Eelgrass (*Zostera marina*): Critical habitat in estuarine waters

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What are seagrasses?

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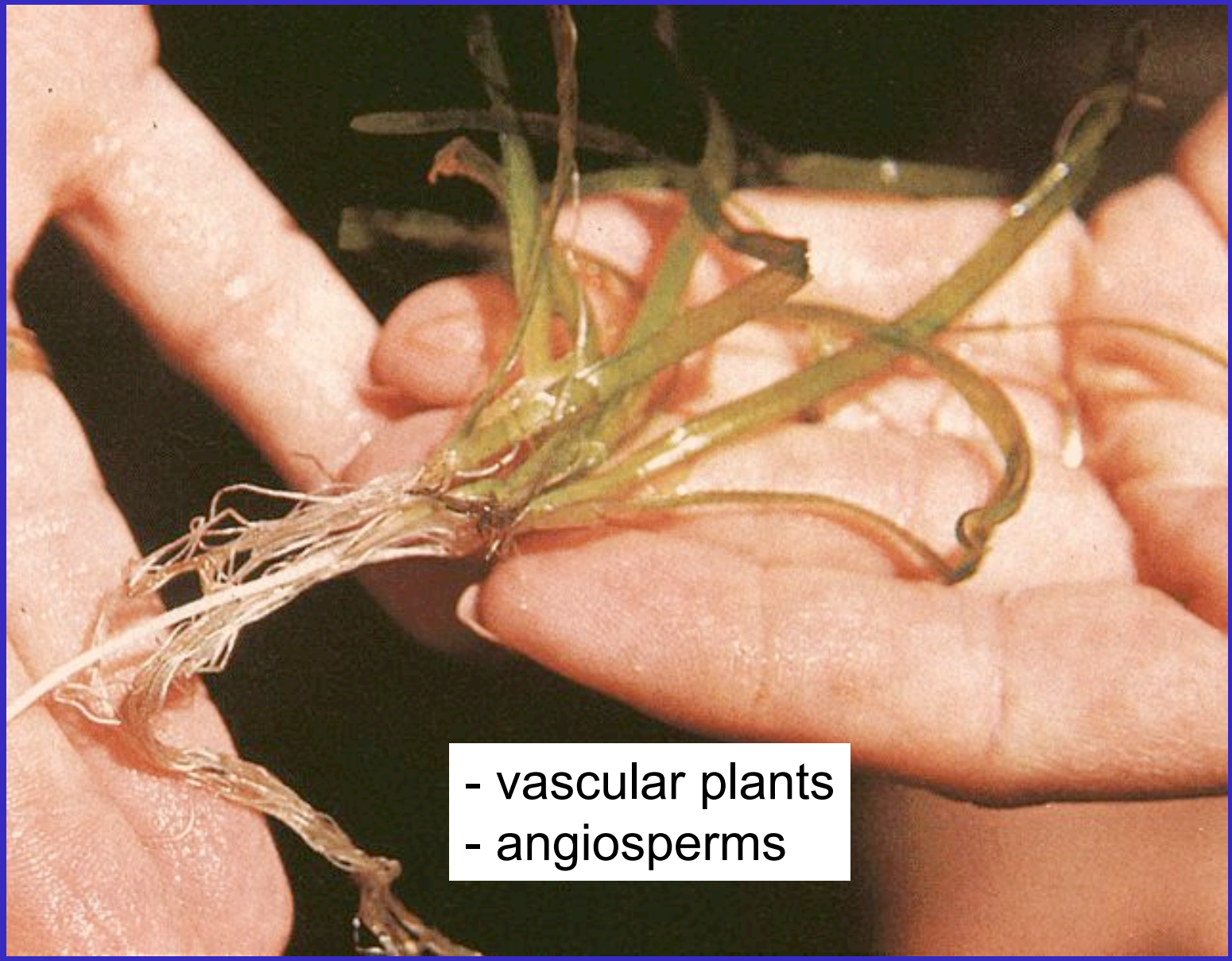
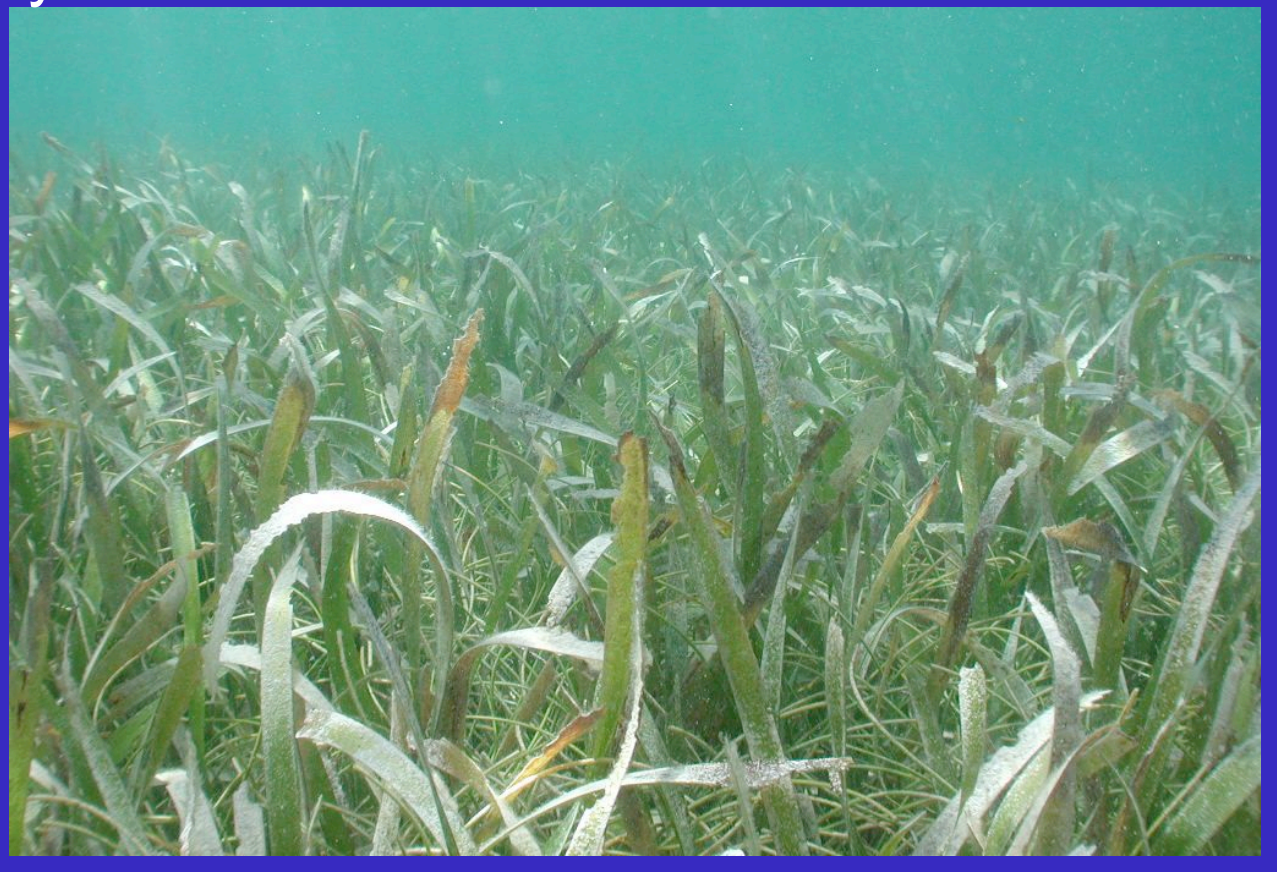


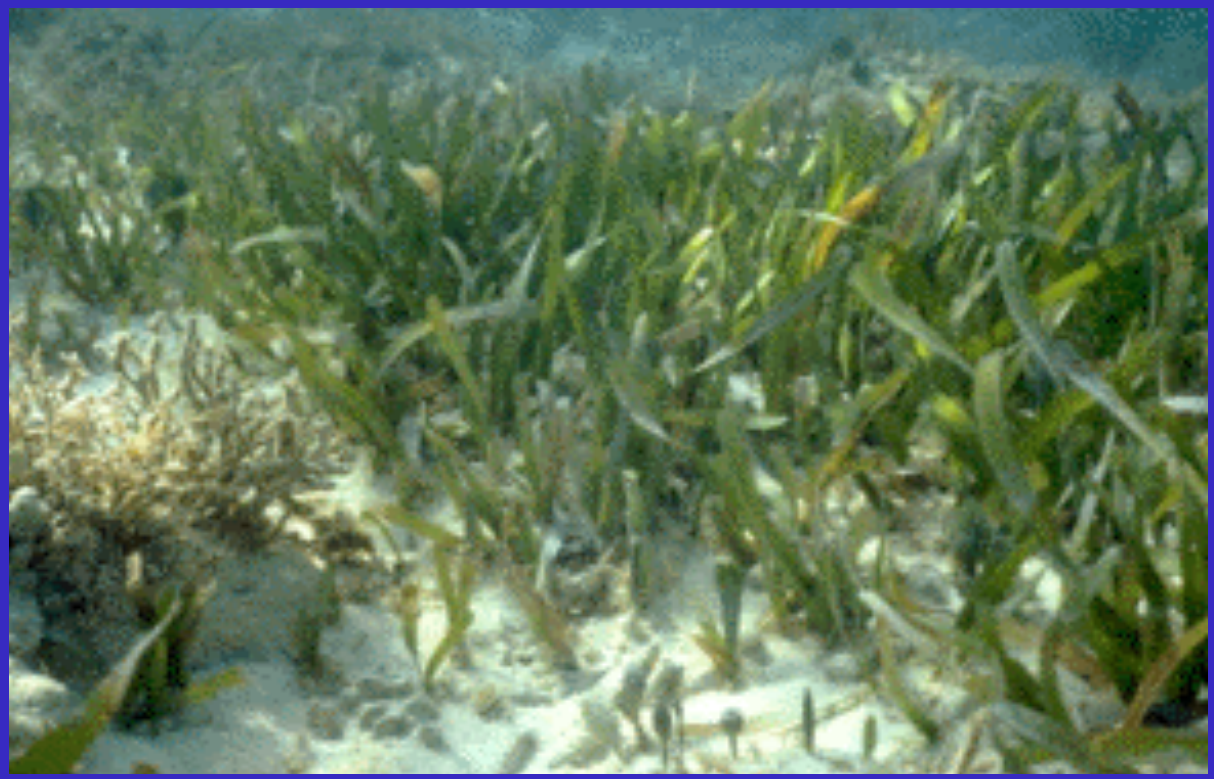
Photos: C. Pickerell

Seagrasses:
50 species, 12 genera, 2 families
Most beds monospecific, on soft sediment
All species are clonal
All have flexible blades
Some intertidal, some subtidal
Need high water clarity

