Pan-Arctic increases in sea ice algal habitat, 1985-2018

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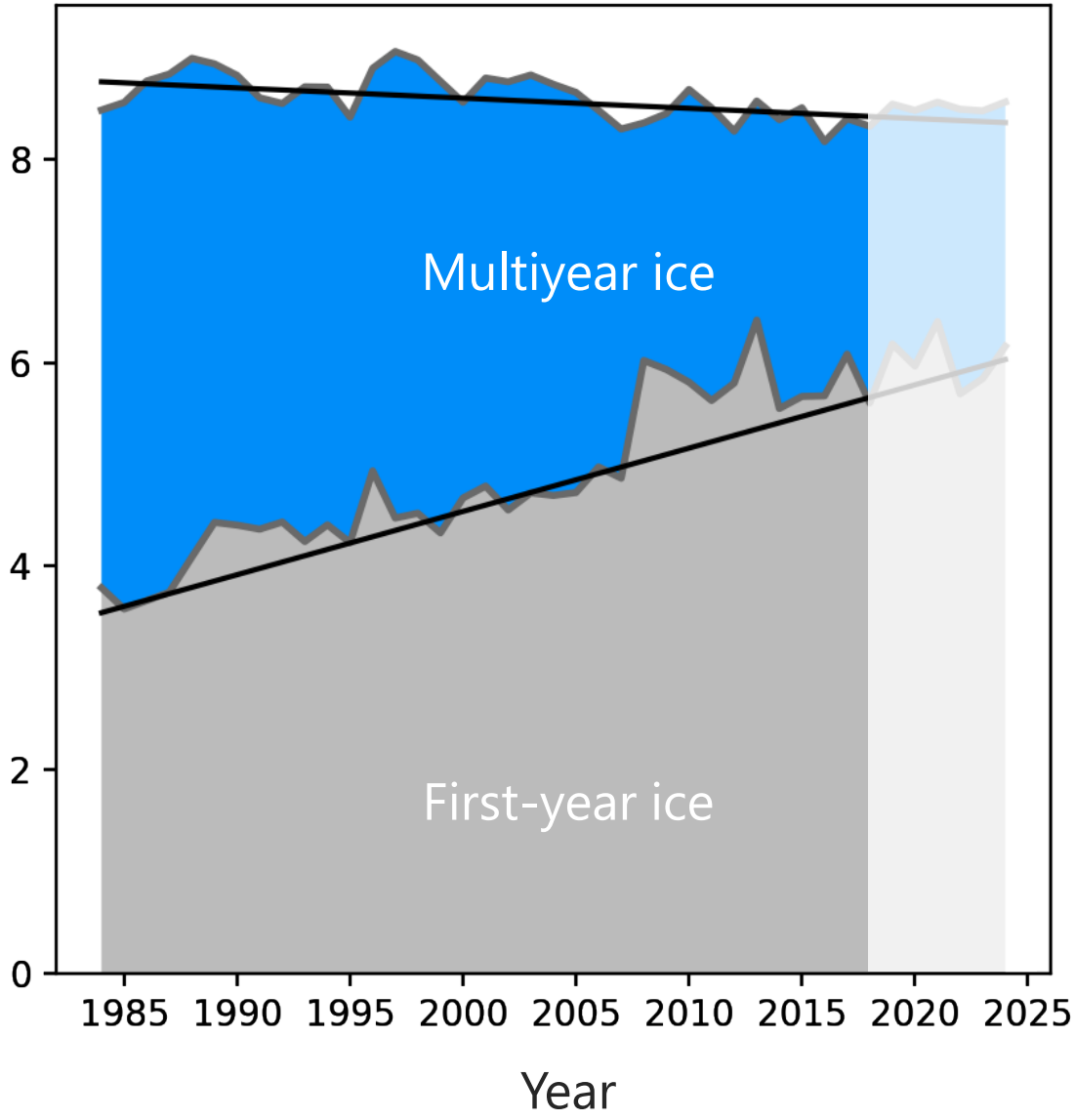
Stanford University

Photo: H. Joy-Warren

Sea ice algae are important early season primary producers.

