

EFFECTS OF ELEVATED TEMPERATURE ON A CORAL REEF FISH AND THE POTENTIAL FOR ACCLIMATION

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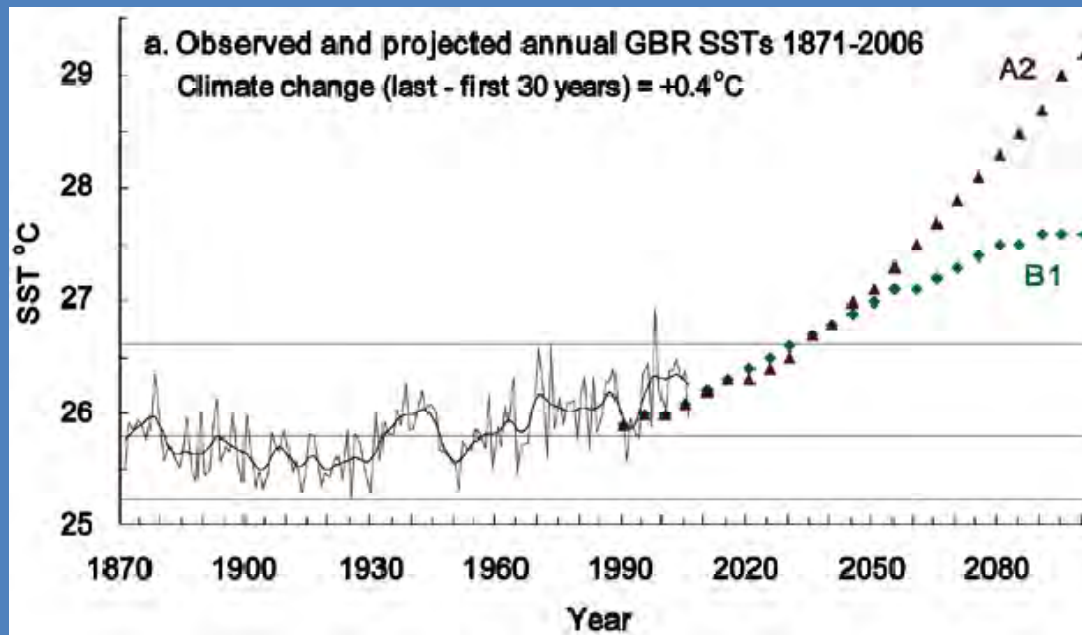
Philip L Munday

