What is *Zostera japonica* and Where did it come from?

James Kaldy, US EPA – Western Ecology Division

With contributions from

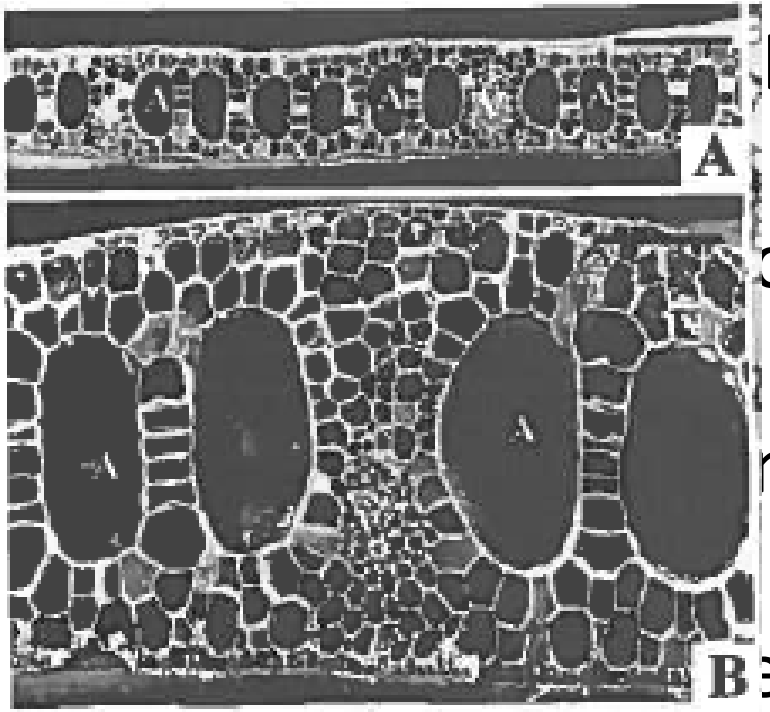
Norio Tanaka, Tsukuba Botanical Garden, Tokyo

Photo by J. Gaeckle

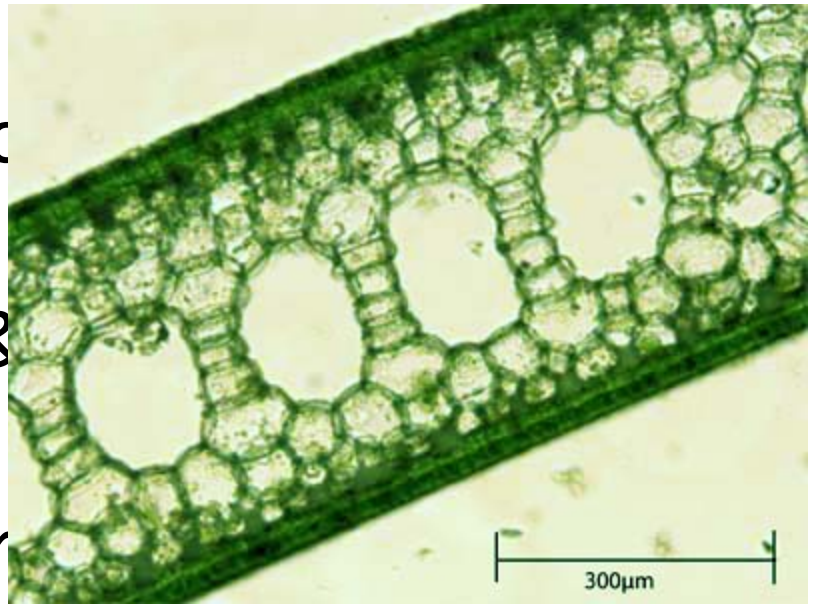
Presentation format

- Seagrass 101- introduction to botany
- Seagrasses of Washington State
- *Zostera japonica* introduction
- *Z. japonica* current distribution (vector)
- Z. japonica vertical zonation
- Potential future distribution

rass 101



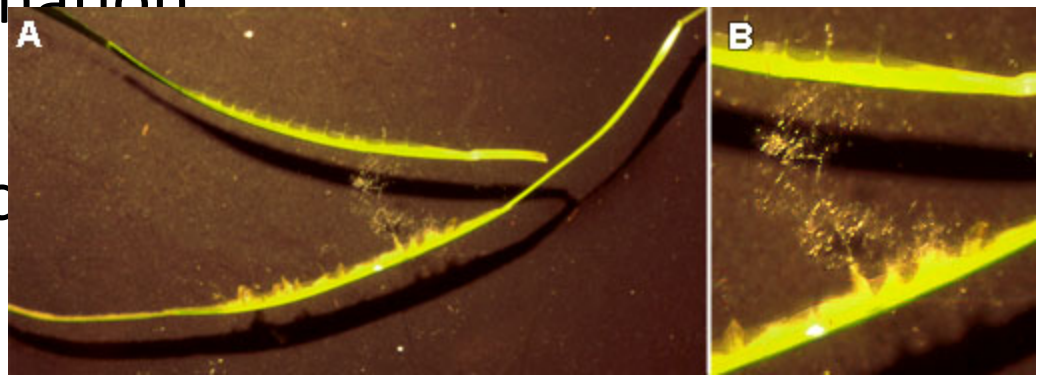
onoc



ms &

envir

- Obligate halophytes (salt water)
- Hydrophilous pollination
- Flexible strap-like l
- Continuous aerenc



Estuarine Ecosystem Services

This fisherman took advantage of a break in the weather to launch from South Beach Marina to set some herring nets in Yaquina Bay. The season, which began Feb. 13, has 10 permit holders vying for 139 tons of herring. (Photo by Clark Gallagher)

Herring arrive in Yaquina Bay

de, sometimes as far inland as
bend.
hones said their numbers are
ut equivalent to last year, but
r than the year before. But it's
s good as the peak years." He
that in 1987, the herring in
ina Bay totaled about 1,200

adison was a little less opti-
c. "It's not a real big spawning
t," he said Tuesday. "We're
ng there will be another run"
re the season is over for the

e big unknown is the ocean
f. Schones noted that "it's been
od ocean for foraging fish" this
year or two, but Madison said
the details of what happens to
herring in the ocean remains
ely unknown.
ast year, ODFW brought in the
pany Biosonics to conduct an
ustic survey of the run in the
, to get a clearer picture of its
. This year, with the state fiscal
crisis, that is not happening.
"We're not able to do a really
accurate survey of it now," Madison
said. "We're doing the best we
can."

Spawned herring eggs on Zostera marina
Photo: WDFW

not die after spawning, but return to
said that while they are in the bay,
they go up and down the river with

The Problem

Fig. 2. Global map indicating ch
or increasing (green) when areal
131 sites in North America, 34 sit

declining (red)
ea. There were

ECOLOGY

Waycott et al. 2009

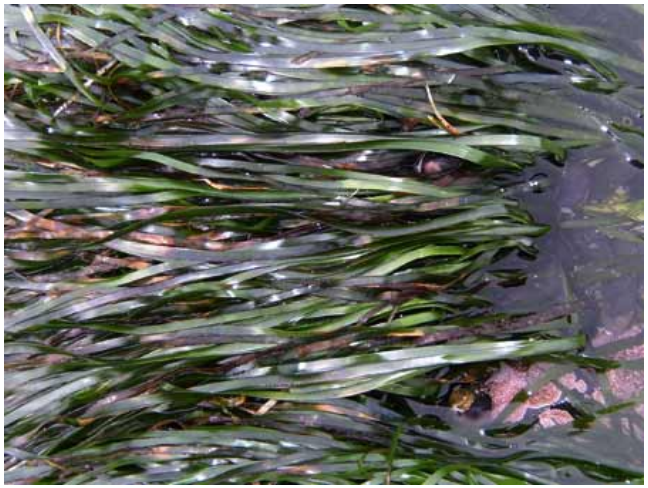
Seagrasses of Washington State

Zostera marina L.

Z. japonica Aschers. & Graeb.

Ruppia maritima L.

