Australian Eel Aquaculture Industry Development Strategy and Business Analysis

Gooley, G.J. and McKinnon, L.J.

State Government Victoria Department of Primary Industries

Australian Government Fisheries Research and Development Corporation

Project No. 2000/264

Australian Eel Aquaculture Industry Development Strategy and Business Analysis

Gooley, G.J. and McKinnon, L.J.

February 2004

Project Number 2000/264

Australian Eel Aquaculture Industry Development Strategy and Business Analysis

Gooley, G.J. and McKinnon, L.J.

Published by Primary Industries Research Victoria, Marine and Freshwater Systems, Department of Primary Industries, Queenscliff, Victoria, 3225.

DISCLAIMER

The authors do not warrant that the information in this book is free from errors or omissions. The authors do not accept any form of liability, be it contractual, tortious or otherwise, for the contents of this book or for any consequences arising from its use or any reliance placed upon it. The information, opinions and advice contained in this book may not relate to, or be relevant to, a reader's particular circumstances. Opinions expressed by the authors are the individual opinions of those persons and are not necessarily those of the publisher or research provider.

ISBN 1 74146 065 4

Formatted/designed by Primary Industries Research Victoria Queenscliff

Printed by PIRVic Queenscliff, Victoria

Table of Contents

NON-TECHNICAL SUMMARY

2000/264 Title: Australian Eel Aquaculture Industry Development Strategy and Business Analysis

Principal Investigator: Geoff Gooley

Co-Investigator: L. J. McKinnon

Address: Primary Industries Research Victoria

PO Box 114

Queenscliff, VIC 3225

Ph.: 03 5258 0111 Fax: 03 5258 0270

Objectives:

1. To analyse shortfin and longfin eel aquaculture investment potential in Australia, including development of an appropriate decision support information database for government and industry.
2. To determine strategic guidelines for development of the Australian eel aquaculture industry, including evaluation of national R&D priorities.

Non Technical Summary:

OUTCOMES ACHIEVED TO DATE

- Recognition by ANZERG, the primary national government coordinating and advisory body on eel resource management, of the potential for further sustainable development of the Australian eel aquaculture industry by increased utilisation and national trading of wild-caught glass eel resources, and the opportunity to facilitate development through providing requisite resource management policy and associated Best Practice industry guidelines for glass eel fishing and aquaculture.
- Key aspects of the report's findings are presently being realised on a commercial basis to varying degrees in all four states by leading, individual industry proponents (if not widespread throughout the industry). Such activities include increased effort in the harvest of longfin glass eels for aquaculture, the national trading of juvenile/sub-adult eel seedstock, the vertical and horizontal integration of different operational levels of the wild eel fishery between and within individual business enterprises, and an increased emphasis on intensification of production of larger (≥ 1 kg) eels for export markets.

The Australian eel aquaculture industry is relatively small in scale, geographically disparate in location, and presently lacks any meaningful organisational structure and strategic direction at a national level. It is also part of a global eel aquaculture sector which is orders of magnitude greater in terms of scale and maturity, thereby imposing significant market pressure on the economic viability of local operations. Indeed market failure is presently evident in a number of areas, to the point where industry development is being impeded. It is against this background that the present study was initiated by the Fisheries Research and Development Corporation (FRDC), as a means of elucidating these constraints and providing some more strategic direction to the Australian eel aquaculture industry, including investors, resource managers and researchers.

Moreover, the FRDC has identified the specific need to describe an appropriate industry development strategy, together with an analysis of the investment potential for eel aquaculture in Australia.

This report takes the form of five key sections. The first section describes the background, objectives and methodological approach to the study. The second section describes the current institutional and organisational arrangements surrounding the Australian wild eel fishery and aquaculture industries. The third section describes the status and operational circumstances of the Australian eel aquaculture industry, with some reference to the wild eel fishery. The fourth section summarises a series of system specific financial analyses and industry-wide production simulations to provide the underlying rationale for a long-term industry development strategy. Section five describes the strategic direction in which the Australian eel aquaculture industry might go over the next 10-20 years, with reference to the requisite management guidelines and R&D priorities designed to facilitate such development.

In order to progress the establishment of an industry vision designed to facilitate appropriate levels of investment, expansion, and long term sustainability, an interactive industry development model is proposed to enable some predictive capability in the absence of real time operations and actual data. In the present study, a simulative model has been constructed which has two main components around which a series of assumed inputs and projected outputs can be determined. These assumptions and projected outputs are then used as the basis for proposing various investment, production and development scenarios at both farm specific and aquaculture (sub) sectoral level. The model and its main components are designed to incorporate a suite of Best Practice scenarios which are progressively implemented over time (from present to 20 years hence) under a 'continuous improvement' regime inherent in a proposed industry-wide strategic development plan.

Based on industry experience, there is clearly a need for a critical mass of glass eels for any purpose built culture system to operate efficiently. The model has determined this on the basis that an operator needs to ensure a reasonable return on investment of purpose built capital plant and equipment, of which a minimum outlay is required for any quantity of glass eels. Summary model outputs indicate:

- More intensive production of larger 1kg eels provides disproportionate financial advantage to the operator compared with production of smaller 300g fish as a final market size.
- Intensive and semi-intensive production of larger eels, with a minimum 50kg glass eel intake per annum, should be profitable with a projected IRR of 20-40%; based on defined Best Practice scenarios and subject to price sensitivity for market value, feed and seedstock costs.
- Intensive production of 10g stockers should be profitable for limited and specialised operations catering for broad domestic market demand, with a projected IRR of > 40%; based on defined Best Practice scenarios, and subject to a minimum glass eel intake of 500kg per annum and price sensitivity for market value and seedstock costs.
- Extensive production of large eels should remain profitable for larger eels with estimated IRR of 15-45% subject to availability of sufficient quantities of 10g seedstock, suitable water to stock and price sensitivity for seedstock and market value.

According to the model, the Australian eel aquaculture industry could potentially produce over 1500 tonnes of marketable eels worth in excess of $30 million in Australia under the assumed Best Practice, seedstock allocation and market pricing regimes. Furthermore, the model estimates that under improved Best Practice conditions, increasing the initial industry-wide glass eel intake to 500-750 kg per annum could potentially increase the relative efficiency of industry utilisation of the wild glass eel seedstock resource by about 9-15%. It is at this level of glass eel supply upon which the potential for optimal production from all culture systems could be fully realised.

Such quantities of shortfin and longfin glass eels are considered potentially available on an annual basis from the wild fishery within 10-20 years from a number of locations across the species' range. For such production to be achieved from the industry, the Australian glass eel resource must be managed at a national level, and industry must coordinate and integrate on a national scale to ensure management within an ESD framework. Institutional and legislative impediments are however, presently limiting industry development, with existing state policies in relation to eel aquaculture development being inherently parochial. This attitude is doing little to facilitate optimal use of what is otherwise a common pool natural resource being shared by multiple stakeholders (including commercial and recreational fishers, fish farmers, and ethnic and indigenous groups) across multiple state and national boundaries. A more flexible approach is warranted to free up and encourage national trade in glass eels and intensively reared restock eels to ensure that the longer term production capacity of the Australian eel aquaculture industry can be optimised in the face of ongoing export market demand.

The Australian eel aquaculture industry needs to establish a long term strategic vision to encourage appropriate levels of investment and compliance with acceptable ESD performance criteria. This vision should have a 10-20 year time frame and address at a national level various issues including relevant aspects of culture technology, R&D, training and education, resource management, organisational structuring, financial management and marketing. Australia presently lacks an effective national focus for development of the eel industry, with a resultant lack of strategic industry development and coordination being apparent. The need in fact is for the eel industry to work across multiple state boundaries, not be constrained by them.

The Australian eel aquaculture industry is not presently limited by technology or informational gaps requiring further R&D investment in the short term. Rather, more resources should be invested in removing institutional and legislative impediments (particularly to national glass eel trading), achieving better integration of key industry sectors, and technical training and extension (designed to enhance recent R&D outcomes). In the longer term, various R&D needs have been identified as part of the draft national eel R&D strategy, and these should be reviewed periodically to determine the level of priority.

Keywords: Anguillid eels, aquaculture, glass eels, seedstock, financial analysis, strategic development, industry vision

Acknowledgements

The authors wish to gratefully acknowledge key contributions to this report from the following research colleagues and industry representatives:

- Mr Will Dalton, formerly School of Business Studies, La Trobe University, Melbourne, for preparation of MS Excel programming forming the basis of the financial analysis of the specific culture systems component of the simulative industry development model used in this report.
- Dr Brett Ingram, Primary Industries Research Victoria, for preparation of MS Excel programming forming the basis of the industry-wide development potential component of the simulative industry development model used in this report.
- Ron and Sharon Elton, East Coast Eels P/L, Stratford Victoria, John Ranicar and Ben Brookman, Eels Australis, and members of the Victorian Eel Fishers Association for provision of relevant eel fishery and aquaculture industry information including commercial production specifications, costs and associated market advice.
- Various state fisheries agency representatives including Anthony Forster, Fisheries Victoria, Phil Boxall, Tasmanian Inland Fisheries Service, Ian Lyall and Steve Boyd, NSW Fisheries, and Rob Swindlehurst, Queensland Department of Primary Industries) contributed detailed information on aspects of the eel fishery and aquaculture sectors in their respective states.
- NSW eel industry representatives including Paul Kirk, Heinz Gress, Phonse Lane, Graeme Bailey and Mick Bennett for information on commercial eel fisheries and aquaculture activities in NSW.

Dr Sena De Silva, School of Ecology and Environment, Deakin University, Dr Brett Ingram, Primary Industries Research Victoria, and Dr Peter Appleford, Fisheries Victoria provided constructive comment on this report and their assistance is much appreciated by the authors.

Finally, the authors also wish to acknowledge the funding support of the Fisheries Research and Development Corporation for this project.

Introduction

Background

The Australian eel aquaculture industry is relatively small in scale, geographically disparate in location, and presently lacks any meaningful organisational structure and strategic direction at a national level. It is also part of a global eel aquaculture sector which is orders of magnitude greater in terms of scale and maturity, thereby imposing significant market pressure on the economic viability of local operations. Not surprisingly therefore the future of the Australian industry is somewhat unclear, with one consequence at the present time being a reduction in new financial investment and 'stalled' commercial eel aquaculture development.

Despite this uncertainty, existing operators within Australia remain committed to establishing viable eel aquaculture businesses in at least four states. Many such operators have a background with and/or ongoing linkages to the Australian wild eel (capture) fishery, and see aquaculture as a logical adjunct to the wild fishery, if not a complete, longer-term alternative. Indeed the transition from a wild fishery base to a combined wild fishery/aquaculture base for the Australian eel industry over the last several years has been quite profound in many respects, to the point where Australia can now legitimately claim to have a 'new and developing' eel aquaculture sector.

Arguably, much of the confidence of the existing operators is based around, not only the inherent suitability and marketability of Australian anguillid eels as a cultured (and wild) product, but also the recent positive achievements of both industry and Government in relation to juvenile eel resource management and research and development. Indeed, on face value, much of the information needed to further develop and ultimately manage the Australian eel aquaculture industry on both a profitable and environmentally sustainable basis is now available. As previously implied however, market failure is presently evident in a number of areas, to the point where industry development is being impeded. It is against this background that the present study was initiated by the Fisheries Research and Development Corporation (FRDC), as a means of elucidating these constraints and providing some more strategic direction to the Australian eel aquaculture industry, including investors, resource managers and researchers.

Recent FRDC Funded Glass Eel R&D

The FRDC of recent years has invested significant funds into the development of the commercial eel fishery and aquaculture sector within Australia. Specifically in support of the latter, the FRDC has funded two major projects which have investigated various aspects of glass eel resource assessment and aquaculture, with an emphasis on the Australian shortfin eel, *Anguilla australis*, and the longfin eel, *A. reinhardtii*. These projects, FRDC Project No. 94/067 and FRDC Project No. 97/312 (incorporating supplementary Project No. 99/330), have also been financially supported by relevant state fisheries and aquaculture management agencies in four states (viz. Queensland, New South Wales, Victoria and Tasmania). The projects were undertaken on a collaborative basis by various research agencies in each of these states, and the final reports have now been published (Gooley *et al.*, 1999; Gooley and Ingram, 2002)(see also Section 3.5 for further details).

Draft National Eel R&D Strategy

Given the ongoing level of interest from the eel industry, government resource managers and researchers for further eel fishery and aquaculture R&D, the FRDC has more recently endeavoured to adopt a strategic approach to investing in this sector through the development of a Draft National Eel R&D Strategic Plan (see Appendix for details). The Plan emphasises national R&D priorities for the eastern Australian eel sector, and has engaged all major stakeholders in the process. It is intended that this Plan be used as a guide to future R&D investment in Australia, but also it is recognised that it will be subject to periodic review to ensure relevance to market conditions, particularly in terms of ensuring that the limited available R&D resources are directed at areas of clear market failure and for which the likelihood of achieving ESD-based outcomes is relatively high.

The Present Study

Given the previous introductory comments, and prior to implementation of the R&D Plan, the FRDC has identified the logical next step in addressing the strategic needs of the Australian eel aquaculture sector. Indeed the FRDC has determined that the R&D Plan in itself is insufficient to determine an appropriate level of R&D investment in Australian eel aquaculture in the absence of key business and economic information. Such a nexus is consistent with the vagaries of many new and developing aquaculture industry sectors in Australia, and there are few suitable examples or templates of such databases to support R&D investment decisions for new commercial entrants. This is further compounded at the present time by the lack of an agreed, medium to long-term eel industry development vision.

The FRDC has therefore identified the specific need to describe an appropriate industry development strategy, together with an analysis of the investment potential for eel aquaculture in Australia. This strategy would complement the existing draft R&D strategy and effectively provide the commercial rationale for further investment in eel R&D and associated industry development in Australia.

Although intended to focus on the new and developing eel aquaculture sector, this analysis also needs to address attendant issues relevant to the wild glass eel fishery, recognising the ongoing dependence of eel aquaculture on wild-caught seedstock.

Accordingly, FRDC has funded the present study (Project No. 2000/264), for which this document is the Final Report. The Project has been managed by the Marine and Freshwater Systems Platform of Primary Industries Research Victoria (formerly Marine and Freshwater Resources Institute, Department of Natural Resources and Environment, Victoria), and has involved contributions from a number of leading Australian eel research, management and industry personnel. The Project commenced in July 2000 for a 12 month period.

Project Objectives

1. To analyse shortfin and longfin eel aquaculture investment potential in Australia, including development of an appropriate decision support information database for government and industry.

2. To determine strategic guidelines for development of the Australian eel aquaculture industry, including evaluation of national R&D priorities.

Project methods

1. Document and summarise past and present eel aquaculture related research undertaken in Australia, including identification of key outputs and evaluation of effectiveness of addressing existing R&D priorities.

2. Develop draft national guidelines for the sustainable utilisation and management of Australian anguillid glass eel resources; to include identification of the dimensions of the Australian glass eel resource and estimates of the scale and sustainability of the potential catch for aquaculture purposes.

3. Describe and document the current industry development in Australia on a state by state basis, including a description of ongoing/future development, and a proposed 20 year development vision for the industry which highlights key drivers, targets and strategies to support such development.

4. Document the current legislative and associated institutional framework relevant to eel aquaculture on a state by state basis, including identification of key institutional and legislative impediments to development.

5. Undertake an economic analysis of the Australian eel aquaculture business, including assessment of potential financial return and critical development factors for different management scenarios and sensitivity analysis of key production parameters.

6. Undertake a strategic planning analysis of R&D needs for Australian eel aquaculture development which an emphasis on identifying areas of market failure and key industry drivers, factoring in previous R&D outcomes; make recommendations on proposed R&D investment priorities to facilitate implementation of the existing draft R&D plan where appropriate.

This report takes the form of five key sections, presented as discrete chapters. The first section (this chapter) describes the background, objectives and methodological approach to the study. The second section describes the current institutional and organisational arrangements surrounding the Australian wild eel fishery and aquaculture industries. The third section describes the status and operational circumstances of the Australian eel aquaculture industry, with some reference to the wild eel fishery.

The second and third sections combined provide the background information upon which the remaining two sections, viz. four and five, are based. The fourth section summarises a series of system specific financial analyses and industry-wide production simulations to provide the underlying rationale for a long-term industry development strategy. Section five describes the strategic direction in which the Australian eel aquaculture industry might go over the next 10-20 years, with reference to the requisite management guidelines and R&D priorities designed to facilitate such development.

Limitations of the Study

Whereas every effort has been made in this report to provide accurate and reliable data, much of the data used has been sourced anecdotally, due to a lack of existing, more formal databases. Where readers have access to data which may in some way vary from that which is described in the report and which is deemed to be more appropriate for whatever reason, they are encouraged to use such data and to make the necessary allowances for the relevant projections where indeed this may lead to a different outcome from that described in this report. Furthermore, as this study has drawn on such information over an extended period prior to the final publication of this report, it is recognised that some key parameters may well have changed of recent times which in turn may likewise have a bearing on some key findings and recommendations of this report. Accordingly readers are again advised to make the necessary allowances for such changes where necessary.

Institutional Framework and Organisational Arrangements for State-Based Glass Eel Fishing and Eel Aquaculture Sectors

Introduction

This section provides a brief summary of the institutional framework and associated industry organisational arrangements at a state level for the Australian glass eel fishing and aquaculture sectors. A brief synopsis of Australian eel market dynamics is also provided for completeness. It is not intended that this summary be exhaustive, rather indicative of the prevailing circumstances within industry and government at the present time[1].

It is also intended that this section of the report complement the next section which summarises the present production and operational status of the industry in Australia. These two sections in combination provide a useful and informative background to latter sections of this report which in more detail refer to opportunities for expansion, the need for change and the strategic direction in which the industry should go to address a long term vision of where it wants to be in 20 years time.

[1] Whereas the information provided in this Chapter was deemed to be accurate at the time of collation for the period ending 2000/01, it is noted that some variation may have occurred in the ensuing period prior to publication, but that such variation would not substantively change the report’s key findings.

Queensland

Based on 2000/01 production returns, there were 26 aquaculture licences in Queensland with endorsements for eel culture. The majority of these also had permits for the collection of glass eels and/or elvers as seedstock for aquaculture, however in practice only 3 or 4 of these have actively undertaken such activity of recent times. Each permit has a Total Allowable Catch (TAC) for juvenile eels which is directly related to the production capacity for eel of the associated aquaculture facility. The export of glass eels from Queensland is currently not permitted; the intention being that all juvenile eels harvested in Queensland be retained in the state for further growout to final market size. Contractors may also be employed as fishers by the aquaculture enterprise to collect eel seedstock on their behalf under the relevant permit.

The majority of the production from Queensland is from a single, semi-intensive, pond-based farming operation in south-east Queensland which produces predominantly longfin eels. Much of the seedstock for this farm is based on wild caught 'restock' although trials using glass eel sourced seedstock are under consideration subject to availability, cost and market demand for product. The industry has 6.8 permanent staff (10 in 1999/00) and employed 9300 hours of casual labour. This equates to 12 full-time equivalents (no change over last 12 months) employed in the industry (Lobegeiger, 2002).

New South Wales

State government policies exist for eel aquaculture and glass eel fishery development in NSW (see www.fisheries.nsw.gov.au for details). In 1999/2000 there were 21 licensed fish farms in NSW with permits for shortfin eel production, including 17 farms with permits also for longfin eel production (source: NSW Fisheries). In this period, two tonnes of cultured longfin eel was produced worth $16,500 (*c.f.* 2.3 tonnes worth $18,700 from 14 licensed growers in 1998/99), and 400 kg of cultured shortfin eel was produced worth $1000 (c.f. 38 kg worth $500 from 12 licensed farms in 1998/99)(source: unpublished data NSW Fisheries, 2002).

In 2000/01 there were nine glass eel collection permits on issue in NSW (of which only four were active), including three which belong to eel farmers who may collect glass eels only for their own use. Permits for the collection of glass eels in NSW are not transferable. A TAC of 300kg of glass eels (total inclusive for both species) was set for the State in 2000/01 and allocated on a one-off, expression-of-interest basis, with consideration for further allocations being subject to industry need. Presently, 18 rivers are open to glass eel fishing with a further limit of 30 kg per river being set under the TAC. Three 'refuge' catchments (Clarence, Hawkesbury and Port Stephens), in which no commercial fishing can occur, provides for some protection of stocks. Glass eel fishers also need an agreement with licensed eel farmers to collect a predetermined quantity of glass eels, if in fact the fishers are not permitted to catch glass eels for their own use. In 1999/2000, a total of 44 kg of glass eels (species not specified) was requested by license holders in NSW, with 15kg (mixed species) being caught. In 2000/01, about 100kg was requested, with approximately 10 kg being caught.

Based on recent anecdotal information, the overall view of the eel farmers in NSW is that both import and export of glass eels should be permitted, however to date there appears to have been little or no commercial trade of glass eels between NSW and other states. Indeed, under existing management arrangements, glass eels collected in NSW are only for use in NSW farms and, like Queensland, cannot be sold interstate, and glass eels sourced in other states are not permitted to be imported into NSW. There is also a somewhat contradictory, but otherwise limited and unofficial, industry view that there should be no exploitation at all of glass eels in NSW waters.

