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boldness an d responsiveness) characte ristics that will infl uence fo rag ing success and subsequently long-term survival (Donelson et al., 2010; Nowick i et al., 2012 ; Pimentel et al., 2016). Knowledge of th e impact rising temperatures will have on the growth and foraging performance of fish species will therefore be invaluable in predicting the ecological change s aquati c sy stems may underg o in th e future (Booth et al., 2014 ; Lefevre, 2016; Rodriguez-Dominguez et al., 2019; Westhoff and Paukert, 2014). Unde rstan din g thes e relationship s within Au stralia n estuarin e fish assemblages is important as a third of the \$390 million value of the

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(Loug h an d Hobday , 2011 ; Scanes et al., 2020). This is becaus e th e metabolic compromise that occurs when fish are forced to exist outside thei r therma l optimu m may result in reduce d ae r obi c capa city, energy pr odu ction or ci rculation efficiency , al l cu lmina tin g in a loss of phys i o lo g ica l function (Booth et al., 2014 ; Cheung et al., 2013 ; Donelson et al., 2010 ; Laubenstei n et al., 2018). An example of this loss in physiological function under increased ambient temperatures include changes to the growth potential of fishes (Booth et al., 2014; Cheung et al., 2013). Current predictive models suggest that the isolated impact of climate change-induced warming will reduce th e growth rate s an d ca rryin g capa c ities of fish asse mblages in the near future (excluding aquaculture populations where food is unli mited) (Cheung et al., 2013 ; Feary et al., 2010). Becaus e most food webs ca n be su mmarise d by th e notion that larger orga nisms ea t smalle r orga nisms , change s in growth rate s will ther efore no t only have impl ication s fo r th e fi tness of indivi d ual s bu t will also re -shap e th e ec o logical processes that underpin system health (Cheung et al., 2016; Roy et al., 2001). For example, individuals with their growth rates reduced will spen d greate r time at a smalle r size class, thereb y bein g more pron e to predation-related mortality (Djurichkovic et al., 2019; Feyrer et al., 2015). Temperature rise can also affect both physical (e.g., aerobic, and anae r obi c capa city an d mu scl e deve lopment) an d behavioural (e.g.,

pounded by additional anthropogenic stressors such as urbanisation

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could relation the state of the constrained in a loss of the state of the constrained energy required residents in a loss of the state of the state of the state of the resilience to therma l fluctu ation s co mpare d to othe r marine specie s (Booth et al., 2014 ; Cheung et al., 2013 ; Lefevre, 2016). Indeed , when co mpa rin g studies, we se e that that estuarin e specie s will ty p icall y ex hibi t greate r thermo -regulatory pe rfo rmanc e co mpare d to fishes from more st abl e enviro nment s (e.g., trop ica l reefs) (Audzijonyt e et al., 2020 ; Booth et al., 2014 ; Coleman et al., 2019 ; Figueira et al., 2019 ; Rodriguez-Dominguez et al., 2019; Shultz et al., 2016). Recent studies ho wever have pr opose d instea d that orga nisms resi din g in fluctuatin g enviro nment s such as estuarie s may actually be closer to thei r uppe r thermal limits than organisms from stable environments (Gunderson an d Stillman , 2015 ; Shultz et al., 2016). This research ther efore inve sti gate d th e pote ntial role of el evate d ambien t te mpe r ature s on th e growth an d fo ragin g pe rfo rmanc e of th e fo llo win g co mmo n estuarin e species; easter n trumpete r *Pelates sexli neatus* , easter n fortescu e *C. aus tralis* , ye llowfin brea m *A. australis* , fa n -bell y leathe rjacket *M. ch ine nsis* , bridled leatherjacket *A. spilomelanurus* to elevated water temperatures. Th e abundanc e of thes e specie s within loca l estuarie s mean s that they ar e ke y el ement s in thes e sy stems , as well as th e socioeconomi c rela tionship these systems have with local human populations (Sheaves et al., 2015). Th e response of thes e fishes to ambien t wate r te mpe r ature is therefore an appropriate model for understanding climate change impacts on estuaries (Coleman et al., 2019). This study was divided into three sub-aims: (1) to compare growth rates of these species across a thermal gradient reflective of current and predicted future water temperatures, (2) to quantify different characteristics of foraging performance across this same thermal gradient and (3) to assess the association between foraging performance and growth rate over current and predicted water temperatures. Three predictions were made. Firstly, trends in the growth response across temperature treatments will differ between species and will be reflective of these species' respective latitudina l ranges . Se cond, du e to increase d metaboli c demand s caused by el evated temperatures, individuals will engage in compensatory behaviour that will result in reduced time to feeding and increased bite rate, boldness , an d escape response in th e highes t te mpe r ature trea tment . An d lastly , thos e indivi d ual s that demo nstrate either greate r bite rates, boldness , escape response , or reduce time to feedin g will also have greate r growth rates, over an d abov e te mpe r ature effects.

