Thermal heterogeneity drives seasonal limpet distributions

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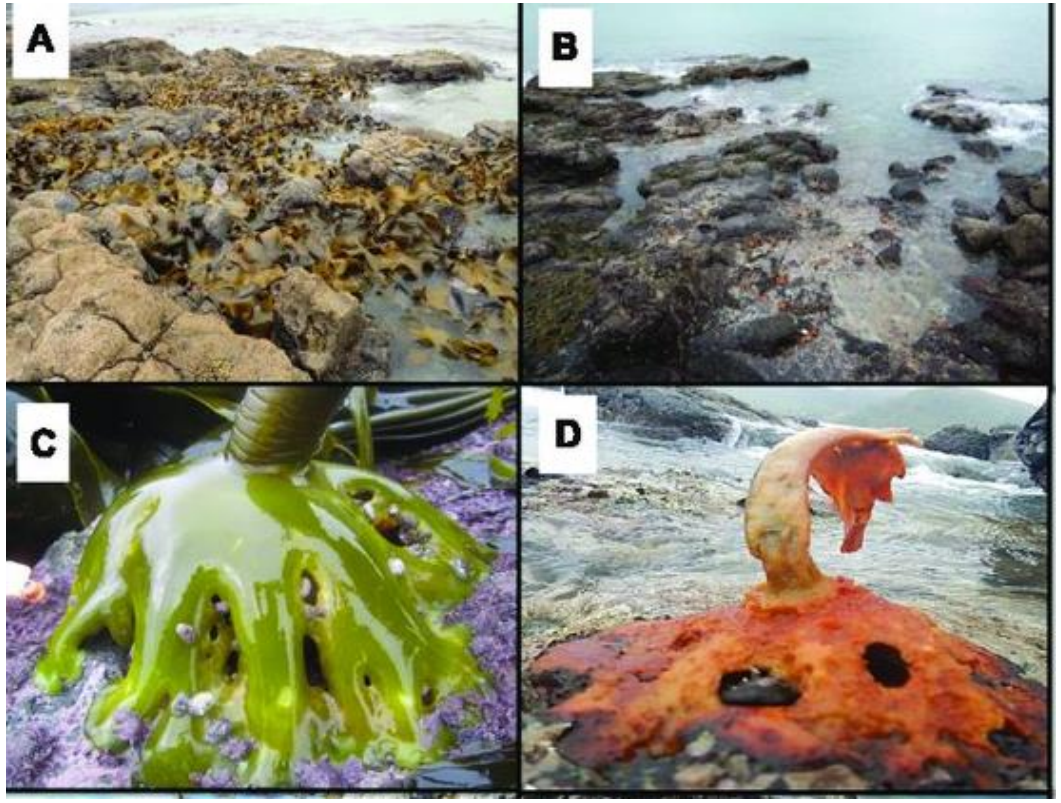
University of Canterbury, NZ

Extreme heat in the intertidal zone

frontiers in Marine Science

Local Extinction of Bull Kelp (*Durvillaea* spp.) Due to a Marine Heatwave



Thomsen et al. 2019

British Columbia CBC

More than a billion seashore animals may have cooked to death in B.C. heat wave, says UBC researcher

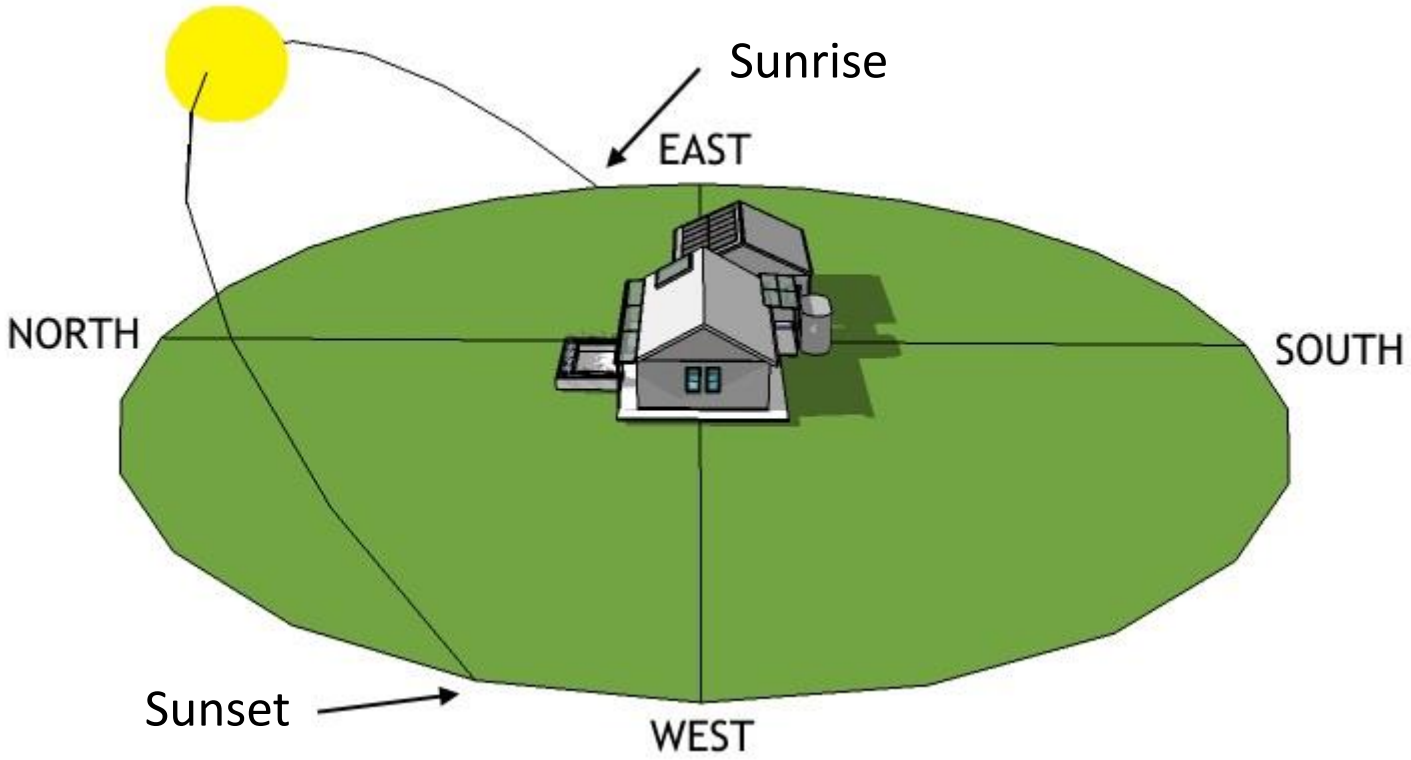
https://www.cbc.ca/news/canada/british-columbia/intertidal-animals-ubc-research-1.6090774

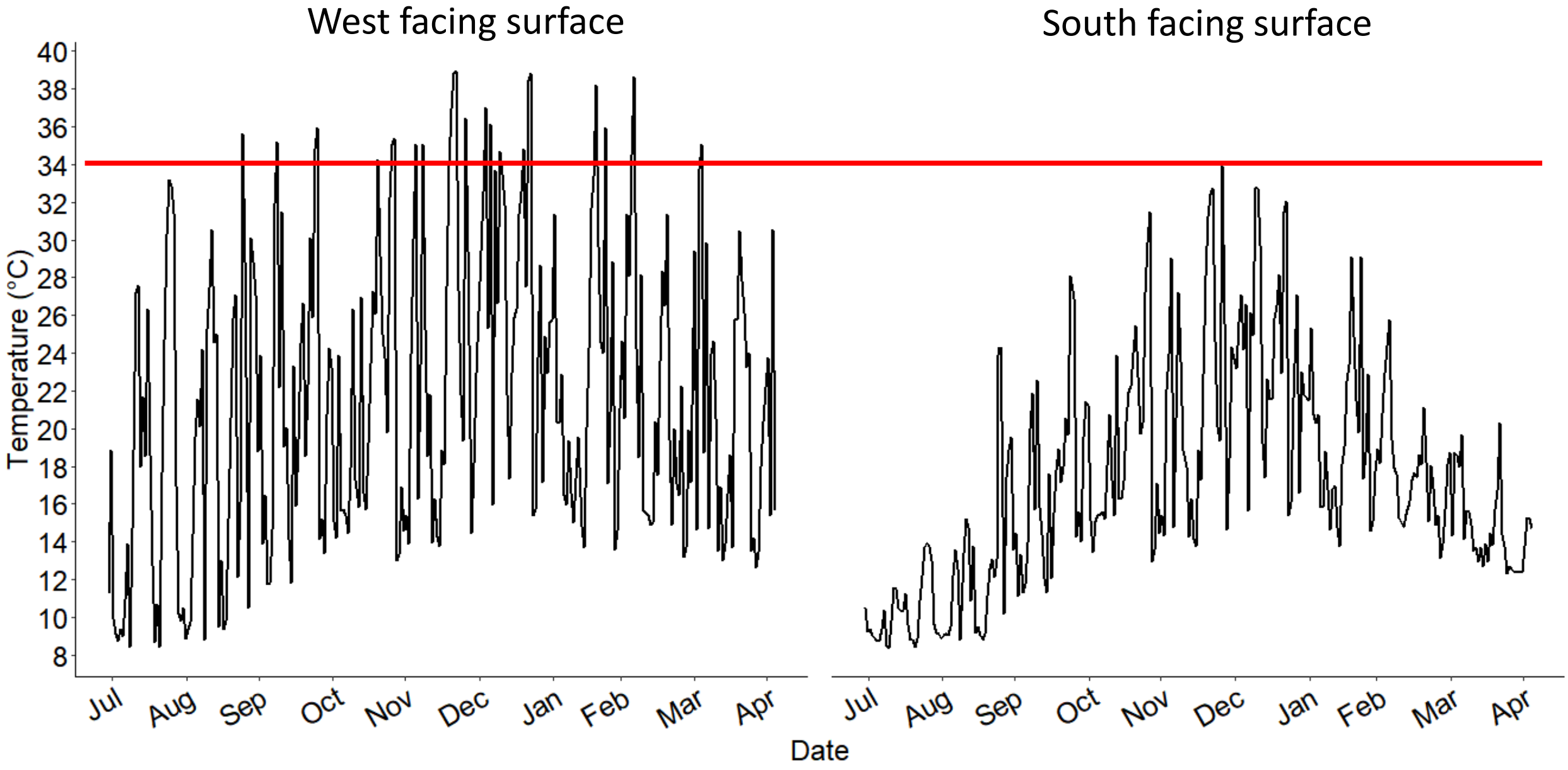
Surviving the intertidal zone

- Hide from the sun!
  - **But**, you can only move at high tide

- Increase wind driven cooling
- Form aggregations
- Produce heat shock proteins

The sun is your enemy




West facing surface
South facing surface
Temperature (°C)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date

Research question

Do limpets choose south facing surfaces to mitigate thermal stress?

