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Ascertaining the potential effects of temperature on growth, survival and feeding of different juvenile clown fish

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PEER REVIEW

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Comments

This work has some new information on cultivation in marine science. The report on the feeding of clown fish juveniles can be further applied in marine science and coastal medicine. The experiment is standard and can be further useful for the followers in the field. This can be further referenced in the future publication.

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ABSTRACT

Objective: To determine the physiological and ecological responses of marine ornamental fishes to the change of water temperature with its potential effects on the growth, survival and feeding in clown fish.

Methods: Three different sea anemone fish (*Premnas biaculeatus*, *Amphiprion clarkii, Amphiprion akallopisos*) were reared in confinement at water temperatures of 26, 28, 30, 32, and 34 °C using thermostat and they were maintained up to the marketable size, and growth, survival and feeding were evaluated during the experimental period.

Results: The results illustrated that water temperature influenced the physiological performance of juveniles of three different sea anemone fish significantly. The growth and survival rates of juveniles of three different clown fish significantly increased with the increase of water temperature from 26 °C to 34 °C ($P<0.05$). Water temperature also influenced the feeding of three different clown fish significantly with feed conversion ratio increased from (0.071±0.020), (0.075±0.030) and (0.079±0.028) to (0.057±0.040), (0.047±0.030) and (0.045±0.028) for *Premnas biaculeatus, Amphiprion clarkii and Amphiprion akallopisos* respectively with increase of water temperature from 26 °C to 34 °C ($P<0.05$). Specific growth rates ($P<0.05$) increased significantly with increase of water temperature and positively correlated with the feed conversion ratio, indicating that growth rates are significantly increased with increase of temperature.

Conclusions: This study deliberately reveals that the physiological response of juveniles of clown fish as the change of water temperature and substantiated that water temperature influenced juvenile growth, survival and feeding significantly. This study also put forward that the reduced growth, survival and feeding of juveniles at lower temperature which have ecological impacts on clown fish juveniles in settlement and population replacement in the wild.

KEYWORDS

Temperature, *Premnas biaculeatus*, *Amphiprion clarkii*, *Amphiprion akallopisos*, Feed conversion ratio, Specific growth rates, Survival

1. Introduction

A number of reef species utilize near shore and estuarine areas for settling in seagrass and mangrove habitats before migrating to reefs as they mature[1,2]. Different stages of many reef fishes undergo a defined ontogenetic sequence of environmental requirements, which is often associated with distinct habitat features[3]. In addition to habitat features, abiotic properties of the environment are also

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important, modifying the energetic (*i.e.* feeding, metabolism, growth rate) and ultimate production of reef fish[4]. Temperature, salinity, oxygen concentration, photoperiod and pH are environmental factors which are well known to have significant impacts on the performance of fish larvae and juveniles, such as survival, growth, feeding and metamorphosis, for instance temperature can influence larval and juvenile metabolism rate of marine fishes in temperate and subtropical waters[5,6], and consequently influence their physiological performance such as growth, development and behavior[7-10].

Temperature is the most important environmental parameter for aquatic life, rising temperature up to certain degree favors aquaculture by reducing the time required to produce marketable sized animal and producing more generation per year[11]. The global mean air temperature may increase 1.5-4.5 °C in the next half century which was projected by the United States National Research Council[12]. Pertinent studies on tropical marine fish species have been principally focused on important species for the purpose of mariculture and human utilization which includes groupers and snappers[13,14].

The marine ornamental fishes are the most popular attraction of the aquarists and very important in the aquarium trade in view of its bright colour, interesting display behavior and ability to live in captive conditions[15]. Artificial breeding of tropical coral reef fishes became admired focus due to the development of the ornamental fish trade[16,17].

The effect of temperature on growth and survivability of different clown fishes [*Amphiprion akallopisos* (*A. akallopisos*), *Amphiprion clarkii* (*A. clarkii*) and *Premnas biaculeatus* (*P. biaculeatus*)], however, have not been documented. The objectives of this study were to investigate the effects of temperature on survival, growth and feeding of the metamorphic juveniles (MJ) of different *Amphiprion* species in captivity and to understand the physiological and ecological responses of the MJs to the change of temperature in confinement.

2. Materials and methods

2.1. Study location

The present study was carried out in the brood Stock bank for Marine Ornamental Fish Facility, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu, India.

2.2. Broodstock

All the anemone fish individuals were obtained from the Gulf of Mannar region; subsequently they were spawned and performed larval rearing in the broodstock unit. Average total length of all the anemone fish were measured about (8.5±0.1) cm and they were placed in the 500 L tanks. Estuarine water was drawn from the Vellar estuary (Latitude 11° 29’ N; Long 79° 45’ E) with the help of 5 Hp pump during high tide and allowed to reconcile in a sump for two days, and then water was passed through sand and UV filters and finally stocked in a storage tank installed with a canister filter from their water was taken for hatchery operations. The water quality parameters such as salinity was around 24‰-26‰, pH was around 7.8-8.0 and temperature was around 26 °C–28 °C.

2.3. Experimental design

Five water temperature groups (26, 28, 30, 32 and 34 °C) were established with the help of thermostat and each had triplicates. The optimum temperature 28 °C is taken as the control tank during the experimental period. The experiment was conducted from September to November, 2013 and terminated when more than two-thirds of juveniles in a group attained their marketable size.

