Lake Argyle Aquaculture Initiative

Fisheries Western Australia

Advice to the Minister for the Environment from the Environmental Protection Authority (EPA) under Section 16(e) of the *Environmental Protection Act 1986*

(This is not an assessment of the Environmental Protection Authority under Part IV of the *Environmental Protection Act 1986*)

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Summary and recommendations

This report provides the Environmental Protection Authority's (EPA's) advice to the Minister for the Environment on a strategic review of the potential development of a 2000 tonne per annum barramundi (*Lates calcarifer*) production industry on Lake Argyle near Kununurra, being facilitated by Fisheries Western Australia (FWA).

FWA requested early advice from the EPA on any potential fatal flaws, from an environmental impact perspective, that could be associated with development of the industry. The EPA's report also highlights areas where further work would be required by proponents as part of a formal environmental impact assessment of a firm development proposal under Section 38 of the *Environmental Protection Act 1986.*

Relevant environmental factors

Although a number of environmental factors were considered by the EPA in the strategic review, it is the EPA's opinion that the following are the environmental factors that would need to be addressed in detail in any assessment of an individual proposal:

(a) Water quality;

(b) Ramsar wetlands and protection of environmental values;

(c) Maintenance of genetic diversity of wild barramundi stocks; and

(d) Visual amenity.

Conclusion

The EPA has strategically reviewed the proposed development of a large scale barramundi aquaculture industry (up to 2000 tonne production per annum) on Lake Argyle.

The EPA has concluded that, with the exception of water quality, all factors identified are likely to be manageable. With the factor of water quality, manageability will need to be demonstrated through additional baseline data collection and 1 dimensional modelling as part of a formal environmental assessment process, and then through subsequent monitoring and development and refinement of 1 and 3 dimensional predictive modelling as part of a staged development process for any approved project, up to 2000 tonne per annum.

Any specific proposal for the development of aquaculture on Lake Argyle will require referral to the EPA for formal assessment under Section 38 of the *Environmental Protection Act 1986.*

As part of a formal assessment, the additional work required would include:

- establishment of agreed water quality criteria, to ensure that the ecological values of the system are protected and maintained.
- baseline data collection (over 3 to 4 months) to improve understanding of the nature of the Lake Argyle system and to provide adequate data to improve certainty associated with 1 dimensional modelling. Details of the specific requirements for data collection will be developed in consultation with the DEP. At this stage, collection of the following type of data is anticipated:
  - (a) Meteorological data (preferably a meteorological station based at Lake Argyle);
  - (b) Standard water quality measurements at several locations in the northern basin, including side-arms. This should include :
    - detailed profiles of conductivity, temperature, dissolved oxygen and depth;
    - nutrient and oxygen measurements in the epilimnion, metalimnion and hypolimnion; and

- sediment oxygen demand, sediment nutrient content and nutrient fluxes under oxic and anoxic conditions on 2 - 3 occasions at a sub-set of these sites;

(c) Temperature, volume and nutrient concentrations of inflows to the Lake.

- further 1 dimensional (1-D) modelling (using a model such as DYRESM), incorporating the additional baseline data to aid in resolving the uncertainty about the hydrodynamics of the Lake (turnover in the main basin and semi-enclosed areas) and, when undertaken for one or more locations, identify key periods in the year when extreme or critical events could occur. This would require about 3 to 4 weeks of effort by a group such as that recommended by the SER, and could be undertaken immediately, requiring only meteorological data as input.

Subject to the outcomes of this additional work and formal assessment, the EPA anticipates that environmental approval could be granted for an industry with a production of up to 2000 tonnes per annum, subject to appropriate conditions. It is noted that further information may be provided during formal assessment of a proposal which may provide greater certainty of impacts and therefore influence the actual conditions to be applied. However, and on the basis of existing information, conditions of approval are likely to include:

- the initial stage not to exceed 500 tonnes per annum at agreed locations, with a monitoring plan to be implemented to confirm that set environmental criteria are met and to provide data for more refined predictive modelling;
- any expansion beyond 500 tonnes per annum would be dependent on monitoring demonstrating that set water quality criteria were being met, and the adequate development of a 3 dimensional (3-D) model constructed for a typical semi-enclosed area in which aquaculture is proposed, which would use information collected in Stage 1 to indicate that performance criteria were likely to continue to be met in the long term;
- because of the cost and computing limitations associated with a 3-D model, modelling should be confined to a short period (eg 2 to 3 months) around any critical period (eg lake overturn periods). The results of the 3-D model could be correlated against the 1-D model and the 1-D model then used to run 10 to 20 year simulations which would allow sufficient time for equilibrium concentrations of total phosphorus, total nitrogen and chlorophyll 'a' to be achieved. This combined 1-D and 3-D approach would permit long time-scales to be modelled with reasonable amounts of power and represents a satisfactory balance between 1-D and 3-D approaches.
- a commitment to long term monitoring, data from which can be used to assess what level of aquaculture in Lake Argyle is likely to be environmentally sustainable. This data can be incorporated into the long term modelling of the Lake Argyle system.

Recommendations to the Minister for the Environment

Recommendation 1

That the Minister for the Environment notes that the EPA has provided environmental advice in this report on the potential development of a 2000 tonne per annum barramundi production industry on Lake Argyle, being facilitated by Fisheries Western Australia.

Recommendation 2

That the Minister for the Environment notes that the EPA advice in this report covers issues related to water quality, Ramsar wetlands and protection of environmental values, maintenance of genetic diversity of wild barramundi stocks and visual amenity.

Recommendation 3

That the Minister for the Environment notes that the EPA has concluded that subject to the outcomes of further studies which would be required as part of formal environmental assessment, an industry of up to 2000 tonnes per annum may be environmentally acceptable. Any development however, would need to be staged with Stage 1 not exceeding 500 tonnes per annum and subject to ongoing monitoring and predictive modelling to demonstrate that performance criteria can be achieved and that unacceptable degradation of lake water quality will not occur.

Recommendation 4

That the Minister for the Environment notes that the advice provided in this report will be provided to the Minister for Fisheries.

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Appendices

1. Introduction

Fisheries Western Australia (FWA) requested the Environmental Protection Authority (EPA) to undertake a strategic review of the concept of developing a large scale barramundi aquaculture industry (up to 2000 tonne production per annum) on Lake Argyle. It is envisaged that the development of such an industry would entail about 5 sites of 40 sea cages each, boat ramps or jetties, on-shore storage and maintenance facilities, administration, accommodation and feed storage facilities, site works and infrastructure (eg power, freshwater, access roads), and bulk fish handling and processing facilities.

The EPA has reviewed the development of such an industry at Lake Argyle and provides advice on the concept to the Minister for the Environment under Section 16e of the *Environmental Protection Act 1986.* The advice is provided to identify any 'fatal flaws' early in the planning of the concept and to provide guidance to potential developers on the environmental issues of concern to the EPA and the type and extent of further work that will be required for environmental approval.

In compiling this report, the EPA has considered the environmental factors associated with the proposal, issues raised in public submissions, specialist advice from the Department of Environmental Protection (DEP) and other government agencies, the proponent's response to submissions and the EPA's own research and expertise.

Further details of the proposal are presented in Section 2 of this report while Section 3 discusses environmental factors relevant to the proposal. The EPA provides general advice on other issues associated with the project in Section 4 Other Advice.

A list of people and organisations that made submissions is included in Appendix 1 and references are listed in Appendix 2.

Appendix 3 contains a summary of the public submissions and the proponent's responses. The EPA has considered issues raised in public submissions and FWA's response to those issues when identifying relevant environmental factors.

2. The proposal

The concept is for FWA to facilitate the development of an ecologically sustainable, intensive aquaculture industry on Lake Argyle which is capable of producing up to 2000 tonnes of fish per annum. Lake Argyle (Figure 1) is located on the Ord River 50 km upstream from Kununurra.

FWA proposes to facilitate this development by seeking 'Expressions of Interest' from developers and investors.

It is anticipated that one single corporate entity (be it a private corporation or a consortium of investors) would be responsible for management of the industry and environmental management of Lake Argyle under the terms of respective conditional licenses and approvals.

Aquaculture sites would be leased to one or more private companies who would be responsible for developing aquaculture on the sites. Indicative locations of farms are shown in Figure 2. It is anticipated that the companies would require access to a range of onshore facilities such as a boat ramp and / or jetty, nursery and processing plant and would need to provide offshore facilities including boats and floating fish cages.

A general description of proposed management arrangements for lease areas, activities likely to be undertaken by any intensive aquaculture operation and other administrative arrangements can be found in the Strategic Environmental Review (SER) document (LeProvost Dames & Moore et al. 1999) which should be read in conjunction with this report.

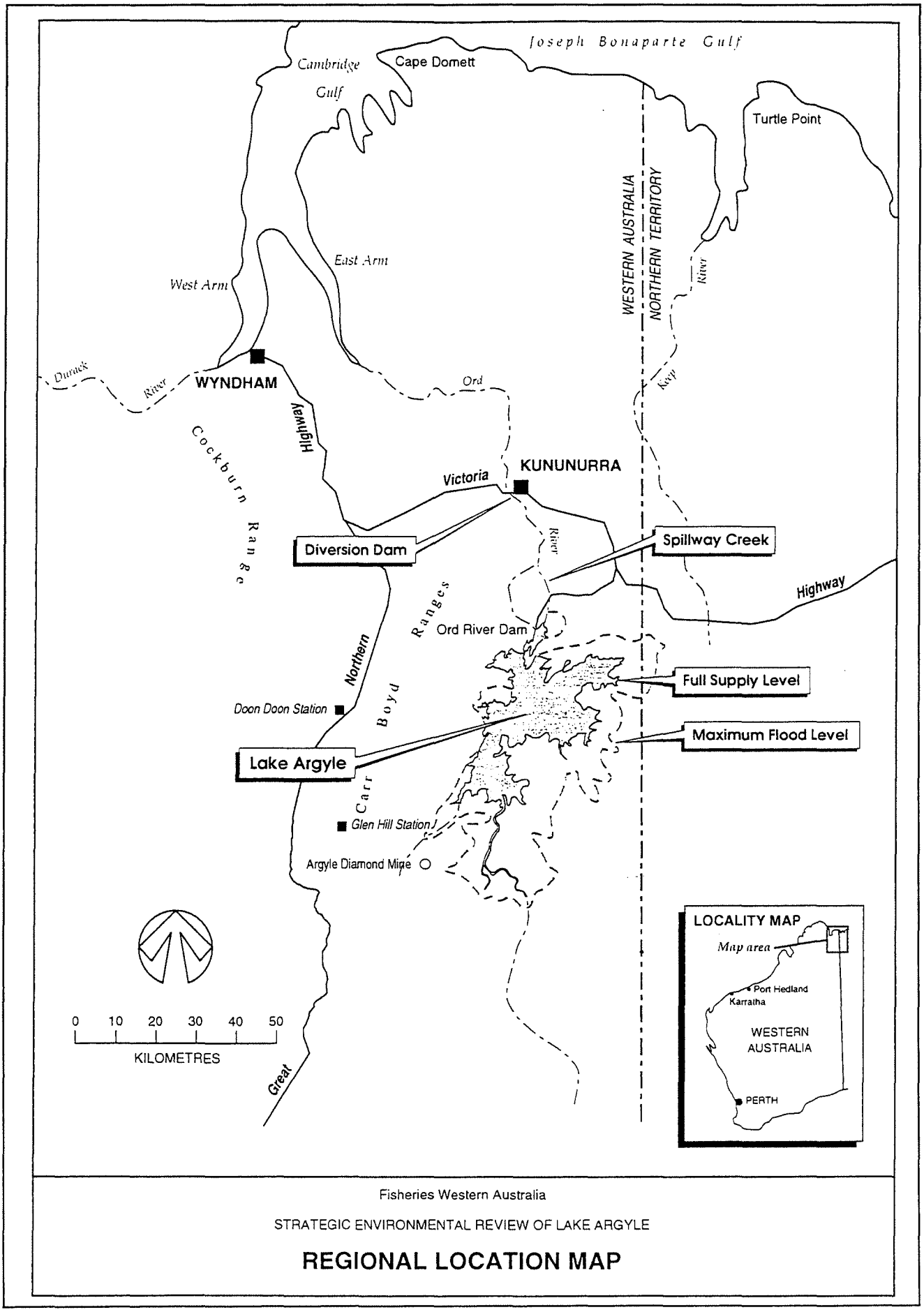

Figure 1. Lake Argyle locality map.

