Science, Service, Stewardship

Quantifying Ecosystem Interactions of a FLUPSY-Based Oyster Nursery

Mark S. Dixon, Yaqin Li, April Croxton, Jennifer Alix, Soledad Fuentes, Shannon L. Meseck, Lisa Milke, Julie M. Rose, Barry C. Smith, Gary H. Wikfors

DOC, NOAA, NMFS, NEFSC, Milford, CT

Karen Rivara Aeros Cultured Oyster Company, Southold, NY

May 19, 2010

NOAA FISHERIES SERVICE

NOAA FISHERIES SERVICE

Presentation Overview

Aquaculture, oysters, and FLUPSYs, oh my!

Mark S. Dixon

Plankton and nutrient cycles – fundamental ecosystem processes and how they interact with oyster aquaculture.

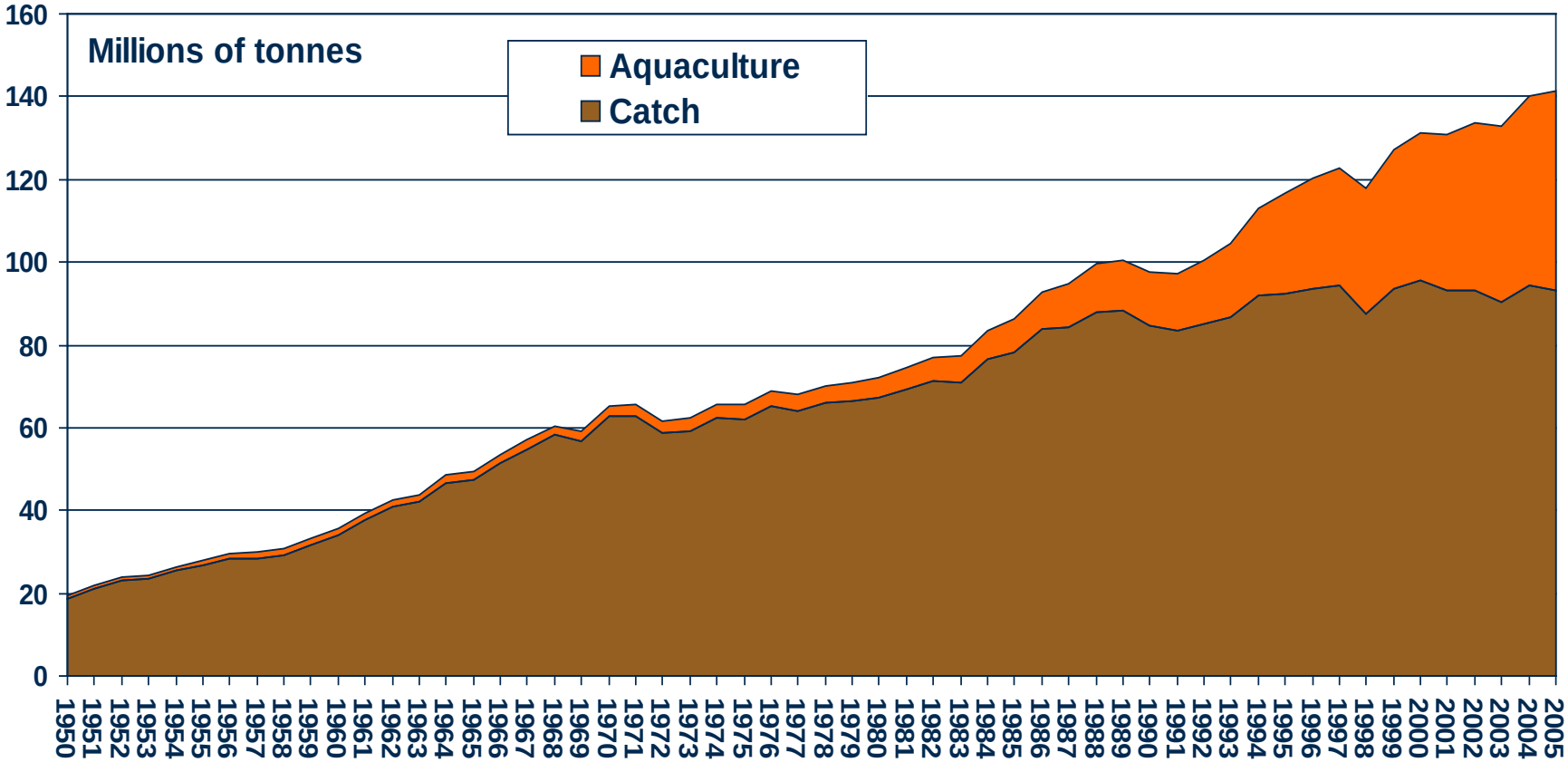
“Judy” Yaqin Li

What do the oysters think about all of this?

April N. Croxton

NOAA FISHERIES SERVICE

World Seafood Production



Fishstat 2007

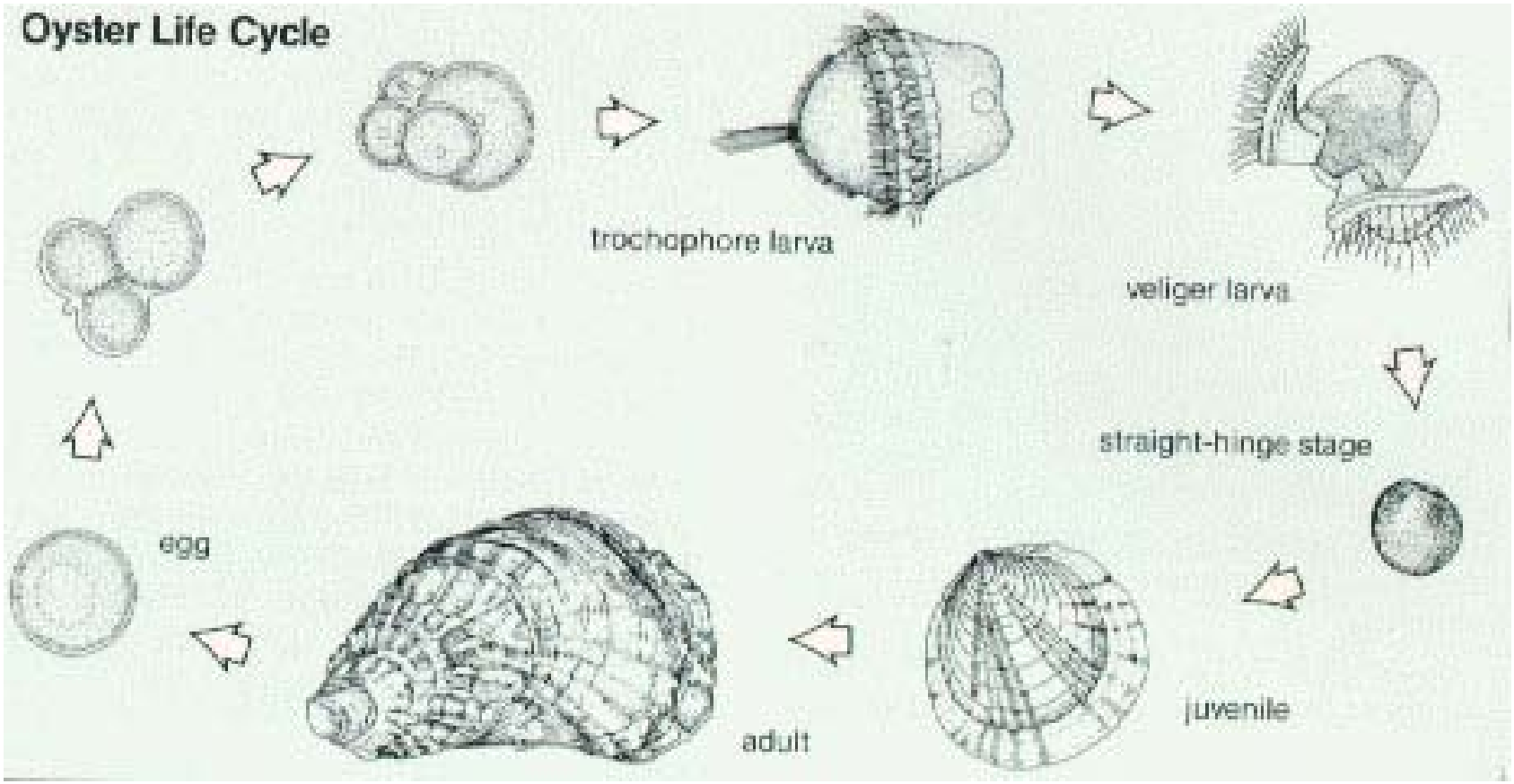
NOAA
FISHERIES
SERVICE

Shellfish Aquaculture

"Shellfish aquaculture involves farming invertebrates such as clams, mussels, oysters, and scallops. Shellfish aquaculture can help to meet an increasing demand for seafood in the U.S. while providing a closely-related field of employment for shell fishermen displaced by declines in wild shellfish stocks."

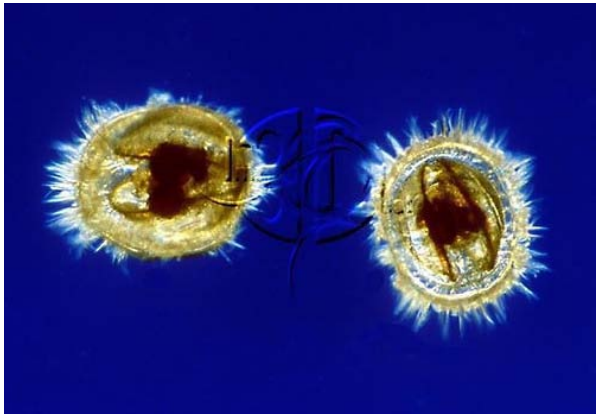
NOAA Aquaculture Program

NOAA
FISHERIES
SERVICE



NOAA FISHERIES SERVICE

Nursery Culture



Larval post-set

Critical growth phase

Business Model

- fast
- efficient
- high volume
- high survivorship

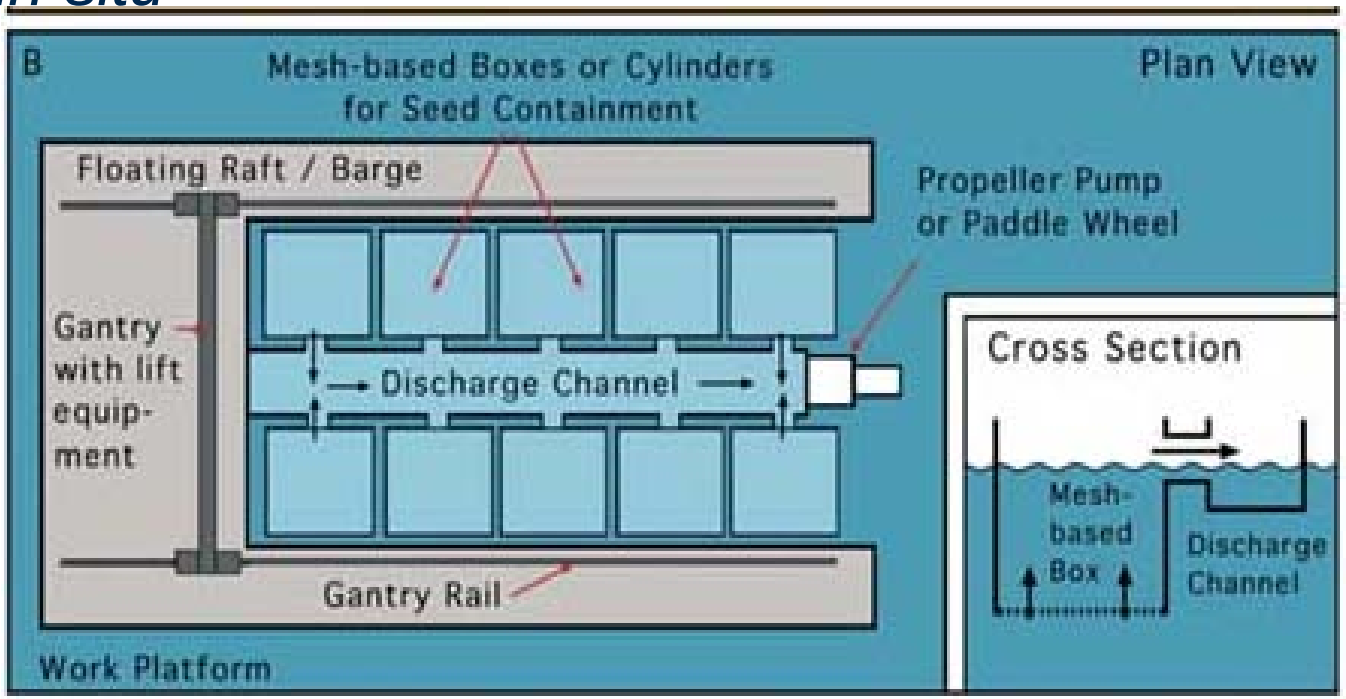
Traditionally Land-based

FLUPSY Innovation

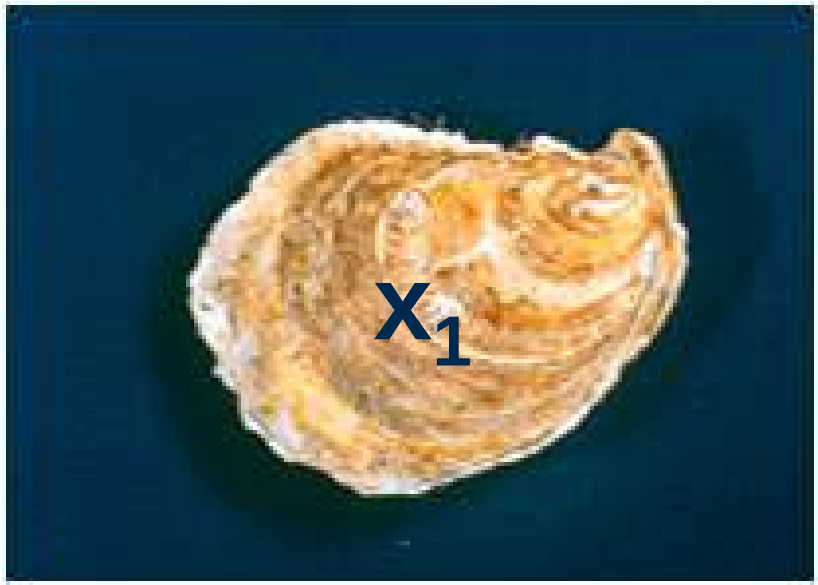
NOAA FISHERIES SERVICE

Floating Upwelling System FLUPSY

- Forced upwelling
- Increased delivery of phytoplankton
- Floating array, *in-situ*
- Cost reduction

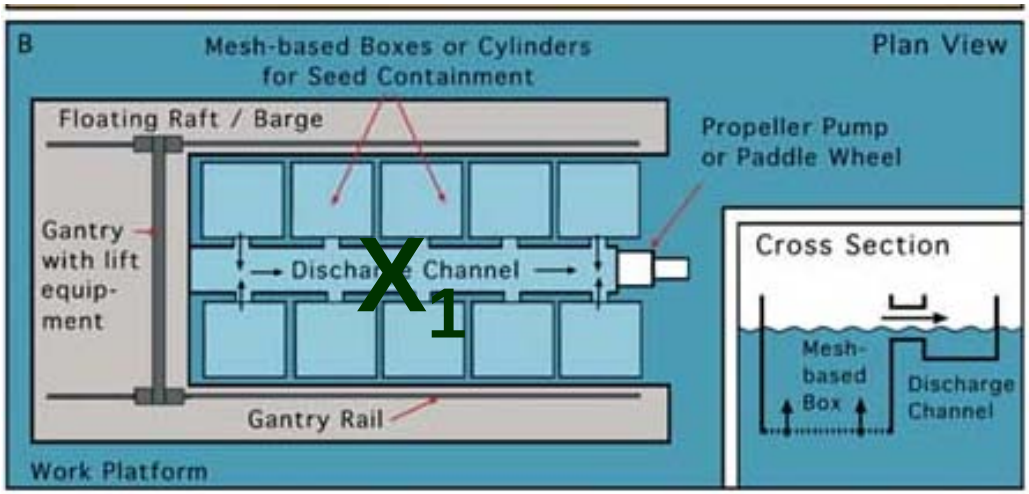


NOAA
FISHERIES
SERVICE



NOAA FISHERIES SERVICE

X



X_1

X_2

X_3

NOAA FISHERIES SERVICE

Shellfish Aquaculture/Environment Interactions

Mitigate Eutrophication

Increase Water Clarity

Restore Ecosystem Functions

Reduce Pressure on Natural Stocks

Compete with Natural Populations

Disrupt Food Webs via Excessive Grazing

Alter Sedimentation a/o Flow Patterns

Neutral or Below Detection

NOAA FISHERIES SERVICE

This Study

What effects do operation of a FLUPSY-based nursery have on the local environment?

