KELP

IN THE
OLYMPIC COAST NATIONAL MARINE SANCTUARY

Thomas Mumford

Sanctuary Advisory Council

Research Seat Alternate

Helen Berry

Washington Department of Natural Resources

Nearshore Habitat Program

Topics for Today's Presentation

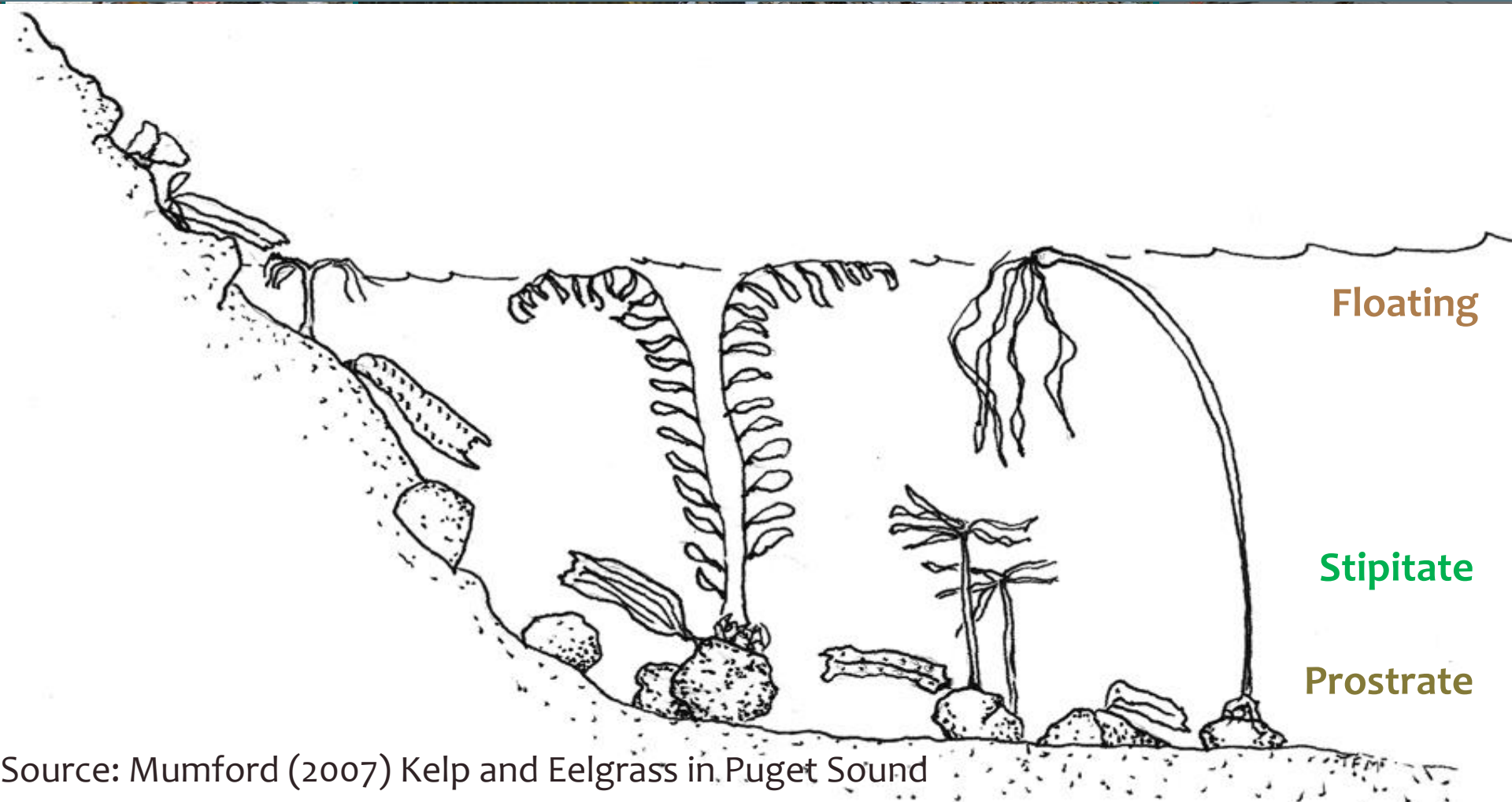
- What is kelp/basic biology
- Where is kelp in the Sanctuary (floating and non-floating)
- What ecosystem functions does kelp provide? primary production/ biogenic habitat
- Trends in kelp distribution and abundance (provided by Helen Berry)
- Kelp/otter interactions
- Effects of sediments and sediment transport
- Effects of ocean acidification and other anthropogenic activities on kelp communities
- Kelp and fisheries interactions
- Kelp management approaches

Kelp Classification and Species

- Phylum Ochrophyta (Phaeophyta)
  - Class- Phaeophyceae
    - Order- Laminariales
      - Family- 5
        - Genus- 16
          - Species- 24

Kelp – A diverse group

- 21 species of kelp (Phaeophyceae, Laminariales) found in Sanctuary
- Another 2 species likely.



Source: Mumford (2007) Kelp and Eelgrass in Puget Sound

So what is NOT Kelp?

Fucus distichus

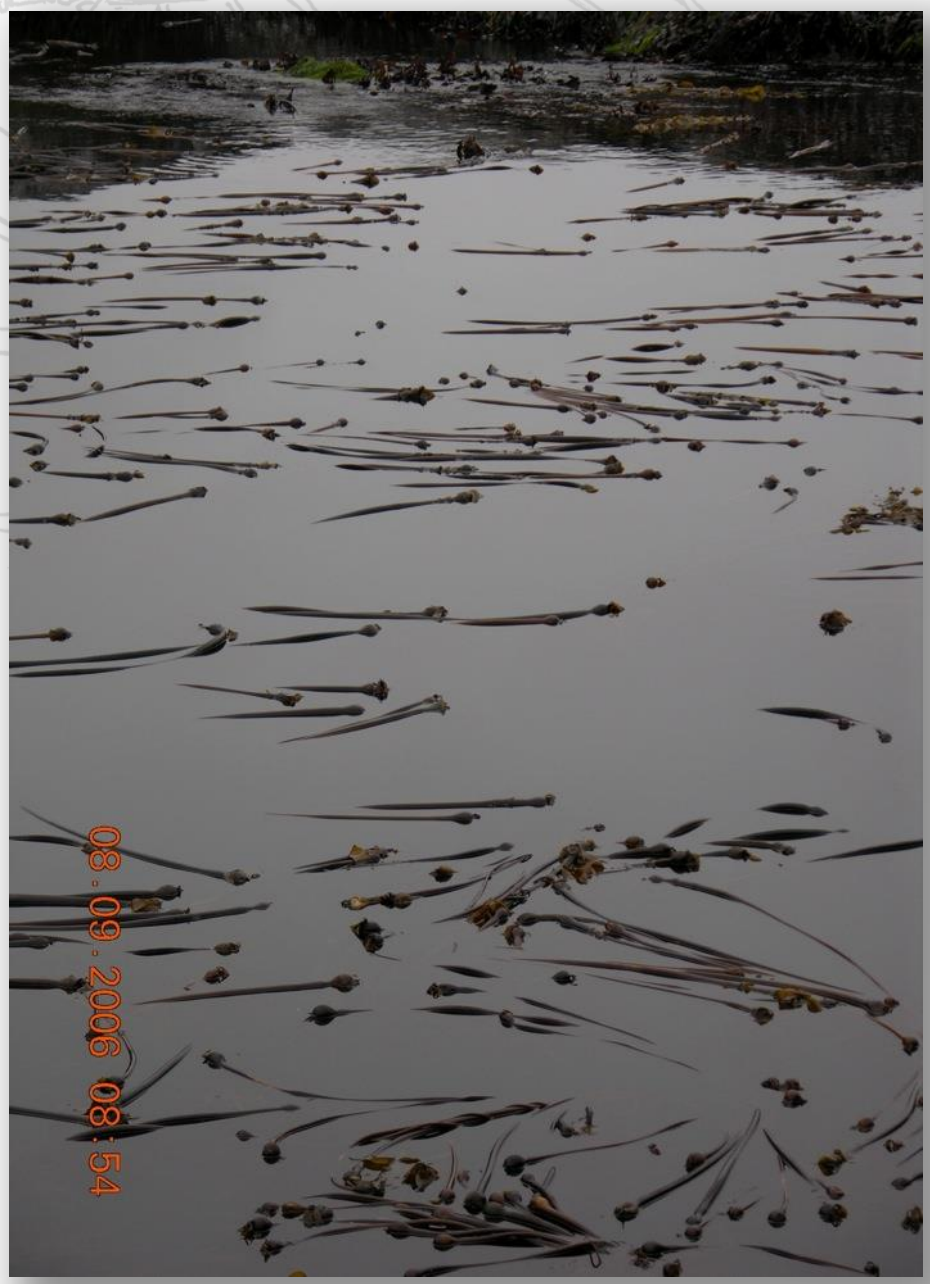
Sargassum muticum

Macrocystis pyrifera – giant kelp

Floating canopy Kelp

- Form floating canopy
- Perennial sporophyte - lives up to 5 years
- A small float on each blade
- Reproductive blades (sporophylls) at base of plant

Nereocystis luetkeana- bull kelp



Floating canopy Kelp

- Forms floating canopy
- Annual sporophyte –
- One float at top of stipe
- All blades are reproductive- deciduous sori

The Other Floating Kelp- *Egregia menziesii*

http://www.solpugid.com/cabiota/egregia_menziesii.htm

http://www.seaweedsofalaska.com/species.asp?SeaweedID=235

Floating Kelp- just the tip of the iceberg…

http://www.divephotoguide.com/user/askphotography/gallery/the-usual-suspects-photo/7701/

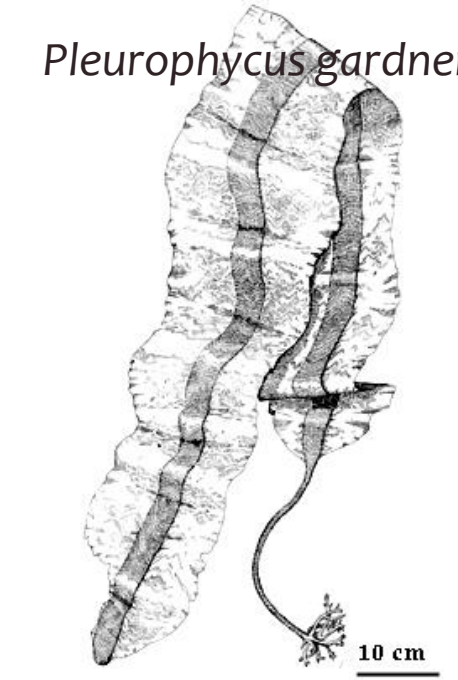
Stipitate kelp

Sessile Kelp

Agarum clathratum


Agarum fimbriatum


Alaria marginata



Pleurophycus gardneri

Sessile Kelp

http://forum.reefcheck.org/phpbb3/viewtopic.php?f=3&t=649

algaeBASE

Sessile Kelp

Sessile Kelp

Saccharina complanata

Saccharina groenlandica

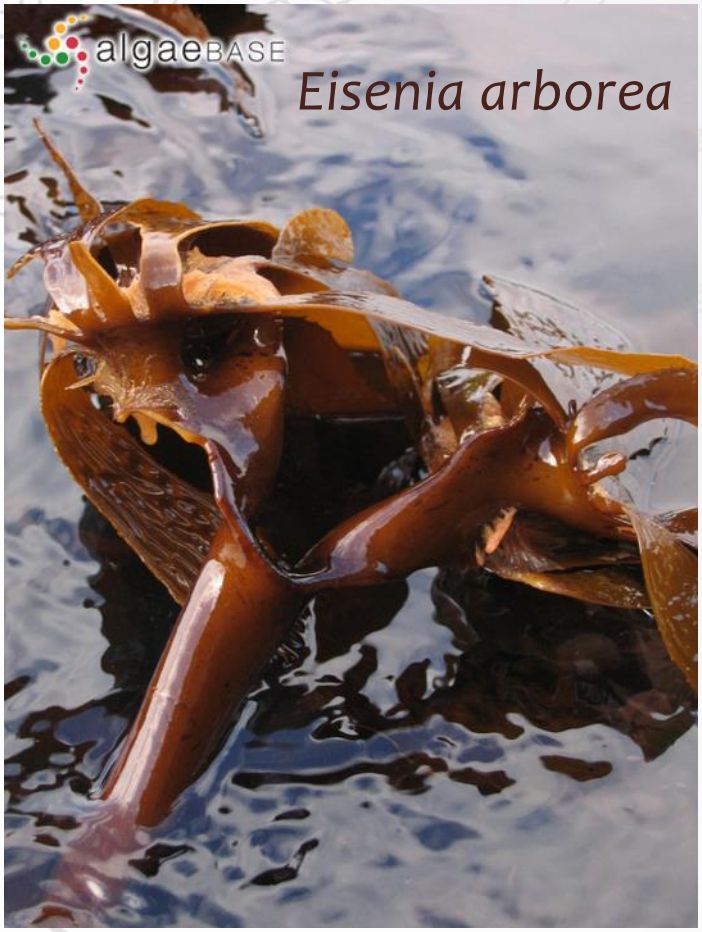
Saccharina latissima

Saccharina dentigera

http://www.seaweedsofalaska.com/species.asp?SeaweedID=240

Saccharina sessile

Probably in Sanctuary- but no records



And a kelp we don't want!

WATCH FOR THE INVASIVE KELP *UNDARIA PINNATIFIDA* (WAKAME)

This brown seaweed, native to Asia, has spread around the world to Australia, New Zealand, Europe, South America and California's harbors!

Its blade is thin, deeply lobed, and has a prominent midrib. It can be 1-6' long. There are tiny dots - tufts of hairs- scattered on the surface of the blade.

Plants appear in late winter. The blade grows through spring and begins to erode in late summer.