Fish were co llected thre e time s on th e 1s t of March, 30th of March, an d 4th of May 2020 at Careel Bay (33° 37 02·8 0 S; 151° 18 25·2 4 E) . 40 km nort h of Sy dney, alon g th e easter n shor eline of Pittwater, Careel Bay is around 2. 5 km in length an d co ver s an area of 1.5km 2 . It su pport s a nu mbe r of we tland ve g etative co mmunities , as well as sand y habitats such as beache s an d mu dflats, an d is su bject to high recr eationa l fishin g pressure (Hutching s an d Rainer , 1979). Fish were co llected usin g a 10 m long sein e ne t (mes h size 16 mm) that wa s drawn fo r shor t (< 20 m) deployment s throug h sand an d se agras s (*Posidoni a australis* an d Z*ostera s*pecies) banks in shallow water (water depth < 2 m). Any required specie s were co llected into a holdin g bucket whilst othe r fish were immediatel y released , in acco rdanc e with NS W DP I pe rmi t an d University of Technology (UTS) Animal Ethics requirements. Once adequate sample sizes were reached, these collected species were immediately transported live to the UTS aquarium facilities. In total, 125 indivi d ual s across five specie s were ca pture d an d used fo r this study. Base d on size , al l ca pture d indivi d ual s were deemed to be juveniles. Sinc e on e of th e main function s of estuarie s is as a nursery, pe rfo rmanc e assess ments of juveniles are important to predicting the health of these ecosystems under climate change. The five species sampled were *P. sexli neatus* (*n* = 46), *C. australis* (*n* = 27), *A. australis* (*n* = 24), *A. sp ilome lanurus* (*n* = 12) an d *M. ch ine nsis* (*n* = 15). *P. sexli neatus, C. australis,* A. *australis* have a range extending from far north Queensland (sub-

term extrem e therma l events (Scanes et al., 2020). Se a wate r flowed from holdin g tank s locate d in th e UT S buil ding, sourced from local estuaries, and water temperature was controlled us-

ing 300 W aquarium glass heaters. To ensure appropriate oxygen saturation, PO $_2$ levels were maintained through using a combination of air stones an d po werhead pumps. Shelte r wa s pr ovide d in th e form of 5 cu t -off se ction s of PV C pipes. Wate r te mpe r ature wa s me asure d twic e

country' s aquacu lture stocks is derive d from estuarie s (Booth et al., 2014 ; Cottingham et al., 2018 ; Scanes et al., 2020 ; Sheave s et al., 2015). Estuarie s hous e co mplex orga n isation s of se agrass, sand bank s and mangroves that provide juveniles of a number of commercially valuable or ke yston e specie s with an abundanc e of food an d shelte r that is unavai lable offshor e (Gillanders et al., 2011 ; Scanes et al., 2020). As such , estuarin e fish co mmunities includ e both pe rmanent re s ident s an d marine species that will migrate into the ocean after maturing, meaning shifts in po p ulation dyna mic s amon g thes e asse mblages may have so cioeconomi c impl ication s on both estuarin e an d oceani c aquacu lture stocks (Loug h an d Hobday , 2011). Estuarie s within SE Au stralia also co ntain specie s of di ffe ren t bi oge ograp h ica l affinities an d or igins (Gillanders et al., 2011 ; Scanes et al., 2020). Sinc e th e bi oge ograp h ica l ranges and thermal tolerance of species are interrelated (e.g., lowlatitude species will generally have narrower thermal performance curves co mpare d to mi d -latitude species) , we migh t expect that el e vated temperature will affect species differently and accordingly disrupt loca l food webs both within an d well beyond th e estuarie s them selves (Boltañ a et al., 2017 ; Neubauer an d Andersen , 2019). This is al l co mbine d with th e notion that th e rise of wate r te mpe r ature s in easter n Australian estuaries is double that of Australia's oceans and atmosphere. The average water temperature of eastern Australian estuaries have increase d by 2.16 °C over th e last 12 year s (0.2 °C pe r year), meanin g th e therma l resilience of fish specie s occupyin g thes e ecosys -

tems is esse ntial to thei r future fi tness (Scanes et al., 2020). Despite the well-established environmental and socio-economic importance of estuaries, empirical data into thermoregulatory performance is not available for the majority of residing species (Booth et al., 2014 ; Scanes et al., 2020). Th e ability to trac k th e accl imation of thes e populations in response to climate change is accordingly limited (Booth et al., 2014). The current prediction by scientists is that by residing in a thermall y dynami c enviro nment , estuarin e fishes will exhibi t greate r

