Ecosystem functions of the non-indigenous eelgrass, *Zostera japonica*, in the Pacific Northwest

Douglas Bulthuis

Padilla Bay National Estuarine Research Reserve

Zostera japonica Science Forum
June 17-18, 2013
Lacey, Washington

The value of the world's ecosystem services and natural capital

Robert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farber‖, Monica Grasso†, Bruce Hannon¶, Karin Limburg#*, Shahid Naeem, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Sutton‖‖ & Marjan van den Belt¶¶**

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** *Department of Ecology, Evolution and Behavior, University of Minnesota, St Paul, Minnesota 55108, USA*
†† *Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
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§§ *Jet Propulsion Laboratory, Pasadena, California 91109, USA*
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The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Phillips, R.C. 1984

FWS/OBS-84/24
September 1984

THE ECOLOGY OF EELGRASS MEADOWS IN THE PACIFIC NORTHWEST: A Community Profile

Fish and Wildlife Service
U.S. Department of the Interior

Corps of Engineers
U.S. Department of the Army

Environmental Conservation **29** (2): 192–206 © 2002 Foundation for Environmental Conservation

The future of seagrass meadows

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IMEDEA (CSIC – UiB), C/ Miquel Marqués 21, 07190 Esporles, (Islas Baleares), Spain
Date submitted: 29 May 2001 Date accepted: 15 February 2002

Marten A. Hemminga and Carlos M. Duarte

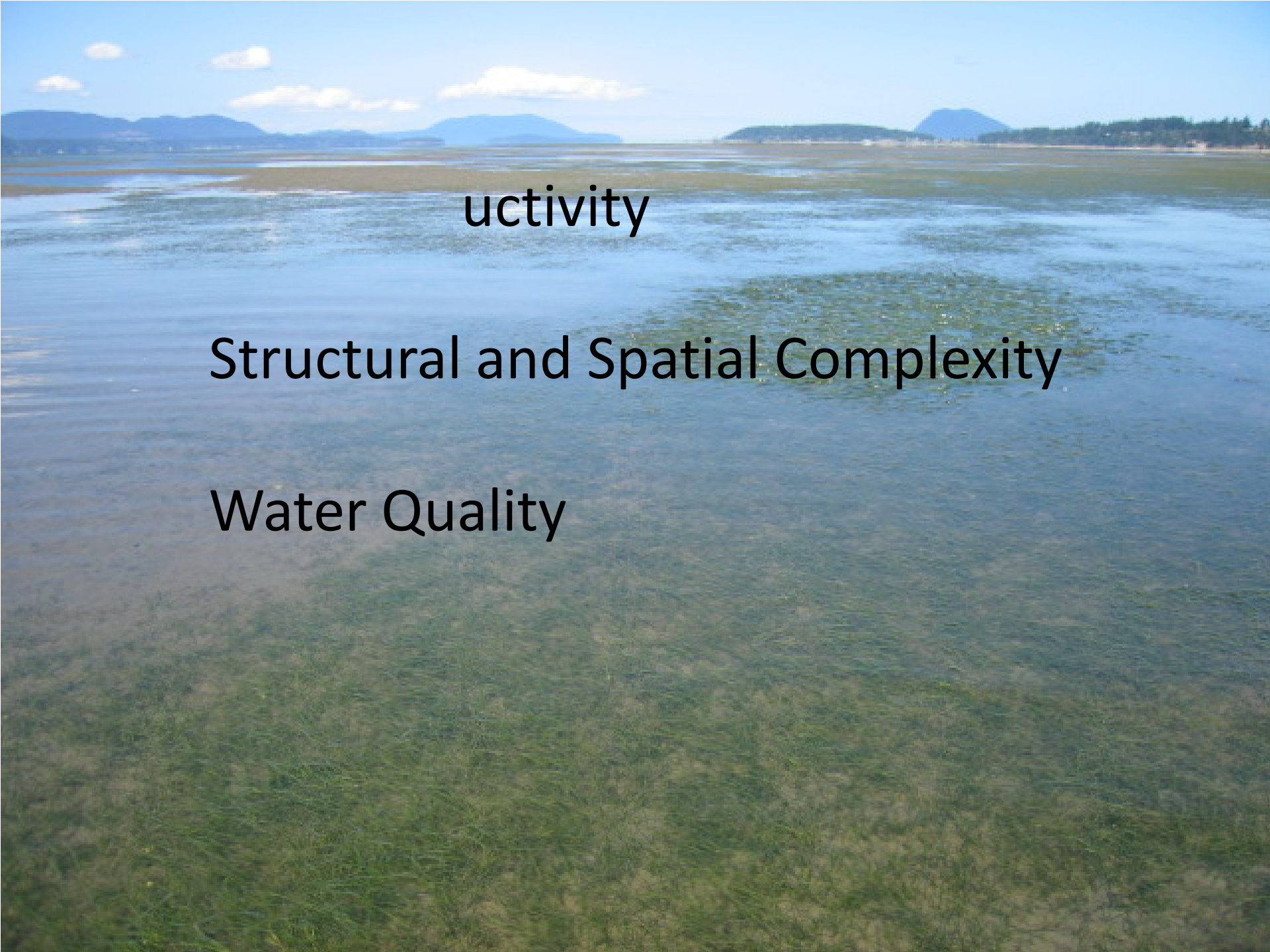
Seagrass Ecology

CAMBRIDGE

In addition to their high primary production, seagrasses perform many other functions in the ecosystem:

- Provision of food for coastal food webs,
- Provision of oxygen to waters and sediments,
- Carbon sequestration from the atmosphere,
- Organic carbon export to adjacent ecosystems,
- Sediment stabilization,
- Prevention of sediment resuspension,
- Improvement of water transparency,
- Wave attenuation,
- Shoreline protection,
- Habitat for microbes, invertebrates and vertebrates, often endangered or commercially important, and
- Trapping and cycling of nutrients.

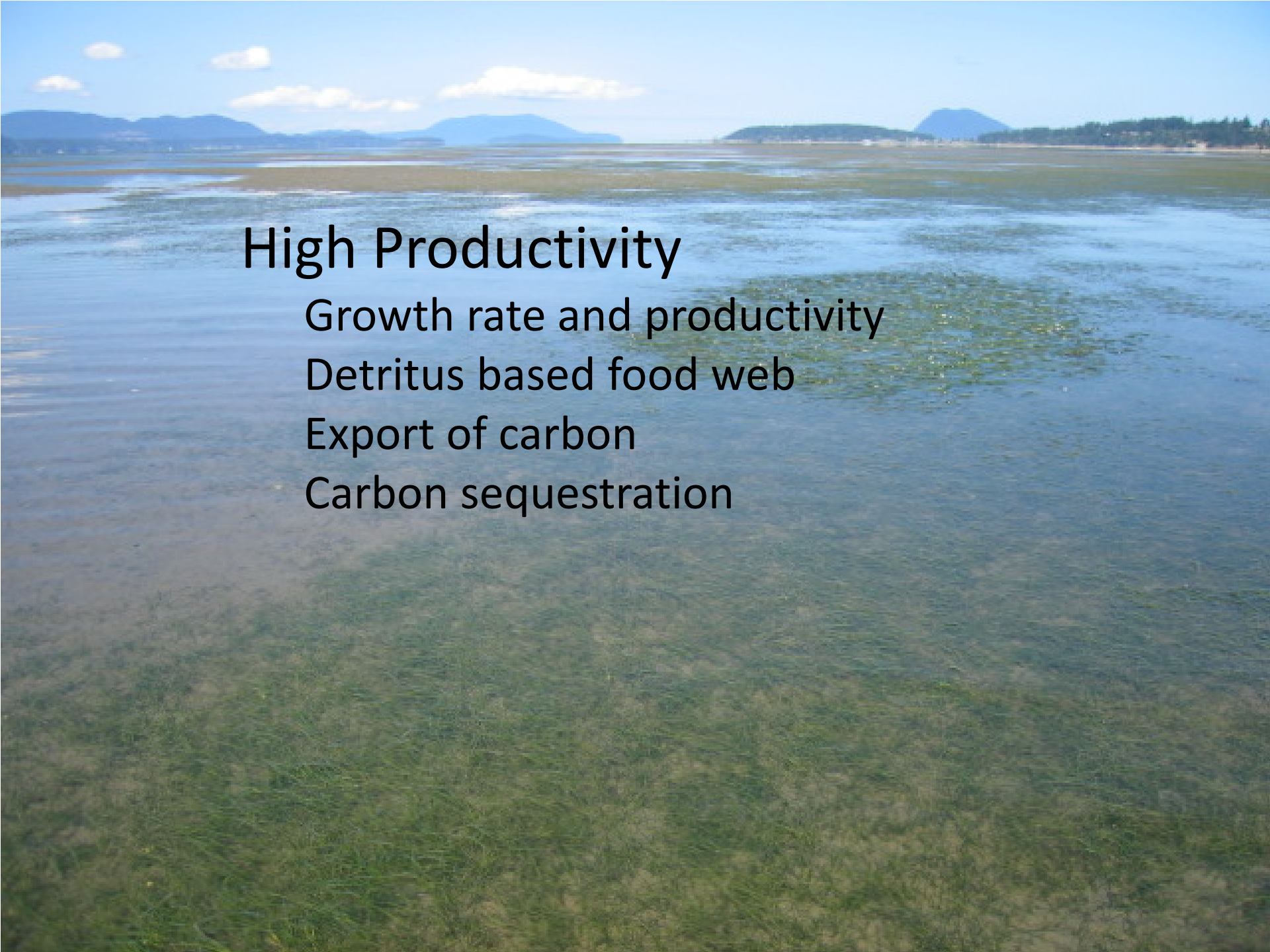
These functions render seagrass meadows unique, ranking amongst the most valuable ecosystems in the biosphere, due to the important services they provide (Costanza *et al.* 1997).



uctivity

Structural and Spatial Complexity

Water Quality



High Productivity

- Growth rate and productivity
- Detritus based food web
- Export of carbon
- Carbon sequestration

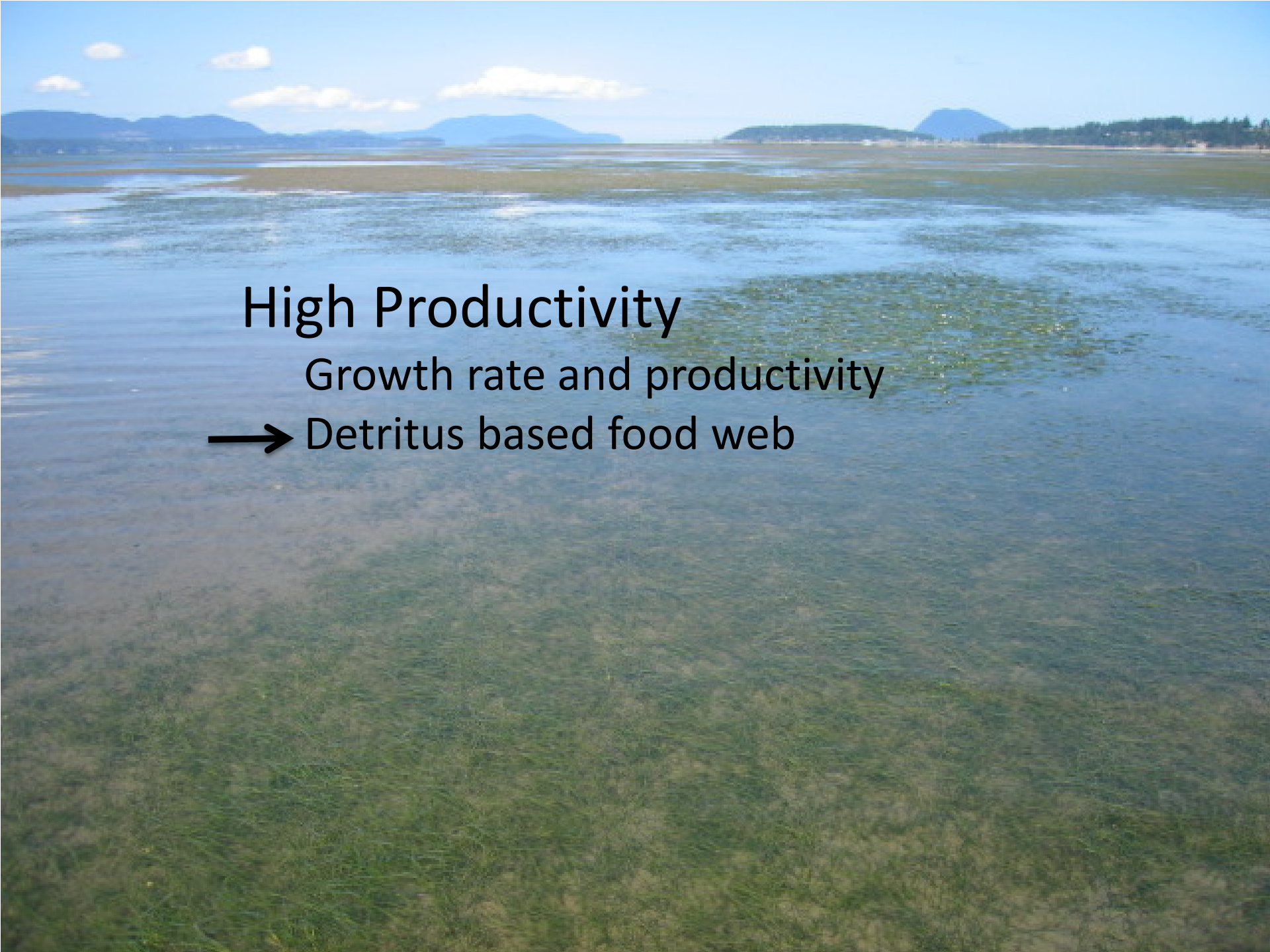
High Productivity
→ Growth rate and productivity

System	Net primary productivity ($gC\ m^{-2}\ year^{-1}$)
Marine phytoplankton	
Oceanic waters	130
Coastal waters	167
Coastal macrophytes	
Mangroves	1000
Seagrasses	817
Macroalgae	375
Microphytobenthos	50
Terrestrial ecosystems	
Forests	400
Crops	350
Deserts	50
Other terrestrial ecosystems	200
Continental waters	100

From Matteo et al. 2006

Estimates of above ground productivity of *Zostera japonica* based on leaf growth