Limpets

- Grazing invertebrates in the intertidal zone
- Some sp. form grazing scars that they return to
- Some sp. move in response to heat stress (e.g., Williams & Morritt 1995)

Experimental setup

- Tagged ~800 limpets on 18 boulders (~45 boulder^{-1})
  - >2 limpets facing each direction
- Boulders assigned to rotate, control, or procedural control treatment
  - Rotate = rotated 180 degrees (South to North, East to West)
  - Procedural control = jostled with a pry bar for 5 minutes

Experimental setup

- Deployed bio-mimic temperature loggers (and regular temp. loggers)

Lima & Wethey 2009

Sampling methodology

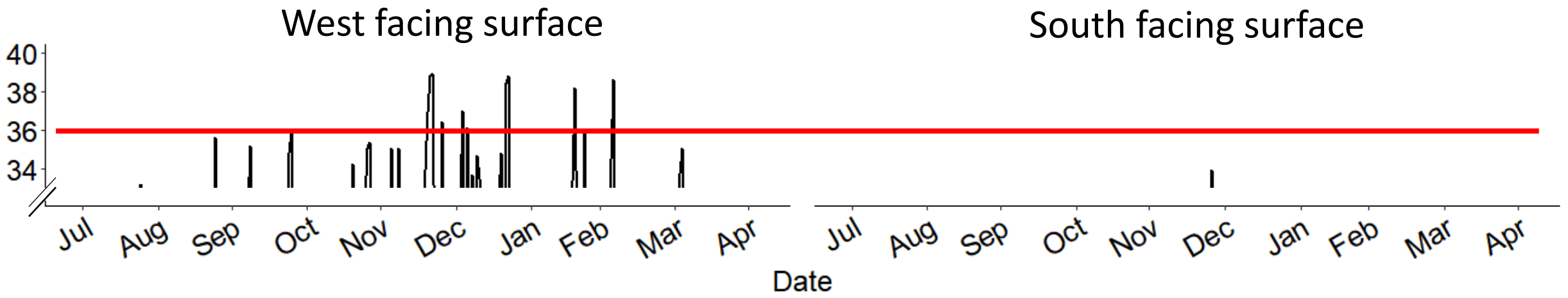
- Returned every 2-4 weeks
- Measured compass direction of every tagged limpet
- Searched for dead shells and individuals that left their home boulders
- Took photos

Overall results

- No effect of **rotational treatment** on any response variables
- Some limpets moved a lot

Overall results

- No effect of **rotational treatment** on any response variables
- Some limpets moved a lot
- Lethal body temperatures (36-38°C) surpassed on some days (not everywhere)



Heading south for summer

- Direction structure changed significantly during early summer
- Higher proportion of limpets facing south