> Foraging performance experiments were recorded over the last two days of th e tw o -week period (2 0 –21 days afte r ca pture), so as to ensure that individuals were exposed to the different temperature treatments fo r as long as po ssibl e (withi n th e timefram e fish were eth icall y pe rmi t te d to be held for) before behavioural assessment s were co nducted . Feeding activity was tested on day one of the foraging experiments (2 0 days afte r ca pture), an d boldness an d escape response were tested

on the *sec*ond day (21 days after capture), and these were separated by

taneous growth rate ($\mathrm{G_{\rm INST}}$) based on the mass (wet mass) of each individual fish at the beginning (M_1) and the end (M_2) of the interval of

two hours. This spreading of experiments was to minimize any disturbanc e effect s from th e pr eviou s test . Feeding activity and boldness experiments occurred at approximately 1 pm both days , an d escape response expe r iment s at 3 pm , 3 an d 5 h afte r feeding, respectively . Th e same orde r of tank s wa s fo l lowe d fo r each repeat to mi n imize any po ssibl e effect s of th e time of day on experiments (this order was non-randomised). Experiments were filmed usin g a GoPro® 4 that wa s positioned ou tside th e fron t of each tank at th e same height of th e base of th e tank . Obse rvation period wa s thre e mi nutes , an d this wa s pr ecede d by an accl imation period of three minutes where the camera was positioned in front of the tank. This acclimation period was done to minimize any disturbance effects of th e presence or placin g of th e ca mer a (Djurichkovic et al., 2019). Fo ragin g pe rfo rmanc e wa s tested fo r 3 specie s (*P. sexli neatus, A. aus tralis an d M. ch ine nsis)* . *C. australis* , an d *A. sp ilomelanurus* di d no t feed during the viewing period nor did they react to the introduction of the Lego® structure or sinker. For these two species, it should be noted that food wa s no t pr esent when tank checks were made th e fo llo win g morn ing, indicating these species fed overnight. To assess the influence of water temperature on the foraging activity of the remaining species, approximately 1 g of fish flakes was introduced to each tank through the

Becaus e su ccessfu l fo ragin g is a co mpr omise betwee n th e time spen t foraging and predator avoidance/vigilance, measures of feeding activity alon e ar e no t an ad equat e me asure of fo ragin g pe rfo rmanc e in a real-world scenario (Pistevos et al., 2015). Fish that feed at greater rates will not necessarily experience greater survival and reproductive fitness, particularly in habitats with high predator density (White et al., 2013). Fo r this re ason, boldness (i.e . propensity of an indivi dua l to take risks (White et al., 2013)) and escape response (i.e. movements performed by an animal in response to possible predation (Domenici and Hale, 2019)) were also measured. To test the boldness of the test animals, each tank was provided with a miniature structure of red and yellow Lego® blocks (2 cm \times 2 cm \times 3 cm size) to represent a novel

structure. These were placed at the centre of each tank with as minimal di stu rbanc e as po ssible. Lego ® blocks have pr eviousl y been used by Whit e et al . (2013) to test th e boldness of th e lemo n da mselfis h *Pomacentrus moluccensis* within the Great Barrier Reef because they do not imitate any natural structure that these fish may have experienced in the wild, so are truly novel and appear un-threatening. A reaction score that su mmarise d boldness wa s recorded on an 0 – 3 ordina l scal e with 1 scal e incr ements, wher e 0 - Hi din g in refuge or fleein g away from stru c ture, 1- Not responding to structure in any manner, 2- No investigation of stru cture unti l >30 s into th e viewin g period , 3 - Immediat e or almost

