Quantifying contribution of mesopelagic fishes to the BCP: constraining respiration rates

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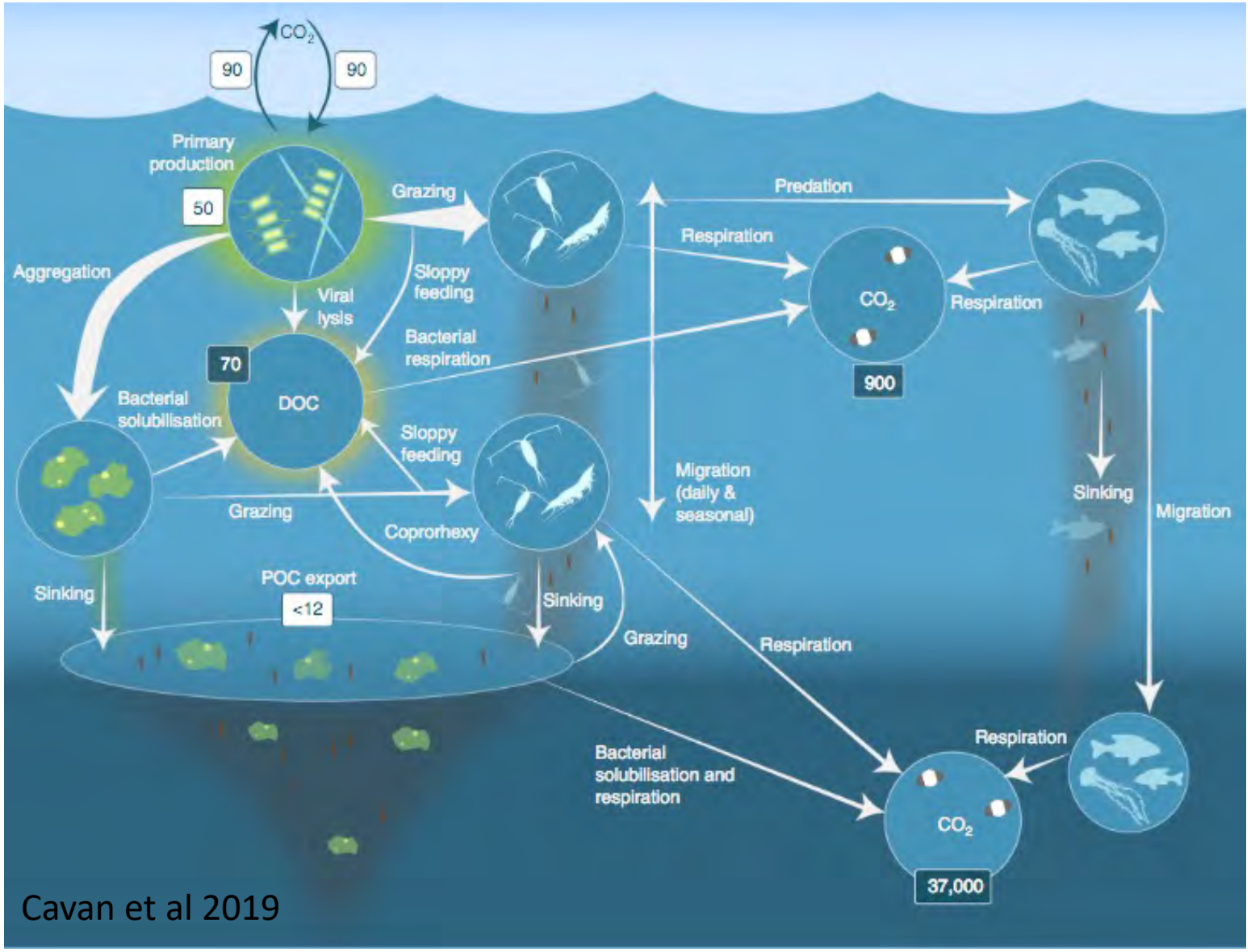


Cavan et al 2019

Fish contribution understudied: estimate 16% active flux C from euphotic zone = 10-55% total ocean passive flux

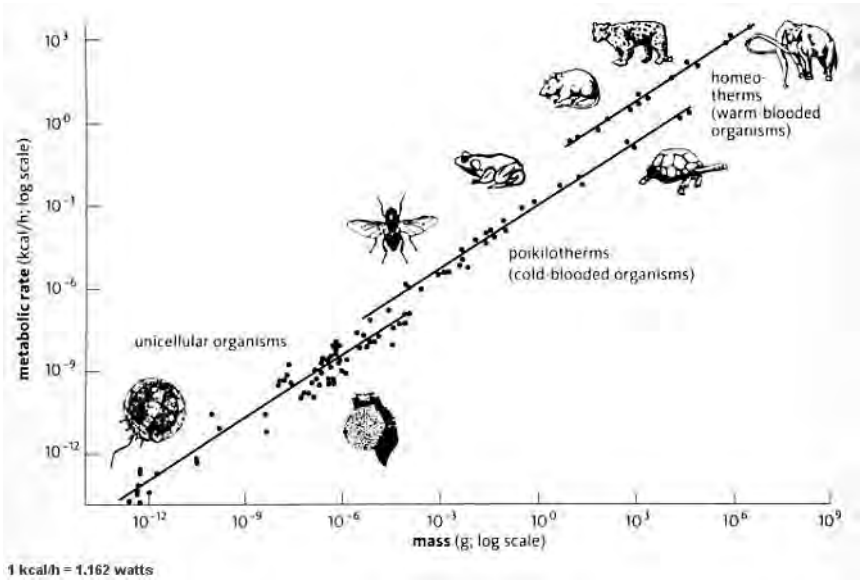
Contribution to C flux (and fish-derived carbonates) constrained by

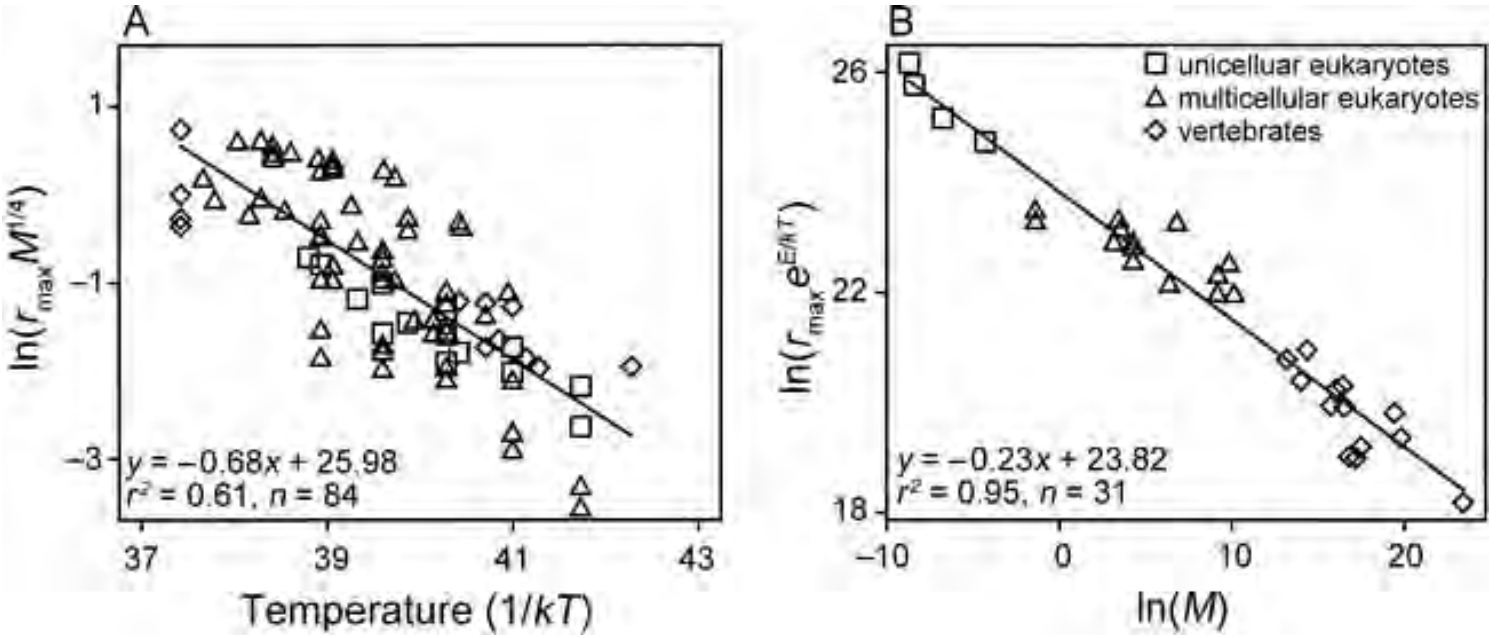
- Number (biomass) (of fish)
- DVM and depth behaviour
- Metabolic / respiration rate