North facing

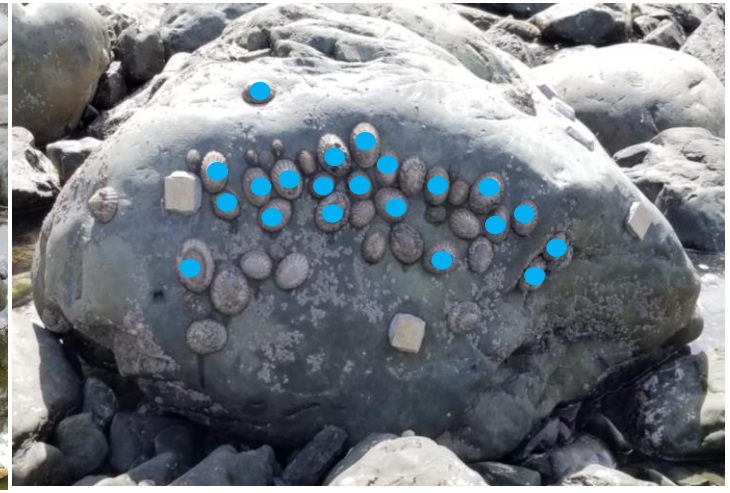
Winter

Summer

South facing

Winter

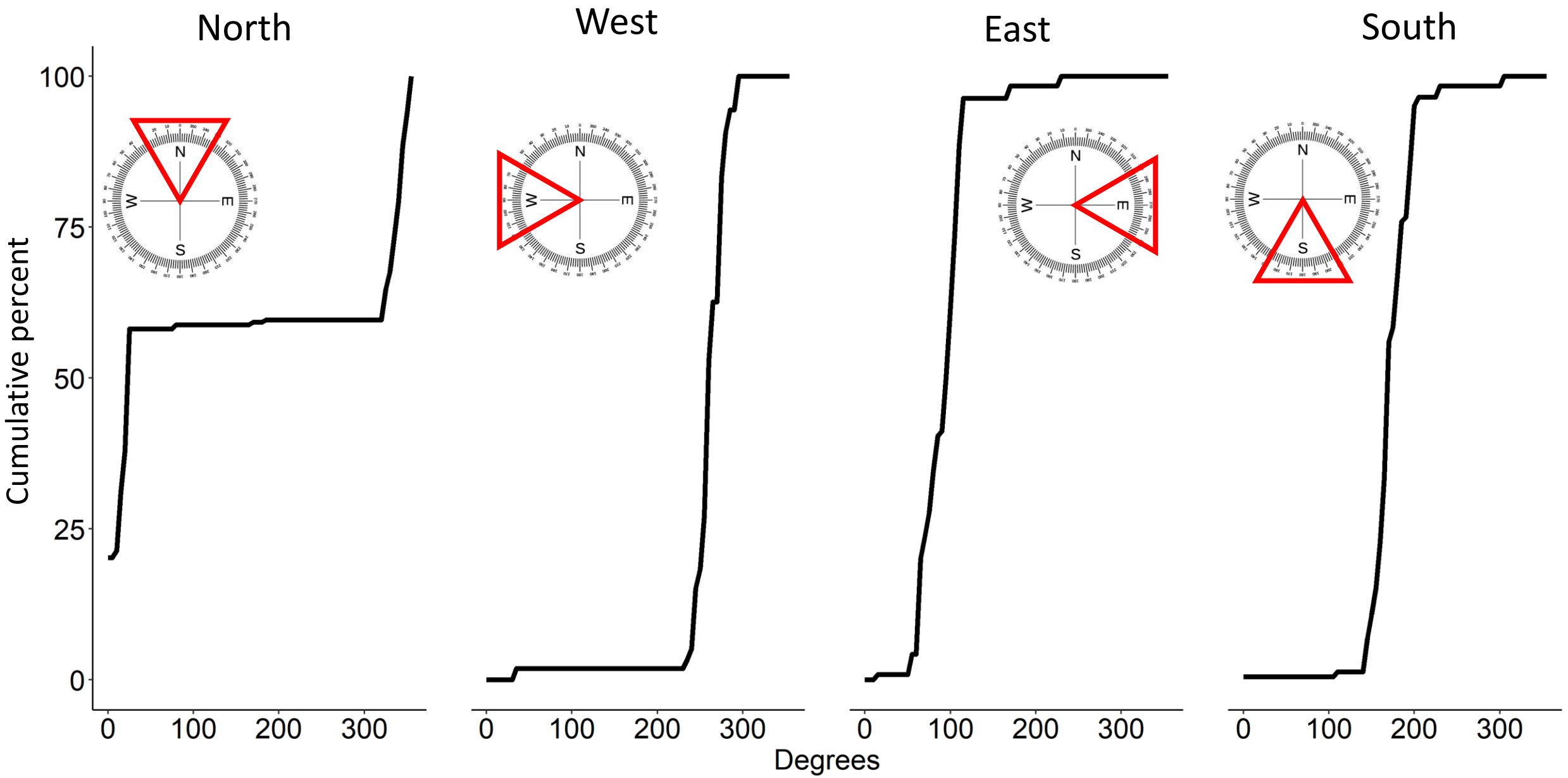
Summer

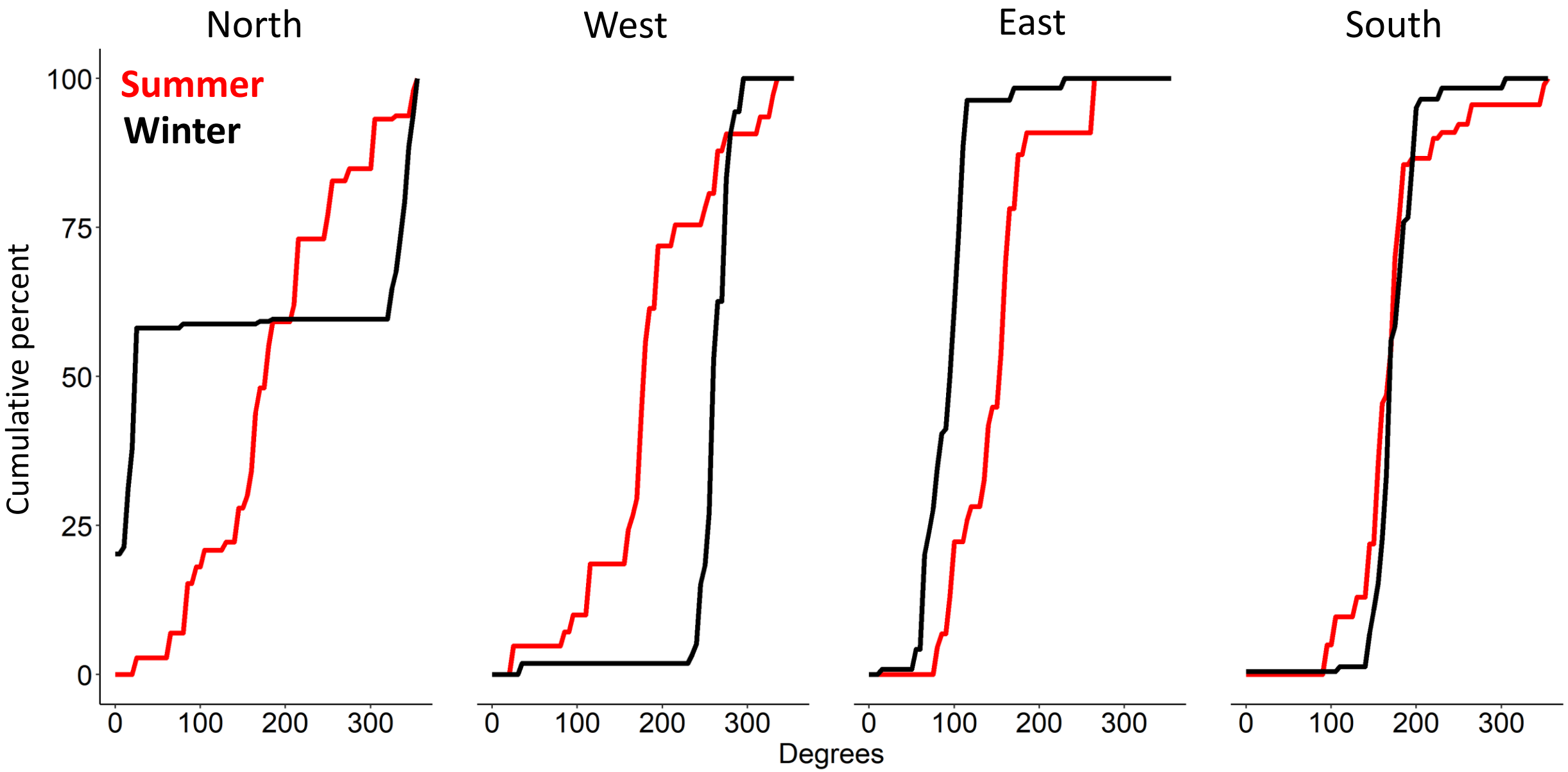


Where do you come from, where do you go?

Where do you come from, where do you go?

- Starting location significantly influenced limpet movement
- South facing limpets stayed south facing
- North, East, and West facing limpets moved to south facing surfaces


North
West
East
South
Cumulative percent
100
75
50
25
0
0
100
200
300
Degrees
N
W
E
S


North
West
East
South
Summer
Winter
Cumulative percent
100
75
50
25
0
0
100
200
300
Degrees

What does this all mean?

- Limpets actively choose south facing surfaces during summer to minimize exposure to potentially lethal heat stress

- This behaviour probably plays a critical role in the resilience of limpet populations to extreme heat events

Can we test this?

- Limpets actively choose south facing surfaces during summer to minimize exposure to potentially lethal heat stress

- This behaviour probably plays a critical role in the resilience of limpet populations to extreme heat events

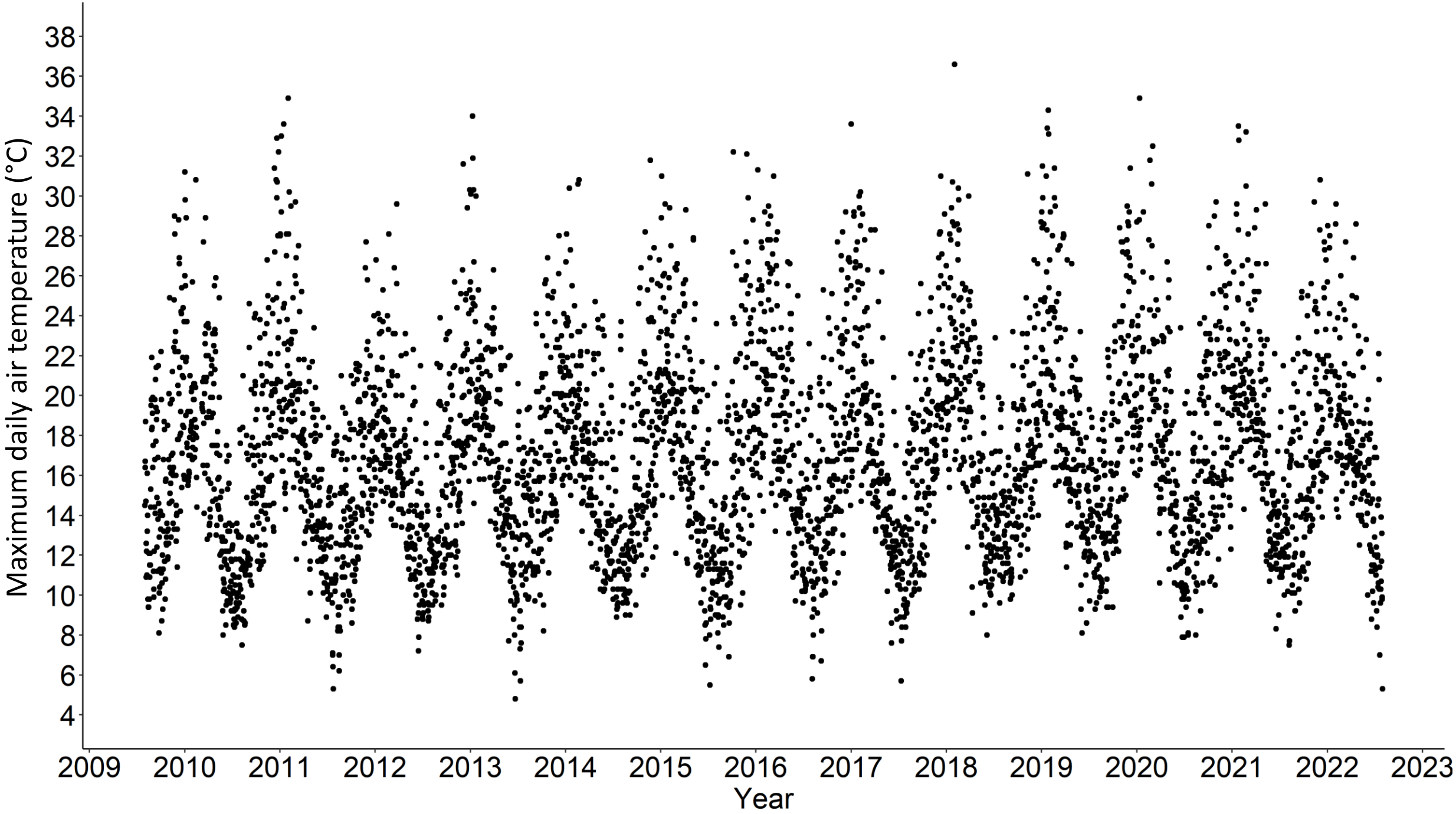
What are we testing?

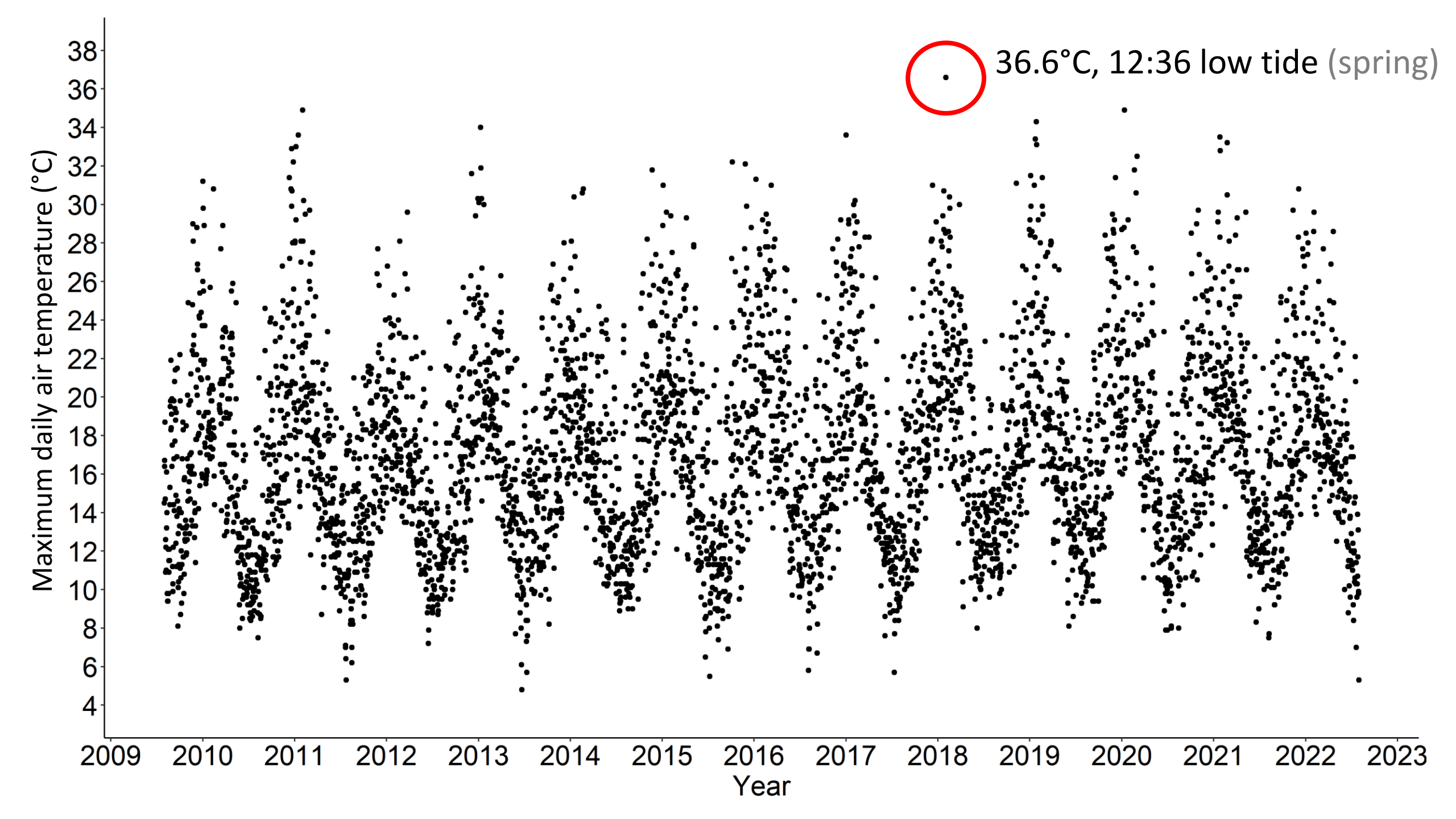
Do these thermal refugia provide viable safe spaces during extreme heat?

What do we need?

Do these thermal refugia provide viable safe spaces during extreme heat?