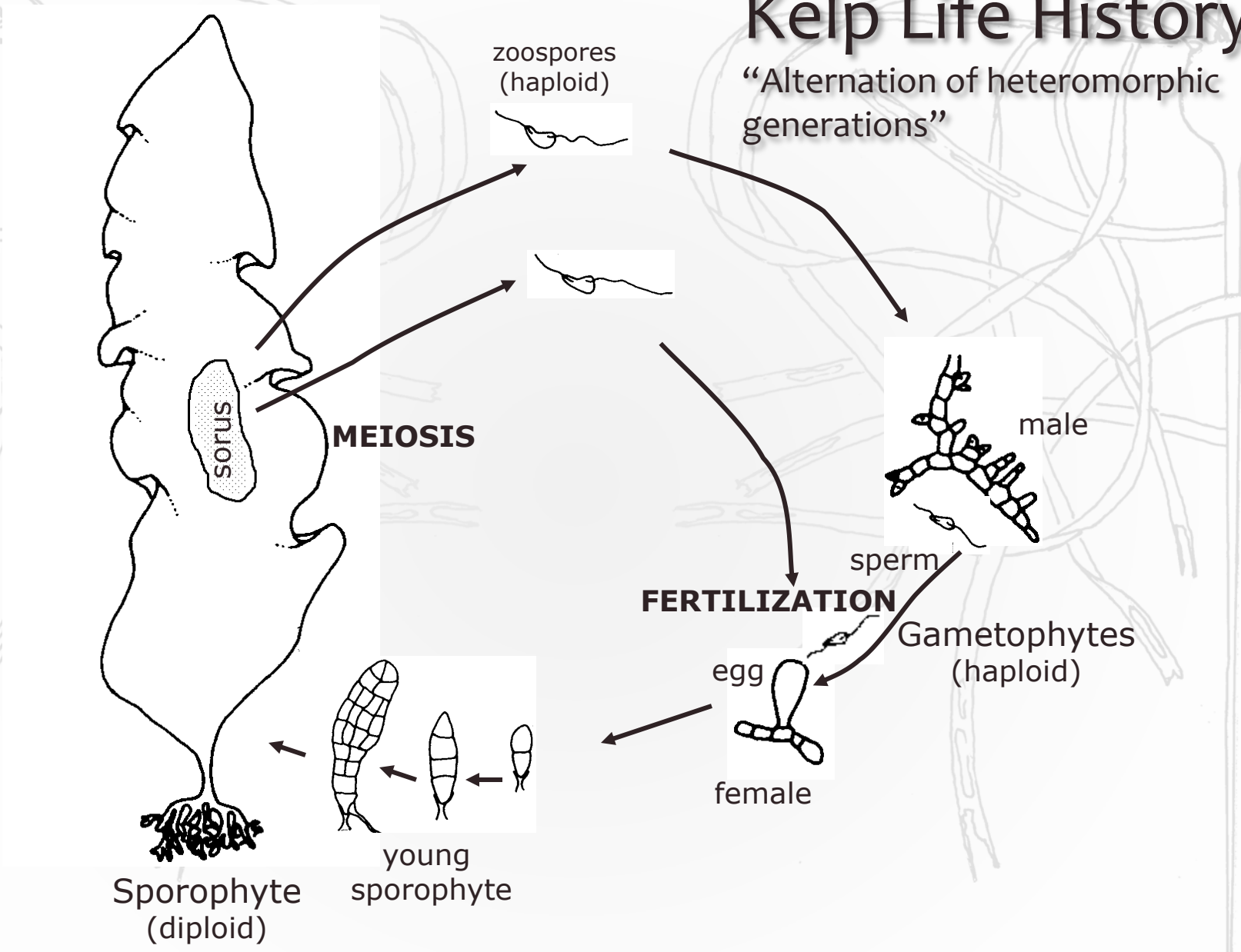
The reproductive structure develops below the blade, just above the holdfast. It is deeply folded and frilled; it looks like ribbon candy or a pinecone.

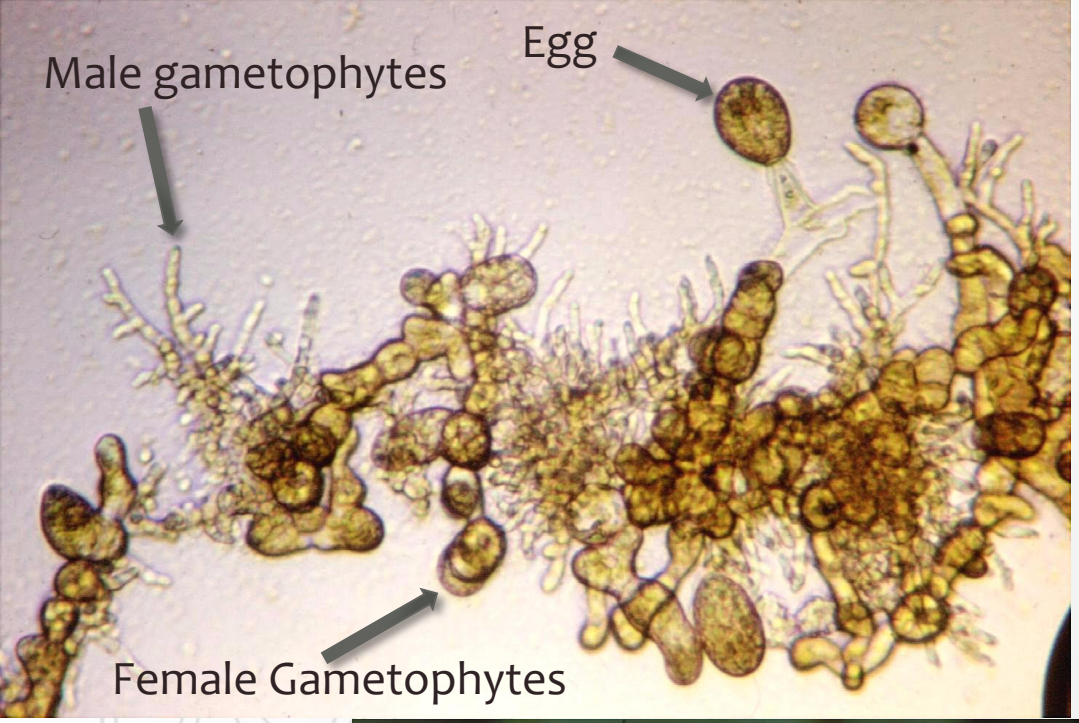
If you find *Undaria*, take a picture and contact:

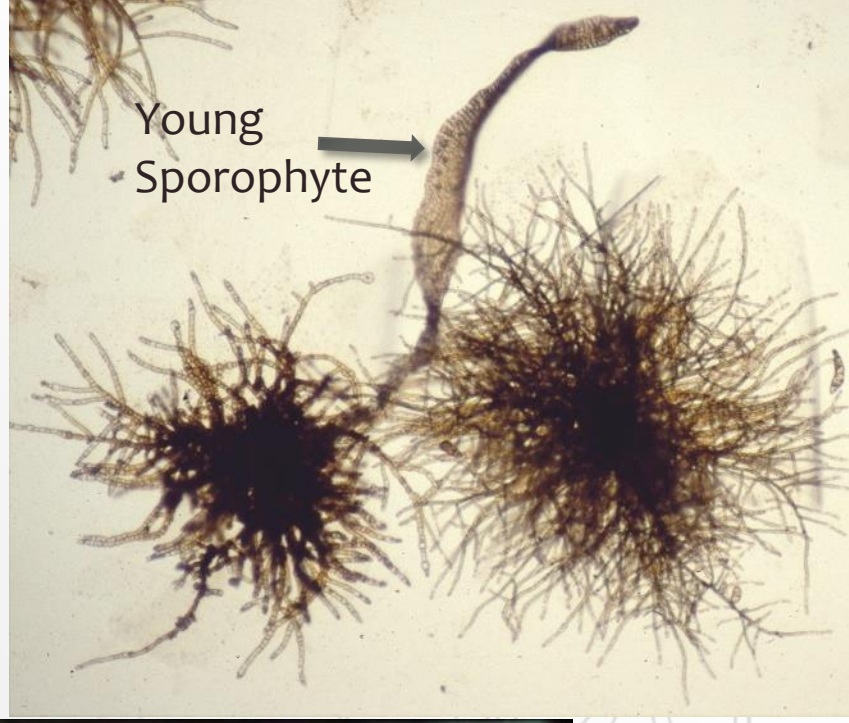
Dr. Kathy Ann Miller
University Herbarium
University of California
Berkeley, CA 94705
510-643-7007

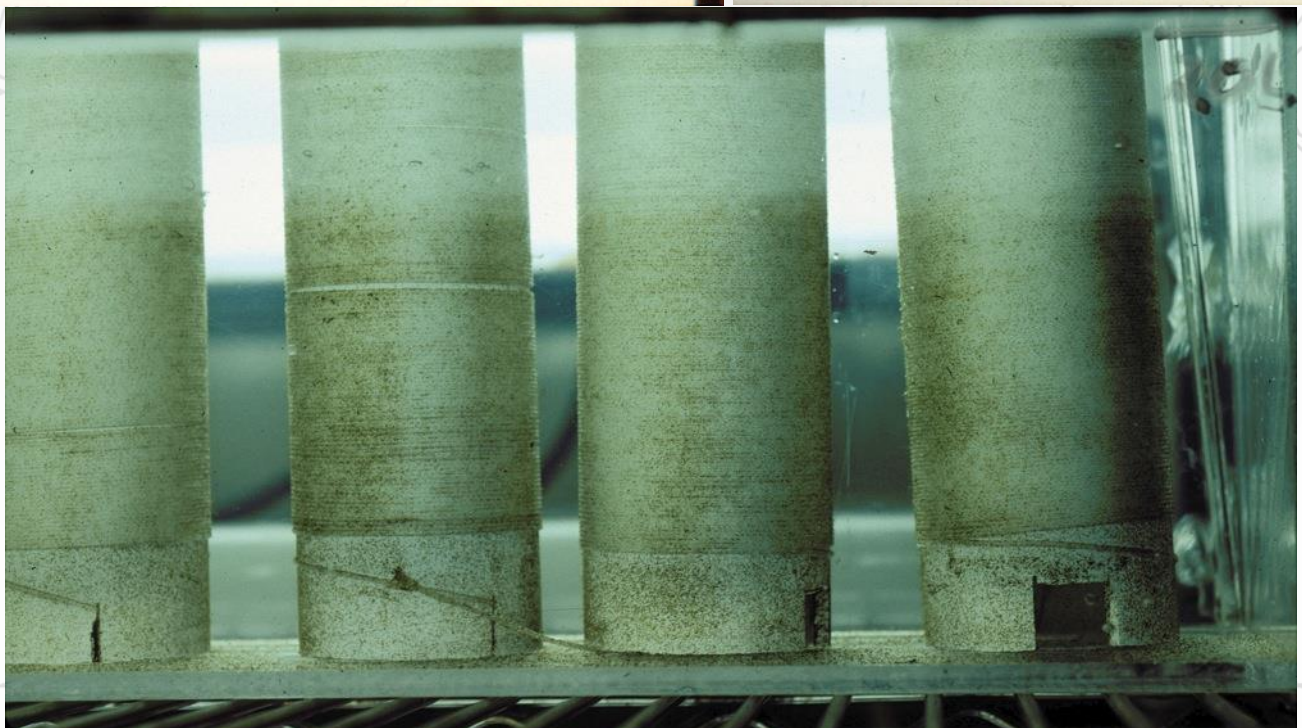
Kelp Life History

"Alternation of heteromorphic generations"