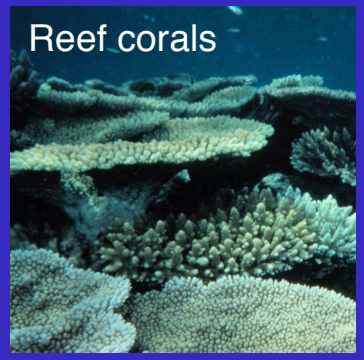


Seagrass beds

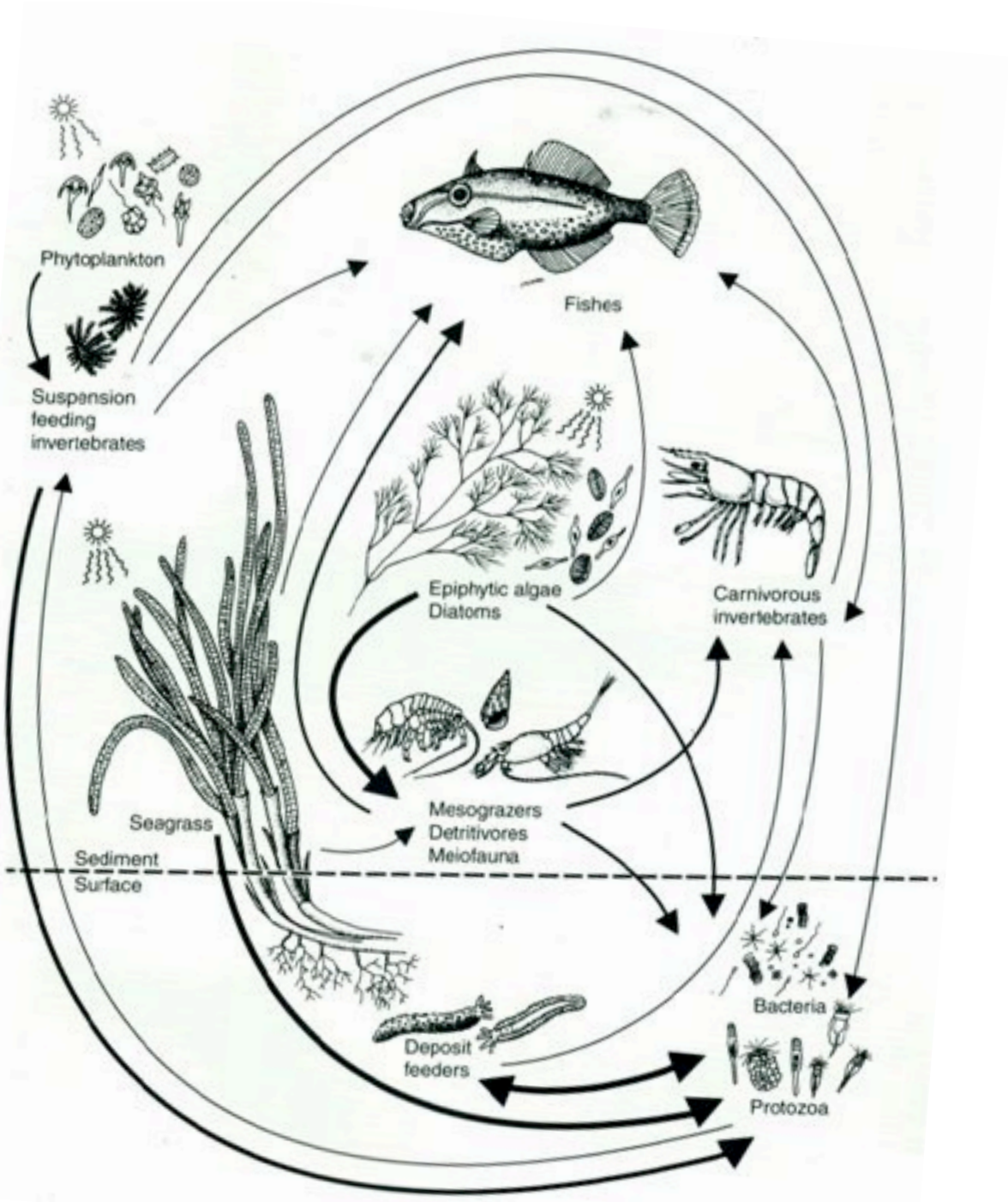
Improve water quality--reduce particle loads
Stabilize sediments
Play a significant role in global carbon and nutrient cycling



Examples of “foundation” or habitat forming species



“Foundation species” essentially form the basis upon or within which the entire community is built


Phytoplankton
Suspension feeding invertebrates
Fishes
Epiphytic algae
Diatoms
Carnivorous invertebrates
Seagrass
Sediment Surface
Mesograzers
Detritivores
Meiofauna
Bacteria
Deposit feeders
Protozoa

Edge effects, habitat modification, and facilitation by seagrass

Cores of infauna: polycheates, oligochaetes, amphipods, isopods

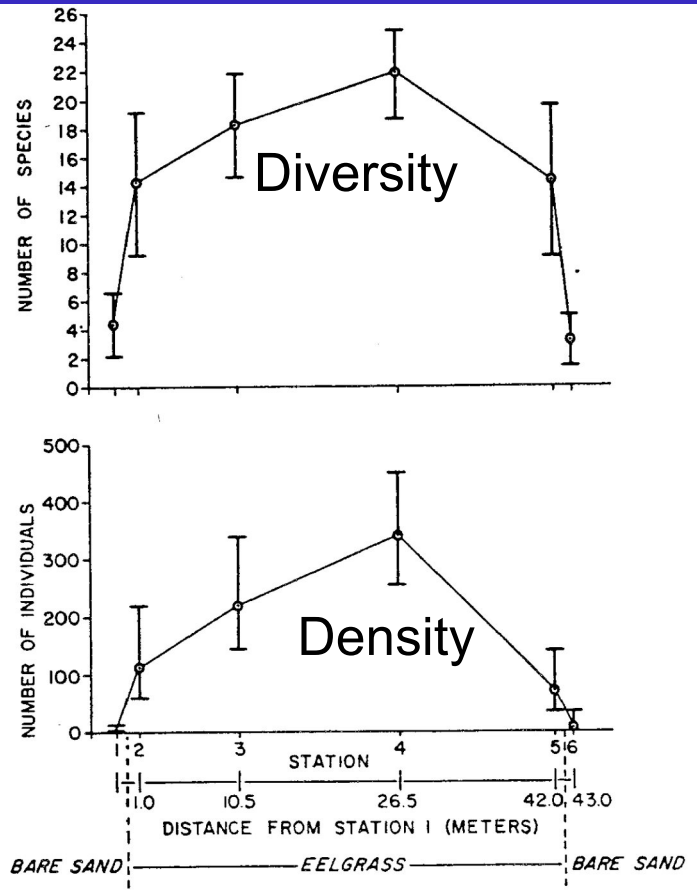


Fig. 5. Mean (o) and 95% confidence intervals ($\bar{X} \pm t_{.05}S_{\bar{x}}$, vertical line) for number of species per core and number of individuals (L-Tr) per core for the six stations along the transect across a *Zostera* bed at Sandy Point, July 1972. (L-Tr indicates data were log-transformed [log (x+1)] statistical calculations performed in the transformed space, and back-transformed to the original scale for presentation in figures.)