Phyllospadix torreyi Watson



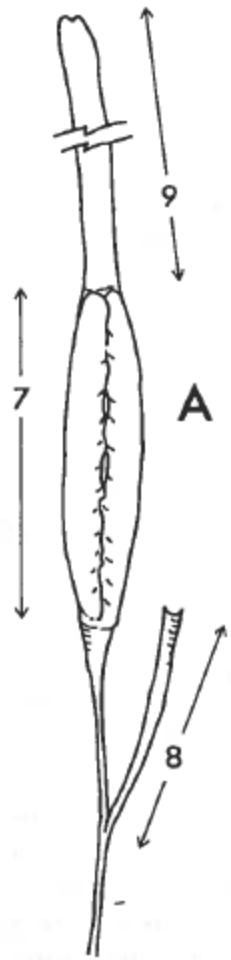
P. Scouleri Hooker

P. Serrulatus
Ruprecht ex Aschers.

Morphological Characteristics of

"The use of characteristics, such as the shape of the leaf tip and the shape of the retinaculum, to separate species of *Zostera* should be discouraged. There is much variability observed from place to place , across tidal zones, and with the age of the plant. Experimental techniques using controlled growth to define seagrass species should be discouraged." Phillips & Menez 1988

"The failure of leaf tip morphology to separate these three species is further evidenced by the fact that Hartog's "*Z. americana*" (putatively separable from *Z. japonica* by leaf tip morpholgy) was later considered identical to *Z. noltii* (Phillips and Shaw 1976), but eventually determined to represent introduced plants of *Z. japonica* (Bigley & Barreca 1982, Harrison and Bigley 1982)." Les et al. 2002



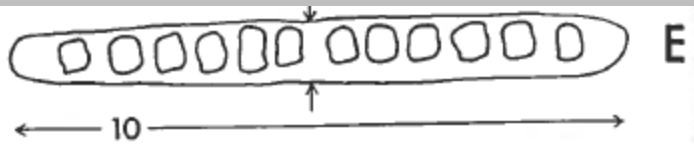


Fig. 1. Characters used to differentiate *Zosterella* taxa. A. Flowering shoot showing generative leaf, spathe, and prophyllum. B. Spadix showing the positions of retinacula and female flowers; male flowers have been omitted. C. Retinaculum. D. Spathe cross-section. E. Generative leaf cross-section. Numbers refer to character numbers from Table I. Drawings not to scale.

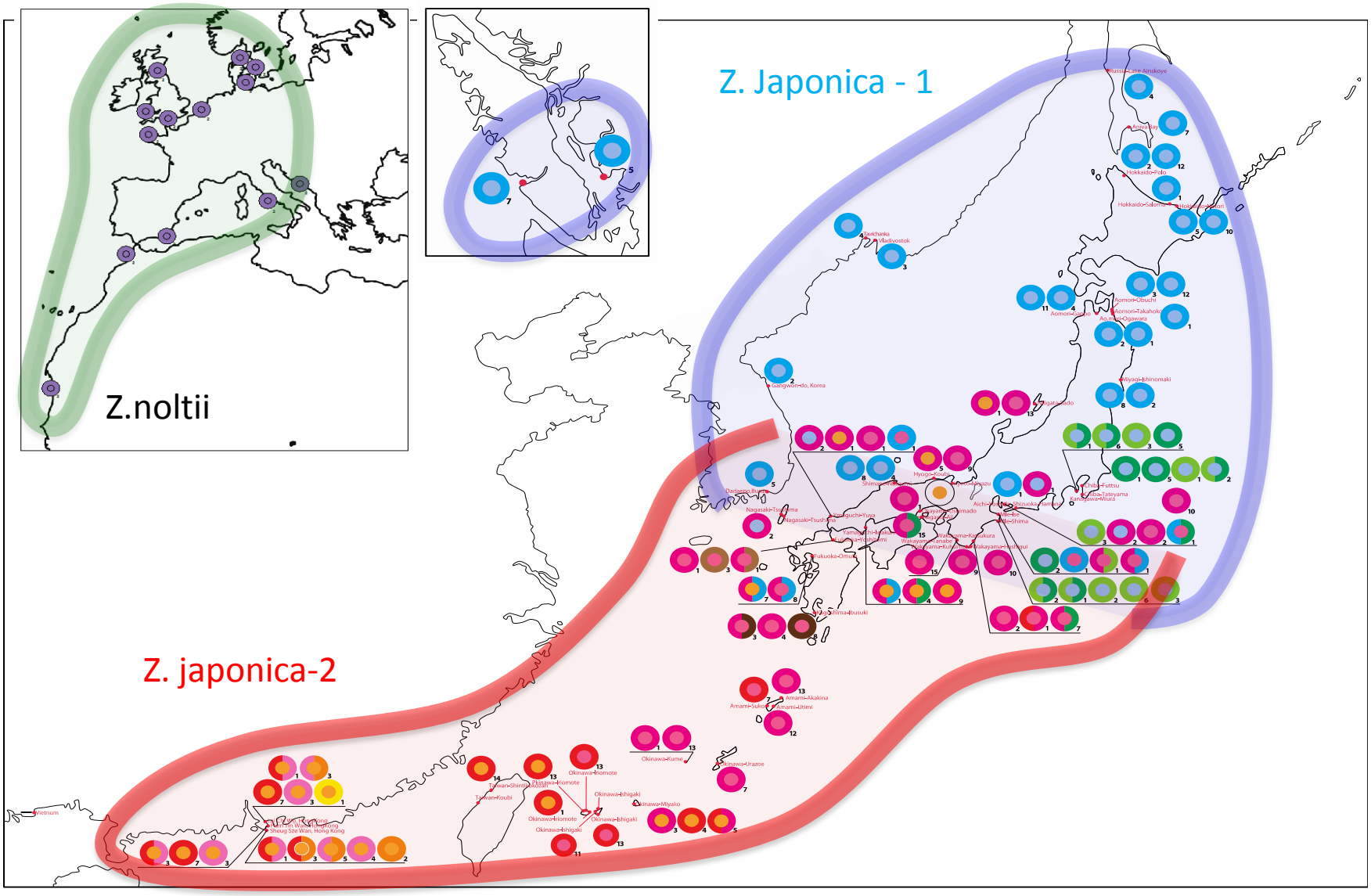
Bigley & Barreca 1982.

Identity Crisis: *Zostera japonica*

- ~~1957 identified as *Zostera nana* Roth. (Hitchcock et al. 1969)~~
- ~~1970 identified as *Zostera americana* den Hartog (Hartog 1970)~~
- ~~1976 identified as *Zostera noltii* Hornem. (Phillips & Shaw 1976)~~
- 1976 identified as *Zostera japonica* Aschers & Graebn. (Harrison 1976)
- 1982 recognized as *Zostera japonica* (Bigley & Barreca 1982).