U Freier

Arctic sea ice is shrinkin er

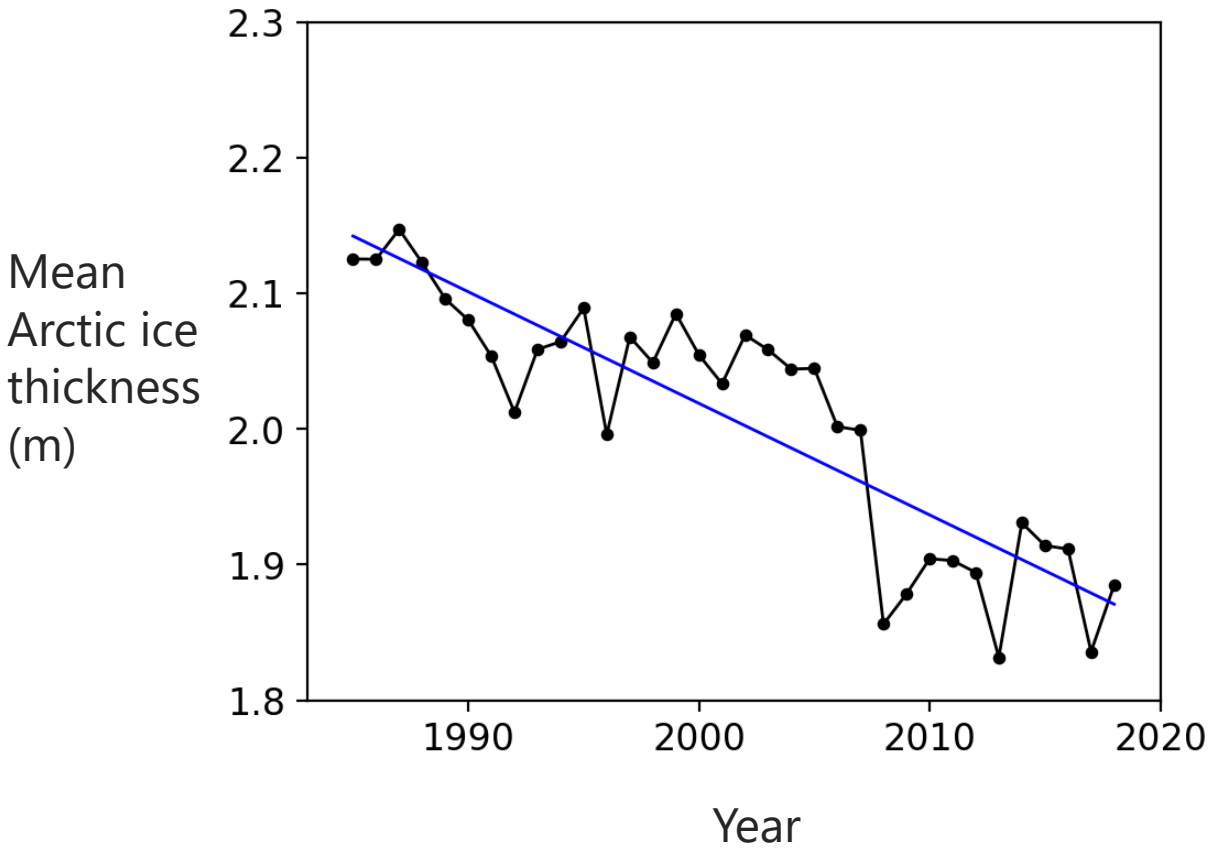


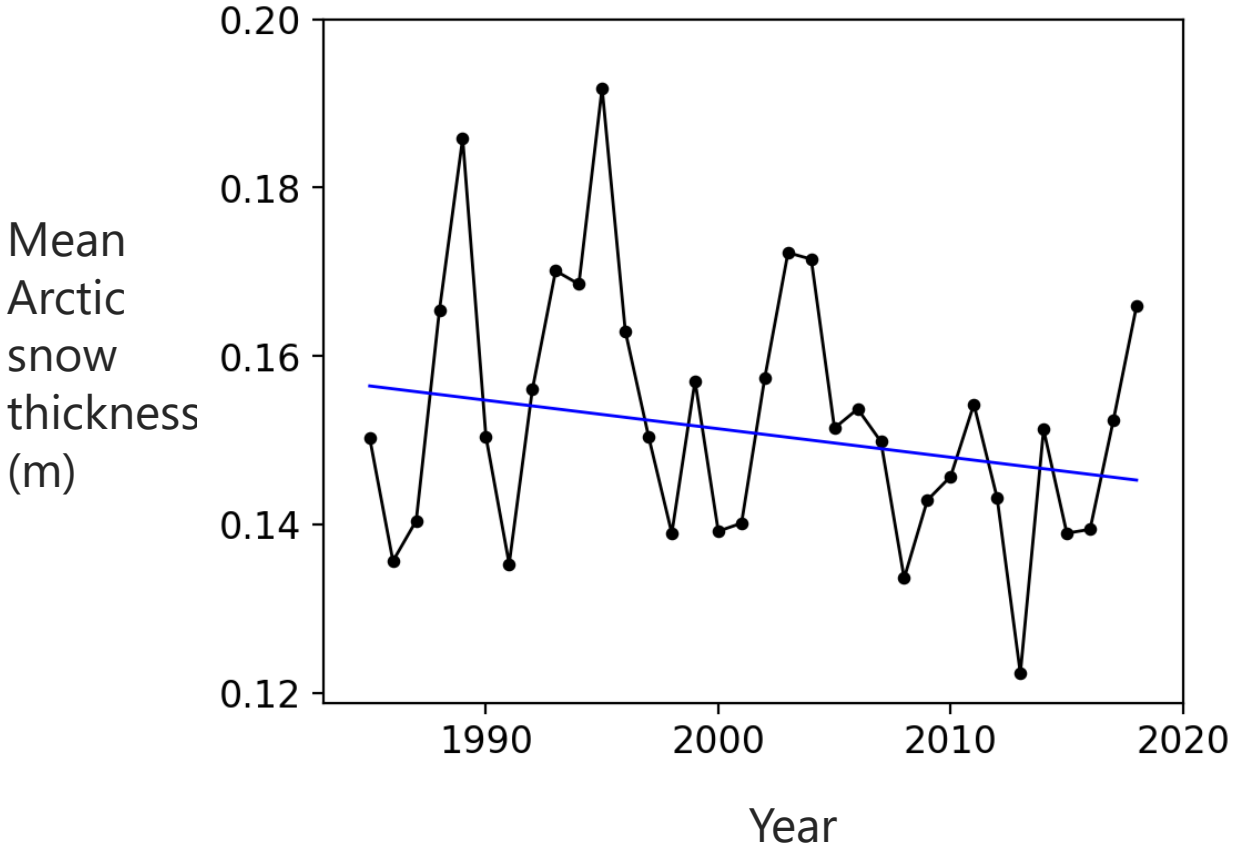
-0.4 million km^2
(above the Arctic Circle, 66.5°N)

2.5 million km^2
45% of ice in 1985, 72% in 2025

Data: Tschudi et al. 2019

Increases in first-year ice correspond to thinner ice and thinner snow





Data: Tschudi et al. 2016, 2019, Liston et al.

Ice algal response to ice and snow melt is unknown

	Documented trend	Expected effect on habitat
Sea ice extent	⇩	⇩
Sea ice season		
Sea ice thickness		
Snow depth		

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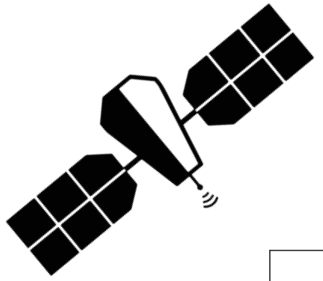
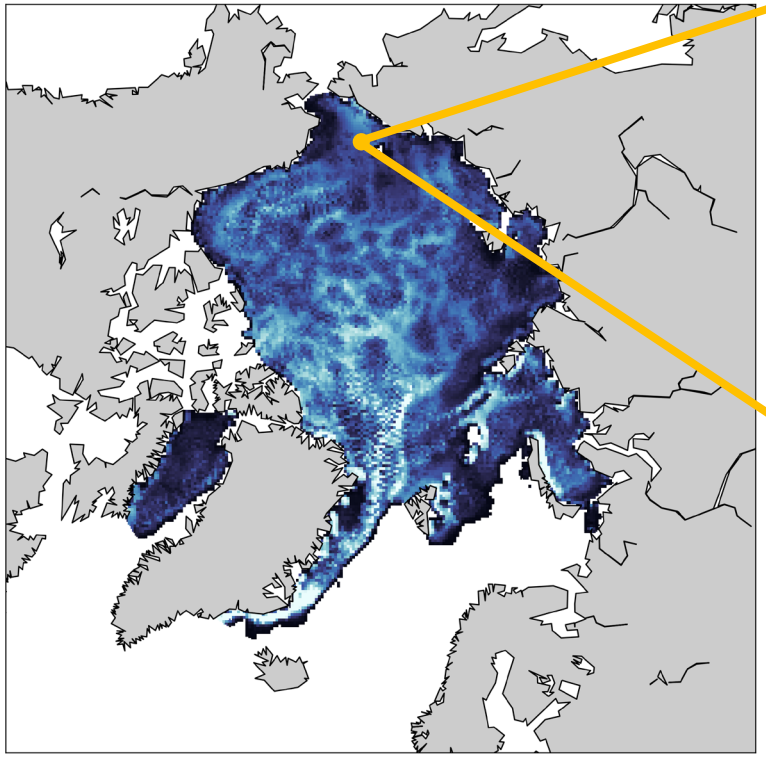
	Documented trend	Expected effect on habitat
Sea ice extent	⇩	⇩
Sea ice season	⇩	⇩
Sea ice thickness	⇩	⇧
Snow depth	⇩	⇧

