Temperature and food-chain length explain kelp forest responses to a marine heatwave

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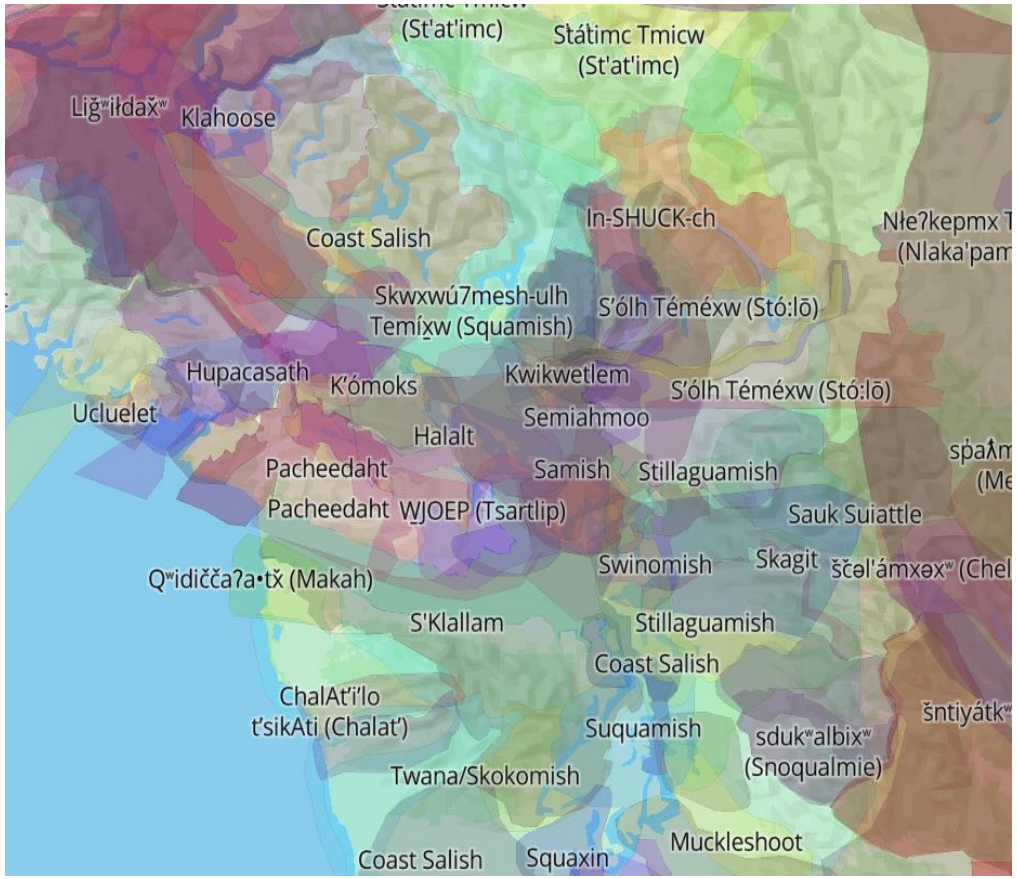
University of Victoria

bmsc BAMFIELD MARINE SCIENCES CENTRE

THE UNIVERSITY OF WESTERN AUSTRALIA

We extend our deep gratitude to the numerous First Nations on whose traditional, unceded or treaty lands and waters this work was conducted



Native-land

PACHEEDAHT FIRST NATION

huu ay aht
ANCIENT SPIRIT, MODERN MIND

MAA-NULTH FIRST NATIONS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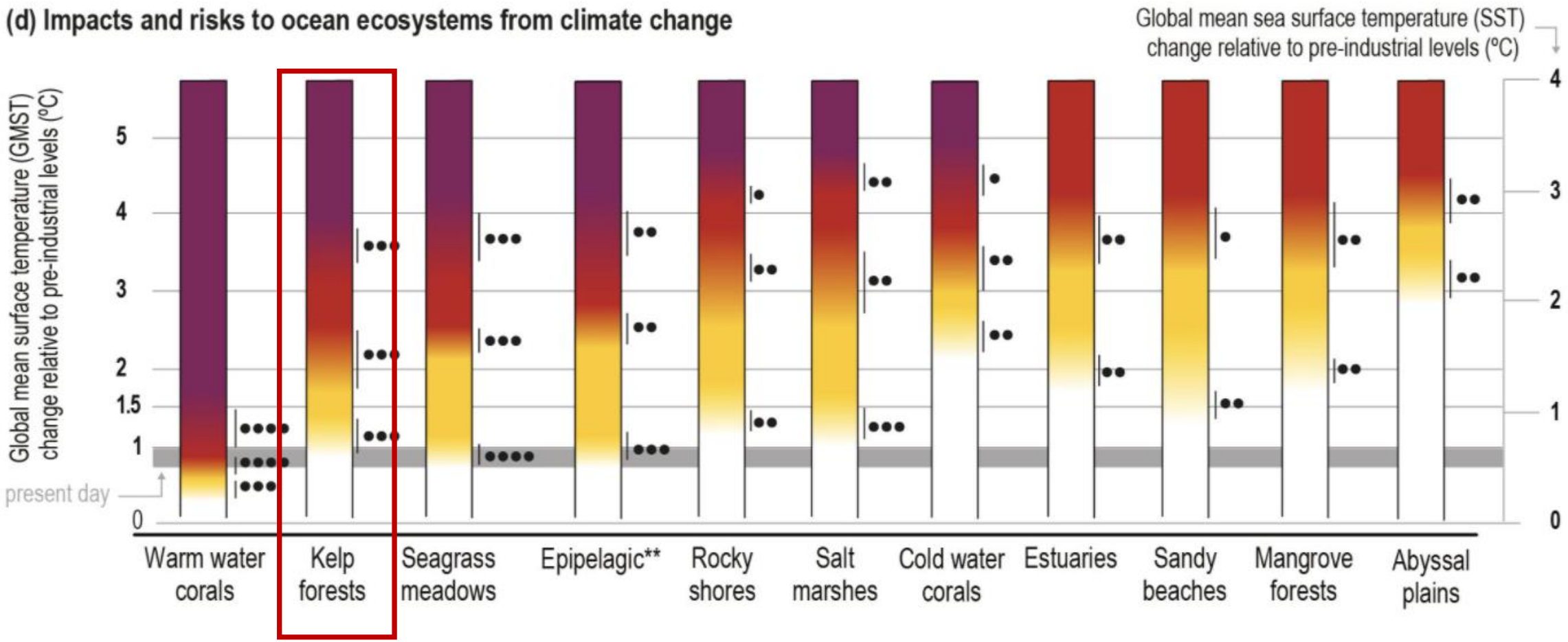
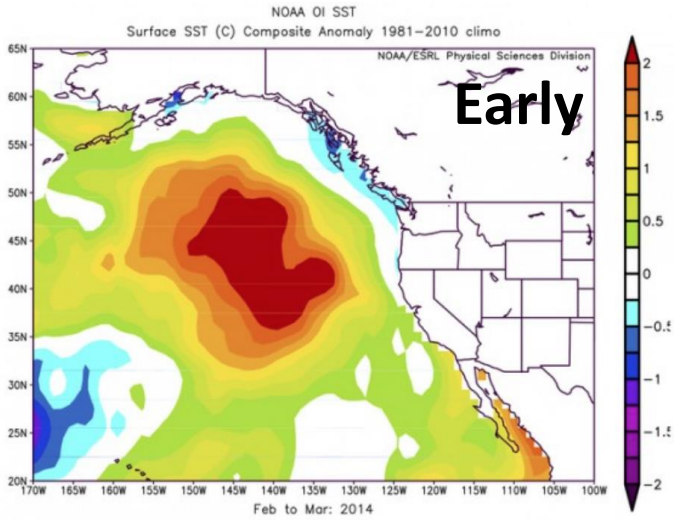
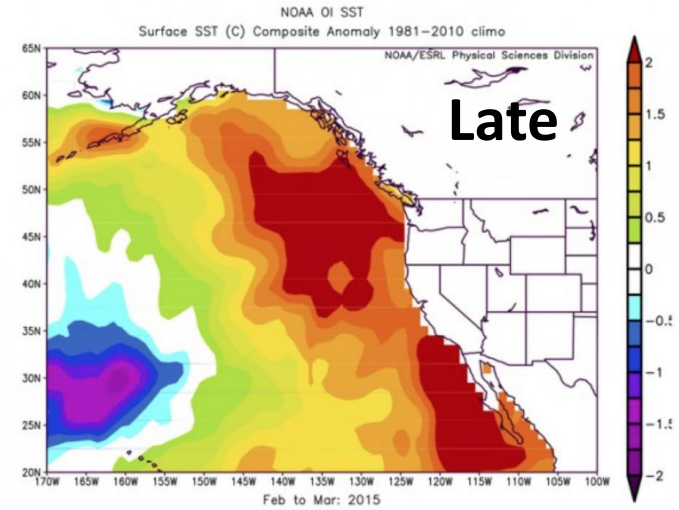
Kelp vulnerable to ocean warming (especially marine heatwaves)