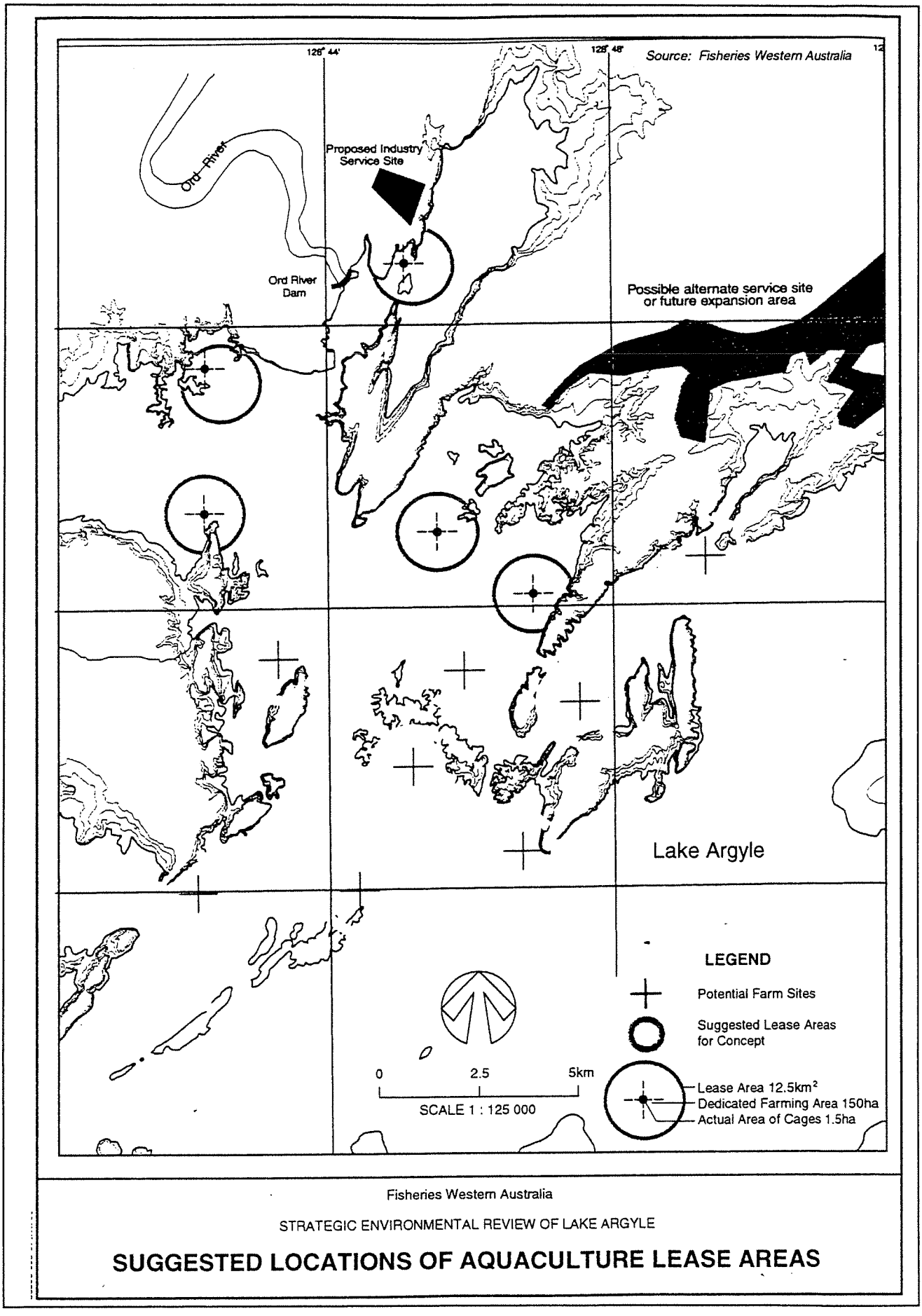

Figure 2. Indicative farm locations.

3. Relevant environmental factors

Appendix A of FWA's SER document contains a copy of the EPA's guidelines for the review and identifies the issues to be addressed during the review.

Having considered appropriate references, public and government submissions and the proponent's response to submissions, in the EPA's opinion, the following are the environmental factors relevant to the proposal:

(a) Water quality;

(b) Ramsar wetlands and protection of environmental functions;

(c) Maintenance of genetic diversity of wild barramundi stocks; and

(d) Visual amenity.

Details on the relevant environmental factors are contained in Sections 3.1 - 3.4. The description of each factor shows why it is important and how the development of an aquaculture industry may impact on it. Objectives for each factor have been included to assist in providing guidance to any potential developers. Objectives for any or all factors may change for any subsequent proposal based on this strategic review and any subsequent information that becomes available.

Submissions on the SER are summarised before the EPA consideration for each relevant factor.

3.1 Water Quality

Description

Seacage culture of finfish inevitably causes some degree of deterioration of water and sediment quality due to uneaten feed and fish faeces. Benthic habitat immediately below cages is at the greatest risk of impact from caged culture due to smothering, alteration of sediment and water quality and shading. However, depending on current movements, circulation patterns and degree of pollutant discharge, impacts can extend far off-site.

FWA, through their consultants, estimated the likely impact of a 2000 tonne per annum barramundi aquaculture industry on Lake Argyle by using Beveridge's FAO aquaculture model, which is based on the model by Dillon and Rigler (these models are explained in more detail in the SER). The results indicated that an annual production of 2000 tonnes can be maintained for all lake water levels above 86.6 m AHD (which occurs most of the time) without changing the lake's current oligotrophic water quality status. When lake levels fall below 86.6 m AHD, production levels will need to be reduced to maintain the lake's oligotrophic status.

The SER goes on to explain that the above estimates are highly conservative and there are a number of aquaculture management options available that could assist in maintaining an adequate water quality.

Submissions on the SER

Most submissions raised the issue of water quality and its potential impact on aspects of the lake, including its current use for drinking water for Lake Argyle Village, water for irrigation downstream, and the value of Lakes Argyle and Kununurra and the Ord River as Ramsar wetlands and waterbird and other wildlife habitats. The requirement for further verification work was supported in most submissions.

Consideration

The EPA's environmental objective for this factor is to maintain the water quality of Lake Argyle and down stream to the Kununurra Diversion Dam to ensure current uses can be maintained.

The Department of Environmental Protection (DEP) commissioned Dr Paul Lavery from Edith Cowan University to comment on the SER focusing on the limitations of the modelling, uncertainty, fatal flaws and further work that should be undertaken to verify the findings of the report (Lavery 1999).

Dr Lavery identified a number of significant limitations of the use of the model as a tool for assessment. The SER recognised the limitations of the model but was restricted in the models available for use by the lack of available data on the Lake. Of particular concern to Dr Lavery is the use of the FAO model as a predictive tool on which a number of conclusions were reached. The model was developed as a pre-development guide (Beveridge, 1984, 1996) with serious limitations as a predictive model on which management recommendations are based.

Some of the assumptions of the model (which are clearly described in the SER) include:

1. steady state conditions in the water body over time;
2. water body being phosphorus-limited;
3. an even distribution of nutrient loading over a waterbody;
4. no account taken of seasonal lateral and vertical turbulent transport which will affect flushing;
5. no account is taken of oxygen dynamics in Lake Argyle which is of serious concern when modelling tropical lakes with warmer water (which have lower dissolved oxygen concentrations and a lower dissolved oxygen saturation point);

Other potential concerns raised by Dr Lavery relate to the lack of data available on the characteristics of Lake Argyle. It was noted that a very limited data set was used in the model and this data takes little account of seasonal or spatial variability in the Lake. This lack of data is also recognised in the SER, and FWA undertook some further limited water quality monitoring to try to increase the certainty of some of the figures used. This further information is an appendix to the response to submissions (Appendix 3). The water quality data "appears broadly consistent with the strategic environmental review assessment of July 1999" (FWA 1999).

The findings of the modelling work undertaken as part of the SER suggested that production of up to 2000 tonnes per annum was sustainable under 'normal' Lake conditions. While the EPA recognises the inherent problems associated with the model and data availability, it also recognises the conservative approach of the modelling and so can gain some comfort that Lake Argyle can support an aquaculture industry. However the maximum extent of this industry and the location of the sites on the Lake require further determination.

Dr Lavery developed recommendations which would provide the EPA with a reasonable degree of confidence about the nature of the system and prediction of potential impacts from aquaculture development on Lake Argyle. These recommendations related to collection of further data both prior to any proposal proceeding, and then as part of ongoing monitoring, to improve the certainty associated with the modelling and the type of modelling that should be undertaken to model extreme events and simulate impacts over 10 to 20 years, accounting for time to equilibrium in the systems (Lavery 1999).

To provide a way forward for the development of an aquaculture industry on the Lake and to ensure the protection of the current environmental values and uses of the Lake, the EPA would require a more clear understanding of appropriate water quality criteria for the Lake and improved certainty associated with the modelling. This could be achieved by collecting the following additional baseline data to assist in validating the model:

(a) Meteorological data (preferably a meteorological station based at Lake Argyle);

(b) Standard water quality measurements at several locations in the northern basin, including side-arms. This should include :

- detailed profiles of conductivity, temperature, dissolved oxygen and depth;
- nutrient and oxygen measurements in the epilimnion, metalimnion and hypolimnion;

- sediment oxygen demand, sediment nutrient content and nutrient fluxes under oxic and anoxic conditions on 2 - 3 occasions at a sub-set of these sites;

(c) Temperature, volume and nutrient concentrations of inflows to the Lake (if not already available from the Water and Rivers Commission).

The EPA recommends that environmental approval could be considered after sufficient data collection is undertaken and a one dimensional (1-D) hydrodynamics model (such as DYRESM) is run. This would require about 3 to 4 weeks of effort by a group such as that recommended in the SER, and could be undertaken immediately, requiring only meteorological data as input. Subsequent 1-D ecological modelling should be undertaken for one or more locations and used to identify key periods in the year when extreme or critical events could occur. This information should be used to decide on the best placement of cage sites on the Lake.

Further 3-D modelling and 10 - 20 year simulations of the 1-D modelling (allowing for sufficient equilibrium time for total phosphorus and chlorophyll 'a' concentrations) would need to be undertaken prior to any approval to expand beyond 500 tonnes per annum. Prior to development of each subsequent stage, the proponent would need to be able to demonstrate that the predictions of potential environmental impacts of previous stages were accurate and then predict impacts from subsequent stages (verified through modelling). Approval to expand would be based on the ability to meet defined criteria, particularly including nutrient and chlorophyll a water quality measures. The criteria would be based on environmental values of the Lake that are being protected and would need to be determined during the assessment of a proposal, based on better background information.

Any intention to develop beyond 2000 tonnes per annum would need to be further assessed based on aquaculture technology of the time, extensive model validation and contingency planning.

Any development of aquaculture of finfish in cages in a 'natural' water body would also require Works Approval and Licensing by the DEP, under Part V of the *Environmental Protection Act 1986*.

3.2 Ramsar Wetlands and Protection of Environmental Functions

Description

Lake Argyle and Lake Kununurra and the portion of the Ord River between them were listed in June 1999 on the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* (Ramsar) (Figure 3). The Lakes have been listed as they satisfy two criteria for 'international importance'. They are:

- "it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species"; and

- "it regularly supports 20 000 waterfowl" (ANCA 1996).

ANCA (1996) state that 74 waterbird species have been recorded at Lake Argyle with 22 species listed under treaties. Over 184 000 birds have been recorded on the Lake and it is estimated that over 100 000 waterbirds use the Lake annually.

Anecdotal evidence suggests that the majority of waterbird use is on the relatively shallow flats of the southern and eastern sides of the lake, away from the areas nominally allocated for farm sites (FWA 1999). However the congregation of fish and feed in one area, as happens with cage culture, may see some species attracted to the cages and either scavenging waste or predating juvenile barramundi. There is a potential for alteration of feeding patterns and diets of some species and will likely result in the need for some predator control devices installed over and around juvenile barramundi growout cages.