Presently, the preferred species for farming in NSW is clearly the longfin eel, which in 2000/01 was bringing a farm-gate price of about $14/kg (headed and gutted). Preferred, marketable product size was >500-600g (whole fish), but supply was very limited. The industry preferred production method in NSW at the present time is pond-based growout of wild-caught, 'sub-adult' stockers (<300g), although there is increasing interest in the potential use of stockers from intensive, nursery systems using glass eel seedstock, for pond growout. More specifically, commercial operators in NSW deem that the major constraint to eel aquaculture industry development is the initial supply of glass eels for seedstock production purposes, whatever the preferred final stocker size may be.

Recently, only one glass eel collection permit holder has fished exclusively for glass eels, although one other has a collection permit for 'own (eel farming) use' purposes. Most glass eel permit holders in NSW are primarily commercial estuary fishermen, and therefore do not necessarily collect glass eels at the appropriate time, rather direct efforts in favour of fishing for other higher priced, seasonally available species. To some extent this problematic arrangement is further compounded by the lack of an effective working relationship within the industry between eel farmers (aquaculture sector) and glass eel suppliers (wild fishing sector). This situation is aggravated further by the fact that both species of eel (longfin and shortfin) are present in the NSW glass eel fishery, often in equal proportions during the main periods of migration, and there is considerable difficulty in distinguishing between species with the naked eye at this early developmental stage. NSW eel farmers generally see the solution to this in permitting growers to routinely source their own glass eels. Despite these constraints however, there is an agreed need in NSW (at least within the aquaculture sector) for establishing a workable, cooperative, vertically integrated arrangement between glass eel supplier, intensive nursery stage, and pond growout components.

The majority of eel production from NSW farms is presently from a single, semi-intensive, pond-based system using both glass eel and 'small' eel seedstock. Although presently small in scale (< 10 tonne/annum production capacity), this system has the potential to expand to > 20 tonne/annum in the future. Another semi-intensive, pond-based system of similar capacity (3.6 ha total pond surface area) is under development presently in NSW, as an extension of what was originally a smaller, pilot-scale, tank-based system. One other smaller pond-based system (2 ha total surface area) is also under development.

Apart from the perceived institutional and legislative impediments imposed on further eel aquaculture industry development in NSW by the existing glass eel fishery restrictions/regulations (see previous comments), some industry representatives believe that further policy constraints include the prevention of eel stock enhancement of public waters. Other stated concerns in relation to statutory planning and approvals processes are considered to be consistent with other sectors of the Australian aquaculture industry (both marine and freshwater) in all states and not unique to eel farming development in NSW.

Victoria

The Victorian commercial eel fishery is an important fishery for the State, comprising both the shortfin and longfin eel, which combined produce 125-450 tonnes, worth approximately $1.4-4.7M annually. Overall, the shortfin eel makes up approximately 90% of total eel production. The eel fishery has been relatively stable, in terms of production over the last 2 decades, however the fishery is strongly affected by seasonal factors, and recent drought conditions have resulted in relatively lower production. Reduced market demand for smaller shortfin eels has also impacted on industry profitability of recent times.

A large component of eel production in Victoria continues to be stock enhancement, whereby elvers and undersized 'restock' eels are stocked into selected (approved) waters (lakes, wetlands etc) for extensive growout under natural conditions. In most years the commercial catch is roughly comprised of up to 40% stock-enhanced/cultured shortfin eel product, however protracted drought conditions since 1994 have resulted in a significant decrease in stock-enhanced eel production.

The wild shortfin and longfin eel components of the fishery are comprised largely of migrating adult eels. The reliance of the existing commercial eel fishery in Victoria on this component of the fishery is consequently very great, particularly during periods of drought when productivity from stock-enhanced waters is low. In 2000/01 there were 18 Eel Fishery Access Licence (EFAL) holders in Victoria, and the industry directly employs around 30 full time, and up to 70 part time people across Victoria. Most eels are exported frozen to Europe (mainly shortfin eels) or live to Hong Kong and Korea (mainly longfin eels). There is also a limited domestic market for Victorian produced shortfin eel in Australia at present.

A new Victorian Eel Fishery Management Plan was released in 2002 (McKinnon, 2002) which provides the legislative framework for the wild fishery. This Plan is intended to provide for the management of Victorian eel resources within an ESD framework, and specifically provides for the sustainable, commercial utilisation of glass eels harvested from Victorian coastal waters for aquaculture purposes.

The commercial fishery is input managed, with limited entry, gear restrictions and fishing and 'culture' water allocation the main input restrictions. There is no minimum size or TAC set for the eel fishery in Victoria. Fyke nets are the only gear permitted for use by EFAL holders and only holders of an EFAL may use or possess fyke nets. A small quantity of eel is also taken commercially in bay and inlet fisheries by haul seine operators. Restrictions on the use of fyke nets include: mesh size of not less than 15mm and not greater than 39mm, and a maximum of 3 wings, each of 46m maximum length, 67cm maximum drop and meshes of no more than 32mm. Currently, each licence holder may use up to 50 fyke nets and nets must be cleared at least once every 48 hours. A fyke net when set must not occupy more than half of the width of a watercourse, and may not be within 5m of another net. Some EFAL holders are permitted to use oversize fyke nets specifically for targeting migrating sea-run eels. Access to glass eels is limited to EFAL holders under permit only.

At the present time the demand for cultured elver (glass eel-sourced) seedstock for extensive, stock enhanced wild fisheries in Victoria is limited, with existing fishers preferentially purchasing wild caught Tasmanian elvers and Victorian sourced sub-adult restock on the basis of perceived cost effectiveness. More specifically, glass eel-sourced seedstock is considered by commercial fishers to be too expensive at any cost greater than the market rate for Tasmanian elvers (typically $180-200/kg). The latter price presently happens to approximate the production cost (based on present techniques and prices) of catching and weaning glass eels ready for sale as seedstock for growout (*eg.* 10g sized elvers), thus partly limiting any competitive advantage for producers taking this option.

Despite these concerns, the Victorian Eel Fishers Association has acquired a permit to harvest glass eels from the Snowy River during the 1999/00 and 2000/01 period, primarily for the purposes of providing seedstock for extensive culture and some limited intensive culture. These permits were issued by the government on a limited basis prior to the release of the new management plan, and include provisions for a subsequent 'conservation stocking' of at least 10% of the harvested glass eels being returned to the wild (usually upstream of the original collection location) as elvers. Permits have also been issued to specific fishers to harvest limited quantities of glass eels from 'allocated' waters in which existing eel fishing licence provisions infer exclusive commercial eel fishing access to the licence holder.

Tasmania

Eel production in Tasmania is based on the wild fishery for shortfin eels. In 2000/01 there were 12 licensed eel fishers operating in the State, with total reported catch being 42.8, 59.2 and 44.6 tonnes/yr respectively for the three year period 1997/98-1999/00. First grade eels (>900 grams) average about $6/kg to the fisher, with smaller 'restock eels' bringing an average of about $3/kg. Licences are transferable. Fyke nets and traps are typically used to harvest eels in Tasmania, with lakes, lagoons and farm dams being the main areas that are fished. Input controls on the fishery include:

- Fyke net size opening height not to exceed 670mm; width not to exceed 670mm; a mesh size not less than 15mm and not more than 39mm; any wing or leader not to exceed 10 meters in length and not to exceed 1200mm in drop (there is no restriction as to number of nets/traps per fisher).
- Fyke nets are not normally permitted in flowing waters (rivers etc); some use is permitted under a special permit.
- Eel trap size does not exceed 500mm in height, does not exceed 500mm in width, and does not exceed 2 meters in length with no wings or leaders; has a mesh of at least 39mm.
- There are provisions for a fisher to apply to use larger equipment in their catchment.
- Only fish greater than 300mm TL can be harvested.
- Fishing is not permitted in National Parks, World Heritage Areas, State Reserves, and local Council water storages.

In Tasmania, licensed eel fishers are entitled to restock catchments with relocated elvers to assist the sustainability of the fishery and to enhance production. Table 1 details the combined elver catch from the Trevallyn Tailrace (Tamar River) and Meadowbank Dam (Derwent River). The total catch of shortfin elvers per year between 1994/95 and 2001/02 ranged between 1.4 and 4.8 tonnes (mean 2.7 tonnes), with up to 1.1 tonnes purchased by industry, both within Australia and on the export market (Table 1). The value of the sold portion of the catch varies from year to year, but is commonly in the order of $180-200/kg. The portion of the total catch not sold is used to restock natural waterways within Tasmania. There is no data in Tasmania to distinguish production returns specifically from stock-enhanced waters using restock eels or translocated elvers.

Table 1 Tasmanian shortfin elver catch and allocation for the period 1994/95-2001/02. (source: unpublished data, Tasmanian Inland Fisheries Service, 2002).

Year	Total Catch (kg)	Sold (Interstate/International) (kg)	Restock (Tasmanian lakes / dams / rivers) (kg)
1994 / 1995	1420	700	720
1995 / 1996	4756.5	1110.5	3646
1996 / 1997	2219.6	1045.5	1174.1
1997 / 1998	2754.5	741	2013.5
1998 / 1999	3957.9	775	3182.9
1999 / 2000	2673	50	2623
2000 / 2001	2315.8	0	2315.8
2001/2002	2213	125	2088

Interest in eel aquaculture appears to be growing and, as of 2000/01 one permit had been issued for ongrowing eel in a small-scale recirculating system. It is expected that if eel aquaculture developed in Tasmania, then elver resources would be allocated to this sector by the Inland Fisheries Service.

Under the *Inland Fisheries Act 1995* there is provision for a juvenile eel licence designed to provide commercial access to license holders for harvesting glass eels and elvers. At this point of time a licence has not been issued for glass eels although some permits for research and development have been issued.

Status of the Australian Eel Aquaculture Industry and Glass Eel Fishery.

Introduction

Historically, Australian eel production has been dominated by wild and stock enhanced capture fishery harvest, with more intensive eel aquaculture production only becoming apparent during the late 1990s. Both wild fishery and aquaculture sectors are based exclusively on longfin and shortfin eels, but the relative importance of the two species varies from state to state and sector to sector. Table 2 summarises, on a state by state basis, the estimated 1999/00 production for both species across both wild fishery and aquaculture sectors (where available, more recent data for relevant states is discussed further in the subsequent text).

Market Dynamics

According to FAO data (FishStat Plus 1996-2000, Version 2.3) total world eel aquaculture production is reported to be 232,815 tonnes worth approximately US$975 million for 2000. The vast majority of this production comes from the three major eel producing countries viz., China (160,740 tonnes), Taiwan (30,470 tonnes) and Japan (24,118 tonnes). Since 1995 annual production has progressively increased substantially in China from about 120,000 tonnes, with smaller increases recorded for Taiwan (about 5000 tonnes in 2000, but varying markedly on an annual basis, including reductions of several thousand tonnes per annum on occasions). Annual production in Japan has fallen over this period by about 4500 tonnes.

Chinese production is for combined Japanese and European eels, whereas only Japanese eels are produced in Taiwan and Japan. Other key producers of European eels (only) in 2000 include The Netherlands (3700 tonnes/annum, up from 1585 tonnes in 1995), Denmark (2676 tonnes/annum, up from 950 tonnes in 1996), and Italy (2450 tonnes/annum and steady since 1996).

Table 2 Australian longfin and shortfin eel production (wild fishery and cultured) on a state by state basis for 1999/00-2000/01, updated from Gooley et al. (2002) (based on industry estimates for 1999/2000 and/or most recent available 'production return' data for this period; where available, actual references for published data listed as footnote to table); LF, longfin eel; SF, shortfin eel; na, not available.

		Wild capture		Cultured	
		Annual tonnage	Value ($,000's)	Annual tonnage	Value ($,000's)
QLD	LF*	42.3	na	21.5	235
NSW	LF	av. 150 (range 100-400)	na	2	16.5
	SF	-	-	0.4	1
VIC	LF	37	444	-	-
	SF**	94	943	44	484
TAS	SF	44.6	178	-	-

* likely to be predominantly longfin eel, although may include some shortfin; source Lobegeiger (2001).

** cultured shortfin eel in Victoria predominantly from stock enhanced waters; source Anon. (2001).

Preferred culture system methods for these countries vary, with China, Taiwan and Japan predominantly using greenhouse covered, intensive/semi-intensive concrete pond-based systems, The Netherlands and Denmark using predominantly intensive tank-based recirculating aquaculture systems (RAS), and Italy using semi-intensive, pond-based systems.

It is apparent that eel production in China has increased dramatically of recent years to the point of oversupplying the market and with a consequent negative impact on price to producers. The vast majority of this oversupply is for smaller eels in the 150-300g size range. Impacts on price for cultured eels have been noted during the same period in all major eel producing countries in both Asia and Europe. Also, there is some question over the quality of cultured eel products in some countries. Recently, Korean markets are known to have preferentially sourced cultured eels from Australia at a premium price over Chinese cultured products on the basis of the perceived higher quality.

The massive increase in Chinese cultured eel production has been largely underpinned by the now ready acceptance of the European eel, *A. anguilla*, by Chinese producers and in the Asian marketplace, as well as the ready availability of large quantities of relatively cheap European glass eels for importation into China (reported to be around 100 tonnes from France in 2000 c.f. around 10-15 tonnes per annum on average for *A. japonica* glass eels sourced locally). By contrast, the demand for wild-caught eels, cultured eels that have the appearance of wild-caught product, and larger eels (≥ 1kg) remains steady throughout Asia and in some traditional European markets (eg. Germany). Australian longfin eels particularly satisfy many of the criteria for Asian markets presently, with some industry sources suggesting that they have a similar physical appearance to the endemic Asian species, the spotted eel *A. marmorata*, which is the basis of a small but lucrative Asian wild fishery. All wild eel fisheries in Asia and many in Europe are presently thought to be in varying stages of decline. European wild eel fisheries at least are increasingly being subject to regulatory controls for sustainability purposes (EIFAC/ICES, 2002).

Although the Australian domestic eel market is considered to be relatively small, already locally produced products (including value added portions) are being subjected to competition from low priced imports of cultured eels from China and wild eels from New Zealand (total of up to 40 tonnes imported annually into Australia; source BRS statistics 2001).

Export of some relatively low valued sub-adult wild seedstock (mixed species around 300mm total length and 200g weight) has occurred from Australia to China for subsequent intensive grow-out and value-adding in China. This export is considered by some industry sources to be competing in demand with the need for seedstock and/or 'restock' for Australian extensive, stock-enhanced eel production.

A summary of anecdotal eel market information from informed industry sources (for the period 2000/01) is as follows (all prices quoted in AUD$):

Shortfin eels

- Price:
  - Domestic \$6-7/kg farm gate, down from ~\$10-12/kg over last 12 months, for wild caught product at larger size (≥ 1kg).
  - Export \$6-7/kg farm gate (~\$10-12/kg landed overseas), down from \$11-15/kg farm gate over the last 10-12 months; European demand is however still strong in some traditional European markets (eg. Germany) with higher prices available for larger sizes (eg. \$18/kg landed for ≥ 1kg size eels).
- At present occasional shipments of 200-300kgs sold with shipments of longfin eels; these eels are not unlike the cultured Japanese eel *A. japonica* in appearance.
- Potential for up to 200 tonne per annum for larger operators exporting to niche European markets.
- Domestic sales in Victoria of 200-300kg/week of smoked eel from stock enhanced culture waters being achieved (export annual demand in order of 10 tonne).
- Ongoing drought conditions severely impacting production from stock enhanced waters due to lack of suitable water.
- Intensively cultured shortfin eels acceptable to the market but for whole fish must be larger (≥ 1kg); smaller fish suitable for smoking.

Longfin eels

- Price:
  - Export (only) \$18-20/kg farm gate with steady demand for wild caught product at larger size (≥ 1kg).
  - No obvious domestic market demand.
- Shipments of 200-300kg of wild caught product are occurring at a time for some operators with a total of about 50 tonne annual sales; potential for larger operators to sell up to 200 tonne per annum of cultured product into Asian markets.
- Key markets are China/Hong Kong, Taiwan, and to a lesser extent Korea.
- Intensively cultured longfin eels (≥ 1kg) acceptable although small/limited quantities only to date.
- To meet this market demand there is a need for longfin eel restock for private stock enhanced culture waters which are being overfished.
- Availability of glass eel seedstock/advanced sized restock is limited and reasonable market price is unclear; steady supply is required for all culture systems.

General

- The prevailing drought conditions in Victoria of recent years have impacted severely on production of wild shortfin eel, but demand has remained high in international markets. Prices have however deteriorated for shortfin eels, due largely to oversupply of farmed product from other producers. The market has also shifted in preference to larger longfin eels, although the feeling is that the size and quality of the eel is perhaps more important than the species (appearance) in some cases.
- Shipping costs for live eels are generally considered to add about \$4/kg (i.e. approximately \$3.50/kg freight and \$0.50/kg packaging) to the farm gate price for Asian markets.

Wild and stock-enhanced capture fishery production

Commercial fishing for Anguillid eels occurs in all Australian States where eels are naturally abundant. The shortfin eel and longfin eel are targeted throughout their range, with shortfins dominating commercial catches in Victoria and Tasmania, and longfins dominating catches in Queensland and NSW. Although shortfin eels occur in south-eastern South Australia, no commercial fishery for eel exists there.

Much of the longfin eel catch in NSW is based around the multi-species estuarine fishery, for which estimates of the specific eel catch are only approximate. Longfin eels in Queensland are typically taken from both estuaries and coastal impoundments. There are currently 30 eel capture licences in Queensland (steady decrease from 61 licences in 1996) which produced 42.3 tonnes in 2000. The commercial fishery is restricted to impounded waters and licences are being progressively withdrawn to reduce pressure in weirs and barrages. The value of the NSW and Queensland sectors has not been reported, but at an assumed minimum wholesale price of $10/kg, total value would be in the order of (minimum) $423,000 for Queensland and $1-4 million for NSW. The longfin catch in Victoria is predominantly from the Gippsland Lakes. The shortfin wild capture fishery in Australia is concentrated in Victoria and Tasmania, with much of the catch being taken from coastal waters (rivers and associated wetlands).

Victorian eel production is also supplemented by stock enhanced capture fisheries based in selected lakes and wetlands in western Victoria. The seedstock for this practice has historically been sourced from the Victorian wild fishery (typically mixed age/size juveniles and/or sub adults, also referred to as 'restock'), and from mixed age/size juveniles (mostly brown elvers) commercially harvested from the tail-race of the Trevallyn Power Station, at Launceston in northern Tasmania, and from Meadowbank Dam on the Derwent River.

Eels subsequently harvested from stock enhanced waters are often referred to as 'cultured' for the purpose of licensing and reporting in production returns to the Government. Consequently, such data is often incorporated into published aquaculture production status reports for Victoria/Australia, although this practice involves little or no active management intervention, other than completing the initial stocking itself. Although referred to as 'cultured' in Table 2, a significant proportion (up to 40%) of the shortfin eel production in Victoria is from stock enhancement, and therefore considered an extension of the wild capture fishery as much as an aquaculture activity *per se*.

A summary of the total catch for the Victorian eel fishery (1979-2000) as determined from the Victorian Fisheries Catch-Effort database (based on industry completed Production Returns), is provided in Table 3. This data suggests that a mean annual production for both species from both the wild fishery and stock enhanced waters is in the order of > 280 tonne for Victoria alone, but the capacity exists for this total to exceed 500 tonnes under 'optimal' circumstances. This represents a potential increase in overall production (by tonnage) of 78%, which includes potential increase in production of >111% specifically for shortfin eels from stock enhanced waters (*c.f.* >60% increase from the wild fishery).

Table 3 Summary of total catch (tonnages; based on industry Production Returns) for the Victorian Eel Fishery for the Period 1979-2000 (source: unpublished data, Victorian Fisheries Catch:Effort database, 2002)

Annual production (tonnes)	Wild longfin	Wild shortfin	Stock-enhanced Shortfin
Mean	14.8	189.7	79.3
Maximum	25.9	306	167.7
Minimum	6	60.3	17.3

Production from stock enhanced 'culture' waters in Victoria of recent times has declined disproportionately against the wild fishery due to prevailing drought conditions severely limiting the availability of suitable waters for stocking. A summary of Victorian production for the three year period from 1998/99 to 2000/01 (Anon., 2001) is provided in (Table 4). These data show that the wild catch for both longfin and shortfin eels has increased steadily in tonnage and value over this period, whereas the production of shortfin eels from stock-enhanced waters has declined substantially in both quantity and value to below mean annual production over the preceding 20 year period (as derived from Table 3).

Table 4 Annual Victorian eel production (quantity and value) for wild catch and cultured (stock-enhanced) sectors for the three year period 1998/99-2000/01 (source: Anon. (2001)); LF, longfin eels; SF, shortfin eels.

