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Opportunities for finfish stock enhancement and restocking in Western Australia

By Neil Loneragan[1], Greg Jenkins[2] and Matt Taylor[3]

[1]Professor Neil Loneragan, Director, Centre for Fish and Fisheries Research, School of Biological Sciences and Biotechnology, Murdoch University, South St, Murdoch, Western Australia

[2]Mr Greg Jenkins, Director, Australian Centre of Applied Aquaculture Research, Challenger Institute of Technology, Fremantle, Western Australia

[3]Dr Matt Taylor, Lecturer in Applied Marine Ecology, School of Biological Earth and Environmental Science, University of New South Wales, UNSW, 2052

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1. EXECUTIVE SUMMARY AND RECOMMENDATIONS

The Aquaculture Development Council (ADC) required the development of a paper outlining the opportunities for finfish stock enhancement in Western Australia and that considered the potential benefits and risks associated with these opportunities and advise on risk mitigation strategies. This report has examined the potential benefits and risks of stock enhancement for different aquatic systems, considered the current status of stock enhancement and restocking globally and around Australia, and examined opportunities for stock enhancement/restocking in Western Australia. In particular, it has investigated the potential for: 1) barramundi stocking in Lake Argyle and Lake Kununurra; and 2) a suitable temperate, marine species in the metropolitan region. In this report, we have also identified the current opportunities and species to consider for future restocking/stock enhancement. The authors of this report cover the disciplines of fisheries ecology (Loneragan and Taylor) and aquaculture (Jenkins) and have extensive experience in research and development programs for restocking/stock enhancement. All are members of the International Scientific Committee for the 4th International Symposium for Stock Enhancement and Sea Ranching (ISSESR) to be held in China in 2011. This committee is chaired by Professor Loneragan at Murdoch University.

Restocking and stock enhancement both involve the release of juveniles of indigenous species into aquatic environments. Although many trials have taken place over the last 100 years, the science of restocking and stock enhancement in marine and estuarine environments is a relatively new and rapidly evolving area of applied ecological science. For example, it was only in 2008 that definitions for restocking, stock enhancement and sea ranching in the marine environment were proposed. Restocking and stock enhancement have been defined by Bell *et al.* (2008) as:

*“**Restocking** - the release of cultured juveniles into wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields. ...*

***Stock enhancement** - the release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation.*”

Restocking may also involve re-establishing a commercial species where it is locally extinct due to overfishing, or the release of juveniles reared in ‘conservation hatcheries’ to help restore endangered or threatened species. Stock enhancement attempts to overcome recruitment limitation is common for many coastal species with pelagic larvae in open ecosystems, even when spawning biomass is at the desired level (Bell *et al.*, 2008).

Stock enhancement and restocking have been carried out at very large scales for over 30 years in Japan and China (sections 3 and 4). Although the scale of juvenile releases into marine environments in other countries has been very much less than in Japan and China, many countries have release programs, particularly for recreational fisheries (Section 4). In Australia, the scale of restocking and stock enhancement in marine environments has been low compared with other countries (Sections 4 and 5). However, significant investment has been made in research and development programs for the release of a variety of species and current research and development activities are being carried out in New South Wales (mulloway and eastern king prawns), Queensland (barramundi) and Western Australia (abalone and black bream). Furthermore, Victoria is developing a plan for releasing juveniles in estuarine and marine environments and South Australia has a policy for these activities.

Key elements of effective programs for research and development on the release of juveniles into marine and estuarine environments are summarised in Sections 3 and 4. They involve engagement with stakeholders to establish a steering group for these programs that evaluates research objectives and priorities, the progress of research and enhancement itself, and provides overall guidance to the program. Research programs also need to be multi-disciplinary and modelling approaches have provided significant advances in understanding restocking/enhancement systems. Modelling has been essential for evaluating the potential success of releases in many cases, and is often coupled with empirical monitoring programs for evaluation purposes.

The main risks from the release of juveniles into marine and estuarine environments include impacts on the genetic diversity of the released species in the wild, potential for the introduction of disease to wild populations and ecological impacts on the target stocks and marine environment. These risks are discussed in both sections 4 and 5 and protocols for minimising the risks are also identified. These protocols, particularly for genetics and disease, have been well developed in Western Australia around the major research and development program for tiger prawns *Penaeus esculentus* in Exmouth Gulf and black bream *Acanthopagrus butcheri* in the Blackwood River Estuary. There is also potential for the transfer of existing research findings from the east coast of Australia to the western king prawn *Penaeus latisulcatus,* mulloway *Argyrosomus japonicus*, and barramundi *Lates calcarifer*. The Western Australian Department of Fisheries has played a significant role in developing these protocols for WA species, particularly for disease, through the work of Dr Brian Jones and his group.

Western Australia has significant capacity in research and development for the release of cultured juvenile fish into aquatic ecosystems. The Challenger Institute of Technology is recognised as a leading provider of applied aquaculture research and training in Australia. Staff and students from Murdoch University's Centre for Fish and Fisheries Research have made major contributions to understanding the biology and population dynamics of many species found in the metropolitan waters of the Perth region. The Western Australian Department of Fisheries has been involved in research on enhancement in estuarine, marine and freshwater environments (mainly stocking). Currently, as in several other states, WA does not have a policy for restocking/stock enhancement. The effectiveness of the capacity in WA has been demonstrated in a collaborative, multi-disciplinary program between Challenger Institute and Murdoch University to trial the restocking of black bream in the Blackwood River estuary. This program of research and development has received recognition at international (3^{rd} International Symposium on Stock Enhancement and Sea Ranching 2006) and national (RecFish Australia award, 2007) levels; and in Western Australia (WA Fishing Industry Council Environmental Award, 2010).

1.1 Recommendations

The background and justification for the recommendations in this report are provided in detail in Section 5. These recommendations are summarised below.

Recommendation 1: Restocking barramundi into Lake Argyle (section 5.2.1)
We recommend that a restocking program be implemented for barramundi in Lake Argyle. This program should follow the guidelines for culture, production, release and monitoring described in section 5.2.1. One of these guidelines is that prior to any releases, a working group of stakeholders and collaborators should be established to set objectives, evaluate progress and guide the program.

Recommendation 2: Candidate species for restocking in temperate waters (section 5.3.1)
We recommend that a steering group is established to evaluate the potential and develop approaches necessary for a trial restocking program of pink snapper in Cockburn Sound. This group should 1) review data on pink snapper and stocking of similar species elsewhere to identify knowledge gaps, 2) use existing information to evaluate the potential for restocking using a model such as EnhanceFish (which provides a cost-benefit analysis) and 3) trial techniques for the production and marking of small, juvenile pink snapper (e.g. strip spawning of snapper, culturing fertilised eggs and harvest/transport and release of juveniles) and their release into Cockburn Sound. A collaboration should be established with recreational fishers to monitor the success of the program, reduce costs, and enhance understanding of the program and fish stock assessment in general.

Recommendation 3: Research on species for future restocking (section 5.3.2)
We recommend that funding is made available to the WA Fish Foundation to investigate the feasibility and further develop aquaculture/restocking techniques for additional species of recreational interest. These species include King George whiting, mulloway and WA dhufish. This funding could be used to develop proposals to leverage funding from other sources such as FRDC or ARC linkage.

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3. DEFINITIONS AND STATUS OF STOCK ENHANCEMENT AND RESTOCKING

Managers of fisheries worldwide are searching for sustainable ways to restore depleted stocks and increase production to help meet the projected global demand for fish and shellfish, which is expected to increase by 1.5% each year over the coming decades (Bell *et al.* 2008). Solutions to the dilemma of declining spawning biomass include incentives to reduce fishing capacity and effort, and protect and repair fish habitats. However, there is debate about the potential for recovery of capture fisheries, and what restored fisheries would look like (see Bell *et al.* 2008). Aquaculture will need to be integrated with capture fisheries to achieve harmonious co-development of the supply chain (Muir and Young, 1998; Garcia and Grainger, 2005). This is particularly true for coastal waters, which have considerable potential for aquaculture.

The opportunity to apply hatchery technology to restore and augment some coastal fisheries through the release of cultured juveniles has been seen as a promising synergy between aquaculture and wild fisheries to rebuild and increase production. Similar interventions have long been used in the management of freshwater fisheries (Cowx, 1994). Interest in the release of cultured juveniles as a possible management tool for coastal fisheries was rekindled by the advent of methods for producing robust juveniles at reasonable cost. Japan spearheaded such initiatives in the 1970s and 1980s (Honma, 1993; Imamura, 1999). However, by the early 1990s, the number of other countries involved merited launching a series of international symposia to share experiences and promote responsible practice and the scale of aquaculture and release of juveniles in China now far exceeds that in any other location of the world (Bell *et al.*, 2008).

The field of marine restocking and stock enhancment is an evolving research discipline, flowing from the publication on responsible approaches to stock enhancement (Blankenship and Leber 1995) and the First International Symposium on Stock Enhancement and Sea Ranching (ISSESR) in Norway in 1997 (Bell *et al.*, 2008). The 1st and 2nd ISSESR (Japan in 2002) were instrumental in developing methods for the mass-production of environmentally fit juveniles, and for releasing them in responsible ways. The 3rd ISSESR, held in the U.S.A. in 2006 (www.searanching.org), marked a new phase in the discipline, with some major advances from the previous symposia, including: 1) definitions of the various objectives for releasing cultured juveniles (restocking, stock enhancement and sea ranching); 2) a framework for integrating releases within their fisheries management context, including tools for quantitative assessment; 3) a systematic, transparent and stakeholder-participatory planning process to determine whether releases have a cost-effective role to play in managing a fishery; 4) a comprehensive case study (blue crabs in Chesapeake Bay) describing the multi-disciplinary approach needed to evaluate the potential benefits of releases; and 5) a suite of other lessons to guide stakeholders in evaluating the potential for, and implementation of, releases. The papers in the Special Issue of Reviews in Fisheries Science (2008, Volume 16) elaborate on how restocking, stock enhancement and sea ranching programs can create synergies between aquaculture and some coastal fisheries to help meet the future demand for seafood, and aid in restoring depleted stocks.