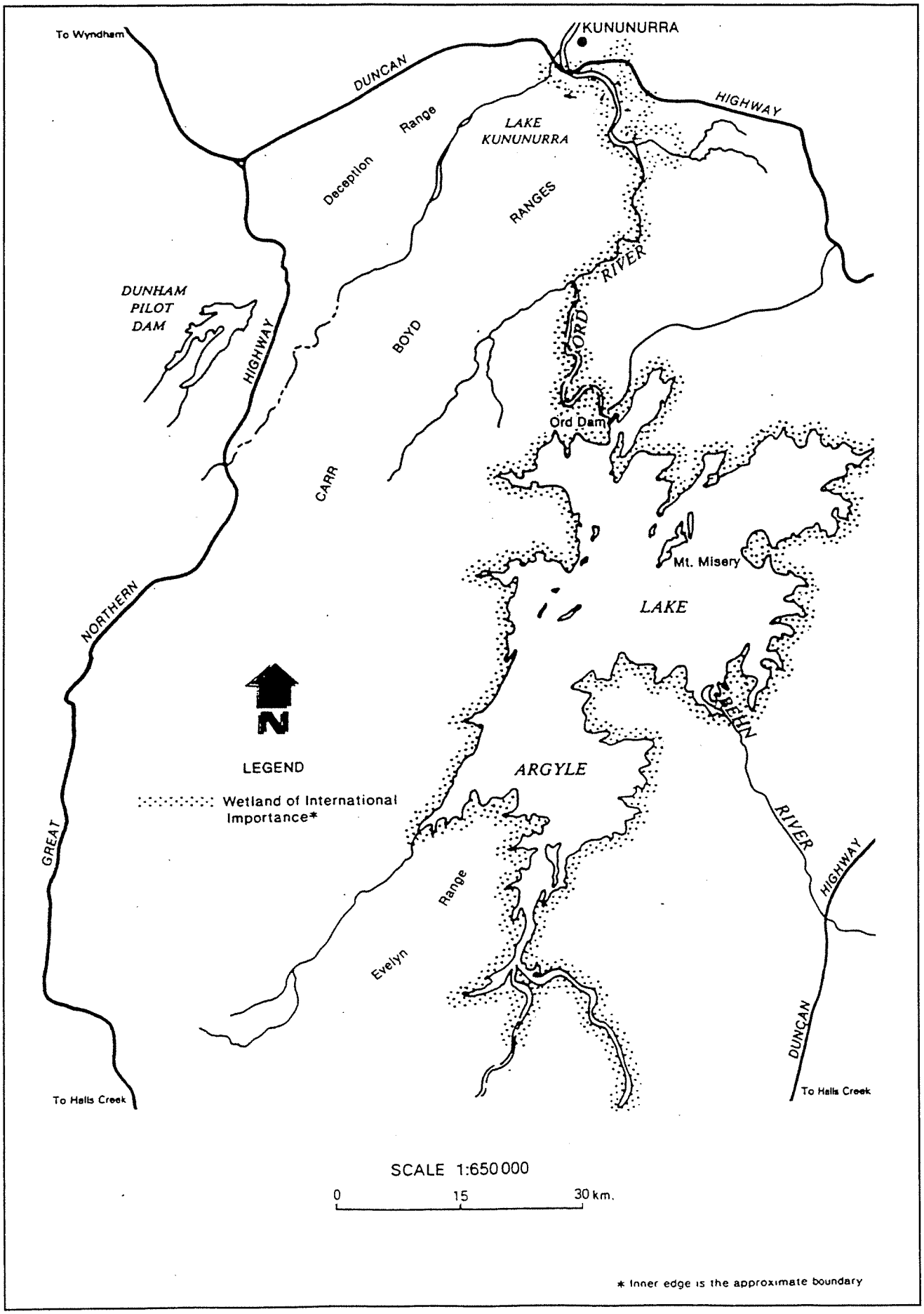

Figure 3. Lakes Argyle and Kununurra Ramsar Wetlands.

Submissions on the SER

Environment Australia (EA) identified two threatened bird species as potentially occurring in the area. EA also raised the issue of nutrient enrichment potentially changing water quality and wetland habitats used by significant populations of migratory bird species and recommended that proponents be required to assess potential impacts on water quality at Lake Argyle and down stream and conduct wildlife surveys in potentially affected areas.

CALM advised that objectives in relation to flora and fauna of the Lake should be developed in consultation with CALM recognising obligations under the Ramsar Convention.

Similar issues were raised in one other submission.

Consideration

The EPA's environmental objective for this factor is to retain the functions and environmental values of protected wetlands.

The majority of the 'significant' bird species that are identified as using Lake Kununurra in ANCA (1996) feed on insects and small fish and / or inhabit shallow and reedy wetland areas (Blakers et al. 1984). However some of the more common species that feed on larger fish, such as the Pied Cormorant and the Australian Pelican, also inhabit the region and may be attracted to the cages if a constant source of food is available. It is likely that cages will require some forms of predator netting or other (non-injuring) control devices to protect fish and feed stocks. Suitable devices should be identified in consultation with CALM.

Provided that the land based infrastructure is away from important habitat areas and water quality is maintained at a level that does not detrimentally affect the established aquatic communities, the development of a large scale aquaculture industry in the areas identified in the SER should not significantly impact on the value of Lake Argyle as a significant waterbird habitat. It is likely that some species may be attracted to the Lake or congregate near cages if a constant 'artificial' source of food is readily available. Management measures are available to farmers to control stock losses however methods must be non-injurious to birds and not intrusive to other Lake users (eg use of shot guns or sirens to scare birds may need to be controlled).

3.3 Maintenance of Genetic Diversity of Wild Barramundi Stocks

Description

There are indications that genetic heterogeneity exists between different barramundi populations (Makaira 1999). There is concern among some authorities that these differences produce biological differences between populations. The concern is that where a population has adapted to a specific environment, the introduction of 'genetic pollution' or a different genetic strain that has not been subject to the same selective pressures during development (ie through a release of hatchery reared barramundi) could lead to weakening of the ability of that population to survive in that environment, in effect reducing the genetic fitness of natural stocks (Makaira, 1999).

This effect has not been recorded in any fishery to date and the argument has been presented that releasing a fish that is not well adapted to its environment will see it out-competed for food and protection very quickly.

A more thorough discussion of the issues associated with translocation of barramundi can be found in Makaira (1999).

Submissions on the SER

Concern was raised in three submissions about the potential for alteration of wild genetic stock from escape, with implications on the biodiversity within the species and ecological implications from a 'mass escape' due to cage failure.

Consideration

The EPA's environmental objective for this factor is to maintain ecological communities.

The risk associated with genetic pollution within the natural range of a species is considered to be low. It is noted that barramundi can not breed in Lake Argyle, as their migration path to the sea is blocked by the dam. Escapees, therefore, can not form a self sustaining population in the lake, and without re-stocking, would eventually die out.

There is evidence to show that there are genetic differences within fish spawned from a single adult stock, primarily related to genetic selection during the period of larval development when selective pressures are high. However the full extent of the potential environmental impacts are not understood and as such it is appropriate to adopt the precautionary principle in the management of farmed and wild stocks.

The management methods available to minimise the potential for genetic pollution of wild stocks and alteration biodiversity, as suggested by Makaira (1999), are:

- for broodstock, using fish captured from wild stocks that inhabit the target stocking area;
- using triploid (sterile) fish; and
- preventing stock escapement.

The technology to produce sterile fish in all offspring is not yet well developed and methods to prevent escape from cage culture, even with best practice management, are not assured. Therefore the best management option currently available to protect the genetic diversity of wild stocks in the Ord River are to use brood stock from the Ord River in hatchery-produced barramundi for growout.

The use of local brood stock does not avoid the potential ecological implications of a mass escape. The use of cage culture within a water body can never produce absolute certainty that large scale escape will not occur, particularly where extreme events such as cyclones can occur. However it is obviously in a farmers best interest to prevent or minimise the escape of stock. The use of best practice management for all farmers should be required by any centralised management body for the industry on the Lake. Regularly checking of cages, floats, predator nets and support equipment will minimise the risk of mass escape from farms and resultant threats to the ecological environment.

3.4 Visual Amenity

Description

Lake Argyle currently supports a relatively small recreational boating industry (including houseboats) and the Lake itself attracts many tourists who come to see such a large fresh waterbody in an arid environment. While the Lake is a man-made creation for which the primary purpose is the supply of irrigation water, it does possess significant environmental values. Given the remoteness of the location the lake can provide a 'high quality' wilderness experience. Any structure (including recreational boats) on the lake potentially reduces the quality of that wilderness experience.

The cages themselves generally have a low profile (less than 2 m above the water depending on the height of protective nets, feeding hoppers etc). Other infrastructure such as floats can be made of dark material so as to reduce there visibility as far as practicable.

Submissions on the SER

The aesthetic impact from the development of this industry was raised as a concern in one submission.

Consideration

Impact on visual amenity is a very subjective assessment. What may be considered to be an unacceptable eyesore by some people may be considered an interesting feature by others.

The siting of around 200 seacages will obviously be visible from a number of areas on the Lake. However as the industry is likely to be limited to the northern section of the Lake there would be vast areas of the Lake where no structures will be visible. The Lake has a surface area of approximately 98 000 ha at full service level. This will allow recreational users the opportunity to experience the Lake in solitude, if desired.

To reduce the impact on the visual amenity of the Lake, equipment should be as low in profile as is practicable and colours of floats etc should minimise intrusiveness on the natural environment. Land based infrastructure should also be designed to be sympathetic with the surrounding landscape as far as is practicable.

4. Other Advice

This review relates to an industry based on barramundi (*Lates calcarifer*). While many of the pollution and visual impact issues would be common to all finfish culture, the issue of translocation and subsequent ecological implications from non-native species would assume a much higher priority. There may also be a need to review modelling requirements should other species be considered.

Any decision to farm an alternative species should be discussed with Officers from the DEP prior to a referral to the EPA.

As part of any formal assessment of an aquaculture development proposal in Lake Argyle, a proponent would also need to give attention to the following matters:

- review the chemicals / antibiotics that might be used, and undertake risk assessment of their potential impacts;
- ongoing fish disease monitoring at the aquaculture site;
- contingency plans for events such as extended drought periods or mass fish deaths;
- archaeological surveys and ethnographic consultations with local Aboriginal communities and Native Title claimants prior to any works commencing.
- location of cages in area which will not interfere with the operations of the dam or the hydroelectric plant;
- location of cages in areas which will not be susceptible to oxygen depletion of the epilimnion, either from declining water quality caused by the cage effluents, or during Lake overturn events.

5. Conclusion

The EPA has strategically reviewed the proposed development of a large scale barramundi aquaculture industry (up to 2000 tonne production per annum) on Lake Argyle.

The EPA has concluded that, with the exception of water quality, all factors identified are likely to be manageable. With the factor of water quality, manageability will need to be demonstrated through additional baseline data collection and 1 dimensional modelling as part of a formal environmental assessment process, and then through subsequent monitoring and development and refinement of 1 and 3 dimensional predictive modelling as part of a staged development process for any approved project, up to 2000 tonne per annum.

Any specific proposal for the development of aquaculture on Lake Argyle will require referral to the EPA for formal assessment under Section 38 of the *Environmental Protection Act 1986.*

As part of a formal assessment, the additional work required would include:

- establishment of agreed water quality criteria, to ensure that the ecological values of the system are protected and maintained.
- baseline data collection (over 3 to 4 months) to improve understanding of the nature of the Lake Argyle system and to provide adequate data to improve certainty associated with 1 dimensional modelling. Details of the specific requirements for data collection will be developed in consultation with the DEP. At this stage, collection of the following type of data is anticipated:
  - (a) Meteorological data (preferably a meteorological station based at Lake Argyle);
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- further 1 dimensional (1-D) modelling (using a model such as DYRESM), incorporating the additional baseline data to aid in resolving the uncertainty about the hydrodynamics of the Lake (turnover in the main basin and semi-enclosed areas) and, when undertaken for one or more locations, identify key periods in the year when extreme or critical events could occur. This would require about 3 to 4 weeks of effort by a group such as that recommended by the SER, and could be undertaken immediately, requiring only meteorological data as input.

Subject to the outcomes of this additional work and formal assessment, the EPA anticipates that environmental approval could be granted for an industry with a production of up to 2000 tonnes per annum, subject to appropriate conditions. It is noted that further information may be provided during formal assessment of a proposal which may provide greater certainty of impacts and therefore influence the actual conditions to be applied. However, and on the basis of existing information, conditions of approval are likely to include:

- the initial stage not to exceed 500 tonnes per annum at agreed locations, with a monitoring plan to be implemented to confirm that set environmental criteria are met and to provide data for more refined predictive modelling;
- any expansion beyond 500 tonnes per annum would be dependent on monitoring demonstrating that set water quality criteria were being met, and the adequate development of a 3 dimensional (3-D) model constructed for a typical semi-enclosed area in which aquaculture is proposed, which would use information collected in Stage 1 to indicate that performance criteria were likely to continue to be met in the long term;
- because of the cost and computing limitations associated with a 3-D model, modelling should be confined to a short period (eg 2 to 3 months) around any critical period (eg lake overturn periods). The results of the 3-D model could be correlated against the 1-D model and the 1-D model then used to run 10 to 20 year simulations which would allow sufficient time for equilibrium concentrations of total phosphorus, total nitrogen and chlorophyll 'a' to be achieved. This combined 1-D and 3-D approach would permit long time-scales to be modelled with reasonable amounts of power and represents a satisfactory balance between 1-D and 3-D approaches.

- a commitment to long term monitoring, data from which can be used to assess what level of aquaculture in Lake Argyle is likely to be environmentally sustainable. This data can be incorporated into the long term modelling of the Lake Argyle system.

6. Recommendations to the Minister for the Environment

Recommendation 1

That the Minister for the Environment notes that the EPA has provided environmental advice in this report on the potential development of a 2000 tonne per annum barramundi production industry on Lake Argyle, being facilitated by Fisheries Western Australia.

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Recommendation 4

That the Minister for the Environment notes that the advice provided in this report will be provided to the Minister for Fisheries.

Appendix 1

List of submitters

Organisations:

Aboriginal Affairs Department

Conservation Council of Western Australia Inc.

Department of Conservation and Land Management

Edith Cowan University, Centre for Ecosystem Management

Environment Australia

Water and Rivers Commission

Water Corporation

Individual:

1 private submission (confidentiality requested)

Appendix 2

References

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Appendix 3

Summary of Submissions

and Proponent's Response to Submissions

30/09/99

FISHERIES WA AND CONSULTANTS
RESPONSE TO LAKE ARGYLE PUBLIC SUBMISSIONS

Background

Responses to public submissions received by the Environmental Protection Authority (EPA) for the Strategic Environmental Review (SER) of Lake Argyle have been developed. To context these responses with the overall perspective of the Lake Argyle aquaculture initiative, a number of issues need to be highlighted. They are:

- The document released by Fisheries WA is a SER under Section 16 (e) of the *Environmental Protection Act* - not a formal development proposal under Section 38.