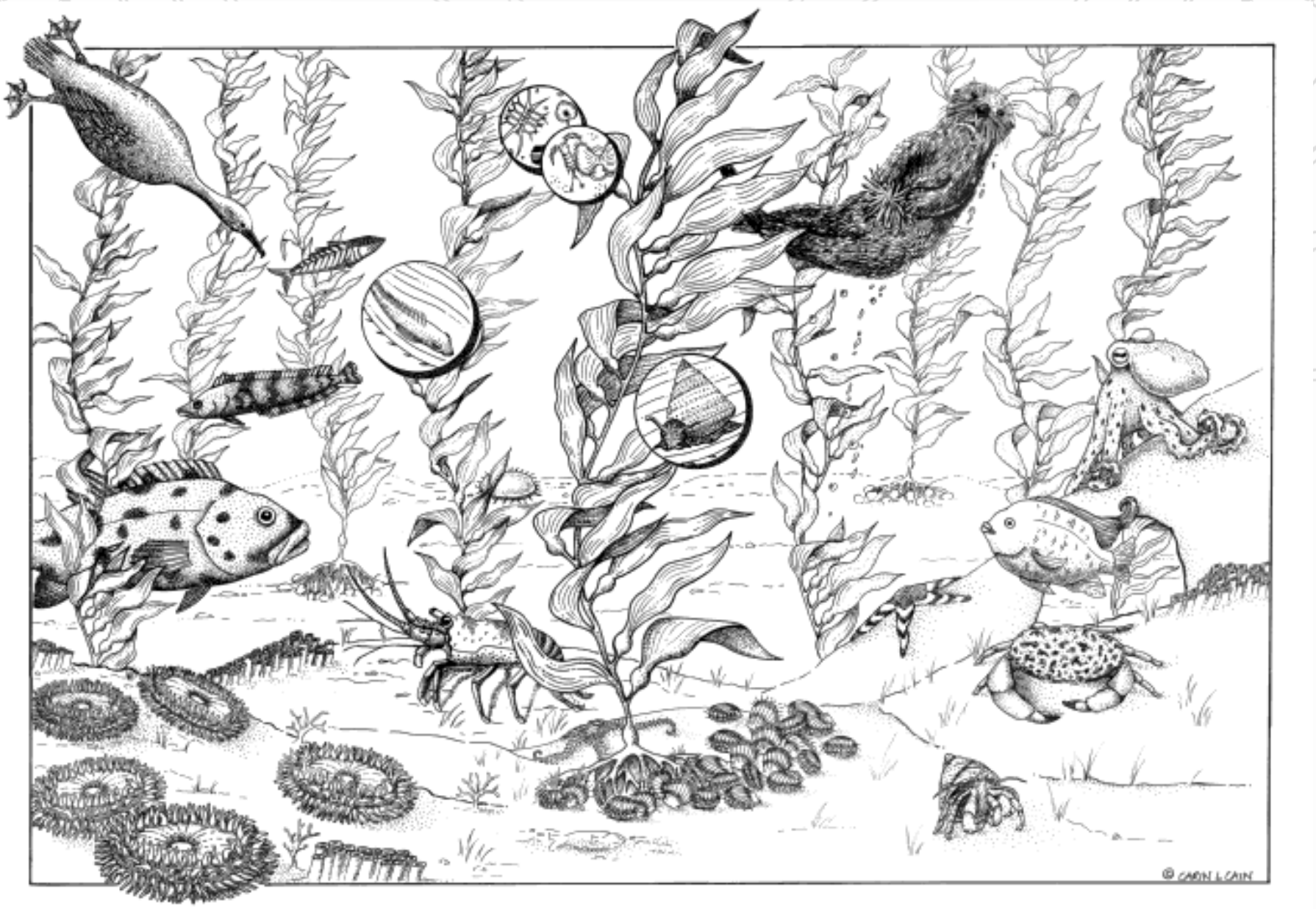



Male gametophytes
Egg
Female Gametophytes

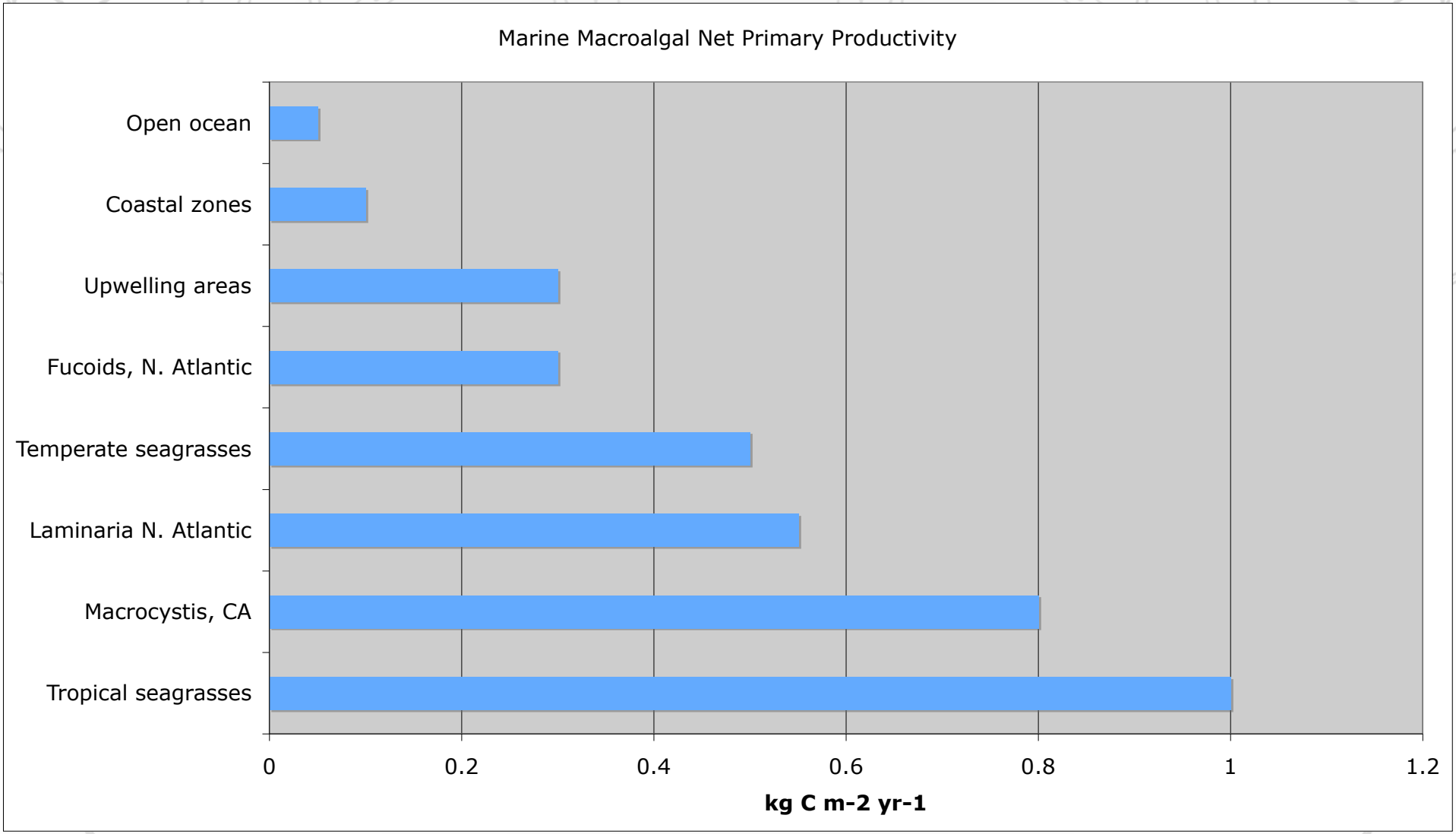

Young
Sporophyte



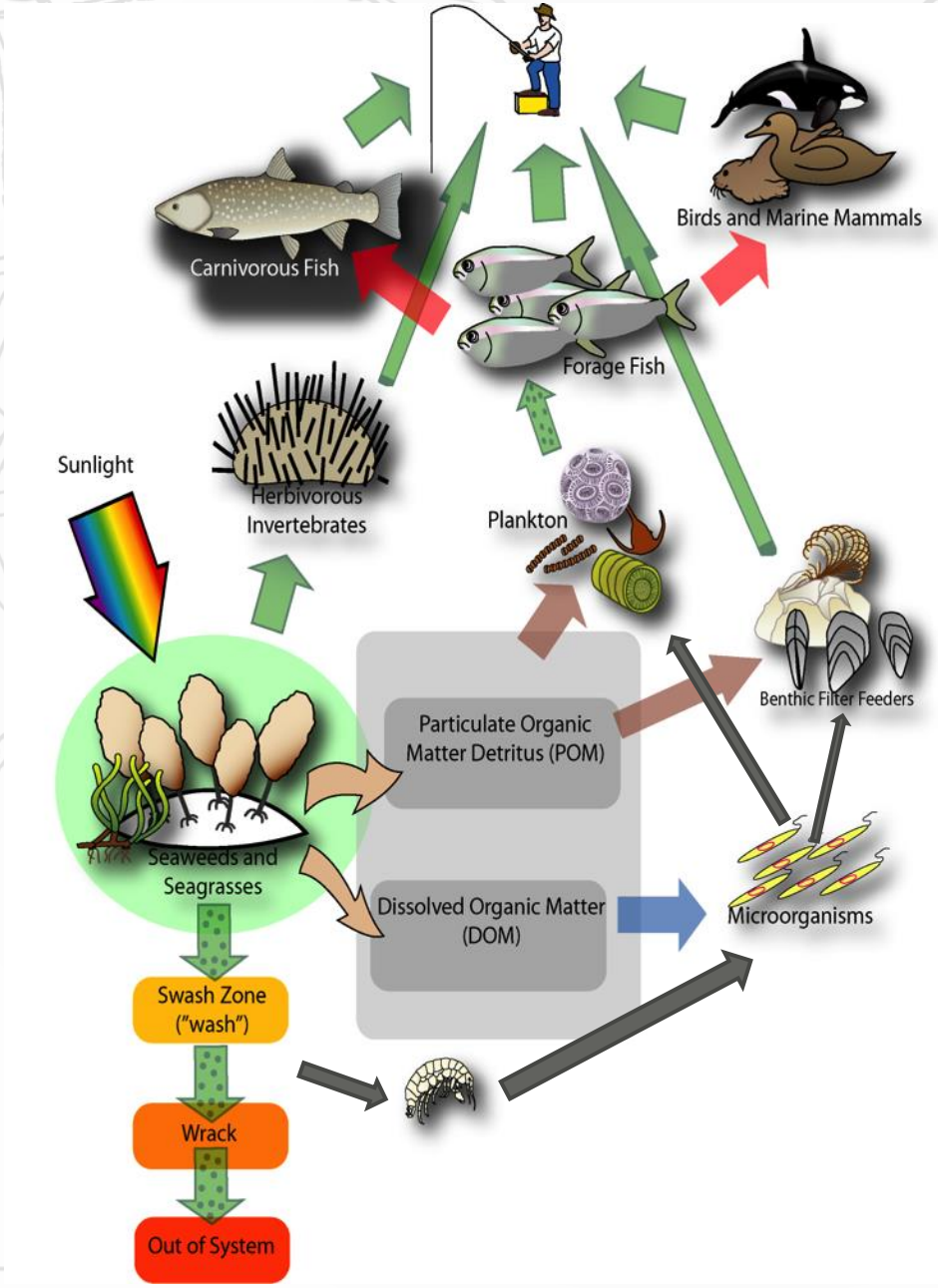
Ecological Importance: Biogenic Habitat

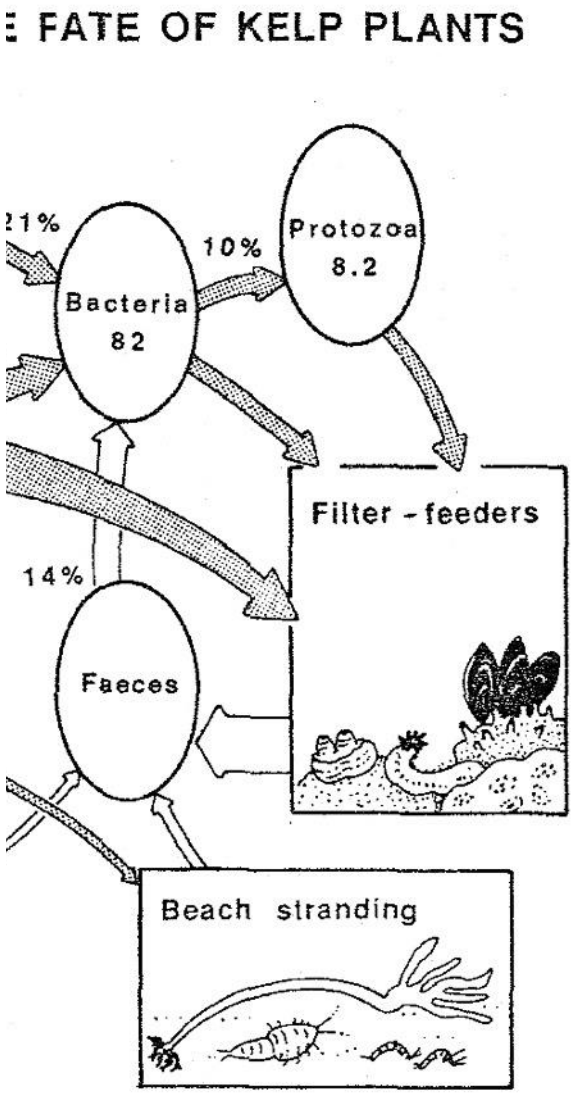


Ecological Importance: Primary Productivity



Ecological Importance: Primary Productivity



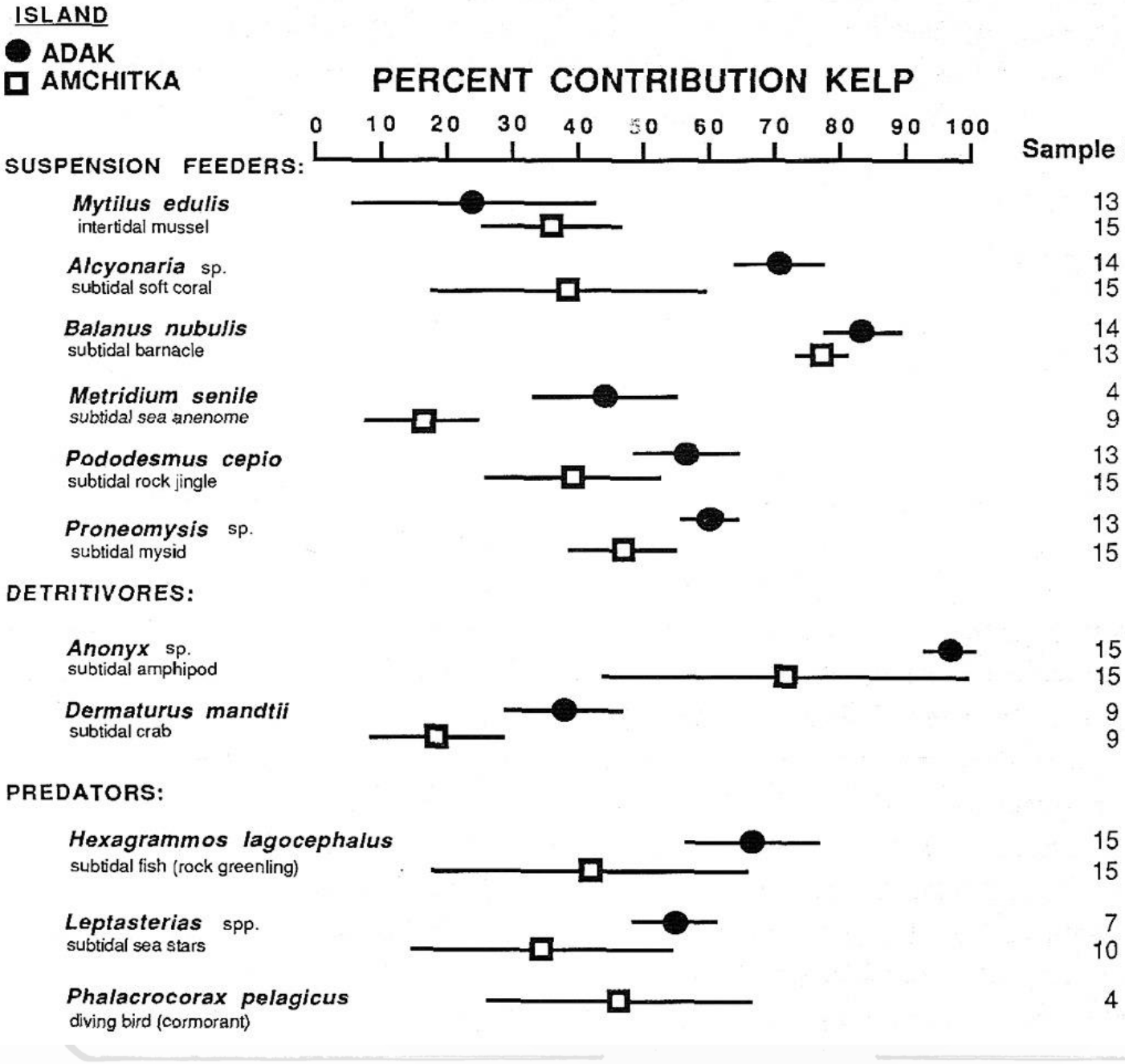


Ecological Importance: Primary Productivity

Kelp detritus is a major food source for residents of:

- Sandy beaches (Zobell 1971, Griffiths et al. 1983)
- Subtidal areas (Duggins et al. 1989)
- Offshore surface waters (Kingsford 1992)
- Submarine canyons (Harrold et al. 1998)
- Deep ocean (Lawson et al. 1993)
- Rocky intertidal areas (Tallis 2009)

Ecological Importance: Primary Productivity



Ecological Importance: Geomorphology

Dallas Bank, Protection Island, Strait of Juan de Fuca, May, 2009.
-35' (10m) MLLW

Kelp sporophytes, upon reaching a critical size can affect:

- Wave energy and distribution
- Substrate movement through saltation

Kelp as Source of Biomass for Energy Production

Figure 9: Scoubidou System Used in France *(CEVA)*

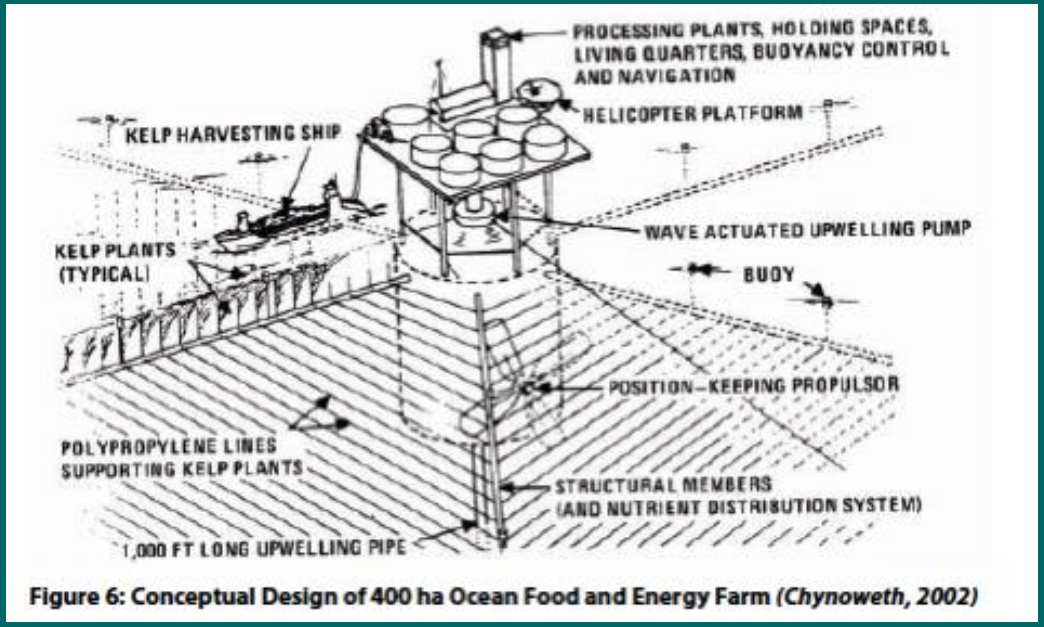


Figure 6: Conceptual Design of 400 ha Ocean Food and Energy Farm *(Chynoweth, 2002)*