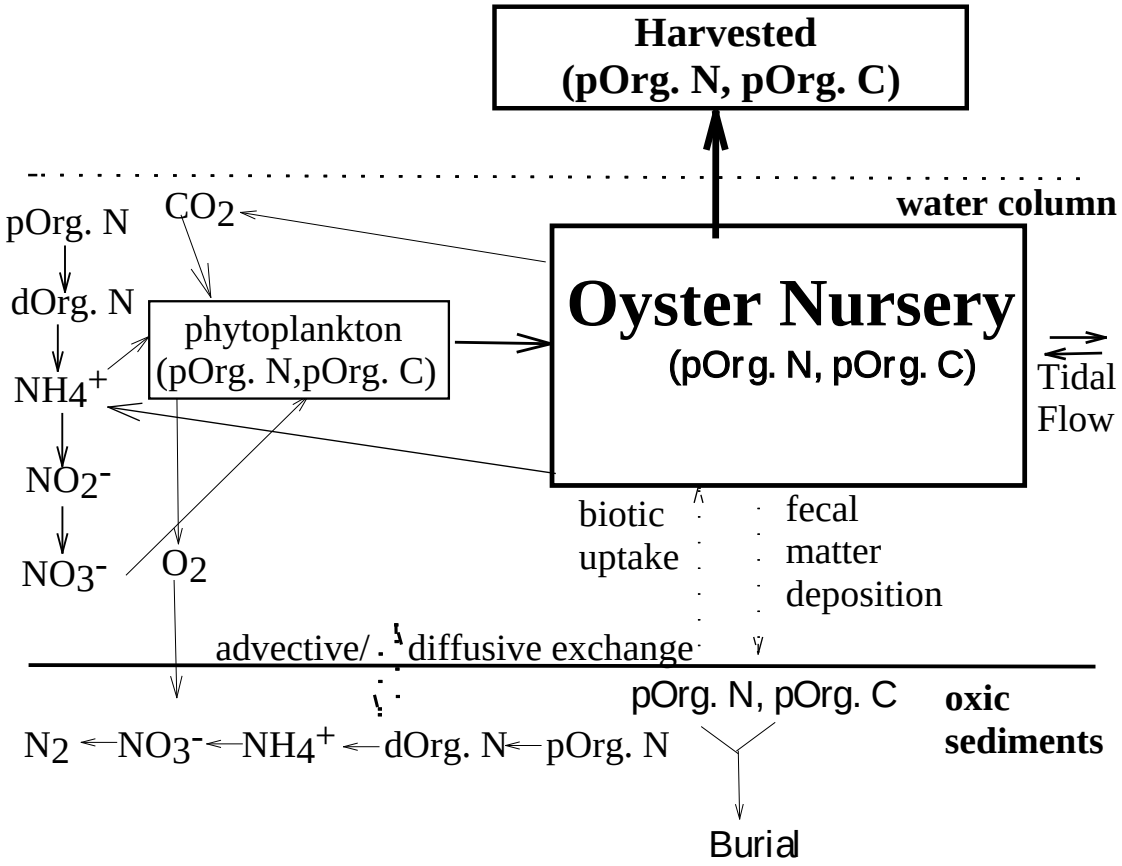
What are appropriate variables to measure?

What are appropriate scales of measurement (spatial, temporal and resolution)?

What tools, instruments, sampling regimen and personnel are needed to effectively quantify the FLUPSY activity? (who will make ferry reservations and get the coffee?)

NOAA FISHERIES SERVICE

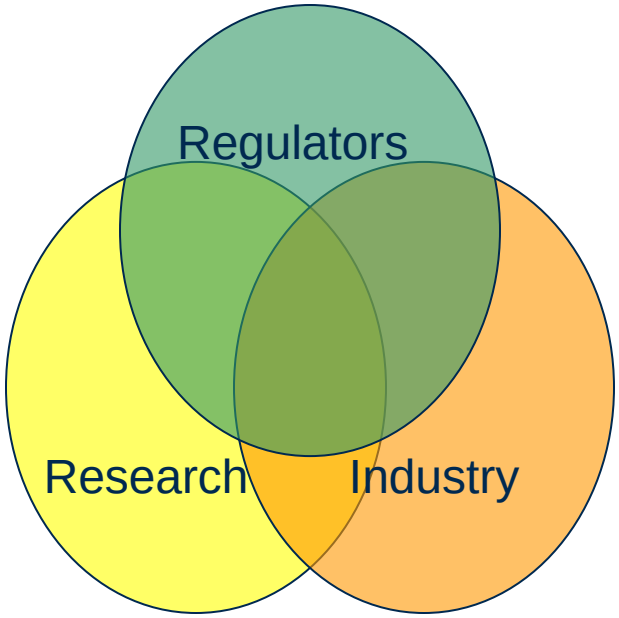
Oysters in Nursery Culture: Conceptual Model



NOAA FISHERIES SERVICE

This Study

Cooperative effort



NOAA FISHERIES SERVICE

Study Site

NOAA
FISHERIES
SERVICE

2009 Field Season

Data logging, long-term automated sensors

Estuarine nutrient transect

Mesocosm “Bag Experiments”