- The purpose of the SER is to provide early identification of flaws in the proposed concept which may adversely affect its environmental viability, and enable the EPA to advise the Minister for Environment on the likely acceptability of the concept.

- In reaching a decision on uses of Lake Argyle it is important to note that:

  a) Lake Argyle is a man made reservoir for supplying water to the Ord River Irrigation area;
  b) Lake Kununurra and the Lower Ord River no longer function as man-modified ecosystems due to the constant water flow and various dams and barrages across the water course. However an ecosystem has been established and Lake Argyle, Kununurra and the stretch of the lower Ord between them have been listed as Internationally Important Wetlands (RAMSAR sites) in the Kimberley region;
  c) The catchment of the Ord River is highly modified and includes cattle grazing around Lake Argyle and irrigated horticulture adjacent Lake Kununurra and the Lower Ord.
  d) The purpose of the Ord River Irrigation Area was to develop a viable horticulture and aquaculture industry in the region;
  e) The proposed aquaculture concept is seen as furthering that purpose by deriving economic benefit from a much under utilised body of water;
  f) A viable and vibrant aquaculture industry requires a chemical and pollution free environment for purposes of product marketing. It will be very much in the industry's own interest to protect the water quality of the lake and hence their investment in fish stock;
  g) Experience elsewhere indicates that aquaculture industries will enhances tourism, provide business opportunities and infrastructure and employment to the region; and
  h) Any developer will be expected to conduct their aquaculture operations in accordance with the Fisheries Management Policy on the translocation of barramundi.

The questions and responses to submissions are detailed below:

Question 1

Lake Argyle being an artificial creation has an emerging ecosystem that is poorly understood. Information on the chemistry and biology of Lake Argyle is at present very poor. There is no viable data available on water quality variations in a spatial and temporal sense. More work will be required within Government to define management goals and methodologies. What further work is planned to help better understand this system?

Response:

- *It is acknowledged that the limnology of Lake Argyle is poorly known. However, Lake Argyle is a large tropical freshwater lake and the limnology of such lakes is relatively well understood based on experience elsewhere in Australia (Northern Territory and North Queensland), Asia, Africa, South America and south-east USA. In many important respects, all of these water bodies have similarities with those in cool temperate northern latitudes. What little data are available indicate that Lake Argyle is similar to these other lakes and is likely to undergo the same process. Additional spatial and temporal data have recently (August 1999) been obtained from five sites around the lake, thereby extending the available data set. The results of this recent sampling have confirmed the assumptions made about the oligotrophic nature of the lake and its present surface concentration of total phosphorus of 6 µg/L (Attachment A). No further sampling is proposed at present by Fisheries WA.*

- *It is anticipated that, should a formal proposal proceed, the proponents will need to undertake additional and ongoing sampling both to support the environmental assessments required for the initial application and also to meet ongoing licence conditions. This monitoring will detect any changes in water quality, as the development expands over time to the 2000 tonnes production level.*

- *It should be noted that the 2000 tonnes target was set as a conservative figure which would not adversely impact the lake water quality.*

- *It is recognised further environmental assessment would be required if industry were to expand beyond the proposed annual production level of 2,000 tonnes. In addition based on the advice received, management strategies would be modified accordingly.*

Question 2

Options for shore-based waste disposal are not detailed (wastewater-settling/filtration, stabilisation ponds, reuse/irrigation/evaporation and solid waste – processing to produce fishmeal/oils). Have shore-based waste treatment or disposal methods been investigated?

Response:

- *No. Shore-based waste treatment and disposal options have not been investigated because to do so at this conceptual stage would be premature and of no assistance in evaluating the objective of the Section 16 (e) review which is to provide early identification of flaws in the proposal concept which may adversely affect its environmental viability. There is no doubt that ecologically sensitive waste treatment and disposal options are available. Furthermore, the issue of waste disposal is raised in Section 5.2.3 and 5.2.4, of the report and identified as an issue to be addressed in detail by any future proponent of a specific project when it undergoes formal assessment under Section 38 of the Environmental Protection Act 1986.*

- *The processing of fish is the single largest generator of solid and liquid wastes. This may be performed away from Lake Argyle most likely near Kununurra or Wyndham, and will be subject to licensing by the Department of Environmental Protection (DEP).*

Question 3

A number of assumptions have been made about feed conversion ratios, waste dispersion in the lake waters, waste assimilation by catfish and scouring via dam outlets. The catfish harvesting (netting) industry on the lake will need to grow with the caged fish industry, if significant amounts of waste P are to be removed from the lake in the form of fish.

The Water and Rivers Commission believe there is significant risk of occasional local algal blooms near cages established in sheltered sub-basins within the lake. This risk is heightened with the complete roll-over about twice a year, along with prolonged periods of stratification and periods of possible sub-basin isolation. The consultants need to demonstrate that there are effective technologies for dealing with these blooms (with particular emphasis on protection of drinking water supply to Lake Argyle village, as disinfection is the only treatment technology currently available). A water filtration system may be required to protect the village water supply. The viability of harvesting catfish from depressions/dead spots in the lake bed is questioned. How will the above concerns be addressed?

Response:

- *As stated in Section 5.3.2.2 of the report, the consultants agree that under certain conditions it is possible that seasonal algal blooms may occur in the vicinity of the cages. These blooms are likely to be temporary and localised to the vicinity of the farms.*

- *However, water quality monitoring by farmers should provide warning of potential blooms, thereby enabling the implementation of one or more of the management methods outlined in Section 5.3.5 (4-7) in an effort to avoid formation of blooms. These include:*

    1. *Implementing an intensive monitoring program for the first two years of operation, and an ongoing monitoring program based on the outcomes from the intensive program;*

    2. *Subsequently funding the development and running of a three dimensional mathematical model of the lakes hydrodynamics and limnology;*

    3. *Obtaining (from the model) a reliable estimate of the lake's carrying capacity for intensive aquaculture;*

    4. *Investigate ways in which to minimise nutrient input to the lake; and*

    5. *Complying with protocols developed by Fisheries WA to minimise potential for both outbreak of disease and introduction of genetically different breeding stock to that of the natural population of fish in the lower Ord.*

- *The water supply to the Lake Argyle village is drawn from the bottom of the lake (approximately 30 metres) and therefore will not be affected by surface blooms. A significant amount of water has been drawn from the lake to supply Lake Argyle Village and in the past 10 years, no problems have been reported regarding the quality of the water (N. Stewart, Lake Argyle Industries Pty Ltd pers. comm.).*

- *According to Lake Argyle Fisheries Pty Ltd (S. Grandison, Lake Argyle Industries Pty Ltd pers. comm.) catfish can be harvested wherever a net can be successfully set and retrieved.*

- *In the absence of a detailed proposal by a developer, it is difficult to specify actual feed conversion ratios, waste dispersal etc. These must, of necessity, be "assumptions" while the strategic concepts are discussed. For example, the feed conversion ratio (FCR) can vary between 1.5:1 and 1.2:1. A conservative FCR (1.5:1) has been assumed for this review. Indeed fish diets are continually being improved and their levels of phosphorous reduced (Hardy 1999). It has been assumed that the risk of algal blooms establishing near cages will be "significant". While this event may be possible the risk of occurrence is not seen as being significant.*

Question 4

It is possible that caged fish may suffer occasional mass fish deaths due to hypoxia, disease, toxic gases, or adverse environmental factors. The proponent should provide a notional plan for management of such an event. Contingency planning is poorly addressed in the Strategic Environmental Review.

Response:

- *As indicated in Section 5.3.2.3 of the SER, the consultants agree that localised mixing events could potentially result in occasional mass fish deaths. Adequate monitoring of water quality and environmental conditions should permit such events to be predictable. Other events hypoxia, disease, toxic gases or adverse environmental factors could be managed by aeration, dispersal and collection of wastes and decreasing stocking density. These practices are used world-wide and are reviewed by Beveridge (1996). It needs to be remembered that it is in a farmer's best interest to avoid mass fish deaths to minimise his/her financial risk.*

- *However, should a mass mortality occur, Fisheries WA aquaculture licence conditions would require the removal of all dead fish from the lake and their disposal in an appropriate location authorised by relevant authorities. This was the experience with the mass mortalities of tuna in Port Lincoln (South Australia).*

- *The purpose of the SER is to determine whether or not the concept proposed by Fisheries WA was environmentally feasible and ecologically sustainable. It is considered that contingency planning needs to be addressed at the formal assessment stage. This would include protocols for the immediate removal, possible sterile disposal and cause of the fish deaths. The report does recommend a number of contingency plans and protocols be developed for the protection of the environment. These include:*

  - *translocation of fish stocks – Section 5.5.2.1;*
  - *disease management – Section 5.5.3; and*
  - *use of chemicals – Section 5.5.3.*

Question 5

With regard to Appendix D (SER) the Water and Rivers Commission considers that 10 µg/L of phosphorous should be considered as a potential trigger level for further investigations. A level of chlorophyll a (eg.10 µg/L) at a defined operational lease boundary of the farms should serve as a regulatory limit provided there is available a defined intervention strategy to control/limit blooms caused by the aquaculture venture. One or more suitably located reference points should be established remote from routine human intervention to serve as background control points for lake water quality.

Response:

- *A (conservative) trigger level should be established at the beginning (as recommended by the consultants), and reviewed as more data become available.*

- *In the interim, the consultants have recommended that a mean surface total phosphorus concentration of 10 µg/L could be set as the water quality target for the lake. This is considered to be a very conservative approach, as Harding Dam in the Pilbara has a phosphorus concentration of approximately 20 µg/L, is not considered to be eutrophic and is used for the drinking water supply for the West Pilbara with no treatment other than disinfection by chlorine (B. Humphries Water Corporation pers. com.).*

- *The consultants and Fisheries WA agree that reference water quality monitoring sites will need to be established remote from farming sites.*

Question 6

If more barramundi are released in Lake Argyle they will return to be the dominant species competing for food with the catfish. The barramundi will also predate on the juvenile catfish. The document is inconclusive and although there are statements which mention the catfishery may be enhanced, this is based on 'anecdotal evidence'. What evidence is there to show that the current catfish fishery will not be severely impacted?

Response:

- *The only way barramundi could return to dominance over the catfish population is if a catastrophic event caused a release of significant numbers of farmed fish at any one time. Given the protected nature of the proposed farming sites, it is difficult to imagine an event capable of such an outcome. Furthermore, barramundi are catadromous which means that they need to return to the sea each year to breed.*

- *The perception of increased predation of juvenile catfish by escaped barramundi, may not be the case due to mouth brooding of small juveniles by the paternal parent. This would reduce the risk of predation during the crucial period of the first few months of life when fish have a low capacity to avoid predation (Attachment B).*

Question 7

The influx of food and antibiotics into the lake and the subsequent downstream impacts on Lake Kununurra and the Lower Ord need further investigation. The submission is inconclusive on the impacts on the lake or Lower Ord. Kununurra is a thriving tourist destination, any adverse impacts will impact on the tourist industry. If there are significant impacts on the water quality then it will adversely impact the irrigation areas in Kununurra. Have the impact on the water quality of Lake Kununurra and the Lower Ord been investigated?

Response:

- *The SER goes to considerable lengths to address the water quality effects of the concept on Lake Argyle. The SER concludes that a 2,000 tonnes intensive fish farming industry is most unlikely to cause substantial change to Lake Argyle's present oligotrophic status. The report also indicates that the concept has been designed (via low stocking densities) to minimise the need for use of antibiotics.*

- *There has been no suggestion that antibiotics will be widely used in the lake. In Australia the use of antibiotics is controlled by veterinary prescription, and residues in fish would prevent the sale of the product. The key to aquaculture is to maintain a clean green product since a premium price is sought. As an example, Tasmanian salmon is* **not** *noted for its adverse environmental impact and use of antibiotics (Attachment C).*

- *Given the above, it is difficult to see how the proposed concept can adversely affect the water quality of Lake Kununurra and the Lower Ord River. Based on the predictive information in the SER and when compared with the assumed influence of run-off from rangelands, irrigation drainage and other anthropogenic influences in the catchment it is hypothesised that the proposed aquaculture project is likely to have no discernible chemical or algal growth influence on the Ord below Lake Argyle (P. Ryan, Water and Rivers Commission pers. comm). The developers in the consultative approval processes will need to consult with the community on the level of risk to river health downstrean of Lake Kununurra.*

- *The artificial situation on the Ord River, Lakes Argyle and Kununurra and the irrigation channels, has already had a substantial, and probably maximal, impact on plant growth in the aquatic systems downstream of Lake Argyle (Rosich and Partridge 1988). Plant growth (weeds and algae) below Lake Argyle is limited by availability of light rather than nutrients, as discussed in the report.*

Question 8

The current aquaculture operation in Lake Argyle produces around 30 tonnes of Barramundi per annum. There has been demonstrated lack of control by Fisheries WA on this small scale operation. Several thousand barramundi have been released into Lake Argyle (of a genetically different strain to Ord River stock). Have the potential effects of a mass escape of barramundi been considered, for example the potential for increased survival rate with mass release of barramundi, and possible change in ecology of the system?

