Development of techniques and evaluation of the potential of cage culture of silver perch for cotton farms

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Summary
Silver perch (*Bidyanus bidyanus*) is an Australian native freshwater fish that is endemic to the Murray-Darling River System. It is a high quality, white-fleshed fish with few bones and high levels of omega oils. Research in the 1990's demonstrated that is an excellent fish for pond culture and provided a technical basis for commercial production. A small industry based on earthen ponds currently produces around 400 tonnes annually, but development has been restricted by poor husbandry practices and production strategies on some farms, difficulties with pond management including losses to bird predation and disease, and the lack of large-scale investment. Recent research at the Grafton Aquaculture Centre demonstrated that silver perch also performs very well in cages, with high survival (> 90%), good growth (1.6 – 3.5 g/fish/day) and high production rates (to 90 kg/m^3) at stocking densities of 100 – 200 fish/m^3. Potential advantages of cage culture include the elimination of bird predation and improved management including efficient feeding, grading, disease control and harvesting. Cages provide a relatively low-cost and flexible form of fish culture that can be readily adapted to existing water bodies such as storages and channels on cotton farms.

A collaborative research project involving NSW DPI and QDPI&F through the Cotton Catchment Communities CRC has commenced to evaluate the potential for aquaculture on cotton farms. The objectives of the NSW DPI component of the project are to: (i) determine optimal culture conditions (stocking density, diets, cage size and shape) for silver perch; (ii) identify cotton farms and infrastructure with potential for fish culture; (iii) evaluate the feasibility and economics of silver perch cultured in cages using on-farm trials; (iv) determine appropriate fish culture strategies for use on cotton farms. Successful integration of silver perch farming will provide cotton farmers with a diversification that adds significant value to irrigation water, and increases the efficiency of water use and environmental sustainability. Involvement of the highly professional cotton industry could provide the infrastructure and associated skill base to provide a new production platform for silver perch and lead to increased production.

Introduction
Silver perch, *Bidyanus bidyanus* (Mitchell) (family Teraponidae) is an Australian native, warmwater, temperate fish, endemic to the Murray-Darling River System. It is a schooling, omnivorous fish that has long been recognised as having potential for aquaculture (Rowland and Barlow 1991; Rowland 1995a). Silver perch is an attractive fish with premium quality, white flesh, a mild, delicate flavour, fine texture, few bones and around 40% meat recovery. A study of over 200 Australian seafood products, found silver perch had the third highest levels of the omega oils that are of significant benefit to human health (Nichols et al. 1998).

Hatchery techniques, based on hormone-induced spawning and extensive larval rearing, were developed in the early 1980's (Rowland 1984; Rowland et al., 1983; Thurstan and Rowland 1995) and up to 5 million fingerlings are produced annually for aquaculture, stock enhancement and conservation purposes (Rowland and Tully 2004). However, it wasn't until 1990 that research into the grow-out of silver perch to market-size (> 400 g) commenced at the NSW Department of Primary Industries' Grafton Aquaculture Centre (GAC). The research demonstrated silver perch is an excellent species for culture in earthen ponds, with high survival rates (> 90%), fast growth rates (2 - 5 g/fish/day) to market-size (~ 500g), at high stocking densities (20,000 fish/ha) leading to high production rates of around 10 tonnes/ha/year (Rowland, 1995b; Rowland et al., 1994, 1995). The costs of feeding silver perch are relatively low because it is an omnivorous fish that performs well on diets with low-protein (28 – 32 % digestible protein) and low energy (~ 15 MJ/kg) (Allan et al. 2000; Allan and Rowland 2002, 2005).

Silver perch farming has great potential and could eventually become one of Australia's largest fisheries (Rowland 1999). Australia has limited wild fisheries, most of which are fully or over-exploited, and around 75% of the white-fleshed finfish consumed is imported. There are abundant sites with high quality water available, freshwater effluent is easily managed enabling environmentally-sound practices and opportunities exist for integration of silver perch culture with established agricultural industries (Gooley et al. 2000; Rowland et al. 2006).

