Understanding risks of invasion to the Bering Sea

The Bering Sea

"Botrylloides violaceus" credit: Dann Blackwood (USGS)

"Carcinus maenas" Credit: © Hans Hillewaert

"Didemnum vexillum" credit: Dann Blackwood (USGS)

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U.S. Fish & Wildlife Service
Sea Grant Alaska
USGS science for a changing world
NOAA
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Land
Deep sea
Continental shelf
Russia
Chukchi Sea
Kivalina
Kotzebue
Bering Strait
Port Clarence
Nome
USA
Bering Sea
Nunivak Island
Togiak
Bristol Bay
Aleutian Islands
Adak
Dutch Harbor
Akutan
Udagak Bay
0
110
220
440
km

The Bering Sea

- Highly productive
- Supports billion dollar fisheries
- Foundation for cultural traditions

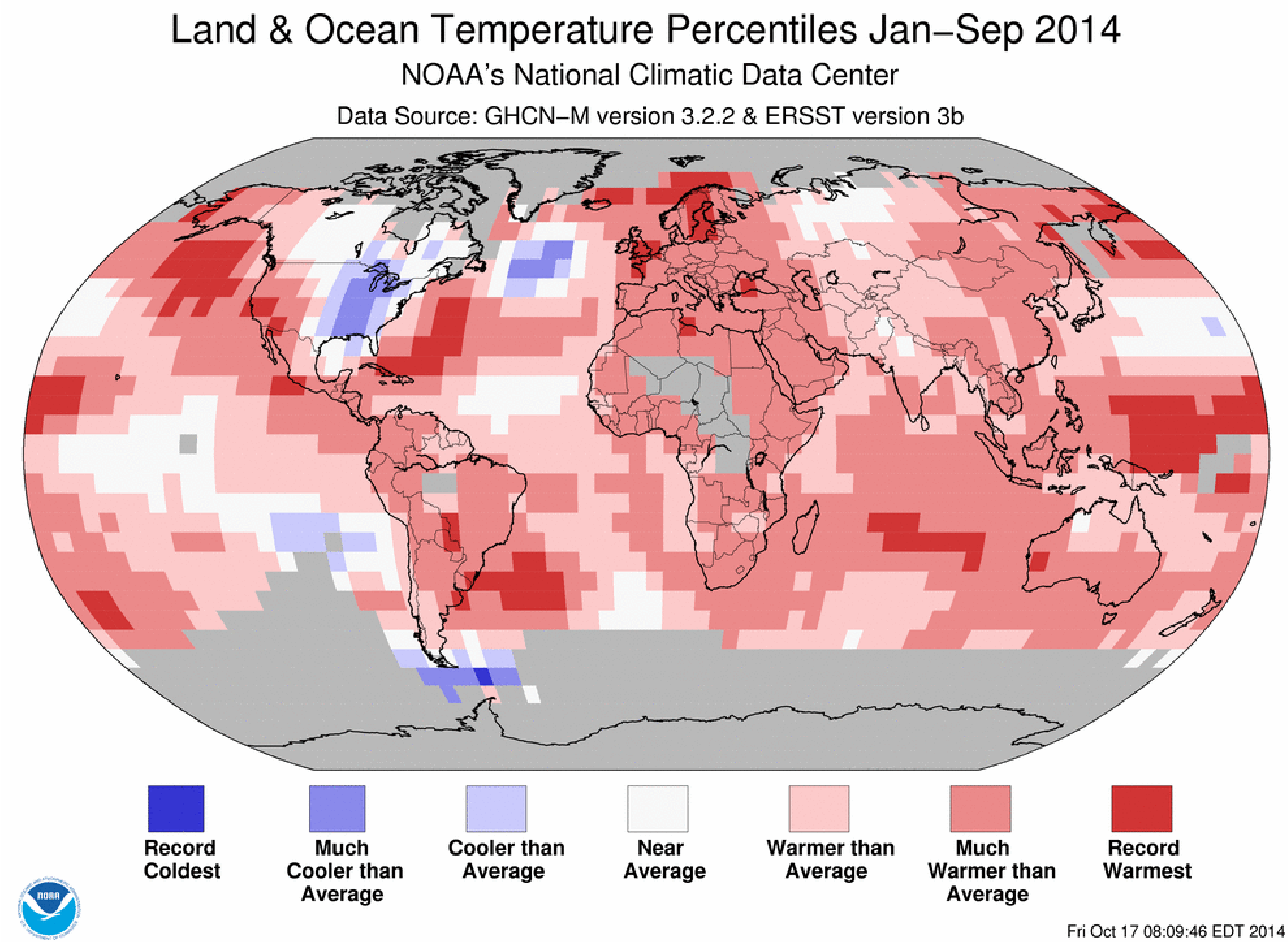
Photo credits: 1) Salty Dog Boating News, 2) A. Droghini, 3) A. Droghini

The Bering Sea

- Few non-native species
- Geographic isolation & climate likely limiting[1,2]




1. de Rivera et al. 2011
2. Ruiz and Hewitt 2009


Land & Ocean Temperature Percentiles Jan–Sep 2014
NOAA's National Climatic Data Center
Data Source: GHCN–M version 3.2.2 & ERSST version 3b
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest
NOAA
Fri Oct 17 08:09:46 EDT 2014

Climate trends

Bering Sea has been warming for past ~50 years[1]

Warming trend is expected to continue[1-3]