Variable fluorescence fluorometer

Zooplankton community analysis

Cellular and Biochemical measures of oyster stress

Sleep deprivation study

NOAA FISHERIES SERVICE

Long-term Automated Sampling and Data Logging

Inflow vs. Outflow

15 minute sampling interval

Long-term deployment

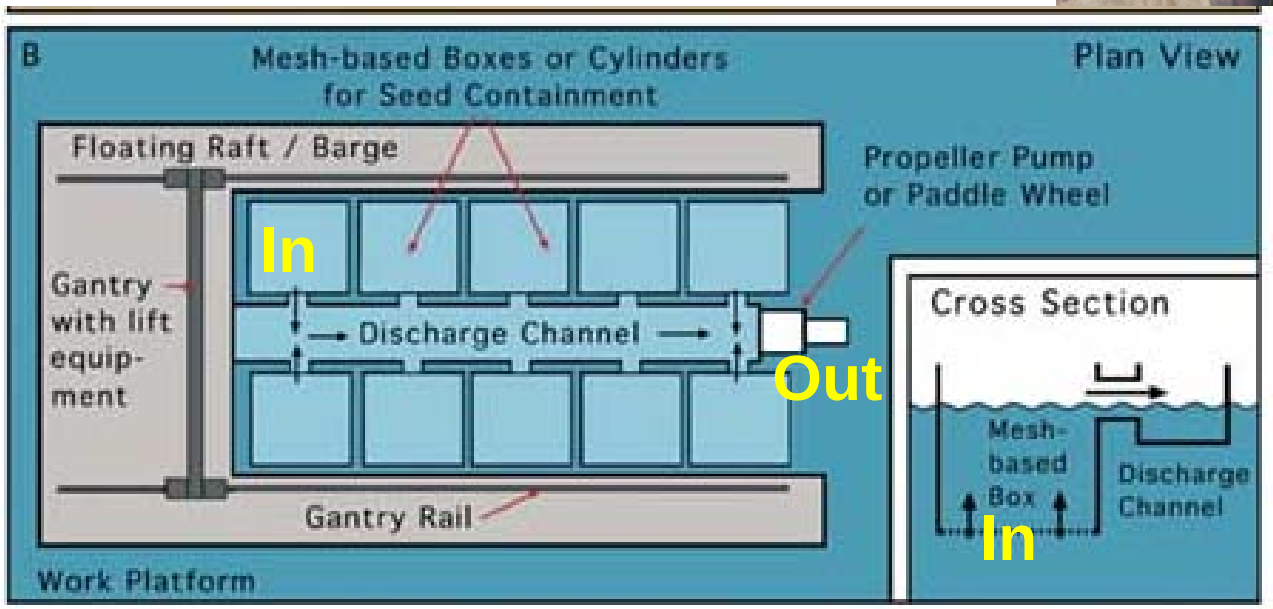
DO

Chl *a*

Temp

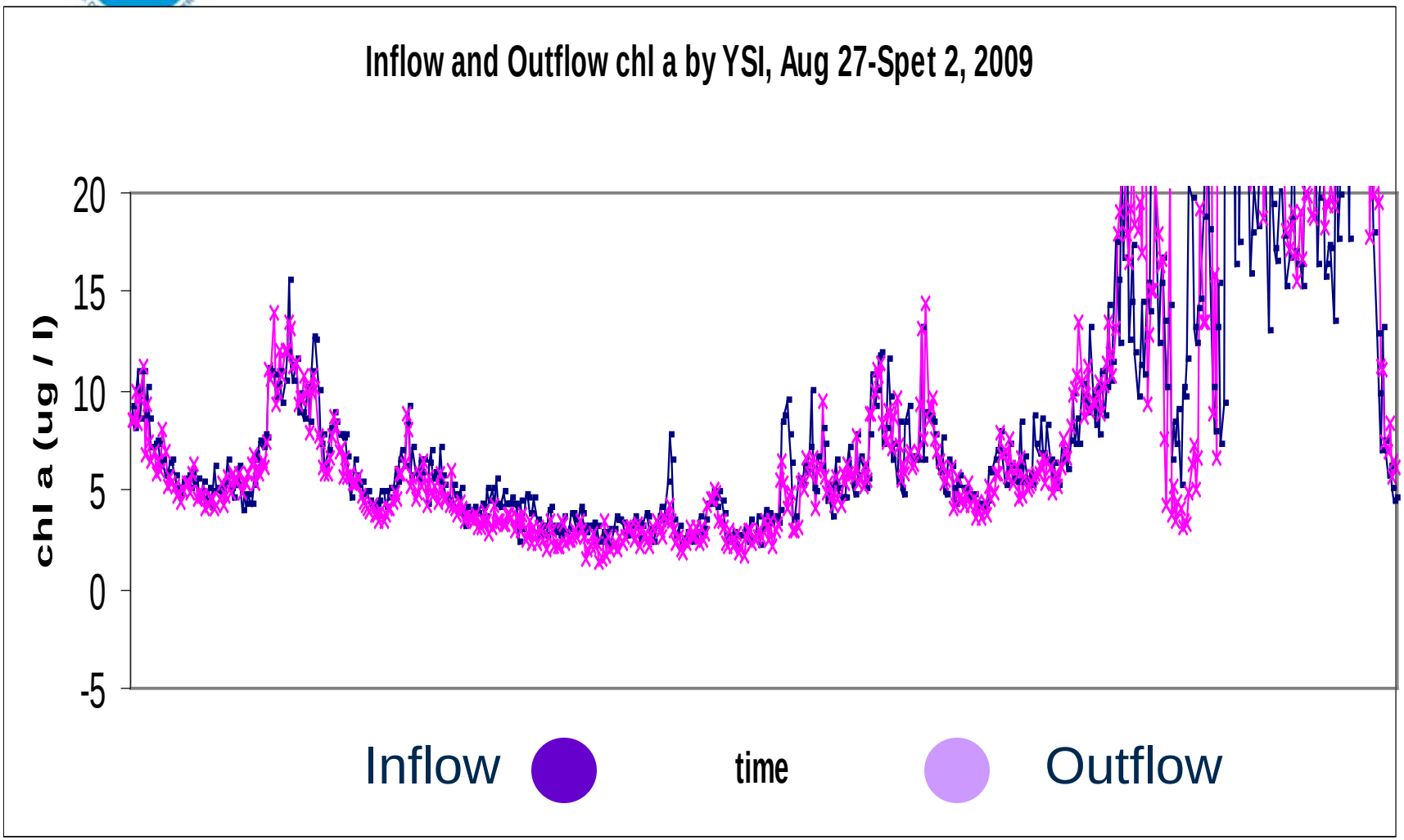
Salinity

pH



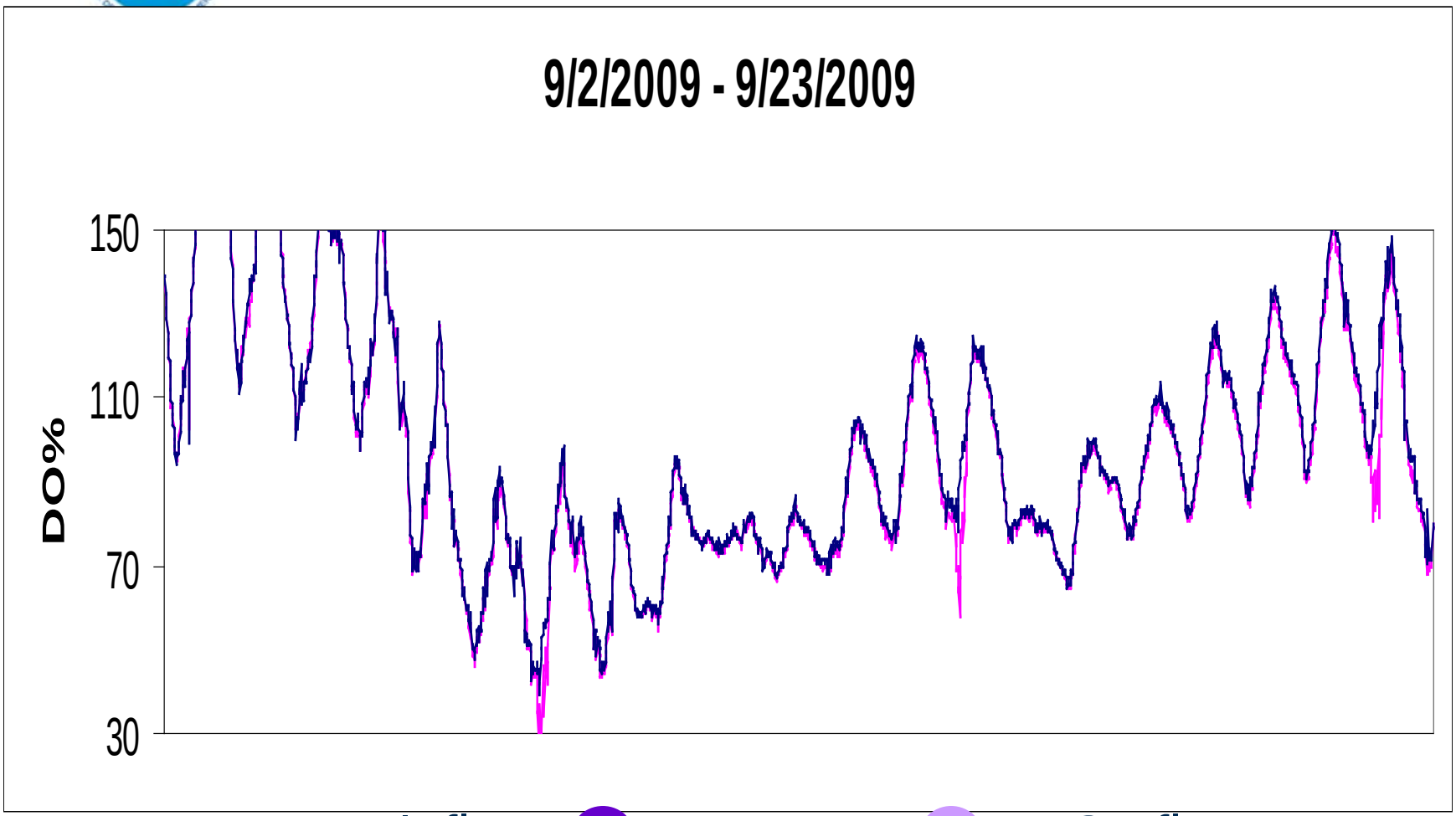
NOAA
FISHERIES
SERVICE

Chlorophyll *a*



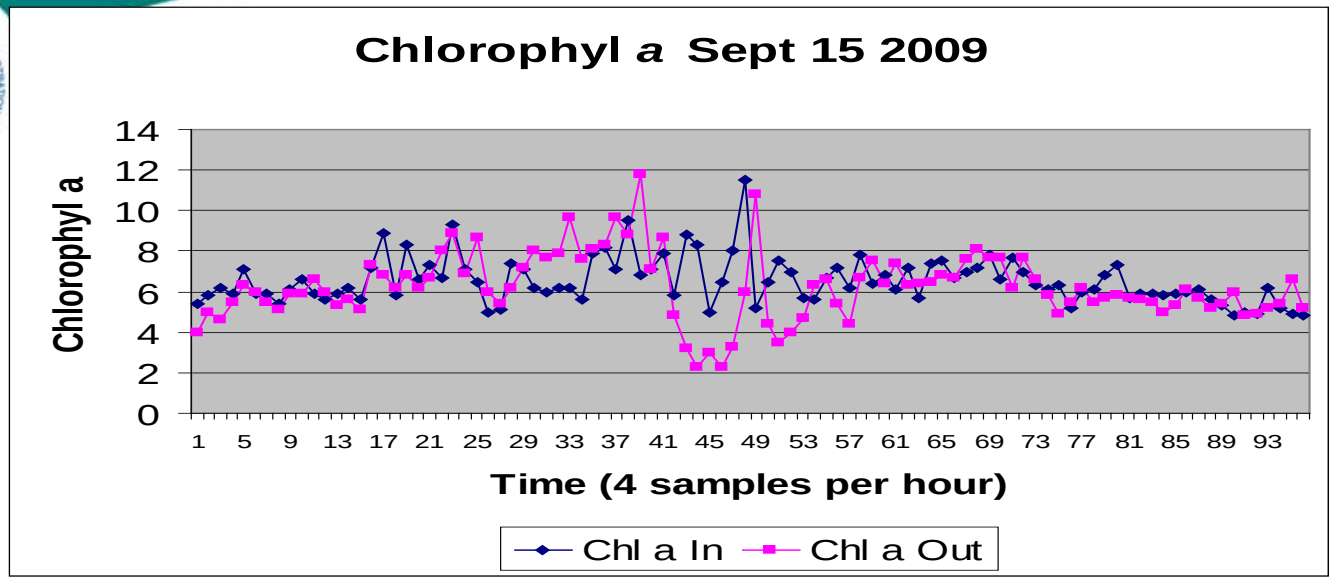
NOAA FISHERIES SERVICE

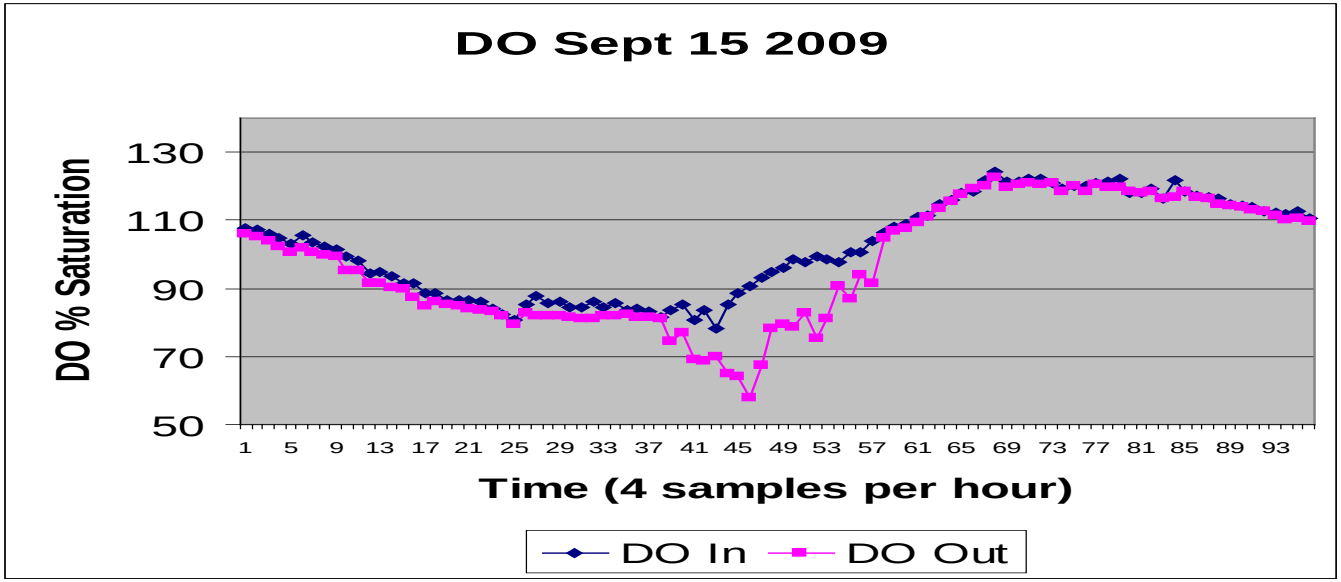
Dissolved Oxygen

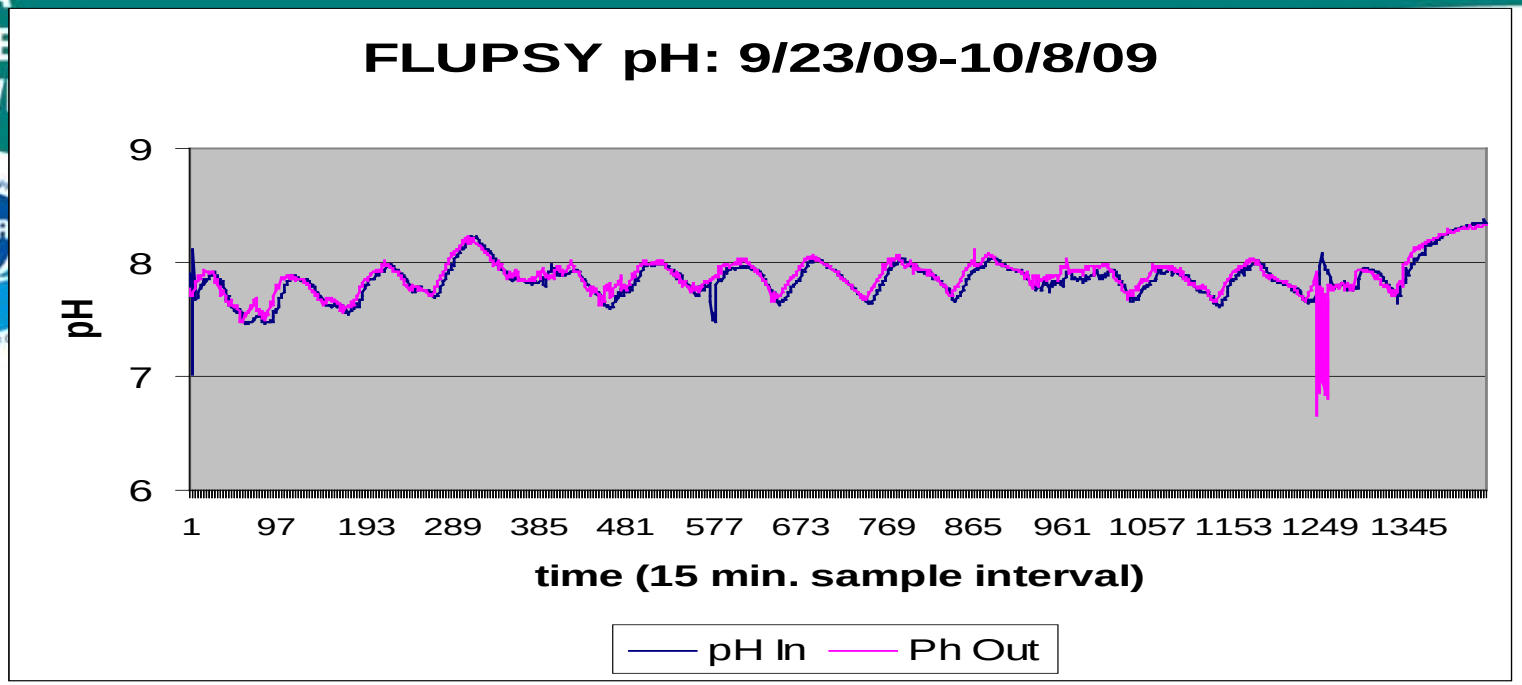


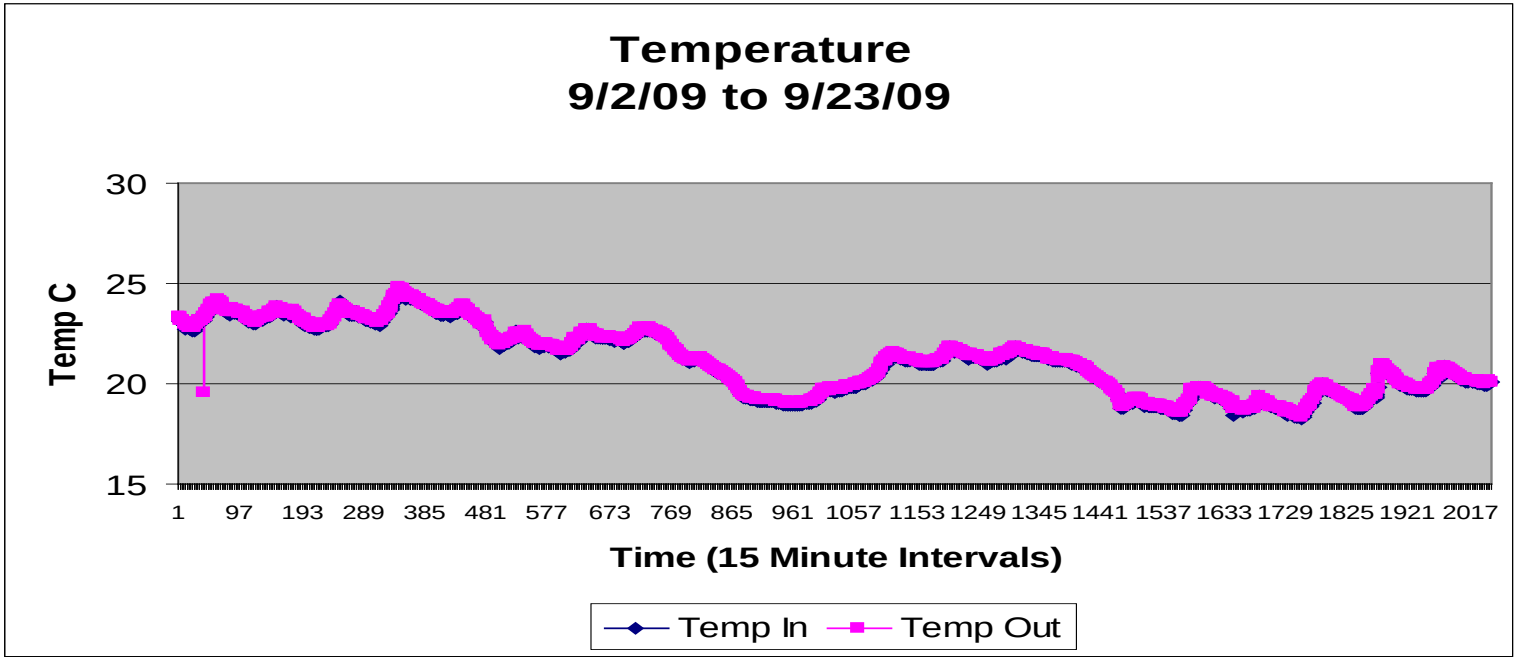
NOAA FISHERIES SERVICE

Closer Look






FLUPSY pH: 9/23/09-10/8/09
pH
9
8
7
6
1
97
193
289
385
481
577
673
769
865
961
1057
1153
1249
1345
time (15 min. sample interval)
pH In
Ph Out

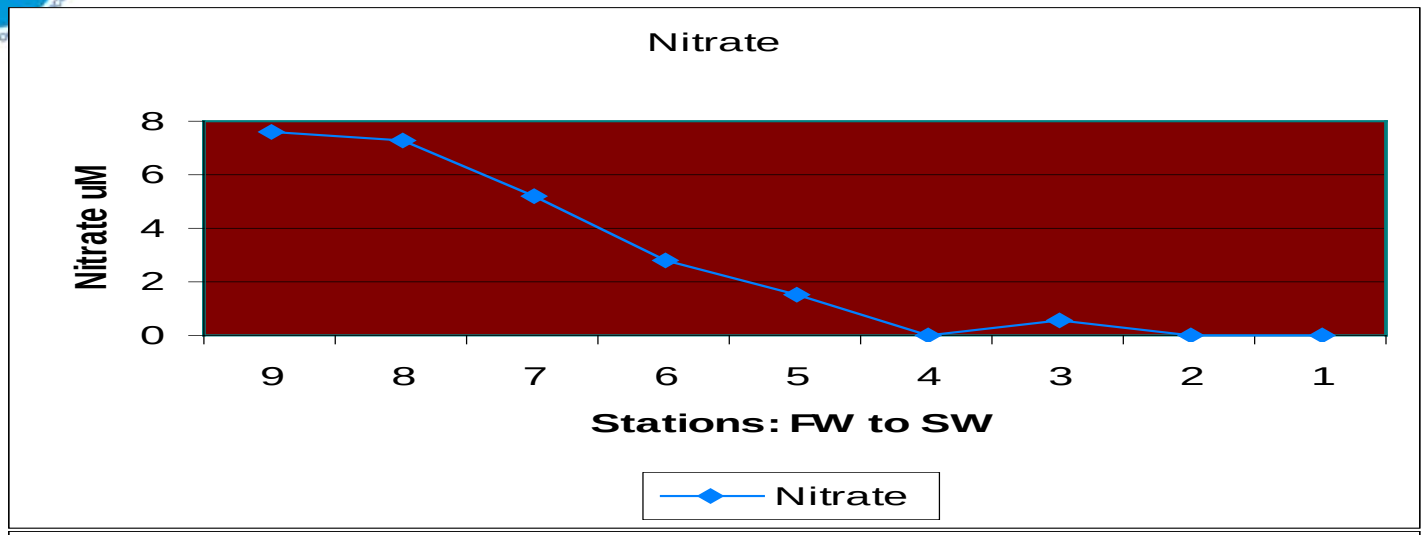

Temperature
9/2/09 to 9/23/09
Temp C
30
25
20
15
1
97
193
289
385
481
577
673
769
865
961
1057
1153
1249
1345
1441
1537
1633
1729
1825
1921
2017
Time (15 Minute Intervals)
Temp In
Temp Out

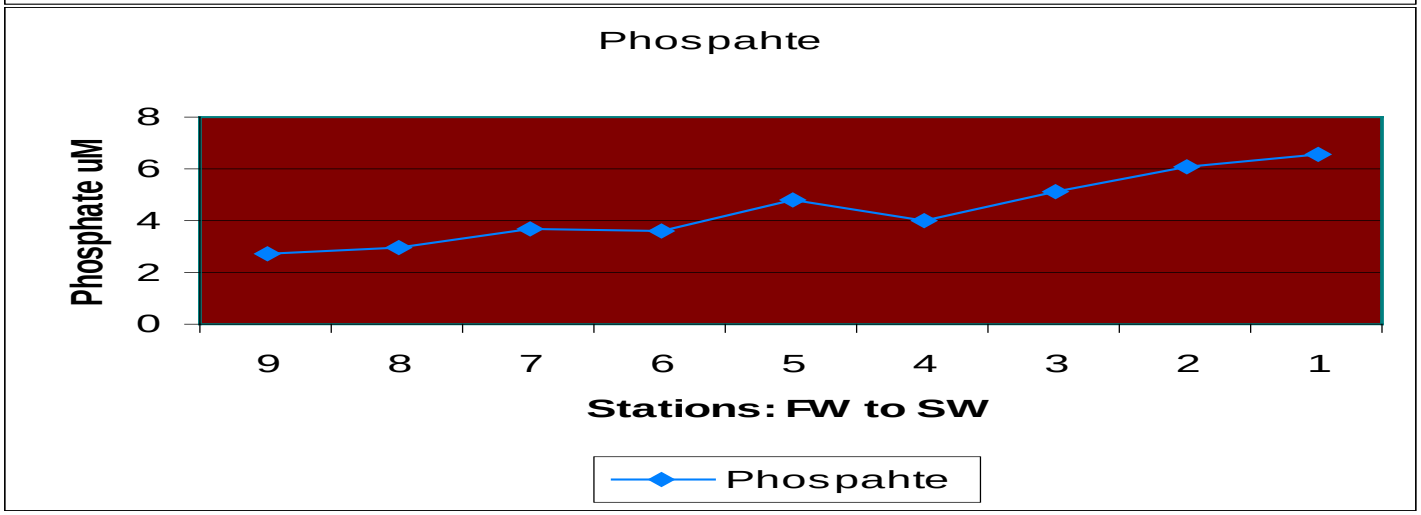
NOAA
FISHERIES
SERVICE

Estuarine Transect

NOAA FISHERIES SERVICE

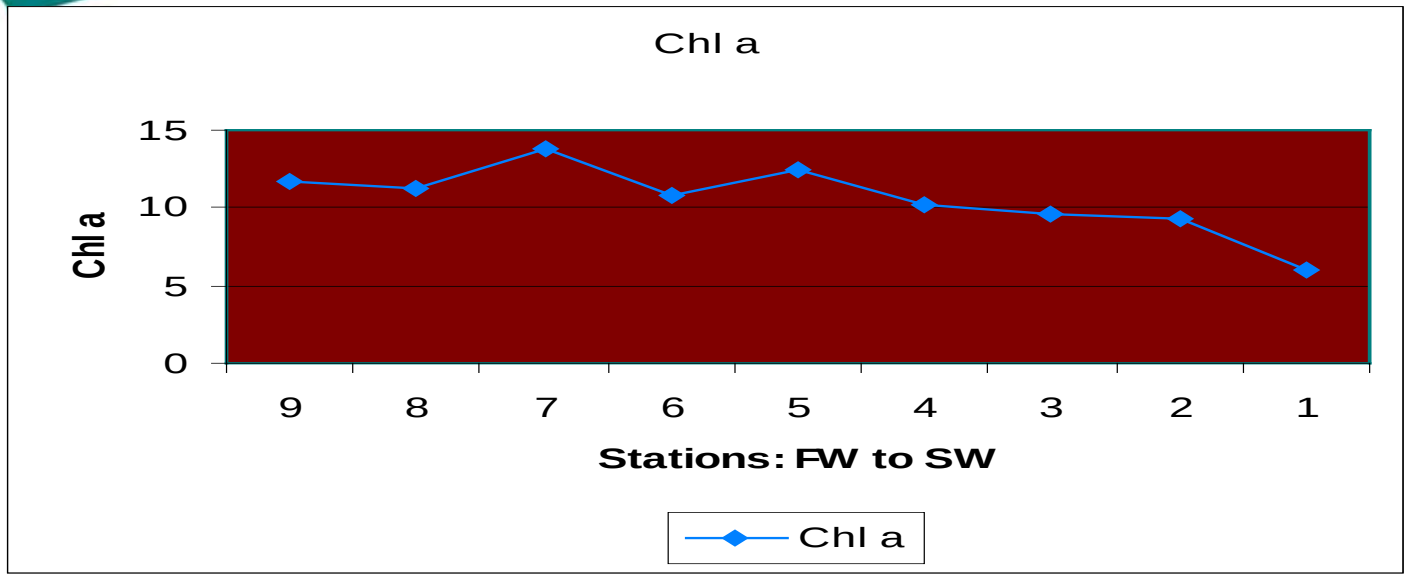
Estuarine Transect

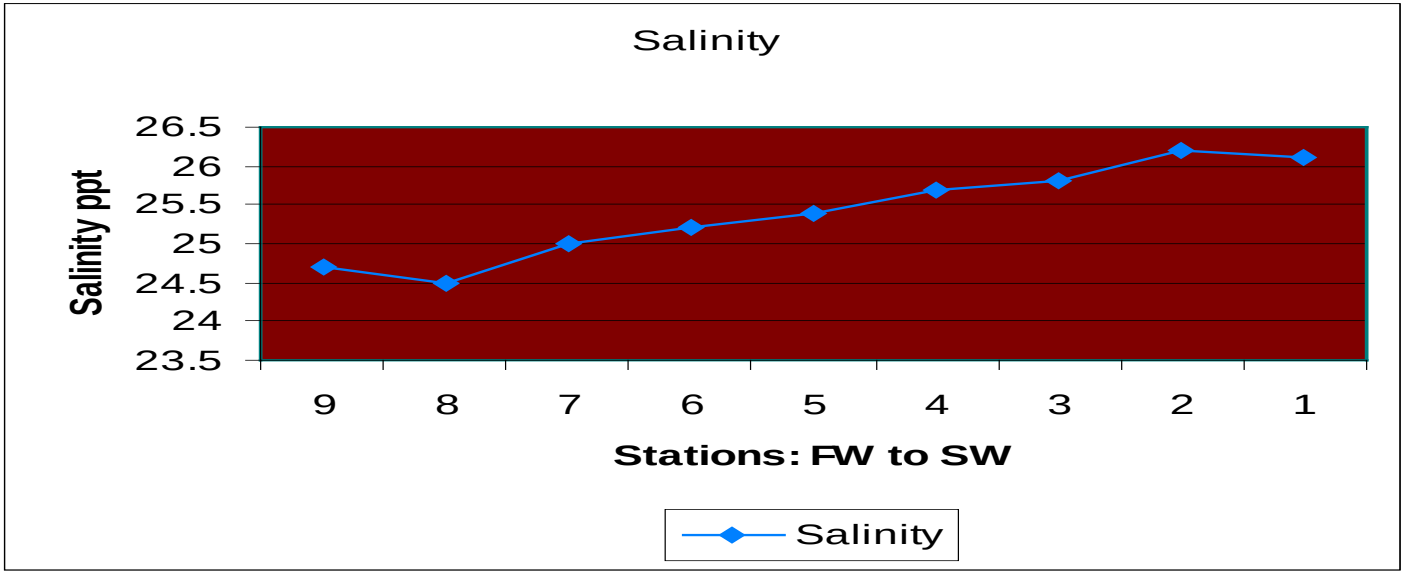




NOAA FISHERIES SERVICE

Estuarine Transect





NOAA FISHERIES SERVICE

Valuable Insights Gained

The long-term monitoring and data logging capabilities provided by the automated YSI greatly improved our ability to monitor and understand the dynamics of East Creek and the associated FLUPSY

