Silver Perch, *Bidyanus bidyanus*

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Geoff L. Allan[1] and Stuart J. Rowland[2]
[1]New South Wales (NSW) Fisheries, Port Stephens Fisheries Centre, Taylors Beach, NSW 2316, Australia; [2]NSW Fisheries, Grafton Aquaculture Centre (GAC), Grafton, NSW 2460, Australia

Introduction

Silver perch, *Bidyanus bidyanus* (Mitchell) (Teraponidae) is a freshwater, temperate fish, endemic to the Murray–Darling river system west of the Great Dividing Range in south-eastern Australia. It is a schooling, omnivorous fish that feeds naturally on zooplankton, insects, crustaceans, molluscs, small fish and some aquatic plants, in particular filamentous algae. Silver perch is an attractive, small-scaled, laterally compressed fish with premium-quality white flesh, a mild, delicate flavour, a fine texture, few bones and about 40% meat recovery. A recent study of over 200 Australian seafood products found that farmed silver perch had the third highest levels of fatty acids beneficial to human health (Nichols *et al.*, 1998).

Hatchery techniques, based on hormone-induced spawning and extensive pond rearing of larvae, were developed in the early 1980s (Rowland *et al.*, 1983; Rowland, 1984) and up to 5 million fingerlings are produced annually for aquaculture, stock enhancement and conservation purposes. However, it was not until the early 1990s that research into the grow-out of silver perch commenced at the New South Wales (NSW) Fisheries' Grafton Aquaculture Centre (GAC), Australia (29° 41′ S; 152° 56′ E). The research demonstrated that silver perch is an excellent species for semi-intensive or intensive culture in earthen ponds. High survival rates (> 90%) and fast growth rates from fingerlings (2–5 g fish^{-1} day^{-1}) to market-size (~500 g), at high stocking densities (20,000 fish ha^{-1}), have routinely produced high production rates of around 10 t ha^{-1} year^{-1} in static, aerated, 0.1 ha earthen ponds (Rowland, 1995a; Rowland *et al.*, 1995).

Most silver perch cultured commercially are grown in static, aerated, earthen ponds that range in surface area from 0.1 to 0.5 ha. Recent research suggests that cages may also be suitable for culture. A three-phase production strategy is recommended for this species: I, hatchery; II, fingerling; III, grow-out (Rowland, 1995b). This strategy is usually combined with a single-batch system, where

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each pond only has fish of the same age or batch, which are totally harvested before the next batch is stocked. Fry (30 mm, 0.5 g) become available from hatcheries in mid- to late summer (January to February), and are stocked at densities up to 150,000 fish ha^{-1} in fingerling ponds for 3 or 4 months. The fingerlings are then harvested, graded and stocked at a density of 10,000–30,000 ha^{-1} for grow-out. The grow-out phase takes 10–18 months, depending on the temperature regime, to reach market size (400–800 g). Fish and ponds are closely managed because of the intensity of production. Major water-quality variables (temperature, dissolved oxygen, pH and ammonia) are monitored every 2–3 days. Fish are sampled monthly to estimate the mean weight and biomass, and the daily ration is adjusted accordingly. Sampled fish are checked for disease; there are no major disease problems in the industry at present. Fish are harvested using seine nets on most farms, and are placed live in clean water for 7 days to purge off-flavours and to ensure a uniform, high-quality product. Silver perch are sold live, principally into Asian communities, or whole chilled with prices ranging from A$7 to A$15 kg^{-1}. The industry is expected to have a large processing component in the future.

Although the silver perch farming industry is currently in its infancy, it has great potential for growth. Australia has limited wild fisheries, most of which are fully or overexploited, and approximately 70% of the white-fleshed finfish consumed is imported. There are abundant sites with high-quality water available for aquaculture and freshwater effluent is easily managed, making possible environmentally sound practices with no release of effluent to natural waterways. Considerable opportunities exist for the integration of silver-perch culture with established agricultural industries, especially where irrigation is used.

Silver perch are farmed predominantly in the states of NSW and Queensland, with small quantities also produced in Victoria, South Australia and Western Australia. Only 2.6 t were farmed in NSW in 1992/93, but production is now increasing rapidly as more farms are constructed and farming practices improve. The established culture techniques, the availability of sites and the premium quality of the product provide a basis for a dramatic increase in production over the next 5–10 years, which is predicted to exceed 1000 t by 2005. There is also much interest in the culture of silver perch in other countries – especially in the People's Republic of China, Taiwan and Israel. Fingerlings and broodfish have been exported to these countries from some hatcheries in Australia.