↓ Ice cover

↑ Temperature of:
- Surface air
- Sea surface
- Sea bottom

1. Mueter and Litzow 2008
2. Wang and Overland 2012
3. Wang et al. 2012

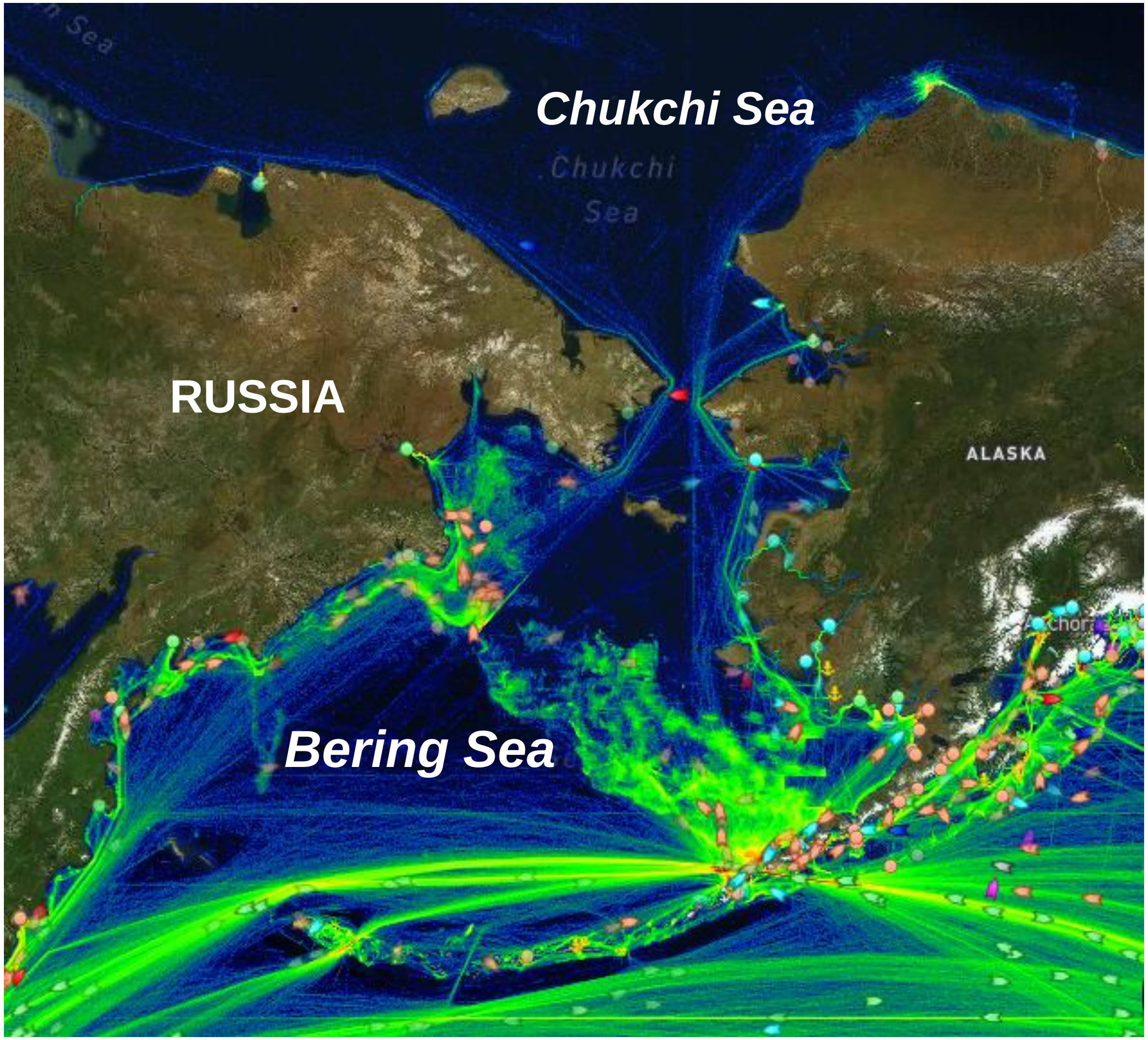
Climate & invasion potential

Intensifies spread and threat of non-native species[1,2]

- Northward range expansions
- Ocean acidification
- Increased human activity

1. Bennett et al. 2015
2. Cheung et al. 2009

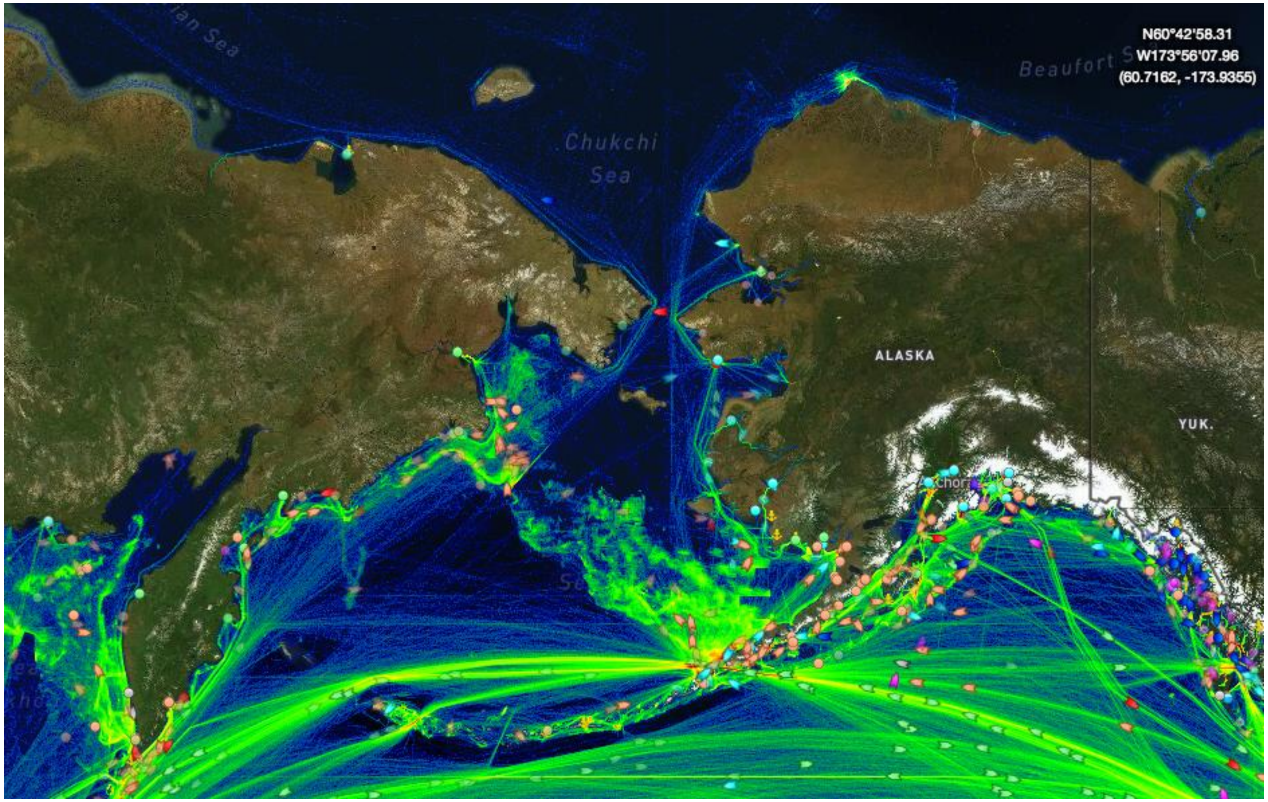
Bering Sea is a hub for Arctic traffic



1. AIS data: http://www.marinetraffic.com

Trends in vessel traffic

- 50% of Arctic traffic in 2004[1]
- 400 to 900 more vessels expected by 2025[2]



1. AMSA 2009
2. ICCT 2015

How do we address these threats?

Prevention and early detection[1]

Which species pose the greatest risk

to the Bering Sea?

1. Lodge et al. 2006

Objectives

1. Develop a ranking system
2. Rank non-native species
3. Generate habitat suitability maps under current and future projections
4. Identify high-risk ports

Ranking system

33 questions across 4 themes

Criteria Themes	Points
Distribution and Suitable Habitat	30
Anthropogenic Influence	10
Biological Characteristics	30
Ecological and Socioeconomic Impacts	30

Ranking system

Scored non-native species in nearby ecoregions

0 — 100

Low invasion potential
Low impact

High potential
High impact

Ranking system: Results

24 76

Paracorophium spp.