- ❑ Extreme heat event(s)
- ❑ High resolution reef surface model
- ❑ Predict body temperatures


Maximum daily air temperature (°C)
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Year


36.6°C, 12:36 low tide (spring)
Maximum daily air temperature (°C)
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2009
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2011
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2023
Year

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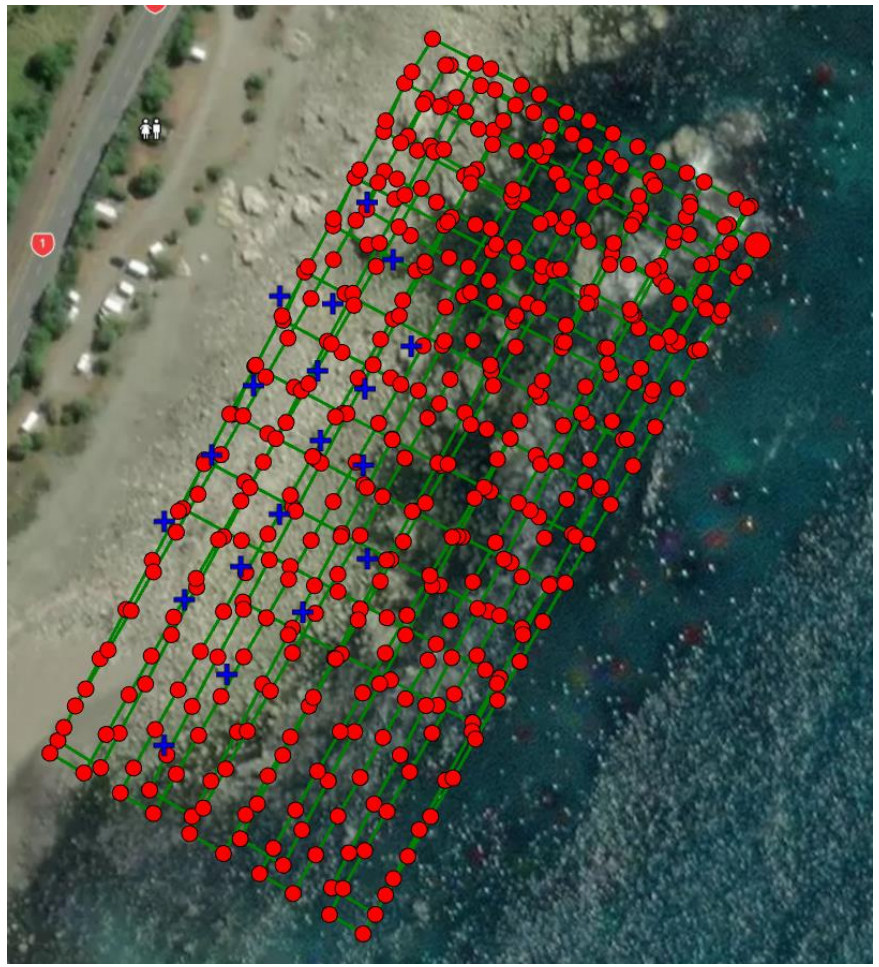
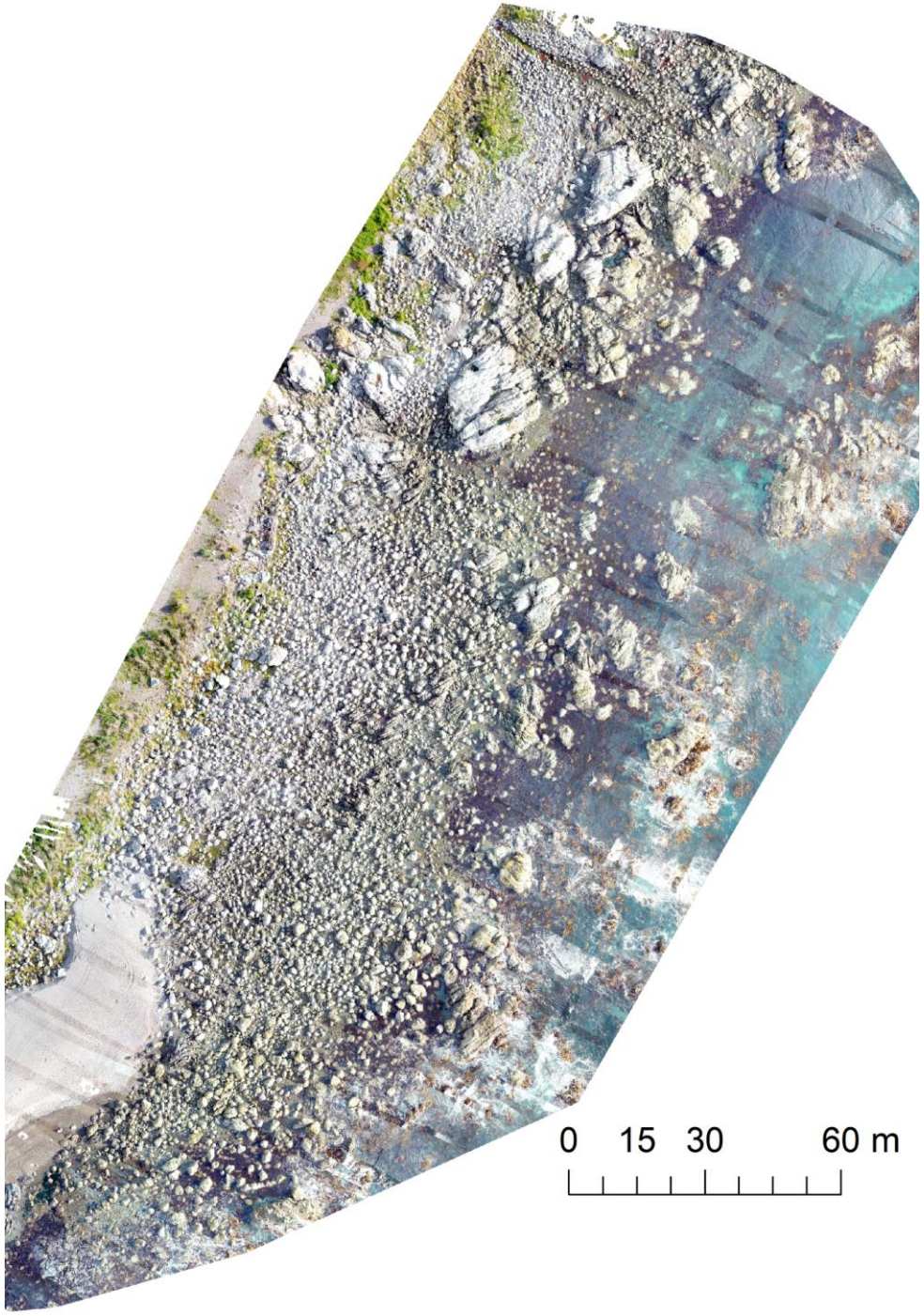
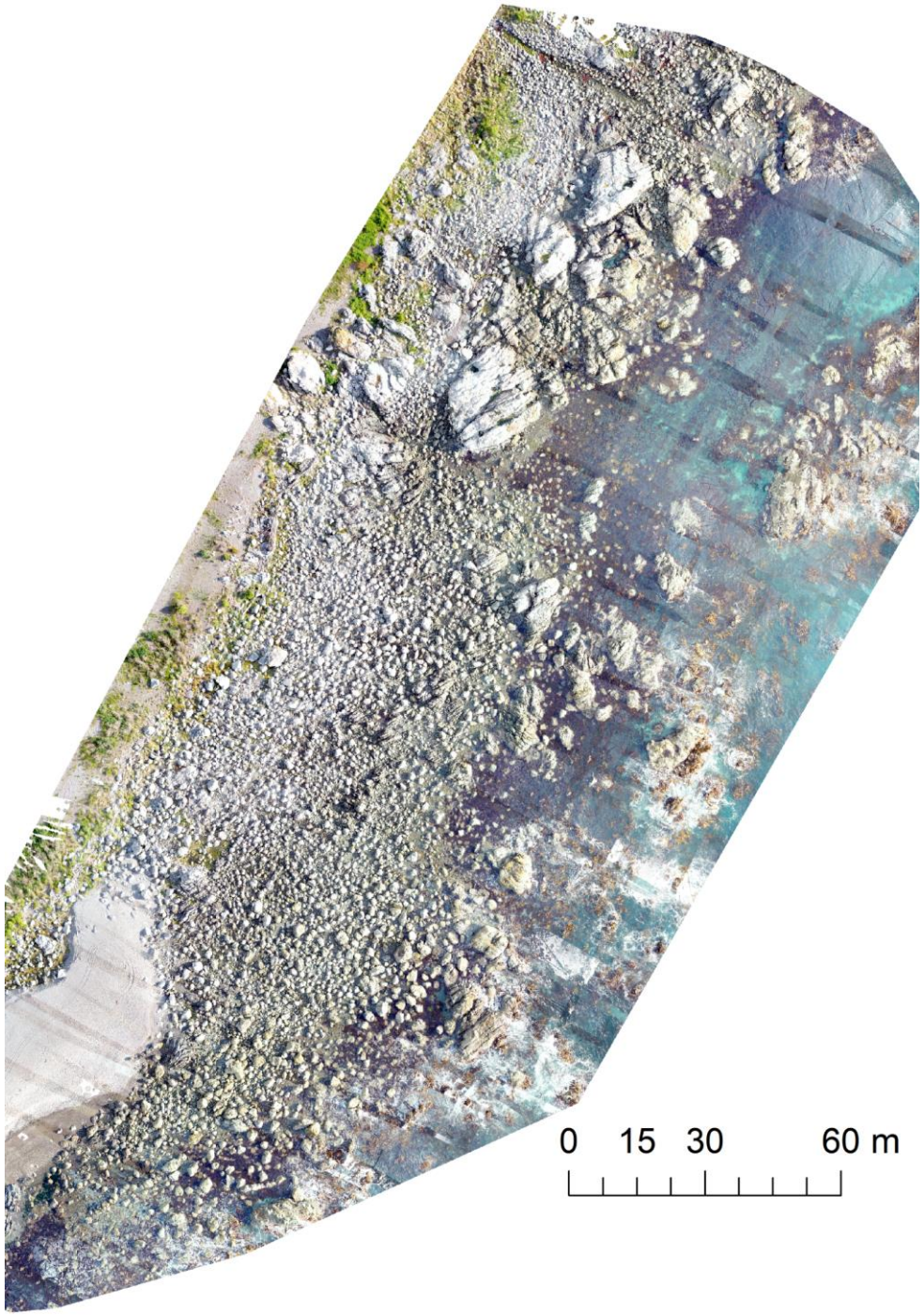
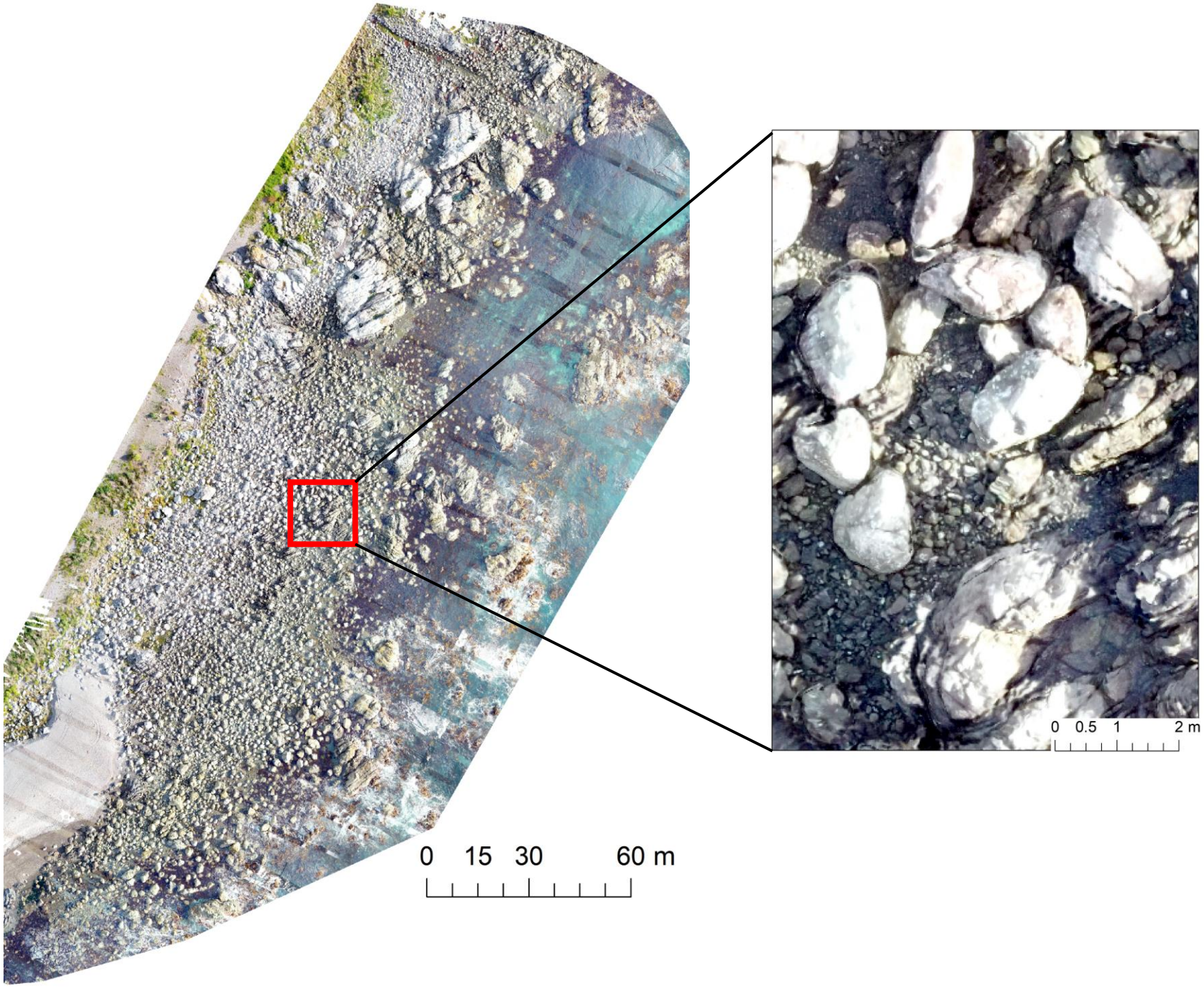
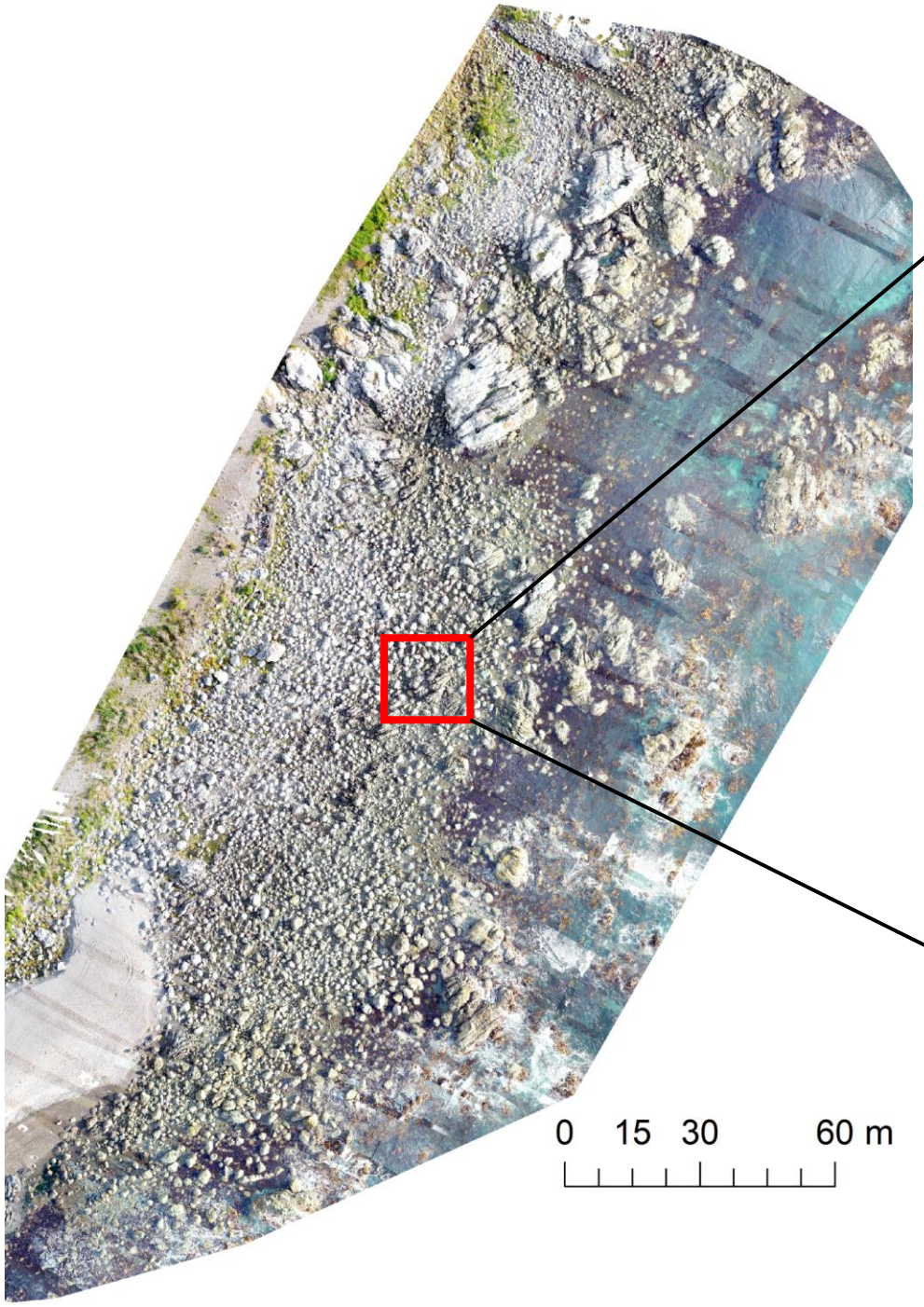
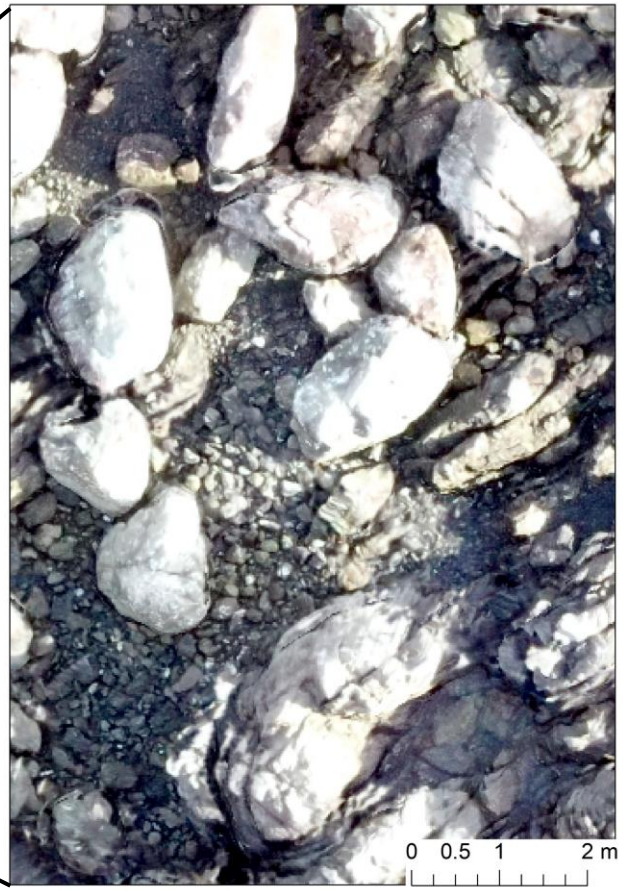


