# Development of Techniques for the Commercial Aquaculture of the Freshwater Fish Silver Perch (*Bidyanus bidyanus*)

**FINAL REPORT TO FRDC**

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**NSW Fisheries**

# FINAL REPORT

to

FISHERIES RESEARCH AND DEVELOPMENT CORPORATION

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# DEVELOPMENT OF TECHNIQUES FOR THE COMMERCIAL AQUACULTURE OF THE FRESHWATER FISH SILVER PERCH *(BIDYANUS BIDYANUS)*

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## SUMMARY

Australia has limited fisheries resources. Over the last few decades, some of the major commercial fisheries have declined dramatically while others are in danger of over-exploitation. Large quantities of fish products are imported annually. Aquaculture has the potential to replace part or all of the lost production, as well as some of the imports. High quality products could also be exported. However, apart from the culture of oysters, aquaculture is a new, relatively small industry in Australia. Recent developments have centred on high-valued species such as Atlantic salmon, barramundi and penaeid prawns. These species are cultured overseas, are costly to produce and have only relatively small markets. Freshwater fish constitute approximately half the world's total aquaculture production. The Australian native freshwater fish silver perch (*Bidyanus bidyanus*) is a species with high biological potential for aquaculture. Abundant land is available in Australia, adjacent to permanent surface and underground water supplies, for the construction of large-scale facilities. In addition, there are fewer pollution problems with freshwater pond culture systems because waste-water can be re-used or used for agricultural production.

In the research project "Development of Techniques for the Commercial Aquaculture of the Freshwater Fish Silver Perch *Bidyanus bidyanus*", a series of trials and experiments were conducted over a 3 year period, 1990-1993, at the Eastern Freshwater Fish Research Hatchery (EFFRH), Grafton, and the Brackish Water Fish Culture Research Station (BWFCRS), Salamander Bay. Production-orientated research was conducted in static, aerated earthen ponds (0.1 and 0.3 ha surface area) at EFFRH, and at BWFCRS, nutrition experiments were conducted in fibreglass tanks and aquaria.

Diets with different protein levels were compared and a reference diet containing 35% crude protein (including 27% fish meal and 20% soybean meal) was developed and used in most production experiments. The performance of silver perch under intensive conditions in earthen ponds was excellent and comparable to, or better than species such as channel catfish, carp and tilapia which form the basis of very large industries overseas.

Techniques enabling the large-scale production of silver perch fingerlings (15g) in ponds were developed. Fry (0.5g) were readily waned onto dry feed and the

food conversion ratios in six ponds over a 12 week experiment ranged from 1.0:1 to 1.3:1. Survival rates were 97% and higher, and the growth and size of fingerlings was determined, in part by stocking density. The use of techniques developed will ensure a regular supply of fingerlings for grow-out operations.

Results of trials and experiments in which fingerlings were reared to market-size include high survival rates (>74%), fast growth rates (to a mean weight of 450g in only 10 months) and very high production rates, up to 10.1 tonnes/ha/yr. In a 10 month production experiment, the survival rates, growth rates, mean weights and food conversion ratios were similar in ponds stocked at 7,000 and 21,000/ha suggesting that even higher stocking densities and production rates are possible. There was a deterioration of water quality during summer, in particular high levels of ammonia in ponds stocked at high densities, demonstrating the need for good management, aeration and an abundant supply of high quality water. Food conversion ratios ranged from 0.7:1 to 2.0:1 and the cost of feeding was approximately $1.50/kg, indicating that the overall costs of production will be relatively low.

The results of the nutrition experiments demonstrated that silver perch can grow on diets based on plant proteins, and that soybean meal, peanut meal, canola meal and lupins have the potential to partly replace fish meal in silver perch diets, further reducing the cost of feeding this species.

The results of the research project demonstrate that silver perch is a hardy species, well suited to intensive culture in earthen ponds. The species has the potential to form the basis of a very large industry, producing in excess of 10,000 tonnes per year. Numerous publications have been written and others are planned, and a series of Workshops, to extend the results to industry and other groups is to be held in April 1994.

## BACKGROUND

Aquaculture is in its infancy in Australia and only a small number of species are cultured on a commercial scale. The successful oyster, rainbow trout, prawn and salmon industries are based on well-established techniques and are supported by continuing government research and management. The small marron industry in Western Australia arose after local research in the 1970's, and the native fish hatchery industry in eastern Australia based on techniques developed at the Inland

Fisheries Research Station, Narrandera, NSW, during the 1970's and early 1980's. However, despite the rapidly growing interest and increasing investment in aquaculture, many other enterprises have failed in recent years, mainly due to the lack of suitable technology and in some cases, the poor selection of species and sites for aquaculture. The ned for a research and development phase in a new industry such as aquaculture cannot be over emphasised.

On a world-wide basis, aquacultural production has increased rapidly over the last two decades and the current annual production of about 15 million tonnes is now approximately 15% of the harvest from wild fisheries. This rate of increase is expected to be maintained and it is predicted that over the next 50 years aquacultural production will come to equal if not surpass the harvest of wild fish, and that much of the production will be by large-scale commercial operations with substantial research accompanying their production facilities.

Finfish constitutes half the world aquacultural production and about 84% is farmed in freshwater. the culture of freshwater finfish obviously has enormous potential in Australia. We have limited wild fisheries, many of which are already over-exploited, and large quantities of white-flesh fish are imported annually. If suitable species are found and techniques developed, freshwater aquaculture could replace some of the lost wild fisheries and the imported product. Significant markets are also available throughout Asia where Australian freshwater fish already have an excellent reputation. Abundant land is available adjacent to permanent surface and underground waters for the construction of large-scale facilities. In addition there are fewer pollution problems with freshwater pond culture systems because waste water can be re-used or used for agricultural production.

The native freshwater fish silver perch (*Bidyanus bidyanus*) has high potential for aquaculture for the following reasons: hatchery techniques have been developed; it is a hardy fish that handles well in captivity; it is omnivorous and readily takes pellets; is not cannibalistic; it grows quickly; major diseases are known; it has a good appearance and a high meat recovery; it has excellent edible qualities.

## OBJECTIVES

1. Determine the feasibility of culturing silver perch under intensive conditions in earthen ponds, cages and tanks.

2. Determine the effects of stocking density and artificial diets on the survival rate, growth rate and production of silver perch.
3. Identify the water quality variables and potential pathogens which affect silver perch under culture conditions, and develop management procedures to alleviate problems caused by poor water quality and disease.
4. Provide base-line data that can be used for an economic evaluation of culturing silver perch.

## RESEARCH METHODOLOGY

The research project was conducted over a 3 year period, 1990-1993, using facilities at the NSW Fisheries Eastern Freshwater Fish Research Hatchery (EFFRH), Grafton, and the Brackish Water Fish Culture Research Station (BWFCRS), Salamander Bay. Production-orientated research was conducted in static, aerated earthen ponds (0.1 and 0.3 ha surface area) at EFFRH, and at BWFCRS, nutrition experiments were conducted in aquaria and tanks. All fry used were produced at the Inland Fisheries Research Station, Narrandera.

The following series of scientific and technical papers provides, in detail, the methodology, results and discussion of the results of the project.

## IMPLICATIONS OF FINDINGS

The results of this research project have important implications for aquaculture in Australia. The exceptional results obtained, in particular the high survival rates, fast growth rates, high production rates and the relatively low cost of production, (hence reasonably priced end product) clearly demonstrate that silver perch has the potential to form the basis of a very large industry, in excess of 10,000 tonnes and possibly as high as 30,000 tonnes annually. The product value alone in such an industry would conservatively be up to $150,000,000. At present, silver perch is the only aquaculture species with the potential for such a large industry.

A successful silver perch aquaculture industry will generate substantial development and employment, not only directly in fish farming but also in associated service industries such as feed production, fish processing, equipment manufacture, and transportation and marketing.

NSW Fisheries is currently formulating a management strategy and policy for the development of a silver perch industry in this state. The policy, as well as the technical information obtained during this and other related research projects (e.g. hatchery technology) will be presented at Silver Perch Aquaculture Workshops at Grafton 11-13 April and at Narrandera 18-20 April, 1994.

**PAPERS PRESENTED IN THIS REPORT**(in the following order)

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Rowland, S.J. and Allan, G.A. (in prep). Culture of silver perch (Bidyanus bidyanus) at different densities in cages and tanks (for Aquaculture).

# GROWTH OF SILVER PERCH *Bidyanus bidyanus* ON DIETS WITH DIFFERENT LEVELS AND SOURCES OF PROTEIN

G. L. ALLAN* and S. J. ROWLAND**

Silver Perch (*Bidyanus bidyanus*) is an omniverous, Australian native, freshwater fish which is easy to breed and has rapid growth rates in captivity (Rowland and Barlow 1991). Anderson and Arthington (in press) found *B. bidyanus* were capable of chain elongation and desaturation of linolenic acid indicating that this species may have a smaller requirement for the 20:5 (n-3) and 22:6 (n-3) long chain higher unsaturated fatty acids (such as are found in fish meal and oil) than are required by marine carnivorous species such as snapper *Pagrus auratus* (NRC 1983). There is no published information on protein requirements for *B. bidyanus*. During this preliminary study, four formulated diets were compared. Diets 1, 2 and 3 were based on equal portions of fish meal and soybean meal with protein (Nx6.25) levels of 20.7, 35.7 or 49.0% and Diet 4 was based on soybean and canola meal with 35.7% protein. Total lipid and digestible energy levels (based on values for catfish *Ictalurus punctatus* [NRC 1983]) were similar for all diets (5.4-6.5% and 11.6-12.3 MJ/kg respectively) while total fibre levels were similar for Diets 1-3 (2.7-3.0%) but higher for Diet 4 (6.8%). 100 juvenile fish (mean weight 1.3 g, range 0.5-2.2 g) were stocked into 16 tanks (1000 l each) and fed twice daily to satiation for 45 days. Temperatures were low (range 18.3-22.8$^{o}$C) for this stage of the life cycle and may have depressed growth.

Average individual weight gains (mean±SE; n=4 replicate tanks) for Diets 1, 2, 3 and 4 were 1.4±0.1, 1.9±0.1, 1.5±0.1 and 1.0±0.1 g fish$^{-1}$ in that order. Weight gain on Diet 2 was significantly greater than on Diets 1 or 4 ($P<0.05$) but similar to Diet 3 ($P>0.05$). Weight gains on Diets 1 and 3 were similar ($P>0.05$). Food conversion ratio (FCR) for Diets 1, 2, 3 and 4 were 3.0±0.2, 1.7±0.1, 2.4±0.3 and 3.6±0.3 in that order. FCR for Diet 2 was lower than on Diet 4 ($P<0.05$) but FCR's for Diets 1, 2 and 3 were similar ($P>0.05$). Results indicate that optimum protein levels for juvenile *B. bidyanus* will exceed 20% and are likely to be closer to those required by omniverous species such as *I. punctatus* (32-36%) than carnivorous species such as *P. auratus* (55%) (NRC 1983). For *B. bidyanus* diets with the same protein levels, replacement of all the fish meal and oil resulted in slower growth and, possibly because of higher fibre levels, poorer FCRs.

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# Development of an experimental diet for silver perch (*Bidyanus bidyanus*)

Stuart Rowland

*NSW Fisheries is conducting a research project aimed at developing technology for growing silver perch in earthen ponds. This article details a diet that has been formulated for the initial experiments and which has produced encouraging results.*

**By Geoff Allan[1] & Stuart Rowland[2]**

Freshwater finfish is the major component of world aquaculture production. In 1987, approximately 6.8 million t of finfish were produced, of which 88.4% was farmed in freshwater (Nash and Kensler, 1990). Although there are many indigenous freshwater fish in Australia that are highly regarded for their edible qualities, many of these species are no longer abundant. Hatchery techniques have been developed for some species (Rowland, 1989); however, with the exception of barramundi (*Lates calcarifer*) there has been no research into the grow-out of native finfish.
Currently there is only a small industry (1613 t in 1989-90) based on the freshwater production of the exotic rainbow trout, *Oncorhynchus mykiss* (O'Sullivan, 1992).

Rowland and Barlow (1991) suggested that the native freshwater fish silver perch (*Bidyanus bidyanus*) has high potential for aquaculture because hatchery techniques are established and the species is hardy, grows rapidly in farm dams, is omnivorous and readily accepts pellets.

A major research project to determine the feasibility and develop techniques for the intensive culture of silver perch commenced at NSW Fisheries', Eastern Freshwater Fish Research Hatchery (EFFRH), Grafton, in 1990. A component of the project, the evaluation of feeds, is being partly funded by the Fisheries Research and Development Corporation. Formulated feed represents one of the major costs in finfish aquaculture, accounting for up to 60% of total operating costs (Manzi, 1989). The development of nutritionally adequate, cost-effective diets is therefore one of the major factors limiting the establishment of an economically successfully aquaculture industry. One of the research priorities for the silver perch project at EFFRH is to determine protein requirements. Requirements for other omnivorous freshwater species, such as channel catfish (*Ictalurus punctatus*) are in the range 25-36% protein (Robinson, 1989) while requirements for carnivorous freshwater species such as rainbow trout (*Oncorhynchus mykiss*) are higher (40-45%; Halver, 1989).

The initial nutrition experiment was conducted with fry (0.6 g) stocked in 1,000 litre aerated tanks and fed isoenergetic diets with protein contents of 21, 36 and 49%. The fastest growth was recorded with the 36% protein diet; however, differences in growth between fish on this diet and the 49% protein diet were not significant (Allan and Rowland, 1991). The results indicated that the dietary protein requirement for juvenile silver perch would exceed 21% and would probably be closer to those required by other omnivorous freshwater species than to those required by carnivorous freshwater species such as rainbow trout.

These results provided the basis for the formulation of a diet to be used in pond trials. The diet, SP35 (Table 1) was also formulated to satisfy or exceed the published requirements for channel catfish of essential amino acids, digestible energy to protein ratio and available phosphorus (NRC, 1983; Lovell, 1989; Robinson, 1989). Published results for nutrient digestibility and phosphorus availability for catfish (NRC, 1983; Robinson, 1989) were also used. Even though requirements for essential fatty acids are likely to be lower for silver perch than for carnivorous marine species (Anderson and Arthington, 1992), fish oil was added to the diet to ensure that essential fatty acid deficiencies did not depress growth in in silver perch.

The diet was manufactured in the form of crumbles (2 mm; 3 mm) for fry and fingerlings, and pellets (3 x 12 mm; 6 x 12 mm) for larger fish. All experimental diets were manufactured by Janos Hoey Pty Ltd, Forbes, NSW, and stored at 15°C until used.

SP35 was first used in a fingerling production experiment. Silver perch fry (0.6 g) were stocked into six, aerated 0.1 ha earthen ponds and fed 2 mm and 3 mm crumbles at rates up to 3% body weight per day. Within two weeks, fry were readily feeding on the crumbles. Fingerlings (16 g) were harvested after 12 weeks; survival rates ranged from 97 to 100% and the food conversion ratios ranged from 1.0 to 1.3 (S. Rowland,

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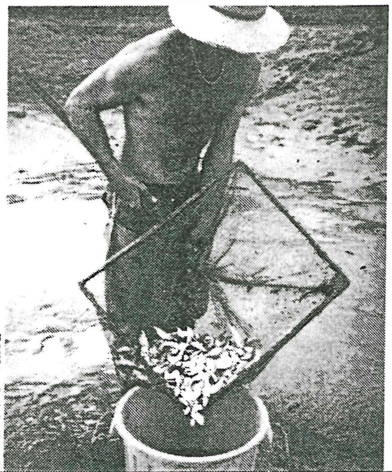
unpublished data, 1992).

A grow-out phase experiment is currently underway in the earthen ponds. Fingerlings were stocked in May and fed SP35 at rates up to 3% body weight daily. Fish fed throughout winter, and growth has been rapid since late spring. Mean weights of silver perch in six ponds at the end of February, 1992, ranged from 436 to 581 g and assuming high survival, estimated standing crops in some ponds may exceed 8 t/ha (S.Rowland, unpublished data, 1992).


Stuart Rowland

**Harvesting fingerlings from EFFRH ponds at Grafton, NSW**

The results of the nutrition and production research to date, suggest that the experimental diet, SP35, is suitable for the pond production of fingerling and market size (400-500 g) silver perch.

The formulation of this diet will probably be modified after further nutrition experiments. Experiments to define the optimum protein requirements and to determine the digestibility of a number of protein sources are underway at EFFRH and Brackish Water Fish Culture Research Station. Subsequent research will concentrate on ways to reduce the cost of silver perch diets by defining optimum protein to energy ratios, and formulating practical diets with reduced fishmeal and increased soybean (or other plant protein) content.

**TABLE 1: Formulation and biochemical composition of the experimental diet, SP35, for silver perch.**

| *Ingredients* | % |
|---|---|
| Fish meal | 27.0 |
| Soybean meal | 20.0 |
| Blood meal | 2.0 |
| Corn gluten meal | 4.0 |
| Wheat | 28.4 |
| Sorghum | 11.0 |
| Millrun | 2.0 |
| Cod liver oil | 1.0 |
| Di-calcium phosphate | 2.0 |
| Vitamin/mineral premix(1) | 2.5 |
| L-methionine | 0.15 |
| *Proximate composition (as fed basis)* | % |
| Crude protein (N x 6.25)(2) | 35.6 |
| Crude fat (ether extract)(2) | 5.5 |
| Linolenic series (n-3) fatty acids(3) | 1.1 |
| Fibre (acid detergent)(2) | 4.4 |
| Carbohydrate (difference)(2) | 52.1 |
| | *(g/kg)* |
| total methionine(4) | 7.4 |
| Total lysine(4) | 22.6 |

(1) Included the following (per kg diet) Retinol 2.4 mg; Cholecalciferol 25 µg; ∞-Tocopherol acetate 125 mg; Menadione sodium bisulfite 16.5 kg; Thiamin. HCI 10 mg; Riboflavin 25.5 mg; Nicotinamide 200 mg; Ca-pantothenate 54.5 mg; Pyridoxine. HCI 15 mg; Cyanobalamin 20 µg; folic acid 4 mg; Biotin 1 mg; Ascorbic acid 450 mg; Myo-inositol 600 mg; Choline chloride 1500 mg; $CaCO_3$ 7.5 g; $MnSO_4$ 0.3 g; $ZnSO_4$ $7H_2O$ 0.7 g; $FeSO_4$ $7H_2O$ 0.5 g; $CuSO_4$ 60 mg; NaCI 7.5 g; $KIO_3$ 2 mg.

(2) Methods described by Faichney and White (1983).

(3) Neutral and polar lipid fractions were separated by chromatoghraphy and lipid classes were separated by thin layer chromatography.

(4) Amino acid profiles analysed using high pressure liquid chromatography and Waters (Lane Cove, NSW) Pico-Tag.

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# THE USE OF AUSTRALIAN OILSEEDS AND GRAIN LEGUMES IN AQUACULTURE DIETS

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## Abstract

As the availability of fishmeal is decreasing and price is increasing the need to find alternative ingredients for aquaculture diets has become urgent. Although very little fishmeal is produced in Australia, abundant supplies of low-priced plant products are available. Oilseeds and grain legumes with potential for use in aquaculture diets include soybeans, canola, cottonseed, peanuts, lupins, chick peas, field peas and cow peas. Formulating cost-effective aquaculture diets using these ingredients requires a knowledge of protein contents and amino acid profiles, nutrient and energy digestibility and availability and potential anti-nutritional factors. This study reports the composition of Australian oilseeds and grain legumes and the results from experiments to determine digestible protein and digestible energy of these ingredients for silver perch (*Bidyanus bidyanus*), a native Australian freshwater, omnivorous fish with excellent potential for aquaculture. Apparent digestibility coefficients (ADC's) for protein ranged from 83 to 100% and compared with fishmeal were similar or higher in all ingredients tested except cow peas and field peas. ADC's for energy ranged from 46% to 97% and were similar for fishmeal, soybean meal, canola meal and peanut meal. ADC's for energy were lower for cottonseed meal and for the grain legumes than for other ingredients. The differences in ADC's for both protein and energy between different ingredients demonstrates the importance of digestibility determinations for evaluating feed ingredients to replace fishmeal in cost-effective diets for aquaculture species.

