AQUACULTURE OF LIVE ROCKS, LIVE SAND, CORAL AND ASSOCIATED PRODUCTS

A DISCUSSION AND DRAFT POLICY PAPER

FISHERIES MANAGEMENT PAPER NO. 196

Department of Fisheries
168 St. Georges Terrace
Perth WA 6000

April 2006

ISSN 0819-4327

Department of
Fisheries

The Aquaculture of Live Rock, Live Sand, Coral and Associated Products

A Discussion and Draft Policy Paper

Project Managed by Andrew Beer

April 2006

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ISSN 0819-4327

CUSTOMER FOCUS
WESTERN AUSTRALIA

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OPPORTUNITY FOR PUBLIC COMMENT

YOUR FEEDBACK IS NEEDED

This discussion paper has been prepared to provide information to assist in the management of live rock, live sand and coral aquaculture in Western Australia. In the development of a new aquaculture sector, consideration must be made of the potential benefits, impacts and issues associated with the economic, environmental and social considerations.

Comments about this discussion paper and draft policy statement are sought from all stakeholders including industry members, existing and potential aquaculture farmers, relevant community interest groups, government agencies and interested members of the public.

Following consideration of the public comments received on this discussion and draft policy paper, a final policy paper will be developed, which will outline the manner in which the Department of Fisheries will manage the aquaculture of live rock, live sand and coral in Western Australia.

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

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

To assist you with the above, an **Issues Submission Sheet** has been compiled and is provided loosely with this document.

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

This paper is being released for comment on 28 April 2006 for a 6 week period. Your comments would be appreciated by the close date, 9 June 2006 (6 week period) and should be addressed to:

Executive Director
Attention: Aquaculture and Pearling Program
Department of Fisheries
3rd Floor, SGIO Atrium
168 St George's Terrace
PERTH WA 6000

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April 2006

ACKNOWLEDGEMENT

A number of Department of Fisheries staff contributed to the development of this policy paper. Thank you to Andrew Beer who managed the development of this paper. Sincere thanks also go to Peter Millington, Greg Finlay, Jo McCrea, Jenny Shaw, Tina Thorne, Barbara Sheridan, Tim Nicholas, Sascha Brand-Gardner, Sagiv Kolkovski, Craig Astbury, Brian Jones and Jordan Bennell.

The Department would also like to thank the members of the aquaculture industry who provided thoughts, ideas and constructive comment on the development of this policy paper. Thanks to Dan Machin, Rick Scoones, Wayne MacKenzie Brown, Peter Fullarton, Simon Hawkes and Jonathon Potter.

The author would like to thank the Marine Aquarium Council for kind permission to reproduce Figure 3 from the *Mariculture and Aquaculture Management: International Performance Standard for the Marine Aquarium Trade. Issue 5 – October 11, 2004*.

SECTION 1 EXECUTIVE SUMMARY & PROPOSED POLICY OPTIONS

INTRODUCTION

Live rock, live sand and coral are used by aquarium enthusiasts to enhance the aesthetics or function of the marine aquaria they keep and enjoy. There is a large and growing market for these products and while the wild harvest fisheries in Western Australia are sustainably managed, output is effectively capped. In order to maintain supply to the market, increased output is required. With a trend towards the capping of wild harvest and additional pressures of introduction of Marine Parks and other forms of marine protected areas, the aquaculture of these products is set for rapid industry development and expansion.

The range of coral and associated species is large and this diversity provides considerable flexibility in the range of culture systems and technologies. They can be grown in onshore recirculating or flow through systems and also in offshore open water systems. It is generally considered a low impact aquaculture industry because the animals are low maintenance requiring no additional feeding (just sunlight), the footprint of farms is relatively small, and relatively low number of 'working days' are required on any one site.

The Department of Fisheries has prepared this discussion paper to outline the position and needs of the emerging industry and the proposed management arrangements and policies in place.

Therefore, the key objectives of this document are to outline and develop:

- The key information about live rock, sand and coral aquaculture that is relevant to the development of an industry in WA; and
- A draft policy for the management of live rock, sand and coral aquaculture, on both onshore and offshore licence sites.

PROPOSED MANAGEMENT ARRANGEMENTS

The Department has examined the management issues and potential risks associated with the emerging coral, live rock and live sand sector. These risks have been identified through Department workshops and include suggestions from sectors of the industry that have expressed an interest in coral and live rock aquaculture.

Based on the understanding of the opportunities and risks associated with the development of the coral, live rock and live sand aquaculture industry, the Department has developed set of proposed management arrangements which together act to minimize those risks and maximize the potential benefits to industry, the State and the environment. Key issues that are addressed in the these management arrangements are the relief to the wildstock from the development of an aquaculture industry, the need to develop mechanisms to ensure that industry can demonstrate its sustainability and in particular to ensure that it is not possible to 'hide' illegal harvests, and the implementation of a sound and equitable licensing and industry develop process.

The proposed management arrangements are below. Please note that these are proposed management arrangements in which the Department seeks comment from all relevant

stakeholder. In two circumstances, the Department is proposing a number of options on which specific comments in sought.

Fit and Proper Person Criterion

- Licence applications will be assessed in accordance with Ministerial Policy Guideline No. 19 *Matters of Importance in Respect of the 'Fit and Proper Person' criterion for authorizations under the Fish Resources Management Act 1994*.

Number of Marine Based Sites per Company at Grant

- Applicants entering the coral, live rock and live sand aquaculture sector and applying for the initial grant of such a licence over a marine based site, will be required to demonstrate performance at that site, in accordance with agreed and specified criteria, prior to eligibility to apply for additional marine based sites.
- Strict performance criterion, including reporting on conditions of licence and conduct within a predetermined timeframe will be in place to ensure site utilization.

Coral Species Identification

There are two possible options with regard to species identification:

1. Retain the existing system of identification of culture stock down to species level and work within the difficulties of identification in the field;
2. Simplify the nomenclature and provide authorizations relating to genus rather than species level.

The Department is seeking specific comment from all stakeholders on a mechanism to address this issue.

Distinguishing between aquacultured live rock and coral

- The Department of Fisheries will include in aquaculture licence conditions the requirement for individual tagging of coral and marking of live rock. The licensees would have the opportunity to develop their own method of tagging that satisfied prescribed criteria. Possible mechanisms for identification include:
  - Numerical tags
  - In vivo staining of cultured coral tissues
  - Genetic markers.

The Department is seeking specific comment from all stakeholders on reliable and reasonable means through which aquacultured and wild harvest stock can be distinguished.

- In order to ensure that there is certainty in distinguishing between wild and aquacultured live rock:
  - No 'natural' reef rock or coral material can be used in live rock culture – rock harvested from the marine environment will not be permitted; and
  - All live rock in culture will be manufactured or quarried rock.

Environmental Management

- Aquaculture applications for coral, sand and live rock will be assessed in terms of environmental sustainability, and where granted, will be conditioned appropriately to ensure sound environmental practices and that adequate monitoring programs are conducted.

Translocation

- Proposals to aquaculture exotic corals in land based systems will be assessed under Ministerial Policy Guideline No.5.
- No species that has been translocated from interstate, overseas or outside its natural distribution within WA will be permitted to be farmed offshore or in flow through open systems. Species identification must be verified prior to movement of any animals in order to ensure that culture is within natural range.

Culture Methods

- Applicants will be required to clearly describe the proposed culture method in the aquaculture licence applications;
- The proposed method(s) of culture described in the aquaculture licence application will be assessed on a case by case basis;
- Licence conditions will specify the approved method of culture.
- Alterations to that culture method shall require a variation to the aquaculture licence and reassessment by the appropriate regulators.

Broodstock Issues

- The following options to collect coral broodstock are proposed:
  - Purchase from commercial fishers
  - Purchase from other aquaculture licence holders or retail outlets
  - Ministerial Exemptions under Section 7 of the *Fish Resources Management Act 1994*

Convention on International Trade in Endangered Species

- Encourage the Western Australia industry to seek certification or recognition of compliance with requisite Convention on International Trade in Endangered Species (CITES) regulations and maintains this as an additional 'brand'.
- The Department will submit a statement to the Commonwealth Department of Environment and Heritage requesting that in addition to products sourced from the Marine Aquarium Fish Managed Fishery, aquaculture live rock, live sand and coral is included in the List of Exempt Native Species (LENS) on the basis that they are products that were lawfully produced by the aquaculture industry in accordance with the *Fish Resources Management Act 1994* (FRMA).

Compliance

- The Department of Fisheries will review the Aquaculture Compliance Risk Assessment Manual and Compliance Plan to incorporate the introduction of a new suite of species;
- Adequate training will be provided to Fisheries and Marine Officers in the relevant regions in order to ensure compliance risks are reduced.
- A program of compliance around the coral, live rock and live sand industry will be developed and implemented in Western Australia in accordance with the Compliance Plan.

SECTION 2 INTRODUCTION

2.1 Background

Live rock, live sand and coral are used by aquarium enthusiasts to enhance the aesthetics or function of the marine aquaria they keep and enjoy. Live rock is substrate (generally a rock or dead coral) that has been colonised by a range of marine flora and fauna. 'Live sand' is 'clean' sand particles colonised by bacteria and other invertebrates and is used in filtration systems and within the marine aquarium. Corals belong to a diverse class of invertebrates most notably the reef building corals, but within this paper both hard limestone skeleton corals and soft corals are considered. A more detailed explanation is provided in Section 3.

There is significant interest in the production of live rock, live sand and coral around the world and the Department of Fisheries has received a number of aquaculture licence applications for the culture of these species assemblages.

While an assessment procedure for aquaculture licensing is well established, the issues specifically relevant to the aquaculture of live rock, sand and coral require further consideration. This discussion paper has been prepared to facilitate consultation and generate discussion in relation to appropriate management of this emerging aquaculture sector.

2.2 Objectives

The principal objective of this paper is to identify and consider issues associated with the aquaculture of live rock, sand and coral and to propose a management framework to address these issues. In considering these matters, the paper provides fundamental information about the biology and ecology of species, the related wild-capture fishery and their aquaculture potential.

Therefore, the key objectives of this document are to outline and develop:

- The key information about live rock, sand and coral aquaculture that is relevant to the development of an industry in WA; and
- A draft policy for the management of live rock, sand and coral aquaculture, on both onshore and offshore licence sites.

The paper will form the basis of consultation with stakeholders and will be the starting point for public involvement in policy development.

The final policy adopted will guide the Department of Fisheries in its decision making role in relation to proposed coral, live sand and live rock ventures and provide clarity to potential industry players and stakeholders in relation to management regimes.

2.3 Why Live Rock, Sand and Coral Aquaculture?

Live rock, sand and coral are used to:

- Develop an architectural structure for aquaria and aquaculture tanks;
- Contribute as a large surface area substrate that facilitates biological filtration of a marine aquarium and stabilises its water chemistry;
- Enhance the aesthetics of aquariums - providing a base to attach other corals, sponges, anemones and clams; giving shelter for the inhabitants; and
- Provide an active biological filter within an aquarium environment.

The biological features of live rock, sand and coral and the interesting life history of corals make them good candidate species for aquaculture. Corals reproduce both asexually and sexually and the techniques for asexual propagation are relatively basic. Similarly, the technology required for the culture of live rock can be as simple as placing a substrate in the marine environment and later harvesting the rock and whatever has settled on it.

Live rock, sand and coral can be cultured using a variety of production systems in a wide range of environments throughout Western Australia, from the Kimberley in the tropical north to the temperate south. While the culture methodology is under development and may require considerable 'fine tuning', the culture of these groups of marine organisms is likely to employ relatively low technology.

From an economic perspective, the species found in WA are generally suitable for commercial production and have been grown profitably in Australia (Willis and O'Sullivan, 2004) and abroad (Falls *et al,* 2003).

Live rock, sand and coral may be cultured in offshore aquaculture sites using bottom culture or in suspended culture longline systems similar to those employed for the culture of pearl oysters and mussels. Operations using flow-through or controlled recirculating water production systems may also be employed in land-based recirculating systems, in order to culture animals outside of their natural distribution and potentially closer to markets or distribution points.

2.4 Market

The global market for marine aquarium products is substantial and growing rapidly, with worldwide trade in aquarium livestock and products estimated to exceed $US 7 billion (Falls *et al* 2003). Growth in the trade of live stony corals (Order Scleractinia) throughout the 1990s increased around 375 per cent - from around 200,000 units (one unit = one saleable piece of coral) in 1990 to 750,000 units in 1999 (CITES, 2002), with industry sources aiming to double that figure by 2010. The trade in live reef rock has increased 1,700 per cent since 1988 (U.S. Coral Reef Task Force 1999).