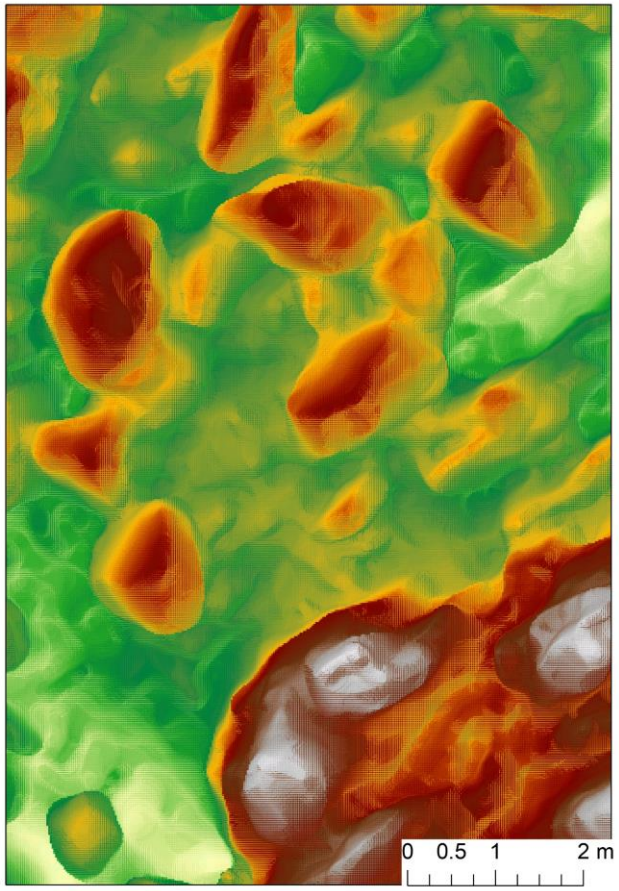

0 15 30 60 m


0 15 30 60 m


0 15 30 60 m
0 0.5 1 2 m







2 cm resolution

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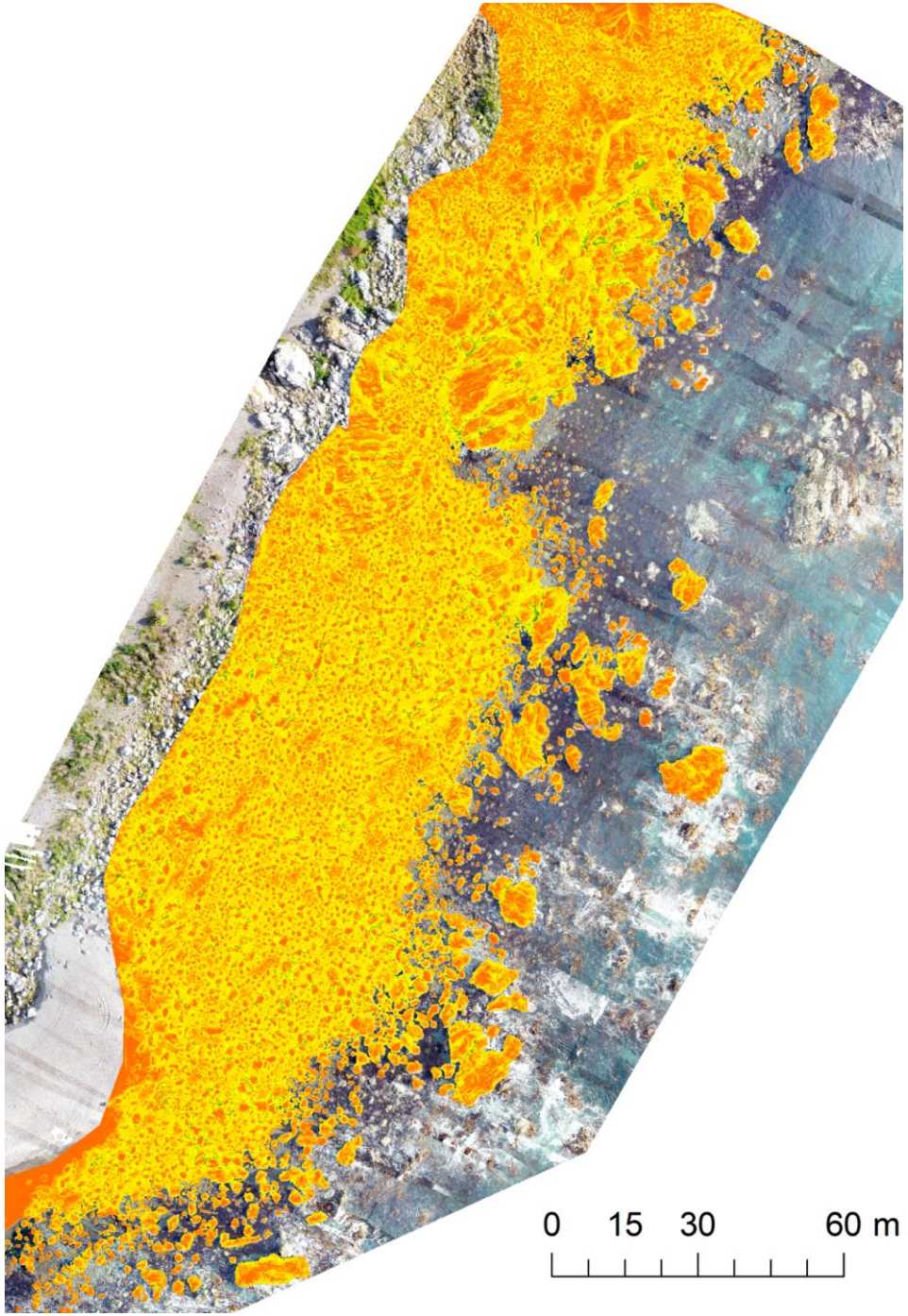
What do we need?

Do these thermal refugia provide viable safe spaces during extreme heat?

- ✓ Extreme heat event(s)
- ✓ High resolution reef surface model
- ✓ Predict body temperatures (Denny & Harley 2006)
  - ➢ Solar radiation
    - ➢ Surface slope, surface aspect, sky view factor



Green = survivable (<38°C)

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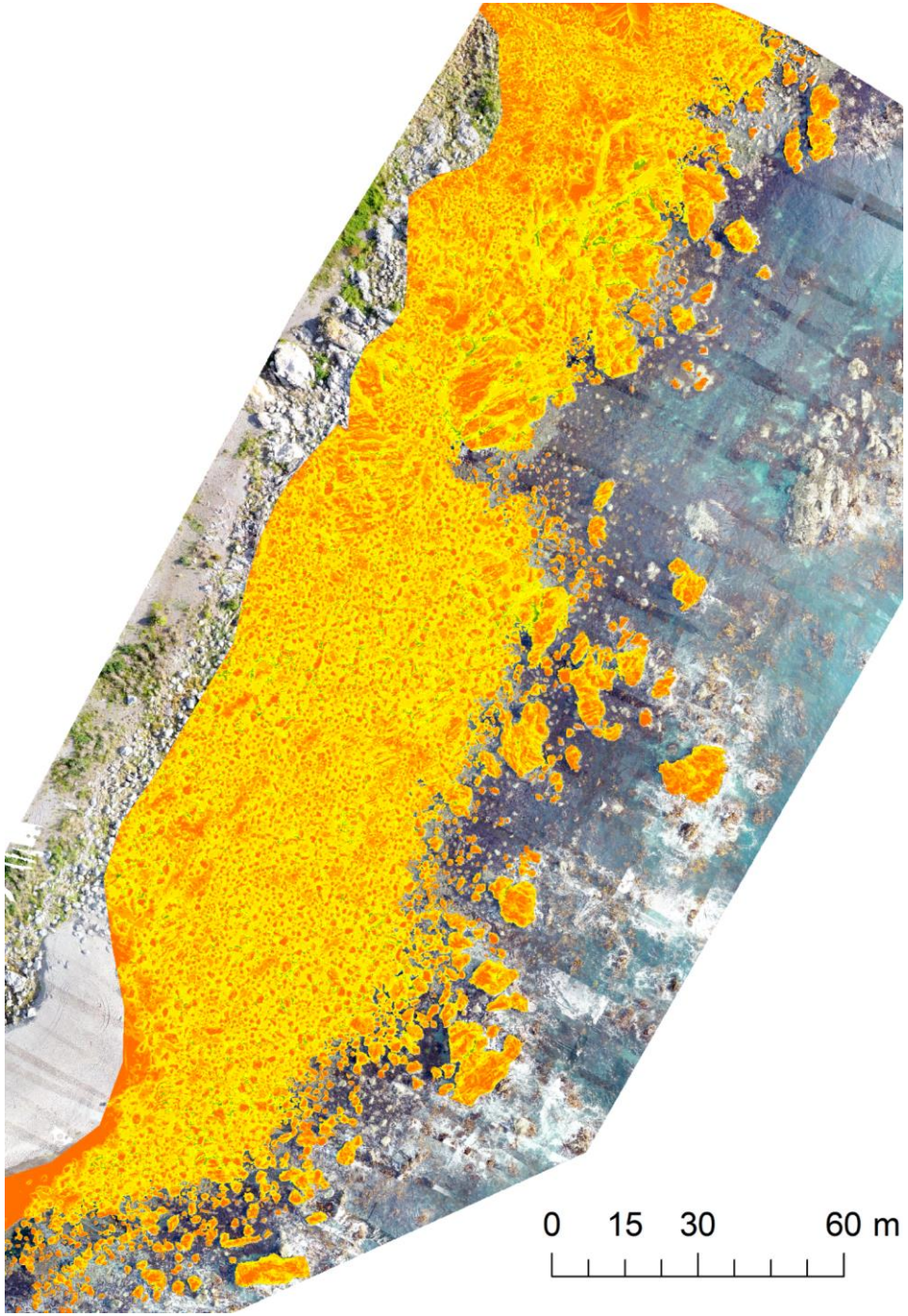

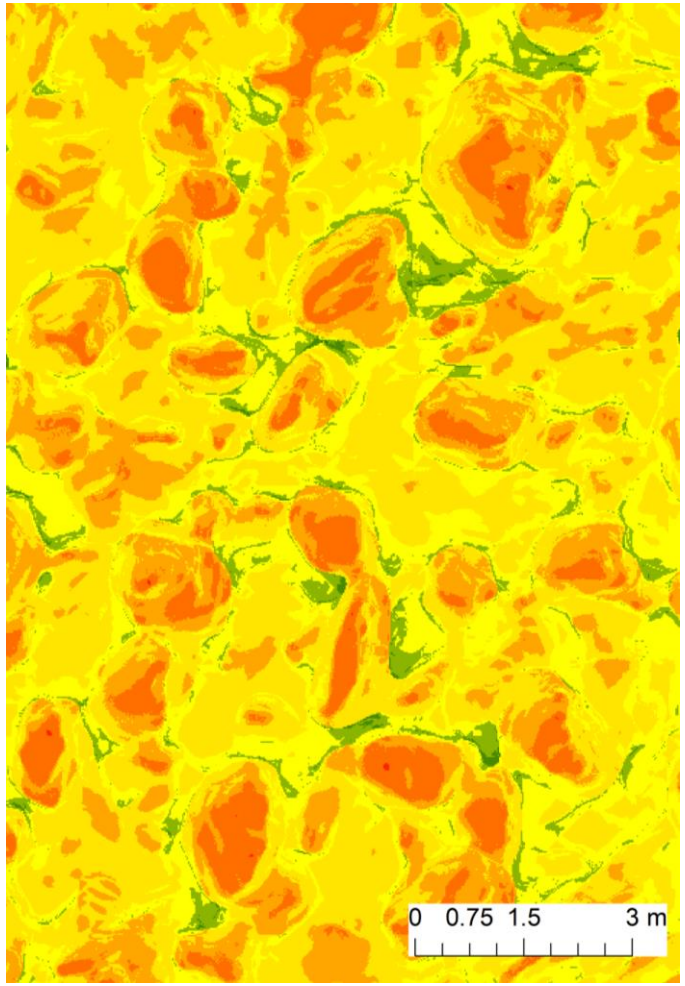

What does this all mean?