3.1 Definitions and status of restocking and stock enhancement

Until very recently, the terms ‘stocking’, ‘restocking’, ‘stock enhancement’, ‘supplementation’, ‘sea ranching’, ‘sea farming’, ‘reseeding’, ‘culture-based fisheries’ or just ‘enhancement’ have often been used interchangeably to describe management interventions in coastal fisheries as disparate as: i) restoring spawning biomass to target levels where severe overfishing has occurred, ii) increasing the supply of juveniles to stabilize production, and iii) increasing yields through ‘put, grow and take’ operations. This shortcoming was recognised at the 3rd ISSESR and the following definitions were developed by Bell *et al.* (2008) for the three main objectives of releasing cultured juveniles of indigenous species to help manage coastal fisheries.

> ***“Restocking*** *- the release of cultured juveniles into wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields.* This may also involve re-establishing a commercial species where it is locally extinct due to overfishing, or release of juveniles reared in ‘conservation hatcheries’ to help restore endangered or threatened species.
>
> ***Stock enhancement*** *- the release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation.* Note that recruitment limitation is common for many coastal species with pelagic larvae in open ecosystems, even when spawning biomass is at the desired level (Doherty, 1999; Bell *et al.*, 2005).
>
> ***Sea ranching*** *- the release of cultured juveniles into unenclosed marine and estuarine environments for harvest at a larger size in ‘put, grow and take’ operations.* Note that the released animals are not expected to contribute to spawning biomass, although this can occur when the size at harvest exceeds the size at first maturity, or when not all the released animals are harvested.”

Stock enhancement attempts to overcome recruitment limitation, while in essence, sea ranching uses the release environment of the estuary or coastal waters as a “grow-out pond”. For example, in some areas in China where shrimp are released, no catch is taken by the fishery when releases are low or no releases are made – although this has been referred to as enhancement, from the definitions above, it is in fact a case of sea ranching.

Stocking refers to the translocation of a species outside its natural range and placing it into a water body where it has not naturally occurred i.e. it applies to the release of introduced species in locations where they were not previously found.

Large scale releases of juvenile fish and invertebrates exceeding 100 million have only been carried out in Japan and China (Bell *et al.*, 2005, 2008). These large scale releases started in Japan in the 1970s and in China in the 1980s. The scale of most other releases worldwide has been less than 10 million juveniles and often closer to one or two million fish.

3.2 Approaches to stock enhancement and restocking

Until recently, little attention has been paid to defining clear objectives for producing and releasing juveniles and identifying different stages in the release program (Loneragan *et al.*, 2004; Bell *et al.*, 2005, 2006, 2008). In many cases, releases have been driven from a production imperative, rather than from a fisheries management perspective (Lorenzen, 2008). As a result, few releases of cultured juveniles have helped to optimise the production from coastal fisheries resources. The most celebrated exception is the stock enhancement of scallops in Japan, although similar success stories are also emerging from China for shrimp, scallops and sea cucumbers (Bell *et al.* 2005; 2008).

The definition of the objectives for the release of juveniles requires a strong engagement with stakeholders (Lorenzen, 2008). A number of recent studies have adopted this approach in defining the objectives of tiger prawn *Penaeus esculentus* enhancement in Western Australia (Loneragan *et al.* 2004), scallop enhancement in New Zealand (for overview see Lorenzen 2008), blue crab *Callinectes sapidus* enhancement in Chesapeake Bay (Zohar *et al.* 2008) and red drum *Scianus oscellatus* enhancement in Florida (Tringali *et al.* 2008). For example, an objective of increasing the catches of tiger prawns in Exmouth Gulf by 25% (100 tonnes) was established by the Steering Committee for this project (MG Kailis, Department of Fisheries WA, CSIRO Marine and Atmospheric Research) and this target helped define the scale of production and releases required to achieve the target (Loneragan *et al.*, 2003, 2004). In this program, four discrete stages in the enhancement were identified: 1. Evaluating the potential for enhancement; 2. Developing approaches and technologies for enhancement; 3. Pilot scale enhancement (releases of 1 to 3 million juvenile prawns) and 4. Commercial scale enhancement to achieve a 25% increase in catch (releases of 20 million juvenile prawns) (see also sections 4 and 5).

Increased catch is one performance measure that can be used to evaluate the success of a release program for restocking or stock enhancement. Lorenzen has defined a broad suite of performance indicators that can be applied to a release program covering the broad categories of biological production, biological resource conservation, economic benefits and costs, contribution to livelihoods, institutional sustainability, and broader ecosystem sustainability (Table 2 in Lorenzen, 2008). The indicators used to evaluate the performance of releases are likely to differ between commercial and recreational fisheries and between stock enhancement and restocking programs. The development of these indicators was based on considering the release of cultured juveniles as part of a complex system that incorporates the biology of the release species, the dynamics and behaviour of the fishery, the characteristics of the production system, the environment and habitat of the releases, the stakeholders of the fishery, the market attributes and the institutional arrangements (termed the situational attributes of the enhancement system). Lorenzen identified that the outcomes of the release program are influence by the dynamics of both the biological and environmental variables but also the response of stakeholders to the fishery and management arrangements of the fishery, including the release program, particularly whether the program will be sustainable in the future (Figure 1 of Lorenzen, 2008). He states that enhancements need to add value to, or outperform, alternative measures such as fishing regulation or habitat management.

Lorenzen also developed a framework for developing or improving fisheries release programs (Figure 2 of Lorenzen, 2008). The first step in the process is to engage with the stakeholders and then identify the status of the different components of the system or the "situational variables". This is followed by a quantitative assessment of the potential for a release program to be successful and a decision on whether to proceed with releases. If releases are made, the success of the release is evaluated and a decision made on whether to continue the program. Stakeholders are involved in all parts of the decision making process. The development of models for release programs has played an important role in guiding research and evaluating success (Ye *et al.* 2005; Loneragan *et al.*, 2006, Lorenzen, 2008; Taylor and Suthers, 2008).

3.3 Scope of this report

The Aquaculture Development Council (ADC) of Western Australia required the development of a paper outlining the opportunities for finfish stock enhancement in Western Australia (see Appendix 1 for the Consultants Brief). This paper was also to consider the potential benefits and risks associated with these opportunities and advise on risk mitigation strategies. In particular, the ADC asked that we investigate opportunities for:

1) barramundi stocking in Lake Argyle and Lake Kununurra; and
2) a suitable temperate, marine species in the metropolitan region.

In this report, we have also identified the current opportunities and species to consider for future restocking/stock enhancement in temperate Western Australia.

The potential benefits and risks of stock enhancement/restocking and the current situation around Australia are summarised in Section 4. This section includes a brief summary of the situation in Western Australia, which is described in greater detail in Section 5. This section also investigates the potential for stocking barramundi and a temperate marine species and makes recommendations on their potential. Stocking, restocking and stock enhancement are considered in freshwater, estuarine and marine environments in both Sections 4 and 5 of the report.

4. POTENTIAL BENEFITS AND RISKS OF STOCK ENHANCEMENT

The potential risks and benefits of stock enhancement and restocking are broadly applicable, although the way in which they perpetuate are often not only ecosystem specific, but also site specific (Taylor *et al.*, 2009). There are several examples in the literature that clearly demonstrate the nature of ecological problems caused by fish releases, and factors that contribute to poor economic outcomes from release events. Developing programs are able to draw from these examples to refine how fish releases are approached to minimise the risks to the receiving systems, and maximise the benefits to the fishery. The specific risks and benefits associated with stock enhancement and restocking are discussed below for three generic ecosystems that are abundant in Western Australia.

4.1 A synopsis of fish releases in Australia from 1861 - present

4.1.1 Freshwater systems

Releases of hatchery-reared fish into freshwater impoundments and rivers have been undertaken throughout the world for many centuries, and many individual programs release millions of fish into freshwaters every year (Hilborn and Winton, 1993). Releases of fish into Australian freshwaters commenced in 1861 with the introduction of salmonids in Tasmania (Dix, 1987). Releases rapidly expanded to other states as aquaculture technology developed, firstly with salmonids, and then with other non-native and native species. The expansion of fish releases over 150 years has led to development of inland recreational fisheries that are completely reliant on stocking, and the subsequent development of communities which rely on these fisheries and the associated economic input. This has produced a situation in many Australian jurisdictions where repeated 'introductions' of hatchery reared fishes are accepted, encouraged and commonplace. Over this time, self-sustaining populations of introduced species have also established, such as brown trout *Salmo trutta* and European carp *Cyprinus carpio* in south-eastern Australia (Kailola *et al.*, 1992).

Whilst releases of introduced species cannot readily be classed as either stock enhancement or restocking, many releases of native fish species fulfil these purposes in response to recruitment limitations arising from drought, barriers to fish passage, or lack of spawners. Some inland releases of native fish, however, lack either justification or any evidence of success (Lintermans, 2006). Releases of native fish in Australia include programs specifically aimed at recovery of threatened species, such as releases of Murray cod *Maccullochella* sp. (Lintermans, 2006). In NSW, releases of threatened species are considered separately to releases of native and introduced species, and other releases are not allowed in the vicinity of populations of endangered species (NSWF, 2004).

The history and current status of freshwater releases in Western Australia are summarised in section 5.1 below. Like other states in Australia, Western Australia has a long history of stocking introduced species into freshwater systems, starting with rainbow and brown trout in 1870 (for details, see section 5.1).