A total of 100, MJ (distinct as the completion of larval body pigmentation) of anemone fish (*A. akallopisos, A. clarkii* and *P. biaculeatus*) were randomly assigned into fifteen 150-L FRB tanks and water temperature in the tanks was controlled at (28.0± 0.5) °C. Water temperature of three buckets were subsequently reduced to (26.0±0.5) °C and another nine tanks were increased to a temperature of (30.0±0.5) °C, (32.0±0.5) °C and (34.0±0.5) °C within 24 h.

2.4. Maintenance of experimental MJs

Gentle aeration was supplied in the experimental tanks and increased with the growth of the MJ. Daily water exchange rate was from 10%-20%, increased as the growth of the juveniles. Fresh water was used to reduce the salinity of the sea water, light intensity was controlled at 1000-2000 lux. MJ were first fed with *Artemia* species and they were maintained at 10-15 individuals/mL in the experimental tanks.

2.5. Data collection

MJs of different clown fish were sampled randomly and measured for total length (mm) and the body weight (mg) at the beginning of the experiment. Thrice in a week, 3 metamorphic juveniles were sampled randomly and measured for total length and body weight till the end of the experiment. Numbers of dead MJ were noted daily and removed from the experimental tanks.

MJs were fed with *Artemia* nauplii at different time intervals such as 6:00 a.m., 9:00 a.m., 12:00 p.m., 15:00 p.m. and 18:00 p.m. Each feeding lasted for 45 min. The numbers of *Artemia* nauplii were calculated after each feeding. The total number of *Artemia* nauplii fed and the number of *Artemia* nauplii remained after 45 min were calculated in each of the experimental tank.

2.6. Statistical analysis

Growth performance of the fish was determined by following the standard formula[18]. Daily growth rate was calculated from:

$GR\ (mm/d)=(TL_t-TL_o)/t$

where TL_t and TL_o are the total length at the end of the experiment and beginning of the experiment, and t is the days for the experiment.

Weight gain (g)=Final weight (g)-Initial weight (g)

% Specific growth rate (SGR)=$100\times(\ln W_2-\ln W_1)/T$

Where W_1 and W_2 are the initial and final weight, respectively, and T is the number of days in the feeding period.

% Feed conversion ratio (FCR)=Feed intake/Weight gain.

% Survival rate=NT/(NO-NS)×100

Where NT is the number of marketable juveniles at the end of the experiment, NO is the number of MJs at the beginning of the experiment and NS is the number of juveniles sampled for measurement during the experiment.

Data were subjected to One-way ANOVA to test the effect of temperature on growth performance, survival rate of different clown fish. Data have been expressed as mean±SD. All statistical analyses were made using the statistic software SPSS version 16.0 as described by Dhaneesh *et al*[16].

3. Results

3.1. *P. biaculeatus*

3.1.1. Effect of water temperature on MJ survival rate and cumulative mortality

With the increase of water temperature from 26 °C to 34 °C, the water temperature influences MJ survival of *P. biaculeatus* significantly and the MJs reared at high water temperature of 34 °C had highest survival rate (73.8%) at the end of the experiment ($P<0.05$) illustrated in Figure 1. Survival rates in all the temperature groups had significantly different and were about 50.7% at 26 °C, 59.5% at 28 °C, 62.9% at 30 °C and 64.1% at 32 °C ($P<0.05$). Survivals were temperature dependent on all the experimental period. The MJ of *P. biaculeatus* raised at 26 °C showed a progressive mortality from Day 3 onwards. On contrary, mortalities at 28, 30, 32 and 34 °C have less mortality and were considerably reduced. As shown in Figure 1, differences in survival patterns were even more evident when the water temperature increased from 26 °C to 34 °C and also influences the MJ survival of *P. biaculeatus* significantly.

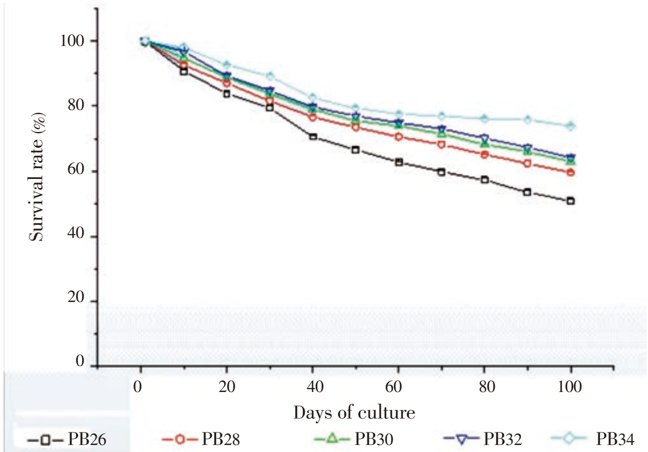

Figure 1. Survival rate (%) (mean±SE, n=3) of *P. biaculeatus* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.

PB: *P. biaculeatus*; PB26: experimental tank with 26 °C; PB28: experimental tank with 28 °C; PB30: experimental tank with 30 °C; PB32: experimental tank with 32 °C; PB34: experimental tank with 34 °C.

