# Biological Productivity of Tidal Marshes and their Role in the Food Web of San Francisco Bay

Michael Josselyn, PhD
Professor Emeritus, SFSU
President, WRA, Inc.

# Overview of Presentation

- Productivity
  - What does it mean?
  - Where does it go?
  - How does it get there?

- How significant is marsh productivity to Bay organisms?
- Does invasive *Spartina* make a difference?

# Tidal marshes

- One of the most productive systems of the world:
  - Tidal marsh: 500-1000 g C/$m^2$/yr
  - Tropical rain forest: 900 g C/$m^2$/yr
  - Annual grassland: 225 g C/$m^2$/yr
  - Woodland: 270 g C/$m^2$/yr
  - Estuarine phytoplankton: 100 g C/$m^2$/yr

# Productivity

- *Productivity*: the rate at which radiant energy is used by producers to form organic substances as food by consumers
  - Measured by carbon dioxide uptake, oxygen production, or organic matter accumulation over time
- *Biomass*: the accumulation of organic matter during a specific time interval
  - Measured as organic matter accumulation or calculated from productivity.
- *Turnover*: Frequency in which standing stock is replaced
  - Measured as productivity/biomass

# Example

- Productivity = 1 g C/day = 365 g C/yr
- Biomass over one year = 300 g C
- Turnover = 1.21

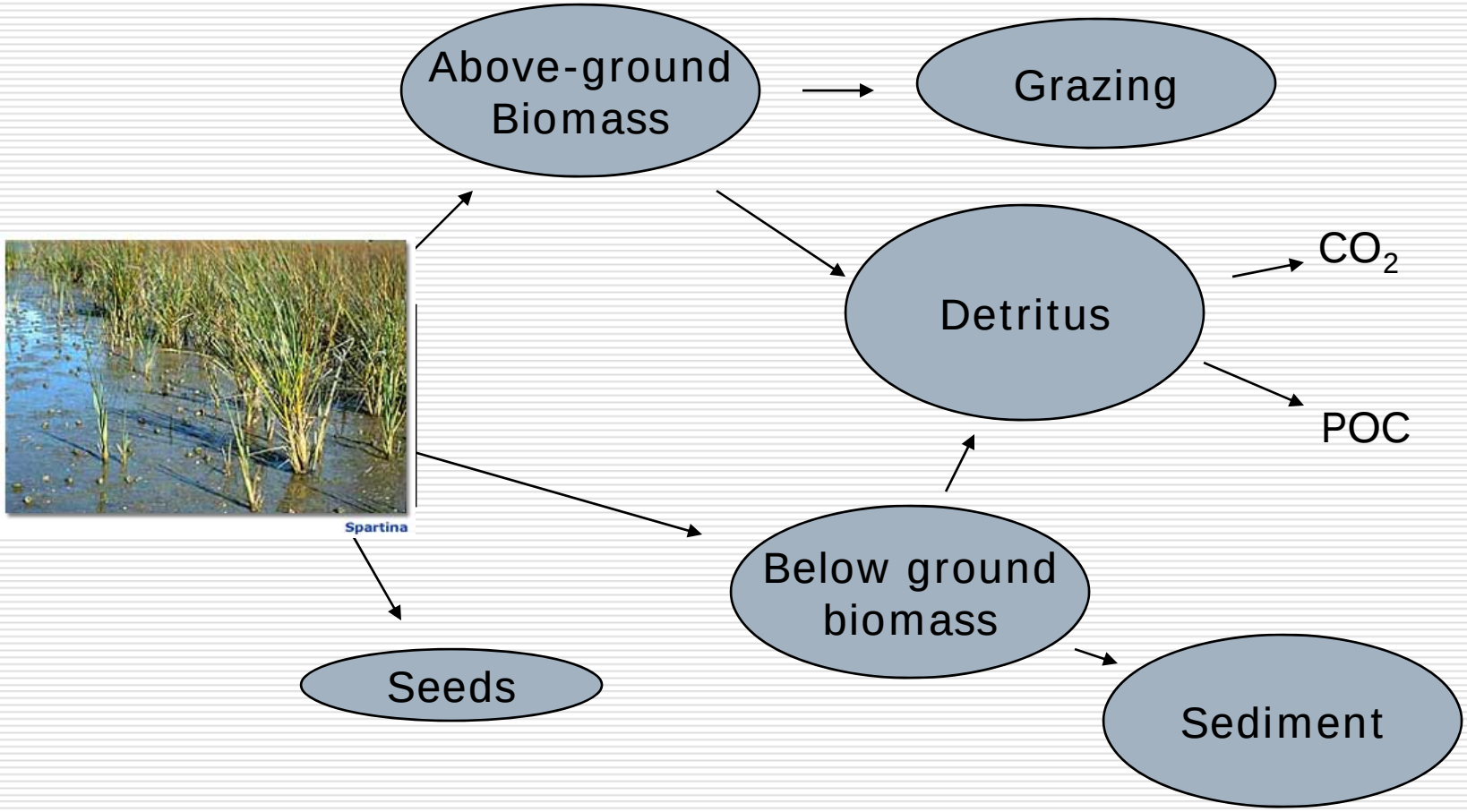
Higher turnover means more rapid influx into food web, either as herbivory or detrital input.