4.1.2 Marine and estuarine releases

The enhancement of marine fisheries in Australia is still in its infancy and at present no ongoing marine finfish-stocking programs are in place. All scale fish releases in Australia have been confined to semi-open and closed systems such as estuaries, whilst invertebrate releases are principally concentrated in open marine systems, with a few exceptions. Many of these intentional releases have not been monitored effectively, and limited information exists on the outcomes of some of these projects. Several of the larger projects were monitored throughout all stages, and provide valuable insight into the development, execution, and assessment of stock enhancement in Australia. Marine fish releases and the outcomes of monitored projects are reviewed here, for each Australian state.

4.1.2.1 New South Wales

Mulloway (*Argyrosomus japonicus*) have been the main focus of fish releases in NSW since 1995. An FRDC funded project aimed to both develop intensive and extensive rearing techniques and assess the feasibility of releasing fish (Fielder *et al.*, 1999). This project was successful in rearing large numbers of mulloway in good condition in 1 ha earthen outdoor ponds. Approximately 75,000 hatchery reared fish were labelled with oxytetracyclene (OTC) and released into three shallow coastal lagoons on the New South Wales coast (<5 m deep, <10 km^2 area). Releases completely failed in two of the lagoons, due to emigration and predation; however, fish did survive and recruit to the commercial and recreational fishery 18 months after release in Smiths Lake (Taylor *et al.*, 2009). Fish grew at around 1 mm d^{-1} regardless of season, and recaptured fish were successfully verified as of hatchery origin by OTC marks in the otoliths of these fish. The initial releases in Smiths Lake were replicated in 2003 and 2004, with little success and negligible recruitment to the fishery (Taylor *et al.*, 2009). The later stage of the project expanded to enhance recreational fisheries in riverine systems. These projects had an emphasis on matching release density and techniques to resource availability and requirements (Taylor *et al.*, 2006a; Taylor *et al.*, 2006b; Taylor and Suthers, 2008; Taylor and Mazumdar, in press). Stocked mulloway in these systems had impressive survival and recruitment to recreational fisheries, and currently up to 20% of the entire recreational fishery in the Georges River originates from fish releases between 2003 and 2008. The impressive outcomes from these releases are attributed to optimising release strategies, and ensuring adequate trophic and habitat resources are available to support stocked fish. The model used to estimate release density on the basis of ecological resources (Taylor and Suthers, 2008), is now available in a generalised format and can be applied to any scale fish or invertebrate species (Taylor *et al.*, In preparation). The model also estimates probability distributions for predatory impact, and harvest of stocked resources.

The second major marine release program investigated the release of eastern king prawns (*Penaeus plebejus*) into NSW coastal lagoons. Over the course of the project, approximately 10.5 million eastern king prawn post larvae were released into Back Lake and Wallagoot Lake in three separate events (Taylor, 2008). The project aimed to optimize release densities, optimize survival, and assess environmental impacts of prawn releases. Releases commenced in January 2007 and concluded in December 2008, and the results from theses releases have critical information to improve the outcomes from releases. Firstly, king prawn postlarvae actively select structured aquatic macrophyte habitat after release (Ochwada *et al.*, 2009), where their survival from certain predators is higher than on bare substratum (Ochwada *et al.*, in press). Wild eastern king prawns were also found to out-compete stocked prawns for shelter from predators within structured habitat such as macrophyte beds (Ochwada *et al.*, In preparation), but wild and stocked prawns had equal competitive abilities for food within these habitats. Prawns were released at low densities relative to other projects (< 5 prawns per square meter, see Bell *et al.*, 2005), and the three stocking events resulted in a harvest of ~10 tonnes by the recreational fishery. The effect of predation by prawns released at these low densities could not be separated from the cyclic seasonal changes in abundance of key invertebrate prey.

After the relative success of these two pilot projects, NSW is currently developing a large scale program to release dusky flathead *Platycephalus fuscus*, mulloway, eastern king prawns, mud crab *Scylla serrata*, blue swimmer crabs *Portunus pelagicus*, sand whiting *Sillago ciliata* and yellowfin bream *Acanthopagrus australis*. A full-scale Environmental Impact Assessment, including risk assessment and cost benefit analyses, is currently underway for this program. Releases and pilot investigations of previously unstocked species are likely to commence in 2011, funded with proceeds from the NSW Recreational Fishing Licence.

4.1.2.2 Victoria

A trial stocking of marked black bream (*Acanthopagrus butcheri*) was undertaken in the Gippsland Lakes by the Victorian Department of Primary Industries in 2004. The aim of this stocking was to assess the technical feasibility and possible benefits of enhancement for recreational fisheries. Since then, no further release trials have been undertaken in Victoria. However, planning is underway to develop an estuarine release program for mulloway, dusky flathead, sand flathead *Platycephalus bassensis*, eastern king prawn, black bream *Acanthopagrus butcheri* and estuary perch *Macquaria colonorum* (Taylor, 2010). The next stage in the development process will involve a full-scale Environmental Impact Assessment, including risk assessment and cost benefit analyses, prior to any pilot releases being undertaken.

4.1.2.3 South Australia

There have been no deliberate releases of marine organisms in South Australian waters to date. A policy on stock enhancement for South Australia is currently being developed by Primary Industries and Resources of South Australia (PIRSA). A draft management paper entitled “Release of Cultured or Translocated Aquatic Organisms (Stock Enhancement)” is currently undergoing final revision.

4.1.2.4 Western Australia (for greater detail see Section 5)

Hatchery-reared black bream (*Acanthopagrus butcheri*) have been released across numerous estuaries for the last 15 years. Releases into the Upper Swan River and Blackwood estuary aimed to determine survival, growth and recruitment to the recreational fishery (Lenanton *et al.*, 1999; Dibden *et al.*, 2000). These releases have shown that up to 12% of tagged fish were recaptured by anglers in three years post release, and that recaptured fish can show faster growth relative to wild fish cohorts in the same estuary. Some smaller marine scale fish releases have been undertaken elsewhere, including snapper (*Pagrus auratus*) releases in Shark Bay.

Marine releases in Western Australia have focused on invertebrate species, with releases aimed at actual enhancement of stocks (as opposed to primary research). Such releases have included saucer scallops (*Amusium balloti*), greenlip abalone (*Haliotis* *laevigata*) and trochus (*Tectus niloticus*) in different regions within the State. The largest invertebrate stock enhancement study in Western Australia involved the release of brown tiger prawns in Exmouth Gulf. This program aimed to develop release technology of *P. esculentus* to provide a fishery enhancement of 100 tonne per year, which was determined from the requirements of industry managers and an estimation of the carrying capacity of Exmouth Gulf (Loneragan *et al.*, 2004). This project involved comprehensive information regarding the species, habitat, and ecology; and developed novel aquaculture technology for the species (Loneragan *et al.*, 2003). Data were used both to develop release strategies and to develop a bioeconomic model to help focus larger scale releases. Modelling predicted that a release of 21 million x 1 g prawns would produce the estimated enhancement target of 100 t to prawn harvest in Exmouth Gulf, and this release scenario had ~67% probability of being profitable i.e. having a cost: benefit ratio of > 1 (Ye *et al.*, 2005). Modelling and empirical measurements suggested the greatest uncertainty in the outcome from large scale stock enhancement for the fishery was the post-release mortality of released prawns, and density dependent mortality caused by released prawns. The rates of mortality in stock enhancement, such as those presented in this study, are difficult to estimate in practice (Ye *et al.*, 2005).

4.1.2.5 Northern Territory
Marine stocking in the Northern Territory involved releases of barramundi *Lates calcarifer* fingerlings in Darwin Harbor and the Howard River, however there was no marking or monitoring carried out of these fish.

4.1.2.6 Queensland
Barramundi (*Lates calcarifer*) have been released in impoundments since 1986, and in open systems since 1993 (Rimmer and Russell, 1998). Impoundment releases were undertaken to develop inland recreational fisheries where stocked fish did not reproduce naturally, and over 21 million fingerlings have been released in impoundments. These releases have led to the establishment of substantial inland recreational barramundi fisheries.

Barramundi releases in open systems have developed through an experimental approach over the previous two decades. Initial releases in the Johnstone River in far north Queensland aimed to provide information on survival and cost-benefit, and included releases of 110,000 coded-wire tagged fish, 30-300 mm in length, between 1993 and 1999 (Russell *et al.*, 2004). From the initial mark-recapture experiments, size-at-release did not affect the probability of recapture (Rimmer and Russell, 1998). However, later releases showed that survival was greatest for 300 mm long fish in the upper estuary (Russell *et al.*, 2004). Cost-benefit analyses indicated that to recover the costs associated with the releases, as few as 0.8 % of the 30 mm released fish would need to be recaptured (Rimmer and Russell, 1998), compared with 9.8 % of the 300 mm fish (Russell *et al.*, 2004);

The Maroochy Estuary fish-stocking program is the largest marine scale fish stocking program undertaken in Australia to date, where 432,000 sand whiting (*Sillago ciliata*) and dusky flathead (*Platycephalus fuscus*) were released over three years (Butcher *et al.*, 2000). This study included a substantial initial phase where aquaculture technology to rear large numbers of fingerlings was developed. Following the development of this technology, releases were undertaken with a comprehensive monitoring program to assess the effectiveness of stocking. Post-stocking mortality after one month was as high as 67%, but this was minimised by refining the release techniques. Contribution to the commercial catch peaked at 28% and 52% for *P. fuscus* and *S. ciliata* respectively, with fish identified using scale circuli analysis (Butcher *et al.*, 2003). Cost-benefit analyses indicated that the estimated cost of each fish caught was about 680% of the retail value, and the project failed to show any increase in population size over the numbers estimated prior to stocking.