3.1.2. Effect of water temperature on MJ total length

The total length and growth rate of MJ of *P. biaculeatus* during the experimental trial is shown in Figures 2 and 3. The maximum growth response in terms of SGR and final body weight was observed at 34 °C [(26.000±0.361) mm in total length] (Table 1). The final weight of the fish, weight gain and SGR increased significantly ($P<0.05$) with the increase of water temperature. Growth rate at 34 °C temperature was significantly different from that of all other temperature groups ($P<0.05$). With the increase of water temperature from 26 °C to 34 °C, a significant differences in the growth rate was observed, which clearly states that the water temperature influences the growth rate of *P. biaculeatus*. The final results of total length in all the temperature groups had significantly differences that were (15.130±0.252) at 26 °C, (18.530±0.252) mm at 28 °C, (21.000±0.458) mm at 30 °C and (22.200±0.436) mm at 32 °C. As shown in Figure 3, growth rates are significantly different and more higher, when the water temperature increased from 26 °C to 34 °C and also influences the MJ growth rates of *P. biaculeatus*.

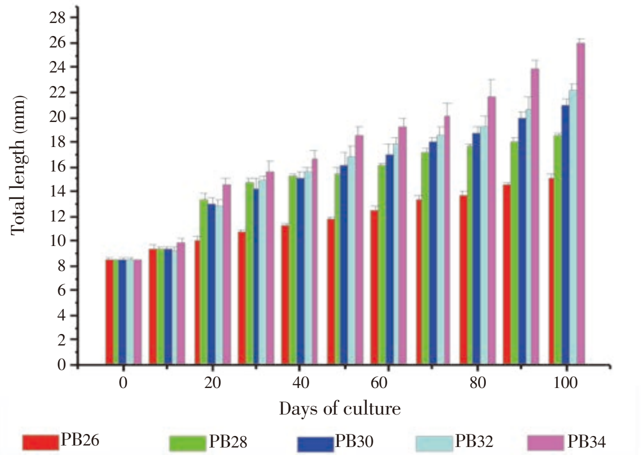

Figure 2. Total length (mm) (mean±SE, n=3) of *P. biaculeatus* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.

PB: *P. biaculeatus*; PB26: experimental tank with 26 °C; PB28: experimental tank with 28 °C; PB30: experimental tank with 30 °C; PB32: experimental tank with 32 °C; PB34: experimental tank with 34 °C.

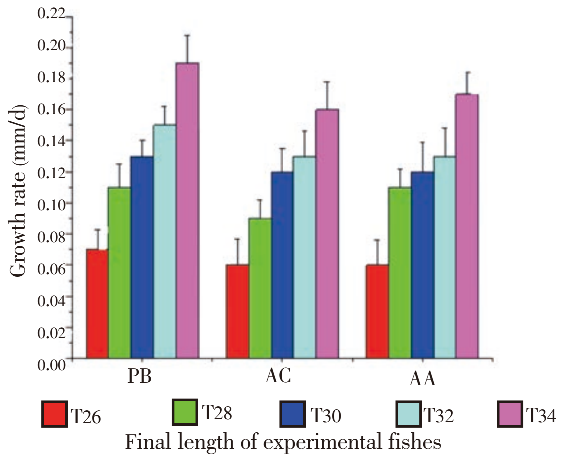

Figure 3. Growth rate (mm/d) (mean±SE, n=3) of different metamorphic juveniles.

PB: *P. biaculeatus*; AC: *A. clarkii*; AA: *A. akallopisos*; They were reared at water temperature of 26, 28, 30, 32 and 34 °C. T26: experimental tank with 26 °C; T28: experimental tank with 28 °C; T30: experimental tank with 30 °C; T32: experimental tank with 32 °C; T34: experimental tank with 34 °C.

Table 1

SGR and FCR of *P. biaculeatus* (mean±SE, n=3) reared at different water temperatures of 26, 28, 30, 32 and 34 °C.

Particulars	PB26	PB28	PB30	PB32	PB34
Initial weight (g)	0.044±0.010	0.049±0.015	0.046±0.014	0.046±0.012	0.051±0.017
Final weight (g)	0.116±0.018	0.163±0.015	0.255±0.016	0.384±0.020	0.455±0.017
Gained weight (g)	0.072±0.010	0.114±0.015	0.209±0.013	0.338±0.015	0.404±0.014
Survival rate (%)	50.700±0.586	59.530±0.451	62.970±0.513	64.100±0.265	73.830±0.306
SGR (g/day/fish)	1.070±0.015	1.330±0.013	0.265±0.016	1.900±0.020	2.430±0.015
FCR	0.071±0.020	0.058±0.070	0.056±0.011	0.048±0.070	0.057±0.040

PB: *P. biaculeatus*; PB26: experimental tank with 26 °C; PB28: experimental tank with 28 °C; PB30: experimental tank with 30 °C; PB32: experimental tank with 32 °C; PB34: experimental tank with 34 °C.

3.2. *A. clarkii*

3.2.1. Effect of water temperature on MJ survival rate (%) and cumulative moratlity (%)

With the increase of water temperature from 26 °C to 34 °C, the water temperature influences the MJ survival of *A. clarkii* significantly and the MJ were reared at high water temperature of 34 °C had highest survival rate (70.3%) at the end of the experiment (P<0.05) illustrated in Figure 3.

Survival rates in all the temperature groups had significantly different and were 48.6% at 26 °C, 57.3% at 28 °C, 60.2% at 30 °C and 62.3% at 32 °C (P<0.05). Survivals were temperature dependent on all the experimental period. The MJ of *A. clarkii* raised at 26 °C showed a progressive mortality from Day 4 onwards. On contrary, mortalities at 28, 30, 32 and 34 °C have less mortality and were considerably reduced. As shown in Figure 4, differences in survival patterns were more evident and effective when the water temperature increased from 26 °C to 34 °C and thus influences the MJ survival of *A. clarkii* significantly.