- This behaviour ~~probably~~ plays a critical role in the resilience of limpet populations to extreme heat events!

Acknowledgements

- **Supervisors:** David Schiel, Mark Denny, Mike Hickford
- **Helpers**: Shawn Gerrity, Steph Mangan, Tom Falconer, Ben Crichton, Shinae Montie, Francois Thoral, Lewis Jones, and the rest of MERG

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Questions?

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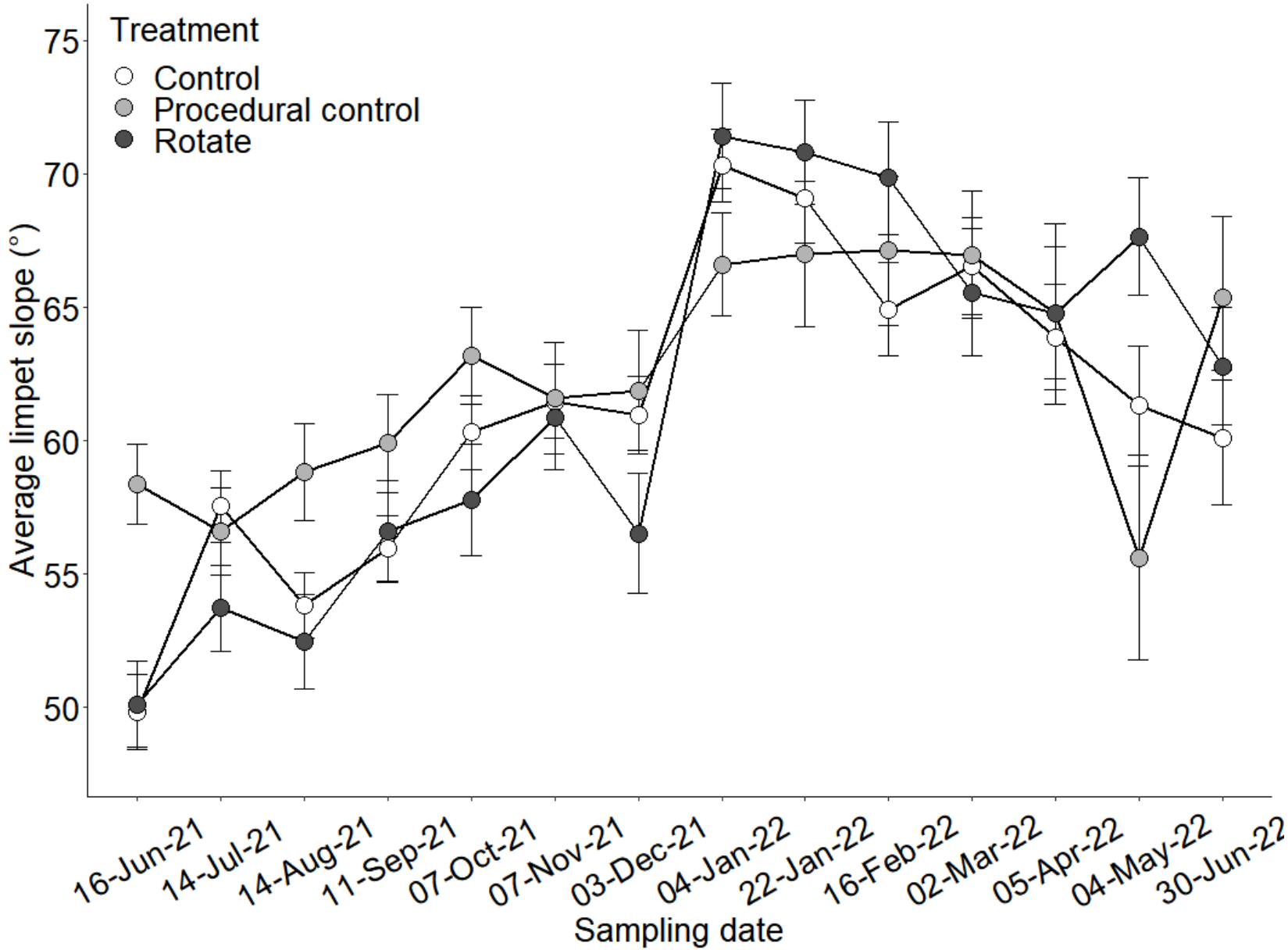
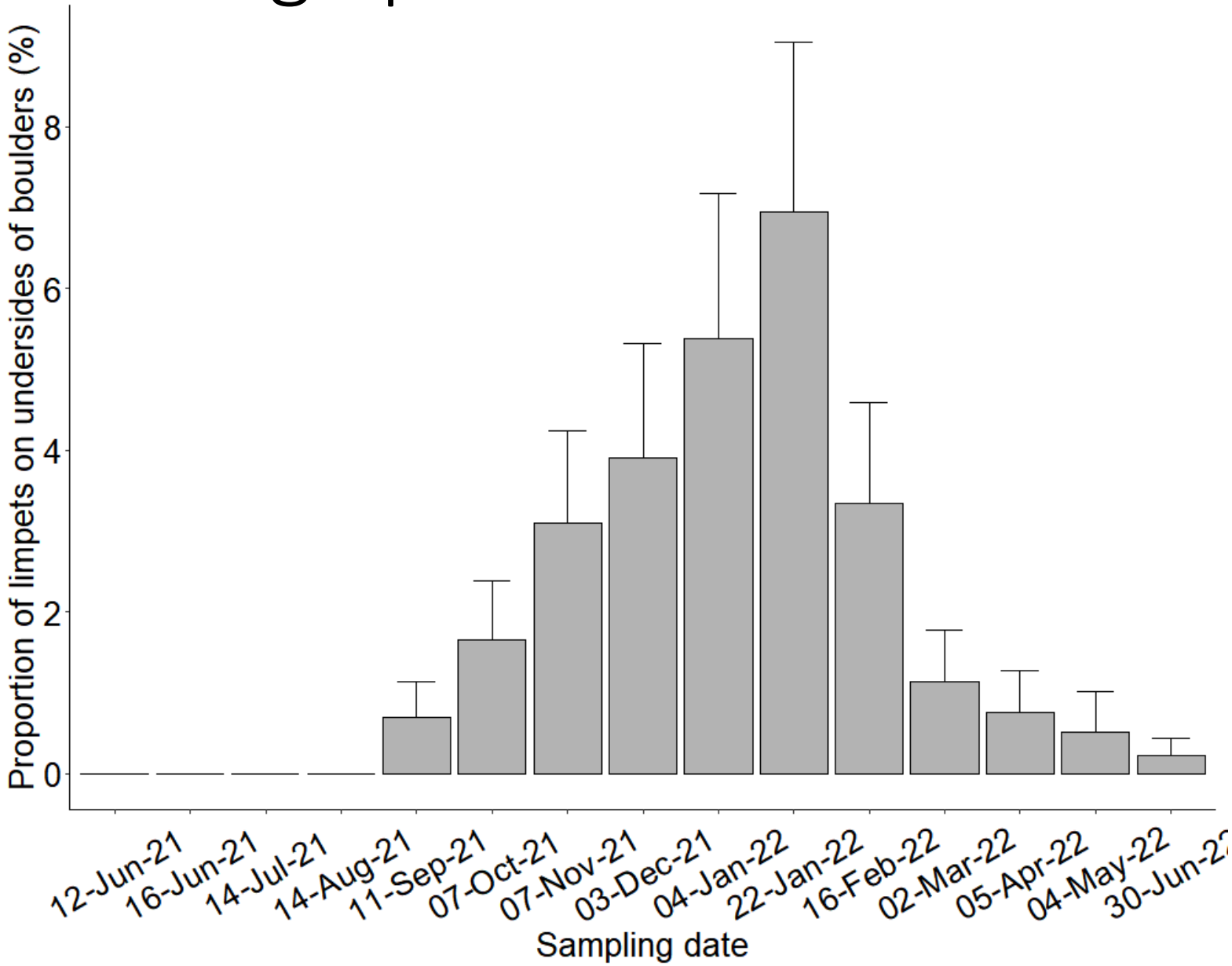
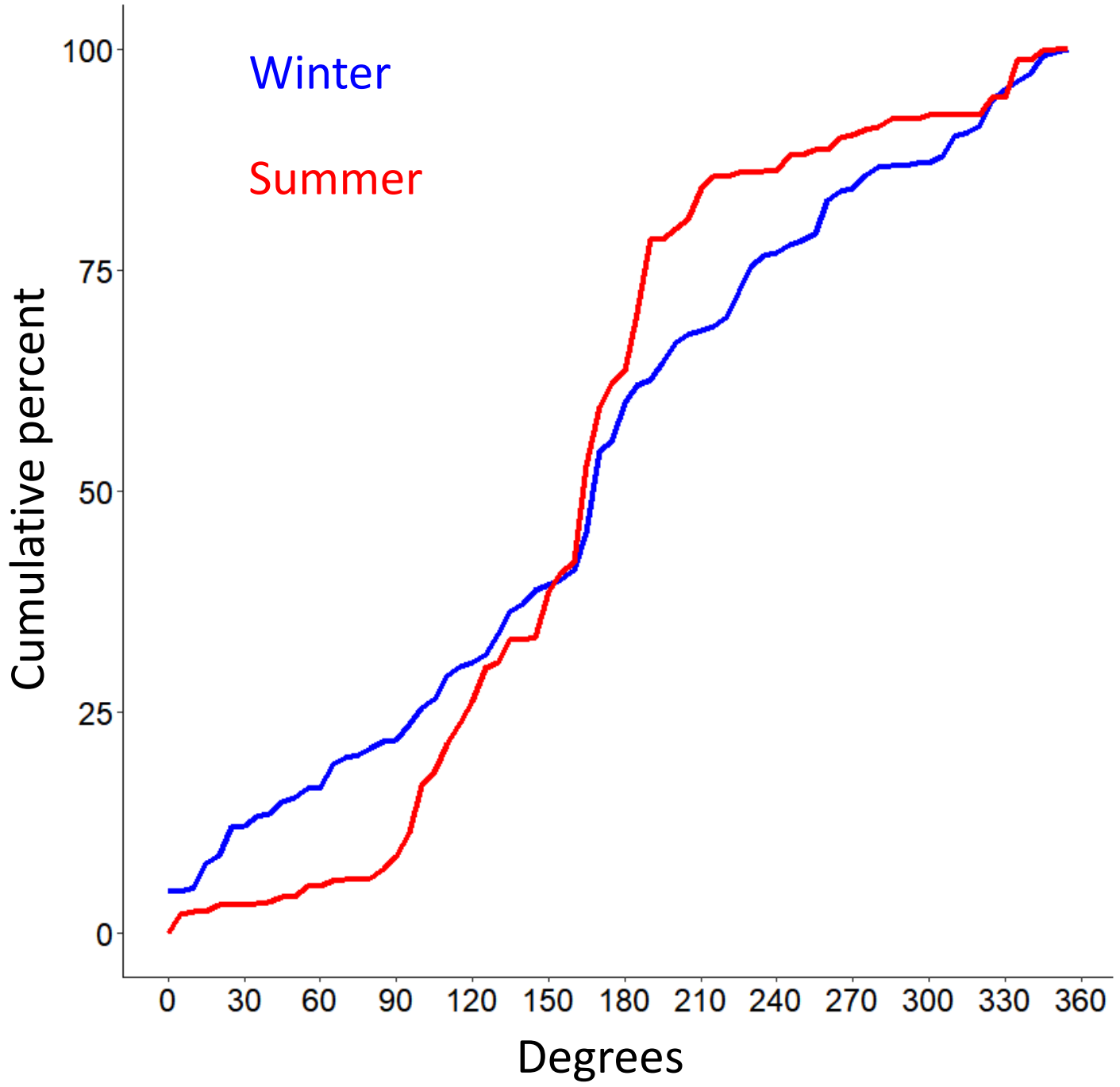
Limpets stay vertical to hide from the sun



