The size, trophic and spatial-temporal scaling of environmental selection in pelagic species

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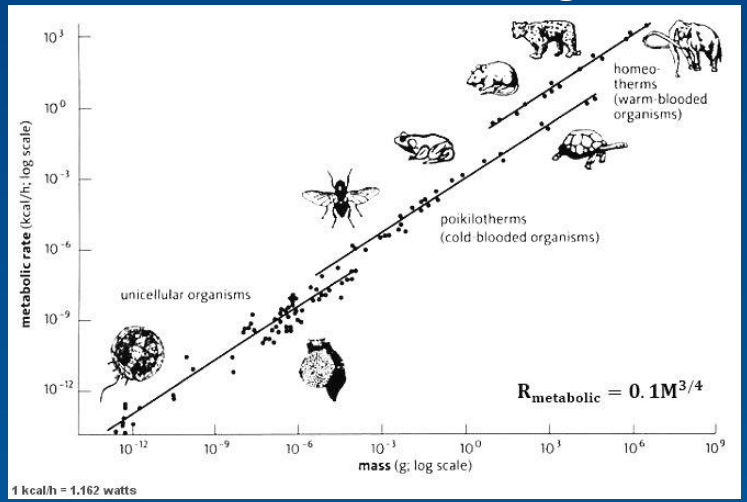
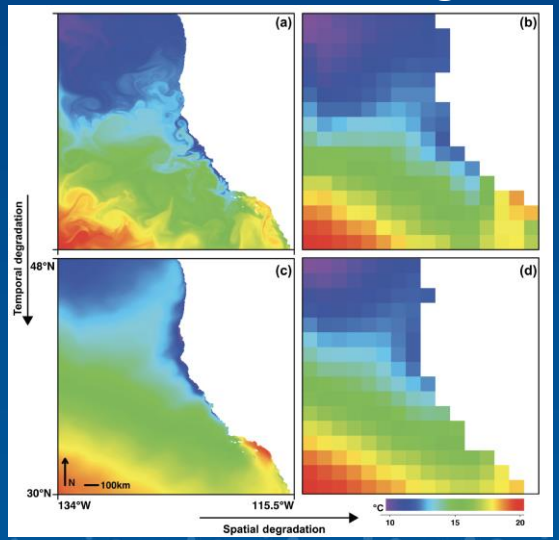
*Metabolic Scaling



Balmer, 2011

*Grain Size Scaling



Scales et al, 2016

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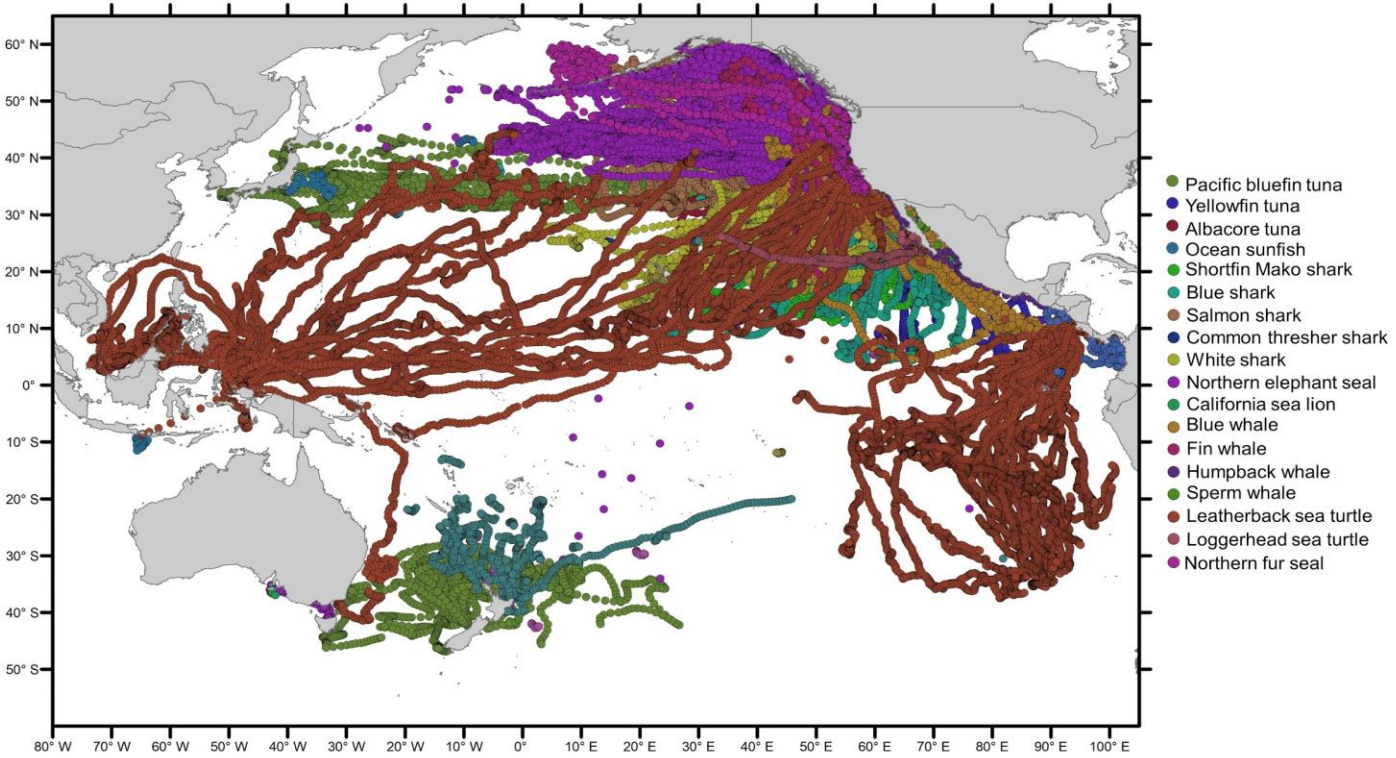
Tagging of Pelagic Predators (topp.org)

Block et al, 2011



Across large swaths of life, there appear to be mass dependent universal constraints to many biological and ecological processes

¾ Slope Rule – Interesting debate about why it is ¾….

Metabolic Theory of Ecology
Very broad rules across many taxa

Ecology, 85(7), 2004, pp. 1771–1789

TOWARD A METABOLIC THEORY OF ECOLOGY

JAMES H. BROWN,[1,2,4]
with JAMES F. GILLOOLY,[1] ANDREW P. ALLEN,[1] VAN M. SAVAGE,[2,3] AND GEOFFREY B. WEST[2,3]