Culture techniques

Production strategy

Silver perch are cultured in static, aerated, earthen ponds that range in surface area from 0.1 to 0.5 ha. A 3-phase production strategy is recommended: I - Hatchery; II - Fingerling; III - Grow-out (Rowland, 1995c). Hatchery techniques are well developed and a Hatchery Quality Control Program has been written and is currently being implemented (Thurstan and Rowland 1995; Rowland and Tully 2004). The 3-phase strategy is combined with a single batch system where each pond has only fish of the same age or batch, which are harvested completely before the next batch is stocked. Fry (30mm, 0.5 g) become available from hatcheries in mid to late summer, and are stocked at densities up to 150,000 fish/ha in the Fingerling Phase, which lasts 3 or 4 months. The fingerlings are then harvested, graded and stocked at densities of 10,000 to 30,000/ha for the Grow-out Phase. Silver perch then take 10 to 18 months, depending on the temperature regime to reach market size (400 to 800g). Growth is temperature-dependant. Optimal temperatures are not known, but are probably in the range 23º - 28ºC (Rowland 1995c). Silver perch grow rapidly when temperatures exceed 18ºC, but prolonged exposure to temperatures > 30ºC adversely affects growth and there is little or no growth at 10ºC or below (Rowland 1995c; Rowland et al. 2005). Consequently, the "growing season" of 18º – 30ºC is longer in northern NSW and southern and central Queensland than in more southern areas. Rowland (1995c) recommended that farmers purchase large fingerlings (50 – 100 g) in early spring to produce 500 g fish by the following March. However, this strategy requires over-wintering of small fingerlings and co-ordination between the hatchery and grow-out sectors and phases, and to date its implementation has been limited.

Fish are sampled monthly to estimate the mean weight and biomass, and the daily ration is adjusted accordingly. Sampled fish are also checked for signs of disease and pathogens. Fish are harvested using seine nets on most farms, and placed in clean water for up to seven days to purge off-flavours and to ensure a uniform, high quality product (Rowland 1995d). Silver perch are sold live (principally into Asian communities) and whole, chilled for prices ranging from $5 to $15/kg. The industry is expected to have a large processing component in the future.

Water quality

Fish and ponds are closely managed because of the intensity of production and the effects that some culture practices have on water quality. Because some variables interact and can change from acceptable to stressful or lethal levels within several days during warmer months, temperature, dissolved oxygen, pH and ammonia are monitored each two or three days (Rowland 1995e). Dissolved oxygen (DO) is the most limiting factor in intensive aquaculture and so fish ponds are aerated nightly to ensure adequate DO. Silver perch is a relatively hardy fish and can tolerate a wide range of most variables; recommended levels of variables and management procedures are given in Rowland (1995e).

Diets and feeding

Feed constitutes around 20% of production costs in silver perch culture (Allan and Rowland 2002) and so the use of high quality, formulated diets and efficient delivery of the diet is necessary for economic viability. The use of poor or inappropriate diets and poor feeding practices increase the cost of production. Silver perch is omnivorous and unlike most other fish currently cultured or considered for culture in Australia is efficient at digesting carbohydrate, especially starch. This means starch-rich plant ingredients can successfully be used to replace protein as an energy source (Allan et al., 2001; Stone et al., 2003). The best protein content for low energy diets (13 MJ/kg digestible energy), medium energy diets (15 MJ/kg digestible energy) and high energy diets (17 MJ/kg digestible energy), were 24.7, 26.1 and 30.1% (digestible protein) respectively. If fish are fed restrictively, that is less than they will eat by choice, the best protein contents for diets are higher than when fish are fed to satiation (Allan and Booth, 2004). Diets with excess protein and energy are unnecessarily costly and can cause problems such as high levels of body fat, liver dysfunction and poor health. In addition to cost advantages of feeding an omnivorous species, extensive research on the determination of nutritional requirements and on the evaluation of agricultural ingredients has led to the development of practical, least-cost diets where most or all of the imported fish meal (now only 0 – 5%) has been replaced with Australian agricultural products such as meat and poultry meals, lupins, canola, peas and wheat (Allan et al. 2000; Allan and Rowland 2002, 2005). Initially steam-pressed pellets were used (Allan and Rowland 1992), but since the formulation of diets specifically for silver perch, extruded, pellets that are slow-sinking or floating are available.

Over-feeding wastes feed and adversely affects water quality, while under-feeding results in reduced growth. Satiation can be difficult to determine in the characteristically turbid silver perch ponds where not all fish feed at the surface. A specific feeding strategy for silver perch has been developed, and feeding regimes for fingerling, market-size silver perch and broodfish are now available (Rowland et al. 2005). Although some silver perch feed aggressively at and near the surface, particularly in the warmer months, many fish feed mid-water and so slow-sinking pellets are recommended for this species to ensure all fish receive their daily ration (Rowland et al. 2002; Rowland et al. 2005). Vehicle-mounted blowers are used to deliver the feed to fish in ponds, and fish in cages and tanks are hand-fed.

