Offshore Aquaculture

In The Southern California Bight

Rationale, Current Status, Challenges and Opportunities


Aquarium of the Pacific
April 28, 2015; Long Beach, California

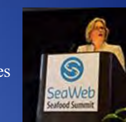
SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego

Paul G. Olin,
Aquaculture Specialist

Sea Grant California

CA Public Resources Code § 826-828 – Aquaculture Development Act
The Legislature finds:
- ✓ It is in the interest of the people of the state that the practice of aquaculture be encouraged
- ✓ To augment food supplies, expand employment, promote economic activity
- ✓ Protect and better use the land and water resources of the state.

Kathryn Sullivan NOAA Administrator February 2015
- ✓ It's very clear that U.S. aquaculture is a job creator in coastal communities
- ✓ Aquaculture is a bright spot and one that we need to continue to nurture

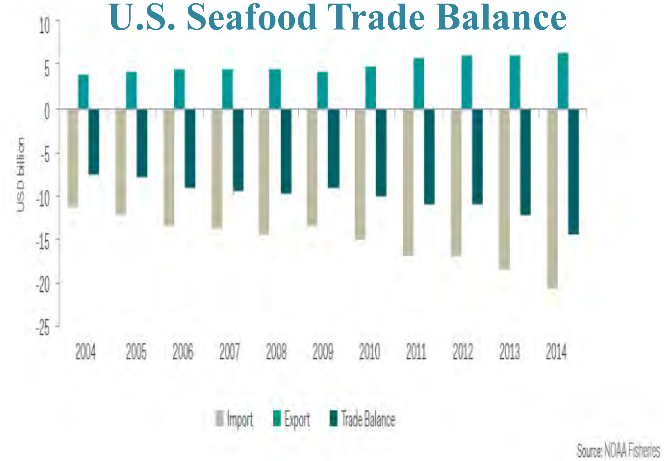


Scientific Report of the 2015 Dietary Guidelines Advisory Committee
- ✓ Seafood consumption be increased to 8 ounces/week based on health benefits including decreased cardiovascular disease risk and improved infant neurodevelopment
- ✓ "farm-raised finfish is more sustainable than terrestrial animal production in terms of GHG (Greenhouse Gas) emissions and land/water use."

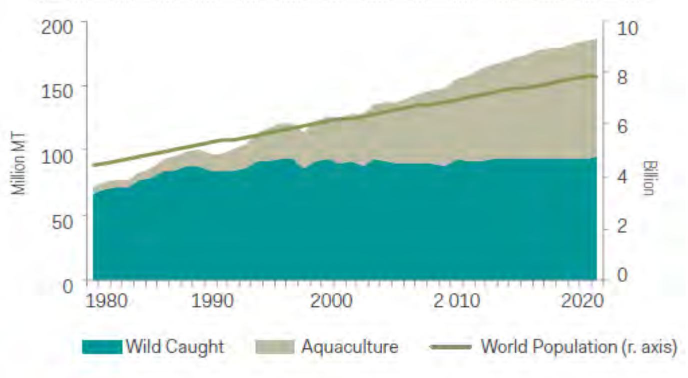
Why Aquaculture ?

- ➢World capture fisheries at plateau for decades
- ➢Global seafood needs up 27 mmt by 2030 (FAO)
- ➢U.S. imports > 90%, > $10 billion Trade deficit
- ➢Doubling U.S. Aquaculture could result in 50,000 jobs and over $1 billion farm-gate value (G. Knapp, Offshore Aquaculture in the United States. NOAA Technical Memorandum, NMFS F/SPO-103

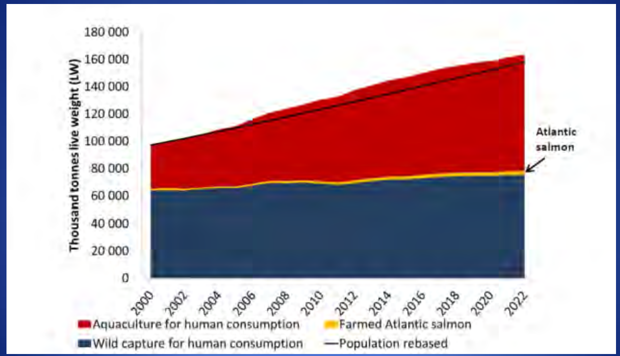
U.S. Seafood Trade Balance



Wild Caught / Farmed



Aquaculture – Seafood for the Future



Source: Marine Harvest Salmon Farming Industry Handbook 2014

California Aquaculture

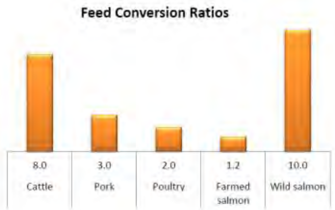
Pacific Oyster	*Crassostrea gigas*
Kumamoto Oyster	*C. sikamea*
Eastern Oyster	*C. virginica*
European Oyster	*Ostrea edulis*
Red Abalone	*Haliotis rufescens*
Bay Mussel	*Mytilus edulis*
Manila Clam	*Venerupis philippinarum*
Channel Catfish	*Ictalurus punctatus*
Blue Catfish	*I. furcatus*
Rainbow Trout	*Oncorhynchus Mykiss*
White Sturgeon	*Acipenser transmontanus*
Striped Bass	*Morone saxatilis*
Hybrid Bass (Striped bass x White bass)	*M. saxatilis X M. chrysops*
Black Bass	*Micropterus salmoides*
Redbelly Tilapia	*Tilapia zillii*
Hornorum Tilapia	*Oreochromis hornorum*
Mozambique Tilapia	*O. Mossambicus*
Algae (Freshwater & Marine)	Spirulina, *Chaetoceros gracilis; Nannochloropsis oculata; Isochrysis galbana, Thalassiosira pseudonana, ;Thalassiosira*

Why Aquaculture?

"Our food should be our medicine and our medicine should be our food"
Hippocrates 431 BC

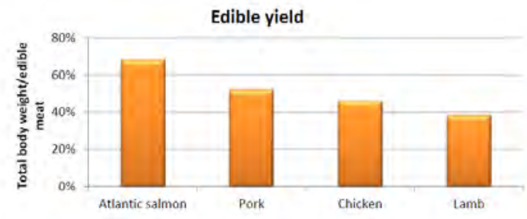
- ✓ "Modest fish consumption reduces risk of coronary death by 36% and total mortality by 17%.... (Mozaffarian and Rimm, JAMA 2006; 296(15): 1885-1899)
- ✓ Potentially saving ~160,000 lives/yr.
- ✓ Fish - Enhances brain development and cognition in babies
- ✓ "The mortality benefits...are remarkable; few medical interventions reduce total mortality to such an extent".
- ✓ EPA - Critical role in cardiovascular health
- ✓ DHA - Proper function of nervous system, especially brain

Why Aquaculture ?



Source: Marine Harvest, article in Fiskaren March 20 2009, British PIG BPEXX Yearbook 2007, www.pork.org

Why Aquaculture ?



Source: Bjørkl, J., Norwegian University and Life Sciences, Norway (2002).

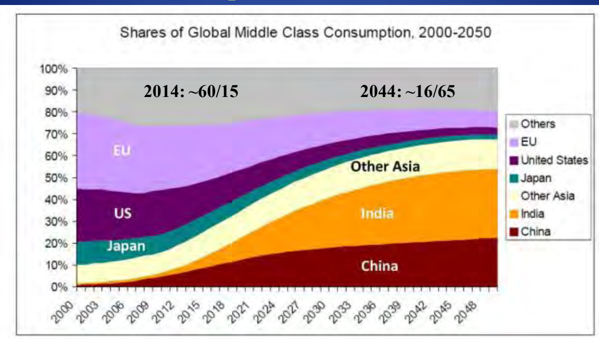
Why Marine Aquaculture ?

The World Ocean

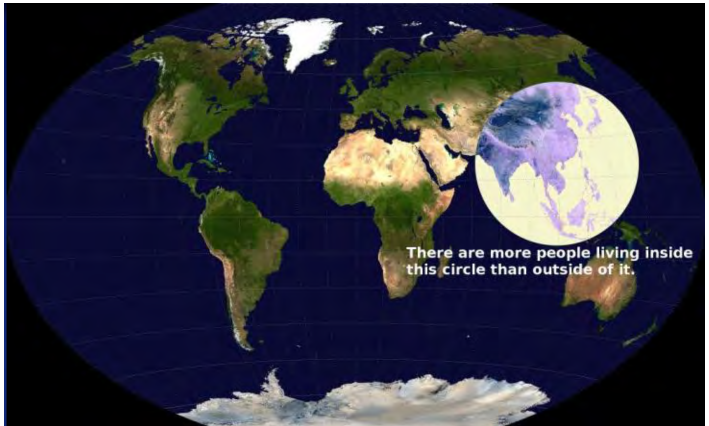
97% of the earth's water and 70% of its surface

- **Capture Fisheries - 1.2 % of the total food**
- **Marine aquaculture - 0.5 % of the total food**
- **Fresh water resources limiting**
- **Ocean net pen aquaculture is a relatively new industry**
- **Marine aquaculture successfully practiced elsewhere**

Why Domestic Aquaculture ?
Global Growth of the Middle Class
EU, US, Japan → India, China, Asia

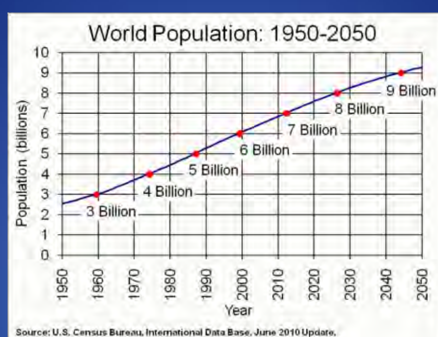


Source: Kharas, Homi. 2010. The Emerging Middle Class In Developing Countries. Working Paper #285. OECD Development Centre. http://www.oecd.org/dev/44457738.pdf



That circle encompasses China, India, Indonesia, Bangladesh, Japan, Vietnam, the Philippines, Burma, Thailand, South Korea, Nepal, Malaysia, North Korea, Taiwan, Sri Lanka, Cambodia, Laos, Mongolia and Bhutan. Source: http://www.vox.com/2014/9/23/6829399/23-maps-and-charts-that-will-surprise-you

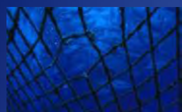
A Growing Concern- Demand for Food



Why Not Practice U.S. Aquaculture ?

- Strong public and private ethic for environmental protection
- Environmental Approach to Aquaculture, California's PEIR
- Stringent regulatory programs
  - Use of drugs and therapeutants (FDA, EPA)
  - Protection of water quality (EPA – NPDES)
  - Prevent aquatic invasive species (USFWS, States)
  - Food safety, HACCP programs (NOAA, FDA)

Why Not Practice U.S. Aquaculture ?



Escapes

Predation, Competition, Disease

Altered Genetic variability

Therapeutants

Pollution

Fish meal issues

Escapes

- Farmers try to avoid them
- Millions...tens of thousands...thousands...tens
- New net pen designs, technology and training
  - escapes negligible
- British Columbia Atlantic Salmon Watch Program
  - Extensive field work , 2011/2012 in 12 freshwater systems on Vancouver Island , No Atlantic salmon found
  - Recent escapes in British Columbia
  - 2011 – **12**; 2012 – **2,754**; 2013 – **200-300**; 2014 – 13,687
  - http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/escape-evasion-eng.html
- California releases 32 million hatchery Chinook salmon

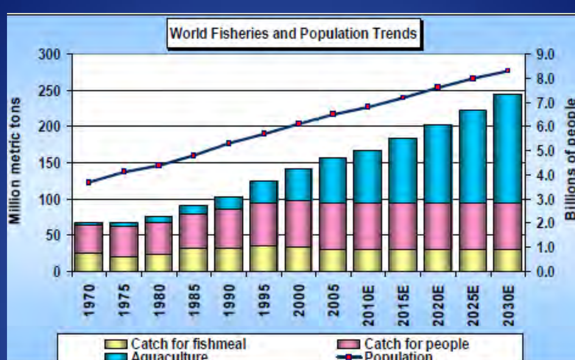


Fig.1 Trends in world fisheries, aquaculture and human population
Courtesy: Jingjie Cho & Anderson, NOAA Aquaculture

25% Fishmeal from Byproducts

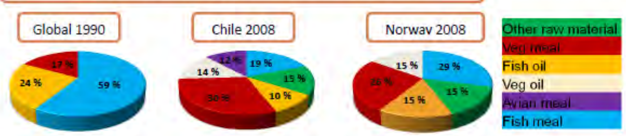
EPA and DHA omega-3 fatty acids.

New Sources

- ✓ **Soybeans**
- ✓ **Microalgae**
- ✓ **Single cell protein**
- ✓ **Genetically improved oil seed**

Changing Feed Formulations

Development in use of ingredients in salmon feed receipts

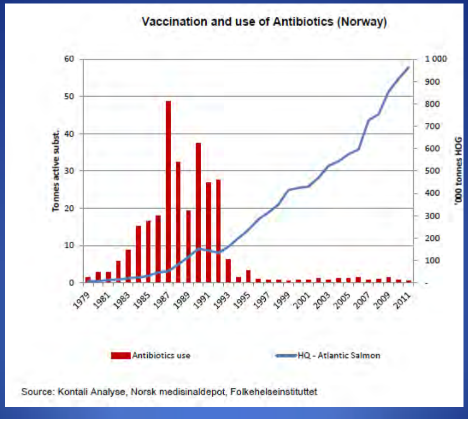


Source: Marine Harvest

Growth intervals	0.1 – 0.2 kg	0.2 – 1 kg	1 – 2 kg	2 – 3 kg	3 – 4 kg	4 – 5 kg
Feed consume*	0.08 kg	0.75 kg	1.00 kg	1.05 kg	1.10 kg	1.20 kg
Time, months	2	4	4	3	2	2

*Estimates for Norway only – typical S1 smolt

Vaccine Research



"In his exploitation of the sea man is still a barbarian, a ruthless hunter slaughtering whole species of animals without heeding the consequences. With earth's burgeoning human populations to feed we must turn to the sea with new understanding and new technology. We need to farm it as we farm the land. This is called mariculture. It has just begun. ... In such controlled volumes the ideal conditions can be maintained all year and by ensuring fertilization and protecting the larvae from predators, incredibly high yields can be obtained from a number of protein-rich populations. **High efficiency sea farms totalling the size of Switzerland would produce more food than all fisheries combined."**

Jacques Cousteau, 1973

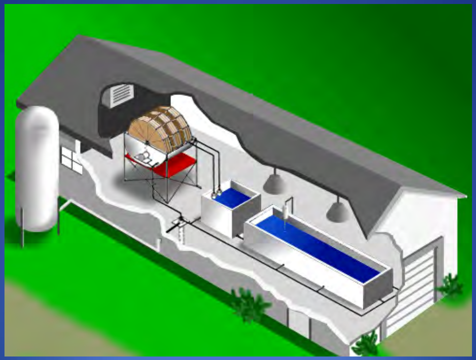
The Precautionary Principle

- **Interpretation I**
  - **Invoke the precautionary principle to strictly regulate and restrict aquaculture development because of concerns about fish meal, escapes, use of therapeutants and pollution**
- **Interpretation II**
  - **Aggressively develop aquaculture to ensure adequate seafood supplies, prevent unnecessary malnutrition and human mortality, and reap the economic and employment benefits that accrue, while managing risk and protecting natural resources**

USA Production Potential

- Increase from 0.5 to 1.5 million tons per year by 2025
- Value up from US$1 billion to more than US$2 billion
- Additional production 1 million tonnes(Nash, 2004)
  - 760,000 tons from finfish, (590,000 tons marine finfish)
  - 47,000 tons from crustacean production
  - 245,000 tons from mollusc production

Recirculating Aquaculture Systems



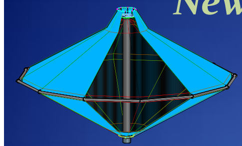
Economic Evaluation of Aquaculture Production Systems

TECHNOLOGY	INITIAL INVESTMENT	THIRD-YEAR INCOME	ROE*
Net pen	$5,000,716	$2,641,147	52%
Recirculating aquaculture system	$22,622,885	$381,467	4%
Rigid–pure oxygen	$24,004,470	$253,079	-2%
Land-based LOX Mech. filtration	$18,858,685	$260,773	-2%
Land-based liquid oxygen injection	$19,628,900	$403,142	-4%
Flexible–pure oxygen	$29,332,086	$2,041,169	-9%
Rigid–with aeration	$23,284,470	$2,125,885	-10%
Land-based below grade	$67,748,173	$13,496,265	-19%
Land-based grade	$72,352,066	$17,417,907	-20%

Source: Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry Prepared by: David Boulet, Alistair Struthers and Eric Gilbert. Innovation & sector strategies Aquaculture management directorate, Fisheries & Oceans Canada. September, 2010

* ROE = Return On Equity

New Technologies



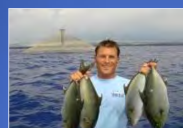
New Cultured Species


California Yellowtail


Hawaiian moi


Cobia


Atlantic cod


Kahala


AquAdvantage Atlantic Salmon

Promising Species


Sablefish


Florida pompano


Bluefin Tuna


Yellowfin Tuna

Research is Crucial

- Fish Health – therapeutants, vaccines
- Broodstock – nutrition, maturation, spawning
- Larval rearing – diets and systems
- OA - biological and ecological impacts/adaptation
- Genomics and applications in selective breeding
- Fish nutrition – life stage specific formulations, dietary requirements, feed formulation

Carlos Gutierrez

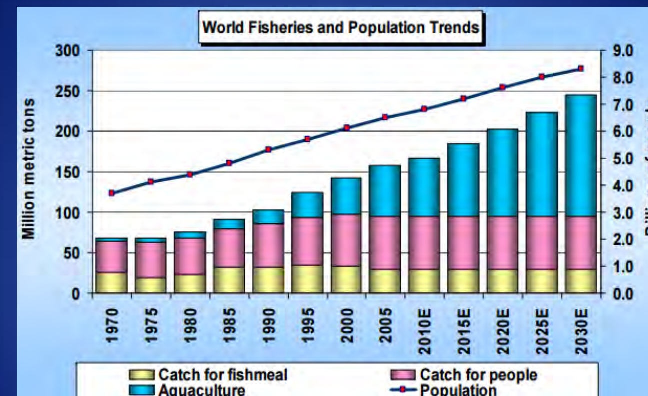
former Secretary of Commerce

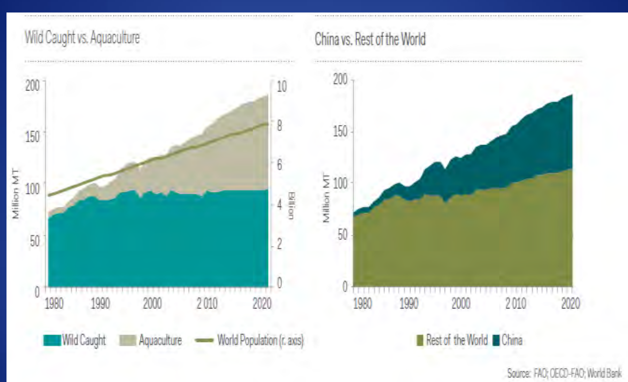
- "We believe we can do it in a way that is environmentally sound
- "This is very much the future, and we need to get to work to be able to have an adequate supply of fish."

"We must plant the sea and herd its animals using the sea as farmers instead of hunters.

Jacques Cousteau

That is what civilization is all about - farming replacing hunting".

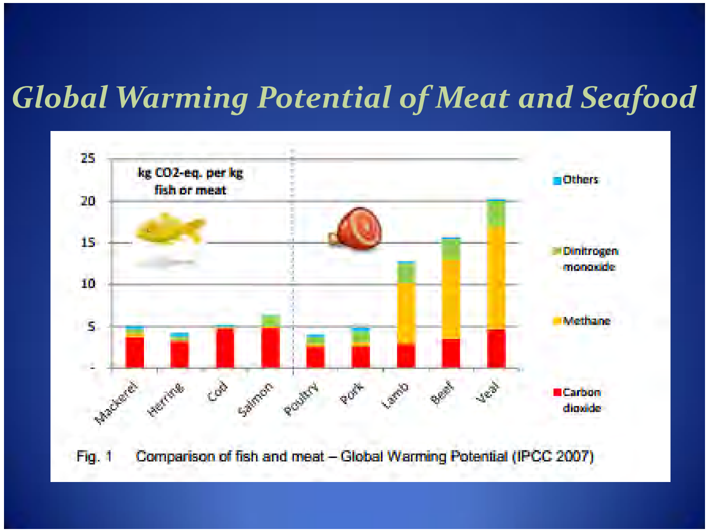




Health benefits of regular consumption of EPA and DHA

Disease or health condition	Strong evidence of significant health benefits	Promising preliminary results	Possible health benefits (require more substantiation)
Coronary heart disease	✓		
High blood pressure	✓		
Irregular heart beat (arrhythmia)	✓		
Asthma		✓	
Rheumatoid arthritis	✓		
Crohn's disease		✓	
Diabetes	✓		
Hypertriglyceridemia	✓		
Cancer			
Bowel cancer		✓	
Laryngeal cancer			✓
Pancreatic cancer			✓
Central nervous system			
Neural development		✓	
Memory			✓
Depression			✓
Psychosis			✓
Multiple sclerosis			✓

Source: Adapted from 'What is so healthy about Seafood?' Australian Government, Fisheries Research and Development Corporation


Global Warming Potential of Meat and Seafood
kg CO2-eq. per kg fish or meat
25
20
15
10
5
Mackerel
Herring
Cod
Salmon
Poultry
Pork
Lamb
Beef
Veal
Others
Dinitrogen monoxide
Methane
Carbon dioxide
Fig. 1 Comparison of fish and meat – Global Warming Potential (IPCC 2007)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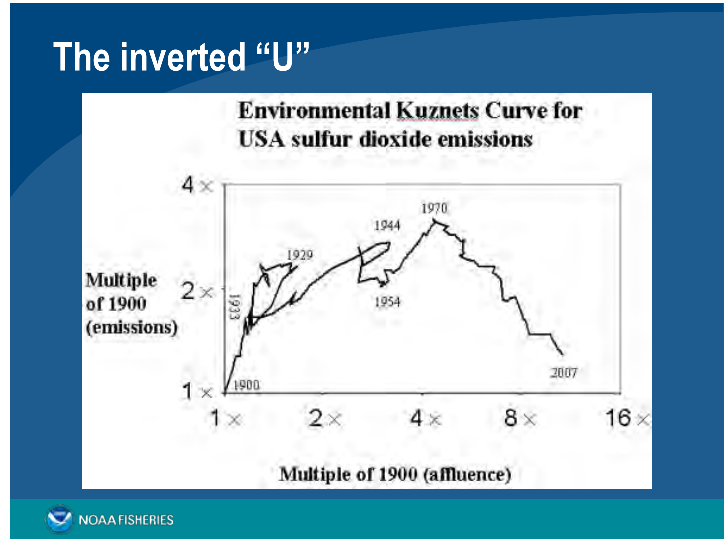
"The Only Thing That Is Constant Is Change"
—Heraclitus
Michael Rust
Science Coordinator
Office of Aquaculture


The inverted "U"
Environmental Kuznets Curve for USA sulfur dioxide emissions
Multiple of 1900 (emissions)
Multiple of 1900 (affluence)
1900
1929
1933
1944
1954
1970
2007
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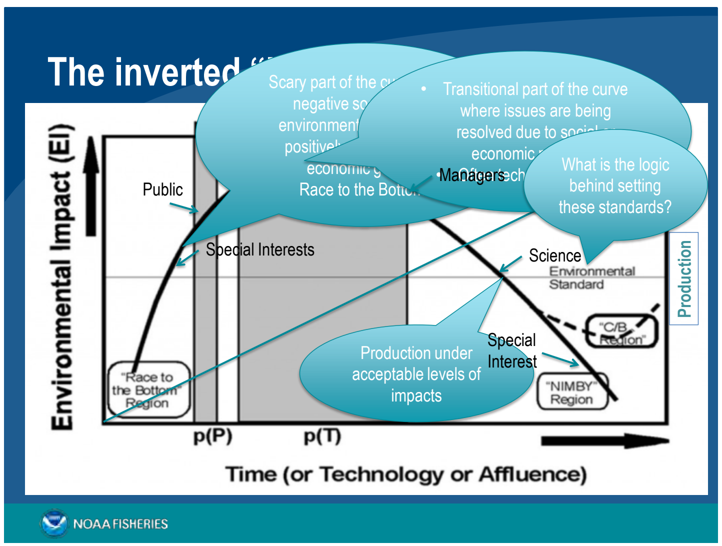
The inverted
Environmental Impact (EI)
Time (or Technology or Affluence)
Public
Special Interests
Managers
Science
Environmental Standard
Production
"C/B Region"
Special Interest
"NIMBY" Region
"Race to the Bottom" Region
p(P)
p(T)
Transitional part of the curve where issues are being resolved due to social
What is the logic behind setting these standards?
Production under acceptable levels of impacts
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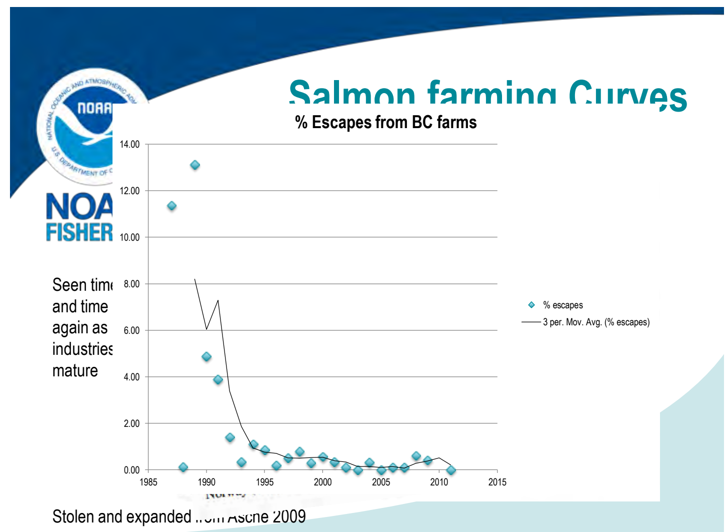
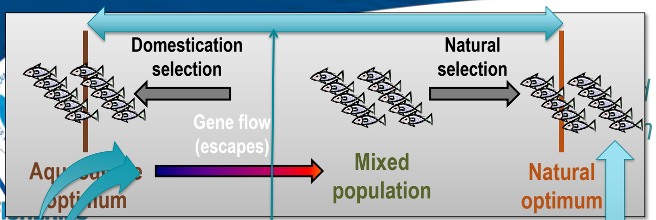

Salmon farming Curves
% Escapes from BC farms
% escapes
3 per. Mov. Avg. (% escapes)
Seen time and time again as industries mature
Stolen and expanded from Asche 2009



Risk Model for genetic change of wild population

Risk = $F(P_e/P_w)(\Delta G)(F_e)$

P_e = Population size for escapes

P_w = Population size for wild population

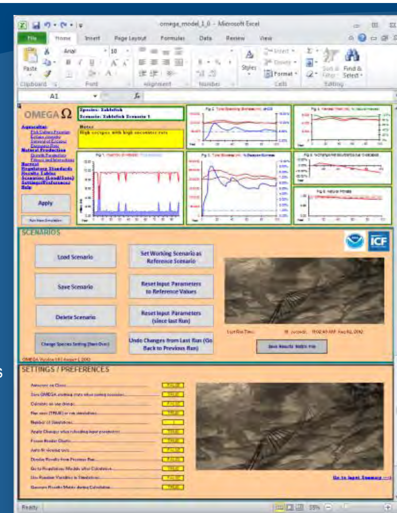
ΔG = Difference in genetic structure between wild and escapes

F_e = Fitness of escaped fish to live in the wild

OMEGA Modules

Nine modules requiring user input

- Cultured Population and Aquaculture Operations
  - Fish Culture Program
  - Escape Scenario
- Wild Population
  - Natural Production
  - Growth and Maturity
  - Harvest
- Interactions
  - Relative Survival of Escapes
  - Encounter Rate
  - Fitness and Interactions
- Regulatory Standards (if any)



R = $(E/W)(\Delta G)(f)$

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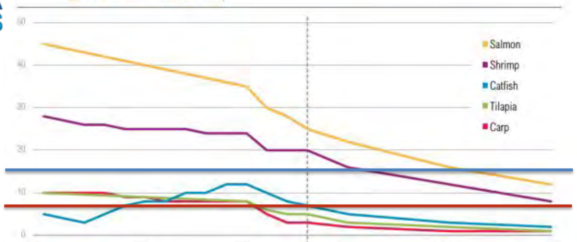
Fishmeal use is falling

Figure 9 | The aquaculture industry has reduced the share of fishmeal in farmed fish diets (percent of fishmeal in fish feed)



Note: Fishmeal use varies within and between countries; the figures presented are global means. Data represent observations between 1995-2008, and projections for 2009-2020.

Sources: FAO (2014b), Tacon and Metian (2008), Tacon et al. (2011).

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Efficiency of aquaculture relative to other animal proteins

TABLE. COMPARISON OF SUSTAINABILITY INDICATORS AMONG ANIMAL PROTEIN PRODUCTION SYSTEMS

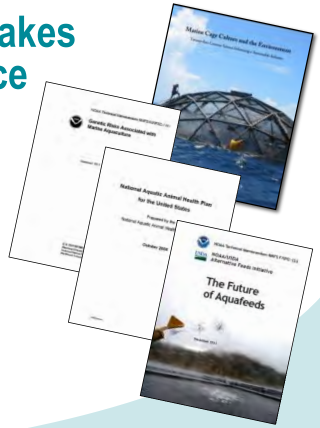
	Food conversion (kg feed/kg edible weight)	Protein efficiency (%)	N emissions (kg/ton protein produced)	P Emissions (kg/ton protein produced)	Land (tons edible product/ha)	Consumptive freshwater use (m^3/ton)
Beef	31.7	5	1,200	180	0.24–0.37	15,497
Chicken	4.2	25	300	40	1.0–1.20	3,918
Pork	10.7	13	800	120	0.83–1.10	4,856
Finfish (average)	2.3	30	360	48	0.15–3.70	5,000*
Bivalve mollusks	not fed	not fed	-27	-29	0.28–20.00	0

*Note: Consumptive use is difficult to compare across the wide spectrum of aquaculture production systems. In the vast majority of cases, water outfalls from aquaculture are much cleaner and more easily recycled than for land animals.

Source: Phillips, Beveridge, and Clarke 1991; FAO 2003; Hall et al. 2011; Bouman et al. 2013.

Research makes the difference

- Feeds
- Genetics
- Benthic impacts
- Cage culture sustainability
- Ecosystem impacts
- GIS models for site selection
- Finfish animal health
- Best Management Practices
- Science outreach



THANK YOU!

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http://aquaculture.noaa.gov

Pulling, Pushing and Creating Change

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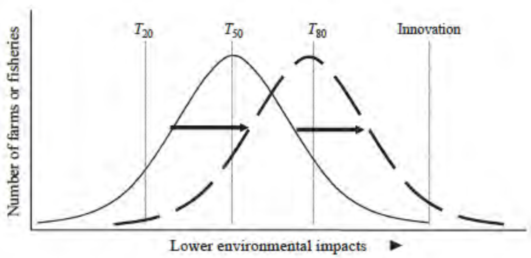
Innovation (structural change) tends to move the whole industry to higher standards if economic gain and environmental gain are both achieved



Stolen and expanded from Tlusty 2012

Pulling, Pushing and Creating Change

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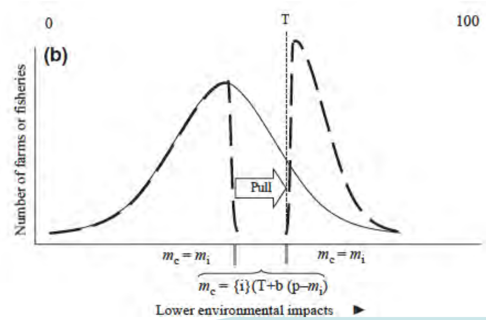
BMP's and certification schemes tend to pull the best farms and can split the industry unless the whole industry can make the bar



Stolen and expanded from Tlusty 2012

Pulling, Pushing and Creating Change

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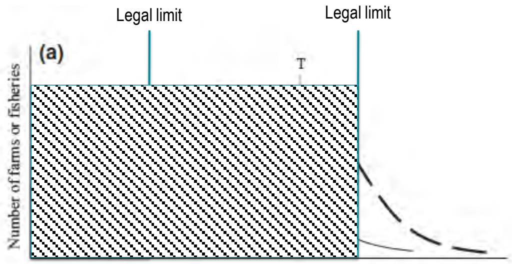
Limits can truncate the industry cutting off the lowest performers and may push the industry



However - Limits are not set this way – they depend on what is being protected

Stolen and expanded from Tlusty 2012

Conclusions

- Innovation leading to economical and environmental improvements can lead to meaningful structural change which can lift the whole industry
- Regulation can provide a "push", but must be at an appropriate level so as not to kill the industry.
- BMP's and voluntary standards can provide a "pull" but might also split the industry.
- Innovation in both technology and regulatory structure has lead to significant improvements in salmon net-pen farming and most of these advances directly relate to offshore.

Science, Service, Stewardship

Perspectives on Aquatic Animal Health

Kevin H. Amos
Aquatic Animal Health Coordinator
NOAA Fisheries
April 28, 2015

NOAA FISHERIES SERVICE

Objectives

1. General understanding of aquatic health challenges and risks (aka "hazards") to farmed aquatic animals.
2. Examine preventative aquatic health programs.
3. Understand pathogens and wild/farmed interactions.
4. Review treatment schemes and outcomes on both animal treated and the environment.
5. Future scientific needs & expectations

2

Health Challenges of Farmed Aquatic Animals

- Relative high density of animals in a confined space.
- "Open system" - rearing facilities at the mercy of *Mother Nature*
- An infection may result in high numbers of pathogens in close contact to farmed animals with potentially adverse outcomes, i.e., a disease episode.
- Mere presence of pathogens or diseased individuals does not necessarily mean an outbreak will occur.
- The science of epidemiology consistent in all animal species

3

Prevention is the key to success!

Implement a health management program to include:

1) An aquatic animal health professional
2) Bio-security measures
3) Avoidance of stress (rearing densities, nutrition)
4) Stock pens with healthy populations
5) Routine monitoring with robust record keeping
6) Use of vaccines if appropriate
7) Consider regulatory approaches in the Gulf of Mexico FMP for offshore aquaculture.

4

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USDA/APHIS *CAHPS Concept*

CAHPS: Commercial Aquaculture Health Program Standards

Non-regulatory, volunteer program. Elements similar to NOAA's Gulf of Mexico aquaculture FMP.

1) Aquatic animal health team
2) Risk characterization and management
3) Surveillance
4) Investigation and reporting
5) Response

5

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Infectious pathogen considerations

- Variety of bacterial, viral, and parasitic pathogens are endemic in the Pacific Ocean in wild/feral populations
- Disease does occur in wild populations
- Historically, the most serious disease episodes on farms occur when "native" meets "non-native" (Atlantic salmon vs IHNV, shrimp vs WSSV).
- Disease events occur in wild or farm when you have:
  1) susceptible hosts that are compromised; and,
  2) sufficient dose of virulent pathogen

6

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Management for bacterial diseases

1. Effective vaccines currently available for some marine bacterial diseases (for example, vibriosis).
2. Antibiotics, applied orally, for bacterial disease outbreaks. NEVER AS PROPHYLACTIC!
3. TM™ and Aquaflor™ available via INADs
4. May be low level of residuals found in immediate vicinity of pens. Insignificant compared to other human inputs to marine system.
5. Naturally occurring antibiotic-resistant bacteria.

7

NOAA FISHERIES SERVICE

Management of viral diseases

- Avoidance
- Limited number of vaccines available (for IHNV and ISAV).
- In extreme situations, depopulation may be appropriate (ISA in Maine & New Brunswick)

8

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Management of ectoparasites

- Hydrogen peroxide is drug of choice for treatment of most ectoparasites in marine waters
- Slice™ (ememectin benzoate) is frequently used to treat sea lice.
- Integrated pest control management programs have been successful (Maine – fallow, single year class, treatment when appropriate)

9

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Research and future prospects

Vaccines

- While effective bacterial vaccines, ongoing research still needed for viral and parasitic vaccines.
- Need for improved immersion delivery systems, improved oral vaccines (micro-encapsulation), and safer and more effective adjuvants (adhesions & lesions).
- Much research still is needed for understanding of immune response in all aquatic animals, especially in area of mucosal immunity.

10

NOAA FISHERIES SERVICE

Research and future prospects

Drugs and biologics

- Drugs approved by FDA for freshwater will work in marine environment. Need money for approval process.
- INAD use critical. Funding needed for AADAP!
- Biologics/immuno-stimulants have been promising, e.g. Beta glucans – yet much research needed in this area.

11

NOAA FISHERIES SERVICE

Genetics

- As in traditional agriculture and all animal medicine, we know that disease resistance has a genetic basis.
- Global research has demonstrated that by selective breeding and molecular adjustments, breeds can be selectively improved for purpose.
- Need for regulators to keep an open mind about the potential for sterile, but genetically improved, animals.

12

NOAA FISHERIES SERVICE

Bottom line on risk

- Risk analysis (RA) is a powerful tool to assess health risk of and to fish farms.
- Access to and use of robust scientific data necessary for robust RA.
- Historic data suggests most significant risk comes from non-native species and/or pathogens.
- Need to continually improve science to assess risk, assess infectious disease interactions between farmed & wild popultions, and develop reliable tools to prevent disease events.

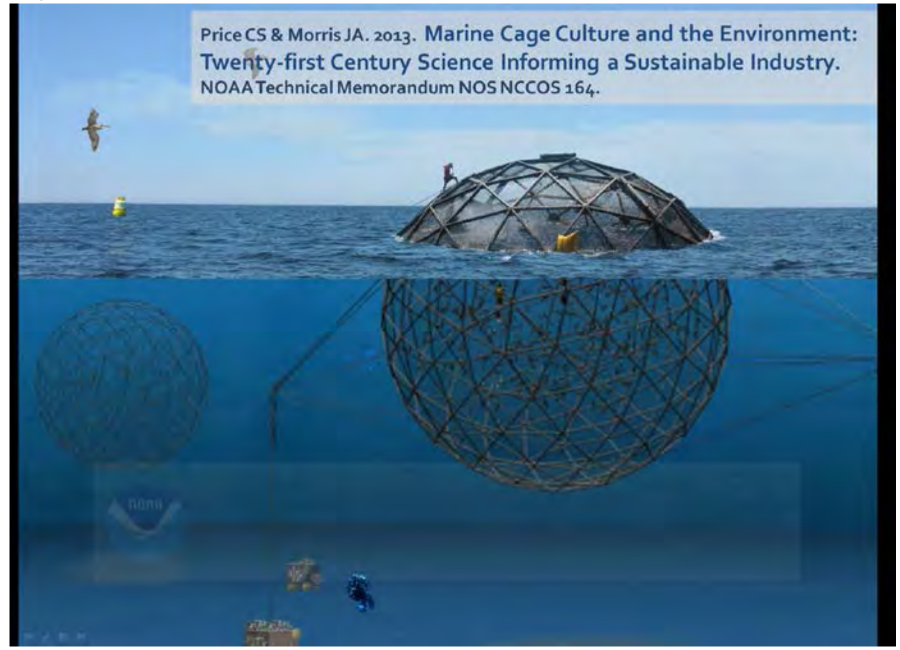
13

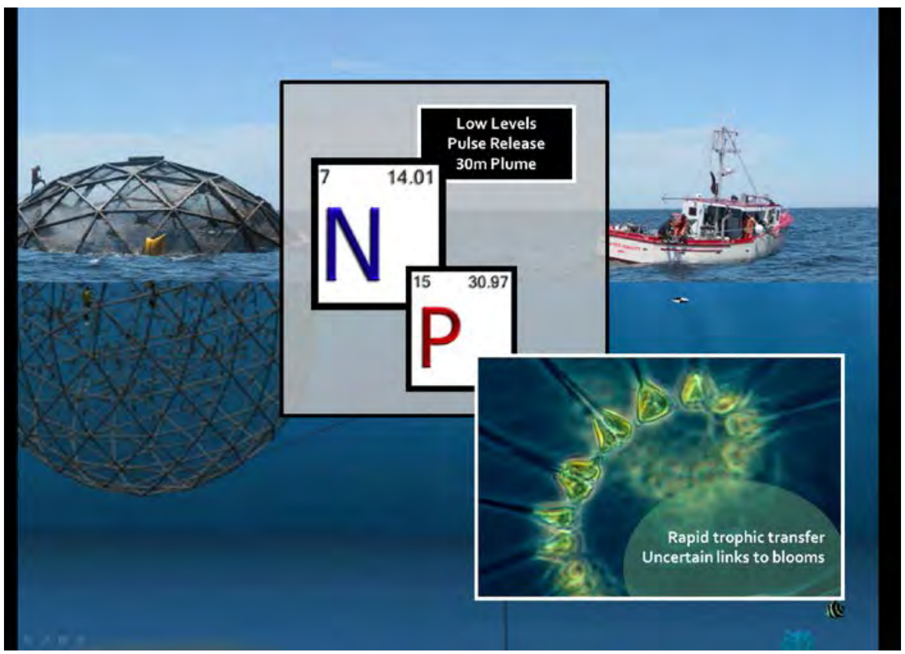
NOAA FISHERIES SERVICE

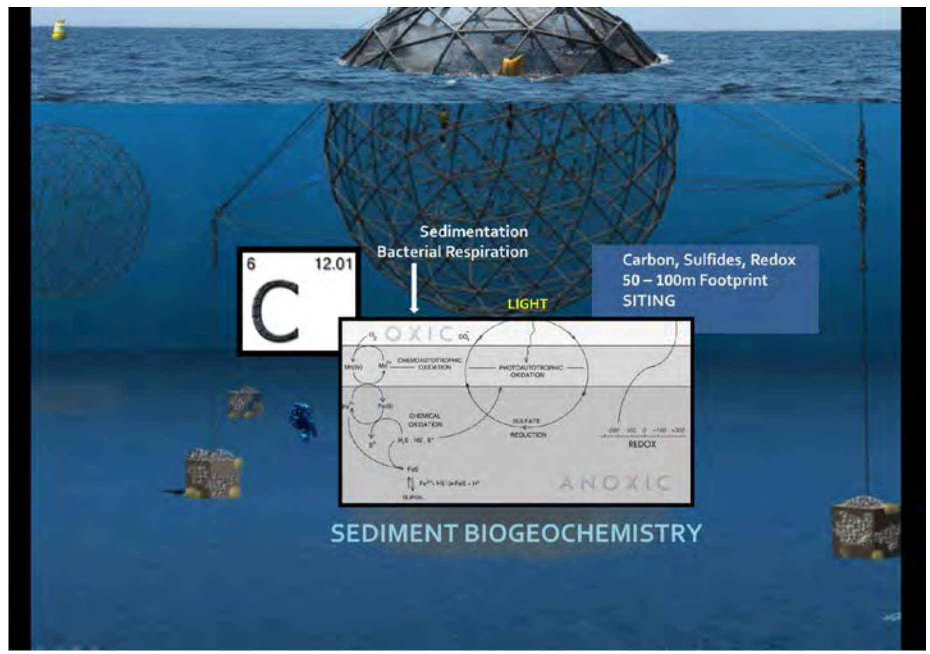
Questions?