# Tidal marsh production

- *Spartina foliosa*: 150-630 g C/m$^2$/yr
- *Spartina alterniflora:* 300-800 g C/m$^2$/yr
- *Salicornia virginica:* 270-700 g C/m$^2$/yr
- *Scripus robustus:* 250-1500 g C/m$^2$/yr
- *Scripus californicus:* 500-1200 g C/m$^2$/yr

- Turnover times: 1-2 times except for *S. alterniflora* 2-4 times the standing biomass.

# Where does it go?

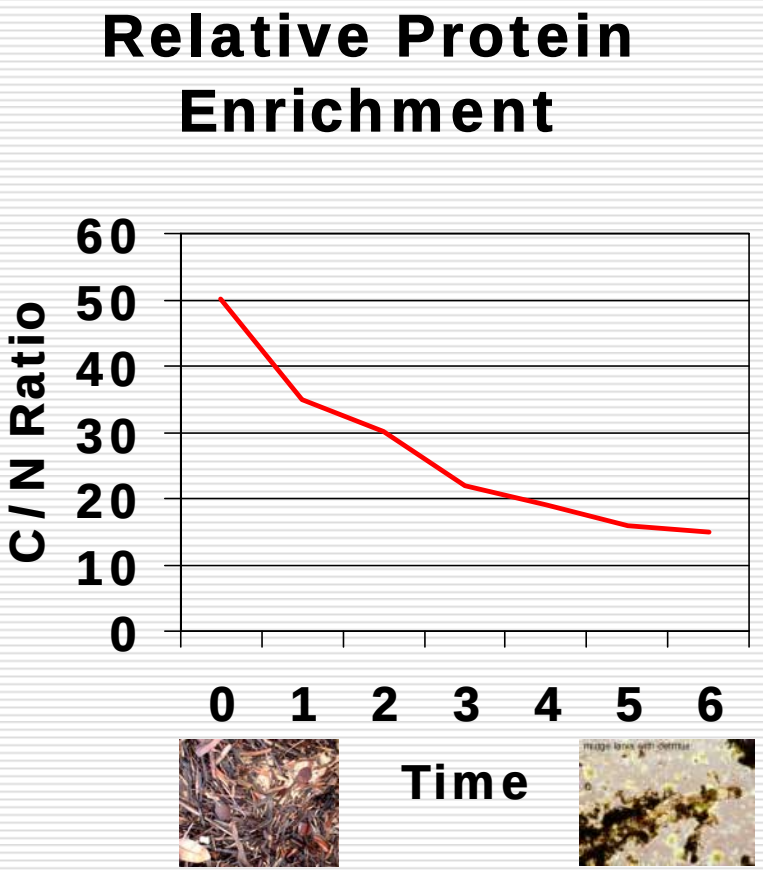


# Detritus as a food source

- Detritus: dead organic matter and associated micro-organisms
- Food source value increased by decay process
- Small particles can be exported or suspended into water column

