Finfish Production in Farm Ring-Tanks

A Scoping Paper

DAQ103C

Prepared For: Cotton Research and Development Corporation

Prepared By: Dr Adrian Collins, Mike Potter, Bill Johnston and Peter Peterson.
Bribie Island Aquaculture Research Centre
144 North St Woorim
BRIBIE ISLAND QLD 4057

Telephone: 07 3400 2000
Facsimile: 07 3408 3535

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1. INTRODUCTION

Irrigation water in many agricultural areas in New South Wales and Queensland is stored in above ground storages referred to as ring-tanks. In Queensland alone these structures number as many as 3,000 which together hold up to 500,000 ML of water (DNR, 1999). Ring-tanks have an average surface area of 10 – 50 ha with average depths ranging between 4 to 9m when at full capacity.

Typically used to store water for use on irrigated crops such as cotton and rice, ring-tanks are also used by farms producing less water intensive crops such as wheat, sorghum or barley. Although water retention systems are employed on-farm to reduce run-off, the water held in ring-tanks is typically used for a single crop. In many countries, irrigation water is first utilised to produce an aquatic crop, fish, before being used to irrigate. This approach not only provides additional farm income, it also reduces the required amount of chemical fertilisers, increases nutrient availability in the soil, encourages alternate application methods for agricultural chemicals, and makes better use of infrastructure and natural resources.

The CRDC provided $4,000 for DPI, specifically BIARC, to conduct field investigations and construct economic models to assess the potential for farming fish using water from farm ring-tanks. Four economic models were constructed using three species and four different production scenarios. The fish fauna in six ring-tanks in the Dalby region was also investigated to assess the potential impact of agricultural chemicals. This information was then used to produce the following document outlining the benefits and difficulties of fish production in on-farm water storages.

While this document explores the potential for using existing ring-tank infrastructure for aquaculture, it is only a preliminary discussion paper, and more detailed field investigations are recommended.

Fig I.1 A typical ring-tank located on a cotton property in the Dalby region.

2. BACKGROUND

The integration of aquaculture with terrestrial farming presents an opportunity to further develop ecologically sensitive and productive farming systems. At present irrigated farming operations use large volumes of water for a single use. Increasingly however, both governments and local communities are placing greater value on available water resources. The deregulation of the water industry, introduction of caps on storage construction, and development of community water allocation management plans (WAMPS), have served to limit the availability of water for irrigated farming and increased its unit cost. The predicted future increase in the cost of water and uncertainty over its supply will place increasing economic pressures on irrigated agriculture, in particular cotton farming, in Australia.

The integration of fish farming with irrigated farming operations has the potential to create additional farming opportunities while making better use of existing farm infrastructure and water allocations. On-farm water storages, commonly referred to as ring-tanks, are used by the cotton industry to store large volumes of water for irrigation. It is this water that may be suitable for growing native freshwater fish.

Fish farming, as an integrated operation with cotton farming, is not a new concept and has been successfully implemented in Arizona in the United States (Olsen et al., 1993) (Fig 2.1). Just under 500t of tilapia and catfish were produced in Arizona in 1997. Virtually all of this production was associated with irrigated crops, including cotton, which utilise the fish farm effluent water on crops (Fitzsimmons, 1999). The nutrient rich fish farm effluent reduces the need for chemical fertilisers and serves to lower water pH which improves nutrient availability in the soil. In terms of measures of economic efficiencies, a cotton farmer in Arizona generates one tenth of a cent for each gallon of water used in cotton production and several cents per gallon from integrated fish farming activities (Fitzsimmons, 1997). Potential exists to incorporate the same facilities on Australian farms using established irrigation infrastructure such as ring-tanks.

Fig 2.1 Integrated cotton and fish farming operations in Arizona, USA. Fish are grown in irrigation channels or tanks with the effluent water then used to irrigate cotton fields.

Existing ring-tanks vary in size from 10 to 50 ha with depths ranging from 4 to 9 m and serve as water storage areas which are filled during times of high stream flow in adjoining watercourses. The supply is accessed for irrigation during the cotton production season from November to March, and provided they are not fully drained, constitute a body of water that has considerable aquaculture potential. Water temperature (which is a critical parameter in aquaculture) in storages located in northern New South Wales and Queensland are such that good growth rates of cultured species and long growing seasons can be achieved.

In assessing the potential of individual ring-tanks for fish production, the availability and quality of water must be considered, particularly in relation to irrigation practices and exposure to pesticides. The origin of the water (the timing and means by which the water enters the ring-tanks) will be of critical importance in determining water quality and pesticide concentrations. In addition, farms with sufficient water quality and storage capacity will require some modification of water resource management practices to accommodate the aquaculture activity.