Mark I McCormick

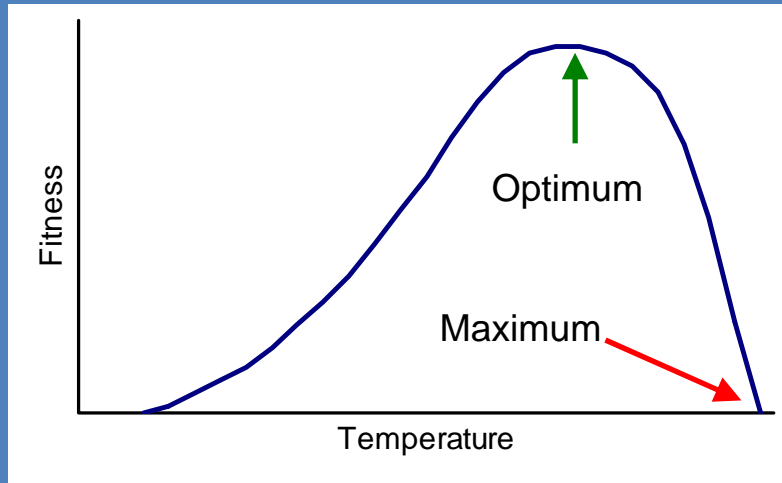


Global Warming in the Tropics

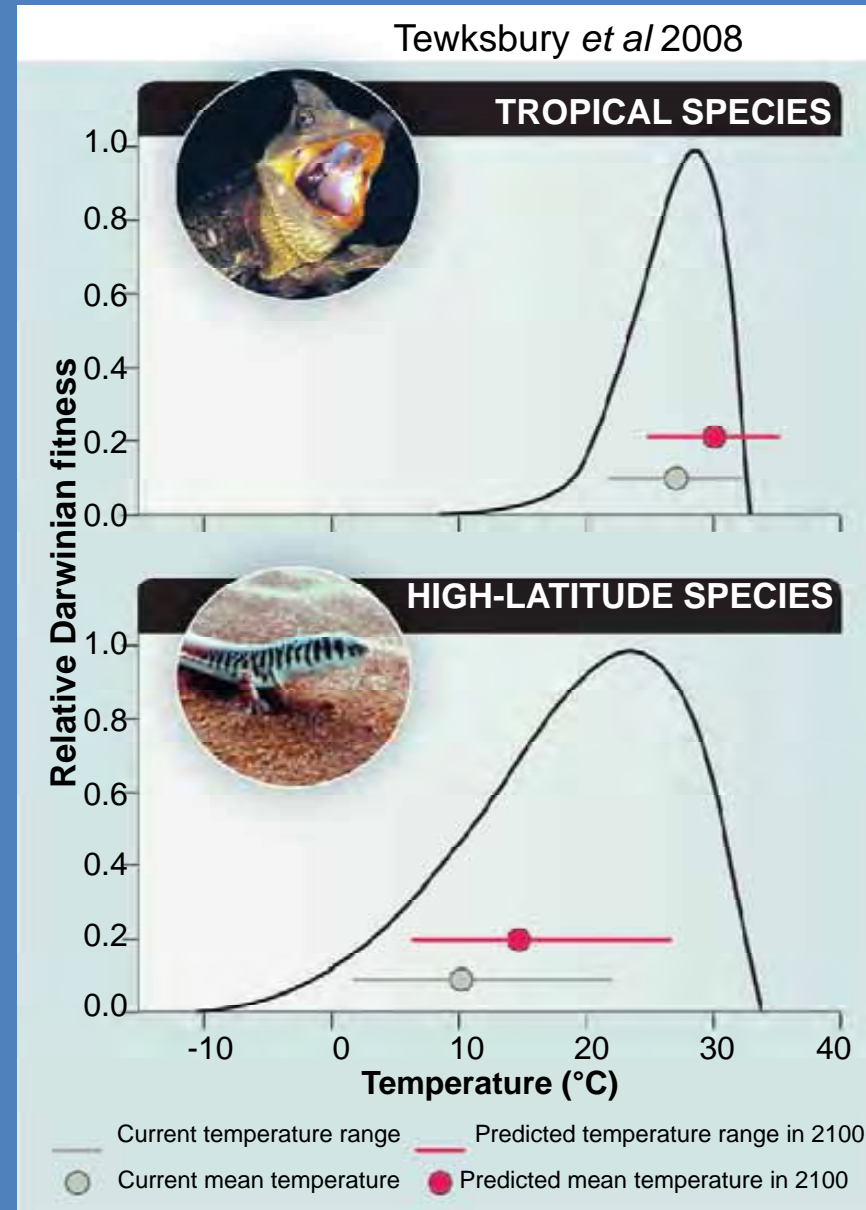
- Global temperatures are predicted to increase between 2-4°C by 2100
- Temperatures will rise less in the tropics than temperate regions
- Tropical sea surface temperature is predicted to increase up to 3°C by 2100



Tropical Ectotherms



- Have narrower thermal tolerances
- Living closer to their thermal optimum and maximum
- Increase may be smaller but are potentially more susceptible
- For tropical reef fish our knowledge on thermal sensitivity is poor



Response to a Changing Environment

Acclimation

- Modification of behavioral, physiological or morphological characteristics
- Phenotypic plasticity and does not involve genetic change → limits to plastic responses
- Modifications that are made to best suit an environment → not all responses may be beneficial

Developmental = response within a generation generally during early ontogeny

Transgenerational = parental effects to offspring phenotype

Potential Effects of Temperature

- Metabolic rate ★
- Physiological condition
- Growth rate
- Reproduction ★
- Development rate



Research Aims



- The effects of elevated water temperature on tropical reef fish
- What is the potential for developmental thermal acclimation
- What is the potential for transgenerational thermal acclimation

Experimental Design

Location:

Central Great Barrier Reef

Study Species:

Spiny Chromis

Acanthochromis polyacanthus

- Wide spread Indo-Pacific reef fish
- Easily reared in captivity
- Mature in 2 years



Experimental Design

Breeding temperature

Current

+ 1.5°C

+ 3.0°C

Summer mean:

28.5°C

30.0°C

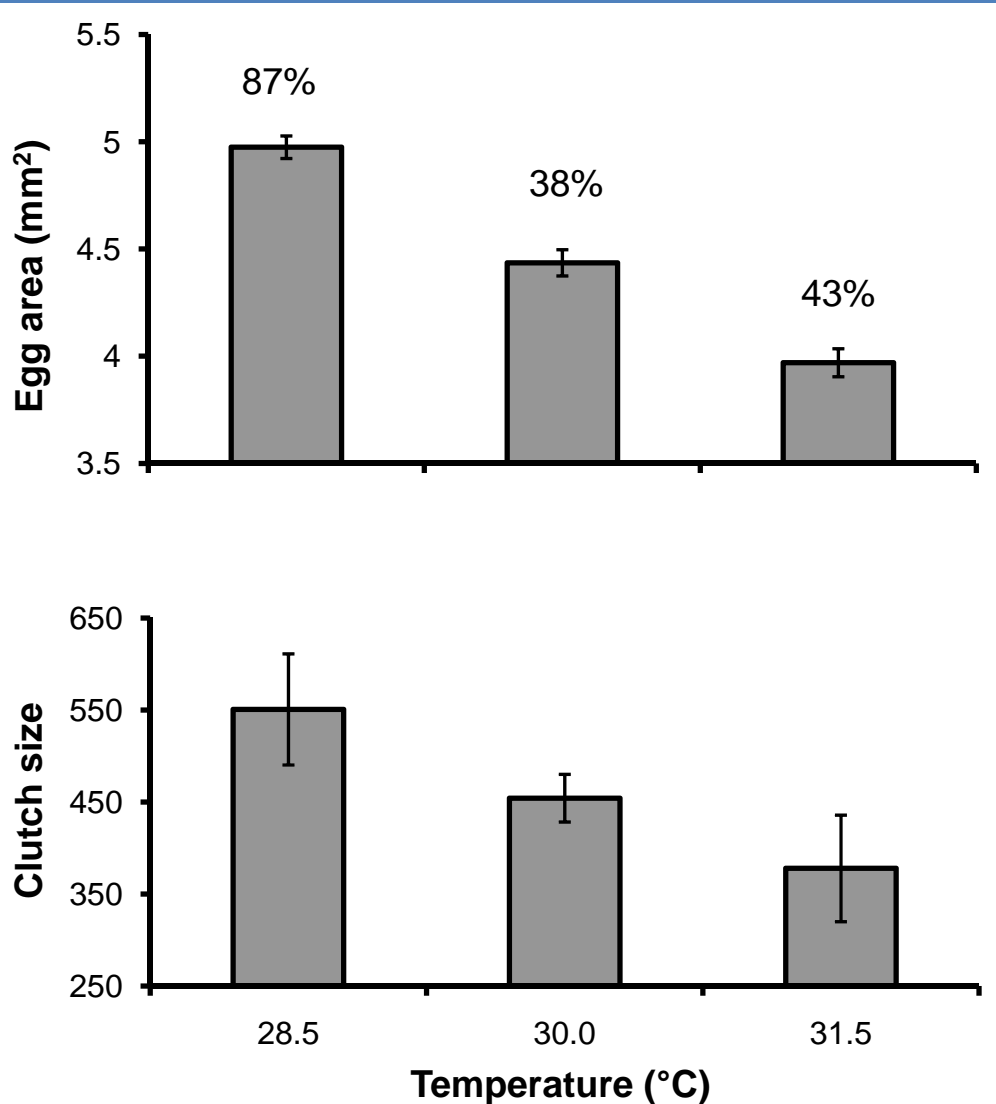
31.5°C

n=7-8 pairs per temperature

- **Reproduction:**
 - Egg size
 - # of eggs per clutch
- **Offspring characteristics:**
 - Length
 - Weight
 - Yolk size



Reproduction



With increasing temperature:

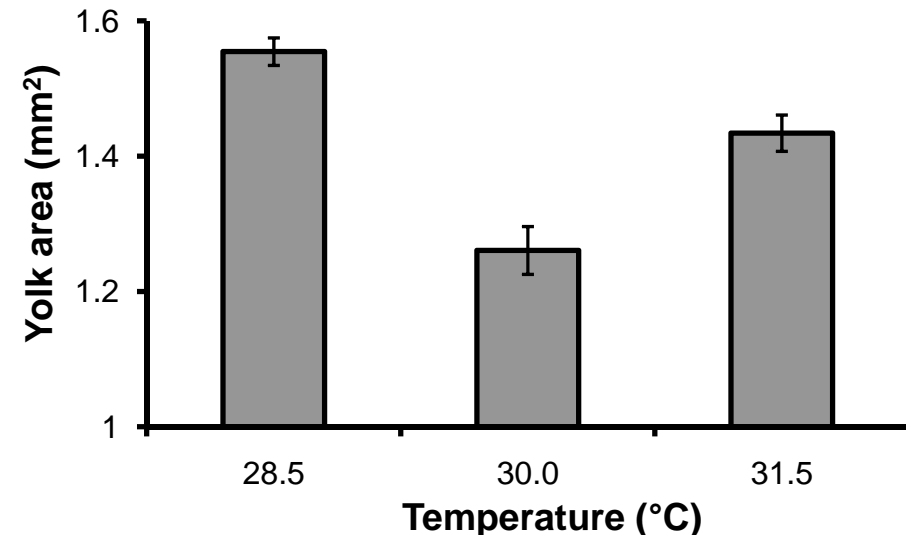
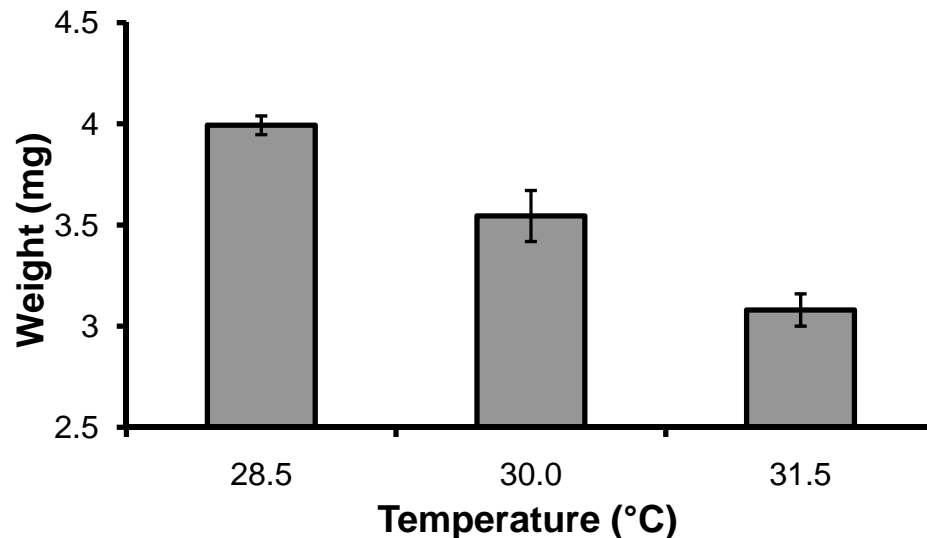
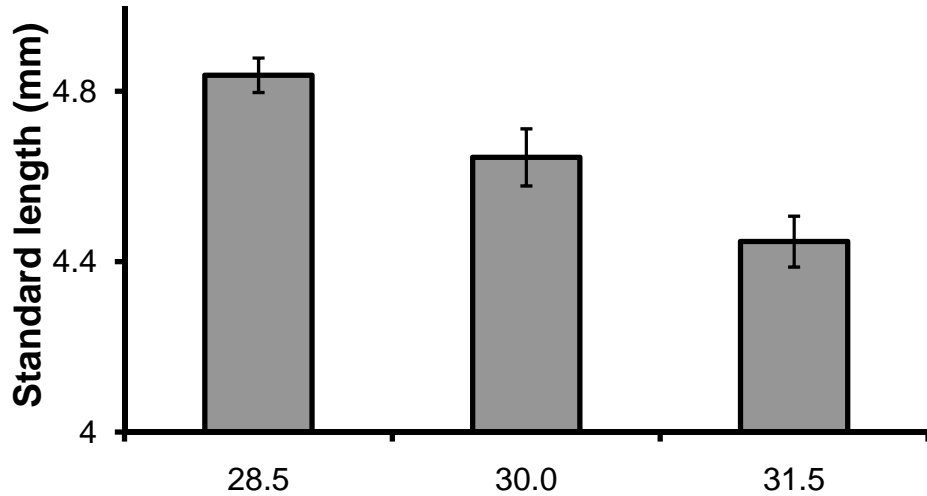
- Reduced number of pairs that reproduced
- Reduced egg size
- Reduced fecundity
- No difference in timing of breeding