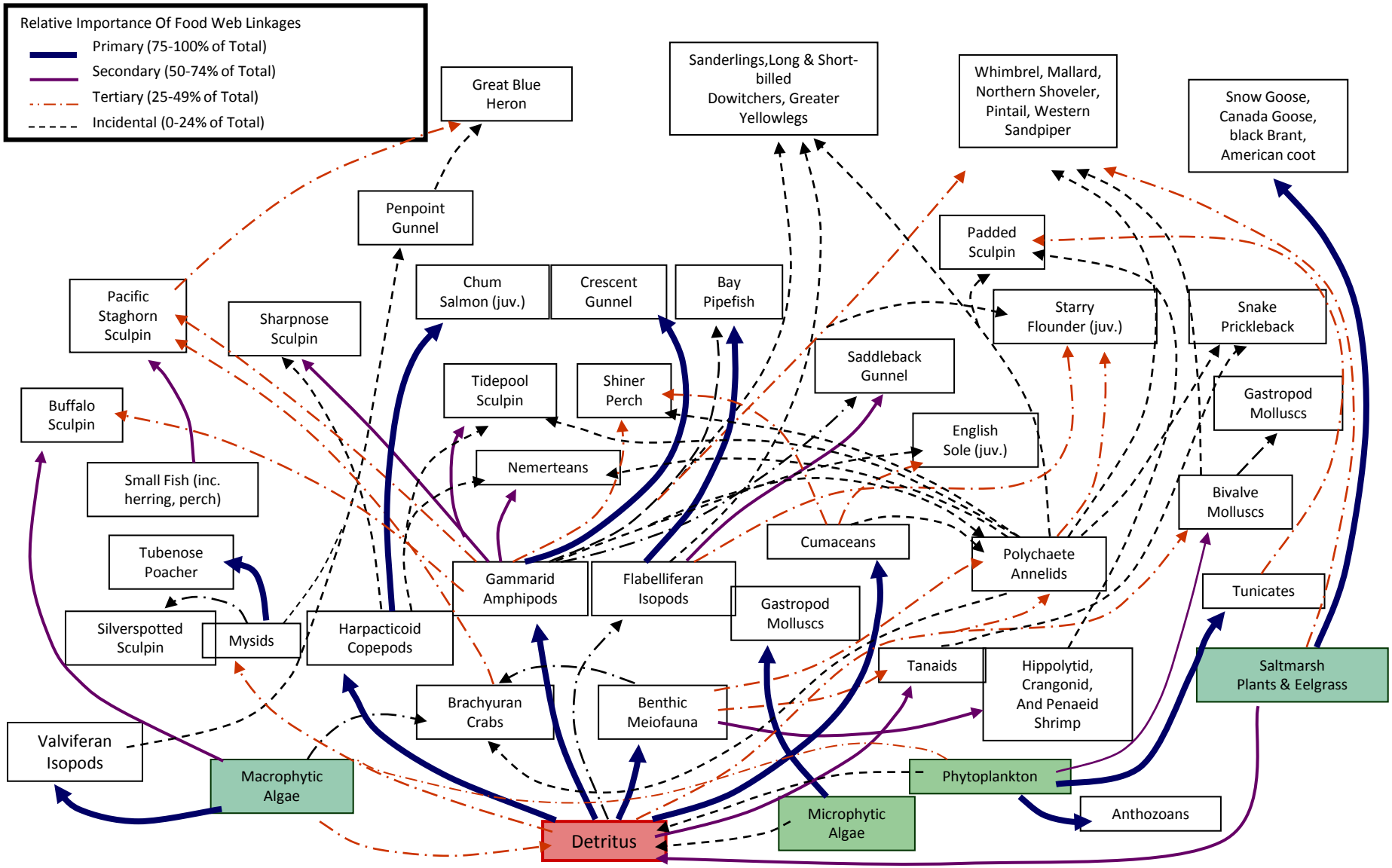
Location	Annual mean (g dry wt/m2/day)	Source
Padilla Bay, WA	0.32	Thom 1990
Yaquina Bay, OR	0.86	Kaldy 2006
West coast of Korea	0.87 - 1.7	Lee et al. 2005
Southern coast of Korea	1.7	Lee et al. 2006
Zostera marina 29 locations northern hemisphere	5.2	Duarte & Chiscano 1999



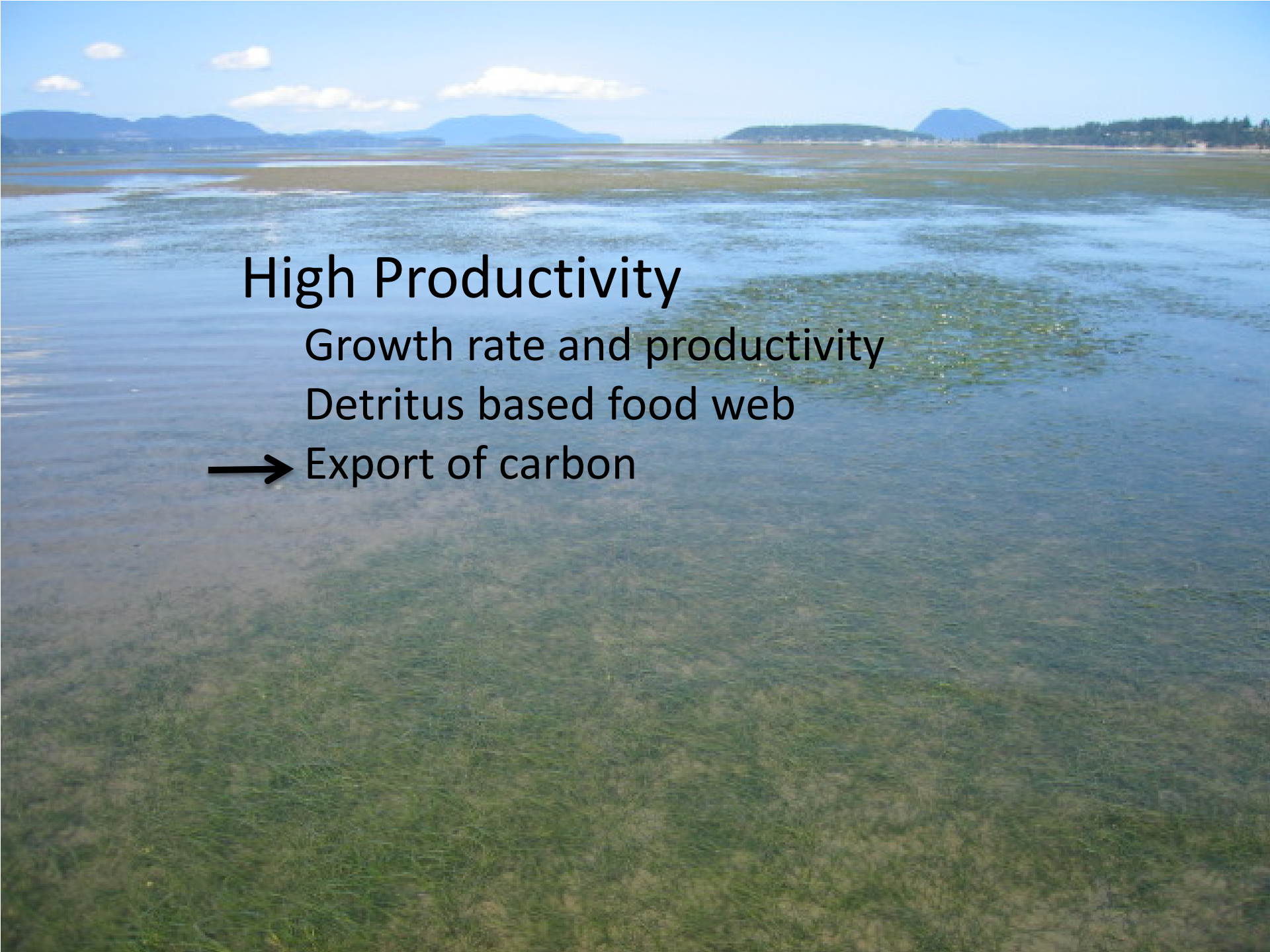
High Productivity

- Growth rate and productivity
- → Detritus based food web

Protected Mud/Eelgrass Shallow Sublittoral Food Web



From Simenstad 1979



High Productivity

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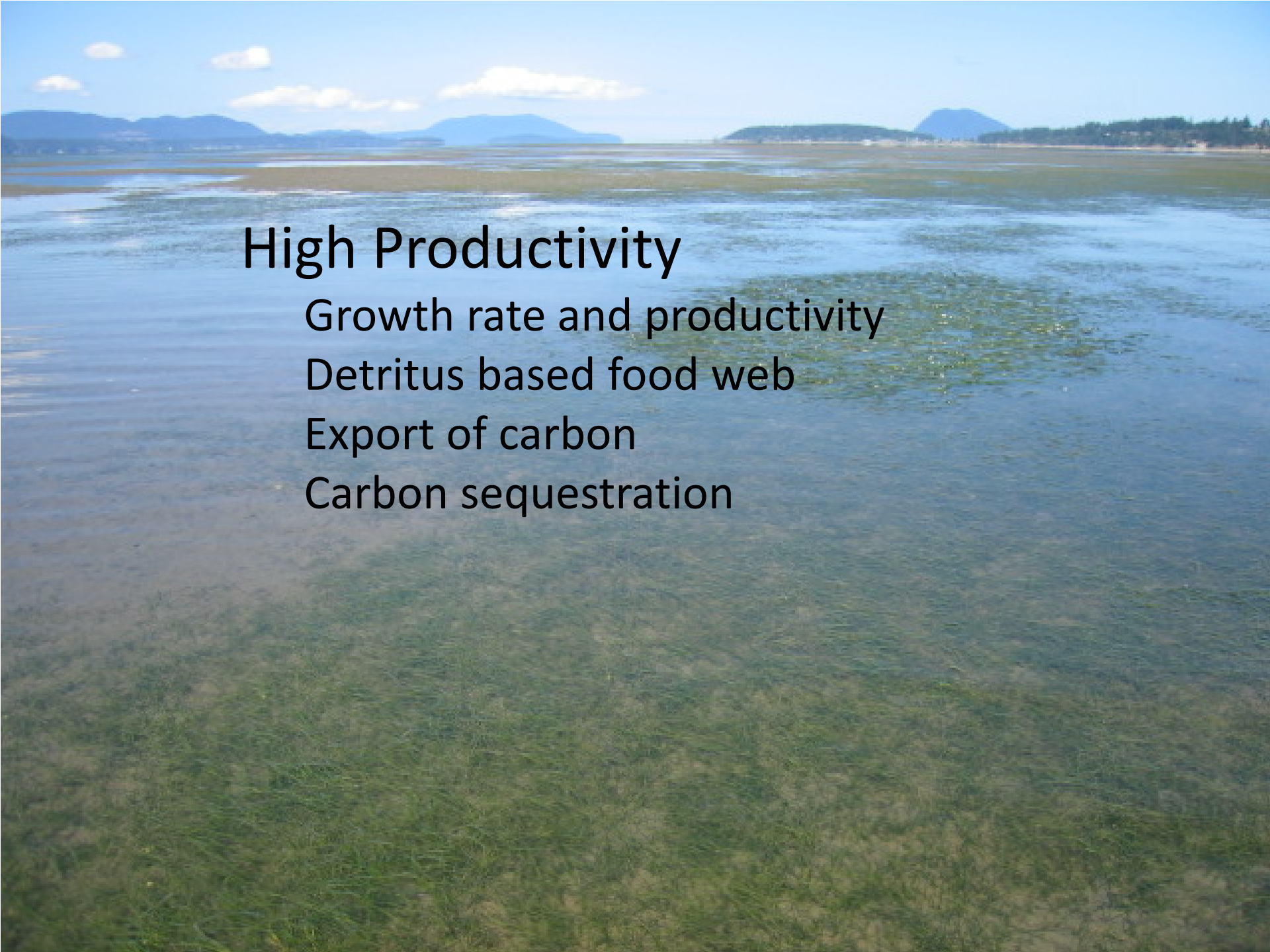

High Productivity

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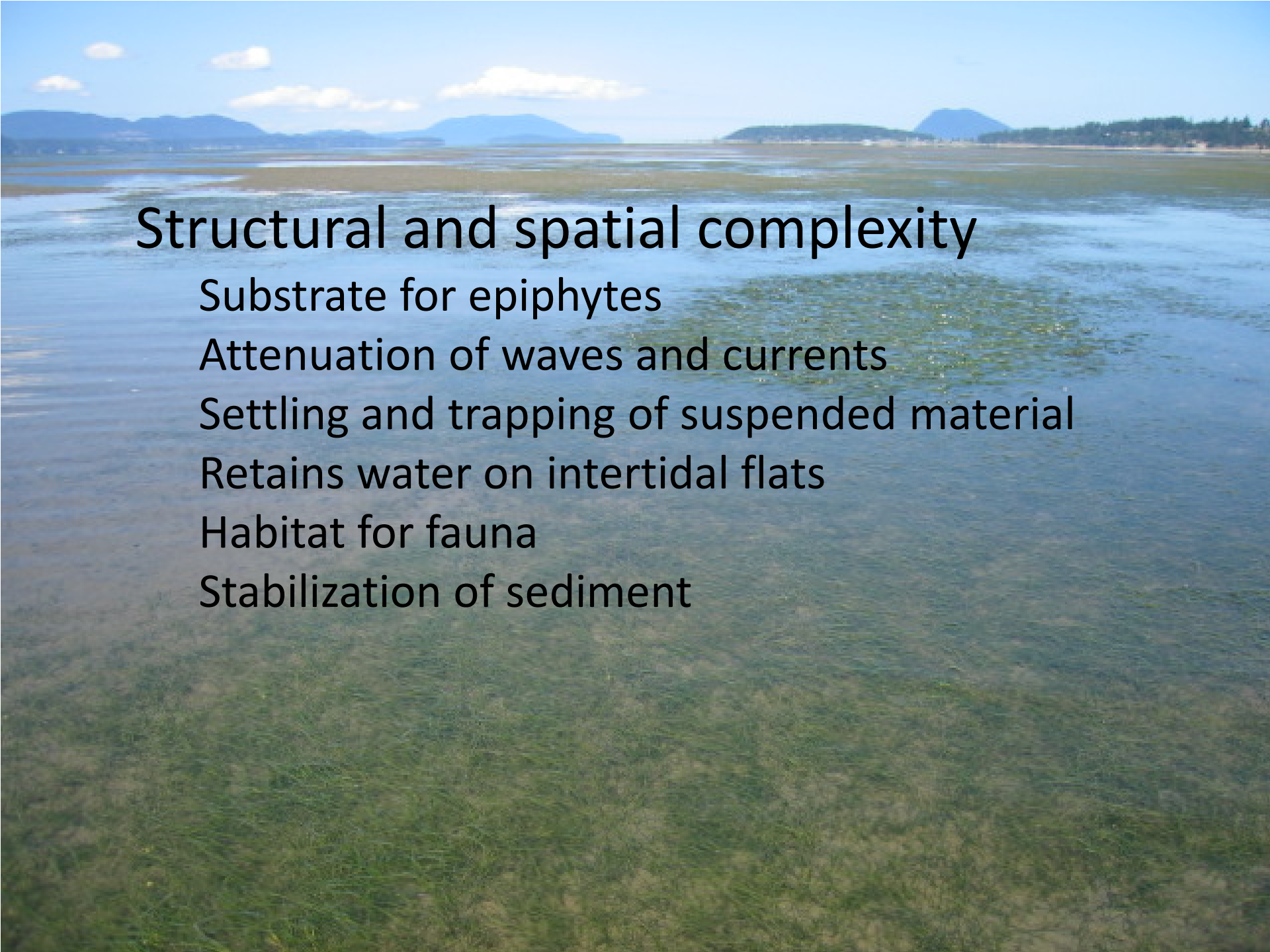
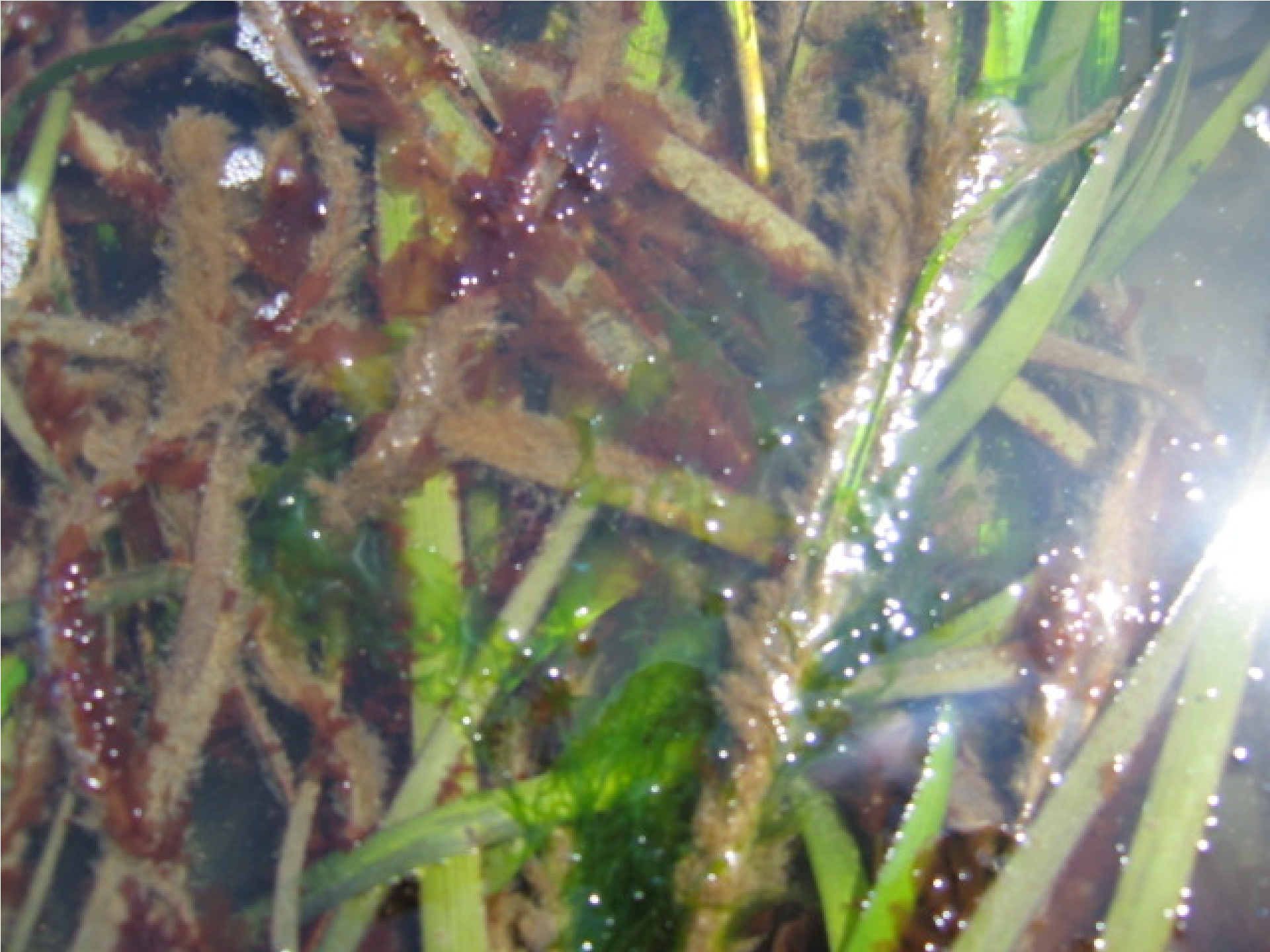


