

Chapter 5

Nutrition and Temperature Regulate Rearing Performance of Golden Pompano *Trachinotus ovatus* Larvae



Qibin Yang, Gang Yu, Jian Guang Qin, and Zhenhua Ma

Abstract Nutrition and temperature are the primary factors affecting development of fish larvae during the early feeding stage. This chapter discusses how nutrient enhancement and ambient temperature affect the rearing performance of golden pompano *Trachinotus ovatus*. *Artemia* nauplii enriched with Algamac 3080 enhanced fish growth and reduced malformation. Fish fed *Artemia* nauplii enriched by *Nanochloropsis* achieved high survival but high jaw malformation. The water temperature of 26–29 °C enhanced growth and survival, while 23 °C was too low for both parameters. Jaw, vertebral column, and caudal vertebra deformity significantly increased at 33 °C. Therefore, the temperature range of 26–29 °C is optimal, and temperature >33 °C and <23 °C may have adverse impacts on fish performance. Information presented in this chapter will improve hatchery management on the production efficiency of golden pompano fingerlings. These findings may also apply to other similar species.

Keywords Nutrition · Temperature · Rearing performance · *Trachinotus ovatus*

5.1 Introduction

Malformation adversely impacts the market value of marine fish (Cobcroft and Battaglene 2009, 2013; Sandel et al. 2010; Ma et al. 2014c). Malformed fish are usually sold at a low price or manually removed during the production phase, thus significantly increasing the production cost (Koumoundourous et al. 1997). In addition, the deformation has adversely affected fish's growth and survival, food conversion, swimming ability, and susceptibility to stress and pathogens

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(Koumoundourous et al. 1997; Andrades et al. 1996; Boglione et al. 2001). Such impact can greatly add production cost on marine fish aquaculture. Existing evidence indicates that malformation during larval development occurs on over 27% of fish, leading to severe mortality at the grow-out phase (Andrades et al. 1996). Although the rearing environment (such as temperature, water current, tank color, salinity, dissolved oxygen) (Koumoundouros et al. 1999, 2001; Sfakianakis et al. 2004; Hattori et al. 2004; Okamoto et al. 2009; Georgakopoulou et al. 2010; Owen et al. 2012), genetic factors (Ferguson and Danzmann 1998; Castro et al. 2007), pesticides, and parasites (Liang et al. 2012; Kusuda and Sugiyama 1981; Liu et al. 2012) have been identified to be associated with boney malformation, and more and more evidence has indicated the nutritional factors in the process of larval fish rearing as a direct result of the deformation of the fish (Afonso et al. 2000; Andrades et al. 1996; Sandel et al. 2010; Cahu et al. 2003a).

In the past decades, the requirements of essential fatty acids in fish larvae have been widely studied (Izquierdo et al. 1992; Morais et al. 2007; Kjörsvik et al. 2009). The long-chain polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid 20:5n-3 (EPA), docosahexaenoic acid 22:6n-3 (DHA), and arachidonic acid 20:4n-6 (ARA) play critical roles in growth, survival, and stress resistance in most marine fish larvae (Watanabe 1993; Bell and Sargent 2003; Faulk and Holt 2003). As the essential fatty acids in marine fish larvae, the dietary requirements of EPA, DHA, and ARA have been well quantified in fish nutrition (Hamre et al. 2002; Bell and Sargent 2003; Faulk et al. 2005). DHA plays a vital role in neutral membrane structure and functions (Sargent et al. 1999a; Copeman et al. 2002), and its requirement differs among fish species (McEvoy et al. 1998; Planas and Cunha 1999; Copeman et al. 2002). The abundances of DHA and EPA in cell membranes serve as a major source of energy to absorb fat-soluble vitamins (A, D, E, and K) and as precursors for prostaglandin hormones (Sargent et al. 1999a, b; Rezek et al. 2010). The DHA/EPA ratio has been considered an index to determine the optimal levels for these fatty acids in the growth and development of fish larvae (Koven et al. 1993; Tocher et al. 1997; Rodriguez et al. 1998). Since a deficiency or excess of DHA and EPA in the diet can affect survival and malformation of fish larvae (Sargent et al. 1999b), it is necessary to provide an adequate amount of these essential fatty acids through dietary manipulation (Palmtag et al. 2006).