The USA is the largest consumer of live rock, sand and coral, with an estimated 1 to 1.5 million hobbyists living in the USA (US Fish and Wildlife Service 2003) importing 80 per cent of live coral and 90 per cent of live rock exported globally. Ornamental aquarium products are a major aquaculture industry in the USA worth approximately $US 1billion, 20 per cent of retail sales being marine species (Falls *et al* 2003). Growth in the market demand for coral and live rock is estimated to be 12 to 30 per cent in the USA per annum,

which is consistent with global annual growth that is estimated to be 10 to 15 per cent or 40 to 60,000 units per annum.

As with any wild fishery, the limits of sustainable take and community expectations regarding resource utilization may lead to a gap between supply and demand. The global market is growing and both local and global supply of wild stock is either capped or in decline in response to calls for improved management arrangements to ensure sustainability of the coral reef communities these industries exploit (Ellis 2002). For example, in many locations in the US and islands under US jurisdiction in the Atlantic and Pacific, the wild harvest of live rock is banned (Falls 2003).

As a result, the aquaculture of live rock, sand and coral is an increasing business opportunity. As well as the economic opportunities, aquaculture can generate environmentally responsible, certifiably sustainable and acceptable products that suit the market, are supplied to specifications, are accustomed to a 'culture system' and can support profitable businesses.

A number of factors contribute to live rock, sand and coral aquaculture having considerable potential in Western Australia. These include the number and type of available sites, a wide range of species (many endemic), expertise in the collection and marketing of wild-caught product and a clean green environment. Consequently, there is significant interest in the commercial aquaculture of live rock, sand and coral in Western Australia.

SECTION 3 THE TAXONOMY AND BIOLOGY OF LIVE ROCK, SAND AND CORAL

The Live Rock, Live Sand and Coral 'group' is populous and diverse in terms of the range of species and their life history strategies. It is these reproductive strategies and inherent flexibility that make many of these species suitable for aquaculture. For example, branching *Acropora* corals that can be produced through fragmentation may be made available to the market in a mass-produced fashion, while other more unusual or rare species may be produced through more specialised culture techniques.

An extensive outline of coral and similar anthozoans taxonomy, biology and aquaculture techniques may be found in Appendix 1.

3.1 Live Rock

Live rock is a 'trade name' for a substrate (generally a rock or dead coral) that has subsequently been colonised by a range of benthic flora and fauna. Clearly the rock is not 'live' but the veneer of organic matter around or on it is alive.

The organic covering may include algae (green, brown and red), crustose coralline algae, sponges, bryozoans, hydroids, gorgonians, zoanthids, tunicates, coralliomorphs, bivalves and polychaetes. The porous nature of 'wild' live rock means that often within it there are other organisms such as crabs, shrimp, fish, nudibranchs and molluscs, taking refuge in this protected lair.

Live rock and live sand serve as the 'backbone' of marine display aquariums. Live rock is known by many names in the aquarium trade, such as reef rock (low density material, usually coral skeleton), inshore rock (more dense and may be limestone or local 'continental' rock) and base rock (low level of colonisation by flora and fauna).

The important factors in the successful colonisation of space in the marine environment and the development of the live rock assemblages are generally:

- Available light for photosynthetic processes;
- Available nutrients for tissue growth;
- Stable growth substrate, because if the rock is overturned it will lead to the death of the encrusting flora and fauna; and
- Stable sediments because being covered by sand, mud or silt, would smother the flora and fauna living on the rock.

3.2 Live sand

'Live sand' is either natural coral sand that is collected live from the ocean or non-living coral sand or aragonite (limestone) sand that is cultured to make it 'live' through 'inoculation' of existing live sand. Sand is made 'live' by the marine bacteria that grows on it, and the many micro and macro-organisms of the benthic fauna that reside in it. Live sand can serve as the main base for biological filtration in a saltwater aquarium as the organisms help consume organic matter in the sand bed. Good quality live sand also adds to the aesthetics of an aquarium system.

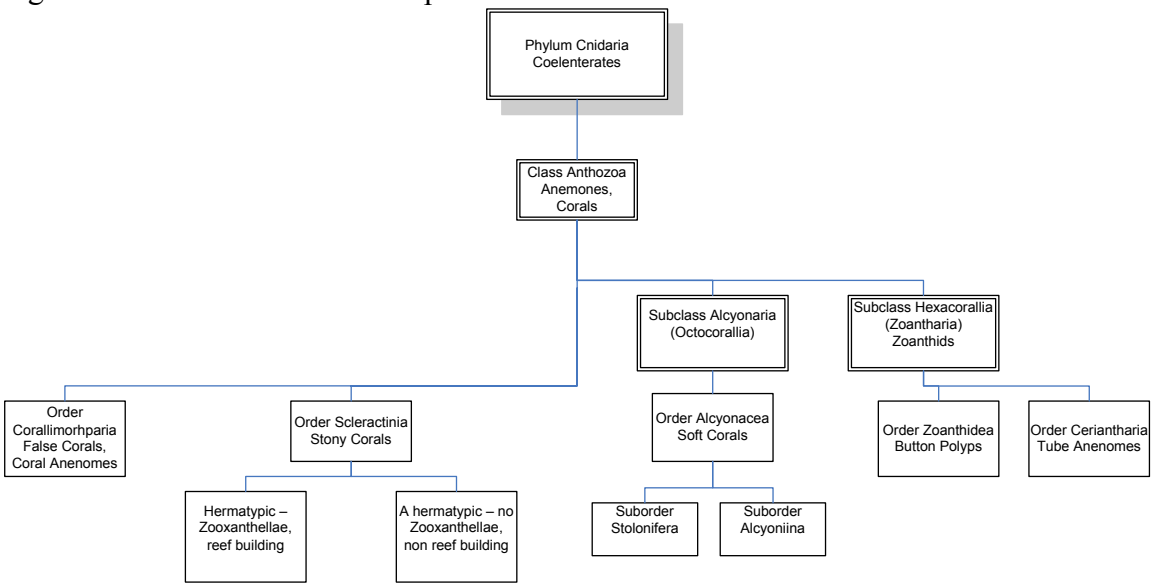
A study of the broad number of species that are included in the live rock encrusting assemblage can provide a detailed explanation of the biology, life history and 'growth' of a particular piece of 'live rock'. The reader is referred to generic Zoology texts such as Ruppert & Barnes (1994) for further information.

3.3 Corals and Associated Orders of Anthozoans

The remaining text in this section will be relevant to coral. Whilst it is not appropriate to provide details of the biology of coral in this document, the following information is relevant to the development of an aquaculture industry and management arrangements.

There are a number of classifications of marine organisms within the Phylum Cnidaria, which include primitive animals generally known as jellyfish, sea anemones and corals. The largest of the Cnidarian Classes is the Class Anthozoa, which contains over 6000 species of coral and 'coral-like' species. Figure 1 represents the taxonomic relationships within this group. In scientific language coral is generally the common name for members of the Order Scleractinia, which all possess hard limestone or carbonate skeletons – the 'stony' corals. Other Anthozoan groups include Soft Corals (Order Alcyonacea), False Corals and Coral Anenomes (Order Coralliomorpha) and the Button Polyps (Order Zoanthidea). It is these groups, alongside the stony corals that are commonly found in the aquarium trade.

Figure 1. Taxonomic Relationships of Corals and Associated Orders



In this paper, the term 'coral' will refer primarily to hard and soft corals. However, the associated Orders noted above and described below form an important and economically lucrative part of the coral aquaculture industry.

3.4 Coral Taxonomy and Biology

3.4.1 Stony Corals

Within the Order Scleractinia there are two forms of stony coral:

- Reef-building coral (hermatypic) that require sunlight to survive as these species incorporate symbiotic algae (zooxanthellae); and
- Non reef-building coral that can survive in the dark (no symbiotic algae) and may be found in caves or the ocean depths (ahermatypic).

There are also a number of non-Scleractinian corals that build skeletons but not of a calcareous structure. These may be referred to as 'false corals' (Veron 1986) and include familiar groups such as *Tubipora* and *Millepora* (Fire Coral).

The secretion of a calcareous exoskeleton is unique to the Scleractinians and provides the colony with a base over which the polyps settle. Within the hard corals classification, there may be further demarcation, based on the polyp size and growth form of the colony. This distinction is also used in the trade and divides the hard corals into Small Polyp Stony (SPS) and Large Polyp Stony (LPS) classifications.

The generic groups and the characters of both Small Polyp Stony and Large Polyps Stony that are currently sold in the aquarium trade or aquacultured are detailed in Table 1.

Scientific (genus) Name	Common Name	Growth Form*	Distinguishing Feature(s)	Abundance
Small Polyp Stony corals				
Acropora	Staghorn Coral	May be any or all forms but usually table or plate like or arborescent – composed of tree like branches.	Axial and radial corallites. Rapid growth	Very common on shallow water reef slopes. 73 species in Australia, 54 from WA.
Montipora	Plating Coral	Variable - Sub massive, encrusting, branching, foliaceous laminar	Very small corallites – most similar to *Porites*	Very common to rare
Pocillopora	Cluster coral	Branching Polymorphic dependent on habitat.	Wart like growths called verrucae covers the colony.	Common to very common
Stylophora		Branching Compact bush	Blunt ended branches	Common
Seriatopora		Branching Compact bush	Corallites are arranged in neat rows along branches. Some species an attractive pink	Common
Porites				
Goniopora		Columnar or massive	Greatly extended polyps day and night (aggressive and attack other corals)	Common in turbid protected waters
Alveopora		Massive or branching	Similar to Goniopora but polyp has 12 rather than 24 tentacles	Uncommon but widely distributed
Pavona	Cactus coral	Foliate,		May form massive monospecific stands
Large Polyp Stony Corals				
Fungia, Heliofungia, Diaseris, Cycloseris, Polyphyllia	Mushroom Coral	Solitary free living disc or cigar shape	Very large polyps can be up to 50cm including tentacles.	Common on reef slope.
Scolymia		Large solitary polyp	Very large polyps can be up to 10cm	Common on south WA coast
Lobopohyllia				
Favia, Favites		Massive often - hemispherical	Large conical corallites,	Common on back reef areas
Goniastrea, Platygyra	Honeycomb or Brain corals	Massive often - hemispherical	Precisely packed corallites sometimes with large 'valleys'. Vibrant colours. Very tough corals and often found in intertidal zone.	
Trachyphyllia		Large free living	Fleshy polyps	Rare on reefs. Common in protected shallow embayments
Euphyllia	Bubble or hammer coral		All polyps are large, long tentacles with lighter coloured tips, some species have a T shaped tip	
Catalaphyllia		Small cylinder	All polyps are large and fleshy – resemble anemone due to large oral disc and ring of tentacles.	Occurs in turbid water
Plerogyra	Grape Corals	Fist sized and shaped colonies	All polyps are large and fleshy – resemble bunch of grey grapes	Uncommon

Table 1 Hard Coral generic groups currently traded or aquacultured, broken into Small and Large Polyp Stony Classifications. (Information sourced from Veron 1986, Hargreaves 2004, Allen and Steene 1996, Fabricius and Alderslade 2002, Ruppert and Barnes 1994)

*Growth forms include massive, columnar, encrusting, branching, foliaceous (forming a whorl), laminar (forming a tier) and free-living (Veron 1986).

3.4.2 Soft Corals

Soft corals are prominent members of the shallow water coral reef community that belong to the Order Alcyonacea. They are known as soft corals because they lack a hard, carbonate skeleton, but maintain body shape using free or fused spicules or sclerites embedded in the colony tissues.

The shape of the sclerites when identified microscopically can determine the species of soft coral; therefore, field identification of soft coral species is commonly limited to genus. Most soft corals look very different depending on whether the tentacles are extended. The soft and flowery appearance of the tentacles is most sought after for aquarium displays.

There are a number of genera commonly found in the market and which are popular with marine aquarium enthusiasts. Within this group, there are a number that are found in Western Australia and may be suited to aquaculture. These are described in Table 2.

Scientific (genus) Name	Common Name	Growth Form*	Distinguishing Feature(s)	Abundance
Sarcophyton sp.	Toadstools or mushroom leather corals	Massive form	Large colonies with a rough and leathery texture and sit on a broad pedal base (Hargreaves 2004)	
Lobophyton sp.	Lobed or ridged leather corals	Encrusting disc	Large disc (up to 1.5m diameter) with radial ridges	
Sinularia sp.	Flat, slimy, digitate or Knobby Leather corals	Various		
Cladiella australis	Finger leather			
Clavularia viridis *Technically Order Stolonifera*	'Tree fern' or 'palm corals' Green tube coral	Encrusting	Produce large sheet like colonies where individual polyps are connected together with a stolon. They are very attractive specimens with eight conspicuous feathery tentacles.	