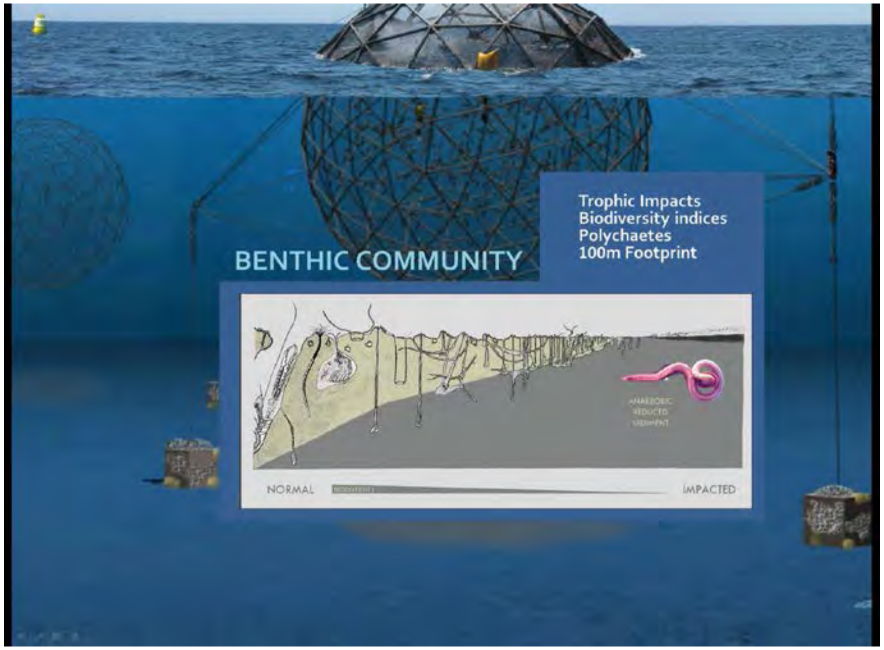
14


MARINE AQUACULTURE &
THE ENVIRONMENT
Carol Price & James Morris
NOAA National Ocean Service
National Centers for Coastal Ocean Science
carol.price@noaa.gov


Price CS & Morris JA. 2013. Marine Cage Culture and the Environment:
Twenty-first Century Science Informing a Sustainable Industry.
NOAA Technical Memorandum NOS NCCOS 164.


Low Levels
Pulse Release
30m Plume
7 14.01
N
15 30.97
P
Rapid trophic transfer
Uncertain links to blooms


Sedimentation
Bacterial Respiration
6 12.01
C
LIGHT
Carbon, Sulfides, Redox
50 – 100m Footprint
SITING
OXIC
ANOXIC
REDOX
SEDIMENT BIOGEOCHEMISTRY


BENTHIC COMMUNITY
Trophic Impacts
Biodiversity indices
Polychaetes
100m Footprint
NORMAL
IMPACTED


CHEMICALS
Antifoulants
Net Treatments
Mechanical Alternatives
Antibiotics
Decreased Use
Vaccination
Therapeutants
Hydrogen Peroxide
Health Management
Heavy Metals
Copper & Zinc
Accumulation


FISH ATTRACTANTS
commercial & recreational fish
consume 27-80% of organic waste


CORAL
SEAGRASS
MANGROVE


Price CS et al. 2015. Marine Aquaculture and Protected Species Interactions. NOAA Technical Memorandum NOS NCCOS ###.


QUESTIONS?
carol.price@noaa.gov

Rose Canyon Fisheries

A Commercial-Scale Proposal to Define the Regulatory Pathway to Farming the U.S.A.'s Exclusive Economic Zone

Don Kent, M.Sc.
President/CEO
Hubbs-SeaWorld Research Institute
&
Rose Canyon Fisheries

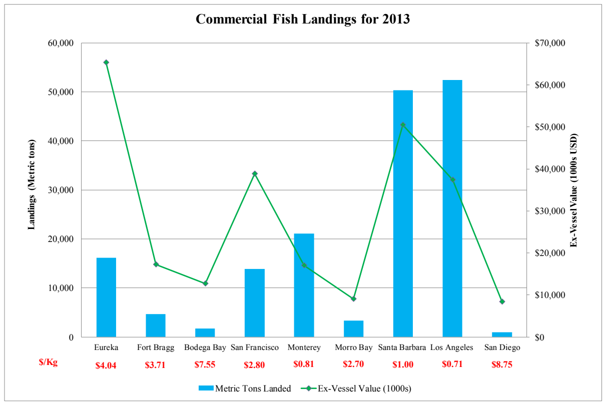
Rose Canyon Fisheries

So Cal's Fishing History

- From the early thirties and up until the late seventies, So Cal was known as the **Tuna Capital of the World**
- Over 40,000 people were employed by the tuna industry including 16 canneries
- Tuna was being served in over 80% of all U.S. households

Rose Canyon Fisheries

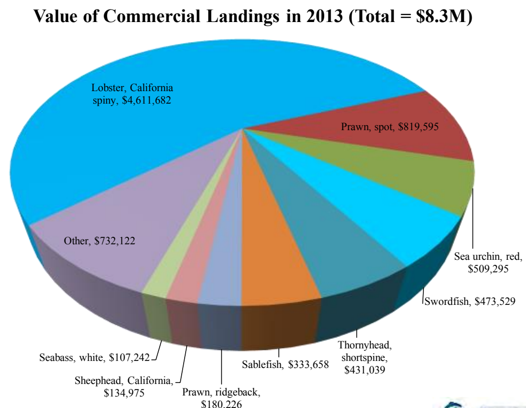
California's Commercial Fishing



2013 Total: **$256 Million, 165K Metric Tons**

Rose Canyon Fisheries

San Diego Commercial Fishing



Rose Canyon Fisheries

California Agriculture (2012 statistics)

- 81,500 farms
- Over 400 commodities
- $43.5 billion total revenue
- #1 state with 11.3% of U.S. farm cash receipts
  - 11% for crops
  - 7.1% for livestock
- $12 billion in livestock sales
- <0.5% is aquaculture

Source of Income	Sales
Aquaculture	$54
Chickens, All	$720
Cattle and Calves	$3,299
Eggs, Chicken	$393
Hogs and Pigs	$39
Honey	$23
Milk and Cream	$6,900
Turkeys	$311
Wool and Mohair	$5
Other Livestock	$412
Total	$12,155

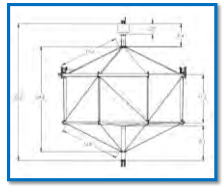
cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

CALIFORNIA CA GROWN

Rose Canyon FISHERIES

Rose Canyon Fisheries - The Project

- A commercial scale, state-of-the-art, offshore aquaculture project
  - Evaluate both economic and environmental sustainability
  - Scale up to 5,000 metric tons (11 million pounds) annual production
  - Annual sales in excess of $50-80 million with potential 2:1 economic benefit to the region



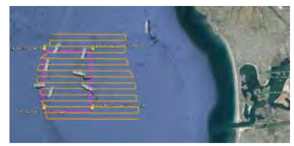
Rose Canyon FISHERIES

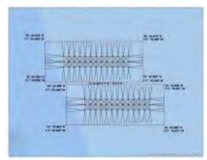
Species to be Cultured

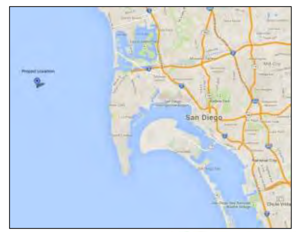
- Yellowtail Jack (*Seriola lalandi*)
  - Native to California Coast
  - Sold as "Hamachi" from Japanese fish farms
  - HSWRI has been culturing this species since 2003
- White Seabass (*Atractoscion nobilis*)
  - Native to California Coast
  - Commercially and recreationally important
  - HSWRI has been rearing this species for three decades
- Striped Bass (*Morone saxatilis*)
  - "Common" within project range
  - Anadromous (spawns in fresh water and matures in sea water)
  - Cannot be caught commercially
  - HSWRI has cultured this species since early 1970s

Rose Canyon FISHERIES

The Proposed Farm Site







Rose Canyon FISHERIES

Permits Required

- **Federal permits/reviews:**
  - **Environmental Protection Agency**:
    - NPDES permit (National Pollutant Discharge Elimination System)
    - Lead agency for NEPA review process is the EPA
  - **U.S. Army Corps of Engineers**: Rivers and Harbors Act-Section 10 permit (including NOAA- EFH (Essential Fish Habitat), ESA (Endangered Species Act), and marine mammal/wildlife interactions)
  - **U.S. Coast Guard**-Aids to Navigation Permit (issued after ACoE)
  - **NOAA** has convened an Inter-agency Working Group to coordinate review process
- **CA State permits/reviews:**
  - **CA Dept. of Fish & Wildlife** aquaculture registration
  - **CA Coastal Commission** certification of consistency with Coastal Act

Rose Canyon Fisheries

San Diego is Ideal

- Mild Mediterranean climate
  - Shaded from storm events
  - Low wave energy
- Existing commercial fishing
- Proximity to So Cal markets
- HSWRI and NOAA are here

Rose Canyon Fisheries

Potential Economic Benefits

Net Sales	$81,791
Expenses:	
Production Costs	$54,818
Sales and Admin	$4,799
Total Expenses	$59,617
Net Earnings	$22,174
Income Taxes:	
Federal	$7,761
State	$1,960
Local	$111
Total Income Taxes	$9,832
Economic Impact	
Direct	$58,948
Indirect	$17,684
Induced	$41,264
Total Economic Impact	$117,896

Source: NOAA Southwest Fisheries Science Center

- Project:
  - Annual sales in excess of $80 million
  - Supporting over 200 seafood jobs
- Region
  - Contribute over $117 million to regional economy
- State
  - Represent a 31% increase in seafood ex-vessel sales
- Nation
  - Help to reduce the growing trade deficit in seafood imports

Rose Canyon Fisheries

Addressing Stated Concerns

Commercial and Recreational Fishing Impacts
- Avoid critical habitats
- Select sites of little import to all other fishing

Minimizing Environmental Impacts
- Avoiding entanglements
- Locating farms to eliminate habitat degradation

Minimizing Net Loss of Protein
- Alternate protein sources for feeds (e.g., processing waste for fish meal)

Preventing Escapement Impacts
- Advanced net pen technology for high energy seas
- Use endemic species from known stocks

Ensuring Product Quality
- Locate farms in cleaner offshore environment
- Adhere to existing USDA/FDA standards

Rose Canyon Fisheries

NOAA Survey

- Originally sited to meet multiple requirements and avoid conflicts
  - In deep, clean water with good current and sandy bottom
  - Outside coastal zone with its more numerous conflicting uses
- In response to commercial fisherman, recreational fishers and the Navy, we moved the farm site southeast to avoid any potential conflict and habitat concerns

Rose Canyon Fisheries

"Maximizing the Value of Offshore Aquaculture Development in the Context of Multiple Ocean Uses"

PI: Sarah Lester sarah.lester@ucsb.edu

Funded By: Sea Grant

Project Objectives:

- Assess potential conflicts and environmental impacts associated with open ocean aquaculture development
- Develop a dynamic spatial bioeconomic model for aquaculture in the Southern California Bight
- Demonstrate how tradeoff analysis can inform spatial planning for offshore aquaculture to maximize and minimize impacts and conflicts

UCSB msi Marine Science Institute Donald Bren School of Environmental Science & Management University of California, Santa Barbara

Rose Canyon Fisheries

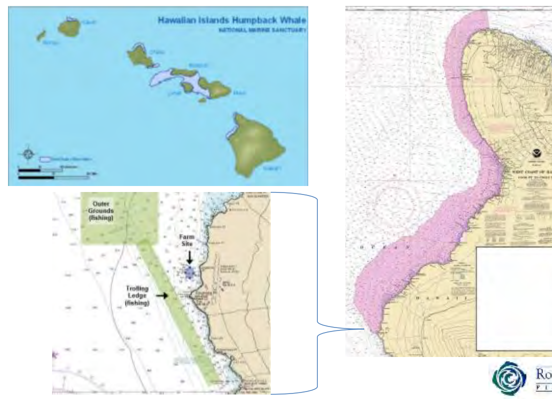
Avoid Entanglements

Rose Canyon Fisheries

Blue Ocean Mariculture (Keahole Pt, Hawaii)

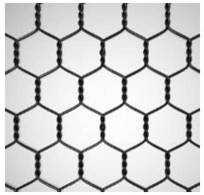
Formerly Kona Blue Farms

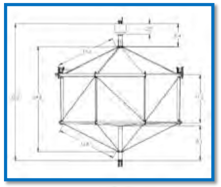
"Since 2005, an Open-Ocean 6 cell grid system, located within the Hawaiian Islands National Marine Whale Sanctuary, has operated without any negative interaction with marine mammals due to the design and selection of materials used in its fabrication and assembly"



Rose Canyon Fisheries

Mooring and Cage System





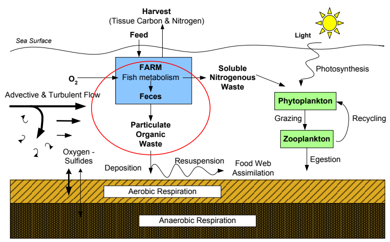
Rose Canyon Fisheries

Sustainable Marine Aquaculture in the Southern California Bight: A Case Study on Environmental and Regulatory Confidence

Dale Keifer-Science System Applications
Jack Rensel- Science System Applications
Randy Lovell- CDFW
James Morris- NOS
Paul Olin- California Sea Grant Extension
Ken Riley – NOS
Jerry Schubel – Aquarium of the Pacific
Diane Windham - NOAA

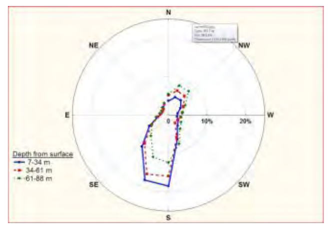
Rose Canyon Fisheries

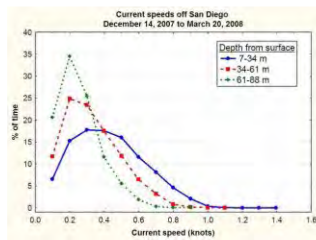
Modeling Potential Impacts



Rose Canyon Fisheries

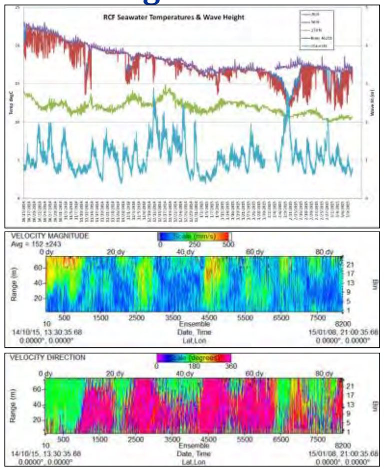
Evaluating the Site





Rose Canyon Fisheries

Evaluating the Site



Rose Canyon Fisheries

What is Needed

- Permitting review process that:
  - brings management agencies together and
  - Clearly defines the process
- Educational outreach that:
  - balances concerns with benefits and
  - authoritatively reports scientific facts, not rhetorical fears
- Public appreciation that:
  - farms will support existing, and underutilized, seafood industry infrastructure and
  - will create may more domestic seafood jobs

Rose Canyon Fisheries

By Comparison:

- To feed Californians fish:
  - 2014 Population of California: 38.8 million
  - 2012 Seafood consumption was 14.6 lbs/person
  - CA needs 257K MTs or ~500K MTs of whole fish
  - At 20 kg/M^3 and depth=10M →**1.2 mile diameter cage**
  - At $6/kg ex-vessel value ⇒ **$3 billion in annual sales**
  - At 43 jobs/1000MT = **21,500 CA jobs**
- Compared to cattle, poultry and swine this would require minimal space on land and fresh water

Rose Canyon Fisheries

Looks something like this:

Rose Canyon Fisheries

FAO Sustainability Criteria

Sustainable Development:

1. *conserves land, water, plant genetic resources,*
2. *is environmentally non-degrading,*
3. *technologically appropriate,*
4. *economically viable and*
5. *socially acceptable*

Managing the Environmental Costs of Aquaculture:

It is apparent from this study that aquaculture has, from an ecological efficiency and environmental impact perspective, clear benefits over other forms of animal source food production for human consumption. In view of this, where resources are stretched, ***the relative benefits of policies that promote fish farming over other forms of livestock production should be considered****.*

Hall, S.J., A. Delaporte, M. J. Phillips, M. Beveridge and M. O'Keefe. 2011. Blue Frontiers: Managing the Environmental Costs of Aquaculture. The WorldFish Center, Penang, Malaysia.

Rose Canyon Fisheries

National Aquaculture Act of 1980

Established the policy that it is in our Nation's interest, and it is the national policy ***to encourage the development of aquaculture in the United States****. Under this act, the* ***Secretary of Commerce is authorized*** *to provide advisory, educational, and technical assistance and* ***to encourage the implementation of aquaculture technology*** *in rehabilitation and enhancement of publicly owned fish and shellfish stocks, and* ***in the development of private commercial aquaculture enterprises.***

Rose Canyon Fisheries

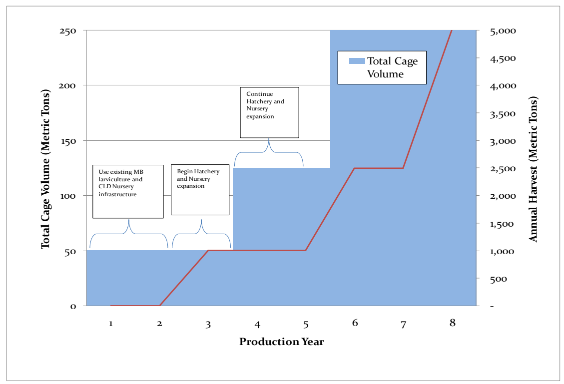
NATIONAL STRATEGIC PLAN FOR FEDERAL AQUACULTURE RESEARCH (2014-2019)

Strategic Goals

1. Advance Understanding of the Interactions of Aquaculture and the Environment
2. Employ Genetics to Increase Productivity and Protect Natural Populations
3. Counter Disease in Aquatic Organisms and Improve Biosecurity
4. Improve Production Efficiency and Well-being
5. Improve Nutrition and Develop Novel Feeds
6. Increase Supply of Nutritious, Safe, High-quality Seafood and Aquatic Products
7. Improve Performance of Production Systems
8. Create a Skilled Workforce and Enhance Technology Transfer
9. Develop and Use Socioeconomic and Business Research to Advance Domestic Aquaculture

Rose Canyon Fisheries

Farm Expansion



Rose Canyon Fisheries

Collaborative Organizations

Fish Health | Nutrition | Community

Production | Environmental Effects

Rose Canyon Fisheries

Questions we can try to answer?

- What does the offshore aquaculture industry want, need and face to move forward?
- What is the technology at issue?
- What is the environmental performance and impact of the technology?
- What are the non-technical barriers?

Rose Canyon Fisheries

If Not Here, Then Where?

- 12 Mexican farms have requested juvenile fish
- Any species we can grow in San Diego, can be grown in Baja California
- It is less than a day's driving time to California's seafood markets
- Technology and know-how is San Diego's edge; simplified permitting is Mexico's

Rose Canyon Fisheries

Conclusion

Eventually producing 5,000 metric tons (11 million pounds) of fish annually, RCF will demonstrate a new domestic source of seafood to meet growing demand

This may encourage a new national industry thereby creating significant economic benefits in our coastal communities by providing safe, healthy, sustainable and locally sourced seafood

Rose Canyon Fisheries

Rose Canyon Fisheries

An innovative collaboration between

HUBBS-SEAWORLD RESEARCH INSTITUTE

cuna del mar

"With Earth's burgeoning populations to feed, we must turn to the sea with new understanding and new technology. We must learn to farm the sea as we have farmed the land"

Capt. Jacques Cousteau

Rose Canyon FISHERIES

Icicle Seafoods at a glance

Icicle is a leading harvester, producer and processor of diversified seafood products in North America.

60,000 tons of wild salmon processed and marketed annually mostly in Alaska.

75,000 tons of pollock, crab, halibut, sablefish and cod harvested and marketed each year.

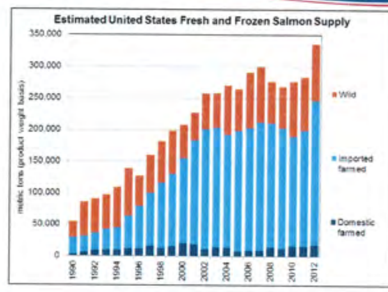
8,000 tons of Atlantic salmon farmed in the U.S.

Products are sold throughout the world to a variety of customers including industrial processors, wholesalers, food service companies and retailers

Revenue by Category

ICICLE SEAFOODS, INC.

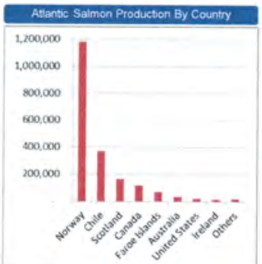
US Consumption of Salmon

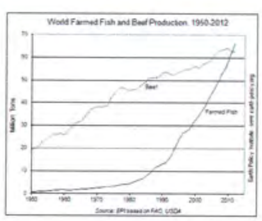


ICICLE SEAFOODS, INC.

Global Aquaculture Production

Atlantic Salmon Production By Country





ICICLE SEAFOODS, INC.

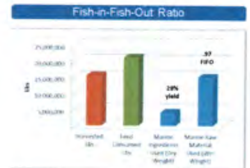
Feed Efficiency

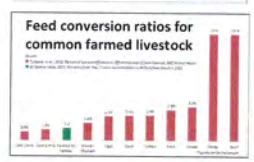
Feed Ingredients

Feed Ingredient	%
Fish Meal and Oil	20
Corn and Soy Meal	10
Canola Oil	10
Wheat	16
Poultry By-Products	44

- Farmed salmon are exceptionally efficient animals
- We are a net producer of marine protein

Fish-in-Fish-Out Ratio





ICICLE SEAFOODS, INC.

Technology

- Existing technology is sufficient and proven
  - Australian Tuna industry routinely farms in cages 16 – 25 miles offshore
- Depending on the species, may need improvements in hatchery technology and feed formulation
- Key challenges:
  - farm at a scale that justifies an investment in an offshore location
  - Develop a business with limited supporting infrastructure
  - Recruiting capable staff when training does not exist and US immigration laws create barriers

ICICLE SEAFOODS, INC.

Permitting

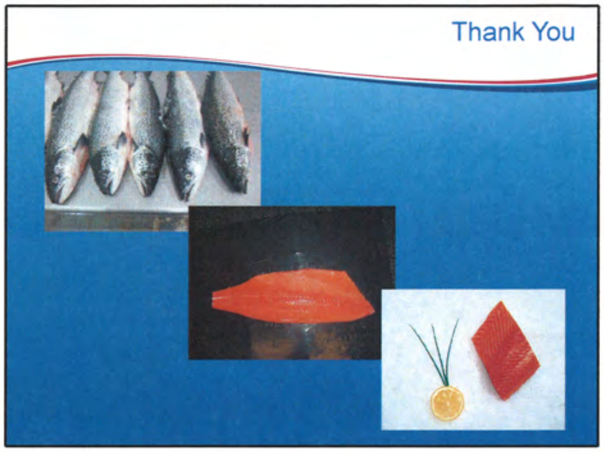
Financing

- Multiple uncertainties stifle investment interest
  - Permitting and regulatory risk
  - Operational risk
  - Market risk
- Green field investments compete with:
  - International opportunities
  - Synergistic opportunities
- Long payback periods
- High working capital requirements

ICICLE SEAFOODS, INC.

Conclusions

- Developing an industry is feasible and can be a vital tool for supporting coastal economies and environments
- We need to reduce our reliance on imported seafood
- We need to create incentives for investment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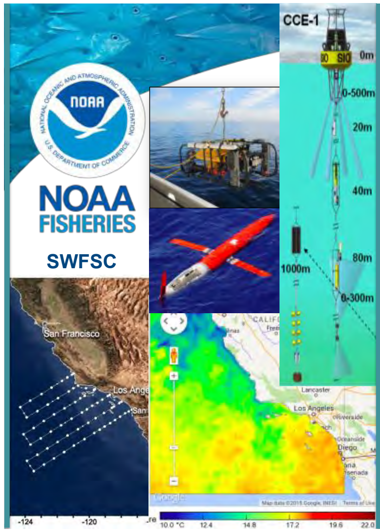


Offshore Aquaculture in the Southern California Bight

Environmental and Oceanographic Data for Farm Siting and Modeling

Cisco Werner
Director, SWFSC

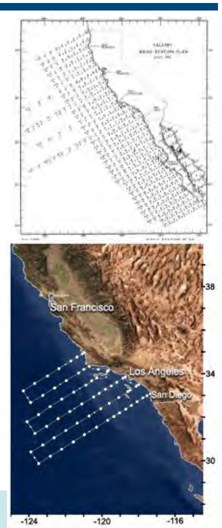
28 April 2015
Aquarium of the Pacific
Long Beach, CA

Outline

- Wealth of oceanographic information for the waters of southern CA
- Existing info/data, what does it mean?
- What can we do with that data?
- Where are the data gaps?
- What tools exist or are in development?

NOAA FISHERIES

Existing Information CalCOFI (multi-decadal backdrop)



- Formed in 1949 to study the ecological aspects of the sardine population collapse.
- Today's focus: the study of the marine environment off California, the management of its living resources, and monitoring indicators of El Niño and climate change.
- CalCOFI conducts quarterly cruises off Southern & Central California.
- Data collected to 500 m include: T, S, O_2, PO_4, Si, NO_3 and NO_2, Chl, PAR, ^{14}C, primary productivity, zooplankton biomass, phytoplankton and zooplankton biodiversity.

NOAA FISHERIES

Existing Information (CalCOFI) – and accessible via ERDDAP

>> Hydrographic Data - 1949 to Latest Update - tabulated bottle data from specific depths

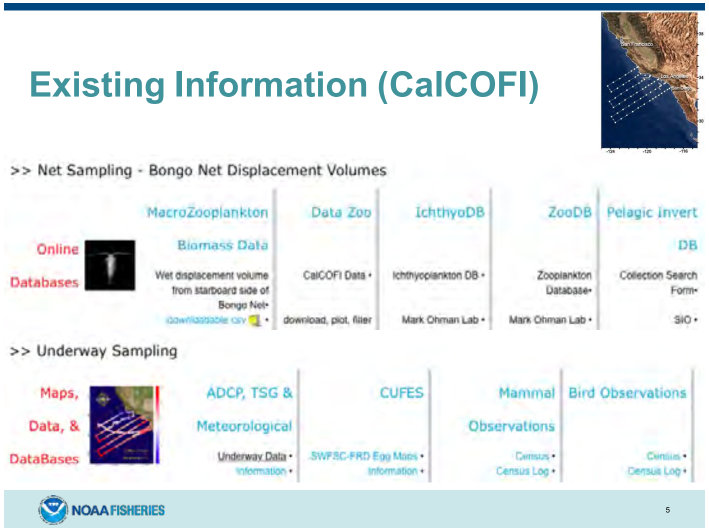
CalCOFI Data Reports	Hydrographic Bottle	Primary Productivity	Macrozooplankton	Spatial Pattern Figures
	description • example • download •	description • example • download •	description • example • download •	description • example • download •

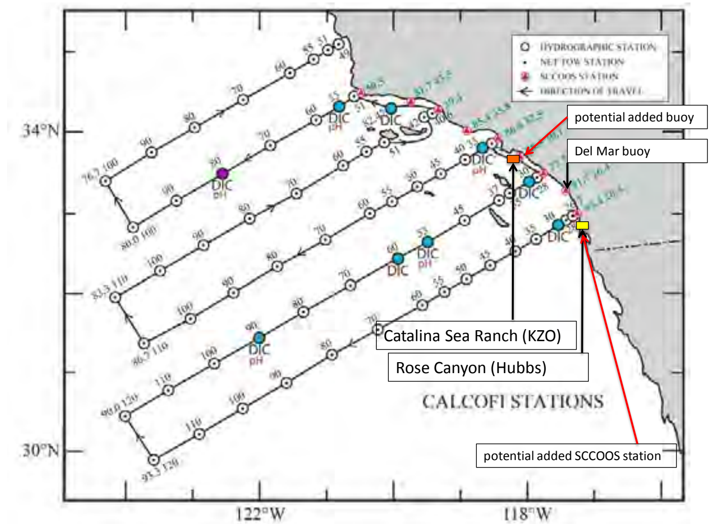
>> CTD Data - 1992 to Latest Update - 1m Bin-averaged CTD sensor data; SBE processed & bottle-corrected

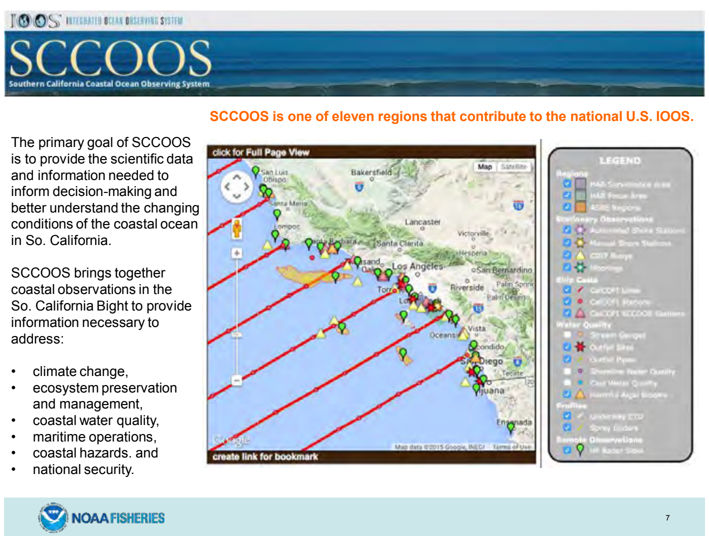
CTD Zip Files	CTD Data	Data Descriptions	SBE Formats	CalCOFI Formats
SBE	latest final 1311 • latest prel. 1501 • browse all •	final • preliminary • cast •	final asc - hdr • preliminary asc - hdr • cast •	final csv-plot • preliminary csv-plot • metadata •

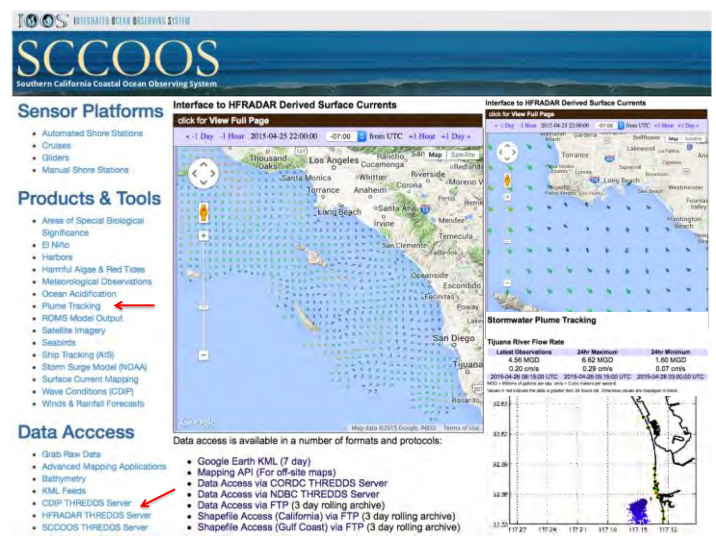
* Latest update: 12Mar2015: **CalCOFI 1501NH preliminary CTD** data posted; **1311 Final bottle-corrected CTD** data & plots posted

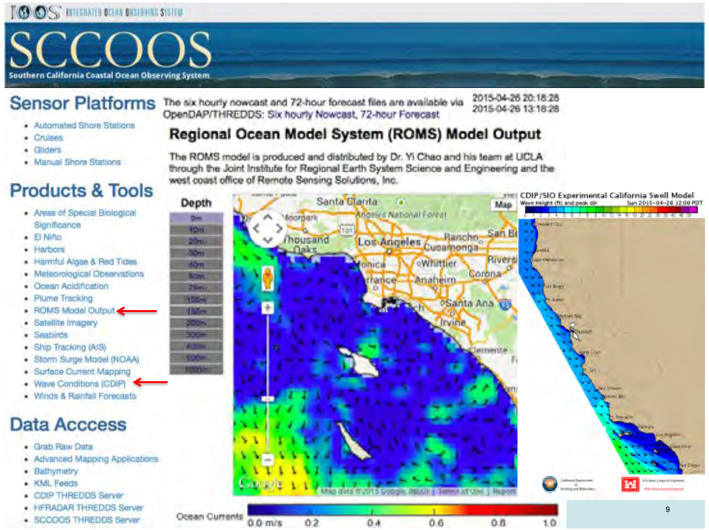
NOAA FISHERIES 4

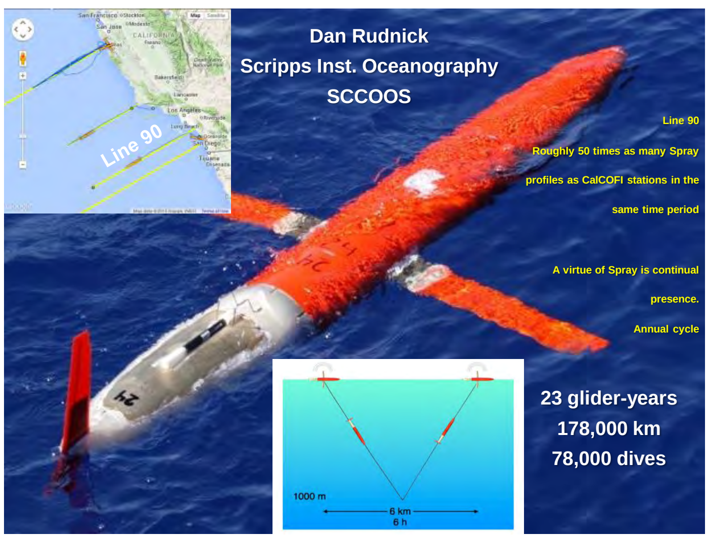

Existing Information (CalCOFI)
>> Net Sampling - Bongo Net Displacement Volumes
Online Databases
MacroZooplankton
Biomass Data
Wet displacement volume from starboard side of Bongo Net
Data Zoo
CalCOFI Data
download, plot, filter
IchthyoDB
Ichthyoplankton DB
Mark Ohman Lab
ZooDB
Zooplankton Database
Mark Ohman Lab
Pelagic Invert DB
Collection Search Form
SIO
>> Underway Sampling
Maps, Data, & DataBases
ADCP, TSG & Meteorological
Underway Data
Information
CUFES
SWFSC-FRD Egg Maps
Information
Mammal Observations
Census
Census Log
Bird Observations
Census
Census Log
NOAA FISHERIES
5


HYDROGRAPHIC STATION
NET TOW STATION
SCCOOS STATION
DIRECTION OF TRAVEL
potential added buoy
Del Mar buoy
34°N
30°N
Catalina Sea Ranch (KZO)
Rose Canyon (Hubbs)
CALCOFI STATIONS
potential added SCCOOS station
122°W
118°W
DIC
pH


IOOS
SCCOOS
Southern California Coastal Ocean Observing System
SCCOOS is one of eleven regions that contribute to the national U.S. IOOS.
The primary goal of SCCOOS is to provide the scientific data and information needed to inform decision-making and better understand the changing conditions of the coastal ocean in So. California.
SCCOOS brings together coastal observations in the So. California Bight to provide information necessary to address:
• climate change,
• ecosystem preservation and management,
• coastal water quality,
• maritime operations,
• coastal hazards. and
• national security.
click for Full Page View
create link for bookmark
LEGEND
NOAA FISHERIES
7

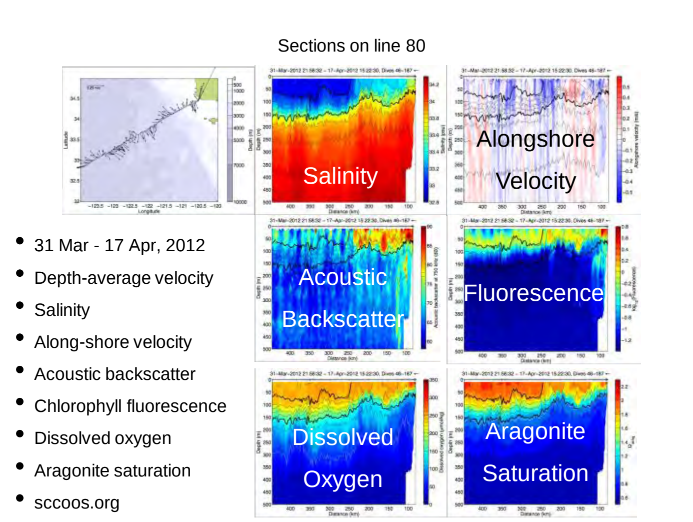

IOOS
SCCOOS
Southern California Coastal Ocean Observing System
Sensor Platforms
Automated Shore Stations
Cruises
Gliders
Manual Shore Stations
Products & Tools
Areas of Special Biological Significance
El Niño
Harbors
Harmful Algae & Red Tides
Meteorological Observations
Ocean Acidification
Plume Tracking
ROMS Model Output
Satellite Imagery
Seabirds
Ship Tracking (AIS)
Storm Surge Model (NOAA)
Surface Current Mapping
Wave Conditions (CDIP)
Winds & Rainfall Forecasts
Data Acccess
Grab Raw Data
Advanced Mapping Applications
Bathymetry
KML Feeds
CDIP THREDDS Server
HFRADAR THREDDS Server
SCCOOS THREDDS Server
Interface to HFRADAR Derived Surface Currents
click for View Full Page
Stormwater Plume Tracking
Tijuana River Flow Rate
Data access is available in a number of formats and protocols:
• Google Earth KML (7 day)
• Mapping API (For off-site maps)
• Data Access via CORDC THREDDS Server
• Data Access via NDBC THREDDS Server
• Data Access via FTP (3 day rolling archive)
• Shapefile Access (California) via FTP (3 day rolling archive)
• Shapefile Access (Gulf Coast) via FTP (3 day rolling archive)

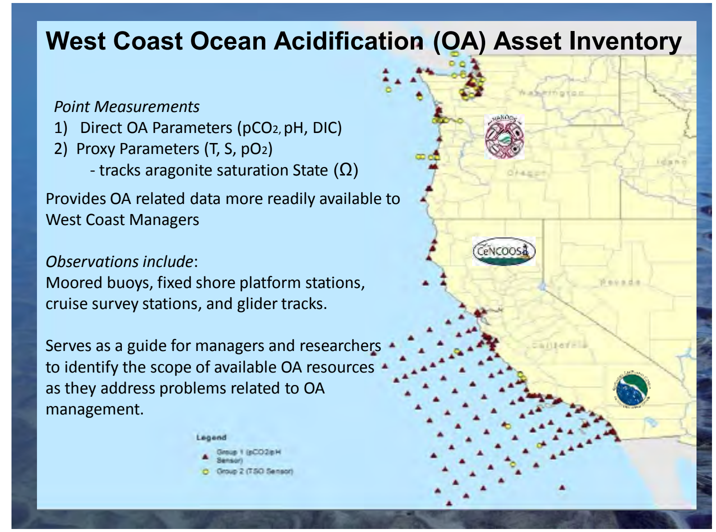


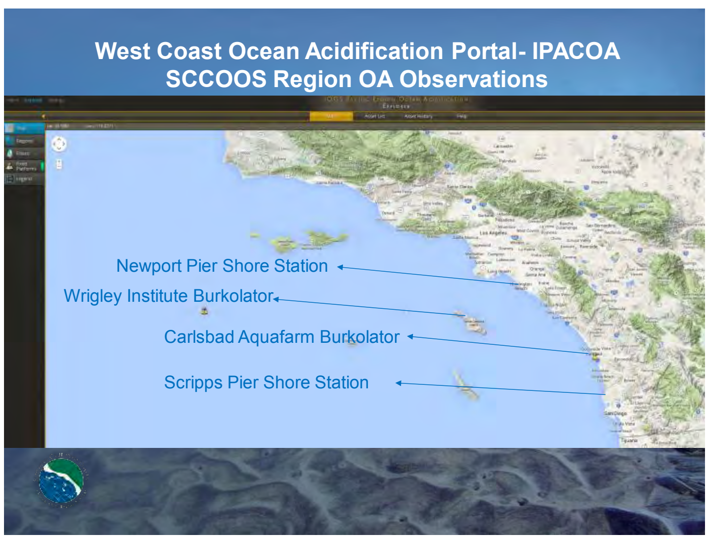


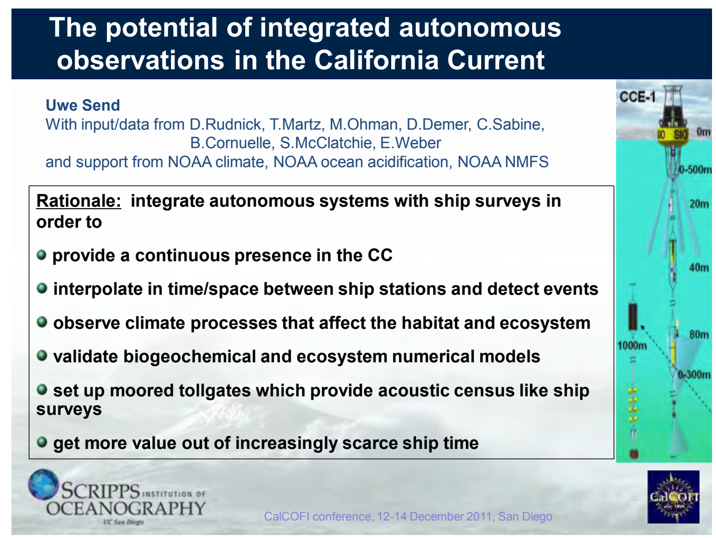
Mission on line 90

Rudnick, SIO


Sections on line 80
31 Mar - 17 Apr, 2012
Depth-average velocity
Salinity
Along-shore velocity
Acoustic backscatter
Chlorophyll fluorescence
Dissolved oxygen
Aragonite saturation
sccoos.org
Salinity
Alongshore Velocity
Acoustic Backscatter
Fluorescence
Dissolved Oxygen
Aragonite Saturation

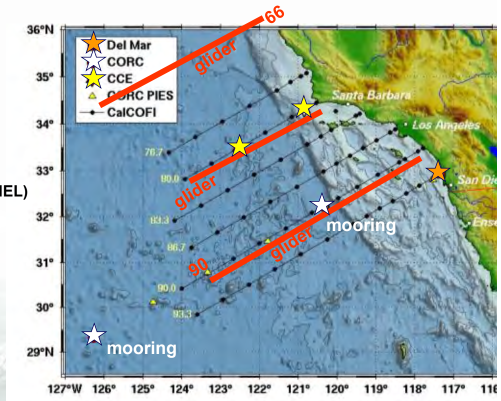

West Coast Ocean Acidification (OA) Asset Inventory
Point Measurements
1) Direct OA Parameters (pCO2, pH, DIC)
2) Proxy Parameters (T, S, pO2)
- tracks aragonite saturation State (Ω)
Provides OA related data more readily available to West Coast Managers
Observations include:
Moored buoys, fixed shore platform stations, cruise survey stations, and glider tracks.
Serves as a guide for managers and researchers to identify the scope of available OA resources as they address problems related to OA management.
Legend


West Coast Ocean Acidification Portal- IPACOA
SCCOOS Region OA Observations
Newport Pier Shore Station
Wrigley Institute Burkolator
Carlsbad Aquafarm Burkolator
Scripps Pier Shore Station


The potential of integrated autonomous observations in the California Current
Uwe Send
With input/data from D.Rudnick, T.Martz, M.Ohman, D.Demer, C.Sabine, B.Cornuelle, S.McClatchie, E.Weber
and support from NOAA climate, NOAA ocean acidification, NOAA NMFS
Rationale: integrate autonomous systems with ship surveys in order to
provide a continuous presence in the CC
interpolate in time/space between ship stations and detect events
observe climate processes that affect the habitat and ecosystem
validate biogeochemical and ecosystem numerical models
set up moored tollgates which provide acoustic census like ship surveys
get more value out of increasingly scarce ship time
CCE-1
0m
0-500m
20m
40m
80m
1000m
0-300m
SCRIPPS INSTITUTION OF OCEANOGRAPHY
CalCOFI conference, 12-14 December 2011, San Diego

Climate and event scale examples from gliders and moorings

- IDG Spray gliders along Lines 90, 80, 66 (Rudnick)
- surface moorings on Line 80 (Send, Ohman, Demer, PMEL)
- Transport moorings on Line 90
- Surface mooring on shelf on Line 93



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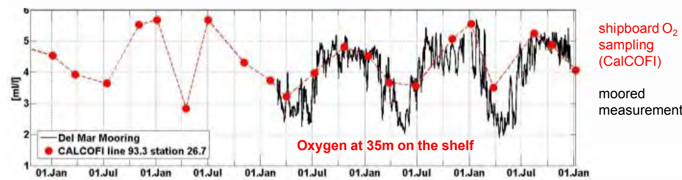
CalCOFI conference, 12-14 December 2011, San Diego

Continuous presence fills the sampling gap in time

Need continuous measurements to understand or guide in-situ sampling



With moored instruments **"we can resolve the fast temporal scales in order to understand ecosystem dynamics"**.