Response:

- *The fish were not released but escaped. Escapes occurred due to inexperience and poor design of equipment. The current operators have improved their culture practices with no significant escapes occurring in the last two years.*

- *The translocation of barramundi into the state and aquaculture of the fish in cages within Lake Argyle has been permitted in accordance with the written approval of the Executive Director of Fisheries WA. Approval to translocate barramundi and operate an aquaculture facility now include conditions to minimise the escape of fish through cage design and operation.*

- *The ecological effect of small numbers of barramundi escaping into Lake Argyle will be assessed as part of the formal environmental assessment required by the EPA. It is expected that small numbers of escaped fish are unlikely to significantly impact on a water body the size of Lake Argyle.*

- *The potential effects that escaped barramundi may have has been considered in the assessment of applications by Lake Argyle Industries Pty Ltd to translocate eyed-ova for the aquaculture of barramundi. In addition, Fisheries WA engaged a consultant to investigate the genetic identity of barramundi in impoundments of the Ord River system. A comprehensive review of the potential impacts that translocation of barramundi may have on the genetic diversity of the species, the natural environment and the biodiversity of native species has been undertaken and summarised in a discussion paper. This discussion paper has formed the basis of consultation with stakeholders and is expected to form the framework of a management plan to guide the translocation decision making process. The issues deal principally with the potential for translocated barramundi to:*
    1. *impact on the genetic diversity of the species;*
    2. *introduce disease; and*
    3. *impact on the natural environment and the biodiversity of native species.*

  The paper was open for public comment until the 29 September 1999.

- *The escape of large numbers of fish from the cages is not likely to occur because the intrinsic value placed on the fish by the developer. However, to reduce the risk of large scale escapes, Fisheries WA will ensure that any aquaculture licence issued will contain conditions that will specify the type of cages and mechanisms required to prevent escape of stock.*

An example of the type of conditions applied to aquaculture licences are as follows:

1. *Cages shall be individually numbered;*

2. *Records shall be kept and maintained recording details of numbers stocked into each cage and any subsequent stock movements such as grading;*

3. *Runts unsuitable for on growing must be culled, records kept of numbers culled and carcases frozen for future inspection;*

4. *Any mass escapes (i.e. greater than 10 fish) must be reported to Fisheries WA within 24 hours;*

5. *All staff involved in net changing activities must be properly instructed and supervised;*

6. *The main cage shall be of a suitable mesh size, type and quality that will reliably maintain a complete barrier that will retain 100% of fish;*

7. *Submerged predator netting shall be complete to above the water line with no holes or openings greater than 1.5 times the size of the mesh;*

8. *Predator meshing shall be hung in such a manner as to be a minimum of 30 cm from the main cage;*

9. *Predator meshing shall be constructed of a mesh that uses cord greater than 2mm in diameter and maintained in good order at all times. Meshing size shall be between 2.5 - 22.5 cm stretched mesh size depending on the size of the fish to be contained;*

10. *Cages and predator meshing shall extend at least 50 cm above the water level. Cages with a freeboard less than 50 cm shall be secured by overhead meshing to prevent escape by jumping; and*

11. *Cages shall have in place predator exclusion or reduction devices.*

Question 9

It has been suggested that a shore based aquaculture facility using Ord River stocks and recirculating systems could meet the demands of intensive aquaculture whilst significantly lower risk of water contamination, spread of disease and adverse impact on the commercial fisheries. Have such alternative operations been considered?

Response:

- *No. That is a commercial decision open to proponents to investigate. Recirculating barramundi farms exist elsewhere in Australia. This proposal deals with aquaculture on the lake.*

- *Intensive land based aquaculture is also being developed in the East Kimberley area and there are several pilot scale farms in the irrigation area that are culturing fin fish in ponds. Commercially sensitive advice and experience given suggests that these systems are not as cost effective as producing barramundi by cage culture in Lake Argyle (Kimberley Development Commission Technical Paper October 1996 - The Economic Impact of Irrigated Agriculture in the Ord River Area).*

Question 10

It has been raised that the infrastructure proposed for Lake Argyle would take away from the beauty of this pristine wilderness area which tourists world wide are in search of. Tourists do not venture to the remote Kimberley to feast their eyes on industry. Will a visual impact assessment be undertaken for this development?

Response:

- *The report indicates in Section 5.2.3 that any proponent undergoing formal assessment through Section 38 of the Environmental Protection Act will need to assess the impacts of their project on the visual amenity of the area and recommend measures to minimise adverse effects. Such measures could include landscaping, building height and style restrictions, and appropriate site selection to avoid tourist view sheds.*

- *However, the contention that tourists may be discouraged from visiting the Kimberley because of "industry" is disputed. Not only is the Ord River Irrigation Area a significant tourist attraction in its own right, but aquaculture elsewhere (eg. Tasmania, SW Australia, the Marlborough Sounds in New Zealand, Stewart Island (a world heritage site), Norwegian fiords or Scottish lochs) has been shown to contribute positively to tourism inventory. The present fish farm operated by Lake Argyle Fisheries is another case in point. It is considered most unlikely that this industry will adversely affect tourism in the Kimberley. It is likely to enhance tourism (Pilbara Development Commission 1995).*

- *This question suggests that Lake Argyle is a "pristine wilderness area". It is in fact a man made lake around a heavily grazed catchment. The Kimberley region as a whole is advertised as a pristine wilderness area, this is largely a promotional position to attract tourism, as the region as a whole has a history of anthropogenic disturbance which has largely gone undocumented.*

- *The area involved in the development concept is only four or at most five lease areas. Thus only some 7.5 ha of the lake's 98,000 ha surface area at full service level will actually support fish cages at 2,000 tonne production level (SER 2.2.1)*

Question 11

It has been questioned what will happen to the fish should the market price drop so much that it is not economic to harvest the fish. Currently if the same situation occurs in agriculture, in Kununurra, crops may be turned back into the soil rather than incurring the expense of harvesting. Will the fish be released into the wild – causing a mass impact on the current environment? Potential developers will need to address this issue.

Response

- *No. Farmers are most unlikely to let their investment swim away. The major cost to a farmer is feed, not harvesting. Experience in Norway has shown that farmers will stop feeding and harvest early to get some return on their investment. This is the experience of the Norwegian salmon industry which substantially overproduced to the point where farmers reduced feeding to slow down growth. The abandonment of farms was never an issue.*

Question 12

The Centre of Ecosystem Management at Edith Cowan University have said that it is incorrect to state that it is "highly unlikely" successful escape will occur. Previous work has shown that cultured fish in Lake Argyle have escaped to Lake Kununurra and barramundi tagged and released in Lake Kununurra have been caught in the estuary some years later. Escape mitigation measures have been proposed by Doupe (1998) and Doupe and Lymbery (1999). What requirements for escape prevention would be required of farmers?

Response

- *Edith Cowan University are correct in stating that work undertaken to date indicates that fish have escaped from cage aquaculture in Lake Argyle and moved from Lake Argyle into Spillway Creek. Separate work indicates that fish are moving between Lake Kununurra and the lower Ord River and estuary. Consequently it is possible that fish which may escape from cage culture in Lake Argyle have the potential to move into Spillway Creek and subsequently migrate into Lake Kununurra, the Lower Ord River and the estuary.*

- *Current approval conditions for the existing aquaculture facility require suitable escape prevention devices to be adopted and any escapes to be reported. Either the single managing corporate entity or the individual companies will be responsible for nominating escape prevention devices for consideration by the agency. Appropriate conditions requiring the installation of such devices will then be included in any approvals issued by the agency. A fall back position may be to place a net across the mouth of Spillway Creek. Either way, this issue is readily manageable.*

- *A management paper on the translocation of barramundi is being developed by Fisheries WA. The framework on which this paper will be based comes from the discussion paper released (Fisheries WA 1999), the responses to that discussion paper and outcomes from an aquaculture genetics workshop held in Perth (1998). In essence one basic premise which is recognised is outlined by Doupe and Lymbery (1999). They suggest that " When translocation is for aquaculture, the question of interest is: what is the maximum level of escapes which should be permitted, beyond which there is an unacceptable probability of adverse genetic effects upon the natural population?. Risk minimisation should concentrate on management solutions that reduce escapes from aquaculture facilities".*

- *It is hoped to use fish from Ord River stock making the issue of genetic translocations irrelevant. The study by Doupe (1998) concludes that "Whether these animals were derived from the Ord River or elsewhere becomes relatively unimportant because artificial selection pressures and small captive populations results in genetic drift and altered population genetic structure. Without redress, the genetic population of the wild barramundi population is perhaps inevitable in the long term". This suggests that the wild population genetic structure may be 'polluted' by escaping domesticated fish or fish released for restocking purposes (Lutz 1999). It is also recognised that the wild population genetic structure is in a state of flux with the environment, and changes naturally from year to year and especially with environmental perturbations (Jorstad et al. 1994, Hansen & Loeschcke 1996). These natural changes may negate many arguments concerning conservation of apparently genetically distinct sub-populations (Lutz 1999).*

Question 13

All proponents should be made aware of the need for archaeological surveys and ethnographic consultations with local Aboriginal communities and Native Title claimants prior to any works commencing. These reports should be lodged with the Aboriginal Affairs Department. Will this requirement be made clear to prospective fish farmers?

Response

- *Yes. This issue is addressed in Section 5.6.3 and in the summary table in the report but could be spelled out in greater detail.*

- *These requirements will also be made clear to prospective fish farmers in the Expression of Interest to be released once approval for the concept is obtained.*

Question 14

Water Corporation is concerned with the strategy to locate the fish farm close to the Ord Dam, i.e. near the intake tower because it shifts the potential problem of nutrient enrichment downstream to the Ord River and Lake Kununurra, and away from aquaculture in the lake. Also the construction of fish cages or increased boating activity near the intake tower is not acceptable, as they would increase the risk of disruption of the operation of the Ord Hydro power station. How does Fisheries WA intend to manage these issues?

Response

- *Fisheries WA and Department of Transport already work together to manage aquaculture around harbours, moorings, shipping channels and the like. The Water Corporation and Fisheries WA should be able to manage exclusion zones around sensitive structures on Lake Argyle.*

- *The issue of nutrient enrichment of the water downstream from the dam has been addressed in response to question 7.*

Question 15

Sediment samples collected under the existing barramundi farm show local phosphorous concentration double the level of background. Given that the existing farm is one fortieth of the size of the proposed industry, how will nutrient management in the sediments be carried out?

Response:

- *It is not possible to compare the existing facility with the proposed development concept. The existing facility has in the past used a poor quality feed. They now use a floating feed. The scale of the proposed development concept, and the capital investment required, will help ensure that feed quality and wastage issues are addressed to maximise investor return. Section 5.3.5 of the report outlines the management strategies and methods available to manage nutrient input to the waters and sediments of the lake. It will be important to monitor rates of nutrient build-up in sediments so that the need for management can be determined and an appropriate strategy developed. The rate of build up of nutrient, the methods employed to instigate such build up and future technology will all be taken into account when developing a detailed contingency plan for final proposal.*

Question 16

Water Corporation offers conditional support for the proposal on the grounds that:

- There is a review of the chemicals/antibiotics that might be used, and a risk assessment of their potential impacts carried out;

- Development and commitment to a comprehensive limnological monitoring program, including lake physical dynamics, water quality and sediment monitoring program at aquaculture sites in Lake Argyle, at control sites in the lake and the upper reaches of Lake Kununurra;

- An ongoing fish disease monitoring program is implemented and in the event of a disease outbreak, instigate a sampling program immediately downstream of the Diversion Dam, which is upstream of irrigation drainage that flows into the Lower Ord; and

- The fish farm is not located within the gazetted water reserve as per Department of Land Administration (DOLA) Plan 18527, Location 786.
  Will Fisheries WA commit to ensuring the above requirements are carried out?