Ice algal response to ice and snow melt is unknown

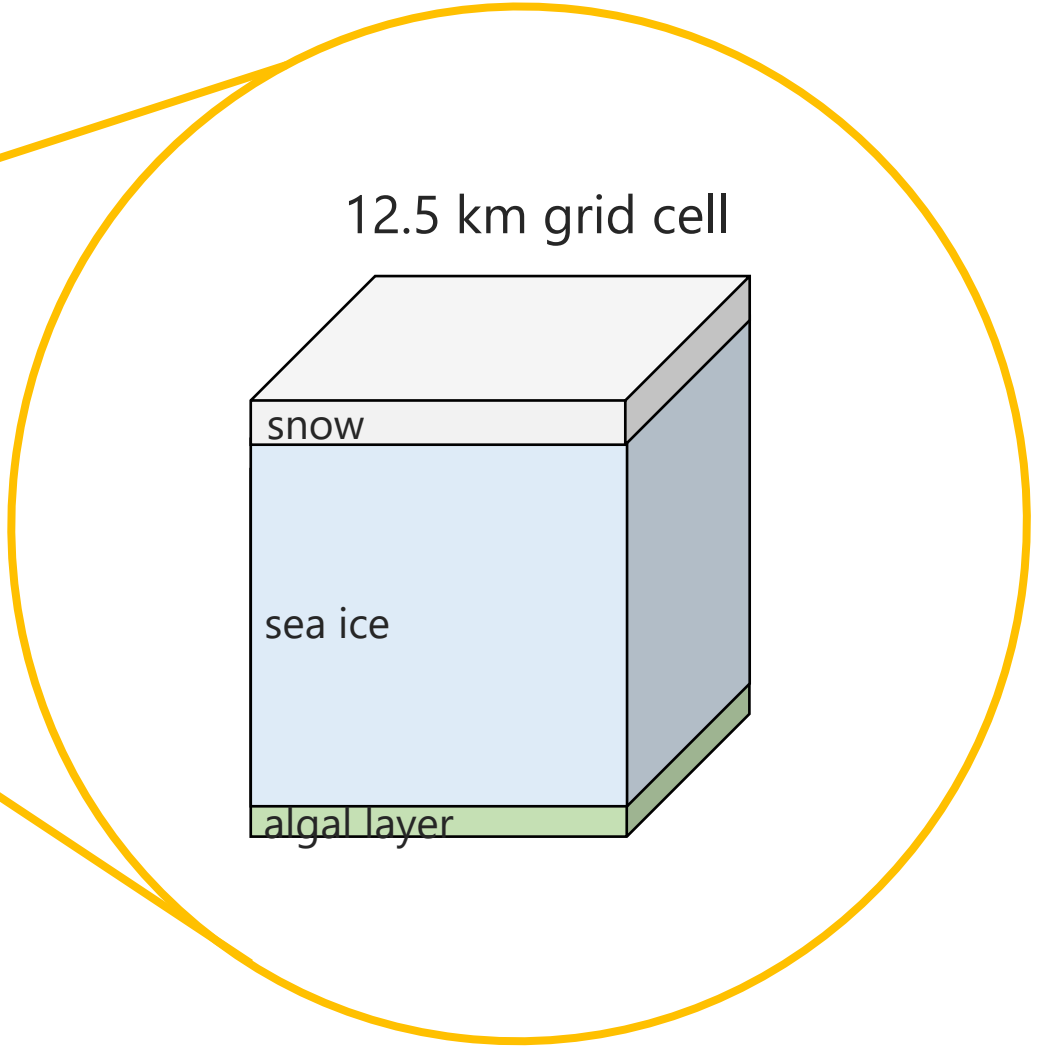
	Documented trend	Expected effect on habitat
Sea ice extent	⇩	⇩
Sea ice season	⇩	⇩
Sea ice thickness	⇩	⇧
Snow depth	⇩	⇧
Net effect		???

Our approach leverages 34 years of pan-Arctic satellite, reanalysis, and model data





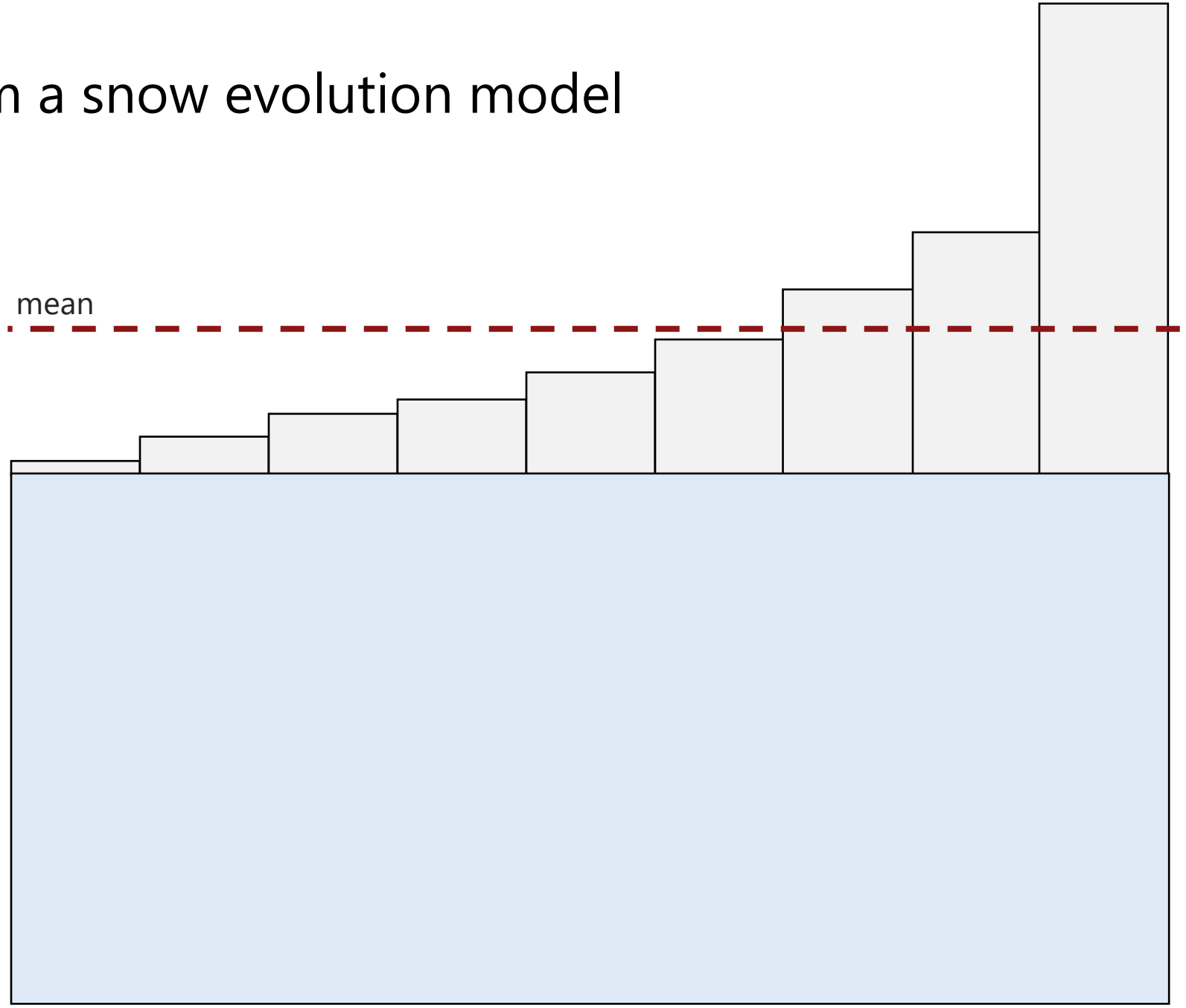
Snow depth



Snow depth is taken from a snow evolution model

Input: snow depth

Snow Model LG
Liston et al. 2020



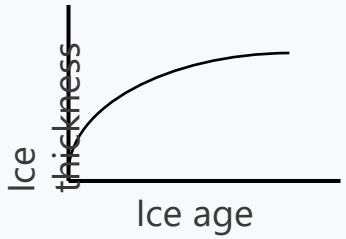
Sea ice thickness is calculated from its age