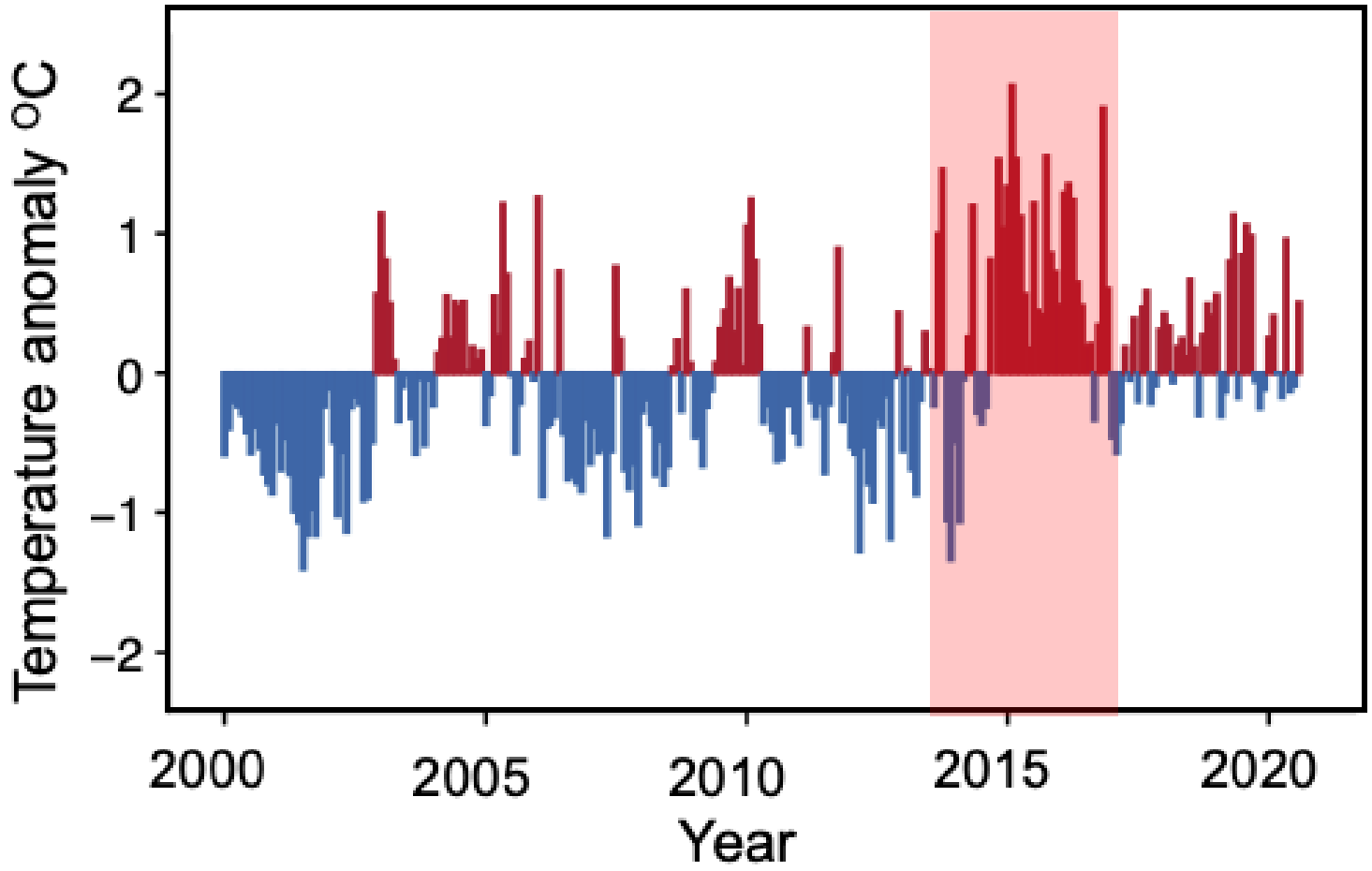


IPCC 2019 – Technical summary

Marine heatwaves in Northeast Pacific



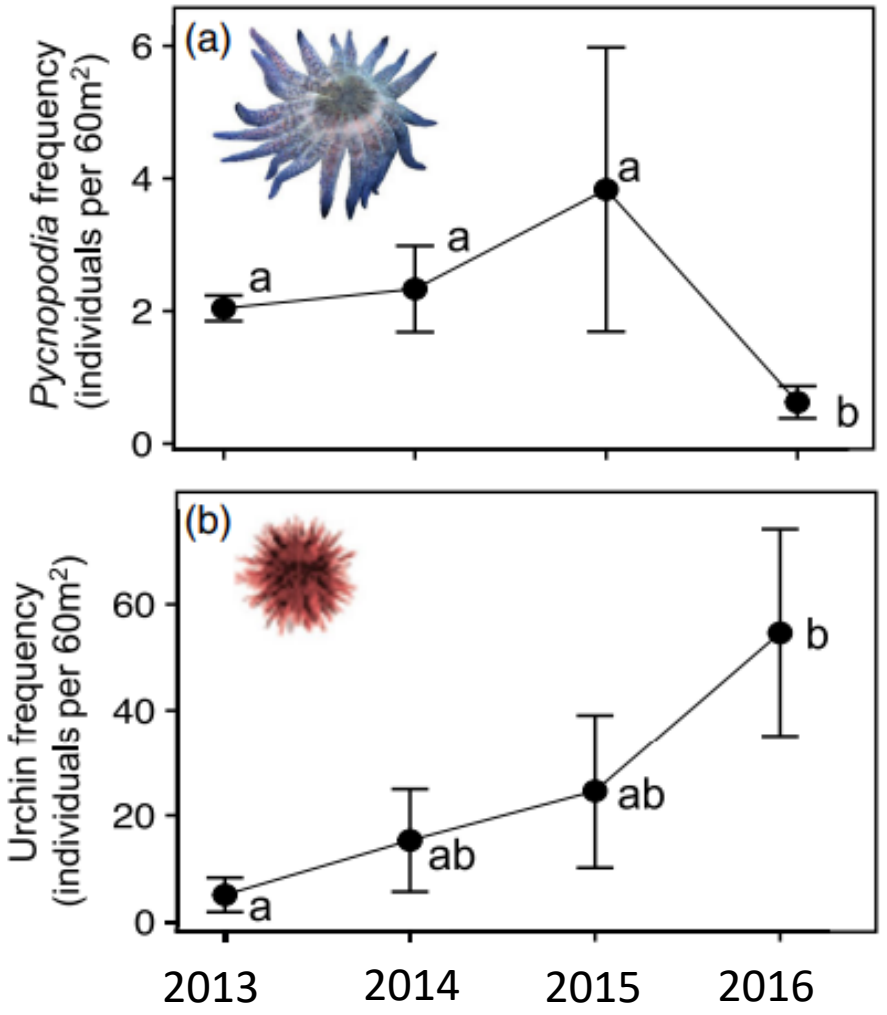




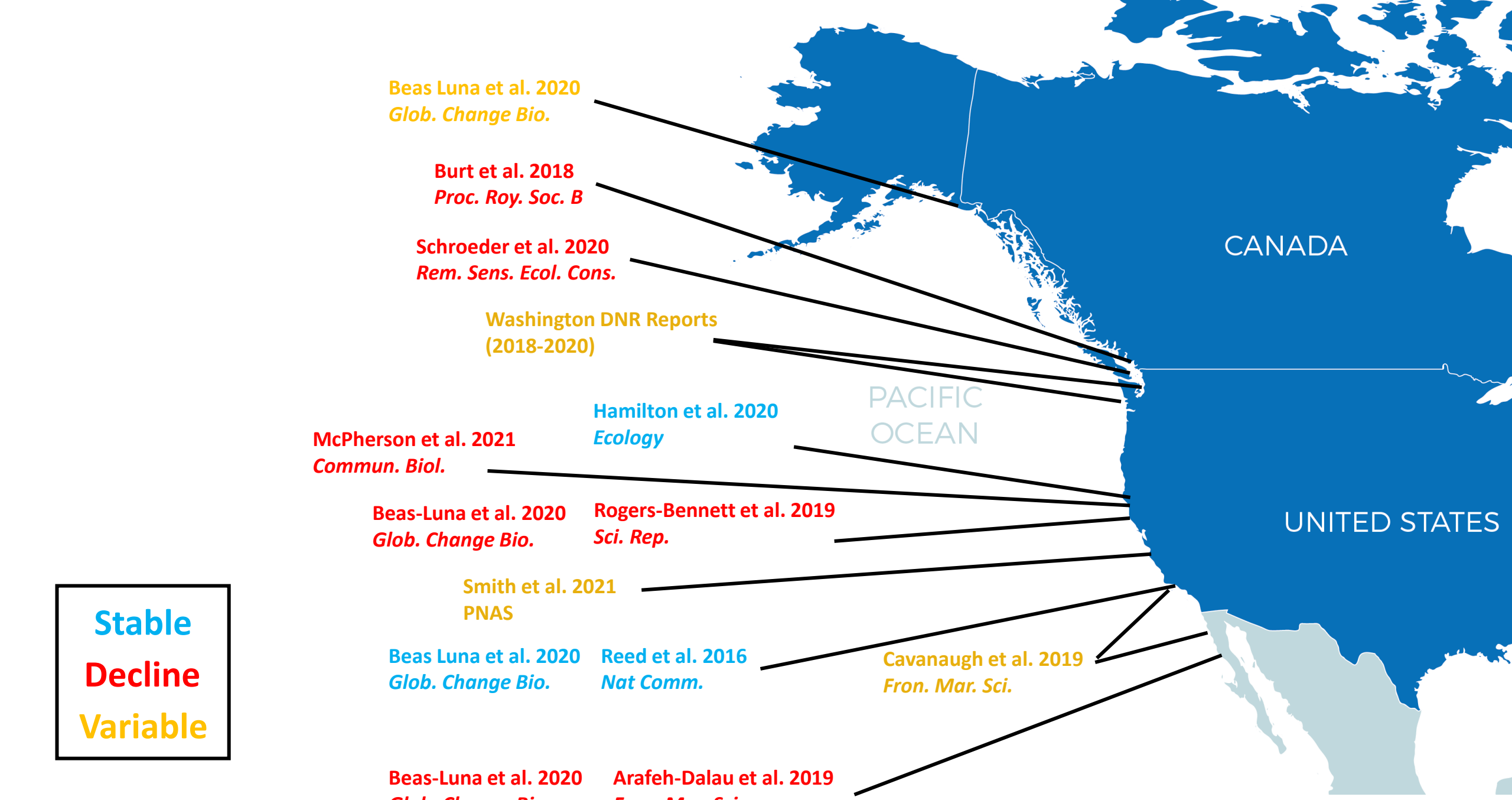
Data from Amphitrite Lighthouse (Outer coast of Barkley Sound, Vancouver Island)

Indirect effect - sea star wasting disease epidemic

Barkley Sound, BC



Starko et al 2022


Beas Luna et al. 2020
Glob. Change Bio.
Burt et al. 2018
Proc. Roy. Soc. B
Schroeder et al. 2020
Rem. Sens. Ecol. Cons.
Washington DNR Reports
(2018-2020)
Hamilton et al. 2020
Ecology
McPherson et al. 2021
Commun. Biol.
Beas-Luna et al. 2020
Glob. Change Bio.
Rogers-Bennett et al. 2019
Sci. Rep.
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PNAS
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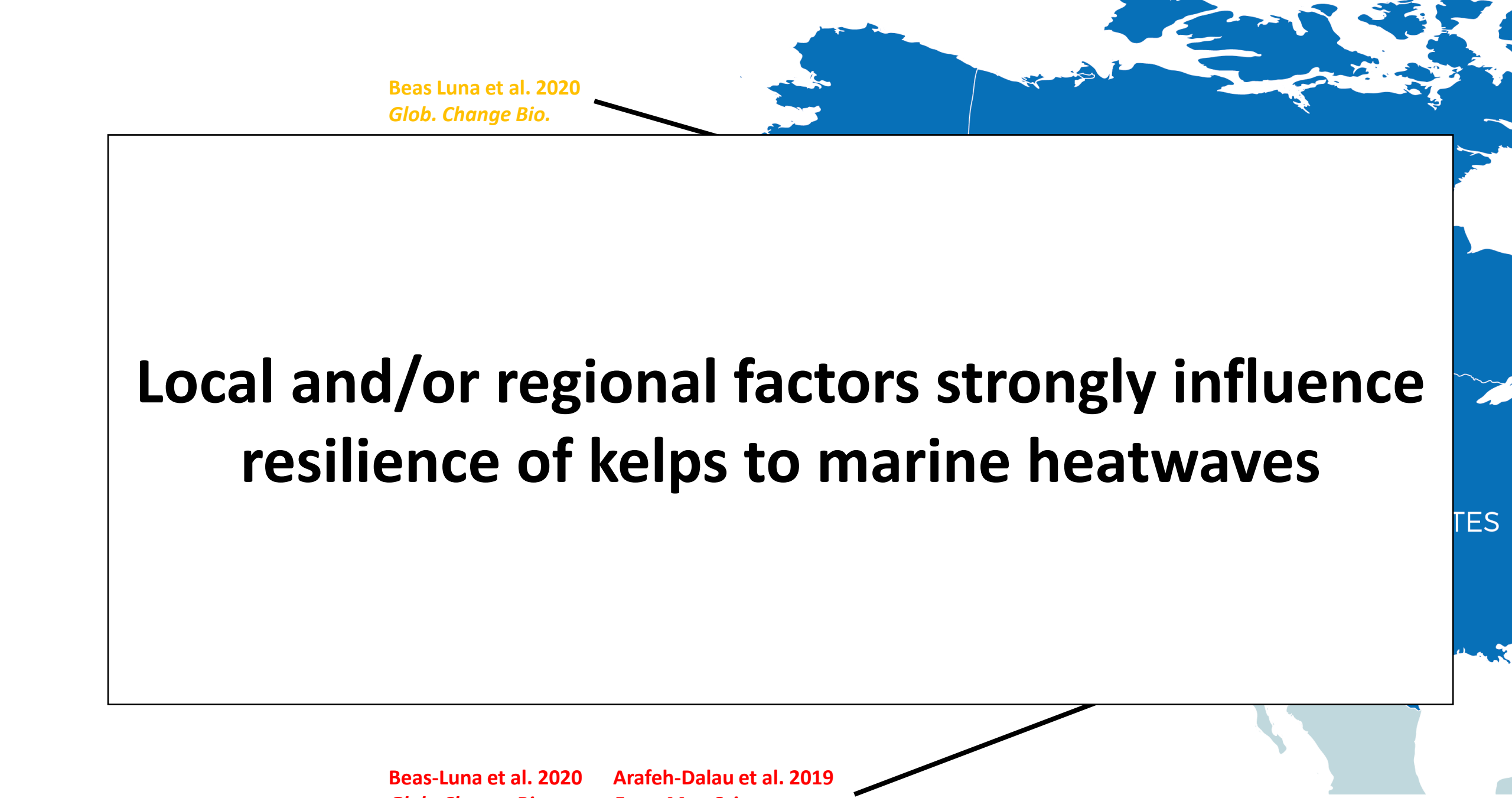
Reed et al. 2016
Nat Comm.
Cavanaugh et al. 2019
Fron. Mar. Sci.
Beas-Luna et al. 2020
Glob. Change Bio.
Arafeh-Dalau et al. 2019
Fron. Mar. Sci.
CANADA
PACIFIC
OCEAN
UNITED STATES
Stable
Decline
Variable