## Introduction

Production of aquaculture feeds in Asia increased by more than four-fold from 1986 to 1990 (Akiyama 1991), much faster than the increase in production of fish and crustaceans from aquaculture. The protein source of choice for most fish and crustacean feeds is fishmeal (Lovell 1989), however, supplies of fishmeal are declining, and prices are increasing. This is impacting severely on the production and price of aquaculture feeds. Perhaps even more important is the increasing conflict in some regions between the use of fish stocks for fishmeal and directly for human consumption. The need to replace fishmeal in aquaculture diets has been recognised as a major international research priority (Manzi 1989; New 1991).

A number of ingredients may have the potential to partially or completely replace fishmeal. These include animal proteins, vegetable proteins and single cell proteins. In Australia, very little fishmeal is produced and imported fishmeal is expensive, can be difficult to acquire and is of variable quality (Foster, 1992). Alternatively, large quantities of vegetable proteins are produced which may be suitable for use in aquaculture feeds. The first task in evaluating the potential for inclusion of any ingredient in a diet is to measure digestibility (Cho et al. 1992). The aim of the study reported here was to measure the digestibility of Australian oilseeds and grain legumes in diets for silver perch (*Bidyanus bidyanus*). Silver perch are native Australian freshwater omnivorous fish which have excellent potential for aquaculture (Rowland and Kearney 1992; Allan and Rowland 1992).

## Materials and methods

About 50-60 juvenile silver perch (1-2 g starting weight) initially bred at NSW Fisheries, Inland Fisheries Research Station at Narrandera NSW, were stocked into 170 litre tanks with steeply sloping (35°) conical bottoms. Continuously-flowing, preheated water (mean 25.5°C; range 24.0 - 26.9°C) was filtered through a sand filter and two cartridge filters (25 and 10 $\mu$m) before being supplied to each tank at a flow rate of 600 ml/min. Effluent water flowed through a 25 mm drain into a 65 mm diameter, 250 mm long settlement chamber and out the side of this chamber to waste or for collection, treatment and reuse. Half of the water used was exchanged daily and the other half was recirculated through a sand filter and a 3 $m^3$ biofilter containing spherical plastic filter media. The settlement chamber for collecting faeces tapered into a 12 mm diameter, 150 mm long length of silicone tubing.

Fish were stocked one week prior to the start of the faecal collection period to allow for acclimation to the experimental conditions. During this period fish were fed a 35% protein reference diet (Allan and Rowland 1992).

Three days prior to the start of the faecal collection period the test diets were introduced. Following Cho et al. (1982) test diets consisted of 30% of the test ingredient and 70% of the reference diet. Fish were fed to satiation three times daily at 0730, 0930 and 1200. One hour after the last feed, all uneaten food was drained from the tanks and the walls of the tank and the settlement chamber were thoroughly cleaned to remove any faeces, uneaten food or bacterial slime. The faeces were collected over 16 h. The silicon tubing into which the faeces settled, was packed in ice and kept at ≤4°C throughout this period. Faeces were collected over 15-21 days, until at least 15 g dry weight of faeces were collected. For each tank faeces were pooled over time. Four consecutive experiments were run, each with a reference diet and three test diets. New fish were used for each experiment. There were three replicate tanks for each diet. During experiments dissolved oxygen was always above 6.0 mg/l, pH was between 7.7-8.3 and nitrite and ammonia were less than 0.2 mg $NO_2$-N/l and 0.4 mg total ammonia - N/l respectively.

All ingredients for the diets were ground before use to a grain size of <0.5 mm, mixed with 1 g chromic oxide per 100 g dry mix and approximately 40% by weight of freshwater and extruded through 1.5 mm die. Pellets were dried at <35°C until the moisture content of the diets was between 25-30%. Solvent extracted oilseed meals were used and chick peas, cow peas and field peas were ground and autoclaved at 121°C for 5 minutes before use. Lupins were untreated. Proximate analyses of faeces, diets and ingredients were as described by Faichney and White (1983) and amino acids profile were analysed, following acid hydrolysis, using high pressure liquid chromatography and waters Pico-Tag (Waters Pty Ltd, Lane Cove, NSW, Australia). Sulphur amino acids were determined separately following performic acid digestion and Tryptophan, which is lost during acid hydrolysis, was not determined. Apparent digestibility coefficients (ADC's) for energy and protein were calculated as described by Cho and Kaushik (1990).

## Results

Total protein contents for the ingredients tested were all considerably lower than for the fishmeals (Table 1). However, apart from lower concentrations of total sulphur amino acids (methionine plus cystine) in peanut meal and the grain legumes, and lower lysine in all ingredients except field peas and cow peas, concentrations of essential amino acids, as a percentage of protein, were not much lower than in fishmeal (Table 1).

ADC's for protein ranged from 83 to 100% (Table 2). The ADC for protein from lupins was higher than for all other ingredients. However, ADC's for protein for other grain legumes were the lowest recorded (Table 2). ADC's for energy ranged from 46% for cow peas and lupins to 97% for Danish fishmeal (Table 2). ADC's for soybean meal, canola meal and peanut meal were similar to the fishmeals while ADC's for cottonseed meal and the grain legumes were lower (Table 2).

Using ADC's and analysed protein and energy contents, digestible protein and digestible energy values were calculated (Table 2). Digestible protein contents for oilseed meals ranged from 40-46% and from 19-31% for grain legumes. Digestible energy was 15-16 MJ/kg for soybean meal, canola meal and peanut meal and 11 MJ/kg for cottonseed meal. Digestible energy for grain legumes was lower than for other ingredients tested; 9-10 MJ/kg (Table 2).

## Discussion

Overall ADC's for protein were all high indicating protein from a number of plant products is well digested by silver perch. Where comparative information is available, the ADC's for protein for silver perch were similar or higher than those determined for trout (Cho and Kaushik 1990), channel catfish (Robinson 1989) and tilapia (El-Sayed and Teshima 1991). However, it should be noted that digestibility coefficients for the grain legumes used here have not been reported for those other species.

With the exception of lower total sulphur amino acids in the grain legumes and lower lysine in lupins and the oilseed meals, the essential amino acid profiles (expressed as a percentage of protein) were higher or similar to those for the fishmeal. As ADC's for protein were also generally high, results for this study indicate that all the ingredients tested have good potential for use as protein sources in diets for silver perch. The relatively low total protein contents, however, will restrict the use of some of these ingredients in their unprocessed form. The ADC's for energy for all plant products were lower than for the fishmeals although differences between soybean meal, canola meal, peanut meal and Peruvian fishmeal were minor. This indicates that silver perch can also utilise the energy yielding components in some plant products.

The ADC's for energy for soybean and peanut meal for silver perch of 77.9% and 80.1% respectively were slightly higher than those reported for channel catfish (72% and 76%) respectively (Robinson 1989). The lower ADC's for protein and energy for cottonseed meal compared with the other oilseed meals may reflect adverse effects of anti-nutritional factors, especially gossypol, present in this ingredient. Gossypol can be found in two forms; a bound form which is non-toxic to monogastrics and a free form which has inhibiting effects on digestive enzymes and also reduces palatability (Ravindran and Blair 1992). However, Robinson and Brent (1990) reported that the use of cottonseed meal in channel catfish diets did not appear to be restricted by direct effects of free gossypol but rather by the bioavailability of lysine. Other species are less tolerant of gossypol. The tolerance of silver perch to gossypol in cottonseed needs to be determined.

In conclusion, results for protein digestibility indicate that all ingredients tested have potential for use as protein sources in silver perch diets. A reduction in the fibre content, possibly through dehulling, could increase the total protein content and the energy digestibility for some of the ingredients, especially the grain legumes. Lupins were the cheapest product tested (AUD$197/tonne) and had the highest ADC for protein. Amongst the oilseeds, the ACD's for protein and energy for soybean meal, canola meal and peanut meal were similar to each other and Peruvian fishmeal. However, the price of these ingredients, especially canola and peanut meals, (AUD$270 and 320/tonne respectively) is much lower than for fishmeal (>AUD$1 000/tonne). Future trials with these vegetable protein sources will focus on determining maximum inclusion levels in fishmeal substitution trials. The significant differences for ADC's for both protein and energy between the ingredients demonstrate the importance of determining accurate digestibility coefficients if effective low-cost diets with reduced contents of fishmeal are to be formulated for aquaculture species.

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TABLE 1

Production, price and composition of Australian oilseeds and grain legumes and two imported fishmeals

| Indice | Ingredient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Oilseeds | | | | Grain legumes | | | | Fishmeals | |
| | Soy-bean | Canola | Cotton seed | Peanut | Lupins | Chick pea | Field pea | Cow pea | Danish fishmeal | Peruvian fishmeal |
| Production (x 1000 tonnes) | 70 | 111 | 673 | 36 | 901 | 196 | 369 | 4 | - | - |
| Price (AUD$/tonne)[1] | 460[2] | 270[2] | 300[2] | 320[2] | 197 | 200 | 250 | 600[3] | 1200 | 1000 |
| *Proximate analysis (%)*[4] | | | | | | | | | | |
| Crude protein | 49 | 44 | 48 | 41 | 31 | 23 | 28 | 25 | 75 | 70 |
| Fat (ether extract) | 2.8 | 3.6 | 4.6 | 1.3 | 7.0 | 5.6 | 1.8 | 2.2 | 13.2 | 11.3 |
| Fibre (ADF) | 5.6 | 19.3 | 11.8 | 10.8 | 24.9 | 16.8 | 12.7 | 10.3 | 2.2 | 4.6 |
| *Amino acids (g/100 g protein)*[4] | | | | | | | | | | |
| Cystine | 1.8 | 2.6 | 2.0 | 1.7 | 1.5 | 1.3 | 1.4 | 1.1 | 0.9 | 0.9 |
| Methionine | 1.5 | 2.0 | 1.8 | 1.2 | 0.8 | 1.1 | 0.8 | 1.4 | 2.9 | 2.7 |
| Aspartic acid | 11.4 | 6.3 | 9.1 | 14.8 | 8.4 | 10.3 | 11.2 | 10.4 | 6.9 | 8.2 |
| Glutanic acid | 18.2 | 16.8 | 20.3 | 25.1 | 18.5 | 15.0 | 16.3 | 16.2 | 10.7 | 12.3 |
| Serine | 4.8 | 4.3 | 4.5 | 6.6 | 4.8 | 4.9 | 4.6 | 5.0 | 3.2 | 4.0 |
| Glycine | 4.1 | 5.0 | 3.8 | 7.1 | 3.7 | 3.3 | 3.8 | 4.0 | 5.0 | 6.3 |
| Histidine | 2.6 | 2.3 | 2.6 | 2.8 | 2.2 | 2.1 | 2.0 | 2.7 | 1.6 | 3.0 |
| Arginine | 8.0 | 6.0 | 11.3 | 16.5 | 9.7 | 10.6 | 10.9 | 7.6 | 5.2 | 6.7 |
| Threonine | 4.0 | 4.1 | 3.4 | 3.5 | 3.1 | 3.0 | 3.3 | 3.4 | 3.6 | 4.1 |
| Glanine | 4.2 | 4.2 | 3.6 | 5.0 | 3.0 | 3.5 | 3.8 | 4.0 | 5.3 | 6.0 |
| Proline | 5.1 | 5.9 | 4.2 | 7.8 | 3.7 | 4.3 | 4.1 | 4.5 | 3.1 | 4.6 |
| Tyrosine | 3.3 | 2.5 | 2.9 | 4.8 | 3.1 | 2.4 | 3.0 | 3.0 | 2.4 | 3.0 |
| Valine | 5.1 | 4.4 | 4.0 | 5.4 | 3.1 | 3.4 | 4.2 | 4.6 | 4.5 | 4.9 |
| Isoleucine | 5.0 | 3.8 | 3.1 | 4.7 | 3.6 | 3.6 | 3.8 | 4.2 | 4.1 | 4.5 |
| Leucine | 7.3 | 4.5 | 5.6 | 8.1 | 5.9 | 6.3 | 6.4 | 7.0 | 6.1 | 7.0 |
| Phenylalanine | 4.7 | 3.7 | 5.0 | 6.4 | 3.5 | 4.8 | 4.0 | 5.0 | 3.1 | 3.8 |
| Lysine | 5.6 | 5.0 | 3.9 | 3.9 | 4.7 | 5.5 | 6.1 | 6.3 | 6.3 | 7.2 |

1 Average prices in October 1992. Price varies with supply and demand

2 Price proximate analysis and amino acid composition are for meal (solvent extracted)

3 High price reflects low availability as this legume is not widely cultivated. If a large market was established the price would probably fall to be comparable with other grain legumes

4 Dry basis, results are means of duplicate analysis

TABLE 2

Apparent digestibility coefficients (ADC), digestible protein (DP) and digestible energy (DE) of Australian oilseeds and grain legumes and two fishmeals fed to silver perch (*Bidyanus bidyanus*)

| | CP[3](%) | GE[4] | ADC(%)[1,2] CP | ADC(%)[1,2] GE | DP[5](%) | DE[6](MJ/kg) |
|---|---|---|---|---|---|---|
| Soybean meal | 48.5 | 19.8 | 94.5±0.4 | 77.9±3.6 | 45.8±0.02 | 15.4±0.7 |
| Canola meal | 43.6 | 20.0 | 92.4±0.03 | 72.6±0.2 | 40.3±0.02 | 14.5±0.03 |
| Cottonseed meal | 48.0 | 19.9 | 86.6±1.7 | 53.9±5.2 | 41.6±0.9 | 10.7±1.0 |
| Peanut meal | 41.2 | 19.7 | 95.8±1.4 | 80.1±6.1 | 39.5±0.5 | 15.8±1.2 |
| Lupins | 30.8 | 19.7 | 100.0±1.2 | 45.6±5.2 | 30.8±0.2 | 9.0±1.0 |
| Field peas | 27.6 | 18.6 | 86.5±1.0 | 52.0±9.0 | 23.9±0.2 | 9.7±1.7 |
| Cowpeas | 25.2 | 18.8 | 83.2±1.7 | 45.8±10.2 | 21.0±0.5 | 8.6±1.9 |
| Chick peas | 22.8 | 18.9 | 82.9±1.2 | 48.7±4.3 | 18.9±0.3 | 9.2±0.9 |
| Danish fish meal | 74.6 | 22.1 | 91.2±1.4 | 97.3±3.3 | 68.0±1.0 | 21.5±0.7 |
| Peruvian fish meal | 69.7 | 20.7 | 88.8±3.5 | 89.5±1.0 | 61.9±2.4 | 18.5±0.2 |

1 Apparent digestibility coefficient

2 Values are means ± SD for 3 replicate tanks

3 Crude protein (dry basis)

4 Gross energy (dry basis)

5 Digestible protein CP*ADCCP/100

6 Digestible energy GE*ADCGE/100

## REPLACEMENT OF FISHMEAL WITH SOYBEAN MEAL, PEANUT MEAL, CANOLA MEAL OR LUPINS IN DIETS FOR SILVER PERCH *BIDYANUS BIDYANUS* (MITCHELL)

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We have been conducting research to evaluate the potential use of Australian oilseeds and grain legumes to replace fishmeal in diets for silver perch, *Bidyanus bidyanus* (Mitchell). Initially, the apparent digestibility coefficients for crude protein, energy, fat, fibre and individual amino acids were determined for a number of oilseeds and grain legumes. The four ingredients with the highest apparent digestibility coefficients for protein were then evaluated in practical diets during a 40 day feeding trial using 70 l acrylic aquaria, each containing 10 fish with initial weights of 1.0 g/fish. Twelve diets with digestible protein contents of 31.8% were formulated. The control diet contained fishmeal as the principal protein source (42 g/100 g diet). Nine diets contained either soybean meal, canola meal or peanut meal replacing 88, 64 or 38% of the fishmeal in the control diet, and in the other two diets lupins replaced 64 or 38% of the fishmeal in the control diet. Fish weight gain in all aquaria ranged from 0.06-0.10 g/fish/day and food conversion ratio from 1.5-2.8:1. Although growth declined when fish were fed diets with increasing amounts of vegetable protein, there were no significant ($P>0.05$) differences between fish fed the control diet and diets which had 38 or 64% fishmeal replaced by soybean, peanut meal or lupins, or 38% fishmeal replaced by canola meal. Food conversion ratio also deteriorated with increasing amounts of vegetable protein but differences between fish fed on the control diet and the diets with 38% fishmeal replaced by soybean meal or peanut meal were not significant ($P>0.05$). These results indicate that silver perch can grow well on diets primarily based on vegetable proteins but that food conversion ratio is poorer, especially for high fibre ingredients, when more than 38% of the fishmeal is replaced. Procedures such as dehulling may significantly improve food conversion efficiency for some vegetable protein ingredients.

# Preliminary Evaluation of the Australian Freshwater Fish Silver Perch, *Bidyanus bidyanus*, for Pond Culture

Stuart J. Rowland

**ABSTRACT.** Silver perch, *Bidyanus bidyanus*, were stocked into two 0.4-ha earthen ponds at densities of 2,788 fish/ha (Pond 1) (mean weight = 7.4 g) and 14,500 fish/ha (Pond 2) (mean weight = 2.5 g). Fish were fed a commercial trout diet (50% protein) at daily rates of up to 3% body weight. Within 2 weeks after stocking, fish were feeding aggressively at and near the surface. In Ponds 1 and 2, survival rates were 97.5% and 73.5%, and mean weights were 116.5 g and 202.0 g after 117 and 181 days, respectively. Water temperatures ranged from 22.0 to 31.3°C. The food conversion ratio was 0.7 in both ponds. These results, achieved with no supplemental aeration or water exchange, suggest that silver perch has potential for intensive culture in earthen ponds in Australia.

## *INTRODUCTION*

The culture of Australian native finfish is in its infancy, and apart from a small but expanding barramundi, *Lates calcarifer,* industry in north Queensland, no freshwater or marine species is farmed commercially for human consumption. There is a need to increase aquacultural production because some major fisheries have declined in recent years due to over exploitation (Rowling 1990) and because large quantities of fish are imported (Jarzynski 1991).

Freshwater fish constitute approximately half the world's aqua-

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cultural production (Nash and Kensler 1990). Australia has many indigenous freshwater fish including the teraponid silver perch, *Bidyanus bidyanus,* which is very highly regarded for its edible qualities but unfortunately is no longer common and does not support a significant commercial fishery.

Techniques for hormone-induced spawning and larval culture of silver perch have been developed (Rowland 1984, 1986). Silver perch survive and grow well when stocked at low densities in farm ponds (Barlow and Bock 1981), and the species is considered to have potential for commercial aquaculture because it is amenable to crowding, is omnivorous, and accepts artificial feed (Barlow 1986; Rowland and Barlow 1991). The objective of this study was to evaluate the potential of silver perch for intensive pond culture.