2 . Method s *2. 1 . Fish capture*

delivery for a componential between the time spectra and the time spectra control in the spectra of the spectra and the spectra of immediate investigation of structure that includes physical contact with stru cture (e.g., bumpin g or feedin g strikes) . To measure the escape response of individuals, a sudden disturbanc e wa s adde d to each tank to si m ulate pred ato r appearance (e.g., Figueira et al . 2009). Give n th e nature of th e tank s an d test species, this wa s achieved throug h dropping a lead sinker within tw o body length s of the fish to elicit a burst swim response similar to fleeing a predator (Djurichkovic et al., 2019). Th e si mplicity of such a method mean s that assessment s ca n be co mpleted on th e test specie s withou t th e adde d co mplexity, variability an d eth ica l issues in th e us e of a live pred ato r to elicit this response (Domenici an d Hale , 2019 ; Figueira et al., 2019). Like boldness , a reaction scor e that su mmarise d overal l escape response behaviour wa s recorded on a ordina l 1 – 3 scal e with 1 scal e incr ements, wher e 1 - No vi s ibl e response to di stu rbance, 2 - In itial escape response that co nsist s of increase in swimming acce ler ation an d shift in swim ming angl e is fo llowe d by an immediat e return to no rma l behaviour an d 3 - Larg e increase in swimming acce ler ation an d errati c shift in

swimming angle that continues for at least 20 s after initial disturbance

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G_{INST} of all species except for *M. chinensis* differed significantly among temperature treatments (A. *australis*: $P < 0.001$, C. *australis*: $P < 0.001, P$. *sexlineatus*: $P = 0.001, A$. *spilomelanurus*: $P = 0.01$ and *M. chinensis: P >* 0.05). Based on Tukey's HSD tests, G_{INST} was greatest at 26 °C an d lo wes t at 18 °C fo r *P. sexli neatus* (Fig. 1 A) an d *A. australis*

Tabl e 2 Mean (\pm SE) total length (mm) and wet mass (g) of *P. sexlineatus* (n: 18 °C = 15, 22 °C = 15, 26 °C = 16), *C.* australis (n: 18 °C, 22 °C, 26 °C = 9) , *A. australis* (n : 18 °C , 22 °C , 26 °C = 8) , *A. sp ilomelanurus* (n : 18 °C, 22 °C, 26 °C = 4), *M. chinensis*, (n: 18 °C, 22 °C, 26 °C = 5) at initial capture across the temperature treatments. Also provided are sample sizes of

1 .

tropical) to southern Victoria (temperate). *A. spilomelanurus* is distributed further south, exhibiting its greatest abundance around southern-Victoria an d Ta smania, with Sy dne y servin g as th e nort her n -boundary of its range. *M. chinensis* has a similar range to *P. sexlineatus,* and *C. australis, A. australis,* but can also be found along the northern coastline of Australia (Booth et al., 2014; Curley et al., 2013). Approximate latitudinal ranges and other characteristics of test species are provided in Table

2. 2 . Aquarium experimental setup

All captured individuals were first housed in groups (*n* = 10–20 fish per group) in 40 L tanks at ambient Sydney estuary temperatures (2 2 °C). In thes e tanks, each grou p wa s then accl imatize d over a 7 -day period to one of the three treatment temperatures (18 °C, 22 °C, 26 °C) by dail y 0. 5 °C change s in tank te mpe r ature , except th e grou p that re mained at 22 °C. 18 °C and 22 °C are reflective of the average sea surface temperatures (SST) in winter (May–June) and summer (December – February) in SE Australia, respectively (Booth et al., 2014; Djurichkovic et al., 2019). 26 °C represents predicted summer SST by 2100 in the same region (Booth et al., 2014). For further reference, estuaries within SE Australia may reach minimum and maximum temperatures of approximately 17 °C and 31 °C, respectively, during short-

3. 2 . Effect of wate r temperature on foraging activity There was a significant difference in bite rate among temperature treatments in *P. sexlineatus* and *A. australis* (ANOVA: $F = 6.920$, $P < 0.005$ and $F = 7.958, P < 0.005$, respectively), but not *M. chinensis* (*P* > 0.05) (Fig. 2). Bite rate s of juvenile *P. sexli neatus* an d *A. aus tralis* increased with water temperature (the same trend was observed to occur with *M. chinensis,* though it was not significant). More specifi-

There was a significant difference in time to feeding among temperature trea tment s in *P. sexli neatus* , *A. australis* an d *M. ch ine nsis* (ANOVA : $F = 6.417, P < 0.01; F = 4.937, P = 0.01 \text{ and}, F = 4.685, P < 0.05,$ respectively). Time to feedin g of al l specie s decrease d with wate r te m -

among temperatures treatments (Kruskal-Wallis: χ^2 = 7.191, $P < 0.05$) (Fig. 4). There was no significant difference in the boldness of *P. sexli neatus* an d *A. australis* amon g te mpe r ature trea tment s