Nutrient Requirements

Protein and energy

Early research indicated that protein requirements of silver perch were similar to those reported for other omnivores, such as channel catfish, and lower than those reported for carnivores (Allan and Rowland, 1991; Allan *et al.*, 1994). Protein efficiency ratios increased with increasing digestible energy (DE) (in the range

12–15 MJ kg^{-1}) and tended to decrease with increasing digestible protein (in the range 25–45%) (Allan *et al.*, 1994). Harpaz *et al.* (1999) reported increased growth of 3 g silver perch fingerlings when fed 41% protein diets compared with the growth of fish fed 23% protein diets. Although gross energy was similar for Harpaz *et al.*'s diets, the DE content of the 23% protein diet was much lower than that of the 45% protein diet. Unfortunately, such differences in the DE content of experimental diets have confounded interpretation of this and other experiments that have tried to estimate the protein requirements of silver perch and other fish species.

Protein and energy need to be kept in balance (NRC, 1993). Research with pigs and poultry has led to the development of the concept of two phases in protein deposition: a protein-dependent phase and an energy-dependent phase. At a constant energy content, protein deposition will increase with increasing protein intake until a plateau is reached, after which there will be no response to increasing protein intake. At a higher energy intake, protein deposition will increase with a higher protein intake (Bikker, 1994).

A study was conducted at our laboratory to estimate requirements of silver perch for digestible protein using isocaloric diets (14 MJ of DE kg^{-1}) made using practical ingredients (fish-meal, maize gluten, peanut meal, wheat, wheat starch and fish-oil) with varying protein contents (11–40% digestible protein). Fish were fed to satiation. The minimum dietary protein content before growth was retarded was 28% (Fig. 25.1; Allan *et al.*, 2001).

The optimum protein requirements for juvenile silver perch at three different DE contents were also evaluated. Using similar methods to those described above, but with three series of diets, each with a different DE content, and with fish fed at about 90% of satiation level, protein retention efficiency was plotted against digestible dietary protein for each series of diets. Results indicate that optimum

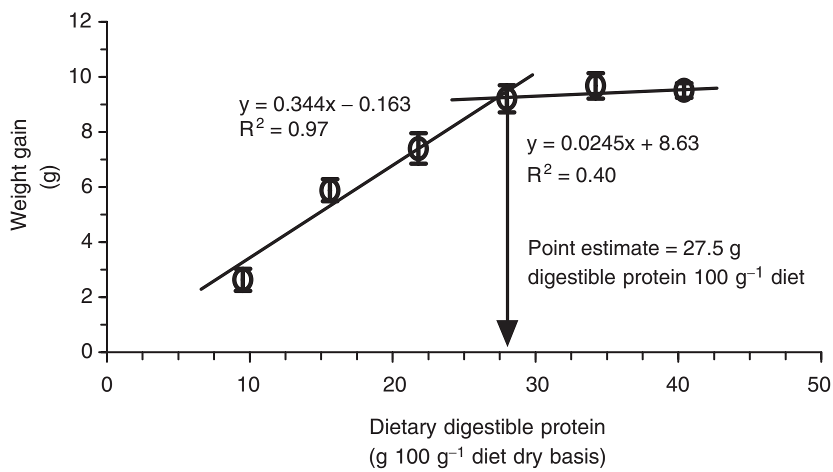

Fig. 25.1. Effect of dietary digestible protein content and a digestible energy content of 14 MJ kg^{-1} on individual weight gain of juvenile silver perch. Error bars indicate standard error of mean (SEM).

digestible protein requirements were 25% for diets with 12–14 MJ of DE kg^{-1}, 26% for diets with 14–16 MJ of DE kg^{-1} and 29% for diets with 16–17 MJ of DE kg^{-1} (G.L. Allan, unpublished data).

Requirements of protein and energy for maintenance were estimated by feeding juvenile silver perch restricted rations (approximately 90% of satiation) of a nutritionally adequate reference diet or diets with different substitution levels of an inert filler (diatomaceous earth). Using this approach, Booth *et al.* (2000a) estimated requirements of protein and energy for maintenance as approximately 2.1 g digestible protein kg^{-1} body weight day^{-1} and 116 kJ of DE kg^{-1} body weight day^{-1}. These amounts were slightly higher than those estimated for some other species (Lupatsch *et al.*, 1998), possibly because in the study by Booth *et al.* (2000a) fish were still expending energy for feeding activity, whereas in the other studies maintenance requirements were estimated by progressively reducing food intake, thereby also reducing feeding activity.

Protein is made up of 20 α-amino acids linked into chains by peptide bonds (NRC, 1993). The protein supplied to fish must contain sufficient quantities of the amino acids that fish cannot synthesize (there are ten of these essential amino acids) to provide for tissue protein synthesis.

