# DRAFT

# AQUACULTURE PLAN FOR EXMOUTH GULF

FISHERIES MANAGEMENT PAPER NO. 172

Department of Fisheries
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Perth WA 6000

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Department of Fisheries

# Draft Aquaculture Plan For Exmouth Gulf

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# AN INVITATION TO COMMENT

The Department of Fisheries invites people to make a submission on the issues discussed in this report - *Draft Aquaculture Plan for Exmouth Gulf.* This plan has been prepared by *ecologia* Environmental Consultants and Makaira Pty Ltd and the Department of Fisheries.

### Why Write a Submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action, including alternative approaches. The Department of Fisheries will collate and summarise all public submissions received. Analysis of the submissions will be undertaken and recommended changes identified and documented. Public submissions will be treated as public documents unless specifically marked confidential, and may be quoted in full or in part in any further reports on Exmouth Gulf.

### Developing a Submission

In your submission you may agree, disagree or comment on general issues or specific strategies listed. It may help to reduce the workload on individuals and increase the pool of ideas and information if you join a group with similar interests and make a joint submission.

When making comment on a specific issue in the report:

- refer each of your comments to the appropriate section or chapter heading in the report;
- clearly state your point of view;
- indicate your reasoning or source of information; and
- suggest alternate strategies, safeguards or information.

### Public Submissions Form

A public submission form is available for use if this approach is preferred. When using the form, your submission need not be limited to the space available on the form.

Please remember to include your name, address, the date and whether you want your submission to be confidential.

### Closing Date

The closing date for submissions is 15 July 2004.

### Contacts

Submissions should be addressed to:

Marine Planner
Fish & Fish Habitat Protection Program
Department of Fisheries
Locked Bag No. 39
Cloisters Square Post Office
PERTH WA 6850

If you wish to discuss the content of the document or require further information, please contact Ms Eve Bunbury on (08) 9482 7397.

## PUBLIC SUBMISSION FORM

## DRAFT AQUACULTURE PLAN FOR EXMOUTH GULF

**Marine Planner**
**Fish & Fish Habitat Protection Program**
**Department of Fisheries**
**Locked Bag No. 39**
**Cloisters Square Post Office**
**PERTH WA 6850**

Name: _____

Organisation
(if applicable): _____

Address: _____

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I would like to make the following comments on the draft aquaculture plan for Exmouth Gulf.

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## EXECUTIVE SUMMARY

This Draft Aquaculture Plan covers the Exmouth Gulf from Point Murat to Rocky Point.

The Plan's objective is to provide a sound strategy for developing future aquaculture activities in Exmouth Gulf, while at the same time conserving the unique environment of Exmouth Gulf for present and future generations, and minimising conflict with existing and future users of Exmouth Gulf.

This Draft Aquaculture Plan builds upon the Gascoyne Aquaculture Development Plan. Public consultation, including a public meeting in Exmouth and face-to-face meetings with other interested groups took place and the results were used to assist preparation of this Draft Plan.

The Draft Plan reviews the physical, biological and social environmental characteristics of the region, and then examines the existing management framework and its application to aquaculture in Exmouth Gulf. There is little information available regarding the region's environment.

The impact of the environment on aquaculture, and vice versa, is reviewed. Aquaculture is sensitive to contaminants, parasites and predators. Environmental impacts from aquaculture are highly dependent on a number of interrelated factors - namely location, production system, species grown and integration with other human activities. Environmental impacts from current aquaculture operations in Exmouth Gulf are believed to be relatively minor, compared to other environmental impacts that have occurred in Exmouth Gulf since European settlement, such as the introduction of alien fauna.

Constraints to aquaculture in Exmouth Gulf include: the potential for conflicting use of resources, particularly with the petroleum industry; lack of infrastructure beyond existing settlements; climate; and environmental constraints, ranging from a lack of baseline information about water circulation to zones in the Marine Park where aquaculture is not permitted. Constraints, which are clearly defined geographically, are later used to identify where aquaculture can and cannot occur.

Candidate species for aquaculture in Exmouth Gulf are analysed using five criteria, namely:

- marketing prospects;
- culture technology viability;
- level of production efficiency;
- commercial viability; and
- compatibility with production systems suitable for Exmouth Gulf.

This analysis produced 13 species of marine finfish and aquarium fish, and eight species of marine shellfish as candidates for aquaculture.

Production systems suitable for Exmouth Gulf are then examined. The most likely production systems onshore would be either systems using tanks and raceways with flow through water, farming high value fish in intensive, small scale systems, or large scale ponds with flow through water, farming high value fish in intensive or semi intensive conditions. Onshore aquaculture production would most likely be vertically integrated (e.g. include hatcheries or other aspects of production) and horizontally integrated (e.g. be undertaken with other ventures such as tourism). Offshore production systems would most likely include longlines, racks, sea cages or floating tanks.

The culture of filter feeding shellfish is likely to predominate offshore. Cages or floating tanks would be small to medium scale semi-intensive systems farming high value fish, with production vertically integrated, and in some instances, horizontally integrated. Links are drawn between

candidate species for Exmouth Gulf and likely production systems.

Onshore production systems or offshore floating tank systems provide the greatest opportunity for sound environmental management and environmentally acceptable operations.

Existing regulatory mechanisms, principally comprising the *Environmental Protection Act 1986,* are considered to provide adequate environmental protection.

The Draft Aquaculture Plan identifies areas where aquaculture can occur by mapping:

(i) *areas where aquaculture cannot occur* due to statutory constraints;

(ii) *areas with significant known constraints* which make approval of aquaculture unlikely based on current technology and government policies; and

(iii) *areas with no known constraints which would preclude aquaculture*, but in which it is recognised that site specific investigations may uncover constraints which would prevent the Executive Director of the Department of Fisheries from approving an aquaculture licence.

The draft plan proposes the following 15 recommendations.

## SUMMARY OF RECOMMENDATIONS

*Recommendation 1:* Ensure that future aquaculture activities are consistent with the Gascoyne Aquaculture Development Plan. (proponent/DoF)

*Recommendation 2*: Consider the species listed as suitable in Table 2 as candidates for aquaculture in Exmouth Gulf. In the event that a proponent lodges an aquaculture licence application for Exmouth Gulf involving species not included in the list, consider these other species according to their merits on an individual case basis. (DoF)

*Recommendation 3*: Consider applications for endemic species not listed as suitable in Table 2 on a case-by-case basis. (DoF)

*Recommendation 4*: Prohibit aquaculture of non-endemic species in Exmouth Gulf, unless the EPA has granted specific approval. (DoF)

*Recommendation 5*:Ensure that licensed aquaculturalists utilise local broodstock. Any translocation of broodstock must be subject to the translocation guidelines. (Proponent/DoF)

*Recommendation 6:* Aquaculture production in the Gulf should be characterised by:

- the selection of high-value species, with the exception of some medium to low-value species used in integrated discharge-water-treatment systems;
- the use of both onshore and offshore locations, varying according to species and production system;
- the use of intensive and semi-intensive production systems, using tanks, raceways, ponds, longlines and sea cages;
- waste-management strategies and discharge-water-treatment systems being employed, particularly for onshore systems; and
- extensive environmental monitoring of impacts of activities. (proponent/DoF)

*Recommendation 7:* Applications for wild stock reseeding and enhancement will be considered on a case-by-case basis. (DoF)

*Recommendation 8*: In the absence of sound biological and environmental data, ensure that all aquaculture licences issued for the Exmouth Gulf contain appropriate licence conditions to monitor the environmental impact of aquaculture activities. Any monitoring should be done to the satisfaction of the EPA, CALM or other government agencies with jurisdiction. The level of monitoring may be reviewed on application from the proponents. (DoF, EPA, CALM)

*Recommendation 9:* Ensure that licence conditions for aquaculture address the issues of removal of infrastructure and reinstatement of any area disturbed by environmental impact. (DoF)

*Recommendation 10*: Assessment of new applications for pearl oyster leases and licences in

Exmouth Gulf should take into account the Department's two to five nautical mile separation guideline. (DoF)

*Recommendation 11:* Adopt the criteria and mapping results for aquaculture detailed in Section 6.7 of this Draft Aquaculture Plan to guide future aquaculture applicants. (proponents/DoF)

*Recommendation 12:* Establish performance criteria to monitor whether licences are being used for the purposes for which the applications were originally made, and to determine compliance with licence conditions. (DoF)

*Recommendation 13:* Review the success and appropriateness of management strategies contained in the plan in five years. (DoF)

# SECTION 1 INTRODUCTION

## 1.1 Significant Features of Exmouth Gulf

Exmouth Gulf is one of the largest marine embayments in Western Australia. It is situated on the north west coast, east of North West Cape between latitudes 21$^{o}$ 45' and 22$^{o}$ 30' south (see Figure 1).

Ningaloo Marine Park extends down the western shore of the Gulf to Bundegi, near Exmouth. The western coast is characterised by limestone pavement, with some corals growing along the western shore.

The eastern coast of the Gulf contains a large area of tidal flats and mangroves, which provide nursery areas for prawns and a major feeding area for migratory birds. Some parts of the southern coast contain similar habitats. A Marine Conservation Reserve, which includes this area, has been recommended to the Western Australian Government. However, the Government has not announced any intention to implement the Marine Conservation Reserve recommendation.

The waters of the Gulf are turbid, and salinity increases south down the Gulf. Depths are rarely more than 20 m, and cyclones regularly affect the area.

The town of Exmouth, located on Northwest Cape to the west of Exmouth Gulf, has approximately 2,050 residents. The region's economic base includes commercial fishing (particularly prawns), tourism, a Naval Communications Station run by the Commonwealth Government, petroleum exploration and high-grade limestone export. Commercial fishing is significantly important to the region. Exmouth is a major tourism destination in Western Australia. A small boat harbour has been built in the south of Exmouth townsite to provide protection from cyclones. Petroleum tenements currently cover the entire Exmouth Gulf.

Large jet aircraft can land at Learmonth Airport, south of Exmouth, and the Naval Communications Station includes a deep-water pier.

## 1.2 Purpose of the draft plan

The Department of Fisheries has prepared this draft aquaculture plan for Exmouth Gulf to provide the public with its views on the future management of aquaculture in the area. The final plan will guide prospective aquaculturists in preparing proposals and the Department of Fisheries in decision-making processes for aquaculture licence applications.

This draft is the basis for further consultation with stakeholders and interested groups and will assist in the development of the final aquaculture plan for Exmouth Gulf.

## 1.3 Area covered by the plan

The study area for this Draft Aquaculture Plan lies to the east of Cape Range and extends north almost to Onslow (See Figure 1).

## 1.4 Approach and method

### *1.4.1 Approach*

The Department of Fisheries contracted *ecologia* Environmental Consultants and Makaira Pty Ltd in October 1998 to prepare a draft aquaculture plan for Exmouth Gulf. The Terms of Reference specified, among other things, the requirement for community consultation in the development of a draft plan, and provided a list of organisations and groups to be contacted.

The consultants contacted stakeholder groups through a combination of direct mailing, a meeting in Exmouth in November 1998, face-to-face meetings with individuals or representatives of groups, and follow-up phone calls to all people who did not attend a meeting with the consultants or respond in writing.

The initial direct mailout list was based on stakeholders, such as professional and recreational fishermen, current and likely aquaculture operators, tourist operators, State Government agencies with interests in the area, and peak conservation groups. Additional stakeholders were identified through the consultation process, and these were all subsequently contacted in writing and by a follow-up phone call.

An extract from the Gascoyne Aquaculture Development Plan, which was prepared in 1996, accompanied the direct mailout because it was considered that:

- several stakeholders groups were probably not familiar with aquaculture as an industry;
- it would be difficult for people to respond to a general request regarding their perceptions of constraints or opportunities for aquaculture without something to react to, which indicated where aquaculture could potentially go; and
- it was appropriate that the draft aquaculture plan build upon the recommendations of the Gascoyne Aquaculture Development Plan.

Unfortunately, some stakeholders mistakenly assumed that the extract from the Gascoyne Aquaculture Development Plan represented the final product of this current planning exercise.

Fourteen people attended the meeting held in Exmouth in November 1998. In addition, seven face-to-face meetings were held in Perth.

Thirty-five written or verbal submissions were received. The submissions have been documented in Appendix A and have been categorised under the following broad headings:

- The Environment;
- Management Arrangements; and
- Future Aquaculture.

The consultants collated and analysed the submissions received through the various consultative processes. Along with the results of extensive research, the submissions were integral in the development of this draft aquaculture plan.

### *1.4.2 Method*

In order to prepare this draft aquaculture plan, the following tasks were undertaken by the consultant:

1. An extensive review of literature covering matters as diverse as:

- existing administrative procedures which apply to aquaculture in Exmouth Gulf;
- the existing physical, biological and social environment of Exmouth Gulf;
- environmental requirements of potential aquaculture species;
- current aquaculture production systems; and
- potential environmental impacts from and environmental management for aquaculture production systems.

2. Public consultation, which involved a meeting in Exmouth and face-to-face discussions with key stakeholders.

3. Identification of potential aquaculture species by utilising a set of selection criteria appropriate to Exmouth Gulf.

4. Identification of production systems that would be suited to Exmouth Gulf.

5. Consideration of the potential environmental impacts and their management from aquaculture production systems likely in Exmouth Gulf.

6. A constraints mapping exercise identifying areas where aquaculture cannot occur, areas with significant known constraints and areas with no known constraints, but which may have constraints when site specific investigations are undertaken.

The completed draft plan was submitted to the Department of Fisheries in August 1999 after a number of revisions. This draft reflects updated information and current government policy, and has been restructured to ensure consistency in format with the existing Abrolhos Islands aquaculture plan.

# SECTION 2 PHYSICAL, BIOLOGICAL AND SOCIAL FEATURES OF EXMOUTH GULF

## 2.1 Physical features

### *2.1.1 Geomorphology*

Exmouth Gulf is one of the largest marine embayments on the coast of Western Australia. Mangrove environments have developed along its eastern and southern shores. As a result of being protected from prevailing winds, the wave environment is relatively low energy and, particularly in the upper reaches, mudflats have developed. The Gulf spans a geomorphological boundary: the mangrove-dominated eastern side belongs to the Pilbara coastal sector, and the western side, which includes Giralia Bay, to the Gascoyne sector.

The few streams that enter Exmouth Gulf are small and only flow after cyclonic rains. When it is in flood, the Ashburton River, which enters its northeastern end, has been known to discharge large volumes of turbid water that can affect the Gulf. The eastern side of the Gulf has several low limestone islands with muddy beaches and rocky shores. The shore on the western side consists of narrow beaches with carbonate sands and rock flats backed by dunes.

The North and South Muiron Islands at the northern end of Exmouth Gulf are a continuation of the Cape Range Peninsula. The western shores of the islands face the prevailing swells, and have low limestone cliffs, sandy shores and rock platforms. The eastern shores are less exposed and have gently sloping, sandy beaches and coral patches.

Ningaloo Reef extends into the northwestern part of the Gulf, where the continental shelf is very narrow and the waters are clear.

### *2.1.2 Climate*

Exmouth Gulf lies in an arid, subtropical climatic zone. The area has variable rain, which falls mainly in summer, is very hot and dry in summer and mild to warm in winter. The average annual rainfall is 268 mm, and is recorded at Learmonth Airport, located approximately 35 km south of the town of Exmouth on the western side of Exmouth Gulf. Much of the rainfall in the region results from cyclones, and the annual amounts can vary significantly.

The mean daily temperatures reach approximate maxima and minima, respectively, from 36-38$^{o}$C to 23-24$^{o}$C between January and March, and from 24-26$^{o}$C to 11-14$^{o}$C between June and August. Highest daily maximum temperatures reach about 44-48$^{o}$C during the summer months.

Exmouth Gulf is protected from the strong prevailing southerly winds of the region by the peninsula forming its western boundary, although it is subject to storms from the north. As for most areas on Australia's western, northwestern and northern coasts, there is a threat from tropical cyclones, which can occur between November and April. A sophisticated cyclone watch and warning system protects the areas.

### *2.1.3 Oceanography and water quality*

The waters of Exmouth Gulf are usually clear at the northern opening where conditions are oceanic. At Point Murat, near the northwestern limit of the Gulf, the water is clear and oceanic in quality. Throughout the remainder of the Gulf, particularly in its upper reaches, the water is turbid. The normal tidal range is about 2 m at the northern end and up to 3 m elsewhere, but can increase dramatically under the influence of storm surges.

The Leeuwin Current probably influences water movements and temperatures at the Muiron Islands and possibly at the northwestern part of the Gulf, but not the waters of the Gulf itself. Exmouth Gulf is a negative estuarine system - that is, the seawater salinity increases with the distance into the Gulf, but not to the extent that it does in Shark Bay. It is likely that water movement within the Gulf is driven mainly by tidal motion and wind-induced currents.

A significant feature of Exmouth Gulf is the limestone substrate of the western shore. The geology of the underlying strata is such that beach wells drilled to the requisite depths can be used to extract limited quantities of seawater, which percolates through the porous rock. This water can be clear, high in quality and used for certain types of aquaculture production. It should be noted, however, that such water-supply systems would have to ensure the layer of freshwater, which often overlies the saline water in the area, would not be affected.

The sea surface temperatures at the northern end of Exmouth Gulf range between approximately 18° and 30°C annually.

## 2.2 Biological environment

There is little information available about the eastern side of Exmouth Gulf. Most of the available biological information relates to the Cape Range Peninsula and the Ningaloo Marine Park, which both have significantly different characteristics to the areas on the south and east of Exmouth Gulf, and to the shoreline and waters of Exmouth Gulf.

### *2.2.1 Terrestrial*

*Flora and vegetation*

Six hundred and thirty species of vascular plant have been recorded from the Peninsula, of which the vast majority has desert affinities of either temperate or tropical origins. This reflects the geographical position of the area and the general composition of the Carnarvon Botanical District. Cape Range is dominated by *Eucalyptus* over a middle storey of *Triodia*, with *Acacia-Cassia* understorey. There are 12 endemic taxa and six other taxa largely confined to the Peninsula. Populations of weed species are confined to areas directly adjacent to settlements and consist of 30 taxa.

*Fauna*

The Cape Range Peninsula has a fauna assemblage of 30 mammals, 84 reptiles, five amphibians, and approximately 200 bird species. The landform units existing in the Peninsula influence distributions, which is especially evident among the birds and herptofauna. Although the mammalian fauna is not yet completely known, especially in regards to bats, numerous recent extinctions have occurred in the region among mammal species. The bird and reptile fauna is typical of the arid and semi-arid north west. However, some species are isolated from their main

population bodies, and this has led to a low level of endemism in some species. The intertidal zone and mangrove habitat are important areas for many migratory birds. The area also has an interesting collection of stygofauna (live in groundwater) and troglobitic (cave-dwelling) fauna that utilise the limestone cave network of the Peninsula.

The diversity of habitats on the Cape Range Peninsula helps maintain a varied assemblage of species. The combination of different sandy habitats, the limestone range, extensive intertidal zone and coastal climate allow the convergence of northern and southern zone mesic species.

### *2.2.2 Marine*

#### *2.2.2.1 Aquatic flora and habitats*

There is a distinct lack of accurate information regarding the marine habitats present within Exmouth Gulf. However, there are broadly three distinct sectors - a sandy beach sector, a sand/ mud tidal flat sector and an offshore islands sector. Each sector has differing flora and fauna constituents relating to the make up of the seabed and associated shore. The sand/ mud tidal flat sector, for example, includes one of the State's largest mangrove populations, and is flanked by areas of tidal mudflats and high water salt flats.

A large belt of mangroves occurs on the eastern side of the Gulf and in parts of the southern shore on sand/ mud tidal flats. Detailed mapping of mangroves in this area has not been undertaken, but the general location is known (Figure 2a). The mangrove, intertidal and sand/ mud tidal flat areas along the eastern coast have very high conservation value due to their high biological productivity, importance as nurseries for prawns, and their value as a major feeding area for migratory birds. Three species of mangroves occur on the sand/ mud tidal flats.

#### ***2.2.2.2 Aquatic fauna***

*Fish*

Estuarine and marine finfish native to Exmouth Gulf include cod, groper, bream, emperors, sea perch, mangrove jack, mahi mahi and snapper species. The northern area of Exmouth Gulf adjacent to Ningaloo National Park has very clear water that supports moderately high species diversity with many oceanic coral reef species.

*Corals*

The distribution of corals is influenced by the substrate. Limestone platforms and coral outcrops occur infrequently along the eastern shore of the Gulf. Many of the islands in the Exmouth Gulf are fringed by shallow subtidal to intertidal limestone platforms supporting coral outcrops. Corals are considered to be influential in the water quality at times of spawning at areas such as Bundegi Reef.

*Invertebrates*

Invertebrates comprise the overwhelming bulk of marine creatures in Exmouth Gulf. Life forms consisting of crustaceans, molluscs, cnidarians, bryozoans, echinoderms and a host of other groups, ranging from benthic to free swimming organisms, are found around Exmouth Gulf. The distribution of these groups is influenced by the salinity profiles in the Gulf as well as the species-

specific food and shelter requirements.

There are four commercially important penaeid prawn species found in the Gulf, namely banana prawns (*Penaeus merguensis*), brown tiger prawns (*P. esculentus*), western king prawns (*P. latisulcatus*) and the endeavour prawn (*Metapenaeus endeavouri*).

Mudcrabs are also found in the area and are caught by recreational fishers.

*Mammals*

As noted above, most of the biological survey information available in this region relates to the western portion of Ningaloo Marine Park. Anecdotal evidence indicates that whales travel to the southernmost parts of Exmouth Gulf, using waters as shallow as 5m and that turtles and dugongs may use the area.

## 2.3 Social features

### *2.3.1 Historic shipwrecks*

The Maritime Museum of Western Australia website lists 30 shipwrecks in the Exmouth Gulf region, although there are only two in the area covered by this plan (see Figure 1). All wrecks are part of Western Australia's heritage and are protected by State and Commonwealth legislation (Shire of Exmouth, 2003).

### *2.3.2 Other historic sites*

There are few locations in the Shire of Exmouth that have significant heritage value, and those of value are relatively recent in origin. Yardie Station Homestead, Vlamingh Head Lighthouse, WWII Radar Site, Mildura Wreck, Yardie Creek, Operation Potshot Site, Rough Range and Cape Range Oil Well Sites, and Wapet Creek are of historical significance (Shire of Exmouth 2003).

## 2.4 Conservation importance of Exmouth Gulf

At its northwestern corner, Exmouth Gulf contains a portion of the Ningaloo Reef Marine Park. The Marine Park (see Figure 2b) has significant conservation importance, and any proposals for aquaculture operations to be located in Exmouth Gulf within the Ningaloo Marine Park would have to comply with any regulation pertaining to aquaculture activities, as set down in the plan.

The eastern and southern shores of the Gulf provide mangrove and mudflat habitats of great importance for the conservation and sustainability of local fisheries.

Exmouth Gulf is important for whales with numbers on the increase. Whales are often present for a week or more, and are seen swimming at about the 10m contour or using waters as shallow as 5m.

# SECTION 3 OTHER HUMAN USES OF EXMOUTH GULF

A range of existing uses occurs in Exmouth Gulf, and many of these are mapped on Figures 3.

In terms of resource use, aquaculture can be either compatible or incompatible with other industries, depending on whether the resource is limiting and how each activity is managed. For example, aquaculture and an industry such as tourism can be mutually beneficial; however, where aquaculture competes for limited resources, such as the use of commercial fishing grounds for locating cages, the industries can be mutually exclusive. The compatibility or otherwise of aquaculture with existing uses of resources in Exmouth Gulf is discussed in more detail in Section 4.4.

## 3.1 Commercial fishing

The main commercial fishery operating in Exmouth Gulf is the Exmouth Gulf Prawn Managed Fishery. The Exmouth Gulf Beach Seine Fishery still operates, but at a very low level with only two fishers.

The Exmouth Gulf Prawn Managed Fishery takes western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus* spp.) and banana prawns (*Penaeus merguiensis*). The fishery has an annual value of about $10 million. Management advice for this fishery comes through the Ministerially-appointed Joint Trawl Management Advisory Committee. Controls include seasonal and spatial openings and closures, gear restrictions and restrictions on vessel capacity. The boundaries of the fishery include waters extending generally southwards from the Muiron and Serrurier Islands. A permanent closure is effective over the prawn nursery area located at the southern part of the Gulf (Figure 3a).

