Asian Sea Bass, *Lates calcarifer*

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**Introduction**

Asian sea bass (*Lates calcarifer*), also known as ‘baramundi’, is a primarily carnivorous finfish widely distributed in the tropical and subtropical areas of the western Pacific and Indian Ocean countries (Greenwood, 1976). Its natural habitat ranges between longitude 50° E and 160° E and latitude 24° N and 25° S. Under natural conditions, its life cycle is biphasic, involving an initial growth period of 2–3 years in the inland fresh waters and a subsequent migration into the sea for sexual maturation and spawning. The attributes of being adaptable to a wide range of water salinity and turbidity probably make sea bass a suitable species for culture under captive conditions.

Sea bass has been cultivated in both brackish-water and freshwater ponds as well as in marine cages. However, a gradual acclimatization of fry to new salinity is necessary. The cage culture remains the preferred system over that of the pond system. Floating or stationary types of cages may be used. The most common and manageable size of floating cage is 50 m\(^3\) (5 m × 5 m with a depth of 2 m). Initial stocking density ranges from 40 to 50 fish m\(^{-3}\). Cannibalism is one of the serious problems encountered during early stages of sea-bass culture. This may be related to the uniform size of the fry and heavy stocking density.

In the Asian Pacific region, Malaysia, Indonesia, Taiwan and Thailand remain the leading countries involved in commercial sea-bass production, with Hong Kong, Singapore and Australia also playing an important role. The difficulty in obtaining approval from the government to establish cages in the Great Barrier Reef Marine Park is a constraint in Australia. Large-scale sea-bass culture has become popular only recently. In Thailand, for example, the first successful spawning and seed production were achieved in 1975, whereas sea-bass farming in Australia began around 1986. Since then, Australia has recorded a rather rapid and continuing increase in sea-bass production. The production in Australia increased from around 22 Mt in 1988 (Lobegeiger and Barlow, 1991).
to 310 Mt in 1996 (FAO, 1998) and is projected to reach 2000 Mt by the year 2005. In contrast, the rate of increase in sea-bass production in Taiwan, Thailand, Malaysia and Indonesia seems to have plateaued. The annual sea-bass production in these countries in 1994 was around 8800, 4000, 2700 and 2400 Mt, whereas in 1996 it was 7000, 3800, 2400 and 1700 Mt, respectively (FAO, 1998). The decrease in production in these countries during the 2-year period seems to be related to a rather limited market demand and relatively low prices. Therefore, future expansion of sea-bass culture will depend on market forces and whether culture technologies can be improved to sustain farm profitability in the face of reducing operating margins.

**Nutrient Requirements**

**Protein and amino acids**

A relatively high dietary protein level may be suggested for sea bass since the fish is primarily a carnivore under natural conditions. Sakaras *et al.* (1988) estimated the dietary crude protein (CP) requirement of juvenile sea bass to be 50%. The research from the same laboratory subsequently showed that the highest growth rate was achieved with a dietary level of 45% CP (Sakaras *et al.*, 1989). The optimal dietary protein level for grow-out sea bass has been reported to range between 40 and 45% (Wong and Chou, 1989). Few studies have been conducted to determine the essential amino acid requirements of sea bass. Coloso *et al.* (1993) reported the tryptophan requirement of juvenile sea bass to be 0.5% of dietary protein. The requirements for methionine, lysine and arginine have been determined to be 2.24, 4.5–5.2 and 3.8% of dietary protein, respectively (Millamena, 1994; Rimmer *et al.*, 1998). Additionally, Boonyaratpalin *et al.* (1990) found that an excessive concentration of tyrosine in the sea-bass diet may result in kidney malfunction. Clearly, much work needs to be done to understand the dietary amino acid concentrations and their interrelationships necessary for optimum sea-bass performance.