The most common method for estimating amino acid requirements involves making a series of diets using an intact protein (e.g. casein plus gelatin) plus a mixture of crystalline amino acids. Graded amounts of the amino acid under investigation are supplied in the crystalline amino acid mix to give a series of diets. The total protein content of the crystalline amino acid mix is balanced in the series of diets using non-essential amino acids. Ngamsnae *et al.* (1999) used this method to estimate requirements of silver perch for arginine and phenylalanine and then estimated the requirements for each of the other indispensable amino acids by multiplying the requirement for arginine by the content of each amino acid (as a proportion of total amino acids) (see Table 25.1).

Growth rates of fish fed diets composed of purified sources of protein plus mixtures of crystalline amino acids are usually inferior to those of fish fed diets based on intact, practical protein sources, probably due to a relatively poor utilization of crystalline amino acids and purified protein sources (Nose and Murai, 1990; NRC, 1993; Cowey, 1994; Ngamsnae *et al.*, 1999). Allan *et al.* (2001) reported that, for diets with 14 MJ of DE kg^{-1}, requirements for essential amino acids could not be as high as those reported by Ngamsnae *et al.* (1999) because the growth of fish did not increase when additional amino acids were added past the contents in the 28% protein diet (see Fig. 25.1). They suggested that the amino acid content of the 28% protein diet could be considered as 'recommended values' for diets at 14 MJ of DE kg^{-1} (Table 25.1).

Lipids and fatty acids

Dietary lipids are an important source of energy and essential fatty acids and help with the absorption of fat-soluble vitamins (NRC, 1993). The DE content of

Table 25.1. Requirements and 'recommended' values of essential amino acids (% of diet) for juvenile silver perch.

Amino acid	Estimated requirements*	Recommended values†
Arginine	2.7	1.9
Histidine	1.0	0.7
Isoleucine	1.8	1.1
Leucine	3.6	2.0
Lysine	3.7	1.5
Methionine	1.5	0.6
Phenylalanine	2.2	1.2
Threonine	2.8	1.0
Valine	2.3	1.3
Tryptophan‡		

* Ngamsnae *et al.* (1999) estimated requirements of juvenile silver perch after fish were fed diets based on casein and gelatin plus a mixture of crystalline amino acids with graded contents of crystalline arginine or phenylalanine.
† Allan *et al.* (2001) fed juvenile silver perch diets with 14 MJ of DE kg^{-1} but graded digestible protein contents, all from intact protein sources rather than crystalline amino acids. The amino acid contents of the lowest-protein diet where growth or protein deposition was not retarded (28% protein diet – see Fig. 25.1) have been listed as the 'recommended' amino acid content for practical diets (digestible protein level 28% – see Fig. 25.1).
‡ Tryptophan was not measured in either study.

fish-oil and lard fed to silver perch was determined as described by Allan *et al.* (1999) (with revised calculations for ingredient digestibility recommended by Sugiura *et al.* (1998)). Digestibility coefficients and DE contents were 92% and 36 MJ of DE kg^{-1} for cod-liver oil and 52% and 21 MJ of DE kg^{-1} for lard. Practical diets for silver perch typically contain 6–10% crude lipid.

Anderson and Arthington (1989) measured the deposition of fatty acids in silver perch fed a soybean meal-based diet. They found that fatty acids accumulated in both the depot lipids and the phospholipids of the fish. When fish were transferred on to a fat-free diet, the preferential incorporation of both arachidonic (20:4n-6) and docosahexaenoic (22:6n-3) acids into the phospholipids during lipid turnover led the authors to conclude that silver perch require both n-3 and n-6 series fatty acids.

Silver perch were able to chain elongate and desaturate dietary linoleic acid (LA) (18:2n-6) and linolenic acid (LNA) (18:3n-3) to their longer-chain metabolites (Anderson and Arthington, 1992). This is in agreement with Hunter (2000), who found that silver perch require both LA and LNA and can chain-elongate and desaturate LA and LNA into their longer-chain polyunsaturated fatty acids. However, as growth was enhanced by the addition of longer-chain n-3 fatty acids to the diet, the conversion process alone is inadequate to optimize growth performance.

Dietary lipid has a major impact on fish lipid content (Buckley and Groves, 1979; Shearer, 1994). Measurement of lipid and fatty acid composition of whole silver perch and fillets confirms this and indicates that the fatty acid profile of farmed fish is strongly influenced by dietary lipid source (Hunter *et al.*, 1994, 2000). The whole-body lipid content of cultured silver perch is relatively high and increases with size. For silver perch grown in different experiments but all on the same diet (SP35–35% crude protein, 14–15 MJ of DE kg^{-1}), carcass contents were 24.6% lipid (dry basis) and 75.1% moisture for 2 g fish; 33.9% and 68.0% for 6 g fish; 41.9% and 59.7% for 72 g fish; and 50.9% and 58.8% for 395 g fish (Allan *et al.*, 2000b; Hunter, 2000; Stone *et al.*, 2000). Indicative fatty acid contents of farmed silver perch are listed in Table 25.2.

