The Introduction and Aquaculture of Non-endemic Species in Western Australia: the 'Rotund' Yabby *Cherax rotundus* and the All-male Hybrid Yabby

A DISCUSSION PAPER

Fisheries Management Paper No. 160

Department of Fisheries
168-170 St Georges Terrace
Perth WA 6000

June 2002

ISSN 0819-4327

CONTENTS

OPPORTUNITY FOR PUBLIC COMMENT

This discussion paper has been prepared to provide information to assist in the assessment of the possible impact of the translocation of *Cherax rotundus* and all-male hybrid yabbies within Western Australia, for the purposes of commercial aquaculture on private properties. In assessing the translocation of any aquatic species, the economic and social benefits must be balanced with biological and environmental risks.

Comments about this discussion paper 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 paper, a policy paper will be developed, if deemed appropriate, which designates the areas within Western Australia where stocking may and may not be permitted and the constraints on translocating *C. rotundus* and all-male hybrid yabbies within the State.

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 may be found at the back of this document in Appendix 4. The information provided in this paper should not be accepted to be conclusive and stakeholders are encouraged to consider additional information from other sources in providing the basis for comment.

Your comments would be appreciated by **29 August 2002** and should be marked to the attention of **Aquaculture and Pearling Program – Senior Program Officer**, and addressed to:

Executive Director
Fisheries Western Australia
3rd Floor, SGIO Atrium
168 St George's Terrace
PERTH WA 6000

DEFINITIONS

Term	Definition
All male hybrid yabby	The offspring of a female *C. rotundus* and a male *C. albidus*
DOF	Department of Fisheries
Facility	Any enclosure used to house *C. rotundus* or hybrid yabbies
Hatchery Operator	A person licenced to hold mixed sex populations of *C. rotundus*
Yabby Producer	A person who producers yabbies for sale to yabby processors
Yabby Processor	A person who purchases yabbies for on-sale to food markers

1.0 BACKGROUND

The term yabby refers to a group of species, of which three are of significance to aquaculture, namely *Cherax albidus*, *C. destructor* and *C. rotundus*. Since being introduced into Western Australia from Victoria in 1932 (Morrissy & Cassells, 1992) the 'white yabby' (*C. albidus*) has formed the basis of a significant inland farm dam aquaculture industry.

The proportion of marketable-sized *C. albidus* yabbies caught from dams is extremely dependent on the density of animals present (Lawrence *et al.*, 1998). In normal dams which contain a mix of male and female yabbies, the density is affected principally by reproduction which is virtually uncontrollable. If the density of yabbies is not countered by regular removal by trapping, a decline in the proportion of saleable yabbies can occur and profits may become marginal.

A method of preventing reproduction in farm dams and controlling density is to stock dams with yabbies of only one sex. Dams stocked with male yabbies show an increase of 70 per cent in gross value of stock compared to normal mixed-sex dams (Lawrence *et al.*, 1998). While the WA Yabby Industry has adopted the idea of 'mono-sex' (male) culture in dams, hand sorting of yabbies into different sexes is very labour intensive and prone to error.

In 1998, the Department of Fisheries (DOF) reported on a means of producing sterile male–only hybrid yabby offspring, by cross-breeding male WA yabbies (*C. albidus*) with female NSW, 'rotund' yabbies (*C. rotundus*) (Lawrence *et al.*, 1998, Lawrence and Morrissy, 2000). The growth of these 'all-male hybrid yabbies' is similar to WA male only yabbies, and greater than populations of normal mixed-sex yabbies (Lawrence 1999).

Recently, significant interest in commercialising all-male hybrid yabbies has become evident. The use of all-male hybrids for aquaculture, however, raises some important issues relating to the potential ecological and biological impacts of translocating new species (in this case, *C. rotundus* and all-male hybrid yabbies), and the associated practicalities of ensuring the sustainable and profitable development in a hybrid farming industry. **(Note: It should be emphasised that the purpose of translocating mixed-sex populations of *C. rotundus* is not for widespread farming purposes, rather for the production of all-male hybrid yabbies.)**

In relation to biological and ecological impacts, it is important to consider the possible effect the introduction of *C. rotundus* and production of all-male hybrid yabbies may have on:

1. the genetic diversity of other crayfish species;
2. the potential to introduce pathogens and diseases; and
3. the possible impact on natural ecosystems and the biodiversity of native species within Western Australia.

Additionally, the DOF is chartered with the responsibility of ensuring that an industry based on all-male hybrid yabbies develops in a sustainable manner which is fair and equitable for all stakeholders.

To ensure the identified risks and equity issues are appropriately addressed, the DOF is considering options for regulating this industry which include:

1. different models for managing the entrants to an all-male hybrid yabby hatchery sector;
2. aquaculture facility requirements and licence conditions that hatchery operators holding *C. rotundus* must achieve and maintain;
3. the areas in which *C. rotundus* broodstock may be held;
4. the areas into which all-male hybrid yabbies may be sold for growing out to supply food markets;
5. the provision of disease free broodstock;
6. the proportion of all-male hybrid yabbies which may be kept by hatchery operators for their own means; and
7. the recovery of compliance costs.