Threats to seagrass beds

Mechanical damage from boating, fishing

Dredging, filling, shading by structures

Increased nutrient loading

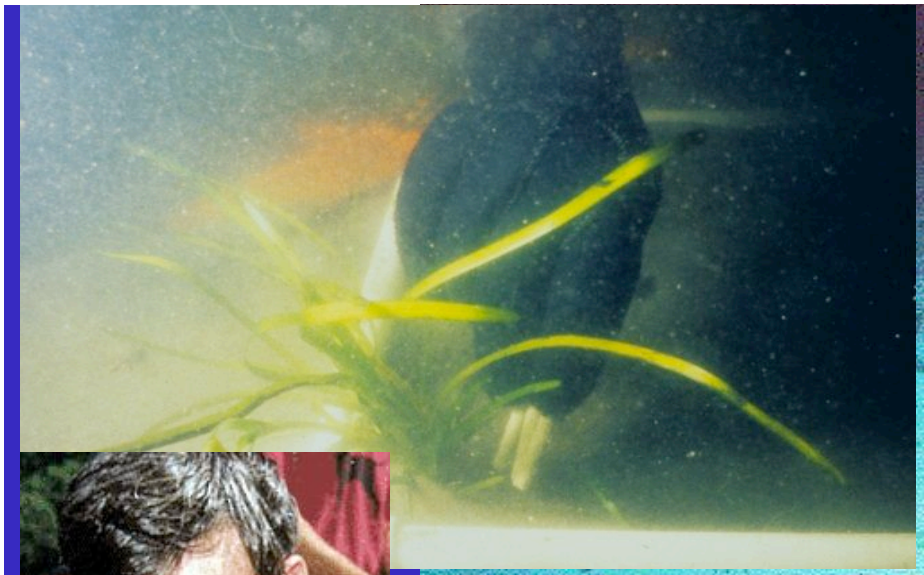
Organic loading--dissolved oxygen reductions

Siltation

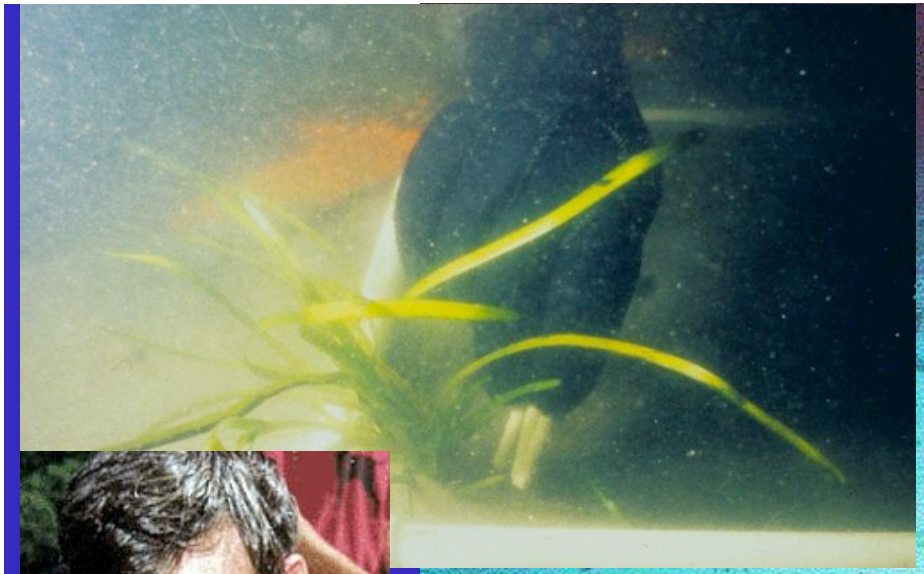
Toxic chemicals--oil

Wasting disease

Harvesting



Restoration in other regions has taken many forms



What will work locally?

Eelgrass, *Zostera marina*

Only seagrass in the soft sediments of San Francisco and nearby bays

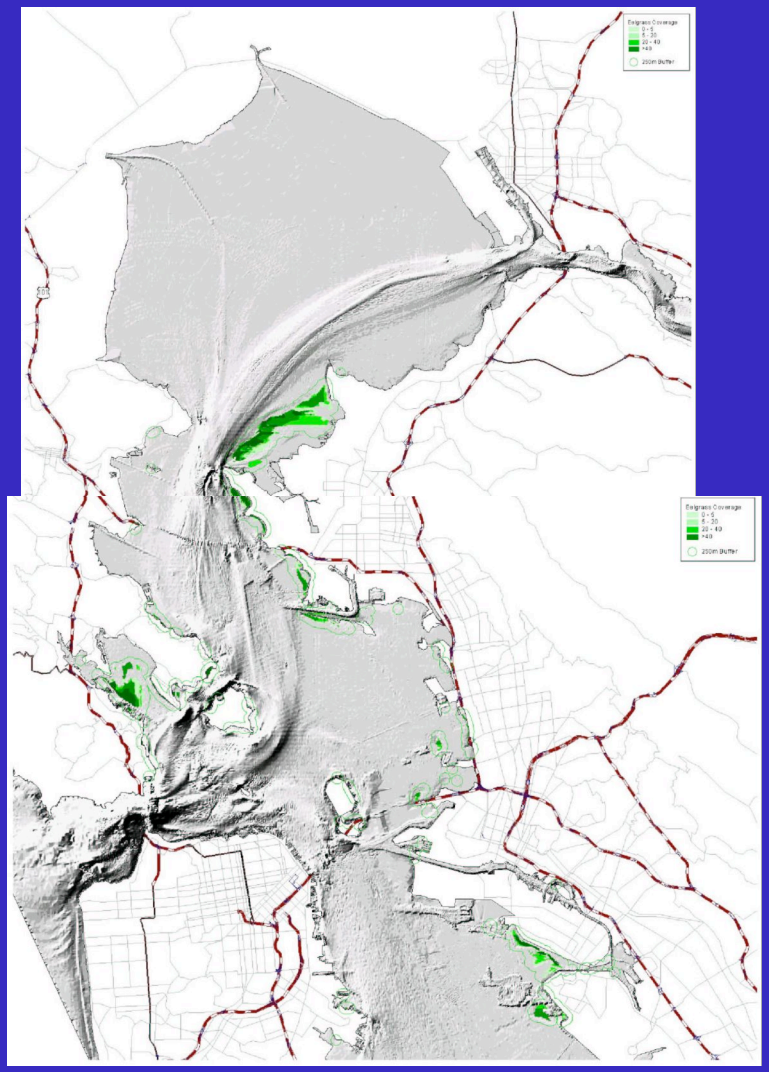
Photo: J. Stalker

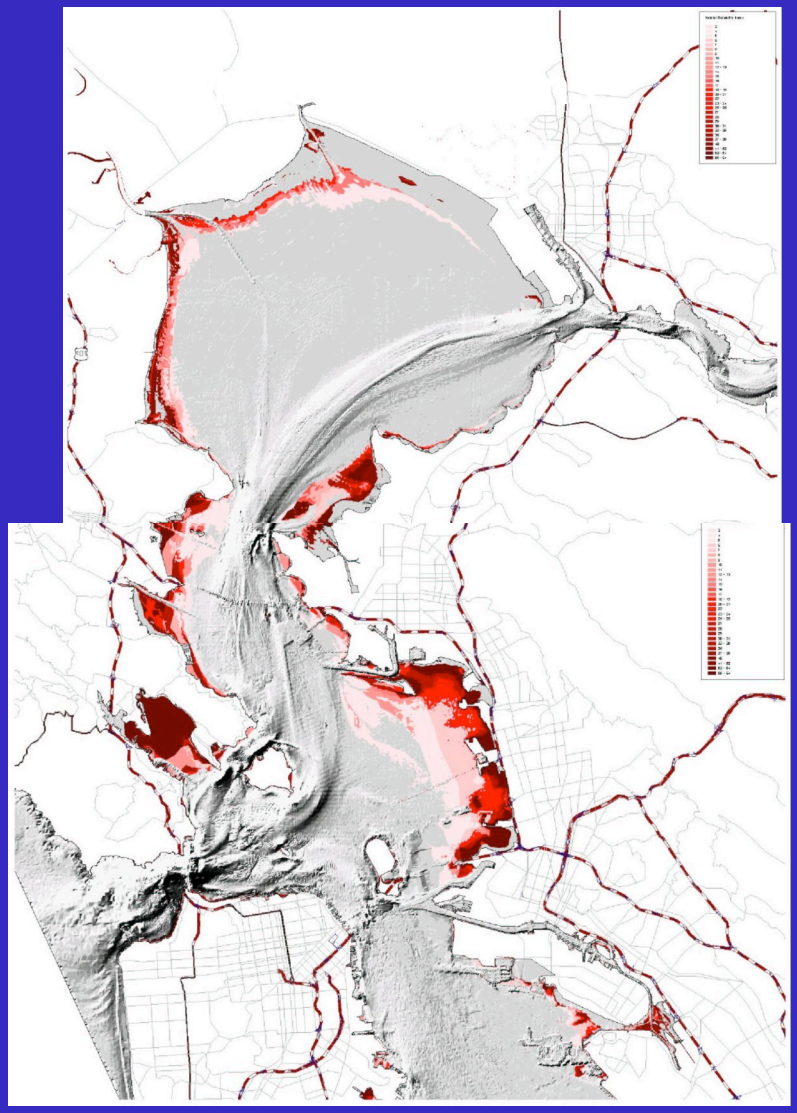
In San Francisco Bay

Photos: Merkel and Associates

Recent and continuing threats

The potential for eelgrass restoration in SF Bay





(Merkel and Associates 2004)

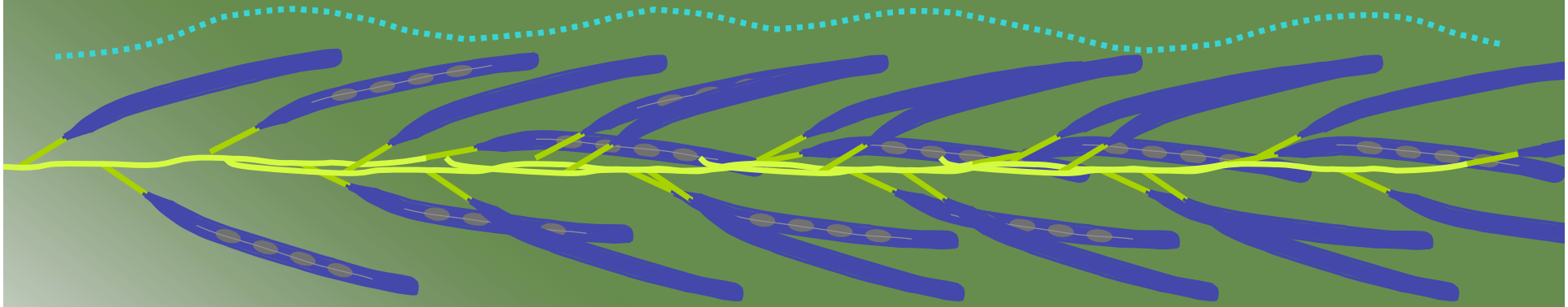
What do we need to know to successfully restore eelgrass in San Francisco Bay?