Hunter *et al.* (1994) reported that, for juvenile silver perch fed diets with protein contents ranging from 25 to 45% and 10.6 to 14.6 MJ of DE kg^{-1}, there was an inverse linear relationship between dietary protein : energy content and fish-fillet lipid content.

Carbohydrates

Although fish have no requirement for carbohydrate, provision of some carbohydrate is important in formulated diets to facilitate pellet binding, and to provide an alternative, lower-cost energy source to spare protein and/or lipid (Lovell, 1989; NRC, 1993). One of the most noticeable differences between diets for different warm-water fish species is that omnivores (e.g. channel catfish, common carp and tilapia) tend to be fed less protein in their diets than strictly carnivorous species (e.g. Asian sea bass = barramundi, gilt-head sea bream and red drum) (Wilson, 1991). However, as the overall protein composition of different fish species (especially on a lipid-free basis) does not vary greatly and net protein retention rates are similar (NRC, 1993), it is likely that this difference reflects the ability of different species to digest and utilize carbohydrate for energy.

One approach to investigating whether a species can tolerate different types or amounts of carbohydrate is to measure the uptake and clearance rates of carbohydrates (e.g. glucose) following intraperitoneal injection. Figure 25.2 shows the uptake and clearance rates of glucose for silver perch and barramundi, demonstrating that silver perch are more efficient at initial uptake and clearance of glucose than barramundi (A.J. Anderson, Z.S. Lipovsek and D.A.J. Stone, unpublished data; D.A.J. Stone, G.L. Allen and A.J. Anderson, unpublished data). Silver perch were also better able to utilize galactose than barramundi but both species were xylose-intolerant (A.J. Anderson, Z.S. Lipovsek and D.A.J. Stone, unpublished data; D.A.J. Stone, G.L. Allen and A.J. Anderson, unpublished data).

Unpublished data from our laboratory indicate that silver perch can efficiently digest diets containing 30% wheat starch, regardless of the degree of gelatinization, without adverse effects on liver enlargement, as indicated by the hepatosomatic index (HIS). However, when starch content was increased to 60%,

Table 25.2. Fatty acid composition of various sizes of silver perch (% of total fatty acids).

Fatty acid	Juvenile fish 2 g*	6 g*	72 g†	Adult fish (~ 500 g)‡
C12:0	0.1	0.1	Nm	Nm
C14:0	3.0	3.6	2.9	3.7
C15:0	0.2	0.3	0.2	Nm
C16:0	24.7	28.3	28.2	24.6
C17:0	0.3	0.2	Tr	Nm
C18:0	4.3	4.6	3.9	3.6
C20:0	0.2	0.1	Nd	Nm
C22:0	0.1	Tr	Nm	Nm
C14:1	0.1	0.1	Nm	Nm
C16:1	8.9	8.3	8.2	12.3
C17:1	0.2	Tr	Nd	Nm
C18:1n-9	27.5	32.0	34.6	31.5
C18:1n-7	2.2	2.2	1.9	2.5
C20:1n-11	0.1	0.6	0.2	Nm
C20:1n-9	0.8	2.7	1.4	1.1
C20:1n-12	Nm	Nm	Nm	0.7
C22:1n-11	0.2	1.6	1.0	Nm
C22:1n-9	0.1	0.3	Nm	Nm
C24:1n-9	0.4	0.4	Nm	Nm
C18:2n-6	9.3	7.3	8.2	7.7
C18:2n-9	Nm	Nm	Nm	0.8
C18:3n-6	0.9	0.4	0.5	Nm
C20:2n-6	0.3	0.2	Tr	Nm
C20:3n-6	0.7	0.3	0.2	Nm
C20:4n-6	0.6	0.2	Tr	Nm
C18:3n-3	1.2	0.7	0.9	1.0
C18:4n-3	0.6	0.5	0.5	Nm
C20:4n-3	0.4	0.3	Nm	Nm
C20:5n-3	2.1	0.8	1.5	1.8
C22:3n-3	0.2	Tr	Nm	Nm
C22:5n-3	1.8	0.6	1.2	1.8
C22:6n-3	5.8	2.3	4.6	6.3