Several invertebrate species have been released in Queensland waters in an effort to enhance fisheries catches, but there have been no comprehensive monitoring programs associated with any of these releases. The species released include the pearl oyster (*Pinctada* spp.), saucer scallop (*Amusium japonicum balloti*), edible oyster (*Saccostrea* spp.) and various species of sea cucumbers.

4.1.2.7 Tasmania

Tasmania has undertaken invertebrate stocking projects, mainly on the sea urchin (*Heliocidaris erythrogramma*), southern rock lobster (*Jasus edwardsii*), blacklip abalone (*Haliotus rubra*) and the greenlip abalone (*Haliotus laevigata*). Excluding sea urchins, these projects all included a research component and currently, scallops and sea urchins are farmed commercially in Tasmania. Much of the enhancement work on *J. edwardsii* represents innovative approaches to improve the economic output of the lobster fishery. For example, reseeding of *J. edwardsii* juveniles was undertaken to compensate for puerulus collected from the wild for aquaculture. Modelling suggested that where survival in culture was high and production costs low, reseeding was a cost effective option for both aquaculture and wild fisheries (Gardner *et al.*, 2006). This research program has also shown how the translocation of rock lobsters from slow-growth to fast-growth areas increased yield by achieving faster growth and producing a more marketable product (Gardner and Van Putten, 2008).

4.2 Risks and benefits of stock enhancement and restocking

4.2.1 Genetic risks

The relatively small spatial scales at which divergent fish populations could develop became apparent in the early 1990s. In freshwater systems, current information confirms that genetic variation can vary between catchments, and even within the same catchment; and stock enhancement or restocking has the potential to alter the genetic structure of wild populations in the receiving system (Ryman and Laikre, 1991). Biogeographic boundaries, often between different freshwater systems and isolation within these different biogeographic regions, can lead to locally adapted genotypes. This can occur through a number of mechanisms, including differing community composition (Kodric-Brown and Brown, 1993), such as different predator assemblages; or other abiotic differences such as temperature and rainfall; and simple geographic isolation. In Western Australia there is a high degree of species endemism in freshwater fishes (Unmack, 2001). This supports the presence of biogeographic boundaries throughout Western Australia, which contributes to the development of localised genotypes.

Releasing fish into such systems, where there is a high probability of localised genetic structure, means that the translocation of genes from outside the receiving biogeographic region could lead to an outbreeding depression and the loss of particular genotypes that are advantageous in each specific environment (Ward, 2006). The translocation of exogenous genotypes into native populations through hatchery releases and their introgression, can adversely affect the fitness of the wild freshwater populations. Genetic problems may be further exacerbated where hatchery populations come from a low number of founder individuals and thus may have low genetic diversity. The risk of adverse genetic effects through these mechanisms is greater when the receiving wild population level is already depressed prior to enhancement (Molony *et al.*, 2003).

The genetic risks of releases can be managed for freshwater populations in the following ways. Generally, an adequate number of effective breeders should be used to produce fingerlings for release, as for marine systems discussed below. Potential translocation issues can be addressed by obtaining broodstock from the receiving population. However, the existing populations of some freshwater fishes are relatively small. If this is the case, the use of too few individuals for broodstock may produce a hatchery population with low genetic diversity, which in turn may adversely affect the genetic integrity of the receiving population. This paradox has been debated in numerous articles in the literature. The basic consensus is that non-destructive sampling needs to be used to determine the genetic structure of the population (by DNA based methods), the genetic identity of the broodstock needs to be determined to assess whether it adequately represents the diversity in the population (Emlen, 1991), and broodstock should be returned to the population after spawning and before domestication takes place.

Marine and estuarine systems are generally open ecosystems and the lack of physical barriers to migration means that exchange amongst populations occurs more regularly than in freshwaters. Typically, populations in marine and estuarine systems are more genetically homogeneous than freshwater/diadromous species and show less evidence for stock separation (Blankenship and Leber, 1995). Mulloway, *Argyrosomus japonicus*, an estuarine and coastal species throughout southern Australia from Western Australia to Queensland, exhibit large panmictic populations (Black and Dixon, 1992), with differentiation only likely across large geographic scales (e.g. between Western Australia and South Australia). *Acanthopagrus butcheri* is another widely distributed estuarine species that is released for stock enhancement and although the species is less genetically homogeneous than *A. japonicus*, there is still frequent gene flow amongst estuarine systems (Burridge and Versace, 2007), except in the estuaries of Western Australia. Barramundi, *Lates calcarifer*, is released throughout Australia from north Queensland to Western Australia and also in warm water impoundments in Victoria. Within its natural range, barramundi exhibits clear genetic differentiation :(Shaklee and Salini, 1985; Salini and Shaklee, 1988); however, releases undertaken in natural or man made impoundments outside the natural distribution precludes genetic considerations as they are essentially species introductions.

As with freshwater systems, stock-specific management practices should be incorporated in stock enhancement programs for species that show geographic population differentiation (Shaklee *et al.*, 1993), to maintain specialized genotypes in the receiving population. An important consideration in developing stock enhancement of these species is close monitoring of the effective size of the hatchery broodstock population. For example, for *L. calcarifer* releases in northern Queensland, only broodstock taken from the genetic subdivision in which the receiving population lies (Shaklee and Salini, 1985) should be used to produce juveniles for release. Responsible genetic resource management includes several elements, many of which should be applied in the planning stage of the release program (Blankenship and Leber, 1995; Taylor *et al.*, 2005). These include: 1) Identifying the genetic risks and consequences of enhancement; 2) Defining an enhancement strategy; 3) Outlining research needs and objectives; and 4) Developing a feedback mechanism. The final element involves implementing genetic controls in the hatchery and a monitoring and evaluation program, which is difficult for a number of reasons.

Aquaculture facilities in Australia are limited in size and number and maintenance of an acceptable effective breeding number breeders (100 and 200 breeders with an equal sex ratio, Bartley *et al.*, 1995) as broodstock lies outside the capabilities of many Australian operators. There are three potential solutions for this:

1. Strip spawning of wild individuals may be feasible for some species (e.g. red drum and black bream, Colura *et al.*, 1990; Haddy and Pankhurst, 2000), depending on the ease of capture and response of the species to handling;
2. If the species is found in panmictic populations across broad geographic ranges, collaborations among hatcheries for broodstock holding and maintenance may help alleviate some of the financial burden associated with holding an adequate number of effective breeders
3. A 100% exchange of broodstock on an annual basis may reduce the number of adult fish that need to be held.

4.2.2 Disease risks

The translocation of marine animals from hatcheries into the receiving environment may provide a vector for the spread of diseases and pathogens. Many viruses, bacteria, fungi and parasites exist in the wild but are not pathogenic in normal circumstances. In fact, most diseases that proliferate in the hatchery environment originate in the wild. The disease risks associated with stock enhancement and restocking are generally similar among freshwater, marine and estuarine systems. The release of diseased fish has the potential to infect wild stocks, which may lead to further damage to already threatened populations (Bakke *et al.*, 1990). Disease is occasionally prevalent in hatchery environments, as high organic or waste loads and high densities of organisms in enclosed systems can allow bacteria, viruses, and, , protozoans to proliferate. In addition, frequent handling of fish in the hatchery environment increases the vulnerability of fish to pathogens. The treatment of bacterial infections can be compromised by antibiotic resistance in bacteria, which may arise through regular use of substances such as oxytetracyclene (Taylor *et al.*, 2005).

Taylor *et al*. (2005) reviewed the prevalence of diseases in Australian finfish aquaculture. Several finfish specific viruses affect Australian species, including herpes virus in *Sardinops sagax neopilchardis* and flounder *Rhombolsolea tapirina*; and nodavirus in *L. calcarifer* (Munday and Owens, 1998), Australian bass *Macquaria novemaculeata* and mulloway *A. japonicus*. Several diseases present in invertebrate aquaculture in Australia may pose a risk to wild invertebrate populations through fish releases, as reviewed by Munday and Owens (1998) and summarised below. Sydney rock oyster (*Saccostrea glomerata*) contracts QX disease as a result of infection by the pathogen *Marteilia sydneyi* (Roubal *et al.*, 1989). Papova virus has been detected in Pacific oyster *Crassostrea gigas* and pearl oyster *Pinctada maxima* and herpes virus in flat oyster *Ostrea angasi*. Australia has a rapidly developing shrimp aquaculture industry and several viruses have been reported in reared species since 1985. These have infected most cultured shrimps including *Penaeus merguiensis*, *P. monodon*, *P. japonicus*, *P. esculentus* and *P. plebejus*. The viruses infecting these species include lymphoidal parvovirus, hepatopancreatic parvovirus, spawner-isolated mortality virus, parvo-like virus, baculovirus, haemocytic virus, gill-associated virus and lymphoid organ virus. White-spot syndrome virus affects many non-Australian shrimp aquaculture operations in south-east Asia, and has also recently been detected in Australia, although this was in a batch of prawns imported for consumption. The disease has not yet been reported in Australian shrimp farms. In May 2006 a herpes-like virus (a highly virulent abalone ganglioneuritis virus AGV) escaped from an abalone farm near Port Fairy Victoria (Prince, 2007). In less than 12 months, this virus had spread to infect reefs over some 90 km of coastline in the Western Zone of Victoria's abalone fishery. On the farms it produced total mortalities of blacklip, greenlip and hybrid abalone; in the wild it has been observed infecting both blacklip and greenlip reefs and causing mortality rates of 40-95% (Prince, 2007).

Taylor *et al*. (2005) and Blankenship and Leber (1995) conclude the spread of disease and parasites is best minimised by appropriate health certification and monitoring, which ideally spans both the hatchery and the receiving population. Releases of red drum in Florida require that all groups of fish pass bacterial, viral and parasite inspections before release, with infection levels benchmarked against infection levels in healthy wild populations. This approach does present some risk, however, as different strains of particular pathogens may exist in the hatchery, but not yet be present in the wild. Most infections manifest in visual pathological symptoms, which can be identified through microscopic and macroscopic analyses.

