**Appendix**

*Dynamic Energy Budget model description*

The DEB model quantifies fluxes of energy (indicated by *ṗ*, Fig. 1a) to track the changes in growth and maturation of the juvenile individual based on four state variables (i.e., reserve, structure, maturation and reproductive buffer, Fig. 1a) (Sousa et al., 2008). When food is available in the environment, the organism can eat and assimilate energy into the reserve compartment (*ṗA*, Fig. 1a). The reserve state variable allows for homeostasis, providing the organism with a certain degree of independence from sudden changes in food availability (i.e., metabolic memory, Kooijman, 2010). Energy reserves are mobilized(*ṗC*) and allocated according to the *κ*-rule: the fraction *κṗC* covers somatic maintenance (e.g., protein turnover, *ṗM*, Sousa et al., 2010) and growth (i.e., increases in structure, *ṗG*), and the remainder, (1- *κ*) *ṗC*, supports maturity maintenance and immune regulation (*ṗJ*) and maturation (i.e., increases in maturity level) or reproduction (i.e., gamete production) (*ṗR*), before and after a reproductive maturity threshold, respectively. For a detailed description of the DEB model, refer to Kooijman (2010).

In the DEB model, non-linear dynamics in energy flow rates and state variables are strongly dependent on changes in temperature and food availability (Lika et al., 2011) (Fig. 1b). For example, in juvenile fish, the negative effect of extreme warm temperatures can lead to a mismatch in energy allocation, where energy mobilized from reserves (*κṗC*) becomes insufficient to cover somatic maintenance costs (*ṗM*, Fig. 1b). Because somatic maintenance takes priority over growth, thermal stress can force a situation analogous to mild starvation in which the energy for maturation (*ṗR*) is reallocated to somatic maintenance (*ṗM*). While growth and maturity are not directly competing because of the *κ-*rule, growth can be compromised under extreme conditions of energy deprivation (Figs. 1a and 1b, Martin et al., 2010). Note that the mild starvation mode used in the current study does not include prolonged starvation involving shrinking of body mass, a response to food limitation that is common among invertebrates (Monaco et al., 2014). The mild starvation mode continues until the energy for the somatic maintenance and growth is restored (e.g., increasing feeding or escaping from harsh conditions) or the energy allocated to maturation runs out (i.e., death).

*Data used in parameter estimation*

DEB model parameters (e.g., volume-specific somatic maintenance cost, energy conductance, Table S2) (Lika et al., 2011) are estimated using data on the species life history (e.g., the size and age at which individuals are born, settle, or reach reproductive maturity, Table S1). These data were obtained from the published literature, the FishBase repository (Froese & Pauly, 2019), and a dedicated aquarium experiment (experimental setting described section below). The DEB parameters were estimated simultaneously using the covariation method (Lika et al., 2011). To aid model convergence, the estimation procedure relies on the pseudo data originated from a wide range of species (Kooijman, 2010). This approach facilitates parameter estimation within biologically reasonable ranges by simultaneously minimising the weighted sum of squared deviations between observed and predicted values using a Nelder-Mead simplex method (Lika et al., 2011). The estimation was performed using the DEBtool package (available at https://www.bio.vu.nl/thb/deb /deblab/) with MATLAB® 2018b, and the accuracy of parameter estimation was assessed using relative error, mean relative error and symmetric mean squared error, computed between observed and predicted species-specific life-history traits (Table S1).

*Life-history traits obtained from the literature*

For both species, we collected published data from focal species as well as phylogenetically, morphologically and functionally similar (i.e., similar diet, similar body size, similar habitat) species (i.e., *Abudefduf saxatilis* for the tropical; *Microcanthus strigatus* and *Labbracoglossa argenteiventris* for the temperate species). The published sources of information for each life-history trait are listed in Table S1. *A. saxatilis* is not only closely related to the tropical species (Tsadok et al., 2015) but also shares a very similar thermal niche (e.g., latitudinal occurrence range of *A. vaigiensis* is 36° N to 39° S and of *A. saxatilis* is 41°N to 39° S (FishBase), and morphology (Vella et al., 2016). While *M. strigatus* and *L. argenteiventris* have morphological similarity with the temperate species, the vertically compressed body shape of the temperate species resembles that of *M. strigatus* most.

The observed (i.e., published) and predicted (i.e., the DEB model simulation) life-history traits, together with the relative error between the observed and predicted value, are shown in Table S1. With estimated parameters (Table S2), we obtained small overall error indicated by mean relative error of 0.096 and 0.097 for the tropical and temperate species, respectively, and within ranges published for 1035 other animal species (i.e., mean relative error: 0–0.45, Marques et al., 2018).

