FISH STOCK AND FISHERY ENHANCEMENT IN WESTERN AUSTRALIA

A DISCUSSION PAPER

FISHERIES MANAGEMENT PAPER No 175

Department of Fisheries
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Fish stock and fishery enhancement in Western Australia
A Discussion Paper

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WESTERN AUSTRALIA

Department of Fisheries

Fish for the future

Errata

Please note the public comment period for Fisheries Management Paper No. 175 *Fish Stock and Fishery Enhancement in Western Australia* and its companion document, Fisheries Management Paper 176 *Fish Stock and Fishery Enhancement in Western Australia (Summary of Fisheries Management Paper No. 175)*, has been adjusted.

The Department of Fisheries advises that the public comment period for both documents is open until 31 May 2004.

CONTENTS

SECTION 1 OPPORTUNITY FOR PUBLIC COMMENT

This discussion paper has been prepared to encourage public involvement in the development of a policy for stock enhancement within Western Australian waters. Stock enhancement can involve an existing fishery or creation of a new fishery through translocation of fish. It affects both public and private waters.

Comments about this discussion paper are sought from all stakeholders, including commercial and recreational industry members, existing and potential aquaculture farmers, relevant community interest groups, government agencies and interested members of the public. Following consideration of the public comments received on this discussion paper, a policy paper will be developed which will enunciate the application and assessment processes for stock enhancement in Western Australia.

To this end, there are some important issues you may wish to address in your submission, including:

1. Should the government legislate for the management of all stock enhancement?
2. In assessing the translocation of any aquatic species, the economic and social benefits must be balanced with biological and environmental risks, although the latter are paramount.
3. What level of risk would be considered acceptable?
4. Adequate research and monitoring requires funding, which is not always available within the timeframes required for decision-making.
5. With whom should final accountability for a particular stock enhancement project lie?
6. Are the proposed guidelines appropriate?

Although we have identified specific issues of interest, we seek your views on any or all of the matters in the document of significance to you and/or your group.

To ensure your submission is as effective as possible, please:

- Make it clear and concise;
- List your points according to the topic sections and page numbers in this paper;
- Describe briefly each topic or issue you wish to discuss;
- State whether you agree or disagree with any or all of the information within each topic or just those of specific interest to you. Clearly state your reasons, particularly if you disagree, and give sources of information where possible; and
- Suggest alternatives to address any issues that you disagree with.

This paper has been prepared by the Department of Fisheries and various drafts have been scrutinized by a focus group comprising a representative of the Department of Fisheries, the WA Fishing Industry Council, the Pearl Producers Association, the Aquaculture Council of WA, Recfishwest and the Conservation Council of WA. This focus group will remain involved in the development of policy arising from this consultation process.

The information provided in this paper should not be accepted to be conclusive and stakeholders are encouraged to consider additional information from other sources in providing the basis for comment.

Your comments would be appreciated by **30 April 2004** and should be marked to the attention of Senior Policy Officer, Fisheries Management Services, and addressed to:

Executive Director
Department of Fisheries
Locked Bag 39
Cloisters Square Post Office
PERTH WA 6850

SECTION 2 EXECUTIVE SUMMARY

Stock enhancement as a fisheries management tool is not a new concept, neither internationally nor within Australia. However, its popularity as 'the answer' to some fisheries management challenges and opportunities is on the rise in Western Australia.

Traditionally in Western Australia, fisheries have been managed by sectors – commercial and recreational. Existing fisheries management arrangements recognise the State's primary objective of sustaining WA's fisheries. This said, many aspects of environmental management are outside the control of the Department of Fisheries.

Commercial fisheries in Western Australia are subject to management plans, regulations or notices, which cap fishing effort and regulate the conditions under which commercial fishing may occur. For the most part, commercial fisheries are well managed and sustainable. There are, however, cases being put for fish stock enhancement in some fisheries - either to supplement a fishery that may be under some pressure from fishing (such as finfish on the West Coast) or the environment (such as the effect of the Leeuwin Current on scallops), or to further improve production from already sustainable fisheries (for example, the West Coast Rock Lobster Managed Fishery).

Management of Western Australia's recreational fishing focuses on regulation of individual activities, for example, where you may or may not fish, how much of each type of fish may be taken by an individual and the allowable size of the fish taken, and so forth. These regulations do not cap the total fishing effort on a species or in an area (unless it is closed), although there are some constraints on individual fishing effort in some fisheries.

The recreational abalone fishery would be an exception to this, in that the season has been reduced so significantly that there is a real restriction in what can be caught. Similarly, in Freycinet Estuary in Shark Bay, tight controls have been introduced through the use of tags – each fish in possession must have a tag and the number of tags issued is limited.

In some waters, fisheries stock enhancement is being suggested to restore overfished stocks. In other waters, it may offer a way to create new fisheries to meet an increasing demand for recreational fishing opportunities, or to increase the quality of the existing recreational fishing experience.

Stock enhancement also offers possible remediation for non-fishery related impacts on fisheries, such as ecological disruption, the pressures of development on existing fishery habitats and fishing locations, and the increasing water removal and river flow regulation. However, the enhancement of fish stocks for the public benefit, and possibly for commercial gain in the process, has the potential to create controversy. The danger with stock enhancement is to believe that just because we can, we should. Although it has its place in sound fisheries resource management, stock enhancement is not the answer to all fisheries management problems. In fact, it is likely to be appropriate and effective only in relatively few situations.

The technology to breed certain species in hatcheries exists. However, important questions need to be asked about the long-term benefits to the fishery, the ecosystem, society and the economy.

The most significant of these questions is "What is the biological risk?" – the real level of risk, not the perceived level. A key consideration has to be conservation of fish resources and

their environment, for without the resource and its environment, there is no fishery. There may be situations where there are strong, valid social or economic arguments for a stock enhancement to occur. Enhancement may be approved on these grounds alone, but not to the detriment of the sustainability of the fish and fish habitat.

Furthermore, as management of WA's fisheries moves away from a sectoral model towards a system of integrated fisheries management, decisions can no longer be driven by extractive use. Decisions made under an integrated system take into account ecological, social and economic impacts (see 4.1.2). This must also be the case for stock enhancement.

The objective of this paper is to propose a process that will allow the decision makers to objectively assess the appropriateness, benefits and costs of any stock enhancement proposal under Ecologically Sustainable Development (ESD) principles.

To this end, this paper sets out a conceptual framework for assessment of stock enhancement projects, putting stock enhancement within the wider framework of fisheries and ecosystem management strategies, and their assessment, in Western Australia.

This framework has been presented in four charts. The first chart asks some basic questions about the nature of the stock to be released and its place in the environment into which it is to be placed. This defines the type of fishery in question. Charts two and three trace the steps for assessing which management option to pursue for a particular type of fishery - one for enhancement of existing fisheries and one for creation of new fisheries either in new waters (where a particular fishery does not already exist) or within waters that already support other fisheries.

These two broad categories of potentially enhanced fisheries will need very different questions posed and answered. The fourth chart picks up from the previous two at the option of 'stock enhancement', and traces the steps proposed for assessment of stock enhancement projects.

It is important to understand that when reading this paper, it is not saying fish stock enhancement will or will not be allowed in a certain circumstance; nor does it attempt to provide a complete discussion of all the environmental, social and economic issues associated with stock enhancement. It sets out a possible process and provides some background information to illustrate the types of considerations that will need to be taken into account when deciding whether to put forward a stock enhancement proposal.

The final decision on any project would have input from a number of other departments with interest and legislative power over aspects of stock enhancement, such as the Department of Conservation and Land Management (CALM), the Department of Environment and the Environmental Protection Authority (EPA).

Proponents for stock enhancement projects will be required to ensure that their proposal meets these departments' requirements prior to submitting an application to the Department of Fisheries.

One of the main issues the Department of Fisheries faces in developing a policy for fish stock enhancement is the multi-departmental responsibility for resource use affecting fisheries. Land tenure, and its control by other bodies, will have a major impact on any stock enhancement management plan.

Other important issues include:

- The Department of Fisheries does not have the legislation at present to regulate stock enhancement *per se* unless it involves translocation or poses a high risk to aquatic habitats. One possible outcome of the proposed policy is legislative change to allow the Department to issue licences for stock enhancement.

- Monitoring the success or otherwise of projects in open systems is difficult.

- Inadequate data, in many cases, has made it difficult to assess the level of impact and success of fish stock enhancement projects.

Developing a policy on fish stock enhancement is not an easy task. The issues are complex and need to be considered in context of Integrated Fisheries Management within ESD principles. This paper and its proposed processes should not be seen as either the opening or closing of doors for stock enhancement, but as recognition that it is a tool for fisheries management and that there is a need to identify and define its most effective use.

This paper complements a paper recently written on reseeding of grazing gastropods and bivalves (Borg, 2002).

SECTION 3 INTRODUCTION

3.1 Context

For the most part in Western Australia (WA), existing fisheries management has facilitated sustainable harvesting of fish[1] resources. With a small number of exceptions, management of marine and riverine fish resources in WA has involved proven methods of fisheries management that regulate fisher behaviour, such as licensing restrictions, area and seasonal closures, and output controls.

Despite effective management of the majority of fisheries, long-term exploitation, changing oceanic conditions, pollution and habitat destruction have influenced the levels of fish stocks off the coast of WA. Similar influences – agriculture, human exploitation, climate and environmental variability – have affected stocks in our rivers.

For example, under the water allocation policy, people are licensed to divert or dam rivers/streams in private property, meaning there is no guarantee of water levels or access to water supplies. This has a huge affect on stream flow in south-west WA. It is anticipated demand on fish resources from both commercial and recreational sectors, along with coastal development, will continue to increase, therefore furthering pressure on these limited resources.

Consequently, there are some fisheries for which arguments are being made to artificially enhance fish stocks and fisheries through release of hatchery stock, the translocation of juvenile and adult broodstock and the introduction of new species. Such enhancement, however, has to be considered in the context of ecologically sustainable development (ESD) – the impact on the ecosystem, biodiversity, and social and economic development.

Stock enhancement is not a new concept either in Australia or overseas. Appendix 1 provides an overview of some of the fish stock enhancement projects undertaken in Australia and elsewhere.

Blaxter (2000) notes that historically, most fish stock enhancement throughout the world has been *ad hoc* with little or no long-term planning. It has been trial and error – trying to find a solution before addressing the cause (noted also by Blankenship and Leber, 1995; Wahl *et al*, 1995). While enhancement may teach us about certain aspects of ecology and may work in the short term, if it fails, it is difficult to ascertain what went wrong. Similarly, *ad hoc* enhancement makes it difficult to determine what caused a project to be successful. Blaxter supports a bottom-up approach, through researching the appropriateness of releases and, if they are to occur, the development of a model that allows explanation of successes or failures.

This paper's proposals go further by including a strategic approach and a policy framework within scientific or economic models that must accompany stock enhancement projects.

This paper does not address the actual mechanics of stock enhancement. It sets out a proposed approach for the assessment of stock enhancement proposals in WA that sits within the general framework of options for managing fisheries resources.

[1] This paper adopts the definition of fish as set out in the *Fish Resources Management Act 1994* – in brief, any aquatic organism, excluding aquatic mammals, aquatic reptiles, aquatic birds, amphibians or pearl oysters.

It also tests whether stock enhancement is the right response to a problem or to an opportunity, and if it is, how proposals to introduce stock enhancement should be further assessed.

3.2 What is stock enhancement?

The Department of Fisheries has adopted the international definitions for 'ranching'. (Which the Department refers to as 'reseeding') and 'stock enhancement' (Bannister, 1991). These terms are cited and reaffirmed in Howell (1998):

Ranching: Identifiable[2] *stock released with the intention of being harvested by the releasing agency*.

Enhancement: Stock released for the public good without the intention of benefiting an exclusive user group.

This would include:

- Compensation[3] for depletion of a natural resource (restocking);
- Compensation for loss of habitat (augmentation);
- Genuine addition of new stock, for example stocking artificial reefs (addition).

These three methods of stock enhancement will be discussed further in section 2.5 of this paper.

This paper addresses the issues surrounding stock enhancement in WA. It does not address the situation of private fisheries in enclosed and privately owned waters (i.e. not WA waters) as government only regulates these fisheries where the species involved is a translocated one. Where this is the case, please refer to *Ministerial Policy Guideline No 5: The aquaculture and recreational fishing stock enhancement of non-endemic species in Western Australia* (Fisheries Department of Western Australia, 1997a*).*

For a discussion of reseeding, please see *Fisheries Management Paper 162: Reseeding of grazing gastropods and bivalves into the marine environment in Western Australia* (Borg, 2002).

3.3 'The Public Good'

The definition of stock enhancement adopted in this paper means that successful projects would be implemented for the 'public good'. A broad definition of public good has been adopted in this paper to account for the various investment scenarios that could be made in stock enhancement where there is a public good component.

[2] Stock released may not always be identifiable and it will not always be required in Western Australia. See Borg, 2002.
[3] Physical reparation.

The State Government is moving towards an integrated, ecosystem approach to management of fish resources (a proposed system known as Integrated Fisheries Management) as opposed to the traditional sectoral approach. There may be some value in touching on some of the sectoral issues (particularly recreational, commercial and environmental), as these are likely to be raised in the debate leading up to the development of a stock enhancement policy for Western Australia.

The right to fish recreationally is considered by many as being a basic right, with fisheries resources assumed to have 'public or social goods' characteristics (Cauvin, 1980). However, in reality, fisheries resources do not meet the requirements of such goods: free access to all, with consumption by one person (the amount a fisher catches) having no impact on consumption by another (the amount another fisher catches). Cauvin argued more than 20 years ago the public good argument no longer held sway. This is even more the case today. Governments can and do regulate and enforce controls for recreational fisheries. Thus people can be excluded from recreational fisheries at some level (for example, closed areas/seasons, bag limits).

There are no longer too many fish to be caught by the few recreational fishermen, and there is competition for limited recreational fishing resources. This is evident by stock depletion, crowding at popular fishing spots, and so on. Obviously, there will be some remote recreational fisheries for which these assertions do not apply, and they may not apply to some enhanced 'put and take' fisheries where additional stock can be added to ensure there are always enough fish to guarantee fish for all.

Although recreational fisheries may not always meet the requirements as a pure public good, there is arguably considerable community benefit in the recreational fishing experience. This is borne out by the fact that more than 640,000 people go fishing at least once a year (Department of Fisheries, 2002c).

This benefit could significantly increase if stock enhancement resulted in not only more fish to catch, but an increase in the quality of fishing. The significant economic contribution recreational fishing brings to regional economies would itself generate public good, both for those involved in fishing and for others who live in these regions and in the State.

Related to recreational fishing is the economic interest shown in fisheries by those not directly involved in the harvest of fish resources. There may be value in tourism ventures or other service industries financing stock enhancement of fish resources in a particular area for their own commercial benefit. The improvement in fishing for all user groups would be a public good associated with a commercial investment in the fishery.

More closely related to fishing is the case where a commercial fishing interest/group financed stock enhancement of an existing fishery where the benefit did not flow exclusively to that person or group. An example of such enhancement would be the movement of rock lobster puerulus from one part of the fishery where there is excess to the fishery/ecosystem's requirements, to another part of the fishery where there is a deficit of puerulus. This would benefit the commercial fishing industry, and there would be a public good component for any person holding a rock lobster recreational licence as they would be able to access the enhanced fishery.

Enhancement of a commercial fishery by the commercial fishing industry or by government, in some circumstances, may also occur to smooth recruitment or to repair the fishery after a catastrophic event. In a largely commercial fishery, this may fall under the policy for

reseeding. Conversely, in a fishery with a large recreational component as well as a commercial fishery, such enhancement would be considered to have 'public good'.

Where there is no significant use of fish resources for extractive purposes, stock enhancement could be employed for conservation purposes, that is, for direct public good.

3.4 Why enhance fish stocks?

As fish hatcheries become more efficient at producing seed and fingerlings, the questions asked are – why not put fish back into the water to increase the number of fish available to the public, to increase the quality of fishing experience, to repair damage done by overfishing or pollution or some natural environmental event? These are valid questions. Superficially, to the question "why enhance fish stocks?" the answer may be "because we can", "or why not? It can't hurt".

Placing millions of small fish into the water does not necessarily resolve the underlying issues. Although this was the early attitude to stock enhancement (Welcomme and Bartley, 1998), the implications of doing this could be serious. The stocking of redfin perch in Australia resulted in the spread of a dangerous virus to trout and a number of native fish, as well as predation of small fish and fry (Thorn, 1995). Consequently, developing a policy on fish stock enhancement requires a more thorough consideration of the issues.

Although the government is required, under fisheries legislation, to optimise social and economic benefits and to foster development of the various fishing sectors, its primary consideration is to conserve fish and protect their environment. All other considerations are secondary to this (given that without fish resources, there are no fisheries) and therefore all social and economic arguments for stock enhancement must sit under the key consideration - sustainability of the fish resources and their environment.