The health assessment index (HAI) used by Palmer *et al*. (2000) includes such an approach and provides a health profile for fish destined for release. This approach not only assesses disease risk, but also provides measures of fingerling quality for covariate analysis of survival from different release batches. An appropriate subsample of fingerlings from each batch is examined macroscopically and rated with an HAI score, which reflects the degree of normality (0–3) of fins, eyes, gills, liver, spleen, kidney, gall and the presence of mesenteric fat, whitespot and trematodes. Numerical values for all parameters are summed for each fish in a sample and averaged for the population, the best score being 0 and the worst 30. The HAI is supplemented with pathological analysis of the liver and nervous system, to detect symptoms of viral infections. A range of molecular techniques, including PCR (Nimitphak *et al.*, 2010) and immunological (Nadala Jr and Loh, 2000; Chaivisuthangkura *et al.*, 2010) assays, are available to complement the above approach in detection of viruses in freshwater and marine invertebrates and vertebrates. These tests are highly sensitive, but expensive to undertake. Overall, the best defence against disease is good hatchery practice and hatchery accreditation. Inspection is a requirement for producers of organisms destined for release in New South Wales. In some cases, vaccines are available to inoculate hatchery reared organisms against certain viral particles (e.g. Witteveldt *et al.*, 2004).

4.2.3 Ecological risks

The release of hatchery reared organisms into open systems has the potential to alter the ecological balance within the receiving system through a number of mechanisms. Resource limitation is thought to result in many of these adverse effects, particularly where high densities of organisms are released within relatively small geographic areas. Resource limitation may result in slower growth (through food limitation), higher mortality (through saturation of juvenile refuge habitat and predation) and displacement and emigration out of the receiving system. Whilst such hypotheses are frequently discussed within the stock enhancement literature (e.g. Blankenship and Leber, 1995; Munro and Bell, 1997; Taylor *et al.*, 2005), the quantitative evaluation of these potential impacts has been rare.

The variability in most marine systems and the exogenous factors affecting fish populations within these systems, mean that detecting impacts using traditional approaches to experimental design are difficult and may result in a lack of any detectable effect (i.e. a type II statistical error), simply due to sample and system variability and the lack of sufficient statistical power to detect a difference. Several projects have tried to apply adequate experimental designs to assess the post-release impacts on prey in stocked systems, but no differences were detected. Eggleston *et al.* (2008) used a Before-After-Control-Impact (BACI) design to test the effect of blue crab (*Callinectes sapidus*) enhancement on prey resources and found no relationship between crab density and prey abundance. The statistical power of this design to detect such impacts, however, was not evaluated. Similarly, Setio (2009) used a repeated measures design to examine the potentials impacts of eastern king prawn *P. plebejus* release density on both predators and prey and found no detectable effect of release. Again, the power of this study to detect any impacts on the predator and prey assemblage was compromised by high variability in densities of different taxa. Similarly, a release of ~30,000 hatchery reared striped mullet (*Mugil cephalus*) into nursery habitats in Kaneohe Bay found no evidence of adverse environmental effects on wild stocks (Leber *et al.*, 1995). Blaxter (2000) states that the published examples of adverse environmental effects arising from stock enhancement are rare; however, this is unlikely to be an accurate representation of dynamics in stocked systems. Investigating release impacts and defining ecological risks is best achieved through modelling, or a combination of modelling and empirical measurements (Taylor *et al.*, 2005; Taylor and Suthers, 2008; Lorenzen, 2008).

In New South Wales, modelling has been used to estimate the environmental impacts on prey resources and this information is used in a feedback-loop to provide estimates on release density (Taylor and Suthers, 2008; Taylor *et al.*, In preparation). Such an approach is useful in evaluating release scenarios and appraising the risk associated with these scenarios in terms of the probability of a particular impact occurring. The Predatory Impact Model was applied to mulloway *A. japonicus* releases in the Georges River, a Recreational Fishing Haven where all commercial fishing licenses had been bought out by the NSW Government by 2001. The model indicated the trophic impacts of small releases of mulloway were unlikely to exceed the former commercial harvest of key prey species within the estuary.

Stock enhancement and restocking can actually provide benefits for marine ecosystems. With the exception of the obvious benefits through recovery programs for threatened marine populations, increasing the density of higher predators can actually increase the productivity of mid- and low-trophic levels in marine and freshwater systems. Fisheries generally target higher trophic levels as they develop and then ‘fish down the food web’ as these higher trophic levels become less abundant and less profitable (Pauly and Palomares, 2005; Bhathal and Pauly, 2008). Inherent recruitment limitations arising from population depletion at high trophic levels, means that wild spawning populations are unlikely to provide sufficient new recruits to capitalise on the productivity at lower trophic levels released as a result of this harvest. The recruitment limitation hypothesis is supported by the fact that fisheries harvest almost always leads to a decline in population abundance, despite only less than 10 % of total aquatic primary productivity being required to sustain current harvests (Pauly and Christensen, 1995; Watson and Pauly 2001). This disconnect indicates marine systems may not be production limited, but rather suffer from lack of new recruits to capitalise on available productivity. Lack of predation can adversely affect aquatic populations, by allowing slower growers to persist in the populations (where they may have otherwise been removed by predation), which over time can decrease the fitness of populations as a whole. In some predator-limited systems, the abundance of herbivores has increased to such a level that density dependent effects come into play where food becomes limiting, as predators no longer regulate populations of these lower trophic levels. The stock enhancement of predatory fish ultimately represents a manipulation of the density of top-level predators towards densities that may have existed prior to fishing (in recruitment limited systems). This has the potential to rebalance ecosystems by elevating the level of "top-down" control in aquatic systems, which may increase productivity at mid-trophic levels. Ultimately, if undertaken within a scientific framework, fish releases provide a remarkable opportunity to further explore factors that contribute to population dynamics in aquatic ecosystems (Walters and Martell, 2004).

5. OPPORTUNITIES FOR RESTOCKING/STOCK ENHANCEMENT IN WESTERN AUSTRALIA

5.1 History of stocking, restocking and stock enhancement in Western Australia

5.1.1 Stocking

Fish 'stocking' is defined as translocating a species outside its natural range and placing it into a water body where it has not naturally occurred. There has been a long history of the stocking of introduced or feral fish species in Western Australia for both recreational fishing and commercial opportunities.

Rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta* were first translocated from the northern hemisphere to Western Australia in the late 1870s (WA Fisheries Management Paper No. 156, 2002). These early attempts were often unsuccessful but by the 1930s trout stocking had created a recreational fishery in the south west of the state. The WA Department of Fisheries took over the trout stocking program in 1971 and developed the South-West Freshwater Research and Aquaculture Centre at Pemberton, which has been the breeding and stocking base for trout in WA since that time. Juvenile and adult trout are stocked into rivers and dams annually, as the species struggle to create a self-sustaining breeding stock in the wild.

Redfin perch *Perca fluviatilis* were introduced from the northern hemisphere into the south west of WA for recreational angling in 1892. All redfin perch in Australia originated from 11 individual animals (Fysh, 1968) and, as for European carp in Australia (Hayne, 2009), there is no evidence of genetic bottlenecking. This feral species has a self-sustaining population in south west WA and is widely regarded as a pest.

Silver perch *Bidyanus bidyanus* were translocated from the eastern states of Australia to WA in 1950 for stocking into farm dams. Aquaculture of silver perch in WA commenced in the 1990s and WA Fisheries Management Paper No. 145 provides the constraints under which silver perch stocking is managed.

Other species of freshwater fish from the Murray-Darling system, such as the Murray cod *Maccullochella peelii peelii*, golden perch *Macquaria ambigua* and Australian bass *Macquaria novemaculeata*, have also been stocked in WA. Historical stocking has occurred in the past (Coy, 1979, Fisheries Management Paper No. 174), especially of Murray cod, which resulted in establishment of a self sustaining population in Lake Grassmere, west of Albany, until changes to the tidal barrage saw them eliminated due to an increase in salinity (Prokop, pers com 2010). In the 1940s, WA had size limit regulations on Murray cod and golden perch (Fry, 1944). Current introductions are mainly by individuals operating without approvals.

The yabby *Cherax albidus* was first translocated and stocked into WA at Narembeen in 1932 (Morrissy & Cassells, 1992) and the WA Department of Fisheries later translocated other yabby species and strains from the eastern states of Australia to produce all-male hybrids in around 2000 (WA Fisheries Management Paper No. 160, 2002). There has been an established aquaculture industry for the yabby in WA since the mid 1980s based mainly on low-input/low-output farm dam production for farm income diversification and a centralised harvesting and marketing service.

5.1.2 Restocking

Fish ‘restocking’ is defined as the release of cultured juveniles into wild populations to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields.

The WA Department of Fisheries invested in trochus *Trochus niloticus* aquaculture and restocking with funding assistance from ACIAR from 1995 to 2001. The project was established in response to concerns that the Trochus shell trade (for high quality buttons and jewellery), centred on King Sound near Broome, was overexploiting the resource (ACIAR Report Project ID: FIS/1994/010). After the transfer of production technology from the Northern Territory University, the partners had mixed success in developing strategies for seeding juveniles on selected coral reefs. In 2000, with some extra assistance from the West Australian Government, the Aboriginal and Torres Strait Islander Commission funded the Kimberley Aquaculture Aboriginal Corporation (KAAC) to construct a $3.2 million multi-species hatchery in which to produce juvenile trochus to enhance depleted reefs. The KAAC intended to reseed trochus-depleted reefs in 17 licensed aquaculture farm sites across the Kimberley region. This project had variable results; the KAAC multi-species hatchery was subsequently sold to private enterprise and has since been sold to a private operator following the liquidation of that company.