# Detrital protein enrichment

- Amount of material decreases
  - Particle size decreases
  - Microbial respiration up to 50% of wt loss
- Carbon content decreases
- Time dependent on species
  - Macroalgae: days
  - Vascular plants: months



# Does it reach open water?

- Nixon (1980); Valiela (1983); Taylor and Alanson (1995)
  - Most marshes are net exporters of DOC and POC.
- Does it mean anything to off-shore detrital feeders?
  - Use of stable isotope tracers $^{13}C/^{15}N$
    - Problems inherent in methodology include multiple sources; decomposition changes

# Summary of findings for SF Bay POC analysis

- Spiker and Schemel (1979):
  - POC in SF Bay primarily from phytoplankton and wastewater sources
  - *Spartina* not a significant source
- Cloren, Canuel, Harris (2002):
  - Used $^{15}N/^{13}C$
  - Found large variation in signatures confounded by degradation

# No clear signatures from salt marsh species

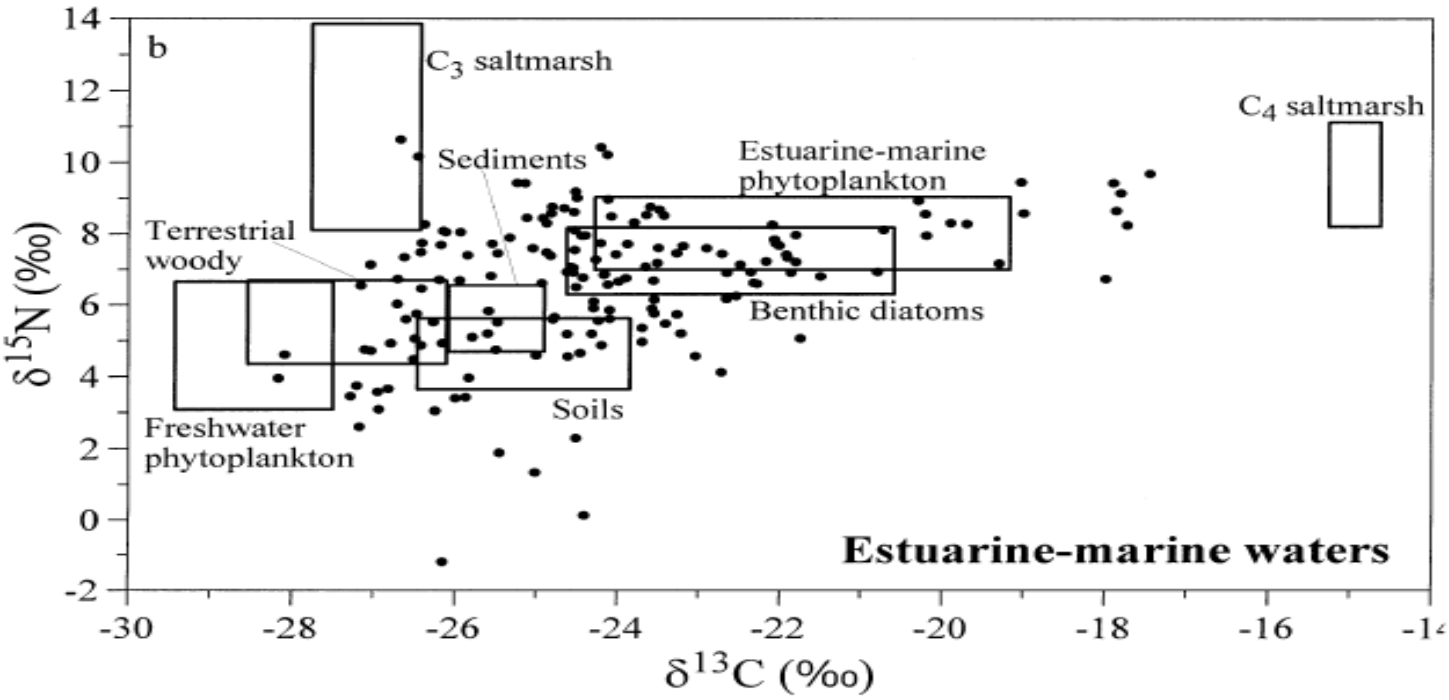



Fig. 8. Comparisons of the isotopic compositions ($\delta^{15}N$ vs. $\delta^{13}C$) of soils, seston, sediments, and plants collected in (a) tidal freshwater domains and (b) estuarine–marine domains of SFBE (*see Fig. 1*). Rectangles show the interquartile ranges of $\delta^{15}N$ and $\delta^{13}C$ measured in each plant group (Fig. 4) and in soils and sediments collected in freshwater domains.