Temperature is vital for the larval fish early development, because it can adjust the fish metabolism and feeding behavior (Ma 2014; Kestemont and Baras 2001). In aquaculture, temperature directly influences the size of fish larvae at hatching, the age and size at yolk absorption, growth, survival, feeding, and digestion in fish larvae (Martinez-Palacios et al. 1996; Rombough 1996; Jobling 1997; Fielder et al. 2005; Bustos et al. 2007). Besides, several studies have demonstrated that high mortality and abnormality of fish larvae are attributed to inappropriate temperature (Ørnsrud et al. 2004; Lein et al. 1997; Ludwig and Lochmann 2009). Furthermore, the way yolk energy is utilized varies between incubation temperatures. In many species, if the temperature is higher than the optimal level, the size at the onset of exogenous feeding can be smaller than in other temperatures, thereby contributing to complication in larval fish rearing, especially in species with small larvae. Within the

temperature range of fish tolerance, the increase of temperature accelerates ontogenetic development, but a high temperature may reduce fish survival. At high temperature, yolk-sac absorption of fish larvae is fast, but the period of endogenous feeding is short (Dou et al. 2005; Bustos et al. 2007; Ma 2014). Therefore, choosing the appropriate temperature is essential to improve the growth and survival of fish larvae in hatcheries.

Golden pompano *Trachinotus ovatus* has been used as a new candidate species for aquaculture. Although the life cycle of golden pompano has been closed and several key aspects such as food and feeding, development of the larval digestive system, and the weaning protocols have been successfully explored (Ma et al. 2014a, b, d), high malformation of golden pompano during the early development stage has severely reduced the production efficiency (Ma et al. 2014c). Chapter 4 has identified the position, type, and frequency of skeletal and jaw malformations in hatchery rearing of larval golden pompano. Nonetheless, factors causing malformations are still unclear in this fish. This chapter discusses the nutritional enhancement and ambient temperature on the rearing performance of golden pompano under a hatchery culturing condition. These chapter results provide better understanding on how nutritional enhancement and temperature regulate larval fish development. This chapter contributes to developing management strategies to improve this fish and other similar species in the hatchery production efficiency.

5.2 Nutritional Enhancement Regulates Fish Growth and Survival

Feed of DHA and EPA in larval fish is vital for the growth of fish (Rezek et al. 2010). As dietary DHA levels increased, improved fish growth has been observed in striped jack *Caranx vinctus* (Takeuchi et al. 1996), yellowtail *Seriola quinqueradiata* (Furuita et al. 1996), and Japanese flounder *Paralichthys olivaceus* (Izquierdo et al. 1992). The growth response of fish larvae to different enrichment products varies among species. For instance, the larval growth of striped bass *Morone saxatilis* and gilthead seabream *Sparus aurata* is not affected by feeding *Artemia* nauplii enriched with Algamac 2000 or PL-Cr (DHA-rich phospholipid extract of *Cryptocodinium* sp.), but the growth of halibut *Hippoglossus hippoglossus* larvae fed *Artemia* nauplii enriched with DHA Seleco is slower than those fed with PL-Cr (Harel et al. 2002). In golden pompano, fish growth was enhanced when fish larvae were fed with *Artemia* nauplii enriched with Algamac 3080 or *Nannochloropsis* (Fig. 5.1). Fatty acid composition of enriched and unenriched *Artemia* nauplii is shown in Table 5.1.

Fish treated with Algamac 3080 had the best SGR, which is consistent with the higher dietary DHA levels in the treated live feed. As a sensitive growth and nutritional condition indicator (Islam and Tanaka 2005; Zehra and Khan 2013), the RNA/DNA ratio indicates that better growth performance occurred in the