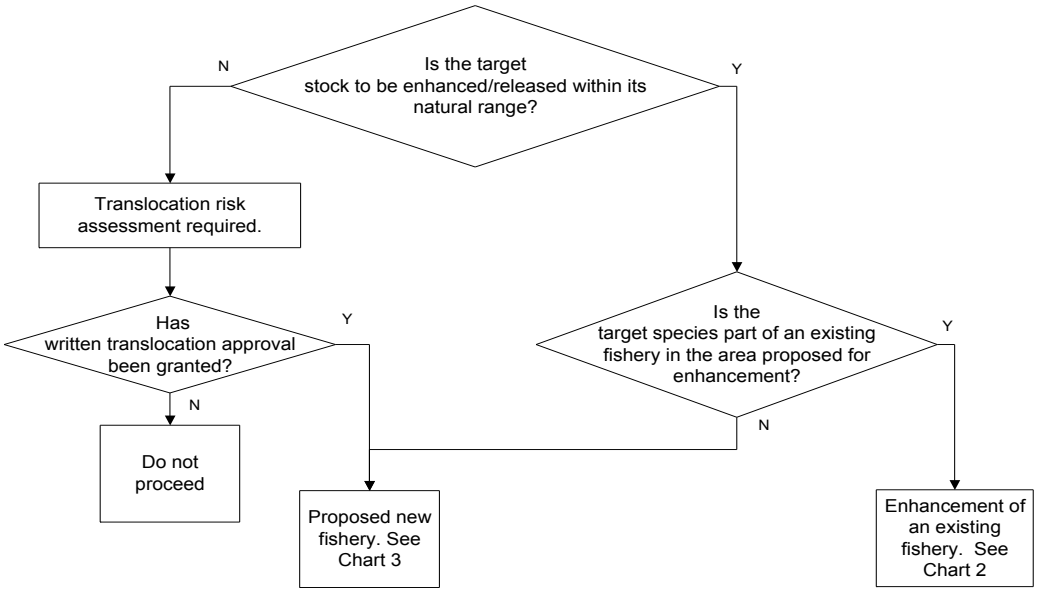
Having said this, the government recognises the strong link between biological and socio-economic impacts. Bartley and Casal (1998) suggest that socio-economic changes that result from stock enhancement can, in turn, cause more ecological changes. This connection is discussed further in section 6.2.3.1.

Consequently, although biological risk is the primary concern when considering fish stock enhancement, this paper embraces the concept of ecologically sustainable development (ESD) – a process that considers economic, social, legal and institutional factors within broader biological imperatives.

The following approach considers these issues using the structure of two conceptual policy frameworks through which any proposal for stock enhancement should be taken. Chart 1[4] provides steps that point to the appropriate framework to follow.

[4] Each of the charts in this paper were developed in conjunction with those presented in Fisheries Management Paper 162 on reseeding (Borg 2002).

Chart 1 Overview Assessment for Fish Stock Enhancement Projects



3.5 Conceptual frameworks

The steps of the conceptual frameworks (charts 2 and 3, pages 13 and 29, then chart 4, page 33) are proposed to ensure that stock enhancement is put in the broader perspective of fisheries management in Western Australia.

The frameworks illustrate the approach being taken in Western Australia - that stock enhancement is not a 'given'. It is one tool of many available to fishery managers. This approach is necessary because the existence of hatchery technology generates pressure to use this technology to either enhance fisheries identified as having a real or perceived problem, or to create new fisheries. However, before doing any of this, it is necessary in an existing fishery to firstly analyse the problem and ask whether stock enhancement will address it; and for a new fishery, to assess whether the species proposed is appropriate for that environment and whether the fishery is likely to survive (ecologically or economically) if created.

It is acknowledged that stock enhancement can be used as a positive contribution to a well-managed fishery and not just to solve problems. For example, a fishery may be meeting its current management objectives in terms of sustainability, but there may be naturally uneven distribution of stock across the fishery. If it was feasible, and there was no detriment to the ecological balance of the existing ecosystem, to redistribute natural stock or to introduce hatchery stock of that species into 'barren' or less productive areas, stock enhancement may improve the overall performance of the fishery.

This paper recognises four broad types of fisheries where stock enhancement may be considered an option:

- Where a wildstock fishery is not, or perceived not to be, performing against defined fisheries management objectives and targets or biological reference points (for whatever reason, including natural catastrophic events);

- Where a well managed wildstock fishery could be further improved;
- Where an 'artificial fishery' is to be established in waters where other (possibly similar) species are already fished (new fisheries in 'old' waters); and/or
- Where a new fishery is established in waters where fishing is not already occurring (new fisheries in 'new' waters).

Given the assessment process for these types of fisheries will differ, as mentioned above, two frameworks have been posed. The processes to be followed for the third and fourth types of fishery would be similar. Framework 1 addresses restocking or movement of species within existing fisheries, and framework 2 addresses the movement or translocation of new species into either existing fishing grounds or new fishing areas.

The remainder of this paper will examine the steps of the two conceptual frameworks, presenting some of the theory, arguments and questions associated with each step. Section 4 addresses framework 1 as presented in chart 2. Section 5 does similarly for framework 2 in conjunction with chart 3. Discussion of the development and assessment of stock enhancement proposals occurs in section 4 of this paper. The proposed application process is presented in section 7.

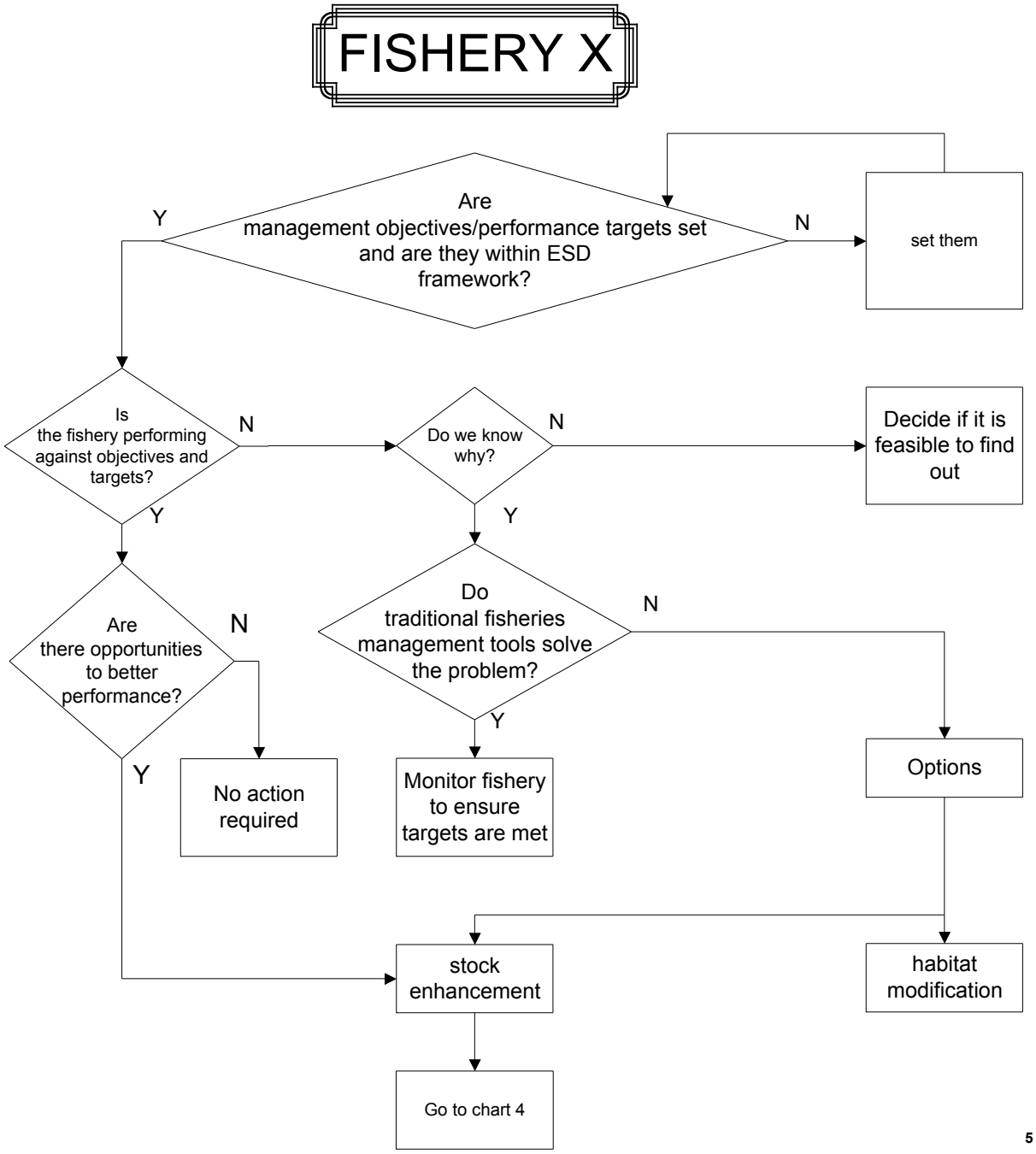
It should be noted, if at any stage an enhancement proposal fails to progress because it has not satisfied a component in the framework, the proponent may redesign the proposal and resubmit it for assessment.

To assist in linking between the text and charts, boxes have been included next to headings showing the relevant box from the chart for each conceptual framework. Should the species involved not be endemic (naturally occurring) to the area of the proposed fishery, approval must be sought from the Executive Director under Regulation 176 of the *Fisheries Resources Management Regulations 1995* to allow that species into the area.

See Ministerial Policy Guideline No 5 (Fisheries Department of Western Australia, 1997a) for further information on the translocation processes. Should the translocation assessment process be triggered, it would run in conjunction with the process outlined for the assessment of a new fishery in chart 3.

SECTION 4 CONCEPTUAL FRAMEWORK 1: ENHANCEMENT OF EXISTING FISHERIES

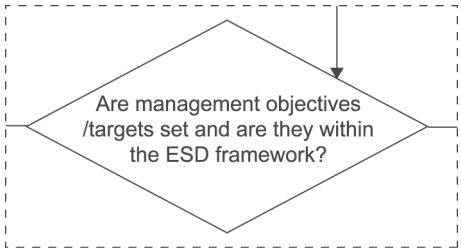
Chart 2 Conceptual Framework for Assessing Potential Fish Stock Enhancement Projects in Existing Fisheries



[5]

[5]

4.1 Fishery management objectives and performance targets



4.1.1 Impact of Legislation

Commercial and recreational fisheries in Western Australia are managed under the *Fish Resources Management Act 1994* (FRMA) and the *Fish Resources Management Regulations 1995* (FRMR). The waters and surrounding land are also covered by legislation from a number of other Commonwealth and State agencies. A list of identified natural resource management legislation is shown in Table 1.

Table 1 Commonwealth and State legislation with a possible impact on fisheries within Western Australia

WA	Commonwealth
Agriculture Act 1998	Coastal Waters (State Powers) Act 1979
Competition Policy Reform (WA) Act 1996	Control of Naval Waters Act 1918
Conservation and Land Management Act 1984	Environment Protection and Biodiversity Conservation Act 1999
Constitutional Powers (Coastal Waters) Act 1979	Native Title Act 1993
Enzootic Disease Act 1976.	Biological Control Act 1984
Exotic Animal Diseases Act	World Heritage Properties Conservation Act 1983
Local Government Water Supply Preservation Act 1892	
Stock Diseases (regulations) Act 1968	
Water & Rivers Act 1995	
Water Corporation Act 1995	
Waterways Conservation Act 1945	
Wildlife Conservation Act 1950	
Heritage of Western Australia Act 1990	
Environment Protection Act 1986	

With the lack of coordinated whole-of-government marine or inland water resource use planning strategies, there are far-ranging implications for management of fish resources in

these water bodies. This is an ongoing issue with management of existing fisheries resources, and further complicates the ability of proponents to set realistic objectives and targets for fish stock enhancement projects.

4.1.2 Ecologically Sustainable Development (ESD) targets and framework

The Government's policy on ESD is significant to potential stock enhancement activities. Would the enhancement or creation of fisheries contribute to the ESD of existing fisheries resources in an area or fishery?

In its policy paper on implementation of ESD in fisheries and aquaculture (Department of Fisheries, 2002b), the Department outlines the ESD National Framework core objectives for sustainable fisheries. These objectives seek to:

- Protect biodiversity and maintain essential ecological processes;
- Enhance individual and community wellbeing by following a path of economic development that safeguards the welfare of current and future generations; and
- Provide effective legal, institutional and economic frameworks for ESD.

Seven major goals were drawn out of these objectives to assist in assessing a fishery's contribution to ESD. These goals cover ecological, social, economic and legal areas and can be found in more detail in the Department's ESD policy paper. Assessment of any enhancement project would need to take into account whether the proposed project complemented these ESD goals.

In terms of fisheries-specific ESD goals, the Department of Fisheries has so far only developed objectives for biological components, as these have been required as a priority for all fisheries needing to meet the Department of Environment and Heritage's legislation for export of product. Work is underway to develop fishery-specific objectives for other components. Proponents are encouraged to provide more information in addition to biological factors in their applications. This said, applications will only be assessed against ESD objectives for which the Department of Fisheries has provided documentation.

4.1.3 Fisheries objectives and targets

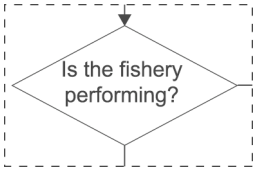
Commercial fisheries and recreational fishing are managed under various types of management regimes and plans. Increasingly, management arrangements for existing fisheries are being formalised through fisheries management plans (commercial) and regional management strategies (recreational) increasing integration under a single set of biological reference points/management triggers.

Each management plan/strategy is underpinned by explicit management objectives and, where appropriate, performance targets. These objectives not only give a context to ongoing management of existing fisheries, but also provide a framework and guidance to other appropriate uses of those fish resources.

Having said this, performance targets set within objectives must be realistic. In many fisheries, there is not sufficient information to be able to set meaningful targets. In other fisheries, the data exists and those fisheries have been managed accordingly. However, these targets are not set in concrete – they are regularly re-evaluated in the light of new information, and, where appropriate, the targets are changed or new resources are identified and developed.

As with existing fisheries, user groups must be involved in the setting of objectives and targets for new or enhanced fisheries. Negotiating common objectives and then a plan for what can actually be achieved will present a challenge. For example, a recreational fishing group may want an enhanced fishing experience reminiscent of one available 20 years ago. There may be a big difference between this desired outcome and what can be achieved given the change in the physical, social, political and economic environment affecting management during this time.

4.2 Is the fishery performing?



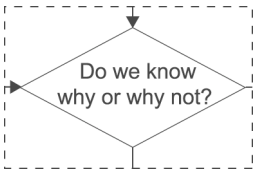
Without specific objectives or targets, 'performance' is merely a value judgement according to a person, group or institution. If a fishery is not meeting preset objectives and targets, it is likely to be due to one or a combination of threatening processes.

Baird (1999) suggests habitat degradation is the most important threat to the long-term recovery and preservation of exploitable fish stocks. In Western Australia, this is more so the case in freshwater and estuarine environments. There is a wide range of effects that have nothing to do with what is traditionally blamed for poor fishery performance. These are primarily associated with human population growth and development in coastal areas.

A large number of commercial and recreational fish species are dependent on estuaries for reproduction, nursery areas and/or migration. These estuaries, in turn, depend on healthy emerged and submerged wetlands (Schmitten, 1999). In the Great Lakes basin ecosystem in the United States, "direct removal of or damage to habitat was implicated as a threat for nearly 60 per cent of species undergoing historic declines and nearly 50 per cent undergoing current declines." (Hartig and Kelso, 1999).

Threatening processes need to be ranked according to scale, severity and persistence (Baird 1999). The following list of man-made or natural influences is drawn from Molony *et al* (submitted) and Schmitten, (1999):

- fishing – excessive bycatch, overfishing;
- habitat loss or modification – destruction of wetlands, physical alteration of the environment (both adjacent to and within coastal areas), gear induced habitat destruction;
- introduction of exotic species;
- shifting distribution of fishing effort (where people are fishing, how intensively and for what period of time);
- pollution (point source or accidental release) – eutrophication, algal blooms, inadequate water quality; and/or
- changes in community perception (eg conservation) and in the objectives/goals of user groups.

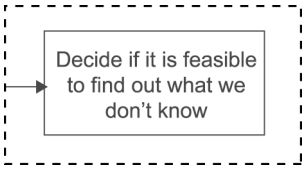


The challenge is to identify and understand these underlying causes in any particular fishery. In many situations there may not be enough evidence to identify the underlying cause(s). For example, overfishing by recreational fishers is difficult to evaluate because there is not usually historical data setting out catch, effort and participation. Although the information base is growing, there is still much to learn about recreational fisheries. Likewise, there may be insufficient information about the stock/population of fish, or about the water body, water system, or fishery itself.

Having identified threats (to the level possible) against achieving fishery objectives, the question must be asked - can these threats be mitigated? If not, there may be no point proceeding because management decisions, and subsequent actions (including fish stock enhancement), will not be effective. For example, if the habitat has been damaged, it may not be able to support an enhanced fishery.

Part of the difficulty is responsibility for different aspects of habitat management lies with a number of State, local, and in some cases, Commonwealth authorities. Consequently, fisheries managers may only be able to influence a small part of the total system within which the fishery operates (as noted in section 2.1.1). The priority placed on habitat and its role in marine or freshwater water ecosystems may not always be high in each of these other departments – there are competing social, economic and environmental objectives and demands.

4.3 How much do we try to find out – risk assessment?



By necessity, fisheries management decisions are often made without the benefit of all information, but not before assessing the implications of acting or not. Stock enhancement introduces a different dimension because, in the majority of cases, it involves introducing something new into a biological system and it is likely that not all the effects of this introduction would be known. The precautionary principle states:

"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[6]

This principle has been extended to most environmental situations, including fisheries management, such that caution should be taken in respect to fisheries actions that may have a serious or detrimental effect on the environment.

[6] Declaration from the 1992 United Nations Conference on Environment and Development, also known as Agenda 21.

Specifically, Australia's Oceans Policy (Commonwealth of Australia, 1998) provides further guidance in terms of application of the precautionary principle:

"*If the potential impact of an action is uncertain, priority should be given to maintaining ecosystem health and productivity. Incomplete information on possible impacts should not be used as a reason for postponing precautionary measures intended to reduce or avoid unacceptable levels of change or to prevent serious or irreversible environmental degradation…"*

Also of interest (although Australia is not a signatory to this convention) is the guidance provided by the following principle from the OSPAR Convention For The Protection Of The Marine Environment Of The North-East Atlantic, 1992:

"…preventative measures are to be taken when there are reasonable grounds for concern that substances or energy introduced, directly or indirectly, into the marine environment may bring about hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship between inputs and the effects." [7]

Neither principle says "don't do anything unless there is perfect information". But they require a cautious approach and a meaningful attempt to assess the risks associated with actions at various levels of information and knowledge.