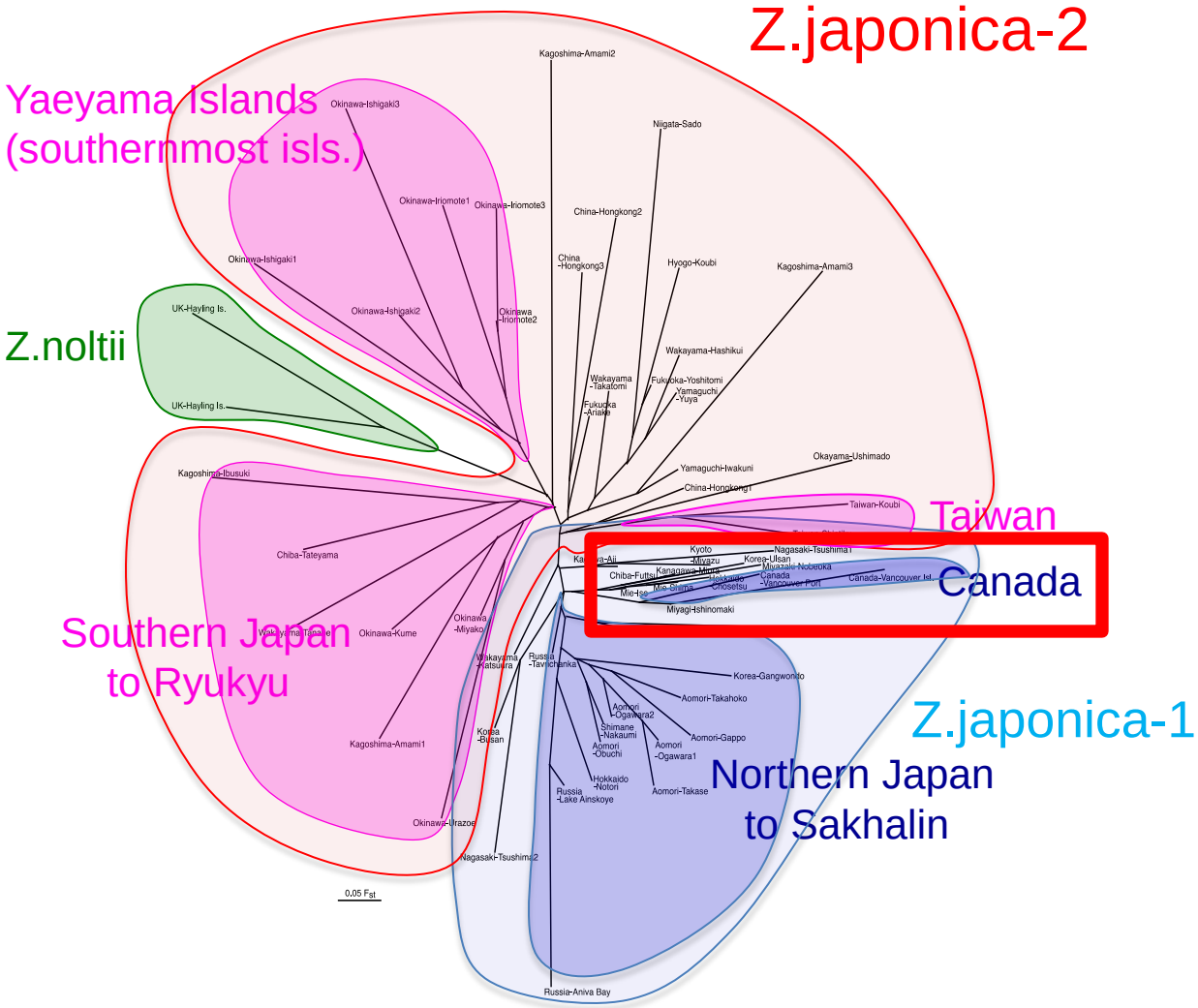
Current taxonomy recognized is *Zostera japonica* Aschers. & Graebn.

Zostera japonica Genetics



Tanaka et al. 2011. Origin and Genetic Structure of Zostera japonica. IBC-Melbourne

Zostera japonica Genetics



NJ tree based on F_{st} values (Weir and Cockerham 1984) among sites of *Z. japonica* and *Z. noltii*. F_{st} were calculated using seven microsatellite markers polymorphisms (Reusch 2001, Coyer et al, 2004).

Tanaka et al. 2011

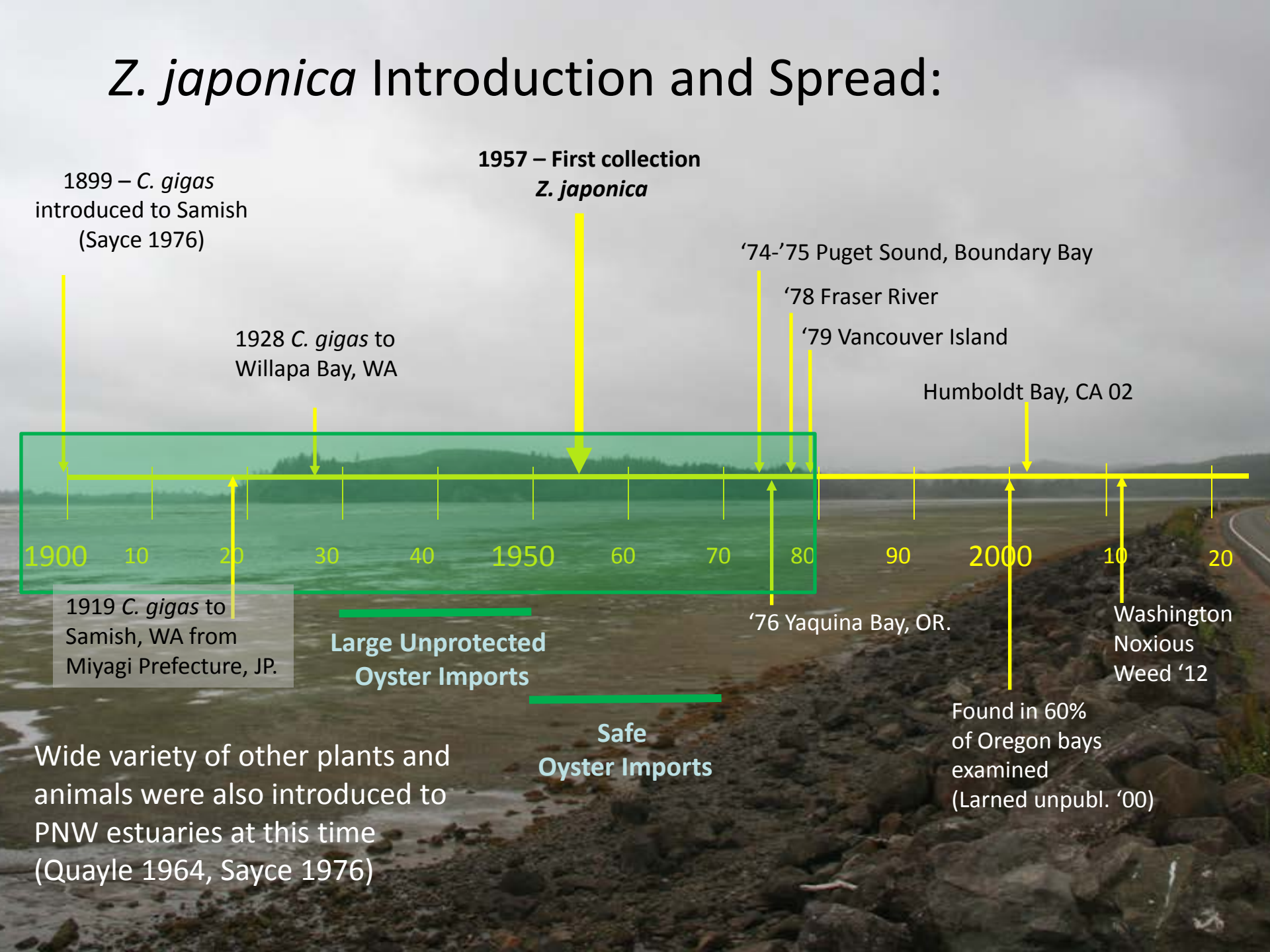
Zostera marina L.

- 30-120 cm leaf length
- 12 mm leaf width
- 60 to 140 shoots m^{-2}
- 30 – 200 gdw m^{-2}
- -2 to +0.5 m MLLW

Zostera japonica Aschers& *Graebn.*

- 10-20 cm leaf length
- 1 mm leaf width
- 2,000 to 10,000 shoots m^{-2}
- 100 – 250 gdw m^{-2}
- +1 to +2.3 m MLLW

