FROM HOBBY TO INDUSTRY: FORWARD DIRECTIONS FOR THE DEVELOPMENT OF INLAND SALINE AQUACULTURE IN WESTERN AUSTRALIA

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ABSTRACT

Interest in inland saline aquaculture is increasing in Western Australia, however production and investment levels are characteristically low. Inland saline aquaculture presents a continuum of production and investment options for landholders and investors, from being a small-scale, hobby-like remedial use of salinised farmland to a novel and legitimate agricultural industry. Successful progress toward the latter depends on a number of factors: appropriate production technology; identification and establishment of sustainable markets; establishment of environmentally sustainable production systems; and industry management. For the new industry to succeed, concurrent growth is required across all these fields. We argue that public investment is often necessary to achieve expansion and illustrate this with examples from finfish aquaculture in inland Western Australia.

INTRODUCTION

Pannell (2001) pointed out that, while considerable effort has gone into estimating the cost of secondary salinity, this is an exercise of little practical value. A more productive approach is to focus on the costs and benefits of different strategies for managing salinity. These strategies fall into three broad categories: prevention (avoiding a further worsening of salinity); treatment (repairing salinity); and adaptation (living with salinity). In Western Australia as with other parts of the continent, the primary preventative tactic is the revegetation of agricultural land with trees and other perennial vegetation (Barson and Barrett-Lennard 1995; Hatton and Nulsen 1999). This approach has experienced mixed success on two telling fronts. First, farmers have been slow to adopt tree planting because, on the scale required to make a substantial impact, it is comparatively less profitable than annual cropping (Pannell 2001). Second, the ability of deep-rooted perennials to lower saline groundwaters is offset by the accumulation of salts in their root zones (Barrett-Lennard 2002). Engineering solutions, such as deep drainage, which aim to treat salinised land and allow the continuation of traditional agriculture, are somewhat controversial, but are increasingly regarded as a necessary complement to prevention (Thomas and Williamson 2001; Pannell 2001). As extensively documented in this and previous PUR$L conferences, there is also strong interest among farmers in living with salinity by making economic use of saline land and water.

We believe that inland saline aquaculture will be an essential component of salinity management in the future, because, unlike many other adaptation strategies, it can be effectively integrated with engineering solutions to treat salinised land. Inland saline aquaculture needs to develop in a manner that both prevents the further degradation of agricultural land, and provides opportunities for an alternative and sustained economic base for dependent rural communities (Doupé *et al*. 1999). For that to occur, concurrent progress in production technology, market development, and environmental and industry management is required. This paper seeks to describe how that might happen for inland Western Australia.

PRODUCTION TECHNOLOGY

Matching Water Resources and Aquaculture Species

The saline groundwater resources of the Western Australian wheatbelt are extensive and could support a significant inland saline aquaculture industry. For example, many farms have at least a few bores from 10-60 m deep that yield between 10 and 28 x 10^3 $L.d^{-1}$ of mostly saline water (10,000-100,000 $mg.L^{-1}$ TDS, see George 1990), and prudent placement of bores in wheatbelt valley floors could achieve discharge rates of 250 x 10^3 $L.d^{-1}$ (George 1992). This water could be used to farm aquaculture species in many different types of production systems, for example natural lakes or playas (George and Coleman 2001), existing salinised dams, constructed earthen ponds, or recirculating tanks. The ubiquitous farm dam is currently the preferred environment for aquaculture on salt-affected farmland in Western Australia (Starcevich 2000), but because farm dams are mostly situated at low elevations in the landscape to intercept surface water run-off, their role as a "water trap" also means they are highly susceptible to nutrient enrichment. Starcevich (2000) found that farm dams are generally not protected from a variety of agricultural influences including access by stock, and exposure to fertilizers, pesticides, herbicides and other farm chemicals, and each could cause potentially deleterious effects on fish welfare. However, he also found that farm dam nutrient levels differed significantly among farms, indicating that farm management practices could influence the degree of eutrophication, and also the suitability of a particular water body for fish culture. Therefore, selection of dams (or proposed sites) for fish production needs careful consideration of topography and exposure to adjacent farm activities.