Limpets hang upside down hide from the sun




Winter
Summer
Cumulative percent
100
75
50
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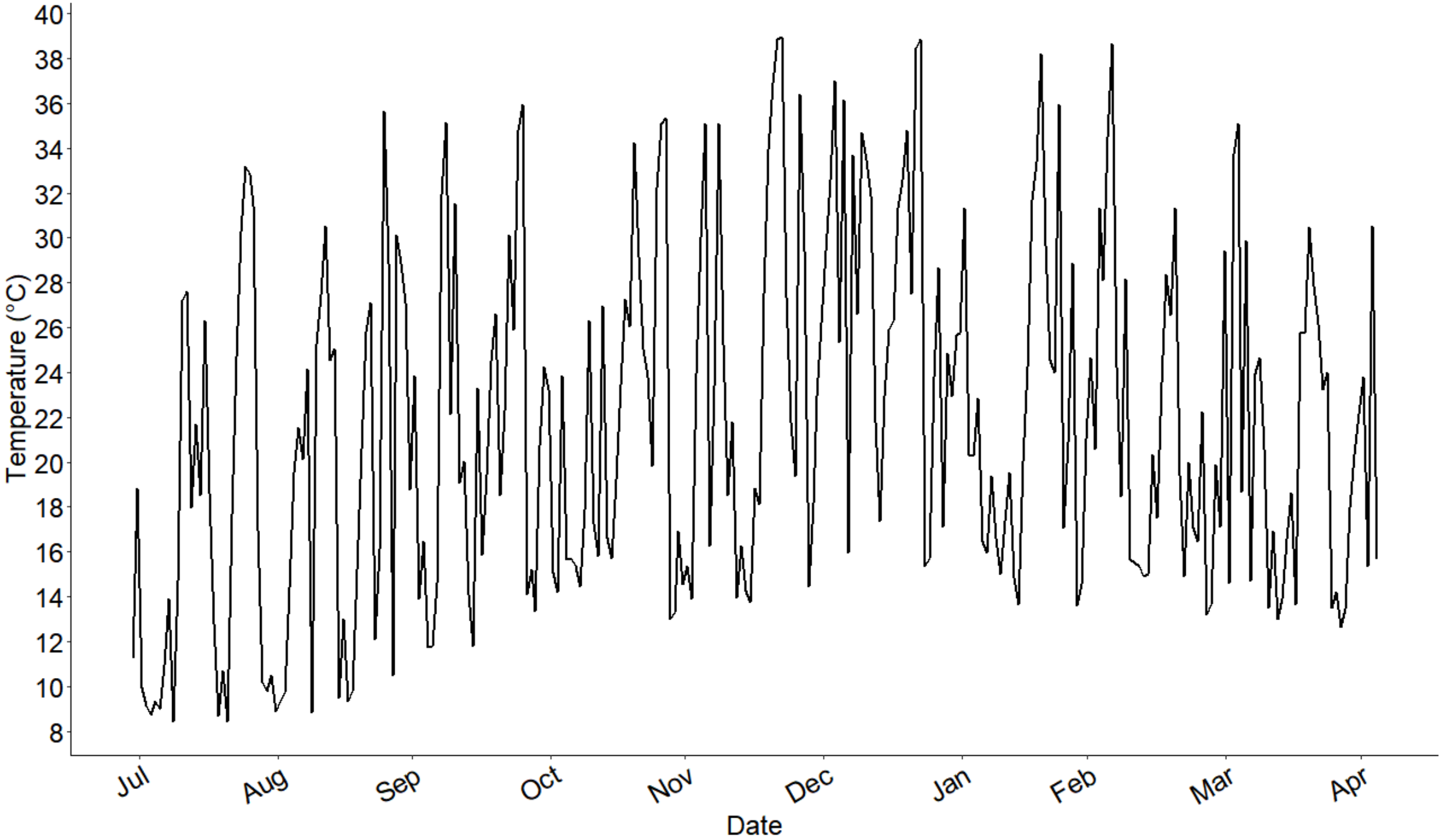
150
180
210
240
270
300
330
360
Degrees


Temperature (°C)
40
38
36
34
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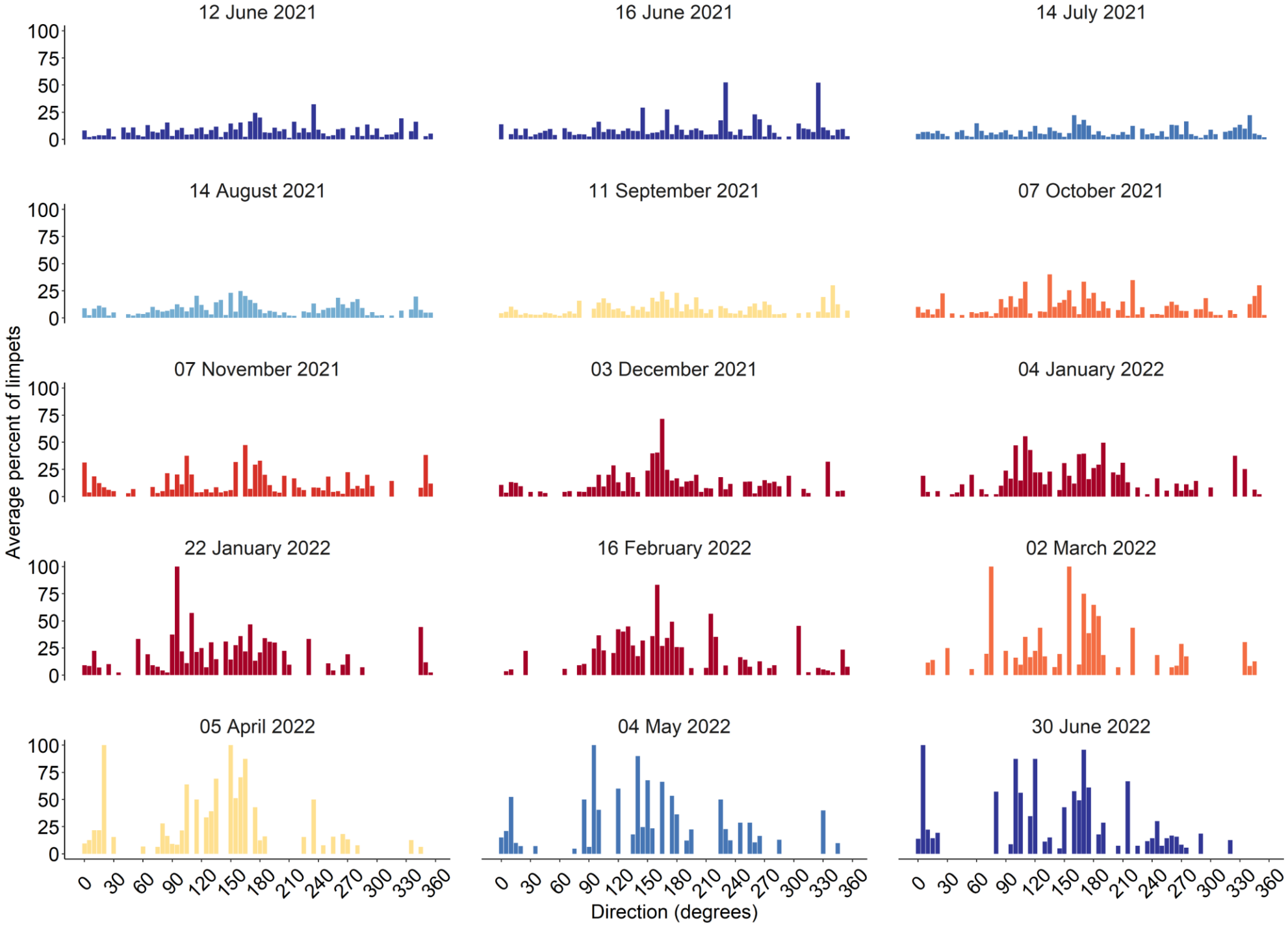
Date


12 June 2021
16 June 2021
14 July 2021
14 August 2021
11 September 2021
07 October 2021
07 November 2021
03 December 2021
04 January 2022
22 January 2022
16 February 2022
02 March 2022
05 April 2022
04 May 2022
30 June 2022
Average percent of limpets
Direction (degrees)
0
25
50
75
100
0
30
60
90
120
150
180
210
240
270
300
330
360