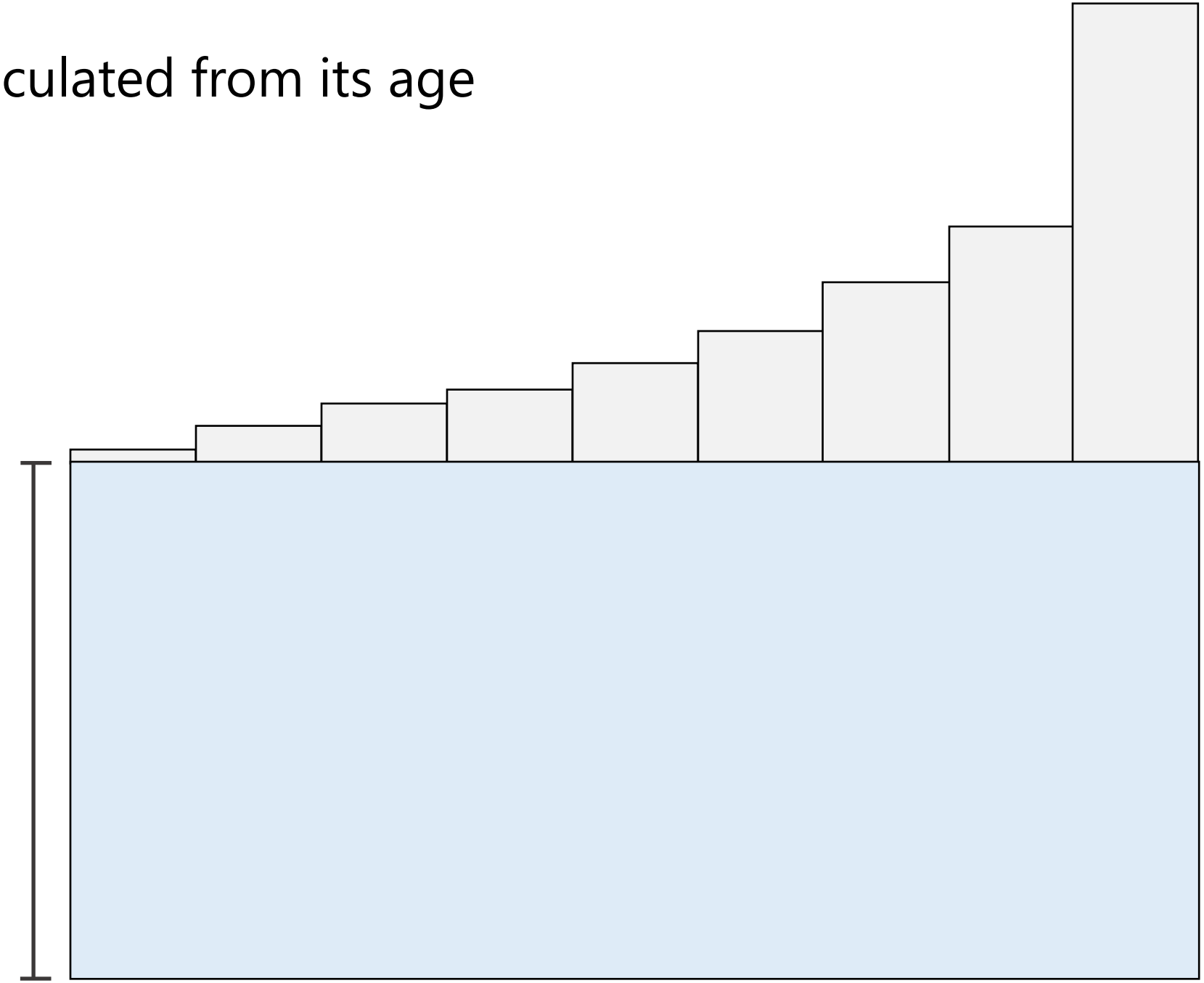
Input: snow depth

Input: ice age → ice thickness

Tschudi et al. 2016, 2019

$$\text{thickness} = \frac{\text{max} * \text{age}}{(K + \text{age})}$$





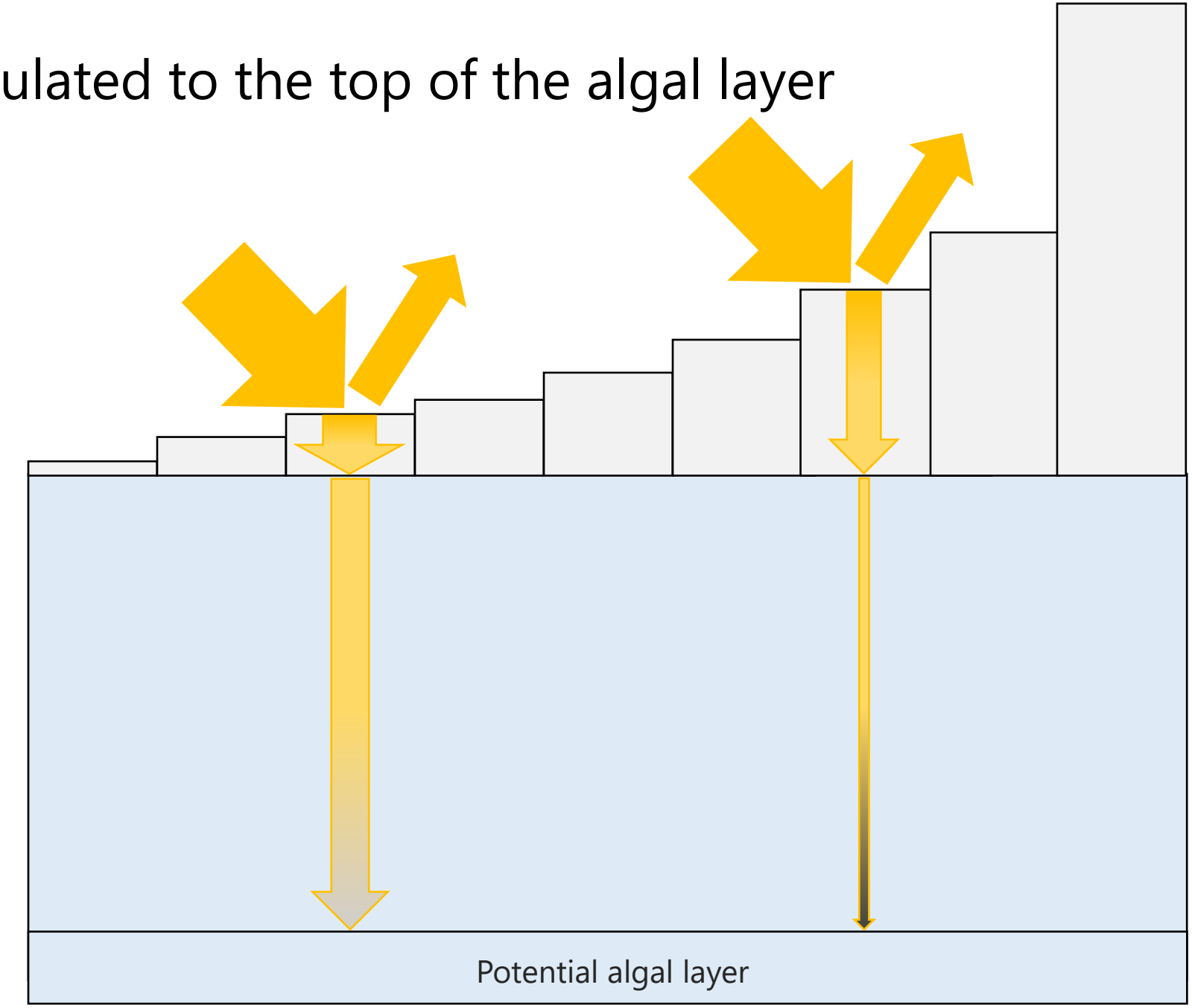
Radiative transfer is calculated to the top of the algal layer