Donelson *et al.* 2010 MEPS
401:233-243

Offspring Attributes

Elevated temperature:

- Offspring are:
 - shorter
 - lighter
 - less yolk
- Only 2 of 3 clutches in 31.5°C surviving till hatching



Developmental Acclimation

8 breeding pairs kept at current temperatures

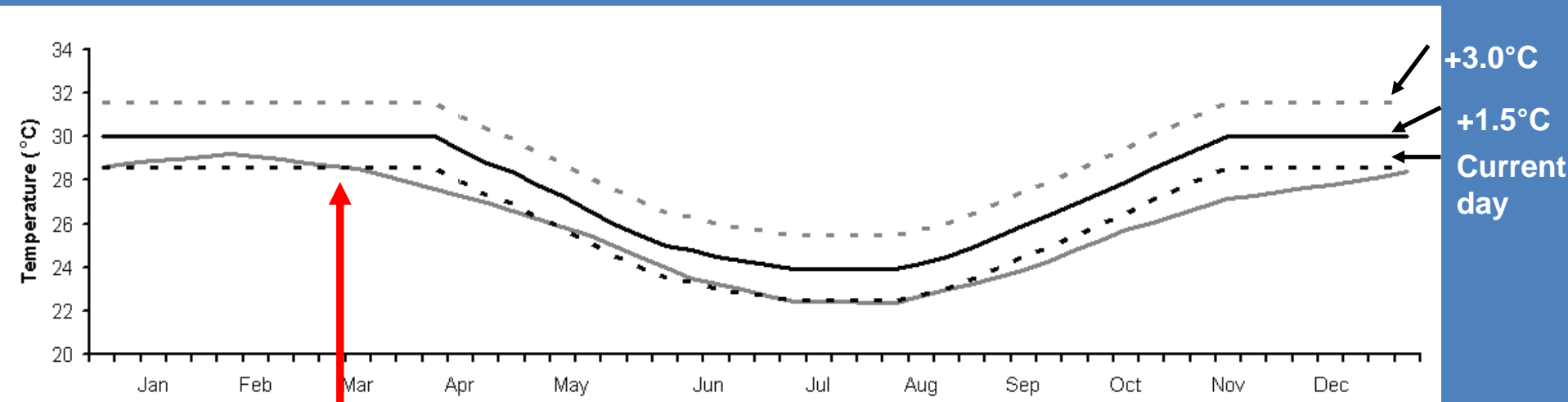
F0

Current day

+1.5°C

+3.0°C

F1



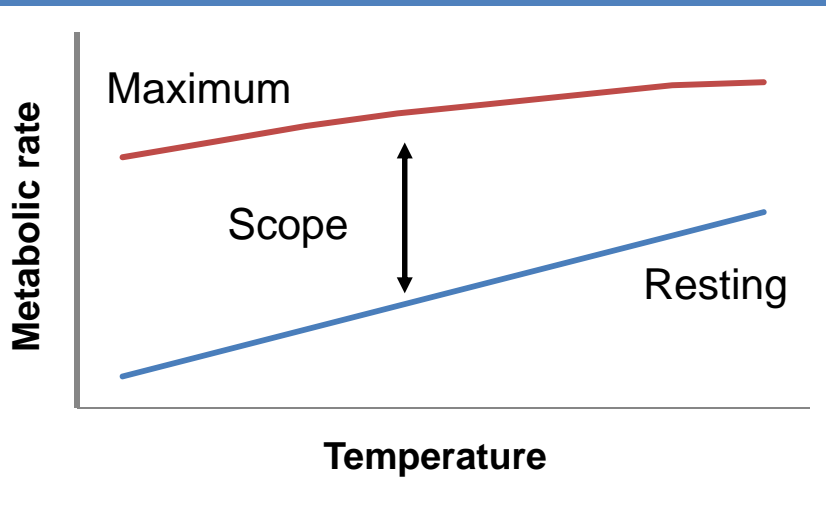
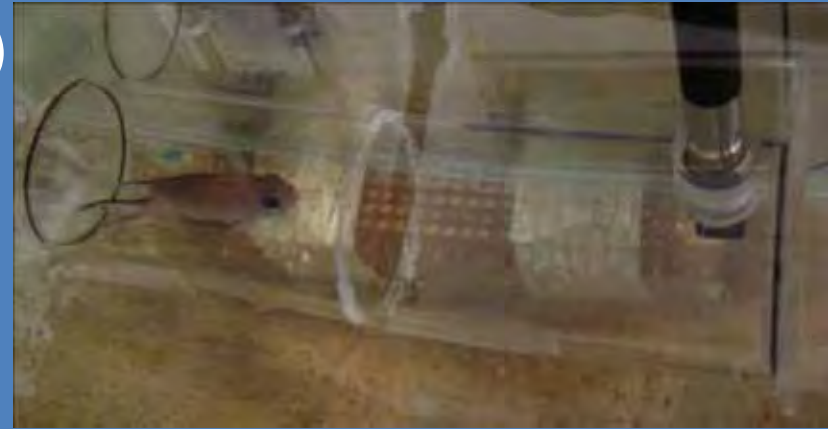
Summer Maturity

2 years

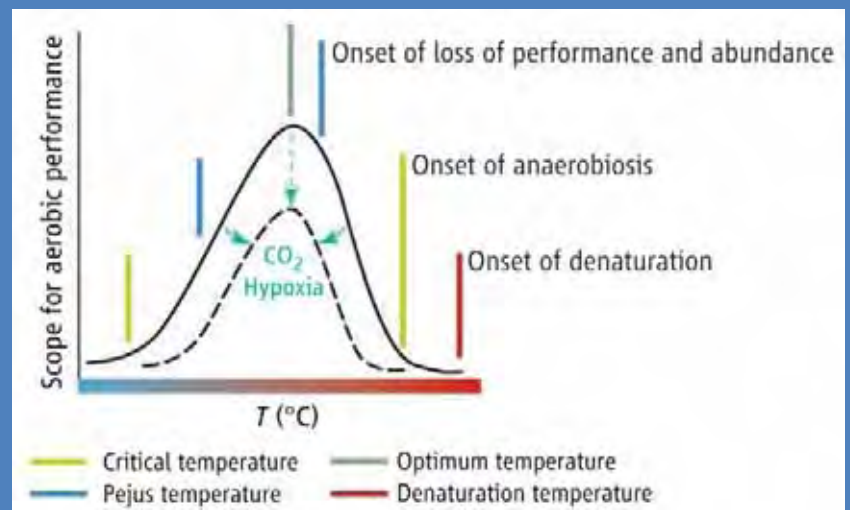
28.5, 30.0 & 31.5°C

Measuring Metabolic Rate

- Resting metabolic rate (RMR) → $\text{mg O}_2 \text{ kg}^{-1} \text{ h}^{-1}$
 - Measures the fall in $\text{O}_2\%$ for up to 30min
- Maximum metabolic rate (MMR)
 - Swum at maximum capacity for 5-10 minutes
- Aerobic scope = MMR/RMR