Local and/or regional factors strongly influence resilience of kelps to marine heatwaves

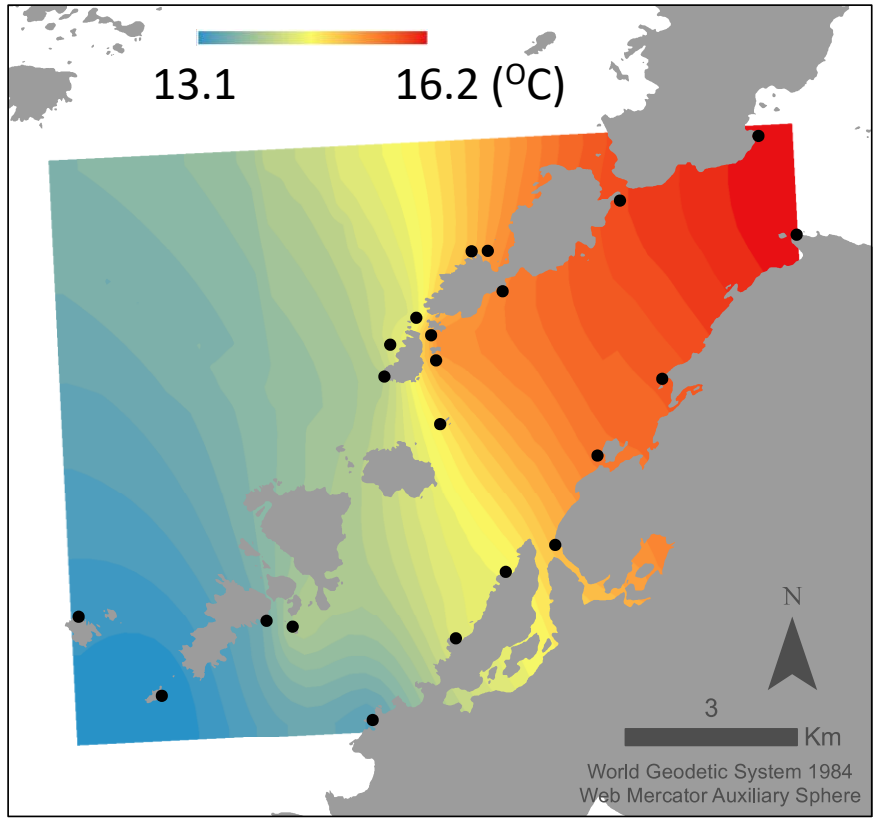
Research questions

- **How were canopy kelp forests (*Macrocystis* and *Nereocystis*) in British Columbia impacted by the 2014-2016 marine heatwave?**
- **How variable were these impacts within and across regions?**
- **What factors predict the resilience of kelp forests in the face of these abiotic and biotic drivers?**

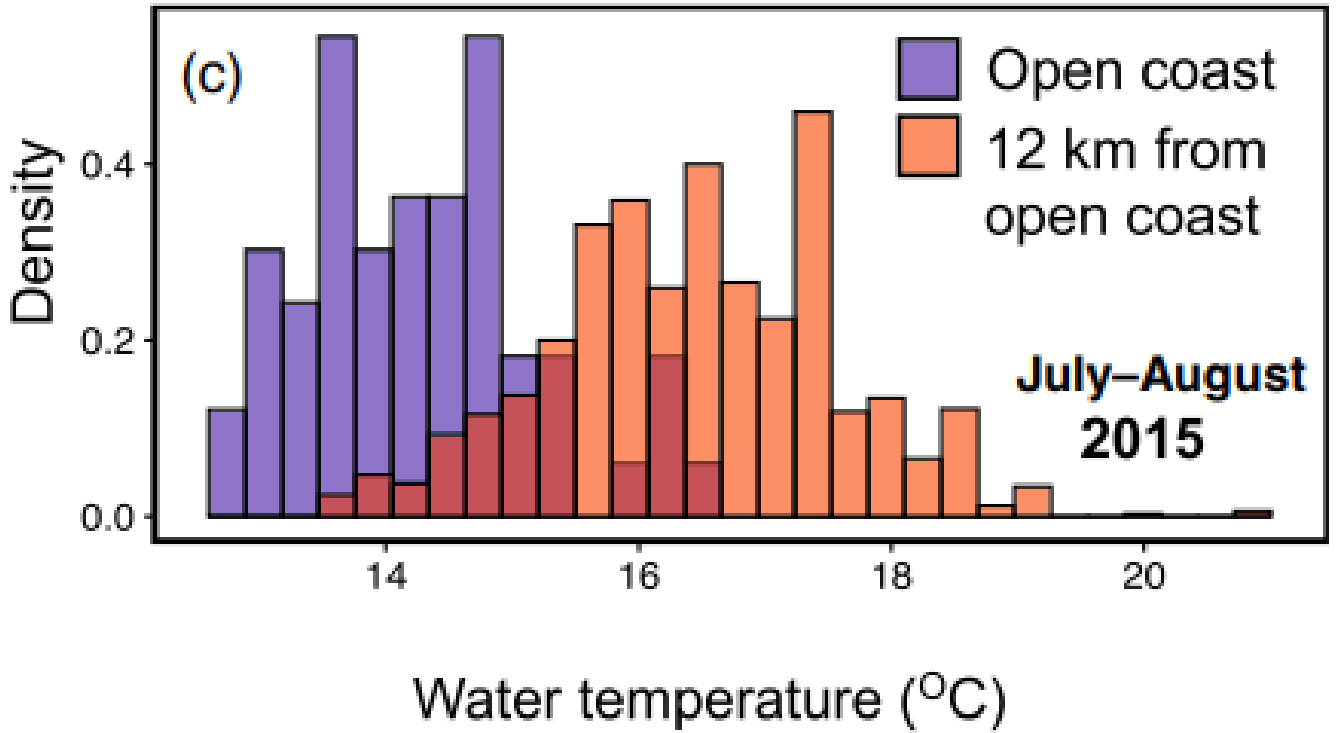
N

100 km

Inshore water substantially warmer (> 3^{O}C) !!!

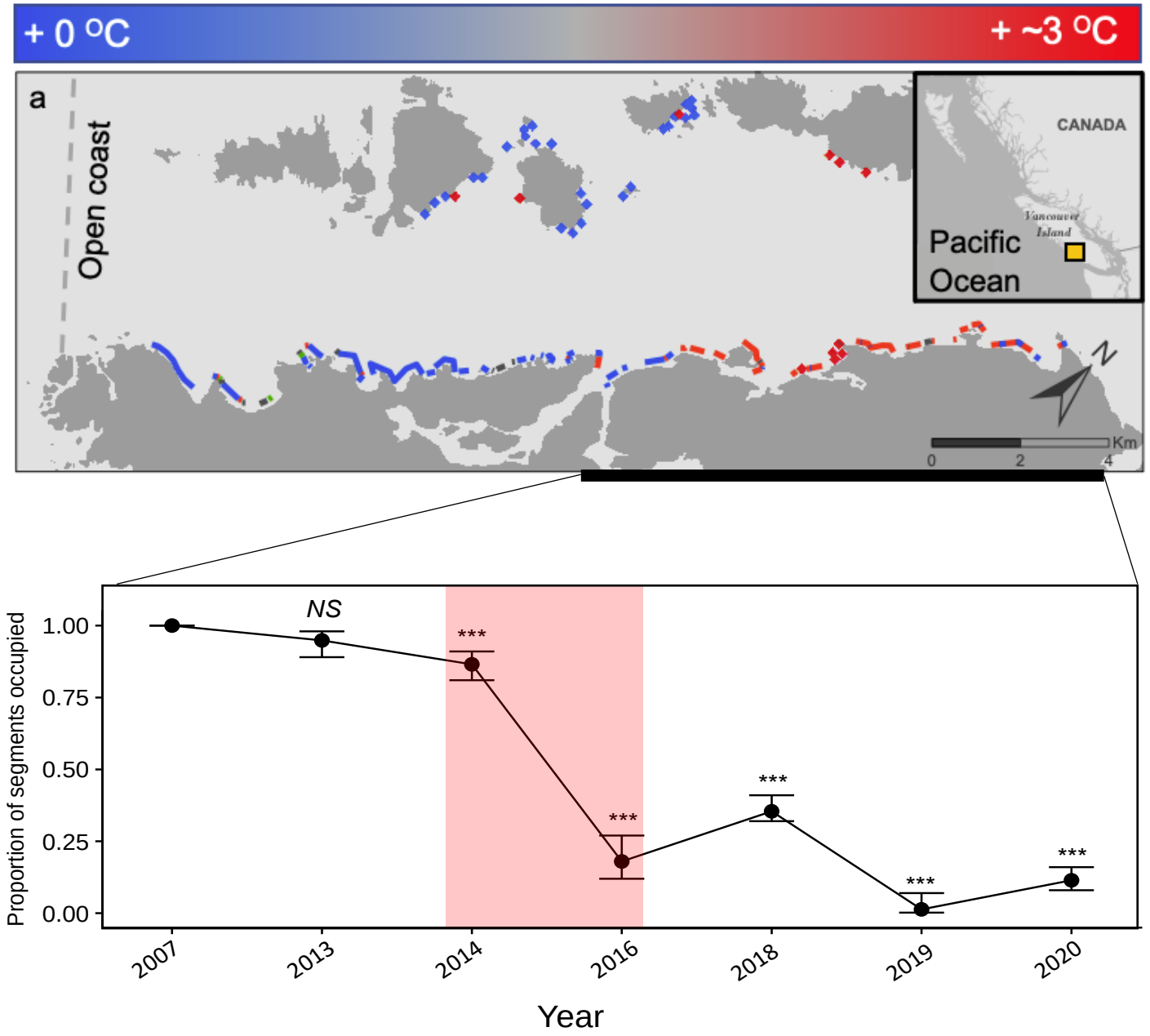


Average water temperature from summer 2019 iButton loggers



Starko et al. 2022 *Ecological Applications*

Most kelp lost from inshore sites but outer coast more resilient



Starko et al. 2022 *Ecological Applications*

How wide spread were these impacts elsewhere in BC?