Input: cloud-corrected light

Gregg & Carder 1990,
NCEP/NCAR Reanalysis 1,
NASA satellite ozone

Input: snow depth

Input: ice age → ice thickness



Sea ice is habitable where light supports net positive photosynthesis

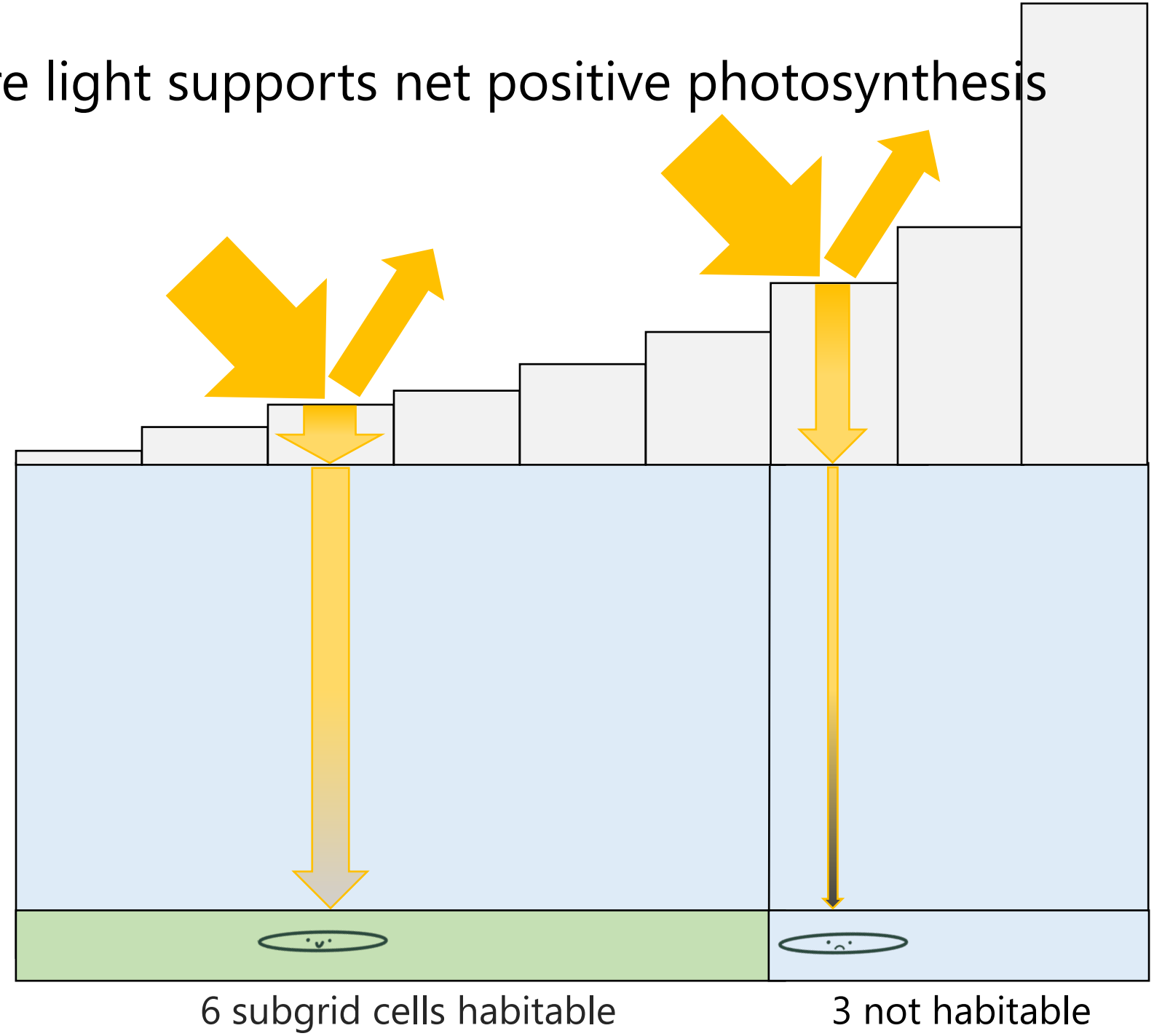
Input: cloud-corrected light

Input: snow depth

Input: ice age → ice thickness

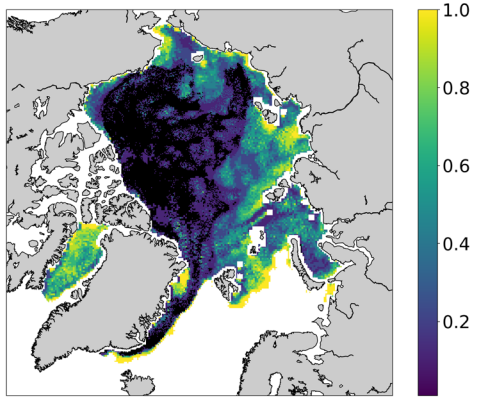
Photosynthesis – respiration over 24 hours

Van Leeuwe et al. 2018
Suzuki et al. 1997



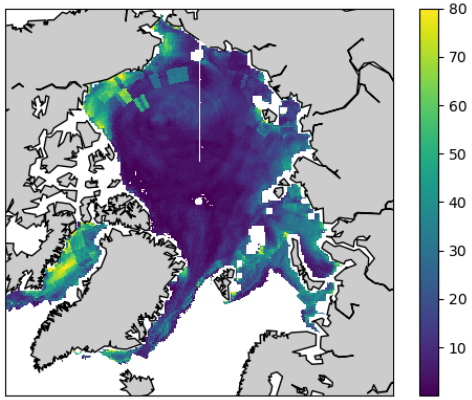
The metric of habitat-days integrates across time and space

Sum over the year



(proportion habitable)

Sum for a region

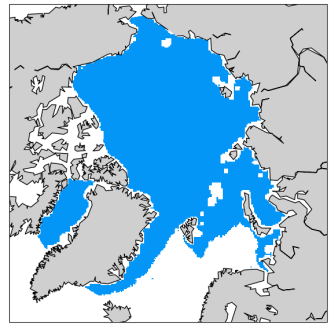


(days)