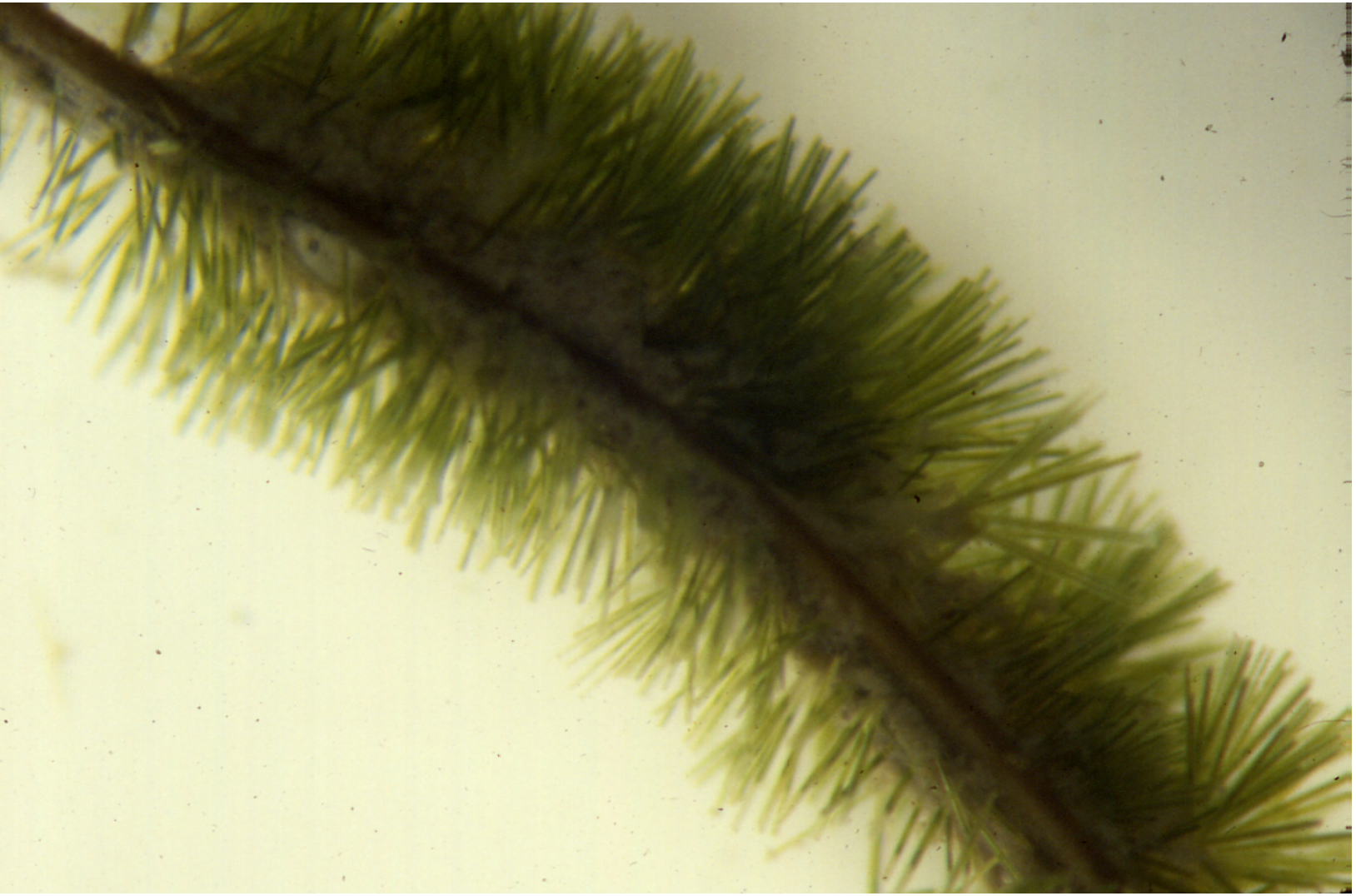
Structural and spatial complexity

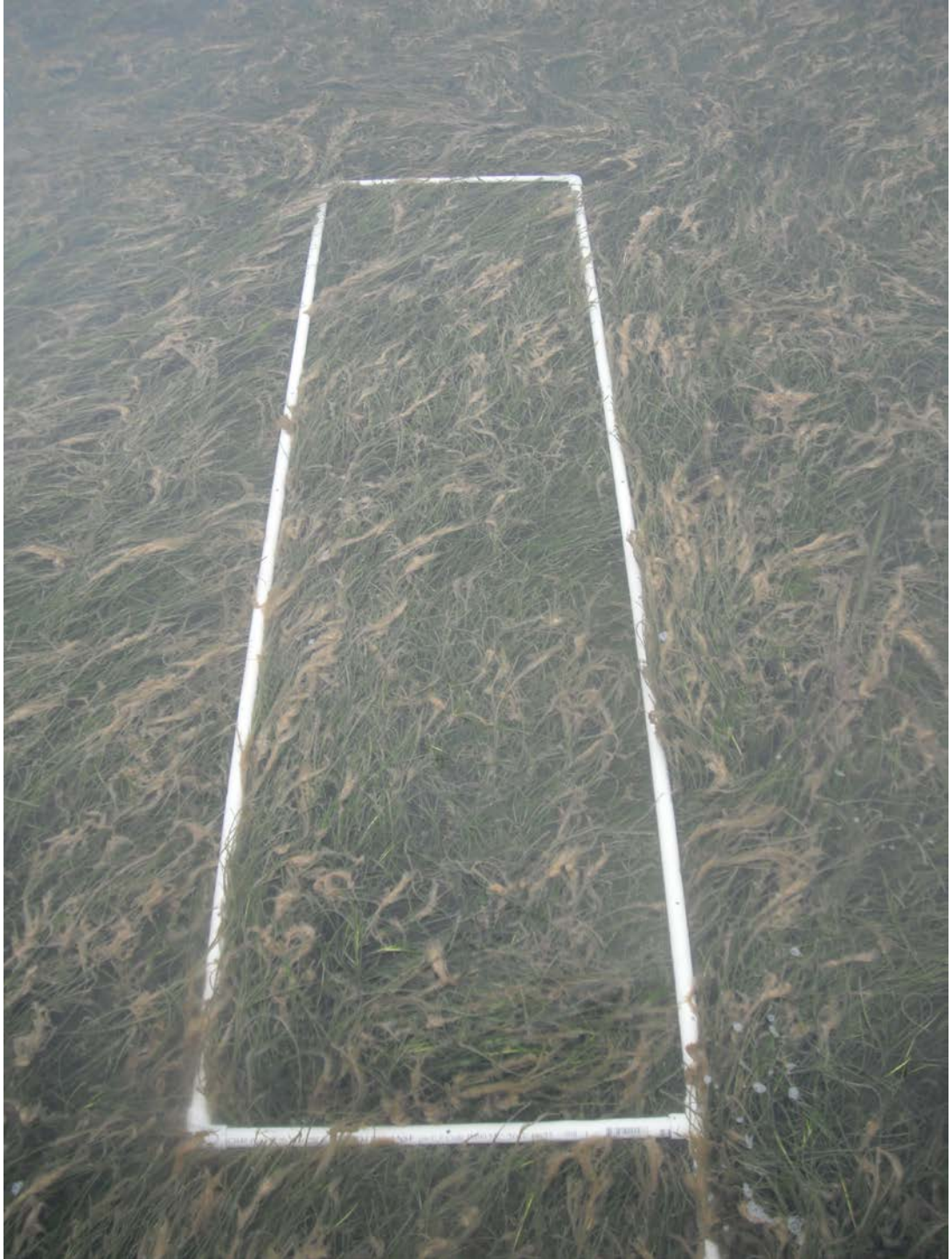
- Substrate for epiphytes
- Attenuation of waves and currents
- Settling and trapping of suspended material
- Retains water on intertidal flats
- Habitat for fauna
- Stabilization of sediment

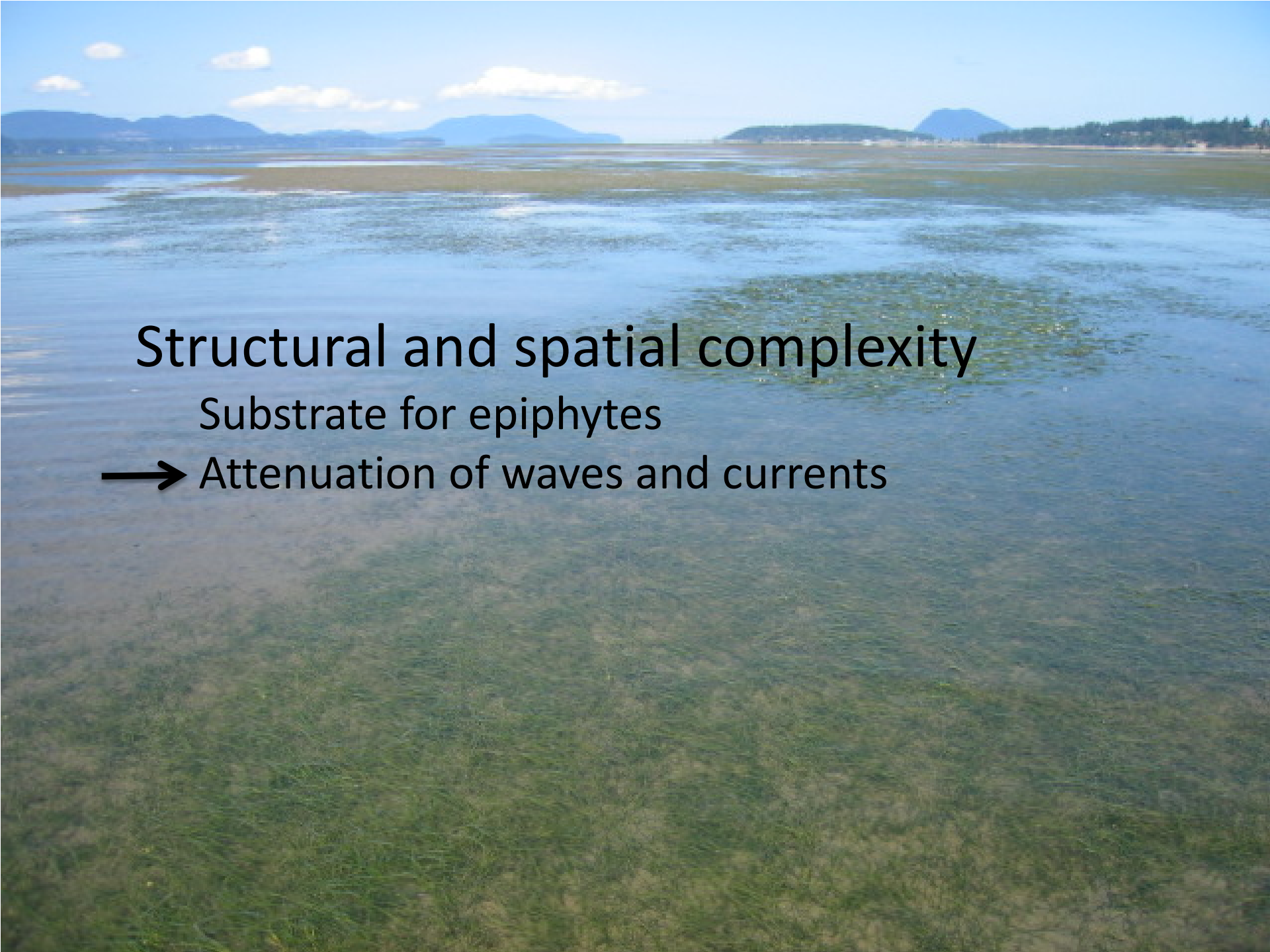
Structural and spatial complexity

→ Substrate for epiphytes



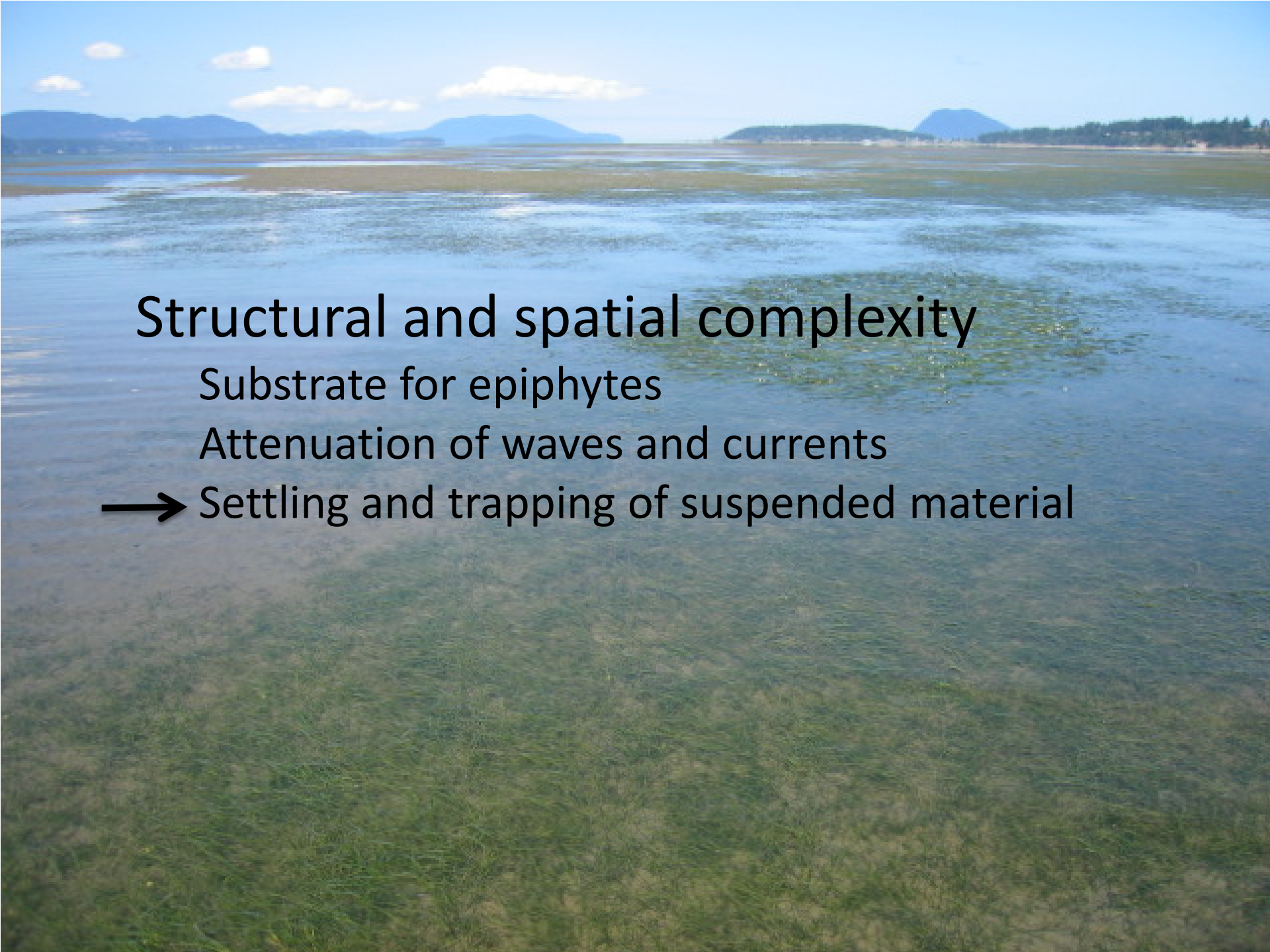






Structural and spatial complexity

- Substrate for epiphytes
- → Attenuation of waves and currents



Structural and spatial complexity

- Substrate for epiphytes
- Attenuation of waves and currents
- → Settling and trapping of suspended material