Table 2 Soft coral generic groups currently traded or aquacultured

3.4.3 False Corals and Coral Anemones – the Coralliomorphs

The Order Coralliomorpha consists of three families, ten genera and between 45 and 85 species (Hargreaves 2004). They are difficult to identify to species level and the taxonomic ambiguity is due to the lack of internal and external characteristics to distinguish between taxa.

Despite difficulties in species identification, Coralliomorphs are very common in the trade and Table 3 outlines some of the species (taxa) that may be suitable for culture in Western Australia.

Scientific (genus) Name	Growth Form*	Distinguishing Feature(s)
*Discosoma***	Oral disc a relatively smooth delicate	Smooth flower like polyps that appear fleshy yet delicate. Asexual reproduction through pedal laceration to rapidly form colonies
*Amplexidiscus**	Flat mushroom like disc that can grow to over 40cm diameter	Oral disc covered in small rounded tentacles, edges of the disc is smooth
Ricordia	Flat mushroom like disc	Small tentacles on surface of oral disc. Asexual reproduction by pedal laceration.
*Metarhodactis** - trade name	To be advised	To be advised

NOTE: *Not collected locally in WA but sourced interstate or over seas. **Collected locally in WA.

Table 3 Coralliomorph generic groups currently traded or aquacultured

3.4.4 Button Polyps – the Zoanthids

This group (Order Zoanthidea) is very commonly found in marine aquaria and is an important encrusting group on live rock. They are primarily photosynthesisers using zooxanthellae, but some small plankton may be ingested by some species. The Order Zoanthidae has either a skeleton or a basal disc and comprises three main groups (Hargreaves 2004):

- Individual polyps that occur singly and are found embedded in sand (*Sphenopus*)
- Polyps living in colonies and may be connected by *stolons* but without a supportive tissue (*coenenchyme*) between polyps – may have sand embedded within supportive column (*Zoanthus, Protopalythoa*)
- Polyps are embedded in coenenchyme and contract completely within (*Palythoa*)

Most product traded is either *Zoanthus* or *Protopalythoa*, but is sometimes incorrectly sold as *Palythoa*. Despite difficulties with identification, Zoanthids are very common in the trade. Table 4 outlines some of the species (taxa) that may be suitable for culture in Western Australia.

Scientific (genus) Name	**Growth Form***	**Distinguishing Feature(s)**
Zoanthus	Can form tightly-packed compact colonies	Small (5-10mm) oral discs with ring of long tentacles around margin. Asexual reproduction through budding off the stolons to rapidly form colonies. No sand embedded in body tissue.
Protopalythoa	Oral disc on a short stem. Individuals or colonies of little 'mushrooms'.	Larger (10-25mm) oral discs with ring of short tentacles around margin. Upright columns with sand embedded in the body tissue.

Table 4 Zoanthid generic groups currently traded or aquacultured

SECTION 4 LIVE ROCK, SAND AND CORAL AQUACULTURE

4.1 Synopsis of the Aquaculture Industry

Coral aquaculture has developed from marine aquarium enthusiasts' skill in propagating various corals and was well established and widely practiced in the USA by the late 1990s. Propagation techniques are well established for about 50 species of coral (CITES 2002).

Hard corals are farmed on some scale in France, the Netherlands, Germany China, Dominica, Fiji, Indonesia, Israel, Marshall Islands, Philippines, Singapore, United Republic of Tanzania, United States, Puerto Rico, Palau, Solomon Islands and Japan (CITES 2002). The industry in Australia is presently characterised by a few small experimental producers, mainly in Queensland (Willis & O'Sullivan 2004).

At present live rock is 'cultured' in the US in Florida, Hawaii, Michigan and Idaho, using calcium carbonate rocks that are either collected from the land or artificially constructed. These are 'seeded' by placing them on leased areas of the seabed or in land-based tanks that already contain live rock.

The greatest constraint to future growth of the aquacultured live rock and coral industry is direct competition from cheap, wild live rock originating from Fiji. Much of this is collected in an unsustainable manner.

Excellent research on the development of large-scale hard and soft coral aquaculture techniques has been conducted through the Centre for Tropical and Subtropical Aquaculture based in Pohnpei in the Federated States of Micronesia (Ellis and Sharron 1998, Ellis and Ellis 2002). Links to the two manuals from this research can be found in Section 9 - 'Further Reading'. This research provided the foundation for the development of a coral aquaculture industry in Micronesia.

Most of the cultured coral is now grown from 'cultured' donor colonies or from a few wild-sourced individuals. The technique may vary, but generally the coral is held in trays secured to the seabed, on racks or suspended culture systems, or in land-based tanks, with either natural or artificial light.

The aquaculture of coral and live rock is potentially a low impact industry. The culture of live rock is as simple as providing a substrate, permitting recruitment of benthic flora and fauna on the substrate and maintaining a high light environment (although crustose coralline algae may be more colourful and therefore valuable when grown in low light conditions). Similarly, coral grows with the benefit of good quality water and light.

'Inoculating' clean limestone or beach sand with sand extracted from the 'wild' benthic environment produces live sand. The live culture of bacteria, worms and other micro invertebrates in live sand maintains optimal water quality and a healthy substrate within the tank environment.
Both coral and live rock are effectively photosynthetic, with some dependence on filter feeding, and therefore require no additional feeding. Live rock does not require cleaning and the bio-fouling of most concern to coral culture is macro algae that may shade the colonies.

4.2 Aquaculture Production Systems

A live rock, sand and coral aquaculture system is described by its location and whether it is ocean-based (*in situ*) or land-based (*ex situ*). The onshore and offshore aquaculture production systems currently used for live rock and coral grow-out are considered in the following sections.

4.2.1 Onshore, Flow-Through Systems

Onshore, flow-through production systems for live rock and coral grow-out use marine water, with different stages of particulate filtration or chemical (biofiltration) treatment. The culture units include tanks, trays, raceways and ponds.

Onshore systems used for grow-out are usually intensive to semi-intensive. At present in Australia, they are small-to-medium scale and support research trials examining coral biology. Vertical integration is important in that there are currently no coral 'hatcheries' to provided seed stock, therefore all production is dependent of vegetative propagation techniques.

The general principle is to maximize surface area and provide adequate light. As a consequence, most coral and live rock tanks are wide and shallow and may have either fluorescent or metal halide lights to enhance growth. Lined earthen, fibreglass or concrete raceways may be used. Corals require a lot of light and outdoor culture is the most economically viable option in locations where the temperatures are suitable. In tropical areas within the natural distribution of the species, culture tanks may be in an outdoor shade house, so that temperature extremes do not overly stress the stock.

The live rock and coral being grown-out are held in racks or trays within the water to maximize light availability, water flow and assist in the management and movement of 'batches'. Large donor or broodstock colonies and live rock may be placed in individual blocks on the bottom of the tank.

Live rock and coral held in these tank or raceway systems can be stocked at the relatively high stocking density of 20 - 50 kg/m^2, depending on the density of the substrate. However, the optimum density is dependent on growth form and water quality, and stocking rates are adjusted to avoid negative density-dependent effects such as diminished growth.

Water flows should vary according to overall stock density, water volume available and species needs (some species are more tolerant or may require high energy or calm conditions) and are generally within the range of 10 per cent of system volume per week.

4.2.2 Onshore, Recirculating Systems

Live rock and coral growout also takes place at onshore locations, beyond the natural distribution of the species, using intensive recirculating water systems. For example, Tropicorium (www.tropicorium.com), located in Michigan is the largest producer of corals and reef invertebrates in the USA.

Recirculating systems are used in insulated buildings, in which the water is artificially or geothermally heated to the optimum temperature. Several of these systems are presently used in Australia to grow live rock and coral (Willis & O'Sullivan 2004) or holding stock outside their natural distribution in major links in the marketing supply chain (wholesalers, etc).

The used water discharged from or contained within the culture units is treated using a combination of physical and biological filtration, before being pumped back into the culture system. Recirculating systems are typically intensive and support high stocking densities. They all require some degree of water changes of synthetic or fresh seawater, due to accumulation of nitrates and the addition of freshwater to compensate for evaporation.

A significant advantage of recirculating systems is their relative independence of the local environment and limited water requirements. However, these systems are expensive to establish and the technology needed for operation at an efficient commercial scale is still developing.

Financial analyses of recirculating systems indicate that the key operating parameters are the energy input (water pumping, water heating and operation of expensive lights) and the efficiency of the water treatment processes. Aquaculture using recirculating water-flow systems will undoubtedly be responsible for an increasing proportion of overall production of corals.

4.2.3 Offshore, Open Systems

Offshore production systems almost invariably use bottom culture on racks, baskets, panels or cages or suspended culture using longline systems, as used in the mussel and pearl oyster industry. The use of suspended culture longline systems is well established in WA, with pearl and mussel farm techniques likely to be well suited to suspended culture of coral once tray and basket systems are developed.

Bottom culture on racks, cages or fence lines is also used in pearl culture and the licence conditions are likely to be similar. The racks or cages may be of any shape or dimension, with the individual design and deployment varying according to the features of the site at which they are located.

Features for consideration include water depth, currents and the degree of shelter the site affords from waves, swells and storms. Ellis and Ellis (2002) demonstrated that rack or table systems were adequate for the culture of a number of hard and soft coral species farmed in a shallow lagoon environment.

4.2.4 Coral Species Cultured

As discussed above, the diversity of corals is great and some morphological and reproductive strategies (See Appendix 1) lend themselves more to aquaculture than others. At the outset, species that are easy to culture by fragmentation or other asexual propagation techniques are likely to dominate the species cultured. The stony coral species most

compatible with vegetative reproduction are the Small Polyp Stony corals, but the greatest market demand/opportunity is for Large Polyp Stony corals, which may not be suited to these techniques.

Over time, and with pressures on the management of the Marine Aquarium Managed Fishery, aquaculture of the Large Polyp Stony species may develop with improved husbandry techniques and experience.

There is a risk that all aquaculture effort will be focused on those species that are both abundant and easy to culture. In order to maximize benefit, industry might consider devoting resources to research and development of culture practices for uncommon, high value species.

SECTION 5 LIVE ROCK AND CORAL FISHERIES

5.1 The Wild-Capture Fishery in Western Australia

The quantity of live rock and coral caught by the Marine Aquarium Managed Fishery in Western Australia is small and capped at 1.5 and 7.5 tonnes, respectively, by quota management. The Commercial Fisheries Program of the Department of Fisheries manages the Marine Aquarium Managed Fishery. Compared to the commercial fisheries of the Northern Territory, Queensland and other countries in the Indo Pacific, the volume harvested by the Western Australian fishery is insignificant.

The commercial catch in Western Australian centres around the Dampier Archipelago, Exmouth Gulf and in other areas of the west coast including the reefs offshore from the metropolitan area. Commercial fishing for live rock and coral can occur anywhere on the Western Australian coastline (excluding those areas where this activity is not permitted such as Marine parks etc), however, proximity to air freight services and/or a market, clean water suitable for the species targeted, and reef locations within an economical distance from port tend to limit the harvest activities to the above locations.

5.2 Recreational Take of Corals and Live Rock

The recreational fishery of Western Australia was banned in 2001 by the gazettal of a Section 43 prohibition on the take of coral and associated groups. This was in response to concerns of the over-fishing of small areas that were convenient to boat ramps and other infrastructure. The issues surrounding recreational take were outlined in Fisheries Management Paper 163 (October 2002).

5.3 Pressures on the Wild Capture Fishery

In recent years there has been increasing pressures on the wild capture fisheries for marine aquarium products including live rock, sand and coral through the proposed zoning and formation of Marine Protected Areas (MPA's) and Marine Parks. The rezoning of the Great Barrier Reef Marine Park in Queensland throughout 2003/04 significantly altered the areas available to collectors/fishers through the designation of new reserves or changing the permitted activities on other reefs. Similar proposals in Western Australia to increase the area preserved within marine protected areas or changes to the permitted activities in existing Marine Parks has or will have a number of impacts on the wild fishery:

- Reduction in the available area for fishing activities;
- May lead to some licence holders leaving the fishery;
- New zoning plans may reduce the availability of some species restricted to those zones; and
- By reducing supply, increase the value of existing product.