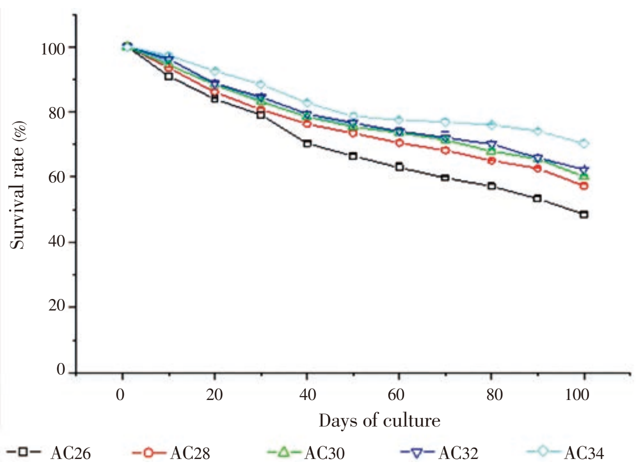

Figure 4. Survival rate (%) (mean±SE, n=3) of *A. clarkii* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.

AC: *A. clarkii*; AC26: experimental tank with 26 °C; AC28: experimental tank with 28 °C; AC30: experimental tank with 30 °C; AC32: experimental tank with 32 °C; AC34: experimental tank with 34 °C.

3.2.2. Effect of water temperature on MJ total length

Growth rate and total length of MJ of *A. clarkii* during the experimental trial are shown in Figures 3 and 5. The maximum growth rate in terms of SGR and final body weight was observed at 34 °C [(23.530±0.513) mm in total length] (Table 2). The final weight of the fish, weight gain and SGR increased significantly (P<0.05) with the increase of water temperature. Growth rate at 34 °C temperature was significantly different from that of all other temperature groups (P<0.05). With the increase of water temperature from 26 °C to 34 °C, a significant differences in the growth rate was observed, which clearly states that the water temperature influences the growth rate of *A. clarkii*. Growth rates in all the temperature groups had significantly different and were between (14.830±0.306) mm at 26 °C, (17.270±0.802) mm at 28 °C, (19.870±0.569) mm at 30 °C and (20.060±0.557) mm at 32 °C. As shown in Figure 5, growth rates are significantly different and more effective, when the water temperature increased from 26 °C to 34 °C and also influences the MJ growth rates of *A. clarkii*.

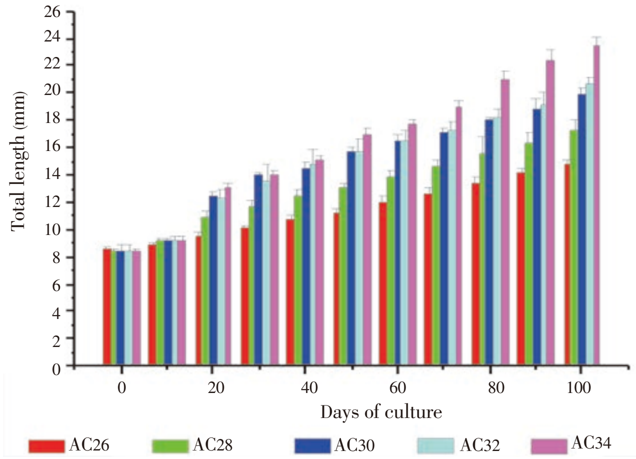

Figure 5. Total length (mm) (mean±SE, n=3) of *A. clarkii* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.

AC: *A. clarkii*; AC26: experimental tank with 26 °C; AC28: experimental tank with 28 °C; AC30: experimental tank with 30 °C; AC32: experimental tank with 32 °C; AC34: experimental tank with 34 °C.

Table 2

SGR and FCR of *A. clarkii* (mean±SE, n=3) reared at different water temperatures of 26, 28, 30, 32 and 34 °C.

Particulars	AC26	AC28	AC30	AC32	AC34
Initial weight (g)	0.044±0.010	0.049±0.015	0.046±0.014	0.046±0.012	0.051±0.017
Final weight (g)	0.104±0.017	0.143±0.015	0.235±0.016	0.334±0.024	0.435±0.024
Gained weight (g)	0.060±0.020	0.094±0.013	0.189±0.015	0.288±0.010	0.384±0.024
Survival rate (%)	48.600±0.500	57.300±0.693	60.200±0.529	62.300±0.529	70.300±0.956
SGR (g/day/fish)	0.950±0.019	1.190±0.015	1.810±0.012	2.200±0.021	2.380±0.013
FCR	0.075±0.030	0.068±0.012	0.076±0.011	0.058±0.023	0.047±0.030

AC: *A. clarkii*. AC26: experimental tank with 26 °C; AC28: experimental tank with 28 °C; AC30: experimental tank with 30 °C; AC32: experimental tank with 32 °C; AC34: experimental tank with 34 °C.

3.3. *A. akallopisos*

3.3.1. Effect of water temperature on MJ survival rate and cumulative mortality

The increase of water temperature from 26 °C to 34 °C influences the MJ survival of *A. akallopisos* significantly and the MJ were reared at high water temperature of 34 °C had highest survival rate (69.8%) at the end of the experiment (P<0.05) illustrated in Figure 6. Survival rates in all the temperature groups had significantly differences that were 47.1% at 26 °C, 56.1% at 28 °C, 59.0% at 30 °C and 61.1% at 32 °C (P<0.05). Survival rate of *A. akallopisos* were temperature dependent during all the experimental period. And at 26 °C *A. akallopisos* showed a progressive mortality from Day 2 onwards. On contrary, mortalities at 28, 30, 32 and 34 °C have eventually less mortality and were considerably reduced. As shown in Figure 6, differences in survival patterns were even more evident and effective, when the water temperature was increased from 26 °C to 34 °C and also influences the MJ survival of *A. akallopisos* significantly.