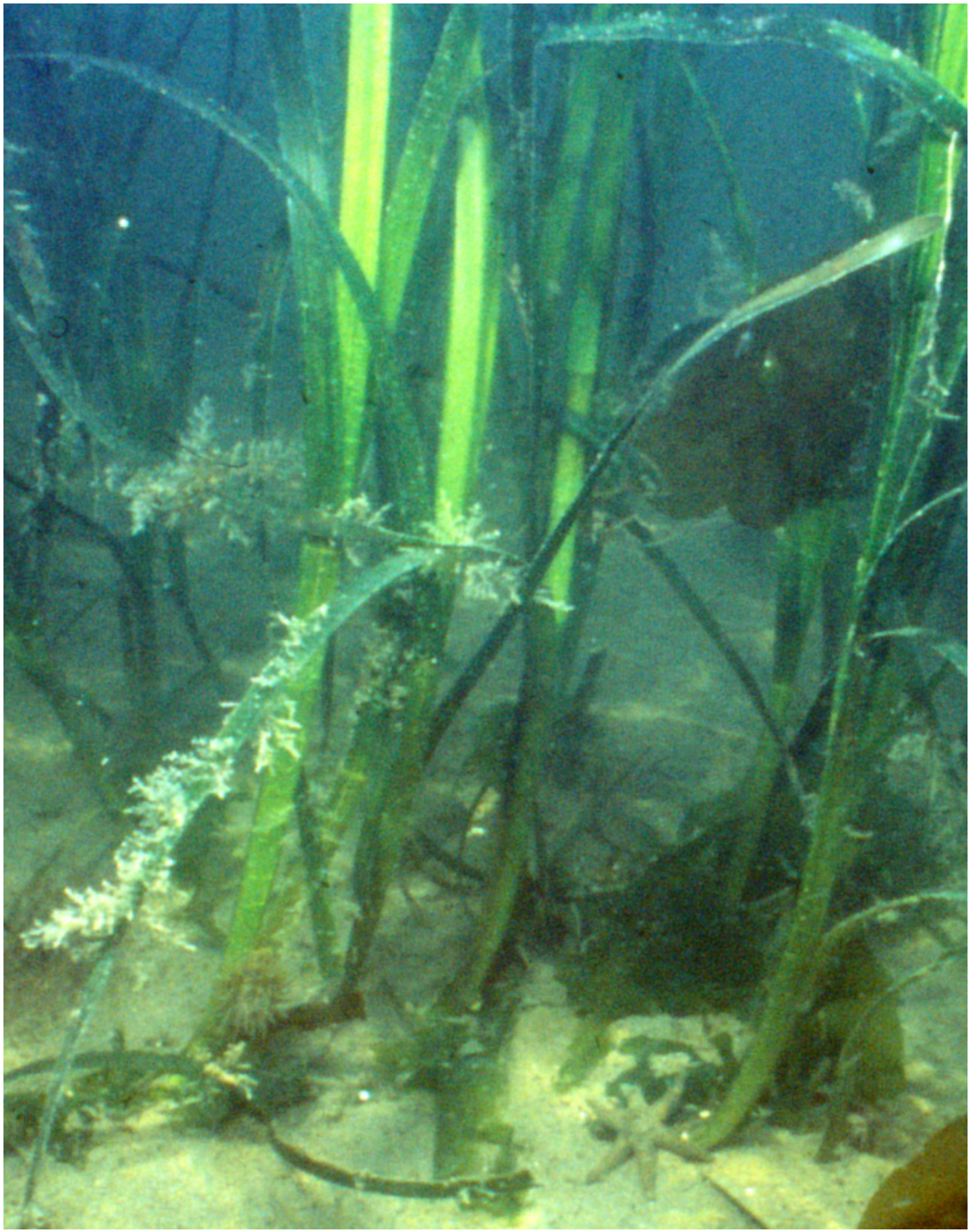


Fig. 1. An experiment conducted to examine the effects of the pesticide carbaryl injected into the intertidal sediment in strips to control burrowing shrimp resulted in a distinct pattern in seagrass (*Z. japonica*) distribution 1 year after pesticide application.

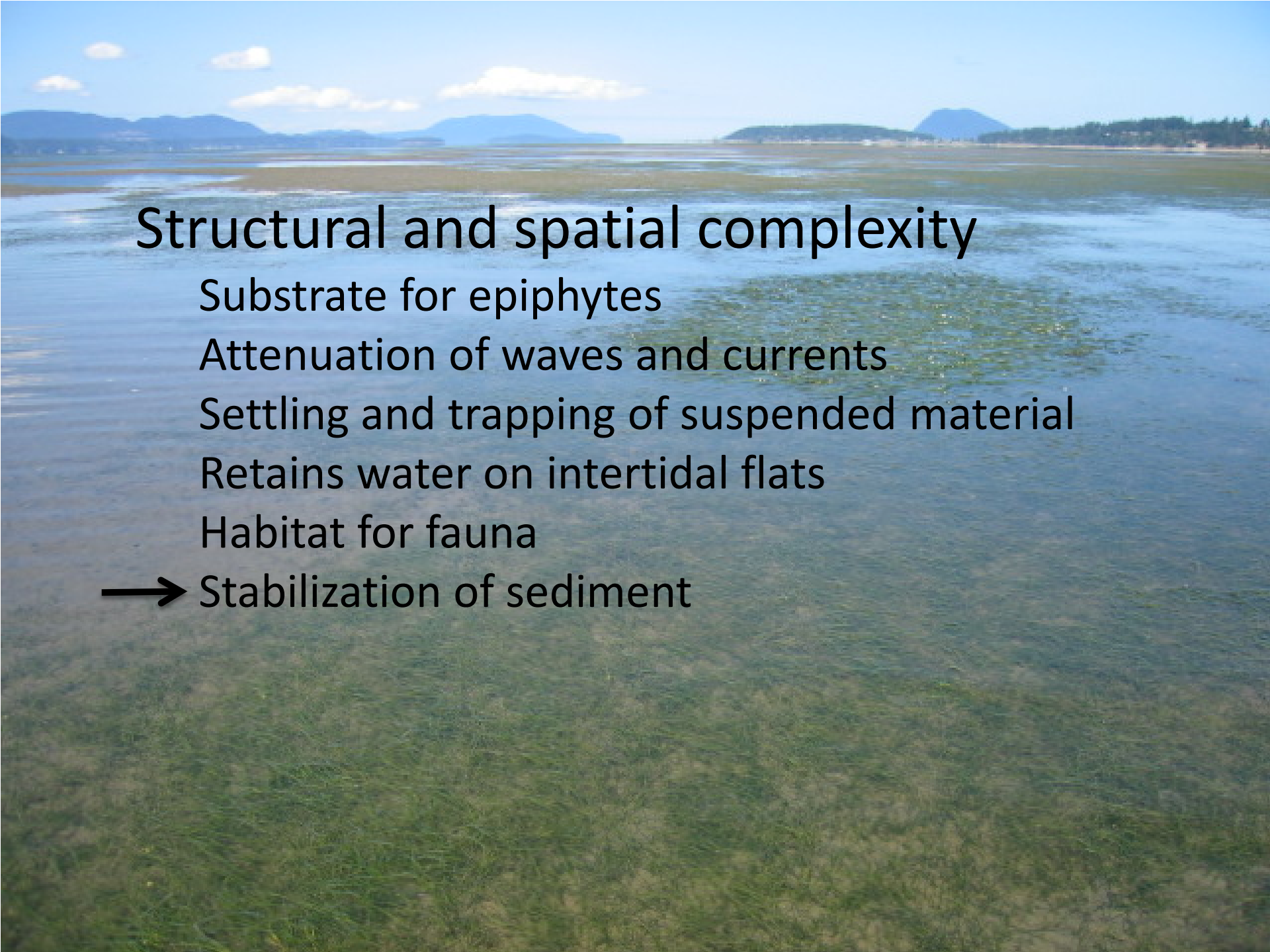
From Dumbauld & Wyllie-Echeverria 2003

Structural and spatial complexity

- Substrate for epiphytes
- Attenuation of waves and currents
- Settling and trapping of suspended material
- → Retains water on intertidal flats

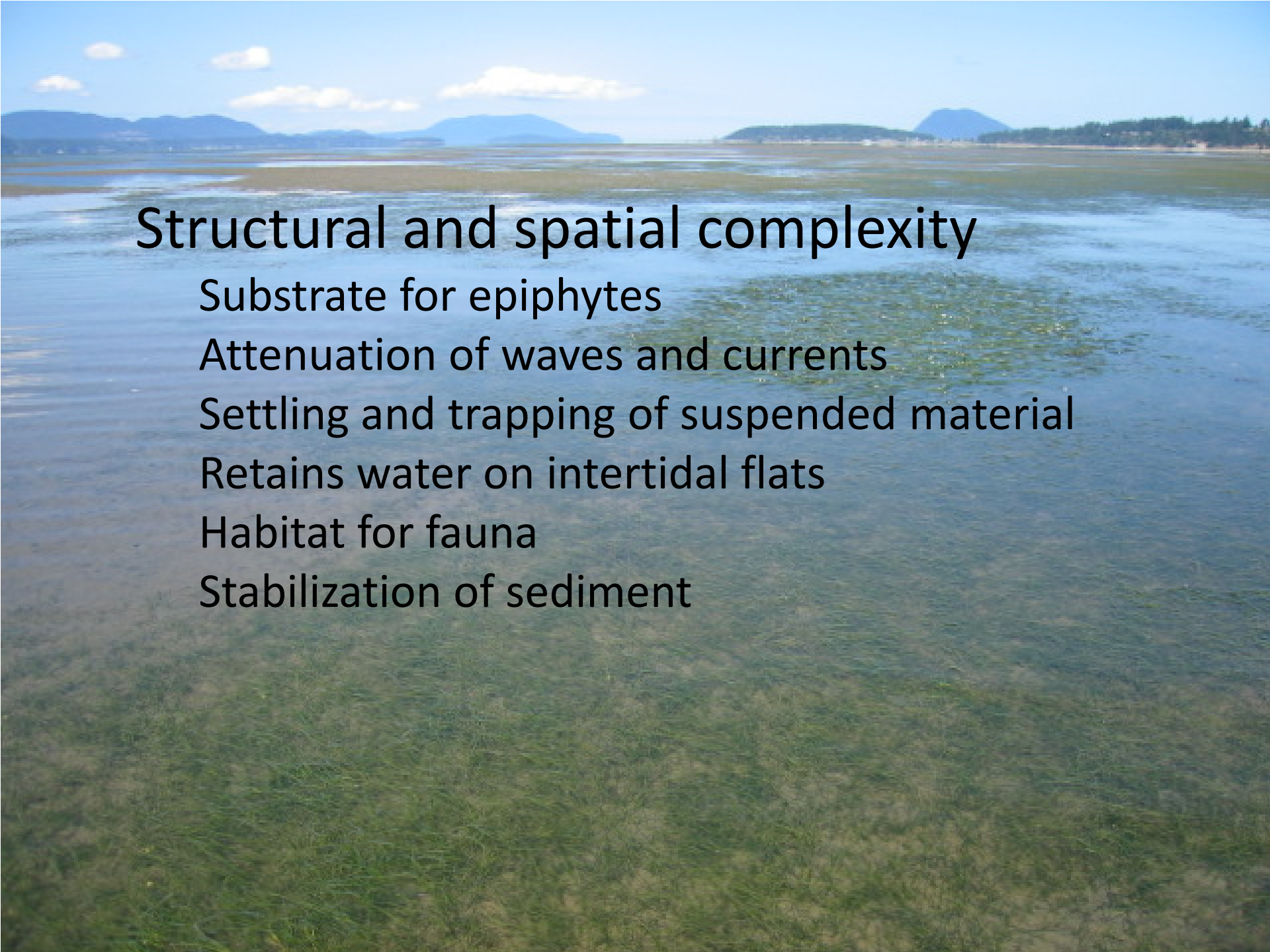
Structural and spatial complexity

- Substrate for epiphytes
- Attenuation of waves and currents
- Settling and trapping of suspended material
- Retains water on intertidal flats
- → Habitat for fauna



Structural and spatial complexity

- Substrate for epiphytes
- Attenuation of waves and currents
- Settling and trapping of suspended material
- Retains water on intertidal flats
- Habitat for fauna
- → Stabilization of sediment