Agricultural chemicals applied to cotton by aerial means, may be transported to the surrounding environment by spray drift, dust deposition, volatilisation, or surface run-off during flood events. Studies indicate that a residual concentration of endosulfan sulphate is present on cotton farms at the commencement of each growing season (Kennedy et al., 1998). Farmers seeking to undertake aquaculture in cotton growing regions must be able to mitigate pesticide movement in order to prevent contamination of fish stocks. In Arizona, modified application methods prevented fish farmed adjacent to cotton fields from becoming contaminated with agricultural chemicals (Fitzsimmons, pers. com.)

There are a number of native fresh water fish suitable for growing in ring-tanks. However, the choice of species is dependent on the style of culture system employed. Farmers aiming to supplement their incomes with minimal effort, would employ an extensive growout system involving fertilising, stocking and harvesting of the ring-tanks. The most suitable species for these activities would be silver perch (*Bidyanus bidyanus*) and golden perch (*Macquaria ambigua*). Those farmers aiming to have an alternate source of income would likely favour more intensive culture systems that require purpose built facilities, higher stocking rates and regular feeding. A more intensive system provides higher returns per unit area but requires additional establishment and operational costs. Suitable species for such an approach include silver perch and perhaps higher value species such as Murray cod (*Maccullachella peeli peeli*).

This document constitutes a preliminary investigation into the potential of establishing fish farming activities in on-farm water storages in New South Wales and Queensland. The economic, environmental, social benefits of cotton farmers diversifying into aquaculture will be discussed.

3. METHODOLOGY

3.1 Economic Modelling

For the purpose of assessing the potential of culturing fish in irrigation ring-tanks a cost-benefit analysis technique was employed. Cost-benefit analysis is a conceptual framework for the economic evaluation of projects, in this case, ring-tank aquaculture projects. This approach differs from financial appraisal in that it considers all gains and losses. The basic premise of cost-benefit analysis is to assist decision making in regard to the allocation of resources.

The model operations are split into the following sections:

- Ring-tank Dimensions
- Production Parameters
- Fingerlings
- Feed
- Marketing
- Labour
- Additional Operating Expenses
- Capital Expenditure

Discounted cash flow analysis was used to determine the annual cost of production and the likely profitability of producing:

- Golden Perch (*Macquaria ambigua*) in an extensive free-range system.
- Silver Perch (*Bidyanus bidyanus*) in an extensive free-range system.
- Silver Perch (*Bidyanus bidyanus*) in a semi-intensive free-range system.
- Murray Cod (*Maccullochella peeli peeli*) in an intensive cage system.

Discounting reduces a time stream of costs or benefits to an equivalent amount in today's dollars. The single amount calculated using the compound interest method is known as the present value (PV) of the future stream of costs and benefits. The rate used to calculate present value is known as the discount rate (opportunity cost of funds).

The objectives of this study were to:

- assess the establishment costs for each system;
- determine the likely profitability of each system;
- establish the size of operation required for commercial viability; and
- calculate the sensitivity of profitability to changes in yield and price.

The analysis of each system assumed a project life of 10 years and used a real discount rate of 8 per cent to calculate the net present value (NPV). The budget incorporates the initial capital and establishment costs.

Two profitability measures are used to evaluate the model operations, Equivalent Annual Return (EAR) and the Internal Rate of Return (IRR).

3.1.1 Equivalent Annual Return

The net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over the life of the project. If the NPV is positive the project is likely to be profitable. When the NPV is converted to a yearly figure it becomes annualised. In this report the annualised return is called the equivalent annual return. It is a measure of annual profit after deducting capital, operating and labour costs generated over the life of the project expressed in today's dollars.

3.1.2 Internal Rate of Return (IRR)

The discount rate at which the project has an NPV of zero is called the internal rate of return. The IRR represents the maximum rate of interest that could be paid on all capital invested in the project. If all funds were borrowed, and interest charged at the IRR, the borrower would break even, that is, recover the capital invested in the project.

The calculations were based on the following assumptions:

- The capital cost of the ring-tanks was not included (assumed established).
- The equivalent annual return was calculated net of owner/operator labour, capital and operating costs.
- Price used in the analysis was an expected price from wholesalers in Brisbane, Sydney and Melbourne.
- The analysis assumed there was no loss of stock over the production period. In reality, losses of stock will occur (and are addressed in the sensitivity analysis).
- The opportunity cost of time spent on setting up the enterprise was not included.

These models were based on conservative production systems assuming that:

- Extensive production of silver and golden perch yielded 12t of 600g fish at a density of 0.6t/ha.
- Semi-intensive model production of silver perch would yield 100t of 600g fish at density of 5t/ha over a period of one or two years.
- Intensive production of Murray cod would yield 50t from 60 net cages stocked at a density of 40kg/m^3.