Response:

- *Fisheries WA will commit to ensuring that the above conditions are implemented.*

- *The possible effect of any chemicals to be used in the aquaculture operation will be assessed by Fisheries WA and the EPA as part of the formal assessment process required by the EPA. Advice with respect to health management including correct chemical usage and dosage of medication will be sought from the Senior Fish Pathologist of Fisheries WA. Fisheries WA actively promotes the adoption of sound health management techniques in aquaculture operations designed to prevent the introduction of disease (ie health certification of stock and quarantine) and should they occur, manage disease outbreaks and the use of chemicals on a sound rational basis.*

- *As part of the assessment process for aquaculture licence applications, the DEP notifies Fisheries WA of the necessity for any aquaculture licence holder to undertake water quality monitoring on the aquaculture site and nominates the parameters that the licence holder is required to measure. The requirement for the licence holder to undertake the monitoring program is enforced by way of a condition on an aquaculture licence. Should the licence holder fail to undertake the required monitoring, they would be in breach of the condition and as a consequence their licence may be cancelled, suspended or not renewed.*

- *Aquaculture licence holders may be required to undertake fish disease monitoring programs. The requirement for the program can also be imposed by way of a Fisheries WA licence condition. The condition below is an example of a condition imposed on a prawn licence and can be modified as appropriate for finfish farming.*

Examples of a Monitoring Programs

The holder of this licence shall, at their own expense, immediately upon the commencement of operation of this condition, establish and at all times thereafter maintain in force, a 'water quality monitoring' program, that -

a) *Is to the satisfaction of the DEP;*

b) *Includes provision for the sampling of discharge waters from the licensed site for the purposes of the analysis. This could include:;*

    - *Temperature, salinity (parts per thousand), dissolved oxygen levels, colour, turbidity, chlorophyll and nutrient content of the water;*
    - *Strength and direction of water current;*
    - *Strength and direction of wind;*
    - *Rate of sedimentation;*
    - *pH of upper sediment layers;*
    - *Appearance of seabed and seagrasses by photography and direct visual examination;*

c) *Provision for all sampling to be undertaken not less than monthly;*

d) *Inclusion of provision for all analyses to be undertaken by laboratories with current NATA registration and for all analyses specified to be conducted in accordance with the current "Standard Methods for the Examination of Water and Wastewater-APHA-AWWA-WEF", unless otherwise approved in writing by the DEP.*

Programs for disease

Aquaculture licence holders may be required to undertake fish disease monitoring programs. The requirement for the program can also be imposed by way of a licence condition. An example of a condition imposed on a prawn licence is given below; it may be modified as appropriate for fin-fish farming.

a) *The licence holder is, on a daily basis, to monitor the water characteristics of all sea water intake, all grow out ponds, all hatchery tanks and discharge from settling ponds for the following -*

   - salinity (ppt)
   - pH
   - turbidity
   - dissolved oxygen
   - temperature

b) *The licence holder must monitor, including visually and by reference to food consumption levels, and keep records of, the daily rate of mortality of all prawns being bred or cultured, including in the hatchery facility or building.*

c) *The licence holder is to carry out sampling (on each batch of prawns from the hatchery to the grow out ponds) of a representative total of 150 post larvae of prawns*

   (PL 8 - PL 12) from each tank within any hatchery building or facility and have carried out testing of the samples in the following way :

   - *Each sample is to be fixed in a fixative of a type approved by the Senior Fish Pathologist of the Agency;*
   - *Each sample is to be delivered for testing to the Fish Health Section of the Agency or to another laboratory that is approved by the Chief Veterinary Officer of Western Australia;*
   - *Each sample is to be tested at the Licence holder's expense for symptoms of ill-health at the discretion of the Senior Pathologist of the laboratory where the testing is taking place; and*
   - *A written 'health certificate' of freedom from disease or any identified diseases is to be obtained from the Senior Pathologist of the laboratory prior to stocking the prawns into the growout ponds.*

d) *The licence holder is to conduct not less than weekly visual assessments of the prawns in each pond in which prawns are being cultured, to measure the growth rates of the prawns in the pond and the estimated survival rates of the prawns.*

Question 17

Environment Australia (EA) have advised that two threatened species protected under the *Endangered Species Protection Act 1992*, occur within the area of the proposal. EA suggest that the proponent provide an assessment of the potential impact of changes to both water quality and conduct wildlife surveys in potentially affected habitats. The proponent should also ensure that the construction of all proposed infrastructure does not impact on the habitat of the above threatened species or other significant species identified in the field studies. Will Fisheries WA ensure this work is undertaken?

Response:

- *This issue is addressed in Section 523 and the summary table which recommend that this work be undertaken by any proponent undergoing formal assessment. The report will be made available to any proponent seeking to establish a project on the lake. Environmental Protection Act guidelines will also be provided to any proponent and it will be the responsibility of the DEP to ensure that this issue is adequately addressed.*

- *Both threatened species are birds (Red goshawk and Gouldian finch).*

Question 18

EA suggests the proponent investigates the potential of employing native Australian mussels on the netting of fish cages to improve water quality and mitigate nutrient enrichment. Has this potential management tool been considered?

Response:

- *No, this potential nutrient management tool has not been considered. However the suggestion will be forwarded to all developers seeking to develop an aquaculture farm on the lake.*

Question 19

There is little mention of potential interaction of freshwater and estuarine crocodiles, that are a protected species, and fish cages. Conservation and Land Management (CALM) has indicated that the size of estuarine crocodiles removed from the lake in recent years suggests

they may still be entering the lake. Has this factor been considered and will appropriate predator prevention netting be used around cages?

Response:

- *This issue is addressed in Section 5.5.2 of the report. The existing barramundi pilot farm has not experienced any problems with predators (S. Grandison, Lake Argyle Industries Pty Ltd pers. comm.). However, should such problems eventuate, appropriate management action is possible.*

- *It should be noted that predator prevention methodology is available and used in South Australia and Tasmania to protect stock from sharks and seals, both of which are protected species.*

Question 20

There is likely to be behavioural changes associated with birds, especially predator species such as cormorants, osprey, wedge tailed eagles, etc. Given the proximity to RAMSAR sites, will Fisheries WA require best practice cage design to minimise behavioural changes to birds?

Response:

- *The proposed farming sites are located some considerable distance from the shallows on the eastern and southern side of the lake which are the favourite habitat for waterbirds. Based on experience to date (mentioned above), it is considered unlikely that predation will be a problem.*

- *However, if a problem does eventuate, it will be in the farmers' best interest to employ cages that will minimise potential for stock losses from bird predation.*

Question 21

Has the potential impact from disturbance of sediments below the cages as a result of the increased number of scavenging catfish been considered?

Response:

- *No. There is no evidence available to suggest that sediments beneath cages will be disturbed by catfish. In fact available evidence, from observations at the existing farm sites, indicates that the catfish stay close to the cages which are suspended at the water surface (S. Grandison, Lake Argyle Fisheries Pty Ltd. pers. comm.).*

Question 22

There are several issues that have not been considered in enough detail and it is unclear what arrangements will be used to control them. What are the potential impacts from the following issues and how will they be managed?

- Epizootic impacts on micro- and macro-invertebrates;

- Risk of introduction of viruses and disease (only assessed by the report in terms of farmed stock and the comment that "there is no documented evidence to show that diseases have been transferred from cultured to wild stocks" is misleading);

- Increased parasitism through translocation;

- Effects on water plants and fauna through possible imbalances in the ecosystem. One example is that there has been an abundant growth of weeds downstream from Lake Kununurra and the Ord River below the dam. This is thought to be carbon limited. The increase in carbon as a result of the proposed barramundi industry; and

- Stringent testing of organisms and parasites and containment waters prior to translocation is required and should be listed.

Response:

- *The notion that green plants (carbon-fixing organisms) can be carbon-limited is a novel one. Epizootic impacts on micro- and macro-invertebrates have not been considered because impacts (if any occur) will be localised to the immediate vicinity of the farm. Under normal operation, the only impacts anticipated are a slight increase in nutrient concentration of sediments beneath cages. What effect this will have is not known, but is unlikely to cause widespread change in the benthic ecosystem of the entire lake. Under abnormal operating conditions, such as a lice infestation, there may be a need to dose the cages with an organophosphate chemical to control the lice. It is possible that this chemical may also adversely affect invertebrate populations in sediment or waters beneath the cages. Again, this is a very localised and temporary impact and one unlikely to materially change the lake's ecosystem.*

- *Since it is proposed that the stock will be Ord River stock, there will not be any introduction of diseases exotic to the Ord system. Advice will be sought from the Senior Fish Pathologist with respect to issues associated with the introduction of disease and licence conditions imposed as appropriate to ensure adequate disease testing is undertaken.*

- *The growth of aquatic plants in Lake Kununurra is known to be light and depth limited, not carbon limited.*

- *There is an existing policy on translocation of aquatic animals, developed with the EPA which specifies the steps required before approval is given for a translocation. This always includes disease certification.*

Question 23

It is extremely inappropriate for consultants in this position to be criticising the water quality guidelines for phosphorous set for the lake and suggest that it should be halved to allow more intensive aquaculture by industry. It should be highlighted that the lake water is used as a drinking water source for Lake Argyle village, as well as other uses such as crop irrigation, and thus must retain high standards. On what basis does Fisheries WA criticise the water quality guidelines?

Response:

- *Neither Fisheries WA, nor their consultants have criticised the water quality guidelines for the lake. To the contrary, in Appendix D (SER) the consultants have noted there are no guidelines for the lake at present and have suggested appropriate interim guidelines for use until a better understanding of the lakes limnology can be developed. The consultants have also drawn attention to the fact that the carrying capacity of the lake for intensive fish aquaculture is governed by the concentration of total phosphorous which is established as the guideline.*

- *Fisheries WA and the consultants consider it extremely inappropriate to be asked to respond to a submission which is so far from the truth as to question both the competence and the motive of the author.*

Question 24

There should be conditions that no use of chemicals/antibiotics in case of fish stock disease. If one considers medical research this is a very poor method of chemical use, especially in the case of antibiotics. There is no clearer method of reducing the efficacy of antibiotics than to use low levels in such systems which do not kill the bacteria targeted, but which clearly result in a heightened multi-resistance to the drug. Please note that oxytetracycline is also a commonly-used antibiotic for human use. What precautions will be taken to ensure the above problems associated with antibiotics do not occur?

Response:

- *There has been no suggestion that antibiotics will be widely used in the lake. On the contrary, the stocking densities proposed for the lake have been selected to reduce stress on fish and therefore avoid the need for use of antibiotics. Antibiotics will be used only if absolutely necessary and under controlled conditions detailed by Fisheries WA and regulated through their aquaculture licence. In Australia the use of antibiotics in aquaculture is controlled by veterinary prescription, and residues in fish would prevent the sale of the product.*
  The responsible use of antibiotics by Australian aquaculture has been demonstrated by the tuna industries in South Australia and the salmon industry in Tasmania. It is not anticipated that the Lake Argyle industry will be any less responsible (Attachment C).

- *The issue of residues is one which is of concern to both the veterinary and medical professions. However their use is still very widespread in the poultry, cattle and sheep industries and also in the human population. Usage in Lake Argyle, should it occur at all, will be a tiny proportion of the large annual usage of oxytetracycline in Australia.*

Question 25

There is some concern on the use of the Dillon & Rigler adaptation of the Vollenwider phosphorous-loading model of trophic status in lakes to Lake Argyle. It is thought that it may not be an appropriate model for this lake system and more evidence to show why it is thought to be an appropriate model should be given. There is some perhaps more appropriate work going in South Africa, which could be applied. Have other models been investigated.

Response:

- *As indicated in Section 1.3.1 of the SER report, a workshop involving limnology experts was held to discuss the most appropriate model to use, and recommendations are provided in Section 6.0 for a three dimensional model. However, such a model is not available for the lake at present, and neither are the water quality and limnological data necessary to drive it.*

- *In the absence of the above, the Dillon & Rigler model is considered the most appropriate to use at present even though it has shortcomings. Appendix B of the SER addresses the range of models available and justifies the choice of Dillon & Rigler as the most appropriate to use at present. In particular, models developed for systems with waters much more turbid than in Lake Argyle, such as many used in South Africa, are shown in Appendix B of the SER to be clearly inappropriate to Lake Argyle.*

Question 26

What assurance will be given that barramundi will be the only species used in this industry?
Response:

- *No assurance can be given. Given present and foreseeable market conditions, barramundi is likely to be the fish grown. However, if a proposal to farm another species of tropical freshwater fish is received, it will be considered a major variation and will need to be re-assessed under the Ministerial Policy Guideline No.8 (1997) process. This will include referral to the EPA*

Question 27

There needs to be long-term management arrangements and controls set in place for such a strategy, both for subsequent translocations to new areas after establishment and for decommissioning of aquaculture infrastructure in the case of bankruptcy or voluntary close-down. Will these arrangements be required by Fisheries WA?

Response:

- *The translocation of non-endemic fish into and within WA is controlled by the Regulations of the Fish Resource Management Act (1994) and is administered by way of a Memorandum of Understanding between the EPA and Fisheries WA. A comprehensive assessment and review process has been established under the principles outlined in Ministerial Policy Guideline No 5.*

- *Aquaculture licences issued for large scale developments are conditioned to ensure that the licence holder pays a bond (or takes out insurance) to insure that the site is cleared and rehabilitated should the licence holder not be in a position to do so. An example of the condition imposed is as follows:*

  "The licensee shall submit to the Executive Director of Fisheries WA a bond (or insurance), of an amount stipulated from time to time by the Executive Director which shall be held in a private trust account administered by the Executive Director. Interest earned on the bond shall be paid to the licensee on a quarterly basis. The bond (or insurance) shall be for the purpose of the removal of all property, equipment, structures, refuse and debris from the licensed area, and the rehabilitation of the area to the satisfaction of the Executive Director, should the licensee not be in the position to do so."

Question 28

This appears to follow a similar precedent as the Fisheries WA proposal for Southern Blue-fin Tuna in the Recherche Archipelago, with respect to Fisheries WA acting as proponent. Did the Minister, Monty House state that Fisheries WA would never do this again?