Crassostrea gigas

N = 53 species

49.4 ± 10.9
mean ± SD

Eusarsiella zostericola

Carcinus maenas

Photo credits: 1) Fofonoff et al. 2003; 2) Ailloud 2010; 3) Gabe Souza

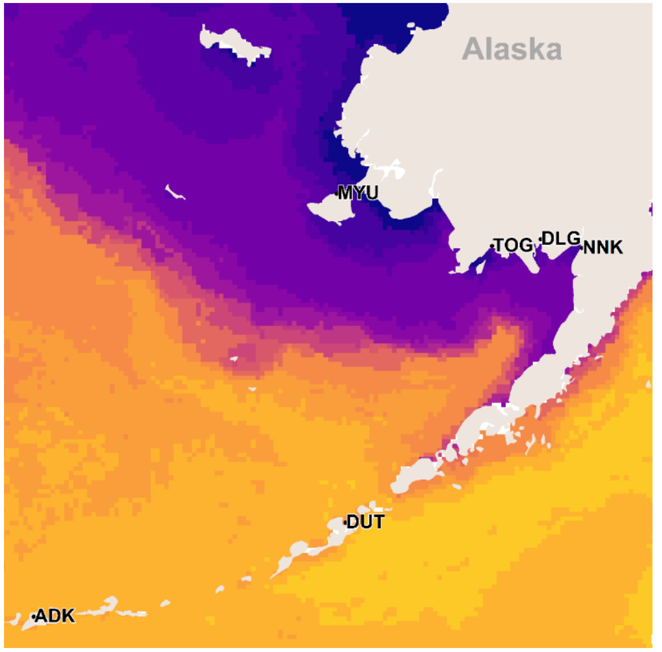
Habitat suitability maps

1) Physiological tolerances

Survival & reproductive thresholds

A) Water temperature

B) Salinity



Habitat suitability maps

2) Environmental variables

Sea temperature and salinity

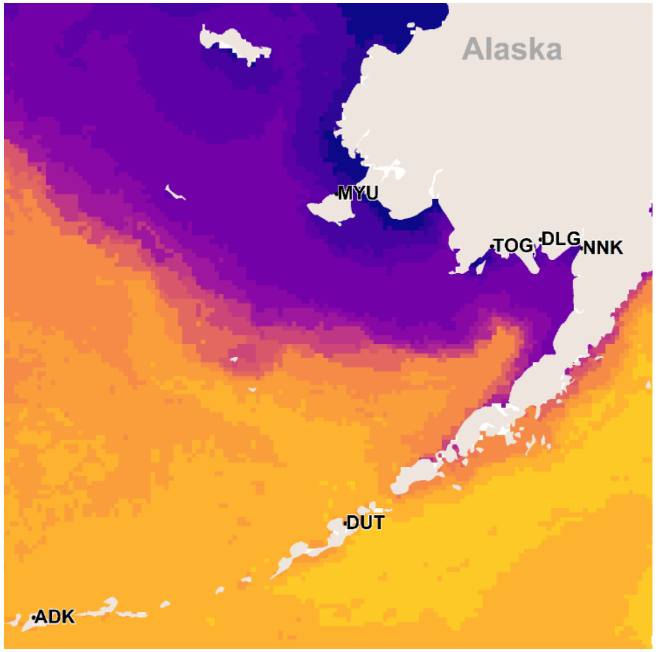
"Bering10K" regional model[1]

Derived from 3 global models

-CGCM3-t47 (CCCma)

