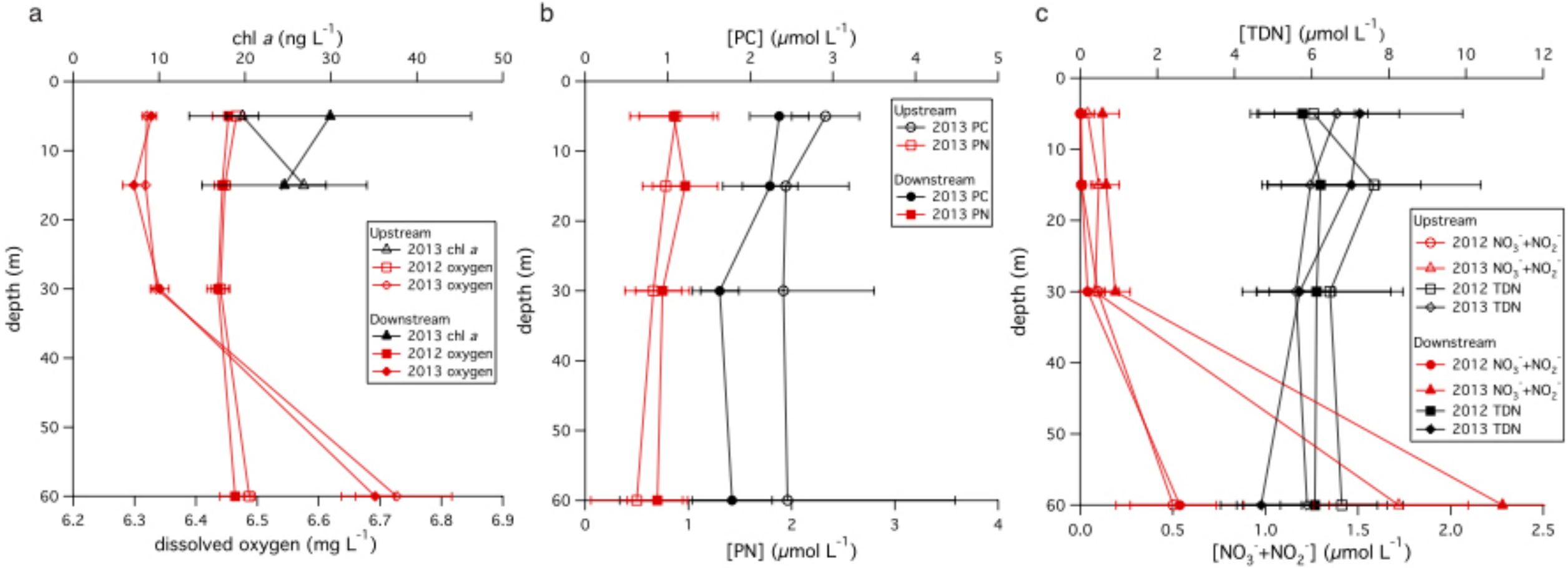
The nutrient footprint of a submerged-cage offshore aquaculture facility located in the tropical Caribbean

Aaron W. Welch[1,2] | Angela N. Knapp[3] | Sharein El Tourky[1] | Zachary Daughtery[1] | Gary Hitchcock[1,2] | Daniel Benetti[1]

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

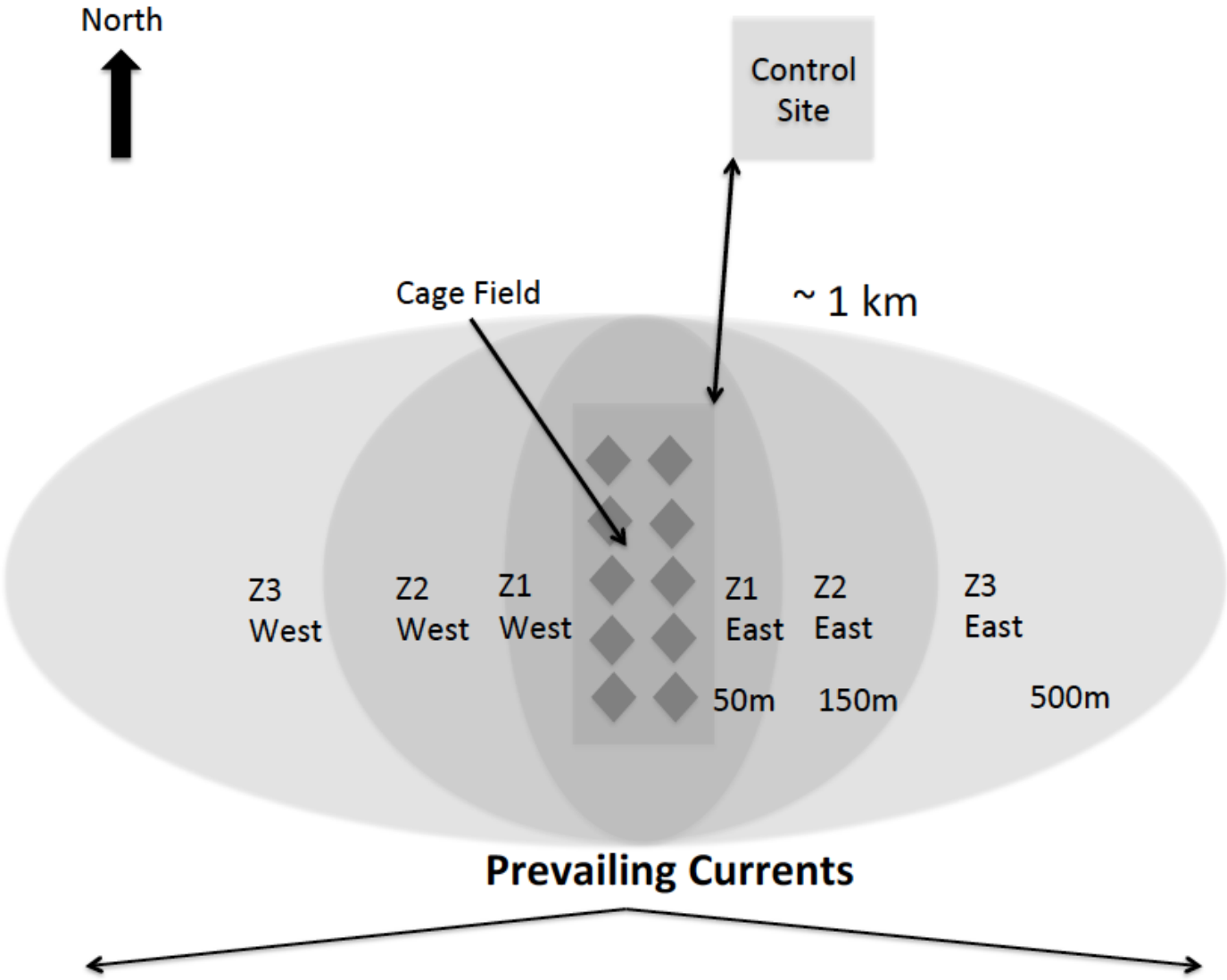
UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Water Column Measurements (2012-2013)