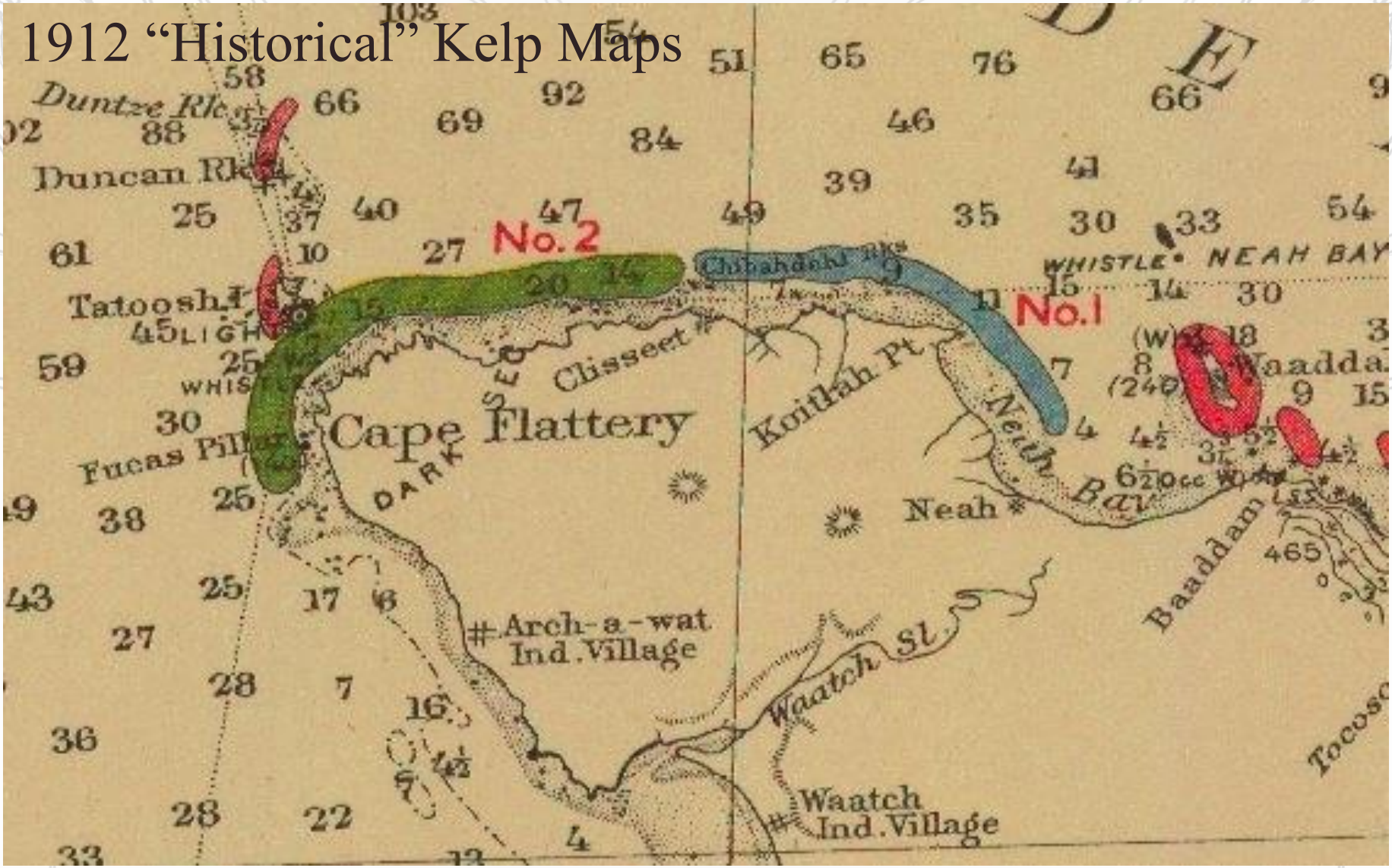
From: A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland February 2009. Report prepared for Sustainable Energy Ireland by:Tom Bruton, Henry Lyons Yannick Lerat, Michele Stanley, Michael Bo Rasmussen .

Harvest

- Kelp used for:
  - Human Food
  - Alginic Acid
  - Fertilizer
  - Animal fodder (incl. abalone
- Regulations
  - 10 lb wet weight
  - No commercial harvest

Trends in Kelp Distribution and Abundance

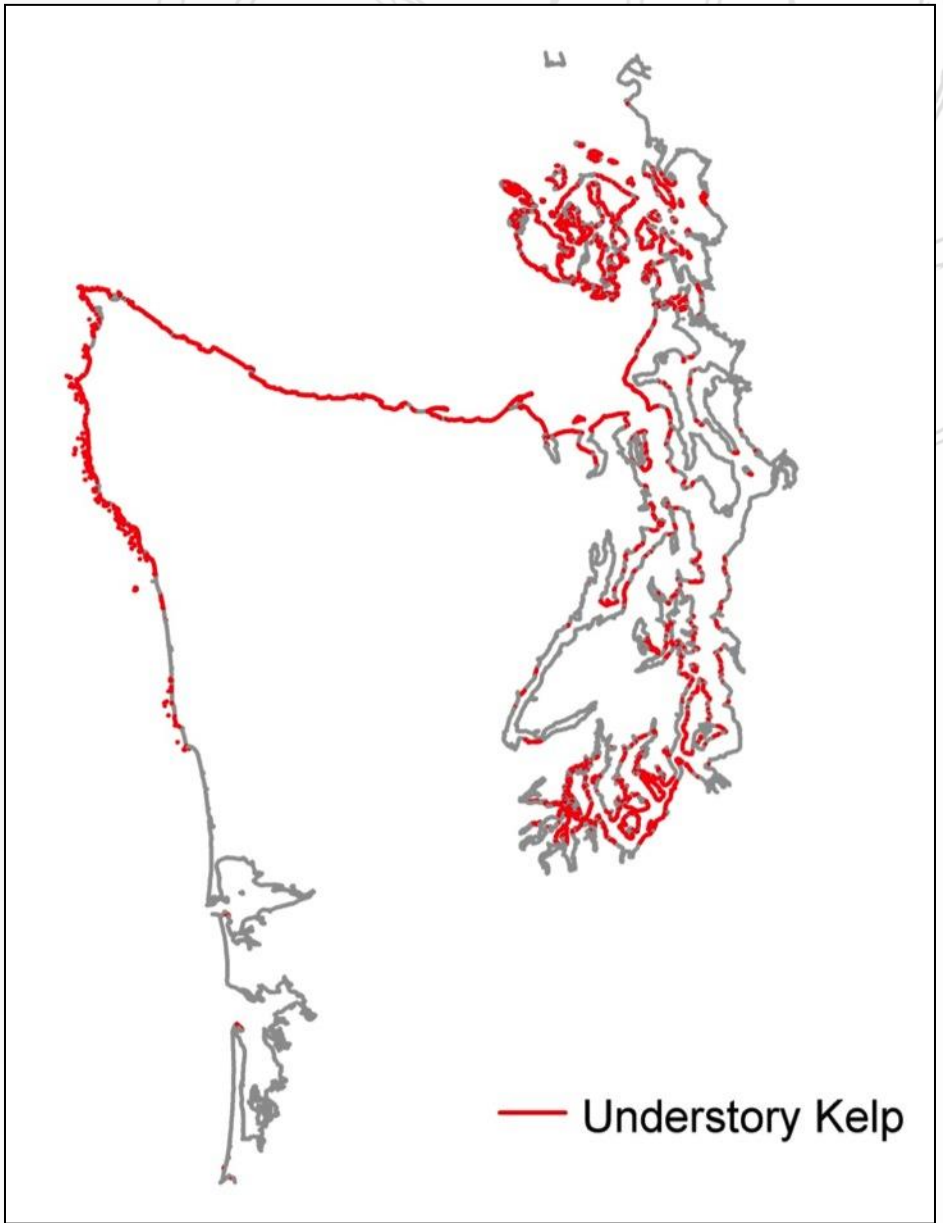
1912 "Historical" Kelp Maps



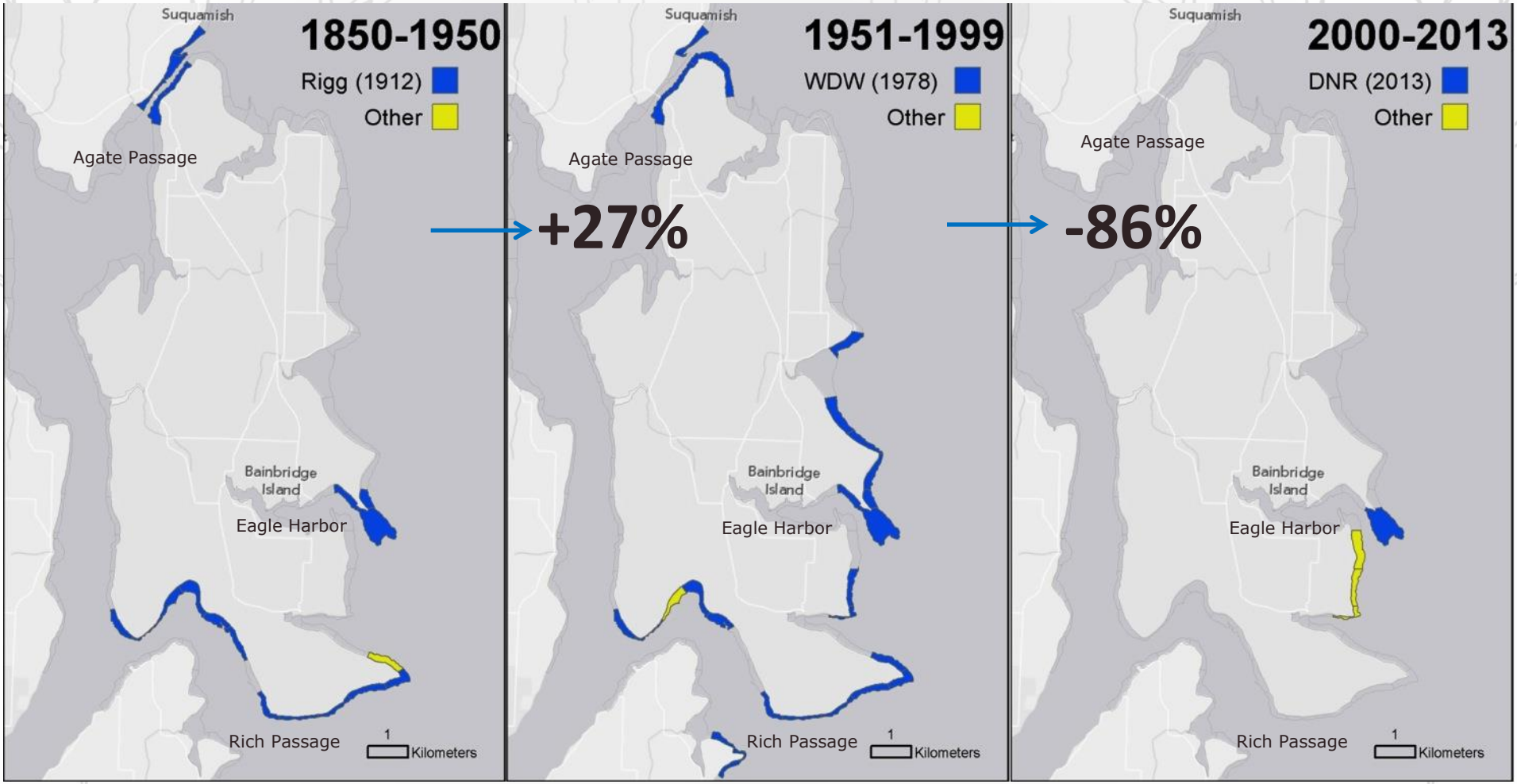
Cameron, F.K., 1912. Potash from Kelp. US Dept of Agriculture Report 100.

Rigg, G.B., 1911. Fertilizer Resources of the United States. US Senate Document 190.

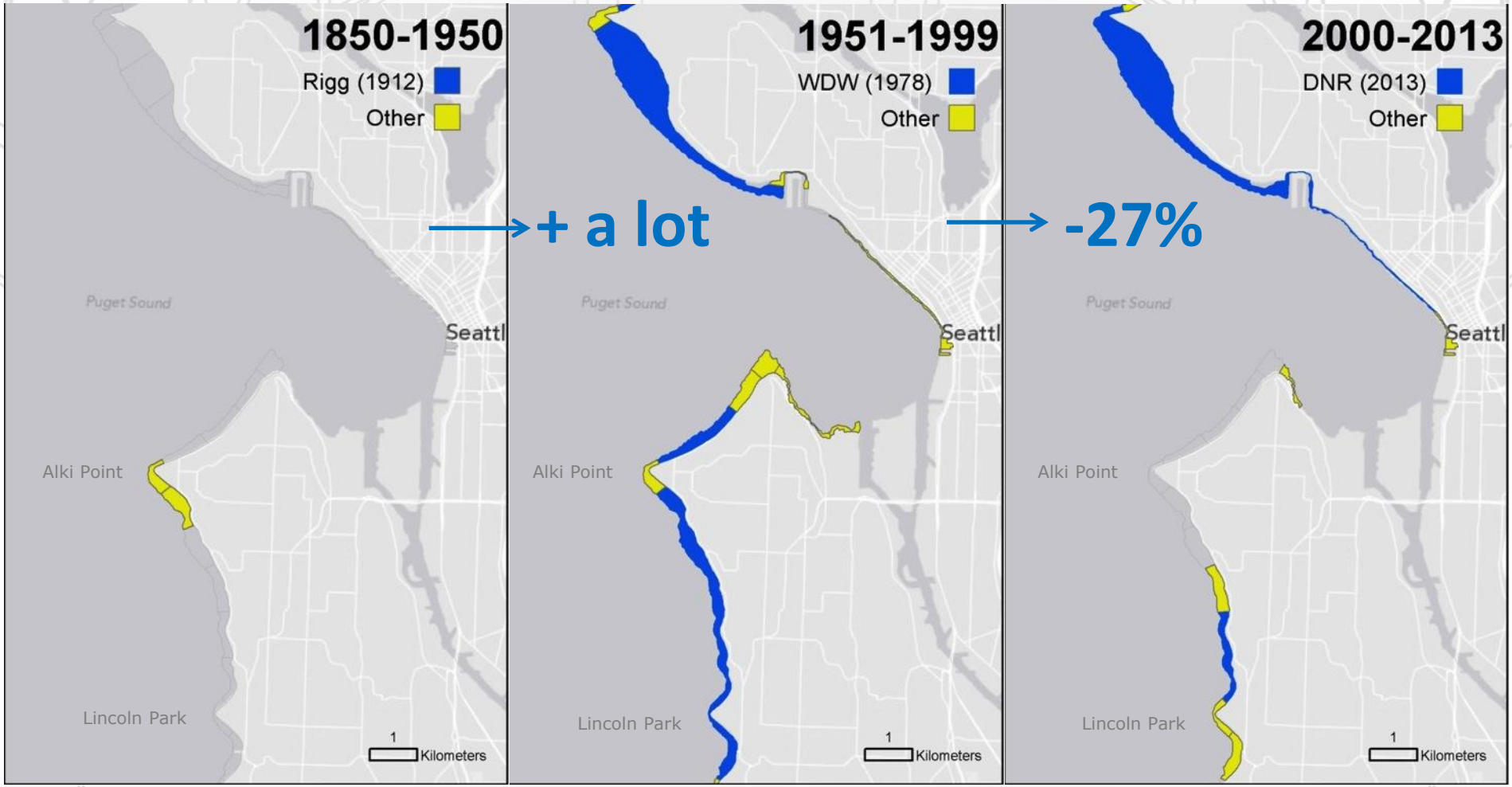
Floating kelp occurs along 11% of the shoreline, while understory kelp occurs along 31% of the shoreline (ShoreZone Inventory).