Divide by ice extent

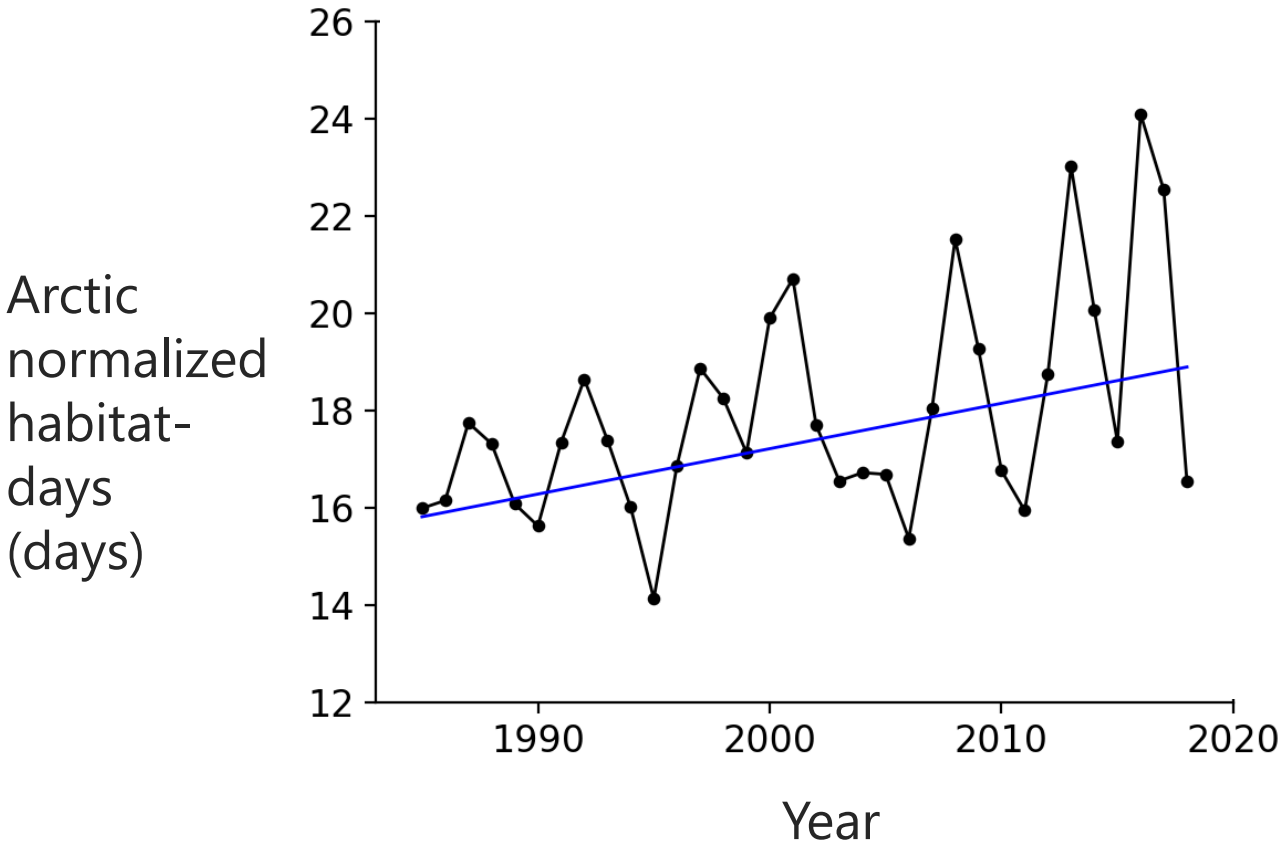
Habitat-days
(km^2 days)

Normalized
habitat-days
(days)



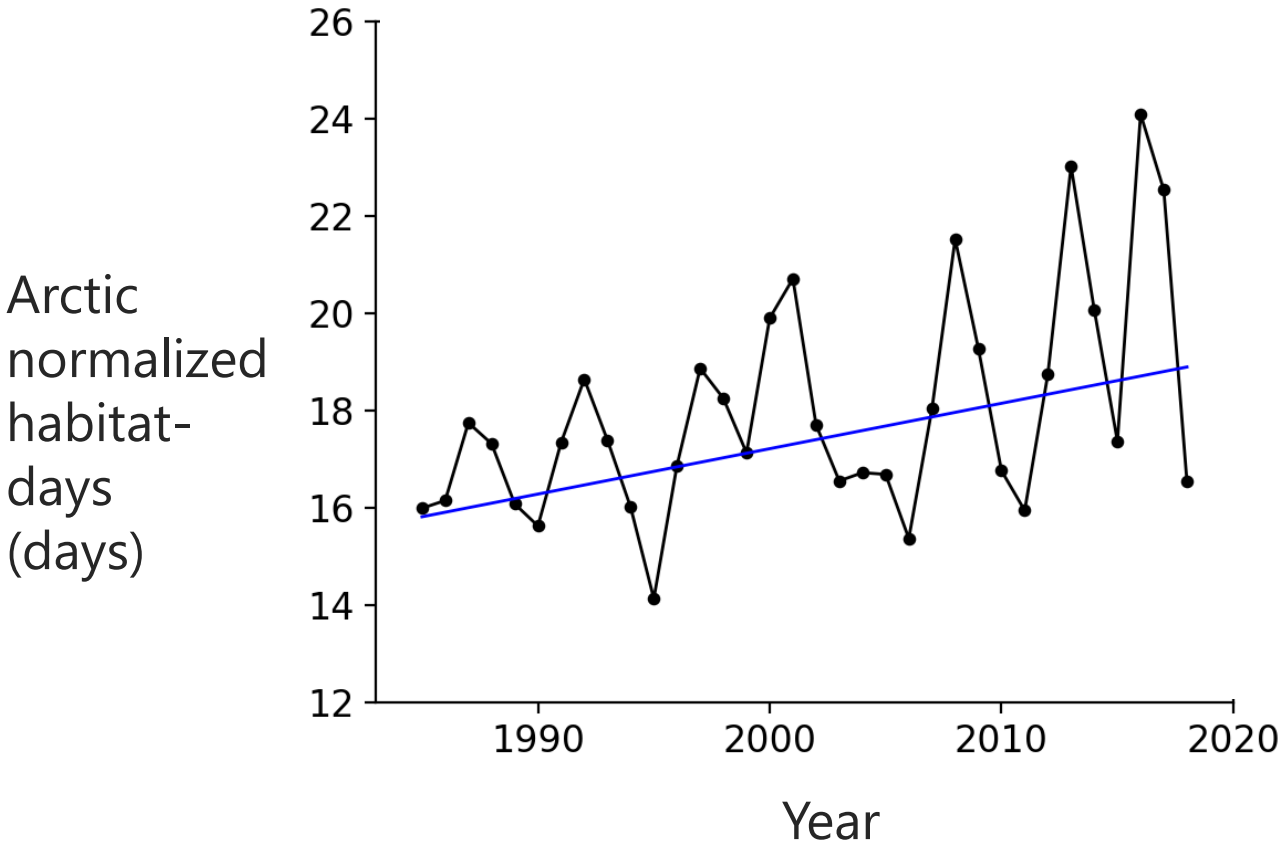
(km^2)

Arctic ice algal habitat increased in extent and duration, outpacing sea ice loss