## *MATERIALS AND METHODS*

The study was conducted between 16 September 1990 and 16 March 1991 (spring and summer) at the Eastern Freshwater Fish Research Hatchery, Grafton, Australia. Silver perch were cultured at the Inland Fisheries Research Station, Narrandera and then held in tanks at Grafton for four months before being stocked into two 0.4-ha earthen ponds (maximum depth = 2 m). Pond 1 was stocked at a density of 2,788 fish/ha. Fish averaged 74.4 mm total length (TL) and 7.4 g. Pond 2 was stocked at a density of 14,500 fish/ha. Fish averaged 57.8 mm TL and 2.5 g. The day before stocking, all fish were given a 60-minute bath of 10 g NaCl/L as a disinfective treatment for protozoan ectoparasites.

During the first 2 weeks, 200-500 g of crumbles were broadcast on the water daily in both ponds in an attempt to initiate feeding on the artificial diet. From the third week until harvest, silver perch were fed a commercial trout starter diet (50% protein; sinking pellet) at rates up to 3% body weight twice daily (0900 and 1600) 6 days per week. Rates during September and October were 1% and 2%, respectively. One- to 3-mm crumbles were fed to 2.5- to 20-g silver perch; 2- to 5-mm crumbles to 20- to 100-g fish; 3-mm × 12-mm long pellets were fed to 100- to 160-g fish; 5-mm × 12-mm long pellets were fed to fish >160 g. Silver perch were not fed on Sundays, when surface dissolved oxygen concentration at 0900 was below 3.0 mg/L, or when total ammonia nitrogen rose above 1.0 mg/L. Fish in Ponds 1 and 2 were fed on 92 and 124 days, respectively.

No water was exchanged during the trial, and there was no supplemental aeration. Every other day, temperature, dissolved oxygen (surface and bottom), and pH were monitored at 0900, using meters. Total ammonia nitrogen was determined using Nessler reagent (Hach[1] Company, Loveland, Colorado) and un-ionized ammonia ($NH_3$-N) calculated after Trussell (1972) and Boyd (1982).

Ten silver perch were sampled monthly from each pond; fish were anaesthetized, measured to the nearest mm, weighed to the nearest gram, and returned to the ponds. The mean monthly weights for fish in each pond were determined and used to adjust the daily ration. Four fish from each pond were sampled bi-monthly, and gill and skin tissues were examined for ectoparasites.

Fish were harvested after 117 days (Pond 1) and 181 days (Pond 2) by draining each pond. Fish were counted, and subsamples of 80 (Pond 1) and 280 (Pond 2) were used to calculate the mean lengths of fish from both ponds and the mean weight of fish in Pond 1. To accurately determine the mean weight, standing crop, and daily production rate of silver perch in Pond 2, all fish were weighed. The food conversion ratios (FCR) were determined for each pond.

Length at age data for fish in Pond 2 were used to determine the growth performance index $\phi' = \log_{10}K + 2\log_{10}L_{\infty}$ (Pauly and Munro 1984) where K and $L_{\infty}$ are the components of the von Bertalanffy Growth Function. $\phi'$ was also calculated using this data and assuming most silver perch reach a length of 350 mm at year 2 (Merrick and Schmida 1984).

## *RESULTS AND DISCUSSION*

During the first 2 weeks, some silver perch were seen feeding on zooplankton near the edges and the surface of each pond. By the end of the third week, some fish were feeding on the crumbles at or near the surface. Fish were then easily trained to feed and usually fed aggressively at and near the surface of the ponds.

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1. Use of trade or manufacturer names does not imply endorsement.

Surface water temperatures reached 30.5 and 31.3°C and averaged 27.1 and 27.0°C in Ponds 1 and 2, respectively (Table 1). There was little stratification in either pond, and bottom temperatures were usually within 1.5°C of surface temperatures.

Dissolved oxygen concentrations were usually above 4.0 mg/L; however, in Pond 2, concentrations ≤3.0 mg/L were recorded both at the surface on 9 days (minimum = 2.3 mg/L) and near the pond bottom on 32 days (minimum = 0.6 mg/L). Silver perch continued to feed at these lower concentrations, although they fed less aggressively.

TABLE 1. Water quality during the culture of silver perch in 0.4-ha earthen ponds. Water quality was monitored on 43 days in Pond 1 and on 101 days in Pond 2. Data are presented as means with ranges in parentheses.

| | Pond 1 | Pond 2 |
|---|---|---|
| Temperature (°C) | | |
| Surface | 27.1<br>(25.2-30.5) | 27.0<br>(23.0-31.3) |
| Bottom | 26.0<br>(22.0-30.3) | 26.4<br>(22.9-29.1) |
| Dissolved Oxygen (mg/l) | | |
| Surface | 5.3<br>(2.7-9.0) | 5.1<br>(2.3-9.8) |
| Bottom | 5.0<br>(2.5-8.8) | 4.0<br>(0.6-8.9) |
| pH | 8.1<br>(7.0-9.1) | 8.1<br>(7.1-8.9) |
| Total ammonia-nitrogen (mg/l) | 0.5<br>(0.4-0.6) | 0.8<br>(0.4-2.4) |
| $NH_3$-N (mg/l) | 0.01<br>(0.01-0.04) | 0.08<br>(0.01-0.25) |

Total ammonia nitrogen did not exceed 0.6 mg/L in Pond 1; in Pond 2, levels in excess of 1.0 mg/L were recorded on 14 days between 18 February and harvest (16 March). On five of these days, total ammonia nitrogen was 2.0 to 2.4 mg/L, and $NH_3$-N reached 0.25 mg/L (Table 1).

A large bloom of blue-green algae, including *Microcystis* sp. and *Anabaena* sp., developed in Pond 1 during the first week in January. Between 6 and 11 January, silver perch did not feed, and five dead fish were collected. Thirteen moribund fish were seen, but no parasites were found on tissue of the four fish examined. During this period, dissolved oxygen concentrations at the surface were 2.7 to 6.9 mg/l, and pH was 7.7 to 9.0. These observations suggest that factors associated with blooms of blue-green algae, possibly toxins, may stress and kill silver perch, as reported for other freshwater fishes (Boyd 1982; Sevrin-Reyssac and Pletikosic 1990).

One of four silver perch sampled from Pond 2 in February had a light infestation of *Trichodina* sp. (up to 10 per field of view at 200X magnification). The pond was not treated, and 4 fish sampled 5 days later were not infested. No other parasites were found on fish sampled from either pond during this study.

Between January and March, predatory birds (the darter, *Anhinga melanogaster*, and the little pied cormorant, *Phalacrocorax melanoleucos*) were seen in Pond 2 on four occasions, and 11 dead or moribund silver perch were found, each with a distinct hole or strike mark, that was presumably caused by the birds.

Survival rates in Ponds 1 and 2 were 97.5% and 73.5%, respectively; the lower survival in Pond 2 was probably due to bird predation. In Pond 2, silver perch grew from a mean weight of 2.5 g to a mean weight of 202.0 g in 181 days; the heaviest fish at harvest was 370 g. A standing crop of 860.8 kg was harvested from Pond 2, giving a production rate of 11.9 kg/ha/day (Table 2). The FCR was 0.7 in both ponds.

This study demonstrated that silver perch can be grown to a marketable size (>200 g) in 6 months in earthen ponds. Although fingerlings initially fed on zooplankton, they readily trained to feed on an artificial diet. Silver perch have been shown to feed near the surface at temperatures as low as 18°C (unpublished data). This

TABLE 2. Mean lengths and weights at stocking and number stocked; growing period; mean lengths and weights at harvest and number harvested; survival; FCR; standing crop; and production rate of silver perch cultured in two 0.4-ha earthen ponds.

| | Pond 1 | Pond 2 |
|---|---|---|
| Fingerlings stocked | | |
| Number | 1,115 | 5,800 |
| Mean length (mm) | 74.4 | 57.8 |
| Mean weight (g) | 7.4 | 2.5 |
| Stocking density (no./ha) | 2,788 | 14,500 |
| Growing period (days) | 117 | 181 |
| Silver perch harvested | | |
| Number | 1,087 | 4,261 |
| Mean length (mm) | 201.8 | 238.1 |
| Mean weight (g) | 116.5 | 202.0 |
| Survival (%) | 97.5 | 73.5 |
| FCR | 0.7 | 0.7 |
| Standing crop (kg) | 126.6 | 860.8 |
| Production rate (kg/ha/day) | 2.7 | 11.9 |

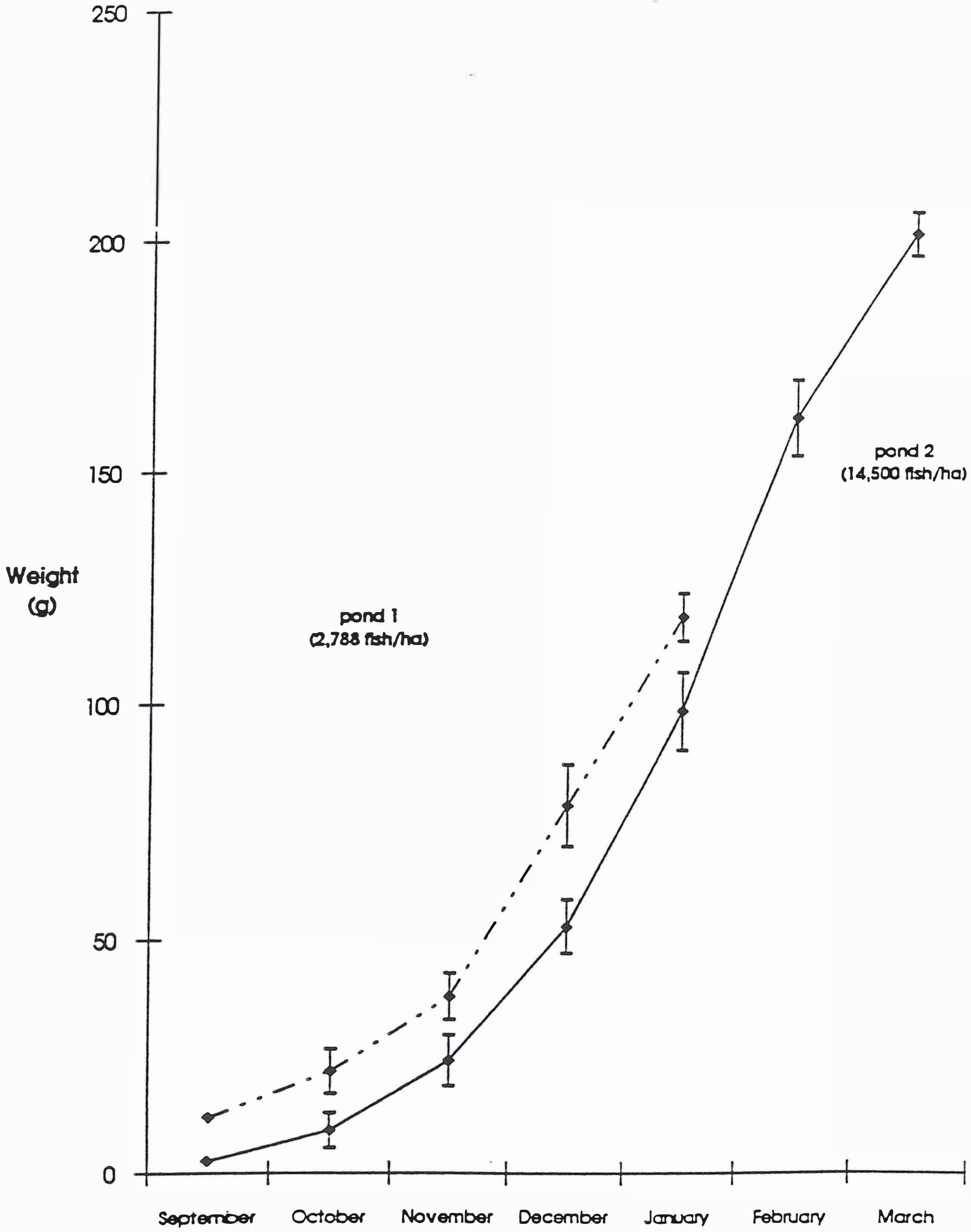
feeding behavior enables daily observation of the fish, which is important in assessing general fish health.

The growth performance index is considered to be a good indicator of the aquaculture potential of a species. The value of ø′ for silver perch in pond 2 of 4.6 (and 4.3 assuming a length of 350 mm after 2 years), although from a relatively small sample in one pond, is higher than the values reported for the successfully cultured species, *Oreochromis niloticus* and *Acanthopagrus cuvieri* (Moreau et al. 1986; Mathews and Samuel 1990) and indicates that silver perch has high growth performance potential and is a good candidate for pond culture.

The similar growth and FCR's of silver perch in Ponds 1 and 2 between September and January (Table 2; Figure 1) suggest that a stocking density of 14,500 fish/ha did not limit growth or food conversion efficiency and that higher densities may result in higher production rates.

Feed costs constitute up to 60% of total production costs in aquaculture, mainly due to the high price and decreasing availability of fish meal (Stickney 1986; Manzi 1989). Consequently, species that grow quickly, convert feed efficiently, and can utilize natural food organisms in ponds are desirable. Zooplankton, chironomid larvae, and aquatic insects were found in the guts of fish harvested from Pond 2 (T. Pontifex, Eastern Freshwater Fish Research Hatchery, Grafton, pers. comm.). The very low FCR of 0.7 in both ponds suggests that silver perch can utilize natural food even at a relatively high stocking density. Silver perch is omnivorous (Barlow et al. 1987), and so a diet with less than 50% protein may be suitable. Commercial feed for the omnivorous channel catfish, *Ictalurus punctatus,* contains about 32% protein, of which soybean meal is the major source (Robinson and Wilson 1985). The replacement of fish meal with soybean or other plant meals in silver perch diets may be possible, decreasing the cost of raising this species further.

FIGURE 1. Growth of silver perch in 0.4-ha earthen ponds. Points represent means, and the vertical bans represent the SE's.



## *ACKNOWLEDGEMENTS*

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# Production of Fingerling Silver Perch, *Bidyanus Bidyanus*, at Two Densities in Earthen Ponds

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Abstract.- Silver perch (*Bidyanus bidyanus*) fry with a mean weight of 0.6g were stocked at densities of 25,000 and 80,000/ha into 0.1-ha earthen ponds and cultured for 12 weeks. Each treatment consisted of three replicate ponds. The ponds were aerated for 11 hours each day and no water was added. Fish were fed an artificial diet containing 35% protein at rates up to 5% of estimated biomass. Fry readily accepted the feed. Mean water temperatures were 26.6, 24.1 and 22.0°C in February, March and April respectively.

Approximately 31,000 fingerlings were harvested. Fish stocked at 25,000/ha (treatment means: total length 98.1mm, weight 16.0g) were significantly larger ($P<0.01$) than fish stocked at 80,000/ha (75.9mm, 7.4g). Stocking density did not affect survival (means: 99.7, 98.7%) or the food conversion ratio (1.2, 1.1). The results demonstrate that large numbers of silver perch fingerlings can be produced in earthen ponds using an artificial diet.

The endemic freshwater fish silver perch, *Bidyanus bidyanus* (Mitchell) is a species with high potential for aquaculture in Australia (Rowland and Barlow 1991). Techniques for the hatchery production of silver perch have been developed, and are based on the hormone-induction of spawning and the culture of larvae in earthen ponds, where they feed on naturally-occurring zooplankton (Rowland 1984, 1986). However, techniques for the large-scale production of fingerling or food-size silver perch have not been developed. To assess if fingerling silver perch can be cultured in earthen ponds using an artificial diet, and to determine the effects of stocking density on survival, growth, food conversion and cost of feeding, an experiment was conducted over 12 weeks, from February to early May (late summer and autumn) at the Eastern Freshwater Fish Research Hatchery, Grafton, Australia.

Six-week-old silver perch fry (mean length = 33.9mm; mean weight = 0.6g) that had been produced in fertilized, nursery ponds at the Inland Fisheries Research Station, Narrandera, were transported for 14 h to Grafton. On arrival, fry were treated with 10g NaCl/L for 60 minutes and quarantined in 1mg methylene blue/L for two days to ensure that they were free of ectoparasites and to prevent fungal infection (Rowland and Ingram 1991).

Fry were then stocked into 0.1-ha earthen ponds at densities of 25,000 fish/ha and 80,000 fish/ha; each density having three replicate ponds. Each pond was aerated using a 1hp paddlewheel aerator for 11 hours daily between 2100 and 0800 h. After initial filling, no water was added to the ponds.

Water temperature, dissolved oxygen concentration (both at a depth of 1m), pH and total ammonia-nitrogen were monitored each second day at 1300 h. Un-ionized ammonia ($NH_3$-N) was calculated after Trussell (1972).

Fish were fed the 35% protein diet of Allan and Rowland (1992). For two weeks after stocking, 200g of dry crumbles (2mm diameter) were broadcast on the water in an attempt to initiate feeding on the artificial diet. From the third to the eleventh weeks, fish were fed twice daily, 0830 and 1500 h, at 5% of estimated fish biomass. For the remaining two weeks, fish were fed at 3% because of decreased feeding activity.

Twenty fish were sampled from each pond after 30 and 60 days. Fish were anesthetized, weighed and measured and returned to the ponds. Mean weights were used to estimate biomass in each pond and to adjust the daily ration. Gill and skin tissues from one fish from each pond were examined for ectoparasites.

Fingerlings were drain harvested after 12 weeks. All fish were counted and fish in a random sub-sample of 2% of the total number from each pond were measured and weighed. The survival rates and mean lengths and weights were calculated. Food conversion ratio (FCR) for each pond was determined by dividing the total weight of crumbles fed, by the gain in wet weight of fish. Analysis of variance was used to determine the effect of stocking density on survival, growth, FCR and cost of feeding, and to compare the mean water temperatures between ponds and between months.

Silver perch fry were feeding aggressively on the artificial diet at or near the surface in all ponds within three weeks of stocking. There was an infestation of the ectoparasitic protozoan, *Chilodonella hexasticha,* in one pond 12 days after stocking; all ponds were subsequently treated with 0.05mg malachite green/L, and no other ectoparasites were found during the routine sampling.

Survival rates were very high, ranging from 97 to 102% with means of 99.7 and 98.7% at the low and high densities respectively (Table 1). The survival rate of 102% in one pond was due to the imprecision of volumetrically counting fry. The mean yield of 384.3 kg/ha in ponds stocked at 25,000/ha was significantly lower ($P<0.01$) than the yield of 583.0 kg/ha in ponds stocked at 80,000/ha (Table 1). Fish stocked at 25,000/ha were significantly larger ($P<0.01$) (treatment means; length 98.1mm, weight 16.0g) than fish stocked at 80,000/ha (75.9mm, 7.4g). The growth rate of fish stocked at 25,000/ha was significantly faster ($P<0.01$)(0.75mm/day, 0.18g/day) than that of fish stocked at the high density (0.49 mm/day, 0.08g/day)(Table 1), and the effect of stocking density on growth was clearly evident after 30 days (Fig. 1). There was no significant difference ($P>0.05$) between the coefficients of variation for both length and weight between the treatments. However, the coefficients of variation for weight (48.4, 49.5) were relatively high (see Shell 1983) and some grading of fingerlings may be necessary before restocking for grow-out to market-size.

The FCR's in the six ponds ranged from 1.0 to 1.3 with means of 1.2 and 1.1 at the low and high densities respectively (Table 1) and were not affected by stocking density. The cost of feed of 1.1 cents/fingerling was significantly lower ($P<0.01$) in ponds stocked at 80,000/ha compared to a cost of 2.3 cents/fingerling in ponds stocked at 25,000/ha; however, because of the faster growth and larger size at harvest of fish stocked at the lower density, there was no significant difference ($P>0.1$) in cost per g of fingerling (Table 1).