3.2 Water Storages

Survey activities were conducted on six water storages in the Dalby region. Four of these were situated on cotton farms and two on a single wheat farm 4km from the nearest cotton farm. The water source of each storage varied but was either principally from the Condamine R., Oakey Ck. and Myall Ck., or from overland flow during rainfall episodes. The vegetative productivity of each storage was noted and the turbidity and water temperature recorded.

Storages that had been actively stocked by farmers with a combination of Silver and Golden Perch were identified and sampled. The remaining storages possessed resident natural fish populations that were presumably introduced as juveniles from adjacent water bodies during water harvesting activities.

Fig 3.1 Ring-tanks are elevated earthen water storages that typically hold between 400 and 2,000 ML of water.

3.3 Fish Survey

The fish fauna of each water storage was sampled using one of three 20m 2 inch monofilament gill nets with a 3 or 4m drop. These nets were set obliquely to the bank, adjacent to aquatic or fringing vegetation (if present) in 3 to 6 m of water. Nets were set prior to dusk and retrieved early the next morning. A single net was used for each storage with up to three nets set on a given night. Up to six fish of each species were retained for the purposes of residue analysis and ageing. The remaining animals, with the exception of feral species, were returned to the water body in the best possible condition. Animals retained for analysis were euthanased in an ice slurry.

Bony bream were designated as the reference species due to their presence in all sampled storages.

3.4 Residue Analysis

The presence of endosulfan sulphate was determined in the muscle tissue of fish as either pooled or individual samples. Due to the high cost of analysis, samples for some species were pooled in an effort to reduce the total number of samples from each site. As a consequence, Bony Bream and Catfish samples were pooled, while Golden Perch samples were assayed individually. When available, examples of other species such as Silver Perch, European Carp, Murray Cod and Goldfish were also analysed.

4 RESULTS

4.1 Economic Modelling

The economic models generated for extensive, semi-intensive and intensive farming activities for silver perch, golden perch and Murray cod were all favourable.

The extensive production of 12t of silver perch (0.6t/ha) yielded an IRR of 61% (Fig 4.1). This return assumes a market size of 600g is achieved in 1 year. If the time taken to achieve market size is 2 years the predicted IRR is reduced to 16% (Fig 4.2). The model of extensive golden perch production yielded an IRR of 44% with a 2-year production phase resulting in an annualised loss over the first 4 years (Fig 4.3). The higher IRR for golden perch in the 2 year extensive model is the consequence of an expected higher market value in comparison to silver perch.

The semi-intensive culture of 100t of silver perch (5t/ha) returned the highest predictive IRR of 158% (Fig 4.4). Again while this model assumes a market size of 600g in 1 year, the increased return is commensurate with the five-fold increase in production. A 2-year model would not be feasible for this production system.

The model for the intensive production of 50t of 600g Murray cod returned an expected IRR of 114% (Fig 4.5).

4.2 Field Observations

The quality of water in each ring-tank appeared to be associated with the age of each structure and the source of water itself. The age and characteristics of each tank sampled are presented below in Table 4.2. Water contained in older tanks drawing from constantly flowing water bodies such as Oakey Ck and the Condamine R were less turbid and possessed more abundant fringing and aquatic vegetation than more recently constructed tanks drawing from overland flow.

Site	*Water Source*	*Stocked*	*Years Since Stocked*	*Fringing and Aquatic Vegetation*
1	Condamine R	Golden Perch	14 years	Abundant fringing grass and aquatic plants
2	Oakey Ck	No	NA	Abundant fringing grass and aquatic plants
3	Oakey Ck	Golden Perch Silver Perch	2 years 2 years	Abundant fringing grass and some aquatic plants
4	Myall Ck	No	NA	Fringing grass but no substantial aquatic vegetation
5	Overland Flow	No	NA	No associate fringing or aquatic vegetation
6	Overland Flow (Wheat Only)	Golden Perch Silver Perch	2 years 2 years	Abundant fringing grass and some aquatic plants

Table 4.2 Characteristics of cotton ring-tanks sampled during this study including age, species stocked, time since initial stocking and presence of associated vegetation.

The construction of ring-tanks involves the creation of earthen walls using soil from within the tank perimeter. Should the tank be drained or a wall fail, the resulting

Fig 4.1 Silver Perch – Extensive – 12t over 1 yr.