Photos: C. Pickerell

Can capitalize on both in restoration

In San Francisco Bay, high flowering rates, at least one annual bed--try seeding techniques!

Natural Seed Dispersal (floating reproductive shoot)



Flowering shoots often float and can be transported long distances from donor meadows (McRoy, 1968)

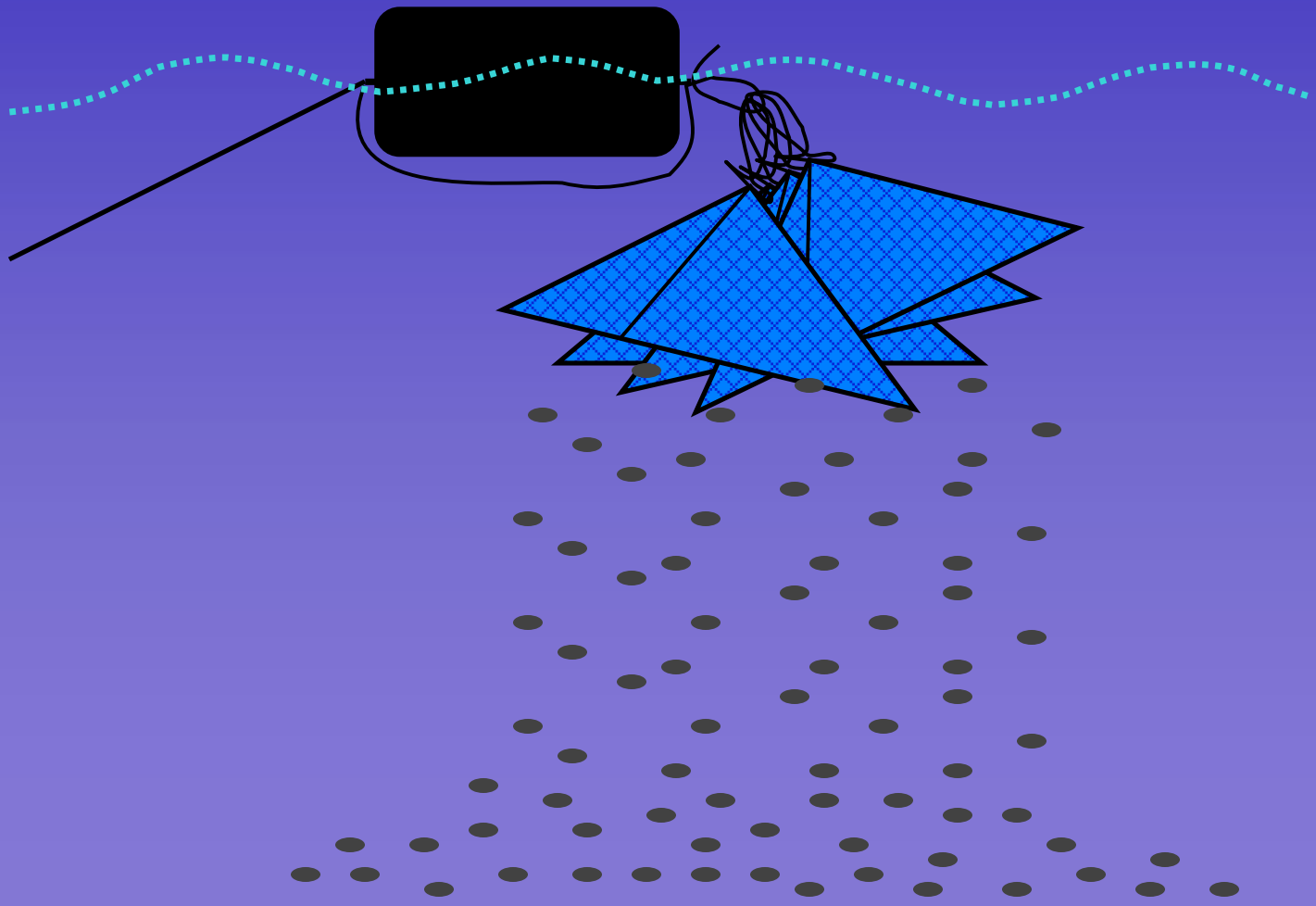
Spathes continue to develop within detached reproductive shoots (DeCock, 1980)

This method of dispersal has recently been shown to have the potential to transport seeds up to 34 km (Harwell & Orth, 2002)

Buoy-deployed seeding, aka “seed buoys” (Pickerell et al. 2005)

Photos: J. Stalker

Buoy Deployed Seeding (BuDS)



Initial questions:

Is seeding a viable option for San Francisco Bay eelgrass restoration?

Where should we get the seed? (Are all donor beds equally good choices for flower collection?)

How do we choose appropriate restoration sites? (location in bay, sediments, etc.)

Initial questions:

Is seeding a viable option for San Francisco Bay eelgrass restoration?
Mesocosm and field experiments

Where should we get the seed? (Are all donor beds equally good choices for flower collection?)
Field surveys, mesocosms and field experiments

How do we choose appropriate restoration sites? (location in bay, sediments, etc.)
Sediment inoculation experiment, sediment texture experiment, field experiment

Donor site selection:

Perennial: Point Molate and Bay Farm Island

Annual:
Crown Beach

Mesocosms

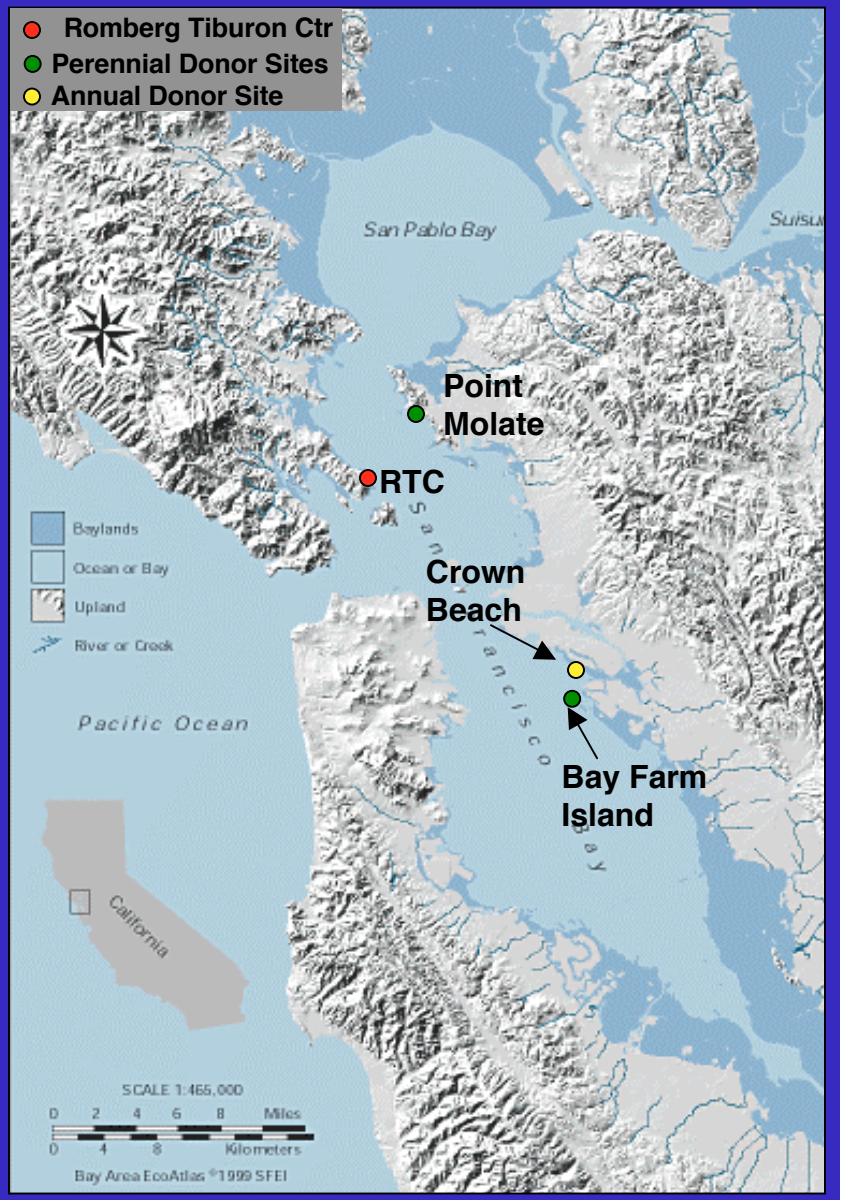
Donors:
Pt. Molate
Crown Beach
Bay Farm Island