Due to these and other pressures on the wild fishery, there is a reasonable argument that aquaculture has a valid role in this social and economic change. The product previously removed from the wild by the commercial fishery should or could be propagated through aquaculture and a greater volume harvested and sold at a later date. This product sold

would be entering a market environment of increasing demand (global and domestic) and a shrinking supply base from the wild capture fishery. The skills of the players within the commercial fishery in biology, technical knowledge and market connections would mean that this sector would be well placed to evolve into an aquaculture production sector likely to succeed.

SECTION 6 LICENSING

Under Section 90 of the FRMA, parties undertaking aquaculture activities are required to have an aquaculture licence granted by the Executive Director of the Department of Fisheries. These requirements extend to the culture of Coral, Live Rock and Live Sand.

In accordance with Section 92 of the FRMA, the Executive Director can only grant a licence (including for coral, live rock and live sand) if he is satisfied that:

i. The person is a fit and proper person to hold such a licence
ii. It is in the better interests of the aquaculture industry to grant the licence
iii. The activities to be conducted under the licence are unlikely to adversely affect other fish or the aquatic environment; and
iv. The activities to be conducted under the licence have been approved by other relevant authorities.

Applications for coral, live rock and live sand aquaculture will be assessed against these criteria. In relation to satisfying these criteria, clarity around expectations is provided within Section 7 as follows:

i. The person is a fit and proper person to hold such a licence – Refer to Section 6.1.
ii. It is in the better interests of the aquaculture industry to grant the licence – Applicants will be expected to demonstrate that the proposed activity is in the better industry of the aquaculture industry. The range of management arrangements referred to in Section 7 are proposed on the basis that these arrangements will ensure that licenses issues will be in the better interests of the industry.
iii. The activities to be conducted under the licence are unlikely to adversely affect other fish or the aquatic environment – Refer to Sections 6.6 Environmental Management and Section 6.7 Translocation.

In relation to iv. 'the activities to be conducted under the licence have been approved by other relevant authorities', a range of other approvals may be required these include:

- Environmental assessment by the EPA;
- Approval under the Commonwealths *Environment Protection and Biodiversity Conservation Act 1999*;
- Planning approval by the Department of Planning and Infrastructure; and
- Local government planning approvals.

In relation to applications that are for coastal waters, the Department of Fisheries has clear processes for the assessment and granting of such licences and this is described in Ministerial Policy Guidelines No. 8 *Assessment of applications for authorisations for aquaculture and pearling in coastal waters of Western Australia* (MPG 8). The MPG8 process was developed to ensure appropriate use of public waters and provide transparent and inclusive consultation with the community.

The MPG8 process will apply to the assessment of applications for coral, live rock and live sand aquaculture in coastal waters. As indicated in Table 5 below, licensees with existing marine based sites, proposing to diversify into coral will be required to apply for a 'major variation' under the MPG 8.

Applications for the aquaculture of coral, live rock and live sand in on-shore systems will be assessed under Section 90 of the FRMA in accordance with existing procedures.

Table 5. Aquaculture Licences and Assessment Processes.

Licence Type	Department of Fisheries process
▪ Application for a new offshore aquaculture licence	▪ MPG 8 Consultation and assessment process.
▪ Variation of an existing offshore aquaculture licence to include live rock and coral 'species'	▪ Major variation and processed through MPG8
▪ Application for a new onshore aquaculture licence.	▪ Application pack as per standard Department of Fisheries licensing process for land based sites.
▪ Variation of an existing onshore aquaculture licence	▪ Variation as per standard Department of Fisheries licensing process for land based sites.

Details of the MPG8 Licensing process are available by contacting the Department of Fisheries or can be downloaded from the web page:
http://www.fish.wa.gov.au/comm/broc/mpg/mpg008/index.html

SECTION 7 MANAGEMENT/POLICY OPTIONS

This section examines the management issues and potential risks associated with the emerging coral, live rock and live sand sector. In considering these issues and potential risks, management arrangements are proposed to address those matters.

In developing the proposed management arrangements, the Department of Fisheries has attempted to put forward a framework that is:

- Environmentally sustainable and safe;
- Economically viable;
- Considers the requirements of other stakeholders;
- Equitable and fair;
- Subject to transparent decision making processes; and
- Supporting an industry that is compliant and maintains a good reputation.

These risks have been identified through Department of Fisheries workshops and include suggestions from sectors of the industry that have expressed an interest in coral and live rock aquaculture. The policies proposed below are draft policies and are intended to encourage discussion and further suggestions. This section is presented as an assessment of the issues and risks according to the industry and Department of Fisheries requirements, and the proposed management arrangements.

For each issue identified the following is considered:

- **Issue/Risk**: What is the relevant issue of concern to the appropriate management of this industry? and/or what is the compliance, regulatory and environmental risk associated with this industry?
- **Industry Requirement**: What the Aquaculture industry requires for efficient and profitable business?
- **Department of Fisheries (DoF) requirement**: What are the boundaries that the Department of Fisheries consider suitable for the conduct of this activity within the context of legislative constraints and community expectations?
- **Proposed Management Arrangements and Options**: What are the policy options the Department of Fisheries proposes to apply to the particular issue?

7.1 Fit and Proper Person Criterion

Issue and/or Risk: Section 92 of the *Fish Resources Management Act 1994* requires that the Executive Director must be satisfied the applicant is 'fit and proper' prior to the grant of an aquaculture licence. The Department needs to clearly communicate its expectations in relation to these criteria as is relevant to the aquaculture of coral, live rock and live sand.

This criterion has an increased significance in relation to crown waters, where the Department needs to be satisfied that persons provided with the opportunity to utilise crown waters for aquaculture have the skills, experience and a 'good track record' in order to maximise productivity and reduce risk of failure or non-compliance.

Industry Requirement: It is in the better interests of the licensees within the aquaculture industry that all licensees have the ability to conduct their proposed activities efficiently and legally. This maintains the reputation of the sector, provides a credible and arguable case for the growth of the industry in an increasingly competitive environment and ensures that future investment may not be hampered by a poor performance history of the sector.

DoF requirement: In order to address this criteria, applicants will be assessed under Ministerial Policy Guideline No. 19 *Matters of Importance in Respect of the 'Fit and Proper Person' criterion for authorizations under the Fish Resources Management Act 1994.* Through the guidelines, the applicant will be required to demonstrate knowledge, honesty and ability to farm coral, live rock or live sand, as is appropriate. This is a consideration of the applicant's skills, experience and legal history to undertake the particular activity. The guidelines can be found at: http://www.fish.wa.gov.au/docs/mp/index.php?0706#a03

Management Options and Proposed Arrangements: The following management arrangements are proposed:

- Licence applications will be assessed in accordance with Ministerial Policy Guideline No. 19 *Matters of Importance in Respect of the 'Fit and Proper Person' criterion for authorizations under the Fish Resources Management Act 1994;*
- In accordance with Ministerial Policy Guideline No.19, the applicants will need to demonstrate that they are fit and proper to undertake live rock, sand or coral aquaculture and provide detailed information regarding the previous skills or contracted skills that will be incorporated in the on site and corporate management of the business.

7.2 Number of Marine Based Sites per Company at Grant

Issue and/or risk: The number of marine sites granted per licensee for live rock, live sand and coral aquaculture at the beginning of industry development is important as there is a limit to the number and location of appropriate sites.

There are a number of risks in granting an individual or company multiple sites upon the grant of a coral, live rock or land sand licence: These include:

- Non performance on any of the sites decreases the value to the state;

- The potential for applicants to acquire 'real estate' and take up valuable waters that may be productively utilised by other aquaculture licensees; and
- Undercapitalization by the licence holder through investment on many sites may lead to total failure of the aquaculture business.

Therefore it would not be appropriate for the Department to issue multiple marine based sites to proponents without a proven ability to successfully utilize such sites for coral, live rock or live sand aquaculture. Given this, there is merit is restricting the number of sites per licensees for a short initial phase, and allowing growth into additional sites based on performance targets.

As the aquaculture of coral and live rock is a new and relatively untrialled industry in Western Australia, demonstration of ability through the development of culture techniques and practices on the first site would provide a basis for assessment and grant of further applications.

Industry Requirement: It is likely that parties entering into this sector will be seeking access to a number of potential sites, either to spread risk (due to impacts such as cyclones), to provide culture conditions suitable for a range of species and to reach production level appropriate to enter markets. It is also likely to proponents would be opposed to the Department granting multiple sites to other proponents at the on set of the industry's development as this would potentially prevent access for themselves.

Management Options and Proposed Arrangements: In order to allow industry to access multiple marine sites while also ensuring that sites are allocated to proponents with demonstrated ability to productively use the site, it is proposed that the initial number of marine sites per company/applicant be limited to one, pending the successful demonstration of farming practices.

This will be implemented through the inclusion of performance criteria on the licence that will include site development and production requirements. Licensees will be eligible to apply for additional marine based sites following the compliance with specified criteria, such as annual production of a specified volume.

In summary, proposed management arrangements with respect to access to multiple marine based sites are:

- Applicants entering the coral, live rock and live sand sector and applying for their initial grant of such a licence over a marine based site, will be required to demonstrate performance at that site, in accordance with agreed and specified criteria, prior to eligibility to apply for additional marine based sites.
- Strict performance criterion, including reporting on conditions of licence and conduct, within a predetermined timeframe will be in place to ensure site utilization.

7.3 Coral Species Identification

Issue and/or Risk: While the identification of species of fish, prawns and molluscs is relatively simple based on gross visual assessment, corals pose a very difficult task. The taxonomy of hard and soft corals is one of the most complicated fields of marine science

and there are some excellent references (Veron 1986, Fabricius & Alderslade 2002) to provide guidance for lab and field based identification of species.

The morphological plasticity of species, affected by location within the natural range, depth and environmental niche, further contribute to ambiguity. Many coral species can only be clearly identified by microscopic examination of the spicules (soft coral), corallites and the arrangement of skeletal septa (hard coral). Given the significant difficulties involved in identification of coral species, the plethora of synonyms in the taxonomy and an even greater number of common or marketing names, a clear and uniform naming system is essential.

There is also a great deal of synonymy (several common names for the one 'true' species) in the market place and the use of rather subjective or descriptive common names that are not very helpful is common. For example, a trade name of 'brown mushroom coral' in a species that may also be blue or purple depending on where it is sourced or the depth it is grown. Correct identification may require referral of preserved specimens to a recognized expert in that particular genus etc. This process is clearly not appropriate for field use by Fisheries and Marine Officers undertaking compliance audits on site.

Inconsistency and uncertainty of nomenclature of the culture animals creates challenges for the management and compliance frameworks of a coral aquaculture industry. The tools and techniques used to gain certainty in the highly technical field of coral taxonomy and identification are not consistent with the practicalities of growing and marketing corals by industry and are not appropriate for use by Department of Fisheries compliance field staff.

For example, by using taxonomy down to the level of the detailed species name on aquaculture licences there may be the situation that the farmer and the compliance officer may not be able to distinguish one species from another, possibly creating confusion and conflict.

Industry Requirement: The aquaculture industry requires a consistent naming system that suits the wholesale and retail market. The name of a product may be very closely linked to the value as a collectable species or ones similar to it and may impact on marketability.

The use of existing common names is not likely to change as they are adopted on a global scale. Therefore, industry must adopt the names for product that is acceptable in the market but also provides sufficient detail to satisfy the statutory reporting requirements of the Department of Fisheries.

DoF requirement: To assist the management of licensing administration systems and to ensure appropriate compliance action in the field, the Department of Fisheries requires consistency in naming of the cultured species and simplicity in identification of these species.

Under the existing legislation (FRMR 1995 – Schedule 7 other species) 'coral' is classified under the Order Scleractinia. While this level of simplicity would remove many of the issues, it would also reduce the ability to ensure sufficient control was available to manage

specific activities of the industry. However, further amendments to the Regulations are required to reflect the culture of other orders (soft corals and zoanthids etc).

For example, the database used to manage licences at the Department of Fisheries requires a common name and a binomial latin name to be entered for all aquaculture species. This is inserted into the species schedule of an aquaculture licence for future reference of the licence holder and also the compliance staff that may undertake field inspections to ensure the cultured species are in fact covered under the authorization of the licence.

A further suggestion is that industry develops a taxonomic guide to the satisfaction of the Department, which meets the needs of industry.

Management Options and Proposed Arrangements: A less complicated identification system is needed. Removing one level of taxonomic complexity from the licence by referring to genus level may assist. It should be noted through that some genera have many species, for example *Acropora spp* includes over 500 species all collectively known in the trade as 'staghorn coral'.