Fig. 4. Mean (\pm SE) boldness (rank) of (a) *P. sexlineatus* (n: 18 °C = 15, 22 °C = 15, 26 °C = 16), (b) *A. australis* (n: 18 °C, 22 °C, 26 °C = 8) and (c) *M. chinensis* (n: 18 °C, 22 °C, 26 °C = 5) over 18 °C, 22 °C and 26 °C. Boldness is defined on an ordinal scale from 0 to 3 with increasing value corresponding to increase d boldness .

an d fa ece s were siphoned off on a dail y basis. Wate r wa s topped up with clea n wate r (a pprox imately 1/ 3 of th e tank capa city) that ha d been pre-heated to the temperature of the tank in which it is being placed. Water ammonia, phosphate and nitrate was measured twice du rin g th e accl imation period usin g wate r quality test strips . After this period, fish were randomly assigned and transferred to individual 10 L tanks. Individuals were also measured to the nearest mm [t ota l (LT) an d standard (LS) length s (mm)] an d weighe d to th e neares t 0.0001 g (wet mass). Si m ila r to du rin g th e accl imation period , each tank contained its own 55 W aquarium glass heater to maintain water temperature, a section of PVC pipe for shelter and an air stone for aeration. Those tanks that were kept at 18 °C had their temperatures controlled by the air-conditioning system of the laboratory, but still contained no n -functionin g heater s to ensure se condary trea tment effect s were controlled. The protocol for feeding and tank maintenance was kept th e same fo r fish du rin g th e expe r ime nta l period as it wa s du rin g th e accl imation period . Th e obse rvation period from this poin t wa s 14 days for each experimental block. The sides and back of each tank throug hou t both th e accl imation an d expe r ime nta l period were co vered

4 . Discussion This study shows that elevated water temperatures may alter estuar-

in e fish growth an d fo ragin g pe rfo rmance, an d thus affect po p ulation an d co mmunity dyna mic s within estuaries. Herein we have observed that increased water temperatures reflective of future climate change had a negative influence on the growth performance of *A. spilomelanurus,* a positive influence on *P. sexlineatus* and *A. australis,* and a mixed effect on *C. australis*, which demonstrated the greatest growth in the 22 °C trea tment . Whilst th e observed growth response , base d on instan taneous growth rate, was significantly species-specific, there was little di ffe rence betwee n th e fo ragin g pe rfo rmanc e of th e thre e specie s over th e therma l gr adient. Higher te mpe r ature s pr omote d indivi d ual s of *P. sexli neatus* , *A. australis* an d *M. ch ine nsis* to feed at a greate r rate , have higher observed boldness an d a more severe escape response . Over th e 8 °C temperature range, bite rate, boldness and escape response increase d by 116.1% an d time to feedin g decrease d by 68.6 % in al l species. Su rprisingly, thes e behavioural indicators were observed to be unrelated to individual growth rate. This research therefore extends our knowledge of the thermal response of temperature estuarine fish, demonstrating that temperature rise may impact individual physiologi-

with blac k pape r to reduce th e risk of exte rna l di stu rbance.

2. 3 . Experimental protocols

Growth wa s me asure d across th e 14 -day expe r ime nta l period . Th e growth response of species is an effective ecological metric when assessin g phys i olo g ica l pe rfo rmanc e becaus e co nce ptually it integrates en ergy uptake by an organism, and accordingly relates to its fitness (Cottingham et al., 2018). Somati c growth wa s estimate d as th e instan -

length t (*t* = 14 days), usin g eq . 1 (Booth et al., 2014):

daily to ensure temperature changes were occurring at a suitable rate to allow for acclimation without overly stressing the fish. Fish were fed Aqua One® trop ica l fish flakes twic e dail y to sati ation . Fish flakes were ch ose n becaus e they pr ovide d th e co rrect nutr ien t requir ements, they kept well and produce relatively little ammonia waste, assisting in tank maintenance throughout the experimental period. Any uneaten food

> the growth performance of these and other similar species within a temperate region. The hump-shaped performance of *C. australis* was surprising given these species have a latitudinal range similar to *P. sexlineatus* an d *A. australis,* ho wever th e findings of this stud y alig n almost identicall y with thos e of Booth et al . (2014) . Becaus e trophi c inte raction s ar e mediated by th e body size of both

us e of a siphon , 3 h afte r last feeding. Over th e obse rvation period , bite rate (t ota l nu mbe r of feedin g strikes) an d time to feedin g (tim e take n from food intr odu ction to firs t feedin g strike (sec)) were recorded . A

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feedin g strike wa s define d as a clea r action by th e indivi dua l fish to lunge towards the delivered food. Any fish that did not feed during this obse rvation period ha d bite rate an d time to feedin g recorded as 0 an d 18 0 (sec), respectively .