		Wild catch		Cultured	
		Tonnage	$,000	Tonnage	$,000
1998/99	LF	35	371	-	-
	SF	92	773	105	1,470
1999/00	LF	37	444	-	-
	SF	94	943	44	484
2000/01	LF	47	559	-	-
	SF	108	1084	67	737

Limited stock enhancement of small-scale, private waters has occurred in NSW using 'small' wild-caught eels (<20 cm) as an adjunct to the wild fishery, however there is no specific production data available for this practice. Eel stock enhancement in public waters is not permitted in NSW at the present time. Eel stock enhancement has also occurred in Tasmania through the combined efforts of the Inland Fisheries Service and licensed eel fishers, predominantly using mixed size/age shortfin elvers taken from terminal waters below Trevallyn Power Station on the Tamar River, and from below Meadowbank Reservoir on the Derwent River. Most eel stocking in Tasmania has apparently taken place within the existing natural range of the species, in order to supplement natural productivity of the wild fishery, but no specific production return data is available for this practice.

Glass eel fishery status

There is presently no glass eel fishery, as such, in Australia, with most glass eels being collected by government as part of recent FRDC funded R&D projects, and by industry under the terms of various state fisheries issued collection permits; the latter being to facilitate relatively small, pilot-scale industry production trials and associated eel aquaculture R&D.

A summary of glass eel harvesting (government and industry combined; not including collections made as part of FRDC funded R&D projects) in Australia over the three year period 1998/99-2000/01 is provided in Table 5. It is noted that in the preceding 3-5 year period, annual harvesting of glass eels as part of FRDC funded R&D projects in both the Albert River in south-east Queensland and the Snowy River in south-eastern Victoria has yielded annual catches in excess of 100kg per site on occasions. The Queensland catch was predominantly longfin eels and the Victorian catch predominantly shortfin eels. Arguably, such catches give some idea of the potential size of the accessible glass eel resource available in Australia.

Table 5 Summary of glass eel harvesting (government and industry) in eastern Australian waters over the three year period 1998/99-2000/01; not including catch from FRDC funded R&D projects (government and industry sources, unless specified).

	Quantity (kg)		
	1998/99	1999/00	2000/01
Queensland*	30.1	35.7	60
New South Wales*	-	44	≈10
Victoria**	-	50	≈53
Tasmania***	-	-	≈8-10

* predominantly longfin eels from the Albert River; source Lobegeiger (2001).

** mixture of longfin (23kg) and shortfin (30kg) eels from the Snowy River.

*** shortfin eels only from the Derwent River.

Intensive/Semi-Intensive Aquaculture Production

Production from more intensive eel aquaculture systems in Australia is still relatively minor in comparison to the wild sector. A summary of published eel aquaculture production data for the three year period 1997/98-1999/00 is provided in Table 6 (after O'Sullivan and Dobson (2001)). It should be noted that these data also include an estimate of shortfin production from stock enhanced waters in Victoria, as well as production from more intensive pond and tank-based farming systems for both species in Victoria and other states.

The reason for the apparent discrepancy between estimates for total Victorian eel production during 1999/00, as summarised in Table 4 and Table 6, is unclear. It is however suggested that the figure quoted by O'Sullivan and Dobson (2001) significantly overestimates the shortfin eel production for the 1999/00 period. More specifically this estimate does not adequately reflect the actual loss of production resulting from the long-running drought which has prevailed throughout much of western Victoria (where the majority of the shortfin fishery is centred) of recent times (last 3-5 years). Put simply, many of the Victorian Western District 'culture' waters have dried up, and coastal streams subjected to low ambient flows which are not conducive to eel fishing. Projected estimates of shortfin eel production from Victoria have therefore not been realised, with the total annual harvest declining from > 200 tonne pa to <100 tonne pa over this period. With improved rainfall conditions during 2000/01, eel production from stock enhanced 'culture' waters in Victoria reportedly increased to 67 tonnes worth approximately $737,000 for this period (Anon., 2001) but is still well short of full production capacity (Table 3).

Table 6 Annual Australian cultured eel production (longfin and shortfin combined) for the period 1997/98-1999/00; from O'Sullivan and Dobson (2001).

States	Production					
	97/98		98/99		99/00	
	Tonnes	$	Tonnes	$	Tonnes	$,000
Qld	-	-	3.4	36.8	21.5	235.6
NSW	0.6	6	2.3	19.3	2.4	17.5
Vic	218	2334	225	2700	180	2250
Total	218.6	2340	230.7	2756.1	203.9	2503.1

If the data for anything other than intensive/semi-intensive aquaculture production is removed from the summary, the total 'aquaculture' output of eels (for both species) across Australia is probably less than 25-30 tonnes per annum, worth less than $0.5 million. This component is from a number of purpose- built eel farms, or fish farms incorporating purpose-built eel farming facilities in NSW, Queensland, Victoria and Tasmania, however collectively these amount to a relatively minor component of overall industry capacity at a national level at the present time.

Eel aquaculture production in Queensland totalled approximately 43 tonnes worth more than $460,000 in 2000/01. This production was from only four farms totalling 4.9 ha of growout pond surface area and about 135 m^3 of growout tank capacity (Table 7). This represents an approximate doubling of Queensland production in both tonnage and value from 1999/00, with projected production estimates for 2001/02 being in the order of 84 tonnes. Farm gate prices for cultured eels in Queensland have consistently ranged between $10-11/kg for mostly live fish (98%), the majority of which is exported (78%), with the balance being sold into Queensland and other Australian states (Lobegeiger, 2002).

Table 7 Eel farm production in Queensland (1997/98-2000/01); from Lobegeiger (2001, 2002); na, not available.

	1997/98	1998/99	1999/00	2000/01
Ponds - Total Area (ha)	0	1.9	2.1	4.9
- Average Area (m^2)	0	3 200	2300	1500
Tanks - Total Volume (m^3)	140.6	26.5	219	133
- Average Volume (litres)	4000	6400	5000	4400
Stocking - Elvers (kg)	6.0	3.0	0	0
- Glass eels* (kg)	67.4	28.3	35.7	60
Total Production* - (kg)	**na**	**3395**	**21494**	**43540**
- ($)	**na**	**36,780**	**235,628**	**462,145**
Average Price ($/kg)	**na**	**$10.83**	**$10.96**	**$10.61**

* mixed longfin and shortfin eels, but predominantly longfin.

Prior to 1999/00, a single, intensive, tank-based farming operation in Victoria, which utilised a European-style RAS, was also producing similar quantities of marketable shortfin eels. This operation has now diversified to include other finfish species (Murray cod and jade perch). The same company has also established a new RAS at another location in Gippsland. This system is likely to concentrate on longfin eels ultimately for grow-out to market size, as well as shortfin and longfin eels for on-selling at the post-nursery stage as seedstock for stock enhanced wild fishery purposes (primarily in Victoria) and possibly for other semi/intensive eel farms in Victoria and other states.

Recent Eel Aquaculture and Glass Eel Fishery R&D

As previously stated, the most significant recent eel aquaculture and glass eel fishery R&D has been funded by FRDC in partnership with state agencies and industry, the results of which have been reported by (Gooley *et al.*, 1999; Gooley and Ingram, 2002). The key findings of these two projects are effectively summarised as follows:

1. Glass eel resources of each species have been identified across their respective ranges in eastern Australia, with sufficient quantities being available in selected waters to support limited commercial harvesting and aquaculture industry trials.

2. Appropriate glass eel fishing techniques have been evaluated and described, glass eel invasion cues and associated environmental criteria have been elucidated, and glass eel resource management implications prescribed to facilitate cost-effectiveness and sustainability of such harvesting.

3. The potential for increased levels of glass eel harvesting will be subject to the provisions of ESD-based management plans and wild-fishery industry sector investment in identifying additional glass eel resources. The latter in turn will be dependent on market demand and the degree to which the wild fishery (stock enhanced component) and the aquaculture industry sectors respond to the production opportunities presented by glass eel utilisation.

4. The aquaculture utility of glass eels for both species has been evaluated and appropriate culture techniques either adapted and/or developed to the point where commercial scale industry production has been achieved under both intensive and semi-intensive conditions.

5. Increased productivity and cost-effectiveness in the Australian eel aquaculture sector will be achieved through enhanced growth and survival rates of glass eels and later eel development stages, and through overall employment of Best Practice culture systems. Specifically, this is likely to be achieved through improved feeding efficiencies, general husbandry and production facility design and operation, with an emphasis on producing more marketable, larger eels at a size of ≥ 1kg.

These findings have been variously used by fisheries managers within respective state agencies and by industry at different levels. On the basis that this R&D was originally undertaken for public good as a result of market failure prevailing at the time, the findings of these two projects have been made freely available to all interested stakeholders by various means including workshops, publications and direct consultation with end users.

It is also noted that due to the dynamic and rapidly developing nature of the industry in Australia, the specific outcomes of these projects are difficult to evaluate in isolation from applied "R&D" undertaken concurrently by some individual industry proponents for private benefit (but which is often shared with selected industry colleagues on a 'quid pro quo' basis), and also from ongoing, day to day natural resource management policy and planning by state fisheries agencies (in which technical advice is routinely provided by R&D service providers to managers in real time).

Furthermore, existing R&D priorities for eel aquaculture and glass eel fishery sectors in Australia (see Appendix) have only been broadly identified to date, without specific performance indicators upon which progress can be quantified. Accordingly, this report makes no attempt to specifically evaluate FRDC funded R&D outcomes to date against these priorities in any quantitative way. The report does however recognise and qualitatively assess the impacts of R&D findings to date by factoring in various technical assumptions gleaned from recent R&D into the simulative industry development model. Furthermore, much of the recommendations included within the proposed Australian Eel Aquaculture and Glass Eel Fishery Development – Strategic Direction, Needs and Vision (see Section 5) are predicated on the basis of key R&D outcomes from these projects, and specific comments are provided about future priorities for the relevant components of the existing Draft Australian Eel Fishery and Aquaculture R&D Plan.
Australian Eel Aquaculture Industry - Scope for Increased Productivity.

Australian Eel Aquaculture Industry - Scope for Increased Productivity.

Background

Ideally, the development of a long term vision for any one Australian aquaculture industry sector would be based on the clearly articulated views of all key stakeholders, at both the producer and resource management level. These views would reflect the opportunity presented by the underpinning, strong and enduring consumer demand for the product. Development of the vision would be facilitated by a robust, fully integrated industry structure, with the support of readily accessible and cost-effective Best Practice, continuously improved technology supported by research and development, extension capacity and associated databases to ensure effective and efficient implementation. Unfortunately, in the case of the new and developing Australian eel aquaculture sector, various aspects of these requirements are fundamentally lacking at the present time.

Accordingly, in order to progress the establishment of an industry vision designed to facilitate appropriate levels of investment, expansion, and long term sustainability, an interactive industry development model is proposed to enable some predictive capability in the absence of real time operations and actual data. In the present study, a simulative model has been constructed which has two main components around which a series of assumed inputs and projected outputs can be determined. These assumptions and projected outputs are then used as the basis for proposing various investment, production and development scenarios at both farm specific and aquaculture sectoral/sub-sectoral level. Ultimately of course the accuracy and reliability of the simulative models need to be validated 'on the ground' for them to be any practical use in the long term. However in the short to medium term, as the industry establishes itself during the early formative stages of development at a national level, such models are likely to be extremely useful in providing indicative guidelines and performance indicators, benchmarks and/or targets.

The first component of the industry development model is the farm specific financial analysis of different culture systems, including intensive, semi-intensive and extensive culture systems, all of which are practised already in Australia to varying degrees. This provides the basis upon which the second component of the model is constructed to simulate industry-wide outputs in a way that realistic scenarios can be generated to speculate on what the industry's potential could be in the future under certain pre-determined conditions.

In this study, the model and its main components are designed to incorporate a suite of Best Practice scenarios which are progressively implemented over time under a 'continuous improvement' regime inherent in a proposed industry-wide strategic development plan. The model employs three hypothetical Best Practice scenarios to be implemented over a twenty year time frame from the present, viz.:

- Best Practice 1 (BP1) – present industry status to five years from now,
- Best Practice 2 (BP2) – industry status five to ten years from now, and
- Best Practice 3 (BP3) – industry status 10-20 years from now.

Financial Analysis of Specific Culture Systems

Introduction

For the proposed industry vision to be at all realistic it is imperative that the range of potential culture systems available to Australian industry have some inherent financial viability to ensure reasonable prospects of long term profitability. However, at the present time there are no actual, documented case studies, and limited data only is available from industry upon which any relevant financial analysis can be based. Accordingly, for the purposes of this study, cost-benefit analyses for each of a range of hypothetical intensive, semi-intensive and extensive culture systems have been undertaken in order to elucidate the relative (if not absolute) profitability of various production scenarios.

These analyses have been undertaken also to incorporate the effect of differing Best Practice scenarios for both intensive and semi-intensive culture systems under an assumed 'continuous improvement' regime, again to highlight the benefits at the farm specific level and also ultimately at the industry wide/national level. The latter outcome is thereby intended to provide some additional motive for the industry to proceed over the next 10-20 years, under attendant strategic guidelines, on a more nationally coordinated basis. Such analyses also provide relevant production benchmarks and associated performance indicators to be used as tentative industry targets under a combined Best Practice/Continuous Improvement-based strategic development regime.

In this study, no Best Practice scenarios are imposed on the extensive culture system analysis, other than that imposed by the varying level of seedstock inputs resulting from improved Best Practice standards within the intensive culture systems supplying the seedstock. Extensive culture systems by definition have limited management controls, thereby inherently limiting the ability of the operator to effect productivity gains through increased efficiency. Much of the extensive culture of eels in Victoria is subject to ambient environmental conditions, with major profitability criteria being about natural productivity and availability of suitable water, and seedstock and market price. Furthermore, extensive culture is typically undertaken as an adjunct to an existing wild fishery enterprise and the stand-alone costs and profitability are therefore difficult to separate. Accordingly, no attempt has been made in this study to evaluate profitability of a stand-alone extensive eel culture operation, rather the analysis is limited to determining sensitivity of relative profitability around the latter two parameters (i.e. seedstock and market price) within a fully integrated wild and cultured eel fishery business.

Methods

The method of financial analysis has been adapted and modified from that which has been previously described by Gooley *et al.* (2002). It basically involves a simple MS Excel spreadsheet-based financial model of hypothetical culture systems, which analyses key financial inputs (including capital and operating), and outputs (including marketable stock, stock on hand and depreciated capital), and estimates standard financial indicators over a ten year timeframe viz. Net Present Value (NPV), Internal Rate of Return (IRR) and Profit Margin (PM) (see Gooley *et al.* (2002) for definitions). Risk, in the form of periodic and catastrophic stock loss (or market access loss for whatever reason), is built into the model where appropriate at different levels linked to the Best Practice culture system scenario under consideration.

Given that the systems being analysed are largely hypothetical, the analysis relies on a suite of assumptions for inputs and outputs, some of which are then varied within defined ranges to determine sensitivity of financial outcomes. The proposed Best Practice scenarios are treated in this fashion also, with increasing Best Practice assumed to impose increased production efficiencies (eg. through improved food conversion, fish survival and stocking density) and reduced risk (eg. reduced scale/frequency of catastrophic stock loss and/or loss of market access etc). For the purposes of this study, growth rates are fixed and identical for both species, based on a combination of industry and research experience, and designed to achieve specified marketable product size after fixed/pre-determined production periods (as described previously by Gooley *et al.* (2002).

Financial model - systems, scenarios and assumptions

The financial model has been developed around three culture systems, viz. intensive, semi-intensive and extensive; the latter as an adjunct to a wild fishery enterprise. Each model assumes a 50 kg input of glass eel seedstock initially. Where the seedstock input is based on later development stages (eg. 10g juveniles for semi-intensive and extensive systems), then the actual quantity of seedstock is based on that which can be initially produced intensively under the relevant Best Practice scenario from 50 kg of glass eels. This enables some degree of consistency for comparative purposes between scenarios and the related industry development strategy which itself is based on a simulative model projecting differing levels of industry-wide production simultaneously across all culture systems.

The fixed growth rate stages used in the model for intensive and semi-intensive culture systems are broadly aligned to production stages to achieve pre-determined market sizes. The model also therefore assumes that the relevant culture systems are operating at optimal temperatures to achieve the fixed growth rates for intensive and semi-intensive systems (around 25^{o} C) and average ambient temperatures for extensive culture within a temperate climate at southerly Australian latitudes (eg. western Victoria). In summary, the key production stages, including fixed growth rates and total production time (from glass eel stage), for intensive/semi-intensive culture systems are (see also Table 8 and Table 9):

- 0.17g (glass eel) – 1g stocker: 3 months (total production time = 3 months).
- 1g stocker – 10g stocker : 3 months (total production time = 6 months).
- 1g stocker – 300g saleable eel: 12 months (total production time = 15 months).
- 1g stocker – 1 kg saleable eel: 21 months (total production time = 24 months).
- 10g stocker – 300g saleable eel: 9 months (total production time = 15 months.
- 10g stocker – 1 kg saleable eel: 18 months (total production time = 24 months).

Intensive and semi-intensive systems are assumed to sell all product live into the market place at either 300g after 15 months (from glass eel stage) or 1kg (after 24 months from glass eel stage). For extensive culture systems the model assumes that intensively reared (from glass eel stage) 10g stocker eels achieve a final mean size of 1 kg immediately prior to harvest after a total of five years from initial stocking, after which all harvested eels are sold live into the market place.

A summary of the scenarios, key assumptions and associated criteria/context for intensive and semi-intensive culture systems analysed by the financial model under different Best Practice scenarios is provided in Table 8 and Table 9. These scenarios are based on projected time frames linked to the proposed three tiered Best Practice/Continuous Improvement regime, as previously described.

Each scenario has specified routine operational (stock) loss rates at different production stages, and 5 year periodic risk in the form of catastrophic loss; the assumption being that with 'continuous improvement', the industry by and large will progress through the specified Best Practice scenarios over the proposed timeframe to the point that all industry will be performing at least at Best Practice 3 (maximum reduction of routine and catastrophic stock loss/risk) after 10-20 years. The financial model therefore projects the estimated increase in profitability that this improvement will provide on a farm specific level.

The routine losses referred to occur annually and include 'conservation stockings' as part of likely glass eel collection permit conditions, disease and cannibalism related losses, and 'leakage' of undersized or otherwise unmarketable eels (runts) due to genetic and/or sex related growth depensation. The 'risk' related catastrophic losses are nominally imposed every five years and partly compensated for by insurance coverage (which also incurs an annual operating cost). During 'risk' years, all models have relevant operating costs, including salaries, transport and packaging, feed, water and energy proportionately reduced, consistent with the scale of the imposed stock loss, to partly offset production costs.

All losses are considered to be able to be reduced over time with 'continuous improvement' of technology and husbandry, thereby providing the basis for the improved Best Practice scenarios over time. All such improvements and the rate at which they are applied in industry are completely nominal at this stage, and intended to be used as an indicative guide only to assist strategic development of the industry.

All Best Practice scenarios for intensive culture systems assume a fixed food conversion ratio (FCR) of 2.5:1 for glass eels and 1.5:1 for subsequent growout. These rates are conservative, already relatively efficient, and consistent with industry standards in Australia and Europe. Therefore these parameters are fixed under all Best Practice scenarios. For semi-intensive systems, given the limited industry development in Australia compared with similar systems in Asia, FCRs are deemed to be increasing progressively (from 2:1 to 1.5:1) with improved Best Practice under the various semi-intensive system production scenarios (see Table 9).

Likewise, stocking densities (maximum at final stages immediately prior to harvest) for intensive system production are fixed in the model at 7.5kg/m^3 for glass eels and 200kg/m^3 for 300g and 1kg growout. These densities are deemed to be existing, already efficient performance standards which are unlikely to change significantly in the future. On the other hand, stocking density for semi-intensive production is deemed to increase progressively (from 5 to 15 kg/m^3) with improved Best Practice under the various semi-intensive production scenarios during the growout phase (see Table 9).

The cost-benefit model makes a number of assumptions about all relevant capital and operating costs and associated revenues. For all systems these are based on nominal and/or median values as determined by reasonable market value, industry experience and/or expert opinion. Some key system design, production and market parameters are varied in the model to determine profitability sensitivity against such parameters. Only one parameter is varied per analysis, during which the other key parameters are fixed at a nominal or median value as specified for Best Practice 1 scenario. Likewise, where Best Practice scenarios are analysed, all costs and revenues are fixed at nominal or median values for these key parameters. All other remaining production/cost parameters are fixed throughout the analysis for each of the scenarios in question. All prices are quoted in AUD$.

Table 8 Best Practice/Risk Scenarios for Intensive Culture System (based on initial 0.17g glass eel seedstock); na, not applicable.

Best Practice Scenario	Time Frame	Market size	Production stage	Production loss/'leakage' as % of standing stock	Risk as % loss of marketable stock prior to sale/5 yrs
BP1	0-5 years	na	0.17g-1g	25*	na
		na	1g-10g	10	na
		300g	10g-300g	10	50
		1 kg	300g-1kg	10	75
BP2	5-10 years	na	0.17g-1g	20*	na
		na	1g-10g	5	na
		300g	10g-300g	5	25
		1 kg	300g-1kg	5	50
BP3	10-20 years	na	0.17g-1g	15*	na
		na	1g-10g	2.5	Na
		300g	10g-300g	2.5	10
		1 kg	300g-1kg	2.5	25

* includes 5% 'conservation' stocking back to the wild of initial glass eel harvest; in form of elvers.