Many aquatic species including algaes, yabbies (*Cherax destructor* and *C. albidus*); abalone (*Haliotis* spp.); rainbow trout (*Oncorhynchus mykiss*); brown trout (*Salmo trutta*); silver perch (*Bidyanus bidyanus*); black bream (*Acanthopagrus butcheri*); pink snapper (*Pagrus auratus*); King George whiting (*Sillaginoides punctata*); barramundi (*Lates calcarifer*) and mulloway (*Argyrosomus japonicus*) have been promoted as potential candidates for inland saline aquaculture (see for example, Trendall and Pitman 1998; Ingram *et al*. 2002). For most species, however, production technologies are rudimentary, and the net economic contribution of inland saline aquaculture to the national fishery statistic is small (Doupé *et al*. 1999). Moreover, the relative commercial value of any given species is often based on only survival rates, and often ignores basic bioeconomic parameters relating interactions between input and output production components like feed and growth or yield. This means that the potential commercial performance of a species could be further underestimated if they are assessed using production systems that do not reflect what is happening on the farm, such as farm dam grow-out, or the potential for improving the performance of production traits using traditional selection practices, are ignored. Below, we illustrate our argument using examples from finfish aquaculture in inland Western Australia.

Rainbow Trout Need Supplementary Feeding

About 150 farmers have stocked more than 50,000 rainbow trout fingerlings into a variety of water bodies across the wheatbelt in the past few years. Stocking rates are often much less than 1 $fish.m^3$, the growing season is mostly confined to the cooler winter months, and production is about 10 t/annum (Starcevich 2000). In many cases (65% of farms), rainbow trout production is totally reliant on the natural food resources available within the farm dams (extensive production systems), however supplementary feeding with pellets (semi-intensive systems) is also practiced by a number of farmers (30%), and less frequently (5%), saline groundwater is pumped through closed recirculating tanks (intensive systems)(Starcevich 2000). The principal question, therefore, relates to the relative yield obtained from the different production systems. Intensive production systems involve considerably higher fixed (e.g. management and investment) and variable (e.g. stock, feed, power and labour) operating costs, and intuitively, one might expect that greater inputs into the fish production system should result in greater outputs, and so the more intensive the system the higher the returns. To test this proposition, Lever (2000) compared the yield of fish from each type of system to determine if the increase in yield in more intensive systems was sufficient to balance their (about five-times) higher input costs. Briefly, stocking densities in intensive systems were about 170 fish.m^3, compared with about 0.14 fish.m^3 in extensive and semi-intensive systems. Over a typical trout grow-out season, fish in extensive systems grew at less than 0.1% body weight.day^{-1}, while fish in semi-intensive and intensive systems grew at over 1% body weight.day^{-1}. Table 1 shows the increase in yield (grams/fish) at a constant stocking density required by more intensive production systems, to balance their greater cost inputs and achieve an equivalent profit to extensive systems. The observed increase in yield in semi-intensive systems is more than sufficient to compensate for the extra costs involved in the partial feeding of fish, whereas the observed increase in yield in intensive systems is only 13% of that required to compensate for the extra costs over semi-intensive systems, and 34% of that required to compensate for the extra costs over extensive systems.

Table 1 Comparison of the difference in yield (expressed as grams per fish at a constant stocking density) required for equivalent net profit between different rainbow trout production systems, and the observed difference in yield after 4 months of growth, calculated from least square means of fish weight.

Comparison	Difference in yield required (g/fish)	Difference in yield observed (g/fish)
Extensive v. Semi-intensive	43.3	95.8
Extensive v. Intensive	441.0	149.5
Semi-intensive v. Intensive	421.7	53.7

These preliminary results show that the improved yield in semi-intensive systems was sufficient to balance the extra costs involved, but not so for intensive systems. At this stage of development, semi-intensive systems seem to provide the most potential for profitable farming of trout over winter in the wheatbelt, primarily because: (a) feed costs per fish were less than half those in intensive systems; (b) they use existing infrastructure and therefore minimise establishment costs; and (c) they achieve satisfactory growth rates through supplementary feeding. The study also indicated that under extensive production systems and without supplementary feeding, there is a high chance that trout would display poor growth and condition, and would be excluded from whole fish or frozen fillet markets. We are aware of instances where extensive feeding regimes have produced better results than those recorded here, but as a guide we advocate supplementary feeding in stocked farm dams, especially until a better understanding of saline dam ecosystems is known. While the aquatic invertebrate fauna of the wheatbelt region is thought to be euryhaline and cosmopolitan in nature (Doupé and Horwitz 1995), specific information will likely be made on a farm-by-farm basis given that dam water qualities appear to reflect local property management practices (Starcevich 2000).