- Used two time-point “snapshot” analyses comparing imagery from before (1995 – 2007) to after (2017 – 2022) the heatwave
  - Presence/absence along 30-100m shoreline units

How wide spread were these impacts elsewhere in BC?

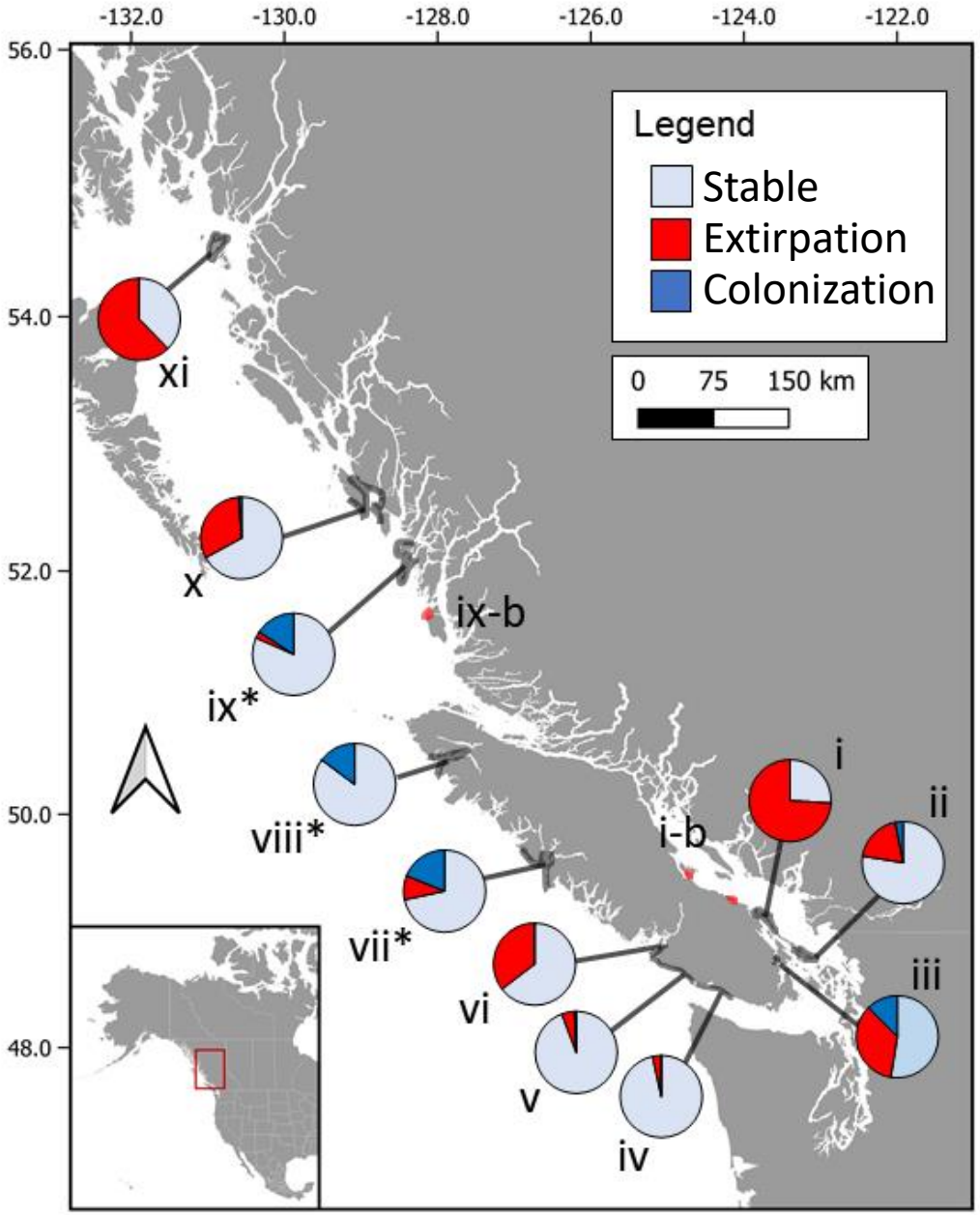
- Used two time-point “snapshot” analyses comparing imagery from before (1995 – 2007) to after (2017 – 2022) the heatwave

- Regions (n = 11) span local and regional temperature gradients as well as areas with and without sea otters
  - H1: Local temperature predicts kelp persistence
  - H2: Sea otters increase resilience through trophic redundancy (e.g., see Burt et al. 2019)

How wide spread were these impacts elsewhere in BC?

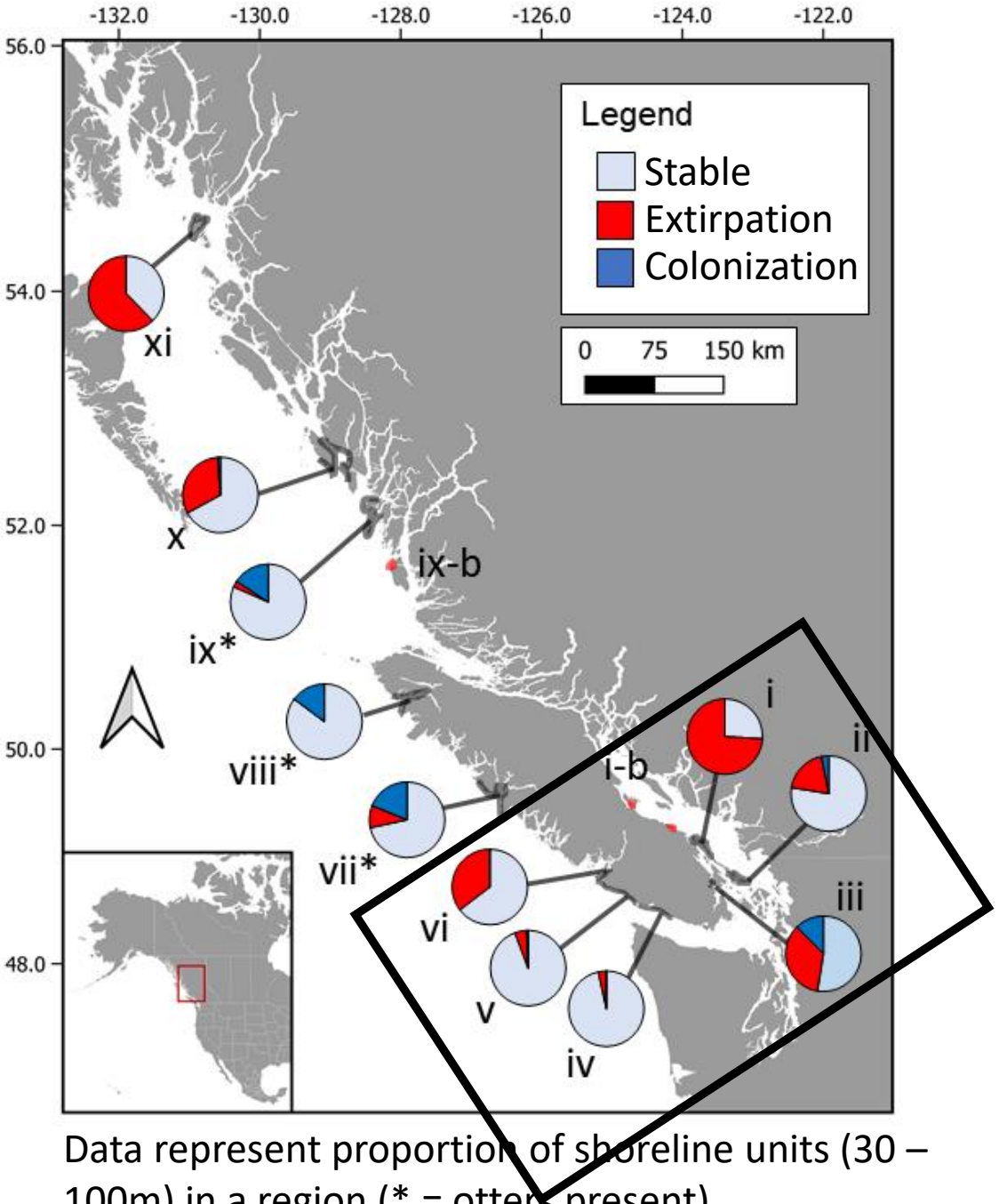
- Used two time-point “snapshot” analyses comparing imagery from before (1995 – 2007) to after (2017 – 2022) the heatwave
- Regions (n = 11) span local and regional temperature gradients as well as areas with and without sea otters
- Compiled time series for regions where data were available (n = 7) to contextualize patterns of change

Kelp persistence varied within and across regions



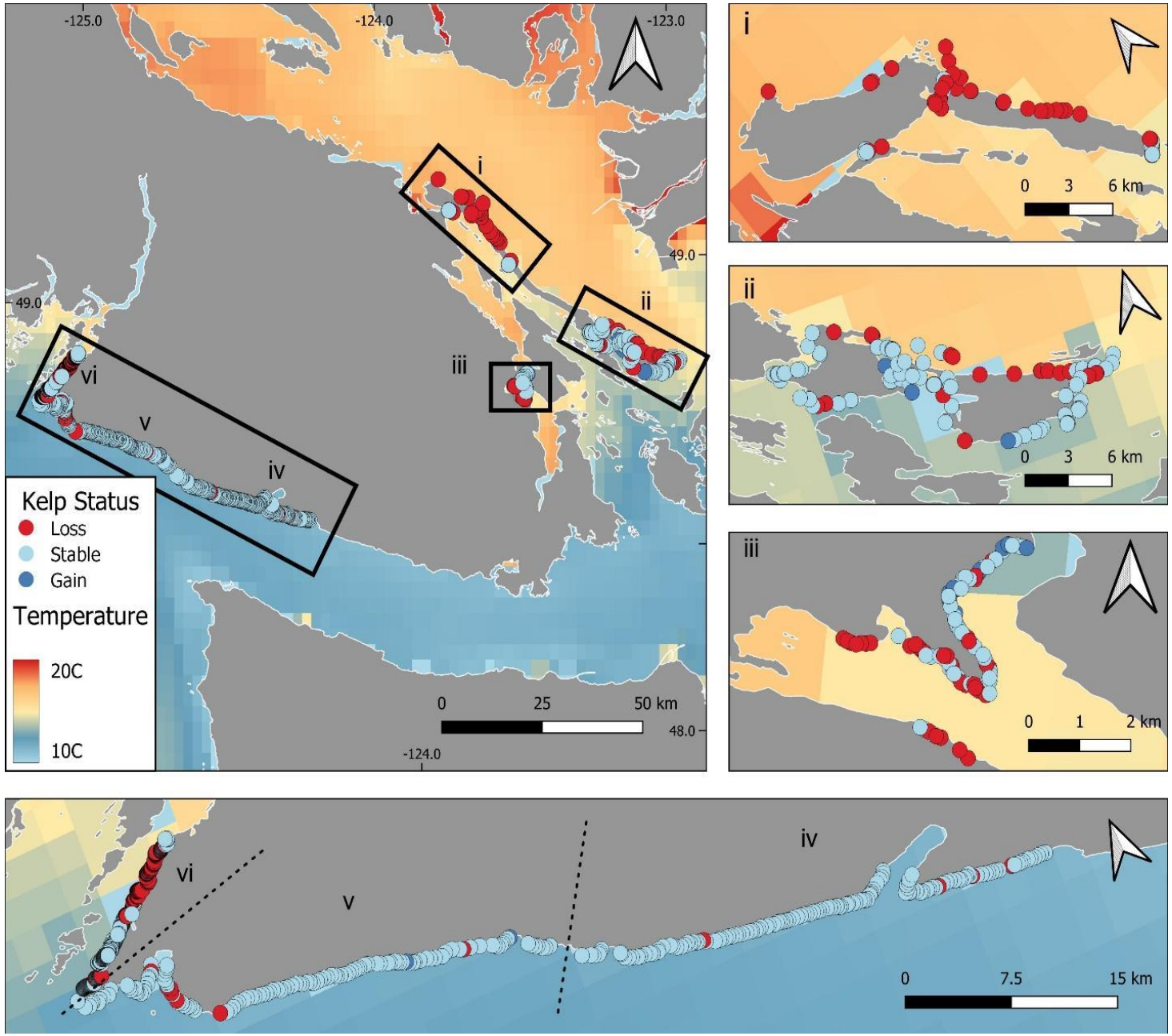
Data represent proportion of shoreline units (30 – 100m) in a region (* = otters present)

What drove variability in southern BC?