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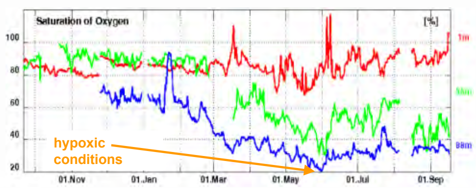
CalCOFI conference, 12-14 December 2011, San Diego

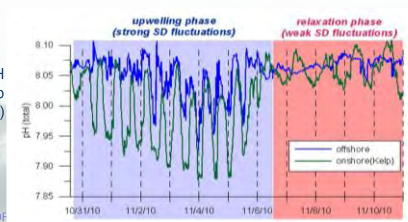
Hypoxic events and pH variability on the shelf

Low-oxygen and low-pH <u>events</u> ("corrosive water", Feely et al 2008) can be observed on the shelf:

Real-time data from mooring, now also near-bottom pH from T.Martz



Large semi-diurnal pH fluctuation in the La Jolla kelp bed (L.Levin, C.Frieder)



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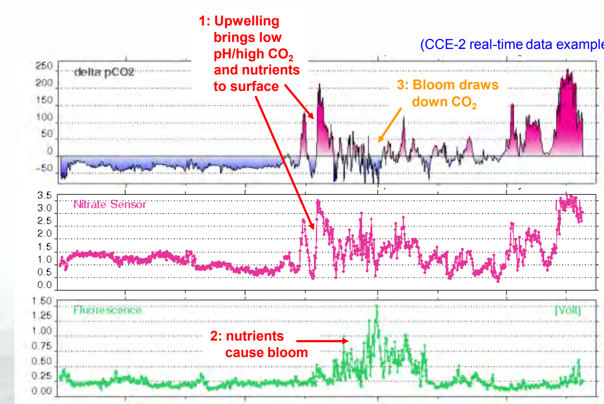
Example for sequence of events directly observed



SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego

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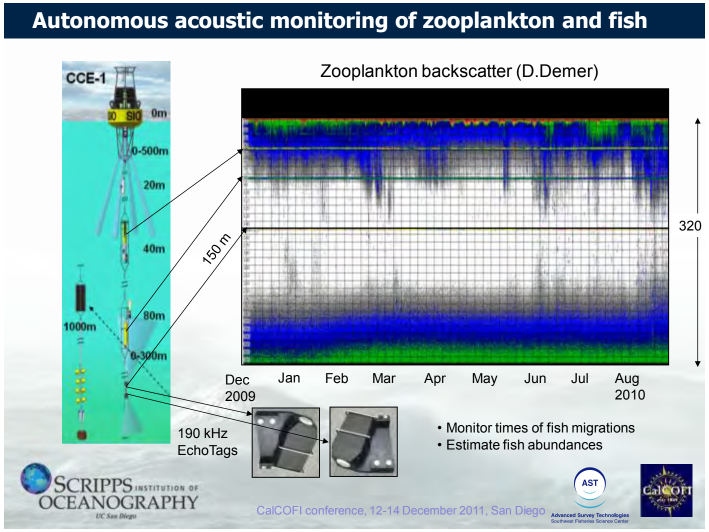

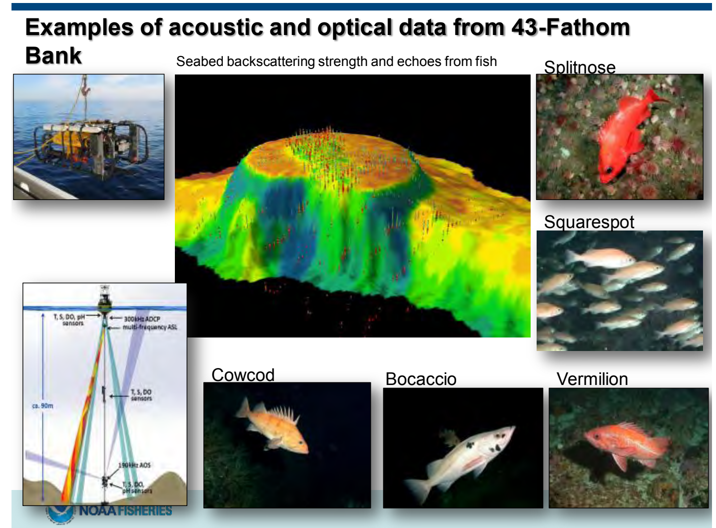

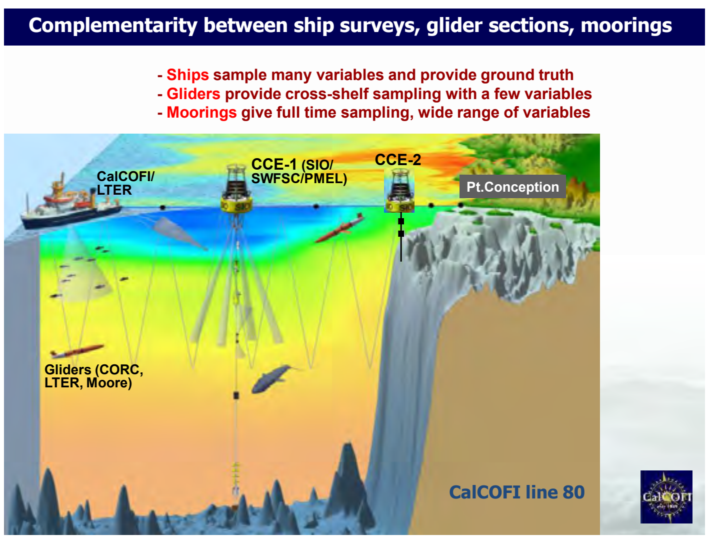

Where are the data gaps?

(all of which are either underway or within reach)

- Scales:
  - Collecting information at the level of offshore sites
  - Modeling at the scales relevant to individual sites
- Benthic environment
- Genetics ('omics)

NOAA FISHERIES

SCCOOS

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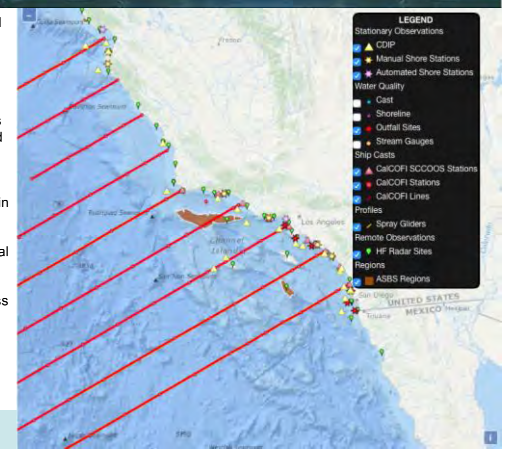
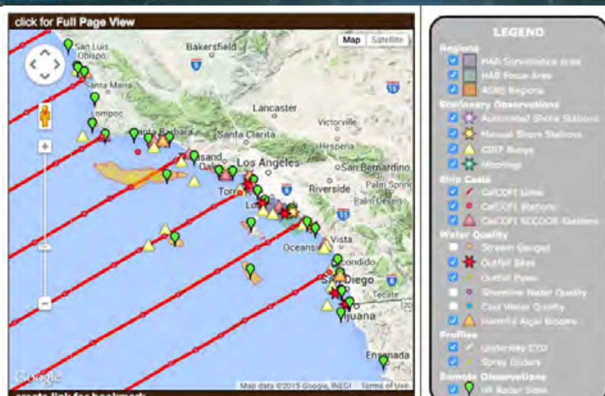


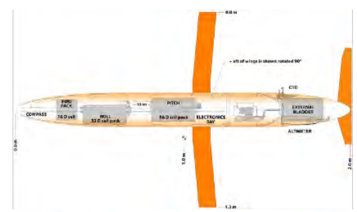
NOAA FISHERIES

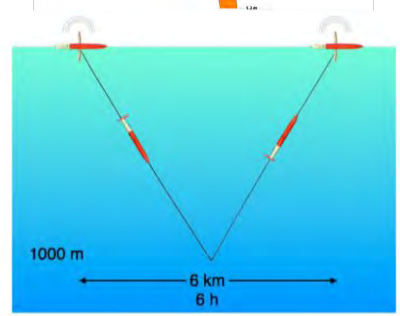
SCCOOS

Southern California Coastal Ocean Observing System



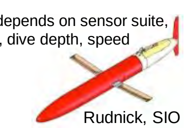
NOAA FISHERIES 27





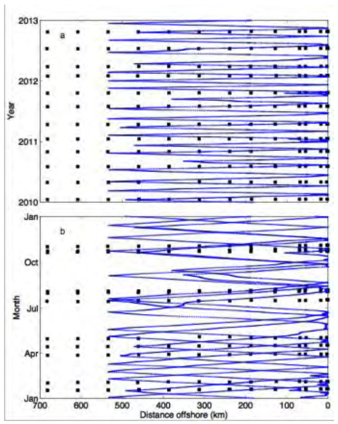
Spray underwater glider

- Weight: 50 kg, length: 2 m, wingspan: 1 m
- Profiles by changing buoyancy
- Steers by changing center of mass
- 2-way Iridium communication
- GPS navigation
- Pressure, temperature, salinity, velocity, chlorophyll fluorescence, acoustic backscatter, nitrate, optical backscatter, dissolved oxygen, ...
- Cycle 0-1000 m, 6 km, 6 h
- Horizontal velocity: 0.25 m/s
- Vertical velocity: 0.1 m/s
- Typical duration: 3-5 months
- Endurance depends on sensor suite, stratification, dive depth, speed



Rudnick, SIO

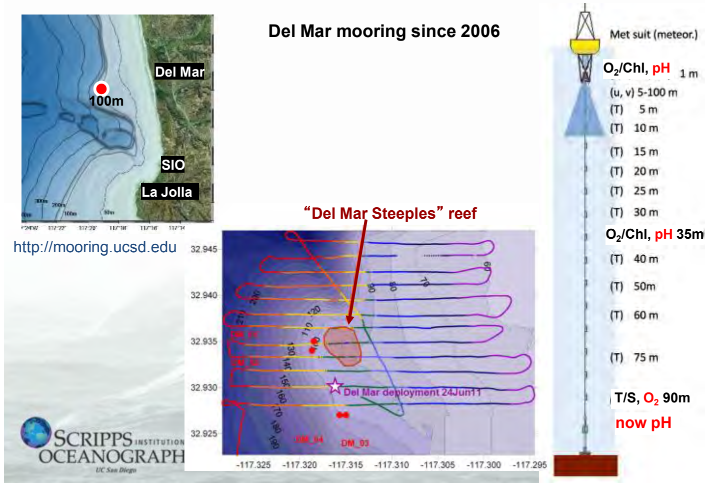
Spray sampling



- Line 90
- Roughly 50 times as many Spray profiles as CalCOFI stations in the same time period
- A virtue of Spray is continual presence.
- Annual cycle

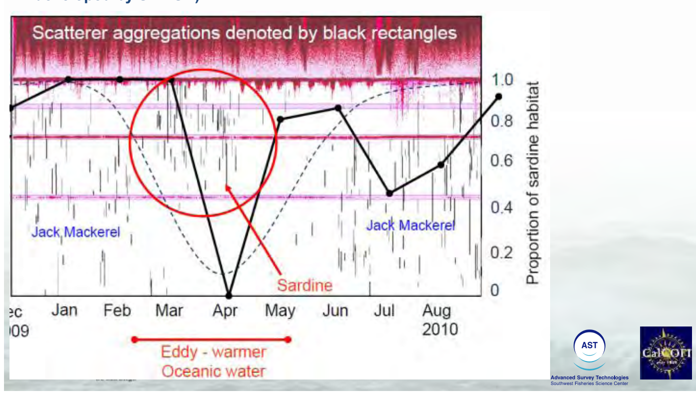
Rudnick, SIO

Real-time shelf mooring: acidification, hypoxia, corrosive intrusions

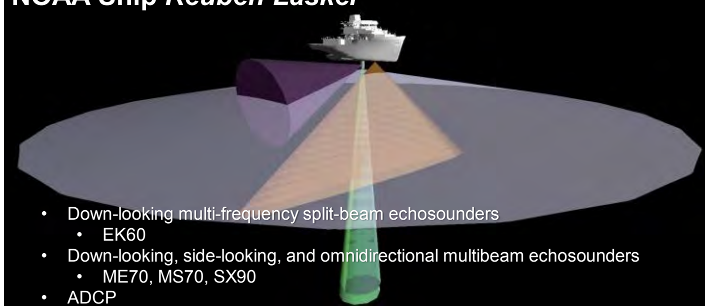


Mooring detecting switch in habitats (from D.Demer):

- acoustic mooring data reveal a shift in type of aggregations, interpreted to be a shift from mackerel to sardine during March/April
- coincides with the appearance of warmer water (eddy) and forcing sardine habitat closer to shore and the mooring (heavy black line, based on a sardine habitat model developed by SWFSC).

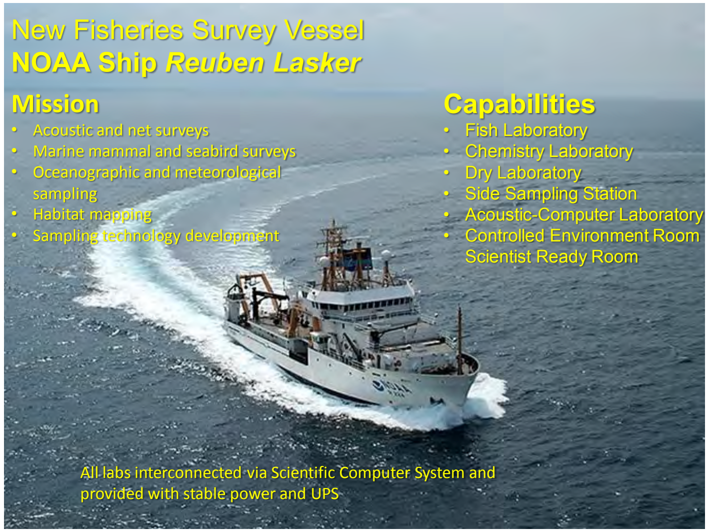


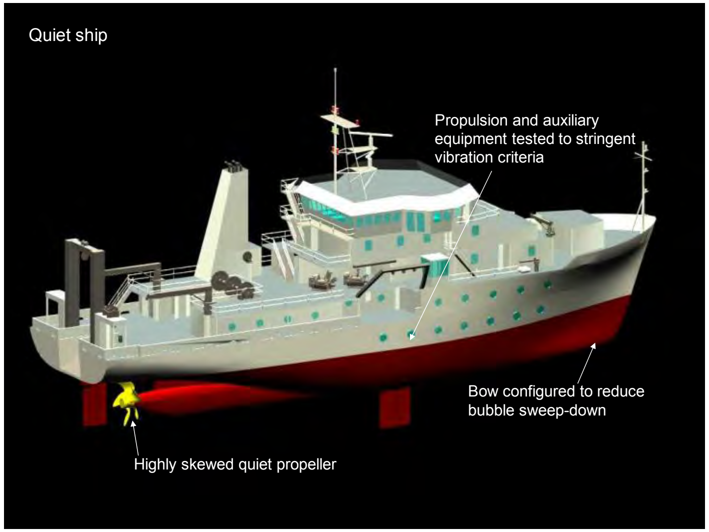
New Fisheries Survey Vessel
NOAA Ship *Reuben Lasker*



- Down-looking multi-frequency split-beam echosounders
  - EK60
- Down-looking, side-looking, and omnidirectional multibeam echosounders
  - ME70, MS70, SX90
- ADCP
- Passive sonar
- Self-noise monitoring
- Acoustic release
- Vehicle tracking (ROV, AUV)

NOAA FISHERIES





New Fisheries Survey Vessel
NOAA Ship *Reuben Lasker*

NOAA FISHERIES

SWFSC Ocean Technology Development Tank

Expanding NOAA's ability to develop and apply advanced technologies for surveys of fisheries resources and their associated ecosystems and to foster collaborations on fisheries management issues

- ***Dimensions***
  - 20 m (L) x 10 m (W) x 10 m (D)
- ***Capacity***
  - 2,000,000 L (528,000 gal)
- ***Environmental range***
  - Temperature: 2-25°C
  - Salinity: 0 to 35 ppt
- ***Other attributes***
  - Vibration and seismic isolation
  - Advanced filtration with 12-h recirculation cycle
  - Life support for live animals
  - Nine observation ports with live CCTV viewing

NOAA FISHERIES

SWFSC Ocean Technology Development Tank

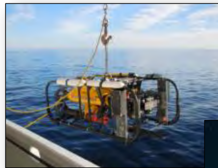
Enables calibrations and highly constrained experiments in filtered seawater environment

A test bed for:

- *Remotely operated vehicles (ROVs)*
- *Autonomous underwater vehicles (AUVs)*
- *Instrumented buoys*
- *Active acoustics*
- *Passive acoustics*
- *Unmanned aerial vehicles (UAVs)*
- *Stereo cameras*
- *Light-field camera*

- *Calibrations improve data quality and precision of population estimates*
- *Ability to test seagoing equipment without going to sea saves time and money, both of which are often limited*

Remotely operated vehicle (ROV)



Time-lapse camera and Acoustic-optical sampler (AOS)

Autonomous underwater vehicle (AUV)

NOAA FISHERIES

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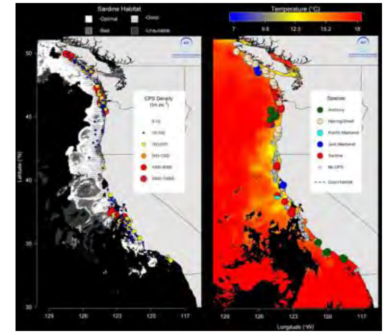
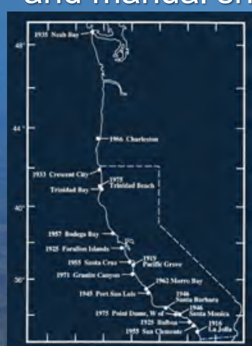


The distribution and abundance of coastal pelagic species (e.g., anchovy, sardine, mackerel) from acoustic-trawl surveys

- Improvements of the acoustic processing methods, made possible by better estimates of acoustic signatures from individual species, will further refine estimates of important species.

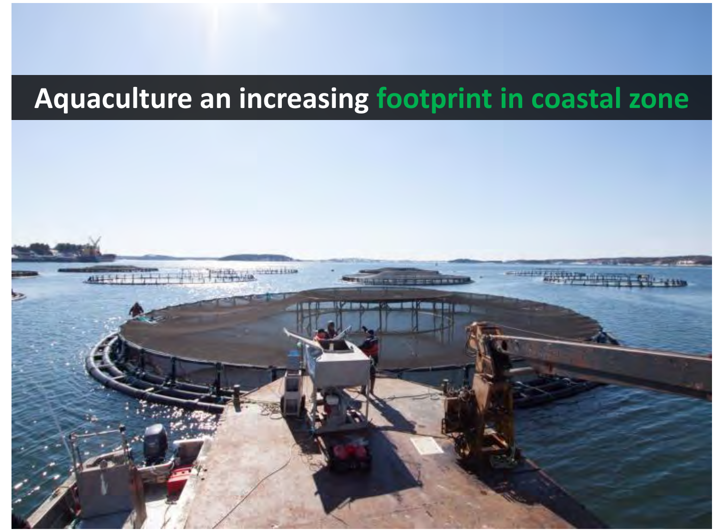
NOAA FISHERIES

Nearshore measurements from automated and manual shore stations since 1916



Data collected (varies by station)
temperature, salinity, chlorophyll fluorescence, turbidity/transmissivity, dissolved oxygen, pH, water level, meteorological variables, phytoplankton & algal toxins to detect Harmful Algal Blooms (HABs)


OFFSHORE AQUACULTURE IN CALIFORNIA: SCIENCE TOOLS TO SUPPORT COASTAL PLANNING AND DECISION-MAKING
Kenneth Riley and James Morris
NOAA National Ocean Service
National Centers for Coastal Ocean Science
Ken.Riley@noaa.gov


Aquaculture an increasing footprint in coastal zone


Aquaculture an increasing footprint in coastal zone

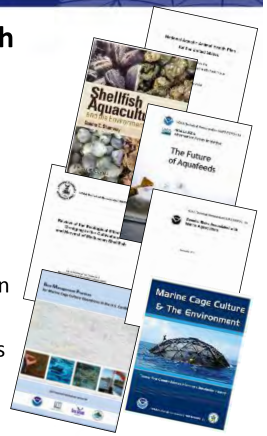

UNITED WE FISH
American Seafood 86% Fisheries Trade Deficit WHO'S RESPONSIBLE?
It's no secret that there is going to be opposition
FISH!

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Collaborative Research Makes A Difference

OAR, NOS, NMFS

- Feeds
- Genetics
- Benthic impacts
- Ecosystem impacts
- GIS models for site selection
- Aquatic animal health
- Best Management Practices
- Science outreach



CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Our Mission

We provide tools and services for coastal managers empowering them to maintain healthy, resilient ecosystems while supporting aquaculture development in the coastal zone.

Our Focus

Environmental assessments and forecasts
Marine spatial planning and siting
Climate change effects

NATIONAL OCEAN SERVICE

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NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Aquaculture Coastal Planning Tools

Marine Spatial Planning

- Regional ocean mappers
- State siting atlases
- Habitat digitizer (delineate habitats from geo-referenced images)

Examples:

- NOAA Digital Coast
- Connecticut Shellfish Aquaculture Atlas
- North Carolina Shellfish Aquaculture Siting Tool

Environmental Models

AquaModel

- *Gulf of Mexico*
- *Hawaii*
- *California*

Farm Aquaculture Research Model (FARM)

- *Long Island Sound*
- *Chesapeake Bay*

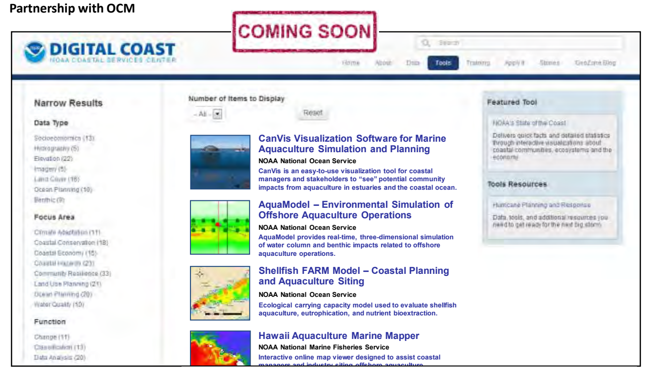
Tool and Data Center

- Marine Cage Culture and the Environment
- Guidelines for Environmental Monitoring Offshore Aquaculture Operations
- Best Management Practices for Offshore Aquaculture in the US Caribbean

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Coastal Aquaculture Planning Portal

Partnership with OCM



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Aquaculture in Southern California Bight

- What is the opportunity?
- How much space will it take up?
- What will the industry look like?
- What are the environmental impacts?

NATIONAL OCEAN SERVICE

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NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Southern California Aquaculture Opportunity at a Glance

- Rose Canyon Project would be first commercial-scale demonstration project in federal waters
- Preliminary MSP studies suggest that >500 km^2 of coastal ocean could support aquaculture development
- Economic projections suggest offshore aquaculture in Southern California Bight could become $1 billion/year industry

CAPES
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NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

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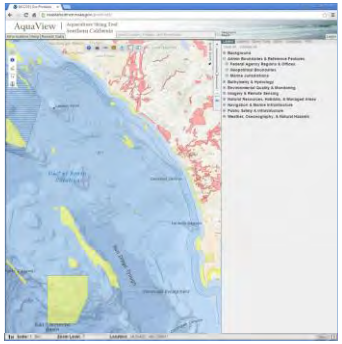
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

California AquaView

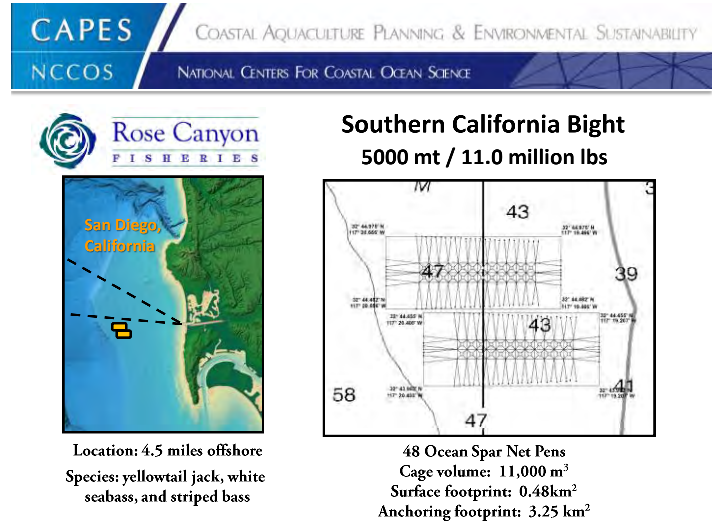
A Planning and Siting Guide for Offshore Aquaculture in Southern California

- ✓ Data for site-selection
- ✓ Identifies unsuitable areas
- ✓ Mapping for co-siting
- ✓ Identifies use conflicts
- ✓ Tool for industry and managers



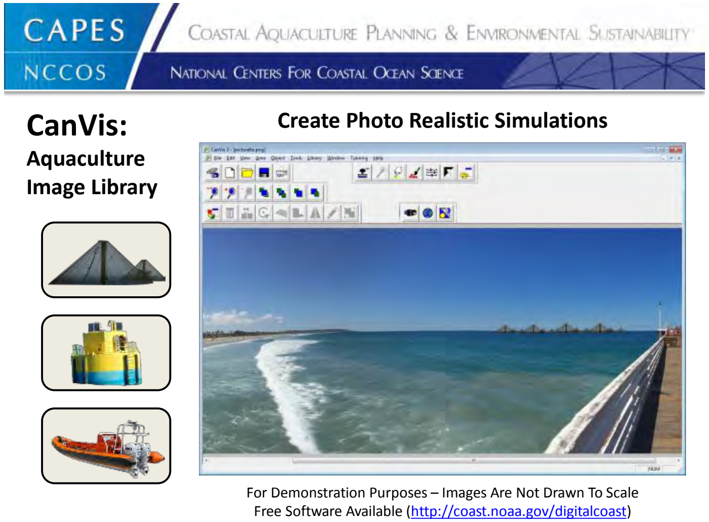
Mapping Habitat Areas of Particular Concern in Southern California Bight


What will the industry look like?
Mission Beach
San Diego, California
Photo by Rafael Rivera


CAPES
COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
Rose Canyon
FISHERIES
Southern California Bight
5000 mt / 11.0 million lbs
San Diego, California
43
47
39
43
58
41
47
Location: 4.5 miles offshore
Species: yellowtail jack, white seabass, and striped bass
48 Ocean Spar Net Pens
Cage volume: 11,000 m³
Surface footprint: 0.48km²
Anchoring footprint: 3.25 km²

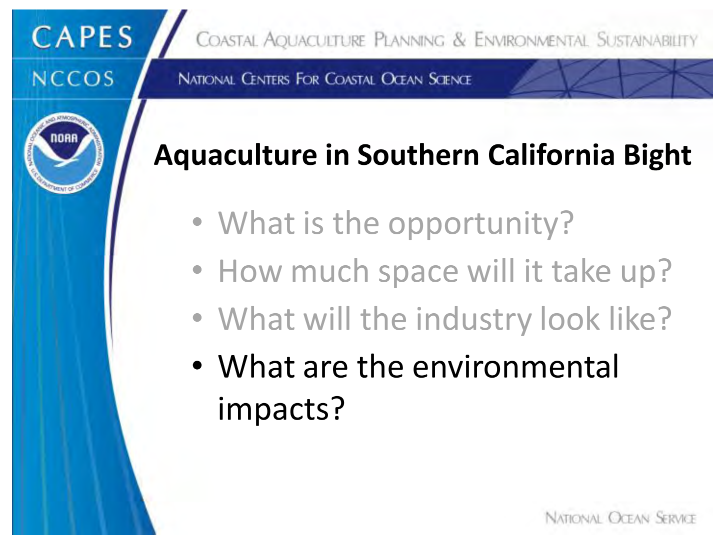

What will the industry look like?
The Concern


What will the industry look like?
The Concern
Actual Coastal Planning
Cage location
5 miles offshore


CAPES
NCCOS
Coastal Aquaculture Planning & Environmental Sustainability
National Centers For Coastal Ocean Science
CanVis:
Aquaculture Image Library
Create Photo Realistic Simulations
For Demonstration Purposes – Images Are Not Drawn To Scale
Free Software Available (http://coast.noaa.gov/digitalcoast)


Creating the Simulation
9.14
Catamaran Resort
Height: 170 ft
Distance: 0.5 mi
Light pole
30 ft
Crystal Pier (872 ft long)
San Diego, California


What will the industry look like?
Mission Beach
San Diego, California


CAPES
NCCOS
Coastal Aquaculture Planning & Environmental Sustainability
National Centers For Coastal Ocean Science
Aquaculture in Southern California Bight
• What is the opportunity?
• How much space will it take up?
• What will the industry look like?
• What are the environmental impacts?
National Ocean Service

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Project Goal

To evaluate technology and operational tools used for siting offshore aquaculture operations that minimize effects on coastal ocean environments

Research Objectives

- **To develop a framework to evaluate marine aquaculture environmental effects models**
- **Conduct model simulations based on commercial-scale netpen operations in Southern California Bight**

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Research Objective

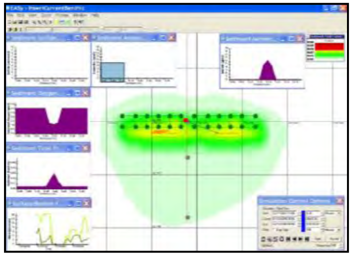
To develop a framework to evaluate marine aquaculture environmental effects models

- AquaModel
- DEPOMOD
- FARM
- MOM
- CSTT Model
- LESV
- ShellSIM
- EcoWin
- Longline
- DEB
- DDB
- Hydro

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Assess the applicability of environmental models within the context of site selection and marine spatial planning

- Application
- Relevance
- Scale
- Reliability
- Robustness
- Accuracy and Precision
- Cost effectiveness



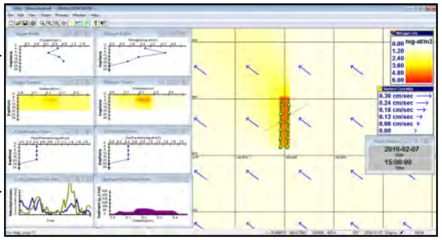
CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY
NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Research Objective

Conduct model simulations based on commercial-scale netpen operations in Southern California Bight

Depth profile plots →

Time series plots →



AquaModel provides real-time, 3D simulation of marine cage culture as well as associated flow and transformation of nutrients, oxygen, and particulate wastes

Expected Results and Project Benefits

- Provide tools and services to help coastal planners and managers make timely and confident decisions siting farms within the coastal ocean
- Develop environmental models and identify thresholds for pollutant effects (nutrient enrichment) that may indicate local and ecosystem level impacts
- Builds upon existing national data systems and develops specialized operational tools for marine spatial planning

CAPES — COASTAL AQUACULTURE PLANNING & ENVIRONMENTAL SUSTAINABILITY

NCCOS — NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Questions?

Kenneth Riley
ken.riley@noaa.gov

Google NOAA Aquaculture
NCCOS Aquaculture

http://coastalscience.noaa.gov/research/scem/marine_aquaculture

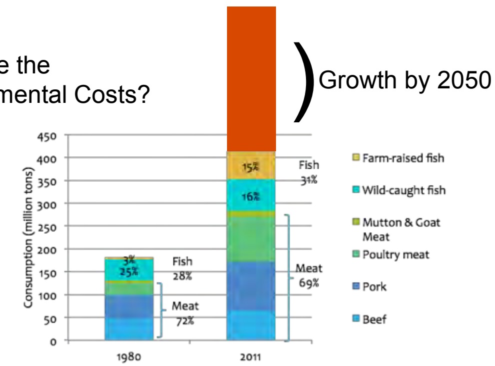
Spatial Planning for Open Ocean Aquaculture

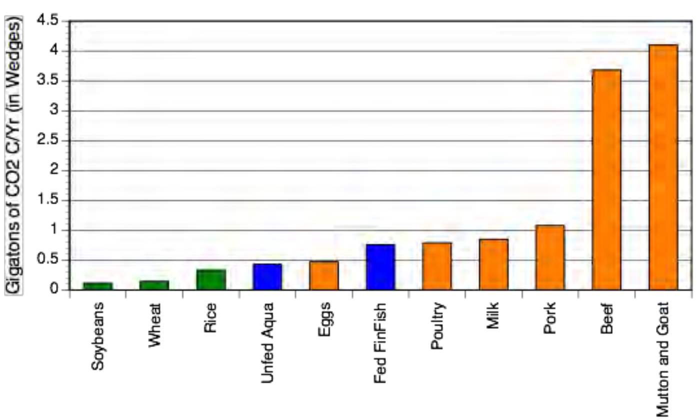
Steve Gaines, Rebecca Gentry, Sarah Lester
Bren School of Environmental Science and Management
University of California Santa Barbara

msi Marine Science Institute
Sea Grant
DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT UNIVERSITY OF CALIFORNIA, SANTA BARBARA

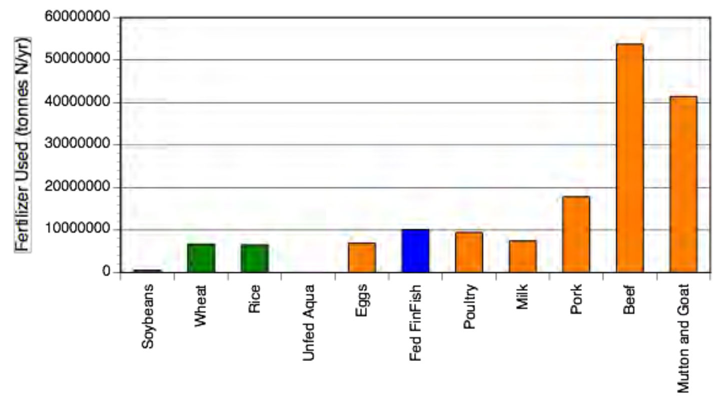
A Thought Experiment

What are the Environmental Costs?