Selecting Faster Growing Black Bream Makes More Cents

Black bream were promoted, three or four years ago, as a candidate species for inland saline aquaculture, but are now rarely stocked by farmers in Western Australia. Despite black bream possessing many desirable ecological attributes, such as hardiness and a wide temperature and salinity tolerance, the fundamental problem is that current growth rates of 150 g/annum are too slow for profitable production. Doupé and Lymbery (2002) developed a partial budgeting analysis for two different black bream production systems supposed to represent either end of the saline aquaculture production continuum; a commercial operation that incurred more operating expenses due to costs associated with fish farm initiation (stand-alone farm model), and an existing farm that diversified into aquaculture using the saline water resources of established farm dams (integrated farm model). Sensitivity analyses (Table 2) indicated that a 33% increase in growth rate to at least 200g/annum (wet weight) would allow either production system to return a profit at a farm-gate price of $6/kg for the whole fish product, with fish survival rates of 98% for the stand-alone farm, and 65% for the integrated farm model respectively. An increase in growth rate of this magnitude should be easily achieved through selective breeding, as has occurred in all terrestrial livestock species (Gjedrem 1997; Lymbery 2000). Preliminary trials of growth performance for straight-bred and crossbred families of black bream are very promising, and indicate that wet weight has an across-line heritability (the proportion of variation in growth rate due to genetic differences among fish) of almost 30% at 90 days of age (Doupé and Lymbery unpublished data). This indicates substantial potential for genetic improvement in growth rate. We are currently working with the black bream hatchery at Challenger TAFE in Fremantle to develop a genetic improvement program for black bream.

Table 2 Comparative farm model break-even price ($/kg, rounded) for a sensitivity analysis accounting for variable growth and survival of black bream.

	Survival rate	Weight following a 12-month grow-out						
		150g	175g	200g	225g	250g	275g	300g
Stand-alone farm model	98%	7.90	6.90	6.15	5.60	5.10	4.75	4.40
Integrated farm model	65%	8.20	7.15	6.35	5.75	5.30	4.90	4.55

IDENTIFICATION AND ESTABLISHMENT OF SUSTAINABLE MARKETS

Inconsistent progress in production technologies for inland saline aquaculture has resulted in similar variation in the awareness, sales, and market planning of specific fish products. For example, despite the existence of an established market for rainbow trout, several large producers on Australia's eastern seaboard supply 75-90% of the national trout product (Anon.

2002). The dominance of these producers is primarily because they can guarantee continuity of supply throughout the year (being traditional fresh water trout producers), and have economies of scale relating to production, vertical integration including their own hatcheries and processing facilities, and purchasing power for important operating costs like feed. Cost calculations show that they can provide a head on, gutted and gilled product at the farm gate for about $4.80/kg, which is about $2-3/kg less than can be expected from producers in the Western Australian wheatbelt (Anon. 2002). At current levels of production, access to these markets by Western Australian producers is unlikely, and indicates that the new industry should concentrate on specific market segments that clearly differentiate the Western Australian product from the imported item, and emphasize the home grown advantage. One method is to promote the superiority of fresh over frozen trout products, as fish from the eastern states are exported to Western Australia in a frozen form. A second niche is to emphasise any quality advantage from trout produced in saline, rather than fresh water, and a third is to exploit the advantages of product diversification and value adding through promoting smoked and canned trout products. All these alternatives can carry the brand of local production and quality assurance (see later), to provide further market differentiation from the whole, frozen import.

For black bream, the market is much less developed than for rainbow trout, and so modelling the potential advantages gained by improved production technologies like enhanced growth rate, are made with more assumptions regarding market behaviour. For example, the growth-return analysis shown in Table 2 (Doupé and Lymbery 2002) assumes a minimum farm-gate price of $6/kg, but that price is what farmers were willing to accept, rather than what the market or at least the wholesalers were willing to pay. Nevertheless, that is not to say we have exaggerated the farm-gate price because it could be the opposite; black bream is both a highly regarded table fish and sport fish that has been promoted as the preferred species for developing farm-stay tourism associated with put-and-take recreational fisheries in contained inland saline waters (Sarre *et al.* 1999). Potential producers could therefore benefit by farming this species for both purposes.