- Contribution of fish to global C flux using implementations of MTE:

$$\text{Rate} \sim b_o M^{\alpha} e^{-E/kT}$$

Strict MTE: $\alpha = 0.75$, E = 0.65eV





Brown, 2004

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Review articles

Variable metabolic scaling breaks the law: from 'Newtonian' to 'Darwinian' approaches

Douglas S. Glazier

Published: 19 October 2022 https://doi.org/10.1098/rspb.2022.1605

Review history

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HOME > SCIENCE > VOL. 377, NO. 6608 > METABOLIC SCALING IS THE PRODUCT OF LIFE-HISTORY OPTIMIZATION

RESEARCH ARTICLE | EVOLUTIONARY ECOLOGY

Metabolic scaling is the product of life-history optimization

CRAIG R. WHITE, LESLEY A. ALTON, CANDICE L. BYWATER, EMILY J. LOMBARDI, AND DUSTIN J. MARSHALL Authors Info & Affiliations

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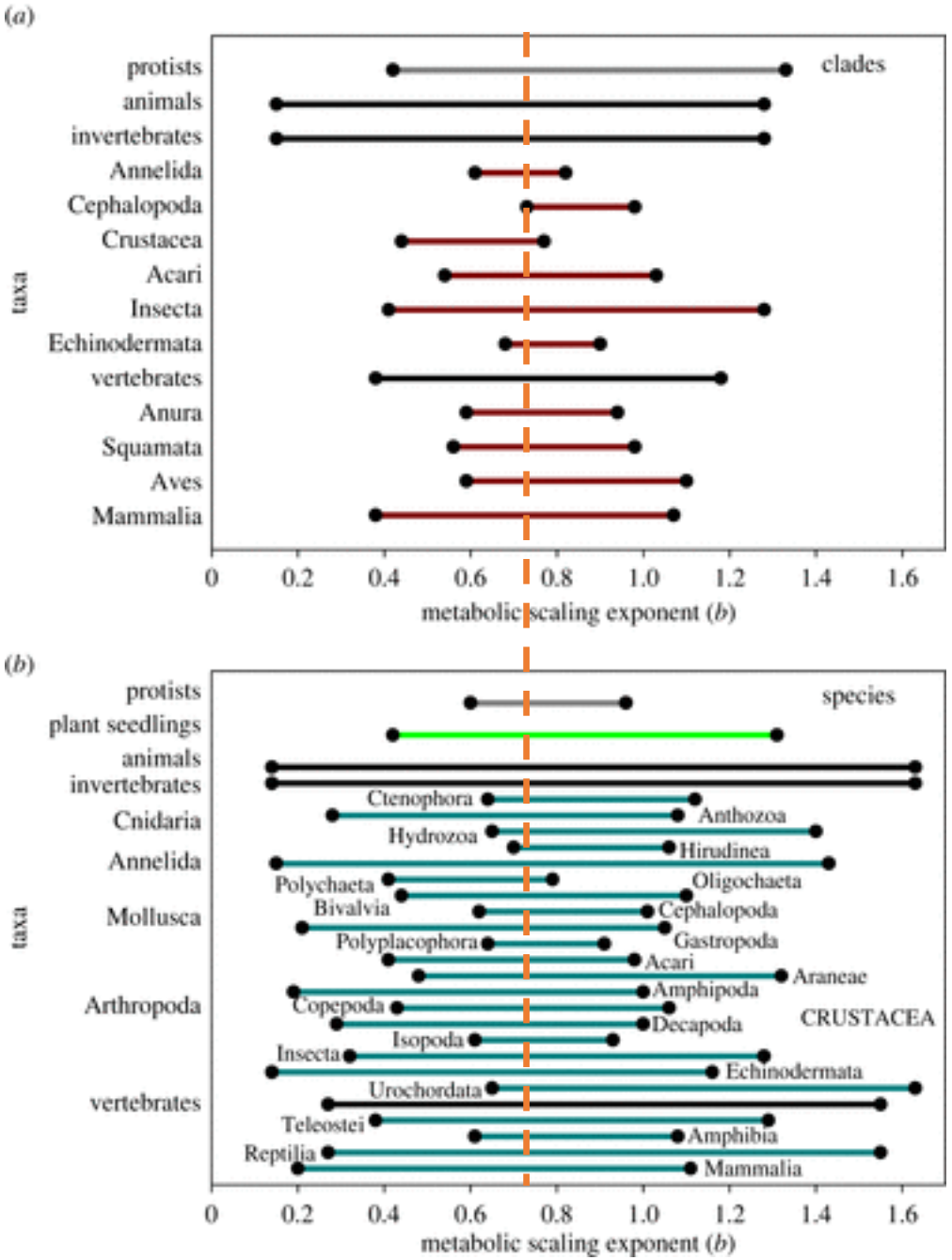
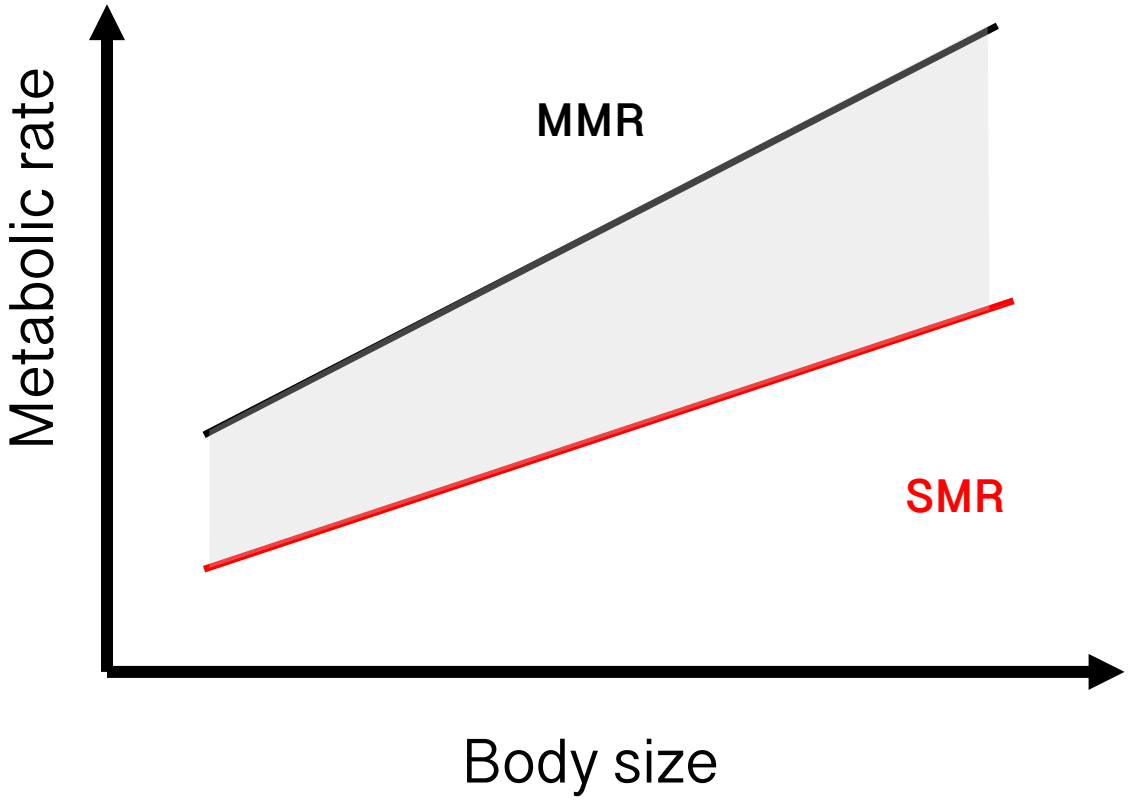
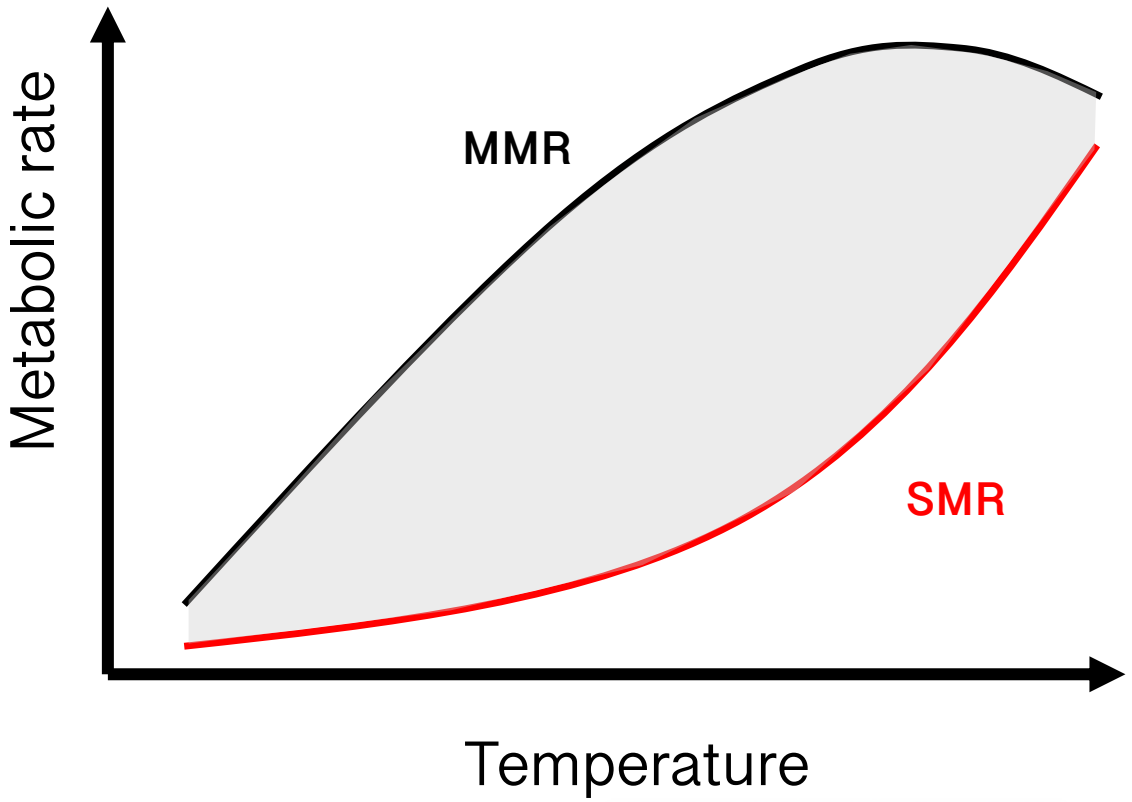



