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Editorial

New Strategies to Increase Fish Larval Physiological Responses against Changes in Water Temperature

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Aquaculture is probably the fastest-growing food-producing sector, accounting for nearly 50 percent of the world's food fish. However, efforts are needed to improve efficiency and to assure the sustainability of the aquaculture sector. Climate change is now considered a challenge to the global food chain and a major threat to fish production [1]. The increase in global temperature will affect offshore and inland aquaculture production, testing the resilience of domesticated fish species. Temperature plays a critical role in the growth and development of aquatic animals [2]. As ectotherms, fish may particularly be sensitive to temperature variations. Increasing temperatures affect fish physiology and behavior through chronic stress and increases in metabolic demands, in addition to having an evident impact on nutrient utilization and growth [3,4].

Aquaculture production output relies, to a high degree, on larviculture efficiency. In marine hatcheries, high mortalities are normally observed in larval stages in optimized farming conditions (70–80%), thus affecting fish production. The consequences and implications of variations in those conditions, such as an increase in temperature, are an important challenge for the future. Thus, understanding the mechanisms that control early development and growth and their relationship with abiotic factors is critical for the identification of strategies promoting climate-resilient adaptations from early stages.

In hearing larvae (*Clupea harengus*), elevated temperatures significantly affected the larval growth and swimming kinematics. Larvae reared at the highest temperature showed the lowest growth. This is probably because increasing temperature reduces the conversion of energy to somatic growth by increasing metabolic demand. Concomitantly, swimming behavior was also affected by temperature owing to changes in growth rates (i.e., larger larvae swim faster) [5]. For common sole (*Solea solea*), a flatfish species with a strong metamorphosis during the larval stage, temperature promoted growth, since metamorphosis at 19 °C started earlier than at 16 °C. However, by the end of metamorphosis, larvae from the 19 °C treatment were shorter and presented incidences of metamorphosis defects compared with those reared at lower temperatures [6]. Similarly, for gilthead seabream (*Sparus aurata*), exposure to high temperatures during early development led to lower fish swimming performance and promoted upper-jaw abnormalities [7].

Since all the results described above present potential threats to aquaculture efficiency and product quality, exploring how to promote climate-resilient adaptations in farmed fish is a key strategy for helping to attain food security under changing environmental conditions. The dietary inclusion of additives with high biological activity may enhance the growth performance and welfare of farmed fish species. The inclusion of grape seed extract in diets for Senegalese sole (*Solea senegalensis*) promoted the activity of antioxidant enzymes and decreased oxidative damage after thermal acute stress [8]. A protective role against thermal stress has been also described for dietary taurine. For heat stress, taurine supplementation led to increased HSP70 gene expression levels and C4 complement levels in tiger puffer (*Takifugu rubripes*) [9], while improved growth performance, oxidative system, and innate immunity of olive flounder (*Paralichthys olivaceus*) and pufferfish (*Takifugu obscurus*) were observed under low-temperature stress [10,11]. Other dietary interventions, such as modification in the concentration of specific macronutrients, may play an important

Citation: Navarro-Guillén, C. New Strategies to Increase Fish Larval Physiological Responses against Changes in Water Temperature. *Fishes* **2023**, *8*, 299. https://doi.org/10.3390/fishes8060299

Received: 24 May 2023
Accepted: 31 May 2023
Published: 3 June 2023

protective role and improve the thermal resilience of aquaculture species. For example, in barramundi (*Lates calcarifer*), a high-fat diet increases juvenile growth, while, by contrast, it reduces fish tolerance to extreme water temperatures [12]. On the other hand, in sea bass (*Dicentrarchus labrax*), feeding a high-fat diet to fish acclimatized to warmer waters has been established as good practice for improving growth [13]. Although the abovementioned studies boost aquaculture resilience to cope with challenging temperatures, most of them were performed on juveniles. To improve production output, studies are also needed on larvae.

New effective strategies promoting fish robustness and resilience from early developmental stages are needed to enable the development of resilient food production systems and ensure sustainable food security in the face of climate change.

Funding: CN-G was supported by the researcher contract DOC_01203 funded by the Andalusian Plan for Research Development and Innovation (PAIDI 2020).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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