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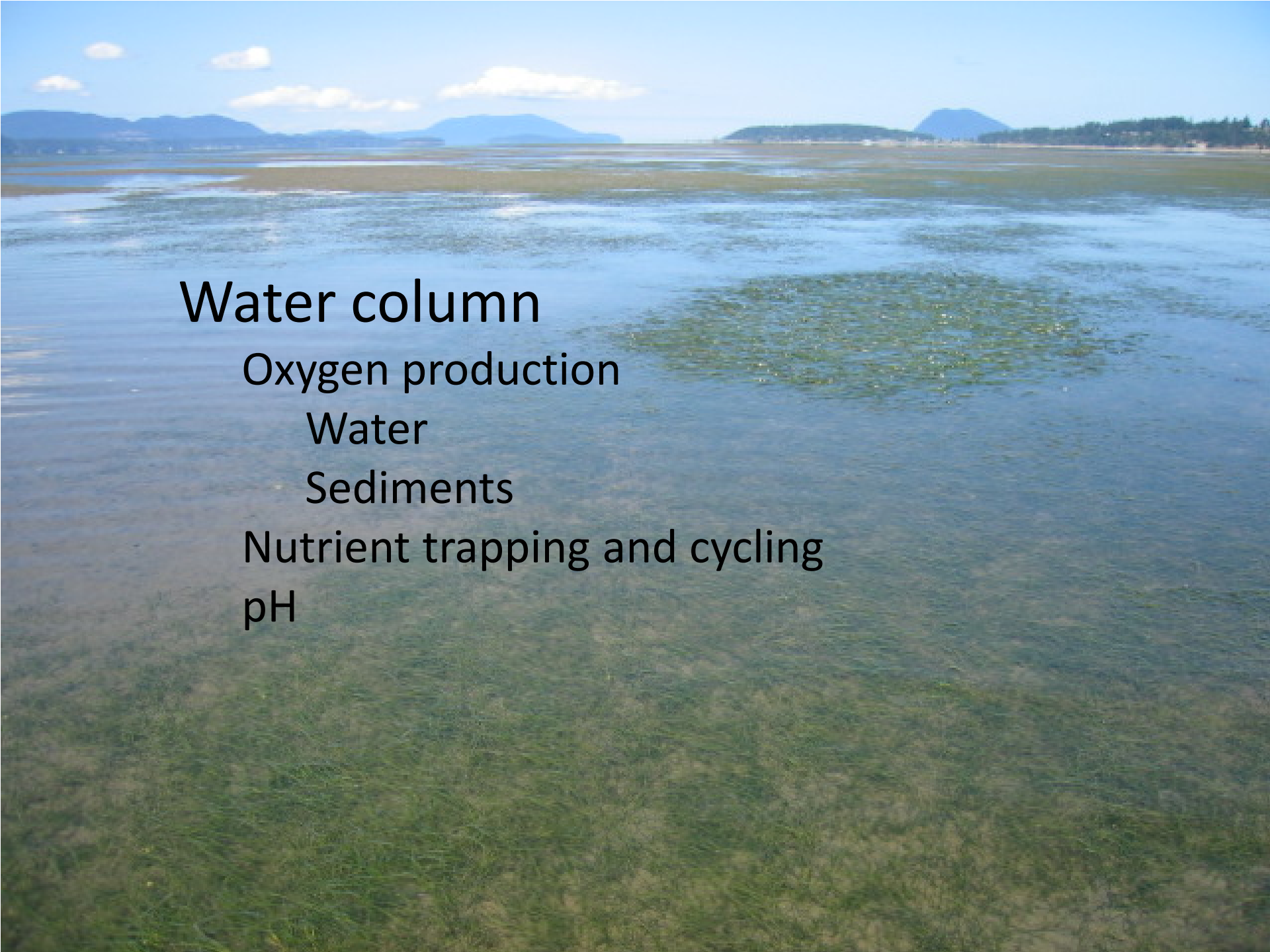
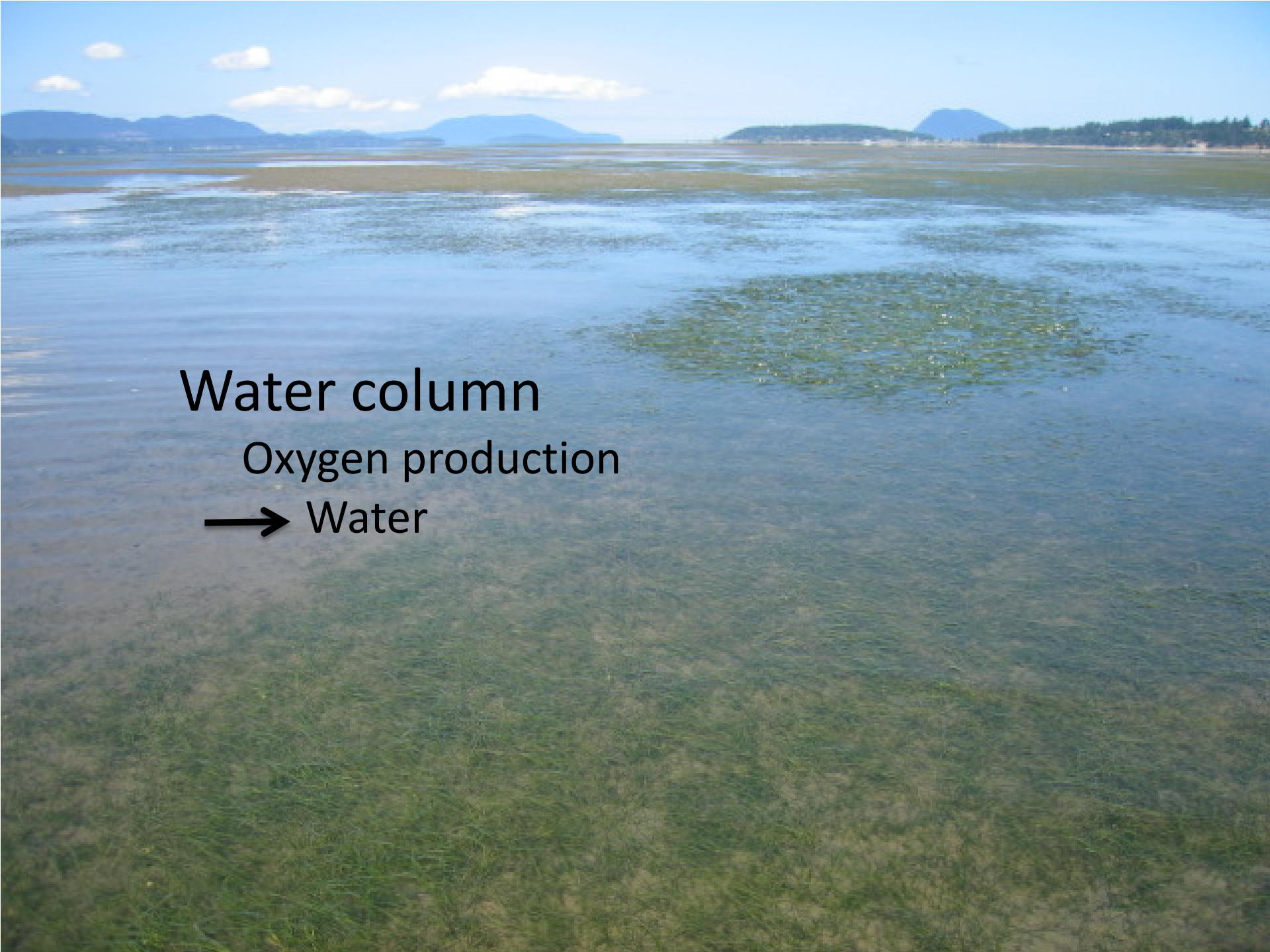


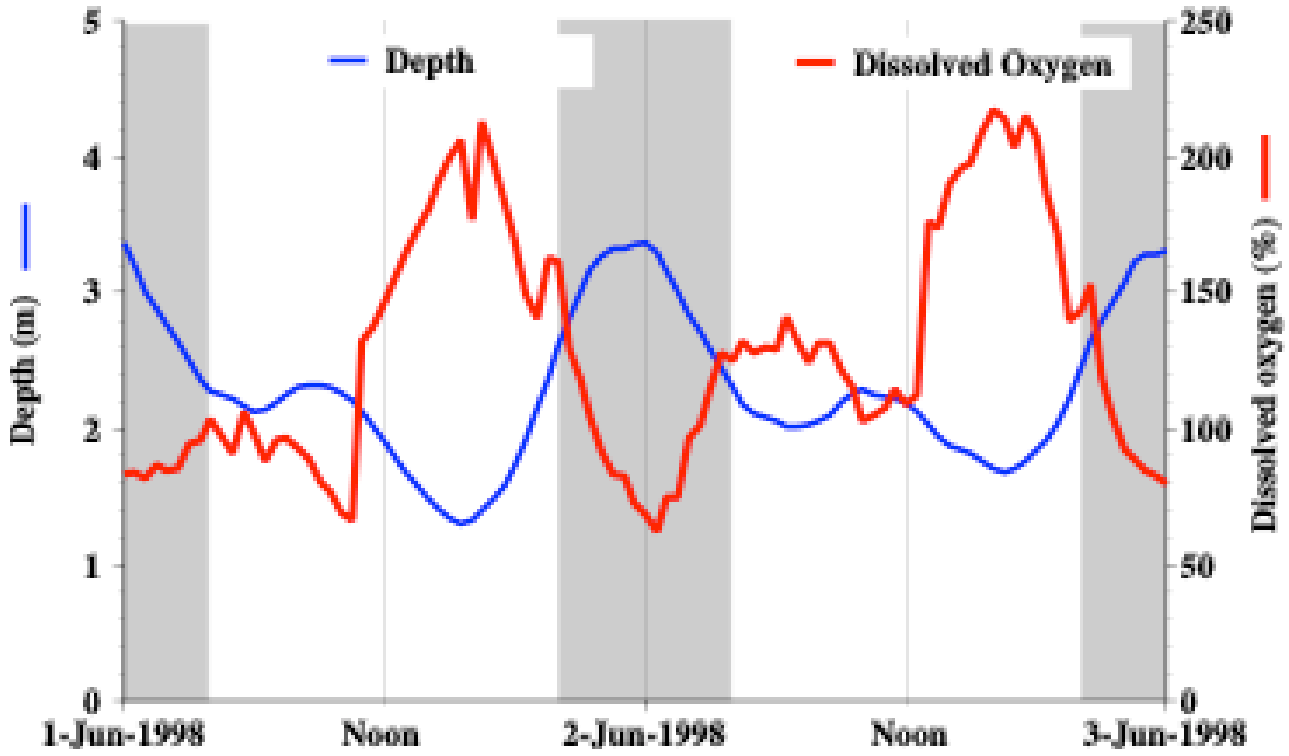
Water column

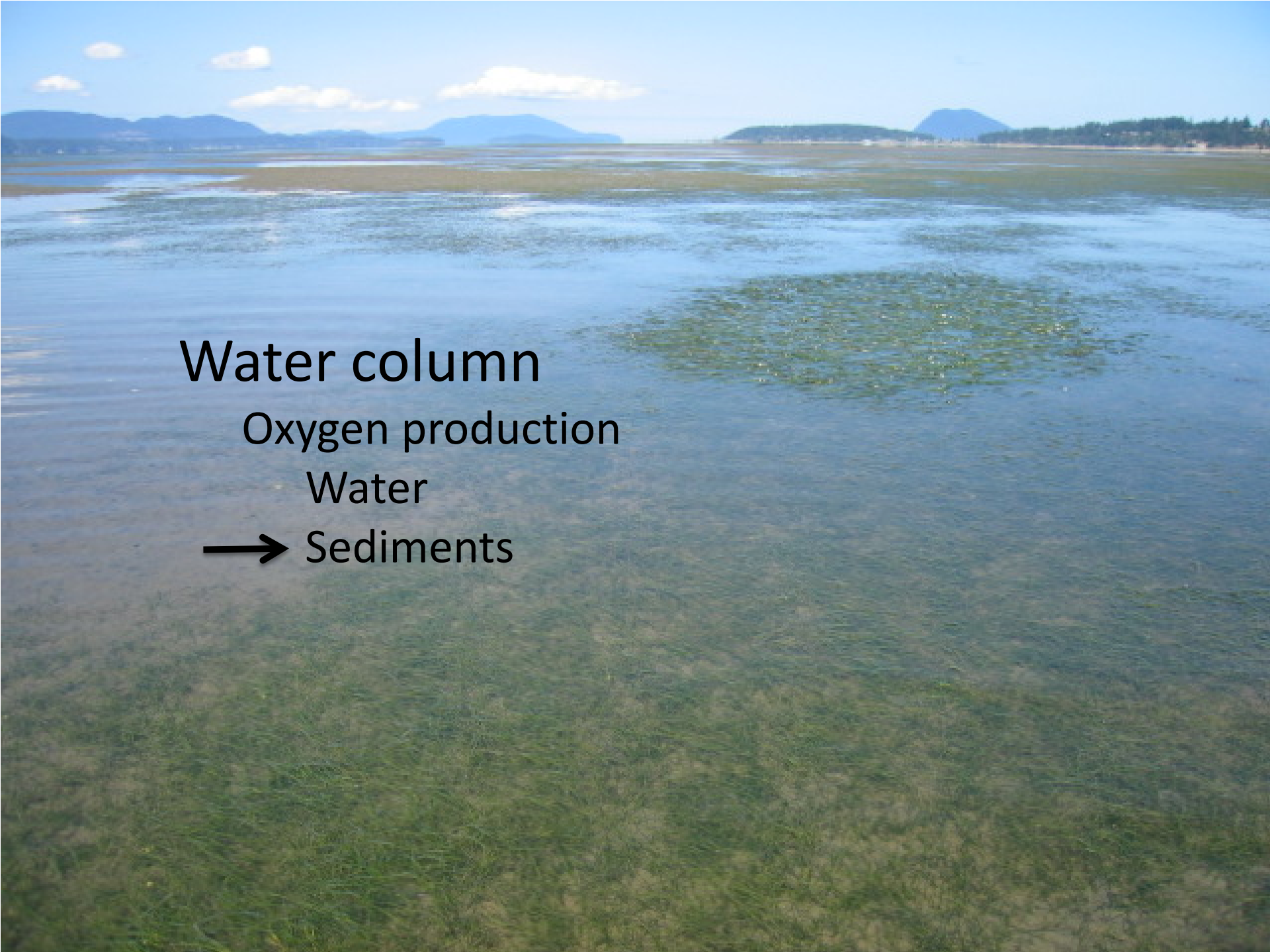
- Oxygen production
  - Water
  - Sediments
- Nutrient trapping and cycling
- pH

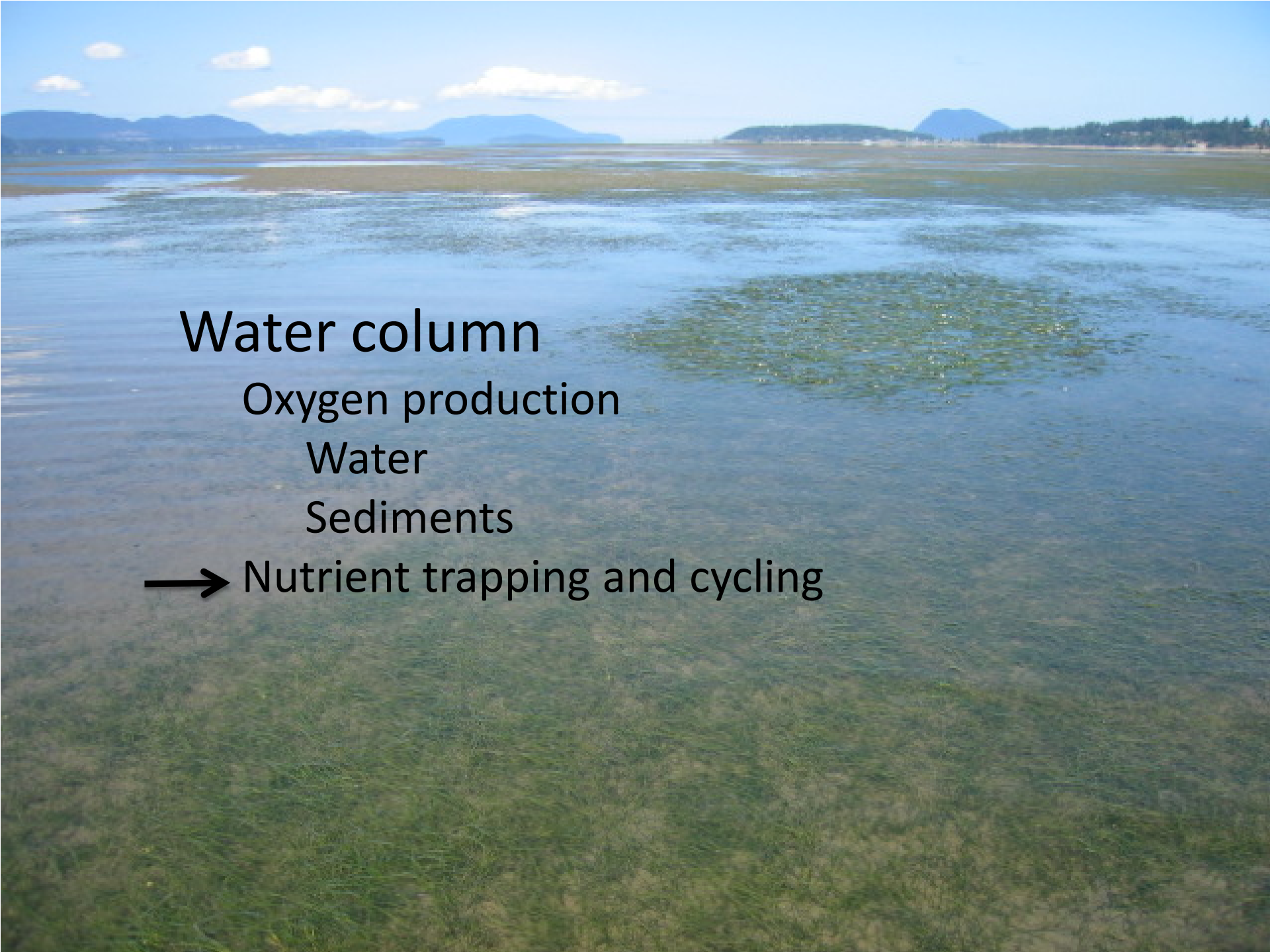

Water column
Oxygen production
→ Water

Photograph by C. Simenstad (Wetland EcosystemTeam, University of Washington); do not publish or distribute without permission.