-ECHO-G

-MIROC3.2



Time periods

Current: 2003 – 2013

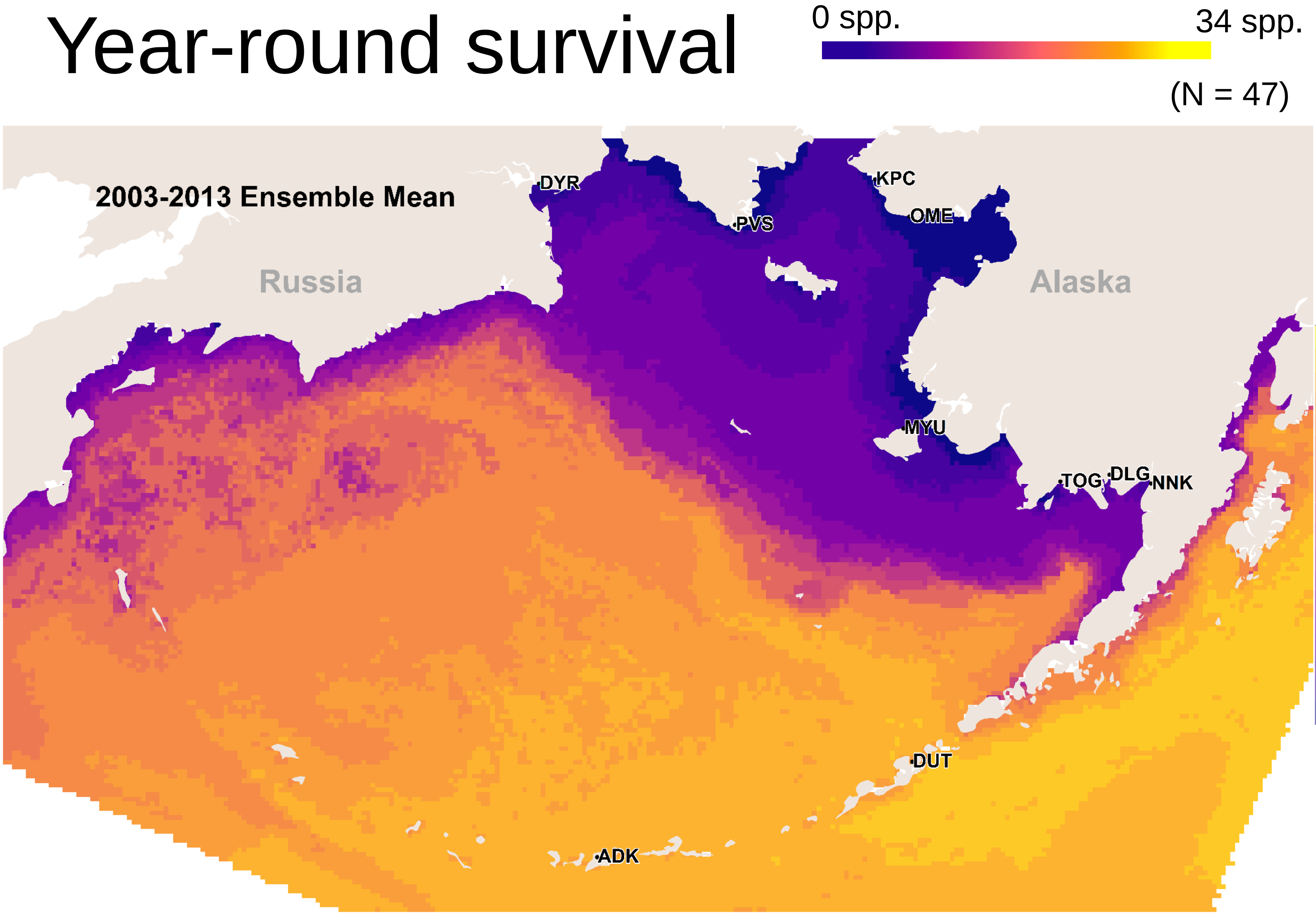
Future: 2029 – 2039

1. Hermann et al. 2016

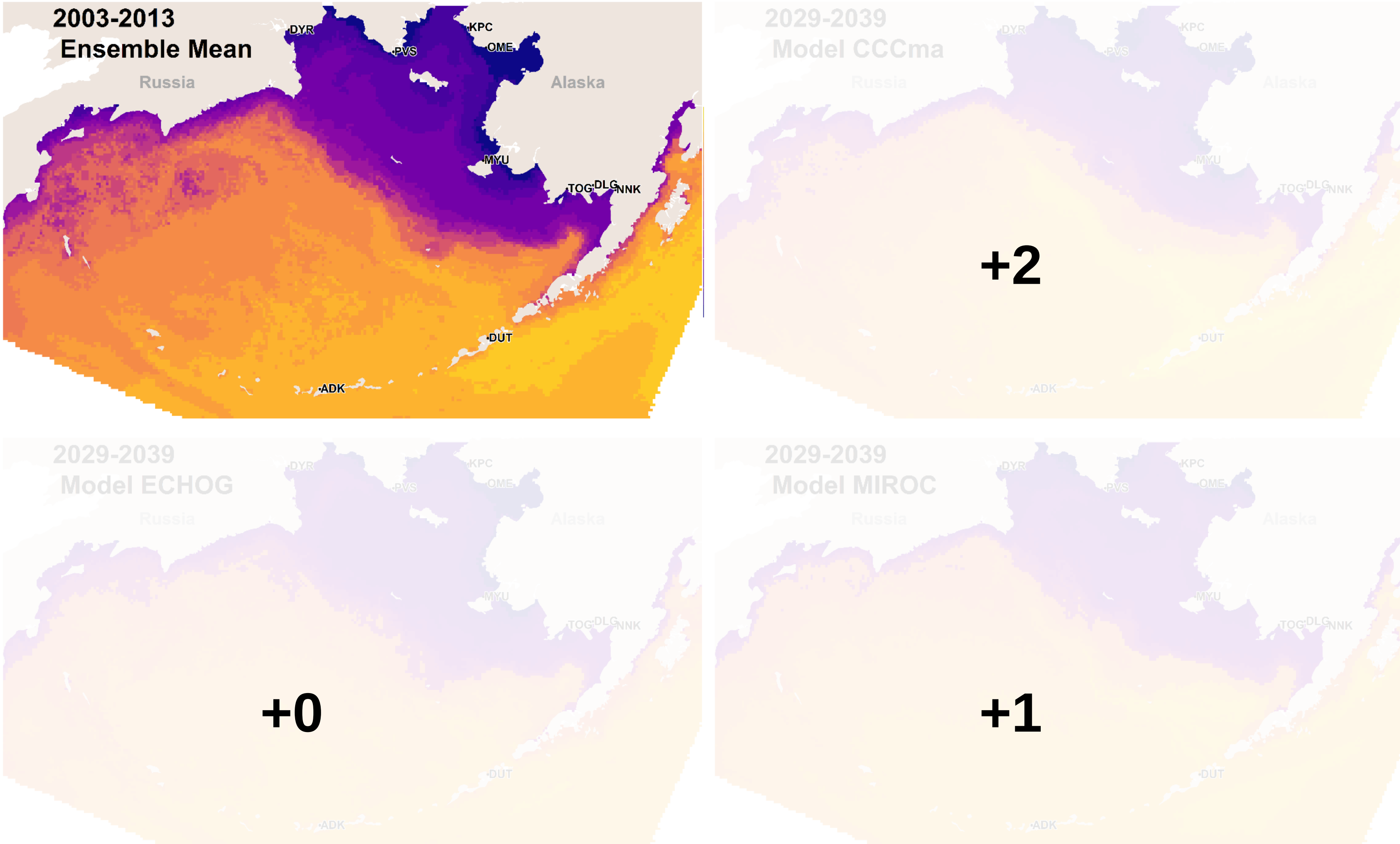
Q1: Do conditions exist for species to **survive**?

- *Year-round survival*: Year-round conditions exist for at least 7 of 10 years
- *Weekly survival*: Average # of weeks a species could survive over a 10 year period

Year-round survival



Year-round survival



Q1: Do conditions exist for species to **survive**?

- *Year-round survival*: Year-round conditions exist for at least 7 of 10 years
- *Weekly survival*: # of weeks a species could survive averaged over a 10 year time period

Q2: Do conditions exist for species to **reproduce and develop**?