Dissolved oxygen concentrations exceeded 6.0 mg/L in all ponds. Total ammonia-nitrogen and $NH_3$-N did not exceed 0.8 mg/L and 0.1 mg/L respectively, and pH values ranged from 7.8 to 9.1. Mean water temperatures differed significantly ($P<0.01$) between months, but there was no difference ($P>0.05$) between ponds. Pooled mean temperatures for February, March and April were 26.6, 24.1 and 22.0°C respectively. The decreased feeding activity and the slower growth of fingerlings during the last three weeks (Fig. 1) occurred in all ponds and was probably due to the lower water temperatures. Faster growth rates would probably be achieved if fingerlings were cultured during summer and higher feeding rates were used.

The results of this study demonstrate that large numbers of silver perch fingerlings can be cultured in earthen ponds using an artificial diet containing 35% protein. The size and growth of the fingerlings can be determined, in part, by stocking density. Adoption of these techniques will ensure a regular supply of fingerlings for grow-out operations.

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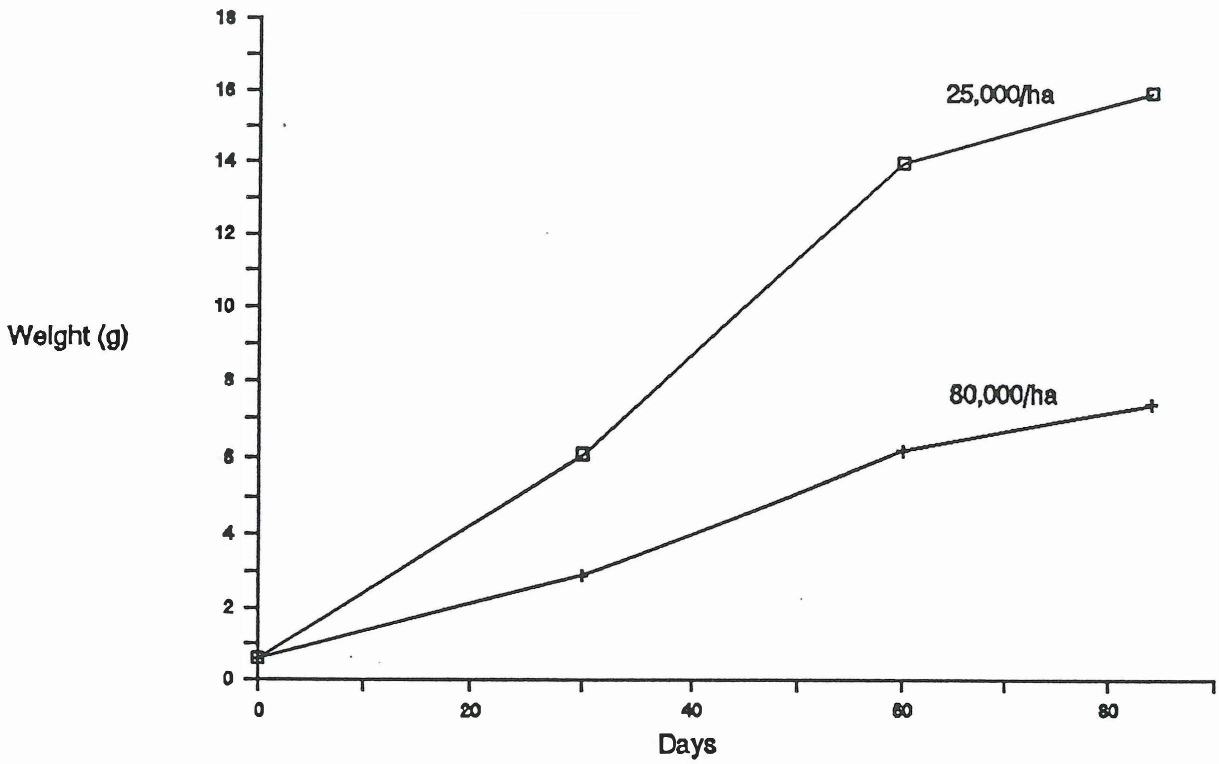
TABLE 1. - Survival, length, weight, coefficients of variation for length and weight, growth rate, yield, food conversion ratio (FCR), and cost of feeding of silver perch fingerlings cultured for 12 weeks at two stocking densities in 0.1-ha earthen ponds. Data are means of three replicates. Asterisks (*) denote means that are significantly different ($P<0.01$).

| | Stocking density (no./ha) | |
|---|---|---|
| | 25,000 | 80,000 |
| Survival (%) | 99.7 | 98.7 |
| Length (mm) | 98.1* | 75.9* |
| Coefficient of variation for length | 17.6 | 18.7 |
| Weight (g) | 16.0* | 7.4* |
| Coefficient of variation for weight | 48.4 | 49.5 |
| Growth rate | | |
| mm/day | 0.75* | 0.49* |
| g/day | 0.18* | 0.08* |
| Yield (kg/ha) | 384.3* | 583.0* |
| FCR | 1.2 | 1.1 |
| Feed costs | | |
| cents/fingerling | 2.3* | 1.1* |
| cents/g | 0.15 | 0.17 |

FIGURE 1. - The growth of silver perch fingerlings stocked at two densities in 0.1-ha earthen ponds. Points represent treatment means from three replicate ponds.



# Production of the Australian freshwater fish silver perch, Bidyanus bidyanus (Mitchell) at two densities in earthen ponds

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## ABSTRACT

Rowland, S.J., Allan, G.L., Hollis, M. and Pontifex, T. Production of the Australian freshwater fish silver perch, Bidyanus bidyanus (Mitchell) at two densities in earthen ponds. Aquaculture.

Silver perch fingerlings (mean weight 15.3g) were stocked at densities of 21,000 and 7,000 fish/ha in six 0.1-ha earthen ponds and cultured for 10 months. There were three replicate ponds for each density. Ponds were aerated for at least 11h a day and water was added every four weeks to replace that lost by evaporation and seepage. Fish were fed an artificial diet containing 35% crude protein at 4% body weight per day for the first four weeks and at rates up to 3% thereafter.

The mean production rate of 9,819 kg/ha/year of fish stocked at 21,000/ha was significantly higher ($P<0.01$) than the rate of 3,699 kg/ha/year of fish stocked at 7,000/ha. The maximum production and growth rates achieved in any pond over a one month period during summer were 97.7 kg/ha/day and 5.1 g/fish/day respectively. Stocking density did not significantly ($P>0.05$) affect survival rate (treatment means for 21,000 and 7,000 fish/ha: 92.8%, 94.7%), growth rate (0.2 - 3.3 g/fish/day, 0.3 - 3.4 g/fish/day), weight at harvest (434.9 g, 473.2 g) food conversion ratio (1.9:1, 1.8:1) and cost of feeding ($A1.55/kg, $A1.47/kg) suggesting that higher stocking densities and production rates are possible. Water temperatures ranged from 11.1 to 30.0°C. Significantly ($P<0.05$) slower growth during December was associated with concentrations of $NH_3$-N up to 0.65 mg/l. The results demonstrate that silver perch is an excellent species for semi-intensive culture in static earthen ponds with the potential to form the basis of a large industry in Australia, based on high-volume, relatively low-cost production.

## INTRODUCTION

Apart from the culture of pearl oysters (Pinctada maxima), Sydney rock oysters (Saccostrea commercialis), rainbow trout (Oncorhynchus mykiss) and goldfish (Carassius auratus) aquaculture is a new industry in Australia. The importation of large quantities of fish and the over-exploitation of some major commercial fisheries have led to a rapid increase in interest and substantial investment in aquaculture since the mid 1980's (Rowland and Kearney, 1992). Aquaculture obviously has the potential to replace part or all of the lost production from wild fisheries, as well as to replace some of the imports (Gooley and Rowland, 1993), however most recent developments have been based on high-valued species such as Atlantic salmon (Salmo salar), barramundi (Lates calcarifer) and the black tiger prawn (Penaeus monodon) (O'Sullivan, 1991) which are also cultured in other countries, and are costly to produce.

Freshwater finfish constitute approximately half the world's total aquaculture production (Nash and Kensler, 1990; New, 1991). The endemic Australian freshwater fish silver perch, Bidyanus bidyanus (Mitchell) is considered to have high biological potential for aquaculture because it is amenable to crowding, grows rapidly, is omnivorous and accepts artificial feeds (Rowland and Barlow, 1991). Hatchery technology for silver perch is well established (Rowland, 1984, 1986) and approximately three million fry are produced annually for stocking farm dams, larger impoundments and natural waters to provide recreational fisheries. Silver perch survive and grow well when stocked at low densities (<500/ha) in farm dams (Barlow and Bock, 1981), however, techniques for the commercial production of food-size silver perch have not been developed.

In a preliminary evaluation, Rowland (1994) found that silver perch stocked into a pond at a density of 14,500/ha and fed an artificial diet grew to a mean weight of 202 g in 181 days with a food conversion ratio of 0.7:1. The results of that study, achieved without supplemental aeration or any water exchange, suggest that silver perch has potential for intensive culture. The aims of the current study were to determine the effects of stocking density on survival, growth, production and food conversion efficiency, and to assess water quality and fish health during the culture of silver perch to a mean weight of approximately 450g in earthen ponds.

## MATERIALS AND METHODS

The study was conducted over ten months, from May 1991 to March 1992 (winter, spring, summer) at the Eastern Freshwater Fish Research Hatchery, Grafton, Australia. Eighteen-week old silver perch fingerlings (mean weight 15.3g) that had been cultured in earthen ponds using an artificial diet (Rowland et al., in press) were quarantined for 14 days in tanks, and treated continuously with NaCl at 5 g/L to ensure that they were free of ectoparasites and to prevent fungal infection (Rowland and Ingram, 1991). The fingerlings were then stocked in 0.1-ha earthen ponds (maximum depth = 2m) at densities of 21,000 and 7,000 fish/ha, with three replicate ponds for each density. Each pond was aerated, using a 1-hp paddlewheel aerator for at least 11h/day between 21.00 and 08.00 h. Water was added to the ponds every four weeks to replace that lost by evaporation and seepage; the ponds were not flushed.

Fish were fed dry, sinking crumbles or pellets of the 35% protein diet of Allan and Rowland (1992). The artificial feed was purchased monthly from the manufacturer and then stored at 15°C until used. The feeding regime that was used is summarised in Table

1. The feed was broadcast by hand over as large an area of the pond surface as possible. Fish were fed twice (at 08.00 and 15.00h) or once (at 15.00h) daily, seven days a week. Fingerlings were fed a daily ration of 4% body weight during May and the first two weeks in June, and 1 - 3% thereafter. When fed twice daily, half the total ration was offered in the morning and the remainder in the afternoon.

Water temperature, dissolved oxygen (DO) concentration (both at a depth of 1m) and pH (at a depth of 20cm) were monitored using meters at 14.00h each second day. In addition, total ammonia-nitrogen (TAN) was measured using Nessler reagent and unionised ammonia-nitrogen ($NH_3$-N) was calculated after Trussell (1975) and Boyd (1982). Mean monthly values for the variables in each pond and each treatment were calculated.

Ten fish were sampled monthly (with the exception of February) from each pond, anaesthetised, measured and weighed and all but one fish were returned to the pond. Gill and skin tissue from the retained specimens were examined microscopically for ectoparasites. The sample mean weight was used to estimate the biomass of fish in each pond. The daily ration was adjusted accordingly, and the mean monthly growth rate (g/fish/day) and production rate (kg/ha/day) in each pond and for each treatment were determined.

After 10 months, fish were harvested by draining the ponds. All fish were counted and bulk-weighed to determine the survival rate, mean weight, standing crop, production rate and the food conversion ratio (FCR) in each pond. The FCR was calculated by dividing the total weight of crumbles and pellets fed, by the gain in wet weight of fish. The length and weight of individuals in a randomly selected sub-sample of 10% of the fish from each pond were measured to determine the mean length, the weight-frequency and the coefficients of variation of length and weight. The cost of feeding was calculated from current ingredient and manufacturing costs and the mean FCRs.

One-way analysis of variance (ANOVA) was used to determine the effects of stocking density on survival, growth, production, FCR and coefficients of variation of lengths and weights. Two-way ANOVA was used to determine the effects of stocking density and month, on each of the water quality variables, and to compare the growth rates in November, December and January.

**RESULTS**

Feeding

Fingerlings commenced feeding on the artificial diet within three days of stocking. During spring and summer when water temperatures were 20°C and higher, fish fed at and near the surface, and were readily attracted to the feeding site by the noise of people or a vehicle. Fish fed less aggressively and at depths of 0.5 to 1.5m during winter. In general, silver perch in the ponds stocked at 21,000/ha fed more aggressively than fish stocked at 7,000/ha.

Survival and growth

The survival rate ranged from 90.4 to 97.4%, and was not affected by stocking density (Table 2).

The growth of fish at the two stocking densities was similar throughout the culture period (Fig. 1) and there was no significant ($P>0.05$) difference between the mean lengths or the mean weights at harvest or in any month. Silver perch grew to mean lengths of 296.9 mm and 308.7 mm, and mean weights of 434.9 g and 473.2 g in ponds stocked at the high and low densities respectively (Table 2). Overall, the mean monthly growth rates ranged from 0.2 g/fish/day in August to 3.4 g/fish/day in January (Fig. 2). The maximum growth rate achieved in any pond over a one month period was 5.1 g/fish/day. Mean growth rates over a six month "growing season" from October to March when water temperatures exceeded 20°C were 2.1 and 2.3 g/fish/day in ponds stocked at the high and low densities respectively (Table 3). The mean growth rate from May to September when temperatures ranged from 20° to 11.1°C was 0.5 g/fish/day at both densities. The mean growth rates at both densities were significantly ($P<0.05$) lower in December than in November or January (Fig. 2).

Production

A total of 3,481 kg of silver perch was harvested from the six ponds. The mean standing crop and the mean production rate were significantly ($P<0.01$) higher in ponds stocked with 21,000 fish/ha than in ponds stocked with 7,000 fish/ha (Table 2). There was little variation between the replicates of each treatment, with annual production rates in ponds stocked with 21,000 fish/ha of 9,527, 9,819 and 10,111 kg/ha and in ponds stocked with 7,000 fish/ha of 3,431, 3,796 and 3,869 kg/ha.

Mean monthly production rates reached 67.5 kg/ha/day in ponds stocked at the high density and 23.6 kg/ha/day in ponds stocked at the low density (Fig. 2). The highest production rate achieved was 97.7 kg/ha/day in a pond stocked with 21,000 fish/ha during January. The mean production rates over the six month "growing season" from October to the harvest in March were 40.9 kg/ha/day and 15.3 kg/ha/day at the high and low densities respectively (Table 3). Mean production rates from May to September were 9.9 and 3.4 kg/ha/day at the two densities.

The weight-frequency distributions of silver perch grown at the two stocking densities were similar (Fig. 3). At harvest, 92.4% of the fish stocked at 21,000/ha and 96.6% of fish stocked at 7,000/ha were 200 g or heavier (Fig.3).

FCR

Stocking density had no significant ($P>0.05$) effect on the FCR which ranged from 1.6 to 2.0 in the six ponds with means of 1.9 and 1.8 at the high and low densities (Table 2).

Water quality

Water temperature varied significantly ($P<0.01$) between months but not between ponds. Mean monthly temperatures (all ponds pooled) ranged from 13.2°C in July to 28.4°C in January (Fig. 4) with an overall minimum of 11.1°C (July) and maximum of 30.0°C (February).

DO concentrations were 4.5 mg/l or higher in all ponds. DO varied significantly ($P<0.01$) between months and between stocking densities, with mean concentrations lowest during summer and in ponds stocked at the high density (Fig. 4).

pH values ranged from 7.0 to 9.6 in the six ponds throughout the 10 month period. Mean monthly pH differed significantly ($P<0.01$) between months and between treatments. From October onwards, values were higher in ponds stocked at the low density (Fig. 4). pH values over 9.0 were recorded in each pond during late spring and early summer when large blooms of phytoplankton were common. There were inconsistent and, at times, rapid changes in pH in individual ponds caused by blooms of phytoplankton, predominantly blue-green algae ( Anabaena and Microcystis). For example in one pond stocked with 21,000 fish/ha, the pH dropped from 9.4 to 7.0 in seven days during January following the crash of a bloom of Microcystis.

TAN differed significantly ($P<0.01$) between both stocking density and months. Mean values were similar during winter and early spring; however, after September there was a dramatic increase in TAN concentrations in ponds stocked with 21,000 fish/ha (Fig. 4). Concentrations of $NH_3$-N in individual ponds ranged from 0.02 to 0.65 mg/l and monthly means differed significantly ($P<0.01$) between months, but not stocking density ($P>0.05$). Highest mean monthly concentrations of $NH_3$-N of 0.14 and 0.11 mg/l were recorded in December (Fig. 4).

Diseases and bird predation

There were no ectoparasites on fish examined during the 10 month culture period.

Two species of predatory birds, the darter (Anhinga melanogaster) and the small black cormorant (Phalacrocorax sulcirostris) were observed on ponds on six occasions during spring. Three darters were sampled; one contained five silver perch up to 30 g and the others each contained one silver perch up to 155 g. In addition, two dead silver perch (118 and 233 g) with distinct holes in the body presumably caused by darters were found on pond banks. Five small black cormorants were sampled and two contained silver perch up to 21.5 g.

## DISCUSSION

This study has demonstrated that silver perch fingerlings can be reared to market-size (mean weight around 450g) in 10 months under semi-intensive conditions in aerated static earthen ponds. The performance of silver perch under these culture conditions was similar to that of the warmwater species, channel catfish (Ictalurus punctatus), tilapia (Oreochromis niloticus) and common carp (Cyprinus carpio), which form the basis of very large, highly successful pond-based aquaculture industries in numerous countries including the United States, Israel and China (Hepher and Pruginin, 1981; Parker, 1988; Cui He, 1990; New, 1991; Sarig, 1992)

The survival of silver perch during several culture phases is high. Rowland et al. (in press) reported survival rates of 97 to 100% in a three month fingerling production experiment, and during the current study survival rates were over 90% (Table 2). The very small losses of silver perch were probably due to bird predation during spring, a typically dry period in this region of Australia. Rowland (1994) also found that predation by the darter and the little pied cormorant (Phalacrocorax melanoleucos) reduced survival of silver perch to 74.3% in a 0.4-ha pond. Cormorants are common predators of Australian native freshwater fishes in farm dams and at fish hatcheries where they may congregate during dry periods (Barlow and Bock, 1984). Cormorants have caused serious depredation problems and significant economic losses for commercial channel catfish growers (Stickley et al., 1992) and preventative techniques such as the provision of buffer prey (Barlow and Bock, 1984; Stickley et al., 1992) or total exclusion by netting may be necessary, particularly for ponds containing silver perch fingerlings.

Fingerlings were successfully over-wintered, with mean growth rates of 0.2 and 0.3g/fish/day (Fig. 2) during the coldest months of July and August when temperatures reached 11.1°C and mean monthly temperatures were 13.2 and 14.1°C (Fig. 4). These data support the finding of Barlow and Bock (1981) that substantial growth of silver perch occurs only at temperatures greater than 12 to 13°C. It is likely that there will be slower or no growth of silver perch during winter in temperate regions such as southern NSW where water temperatures as low as 4°C have been recorded in ponds at the Inland Fisheries Research Station, Narrandera (Stuart Rowland, unpublished data) and 5°C in farm dams (Barlow and Bock, 1981). Problems are encountered with the over-wintering of some warmwater fish in ponds (Halevy, 1979; Stickley and Winfree, 1983; Busch, 1985) and further research is needed to evaluate the effects of water temperatures below 10°C on the survival and growth of silver perch under semi-intensive conditions.