One proposed option may be the submission of skeletal types and associated photos of the colony *in situ* submitted to a number of 'experts' in order to validate the name of the species cultured. From the validation, compliance officers, licensing and management staff will then add a colour photographic record of the permitted species to the aquaculture licence file, which would be available for use in the field. This information could also be used to ensure accurate reporting of collected species through the Marine Aquarium Managed Fishery that is submitted in full to the Department of Fisheries catch statistics unit.

There are two possible options with regard to species identification.

1. Retain the existing system of identification of culture stock down to species level and work within the difficulties of identification in the field;
2. Simplify the nomenclature and provide authorizations relating to genus rather than species level.

Whilst the Department has a preference for option 1, the specific comment is sought from stakeholders on the most appropriate approach to adopt. Other mechanisms to manage this issue are also encouraged.

7.4 Distinguishing between aquacultured live rock and coral

Issue and/or Risks: With the development of an aquaculture industry around coral, the Department needs to ensure that appropriate mechanisms are in place to ensure that the aquaculture industry is not used as a mechanism to 'hide' illegal harvesting of live rock and coral from the wild. This will require some mechanisms to distinguish between live rock and coral product sourced from the wild or derived from aquaculture production.

Reliable means to distinguish between wild caught and aquacultured product might also provide the industry with an opportunity certify its product and market it under an 'environmentally sound' badge.

Industry requirement: The requirement to demonstrate that its live rock and coral product is aquacultured will require diligence from industry. It will also be an administrative cost to industry and the Department of Fisheries, and the system adopted should not severely impact on the economical viability of the industry. Similarly, the benefit to the Department of Fisheries in having a system in place that can demonstrate sustainability (track coral from wild take through fragmentation and subsequent culture to provide new coral colonies) must not have a prohibitive administrative cost.

The global coral market is increasingly concerned with the source of the product and is sensitive to purchasing from sources that cannot be demonstrated to be sustainable. Within the wider marine aquarium market, the ability to certify sustainably produced aquaculture product could enhance the value of the product, providing it is properly marketed and non aquaculture products are not sold as such (substitution). The ability for industry to demonstrate that the product has been lawfully obtained and sold is also a Commonwealth requirement (Department of Environment and Heritage) for the grant of export permits.

The Marine Aquarium Council (MAC) (http://www.aquariumcouncil.org/) is a global, not for profit organisation that promotes the development of sustainable Marine Aquarium Trade. The MAC has developed a number of core standards for the industry and development of clearly branded sustainable product ensures a clear link between the producers, wholesalers and consumers that want a certified product.

Department of Fisheries requirement: The Department of Fisheries will require that a system be in place that provides certainty that illegally harvested product is not 'laundered' through the aquaculture industry. Thus, the Department will need to ensure that the system provides for product to be distinguished and demonstrated to be aquacultured.

Management Options and Proposed Arrangements: Possible mechanism for identification include:

- Numerical tags. A numeric tag can be inserted that correlates to other consignments or farm management paperwork and/or another unique tag that would identify the stock as cultured. This will clearly distinguish between wild product and cultured product and uses a traceable and transparent procedure. The use of tags would assist in determining between cultured coral, source colony and the history behind the culture of an individual specimen on the farm.
- In vivo staining. In vivo staining is the process of dyeing living tissues using stains that are called vital stains. They are introduced to the organism while the cells are still living. However, these stains are eventually toxic to the organism, some more so than others. To achieve desired effects, the stains are used in very dilute solutions ranging from 1:5,000 to 1:500,000. One vital stain previously used to mark coral colonies is Alizarin, or 1,2-dihydroxyanthraquinone.
- Genetic markers. With the development of more advanced molecular science techniques, genetic tags may provide an important compliance and management tool. By correlation of the genetic information from donors and a sample of the fragments in culture, the Department of Fisheries could ensure that the lines of fragmented clones

are in fact derived from the donor stock. Therefore, this tool could ensure that the records correctly relate to the tags of each generation.

The encrusting nature of corals and live rock fauna mean that many tags are not visible and this may pose difficulties in developing a method that is appropriate in the market, accessible if required (e.g., during a compliance audit) and cost effective for the grower. Given the fact that these products are destined for display purposes, outwardly visible tags may not be appropriate, however, the aquarium enthusiast may remove them or retailer after purchased at the retail point of sale.

The DOF seeks the comment of stakeholder and potential industry members on the mechanisms discussed above.

It is proposed that the Department of Fisheries will include in aquaculture licence conditions the requirement for individual tagging of coral and marking of live rock to the satisfaction of the Executive Director. Licensees would have the opportunity to develop their own method of tagging that satisfied prescribed criteria.

It is proposed that in order to be compliant with this condition, the tagging method shall:

- Incorporate into the matrix of the live rock or attach to the substrate, a 'tag' that identifies the producing company;
- Incorporate a tag into the plug that the coral fragment is secured to,;
- Each tag must bear a unique and recordable identification which will correspond to logbook returns identifying date of propagation/fragmentation, species, source colony tag # and 'batch #';
- These returns will be filled out when processing/propagating fragments (gluing them into reef plugs or similar) and submitted with periodic production returns.
- In addition, the ED may require that all aquacultured corals be subject to *in vivo* vital staining in order to incorporate a coloured mark into the skeleton of the colony.

In order to ensure that there is absolute certainty in distinguishing between wild and aquacultured live rock, the following is proposed:

- No 'natural' reef rock or coral material can be used in live rock culture – rock harvested from the marine environment will not be permitted;
- All live rock in culture will be manufactured or quarried rock;
- Approved substrates may be a manufactured composite mixture of limestone sand, gravel, shells and/or concrete;
- Quarried or manufactured rock will incorporate an approved tag/marking system (makers mark);
- No rock sourced from the Marine Aquarium Managed Fishery industry can be (or needs to be) used in open system aquaculture licence areas. There may be a need for live rock in closed recirculating systems in order to 'seed' substrate.

In addition, the following policy is proposed in respect to tagging product:

- The proposed method of tagging or marking systems to be used will be clearly defined in aquaculture licence applications and subject to the approval of the Executive Director of the Department of Fisheries;

- The proposed method or type of substrate to be used will be clearly defined in aquaculture licence applications and subject to the approval of the Department of Fisheries.
- All tags will remain on product in culture and transport to market;
- The Department of Fisheries will supply appropriate consignment books to coral and live rock aquaculture licencees (See Appendices for examples).

7.5 Environmental Management

Issue and/or Risk: The development of a coral, live rock and live sand aquaculture industry has the opportunity to reduce the long-term take of such species from the wild.

The major potential environmental impacts to the environment from unmanaged aquaculture activities are as follows:
- Physical removal, breakage and shading and other disturbance of the benthic habitat;
- Physical impact of farming gear such as anchors;
- Interactions between aquaculture gear and charismatic megafauna (dolphins, whales, seals, turtles and dugong);
- Loss of equipment during catastrophic events (cyclones etc) and the harm that this gear may cause if it remains outside of the aquaculture licence area and not managed or removed.

Appropriate environmental management measures need to be constructed around this industry to ensure that these potential sustainability opportunities are realised and that the industry itself does not contribute to a sustainability issue.

Industry Requirement: This aquaculture sector needs to develop sites to accommodate the growout infrastructure and boating access to permit the aquaculture of these species to support an efficient business. Where offshore growout is undertaken, this may would the installation of suspended culture longlines, trays, racks and placement of equipment directly on the seabed.

DoF requirement: Environmental conditions on aquaculture licences are prepared taking into consideration issues raised during the MPG8 consultation process and include technical advice and input of relevant agencies such as the Department of Environment (DoE) and Conservation and Land Management (CALM). In some cases, separate environmental assessments and approvals are required, for example by the DoE, particularly considering requirements to undertake earthworks and discharge of water from an aquaculture facility.

The Department of Fisheries has a suite of standard aquaculture licence conditions that require licence holders to submit environmental monitoring data as specified and these take into account the surrounding sensitive habitat. In some instances, conditions prohibit the installation of aquaculture infrastructure in areas of seagrass beds and coral.

Where applicants are seeking to aquaculture in areas that has coral habitat, the applicant will need to demonstrate how this will be effectively managed to avoid impact on this habitat.

Generally, aquaculture licences for coral, live rock and live sand shall be conditioned to ensure that these risks are ameliorated, including but not limited to:

1. The licensee must ensure that all anchors and aquaculture apparatus are of a type that has been previously specified to and approve by the Department of Fisheries. The anchors and aquaculture apparatus will be described in the licence application or variation application.
2. No anchors or aquaculture apparatus shall be placed on or within swinging distance of corals or seagrass beds and must be located greater than 20 metres from any hard coral reefs, unless it has be proven that the positioning of the anchors or ropes will minimise damage to the coral or seagrass.
3. The licensee must provide the Department of Fisheries with clear photographs of the anchorage system currently in use at the site or a copy of a current mooring inspection report from a licensed mooring contractor.
4. The licensee must, prior to the commencement of operation, establish, and at all time thereafter maintain in force, a 'environmental management and monitoring program', to the satisfaction of the Executive Director of the Department of Fisheries.
5. The licensee must, before 31 July of each year, submit a report with a true copy of all results of the 'environmental management and monitoring program' to the Executive Director of the Department of Fisheries.
6. The licensee must undertake all direction given by the Department of Fisheries to mitigate any environmental impact that has occurred because of aquaculture activities.

In addition to the standard monitoring conditions, further licence conditions that deal with the impact on the environment are considered on a case-by-case basis. The conditions will be developed to ensure that the management arrangements imposed are consistent with the severity of the likely risks when the aquaculture business is in operation. Once again, the detail provided by the proponent in an aquaculture licence application may provide relevant information to the Department of Fisheries, alternatively, further on site assessment is required.

The Department of Fisheries will, in consultation with industry, other government departments and relevant stakeholders, undertake an environmental risk assessment around the activities of this industry and develop a code of conduct and minimum standard environmental monitoring program to guide sustainable activities within this industry.

Management Options and Proposed Arrangements: Aquaculture applications for coral, sand and live rock will be assessed in terms of environmental sustainability, and where granted, will be conditioned appropriately to ensure sound environmental practices and that adequate monitoring programs are conducted.

7.6 Translocation

Issue and/or Risk: The ornamental fish and aquaria trade is in the business of providing species that are non endemic or may not be collected locally to hobby enthusiasts. Due to the strong domestic and global demand for these products, the culture of non-endemic

species within Western Australia may provide significant business opportunities to aquaculturists.

The three main risks associated with the translocation of aquatic organisms are the potential of the translocated species to:

i. Impact on the genetic diversity;
ii. Introduce disease; and
iii. Impact on the natural environment and the biodiversity of native species.

These risks are discussed further below:

Genetic diversity

Where individuals are introduced to the wild from a different gene pool to the natural population, there is a risk that this introduction could alter the natural genetic structure of the population.

Introduction of disease

The accidental spread of pathogens accompanying non-endemic fish can be a major concern. Coral or live rock that has been translocated from interstate, overseas or outside its natural distribution within Western Australia may introduce pathogens or parasites and therefore may not be farmed in offshore systems that may expose native species to disease risks.

Most corals show signs of disease following chronic environmental stress or acute interference (i.e. taking cuttings for propagation). Given that understanding of the pathology of coral disease is very limited and broader questions of the epidemiology of specific pathogens unknown, a conservative approach to relocation of species in open systems should be encouraged while still allowing for the reasonable development of the industry.

Impact on the natural environment and the biodiversity of native species

The translocation of aquatic organisms to a water body can affect the ecosystem either directly, through predation or competition, or indirectly, through alterations of the environment. While there are no recorded instances of 'feral' coral and live rock populations becoming established in the world, the introduction of unwanted non endemic algae species associated with live rock and aquarium systems are of considerable concern. Some species of bryozoans are significant fouling species and are difficult to control because of resistance to anti fouling treatments. Similarly, some species of serpulids (plume worms), barnacles and a range of other species are also of concern.

For example, in Western Australia, the green algae *Caulerpa taxifolia* is an illegal import. It has caused major problems in the Mediterranean, New South Wales and South Australia where 'escapes' from releases by aquarium enthusiasts have caused significant habitat modification. The alteration of an ecosystem can have significant effects since the entire aquatic community can be affected, rather than specific prey or competitor species.

DoF requirement: The Department of Fisheries has clear processes for the assessment and granting of approvals for the translocation of non-endemic species described in Ministerial Policy Guidelines No. 5 (MPG 5). Details of the Departments translocation

policy and the manner in which applications are assessed can be provided by the Translocation Officer or on the Department of Fisheries' web page:

http://www.fish.wa.gov.au/docs/mp/index.php?0706#a03

While there is a recognisable economic benefit to the aquaculture of live rock and coral, there is also a need to ensure the aquaculture will not adversely impact upon the natural environment and biodiversity.