Data represent proportion of shoreline units (30 – 100m) in a region (* = otters present)

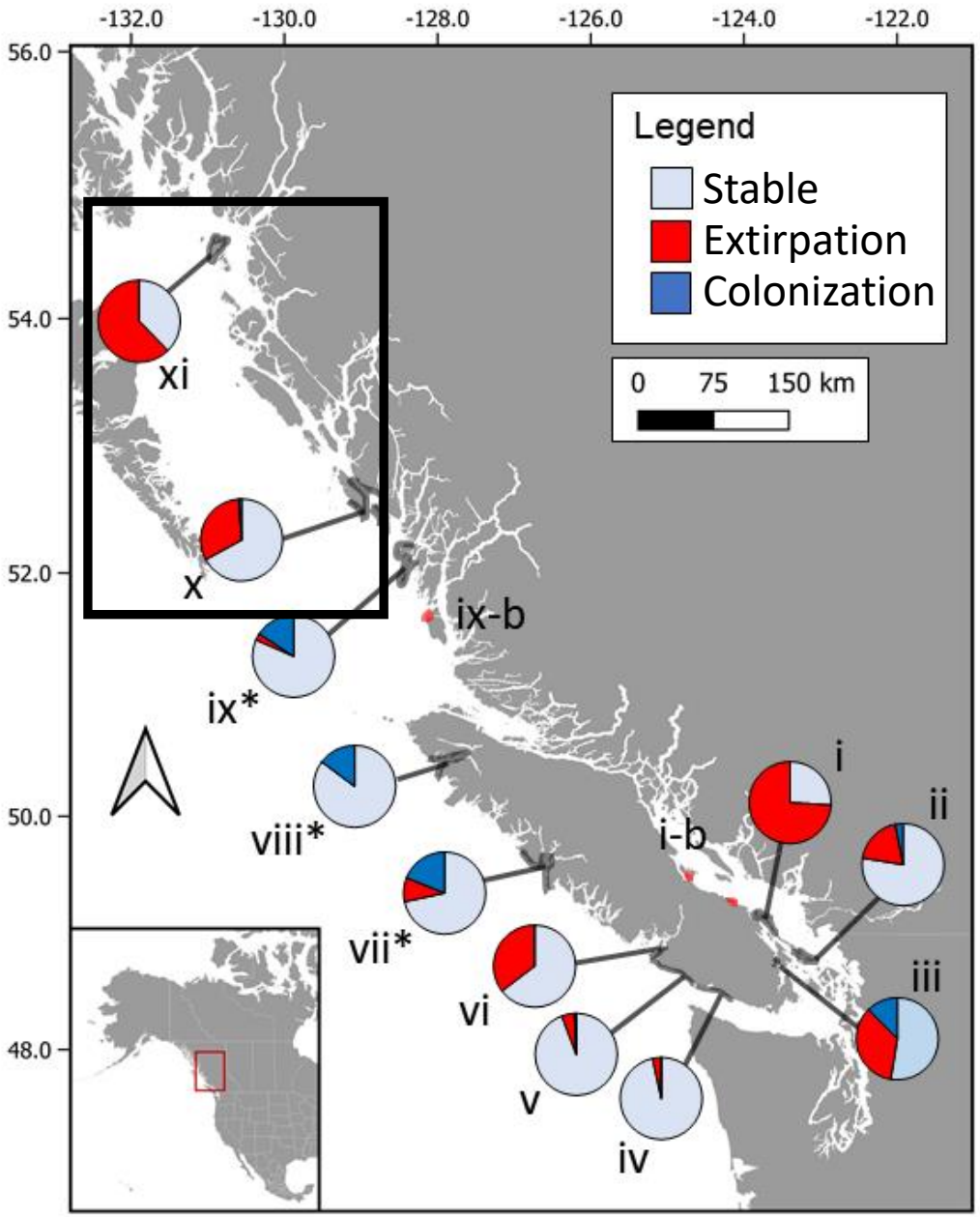
Temperature strongly predicted kelp persistence



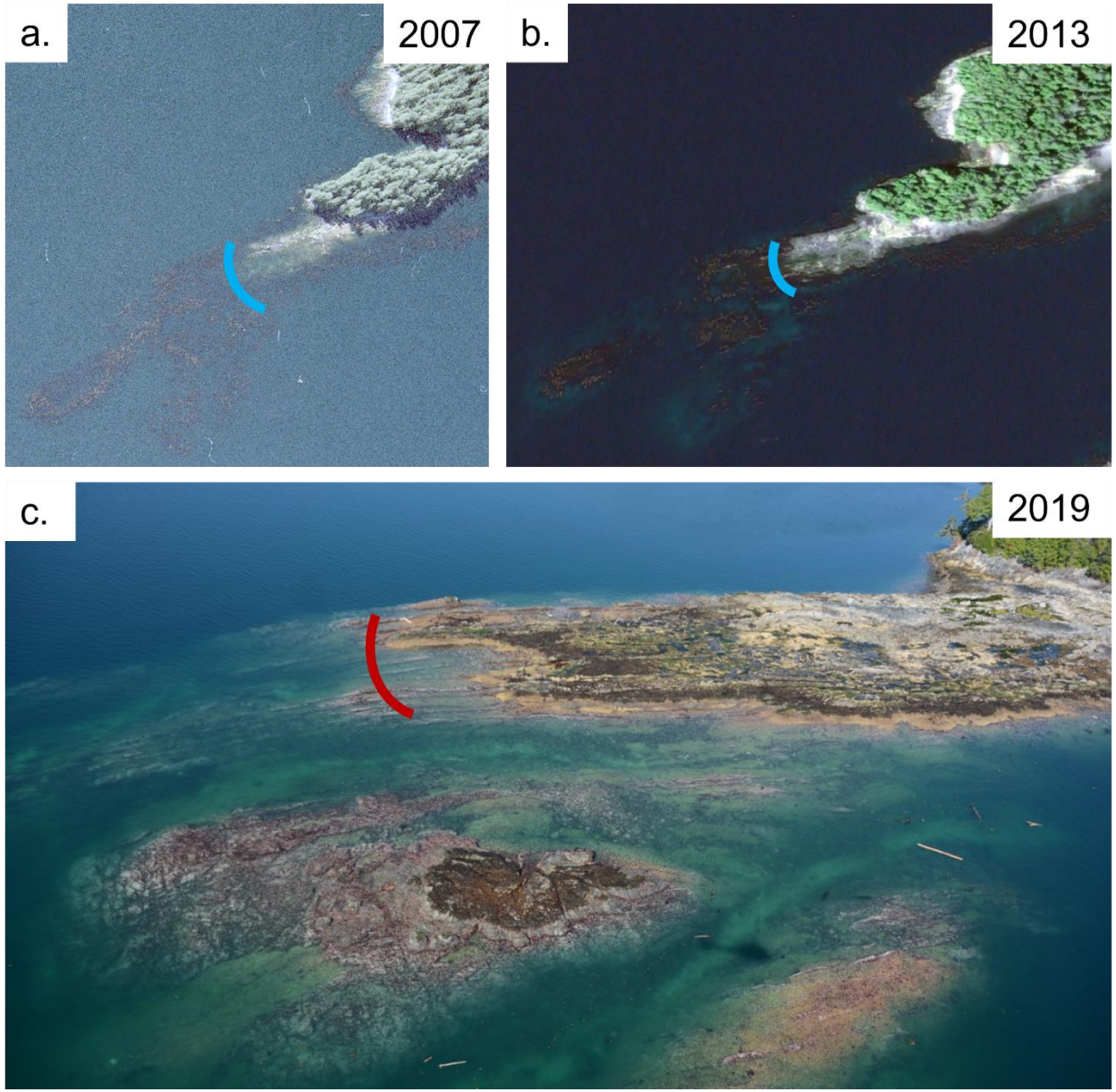
Spatially explicit binomial GLMM (spaMM):
$P < 0.001$***

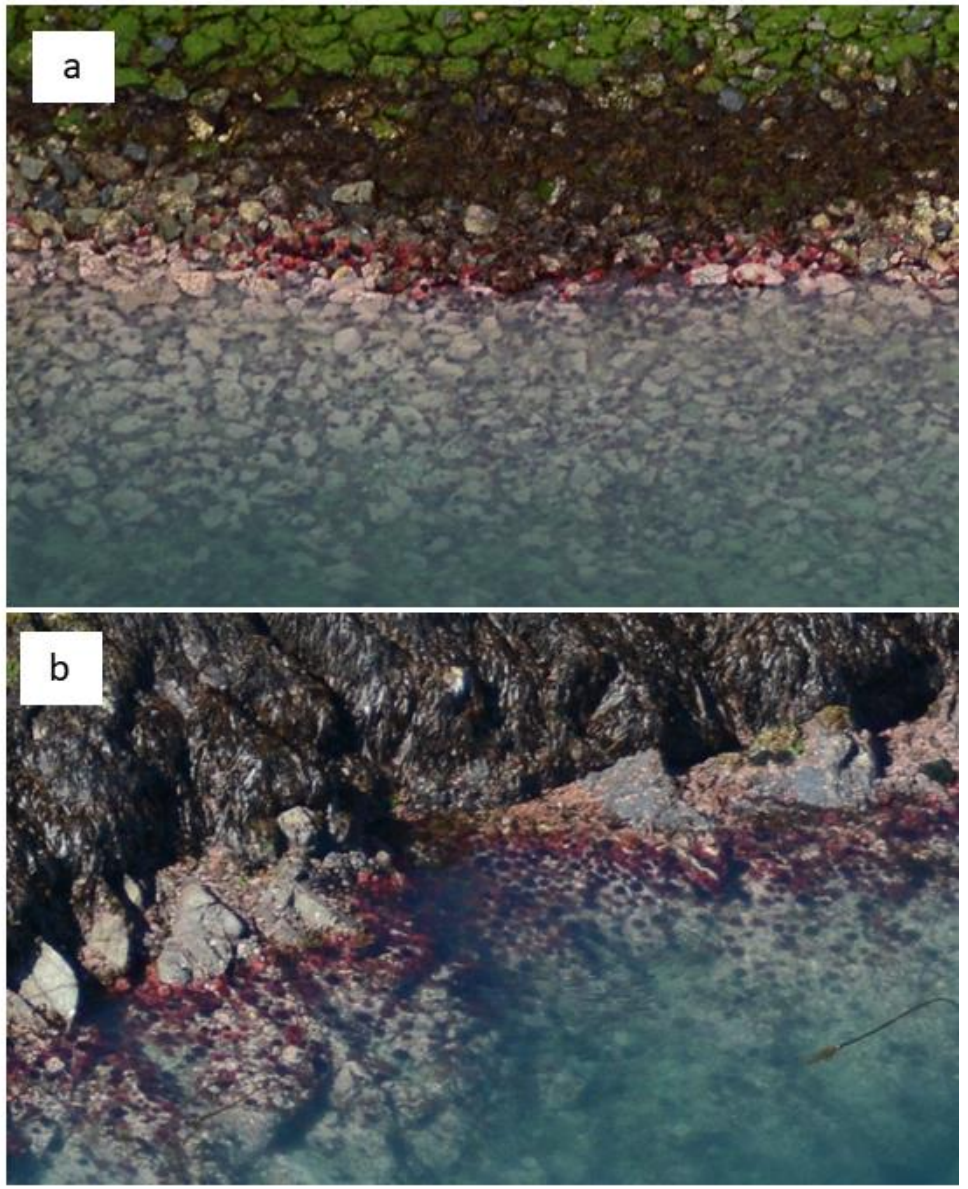
Temperature data from LiveOcean Model (August 2017)