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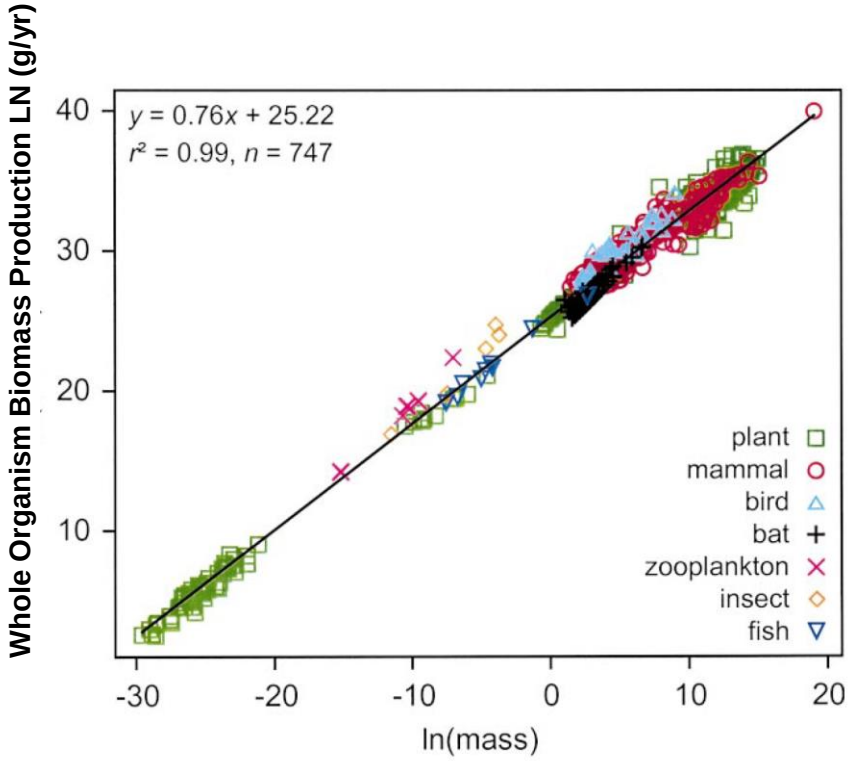
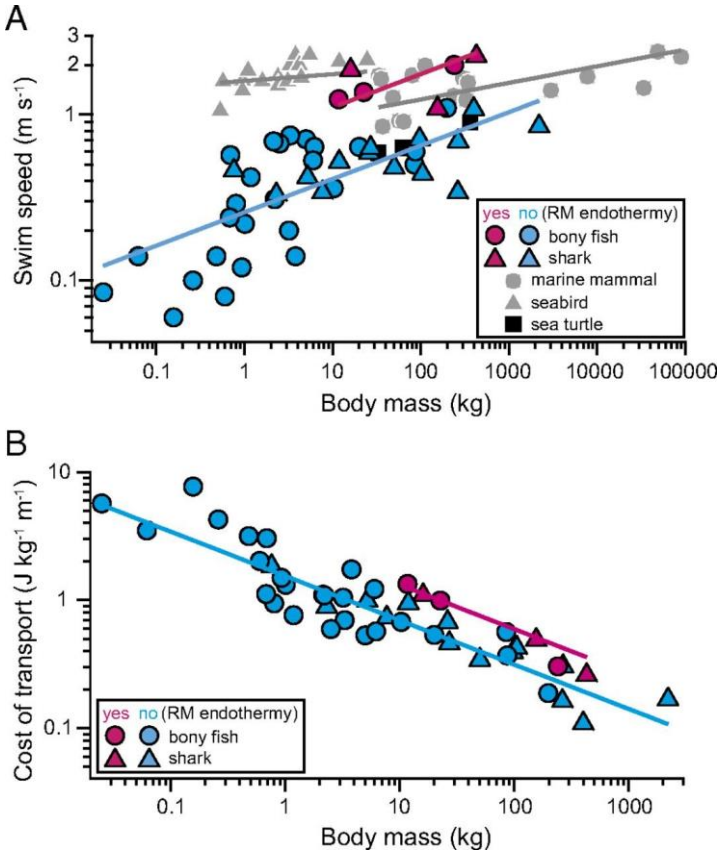
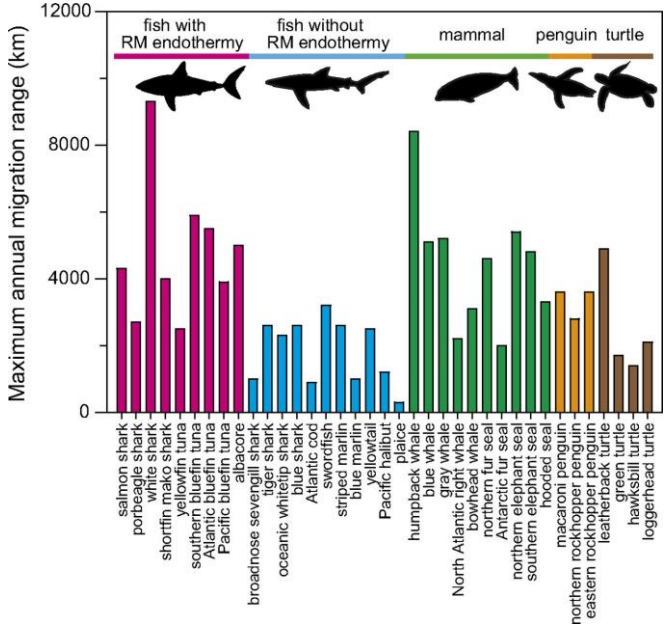




Metabolic innovation like endothermy increases range coverage of predators, but costs are much higher!

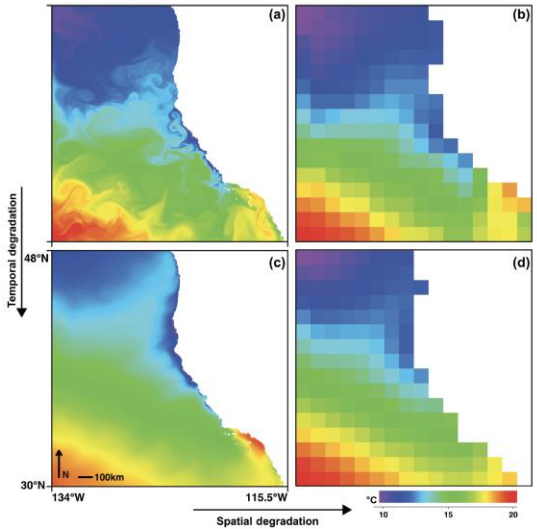


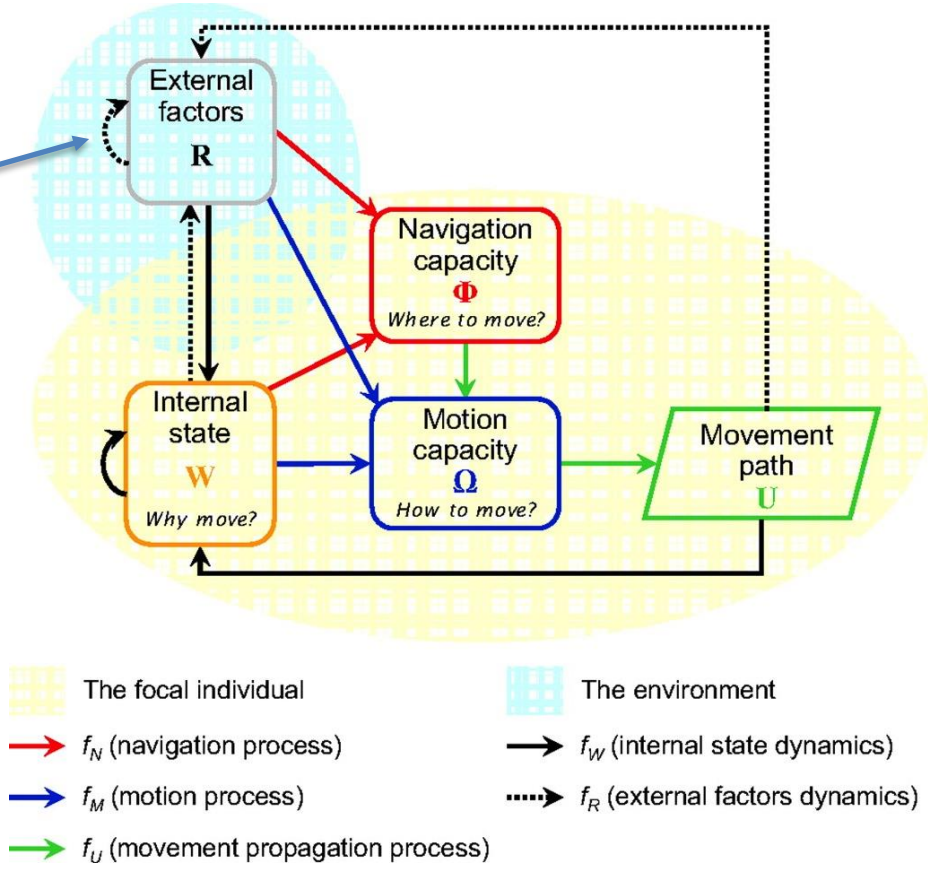
Watanabe, Y. Y., Goldman, K. J., Caselle, J, Chapman, D. D., and Papastamatiou, Y. P. (2015) Comparative analyses of animal-tracking data reveal ecological significance of endothermy in fishes. Proceedings of the National Academy of Sciences USA, 112 (19), 6104-6109.