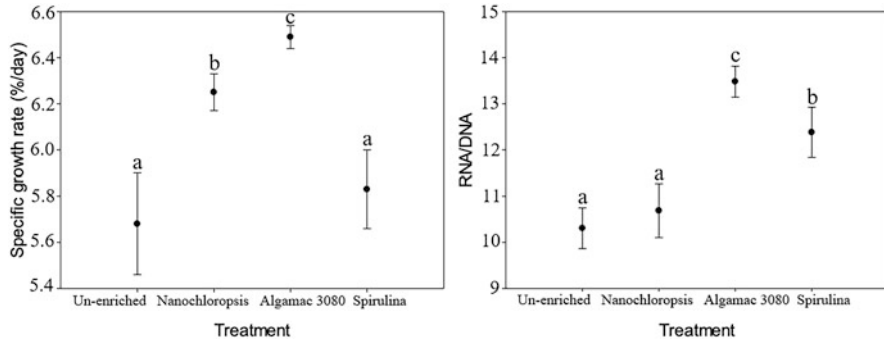


Fig. 5.1 Specific growth rate and RNA/DNA of golden pompano in different nutrient enhancements (Ma et al. 2016)

Table 5.1 Fatty acid composition (% of total fatty acids) of enriched and unenriched *Artemia* nauplii (Ma et al. 2016)

| | Unenriched | Nannochloropsis | Algamac 3080 | Spirulina |
|------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 14:0 | 1.14 ± 0.21 ^a | 0.80 ± 0.10 ^a | 1.18 ± 0.32 ^a | 0.94 ± 0.07 ^a |
| 16:0 | 16.71 ± 2.4 ^a | 12.13 ± 0.55 ^a | 18.74 ± 4.68 ^a | 13.46 ± 0.80 ^a |
| 16:1n-7 | 0.44 ± 0.05 ^b | 0.51 ± 0.09 ^c | 0.25 ± 0.24 ^a | 0.52 ± 0.01 ^c |
| 18:0 | 5.88 ± 0.52 ^{ab} | 6.12 ± 0.24 ^b | 6.42 ± 0.44 ^b | 5.1 ± 0.14 ^a |
| 18:1n-9 | 9.27 ± 0.74 ^a | 11.71 ± 0.72 ^b | 9.74 ± 1.48 ^b | 9.59 ± 0.32 ^{ab} |
| 18:1n-7 | 19.44 ± 2.1 ^a | 21.83 ± 1.75 ^a | 19.87 ± 1.55 ^a | 20.45 ± 0.19 ^a |
| 18:2n-6 | 2.62 ± 0.41 ^{ab} | 2.82 ± 0.30 ^{ab} | 2.01 ± 0.86 ^a | 3.74 ± 0.22 ^b |
| 18:3n-3 | 0.32 ± 0.11 ^a | 0.80 ± 0.45 ^{ab} | 0.32 ± 0.10 ^a | 0.91 ± 0.04 ^b |
| 20:1n-9 | 0.61 ± 0.04 ^b | 0.43 ± 0.03 ^a | 0.35 ± 0.20 ^a | 0.62 ± 0.09 ^b |
| 20:4n-6 (ARA) | 1.22 ± 0.10 ^{ab} | 1.16 ± 0.03 ^a | 1.30 ± 0.07 ^b | 1.10 ± 0.10 ^a |
| 20:5n-3 (EPA) | 6.28 ± 0.87 ^a | 8.49 ± 0.49 ^b | 7.23 ± 1.00 ^{ab} | 6.31 ± 0.46 ^a |
| 22:6n-3 (DHA) | 0.45 ± 0.06 ^a | 1.87 ± 0.08 ^b | 2.56 ± 0.31 ^c | 1.74 ± 0.24 ^b |
| DHA/EPA | 0.07 ± 0.00 ^a | 0.22 ± 0.02 ^b | 0.36 ± 0.09 ^c | 0.28 ± 0.06 ^b |
| EPA/ARA | 5.10 ± 0.31 ^a | 7.31 ± 0.23 ^b | 5.62 ± 1.07 ^a | 5.75 ± 0.10 ^a |
| DHA/ARA | 0.37 ± 0.02 ^a | 1.61 ± 0.11 ^b | 1.96 ± 0.13 ^b | 1.62 ± 0.37 ^b |
| Total n-3 | 7.05 ± 1.04 ^a | 11.16 ± 0.86 ^c | 10.11 ± 0.79 ^b | 8.96 ± 0.26 ^b |
| Total n-6 | 3.84 ± 0.05 ^{ab} | 3.98 ± 0.33 ^{ab} | 3.31 ± 0.79 ^a | 4.84 ± 0.32 ^b |
| Total n-7 | 19.88 ± 2.15 ^a | 22.35 ± 1.84 ^a | 20.11 ± 1.78 ^a | 20.97 ± 0.20 ^a |
| Total n-9 | 9.87 ± 0.70 ^a | 12.14 ± 0.75 ^b | 10.09 ± 1.28 ^a | 10.21 ± 0.23 ^a |
| Total saturated | 23.73 ± 3.13 ^a | 19.05 ± 0.22 ^a | 26.34 ± 5.44 ^a | 19.50 ± 0.73 ^a |
| Total poly unsaturated | 40.64 ± 4.39 ^a | 49.63 ± 3.78 ^a | 43.61 ± 4.63 ^a | 44.97 ± 0.60 ^a |