* Ground whole fish (results are means for *n* = 4 fish) (Hunter, 2000).
† Ground, head-off, gutted fish (results are means for *n* = 4 fish) (Hunter *et al.*, 2000).
‡ Skinless fillets (results are means for *n* = 4 fillets) (B.J. Hunter, personal communication).
Tr, trace; Nd, not detected; Nm, not measured.

digestibility was positively correlated with the degree of gelatinization and HIS was elevated. Digestibility coefficients of various carbohydrate sources by silver perch and barramundi are presented in Table 25.3. The experimental diets were the same for both species but faeces of silver perch were collected by settlement

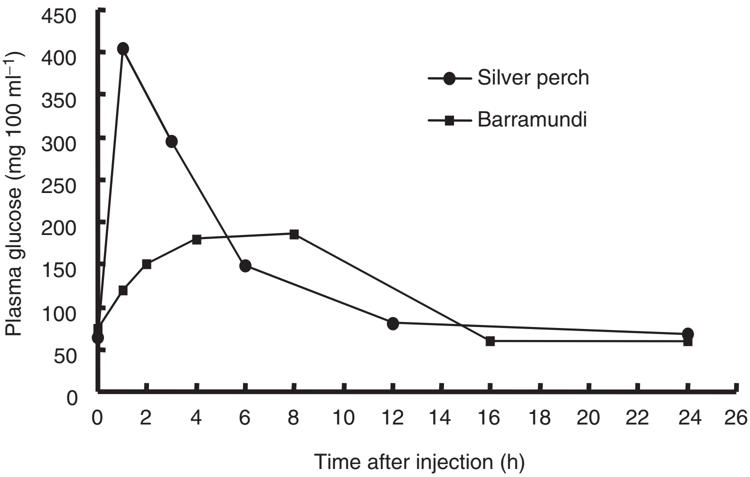

Fig. 25.2. Plasma glucose levels of silver perch and barramundi following an intraperitoneal injection of glucose (dose rate = 0.1% body weight).

Table 25.3. Apparent digestibility coefficients (%) for different carbohydrate sources for silver perch and barramundi (all ingredients were included at 30% with a basal diet of fish-meal 80.2%, wheat gluten 10%, fish oil 7%, vitamins and minerals 27%) (D.A.J. Stone, G.L. Allan and A.J. Anderson, unpublished data).

Starch/ingredient	Silver perch	Barramundi
Pea starch	75.1	39.6
Wheat starch	82.7	7.6
Pregelatinized wheat starch	95.2	–6.5
Dextrin (9%)	97.6	78.4
Dextrin (17%)	95.5	56.2
Dextrin (30%)	97.7	62.4
Maltose	98.4	59.0
Glucose	99.5	40.0

(Allan *et al.*, 1999), while those of barramundi were collected by stripping. Although this difference may have led to an overestimation of digestibility for silver perch and/or an underestimation for barramundi, previous results for protein-rich ingredients have been in much closer agreement (Williams *et al.*, 1998), indicating that the differences reflect differences between the species.

Vitamins and minerals

No research has been conducted on vitamin or mineral requirements for silver perch. The vitamin and mineral mixes used in experimental and commercial diets

Table 25.4. Recommended vitamin and mineral mixes in experimental and some commercial silver-perch diets.

Vitamin*	IU kg^{-1} diet*	mg kg^{-1} diet	Mineral*	mg kg^{-1} diet
Retinol (A)	8000		Calcium iodate (62% I)	0.47
Cholecalciferol (D_3)	1000		Manganese sulphate monohydrate (31% Mn)	10.0
D,L-α-Tocopherol acetate (E)		125.0	Zinc sulphate monohydrate	100.0
Menadione sodium bisulphite (K_3)		16.5	Copper sulphate pentahydrate	3.0
Thiamine hydrochloride (B_1)		10.0	Ferrous sulphate heptahydrate	29.9
Pyridoxine hydrochloride (B_6)		15.0	Sodium chloride	0.33
Folic acid		3.8	Magnesium sulphate (10% Mg)	500.0
Ascorbic acid (C)		1000.0	Lime	2.0
Calcium D-pantothenate		49.6		
Myoinositol		600.0		
Choline chloride		1500.0		
Niacin		200.3		
Cyanocobalamin (B_{12})		0.02		
Ethoxyquin (antioxidant)		150.0		
Calcium propionate (mould inhibitor)		250.0		

* Amount of active ingredient.

of silver perch are given in Table 25.4. Diets supplemented with these premixes have been used successfully for silver perch grown in static, earthen ponds. Premixes containing similar vitamin and mineral levels have been used in the commercial feeds for silver perch for around 5 years and deficiency symptoms have not been reported to date.