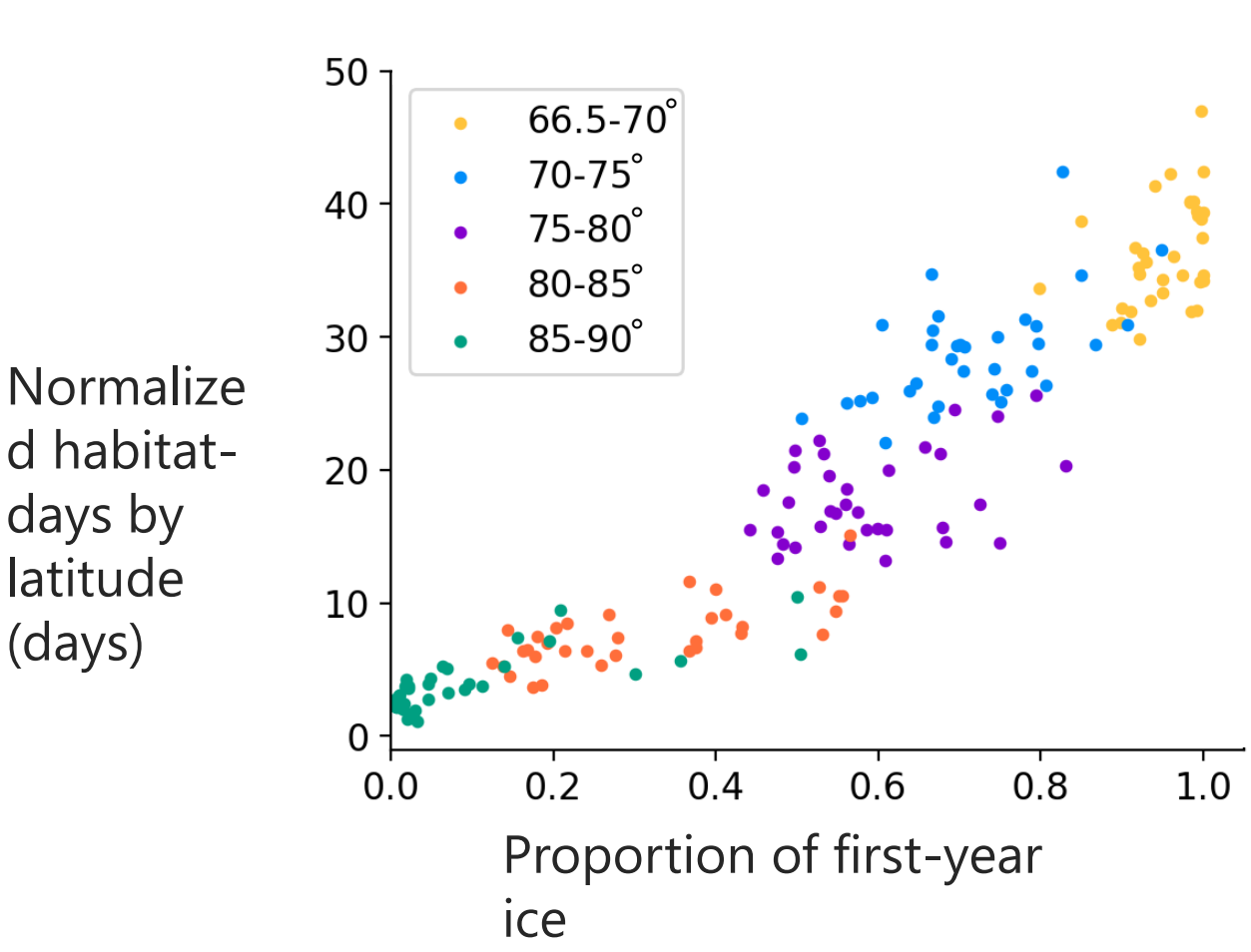
	Variation explained
Snow depth	29%
Ice thickness	22%
Melt date	21%

Arctic ice algal habitat increased in extent and duration, driven by decreased snow depth and ice thickness



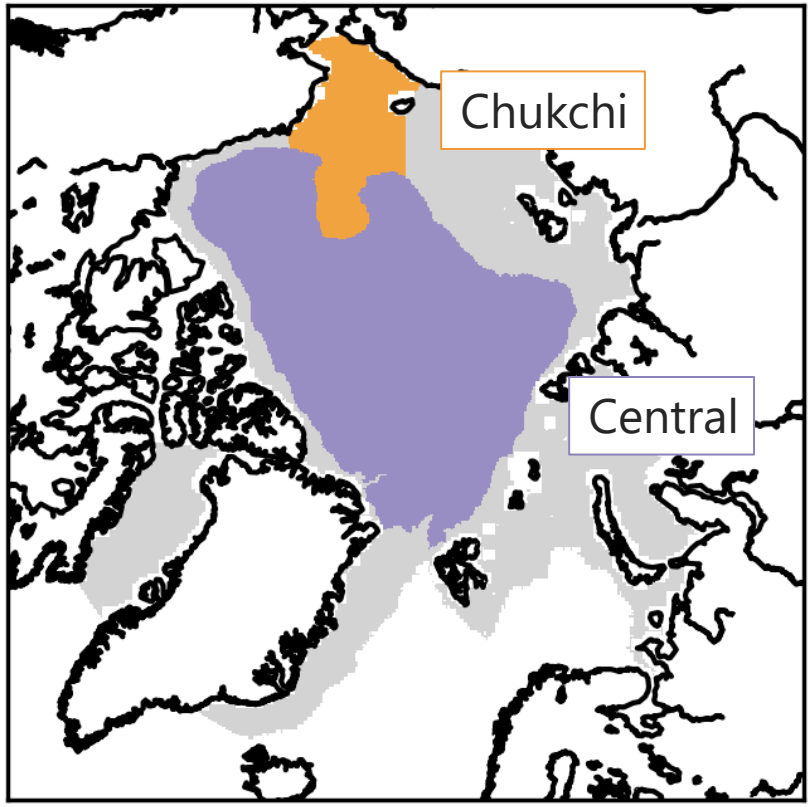
	Variation explained	Trend	Habitat Response
Snow depth	29%	⇩	⇧
Ice thickness	22%	⇩	⇧
Melt date	21%	⇩	⇩

The shift from multiyear ice to first-year ice supports more habitat



	Variation explained	Trend	Habitat Response
Snow depth	29%	⇩	⇧
Ice thickness	22%	⇩	⇧
Melt date	21%	⇩	⇩

Habitat increases were localized in the Chukchi S Basin



Change from 1985 to 2018:

2.4 days (+15%)