Technique: Seed Buoys

Additional treatment:
Inoculation with donor bed sediment

Replication: 3 mesocosms w/ one buoy each

Total seed buoys (mesocosms) in experiment:
3 x 2 x 3 = 18



Mesocosms

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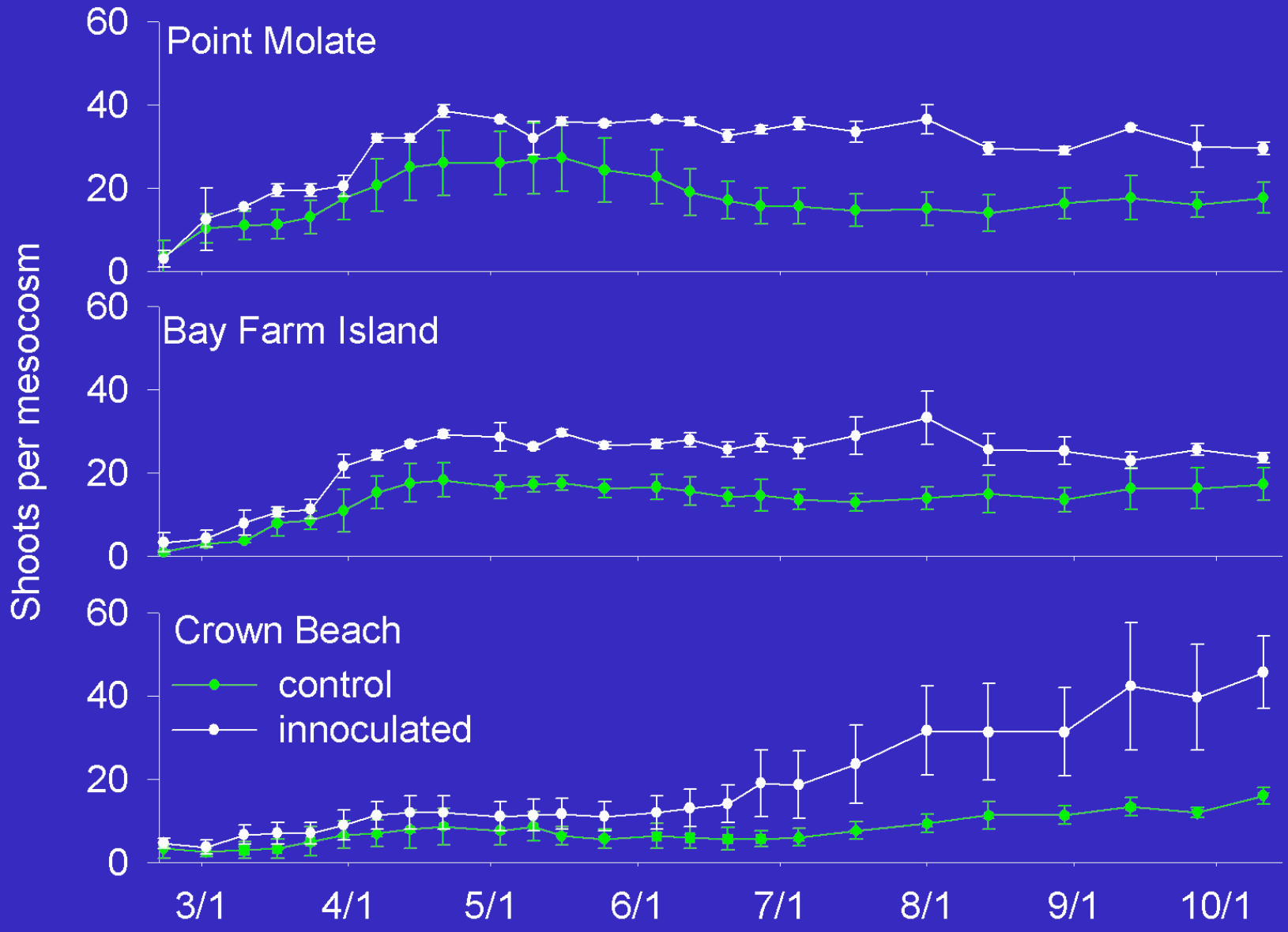
Mesocosm Recruitment



Mesocosm experiment lessons:

Seed bag technique worked

All donor seed sources resulted in seedlings

Inoculation of sand with donor-site sediments may aid restoration at sandy sites

Seedlings maintained levels of genetic diversity found in donor populations (Sarah Cohen and Brian Ort)

Mesocosm experiment lessons:

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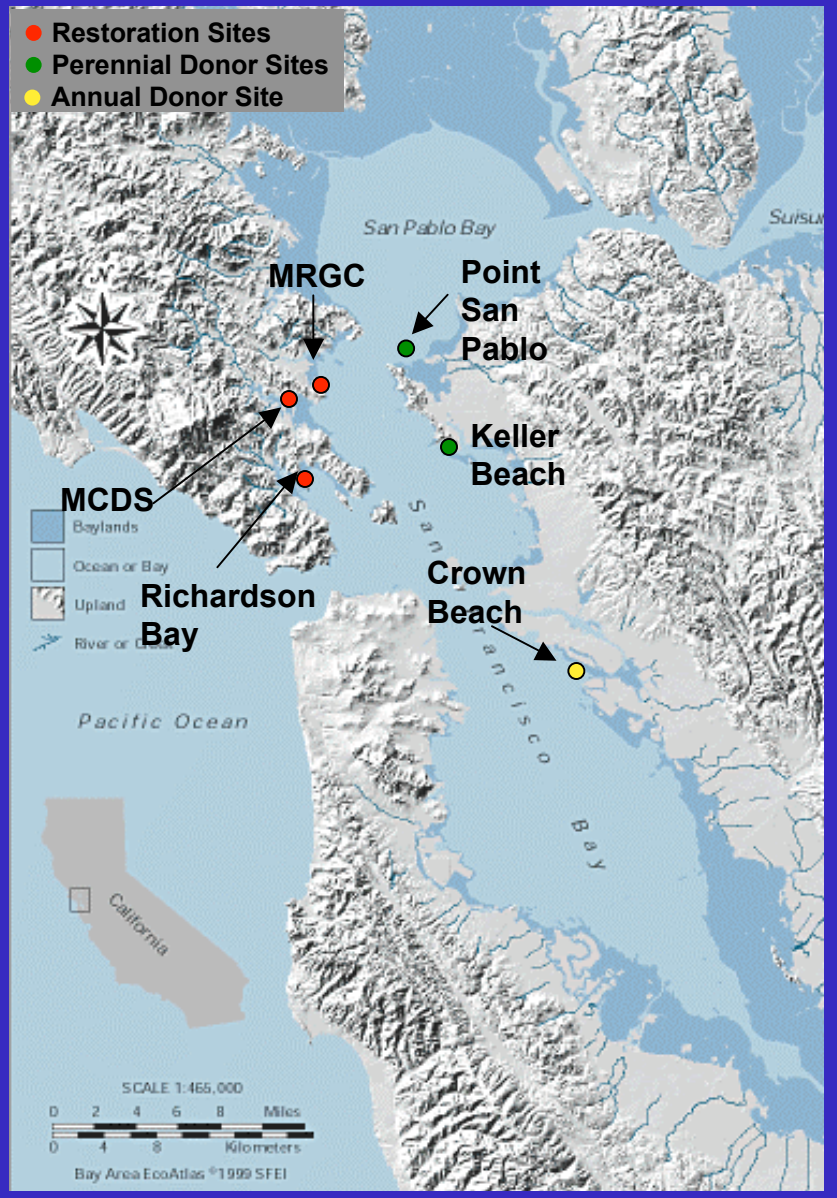
How about in a more natural setting?

Field trials of eelgrass restoration techniques

Donors:
Pt. San Pablo
Keller Beach
Crown Beach

Restoration sites:
Marin Rod and Gun Club
Marin Country Day School
Richardson Bay (Audubon)

Techniques:
Seed Buoys
TERFS
broadcast seeding



Donor site selection and monitoring of flowering phenology

Perennial:

Annual:

Photos: K. Boyer

Two seeding techniques:
Bouy-deployed seeding
Hand broadcasting

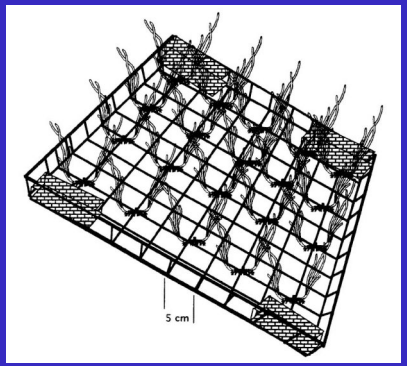
Marin Country Day School (San Quentin)