Summary Statistics

Annual Profit	$43,180
Internal rate of return	61%
Total production cost per kilogram	$4.40

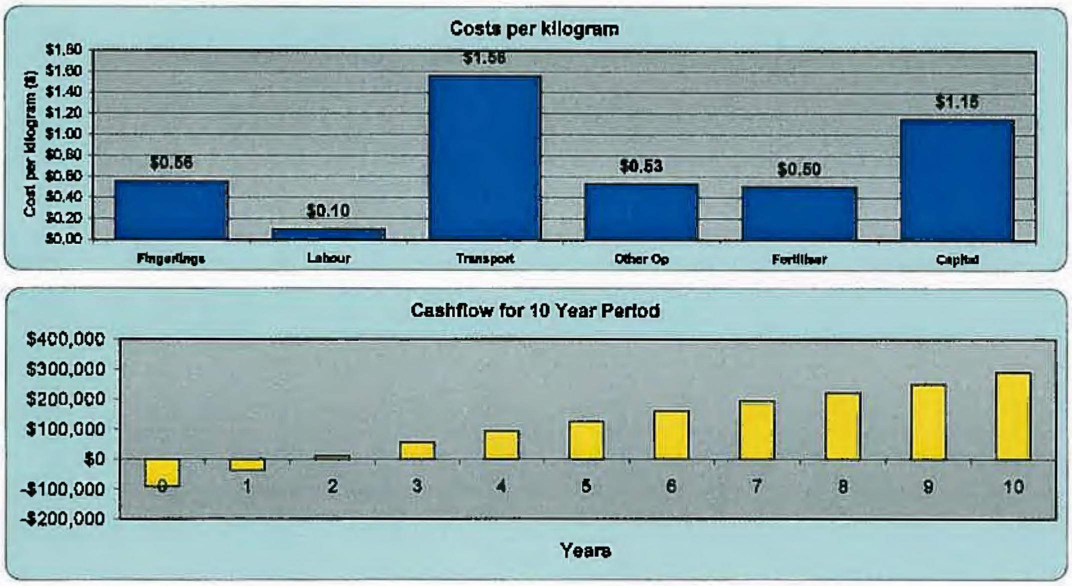
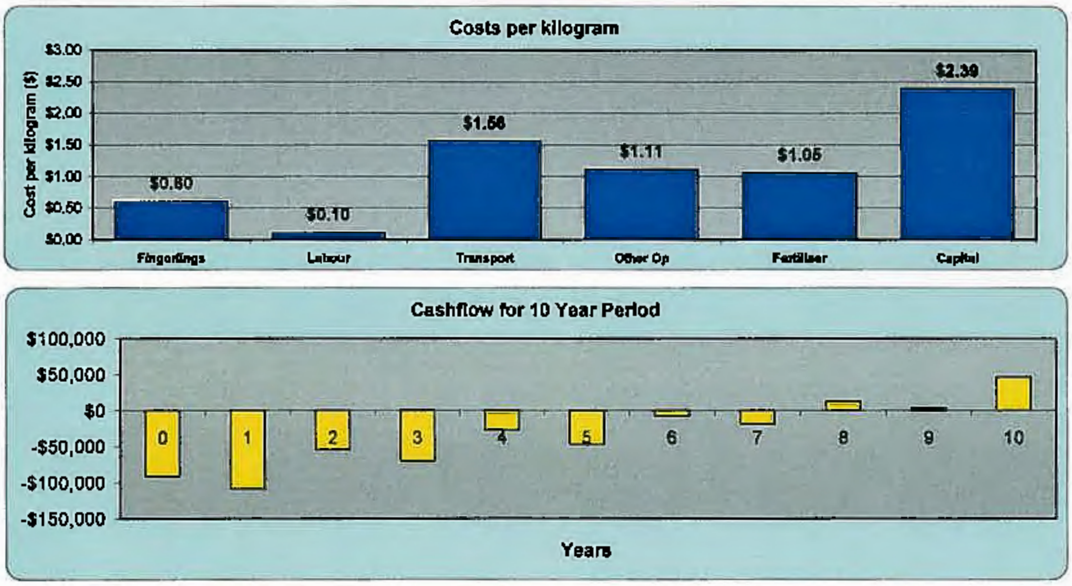


Fig 4.2 Silver Perch – Extensive – 12t over 2 yrs.

Summary Statistics

Annual Profit	$6,883
Internal rate of return	16%
Total production cost per kilogram	$6.81



Figs. 4.1 & 4.2. Summary statistics for economic models for an extensive silver perch farm producing 12 t per year (Fig 4.1) or 12 t over 2 years (Fig 4.2). Statistics shown include a breakdown of the estimated cost of production assuming current market prices and the resulting annualised cashflow over a period of 10 yrs.

Fig 4.3 Golden Perch – Extensive – 12t over 2 yrs.