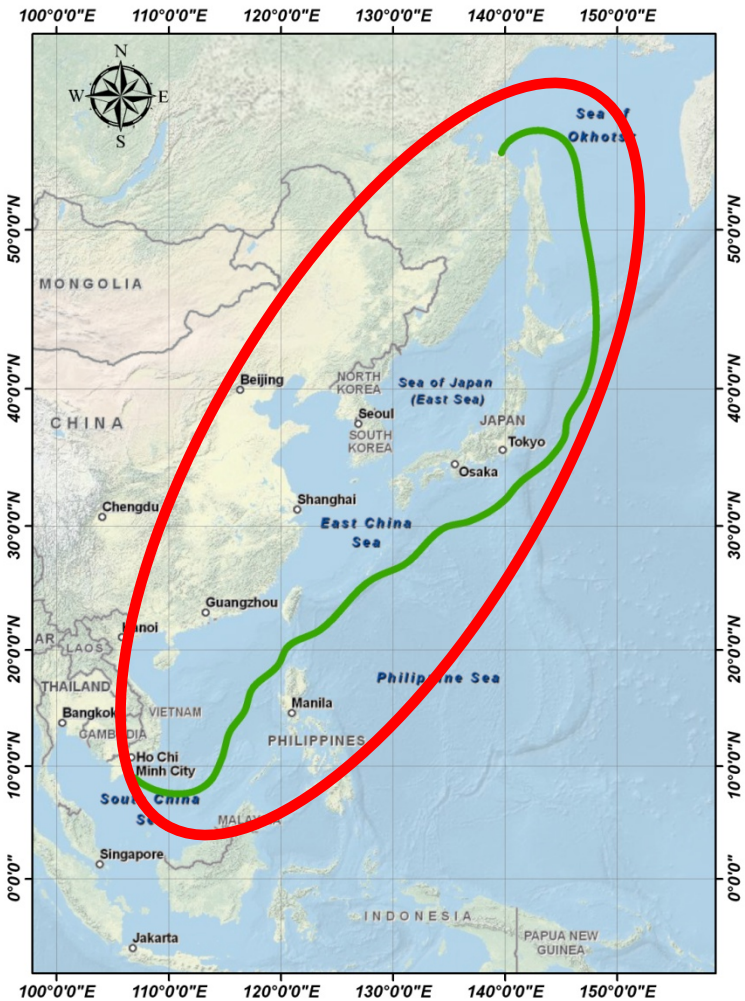
Z. japonica Introduction and Spread:



Wide variety of other plants and animals were also introduced to PNW estuaries at this time (Quayle 1964, Sayce 1976)

Distribution of *Zostera japonica* Aschers. & Graebn.

Native Range



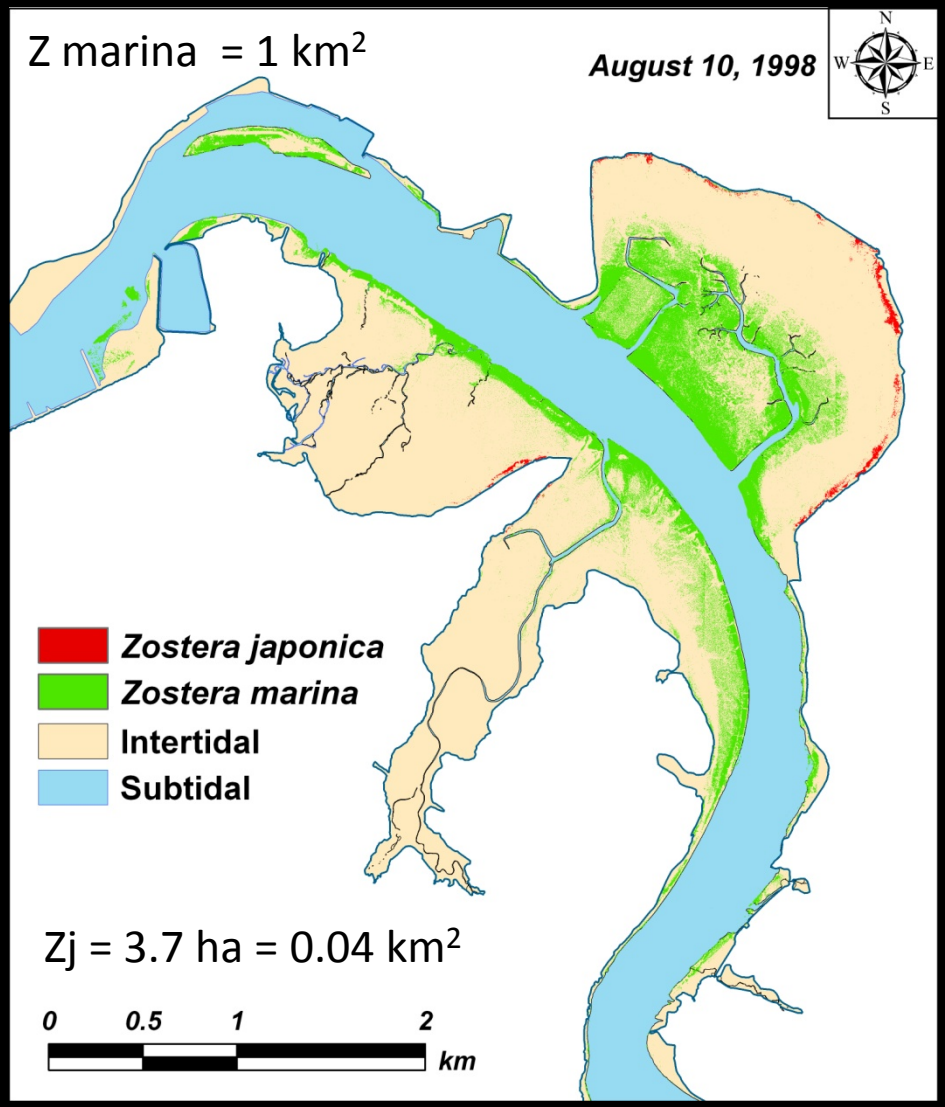
Introduced Range

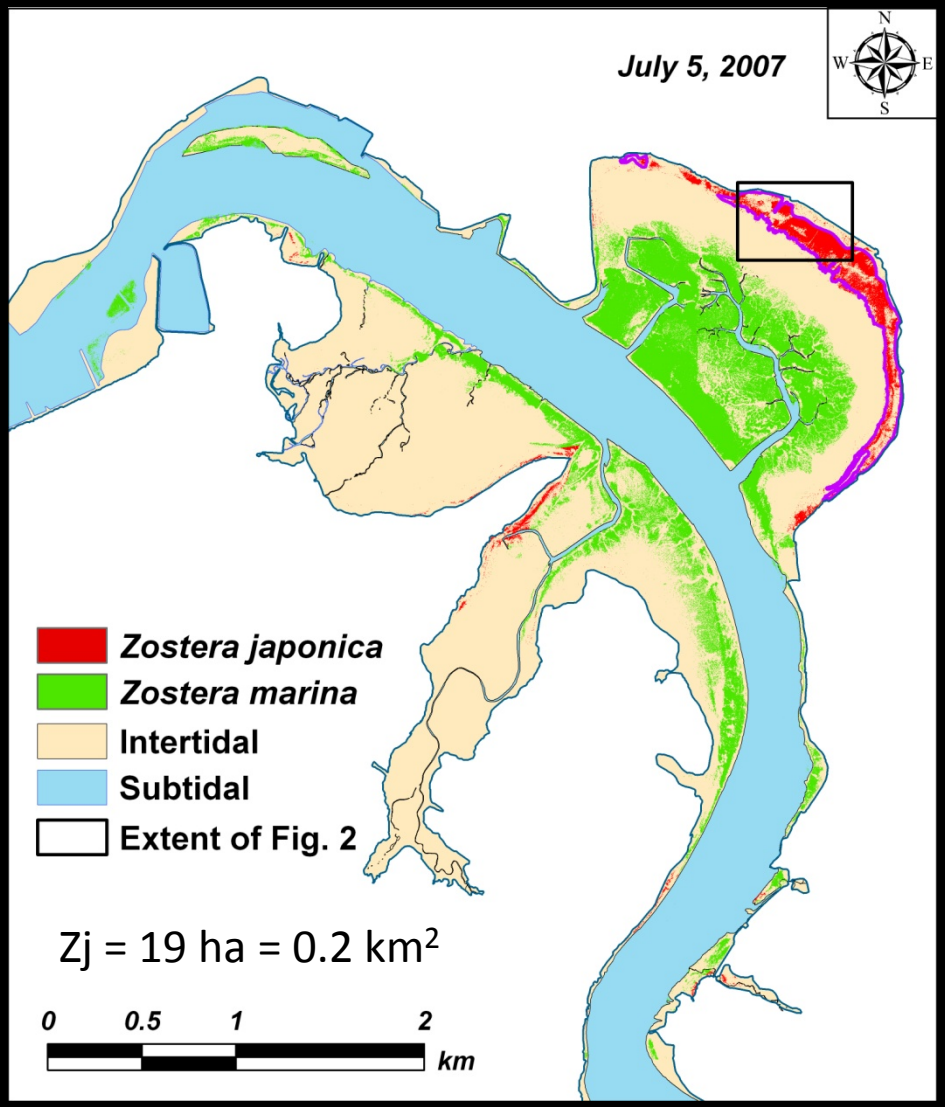
Migratory Waterfowl as Biological Dispersal Mechanisms

- Pacific Black Brant migratory routes encompass the entire Pacific coast of North America (Ganter 2000)
- Timing of waterfowl migration in relationship to seed maturation may be less important than previously thought (Figuerola et al. 2002)
- *Zostera marina* seeds pass through the gut of fish, turtles and birds and successfully germinate (Sumoski & Orth 2012)

- Preliminary evaluation found no evidence that birds will be negatively impacted by *Z. japonica* in Yaquina Bay (Lamberson et al. 2011).