**Energy**

Catacutan and Coloso (1995) reported that sea bass can grow adequately on a diet containing 42.5% CP with an estimated protein-to-digestible energy (DE) ratio of about 30.7 mg CP kJ⁻¹ DE, which corresponds to 25.2 mg CP kJ⁻¹ gross energy (GE) or 27.1 mg digestible protein (DP) kJ⁻¹ DE. Williams and Barlow (1999) demonstrated that a diet containing 42% DP and 15.5 kJ DE g⁻¹ provided optimal feed conversion ratio (FCR) and nitrogen retention. They suggested an optimal DP : DE ratio of 26.7 mg kJ⁻¹ or a CP : GE ratio of 24.5 mg kJ⁻¹. These data agree with the CP : GE value of 25.8 mg kJ⁻¹ and 25.2 mg kJ⁻¹ reported by Tubongbanua (1987) and Catacutan and Coloso (1995), respectively. In a more recent work, Williams *et al.* (1999) showed that 55% CP and 20 kJ DE g⁻¹ were
necessary to realize the growth potential of juvenile sea bass. These results indicate that diets with relatively high protein and energy density can support a higher rate of fish growth compared with that achieved by using standard diets containing 45% CP and 15.5 kJ DE g\(^{-1}\).

**Lipid and fatty acids**

Sakaras *et al.* (1988, 1989) showed that the optimum dietary lipid level for sea-bass fingerlings is between 15 and 18%. Tucker *et al.* (1988) found that when 9–62 g sea bass were fed diets containing 9.3 and 12.9% fat, growth was similar but the FCR was significantly lower with the 12.9% fat diet. Borlongan and Parazo (1991) found that growth and survival of sea-bass fry fed a diet containing 9% supplemented lipid comprising 4.5% cod-liver oil and 4.5% soybean oil were higher compared with those fed cod-liver oil alone or soybean oil alone. In addition, the performance of the fry decreased when these dietary lipid sources were replaced with coconut oil and the poorest performance was observed when the diet contained no lipid supplement. These researchers also reported that the fatty acid profiles of the fry were influenced by the fatty acid composition of the dietary lipid.

Wanakowat *et al.* (1993) fed sea-bass fingerlings with diets containing 13% lipid and graded levels of n-3 highly unsaturated fatty acids (HUFA). They observed signs of essential fatty acid (EFA) deficiency after 2 weeks when the n-3 HUFA dietary level was 0.46%. Signs of mild EFA deficiency were also observed in fish fed a diet containing 0.88% n-3 HUFA and no such signs were detected in fish fed a diet containing 1.72% n-3 HUFA. The diet with the highest level of n-3 HUFA also gave the best performance in terms of growth. Early EFA deficiency signs were characterized as reddening of the fins and skin, which was followed by abnormal appearance of eyes, loss of appetite, poor growth and swollen and pale livers. Wanakowat *et al.* (1993) also fed sea bass six diets comprising fish-meal and casein with levels of n-3 HUFA ranging from 1 to 2% of the diet for a 10-week period. Levels of n-3 HUFA in the diets were adjusted using graded levels of squid liver oil. They observed no significant difference in growth, feed efficiency or mortality. Neither did they detect any signs of EFA deficiency. The results obtained by Wanakowat *et al.* (1993) indicate that dietary n-3 HUFA levels of 1% are adequate. Dhert *et al.* (1990) showed that the n-3 HUFA deficiency in sea-bass larvae led to a delayed metamorphosis or a complete lack of metamorphosis as well as a decreased tolerance to stress caused by a high salinity of 65 p.p.t. Rimmer *et al.* (1994) reported that 20 : 5n-3 is required by 20-day-old sea-bass larvae for survival. Ambient water temperature appears to influence EFA requirement and ratios. Williams *et al.* (1999) demonstrated that sea-bass growth was poor and unaffected by EFA dietary level at 20°C. At a water temperature of 29°C, however, the growth responded linearly with an increasing dietary ratio of n-3 : n-6 (0.58 : 1 to 2.24 : 1). The researchers recommended an n-3 : n-6 ratio of about 1.5–1.7 : 1 and a dietary level of...
eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) of about 1.8% for juvenile sea bass.

