

Feeding method also alters social behavior and risk responses. In juvenile seabream, hand-feeding improved body weight relative to self-demand feeding, while self-demand systems appeared to reinforce social hierarchy and competitiveness for resources within the group. Behavioral responses to rearing conditions are also density dependent but not always linear, because zebrafish held at the lowest density showed more aggression and higher cortisol than fish at intermediate or high density, even though high-density fish had lower and more variable growth rates (Sarma et al., 2023). This suggests that behavioral adaptation in aquaculture involves balancing social stress at both extremes: overly sparse groups can destabilize social interactions, whereas overly crowded groups can suppress feeding performance and increase competition, making intermediate density and predictable feeding especially important for sea bass welfare.

7.3 Nutritional physiology and energy allocation trade-offs

Nutritional physiology in farmed fish reflects a trade-off between growth, maintenance, and the metabolic capacity to cope with environmental challenge. Longitudinal data across teleosts show that faster ontogenetic growth is positively associated with standard metabolic scaling but negatively associated with aerobic scope, indicating that accelerated growth can reduce the metabolic margin available for functions beyond maintenance. A broader ecophysiological analysis in salmonids identified a similar dominant trade-off between high growth and consumption on one side and high aerobic scope and active metabolism on the other. In farming terms, systems that maximize growth through high ration and frequent feeding may therefore also narrow the physiological buffer available for activity, hypoxia tolerance, or other stress responses.

These trade-offs become more visible under intensive farming conditions that alter oxygen demand and energy partitioning. In high-density seabream, elevated swimming activity and respiration were accompanied by reduced energy partitioning for growth and impaired FCR, showing that more energy was diverted toward activity and coping functions rather than tissue deposition (Holhorea et al., 2023). Experimental and comparative work also shows that nutrient use depends on balancing intake with metabolic demand: protein synthesis requires both amino acids and energy, while absorbed protein and energy are under-utilized when their ratio is mismatched (Konnert et al., 2022). For *L. maculatus*, this means that feeding management should be evaluated together with farming system effects on density, oxygen, and activity, because the same diet can support either efficient growth or costly stress compensation depending on the rearing environment.

8 Case Study: Comparative Evaluation of Pond vs. Cage vs. RAS Systems in Commercial Chinese Sea Bass Farming

8.1 System design and operational characteristics

Commercial Chinese sea bass production is still centered on pond and marine net-cage culture, with pond farming especially established in the Bai Jiao area of Guangdong and cage farming concentrated in sheltered coastal waters such as Fujian (Huang et al., 2025). Pond systems are relatively simple and locally adapted, but they remain open to environmental fluctuation and disease-related microbial shifts, as shown by clear bacterial community differences between low- and high-mortality sea bass ponds (Deng et al., 2021). In contrast, cage systems use large open-water production units that increasingly approach industrial scale, and performance can change substantially with cage volume rather than density alone.

RAS differs from both pond and cage farming by replacing natural water exchange with engineered purification and near-continuous environmental control. Integrated land-based RAS can combine recirculating ponds with a primary biological pond, constructed wetlands, and ecological ditches, creating a managed treatment train rather than a single grow-out unit. Indoor RAS is also less exposed to rainfall, drought, salinity fluctuation, and other climatic disturbances than ponds or cages, although this operational stability comes with higher capital cost, higher energy demand, and greater design complexity (Ahmed and Turchini, 2021). For commercial Chinese sea bass farming, the core design trade-off is therefore between the low infrastructure burden of ponds, the spatial efficiency of cages, and the environmental controllability of RAS (Figure 2).