Currently, the only example of the restocking of finfish in WA is for black bream *Acanthopagrus butcheri* in estuaries. The most studied of these is the FRDC supported restocking of the Blackwood River Estuary with black bream, conducted by the Challenger Institute of Technology and Murdoch University from 2000 – 2005 (Jenkins *et al.*, 2006; Potter *et al.,* 2008). This project restocked 220,000 juvenile fish over two years. Six years later, it has been estimated two thirds of the legal sized fish in the river comprised the restocked, mature fish. Therefore, the successful black bream spawning and recruitment in 2009 in the Blackwood River Estuary can largely be attributed to this restocking project (Potter and Jenkins, unpublished data). This project has won numerous accolades including being voted in the top two presentations at the 3rd International Symposium on Sea Ranching and Stock Enhancement in Seattle USA in 2006, winning RecFish Australia’s Inaugural Award for Best Recreational Enhancement Project, 2006 and winning WAFIC’s Seafood Industry’s Environment Award in 2010.

The WA Department of Fisheries has recently commenced a Natural Resources Management funded restocking program for threatened, small freshwater native fish in the south west of WA. These fish are under threat due to a combination of the declining rainfall, increasing salinisation and predatory feral freshwater fish such as redfin perch and trout. No fish have been stocked as yet and, unless the identified threats are ameliorated, it will be difficult to judge success.

5.1.3 Stock Enhancement

'Stock enhancement' of fish stocks refers to the release of cultured juveniles into wild populations to augment the natural supply of juveniles and optimise harvests by overcoming recruitment limitations. This is sometimes carried out to 'even out' recruitment years for species with sporadic recruitment.

The southern saucer scallop *Amusium balloti* is a species with very irregular natural recruitment. Historic catches have been highly variable with annual landings ranging from 150 to 4,400 tonnes of meat worth between $2 million and $59 million (Fisheries Research Report No. 114, 1999). The WA Department of Fisheries, in collaboration with West Coast Scallops Pty Ltd and with funding support from the FRDC, undertook a trial scallop enhancement project off the Geraldton coast from 2002 to 2005. The aim of this project was to even out the irregular natural recruitment years to optimise harvests. This project was not successful, due mainly to an inability of the hatchery to deliver sufficient spat to test the project objectives. (Lindsay Joll, pers. com. 2010)

The most recent fish enhancement project carried out by the WA Department of Fisheries was in association with Great Southern Marine Hatcheries (GSMH) in Albany, Western Australia. This project commenced in 1994 when 6,000 greenlip abalone *Haliotis laevigata* were released onto reefs near Augusta (WA Fisheries Management Paper No. 162). This first study concluded that high survival rates could be achieved if the animals were stocked on high quality reef structures and postulated that genetic diversity could be maintained provided an enhancement rate of 35% of natural recruitment to the breeding stock was not exceeded (WA Fisheries Research Report, No. 166, 2007). This appears to be a novel method of forecasting genetic implications in an enhancement project. The stock enhancement of abalone by the Department of Fisheries is ongoing.

The WA Department of Fisheries collaborated with CSIRO and the MG Kailis Group to evaluate the feasibility and develop technologies for enhancing stocks of brown tiger prawns *Penaeus esculentus* in Exmouth Gulf from 1997 to 2002. This research was funded by the FRDC, MG Kailis, CSIRO and the Department of Fisheries. The project was planned in 4 phases: 1. Evaluating the potential for enhancement; 2. Developing approaches and technologies for enhancement; 3. Pilot scale enhancement and 4. Commercial scale enhancement. Only the first two phases of the research and development were completed. The research in these initial phases was successful in developing a bio-economic model to evaluate the potential of enhancing brown tiger prawns, identifying the potential release sites for enhancing prawns and developing high density culture techniques for juvenile prawns. It also identified a number of genetic primers that would aid in identifying the enhanced prawns from the released prawns but required a further three markers to do this reliably. The next phase of the project was to complete pilot scale releases of about 1 to 2 million juvenile prawns. This would have required a significant investment from the MG Kailis Group to build raceways for the production of juveniles. The company made the decision not to proceed with the additional investment and research on enhancing brown tiger prawns in Exmouth Gulf stopped in 2002 (Loneragan *et al.,* 1999; 2003; 2004) .

5.2 Barramundi stocking in Lake Argyle and Lake Kununurra

The Ord River in the Kimberley region of Western Australia was home to wild barramundi *L. calcarifer* throughout its range until construction started on the Ord River Irrigation Scheme in 1958. The Scheme took 14 years to complete and was officially opened in 1972.

The main structure of the Ord River Irrigation Scheme is the Ord River Dam, some 40 km to the south of Kununurra, which stores approximately 11,000 million cubic metres of water in Lake Argyle, making it the largest man-made storage dam in Australia. From Lake Argyle, water is released into Lake Kununurra which is retained by the second structure of the Scheme, the Lake Kununurra Diversion Dam at the Kununurra township. The Diversion Dam was constructed to supply water to the extensive system of open irrigation channels of the Ivanhoe Plains (more commonly referred to as the 'Black-soil Plains') to the north of the township.

At sometime early within the construction period of the Scheme, the free movement of barramundi was restricted. Barramundi larvae require brackish water to survive so it is assumed that once the fish that were retained within Lake Argyle and in Lake Kununurra had died through old age, predation, capture or escape, the wild barramundi would only naturally occur in the Ord River below the Diversion Dam wall.

Experience gained from restocking projects in Queensland indicate the potentially large benefits to the local and state economies and to recreational anglers if Lake Argyle and, or, Lake Kununurra were to be restocked with barramundi. The stocking of Queensland impoundments with barramundi commenced in 1985 when biologists from the Queensland Dept of Primary Industries stocked the species into Lake Tinaroo (Sawynok 2006). Numerous other impoundments throughout Queensland were subsequently stocked with barramundi and most have resulted in the successful creation of inland fisheries (Hollaway and Hamlyn, 2001). The barramundi stocking in Lake Tinaroo has resulted in a return of investment to the state of $31 for each dollar spent. Barramundi release programs in three other Queensland dams have been estimated to give annual returns of between 1 and 1.5 million dollars per dam to the State (Rutledge *et al.*, 1990).

Small barramundi trapping and tagging trials were carried out in the Kimberley in the 1991/1992 (Bird, 1992) and the 2000/2001 wet seasons (WA Fisheries Management Paper No 175). Approximately 700 barramundi were captured in the Ord River below the Lake Kununurra Diversion Dam wall and were tagged and relocated into Lake Kununurra close to the wall. Of the fish stocked from these two programs, only 20 are reported to have been recaptured up to 3 years after stocking, with the majority caught back below the dam wall.

Doupé and Bird (1999) suggest that any stocked barramundi may try to leave the dam in order to spawn in brackish water to complete their lifecycle. However, they note that barramundi are rarely sought in the dam by recreational fishers whereas considerable effort is expended in the Ord River below the Diversion Dam wall where barramundi are known to occur. It is thus not surprising that so few were recaptured in the Lake. Doupé and Bird (1999) suggest that in the future, any fish placed into the Lake should be stocked further away from the dam wall.

Whether cultured barramundi would attempt to leave the dam is unknown although they may attempt to do so when they reach maturity. A barramundi aquaculture operation in Lake Argyle operated from approximately 1994 to 2004. There were occasional escapes of barramundi from the farm into Lake Argyle and numerous reports of large barramundi captured by anglers in the lakes over several years. Doupé and Lymberry (1999) reported that some of these escaped barramundi were recaptured either in Lake Argyle itself or in Spillway Creek, between Lake Argyle and Lake Kununurra.

There appears to be some good justifications to undertake a pilot restocking of barramundi in Lake Argyle. Some of these are:

- As barramundi naturally occurred throughout the region to the south of the Ord River Dam wall prior to, and for some time following 1960, this would constitute a re-introduction rather than stocking a new species; i.e. there are no native barramundi to displace.
- It is difficult to foresee significant negative environmental consequences when massive environmental change has resulted due to the construction of the Ord River Irrigation Scheme and barramundi have only been excluded from free movement in that region for the past 50 years.
- Due to previous escapes from a now-defunct commercial farm, it is known that barramundi will survive, grow and can be caught in Lake Argyle.
- If barramundi were to move below the Lake Argyle Dam via Spillway Creek, then some of these fish are likely to be captured in Lake Kununurra, providing additional information on their movements.
- If negative environmental consequences were to be detected, the restocking program can be halted. As barramundi cannot successfully breed in freshwater, there would be no barramundi remaining within a few years.

WA Fisheries Management Paper 159 by Thorne (2002) provided guidelines to be taken into account when proposing to stock barramundi into public water bodies where barramundi did occur, but are now depleted. They are:

1) A stock assessment must be conducted to determine the extent of the depletion prior to any stocking program being undertaken. This should include an evaluation to identify the cause of stock depletion.
    - This step would not be necessary as there are no naturally occurring barramundi in the two dams proposed for restocking.
2) Remedial action should be taken to improve habitat or regulate recreational or commercial take if that is the cause of the initial depletion, and the effectiveness of the stocking program should be evaluated against other management methods.
    - As the initial depletion was caused by the damming of the Ord River, the only management measures that could be taken to increase the numbers of barramundi in the dams are via restocking or the construction of fish ladders around both dam walls. Of these two options, restocking has the greater chance of success since fish-ladders are, as yet, unproven for barramundi (Doupé & Lymbery, 1999) and restocking could potentially be funded long term via recreational fishing licences.
3) All stock to be placed into the natural environment should preferably originate from broodstock obtained from that water body or an interconnecting system. If broodstock from that system are not readily available as natural stock

populations are depleted, then broodstock with a similar adaptive potential should be sourced (i.e. with a common evolutionary history).
    - As Ord river barramundi are still in evidence below the Lake Kununurra dam wall, it is feasible to use Ord River broodstock to produce juveniles for restocking Lake Argyle.