A COLLECTIVELY GREEN SALES PITCH

The saline groundwaters in southern Western Australia are believed to be pollution-free, and these conditions need to be maintained to sustain a high quality water service for fish farming. While some argue that the government should not stifle economic growth through over-regulation, the environment is an issue of growing importance to consumers who are unwilling to buy food without regard to how it was produced (Beveridge *et al.* 1997). To satisfy both consumers' aspirations and legal obligations regarding food safety, retailers are beginning to seek products that are produced under quality assurance schemes (Doupé *et al.* 1999).

Environmental quality is necessary from the outset, and environmental management practices that add value to but do not further degrade the saline groundwater resource, could provide the basis for a locally produced commodity that meets consumer expectations. Getting the marketing approach right so the product is correctly presented to discerning customers is crucial for development. Doupé *et al.* (1999) argued that the management and maintenance of environmental quality throughout the production and processing stages of the operation should result in a quality-assured product. They suggested that the voluntary imposition of codes of practice could underpin assurances of product quality, and allow the industry to develop with minimal interference and a greater sense of autonomy. Quality assurance may be achieved in a number of ways, such as recording water quality, disease incidence and stock turnover, and setting specified levels of discharge, chemical use and stock escape. These initiatives should be undertaken in conjunction with accredited programs (e.g. ISO 14000) so that these benchmark standards become the language that links the grower to the branded, quality-assured product in the market (see Doupé *et al*. 1999). This process has started among trout producers in Western Australia, with a number of farmers currently participating in a pilot study to develop both a quality assurance scheme (HACCP) and an environmental management system for trout produced in inland saline waters.

INDUSTRY MANAGEMENT

Production Scales, Profitability and Concurrent System Development

Managing an aquaculture system to optimise profits requires decisions to be made on various investment strategies that realise returns over different time frames. Optimising profits in the short-term is primarily related to input costs and the market value of outputs. In the short-term at a low level of production, only small substitution is possible in feed and labour inputs (see Table 3), but it can make a difference, especially if there is a concurrent development at the marketing end of the production cycle. For example, occasional feeding of trout in farm dams makes a significant difference in yield and profit with a relatively low input cost. Short-term profits can also be optimised through product diversification; such is the variability of inland water bodies that we still have fairly limited ideas of which species can be grown, and where and when (e.g. Sarre *et al*. 1999; Ingram *et al*. 2002). There are windows of opportunity that should allow production of specific products throughout the year in outdoor conditions, like barramundi during the warmer months and trout over winter.

Table 3 Relative importance of variable production factors for planning and management during differing time scales (after Burbridge *et al*. 2001).

	Options for system management		
Time horizons	Labour, feed & energy	Capital investments	Technological developments
Short-term	+ +	__	__
Intermediate term	+ +	+	__
Long-term	+ +	+ +	+ +

+ + indicates option for change; __ indicates options are not variable during time frames.

Within an intermediate time frame (Table 3), options become available that may allow capital investment to improve productivity and economies of scale, although the benefits will not necessarily translate to an immediate improvement in profit. For instance, reduced prices may be negotiated to account for increased production scales, and the benefits from the capital investment may be seen where inputs such as feeds and labour become cheaper due to improved purchasing power and production efficiencies (Burbridge *et al*. 2001). In this scenario, the construction of purpose-built fish ponds that are not affected by those landscape influences that often affect many farm dams, would allow higher stocking densities and greater production per unit of management and labour effort, and higher yields per unit of investment.

In the long-term, all production factors are variables and new ventures may enter the sector and change the mass of products in the market (perhaps collectively), while increasing cost-effectiveness through implementing innovations (Table 3). Semi-intensive feeding regimes may be appropriate where a farmer may wish to supplement income lost by a reduction in cropping area, however fish production will be low. The required scale for intensive production systems to be profitable may be impractical for one farmer, but economical for a group. Theoretically, least-cost methods of production and economies of scale should lead to more efficient resource allocation, however in reality it is the marginal change in inputs and management that makes the difference. Examples include the potential advances gained in breeding and culture technologies that may allow across-the-board improvements in the production system.