Different letters represent significant differences ($P < 0.05$)

treatment of Algamac 3080. However, the fish growth in the treatments of *Nannochloropsis* and *Spirulina* is not consistent with their RNA/DNA ratios and dietary DHA levels (Fig. 5.1). As Faulk et al. (2005) suggested, such inconsistency

may be possibly due to the difference in the protein content or amino acid profiles of live prey fed with different enrichment formulas.

Highly unsaturated fatty acids, especially DHA, EPA, and ARA, are necessary to marine fish growth, development, and survival (Cahu et al. 2003a; Sargent et al. 1999b; Rezek et al. 2010). In order to develop lipid-enriched food of fish larvae, the requirements of essential fatty acids of fish larvae have been extensively researched by using live bait enriched with different oils and micronutrients, and the aim is to enhance the content of essential fatty acids of live bait (Takeuchi 1997; Sargent et al. 1997; Izquierdo et al. 2000). However, excessive content of lipid or unbalanced composition of lipid classes leads to low growth and skeletal malformation in species such as gilthead seabream *Sparus aurata* (Salhi et al. 1999), Atlantic cod *Gadus morhua* (Kjørsvik et al. 2009), yellowtail kingfish *Seriola lalandi* (Ma and Qin 2014), and Atlantic halibut *Hippoglossus hippoglossus* (Olsen et al. 2000). Enrichment did not change the DHA/ARA ratio, but *Artemia* nauplii enriched with Algamac 3080 resulted in a higher DHA/EPA ratio (0.36:1, Table 5.1). The high DHA/EPA ratio treated with Algamac 3080 resulted in rapid growth but low survival. In contrast, the unenriched and *Nannochloropsis* treatments showed better survival where the DHA/EPA ratio was 0.07:1–0.22:1. Low fish survival rate of Algamac 3080 treatment supports the claim of a previous study that a high DHA/EPA ratio and a high DHA content may reduce the survival of larval fish (Planas and Cunha 1999) as the composition of unbalanced lipid classes in the diet affects the digestion and absorption of fatty acids in fish larvae (Salhi et al. 1997, 1999).

5.3 Malformation

Skeletal malformation on fish in marine aquaculture is a recurrent issue (Ma and Qin 2014; Ma et al. 2014c), and skeletal malformation negatively affects fish quality in commercial production via suppressing fish growth and survival (Andrades et al. 1996; Boglione et al. 2001). The abnormalities in fish larvae can have sublethal (Barahona-Fernandes 1982; Cobcroft et al. 2001) or lethal effects on fish larvae (Boglione et al. 2013) as the distorted mouth shape would affect the efficiency of food ingestion (Pittman et al. 1989), while notochord anomalies in newly hatched larvae can severely affect fish swimming (Boglione et al. 2013). Jaw malformations are a common type of skeletal malformation, and there are many different forms (Cobcroft et al. 2001) that have been frequently found in both wild-caught and artificially reared marine fish (Boglione et al. 2001). Izquierdo et al. (2010) believed that PUFA play a key role in bone formation, and the composition of fatty acid composition in bone and cartilage can also be affected by dietary lipids (Watkins et al. 1997; Kokkinos et al. 1993; Liu et al. 2004). As the dietary lipids are primarily from live feeds, enrichment on live feeds may affect jaw malformation. In golden pompano, enrichment significantly affected jaw malformation. Fish fed *Artemia* nauplii enriched with Algamac 3080 or *Spirulina* showed two times lower in jaw