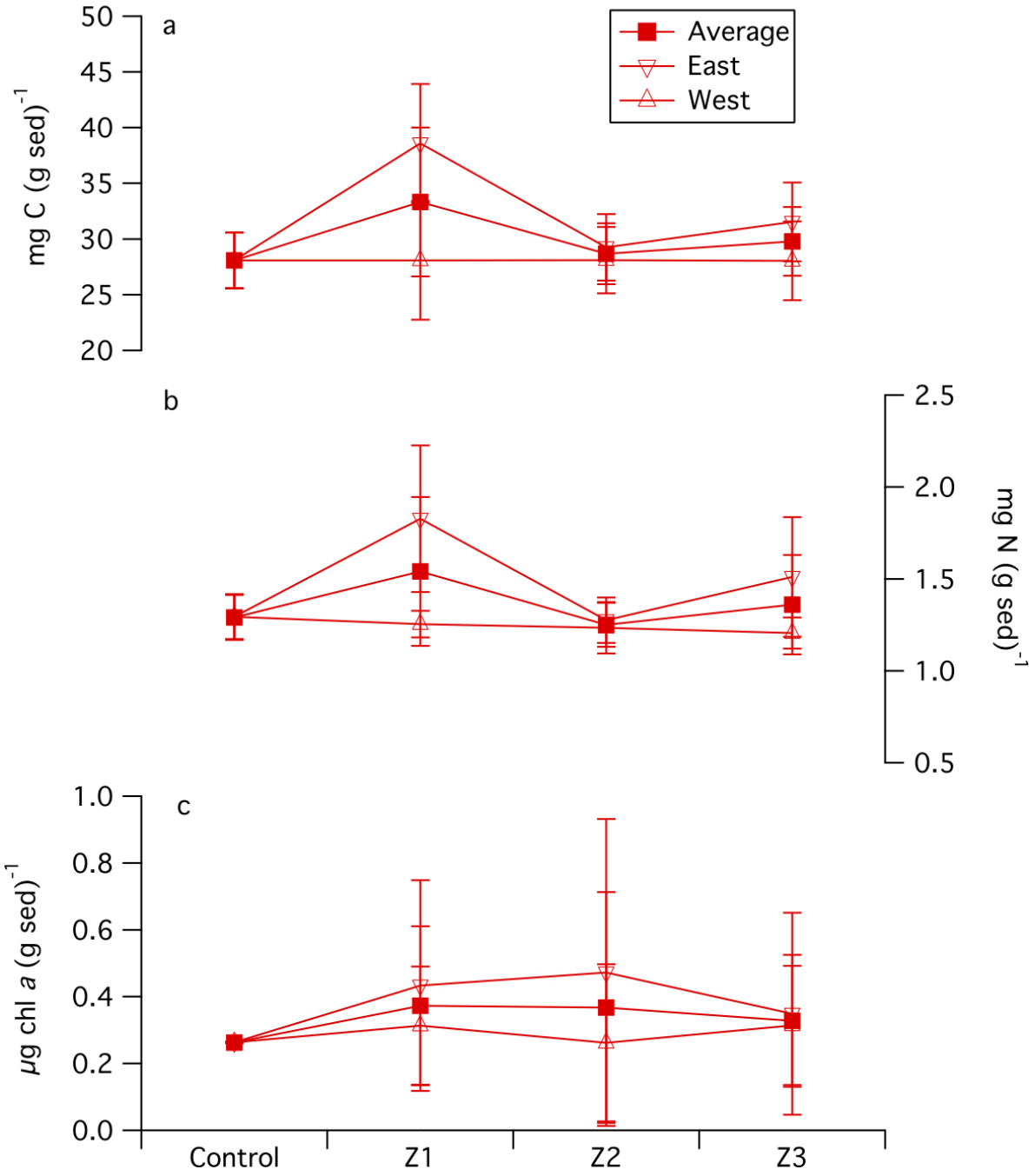


UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Phase 1 Sampling Scheme (2012-2013)