Metabolic rate
MMR
SMR
Body size


Metabolic rate
MMR
SMR
Temperature

Key knowledge gaps –

- Absolute (field) metabolic level for mesopelagic fishes
- Mass scaling of FMR
- Thermal sensitivity of FMR
- Ecological, environmental and phylogenetic associations

- How does metabolism respond to combined stressors (e.g. temperature + food availability, oxygen..)

Carbon sources in biominerals as natural tracers for field metabolic rate

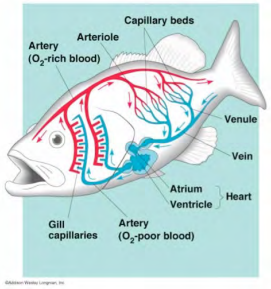
high $\delta^{13}C_{oto}$

Proportionally less metabolic C

External water

$\delta^{13}C$: c -1 to 2‰

HCO_3^-



$\delta^{13}C$: c -7 to 0‰

ε

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + energy$

In the cell

$\delta^{13}C$: c -25 to -14‰

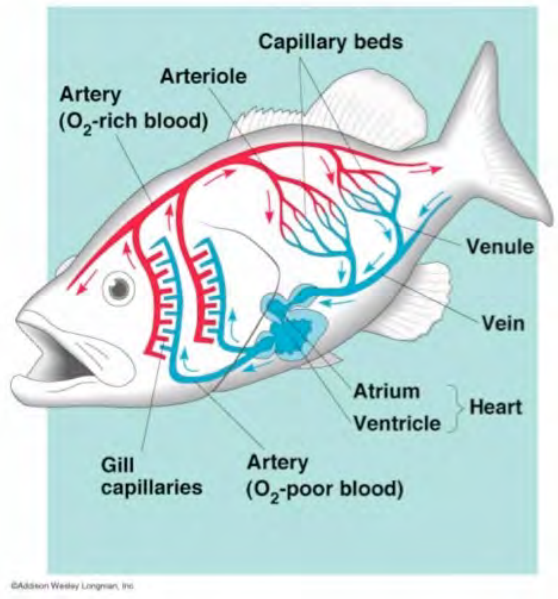
Proportionally more metabolic C

low $\delta^{13}C_{oto}$

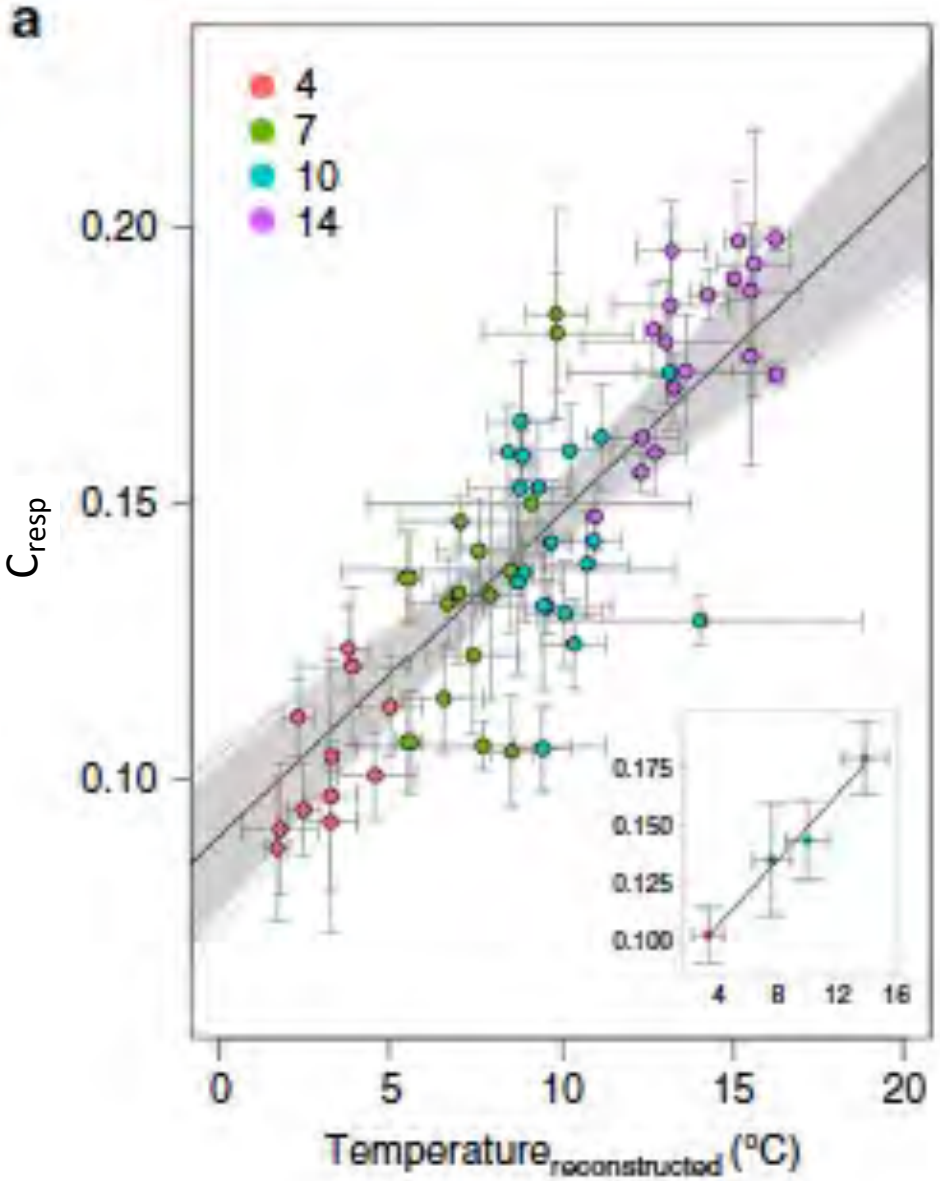
Simple two component mass balance:

$$\delta^{13}C_{oto} = P^* \delta^{13}C_{diet} + (1-P)^* \delta^{13}C_{DIC} + \varepsilon$$

$$P = C_{resp}$$



Field metabolic rates of fishes are recorded in otolith $\delta^{13}C$ values

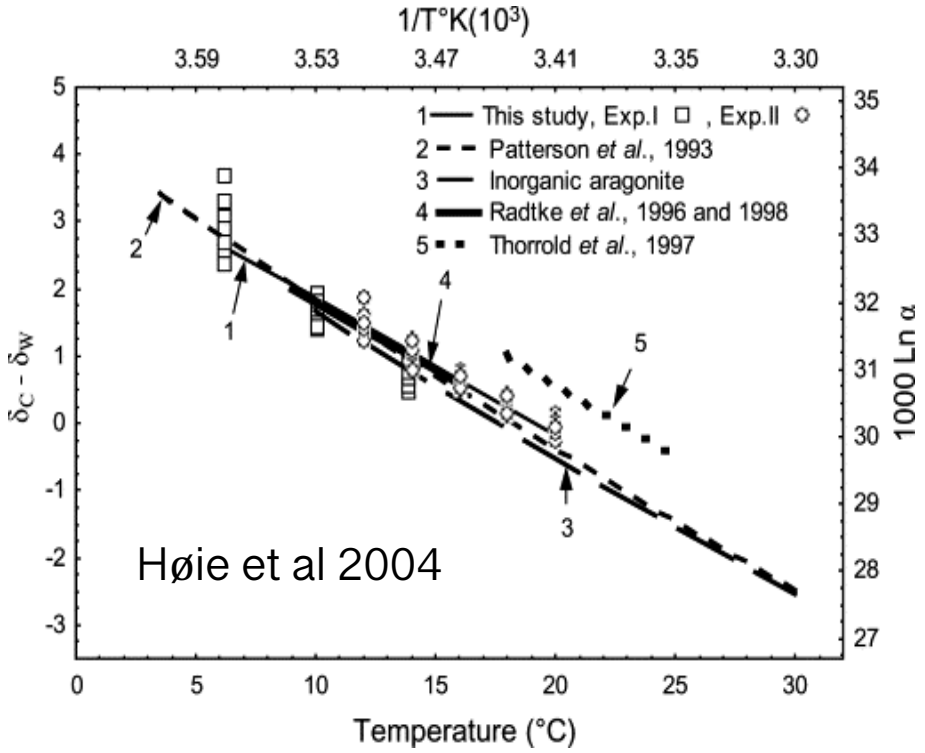


COMMUNICATIONS BIOLOGY

ARTICLE

Field metabolic rates of teleost fishes are recorded in otolith carbonate

Experienced temperature is recorded in otolith $\delta^{18}O$ values



- Average temperature experienced by an individual fish
- The field metabolic rate expressed at that temperature
- The age and growth rate of the fish

For (almost) any marine teleost
Over the whole life history

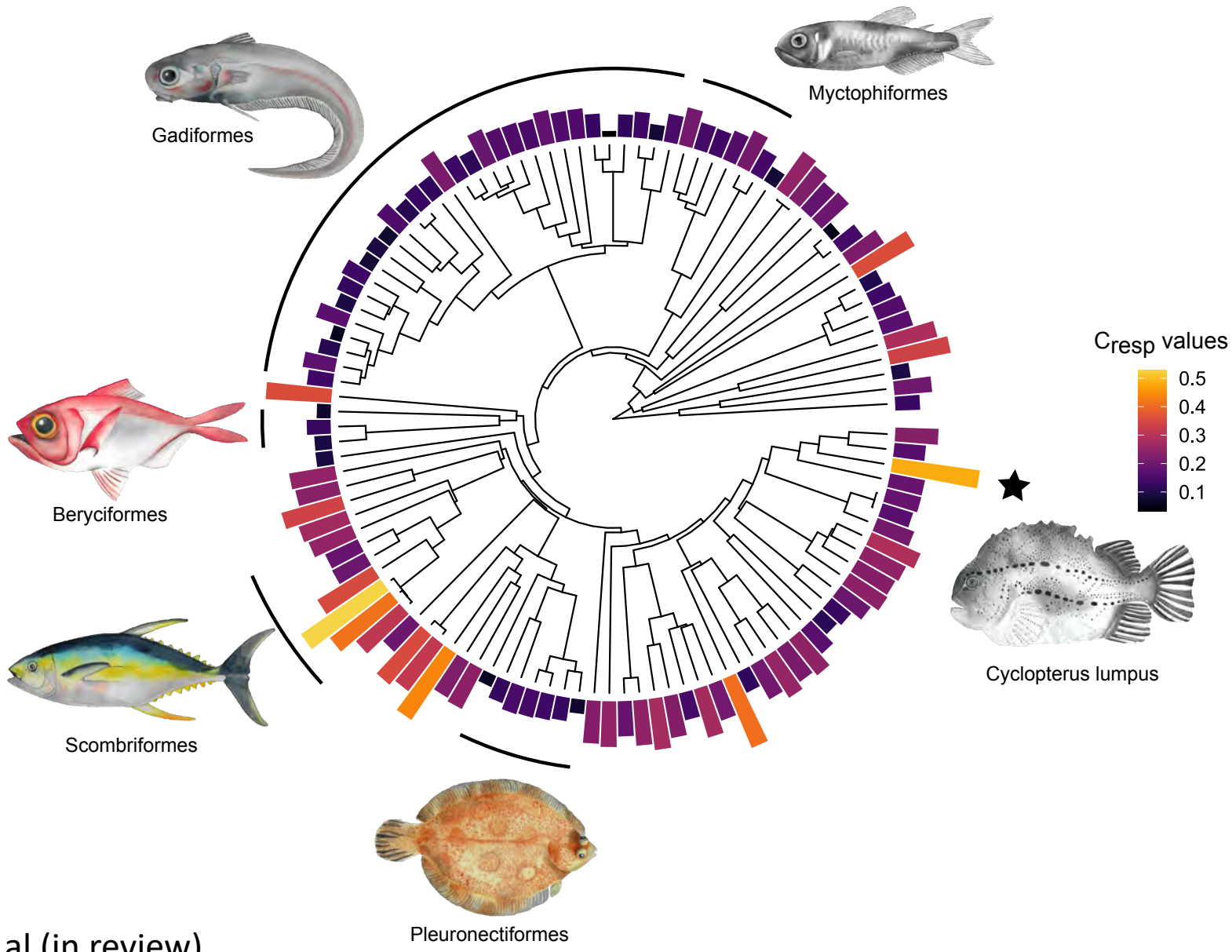
Key knowledge gaps

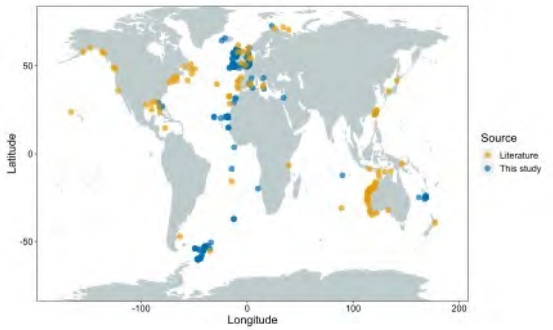
- Absolute (field) metabolic level for mesopelagic fishes
- Mass scaling of FMR
- Thermal sensitivity of FMR
- Ecological, environmental and phylogenetic associations

- Calibration of otolith and ETS proxies for FMR in mesopelagic fishes

- How does metabolism respond to combined stressors (e.g. temperature + food availability, oxygen..)