Nathan R et al. PNAS 2008;105:19052-19059

Movement Ecology focuses more on the individual, rather than broad taxonomic groups

External factors are important, but at what space and time scales?





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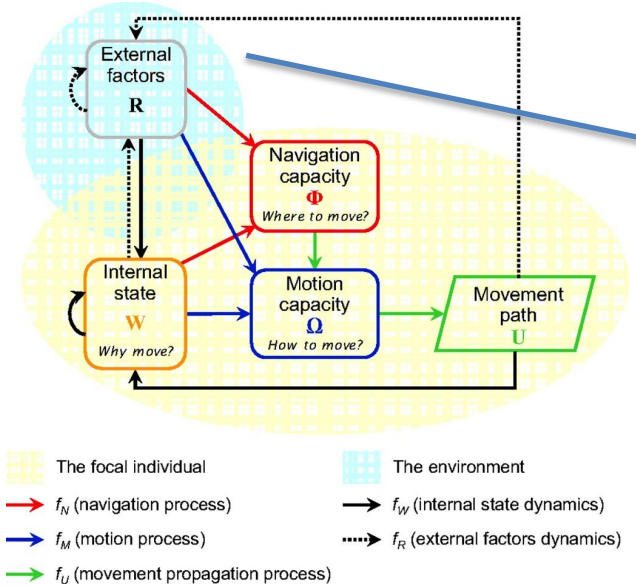
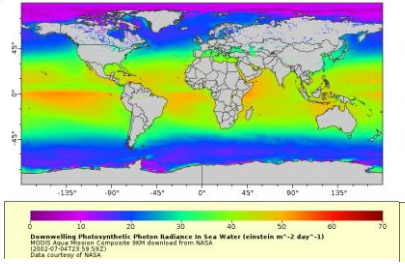
NASA