Central Puget Sound - West



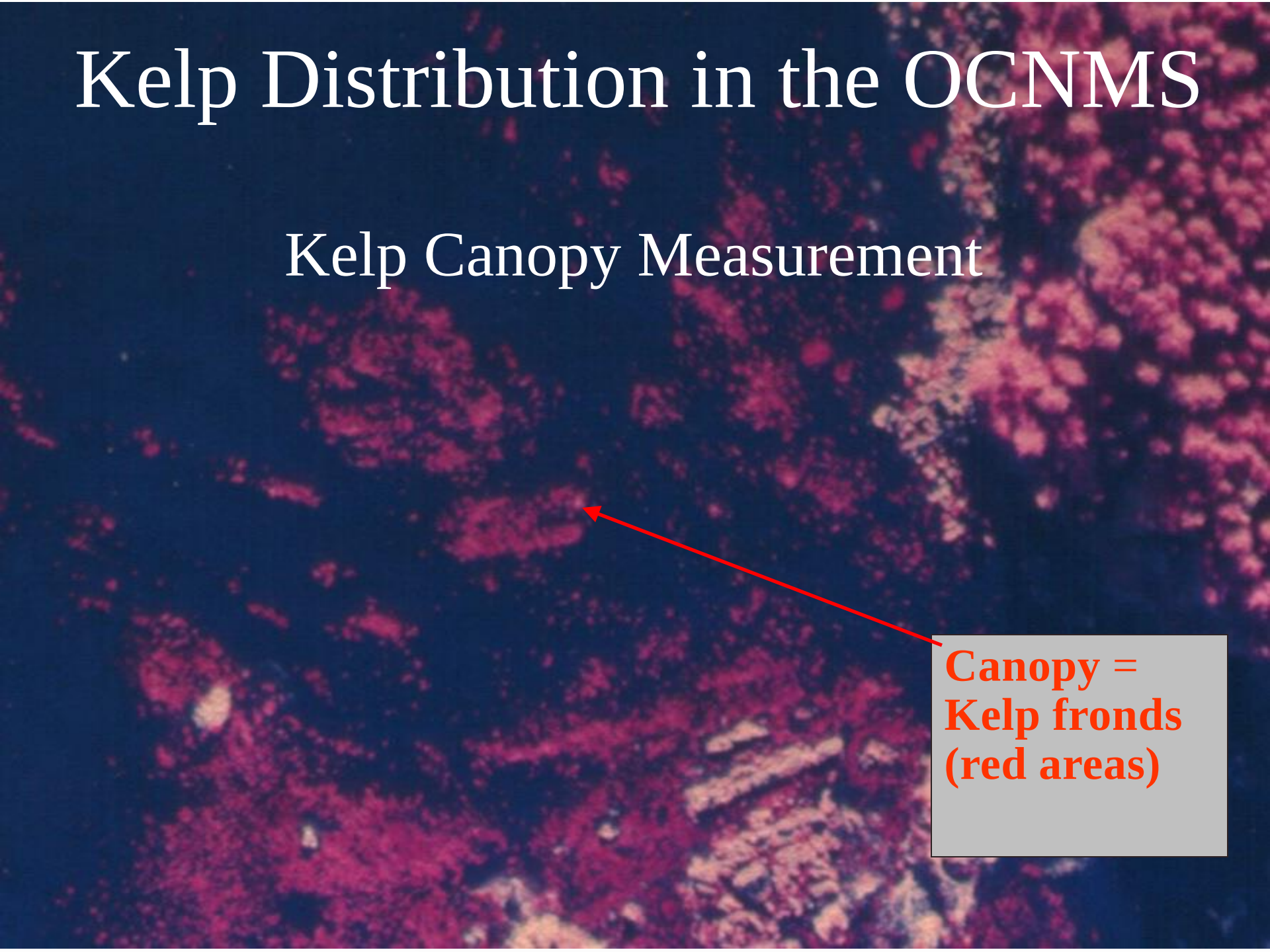
Central Puget Sound - East



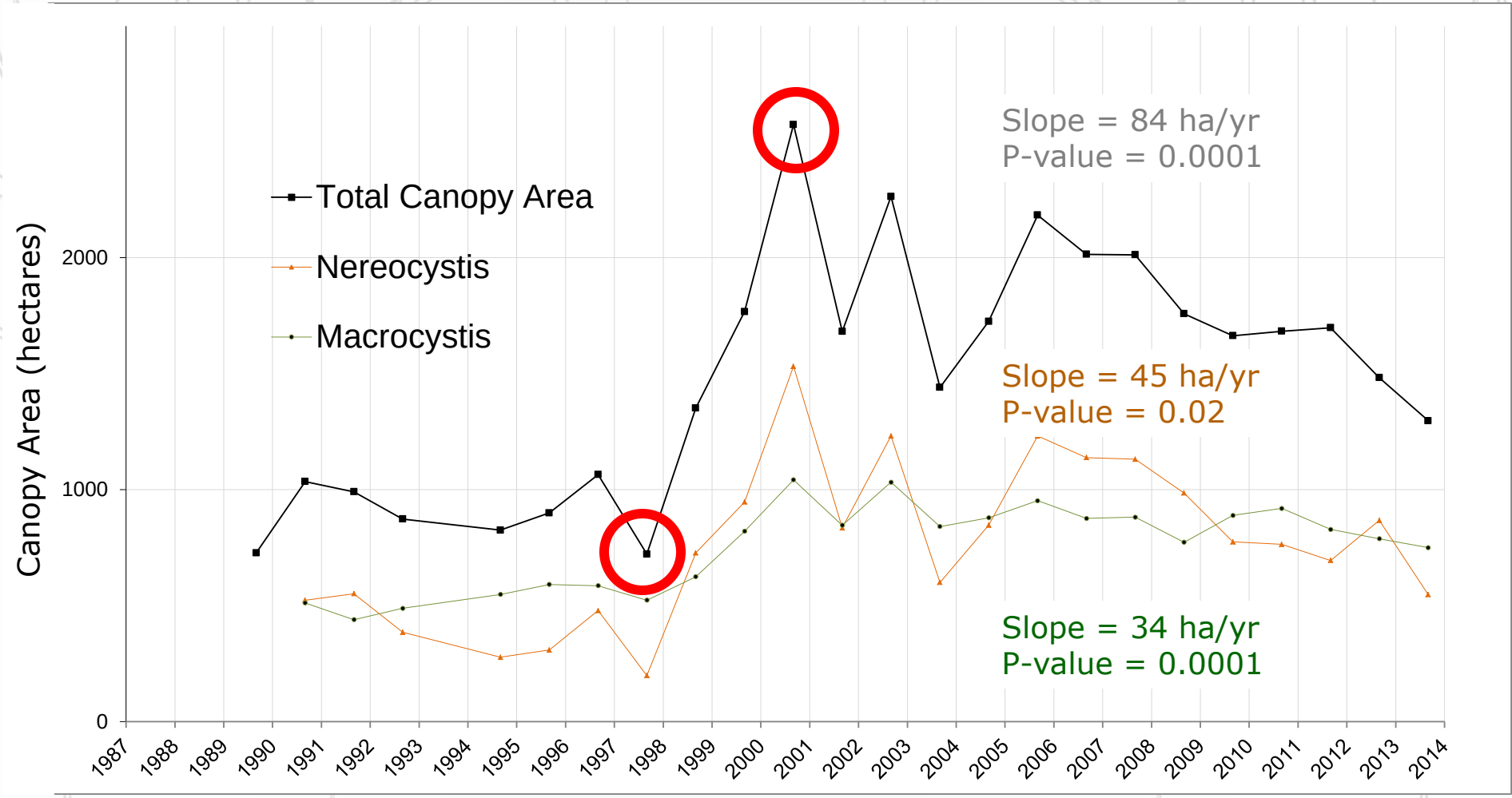
DRAYTON PASSAGE
Devils Head
NISQUALLY REACH
HENDERSON'S INLET
ORO BAY

Kelp Distribution in the OCNMS

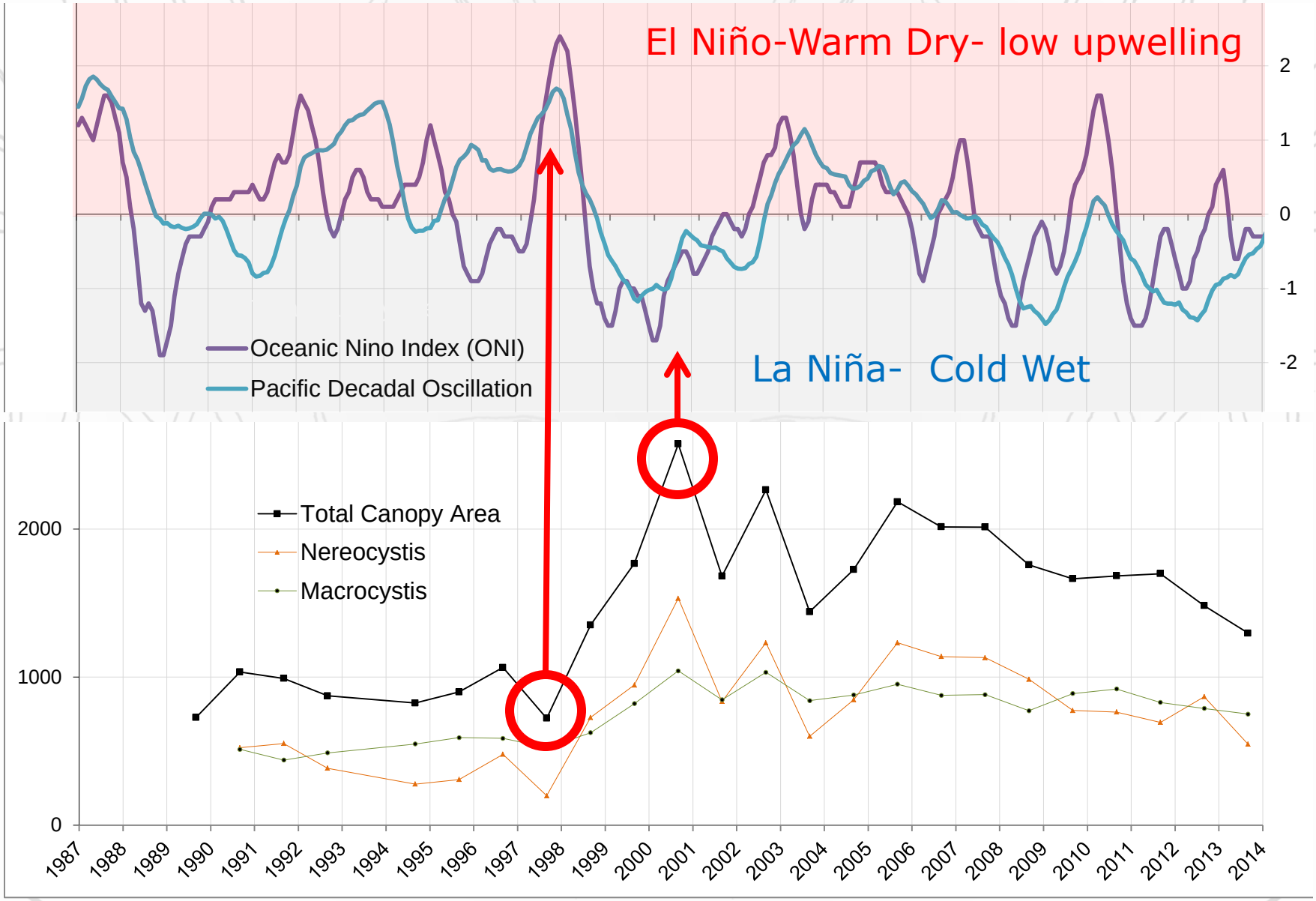
Kelp Canopy Measurement



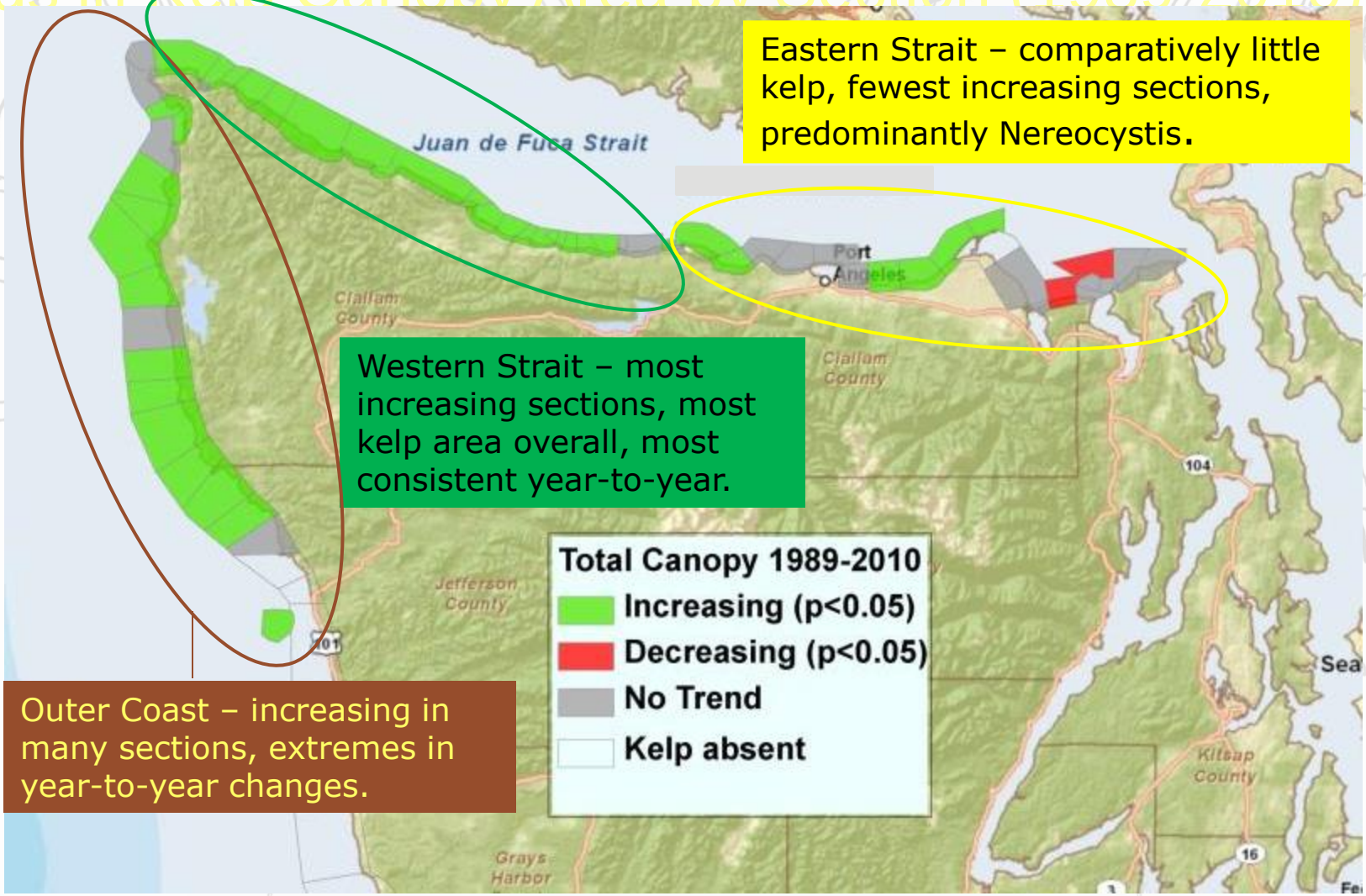
Kelp Canopy Area: WA Outer Coast and Strait of Juan De Fuca