Summary Statistics

Annual Profit	$38,729
Internal rate of return	44%
Total production cost per kilogram	$7.29

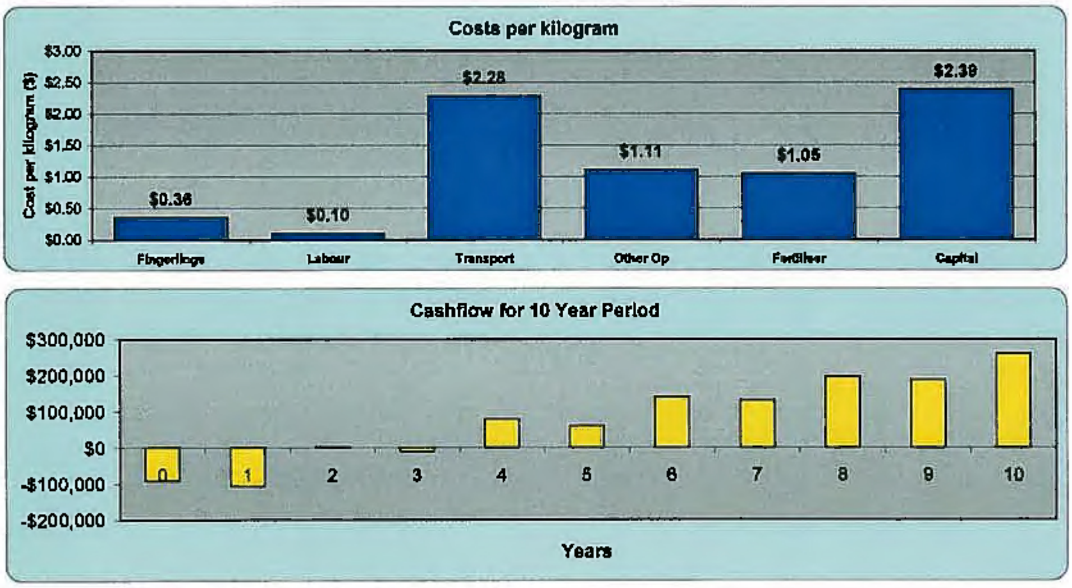
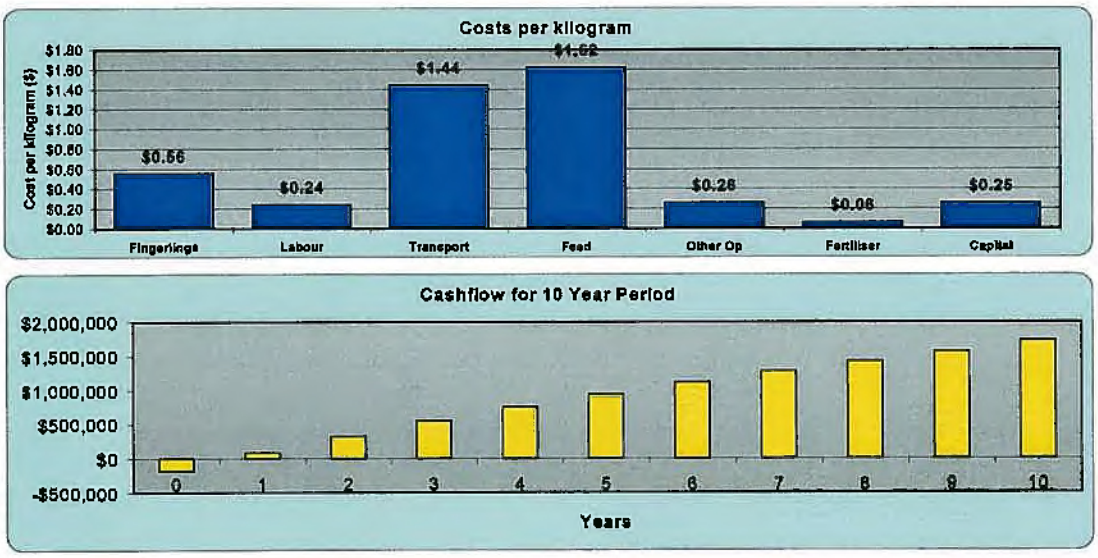


Fig 4.4 Silver Perch – Semi-intensive – 100t over 1 yr

Summary Statistics

Annual Profit	$257,233
Internal rate of return	158%
Total production cost per kilogram	$4.43