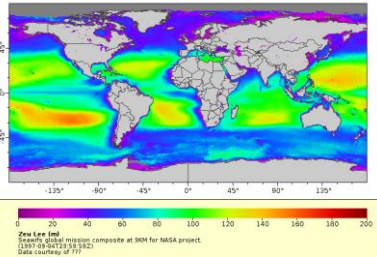


Potential environmental conditions forcing movement

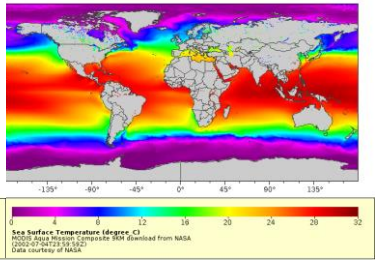
PAR

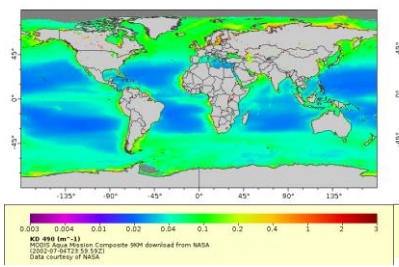


Euphotic Depth

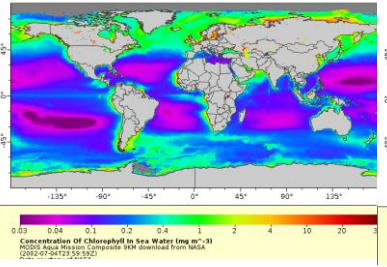


Temperature

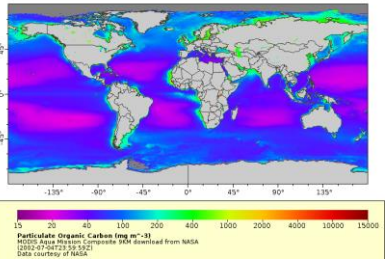




Diffuse Attenuation

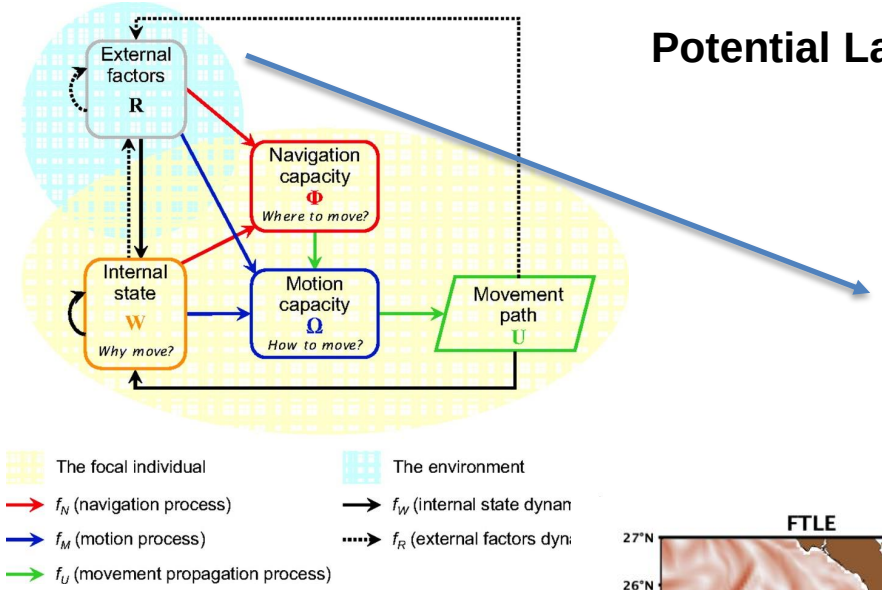


Chlorophyll

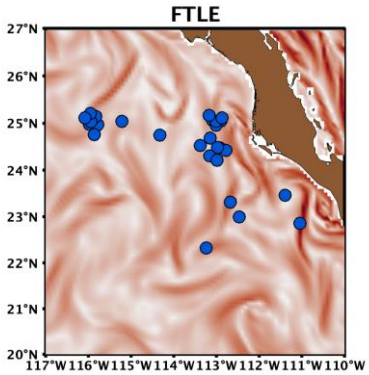


POC

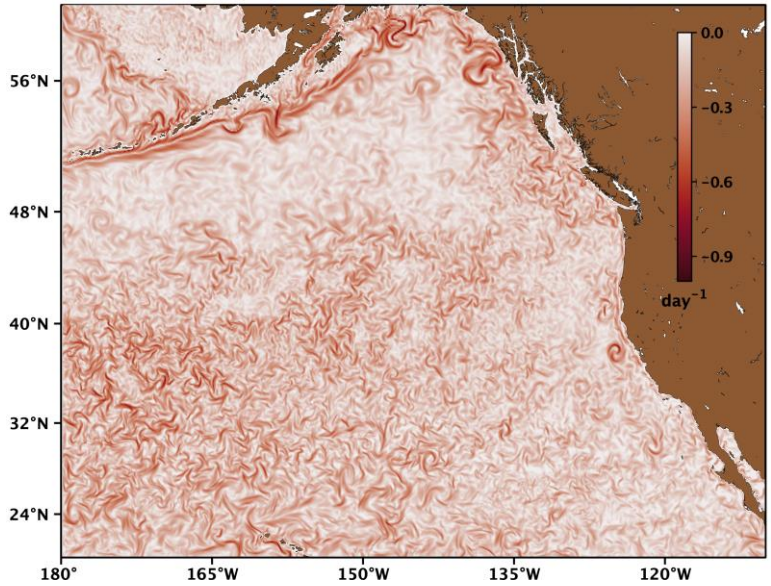
Potential Lagrangian conditions affecting movement



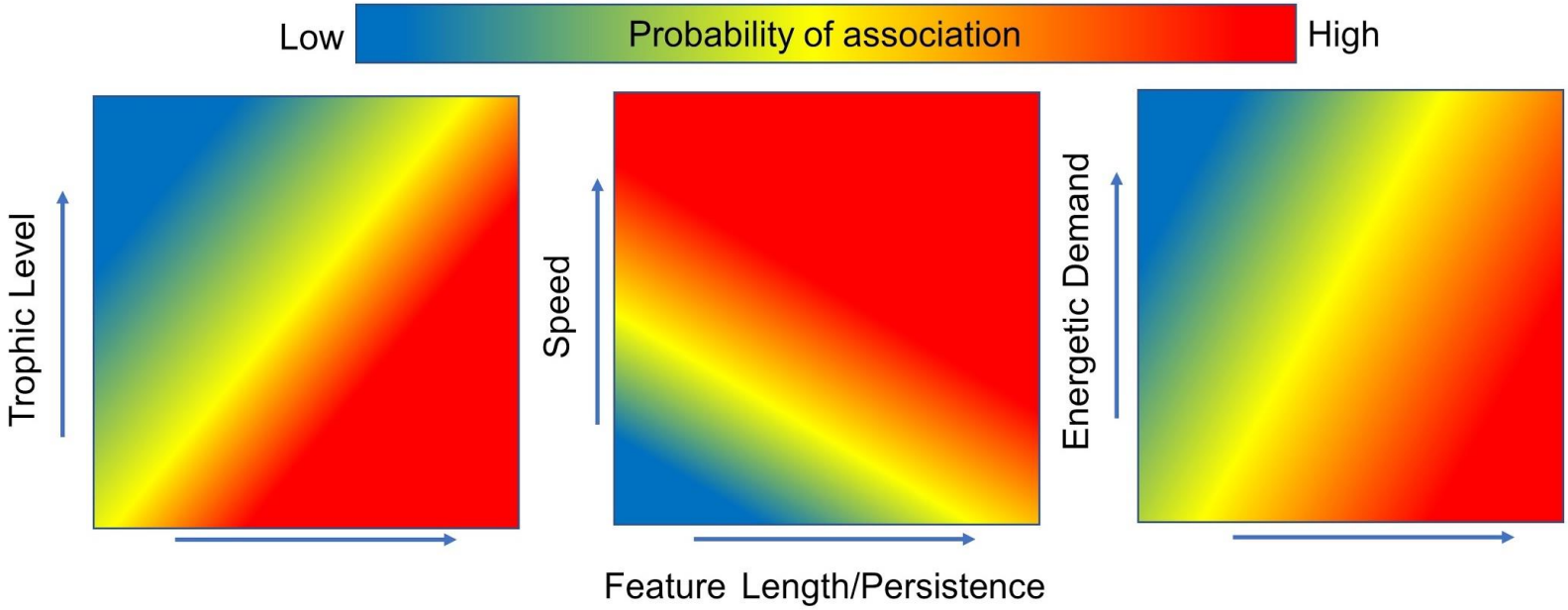
Yellowfin tuna appear to be located near FTLE ridges (potential prey attractors)



FTLE from HYCOM reanalysis



General Expectations



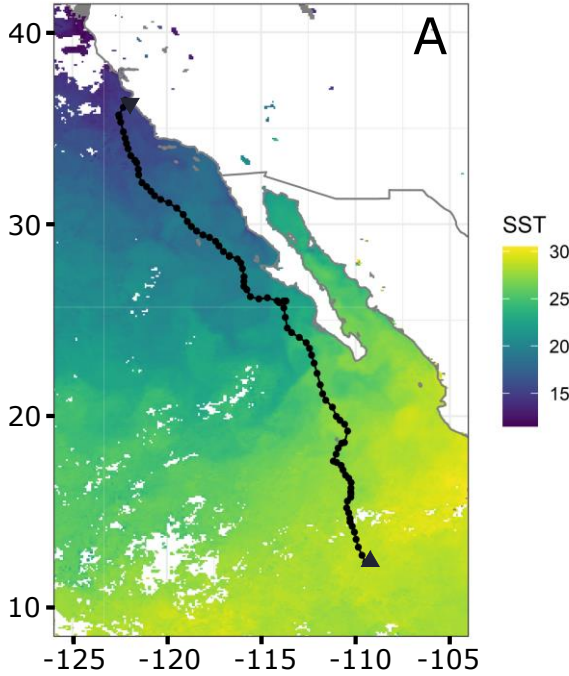
While we are busy computing environmental grids at multiple spatial and temporal scales……

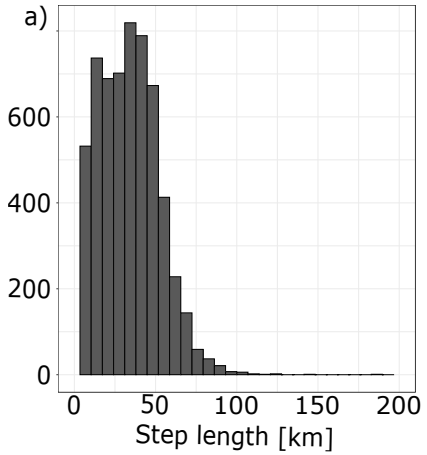
Problem of trivial NULL selection models

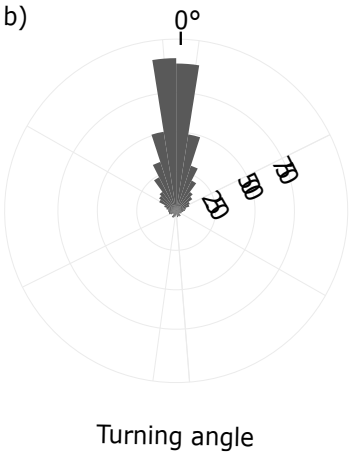
Very few fish on the land…

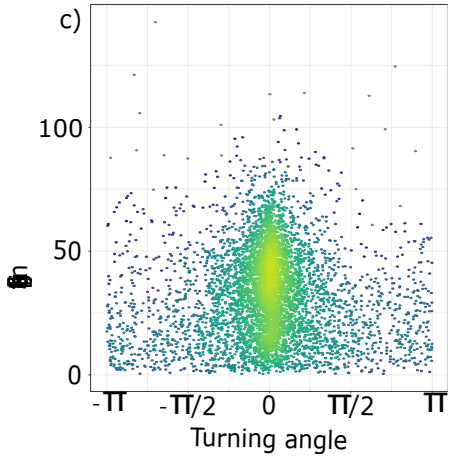
Build NULL models based on movement constraints of each species.