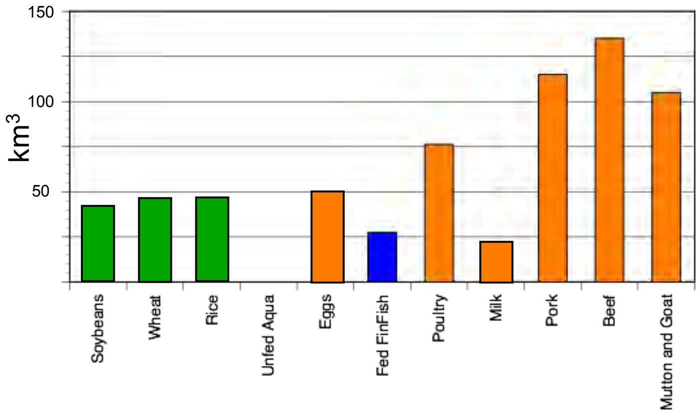




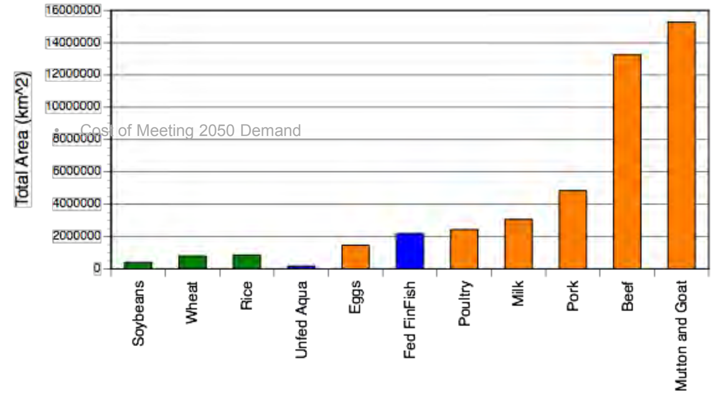
Greenhouse Gas Emissions



Fertilizer Demand



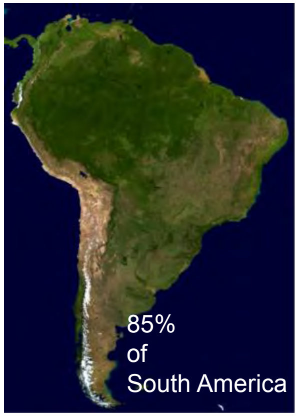
Water Used



Area Used

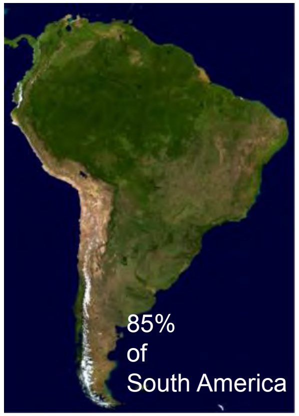
Thought Experiment

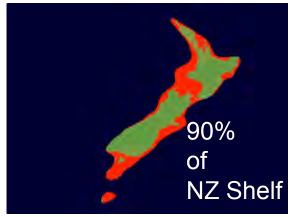
- Area needed by 2050



Thought Experiment

- Area needed by 2050



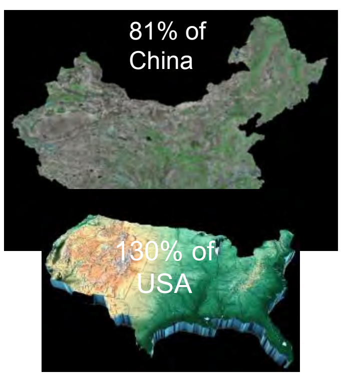


Thought Experiment

- Area needed by 2050

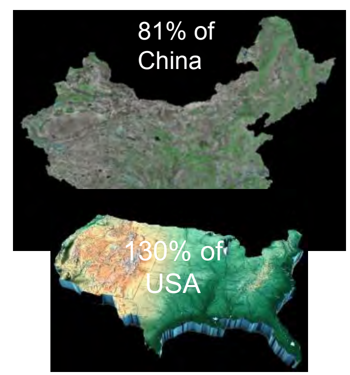
Thought Experiment

- Greenhouse Warming Potential
- (Gigatons CO2 Equiv) by 2050



Thought Experiment

- Greenhouse Warming Potential
- (Gigatons CO2 Equiv) by 2050



Thought Experiment

- Greenhouse Warming Potential
- (Gigatons CO2 Equiv) by 2050



Thought Experiment

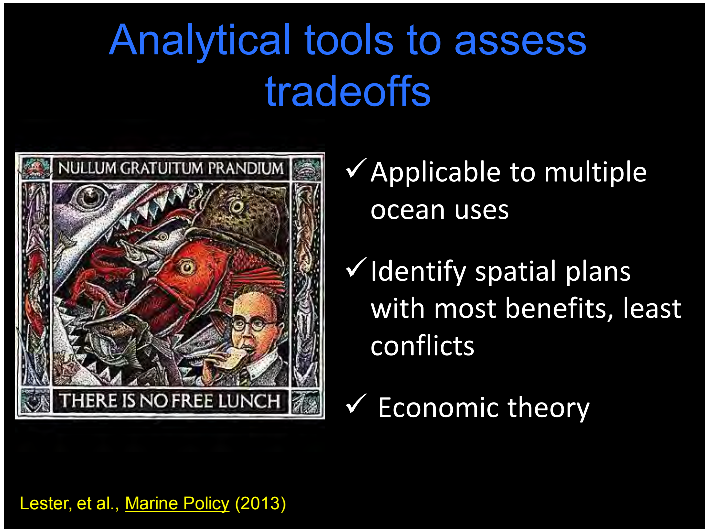
- Freshwater

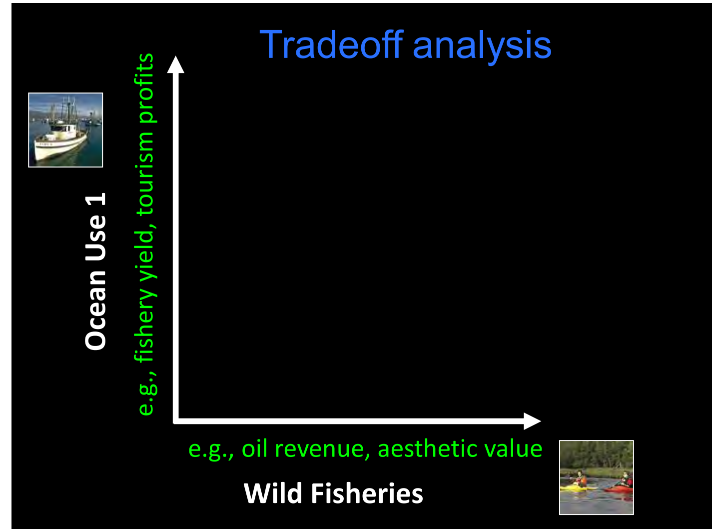

Thought Experiment

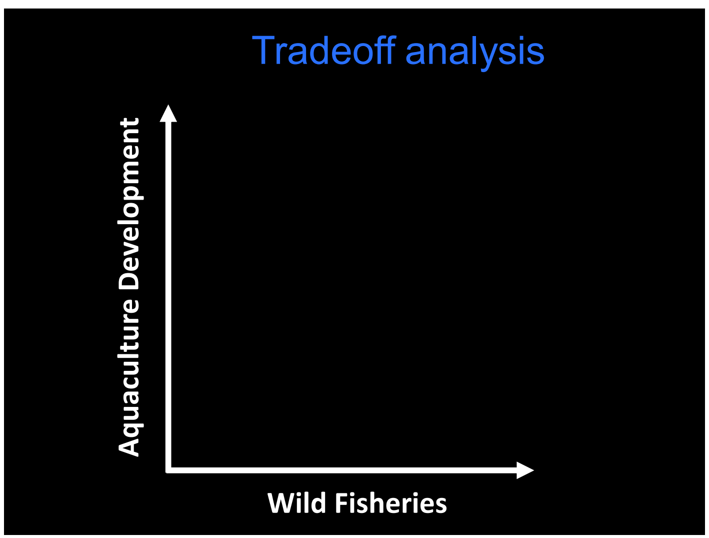
- Freshwater

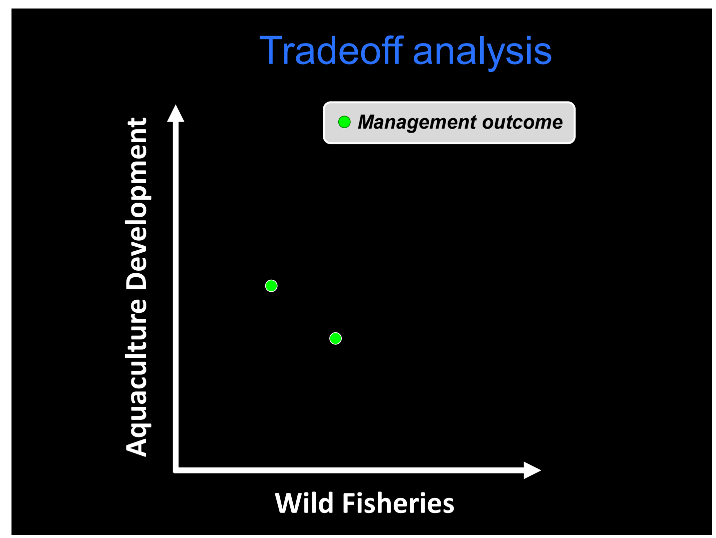
Thought Experiment

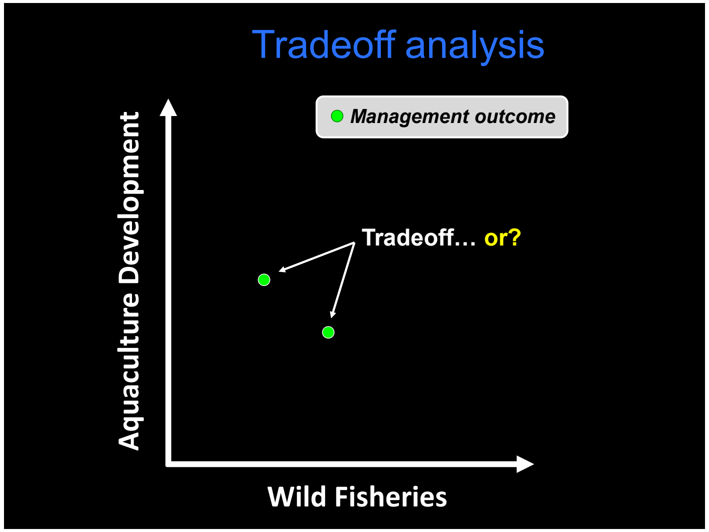
- Freshwater

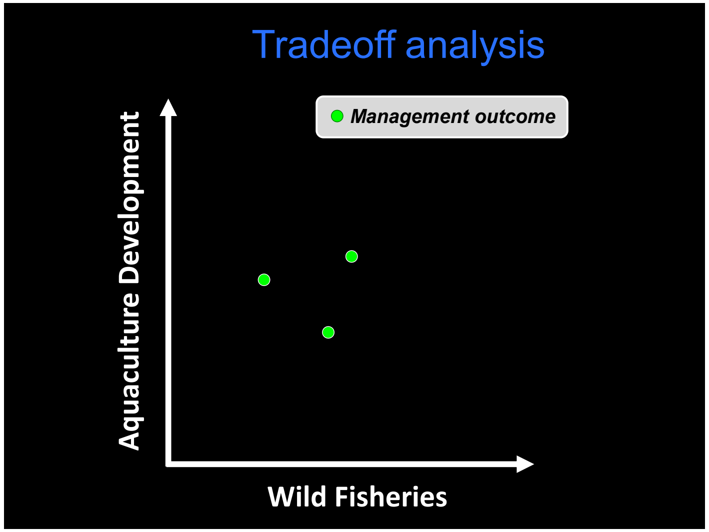

Analytical tools to assess tradeoffs
NULLUM GRATUITUM PRANDIUM
THERE IS NO FREE LUNCH
✓Applicable to multiple ocean uses
✓Identify spatial plans with most benefits, least conflicts
✓ Economic theory
Lester, et al., Marine Policy (2013)

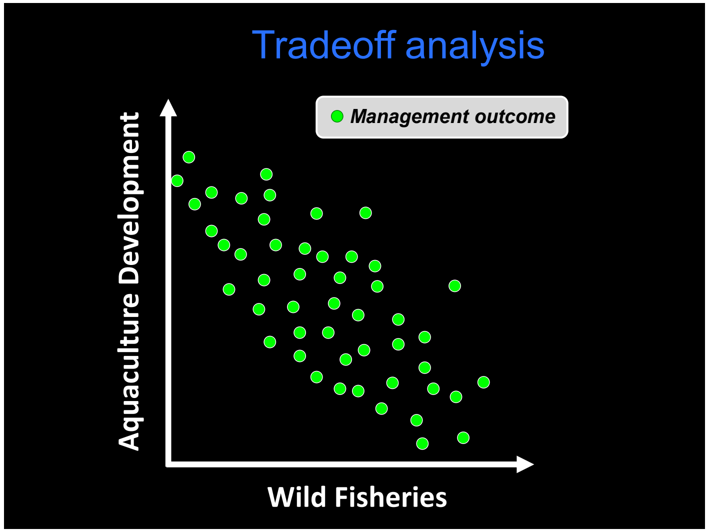

Tradeoff analysis
Ocean Use 1
e.g., fishery yield, tourism profits
e.g., oil revenue, aesthetic value
Wild Fisheries

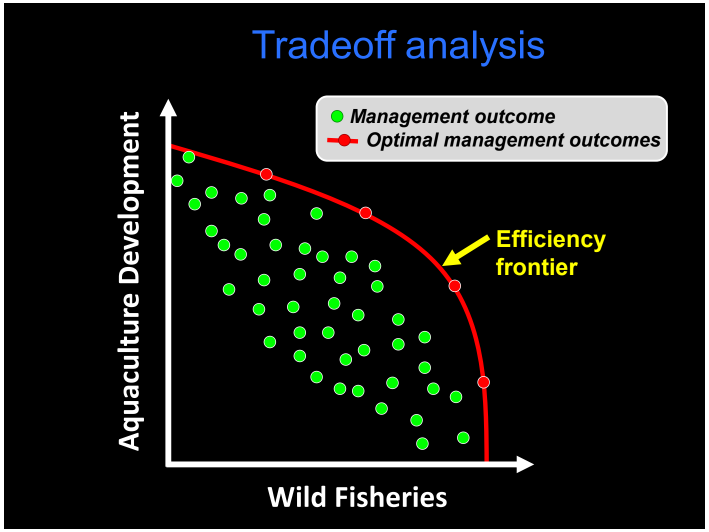

Tradeoff analysis
Aquaculture Development
Wild Fisheries

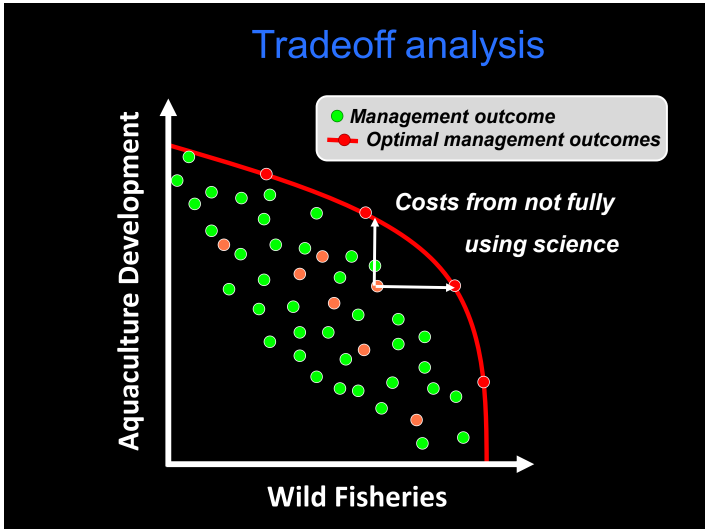

Tradeoff analysis
Management outcome
Aquaculture Development
Wild Fisheries

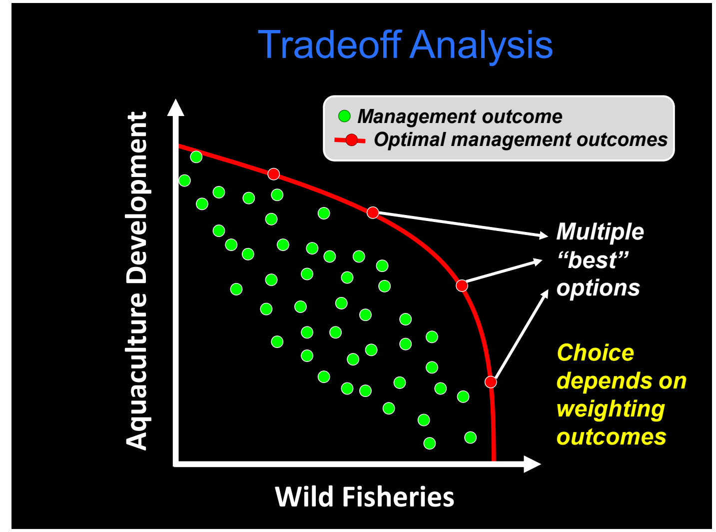

Tradeoff analysis
Management outcome
Tradeoff… or?
Aquaculture Development
Wild Fisheries


Tradeoff analysis
Management outcome
Aquaculture Development
Wild Fisheries


Tradeoff analysis
Management outcome
Aquaculture Development
Wild Fisheries

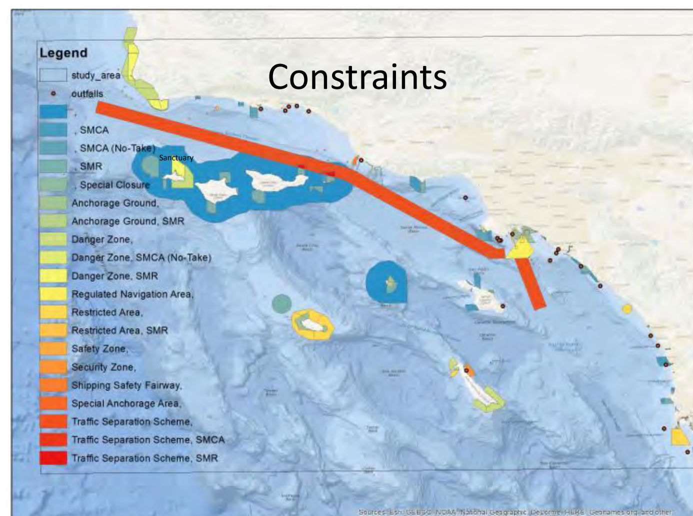

Tradeoff analysis
Management outcome
Optimal management outcomes
Efficiency frontier
Aquaculture Development
Wild Fisheries



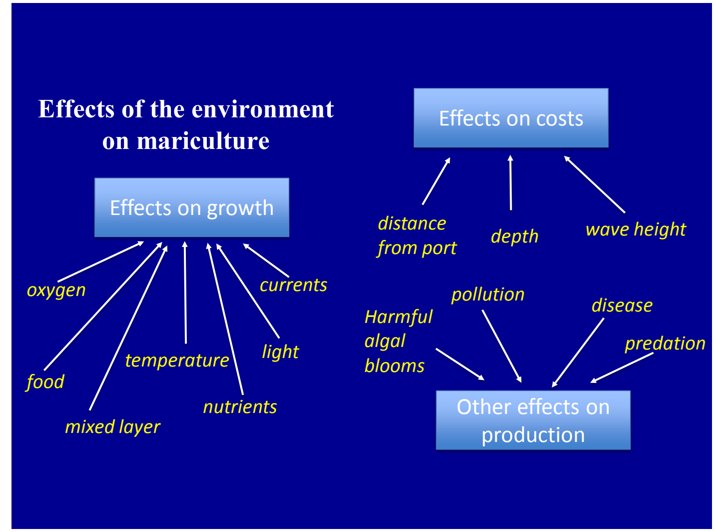


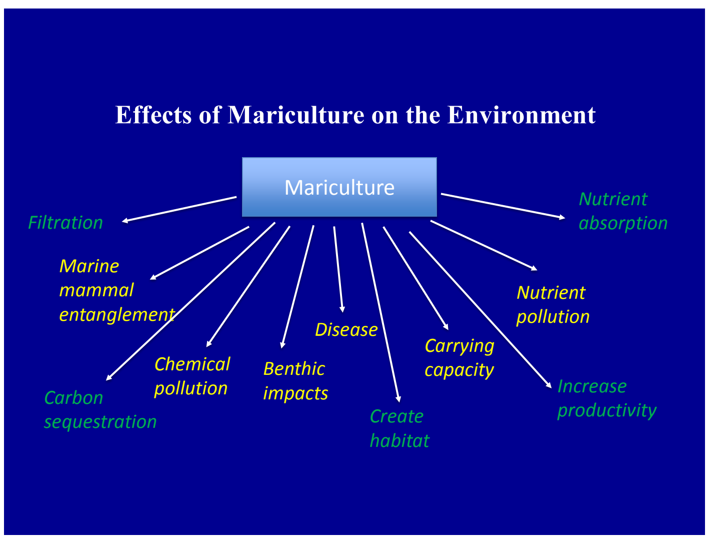
Aquaculture scenarios

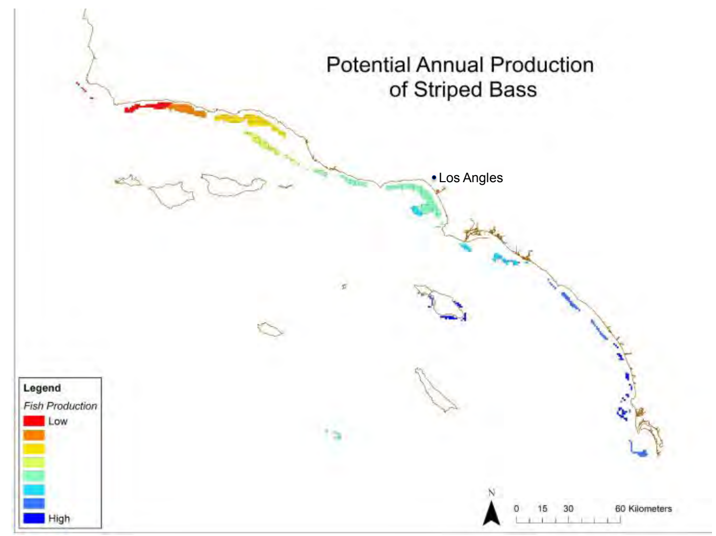
- Finfish net pens (striped bass)
- Bivalve long lines (Mediterranean mussel)
- Seaweed long lines (sugar kelp)

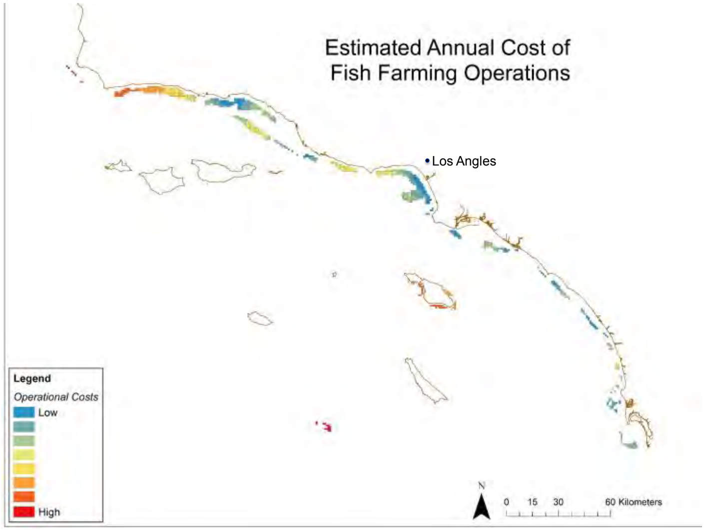


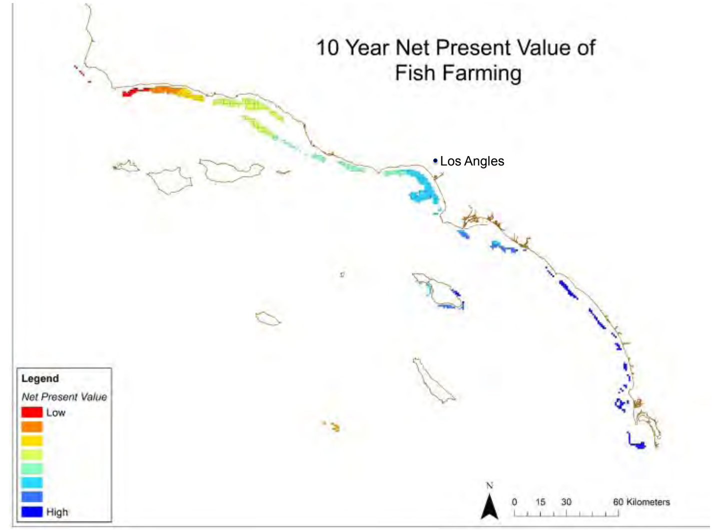

Developable areas
Legend
All
Fish
NoFish
Los Angeles
San Diego

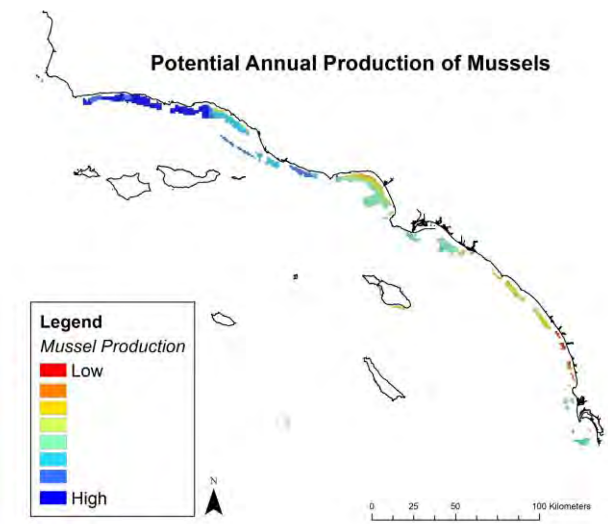

Effects of the environment on mariculture
Effects on growth
oxygen
food
mixed layer
temperature
nutrients
light
currents
Effects on costs
distance from port
depth
wave height
Other effects on production
Harmful algal blooms
pollution
disease
predation

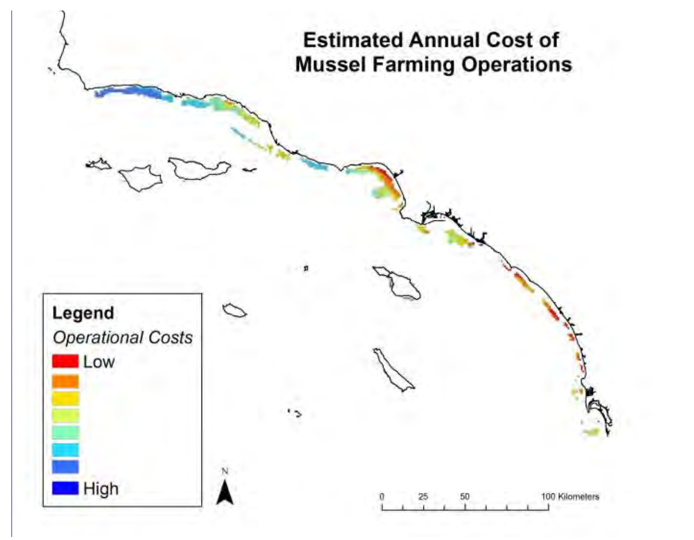

Effects of Mariculture on the Environment
Mariculture
Filtration
Marine mammal entanglement
Carbon sequestration
Chemical pollution
Benthic impacts
Disease
Create habitat
Carrying capacity
Increase productivity
Nutrient pollution
Nutrient absorption

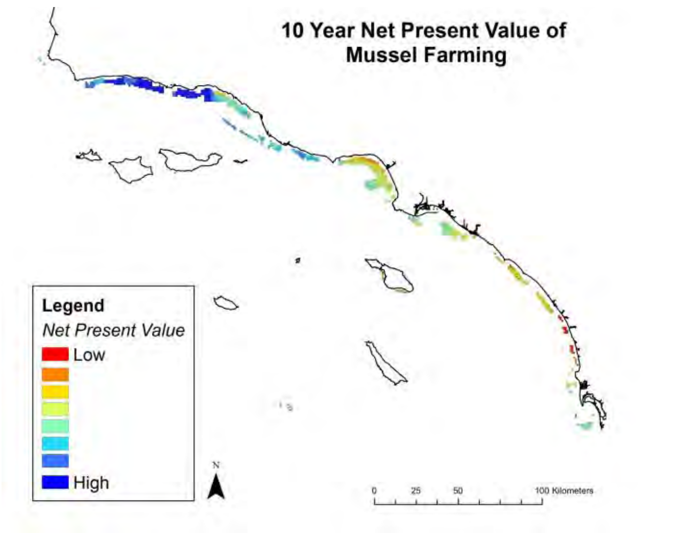

Potential Annual Production of Striped Bass
Los Angles
Legend
Fish Production
Low
High
N
0 15 30 60 Kilometers

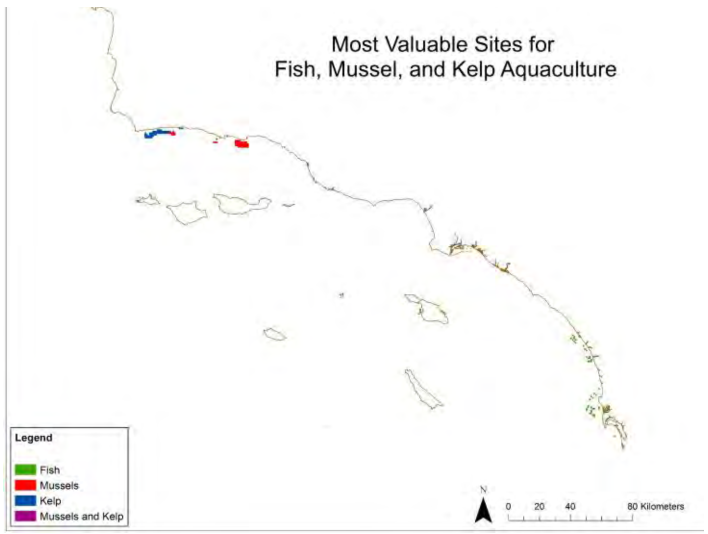

Estimated Annual Cost of
Fish Farming Operations
Los Angles
Legend
Operational Costs
Low
High
N
0 15 30 60 Kilometers

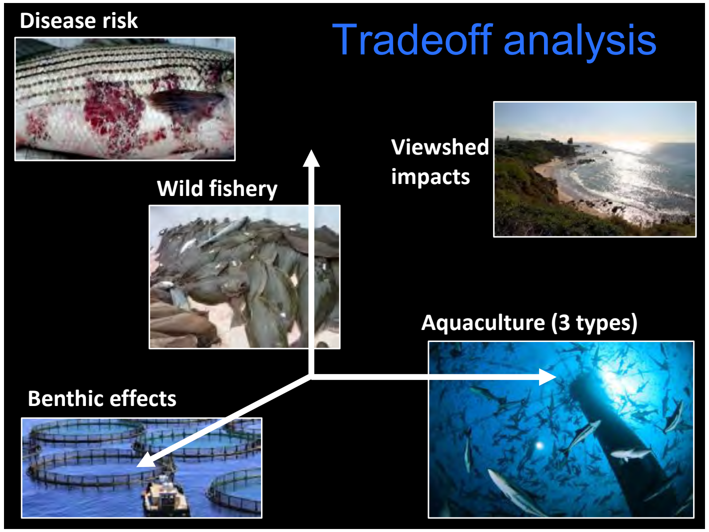

10 Year Net Present Value of
Fish Farming
Los Angles
Legend
Net Present Value
Low
High
N
0 15 30 60 Kilometers

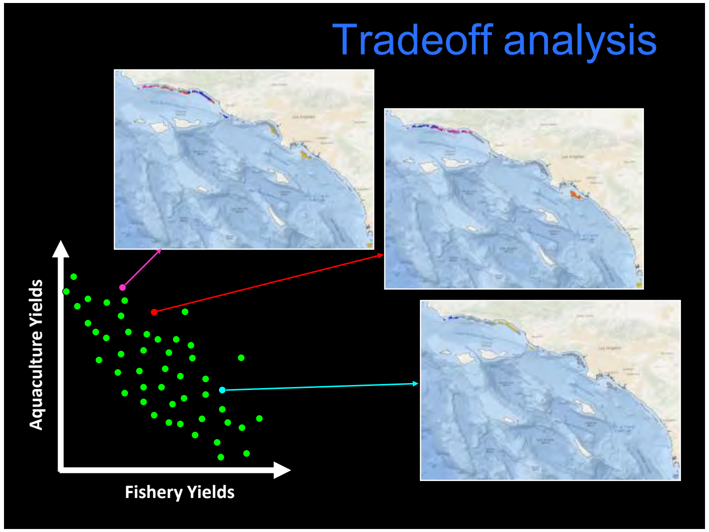

Potential Annual Production of Mussels
Legend
Mussel Production
Low
High
N
0 25 50 100 Kilometers

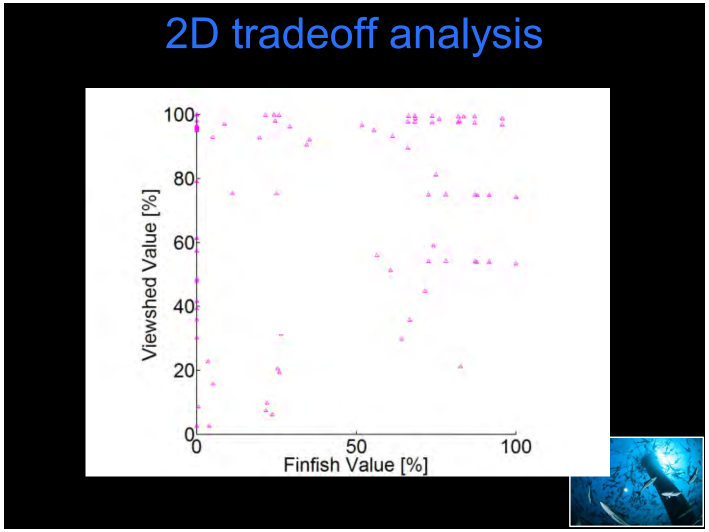

Estimated Annual Cost of
Mussel Farming Operations
Legend
Operational Costs
Low
High
N
0 25 50 100 Kilometers

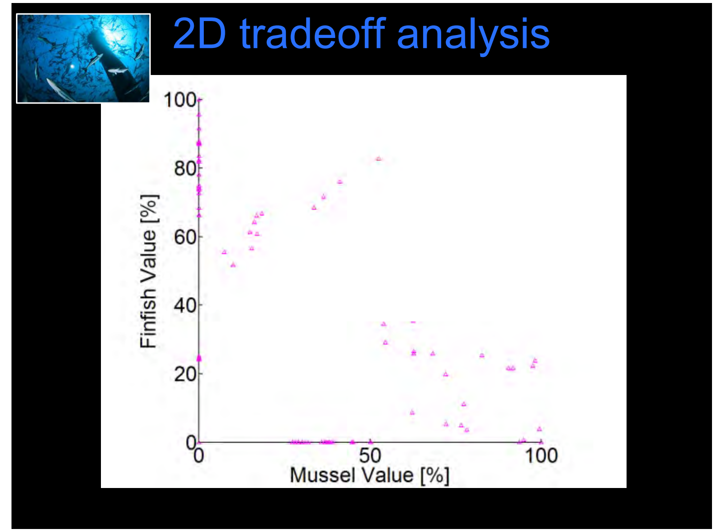

10 Year Net Present Value of
Mussel Farming
Legend
Net Present Value
Low
High
N
0 25 50 100 Kilometers

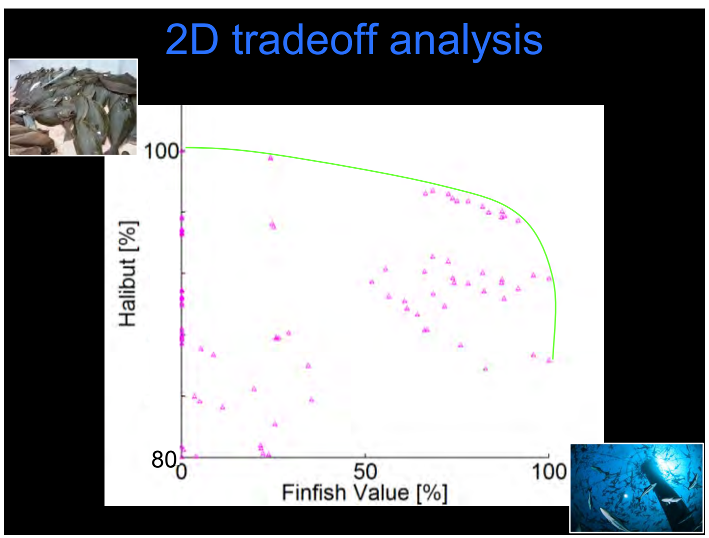

Most Valuable Sites for
Fish, Mussel, and Kelp Aquaculture
Legend
Fish
Mussels
Kelp
Mussels and Kelp
N
0 20 40 80 Kilometers

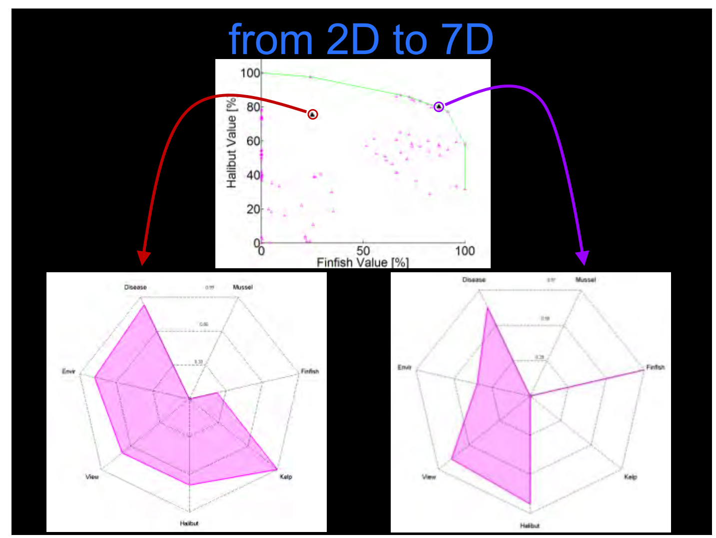

Tradeoff analysis
Disease risk
Wild fishery
Viewshed
impacts
Aquaculture (3 types)
Benthic effects


Tradeoff analysis
Aquaculture Yields
Fishery Yields

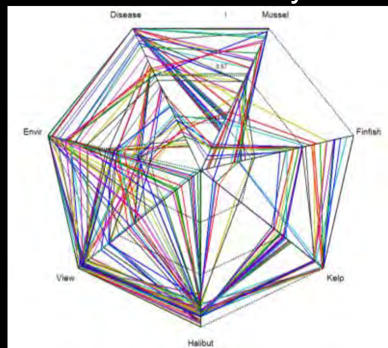

2D tradeoff analysis
Viewshed Value [%]
Finfish Value [%]
0
20
40
60
80
100
0
50
100


2D tradeoff analysis
Finfish Value [%]
Mussel Value [%]
0
20
40
60
80
100
0
50
100


2D tradeoff analysis
Halibut [%]
Finfish Value [%]
80
100
0
50
100


from 2D to 7D
Halibut Value [%]
Finfish Value [%]
0
20
40
60
80
100
0
50
100

7D Tradeoff Analysis

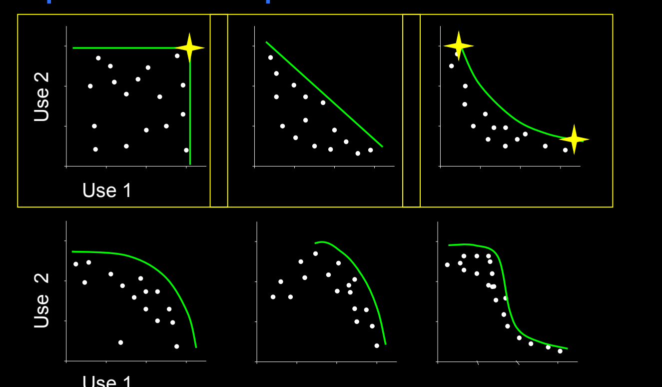


QUESTIONS and DISCUSSION

Project applications

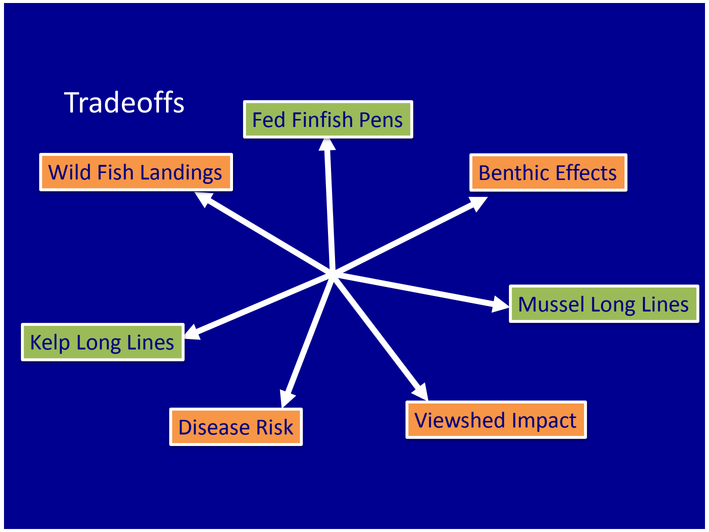
- California
  - Regulators, policy-makers
  - Industry
- Extending framework to other regions

The shape of the frontier provides important information

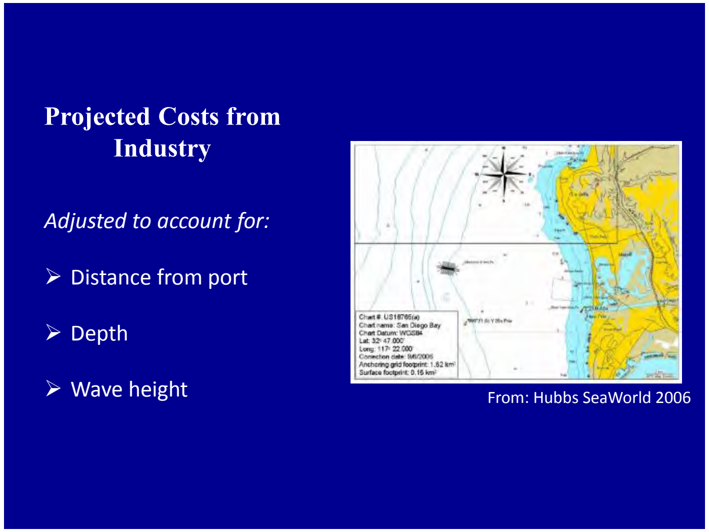


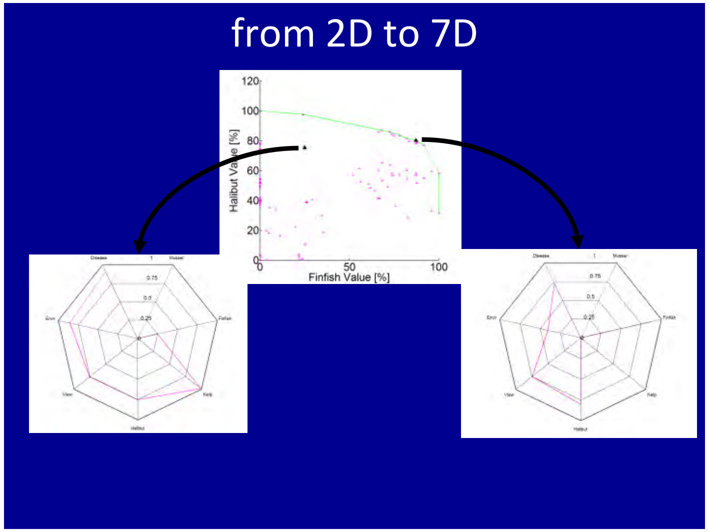
Lester, et al., Marine Policy (2013)


Conflicts with other Ocean Uses
© Brandon Cole / www.brandoncole.com


Tradeoffs
Fed Finfish Pens
Wild Fish Landings
Benthic Effects
Mussel Long Lines
Kelp Long Lines
Disease Risk
Viewshed Impact


A solid proposal for growing fish in the sea off San Diego
ignite SAN DIEGO
Sustainable Fish Farm Planned Off San Diego Coast
What is the best way to plan for offshore aquaculture in Southern California?
Los Angeles Times
Long Beach entrepreneur has fresh idea for shellfish farm
KTLA 5
Connected Seafood Farm Grows Harvest Using Tech
Science / Science Now
California panel approves first shellfish ranch in federal waters


Projected Costs from Industry
Adjusted to account for:
Distance from port
Depth
Wave height
From: Hubbs SeaWorld 2006


from 2D to 7D
120
100
80
60
40
20
0
Halibut Value [%]
0
50
100
Finfish Value [%]

Strongest Brand in North America

Strongest Brand in North America

ARAMARK
Disney
COMPASS GROUP
sodexo
MARS

Seafood Watch Criteria

Criterion	Score (0-10)	Rank	Critical?
C1 Data	9.20	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	7.73	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	4.96	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	8.00	GREEN	NO
C8 Source	10.00	GREEN	
C9X Wildlife Mortalities	-6.00	YELLOW	NO
C10X Introduced Species Escape	-0.80	GREEN	
Total	**61.06**		
Final score	**7.63**		

http://www.seafoodwatch.org/about-us/our-criteria
Corey Peet – Aquaculture Program Manager
cpeet@mbayaq.org


OFFSHORE AQUACULTURE FEDERAL PERMITTING IN CALIFORNIA
U.S. Army Corps of Engineers
• §10 Permit Rivers and Harbors Act (Navigation)
• §404 Permit Clean Water Act (Dredge and Fill)
• Coordinate with EPA, NOAA, USCG, BOEM, & USFWS
• National Environmental Policy Act
Environmental Protection Agency
• §402 Permit National Pollutant Discharge Elimination System
• §403 Permit Ocean Discharge (Point-source Discharge)
• Consultation† on §10 and §404 Permits
• Coordinate with USACE, NOAA, USCG, BOEM, & USFWS
• National Environmental Policy Act
National Oceanic and Atmospheric Administration
• National Marine Fisheries Service and National Marine Sanctuaries
• Review and comment on §10, §404, and §402 Permits
• Consultation on § 7 Endangered Species Act and Marine Mammal Protection Act
• Consultation on Essential Fish Habitat Magnuson-Stevens Fishery Conservation Act
†Consultation satisfies the legal Federal agency response requirements for activities affecting essential fish habitat, endangered species, or cultural resources.
Offshore
AQUACULTURE
In The Southern California Bight
April 28-29, 2015
Aquarium of the Pacific


OFFSHORE AQUACULTURE FEDERAL PERMITTING IN CALIFORNIA
U.S. Coast Guard
• Review and recommendations for §10 and §404 Permits that require private aids to navigation
Bureau of Ocean Energy Management
• Consultation on §106 National Historic Preservation Act
• Guidance and permitting on geophysical surveys
U.S. Fish and Wildlife Service
• Consultation and review pursuant to § 7 Endangered Species Act , Migratory Bird Treaty Act, and Fish & Wildlife Coordination Act
California Coastal Commission
• Consistency determination for Coastal Zone Management Act
• Review and comment on federal notices
†Consultation satisfies the legal Federal agency response requirements for activities affecting essential fish habitat, endangered species, or cultural resources.
Offshore
AQUACULTURE
In The Southern California Bight
April 28-29, 2015
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OFFSHORE AQUACULTURE FEDERAL PERMITTING IN CALIFORNIA

U.S. Army Corps of Engineers

- §10 Permit Rivers and Harbors Act (Navigation)
- §404 Permit Clean Water Act (Dredge and Fill)
- Coordinate with EPA, NOAA, USCG, BOEM, & USFWS
- National Environmental Policy Act

Environmental Protection Agency

- §402 Permit National Pollutant Discharge Elimination System
- §403 Permit Ocean Discharge (Point-source Discharge)
- Consultation† on §10 and §404 Permits
- Coordinate with USACE, NOAA, USCG, BOEM, & USFWS
- National Environmental Policy Act

National Oceanic and Atmospheric Administration

- National Marine Fisheries Service and National Marine Sanctuaries
- Review and comment on §10, §404, and §402 Permits
- Consultation on § 7 Endangered Species Act and Marine Mammal Protection Act
- Consultation on Essential Fish Habitat Magnuson-Stevens Fishery Conservation Act

U.S. Coast Guard

- Review and recommendations for §10 and §404 Permits that require private aids to navigation

Bureau of Ocean Energy Management

- Consultation on §106 National Historic Preservation Act
- Guidance and permitting on geophysical surveys

U.S. Fish and Wildlife Service

- Consultation and review pursuant to § 7 Endangered Species Act, Migratory Bird Treaty Act, & Fish & Wildlife Coordination Act

California Coastal Commission

- Consistency determination for Coastal Zone Management Act
- Review and comment on federal notices

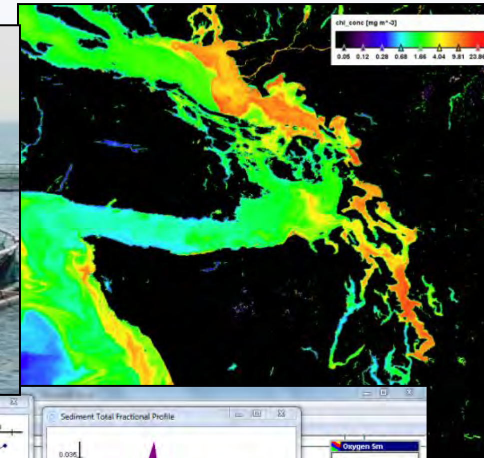
†Consultation satisfies the legal Federal agency response requirements for activities affecting essential fish habitat, endangered species, or cultural resources.