NOAA
FISHERIES
SERVICE

Results Summary

When viewed in total the parameters measured at the inflow and outflow of the FLUPSY are very similar

The large, nearly continuous data set generated by the YSI reveals that there are time intervals when the FLUPSY activity is measurable

Measurable oyster feeding is intermittent

…But can be explained by nutrient cycles, productivity peaks, and oyster physiology

The overall impact of the FLUPSY is insignificant when compared to the activity ; seasonal, diel and tidal, of the East Creek system

NOAA
FISHERIES
SERVICE

NOAA
FISHERIES
SERVICE

Why Mesocosm Experiments:

Quantify the interaction of Flupsy with surrounding without:

1. **Effects from tides**
2. **Effects from sediments**

Mesocosms = 90 L Bags incubated *in situ*

INFLOW Water

OUTFLOW Water

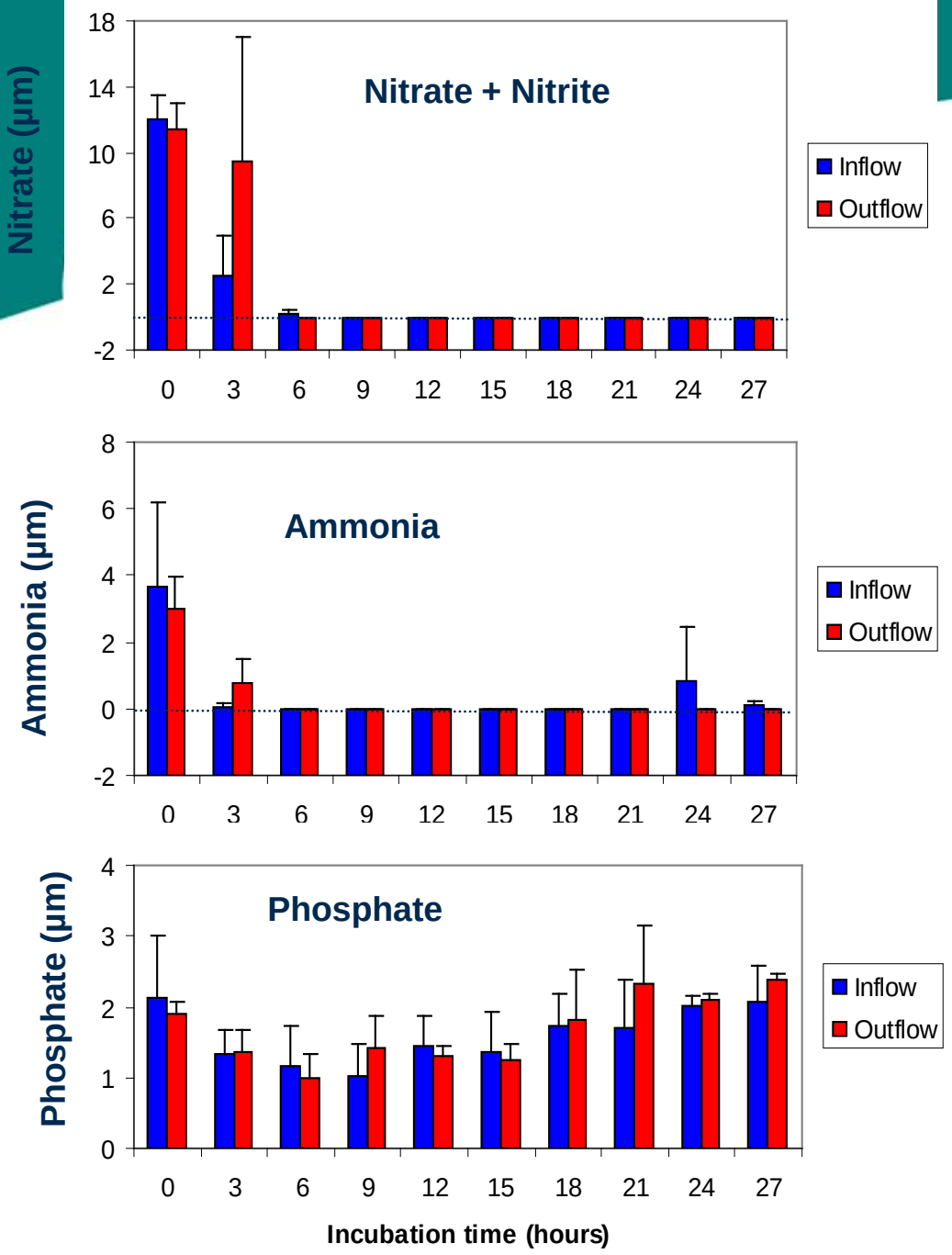
Ambient Bay Water

Water Chemistry

Phytoplankton

Zooplankton

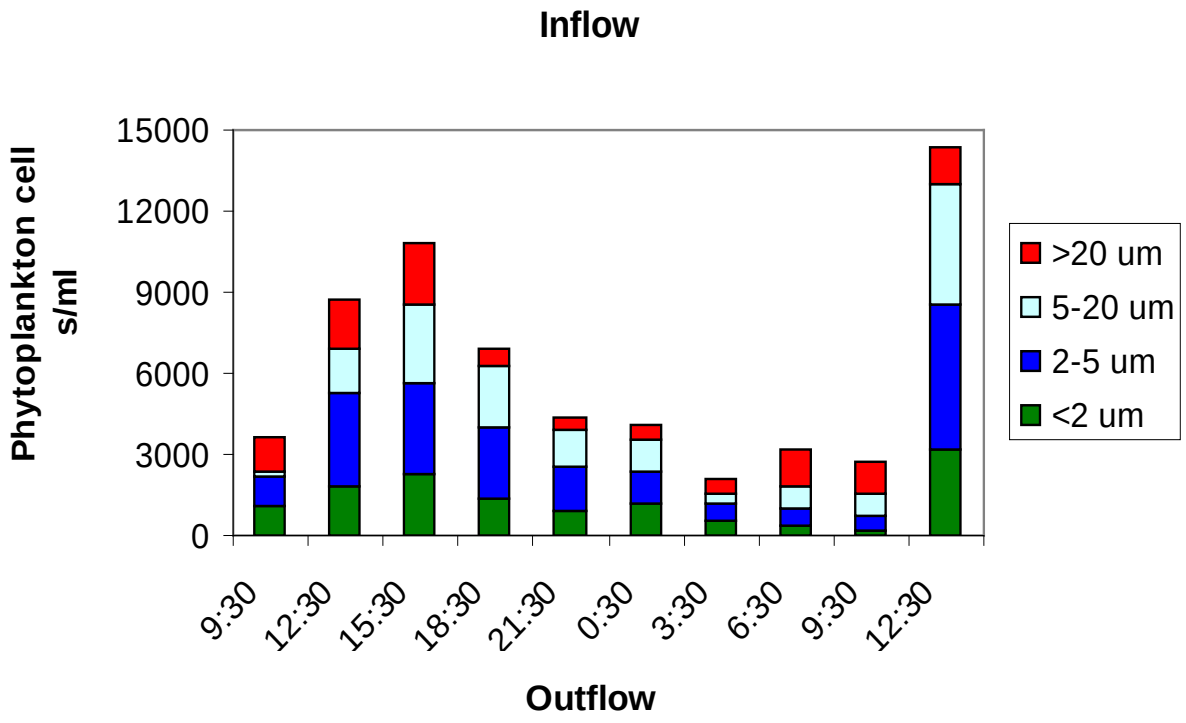
Measured Every 3 hours for 27 hours

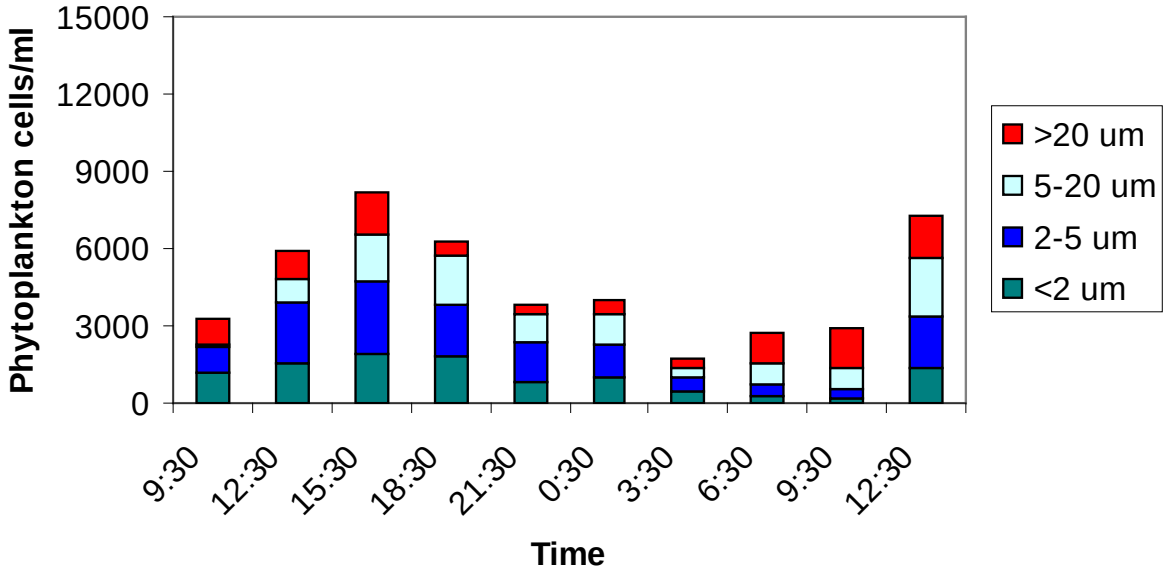


Nitrate and ammonia were depleted within 6 hours

Phosphate level stayed fairly constant

Local regeneration low





Inflow water had a large recovery toward the end of the experiment

Outflow phytoplankton was stressed

Phytoplankton Community:

--- Not common

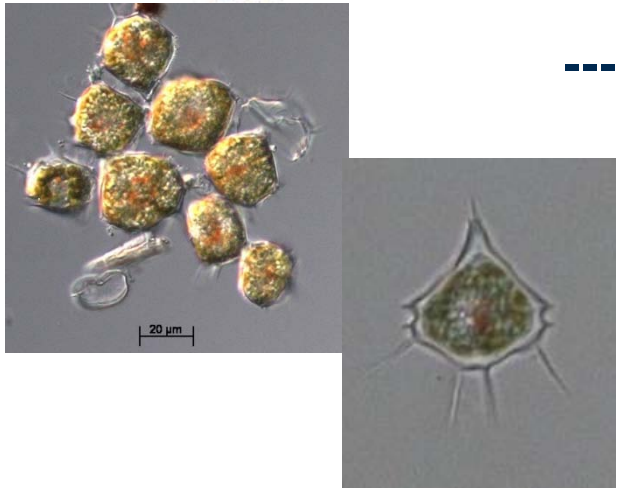
--- *Peridinium quinquecorne* dominated

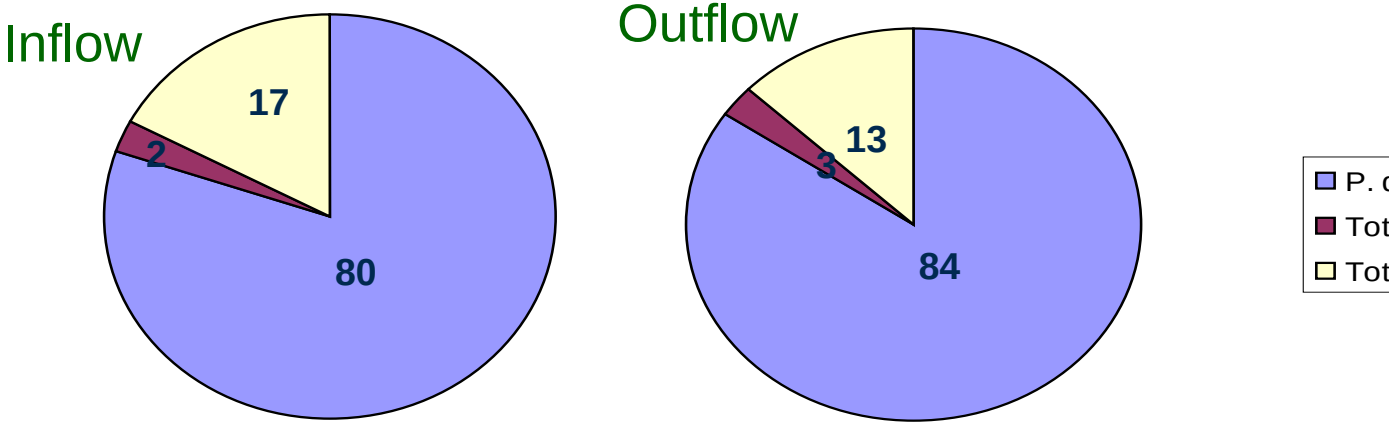
Not reported in Northeast

80% of total phytoplankton

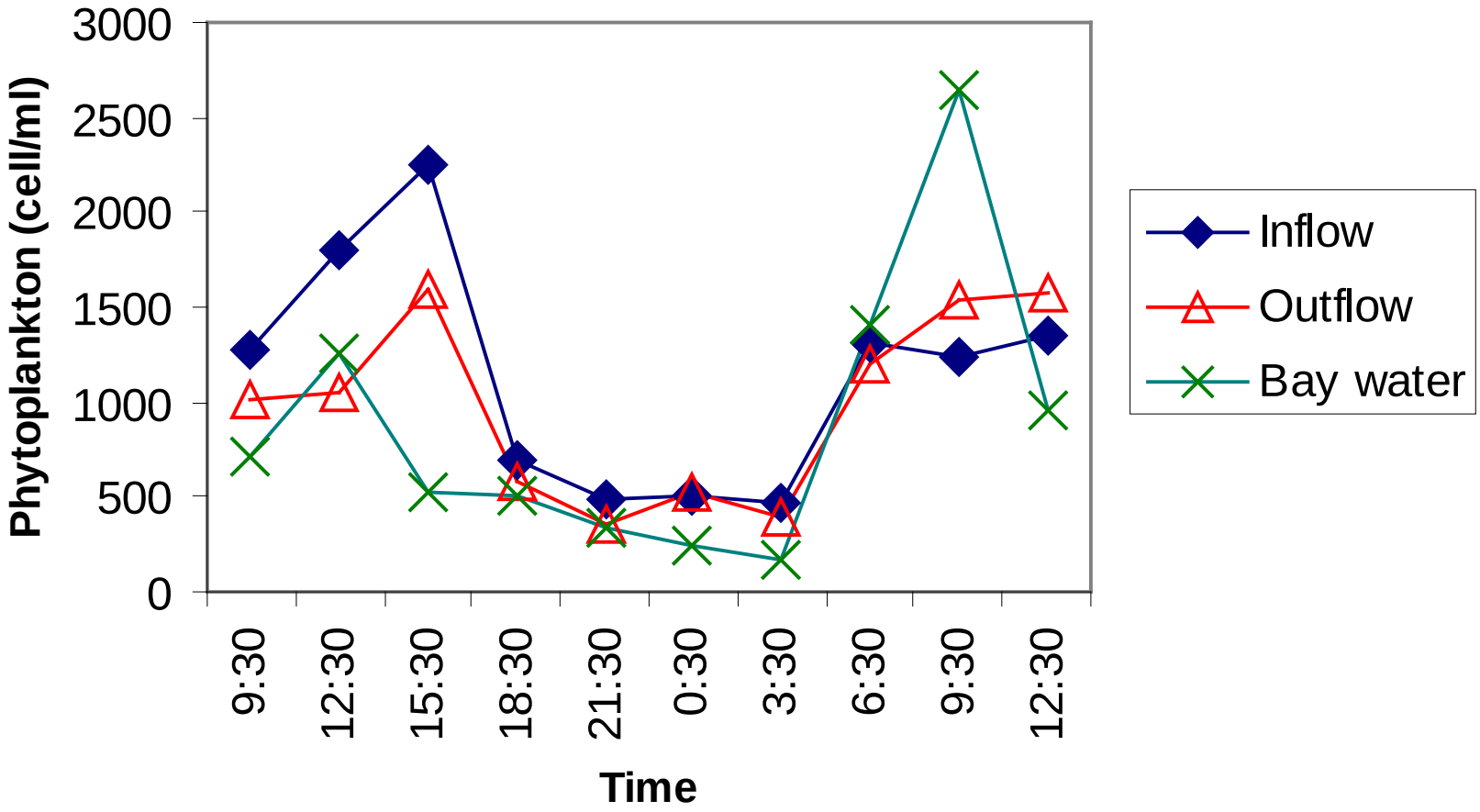
high abundance, 1-3,000 cells ml^{-1}

occurred after heavy rain events elsewhere



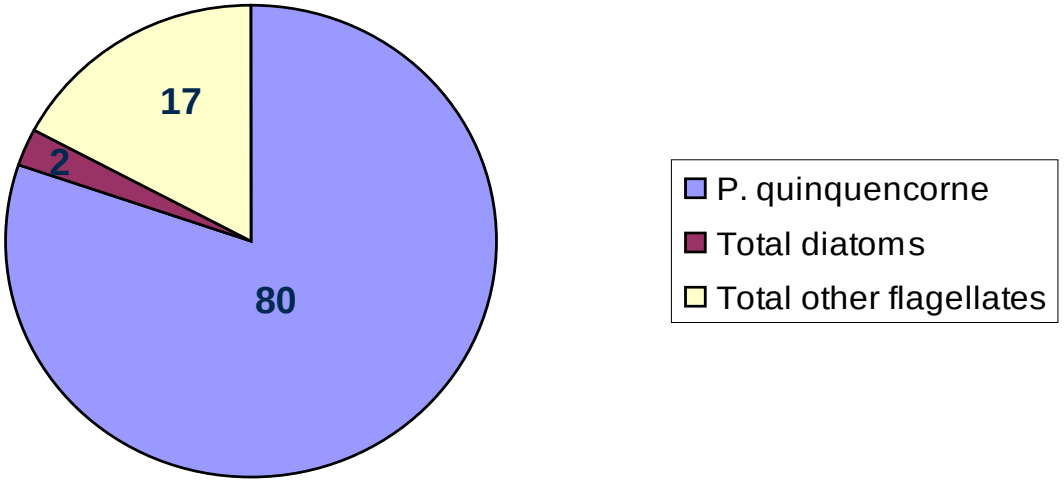


Large phytoplankton (>20 µm) abundance (mostly *Peridinium quinquecorne*), evidence of diel vertical migration