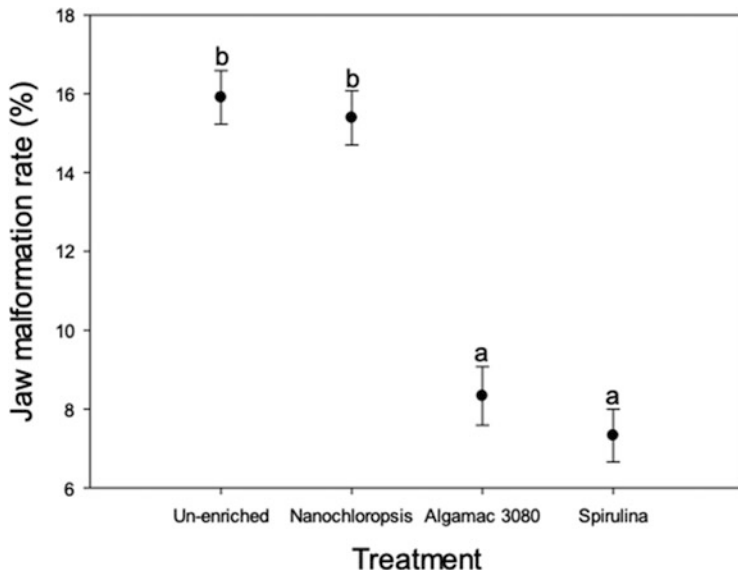


Fig. 5.2 Jaw malformation of golden pompano fed with *Artemia* nauplii enriched with different nutrient enhancement (Ma et al. 2016)

malformation than those fed unenriched *Artemia* nauplii or *Artemia* nauplii enriched with *Nannochloropsis* (Fig. 5.2). The results of low jaw malformation treated by Algamac 3080 and *Spirulina* may indicate that such nutrient enrichment is sufficient to meet the needs of jaw development during this stage.

Up to present, the relationship between the deficiency of essential fatty acids and the development of skeletal anomalies is poorly understood (Bogliione et al. 2013).

Hamre et al. (2002) suggest that insufficient intake of n-3 HUFA in *Artemia* nauplii may cause abnormal development of fish larvae. Recent evidence has demonstrated that fatty acids, such as EPA, DHA, and ARA, play a key role in the development of bone.

For example, a 50% reduction in deformed fish was found in diet supplement with higher levels of DHA (Izquierdo et al. 2010), and changes in dietary ARA/EPA may indirectly affect osteoblast development and bone metabolism (Berge et al. 2009). In golden pompano, skeletal malformation was improved in the treatment of Algamac 3080, and this result is in line with high levels of DHA in feed. The results of this study indicate that 2.56% DHA level may be suitable for the larval golden pompano's skeletal development. Vertebral column malformation and caudal complex malformation are the most frequently reported body deformity in commercially cultured species (Negm et al. 2013). Up to present, little is known on the causes triggering the deformity in the caudal complex (Haga et al. 2011). In the literature, vertebral deformities are often associated with swim bladder abnormality (Daoulas et al. 1991; Chatain 1994), but vitamin A deficiency can also induce vertebral column deformities (Negm et al. 2013). In golden pompano, the highest vertebral