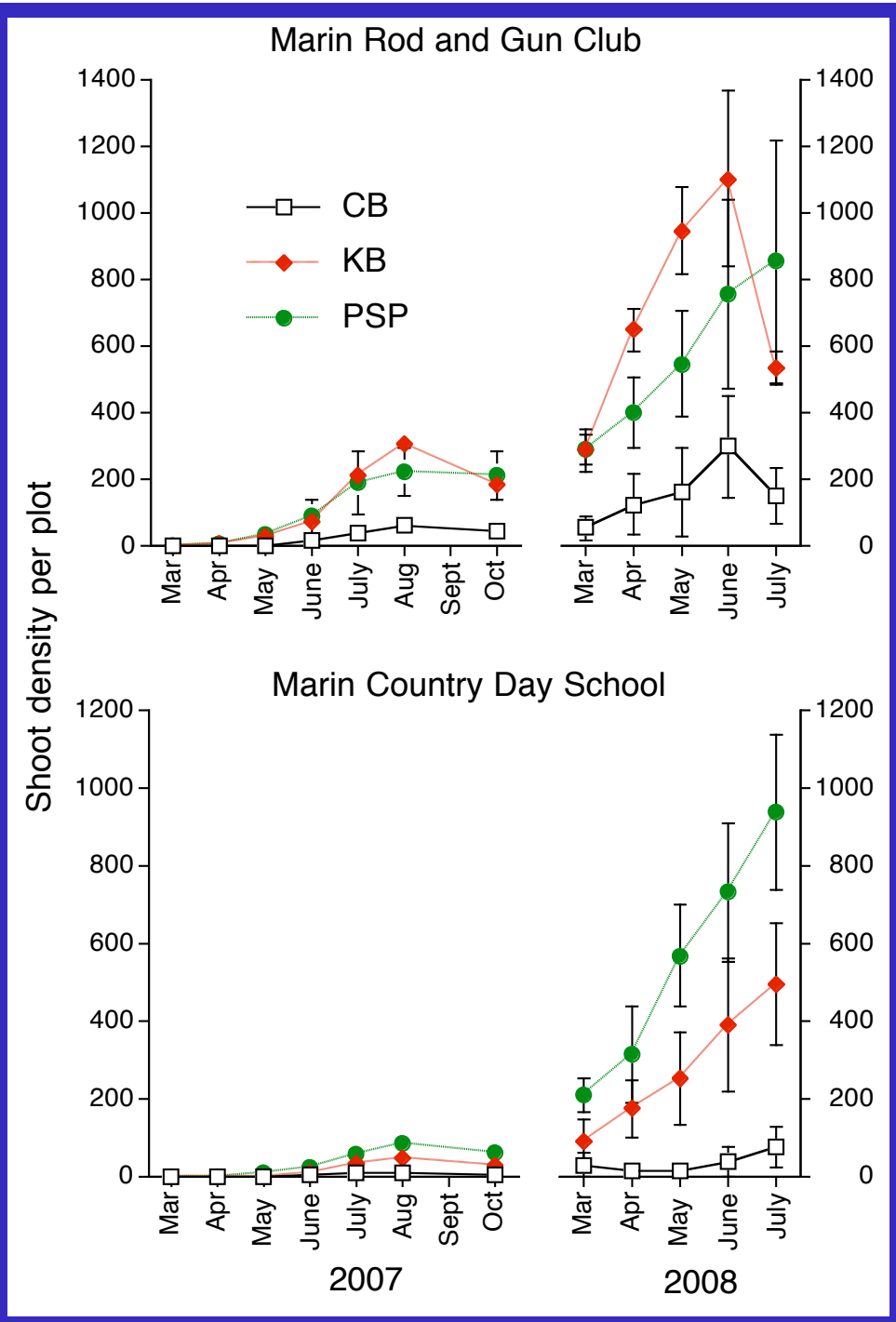
Marin Rod and Gun Club

Richardson Bay

Vegetative shoot transplants with modified TERFS*

**Transplanting Eelgrass Remotely with Frames System*
™University of New Hampshire, Short et al. 2002




Marin Rod and Gun Club
Shoot density per plot
CB
KB
PSP
1400
1200
1000
800
600
400
200
0
Mar
Apr
May
June
July
Aug
Sept
Oct
Marin Country Day School
2007
2008

	Marin Rod and Gun Club		Marin Country Day Schoo l	
Donor	July 2007	July 2008	July 2007	July 2008
Crown Beach	117	458	30	238
Keller Beach	639	1610	113	1491
Point San Pablo	581	2567	184	2882
Total	**1337**	**4635**	**327**	**4551**

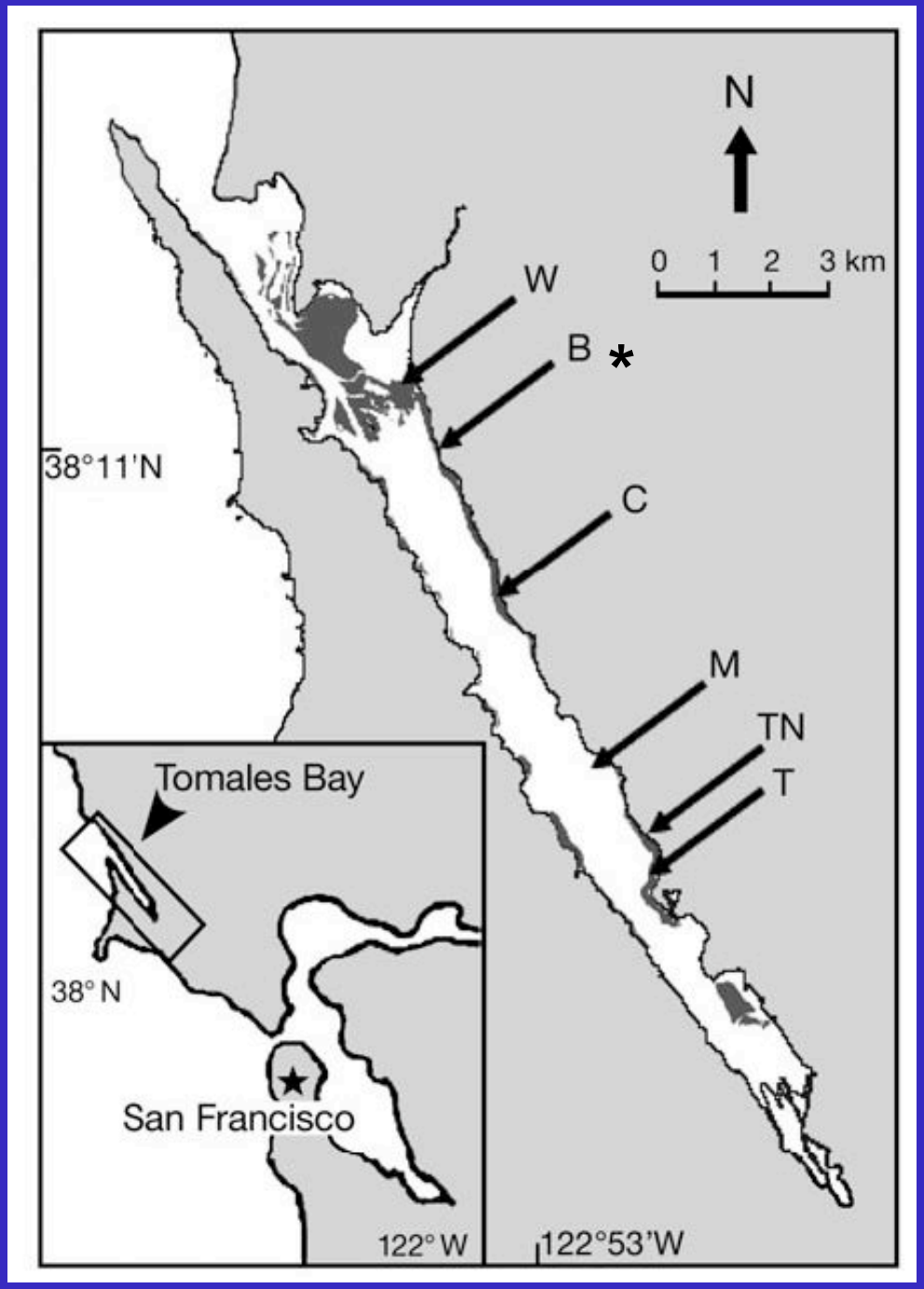
Lessons from Experimental Restoration studies

Seed buoy technique worked in mesocosms and in field at two sites (far exceeded success of TERFS and broadcast seeding)--experimental restoration instead of trial and error

Seedlings from perennial and annual donors recruited--annual more successful in mesocosms but not in field--sediment effects?

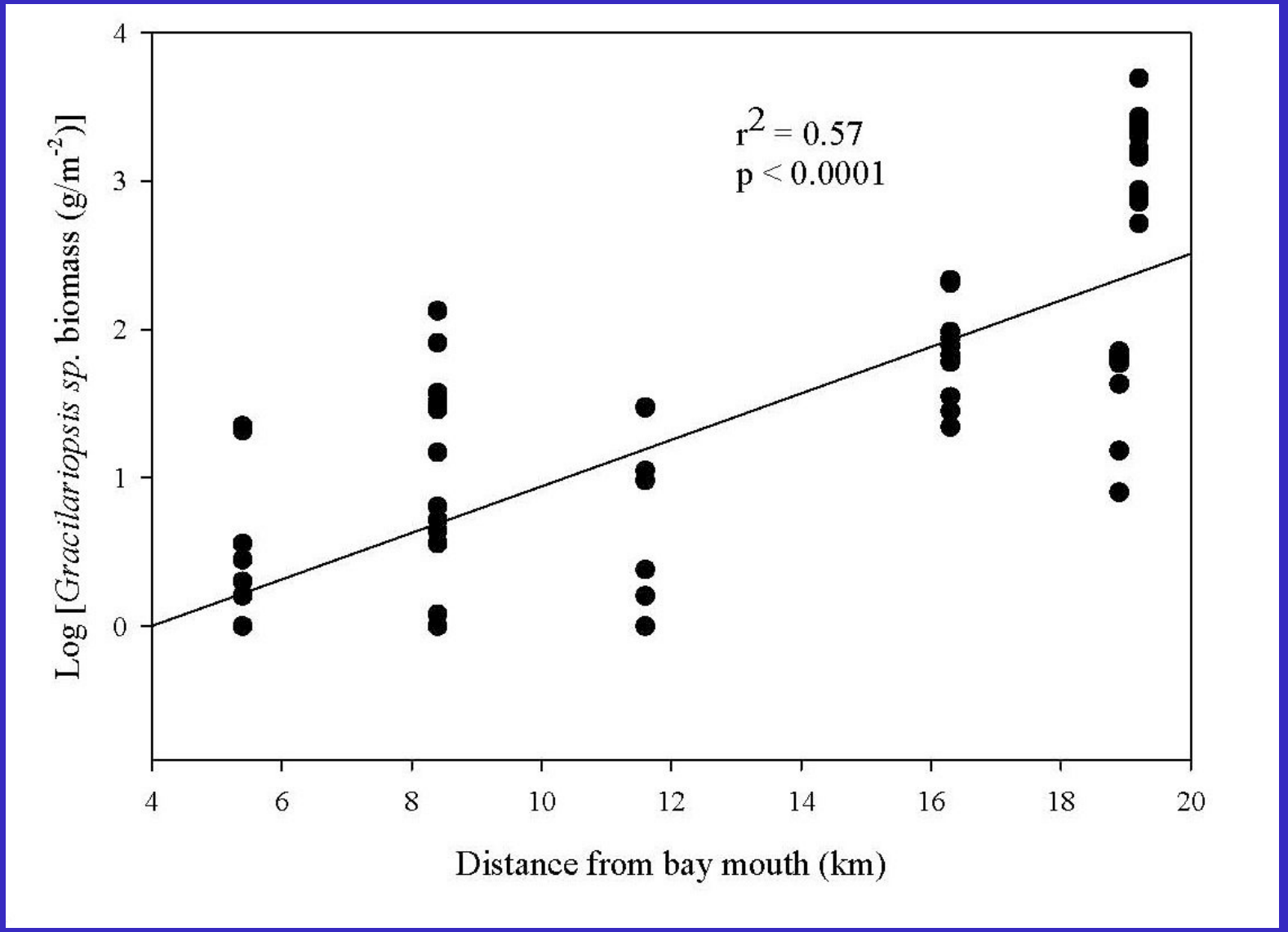
Genetic diversity of donors maintained by BuDs technique