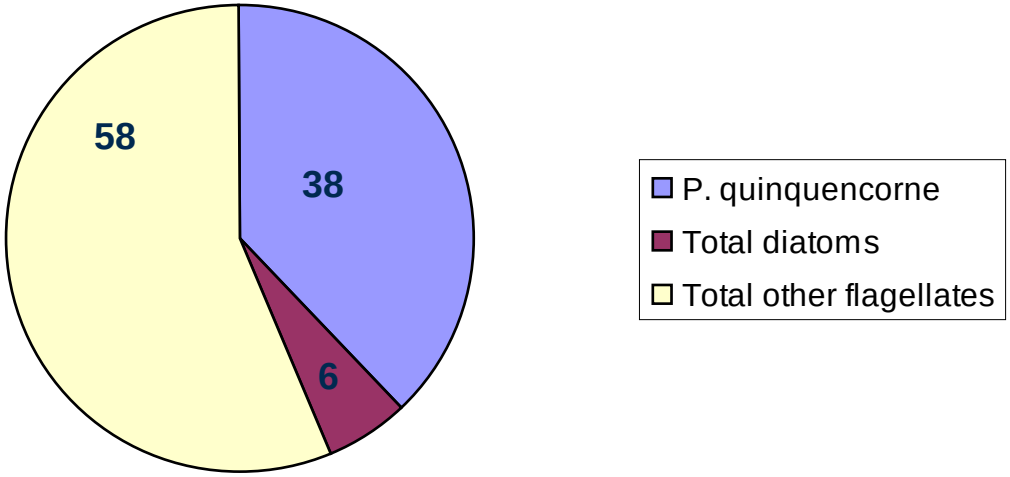


Phytoplankton community change during the experiment -- Inflow water

Time 0

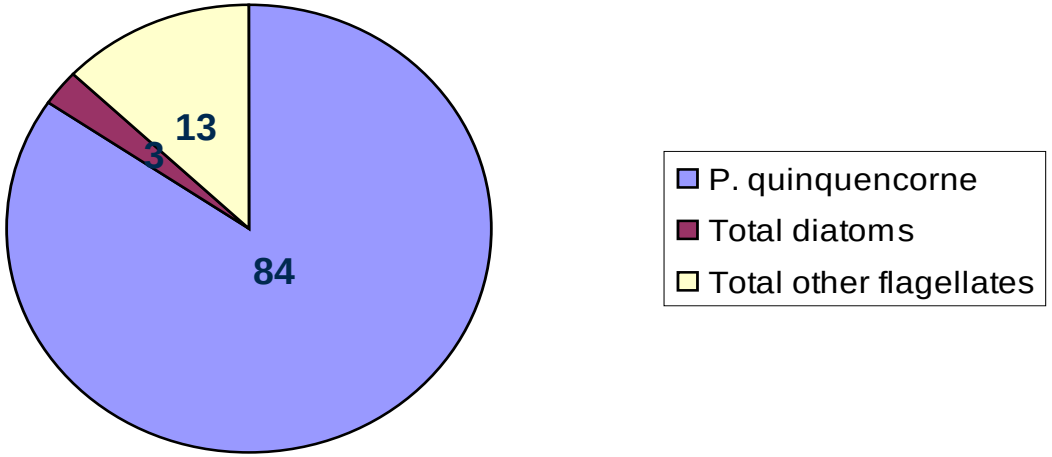


Time 27 hours

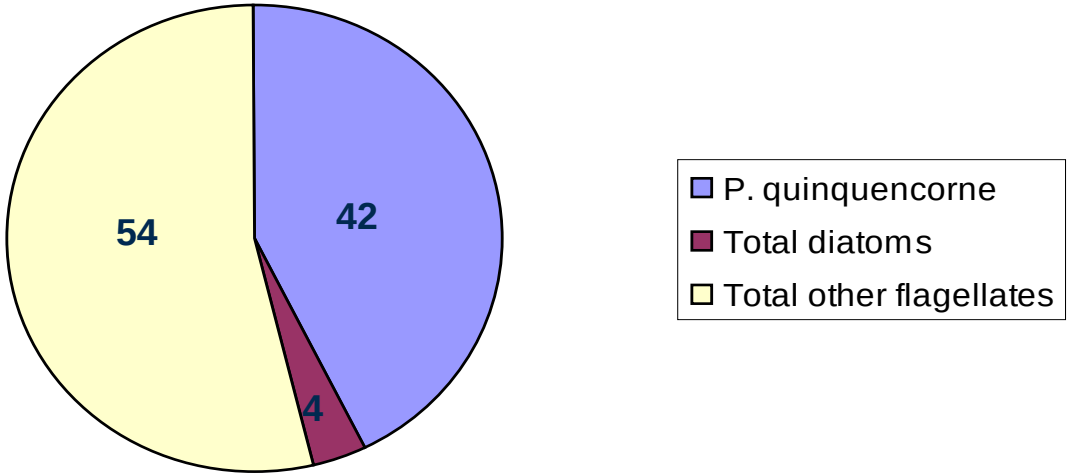


Phytoplankton community change during the experiment -- Outflow water

Time 0



Time 27 hours

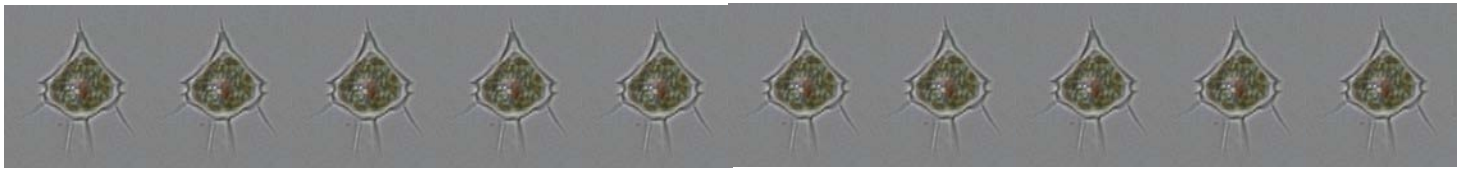


NOAA
FISHERIES
SERVICE

Summary for July Experiment:

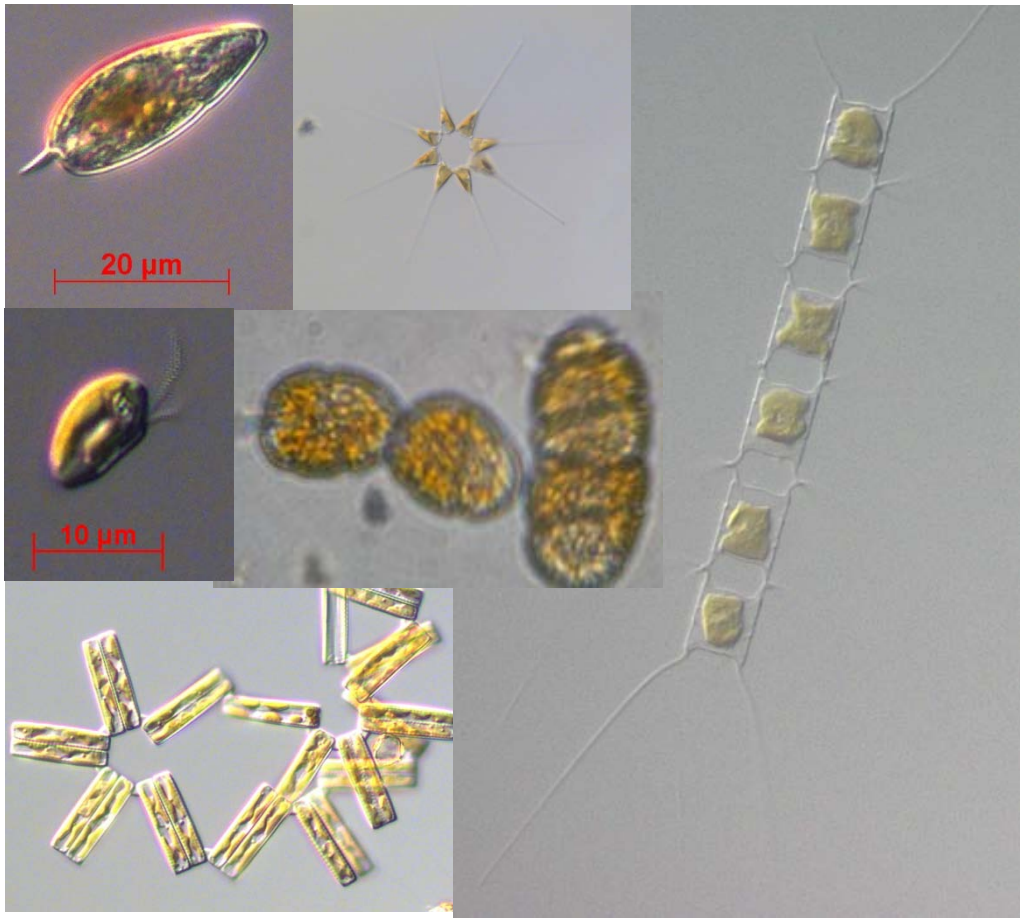
1. Evidence of stress to phytoplankton after water passed through the FLUPSY.
2. Nitrogen nutrients depleted quickly --- local regeneration was very limited.

But, this happened when the phytoplankton community was NOT typical!!



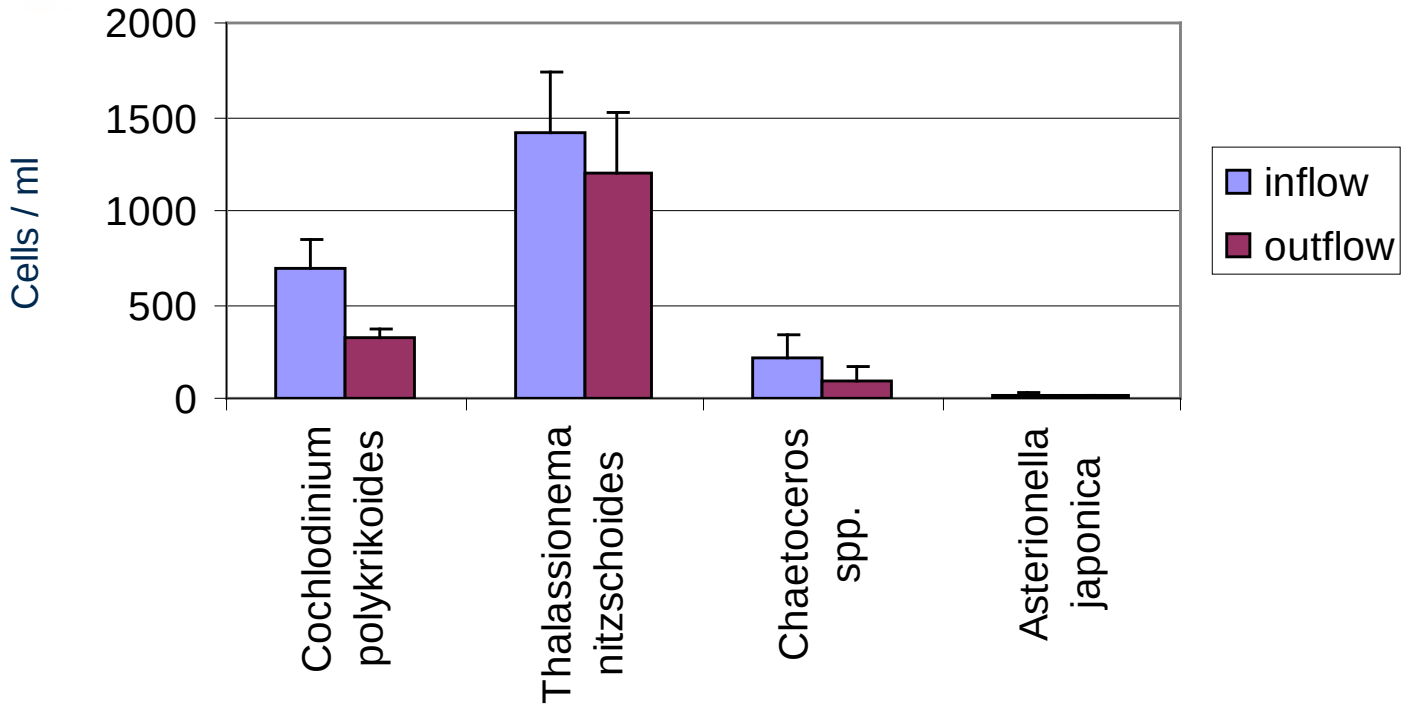
Phytoplankton Community:

- **Late summer / early fall assembles**
- **Diversed community**
- **Harmful alga** *Cochlodinium polykrikoides* **present**