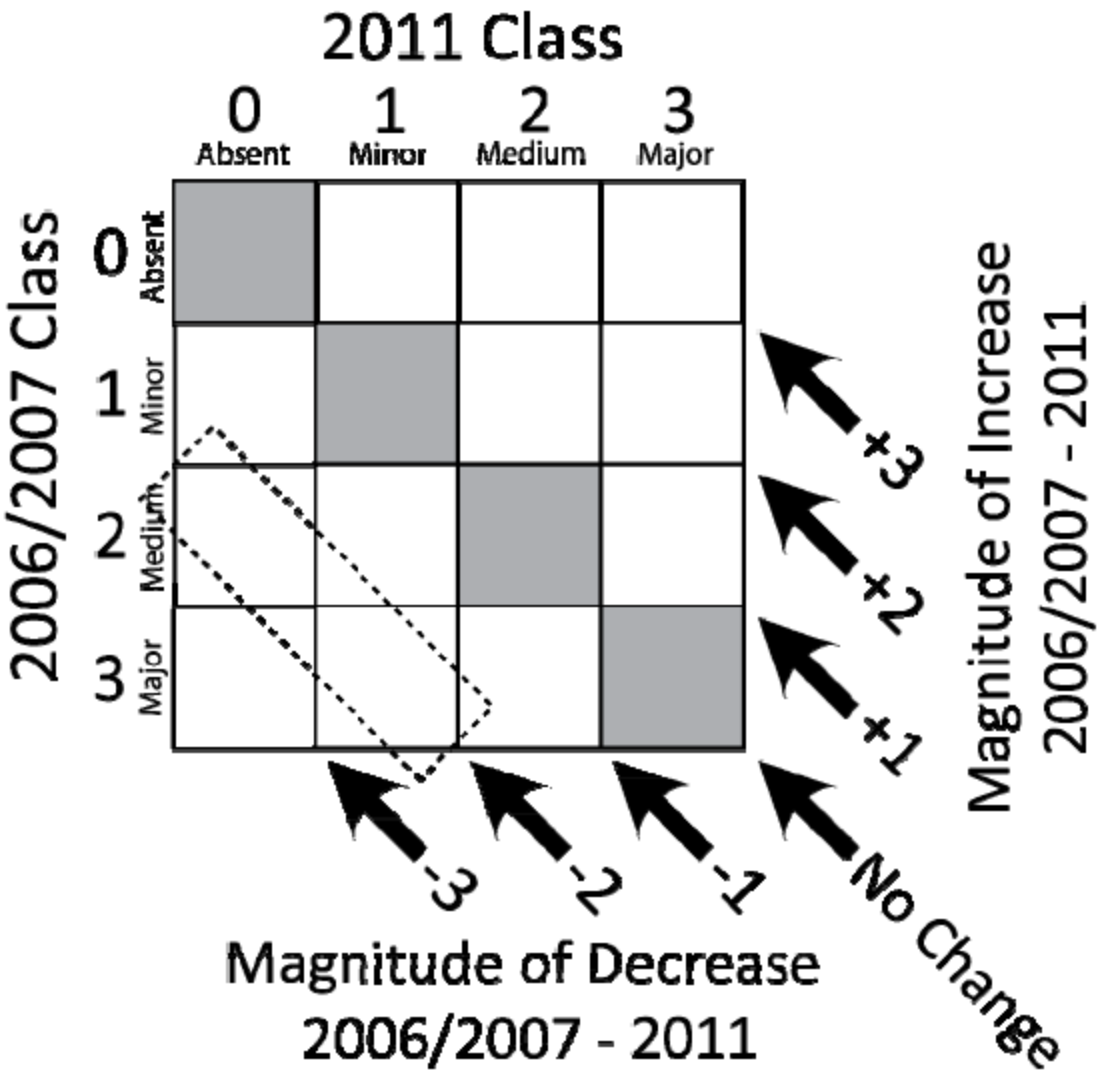
Increase in areal distribution over 10 years
Yaquina Bay





Young et al. 2008. J. Spatial Sci. 53:87-97

Zostera change in Willapa Bay



- Change analysis of sampling conducted in 2006/2007 and in 2011
- 214 sites surveyed
- <u>Diagonal</u> indicates # of sites with no change.
- <u>Above</u> diagonal indicates # of sites that increased in class
- <u>Below</u> diagonal indicates the # of sites that decreased in class

McCoy, 2011. Z. japonica survey report

Zostera change in Willapa Bay

Z. japonica
July-August Only

B

2006/2007 \ 2011	Absent	Present Minor	Present Medium	Present Major
Absent	5	3	1	3
Present Minor	1	3	0	2
Present Medium	3	5	1	15
Present Major	7	4	4	49

Z. japonica

Z. marina
July/August Only

D

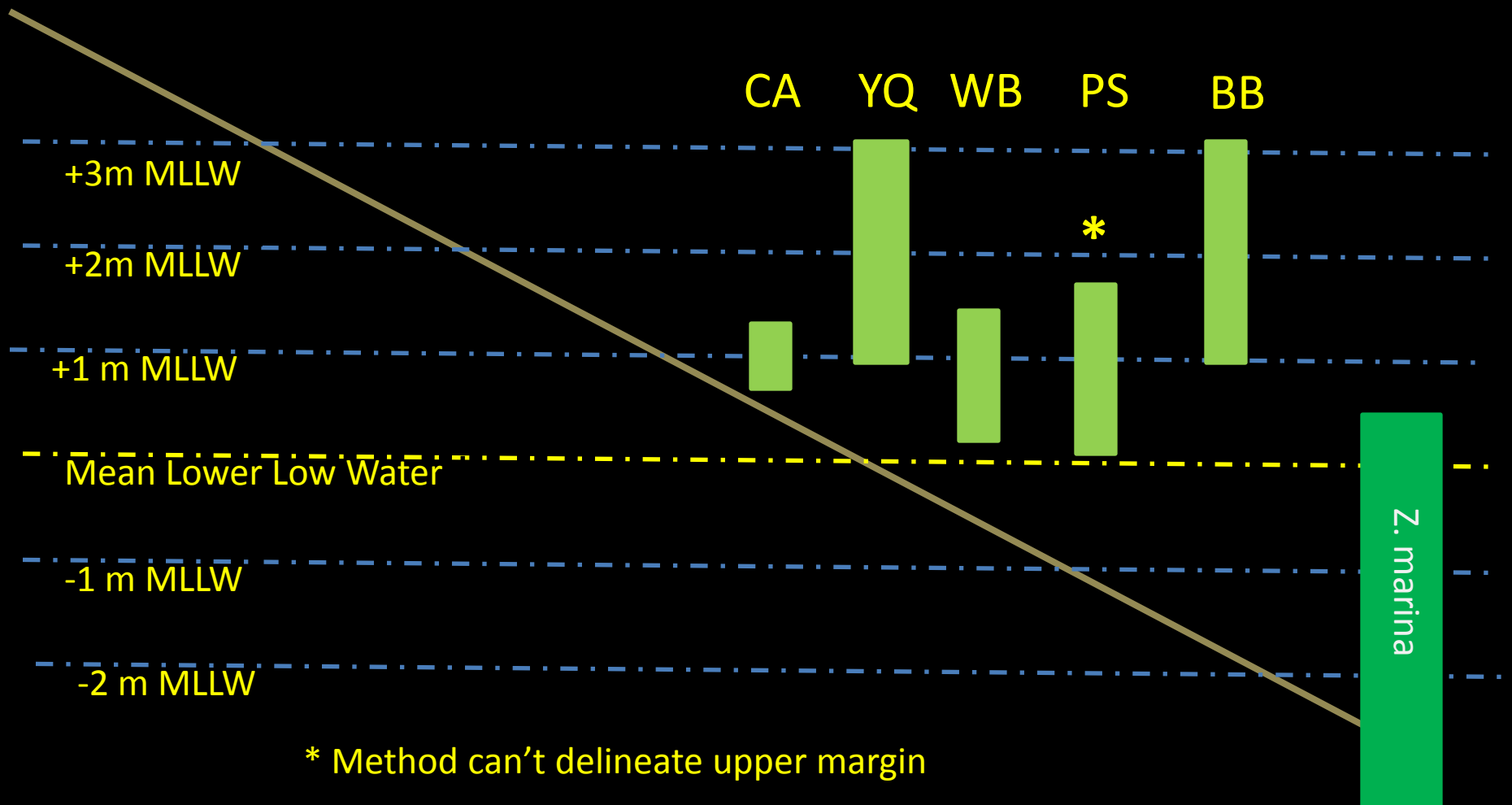
2006/2007 \ 2011	Absent	Present Minor	Present Medium	Present Major
Absent	17	21	14	5
Present Minor	0	4	6	4
Present Medium	0	1	3	18
Present Major	0	0	0	13