**Carbohydrates**

Most fish have a limited capacity to assimilate and metabolize dietary carbohydrate (Cowey, 1988). Since the natural food of sea bass is high in protein, it is assumed that they utilize carbohydrate poorly. Catacutan and Coloso (1997) found that carbohydrate has a sparing effect for lipid as an energy source in practical diets for juvenile sea bass. They recommended a dietary carbohydrate level of 20% for diets containing lipid levels ranging from 6 to 18% and 42.5% CP. Carbohydrates are useful not only as a source of energy but also as a binder for pelleted feeds.

**Vitamins and minerals**

The vitamin requirements for sea bass have been established for young fish by supplementing both practical and semipurified diets with various levels of a specific vitamin. The addition of a vitamin mix to trash fish fed to sea-bass fingerlings increased body weight from 9.36 to 23.48 g and reduced the FCR from 7.44 to 3.83 during a 9-week rearing period (Phromkhuntong et al., 1987). These requirements are based on dietary levels that support maximum growth or tissue storage and prevent deficiency signs. No differences in weight gain, feed efficiency and mortality were observed when sea bass were fed practical diets without the addition of choline, niacin, inositol or vitamin E (Boonyaratpalin et al., 1988) and pyridoxine or pantothenic acid (Pimoljinda and Boonyaratpalin, 1989). Poor weight gain and feed efficiency were observed in fish fed diets without supplemental thiamine and riboflavin after 60 days (Pimoljinda and Boonyaratpalin, 1989).

In a study using semipurified diets, Wanakowat et al. (1989) demonstrated that 5 mg kg\(^{-1}\) of pyridoxine was required for normal growth, whereas 10 mg kg\(^{-1}\) was needed for normal lymphocyte levels. Boonyaratpalin and Wanakowat (1993) fed sea bass with semipurified diets deficient in several vitamins for 10 weeks and found that thiamine, pantothenic acid, inositol and vitamin E were essential for fish growth. The requirement of pantothenic acid for juvenile sea bass (3–30 g) was determined by Boonyaratpalin et al. (1994b) using semipurified diets containing 0, 15, 30, 60 and 90 mg kg\(^{-1}\) of calcium D-pantothenate. Growth ceased after 2 weeks in fish fed diets without supplemental calcium D-pantothenate and total mortality occurred within 6 weeks. The authors estimated the pantothenic acid requirement to be 15 mg kg\(^{-1}\) diet for normal growth, feed efficiency and survival. However, highest tissue storage was found to occur at a level of 90 mg kg\(^{-1}\) diet. Whether the tissue storage level continues to increase at dietary levels of calcium D-pantothenate higher than 90 mg kg\(^{-1}\) diet is not known since the highest level of this vitamin tested was 90 mg kg\(^{-1}\) diet.
The vitamin C requirement of sea-bass fingerlings was determined in a series of studies by Boonyaratpalin et al. (1989a,b, 1994a). The results indicated that the dietary level of L-ascorbic acid required for normal growth ranged from 500 to 700 mg kg\(^{-1}\) and a supplemental level of 1100 mg kg\(^{-1}\) was required for normal tissue storage. Fish fed diets without added ascorbic acid had normal growth rates for about 15 days. Thereafter, growth decreased and deficiency signs developed. Severe mortality occurred after 45 days and all vitamin C-deficient fish died within 60 days. However, with a stable form of vitamin C, such as ascorbyl-2-monophosphate-magnesium (Mg), a supplementation level of 30 mg kg\(^{-1}\) diet was sufficient for normal growth and prevention of deficiency signs. The bioavailability of other stable forms of vitamin C derivatives continues to be a subject of investigation. Also, the role of ascorbic acid in the disease resistance and immunocompetence of sea bass remains unclear to date. The dietary requirements for various vitamins with their respective signs of deficiency in sea bass are summarized in Table 3.1.