Kelp Canopy Area and Climate Indices



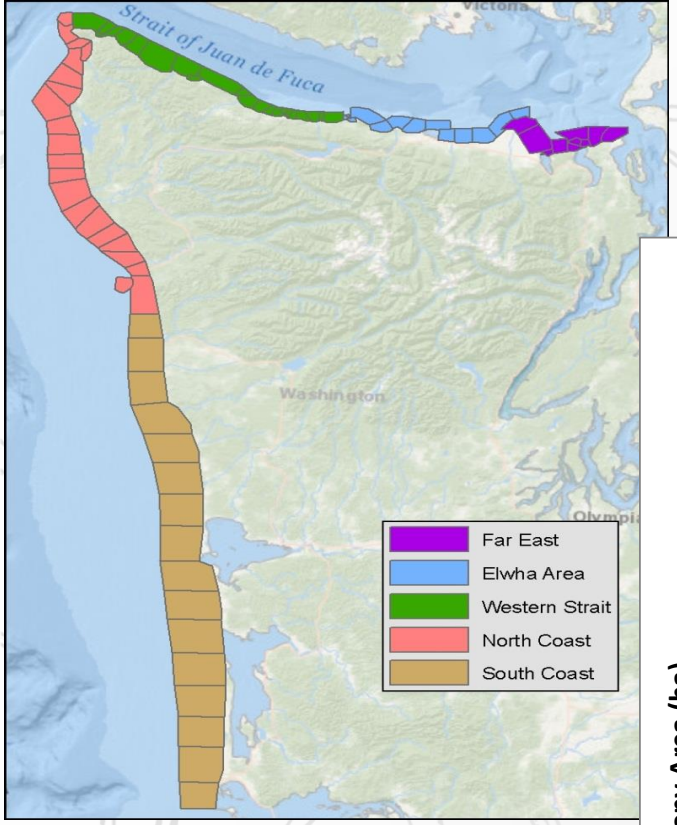
rends in Kelp Canopy Area by Section (1989-2010)

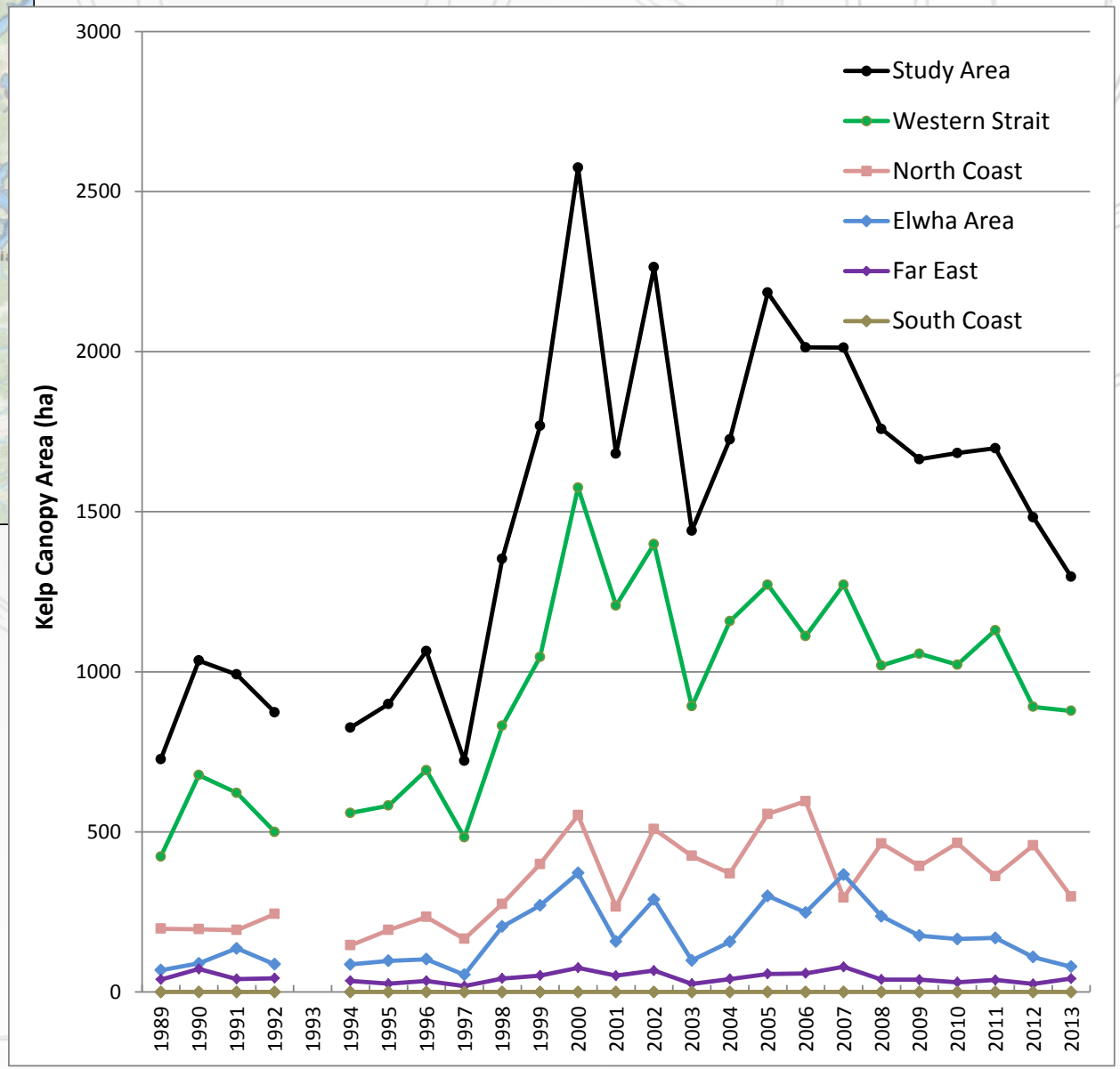


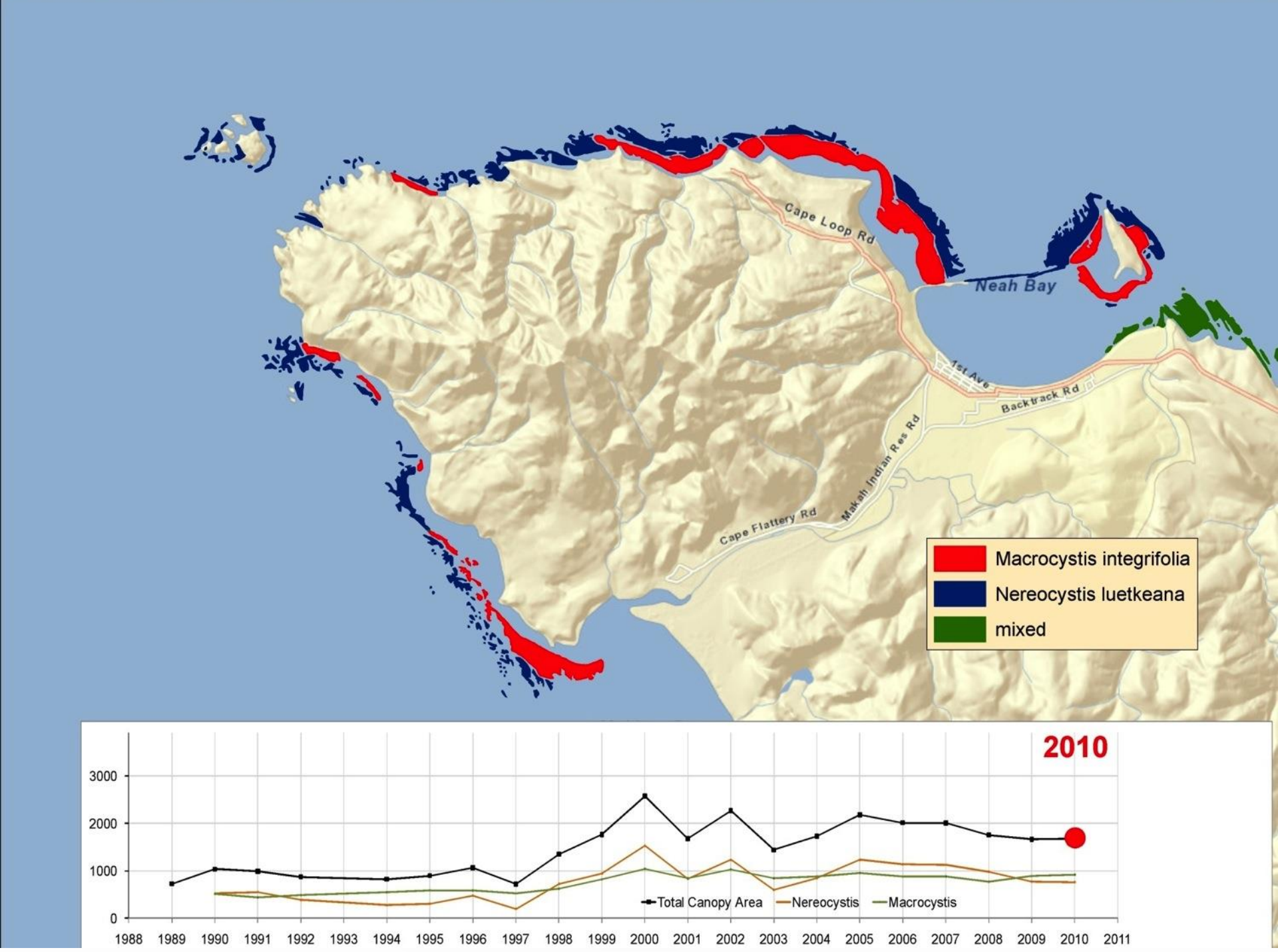
Eastern Strait – comparatively little kelp, fewest increasing sections, predominantly Nereocystis.

Western Strait – most increasing sections, most kelp area overall, most consistent year-to-year.

Outer Coast – increasing in many sections, extremes in year-to-year changes.


Strait of Juan de Fuca
Victoria
Washington
Olympia
Far East
Elwha Area
Western Strait
North Coast
South Coast

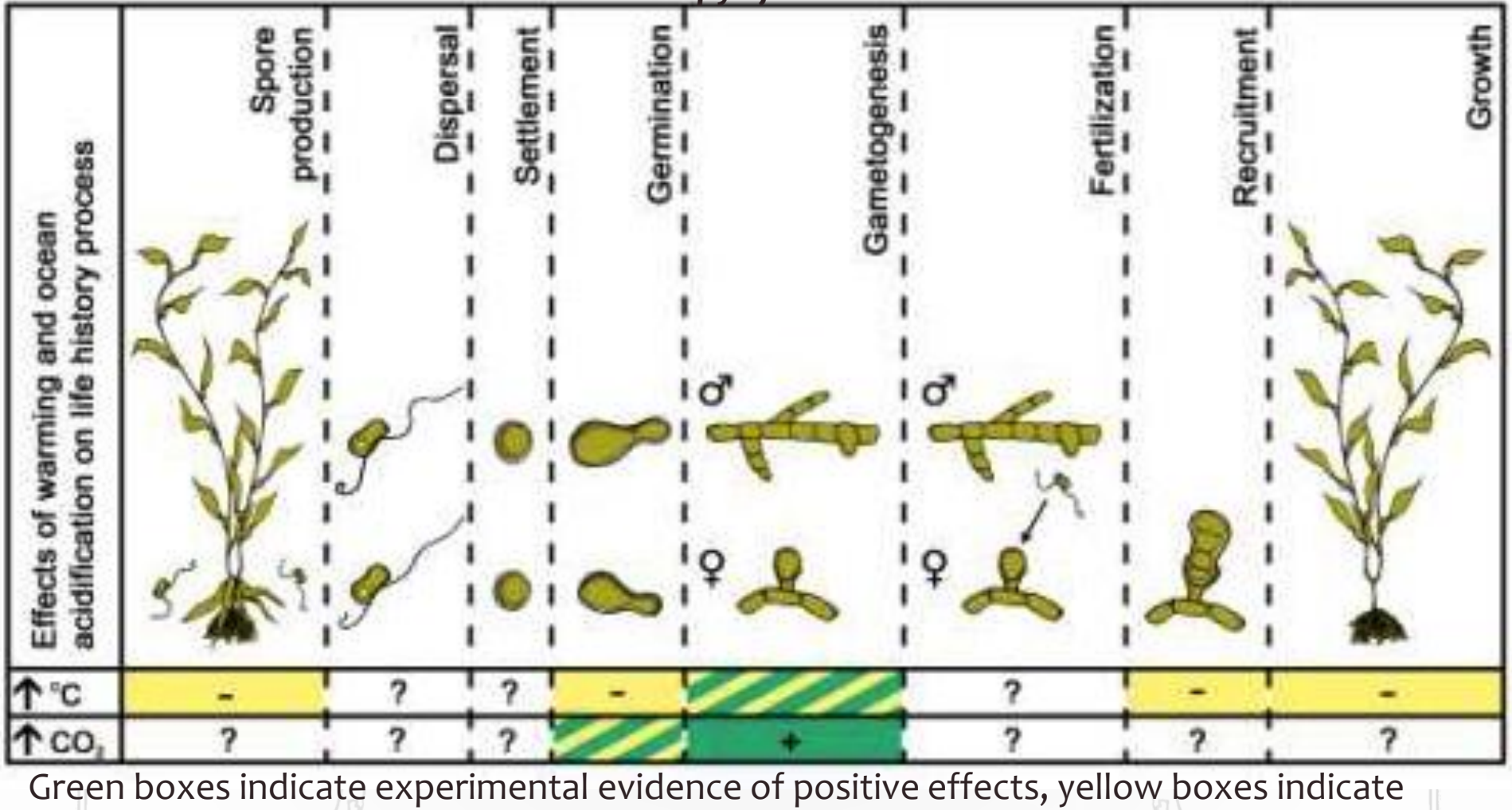

Kelp Canopy Area (ha)
3000
2500
2000
1500
1000
500
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Study Area
Western Strait
North Coast
Elwha Area
Far East
South Coast


Cape Loop Rd
Neah Bay
1st Ave
Backtrack Rd
Makah Indian Res Rd
Cape Flattery Rd
Macrocystis integrifolia
Nereocystis luetkeana
mixed
2010
3000
2000
1000
0
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Total Canopy Area
Nereocystis
Macrocystis

Global Climate Change Effects on Kelp

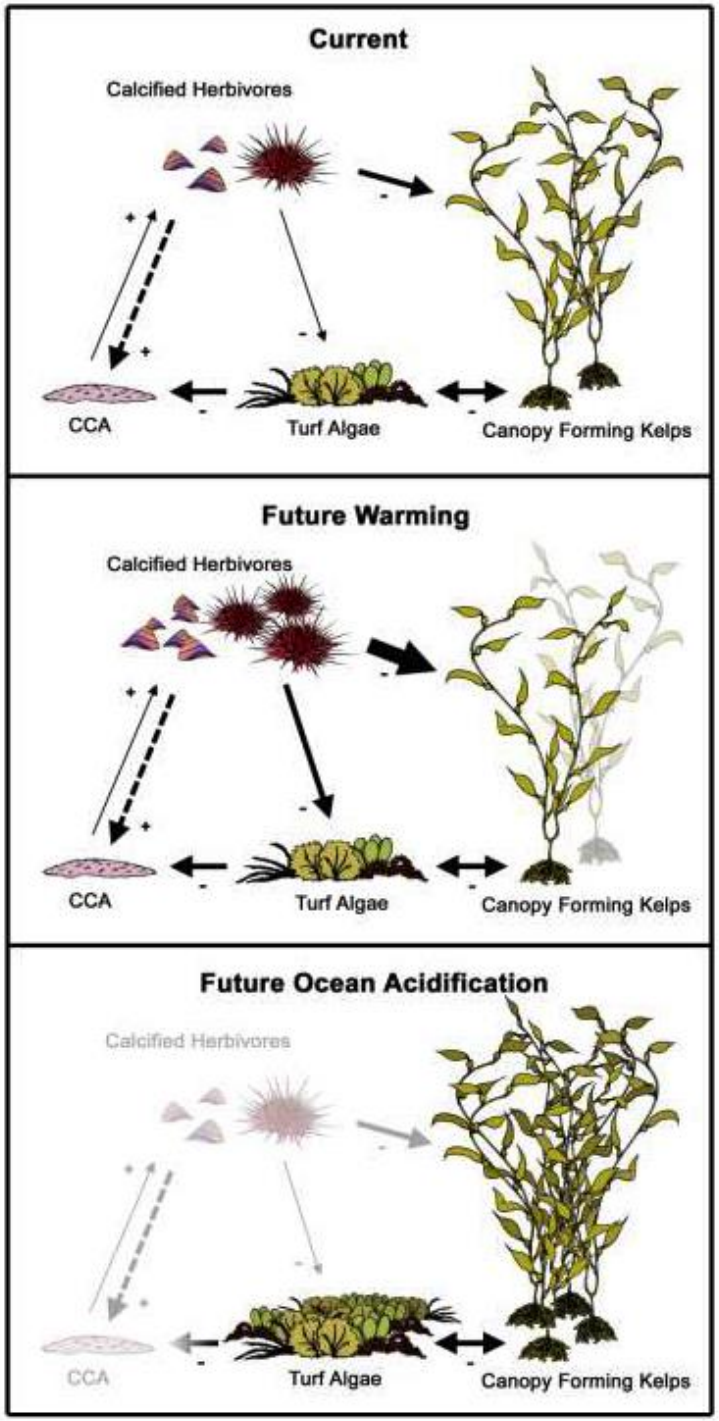
- Increasing sea surface temperature
- Acidification of ocean water
- Sea level rise
- Increasing frequency and severity of storms
- Changing ocean current patterns (including upwelling)
- Increasing occurrence of coastal hypoxia and anoxia
- Altered hydrologic patterns

Effects of increasing temperature and CO_2 on life history processes in *Macrocystis pyrifera*.