Silver perch grew rapidly when water temperatures exceeded 20°C and the mean daily growth rates of 2.1 and 2.3g/fish (Table 3) are similar to, or faster than those reported for other species under similar culture conditions. Sarig and Arieli (1980) report daily individual growth increments of 2.3g for tilapia stocked at 20,000/ha, and grown to 200 - 400g in 170 days, and Lovshin et al. (1990) found that tilapia grew at 1.3 g/day when stocked at 10,000/ha in 0.04-ha earthen ponds for 104 days during summer. Rappaport and Sarig (1979) reported daily growth rates of 2.8 - 4.1g for carp stocked at 20,000/ha and grown to 324 - 478g with an inverse relationship between stocking density and growth; the carp stocked at 7,000/ha grew faster than those stocked at 20,000/ha. However, silver perch stocked at 21,000/ha grew at similar rates to those stocked at 7,000/ha (Fig. 1, Table 3) suggesting that this species could be stocked at even higher densities without adversely affecting growth rate.

The stocking densities used, and the production rates of silver perch in this initial production experiment are similar to those achieved in the large-scale commercial culture of warmwater species in other countries. Stocking densities of 8,000 to 20,000/ha lead to production rates of 3,000 to 6,000 kg/ha/year with an average of 4,400 kg/ha/year in the channel catfish industry (Tucker, 1985; Stickley, 1988; Parker, 1988). Although production rates can be higher under experimental conditions than on commercial fish farms (Shell, 1983; Parker, 1988), the mean production rate of 9,819 kg/ha/year of silver perch stocked at 21,000/ha (Table 2) suggests that annual rates of at least 5,000 kg/ha are achievable under commercial conditions. The use of densities of 10,000 to 20,000/ha result in production rates of 4,000 to 10,000 kg/ha/year of tilapia under both experimental and commercial conditions (Hepher and Pruginin, 1981; Lovshin et al., 1990; Hanley, 1991). In China, the world's largest producer of cultured finfish (Nash and Kensler, 1990) the average annual pond production of carp and tilapia is about 2,100 kg/ha, although in the southern regions of China, rates may exceed 9,000 kg/ha (Cui He, 1990).

The daily production rate of 40.9 kg/ha of silver perch stocked at 21,000/ha (Table 3) is similar to the daily production of 45 kg/ha reported for tilapia stocked at 20,000/ha and grown for 170 days (Sarig and Arieli, 1980), but less than the 66 kg/ha for carp cultured at 20,000/ha for 153 days (Rappaport and Sarig, 1979). The loss of production of silver perch caused by the significantly slower growth during December compared to November and January (Fig. 2) and a daily production of 97.7 kg/ha in one pond stocked at 21,000/ha during January (Table 3), suggest that higher production rates are possible for this species, even at similar stocking densities. Because stocking density did not significantly affect growth rate (Fig. 1, Table 3), the use of higher stocking densities may also result in much higher production rates.

The FCRs for silver perch, which ranged from 1.6 to 2.0:1 over the six ponds are comparable to those reported for carp and tilapia (Rappaport and Sarig, 1979; Sarig and Arieli, 1980; Lovshin et al., 1990). FCRs in commercial channel catfish ponds are near 2.0:1 (Lovell, 1992) and while such values are common and acceptable, the high and increasing cost of feeds in aquaculture (Manzi, 1989) necessitate the development of diets, feeding regimes, fish husbandry and pond management techniques that minimise food conversion ratios. Significantly lower FCRs for silver perch during the grow-out phase are achievable. Previous studies reported FCRs of 1.0 to 1.3:1 for fingerlings reared in 0.1-ha earthen ponds (Rowland et al., in press) and 0.7:1 for fish stocked into a 0.4-ha pond at 14,500/ha and grown to a mean weight of 202g in 181 days (Rowland, 1994). In addition, the actual FCRs in the current study may have been over-estimated because the artificial feed contained up to 15% dust. Pellets were not sieved before feeding and the dust was probably not utilized by the silver perch, and may have also contributed to the deterioration of water quality during summer.

An important finding from our study is that feeding costs for silver perch cultured in static earthen ponds are relatively low. Based on current ingredient costs, manufacturing cost of $A100.00/tonne, and FCRs of 1.9 and 1.8:1, feed costs were $A1.55 and $A1.47/kg at the high and low stocking densities respectively (Table 2). The experimental diet contained 27% fishmeal (Allan and Rowland, 1992) and because recent studies by Allan and Rowland (in press) and Allan et al. (in press) have found that some sources of plant proteins, including soybean meal, peanut meal, canola meal and lupins have the potential to replace much of this fishmeal, it is likely that significantly cheaper diets and hence lower feeding costs for this omnivorous species (Barlow et al., 1987) will be developed. Assuming the cost of feed is approximately 50% of total production costs as in other aquaculture industries (Waldrop & Dillard, 1985; Manzi, 1989), the cost of producing silver perch on commercial farms may be around A$3.00/kg or lower.

Nightly aeration of silver perch ponds ensured that DO concentrations remained above 4.4 mg/l as reported for channel catfish cultured under similar conditions (Hollerman and Boyd, 1980; Zhang & Boyd, 1988; Thomforde & Boyd, 1991). Critical levels for silver perch are not known, although Rowland (1994) reported that fish continued to feed, albeit less aggressively, when the DO concentration was 2.3 mg/l near the surface of an unaerated pond. As in the pond culture of channel catfish (Tucker et al., 1979; Tucker & Boyd, 1985; Cole & Boyd, 1986) the greater amount of feed added to silver perch ponds stocked at the high density (Table 3) probably contributed to the significantly lower concentrations of DO in these ponds during summer (Fig. 2). Regular or continuous aeration of ponds in semi-intensive and intensive culture of finfish, besides avoiding mortalities due to low concentrations of DO, results in increased feeding efficiency and profitably increases yields (Hollerman & Boyd, 1980; Boyd, 1985; Zhang & Boyd, 1988; Sarig, 1989). Supplemental aeration should therefore be an essential management practice when stocking densities of silver perch of 21,000/ha or higher are used.

The values of pH, which ranged from 7.0 to 9.6, are similar to those normally encountered in the pond culture of warmwater fishes (Hepher & Pruginin, 1980). Values were significantly higher in spring and early summer (Fig. 2) during large blooms of phytoplankton. Silver perch continued feeding and did not display any obvious signs of stress when the pH reached 9.6, and values of 9.5 are common in productive, warmwater fish ponds, where levels can reach 10.2 for short periods without harmful effects (Hepher & Pruginin, 1980; Hollerman & Boyd, 1980).

During late spring and summer, high concentrations of TAN (1.0 - 3.0 mg/l) were common in the high density ponds, whereas concentrations were significantly lower in the low density ponds (Fig. 4). TAN in fish ponds is positively correlated to the feeding rate (Tucker & Boyd, 1985) and the percentage of protein (Li & Lovell, 1992), and the concentrations recorded in the silver perch ponds were similar to those reported in channel catfish culture. Tucker et al. (1979) recorded average TAN concentrations between 1.0 and 2.3 mg/l in ponds stocked with 20,385 fish/ha and given a maximum daily feeding rate of 78 kg/ha of a 35% protein diet, whereas concentrations did not exceed 0.5 mg/l in ponds where fish were fed 34 kg/ha/day, and Cole & Boyd (1986) found that concentrations of TAN were frequently 2 to 4 mg/l in ponds receiving 84 kg/ha or more feed per day. The lower concentrations of TAN in silver perch ponds during March (Fig. 4) were probably due, in part to the decreased feeding rate (Table 1).

The 24-h LC50 of $NH_3$-N to channel catfish ranges from 1.39 to 2.36 mg/l (Robinette, 1976; Tomasso et al., 1980) and concentrations as low as 0.12 and 0.2 mg/l have been reported to reduce growth in channel catfish (Robinette, 1976; Colt and Tchobanoglous, 1978). Un-ionised ammonia is the major growth inhibitor that restricts the production period to 50 -100 days in intensively stocked Israeli warmwater fish ponds (Rimon and Shilo, 1982; Shilo and Rimon, 1983). A concentration of 0.65 mg/l, and the highest mean monthly concentrations of $NH_3$-N in silver perch ponds stocked at both densities were recorded in December (Fig. 4), and although there were no obvious signs of stress, prolonged exposure to concentrations over 0.1 mg/l may have caused the significant reduction in growth and production rates during this month (Fig. 2). It is also possible that nitrite ($NO_2$-N) which was not monitored, but is known to reach levels harmful to warmwater fish in ponds (Schwedler and Tucker, 1983; Li and Lovell, 1992) reached relatively high levels and adversely affected the growth of silver perch during December.

There were blooms of phytoplankton, predominantly the blue-green algae or cyanobacteria Microcystis and Anabaena in each pond during spring and early summer. Blue-green algae are common in fish culture ponds where they may cause problems with water quality and are potentially toxic to fish and zooplankton (Boyd, 1979; Panaloza et al., 1990; Sevrin-Reyssac and Pletikosic, 1990). Rowland (1994) found dead and moribund silver perch in a pond and suggested that toxins produced by blue-green algae may have stressed and killed these fish; however, the excellent performance of the silver perch during the current study, suggests that blooms of Microcystis and Anabaena do not always have an adverse affect. The silver perch harvested from some ponds had a strong earthy, musty odour and flavour. This condition is referred to as off-flavour and is a major economic problem in some freshwater aquaculture industries because the fish must be held in ponds or transferred to clean water until the flavour is eliminated (Tucker and

Martin, 1991). The off-flavour is thought to be caused principally by the compounds geosmin and 2-methylisoborneol which are synthesised by some species of blue-green algae and actinomycetes (Tucker & Boyd, 1985). Off-flavour is a potential problem for the silver perch culture industry.

## CONCLUSIONS

The survival, growth and production of silver perch in this experiment were similar to those reported for channel catfish, tilapia and carp. Efficient, large-scale production of these species is based on techniques developed over decades of research and development, as well as traditional practices. The performance of silver perch should be improved with further research to develop cost-effective diets, optimum stocking densities and feeding regimes, fish husbandry techniques, production strategies, and the implementation of selective breeding programs. Silver perch culture has the potential to develop into a very large industry in Australia, based on high-volume, relatively low-cost production.

## ACKNOWLEDGMENTS

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TABLE 1. Feeding regime used for silver perch stocked at densities of 21,000 and 7,000/ha in 0.1-ha earthen ponds.

| Period | Temperature range (°C)[a] | Range of mean weights (g)[a] | Feeding rate (% body weight) | Feeding frequency (no. times/day) | Size of feed |
|---|---|---|---|---|---|
| May, June | 18.1 - 21.1 | 13 - 19 | 4 | 2 | 3C[b] |
| June (2 weeks) | 14.1 - 18.4 | 41 - 48 | 2 | 2 | 3C |
| July | 11.1 - 15.5 | 52 - 56 | 1 | 1 | 3C |
| August | 12.2 - 16.5 | 58 - 70 | 1 | 1 | 3P[c] |
| September - October | 14.1 - 25.9 | 77 - 147 | 2 | 2 | 3P |
| November | 21.1 - 26.8 | 199 - 265 | 3 | 2 | 3P |
| December - February | 22.3 - 30.0 | 260 - 419 | 3 | 2 | 6P[d] |
| March | 24.4 - 26.7 | 413 - 489 | 2.5 | 2 | 6P |

[a] Range over the 6 ponds

[b] 3mm diameter crumble

[c] 3mm diameter x 10mm long pellet

[d] 6mm diameter x 10mm long pellet

**TABLE 2** Survival, length, weight, coefficients of variation (COV) of length and weight, standing crop, production rates, food conversion ratio (FCR) and cost of feeding silver perch stocked at densities of 21,000 and 7,000/ha in 0.1 - ha earthen ponds and cultured for 10 months. Data are presented as the means ± s.d. of three replicate ponds.

| Parameter | Stocking density (no./ha) 21,000 | 7,000 |
|---|---|---|
| Survival (%) | 92.8 ± 3.1 | 94.7 ± 2.0 |
| Length (mm) | 296.9 ± 3.8 | 308.7 ± 5.5 |
| COV length | 10.5 ± 0.8[a] | 8.2 ± 0.7[a] |
| Weight (g) | 434.9 ± 17.7 | 473.2 ± 17.3 |
| COV weight | 31.4 ± 2.3 | 24.9 ± 2.5 |
| Standing crop (kg) | 846.6 ± 18.0[b] | 313.7 ± 15.6[b] |
| Production rate | | |
| kg/ha/day | 26.9 ± 0.7[b] | 10.1 ± 0.5[b] |
| kg/ha/year | 9819 ± 238[b] | 3699 ± 192[b] |
| FCR | 1.9 ± 0.1 | 1.8 ± 0.1 |
| Cost of feeding[c] | | |
| A$/fish | 0.65 | 0.67 |
| A$/kg | 1.55 | 1.47 |

[a] Means significantly different $P<0.05$

[b] Means significantly different $P<0.01$

[c] Calculated using mean FCRs, current cost of ingredients and a manufacturing cost of $100.00/tonne.

**TABLE 3** Growth rates, production rates and maximum daily feeding rates over the "growing season" from October to March.

| Stocking density no./ha | Growth rate[a] (g/fish/day) | Production rate[a] (kg/ha/day) | Maximum feeding rate[b] (kg/ha/day) |
|---|---|---|---|
| 21,000 | 2.1 ± 0.1 | 40.9 ± 1.4 | 210 |
| 7,000 | 2.3 ± 0.1 | 15.3 ± 0.8 | 66 |

[a] Mean ± s.d. of three replicate ponds

[b] Maximum from three replicate ponds

Fig. 1 Growth of silver perch stocked at densities of 21,000 and 7,000/ha in 0.1-ha earthen ponds. Data are monthly means of the three replicate ponds.

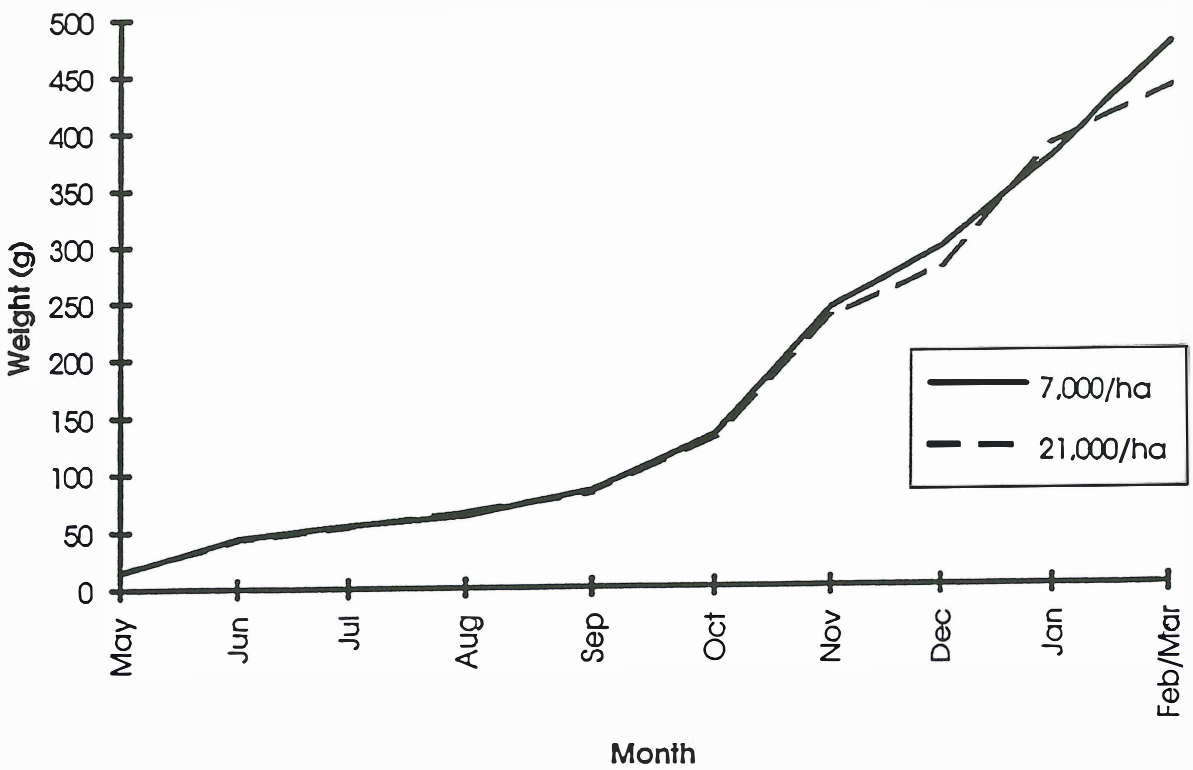


Fig. 2 Mean monthly growth rate and production rate of silver perch stocked at densities of 21,000 and 7,000/ha. Data are from the three replicate ponds in each treatment.

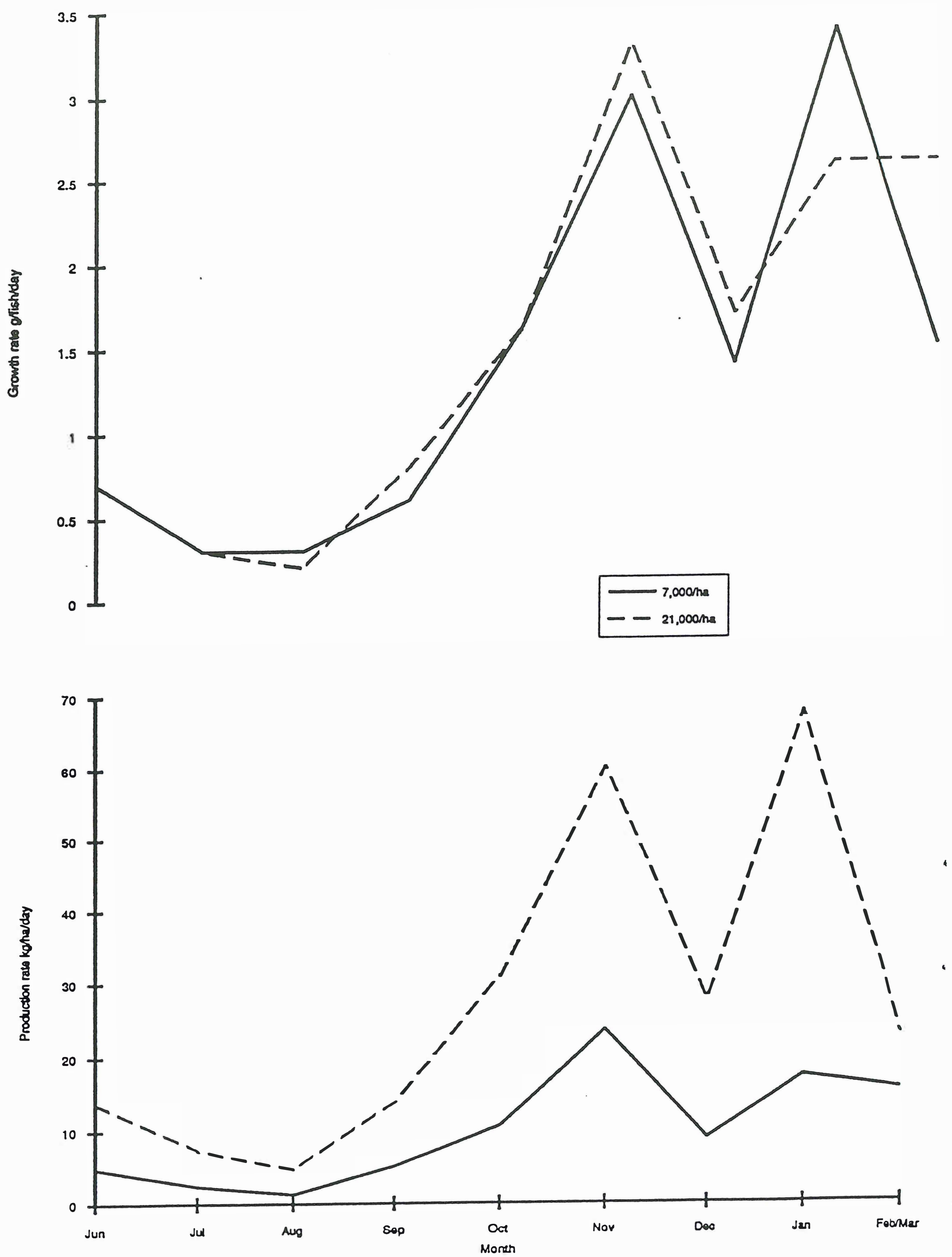


Fig. 3 Weight-frequency distribution of silver perch harvested from 0.1-ha earthen ponds stocked at densities of 21,000 and 7,000/ha.