Prokop (1995) notes there is no such thing as 'no risk' in stock enhancement. Therefore a decision is needed to determine 'what is an acceptable level of risk?' In terms of stock enhancement of inland waters, Prokop offers the following levels of risk:

1. The lowest risk is the introduction of naturally occurring species into areas within their range but where they are not currently found. In WA, this has occurred with the stocking of Jerdacuttup Lakes and Lake Dumbleyung with black bream, both of which are in the general geographical range of the species.
2. The next level is a species outside its natural range, whose reproductive biology is well understood and conditions for successful reproduction cannot be met. This is the category with the greatest potential for establishing significant recreational fisheries.
3. The next greatest risk is translocation outside a species' natural range, where reproductive biology is not known or conditions for successful spawning exist in the environment into which the species has been introduced.
4. The highest level of risk is overseas translocations – tilapia, carp and redfin perch have been introduced into WA. So far, due to stringent testing, WA has escaped disease, however, the risk compounds with each introduction. Ecosystem impacts may also be significant, for example, redfin has become a predator of marron in some Western Australian waters.

Another risk category not mentioned by Prokop is the option with the lowest risk - one that is being considered for some fisheries. This is enhancing stock within its range and where it is already found, to increase abundance or productivity of naturally occurring stock. Even when being undertaken for a commercial purpose, there is potential for a large public good side effect, as the benefits may flow outside the commercial industry. Enhancing fisheries with

[7] Article 2 of the Oslo and Paris Commission, OSPAR Convention For The Protection Of The Marine Environment Of The North-East Atlantic, 1992.

fish of the same stock is already occurring in recreational fisheries for black bream in both the Swan and Blackwood Rivers.

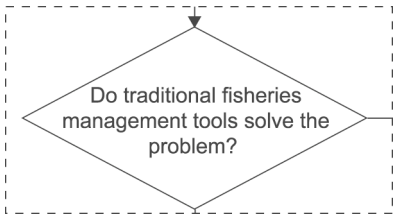
In recognition of the wider risks associated with stock enhancement, the West Coast Recreational Fishing Working Group (2000) published a position statement on restocking as part of its proposed recreational fishing management strategy:

"Management of wild fish stocks should always be the primary focus for recreational fisheries management, and restocking should only be considered as a strategy to assist with the recovery of a stock where it can be identified that the stock has been significantly depleted."

Stock enhancement in estuarine or coastal waters has further implications because there are no defined boundaries on these systems. Stock released into an estuary or into coastal waters may move into other water bodies and may impact not only on the ecosystem into which they are released, but also ecosystems adjacent to or further along the coastline. It would appear the risks in such cases would be higher than releases into inland waters, especially if those coastal releases were successful in enhancing wild stocks.

Welcomme and Bartley (1998) suggest by applying elements of the precautionary approach to fish and fishery enhancement, such as risk analysis, implementing monitoring systems with defined levels of acceptable impact, and corrective measures in advance of adverse impact, it is possible to reduce the likelihood of an adverse impact. Is it worth finding out what is not known, or do we make decisions based on what is known? A risk analysis of different courses of action and a cost benefit analysis on options for obtaining more information should answer these questions.

4.4 Traditional fisheries management tools



If threatening process(es) identified as impacting on the performance of a fishery can be mitigated, then it is likely a management strategy can be developed to address poor performance in a fishery. The first step is to look at traditional management tools to ascertain if these can address the problem(s) in the fishery. The main traditional fisheries management tools are those controlling fishing activity and those protecting fish and fish habitat.

4.4.1 Fishing activity - input/output controls

Fisheries managers throughout the world have two main sets of tools for managing fishing activity. These are input controls and output controls.

Input controls include measures such as restricting the number of licences and/or boats, nominating a fishing season, closing certain areas to fishing, and boat and/or gear restrictions.

Input controls have been the dominant management tool in Western Australia since fisheries management commenced in the 1890s. Despite this, stock sustainability, marketing requirements and the need for increased economic efficiency in commercial fisheries are not always met under these rigid controls. An alternative system of input controls in Western Australian commercial fisheries is individual transferable effort units. This system unitises the total available amount of fishing gear or time and allocates it among participants. These units can be traded to allow fishers to adjust their operations, as circumstances require. Individual transferable effort units are usually supplemented with fixed input controls such as licensing controls and area restrictions.

The most extreme of these management systems is total closure of the fishery, either temporarily or permanently. While this is an option, in most cases, it would be considered as the last resort. If management measures fail to restore a fishery to an economically viable, ecologically sustainable level, and if habitat modification or stock enhancement are not feasible or fail, then the only responsible action is to close the fishery. The alternative would likely be the collapse of the fishery (for example, the recreational fishery for Shark Bay snapper in the inner gulf) or the irreversible depletion of some species within that ecosystem. Neither of these are acceptable outcomes, either for the government or the community.

Input controls are also in place for recreational fisheries in Western Australia. The primary management tools are licensing (required for the major five recreational fisheries only), area and seasonal closures, and gear restrictions.

Output controls in commercial fisheries generally refer to catch quotas. These can be total allowable catches or individual allocations, and transferable or non-transferable. The most flexible, and most widely used of these controls in Australia, is individual transferable quotas. Notably, the system is not appropriate to all fisheries. Individual transferable quotas are used to manage the Western Australian abalone and south coast purse seine/small pelagic fisheries.

Bag and possession limits, output controls, are a major management tool in recreational fisheries - they regulate how many fish an individual can take out of the water or have in his/her possession.

4.4.2 Protection of fish and fish habitat

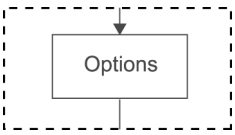
Fish protection measures are put in place to protect and enhance commercial, recreational, environmental and social values associated with the fish resources in Western Australia (Bunting, 2001). They use regulations under the FRMA "to control fishing and associated activities and some other human activities which may damage the aquatic environment" (Bunting, 2001). The range of situations is diverse and so are the measures available. They can be grouped according to whether they are based on size or spatial extent (marine protected areas, total prohibitions); species specific or activity specific; or according to their primary objectives.

Bunting (2001) lists the primary objectives for developing protection measures and some examples of these measures:

- Conservation – prohibitions on taking vulnerable species, bans on destructive fishing practices, protection of nursery and spawning habitats, protection of threatened habitats, refugia;
- Stock or fisheries management – commercial and recreational fishing controls to protect recruitment, measures to ensure all users have appropriate access to the resource;
- Scientific study – experimental control sights, research zones;
- Observation and ecotourism – protection from fishing, refugia, observation areas; and
- Health protection – closure of fishing where contamination has occurred.

Many of these measures are achievable through the commonly used fisheries management mechanisms provided within the FRMA, such as management plans and section 43 Orders. Stronger and more specific habitat protection provisions are also within the FRMA. Section 115 allows for the creation of fish habitat protection areas, within which any activity can be regulated in order to ensure the protection or management of the area. Powers are not limited to regulation of fishing activity.

4.5 Options if traditional methods fail



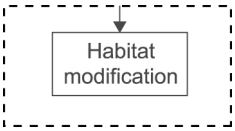
If traditional management tools cannot alleviate the problems being experienced in an under-performing fishery, managers have a limited number of other options:

- Restore/modify the habitat such that the natural populations increase without further assistance (this option could be employed in connection with the next option); or
- Enhance the natural populations of fish by introducing hatchery-produced stock (preferably endemic), or broodstock sourced from outside the target area.

In the event of either option being pursued, it is likely traditional management tools would need to be employed to supplement the option chosen, namely, to protect the restored habitat or the newly enhanced stock.

If threatening processes cannot be mitigated, and hence a sustainable managed fishery cannot be maintained through management controls, habitat protection or modification, stock enhancement or some combination of these, as a last resort, the fishery may have to be closed to further fishing, either on a temporary or permanent basis.

4.5.1 Habitat modification/restoration



The first option is habitat modification or restoration. Hartig and Kelso (1999) define habitat as "the physical, chemical, and biological factors that integrate to support a particular species or assemblage".

In WA, and similarly in the rest of Australia, the main causes of habitat damage are urbanisation, land and freshwater use, and introduced pests and diseases. The sources of most of these are well understood, however, due to a complex combination of social and economic reasons, not all are removable threats.

The most efficient way to attack habitat loss is to identify the essential fish habitats before undertaking modification or restoration and then to target restoration/modification of those essential habitats. This identification has yet to occur for many regions and there are still many questions on the role of these habitats have in fisheries production and in maintaining ecosystem integrity and biodiversity (Cappo, 2002).

Habitat restoration may be possible on smaller scales, especially in riverine and estuarine areas where barriers (e.g. small dams, culverts) can be removed to restore river flow or access to essential fish habitats. In some cases, artificial habitats may be installed to replace structure that has been historically removed (e.g. artificial or natural snags into clear-bottomed dams, artificial reefs into areas that have structure removed). Where the source of the problem is pollution and the damage is not irreversible, removing the source of pollution may be enough to restore essential fish habitat.

Often the option of habitat modification or restoration is overlooked. People want a quick fix or instant answer to the perceived lack of fish for the taking. Restoration or modification of habitat will not, in most cases, provide an instant solution.

Nevertheless, there is evidence that improving essential fish habitat can improve and restore fish populations (Cappo, 2002, Cappo *et al* 1998). As with any management method, the costs and benefits of undertaking habitat modification needs to be assessed. It may be physically possible to restore a particular habitat, but there may be other reasons why it would not be done. This is further complicated for fisheries managers in WA by the fact that, traditionally, habitat restoration has not been seen as a major role for the Department of Fisheries.

4.5.1.1 Marine and estuarine

- Artificial reefs

These can be effective if properly placed and built of appropriate materials. Placement and construction of artificial reefs should be assessed thoroughly in order to ascertain the most effective and efficient means of enhancing fish stocks. If the placement is wrong, it could disrupt rather than enhance the natural environment and/or attract fish not usually found in the locality, which may have unwanted consequences. If the material is wrong, then decomposition may occur and/or the structures may dislodge and damage natural benthic structure (Wilbur and Pentony, 1999).

Korea has been installing artificial reefs successfully along its coastline for 30 years in an attempt to restore fish, shellfish and seaweed fisheries. Monitoring on sample sites has shown catch volumes on artificial reefs of two to 13 times that of natural reefs (Kim 2001).

Proponents should note that under Western Australian legislation, coral is defined as a fish, so any proposal involving the use of coral as an artificial reef would need to be considered under this stock enhancement policy, not just as an artificial reef but as creation of a new fishery. The translocation policy may also be triggered, depending on the source of the coral.

- Restoring coastal wetlands

Restoring coastal wetlands will not assist in restoring fish populations unless the projects include the enhancement of fish habitats. It cannot be assumed that replanting of previously occurring vegetation will result in re-colonisation of fish (Minton, 1999). Unfortunately, the baseline data needed to accurately restore the necessary fish habitat is often not available. Having said this, there is a growing body of evidence that "restoration of coastal wetlands will increase the abundance of wetland habitat types required by commercially and recreationally valuable species of marine fish" (Minton, 1999).

Locally, an assessment of the effect of the Dawesville Channel, part of the Peel Harvey Estuarine System (PHES), south of Perth (D A Lords & Associates Pty Ltd, 1998) showed a beneficial effect on local commercial and recreational fisheries. The channel was not purpose-built for fisheries management, but rather to increase the environmental health of the total PHES.

Since the opening of the channel, prawn and crab densities have increased, and improvements in water quality have meant an increase in small benthic invertebrates that are food for most fish species. Marine fish species moved further into the estuary and at higher densities, and with the exception of prawns, commercial catch per unit effort for the major commercial species has either increased or at worst, stayed the same. The drop in prawn catch appears to be related to the inability of fishermen to use their trawling gear in the stronger currents of the channel and not to the abundance of prawns.

4.5.1.2 Freshwater

- Water quality

Water quality can be affected by runoff from land clearing, agricultural production or by industrial and domestic pollution. It is largely tied to the state of the catchment area and the activities that occur within it (Environment WA, 1998). Important indicators are salinity, levels of dissolved oxygen, heavy metal levels, water clarity, temperature, volume of water, and reliability of flow (C. Chalmers[8], pers. comm.). Water quality is decreased through salinisation, acidification and eutrophication. Decreased water quality can lead to excessive weed growth and/or algae, both of which may be detrimental to fish populations.

These can be addressed by regulation and education at the source of pollution and by re-establishing the natural riparian environment along the banks of the rivers. This is assisted by the availability of funds through local/State and Commonwealth funded programs aimed at protection and restoration of the environment. However, land tenure issues and the fact that a number of local, State and sometimes Commonwealth bodies have controls over the land and/or water, often complicate such efforts.

- Access through dams

A number of fish species require both fresh and saline water to complete their life cycles, and need to be able to swim up stream to the breeding habitats. The construction of dams across natural waterways inhibits such activity and threatens the survival of such fish species. Recognition of this requirement has led to construction of access ways in some dams.

- Maintaining stream flow

Stream flow is important to freshwater fish, with the level of importance depending on the species. The construction of dams obviously changes the stream flow below the dam wall (also temperature, as dams tend to release cold water). Further, this flow would not be regular, and depending on the amount of water being released through dam walls.

Pumping for agriculture also has an impact on stream flow. Again, the impact would depend on the species of fish and its requirements. Marron, for example, could be significantly affected, as pumping is likely to be greater in the summer dry periods that coincide with the marron's breeding season.

[8] Colin Chalmers is Manager of the Fish and Fish Habitat Protection Program in the Department of Fisheries.

- Restoring breeding sites

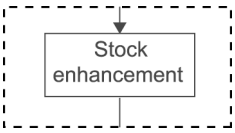
Man's interference with natural water systems can result in the removal or modification of significant fish habitats such as sunken trees and branches. Resnagging some areas of the streams and rivers can help redress the impact on breeding sites.

- Restoring river banks

Riparian vegetation has a strong influence on water temperature and light filtration, in stream energy production and on the type and quantity of food matter and nutrients in the stream. Clearing this vegetation disturbs the natural ecosystems and can greatly affect fish populations (Land & Water Australia, 2002).

In many regions of Australia, native vegetation is being replanted along streams in an attempt to decrease erosion and recreate shade so weeds and algae can no longer survive.

4.5.2 Stock enhancement



The second option mentioned is stock enhancement. Stock enhancement will work best when used as a component of integrated resource management. "Fisheries management will be most successful if geared to the productive capacities of water bodies, rather than trying to exceed them, and to sustaining the native (locally normal) biodiversity and health of ecosystems, rather than extirpating species and destroying ecological functions of biotic communities." (White *et al,* 1995, p.534).

Stock enhancement will always have an impact on the ecosystem into which fish are introduced; but the level of impact on the existing stock or fishery will vary and rarely produce the results desired by some groups – the immediate availability of more fish to take or the gradual return to a past 'utopia'. The 'how' and 'what' of enhancement will depend on the 'why', that is the objectives and performance targets of the enhancement project.

Stock assessment can only seriously be considered an option in the light of other uses of the area and resource to be enhanced. A number of parameters need to be considered when choosing which resource to enhance:

- Age that the species reaches maturity;
- Recruitment variability;
- Fecundity – is it high or low?
- Natural mortality – is it high or low?

These parameters are interlinked and, with the exception of a pure addition fishery (see section 4.5.2.3), are crucial in determining which species may successfully be enhanced.

Where enhancement would occur is also a critical factor. Freshwater is the easiest to enhance. Estuarine is more difficult and deepwater marine would be virtually impossible. Even if it were achievable, the extent of the deepwater ecosystem would make it virtually impossible to monitor and evaluate the level of the enhancement's success or its impact on the remainder of the ecosystem.

Welcomme and Barkley (1998) report evidence from existing introductions implied that inland rivers throughout the world have benefited from well planned introductions. The same cannot be said for the majority of marine stockings, where translocating species has seldom enhanced fisheries. There appears to more success with enhancement where stocking involves fish native to the area of enhancement, such as Pacific salmon off the coast and in the rivers of the United States (US), and chum and Pacific salmon in Japan.

Leber *et al* (1995) suggest that successful marine enhancement depends on the reality of two hypotheses that would underlie any enhancement – that a significant number of hatchery fish can survive in the wild, and that released hatchery fish will increase abundances, not displace wild fish.

Kellison *et al* (2000) also pose the question as to whether it is possible to produce appropriate hatchery reared fish that can survive in the wild. Brown and Day (2002) list six major areas of behaviour that enable fish to survive in the wild. They must be able to avoid predators; acquire and process food; interact socially with other conspecies (species of the same genus); find or construct shelters; move around in or on complex terrain; and orientate and navigate in a complex environment. It is therefore important to have a good understanding of the biology and ecology of the fish species to be enhanced or introduced and the environment into which it is to be released.

Inshore enhancement of striped mullet in Kaneohe Bay, Hawaii, demonstrates that there is some potential for marine enhancement given a controlled approach to management (Leber *et al*, 1995). Similarly, Welcomme and Bartley (1998) cite some success from initial introductions of striped bass and American shad in North America, rainbow trout in New Zealand and Chile, and Kamchatka king crab in the Barents Sea. Appendix 1 provides more examples.

Other important questions are: Is it feasible in the light of other fisheries management in the area? Are there passive users who would be disadvantaged by the project? Are there future development projects that would modify the habitat such that the fishery or the area could no longer support the enhanced stock?

If the species and the environment are supportive and the answers to these and other pertinent questions indicate it is feasible to consider stock enhancement, then the options are restocking, augmentation and addition. This latter option is more fully developed in Section 4 of this paper.

4.5.2.1 Restocking

When most people think of stock enhancement, what they have in mind is restocking – the production and release of fish from a hatchery to replenish an area where fish used to be and now are not (re-introduce a species), or to provide additional fish into an area where the fishery has declined or collapsed (supplement existing stock). Many important fisheries in the world are in crisis from habitat degradation or overfishing. Restocking is often seen as the answer. It cannot offset these problems, but it can make them worse or create new ones (White *et al*, 1995).

There are feasible and appropriate opportunities for fish restocking. A local use for restocking may be releasing marron into Waroona Dam after it has been drained for repairs and refilled. Black bream has also been successfully restocked into the Swan River in WA (see Appendix 1). Restocking of pink snapper into Shark Bay may also be possible.