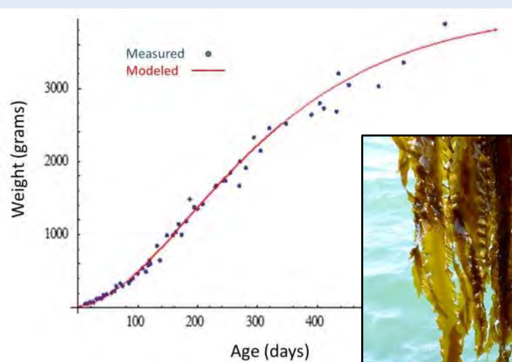
Offshore
AQUACULTURE
In The Southern California Bight
APRIL 28-29, 2015
AQUARIUM OF THE PACIFIC

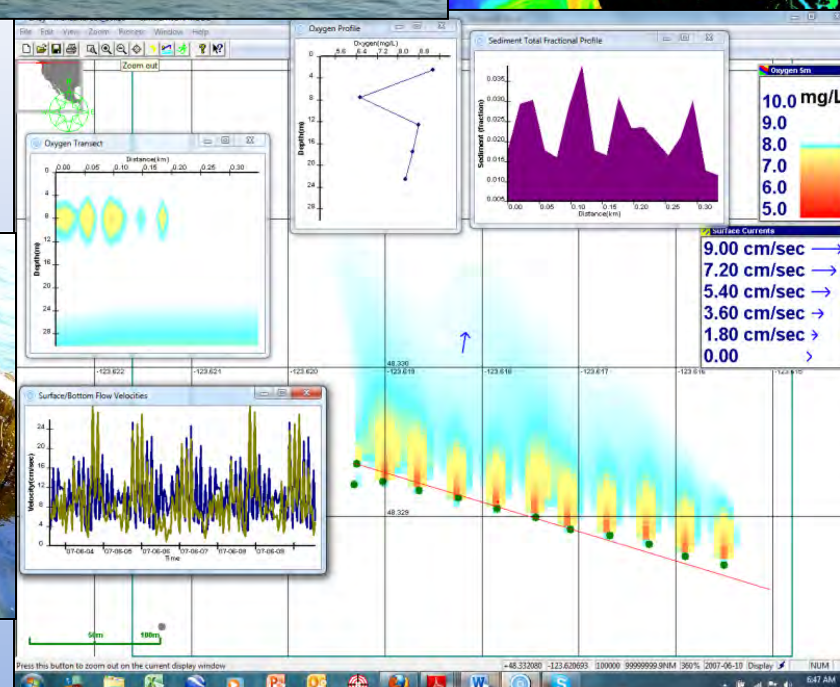
Offshore Net Pens: Benthic Effects & Prevention of Coastal Eutrophication

Workshop on Marine Finfish Aquaculture in the Southern California Bight, Long Beach Ca. April 2015

Jack Rensel, Ph.D.



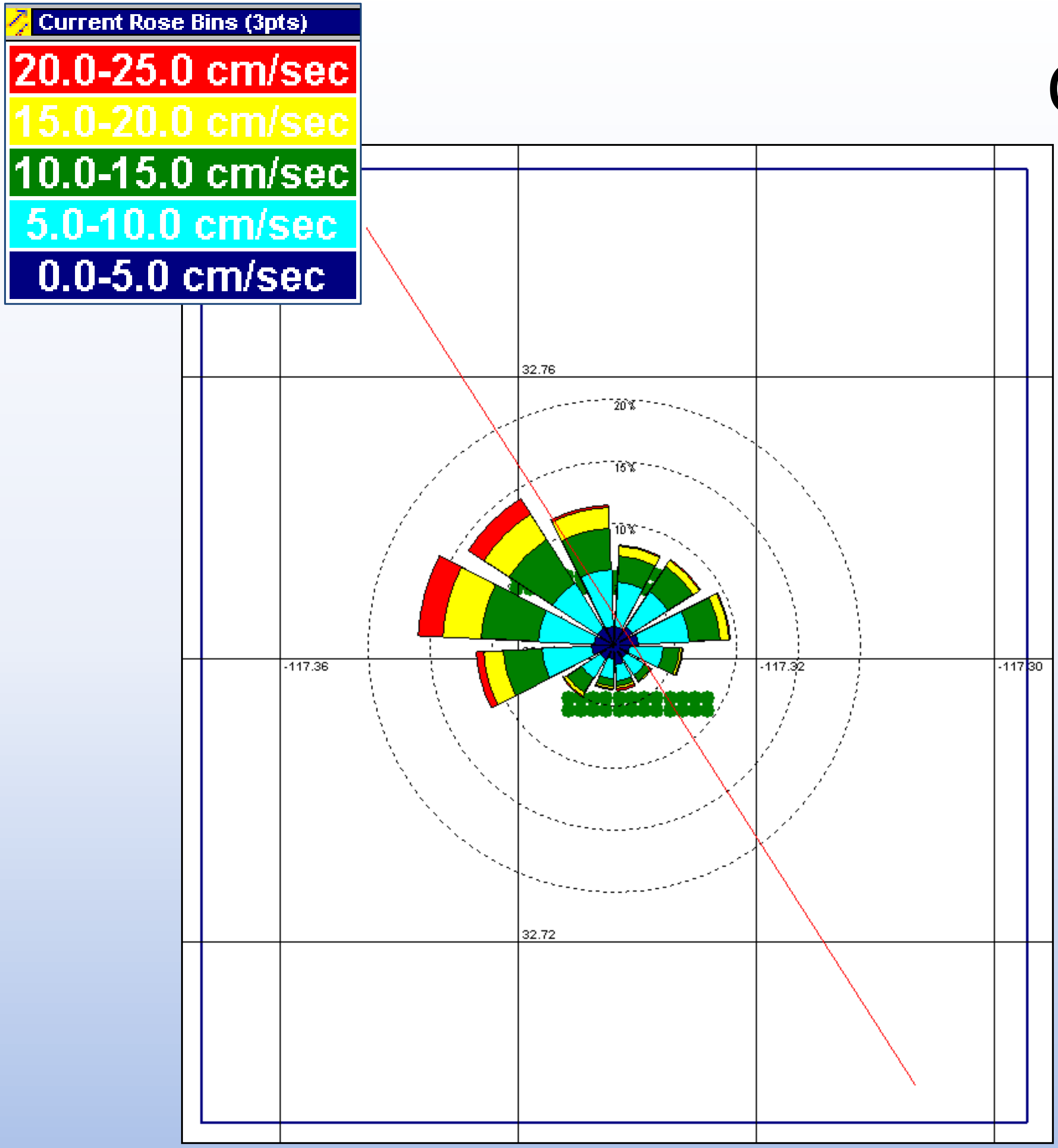




Benthic Effects: 1 minute Primer

- MOST measurable and regulated effect
- Particulate organic matter (POM) → benthos D.O. demand, dose related
- Site specific: ranging from beneficial to adverse effects
- "Near Field" = local, under and near pens, not remote
- Offshore depths allow ↑dispersion, but solution is not dilution
- "Physics Rules" i.e., modest current velocity & direction essential for resuspension, transport and food web assimilation of organic wastes
- Prior work suggests minimal effects at 90m deep SoCal Bight sites due to persistent current

Current Vector Rose: RCF Site S. Ca. Bight



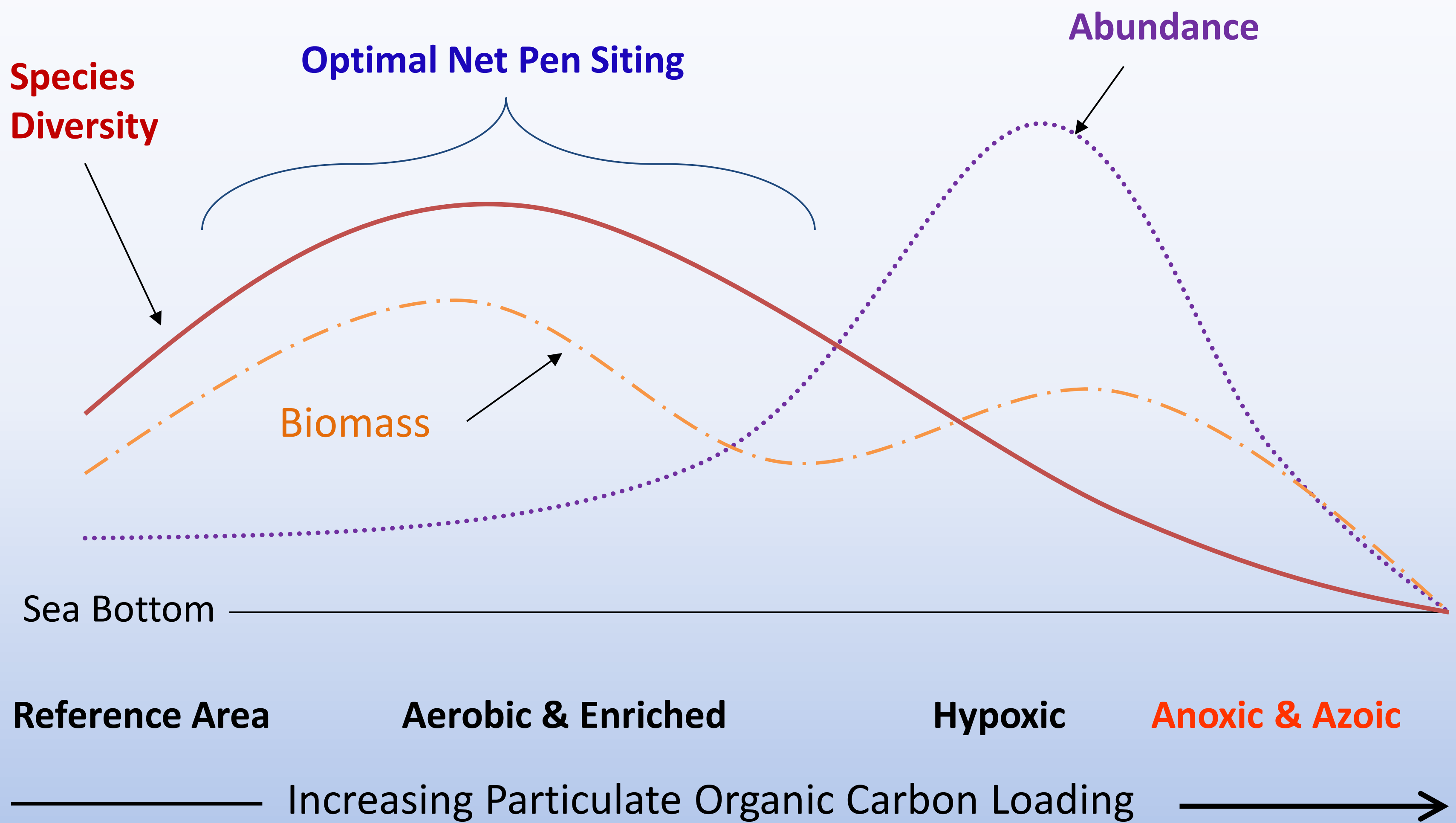
- Many depths measured
- 5m depth example here
- five month duration
- 20 min time intervals

Relative current speeds are strong & near-ideal for the fish and the environmental effects

Strongest and most persistent currents are offshore to the NW

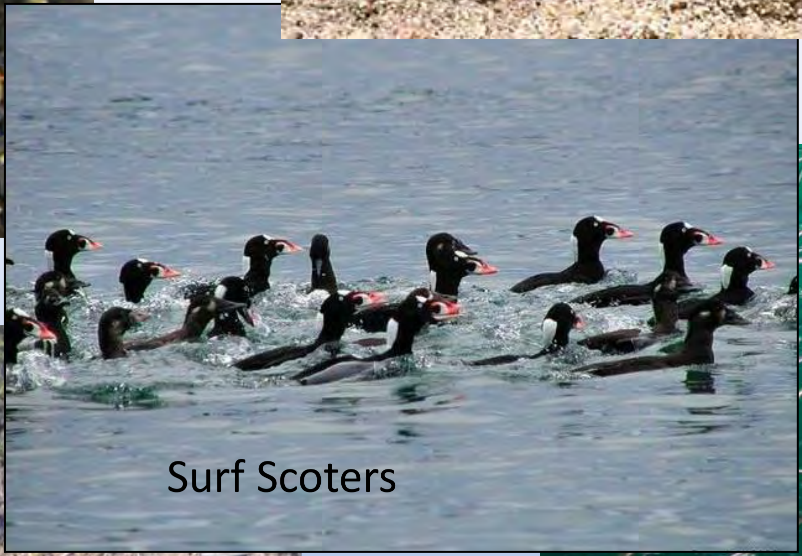
Raw Data Courtesy of HSWRI, Mike Shane et al.

Marine Sediments and Invertebrates
Classic Pearson-Rosenberg Organic Enrichment Model



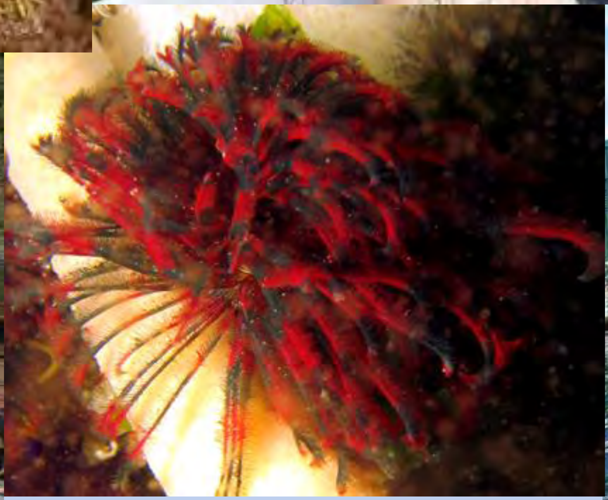
Higher Food Web Effects

Abundant Species at
Puget Sound & Columbia River Net Pens:
- Habitat and Food
- Stable Isotope Tracer Studies



‘Beneficial Effects’ Study for NOAA

For more information: Google Net Pen Beneficial Effects



- San Juan Islands sites
- More than 100 native or non-invasive species
- 30+ years of operation

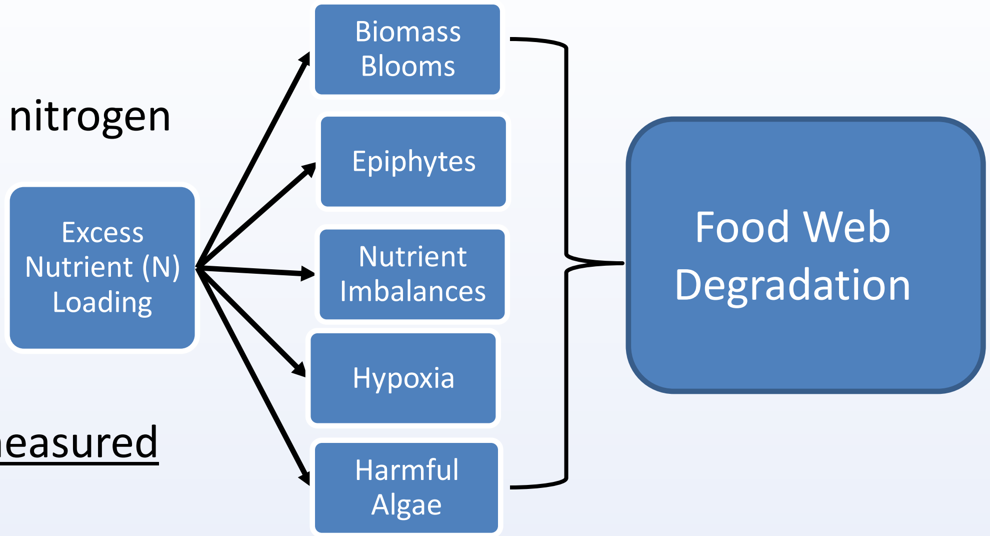
Coastal Eutrophication

Fish → ammonia and/or urea dissolved nitrogen

Eutrophication risk ↑ inshore

Not something to monitor at farm level

N production & dispersion can be modeled much more accurately than measured



Are there **Nutrient Sensitive habitats at risk to net pen development**?

- No: if flux and concentration of N are **high**. Light limited algae, e.g., most of Puget Sound, the Strait of Georgia, Georgia Strait, offshore waters of the entire U.S. west coast (low N at times but high flux rate)
- Yes: if flux and concentration of N **Low.** Some exceptions. Avoid immediate onshore flows!

Fish Farm Dissolved Nutrient Management

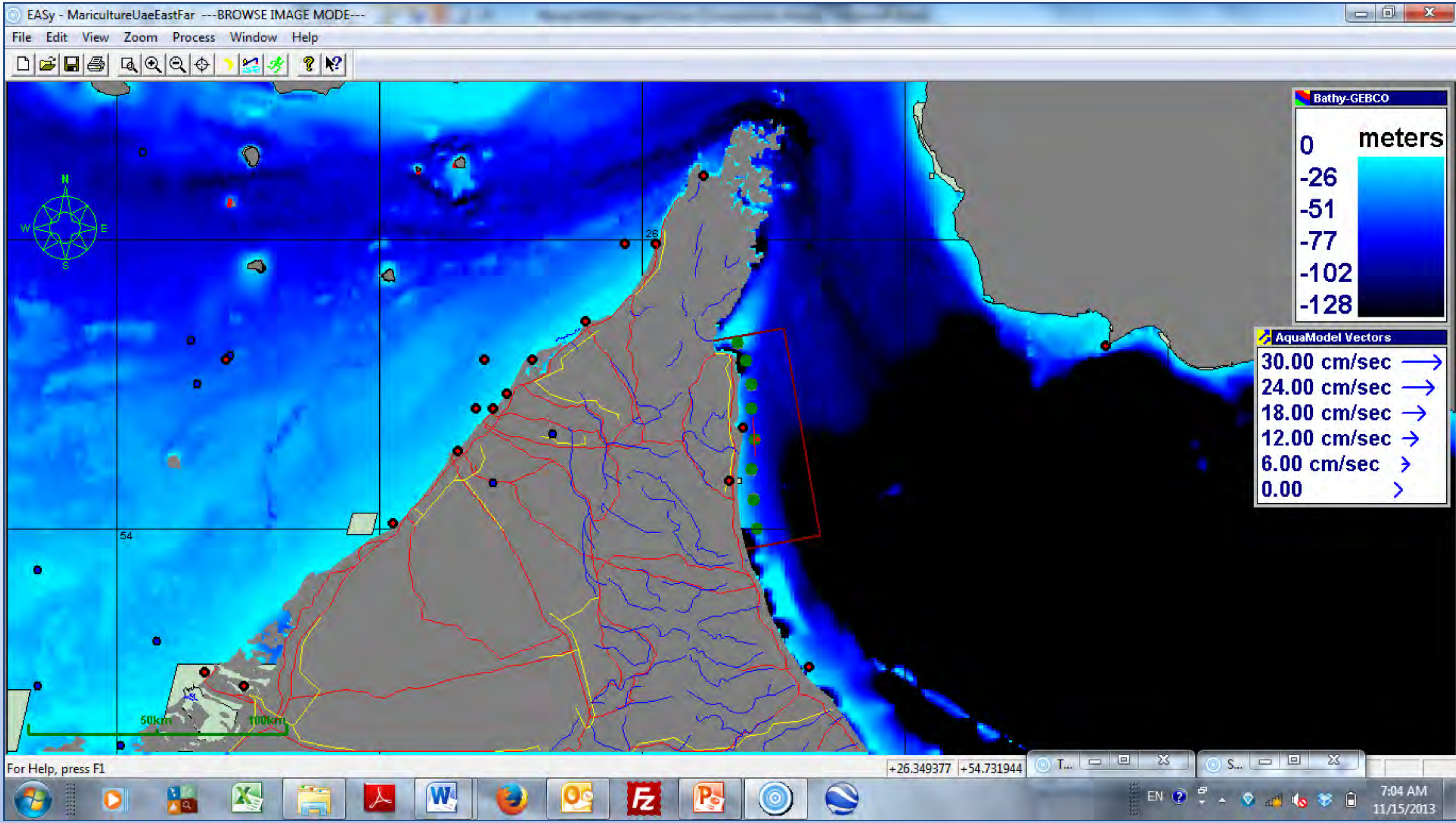
- Only in Washington State, not Maine, Canada or Mexico
- Rare overseas but changing
- U.S. net pen nitrogen incredibly small at present
- Natural and other anthropogenic sources dominate

Solutions:

- Use computer models to simulate, impossible to accurately measure!
- Consider cumulative effects of many, many farms on coastal ecosystem
- Allow net pens if receiving waters clearly not nutrient sensitive
- Consider distance/flow direction to nearshore and habitats of special significance
- Allow in sensitive areas if nutrient production is truly mitigated (seaweed IMTA?)
- Risks in offshore areas generally much lower, but should be assessed

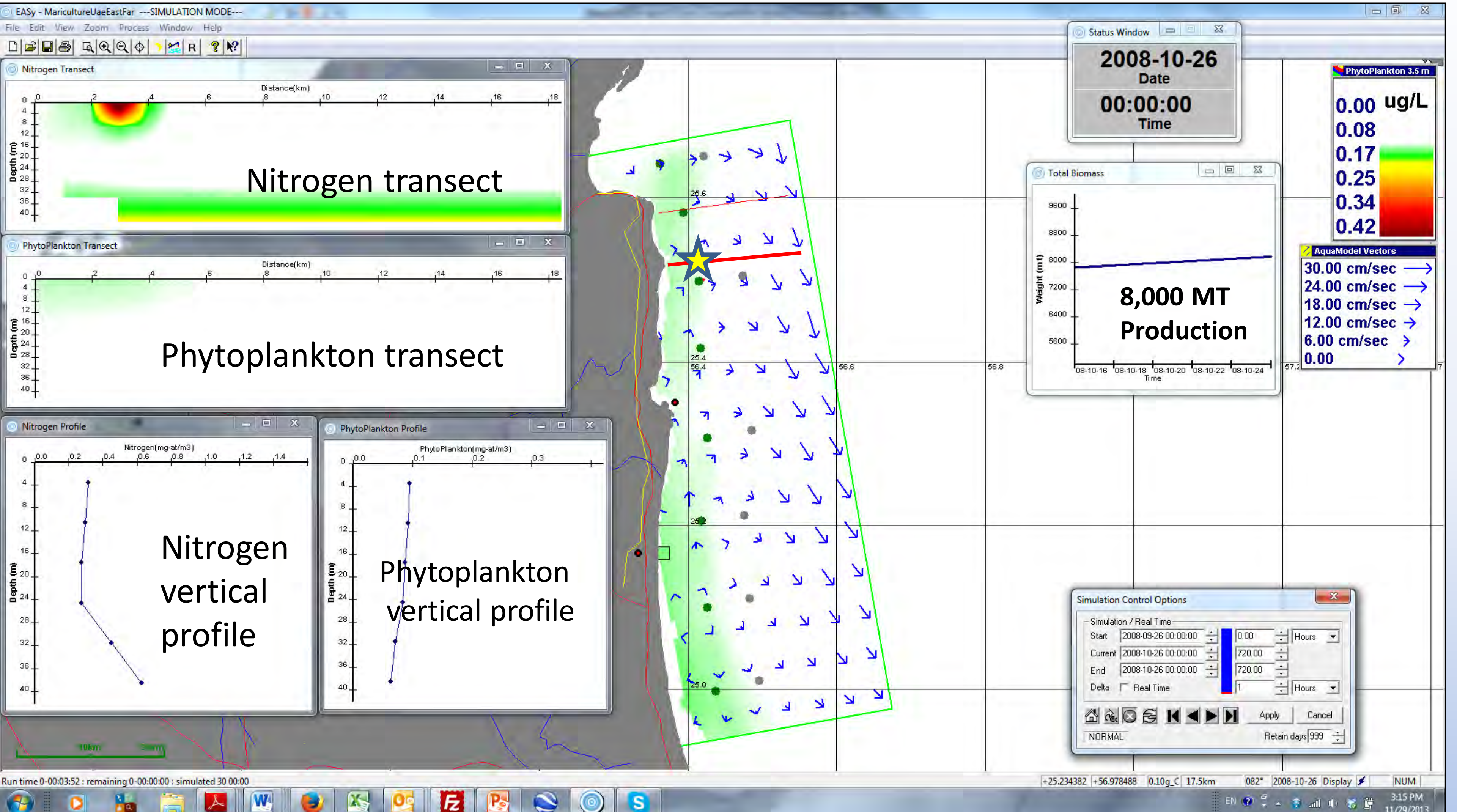
AquaModel: Eight Farms: Arabian Sea – Gulf of Oman

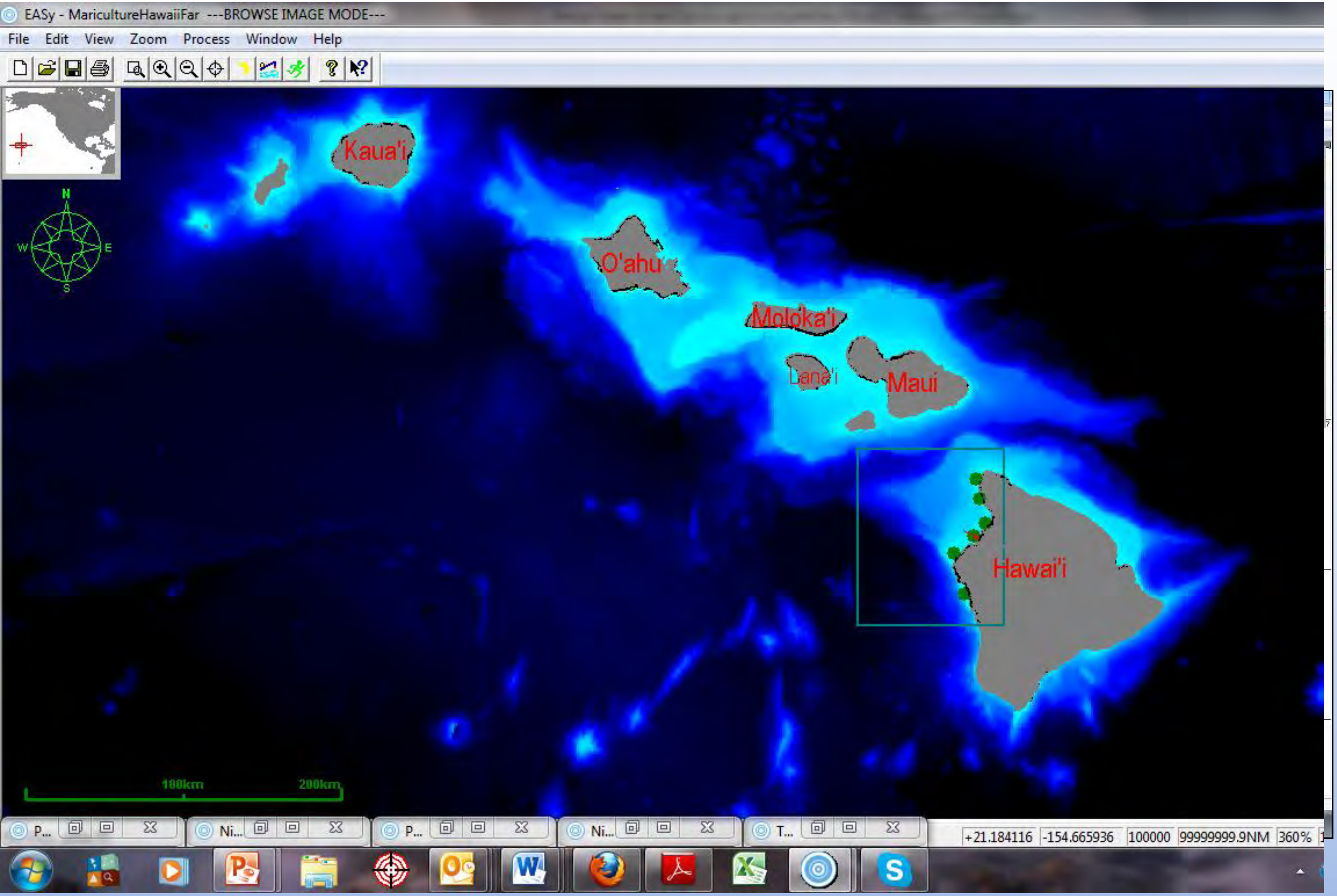
for UAE Ministry of Environment and Water

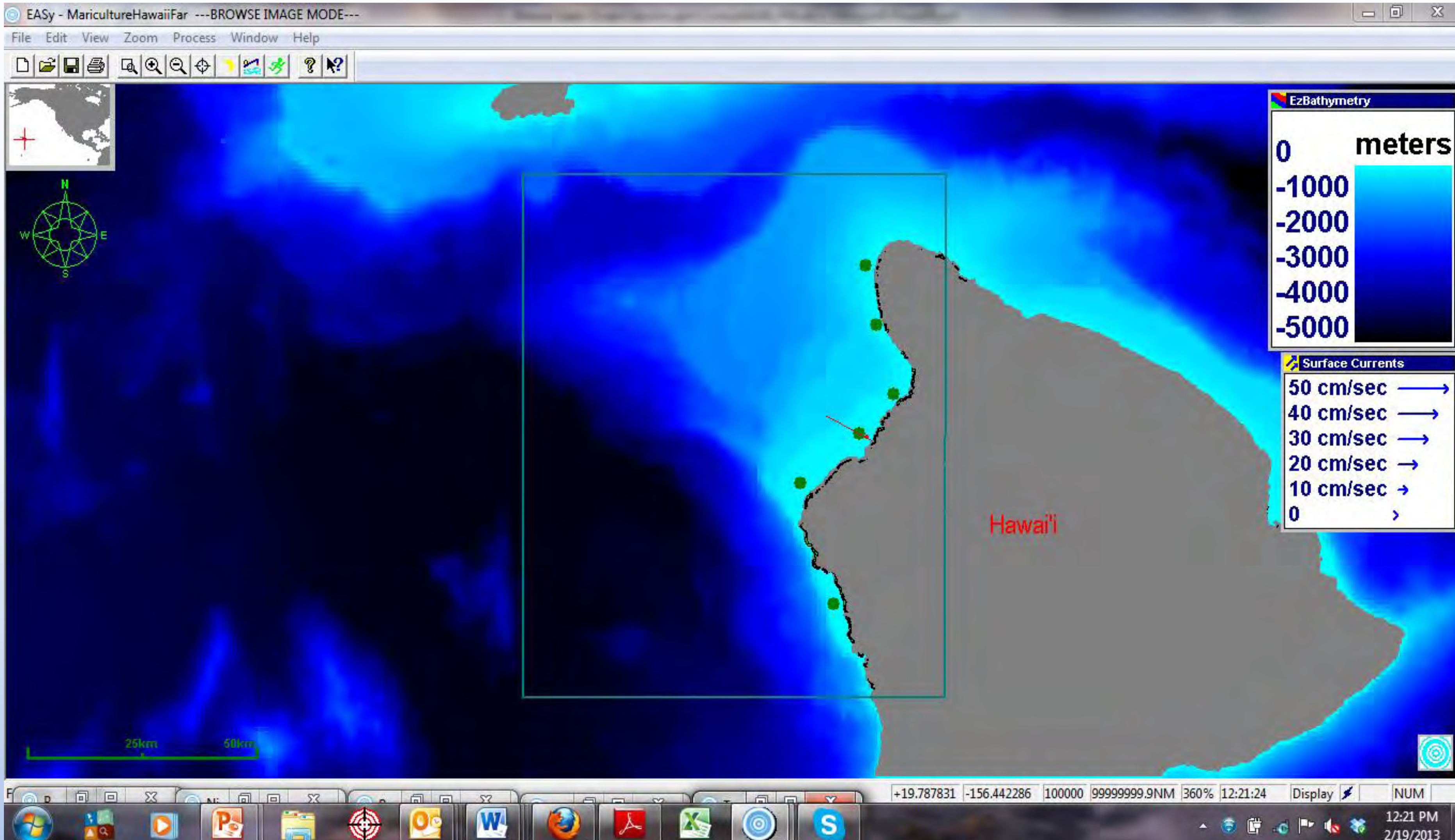


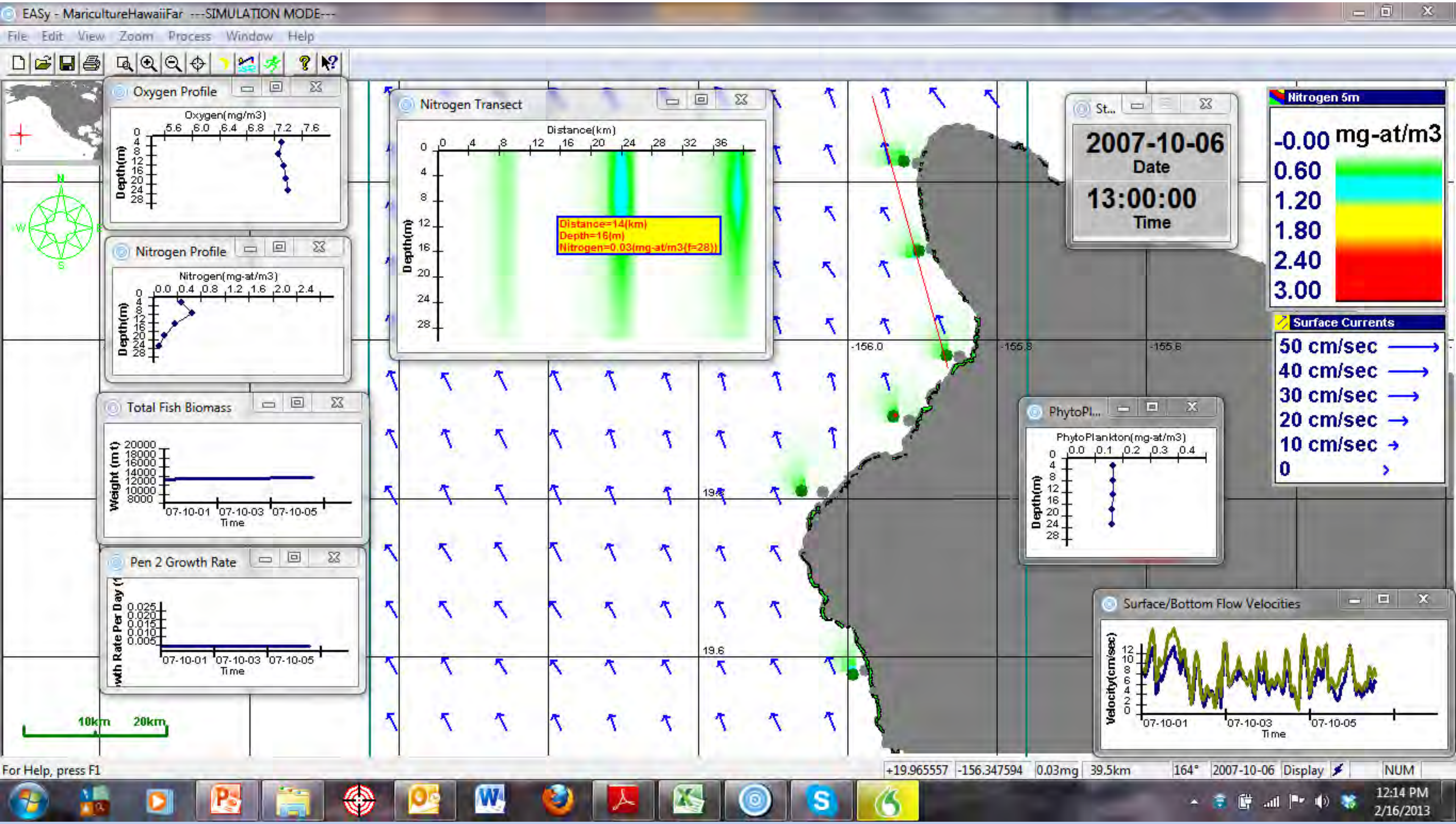
UNITED ARAB EMIRATES
MINISTRY OF ENVIRONMENT & WATER

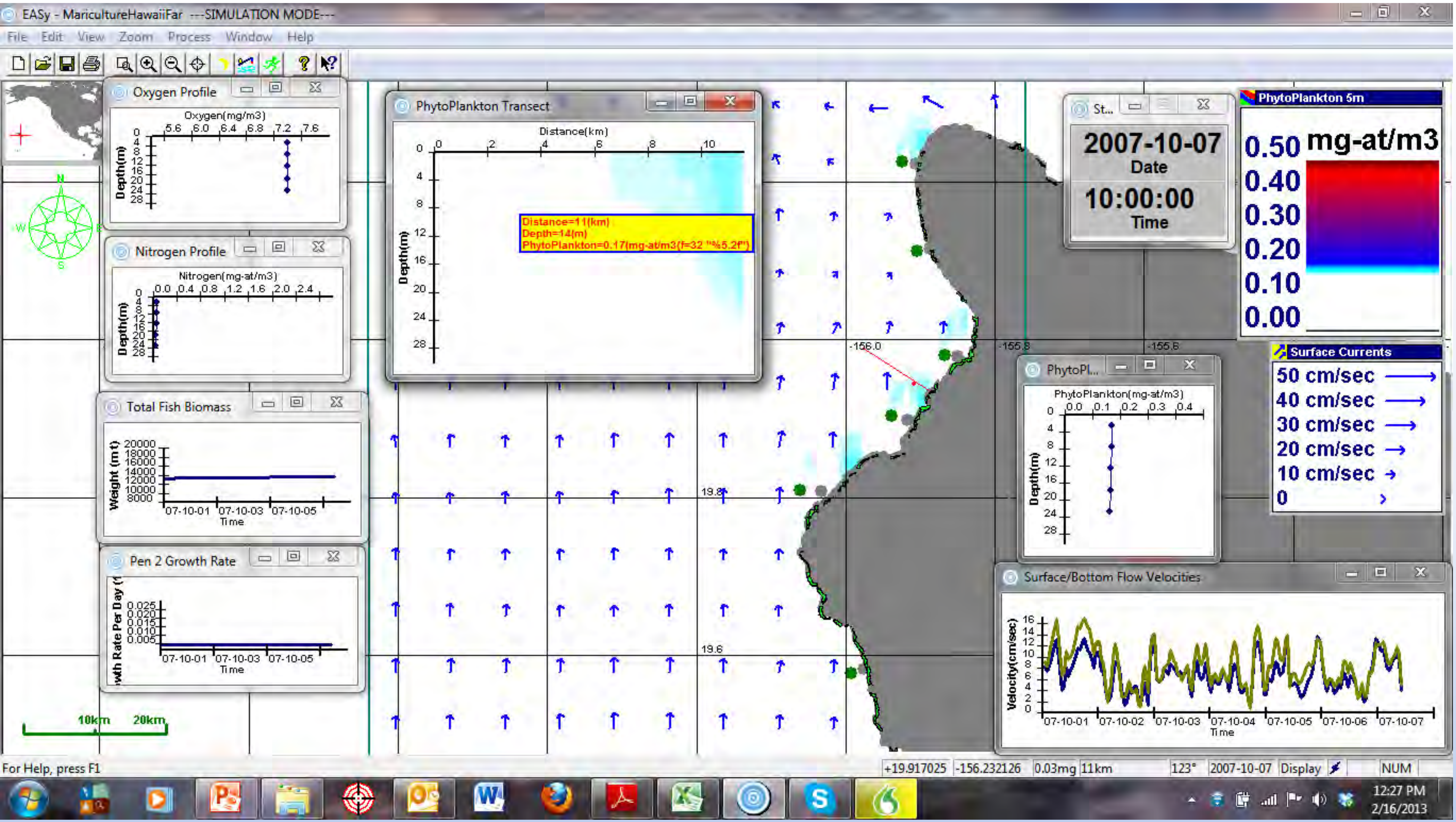
Arabian Sea: Eight Small Farms, Nitrogen-Phytoplankton Dynamics




EASy - MaricultureHawaiiFar ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Kaua'i
O'ahu
Moloka'i
Lana'i
Maui
Hawai'i
N
W
E
S
100km
200km
+21.184116
-154.665936
100000
99999999.9NM
360%


EASy - MaricultureHawaiiFar ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
EzBathymetry
0 meters
-1000
-2000
-3000
-4000
-5000
Surface Currents
50 cm/sec
40 cm/sec
30 cm/sec
20 cm/sec
10 cm/sec
0
Hawai'i
N
S
E
W
25km
50km
+19.787831 -156.442286 100000 99999999.9NM 360% 12:21:24 Display NUM
12:21 PM
2/19/2013


EASy - MaricultureHawaiiFar ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Oxygen Profile
Oxygen(mg/m3)
Depth(m)
Nitrogen Profile
Nitrogen(mg-at/m3)
Total Fish Biomass
Weight (m t)
Time
Pen 2 Growth Rate
Time
Nitrogen Transect
Distance(km)
Depth(m)
Distance=14(km)
Depth=16(m)
Nitrogen=0.03(mg-at/m3(f=28))
2007-10-06
Date
13:00:00
Time
Nitrogen 5m
mg-at/m3
-0.00
0.60
1.20
1.80
2.40
3.00
Surface Currents
50 cm/sec
40 cm/sec
30 cm/sec
20 cm/sec
10 cm/sec
0
PhytoPlankton(mg-at/m3)
Depth(m)
Surface/Bottom Flow Velocities
Velocity(cm/sec)
Time
10km 20km
For Help, press F1
+19.965557 -156.347594 0.03mg 39.5km 164° 2007-10-06 Display NUM
12:14 PM
2/16/2013



- Background N ~ 0.16 µM at this time step in the simulation.
- 0.01 µM dissolved nitrogen increase near shore along the red transect line during slow current velocity. This is far below laboratory detection limits.