The Exmouth Gulf Beach Seine Fishery takes a mixed catch of mullet, Perth herring, shark, whiting and yellowfin bream. The main species are Perth herring, western sand whiting and shark; whiting is the only recreationally significant species recorded. The fishery operates within Exmouth Gulf (Figure 3b), mainly using beach seines and gill nets. Due to confidentiality, catch and values for fisheries with fewer than five operators cannot be reported.

## 3.2 Pearling and aquaculture

Pearling and aquaculture sites as of February 2003 for Exmouth Gulf are shown in Figure 4.

Two companies are licensed and hold pearling leases for silver-lip pearl oyster (*Pinctada maxima*) within the Gulf, and a pearl oyster hatchery became operational in early 1996.

Ocean West Farms has a licensed, land-based, multi-species hatchery and grow-out facility at Giralia Bay, in the south east corner of Exmouth Gulf. Species include finfish, beche-de-mer, non-maxima pearl (black-lip oyster and wing oyster), shrimp and mudcrab.

Cape Sea Farms Pty Ltd has approval from the Minister for the Environment to establish a 120ha prawn farm on the coast at Heron Point, 35 km south of Exmouth. Work has not yet commenced on the prawn farm. The culture of several additional finfish and shellfish species in the Gulf is imminent; however, since they are not under culture at the time of writing, these species are still considered candidates and dealt with later in this document.

## 3.3 Recreational fishing

Recreational fishing comprises predominately shore-based and near shore activities. Shore-based fishing and netting occurs along much of the western side of the Gulf where the coast is accessible to the public. Near shore dinghy based fishing also occurs along the western side (Figure 3c). More remote recreational fishing is undertaken from larger boats and charter boats around outlying islands, along the eastern shore in the vicinity of Tent Point and down into Gales Bay.

Detailed information on recreational catch and effort for the Gascoyne bioregion has been compiled by the Department of Fisheries (Fisheries Research Report No 139, 2002).

## 3.4 Tourism

Exmouth, along with Coral Bay and Denham/ Monkey Mia, is one of the major tourist destinations in the Gascoyne Region, and is most popular during the milder months of March to October.

The tourism industry is increasing in importance in the Exmouth Gulf region, as the area's unique qualities are further developed to meet the tourist demands. Pastoral stations, such as Nanga Station, incorporate tourist operations such as accommodation, diversifying the economic base. Attractions of the marine environment include wildlife interactive adventures, such as whale shark and manta ray diving, sailing, windsurfing and fishing. Whale watching is also economically important, with 13 commercial whale-watching licences issued.

Key shore-based tourism locations are Bundegi Beach, Exmouth township area, Pebble Beach, Learmonth jetty, Wapet Creek and Bay of Rest.

## 3.5 Mining, petroleum and minerals

Petroleum exploration tenements cover the entire Exmouth Gulf (Figure 5). However, there is currently no production of petroleum or gas in Exmouth Gulf. Dampier is the preferred port for these industries in the case of further expansion (Western Australian Planning Commission, 1998).

The Temporary Reserve on the eastern side of the Gulf is for limestone extraction, and on the western side, it is for salt production (Figure 5).

Mining of high-grade limestone deposits has commenced about eight kilometres from Exmouth. It is believed that the limestone represents a considerable resource that is capable of significant financial returns. Export is proposed to Kwinana and South East Asia, initially through Point Murat and then from a barge loading facility/ multiple user berthing facility near the proposed mine.

## 3.6 Potential future uses

It is currently expected that there will be more growth in a number of established industries, including tourism, aquaculture, limestone extraction and oil and gas extraction.

# SECTION 4 CONSTRAINTS ON AQUACULTURAL OPERATION IN EXMOUTH GULF

## 4.1 Environmental constraints

The environmental constraints that apply to aquaculture in Exmouth Gulf depend upon location, the proposed operation and how it is managed. Many environmental constraints are well known and clearly identifiable, such as the location of existing and proposed National Parks and Nature Reserves. Other environmental constraints do not have sufficient baseline information to determine precisely where they apply, such as the need to protect whales.

Therefore, the approach taken is to list environmental constraints along with the status of the constraint, its applicability across aquaculture types and the effect on aquaculture development (see Table 1).

**Table 1: Environmental constraints, their status and applicability to aquaculture in Exmouth Gulf.**

| Environmental constraint | Status | Applicability to aquaculture types/ Effect on aquaculture development |
|---|---|---|
| Existing and proposed National Parks, Nature Reserves, Marine Nature Reserves, Marine Parks. | Clearly defined. | May limit aquaculture in certain areas. |
| Benthic habitats (including seagrass, corals, mangroves). | Distribution poorly known or doubts about reliability of mapping. Existing policies are draft, but precedents exist for their application in most instances. | All types of aquaculture - Land-based discharges may also impact benthic habitats. Prevents aquaculture in certain areas, and may limit effluent discharges in others.<br>EPA limits aquaculture over seagrass. |
| Water circulation. | Poorly known in Exmouth Gulf. | All types of aquaculture. May limit aquaculture in certain areas (e.g. where contaminants concentrate), but can be of benefit for other types (e.g. where high salinity water is desired such as beta carotene production). |
| Existing settlements (and zoning). | Locations known. | All types of aquaculture. May limit or encourages aquaculture in certain areas. |
| Coastal scenery. | General areas of high scenic value known. | May limit certain types of aquaculture in certain areas. |

| Environmental constraint | Status | Applicability to aquaculture types/ Effect on aquaculture development |
|---|---|---|
| Important sites for marine fauna. | Information base poor. | Important areas for fauna may be identified as knowledge base improves. |
| Important sites for terrestrial fauna. | General areas of occurrence known. | Would prevent aquaculture in certain locations. Where general occurrence known, need to do detailed work to demonstrate no adverse impacts. |
| Endangered/ threatened and rare species of flora and fauna. | General areas of occurrence known. | Would prevent aquaculture in certain locations. Where general occurrence is known, need to do detailed work to demonstrate no adverse impacts. |

## 4.2 Climatic constraints

Exmouth Gulf is sheltered from the prevailing southerly winds, but exposed to storms from the north. The western sides of the Muiron Islands are exposed to swells, but the eastern sides provide some shelter. Tropical cyclones often pass and occasionally directly hit the area. Generally, under normal seasonal conditions, there are few climatic constraints to aquaculture development in Exmouth Gulf.

## 4.3 Operational constraints

The southern and eastern shores of the Gulf are well suited for the aquaculture of several species, but some are remote and difficult, if not impossible, to reach by road. All coastal areas are accessible by boat.

Infrastructure and services within and near the town of Exmouth are generally very good. With the exception of the southern and eastern areas, most of Exmouth Gulf and its coastal areas are readily accessible, in many cases to within a few hundred metres of the high water line, by sealed or good-quality gravel roads. The newly constructed boat harbour south of the town will include additional residential and tourism developments that will add to the existing infrastructure and services. The inner boat harbour provides shelter to small and large vessels. The further development of Learmonth Airport south of Exmouth to accommodate international air traffic will provide ready airfreight access to Australian and export markets.

Services and utilities such as electrical power and potable water are available near Exmouth. The town also has a limited manufacturing capability. Road freight services are available at competitive rates, and raw materials, such as concrete, are available for construction purposes.

## 4.4 Conflicting use of resources

### *4.4.1 Basic principles*

The conflicting use of resources is considered one of the most significant constraints to aquaculture development in coastal areas of Western Australia.

Conflict arises when aquaculture competes directly with an alternate use of a limited resource and the two uses are mutually exclusive. In the case of an existing value such as visual amenity, for example, the establishment of a cage farm may be perceived as constituting a loss of visual amenity, unless appropriate management measures are taken to reduce the impact.

In some cases, aquaculture may be compatible with an existing or planned use of the resource, and may even augment income from activities such as tourism and recreational fishing, despite some concerns or assertions to the contrary.

Mechanisms that can be adopted to resolve conflict include spatial and temporal zoning, improved control of water and land resource development schemes, establishment of nature reserves, rehabilitation of degraded habitats, stock enhancement and integrated management. In addition, design and management of the facility may remove what might otherwise have been a conflict. Some of these mechanisms are already in place in Exmouth Gulf, and others are being contemplated.

In Exmouth Gulf, the principal aquaculture-oriented resources are water, land, and an abundant and diverse aquatic fauna. The main users of the resources include the commercial fishery, the recreational fishery and the tourism industry. In addition, local people frequently use the beaches south of Exmouth for swimming and recreation.

### *4.4.2 The compatibility of aquaculture with existing resource uses*

#### *4.4.2.1 General land and water use*

Aquaculture can compete directly with other resource users where it requires the exclusive use of certain land or water areas.

Onshore aquaculture operations or facilities, particularly those located in coastal areas, can compete directly for land with many high-value industries that include property and industrial development and tourism. The hotels and associated facilities of tourist resorts, such as golf courses, usually need large areas and can occupy entire bays or extend along several kilometres of beaches.

Manufacturing industries important for economic development also have high demands for land and water. Land and sea areas may also be devoted to conservation and open to the public. In some cases, the use of some land areas for aquaculture can also place restrictions on the use to which adjacent land may be put, particularly where environmental discharges are of concern. In addition, continuous and significant demands often ensue from normal population growth.

Aquaculture also requires land and water areas that vary according to the type of production system used (Appendix B). Frequently, given the wide range of production systems that are available today, it is possible for aquaculture to be located in comparatively limited land areas and to co-exist with a variety of other users of limited resources. More intensive aquaculture production systems

can be located in close proximity to, and co-exist with, many of the uses to which coastal land can be put. Recirculating systems, for example, are presently located adjacent to large cities and, in many cases, within the boundaries of ports and marinas.

On the land, aquaculture will usually be incompatible with mining activities, which invariably require the exclusive use of a given land area. Offshore aquaculture can be compatible with the petroleum industry, for instance, where sea cages may be supported by or suspended from offshore structures or platforms.

#### *4.4.2.2 Wild-capture and recreational fisheries*

Onshore aquaculture can be incompatible with the wild-capture fisheries where it competes for coastal land required for ports and port infrastructure, including processing plants. In most cases, however, aquaculture and wild-capture fisheries are compatible and synergetic, with positive benefits arising from opportunities to share transportation and marketing costs and to optimise the use of common infrastructure such as processing facilities.

Offshore aquaculture can be incompatible with fisheries in cases where sea cages and other floating and sub-surface equipment restrict or otherwise interfere with commercial fishing operations.

Onshore and offshore aquaculture operations can also conflict with recreational fishing if they restrict or prevent access to fishing spots. Conversely, aquaculture can be compatible with and provide positive benefits to recreational fishing activities in cases where it can be used to enhance stocks of depleted wild-stock fisheries.

Offshore recreational fishing is unlikely to conflict with aquaculture operations, except on a localised basis immediately adjacent to any aquaculture facility. Shore-based activities and near shore netting would only be constrained by aquaculture on a local basis immediately adjacent to any facility. The area in which charter and larger boats carry out recreational fishing is large (see Figure 3c), and thus the presence of and degree of recreational fishing in an area must be considered in the selection of suitable sites.

#### *4.4.2.3 Tourism and Recreation*

Aquaculture is generally considered to be highly compatible with tourism. The southern bluefin tuna industry operating off Port Lincoln, South Australia demonstrates the high level of interest generated by onshore and offshore aquaculture activities. Local tourist operators can take advantage of the opportunities to generate additional revenue by arranging visits to local aquaculture facilities. The Pilbara/Gascoyne Islands Ecotourism Management Strategy (Pilbara Development Commission, 1995) outlines the synergies between tourism and aquaculture and the mutual benefits that can result.

Sea cages may be incompatible with recreational activities such as SCUBA diving, since there is a perception that they may attract and increase the threat from large predators such as sharks. However, the initial public consultation process for this draft plan revealed that one existing operator is currently using his aquaculture site as a tourist dive site.

The main draw card for tourism in the region is the relatively pristine environment, which is rich in flora and fauna. The area is a major breeding ground for turtles and dugongs, and this attracts visitors to the area. The region has been identified as an important zone of opportunity for the development of Western Australia's tourism product. The Naval Communications base has major potential for the development of tourism accommodation now that the U.S. Navy has vacated the area.

There are a number of potential sites for aquaculture that are already being used as tourism and recreation sites. Areas around the township, for example, while being suitable for aquaculture, are popular for recreation and tourism. While in some instances, aquaculture operations may embrace tourism by offering a tourism experience, it should be noted that the primary business of aquaculture operators is not tourism, and therefore the quality of the tourism experience within high visitation areas is likely to suffer unless substantial resources are allocated to this aspect of the facility.

In areas of tourism or recreational activities, any aquaculture will need to take into account visual, odour and noise issues in relation to the proposal, with the recognition of the importance of nature based tourism and significant conservation values of the area. In some instances, a Visual Resource Management approach should be adopted to assess visual impacts.

Offshore aquaculture is usually incompatible in water areas reserved or generally used for recreational activities such as boating, sailing and other water sports. These activities are mainly undertaken in the vicinity of Exmouth township and Learmonth jetty.

# SECTION 5 MANAGEMENT STRUCTURE AND LEGISLATIVE ENVIRONMENT

## 5.1 Department of Fisheries

### *5.1.1 Fisheries Legislation*

With the exception of *Pinctada maxima*, fisheries and aquaculture in Exmouth Gulf are managed under the *Fish Resources Management Act 1994* (the Act). All objects of the Act are important, but the most relevant to aquaculture development in the Gulf include:

- To conserve fish and protect their environment;
- To enable the management of fishing, aquaculture and associated industries and aquatic ecotourism;
- To foster the development of commercial and recreational fishing and aquaculture; and
- To enable the allocation of fish resources between users of those resources.

To assist in fulfilling these objects, the Department of Fisheries maintains a District Office at Exmouth.

The Act also establishes the Aquaculture Development Council, whose functions are to identify issues that affect aquaculture; advise the Minister on such issues and the management of aquaculture; and to advise the Minister on other issues relating to aquaculture about which he may seek advice. The Department is a member of this Council and provides executive support.

*P. maxima* is managed under the *Pearling Act 1990*. A similar Ministerial advisory committee, the Pearling Industry Advisory Committee, exists for advising the Minister on the management of pearling.

### *5.1.2 Gascoyne Aquaculture Development Plan*

The Aquaculture Development Plan was prepared by the then Fisheries Western Australia and the Gascoyne Development Commission. The plan identifies species and locations along with the aquaculture potential of these for the Gascoyne Region, including Exmouth Gulf.

It made a number of recommendations in terms of general aquaculture development in Exmouth Gulf, which will be noted in Section 6 of this plan, as well as some specific recommendations in terms of actual sites:

*21. Determine the possibility of excising land from the northeast corner of the Harold E Holt Communications Base area for aquaculture development.*

*22. Identify potential aquaculture sites between the Kailis prawn processing operations and the former Nor West Seafoods site at Learmonth.*

*23. Identify and investigate the release of potential aquaculture development sites at Wapet Creek, Point Lefroy and the Sandalwood Peninsula.*

*24. Facilitate and support the establishment of a Tropical Marine Research Facility at the Harold E Holt Communications Base or at another appropriate location.*

### *5.1.3 Translocation policy*

The translocation of a species to an area in which it does not occur naturally for the purpose of aquaculture or stock enhancement is regulated according to Regulation 176 of the *Fish Resources Management Regulations 1995*. This states that a person may only move a non-endemic species into or within Western Australia subject to the written approval or authority of the Executive Director of Fisheries.

The principal issues that need to be considered in relation to the translocation of non-native species include the potential of the species to impact on genetic diversity, introduce disease and impact on the natural environment and the biodiversity of native species.

Issued pursuant to Section 246 of the *Fish Resources Management Act 1994*, Ministerial Policy Guideline No. 5, entitled *The aquaculture and recreational fishing stock enhancement of non-endemic species in Western Australia* (Fisheries WA 1997a), assists in the consideration of an application for the translocation of non-endemic species into and within Western Australia for aquaculture or stock enhancement purposes. The five policy guidelines may be summarised as follows:

- authorisation of the translocation of non-native species will be subject to a risk management assessment being carried out;
- the assessment would be undertaken by Fisheries WA within the context of an application and translocation synopsis provided by a proponent. Authorisation of the translocation would be conditional upon the assessment showing the translocation would present a low risk to the environment;
- the risk assessment must be based on the best scientific data available for the species and the environment into which it is to be introduced;
- the translocation application would be referred to relevant industry groups for consultation and public comment sought before any decisions are made; and
- the translocation decision should balance significant economic and social benefits with biological and environmental risks.

The assessment procedure that deals with applications for the translocation of non-native species for aquaculture and stock enhancement purposes has been developed by way of a Memorandum of Understanding between the Department of Fisheries and the Environmental Protection Authority.

Species for which translocation policies have already been developed are redclaw crayfish (*Cherax quadricarinatus*), silver perch (*Bidyanus bidyanus*), silver-lip pearl oyster (*P. maxima*) and barramundi (*Lates calcarifer*). Papers are currently being developed for Trout, Murray Darling species (Murray cod, Australian bass and golden perch) and black bream.

## 5.2 Gascoyne Development Commission

In 1996, the Gascoyne Development Commission published the Gascoyne Region Economic Development Strategy, which included broad strategies to "foster the development of a commercially significant aquaculture sector at appropriate locations throughout the region". Some

of the strategies proposed included:

- Appoint an Aquaculture Development Officer in the Gascoyne Region to promote aquaculture across the region;
- Publish a full inventory of suitable marine and terrestrial aquaculture sites within the region;
- Promote the Gascoyne Region as a centre of excellence for future pearl, shellfish and finfish developments;
- In order to achieve technology transfer and to provide information relating to the identification of marketable species, link commercial expansion of the industry to an appropriate learning institution;
- Develop a finfish hatchery in the region targeting high value fish product;
- Provide for the establishment of aquaculture activities in local government planning schemes throughout the region.

## 5.3 WA Planning Commission

### *5.3.1 Exmouth-Learmonth (North West Cape) Structure Plan*

This plan covers the western, southern and part of the eastern coast of the Exmouth Gulf and was prepared to ensure a number of major objectives would be met, including (but not only):

- to ensure that any future industrial development will have the least undesirable impact on the natural environment;
- to ensure the conservation and preservation of land with environmental value; and
- to promote sustainable uses that enable diversification of the economy while protecting the fragile environment of the North West Cape.

The structure plan is intended to aid in decisions relating to the region and to be dynamic with reviews and assessments occurring as the region develops and priorities change.

The plan divides the area into four planning units. Planning units one and four are of interest to this aquaculture plan. Planning unit one extends from North West Cape/ Point Murat south to Heron Point/ Point Lefroy, and abuts Planning Unit four, which takes in the southern coast and much of the eastern coast.

Within planning unit one, the structure plan recommended that aquaculture, along with a range of other "low impact activities", should be promoted at the naval communications station.

Many of the structure plan recommendations required proposals to consider a land capability study of the area. Utilisation of the land capability study would also aid aquaculture planning.

It was also recommended the Shire of Exmouth and Ministry for Planning prepare a Visual Amenity Plan to control building development on either side of the Minilya-Exmouth/ Murat Road between the Learmonth Airport and the Exmouth townsite. The Visual Amenity Plan may have implications for coastal aquaculture proposals in this area.

In planning unit four, the following guidelines and actions were recommended in the context of promoting sustainable uses that enable diversification of the economy while protecting the fragile environment:

- Promote the development of aquaculture projects in the area, including pearls, clams and wet fish (FWA, GDC, DOE, LG).
- Protect and manage the southern and eastern side of the Exmouth Gulf as a Marine Park (CALM, FWA, GDC).
- Encourage the Department of Fisheries to prepare an aquaculture development plan aimed at identifying specific sites in the Exmouth Gulf for aquaculture (GDC, FWA, MfP, WRC).
- Promote the identification of inland sites on pastoral land suitable for aquaculture (DOLI/ AgWA, PBWA, GDC).

The structure plan notes that the following areas are listed on the Register of the National Estate:

- mangrove communities in the southern and eastern coasts;
- a number of offshore islands; and
- marine terraces along the Gulf Coast which provide evidence of tropical cyclone events.

The Geological Society of Australia has identified four exposed marine terraces of the Pleistocene era on the west coast in the classic member of the Exmouth Sandstone as having geological heritage values.

The structure plan acknowledged the lack of biological information about the region.

## 5.4 Environment Protection Authority

### *5.4.1 EPA Draft Guidance Note 29: Benthic Primary Producer Habitat Protection*

Benthic primary producer habitat includes reef communities, seagrass, mangroves, corals and algal mat communities.

This guidance statement intends "to maintain the ecological integrity and biodiversity of the marine ecosystems of Western Australia" and "to maintain the integrity of the marine ecosystems of Western Australia to support the widest possible range of environmental values while recognising the current and projected future uses".

The guidance note details means of assessing the impacts related to the development of aquaculture on the loss of the primary producer habitat areas. The evaluation utilises a series of questions which consider the biophysical environment, previous ecosystem impacts and how much more will be lost if the development goes ahead. Criteria are also provided for the evaluations to be ranked in a system detailing acceptable levels of disturbance.

Of particular interest to aquaculture is that:

- in Category B areas, which includes the majority of zones in existing or proposed marine parks, "Development proposals should conform with the operational objectives of minimum

indirect disturbance and no loss of benthic primary producer habitat";

- in Category C areas, (i.e. areas not identified as having high conservation significance) "Development proposals should conform with the operational objectives of preventing the avoidable destruction of benthic primary producer habitat, and cumulative (total) losses should be kept within strict limits (see Table 1) whilst recognising uses designated prior to the formulation of this guidance". Table 1 specifies that for any given "management unit" the maximum cumulative (total) impact of irreversible change should be less than or equal to five per cent and for reversible changes, less than or equal to 10 per cent. A management unit "is a specific geographical area which provides the most effective boundaries for management of cumulative impacts on marine habitats".

### *5.4.2 Draft Environmental Protection (WA Marine Waters) Policy*

The EPA draft State Marine Waters Environment Protection Policy (EPP) aims to provide a consistent regulatory framework to protect Western Australia's marine environment. The policy considers activities that have the potential to degrade the State's marine waters, the environmental values of marine waters and the beneficial uses that are supported by those values, and establishes a program to protect environmental values.

The EPP specifies default environmental values to be protected, which includes sustainable aquaculture. The policy applies to three nautical miles off the coast.

### *5.4.3 EPA Guidance Note 34*

EPA Guidance Note 34 explains the linkage between EPA assessment and management strategies, policies, scientific criteria, guidelines, standards and measures adopted by National Councils. In essence, the Guidance Note endorses the spirit of existing and future management strategies, policies, scientific criteria, guidelines, standards and measures adopted by bodies including the:

- Council of Australian Governments (COAG);
- Australian and New Zealand Environment and Conservation Council (ANZECC);
- National Environment Protection Council (NEPC);
- National Health and Medical Research Council (NH&MRRC).

For aquaculture, this gives proponents guidance on air quality impacts, ecologically sustainable development, waste management, how water quality impacts should be addressed using the concept of environmental values, and the water quality standards associated with each environmental value.

## 5.5 Department of Conservation and Land Management (CALM)

Any application to the Department of Fisheries for aquaculture leases or licences goes through a consultation process with relevant government agencies, including CALM. CALM's environmental guidelines and procedures for advising on aquaculture and pearling proposals in Western Australia were released in December 1998 (Simpson, 1998).

Proposals should not compromise the principles of ecologically sustainable development, namely:

- maintenance of biodiversity;
- ecological integrity; and
- maintenance of intra-generational equity (i.e. equity among current users and avoidance of irreversible impacts).

CALM encourages a precautionary approach where information deficiencies exist for a proposal where there are serious concerns about environmental impacts. Of most significance to CALM is ecological risk, potential community conflict and location. To assess these factors, CALM has information requirements, including:

- mapping of benthic habitats at aquaculture sites;
- information about water circulation, bathymetry, tidal range etc;
- mapping of existing and proposed activities in the vicinity of the aquaculture site; and
- location with respect to substrate type, high usage areas, important biological resources, parks and reserves.

Within marine conservation reserves, the power of veto lies with the Minister for Environment.

## 5.6 Commonwealth Legislation

### *5.6.1 Ningaloo Marine Park Management Plan (1989)*

Ningaloo Marine Park extends south from Point Murat to just north of Exmouth townsite.