Case study: *Carcinus maenas*

Photo credits: Gabe Souza

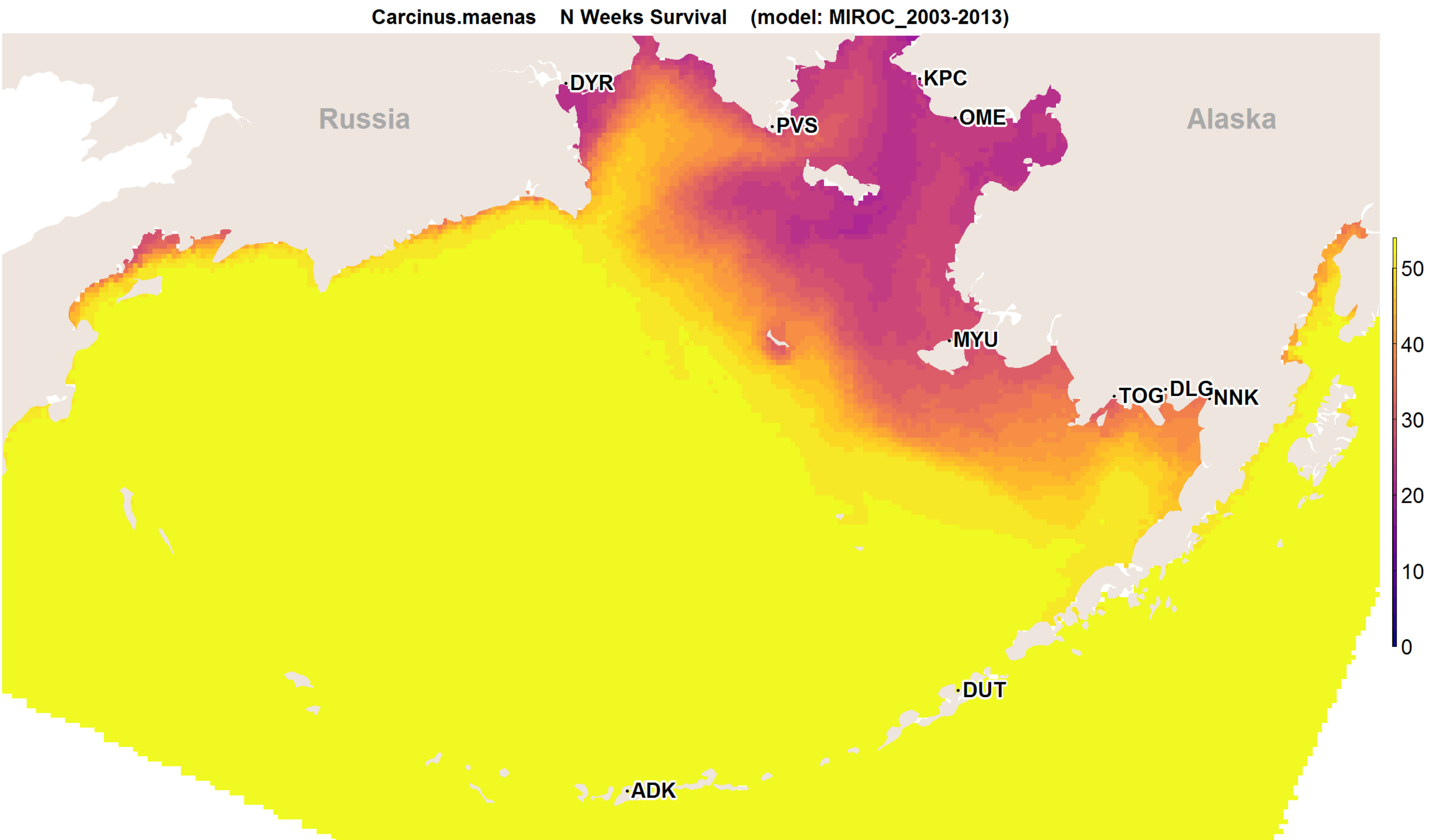
Case study: *Carcinus maenas*

	Survival	Establishment
Salinity (ppt)	10 to 54[1]	17 to 35[1]
Temperature (°C)	-1 to 35[1]	10 to 22.5[2]

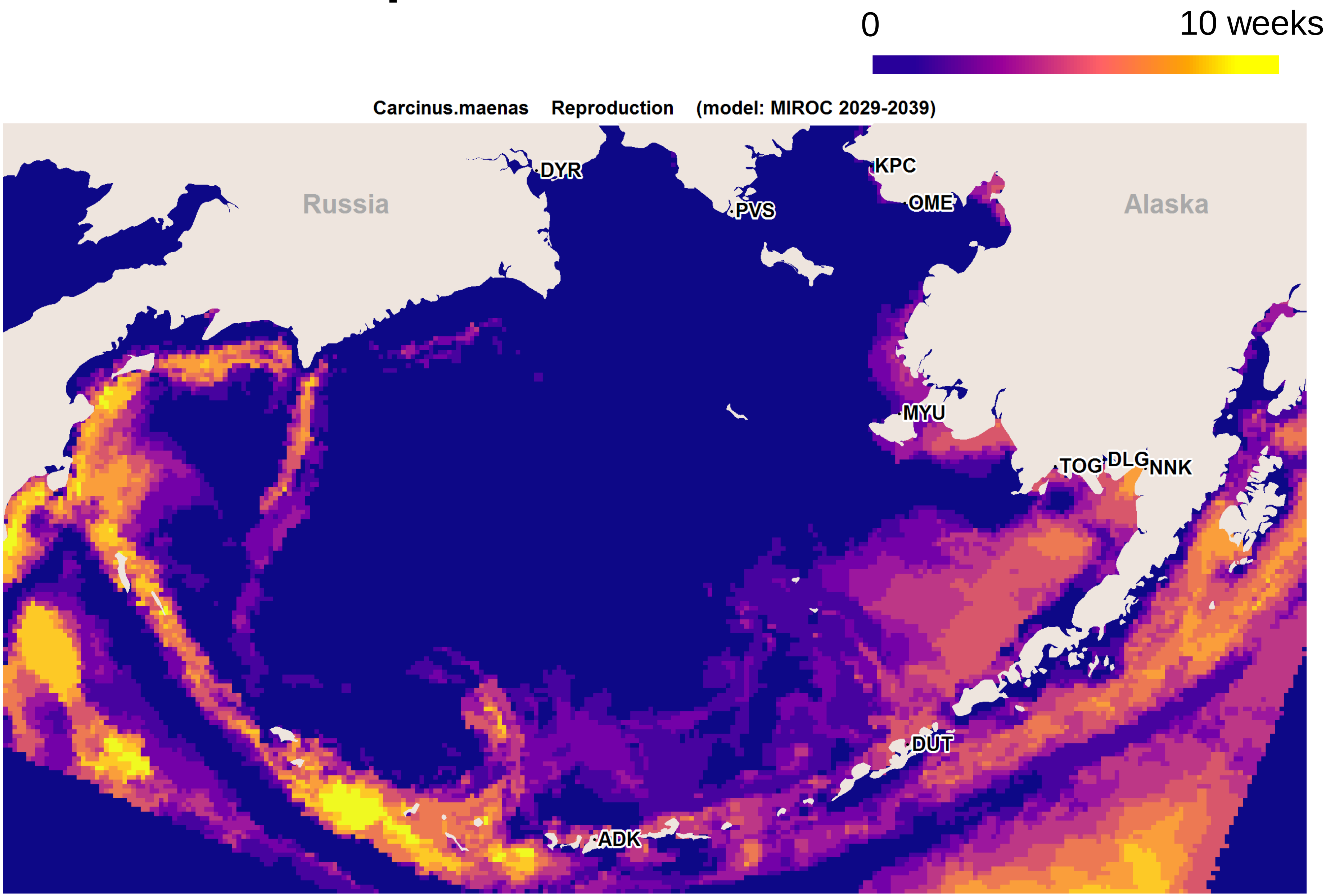
Time to development: 42 to 59 days[2]