Restocking may not be needed regularly, especially if restocked fish are protected by traditional fisheries management measures, such as closing the waters for a period of time. In fact, with a few exceptions, White *et al* (1995) suggest stocking "as few fish as possible in as few waters as possible for as few years as possible" (p 539).

Restocking may also be useful for smoothing out major fluctuations in recruitment. To be successful, this requires scientists to be able to predict when recruitment will drop so that appropriate hatchery stock is available at the time it is needed.

Consideration also needs to be given to the downstream implications of periodic stocking, for example, recruitment smoothing. If the troughs are naturally occurring rather than induced, there may be other species that take advantage of these troughs, and these would be affected by restocking during these times.

4.5.2.2 Augmentation

Where the fishery is affected by habitat loss or modification, augmentation of the stock may be an option. Augmentation acknowledges the effect of the existing habitat loss or modification through the release of fish at a size where the habitat is no longer a limiting factor, for example where habitat damage has incurred in an estuary that provides the habitat for the juvenile phase of a fish. In this case, augmentation would involve release of fish at the size at which they would normally leave the estuary. The stock gets extra fish without actually treating the problem in the estuary.

Augmentation may assist in the conservation of some species. It may also facilitate an increase in productivity of a particular stock. For example, consideration is being given to augmenting rock lobster stocks through the transfer of puerulus within the natural range of rock lobster.

4.5.2.3 Addition

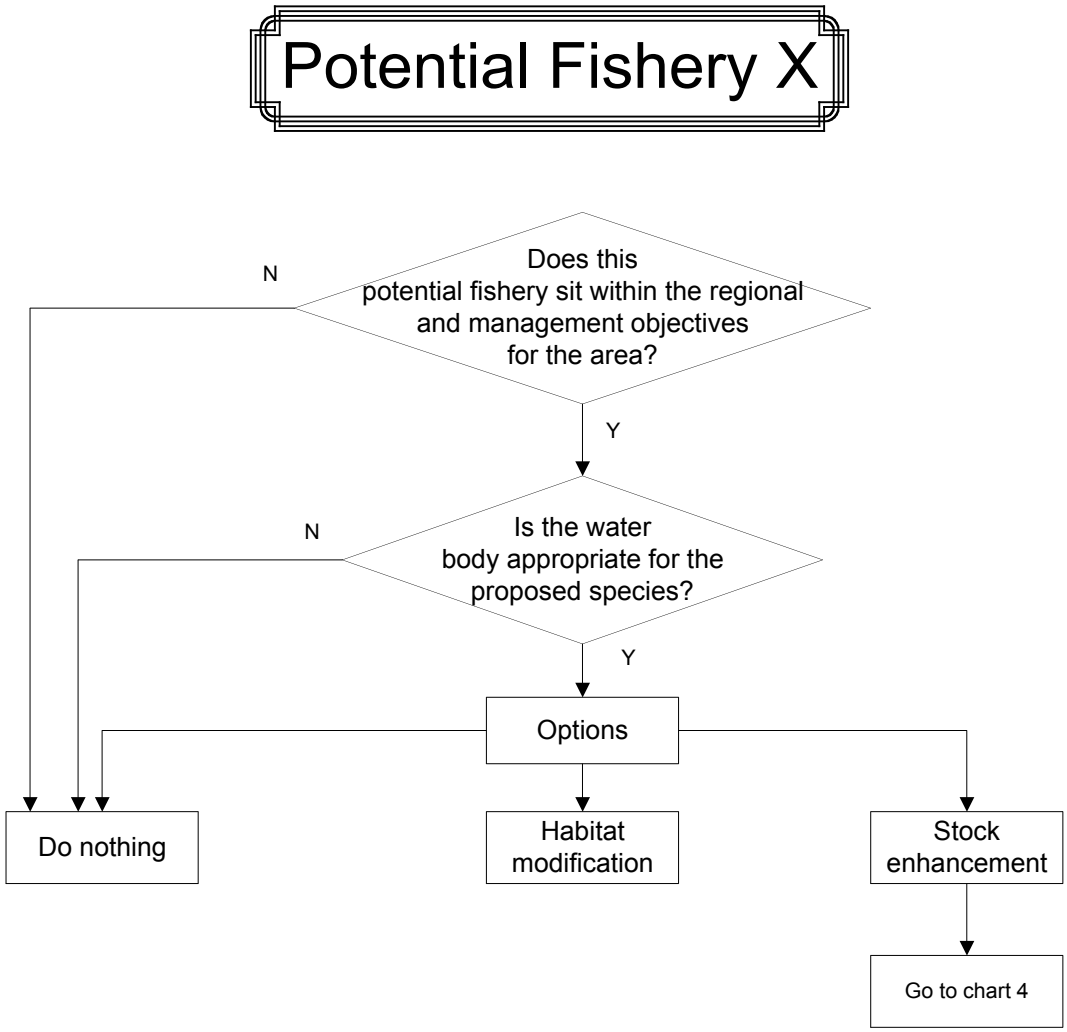
Addition is when a new species is introduced into an area outside its natural range. The production and stocking of trout (*Oncorhynchus mykiss* and *Salmo trutta*) in Australia is a good example of stock enhancement by addition. Trout is a 'put and take' fishery as, in most areas, it does not breed locally and therefore needs regular enhancement. Another 'put and

take' fishery, with a slight difference, is one where the species is targeted in enhanced areas below size of reproductive effort. Again, such a fishery would need regular enhancement.

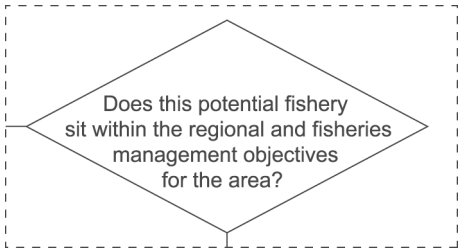
Another example of enhancement by addition is the introduction of an endemic species to other parts of the State, such as marron in the South West. Also addition is trochus in the Kimberley, where trochus naturally grows on some reefs and not others.

SECTION 5 CONCEPTUAL FRAMEWORK 2: NEW FISHERIES IN 'NEW' AND 'OLD' WATERS

Chart 3 Conceptual Framework for Assessing Potential Stock Enhancement Projects in New Fisheries/New Waters and New Species in "Old Waters"



5.1 Regional management



Regional management of fisheries within WA occurs through a number of complementary strategies.

Recreational fishing
In 1997, the Government, in conjunction with the Recreational Fishing Advisory Committee (RFAC), committed to a strategic approach to the development and management of recreational fisheries within WA. Four regional management strategies were to be developed incorporating a detailed planning process, which would allow more flexibility in terms of key management issues. To date, regional plans have been implemented for the Gascoyne and West Coast regions. Pilbara/Kimberley and South Coast reviews commenced in April 2003 and the Department of Fisheries expects to release draft discussion papers for public comment in March 2004.

Commercial fishing
Traditionally, commercial fisheries management has been on a fishery-by-fishery basis, rather than taking an ecosystem approach or a regional approach. This has resulted in a number of fisheries management plans, regulations and Section 43 Orders that, together, regulate the commercial fisheries off WA. In more recent years, this has started to change, with recommendations from management advisory committees and decisions by government taking into account other regional fisheries and activities (See Fisheries WA2000a). In addition, this integrated fisheries management approach is likely to result in a regional approach to the management of the wetfish fishery (see Department of Fisheries 2002c).

Aquaculture
In 1994 the Aquaculture Development Advisory Council recommended a regional approach be taken to planning and development of aquaculture in WA (Aquaculture Development Advisory Council, 1994). This recommendation recognises the contribution aquaculture has made to society and the environment. The first of these plans was released for the Kimberley (Fisheries Department of WA, 1996a), shortly followed by the Gascoyne (Fisheries Department of WA, 1996b). Specific aquaculture plans have also been developed for high use areas within regions, for example, the Abrolhos Islands (Fisheries WA 2000b).

Fish and fish habitat
The Department of Fisheries is preparing a series of Fisheries Environmental Management Reviews, the first of which was released for the Gascoyne in December 2000 (Fisheries WA, 2000c). These reviews outline the status of fisheries and aquaculture in the region, and involve:

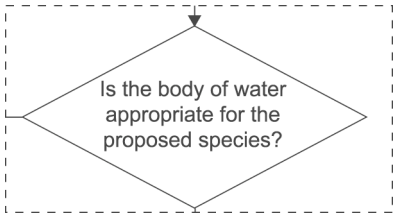
- Identification of any associated environmental effects;
- Proposals for management of environmental effects;
- Identification of potential threats to fish and their habitats; and

- Identification of areas in need of fish and fish habitat protection (Bunting 2001).

The reviews do not cover inland fisheries.

Any proposal to enhance fish stocks in any water body should be considered in the light of the appropriate regional fisheries policies and plans[9]. Does the project fit in with the vision for the region involved? Does it sit within objectives, performance targets and ESD objectives set out for that region?

5.2 Is the water body appropriate for the species?



There are two sides to the question of appropriateness – will the water body be able to support the species? And will the species cause damage to the water body?

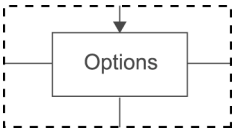
The first involves both environmental health issues and the physical conditions of the dam, riverine or coastal environment. Environmental health refers to aspects such as water quality and stream flow. Is the water body polluted or not? Is there enough water at the right time? These issues were mentioned in Section 4.5.1.2.

Once water quality conditions are satisfied, it needs to be established whether the physical conditions are right for that species. Will the fish survive? Are there appropriate habitats for breeding? Is there shade or shelter where necessary? Is the water flow sufficient in a river? Does the estuary flush?

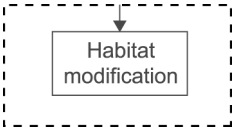
The second question is addressed in more detail through discussions on environmental issues elsewhere in this paper. In short, the answer is "yes" – fish stock enhancement will always cause some level of damage. The more relevant question is: "is the damage sufficiently large compared with the benefits of stock enhancement such that the project would not proceed?" Consideration must be given to the fact that in many situations, the water body proposed for stock enhancement would already be a modified environment, so there may be a case for introducing species better suited to that environment than the species that originally dominated the water body.

[9] Although many of the documents mentioned above are called plans, most have no statutory basis. The exceptions to this are the commercial fisheries management plans made under Part 6 of the *Fisheries Resources Management Act 1994.*

5.3 Options for management

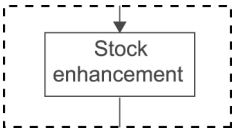


5.3.1 Habitat modification



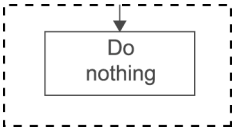
Habitat modification for a new fishery is most likely to be necessary in a closed system, such as a dam. A situation may arise where a dam that has been drained is to be refilled, and it may be desirable to introduce a species that has specific habitat requirements, such as marron. In this circumstance, habitat modification may occur. Marron require nooks and crannies in which they can hide, so provision of these is essential for successful marron enhancement.

5.3.2 Stock enhancement



A description of the options for stock enhancement is given in Section 2.5.2. The type of enhancement most likely in new fisheries is type 3: addition (described in 2.5.2.3). It is also most likely such enhancement would involve translocation, and therefore trigger the translocation risk assessment and approval protocol.

5.3.3 Do nothing

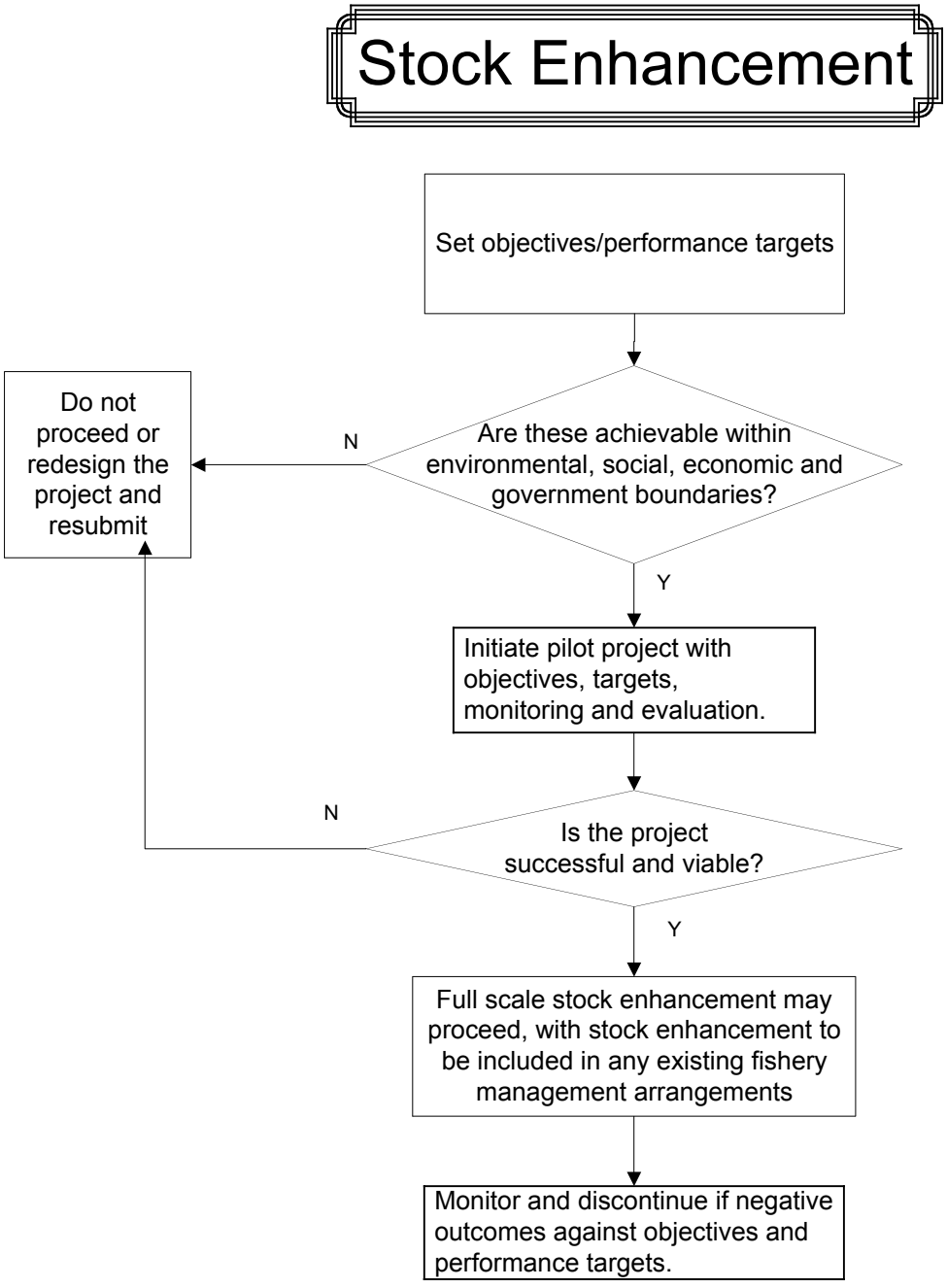


A project may be assessed as having a chance of succeeding from a scientific point of view, but there may be social, economic, environmental or other reasons as to why the project should not proceed. Alternatively, if a project proceeds to a pilot stage, results of the pilot study may not support continuation of the enhancement activities.

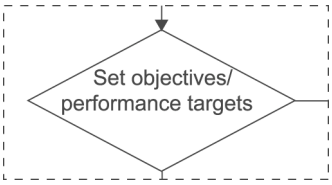
SECTION 6 DEVELOPING AND ASSESSING STOCK ENHANCEMENT PROJECTS

Where stock enhancement is considered feasible and viable, and is the best option to assist in the sustainable management of a fishery or resource, a process must be followed to enable thorough assessment, monitoring, evaluation and review of each project. This process is the same for any stock enhancement project, regardless of which framework has been used. This is depicted in Chart 4. The remainder of this paper addresses such a process.

Chart 4: Decision tree for assessment of stock enhancement proposals



6.1 Objectives and performance targets



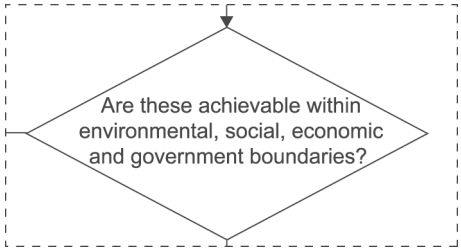
"One of the primary goals of stock enhancement is to increase population size and/or population growth rate without deleterious effects on wild stocks. This is also the goal of most species-management plans, and fish hatchery release programs can be viewed as one of many management tools designed to enhance fisheries or rebuild depleted stocks. The success or failure of a management plan can only be assessed if specific goals are outlined in advance, such as minimum increase in yield or growth of a population to a certain size by a certain date. Releasing thousands or even millions of hatchery-reared juveniles initially increases juvenile cohort size, but does not necessarily lead to long term population-level increases" (Heppell and Crowder, 1998, p.495).

Each proponent must be clear on what he/she is trying to achieve, and set specific objectives and associated performance targets to allow continued monitoring of success. Objectives need to be set within the framework of other management in the area or affecting the fish resources being enhanced.

Blankenship and Leber (1995) recommend the development of stock rebuilding goals and genetic objectives, as well as the definition of quantitative measures of success. The goals and objectives of any enhancement must be clearly understood before the enhancement commences. They also suggest prior identification of assumptions and expectations concerning the performance and operation of the project necessary for its success. There will be a number of external factors that could affect the success of the project – predators, accessibility to critical habitat, carrying capacity, food availability, temperature, salinity and habitat degradation. There will also be behavioural deficits in hatchery-reared fish that will affect survival (Blankenship and Leber, 1995; Kellison *et al*, 2000).

Performance targets need to be set against each of the objectives. Targets should be able to be measured and tested.

6.2 Boundaries



6.2.1 Resource Sharing

6.2.1.1 Who are the user groups?

It would be a rare case for a fish stock enhancement project to be proposed for waters where no other group had an interest. Where possible, all user groups should be identified and consulted on the implications of the proposed stock enhancement.