As sea bass do not readily accept purified diets, mineral requirements have not been adequately evaluated. Neither have the mechanisms that are involved in mineral absorption, utilization and homoeostasis been adequately defined. Boonyaratpalin and Phongmaneerat (1990) supplemented fish-meal-based diets with 0, 0.5, 1.0 and 2.0% monosodium phosphate and showed that the growth of sea bass fed a diet with 0.5% monosodium phosphate supplementation was superior to the growth of fish fed diets with higher phosphate levels. However, they found that 1.0% monosodium phosphate supplementation gave the best feed efficiency and protein efficiency ratio. They estimated the dietary available phosphorus requirement of sea bass to be about 0.55–0.65%. Growth rate and bone mineralization were not affected by feeding sea bass on a low-ash fish-meal diet that contained no additional phosphorus (Chaimongkol, 1998). Furthermore, utilization of other minerals was not compromised on this diet. Supplementation of the diet with 0.25% monosodium phosphate did result in higher bone concentrations of phosphorus and zinc. Zinc absorption in fish fed low-ash diet was significantly higher than those fed a high-ash diet.

**Practical Diets**

A potential difficulty in determining the digestibility of a feed ingredient for an aquatic animal is obtaining faeces samples that are unaffected by nutrient leaching or contamination. Table 3.2 summarizes the apparent digestibility of ingredients commonly used in sea-bass diets. The protein and energy digestibility of meals of marine origin is high and generally higher than meals of terrestrial ingredients. An exception to this is wheat gluten, which is found to be almost completely digestible. Digestibility of meat meal is lower than that of fish-meal, probably owing to its high ash content. Chaimongkol (1998) reported that digestibility of protein as well as absorption of calcium, magnesium, zinc and phosphorus decreased with increasing dietary ash. Variable ash concentration in meat meals also make their digestibility quite variable. The relatively low digestibility...
of ingredients of plant origin is probably a result of the presence of indigestible fibre. Variability in digestibility of oil-seed meals is sometimes related to their inadequate processing and the presence of antinutritional factors. It appears that, similar to other carnivorous fish, sea bass is able to digest well a variety of feed ingredients of terrestrial origin (Hajen et al., 1993; Gomes et al., 1995; Gaylord and Gatin, 1996).

As world supplies of fish-meal are becoming limited, research continues to evaluate the usefulness of terrestrial feed ingredients as substitutes for fish-meal. Pongmaneerat and Boonyaratpalin (1995) found that a mixture of soybean meal and maize-gluten meal at a ratio of 5 : 3 could replace 25% of fish-meal protein in

<table>
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<th>Table 3.1. Vitamin requirements and deficiency signs for sea bass (from Boonyaratpalin et al., 1989a,b, 1993, 1994a,b; Wanakowat et al., 1989; Boonyaratpalin and Wanakowat, 1993).</th>
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<tbody>
<tr>
<td><strong>Vitamins</strong></td>
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<tr>
<td>Thiamine</td>
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<tr>
<td>Riboflavin</td>
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<td>Pyridoxine</td>
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<tr>
<td>Pantothenic acid</td>
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<tr>
<td>Nicotinic acid</td>
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<td>Biotin</td>
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<td>Choline</td>
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<td>Vitamin E</td>
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<td>Vitamin K</td>
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* For maximum tissue storage.
† For crystalline ascorbic acid.
‡ For ascorbyl-2-monophosphate-Mg or ascorbic acid glucose.
R, required but quantitative requirement not established; n/a, no information available.

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the diet of juvenile sea bass without any adverse effects on performance. Similarly, Boonyaratpalin et al. (1998) have shown that nearly 37% of protein from fish-meal in sea-bass diet can be replaced with solvent-extracted soybean meal without compromising their performance. It was also demonstrated that soaked raw soybean was a relatively poor protein source for sea bass and extruded full-fat soybean meal was found to be less palatable for juvenile sea bass. Cuzon and Thouarde (1993) showed that diets containing 22% greaves meal supported good growth of sea bass. They found lipid infiltration of the liver cell but no other pathology was evident.