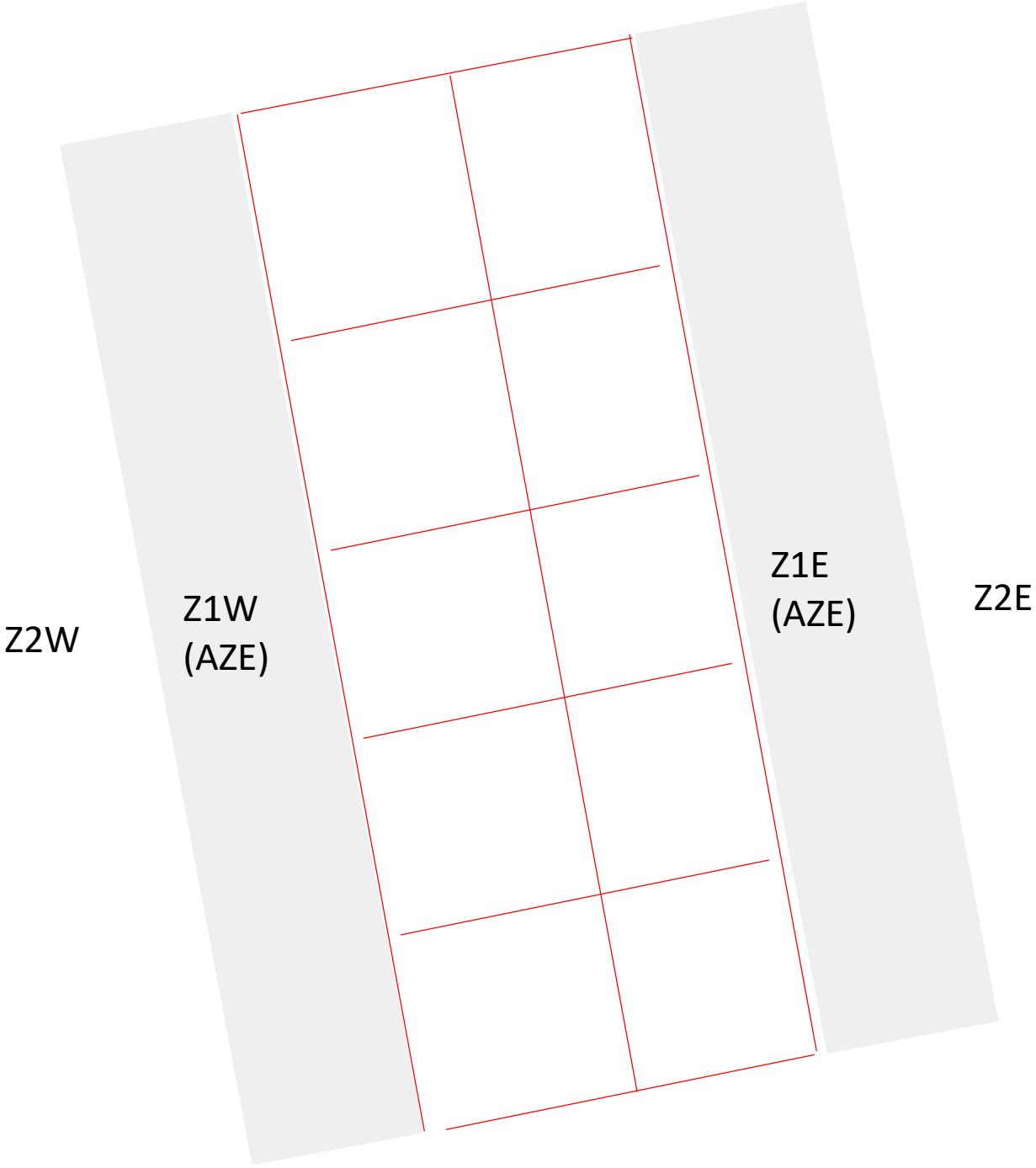


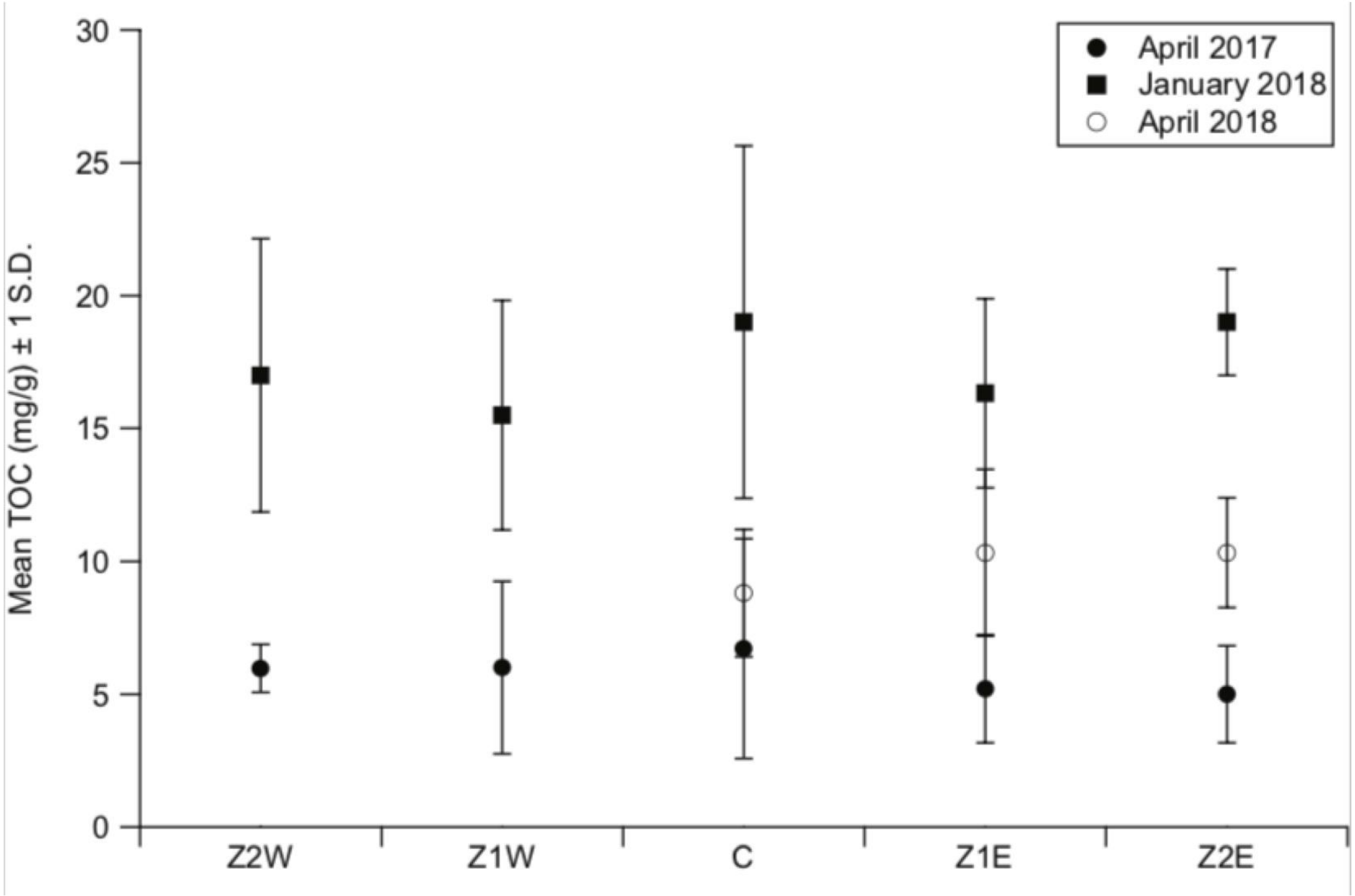
Sediment Measurements 2012-2013



UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

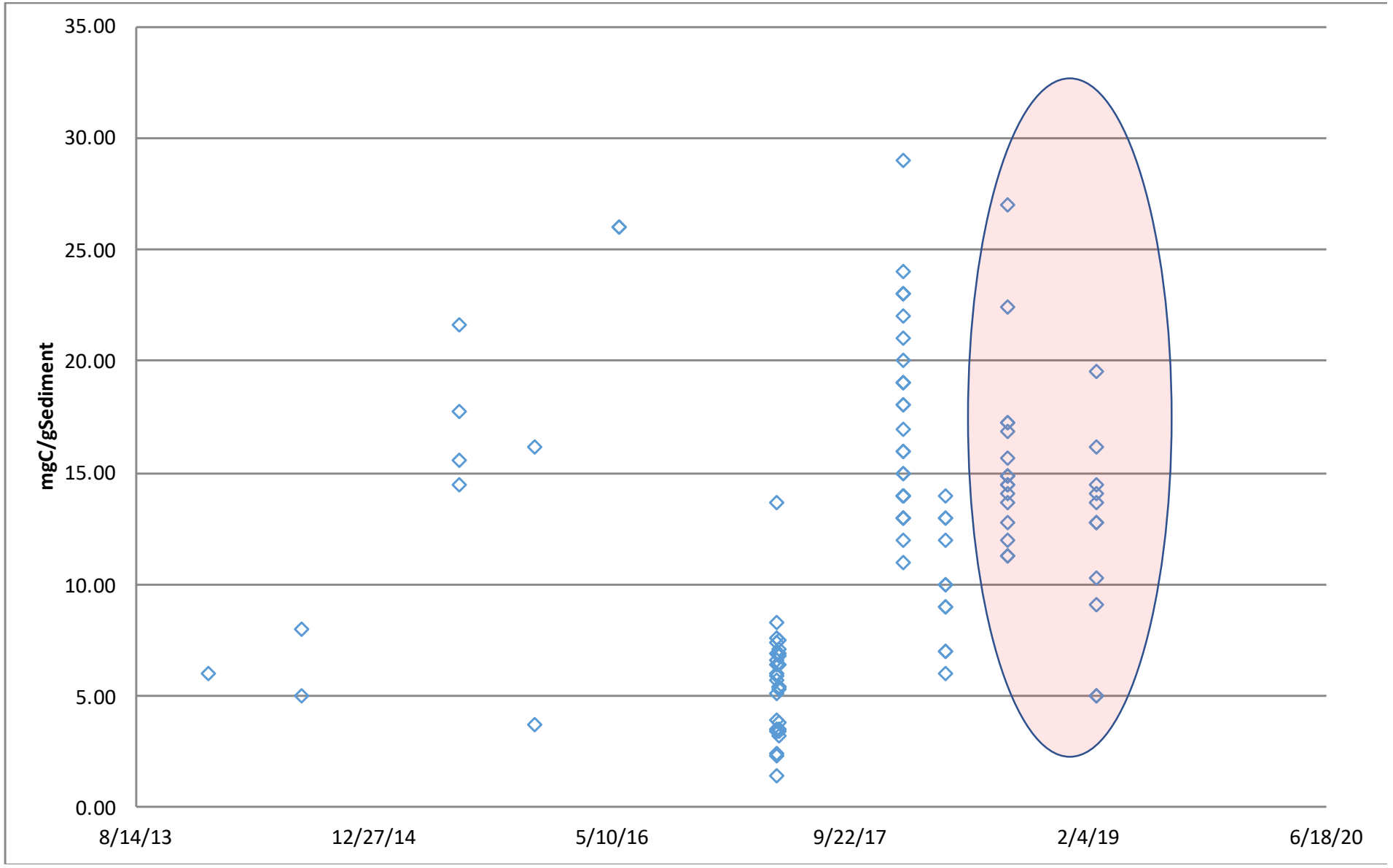
Current Sediment Sampling Scheme





UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

The Current Situation



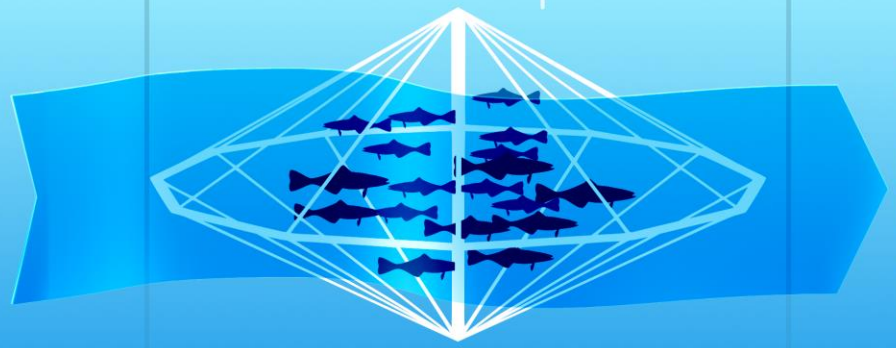
UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