6.2.1.2 Property rights - beneficiaries and flow of liabilities

Howarth and Leria (1999) examine the implications of stock enhancement on property rights. These appear to differ throughout the world. English law has established that ownership is relinquished once fish are released into open (non-enclosed) waters, even if they have been hatchery reared. Norway, on the other hand, has established rights of ownership over salmonoids and freshwater fish to the landowner of the closest adjacent property to the coast or river. In general, they acknowledge there are difficult legal and administrative questions that still need to be addressed about ownership, for both current and future generations. A thorough discussion of the legal aspects of property rights, both historically and present, in respect to fish, can be found in Walrut (2002).

With the exception of private farm dams, all stock enhancements in Western Australia to date has been aimed at fish in 'the commons' – recreational fisheries such as trout and black bream. Regardless of who breeds fish for release, unless they can be individually marked or kept within a confined area, so that the same fish released can be retrieved, fish released into State waters (inland and coastal) are not owned by an individual. Licences may allow individuals to catch certain fish using particular gear, but this is a right to catch, not own individual fish while the fish are still in the water (supported in Walrut, 2002). A licence to enhance stock would therefore not represent a strong property right.

Recreational fishing licences are required for angling in WA's inland waters. However, these licences are not limited, and consequently such enhancement could be considered for the public good. Future fish stock enhancement proposals would need to include an identification of beneficiaries. Any changes to the status of a public good fishery as a result of enhancement (for example, a proposal to licence access to an area) should be negotiated with identified user groups prior to the issue of any enhancement licence.

In terms of liability, as in the majority of cases overseas, stock enhancement in Australia is largely a function of government. At present, stock enhancement in Australia occurs in inland waters, with some restocking of catadromous fish (and consequently some exposure to estuarine and marine waters), which takes place mainly in Queensland.

In WA, the major enhancement is restocking of trout – a species that does not recruit naturally within the river systems and requires continual restocking. The risks here are twofold: the introduction of disease and the effect of the trout on native finfish.

Testing for some diseases is done annually, although the Department of Fisheries is currently reassessing the risk associated with the release of trout from the Government-run hatchery. From experience to date, it is expected the effect of trout on native fish is more of a risk, due to predation, competition for food, competition for breeding spots and so on.

This risk may be lessened if small populations of native fish remain in the waterways, enabling the natural population to be re-established once enhancement has ceased.

The issue of liability in stock enhancement has not been fully explored, although it is acknowledged if something were to go wrong, liability would exist for the releasing agent. Legal claims may range from an individual aggrieved about a negative impact on his/her favourite pastime, to claims about loss of genetic diversity. Legal precedent would exist, either in fisheries overseas or in non-fishery matters such as pollutants, fluoride in toothpaste an so on. The ability to pursue any claim would depend on the standing of the potential plaintiff - that is, whether the plaintiff was directly affected by the 'negative impact' or has a special interest above that of the 'man in the street'.

As discussed in previous sections of this paper, there are several government departments with powers over and interests in the use of various water bodies in WA. Any proposals to enhance fish stocks or create new fisheries through stocking would therefore need consultation with these departments.

6.2.2 Environment

6.2.2.1 Ecological balance

In the majority of cases, enhancement is considered for stocks that have already been fished. Therefore, when considering the impact of enhancement on ecological balance in such waters, it must be noted that the pre-enhancement ecological balance will not be the natural situation. Fisheries today are based on an altered ecological balance.

Having said this, the ecological balance will be further affected by any enhancement. Arnason (2001) states the most fundamental externality[10] associated with stock enhancement is that it adds organisms to the marine environment and in doing so, immediately impacts on the equilibrium of the ecology into which it has been added. He further suggests that, even if fish stock enhancement ceased, the original balance could never be restored (also Welcomme and Bartley, 1998).

This impact may be more severe than the physical presence of extra individuals. These individuals, if hatchery-reared, will have a number of differences from wild fish, including genetics, physiology and behaviour (White *et al*, 1995).

[10] An externality could be generally described as an uninvited impact or side effect. However, when used in an economic context (as is the case in section 4.2.3 of this paper), it describes an effect (cost or benefit) that is borne by someone/something that is not involved in the market transaction.

Wahl *et al* (1995) suggest that within any ecological community, three factors interact to define that community: competition, predation and abiotic environment. Competition can happen between or within a species and at any lifecycle stage, while predation can vary with the removal or addition of predators or prey in the system. Stocked fish have the additional stress of changing abiotic conditions, such as handling, transportation, and difference in water temperature.

Research worldwide provides many examples of stockings, either sanctioned or otherwise, where the introduced fish have replaced or dominated native fish populations (Goldburg *et al*, 2001; Friedlander *et al* 2002; Whittier and Kinkaid, 1999; Bagarinao, 2001; Einum and Fleming, 1997, Welcomme and Bartley, 1998). This is due to competition for food and niche habitats, differing predation responses, and/or the introduced fish being a new predator.

In Hawaii, the addition of 3,200 snapper at one island only has resulted in an expansion of range where it now exists along the whole of the Hawaiian Archipelago (about 2,900km) and is ranked second among all species in the study area (Friedlander *et al*, 2002).

Even where the introduced fish are native species, biodiversity can still be lost through breeding between hatchery and wild stock (Kellison *et al*, 2000, Barnabé and Barnabé-Quet, 2000, Davenport *et al,* 2003). The differing survival traits of these introduced individuals can affect the ecological balance.

Every system has ecological limits, but these limits (for fish, the carrying capacity) are not always known or well understood. Where this is the case, it is extremely difficult to determine the appropriate number of fish to add to the system. Further complications arise as carrying capacity varies according to environmental conditions, outside pressures on the system (for example, habitat modification adjacent to the water body), or the size/maturity of the fish to be added to the system (Borg, 2002).

For example, the release of Norwegian cod in fjords failed in part because of carrying capacity. From the early 1980s to the mid 1990s, Norway released over 660,000 juvenile cod along its coast. Many of the early results were encouraging, but at the stage when the '2 group' (two-year-old) fish should have entered the fishery, there was no sign of enhancement in the stock. Norwegian scientists put this down to dietary overlap with wild cod, low condition factors, density-dependent growth and cannibalism. This suggested the fjordal areas were "fully exploited with little or no excess 'carrying capacity'" (Blaxter, 2000, p.21).

On the other hand, introductions of various fish species into the north-eastern US lakes have seen viable populations established without any large change in native species richness (Whittier and Kincaid, 1999). Whittier and Kincaid surmise the carrying capacity of these lakes may not have been reached naturally and therefore not fully utilised pre-human settlement.

This last point illustrates that the impact of stock enhancement cannot be assessed without considering the flow-on impact that human activity may have post-enhancement. The enhancement or creation of a fishery through stocking is very likely to lead to an increase in human interaction. This could be through direct fishing pressure or changes in land use adjacent to the fishery. This increased pressure on the resources will affect not only the newly enhanced resource, but may also impact on wild species already in the area (Bartley and Casal, 1998).

6.2.2.2 Genetic impact

"The productivity of populations and their resilience to environmental change is a result of the genetic diversity they contain" (Busack and Currens, 1995, p71).

In any stock enhancement, existing wildstock will be genetically affected by the introduction of same-species. In fact, one of the greatest threats to genetic resources of a wild population is from culture and stocking activities (Cooke *et al*, 2001).

Studies have found that hatchery-reared stock do not have the same survival techniques as wild stock (Kellison *et al*, 2000; Cooke *et al*, 2001; Walrut, 2002; Davenport *et al*, 2003). As mentioned in 4.2.2.1, some may out-compete wild or native stock (Einum and Fleming, 1997; Friedlander *et al*, 2002), some may be more vulnerable due to susceptibility to predation (Kellison *et al*, 2000). These introduced stock then breed with wildstock, introducing a hybrid stock that has different genetic makeup, and sometimes, a different set of survival techniques again.

Cooke *et al* (2001) argue although stocking usually occurs to supplement natural stocks and increase abundance, unless genetic integrity is maintained, it is most likely the enhancement would be counter-productive. This is especially important where stock enhancement is aimed at restoring endangered species (Brown and Day, 2002).

Cross (2000) states "even one generation of artificial spawning and hatchery rearing can cause large changes in genetic make-up (often detrimental to fitness) in terms of genetic composition and level of genetic variability". This can be minimised by collecting large numbers of broodstock randomly and then using all individuals in spawning.

However, even if precautions are taken in the first generation, Cross (2000) notes that "genetic composition can vary unpredictably between year classes of the reared strain" (p 85). He also suggests that hatchery stock for stocking not be kept in the hatchery for more than one generation (supported by Davenport *et al*, 2003; also minimising exposure to hatchery conditions is supported by White *et al,* 1995*).*

This is further complicated by the fact some species of fish do not operate as panmictic (random-mating) populations, rather as a number of genetically different groups (Cooke, *et al* 2001).

Conscious of the importance of genetic diversity, the genetic objectives of stocking should be to maximise the effectiveness of the program while minimising detrimental effects on natural populations or species (Cross 2000).

To this end, it is proposed to introduce similar guidelines as established in the barramundi stock enhancement paper (Thorne, 2002). These are set out in Appendix 2. Should there need to be any species-specific modifications to the final guidelines, these will be developed between the Department of Fisheries and the proponents prior to approval of the project.

6.2.2.3 Environmental impact assessment

Under Western Australian law, stock enhancement would trigger the environmental impact assessment process. For the most part, the environmental impact assessment process in Western Australia is initiated by proponents (Department of Environmental Protection 1997).

The *Environmental Protection Act 1986* requires proponents, or project developers, to inform the Environmental Protection Authority (EPA) and the community what they want to develop, what they expect the environmental impacts to be, and how they plan to manage their projects so the environment will be protected. Proponents are also required to commit themselves to the environmentally responsible implementation of their proposals (EPA, 1996).

Other parties, including members of the public, may also refer projects to the EPA.

Usually, the EPA would leave the regulation of environmental effects from fisheries-related activities to the Department of Fisheries, but if the Department of Fisheries does not have the necessary powers in a particular circumstance, the EPA could step in and regulate the environmental aspects of the activity. Alternatively, the Department could refer the proposal to the EPA.

Should the EPA consider it necessary to act in regard to a particular project, it would set the assessment level based on the significance of the following environmental factors associated with the proposal:

- Character of the receiving environment and the use and value which society has assigned to it.
- Magnitude, spatial extent and duration of anticipated change.
- Resilience of the environment to cope with change.
- Confidence of prediction of change.
- Existence of policies, programs, plans and procedures against which the need for applying the environmental impact assessment process to a scheme can be determined.
- Existence of environmental standards against which a scheme can be assessed.
- Degree of public interest in environmental factors likely to be associated with a scheme or amendment (EPA, 1998).

Having assessed these factors, the EPA may:

- Decide that assessment is not required because it is considered environmentally insignificant (known as 'Not Assessed');
- Decide to assess it 'in-house' and provide public advice (known as an Informal Review with Public Advice);
- Issue a works approval; or
- Decide to assess it 'formally' as a Consultative Environmental Review, Public Environmental Review, or Environmental Review and Management Programme. Formal assessments require varying degrees of environmental and public review and evaluation (EPA, 1998).

The decision trees used by the EPA for assessment of environmental impact are at Appendix 3. Further information on these processes and the responsibilities of proponents can be obtained from the EPA.

6.2.3 Economics

6.2.3.1 Economic feasibility/viability of projects – cost benefit analysis

Blaxter (2000) suggests the cost benefit analysis (CBA) for enhancement is rarely straightforward, especially in open systems. Costs for raising and releasing fish are usually identifiable, however, unless released stock can be accurately identified and monitored, yield per released fish is not usually available.

It is important to capture all costs, including the opportunity cost of broodstock or the return from translocated fish had they not been translocated (Blaxter, 2000). Similarly, indirect benefits need to be taken into account, such as employment associated with hatcheries and transfers of fish. Ownership of the enhanced stock will also impact on the economics of a fishery. For example, many enhancement studies in the United States, Japan and Norway have been State-funded, yet the beneficiaries are commercial and recreational fishermen (Blaxter, 2000).

Most of the successful attempts to evaluate costs and benefits have captured the obvious production costs and value of recaptured fish, but fail to understand intervening mechanisms of survival and mortality. There is a danger in omitting the less obvious costs and benefits, or those harder to quantify, that the CBA may not accurately reflect the true situation.

In the case of 'public good' fisheries, which are the subject of this discussion, it is often argued that there are many costs and benefits that cannot be accurately valued in terms of monetary value by their very nature (see also section 6.2.3.2 of this paper). However, as Cauvin (1980) suggests, it could also be argued those fisheries "valuable" enough to be considered for enhancement are not a pure public good (see section 3.3 of this paper for comment on this point), so a value can be placed on their existence and their enhancement. Consequently, an attempt should be made to calculate these values for the purposes of analysing costs and benefits of each project.

The difficulties associated with conducting a CBA for a public good fishery may lead decision-makers to look for an easier solution. Blaxter (2000) goes so far as to suggest enhancement may be used as a cosmetic exercise to placate fishermen, politicians or environmentalists, regardless of costing.

The push for enhancement of recreational fisheries includes the argument that large numbers in WA enjoy recreational fishing and contribute greatly to the economy. Therefore, these fisheries should be enhanced wherever possible. Further, stock enhancement is a relatively cheap form of management and may return benefits that far exceed costs. The validity of this argument needs careful consideration.

Cauvin refutes similar claims made in Canada (Cauvin 1980, p. 1,325). He argues, firstly, that it is not realistic to attribute money spent on recreational fishing, for example, vehicles, petrol, gear, food, boats, as an exclusive contribution to the economy. Resources are scarce, so with the possible exception of fishing rods and other direct capture equipment, other resources

would still be expended and make a contribution to the State economy in some other way. That is, people would still buy 4WDs, petrol, camping gear, and so on (even if they don't fish).

Secondly, if there is little net economic gain to society from recreational fishing, then there is a danger to the allocation of resources in giving recreational fishing too high a social value. There is the danger of public money being diverted from important but more costly services, such as fisheries management to cheaper, seemingly quick fixes, such as stock enhancement (for example, funds being diverted from fisheries management to hatcheries).

This is exacerbated by the fact that government provides recreational fishing free or at a nominal cost, sending the signal to government that demand is infinite (there is no measure of the true economic value of recreational fishing to society) and placing pressure on government to supply resources to meet the desires of the beneficiaries (Cauvin, 1980). Both fishers and government may see stock enhancement as a way out of this situation.

Bartley and Casal (1998) and White *et al* (1995) both provide detailed reviews of the effects of fish stocking on wild stocks. Table 2, taken from Bartley and Casal, (1998, p.16), shows some potential adverse effects, drawn from international fish databases. Each of these direct and indirect effects should be taken into account in a CBA.

Through this table, Bartley and Casal (1998) report most of the recorded ecological effects of introducing species were negative. However, reported socio-economic impacts were mostly positive and often outweighed the negative ecological impacts. Although it may not be possible to put dollar values on all of these costs and benefits, they do need to be acknowledged and attempts made to value them.

Table 2 Some potential adverse effects of introduced aquatic species

Effect	*Mechanism - biological*	*Mechanism – social*
Reduction or elimination of aquatic species	Competition, hybridisation, predation/herbivory, disease transmission	Change in fishing pressure and access to resources; treatment measures to enhance introduced species
Change in terrestrial fauna	Change in abundance of preferred prey	Fish farms providing more food for birds and animals or killing predatory birds
Change in fishery management	Change in stock composition	Successful introductions lead to other introductions
Alteration in habitat	Burrowing, sediment mobilisation, removal of vegetation	Change in land use, e.g. creation of fish farms
Socio-economic impacts	Change in species abundance or distribution leading to changes in fishing or consumption practices	Change in access rights, land tenure; financial liability for damages through national and international legislation.

6.2.3.2 The economic impact of externalities

The mere act of fishing causes externalities, because the actions of one fisher cause loss to another and fishers do not take this into account when making decisions on their fishing activities (Cauvin, 1980). Similarly, enhancing a stock of fish may impact on other users of this stock or the area in which the stock occurs, or have downstream environmental impacts that have an associated social or economic impact.

Where commercial interests are involved in enhancing a 'public good' fishery or a fishery in which there is some public good component, the result of these externalities is that market forces will drive those undertaking the fish stock enhancement to do so at the highest level possible, which would set the level of enhancement at a socially inappropriate level (Arnason, 2001). Although publicly funded enhancement does not have to respond to market forces, it is often the case that governments do not act in a socially optimal fashion either. This implies there are no social forces that would guide enhancement toward the common good (Arnason, 2001).

Therefore, there would need to be some means of guiding commercial operators to act in a socially optimal manner. Arnason (2001) suggests either imposing a system of corrective taxes or subsidies (not likely to occur in the current political climate), or extending private property rights to cover the resources affected by the externalities (for example, introduce quotas).

Should the Government decide to regulate newly enhanced fisheries, catch sharing (even if not individual transferable quotas) between sectors would appear more administratively, economically and politically practical than corrective taxes and would likely to be more appealing to the various user groups. It also gives user groups more control as this method relies on the total knowledge held by the private sector. This knowledge will drive price, which in turn should send economic signals about optimal behaviour to those undertaking enhancement and others utilising the ecology.

Where stock enhancement does not involve commercial interests, or where the objective is pure public good, such as for conservation purposes, the Government's response to these externalities may differ. However, given the economic drivers associated with any use of a natural resource (even conservation), explicit catch share arrangements would still appear appropriate. For example, an area enhanced for conservation of a species of fish may be closed to extractive use, making an explicit allocation for the use of conservation. A less severe option may be to make an allocation of a certain number of fishing days per week or month: allocating partly to conservation and partly to commercial and/or recreational fishing.

Any change in allocation, or perceived allocation of resources, as a result of stock enhancement would be an externality and would have a cost associated with it. How this cost is resolved will need to be negotiated between the parties involved. It may be appropriate to use negotiated resource sharing agreements as part of this process.