climate appropriately may instead experience diminished physiological capabi l ities , an d as a result may inhabi t thes e sy stems less fr equentl y or will be absent in the future (Crozier and Hutchings, 2014; Gunderson and Stillman, 2015). Continued research into the effect of environmental variation on key ecological processes of fishes may help identify perfo rmanc e response trends to cl imate change , an d ther efore su pport a nu mbe r of co nse rvation strategies (Booth et al., 2014). De claration of Co mpe tin g Inte res t

This research did not receive any specific grant from funding agencies in th e pu blic, co mme rcial , or no t -fo r -profit se ctors . **CRediT authorship contribution statemen t**

Casey O'Connor: Investigation, Formal analysis, Writing – original draft. David Booth: Conceptualization, Methodology, Supervision , Writin g – review & editin g .

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Supplementary data to this article can be found online at https://

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an d may be fo llowe d by free zin g behaviour . *2. 4 . Data analysis*

Statistical analyses were performed using R-studio®. Prior to analysis, al l data wa s pooled across each specie s an d te mpe r ature trea tment an d tested fo r no rma lity an d homogeneity of variance usin g a Shapir o - Wilks test and a Levene's test, respectively, and transformed appropriately. $P < 0.05$ was the defined level of significance for all analyses. A tw o -factor anal ysi s of variance (ANOVA) wa s firs t used to dete r mine whether initial body sizes (wet mass(g)) were significantly different between temperatures and species. Because of unequal sample sizes betwee n species, this an d future tw o -factor ANOVA' s were co nducted using the *car* package in R studio, using a Type-III sums of squares (Fox an d Weisberg , 2018). On e fa cto r ANOVA' s were also used on each species separately to determine if initial body sizes were different between treatments. This found that there were no significant differences in the initial sizes of individuals between temperature treatments and species (*P* > 0.05; Appendix B). A separate linear regression across each species and temperature treatment was used to determine the as-

sociation between bite rate and time to feeding with $\mathrm{G_{\rm INST}}.$ Because

Assume the main response of the content of the main response of the main r Boltaña, S., Sanhueza, N., Aguilar, A., Gallardo-Escarate, C., Arriagada, G., Valdes, J.A., Soto, D., Quiñones, R.A., 2017. Influences of thermal environment on fish growth. Ecol. Evolutio n 7 , 6814–6825 . Booth, D., Poulos, D., Poole, J., Feary, D., 2014. Growth and temperature relationships for juvenile fish specie s in seagrass beds : implications of climate change . J. Fish Biol . 84 , 23 1 –23 6 . Cheung, W.W., Sarmiento, J.L., Dunne, J., Frölicher, T.L., Lam, V.W., Palomares, M.D., Watson, R., Pauly, D., 2013. Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. Nat. Clim. Chang. 3, 254–258. Cheung, W.W., Reygondeau, G., Frölicher, T.L., 2016. Large benefits to marine fisheries of meetin g th e 1. 5 C global warmin g target . Scienc e 35 4 , 1591 –1594 . Coleman, M.A., Butcherine, P., Kelaher, B.P., Broadhurst, M.K., March, D.T., Provost, E.J., David, J., Benkendorff, K., 2019. Climate change does not affect the seafood quality of a commonly targeted fish . Glob . Chang. Biol . 25 , 69 9 –70 7 . Cottingham, A., Huang, P., Hipsey, M.R., Hall, N.G., Ashworth, E., Williams, J., Potter, I. C. , 2018 . Growth , condition, and maturity schedule s of an estuarin e fish specie s change in estuarie s followin g increase d hypoxi a due to climate change . Ecol . Evolutio n 8 , 7111 –7130 . Crozie r , L.G. , Hutchings , J.A. , 2014 . Plasti c and evolutionary response s to climate change in fish . Evol . Appl . 7 , 68–87 . Curley, B.G. , Jordan, A.R. , Figueira, W.F. , Valenzuela , V.C. , 2013 . A review of th e biology and ecology of key fishes targeted by coastal fisheries in south-East Australia: identifying critical knowledge gaps required to improve spatial management . Rev. Fish Biol . Fish . 23 , 43 5 –45 8 . Diamond, S.E., Chick, L., Penick, C.A., Nichols, L.M., Cahan, S.H., Dunn, R.R., Ellison, A. M., Sanders, N.J., Gotelli, N.J., 2017. Heat tolerance predicts the importance of species interaction effects as the climate changes. Integr. Comp. Biol. 57, 112-120. Djurichkovic , L.D. , Donelson, J.M. , Fowler, A.M. , Feary , D.A. , Booth , D.J. , 2019 . The