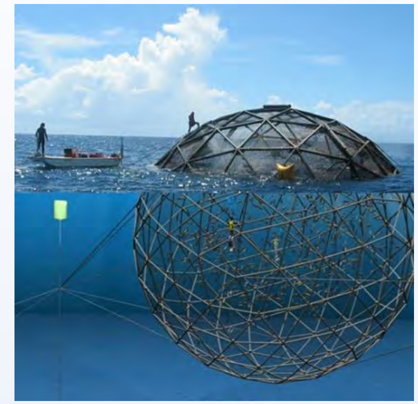
Summary Comments

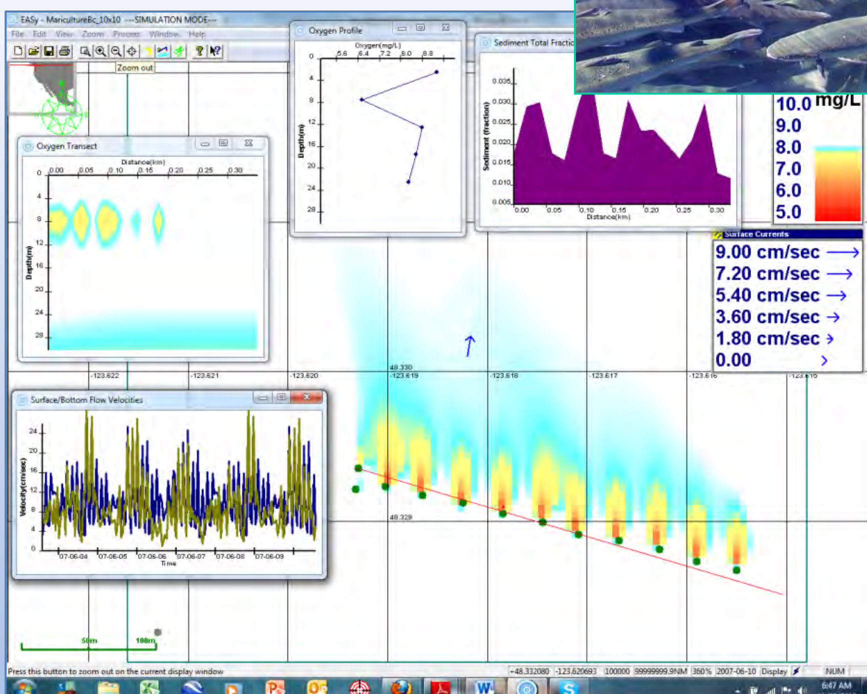
- Planning/modeling/GIS: acceptable or beneficial benthic and higher food web effects
- Adverse benthic effects: near field and avoidable
- Coastal eutrophication: hard to measure, but entirely preventable with planning
- Modeling and monitoring tools to protect environment & optimize fish production
- Mistakes made elsewhere can be avoided, advisable to consider what others have done.

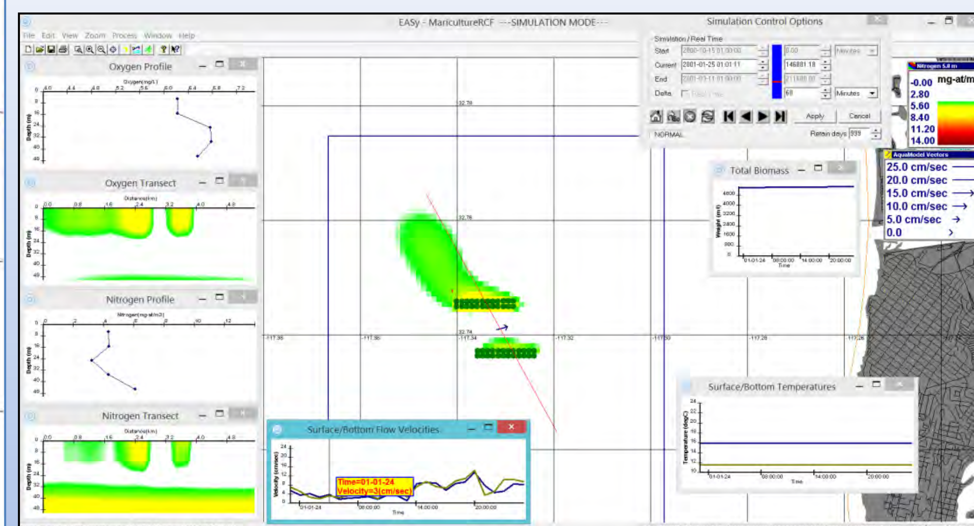
Computer Modeling of Net Pen Effects

Workshop on Marine Finfish Aquaculture in the Southern California Bight, Long Beach Ca. April 2015

Jack Rensel, Ph.D.







Why Net Pens Computer Simulations?

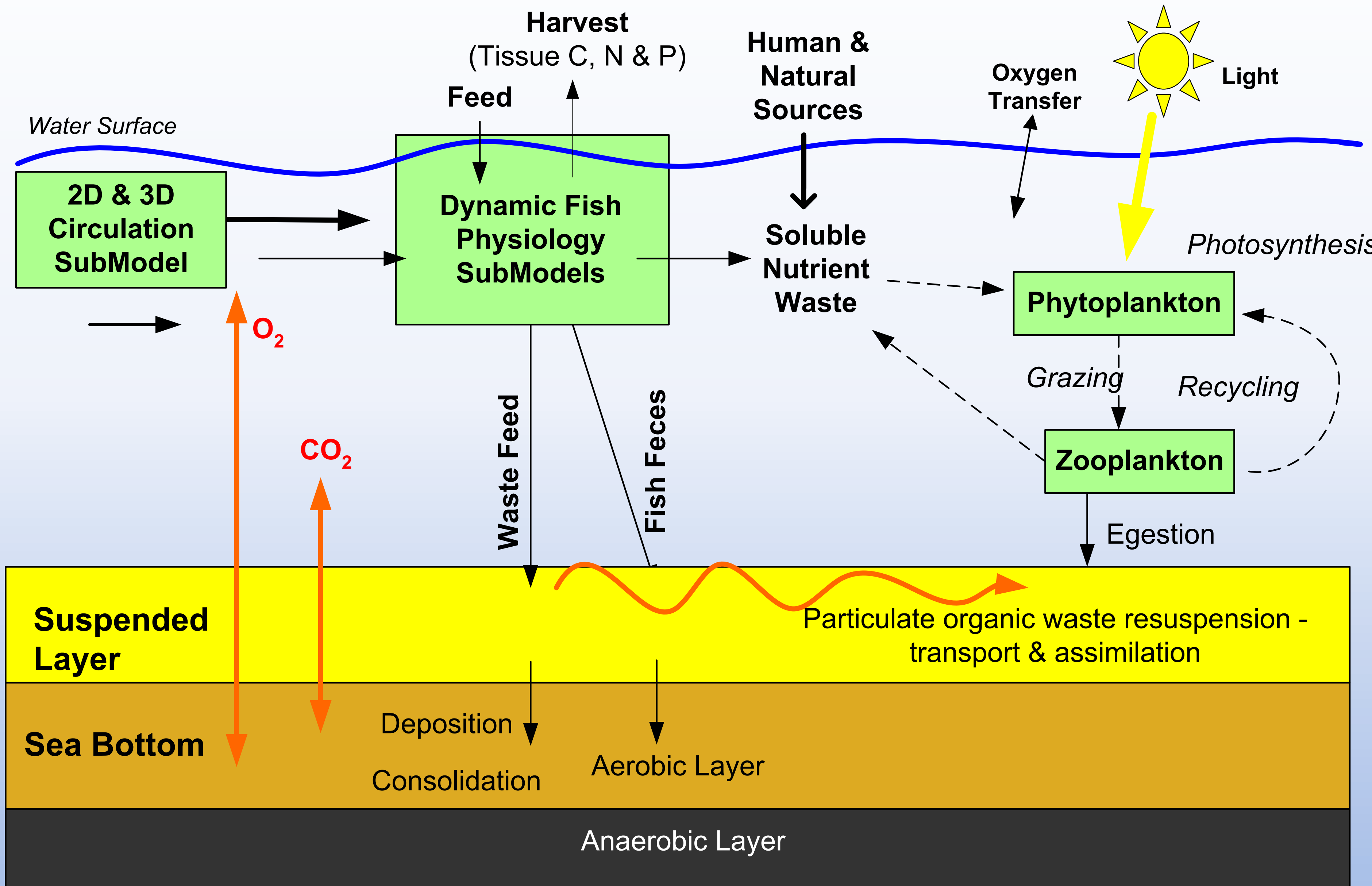
Near Field

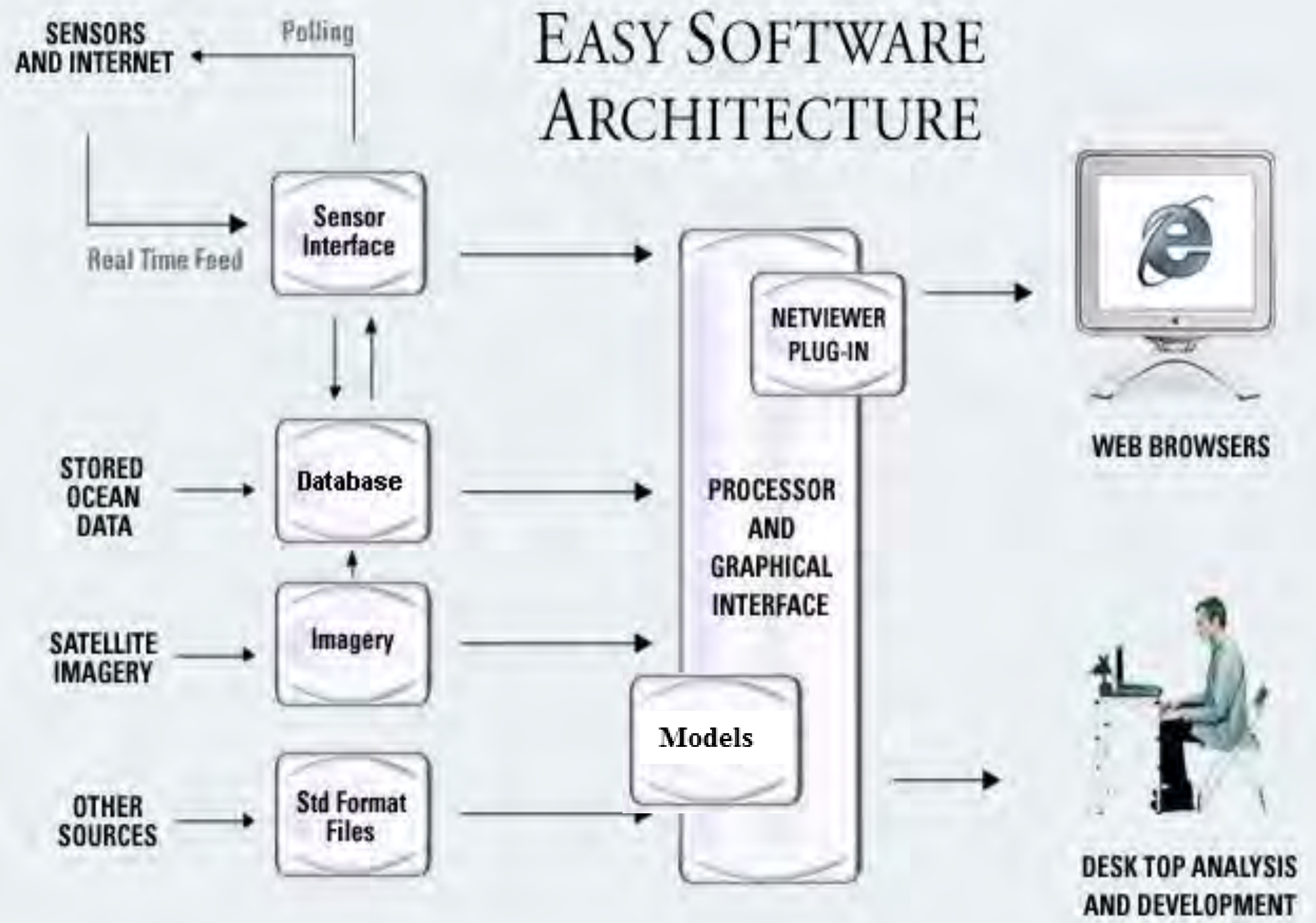
- Benthic effects: minimize sediment organic matter effects
- Water column effect: near field, DO, nitrogen, pen interactions
- Fish health: DO supply, stress reduction, optimize current speed
- Site planning, configuration, feed & operational efficiency
- Planning **I**ntegrated **M**ulti **T**rophic **A**quaculture (IMTA ~ Integrated Aquaculture)
- To inform intelligent planning and execution of monitoring

Far Field

- Cumulative carrying capacity: Nitrogen/Phytoplankton/Zooplankton
- Temperate waters: virus management, determine connectivity of sites
- Fish escapes: No spatially enabled (bio-physical) models presently
- Fish therapeutant transport and dilution
- For improved effects estimates: better than each-site monitoring

Existing AquaModel Conceptual Design



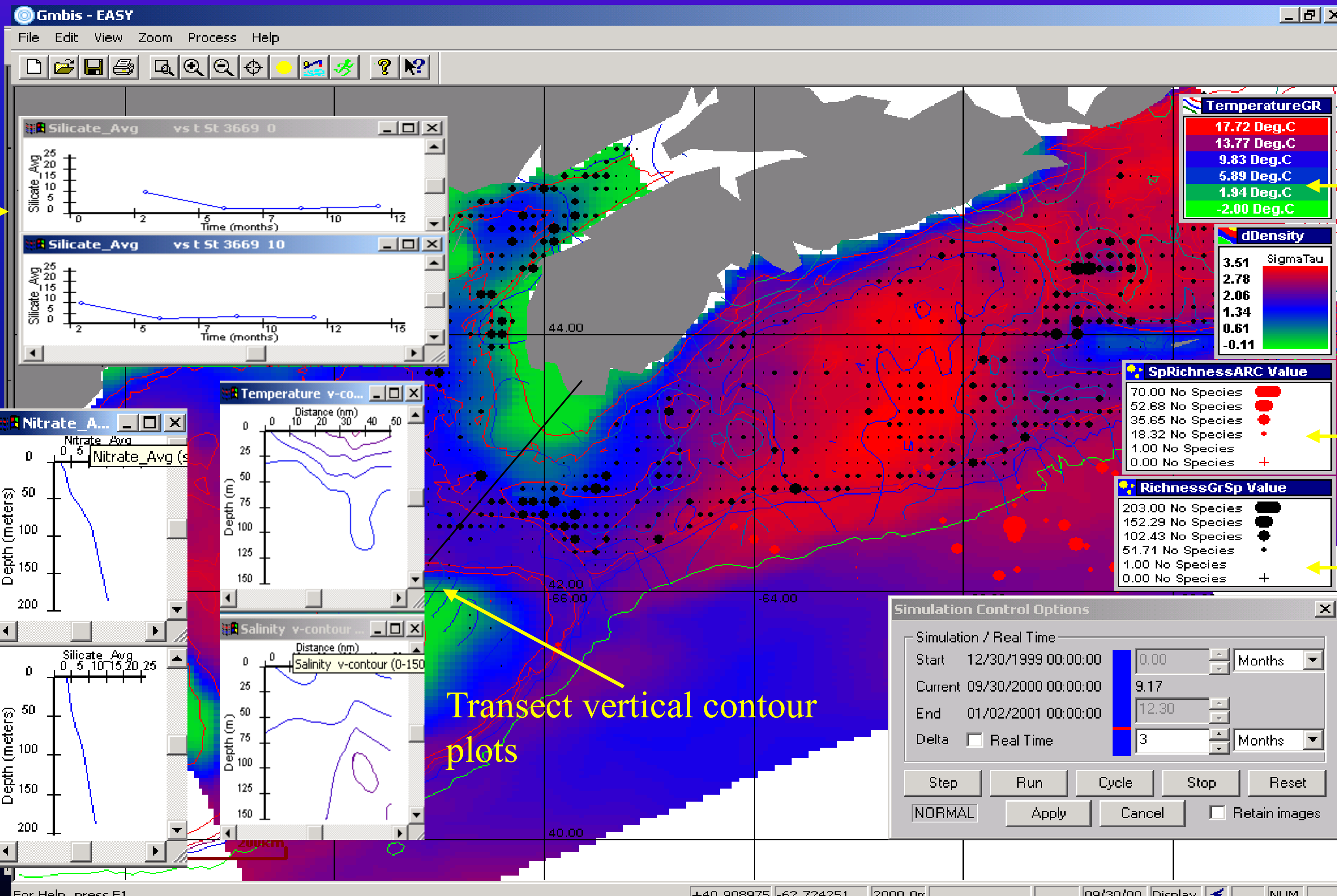

EASY SOFTWARE ARCHITECTURE
SENSORS AND INTERNET
Polling
Real Time Feed
Sensor Interface
STORED OCEAN DATA
Database
SATELLITE IMAGERY
Imagery
OTHER SOURCES
Std Format Files
NETVIEWER PLUG-IN
PROCESSOR AND GRAPHICAL INTERFACE
Models
WEB BROWSERS
DESK TOP ANALYSIS AND DEVELOPMENT

EASy Graphical Environment

Species richness relative to bathymetry, water density differentials & bottom temperature

Time Series plots

Depth profile plots



Contour plot

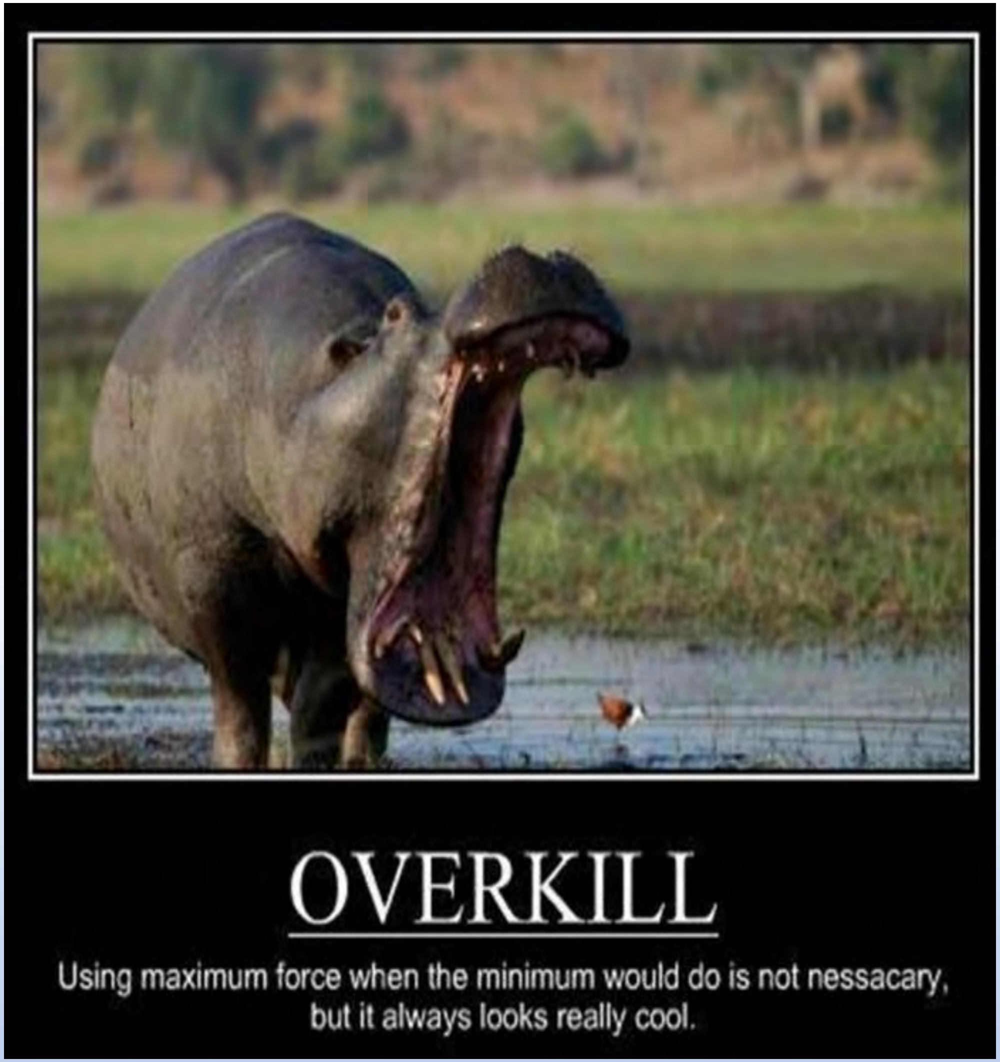
False colour plot

Bubble Plots

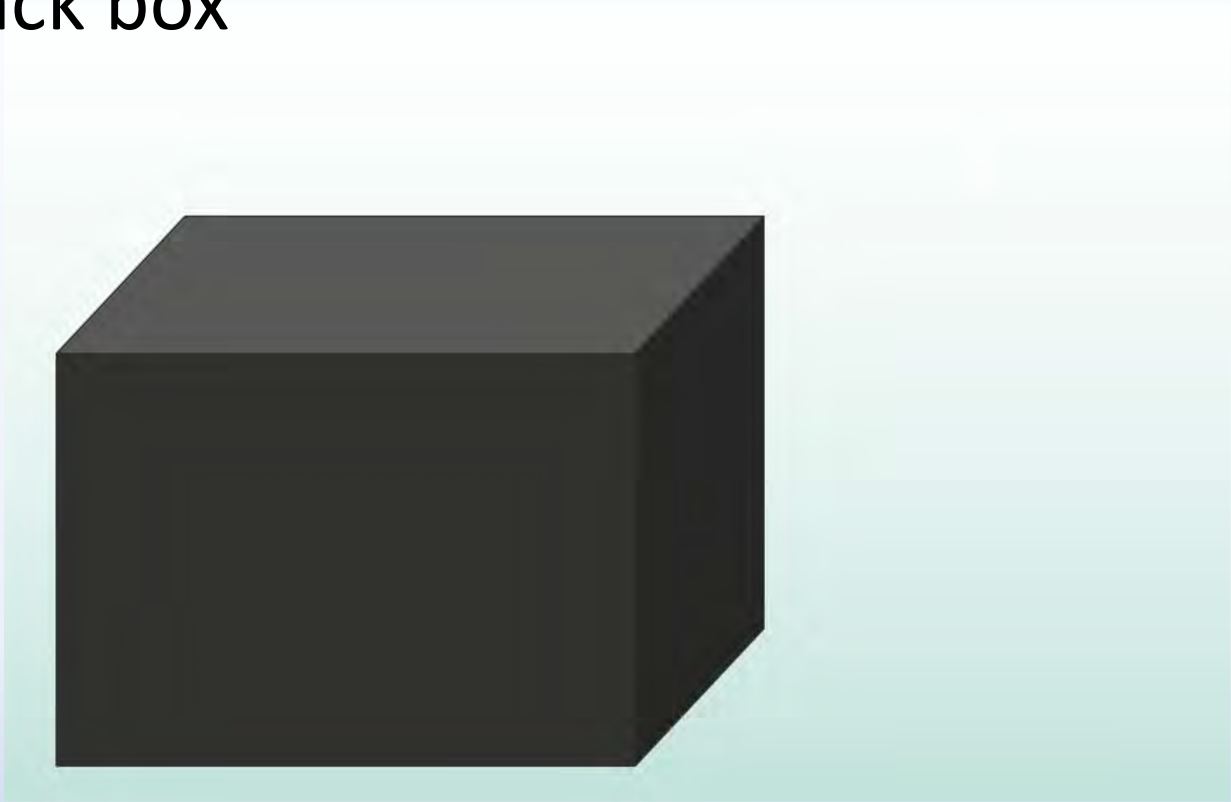
Simulation control panel

Tsontos, V. M. and D. A. Kiefer. 2000. Oceanography 13(3): 25-30.

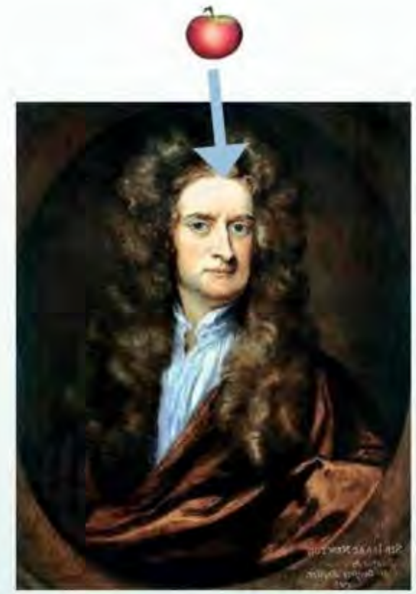
- Complex models not always better
- Sometimes worse
- Complexity costs more $$
- Find the right balance of accuracy and simplicity



- “I don’t believe in models”
- “It’s a black box”



It is Not a Black Box!



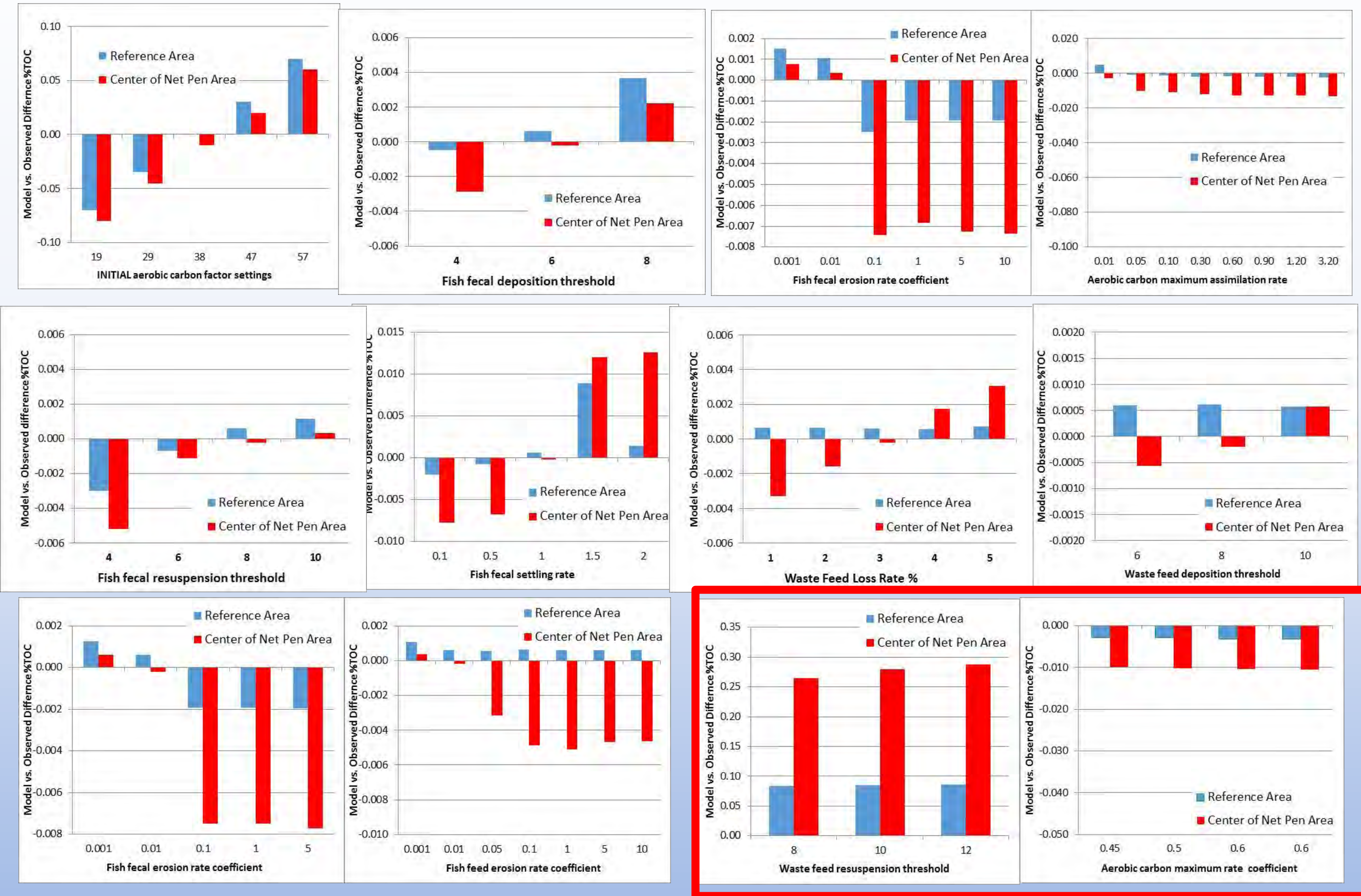
- Conservation of Mass
- Conservation of Momentum
- Conservation of Energy
- Known Water Quality Processes
- Checked Against Measurements

Source: Jason Cope, Region 10 USEPA

Model Calibration ~ Model Validation

Parameter	Units	Parameter Components	Relative Uncertainty (1 low – 3 high)
Sediment carbon factors	grams C m^2	1. Sediment aerobic carbon factor 2. Sediment anaerobic carbon factor*	1
Sediment carbon assimilation rate coefficient	per day (d^{-1})	3. Sediment carbon maximum aerobic assimilation rate coefficient 4. Sediment carbon maximum anaerobic assimilation coefficient*	2
Waste deposition & resuspension thresholds	centimeters per second (cm s^{-1})	5. Fish fecal deposition velocity threshold 6. Fish fecal resuspension velocity threshold 7. Waste fish feed deposition velocity threshold 8. Waste fish feed resuspension velocity threshold	2
Erosion rate constants**	g carbon m^2 d^{-1}	9. Fish fecal erosion rate coefficient 10. Waste feed erosion rate coefficient	3
Sediment consolidation rate	fraction d^{-1}	11. Fish fecal consolidation rate 12. Waste fish feed consolidation rate	2
Fish fecal settling rate	centimeters per second (cm s^{-1})	13. Mean velocity fish feces settling rate (uncertainty varies by fish species)	1 - 2

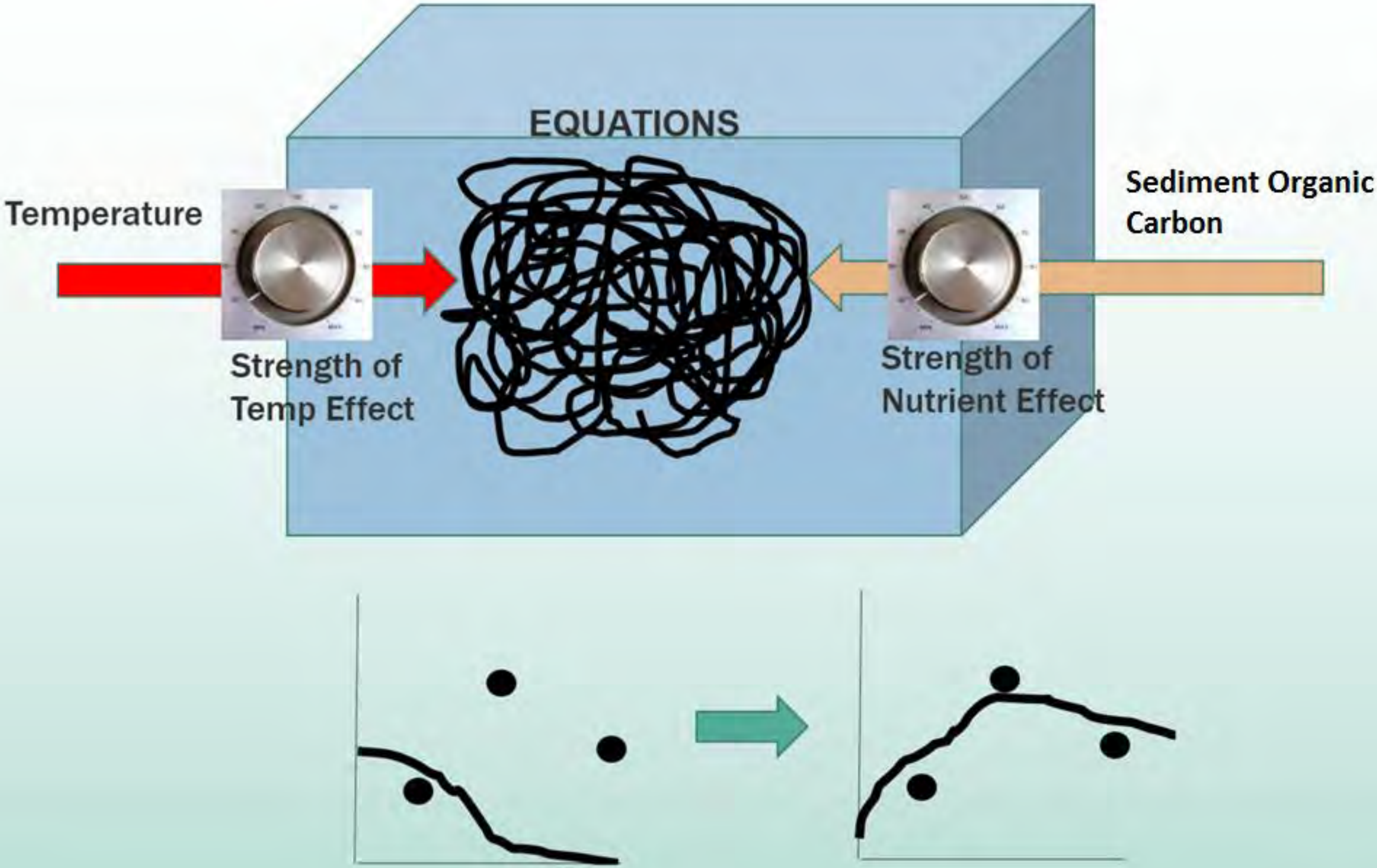
One and Two-at-a-Time Parameter Calibration Examples



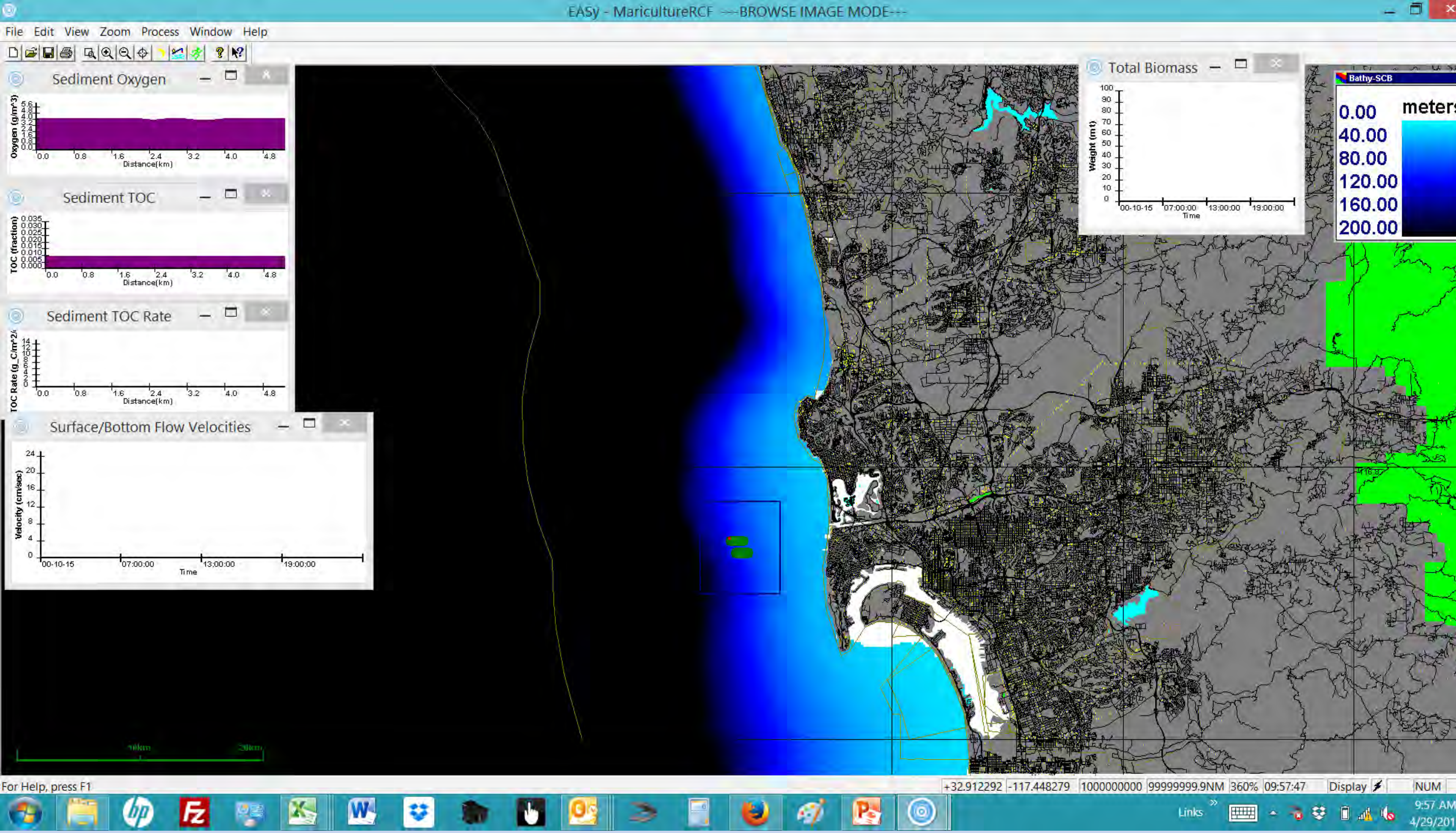
Prediction is poor?