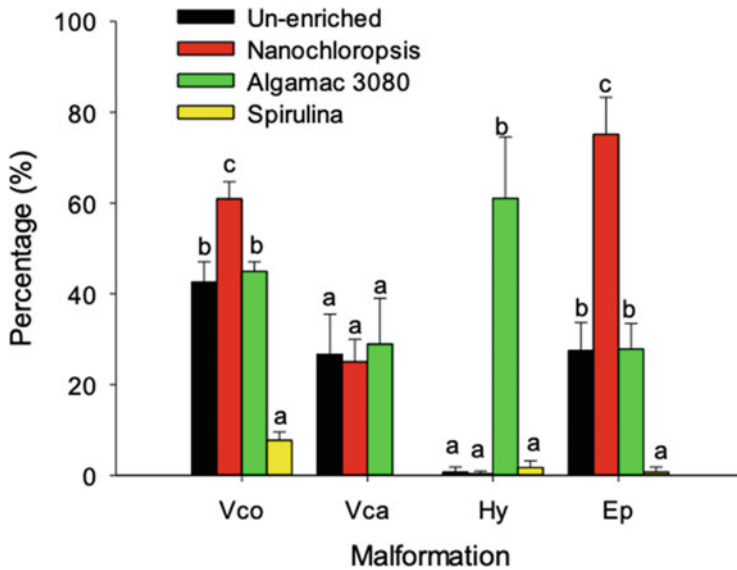


Fig. 5.3 The vertebral column (Vco), caudal vertebra (Vca), hypural (Hy), and epural (Ep) malformations and vertebral malformation of larval golden pompano of four enrichment treatments on 27 DPH (Ma et al. 2016)

column (Vco) malformation (60.9%) and epural (Ep) malformation (75.1%) were observed in the fish fed *Artemia* enriched with *Nannochloropsis*, and the lowest Vco malformation (7.7%) and Ep malformation (0.7%) were found in the treatment of *Spirulina* enrichment. Significantly higher hypural malformation (61.0%) was observed in the treatment of Algamac 3080 enrichment than in other treatments (Fig. 5.3). This result may suggest that nutrient enhancement in *Artemia* nauplii affects vertebral deformities, and the impact of nutritional components in *Artemia* nauplii on larval fish development warrants further study in future.

5.4 Temperature Affects Fish Performance

Temperature affects fish growth, metabolism, and food intake, and the effects of temperature on body growth have been recorded in many larval fish species including nase *Chondrostoma nasus* (Keckeis et al. 2001), striped trumpeter *Latris lineata* (Choa et al. 2010), haddock *Melanogrammus aeglefinus* (Martell et al. 2005), Australian snapper *Pagrus auratus* (Fielder et al. 2005), yellowtail kingfish *Seriola lalandi* (Ma 2014), and Atlantic halibut *Hippoglossus hippoglossus* (Lein et al. 1997). In golden pompano, the newly hatched golden pompano grow slowly in the first 9 days. After 12 DPH, the size of the different temperature treatment of fish larvae of differences began to emerge. Temperature has an effect on fish growth on

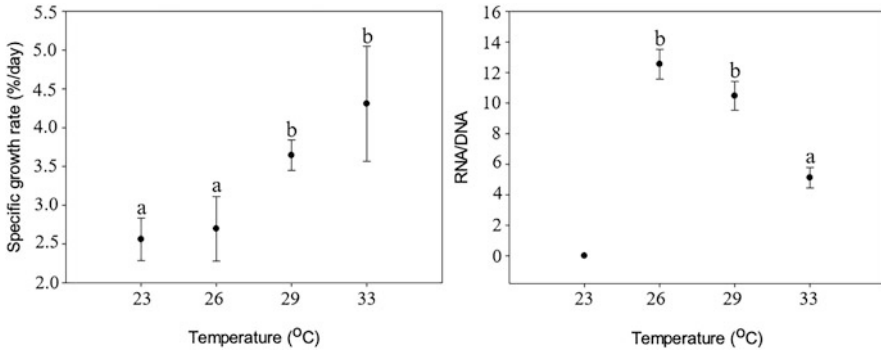


Fig. 5.4 Specific growth rate of standard length and RNA/DNA ratio of golden pompano larvae reared at 23, 26, 29, and 33 °C (Yang et al. 2016)

18 DPH, which accelerates when the temperature increases from 29 to 33 °C (Fig. 5.4).

The rapid growth of golden pompano at high temperature may be related to the improvement of larval feeding and digestive function after 15 DPH, as Ma et al. (2014b) found that the gastric glands and goblet cells appeared in the intestines of larval golden pompano after 15 DPH at the temperature of 27–29 °C. As the Florida pompano *Trachinotus carolinus* (Riley et al. 2009), the mouth gape height of 1.05 mm should allow larval golden pompano to ingest *Artemia* nauplii and other similar particle sizes by 12 DPH.

Therefore, the significant differences in fish size between thermal treatments after 18 DPH may be also related to the use of more energetic food from 9 DPH onward. Riley et al. (2009) found that the growth trajectories of *T. carolinus* could vary substantially between progenies, with some progenies exhibiting slower growth and others much faster growth.

