# Introduction

Increasing global temperatures are causing species to undergo range redistributions or rapidly adapt to new thermal conditions 1–3. How species respond to warming temperatures will depend on the collective response of populations 4,5. Spatial variation in traits across populations represents genetic adaptation and phenotypic plasticity along geographic and environmental gradients 5–8. Co-gradient variation across thermal clines, whereby genetic and environmental influences on phenotype are aligned (e.g., populations exposed to higher temperatures have high optimal performance temperatures), has been demonstrated in plants 9,10, insects11,12, crustaceans6,13,14, and fish (see review by Conover *et al.,* 2009)15. However, optimal performance temperatures typically do not follow the trajectory of environmental gradients. Counter-gradient variation, whereby genetic and environmental influences on phenotypes are opposed, has been recorded in several taxa (fish16, lizards 17,18, and turtles 19) and appears more frequently in nature than co-gradient variation 15. Evidence of counter-gradient variation suggests limited thermal plastic potential in low-latitude populations.

Low-latitude environments characterized by historically (or evolutionarily) stable temperatures near physiological maximums favor specialized (narrow) thermal niche breadths that evolve primarily through genetic adaptation rather than phenotypic plasticity– Climate Variability Hypothesis (CVH) 20,21 (*but see* 22,23). Narrow thermal niche breadths, limited plasticity, and evidence of hard ceilings for upper thermal tolerance 24–26, suggest that low-latitude populations are more vulnerable to shifting temperatures than high-latitude conspecifics 27–31. Wider thermal niche breadths, present in high-latitude populations with greater levels of phenotypic plasticity, can increase thermal tolerance4; however, heat-tolerant phenotypes present in low-latitude populations may be unattainable within high-latitude populations 32. Therefore, locally adapted populations may possess thermal niches that are narrower than the species as a whole33.

Thermal variation between populations within marine systems has not received the same attention as terrestrial systems; despite marine organisms having greater confinement to thermal tolerance limits 30,34–36. Marine systems have previously been viewed as demographically open networks with minimal dispersal barriers. However, a growing body of evidence suggests that oceanographic features, life history traits, and larval dispersal/establishment ability act as challenges to gene flow and promote local adaptation 34. To date studies that have addressed intraspecific variation in marine species have focused on invertebrates (see review Sanford and Kelly., 201134) including copepods 32,37,38, porcelain crabs 39, intertidal snails 6,14, and coral 40; few broach the topic among marine fishes.

Studies on intraspecific variation in marine fishes have previously examined populations on the Great Barrier Reef (GBR), Australia, which represents a broad spatial (over 340,000 km2) and thermal gradient. Pratchett *et al.,* (2013)41 compared aerobic physiology and hematological metrics among low- and high-latitude populations of coral trout (*Plectropomus leopardus*); however, no significant differences were identified. Further analysis suggests there is little genetic variation between coral trout populations across the GBR because…42,43. Gardiner *et al.,* (2010)16 and Donelson and Munday (2012)44 compared thermal performance and acclimation capacity, respectively, between low- and high-latitude populations of a tropical coral reef damselfish, *Acanthochromis polyacanthus*. Gardiner *et al.,* (2010)16 found evidence that high-latitude populations maintained higher aerobic capacity than low-latitude populations at warmer temperatures – counter-gradient variation. Donelson and Munday (2012)44 reported that high-latitude populations displayed increased acclimation capacity (i.e., developmental plasticity) compared to low-latitude populations – evidence supporting the CVH. Differences in intraspecific variation between coral trout and *A. polyacanthus*, are perhaps unsurprising considering ecological differences between species; in particular, *A. polyacanthus’s* lack of a pelagic larval stage. Nonetheless, evidence of intraspecific variation within *A. polyacanthus* suggest the potential to explore intraspecific variation in a non-commercial marine fish species, a currently underexamined area of research that has important implications for the conservation of coral reef fishes.

Robust genetic variation between *A. polyacanthus* populations 45–47 suggests that existing physiological studies provide a rudimentary understanding of the *A. polyacanthus’s* thermal landscape. Gardiner *et al.,* (2010) and Donelson and Munday (2012) both focused on a single high-latitude population, however, genetic analysis suggests high levels of genetic differentiation between populations throughout *A. polyacanthus’s* range; particularly within the southern region of their distribution. Therefore, to increase the resolution of *A. polyacanthus’s* thermal landscape and allude to a greater understanding of intraspecific variation within marine environments, further exploration of intraspecific variation is required. This study compares thermal performance curves of key physiological traits within *A. polyacanthus* from three different populations among two regions of the GBR, Cairns and Mackay, which exhibit different thermal profiles. Thermal performance curves were used to compare physiological metrics including resting oxygen uptake (*M*O2rest), maximal oxygen uptake (*M*O2max), absolute aerobic scope (AAS), immune response, and enzyme activation, between regions. Hematocrit ratios were also compared at a single temperature. Testing temperatures included the approximate daily mean summer temperature for both Mackay (~27°C) and Cairns (~28.5°C) regions, as well as 30°C (mid-2100 century; SSP2-4.5, SSP3-7.0, and SSP5-8.5), and 31.5°C (end of 2100 century; SSP2-4.5 and SSP5-8.5)48. We tested the hypothesis for counter-gradient variation across a thermal gradient between northern and a novel southern region. Based on evidence of greater phenotypic plasticity among low latitude populations 44, populations from Mackay are expected to have increased thermal tolerance and performance at warmer temperatures than populations from the Cairns region. However, co-gradient variation represents an alternative hypothesis considering the limited amount of research available on the topic, and the observed genetic differences between populations from the Mackay region compared with previously examined southern populations.