Diseases and health management

Fish are susceptible to infectious diseases caused by many different types of organisms such as protozoans and bacteria. Non-infectious diseases are caused by environmental conditions such as low oxygen or poor nutrition. Diseases have had a significant impact on commercial production and the viability of some farms through induced stress on fish, loss of growth and production, death of stock, and high costs of treatments. The infectious diseases of silver perch are well known and methods for diagnosis, treatment and prevention have been described (Rowland and Ingram 1991; Callinan and Rowland 1995; Read et al. in press).

There is a significant and inverse relationship between environmental quality and the health status of fish. Good health management provides environmental and culture conditions that reduce the incidence and severity of diseases, enable rapid and appropriate response to disease outbreaks, and optimise the health, performance and production of cultured fish. Health management begins with site selection and design of farms, and is based on the use of good aquaculture practices and preventative measures, in particular quarantine procedures, maintenance of good water quality, use of high quality feeds and appropriate feeding regimes, regular monitoring of fish for diseases and prompt, appropriate action to control disease outbreaks. A recent research project has developed a Health Management Plan for farms, and an overall Health Management Strategy for the silver perch industry (Rowland et al. in press).

Industry

Silver perch aquaculture is an emerging industry with the potential to become one of Australia's largest fisheries. The species is farmed predominately in NSW with smaller quantities in Queensland, Victoria, South Australia and Western Australia. There are several industry groups that represent the farmers; the NSW Silver Perch Growers Association (SPGA), the NSW Aquaculture Association and the Aquaculture Association of Queensland. The SPGA has produced a Quality Assurance Program and some promotional material. However, to date promotion and marketing of silver perch have been very limited, and the species is not well known in the market place. Ruello (1999), examined the market potential of silver perch and concluded that if production costs could be decreased and farm gate prices reduced to $6/kg for whole fish, the demand would expand enormously because the fish could then be retailed at $9.99/kg and sold as a boneless, skin-on fillet for just under $20/kg. At those price levels, silver perch would have a tremendous future domestically and on overseas markets (Ruello, 1999). In 2001, the President of the SPGA reported that costs of production for silver perch cultured in ponds varied from $6 – 9.50/kg depending on scale of operation, degree of mechanisation, and climate/growing time (O'Sullivan, 2001) Bill Johnstone from the Queensland Department of Primary Industries & Fisheries (QDPI&F) (Anon., 2001) produced an interactive "profit model" to assist existing and potential silver perch farmers estimate costs and returns from silver perch farms.

Between 1992 and 2002/03, production increased steadily to 400 tonnes, but has stagnated over the last few years. Despite the biological suitability of silver perch and the strong technological base for pond culture (Rowland and Barlow 1991; see References in this paper), the industry has not expanded as quickly as predicted. A number of factors are thought to be responsible. Silver perch culture is an intensive animal industry requiring substantial capital investment (Kable 1995), good technical knowledge and diligent application. Some farmers have entered the industry with limited capital and knowledge, and have had difficulty in establishing efficient farms. Bird predation can cause significant losses and the use of netting over ponds, especially fingerling ponds has been recommended (Rowland 1995f; Barlow 1995). However, few farms have adopted this management practice and losses to bird predation continue on some farms. Since 1998, the fungal disease winter saprolegniosis has caused high mortalities on some farms, particularly those in regions where water temperatures fall below 10ºC during winter. Fungal diseases are inherently difficult to treat, and control of this disease is based on prevention through good husbandry and pond management (Read et al. in press; Rowland et al. in press). The use of a 3-phase production strategy, a single batch system, grading and strategic stocking are essential for efficient production (Rowland 1995c). Unfortunately some farmers have not followed this advice leading to inefficient production and reduced economic viability of their farms. There is also limited knowledge-base and extension services, compared to established agricultural industries in Australia. To date, there has been no large-scale investment in silver perch, and the largest farm produces only 100 tonnes annually compared to individual barramundi farms in north Queensland and the Northern Territory that produce over 750 tonnes annually.

The established husbandry and production techniques, the potential of cage culture and its integration with irrigation industries, and the premium quality of the product provide a basis for a significant increase in production over the next 10 – 20 years. Silver perch continues to have the potential to become one of the largest fisheries industries in Australia.