The Ningaloo Marine Park Management Plan identifies 10 objectives for the Ningaloo Marine Park, with four requiring consideration in developing aquaculture proposals, namely:

2. To integrate management and development of the Park with adjacent areas of land to achieve maximum effectiveness and optimum allocation of management resources.

4. To conserve native species, habitats and natural processes.

9. To ensure that all development activities are consistent with the maintenance of species populations, habitats, natural features, and cultural and scenic values.

10. To conduct research programmes aimed at understanding how impacts of use and natural processes affect the maintenance and management of the park.

Except for an area of Sanctuary Zone around the mangroves just south of Bundegi, a Recreation Zone applies for between two to five kilometres seaward, and then a General Use Zone extends a further 12km seaward to 114º 19' East. It is understood that the Sanctuary Zone may be enlarged

towards Bundegi.

Unlike more recent Marine Park Management Plans, the Ningaloo Marine Park Management Plan makes no reference to aquaculture as a potential use in the area or the compatibility of aquaculture with each zone. The Shark Bay Marine Park Management Plan does not permit aquaculture in Recreation and Sanctuary Zones. It is understood that the situation at Shark Bay should be considered to apply at Ningaloo with respect to compatibility of management zones with aquaculture.

The management plan notes that the situation regarding ballast water discharges from the Pier at the Naval Communications Station is not known.

### 5.7 Other policies and approvals

A number of other policies and approvals apply to aquaculture in Exmouth Gulf, and include:

- The Shire of Exmouth Town Planning Scheme. Aquaculture is a permitted use in the Marina, Industry, Pastoral and Special Rural zones. Town Planning Scheme Policy No 5 deals with the assessment of aquaculture proposals and focuses on amenity, visual impacts, roads and pollution prevention.

- Water and Rivers Commission. Discharges of less than 5,000 litres of wastewater per day that meet certain water quality criteria are acceptable. For larger scale projects, wastewater should be fully contained within the project site or be treated to a standard acceptable to the Department of Environment and Water and Rivers Commission prior to discharge.

# SECTION 6 THE EXMOUTH GULF DRAFT AQUACULTURE PLAN

## 6.1 Objective

The objective of the Draft Aquaculture Plan is to:

> *Provide a sound strategy for developing future aquaculture activities in Exmouth Gulf, while at the same time conserving the unique environment of Exmouth Gulf for present and future generations, and minimising conflict with existing and future users of Exmouth Gulf.*

## 6.2 Underlying assumptions

Given the significant natural value of Exmouth Gulf and the existing fishing, aquaculture and tourism industries, there are pre-existing conditions that will set boundaries for the development of aquaculture. Section 5 of this draft plan outlines the various plans and policies that will impact on aquaculture development in Exmouth Gulf. The most relevant of these is the Gascoyne Aquaculture Development Plan, as it was written with all other legislation and policies as the backdrop.

In general, the Gascoyne Aquaculture Development Plan suggests Exmouth Gulf is well suited to land and water-based culture systems because there is a supply of good quality water, existing compatible infrastructure present, including Learmonth Airport, and potential for integration with existing industries.

The southern and eastern shorelines may suit penning enclosures, racks, longlines and ranching a variety of shellfish species. The report notes that the occurrence of storm surges and their contribution to sedimentary processes on the tidal flats should be understood before approving land-based aquaculture proposals in this zone.

The southern and eastern sections of the Gulf, which are more sheltered, offer good sites for the use of sea cages for the growth of finfish and shellfish if sites of sufficient depth can be found. On-growing of wild caught fish so that they may be sold at premium prices outside the typical harvest season is also an option.

> Recommendation 1: Ensure that future aquaculture activities are consistent with the Gascoyne Aquaculture Development Plan. (proponent/DoF)

## 6.3 Species suitable for aquaculture in Exmouth Gulf

### *6.3.1 Species selection criteria*

A comprehensive assessment and selection of species is usually carried out during the early planning stages of a proposed aquaculture project, as one component of a detailed feasibility study. Numerous criteria need to be considered and evaluated when selecting a species of finfish or shellfish for commercial aquaculture. Each criterion can be considered for a range of aquaculture

candidate species, with particular reference to the region in which the proposed aquaculture project is to take place. To facilitate the selection procedure, the criteria may be arranged into four principal categories:

i marketing;
ii culture technology;
iii production efficiency; and
iv commercial viability.

A summary of the key elements of the species selection process, with specific reference to Exmouth Gulf, is provided below.[1]

#### *6.3.1.1 Marketing*

Due to the remote location of the North-West Cape, aquaculture projects in Exmouth Gulf will almost certainly be characterised by producing products with a high value and demand in domestic and export markets. Some limited quantities of product are likely to command reasonably high prices in the local, principally tourist market. Aquaculture projects would generally need to be structured to supply distant markets with premium-quality, high-value products that command a premium price to offset the disadvantage of distance from markets. An innovative marketing strategy could emphasise the production of premium-quality marine products in a pristine environment adjacent to a world-class coral reef and Marine Park.

Learmonth Airport, located approximately 35 km south of Exmouth, provides services for transporting freight by air to domestic and overseas markets. As tourism and other industries in the region continue to grow, it is anticipated that opportunities to export products from Learmonth Airport will increase.

#### *6.3.1.2 Culture technology*

Culture technology refers to the specific techniques used to rear a species in captivity under commercial conditions. More specifically, in respect to the contemplation of the suitability of a species for aquaculture, culture technology refers to the ability of the species to reproduce in captivity and the simplicity of the larval and early juvenile phases of its life history.[2] The culture technologies for many of the species of marine finfish that may be suitable for aquaculture in Exmouth Gulf are either poorly known or at an early stage of commercial development. Those of many of the marine shellfish species are better known and are already used in commercial projects.

Species selection criteria relevant to the reproduction in captivity of marine finfish and shellfish consider the broodstock (their occurrence, ease of capture and adaptability to captive conditions), their reproductive biology, captive spawning and factors in respect of egg production and viability.

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[1] For a more detailed description and discussion of species selection criteria for aquaculture, please refer to publications such as Aquaculture Planning in Western Australia: Part A: Synopsis and Review (Aquaculture Development Council and Fisheries WA, 1997).

[2] Within the context of this document, the expression *culture technology* refers to the technical procedures used to rear the larvae and early juvenile stages of finfish and shellfish, predominantly during the hatchery and nursery stages of the culture cycle. The term *grow-out*, which refers to the growing of post-hatchery or post-nursery juveniles to market size, is dealt with under the heading *Production Efficiency*.

The criteria relevant to larviculture and juvenile production factors for finfish and shellfish consider the size and development of the eggs and larvae, duration of the larval phase, various nutritional and physiological requirements of larvae and early juveniles and generally, the available larviculture and weaning technology.

#### *6.3.1.3 Production efficiency*

Production efficiency refers fundamentally to productivity. Linked by definition to the commercial viability of any aquaculture project, the production efficiency of a species deals mainly with factors such as nutritional requirements and the natural ability of the species to thrive under commercial grow-out conditions. An assessment of production efficiency contemplates criteria such as diet, growth rate, food conversion ratio (FCR), behaviour, disease resistance and the ability to withstand stress, crowding and handling. Given factors such as high operational costs and distance from major markets, aquaculture farms located in Exmouth Gulf will almost certainly have high production efficiencies.

Species for which supplementary feeding is not required, such as the *P. maxima* and non-*P. maxima* pearl oysters being cultured, will probably still be preferred to less profitable species and sites as their culture will be located in the optimum, most productive offshore sites. To minimise waste production and optimise production efficiency, farms growing species that require supplementary feeding will need to have access to pelletised diets that provide efficient FCRs.

Offshore production systems are likely to be limited in most areas of Exmouth Gulf, due principally to concerns by other users of the resource about the large-scale use of sea-cage farming systems in the well used offshore waters. Where they may be permitted, sea-cage production systems will have to reflect high production efficiency since they may be limited in area. Onshore production systems are considered ideal for aquaculture in coastal areas on the western side of the Gulf, due to the occurrence of suitable land areas and the ability of these systems to control and treat waste waters. Accordingly, species suited to intensive culture in onshore tanks, raceways and ponds are likely to be favoured.

#### *6.3.1.4 Commercial viability*

Stated simply, commercial viability refers to the relationship between the selling price and production cost of the product. Under the economic and environmental conditions prevailing in Exmouth Gulf, the comparatively high costs of establishing and operating aquaculture farms will also have a major impact on commercial viability.

The species selection criteria relevant to commercial viability or profitability factors in Exmouth Gulf are profitability, the potential for diversification, infrastructure requirements, competitiveness, regulatory factors and industry commitment and support.

A farm designed to have potential to diversify by producing several species or by integrating its activities with tourism may have competitive advantages over others. A farm that selects a species with a culture that requires minimal infrastructure may have advantages in terms of reduced capital costs. A species with culture technologies and production efficiencies compatible with automation and other means of reducing high production costs may have significant advantages in Exmouth Gulf.

In most cases, it is likely that aquaculture development projects would be staged. The life cycle of an aquaculture project generally proceeds through various periods and stages of development, with

some stages being further divided into a series of steps, according to the complexity of the project. The two main periods, which are *project formulation* and *project implementation*, can be divided into five principal stages, namely:

i. project identification;

ii. project preparation;

iii. project appraisal;

iv. project implementation; and

v. project evaluation.

The first three stages collectively constitute the project formulation period and the last two the project implementation period. The above stages normally proceed through two cycles - a pilot-scale project and then a full-scale commercial project. Commercial development may then proceed through a series of successive stages, as the production capability of the project is increased.

It is beyond the scope of this document to elaborate fully on this concept. However, it should be pointed out that as a conceptual or existing aquaculture project develops, it almost invariably increases in size and complexity. Aquaculture proponents have several options to deal with this attribute. They can take full responsibility for the development and implementation of the project themselves, or partially or fully assign responsibility to other personnel, private consultants or consulting companies specialising in project development and management.

### *6.3.2 Species with aquaculture potential in Exmouth Gulf*

Once evaluated according to predetermined selection criteria, aquaculture species can be classified according to their aquaculture potential, with specific reference to the area in which they are to be cultured and the characteristics of the individual projects.

The selection and classification of candidate species for aquaculture is predominantly subjective and based on other, similar planning studies undertaken for Western Australia, including Aquaculture Planning in Western Australia (Aquaculture Development Council and Fisheries WA, 1997) and the Gascoyne Aquaculture Development Plan (Fisheries WA and Gascoyne Development Commission, 1996).

The species considered suitable candidates for aquaculture in Exmouth Gulf would generally have:

- favourable marketing features;
- a well-known or moderately-known culture technology;
- a high level of production efficiency;
- a potentially-high commercial viability; and
- aquaculture requirements compatible with production systems considered technically, environmentally and economically suitable for Exmouth Gulf.

Further, given the environmental sensitivity and conservation values of Exmouth Gulf and adjacent waters, there is a strong preference for aquaculture candidates to be native species.

The following species list is inclusive. While it is considered reasonably comprehensive at this stage, it does not include all possible aquaculture candidates. Factors such as the development of new technologies and identification of new market opportunities will, in the future, qualify

additional species for commercial aquaculture in Exmouth Gulf.

### *6.3.3 Marine finfish*

Marine finfish species considered being candidates for aquaculture in Exmouth Gulf include the following (this list is not in priority order or in order of predicted success):

- mahi mahi (*Coryphaena hippurus*);
- amberjack (*Seriola dumerili*);
- trevally (*Caranx* spp., *Pseudocaranx* spp.);
- sea mullet (*Mugil cephalus*);
- barramundi cod (*Cromileptes altivelis*);
- mangrove jack (*Lutjanus argentimaculatus*);
- coral trout (*Plectropomus* spp.);
- red emperor (*Lutjanus sebae*);
- estuary cod (*Epinephelus coioides*);
- pink snapper (*Pagrus auratus*);
- western school whiting (*Sillago vittata*);
- marine aquarium fishes (various species);
- southern bluefin tuna (*Thunnus maccoyii*); and
- yellowfin tuna (*Thunnus albacares*).

#### *6.3.3.1 Pelagic fishes*

Mahi mahi may have good prospects for aquaculture in Exmouth Gulf. As mahi mahi require oceanic-quality water with very low turbidity, they would probably be restricted to being cultured in the northern areas of the Gulf. The market potential for mahi mahi has yet to be determined, but there is anecdotal evidence to suggest it would have high value in domestic and export markets. Despite several attempts, mahi mahi have not yet been successfully cultured at a commercial scale, although significant research has been undertaken to develop the culture technology. The commercial viability of mahi mahi aquaculture has yet to be determined.

The natural distribution of yellowtail kingfish does not extend as far north as Exmouth Gulf; however, the closely related species amberjack (*Seriola dumerili*) may be suitable for culture in the region. Given their close relationship, similar culture technology and production systems could be applied to both species. The market prospects, production efficiency and commercial viability of the species are unknown under Australian conditions, but may be marginal in Exmouth Gulf.

Trevally is common in all coastal waters of Western Australia. Numerous species of trevally exist and some may be suitable for aquaculture. Little is known about the culture of local species; however, numerous members of the family Carangidae are cultured worldwide and it is likely that the requisite technology can be adapted or transferred relatively simply. Marketing factors, particularly demand and price, are likely to be more important factors than culture technology and production efficiency in the aquaculture of trevally, the commercial viability of which will be determined principally by profitability and a low unit production cost. Unless a high profitability can be expected, trevally is considered marginal aquaculture candidates for Exmouth Gulf.

Sea mullet may appear unlikely candidates for aquaculture, but are included because aquaculturists are contemplating their use in integrated aquaculture systems, in which the species would be used as part of a waste-treatment process.

#### *6.3.3.2 Reef fishes*

Barramundi cod, mangrove jack, coral trout, bar-cheeked coral trout and red emperor are reef fishes all characterised by a high market demand and value.[3] It is also likely that this category of fishes may be expanded in the future to include other high-value reef species, such as emperors (*Lethrinus* spp.) and sea perches (*Lutjanus* spp.)[4] Exmouth Gulf is at or near the southern end of the ranges of many of these reef species.

Culture technologies for the reef species are in the process of being developed in countries that include Australia, Taiwan and Japan. Given their high value, it is expected that the technologies needed for their commercial culture will be available in the near future. Based on the culture of similar species elsewhere, it may be expected that the production efficiency and commercial viability of these species will be suitable for their successful commercial aquaculture. The species are considered suitable to the types of aquaculture systems that may be permitted in Exmouth Gulf; that is, in offshore cages located at the northern end of the Gulf and near the Muiron Islands and, more likely, under intensive culture in onshore systems with the ability to treat discharge waters.

Estuary cod inhabit areas northwards of Rottnest Island on the Western Australian coast and have a relatively high value in export markets, particularly in live form. The species is currently grown in Taiwan and the requisite culture technology is being developed in Australia. Preliminary work has been carried out on the species in Western Australia and Queensland, but very limited success has been achieved to date. Possibly less suited to aquaculture in Exmouth Gulf than the other reef fishes, there may be some limited potential for estuary cod grown in onshore systems for the live fish market.

#### *6.3.3.3 Demersal and benthic species*

Notwithstanding that the northern limit of the natural distribution of pink snapper is Coral Bay, the species is included as a candidate as an existing aquaculturist proposes to culture the species and possesses the requisite licence. The species has moderate market prospects, but a well-known culture technology. The production efficiency is poorly known at this stage and the commercial viability is likely to be marginal, particularly because the species is likely to adapt poorly to higher temperatures at the higher densities that would probably be required for its commercial culture to be viable.

Western school whiting, found between Coral Bay and Geographe Bay, is considered a marginal candidate for aquaculture in Exmouth Gulf. While it is likely to be a comparatively simple species to culture, its market features are such that its successful commercial culture in Exmouth Gulf is considered marginal at best.

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[3] Coral trout includes the true coral trout, *P. leopardus*, and the closely-related bar-cheeked coral trout, *P. maculatus*. Both species are native to coastal waters of Exmouth Gulf.

[4] To avoid confusion, it should be noted that red emperor, despite its common name, is actually a sea perch of the genus *Lutjanus*. It is also noted that barramundi cod is a true marine species and no relation to barramundi, a diadromous species with a more tropical distribution.

#### *6.3.3.4 Aquarium fishes*

Marine aquarium fishes with potential for aquaculture particularly include the species that inhabit coral reefs in tropical waters. These species have a reasonably high market value, particularly in terms of value per unit weight. At present, however, the technology required for their mass production is relatively poorly known; most marine aquarium fish supplied to domestic and export markets are captured in the wild. Once suitable culture technology is available, the production efficiency of these fishes is likely to be quite good, since they would be sold at an early age and for a comparatively high value per unit weight.

As culture technologies are developed, the same or similar species are produced in South East Asian countries, which have an established marketing network and other competitive advantages such as cheap labour. The commercial viability of aquaculture enterprises growing aquarium fishes in Exmouth Gulf will be governed largely by the extent to which local competitive advantages can be exploited and the relative costs and availability of cultured and wild-caught fish in global export markets.

#### *6.3.3.5 Tuna species*

Southern bluefin tuna and yellowfin tuna occur naturally in all offshore oceanic waters along the Western Australian coast.[5] These species may be ideally suited for aquaculture in Exmouth Gulf in the northern areas where the waters are more oceanic and turbidity is low.

At present in Australia, tuna aquaculture is limited to the grow-out or fattening of wild-caught juvenile fish in sea cages located off the coast of the Eyre Peninsula, near Port Lincoln in South Australia. The aquaculture of southern bluefin and yellowfin tuna off the western coastline of Western Australian is considered feasible from a technical perspective in the future, by growing out wild-caught juveniles as well as hatchery-reared seed stocks.

Preliminary research in several countries has indicated the viability of tuna aquaculture using hatchery-reared seed produced from captive broodstock. Their very high market value, particularly for southern bluefin tuna, makes the commercial aquaculture of these species feasible in difficult, remote locations. From a physiological perspective, there is no reason the tunas cannot be cultured in warmer waters than previously considered suitable; indeed, warmer waters could have significant positive effects on production efficiency factors, such as growth rate and FCRs.

The commercial viability of the aquaculture of southern bluefin and yellowfin tuna in Exmouth Gulf is considered promising.

Given the high market value of the species and the high degree of national and international interest in their culture, the hatchery production of southern bluefin tuna and yellowfin tuna may be achieved in Australia in the near future. Exmouth has oceanic-quality water and is the closest point on the Australian mainland to the natural spawning grounds of southern bluefin tuna, and may provide an ideal site for the establishment of a tuna hatchery.

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[5] Tuna are pelagic fish; however, in this study they are considered separately from other pelagic species as they comprise a distinct group, generally with very high market values, similar culture technologies and production efficiencies.

### *6.3.4 Marine shellfish*

Marine shellfish species considered to be candidates for aquaculture in Exmouth Gulf include:

- black tiger prawn (*Penaeus monodon*);
- artemia (*Artemia* spp.);
- tropical abalone (*Haliotis assinina*);
- trepang (*Holothuria* spp.);
- mud crab (*Scylla serrata*);
- giant clam (*Tridacna* spp.); and
- edible oyster (*Crassostrea commercialis*).

#### *6.3.4.1 Black tiger prawn*

The black tiger prawn is considered an excellent candidate for aquaculture in Exmouth Gulf, where a commercial venture is planned. The species is characterised by high market values in domestic and many export markets, and known culture technology. Hatchery and grow-out procedures are well known, but broodstock maturation in captivity is difficult, and the industry currently relies on the supply of wild-caught spawning stock for its egg supply.

The production efficiency and commercial viability of the species under Australian conditions are well known. Little is known at present about the viability of the species in Western Australia; however, it is the most widely produced marine prawn in Australia and one of the most widely produced worldwide. Australian farms are located mainly in Queensland, where the industry is characterised by several small producers. It is likely that fewer, larger producers would be able to attain a competitive advantage in the market by taking advantage of economies of scale.

The brackish-water systems commonly used to culture marine prawns would not be suited to the Exmouth Gulf region, given the lack of brackish and freshwater resources. However, the black tiger prawn is now frequently cultured in water with salinity equal to or greater than that of seawater (35,000 ppm) and there are reports of the species being cultured at a salinity of 40.

A disadvantage of black tiger prawn aquaculture in the Gulf is the low temperatures that can be experienced during the winter months: it has been reported that the sea surface temperature in the upper reaches of the Gulf can decline to about 11ºC. Management methods to mitigate the impact of low winter temperatures would include staging production schedules so the ponds would be empty during the critical months, during which time they would presumably be dried out and prepared for subsequent stocking.

In the future, black tiger prawn farms located in Exmouth Gulf may be subject to competition from producers in the Pilbara and Kimberley regions of Western Australia, which have good sites for marine prawn aquaculture and the added advantage of warmer growing temperatures.

The culture of black tiger prawns, and possibly other marine species suitable for the local environment, may offer future opportunities for polyculture with finfish species. In a typical marine prawn pond, the dominant bacteria are gram-negative, while in a fish pond they are gram-positive. Species cultured in a gram-positive pond are reported to be less susceptible to disease, so marine prawns grown in ponds in which fish are cultured, or in a system in which water discharged from fish ponds is supplied to marine prawn ponds, can take advantage of the gram-positive bacteria produced by the fish, and may therefore become less susceptible to disease.

In a system that grows fish and marine prawns in the same pond, the fish should be cultured in cages located within the ponds.

#### *6.3.4.2 Artemia*

Artemia or brine shrimp are produced in arid tropical and subtropical environments and used worldwide as a live food in marine and freshwater aquaculture hatcheries. Per unit weight, artemia may be considered a high-value aquaculture product. Market prices range according to supplies, which may vary from year to year.

The product from this species would principally be desiccated cysts for use in hatcheries, but could also include limited quantities of biomass for sale to the aquarium trade.

The culture technology for artemia is well known; however, as a rule, aquaculture operations producing the species do not have any operational inputs and hence costs, but depend instead on the natural productivity of salt lakes and harvest the desiccated cysts seasonally. Using this production method, the production efficiency is high. The commercial viability of artemia aquaculture in Exmouth may be good if salt lakes that can provide the requisite production and harvesting areas can be established economically. Large areas on the eastern side of the Gulf have previously been contemplated for salt mining, so the area may suit the construction of evaporative ponds for artemia production, possibly integrated with salt mining.

#### *6.3.4.2 Tropical abalone*

Exmouth Gulf is well within the range of the tropical abalone. As for most abalone species, the market potential for tropical abalone is very good. Culture technology for the species, currently being developed but unproven under commercial conditions, is likely to be available in the near future. Production efficiency and commercial viability are also unknown, but given the good market prospects and probable high value, are likely to be positive.

The culture of the species in the Gulf will be governed to some degree by the availability of suitable sites and the demonstration of some competitive advantage over warmer sites that would be available in the Pilbara and Kimberley regions. Aquaculturists contemplating the production of tropical abalone would probably seek sites north of Exmouth and preferably in the Pilbara or Kimberley regions, where improved production efficiencies and commercial viabilities would probably be achieved.

#### *6.3.4.3 Trepang (Beche de mer)*

Trepang or sea cucumbers have a high market value in South-East Asian markets. The culture technology for the various species is currently being developed and the production efficiency and commercial viability are presently unknown. The species occurs naturally in the Gulf and, subject to the development of the requisite technologies, may be a good aquaculture species in the future.

#### *6.3.4.4 Mud crab*

Mud crabs have moderate to high values and are very popular in South-East Asian markets, including Malaysia, Singapore, Hong Kong, China and Taiwan. Better prices are usually achieved for live product. The supply of mud crabs from traditional sources is decreasing due to over-exploitation and importers are now constantly seeking new sources of supply. The culture

technology for the species is still being developed and its production efficiency and commercial viability are poorly known.

#### *6.3.4.5 Giant clam*

Giant clams have moderate market prospects in South East Asian markets, and there is a limited market for small specimens in the aquarium trade. Generally grown at sites with oceanic-quality seawater, there may be limited potential for the species in the Gulf. The culture technology is available and the species is cultured in several Pacific Ocean island nations. The production efficiency and commercial viability of the species under conditions that prevail in the Gulf have yet to be determined.

A previous giant clam aquaculture operation in Exmouth Gulf failed for reasons that have not been disclosed.