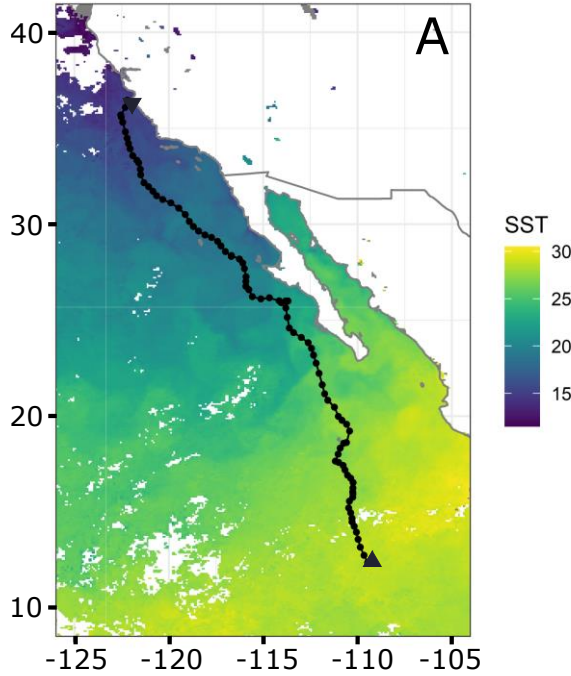
Need to consider null models on a species level capacity



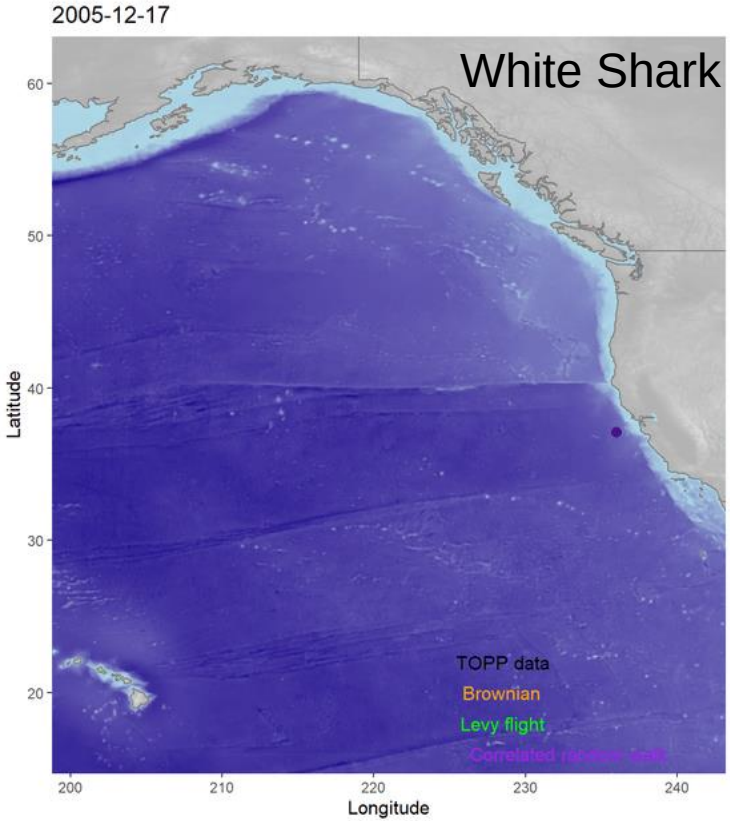

a)
600
400
200
0
0
50
100
150
200
Step length [km]


b)
0°
Turning angle

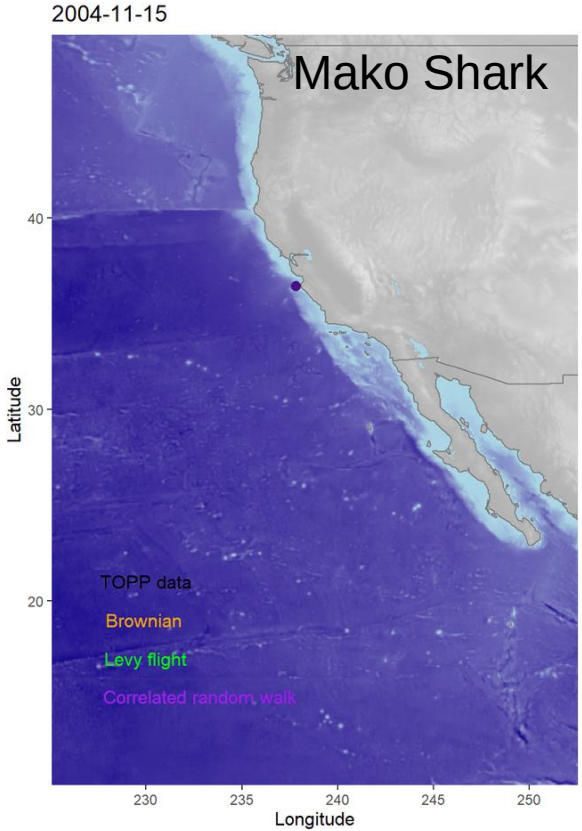

c)
100
50
0
-π
-π/2
0
π/2
π
Turning angle


A
40
30
20
10
-125
-120
-115
-110
-105
SST
30
25
20
15

Create Null Animal Models (Brownian, Correlated Random Walk, Levy Flight)



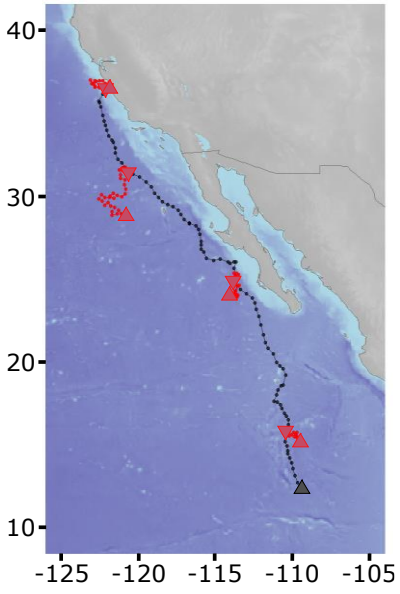
Are these still trivial models?