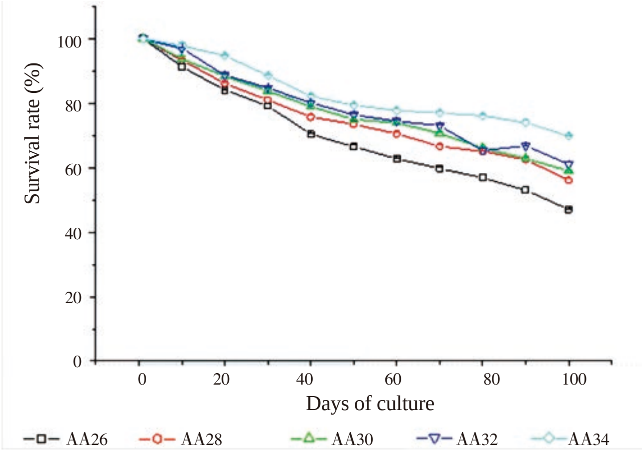

Figure 6. Survival rate (%) (mean±SE, n=3) of *A. akallopisos* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.
AA: *A. akallopisos*; AA26: experimental tank with 26 °C; AA28: experimental tank with 28 °C; AA30: experimental tank with 30 °C; AA32: experimental tank with 32 °C; AA34: experimental tank with 34 °C.

3.3.2. Effect of water temperature on MJ total length

During the experimental trails, the growth rates of MJ of *A. akallopisos* were increased from 26 °C to 34 °C which influences the growth rates (Figures 3 and 7). The maximum growth response in terms of SGR and final body weight was observed at 34 °C [(24.170 ±0.306) mm in total length] (Table 3). The final weight of the fish, weight gain and SGR increased significantly (P<0.05) with the increase of water temperature. Growth rate at 34 °C temperature was significantly different from that of all other temperature groups (P<0.05). With the increase of water temperature from 26 °C to 34 °C, a significant difference in the growth rate was observed, which clearly states that the water temperature influences the growth rate of *A. akallopisos*. The final results of total length in all the temperature groups had significantly differences that were (14.100±0.600) mm at 26 °C, (18.870±0.252) mm at 28 °C, (20.130±0.351) mm at 30 °C and (21.100±0.265) mm at 32 °C. As shown in Figure 7, growth rates are significantly different and more effective, when water temperature increases from 26 °C to 34 °C and also influences the MJ growth rates of *A. akallopisos*.

Predominantly it was observed that *P. biaculeatus* had significantly higher growth rate and survival rates than the other clown fishes at 34 °C (Figure 3). At 34 °C temperature, all the clown fishes (*P. biaculeatus*, *A. clarkii* and *A. akallopisos*) have showed a higher growth rates and survival rates. And at 26 °C temperature, all the experimental clown fishes have displayed a significantly lower growth rates and survival rates. And the FCR in all the experimental tanks displays less at 26 °C temperature, and at 34 °C temperature had significantly higher (P<0.05). Comparing *P. biaculeatus, A. clarkii*, and *A. akallopisos*, *A. akallopisos* had displayed lower growth rates, FCR and survival rates at all the experimental temperature groups (P<0.05) (Figures 3, 6 and 7, Table 3). In *A. clarkii*, moderate growth rates, FCR and survival rates (Figures 3-5, Table 2) at all the temperature groups were observed (P<0.05). There is a signs of sluggish movements; weak swimming movements in all the experimental fish were noticed at 26 °C temperature. Food intake was significantly higher in all the experimental fishes at 34 °C temperature.

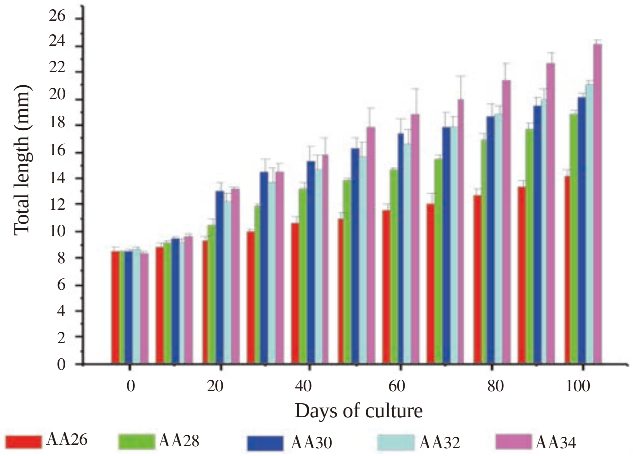

Figure 7. Total length (mm) (mean±SE, n=3) of *A. akallopisos* of MJs reared at water temperature of 26, 28, 30, 32 and 34 °C.
AA: *A. akallopisos*; AA26: experimental tank with 26 °C; AA28: experimental tank with 28 °C; AA30: experimental tank with 30 °C; AA32: experimental tank with 32 °C; AA34: experimental tank with 34 °C.