#### *6.3.4.6 Edible oyster*

Western rock oysters, the same species as the highly-regarded Sydney rock oyster, occur naturally in Exmouth Gulf and are known for their excellent eating quality. The culture technology for many edible oyster species is well known and the western rock oyster has previously been produced in a commercial hatchery. Subject to the availability of suitable sites and conditions, the production efficiency is high. The commercial prospects for western rock oyster aquaculture in the Gulf are considered good, provided that suitable sites with the requisite tidal characteristics are available, possibly near the eastern shore, for rack and longline production systems.

It is unlikely that the translocation of non-native edible oysters, such as the Pacific oyster (*Crassostrea gigas*), to Exmouth Gulf would be permitted.

### *6.3.5 Excluded species*

Several species identified in the various aquaculture planning studies have been excluded from the above lists because, for various reasons, they are considered unsuitable for aquaculture in Exmouth Gulf at present. The excluded species are listed below.

- Diadromous, freshwater and non-native or introduced species, the successful culture of which is unlikely under the conditions prevailing at Exmouth Gulf due to the very limited availability of freshwater. This category includes eels, barramundi, freshwater aquarium species, other freshwater fishes and kuruma prawn.
- Native marine species whose natural distribution does not include Exmouth Gulf; such as yellowtail kingfish, Westralian dhufish, black bream, King George whiting, large-toothed and small-toothed flounder, baldchin groper, cobbler, greenback flounder, trochus, greenlip and brownlip abalone and blue swimmer crab.
- Species that are native to coastal seas in the vicinity of Exmouth Gulf but with marginal prospects for commercial aquaculture due to low market value or inappropriate current production systems and aquaculture technologies. These include milkfish, western yellowfin and silver bream, mulloway, baldchin groper, southern Australian herring, breaksea cod and saucer scallop.

As aquaculture technologies and market conditions change, some of these species may become suitable, and hence, although excluded from detailed consideration, applications would be

considered on a case-by-case basis.

**Table 2: Summary of the merits of current and candidate aquaculture species for Exmouth Gulf.**

| Species | Status | Comments |
|---|---|---|
| Silver-lip pearl oyster | Currently cultured in Exmouth Gulf and widely in the Pilbara and Kimberley regions. Market prospects are excellent and all aspects of the production of the species are known. | A *P. maxima* hatchery has been built in the Gulf and the area has good prospects for the culture of the species. |
| Blacklip oyster | Currently cultured in the Gulf. As for other pearl oyster species, market prospects are excellent, though less lucrative that for the silver-lip pearl oyster, and all aspects of the production of the species are known. | The culture of the species in the Gulf is likely to expand. |
| Southern bluefin tuna<br>Yellowfin tuna | Market prospects are very good. Production technologies are available for on-growing wild fish and developing for hatchery production. Commercial viability will probably be very good. | Well suited to culture in offshore cages in areas with oceanic-quality water. One of the more viable marine finfish candidates due to high value. |
| Mahi mahi<br>Amberjack<br>Trevally<br>Sea mullet | Market values and demand varies and culture technologies generally poorly known. At suitable sites, production efficiencies are likely to be high and commercial viability high. Sea mullet likely to be viable only in integrated systems. | Suited more to production in onshore systems employing water treatment or recirculating systems. Suitable offshore sites for cage culture may be feasible but are likely to be limited. |
| Barramundi cod<br>Mangrove jack<br>Coral trout<br>Emperors<br>Sea perches<br>Estuary cod | Market demand and values are high, particularly for live fish. Culture technologies are poorly known but being developed. Production efficiency and commercial viability will probably be good. | Possibly suited to production in onshore systems employing water treatment or recirculating systems. Suitable offshore sites are limited for species other than estuary cod, which can be grown in turbid water. |
| Snapper<br>Western school whiting | Markets can only be considered moderate. Technology is available for both species. Production efficiencies and commercial viability are unknown. | Possibly suited to onshore systems with treatment or recirculating systems. Ponds may provide the means to lower production costs and improve commercial viability. Offshore sites are limited and likely to be used for higher-value species. |

**Table 2 continued**

| Species | Status | Comments |
|---|---|---|
| Marine aquarium species | High-value markets but poorly-known culture technologies and unknown viability. | Ideally suited to onshore systems due to limited water requirements. Possibly excellent future prospects. |
| Wing oyster | Market prospects are good, though less lucrative that for the silver-lip and possibly other pearl oyster species, and all aspects of the production of the species are known. | The culture of the species is currently being undertaken. |
| Black tiger prawn | Good market prospects, well known culture technology, probably good production efficiencies and commercial viability, particularly for high-yield projects. | A project is planned. There may be future competition from farms at warmer sites in the Pilbara and Kimberley growing the same species. |
| Artemia | Worldwide high value markets, well known culture technology and production efficiencies in certain systems. | May be commercially viable in the Gulf if suitable sites can be found and evaporative ponds established economically. |
| Tropical abalone | Good market prospects. Indications are that the culture technology will be available soon and the species will probably have good production efficiency and commercial viability. | Tropical abalone is considered a very good candidate for tropical aquaculture |
| Trepang<br>(Beche de mer) | Good market prospects. The species is not currently cultured but the requisite technology is being developed. Other factors relating to production and commercial viability are unknown for conditions at Exmouth Gulf. | Since the species is targeted for culture in several Pacific Ocean nations, the viability of its culture in the Gulf may be poor, unless there are significant local advantages. |
| Mud crab | Reasonable prospects in export markets. Culture technology is likely to be available soon, but production efficiency and viability may be marginal. | Any mud crab industry established in the area would have to be able to compete effectively with South-East Asian producers. |
| Giant clam | Reasonable market prospects and developed culture technology. Production efficiency and viability are unknown. | Considered a marginal candidate for Exmouth Gulf. Other areas are likely to be more viable. |

**Table 2 (continued)**

| Species | Status | Comments |
|---|---|---|
| Edible oyster | Market demand and prices are good for high-quality product. Culture technologies are well known. Production efficiencies and viability are unknown but may be good at suitable sites. | Considered a moderately good aquaculture candidate for Exmouth Gulf. |

Recommendation 2: Consider the species listed as suitable in Table 2 as candidates for aquaculture in Exmouth Gulf. In the event that a proponent lodges an aquaculture licence application for Exmouth Gulf involving species not included in the list, consider these other species according to their merits on an individual case basis. (DoF)

Recommendation 3: Consider applications for endemic species not listed as suitable in Table 2 on a case-by-case basis. (DoF)

Recommendation 4: Prohibit aquaculture of non-endemic species in Exmouth Gulf, unless the EPA has granted specific approval.(DoF)

Recommendation 5: Ensure that licensed aquaculturalists utilise local broodstock. Any translocation of broodstock must be subject to the translocation guidelines. (proponent/DoF)

## 6.4 Production systems suitable for Exmouth Gulf

The relative costs of establishing onshore and offshore aquaculture systems with equivalent production capabilities can vary significantly, according to certain, site-specific factors. Onshore systems usually cost more to establish than equivalent offshore ones; however, in some cases they can be cheaper. The operating costs of the two are similarly influenced by site-specific factors. The principal benefits associated with onshore production systems include the more comprehensive management and control over the stock and environment that are possible. Further, well-designed onshore systems with adequate back-up capabilities are generally far less risky to the aquaculturist and permit a significantly greater degree of control over the quality of water being discharged back into the environment.

Generally, the aquaculture production systems preferred in Exmouth Gulf should be those with a capacity for financial and environmental sustainability; that is, those characterised by, and which can demonstrate, a high level of management and control over the aquaculture processes and the quality of water being discharged.

The onshore and offshore aquaculture production systems that may be suitable for Exmouth Gulf are discussed in the following sections and in Appendix B.

### *6.4.1 Onshore production systems*

#### *6.4.1.1 Location and water type*

The onshore locations in the Exmouth Gulf study area are all coastal.

From a technical perspective, onshore systems may be located in the coastal land areas of Exmouth Gulf at sites that satisfy certain physical, biological, social and economic criteria, such as topography, water quality and infrastructure. Onshore operations would be required to comply with guidelines or regulations governing the amount of seawater drawn from the Gulf, the means by which the seawater is supplied and discharged, and the quality of the water being discharged. Subject to these requirements being met and land areas being available, much of the coastal land encompassing Exmouth Gulf is considered suitable for the aquaculture of a range of native species using the most appropriate production system.

All onshore systems are likely to use seawater and culture marine species only. The scarcity of freshwater in the area would preclude the production of species that require fresh or brackish water.

#### *6.4.1.2 Culture units*

The culture units that would be used in onshore aquaculture systems would predominantly include tanks, raceways and ponds. In intensive systems, tanks are likely to be used for the production of finfish and raceways for some shellfish species. Small, lined ponds may also have some applications, according to the requirements of the species under culture. Larger ponds would be used for the culture of species such as marine prawns under semi-intensive to intensive culture conditions.

The proper planning and design of onshore aquaculture production systems will be essential to ensure their efficient management, cost-effective operations and the effective treatment of water being discharged.

#### *6.4.1.3 Water flow*

Onshore systems located in coastal areas of Exmouth Gulf would almost certainly flow-through and depend on pumped water.[6] For most species, recirculating systems are not considered commercially viable for use in the Exmouth Gulf area, since they are unlikely to be competitive. The onshore production systems would usually require large volumes of high-quality sea water as well as suitable structures for water intake and discharge.

#### *6.4.1.4 Intensity*

Due to the importance of the Exmouth Gulf environment in terms of its conservation value and the various commercial and recreational activities it supports, a critical feature of any onshore aquaculture farms that may be established in the area will be the capacity to treat the water discharged from the system to meet defined quality standards. The cost of discharge-water

[6] Some recirculation may be used in hatcheries to facilitate control over certain water quality or environmental parameters; however, the commercial grow-out of most species would almost certainly depend on the use of flow-through systems.

treatment plant and equipment needed for this purpose suggests that onshore, coastal aquaculture production systems in the Exmouth Gulf region are likely to be predominantly intensive and target high-value species. Because the area is remote, onshore production systems will probably be more expensive to establish than comparable systems located closer to Perth. The anticipated trend towards intensive systems will also ensue from the need to maximise the yield from the systems by using high densities and intensive management and husbandry techniques.

The establishment of semi-intensive to intensive systems is likely to be feasible in areas where larger land areas are available for the construction of ponds.

Sites located on the western coast of the Gulf would probably be more suited to intensive aquaculture, since they are more easily accessed by road and infrastructure and services are more readily available. Sites on the southern and eastern coasts are more remote and difficult to access by road, but may have larger land areas available. The latter areas are therefore more likely to support semi-intensive systems.

#### *6.4.1.5 Scale*

Aquaculture developments in coastal areas of Exmouth Gulf are likely to occupy small, medium and large-scale areas. More intensive operations on the western coast, particularly those growing high-value species, are likely to be predominantly small-scale, but some medium-scale operations may be feasible. Semi-intensive onshore systems growing finfish and shellfish species in ponds located on the southern and eastern coasts of the Gulf will be medium to large scale and may occupy areas in excess of 100-200 ha.

#### *6.4.1.6 Integration*

Most onshore systems will be characterised by some degree of vertical integration, in that they would comprise a hatchery, with the ability to reliably and consistently produce mass quantities of juveniles of the target species, and a grow-out facility. Some operations may focus on hatchery production, and others on grow-out. It is further contemplated that early diversification will be a priority in the region and that some leading operations will become multi-species producers.[7]

Horizontal integration is considered likely in Exmouth Gulf, principally between aquaculture and the tourism industry. The use of polyculture as a component of wastewater management and treatment systems for grow-out farms is also likely.

### ***6.4.2 Offshore production systems***

#### *6.4.2.1 Location and water type*

Offshore locations in Exmouth Gulf are all classified as nearshore; there are no locations in the region that can be described as open ocean.

[7] It is worth noting an important difference between polyculture and multi-species aquaculture. Both types of aquaculture involve the production of more than one species within a single production system; however, in polyculture, there is some interdependence between the species, while in multi-species aquaculture there is not, and each species is produced independently of the others.

From a technical perspective, offshore systems may be located in nearshore areas at sites that satisfy certain physical, biological, social and economic criteria, such as water quality, hydrography, hydrology, fishing areas and proximity to a shore base. Any offshore operations would be required to comply with regulations in place to protect native aquatic species. It is anticipated that, within the Gulf, the most suitable offshore sites would be those that do not interfere with the trawl fishery and other existing activities.

By definition, all offshore production systems would be marine systems. In the Gulf, the salinity will usually approximate that of seawater.

#### *6.4.2.2 Culture units*

Offshore production systems in Exmouth Gulf would principally include longlines, racks and sea cages. The culture units would be subject to varying degrees of exposure, water quality and several other factors, according to their type and location. The main factors that need to be considered in their selection and design include the species under culture, tides, currents, waves, wind and exposure to storms.

Within the Gulf itself, particularly in its upper reaches, offshore production systems using longlines as culture units for filter-feeding shellfishes are likely to predominate. In suitable intertidal areas, racks could be used for the culture of edible oysters. Sea cages may also be used for the culture of some finfish species, such as estuary cod, that would be suited to the relatively turbid water. Longline systems are already used in the region to culture silver-lip pearl oysters and non-*P. maxima* pearl oysters, an industry sector that holds significant promise. These culture units are well suited for shellfish and likely to expand, subject to determinations in respect of site availability, productivity and sustainability.

The use of barrels and small cages, suspended from longlines for the offshore production of species that require feeding, such as abalone, may also present opportunities for offshore aquaculture. Due to their requirement for supplementary feeding, culture units growing these species would be subject to similar constraints as those producing finfish. Several sites in the Gulf area may be suitable for the aquaculture of a range of species, using longlines, racks and cages.

Subject to the availability of adequate quantities of juvenile fish for seed stock, limited numbers of cages may be established in nearshore locations at the northern end of the Gulf, where conditions are more oceanic.[8] Where they do become established, floating sea cages are likely to predominate.

#### *6.4.2.3 Water flow*

Based on current technology, by definition, all offshore production systems in Exmouth Gulf would be open.

[8] The sea cages that may be established in the northern areas of Exmouth Gulf are likely to be limited in number because of the possibility of conflicting resource use. Further, the water depth in areas with oceanic-quality water is considered marginal for commercial-size cages. There may be some possibilities further offshore, in the vicinity of islands such as North and South Muiron, for locating sea cages.

#### *6.4.2.4 Intensity*

Offshore aquaculture production systems in Exmouth Gulf are likely to be predominantly intensive to semi-intensive. Longline systems that support a moderate stocking density of filter-feeding species that require no supplementary feeding are usually considered semi-intensive. The culture of pearl oyster species on longlines involves a high level of technical expertise, management and husbandry, so these systems are usually considered semi-intensive to intensive. Racks used to culture species such as edible oysters will generally require a semi-intensive level of management.

Cage systems used to grow finfish will vary from semi-intensive to intensive, according to the species under culture and the location of the cages. The intensive production of large volumes of high-value species will probably be necessary at the more remote, offshore sites at the northern part of the study area to justify the initially-high capital costs that will be necessary to establish suitable production systems.

#### *6.4.2.5 Scale*

It is anticipated that offshore aquaculture in Exmouth Gulf will include small to medium-scale production systems.[9]

#### *6.4.2.6 Integration*

Some degree of vertical integration will be necessary, since offshore production systems invariably need to be supported by onshore facilities or bases. Horizontal integration is likely to be limited to the tourism operators; polyculture systems are unlikely.

## 6.5 Types of aquaculture for Exmouth Gulf

### *6.5.1 Aquaculture*

From the perspective of the development of sustainable, commercial aquaculture, Exmouth Gulf has several features that will govern the selection of species and production systems. These are principally:

- the availability of a reasonable number of suitable onshore and offshore sites;
- water temperatures and habitats suitable for the culture of numerous tropical and subtropical species; and
- the general availability of good infrastructure and services.

Given the conservation, commercial, recreational and tourism values of Exmouth Gulf, aquaculture ventures proposed for the area would need to demonstrate that their activities would have minimal impacts on the local environment. One of the best ways to achieve this outcome is by including equipment and processes in the farm design that permit efficient control over the culture environment and effective waste treatment.

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[9] Some licences or leases may be issued for areas greater than 200 ha; however, within the context of this study, the scale refers to the area the production system physically occupies, not the total site area.

Therefore, aquaculture in the Gulf will almost certainly be characterised by intensive and semi-intensive production systems that include an effective waste management system. Similarly, the commercial returns from aquaculture ventures will need to be such that the additional capital and operating costs are warranted; accordingly, it is anticipated that these production systems, whether onshore or offshore, will be used to grow high-value species.[10]

Aquaculture in onshore locations is expected to predominantly use intensive systems and feature efficient processes for the treatment of water discharged from the growing units. Offshore production systems are anticipated to be semi-intensive to intensive, varying according to site and species.

The different elements of aquaculture production systems may be combined in a variety of ways to provide the combination that will best suit the species under culture, the environment and the aquaculturist. The combination will have a significant influence on the long-term environmental and commercial sustainability of an aquaculture operation.

Table 3 provides a summary of the respective merits of the various elements, with specific reference to the environment and other conditions prevailing in Exmouth Gulf.[11]

Table 4 links candidate aquaculture species with production systems and provides relevant comments. Species currently being cultured in Exmouth Gulf are not included, since their production systems are already developed.

[10] The species of finfish and shellfish considered suitable for aquaculture in Exmouth Gulf are discussed in Section 6.3

[11] It should be noted that the information contained in Table 3 is subjective and not considered unequivocal. The objective is to provide guidelines to aquaculturists:

i about the elements of aquaculture production systems that may be used to assess the merit of an initial concept; and

ii to assess the best means whereby waste management controls may be most efficiently effected.

**Table 3: Summary of aquaculture production systems considered suitable for Exmouth Gulf.**

| Element | Onshore | Offshore |
|---|---|---|
| Water type | Marine. | Marine. |
| Culture unit | Tanks, raceways and ponds, according to the species, location and intensity. Tanks and raceways for more intensive systems on the western coast, ponds in southern and eastern areas. | Predominantly longlines, with racks possible in areas near the eastern coast and cages in northern areas with oceanic-quality water. |
| Water flow | Flow-through systems will predominate. Some recirculation for specialist applications. | Open-flow systems will be used. |
| Intensity | Intensive to semi-intensive, according to the species and type of culture unit. Tanks are more likely to be intensive and ponds semi-intensive to intensive. | Principally semi-intensive to intensive, according to species, culture unit type and management level. |
| Scale | Small, medium and large-scale operations. Generally, smaller scale for finfish and larger scale for shellfish such as marine prawns. | Small to medium-scale operations. |
| Integration | Most operations would have some degree of vertical integration. There are reasonable prospects for polyculture. Opportunities exist for integration with the tourism industry. | Offshore systems are likely to be integrated with onshore hatcheries and other infrastructure. Good opportunities exist for integration with tourism, particularly for sea cages. |
| General | Onshore farms should ideally include effective wastewater management systems, focusing on the minimisation and removal of wastes by efficient feeding, filtration and concentration. | A reasonably large area is considered to have no current constraints for aquaculture. High operating costs are likely for offshore operations in more exposed, northern areas. Strategies for waste management would be largely limited to improving feeding efficiencies. |

**Table 4: Summary of aquaculture species for Exmouth Gulf, in relation to likely culture units.**

| Species | Production system | Comment |
|---|---|---|
| Southern bluefin tuna<br>Yellowfin tuna | Semi-intensive to intensive offshore systems using large-diameter cages located in oceanic-quality water. Intensive, onshore production in tanks may be possible if and when hatchery-reared stocks become available for aquaculture. | Seed stock would have to be acquired from the wild or, in the future, a hatchery that may be established. |
| Mahi mahi<br>Amberjack<br>Trevally<br>Sea mullet | Intensive to semi-intensive, onshore, flow-through systems, mainly using tanks, raceways and ponds, according to species and location. Semi-intensive to intensive offshore systems using longlines, racks and sea cages. Sea mullet mainly included as a low to medium value species for use in polyculture. | Offshore systems are likely to mainly use longlines within the Gulf itself. Cages may conflict with existing uses and may be restricted to northern, oceanic areas. Onshore systems have an added advantage of being able to treat discharge water. |
| Barramundi cod<br>Mangrove jack<br>Coral trout<br>Emperors<br>Sea perches<br>Estuary cod | Mainly intensive, onshore, flow-through systems using tanks located on the western coast, or intensive to semi-intensive offshore systems using cages. Estuary cod may be grown in more turbid water. | The high value of these species would override many constraints applied to other marine finfish species. Additional investment would be warranted in intensive onshore systems to treat discharge water. |
| Pink snapper<br>Western school whiting | Due to the lower value of these species, their commercial culture will probably only be feasible in onshore, semi-intensive, flow-through systems using ponds. | Pink snapper will possibly be marginal are more suited to cooler areas to the south. |
| Marine aquarium fish | Intensive to semi-intensive, onshore, flow-through systems, using tanks and small ponds. | Exmouth Gulf is considered an excellent location for marine aquarium fishes. |
| Wing oyster | Offshore, semi-intensive systems using longlines. | Appears to have reasonably good prospects for commercial culture. |

**Table 4 (continued)**

| Species | Production system | Comment |
|---|---|---|
| Black tiger prawn | Onshore, semi-intensive to intensive systems using levee ponds located on southern areas of the western coast and the southern and possibly eastern coasts. | Competition may occur with producers in warmer areas to the north. Management methods would need to be used to cope with low water temperatures during the colder months. |
| Artemia | Extensive systems using evaporative salt lakes on the eastern coast. Successful systems are likely to feature minimal or no production costs and efficient harvesting and processing methods. | Good potential for cyst production due partly to the arid environment and high evaporation rates. Potential for integration with salt mining operations. |
| Tropical abalone | Semi-intensive to intensive offshore systems, using barrels or other containers suspended from longlines. Semi-intensive to intensive onshore systems, using tanks and raceways. | All systems would probably need oceanic-quality seawater, so onshore sites pumping filtered ground water and offshore sites located in oceanic-quality water in northern areas are more likely. Possible competition from growers in warmer areas to the north. |
| Trepang (Beche de mer) | Preferred production systems are presently under development and poorly known. | Significant competition from overseas producers with more suitable sites is anticipated. |
| Mud crab | Principally onshore production systems using ponds located in turbid areas to the south and east. | Commercial culture may be feasible when the technology is available. Competition will exist with South-East Asian producers, who will have access to the same technology but lower production costs. |
| Giant clam | Principally offshore, open systems. Considered less suited to turbid conditions, so sites may be limited to northern areas. | Significant competition from overseas producers in the Pacific Ocean with more suitable sites is anticipated. |
| Edible oyster | Semi-intensive, intertidal, offshore systems, mainly using racks. | Suitable sites may occur on the eastern coast, but may be limited due to the presence of mangroves. |

Recommendation 6: Aquaculture production in the Gulf should be characterised by:

- the selection of high-value species, with the exception of some medium to low-value species used in integrated discharge-water-treatment systems;
- the use of both onshore and offshore locations, varying according to species and production system;
- the use of intensive and semi-intensive production systems, using tanks, raceways, ponds, longlines and sea cages;
- waste-management strategies and discharge-water-treatment systems being employed, particularly for onshore systems; and
- extensive environmental monitoring of impacts of activities. (DoF)

### *6.5.2 Management of aquaculture-related activities*

Applications may be made from time to time to replenish wild stocks of existing fish resources, either through reseeding or stock enhancement. Provision of hatchery stock for such purposes is accepted as a potentially viable aquaculture activity. Management policies for reseeding and stock enhancement within Western Australia are currently being developed and proponents should consult with the Department of Fisheries to ascertain what guidelines and regulations are in place.

Recommendation 7: Applications for wild stock reseeding and enhancement will be considered on a case-by-case basis. (DoF)

## 6.6 Environmental management of aquaculture

### *6.6.1 Environmental impacts associated with aquaculture activities in Exmouth Gulf*

No specific information exists on environmental impacts arising from existing aquaculture operations within the Gulf; however, a general discussion of the impacts of the environment on aquaculture and the impacts of aquaculture on the environment follows.

### *6.6.2 The impact of the environment on aquaculture*

Almost invariably structured around the use of natural waters and sometimes utilising the natural food chain, aquaculture systems are an integral part of the environment. They therefore affect, and are affected by, the local environment. In most cases, adverse ecological changes become risk factors to aquaculture, which is usually the first user of the resource to suffer from environmental mismanagement. Some natural factors that can influence aquaculture, such as storms and floods, are beyond human control; others, which ensue from some form of human intervention, can usually be mitigated to some degree by the establishment of effective management strategies (Phillips, 1995).