A Role for Industry Collaboration

The development of new industries in Australia has traditionally followed an enterprise-based approach, which targets the short to medium-term needs of individual enterprises, often defined through individual business plans. There is increasing support for the view that developing industries exhibit emergent properties, that is, properties that cannot be predicted from an understanding of the operations of individual enterprises. These emergent properties arise from collaborative associations among enterprises and the interactions of these collaborative associations with other players in the value chain. If new industry development is at least part-driven through the dynamics of an emerging social system, then strategic intervention in this system can influence development outcomes (Wollin 1996).

The current size of the fresh trout market in Western Australia is about 23 t/annum and suggests that there is unlikely to be room for more than one producer of this size in the wheatbelt until new markets are developed (Anon. 2002). It is probable, therefore, that the industry will continue to comprise a number of micro-producers (i.e. $\leq$ 1 t/annum) who avoid competition with their interstate counterparts, although a fresh, “as is” marketing strategy will possibly cause competition among these farmers as they attempt to price cut each other and take whatever price is offered (Anon. 2002). Producer collectives might overcome such problems by co-operatively managing sales and marketing while the producer concentrates on supply. At present, rainbow trout production in Western Australia chiefly comprises one large, independent producer, and two representative producer groups. One, the Saltwater Trout Alliance, intends gaining a competitive advantage through small-scale vertical integration of resources from hatchery to market and the development of markets for value-added products, whereas the Western Inland Fisheries co-operative means to gain their advantage by horizontal integration of production resources.

A Role for Government

Financial analyses and the formation of collaborative industry structures can help aquaculture enterprises deal with a long-term approach to innovation and industry development. This, however, does not address industry externalities; the wider societal benefits and costs of a new rural industry. The net result is the social forfeiture of potential economic development in sustainable resource management, and Australia urgently requires exemplary leadership in this area. The entrepreneurs and farmers should not be expected to gamble their funds without some form of support structure, but neither should public investment result in their losing control over the emerging industry.

In many ways the Western Oil Mallee Project (see Bell *et al*. 2001) is similar to inland saline aquaculture. Both are examples of up-and-coming and alternative agricultural industries that are focussed on the salt-affected wheatbelt region of Western Australia, and because both are limited by competing demands on the capital to farmers, the farmers themselves are unable to provide the necessary funds to enable the industry to develop solely under their direction. However, unlike inland saline aquaculture, the federal and state governments have provided significant funding for research and development of the oil mallee project. Continued investment in it is contingent on technical success and commercial viability including market development, and indicates the way forward for the development of an inland saline aquaculture industry. Technical success requires the translation of innovation into practical operation by educated labour, but that depends on new inventions being supported from the laboratory bench via pilot units to full-scale operations. For this to occur, public investment in research and development is required, and without it, it is difficult to envisage sustainable industry growth or environmental management. For example, the role of state government in the Australian prawn industry has been the establishment of a discretionary assistance scheme to encourage aquaculture businesses to adopt a quality assurance scheme linked to an industry code of practice in Queensland (Doupé *et al*. 1999). A similar approach should be considered for inland aquaculture in Western Australia.

CONCLUSIONS

The embryonic nature and limited capital base of inland saline aquaculture in Western Australia presents a range of production and investment options for landholders and investors. The variable intensity of participation and investment, however, has resulted in different stages of development along the production continuum. The key to development is a coordinated approach. Without such an approach, we will constrain the progress of inland saline aquaculture from hobby to industry status, and the rehabilitation of saline land and water resources. For example, low-level production effort growing comparatively few fish in farm dams will probably limit the extent to which fish production can contribute to the cost of surface or sub-surface water management systems. Further, sporadic development at an enterprise level will result in wastage of limited resources and opportunities, because individuals will seek to allocate resources relative to their specific and often short-term needs. A co-ordinated direction to inland saline aquaculture development promises much more. A whole-of-industry approach should enable the progression of local fish production systems that turn out quality-assured commodities that are recognizable in the market. Nevertheless, advancement toward industry status is more likely to occur if the support mechanisms associated with public investment are made available to inland saline aquaculture that have been provided to other, alternative agricultural enterprises in the salinised landscapes of inland Western Australia.

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