Table 9 Best Practice/Risk Scenarios for Semi-Intensive Culture System (based on initial 10g seedstock).

Best Practice Scenario	Time Frame	Market size	Production stage	Production loss/'leakage' as % of standing stock	Risk as % loss of marketable stock prior to sale/5 yrs
BP1	0-5 years	300g	10g-300g	20	50
(FCR@2:1)		1 kg	300g-1kg	10	75
(SD@5kg/m^3)					
BP2	5-10 years	300g	10g-300g	10	25
(FCR@1.75:1)		1 kg	300g-1kg	5	50
(SD@10kg/m^3)					
BP3	10-20 years	300g	10g-300g	5	10
(FCR@1.5:1)		1 kg	300g-1kg	2.5	25
(SD@15kg/m^3)					

Production Returns/Revenue

- **Intensive and semi-intensive systems**

Both systems assume that in practice glass eels will be available each year and that seasonality restrictions on glass eel numbers will not affect production and therefore projected financial returns; semi-intensive system also assumes that intensively reared 10g stockers (from glass eels) are available in the market place.

Annual production is based on a 50kg annual glass eel intake provided directly to the farmer for intensive systems and as the equivalent quantity of 10g elvers for semi-intensive systems.

All fish harvested and sold live to Asian markets, at a delivered (CIF) price to the farmer (inclusive of packaging and freight costs) of $12.5, $15 and $17.5/kg for 300g fish (after 15 months from glass eels; 12 months from 10g stocker) and $17.5, $20 and $22.5/kg for 1 kg fish (after 24 months from glass eels; 21 months from 10g stocker)

Revenue assumed to be generated within 300g production system within second year of operation and each year thereafter (assuming 15 month total production period from glass eel), and within two years for 1 kg production system and each year thereafter (assuming 24 months total production period from glass eel).

The quantity of marketable biomass/stock on hand at end of the specified production period for 300g and 1 kg fish under each culture system determined by the combination of fixed growth rates, and relevant production parameters as specified under each Best Practice scenario, including stock loss rates and risk, and for semi-intensive systems also FCRs and stocking density (see Table 9); stocking densities fixed for glass eel production (to 1g stocker) @ 7.5kg/m^3, and for 1g to 300g/1kg growout stage @ 200kg/m^3 for intensive systems.

Stock on hand after 10 years priced at minimum market value for 300g fish; insurance refund during risk years (5th and 10th) based on 25% value of lost stock at specified market price.

- **Extensive systems**

Annual production is based on the equivalent quantity of 10g intensively reared stockers from a 50kg annual glass eel intake to industry (actual quantity varying with specified Best Practice conditions).

Assumed that intensively reared 10g stockers (from glass eels) are available in the market place (based on minimum 50kg glass eel intake to the industry).

All fish harvested and sold live to Asian markets, at a delivered price to the farmer (inclusive of packaging and freight) of $17.5, $20 and $22.5/kg for 1 kg fish (after 5 years from glass eels), with $20/kg being the nominal median value for all other scenarios.

Revenue assumed to be generated within five years for 1 kg production system and each year thereafter (assuming 5 years total production period from 10g stocker).

The quantity of marketable biomass/stock on hand at end of the specified production period determined by the combination of fixed growth rates and loss rates (75%) over the five year production period.

Capital costs:

- **Intensive system**

Recirculating Aquaculture System (RAS)(not including culture tanks) at nominal $750k for 300g production system and $2.5 million for 1 kg production system; culture tanks @ nominal $1.5k/1.6m^3 glass eel weaning tanks and $5k/16m^3 growout tanks (actual number of dependent on whether 300g or 1 kg production scenario and proportional to need).

5ha of industrial land @ nominal $10k/ha.

Miscellaneous infrastructure including building housing culture system, office, stores, maintenance and post-harvest areas, miscellaneous plant and equipment (not RAS) etc @ nominal $150k for 300g production system and $300k for 1 kg production system.

- **Semi-intensive system**

Pond costs @ nominal $15k/1000m^3 capacity with actual total pond capacity dependent on whether 300g or 1 kg production scenario and proportional to need.

10ha of irrigated farm land @ nominal $15k/ha

Miscellaneous infrastructure including office, stores, maintenance and post-harvest areas, miscellaneous plant and equipment etc @ nominal $150k for 300g and 1 kg production systems; miscellaneous plant and equipment, including bird netting and holding tanks, at nominal costs of $15k and $25k respectively for 300g and 1kg production; aerator costs at nominal $750 each and 2 aerators/ha of pond surface area.

- **Extensive system**

Nominal contribution of 25% to overall cost of commercial eel fishing licence (@ nominal cost of $200k), business head-office/operational base (@ nominal land cost of $50k), and miscellaneous infrastructure, plant and equipment (@ nominal $150k).

Operating Costs

- **Intensive system**

All initial capital set-up costs and first year operating costs are borrowed at a commercial interest rate of 8% per annum (assuming the borrower has sufficient collateral); annual loan repayments are based on principle and interest, with the loan paid off after ten years.

Seedstock is based on annual 50kg glass eel intake directly to the grow-out farm @ varying costs of $100, $200 and $300/kg, with $200/kg being the fixed median price for analysis of all other scenarios.

Labour costs based on 2.5 x 'full-time equivalent persons' (FTEs) for 300g production scenario which includes a full time manager and 1.5 FTE assistants, and 5 x FTEs for 1kg production scenario, which includes 2.5 extra FTE assistants; one FTE value fixed at nominal $45k per annum.

Transport and packaging combined based on nominal $4/kg cost (incl. freight @ $3.5/kg and packaging @ $0.5/kg) to the farmer to land live fish in Asian export markets.

Depreciation is treated as an annual fixed cost. It is calculated according to the straight line method which uses the initial value of the goods being `depreciated (capital assets) (iv), the life of the asset (L) and the residual value (rv) expressed as a %. Annual depreciation is then equal to (iv-(iv*rv))/L.

Feed costs based on final production (tonnage) estimates @ nominal FCR of 2.5:1 for glass eels (to 1g stockers) and 1.5:1 for growout of 1 g seedstock to market size; price of feed varying between $1.25, $1.50 and $1.75/kg for post 1g growout stage, with $1.5/kg being the nominal median feed cost for all other scenarios.

Water based on 10% daily exchange @ $650/ML for domestic supply.

Energy primarily electricity/other for pumps, aerators, heating, oxygen generation etc @ nominal $0.60/kg of final production biomass.

Other operating based on nominal estimates for administration, maintenance, rates, insurance etc @ $0.70/kg of final production biomass.

- **Semi-intensive system**

All capital costs and first year operating costs are borrowed at commercial rate of interest @ nominal 8% per annum for capital and 10% for year 1 operating (assume that the borrower has sufficient collateral); annual loan repayments are based on principle and interest, with the loan paid off after ten years.

Seedstock is based on annual 50kg glass eel "allocation", weaned and grown out to 10g stockers by intensive farmers at mortality/loss rates as determined under varying Best Practice specifications (see Table 9) and on-sold to the semi-intensive growout farmers @ nominal price varying between $25, $50 and $75/kg; with $25/kg being the fixed price for all other scenarios.

Labour costs based on 2.5 x FTEs for 300g production scenario which includes a full time manager and 1.5 FTE assistants, and 5 x FTEs for 1kg production scenario, which includes 2.5 extra FTE assistants; one FTE value fixed at nominal $45k per annum.

Transport and packaging combined based on nominal $4/kg cost (incl. freight @ $3.5/kg and packaging @ $0.5/kg) to the farmer to land live fish in Asian export markets.

Depreciation is treated as an annual fixed cost. It is calculated according to the straight line method which uses the initial value of the goods being depreciated (capital assets) (iv), the life of the asset (L) and the residual value (rv) expressed as a %. Annual depreciation is then equal to (iv-(iv*rv))/L.

Feed costs based on final production (tonnage) estimates @ nominal FCR varying between 1.5:1, 1.75:1 and 2:1 under differing Best practice scenarios (see Table 9), with FCR of 2:1 being fixed for all other scenarios; price of feed varying between $1.25, $1.50 and $1.75/kg for post 1g growout stage, with $1.5/kg being the nominal median feed cost for all other scenarios.

Water based on 10% weekly exchange @ $200/ML for commercial irrigation supply.

Energy primarily electricity/other for pumps and aerators @ nominal $0.20/kg of final biomass.

Other operating based on nominal estimates for administration, maintenance, rates, insurance etc @ $0.70/kg of final production.

- **Extensive system**

All seedstock purchased as intensively reared 10g stockers at nominal cost varying between $25, $50 and $75/kg, with $25/kg being the nominal fixed price of stockers for all other scenarios.

Labour costs fixed at one FTE @ nominal $40k/yr/FTE (in practice two x 0.5 FTEs) to tend to allocated stockers and associated waters and requisite fishing activity; not costed in until the fifth year of production after initial stocking.

Depreciation is treated as an annual fixed cost. It is calculated according to the straight line method which uses the initial value of the goods being depreciated (capital assets) (iv), the life of the asset (L) and the residual value (rv) expressed as a %. Annual depreciation is then equal to (iv-(iv*rv))/L.

Transport and packaging combined based on nominal $4/kg cost (incl. freight @ $3.5/kg and packaging @ $0.5/kg) to the farmer to land live fish in Asian export markets.

As previously mentioned, the present study assumes that semi-intensive and extensive culture systems rely completely on intensively reared (from glass eel) 10g stockers as the sole source of seedstock for production.

A further model is therefore proposed of a hypothetical production system to estimate likely profitability of such a nursery stage under commercial conditions. Indeed it is conceivable that under a national, vertically integrated industry scenario, such an intensive juvenile/seedstock eel nursery operation would be viable as a stand-alone enterprise servicing the needs of other growers using intensive, semi-intensive and extensive systems to produce finished product (i.e. minimum 300g to 1kg final market size).

The model of the proposed intensive 'nursery' stage culture system is based on the following assumptions and specifications:

Intensive 'nursery' system (glass eel to 10g stocker)

- **Returns/Revenue**

Production returns revenue based on minimum annual glass eel intake of 100kg, 250kg and 500kg under three different intensive system Best Practice scenarios specifying routine operational losses and risk (see Table 8), with 500kg being the nominal intake fixed for all other scenarios.

Revenue based on sale of final biomass after 6 month production stage (allowing for two x 6 monthly production cycles per annum eg. one cycle for shortfin and one cycle for longfin), from glass eel to 10g stockers which are sold to other growers (intensive, semi-intensive and/or extensive) at prices ranging between $25/kg, $50/kg and $75/kg, with $25/kg being the sale price for all other scenarios.

- **Capital costs**

As for intensive systems producing 300g, other than a smaller RAS and culture building required at a cost of $250k and $50k respectively, and miscellaneous infrastructure costs reduced to $50k.

- **Operating costs**

Purchase price of glass eels ranging between $100/kg, $200/kg and $300/kg, with $100/kg being the nominal purchase price fixed for all other scenarios.

All other costs as for intensive systems producing 300g fish, but proportionately reduced consistent with the smaller size and maximum standing crop of the final biomass (of 10g stockers).

Results of Financial Analyses

The financial model outputs are summarised for each system under the range of tested Best Practice scenarios and associated key production parameters in Table 10-15. A summary of the total production output of marketable biomass for each system and Best Practice scenario is provided in Table 16.

Profitability of Intensive Culture Systems

Profitability across all indicators increases substantially with improved Best Practice for 300g production systems, but under Best Practice 1 scenarios, such systems are either not profitable or marginal at best; the latter being only at the higher market price of $17.50/kg. Indeed reduced feed prices and glass eel prices over the range tested have little impact on overall profitability compared with improved Best Practice. More specifically, the model suggests that intensive production of 300g eels is only profitable under Best Practice scenarios 2 and 3, in which increased survival rates and lower risk of catastrophic loss result in markedly increased quantities of marketable biomass per unit of cost. Realistically, it is unlikely that an intensive, 300g production enterprise could be commercially viable for sufficient time (possibly up to five years) before achieving the type of production efficiencies specified under Best Practice 2 and 3 scenarios.

Conversely, intensive production of 1kg eels appears to be profitable across the full tested range of Best Practice scenarios and various key production parameters, despite the increased levels of up front capital costs, and higher risks imposed in the model. This suggests that any investment in production of 1kg eels under intensive production systems in Australia at the present time is likely to have a higher probability of achieving profitability (according to conventional financial standards), assuming that specific production standards, efficiencies and associated costs can be appropriately managed and subject to specified market prices being maintained.

The profitability of intensive, 10g stocker production systems is less clear, but the model suggests that a minimum glass eel intake of 500kg per annum would be required for such a system to be financially viable. It is also apparent that increasing the cost of glass eels from $100/kg over the tested range in the model renders the operation largely unprofitable at the 500kg annual intake level, and that increasing the sale price from $25/kg at this intake level over the tested range substantially increases profitability of the enterprise.

Having said that, it is suggested from the model that stand-alone intensive production of 10g stockers can be profitable at a glass eel price of (maximum) $100/kg and if all other specified parameters can be met. In practice, it is likely that intensive production of 10g stockers for on-selling to other producers would be undertaken as an adjunct operation to other eel/finfish growout enterprises using RAS, thus making the production an even more viable option for producers. Accordingly, the key outcome of this part of the analysis is that it is reasonable to assume that the commercial availability of 10g stockers at a realistic/cost-effective price to industry is a viable option for investors to consider in the short to medium term should market demand dictate the need.

Based on industry experience, there is clearly a need for a critical mass of glass eels for a purpose built culture system to operate efficiently. The model has determined this on the basis that an operator needs to ensure a reasonable return on investment of purpose built capital plant and equipment, of which a minimum outlay is required for any quantity of glass eels. Effectively, the more that are put through, the greater are the cost savings on the use of this infrastructure on a unit cost of production basis. However, it is also known from experience that acclimating, weaning and rearing glass eels at this early stage (up to 10g size) is far more effective when large quantities are reared simultaneously due to various density-dependent behavioural effects which improve biological performance of the eels themselves, and physical performance of the culture system.

Profitability of Semi-intensive Culture Systems

Not unlike the situation for intensive culture systems, the model suggests that the profitability of semi-intensive, pond-based production of 300g eels is likely to be marginal at best at anything other than maximum market prices and/or under substantially improved Best Practice operating conditions. Furthermore, profitability is likely to be deleteriously impacted by seedstock prices (for 10g stockers) at anything greater than $25/kg and from any substantial increase in feed price. The opportunity to increase profitability with improved Best Practice is a consequence of increased production efficiencies such as lower FCRs, higher stocking rates and reduced operational losses and risk. Such improvement arguably can be more readily obtained for semi-intensive production in Australia, at least initially, due to the relatively limited stage of industry development presently.

Again, as for the intensive production scenario, semi-intensive production of 1kg eels is likely to be profitable under all of the tested scenarios and production/cost parameters, with profitability predictably increasing dramatically with improved Best Practice, increased market price, and reduced feed price. Furthermore, the profitability of such production appears to be able to adequately absorb production cost increases, due to feed and seedstock price increases and market price falls over the tested ranges, and still remain profitable. This is despite the greater up front capital cost of infrastructure, plant and equipment, and higher levels of attendant risk of catastrophic stock losses over the longer production term.

Summary

Effectively the production of the larger 1kg eels provides disproportionate financial advantage to the operator by providing market access to a premium priced product (i.e. 1kg fish compared with 300g fish), together with a larger quantity of marketable biomass for the same glass eel input costs. Accordingly, the study suggests that growing larger quantities of bigger fish (at least up to 1kg) by either method can be profitable if certain realistic standards of production efficiency can be achieved. Furthermore, profitability is likely to be far greater than for producing smaller fish up to 300g in size.

To this end it is also suggested that the specified production and cost parameters utilised in the intensive and semi-intensive culture system models in this study should provide a useful, indicative guide to operators and investors to achieving profitability in actual culture systems on the ground. Critical to this development however is the need to secure a reliable and cost-effective supply of juvenile seedstock (in addition to glass eels), which the present study suggests could take the form of intensively-produced 10g stockers. This could be profitably achieved as a stand-alone operation under certain conditions and/or more possibly as an adjunct to an existing growout business producing larger fish for retail consumers. It is also essential that eel farmers, using whatever system, continue to refine and develop Best Practice standards over time to achieve operational efficiencies in production and associated increased profitability.

The profitability of extensive production is more difficult to elucidate using the methodology in this study, due to the usual linkage to the related wild fishery business. Accordingly no attempt is made in this study to determine the profitability of stand-alone extensive culture. Nonetheless, it is apparent from the model that in most cases extensive culture will provide a profitable adjunct to the wild fishery business through production of larger (and therefore more marketable) 1kg fish, with relatively minimal capital and operational cost inputs. Risks have not been included in this analysis due to the likely error associated with making assumptions about key production parameters. Little accurate information is available on the productivity of extensive culture systems in Australia, other than that provided by Skehan and De Silva (1998). Indeed this work determined quite variable production estimates for stock enhanced waters in Victoria in absolute terms.

Predictably, the analysis in the present study does show that profitability is likely to be affected by changing seedstock prices (for 10g stockers) and market prices, but that under most conditions, where all other production parameters meet reasonable standards of operation, the extensive culture of eels under ambient conditions is likely to make a profitable contribution to an established wild eel fishery-based enterprise.

Table 10 Summary of financial model key inputs and profitability indicators for intensive production of 300g eels under all tested Best Practice scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Best Practice Scenario	Market price ($/kg)	Glass eel price ($/kg)	Feed price ($/kg)	NPV ($)	IRR (%)	PM (%)
BP1	15.00	200	1.50	-96,077	8	0.2
BP2	15.00	200	1.50	238,317	13	7.6
BP3	15.00	200	1.50	455,066	16	11.6
BP1	12.50	200	1.50	-552,591	1	-19.8
BP1	15.00	200	1.50	-96,077	8	0.2
BP1	17.50	200	1.50	360,437	15	14.4
BP1	15.00	100	1.50	-72,946	9	0.9
BP1	15.00	200	1.50	-96,077	8	0.2
BP1	15.00	300	1.50	-119,209	8	-0.6
BP1	15.00	200	1.25	-17,242	10	2.8
BP1	15.00	200	1.50	-96,077	8	0.2
BP1	15.00	200	1.75	-174,912	7	-2.5

Table 11 Summary of financial model key inputs and profitability indicators for intensive production of 1kg eels under all tested Best Practice scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Best Practice Scenario	Market price ($/kg)	Glass eel price ($/kg)	Feed price ($/kg)	NPV ($)	IRR (%)	PM (%)
BP1	20.00	200	1.50	2,330,828	21.5	19.7
BP2	20.00	200	1.50	4,383,125	29	24.5
BP3	20.00	200	1.50	6,062,928	33.9	26.7
BP1	17.50	200	1.50	1,051,051	15.5	12.3
BP1	20.00	200	1.50	2,330,828	21.5	19.7
BP1	22.50	200	1.50	3,610,605	27	25.4
BP1	20.00	100	1.50	2,353,959	21.6	19.8
BP1	20.00	200	1.50	2,330,828	21.5	19.7
BP1	20.00	300	1.50	2,307,697	21.4	19.5
BP1	20.00	200	1.25	2,541,668	22.5	21.0
BP1	20.00	200	1.50	2,330,828	21.5	19.7
BP1	20.00	200	1.75	2,119,988	20.5	18.3

Table 12 Summary of financial model key inputs and profitability indicators for semi-intensive production of 300g eels under all tested Best Practice scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Best Practice Scenario	Market price ($/kg)	Stocker eel price ($/kg)	Feed price ($/kg)	NPV ($)	IRR (%)	PM (%)
BP1	15.00	25	1.50	-38,681	8	-13.2
BP2	15.00	25	1.50	367,855	26	1.7
BP3	15.00	25	1.50	659,965	40	9.9
BP1	12.50	25	1.50	-384,599	-6	-35.9
BP1	15.00	25	1.50	-38,681	8	-13.2
BP1	17.50	25	1.50	307,237	23	2.9
BP1	15.00	25	1.50	-38,681	8	-13.2
BP1	15.00	50	1.50	-192,246	2	-21.2
BP1	15.00	75	1.50	-345,811	-5	-29.2
BP1	15.00	25	1.25	29,066	11	-9.6
BP1	15.00	25	1.50	-38,681	8	-13.2
BP1	15.00	25	1.75	-106,428	5	-16.9

Table 13 Summary of financial model key inputs and profitability indicators for semi-intensive production of 1kg eels under all tested Best Practice scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Best Practice Scenario	Market price ($/kg)	Stocker eel price ($/kg)	Feed price ($/kg)	NPV ($)	IRR (%)	PM (%)
BP1	20.00	25	1.50	1,928,466	33	23.7
BP2	20.00	25	1.50	2,934,120	48	28.9
BP3	20.00	25	1.50	3,814,528	59	31.9
BP1	17.50	25	1.50	1,073,821	23	16.9
BP1	20.00	25	1.50	1,928,466	33	23.7
BP1	22.50	25	1.50	2,783,110	41	28.9
BP1	20.00	25	1.50	1,928,466	33	23.7
BP1	20.00	50	1.50	1,744,966	30	22.3
BP1	20.00	75	1.50	1,561,466	28	20.8
BP1	20.00	25	1.25	2,139,614	35	25.7
BP1	20.00	25	1.50	1,928,466	33	23.7
BP1	20.00	25	1.75	1,717,318	30	21.8

Table 14 Summary of financial model key inputs and profitability indicators for intensive production of 10g stocker eels under all tested Best Practice scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Best Practice Scenario	Glass eel intake (kg)	Glass eel price ($/kg)	Market price ($/kg)	NPV ($)	IRR (%)	PM (%)
BP1	500	100	25.00	44,719	11	12.2
BP2	500	100	25.00	262,774	16	18.7
BP3	500	100	25.00	414,131	19	23.0
BP1	100	100	25	-674,063	-	-
BP1	250	100	25	-404,520	-4	-31.9
BP1	500	100	25	44,719	11	12.2
BP1	500	100	25	44,719	11	12.2
BP1	500	200	25	-166,595	5	0.6
BP1	500	300	25	-417,909	-1	-11.0
BP1	500	100	25	44,719	11	12.2
BP1	500	100	50	1,756,646	46	56.1
BP1	500	100	75	3,468,574	71	70.7

Table 15 Summary of financial model key inputs and profitability indicators for extensive production of 1kg eels (as adjunct to wild fishery) under all tested scenarios (NPV, Net Present Value; IRR, Internal Rate of Return; PM, Profit Margin).