Pan-
Arctic

5.8 days (+25%) → only region with both snow and ice thickness decline

Chukchi Sea

7.1 days (+145%) → most multiyear ice to lose

Central Basin

⇧ habitat duration

⇧ habitat extent

47% to 65% of sea ice

imply

⇧ primary production potential

& shifting phenology

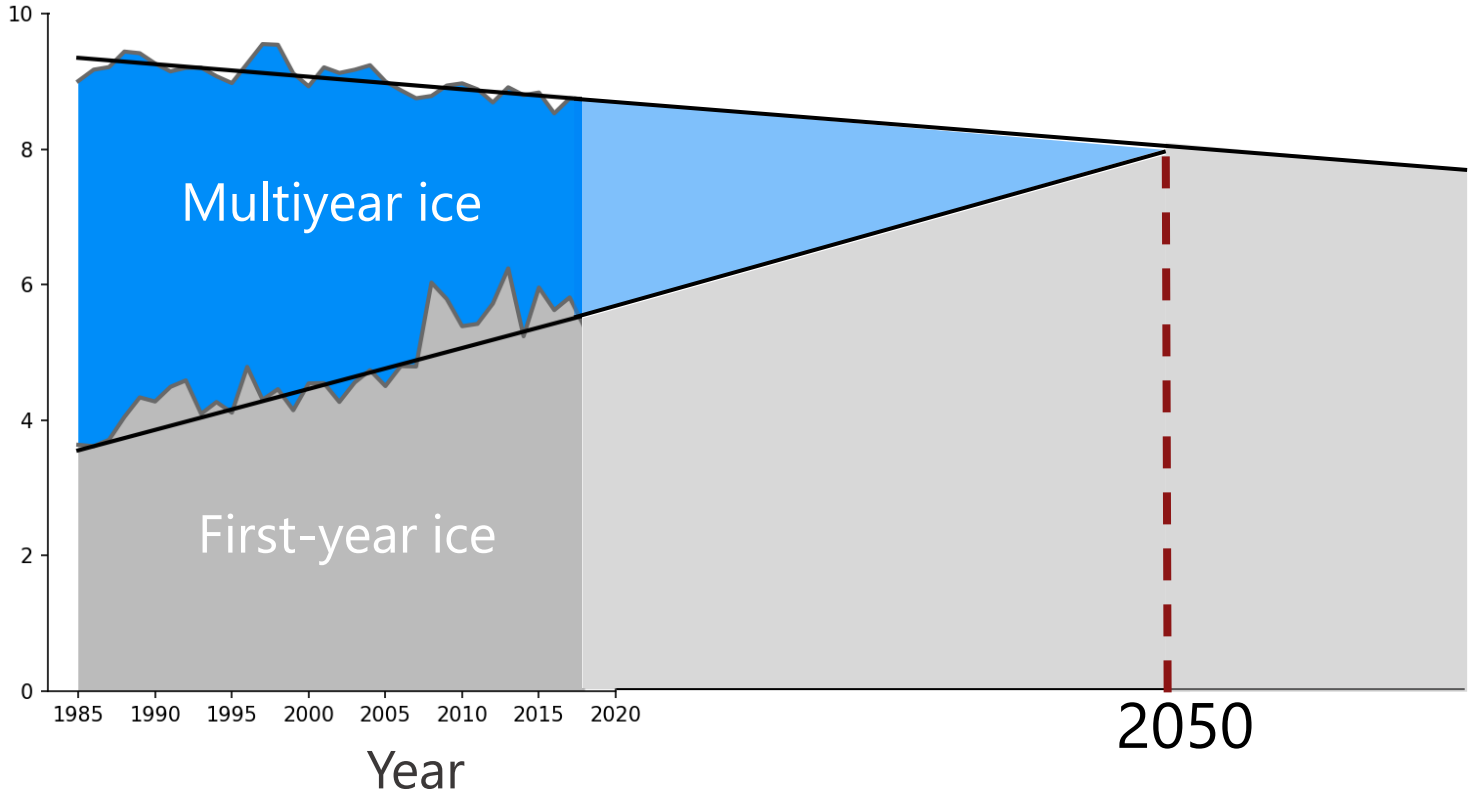
Photo: H. Joy-Warren

These increases in habitat will likely be short-lived

Increased ice algal habitat 1985-2018

Tied to shift from multi-year ice to first year ice

Predict habitat increase until there is no more multi-year ice, then a decline



Lim et al. 2022, *Elementa*

Our large-scale understanding and predictions of Arctic ice algae are evolving

Five sea ice ecosystem models show no agreement in primary production trends

Watanabe et al. 2019

Some major unknowns surround nutrients, seed population with later freeze-up, and ice algal growth parameters

Watanabe et al. 2019
Haddon et al. 2024

Expecting "more" ice algae in the highest latitudes due to thinner sea ice and snow

Expecting "less" ice algae at lower latitudes due to decreasing sea ice extent

Recent past

- Watanabe et al. 2019
- Lim et al. 2022
- Stroeve et al. 2024

Future: end of century

- Tedesco et al. 2019
- Haddon et al. 2024
- Heorton et al. 2025

Ecosystem importance is under question with regards to zooplankton diet and ice algal export

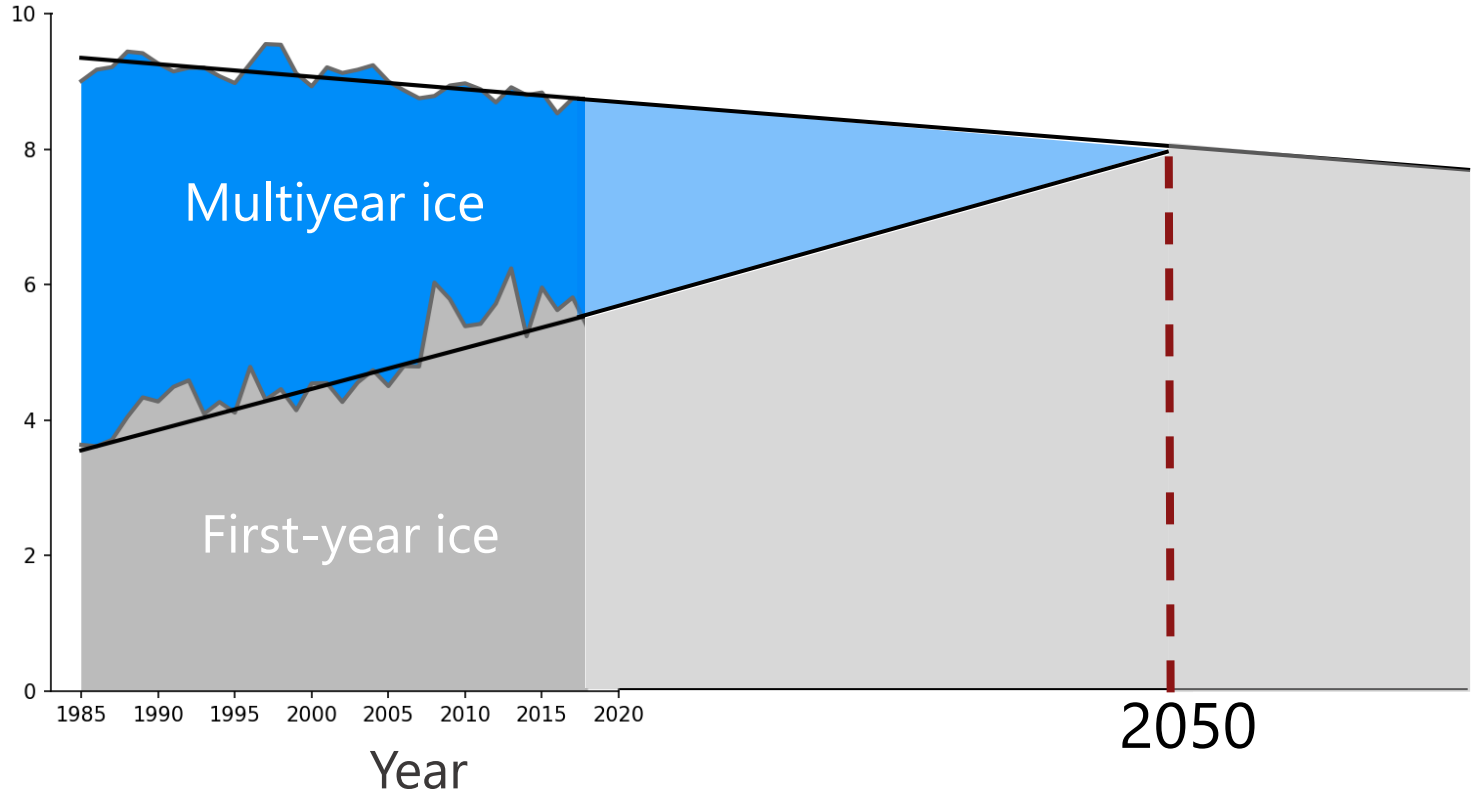
Kohlbach et al. 2022
Lauer et al. in revision
Lim et al. poster

Thank you!

Courtney Payne

Gert van Dijken

Kevin Arrigo



Predict habitat increase until there is no more multi-year ice, then a decline

Lim et al. 2022, *Elementa*

GRFP

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