Practical Diets

The proximate composition and digestibility coefficients for dry matter, energy and protein of various ingredients for silver perch were determined by Allan *et al.* (2000a) and are presented in Table 25.5. Booth *et al.* (2000b) showed that, for silver perch > 17 g, grinding ingredients to ensure that 80% of particles were < 500 μm did not improve digestibility compared with when 80% of particles were between 710 and 1000 μm. They also demonstrated that steam conditioning or extrusion processing significantly improved digestibility, weight gain and feed conversion ratio (FCR) compared with when diets were pelleted without steam.

In Australia, several diets are commercially available for silver perch. Initially, formulations (e.g. SP35) were based on published requirements for other commonly cultured omnivorous species and on high-quality feed ingredients not readily available in Australia (Allan and Rowland, 1992). Following research on nutritional requirements and ingredient digestibility, diets with relatively low protein (35%–28% digestible protein) and energy (< approximately 15 MJ of DE kg^{-1}) were formulated (Allan and Rowland, 1999; Allan *et al.*, 2000b;

Table 25.5. Dry-basis proximate composition and apparent digestibility coefficients of ingredients for silver perch (Allan *et al.*, 2000a).

Test ingredient	Protein* (%)	Fat (%)	Ash (%)	GE (MJ kg^{-1})	Apparent digestibility coefficient (%) Protein	Apparent digestibility coefficient (%) Energy
Fish meals						
Australian fish-meal†	73.2	9.9	14.2	21.3	92.3	89.6
Danish fish-meal	72.9	11.4	13.0	21.5	94.2	98.0
Peruvian fish-meal	70.2	11.3	17.6	20.9	89.0	88.6
Animal meals						
Blood meal (spray dried)	94.9	–	3.1	23.9	90.2	99.9
Meat-and-bone meal (beef)	49.2	9.2	36.0	16.1	71.5	75.2
Meat-and-bone meal (lamb)	54.3	7.2	34.5	16.2	73.9	80.8
Poultry meal	60.3	18.2	15.0	22.7	85.4	93.7
Feather meal (hydrolysed, ring-dried)	84.3	11.2	3.0	24.9	92.8	101.0
Oilseeds						
Soybean meal (solvent)	47.8	3.7	8.0	17.0	94.8	78.0
Soybean meal (whole, expeller)	47.5	6.4	6.3	20.9	95.7	84.1
Soybean meal (dehulled, full-fat)	35.8	19.5	5.5	23.3	92.3	79.8
Canola meal (solvent)	36.6	2.6	7.4	19.9	83	58.1
Canola meal (whole, expeller)	31.8	12.5	6.6	21.8	79.6	58.6
Groundnut meal	41.2	1.3	5.2	19.7	98.2	7.0
Cottonseed meal (dehulled)	48.1	4.6	8.3	19.9	83.0	53.1
Linola (linseed meal)	29.8	11.3	6.1	21.2	77.7	44.3
Legumes (whole)						
Lupins, *Lupinus angustifolius* (cv. Gungurru)	34.1	5.7	2.8	17.9	97.1	51.2
Lupins, *Lupinus albus*	37.6	6.2	3.7	20.9	95.9	70.1
Field pea, *Pisum sativum* (cv. Dunn)	25.5	1.1	3.4	17.0	81.0	51.0
Faba bean, *Vicia faba* (cv. Fijord)	27.7	1.3	3.6	17.3	90.5	59.2
Chick-pea, *Cicer arietinum* (cv. Desi)	20.8	4.7	3.4	19.4	82.2	54.8
Vetch, *Vicia sativa* (cv. Blanch-fleur)	30.9	0.9	3.3	17.9	71.2	52.8
Cow-pea, *Vigna unguiculata*	25.2	2.3	3.7	18.8	96.5	44.7
Cereals						
Wheat gluten	76.9	–	–	23.1	99.8	94.0
Maize gluten meal	62.0	–	1.1	24.1	95.4	104.5
Wheat 1 (Aust. Std. Wheat)	12.2	–	–	18.3	99.5	53.2
Wheat 2 (high protein)	15.2	–	–	18.5	106.1	31.0
Mill-run	22.3	–	4.3	19.6	86.2	55.2
Sorghum	14.5	–	2.3	18.8	77.8	37.8

* N × 6.25.
† Sea Fish Pty Ltd, Triabunna, Tasmania, Australia.

Table 25.6). Lower-energy diets were used in an attempt to limit the excess carcass lipid deposition that some silver-perch farmers had reported to be a problem. Performances of silver perch on these diets were compared during a series of large-scale farming trials, with the fish being grown to over 400 g in replicate 0.1 ha earthen ponds at GAC, using very similar methods to those used by commercial farmers. A summary of the results of two experiments is given in Table 25.7. Sensory profiles of fish fed different diets were compared by accredited

Table 25.6. Composition of practical diets SP35,* 95LC1,* 95LC2,*† GRC2† and GRC3† used in two separate experiments, each using nine 0.1 ha static, aerated earthen ponds.