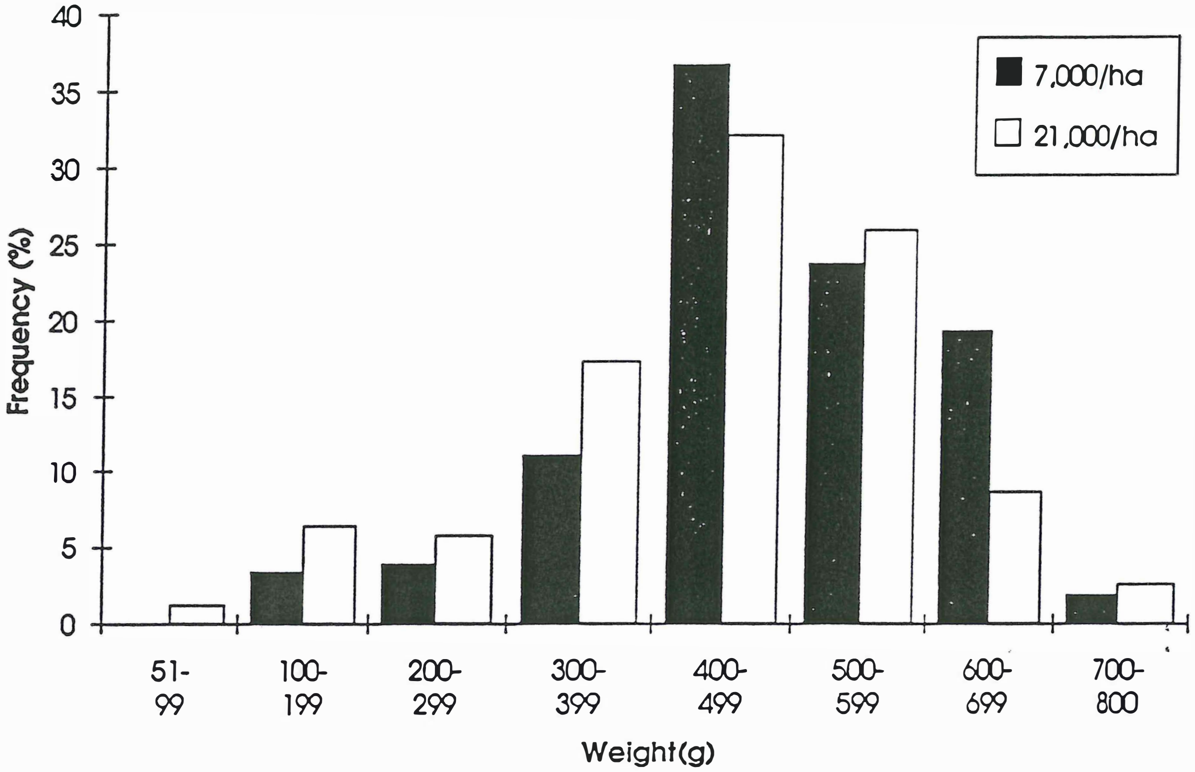
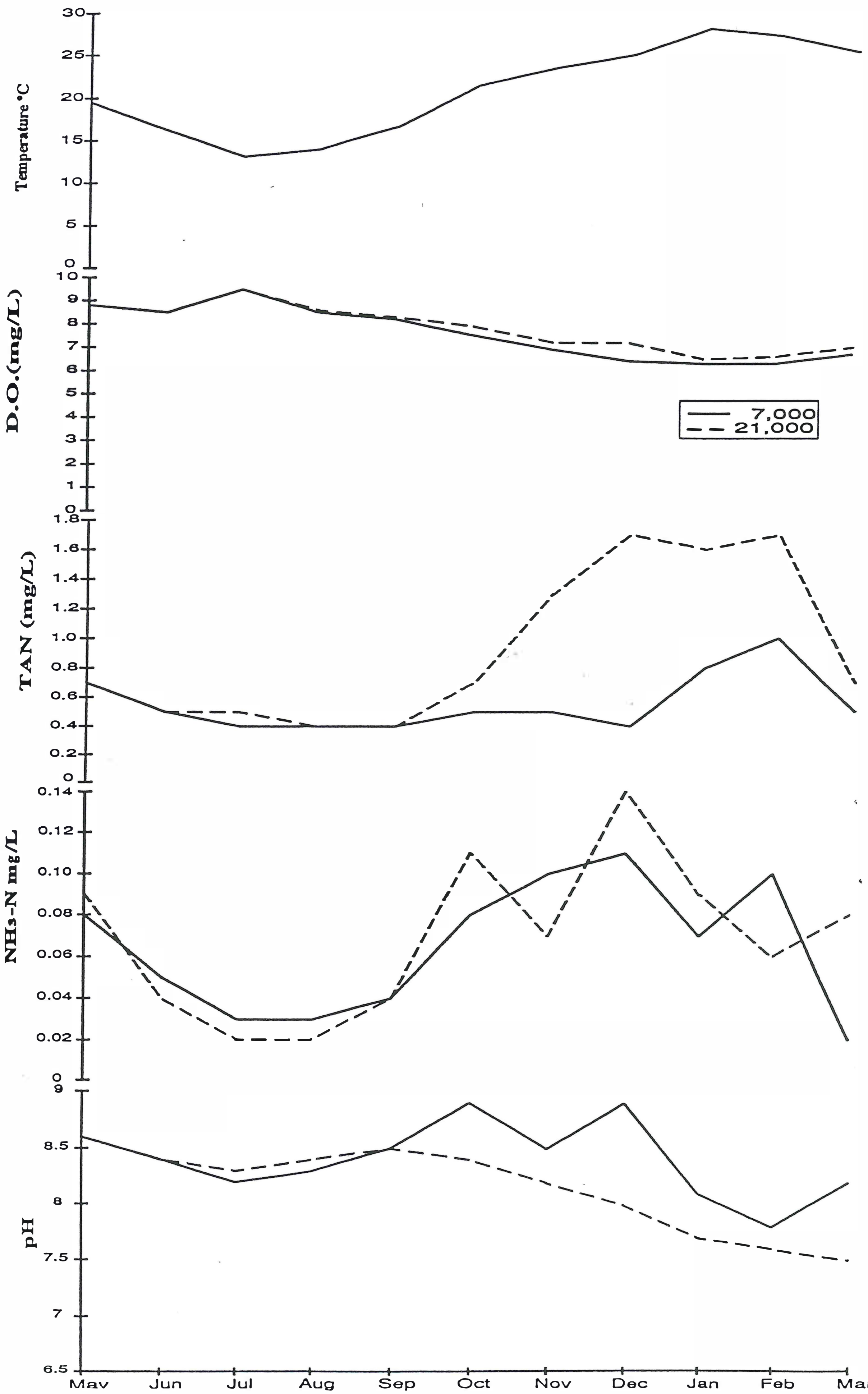


Fig. 4 Mean monthly water temperatures, dissolved oxygen (DO) concentration, total ammonia-nitrogen (TAN), un-ionised ammonia ($NH_3$-N) and pH in ponds stocked with silver perch at densities of 21,000 and 7,000/ha. Data are from the three replicate ponds in each treatment.



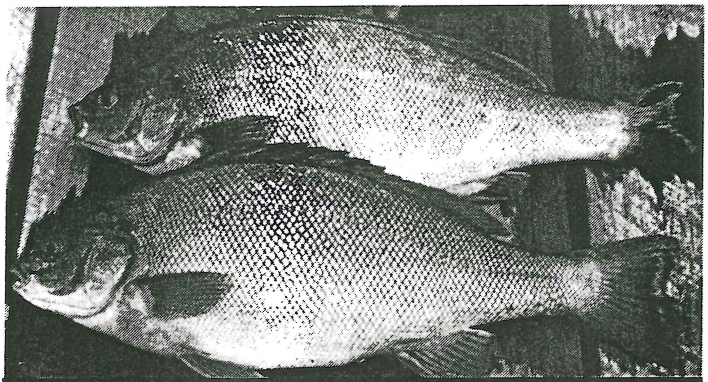
F E A T U R E

# FISH BIOLOGY

## THE RIGHT PREREQUISITES

**A case study with freshwater silver perch (*Bidyanus bidyanus*)**

**By Stuart J. Rowland and Christopher G. Barlow.**



Silver perch caught from a farm dam at Casine, NSW. 12-month old fish such as these weigh 0.7-1.1 kilograms.

On a world-wide basis, aquacultural production has increased rapidly over the last two decades, and the current annual production of about 11.0 million tonnes is approximately 13% of the harvest from wild fisheries (Shepherd and Bromage, 1988). This rate of increase is expected to be maintained, and it is predicted that by 2010 global aquacultural production will contribute over 24% of total fisheries production (IAF, 1985). In fact, Larkin (1988) predicted that over the next 50 years, aquacultural production will come to equal if not surpass the harvest of wild fish.

Finfish constitute about half of the world aquacultural production (by weight), with the great majority of this being farmed in freshwater ponds (Rhodes, 1989; Nash and Kensler, 1990). The culture of freshwater finfish obviously has enormous potential, particularly in Australia where large quantities of white-fleshed fish are imported. Although the demand for seafood is increasing in Australia, most of our wild fisheries are already fully or over-exploited. Australia has many indigenous freshwater fish that are excellent to eat, and with the increased interest in Australiana, and the growing awareness of the nutritional and health benefits of fish in diets, there is certainly a future for farmed native fish — that is if any are suitable for aquaculture!

Aquaculture is in its infancy in Australia and few species are cultured commercially on a large scale. The successful oyster (*Saccostrea commercialis* and *Crassostrea gigas*), goldfish (*Carassius auratus*), rainbow trout (*Oncorhynchus mykiss*) and Atlantic salmon (*Salmo salar*) industries are based on long-established techniques, and are supported by continuing government and/or industry research and management. The relatively small marron (*Cherax tenuimanus*) industry in Western Australia arose after local research in the 1970s (Morrissy, 1986), and the native fish hatchery industry in eastern Australia is based on techniques developed at the Inland Fisheries Research Station, Narrandera, NSW, during the 1970s and the early 1980s (Rowland, 1989).

However, despite the rapidly growing interest and increasing investment in aquaculture, (e.g. penaeid prawns, freshwater crayfish — *Cherax* spp. — and barramundi — *Lates calcarifer*), many enterprises are struggling or have failed in recent years, mainly due to a lack of technology or, in some cases, the selection of unsuitable species and/or sites for aquaculture.

This paper arose from our recognition of the general lack of awareness of some people involved with the industry, of the biological prerequisites necessary for successful aquaculture of a species. We list these requirements, and then discuss why we consider silver perch (*Bidyanus bidyanus*) to be a native freshwater fish with high potential for commercial farming.

### Biological Prerequisites

Of the many thousands of fish species throughout the world, less than 100 are farmed commercially, and of these, very few are farmed on a large scale. The main freshwater fishes cultured for human consumption are: carp (several species, mainly *Hypophthalmichthys molitrix* and *Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), *Tilapia* spp., eels (*Anguilla* spp.), milkfish (*Chanos chanos*), rainbow trout and salmon. These species are biologically suitable for aquaculture.

The following characteristics are prerequisites, and failure to meet one or more of these may make a particular species unsuitable for commercial aquaculture.

- Established hatchery techniques.
- Ability to be held in captivity at high densities.
- Rapid and uniform growth.
- Appropriate dietary requirements.
- Amenable to artificial feeding.
- Efficient food conversion ratio (FCR).
- Non-cannibalistic.
- Disease resistant.
- High meat recovery.

*Harvesting silver perch fry from a pond.*

In addition to these biological factors, a species must have high market acceptance. The ultimate goal of commercial fish culture is to make a profit and so obviously the farmer must produce fish that are marketable in sufficient quantities at acceptable prices. The more marketable the fish, the greater the chance of establishing an economically viable enterprise.

In determining the potential of a species for aquaculture, one of the first steps would be to determine and evaluate the marketability of the species.

### Silver Perch

The silver perch (a member of the family Teraponidae) is an Australian native freshwater fish found naturally in the Murray-Darling river system. It is one of four native species in this system that are keenly sought by inland recreational and commercial fishermen for their sporting and edible qualities. The distribution of silver perch is patchy, and like some

## Biological prerequisites

### 1. Established hatchery techniques.

Large numbers of fry must be available for grow-out operations. Broodfish must be available and the species should be fecund, and capable of spawning, or being induced to spawn, in captivity.

In Australia, fish farmers are generally not permitted to collect juvenile fish from the wild (an unreliable source anyway), and so hatcheries are the only source of fish.

A species does not have potential for farming until the hatchery technology has been developed.

### 2. Ability to be held in captivity at high densities.

Cultivated species must thrive in captivity and be amenable to crowding. Obviously, the more fish that can be stocked into a given space, the greater the potential production.

### 3. Rapid and uniform growth.

Rapid growth ensures efficient use of facilities and food. All freshwater species that are farmed successfully throughout the world grow rapidly under culture conditions and most reach minimum market size (400-500 g) in 18 months or less (Shepherd and Bromage, 1988; Stickney, 1988).

To enable maximum growth, the facilities must be located in an area with the optimum temperature regime of the selected species. Obviously regions where lethal temperatures are reached, or even approached, are totally unsuitable for pond culture.

Variable growth amongst fish within a rearing unit is undesirable and necessitates culling, which increases stress and susceptibility to disease, damages the fish, and requires extra labour and facilities.

### 4. Appropriate dietary requirements.

In general, fish that feed lower in the food chain are most efficient in the use of that food. Although some carnivorous species accept artificial feeds, they are unable to use most of the natural food items in ponds.

### 5. Amenable to artificial feeding.

Semi-intensive and intensive fish culture is based on the use of medium to high stocking densities, prepared feeds (usually specially formulated pellets) and, with some species, fertilization of pond water.

Very high production rates can only be achieved with species that accept prepared feed.

### 6. Efficient food conversion ratio (FCR).

The FCR is the ratio of dry weight of food fed, to the wet weight gain of fish. The lower the ratio, the more efficiently food has been converted to fish flesh.

Feed costs may constitute 40-55% of total production costs and so species that convert food efficiently must be used.

Modern diets enable FCR's of 2:1 or better in trout and carp (Shepherd and Bromage), 1988)

### 7. Non-cannibalistic.

Cannibalism reduces survival rate and production directly by predation or, indirectly through damage and increased stress-related susceptibility to disease.

The greater the degree of cannibalism, the greater the losses.

Most piscivorous and many carnivorous species can be cannibalistic in ponds and so must be culled to reduce losses; culling is undesirable.

### 8. Disease resistant.

Although all species are susceptible to diseases under culture conditions, some are more so than others. This should be considered when selecting a species or geographic region for aquaculture.

### 9. High meat recovery.

Species that have a high fillet to total body weight ratio are desirable because of their more efficient conversion of feed into edible flesh. This is particularly important if the end product is to be processed.

other native species, its numbers have declined since the early 1900s. It is now uncommon in most areas. We believe that the silver perch is the species of fish with the most biological potential for aquaculture in Australia.

The reasons for this potential are discussed below.

1. **Hatchery techniques** that enable the large-scale production of fry were established in the early 1980s (see Rowland 1984, 1989) and are used to produce over one million fry annually at hatcheries in N.S.W., Queensland and Victoria. Consequently large numbers of fry are readily available for grow-out operations.
2. **Silver perch is a hardy fish** that handles well under hatchery and pond conditions. The survival rates of silver perch reared in earthen ponds, at densities up to 1000/hectare at the Eastern Freshwater Fish Research Hatchery, Grafton, were greater than 90% in all six ponds after 15 months. Adults and juveniles school and can often be seen near the surface and edges of ponds and dams. These are desirable characteristics which aid management.
3. **Silver perch can grow rapidly**; fingerlings (50 millimetres and 2 grams) have grown to 1.3 kilograms in 12 months in unmanaged farm dams on the NSW north coast. The growth of silver perch is negligible at water temperatures below 13°C (Barlow and Bock, 1981), and although the optimum temperature for growth is not known, it is likely to be between 20 and 26°C. Consequently silver perch are ideally suited for farming in north-eastern New South Wales and south-eastern Queensland. All silver perch reared in ponds at Grafton grew uniformly, and reached 500 grams in 15 to 18 months, without fertilization or supplementary feeding.
4. **Silver perch is omnivorous** and feeds on a wide variety of items including zooplankton, algae, aquatic insects, molluscs, crustaceans and periphyton (Barlow and Bock, 1981; Merrick and Schmida, 1984). Barlow et al. (1986) found that the diet of silver perch reared extensively in farm dams consisted predominantly of zooplankton.
5. **Juvenile and adult silver perch readily take supplementary feeds** such as pellets, bread, crumbed insects, fish and crustacean flesh. Artificial foods are eaten even when other natural foods are available in ponds. Anderson (1986) found that silver perch in laboratory tanks accepted a variety of textures and flavours. He concluded that they were not nutritionally demanding, and that feed formulations would not be critical for intensive culture.
The amount of fat in the flesh of silver perch can be adjusted by varying the levels of fat in the diet (Anderson and Arthington, 1989).
6. **Food conversion ratios** are not known at this stage, but given the diet of the species, it is likely that supplementary protein requirements will not be great, and comparatively cheap diets may be suitable for semi-intensive pool culture.
7. **Silver perch is not cannibalistic.**
8. **The major diseases** of silver perch under hatchery conditions **are known**. Descriptions of the pathogens and their seasonal incidence, plus the diagnosis and treatment of the diseases are detailed in Rowland and Ingram (in press). Although diseases do not restrict the production of fry in hatcheries, their incidence and effects in intensive culture are not known.
9. **Silver perch has a relatively high meat recovery**, with a fillet to total body weight of 1:2.5 (40%).
10. **Silver Perch has the following marketing attributes:**
   - an Australian native fish,
   - attractive appearance and colour,
   - excellent cooking and edible qualities,
   - white flesh and few bones.

During 1989, small numbers of extensively-reared silver perch sold in Sydney for $12.00/kilogram whole fish and $22.00/live fish (350-400 grams).

## A Word of Caution

The need for a research and development phase cannot be over-emphasised. Pinning hopes in underdeveloped technology is one of the most common pitfalls in aquaculture (Lindbergh and Pryor, 1984). The sea bass (Dicentrarchus labrax) industry in Europe took approximately 20 years andmuch research in several countries before it became commercially viable. Approximately 15 years research and development, with massive government and foreign aid input, was required for barramundi culture to become established in Thailand. Assuming its potential is realised, we envisage that the successful establishment of an aquaculture industry based on silver perch in Australia would take 5 to 10 years from the initial research phase. The need for an appreciation by funding agencies of the likely developmental time, and sustained support through the period, is obvious.