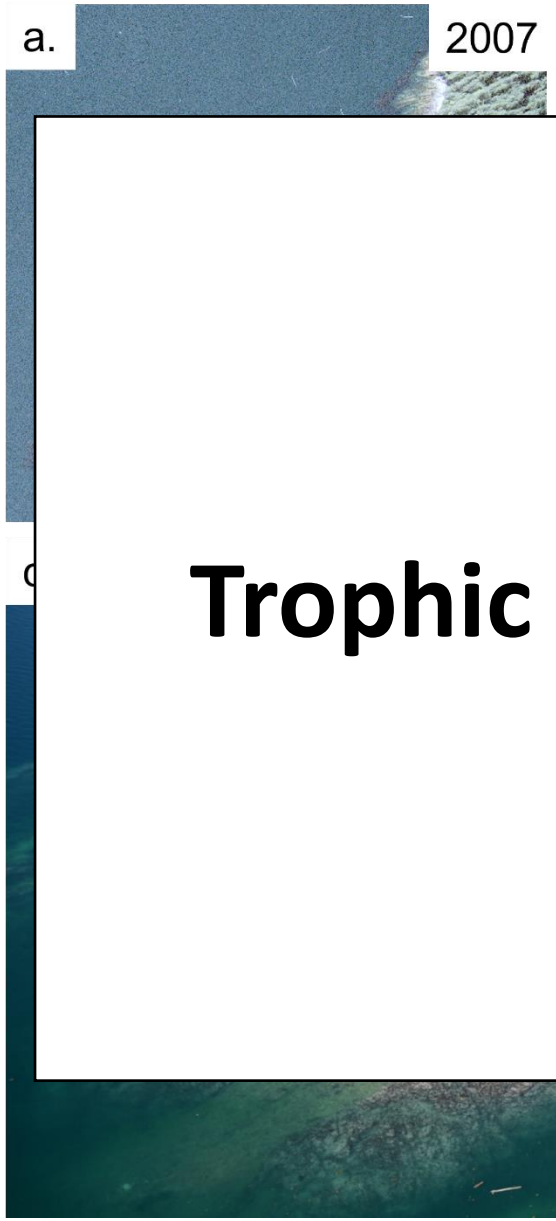
What caused losses in Northern BC where temperatures rarely exceed 15C?

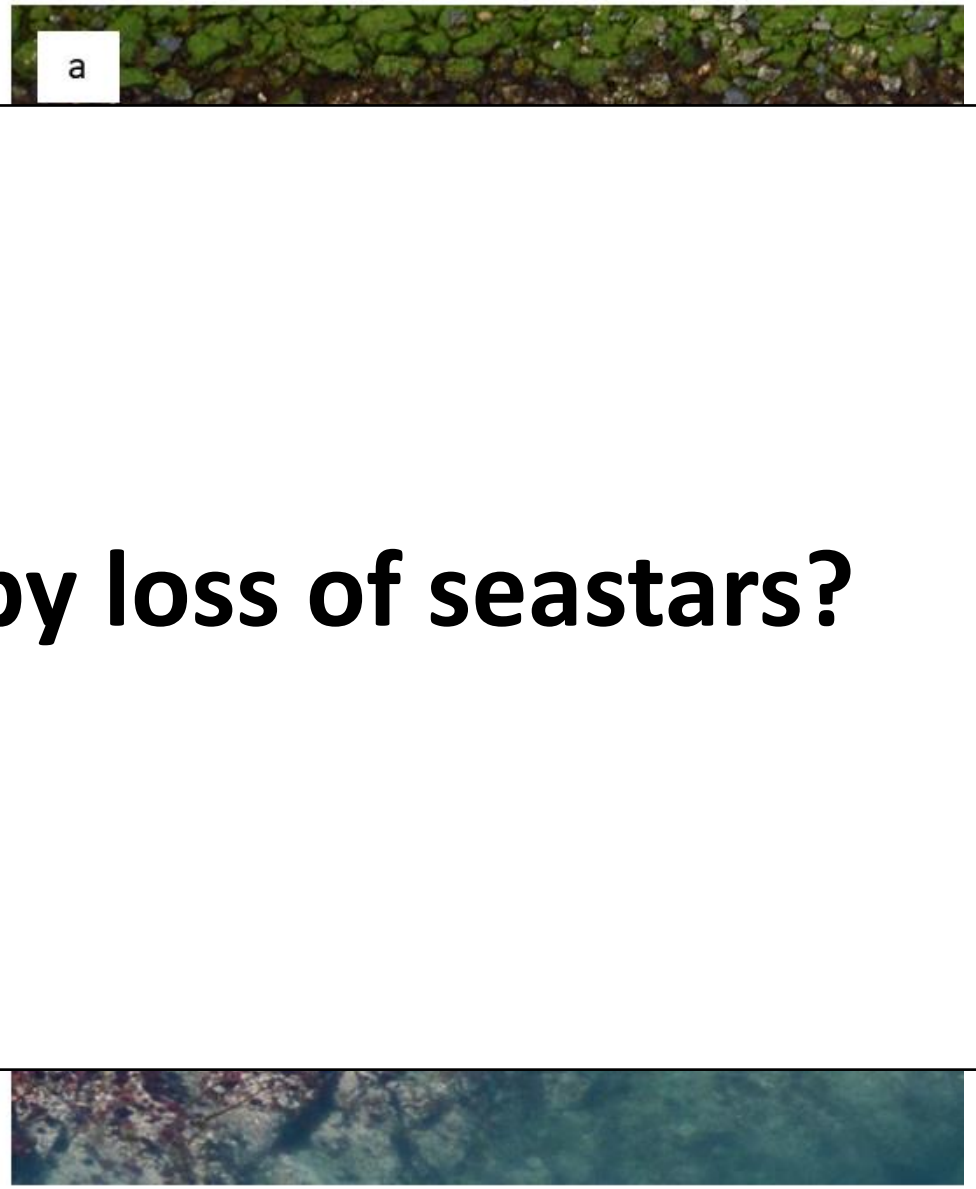


Data represent proportion of shoreline units (30 – 100m) in a region (* = otters present)