*Life-history traits obtained from aquarium experiments*

We conducted an aquarium experiment at the Sydney Institute of Marine Science to quantify the effect of temperature and species interactions on the performance of juveniles of the tropical and the temperate fish species*.* Fish were collected using hand and barrier nets and clove oil anaesthetics at Little Manly (33°48'23.85"S, 151°17'8.76"E) and Freshwater Beach (33°46'50.69"S, 151°17'34.14"E) 5 km apart in New South Wales, Australia, between February and March 2019. Collected fish were kept at an ambient temperature of 23 °C until the start of the experiment, when the water temperatures were gradually modified by 0.5 °C/day to reach the experimental temperatures of ~ 20 °C and 26 °C (in addition to the control of 23 °C). This range of temperature represents those in the geographical distribution where both species coexist in summer. All fish were exposed to a mean target temperature with < 0.5 °C fluctuation for 3 weeks and fed *ad libitum* with frozen brine shrimp *Artemia* three times a day. The light regime was 12 hours of daytime and 12 hours of night-time (Figueira et al., 2009). To test the effect of species interactions, for two temperature treatments (23 and 26 °C) we had 10 replicates per species of single-housed fish in 10-L tanks, and 10 replicates of paired species (i.e., one tropical plus one temperate) in 20-L tanks to avoid density-dependent effects. Measurements of feeding rate and somatic growth rate were used to estimate assimilation efficiency, temperature sensitivity, and ingestion rate as described below. We used measurements obtained from both 23 and 26 °C for the DEB model.

*Feeding related parameters*

We estimated two parameters relating to feeding: functional response and assimilation rate. DEB theory assumes that ingestion is proportional to food availability following a type II functional response (Holling, 1959), and food density (*x*, Fig. 1) regulates feeding rate by defining the amount of time for a consumer to search for and handle prey (Kooijman, 2010). In this regard, DEB theory can accommodate the effect of species interactions on feeding as a cost to search time for prey because the time it takes to search for prey increases with increased time spent on social interactions (Kooijman, 2010). If the feeding rate of fish housed in paired-species tanks is different from singly housed fish, the difference would be reflected in the ingestion rate and consequently influences the growth of fish. To describe this process, we parameterised the scale functional response, *f*, which characterises the ingestion rate of a certain food type as a fraction of maximum ingestion rate (Kooijiman, 2010) and varies between 0 (absence of food) to 1 (*ad libitum*). We initially set *f* = 1 for single-housed fish (*f\_single*), which were fed *ad libitum* without species interaction. We then used the covariation method to approximate functional response for paired fish (*f\_paired*) relative to *f\_single* for single-housed fish using standard length and instantaneous growth rate. Where instantaneous growth rate was not properly predicted using standard length at *f\_single* = 1 for single-housed fish, we estimated *f\_single* using covariate method as well.

We found that, after 3 weeks of experiments, the presence of the temperate species increased the instantaneous growth rate of the tropical species compared to the same-sized tropical species without the temperate species. This has allowed the covariation method to parametrise functional response of paired tropical species (*f\_paired*)be 1.64 while that of single-housed tropical species (*f\_single*) be 1.316 (Table 2). In contrast, the presence of the tropical species slightly reduced the rate in the temperate species compared to same-sized temperate species without the tropical species. From this result, we obtained functional response of paired temperate species be 0.81 and that of single-housed temperate species be 0.89 (Table 2). It was also evident that aquarium-based *f* in the temperate species (i.e., *f\_paired* and *f\_single*) was slightly lower than the literature-based *f* in the temperate species (*f* = 1) (Table S2). This suggests social deprivation for the temperate species, which is known to cause adverse effects in many of social species during captivity (Hetts et al., 1992; McLeod et al., 1997; Carbajal & Orihuela, 2001).

We also estimated assimilation efficiency because the assimilation of the ingested food depends on a diet-specific assimilation efficiency parameter, (Kooijman, 2010). We initially estimated using daily consumption rate (g food/day) and wet weight (g) of single-housed fish, and then we optimized values using the covariation method in DEBtool. The daily feeding rate was inferred from the feeding trials done in the morning when both species are known to feed actively (Fishelson, 1970; Russell, 1983; Pankhurst, 1989). Each fish was fed *ad libitum* and allowed to feed for three hours, thus limiting the degradation of left-over *Artemia* that could take place during longer feeding trials. The total provided (at the start) and left-over (after 3 h) food in wet weight was recorded and used to calculate individual feeding rates. The resultant ingestion rate was multiplied by three (based on feeding three times a day) and expressed as oven-dried weight in grams per day. This estimate was only done for single-housed fish because this approach did not allow us to discriminate between the feeding rates of individual fish housed in pairs. The covariation method in DEBtool estimated that at 20 ºC the tropical species ( = 0.050) converts food into assimilated energy less efficiently than the temperate species ( = 0.1861) (Table S2).