Introductions of corals from out of Western Australia may be permitted in on shore based closed recirculating systems following translocation assessment and provision of an approval from the Executive Director.

Leakage of animals or embryos/gametes from open flow through aquaculture systems pose a risk to the genetic diversity of the corals etc at the culture site. Generally, threats from aquaculture within the natural range of the species should be considered low risk, however, trying to outline genetic zones for so many species of corals would be fraught with difficulty. Therefore, the Department of Fisheries is unlikely to support offshore culture of any species outside of its recognised biogeographical range.

The Department must ensure that the operation of aquaculture industries maintain good animal health to sustain strong businesses and to protect the natural environment. Animal health protocols currently in place for other aquaculture species are enforced under licence conditions. This includes the requirement that the aquaculture licensee:

1. Notifies the Senior Fish Pathologist if high or unexplained mortalities occur;
2. Submits a sample for examination (histological sectioning and analysis) of juveniles produced in a hatchery;
3. Juveniles are not to move from hatchery to grow out farm without a valid Fish Health Certificate.

These and other similar licence conditions will be applied to the development of the industry in order to protect the environment and the interests of other coral and live rock licence holders.
Under the licence conditions for operation of licensed aquaculture hatcheries in WA, prior to the removal of juveniles from the hatchery and placement on a grow out site, disease testing of the batch by the Department of Fisheries' Fish Health Laboratories is required. While coral diseases and their causes is currently poorly understood, processes for screening other invertebrates (oysters and abalone etc) tissues for bacteria, fungi and protozoan pathogens would be applied under licence conditions.

Management Options and Proposed Arrangements: In summary the following management arrangements are proposed:

- Due to difficulties distinguishing between species (hence difficulty in identifying endemic and non endemic species), non-endemic species will not be permitted outside onshore, biosecure facilities.
- Proposals to aquaculture exotic corals in land-based systems will be assessed under Ministerial Policy Guideline No.5.
- No species that has been translocated from interstate, overseas or outside its natural distribution within Western Australia will be permitted to be farmed offshore or in flow

through open systems. Species identification must be verified prior to movement of any animals in order to ensure that culture is within natural range.

- Species translocated from interstate or overseas may be farmed in onshore systems subject to assessment through the Department of Fisheries translocation assessment process and site biosecurity.
- Existing hatchery inspection and accreditation/certification processes currently in place for aquaculture hatcheries in Western Australia are to be applied.
- The standards and conditions for mollusc hatcheries in Western Australia will be applied to the sexual reproduction of corals. Minor modification of these protocols may be considered.
- Submissions of samples, health reporting and screening procedures developed for other hatchery-produced species should form the basis for coral disease management, surveillance and response.
- Translocation assessment for non-endemic species takes into account the risk of escape and establishment of the species within the marine environment. Existing protocols remain sufficient to manage this risk.

7.7 Culture Methods

Issues and/or Risks: Coral and live rock aquaculture may take place on land or in the sea, depending on the location, species cultured and intensity/scale of operations. In land based closed recirculating or flow through systems, tank systems are clearly the likely method of culture. However, in open systems, a range of techniques may be utilised. Both suspended culture using longlines and bottom culture on racks, tables or other methods may be appropriate. Whatever system is proposed, the application for an aquaculture licence needs to adequately describe the proposed method of culture in order to provide sufficient details to enable persons providing comment on the application and understanding of the relevant issues.

The licence application is assessed on the information provided by the proponent and conditions are drafted appropriate to the system proposed. If adequate information is not provided, appropriate assessment of the application is not possible and this impacts on the time taken to assess a proposal and may impact negatively on the application if a number of persons or organizations consider that insufficient detail has been provided in the application they are providing comment on.

Over time, systems design may change radically through improvements to early types or complete revisions of the technology (eg a move from racks and trays to fence lines or suspended longlines) may occur.

Industry Requirement: Proponents within the coral and live rock and live sand aquaculture industry require confidential treatment of the intellectual property (whether real or perceived) during the public consultation process. By provision of detailed technical explanations of the proposed culture systems, they may provide competitors with the requisite information to develop the same or similar systems.

DoF requirement: The types of culture equipment may be similar from farm to farm, using equipment designs and specifications that are widely known or available. However,

the Department of Fisheries will assess each application on a case by case basis. The licence conditions drafted will be based on those with similar culture systems and take into consideration the advice of other Government agencies.

Management Options and Proposed Arrangements:

The following management arrangements are proposed:

- Applicants will be required to clearly describe the proposed culture method in the aquaculture licence applications;
- The proposed method(s) of culture described in the aquaculture licence application will be assessed on a case by case basis;
- licence conditions will specify the approved method of culture.
- Alterations to that culture method shall require a variation to the aquaculture licence and reassessment by the appropriate regulators.

7.8 Broodstock Issues - Current Policy and Legislative Mechanisms

Issue and/or Risks: In order to grow any animal in an intensive system, the aquaculturists need a starting point whether that be for sexual or asexual reproduction. This requires access to 'broodstock' that may be spawned or alternatively, used as donor colonies for asexual fragmentation.

Industry Requirement: Industry requires a reliable and fair means of accessing culture stock that will provide a starting point for the culture of the various target species. Industry needs to know how much product they can source from where and how long they have this authorization in order to plan the production on the farm, develop the business and undertake appropriate marketing activities. Industry also needs to know when it must be self-sustaining from within the aquaculture system and is 'weaned' off accessing new culture stock from the wild.

DoF requirement: The Department of Fisheries seeks to provide industry access to coral to develop the industry without impacting on existing wild fisheries activities and the market they support. This process will also ensure the development of this industry is consistent with community values regarding the take of coral from the wild.

Under the current legislative framework, the grant of an aquaculture licence provides authority to conduct aquaculture activities for commercial purposes. An aquaculture licence does not however, confer approval to collect fish from the wild for farming purposes. To conduct aquaculture activities, aquaculturists usually need to collect a small number of broodstock to produce a large number of juveniles. In the case of coral aquaculture, the donor colonies for fragmentation (asexual propagation) would be essentially 'broodstock'.

Management Options and Proposed Arrangements: The following options to collect coral broodstock are proposed:

A. Purchase from commercial fishers

Aquaculturists may purchase coral from licensees of the Marine Aquarium Fishery. It is noted that in general purchasing stock from commercial fishers poses a number of constraints and limitations on the development of the aquaculture industry including:

- Commercial fishing technology does not always address the requirements of the aquaculture sector in ensuring that the stock is collected in a manner suitable for aquaculture purposes (i.e. alive, undamaged and in suitable spawning condition).
- Aquaculturists usually need to control the collection of stock to ensure that they are obtaining the best genetic stock available.
- Commercial fishing activities may not occur at the time of the year when the stock is required for aquaculture purposes.
- In order to minimise environmental impact, aquaculturists are encouraged to source their stock from the vicinity in which they intend to conduct farming activities. Commercial fishing for the species they require may not always occur in the locality of the farming operations.

In such cases that the aquaculture licence holder is also the holder of a Marine Aquarium Managed Fishery Licence, they are able to 'sell', trade or transfer some of the coral to the aquaculture licence under the following conditions:

- The transfer is recorded in quota management paperwork from the Marine Aquarium Managed Fishery to the aquaculture licence, in exactly the same fashion as they would record the transaction to another aquaculture licence holder or aquarium wholesaler;
- The colony transferred is identified with a tag with a unique numeric code. All frags from that donor will share the tag number of the donor. As they are clones, biotechnology can verify whether the frag is a clone of the parent colony or another colony introduced from the wild;
- There would be no limit (within quota) on the volume traded by Marine Aquarium Managed Fishery licence holders to aquaculture licence holders - the entire quota may be sold or traded to holders of the appropriate aquaculture licence.

B. Purchase from other aquaculture licence holders or retail outlets

Aquaculturists may source broodstock or juvenile fish (coral) from the holder of an aquaculture licence endorsed for that species, or may purchase the required stock from a retail outlet if it is available (e.g. some ornamental species).

C. Ministerial Exemptions under Section 7 of the FRMA

In some circumstances, the Department of Fisheries is able to provide access to broodstock by the granting of an Exemption under Section 7 of the FRMA. The Minister for Fisheries may grant an Exemption for any purpose, including the take of broodstock for aquaculture purposes.

It is proposed that aquaculture licence holders that do not hold a Marine Aquarium Managed Fishery licence and are unable to purchase stock from such a licensee would be able to source stock under a Ministerial Exemption subject to the following conditions:

- Coral collected for production by fragmentation would be limited to a moderate yet equitable take (for example, 250kg per year) irrespective of size of farm.
- The Department will also put a cap on the total weight of coral permissible to be collected through exemption.
- Exemptions would be authorized for three years.

- Annual reporting of total take, survival, growth and production.
- Requirement to notify the local Department of Fisheries office when exemption holders intend to fish for coral, and advise of information outlining the vessel and vehicle used, the intended location of collection and landing, the species and intended volume to be taken and who will be undertaking the collections.
- Holders of a Marine Aquarium Managed Fishery licence will not be eligible to collect under a Ministerial Exemption unless under exceptional circumstances (cyclone damage etc).

7.9 Convention on International Trade in Endangered Species

Issue and/or Risk: International trade in coral and coral reef animals continues to be largely unregulated, unreported, and illegal. Over 400 coral reef species have been identified as inappropriate species for the aquarium trade - such as those that do not survive well in aquaria or are highly poisonous. Despite this, these species continue to be traded.

The Convention on International Trade in Endangered Species (CITES) Coral Working Group has noted a lack of agreement on marking systems to distinguish cultured from wild corals and the application of source codes. The application of CITES source codes for cultured corals would provide consistent language and understanding in this global trade.

The CITES Coral Working Group proposed the following source codes:
- "w" for wild, maricultured or farmed corals;
- "f" for aquacultured corals;
- "c" for captive bred or cultured corals; and
- "r" for ranched corals.

The group also considered techniques and marking systems to distinguish cultured from wild-taken corals, and called for an ecosystem approach to the management of corals harvested for export. The working group also addressed:
- Recognition of coral at either the species or genus level;
- Taxonomic reference to corals;
- Identification guides; and
- Synergy with other initiatives and agreements.

Industry Requirement: Industry needs to be globally recognised as sustainable and using world best practice in collection, culture and marketing. Alignment with existing global standards would provide immediate recognition of achieving these values.

Non compliance with CITES treaties and codes of conduct may jeopardize the ongoing global market and distribution of these products.

DoF requirement: The Department of Fisheries requires advice regarding the development of CITES approved source codes and marking systems. Incorporation of the appropriate source codes into producers tag numbers and consignment paperwork would provide a consistent standard that may facilitate greater acceptance of the WA product and improve management.

In addition, the Department of Fisheries provides information to the Commonwealth regarding the sustainability of fisheries (and aquaculture) industries in order to get the appropriate export approvals from the Dept of Environment and Heritage (DEH). (http://www.deh.gov.au/coasts/fisheries/)

The implementation of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides the Commonwealth Government with a stronger role in promoting ecologically sustainable management of fisheries and assessing their environmental performance.

The Sustainable Fisheries Section (SFS) of the DEH is responsible for the assessment of fisheries managed under Commonwealth legislation and state export fisheries to ensure that, over time, fisheries are managed in an ecologically sustainable way.
The DEH primary role is to evaluate the environmental performance of fisheries, including:

- the strategic assessment of fisheries under Part 10 of the EPBC Act;
- assessments relating to impacts on protected marine species under Part 13; and
- assessments for the purpose of export approval under Part 13A.

Management Options and Proposed Arrangements:

It is proposed that:

- The industry in Western Australia seeks certification or recognition of compliance with requisite CITES regulations and maintains this as an additional 'brand'.

- The Department submits a statement to the DEH requesting that in addition to products sourced from the Marine Aquarium Fish Managed Fishery, aquaculture live rock, live sand and coral is included in the List of Exempt Native Species (LENS) on the basis that they are products that were lawfully produced by the aquaculture industry in accordance with the FRMA 1994.

7.10 Compliance

Issue and/or Risk: Compliance effort in this developing industry is required to monitor risks including interactions with wild capture sector. The proposed management arrangements, relationships with an existing quota managed fishery and access to culture stock through exemptions introduces several compliance pressure points not found in other aquaculture industries. This will necessitate a greater effort to ensure that conditions are adhered to and both industry and Department of Fisheries can demonstrate that the industry is operating in a sustainable manner.