Z. marina

- **No significant change in *Z. japonica* between 2006/2007 and 2011 when season is controlled.**
- **Apparent change in Z. japonica when all sites compared is due to seasonal differences.**
- **Significant increase in *Z. marina* occurrence, even when season is controlled**

McCoy, 2011. *Z. japonica* survey report

Schematic cross section of estuary shoreline



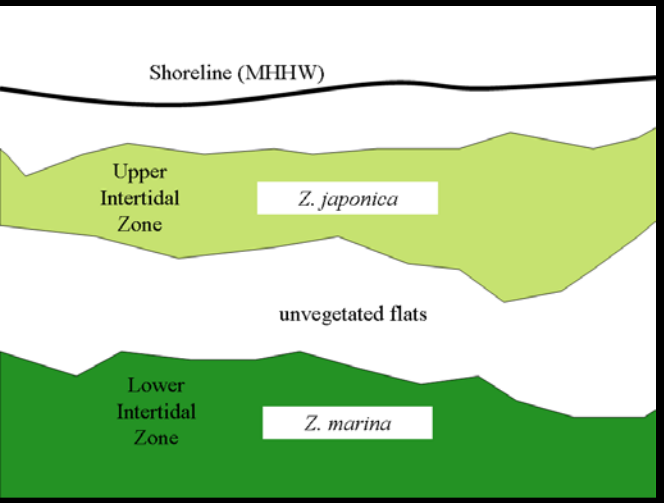
* Method can't delineate upper margin

Zonation Patterns of *Z. japonica* with the Native Seagrass Z. *marina*

(Shafer 2007, Shafer et al. in review)

Disjunct Distribution

70%

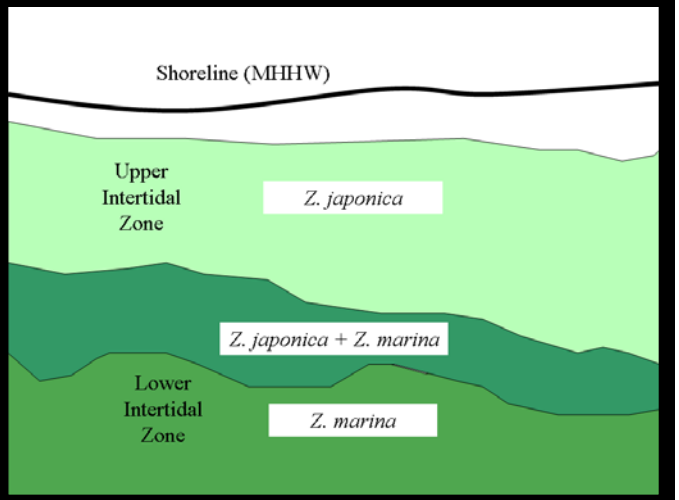


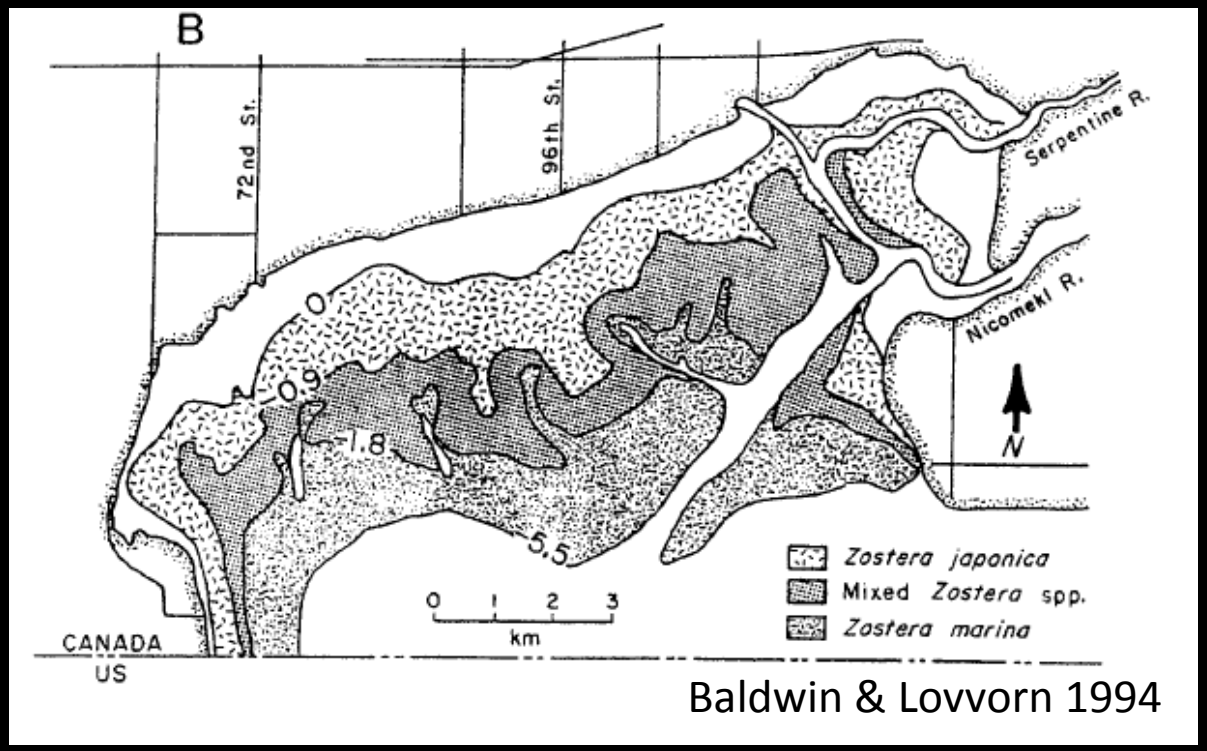
Zonation Patterns of *Z. japonica* with the Native Seagrass Z. *marina*

(Shafer 2007) (Shafer 2007, Shafer et al. in review)