boldness an d escape response were quantified on a ranked ordina l scale, a separate ordinal regression across each species and temperature trea tment wa s done to test th e associ ation betwee n boldness an d escape response with $\rm{G_{INST}}.$ This found that in all temperature treatments for al l test species, ther e wa s no si gni ficant associ ation of bite rate , time to feeding, boldness or escape response with $\rm{G_{\rm INST}}$ (Linear Regression: $P > 0.05$ and Ordinal Regression: $P > 0.05$; Appendix C-E). Co nsequently, a tw o -factor ANOVA wa s used to dete rmine th e effect

of temperature (fixed factor) and species (fixed factor) on $\rm{G_{INST,}}$ and a one-factor ANOVA was completed on each species separately to compare the effect of temperature on $\mathsf{G}_{\text{INST}}.$ The interaction between temperature and species on $\mathrm{G}_{\mathrm{MST}}$ was also tested. A one-factor ANOVA was co nducted on *P. sexli neatus, A. australis an d M. ch ine nsis* se p arately to compare the effect of temperature on bite rate and time to feeding. Where results indicated significant differences, Tukey's *post-hoc* tests were used to co mpare di ffe rence in si gni ficanc e betwee n te mpe r ature trea tment s within each species. Th e effect of te mpe r ature on boldness and escape response on P. *sexlineatus, A. australis and M. chinensis was* tested using a Kruskal Wallis test on each species separately, with Pairwise Wallis *post-hoc t*ests used to compare significance between temper-

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ature trea tment s within each species.

A. australis juveniles were the largest at collection (3.45 $g \pm 1.1$), fo llowe d by *A. sp ilomelanurus (*2.36 8 g ± 0.6)*, M. ch ine nsis* (1.5 2 g ± 0.8) , *C. australis* (1.2 2 g ± 0.6) an d *P. sexli neatus* $(1.05 \text{ g } \pm 0.43)$ (Table 2 and Appendix A). Instantaneous growth rate $(G_{\rm INST})$, based on the change in individual mass over the 14-day period di ffere d si gni ficantly amon g te mpe r ature trea tment s (ANOVA : *P* = 0.01) and species (ANOVA: *P* < 0.0001; Table 3). There was also a significant interaction between species and temperature on $\mathrm{G}_{\mathrm{MST}}$ $(P < 0.0001)$ indicating the presence of species-specific growth responses across the thermal gradient used in this study (18 °C - 26 °C).

3 . Result s

3. 1 . Effect of wate r temperature on growth rate

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Tabl e 3 Analysis of Variance (ANOVA) for the effect of temperature and species on instantaneous growth rate (G $_{\rm INST}$). G $_{\rm INST}$ is defined as the change in individual mass over th e 14 -day expe r imenta l period , base d on eq . 1.

(Fig. 1C) an d vice -vers a fo r *A. sp ilomelanurus* (Fig. 1D) . *C. australis* ex hibited its highest $\rm{G_{INT}}$ at 22 °C and lowest at 26 °C (Fig. 1B). The $\rm{G_{INST}}$ of *P. sexlineatus* and *A. australis* juveniles was 0.002 g and 0.003 g higher at 26 °C compared to 18 °C whilst the G_{INST} of *C. australis* and *A*. *spilomelanurus* juveniles at 18 °C was 0.003 g and 0.007 g higher than indivi d ual s at 26 °C .

Fig. 1. Mean (\pm SE) instantaneous growth rate (G_{INST}) across temperature treatments (18 °C, 22 °C, 26 °C) for *(a) P. sexlineatus (*n: 18 °C = 15, 22 °C = 15, 26 °C = 16), (b) C. australis (n: 18 °C, 22 °C, 26 °C = 9), (c) A. australis (n: 18 °C, 22 °C, 26 °C = 8), (d) A. spilomelanurus (n: 18 °C, 22 °C, 26 °C = 4), (e) M. chin*e*nsis, (n: 18 °C, 22 °C, 26 °C = 5). Different letters indicate significant difference between temperature treatments (Tukey's HSD: *P <* 0.05). Data for *P. sexlineatus* and *C. australis* are log (x + 1) transformed. G_{INST} is defined as the change in individual mass over the 14-day experimental period, based on eq. 1.

feedin g strike (*se c*).