4) Large numbers of broodstock should be used to produce the fingerlings or yearlings necessary for the restocking. The use of large numbers of broodstock will assist in preventing loss of genetic diversity through inbreeding and genetic drift. Any breeding program should be developed in liaison with a geneticist with expertise in fish population genetics, preferably of barramundi.
    - It is possible to use large numbers of Ord River broodstock to produce the required juveniles for restocking. However, current restocking wisdom to maintain genetic diversity includes the use of smaller numbers of broodstock, with these broodstock replenished each year.
5) Some selection to improve the stock may be permitted to ensure optimum fitness and therefore increase its chances of survival in the system.
    - This should not be necessary or desirable.
6) All fish must be disease-tested prior to release into the environment.
7) A sound scientific monitoring program must be implemented to evaluate the success and determine the cost benefits of the stocking program.
    - Both these last two points are strongly supported by international good practice.

Additional questions on the restocking of barramundi were raised in the Sawynok 2006 Workshop Report and should be considered prior to a Lake Argyle restocking program. The relevant questions are:

- What is the optimum stocking density?
- What size is most cost effective?
- What stocking frequency works best?
- Are anglers getting the benefits?
- What 'harvest' management strategies give the best outcome? (e.g. Size/bag limits and/or catch and release).

5.2.1 Recommendation 1: Restocking barramundi into Lake Argyle

It is recommended that a restocking program be implemented for barramundi in Lake Argyle.

The prerequisites for such a program include:

- Ord River broodstock should be used to produce the juveniles for the restocking;
- A small number of broodstock could be utilised provided they are only used for one year's stocking;
- The TAFE sector, with its current infrastructure, could be engaged to carry out the hatchery work;
- Lake Argyle is the preferred location for the restocking as it allows escapes from the lake to be assessed via recreational catches from Lake Kununurra;
- A substantial number of juveniles should be released (a minimum one million per annum for three years);

- Identification marks are not required for the juveniles, given that there are currently no (or very few) barramundi in either Lake Argyle or Lake Kununurra and the broodstock used will be sourced from the Ord River. However, if the budget is sufficient then marking of the restocked fish would be desirable;
- Juvenile fish will require disease testing prior to release from the hatchery;
- Given the size of the lake and the lack of knowledge of where juveniles would congregate (i.e. no established nursery grounds), it may be difficult to assess juvenile survival. A monitoring program could be established however, via the Silver Cobbler fishery to estimate rates of growth and survival;
- Medium to longer term monitoring should be established via local fishing clubs and tour operators with professional advice and supervision mandated; and
- Prior to commencing the project, a Working Group should be formed under the Chairmanship of the WA Fish Foundation (See Appendix 2), to: identify and form the partnerships and collaborative relationships required for the program; consider the issues identified in the 2006 Sawynok Report; and manage the project.

5.3 A suitable temperate, marine species in the metropolitan region

Coastal stock enhancement and restocking has been with us for well over 100 years, initially with the stocking of salmon in the US and cod in Norway (Kitada 1999, Leber 2008). It was not until the 1990s however, that the measure of success of restocking programs changed from the number of fish stocked to measuring the results of the restocking programs. Around this time, the science of restocking was born and scientists turned their attention to the identification of the stocked fish, aquaculture technology to grow fitter fish, methods to improve post-stocking survival and implications for wild fish (Leber, 2008). As a consequence of the newness of restocking as a science, examples of successful coastal stock enhancement are derived mainly from the more recent programs. As detailed by Bell *et al.* (2008) the scientific base for restocking has grown quickly and strongly since the First International Symposium on Stock Enhancement and Sea Ranching was held in Norway in 1997. An increasing number of successful coastal restocking and enhancement programs have resulted although as Lorenzen (2008) warns '…. enhancements need to add value to or outperform alternative management measures such as fisheries regulation or habitat restoration, which are either cheaper or provide a wider range of benefits.' A multi-disciplinary approach is strongly suggested for any future marine restocking/stock enhancement programs for Western Australia.

In temperate Western Australia there are several metropolitan marine fish species that could be cultured and restocked within a relatively short time frame. Local expertise exists for the culture of commercial quantities of snapper *Pagrus auratus*, mulloway *Argyrosomus japonicus*, King George whiting *Sillaginodes punctata* and the yellowtail kingfish *Seriola lalandi*.

Over 50 marine fish species have been restocked in Japan since 1963. Kitada & Kishino (2006) examined survey data from releases of red sea bream *Pagrus major* in Japan over nearly 30 years. A total of 20.8 million juvenile red sea bream were released into Kagoshima Bay from 1974 to 2002 and 22.9 million juveniles released between 1978 and 2000 into Sagami Bay and Tokyo Bay (Kanagawa Prefecture). Surveys were conducted at selected fish markets in Japan where hatchery-derived and wild red sea bream were able to be distinguished. Analysis of the results showed that hatchery-derived fish contributed 36.4% towards total production in the Kanagawa Prefecture. However, a comparative analysis of catch history suggests that nearly 26% of this contribution could be replacing the wild population, leaving a little less than 10% of actual enhancement. Interestingly, it was found the red sea bream stocks in Kagoshima Bay did not increase, supposedly due to a reduction in nursery habitat, and therefore reduced carrying capacity for juvenile red sea bream, through substantial reclamation activities. A similar finding has been reported for the restocking of karuma prawns *Penaeus japonicus* in Japan, where the success of the release program has declined over time and this decline has been attributed to a reduction in the area of available juvenile habitat (Hamasaki and Kitada, 2006). It is suggested that although red sea bream stock enhancement can be successful, the number of fish released should be carefully considered in relation to the local carrying capacity to avoid the hatchery fish replacing wild juveniles.

A relative of the mulloway, red drum *Sciaenops ocellatus*, have been successfully restocked in the US, initially in Texas after the stocks of the species suffered a dramatic decline in the early 1970's due to overfishing (McEachron *et.al.* 1993). Scientists considered that larval recruitment into estuaries from near shore spawning grounds was a limiting factor for recruitment and that restocking of juveniles directly to the spawning grounds would assist in the stock recovery. Over the next 20 years 115 million juvenile red drum were restocked and subsequent long term monitoring demonstrated that restocking had helped the red drum fishery to rebound, although with variable survival (McEachron *et.al.* 1993, 1998, Willis *et.al*. 1995).

A state government funded marine fish stocking program was established in Florida in 1985 (Tringali *et.al.* 2008). The program was initially funded via the state, but later by fishing licence revenues. Public pressure ensured that large numbers of unmarked small fish (25-40 mm) were released for some years around Miami, a popular fishing location. This approach however, with no monitoring in progress, was replaced in the mid 1990s by a structured program releasing marked fish of a range of sizes into areas with good quality nursery habitat for the species. Six separate research groups took a multi-disciplinary approach to the restocking covering areas of hatchery, health, catch and effort monitoring, direct monitoring (via captures), telemetry and movements, and genetics. Although the recapture rates have been low for this program (less than 0.1 %), the program has been considered successful enough to justify the commencement of a large-scale release program.

Mulloway culture is well established throughout southern Australia, principally in New South Wales, South Australia and Western Australia. Restocking research for mulloway has been undertaken in NSW since 1996 (Taylor *et al.*, 2009). Dr Matt Taylor of UNSW has undertaken a number of pilot mulloway stocking investigations in several intermittently opening coastal lakes and riverine estuaries in NSW from 1996 to 2004. The difficulty in monitoring restocked mulloway was highlighted in these studies as the species is highly mobile between such waterways and the ocean and will quickly move if the location they are stocked into does not contain their preferred habitats. However, stocked fish were found to have grown and recruited to the fishery in the two releases in the Georges River and in two of the three releases in Smiths Lake.

Given the variable results of the restocking for mulloway and related species, it may be prudent to investigate options further prior to attempting this in WA.

There are no known restocking events for King George whiting in Australia although there has been a trial restocking program in southern Queensland for the sand whiting *Sillago ciliata*. This species was restocked into the Maroochy River (along with dusky flathead (*Platcephalus fuscus*) by the Queensland Department of Primary Industries with 250,000 whiting released throughout the river system in 1997 and 72,000 in 1998 (Butcher *et al.*, 2000). The survival rates of the whiting were assessed after one month at 75%, which is an excellent result. A fish kill event in February 1998 prevented the effectiveness of the program being fully evaluated.

The yellowtail kingfish is a migratory pelagic species and is not seen as a likely candidate for restocking in the medium term in Western Australia by the authors.

5.3.1 Recommendation 2: Restocking of snapper in Cockburn Sound

Pink snapper represent a promising and justifiable focus for a stock enhancement trial in temperate Western Australia, given the Japanese experiences with red sea bream, and considering the depleted stock in Cockburn Sound. Pink snapper has a proven 20 year culture history in WA, and low adult abundance in Cockburn Sound creates a potential for recruitment limitation. A number of closures have been introduced to reduce fishing mortality by 50% from 2007 levels to help rebuild this depleted stock, including closing commercial fishing for demersal species in metropolitan waters. Releasing juvenile snapper provides an additional option for rebuilding stocks. Previous research (WA Fisheries Research Report No 174, 2009) demonstrates Cockburn Sound is the most important spawning and nursery site for snapper in the West Coast Bioregion and that juvenile snapper remain in the area for the first 14 months of their life. This research also found adult snapper in the Metropolitan Zone migrate inshore to spawn in Cockburn Sound. The combination of the heavily fished snapper stock, the importance of Cockburn Sound for spawning and for nursery grounds and the fact that fish either remain within the Sound, or return to it for spawning highlight this as an excellent opportunity for restocking and subsequent monitoring.