1. Fofonoff et al. 2003
2. de Rivera et al. 2007

Suitable habitat for survival currently exists in Bering Sea

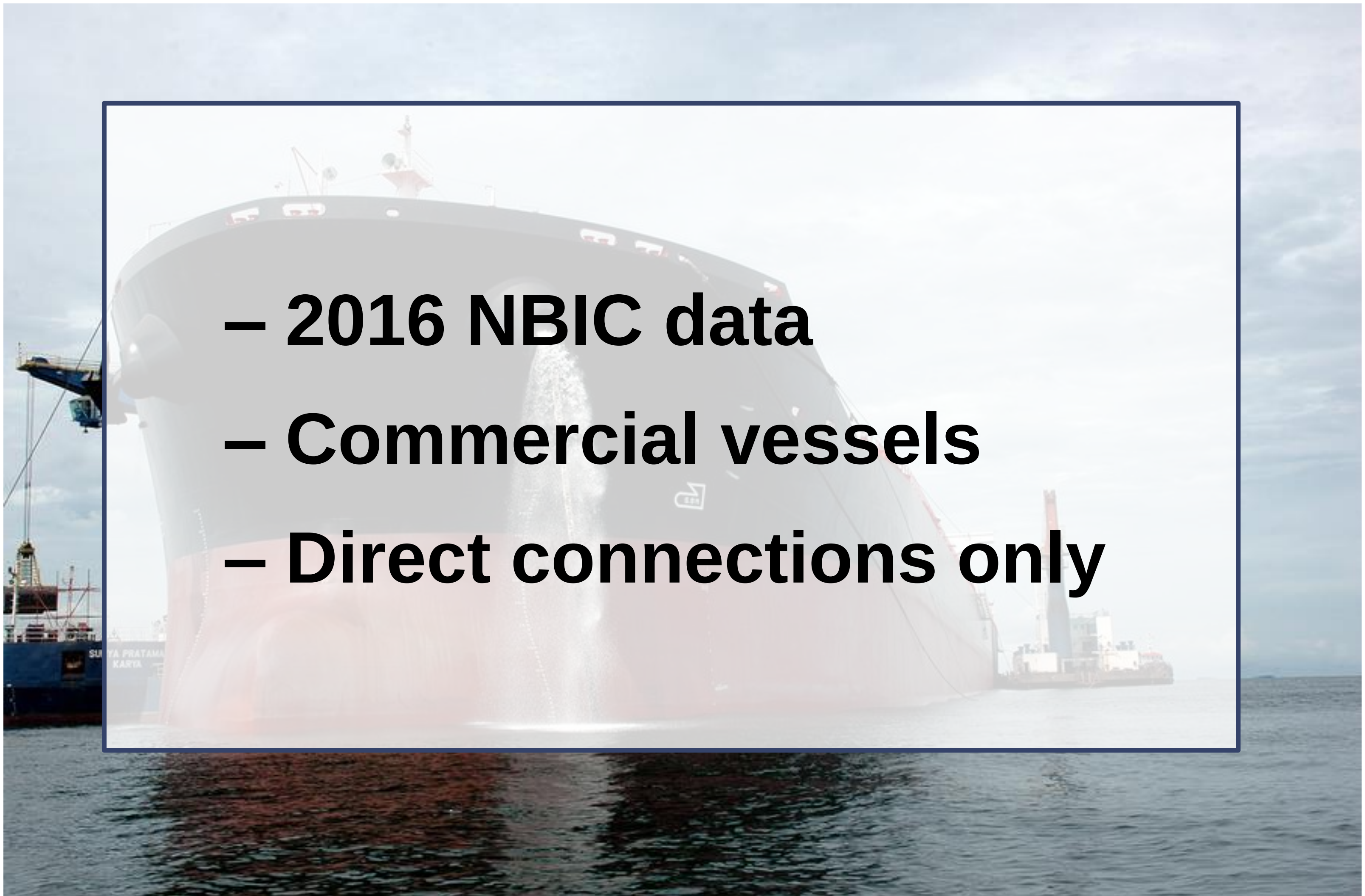


Limited reproductive habitat



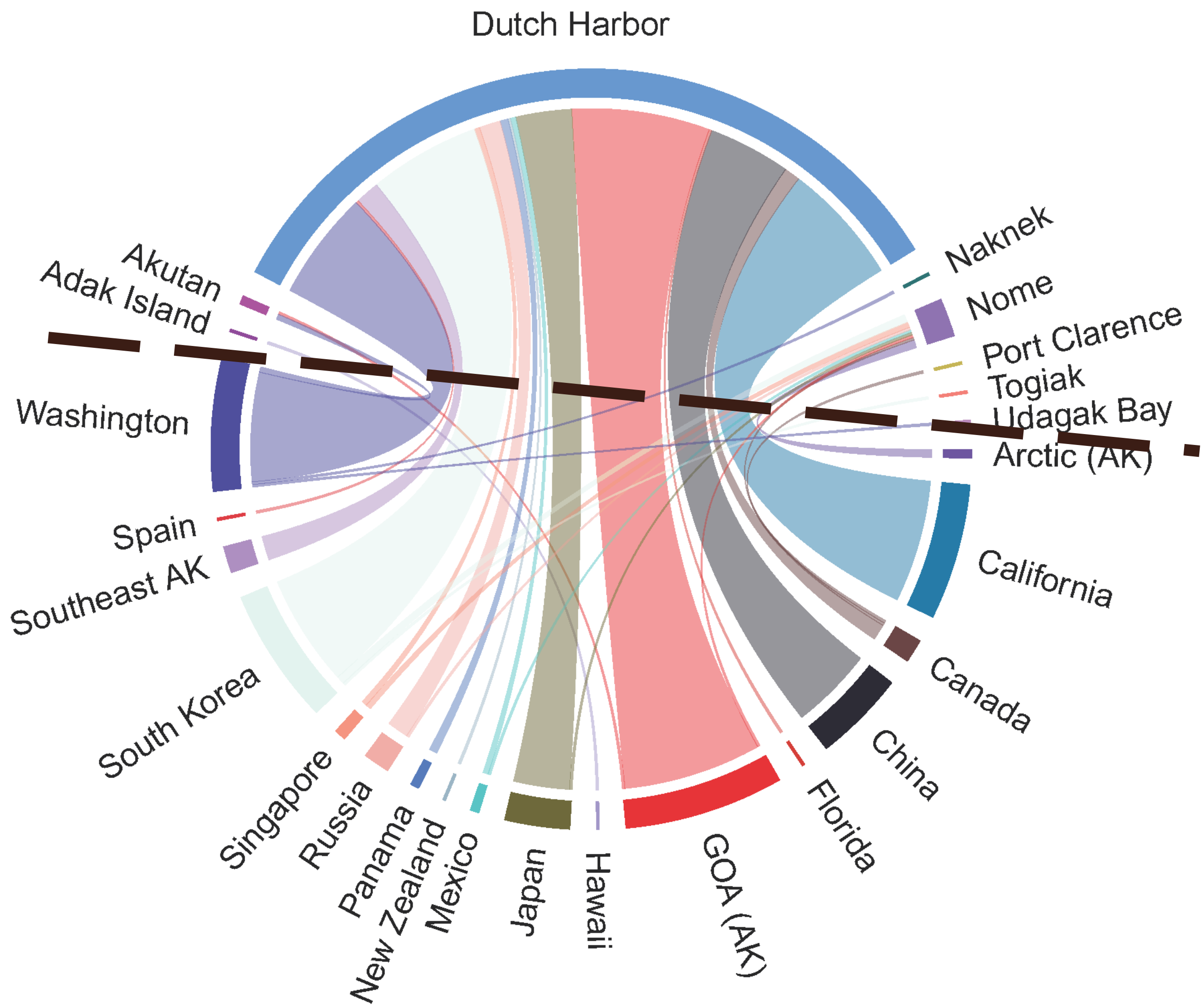
Identifying high-risk ports

Identifying high-risk ports



- – 2016 NBIC data
- – Commercial vessels
- – Direct connections only

Identifying high-risk ports

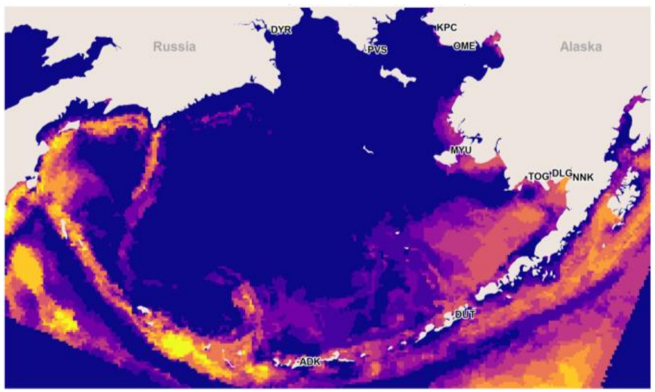


Receivers

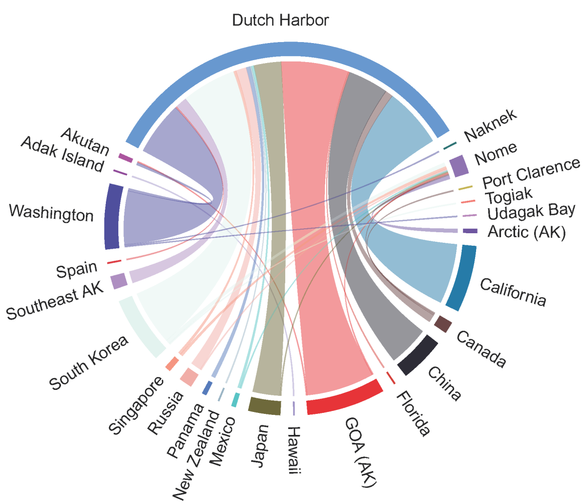
Contributors

Criteria Themes	Points
Distribution and Usable Habitat	30
Anthropogenic Influence	10
Biological Characteristics and Dispersal	30
Ecological and Socioeconomic Impacts	30

Ranking system: **WHO** to look at



Habitat maps: **WHEN** and **WHERE** is there suitable habitat



Shipping network: **WHERE** will they come from