MINIMAL NUTRIENT FOOTPRINT OF A COMMERCIAL OFFSHORE AQUACULTURE FACILITY

22 cages
1,360,000 kg/year
Cobia

WATER COLUMN SAMPLING

Chl-a
NO_3 NO_2
Nitrogen
Carbon
Oxygen



SIMILAR NUTRIENT LEVELS BEFORE AND AFTER THE FACILITY

UPSTREAM

DOWNSTREAM

BENTHIC SAMPLING

SMALL INCREASE IN C AND N

Research conducted with funding support from NOAA to the University of Miami Aquaculture Program

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

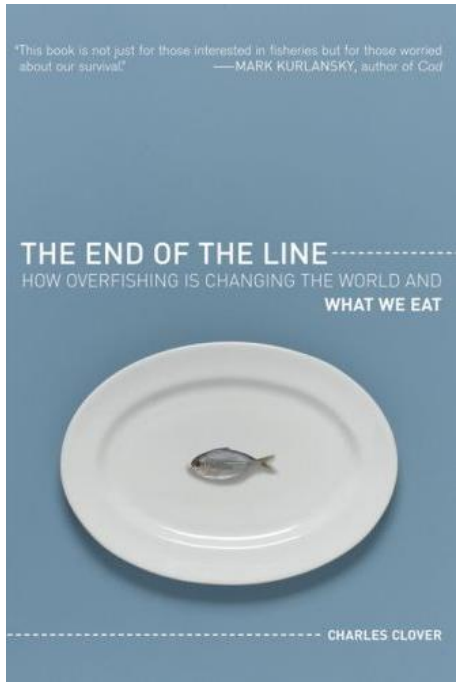
Designed by Scite®
Science Communication

The FISH IN-FISH OUT Objection

Marine aquaculture relies on large amounts of fishmeal and fish oil processed from wild caught “reduction” fish to produce small amounts of farmed fish. ***As the industry grows, demand for fishmeal and fish oil will eventually outstrip the productive capacity of reduction fisheries and the entire enterprise must fail.***

“***Aquaculture is not the answer. It takes 5 pounds of wild fish to make 1 pound of farmed salmon***.” Ted Danson. Former ‘Cheers’ star and founder of the conservation group Oceana.

“***We are robbing Peter to pay Paul***.” Daniel Pauly. Fisheries biologist and founder of the The Sea Around Us Project

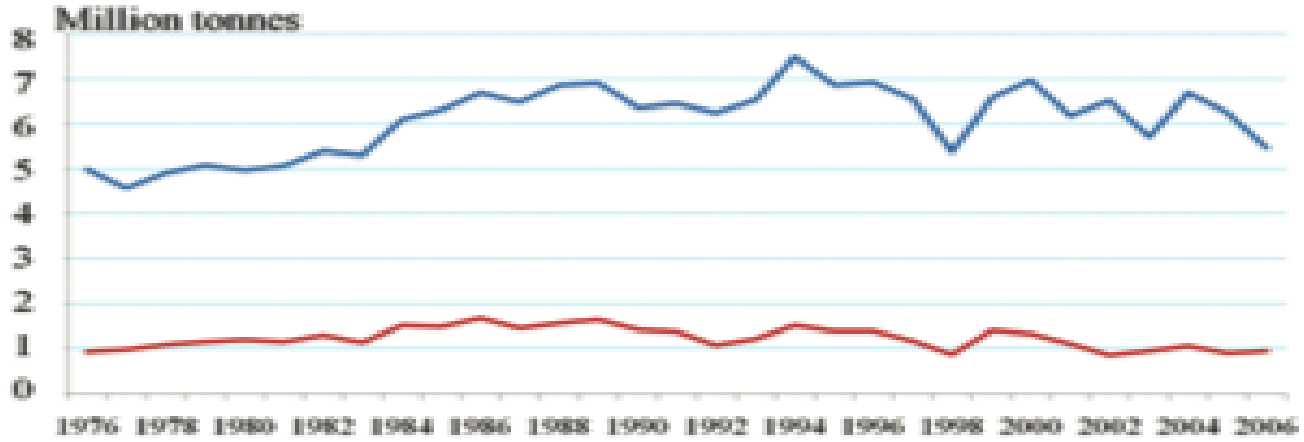


UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Fishmeal and Fish Oil…
Are we “Robbing Peter to Pay Paul?”

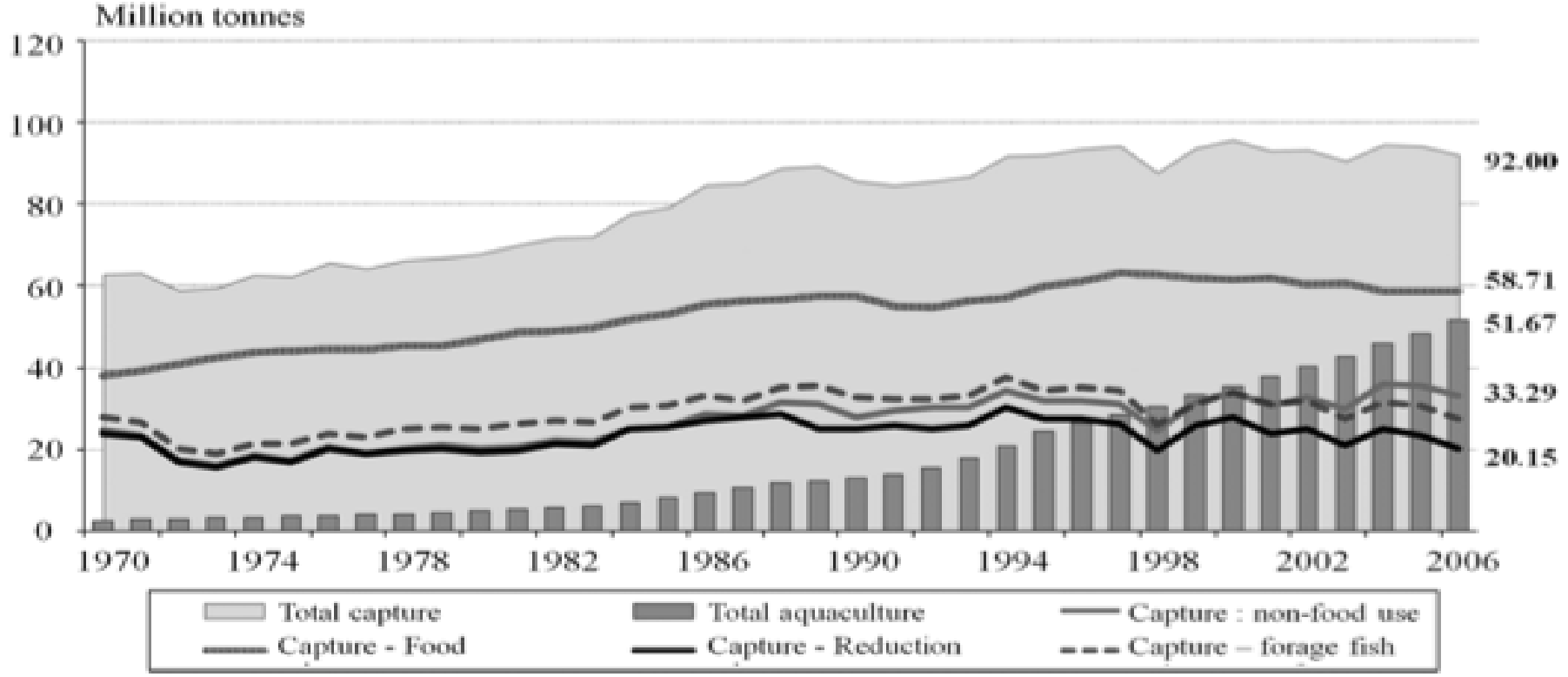
UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Total Global Fishmeal and Fish Oil Consumption: 1975 to Present