The timing and exact locations for spawning aggregations and egg and larval movements of the species in Cockburn Sound are known. It is proposed that one option for producing juvenile snapper for release is to collect fertilised snapper eggs from the water column of the spawning aggregation in Cockburn Sound and culture the eggs to juvenile stages for release. This is a key point in both minimising costs for this project and in maintaining a healthy genetic variation in the restocked population. An objective for stocking might be to release 1,000,000 early juvenile snapper each year for three years; however, quantitative objectives of a release program should be developed by a steering group and an evaluation of the existing information using models such as EnhanceFish.

Considering the current stock of snapper in Cockburn Sound is considered to be well below those of historic levels, there appears to be no reason to consider that restocking of these magnitudes would replace wild fish. The Japanese experience with red sea bream and prawns will need to be taken into account as the condition and extent of snapper nursery habitats in Cockburn Sound will be an important consideration for any release program. The continuing well documented destruction and removal of nursery habitats in Cockburn Sound is a complicating factor and should be considered when the planning for this program is undertaken.

It is recommended that the cost of monitoring the restocked fish is kept to a minimum through the involvement of recreational anglers in sample collection as they have proven to be a reliable resource for this kind of collection in the past. In addition to cost savings, this would also provide recreational anglers with an important stewardship role in the project.

Prior to commencing the project a Working Group should be formed, under the Chairmanship of the WA Fish Foundation (see Appendix 2), to identify and form the partnerships and collaborative relationships required for the program, consider the issues as identified in the 2006 Sawynok Report and manage the project. The first stage in the release program should include the following components 1) review data on pink snapper and stocking of similar species elsewhere to identify knowledge gaps, 2) use of existing information to evaluate the potential for restocking pink snapper in Cockburn Sound using a model such as EnhanceFish (which provides a cost-benefit analysis) and 3) trial techniques for the production, marking and release of small, juvenile pink snapper (e.g. strip spawning of snapper, culturing fertilised eggs and harvest/transport and release of juveniles). A collaboration should be established with recreational fishers to monitor the success of the program, reduce costs, and enhance understanding of the program and fish stock assessment in general.

5.3.2 Recommendation 3: Future Restocking Species Research

It is also recommended that funding be made available to the WA Fish Foundation for the further development of aquaculture/restocking/stock enhancement techniques for additional species of interest including King George whiting, mulloway and WA dhufish.

5.4 Research Capabilities and Infrastructure in WA

Clearly, Western Australia has the capacity and capabilities required for undertaking substantial restocking projects for snapper in Cockburn Sound and barramundi in Lake Argyle.

The WA Department of Fisheries has capable managers and wild fisheries research scientists to provide advice on various aspects of marine finfish restocking projects including interactions with wild stocks. The WA Department of Fisheries also has a long history in the stocking/restocking/enhancement field for freshwater trout, yabbies and the marine species of trochus, scallops, abalone and prawns in WA and so are therefore demonstrably supportive of restocking *per se*.

The Australian Centre for Applied Aquaculture Research (formerly the Aquaculture Development Unit) of the Challenger Institute of Technology (ACAAR) has the aquaculture skills and species culture history (in conjunction with Broome TAFE for barramundi) and the necessary infrastructure and logistic support to provide the aquaculture support and juveniles for these projects.

The ACAAR is recognised as a leading provider of applied aquaculture research and training in Australia. Established in 1994, it has the capability and track record of producing commercial quantities of a range of marine fish species over many years, including those recommended in this paper. Involved in developing restocking skills for marine and estuarine fish in WA since 1992, it is the only facility with the capability to deliver the numbers of competent cultured juveniles of the quantities required for these projects. In addition to possessing the commercial culture skills for snapper and barramundi, the ACAAR has also cultured King George whiting, mulloway, yellowtail kingfish and WA dhufish.

The Centre for Fish and Fisheries Research (CFFR) at Murdoch University (MU) has an exceptional history of research on fish biology and fisheries, including the science of restocking and monitoring fish stocks. Staff and students in the CFFR have published a very significant number of papers on fishes and fisheries in Western Australia in international journals and in major technical reports, particularly to the Fisheries Research and Development Corporation of Australia. Many of the crucial parameters for the biology of the heavily exploited, temperate demersal fish species in WA were obtained from research by members of the CFFR. The CFFR has also trained a significant number of the current DOF scientists and managers at the DOF Research Division.

The Challenger Institute/Murdoch University partnership is very highly regarded by restocking scientists from around the world. The Blackwood project was presented to the 3rd International Symposium on Sea Ranching and Stock Enhancement in Seattle, USA in 2006 and was voted in the top two presentations at the Conference. Professor Neil Loneragan of MU is the Chair of the International Scientific Organising Committee for the 4th Symposium to be held in Shanghai in 2011 and Mr Greg Jenkins of the ACAAR is also a member of this Committee. This partnership therefore has direct access to advice and assistance from the recognised world experts in the field of restocking and stock enhancement of marine fishes.

5.5 Conclusion

The authors of this report all have experience in estuarine and marine restocking projects and are highly regarded internationally among their peers. The authors do not, however, consider restocking to be a panacea for declining fish stocks around the world, and maintain that it cannot be effective when used in isolation from other fisheries management measures. Fish releases represent an effective tool relevant for rebuilding or enhancing otherwise declining fish stocks for some species, and in some marine ecosystems, but must be complemented with other effective measures to better protect and support the recovery of wild stocks.

Considering the wealth of restocking expertise held between the CFFR at Murdoch University, the ACAAR of the Challenger Institute and the Research Division of the WA Department of Fisheries, it is now considered appropriate and timely to undertake a marine restocking research project for a marine fish species in a WA marine embayment. Similarly, given the experience in Queensland and the expertise in WA, it is also timely to stock Ord River barramundi into Lake Argyle or Lake Kununurra.

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7. APPENDIX 1. CONSULTANTS BRIEF

AQUACULTURE DEVELOPMENT COUNCIL

PROJECT: FINFISH STOCK ENHANCEMENT OPPORTUNITIES

CONSULTANT'S BRIEF

PROJECT DESCRIPTION

The Aquaculture Development Council (ADC) requires the development of a paper outlining the opportunities for finfish stock enhancement in Western Australia. The paper should also consider the potential benefits and risks associated with these opportunities and advise on risk mitigation strategies.

BACKGROUND

The ADC was established under the *Fish Resources Management Act 1994* to identify issues that affect aquaculture, provide advice to the Minister for Fisheries regarding aquaculture matters and management and develop and implement strategies to enhance the Western Australian aquaculture industry.

Finfish stock enhancement has been determined as an opportunity for aquaculture development in Western Australia. Production of juveniles for stock enhancement activities will also support the existing and future commercial aquaculture operators by providing a reliable supply of juvenile seed stock.

PROJECT SCOPE AND PROPOSED OUTLINE

The paper should include, but not necessarily be limited to, the following:

- An analysis of the potential benefits and risks of stock enhancement for:
  - Freshwater systems;
  - Estuarine systems; and
  - Marine systems

  Experience gained through similar projects globally should be considered.
- A discussion on the current state of stock enhancement as a globally recognised science
- Identification of opportunities for:
  - Barramundi stocking in Lake Argyle and Lake Kununurra
  - A suitable temperate, marine species in the metropolitan region

  This may be achieved through conducting a case study on relevant species.
- Other information as considered relevant by the consultant

PROJECT MANAGEMENT AND TIMEFRAMES

The Consultant will liaise with the Project Steering Committee, consisting of:

- An ADC Member
- The Manager, Pearling and Aquaculture, Department of Fisheries

- The Senior ADC Management Officer

The completed, final paper should be submitted three weeks from engagement.

QUOTATION AND APPOINTMENT

A quotation addressing the project scope should be forwarded to Michelle Hanlon, Senior ADC Management Officer: michelle.hanlon@fish.wa.gov.au

The project will be awarded via a standard Department of Fisheries letter of appointment.

8. APPENDIX 2. THE WEST AUSTRALIAN FISH FOUNDATION

The West Australian Fish Foundation (WAFF) is a not-for-profit organisation that was formed in 2003.

The Objects of WAFF include:
1. to conduct, assist and promote research associated with stock enhancement;
2. the provision of fish for stock enhancement projects;
3. the provision of scientific monitoring following fish stocking programs;
4. to establish and maintain a public fund to be called the "West Australian Fish Foundation Fund" for the specific purpose of supporting the environmental objects and purposes of the Association and to receive all gifts of money or property for this purpose;

The aims of WAFF are therefore not only to coordinate all aspects of restocking including the research, stocking and monitoring programs, but also to raise private funds to do so.

The founding members of WAFF are the Australian Centre for Applied Aquaculture Research of the Challenger Institute of Technology, the Murdoch University Centre for Fish and Fisheries Research and the WA Department of Fisheries. Recfishwest is also a WAFF member. The WAFF therefore consists of all of the groups interested in stocking, restocking and stock enhancement programs in WA.

Professor Neil Loneragan is the Director of the Centre for Fish and Fisheries Research at Murdoch University and Mr Greg Jenkins the Director of the Australian Centre for Applied Aquaculture Research at the Challenger Institute of Technology. Murdoch University provides the fish biology and monitoring expertise while the ACAAR provides the aquaculture and marking skills. The team also have access to the worlds most eminent restocking and enhancement scientists for advice on this project via Professor Loneragan's role as Chair of the International Steering Committee for the 4th Stock Enhancement and Sea Ranching Symposium to be held in Shanghai in 2011. Greg Jenkins is also a member of the International Scientific Committee for this Symposium.