Table 3
SGR and FCR of *A. akallopisos* (mean±SE, n=3) reared at different water temperatures of 26, 28, 30, 32 and 34 °C.

Particulars	AA26	AA28	AA30	AA32	AA34
Initial weight (g)	0.044±0.010	0.049±0.015	0.046±0.014	0.046±0.012	0.051±0.017
Final weight (g)	0.098±0.015	0.113±0.013	0.215±0.010	0.314±0.020	0.405±0.021
Gained weight (g)	0.054±0.021	0.064±0.017	0.169±0.014	0.268±0.015	0.354±0.027
Survival rate (%)	47.100±0.208	56.170±0.709	59.000±0.265	61.100±0.721	69.800±0.300
SGR (g/day/fish)	0.880±0.015	0.920±0.016	1.710±0.013	2.130±0.025	2.300±0.016
FCR	0.079±0.028	0.071±0.015	0.070±0.011	0.060±0.027	0.045±0.028

AA: *A. akallopisos*. AA26: experimental tank with 26 °C; AA28: experimental tank with 28 °C; AA30: experimental tank with 30 °C; AA32: experimental tank with 32 °C; AA34: experimental tank with 34 °C.

4. Discussion

Various developmental phases of the fish in their life cycle were prejudiced by many environmental factors in wild condition as metamorphic stage is one of the most sensitive phases to the change of environmental conditions[9,19]. Developmental rates of fish embryos, larvae and young juveniles were significantly affected by the water temperature[20-22].

This study demonstrated that the change of water temperature had significant influences on physiological responses of the MJs of different clown fishes (*P. biaculeatus*, *A. clarkii* and *A. akallopisos*) which are widely distributed marine fish species from the tropical to temperate waters. Temperature had strong effects on the feeding and growth rates of clown fishes under laboratory conditions. The response to temperature was not constant through all of the treatment levels, increasing more rapidly through the lower portion of the range, and leveling off at higher temperatures. It appears from the present study that water temperature has affected the growth and survival rates of different clown fishes.

In the present study, MJs of all the experimental fishes exposed to low water temperature (26 °C) had significantly higher mortality, low growth rates and low survival rates. Moderate growth rates and survival rates have been observed when the fishes are exposed to the 28 °C and 30 °C. High growth rates and high survival rates have been noticed when the clown fishes were exposed to 34 °C. It is also known that juvenile fish live in lower water temperature reduce swimming ability, and eventually led to slow capability to avoid predators, low ability to catch prey and low survival rate[22,23].

Fish showed an increase in growth and feeding, metabolism rate, and food digestion and absorption under optimal water temperature and craving the increase of water temperature[24]. In the present study, MJs of different clown fishes (*P. biaculeatus*, *A. clarkii* and *A. akallopisos*) grew faster when reared at higher water temperature.

In different experimental groups from the present study, *P. biaculeatus* showed significantly higher growth rates and survival rates when they were reared at 34 °C temperature and low growth rates and low survival rates are predominantly appeared when they were reared under 26 °C temperature. While comparing with the different clown fishes (*P. biaculeatus* and *A. clarkii*) in the experiment, *A. akallopisos* showed low growth rates and low survival rates when they were reared at 34 °C and gradually reduced when they were reared at 26 °C than the other clown fishes. Ye Le *et al.*[25], evidently showed that change of water temperature influenced larval survival and growth rates; the results from the present study also clearly states that, the water temperature influenced the juvenile fishes growth and survival rates. Thus, the growth potential is greater at higher water temperatures, providing that higher ingestion requirements are met to promote survival[9]. The present study clearly shows that increasing water temperature influences the growth and the survival rates of the clown fish (73.8% for *P. biaculeatus*, 70.3% for *A. clarkii* and 69.8% for *A. akallopisos* at 34 °C) .

However, in *A. melanopus*, larger juveniles reared at low temperature did not show better swimming ability than those smaller ones reared at the higher temperature[26]. High swimming performance are observed with the increase of water temperature (34 °C) and sluggish movements are observed when the clown fishes were reared in the low water temperature (26 °C). And this is very important for the juvenile survival, since it affects the prey capture[27,28].

The FCR of the fishes increased with water temperature increasing under the delimitation of diets and they have eventually decreased after reaching to maximum[29,30]. The present study also substantiates that FCR and SGR are increased with the increase of water temperature in all the experimental tanks, and FCR is significantly positively correlated with SGR ($P<0.05$). Thus, the present results also signify that FCR has significantly influence on growth of the juveniles of different species of clown fish. The adaptive methods which can regulates the fish capacity for utilization of feed for growth above a range of temperature was universally accepted[31].

Archosargus rhomboidalis and *Achirus lineatus* are some of the subtropical marine fish species which had less growth rates when they were reared under different temperatures[32]. The present study revealed that temperature has influenced the growth rates. Different clown fish in high temperature water show higher growth rates than that of *A. melanopus*[26], *Brevoortia tyrannus* and *Gadus morhua*[27].

The present study demonstrates that *P. biaculeatus*, *A. clarkii* and *A. akallopisos* can survive and grow over a wide range of temperatures. However, increased energy costs at high temperature will hinder growth if food is not abundant. The descriptive equations for feeding and growth predict that at a constant ration level across a range of temperature, growth would be higher at higher temperatures due to the increased conversion efficiency. Lower growth efficiency at 26 °C indicates that a juvenile would need to consume additional 5%-8% body weight per day comparing to fish at 34 °C to achieve similar growth. Although temperature effects appear small, they may have considerable impact on growth when integrated over the entire (90 d) juvenile period. The increase in consumption can only be met through increased time foraging, which possibley may not be realized since the avoidance of predators appears to be a stronger motivating force than the consequences of slower growth[33,34].