Cage culture

Cage culture techniques are well-established for many fish species and cages are becoming a significant contributor to production in numerous countries (Beveridge, 1996, 2002; Chua and Tech, 2002; El-Sayed 2006). The most successful finfish industries in Australia (Atlantic salmon, barramundi and southern bluefin tuna) are based on cage culture. Advantages of cage culture include: (i) relatively low cost; (ii) ease of observation and management; (iii) control of bird predation; (iv) efficient delivery of feed; (v) ease of sampling and harvesting; (vi) high production rates; (vii) ease of movement and relocation of cages.

Cages enable the use of existing water bodies and Australia has many such bodies of freshwater including natural billabongs, creeks and lakes, disused mine pits, large impoundments (reservoirs), on-farm irrigation canals and storage dams, and undrainable farm dams that are used for domestic supplies and stock watering. Agriculture based on irrigation accounts for over 25% of total production in Australia and utilises > 13,000 GL of water annually, 2,000,000 ha of land, over 20,000 km of water supply channels and many farm storages (Gooley et al., 2000). The established infrastructure in irrigation areas provides opportunities for the integration of aquaculture and agriculture, with the potential of enhancing productivity, efficiency of water-use and environmental sustainability (Gooley et al., 2000; Ingram et al., 2000). Consequently, if silver perch can be cultured in cages, numerous additional sites may become available to industry.

Cage culture is a very intensive form of aquaculture and species-specific research in required to develop optimal culture conditions. Stocking density is one of the most important variables in aquaculture because it directly influences survival, growth, behaviour, health, water quality, feeding and production. In cage culture, optimal stocking densities and carrying capacities vary with species, fish size, size of cages, rate of water exchange, size of ponds and length of growing season (Beveridge 2002, Masser 2004; Rowland et al. 2006). Production strategies usually involve the manipulation of density by harvesting, grading and transferring fish to larger-mesh cages during the culture period. Consequently, optimal stocking densities need to be determined for each production phase to enable efficient management and to maximise production and profitability (Rowland et al. 2006). High quality diets are necessary in cage culture, and the levels of protein and energy may need to be higher than in pond culture where free-ranging fish have access to some natural food. Management of water quality and diseases are also very important components because of the high stocking densities and proximity of cages. Little is known of the effects of the size and shape of cages.

Silver perch in cages

Preliminary research at GAC has demonstrated that silver perch perform well in cages suggesting that cage culture is a viable alternative to ponds for commercial production. Growth of fingerlings in cages was similar to growth in earthen ponds, and overall performance in cages was significantly better in cages than in tanks on a flow-through system (Rowland et al. 1994; Rowland et al. 2004). Survival of fingerlings in cages was high (> 90%) and the use of cages to produce fingerlings would eliminate losses due to bird predation. In a series of feeding experiments in cages, growth rates of large silver perch were up to 3.5 g/fish/day and FCRs around 2 (Rowland et al. 2005). Stocking density has a significant effect on performance, with survival, size variation, food conversion and production all density-dependant in silver perch grown from 100 g to 450 g (Rowland et al. 2006). At stocking densities of 100 – 200 fish/m^3 survival rates were above 97% and production rates were up to 90 kg/m^3 (Rowland et al. 2006). There were no major problems with disease or water quality, but Rowland et al. (2006) suggested that diseases and water quality, particularly the maintenance of dissolved oxygen are potential problems in the cage culture of silver perch in large ponds or open waters with limited or no artificial aeration. Further research is needed to optimise techniques and strategies before the cage culture of silver perch can be commercialised.

Cotton CRC project

A collaborative research project involving NSW DPI and QDPI&F in partnership with the Cotton Catchment Communities (CCC) CRC has commenced to develop techniques and evaluate the potential of aquaculture on cotton farms. The NSW DPI component will investigate the potential for cage culture of silver perch. Objectives of the project are to: (i) determine optimal culture conditions (stocking density, diets, cage size and shape); (ii) identify cotton farms and infrastructure with potential for fish culture; (iii) evaluate the feasibility and economics using on-farm trials; (iv) determine appropriate fish culture strategies for use on cotton farms.

Successful integration of silver perch cage culture will provide cotton farmers with a diversification that adds significant value to irrigation water, and increases the efficiency of water use and environmental sustainability. Involvement of the highly professional cotton industry could enable silver perch to realise its potential and become one of Australia's largest fisheries.

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