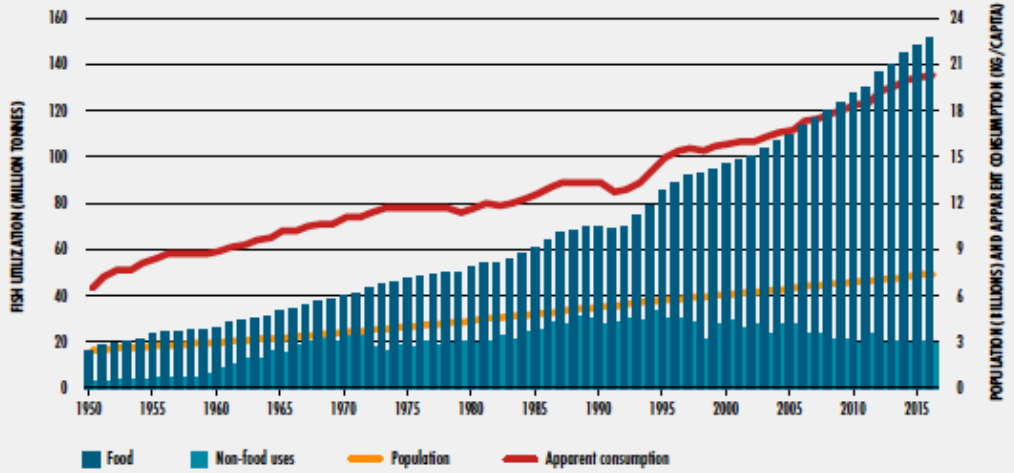
Source: Tacon and Metian 2009

NON–FOOD USE OF SMALL PELAGIC FORAGE FISH



Non Food Use of Fish Since 2006

FIGURE 2
WORLD FISH UTILIZATION AND APPARENT CONSUMPTION

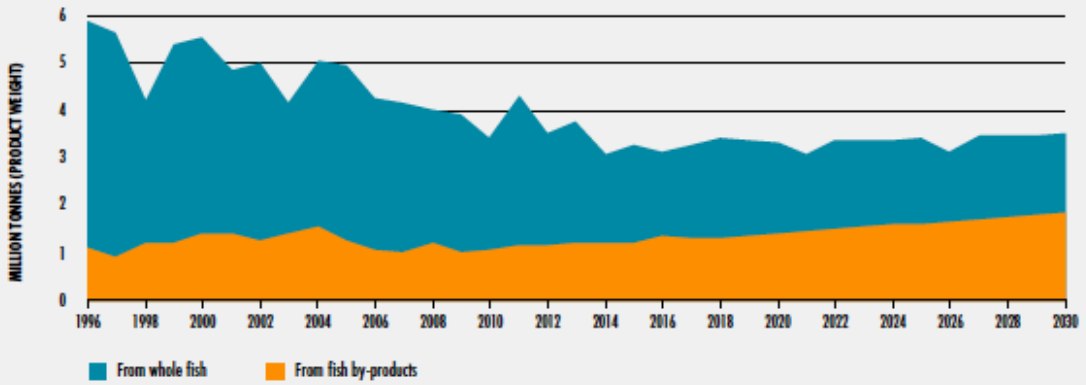


NOTE: Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants

131

Global Fishmeal Production Since 2006

FIGURE 51
WORLD FISHMEAL PRODUCTION, 1996–2030

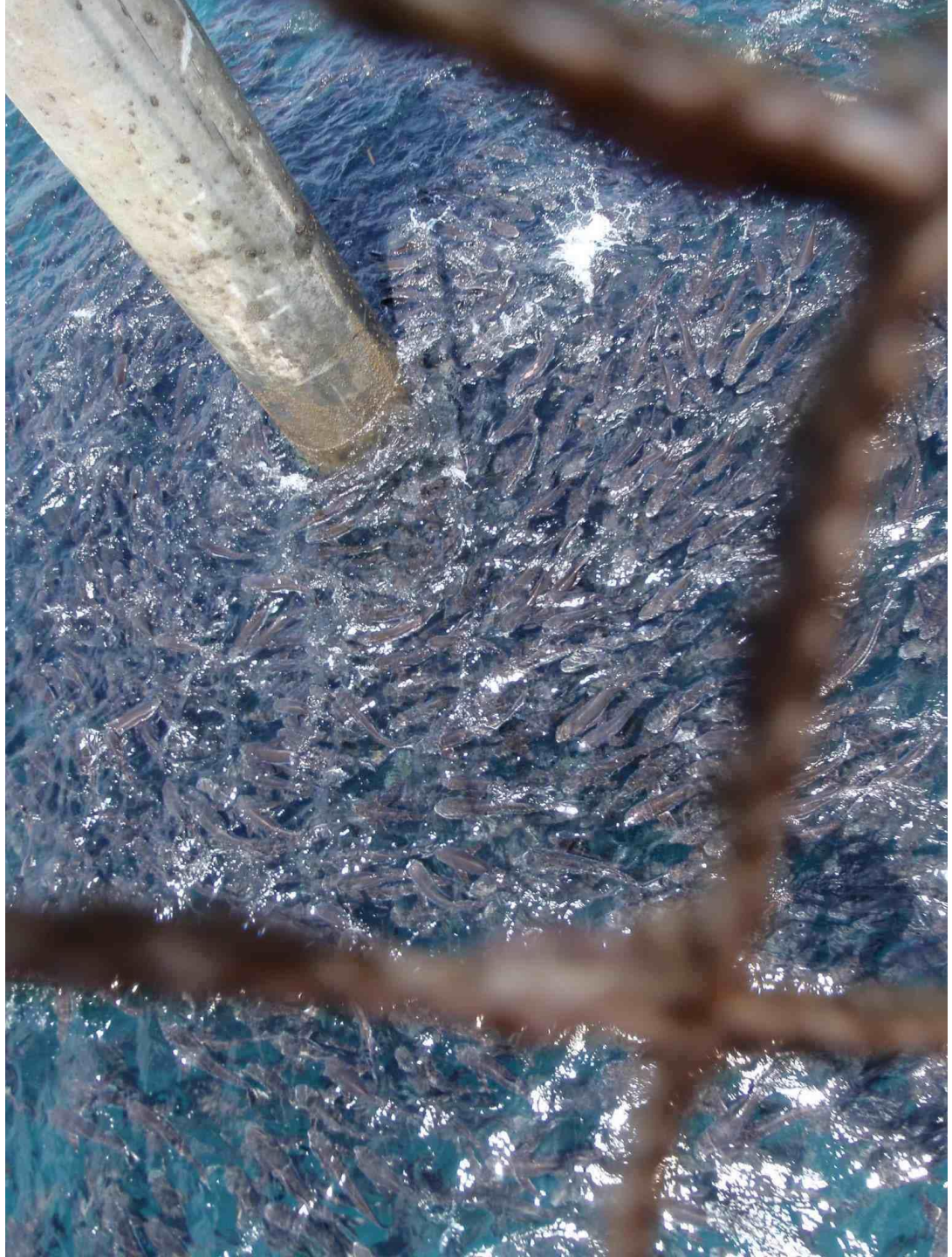


UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

How is this Possible?

1. **<u>Markets:</u>**

The global fishmeal industry did not expand due to aquaculture. Instead, fish farmers priced other fishmeal users out of the market.



UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

The Changing Global Fishmeal Market