Stocker eel price ($/kg)	Market price ($/kg)	NPV ($)	IRR (%)	PM (%)
25	20.00	1,402,300	41	65.5
50	20.00	885,104	25	57.5
75	20.00	367,908	15	49.5
25	17.50	1,094,392	36	60.5
25	20.00	1,402,300	41	65.5
25	22.50	1,710,209	45	69.3

Table 16 Summary of financial model production inputs and outputs for intensive and semi-intensive culture systems under all tested Best Practice scenarios.

Culture system /Best Practice	Product size	Seedstock Quantity (kg)	Seedstock type/size	Final production quantity (tonnes)
Intensive				
BP1	10g	500	Glass eels	19.9
	300g	50	Glass eels	52.9
	1kg	50	Glass eels	154.4
BP2	10g	500	Glass eels	22.4
	300g	50	Glass eels	63.5
	1kg	50	Glass eels	200
BP3	10g	500	Glass eels	24.4
	300g	50	Glass eels	71.3
	1kg	50	Glass eels	231.3
Semi-intensive				
BP1	300g	1408	10g stockers	33.8
	1kg	1408	10g stockers	98.5
BP2	300g	1579	10g stockers	42.6
	1kg	1579	10g stockers	110.5
BP3	300g	1716	10g stockers	48.9
	1kg	1716	10g stockers	120.1

Evaluation of Industry-Wide Development Potential

Introduction

This study is predicated on the assumption that sustainable utilisation of glass eels can provide the basis for substantial expansion of the Australian eel industry, specifically the aquaculture sector, within acceptable ESD performance criteria. In this context, international experience is mixed, with little documented information from the Asian industry to provide any useful direction. The European experience is cautiously optimistic about the longer-term utilisation of glass eels for commercial purposes. The socio-economic benefits of utilising glass eels are well documented. There are however parallel concerns that environmental sustainability of eel stocks may be compromised in preference to these benefits, noting the compelling evidence for recent declines in the European eel stocks eg. EIFAC/ICES (2002).

Frost *et al.* (2001) in a socio-economic cost-benefit analysis of the use of glass eel in the European industry indicate that the input of one tonne of glass eel to the industry can result in more than five times the economic benefit to the community if used as seedstock for intensive aquaculture, compared with use as restock for the commercial fishery. These benefits are however price sensitive for both glass eel costs and final market price and do not account for market price dynamics in response to substantially increased production. A case is made for the introduction of policies in the European Union for the increasing use of glass eels to support industry development.

The study also makes the point that economic viability for local eel farmers and associated community benefits in Europe are subject to global market pressures from the rapidly increasing Chinese eel culture industry (Frost *et al*., 2001). Much of the European glass eel harvest presently is sold to China to supplement production of locally sourced Japanese glass eels, much of which is then targeted at the traditional Japanese 'kabayaki' consumer market. Of recent times, glass eel import quotas have been imposed by Chinese regional governments, presumably as a means of restraining over-production and associated market price reductions, rather than over concerns for glass eel stock conservation.

In an economic evaluation of eel and elver fisheries in England and Wales, (Knights, 2001) suggests that following rapid increases in production and value of local glass eel fisheries during the 1980s and early 1990s, mostly in response to increasing demand from China for aquaculture seedstock, demand and price has now stabilised with increasing competition following global oversupply of cultured eels (mostly from China).

Simulative Industry Model

Introduction

The interactive, simulative eel industry model constructed in the present study is designed to determine production outputs at an industry-wide scale under various Best Practice and seedstock allocation scenarios across different culture system-based sectors (intensive, semi-intensive and extensive). The intention is to be able to evaluate the potential scale of the industry, and thereby scope for expansion in terms of quantity and value of production, as well as evaluate how such production might vary over time with improved Best Practice standards, and under different juvenile eel seedstock allocation regimes. The combined ESD imperatives of economic development and glass eel resource management can then be jointly addressed to assist in the process of formulating a long term strategic vision for sustainable development of the Australia eel aquaculture industry.

This approach in the present study is conceptually inspired by the rationale and methodological approach adopted by Borch (1999) in a study focussing on "..the relations between the choice of market strategy and organisational architecture", with the latter taking the form of a virtual fish farming enterprise within the Norwegian salmon industry. The starting point for the Borch (1999) study is the "..rivalry of the market and the resources needed for improvements in competitive positioning strategy". The underlying rationale is that globalisation and its various manifestations in the salmon industry has imposed increasing competitive pressures across the industry in many countries, further testing the underlying strategic direction of these same sectors. A compelling case is presented for increased networking and greater flexibility in organisational structure to facilitate integration on an industry-wide basis (Borch, 1999).

Conceptually at least, it is proposed in the present study that the Australia eel aquaculture industry could be similarly viewed within a 'virtual' context in the first instance. This then may provide a means for simulating various production and management scenarios at an industry-wide scale to theoretically evaluate combinations of various parameters, ultimately to enhance key industry and resource inputs and outputs. Such an approach is likely to be essential for the Australian industry to be able to fully elucidate and ultimately to optimise the cultured eel supply chain from glass eel fishers through to export consumers. The need for increased networking and organisational flexibility, along the lines proposed for the salmon industry by Borch (1999) is also discussed.

Methods

The range of possible scenarios which factor in all of the previously mentioned parameters is endless, therefore the analysis has focussed on a total of twelve potential scenarios to provide some broad indication of the relevant trends, which in turn should provide the industry with some useful input to the strategic planning and development process.

As for the farm-specific financial analysis model, the industry-wide simulative model is a simple MS Excel-based spreadsheet which incorporates fixed and identical growth rates for both shortfin and longfin eels, but allows for variable annual loss rates (operational mortalities and 'leakage') during each of the key, nominated developmental/production stages. The latter are consistent with those previously described for the financial analysis, but do not include catastrophic losses associated with 'risk' (see Table 9 and 9).

The model allows for variable allocations at each of the key production stages in order to optimise overall industry production levels (quantity and value) and resource use efficiency (as measured by % of initial seedstock in number sold as marketable eels – not including those sold as seedstock/restock for other growers). It also enables varying glass eel intakes (at an industry-wide scale) and determines the subsequent seedstock input quantity (total weight and numbers) available for each of the later production stages under each culture system, thereby enabling some evaluation of the feasibility and potential of achieving realistic levels of vertical integration within the different eel culture industry sectors in future. In summary, the key production stages which the model simulates are:

Intensive systems

- 0.17g glass eel ⇒1 g stocker
- 1g stocker ⇒10g stocker
- 10g ⇒300g saleable eel
- 300g ⇒1kg saleable eel

Semi-intensive systems

- 10g ⇒300g saleable eel
- 300g ⇒1kg saleable eel

Extensive systems

- 10g ⇒1kg saleable eel

For the purposes of this study, the model is run over four potential, industry-wide, annual glass eel intakes (incorporating both species) viz., 100kg, 200kg, 500kg and 750 kg. For each intake the allocation across the different sectors is varied according to hypothetical but otherwise realistic industry seedstock needs and likely market demand. The model assumes hypothetically that each of the intensive and semi-intensive culture system sectors will allocate on average 50% of the available 300g production for ongrowing to 1kg eels and the extensive culture sector is assumed to produce only 1 kg eels with all available seedstock. All other seedstock inputs to each of the different sectors and market sizes analysed by the model are completely nominal, but intended to reflect a combination of likely industry need and production capacity.

Results and Discussion

A summary of hypothetical industry-wide production and efficiency outcomes under varying industry development scenarios (Best Practice, glass eel intake and seedstock allocation) is provided in Table 17. Based on an industry-wide glass eel allocation of 100-200kg alone, the model estimates that the Australian eel culture industry could achieve approximately 150-300 tonnes of production per annum worth around $2.9-5.8 million under existing Best Practice industry standards and assuming a 25/25/50% allocation of seedstock across sectors ie. 25% for intensive, 25% for semi-intensive and 50% for extensive. This level of output potentially could increase substantially over time with improved Best Practice, increased glass eel intake, and increased allocation to intensive and semi-intensive culture sectors once the total seedstock requirement for the extensive culture sector was satisfied (and assuming little or no major expansion of this sector in the foreseeable future).

According to the model, the industry could potentially produce over 1500 tonnes of marketable eels worth in excess of $30 million in Australia (based on present values) under the assumed Best Practice, seedstock allocation and market pricing regimes. Furthermore, the model estimates that under improved Best Practice conditions, increasing the initial industry-wide glass eel intake to 500-750 kg per annum could potentially increase the relative efficiency of industry utilisation of the wild glass eel seedstock resource by about 9-15% (as measured by the % of initial glass eel seedstock being finally harvested as marketable eels for the retail consumer).

Table 17 Summary of hypothetical industry-wide production and efficiency outcomes under varying industry development scenarios (Int., intensive; Semi., semi-intensive; Ext., extensive).

Best Practice/ Scenario	Glass eel intake (kg)	System Int/Semi/Ext (%)	Production		% initial stock at harvest
			Biomass (tonnes)	Value ($,000)	
1.1	100	25/25/50	152.7	2925.6	36
2.1			186.5	3574.1	44
3.1			211.3	4049.9	50
1.2	200	25/25/50	305.3	5851.2	36
2.2			373	7148.2	44
3.2			422.6	8099.9	50
1.3	500	42.5/32.5/25	901.2	17055.0	46
2.3			1122.7	21277.0	57
3.3			1283.4	24338.7	65
1.4	750	43.3/23.4/33.3	1295.9	24611.4	43
2.4			1597.5	30370.9	53
3.4			1817.4	34570.2	60

<u>Intensive/Semi-Intensive aquaculture</u>

A summary of the existing and potential intensive/semi-intensive Australian eel aquaculture production capacity is provided in Table 18. For this summary, the existing data are based on information extracted from published sources where available (eg. annual production returns for Victorian and Queensland industry), and anecdotal information from reliable industry and government sources where published data is unavailable.

These data are intended to correlate with actual industry scale for the present period to five years hence. Estimates of the potential scale of the Australian eel aquaculture industry over a five-ten year time frame are based entirely on expert opinion from relevant industry and government sources, and at best are intended to be 'indicative' only for the specified period. No attempt is made in the present study to estimate by expert opinion industry production capacity beyond the specified 10 year timeframe, other than to allude to the estimated scale determined by the industry simulation model. To what extent the model's projections for the period > 10 years are pragmatic remains to be seen, however the simulated outcomes appear to correlate reasonably well with the anecdotal, but otherwise informed and expert, opinion of key eel aquaculture personnel in Australia.

More specifically, the simulation model suggests that Australian production could reach up to 1100-1600 tonnes per annum from intensive and/or semi-intensive culture systems under Best Practice scenario 2 (5-10 year time frame) and with an annual glass eel allocation to industry of 500-750 kg per annum. This data approximately complements the potential industry production capacity of (maximum) 1400 tonnes per annum estimated by anecdotal opinion to be achieved within the same 5-10 year time frame.

This latter production estimate is based on the likelihood that at least one or two large-scale RAS-type intensive eel culture systems could be established in each of Victoria and Tasmania, and at least one or two large-scale pond-based semi-intensive and/or RAS-type intensive culture systems could be established in New South Wales and Queensland. RAS –based eel culture is more likely in Victoria and Tasmania under the cooler prevailing climatic conditions, and pond-based culture systems are more feasible under the warmer ambient conditions at the more northerly latitudes in NSW and Queensland. Additionally, it is possible that several existing pond-based barramundi farms in Queensland could diversify into eel culture as an adjunct enterprise, adding a further production capacity to the industry. Such diversification is already apparent in Queensland, although production is still at a relatively low level (Table 7).

Tasmania has the added advantage that the annual harvest of elvers from below the Trevallyn Power Station in the Tamar River and from Meadowbank Dam on the Derwent River could provide an additional source of juvenile eel seedstock for one or two relatively large-scale, intensive, RAS-based eel culture systems. Given that the local access to glass eels is still limited (McKinnon *et al.*, 2002), elvers from the Tamar and the Derwent may provide a viable short to medium term alternative to glass eel seedstock, although actual intensive production outputs from elvers is unknown at this stage.

Table 18 Estimated Intensive/Semi-Intensive Australian Eel Aquaculture (Grow-out) Production Capacity – Present (2000/01) and Potential (within 5-10 years) (source: various industry and government data); (na, not applicable).

	No. existing licensed farmers	No existing farms	Existing production capacity tonnes/yr	No. potential farms (5-10 yr timeframe)	Potential production capacity tonnes/yr
Queensland	26	4	50-75	5-10	150-500
NSW*	21	3	15	3-5	75-300
Victoria**	5	2	10	3-5	75-300
Tasmania	1	1	na[#]	3-5	75-300
Total	53	10	75-100+[##]	14-25	375-1400

* assuming average semi-intensive stocking densities (estimated after Gooley and Ingram, 2002).

** not including licensed eel fishers with endorsement for culture waters (stock enhancement).

[#] experimental/pilot operation.

[##] some farms have the capacity to scale up production subject to market demand.

As previously mentioned, the simulation model assumes that 50% of all 300g eels produced by both intensive and semi-intensive systems would be ongrown to 1kg eels before sale into the market place for human consumption. The financial analysis clearly shows that the latter option is potentially far more profitable. It is therefore more likely that a greater percentage of 300g eels is likely to be ongrown to a larger size in future, and the simulation model estimates of potential scale of industry-wide production may well be conservative.

As a means of reality checking the simulation model estimates, it is instructive to note that the simulation model dictates that, according to the specified scenarios under an initial 500kg glass eel intake, the total industry-wide input needs of 10g stocker eels is in the order of 15-18.5 tonnes per annum for intensive and semi-intensive culture systems alone. The financial analysis of a single, hypothetical, purpose built intensive RAS-based nursery system producing 10g stockers eels suggests that such a system would be profitable with a 500kg glass eel intake and producing from 19.9 to 24.4 tonnes of saleable product per annum; more than adequate for the projected industry's needs over the next 10-20 years.

<u>Extensive culture</u>

The only realistic opportunity for significant expansion of extensive eel culture practices in Australia exists in Victoria, in which such operations are both well established and historically quite productive. By definition, extensive culture provides for the ability to impose some management intervention on the target species to increase productivity, but with few inputs (if any), other than seedstock. As previously indicated, the Victorian eel fishery consists of two distinct components, viz. the traditional capture fishery based around coastal rivers and associated wetlands, and the stock-enhanced capture fishery based around various other private and public lakes, wetlands and water storages, predominantly in western Victoria. Given that this has been an established practice in Victoria for many years (Hall *et al.*, 1990), it does not logically follow that such an approach could be followed in other states, at least in public waters, where resource-use conflict with other stakeholders is likely to be a key constraint.

Having said this, translocation of juvenile/sub-adult eel stocks within their natural range has occurred in Tasmania as a result of elver harvests from below Meadowbank Dam on the Derwent River and the Trevallyn power station on the Tamar River. However this practice is more to supplement the existing wild eel fishery rather than to pursue 'extensive culture' *per se*, and no specific data is available to determine yield from such practice. Some industry proponents have also expressed interest in undertaking extensive culture in private waters in NSW using wild-caught restock, but the likely scale of such a development appears to be relatively small and geographically localised within a national context.

Based on industry sources, the total surface area of water bodies that are likely to be both suitable and available for stock enhancement in Victoria is in the order of 16,000 ha (source: Victorian Eel Fishers' Association). These waters have been ear-marked by industry on the basis that they are either existing, endorsed 'culture' waters (nominated licensed fishers permitted to stock and commercially harvest eels), or are existing allocated waters for commercial eel fishing only, but which are considered sufficiently productive and in need of stocking to increase yield.

Skehan and De Silva (1998) determined a series of significant positive correlations between fish yield ($kg.ha^{-1}.yr^{-1}$) and stocking rate ($kg.ha^{-1}.yr^{-1}$) for both 'restock' eels (around 200-300 mm total length size range) and elvers (around 1-2 g in weight and <100mm in length) for shortfin eels in stock-enhanced, western Victorian waters. More specifically, this study suggests that yield typically ranges from about 5 to 20 $kg.ha^{-1}.yr^{-1}$ at stocking densities ranging from 2 to 6 $kg.ha^{-1}.yr^{-1}$ for 'restock' eels, and from about 0.01 to 0.03 $kg.ha^{-1}.yr^{-1}$ for elvers after about 3-11 years respectively. The same data indicates a potential average yield of about 10-15 $kg.ha^{-1}.yr^{-1}$ for every 250-500 ha of surface area for the same stocked waters. The loss (mortality) ratio for all studied waters ranged from 0.24 for 500g weight class (size at harvest), to 0.62 for 1 kg weight class, with an average loss ratio of 0.47 for all weight classes (Skehan and De Silva (1998).

For the purposes of this study it is conservatively estimated that average annual yield for western Victorian waters stocked with intensively reared (from glass eel stage) 10g juvenile restock eels would be approximately (min.) 15 $kg.ha^{-1}.yr^{-1}$ of 1 kg eels after about 5 years at a stocking rate of (min.) 0.75 $kg.ha^{-1}.yr^{-1}$ (based on nominal/median values from Skehan and De Silva (1998). To instantaneously stock all available waters to an optimal level would therefore require approximately 12 tonnes of juvenile restock eels. In practice such a stocking could initially be undertaken over a five year cycle such that only 20% of waters would be stocked per annum requiring a total of about 2400kg of 10g restock. After the fifth year, effectively all waters would continue to be stocked and harvested on a 5 year cyclical basis (assuming water is not limiting), yielding approximately 48 tonne per annum. As more restock becomes available, stocking rates and frequency could conceivably be increased to the point where all waters were stocked to the maximum and harvested each year potentially yielding in excess of 240 tonne per annum.

Under Best Practice 1 scenario, The simulated industry production model in the present study predicts approximately 50 tonnes annual production of 1 kg eels with a market value of approximately $1 million from extensively stocked waters. This is based on an input of approximately 2200 kg of intensively reared 10g elvers from the initial 'industry allocation' of 100kg of glass eels.

Hypothetically, with increasing availability of glass eels, and subsequently 10g restock, the model predicts under Best Practice 3 scenario (and 750 kg annual glass eel industry allocation), that the output of 1 kg eels from extensively stocked waters in Victoria could increase to more than 300 tonnes per annum from an annual input of over 12 tonnes of restock. These data are broadly consistent with the yield predictions from Skehan and De Silva (1998) and the related yield predictions for the present study (as previously mentioned). Accordingly, the model is considered sufficiently relevant to provide a general guide to productivity gains for stock enhanced extensive culture under a series of 'continuous improvement' Best Practice scenarios.

To fully capitalise on the potential for optimal production out of all culture systems, the simulation model estimates that more than 35 tonnes of 10g stocker eels would be required per annum. The financial analysis in the present study estimates that intensive RAS-based production of 10g eels could profitably produce 24.4 tonnes from a 500kg glass eel intake under Best Practice 3 conditions. It is likely therefore that with a glass eel intake of up to 750 kg per annum, a combination of one purpose-built farm, and two or three additional

RAS-based farms producing larger (300g/1kg) ongrown eels and 10g stockers as an adjunct enterprise, could easily produce sufficient 10g stockers in total to meet the entire industry's future annual seedstock needs.

Australian Eel Aquaculture and Glass Eel Fishery Strategic Development - Directions, Guidelines, Needs and Vision

Background

Recent R&D and industry trials in all states have clearly identified a commercially valuable glass eel resource in Australia, based on the longfin and shortfin eel. Products from both species are subject to ongoing, predominantly export, market demand to varying degrees. Both are suitable for commercial production under intensive aquaculture conditions within pond and tank-based culture systems, and at least shortfin eels have proved to be suitable for extensive production under stock enhanced wild fishery conditions.