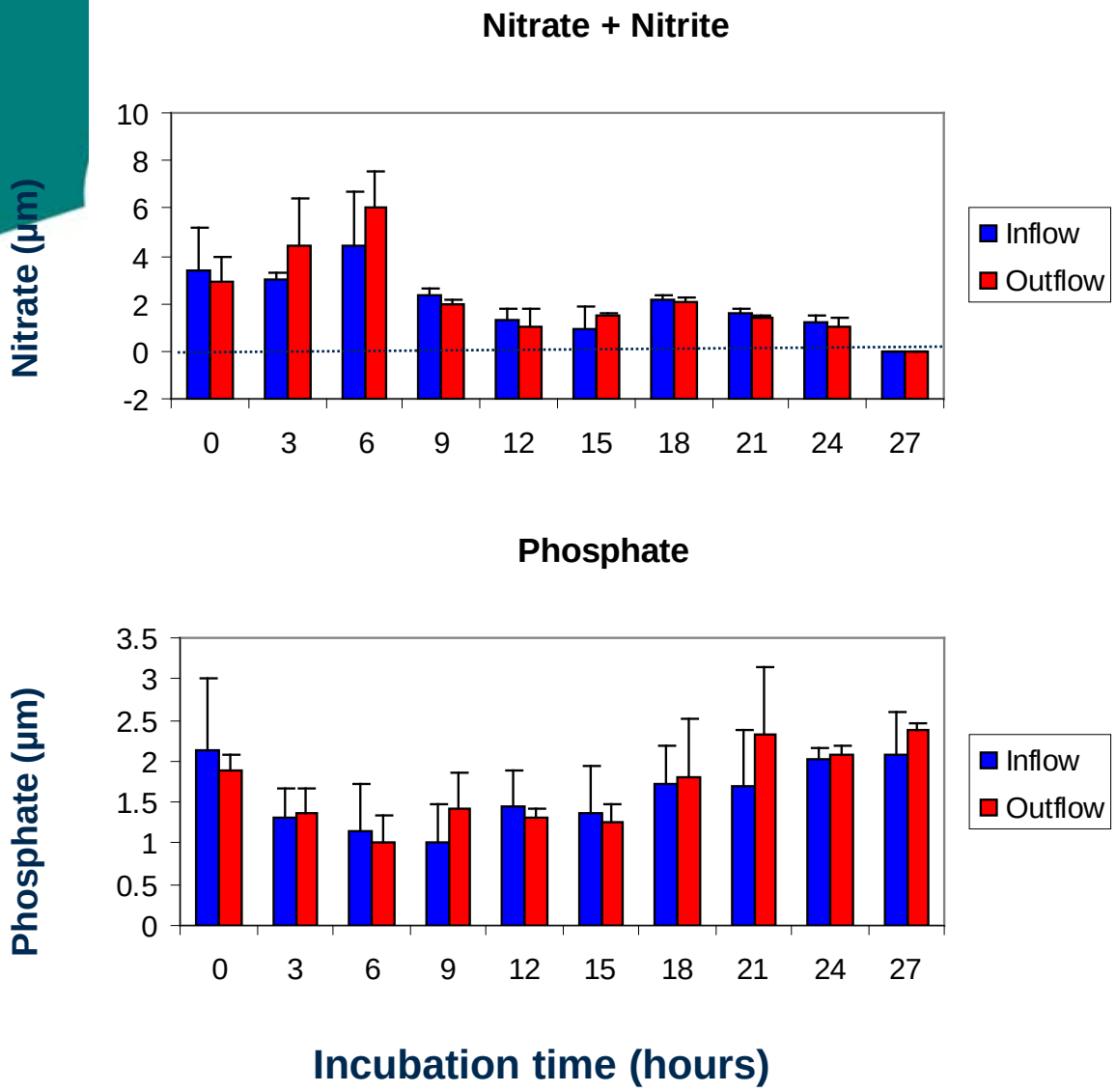


Time 0

Abundance of the 4 main species / groups of phytoplankton

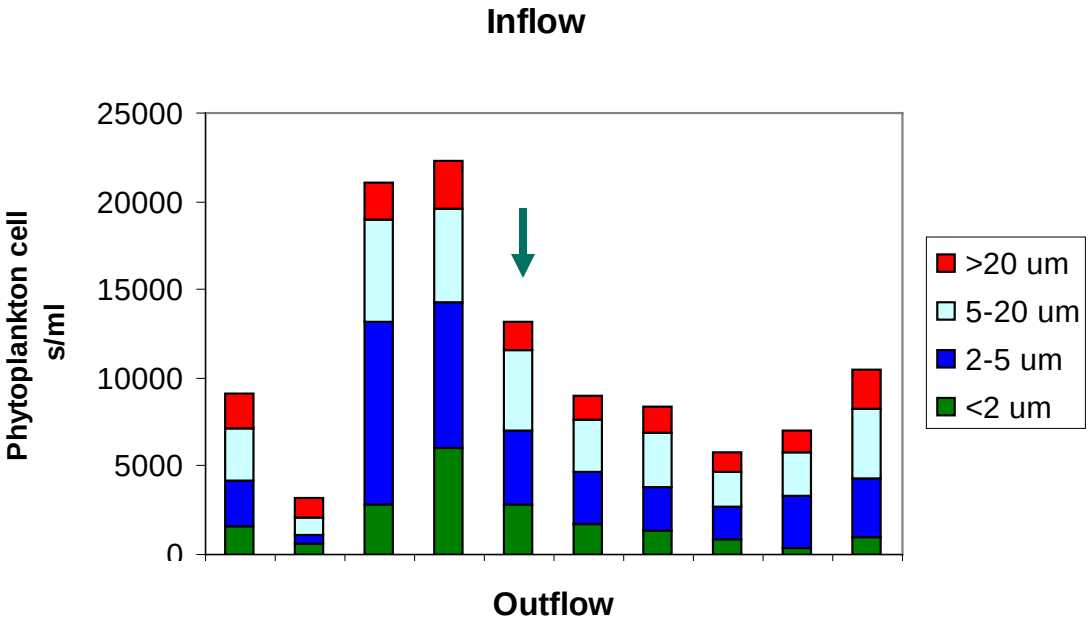


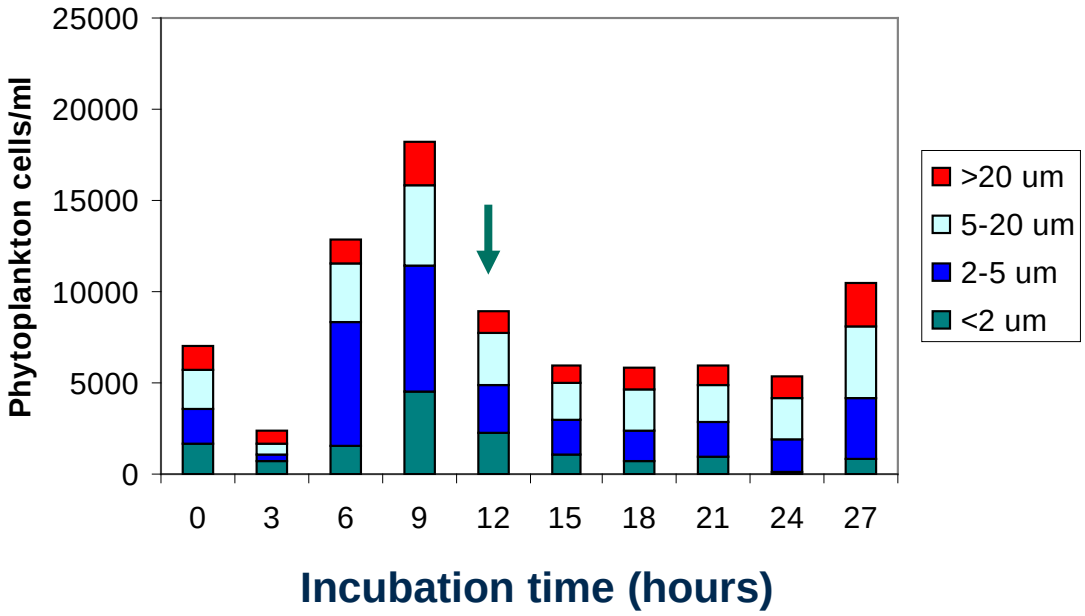
The 4 main species totals >90% of phytoplankton



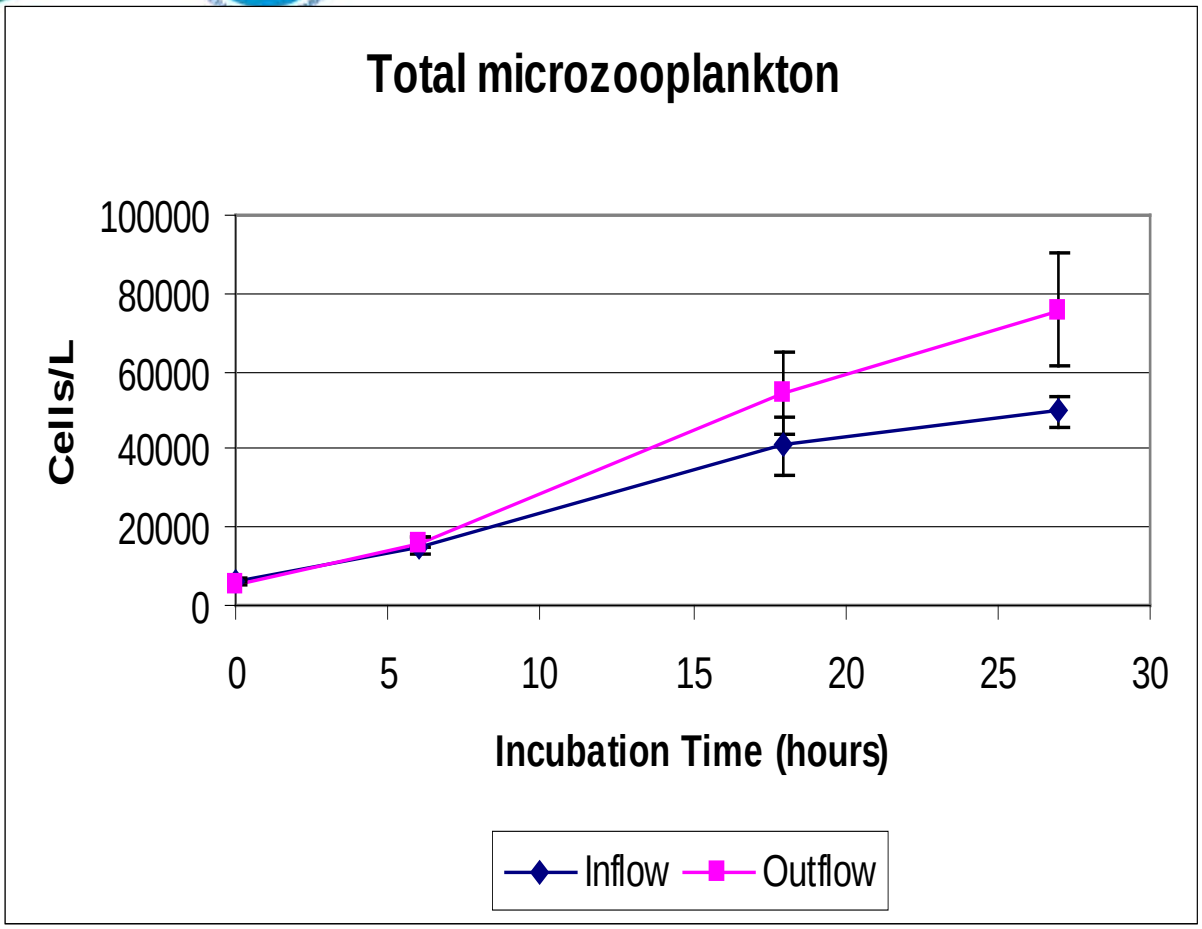
- Nitrate not depleted until 27 hours
- Phosphate stayed at a constant, high level
- High regeneration rate of nutrients in the water column

Ammonia undetectable



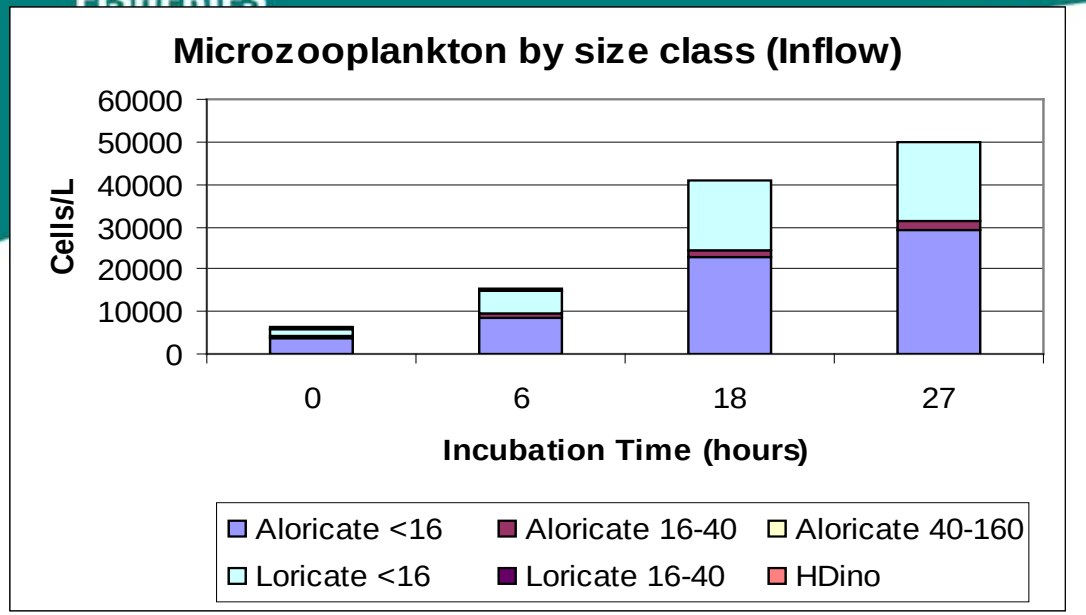


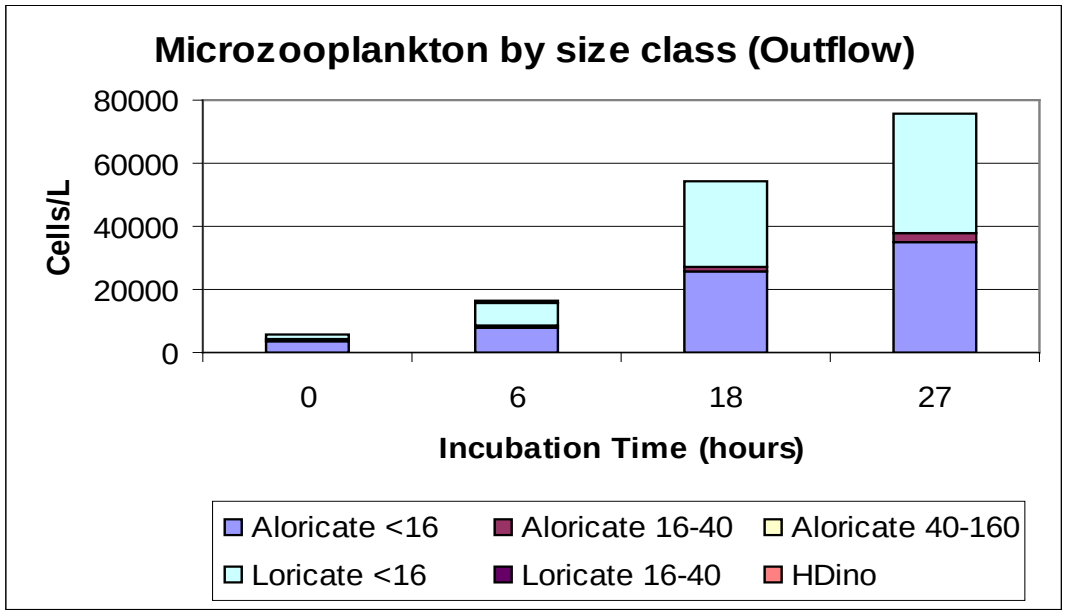
Large drop in 2-5 µm phytoplankton in 9 to 12 hours (night)



Number increased over time

A more rapid increase from 5 to 18 hours, coincide with the drop in small phytoplankton

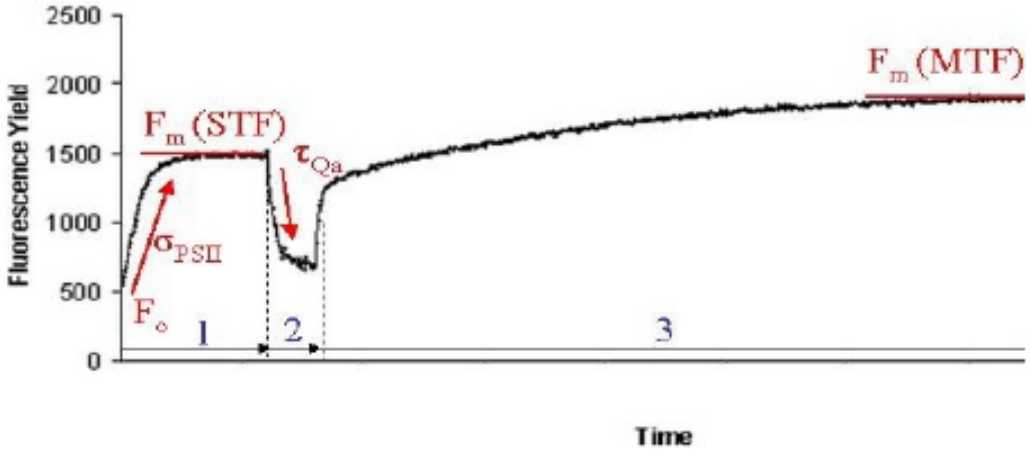




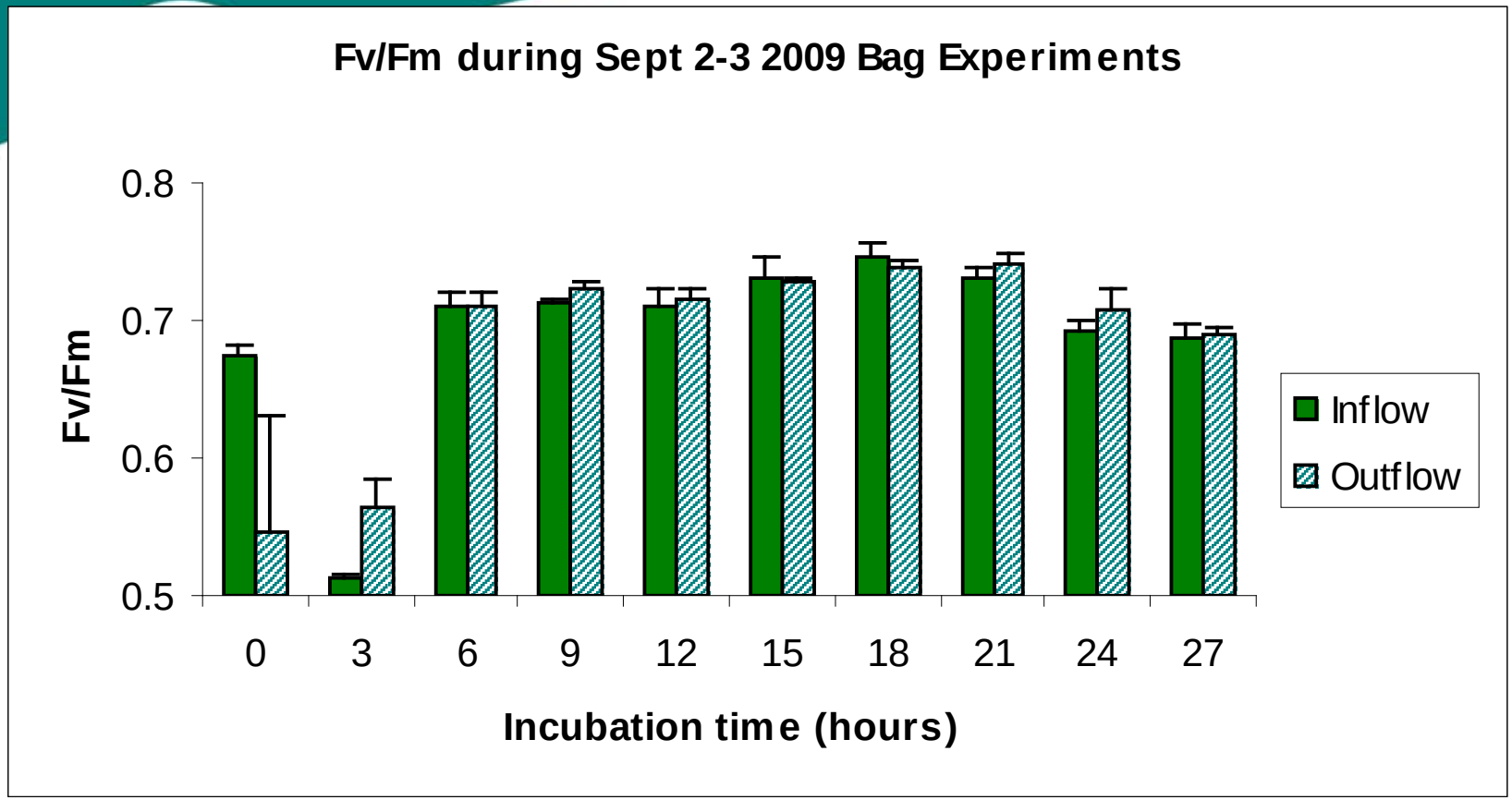
<16 µm dominated

Variable fluorescence by FIRe = *Fluorescence Induction and Relaxation*

- **Measures the minimum (Fo) and maximum fluorescence yield (Fm) in the dark and light**
- **Fv/Fm is the maximum quantum efficiency of photochemistry in PSII, also indicates the physiological status of phytoplankton**
- **Parameters derived can be used to estimate the primary productivity**