Alewijnse et al., 2021

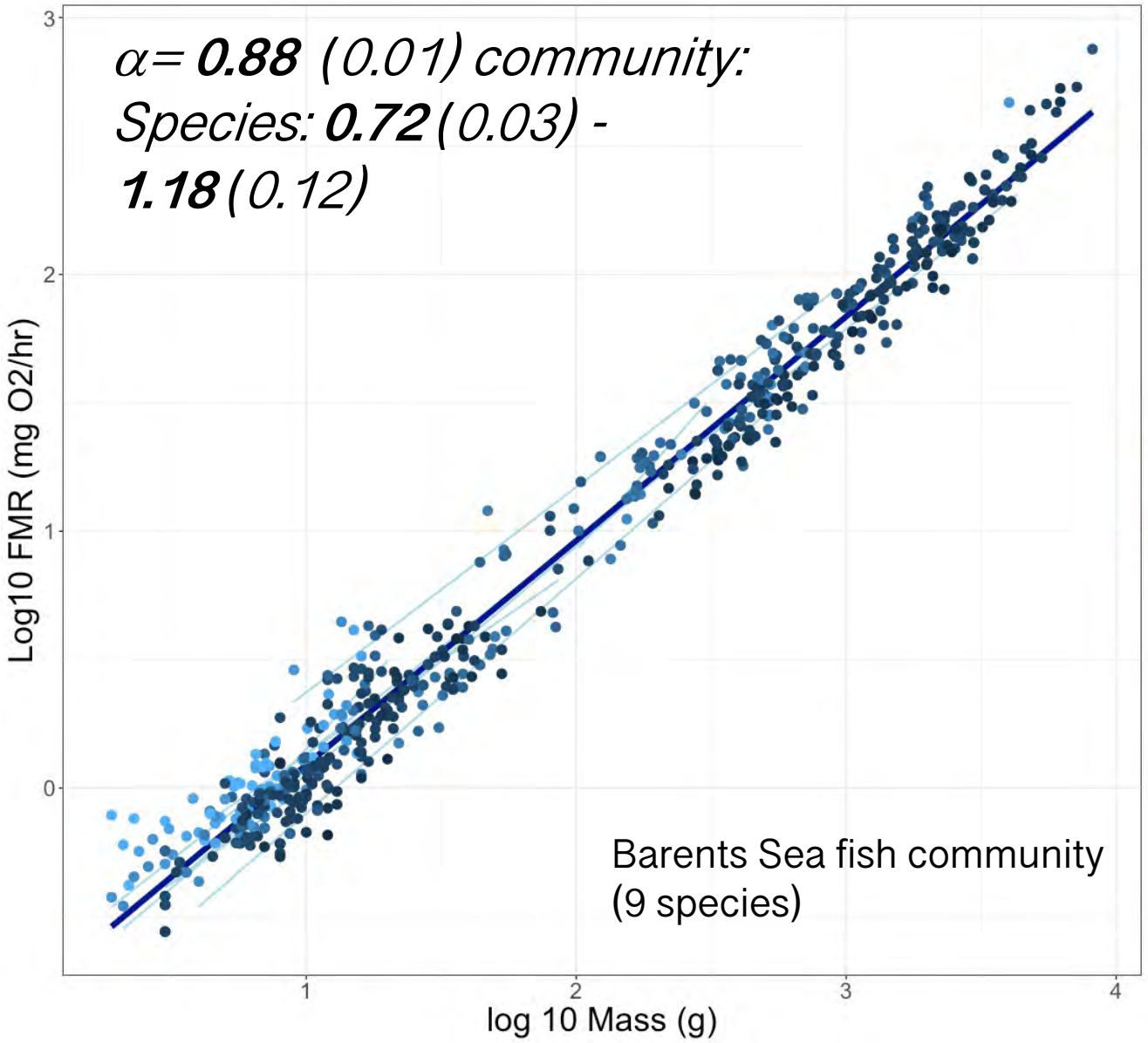


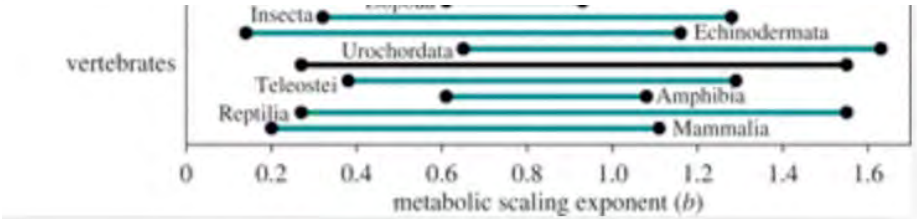


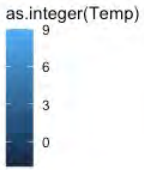
Alewijnse et al (in review)