Findings of the present study also supports the studies done by Ronzani Cerqueir[28], and Fielder *et al*[14], who investigated that the temperature can also affect feeding efficiency of the juveniles by influencing processes such as metabolism, oxygen consumption, behavior, swimming speed and gut evacuation time.

This study suggests that the effect of temperature on growth and survival rates of different clown fish species (*P. biaculeatus*, *A. clarkii* and *A. akallopisos*) occurs in both tropical and temperate waters. It is important to note that this study has traditionalized the fact that high water temperature influenced the growth and survival rates of the clown fish juveniles. In spite of the limitations, temperature tolerance described herein should provide a base for future studies on clownfish and help in achieving conservation. It will be of great interest to compare the effect of temperature with more different species of clown fish from different latitude in future studies.

Conflict of interest statement

We declare that we have no conflict of interest.

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Comments

Background

Temperature, salinity, oxygen concentration, photoperiod and pH are environmental factors which are well known to have significant impacts on the performance of fish larvae and juveniles, such as survival, growth, feeding and metamorphosis.

Research frontiers

This report shows some new information on cultivation in marine science. It can be useful for further studies in this field.

Related reports

There are some relating reports. Ye Le *et al.* evidently showed that change of water temperature influenced larval survival and growth rates. Findings of the present study also supports the studies done by Ronzani Cerqueir, and Fielder *et al.*, who investigated that the temperature can also affect feeding efficiency of the juveniles by influencing processes such as metabolism, oxygen consumption, behavior, swimming speed and gut evacuation time.

Innovations and breakthroughs

There are some new information on the new method and data from evaluation of the potential effects of temperature on growth, survival and feeding of different clown fish juveniles. This can be further referenced in the future publication.

Applications

The work can be further applied in marine science and coastal medicine. The problem on the feeding of clown fish juveniles can be referenced to this article.

Peer review

This work has some new information on cultivation in marine science. The report on the feeding of clown fish juveniles can be further applied in marine science and coastal medicine. The experiment is standard and can be further useful for the followers in the field. This can be further referenced in the future publication.

References

[1] Chester AJ, Thayer, GW. Distribution of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) juveniles in segrass habitats of Western Florida Bay. *Bull Mar Sci* 1990; **46**: 345-357.

[2] Allman RJ, Grimes CB. Temporal and spatial dynamics of spawning, settlement, and growth of gray snapper (*Lutjanus griseus*) from the West Florida shelf as determined from otolith microstructures. *Fish Bull* 2002; **100**: 391-403.

[3] Nagelkerken I, Dorenbosch M, Verberk WCEP, de la Morinièr EC, van der Velde G. Importance of shallow-water biotopes of a Caribbean bay for juvenile coral reef fishes: patterns in biotope association, community structure and spatial distribution. *Mar Ecol Prog Ser* 2000; **202**: 175-192

[4] Fry FEJ. The effect of environmental factors on the physiology of fish. In: Hoar WS, Randall DJ, editors. *Fish physiology.* Vol. 6. New York: Academic Press; 1972, pp. 1-98.

[5] Peck MA, Buckley LJ. Measurements of larval Atlantic cod (*Gadus morhua*) routine metabolism: temperature effects, diel differences and individual-based modeling. *J Appl Ichthyol* 2008; **24**(2): 144-149.

[6] Rombough PJ. The effects of temperature on embryonic and larval development. In: Wood CM, McDonald DG, editors. *Global warming: implications for freshwater and marine fish.* Cambridge: Cambridge University Press; 1997, pp. 177-224.

[7] Houde, ED. Comparative growth, mortality, and energetics of marine fish larvae: temperature and implied latitudinal effects. *Fish Bull* 1989; **87**: 471-495.

[8] Martinez-Palacios CA, Barriga Tovar E, Taylor JF, Ríos Durán G, Ross LG. Effect of temperature on growth and survival of *Chirostoma estor estor*, Jordan 1879, monitored using a simple video technique for remote measurement of length and mass of larval and juvenile fishes. *Aquaculture* 2002; **209**: 369-377.

[9] Koumoundouros G, Divanach P, Anezaki L, Kentouri M. Temperature-induced ontogenetic plasticity in sea bass (*Dicentrarchus labrax*). *Mar Biol* 2001; **139**: 817-830.

[10] Koumoundouros G, Sfakianakis DG, Divanach P, Kentouri M. Effect of temperature on swimming performance of sea bass juveniles. *J Fish Biol* 2002; **60**(4): 923-932.

[11] Krishnamoorthy R, Syed Mohamed HE, Shahul Hameed P. Temperature effect on behavior, oxygen consumption, ammonia excretion and tolerance limit of the fish fingerlings of *Alepes djidaba*. *J Environ Sci Eng* 2008; **50**(3): 169-174.

[12] Beitinger TL, Bennett WA, McCauley RW. Temperature tolerance of

North American freshwater fishes exposed to dynamic change in temperature. *Environ Biol Fish* 2000; **58**: 237-275.

[13] Ellis SC, Watanabe WO, Ellis EP. Temperature effects on feed utilization and growth of postsettlement stage Nassau grouper. *Trans Am Fish Soc* 1997; **126**(2): 309-315.