Green boxes indicate experimental evidence of positive effects, yellow boxes indicate negative effects, hatched boxed indicate both positive and negative (i.e. context-specific) effects, and blank boxes represent unquantified responses owing to a lack of published information.

Harley, C. D. G., K. M. Anderson, K. W. Demes, J. P. Jorve, R. L. Kordas, T. A. Coyle, and M. H. Grahan
Effects of Climate Change on Global Seaweed Communities. Accepted for publication in J. Phycolog
August 2012.



Future ecological scenarios for temperate kelp forests.

Solid and dashed arrows represent direct and indirect effects of one species on another, respectively (the flow of energy via trophic interactions is omitted for clarity). Faded icons represent functional groups that may still be present but play a strongly reduced ecological role. Relative to present-day conditions (upper panel), future warming (middle panel)will favor grazers and have direct and indirect negative impacts on canopy-forming kelps. Future increases in CO_2(lower panel) will have strong negative effects on crustose coralline algae (CCA) and positive effects on non-calcified seaweeds both directly via improved growth and indirectly via reduced consumption by calcified herbivores. The combined impacts of simultaneous warming and acidification in a more realistic climate change scenario remains poorly understood.

Harley, C. D. G., K. M. Anderson, K. W. Demes, J. P. Jorve, R. L. Kordas, T. A. Coyle, and M. H. Graham. Effects of Climate Change on Global Seaweed Communities. Accepted for publication in J. Phycology, August 2012.

Effects of Sediments and Sediment Transport on Kelp

Canopy-forming Kelp Distribution Near Elwha River

Floating Kelp Canopy Area Changes Following Elwha Dam Removal in fall 2011
-53% (2011-2013)

Crescent Bay -54%

Tongue Pt – Observatory Pt -42%

Freshwater Bay -74%

Angeles Point – Elwha Bluffs -100%

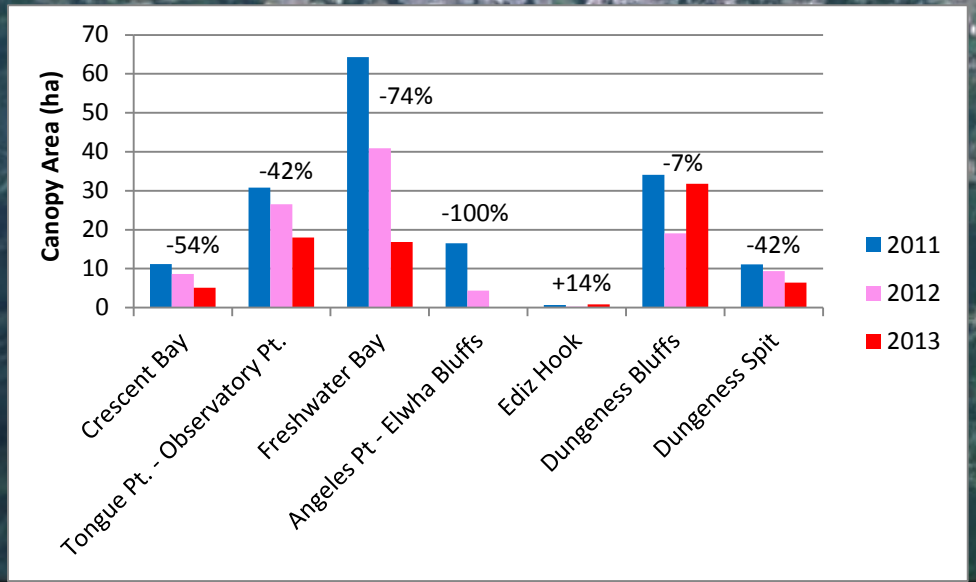
Ediz Hook +14%

Dungeness Bluffs -7%

Dungeness Spit -42%

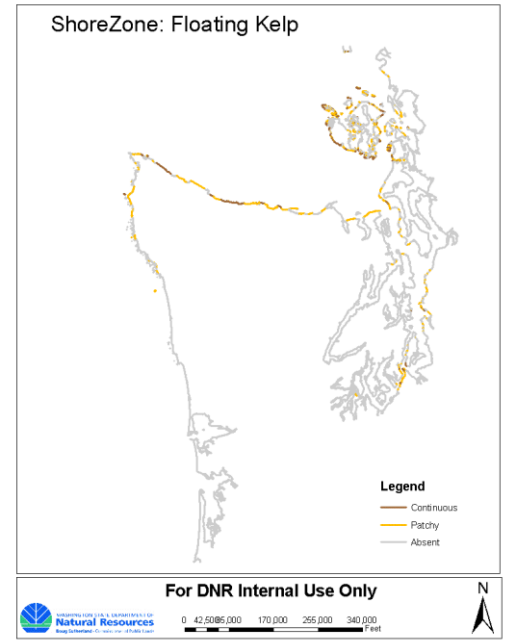
Floating Kelp

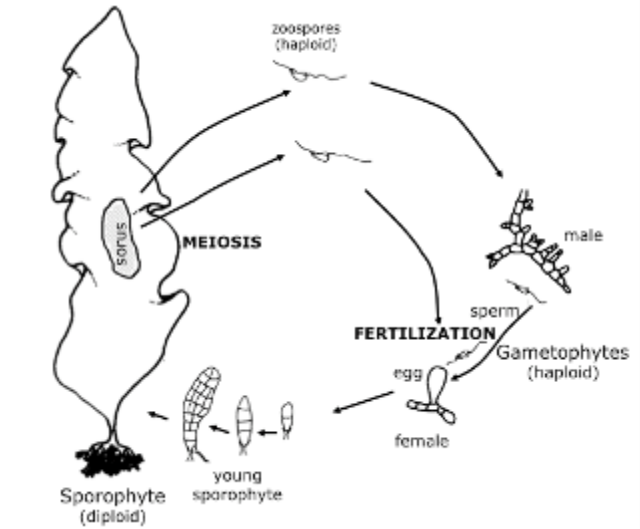
- 1989 - 2010
- 2011
- 2012
- 2013



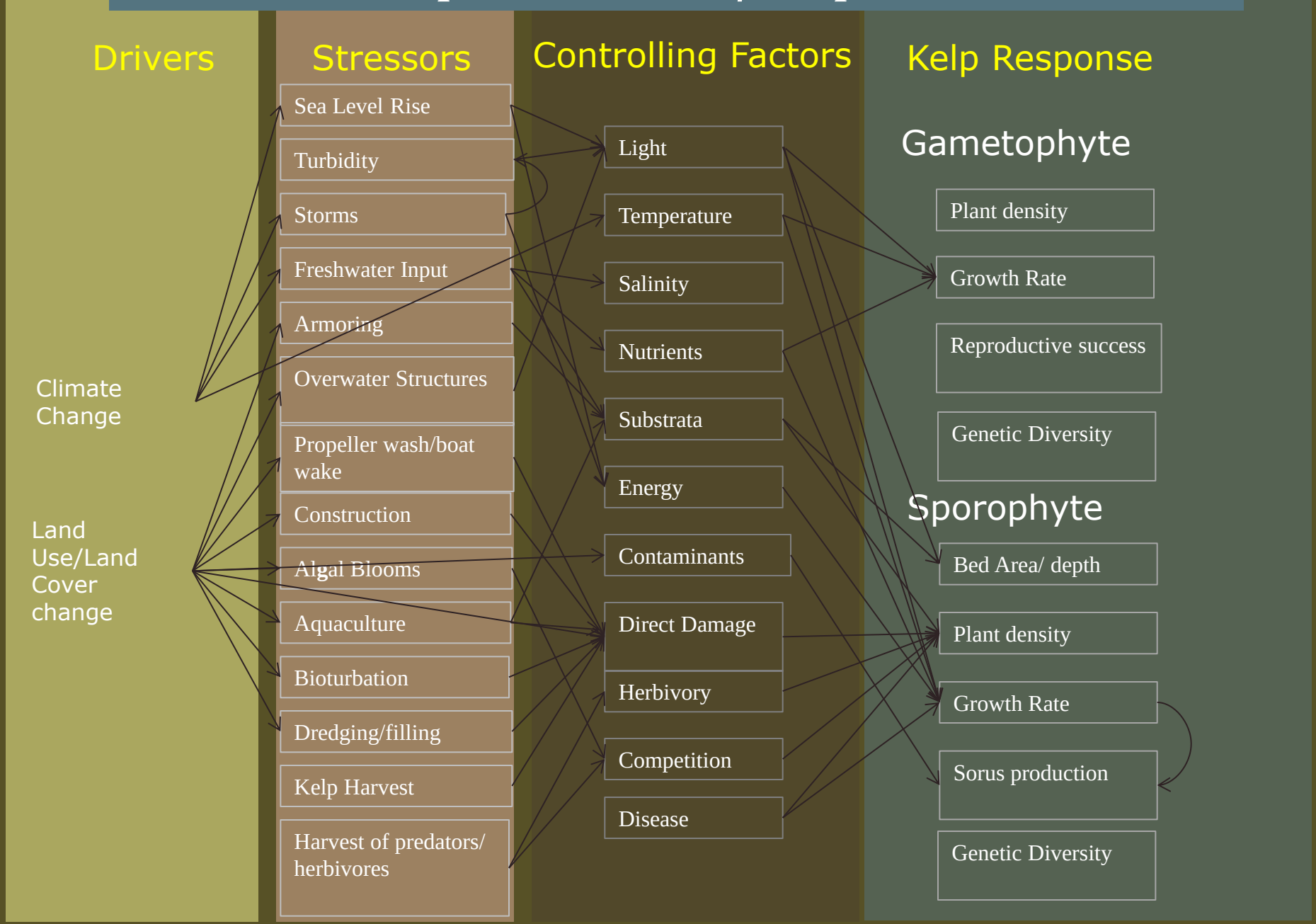
Kelp Losses

- Hypothesized stressors could include:
  - Water quality
  - Change in light availability (turbidity, docks)
  - Substrate- too small, silted over
  - Sea urchin or kelp crab abundance
  - Change in of sea cucumber abundance
  - Cyclic shifts in algal community structure toward climax species.
  - Climate change
- Hypothesized factors leading to changes in kelp abundance are likely to differ among regions.
- Factors leading to change in sporophyte abundance may be due to impacts to gametophyte phase.





Conceptual Model of Kelp Stressors



The Sea Otter/Urchin/Kelp Story

Sea

Otters come back

Sea otters are rebounding in Washington state, leading to conflicts with shellfish fishermen. Wiped out by fur traders a century ago, the mammals were re-established with otters transplanted from Alaska.

Sea otter

- With no blubber to insulate them from cold water, sea otters must keep their fur groomed to preserve body heat.
- Sea-otter fur has up to 650,000 hairs per square inch.
- Male sea otters average 85 pounds and nearly 5 feet long.
- River otters, sometimes seen on Olympic beaches, are much smaller – less than 25 pounds.

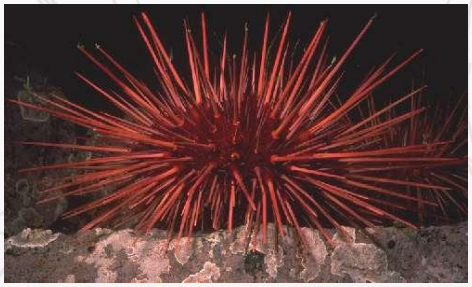
Source: Washington Department of Fish and Wildlife

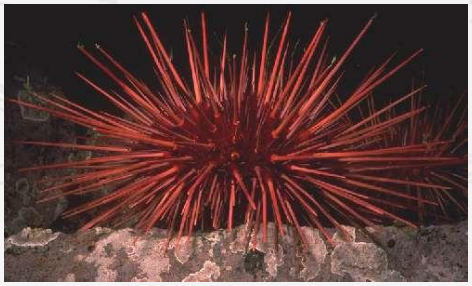
THE SEATTLE TIMES

Kelp and Urchins

Some references: Estes & Palmisano (1974), Duggins (1980), Foster & Shiel (1988), VanBlaricom & Estes (1988).