	Per cent in diet (dry matter basis)				
Ingredient*	SP35	95LC1	95LC2	GRC2	GRC3
Fish-meal (Danish)	27.0	10.0	5.0	0	0
Meat meal (lamb meal)	–	21.7	36.9	37.5	29.4
Blood meal (ring-dried)	2.0	2.1	–	1.7	0
Maize-gluten meal	4.0	3.8	5.2	0	0
Soybean meal (solvent-extracted)	20.0	–	–	5.0	0
Canola	–	–	5.0	0	0
Groundnut meal	–	–	5.0	5.0	0
Field peas (*Pisum sativum*)	–	14.9	10.4	0	0
Lupins (cv. Gungurru) dehulled	–	25.5	7.4	0	0
Wheat	26.9	–	–	10.6	25.9
Sorghum	11.0	4.7	–	0	0
Mill-run	2.0	10.0	17.7	20.0	20.0
Fish-oil (cod-liver oil)	1.0	2.9	3.2	3.2	7.6
D,L-Methionine	0.2	0.4	0.3	0.1	0
Vit./min. premix	4.0	4.0	4.0	1.5	1.5
Dicalcium phosphate	2.0	–	–	0	0

* Allan *et al.*, 2000b.
† 95LC2 was manufactured separately for both experiments. For the second experiment, minor changes to the vitamin and mineral premixes were made and an additional 2.5% mill-run was added (Allan and Rowland, 1999).

Table 25.7. Final weight, growth rate, food conversion ratio and production rate for silver perch fed different diets during two separate experiments in 0.1 ha earthen ponds.*

Experiment†	Diet	Final weight (g)	Growth rate (g fish^{-1} day^{-1})	FCR	Production (t ha^{-1})
1	SP35	395.4 ± 11.9^a	2.2 ± 0.07^a	2.2	5.8 ± 0.13^a
1	95LC1	433.8 ± 10.8^b	2.5 ± 0.09^b	2.0	6.3 ± 0.12^b
1	95LC2	441.7 ± 7.2^b	2.5 ± 0.03^b	1.9	6.5 ± 0.08^b
2	95LC2	461 ± 9.7^a	2.4 ± 0.05^a	1.6	6.5 ± 0.14^a
2	GRC2	453 ± 6.1^a	2.4 ± 0.03^a	1.7	6.5 ± 0.10^a
2	GRC3	433 ± 6.9^a	2.3 ± 0.05^a	1.7	6.2 ± 0.11^a

* Values are means ± SEM for three replicate ponds. For each experiment means in columns which share the same superscript were not significantly different ($P < 0.05$).
† Experiment 1 fish were stocked at 15,000 fish ha^{-1} at a mean weight of 81 g and cultured for 143 days (Allan *et al.*, 2000b). Experiment 2 fish with a mean weight of 58 g were stocked at 15,000 fish ha^{-1} and cultured for 187 days (Allan and Rowland, 1999).

taste panels. The most successful diets contained fish-oil but much less fish-meal (0 to 10%) and produced fish that tasted as good as or better than fish fed a fish-meal/soybean-meal-based diet (SP35). They were also much more cost-effective (Allan and Rowland, 1999; Allan *et al.*, 2000b) and several (95LC2, GRC3) have been adopted or are being considered for adoption by commercial feed-manufacturing companies. The replacement of expensive imported fish-meal and other protein sources with high-quality Australian agricultural protein sources has reduced ingredient costs for silver-perch diets by approximately 60% to around A$0.74 kg^{-1} without compromising performance. Silver-perch diets are currently the cheapest diets for any fish cultured in Australia.

Feeding Practices

Feed currently constitutes approximately 20% of production costs in silver-perch culture and efficient delivery of the diet is necessary for economic viability. Poor feeding practices increase the cost of production; overfeeding wastes feed and adversely affects water quality, while underfeeding results in reduced growth. Practices vary across the industry, from feeding to satiation to feeding a restricted amount based on a proportion of body weight. Satiation can be difficult to determine in the characteristically turbid silver-perch ponds where not all fish feed at the surface. Until recently, a feeding strategy specifically for silver perch had not been developed, and recommendations to industry were based on regimes used in other warm-water finfish industries, such as the channel catfish industry in the USA (Allan, 1995).