Pörtner and Farrell *Science* 2008

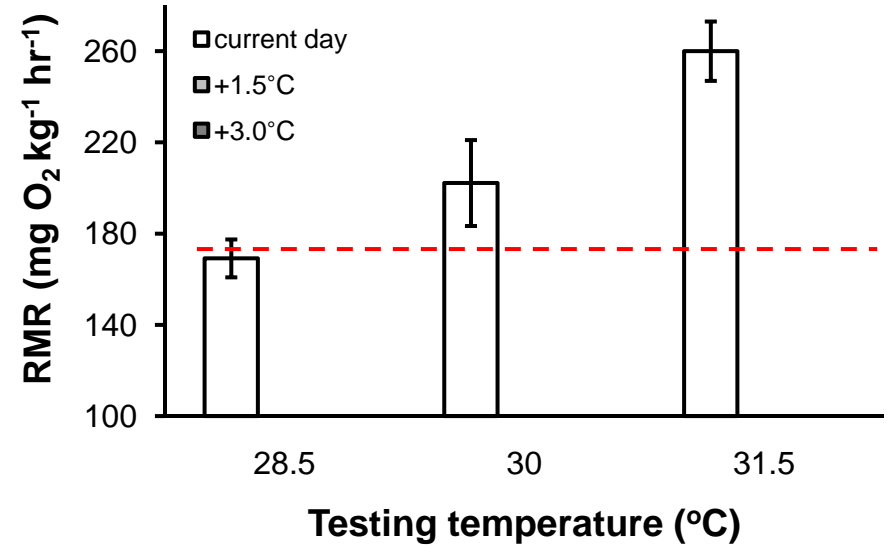


Metabolic Rate and Aerobic Scope

Donelson *et al.* 2011 GCB 17:1712-1719

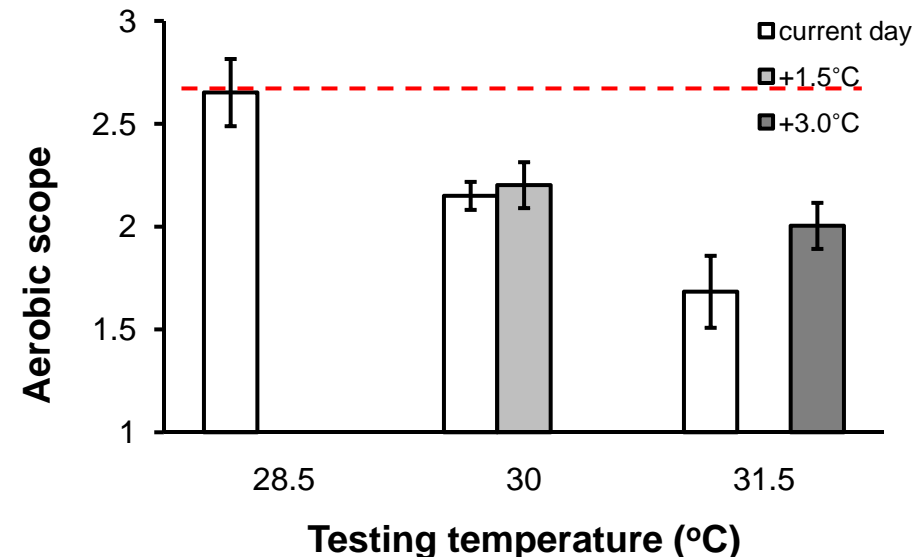
Resting metabolic rate:

- Current day fish increase in RMR
- No acclimation at +1.5°C
- Reduction in RMR +3.0°C

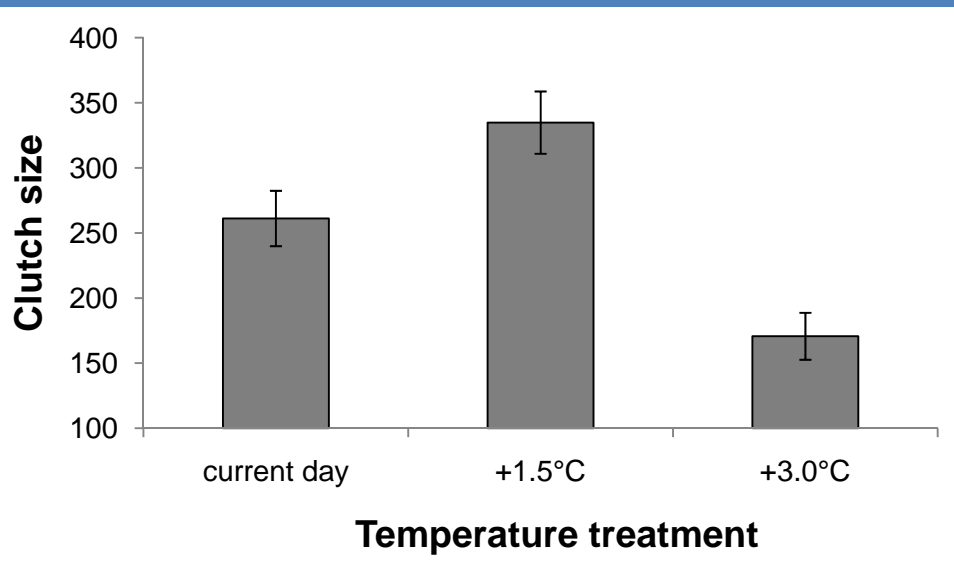
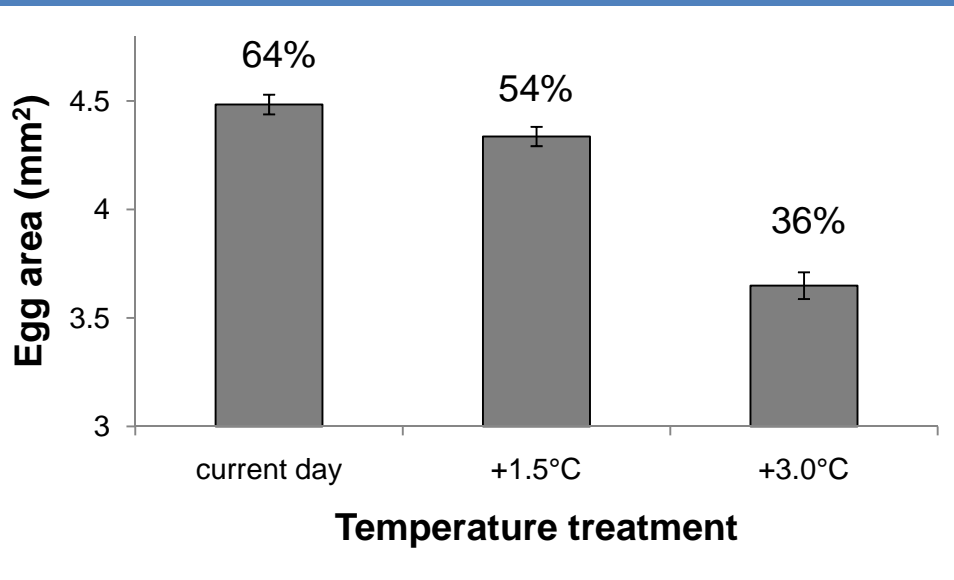