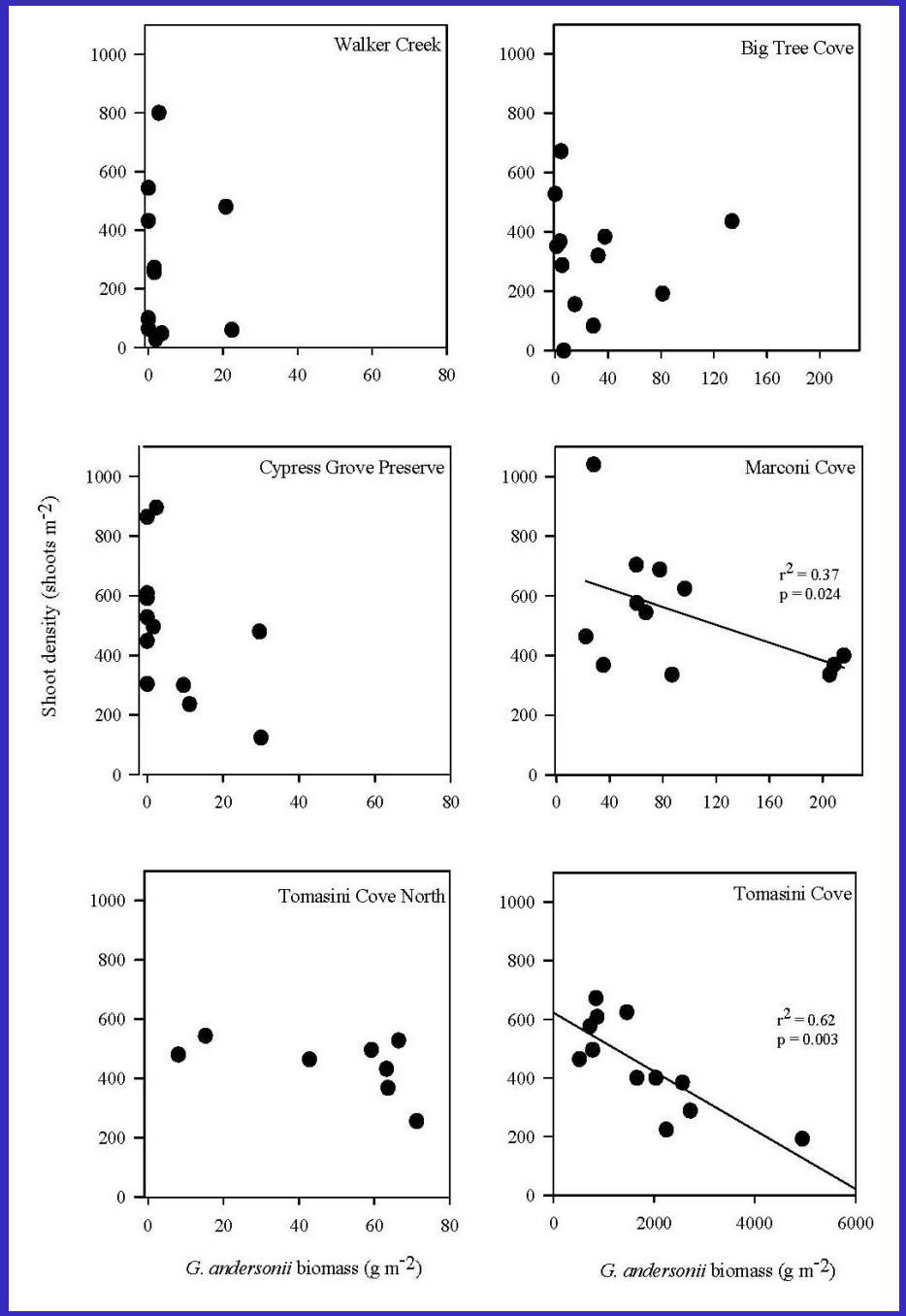
How about Tomales Bay?



Eelgrass coverage from California Department of Fish and Game
surveys in 1992, 2001, and 2002.

W = Walker Creek
B = Big Tree Cove
C = Cypress Grove
M = Marconi Cove
TN = Tomasini Cove North
T = Tomasini Cove


$r^2 = 0.57$
$p < 0.0001$
Log [*Gracilariopsis sp.* biomass (g/m^{-2})]
Distance from bay mouth (km)
0
1
2
3
4
4
6
8
10
12
14
16
18
20


Walker Creek
Big Tree Cove
Cypress Grove Preserve
Marconi Cove
$r^2 = 0.37$
$p = 0.024$
Tomasini Cove North
Tomasini Cove
$r^2 = 0.62$
$p = 0.003$
Shoot density (shoots m^{-2})
G. andersonii biomass (g m^{-2})
G. andersonii biomass (g m^{-2})

What is the role of varying densities of *Gracilariopsis* on eelgrass in Tomales Bay?

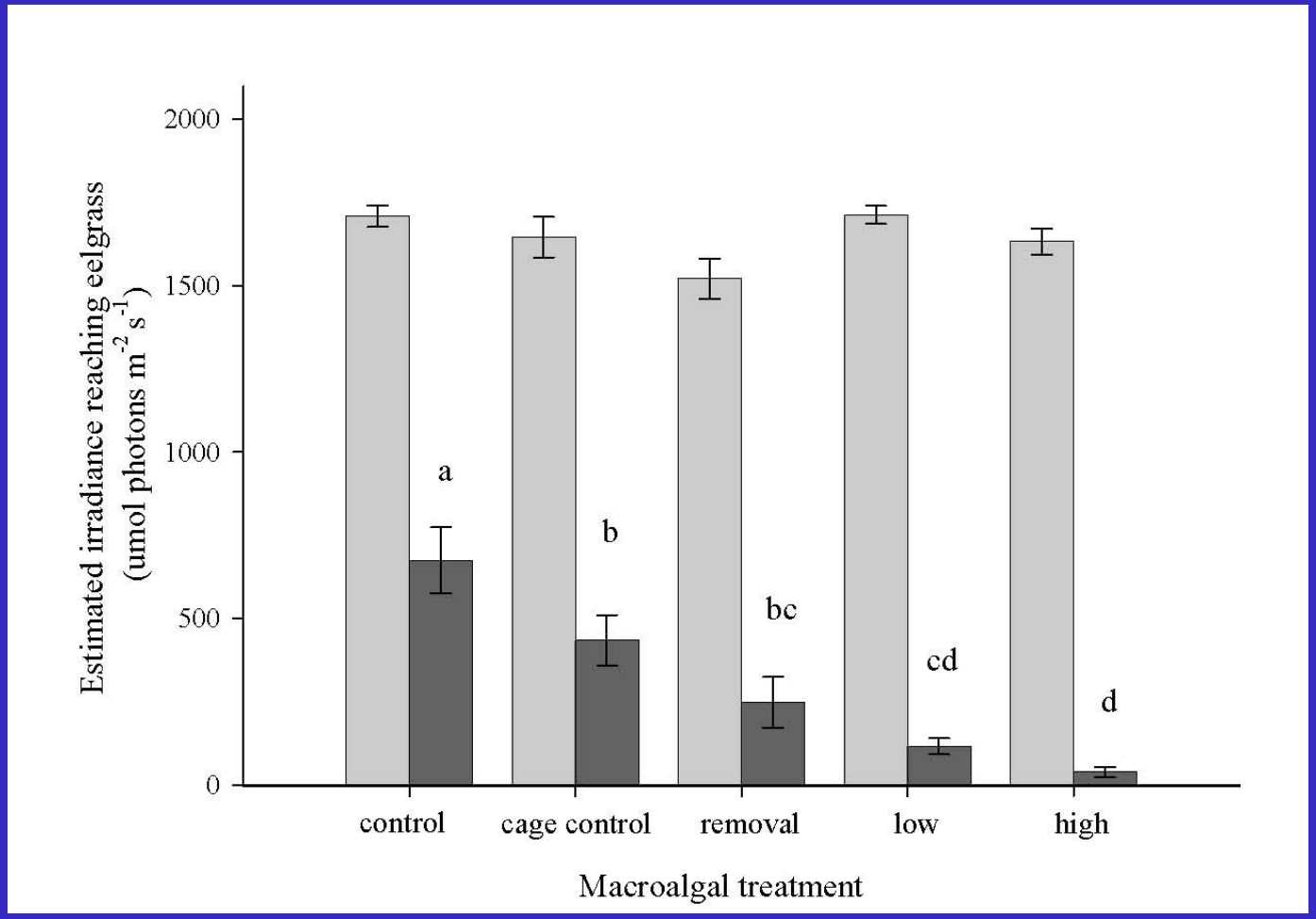
Field experiment with cages to enclose/exclose algae:
- Control (no manipulation of algae)