The RNA/DNA ratio has been proven as a sensitive indicator of growth and nutritional condition in fish larvae and juveniles (Buckley et al. 1999; Islam and Tanaka 2005; Zehra and Khan 2013). Previous studies have demonstrated that water temperature and food availability can affect the RNA/DNA ratio of fish larvae (Goolish et al. 1984; Mathers et al. 1992). In golden pompano, the RNA/DNA ratio of fish significantly dropped when temperature increased from 29 to 33 °C at 18 DPH (Fig. 5.4). Reduction in RNA/DNA ratio can be regarded as a result of nutrient deficiency in fish larvae (Tanaka et al. 2008). The reduction of RNA to DNA ratio of fish at 33 °C may indicate a slow growth status of fish larvae at 18 DPH. At the end of this study, the high SGR of a few larger fish may be due to cannibalism. However, the reason for the lower RNA/DNA ratio at 33 °C is not clear.

Fish mortality frequently occurs at the key period of nutritional transition from endogenous to exogenous nutrition (Ma et al. 2012; Otterlei et al. 1999). During the period of transitional feed, when food supply and photoperiod are within the range of fish requirements, the temperature can strongly impact fish survival (Gardeur et al. 2007; McGurk 1984; Kamler 1992; Ma 2014). For instance, mortality is closely

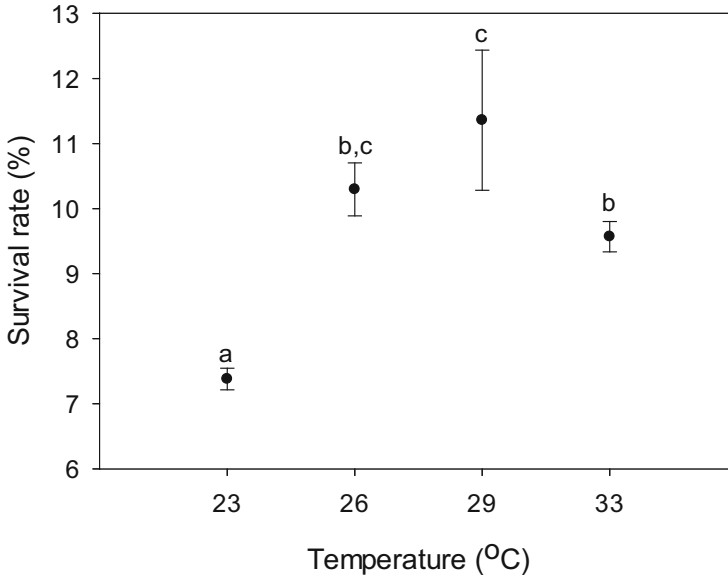


Fig. 5.5 Survival rate of golden pompano larvae at 23, 26, 29, and 33 °C (Yang et al. 2016). (The letters of “temperature” in the *x*-axis is crowding)

related to temperature in the larvae and juveniles of *Pangasianodon hypophthalmus* (Baras et al. 2011), *Seriola lalandi* (Ma 2014), *Glyptocephalus cynoglossus* (Bidwell and Howell 2001), and *Inimicus japonicus* (Wen et al. 2013). Ma (2014) suggests a temperature-sensitive period where mortality is likely to occur during the early ontogeny of golden pompano. In golden pompano, survivals of fish larvae were low in all the temperature treatments (Fig. 5.5). There could be many reasons why survival rates were so low, including egg quality, the inadequacy of feeding schedules, or cannibalism (May 1974; Baras and Jobling 2002; Baras et al. 2011; Ma et al. 2012). Nevertheless, there is some clear-cut tendency here that the survival of golden was highest at 29 °C and declined at lower or warmer temperatures, with 23 °C being unsuitable for their rearing.