Summer

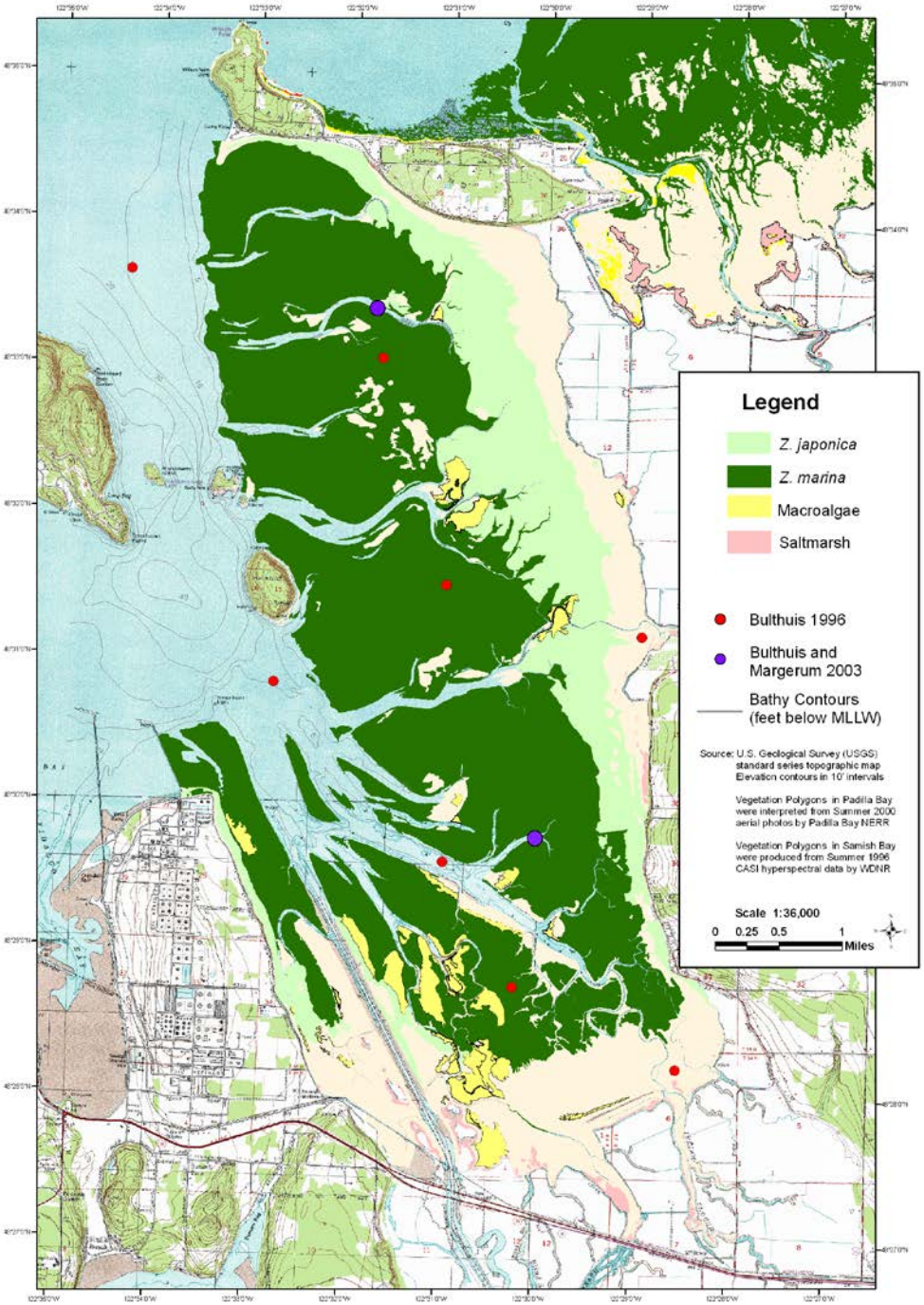

Depth
Dissolved Oxygen
Depth (m)
Dissolved oxygen (%)
5
4
3
2
1
0
250
200
150
100
50
0
1-Jun-1998
Noon
2-Jun-1998
Noon
3-Jun-1998

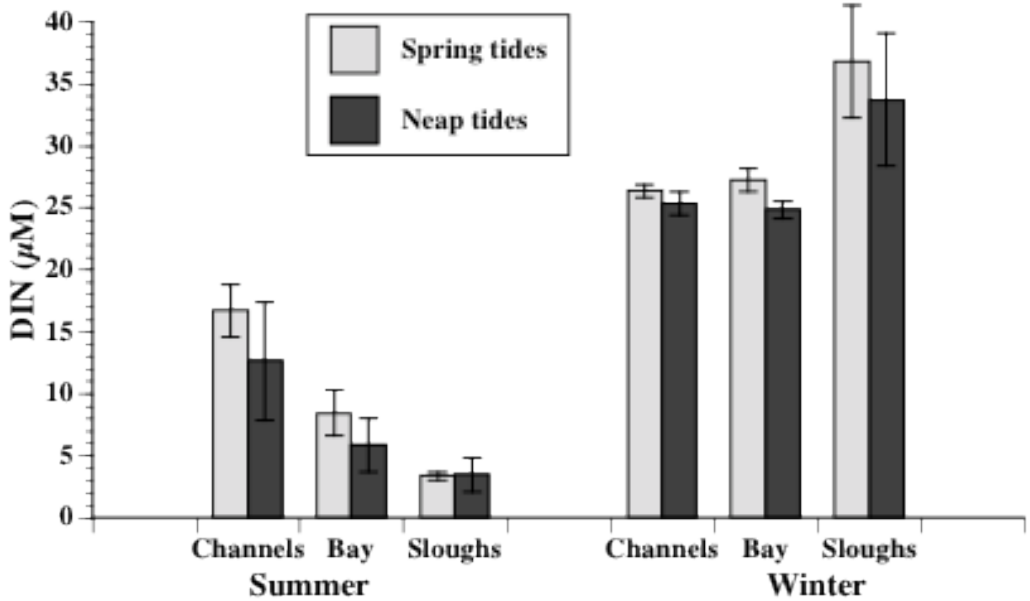

Water column
Oxygen production
Water
→ Sediments

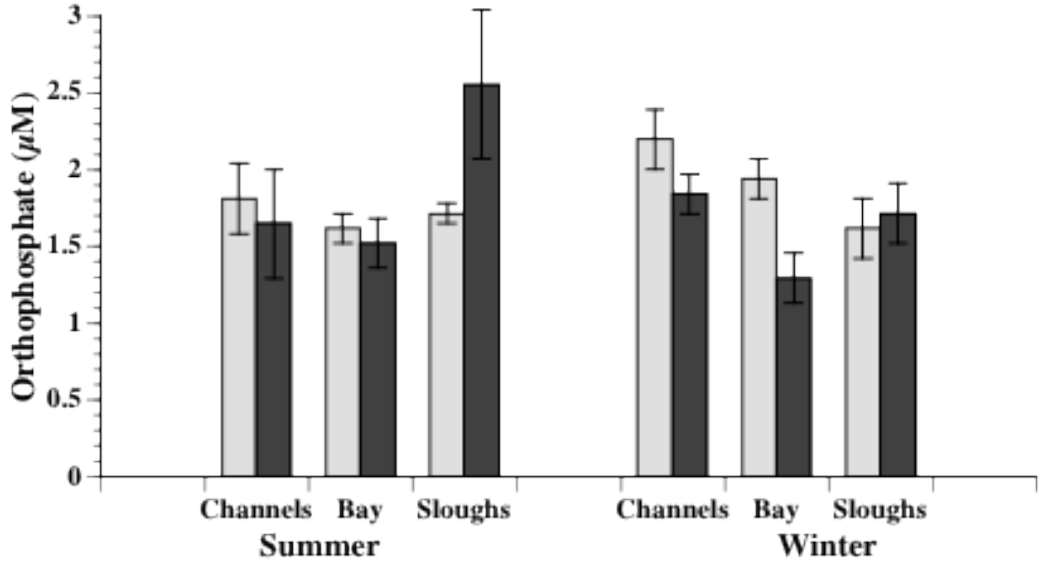


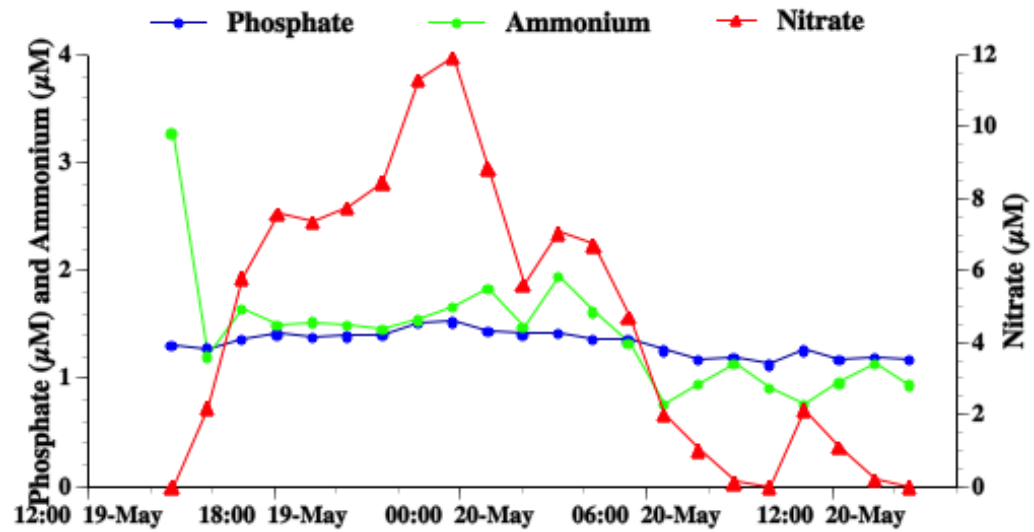
Water column

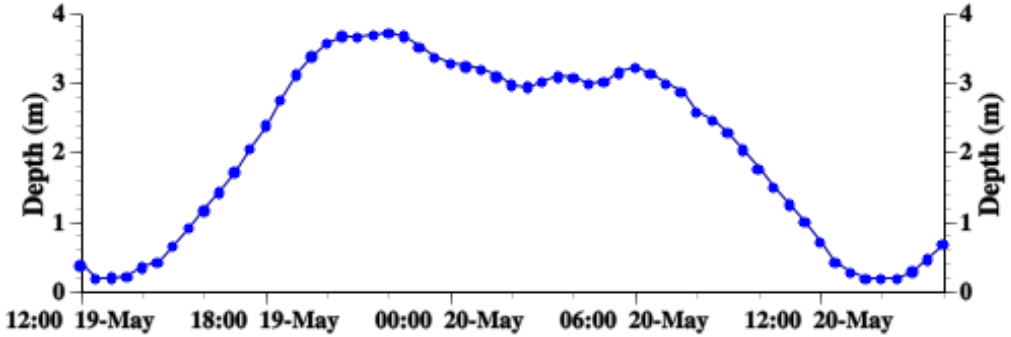
- Oxygen production
  - Water
  - Sediments
- → Nutrient trapping and cycling

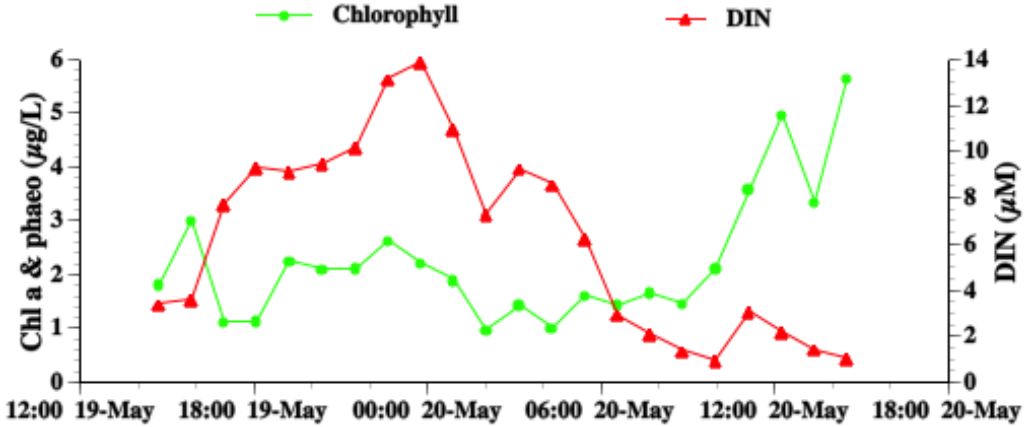

Legend
Z. japonica
Z. marina
Macroalgae
Saltmarsh
Bulthuis 1996
Bulthuis and Margerum 2003
Bathy Contours (feet below MLLW)
Source: U.S. Geological Survey (USGS) standard series topographic map Elevation contours in 10' intervals
Vegetation Polygons in Padilla Bay were interpreted from Summer 2000 aerial photos by Padilla Bay NERR
Vegetation Polygons in Samish Bay were produced from Summer 1996 CASI hyperspectral data by WDNR
Scale 1:36,000
0 0.25 0.5 1 Miles

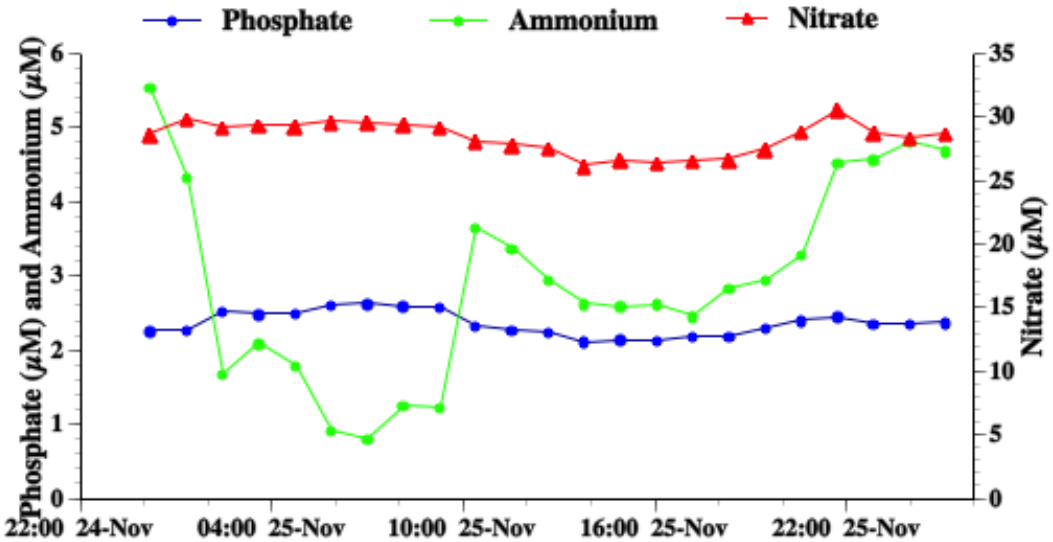

Spring tides
Neap tides
DIN (μM)
40
35
30
25
20
15
10
5
0
Channels
Bay
Sloughs
Summer
Channels
Bay
Sloughs
Winter