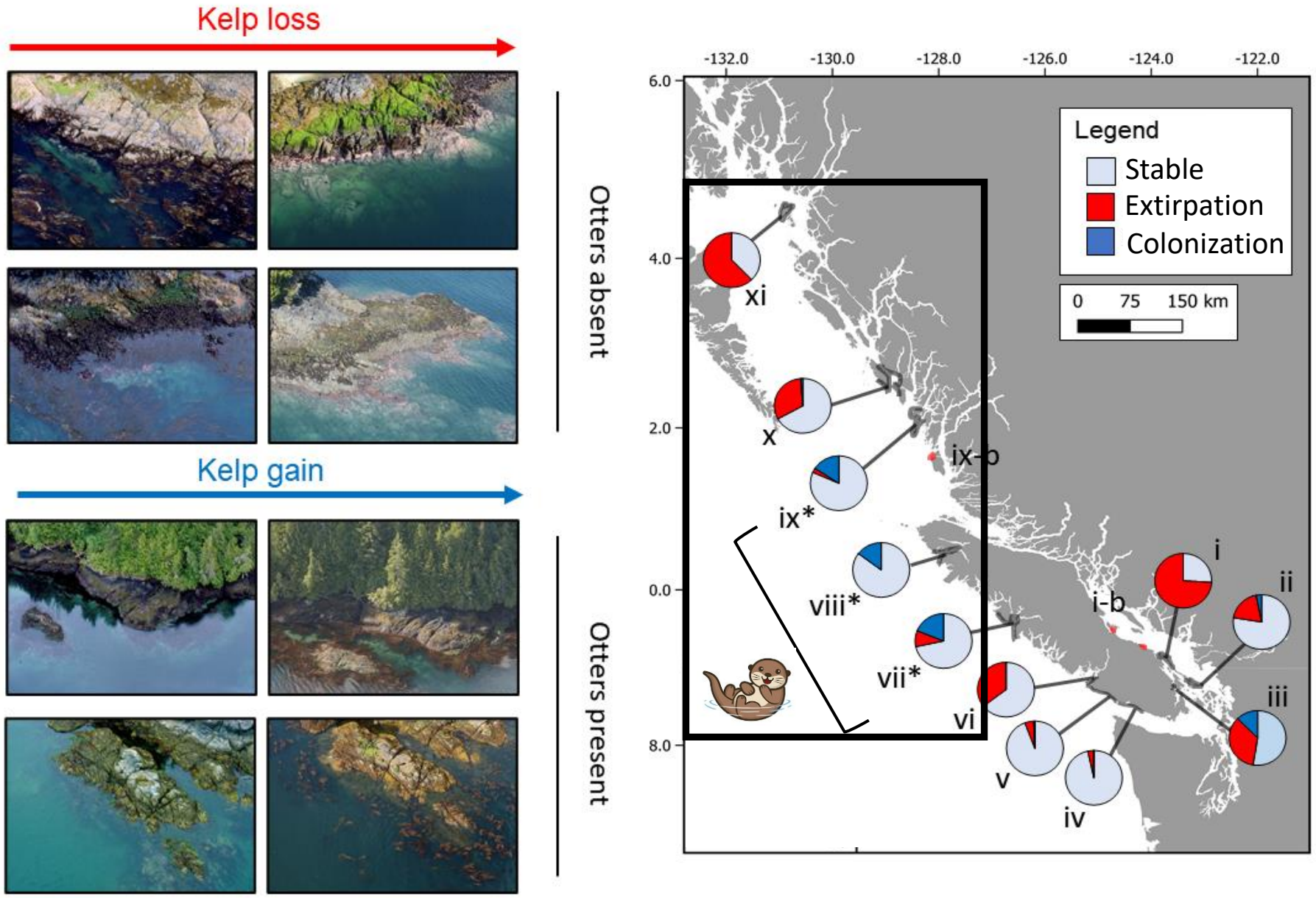

a.
2007
b.
2013
c.
2019


a
b

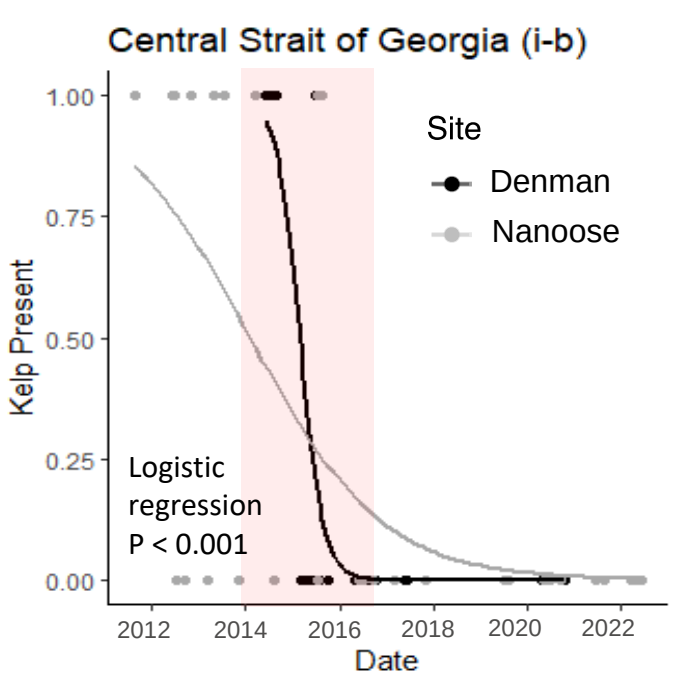


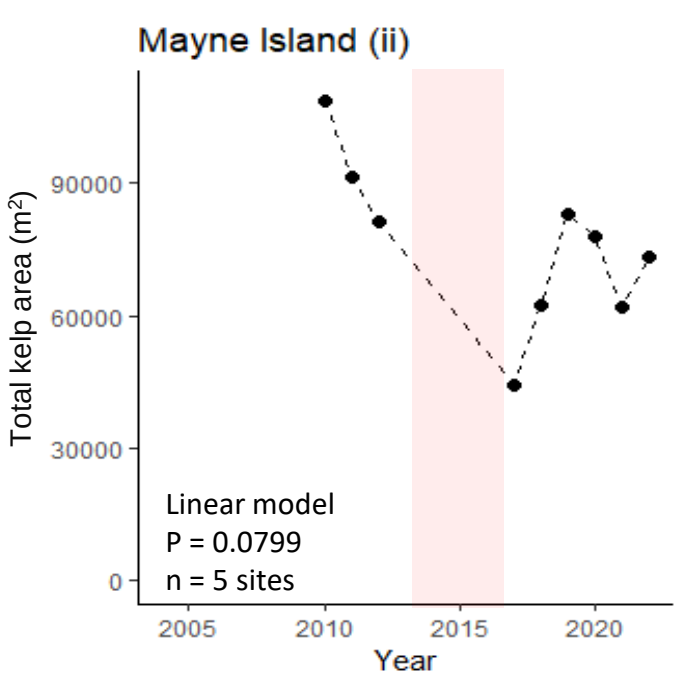


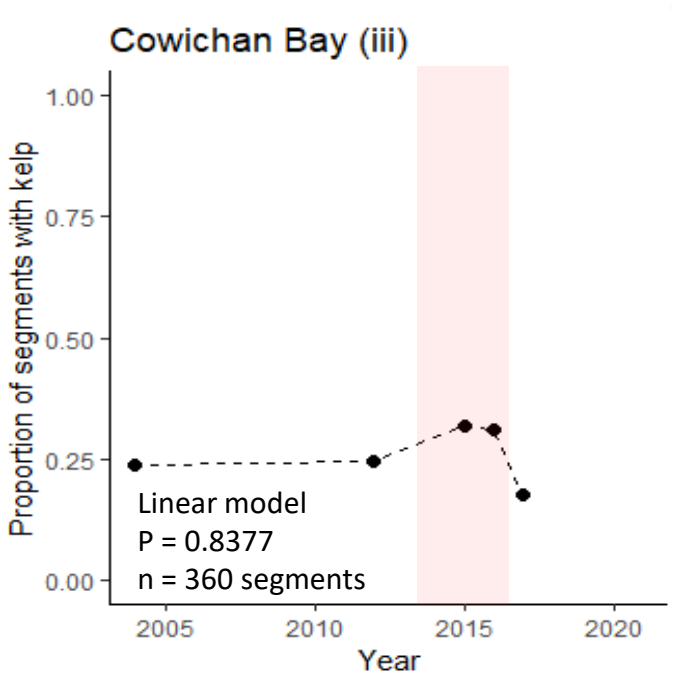
Trophic cascade driven by loss of seastars?

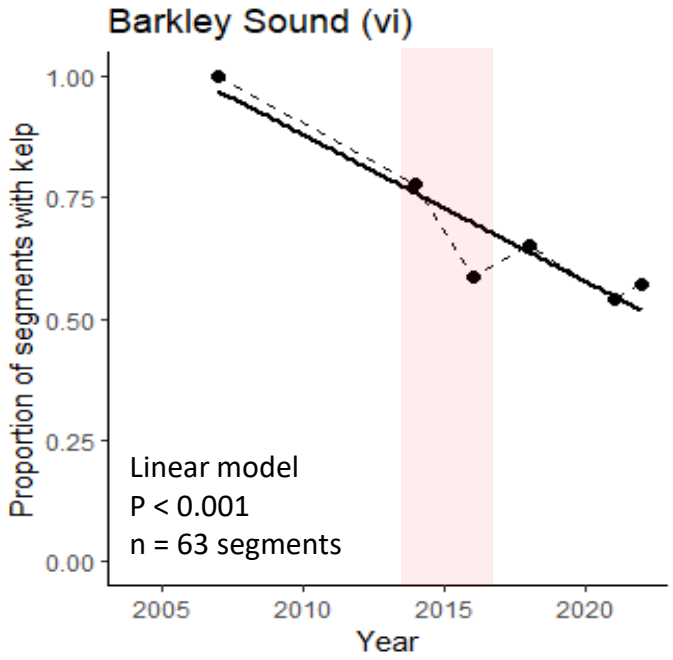


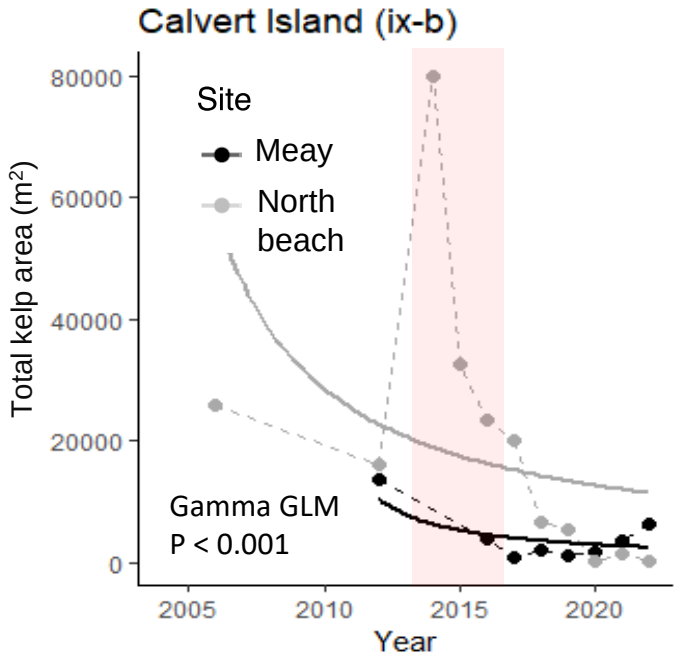
Increased persistence in regions with sea otters and some colonization of new coastline…

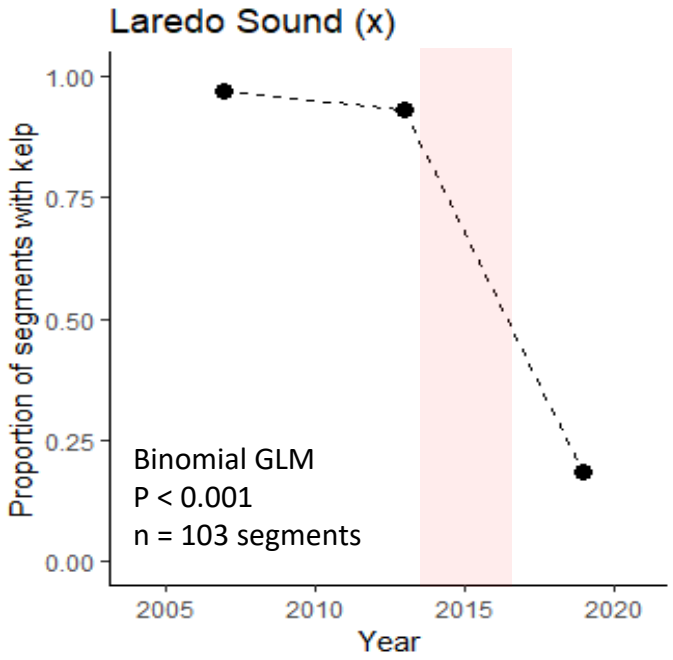

Central Strait of Georgia (i-b)
Kelp Present
Date
Site
Denman
Nanoose
Logistic
regression
P < 0.001


Mayne Island (ii)
Total kelp area (m²)
Year
Linear model
P = 0.0799
n = 5 sites


Cowichan Bay (iii)
Proportion of segments with kelp
Year
Linear model
P = 0.8377
n = 360 segments