Future research

Develop probabilistic models of spread

Collaborate with UAA economists to quantify socioeconomic costs of invasions

Acknowledgements

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Marine Invasive Species subcommittee

Committee for Noxious and Invasive Pest Management

North Pacific Research Board

Sea Grant Alaska

USGS science for a changing world

U.S. Fish & Wildlife Service, Department of the Interior

NOAA

absi Aleutian and Bering Sea Islands Landscape Conservation Cooperative

UAA Alaska Center for Conservation Science, University of Alaska Anchorage

Interested in learning more, or in being part of our expert review?

adroghini@alaska.edu

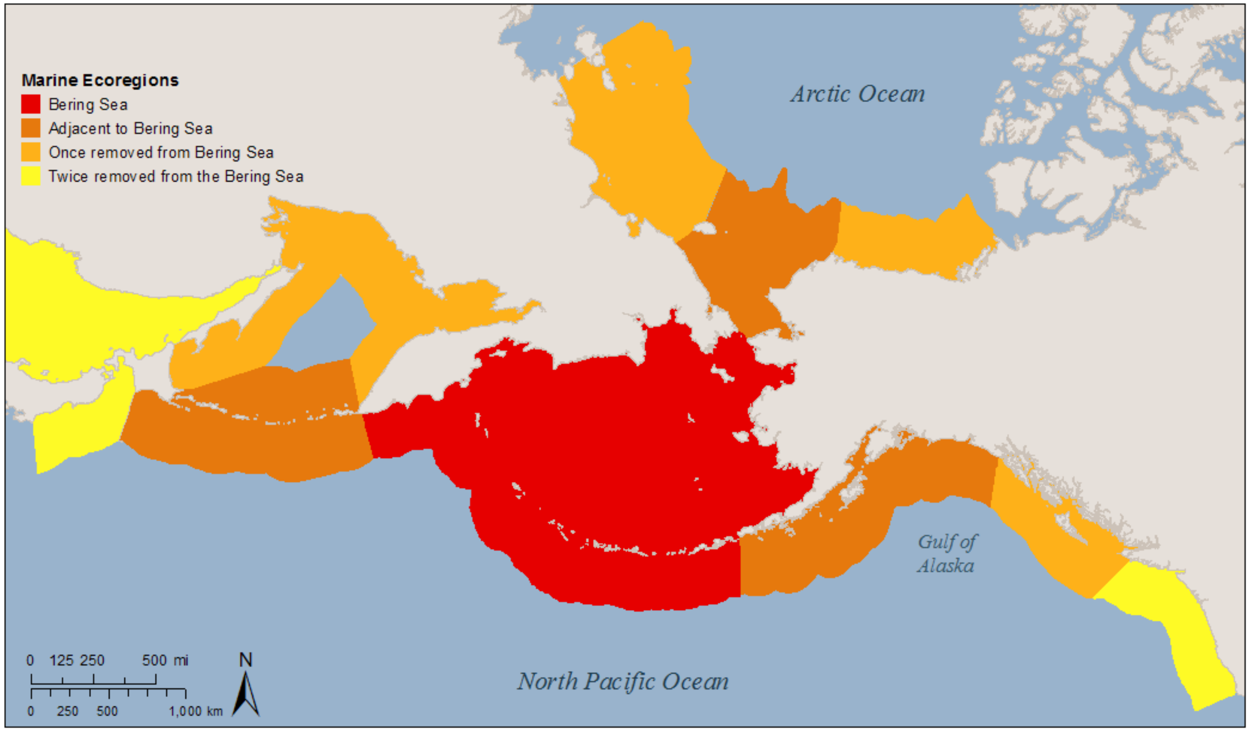
http://accs.uaa.alaska.edu/bering-sea-marine-invasives

Questions?