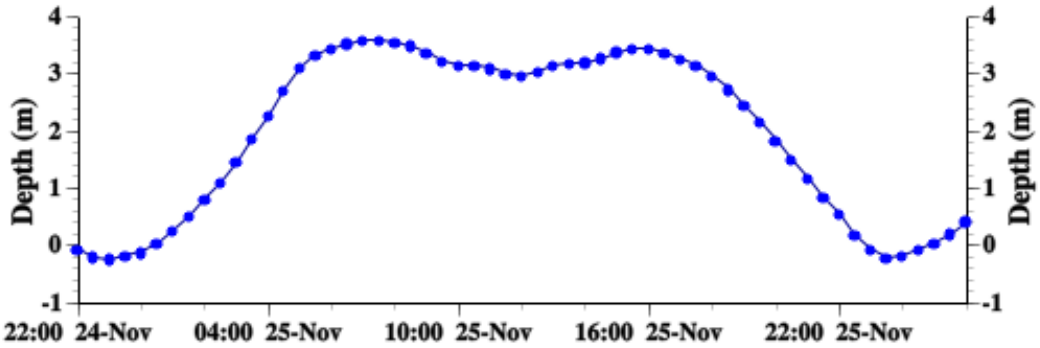

Orthophosphate (μM)
3
2.5
2
1.5
1
0.5
0
Channels
Bay
Sloughs
Summer
Channels
Bay
Sloughs
Winter

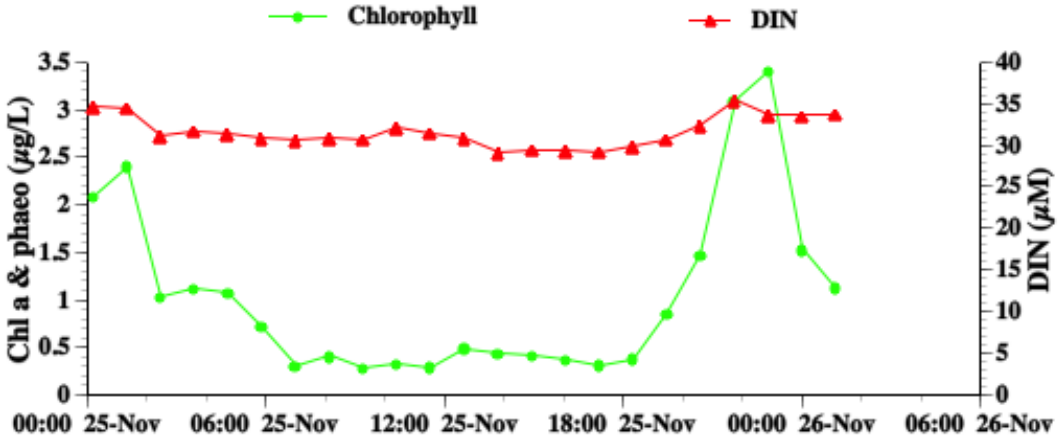

Phosphate
Ammonium
Nitrate
Phosphate (μM) and Ammonium (μM)
Nitrate (μM)
0
1
2
3
4
0
2
4
6
8
10
12
12:00 19-May
18:00 19-May
00:00 20-May
06:00 20-May
12:00 20-May

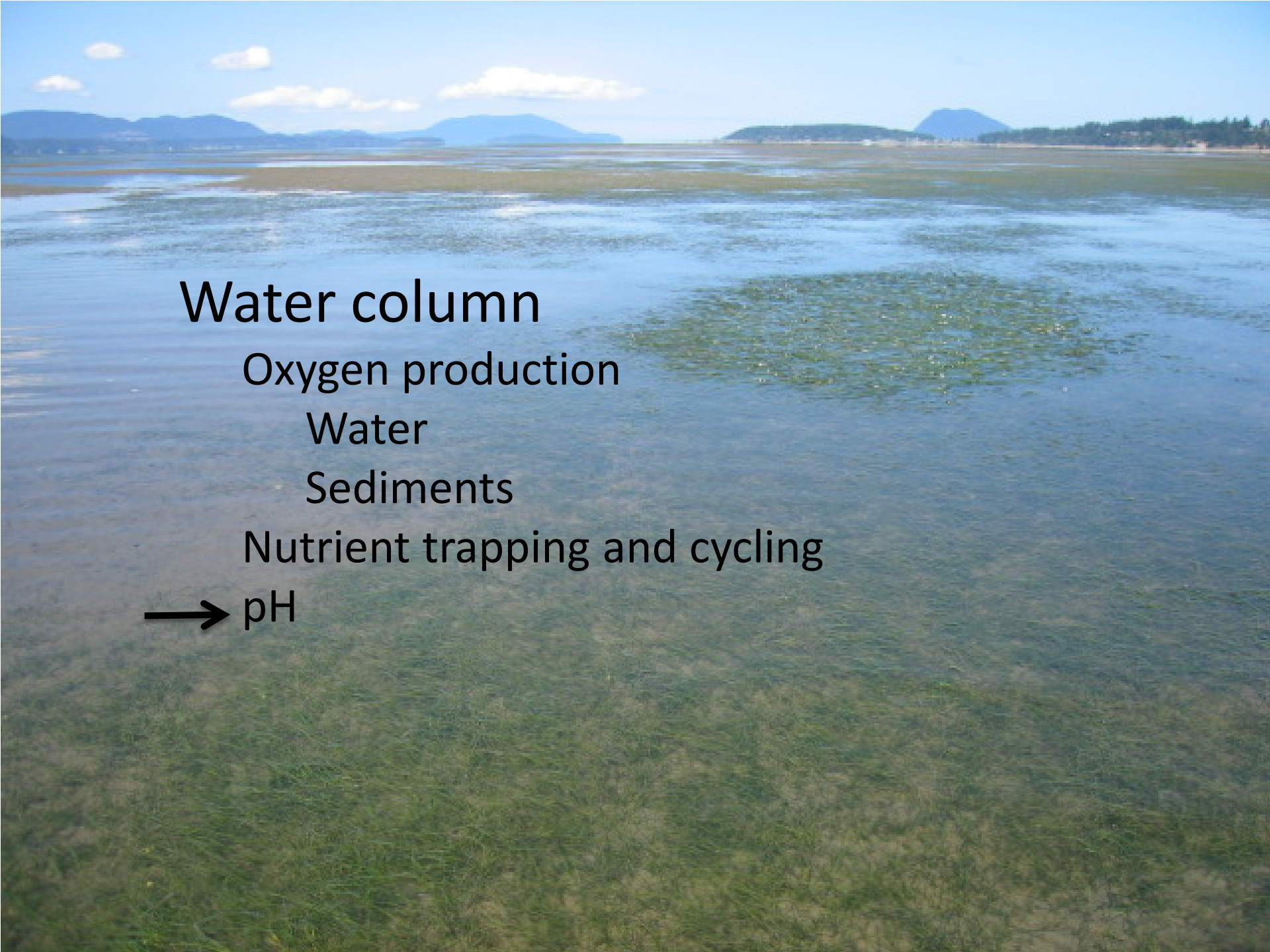

Depth (m)
Depth (m)
0
1
2
3
4
12:00 19-May
18:00 19-May
00:00 20-May
06:00 20-May
12:00 20-May


Chlorophyll
DIN
Chl a & phaeo (μg/L)
DIN (μM)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
12:00 19-May
18:00 19-May
00:00 20-May
06:00 20-May
12:00 20-May
18:00 20-May


Phosphate
Ammonium
Nitrate
Phosphate (μM) and Ammonium (μM)
Nitrate (μM)
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
22:00 24-Nov
04:00 25-Nov
10:00 25-Nov
16:00 25-Nov
22:00 25-Nov

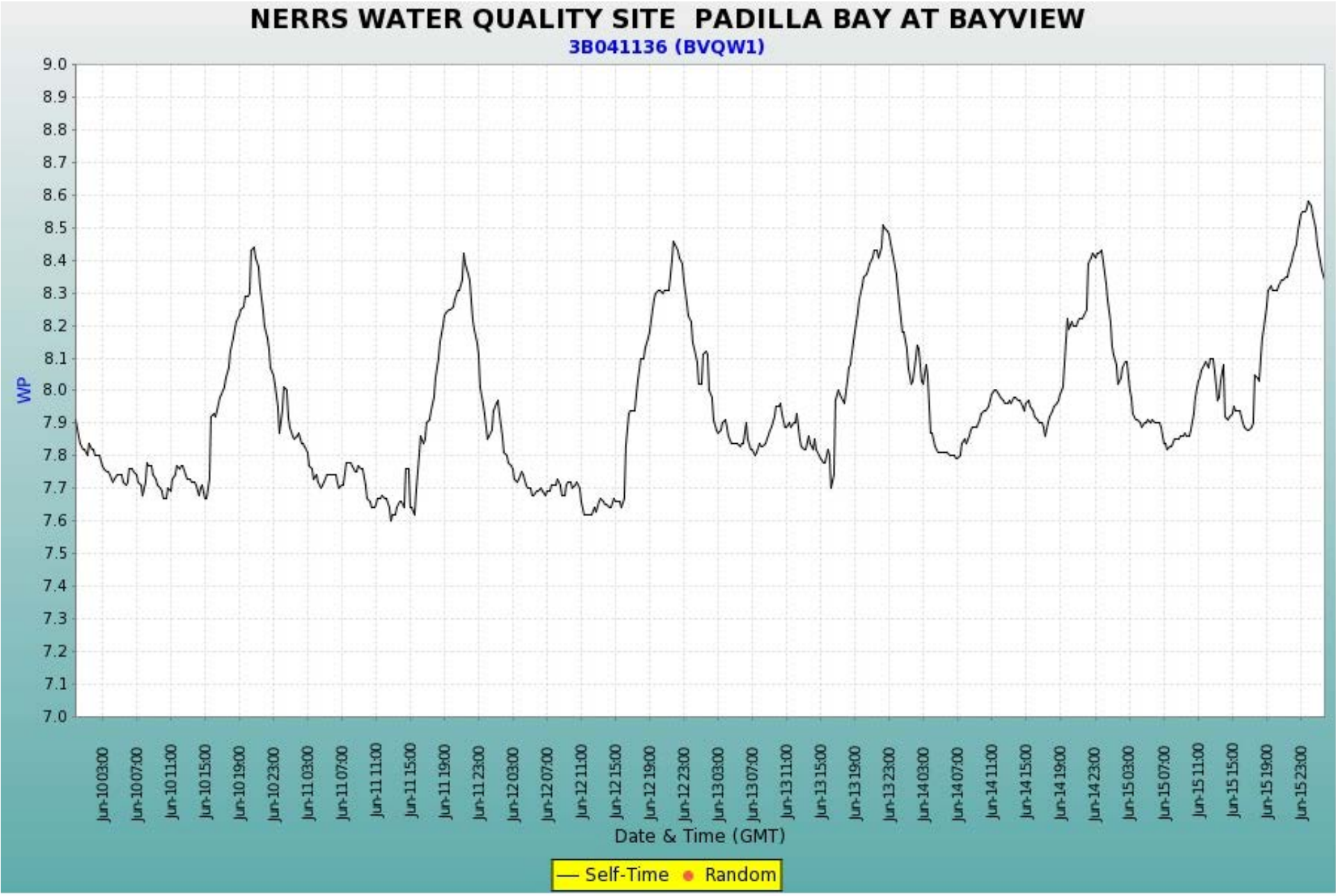

Depth (m)
Depth (m)
-1
0
1
2
3
4
22:00 24-Nov
04:00 25-Nov
10:00 25-Nov
16:00 25-Nov
22:00 25-Nov

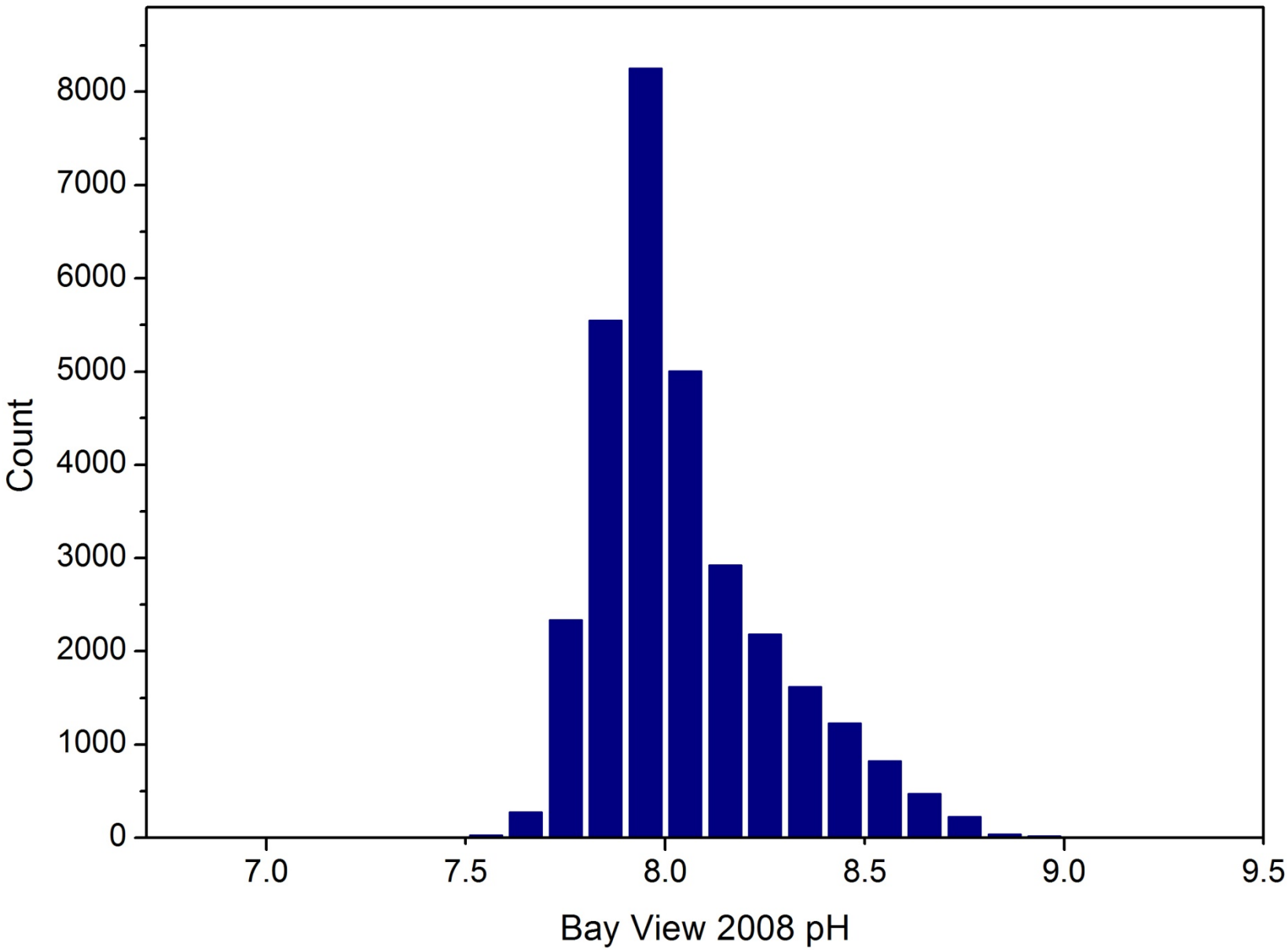

Chlorophyll
DIN
Chl a & phaeo (μg/L)
DIN (μM)
0
0.5
1
1.5
2
2.5
3
3.5
0
5
10
15
20
25
30
35
40
00:00 25-Nov
06:00 25-Nov
12:00 25-Nov
18:00 25-Nov
00:00 26-Nov
06:00 26-Nov