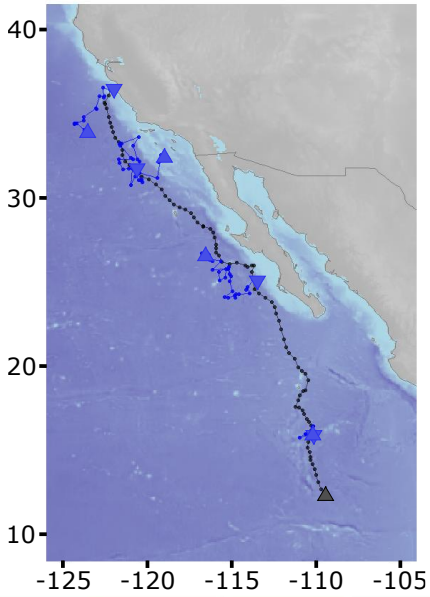
To avoid trivial results, we restart each NULL model comparisons every 30 days.

How do we test this approach?

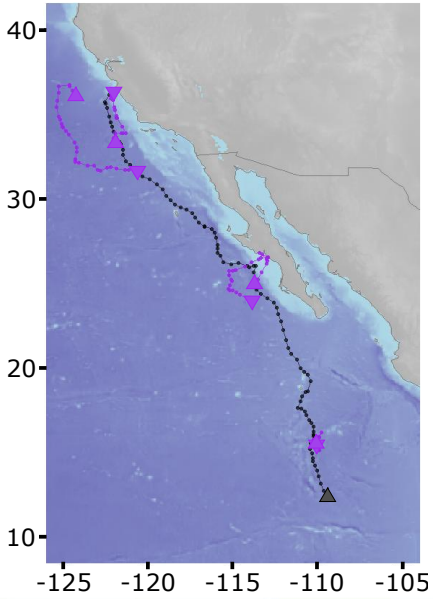
Brownian



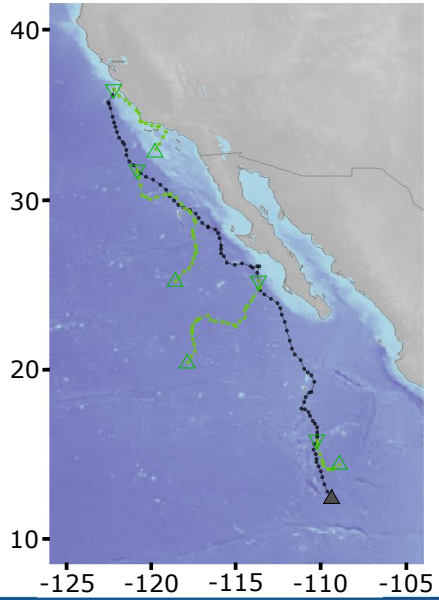
Levy Flight



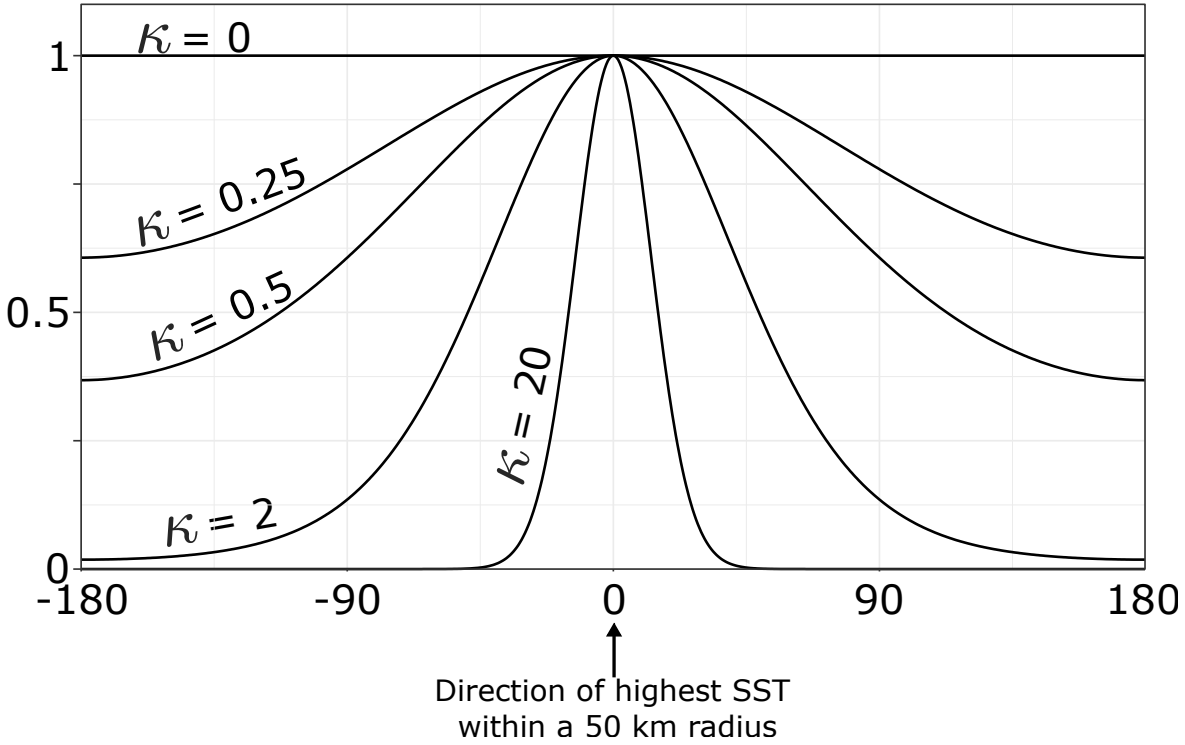