Market research and development is also vital, and every bit as important as biological studies. The development of the channel catfish industry in U.S.A. is evidence that markets can be created. On the other hand, problems currently being experienced in marketing Atlantic salmon reared in Tasmania, and barramundi in Queensland, demonstrate the need for market development, even with well-known and highly regarded species. The success or otherwise of the rapidly expanding freshwater crayfish (Cherax quadricarinatus) industry in Queensland will undoubtedly be determined by the ability to locate, develop and consistently supply the market-place. Similarly, a silver perch industry will need to incorporate market research and development at the earliest opportunity.

## Research

A research project aimed at developing techniques for the commercial aquaculture of silver perch is to commence at the Eastern Freshwater Fish Research Hatchery, Grafton in 1990. The project is being funded by the N.S.W. Agriculture & fisheries and a private company. Factors affecting the survival, growth, food conversion ratio and production of silver perch under intensive conditions will be determined. In addition, funds granted by the fishing Industry Research and Development Council will be used to evaluate the effects of different feed types on the culture of silver perch.

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# THE PROSPECTS FOR THE COMMERCIAL AQUACULTURE OF SILVER PERCH (*Bidyanus bidyanus*)

**A research project arising from a review of freshwater aquaculture**

by


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**NSW Fisheries**

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## INTRODUCTION

Apart from the farming of the Sydney rock oyster (*Saccostrea commercialis*) and the pearl oyster (*Pinctada maxima*), rainbow trout (*Oncorhynchus mykiss*) and goldfish (*Carassius auratus*), aquaculture is a relatively new industry in Australia. During the early 1980's a hatchery industry for native freshwater fish [silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*) and Murray cod (*Maccullochella peeli*)] developed in eastern Australia and techniques for farming the marron (*Cherax tenuimanus*) were developed in Western Australia. During the last five years there has been a large increase in interest in aquaculture and substantial investment into new industries based on Atlantic salmon (*Salmo salar*), barramundi (*Lates calcarifer*), marine prawns (*Penaeus monodon*), freshwater crayfish (*Cherax* spp.) and the Pacific oyster (*Crassostrea gigas*). Although the value of Australian aquaculture production has increased in recent years (O'Sullivan, 1991) many enterprises have struggled or failed due to a lack of technology, poor selection of species and sites, or economic difficulties resulting from high establishment and operational costs. Species such as salmon, barramundi and prawns are high-priced products and so potential markets are relatively small, particularly during periods of recession. These species are also produced overseas and so Australian aquaculturists must compete in the world market and against imported products. In addition, most species (except crayfish) require high levels of protein and so are costly to feed; current feed costs in the salmon, barramundi and prawn industries are $1200-$1500 per tonne.

The silver perch is an Australian native freshwater fish which has been recognised as a species with high biological potential for aquaculture (Rowland and Barlow, 1991). It is omnivorous and should be relatively cheap to feed in ponds because its protein requirements will be lower than those of carnivorous species, and naturally-occurring food organisms such as zooplankton, aquatic insects and algae form part of its diet. It is also expected that the costly fish meal can be partly or completely replaced by vegetable protein e.g. soybean bean, further reducing the cost of the diet.

NSW Fisheries has recognised the potential of silver perch for aquaculture. This paper briefly reviews world and Australian aquacultural and fisheries production, freshwater aquaculture and the potential of silver perch for culture. The difficulties of conducting aquaculture research are briefly discussed and the objectives and preliminary results of a major research project to determine the feasibility and develop techniques for farming silver perch are outlined.

## AQUACULTURE

### Definition and History

Aquaculture is the rearing of aquatic organisms under controlled or semi-controlled conditions.

Fish culture was first practiced in China approximately 2000 BC, and the Pharaohs of Egypt and the Romans also farmed fish (Shepherd and Bromage, 1988). Aquaculture has long been an "art", with methods and ideas being passed from generation to generation by example and word of mouth. Scientific research into the pond culture of fish did not commence, even on a small scale, until the 1930's (Shell, 1983). Consequently the information base for aquaculture is very meagre compared to that for other disciplines such as medicine and agriculture.

## World Production

Aquacultural production has increased rapidly over the last two decades (Table 1). The current annual production of about 14.5 million tonnes is approximately 16% of the harvest from wild fisheries. Finfish constitute about half the aquacultural production and in 1987, 88.4% of these were farmed in freshwater (Rhodes, 1989; Nash and Kensler, 1990), making freshwater fishes the major contributor to world production. Between 1975 and 1985 there was a 79.5% increase in the production of fish on a world-wide basis. World aquacultural production in 1987 consisted of finfish (51.4%), algae (23.8%), mollusca (20.2%), crustacea (4.4%) and other products (0.2%) (Nash and Kensler, 1990).

**Table 1.** Global aquacultural production of fish, shellfish and seaweed.

| Year | Tonnes (x $10^6$) |
|---|---|
| 1966 | 1.0 |
| 1972 | 2.6 |
| 1975 | 6.0 |
| 1983 | 10.2 |
| 1988 | 14.5 |

Aquaculture is increasing in both developed (e.g. North America, Norway, Israel) and under-developed (e.g. South America, China and other parts of Asia) countries. For example production in the channel catfish (*Ictalurus punctatus*) industry in the USA has increased from less than 10,000 tonnes in 1976 to 270,000 tonnes in 1989; this industry, has an annual growth rate of approximately 20% and is now the third largest rural industry in the state of Mississippi and the fastest growing agriculture or fisheries industry in the entire USA (Gary Edwards, Assistant Director - Fisheries, US Fish and Wildlife Service, Personal Communication 1991).

In contrast to the rapid growth of aquaculture, world fisheries production has remained relatively stable, at a maximum of about 90,000,000 tonnes (90 MT) since the early 1970's. Production of premium white flesh table fish has actually declined in many areas. Future expansion of wild fisheries is unlikely because many commercial species have been overexploited and there is very limited potential for finding additional resources. In addition, costs involved in establishing and running major fishing industries are extremely high, and there is increasing habitat destruction and pollution throughout the world.

Aquaculture is the only means of significantly increasing fisheries production, and it is predicted that by 2010 global aquacultural production will contribute over 24% of total fisheries production (IAF, 1985). Larkin (1988) predicted that over the next 50 years aquacultural production will come to equal if not surpass harvest of wild fish, and that much of the production will be by large-scale commercial operations with substantial research accompanying their production facilities.

## Role of Research: Channel Catfish Industry

The rapid increase in aquacultural production since the 1960's has been made possible by major contributions from research. An example of such development is the channel catfish industry in the USA. This example has many similarities with the proposed development of a silver perch industry in New South Wales. Much of the success of the catfish industry can be attributed to active research programs by federal and state governments (Stickney, 1986). Initial research centred on developing pond management procedures, particularly determining optimum stocking densities, maintenance of water quality, prevention and control of diseases, and the formulation of prepared feeds. More recent research has resulted in intensive production (over 4000 kg/ha/yr) through improved diets and pond management. The revenue to farmers in the channel catfish industry even in the early 1980's was $100 million annually (Stickney, 1986).

The need for a research and development phase in a new industry such as aquaculture cannot be overemphasised. In the USA one of the most common ways to lose money in aquaculture is to pin hopes on undeveloped technology (Lindbergh and Pryor, 1984). Research is needed not only to develop the actual techniques, but also to provide a data base for an economic evaluation of farming each particular species.

## STATUS OF WILD FISHERIES AND THE NEED FOR AQUACULTURE

Australia has very limited fisheries resources compared to other continents. In addition, during the last three decades some of the major commercial fisheries [e.g. gemfish (*Rexea solandri*), southern bluefin tuna (*Thunnus maccoyii*) and snapper (*Pagrus auratus*)] have declined dramatically and others, such as the orange roughy (*Hoplostethus atlanticus*) fishery of Australia's southern waters, are in grave danger of overexploitation in the near future. Inland freshwater fisheries are very limited and do not make a significant contribution to overall production.

Large quantities of fish are imported into Australia for human consumption. In 1989/90 approximately 70,000 tonnes of fish (not including crustaceans and molluscs) valued at $252,300,000 were imported (Jarzynski, 1991). Australia's largest fish processing company, Edgels, use no locally-caught fish and import all their product.

Aquaculture has the potential to replace part or all of the lost production from the overexploited fisheries such as gemfish (catches peaked at 5,100 tonnes in 1980 but will be less than 500 tonnes in 1992) as well as replace some of the imports. High quality fish products could also be exported. There is an urgent need to develop efficient aquaculture industries in Australia, particularly for finfish. The demand for white-fleshed fish will continue to increase as Australia's population rises and people become better informed about the nutritional and health benefits of eating fish.

## NSW FISHERIES

Governments in N.S.W. have made significant commitments to the study of the biology and aquaculture of native freshwater fishes, commencing with the establishment of the Inland Fisheries Research Station (IFRS) at Narrandera in 1960-61. The late John S. Lake brilliantly pioneered research into the reproductive biology of inland fishes, and the IFRS remains one of Australia's premier freshwater fisheries research stations. Other outstanding fisheries facilities in NSW are the Fisheries Research Institute, Cronulla, the Brackish Water Fish Culture Research Station (BWFCRS), Salamander Bay and the Eastern Freshwater Fish Research Hatchery (EFFRH), Grafton. Aquaculture research is conducted by some of Australia's most experienced biologists at each of these facilities, and they are well supported by, biometricians, chemists, geneticists, physiologists, nutritionists, librarians, pathologists and administrative, technical and general support staff.

An example of the role that research has played in aquaculture in N.S.W. is the recent development of the small, but very successful, native freshwater fish hatchery industry in eastern Australia. A research project aimed at developing techniques to breed silver perch, golden perch and Murray cod commenced at the IFRS in 1971. By the early 1980's techniques enabling the large-scale production of these fishes had been developed and numerous scientific and technical papers are available (Rowland, 1983, 1984, 1986 a,b,c, 1988, 1989). The techniques are now used to produce millions of juvenile native fish annually at government, angling club and private, commercial hatcheries in NSW, Victoria and Queensland. Although this hatchery technology is well developed, there has been no previous research into the production of edible native finfish.

## TECHNIQUES USED TO CULTURE FRESHWATER FISHES

### Species Cultured

Fish that are farmed on a large scale throughout the world include carp, tilapia, salmon, trout, channel catfish, eels, sturgeon (all freshwater) milkfish, mullet, seabream, yellowtail (estuarine or marine) (Table 2).

**Table 2.** World production of finfish in 1987 (From Nash and Kensler, 1990).

| Common name | Scientific name | Tonnes |
|---|---|---|
| silver carp | *Hypophthalmichthys molitrix* | 1,340,718 |
| common carp | *Cyprinus carpio* | 927,735 |
| bighead carp | *H. nobilis* | 631,435 |
| grass carp | *Ctenopharyngodon idella* | 535,691 |
| milkfish | *Chanos chanos* | 330,148 |
| rainbow trout | *Oncorhynchus mykiss* | 213,642 |
| white amur bream | *Parabramis pekinensis* | 174,200 |

| | | |
|---|---|---|
| channel catfish | *Ictalurus punctatus* | 170,000* |
| amberjack | *Seriola quinqueradiata* | 160,285 |
| crucian carp | *Carassius carassius* | 108,915 |
| tilapia | *Oreochromis niloticus* | 97,700 |
| Atlantic salmon | *Salmo salar* | 67,732 |

* Channel catfish production now exceeds 270,000 tonnes.

## Management Systems

Fish farms may combine hatchery, nursery and grow-out operations, but in large industries (e.g. channel catfish) many farmers specialise. The normal strategy for farming channel catfish is to have separate nursery and grow-out phases. Fry are stocked at high densities and reared to fingerling size during the first growing season. These fish are then harvested and restocked at a lower density for grow-out to market size. Alternatively, grow-out operations can use a continual harvest technique whereby marketable fish are removed periodically throughout the year. Fry or fingerlings are then restocked, so that several size classes may be present in a given pond.

Both systems have advantages and disadvantages. The trend towards intensive culture favours the former system because of its more efficient utilization of pond space.

## Pond Production

More than 90% of the tonnage of cultured fish and crustaceans is produced in earthen ponds (Allen *et al.*, 1984; Rhodes, 1989). Production ranges from extensive culture where fish are stocked at low densities, artificial feed is not provided and there is minimum management input, to highly intensive culture where ponds are stocked at very high densities, all dietary requirements are met by a specially formulated "complete" feed and there is very close monitoring and efficient management of water quality and disease. Most fish are cultured under pond conditions that lie between these extremes: static water, medium stocking densities, supplementary feeding, regular monitoring and management.

## Production Rates

Production rates vary enormously world-wide depending on species cultured and systems used. In Israel where carp, tilapia and mullet are the main fishes cultured, pond production rates under extensive, semi-intensive and highly intensive systems can reach 3,000, 9,000 and 20,000 kg/ha respectively (Shepherd and Bromage, 1988). The production on commercial catfish farms in the USA, where water is not exchanged, but high quality feeds and aeration are used is 3,000-6,000 kg/ha/yr, with an average of 4,400 kg/ha/yr; production without aeration ranges from 2,500-3,000 kg/ha/yr (Tucker, 1985; Stickney, 1986; Shepherd and Bromage, 1988).

## Other Facilities

Other facilities used for intensive culture are raceways, tanks and cages. Although these facilities are major components of many salmonid farms, they have not been used successfully to produce catfish and other warmwater fishes on a large scale in the USA (Stickney, 1986; Shepherd and Bromage, 1988). Limitations that apply to one or more include a higher incidence and difficulty in treating disease, need for large amounts of high quality water, problems with biological fouling, deterioration of materials, the need for recirculation of some or all of the water, and subsequent high energy requirements and costs of back-up units. In future years, as the technology on recirculating systems improves, the use of such facilities may become viable.

## Major Factors Affecting Production

A large number of factors, many of which interact with each other, affect production rates. The most important of these are:

(i) species: selection of species suitable for culture is of utmost importance (see following section),

(ii) temperature: fish are poikilotherms (cold-blooded) and so temperature affects all aspects of their biology, most importantly growth rate and range of environments within which optimum growth occurs. Temperature is an extremely important factor to be considered when selecting a site for aquaculture (Barlow, 1986; Rowland, 1986c).

(iii) stocking density: probably the single most important variable in fish culture after species selection, and can affect survival rate, growth rate, feeding requirements, transmission of pathogens, accumulation of waste products, production and most importantly cost of production. In general, at low stocking densities little or no supplementary feeding is required, there are relatively few disease and water quality problems, costs are low, but production is also low, whereas at high densities, supplementary feeding is required, disease and water quality problems increase with increasing densities, costs are high, but production rates can also be very high.

(iv) nutrition: for normal growth, fish need adequate quantities of proteins, carbohydrates, lipids, vitamins and minerals. These dietary requirements may be provided by natural organisms in a pond, by prepared diets (usually pellets) or by a combination of these sources. Although the general nutritional requirements of fish species are similar, the exact proportions of some components required for optimum growth vary for different stages of the life cycle and between different species. Successful semi-intensive or intensive aquaculture is dependent on the use of supplementary or complete diets. The cost of feed may comprise up to 55% of total production costs (Hepher and Pruginin, 1981; Stickney, 1986) and so the formulation of cost-effective diets is a major factor determining the economic viability of aquaculture.

(v) water quality: an abundant supply of good quality water is essential for successful aquaculture. The major problem in intensive aquaculture is the deterioration of water quality with increasing stocking densities and feeding rates. Obviously lethal levels must be avoided, but sub-lethal levels also create problems by decreasing growth rates and increasing the susceptibility of fish to diseases.

(vi) disease: outbreaks of disease are much more prevalent on fish farms than in the wild. Pathogens are rapidly transmitted and result in increased stress, decreased growth rates and ultimately death. Efficient identification and monitoring of pathogens, and diagnosis and treatment of diseases are essential for successful aquaculture.

## BIOLOGICAL PREREQUISITES FOR AQUACULTURE

Of the many thousands of fish species throughout the world, less than 100 are farmed commercially, and of these, very few are farmed on a large scale.

The following characteristics are prerequisites, and failure to meet one or more of these may make a particular species unsuitable for commercial aquaculture:

- established hatchery techniques
- ability to be held in captivity at high density
- behaviour that enables regular observation
- rapid and uniform growth
- appropriate dietary requirements
- amenable to artificial feeding
- efficient food conversion
- non-cannibalistic
- disease resistant
- hardiness
- high meat recovery

In addition to these biological factors, a species must have high market acceptance. The ultimate goal of commercial fish culture is to make a profit and so obviously the farmer must produce fish that are marketable in sufficient quantities at acceptable prices. The more marketable the fish, the greater the chance of establishing an economically viable enterprise.

## SILVER PERCH

The silver perch (a member of the family Teraponidae) is an Australian native freshwater fish found naturally in the Murray-Darling river system. It is one of four native species in this system that are keenly sought by inland recreational and commercial fishermen for their sporting and edible qualities. The distribution of silver perch is patchy, and like many other native species, its numbers have declined since the early 1900's. It is now uncommon in most areas.

The silver perch has high potential for aquaculture for the following reasons.

1. **Hatchery techniques** that enable the large-scale production of fry were established in the early 1980's (Rowland 1984, 1986 a,b, 1989) and are used to produce over 1 million fry annually at hatcheries in NSW, Queensland and Victoria. Consequently large numbers could easily be made available for grow-out operations.

2. **Silver perch is a hardy fish** that handles well under hatchery and pond conditions. Adults and juveniles school and can often be seen near the surface and edges of ponds and dams. These are desirable characteristics which aid management under intensive conditions.

3. **Silver perch can grow very rapidly**; up to 1.3 kg in 12 months in unmanaged farm dams on the N.S.W. north coast. Barlow and Bock (1981) found that substantial growth of silver perch in farm dams occurs only at water temperatures above 12°C. The optimum temperature for growth is likely to be between 25 and 30°C. Consequently silver perch are ideally suited for farming in north-eastern New South Wales and south-eastern Queensland where a growing season of 10-12 months can be expected.

4. **Silver perch is omnivorous** and feeds on a wide variety of items including zooplankton, algae, aquatic insects, molluscs, crustaceans and periphyton (Barlow and Bock, 1981; Merrick and Schmida, 1984).

5. **Juvenile and adult silver perch readily take supplementary feeds** such as pellets, bread, insects, fish and crustacean flesh. Artificial foods are eaten even when other natural foods are available in ponds.

6. **Food conversion ratios** are very low (0.7-1.3) in pond culture and given the diet of the species, it is likely that supplementary protein requirements will not be great and comparatively cheap diets may be suitable for intensive pond culture.

7. **Silver perch is not cannibalistic.**

8. **The major diseases** of silver perch under hatchery conditions are known (Rowland and Ingram, 1991).

9. **Silver perch has a high meat recovery.**

10. **Silver perch has the following marketing attributes:**

    - an Australian native fish,
    - attractive appearance and colour,
    - excellent cooking and edible qualities,
    - white flesh and few bones,
    - easily transported live.

## PROBLEMS AND DIFFICULTIES IN AQUACULTURE RESEARCH

Conducting experiments in aquaculture is much more difficult than in other fields such as agriculture, and some of the problems and difficulties are briefly discussed below.

1. **Accessibility of fish.** Efficient and effective collection of relevant data is the basis of good scientific research. One of the major problems in fisheries and aquaculture research is obtaining sufficient numbers of unbiased, representative samples for data collection. Fish can be very difficult to capture, particularly in large ponds. Generally

fish can't be seen or observed before capture. Healthy fish may actively avoid nets and traps, whereas slow growing, weak, stressed and diseased fish may be easier to sample, leading to sample bias.