Williams et al. (1999) determined growth rate and nitrogen retention in sea bass subsequent to incremental replacement of up to 70% of nutritionally adequate summit diet with soybean meal, casein, dehulled lupins and meat meal. Nitrogen retention was more adversely affected by lupins and soybean meal than by casein and meat-meal inclusions. These results show the superior nutritional value of animal sources over the vegetable sources and their potential as replacements of fish-meal in practical diets of juvenile sea bass. Williams et al. (1993) also showed that meat meal could replace all of the fish-meal in sea-bass diet without causing any deleterious effects on growth, efficiency of feed utilization or eating quality of the fish. Williams and Barlow (1999) demonstrated that a mixture of meat meal and spray-dried blood meal at a ratio of 5.5 : 1 can be used to replace all fish-meal in grow-out sea-bass diets without altering growth, FCR or survival.

Despite investigations to explore alternative diet ingredients, practical sea-bass diets in South-East Asia remain primarily composed of trash fish made into moist pellets. In contrast, sea bass cultured in Australia are reared entirely on dry pelleted diets. Some examples of commonly used sea-bass diets are provided below. Each of these diets has its own advantages and farmers may select one, taking into account price, availability, acceptability and performance.

<table>
<thead>
<tr>
<th>Feed ingredient</th>
<th>Protein</th>
<th>Energy</th>
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<tr>
<td>Danish fish-meal</td>
<td>87.9 ± 1.0</td>
<td>83.3 ± 1.3</td>
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<tr>
<td>Tuna fish-meal</td>
<td>92.3 ± 1.0</td>
<td>69.3 ± 1.3</td>
</tr>
<tr>
<td>Poultry offal meal</td>
<td>78.8 ± 3.5</td>
<td>76.7 ± 5.6</td>
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<tr>
<td>Meat meal (high ash)</td>
<td>53.9 ± 3.9</td>
<td>58.2 ± 6.5</td>
</tr>
<tr>
<td>Meat meal (low ash)</td>
<td>63.5 ± 3.4</td>
<td>66.5 ± 3.4</td>
</tr>
<tr>
<td>Soybean meal (full-fat)</td>
<td>84.8 ± 3.8</td>
<td>75.9 ± 7.8</td>
</tr>
<tr>
<td>Soybean meal (solvent-extracted)</td>
<td>86.0 ± 0.8</td>
<td>69.4 ± 1.7</td>
</tr>
<tr>
<td>Canola meal</td>
<td>81.0 ± 2.3</td>
<td>56.1 ± 3.0</td>
</tr>
<tr>
<td>Lupin meal (dehulled)</td>
<td>98.1 ± 1.3</td>
<td>61.5 ± 1.8</td>
</tr>
<tr>
<td>Groundnut meal</td>
<td>91.9 ± 8.0</td>
<td>68.7 ± 5.0</td>
</tr>
<tr>
<td>Wheat-gluten meal</td>
<td>101.9 ± 1.6</td>
<td>98.8 ± 3.1</td>
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* Mean ± standard error. Data derived from faeces collected either by hand-stripping or by intestinal dissection.
1. A moist weaning diet is made by adding vitamins to minced fish flesh. It is fed to fry (25 days old) as a weaning diet, the larvae being typically fed twice daily to satiation.

2. Crumbled pelleted diets that are dust-free and uniform in size may be used in conjunction with a moist weaning diet to facilitate the change-over to a dry diet. The size of the crumbs is increased as the fry grow. Crumbled shrimp diets top-dressed with 8–10% fish-oil are also used for fry.

3. Moist pellets are usually prepared at the farm site using a mincer by mixing a meal-form formulated diet and minced trash fish at a ratio of 1 : 1. The moist diet is made daily and fed on the same day. The formulated powder comprises a mixture of fish-meal, grains or grain by-products, vitamin and mineral premixes and fish-oil.

4. Another form of moist-pellet diet is prepared at the farm site by mixing a meal-formulated diet with fresh water at a ratio of 10 : 4.

5. Floating or slowly sinking extruded dry pellets are also used. In Australia extruded pellets are fed twice a day for fish weighing 20–100 g and once daily for fish larger than 100 g. These diets typically contain about 50% protein and 20% lipid.

6. Brood-stock diet is usually comprised of fresh or frozen trash fish fed at about 2% of body weight, three times a week. Vitamin and fish-oil supplements are usually added to the baitfish prior to feeding the brood-stock. In Thailand, sardine and yellowstripe are commonly used for the same purpose.

References


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