Overlap Distribution

31%





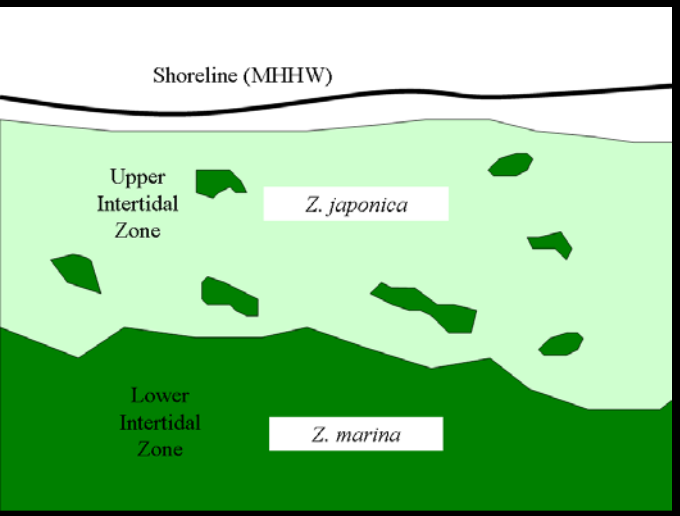
Baldwin & Lovvorn 1994

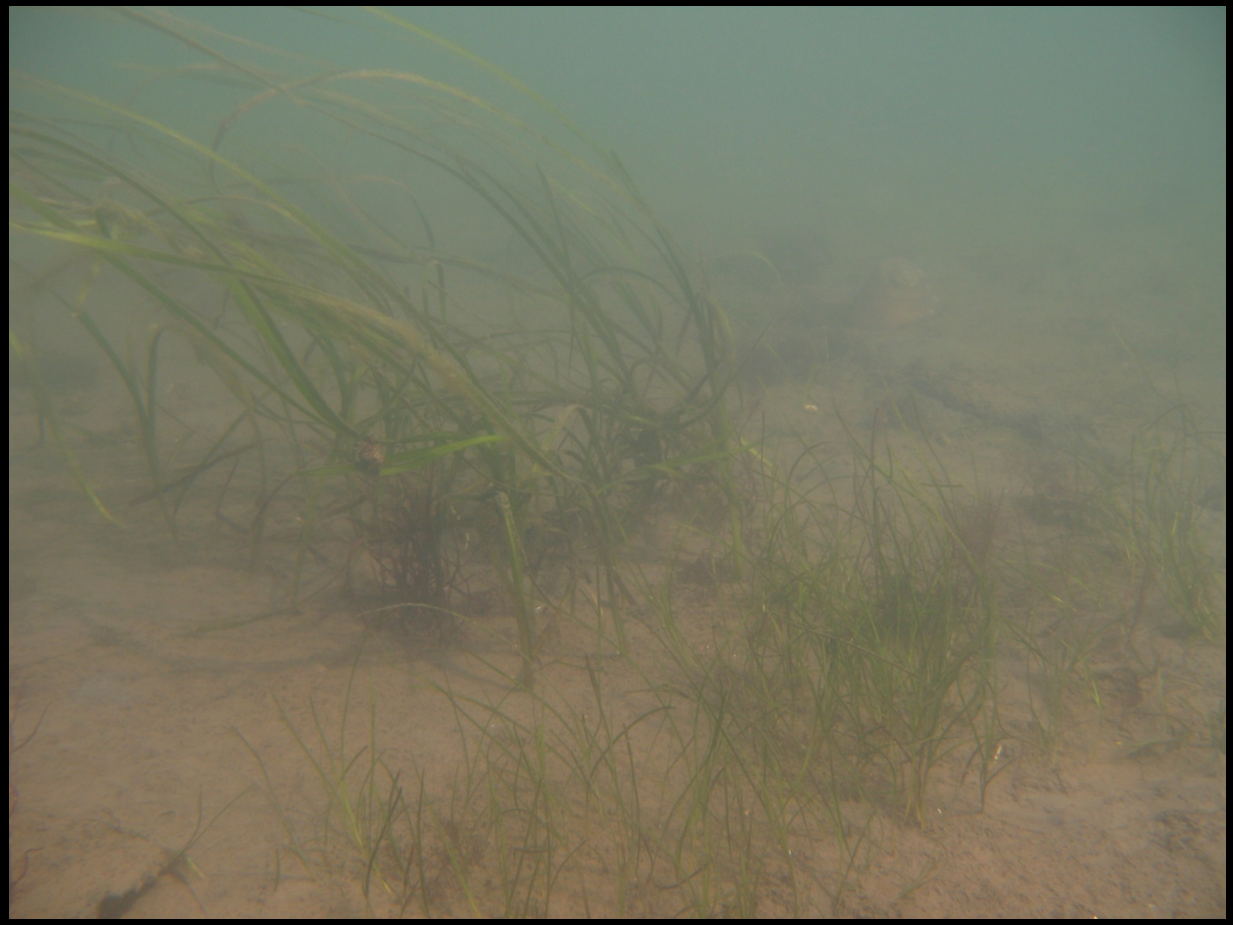
Zonation Patterns of *Z. japonica* with the Native Seagrass Z. *marina*

(Shafer 2007, Shafer et al. in review)

Mosaic Distribution

13%



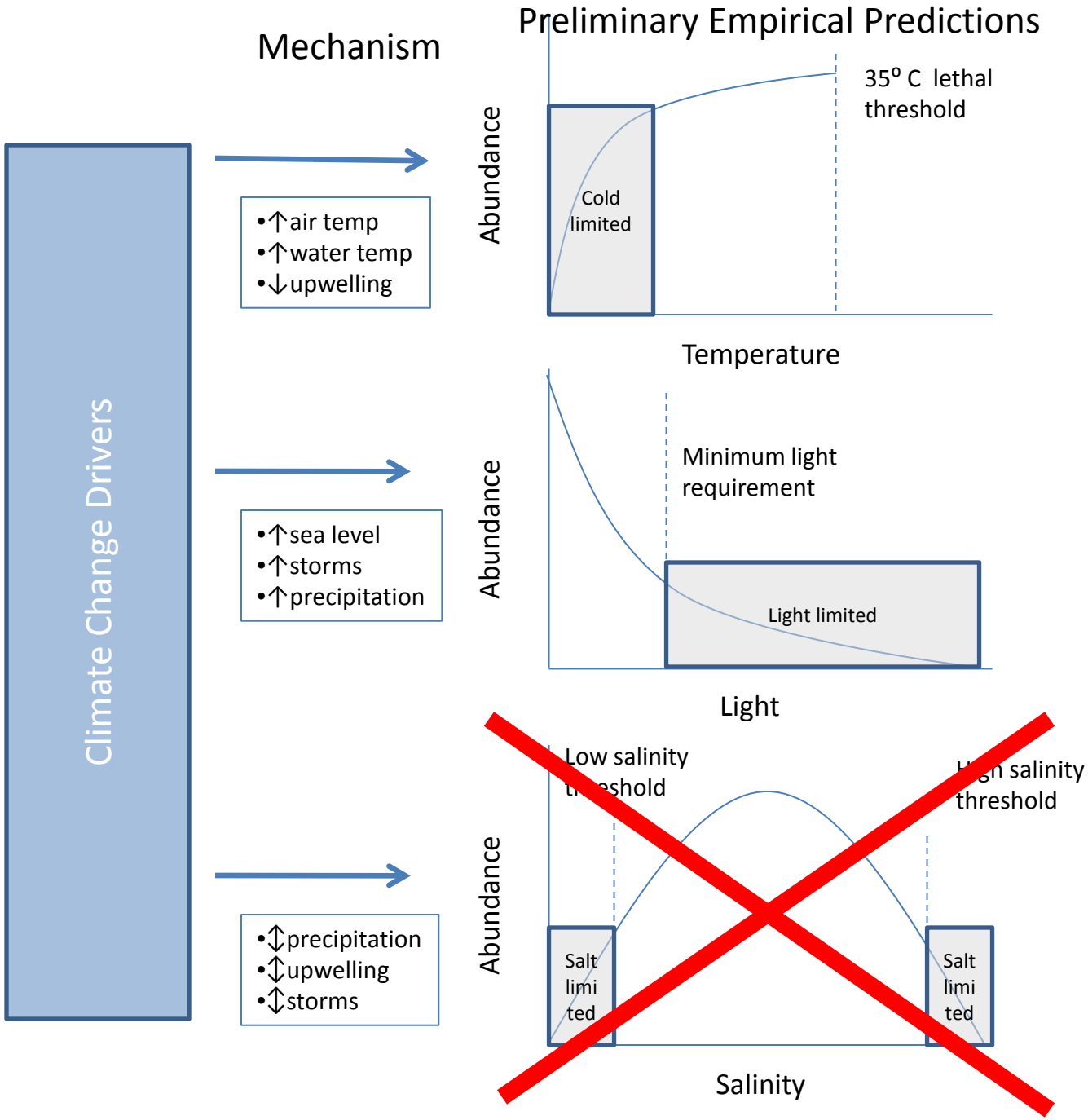


Padilla Bay, Photo by J. Gaeckle

Zostera japonica physiology

- Lethal temperature 33-35 ^{o}C (Kaldy & Shafer 2012)
- Optimum temperature ~20 C (Shafer et al. 2011)
- Euryhaline, salinity optimum ~20 (Shafer et al. 2011)
- Whole plant (Kaldy & Shafer, unpubl.)
  - P_m = 180 µmols O_2 gdw^{-1} h^{-1}
  - R = 22 µmols O_2 gdw^{-1} h^{-1}
- Leaf growth rates (Kaldy & Shafer, unpubl.)
  - 8 ^{o}C = 0.1 mg dw sht^{-1} d^{-1}
  - 20 ^{o}C = 0.55 mg dw sht^{-1} d^{-1}