Table 1 Reported global usage of fish meal and fish oil by major user (values given in %)

Year	Use	Aquaculture	Poultry feed	Pig feed	Other feeds	References
1988	Fishmeal	10	60	20	10[1]	New and Csavas (1995)
1990	Fishmeal	14	58	20	8[2]	Pike (1991)
1994	Fishmeal	17	55	20	8[3]	Pike (1998)
1995	Fishmeal	15	50	25	10[4]	Kilpatrick (2003)
2000	Fishmeal	35	24	29	12[5]	Barlow and Pike (2001)
2001	Fishmeal	40	39	14	7[6]	Kilpatrick (2003)
2002	Fishmeal	46	22	24	8[7]	Pike (2005)
2006	Fishmeal	57	13	21	6	Jackson (2007a)
Year	Use	Aquaculture	Edible[8]	Indust/Pharm[9]	Animal feed	
1994	Fish oil	24.7[10]	68.5	6.8	—	Pike (1998)
1995	Fish oil	18	70	7[11]	5	Kilpatrick (2003)
2000	Fish oil	54	34	26[12]	—	Barlow and Pike (2001)
2001	Fish oil	70	19	8[13]	3	Kilpatrick (2003)
2002	Fish oil	81	14	5	—	Pike (2005)
2006	Fish oil	87[14]	—	—	—	Jackson (2007a)