FMR scaling with body mass

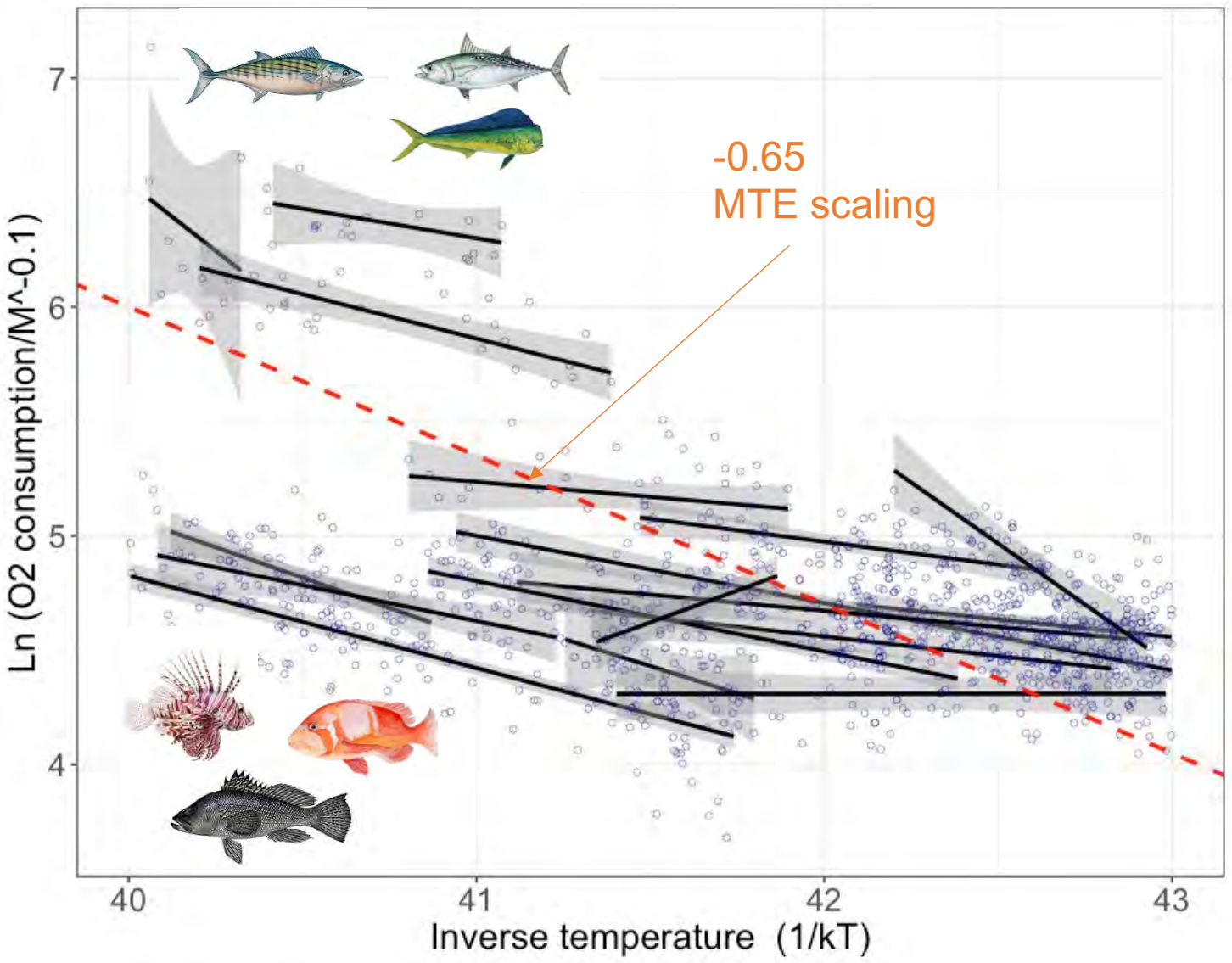
Rate ~ $b_o M^{\alpha}\ e^{-E/kT}$





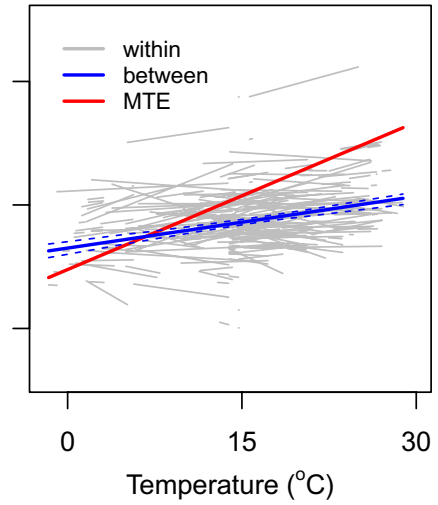


Compensation (energy budgeting, acclimation, plasticity) reduces thermal sensitivity of FMR by 50-75% : Q_{10} ~1.2



Rate ~ $b_o M^{\alpha}\ e^{-E/kT}$

Strict MTE: α = 0.75, E = 0.65eV



Global analysis of fish growth rates shows weaker responses to temperature than metabolic predictions

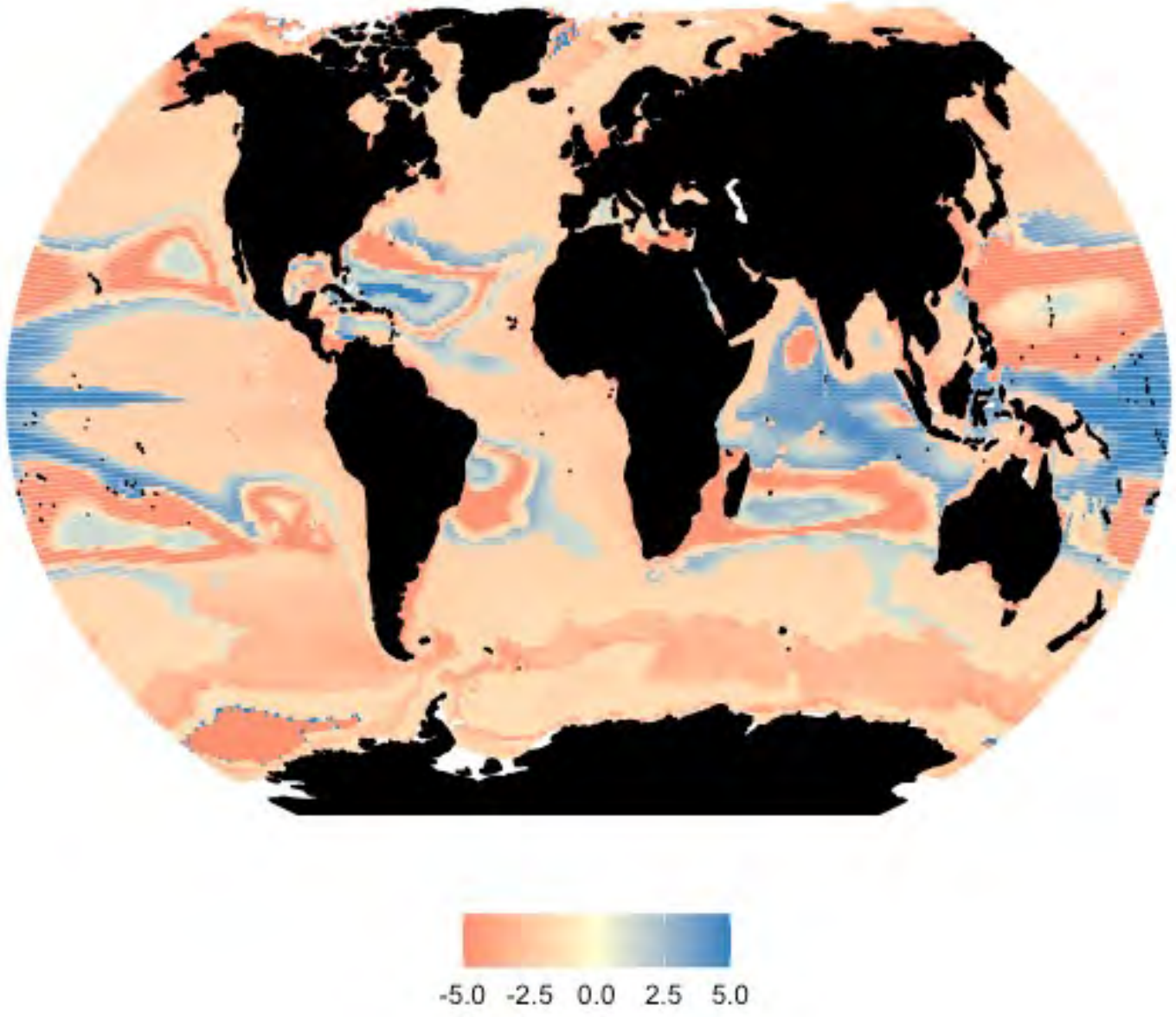
Daniël van Denderen[1] | Henrik Gislason[1] | Joost van den Heuvel[2] | Ken H. Andersen[1]