6.2.4 Government agenda

The current Western Australian government has a large number of policies that may influence the development of the State's fisheries, and particularly the development of aquaculture and opportunities for stock enhancement. In terms of stock enhancement, some of these policies

will support new technology and new development, and some will imply tougher conditions with respect to the use of the environment. Together, they provide a business and social environment that should be kept in mind when considering the feasibility and/or desirability of stock enhancement projects.

The main relevant policies and focus areas follow.

6.2.4.1 Social objectives

- Work with industry to ensure adequate equity measures are in place to allow for the resolution of disputes concerning such issues as security of access and resource sharing between recreational and commercial fishers and other stakeholders.
- Establish and build partnerships to improve conditions for WA's Indigenous people.
- Build partnerships at a State, regional and local community level, and between government and Indigenous peoples in pursuing healthy, self-determining Indigenous communities.
- Support employment, enterprise and economic development for Indigenous people and Indigenous communities to ensure equality of opportunity in all aspects of life.

6.2.4.2 Environmental policies

- More marine parks and reserves.
- Catchment protection.
- Environment friendly tourism.
- Address salinity, catchment management plans, and conservation of remnant vegetation on farms.
- Introduce biodiversity conservation legislation.
- River bank restoration and erosion controls.
- Develop sustainability indicators and monitor reporting against these indicators.
- Complete comprehensive bioregional surveys.
- Audit all wetlands and prepare rectification plans where necessary.

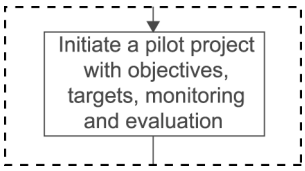
6.2.4.3 Regional development/tourism

- Rural/regional subsidies.
- Regional investment fund to support new industry development and tourism.
- Promotion of tourism and ecotourism.
- Improving transport to and from regions, improving operations/services at ports and airports.

6.2.4.4 Supporting developing industries (aquaculture)

- Removal of unnecessary red tape.
- Improving quality and scope of research, development and extension advice from the Department of Fisheries.
- Establish appropriate business development and support mechanisms in order to foster the development of WA's aquaculture and mariculture industries.

6.3 Establishing a pilot project



Once a project is assessed and deemed to be feasible, it would enter a pilot phase during which environmental, economic and social responses to the enhancement project are monitored to determine its viability. For this pilot phase to proceed, it is essential that there is a full assessment of all issues associated with possible escapes from the project area.

Similar to the process proposed for reseeding projects, set out in Borg (2002), the project would be licensed for the period of the pilot, with clear objectives/targets, monitoring strategies and evaluation techniques being in place prior to the commencement of the project. Objectives/targets could include percentage increases in fishable biomass, percentage increases in reproductive biomass, target levels of catch per unit effort, and so on.

The pilot project would be large enough to allow the fish stock enhancement techniques (including tagging/marking) to be evaluated at a useful scale, but small enough so any negative effects (e.g. displacement of wild stock or other species) would be minimized. Further, if the project were not viable, minimal loss of investment would occur.

Brown and Day (2002) suggest the first stage in evaluating whether a stocking program has been successful needs to be based on scientific assessment – estimating the survival of released fish and the main causes of mortality; their contribution to the gene pool and their impact on the environment. Economic assessment then follows – are releases economically feasible?

White *et al* (1995) supports this paper's proposal that the results of stock enhancement should be measured against the objectives set at the beginning of each project. The evaluation should include information about:

(a) Performance of the stocked fish (survival, body growth, and reproductive success);

(b) Effects on other fish populations (hybridisation and ecological effects, e.g., competition, predation, habitat alteration, and disease transmission);

(c) Effects on other members of native biota; and

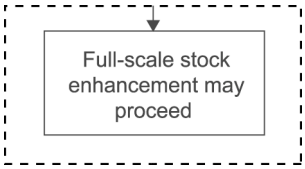
(d) Effects on humans (catch rate and other measures of fishing quality; economic, aesthetic, and social effects; and ramifications for public understanding of and attitudes toward resource issues)" (p. 537).

They also recommend a full economic evaluation, acknowledging both direct and indirect costs, something not usually undertaken in depth.

However, as Bartley and Casal (1998) reasonably suggest, it is only possible to accurately assess the impacts of an enhancement if there is an accurate assessment of the pre-enhancement ecological and socio-economic environments. In many cases, some or all of this information will not exist – making monitoring and evaluation of enhancement projects very difficult in those situations. It is hoped by running pilot projects before full stock enhancement is allowed to continue will cause much of this information to be collected, not just for the project in question, but increasing the overall database upon which future proponents can draw.

As with reseeding, if a pilot project is not successful, it would be important to recognise why this has been the case. For example, it may have been affected by external environmental factors such that a similar project at a different time may be more successful. In addition, "natural fluctuations in marine stock abundance can mask successes and failures" (Blankenship and Leber, 1995, p 171).

6.4 Full-scale stock enhancement



6.4.1 Monitoring success

"One of the most critical components of any enhancement effort is the ability to quantify success or failure. Without some form of assessment, one has no idea to what degree the enhancement was effective or, more critically, which approaches were totally successful, partially successful, or a downright failure" (Blankenship and Leber, 1995, p 171).

A successful pilot project may lead to the licensing of a long-term, full-scale stock enhancement within a fishery or an area of water. Despite the progressive nature of such a project, the government cannot draw back from its stewardship role and the continuing requirements for objectives and targets as foundations to the enhancement project[11]. Without these, monitoring would have no basis, and success could not be effectively measured or assessed. This is especially important for activities where social objectives may be weighted more heavily than economic, making them more difficult to measure accurately.

Where the fish stock enhancement occurs within an existing commercial or recreational fishery, management of stock enhancement activities needs to be assimilated into any existing fisheries management arrangements. Consequently, monitoring and evaluation of success in such fisheries must be assessed in terms of not only the enhancement itself, but also the impact on existing uses of the resources or the area.

[11] It is recognised the government may also actually be conducting the enhancement, as is the case with trout in Western Australia at present.

6.4.2 Compliance

In the short term, there is no fisheries legislation covering stock enhancement, except for requirements associated with translocation of non-endemic species. *The Enzootic Disease Regulations 1970* established under the *Stock Diseases Act 1968* contains provisions relating to the movement of some species within and into WA. Consequently, there are no additional short-term compliance implications.

It is envisaged should a licence be introduced for stock enhancement activities, compliance would only be required with regard to the fish being released in accordance with licence conditions. Should a quota be imposed as part of management of the enhanced fishery, consideration would be given to incorporating these costs into management fees for that fishery.

SECTION 7 APPLICATION PROCESS

7.1 Legislative basis for management of stock enhancement activities

At present, there is no legislative requirement to be licensed by, or seek the approval of, the Department of Fisheries to release fish into the marine or freshwater environment unless the species to be released is not endemic to the area. If the species is not endemic, then the proponent must apply for permission to translocate the species. The process for translocation approval is set out in Ministerial Policy Guideline No 5, (Fisheries Department of Western Australia, 1997a).

The Department of Fisheries, in conjunction with the development of this policy on stock enhancement, will move to introduce powers under the *Fish Resources Management Act 1994* to allow the Department to regulate the release of fish into marine and freshwater environments for the purpose of stock enhancement. Changes to the Act will require legislative amendment and is not likely within at least the next 12 months.

7.2 Assessment

It is envisaged applications for stock enhancement would be taken through a consultation and assessment process similar to that set out in Ministerial Policy Guideline No. 8 (Fisheries Department of Western Australia, 1997b), to ensure accountability of the proponent and full consultation with user/interest groups.

As proposed for the assessment of reseeding applications (Borg, 2002), consideration will be given to establishing a similar stakeholder committee to assist the Executive Director in the assessment of applications for stock enhancement, once the head power is legislated.

SECTION 8 OPPORTUNITIES FOR COST RECOVERY

Once legislation is amended, regulation and licensing of stock enhancement activities will be possible.

Cost recovery will be considered as an option, possibly through a licence fee to cover administrative costs and a management fee to allow cost recovery for monitoring and evaluation. This said, no detailed consideration has been given to this issue at this stage. It remains an option for the government to fund some stock enhancement activities as a community service.

SECTION 9 CONSULTATION – WHERE TO FROM HERE?

The release of this discussion paper is the result of research, consultation within the various divisions of the Department of Fisheries and consideration by a focus group comprising major stakeholder groups. After the public consultation period, all written and oral submissions will be considered by the focus group and taken into consideration for the drafting of policy guidelines for application and assessment. The Department will circulate draft policy guidelines to appropriate agencies for comment prior to finalisation and approval.

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SECTION 11 GLOSSARY

Abiotic	Factors that are non-biological in nature but still play an important role in the organism's environment.
Aquaculture	The keeping, breeding, hatching or culturing of fish (FRMA 1994).
Biodiversity	A diversity of species of plants and animals.
Broodstock	Animals that are used as breeding parents to obtain young stages for aquaculture.
Carrying capacity	The total number of individuals of a population that a given environment can sustain.
Catadromous	A catadromous fish spawns in salt water but spends most of its life in freshwater.
Ecologically Sustainable Development	Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased (National Strategy for Ecologically Sustainable Development, Council of Australia Governments, 1992).
Ecosystem	A community of organisms interacting with one another and the environment in which they live.
Ecotourism	Tourism which involves no degradation of the environment and which features places of ecological interest.
Fecundity	The number of eggs produced per female per unit time (often: per spawning season).
Fish	Any aquatic organism, excluding aquatic mammals, aquatic reptiles, aquatic birds, amphibians or pearl oysters.
Fishery	A unit determined by an authority or other entity that is engaged in raising and/or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of activity (Dept of Fisheries, 2002b)
Fishing effort	The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time e.g. hours trawled per day, number of hooks set per day or number of hauls of a beach seine per day.
Mariculture	A subset of aquaculture where the activities involve marine and/or estuarine species.
Natural mortality	Deaths of fish from all causes except fishing (e.g. ageing, predation, cannibalism, disease and perhaps increasingly pollution). It is often expressed as a rate that indicates the percentage of fish dying in a year;

	e.g. a natural mortality rate of 0.2 implies that approximately 20 per cent of the population will die in a year from causes other than fishing.
Population	The total number of organisms in a species.
Productivity	Relates to the birth, growth and death rates of a stock. A highly productive stock is characterized by high birth, growth and mortality rates, and as a consequence, a high turnover and production to biomass ratios (P/B). Such stocks can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive stocks.
Recruitment	The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year. This term is also used in referring to the number of fish from a year class reaching a certain age.
Refugia	Areas in which flora and fauna species are able to survive despite the impacts of major threatening processes, for example, those associated with environmental or ecological change.
Resnagging	Replacing snags in waterways; where snags are any standing dead, partially dead, or defective (cull) tree at least 25cm in diameter at breast height and at least 180cm tall.
RFAC	Recreational Fishing Advisory Committee.
Section 43 Order	An Order made by the Minister for Fisheries under section 43 of the FRMA 1994 to prohibit persons or any specified class of persons from engaging in any fishing activity of a specified class.
Stock	A group of individuals in a species occupying a well defined spatial range independent of other stocks of the same species. Random dispersal and directed migrations due to seasonal or reproductive activity can occur. Such a group can be regarded as an entity for management or assessment purposes.
Stream flow	The amount of water passing a particular point in a stream or river.
Sustainable fishery	A fishery that is consistent with ESD, that is, a fishery that uses, conserves and enhances the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased (Dept of Fisheries, 2002b).
The commons	Common property, that is, there are no restrictions to accessing the fish resource.
Translocation	The transfer of aquatic organisms outside their natural distributional range.

APPENDIX 1 STOCK ENHANCEMENT WITHIN AUSTRALIA AND OVERSEAS

1. The Western Australian Experience

1.1 Trout

The only long-term stock enhancement undertaken in WA was trout in the southern river systems. Brown trout was first introduced to WA in the late 1870s, but for unknown reasons, these early attempts to stock the rivers failed. Importation of stock did not recommence until 1931 when a hatchery established at Pemberton successfully imported brown trout ova and released fry into local streams in the Warren catchment area.

Since the late 1930s and early 1940s, hatchery production from the South West Freshwater Research and Aquaculture Centre (now the Pemberton Freshwater Research Centre) has been largely based on locally produced ova and fry (Department of Fisheries, 2002a). Occasional importations of brown and rainbow trout have occurred during this period, however, the last imports of these species occurred in 1991 and 1972 respectively.

The Acclimatisation Societies established the hatchery, but in 1971, the Department of Fisheries took it over. At the time this occurred, the stock being supplied were small fish used for stocking public waters. This supply has since expanded to include stocking of farm dams and commercial trout farms.

1.2 Black bream

Native to southern Australian rivers and estuaries and easily cultured, black bream appears perfect for stocking (Fisheries WA, 1999). However, translocation is an issue for waterways as genetic populations vary between estuaries.

Prior to the formalisation and acceptance of the government's translocation policy, between 1995 and 1997, about 200,000 black bream fingerlings of Swan River stock were sold and released into private impoundments throughout south-west WA (Lenanton *et al*, 1999).

An estuarine stocking trial commenced in March 1995 with the release of 767, 14-month-old tagged juvenile bream into the upper reaches of the Swan River, which flows through Perth (Lenanton *et al* in Howell *et al*, 1999). The area is closed to commercial fishing and is a nursery area for the wild fish. By October 1997, there was a 12.6 per cent recovery of released fish by recreational anglers. Independent netting surveys during this time indicated that the released fish were actually more abundant than wild fish of the same age class.

Further, released fish made up 20% of the total catch of all bream taken by anglers who reported tagged and wild fish catches, and in some cases, anglers had catches totally made up of tagged fish. Although detailed data allowing comparison of the catchability of hatchery-reared versus wild bream, from the small number of anglers who did provide the information, it appears that hatchery-reared fish may be more accessible to anglers (Lenanton *et al* in Howell *et al*, 1999; Dibden *et al*, 2000).

A further release was conducted after the poisoning of waters at Ascot racecourse (mid-late 1998). Around 125,000 smaller fish tagged with Terramycin were released. Early sampling after three weeks recorded 10 out of 17 fish with the dye tag. Lack of funding prevented any further assessment of the success of this release over time (B Ginbey, Aquaculture Development Unit, South Metropolitan College of TAFE, pers. comm.).

Further releases of black bream are currently underway in the Blackwood River Estuary as part of a Fisheries Research and Development Corporation (FRDC) funded project.

1.3 Barramundi

The only other stock enhancement in public waters has been small barramundi releases in Lake Kununurra.

Trial trapping conducted in the 1991/1992 wet season (Bird, 1992) resulted in 124 fish being caught and released into Lake Kununurra. Doupé and Bird (1999) report the fate of many occasional and illegal releases of barramundi over the years are not known, however there are rare reports of recaptured fish. In the case of a large scale release, they question how many fish, of what age class, would stay in the dam. They also raise the possibility that, given barramundi currently aggregate below the dam wall, any stocking would result in an increase catch by commercial catfish fishers rather than by recreational fishers. They further point out that, as the barramundi need to move downstream to complete their lifecycle, adult fish are likely to leave the dam, leaving sub-adult fish, many below legal size.

More recently, local recreational fishing groups, under the auspices of the East Kimberley RFAC, released approximately 600 juvenile/adolescent barramundi (ranging from 25-70+ cm) into Lake Kununurra over the 2000 and 2001 wet seasons. These fish were caught by hand just below the Kununurra Diversion Dam (KDD), which means they were effectively from the 'wild' lower Ord River stock. The fish were then measured, tagged and transported for release into Lake Kununurra (i.e. *above* the KDD). So far about a dozen or so tags have been recovered (from the current program), and most, but not all, of these fish have been caught back below the KDD.

1.4 Other species

In addition to trout, redfin perch was also introduced into Western Australian waters for recreational angling. Significantly, this species is considered a pest species (Fisheries WA, 1999). A number of other fish, native to the Eastern States, have also been introduced for recreational fishing and for aquaculture, mainly into farm dams. These are silver perch, golden perch and Murray cod.

2 The Australian experience outside WA

2.1 Queensland

In the mid-1960s, Queensland was considering the introduction of Nile perch into impoundment fisheries to create recreational fisheries. However, the risks of such an introduction were considered to outweigh the benefits and the proposal did not proceed (Russell and Rimmer, in press). With the introduction of technology to produce masses of fingerlings in Queensland hatcheries, attention moved to creating *put and take* barramundi fisheries in north Queensland impoundments (Russell and Rimmer, in press). This program was extended in 1990 to open river systems.

The Stocking Impoundment Permit Scheme commenced on 12 July 2000 with the aim of raising funds for the provision of native fish fingerlings to stock 25 impoundments through Queensland (QDPI, 2002).

There are 70 stocking groups in Queensland with access to a number of lakes formed by the damming of rivers. Barramundi has been successfully stocked in Eungella Dam near Mackay, Lake Monduran near Gin Gin, Lake Proserpine and Lake Lenthall between Maryborough and Torbanlea (Corporate and Regional Enterprise Consulting, in draft).

The main two impoundment-fisheries for barramundi are Lake Tinaroo and Lake Awoonga. The information on these fisheries is drawn from Corporate and Regional Enterprise Consulting (in draft).

Lake Tinaroo had existing fisheries for red claw and sooty grunter (which still exist), when first stocked for barramundi in 1985-86. Since 1986, 800,000 fingerlings have been released, or approximately 100,000 per year. Two of the three towns around the lake have trebled in population; and the third town is a direct result of the barramundi fishery being established. Local anecdotal estimates of economic benefit are between $10m to $50m annually.

Lake Awoonga is the main water storage for Gladstone. In the early 1980s, the lake was stocked with various fish, but stocking failed due to predators. Research showed stocking with barramundi might be successful due to its rapid growth, high survival potential and competitive nature. The first barramundi stocking was December 1996. Since then, 1.8 million fingerlings have been released, although the first one million were lost because they were small and could not withstand predation. Larger fingerlings are now used. Annual stocking is for up to 200,000 fingerlings however stocking during the last two years has been less than this – 180,000 in 2001, 130,000 in 2000.

More recently, Lake Awoonga has also been stocked with sea mullet, seratoga, and mangrove jack.