The primary requirement of the Australian industry is to optimise commercial glass eel resource utilisation within acceptable sustainability criteria and to facilitate long term eel aquaculture industry development. In summary, the purpose of this section of the report is therefore :

To prescribe broad guidelines which facilitate a degree of uniformity/consistency in management of glass eel stocks across state/regional boundaries and according to Best Practice industry standards and principles of ESD,

To facilitate eel aquaculture industry development and to identify the need for change in order to optimise the value of the Australian eel industry, and to create new opportunities specifically through Best Practice, sustainable glass eel utilisation and intensive production methods, and

Collectively to articulate strategic direction and a long term vision for the Australian eel aquaculture industry.

For added emphasis key issues are sometimes repeated under different headings due to overlapping context, and key findings and recommendations are summarised and highlighted in borders following the relevant text in this section of the report.

Eel Fishery Sustainability

Commercial techniques are now well established in Australia for catching shortfin and longfin glass eels, although suitable sites for collecting commercial quantities of both species are still somewhat limited in number. Accordingly, the actual sustainable yield of glass eels in Australia is yet to be determined, however existing market forces are effectively limiting the level of exploitation to a manageable, arguably very conservative, level at the present time. In practical terms, the broad distribution of shortfin and longfin eels in eastern Australia far exceeds the relatively limited number of suitable fishing sites at the present time, thus ensuring overwhelming spatial options for both migrating glass eel recruits (to estuaries) and the escapement of migrating silver/spawner eels (to the sea).

Recruitment variability is a key life history feature of all anguillid eel species, with many local and oceanic-scale physical and environmental factors impacting on recruitment levels to any one river system. This has been shown to be the case in Australian species following recent investigations, with consistent commercial scale catch-effort data being limited to only two locations viz. the Snowy River in eastern Victoria and the Albert River in south-eastern Queensland. It is also clear that despite the substantial level of investment in glass eel resource identification to date in Australia across four states, very little of the total range of both species has in fact been investigated.

Glass Eel Fishery Opportunities

The results from the most recent FRDC funded glass eel project in Australia suggest that, subject to industry needs, commercial harvesting of glass eels should proceed on a conservative, risk-managed basis, with total harvest in the first instance being in the order of 100-200kg (mixed species) from each of Queensland and Victorian waters (Gooley and Ingram, 2002). This quantity could reasonably be expected to increase to at least 500kg of shortfin glass eels alone (mostly from Victoria) in the longer term (next 5-10 years), with additional quantities of 200-250 kg of longfin glass eels from both Queensland and NSW once additional collections sites are identified. Additional quantities of both shortfin glass eels, perhaps from the Tamar or Derwent in Tasmania, and longfin glass eels from the Snowy River in Victoria could also be sourced subject to resolving various regulatory issues regarding access to the resource.

Ultimately, a total harvest of at least 500-750 kg of glass eels per annum of mixed species could be available to industry in Australia on a regular basis over a 10-20 year timeframe. This quantity could theoretically support a total cultured eel production of 1500-2000 tonnes per annum worth > $30 million, including satisfying all of the potential demand for extensive culture system restock from Victoria. Glass eel harvesting of this scale is unlikely to have any significant impact on eel stock conservation status within Australia due to the expected high inherent levels of natural mortality at the freshwater invasion life-history stage (McKinnon *et al.*, 2002).

By and large it is known where and how to catch shortfin and longfin glass eels in Australia to enable immediate industry expansion. Longer term expansion can be achieved as further glass eel resources are identified and accessed under appropriate ESD-based management regimes.

Australian glass eel harvest potentially (subject to demand) can proceed immediately to a level in the order of 100-200 kg/annum (both species), increasing up to 500kg within 5-10 years and to 750kg within 10-20 years. This could be achieved within an ESD framework and theoretically result in total production of 1500-2000 tonnes of cultured eels per annum worth > $30 million (based on present values).

Although the ready access to glass eel resources is often claimed by industry to be limiting eel aquaculture industry investment and development in Australia, it is likely that global market forces and the fundamental lack of any industry coordination at a national level are at least as relevant in this respect. Institutional and legislative impediments are presently limiting industry development, with existing state policies in relation to eel aquaculture development being inherently parochial. This attitude is doing little to facilitate optimal use of what is otherwise a common pool natural resource being shared by multiple stakeholders (including commercial and recreational fishers, fish farmers, and ethnic and indigenous groups) across multiple state and national boundaries. A more flexible approach is warranted to free up and encourage national trade in glass eels and intensively reared restock eels to ensure that the longer term production capacity of the Australian eel aquaculture industry can be optimised in the face of ongoing export market demand. The competitive advantage of marketing high quality 'clean and green' eel products within the massive Asian marketplace is not likely to be sufficient in itself to ensure financial viability for Australian producers. Industry structuring to achieve high levels of vertical (between producers) and horizontal (across sectors) integration, is imperative to achieve adequate scales of production efficiency and critical mass in the market place.

In the absence of any higher level coordination, glass eel fishing policies at the state level to date have effectively imposed 'barriers' to interstate trade in glass eel. Coupled with the general lack of economic information and appropriate risk management-based policy to facilitate allocation and utilisation of glass eels in Australia, there is evidence of market failure. Australian glass eels are a common pool natural resource which needs to be managed where appropriate within a national context, albeit with administration at the respective state agency levels.

A national market for longfin and shortfin glass eels would need to be consistent with national and state translocation policies and meet fish health standards as prescribed by future federal government guidelines. It is expected that appropriate disease-free certification at the point of sale of glass eels would be a minimum requirement. For translocation purposes appropriate spatial management units could include diseases by catchment and exotics by river basin. Unless proved otherwise, both eel species are assumed to be of genetically homogeneous stock, with genetic integrity not generally a translocation issue for eels in Australia.

There needs to be a national market for interstate glass eel trading in Australia, supported by ESD based resource management policy framed within a national context and administered at a state level.

To achieve national management of glass eels within an ESD framework, it will be necessary to maintain long term nationally coordinated databases for resource management purposes, and that to a large extent, state-based resource management plans will need to be complementary at a national scale. Equally, at least with shortfin glass eels, some coordination of resource management initiatives should also be addressed at an international level between Australia and New Zealand, given that both countries are thought to share a common genetic stock of this species.

To this end, the Australia New Zealand Eel Reference Group (ANZERG) is likely to play a key role in eel aquaculture (and glass eel fishing) resource management and associated industry development. Presently ANZERG meets irregularly, without any strategic direction and with little input from industry. Indeed ANZERG was originally established largely to help coordinate and facilitate eel fisheries and aquaculture R&D at a national level, and to act as a forum for government resource managers and researchers. It is suggested that the Terms of Reference for ANZERG now be revised to accommodate a more active industry development portfolio, or at least ANZERG should formally seek appropriate collaborative linkages with other peak/representative industry bodies for this purpose. ANZERG also needs to assume responsibility for ensuring the ongoing maintenance of a national glass eel database to be used as a key, long-term management tool, and also the preparation of comprehensive extension resources for industry.

The Terms of Reference for ANZERG should be revised to reflect changing industry development and resource management needs, particularly in the utilisation and management of the Australian glass eel resource.

Resource Management Needs and Directions

It is instructive to note that the proposed level of harvesting in Australia is only a fraction of the annual glass eel harvest for the European eel *A. anguilla*, which is in the order of several hundred tonnes. Despite this level of exploitation, declines in the European eel stocks are being addressed principally through managing adequate escapement of mature migratory eels (also referred to as 'silvers'). The main problem here is the broad geo-political scale in which the eels are distributed and exploited. Multiple management jurisdictions complicate the management process to the point where a uniform suite of effective regulations is almost impossible to achieve.

Conversely, in Asian countries there is little effort to manage endemic glass eel resources with input controls such as fishing time, number and types of nets and boats etc, or output controls (no protection of spawners), and compliance is therefore inherently low. Interestingly, production from the annual glass eel harvest appears to have more to do with prevailing climatic conditions than the level of fishing effort. Poor harvests are typically followed by abundant harvests on a cyclical basis following above average seasonal flooding in coastal rivers; arguably a testament to the resilience of the endemic eel stocks in the face of myriad other deleterious stock conservation impacts in the region.

The Australian situation is quite different again to both the European and Asian situation. In Australia, scope exists for coordinated effort and uniform management measures to protect eel resources. Furthermore, the proposed scale of exploitation is relatively small by comparison, the scope for escapement very high, existing management of input/output controls is comprehensive (if not consistent) and compliance is high. A conservative, risk management approach to glass eel fishing in Australia would include much of what already occurs by default. The emphasis on input controls (licence holders, effort, gear type & no., water access dependent on season etc) should continue, and limited entry imposed where not already existing.

In future it may be necessary to establish quantifiable, catchment-specific trade-offs between glass eels, elvers, standing crop and spawners i.e. gaining access to one by retiring proportional effort in another. Closed catchments and nursery waters may be considered, although in practical terms, if total effort in the

Australian industry does not increase over present levels, sufficient 'reserves' already exist by default. The actual physical amount of water fished at any one time in Australia is considered extremely small presently compared with the total amount of water available to the eels. To avoid 'hot spots' at certain times of the year, some site specific controls (eg. "no go" fishing reserves) may be required in the future, at least on a rotating basis within a certain region. Finally, the practice of imposing conservation-based stock enhancement in the wild for sustainability purposes (eg. a proportion of catch returned as elver upstream of capture site) is an additional means by which the eel resource can be conservatively risk managed, but still provide for expansion through glass eel utilisation.

The primary focus for managing the Australian eel resource should be on optimising protection and escapement of spawners (silvers) over nationally relevant units of time and space. A conservative 'risk managed' approach should be adopted at a national level for the sustainable production of Australian eels.

Given that glass eels typically migrate into estuaries in Australia over a broad spatial and temporal scale and in large numbers to compensate for inherent recruitment variability and other associated complex life history characteristics (eg. long-lived, oceanic spawning, extended oceanic migratory larval phase etc), it is also reasonable to assume that natural mortality at the glass eel stage is inherently high. For this reason, glass eel fishing *per se* is thought to have minimal impact on standing crop, compared to potential impacts from exploiting later life history stages including elvers, yellow eels and silver eels.

In short, the shortfin and longfin glass eel resource in Australia is likely to be a robust and resilient resource within reasonable limits yet to be realised, even in the absence of completely reliable stock assessment data. It is however incumbent on relevant agencies to manage the resource conservatively within a national context and to reduce risk of over exploitation at a catchment specific level through adoption of a conservative, risk managed, ESD-based approach where appropriate. Indeed Commonwealth Government requirements for ESD compliance for export fisheries in Australia already dictate the legislative need in the near future for an appropriate ESD-based management and reporting framework for the Australian eel industry, including aquaculture due to its ongoing reliance on wild glass eel seedstock.

The Australian glass eel resource can be managed sustainably, despite limited existing stock assessment information, on the basis of this being an inherently resilient and robust resource. Management should adopt a 'conservative', risk managed approach within an ESD framework

Consistent with European trends, and the recently released Victorian Eel Fishery Management Plan (McKinnon, 2002), it is also suggested that escapement of silver eels should be the primary management criteria for eel resource sustainability purposes in Australia, and that glass eel utilisation should be the means by which production can be substantively increased across both wild fishery and aquaculture sectors. There is little evidence from within Australia or from overseas studies presently to suggest that glass eel harvesting at the recommended levels could in any way impact on standing stock of eels within their natural distribution in Australia, or on the conservation status of the target species. Neither species is presently classified under any threatened status.

Within reasonable spatial limitations, it's assumed that escapement of spawners and subsequent recruitment of glass eels are highly dependent and relatively homogeneous throughout the range of the species. Further, within any one waterbody, excessively high mortality of spawners is highly unlikely to affect long term standing crop within that water body, so long as sufficient escapement occurs within neighbouring catchments. Having said that, such mortality will cause significant short term impacts on the fishery as well as deleterious impacts on biodiversity, social, recreational and cultural values. This is therefore not considered an appropriate approach under any circumstance, rather the means to make a point about the relevance of spawner escapement as a management tool.

Escapement of mature, migratory stock (silvers) should be the principal management criteria for eel resource management in Australia, with glass eel harvest levels being set at a national level but with site/catchment specific catch limits.

In relation to monitoring and assessment of eel resources, limitations are recognised with all traditional fisheries assessment methods when applied to eels due to the highly variable life history, broad geographic range and long life span. However minimum monitoring and assessment requirements (eg. glass eels and spawners) applied over a minimum time-frame of >10 years will provide some useful indices of recruitment/production for resource management and industry development purposes. The existing national glass eel CPUE database (Gooley and Ingram, 2002) has limited application for site specific purposes due to the inherent spatial and temporal variability of the data, but is likely to be relevant at a national scale when viewed over long periods. This database is also useful for resource identification for industry development purposes in terms of quantifying scale of reliable/available glass eel stocks and as a measure of industry production capacity.

Ongoing, long-term (10-20 year) monitoring of glass eel harvesting levels as a key recruitment index and silver eel harvesting levels as a spawning index are required at a national level.

Although compliance of eel fishery regulations is not generally considered to be an issue in Australia, examples are known to exist within the industry which can impact on market access, if not resource sustainability. Significant illegal fishing and trading in wild caught eel is claimed by some industry sources to occur in Victoria, where at certain times Western District lakes are targeted by organised poachers. It is claimed that 1-2 operators can take 100-200kg eels/night by multiple rod and line sets. These eels are then sold illegally into the domestic market and thereby depressing demand for legal eel trade. Compliance efforts however are resource limited, clearly subject to varying state agency-based priorities, and outside the terms of reference for this study.

Industry Structure and Development Constraints

The Australian eel aquaculture industry needs to establish a long term strategic vision to encourage appropriate levels of investment and compliance with acceptable ESD performance criteria. This vision should have a 10-20 year time frame and address at a national level various issues including relevant aspects of technology, R&D, training and education, resource management, organisational structuring, financial management and marketing. Australia presently lacks an effective national focus for development of the eel industry, with a resultant lack of strategic industry development and coordination being apparent. The need in fact is for the eel industry to work across multiple state boundaries, not be constrained by them.

There is presently a lack of coordination between industry sectors (wild fishery and aquaculture) and across state boundaries (partly compounded by state-based resource management policy), meaning that the small and geographically disparate producers have little chance to achieve critical mass within the export market place. Furthermore, there is a general lack of broad-scale market intelligence regarding domestic and export consumer demand for wild and cultured eel, particularly in relation to value-adding, import replacement and associated niche marketing. All such information is typically held within individual businesses, where in fact it exists at all.

There is a consequent lack of understanding within the industry, particularly for new entrants, of the supply chain requirements for large-scale production and marketing of Australian cultured eels. In turn this has resulted in depressed levels of new investment of recent times, despite latent interest from many candidates. Vertical integration of the supply chain is presently limited within a small number of individual businesses in both scope and scale. By and large, integration at an industry scale is limited again to within state arrangements, and even then is only occurring on an ad hoc basis.

Where appropriate, the existing wild eel fishery needs to diversify into glass eel fishing and to on-sell glass eels to specialised nursery operations for intensive aquaculture production of seedstock for intensive/semi-intensive grow-out and stock enhancement of extensive culture waters. These linkages could be a fully integrated chain of production within one business, or more likely integrated across two or more businesses anywhere in Australia.

By and large, the skills required for glass eel fishing reside with commercial fishers, albeit after some training and education in Best Practice techniques regarding the specific requirements for glass eels compared with larger/later stage eels. In practice it is suggested that commercial fishers, where available, should be encouraged to harvest and sell glass eels to the aquaculture industry as required. At the present time however, linkages between the two sectors to realise on mutual opportunities vary between the states and overall are limited in scope.

There is little to be gained by providing additional access to the glass eel fishery beyond the existing commercial fishers. Having said that, it is incumbent on existing fishers to reasonably supply the aquaculture industry to agreed levels, appropriate prices and market demand, that seedstock which is required for growout at an appropriate quality standard. A 'whole-of-supply-chain' approach to producing and marketing Australian eels within a fully integrated (vertically and horizontally) industry structure is a pre-requisite, as are organisational flexibility and communication between the different sectors, to ensure this view is pragmatic. Moreover the Australian eel aquaculture industry, in partnership with the wild eel fishery sector, needs to promote the long term environmental sustainability merits of the industry, highlighting the Best Practice approach to development and the social and economic benefits to regional areas. The industry should be supported in this endeavour through improved extension services, provision of reliable and comprehensive eel business development and investment analysis data, and ongoing R&D targeted at nationally prioritised information gaps.

For the eel aquaculture industry to expand in Australia there needs to be an increased emphasis on utilisation of the glass eel resource for both shortfin and longfin eels to increase both productivity and profitability. More specifically, there is a need to establish adequate scale and capacity within the industry, underpinned by reliable access to and sustainable management of Australian glass eel resources to encourage further investment in Best Practice aquaculture production. The Australian eel industry is very small and organisationally fragmented over four eastern states, viz. Queensland, NSW, Victoria and Tasmania. It is also effectively spread across two sectors (wild fishing and aquaculture) with operational linkages in the extensive culture practices in Victoria, but with otherwise ad hoc and tenuous linkages in all other respects. Some eel fishers are diversifying into glass eel harvesting for their own restock needs, other fishers are harvesting glass eels purely for on-selling to culturists (intensive through to extensive systems), and yet others are doing both.

This lack of coordination is further compounded by the lack of a defined organisational structure within the eel aquaculture sector to facilitate any meaningful horizontal integration between sectors. Also, each of the state fisheries management agencies has adopted largely parochial management and policy positions regarding cross border trading in locally harvested glass eels. Through limiting cross border trading, ostensibly to facilitate local value-adding and associated eel industry development, current glass eel management practices appear to be unnecessarily constraining industry development. Indeed, without high level coordination at a national level, arguably the eel aquaculture industry in Australia will not realise its full potential. Moreover, national trading in glass eels is critical to the medium-long term viability of the eel aquaculture industry in Australia.

At the present time, the availability of glass eels in Australia is not limiting industry development *per se*, despite comments to the contrary by some industry proponents. Commercial and government supported efforts to harvest glass eels have been initiated in all four eastern states, with relatively substantial quantities being harvested in at least Queensland and Victoria to date. More effort should be expended in facilitating optimal harvest by industry of known stocks (eg. shortfin glass eels in the Snowy River in Victoria) and ongoing pilot-scale fishing for new stocks (eg. shortfin glass eels in the Derwent and Tamar Rivers in Tasmania, and longfin glass eels in the Snowy River and various Queensland/NSW rivers).

On the other hand, demand for glass eel seedstock has eased in the last 2-3 years, partly due to depressed export prices due, in turn, to over-production in China, but also partly due to a lack of any strategic vision for the industry in Australia. For the former reason, some producers have diversified into other species, and some potential new investors have not proceeded to an operational stage. Nonetheless, those eel 'fishers-cum-farmers' who are targeting export Asian markets for larger (around 1 kg) eels from stock enhanced waters are still highly profitable. Subject to favourable climatic conditions (with sufficient rainfall to fill extensive culture waters), and availability of sufficient quantities of restock at the right price, profitable production can be achieved. Likewise, the demand for high-priced (>$20/kg), larger longfin eels from the wild capture fishery has stimulated the prospects of culturing large longfin eels from the glass eel stage. Market intelligence suggests that quality standards and product specification are the keys to export market access in Asia, rather than whether the product is cultured or wild fished. There appears to be ample demand for both within the global eel marketplace.

With national glass eel trading, an effective industry structure could be achieved, in a way that all key production stages, including glass eel fishing, nursery and grow-out, could become vertically integrated to provide the basis for a robust cultured eel supply chain in Australia. This supply chain could in turn be directed to complement the existing export demand for 'clean and green' high quality eels of a larger size to a quality accredited standard. At the present time it is apparent that Australia eel culture producers are not able to satisfy there general seedstock/restock needs (in addition to glass eels) in terms of quantities, size and cost. The lack of a stand-alone glass eel nursery sector, based on intensive acclimation and rearing, is clearly a limitation to the expansion of other producers for all growout systems in this respect.

A schematic summary of a conceptual eel aquaculture industry structure fully integrated with the existing wild eel fishery supplying glass eels is provided in .

It should be noted in this context that at the present time there has been no record of any 'notifiable' diseases in Australian cultured or wild eels, and the most common fish pathogens are typical of most cultured freshwater fishes and are able to be readily managed using conventional, well established fish health management measures. Accordingly, with the introduction of effective and efficient quarantine and associated fish health management procedures, national trading in glass eels and larger restock sizes is likely to be able to proceed within acceptable levels of management risk.

In contrast to the proposed domestic opportunity, little can be gained by Australian industry in harvesting Australian glass eels for export given the relatively small quantities on offer by global standards. Invariably, the few shipments that have gone overseas in the past for 'R&D' trials have resulted in little follow up from the Asian importers once the full implications of Australia's ESD-based resource management imperatives become apparent.

There is evidence of market failure in the Australian eel aquaculture sector as a result of the present emphasis on state-based eel industry development initiatives utilising glass eels, and with the lack of a nationally coordinated focus on resource management, R&D, industry structure and representation.

The Australian eel aquaculture industry needs to be better structured to take advantage of greater levels of integration to achieve critical mass and associated supply chain efficiencies and to fully realise the potential benefits of increased glass eel utilisation and national trading.