From the perspective of sustainability, the impact of the environment on aquaculture is as important as that of aquaculture on the environment. The consideration of environmental issues in respect of aquaculture almost invariably focuses on the waste materials produced by aquaculture activities and their effect on the surrounding environment. The effect of the environment on aquaculture,

however, is seldom considered in the same context. In considering the suitability of a site for marine aquaculture (both onshore and offshore), the quality of the seawater and the capacity of the aquatic system to carry and assimilate nutrients that may arise from aquaculture need careful consideration.

In respect of the impact of the environment on aquaculture, two main issues need to be considered, *viz*.: the potential impact of the natural environment and the impact of the environment that may be modified as a result of the planned aquaculture activities. The latter can be very difficult to determine until operations are underway. Because of the critical impact that the environment can have on aquaculture, the sustainability and long-term success of a fish farm will depend on the preservation of a healthy environment.[12]

The environment can impact on aquaculture through environmental changes resulting from natural and unnatural factors, such as the presence of pollution, contamination (some of which may be due to aquaculture itself), parasites and predators. Naturally occurring toxic algal blooms have not yet been an issue in Western Australia, but may occur in the future.

#### *6.6.2.1 Pollution and contamination*

In marine systems, the major environmental factors that can influence aquaculture are the concentrations of dissolved oxygen and nutrients. Aquatic plants capable of utilising dissolved nutrients may increase the assimilative capacity of a water body and so benefit aquaculture; similarly, some aquatic plants may themselves benefit from the availability of additional nutrients, if these are limiting in the environment.

Existing or potential sources of pollution and contamination from industrial, agricultural and residential sources may impose risks on aquaculture. An aquaculture proponent should consider not only the effect a polluted environment may have on the proposed aquaculture enterprise but also the pollutive effects the aquaculture operation may itself have on the environment (Section 2). Notwithstanding restrictions that may be imposed on aquaculture operations to maintain water quality, it makes commercial sense to ensure that aquaculture is not self-polluting. This practice not only ensures the long-term sustainability of the aquaculture industry, but also nurtures future support from local communities, other users of the resource and government authorities.

#### *6.6.2.2 Parasites and predators*

The environment can also impact on aquaculture as a result of the presence of parasites and predators. For example, *Kudoa thyrsites*, a protozoan parasite known to occur in Western Australian waters, has been known to affect some fish species. Predators can include fish and other aquatic species, as well as predatory birds, reptiles and mammals. Various methods are in use for controlling parasites and predators or excluding them from the production system.

### *6.6.3 The impact of aquaculture on the environment*

There have been concerns about the potential impact that aquaculture may have on ecosystems,

[12] Various means exist to control the amount of wastes entering an aquatic system as a result of aquaculture. These wastes and the means by which they can be controlled or eliminated will vary according to the species under culture and the production system employed. Waste management is discussed in Section 6.5.1.

either directly through the spread of pathogens and by predation or competition, or indirectly through alterations to the environment. In practice, for well-managed projects, these threats rarely materialise. Problems associated with disease outbreaks usually only occur when environmental conditions are unsuitable for the fish (Pechmanee, 1993). Contemporary aquaculture practices place significant emphasis on the quality of water discharged from culture units, on the simple premise that, should pollution of the aquatic environment occur, the aquaculturist is almost invariably the first to suffer economic losses. Further, under the existing legislation in Western Australia, it is unlikely that aquaculture projects that have not adequately dealt with environmental issues, such as pollution and water quality, would be allowed to proceed.

The impact of an aquaculture operation on the environment is highly dependent upon its location, the production system used, species grown, its integration with other human activities and its purpose. Most of these aspects are interdependent. Aquaculture operations may have positive or negative impacts on the environment.

#### *6.6.3.1 Positive impacts*

Examples of where aquaculture can have a positive impact include:

- restocking of depleted fisheries;
- the protection and enhancement of endangered species through cultivation; and
- aquaculture operations that utilise waste products from other industries (e.g. warm water from power stations).

Recfishwest views aquaculture infrastructure positively. In many instances, the infrastructure acts as fish aggregating devices (FADs) or favours certain species by habitat alteration (e.g. mussel ropes providing food for demersal fishes and crabs). It is considered that the infrastructure provides additional habitat and resources, which encourages fish to the operation. This increase in local fish density in turn attracts recreational fishing activities. Recfishwest encourages aquaculture operators to accommodate recreational fishing to the degree of providing fishing platforms at the corners or periphery of the facility (F. Prokop, *pers. comm.).*

#### *6.6.3.2 Negative impacts*

*Disease and genetics*

Two of the biggest ecological concerns of aquaculture are disease and genetics, especially where the aquaculture results in a mixing of hatchery and wild stock, or wastewater and marine ecosystems. Fortunately in Western Australia, there are stringent controls in place concerning the translocation of stocks and the release of hatchery stock into the marine environment. Disease testing requirements for hatchery stock are aimed at removing the risk of introducing disease from this source.

Genetic impact is likely with the introduction of any fish resources into the local wildstock. Requirements for the collection and release of broodstock are developed by the Department of Fisheries in consultation with relevant authorities, and are intended to minimise genetic impact of introduced animals. Genetic mutation will occur in hatchery-reared fish, the extent of which will increase with the amount of time the fish remain in the hatchery. The use of limited numbers of broodstock in aquaculture hatcheries, and the selective improvement of desirable characteristics in hatchery breeding programmes, can affect the genetic diversity of the farmed fish (Doupe', 1998;

Doupe' and Alder 1998).

There have been some concerns that an impact on the genetic diversity of wild stocks may occur if these cultured fish escape and subsequently interact with the wild stocks. However, genetic variation occurs within local wild populations and is evolving continually. Where there is intentional release of hatchery reared stock (enhancement/reseeding), there will be some genetic impact; however, the aim is not necessarily to stop it but to recognize it is a reality and minimize the negative impact on the ecosystem. In terms of pure aquaculture (with no intentional release of stock into the wild), it is significant that there are no recorded instances where fish produced by aquaculture have weakened the genetic fitness of wild stocks (B. Jones, pers. comm.).

The introduction of exotic or non-native species can reduce productivity and diversity in native stocks. The aquaculture of non-native species is unlikely to be permitted in Exmouth Gulf; accordingly, genetic threats from this source are likely to be minimal.

*Poor location*

Examples of negative environmental impacts that can occur from poorly located aquaculture projects and proposals include:

- impacts on biodiversity and the conservation estate through clearing operations;
- impacts on areas of marine primary productivity of particular importance such as seagrass, mangroves and corals. These impacts can either be direct through accidental (e.g. from boat anchors) or deliberate clearing; or indirectly as a result of contaminant/ pollutant inputs. An example of indirect impacts from contaminant inputs would be changes in nutrient concentrations leading to growth of epiphytic algae on the seagrass leaves, which reduces light levels to the leaves to the extent that the seagrass dies;
- disturbance to wildlife;
- enhanced impacts from nutrients due to poor water circulation at the aquaculture site;
- aquaculture projects which need natural resources (e.g. freshwater) in excess of those available sustainably at the location; and
- visual impacts from poorly located or poorly managed facilities.

Some of the environmental effects of aquaculture are common to all systems; for example, most open and flow-through systems produce a quantity of waste materials that is governed by factors such as the level of production, type of feed and food conversion efficiency. Other effects vary according to the type of production system. Within the context of planning for aquaculture development, it is useful to contemplate the more specific effects that each component of an aquaculture production system may have on the environment.[13]

The location of an aquaculture operation can influence its impact on the environment. Location refers principally to whether a farm is established onshore or offshore. The most evident effect that an onshore farm may have on the environment involves the clearing or removal of terrestrial vegetation. In the more environmentally sensitive areas, such as mangroves, this effect may preclude, or limit, aquaculture development.

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[13] The elements that comprise aquaculture production systems are described in Chapter 12 and Appendix C. They are location and water type; culture units; water flow; intensity; scale; and integration (Nash, 1995).

More intensive onshore farms invariably use less land areas but greater water-flow requirements than those employing semi-intensive production systems (Nash, 1995). Where land areas are limited, intensive onshore farms can have advantages and are usually preferred, from the perspective of potential environmental impact. The establishment of semi-intensive onshore systems in the vicinity of mangroves can be environmentally sustainable; however, these systems require detailed consideration of environmental impacts in areas such as coastal erosion, salinity intrusion and acidification of pond soils (Phillips, 1995).

The location-dependent environmental impacts that can ensue from offshore farms mainly include issues such as shading of sea grasses and damage caused by anchors and anchoring systems.

Other location-dependent environmental effects of aquaculture include issues such as the treatment of used water. For any given level of production, onshore and offshore farms would produce similar quantities of waste materials. The ability to treat wastewater, and hence its effect on the environment, can differ according to location. Onshore farms, particularly intensive ones, can have the ability to more effectively and economically treat and remove waste materials from used water before it is discharged back into the environment. These farms can have significantly-reduced environmental impacts.

*Water quality*

Water type influences contaminants that may be of concern. For example, in a freshwater system, phosphorus is a limiting factor in seeking to prevent algal blooms, while in a seawater environment, nitrogen is the limiting factor. Water type does not influence the potential adverse impacts of some contaminants such as antifouling agents used for cage aquaculture.

The culture unit and water flow used greatly influences the extent of control over adverse water quality impacts. For example, a land-based tank system provides the opportunity to remove faecal matter from outgoing water, while in a cage aquaculture system, this is not possible. Similarly, a land-based tank system can divert and treat nutrient laden water and sediment, whereas this is not possible in some other culture units. Low levels of dissolved oxygen, high levels of turbidity, hydrogen sulphide build-up and high levels of nutrients are common water quality impacts associated with some aquaculture culture units.

The intensity of an aquaculture operation affects contaminant loads to the environment.

The scale of the operation also affects environmental impacts. However, a poorly located or managed small-scale operation can have significantly greater impacts than a well-sited large-scale operation.

Integration in the context of production systems (i.e. horizontal and polyculture integration) is considered in the examples illustrating the potential positive impacts of aquaculture above.

The species grown affects the potential severity of water quality impacts, food web composition, genetic impacts, and the potential for adverse impacts from introduced species. Water quality impacts are largely dependent on whether or not the species are fed, although filter feeders in the wrong location can allow the concentration of nutrients through accumulation of faecal matter, thus affecting water quality.

*Food web*

Food web composition can be significantly affected by high concentrations of filter feeders. For

example, in intensive mussel growing areas in New South Wales, zooplankton composition has changed, resulting in a community dominated by epifaunal larvae rather than copepods.

*Other effects*

The adverse impacts from introduced species have been documented from other human activities, such as ballast water disposal. Consideration must be given to the consequences of escape both in respect to the species being grown and any live food consumed by that species (e.g. algae).

Other environmental effects can be associated, directly and indirectly, with aquaculture activities. Direct effects can ensue as a result of the production system or equipment used; for example, anchoring systems used to secure cages or longlines can affect the sea bed and, in extreme cases, shading from sea cages or other structures may inhibit the growth of sea grasses.

Indirect or secondary effects, which may arise as a consequence of the activities of the aquaculturists, can include the treatment of household wastes. It should be noted that all proponents are required to identify and deal with all these issues as a part of the standard aquaculture licence application process.

*Site rehabilitation*

In the event that an aquaculture facility ceases operation or is abandoned, mechanisms are required to ensure that the site is rehabilitated. This can be achieved through licence conditions, including the requirement to lodge bonds and to attain appropriate levels of insurance. Such licence conditions are currently contained on existing aquaculture licences.

Recommendation 8: In the absence of sound biological and environmental data, ensure that all aquaculture licences issued for the Exmouth Gulf contain appropriate licence conditions to monitor the environmental impact of aquaculture activities. Any monitoring should be done to the satisfaction of the EPA, CALM or other government agencies with jurisdiction. The level of monitoring may be reviewed on application from the proponents. (DoF, EPA, CALM)

Recommendation 9: Ensure that licence conditions for aquaculture address the issues of removal of infrastructure and reinstatement of any area disturbed by environmental impact. (DoF)

### *6.6.4 Regulatory mechanisms*

Section 5 of this draft plan notes that the aquaculture of all species of finfish and shellfish other than *P. maxima* pearl oysters are managed under the provisions of the *Fish Resources Management Act 1994.*

Under the *Environmental Protection Act 1986,* the Department of Fisheries (as a decision-making authority) is required to refer a proposal that, if implemented, appears likely to have a significant effect on the environment, to the Environmental Protection Authority. In practice, the Department of Fisheries accepts the advice of the Department of Environment (DOE) regarding the need for referral to the Environmental Protection Authority and all proposals are given to the DOE for their consideration.

If a proposal is not subject to a formal level of environmental impact assessment, the Department of Fisheries obtains advice from the Department of Environment and Department of Conservation and

Land Management as a matter of course.

The existing regulatory mechanisms are considered adequate to ensure protection of the environment.

### *6.6.5 Distances between aquaculture sites*

To allow for expansion within, and minimise the risk of spreading diseases between, pearling and aquaculture sites, a policy has been developed about the minimum distances between two *P. maxima* sites, between two non-*P. maxima* aquaculture sites, and between non-*P. maxima* and *P. maxima* sites. This policy only applies to the above species of pearl oysters and not to other shellfish and finfish species.

Commonly known as the two to five nautical mile separation guideline, key elements of the policy are paraphrased as follows.

- An application made for the issue of an authorisation for pearl oyster aquaculture will be refused if the proposed boundaries of the proposed site lie within 5 nm of the nearest boundary of any pre-existing pearl oyster farm or holding area, unless: there is a clear physical division between the existing and the proposed farm areas; or the holder of any existing farm consents to the application.

- The existing pearl farm licensee or lessee can expand within the 5 nm exclusion zone towards the new farm site, but to no closer than a minimum distance of 2nm from the new farm site.

Additional details of the policy may be obtained from the Department of Fisheries if required.

Recommendation 10: Assessment of new applications for pearl oyster leases and licences in Exmouth Gulf should take into account the Department's two to five nautical mile separation guideline. (DoF)

## 6.7 Categorisation of areas for aquaculture potential

Based on an analysis of the above information, Exmouth Gulf has been categorised into three areas, namely:

(i) *areas where aquaculture cannot occur* due to statutory constraints;

(ii) *areas with significant known constraints* which make approval of aquaculture unlikely, based on current technology and government policies; and

(iii) *areas with no known constraints which would preclude aquaculture* but in which it is recognised that site specific investigations may uncover constraints that would prevent the Executive Director of the Department of Fisheries approving an aquaculture licence.

Figure 7 maps Exmouth Gulf using the three categories in italics above, and the criteria used are described more fully below.

### *6.7.1 Areas where aquaculture cannot occur*

The following areas have statutory protection and therefore are areas where aquaculture cannot occur:

- Marine and Terrestrial Nature Reserves, including island Nature Reserves;
- National Parks and Conservation Parks;
- Sanctuary and Recreation Zones of the Ningaloo Marine Park;
- Gazetted navigation channels; and
- Shipwrecks recognised under State and Commonwealth Acts.

Channels identified by markers are not necessarily gazetted channels. Such channels have been identified as areas with significant known constraints.

### *6.7.2 Areas with significant known constraints*

Areas with significant known constraints include:

- benthic primary producer habitats as defined by the Environmental Protection Authority. Benthic primary producer habitat includes reef communities, seagrass, mangroves, corals and algal mat communities;
- marked channels used by boat and ship traffic or areas with high levels of boat traffic, and
- areas of high use recreational, charter and commercial fishing and boating activities.

Section 5.4.1 of this Draft Aquaculture Plan outlines the Environmental Protection Authority's current position on benthic primary producer habitat.

With respect to seagrass, proponents should note the following information:

- the Marine Parks and Reserves Authority and Department of Conservation and Land Management have clearly stated in submissions that there should be no impacts from aquaculture on seagrass;
- the Environmental Protection Authority's position regarding seagrass is detailed in Section 5.4.1; and
- in its assessment of mining lime sands in Cockburn Sound, the Environmental Protection Authority considered that its policy applied in areas with seagrass coverage of greater than 25 per cent.

The situation regarding other benthic primary producer habitats such as mangroves has not been evaluated, and proponents should refer to Section 5.4.1 for guidance.

The Department of Conservation and Land Management and the Marine Parks and Reserves Authority have highlighted the importance of and the need to avoid impacts on habitats such as mangroves and corals.

### *6.7.3 Areas with no known constraints*

Broadly, coastal sites in Exmouth Gulf considered to have potential for onshore aquaculture development include parts of the western coast, the southern coast and the eastern coast. Generally, onshore sites for which there are no known constraints to development occur on the western side of the Gulf between the town of Exmouth and Learmonth. This area has previously been identified as having good potential for onshore aquaculture development (Makaira and Ecologia, 1997).

However, proponents should recognise that site specific investigations of areas in this category may uncover constraints that would prevent the Executive Director of the Department of Fisheries from approving an aquaculture licence. These constraints would normally become apparent during site investigations by the proponent or through the aquaculture licensing process.

Proponents should refer to Figures two to six in the first instance to create a preliminary listing of the potential interests or constraints in an area. Figures two to six are based on the best information available, but are not all inclusive, and other matters such as Aboriginal and petroleum interests in the area would need to be investigated as they change over time. Furthermore, different aspects mapped have different levels of accuracy. For example, the seagrass mapping should always be verified in the field, while the location of shipwrecks can be accurately determined from maps (see Figure 1).

# SECTION 7 APPLICATION PROCEDURES FOR PEARLING AND AQUACULTURE

Applications for leases, licences and permits for pearling and aquaculture in Western Australia are dealt with in various ways.[14] Under section 23 of *the Pearling Act 1990*, the Executive Director of the Department of Fisheries determines applications and may grant leases, licences and permits for pearling operations. Under section 92 of the *Fish Resources Management Act 1994*, the Executive Director determines applications and may grant licences to enable aquaculture operations. Recent amendments to the *Fish Resources Management Act 1994* mean that the Minister for Fisheries may also grant leases for existing or new aquaculture ventures.

Similar processes are used in the consideration of applications for pearling and aquaculture; however, they are managed under separate Acts (see Section 5.1.1). The same consultation process (see Section 7.3) is used for assessing lease and licence applications for pearling and aquaculture; Ministerial Policy Guideline No. 8 (MPG8) provides guidance to the Executive Director on the consultation process to be used.

## 7.1 Pearling

Applications for pearling licences and leases are made to the Executive Director of the Department of Fisheries. While numerous parties are consulted prior to the determination of such an authorisation (in accordance with MPG8), the right of appeal against decisions made by the Executive Director is limited to holders of existing leases and licences and third parties who may be significantly affected by the proposal.

## 7.2 Aquaculture

Aquaculture licence applications are also made to the Executive Director of the Department of Fisheries. As specified in MPG8, the Executive Director may grant an aquaculture licence upon being satisfied that the proposed activities have been approved by the relevant authorities in the best interests of the aquaculture industry, and will not affect fish or aquatic habitats.

The Department of Fisheries provides prospective aquaculturists with an information package for aquaculture licence applications. The Environmental Protection Authority and Department of Conservation and Land Management provide similar information packages that detail their requirements.

Subject to the proposed site, species and production system, some aquaculture licence applications can be complex, and significant supporting documentation and research may be required. Further information about the licence application procedures and requirements is available in the information package.

Although the term of an aquaculture licence is limited to 12 months, under section 94 of the *Fish Resources Management Act 1994*, if a person applies to the Executive Director for renewal of the

[14] Pearling refers exclusively to the culture of the silver-lip pearl oyster *Pinctada maxima*. Aquaculture refers to the culture of all finfish species and shellfish species other than *P. maxima*. The pearl oysters in the latter category are commonly referred to as non-*P. maxima* pearl oysters.

licence, the Executive Director is to renew the licence subject to section 143 of the same Act. The latter section allows the Executive Director to refuse to renew the authorisation under circumstances that include: the contravention of a condition of the licence; the authorisation not being used for two years; the failure of the holder to keep records or submit returns; and other specified grounds.

## 7.3 The consultation process

Ministerial Policy Guideline No. 8 (MPG No. 8), entitled *Assessment of applications for authorisations for Aquaculture and Pearling in coastal waters of Western Australia* (Fisheries WA 1997b), outlines the consultation process to be followed for a pearling or aquaculture application. The objective of MPG No. 8 is to indicate to the Executive Director of the Department of Fisheries the preferred approach of the Minister for Fisheries for the assessment and community consultation procedure to be followed when considering applications for authorisations for pearling and aquaculture in coastal waters.

Once accepted as competent, pearling and aquaculture lease and licence applications are referred for comment to four principal groups, namely the decision-making authorities; involved agencies; representative community and industry groups; and the public.

*Decision-making authorities*

The Executive Director refers applications to and consults with the decision-making authorities whose approval is required for the activities to be conducted. Depending on the circumstances, they may include the Department of Environment, Environmental Protection Authority, Department of Conservation and Land Management, Department for Planning and Infrastructure, Department of Land Information, the Local Port Authority and the Local Government Authority.

*Involved agencies*

The Executive Director consults with agencies that may have expertise in, be directly affected by or have an interest in the proposed activities. These include the Local Government Authority, Department of Land Information, Department of Conservation and Land Management, Marine Parks and Reserves Authority, Department for Planning and Infrastructure, Water and Rivers Commission, Department of Industry and Resources, Aboriginal Affairs Department, Department of Minerals and Energy, WA Tourism Commission and Regional Development Commissions.

*Representative community and industry groups*

The Executive Director consults with peak community and industry representative groups that may have expertise in, be directly affected by or have an interest in the proposed activities. These include the WA Fishing Industry Council, Recfishwest, Aquaculture Council of WA, Pearl Producers Association, Recreational Fishing Advisory Committee, holders of pearling or aquaculture authorisations within 5 nm of the proposed site, Native Title holders and claimants, the Conservation Council of WA (Inc.), and the Australian Petroleum Production and Exploration Association Ltd. These groups are asked to ensure that relevant regional organisations are notified of proposals.

*Public comment*

The Executive Director advertises proposals in the press to seek public comment, unless they conform to a previously approved area plan or are for emergency use of a site.

Proposals may also be sent to the Environmental Protection Authority for assessment of environmental impact, under Section 38 of the *Environmental Protection Act 1986.* Various time limits apply to the respective stages of the process, and these are elaborated in MPG No. 8.

Recommendation 12: Establish performance criteria to monitor whether licences are being used for the purposes for which the applications were originally made and to determine compliance with licence conditions. (DoF)

# SECTION 8 PLAN IMPLEMENTATION AND REVIEW

The Exmouth Gulf Aquaculture Plan will provide a guide for prospective aquaculture proponents. Although not a statutory plan, it will guide decision makers when assessing applications for new or extended aquaculture ventures in Exmouth Gulf.

This Draft Aquaculture Plan, once approved for circulation by the Minister for Fisheries, will be made available for public comment. After that period has concluded and the plan is amended where necessary, the Minister will approve it for implementation.

This plan will be in effect for five years from the date it receives Ministerial approval, and remain in effect until the management plan for the subsequent five years is approved. Amendments can be made to the management plan while it is in effect, but only after public consultation.

The five year review should evaluate:

- the successes and failures of the first five years of the plan;
- new information with the potential to affect management practices and strategies for aquaculture in Exmouth Gulf; and
- new proposals for the management of aquaculture in Exmouth Gulf.

The information used for this Draft Aquaculture Plan, and subsequently for the final plan, will date rapidly, and therefore proponents should consult with appropriate authorities to collect up to date information and any detail required to identify site-specific concerns.

Recommendation 13: Review the success and appropriateness of management strategies contained in the plan in five years. (DoF)

## SECTION 9 GLOSSARY OF TERMS

| | |
|---|---|
| Benthic | includes all the bottom terrain of the sea, from the shoreline to the greatest depths. |
| Broodstock | mature animals used for spawning to produce young animals to grow-out. |
| Endemic species | species occurring naturally in an area. |
| Translocation | moving a plant or animal from one place to another. |

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The original consultation and draft report were undertaken by:
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Project staff were Mr G W Connell, S Nel, and R J Van Delft.

Mrs Jane Borg, Department of Fisheries, compiled the final draft report.