Photo by J. Gaeckle

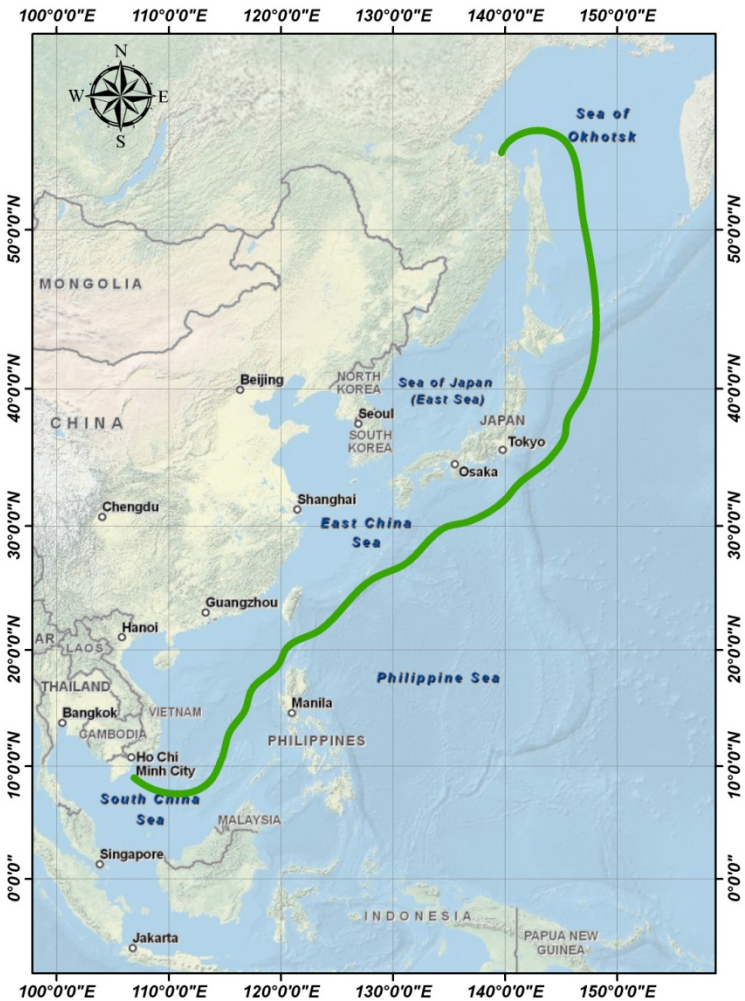


Products/Models

- Empirical physiological tolerance publications (Kaldy & Shafer)
- Conceptual model on Zj and Zm site specific distribution shifts
- Expand to evaluate regional model application

Distribution of *Zostera japonica* Aschers. & Graebn.

Native Range



Introduced Range

Potential Change in *Zostera japonica* Latitudinal Distribution in North America

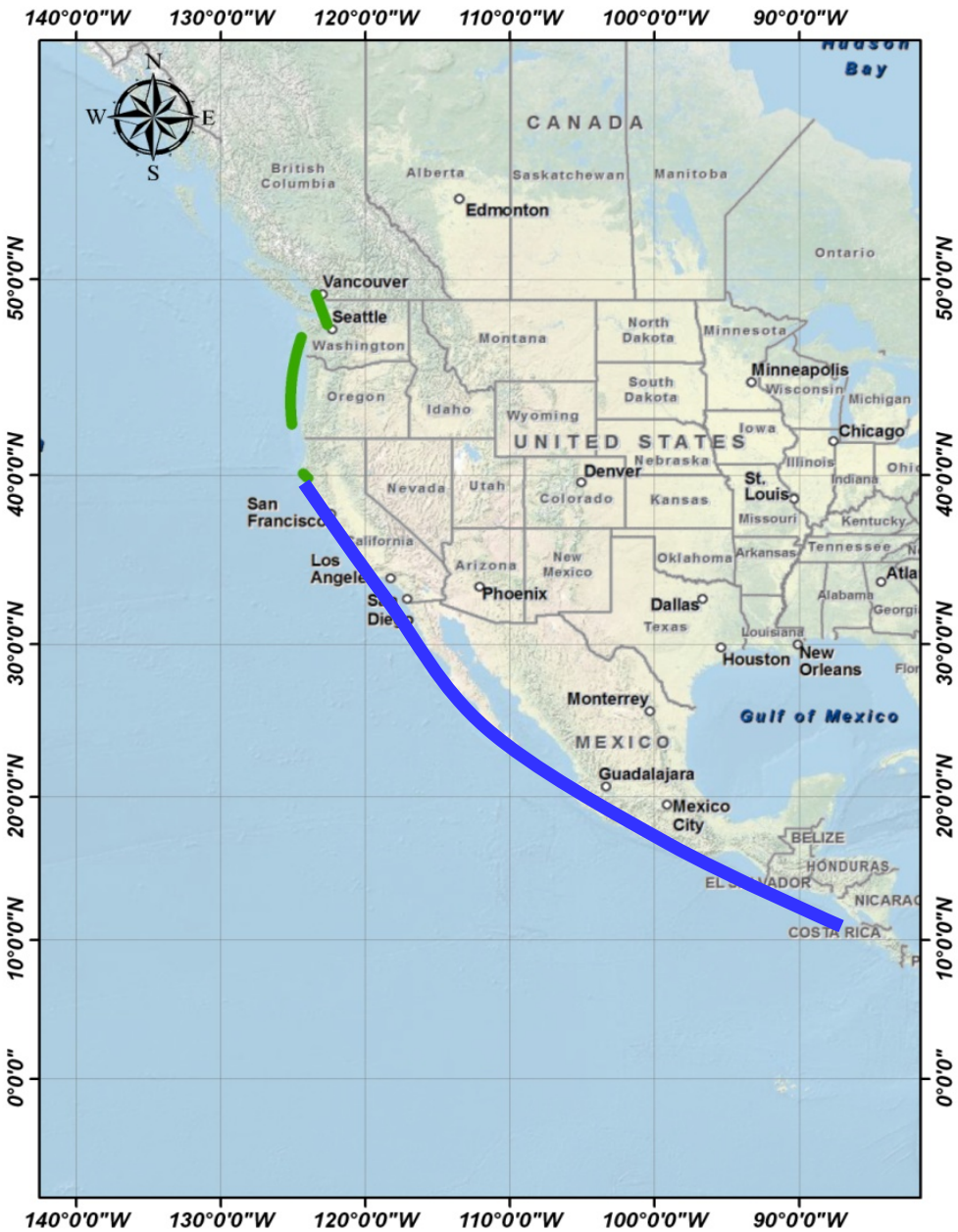
Zostera japonica

Future *Z. japonica* distribution ?

Spread by about 6 km y^{-1}
(Kinlan & Gaines 2003, Shanks et al. 2003)

San Francisco Bay ~2080

Abe et al. 2009
Kaldy & Shafer 2012



Summary

- Worldwide declines in seagrass cover
- PNW one of the few places in the world where seagrass is expanding
- Lack of science to evaluate ecological interactions of Zj.

- *Zostera japonica* is the appropriate nomenclature
- PNW Zj genetically similar to Japanese populations
- PNW populations expanding within and among estuaries
- Zj generally reported from mid- to upper intertidal
- Zonation patterns appear to be related to bathymetric slope
    - Shallow slope tends to have warmer water, favoring Zj expansion
- Based on physiology expect continued southward expansion
    - Propagule vectors most likely birds

Photo by J. Gaeckle

Unstudied Ecological questions

- Utilization of Zj by ESA listed Salmon and Sturgeon
- Impact/recovery of chemical or mechanical control to associated benthic infauna
- Alteration of food web structure & quality
- Mechanisms of Zj dispersal
- Impact of colonization to native habitats
- Impact of loss of mudflat habitat
- Altered biogeochemical cycling

Photo by J. Gaeckle