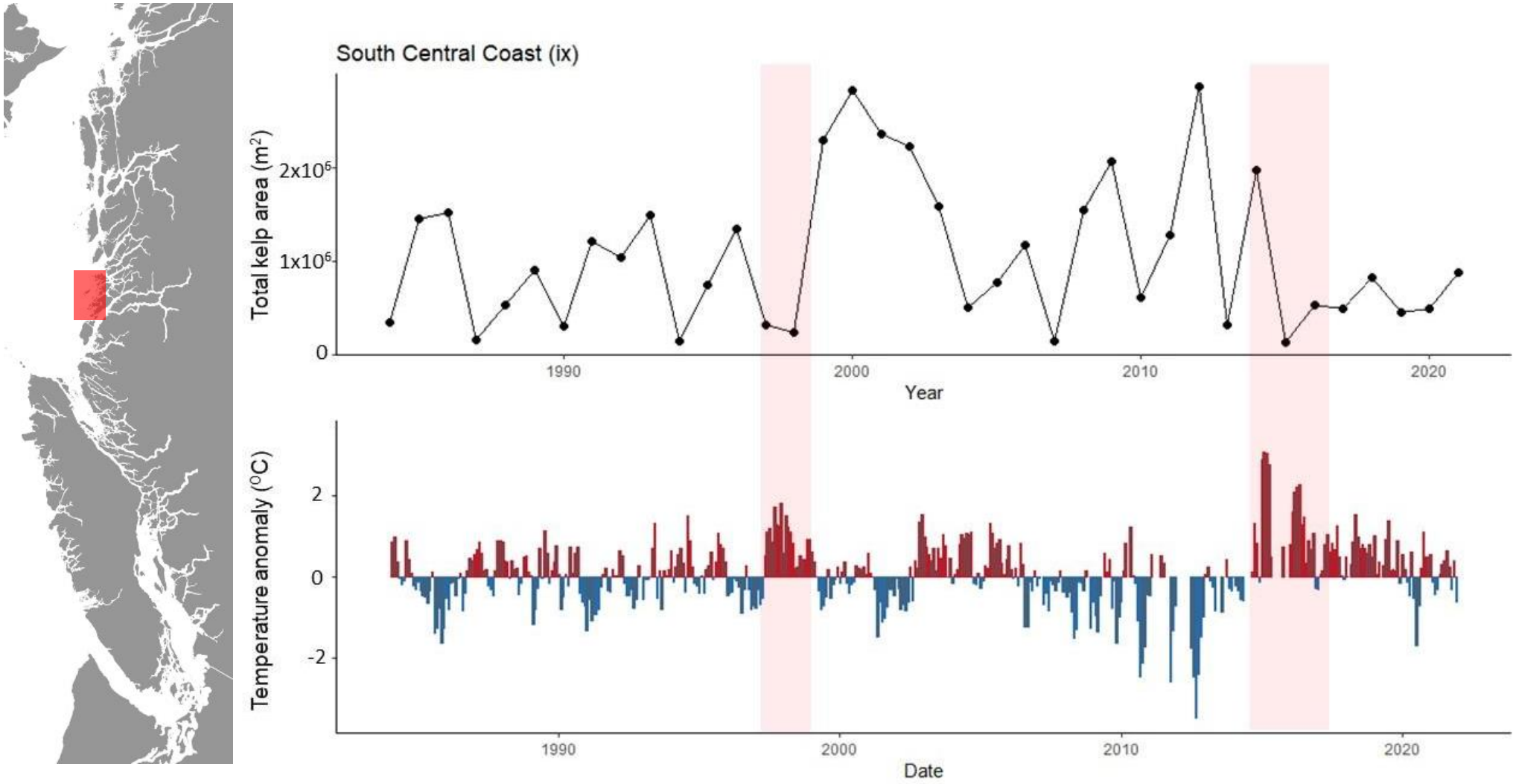

Barkley Sound (vi)
Proportion of segments with kelp
Year
Linear model
P < 0.001
n = 63 segments


Calvert Island (ix-b)
Total kelp area (m²)
Year
Site
Meay
North
beach
Gamma GLM
P < 0.001


Laredo Sound (x)
Proportion of segments with kelp
Year
Binomial GLM
P < 0.001
n = 103 segments


N
x
ix-b
i-b
vi
iii
ii

Reduced resilience on the Central Coast following 2014-2016 marine heatwave



LandSat satellite imagery

Data contributed by Luba Reshitnyk of the Hakai Institute

Conclusions

- Kelp forest responses to the marine heatwave were highly variable but there is an overall pattern of decline
- Local temperature conditions strongly predicted persistence in the face of warm conditions
- On the Central and North Coasts, top-down drivers appeared most important with sea otter occupancy explaining variation in kelp persistence

Acknowledgements

Undergraduates
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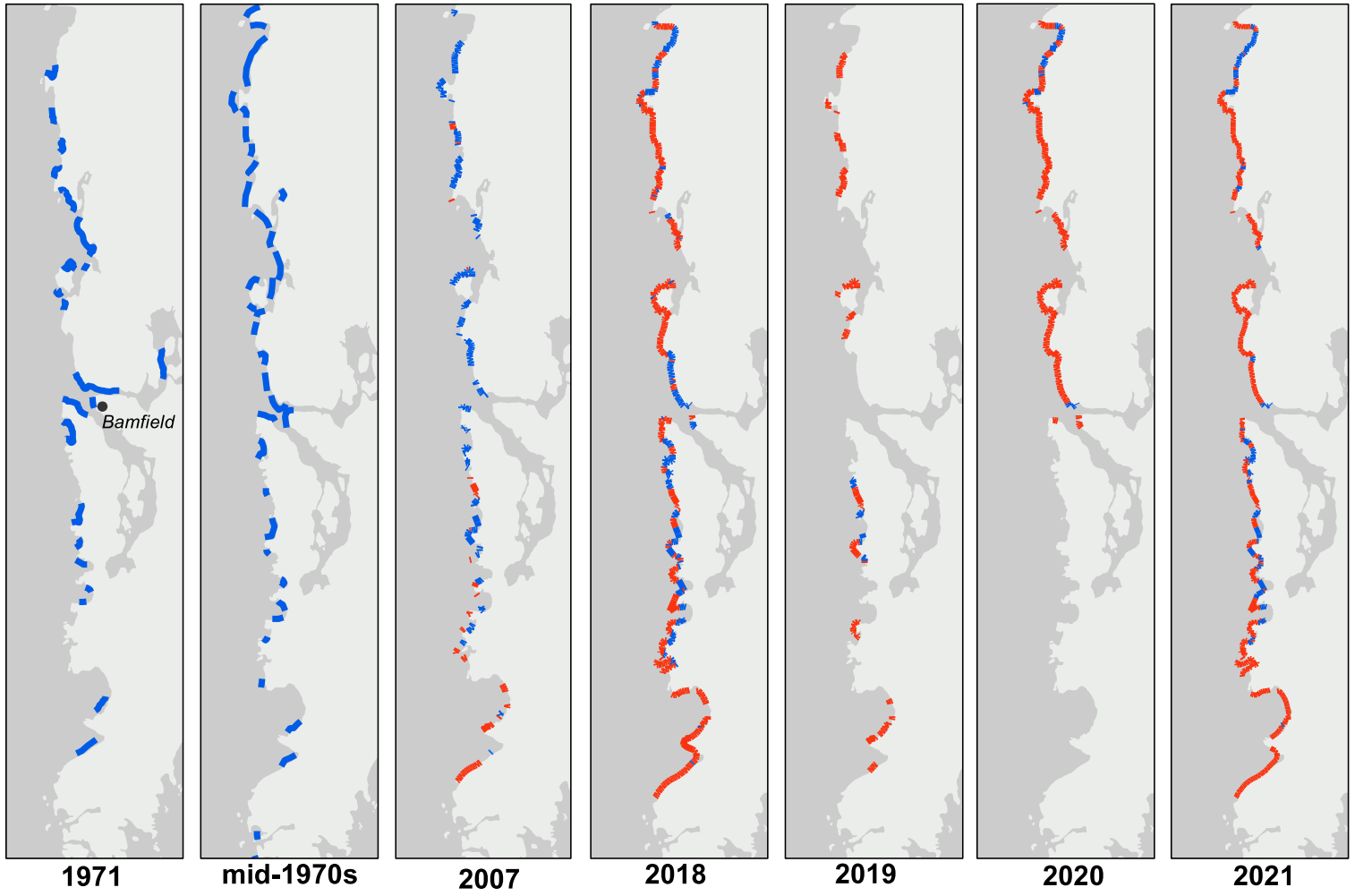
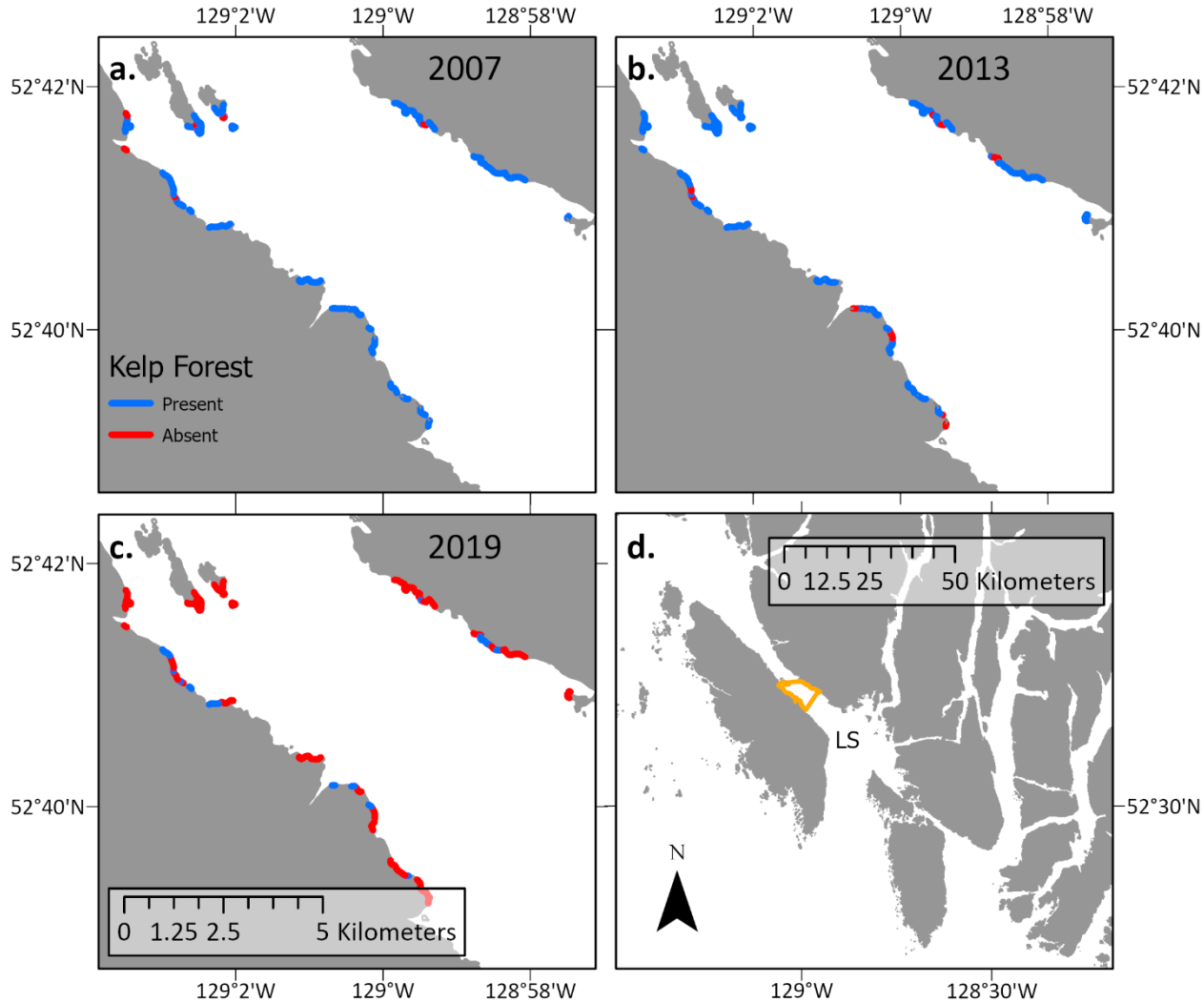
Mayne Island Conservancy
ShoreZone Initiative
Environment and Climate Change Canada

Temp data graciously provided by…
Jane Watson
Brianna Iwabuchi and Louis Gosselin

Questions?

Inshore sites have declined relative to every time point




a.
2007
b.
2013
c.
2019
d.
Kelp Forest
Present
Absent
0 1.25 2.5 5 Kilometers
0 12.5 25 50 Kilometers
LS
N
129°2'W
129°W
128°58'W
128°30'W
52°42'N
52°40'N
52°30'N