Aerobic scope:

- Decline in scope with increasing temperature for current day
- Increase in scope in +3.0°C, but not to level of current day at 28.5°C



Reproduction with Acclimation



With acclimation:

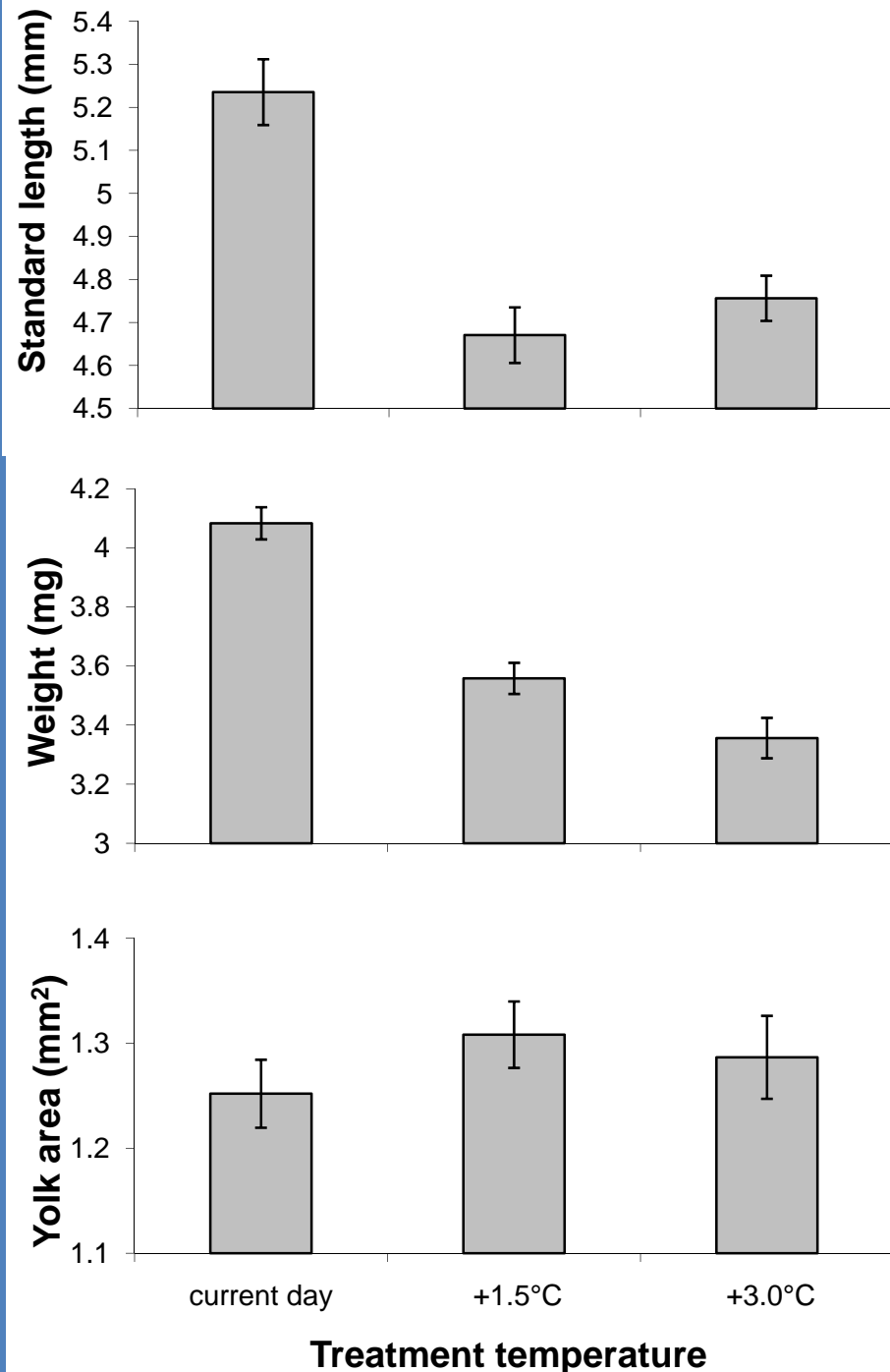
- Increased number of pairs reproducing in +1.5°C
 - Still less reproducing in +3.0°C
 - Reduced egg size only in +3.0°C
 - Increased fecundity in +1.5°C
 - +3.0°C only reproduce during start of summer
- +1.5°C no acclimation in RMR, but in reproduction
- +3.0°C previously showed thermal acclimation, but poorer reproduction

Offspring Attributes

With acclimation:

- Current day offspring largest and heaviest
- Reduced size in +1.5°C and +3.0°C
- No differences in yolk size

→ Since no difference in yolk +1.5 and +3.0°C have more provisioning proportionally