Cloern et al (2002)

# Results not surprising

- Marsh productivty higher, but area is less
- Significant riverine sources as well
- Not all marsh productivity is exported, restricted flows

| Component | Productivity g C/m$^2$ | Size ( $10^8$ m$^2$ | Annual Production $10^{10}$gC/m$^2$ |
|---|---|---|---|
| Phyto-plankton | 115 | 12.4 | **14.0** |
| Marsh | 360 | 1.25 | **4.5** |

# Southern California studies

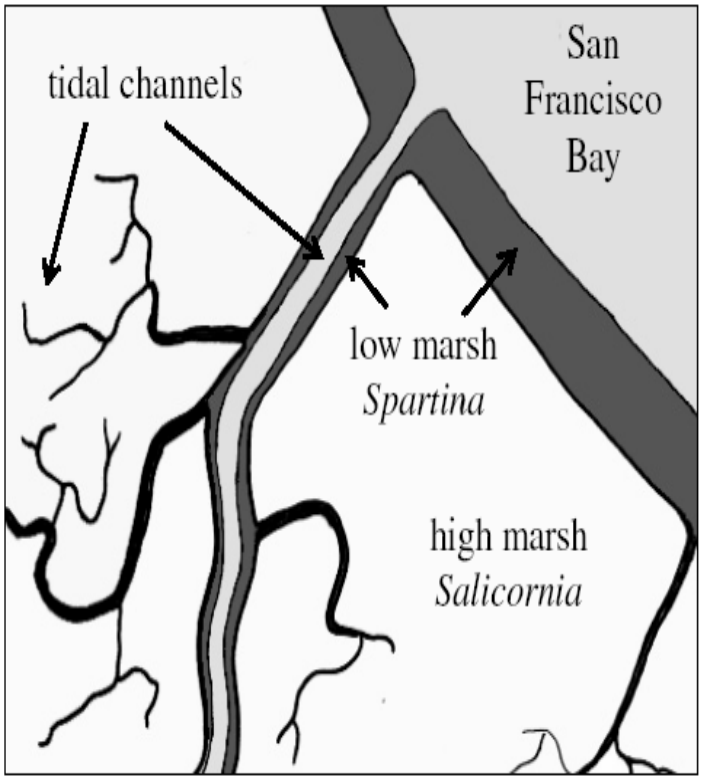
- Kwak and Zedler (1997)
  - For fish species near marsh; noted *Spartina* signature
  - For invertebrates and clapper rail, found micro- and macro-algae signature
- West (2001); Madon (2001)
  - Killifish with access to high marsh surface had higher bioenergetic growth balance.
  - Fish confined to channels had lower gut content

# Another source of marsh production

- Microalgae on sediment surface
  - Zedler (1980)—185-341 g C/$m^2$/yr
  - Other studies: 25 to 50% of total marsh productivity attributable to microalgae
  - Sullivan & Currin (2000) found consistent linkages to marsh grazers

# Do animals come to the marsh?

- Grenier, Collins, Davis, Greenfield (2002)
  - Focused on China Camp nearshore areas
  - Examined high, low, and tidal channel areas.