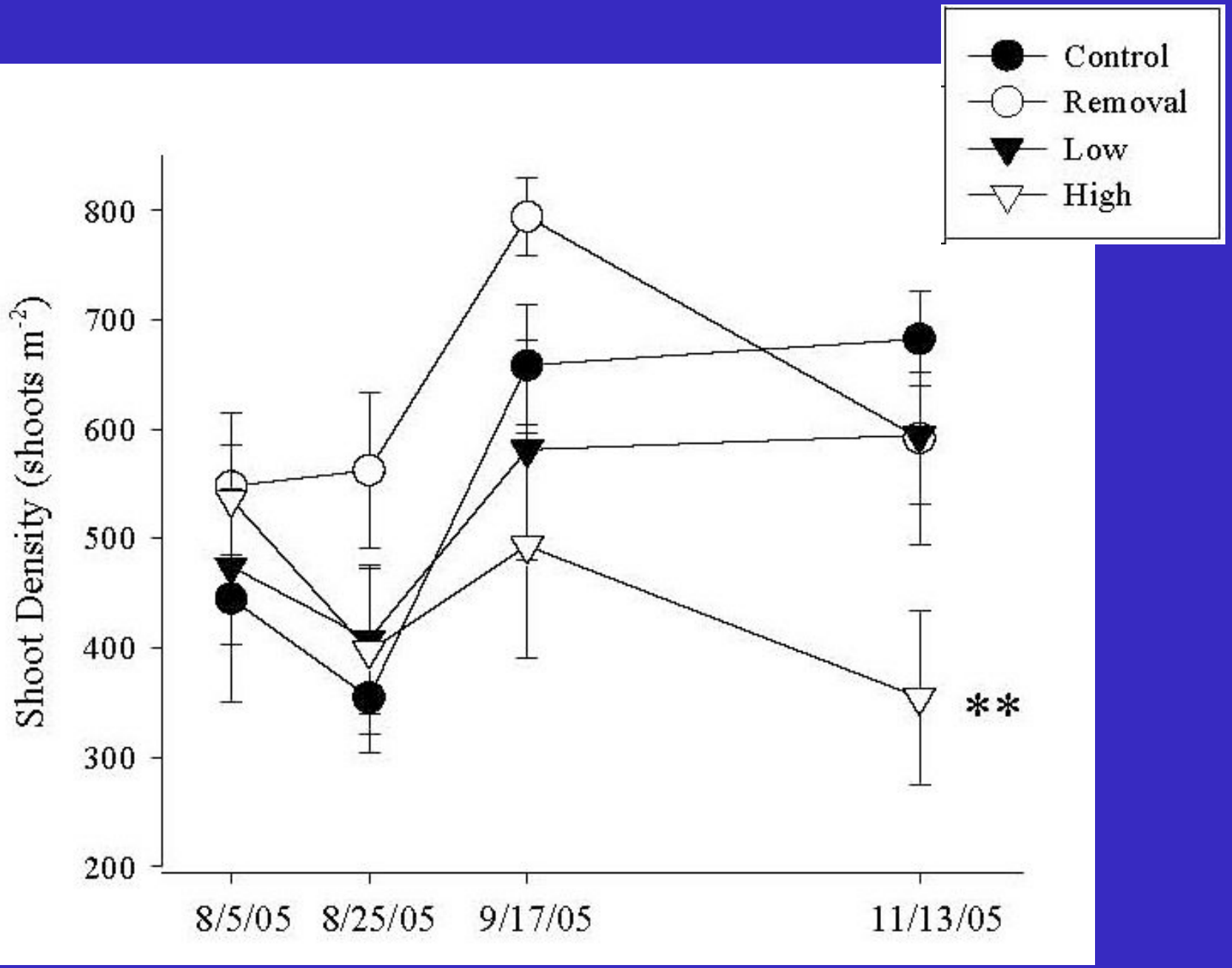
- 0 g algae (removal)

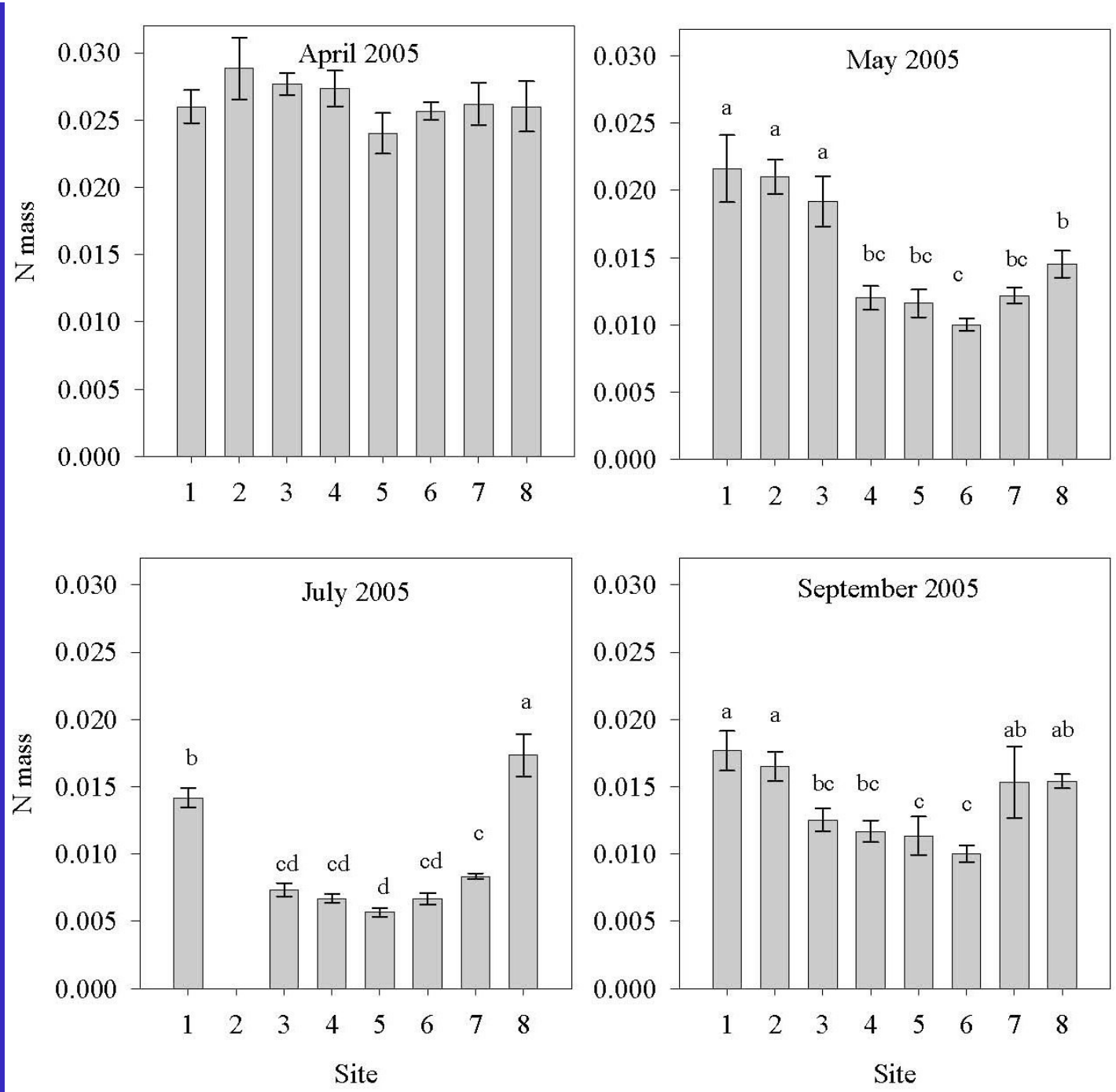
- 325 g algae (average found in surveys

- 1700 g algae (average maximum across surveyed sites)

Big Tree Cove


Estimated irradiance reaching eelgrass (umol photons m-2 s-1)
2000
1500
1000
500
0
a
b
bc
cd
d
control
cage control
removal
low
high
Macroalgal treatment


Control
Removal
Low
High
Shoot Density (shoots m-2)
800
700
600
500
400
300
200
8/5/05
8/25/05
9/17/05
11/13/05
**


April 2005
May 2005
July 2005
September 2005
N mass
Site
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1 2 3 4 5 6 7 8
a a a bc bc c bc b
b cd cd d cd c a
a a bc bc c c ab ab

Tomales Bay—pristine?

Nutrients, mercury, pathogens

Macroalgae seems to be increasing—
Due to nutrients?

Macroalgae at high densities has negative impacts on eelgrass—suggest watching water quality closely

Restoration lessons from SF Bay?
need to test techniques in other locations

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