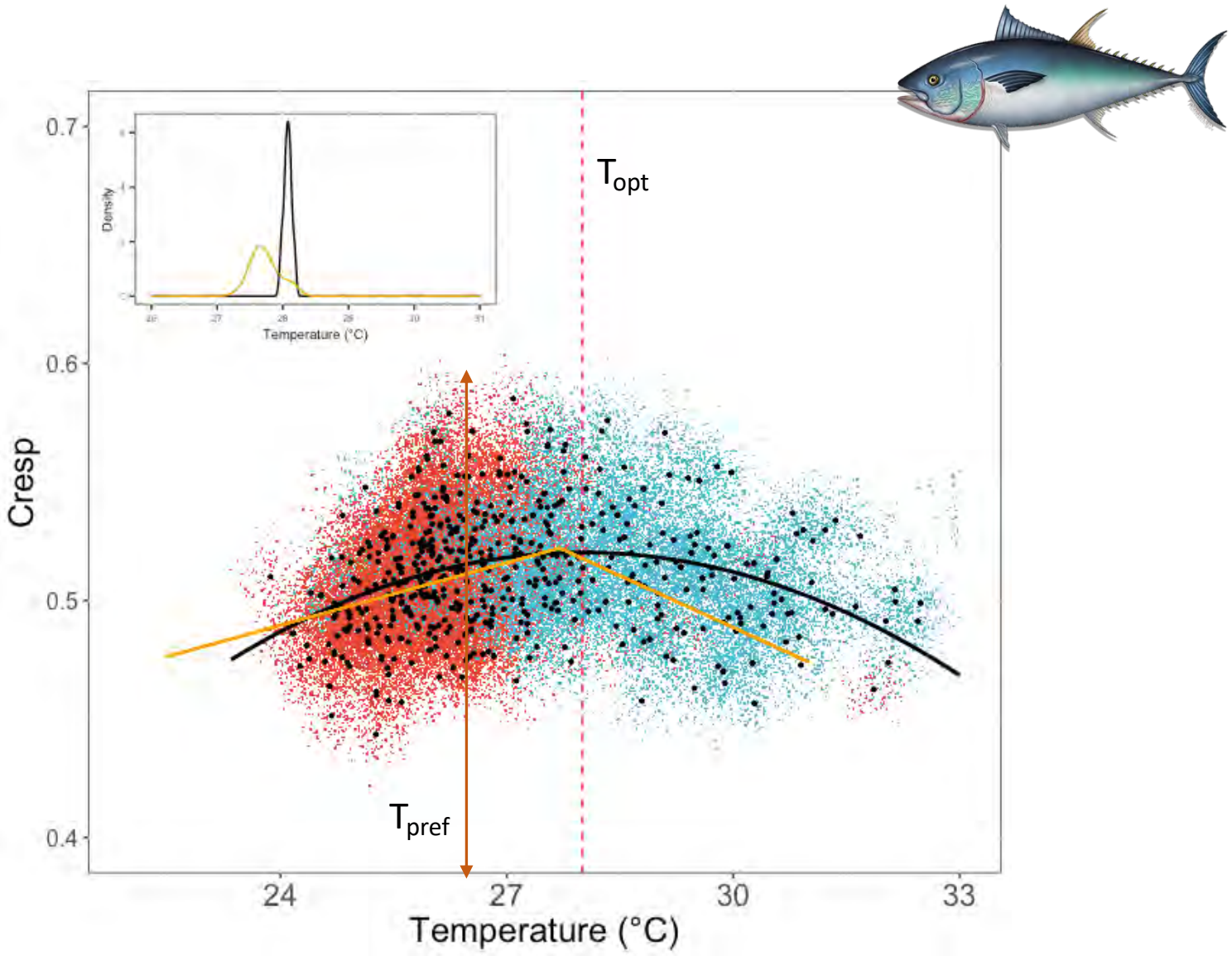
Global predictions of fishery potential: Sensitivity to metabolic scaling terms

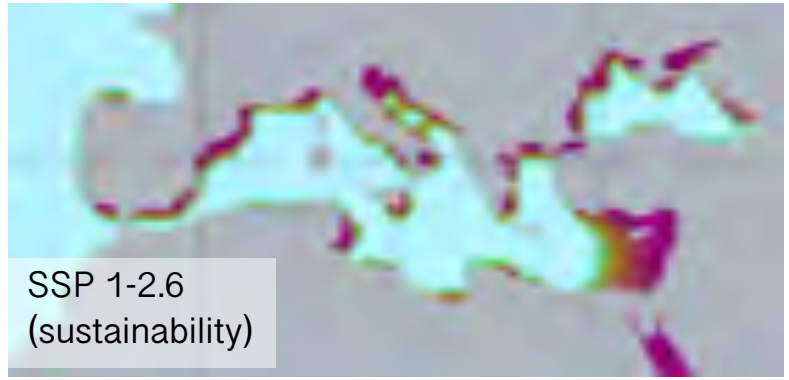
Factorial change in mass flux to fisheries between model runs using MTE scaling and FMR scaling

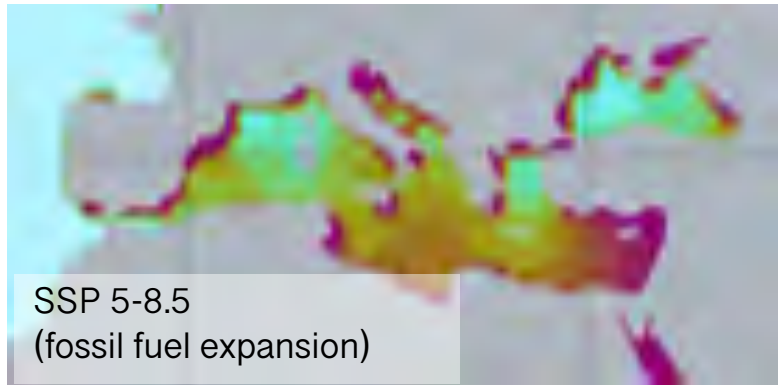
(FMR scaling reduces fishery potential estimates) except in tropics

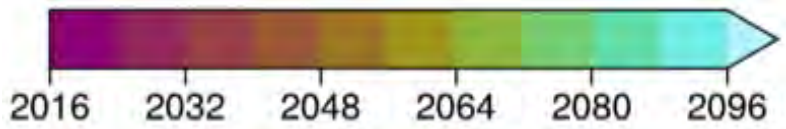
FEISTY output simulation provided by Daniël van Denderen











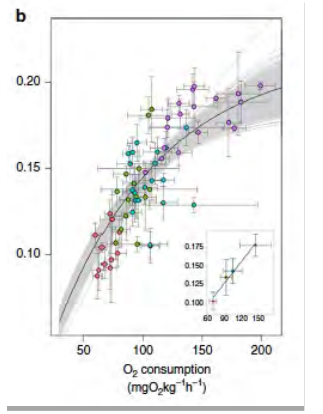
Simulations produced by Rahul Sivankutty

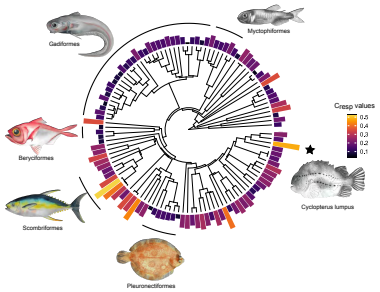
Trueman et al. 2023 *in review*

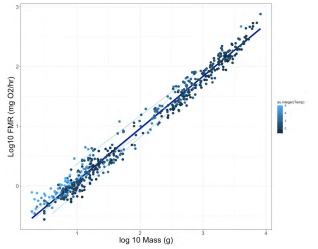
Project aims

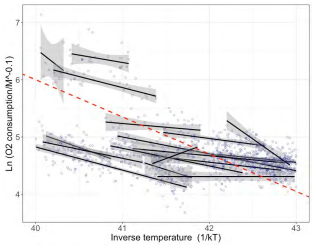
- Determine relative FMR across at least 25 species of mesopelagic fishes
- Calibrate otolith FMR against ETS for select species
- Estimate mass and temperature scaling of FMR
- Estimate effect of traits on FMR and FMR scaling

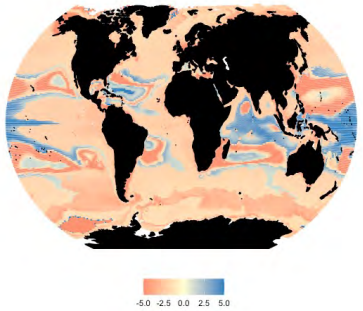
- Provide updated estimates of metabolic rate, body size, functional trait and thermal effects on MR for mesopelagic fishes
- Estimate effect of variable scaling terms for models of fish based C flux (and biomass)