EXTRA SLIDES

Ranking system: Species list

- Literature review and ranking of 53 potential invaders
- ≤ 3 marine ecoregions[1] away



1. Spalding et al. 2007

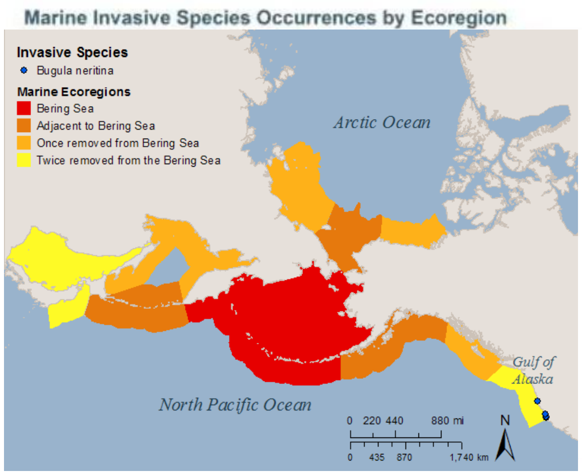
Bering Sea Marine Invasive Species Assessment

Alaska Center for Conservation Science

Scientific Name: *Bugula neritina*

Common Name *brown bryozoan*

Phylum	Bryozoa
Class	Gymnolaemata
Order	Cheilostomatida
Family	Bugulidae



Final Rank

Category	Range	Score	Data Deficiencies
Distribution and Habitat:	0 to 30	28	0
Anthropogenic Influence:	0 to 10	6	0
Biological Characteristics:	0 to 25	22	1
Impacts:	0 to 27	7	0
Totals:	92	62	1

General Biological Information

Tolerances and Thresholds

Minimum Temperature (°C)	2	Minimum Salinity (ppt)	18
Maximum Temperature (°C)	30.6	Maximum Salinity (ppt)	40
Minimum Reproductive Temperature (°C)	7	Minimum Reproductive Salinity (ppt)	33
Maximum Reproductive Temperature (°C)	999	Maximum Reproductive Salinity (ppt)	35

Additional Notes

Bugula neritina is a widespread, colonial bryozoan and a common fouling organism. It is a species complex comprised of at least three species that can only be distinguished through molecular work. Colonies branch out in a shrub-like pattern and are dark red to purple or brown. They can grow over 100 mm in height.

2. Anthropogenic Transportation and Establishment

2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish

Choice: A Readily establishes independent of anthropogenic disturbance/infrastructure (once introduced, can establish in natural, undisturbed areas)

Score: 4 of 4

Ranking Rationale:
This species grows on both natural and anthropogenic substrates.

Background Information:
This species has been reported from several anthropogenic and natural substrates, including oysters, seaweed, tunicates, rocks, ship hulls, and docks (Walters 1992; Fofonoff et al. 2003).

Literature Cited:
NEMESIS; Fofonoff et al. 2003 Walters 1992

Choice: B No

Score: 0 of 2

Ranking Rationale:
This species is not farmed or cultivated.

Background Information:

Literature Cited:
NEMESIS; Fofonoff et al. 2003

Choice: B Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced

Score: 2 of 4

Ranking Rationale:
This species has been introduced worldwide by anthropogenic vectors. Because adults are sessile and the free-swimming larval stage is very short-lived, it is unlikely that this species can travel long distances on its own.

Background Information:
This species has been transported globally by ship fouling and hitchhiking on oysters (Mackie et al. 2006; Cohen 2011; Ryland et al. 2011). The free-swimming larval stage usually lasts between 2 to 10 hours (Cohen 2011).

Literature Cited:
Cohen 2011 Ryland et al. 2011 Mackie et al. 2006

Total Scored:	6
Total Possible:	10
# Data Deficient:	0

Taxa	N	Average_Score
Crustaceans - Ostracods	1	27.95
Crustaceans - Cumaceans	1	33.45
Crustaceans - Copepods	3	33.67
Crustaceans - Amphipod	4	40.41
Crustaceans - Tanaids	1	41.05
Cnidarians - Anthozoans	2	42.63
Mollusks - Gastropods	4	44
Annelid - Polychaete	3	44.67
Crustaceans - Isopods	2	45
Crustaceans - Shrimp	2	45.5
Tunicates - Tunicates	8	51.61
Bryozoans	3	53.97
Cnidarians - Hydrozoan	2	53.98
Crustaceans - Crayfish	1	54.3
Fishes	5	55.77
Mollusks - Bivalves	7	57.95
Crustaceans - Barnacles	2	60.38
Crustaceans - Crabs	2	67.83

How will they get here?

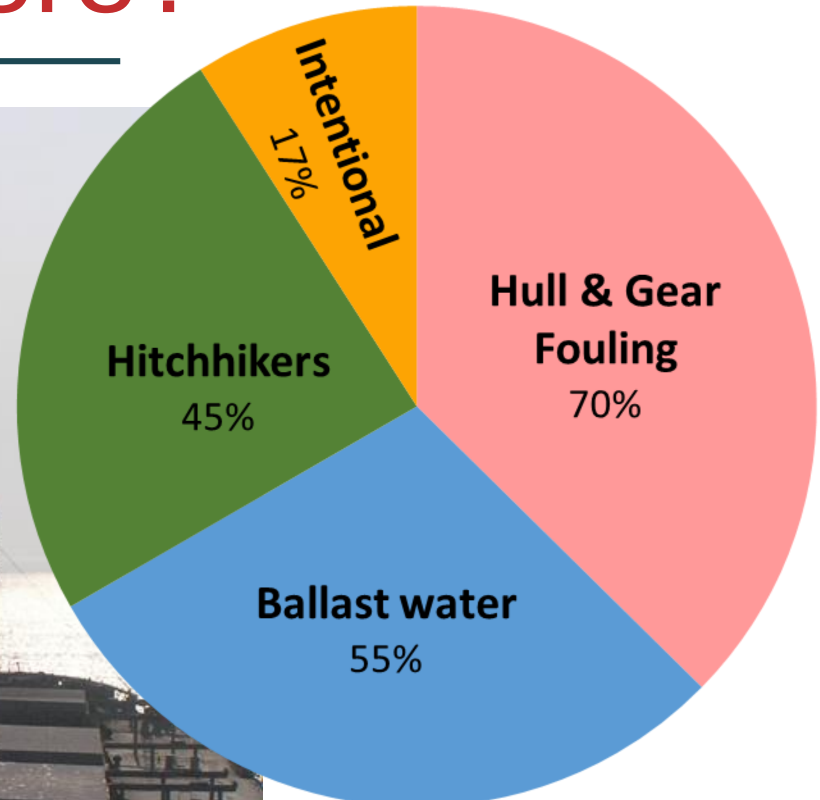


Photo credits: www.mxak.org/community/kivalina/kivalina2.html

VMS data

- 2003 to 2016 data
- Large fishing vessels
- ~250 000 trips from 888 vessels

- Important connections to BC and NWP states
- Major contributors: Seattle (WA), Anacortes (WA) and Newport (OR)
- Major receivers: Dutch, Kodiak