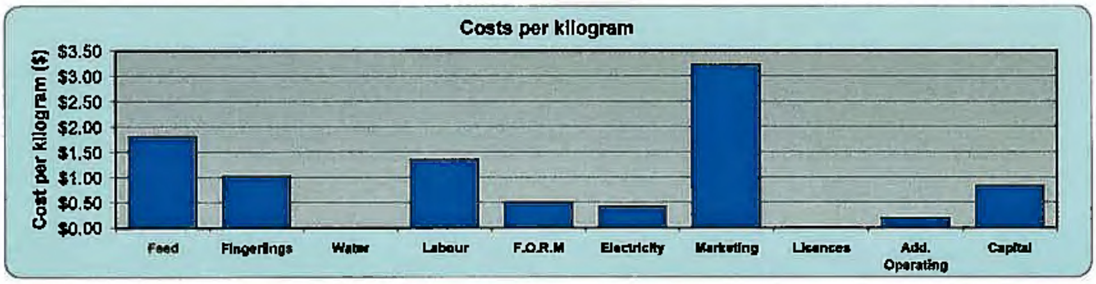


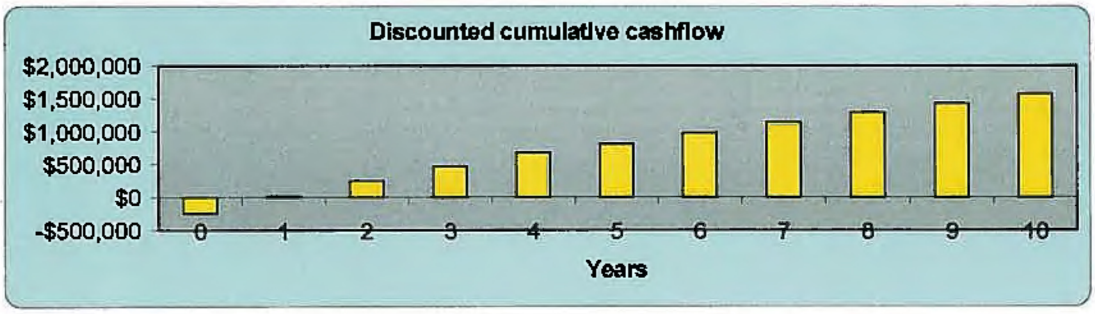
Figs. 4.3 & 4.4. Summary statistics for economic models of an extensive golden perch farm producing 12t every 2 years (Figs 4.3) and a 100 t per year semi-intensive silver perch farm (Fig 4.4). Statistics shown include a breakdown of the estimated cost of production assuming current market prices and the resulting annualised cashflow over a 10 yr period.

Fig 4.5 Murray Cod – Net Cages - 50t

Summary Statistics

Equivalent annual return	$160,091
Internal rate of return	114%
Total production cost per kilogram	$9.32
Price received per kilogram	$14.00





Figs. 4.5. Summary statistics for economic models for an intensive, cage or net pen, Murray cod farm with a 1 yr production phase. Statistics shown include a breakdown of the estimated cost of production assuming current market prices and the resulting annualised cashflow over a 10 yr period.

"borrow pit" typically remains full of water. This construction method while simple, would prevent drain harvesting of the tanks making alternative, but less dependable, methods of harvest necessary.

4.3 Fish Fauna

Survey activities resulted in the capture of several species from a number of ring-tanks. The fish collected during this survey and their relative abundance are shown below in Table 4.3. The most predominant species was bony bream (*Nematalosa erebi*), followed by golden perch (*Macquaria ambigua*) and eel-tailed catfish (*Tandanus tandanus*). Single specimens of silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peeli peeli*), goldfish (*Carassius auratus*) and European carp (*Cyprinus carpio*) were also obtained.

Species	Common Name	Site Recorded	Abundance
Nematalosa erebi	Bony Bream	1, 2, 3, 4, 5, 6	Abundant
Macquaria ambigua	Golden Perch	1, 2, 3, 4, 6	Common
Tandanus tandanus	Eel Tailed Catfish	3,4	Common
Bidyanus bidyanus	Silver Perch	3	Rare
Cyprinus carpio	European Carp	4	Common*
Maccullochella peeli peeli	Murray Cod	4	Rare
Carassius auratus	Goldfish	3	Rare

Table 4.3 Summary of fish species and their relative abundance in individual tanks. *Although not observed in this study evidence indicates the presence of European carp in ring-tanks is common in this region.

The yield of silver perch in stocked waters was low despite the presence of good numbers of bony bream and golden perch. Reasons for such low comparative numbers in this survey are uncertain but may be associated with seasonal affects of water temperature and behaviour. Extended sampling regimes are likely to return more indicative relative species abundances.

4.4 Residue Profiles

Concentrations of endosulfan in the muscle tissue varied markedly depending on the water source for each ring-tank and from one species to another (Table 4.3). The lowest endosulfan levels were obtained in tanks drawing water from Oakey Ck and the Condamine R. These tanks also displayed the best water quality characteristics (see section 4.2). In these tanks (sites 1,2 & 3) endosulfan residues were highest in golden perch with concentrations ranging from 2.6 to 22 µg/kg (Table 4.3). In comparison bony bream endosulfan residues were either not detectable or returned a mean value of up to 4.4 µg/kg. This specific residue profile is likely to be a reflection of not only prey preferences but also habitat preferences (Napier et al., 1996).