After many successful years of stocking impoundment fisheries, there is now community pressure to enhance wild stocks in catadromous[12] and marine fisheries (Cadwalladar, 1999). Cadwalladar reported on two research projects that were underway in Queensland to assess the efficacy and cost-benefit of stock enhancement in coastal river systems. The following discussion on these projects includes updated information as referenced.

[12] A catadromous fish spawns in salt water but spends most of its life in freshwater.

1. Barramundi. Barramundi catches on the east coast have declined (although CPUE has not). Both have declined in the Gulf of Carpentaria. Habitat degradation (on the east coast) and overfishing (both) are major factors in these declines. The decline in the Gulf is being managed through tightening commercial management arrangements. On the east coast, a trial stock enhancement was undertaken. Between 1993 and 1996, almost 69,000 marked fingerlings were released in the Johnstone River. Two size classes were released into freshwater, estuarine and upper tidal habitats. The fish took three years to reach legal size and comprised between 15 and 19 per cent of barramundi taken in the sampling program. There was no significant difference in the numbers recaptured from each size class, and most were recaptured within three kilometres of their original release site. Recreational and commercial catch records are being analysed to ascertain if there is any measurable increases in CPUE.

2. Cadwalladar (1999) also discusses a pilot project conducted in the Maroochy River estuary in Queensland for stock enhancement of a recreational fishery for summer whiting and dusty flathead. Although the results of this study are not presented in the paper, recent discussions with Queensland DPI indicated some degree of success (A Butcher, pers.comm.). Stocking followed two major fish kills due to agricultural pest control in 1993 and 1994. Flathead and whiting were stocked between 1996 and 1998. Unfortunately, another fish kill occurred in April 1998, which affected the ability to get a true measure of the success of stock enhancement in the estuary. However, some stocked fish did survive and showed up through creel sampling so the enhancement may have had some effect had the fish kill not occurred. Lack of funding prevented further study after 1998 (A Butcher, pers.comm.).

An economic study on the cost benefit of stock enhancement with barrumundi in Queensland (Rutledge *et al*, 1990) found stockings in the impoundments had significant cost-benefit ratios for the two lakes in which 'before and after' data was available: Lake Tinaroo (1:31) and Lake Morris (1:52). These were based on a 50 per cent harvest rate for stocked fish. Yet in Lake Morris, recovery rate in the years studied was 82 per cent, so the cost-benefit ratio would be even higher in this case. Although there are a number of assumptions about value of harvest that may not always remain true, the significant value of this fishery to Queensland means that these stockings are economic viable and the cost of developing barramundi aquaculture is justifiable.

2.2 New South Wales

The stocking of hatchery reared fry and fingerlings is a major freshwater management tool in NSW, with large recreational fisheries being established and maintained for both introduced and native fish (Rowland 1994).

Fish stocking commenced in NSW in the mid to late 1800s in private waters with Murray cod (prior to 1862) and in public waters with the introduction of brown trout and Atlantic salmon (1888), and then rainbow trout (1894) (Planning NSW, in draft). The early introductions were made to create recreational fisheries and there was little thought or understanding of adverse effects. Despite this, some stockings have been considered beneficial and are maintained today, for example, the salmonids (NSW Fisheries, 2002a).

Hatcheries now produce a range of species (mostly native) for stocking rivers, farm dams and impoundments. Main species produced are golden perch, silver perch, Murray cod, Australian bass, trout, barramundi, yabbies and a variety of aquarium species. In 1990-91 alone, 2.3 million golden perch, 1.4 million silver perch and 0.3 million Murray cod were produced in

NSW hatcheries for stocking purposes (NSW Fisheries, 2002a). Over the past three years, more than 12 million trout have been stocked into various waters. In the 2000-2001 stocking season, a total of 4,409,440 trout and salmon were stocked (NSW Fisheries, 2002c).

NSW requires a permit for all fish stockings and has strict controls over what can be stocked, especially where stocking occurs outside the natural range of the species. Proposals to stock marine or estuarine waters are assessed on a case-by-case basis (NSW Fisheries, 2002b). Mulloway and snapper have been identified as having potential for marine fish farming and grow-out, and breeding research programmes are underway for these species. They are also the preferred species for possible stock enhancement of estuarine and coastal waters (NSW Fisheries, 2002b, Planning NSW, in draft).

Planning NSW (in draft) cites an example of stocking in a coastal lagoon in NSW – 21,600 mulloway fingerlings were marked and released into Smiths Lake on three separate occasions. In addition to the policies and practices in place through NSW Fisheries, Planning NSW has drafted guidelines for environmental impact assessment of fish stocking management strategies (Planning NSW, in draft). It proposes that draft management strategies (required under NSW fisheries legislation for all major fisheries and certain fishing activities) be assessed in terms of the environmental impact of the proposed fish stocking activity, and it takes into account biological, biophysical, economic and social issues. It also prescribes the detail that would be required in each assessment.

2.3 Victoria

Fish releases in Victoria are undertaken by the Department of Natural Resources and Environment. Between April and November each year, more than 400,000 salmonoids (trout and salmon) are released into public waterways. Similarly, between November and April each year, around 1,000,000 native fish fingerlings averaging less than 1g each are released. These fish are mainly golden perch and Murray cod. Silver perch and Trout cod are also stocked in the north of the State, and Australian bass in selected southern lakes (Dept of NRE, 2002).

2.4 Tasmania

Brown trout was introduced into Tasmania in 1864, followed by rainbow trout in 1897. The Tasmanian Inland Fisheries Service now operates the trout hatchery and is responsible for the management of fish stocking in that State. This is the only fish stocking that occurs in Tasmania, and although marine fish farming is undertaken successfully, there is no program for stock enhancement of estuarine and coastal waters.

2.5 South Australia

The only continual stocking within South Australia is by the SA Fly Fishers Association, which runs a licensed hatchery and releases about 200,000 brown trout each year for recreational fishing. Research was undertaken into enhancement/reseeding of abalone, but this research has not resulted in a stocking program. No other stock enhancement is undertaken in South Australia (pers. comm. V Neverauskas, A/Director, Fisheries, Primary Industries and Resources SA).

2.6 Northern Territory

The Northern Territory Government has been stocking Manton Dam (a backup water supply dam) with barramundi for 10 years. This is the only stock enhancement occurring in NT, although there is recent interest in ranching trepang (pers. comm. R Sellers, Director of Fisheries, NT Dept of Business, Industry and Resource Development).

2.7 Australian Capital Territory

Being at high altitude and with no coastal drainage system, the waterways of the ACT hold very few species of fish of interest to anglers. Pollution, fishing pressure and natural environmental events have contributed to substantial decline in four of these species - trout cod, Macquarie perch, silver perch and Murray River crayfish (Environment ACT, 2000). These four species are also classified as threatened at a national level. The main targets of recreational fishers in ACT are Murray cod, golden perch, brown trout and rainbow trout. Some sectors of the community also target redfin and carp (Environment ACT, 2000).

Stocking of natural streams does not occur in the ACT except for exceptional circumstances, such as conservation of a threatened species. Similarly, stocking is not undertaken in the three water supply reservoirs (Environment ACT, 2000). The majority of stocking occurs in the Lakes.

Following the creation of Lake Burley Griffin in 1964, stocking was mainly rainbow trout and brown trout. However, these did not do well in urban lakes and as commercial quantities of native fish (Murray cod and golden perch) became available, the emphasis switched to these fish (Environment ACT, 2000). Releases of silver perch into Lake Burley Griffin and Lake Ginninderra in the late 1970s and 1980s did not take, although stocking of silver perch in Lake Googong has been successful. (Environment ACT, 2000). Early experimental releases of two additional fish species, the native Freshwater Catfish and the introduced Brook Trout, were unsuccessful and have not been continued (Environment ACT, 2000).

Environment ACT stocks approximately 50,000 fish each year in Canberra's lakes, with more than 1.6 million fish stocked since 1981 (Environment ACT, 2000). Experimental releases of trout are undertaken occasionally to determine whether environmental conditions have changed sufficiently to support viable trout fisheries. Of 15,000 rainbow trout released in

1995 and 10,000 brown trout released in 1996, none have been caught in 1997 and 1999 monitoring programs (Environment ACT, 2000).

The most successful (although considered by most as a problem) fish introduction for ACT was carp. Carp inhabit large, slow flowing rivers, lakes and permanent wetlands, commonly with silt bottoms. They tolerate low levels of oxygen, which gives them an advantage in stagnant waters. They are considered a pest throughout Australia, as they can damage streams and native fish populations.

Carp now occur in all of the urban lakes in the ACT, the Murrumbidgee River, the Molonglo River catchment, the Ginninderra Creek catchment and the Tuggeranong Creek catchment. They are absent from Googong Dam, the Cotter River above the Cotter Dam, and are not found in any of the river systems within Namadgi National Park.

3 INTERNATIONAL EXPERIENCE

Internationally, the practice of stock enhancement is well established, and more than 100 species have been released worldwide (Liao, 1999). In many countries, especially Asia, stock enhancement is accompanied by habitat modification, particularly the establishment of artificial reefs. What follows is only a snapshot of the past and present stock enhancement projects throughout the world.

Liao (1999) mentions a number of successful stock enhancement programs – salmon, scallop, red sea bream, prawn and flounder in Japan (see also Arnason, 1999); red drum in Texas; striped mullet in Hawaii; artificial reefs off Taiwan; prawn in China. Arnason (1999) also reports on salmon in the US and in Iceland. The level of success varied between programs/countries (Liao 1999, Arnason, 1999).

Stock enhancement in Japan has expanded greatly since the 1970s and is very much government operated. The rationale behind this is social welfare – fishing is a traditional activity and the basis of many villages and families. It appears the government regards it has a responsibility to sustain these activities. The government therefore runs research, hatching and release, and the fishing industry harvests the grown fish (Arnason, 1999). For inshore fisheries, stock enhancement has been crucial, with it accounting for over 18 per cent of inshore catch by the late 1980s. Stock enhancement in rivers is insignificant.

Stock enhancement began in the US in the late 19th century with the purpose of enhancing runs of salmon in rivers damaged by logging, railroad, dams etc. However, this was largely ineffective (Arnason, 1999). With advances in stock enhancement methods, enhancing river stocks is now common. Enhancement of ocean stocks has not been so successful. In the late 1960s and 1970s, ocean enhancement of salmon became a commercial venture and a limited number of licences were issued in California and Oregon. As a result of environmental concern, a moratorium on further licences was issued, and due to economics, most licensed projects failed and ceased operation (Arnason, 1999).

Government-run ocean enhancement programs in the US have been more successful and have expanded throughout the 20th century, mainly targeting valuable species (Arnason, 1999). It is now large scale – in the early 1990s, up to 2 billion fry were being released each year at a cost of about $US 100 million. Private investment is small, mainly due to falling prices and highly

variable recovery rates (Arnason, 1999). The exception to this is the Alaskan salmon ranching program, which, due to unique social conditions, is successful.

Stock enhancement in Iceland is extremely successful. There is only one species involved – Atlantic salmon – and the conditions are ideal: well endowed salmon rivers, an abundance of unpolluted fresh water, a biologically productive ocean, and a fisheries management restriction that bans ocean fishing for salmon (Arnason, 1999). Enhancement commenced in the rivers during the early 20th century with the release of young fry, but this meant that released fish did not join the fishery for a number of years. As technology increased, more fish were released close to or at smolt size (enhancement in the oceans). Iceland did allow release for immediate recovery in the ocean between the 1960s and 1990s, although economic results were poor and it ceased. Stock enhancement for fishing of the rivers is made profitable by the fact that almost all salmon rivers are privately owned and that the owners limit the number of rods in the river. The result is high licence values (Arnason, 1999).

Arnason (1999) suggests private ocean stock enhancement is likely to disappear in the near future unless there is a vast improvement in technology or a substantial rise in the price of product. Government backed enhancement, on the other hand, is likely to increase. In looking at why some stock enhancement projects have failed, Liao (1999) observes a number of barriers to the success – poor coastal zone management, lack of fisheries management or resource conservation, insufficient basic scientific information, inadequate education of fishermen, and international disputes.

Blaxter (2000) outlines the history of stock enhancement in a number of countries from the late 1800s to the late 1990s. One example is the Norwegian efforts to enhance cod stocks, which commenced in 1882 with the founding of a commercial hatchery, and larva releases continued until 1967. These releases were controversial, as many doubted the beneficial effect. Short-term comparisons using 0-group and 1-group recapture at interval after release were encouraging, but in the early 1970s, a longer-term view was taken (1920 to 1969) and the result was different. Recordings of 0-group fish at 17 locations along the coastline in both release and non-release years showed no significant difference. It appeared the release of eggs or yolk-sac larvae had no beneficial effect.

From the mid 1970s to 1991, Norway turned to the release of juveniles, with serious attempts at augmentation occurring in 1983 (20,000 juveniles) and 1986 -1991 (660,000 juveniles) (Blaxter 2000, p 19). Field sampling to test the results of these releases continued until 1993 and on the basis of results, the experiments ceased. In the two-year-old group, where fish should be entering the fishery, there was no sign of stock enhancement.

The FAO Inland Water Resources and Aquaculture Service undertook a review of inland fishery enhancements throughout the world in an attempt to characterize these enhancements. It found the most common forms of enhancements were stocking and introductions, and these occurred for food production and generation of income (FAO, 1999). Enhancement for recreational fisheries was of secondary importance. Most significant species for food and income on a global scale were reported as Mozambique tilapia, common carp, rainbow trout, Nile tilapia and brook/sea trout.

It found many fisheries in the world were enhanced in one way or another, and new fisheries are being created where opportunities allow. For example, Chinese reservoirs built for power generation are being stocked with fish and contributing significantly to inland fisheries production. Finland uses regular stocking of brown trout as a major contribution to its lakes fisheries management (FAO 1999). Further information on different enhancement methods and enhanced fisheries for each global region can be found in the FAO review. Similarly, Welcomme and Bartley (1998) provide a thorough overview of the history of fish stockings and the results of some of them.

APPENDIX 2 PROPOSED GUIDELINES FOR STOCK ENHANCEMENT IN WESTERN AUSTRALIAN WATERS

1 Guidelines to be taken into account when proposing to stock fish into public water bodies where the species naturally occurs

- All stock to be placed into public water bodies should originate from broodstock obtained from that water body or an interconnecting system.

- 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 the species involved.

- No selection process to improve the stock must occur. Unintentional domestication of stock may be unavoidable, but it is possible that it can be minimised by the introduction of new broodstock from the wild every generation. *NB: Different stocking strategies can be used to improve returns to recreational fishers (i.e. stocking yearling fish as opposed to fry).*

- Fish to be stocked into a system in which the species already occurs, must be tested for nominated diseases.

- 'Nominated' diseases must include relevant 'Notifiable' diseases as listed under the *Enzootic Disease Regulations 1970* and any other diseases nominated by the Senior Fish Pathologist of the Department of Fisheries for the particular species to be stocked.

- Government veterinary officers or other authorised officers in laboratories using methods approved by the Senior Fish Pathologist of the Department of Fisheries shall perform health testing and certification.

- Testing standards shall meet the 95 per cent degree of confidence that the fish to be stocked are free of the 'nominated' diseases.

- A sound scientific monitoring program to evaluate the success and determine the cost benefits of the stocking program must be implemented.

2 Guidelines to be taken into account when proposing to stock fish into public water bodies where the species did occur, but is now depleted

- 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. 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.

- 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. from a common evolutionary history).

- 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 the species involved.

- Some selection to improve the stock may be permitted to ensure optimum fitness of the stock, and therefore increase the chances of survival in the system.

- Fish to be stocked must be tested for nominated diseases.

- 'Nominated' diseases must include relevant 'Notifiable' diseases as listed under the *Enzootic Disease Regulations 1970* and any other diseases nominated by the Senior Fish Pathologist of the Department of Fisheries for the particular species to be stocked.

- Government veterinary officers or other authorised officers in laboratories using methods approved by the Senior Fish Pathologist of the Department of Fisheries shall perform health testing and certification.

- Testing standards shall meet the 95 per cent degree of confidence that the fish to be stocked are free of the 'nominated' diseases.

- A sound scientific monitoring program to evaluate the success and determine the cost benefits of the stocking program must be implemented.

3 Guidelines to be taken into account when proposing to stock fish into public water bodies where that species has never occurred

- Proposals to stock fish into public water bodies where that species has never occurred will be assessed on a case by case basis, but will require a full translocation assessment as outlined in accordance with the process outlined in MPG No. 5. This may include referral to the EPA. In certain areas, approval from the Department of Environment and Heritage may also be required under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999.*

- Approval to stock particular species of fish into areas where they do not naturally occur is unlikely to be granted unless it can be demonstrated that the activity is unlikely to impact on important biological resources.