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# APPENDIX A: SUMMARY OF SUBMISSIONS

## 1. THE ENVIRONMENT

### 1.1 Availability of information/ understanding of the environment

The following issues were raised during the consultation process:

1. An understanding of currents in Exmouth Gulf is essential for aquaculture. A recent study found shifting intake pipes a short distance made the difference between accessing poor (dead) or good (recirculating) quality water significantly affecting the likelihood of success of the project.

2. A general study of bathymetry and currents should be undertaken to provide information that would assist future aquaculture applications. Currently there is duplication with each applicant doing his or her own study, which is then generally difficult to obtain.

3. Any areas where feeding operations (nutrients are added to the water via a food source) are proposed will need to be well flushed to prevent any nutrient enrichment. Logically, therefore, it is necessary to have an understanding of water circulation in the Exmouth Gulf area.

4. Base line studies do not exist for the abiotic (water flow, geomorphology, chemical processes, etc) and biotic (plankton, invertebrates, etc) parameters of the Gulf. These should be established and monitored to determine changes over time. This should involve monitoring of stakeholders (aquaculture, tourism, fishing, conservation).

5. There is limited knowledge for the development of aquaculture whether in the Gulf or elsewhere in the State. Knowledge needs to be generated and disseminated in a timely fashion. This can be achieved through incentives and collaboration of industry members (industry, research institutes and government).

6. Aquaculture operations should not impact on important marine megafauna, such as bird and turtle rookeries, whale and dugong feeding areas and migration routes etc. Therefore, it is necessary to have a map of the distribution of these biological resources.

7. Lack of knowledge regarding the marine environment of the Exmouth Gulf. No baseline studies have been conducted in the Gulf, which means that the negative impacts from aquaculture practices cannot be monitored satisfactorily.

8. The current lack of information about flora, fauna, water circulation and impacts from operations should be viewed as a no-go constraint to aquaculture until appropriate baseline information is collected.

### 1.2 Important habitats and fauna

It was noted that Exmouth Gulf produces juveniles for huge areas and that the mangroves on the eastern side are particularly valuable in this regard. Mangrove areas should not be cleared.

Seagrass should not have a blanket policy approach of no impacts from aquaculture. The impacts

of disturbance vary according to the type of seagrass, and there is significant natural variation in the distribution of seagrass and the species dependent upon it. The loss of seagrass from cyclone activity in the Gulf of Carpentaria and the migration of dependent species from there to the east coast of Australia demonstrates this variability. The seagrass sub-program being conducted by the Fisheries Research Development Corporation is expected to add significantly to our current knowledge base.

The impacts on bethnic habitat such as seagrass meadows, coral growth, algal gardens and sand/mud substrate also need to be understood prior to implementation of any aquaculture development.

Bethnic communities: There should be no significant direct or indirect impact to key sensitive bethnic communities; including seagrass and mangroves etc. Therefore, it is necessary to have habitat maps of these communities. We believe Department of Fisheries policy is that there should be no aquaculture and pearling operations over seagrass meadows. A paper of "Seagrass communities in Exmouth Gulf, Western Australia: A Preliminary survey" by LJ McKool et al (1995) may provide some bethnic habitat data.

Aquaculture development should not impact upon the reef system.

Exmouth Gulf is important for whales, with whale numbers increasing and whales using the entire Gulf. Whales are often present for a week or more, and seen swimming at about the 10 m contour or using waters as shallow as 5 m. Whale watching is of considerable economic importance, with 13 commercial whale watching licences currently issued. Concern was expressed about increases in boat traffic from aquaculture, and increased likelihood of whales becoming tangled in aquaculture apparatus.

## 1.3 Aboriginal heritage

There is a Native Title claim over Exmouth Gulf, Registration No WC97_028 and the legal representative is Mr. Alex Shaw of the Aboriginal Legal Service. There are also Aboriginal sites in the area (a map was provided).

## 1.4 Visual impacts

Visual Amenity: Much of Western Australia's tourism product is based around an image of a pristine wilderness. Visual amenity is an important aspect of this product offer, and it is therefore important that the areas that are popular with the tourists and recreational users are not degraded in any way, particularly at the Naval Communications base.

Amenity. Any proposal will need to take into account visual, odour and noise issues in relation to the proposal with the recognition of the importance of nature based tourism and significant conservation values of the area. In some instances a Visual Resource Management approach should be adopted to assess visual impacts.

Based on current experience with aquaculture in Exmouth Gulf, visual impacts are not a concern.

## 1.5 Species and introductions

There is concern about the potential impacts of exotic species (i.e. translocated species), including feed species (i.e. algae and copepods) on the environment. Even small organisms can have

significant ecological impacts and alter trophic levels. There should be a strong focus on using endemic species.

There was discussion about the ability of current filtration technology to remove exotic algae and aquatic fauna prior to wastewater discharge from aquaculture operations. Some people felt confident all algae and fauna would be removed by filtration, while others disagreed. A view was expressed that independent monitoring of algae filtration was essential because of the potential environmental impacts associated with the escape of exotic algae.

Controls need to be developed to limit the potential vectors for non-endemic pathogens entering the ecosystem. Potential and as yet uncontrolled vectors include ship ballast water and imported fishing bait for recreational and commercial fishing.

The petroleum industry has had conditions/ quarantine operations to guard against the introduction of exotic plants and animals and the same conditions should apply to aquaculture so the benefits of past practices remain.

There should be no aquaculture or pearling operations that grow species not native to the Exmouth Gulf bioregion.

## 1.6 Land based aquaculture water quality, coastal impacts

It was considered that the level of wastewater treatment needed for land-based aquaculture activities would depend on location.

Effluent from land-based aquaculture developments: The water circulation and water quality of the receiving waters will need to be known to ensure the potential environmental impacts can be managed. All effluent will need to comply with the appropriate water quality guidelines to minimise the potential impacts.

The potential for wastewater from land-based operations to pollute groundwater, which may include rare cave dwelling fish, was raised at the Exmouth meeting by the Australian Marine Conservation Society and WA Tourism Commission. At the meeting, it was decided that this was probably not a concern with land-based operations being located adjacent to the coast.

It is important to ensure that any land-based tanks do not have a negative impact on the fragile dune system along the shores of the Gulf.

Exmouth Gulf is important from a conservation point of view, and it is therefore recommended that an environmental assessment of the potential impacts of using ground water, running pipelines through the dune system and pumping waste water into the Gulf be undertaken for all land-based aquaculture projects.

## 1.7 General

There was general agreement that land-based aquaculture was preferable and that sea cages would only be acceptable if wastes could be contained and managed.

The environmental impacts associated with sea cage aquaculture have changed significantly over the last few years, and should be re-considered on the basis of current management practices. Food conversion ratios of less than one are being achieved in Scandinavia. Poor husbandry and management are often responsible for disease. A risk analysis has been completed on disease, with

most disease coming from background pathogens and occurring in overcrowded cages.

Technologies to reduce feed loss from sea cages were discussed, including sewing a sock around a cage and stocking the sock with mullet to reduce feed wastage by about 70 per cent.

There is a concern that aquaculture operations have the potential to increase levels of pollution in the Gulf. The Marine Parks and Reserves Authority has identified the Exmouth Gulf as a possible area for reservation. It is therefore important to ensure that the marine environment is not damaged as a result of aquaculture operations.

The issue of impacts from boats providing accommodation for the workforce (e.g. waste disposal, litter, sewage, worker recreation) has not been adequately considered.

# 2. MANAGEMENT ARRANGEMENTS

## 2.1 Consultation

The Department of Minerals and Energy should be a member of the IDCA or be consulted on new aquaculture proposals, because they may affect developments planned under Temporary Reserves and exploration proposals.

Operators of individual petroleum tenements/exploration permits should be consulted for aquaculture proposals.

Prior to the Draft Aquaculture Plan being released, further discussion with interested stakeholders would be valuable. This discussion should revisit key points of the initial meeting and provide a forum for comments on material not covered. For example, culture species, culture methods and research and development directions.

The scope of the people contacted in relation to the plan should be greater.

## 2.2 Licensing arrangements and practices

The need to re-apply for an aquaculture licence every 12 months means banks won't provide finance. Support for replacement with a 21 year performance-based licence of three times seven years.

At the Exmouth meeting, concern was expressed about the time taken to get approvals. However, most people present at the meeting recognised the reasons for and the need to take a long period of time.

Amateur fishing bodies can cause long (18 month) delays in the processing of aquaculture licensing. The process should be improved as such delays discourage applicants and should be considered unacceptable.

A whole of government approach for processing aquaculture proposals as embodied in the Inter Departmental Committee - Aquaculture (IDCA) is supported.

Aquaculture leases should be marked on navigation charts so that petroleum exploration activities can avoid the leases. This is particularly important in areas such as Exmouth Gulf where Petroleum

Exploration Permits cover the Gulf.

The Water and Rivers Commission's advice in its *Water Quality Protection Note - Aquaculture projects*, which deals with site selection, waste management, water supplies, pond design and water quality for discharges, should be considered.

Any land clearing associated with the land-based proposals will need to take into account the conservation value of the surrounding vegetation. Any clearing in excess of 1ha will require authorisation from the Commissioner for Soil and Land Conservation.

All proposals should be required to gather enough baseline monitoring information prior to implementation of the project to determine the actual impacts.

Pre-construction monitoring is essential.

Concerned about clean-up of aquaculture infrastructure if an operation becomes bankrupt. Would like Department of Fisheries to determine economic feasibility of a project before it commences and enforce a bond system to ensure clean-up.

Concerned at the lack of audit by Fisheries Officers of aquaculture proposals. This may arise from local officers having a lack of expertise in aquaculture.

Difficult to access broodstock from the wild because not allowed to harvest juveniles. Can’t get larvae, juveniles or mature stock. Current fisheries management means more medium sized fish and few mature stock.

Seed Stock Availability: Currently, there are no commercial quantities of potential finfish culture species seed stock (egg, larvae or fingerlings). This is serious impediment to the development of aquaculture in the region and one which does not seem to be able to obtain support from private, research or government agencies.

Difficult to obtain endemic feed (i.e. algae and copepods) for hatcheries. It is technically possible to obtain seed stock but much cheaper to purchase alien species (e.g from CSIRO). Life cycle of some endemic species not fully understood. Endemic species are not fully exploited. Department of Fisheries should assist with research on seed stock so that endemic species can be used for feed.

Farmers should be able to purchase seed stock from other hatcheries where it can be shown that they are genetically the same as local species.

Environmental management and waste management practices should be complementary across the petroleum and aquaculture industries. Aquaculture operations in the vicinity of petroleum operations should be aware of the conditions that are in force at the petroleum operation and also be required to abide by them.

## 2.3 Access over leases

Security: This is an issue that will be important to potential license holders but it could also impact upon visitors to this area. If security measures are too aggressive, they may have an impact on visitor's enjoyment of the area. While it is understood that the licence holder must protect their interests, the appropriate placement of operations will reduce the risk of tourists accidentally trespassing.

Problems were being experienced by some existing licence holders with fishing and the use of echo

sounders over their lease.

Cage structures to keep turtles out provide a haven for fish and therefore attract fishermen to the area. One operator considered this an advantage, rather than a problem.

## 2.4 Aquaculture planning

We appear to be seeing a "land-grab" for pearling leases in response to the release of the Wilson Report that is generating a large administrative burden for groups such as RFAC.

While existing approach seems to permit land-grabs, happy with current management arrangements which require performance reports for licences to stay current.

Water-grabbing currently taking place cannot be condoned.

Cumulative impacts: Any aquaculture development plan should attempt to quantify the extent to which the industry can develop in the area. This should take into account cumulative impacts from other activities and the multiple and often competing uses of the area.

Concerned about incremental growth of licence sites. Need to assess the cumulative impact on the basis of a 10 year plan, which has consideration for impacts such as noise (from planes/ helicopters and boats), rubbish, refueling fuel losses, visual pollution and recreation impacts from the workforce)

The sustainable level of aquaculture in the Gulf should be determined - it is currently unknown. Concerned about ad-hoc approach to aquaculture approvals. There was some discussion about the feasibility of a study to determine what level is sustainable. It was suggested that the growth of aquaculture should be staged, with independent monitoring so if anything is going wrong we would find out quickly. Existing pollutant loads from human activity and industries (e.g. fish processing works) would also need to be monitored. It was suggested that if government is pushing aquaculture, it should do the monitoring.

There is an urgent need for Environmental Protection Policy and Statement of Planning policy for North West Cape before aquaculture goes ahead. Aquaculture must be developed in an overall planning context.

Further aquaculture development in the Gulf should not occur until the proposed Marine Park has been finalised and a management plan developed. Aquaculture development pre-empts the marine conservation process and zoning of the park. Aquaculture is not allowed in sanctuary and recreational zones and conflicts will develop if an aquaculture plan allows activity in what should be such a zone. Marine conservation must be finalised before exploitation of the marine environment proceeds.

The whole of government, and in particular CALM and the MPRA (Marine Parks and Reserves Authority) should be in accord with the aquaculture plans.

The 5/2 rule should apply where the species farmed draw upon the same natural resources (e.g. phytoplankton) and where there is a risk of inter-species disease transmission. Each application of the 5/2 rule should be based on a site-specific evaluation of these matters. The 5/2 should not otherwise apply (i.e. where there is no risk of interference between operations).

The 5/2 separation distance/ buffer zone rule which currently applies to pearling operations should

apply to all types of aquaculture. Five miles should be the normal separation distance. This would minimise bacteria and virus transmission, theft problems and provide opportunities for licence expansions. It would also minimise the potential for impact to an existing successful operation from a small operation adjacent with significant impacts (e.g. a seacage operation polluting the intake of a large successful land-based operation).

Buffer zones between sites: A minimum distance needs to be determined for adjacent projects. An example of this is the 5 in 2 rule of the shellfish industry.

A reliability diagram should be provided with the base mapping provided by Fisheries.

## 2.5 Information collation and use

Data collected by aquaculturalists in preparing applications or doing monitoring should be collected and put into a database for use by agencies and for monitoring changes. It could be a role of an Aquaculture Development Officer to collate the data, enforce the collection and ensure that the data collected will be (or is) reliable.

Monitoring of aquaculture should be done collectively but independently. FRDC funding should be sought to do this. Details of information ownership would need to be sorted out.

Need to implement a Decision Support System (e.g. as has been developed by CSIRO) to assist future aquaculture proposals, which is designed so that new information can be easily plugged in. Current system provides snapshots, which are quickly out of date. It should link with information from CALM and information such as the CSIRO's databases that include phytoplankton densities (important for mussels) and thermal data. The available planning tools are not currently being taken up so that they are easily updated and accessed by industry.

There should be more emphasis on monitoring existing licences and all discharges to the Gulf - including that from the marina, to protect existing aquaculture operations.

## 2.6 Miscellaneous

Scope of nomenclature used by difference agencies with an interest in marine park management is confusing (e.g. Department of Environment State Marine Water EPP document uses different nomenclature to CALM). Western Australia should adopt the ANZECC national nomenclature approach.

There should be greater cooperation between existing aquaculturalists. As the industry grows it may be appropriate to establish a formal group.

Failed projects and unprofessional operators (e.g. the clam farm in Exmouth Gulf) tarnish the industry and management arrangements should be put in place so this does not re-occur.

It is often the small, unprofessional operator that causes problems.

# 3. FUTURE AQUACULTURE

## 3.1 Compatibility with existing industries and activities

Future aquaculture must be sustainable and integrate well with existing businesses.

Some types of aquaculture should not pose any problems because most of the infrastructure is well beneath the surface.

All developments that could affect the environment near an aquaculture operation should be assessed for their potential impacts. This assessment needs to pay particular attention to the impact of development on currents (e.g. at Exmouth it is believed that a marina development in the townsite may affect currents and tidal flushing as far south as Herron Point). A sound understanding of currents in Exmouth Gulf is essential for site selection for all coastal developments in the Gulf.

Petroleum drilling operations are compatible with aquaculture, unless situated immediately adjacent. Current technology enables drilling to occur in any direction but non-vertical drilling is more expensive.

Concerned about compatibility of petroleum production activity with aquaculture operations, primarily with respect to responsibility for impact monitoring and management. Also, water is usually a by-product of petroleum operations and clean water is dumped into the ocean. If something goes wrong with an aquaculture operation it would be easy to blame the clean water discharge.

Large pond-based aquaculture and small land-based aquaculture activities are compatible with petroleum exploration activities. Drill sites normally have a 100 m safety zone and can be located on pond banks. Laydown areas occupy 5-10 ha.

Aquaculture sites should not take up the whole (or the majority) of a Mineral Tenement or Exploration Permit area.

Access is required for petroleum exploration activities (e.g. seismic lines). Petroleum Exploration Permits cover the entire Exmouth Gulf (map provided with submission). Small land or sea sites can be avoided but aquaculture operations which use large areas (e.g. longlines) could interfere with exploration. The area and locations occupied by aquaculture sites should be managed so that petroleum exploration can continue without too many constraints, particularly as large turning circles are needed by exploration vessels. Exploration activity is already constrained by the tiger prawn fishery. With regard to sea cages, seismic exploration activities can temporarily disorientate fish, but there are no long-term impacts.

Capped well sites underwater may present an obstruction or impediment to some aquaculture operations.

Temporary Reserves under the *Mining Act 1978* occur along the eastern and western sides of Exmouth Gulf (map provided by Department of Minerals and Energy). The Temporary Reserve on the western side is for future limestone production and extends to the coast to permit future development of port and haul road infrastructure. Port facilities to allow limestone export to Kwinana and Asia are currently proposed. The Temporary Reserve on the eastern side is for salt production. While a Temporary Reserve does not constrain aquaculture, the Department of Minerals and Energy should be consulted for aquaculture proposals in Temporary Reserves in case developments are proposed which would impact on aquaculture proposals or vice versa.

The opportunity to combine aquaculture and tourism was highlighted. One suggestion was onshore

pond fishing.

One operator noted he is currently using his aquaculture site as a tourist dive site.

The Tourism Commission recommends that due consideration be taken of the tourism and recreation value of an area before any aquaculture licences are granted.

The main selling points for tourism in this area is the fact that it is relatively pristine and rich in flora and fauna. The area is a major breeding ground for turtles and dugongs and this acts as an attraction for visitors to the area. It is important that the quality of the natural environment is protected and that the marine fauna are not endangered by increased commercial activity.

This area has been identified as an important zone of opportunity for the development of Western Australia's tourism product. The Naval Communications base has major potential for the development of tourism accommodation now that the US Navy has vacated the area.

User Conflict: There are a number of areas that have been proposed as potential sites for aquaculture which are already being used as tourism and recreation sites. Areas around the township, for example, while being suitable for aquaculture are also popular for recreation and tourism. While it is understood that there have been some instances of aquaculture operations embracing tourism and generating additional income from offering a tourism experience to visitors to the local area, it should be noted that the primary business of aquaculture operators is not tourism and therefore the quality of the tourism experience is likely to suffer unless substantial resources have been pumped into this side of the operation.

Although recreational usage data is limited, CALM Exmouth have collected data since 1997 from aerial surveys conducted during the tourist season.

Impact of existing and future industries. The impact from other industries (tourism, fishing) needs to be assessed and limited.

Oceanwest Fisheries, like other stakeholders in the region, believe that aquaculture, and other developments should be ecologically sustainable and compatible with existing uses (tourism, recreational fishing, commercial fishing, industry, aquaculture and conservation).

Future aquaculture should not encroach on already successful industries such as the prawn fishery and pearling. There should not be encroachment of existing fishing grounds.

Aquaculture should occur away from the areas supporting pearl farming at present.

Beach access should be maintained for tourists and seine fishermen. Any inlet/ outlet pipes across the beach should be buried and/or designed so access along the beach is maintained.

Commercial fishing areas for shell of the pearl oyster *P. maxima* are now limited to several areas at the periphery of the southern end of Exmouth Gulf. These fishing areas have possibly been limited by the activities of prawn trawlers that operate in the Gulf. For future aquaculture activities, it will be important to preserve the remaining *P maxima* fishing grounds.

Apart from entrance to marina, there are no navigation channels etc that need protection.

Ballast water discharges would be a concern if large ships come into Exmouth to service the proposed limestone mine. It was noted that the Department of Industry and Resources is funding the development of black-box technology (like in aircraft and trucks) to record ballast water

discharges to ensure compliance with international conventions.

TBT may also be a concern if large ships come into Exmouth to service the proposed limestone mine. Oysters are particularly susceptible to adverse effects from low levels of TBTs.

Where land access is required, it should be done properly. That is:

- in consultation with the pastoralist;
- with gazettal/ resumption and fencing of road access; and
- control of access to the foreshore/ mangroves and pastoral station by design and active intervention of the operator/ management of the aquaculture facility.

If done properly, most pastoralists would not object to the granting of access. Pictures of environmental damage to mangroves caused by uncontrolled access (i.e. no fencing and "informal" roads to land-bases) were presented to the meeting. Other consequences of uncontrolled access included illegal shooting of the pastoralists stock, squatter camps and rubbish/ litter.

Existing examples of amicable "gentlemen's agreements" between pastoralists and aquaculturalist were noted.

Aquaculture proponents should detail their logistical support (i.e. refuelling, infrastructure, accommodation, re-supply) and emergency response measures, and establish their operations in a manner that affords them the highest level of self-sufficiency while observing sound environmental management practices.

## 3.2 Aquaculture planning

There are concerns relating to the development of aquaculture in the area and these include the lack of knowledge regarding the impacts of aquaculture practices due to the fact the industry is relatively new, and the lack of knowledge regarding impacts over a significant amount of time.

It is vitally important that an aquaculture plan be developed within a framework of a complete conservation management plan for the North West Cape area.

This aquaculture plan should identify deficiencies in our baseline information, identify data needs and recommend studies required to correct those deficiencies.

Aquaculture plans should acknowledge the hydrocarbon potential of an area and the importance of maintaining the opportunity for petroleum tenement holders to continue to exercise their rights and obligations.

The existing and proposed boundaries for the Exmouth Water Reserve along the Exmouth coast should be taken into account. The water reserve is currently managed as a Priority 1 source protection area, in which aquaculture projects are deemed incompatible.

Preference for aquaculture operations to be located in estates to force good housekeeping and good waste management.

The constraints to aquaculture at Bundegi and Pt Murat should be listed as severe, and these areas should be identified as a no-go area for aquaculture.

Aquaculture should not occur near the existing Marine Park or around the islands.

There is some opposition to aquaculture developments in the Ningaloo Marine Park, areas proposed as marine parks or areas recommended for conservation. A significant area of Exmouth Gulf is recommended in the Wilson Report (Marine Parks and Reserves Working Group's Report on a Representative Marine System for WA).

The southern area of Exmouth Gulf is of significant conservation and recreational value, and is identified as such in the Marine Parks and Reserves Selection Working Group's report, "A Representative Marine Reserve System for Western Australia". Therefore, it is important that recognition is given to both existing and future social usage (i.e. recreational usage) in the area to avoid potential conflicts that may unnecessarily deny public access to sites that have traditionally been used for recreation.

Doole Island is a release site for the Djoongari or Shark Bay mouse (*Pseudomys fieldii*), and one of the reasons for choosing this site was the remote location and undisturbed habitat. Quarantine plans would be required for operations near island nature reserves to prevent the introduction of exotic plants and animals. Location of aquaculture close to island reserves will also mean an increase in the number of people using the islands for recreational activities. Aquaculture operators would be required to abide by regulations under the Wildlife Conservation Act.

Island nature reserves: A list of island nature reserves in Exmouth Gulf and information on important biological resources was provided by the Department of Conservation and Land Management.

Island Nature Reserves should be no-go for aquaculture.

## 3.3 General comments, including aquaculture potential

The Shire of Exmouth is conscious of the environment but wants to promote other industries to diversify the economic base of the town (which is currently heavily dependent upon tourism) and will provide support to aquaculture on that basis. The Shire has an aquaculture policy (copy provided) and aquaculture is a permitted use in the rural zone.

Learmonth airport provides a link to the Asian markets, providing an opportunity to airlift seed stock out.

Skilled workforce: There is currently a lack of locally skilled personal to assist in the production of aquaculture products endemic to the Gulf. Training is based in other regional centres, e.g. Perth, Broome, Albany and Geraldton.

Aquaculture facilities (including sea cages and land-based facilities) must be able to withstand cyclones.