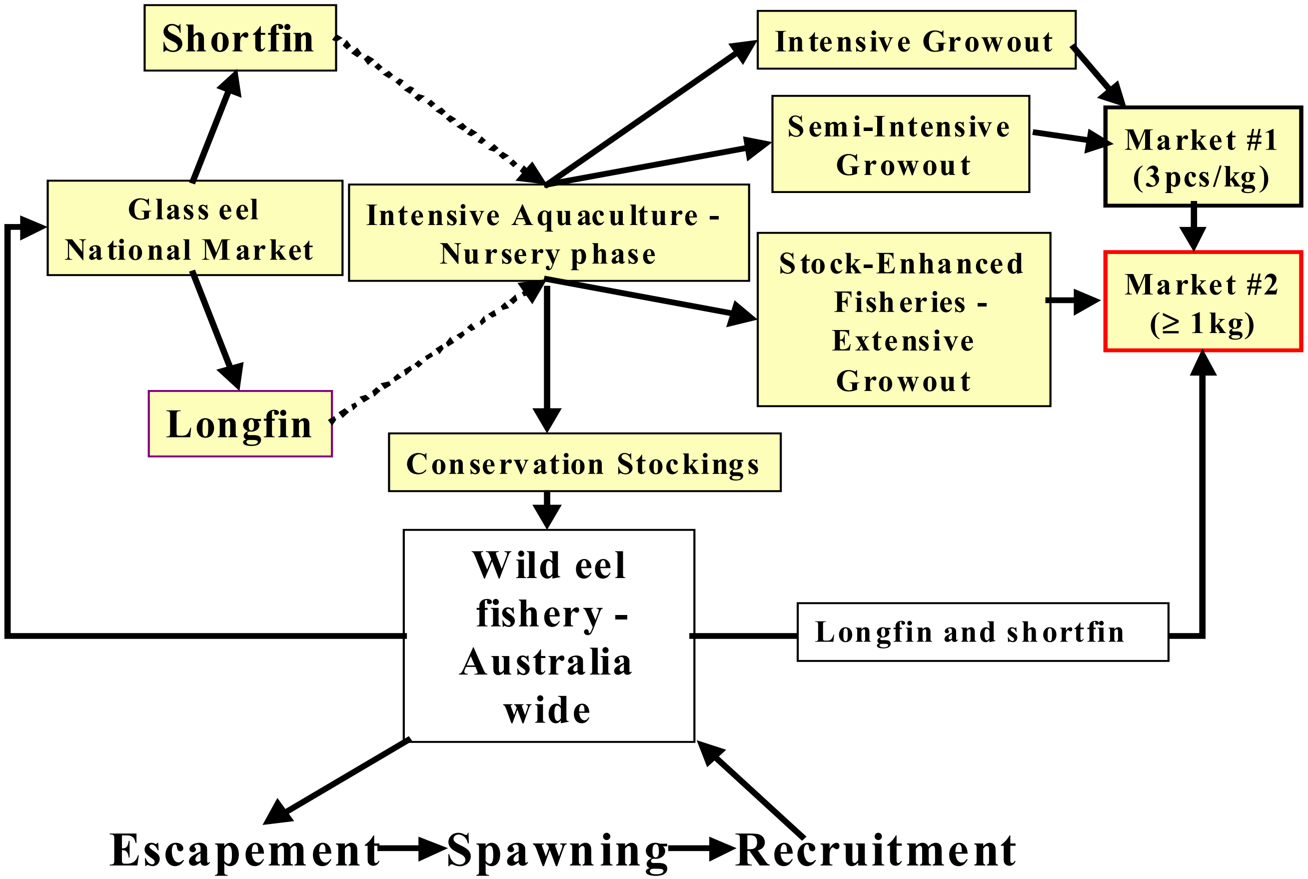

Figure 1 Schematic summary of conceptual fully integrated Australian eel aquaculture industry and glass eel fishery

Technical developments

The eel aquaculture industry in Australia now has a viable R&D base in relation to glass eel fishing and high density production technologies, largely as a result of recent FRDC and state government funded projects and concurrent industry investment. This base is also complemented by ongoing industry developments in fishing and farming technologies and is sufficient to enable consolidation of a small but otherwise motivated and potentially productive eel sector in the Australian seafood industry.

Commercial fishers in all four states are now conversant with glass eel fishing techniques and to varying degrees are being given direct access to known glass eel resources in selected catchments/rivers. Having said that, it is also clear that the ability of fishers to deliver a quality assured glass eel product to purchasers, be they for stock enhancement purposes or as seedstock for higher density culture systems, is of some concern. The role of purpose-built nursery systems operating on the basis of 'best practice' technology and serviced by appropriately trained operators is critical to ensuring that survival and condition of acclimated and weaned glass eels is maximised. Conversely, a lack of expertise and/or appropriate systems, technology and infrastructure at this stage can lead to significant mortalities of harvested glass eels. Guidelines for 'best practice' fishing and aquaculture of glass eels, published as part of recent FRDC funded glass eel R&D projects, are now available for Australian anguillids (McKinnon *et al.*, 2001).

Various indicators of sustainable industry development may be considered to underpin a long term (10-20 year) strategic vision. As a starting point it is suggested that the eel culture sector in Australia establish an agreed set of Best Practice technical standards within which the industry can be managed within an ESD framework. Financial viability and environmental sustainability will in part be determined by the efficiency with which the natural glass eel resource is utilised from the point of harvest to the point of final sale to consumers. Accordingly, Best Practice standards based around achieving increasing levels of survival and reduced operational risk of loss of eels during all production stages as part of a national 'continuous improvement' industry imperative is likely to be a useful starting point.

The Australian eel aquaculture industry should establish a national Best Practice technical standards framework which allows for progression over time under a 'continuous improvement' regime as part of an agreed strategic vision.

In a broad sense the Australian eel aquaculture industry is not presently limited by technology or informational gaps requiring further R&D investment in the short term. Rather, more resources should be invested in removing institutional and legislative impediments (particularly to national glass eel trading), industry structuring (to achieve better integration of key sectors), industry training and extension (based on recent R&D outcomes). In the longer term, various R&D needs have been identified as part of the draft national eel R&D strategy (see Appendix), and these should be reviewed periodically to determine the level of priority.

For practical reasons, minimum commercial quantities of glass eels need to be supplied to "key producers at critical developmental stages" for initial acclimation and weaning. Consolidation of the glass eel catch within appropriate geographic regions of the industry to ensure that the most experienced and efficient operators using the best facilities become the production focal points at these critical stages should be encouraged wherever possible. These producers would be expected to apply Best Practice culture methods according to industry agreed standards. From here glass eels would be distributed and used for intensive growout or for on-sale and/or reallocation for stock enhancement of wild fisheries. Furthermore, glass eels should not be used for stock enhancement of extensive culture waters without value-adding through acclimation, weaning and intensive nursery production to a larger size before release.

Efforts should be made to establish purpose-built glass eel nursery operations employing Best Practice standards as part of a fully integrated eel industry structure. All glass eel-based seedstock should be directed through such operations wherever possible to achieve critical mass of glass eel inputs to the culture system.

R&D requirements for technical development of the industry may increase in the medium to longer term, depending on the scale and type of industry investment. From a wild fishery perspective, if increased levels of glass eel harvesting are to occur to facilitate industry growth, further R&D may need to be focussed on the development of bycatch reduction techniques to ensure that biodiversity impacts from commercial fishing are managed within acceptable ESD limits. The existing Best Practice glass eel fishing guidelines (McKinnon *et al.*, 2001) are not presently linked to any specific performance criteria. With some modification these guidelines could be utilised as part of an ESD accredited reporting framework in the future.

Furthermore, it is apparent that the early maturation of male eels under culture in both species, particularly for shortfin eel, is causing some degree of lost production, but this cannot be quantified at the present time. Increased production of larger eels (≥ 1 kg) under intensive culture could potentially exacerbate this problem, and some investigation of the impacts and management methods to ameliorate the problem may be warranted in future.

Medium to longer term R&D priorities for technical development of the Australian eel aquaculture industry should focus on deficiencies in commercial scale production systems and/or glass eel fishing practices, subject to determining an appropriate balance of public and private benefit and associated R&D investment.

ANZERG has assisted in the national prioritisation and coordination of eel R&D in Australia over recent years, however this has been in the absence of a comprehensive, industry supported strategic R&D plan. Consequently, R&D is still proceeding at a state level with limited extension across state boundaries. Also, extension of the existing FRDC funded glass eel R&D project outcomes from recent years could be vastly improved using a national forum such as ANZERG as a vehicle for information dissemination. At the present time, the benefits to industry from this research has been variable from state to state, apparently also compounded by the lack of adequate government resources in the face of competition from larger, more established aquaculture sectors in each state.

A national eel R&D plan needs to be adopted and coordinated by ANZERG as a means of providing strategic direction to prioritised investment in the R&D needs of the Australian eel aquaculture industry. Short term emphasis should be on industry structuring, removal of institutional and legislative impediments to national glass eel trading, industry training and extension.

Market Dynamics, Needs and Directions

Both Australian species are perfectly adapted to intensive tank and pond production under certain circumstances and where appropriate; at least for juvenile and sub-adult production stages up to 300g. The grow-out to larger sizes (up to 1kg) under these conditions is still to be commercially tested on the ground, although there is presently no obvious technical constraint and the financial analysis in the present study suggests both intensive and semi-intensive culture systems could be profitable for this purpose. Certainly the extensive culture of larger eels for export markets continues to be a profitable enterprise, albeit typically as an adjunct to a commercial, wild catch fishery business in most cases.

Australia by and large has the production skills and access to suitable culture systems and associated infrastructure needs. A couple of small-medium scale farms already exist employing purpose built facilities. Although farmers in Queensland have typically employed semi-intensive pond-based culture systems to date (largely due to the favourable ambient climatic conditions), the potential use of RAS-type intensive systems is also under consideration by industry. Overseas experience, particularly from European countries such as Holland and Denmark, is useful in the development of RAS-type culture systems for eel production in Australia. Recent experience suggests that RAS and the European industry experience can be readily adapted to the specific requirements of local eel species. Ensuring that controlled environmental conditions are matched to the requirements of local species is crucial to achieving high productivity levels.

The industry needs to identify and implement targeted strategies to increase and secure market access for cultured Australian eels. This should include increased branding and other forms of identification of Australian cultured and wild eel produce in the market place, and associated promotion of Australian QA/food safety standards under a ‘clean and green’ theme. Further investment from both government and industry is required to improve market appraisal (domestic and export) and product promotion and demand for value-adding at the consumer end of the supply chain.

Viable export markets do exist presently for cultured Australian eel products, albeit many of which are in some state of flux due to global market forces, particularly the scale of (over) production in China. The latter has apparently depressed the production in Taiwan to the point where many farms have now closed down or diversified into other species of recent years. The opportunity exists in Australia to capitalise on the environmental sustainability of the eel industry in terms of maintaining, and indeed increasing, its share of the export market. In particular, the eel industry is a potential candidate for the use of eco-labelling as a tool for attracting premium prices, while at the same time meeting stringent ESD criteria. Certification under the Marine Stewardship Council for example, is one means whereby international recognition of the environmentally sustainable performance of Australia's eel industry may enhance the value of eel industry products in export markets.

Value-adding to eel industry products is an area which also requires development in Australia. At present a small number of eel producers in Victoria and Tasmania supply smoked whole eel and/or eel pâté to the domestic market, with at least one fisher assertively marketing a branded smoked product. The potential for expansion into the domestic market, by the industry could be realised to a greater degree through coordinated training and development in post-harvest handling and value-adding of eel products. Combined with a concerted marketing strategy, this would be expected to increase the competitiveness of local eel products with imported product on the domestic market.

Overall there is a specific need for the Australian eel industry to gain a better understanding of supply chain mechanisms, from the point of glass eel harvest, through all production stages and systems (wild fishery and aquaculture) to the market place, both domestically and export. Individual, long established wild fishery eel businesses have some understanding of the supply chain, however this cannot generally be said for some more recent eel aquaculture entrants, and there appears to be little appreciation of the broader, longer term opportunities on offer for the industry through better integration between discrete businesses. Industry education and training is required to better inform producers, particularly using templates from other existing and successful primary industry sectors and products in Australia. Where possible, recognised industry leaders should play a greater role in this respect and in facilitating more effective integration between various eel producers.

The Australian eel industry needs to have a better understanding and appreciation of the 'whole-of-supply' chain from glass eel to export market. Training and education should be tailored to suit this need with recognised industry leaders playing a greater role where possible.

R&D Priorities - Summary

Generally speaking, further R&D of a bio-technical nature should be undertaken by industry under commercial operating conditions, preferably with the input of state agency and university-based researchers on a collaborative basis. State fisheries and/or regional development agencies should be encouraged to form R&D partnerships for co-investment to underwrite such work, particularly where a compelling benefit can be attributed to regional development and/or environmental sustainability from R&D outputs and outcomes. Such benefits clearly justify the role of Government in making R&D investment in the eel aquaculture industry in Australia. The more immediate private benefits from bio-technical-type R&D which contribute to industry's 'bottom line' should justify their ready and ongoing investment.

Likewise, further investment in identifying new glass eel resources and associated efficiencies in harvesting should predominantly be underwritten by industry, with government co-investment where appropriate. This will ensure that future investment in this area is market driven and costs are met by the major beneficiaries in a proportional manner, subject to an agreed assessment of public and private benefit from the R&D.

In summary, future state and federal government investment in the eel aquaculture industry should focus on structural reform to address market failure issues, securing export market access, establishment of management guidelines and coordination to achieve ESD compliance, and training and extension for adoption of industry-wide Best Practice standards. Accordingly, based on the existing draft national eel R&D plan, and the information provided in the present study, the following key Australian eel aquaculture and glass eel fishing R&D priorities are proposed for the next five years:

1. Provision of comprehensive and up-to-date extension resources including documented Best Practice standards, key investment criteria and market intelligence (see Draft R&D Plan re AQ1a &c, 2a, 4b, c&d).

2. Development of state-based management guidelines to encourage sustainable ESD-based glass eel utilisation and to facilitate national glass eel trading within the eel aquaculture and fishing industry; emphasis on removal of existing institutional and legislative impediments and EA Schedule 4 compliance (see Draft R&D Plan re WF2c & 6c).

3. Development and application of supply chain strategies to facilitate and coordinate export market access and industry integration and expansion (see Draft R&D Plan re AQ5a & 5b).

4. Provision of technical training support for the adoption of Best Practice standards in glass eel fishing and aquaculture, and in post-harvest, QA/food safety to complement new supply chain strategies (see Draft R&D Plan re WF6c, AQ1a, &c, 2a, 4b, c & d, 5a &b).

5. Market research to determine post-harvest, value-adding and 'branding' opportunities as part of new supply chain strategies designed to secure market access (see Draft R&D Plan re AQ5a & b)

6. Establishment and maintenance of national databases for monitoring of glass eel catch and silver eel escapement and/or other key indices of eel resource sustainability (see Draft R&D Plan re WF2a)

These six priorities are not necessarily in priority order, rather should be seen as a package in addressing industry's immediate needs (next five years) to compliment their own strategies for achieving development targets and specific Best Practice standards under a 'continuous improvement' regime over the next 20 year timeframe. This of course assumes that the industry shares such a vision and that projections of potential industry productivity over this (20 year) time frame, as determined in the present study, are at all realistic. R&D priorities beyond the next five years will need to be determined as part of a process of periodic (eg. biennial/triennial) review of progress.

Not all of these priorities are clearly articulated in the existing draft National Eel R&D Plan (see Appendix), but they are all broadly covered in one form or another, remembering of course that the specific emphasis of this study is on eel aquaculture and associated glass eel fisheries rather than eel fisheries in general. To assist in correlating the two sets of priorities, the reference numbers for the relevant R&D priorities in the draft R&D Plan are included in brackets.

It is worth noting that although the R&D priorities in this study have been determined from a somewhat different perspective (simulative modelling and expert opinion) to the draft R&D Plan (broad consultation and consensus), the two respective sets of recommendations are broadly compatible and are underpinned by similar development rationale and strategic vision, albeit more clearly elucidated in this study. It should also be noted that no attempt has been made to consider related issues in the New Zealand industry in this study, and therefore the R&D priorities are consciously Australian-centric.

References

Anon. 2001. Fisheries Victoria. Commercial Fish Production. Information Bulletin 2001. Marine & Freshwater Resources Institute, Queenscliff. 28.

Borch, O.J. 1999. New organisational forms within the aquaculture industry: the fish-farming enterprise as a `virtual' organisation. *Aquaculture Economics and Management*. 3:105-120.

EIFAC/ICES. 2002. Report of the EIFAC/ICES Working Group on Eels. International Council for the Exploration of the Sea, Copenhagen. 59pp.

Frost, H., Jensen, C.L., Nielsen, M., Vestergaard, N. and Pedersen, M.I. 2001. A socioeconomic cost-benefit analysis of the use of glass eel. Danish Institute of Agricultural and Fisheries Economics, Copenhagen. 68pp.

Gooley, G., Dalton, W. and Rawlinson, P. 2002. Preliminary economic analysis of selected Australian eel aquaculture systems. *In* Assessment of Eastern Australian Glass Eel Stocks and Associated Eel Aquaculture. Final report FRDC Project No. 97/312 and No. 99/330. G.J. Gooley and B.A. Ingram, editors. Dept. Natural Resources & Environment, Alexandra, Victoria.

Gooley, G.J. and Ingram, B.A. 2002. Assessment of Eastern Australian Glass Eel Stocks and Associated Eel Aquaculture. Final report FRDC Project No. 97/312 and No. 99/330. Dept. Natural Resources and Environment, Alexandra, Victoria.

Gooley, G.J., McKinnon, L.J., Ingram, B.A., Larkin, B., Collins, R.O. and De Silva, S.S. 1999. Assessment of Juvenile Eel Resources in South-Eastern Australia and Associated Development of Intensive eel Farming for Local Production. Marine and Freshwater Resources Institute, Alexandra. 124pp.

Hall, D.N., Harrington, D.J. and Fairbrother, P.S. 1990. The commercial eel fishery in Victoria. Arthur Rylah Institute for Environmental Research, Dept. of Conservation and Environment, Heidelberg, Victoria. 41pp.

Knights, B. 2001. Economic evaluation of eel and elver fisheries in England and Wales. Environment Agency, Bristol. 44pp.

Lobegeiger, R. 2001. Report to farmers. Queensland aquaculture production survey 1999-2000. Department of Primary Industries, Brisbane. 24pp.

Lobegeiger, R. 2002. Report to farmers. Queensland aquaculture production survey 2000-2001. Department of Primary Industries, Brisbane. 24pp.

McKinnon, L. 2002. Victorian Eel Fishery Management Plan. Marine and Freshwater Resources Institute, Queenscliff. 48 pp.

McKinnon, L., Gasior, R., Collins, A., Pease, B. and Ruwald, F. 2002. Assessment of eastern Australian *Anguilla australis* and *A. reinhardtii* glass eel stocks. *In* Assessment of Eastern Australian Glass Eel Stocks and Associated Eel Aquaculture. Final Report to the Fisheries Research and Development Corporation (Project No. 97/312). G.J. Gooley and B.A. Ingram, editors. Marine and Freshwater Resources Institute, Alexandra. 11-72.

McKinnon, L.J., Ingram, B.A., Larkin, B. and Gasior, R.J. 2001. Best Practice Guidelines for Australian Glass Eel Fishing and Aquaculture. Marine and Freshwater Resources Institute, Queenscliff. 21pp.

O'Sullivan, D. and Dobson, J. 2001. Status of Australian aquaculture in 1998/99 (sic). *In* Austasia Aquaculture Trade Directory 2001. T. Walker, editor. Turtle Press, Rosny, Tasmania. 3-19.

Skehan, B.W. and De Silva, S.S. 1998. Aspects of the culture-based fishery of the shortfinned eel, {IAnguilla australis}, in western Victoria, Australia. *Journal of Applied Ichthyology - Zeitschrift Fur Angewandte Ichthyologie*. 14:23-30.

Appendix

Australia-New Zealand Eel R&D Plan 2000/01-2005/6

Draft date: 26 November, 1999

Background

The Fisheries R&D Corporation of recent years has, in partnership with industry and a number of state agencies, invested significant funds into the development of the commercial eel fishery and aquaculture sector within Australia. Most notably the FRDC has funded two major R&D projects managed by the Marine and Freshwater Resources Institute in Victoria, Australia, which have investigated aspects of glass eel stock assessment and aquaculture. These projects (one completed and the other in progress) have involved extensive collaboration between MAFRI, Deakin University and the Queensland Department of Primary Industries, NSW Fisheries and the Tasmanian Inland Fisheries Commission. The FRDC also is presently funding R&D projects investigating aspects of the wild eel fishery in Queensland and NSW, both of which are presently in the first of three year programs.