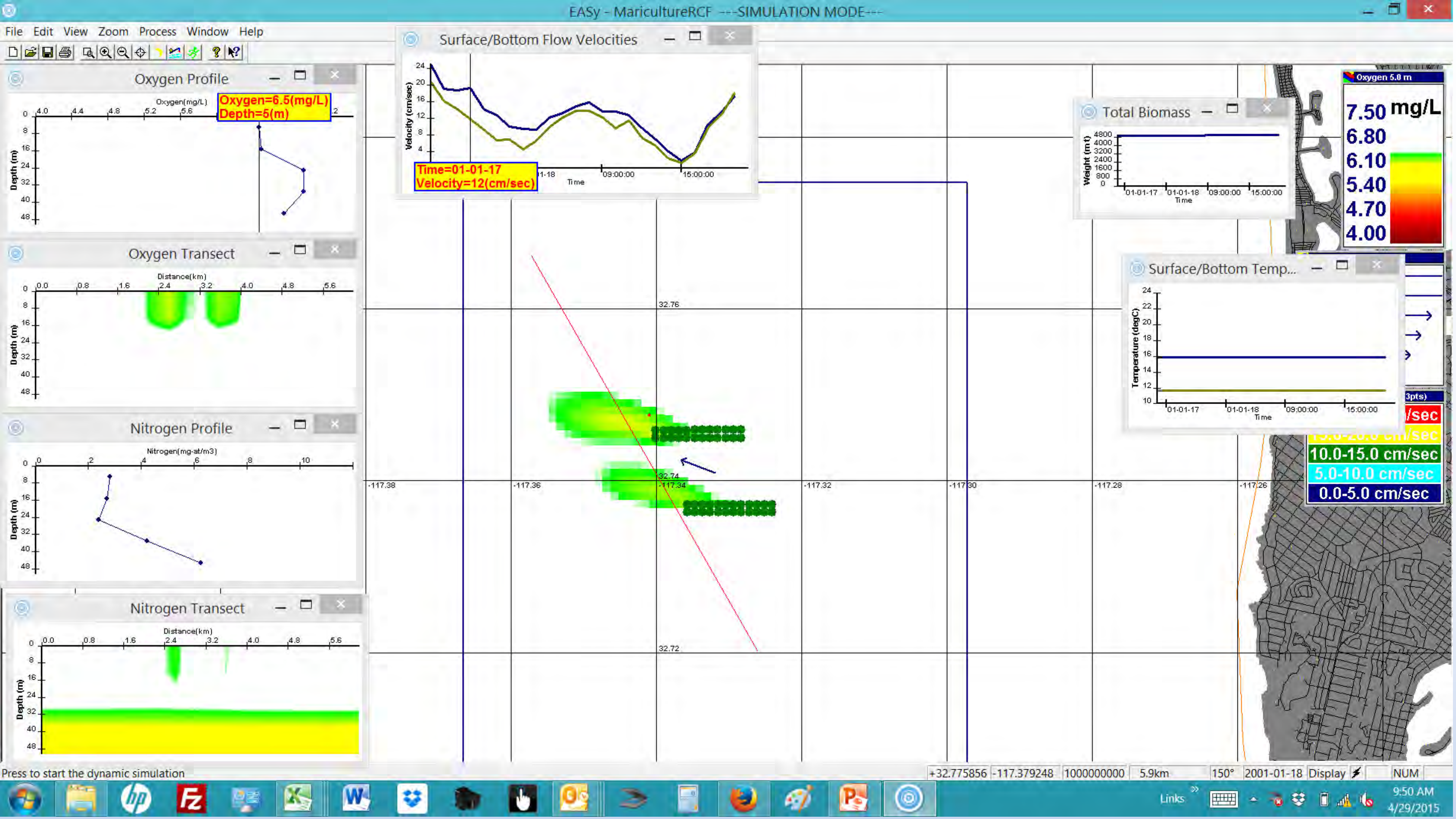
- Physical circulation data not representation
- Conceptual design assumptions incorrect
- Input data incorrect
- Conceptual model or coding errors
- Boundary condition settings incorrect
- Large range of literature data values
- **Two separate trials AquaModel best fit:**
  ~ 1% of measured sediment organic carbon

Rate Constants: “volume knobs” for some parameters

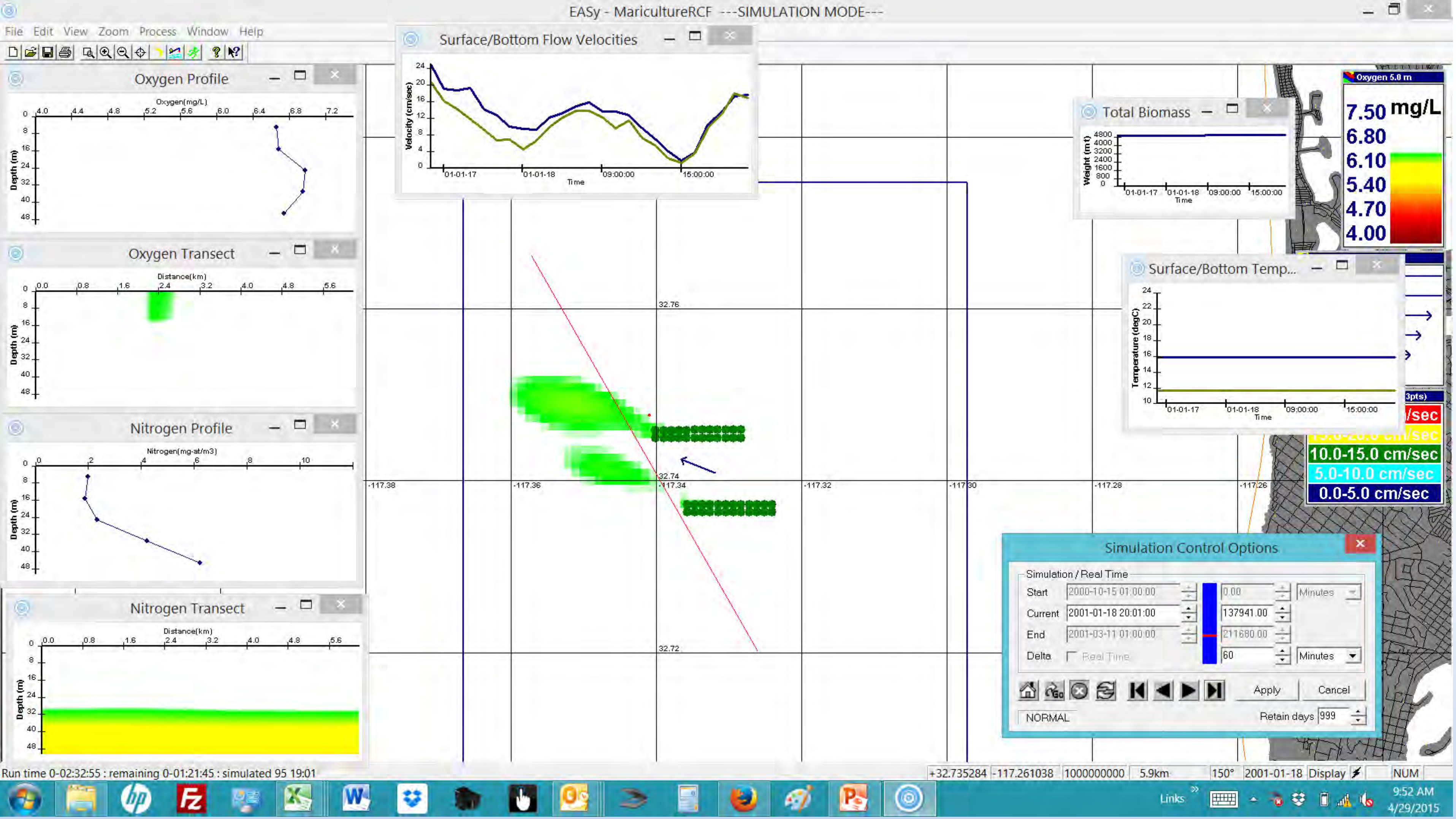


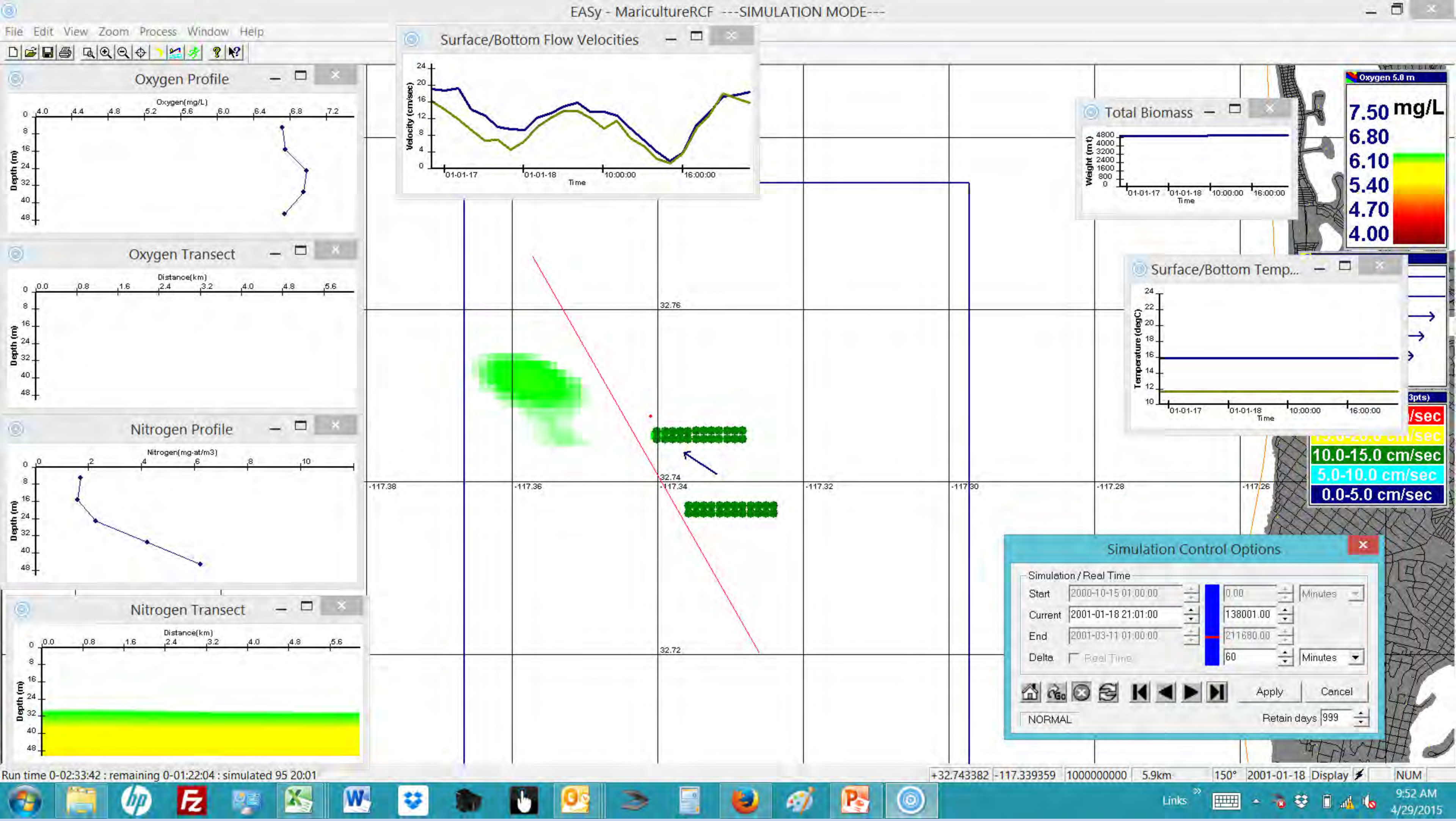
- Model Live Demonstration of preliminary Rose Canyon Fisheries project site shown, subject to change with additional input data.
- Some excerpts show in the next several slide

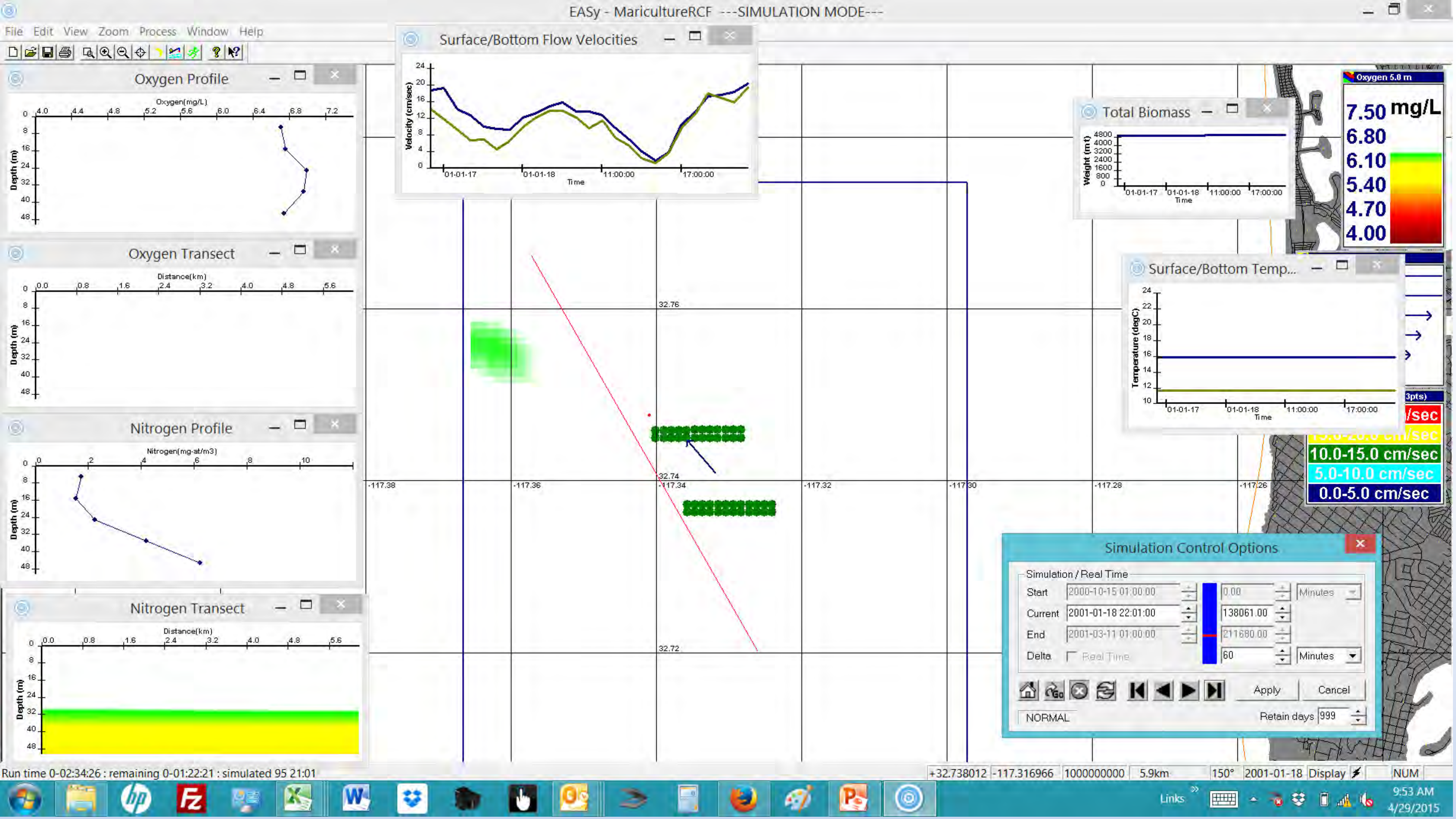

EASy - MaricultureRCF ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Sediment Oxygen
Oxygen (g/m^3)
Distance(km)
Sediment TOC
TOC (fraction)
Distance(km)
Sediment TOC Rate
TOC Rate (g_C/m^2/
Distance(km)
Surface/Bottom Flow Velocities
Velocity (cm/sec)
Time
Total Biomass
Weight (m t)
Time
Bathy-SCB
meters
0.00
40.00
80.00
120.00
160.00
200.00
For Help, press F1
+32.912292 -117.448279 1000000000 99999999.9NM 360% 09:57:47 Display NUM
Links
9:57 AM

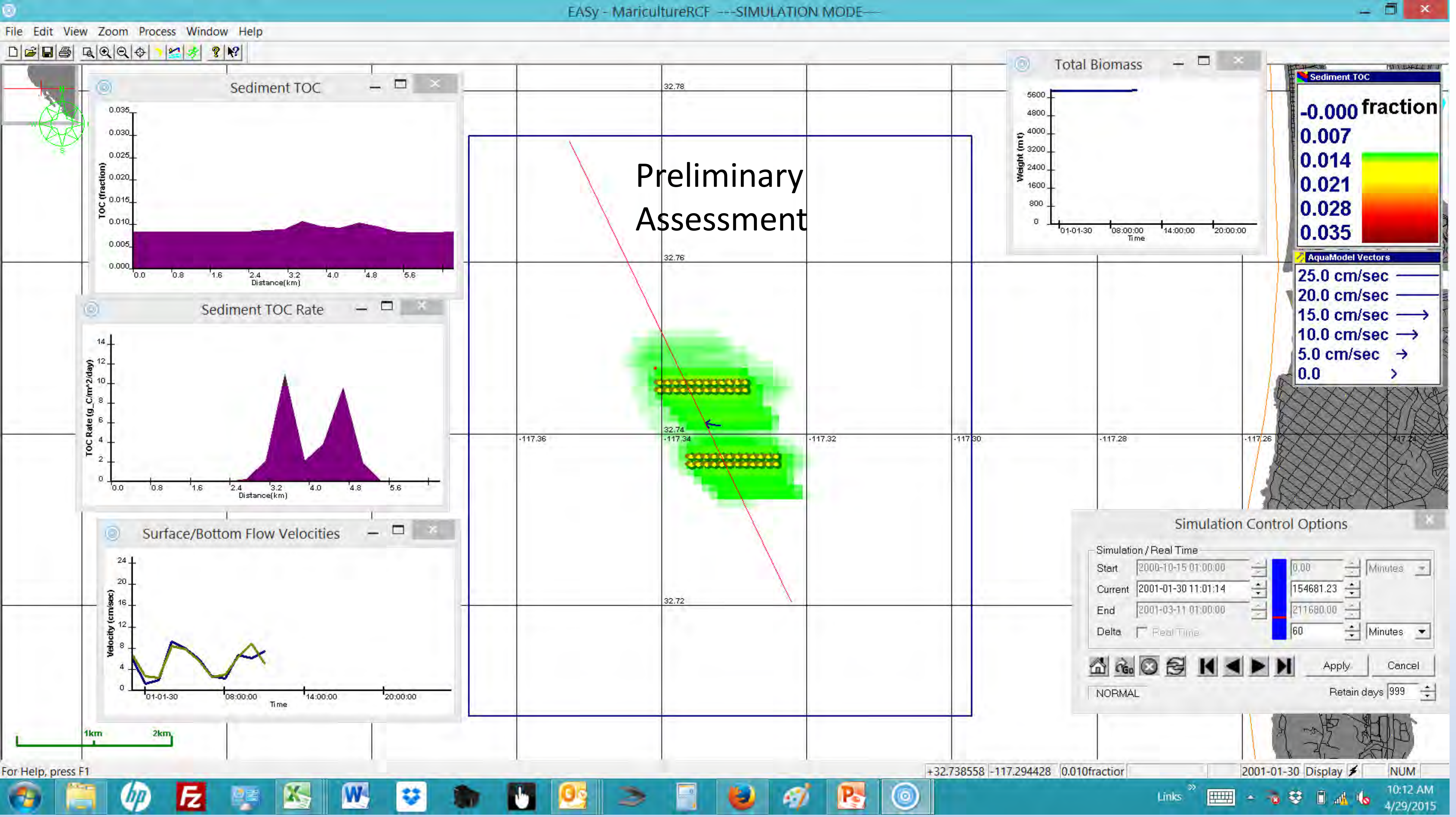


- Small decrease of dissolved oxygen outside the cages that disappears as the current speed increases toward the mean.
- Striped bass biomass of ~ 5,000 metric tons (project build out)
- The next few slides shows subsequent 20 minutes model time steps.

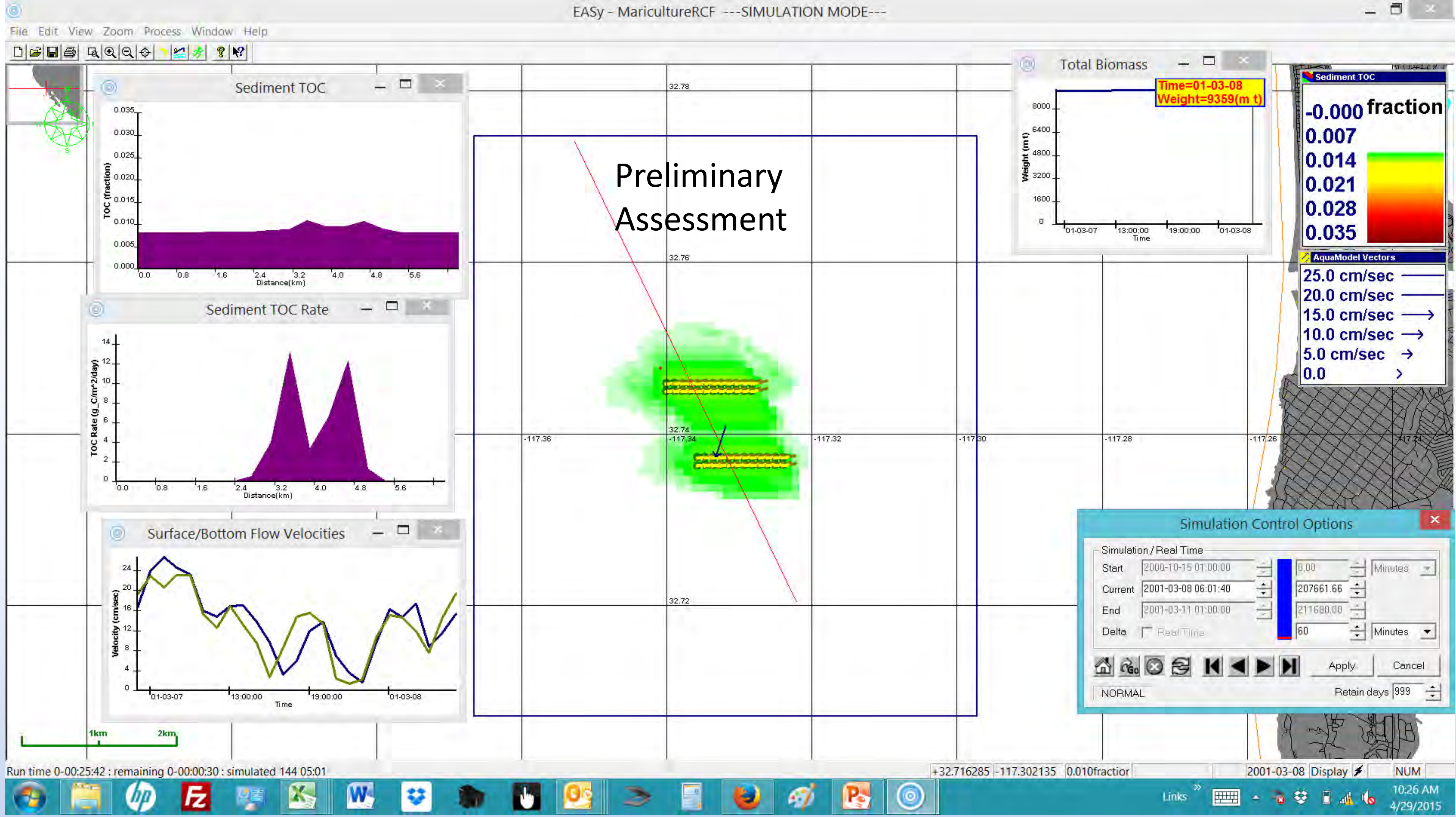

EASy - MaricultureRCF ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Oxygen Profile
Oxygen(mg/L)
Depth (m)
Oxygen Transect
Distance(km)
Nitrogen Profile
Nitrogen(mg-at/m3)
Nitrogen Transect
Surface/Bottom Flow Velocities
Velocity (cm/sec)
Time
Total Biomass
Weight (mt)
Oxygen 5.0 m
7.50 mg/L
6.80
6.10
5.40
4.70
4.00
Surface/Bottom Temp...
Temperature (degC)
10.0-15.0 cm/sec
5.0-10.0 cm/sec
0.0-5.0 cm/sec
Simulation Control Options
Simulation / Real Time
Start 2000-10-15 01:00:00 0.00 Minutes
Current 2001-01-18 20:01:00 137941.00
End 2001-03-11 01:00:00 211680.00
Delta Real Time 60 Minutes
Apply
Cancel
NORMAL
Retain days 999
Run time 0-02:32:55 : remaining 0-01:21:45 : simulated 95 19:01
+32.735284 -117.261038 1000000000 5.9km 150° 2001-01-18 Display NUM
9:52 AM
4/29/2015


EASy - MaricultureRCF ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Oxygen Profile
Oxygen(mg/L)
Depth (m)
Oxygen Transect
Distance(km)
Nitrogen Profile
Nitrogen(mg-at/m3)
Nitrogen Transect
Surface/Bottom Flow Velocities
Velocity (cm/sec)
Time
Total Biomass
Weight (mt)
Oxygen 5.0 m
7.50 mg/L
6.80
6.10
5.40
4.70
4.00
Surface/Bottom Temp...
Temperature (degC)
10.0-15.0 cm/sec
5.0-10.0 cm/sec
0.0-5.0 cm/sec
Simulation Control Options
Simulation / Real Time
Start 2000-10-15 01:00:00 0.00 Minutes
Current 2001-01-18 21:01:00 138001.00
End 2001-03-11 01:00:00 211680.00
Delta Real Time 60 Minutes
Apply Cancel
NORMAL
Retain days 999
Run time 0-02:33:42 : remaining 0-01:22:04 : simulated 95 20:01
+32.743382 -117.339359 1000000000 5.9km 150° 2001-01-18 Display NUM
9:52 AM
4/29/2015


EASy - MaricultureRCF ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Oxygen Profile
Oxygen(mg/L)
Depth (m)
Oxygen Transect
Distance(km)
Nitrogen Profile
Nitrogen(mg-at/m3)
Nitrogen Transect
Surface/Bottom Flow Velocities
Velocity (cm/sec)
Time
Total Biomass
Weight (mt)
Oxygen 5.0 m
7.50 mg/L
6.80
6.10
5.40
4.70
4.00
Surface/Bottom Temp...
Temperature (degC)
10.0-15.0 cm/sec
5.0-10.0 cm/sec
0.0-5.0 cm/sec
Simulation Control Options
Simulation / Real Time
Start 2000-10-15 01:00:00 0.00 Minutes
Current 2001-01-18 22:01:00 138061.00
End 2001-03-11 01:00:00 211680.00
Delta Real Time 60 Minutes
Apply Cancel
NORMAL
Retain days 999
Run time 0-02:34:26 : remaining 0-01:22:21 : simulated 95 21:01
+32.738012 -117.316966 1000000000 5.9km 150° 2001-01-18 Display NUM
Links
9:53 AM
4/29/2015

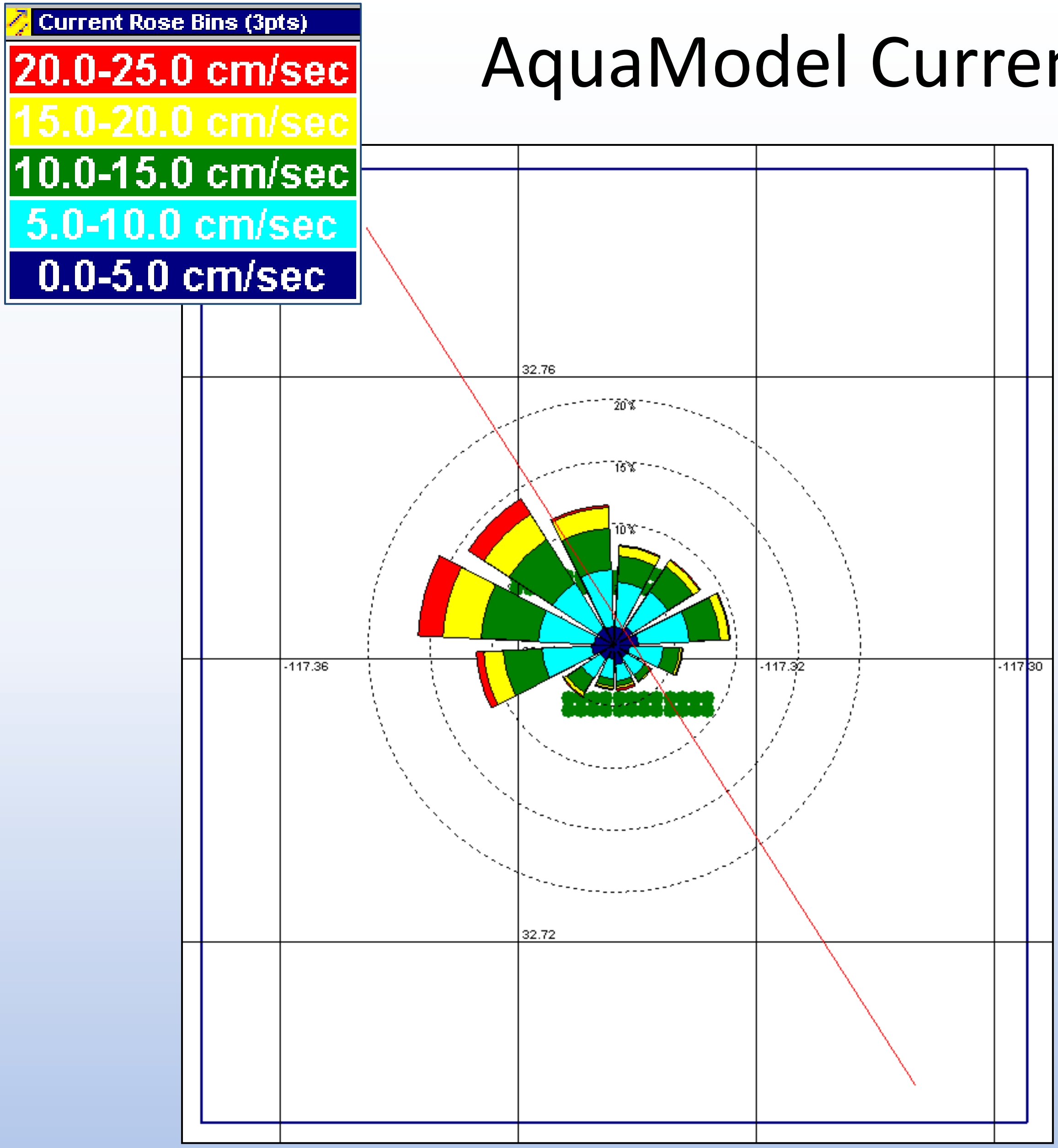


- Background sediment total organic carbon = 0.008 fraction = 0.8% dry weight
- Increase of 0.2% TOC immediately under the cages at **5,600 metric tons** fish
- Experience in other locations of similar temperatures has shown that this amount of increased TOC should not produce adverse changes in the sediment chemistry or benthic infauna



- Increase of 0.23% TOC immediately under the cages at **9,400 metric tons fish**
- Effect grades away to light blue indicating 0.1% TOC a few 100m away.
- Field measurable effects will only be detected to about 100 m away
- None of these effects are expected to adversely influence the benthos
- Some beneficial effects are expected with increased abundance and diversity of infauna

AquaModel Current Vector Rose



RCF Site
S. Ca. Bight

- Many depths measured
- 5m depth example here
- five month duration
- 20 min time intervals

Relative current speeds are strong & near-ideal for the fish and the environmental effects

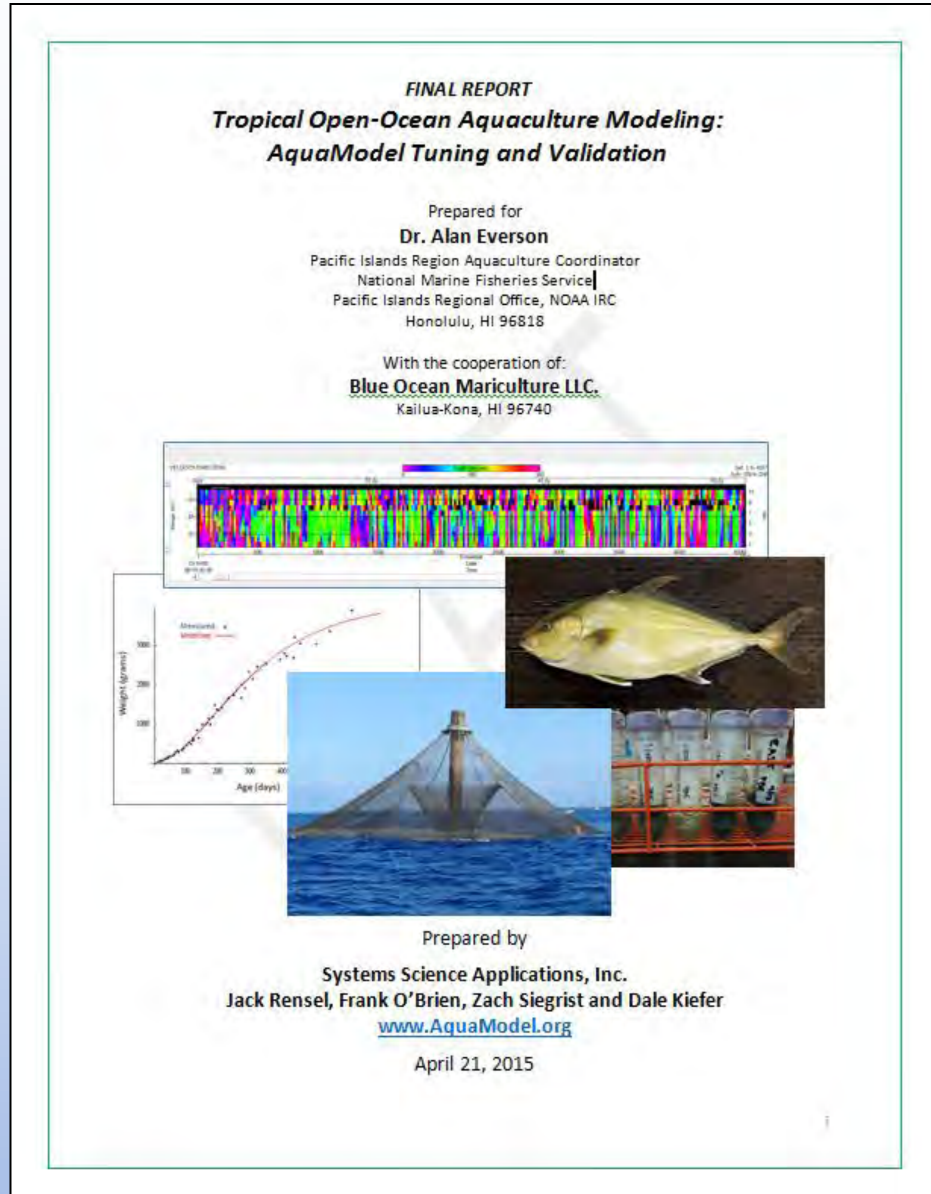
Strongest and most persistent currents are offshore to the NW

Raw Data Courtesy of HSWRI, Mike Shane et al.

- Examples of other ongoing or completed model validation studies follow

Oligotrophic Habitats

Tropical Hawai'i near Kona: Blue Ocean Mariculture Farm



FINAL REPORT

Tropical Open-Ocean Aquaculture Modeling: AquaModel Tuning and Validation

Prepared for

Dr. Alan Everson

Pacific Islands Region Aquaculture Coordinator
National Marine Fisheries Service
Pacific Islands Regional Office, NOAA IRC
Honolulu, HI 96818

With the cooperation of:

Blue Ocean Mariculture LLC.

Kailua-Kona, HI 96740

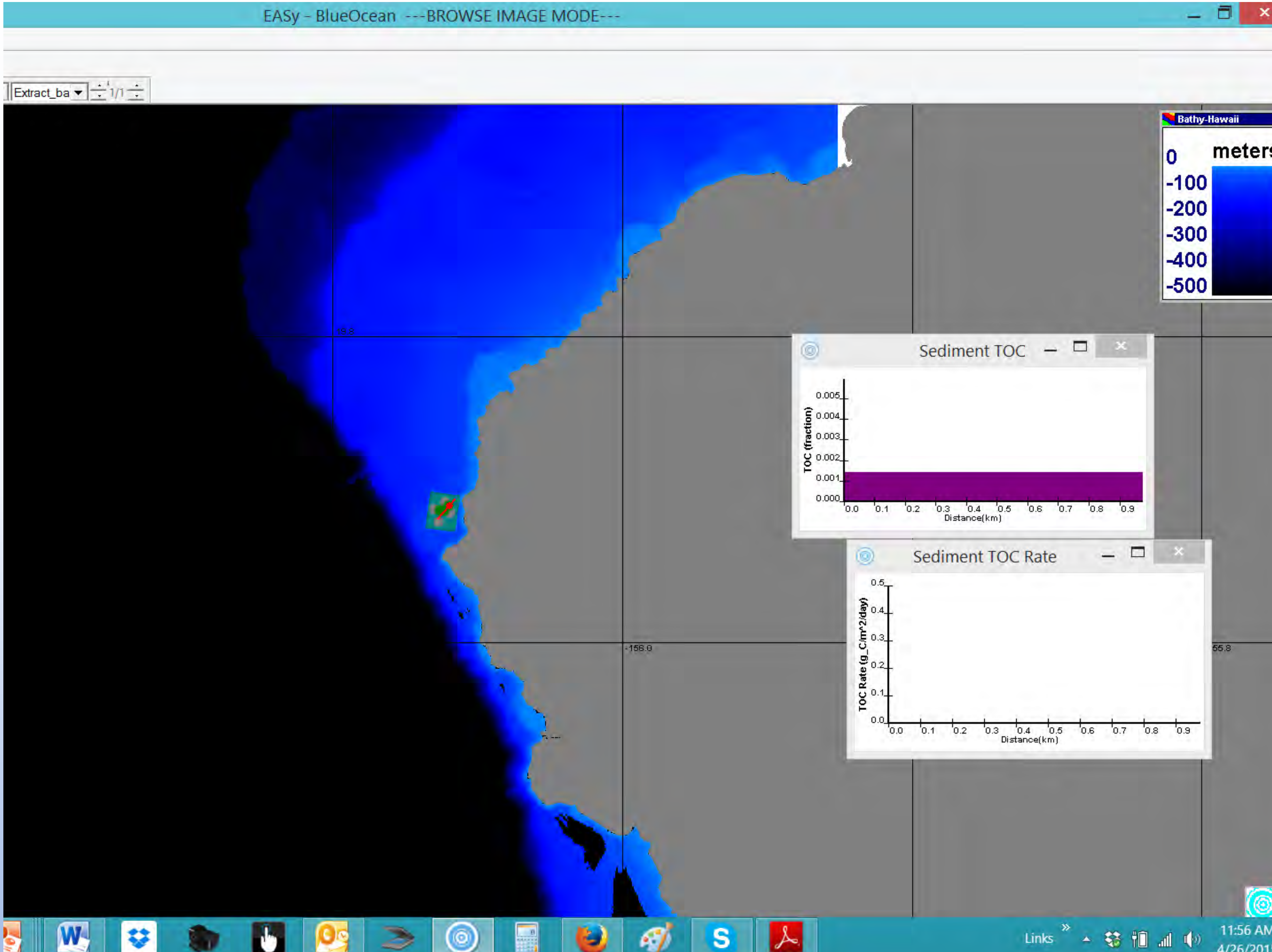
Prepared by

Systems Science Applications, Inc.