Species considered to have potential include abalone, finfish, prawn farming in the south of the Gulf, and oysters.

Brackish water farming is a potential form of aquaculture for pastoralists and should be investigated further. The water temperature of artesian water is likely to be of significant benefit.

# APPENDIX B: OVERVIEW OF PRODUCTION SYSTEMS

## 1. OVERVIEW OF PRODUCTION SYSTEMS

Any aquaculture operation may be classified according to three factors: the site at which the operation is being undertaken; the species under culture; and the production system used. This appendix provides a synopsis of modern aquaculture production systems.

To achieve the predictability and reliability that are essential for modern aquaculture to satisfy market demand, an adequate degree of control has to be exerted over all stages of production and the culture cycle. Contemporary aquaculture is therefore characterised by production systems that allow increasing control over the culture environment, particularly in the areas of water quality, feeding and stock density.

In this text, the term *production system* describes the integrated elements collectively used to culture a selected species at a given site. Six principal elements can be used to describe and define an aquaculture production system (Pillay, 1993). These are:

1. location and water type;
2. culture units;
3. water flow;
4. intensity;
5. scale; and
6. integration.

## 2. LOCATION AND WATER TYPE

Aquaculture production systems may be located either onshore (land-based) or offshore (water-based). Onshore locations may be classified as coastal or inland and offshore locations as nearshore or open ocean. For aquaculture purposes, the distinction generally applied to distinguish between nearshore and open ocean locations is the influence of coastal processes: nearshore locations are influenced by coastal processes, while open ocean locations are not.[15] Today, it is technically feasible to locate both onshore and offshore aquaculture production systems at almost any location; however, financial factors usually govern the practicability and hence the selection of a particular system for any given site.

The types of water used in aquaculture production are fresh, brackish, marine and hypersaline, according to salinity. Onshore coastal production systems usually use marine or brackish water. Inland systems are usually freshwater; however, much of inland Western Australia is characterised by large reserves of brackish ground water the salinity of which varies from nearly fresh to greater than 35‰, which approximates the salinity of sea water. Offshore systems are usually marine, but

[15] From a legislative perspective, the open ocean can also be considered to constitute ocean waters beyond a 12nm territorial limit. The open ocean has also been described as offshore areas with significant wave heights of no greater than four metres; however, for practical purposes this definition is considered inadequate due to the variability of wave heights with weather conditions and the new generation of sea cages being designed and engineered to withstand progressively bigger seas.

can be freshwater in the case of large, fresh-water lakes such as Lake Argyle in the Kimberley region of Western Australia.

## 3. CULTURE UNITS

Culture units typically include tanks, raceways, ponds, cages, longlines and racks. Stock enhancement uses natural production systems. Offshore culture units not generally used in Australia, such as pens and enclosures, are not discussed in any detail.

*Tanks and raceways*

Tanks and raceways are often used in intensive, onshore production systems, and share many common features in appearance, construction and operation. The main distinction between them is their water-flow characteristics. Tanks and raceways are usually characterised by high water exchange rates and high stocking densities. Due to their comparatively high capital cost, they are almost invariably used in intensive systems. Solid and flexible floating tanks, which have some advantages over cages, are now being tested for use in offshore locations.

*Ponds*

Ponds are used in some of the world's major aquaculture industries for the semi-intensive production of marine prawns and various freshwater species. Usually earthen, constructed from clay soil, and excavated from flat land, ponds may be classified according to their type (watershed or levee) and whether they provide a static or dynamic environment.

Watershed ponds, created by building a dam across a water course, are rarely used for traditional aquaculture production. Levee ponds, the main type used for aquaculture, are constructed either by excavating holes and building levees around them, or by constructing above-ground levees to hold water.

Static pond systems have no regular water input, generally depend on rainfall and are uncommon in modern aquaculture. Ponds with dynamic systems have continuously or intermittently-flowing water and are more expensive to build and operate; however, their yield is invariably higher and the extra initial cost frequently warranted.

*Cages*

Cages are offshore culture units enclosed on the bottom, sides and sometimes the top by net or mesh screens.[16] A wide variety of cages is used for aquaculture. Floating cages, which utilise a flexible frame supporting a pliable net, constitute the vast majority of cages in use today. Cage production systems commonly used in modern aquaculture are designed for use in relatively exposed, nearshore locations. They comprise circular cages and flotation collars with a degree of elasticity for impact absorption and manufactured from high-density polyethylene, which provides the flexibility needed to adapt to wave forces. Open-ocean aquaculture production systems

[16] Cages are often confused with and incorrectly called pens or enclosures, terms with which, in aquaculture, they are not synonymous. In aquaculture, the term *enclosure* is used to describe an enclosed, natural bay, where the shore forms all sides but one, which is typically closed off by a solid or net barrier. The term *pen* describes a structure transitional between an enclosure and a cage, in which all the sides are enclosed by a net or other material and the bottom is formed by the natural sea or lake bed.

currently being developed are usually extremely expensive and more characteristic of mature, well-developed aquaculture industries.

Advantages of cage systems include the use that can be made of offshore water bodies and the ability of the system to be easily expanded and moved. Disadvantages include the lack of control over water quality and weather conditions. There are several environmental disadvantages associated with cage production systems, such as increased nutrient loadings.

*Longlines and racks*

Longlines and racks are the main production systems used in shellfish aquaculture. The former comprises a line suspended at the water surface or in the water column and typically supporting several secondary lines, to which are attached an array of structures in which shellfish are contained, or to which they are attached. More traditionally used in rougher and deeper water bodies, longline production systems are being used with increasing success for the nearshore, subtidal production of species such as pearl and edible oysters.

Racks are used to support bivalves off the seabed, usually in shallow, intertidal areas where tidal fluctuations sequentially submerge and expose the shellfish. Longline and rack systems usually involve no supplementary feeding and they are relatively inexpensive to operate; however, there is a lack of control over predators, pollution and toxic algal blooms.

*Stock enhancement*

Stock enhancement, ranching and/or reseeding can most commonly utilise either broodstock or hatchery-reared juvenile stock.

For a more thorough discussion of these management tools, please refer to the Department of Fisheries' forthcoming discussion paper *Fish Stock Enhancement in Western Australia*.

# 4. WATER FLOW

Aquaculture production systems are further described by the way in which water flows through the culture units, and may be open, flow-through or recirculating.[17]

Open aquaculture systems usually refer to those in natural water bodies such as oceans, bays, lagoons and fresh-water lakes. By definition, therefore, most offshore systems are open and usually use culture units such as cages, longlines and racks. By definition, stock enhancement constitutes an open aquaculture production system.

Flow-through production systems, the most common in aquaculture, are those in which the water flow is continuous. The water usually passes once through the culture units and is made to enter and leave the culture unit simultaneously, generally at equal flow rates.[18] The incoming and discharged water is frequently treated to some degree. Flow-through systems are generally located onshore, are used for tanks, raceways and ponds, and require large volumes of high-quality water for their operation. Water flow rates vary according to the type of culture unit, the species under

[17] Closed systems, which, by definition, have no water exchange, are rarely seen in contemporary aquaculture.

[18] These systems are also known as *single pass systems*.

culture and the production intensity.[19] A flow-through system imparts several significant advantages that compensate for its often-higher establishment and operating costs. These include:

- more efficient management of water quality parameters;
- more efficient flushing of particulate wastes from the culture units;
- more efficient removal of waste materials and treatment of water being discharged;
- fitter and healthier stock as a result of the flowing water;
- improved stock husbandry and health management practices; and
- more efficient feeding and harvesting.

Recirculating systems, in which the water circulated through the culture units is continuously treated and recycled, are comparatively expensive to establish and employ a more complex technology than other systems. They are usually used to culture high-value species in intensive conditions, usually under circumstances when, for various reasons, flow-through systems are not practicable.

## 5. INTENSITY

The intensity of an aquaculture production system is defined principally by the level of management, the stock density and the yield per unit area. According to these parameters, aquaculture production systems are usually classified as intensive, semi-intensive or extensive. As culture technologies improve and natural resources become increasingly scarce, yield per unit water volume is increasing to the extent that some systems, described as super-intensive or hyper-intensive, are now characterised by very high levels of management and control, limited water renewal, very high stocking densities and increasingly-sophisticated waste management methods.

*Intensive systems*

Intensive systems typically feature a high level of management and control, high culture densities, the use of artificial feeds and some degree of vertical integration. They have high capital demands, are usually devoted to the culture of high-value species and operate to maximise sustainable yields and profitability. The most common culture units used for intensive aquaculture are tanks and raceways, which require high flow rates to provide a suitable growing environment and remove wastes.

Intensive systems are the most productive systems in terms of yield per unit volume or area and often the most efficient in respect of waste water treatment and hence sustainability and environmental protection.

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[19] Water flow rates are often incorrectly quantified as a given number of exchanges per unit time. In well mixed systems, new water added to a tank is mixed with “old” water already in the tank, so the effluent will comprise a mixture of old and new water. The addition of a single volume, therefore, does not constitute one complete water exchange. In fact, a flow rate of four volumes per hour will only result in an exchange rate of about 95 per cent. Water flow is therefore more accurately described as a number of volumes per unit time, as opposed to exchanges per unit time.

*Semi-intensive systems*

Semi-intensive systems typically have an intermediate level of management, medium culture densities and depend on both increased natural productivity and supplementary feeding. Inputs such as aeration and water exchange are also provided. These systems support higher yields and are more profitable than extensive systems. To maximise return on invested capital, the trend in semi-intensive aquaculture has been towards the production of higher-value species and increasing the level of intensity and yield.

Onshore, semi-intensive systems typically use medium to large ponds, depend on a flow-through, pumped water supply and grow marine, brackish water and freshwater finfish and shellfish. The highly-successful marine prawn aquaculture industry predominantly uses semi-intensive pond systems. Offshore, semi-intensive systems are commonly used to culture finfish in cages, at lower densities than intensive systems, and filter-feeding shellfish in longlines and racks.

*Extensive systems*

Extensive systems have a low level of management, low culture densities and depend on natural productivity, which may be augmented by fertilisation. Using low levels of technology and relying on few inputs, these systems are usually restricted to fisheries enhancement and subsistence-level aquaculture in developing countries.

## 6. SCALE

For aquaculture production systems, the term *scale* refers to the physical size of the operation or the area it occupies, not its level of production or yield, so it is correctly expressed as an area or other comparable unit. Usually governed by a minimum economic unit for the species under culture, scale is also influenced by the intensity of the production system and the culture technology being applied. For the purpose of this study, small, medium and large-scale aquaculture production systems are defined, somewhat arbitrarily, as those that occupy areas up to 20 ha; between 20 and 200 ha; and greater than 200 ha respectively.

The more intensive production systems are usually small-scale. Some, according to the degree of intensity, may be small to medium-scale. They are generally privately owned, operated by company structures or other incorporated bodies, and associated with developed countries. Small-scale systems that are not intensive are usually operated by their owners, who frequently form co-operatives to negotiate and coordinate activities such as processing, marketing and transportation.

Semi-intensive systems are usually medium to large-scale. As the scale of a semi-intensive system increases, there is usually an increasing need for sophisticated management and technology. If high yields and large profits are the principal business objectives, medium-scale to large-scale areas will be required to achieve sufficient production levels, market sales and economies of scale. Medium to large-scale aquaculture operations usually have some degree of vertical integration and many are privately owned.

## 7. INTEGRATION

As an aquaculture industry matures, greater use of integrated technologies can be expected, due to environmental pressures. Three main types of integration characterise aquaculture production

systems, namely vertical integration, horizontal integration and polyculture.[20]

*Vertical integration*

Vertically-integrated production systems comprise several or all of the mutually-dependent elements that collectively constitute the production cycle, such as the hatchery, grow-out farm, processing operations and associated activities such as feed production, packaging and marketing. The selection of the elements to be integrated depends on a variety of factors; for example, the lack of a reliable supply of juveniles may necessitate the inclusion of a hatchery in the production system. Some owners choose to limit their aquaculture activities to grow-out, while others prefer to produce their own seed stock and control the grow-out stage. Many also control their own processing and packaging. Most intensive and semi-intensive aquaculture operations are vertically integrated to some degree.

*Horizontal integration*

Horizontal integration involves the merging of aquaculture with agricultural or other industries, to utilise by-products or other operations to maximise the income that can be generated from a limited resource. Examples include the use of nutrient-rich water discharged from fish farms to irrigate crops and using thermal effluent from power-generating stations to cultivate species outside their natural range. Horizontally integrated aquaculture production systems are becoming more common in developed countries, as their financial and environmental benefits have become evident.

*Polyculture*

Polyculture describes the situation where more than one aquatic species is cultured within a single production system and where there is some degree of interdependence between the species.[21] The output from a single aquaculture production system can be improved by growing different but complementary species, which generally occupy different ecological niches, to make optimum use of available resources. In addition to improving profitability, polyculture can have positive environmental influences; the utilisation of shellfish and algae to strip nutrients from the waste water discharged from marine shrimp farms prior to its release into the environment is one example.

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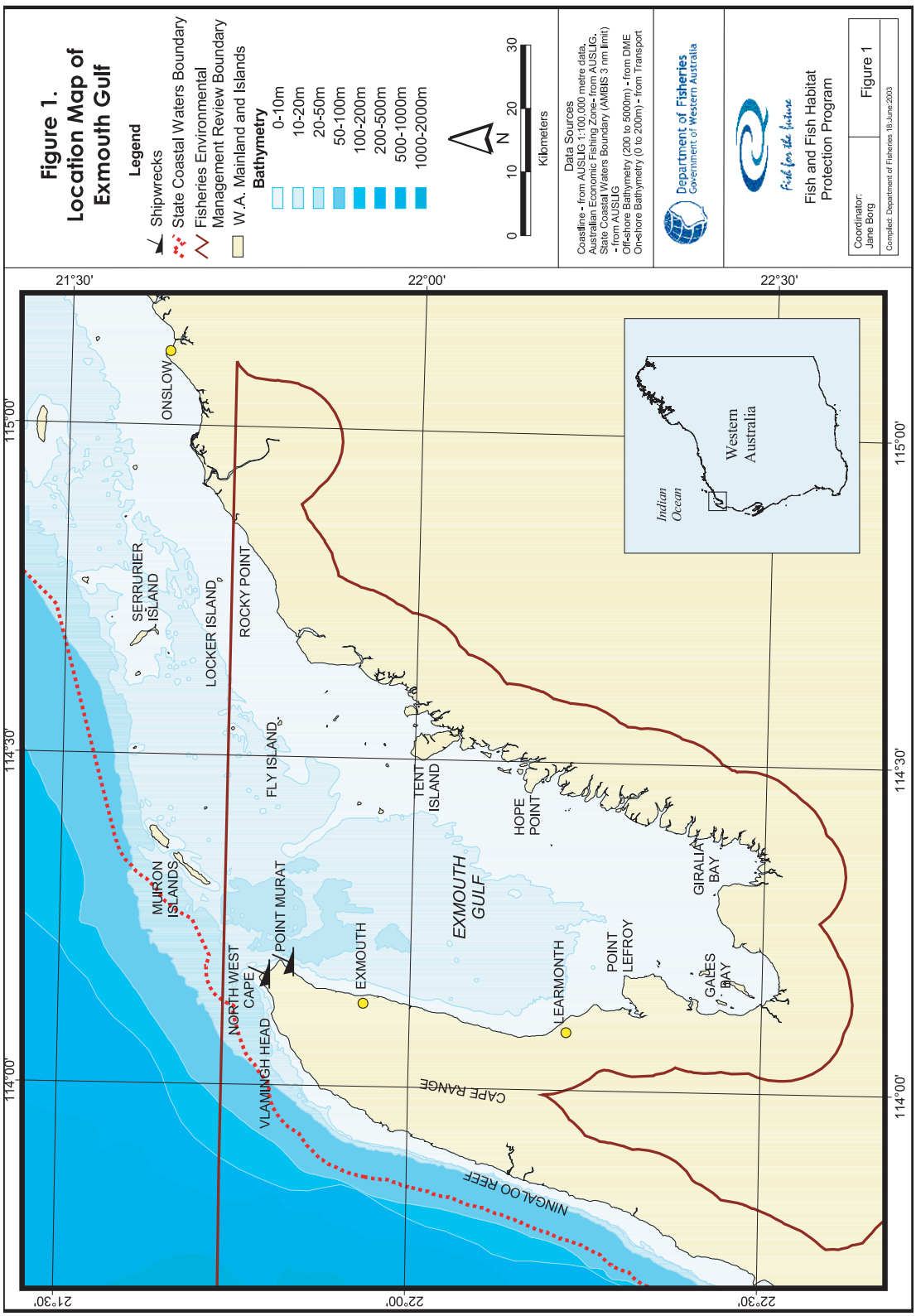
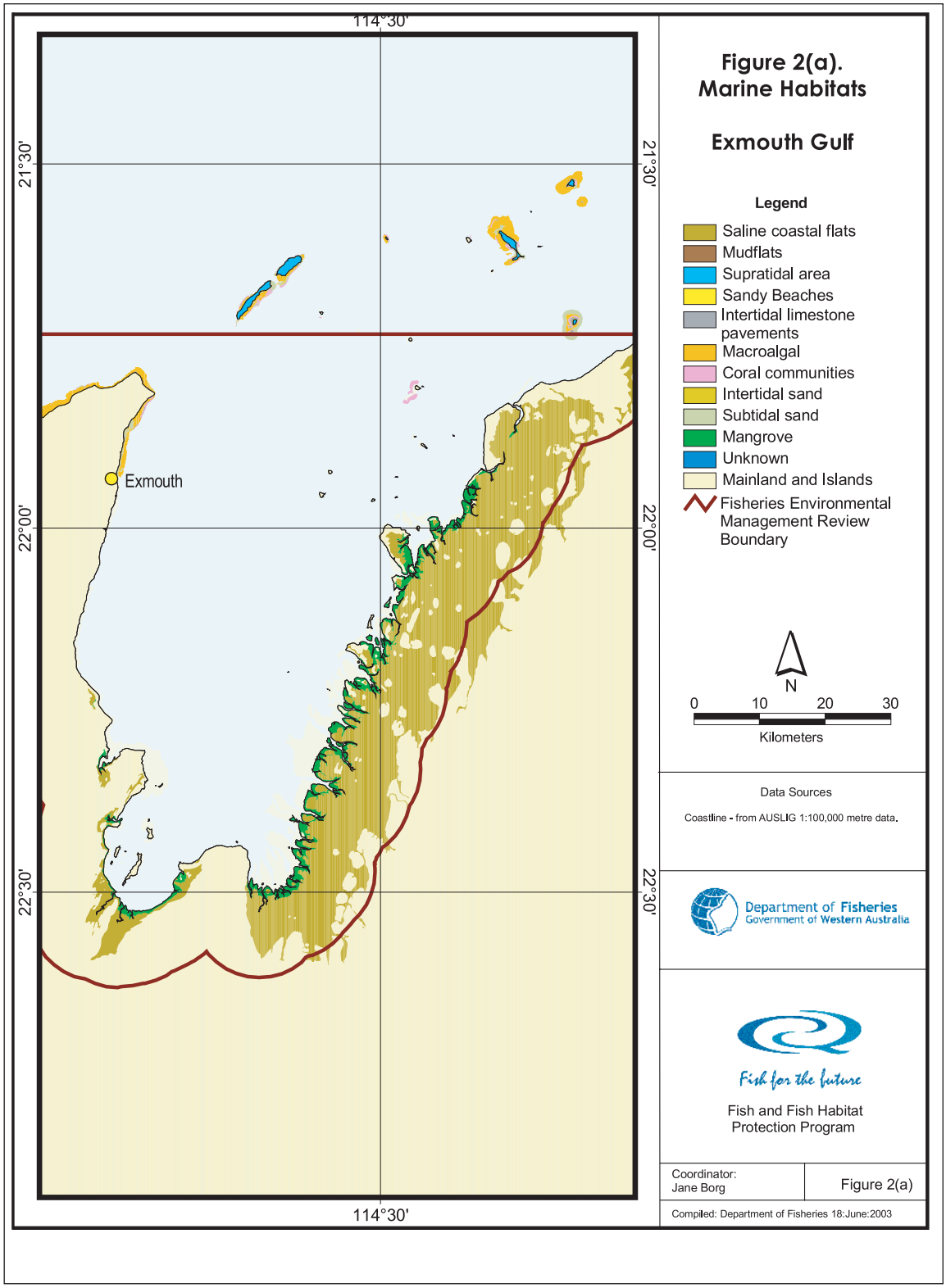
[20] The degree and type of integration that may be possible can have a significant influence on the selection of a suitable production system. For example, with water flow, the production of a tropical species in a temperate area may require a recirculating production system; however, the integration of aquaculture with an industry that discharges 20 The degree and type of integration that may be possible can have a significant influence on the selection of a suitable production system. For example, with water flow, the production of a tropical species in a temperate area may require a recirculating production system. However, the integration of aquaculture with an industry that discharges heated water, such as one generating electrical power, may permit the selection of a flow-through system.

[21] Polyculture has previously been defined as the culture of more than one species within a single rearing unit, such as a pond. For the purpose of contemporary aquaculture production systems, however, *polyculture* means the simultaneous production of more than one aquatic species within a single production system, irrespective of the number of culture containers, whether tanks, raceways or ponds, that collectively make up the system, and where there is some degree of interdependence between species.