*Temperature sensitivity (in the absence of species interactions)*

In the DEB model, the physiological thermal sensitivity of each species across their temperature tolerance range, , can be described as (Kooijman, 2010):

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where *TA* (i.e., Arrhenius temperature) is the species thermal sensitivity across the upslope section of the curve, *TL* and *TH* are the lower and upper boundaries of the species thermal breadth (measured in Kelvin), respectively, where the level of performance is higher than 69% of maximum level, and *TAL* and *TAH* are Arrhenius temperature at *TL* and *TH,* respectively. These five parameters were estimated for the tropical species using growth rate (i.e., changes in length per day) at different temperatures, e.g., 289.15 K (Figueira et al., 2009), 293.15 to 299.15 K (current aquarium experiment), and 305.15 K (Nakano et al., 2004), with nonlinear least squares regression using the nls.multstart package (Padfield & Matheson, 2023) in R (R Core Team, 2021), following the approach in Agüera et al. (2015). As starting values, we used the estimated parameters of the damselfish *Chromis chromis* from Add-my-pet database (AmP, 2022) as *TAL* and *TAH*.

For the temperate species, we estimated *TA* using growth rate obtained from the aquarium experiment (temperature range from 293.15 to 299.15 K) and obtained *TAL* and *TAH* from Lika et al.(2011). These estimated parameters were further improved by the covariation method in DEBtool. We found that the thermal sensitivity of the tropical species (*TA* = 6027) was higher than that of the temperate species (*TA* = 4203.8) (Table S2). The results agreed with the observation that the species living in the environment where temperature is more constant and hotter (e.g., tropical regions) generally have higher Arrhenius temperature compared to species living in environments with larger seasonal temperature fluctuations (e.g., temperate regions) (Kooijman, 2010).

*DEB to individual-based model (IBM)-DEB*

While the model parameter estimation was performed under the standard DEB model, the estimated DEB parameters (reserve, maturity, and reproduction) are scaled by dividing these parameters by the maximum surface-area-specific rate for simplifying the model for further simulation as implemented in DEB\_IBM-model (Martin et al., 2012). The standard DEB parameters and associated scaled parameters are listed in Table S2.

The rule of standard model of DEB is that no assimilation occurs during embryonic phase (e.g., embryos use energy from their yolk), juveniles start to acquire energy from the environment and invest energy into growth and maturation, and the invested energy into growth and maturation during the juvenile phase will shift to a reproductive buffer as the organism enters into the adult stage (Marques et al., 2018). The standard DEB model follows the assumption of isomorphism (i.e., the shape of an individual is maintained throughout its life) (Kooijman, 1993), and thus the von Bertelanffy growth function can be used to describe post-embryonic growth (Kooijman et al., 2011). However, as indicated by Kooijman et al., (2011), the standard model is not appropriate for describing growth of early juveniles in many fish species as their shape changes in early life stages. Departure from isomorphy implies that surface-area to volume ratio increases (i.e., from volume2/3 to volume), which results in accelerated growth. In order to accommodate growth acceleration in the DEB-IBM model, the shape correction function *M*(*L*) (Zimmer et al., 2014) was included as metabolic acceleration sub-model in the DEB-IBM. The calculation of *M*(*L*) follows Zimmer et al., (2014):

The role of this function in DEB-IBM is to alter mobilization flux *ṖC* and the assimilation flux *ṖA*.

*Model fit*

To quantify the model fit, we used maximum standard length of the tropical and the temperate species. We collected and measured fish from 5 sites spanning latitudes between 30.5 ºS to 37.5 ºS between March and June 2018 (sites and dates shown in Fig. S1). To compare the body size between field-caught individual and simulated individual, we simulated the growth of fish as a function of temperature at each sampling site and sampling year (from 1 January to 31 December) and extracted the size from sampling date. We assumed that the settlement of field-caught individuals had occurred on the 1st of January each year and compared their body lengths against the maximum standard length predicted by the model for the specific date of collection.

To test the model performance, we computed mean absolute percentage error (MAPE) between field-caught standard length (maximum) and simulated standard length for both tropical and temperate species using *MLmetrics* in R. MAPE of 0 indicates exact match between the observed and predicted size and increases proportionally to the model error. We also tested whether the relationship between simulated and observed size significantly differ from a 1:1 relationship (i.e., exact match), using *smatr* in R (Warton et al., 2012).

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