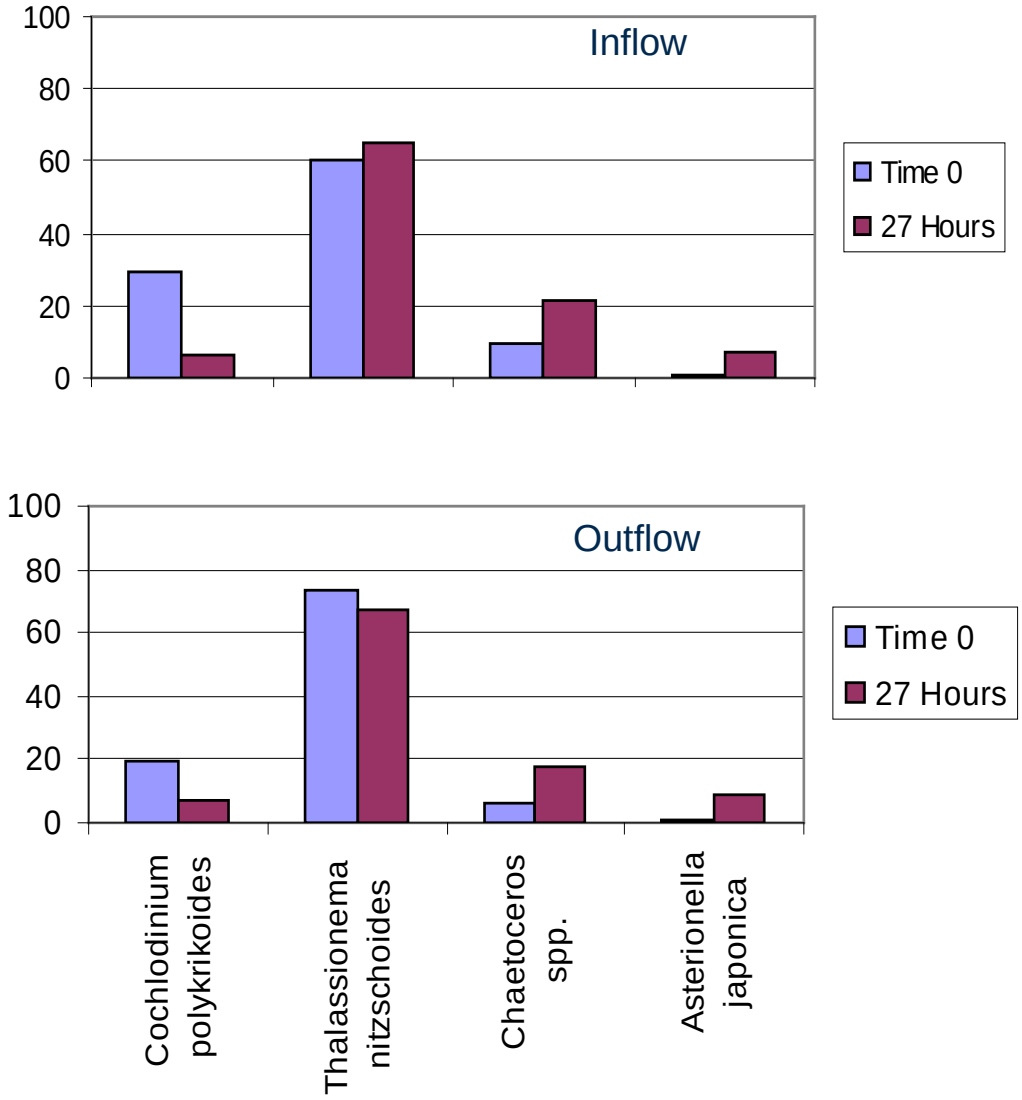
Fluorescence Induction and Relaxation Profile as measured with the FIRe



Phytoplankton was stressed after passing the FLUPSY and being pumped into the mesocosms

They recovered within 6 hours.

Change in phytoplankton community during the experiment



- **Dinoflagellates decreased**
- **Diatoms increased**
- **The phytoplankton community composition appeared NOT to be influenced by the FLUPSY**

Summary of September Experiments:

1. Phytoplankton was stressed after water passed through the FLUPSY, but recovered in 6 hours
2. Phytoplankton community composition appeared not affected by FLUPSY.
3. Regeneration of nutrients was HIGH! As evidenced by the presence of nutrients and high microzooplankton abundance.

This happened when the phytoplankton community was more-or-less typical!!

NOAA
FISHERIES
SERVICE

What have we learned:

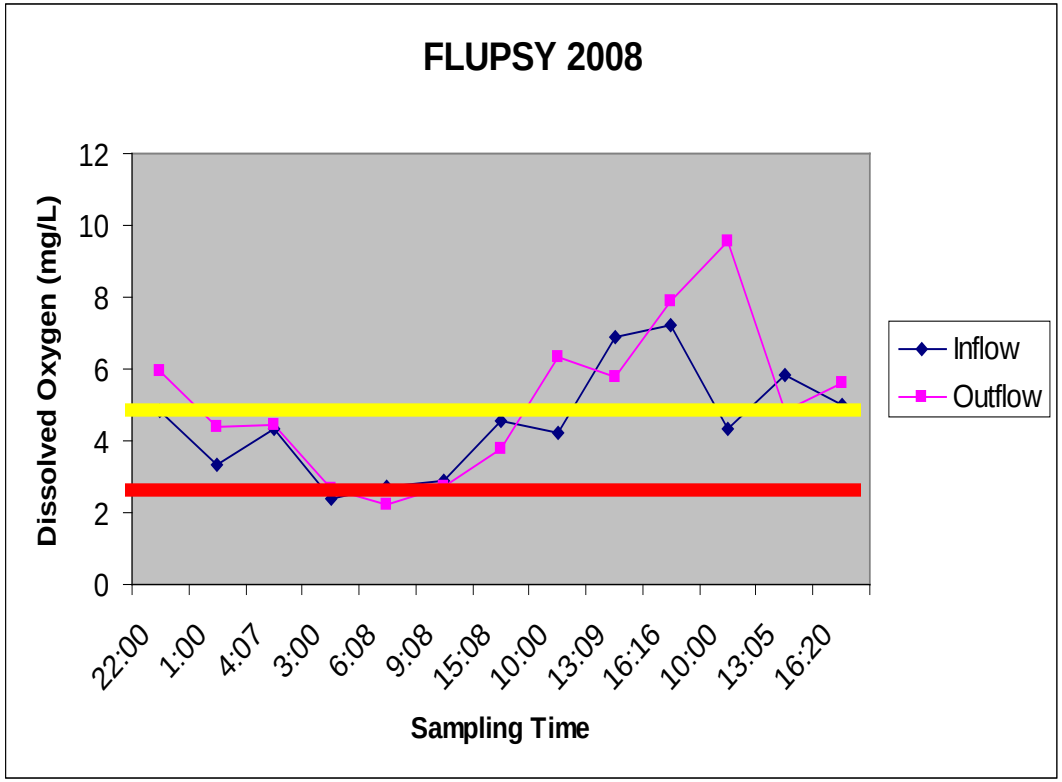
The trophic and nutrients dynamics in the system were different when the phytoplankton community composition was different.

So, it is all about VARIABILITY..... And temporal scale of sampling to catch such variability……high frequency measurements will be necessary.

NOAA
FISHERIES
SERVICE

NOAA FISHERIES SERVICE

2008 FLUPSY Data

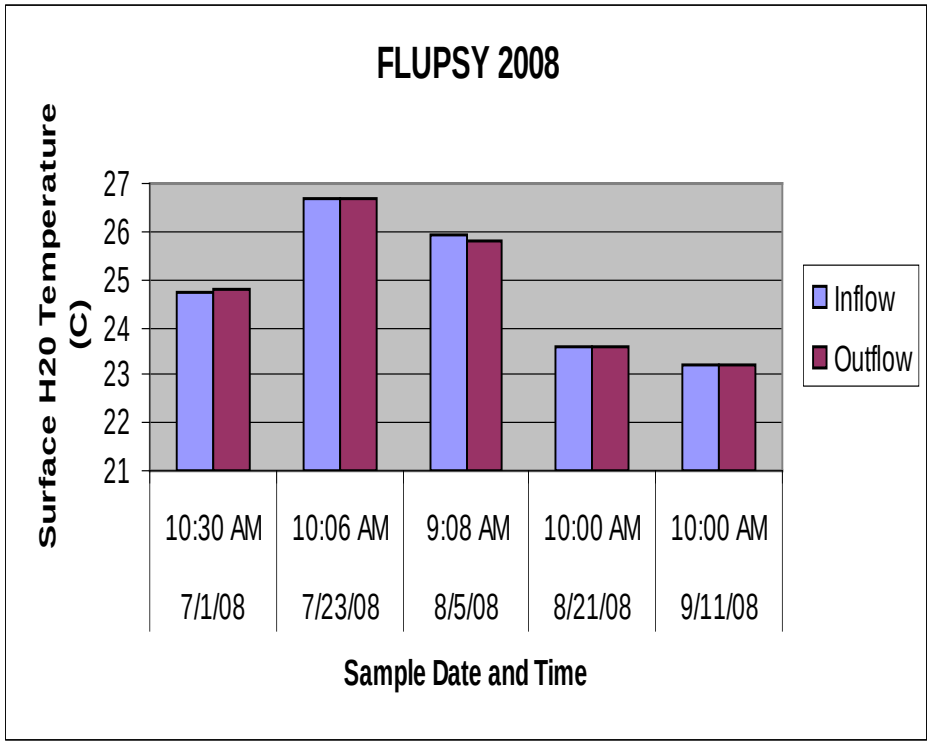


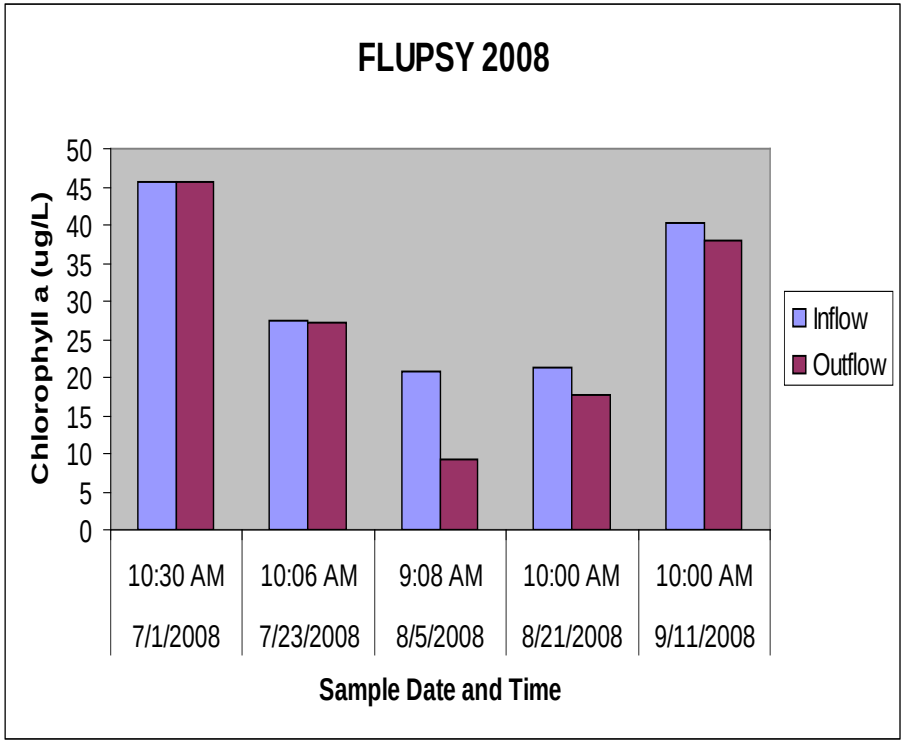
EPA Criteria for Dissolved Oxygen

- 4.8 mg/L suitable for growth
- 2.3 mg/L criterion for juvenile/adult survival

NOAA FISHERIES SERVICE

2008 East Creek Data



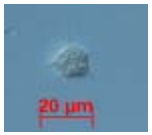


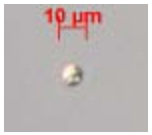
P. minimum *bloom during sampling period*

NOAA FISHERIES SERVICE

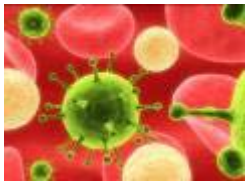
Hemocyte Defense Functions

- Oyster cellular immunity
  - open circulatory system
  - cell types (*granular and agranular*)
  - functions (*nutrition, waste disposal, defense*)



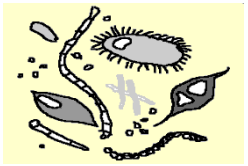


- Defense functions
  - adhesion
  - phagocytosis
  - ROS production



hemocyte

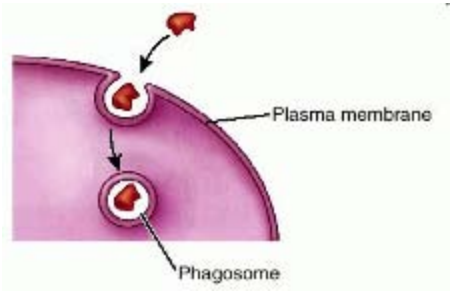
recognition



foreign particle

aggregation/adherence

ingestion



Intracellular digestion

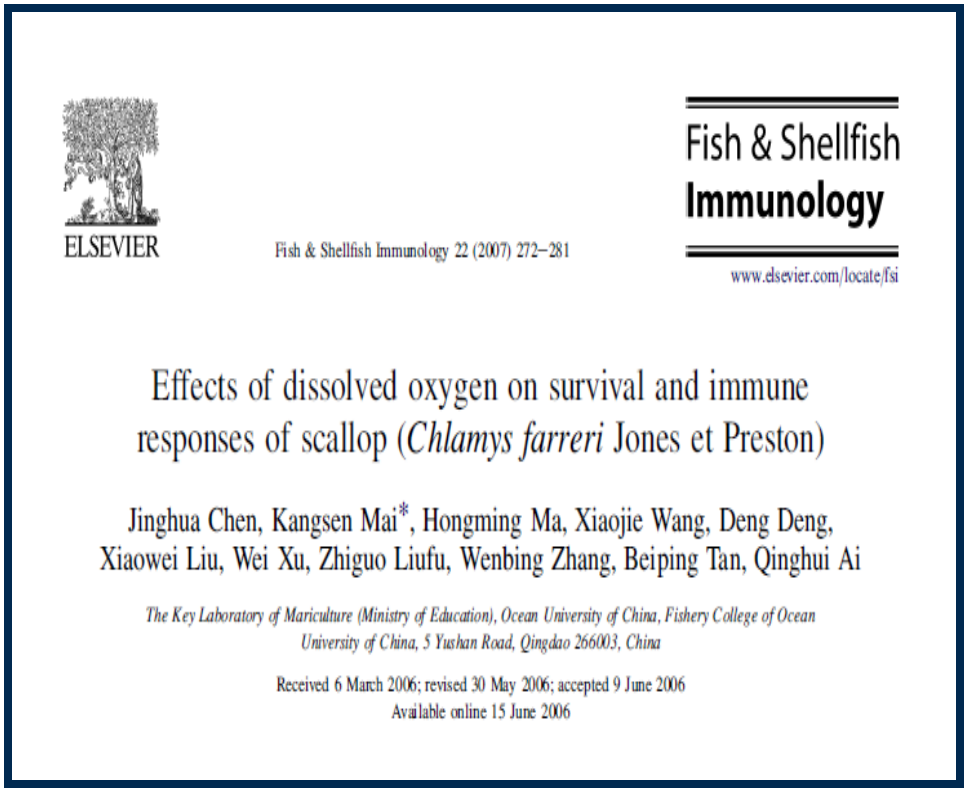
H_2O_2 , O_2^-

Reactive oxygen species

- Environmental Factors
  - water quality (*temp, DO*)
  - pollutant stressors
  - food availability

NOAA FISHERIES SERVICE

Previous Field Research



ELSEVIER

Fish & Shellfish Immunology 22 (2007) 272–281

Fish & Shellfish Immunology

www.elsevier.com/locate/fsi

Effects of dissolved oxygen on survival and immune responses of scallop (*Chlamys farreri* Jones et Preston)

Jinghua Chen, Kangsen Mai*, Hongming Ma, Xiaojie Wang, Deng Deng, Xiaowei Liu, Wei Xu, Zhiguo Liufu, Wenbing Zhang, Beiping Tan, Qinghui Ai

The Key Laboratory of Mariculture (Ministry of Education), Ocean University of China, Fishery College of Ocean University of China, 5 Yushan Road, Qingdao 266003, China

Received 6 March 2006; revised 30 May 2006; accepted 9 June 2006
Available online 15 June 2006

2.5 mg/L

- ⬇ total hemocyte count
- ⬇ survival of scallops

“ the low level of THC… revealed that low DO depressed the immune ability of C. farreri”

NOAA FISHERIES SERVICE

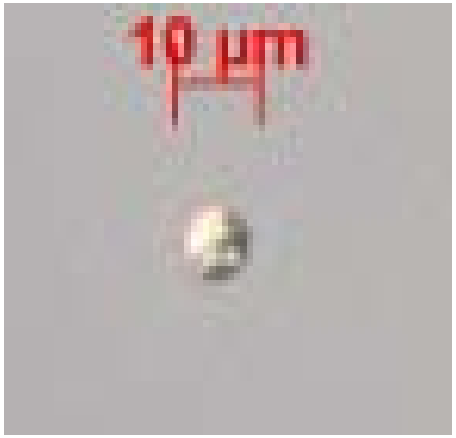
FLUPSY Approach

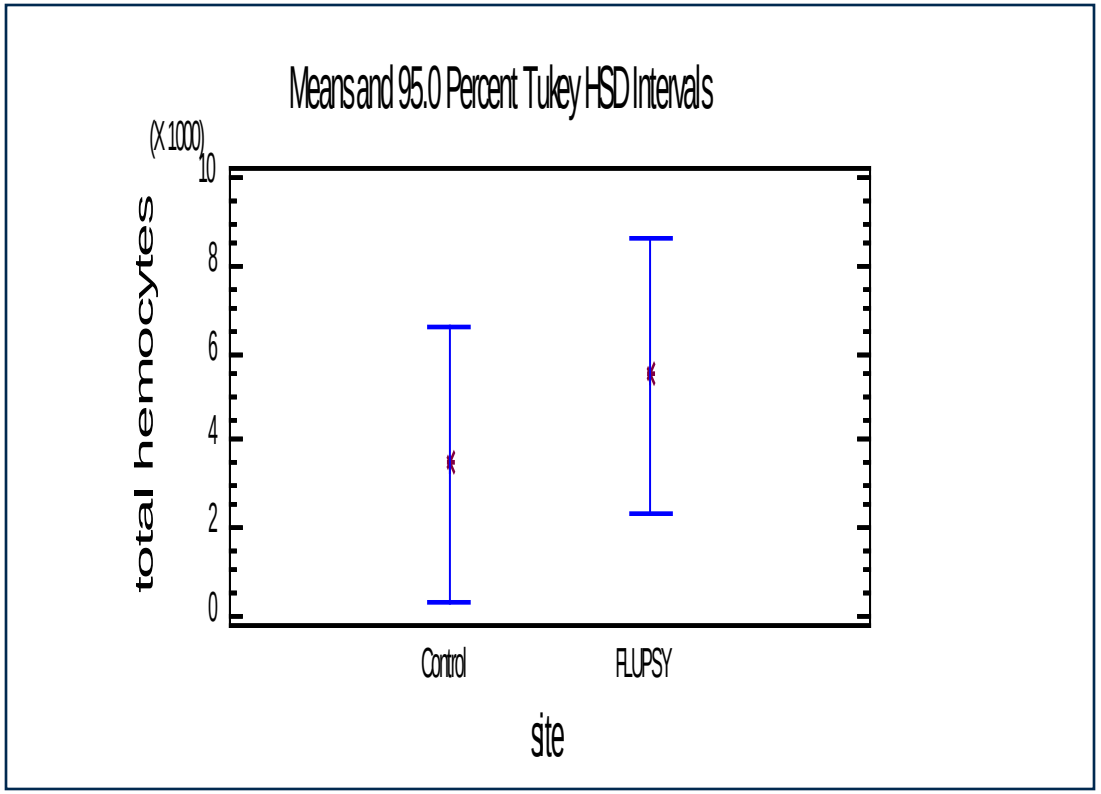
use of adult oysters as a proxy to measure immune status in juvenile oysters