Source: Tacon and Metian 2009

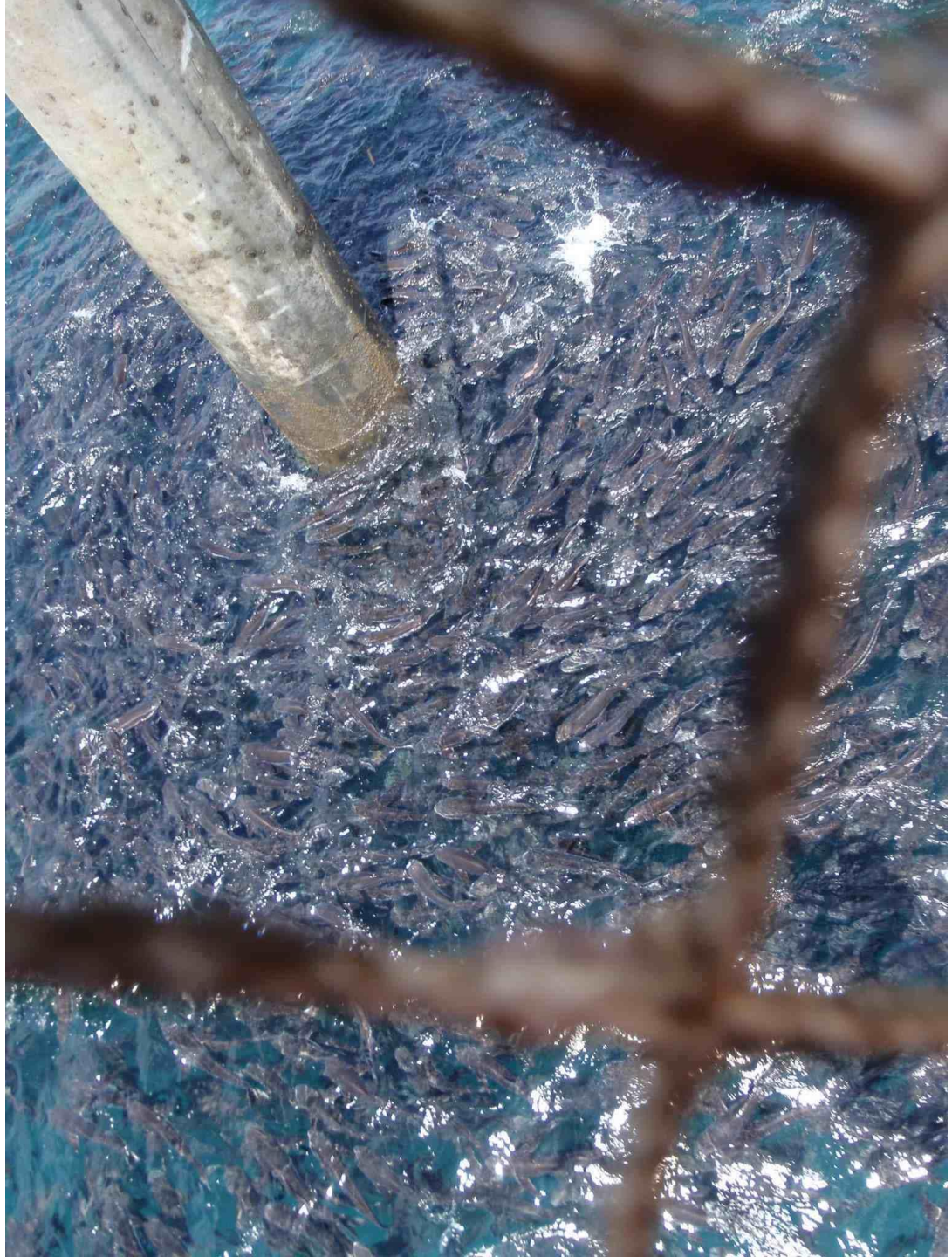
How is this Possible?

1. Markets:

The global fishmeal industry did no expand due to aquaculture. Instead, fish farmers priced other fishmeal users out of the market.

2. Technology:

Fish farmers began to find substitutes for fishmeal. Fish, even carnivorous marine finfish, do not need fishmeal per se. The need the omega-3 fattch acids and other nutrients found in fishmeal.



UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Changing Feed Technologies

Table 1. Feed use and efficiencies (1995 and 2007)

Species group	Percentage on feeds*	Average FCR†	Average % fishmeal in feed‡	Average % fish oil in feed‡	Total feeds used§
Shrimp					
1995	75	2.0	28	2	1,392
2007	93	1.7	18	2	5,603
Salmon					
1995	100	1.5	45	25	806
2007	100	1.3	24	16	1,923
Marine fish					
1995	50	2.0	50	15	498
2007	72	1.9	30	7	2,311
Chinese carp (nonfilter feeding)					
1995	20	2.0	10	0	1,970
2007	47	1.7	5	0	8,578
Tilapia					
1995	70	2.0	14	1	
2007	82	1.7	5	0	

Naylor et al. 2009

Long term trend towards reduced fishmeal….made possible by increased use of novel ingredients (e.g. algal meal).

Salze et al. 2009

Table 2

Dietary composition of the experimental diets utilized in feeding trial 2. The + sign indicates MOS supplementation; SB = soybean-based diet; MXSB = soybean-based diet in which the incorporation of soybean meal has been maximized; NOFM = fish meal-free and fish oil-free diet. Values are in g/100 g of dry diet.

Ingredients	Control	SB	SB+	MXSB	MXSB	NOFM
Herring meal[a]	25.3	12.6	12.6	8.5	8.5	0.0
SPC[b]	12.6	25.3	25.3	23.8	23.8	25.3
Soybean meal[c]	32.4	32.4	32.4	39.9	39.9	0.0
Worm meal[d]	0.0	0.0	0.0	0.0	0.0	30.0
Dextrin[e]	10.0	10.0	10.0	8.6	8.3	9.5
Soy oil	0.0	0.0	0.0	0.0	0.0	7.3
Fish oil[f]	8.7	10.0	10.0	10.2	10.2	0.0
DHA Gold[g]	0.0	0.0	0.0	0.0	0.0	1.5
Mineral mix[h]	4.0	4.0	4.0	4.0	4.0	4.0
Vitamin mix[i]	3.0	3.0	3.0	3.0	3.0	3.0
CMC[e]	1.0	1.0	1.0	1.0	1.0	1.0
Amino acid mix[j]	0.0	0.0	0.0	1.0	1.0	0.0
BioMos[®][k]	0.0	0.0	0.3	0.0	0.3	0.3
NuPro[®][k]	0.0	0.0	0.0	0.0	0.0	17.5
Celufil[e]	3.0	1.7	1.4	0.0	0.0	0.6
Crude protein[l]	43.3	43.8	44.2	43.5	43.9	43.2
Crude lipid[l]	10.5	10.9	10.2	10.8	11.0	10.6
Available energy (kJ/g diet)[m]	12.9	13.1	12.9	12.8	12.9	12.8

So What?

- Pollution and Fishmeal/Fish oil use are ***two of the most contentious issues*** surrounding offshore aquaculture.

- Skepticism among environmental community is considerable, and, frankly, not unreasonable.

- Progress on regulatory initiatives (e.g. ***Gulf Council FMP***, Rose Canyon Proposal, AQUAA Act, etc...) will require industry to be able to speak authoritatively about the impacts of the proposed enterprises.

- Data is the path to achieving consensus within the stakeholder community.

Thanks to the

- NOAA S/K
- FL Sea Grant
- Open Blue

Thanks to you for your time.

Questions?

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

openblue

NOAA