Given the ongoing level of industry support for R&D in this area at both the state and national level, the FRDC has now identified the need to adopt a more strategic approach to investing in this sector. Accordingly, an appropriate R&D strategic plan is now under development which will emphasise national R&D priorities for the eel sector (eastern Australian states) and will engage all relevant stakeholders including industry, government and researchers. It is also intended that this plan will address the broader regional interests and priorities of New Zealand are also being considered. This in turn recognises the fact that to a large extent the two countries share a common eel stock and eel management issues, and that there is intrinsic merit for a number of reasons in facilitating wherever practical and possible a collaborative approach to eel R&D at a regional level. Indeed significant eel research is also underway in New Zealand through NIWA, and broader eel resource management and industry development issues are becoming apparent at the national level.

Consequently, it is proposed that the Australia and New Zealand Eel Reference Group (ANZERG), the peak eel advisory body to Standing Committee on Fisheries and Aquaculture in Australia, will act as a steering committee for the development of the strategy. Furthermore, it is intended that ANZERG will be the vehicle for implementing and managing the strategy in the longer term. This is on the understanding that, where appropriate, eel industry stakeholders in both Australia and New Zealand, including FRDC and other R&D funding providers, fisheries agencies and resource managers, eel fishers, farmers and associated industry peak bodies, and eel researchers and associated institutes, will actively engage ANZERG for the purpose of supporting the strategy. It is expected that the joint Australia-New Zealand membership of ANZERG will effectively facilitate the necessary consultation and coordination between states and nations to achieve this aim. ANZERG membership and contact details are provided in Attachment 1.

The development of the strategy to this point has followed a number of steps, formally commencing during October/November 1999 with circulation of a questionnaire to all stakeholders seeking input from as wide a spectrum of the eel industry as possible. This was followed by a workshop held in Melbourne on 18 November, 1999. Workshop delegates, both present and invited, are listed in Attachment 2. The combined outcomes of both the questionnaire and the workshop have resulted in this draft R&D Plan.

The Draft R&D Plan

The Plan is essentially based on two key imperatives, being sustainability of the eel resource and profitability of the eel industry. Accordingly, two key outcomes are proposed which underpin the future direction of associated eel R&D in Australia and New Zealand, viz.:

Outcome 1
To manage and utilise the eel resource in an ecologically sustainable manner consistent with broad community expectations.

Outcome 2
To develop and maintain a competitive and profitable, viable, secure and well structured commercial eel industry.

The specific details of the Plan, including key issues, associated project topics, relevance, feasibility and present status are summarised in the following spreadsheet. Explanatory details regarding the definition and/or interpretation of the specified criteria are provided in Attachment 3. The listed Issues and Research Topics included in the Draft Plan are largely those which were identified during a preliminary discussion at the most recent ANZERG meeting in Melbourne (16/9/99). These issues and topics were further expanded and modified following comments from respondents to the questionnaire, and from feedback at the Melbourne workshop.

In general, the Plan is expected to take a "whole-of-(industry)chain" approach to facilitate relevant R&D projects, each with planned outcomes. Accordingly, based on the above outcomes, there needs to be a balance of sustainability and profitability-based projects underpinned by good science, which address strategic priorities, are well coordinated, and have significant industry support and, where appropriate, participation.

Priorities
The relative priorities assigned at the Melbourne workshop to the various issues identified in the Draft plan for the wild fisheries and aquaculture sectors are summarised according to the relevant outcome described above, and in order of decreasing importance:

Outcome 1 - Sustainability	Priority (1 = highest)
WF1	1
WF2	2
WF6	3
WF7	4
WF4	5
WF5	6
WF3	7
Outcome 2 - Profitability	
AQ1	1
AQ2	2
AQ5	3
AQ3	4
AQ6	5
AQ4	No priority assigned *

* no priority assigned as deemed to be a general category already covered adequately in other areas

It should be noted that the associated project topics as listed for each of the key issues within the wild fisheries and aquaculture sectors of the draft Plan are provided as a guide. Indeed they are therefore indicative only and are not intended to be exclusive of possible variations and or additions, assuming such "new" projects fundamentally address one or more of the key issues. It should also be noted that these priorities may vary between Australia and New Zealand to some extent and, subject to further advice from key stakeholders in New Zealand, may need to be further qualified at a regional level.

Another point to note is that the Plan is for a five year period from 2000/01 to 2005/6, and key issues and associated project topics should be considered prioritised within this timeframe ie. what can should be done within the next five years. Some issues may be relevant but not sufficiently urgent that they need to be addressed during this timeframe.

Wild Fisheries (WF1)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Impacts of impoundments Impoundments on coastal streams restrict passage of juveniles recruiting to freshwater and silver eels returning to sea to spawn	Impact assessment of barriers on freshwater eel migration patterns (up and downstream), standing crop, associated population dynamics, eel habitat, accessibility & suitability; goal is to improve existing management practices.	NZ, Tas. & Qld – specific relevance Outcomes generally relevant to all waters in Australia & NZ	Both	High	High	Partly u'way in NZ & Qld
	Efficacy of stock enhancement, translocation & fishways to mitigate impacts of barriers on fish passage; including design & development of fishways & integral monitoring devices for all stages; emphasis on measuring performance of impoundment specific solutions.	NZ, Tas. & Qld Outcomes generally relevant to all waters in Australia & NZ	Both	High	High	Partly u'way in NZ, Tas. & Qld
	Impact of river mouth closure on glass eel and silver eel migration	Vic.	Both	High	High	None
	Impacts of hydro operations including turbine-induced mortalities & methods to minimise such impacts.;	Tas.	Both	High	High	None

Wild Fisheries (WF2)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Sustainability Criteria Resource managers have a need to develop ESD-based fisheries management plans with an emphasis on use of reliable sustainability criteria and/or indicators for stock conservation purposes; particularly relevant in Australia as a result of recent initiatives by Environment Australia dictating the need for such information as part of management plans.	Development of standardised & quantifiable recruitment &/or other production indices in association with national database; including development of standard indicators for monitoring & assessment purposes.	All	Both	High	High	Partly u'way
	Development of reliable estimates/predictive models for standing stock &/or fishery yield for different developmental stages, incl. glass eels, elvers & adult eels.	All	Both	Med.	Med.-low	U'way for adults in NZ & Qld.
	Develop and identify risk management options and associated harvest strategies for enabling sustainable eel resource utilisation; including glass eel, elver & adults; where possible need to quantify performance of existing & proposed management strategies.	All	Both	High	High	Partly u'way
	Investigation into sustainability of NZ longfin stocks & associated fisheries, including reasons for apparent declines and options for restoration of stocks.	NZ	Both	High	High	U'way in NZ

Wild Fisheries (WF3)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
By-catch reduction Preliminary harvesting of glass eels by researchers and industry has resulted in varying, frequently high, levels of by-catch, including other juvenile fish & aquatic fauna. There is a need therefore to reduce all forms of by-catch in the developing Australian glass eel fishery for both economic and environmental purposes. Bycatch in the elver and adult wild eel fishery is less significant & development of improved methods is largely routine & being handled by industry.	Evaluation of impact of existing and new fishing techniques on by-catch & associated bio-economic indicators; emphasis on glass eel resource; including site selection & gear choice/selectivity.	All	Both	High	High	U'way
	Development of by-catch reduction devices for both longfin and shortfin eels which are able to mitigate impacts on different aquatic fauna.	NSW	Both	Med.	High	Partly u'way

Wild Fisheries (WF4)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Habitat Requirements Protection and restoration of critical estuarine &/or freshwater habitat is essential to maintenance of standing stock and associated conservation status. It is noted that various land-based, catchment management and associated R&D activities impacting on freshwater eel habitats are being addressed by other "non-eel" initiatives. It is also noted that much relevant R&D on this topic is being undertaken by default as a key component of other eel project topics.	Identification of critical habitat, including environmental flow requirements, and associated threatening processes for all estuarine and freshwater developmental stages.	All	Both	High	Med.	Partly u'way Note much relevant R&D done in other "non-eel" sectors.
	Identify availability of suitable habitat on catchment by catchment basis (GIS?) & evaluation of options for fishery reserves.	All ?	Both ?	High ?	High ?	None
Heavy metal impacts Historical mining operations on the west coast of Tasmania have resulted in concerns over the impacts of heavy metal accumulation in resident eels within certain catchments.	Evaluation of heavy metal accumulation by eels and associated biological impacts on west coast of Tas.	Tas.	Both	High	High	None (nb. recent Victorian study by MAFRI)

Wild Fisheries (WF5)

Issues	Project topics	Relevance			Feasibility	Status
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Fisheries Development, Policy & Management Juvenile eels (glass eels & elvers) from the wild are exclusively the requisite seedstock for intensive eel aquaculture. However, reliable sources of commercial quantities of such seedstock in Australia are presently limited, and industry demand exceeds supply. Accordingly there is a need to identify new glass eel and elver resources, consistent with the needs of new and developing intensive industry investment.	Identify new glass eel collection sites and develop and adapt relevant fishing techniques for routine use; including practical methods for identifying/separating different spp. (primarily for NSW waters). Much of this work is to be done either by or in collaboration with industry where appropriate.	All	Private	High	High	U'way
	Evaluation of impacts from exploiting stocks at different life history stages, including benefits and associated potential trade-offs between catch/effort, eel fishery reserves and escapement requirements for all parts of the existing fishery; including environmental risk assessment & cost/benefit analysis; to be undertaken at broad geographic scale to achieve national/regional approach.	All	Both	High	Medium	Partly u'way
	Development of stock enhancement strategies & associated studies to optimise stocking rates, productivity etc	NZ, NSW & Tas.	Both	High	High	Partly u'way in NZ and Vic.

Wild Fisheries (WF6)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Fisheries Development, Policy & Management continued	Development of national guidelines & operational procedures to facilitate live trade of juvenile and sized eels between States; emphasis on biodiversity, disease & genetic issues. It is noted that relevant generic national guidelines regarding fish translocation have been developed and will be used as a benchmark.	Australia	Private	High	High	Partly u'way
	Development of strategies to determine equitable allocation of/access to eel resources; incl. juv. v adult, aquac. v wild fishery, commercial v recreation., customary v other etc	All	Both	High	Med.	Partly u'way

Wild Fisheries (WF7)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/nat./reg.	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
General biology, Ecology & Stock Assessment There is insufficient knowledge on basic eel life history, population dynamics and associated research technologies to address other key issues and information gaps in relation to both wild fisheries and aquaculture	Development and validation of reliable, cost-effective ageing techniques for all developmental stages.	All	Both	High	High	Partly u'way in all areas
	Investigation of reproductive cycle and general population dynamics to determine rates and key stages of development and overall productivity during the inland life history phase and in relation to commercial utilisation impacts.	All	Both	High	High; although intrinsic complexity of eel life history & associated R&D is noted.	U'way in all areas; note Qld, NSW & NZ.
	Development and use of mark-recapture/tracking techniques to estimate population size and to monitor movement, growth & survival.	All	Both	High	High	Partly u'way in most areas
	Estimation of productivity in different habitats & associated variability in population dynamics & ecological interactions	All	Both	High	high	Partly u'way

Aquaculture (AQ1)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Nursery & Growout Techniques There is a need to further develop and enhance both nursery and growout techniques, with an emphasis on system design and husbandry practices, for extensive, semi-intensive and intensive production. Such evaluations need to be undertaken jointly between researchers and industry and include documentation and dissemination of Best Practice Guidelines for different species and systems..	Technical and economic evaluation of pond culture compared with tank culture for all spp., including a comparison of husbandry practices relevant to different systems & preparation & dissemination of Best Practice Guidelines.	All	Private	High	High	Partly u'way
	Development of species specific diets for different developmental stages of commercial production systems.	All	Private	High	High	U'way
	Optimising of acclimation, weaning & associated husbandry of newly caught glass eels, including establishment of Best Practice Guidelines	All	Private	High	High	U'way
	Economic & technical assessment of relative suitability of glass eel and elver as aquaculture seedstock	Tas & Vic.	Private	High	High	Partly u'way

Aquaculture (AQ2 & 3)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Fish health With the increasing trend towards intensification of eel culture production systems comes the attendant threat of disease, including ectoparasitic bacterial and protozoan infections. Best practice Guidelines are required for addressing such issues	Development and testing of relevant therapeutic and prophylactic disease treatments consistent with relevant food safety standards; incl. monitoring of Australia/NZ eel disease status	All	Both	High	High	Partly u'way
Artificial propagation The ongoing dependence on, and inherent variability of, wild glass eel seedstock is a major constraint to long term industry development, in addition to being a potential threat to stock conservation.	Evaluation of the feasibility of artificial propagation techniques for freshwater eels as a means of providing hatchery progeny for aquaculture seedstock.	All	Both	Low	Low	None (although much work being done o'seas)

Aquaculture (AQ4)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Policy & Management Several Australian states and New Zealand to a large extent share in the management and utilisation of common eel stocks, dictating the need for a uniform approach to policy and management guidelines.	Genetic stock characterisation using DNA techniques to discriminate relevant management units for key species.	All	Both	Medium-low	High	U'way
	Risk analysis for disease, genetic and biodiversity impacts of juvenile eel translocation..	All	Both	Medium	Medium	Partly u'way
	Development of ESD-based guidelines for translocation of juvenile eel stocks for aquaculture and stock enhancement purposes.	All	Both	High	High	Partly u'way
	Development of cost-benefit/economic models for prospective investors/farmers; including financial management support to secure venture capital for eel aquaculture investment	Vic. & NSW	Private	High	High	Partly u'way

Aquaculture (AQ5)

Issues	*Project topics*	*Relevance*			*Feasibility*	*Status*
		state/region	publ./priv./both	high/med./low	high/med./low	No prog./u'way.
Post-harvest handling, Quality Assurance & Marketing Cultured eels are part of a dynamic and highly competitive, multi-faceted and high value global market, in which quality assurance requirements are at a premium.	Development of market strategies and associated value-adding and post-harvest handling procedures, including live transport protocols, designed to facilitate access to both domestic and export eel market niches.	All	Private	High	High	Partly u'way
	.Development of appropriate quality assurance-based, industry Codes of Practice and associated HACCP-based food safety protocols to satisfy legislative and market requirements.	All	Both	High	High	Partly u'way

Industry structure

As part of this strategic planning process some clearer vision is becoming apparent for the structure of the Australian and New Zealand eel industry than perhaps is presently the case. Given that much of the industry is going through some degree of transition for various reasons, including the establishment of new and developing sectors such as the glass eel fishery and intensive eel farming, proposing some form of industry structure is considered likely to provide a useful guide for R&D planning purposes. It is not intended however that such a guide be at all binding on industry or government. This is a particularly interesting question given the global nature of the industry and current industry trends at this scale. Comments on such matters from respondents to the questionnaire, particularly thoughts on how the industry may ultimately be structured and integrated at and between the different levels/sectors, are summarised here (in no particular order) for information:

- Requirement for dedicated glass eel nurseries taking juveniles from anywhere in Australia & on-selling for grow-out anywhere in Australia ie. unrestricted trade across State boundaries.
- Emphasis on continuation of Government/industry partnership approach to development of the eel industry (nb. ANZERG's role).
- NZ – clear understanding of eel resource allocation & associated stewardship, including equitable allocation between customary and commercial stakeholders via co-management arrangements and associated management plans.
- Collaborative R&D with active industry participation & effective extension.
- Orderly organisation of industry to recognise differing requirements of seedstock for intensive aquaculture and restock for extensive grow-out.
- Sufficient flexibility to allow market forces to dictate industry development trends.
- ANZERG to play a key steering role, rather than wholly prescriptive role; management plans to provide the means.
- Increased role of industry in collection of glass eels.
- Increased role of researchers in diet development and disease control.
- Nurseries to be intensive systems and growout to be either intensive through to extensive (ponds), subject to ambient conditions.
- Need for a cooperative marketing approach to even out supply and regulate prices.
- Fishers should fish (for glass eel) and farmers should farm.

R&D evaluation, communication, and marketing

Advice has also been sought on the most appropriate means by which eel R&D may be objectively evaluated and the results effectively communicated and promoted. Given the need to facilitate effective eel R&D collaboration across broad geographic boundaries, it is suggested that ANZERG will provide the most appropriate forum to coordinate such activities. The establishment of a research sub-committee of ANZERG to take on this responsibility is one option, which could also provide the means by which other international eel researchers could engage and/or collaborate with Australian and New Zealand researchers in an effective and efficient way. It should be noted that ANZERG is already seeking to make formal contact with the European Inland Fisheries Advisory Commission (EIFAC) Eel Working Group for similar reasons. A summary of general comments on this matter from respondents to the questionnaire includes:

- ANZERG is a logical forum for R&D management; perhaps through R&D sub-committee; role to include research coordination, evaluation, marketing and review.
- Linkage with international networks is required eg. through NACA, APEC, ICES/EIFAC etc
- NZ R&D requirements inherently difficult due to existing industry arrangements
- Require bi-annual symposia & other media eg. internet listing (nb. Australian & European)

Attachment 1 -ANZERG membership details

(current as of 1999 workshop; more recent membership changes need to be confirmed with relevant state and federal government agencies).

Contact details:	Phone	Facsimile	Email
Robert Swindlehurst Aquaculture and Industry Development, QDPI GPO Box 2454 BRISBANE QLD 4001	(07) 32242257	(07) 32298146	swindlr@dpi.qld.gov.au
Geoff Gooley MAFRI Manager, Aquculture Program Private Bag 20 ALEXANDRA VIC 3714	(03) 5774 2208	(03) 5774 2208	geoff.gooley@dpi.vic.gov.au
Adrian Collins Bribie Island Aqucaulture Research Centtre QDPI PO Box 2066 BRIBIE ISLAND, QLD 4507	(07) 3400 2024	(07) 3408 3535	Collins@dpi.qld.gov.au
Anthony Forster, Fisheries Victoria, NRE, 232 Victoria Pde, E. Melbourne, VIC, 3002	(03) 9412 65710	(03) 94125770	a.forster@dpi.vic.gov.au
Ian Lyall Locked Bag 9 NSW Fisheries PYRMONT NSW 2009	(02) 9566 7842	(02) 9566 6627	Lyalli@fisheries.nsw.gov.au
Stan Jarzynski AFFA GPO Box 858 CANBERRA ACT 2601	(02) 6272 4413	(02) 6272 4215	Stan.jarzynski@affa.gov.au
Warwick Nash Inland Fisheries Comm. PO Box 288 MOONAH TAS 7009	03 6233 3548	03 6233 4141	Warwick.nash@dpiwe.tas.gov.au
Frances Ruwald Inland Fisheries Comm. PO Box 288 MOONAH TAS 7009	03 6233 8756	03 6233 4141	Fruwald@ifc.tas.gov.au
Ian Lyall Locked Bag 9 NSW Fisheries PYRMONT NSW 2009	(02) 9566 7842	(02) 9566 6627	Lyalli@fisheries.nsw.gov.au
Phil Boxall Inland Fisheries Comm. PO Box 288 MOONAH TAS 7009	03 6233 8756	03 6233 4141	
Don Jellyman NIWA PO Box 8602 RICCARTON, CHRISTCHURCH NZ	0011 64 3 348 8987	0015 64 3 348 5548	d.jellyman@niwa.cri.nz

Sean Kerin TE OHU KAI MOANA PO Box 3277 WELLINGTON, NZ	0011 64 4 499 5199	0015 64 4 499 5190	Sean.kerin@tokm.co.nz
Dr Peter Todd Ministry of Fisheries Private Bag 14 NELSON, NZ	0011 64 3 548 1069	0011 64 3 546 9327	toddp@fish.govt.nz
Dr Bruce Pease NSW Fisheries 202 Nicholson pde CRONULLA, NSW	02 9527 8411		Peaseb@fisheries.nsw.gov.au

Attachment 2 - Australia-New Zealand Eel R&D Workshop delegates (present and invited)

Chair

Patrick Hone, FRDC
Geoff Gooley, MAFRI

Victoria

Roger Camm, industry
Ron & Sharon Elton, industry
Louis Vorsterman, industry
Barry Dance, industry
Bill Allan, industry
Anthony Forster, government
David Molloy, government

NSW

Karl Tesar, industry
Bruce Pease, government
Nick Lambert (apology)

Tasmania

Frances Ruwald, government
Warwick Nash, government
Nigel Forteath, industry
John Ranicar, industry

Queensland

John Olsen, industry
John Ranicar, industry
Clive Jones, government

Attachment 3 - Background/explanatory notes on the Draft R&D Plan

Relevance

Reference to the geographic areas, sectoral interest and degree of relevance for each issue/project topic:
State - Tas., Vic, NSW, Qld, all
Region - Aust., NZ, all

Publ – public/community (interest/good)
Priv. – private/commercial (interest)
Both – both public and private imperatives

High – highly relevant to above
Med. – of medium relevance to above
Low – of low relevance to above

Feasibility

Reference to the relative feasibility of successfully undertaking/completing R&D in the specified issue/topic:
High – high scientific/technical/practical/logistic feasibility (elaborate if necessary)
Med. – medium scientific/technical/practical/logistic feasibility (elaborate if necessary)
Low - low scientific/technical/practical/logistic feasibility (elaborate if necessary)

Status

Reference to how much work already undertaken or in progress in the specified issues/topic:
No prog. – no progress; research yet to commence or existing research experience not contemporary (elaborate if necessary)
U'way – research underway, either in part and/or incomplete (elaborate if necessary)