2. **Biological variation - need for replication.** Genetics and sexual reproduction ensures that all members of out-breeding species are different (with the exception of monozygotic twins). Hence there is natural variation between any two members of a population, and specimens sampled randomly will differ biologically. This biological variation leads to variation between the fish in two experimental units in aquacultural research, i.e. ponds, tanks or cages. This necessitates careful experimental design, in particular replication of treatments so that the researcher can determine if an observed difference (or lack of difference) between treatments is real or just the result of chance arising from natural variation.

3. **Mortality.** The mortality of stocked fish is probably the most difficult problem encountered in production experiments. If only a small number or percentage die in a pond, the problem is minimal, but if many fish die the value of that pond or replicate diminishes to a stage where it is lost. If there is high mortality in more than one replicate, a treatment can be lost.

   Another problem is knowing when the mortality occurred and which fish died. Not all dead fish float and there is often differential mortality in fishes, e.g. under anoxic conditions the larger fish die first. Stress and injury from sampling can lead to death after restocking. Undetected mortality will lead to excess food being added to ponds, creating unsuitable water quality. It is difficult to compensate for mortality and the above factors must be considered when designing an aquacultural research project.

4. **Water quality and disease.** The quality of water and the incidence of disease are factors that change continually. Both may reach lethal or sub-lethal levels in one or more ponds. Complete treatments, as well as single replicates can be lost through deterioration of water quality or outbreaks of disease. Management practices to alleviate the poor water quality or disease in a pond will change that particular replicate. Another problem is that stress induced by sub-lethal levels may cause undetectable changes to fish in a replicate.

5. **Innate variability.** A common feature of pond culture is the innate variability between ponds, even adjacent ponds built at the same time. Once built, each pond takes on its own "character". When filled, the pond is a dynamic, ecological system consisting not only of the experimental fish but also of bacteria, protozoans, algae, zooplankton, aquatic insects, larvae of terrestrial insects, detritus etc. The population of each species is continually changing as organisms grow, reproduce and die. Many of these organisms and their effects cannot be detected by the aquaculture researcher. The changes are often independent of the treatment and may differ from replicate to replicate.

6. **Extrapolation of results.** Extrapolation of production estimates from the results of experiments conducted in small containers such as aquaria and tanks, is usually misleading and in many cases represents a very poor utilization of research resources. If a major aim of a research project is to develop techniques for the production of fish

in ponds, the experimental unit must be ponds. Shell (1966) found that there were considerable differences in relative yields of channel catfish in 0.00059 ha plastic-lined pools, 0.002 ha concrete tanks and 0.1 ha earthen ponds. Ponds, 0.1 ha surface area are suitable experimental units for fish culture in the U.S.A. (Professor Claude Boyd, Auburn University, personal communication).

## RESEARCH PROJECT

In 1990, NSW Fisheries commenced a research project on the development of techniques for the commercial aquaculture of silver perch at EFFRH, Grafton.

The objectives of the project are to:

1. Determine the feasibility of culturing silver perch under intensive conditions in earthen ponds, cages and tanks.

2. Determine the effects of stocking density and artificial diets on the survival rate, growth rate, efficiency of food conversion and production of silver perch.

3. Identify and quantify the water quality variables and potential pathogens which affect silver perch under intensive conditions and develop management procedures to alleviate problems caused by poor water quality and diseases.

4. Provide base-line data that can be used for an economic evaluation of intensive aquaculture of silver perch.

### Facilities, staff and artificial diets

A grant of $163,000 for three years from the Fishing Industry Research and Development Council, FIRDC, (a Commonwealth Government funding body) supplements NSW State government funding and enables the evaluation of artificial feeds. An additional Technical Officer and Technical Assistant have been employed on FIRDC funds.

### Preliminary results

In a preliminary grow-out trial, silver perch fry (2.5 g) were stocked into a 0.4 ha pond at a density of 14,500 fish/ha and grown for 181 days between September and March. Water was not aerated or exchanged. Poor water quality developed during the summer, with dissolved oxygen falling as low as 2.3 mg/L and un-ionised ammonia reaching 0.25 mg/L. These levels are lethal to many species (e.g. rainbow trout). Such stressful conditions usually predispose fish to disease; however, very few parasites were found on the silver perch. These findings demonstrate that the silver perch is a hardy species, ideally suited to static pond culture.

The silver perch grew rapidly, reaching a mean weight of 202 g (largest fish 370 g) by March (Figure 1). A total of 861 kg was harvested giving a production rate of 12 kg/ha/day, equivalent to 4,380 kg/ha/year. The food conversion ratio (FCR) was a very low 0.7 (i.e.

0.7 kg of dry feed produced 1.0 kg live weight of fish). Silver perch utilize natural food in ponds, even at a high density.

The above production was achieved without supplementary aeration or any exchange of water; management practices that are normally used in intensive aquaculture.

## Completed experiments

A fingerling production experiment and a nutrition experiment have been completed. Fry (0.5 g) were reared to fingerlings (10-30 g) at two densities in aerated 0.1 ha ponds. Fish were fed a 35% protein diet. Survival rates were 97-100% and FCRs ranged from 1.0 to 1.3.

Results of our first nutrition experiment indicate that optimum protein levels for silver perch are likely to be around 32-36% compared to 50% for carnivorous species (Allan and Rowland, 1991).

## Current experiments

A grow-out phase experiment is underway in seven aerated ponds. Fingerlings that were stocked in May fed and grew well during winter, and growth has been rapid during late spring and summer (Figure 2). Mean weights of fish in the ponds ranged from 260 to 330 g at the end of December 1991. This experiment will be terminated in February or March, 1992. If survival rates have been high, production rates could range from 5-10 tonnes/ha/yr in ponds stocked at a density of 20,000 fish/ha.

## SUMMARY

Results of the research to date include high survival rates, fast growth rates, efficient food conversion including the utilization of zooplankton and insects in ponds, and high production rates similar to those achieved with species such as carp and channel catfish that are the basis of large, highly successful aquaculture industries in other countries.

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Figure 1. Growth of silver perch stocked at a density of 14,500 fish/ha in a 0.4 ha earthen pond. Points represent the mean weight of 10 fish.

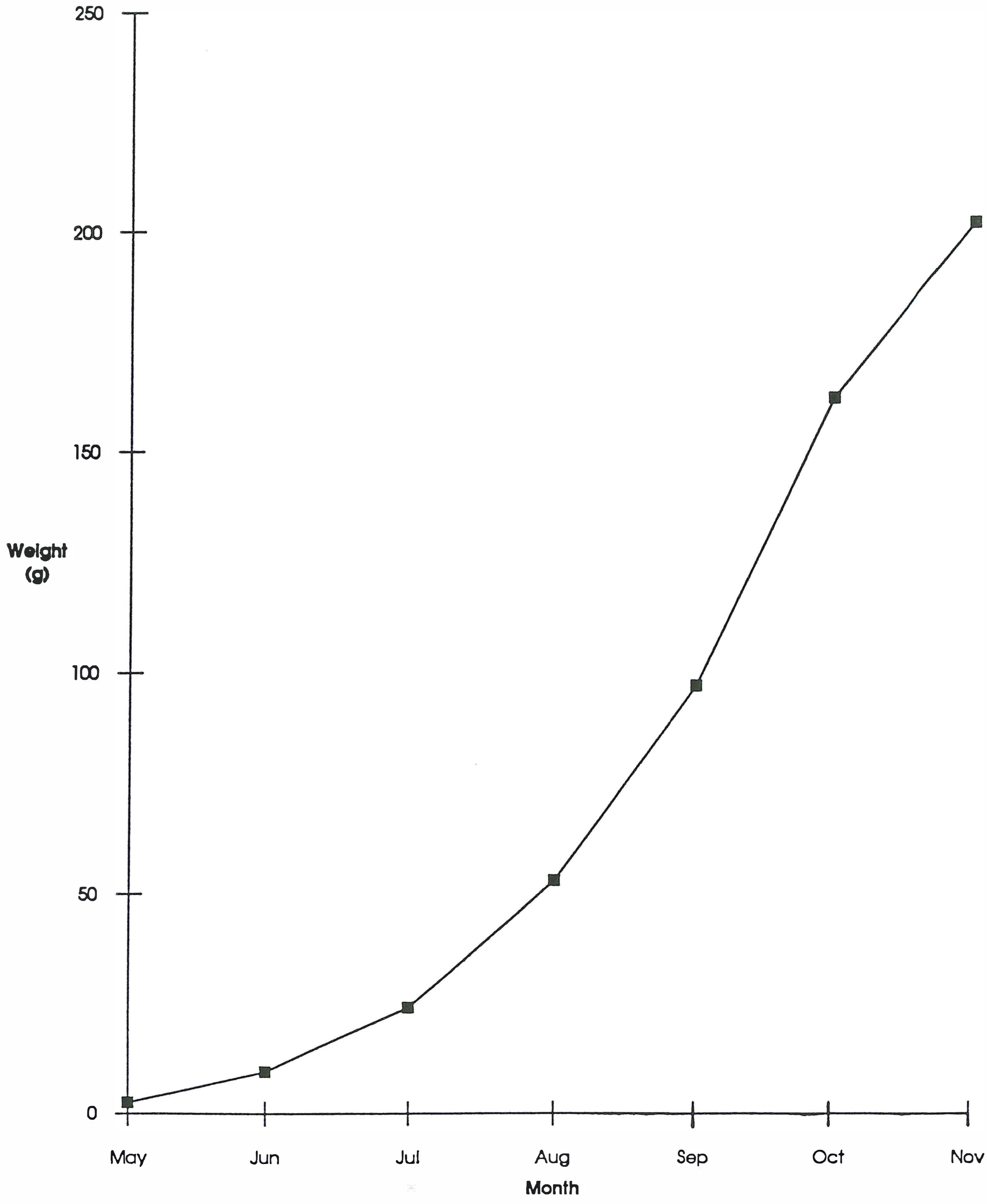
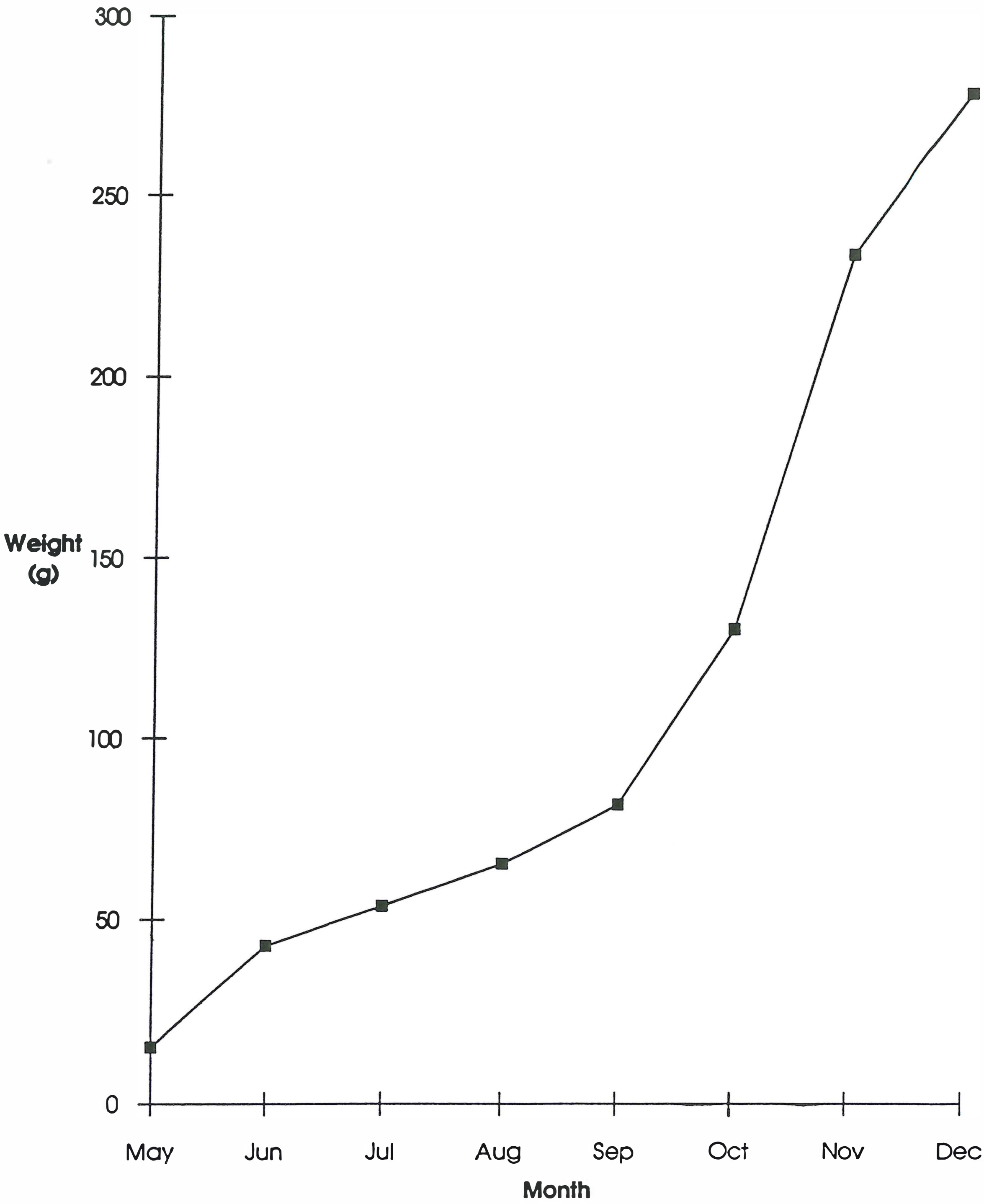


Figure 2. Growth of silver perch stocked at a density of 20,000 fish/ha.. Points represent the treatment mean of 30 fish from three 0.1 ha ponds in an experiment.



# SILVER PERCH
## *Bidyanus bidyanus*

*An Australian native freshwater fish, endemic to the Murray-Darling river system. Highly regarded for its edible qualities and as a sports fish.*

Hatchery techniques for silver perch were developed at the Inland Fisheries Research Station, Narrandera, and transferred to private industry in the early 1980s.

The results of a three year (1990-1993) research project, "Development of Techniques for the Commercial Aquaculture of the Freshwater Fish Silver Perch, "*Bidyanus bidyanus*" funded by NSW Fisheries and the Fisheries Research and Development Corporation, and conducted at the Eastern Freshwater Fish Research Hatchery, Grafton, have demonstrated that silver perch is an excellent species for intensive culture in earthen ponds, with the potential to form a large industry.

## THE WORKSHOPS

To provide a technical basis for the development of an industry, results of NSW Fisheries' research will be presented at the workshops. Papers with clear practical guidelines on site selection and design, hatchery techniques, production of fingerling and market-size fish, nutrition and feeding, the management of water quality, disease and the problems of bird predation and off-flavour will be presented both at the Workshops and in the Proceedings to be published in 1994.

There will also be papers on aquaculture policy, management and permit conditions in N.S.W., as well as farm budgets and marketing. Each workshop will consist of two days of papers and discussions, and a third day of tours of aquaculture facilities.

## TRADE SHOW

Aquaculture equipment, feeds, chemicals, etc. will be displayed at Trade Shows to be run in conjunction with the workshops.

## REGISTRATION

There will be a maximum number of 200 places available at each workshop.

A registration fee of $250 per person will cover the cost of administration, lunches, morning and afternoon teas, a workshop dinner, a BBQ and the Proceedings of the Workshop.

### Grafton

Population approximately 17,000 located on the Clarence River in north eastern N.S.W. The NSW Fisheries' Eastern Freshwater Fish Research Hatchery is situated 7 km to the north of the city.

Nearby is the National Fishing Industry Education Centre of TAFE. Grafton is serviced by Eastern Australian Airlines, rail and buses.

*The workshop will be held at the Grafton Race Course, Powell Street, Grafton.*


### Narrandera

Population approximately 5,000, located on the Murrumbidgee River in central, southern N.S.W.

The Inland Fisheries Research Station is situated 5 km east of the town and is the site of the initial research into the artificial breeding of Australia's native freshwater fish. Narrandera is serviced by Hazelton Airlines and buses.

*The workshop will be held at the Narrandera Ex-Servicemen's Club, Bolton Street, Narrandera.*

## FIELD TRIPS

Visits to aquaculture facilities have been arranged for the third day of each workshop.

### Grafton

The trip will commence with a visit to the National Fishing Industry Education Centre of TAFE where courses in freshwater aquaculture are run.

There will be demonstrations of fish handling, use of anaesthetics and techniques for disease diagnosis. Participants will then visit the Eastern Freshwater Fish Research Hatchery where research into the aquaculture of silver perch is conducted.

This is a model freshwater aquaculture system. The hatchery was built in 1984-1986 and until 1990 was used to produce juvenile eastern freshwater cod, an endangered species found only in the Clarence and Richmond river systems on the north coast.

*This will be followed by a tour of commercial prawn farms in the Clarence River estuary.*

## Narrandera

There will be a tour of the Inland Fisheries Research Station where around one million silver perch, golden perch, Murray cod and the endangered trout cod are produced annually for stocking public waters in N.S.W. Research into the biology and ecology of the fishes and other aquatic fauna of the Murray-Darling system is also conducted here. Participants can visit the John Lake Centre and view live displays of freshwater fish and crustaceans.

*This will be followed by a tour of "Barraclear", a farm using an intensive, recirculation system to produce barramundi.*

## PAPERS TO BE PRESENTED

**Prospects for aquaculture**
*- Robert Kearney (Director of Research, NSW Fisheries)*

**Aquaculture policy and management in NSW**
*- Paul O'Connor and Damian Ogburn (NSW Fisheries)*

**Site selection, design and operation of pond-based aquaculture systems**
*- Damian Ogburn and Stuart Rowland (NSW Fisheries)*

**Culture of silver perch in farm dams: limitations and problems**
*- Chris Barlow (Queensland Department of Primary Industries)*

**Techniques for the hatchery production of silver perch**
*- Stephen Thurstan and Stuart Rowland (NSW Fisheries)*

**Production of fingerling and market-size silver perch in ponds, cages and tanks at different stocking densities**
*- Stuart Rowland*

**Water quality in the intensive culture of silver perch**
*-Stuart Rowland*

**Development of artificial diets for silver perch**
*- Geoff Allan (NSW Fisheries)*

**Diseases of silver perch**
*- Dick Callinan (NSW Fisheries) and Stuart Rowland*

**Problems in the pond culture of silver perch: bird predation and off-flavour**
*- Stuart Rowland and Chris Barlow*

**Aquaculture permit requirements in NSW**
*- Damian Ogburn*

**Business plan for a pond-based silver perch farm**
*-John Kable (Northern Rivers Regional Development Board)*

**Current seafood marketing practices**
*- Norm Grant (Seafood Australia)*

**Marketing of aquaculture products**
*- Bob Neander ( Jareena Pty. Ltd. aquaproducts & exotic foods)*

Most papers will be followed by a 20 minute question time and there will be an open forum at the end of each day.

**NSW FISHERIES**

# SILVER PERCH AQUACULTURE WORKSHOPS 1994

## Grafton: April 11-13
## Narrandera: April 18-20

*For information and registration ( both venues):*
**Carole Bryant, NSW Fisheries,**
Eastern Freshwater Fish Research Hatchery,
Locked Bag 3, GRAFTON. 2460.
Phone: 066 447633 Fax: 066 447633

*For information on the Narrandera Workshop and Trade Show:*
**Jim Beattie, NSW Fisheries,**
Inland Fisheries Research Station,
P.O. Box 182, NARRANDERA. 2700.
Phone: 069 591488 Fax: 069 592935

*Information on the Grafton Trade Show:*
**Mandy Sansom, National Fishing Industry Education Centre of TAFE,**
P.O. Box 557, GRAFTON. 2460.
Phone: 066 447353 Fax: 066 447767