Industry Requirement: Industry needs to work in an environment where the rules are clear and practical and there are incentives to be compliant rather than disincentives to non compliance through a heavily punitive regulatory environment.

DoF requirement: The Department requires that the industry and its individual operators operate within the regulatory framework outlined within policy and licence conditions. If there are breaches of the legislation, the Department of Fisheries will act and through

prosecution of these offences, the courts may impose heavy fines or the Department of Fisheries may cancel licences.

Given the links with another closely related commercial managed fishery (the Marine Aquarium Managed Fishery) and the unknown issues surrounding the development of a new industry, the Department of Fisheries will maintain close scrutiny of the coral, live rock and live sand aquaculture industry.

Management Options and Proposed Arrangements:

- The Department of Fisheries review the Aquaculture Compliance Risk Assessment Manual and Compliance Plan to incorporate the introduction of a new suite of species;
- Adequate training will be provided to Fisheries and Marine Officers in the relevant regions in order to ensure compliance risks are reduced.
- A program of compliance around the coral, live rock and live sand industry will be developed and implemented in Western Australia in accordance with the Compliance Plan.

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APPENDIX 1 CORAL BIOLOGY

Description and Taxonomy

Corals form significant components of marine benthic communities, along with soft and unconsolidated sediments, encrusting invertebrates (that are usually found on live rock) and macro algae.

The taxonomy of coral is roughly broken into reef-building and non reef-building types (as described above). However, the details of taxonomy and species identification are beyond the scope of this paper. The reader is referred to *Corals of Australia and the Indo Pacific* (1986) by Veron (1986) for a detailed examination of the biology and taxonomy of stony corals present in the Indo-Pacific region.

Distribution

The 1,500 or so species of coral have quite different spatial distribution patterns and biogeography. Some are widely distributed throughout the Indo Pacific, with pan tropical distributions from the Red Sea to the eastern Pacific (e.g. *Pocillopora* spp), while others species are more restricted.

Australia is central in this pan-tropical swathe and approx 70 per cent of the coral species known are found in our waters. There are around 20 genera of reef-building corals in the Atlantic, with the greatest diversity found in the Caribbean.

Ability to cope with changes in environmental conditions is reflected in the distribution of many coral species. Live rock and coral require high-quality seawater and are likely to suffer significant stress, for example, when salinity fluctuates during flooding events.
For example, inshore species generally are able to withstand more turbid water, a wider range of salinities (due to flood events, etc) temperature ranges (both high and low for short periods), and exposure to air in those found intertidally (e.g. *Goniastrea*) than oceanic deepwater or offshore species.

Age and Growth

Coral growth and age is a matter as complex as corals are diverse. The growth rate and the longevity of a coral are dependent on growth form, temperature, food availability and depth (light penetration) and vary considerably with species. Some solitary species with a massive growth habit can grow to several metres in diameter and be many centuries old (e.g. *Porites*). Large mono-specific stands of colonial species may in fact be clones (*Pavona cactus, Acropora noblis*) therefore the discussion of 'individual' size becomes hard to delineate.

The life history of coral is generally well known and can be clearly broken down into sexual reproduction and asexual reproduction; however, the interesting synchronous spawning events associated with coral reproduction were only described in the 1980s and was the subject of much research in the 1990s. Much of the research was conducted on the Great Barrier Reef in Queensland.

Reproduction and application of aquaculture techniques in research and large-scale production

The reproductive history of coral encompasses five main periods of development, viz: embryonic, larval, juvenile, adult and senescent. They employ, depending on species and growth form, a range or reproductive strategies that are either sexual or asexual reproduction (Table A1) and while this is an extensive list of strategies, the inventive nature of coral reproduction would indicate that other methods are yet to be discovered.

However, it is the process of reproduction that is interesting and relevant to the aquaculture of corals. In order to avoid repetition of the processes in the wild and the application to aquaculture, the natural processes and culture practice are addressed together.

Sexual Reproduction	**Asexual Reproduction**
Broadcast Spawning	Budding/fission – longitudinal or transverse
Brooding	Fragmentation
	Stolons – runner formation
	Pedal laceration
	Polyp Bailout
	Asexual planula development (*P.damicornis*)

Table A1 Reproductive Strategies of Corals

Sections 2.6 and 2.7 provide a brief account of the sexual reproduction culture technology for coral, with respect to broodstock, spawning, larviculture and grow-out. More detailed accounts of coral aquaculture are provided by Baird *et al* (in prep). Section 2.8 provides an outline of the asexual propagation strategies of coral.

Sexual Reproduction - Broodstock and Spawning

Sexual Reproduction in hard and soft corals is either a broadcast spawn of eggs and sperm or the release of brooded larvae. To be successful in the aquaculture (broodstock collection, spawning and larval culture) of these species, the operator requires good hatchery facilities, skilled staff and excellent preparation as the animals generally spawn on one occasion per year unless there is a 'split spawning'.

Brooding

This strategy is employed by species from the family Pocilloporidae and some soft coral species (Fabricius & Alderslade 2001). Following the broad cast spawning of sperm only, fertilization occurs within the polyp where the planula develops in situ. Following development during this brooding period, planula are released at regular or irregular intervals throughout the year.

Broadcast

One of the most spectacular displays of reproductive fecundity and perhaps excess is the annual coral spawning event. The predictable and synchronous release (Willis *et al* 1985) of coral gamete bundles occurs during a mass broadcast spawn, several days after the full moon in late spring on the Great Barrier Reef or in late summer in WA (Babcock *et al* 1994).

The bundles break up to release eggs and sperm packets which fertilise in the water column and follow a 'standard' embryogenesis to produce planula larvae (Veron 1986).

The cigar-shaped planula larvae 'swim' until at a stage where they are developed and 'competent' to settle, find a suitable substrate, attach, metamorphose and begin forming the calcareous skeleton of a stony coral. These settled coral juveniles are called spat. The spat grow and develop and in colonial species divide and continue to lay down skeleton.

Spawning generally involves the natural cycles of the coral in synchrony with lunar phase and day length; at this stage they cannot be induced to spawn. Wild coral collected during their natural reproductive season can be used for captive spawning. Alternatively, they can be held in captivity and their repetitive maturation over several successive spawning seasons can be utilized for the life of the coral 'broodstock'. On a smaller-scale domestic operation with a closed system, one of the problems faced by aquarium owners is the problem caused when corals spawn in the tank – unless gamete bundles are removed, water quality problems can eventuate.

Broodstock can be collected from the reef when the gamete bundles are visible and swollen within the polyp. In branching species, a small fragment can be broken off the parent colony and examined to see the stage of gamete development. If the egg bundle is of the right size or colour compared to known "ripe" individuals, and the bundle is in the centre of the polyp pushing under the oral disc (known as 'setting') around the full moon, the spawn is highly probable during the neap tides a few days later.

Gametes can be collected at sea or under controlled hatchery conditions. Using egg nets has the advantage of not removing the parent colony from the wild but requires night diving, calm conditions with little 'surge' and transport of gametes/embryos at a critical stage of development.

For coral spawned on land, gamete bundles should be gently scooped up to prevent damage to the cells. In the past, gametes have been collected using suction (bun sucking), but this reduces larval quality significantly (Baird *et al*, in prep). The process of sucking the embryos up appears to 'split' the embryos into two or more smaller pieces. As they are undifferentiated, these smaller embryonic fragments eventually develop into planula, albeit significantly smaller. With less maternal energy reserves in the body tissues, the survival and settlement rate is much lower than for 'whole' embryos (Baird *et al*, in prep).

Brooding species can also provide larvae for mass culture. Using specialized collection sieves and broodstock held in flow through tanks/units, the planula released are retained ready for contribution to a mixed larval cohort. The steady stream of planula, rather than the excessive fecundity of broadcasters, means that the number of brooding broodstock required may be greater in order to provide sufficient numbers to ensure an efficient hatchery 'run'.

Cleanliness is very important once the gamete bundles or embryos are collected. Excess mucus and sperm must be rinsed from the larvae prior to stocking the larval tanks. The break down of small or non viable embryos creates further management problems because foul larval culture water requires more frequent changes. All larval culture water should be at least 1um filtered.

Larval Rearing

Larval rearing can be carried out using intensive or semi-intensive techniques. Intensive larviculture involves the maintenance of planula in high densities, with good water quality maintained for the four to 10-day larval period prior to settlement and metamorphosis. Intensive larval rearing procedures were first implemented in research facilities on the Great Barrier Reef in 1997 when the scale of larval culture for *Acropora* species was increased from small aquaria (<5L) to full-scale larval culture techniques (tanks up to 100L) (Baird *et al*, in prep).

Semi-intensive culture techniques generally require larger volumes of seawater and lower larval densities, such that over the period of planula development, water exchange is nil or minimal. This may be conducted in a swimming pool or raceway, but control is limited and may result in spat settled on the tank walls rather than on settlement tiles, due to the formation of a biofilm.

As the planula does not feed during the planktonic stage, this significantly simplifies larval culture. The primary requirements in the larval culture system are to maintain good water quality and maintain larval density at a level where larval survival is not negatively affected.

Planula change from being positively buoyant with low motility in the early stages of development (12 – 72 hours) to being highly mobile swimming larvae that are more evenly distributed though the water column. As a result, water quality management and the process of changing water is modified through the grow-out period.

Flow-through screens below the surface ('banjos') work effectively early on in the larval phase, but planula can block screens later on when they move from the surface to within the water column. As a result, flow-through systems face significant problems and static cultures with daily drain-downs (or more frequently, as time permits) and water exchange work reasonably well.

The soft body of planula means that they are particularly susceptible to damage when caught on the screens used to retain the larvae when conducting flow-through operations or catching larvae during a tank drain-down. Therefore, low water flow rates must be maintained and/or the surface area of the screens must be large to reduce peak flow points.

The use of aeration around the screen may dislodge planula on or near the screen mesh. However, this does not appear as successful as this method when used with bivalve larvae.
Larval settlement appears imminent when the planula are noted coming out of the water column and crawling on the substrate, 'testing' the surface for suitability. Settlement tiles of terracotta have been use with considerable success in research trials on the Great Barrier Reef (Baird *et al*, in prep).

Tiles should be 'aged' and the presence of a biofilm of marine bacteria and coralline algae appears to induce or facilitate settlement. Indeed, planula that are held in an environment free of a bacterial biofilm will postpone metamorphosis for many weeks (Baird *et al*, in prep). For more information on the process settlement and cues, refer to Morse 1996.

Temperature control (where possible) is important as planula larvae die when water temperature exceeds 30^{o}C (Baird *et al*, in prep).

Asexual propagation

Asexual propagation is common in hard and soft corals, providing a rapid means of colonizing an area in dense aggregations of clones. Fragmentation of branching corals (e.g. *Acropora noblis, Pavona cactus*) following storm damage or other breakage may lead to a rapid regeneration of the dominance of the species in the location.

Asexual means are also the predominant mode of reproduction in soft corals, leading to highly aggregated patches of a species.

The 'plant-like' propagation strategies that hard and soft corals use may also be of advantage to aquaculture, as they provide a rapid means of creating a large number of small pieces of a desirable colony. Propagation of small poly stony coral and soft coral by way of cuttings and fragments from donor colonies (as described above) is a simple and cheap method to quickly increase the number of colonies of coral with a particular trait.

For example, for species *a*, 95 per cent of individuals are a boring brown colour, but there are a few individual colonies that display an attractive and highly-marketable bright green colour. By selecting individuals of this trait and making as many frag colonies as possible, the exact phenotype of the donor is represented in the growth form of the cuttings because they are genetically identical (clonal genotype).

This presents real benefits in producing large numbers of identical animals – an excellent marketing strategy. The disadvantage is that should this clone be susceptible to stress from a pressure such as temperature, water quality or disease, all will be identically susceptible and all may die.

In contrast, a sexually-produced (hatchery) coral may not be identical to the others in the cohort, but the increased genetic diversity provides some protection as the responses to stresses and other selective pressures will not be identical.

In reality, the ease of vegetative, asexual reproduction propagation techniques will delay the implementation of hatchery culture of coral larvae using sexual reproduction methods. However, specific coral traits may be selected and similar individuals bred in a hatchery. This would only be necessary if the clone that had a trait was also susceptible to other selective pressures.

Budding/Fission

In order to permit growth of a colony, the polyp must divide. In some instances, once the colony has numerous polyps, the former may divide by the development of daughter colonies on the side of the parent (extratentacular budding). When a polyp divides in two (intratentacular budding), the process is similar to cell division, and further multiplication of polyp numbers creates new colonies.