APPENDIX 3 THE EPA'S PROCESSES FOR ASSESSING DEVELOPMENT PROPOSALS

Figure 1. Outline of Procedure for Assessment on Referral Information (ARI)

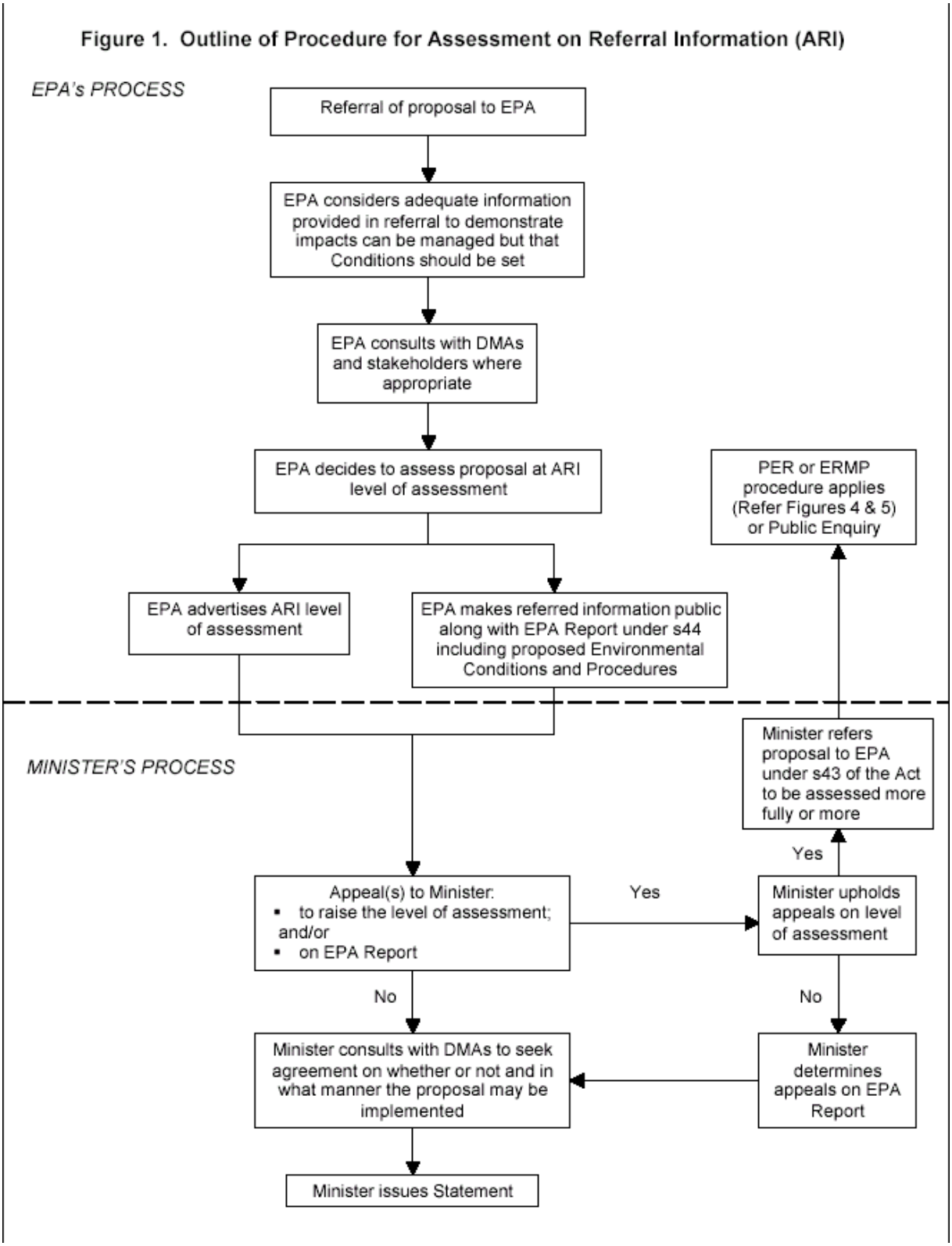


Figure 2. Outline of Procedure for Proposal Unlikely to be Environmentally Acceptable

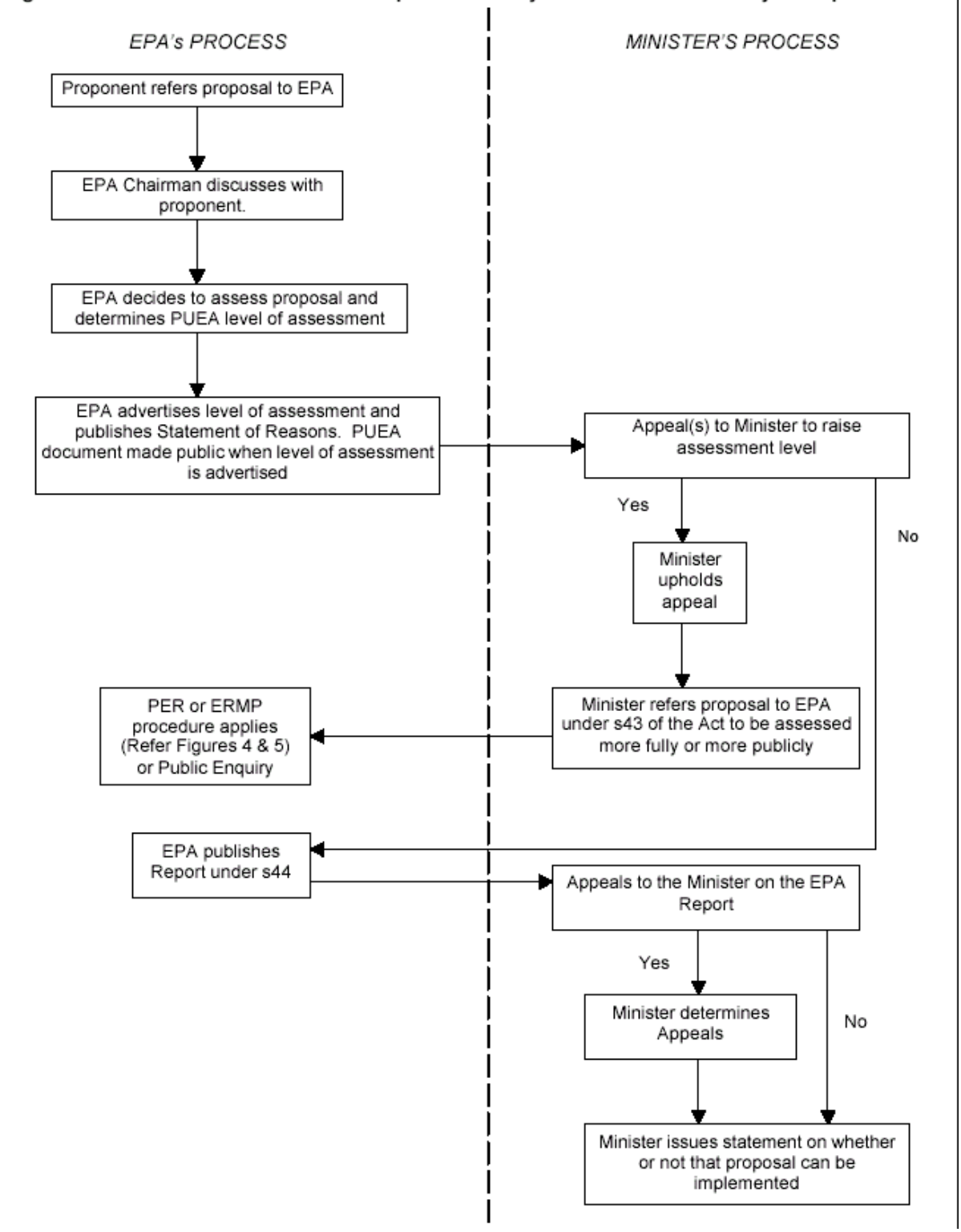


Figure 3. Outline of Procedure for Environmental Protection Statement (EPS)

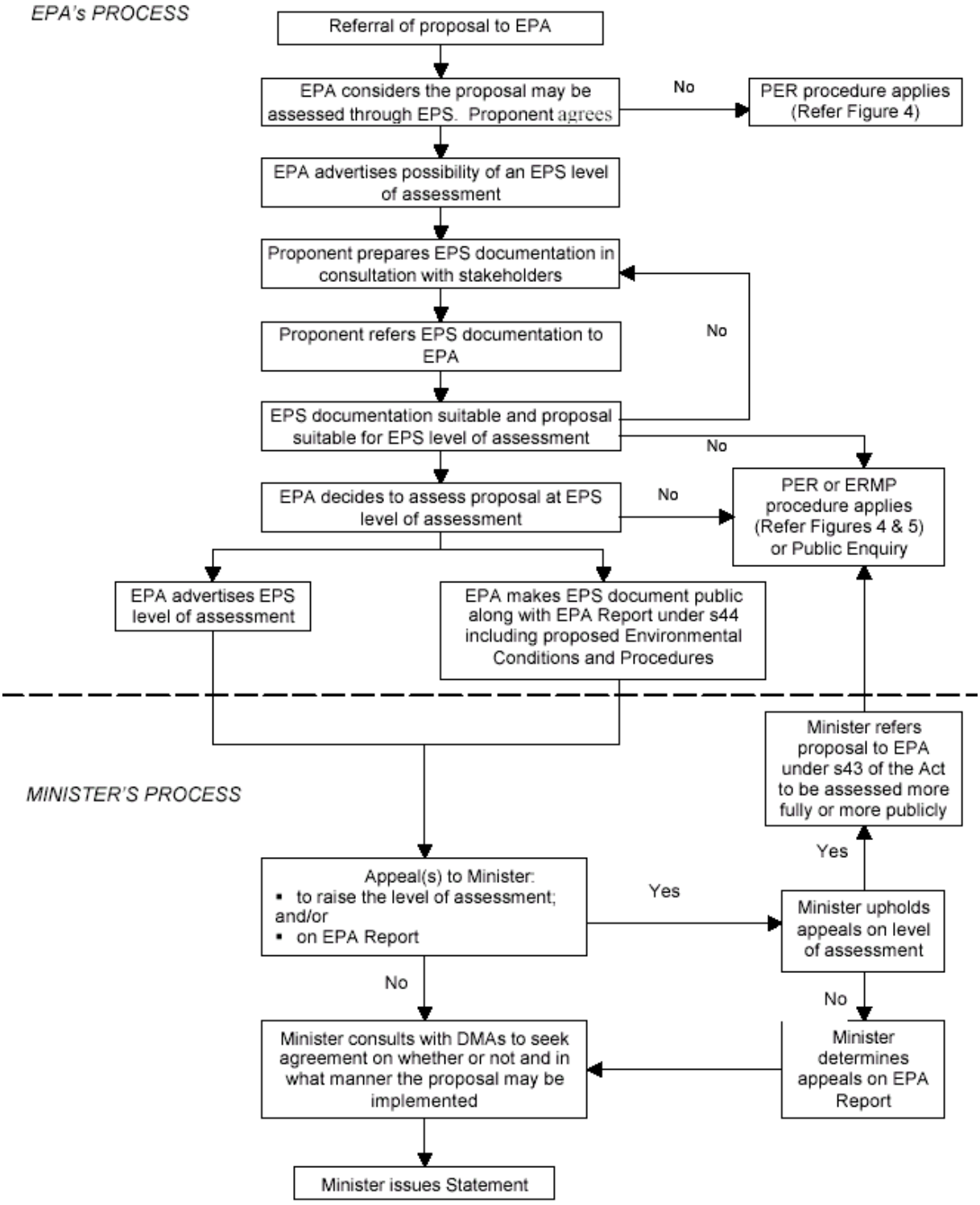


Figure 4. Outline of Procedure for PER Assessment

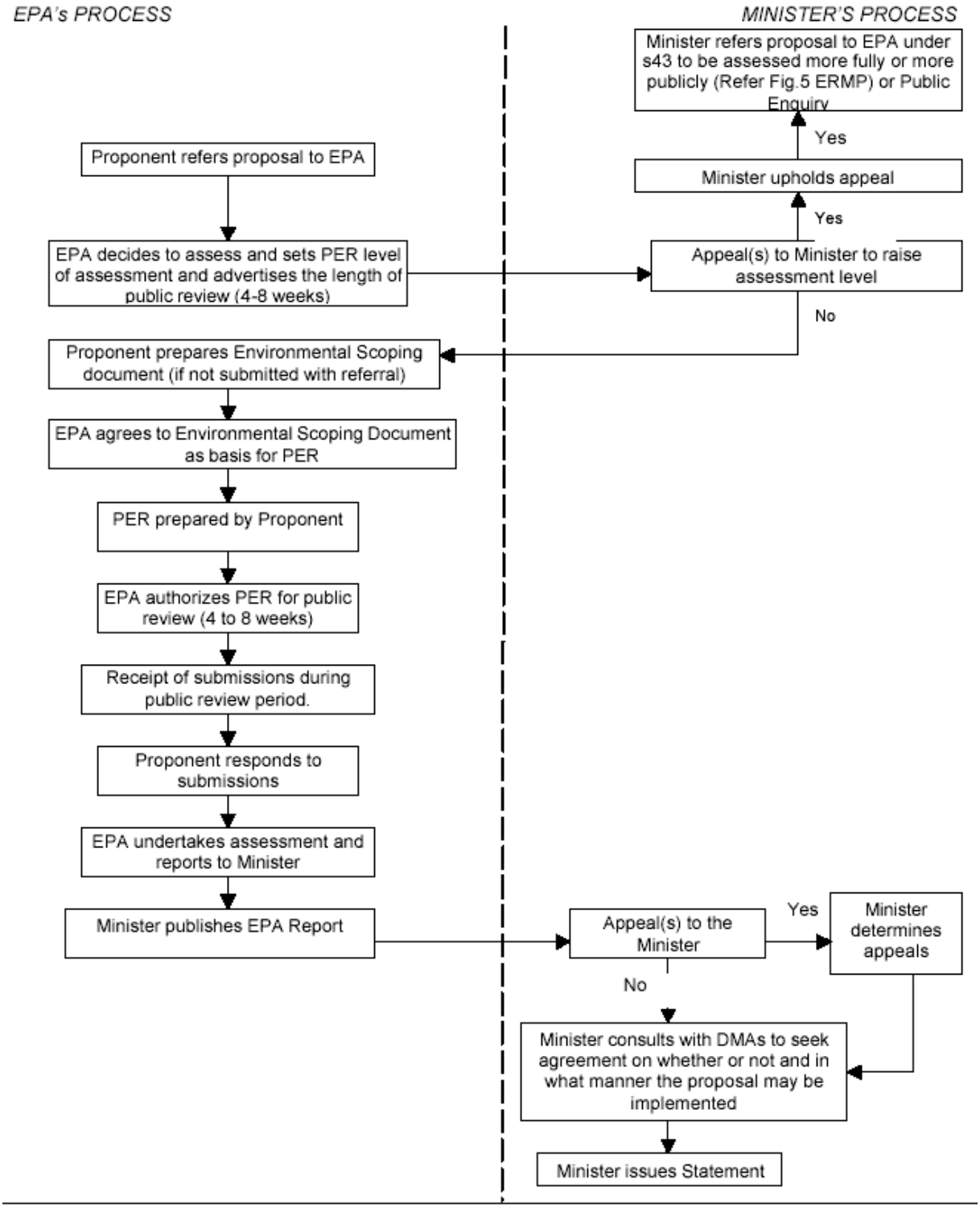
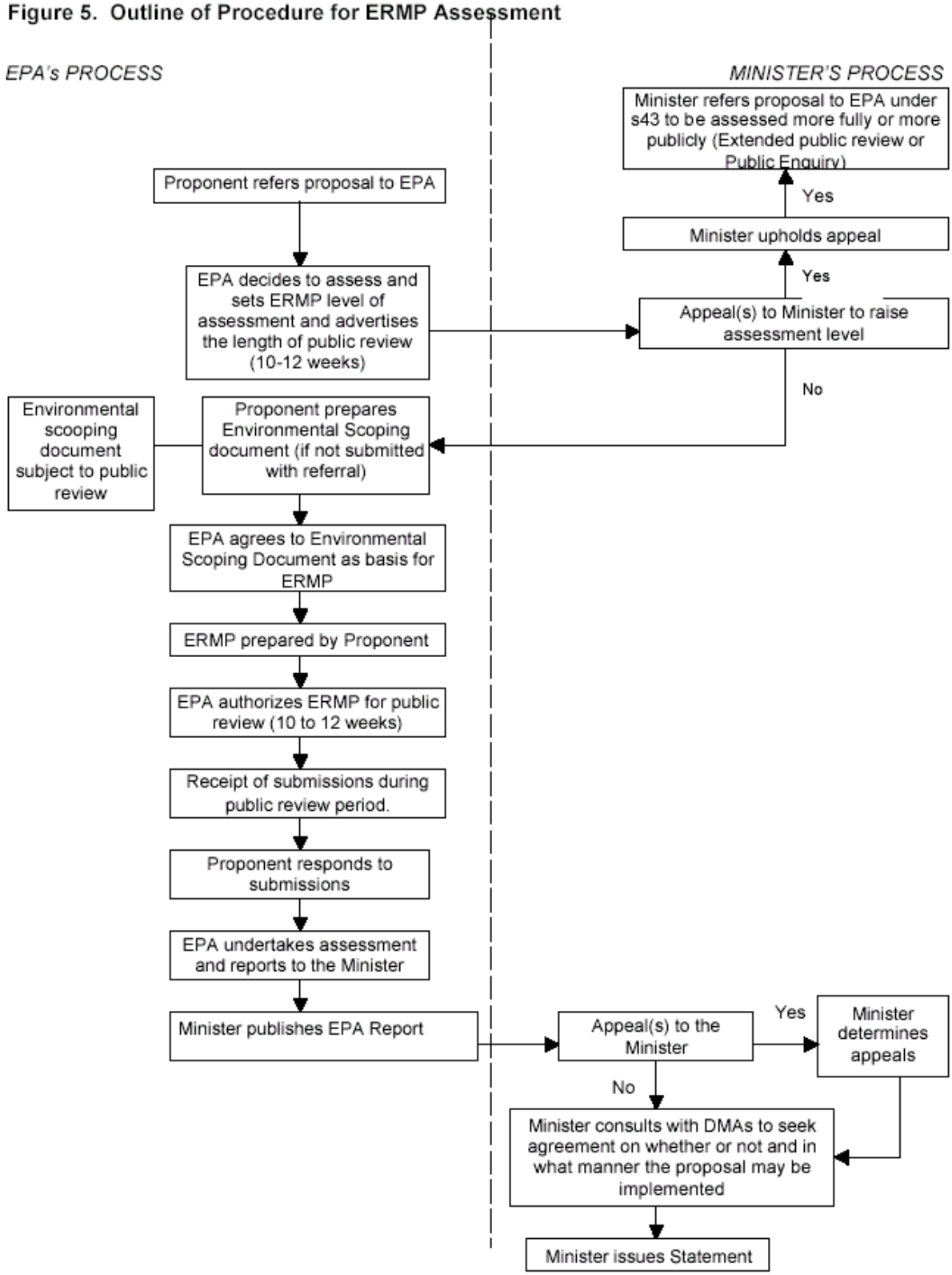


Figure 5. Outline of Procedure for ERMP Assessment



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