Fish from cotton ring-tanks that source water from Myall Ck (site 4) and overland flow (site 5) returned the highest endosulfan residue levels. The high endosulfan levels in fish from the Myall Ck tank may either be a reflection of the level of endosulfan in the creek, the return of tailwater, the result of spraying patterns or a combination of each. Golden perch and bony bream from both sites 4 and 5 possessed endosulfan levels of up to 321 and 227 μg/kg respectively. The maximum permissible limit for endosulfan in cattle for domestic consumption is 200 μg/kg.

Overland flow was not necessarily associated with high residue levels. Golden perch and bony bream collected from the ring-tank located on a wheat farm (site 6), 4km from the nearest cotton farm, returned typically low residue levels. These results indicate that water harvested from overland flow may be suitable for the purposes of aquaculture provided it does not originate from neighbouring cotton farms.

Site	*Water Source*	*Stocked*	*Species*	*No.*	*Low*	*High*	*Av.*
1	Condamine R	Golden Perch	Golden Perch	6	3.1	19	10.6
			Bony Bream	6			4.4
2	Oakey Ck	No	Golden Perch	4	2.6	20	10.7
			Bony Bream	6			ND
3	Oakey Ck	Golden Perch Silver Perch	Golden Perch	4	3.7	22	10.5
			Bony Bream	6			2.5
			Silver Perch	1			ND
			Murray Cod	1			ND
			Catfish	1			5.4
4	Myall Ck	No	Golden Perch	3	63	321*	150
			Bony Bream	4			114
			Catfish	4			78
			Carp	1			17
5	Overland Flow	No	Bony Bream	2			227*
6	Overland Flow (Wheat Only)	Golden Perch Silver Perch	Golden Perch	2	3.7	4.4	3.7
			Bony Bream	4			10

Table 4.4 Endosulfan residues in muscle tissue of various freshwater fish caught in ring-tanks on the Darling Downs. ND – not detectable. * Denotes endosulfan levels in excess of permissible residue limits of 200μg/kg.

5 DISCUSSION

The results of this preliminary study indicate there is significant potential for conducting successful fish farming activities in on-farm water storages in cotton growing regions. Integrated farming activities utilise water resources more efficiently while increasing farm productivity and diversifying farm activities. Improved utilisation of natural resources also delivers positive environmental benefits while the creation of additional employment opportunities provides significant social benefits in rural areas. Success of such activities will however, be dependent on the ability of individual growers to manage their farms appropriately by selecting suitable integration and management strategies.

5.1 Economic Modelling

The multiple use of water is an environmentally sound idea which may also prove economically beneficial as in other cotton growing areas such as the United States (Olsen et al., 1993: Shariff, 1997). The favourable economic models generated in this document (internal rates of return of 16 to 158%) result from the ability to utilise existing farm infrastructure for the purpose of aquaculture. These models assume that the capital cost of each ring-tank is not included in initial establishment costs and that no new water allocations are required for the activity. The ability to utilise existing farm water storages allows the major capital costs associated with establishing fish farms to be avoided. The economic viability of the extensive and intensive production systems improves with increasing yield and decreasing feed costs.

The economic models presented in this study are limited to fish production. Future models must evaluate the cost-benefit of diversification into aquaculture on a farms overall viability. However, there is a cost associated with the establishment of integrated fish and cotton farms. Establishment expenses were not estimated in this study for systems involving construction of additional ponds or tanks. Such considerations would constitute a focus of future investigations once less capital intensive options have been investigated. These resultant agri-aquaculture models will assist in the formation of sustainable integration and diversification strategies that cater for the needs of both the cotton and aquaculture industries.

5.2 Pesticide Residues / Water Resource Management

Pesticide residues in fish from rivers located in cotton growing regions are well documented (Sunderman et al., 1992; Napier et al., 1998), as are the mechanisms facilitating the movement of pesticides from farms to adjacent rivers and creeks (Kennnedy et al., 1998; Muschal and Cooper, 1998; Simpson et al., 1998). Unfortunately, little information exists as to the movement of pesticides on-farm, specifically in relation to on-farm water storages. The pesticide residue aspect of this study represents a mere snapshot of the annual cycle of endosulfan exposure and uptake.

The last endosulfan sprays in the study region were conducted seven to eight months prior to any sampling activities. Previous in-catchment studies have observed that while some low residues are found in winter, endosulfan is not bioaccumulated from one season to the next (Kennedy et al., 1998; Chapman, 1998). Consequently, the results presented in this report are likely to be representative of the lower end of annual residue profiles for these fish. Those farms that source water from rivers with consistent environmental flows and minimal tailwater return, yielded the lowest residue levels for all species. These comparatively low residue levels suggest that pesticide residues in fish may potentially be avoided provided the appropriate management practices are implemented. In Arizona, fish farms integrated with irrigated crop farms were free of chemical residues as a result of switching from aerial application of pesticides to tractor application (Fitzsimmons, 1999). The ability to achieve residue free fish on a consistent basis must be demonstrated under Australian conditions. Otherwise, the confidence of farm owners, markets and consumers of the product will be poor.