Response:

- *The approach to the Lake Argyle initiative is different in a number of respects, to the approach taken at Esperance. As a matter of policy, Fisheries WA will not take on the role of developer for aquaculture proposals. The agency however has responsibility to promote and lead aquaculture development in Western Australia and therefore will continue to identify and promote sustainable opportunities and encourage quality developers to enter the industry for the benefit of all West Australians.*

- *The agency is putting forward the concept as a sustainable economic development opportunity for the Kimberley region. Depending on the outcome of the SER it is proposed that an Expression of Interest process to attract a developer or developers will be initiated. This will move the project forward to the stage where an aquaculture licence can be considered under Ministerial Policy Guideline No 8 (1997). At this stage Fisheries WA is undertaking a SER to identify the environmental criteria that will need to be addressed by any developer. The developer will need to undergo a formal assessment by the (EPA) under Section 38 of the Act.*

Question 29

Production tonnages up to 10,000 tonnes per annum are mentioned in the Executive Summary. Comments provided are based on 2,000 tonnes. Proposals for production above 2,000 tonnes should be subject to separate environmental impact assessment based on research and monitoring data collected in the interim as production up to 10,000 tonnes may impact on water quality.

Response:

- *Fisheries WA agrees that future proposals for production above 2,000 tonnes should be subject to separate environmental impact assessment based on research and monitoring data collected in the interim.*

- *Comments included in the report do consider tonnages up to 10,000. In part, consideration of such tonnages assists in developing confidence in recommendations for initial development up to 2,000 tonnes.*

Question 30

The summary table states "Lake Argyle wetlands restricted to shallow fringe which varies seasonally and annually". This is not correct. The Lake Argyle component of the Ramsar site includes the whole lake.

Response

- *It is acknowledged that the whole of Lake Argyle is listed on the RAMSAR Wetland. The statement in the summary was not meant to be misleading but was meant to indicate that part of the lake which is most heavily utilised by waterbirds.*

Question 31

CALM advises that on Page 46, Section 3.7.5 the first sentence should read "Lake Argyle is listed as a wetland of international importance under the Ramsar Convention because it meets ...".

Response:

- *Agreed. Section 3.2.5 should confirm that the whole of Lake Argyle has now been listed as a wetland of international importance under the Ramsar Convention.*

Question 32

CALM further advises that on Page 56, Section 5.2.3 the definition of objectives with respect to flora and fauna of the lake (and in particular rare and priority flora, specially protected fauna and migratory birds) and with respect to obligations under the Ramsar Convention should be drawn up in consultation with CALM. There is clarification needed concerning what is meant by the term "compromised".

Response:

- *Fisheries WA agrees that the definition of objectives for the above issues should be drawn up in consultation with CALM and that CALM should be one of the stakeholders consulted by any further proponents.*

- *The term "compromised" as used here means "reduced in effect". Perhaps a better phrase would be to substitute the term "not compromised" by the word "achieved".*

Question 33

Note that the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999,* which has been recently passed but has not commenced operation, includes specific provisions in respect of significant impact on the ecological character of a Ramsar wetland. This should be brought to the attention of any prospective fish farmers.

Response

- *Any prospective fish farmer will be expected to operate according to the provisions of all laws of Australia. However, the application of this new law will be brought to the attention of prospective farmers in the Expression of Interest to be released once the Minister for the Environment has received advice on the likely acceptability of the concept from EPA under Section 16 e of the Environmental Protection Act 1986.*

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ATTACHMENT A

WATER SAMPLING LAKE ARGYLE - SEPTEMBER 1999

Background

A meeting with representatives from the Department of Environmental Protection, Water and Rivers Commission and Fisheries WA was held on 12 August 1999 to discuss the need for further water quality data of Lake Argyle to

- support the Fisheries WA Kimberley Aquaculture Development Strategy - Strategic Environmental Review; and
- assist in the understanding of the dry season quality of the lake.

A joint water sampling exercise on Lake Argyle was planned to be undertaken by Fisheries WA and the Water and Rivers Commission during the week commencing 16 August 1999.

Sampling Program

The sampling program involved 4 sites at the northern end of the lake as shown on the map (see attachment to Attachment A) at dam wall, above drowned river channel at southern end of the notional fish farm area and at two embayment locations where fish cages may be located.

These site locations will, if possible be confirmed by hand held GIS instruments or referenced to shore based location points.

The analyses of the samples collected will be undertaken by Australian Government Analytical Laboratories (AGAL) and paid for by Fisheries WA. The Water and Rivers Commission will provide an officer to support the Fisheries WA officer, boat, hydrolab testing equipment, sample bottles and esky as needed.

- Physical parameters - at least 3 water depths in lake profile: pH, temperature, DO, EC, turbidity at each measured depth referenced to current lake level;
- Nutrients- TKN, NO2 + NO3, TP and filterable P;
- Suspended solids; and
- Chlorophyll "a".

Note: The critical elements of this exercise are P concentrations (to detection limit of 5ug/L) and presence suspended matter especially phytoplankton as evidenced by chlorophyll " a".

Test/Analyses: liaise with AGAL concerning sample volume and preservation techniques.

Method

Lake Argyle water samples were collected on 23 August 1999.

Surface samples were collected directly into the sample bottle by holding it under the surface. The other samples were collected using a Niskin bottle (see Table 1). The samples were decanted into 1L polyethylene plastic sample bottles and placed immediately on ice in the dark.

The samples were sent to AGAL (Ansett Air Freight - Con No. AF336779) on the 1400 hour flight from Kununurra to Perth. They were packaged with ice in a blue "Coleman" esky. The package arrived at AGAL the morning of 24 August 1999 and a call from AGAL confirmed their arrival.

Table A1: Water Samples collected from Lake Argyle for N, P and chlorophyll "a" analysis

Site No	Location	Water sample
1	Dam Wall N 8 217300 E 472000	A) 0 to 1 m deep B) 10 to 15 m deep C) 27 m deep (full length of cord)
2	Pinpot Bay N 8 213000 E 464200	A) 0 to 1 m deep B) 10 to 15 m deep C) 20 to 25 m deep (1 m off bottom)
3	Bay of Islands N 8 210200 E 476900	A) 0 to 1 m deep B) 10 to 15 m deep C) 20 to 25 m deep (1 m off bottom)
4	Bullanyin Island N 8 206500 E 471900	A) 0 to 1 m deep B) 10 to 15 m deep C) 20 to 25 m deep (1 m off bottom)

The Hydrolab was used at the above sites to record basic water quality parameters to a 15 m depth (max length of cable). The results from the Hydrolab and from AGAL are detailed in Tables 2 and 3 respectively.

Table A3: Water Samples collected from Lake Argyle
Fisheries WA and Water and Rivers Commission

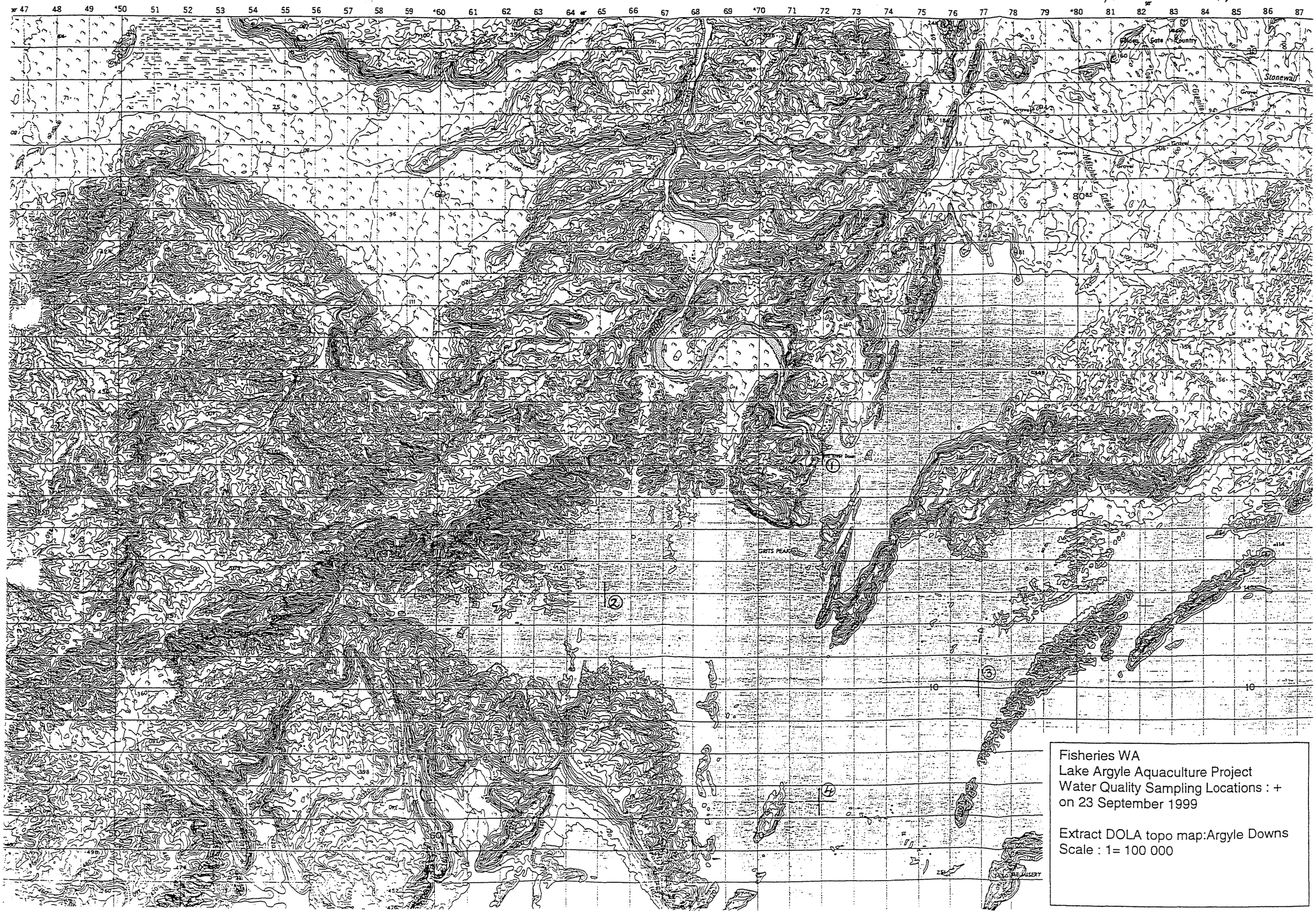
Number of samples	12	Number of results	6				
Sample information SAMPLE REFERENCE	SAMPLE DESCRIPTION	DATE SAMPLED	DATE RECEIVED	DATE REPORTED	ARRIVAL CODE	AGAL LRN	REPORT NUMBER Method Units Limit of Reporting
SITE 1 (TOP)	WATER DAM WALL		24-Aug-99	07-Sep-99	M	W99/019567	RN116499
SITE 1 (10M)	WATER DAM WALL	23-Aug-99	24-Aug-99	07-Sep-99	O	W99/019568	RN116499
SITE 1 (BOTTOM)	WATER DAM WALL		24-Aug-99	07-Sep-99	O	W99/019569	RN116499
SITE 2 (TOP)	PINPOT BAY		24-Aug-99	07-Sep-99	O	W99/019570	RN116499
SITE 2 (MIDDLE)	PINPOT BAY		24-Aug-99	07-Sep-99	O	W99/019571	RN116499
SITE 2 (BOTTOM)	PINPOT BAY		24-Aug-99	07-Sep-99	O	W99/019572	RN116499
SITE 3 (TOP)	BAY OF ISLANDS		24-Aug-99	07-Sep-99	O	W99/019573	RN116499
SITE 3 (MIDDLE)	BAY OF ISLANDS		24-Aug-99	07-Sep-99	O	W99/019574	RN116499
SITE 3 (BOTTOM)	BAY OF ISLANDS		24-Aug-99	07-Sep-99	O	W99/019575	RN116499
SITE 4 (TOP)	BULLANYIN ISLAND		24-Aug-99	07-Sep-99	O	W99/019576	RN116499
SITE 4 (MIDDLE)	BULLANYIN ISLAND		24-Aug-99	07-Sep-99	O	W99/019577	RN116499
SITE 4 (BOTTOM)	BULLANYIN ISLAND		24-Aug-99	07-Sep-99	O	W99/019578	RN116499

Site 1 DAM WALL N 8 217300 E 472000
Site 2 PINPOT BAY N 8 213000 E 464200
Site 3 BAY OF ISLANDS N 8 210200 E 476900
Site 4 BULLANYIN ISLAND N 8 206500 E 471900

Inorganics Chlorophyll A WL177 mg/L <0.001	Nitrate as NO3-N WL119WL239 mg/L <0.01	Nitrite as NO2-N WL119WL239 mg/L <0.01	Ortho-Phosphate as PO4-P WL195WL239 mg/L <0.005	Total Kjeldahl Nitrogen (Calc) WL119WL239 mg/L <0.025	Total Phosphorus WL195WL239 mg/L <0.005
<0.001	<0.010	<0.010	0.006	0.18	0.006
<0.001	<0.010	<0.010	<0.005	0.16	<0.005
<0.001	0.045	<0.010	<0.005	0.14	<0.005
<0.001	<0.010	<0.010	<0.005	0.2	0.006
<0.001	<0.010	<0.010	<0.005	0.16	<0.005
<0.001	0.037	<0.010	<0.005	0.26	0.011
<0.001	<0.010	<0.010	<0.005	0.15	<0.005
<0.001	<0.010	<0.010	<0.005	0.17	<0.005
<0.001	0.03	<0.010	<0.005	0.18	0.013
<0.001	<0.010	<0.010	<0.005	0.27	<0.005
<0.001	<0.010	<0.010	<0.005	0.15	<0.005
<0.001	0.041	<0.010	0.007	0.21	0.009

TOPOGRAPHIC SURVEY

ATTACHMENT A



Fisheries WA
Lake Argyle Aquaculture Project
Water Quality Sampling Locations : +
on 23 September 1999

Extract DOLA topo map:Argyle Downs
Scale : 1= 100 000

ATTACHMENT A

Discussion Comments from Water and Rivers Commission

The sampling report and results from AGAL (7 September 1999) were provided by the Fisheries WA to the Water and Rivers Commission on 17 September 1999. In summary samples were taken from 4 sites at the northern end of Lake Argyle in the area designated for possible establishment of aquaculture project. Previous sampling of the lake has been undertaken in the wet season. The aim of this sampling run was to obtain a 3 dimensional snapshot of key physical and chemical parameters within the lake in its dry season condition and compare this data with the model assumptions provided in the Lake Argyle Barramundi Aquaculture Industry - Strategic Environmental Review prepared by LeProvost Dames and Moore (July 1999).