Russell *et al.* (1996) conducted a 4-week study in tanks and suggested that feeding between 5% and 10% body weight day^{-1} twice daily at water temperatures around 25°C would produce optimum growth and FCR (food conversion ratio) in small (1.3 g) fingerlings. A series of experiments was recently conducted at GAC to identify appropriate feeding rates and frequencies for fingerling and market-size silver perch at different ambient water temperatures. In each experiment, fish were stocked in floating cages in a 0.32 ha aerated pond and fed the commercial least-cost diet 95LC2 (35% crude protein, 5% fish-meal; extruded, slow-sinking) that had been specifically developed for silver perch (Allan *et al.*, 2000b). Silver perch performed well in these experiments, with very high survival (> 98%) and growth rates, similar to those reported in open pond culture (Rowland *et al.*, 1995). The new recommended feeding regimes for fingerling and market-size silver perch are given in Table 25.8. It is also recommended that the application of feed does not exceed 150 kg ha^{-1} day^{-1} in individual ponds.

Silver-perch broodfish are fed 2% body weight daily, commencing in early spring in the lead up to the breeding season when the water temperature reaches about 18°C; this rate is maintained during the summer. At lower water temperatures, rates of 0.5–1.0% are adequate for growth, health and gonadal development. First-feeding larvae (4.5 mm) are stocked in ponds, where they feed

Table 25.8. Suggested feeding rates and frequencies for fingerling and large silver perch at different water temperatures.

	Fingerlings (2–50 g)		Large fish (> 50 g)	
Water temperature(°C)	Feeding rate (% BW day^{-1})	Feeding frequency (no. of times day^{-1})	Feeding rate (% BW day^{-1})	Feeding frequency (no. of times day^{-1})
10–12	0.5	1	0.5	Alternate days
12–15	1	1	0.5	1
15–20	2.5	1	2	1
20–25	5	2	3	2 (50–500 g)
			1.5	2 (> 500 g)
25–30	7.5	2	2	2 (50–500 g)
			1	1 (> 500 g)

BW, body weight.

on zooplankton for several weeks before being weaned on to a commercially available diet containing 50% protein. Post-larvae and fry (up to 2 g) are fed this diet to satiation, four times daily.

A range of feeding techniques are used in the silver-perch industry. At the GAC and smaller farms fish are fed by hand, while on larger farms (> 10 ha of ponds) vehicle-mounted blowers are used to deliver the feed. Several farmers have recently started using automatic feeders.

Initially cold-pressed pellets were used (Allan and Rowland, 1992), but since the formulation and evaluation of 95LC2 (Allan *et al.*, 2000b) a majority of silver-perch farmers use extruded, slow-sinking or floating pellets. Although some silver perch feed aggressively at and near the surface, particularly in the warmer months, many fish feed mid-water. Thus, slow-sinking pellets are recommended for this species to ensure that all fish receive their daily ration.

Future Nutrition Research Priorities

Relatively low-cost production of silver perch is possible because the species performs well on low-protein diets composed of agricultural ingredients. An examination of the relative cost–benefit of using different proportions of protein, lipid and carboyhydrates as energy sources could also lead to more cost-effective diets. Further cost savings may be possible if reduction in the content of expensive vitamins can be achieved without compromising performance or immune response. Research to clarify amino acid requirements and the ability of silver perch to utilize crystalline amino acids is warranted. Recent reports of apparently stress-related ‘winter diseases’ indicate that research on immunostimulants may be of value. Further research to determine requirements for long-chain n-3 fatty acids to optimize performance is also needed. In all nutrition research with silver perch, it is necessary to investigate the impacts of diet on carcass composition and sensory characteristics.

Conclusions

1. Silver perch is a new species for aquaculture, is relatively easy to culture and performs well on low-protein (e.g. 28% digestible protein) and low-energy (e.g. 15 MJ of DE kg^{-1}) diets because of the efficient digestion and utilization of dietary carbohydrates, especially starch.
2. Maintenance requirements for protein and energy were estimated as 2.1 g digestible protein kg^{-1} body weight day^{-1} and 116 kJ of DE kg^{-1} body weight day^{-1}.
3. Recommended amino acid contents were estimated as those contents sufficient to ensure that growth was not retarded for diets made from intact protein sources with 15 MJ of DE kg^{-1}.
4. Silver perch are 'fatty' and, although they are able to chain-elongate and desaturate dietary linoleic and linolenic acid, growth is enhanced by the addition of longer-chain n-3 fatty acids in the diet. There is an inverse linear relationship between dietary protein : energy content and fish lipid content.
5. Australian agricultural ingredients, such as meat and poultry meals, lupins, peas and wheat, can be used in low-cost rations to replace most or all fish-meal without compromising performance or taste.

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