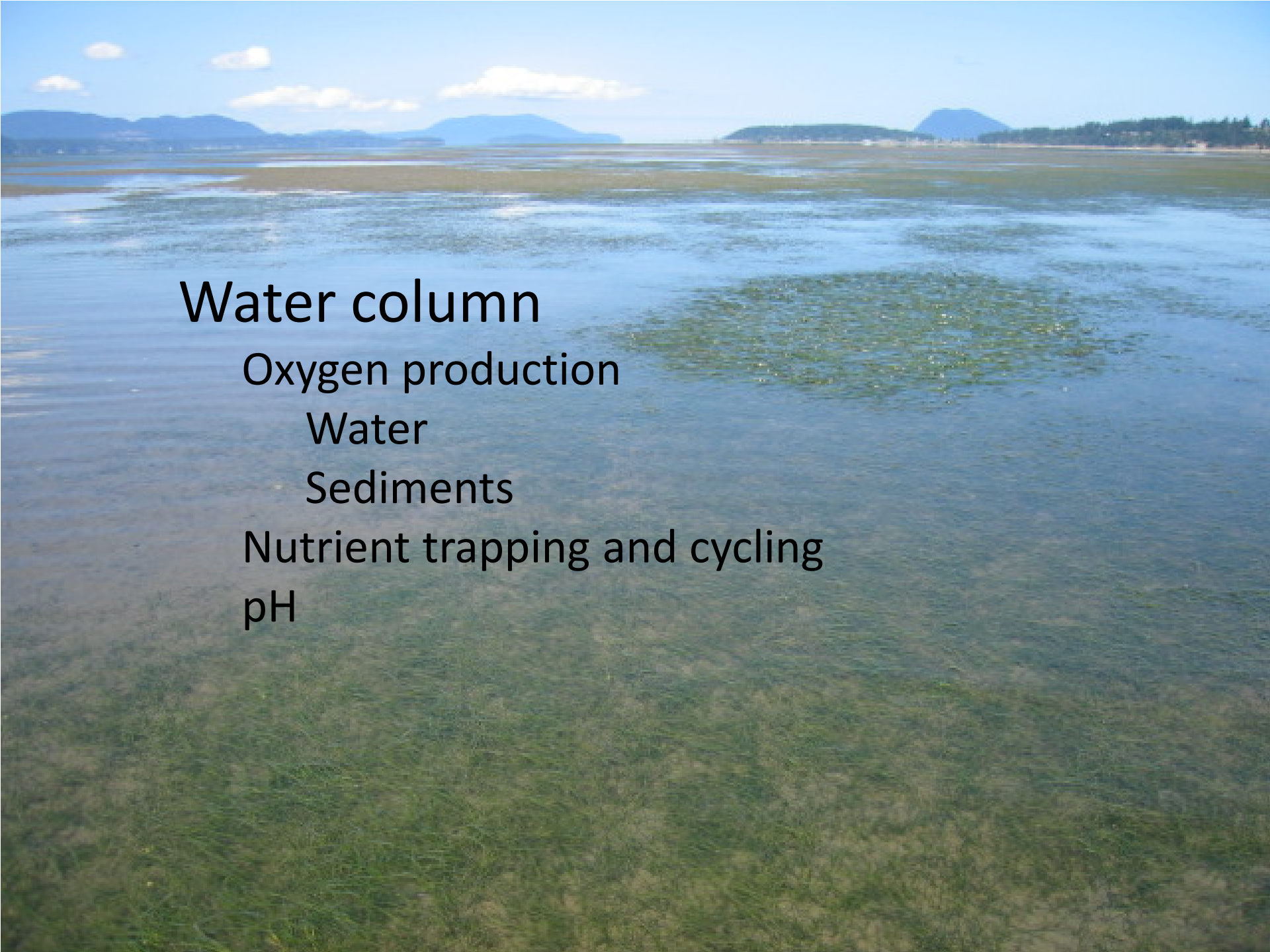


Water column

- Oxygen production
  - Water
  - Sediments
- Nutrient trapping and cycling
- → pH


NERRS WATER QUALITY SITE PADILLA BAY AT BAYVIEW
3B041136 (BVQW1)
WP
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
Jun-10 03:00
Jun-10 07:00
Jun-10 11:00
Jun-10 15:00
Jun-10 19:00
Jun-10 23:00
Jun-11 03:00
Jun-11 07:00
Jun-11 11:00
Jun-11 15:00
Jun-11 19:00
Jun-11 23:00
Jun-12 03:00
Jun-12 07:00
Jun-12 11:00
Jun-12 15:00
Jun-12 19:00
Jun-12 23:00
Jun-13 03:00
Jun-13 07:00
Jun-13 11:00
Jun-13 15:00
Jun-13 19:00
Jun-13 23:00
Jun-14 03:00
Jun-14 07:00
Jun-14 11:00
Jun-14 15:00
Jun-14 19:00
Jun-14 23:00
Jun-15 03:00
Jun-15 07:00
Jun-15 11:00
Jun-15 15:00
Jun-15 19:00
Jun-15 23:00
Date & Time (GMT)
Self-Time
Random


Count
8000
7000
6000
5000
4000
3000
2000
1000
0
7.0
7.5
8.0
8.5
9.0
9.5
Bay View 2008 pH



Water column

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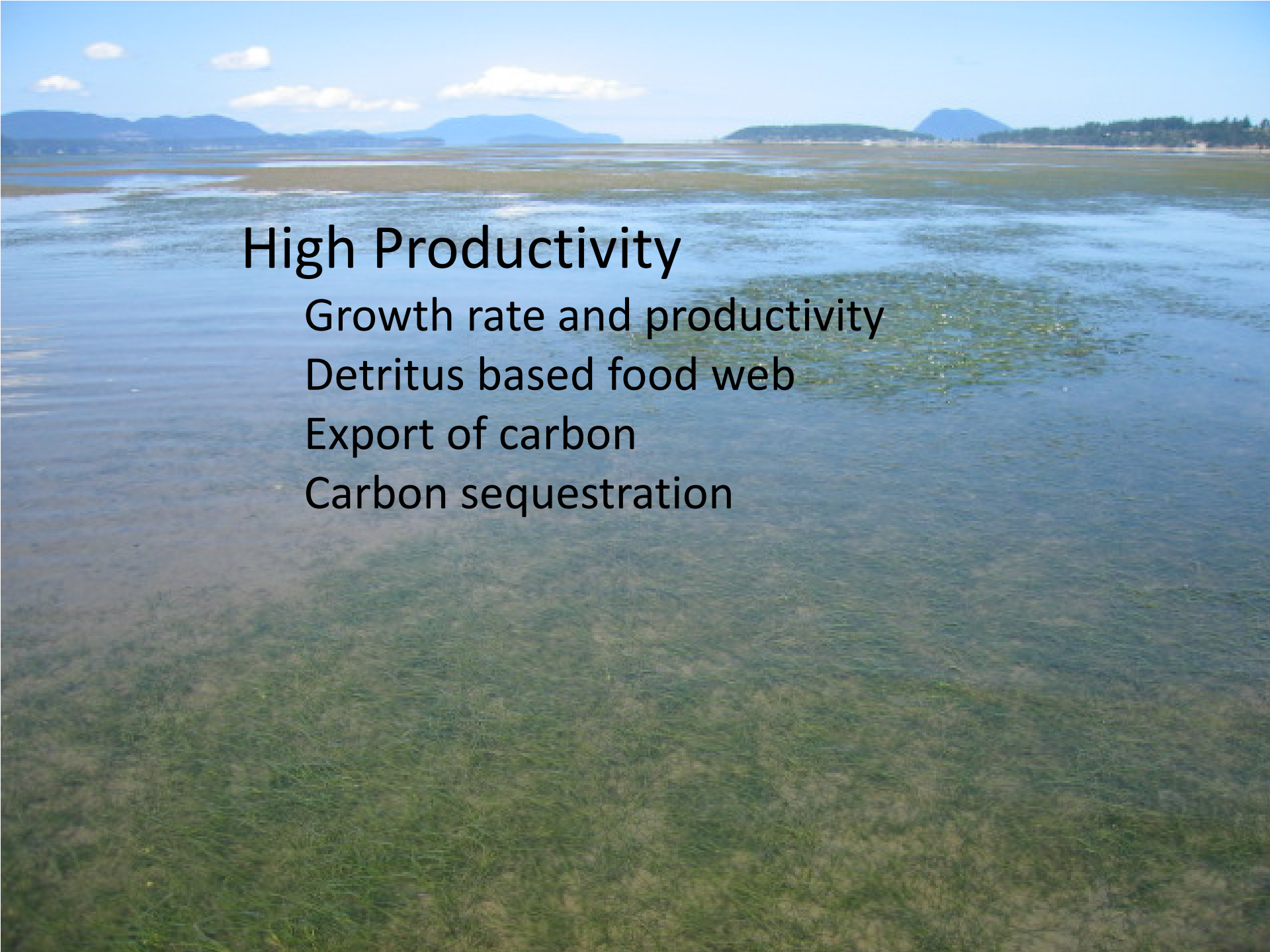

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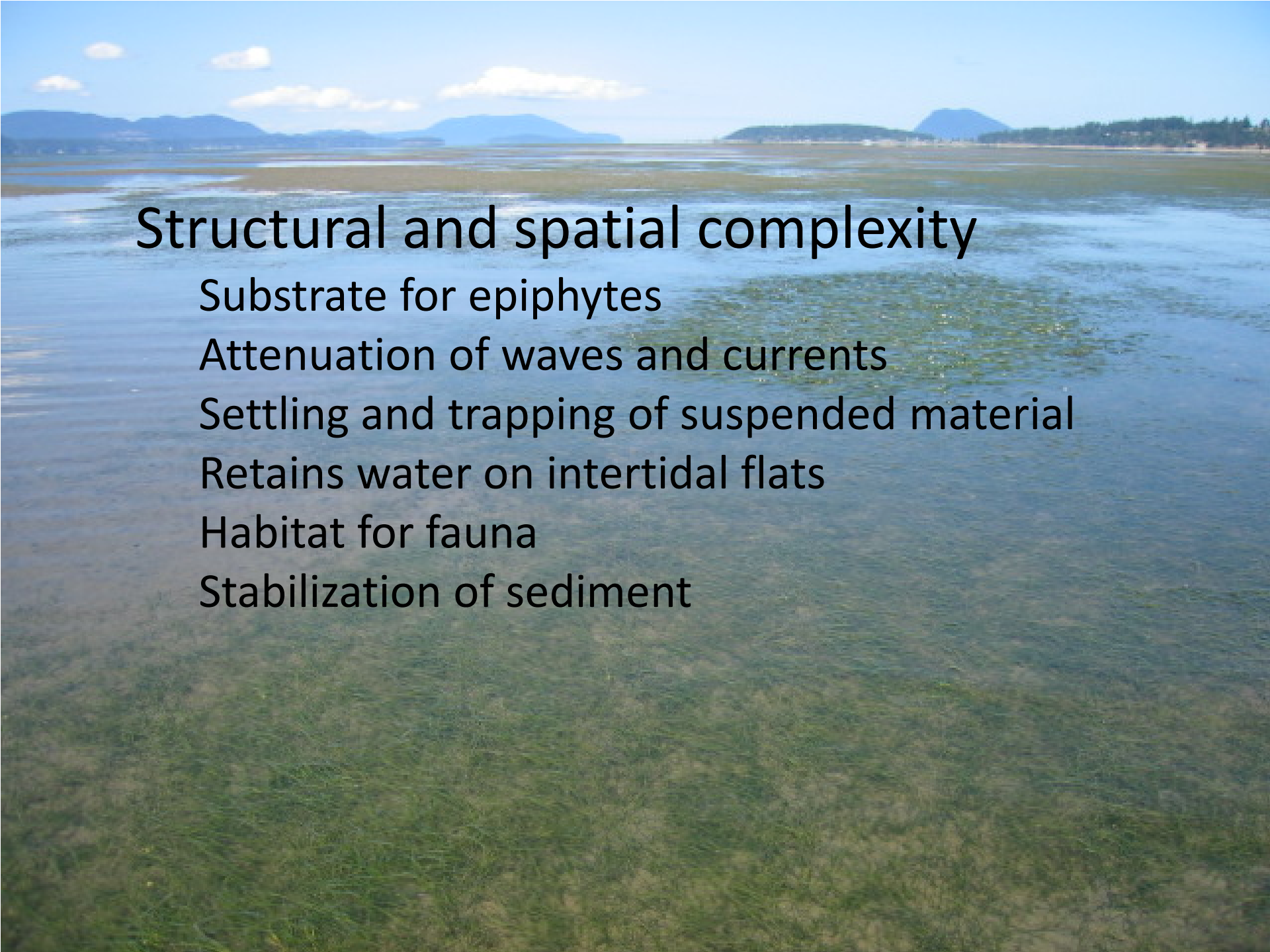
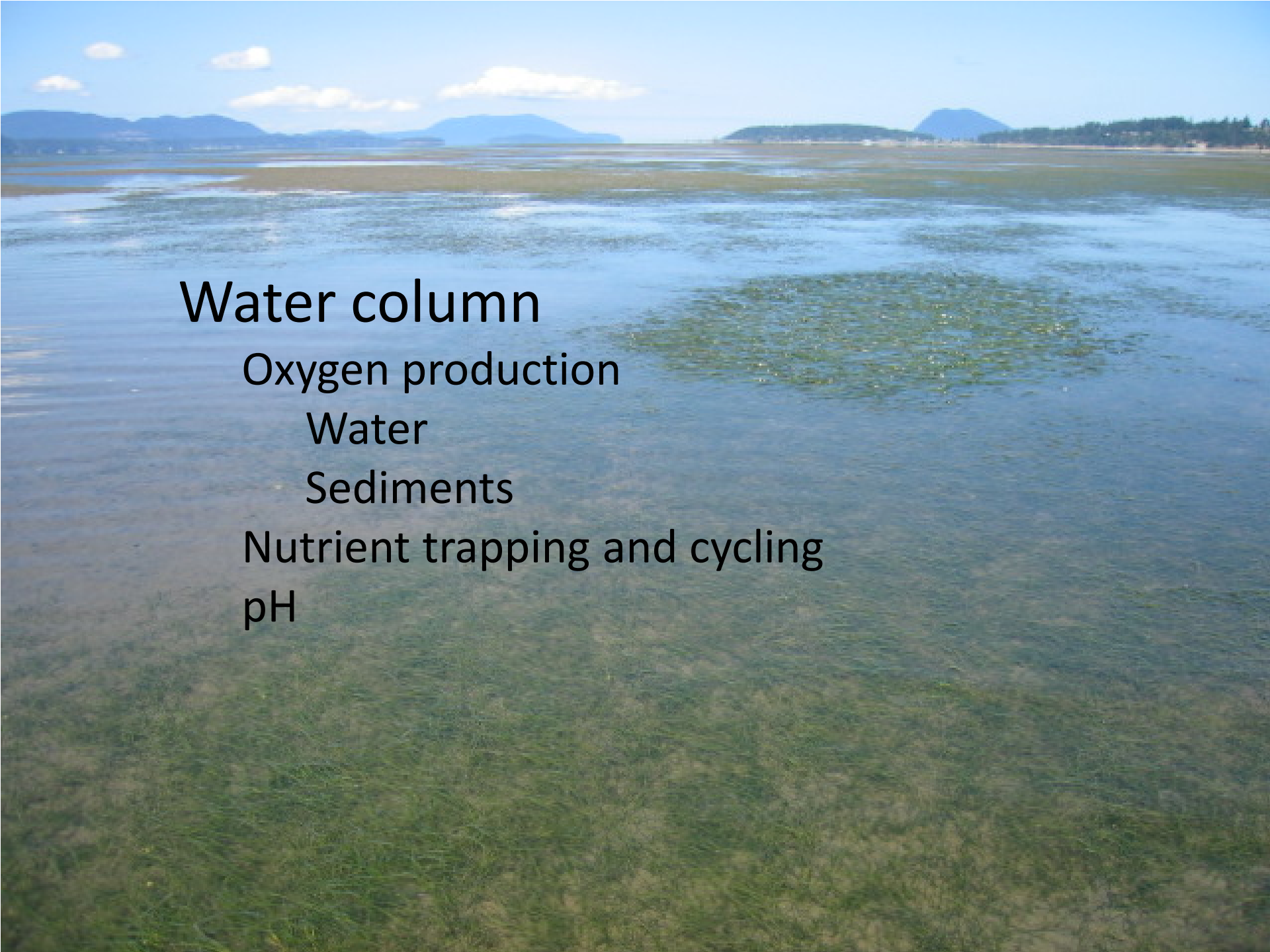
- Export of carbon
- Carbon sequestration



Structural and spatial complexity

- Substrate for epiphytes
- Attenuation of waves and currents
- Settling and trapping of suspended material
- Retains water on intertidal flats
- Habitat for fauna
- Stabilization of sediment



Water column

- Oxygen production
  - Water
  - Sediments
- Nutrient trapping and cycling
- pH

Thank you