[14] Fielder DS, Bardsley WJ, Allan GL, Pankhurst PM. The effects of salinity and temperature on growth and survival of Australian snapper, *Pagrus auratus* larvae. *Aquaculture* 2005; **250**(1-2): 201-214.

[15] Ajith Kumar TT, Gopi M, Dhaneesh KV, Vinoth R, Ghosh S, Balasubramanian T, *et al*. Hatchery production of the clownfish *Amphiprion nigripes* at Agatti Island, Lakshadweep, India. *J Environ Biol* 2012; **33**: 623-628.

[16] Dhaneesh K, Ajith Kumar T, Swagat G, Balasubramanian T. Breeding and mass scale rearing of clownfish *Amphiprion percula*: feeding and rearing in brackishwater. *Chin J Oceanol Limnol* 2012; **30**: 528-534.

[17] Arvedlund M, McCormick MI, Ainsworth T. Effects of photoperiod on growth of larvae and juveniles of the anemonefish *Amphiprion melanopus*. *Naga: the ICLARM quarterly* 2000; **23**(2): 18-23.

[18] Olivotto I, Capriotti F, Buttino I, Avella AM, Vitiello V, Maradonna F, *et al.* The use of harpacticoid copepods as live prey for *Amphiprion clarkii* larviculture: effects on larval survival and growth. *Aquaculture* 2008; **274**(2-4): 347-352.

[19] Abdel-Tawwab M, Abdel-Rahman AM, Ismael NEM. Evaluation of commercial live bakers' yeast, *Saccharomyces cerevisiae* as a growth and immunity promoter for Fry Nile tilapia, *Oreochromis niloticus* (L.) challenged in situ with *Aeromonas hydrophila*. *Aquaculture* **280**: 185-189.

[20] Ferron A, Leggett WC. An appraisal of condition measures for marine fish larvae. *Adv Mar Biol* 1994; **30**: 217-303.

[21] Benoît HP, Pepin P. Interaction of rearing temperature and maternal influence on egg development rates and larval size at hatch in yellowtail flounder (*Pleuronectes ferrugineus*). *Can J Fish Aquat Sci* 1999; **56**(5): 785-794.

[22] Björnsson B, Steinarsson A, Oddgeirsson M. Optimal temperature for growth and feed conversion of immature cod (*Gadus morhua* L.). *ICES J Mar Sci* 2001; **58**: 29-38.

[23] von Herbing Hunt I, Boutilier RG, Miyake T, Hall BK. Effects of temperature on morphological landmarks critical to growth and survival in larval Atlantic cod (*Gadus morhua*). *Mar Biol* 1996; **124**(4): 593-606.

[24] Miller TJ, Crowder LB, Rice JA, Marschall EA. Larval size and recruitment mechanisms in fishes: toward a conceptual framework. *Can J Fish Aquat Sci* 1988; **45**(9): 1657-1670.

[25] Zhang B, Sun Y, Tang QS. Gastric evacuation rate of fish and its influence factors. *Acta Ecol Sin* 2001; **21**(4): 665-670.

[26] Ye L, Yang SY, Zhu XM, Liu M, Lin JY, Wu KC. Effects of temperature on survival, development, growth and feeding of larvae of *Yellowtail clownfish Amphiprion clarkii* (Pisces: Perciformes). *Acta Ecol Sin* 2011; 31: 241-245.

[27] Green BS, Fisher R. Temperature influences swimming speed, growth and larval duration in coral reef fish larvae. *J Exp Mar Biol Ecol* 2004; **299**(1): 115-132.

[28] Fitzhugh GR, Nixon SW, Ahrenholz DW, Rice JA. Temperature effects on otolith microstructure and birth month estimation from otolith increment patterns in Atlantic menhaden. *Trans Am Fish Soc* 1997; 126(4): 579-593.

[29] Ronzani Cerqueira V. Food consumption of European seabass *Dicentrarchus labrax*, larvae reared at different water temperatures. In: Lavens P, Sorgeloos P, Jaspers E, Ollevier F, editors. Larvi '91-Fish and Crustacean larviculture symposium. (Special Publication, No. 15.). Gent, Belgium: European Aquaculture Society; 1991, p. 303-310.

[30] Buentello JA, Gatlin III DM, Neill WH. Effects of water temperature and dissolved oxygen on daily feed consumption feed utilization and growth of channel catfish (*Ictalurus punctatus*). *Aquaculture* 2000; **182**: 339-352.

[31] Sun L, Chen H. Effects of ration and temperature on growth fecal production, nitrogenous excretion and energy budget of juvenile cobia (*Rachycentron canadum*). *Aquaculture* 2009; **292**: 197-206.

[32] Cui Y, Wootton RJ. Bioenergetics of growth of a cyprinid *Phoxinus phoxinus* (L): the effect of ration and temperature on growth rate and efficiency. *J Fish Biol* 1988; **33**(5): 763-773.

[33] Houde ED. Effects of temperature and delayed feeding on growth and survival of larvae of three species of subtropical marine fishes. *Mar Biol* 1974; **26**(3): 271-285.

[34] Sogard SM. Use of suboptimal foraging habitats by fishes: consequences to growth and survival. In: Stouder DJ, Fresh KL, Feller RJ, editors. *Theory and application of fish feeding ecology.* Columbia, USA: Published for the Belle W. Baruch Institute for Marine Biology and Coastal Research by the University of South Carolina Press; 1994, p.103-132.