- 1 week deployment
- measurement of hemocyte characterization and function (*total hemocyte count, mortality, phagocytosis*)
  - hemolymph extraction
  - fcm analysis (*molecular probes and fluorescent beads*)

NOAA FISHERIES SERVICE

Total Hemocyte Counts



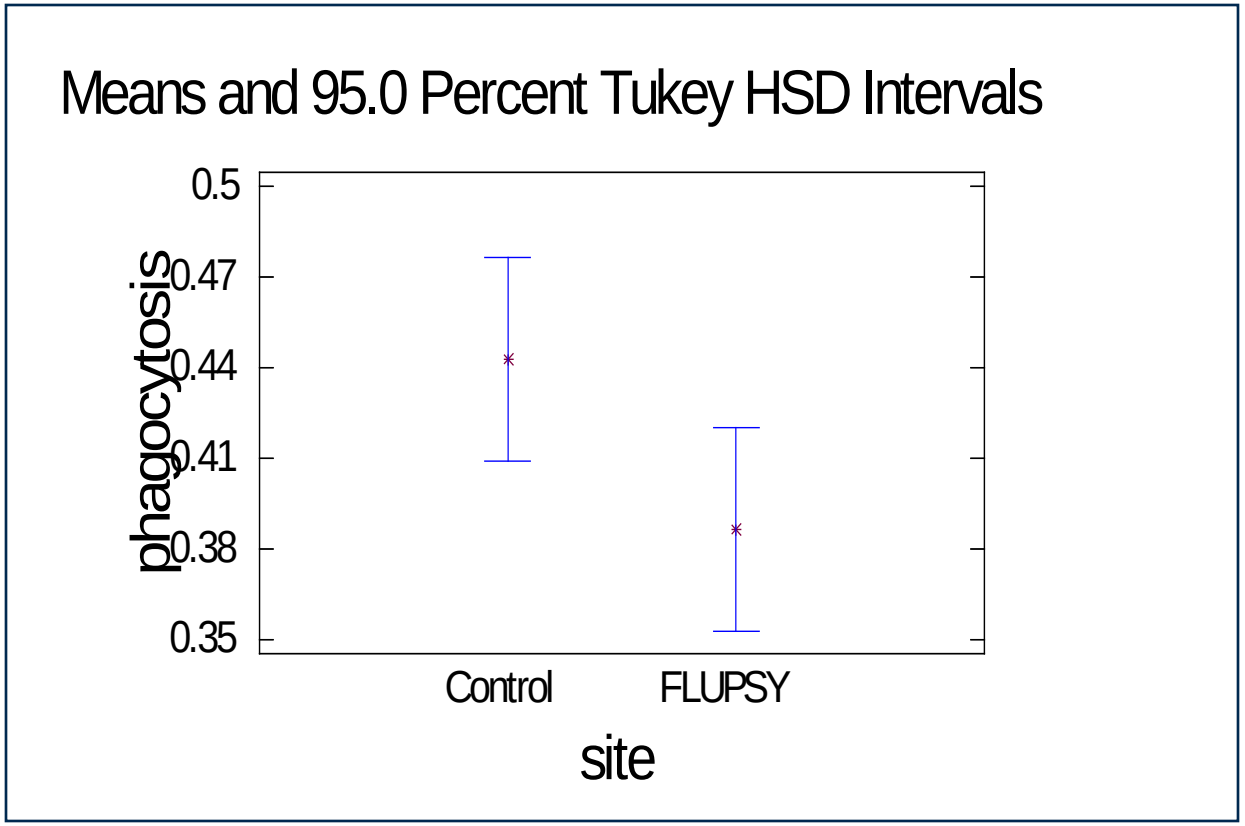


* P value= 0.50

- **circulating hemocyte counts were not significantly altered in FLUPSY compared to Milford Lab control**

NOAA FISHERIES SERVICE

Phagocytosis

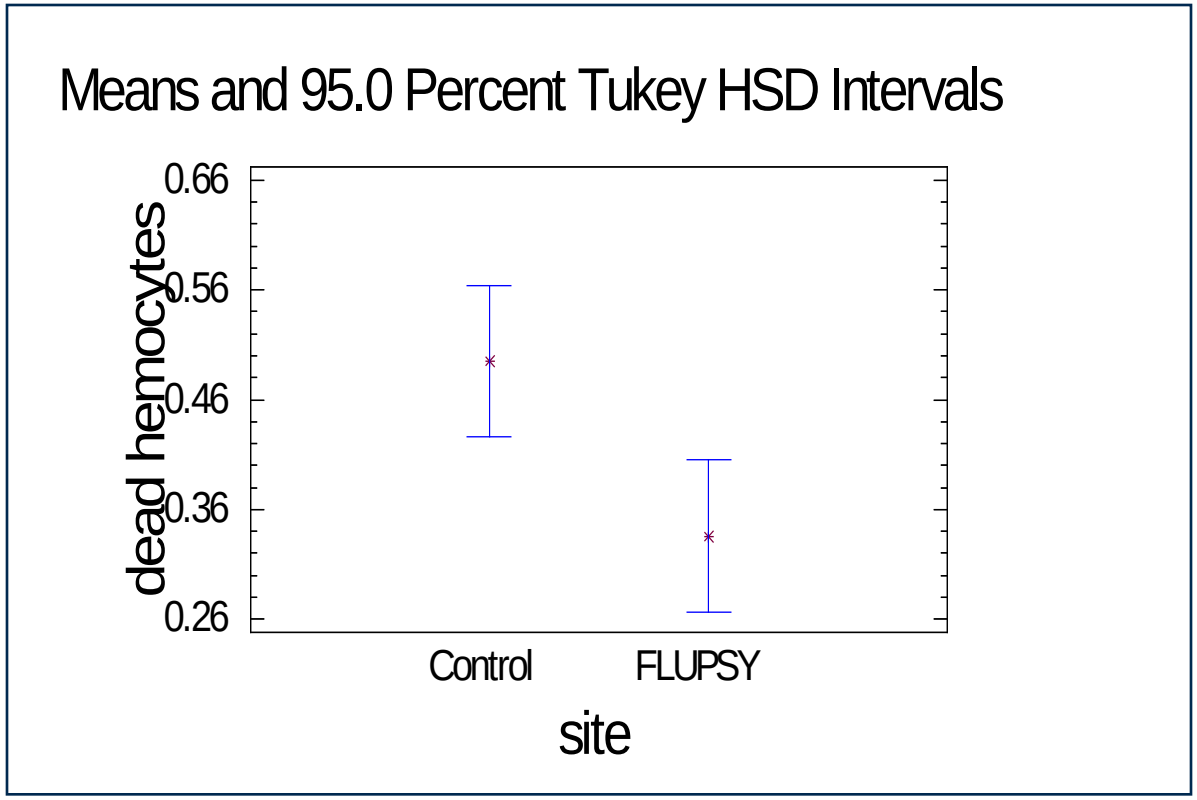


* P value= 0.95

- **phagocytosis was not altered in adult oysters deployed in the FLUPSY**

NOAA FISHERIES SERVICE

Dead Hemocytes

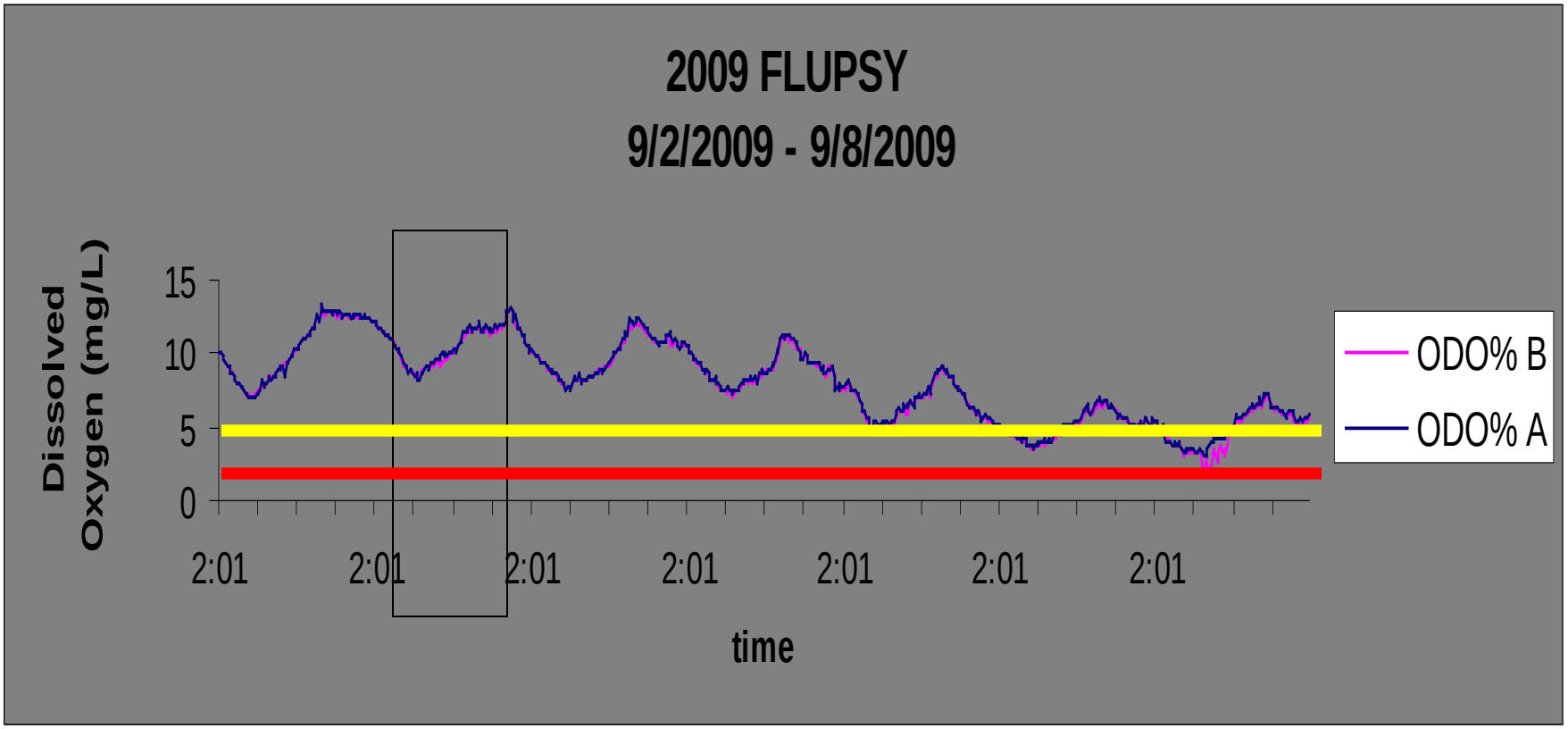


* P value= 0.02

- **more dead hemocytes were measured in control oysters**
  - **heavy rainfall ???**

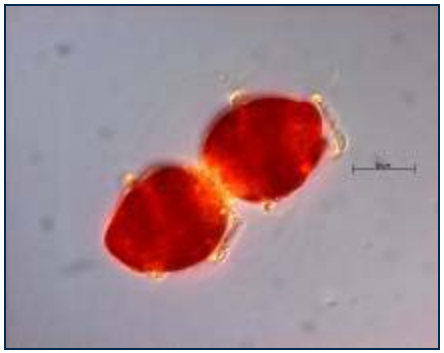
NOAA FISHERIES SERVICE

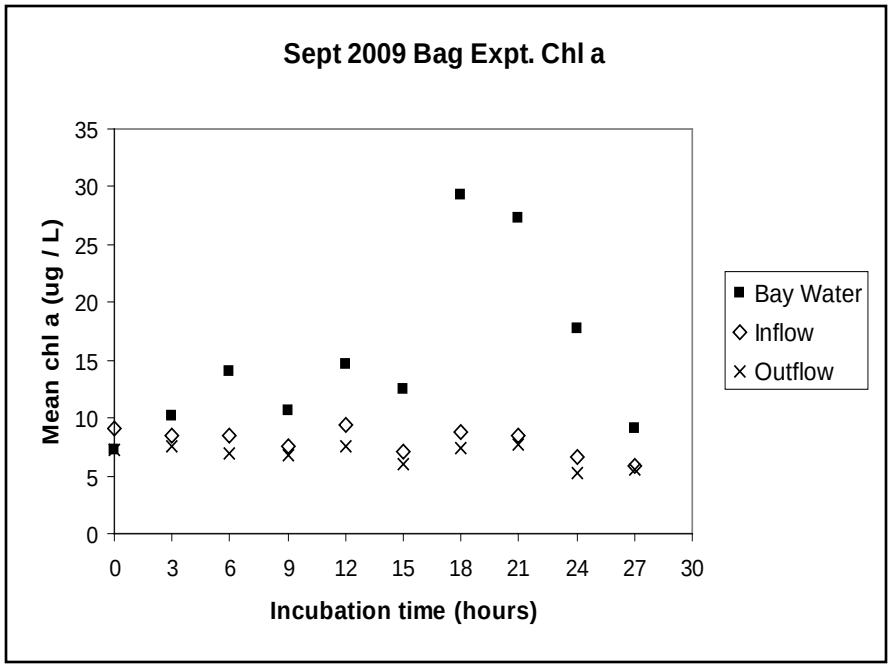
2009 FLUPSY Data

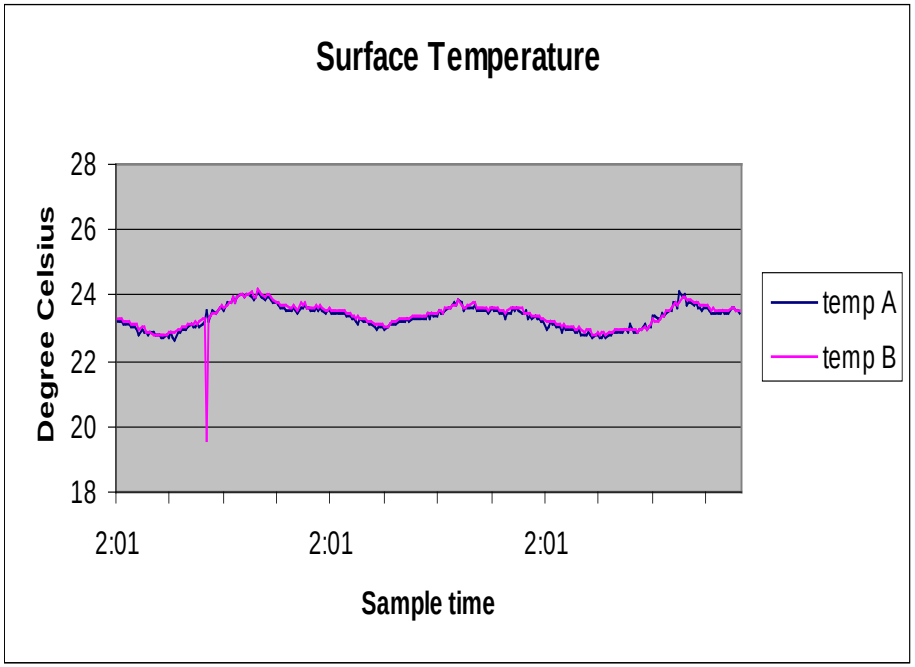


NOAA FISHERIES SERVICE

2009 FLUPSY Data







Cochlodinium polykrikoides *bloom during sampling period*

NOAA FISHERIES SERVICE

What did we learn in 2009 ?

- environmental conditions in the FLUPSY system did not induce stress-related responses during deployment

- variability between hours, days, and years

NOAA FISHERIES SERVICE

Future Work

- an extended sampling period
  - *time-series analysis*
- laboratory analyses to complement field studies
  - *dopamine assays*
- addition of humoral assays to evaluate immune status

NOAA FISHERIES SERVICE

Expectations confirmed and surprises

East Creek, a micro-estuary, is a very variable environment

This ecosystem presents nursery-grown oysters with both sustenance and stress

Oyster impacts on plankton and nutrient cycles are controlled by the ecosystem, not so much by the oysters, under current conditions

High-frequency monitoring is necessary to sum interactions over time, yielding data and models to inform regulation

NOAA FISHERIES SERVICE

What next?

2010 high-resolution monitoring for entire growing season (starting tomorrow through September)

Calculation of grazing and nutrient-regeneration rates that can be used in scaling and regulatory actions

Initiate “eutrophication-to-fish-feed” project, employing bivalves to recycle coastal nutrients back into a human food chain

NOAA FISHERIES SERVICE

Acknowledgements:

NOAA Aquaculture program and NEFSC for support

Town of Riverhead, New York

Carsten Krome and Aurelie LeLong participated in field sampling








NOAA
FISHERIES
SERVICE