The sampling run was performed by experienced regional officers from the Water and Rivers Commission and Fisheries WA. It consisted of "hydrolab" site determination of physical parameters and collection, preservation and laboratory analysis of unfiltered water samples for nutrients and algal matter concentrations at 3 depths using a Niskin bottle at each site. Sampling sites were selected to capture as much diversity of water quality as possible within the focus area. Refer to the map.

Two areas of concern in the tabulated data presentation. They are:

- The specific conductivity reading (EC). An approximate conversion factor of 0.68 between EC and salinity expressed as mg/litre is commonly used for comparisons (ANZECC 1998); and

- The physical data indicates that small thermocline (< 3^0 C) existed over 15 metres (ie ~50% of water depth limited by the hydrolab operational cord). Turbidity was consistently below the level of detection. The salinity record indicated a fairly constant fresh water profile (~150 mg/litre). Dissolved oxygen levels varied between ~ 5.5 and 8 mg/litre, generally suited to maintenance of fresh-water aerobic aquatic fauna. The pH is consistently in the mildly alkaline range around 8.

The nutrient analyses indicated total N consistently below 0.3 mg/litre and total P below 0.015mg/litre. The snapshot data suggests that the lake was at the time in an oligo- to meso- eutrophic state. This was supported by chlorophyll "a" counts below a detection limit of 0.001mg/ litre. The highest nutrient concentrations were recorded at the deepest locations (ie >20m deep). The water quality data appears broadly consistent with the strategic environmental review assessment of July 1999.

Table A2: Lake Argyle Water Quality Data 23/08/99

Location	Site "1"	Dam Wall		11:45 am		
Depth (m)	Temp (oC)	Spec Cond (microS/cm)	Turbidity (NTU)	pH	DO (mg/L)	Salinity (ppt)
1	25.18	229	0	8.06	7.83	0.1
3	24.34	228	0	8.01	7.89	0.1
5	23.41	227	0	8.00	7.88	0.1
7	23.08	227	0	8.00	7.89	0.1
9	22.91	227	0	8.04	7.91	0.1
11	22.7	227	0	8.06	7.93	0.1
13	22.62	227	0	8.07	7.52	0.1
15	22.45	226	0	8.01	7.25	0.1
delta	-2.73	-3.00	0.00	-0.05	-0.58	0
mean	23.33	227.25	0	8.03	7.76	0.1
Location	Site "2"	Pinpot Bay		11:00 am		
1	24.45	227	0	8.07	7.94	0.1
3	24.45	227	0	8.04	7.98	0.1
5	23.61	227	0	8.01	7.94	0.1
7	23.16	227	0	7.99	7.82	0.1
9	22.84	227	0	8.02	7.63	0.1
11	22.75	227	0	8.02	7.59	0.1
13	22.5	227	0	7.97	7.13	0.1
15	22.3	227	0	7.93	7.03	0.1
delta	-2.15	0.00	0.00	-0.14	-0.91	0.00
mean	23.2575	227	0	8.00625	7.6325	0.1
Location	Site "3"	Bay of Isl		7:00 am		
1	24.82	228	0	8.09	7.97	0.1
3	24.2	227	0	8.05	7.93	0.1
5	23.84	227	0	8.05	7.79	0.1
7	23.37	227	0	8.05	7.86	0.1
9	23.11	227	0	8.04	7.69	0.1
11	22.78	227	0	8.00	7.21	0.1
13	22.3	227	0	7.83	6.28	0.1
15	22	227	0	7.4	5.49	0.1
delta	-2.82	-1.00	0.00	-0.69	-2.48	0.00
mean	23.3025	227.125	0	7.93	7.53	0.1
Location	Site "4"	Bullanyin	Isl	10:10 am		
1	24.41	228	0	8.10	7.75	0.1
3	24.11	227	0	8.04	7.79	0.1
5	23.61	227	0	8.01	7.77	0.1
7	23.31	227	0	8.04	7.7	0.1
9	22.9	228	0	8.04	7.64	0.1
11	22.45	227	0	8.00	7.35	0.1
13	22.19	228	0	7.86	6.65	0.1
15	23.01	228	0	7.83	6.48	0.1
delta	-1.40	0.00	0.00	-0.27	-1.27	0
mean	23.2488	225.625	0	7.99	7.39125	0.1

ATTACHMENT B The history of barramundi in Lake Argyle

(Troy Sinclair Fisheries WA Officer pers. comm)

In assessing the impact of reintroducing the barramundi on the ecology of Lake Argyle it needs to be remembered that barramundi were naturally endemic to the area before the damming of Lake Argyle. The dam isolated the fish from their breeding areas and they slowly died due to a lack of recruitment. Furthermore, before the raising of the spillway there was potential for a level of recruitment. Nevertheless, the population levels in Lake Kununurra were very low, hence few fish were available for recruitment up the spillway.

It could be argued that the reintroduction of barramundi to Lake Argyle would help restore the ecosystem to a more natural structure by the reintroduction of a higher order predator. Moreover, if the Ord Dam was built today (or in the last few years) there would undoubtedly be a requirement that the protection of barramundi populations be included into the design, construction and management regime, so no change to the overall structure of the food web would occur. This may have been implemented by restocking with the use of fish ladders and/or restocking programs.

It is of interest that, the East Kimberley Regional Recreational Fishing Advisory Committee (EKRRFAC) is currently undertaking a study to restore a more natural assemblage of fish populations in Lake Kununurra, by the reintroduction barramundi. Currently, the EKRRFAC has a high level of local public acceptance for this program. Therefore, it is likely that if this committee can source the resources and demonstrate a level of success with Lake Kununurra that they would turn their attentions to the change in the assemblage of the fish population that has occurred in Lake Argyle

The Effect of Predation on the Catfish Population by Barramundi

Barramundi are accepted to be opportunistic predators thus they will target a range of species depending upon what is available. Therefore, it can be assumed that barramundi will also predate on juvenile catfish, as well as other species. The level of impact of this is difficult to quantify given the current level of knowledge of Lake Argyle's fish populations. However, the risks on the Lake Argyle Catfish population may be estimated by the following calculations and information.

Estimates of the catfish population in Lake Argyle.

Currently, there is little reliable data available to estimate the catfish population. However, the population can be roughly estimated by assuming that the catfish industry is catching approximately 5 to 15 % of the total stock per year. Therefore, a catch rate of 360 tonnes per year of catfish would put the stocks in the range of 2400 to 7200 tonnes. Furthermore, assuming the average size for the catfish in Lake Argyle to be 1 kg, the population of these fish would range from approx. 2.4 to 7.2 million fish. Of these catfish, approximately 10 % would be at reproductive age, and of these half would be female. This would represent a breeding female population of approximately 120,000 to 360,000 fish.

The female catfish are believed to develop reproductive capacity at around 50 cm. Fecundity is low at around 200 ripe eggs per a 3 to 5 kg female, however the fertilised eggs are mouth incubated by the paternal parent until early fry stage which can result in very high survival to the free swimming fingerling stage. This reduces the risk of predation during the crucial period of the first few months of life when juvenile fish have a low capacity to avoid predation. The success of this reproductive stage was evident by the rapid development of the stock during the 1970's, at a time when some barramundi would still be living in Lake Argyle after damming. This is an indication that the catfish species has a high capacity for successful recruitment despite barramundi predation. It is likely therefore that the survival rate from egg to fingerling would be approximately 50 %. From this information an estimate of the recruitment of catfish fingerlings per year in Lake Argyle can be made and shown to range from 12 to 35 million. These results are summarised in Table B.1 and Table B.2.

Table B.1. Estimation of catfish to population in Lake Argyle.

Catfish catch rate/ year (tonnes/year)	Catfish catch rate % of the total population [a]	Total catfish population [b]	Female breeding population [c]
360	15 %	2.4 million	120,000
360	5 %	7.2 million	360,000

[a] Based on the Catfishery catching 5 to 10 % of the total catfish population.
[b] Based on the average catfish size of 1 kg.
[c] Assuming 10 % of the population being of reproductive age; half being female.

Table B.2. Estimated recruitment of catfish to fingerling stage per year.

Female breeding population [a]	No eggs/ female	Percentage survival to fingerlings	Estimated recruitment to fingerlings/ year[b,c]
120,000	200	50 %	12 million
360,000	200	50 %	36 million

[a] See Table B.1.
[b] Estimated recruitment to fingerling stage = No of females x No eggs x % survival
[c] Note the above fails to take into account that recruitment in fish populations is not limited by predation. It is generally heavily influenced by environmental conditions and abundance of food.

Estimated effect of barramundi predation on the catfish population.

The catfish species are believed to be fast growing, reaching harvest size (approximately 55 cm) at about 2-4 years of age, however the fishery does catch and target bigger fish (15 kg) that would be well over 10 years of age. The catfish are believed to reach a length of 20-30 cm in one year, placing them quickly beyond the normal prey range of barramundi. Therefore, an extremely high population of barramundi would be required to impact on this level of recruitment. A theoretical estimation of predatory effects can help put this in perspective (Table B.3.).

Table B.3. Estimated predation of catfish by escaped barramundi in Lake Argyle.

Number of escaped brramundi/year[a]	Food consumption for individual barramundi/ year (kg/year)[b]	Number of catfish consumed/barramundi / year[c]	Number of catfish consumed by escaped barramundi population[d]
7000	33	700	5 million

[a] Estimated from a 2000 tonne/year barramundi aquaculture industry (3 kg fish) consisting of approx. 700,000 barramundi and a 1% escape rate per year (7000 fish/year).
[b] Barramundi consume approx. 3 % of their body weight/day (3 % x 3kg x 365 days = 33 kg/year).
[c] Based on the average prey size of catfish for barramundi being 0.045 kg.
[d] Number of catfish consumed per year = number of escaped barramundi per year x number of catfish consumed per barramundi per year.

However, there is no data on prey composition of Lake Argyle barramundi. Although anecdotal evidence shows that they tend to target species such as archer fish, small grunter, glass fish and other such small species. It is possible that they avoid preying on catfish due to the presence of the strong dorsal and pectoral spines of catfish.

If we assume a equal predation by barramundi of all species in the lake (ie an equal spread over 15 different species) then only 1 to 3 % of the total catfish population recruited per year undergoes predation (Table B.4.).

Table B.4. Summary on the effects of predation on catfish by escaped barramundi in Lake Argyle.

Estimated recruitment to fingerlings/ year[a]	Number of catfish consumed by escaped barramundi population	Number of different species	Percentage of catfish population consumed by escaped barramundi
12 million	5 million	15	3 %
36 million	5 million	15	1 %

[a] See Table B.2.
[b] See Table B.3.

ATTACHMENT C

University of Tasmania web-page.
Address: http://www.utas.edu.au/docs/aquaculture/salmon/overview.html

"The seacage production of Atlantic salmon and rainbow (Ocean) trout in Tasmania began in the early 1980s and has proved a successful industry for the state, approaching a value of approximately $100 million.

The seven companies operating in the southern and western coastal areas employ a significant number of personnel. Juvenile fish are produced by 4 hatcheries across the north and south of the state. The industry has developed rapidly by incorporating a structured research and development program and regulated smolt supply at start-up through the formation of Saltas, a coastal management policy, site fallowing and an **environmental monitoring program**, combined with an innovative industry approach and excellent growing conditions.

The resultant quality products have attracted the attention of other salmon-producing countries and a premium price in the Japanese market. **Salmon are produced in clean water and without the use of any antibiotics or biocidal net antifoulants**. Production is currently about 10,000 tonne/annum and is expected to continue to increase. Many of the companies are vertically integrated incorporating hatchery, seacage grow-out, processing, marketing and sales".

Conclusion

It appears, there would be little impact on the catfish fishery from the expected release of barramundi in Lake Argyle which is likely to be associated with proposed barramundi aquaculture initiative.. This is evident from the estimated escape of 1 % (7000 barramundi per year) from barramundi aquaculture facilities when compared to 12 to 35 million catfish recruited per year. Furthermore, it is unlikely that the escaped barramundi will compete for food with the catfish due to the significantly larger population of the catfish. Therefore, the main effect on cat fishermen, if a larger populations of barramundi were to establish in Lake Argyle, would be an additional catch of barramundi.