Kelp and Urchins



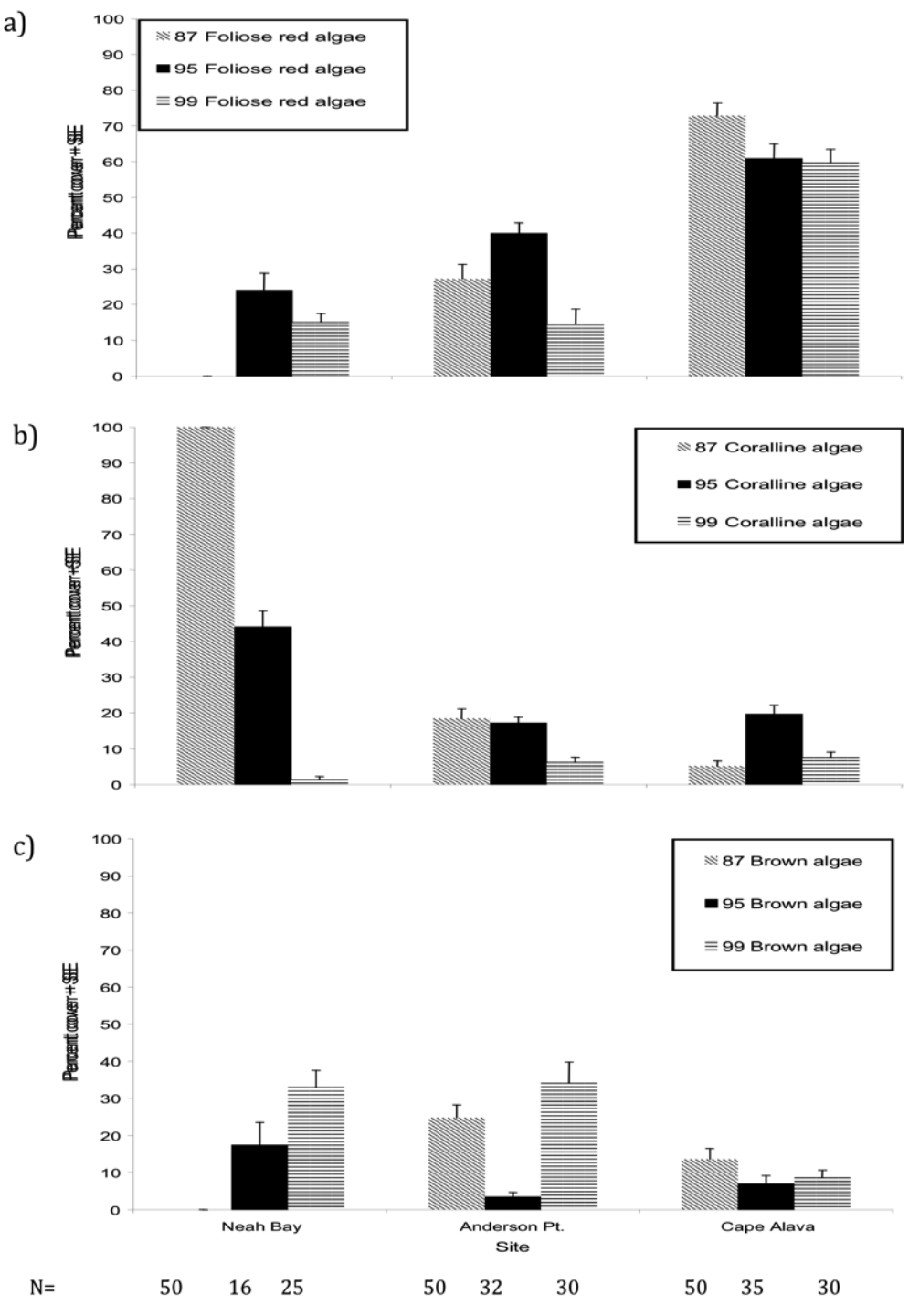


Some references: Estes & Palmisano (1974), Duggins (1980), Foster & Shiel (1988), VanBlaricom & Estes (1988).

Kelp and Urchins

Some references: Estes & Palmisano (1974), Duggins (1980), Foster & Shiel (1988), VanBlaricom & Estes (1988).

Figure 3. Changes in percent foliose red, coralline and brown algal cover following sea otter expansion from 1987 to 1999. N = number of 0.25m² quadrats



Kvitek, R. G., P. J. Iampietro and K. Thomas. 2000. Changes in sea otter benthic prey and algal communities within the Olympic Coast National Marine Sanctuary: 1999 re-survey of 1995 and 1985 monitoring stations . Final Report to Olympic Coast National Marine Sanctuary. Unpublish. Mss.

Kelp in the Regulatory World

- Harvest regulations
- Permits to Grow
- Protection under CAO, SMA, HPA, etc.

RCW 77.08.010 (48) "**Seaweed**" means marine aquatic plant species that are dependent upon the marine aquatic or tidal environment, and exist in either an attached or free floating form, and includes but is not limited to marine aquatic plants in the classes Chlorophyta, Phaeophyta, and Rhodophyta.

Current Regulatory Protections

- **Hydraulic Code Rules-** WAC 220-110-250 Saltwater habitats of special concern.
- **Shoreline Management Act**
- **Critical Areas Ordinances-**
- **Fish and Wildlife Habitat Conservation Areas**
- **WDFW Priority Habitats**
- **WAC 173-26-221 General master program provisions**
- **Corp's Regional General Permit 6 (overwater structures) and proposed NWP 48 (shellfish aquaculture)**
- **Washington Dept. of Natural Resources- Habitat Conservation Plan- all 24 species**

Kelp is well protected

Kelp and Fisheries

- Direct association- habitat or behavior
  - Ask anybody who fishes....
    - Rockfish
    - Salmon
- Indirect Associations
  - Base of food web
  - Spawning substrate- herring
  - Refuge from predation
  - Critical Habitat for juveniles
    - ESA listing of canary and bocaccio rockfish

Endangered and Threatened Species; Designation of Critical Habitat for Yelloweye Rockfish, Canary Rockfish and Bocaccio of the Puget Sound/Georgia Basin.

A Proposed Rule by the National Oceanic and Atmospheric Administration on 08/06/2013 (78 FR 47635)

Physical and Biological Features Essential to the Conservation of Juvenile Canary Rockfish and Bocaccio

Juvenile settlement habitats located in the nearshore with substrates such as sand, rock and/or cobble compositions that also support **kelp (families Chordaceae, Alariaceae, Lessoniacea, Costariaceae, and Laminaricea)** are essential for conservation because these features enable forage opportunities and refuge from predators and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats

OCNMS Final Management Plan and Environmental Assessment

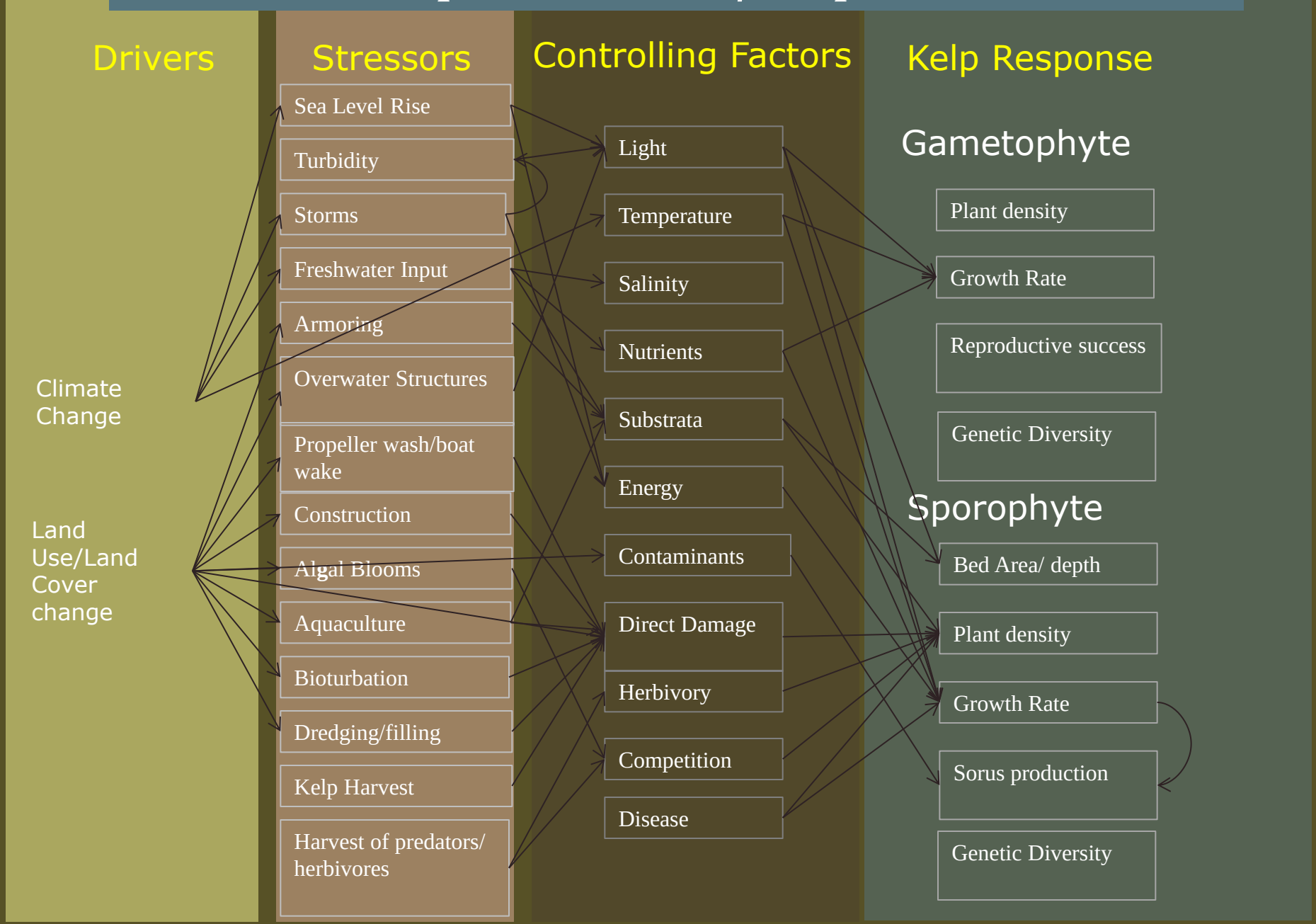
September 2011

Strategy HP1: THREAT ASSESSMENT AND MITIGATION

Assess existing and potential natural and human-caused **threats** to physical and biogenic marine habitats (e.g., deep sea corals and sponge, **kelp and other macroalgae**), and collaboratively **develop appropriate management measures** to protect and conserve physical and biological habitats.

- Activity A: Identify in consultation with co-management authorities, existing and potential **impacts and threats** to, as well as relative vulnerability of, physical and biogenic marine habitats in the sanctuary. Recommend and/or implement **monitoring** to assess relative habitat vulnerabilities to, and impacts and threats from natural disturbances and human activities, including **cumulative impacts**.
- Activity B: Recommend, or implement collaboratively with co-managers, **management measures** minimizing and mitigating human-caused impacts to physical and biogenic marine habitats.
- Activity C: **Monitor** the recovery rates of habitats, associated biological communities, and habitat-forming biogenic structures following disturbance by human activities.

Conceptual Model of Kelp Stressors



Management Recommendations

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Why

"In the middle"
Responds to a variety of stressors
Provides biogenic habitat
High primary productivity- food web support
Widely monitored elsewhere so it has excellent context

What to do…

Use DSCR conceptual model to craft monitoring plans

Continue floating kelp monitoring

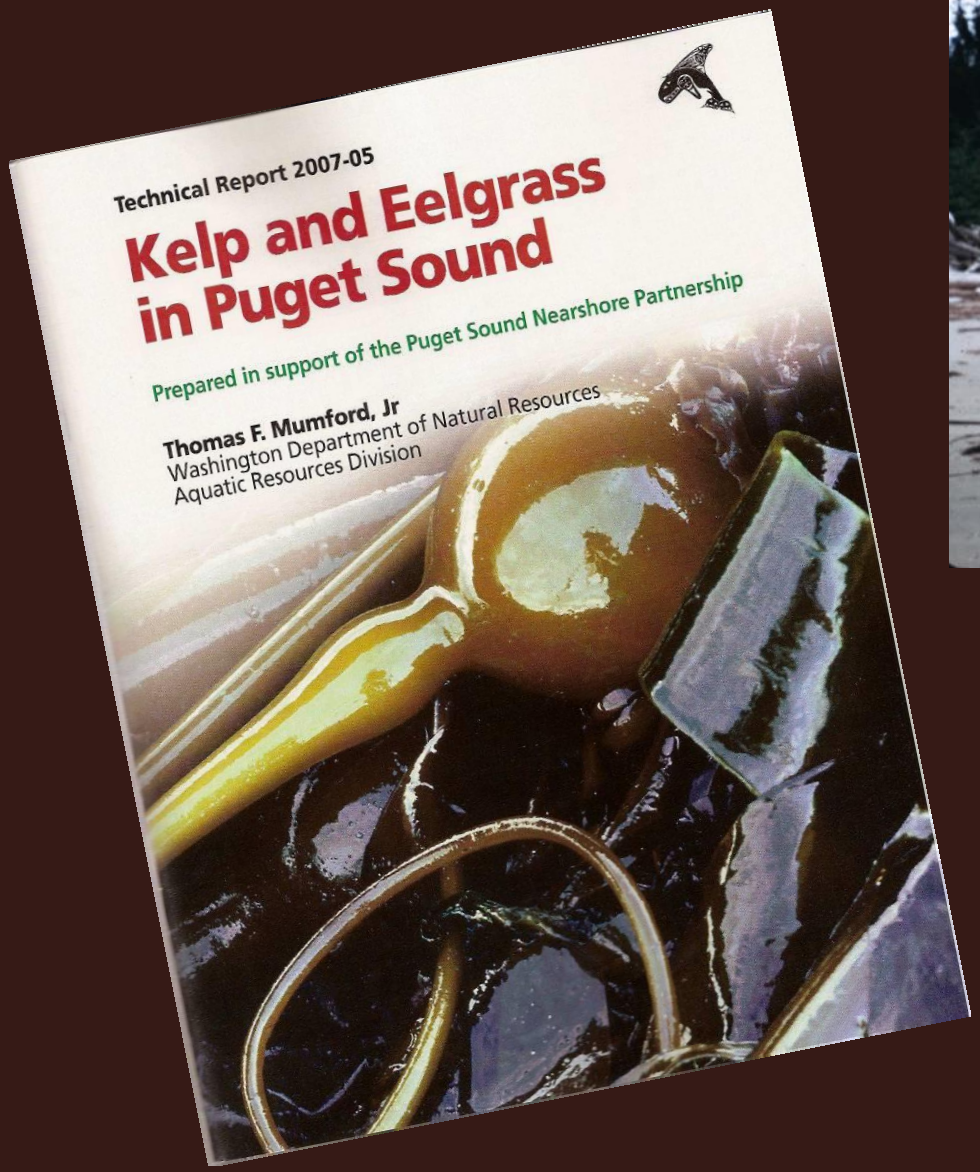
Expand monitoring to map and track sub tidal non-floating kelp

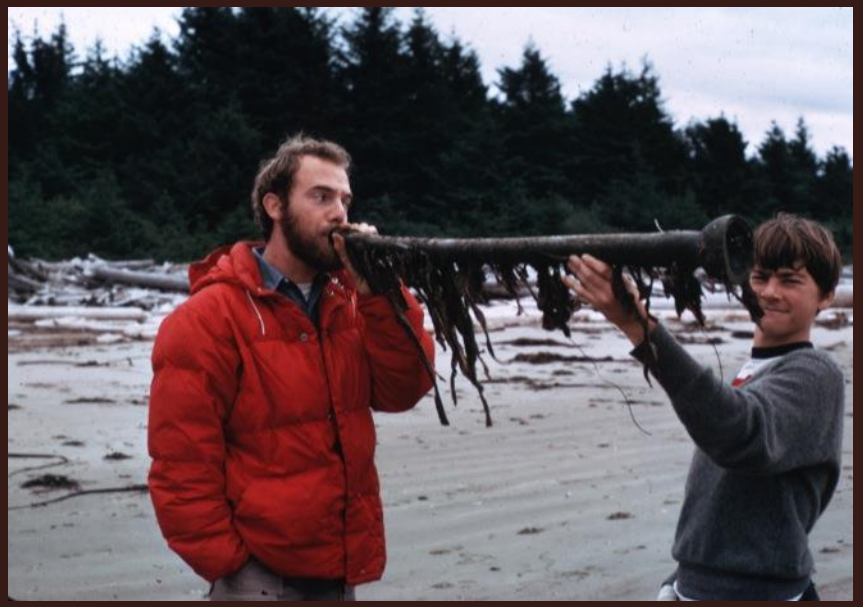
Determine changes of kelp beds at La Push

Collaborate with rockfish habitat researchers

Research kelp contributions to off-shore deep water ecosystem

Prepare to respond to oil spills





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http://www.pugetsoundnearshore.org/technical_papers/kelp.pdf