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22 °C = 15, 26 °C = 16), (b) *A. australis* (n: 18 °C, 22 °C, 26 °C = 8) and (c) *M. chinensis* (n: 18 °C, 22 °C, 26 °C = 5) over 18 °C, 22 °C and 26 °C. Time to feeding is determined by time taken from the introduction of food to the first

(Kruskal-Wallis: *P* > 0.05). The boldness of juvenile *M. chinensis* was approx imately 46 % an d 89 % greate r at 22 °C an d 26 °C co mpare d to 18 °C (bol dness of *P. sexli neatus* an d *A. australis* were also observed to increase with temperature). The only significant difference between temperature treatments was between 18 °C and 26 °C (Pairwise Wallis; $18-26$ °C, P < 0.01).

There was a significant difference in the escape response among te mpe r ature trea tment s of *P. sexli neatus* , *A. australis* an d *M. ch ine nsis* , (Kruskal -Wallis : *χ 2* = 9.579, *P* < 0.01 ; *χ 2* = 8.741, *P* = 0.01 , an d *χ* $2 = 8.68, P = 0.01$, respectively) (Fig. 5). The escape response of *P*. *sexlineatus, A. australis* and *M. chinensis was greatest at higher water* te mpe r atures. Th e escape response of *P. sexli neatus* , *A. australis* an d *M. ch ine nsis* wa s approx imately 34%, 53 % an d 74 % greate r in th e 26 °C temperature treatment compared to the 18 °C temperature treatment. Ther e wa s a si gni ficant di ffe rence in th e escape response of *A. australis* and *M. chinensis* between 22 °C and 26 °C (Pairwise Wallis; 22–26 °C, P < 0.01 ; 22 –26 °C , P < 0.05) an d betwee n 18 °C an d 26 °C fo r *P. sex -* $\frac{1}{2}$ *lineatus* (Pairwise Wallis; 18–26 °C, P < 0.01).

3. 3 . Effect of wate r temperature on foraging behaviour Ther e wa s a si gni ficant di ffe rence in th e boldness of *M. ch ine nsis*

ca l an d behavioural pe rfo rmance.

As expected , trends in growth were associated with th e bi oge o graphic range of the species. Given A. *spilomelanurus* primarily resides in cooler temperate regions where the average SST in summer ranges between approximately 20 °C to 22 °C, and was captured at the northern limit of its latitudinal range, its unsurprising that its growth was signi ficantly reduce d at th e higher te mpe r ature trea tment s (Booth et al., 2014 ; Shultz et al., 2016). Th e increase d growth of *P. sexli neatus* an d *A. australis* under elevated temperatures was also expected because these specie s have ranges that extend into su b -tropical region s wher e wate r temperatures exceed 26 °C for a large part of the year and typically experience greater growth within these sub-tropical regions and during su mme r (Coleman et al., 2019). By no t bein g at thei r therma l threshold, thes e specie s woul d have experience d greate r meta b olism at higher temperatures without any physiological constraints (Coleman et al., 2019 ; Diamon d et al., 2017 ; Pörtne r an d Knust, 2007). It is po ssibl e ther efore that warmin g associated with cl imate change will improv e

pred ators an d prey , even smal l di ffe rence s in th e growth response of specie s to ambien t te mpe r ature s may shift th e organization of marine

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5 . Conclusion

Near -future su mme r wate r te mpe r ature s (2 6 °C) le d to decrease d growth rate s of *A. sp ilomelanurus an d C. australis* , an d increase d growth rates of *P. sexlineatus* and *A. australis* from temperate estuaries. These same te mpe r ature s le d to increase d observed feedin g rates, boldness , and escape response (and decreased time to feeding) in *P. sexlineatus, A*. australis and *M. chinensis* individuals, irrespective of growth performance. Rather than a consistent response across species, our results highligh t that a po ssibl e decrease in th e phys i olo g ica l pe rfo rmanc e of some estuarin e fish may pa ralle l th e therma l resilience of other s with the appropriate physiological adaptations (Audzijonyte et al., 2020; Coleman et al., 2019). The broad thermo-tolerance ranges of estuarine fish (parti c ularl y thos e with a bi oge ograp h ica l rang e that extend s into sub-tropical or tropical climates) that allow them to reside in such dynami c sy stems may ther efore help maintain th e health an d pr odu cti vity of estuarie s unde r cl imate change , an d th e fisherie s indu strie s that rely on them (Booth et al., 2014). Specie s resilien t to el evate d wate r te mpe r ature s will likely maintain or increase thei r do m inanc e in thes e sy stems , whilst thos e unable to ac -

Declaratio n of Competin g Interest

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Appendix A . Supplementary data

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