CRW

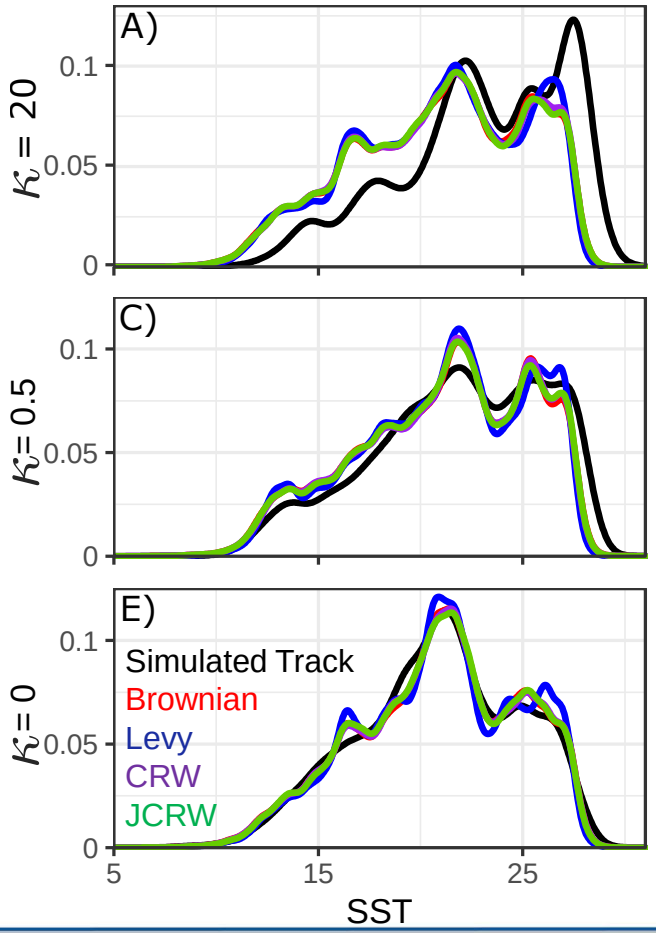


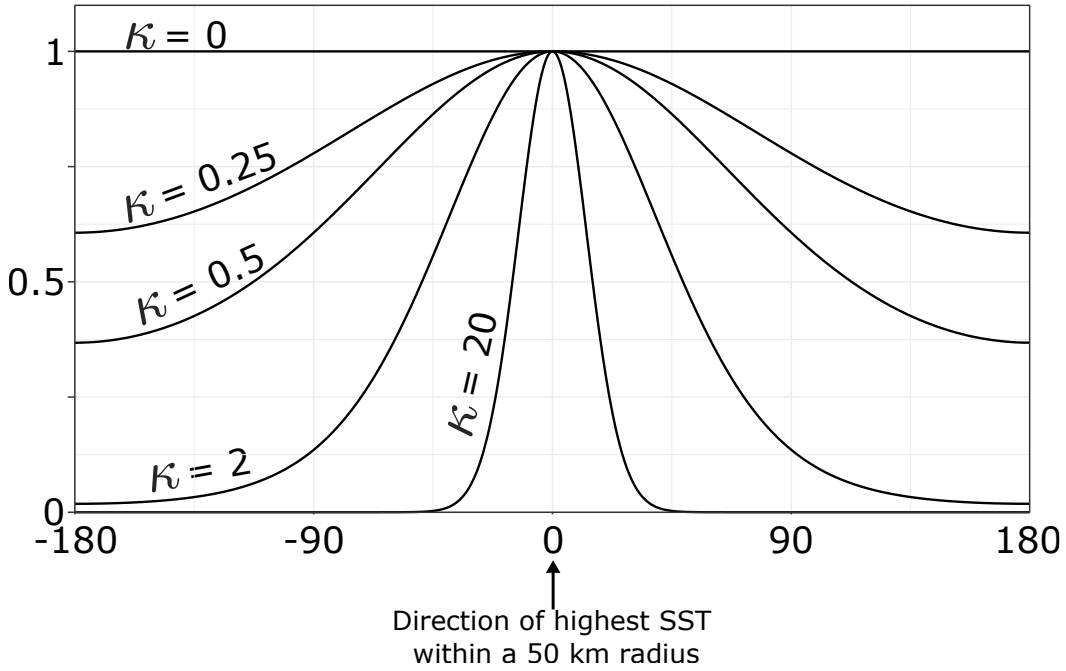
JCRW

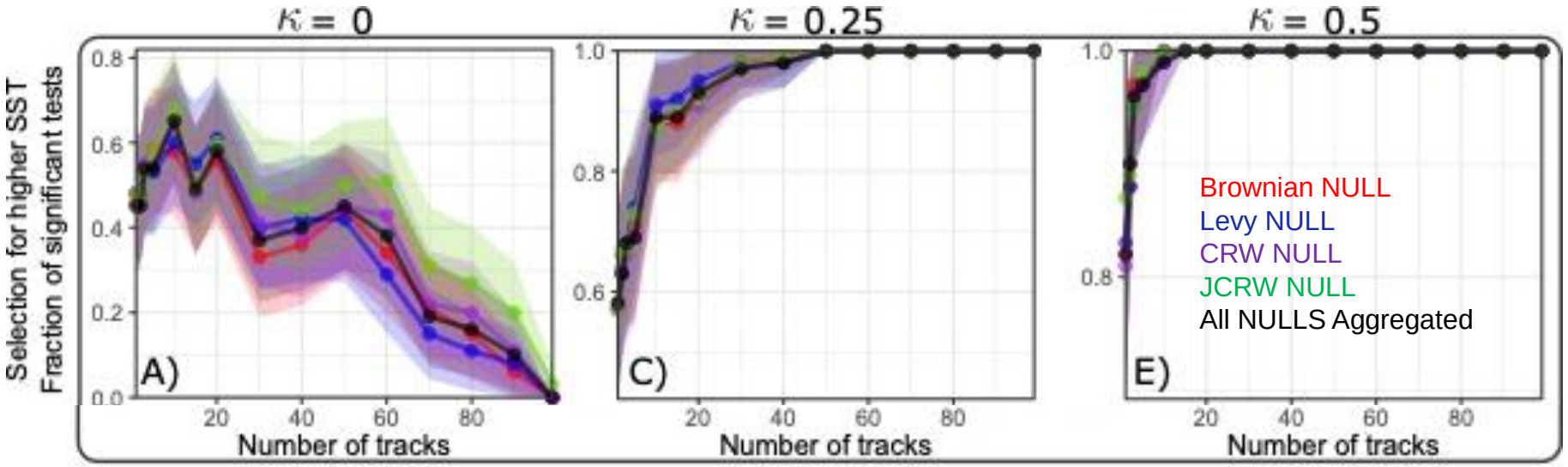


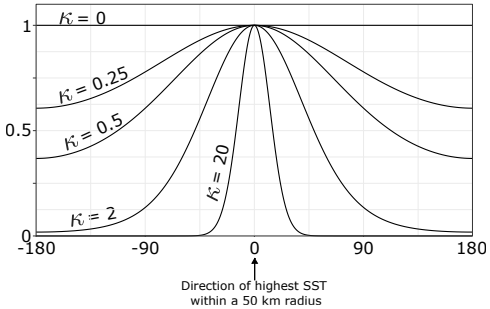
Create simulated animals with known selection for higher temperatures to compare against our NULL models.