Trangenerational Methods

8 breeding pairs kept at current temperatures F0

Current day

+1.5°C

+3.0°C

F1

Current day

Current day

+3.0°C

+1.5°C

+3.0°C

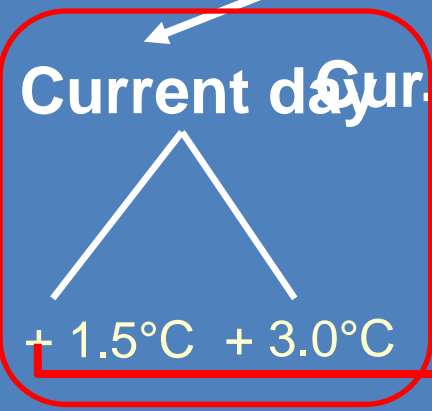
F2

No acclimation

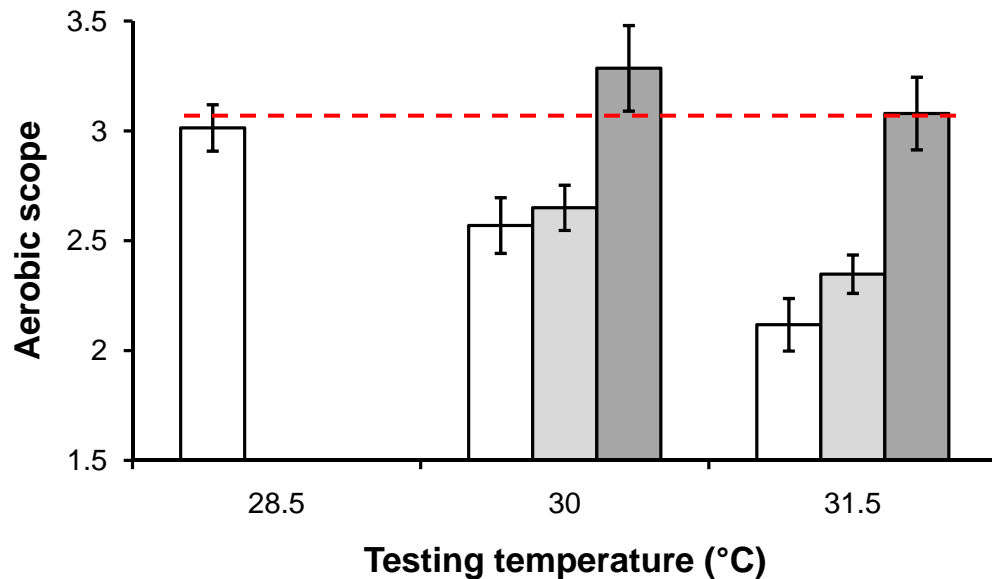
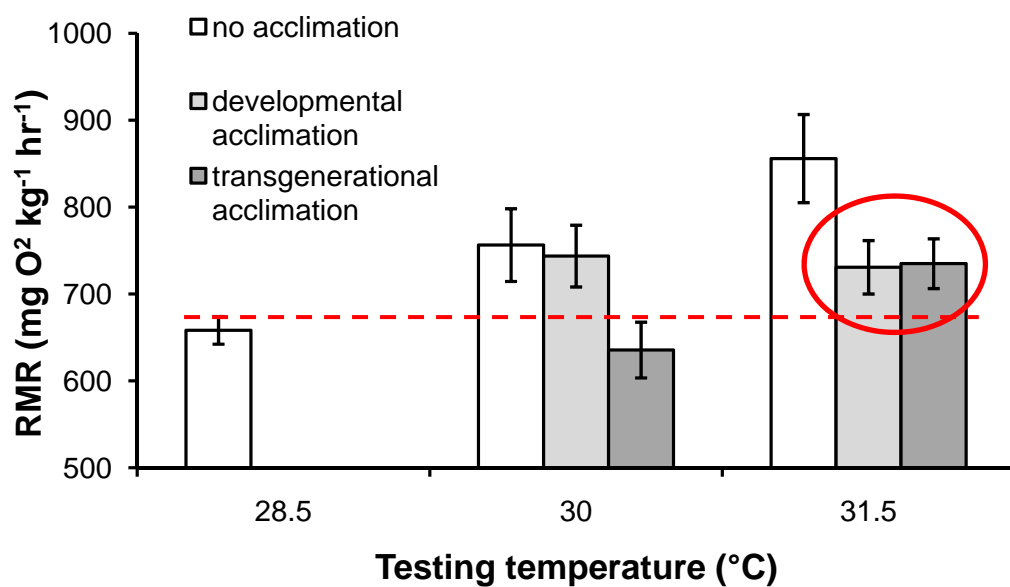
Testing at 3 months post-hatching
RMR, MMR and aerobic scope

Developmental acclimation

Trangenerational acclimation



Transgenerational Acclimation



Developmental acclimation:

- Only at +3.0°C RMR

Transgenerational acclimation:

- Both +1.5°C and +3.0°C RMR and aerobic scope

→ Both developmental and transgenerational similar reduction in +3.0°C

→ Transgenerational fish have equaled current day fish values of some RMR and scope

Summary

- Current populations of tropical reef fish are sensitive to relatively small increases in water temperature
- Limited ability to cope with warmer water temperatures through developmental acclimation
- Transgenerational acclimation produces offspring with metabolic performance equivalent to current day populations at current temperatures

Future:

- F2 offspring at maturity
- Investigate acclimation in a range of fish species and different populations

Acknowledgements



- Australian Coral Reef Society Student Award
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- ARC Centre of Excellence for Coral Reef Studies

National Research
FLAGSHIPS
Climate Adaptation