As one of the primary physical factors, the water temperature can affect early morphological abnormalities during the ontogenetic development of fish larvae (Seikai et al. 1980, 1986; Klimogianni et al. 2004). Evidence indicates that high water temperature can increase the percentage of malformation during the ontogenetic development in fish species such as tilapia *Oreochromis mossambicus* (Wang and Tsai 2000), Senegalese sole *Solea senegalensis* (Dionisio et al. 2012), and gilthead seabream *Sparus aurata* (Georgakopoulou et al. 2010). The present study demonstrates a significant temperature effect on the vertebral column and caudal vertebra malformation in golden pompano. This result is consistent with similar findings in *Dicentrarchus labrax* (Sfakianakis et al. 2006). In golden pompano, temperature associated abnormality in the vertebral column of the larval golden pompano was the most prevalent malformation (Fig. 5.6). Additionally, the

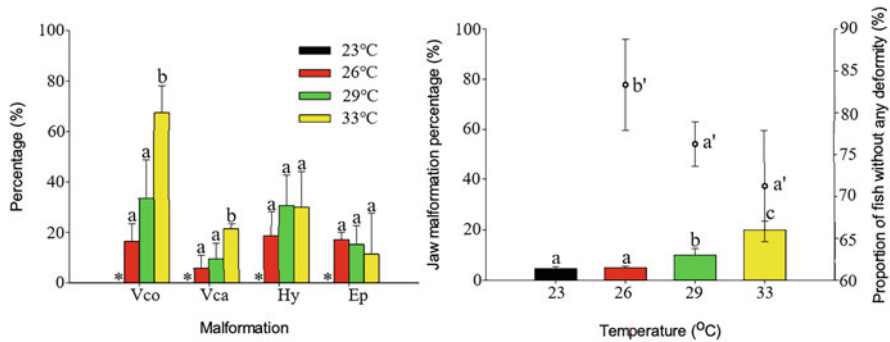


Fig. 5.6 Malformation of golden pompano larvae reared at 23, 26, 29, and 33 °C. *Vco* the vertebral column malformation, *Vca* caudal vertebra malformation, *Hy* hypural malformation, *Ep* epural malformation (Yang et al. 2016). You should indicate the meaning of bar diagram and scattered diagram (i.e., jaw malformation vs. without deformity) in the right diagram

V-shaped malformation accounted for >50% of the whole deformations. A previous study indicates that the absence of swim bladder or its malfunction could account for over 50% of V-shaped deformations in fish (Daoulas et al. 1991). Hemal lordosis can also result from the exposure to high flow velocities (Divanach et al. 1997) or turbulent flows (Kihara et al. 2002; Kranenbarg et al. 2005). In the present study, deformities frequently occurred at all temperatures, suggesting that other factors may also prevail in the present study causing deformity. Future research is required to further identify these factors.

The caudal fin complex is one of the most sensitive parts of the skeletal system in fish, and deformities can occur even in the range of normal rearing temperature (Takeuchi et al. 1998; Haga et al. 2002, 2011). Rates of deformities can increase with increasing temperature, but this is not consistent in gilthead seabream *Sparus aurata* (Fernández et al. 2008; Georgakopoulou et al. 2010). In golden pompano, however, the proportion of fish with deformed caudal fin complex did not vary significantly with water temperature (Fig. 5.6). Jaw malformation is a significant concern in fish culture because it affects fingerling quality (Von Westernhagen 1988). Frequently, as the temperature of water rises, the proportion of larval fish exhibiting jaw deformities increases (Alderdice and Velsen 1971; von Westernhagen 1974; Bolla and Holmefjord 1988; Lein et al. 1997), and we observed the same pattern in golden pompano. This temperature-dependent pattern is often attributed to higher oxygen (Rombough 1997) and nutritional requirements at high temperatures, which may not be met unless feed with higher energy or protein contents is provided (Cahu et al. 2003a, b; Ma 2014).

5.5 Conclusion

In summary, *Artemia* nauplii enriched with Algamac 3080 can enhance fish growth performance and reduce malformation. Fish fed *Artemia* nauplii enriched with *Nanochloropsis* showed high survival but with high jaw malformation. Nutritional enhancement in *Artemia* nauplii can significantly affect the performance of golden pompano larvae. The water temperature of 26–29 °C enhanced growth and survival, while 23 °C was too low for both. The deformity of the jaw, vertebral column, and caudal vertebra significantly increased at 33 °C. Therefore, the temperature range of 26–29 °C is optimal, and temperature >33 °C and <23 °C may have adverse impacts on fish performance. Future study should focus on refining the optimum dietary enrichment and rearing temperature in golden pompano larvae to improve growth and survival and decrease boney malformation of fish larvae.

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