# Food web at China Camp

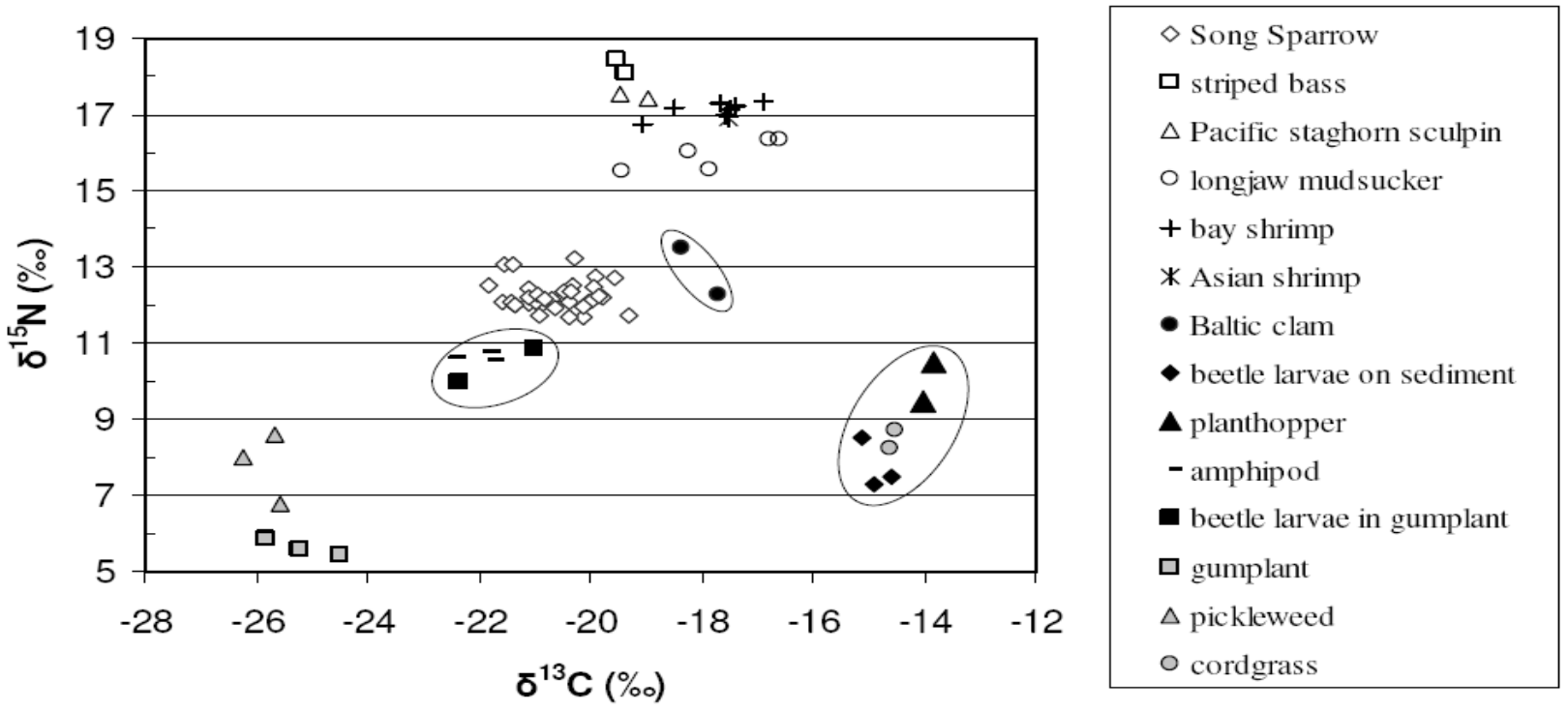
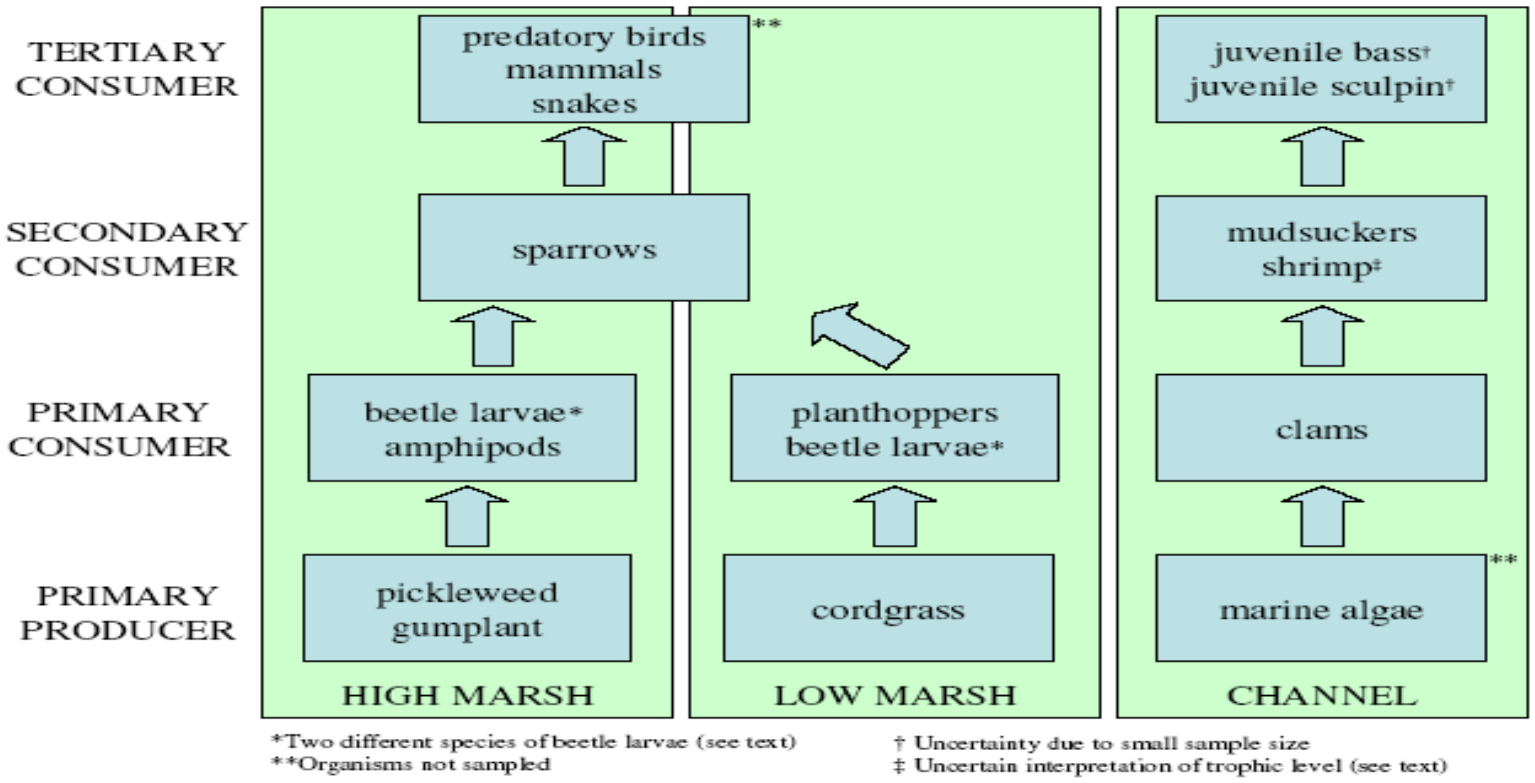



Figure 2. Dual isotope plot of salt marsh primary producers (gray symbols), primary consumers (black symbols), and secondary and tertiary consumers (open and line symbols). Distinct groups of primary consumers are circled.

Gernier et al (2002)

# Hypothesized food web




Gernier et al (2002)

# Implications to marsh restoration design

- Amount of tidal exchange for export of organic matter less important
- Creation of tidal channels to promote higher productivity and access to marsh by fish
- High marsh habitat for fish and birds
- With restoration, potential for shift in productivity balance in estuary

# What will be the effect of *Spartina alterniflora?*

- Higher productivity (turnover rate)
- Slower decomposition rates; high wrack deposition in high marsh
- Decreased invertebrate density (Brusati & Grosholz 2003)
- Lower benthic chlorophyll levels (Josselyn et al. 1993)
- Potentially reduced tidal channel area
- Reduced access to marsh surface by fish
- Selective grazing of native cordgrass by Canada geese (Blake 2003)

# Summary

- Much of marsh productivity utilized within marsh
  - Bacterial decomposition
  - Detrital utilization by inverts/fish
- Marsh design should maximize channel configurations
- Tidal flats important habitat element
- *Spartina* hybrids are damaging to natural food webs