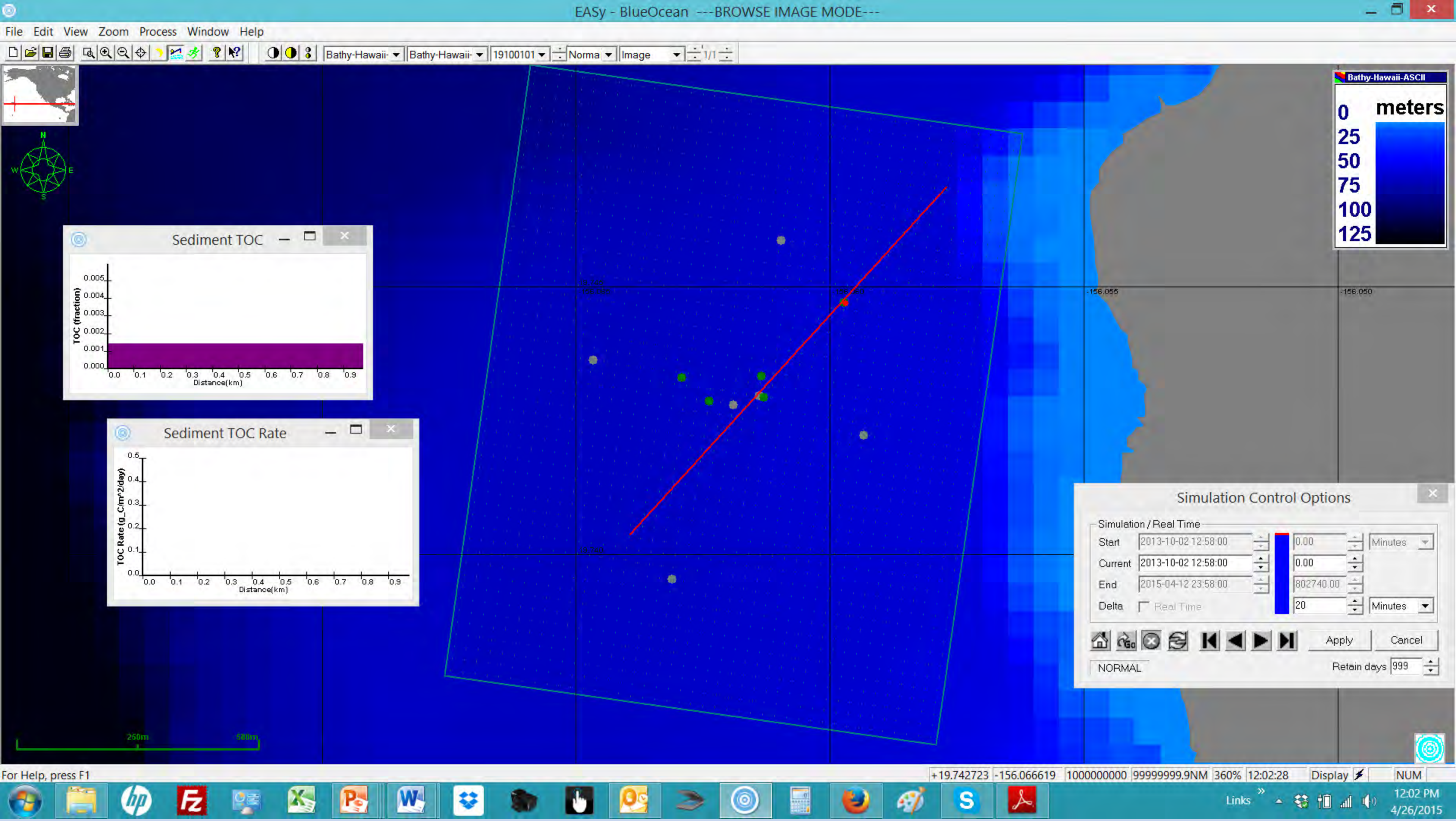
Jack Rensel, Frank O'Brien, Zach Siegrist and Dale Kiefer

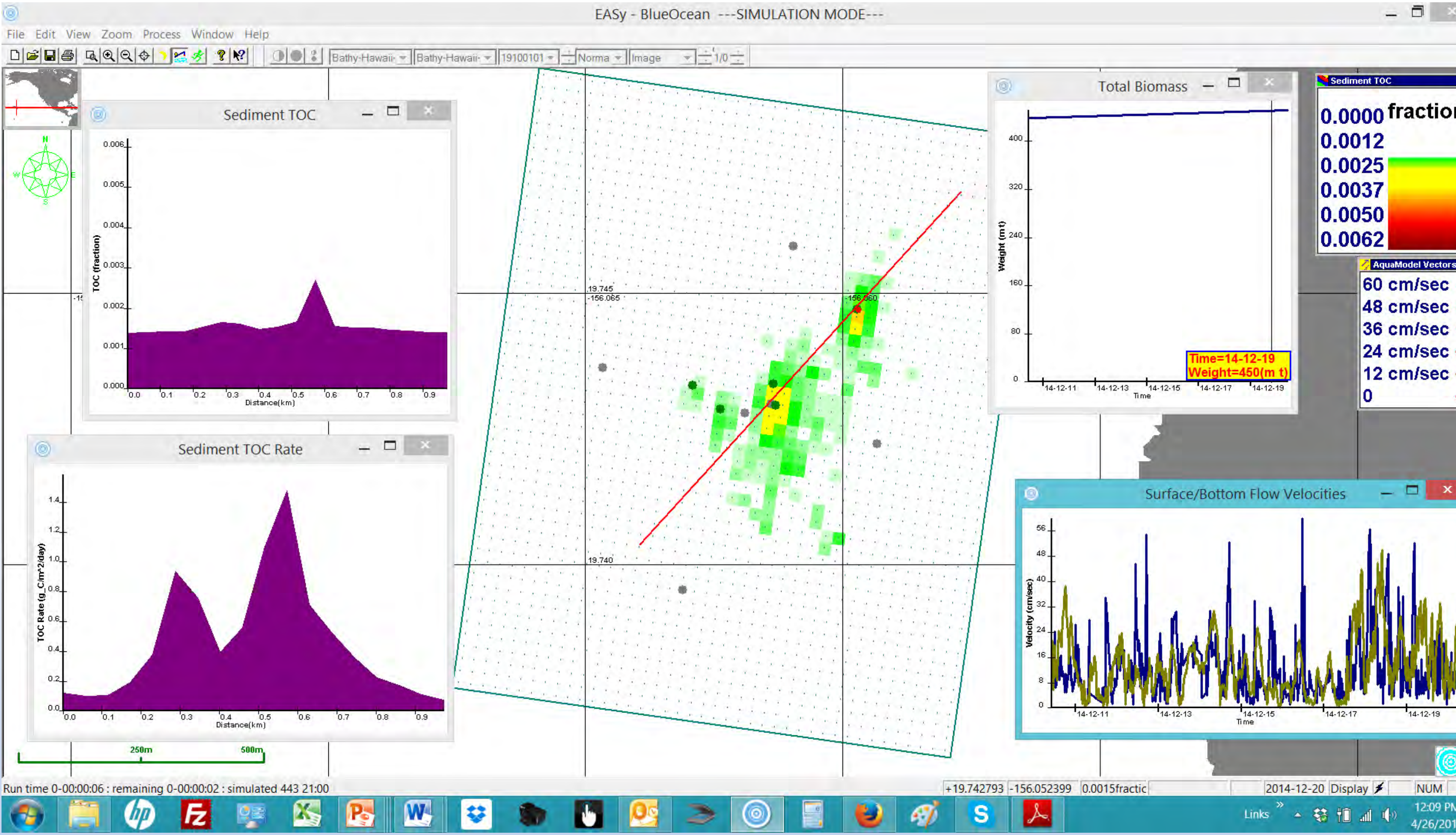
www.AquaModel.org

April 21, 2015



EASy - BlueOcean ---BROWSE IMAGE MODE---
Extract_ba
1/1
Bathy-Hawaii
meters
0
-100
-200
-300
-400
-500
-156.0
Sediment TOC
TOC (fraction)
0.005
0.004
0.003
0.002
0.001
0.000
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Distance(km)
Sediment TOC Rate
TOC Rate (g_C/m^2/day)
0.5
0.4
0.3
0.2
0.1
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Distance(km)
Links
11:56 AM
4/26/2015


EASy - BlueOcean ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Bathy-Hawaii-
Bathy-Hawaii-
19100101
Norma
Image
Sediment TOC
TOC (fraction)
Distance(km)
Sediment TOC Rate
TOC Rate (g_C/m^2/day)
Distance(km)
Bathy-Hawaii-ASCII
meters
0
25
50
75
100
125
Simulation Control Options
Simulation / Real Time
Start 2013-10-02 12:58:00 0.00 Minutes
Current 2013-10-02 12:58:00 0.00
End 2015-04-12 23:58:00 802740.00
Delta Real Time 20 Minutes
Apply
Cancel
NORMAL
Retain days 999
For Help, press F1
+19.742723 -156.066619 1000000000 99999999.9NM 360% 12:02:28 Display NUM
Links
12:02 PM
4/26/2015

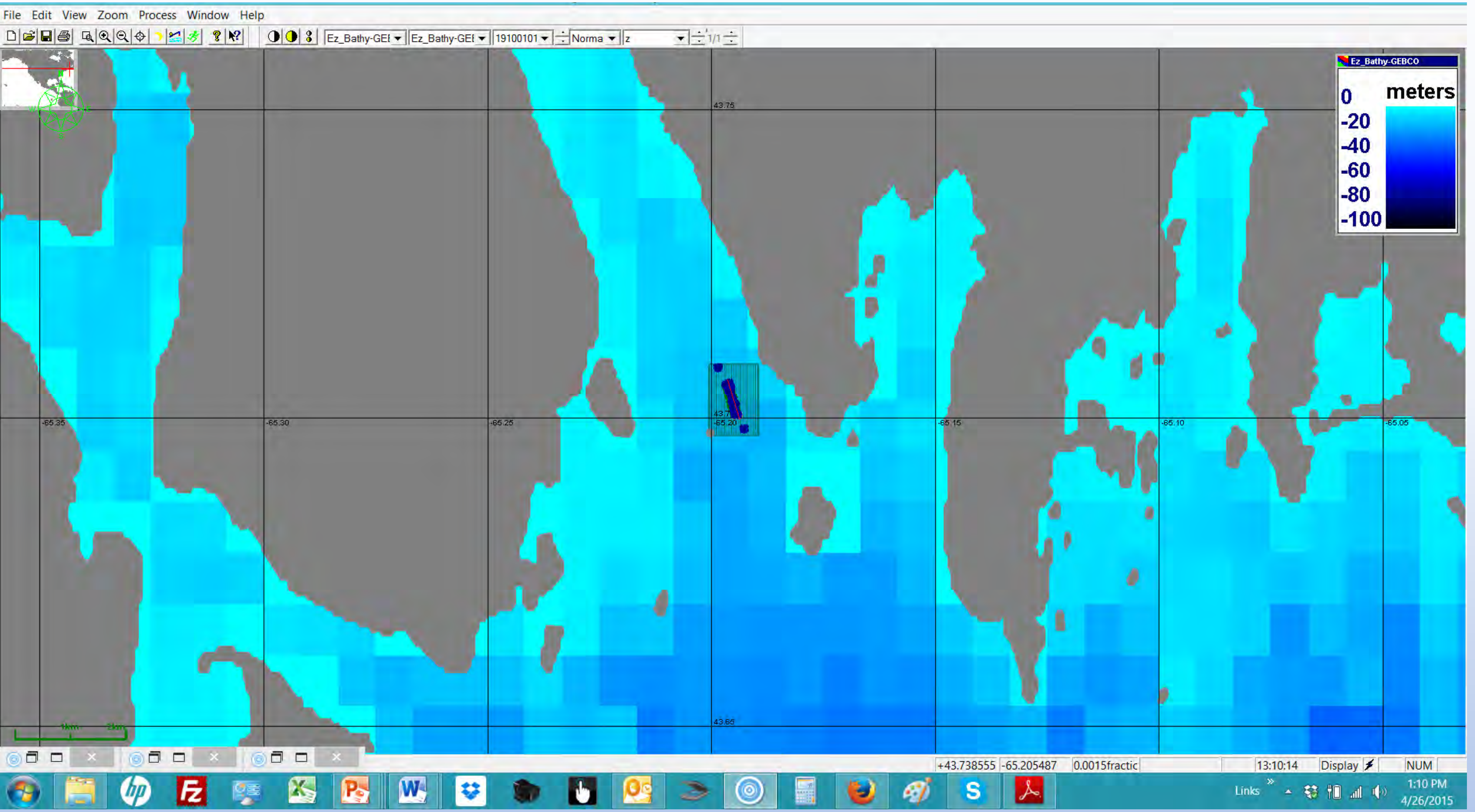


Very small sediment chemistry effect near pen from background of 0.14% TOC to 0.16% TOC except near two of the larger cages. Biological perturbation unlikely.

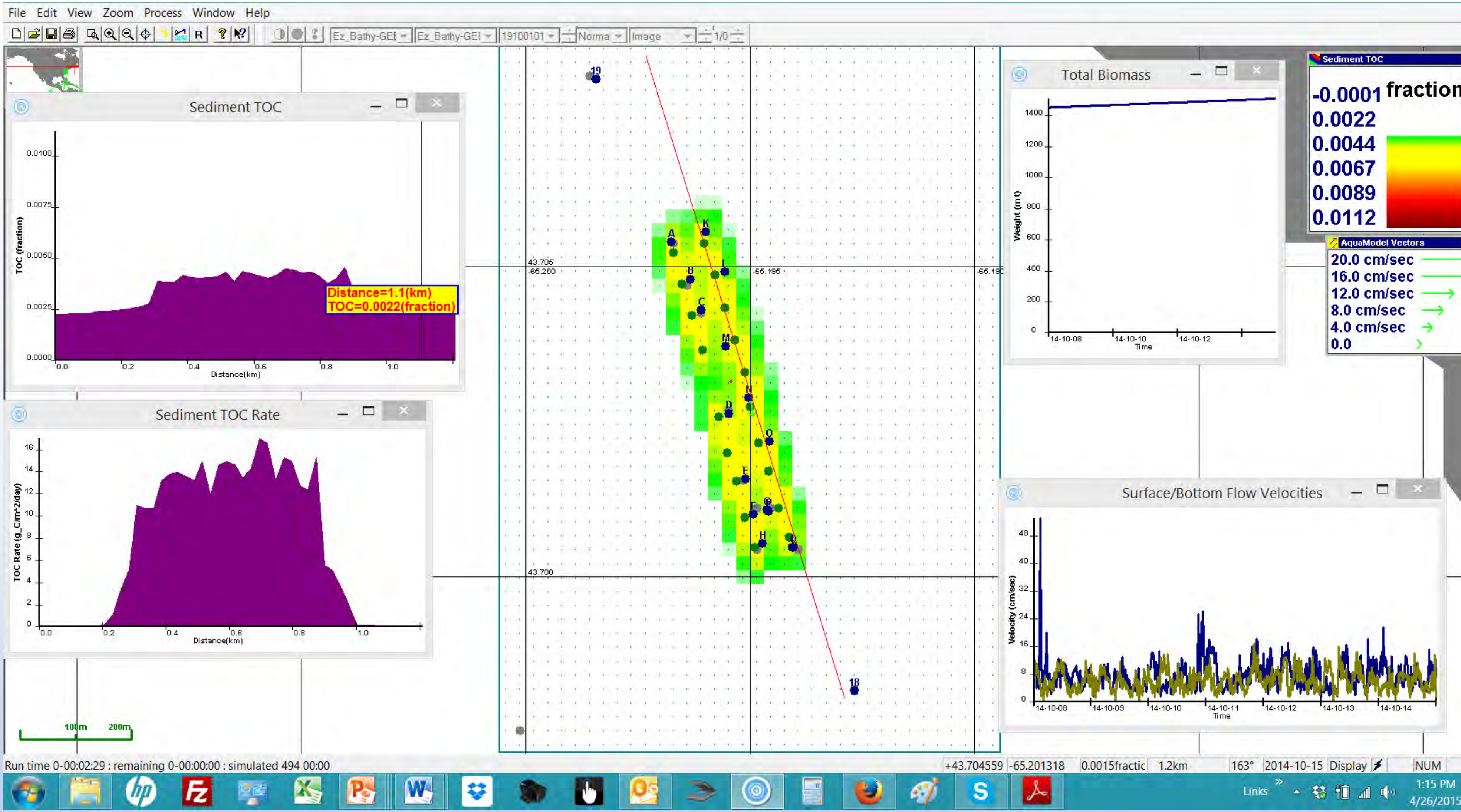
See report to NOAA for details.

Mesotrophic Habitats

"Temperate" Nova Scotia



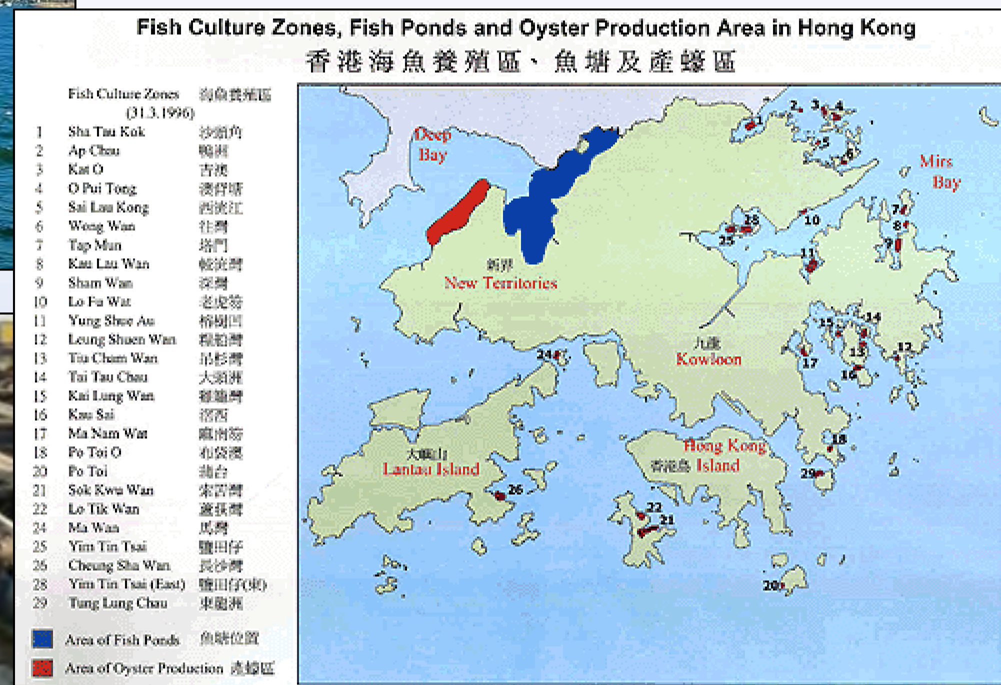
Chiloe Atlantic Salmon Farms model validation also underway

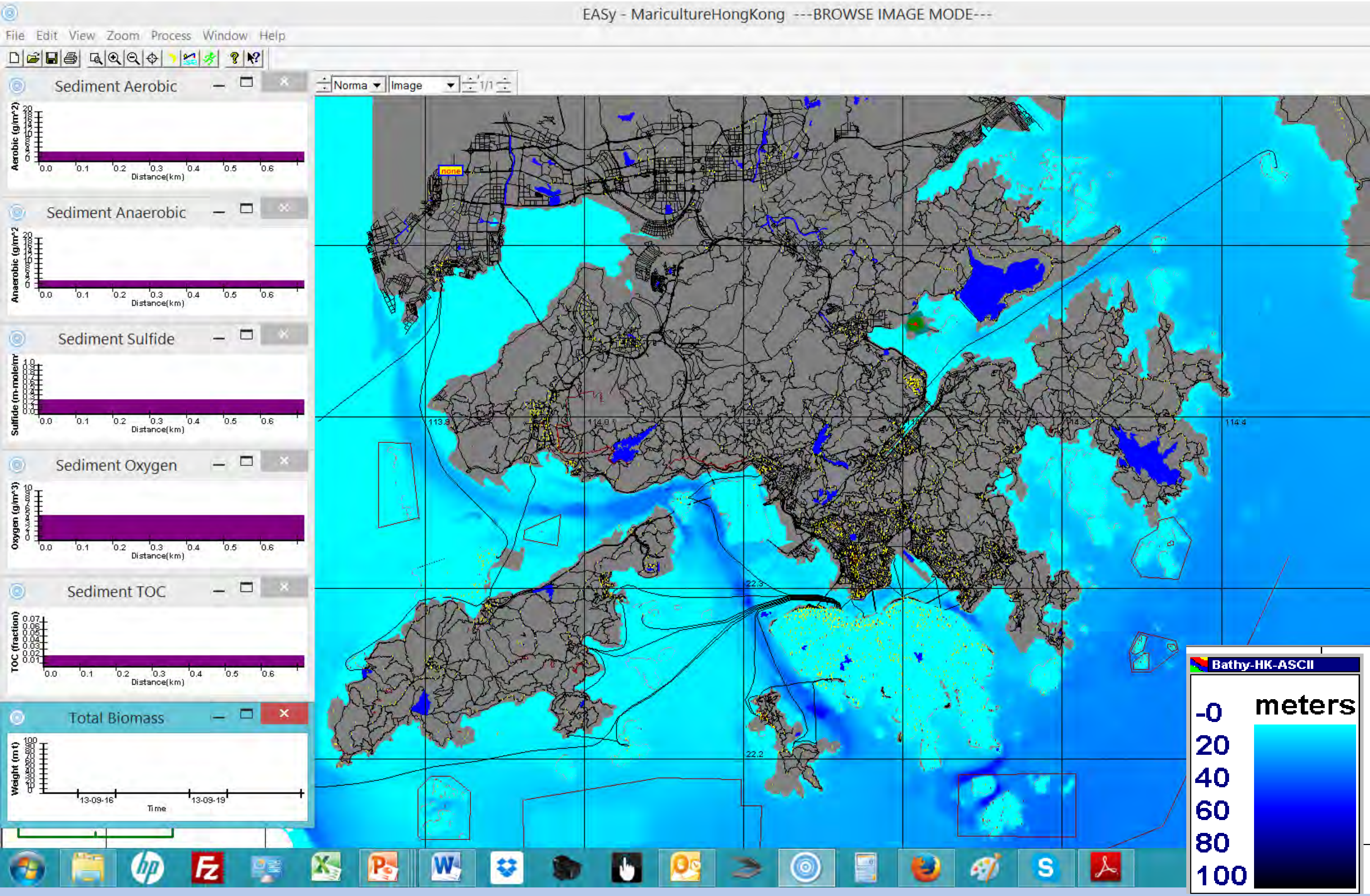


File Edit View Zoom Process Window Help
Sediment TOC
TOC (fraction)
Distance(km)
Distance=1.1(km)
TOC=0.0022(fraction)
Sediment TOC Rate
TOC Rate (g_C/m^2/day)
Distance(km)
Total Biomass
Weight (mt)
Time
Sediment TOC
-0.0001 fraction
0.0022
0.0044
0.0067
0.0089
0.0112
AquaModel Vectors
20.0 cm/sec
16.0 cm/sec
12.0 cm/sec
8.0 cm/sec
4.0 cm/sec
0.0
Surface/Bottom Flow Velocities
Velocity (cm/sec)
Time
43.705
-65.200
-65.195
43.700
100m
200m
Run time 0-00:02:29 : remaining 0-00:00:00 : simulated 494 00:00
+43.704559
-65.201318
0.0015fractic
1.2km
163°
2014-10-15
Display
NUM
1:15 PM
4/26/2015

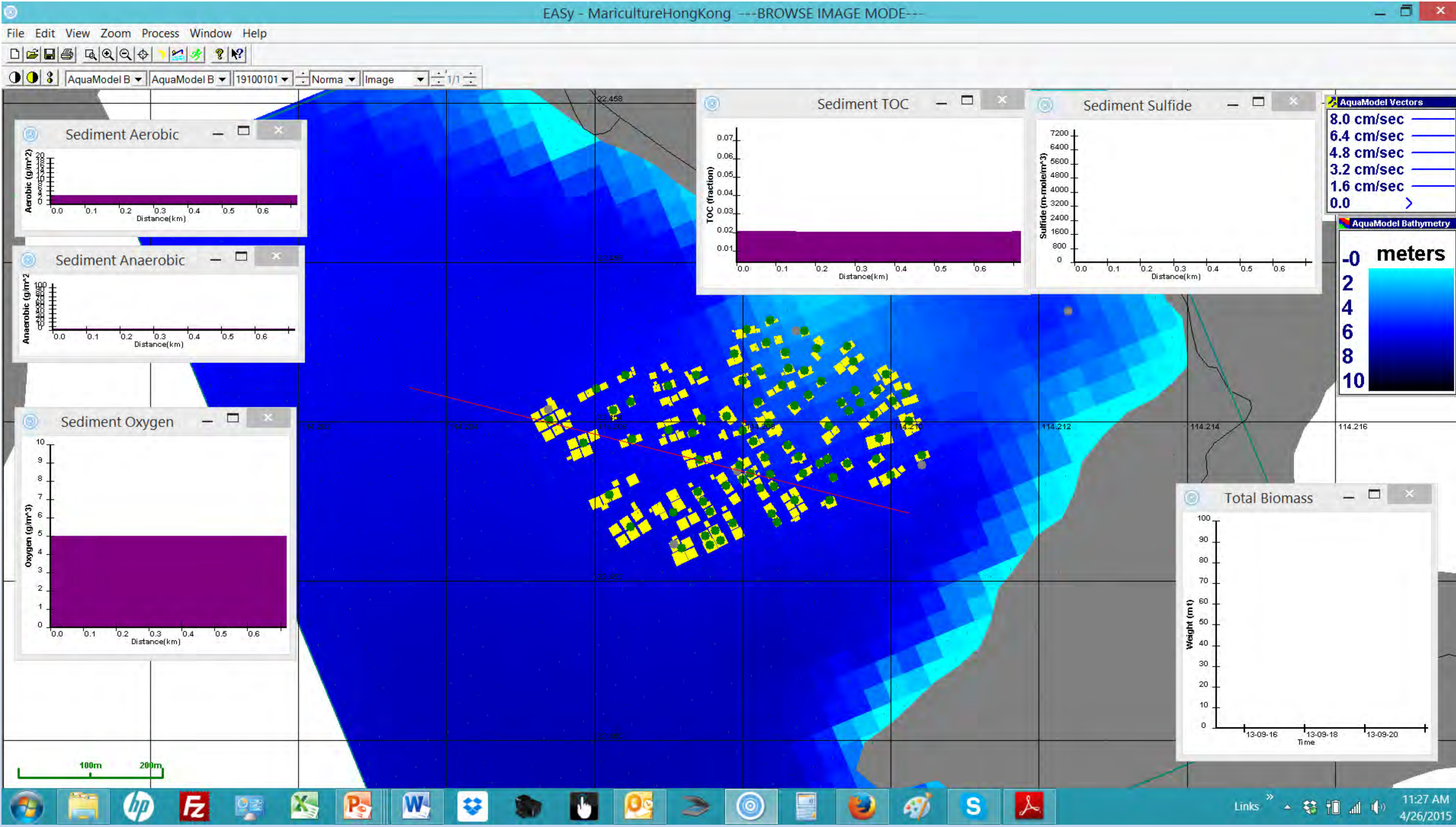
Eutrophic Habitats

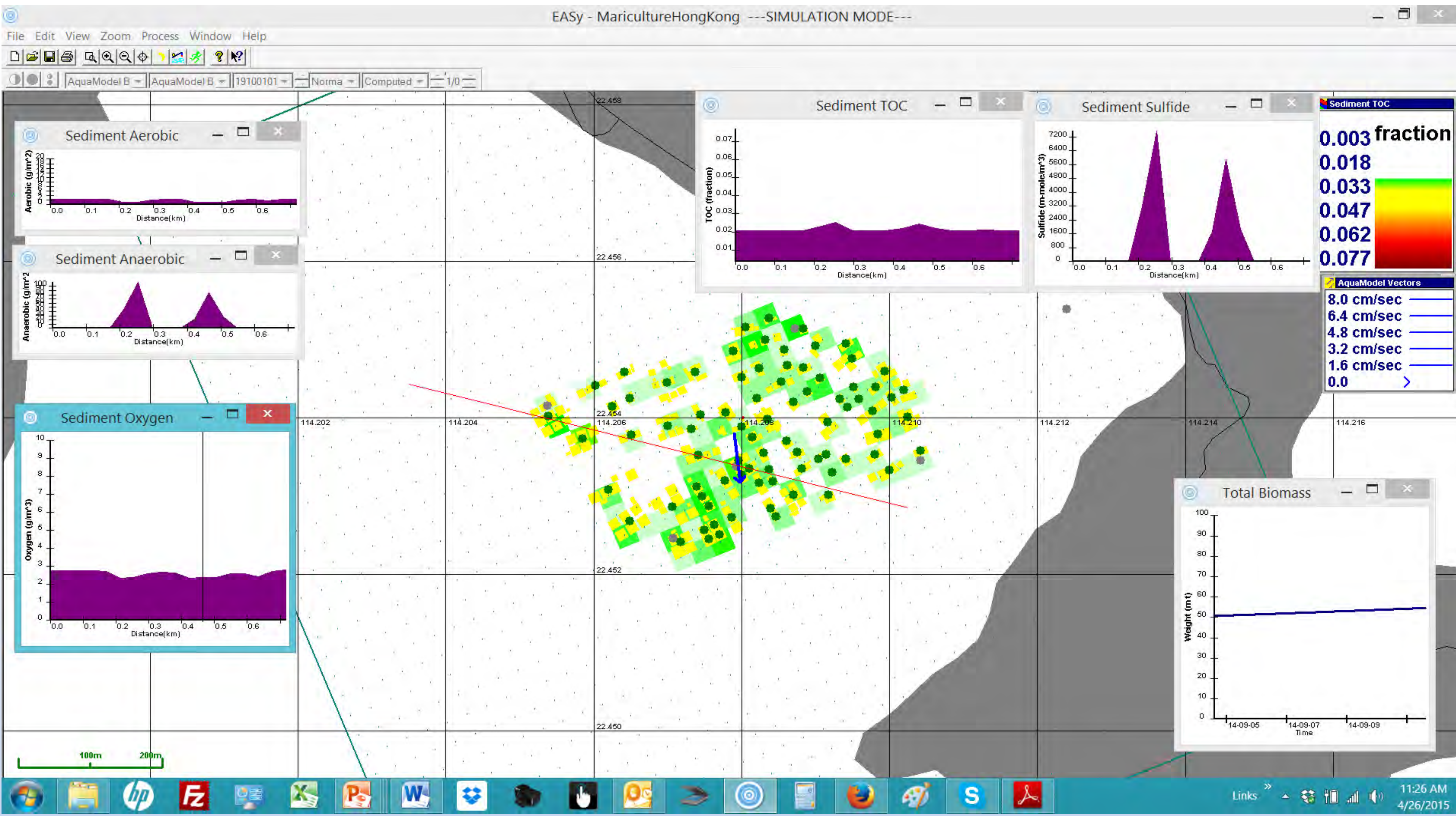
Semi-Tropical - Hong Kong Fisheries and Conservation Dept.





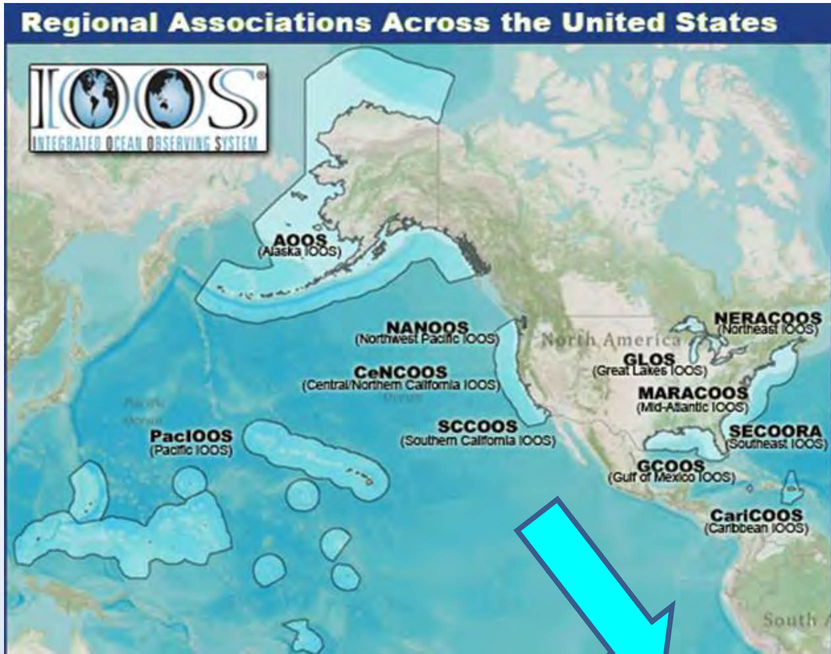
EASy - MaricultureHongKong ---BROWSE IMAGE MODE---
File
Edit
View
Zoom
Process
Window
Help
Norma
Image
1/1
Sediment Aerobic
Aerobic (g/m^2)
Distance(km)
Sediment Anaerobic
Anaerobic (g/m^2
Distance(km)
Sediment Sulfide
Distance(km)
Sediment Oxygen
Oxygen (g/m^3)
Distance(km)
Sediment TOC
TOC (fraction)
Distance(km)
Total Biomass
Weight (mt)
13-09-16
13-09-19
Time
none
113.9
114.4
22.3
22.2
Bathy-HK-ASCII
meters
-0
20
40
60
80
100

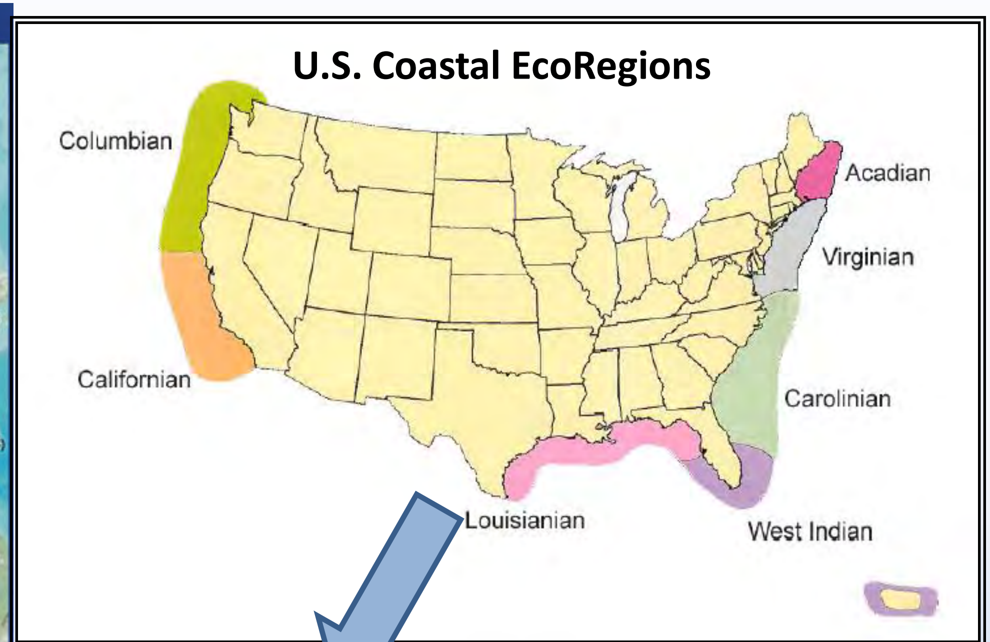

EASy - MaricultureHongKong ---BROWSE IMAGE MODE---
File Edit View Zoom Process Window Help
Sediment Aerobic
Sediment Anaerobic
Sediment Oxygen
Sediment TOC
Sediment Sulfide
Total Biomass
Distance(km)
AquaModel Vectors
8.0 cm/sec
6.4 cm/sec
4.8 cm/sec
3.2 cm/sec
1.6 cm/sec
0.0
AquaModel Bathymetry
meters
100m
200m
11:27 AM
4/26/2015

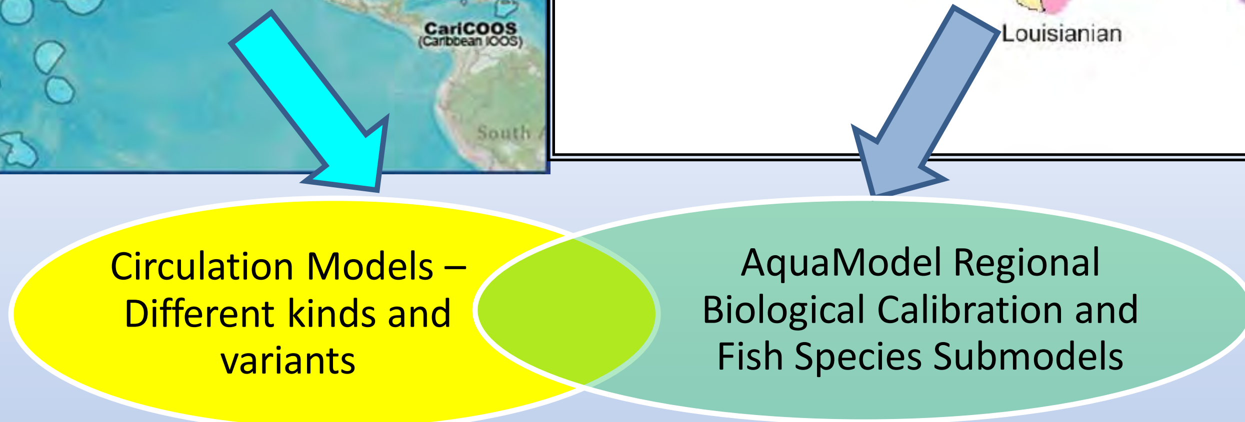


EASy - MaricultureHongKong ---SIMULATION MODE---
File Edit View Zoom Process Window Help
Sediment Aerobic
Sediment Anaerobic
Sediment Oxygen
Sediment TOC
Sediment Sulfide
Sediment TOC
0.003 fraction
0.018
0.033
0.047
0.062
0.077
AquaModel Vectors
8.0 cm/sec
6.4 cm/sec
4.8 cm/sec
3.2 cm/sec
1.6 cm/sec
0.0
Total Biomass
Weight (mt)
Time
Distance(km)
100m
200m
11:26 AM
4/26/2015

U.S. Integrated Ocean Observation System (IOOS)
+ EcoRegion Calibrated Biological-Chemical Models

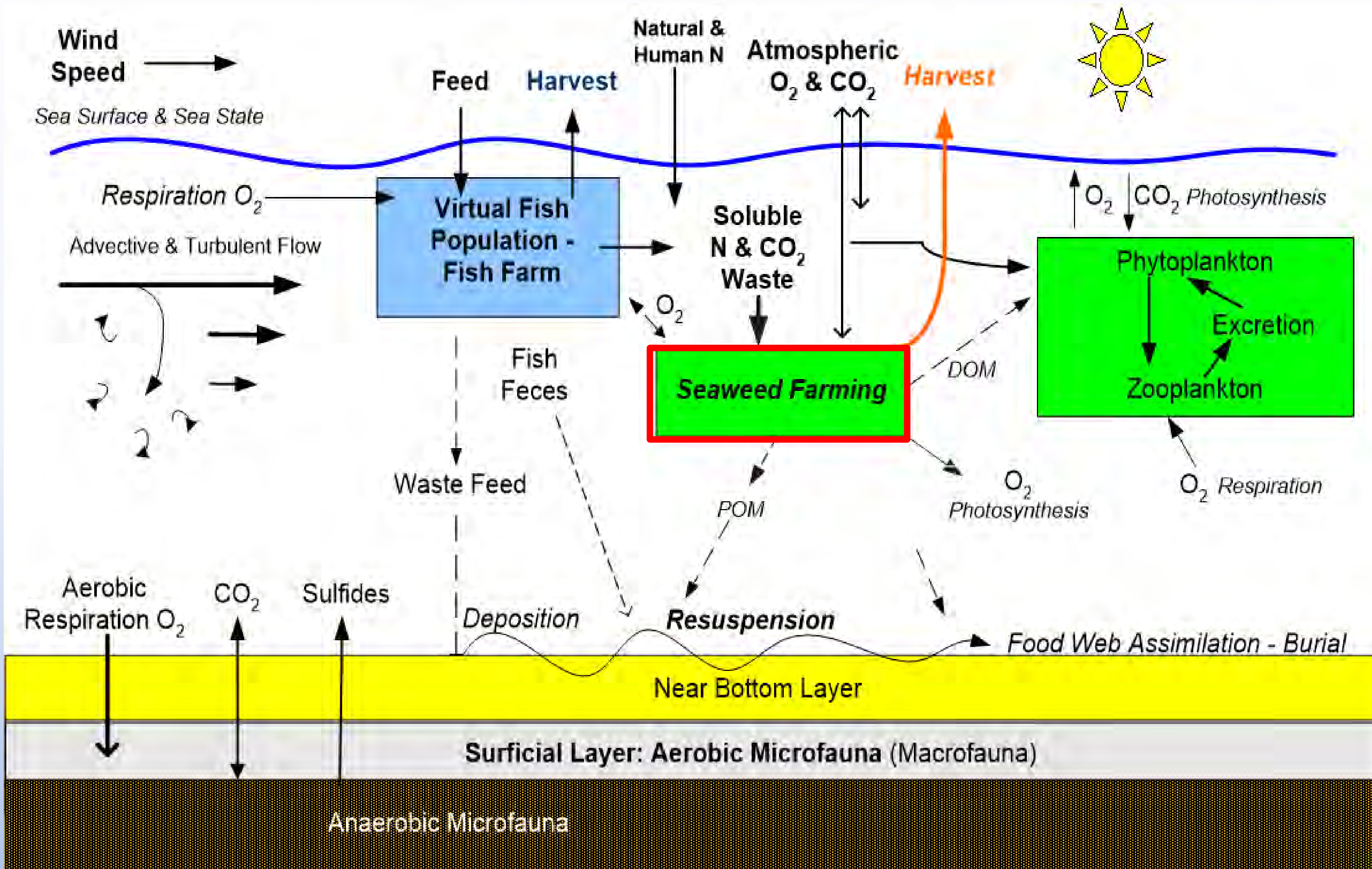


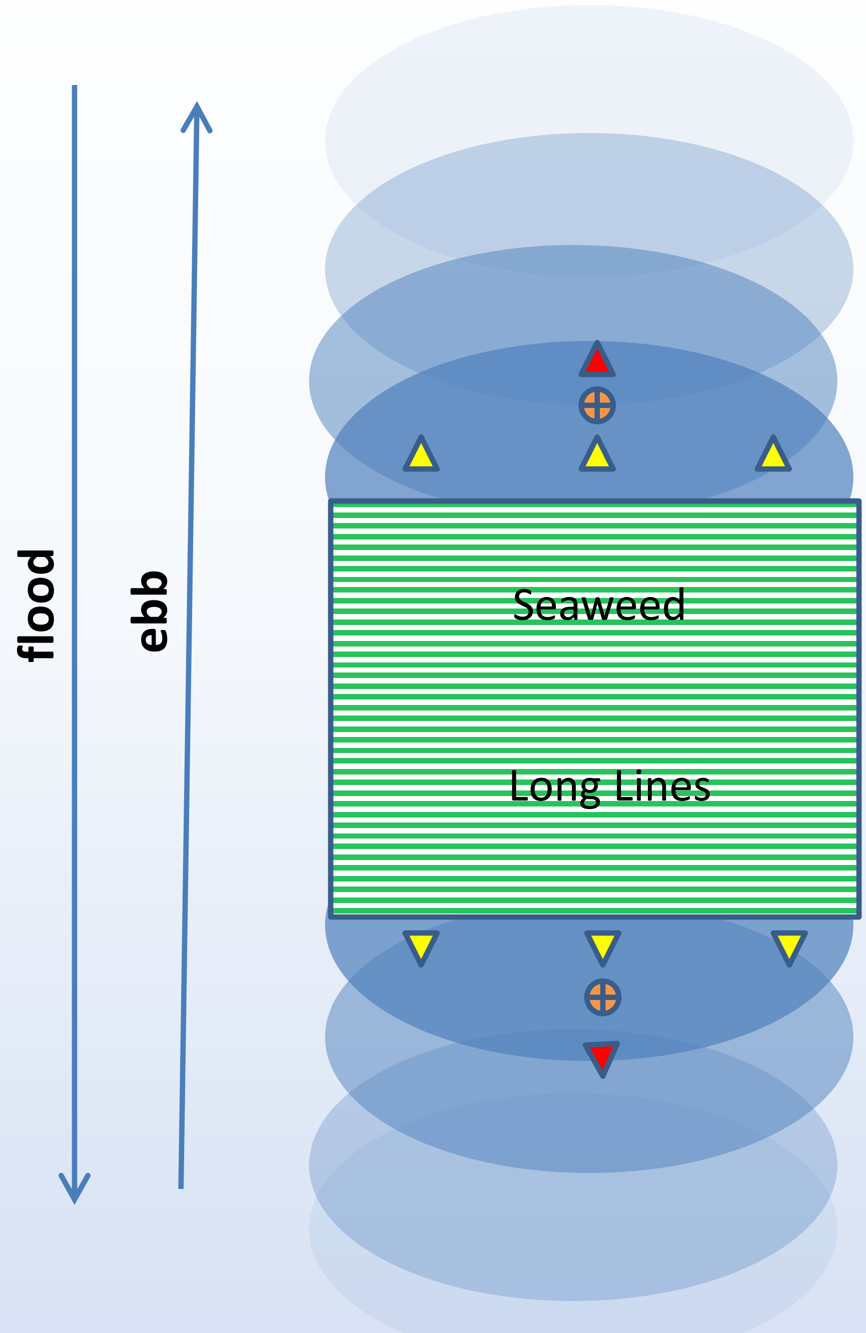




- No two regional circulation models constructed exactly the same
- AquaModel programed to read and integrate the outputs for each
- Regional calibration of water, sediment, chemistry, biology and fish species dynamics

Future AquaModel: Conceptual Model





Seaweed Aquaculture and Ocean Acidification Refugium Experimental Layout

Paul Allen Family Foundation
Ocean Challenge Competition Funding

- Economically self-sustaining goal
- Mitigate acidity locally, sensitive spp.
- Seaweed-Fish Aquaculture for N removal and DO supplementation

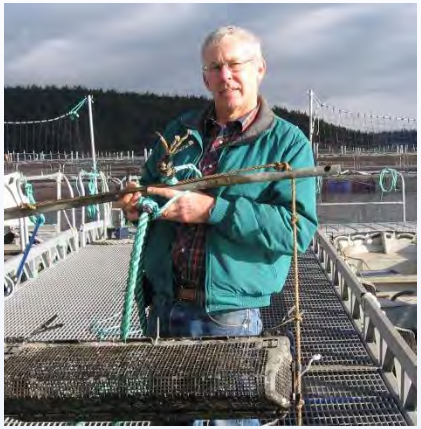
Permanent instrument moorings
ADCP current meters
Spot WQ measurements and analog current meter observations

One hectare sugar and bull kelp
Later Gracilaria (red) higher value

AquaModel Team: System Science Applications, Inc. (SSA)

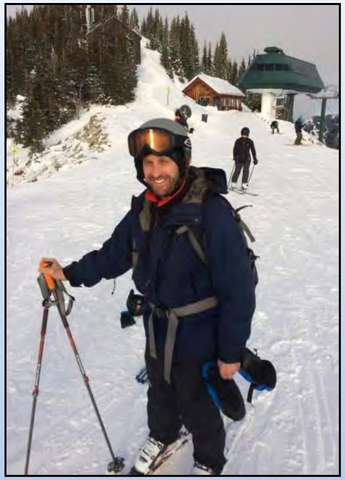
Dale A. Kiefer Ph.D.
USC – SSA Inc. President

Frank O'Brien
SSA, Inc.
Software Engineer



Jack Rensel Ph.D.
Scientist

Zach Siegrist
SSA, Inc. Assistant
Software Engineer &
Field Technician



David W. Fredriksson
U. S. Naval Academy
Adjunct AquaModel Team

For more Information
Google: AquaModel
www.AquaModel.org