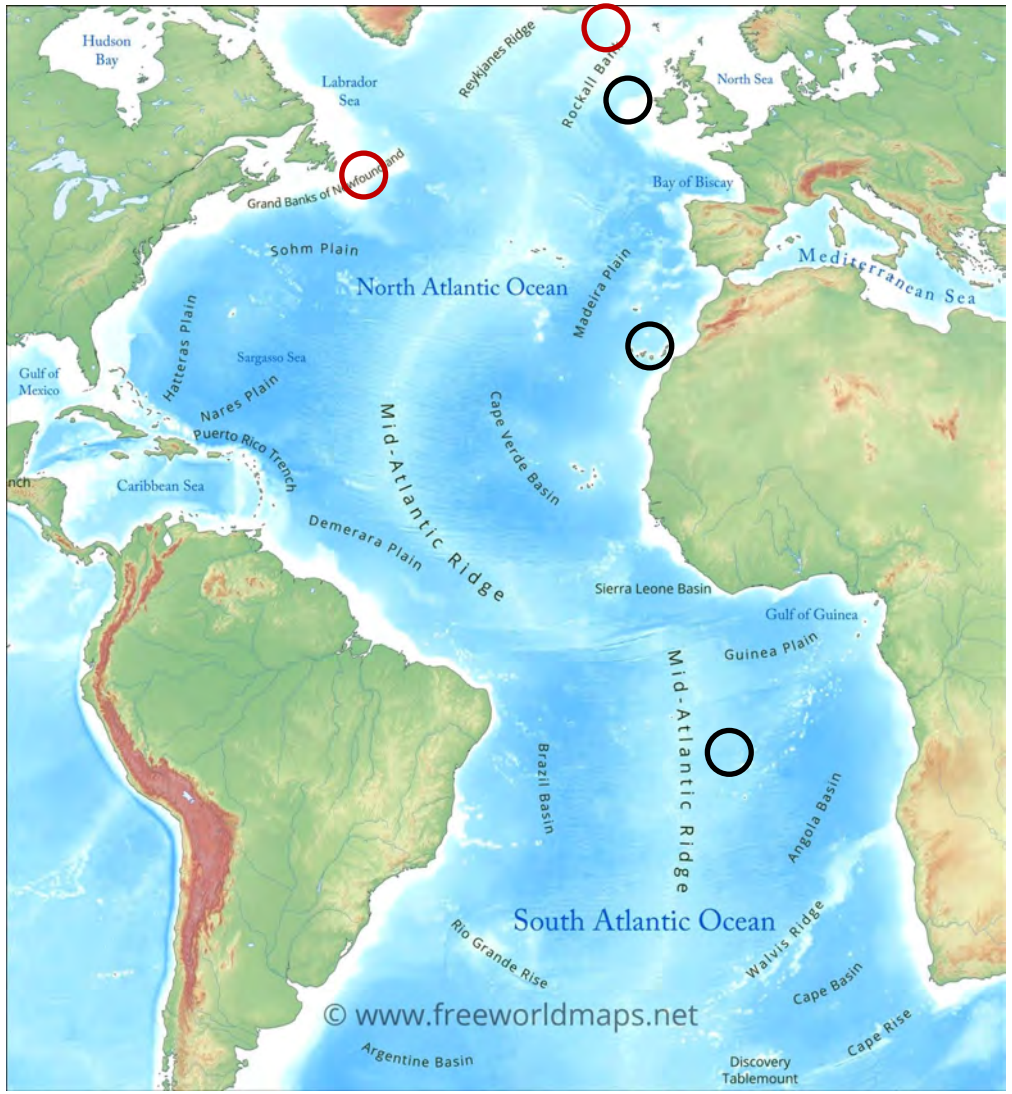


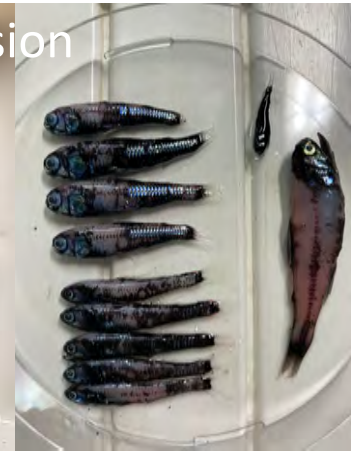


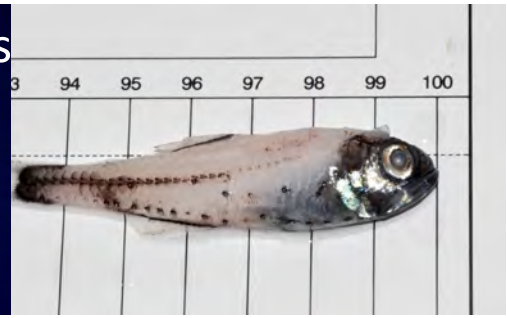




Progress to date







>40 Species including myctophids, bristlemouths…

Progress to date

Individuals from >40 species recovered

Training on otolith extraction / preparation complete

Successful extraction of otoliths


Marine Scot.
S. salar
Slide 2 [DH]
97
103
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89
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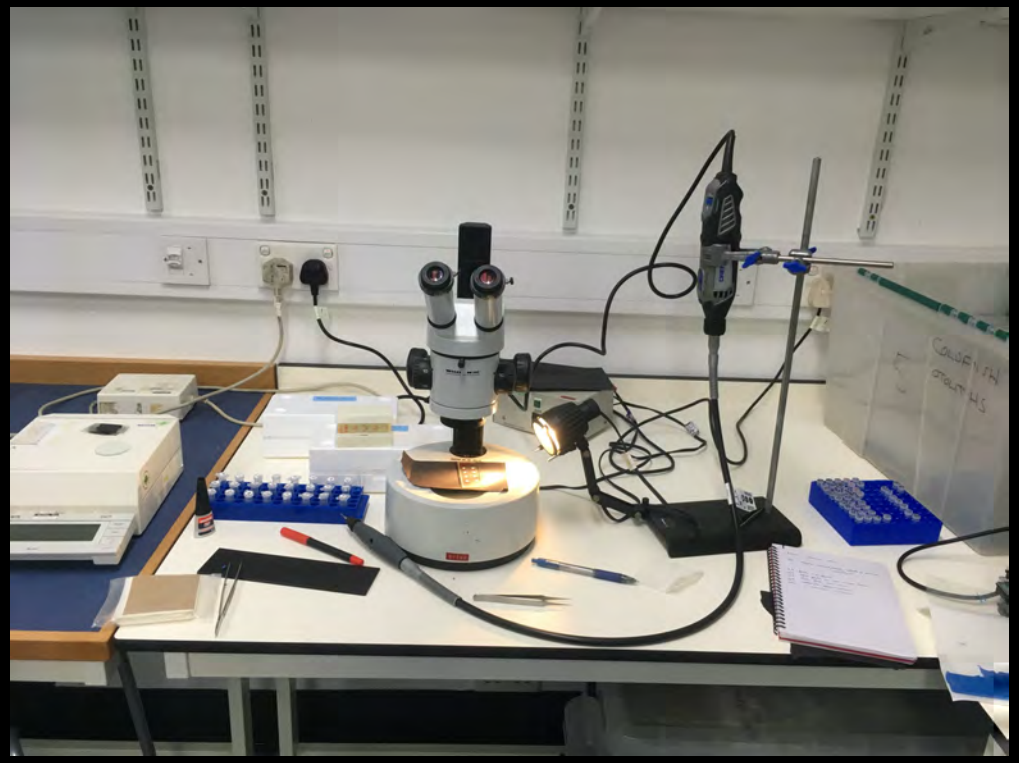
108
85
76

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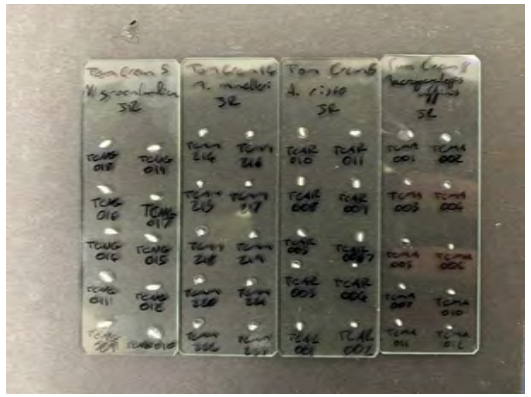
Progress to date



Next 6 months:

- Complete sampling of existing samples from Irish N Atlantic
- Collection + preparation of samples with existing individual-level, ETS-based assessments of metabolic rate (at least 5 species with sufficient data)
- Preparation of specimens from Ireland and St Helena/Ascension
- Opportunistic additional sampling N Atlantic to collect samples for ETS calibration

Follow-on

- How does FMR (and thermal sensitivity of FMR) vary with food availability / oxygen?

- Global view of mesopelagic fish respiration across phylogeny, functional traits and ecological context

- Quantifying ecosystem models – food web models with physiology