As cotton farming is conducted under a wide range of environmental, commercial and social conditions (Williams, 1998), the incorporation of aquaculture into conventional cotton farming regions will require flexible BMP strategies. Growers will have to adhere to largely site-specific methods to limit pesticide use and the potential for water storage contamination. The ability of individual growers to achieve such outcomes will largely depend on circumstance, making the potential of each site for aquaculture different. Those operators in areas with good environmental flows and larger water allocations are likely to benefit in the initial stages of diversification.

5.3 Fish Farming in Non-Specific Structures

The most difficult aspects of farming fish in non-specific structures such as ring-tanks is the ability to efficiently harvest or sort the stock. Typically aquaculture facilities have purpose built ponds which can be fully drain harvested. Options to overcome this difficulty include the use of nets and traps, caging or net penning stock, or the construction of specific production ponds. Extensive and semi-intensive production systems may utilise less intensive harvest methods such as netting or trapping. These methods, while less efficient, may be economically feasible if used to supply smaller volumes of product over a more extended period. Intensive cage or net pen production systems will enable farmers to readily sort and harvest stock making it a more efficient but capital intensive operation. The construction of new fish ponds (using the ring-tank merely as a water storage), will also be more efficient but will require comparatively greater capital and operational inputs. The latter option was not investigated in this study as the aim of this exercise was to avoid large development and operational costs.

5.4 Environmental Impacts

The cotton industries BMP program, the ongoing development of pest resistant cotton, and efforts to improve rural water use efficiency will all reduce the impact of cotton growers on the riverine environment. The scope for development of aquaculture on cotton farms is likely to improve as the frequency and volume of chemicals used by this industry is reduced. Those farms which can mitigate on and off-farm pesticide movement and make better use of water resources, will deliver immediate benefits to the local environment. Discussions with farmers indicate that aquaculture may provide an economic impetus to further develop BMP and improve water use efficiency.

The environmental impact of fish farming itself is directly related to the method of production and volume of product. As systems are intensified there is potential for the release of increasing nutrient levels (N & P) into the surrounding environment. The amounts of N and P produced by a particular operation can be modelled and their impact evaluated. However, as mentioned previously, irrigated crops are likely to benefit from the nutrients discharged with fish farm effluent. The effluent will provide a source of organic fertiliser while improving nutrient availability in the soil itself by decreasing water pH (Fitzsimmons, 1999).

5.5 Social Benefits

The socio-economic benefits of fish farming in cotton growing regions were not investigated in this study and cannot therefore be fully evaluated. However, the nature of the production systems proposed in this study will benefit from the establishment of regional co-operatives or business groups, so that processing and marketing of products can be coordinated. As a consequence, it is expected that additional opportunities will be created off-farm, as result of fish farming development in rural areas.

In 1997 aquaculture represented 26% of the value of Australia's fisheries production and was valued at almost $500m (Australian Bureau of Agricultural and Resource Economics, 1998). Assuming integrated aquaculture is conducted in 5% of water storages, conservative estimates predict a rural aquaculture industry with an annual production in the order of 1,000t and a value exceeding $5m. Estimates of this potential assume that the market will absorb the increased supply of freshwater fish. Further analysis of the potential of the domestic fish market should be conducted to fully evaluate its potential.

Aquaculture has increased in value by an average of 12% per annum in recent years and will constitute a comparatively larger portion of Australia's fisheries industry in the near future. This rate of growth makes aquaculture a potentially valuable new industry for rural communities.

RECOMMENDATIONS

The purpose of this document was to explore the potential for fish farming in on-farm water storages, specifically ring-tanks, used to irrigate crops such as cotton. The potential economic, environmental and social benefits/limitations of the proposed activities necessitate the following actions:

- A small number of pilot scale fish farms should be established on existing irrigated cotton farms with the aim to produce fish free of agricultural chemical residues.
- The ability of domestic markets to absorb increased volumes of freshwater fish should be investigated along with export market opportunities.
- Any fish farming activities should be considered as an integrated part of an agri-aquaculture venture operating under specific chemical and water resource management guidelines.
- The economic impact of fish farming on existing terrestrial farming operations be investigated in order to assist development of economically sustainable integration and development strategies.
- The environmental benefits of altered spraying, tilling and cropping strategies resulting from diversification activities should be monitored.
- The socio-economic benefits of farm diversification should be evaluated.

The potential to develop a significant rural industry exists and efforts should be made to ratify this potential and develop it accordingly.

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