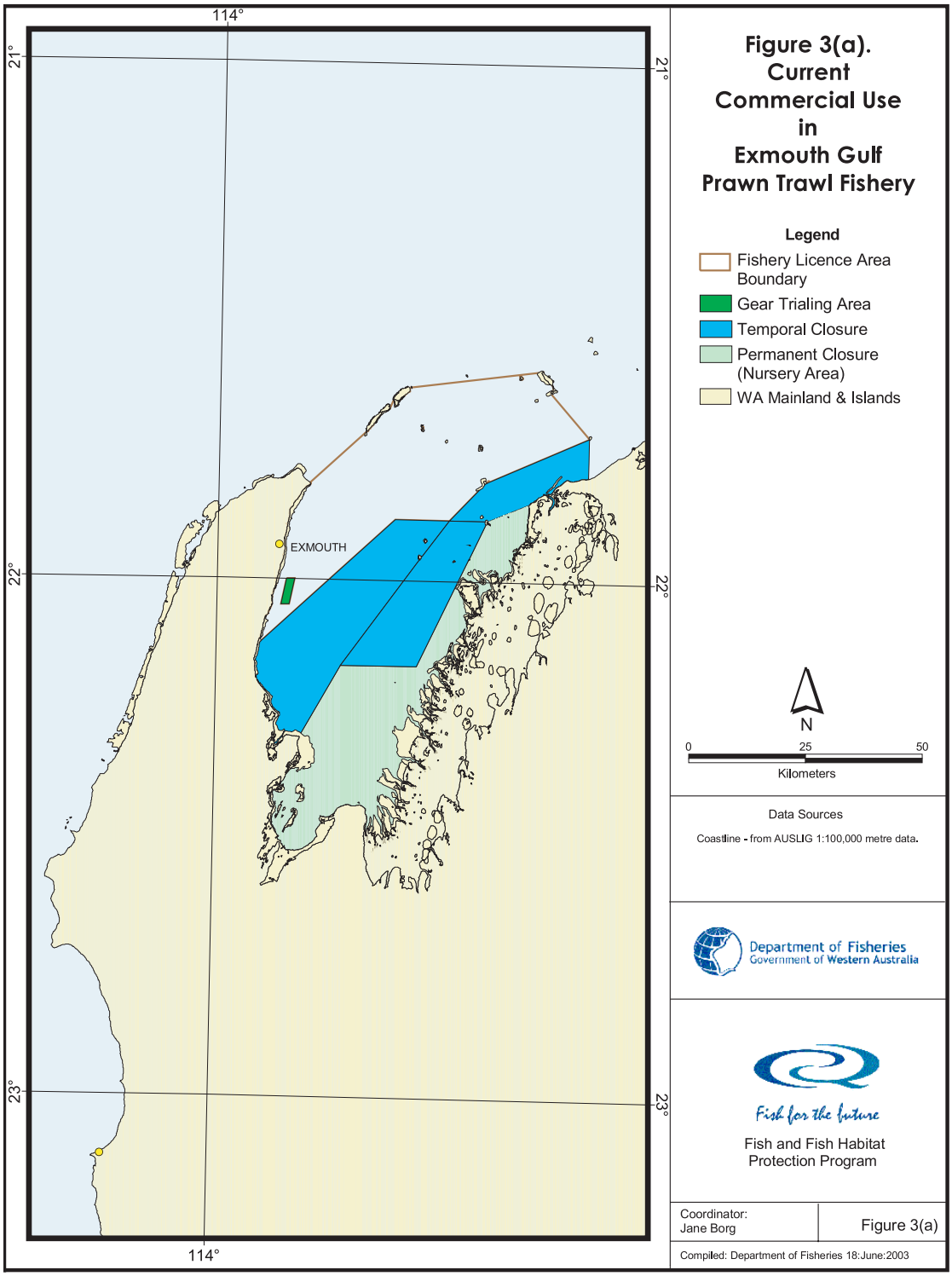
# Figure 1: Location map of Exmouth Gulf



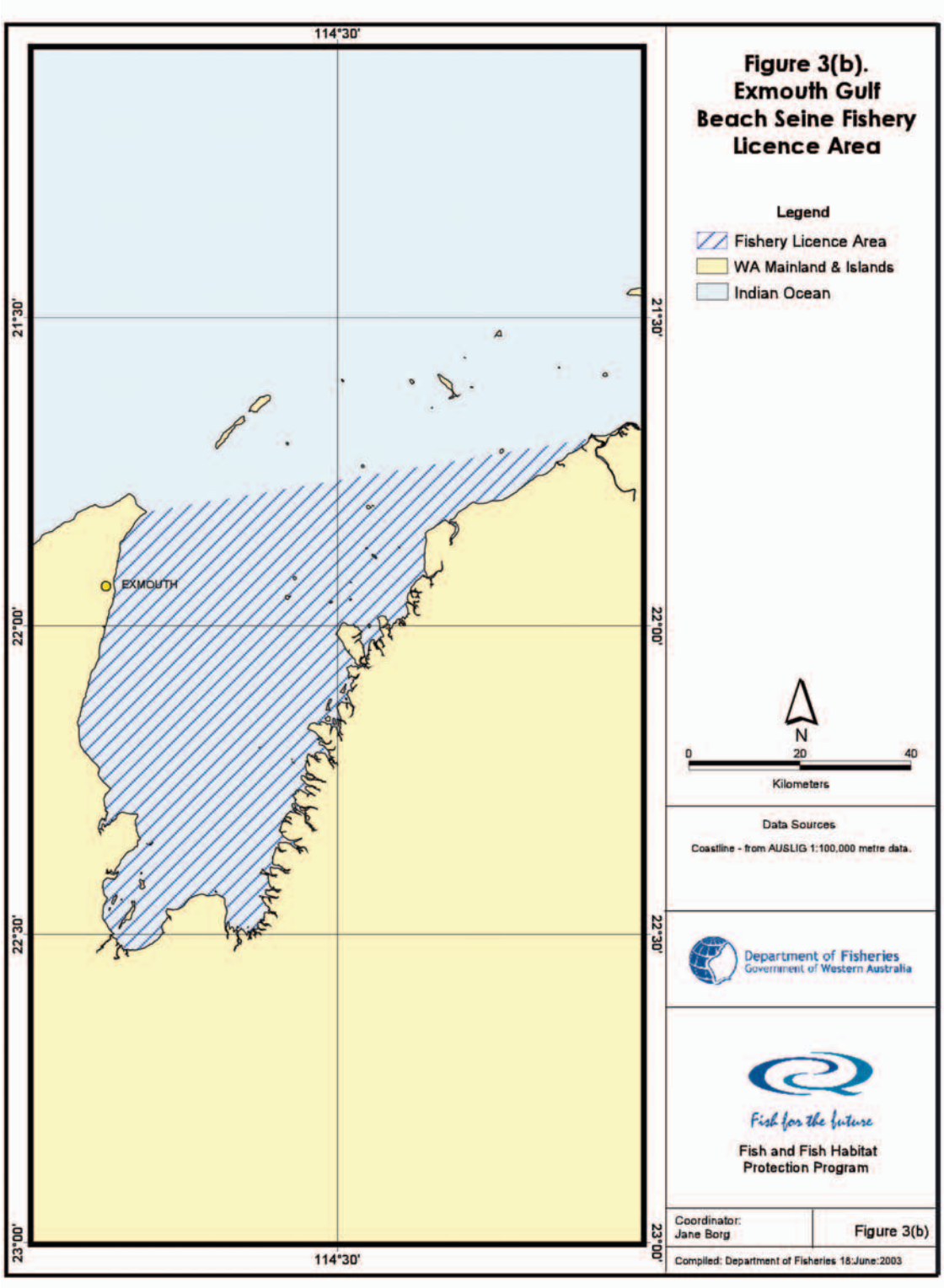
# Figure 2: Marine Habitats, Exmouth Gulf



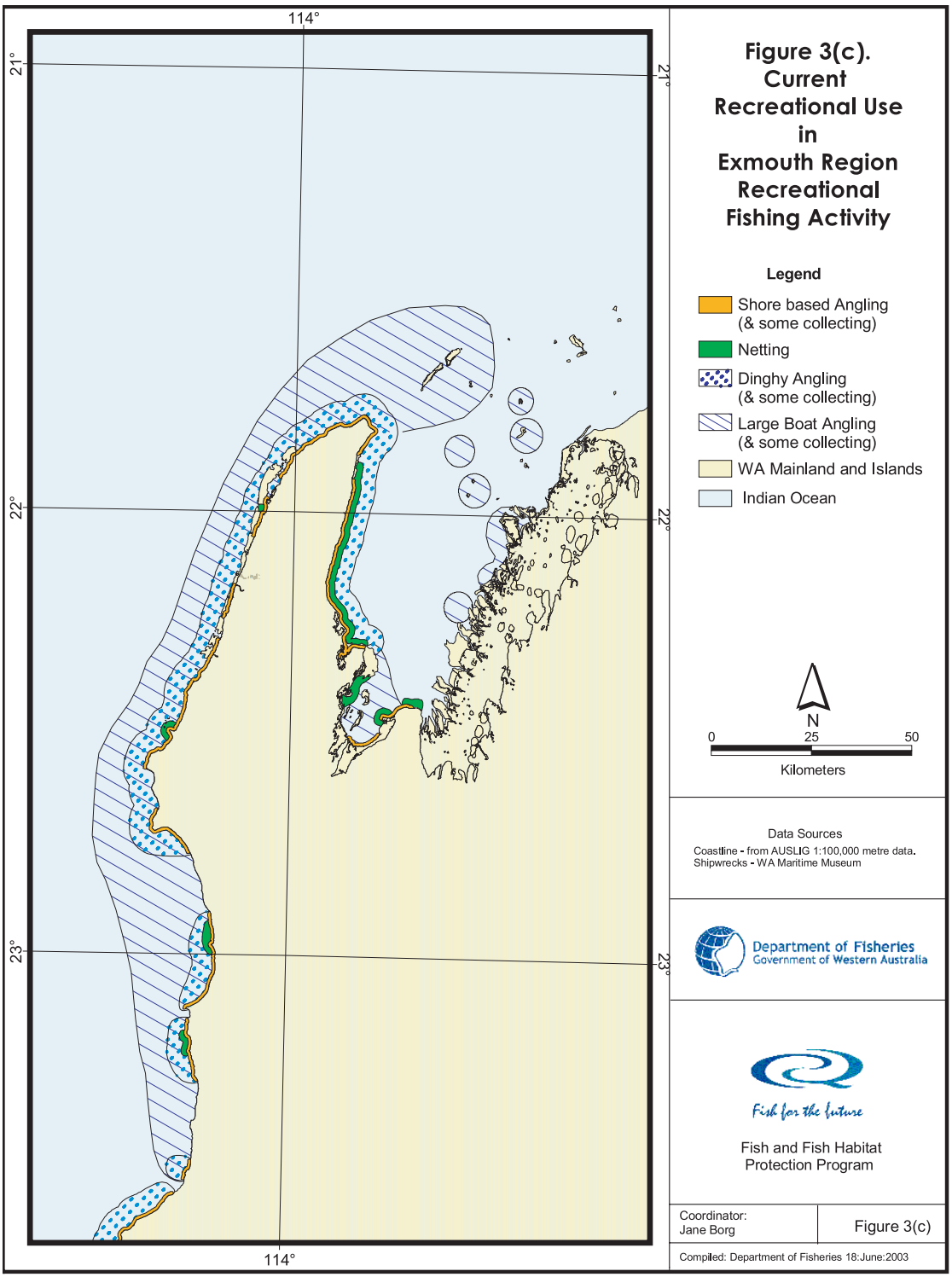
# Figure 3a: Current Marine Uses, Exmouth Gulf



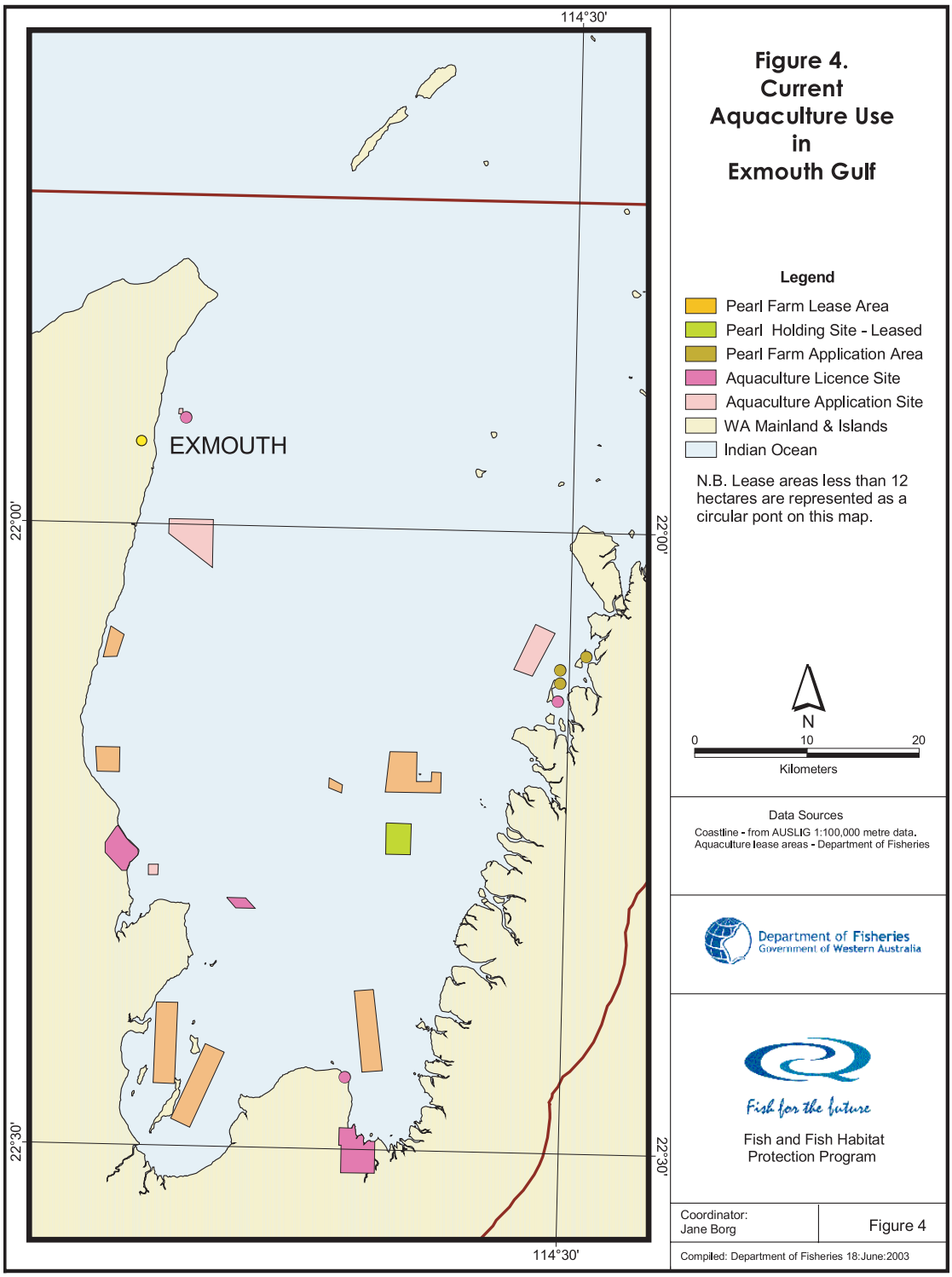
# Figure 3b: Current Marine Uses, Exmouth Gulf



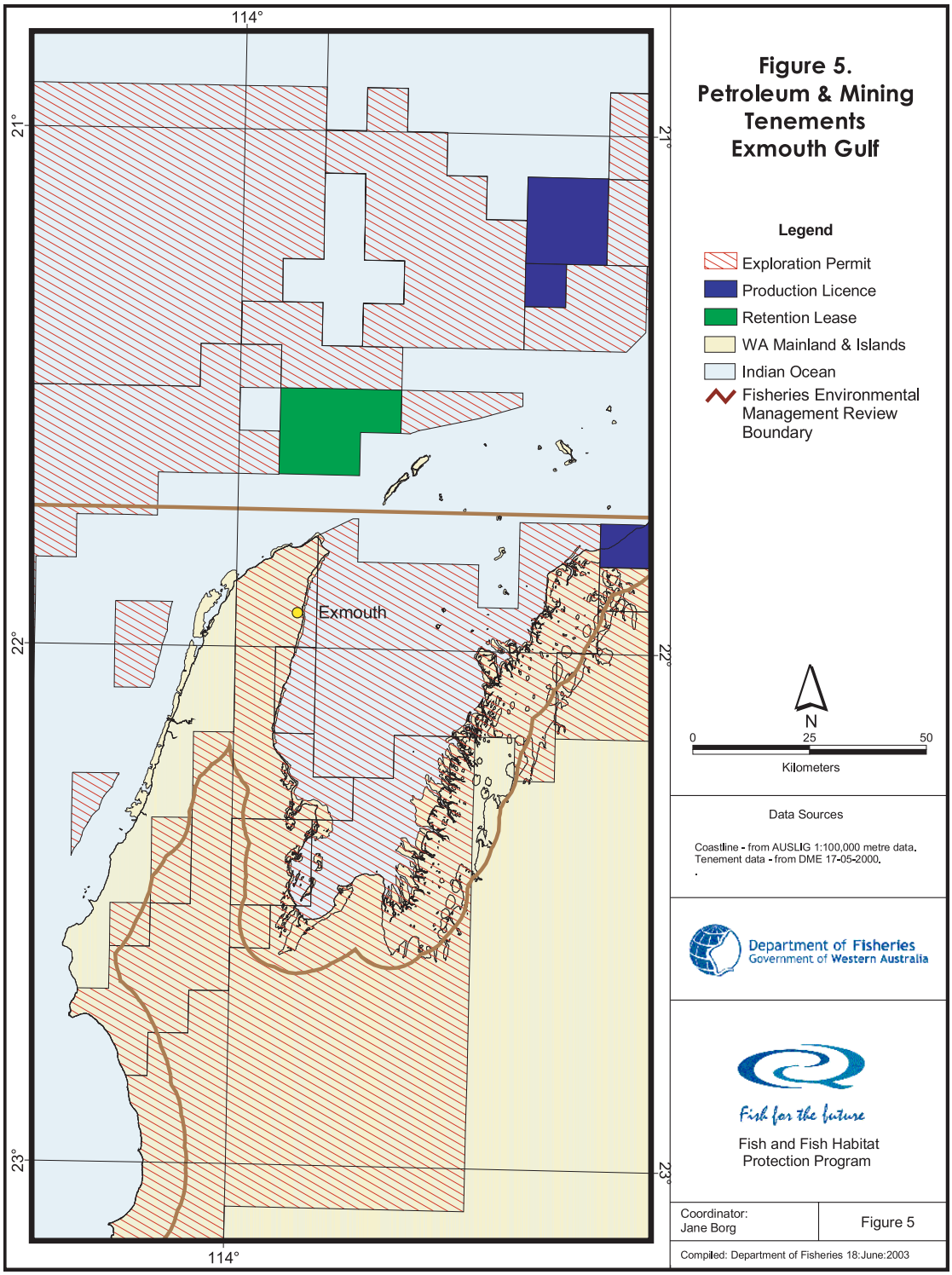
# Figure 3c: Current Marine Uses, Exmouth Gulf



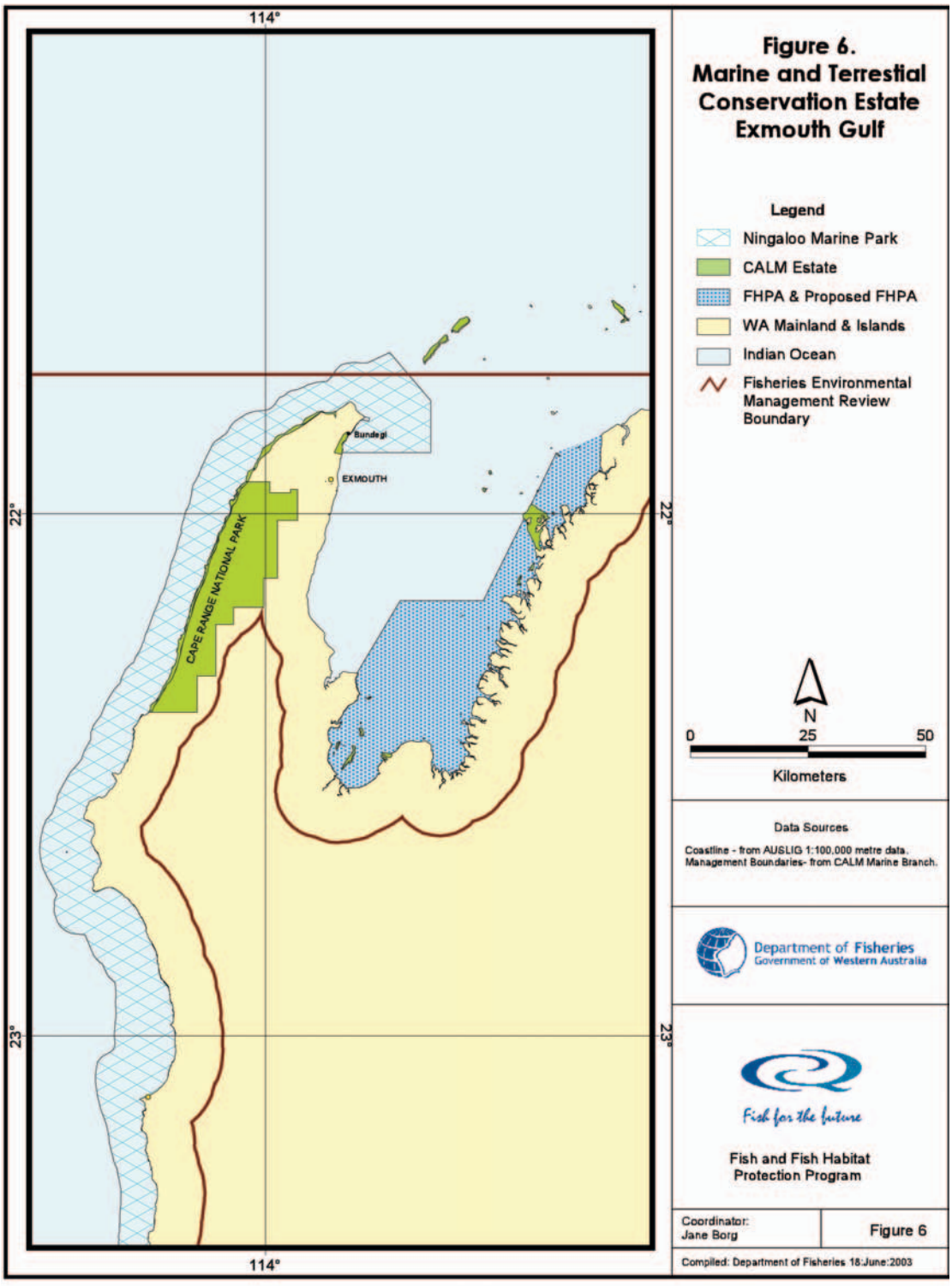
# Figure 4: Current pearling and aquaculture sites and applications as at December 1998 for Exmouth



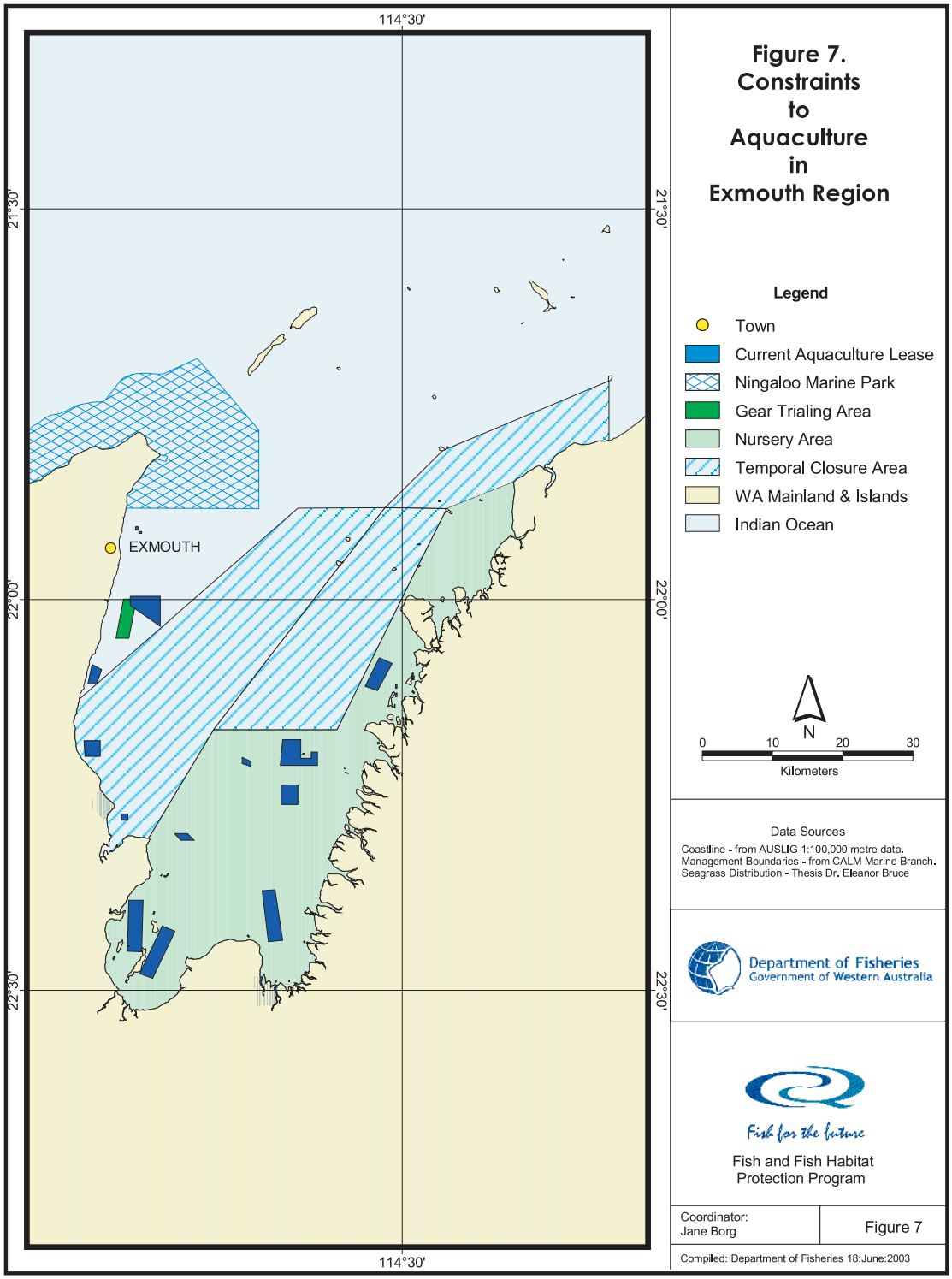
# Figure 5: Mining and petroleum tenements, Exmouth Gulf



# Figure 6: Marine and Terrestrial Conservation Estate, Exmouth Gulf



# Figure 7: Areas where aquaculture can and cannot occur



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