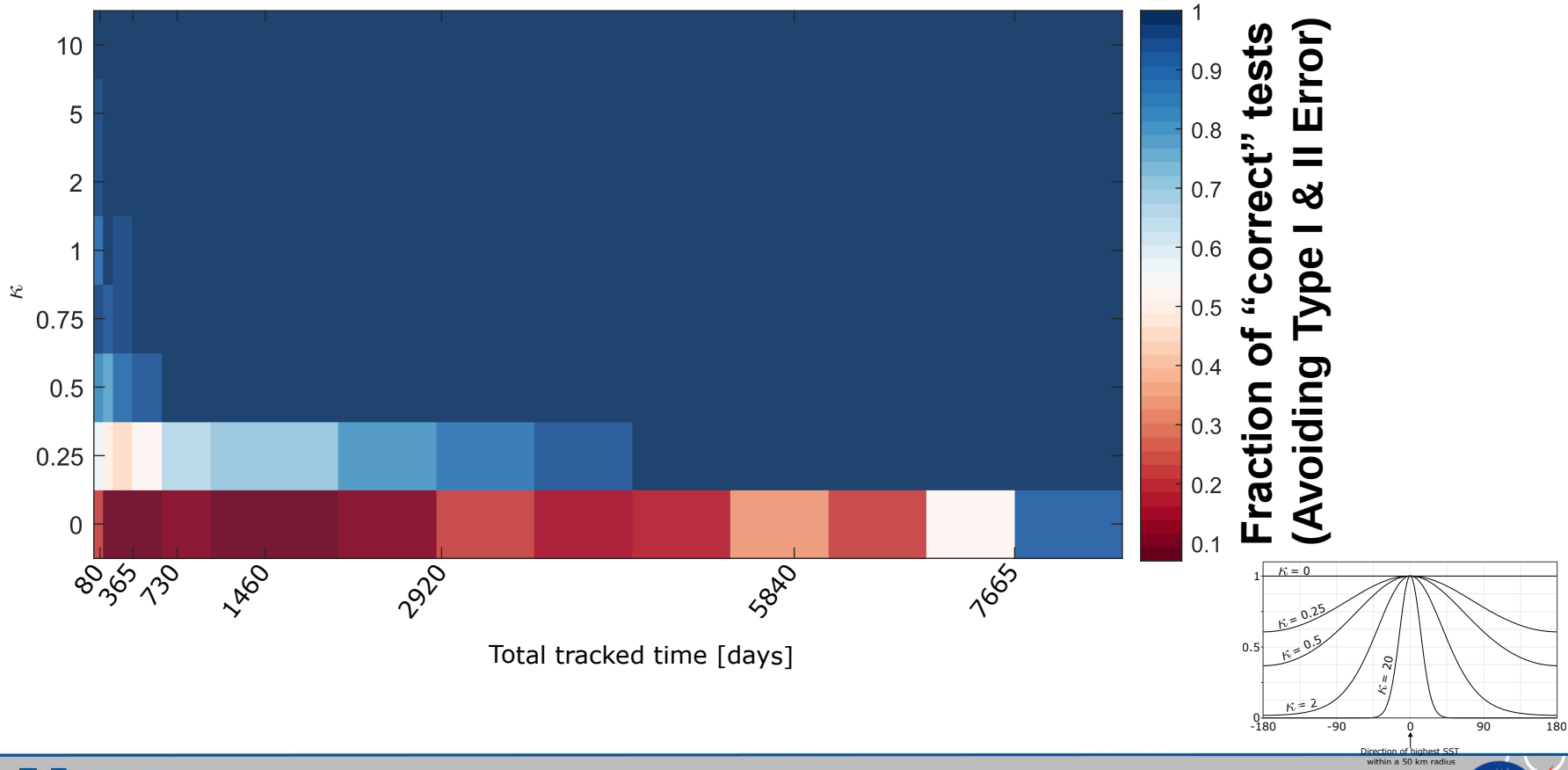

A)
C)
E)
κ = 20
κ = 0.5
κ = 0
0.1
0.05
0
Simulated Track
Brownian
Levy
CRW
JCRW
5
15
25
SST

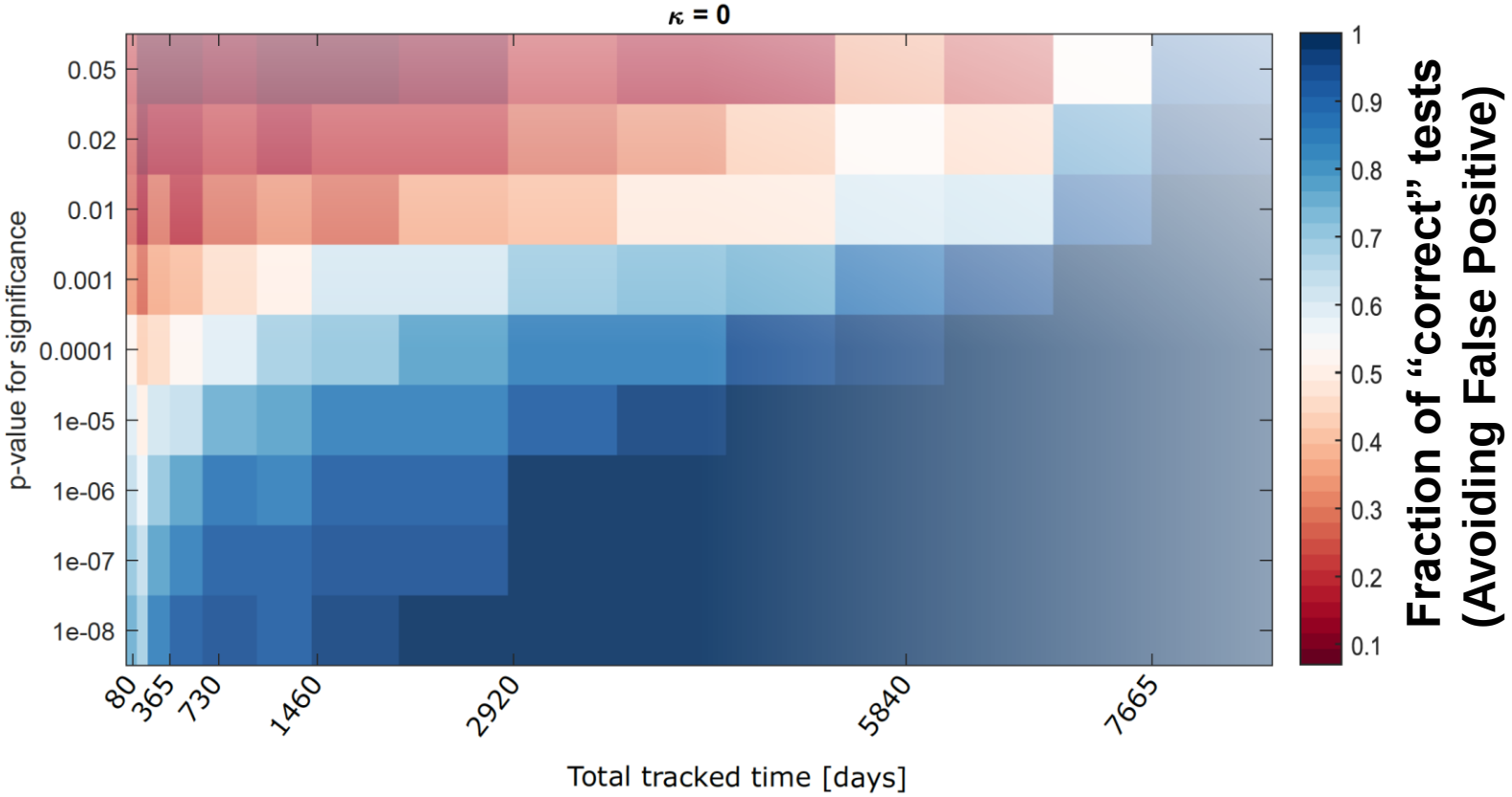

κ = 0
κ = 0.25
κ = 0.5
κ = 20
κ = 2
1
0.5
0
-180
-90
0
90
180
Direction of highest SST
within a 50 km radius


κ = 0
κ = 0.25
κ = 0.5
Selection for higher SST
Fraction of significant tests
A)
C)
E)
Number of tracks
Brownian NULL
Levy NULL
CRW NULL
JCRW NULL
All NULLS Aggregated


κ = 0
κ = 0.25
κ = 0.5
κ = 2
κ = 20
Direction of highest SST
within a 50 km radius

P = 0.05


κ
10
5
2
1
0.75
0.5
0.25
0
80
365
730
1460
2920
5840
7665
Total tracked time [days]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Fraction of "correct" tests
(Avoiding Type I & II Error)
κ = 0
κ = 0.25
κ = 0.5
κ = 2
κ = 20
1
0.5
0
-180
-90
0
90
180
Direction of highest SST
within a 50 km radius


κ = 0
p-value for significance
0.05
0.02
0.01
0.001
0.0001
1e-05
1e-06
1e-07
1e-08
80
365
730
1460
2920
5840
7665
Total tracked time [days]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Fraction of "correct" tests
(Avoiding False Positive)

Summary

1. We expect MTE to limit home range, and to affect environmental selection across metabolic strategies

2. We expect to determine what grain sizes (or multi grain sizes) affect predator distribution

3. We expect persistent Lagrangian features to explain animal movement

4. False positives for environmental selection are very common.

5. We recommend several years of daily track data to avoid false positives