Fragmentation

Branching corals may utilize fragmentation as a means of rapidly regeneration, following a catastrophic event (e.g. a storm, etc). This is common in the small polyp stony species and in the wild may account for the presence of large monospecific stands that may well be the one 'individual' or clone. It is this life history strategy that most lends itself to aquaculture operations.

Pedal Laceration

The soft corals, coralliomorphs and anemones have limited mobility and during movement across a substrate, small pieces of the 'parent' colony will remain on the surface in the trail. Cells from this will divide and regenerate into clones of the parent colony.

Summary

Table A2 (below) provides a comparison of asexual and sexual reproductive strategies and how this may provide a benefit to aquaculture in terms of the production considerations or constraints.

Variable	Asexual Reproduction	Sexual Reproduction
Genetics	Clones of parent colony	Each individual from hatchery genetically distinct
Growth time to harvest	Fast – 30 – 60 days from transplant	May take up to 12 months from spawning to reach cutting size (30-50mm stem length)
Control by Aquaculturist	High – aquaculturist can take cutting when suited to them	Low – spawning at limited number (1 – 5) nights per year during synchronous mass spawn.
Technology required	Very low tech method of culture	Low tech hatchery required but significantly more sophisticated than cuttings. Technically demanding – broodstock, collect gametes, larval culture, spat settlement, condition settlement plates, transfer to nursery, growout, manage algae overgrowth etc.
Output (per parent colony)	Size of donor colony dependent, however, 10s to 10^2s of clones	10^2s to 10^6s per hatchery run depending on species and broodstock numbers
Species types suited	Small polyp stony, soft corals	All species, branching, massive, solitary, broadcasters, brooders etc.

Table A2 A Comparison Of Asexual And Sexual Reproductive Strategies Of Hard And Soft Corals

Feeding and Behaviour

Whilst the symbiotic algae, zooxanthellae, produce as much as 98% of the corals organic nutrient requirement (Veron 1986), corals also 'prey' on organic matter in the water column. When the tentacles of coral are extended (usually at night when plankton is abundant and polyp-eating fish are asleep), the capture of aquatic micro organisms (zoo plankton, small crustaceans and fish) contributes to the nutrient budget of the coral polyp/colony.

Other species that either lack the tentacles or stinging cells to immobilize prey are more passive feeders, consuming incident organic matter or bacteria and debris that are trapped in mucous on the polyp surface or strands that are moving in the water column.

Some species of coral are aggressive and maintain territories through the removal of rivals by digesting them with extruded mesenteric filaments (Veron 1986). Another strategy is for one species to sting a competitor with specialized tentacles called 'sweeper tentacles'. This is common to a number of the Large Polyp Stony species.

The competition for light and the subsequent shading of one colony by another is common in many species. Many encrusting species and the Small Polyp Stony branching corals, particularly the table and plates grown by *Acropora* spp, use rapid growth rates and shading to out-compete slower-growing species that may be better adapted to predation or damage.

Diseases, Parasites and Predators

Coral diseases were first noted around 30 years ago. Since then, the prevalence of the approximately 30 diseases of corals has increased, particularly in the last five years (CRC 2005). They are not well understood, as far as the specifics of infection and pathology, but are probably caused by bacteria, cyanobacteria, ciliates, fungi, algae and worms (CRC 2005).

Corals share with other fauna the development of uncontrolled growth, unusual physical forms consistent with cancers (Veron 1986) and a range of disease syndromes where skeleton is exposed, following the necrosis and death of tissues behind a black, white or brown 'band' (CRC 2005).

However, a common symptom of stress and imminent pathological impact is demonstrated as coral *bleaching*. This occurs when the zooxanthellae are expelled from the polyp or they die and the coral begins to die. Bleaching events may occur on very large spatial scales and result in mass mortalities.

Current evidence supports theory that bleaching events are linked to elevated sea surface temperatures (Mahoney 2003) and are one of the tangible effects of the early stages of global warming. Further information on coral diseases and bleaching is available on a number of web pages noted in the further reading section within this document.

Commensal associations are very commonly found between coral species and fish, crabs, shrimp, bivalves, flatworms, etc, and in some instances the demarcation between commensalism and parasitism can be unclear.

Whilst many reef invertebrates have elaborate chemical defences through the production of toxic secondary metabolites, there is a range of vertebrate and invertebrate predators of hard and soft corals. The crown of thorns starfish (*Acanthaster plancii*) is responsible for widespread outbreaks of coral predation, but generally target the fast-growing species (or avoid massive colonies). In WA they have not been recorded south of Ningaloo Reef.

Molluscs are common predators of corals. Small gastropods (*Drupella*) have caused widespread damage on coral reefs in WA and cowries and false cowries (*Cypraea, Ovula*, *Calpurnus* spp) are known to prey on a range of corals and sponges. For example, egg 'cowries' *Ovula ovum* and *Ovula costellata* eat the soft corals *Sarcophyton* and *Sinularia* (Gosliner *et al* 1996).

Nudibranchs also eat the toxic tissues of soft corals, sponges, bryozoans and gorgonians. Minute nudibranchs are reported to inflict heavy losses to coral in land-based culture if populations boom under ideal conditions (Peter Fullarton, pers. comm.).

More widespread, but often hidden, is the damage done by the activities of boring animals such as *Lithophaga* spp, various polychaete worms, and boring sponges (*Cliona* spp). The bioerosion of the coral skeleton may contribute to damage in storms and subsequent regeneration of fragments.

There are dozens of species of fish that have evolved to eat coral by both biting and grinding up the skeleton and polyps (e.g. Scaridae - parrot fish) or very accurately biting the flesh out of individual polyps (e.g. Chaetodontidae - butterfly fish). On some areas of reef it is estimated that parrotfish may eat one third of the annual growth of coral tissue and skeleton (Veron 1986).

APPENDIX 2 GLOSSARY

Amino acids:	the basic components of protein.
Aquaria or aquarium:	a fish tank.
Arborescent:	branched or treelike in appearance.
Asexual:	reproduction that occurs without the union of male and female gametes.
Asexual budding:	a form of reproduction where a soft coral polyp forms an exact replica of itself without releasing gametes.
Asphyxiation:	death induced by lack of oxygen.
Benthic:	the community of organisms living on or in the sea bed.
Bioerosion:	the breakdown of organic and inorganic matter through the action of animals or plants.
Biofilm:	the layer of bacteria, algae and protozoans that form on and coat various surfaces. That may be a food source for grazing animals or may a chemical cue to encourage larval settlement.
Biosecurity:	systems and policies put in place to manage potential exotic pest, disease and genetic quarantine issues identified through risks analysis.
Brand:	A trademark or indicating identity or ownership or a distinctive name identifying a product or a manufacturer.
Broodstock:	an individual animal or colony that is used to propagate more of the species in subsequent generations. If sexual reproduction, this animal will be spawned and the gametes collected mixed with another's to produce embryos. If asexual reproduction, the colony may be broken up into many fragments which will be identical to the parent/donor/broodstock colony.
Calcium carbonate:	the chemical from which hard corals and shells are made.
CITES:	Convention on the International Trade in Endangered Species.
Clone:	An organism descended asexually from a single ancestor.
Coenenchyme:	material secreted by soft corals as they grow which houses and is fed by the polyps.
Colonies:	A group of corallites grown from a single parent polyp.
Competence:	Physically capable and physiologically prepared to settle and metamorphose.
Consignment books:	Records that document the delivery of aquaculture product for sale or disposal.
Crustose:	algal or coral having a thin crusty growth form that adheres closely to the surface on which it is growing.
Digitate:	Having fingerlike growth form or projections.

Embryogenesis:	the development and growth of an embryo.
Endemic:	Prevalent in or peculiar to a particular locality or region.
Fatty acids:	one of the basic components in fats or lipids.
Fission:	process of splitting into parts.
Foliose:	an appearance or growth form like a leaf or sheet.
Foot valve:	also called a check-valve, a spring loaded valve placed in an intake pipe that closes when suction is lost and traps the remaining water in the pipe. This is used to assist in priming pumps after power outages and pump maintenance.
Fragmentation:	the process by which small pieces are taken from a parent soft coral to form a new colony. These small bits are called 'frags'.
Genotype:	The genetic makeup, as distinguished from the physical appearance, of an organism or a group of organisms.
Geothermal:	relating to the internal heat of the earth.
Hookah:	a diving apparatus where the diver is supplied with air through a hose from a surface based compressor.
In vivo:	Within a living organism.
Larval:	referring to the earliest stages of an animal's development.
Larviculture:	the care and cultivation of coral larvae
Lobate:	a body part having rounded projections or divisions.
Massive:	Consisting of a large mass; generally rounded and solid without branching.
Mono Specific:	a community that is composed of a single species. Multiple species in a community are considered multispecific.
Motility:	Moving or having the power to move spontaneously.
Mucus:	a slippery coating produced by corals as natural protection. Mucus is often produced in response to handling and cutting and can contribute to bacterial infection if not removed.
Neap (tides):	the lowest tides of the lunar month, which occur in the second and fourth quarters of the moon; -- opposed to spring tides.
Necrosis:	Localized death of living tissue, in the case of soft corals around the cut after fragmentation.
Nematocyst:	stinging cell used by the polyp to capture planktonic prey.
Ornamental:	serving an aesthetic rather than a useful purpose; e.g. any plant or animal grown for its beauty or ornamental value.
Phenotype:	The observable physical or biochemical characteristics of an organism, as determined by both genetic makeup and environmental influences.
Photosynthesis:	the ability to convert sunlight into energy.

Pinnate:	having featherlike side branches.
Plankton:	microscopic animals (zoo plankton) and plants (phytoplankton) that occur naturally in the ocean and freshwater.
Planktonic:	phase in aquatic organisms life history when the swimming larvae are part of the plankton.
Planula:	free-swimming, ciliated larvae.
Polyp:	any individual animal of the soft coral colony.
Propagation:	the act or action of propagating leading to an increase (as of a kind of organism) in numbers.
Reef tank:	a home or commercial closed system tank display, designed to replicate life on coral reefs. These generally contain soft and hard corals, fish, live rock and other invertebrates.
SCUBA	(Self Contained Underwater Breathing Apparatus) a diving apparatus where all the equipment needed for breathing underwater is attached to the diver, including a tank containing pressurized air.
Sessile:	Permanently attached or fixed; not free-moving.
Settlement:	Phase of life when the planktonic larvae move out of water column and onto benthic surface.
Sexual reproduction:	Reproduction characterized by the union of male and female gametes.
Spat:	When larvae settles and undergoes metamorphosis, the juvenile coral (and more commonly oyster) is known as a spat.
Spawn:	The eggs and sperm of aquatic animals such as bivalve molluscs, other invertebrates and fishes.
Spawning:	The reproductive event of many sessile invertebrates where the release of gametes (sperm and eggs) occurs with many individuals simultaneously.
Spicules:	Calcium carbonate structures that help support soft coral colonies. Occurring in different shapes and sizes, spicules are used to speciate soft corals.
Spiculose:	Having spicules.
Stolon:	An elongated ribbon like part of a soft coral colony that lies flat on the substrate and links polyps.
Substrate:	A surface on which an organism grows or is attached. In the case of live rock ‘culture’, this substrate may be concrete (perhaps cast into shapes or sizes most suited to the market) or natural rock cut or quarried to suit the application.
Suite:	A group of related things intended to be used together; a set.
Symbiotic:	A biological relationship between two organisms that is mutually beneficial.

Taxa:	A taxonomic category or group, such as a phylum, order, family, genus, or species
Taxonomy:	The classification of organisms in an ordered system that indicates natural relationships.
Tentacle:	One of the eight arm-like projections surrounding the mouth of a polyp. Tentacles are generally used for gathering food.
Translocation:	The movement of organisms (or genetically distinct stocks) to areas outside of their natural range. These may include species from within the state, from interstate or those introduced from an international source.
Undulating:	Having a wavy surface or edge.
Zooxanthellae:	Any of various yellow-green algae that live symbiotically within the cells of other organisms, such as marine invertebrates e.g. giant clams and corals.

(some entries sourced from Ellis and Sharron 1999 and Dictionary.com)

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No.3 Determining a "fit and proper person" for rock lobster authorizations (July 1996). Notice published in the Gazette of 11/6/96

No.4 Determining what is "in the better interests of the industry" for rock lobster processing authorisations (July 1996). Notice published in the Gazette of 11/6/96

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No.6 *Vacant*

No.7 *Vacant*

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