2.0 OBJECTIVES

This discussion paper details the issues relevant to the proposed translocation *C. rotundus* onto private properties within Western Australia for the purposes of producing all-male hybrid yabbies, and where hybrid yabbies are to be translocated for growout. The objective of this paper is to generate comment from key stakeholders, government agencies and the members of the public in order to develop, if appropriate, a Policy Paper for the translocation of *C. rotundus* and all-male hybrid yabbies within Western Australia. The Policy Paper generated out of this process would detail the means by which the *C. rotundus* and all-male hybrid yabbies will be distributed within Western Australia for commercial purposes, subject to translocation approval being granted for this species.

This paper addresses Stages 1 – 3 (inclusive) of the commercialisation process as shown in Figure 1. The Policy Paper which arises out of the public consultative process undertaken in these stages will be used to address Stage 4. The subsequent stages of the commercialisation process will proceed only if Stages 1 – 4 can be satisfactorily resolved.

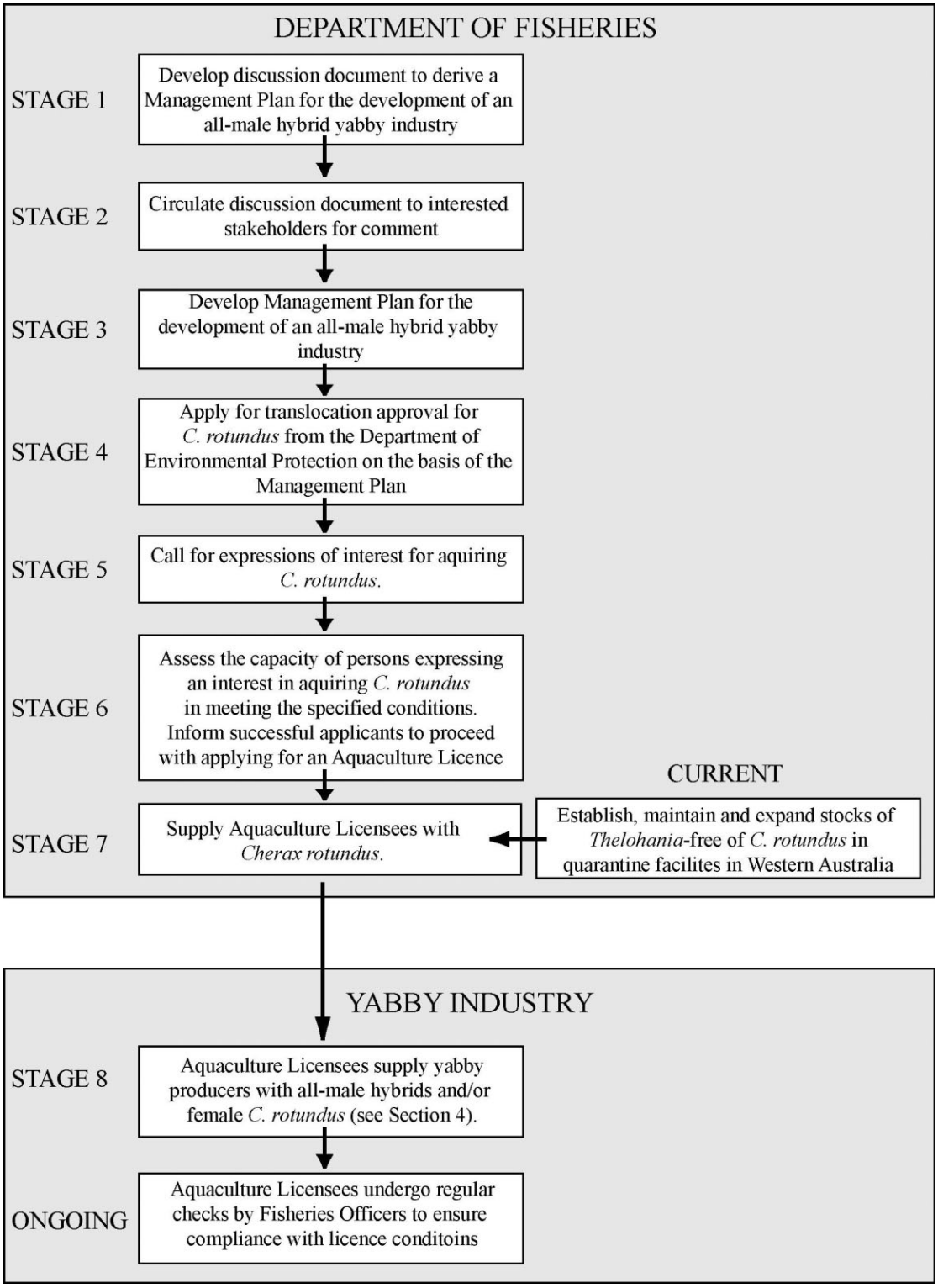

Figure 1. Stages of the commercialisation of the all-male hybrid yabby

3.0 TRANSLOCATION

3.1 Summary of attributes of *C. rotundus* and all-male hybrid yabbies as they apply to their proposed translocation within WA.

The impact associated with the translocation of any non-endemic species will depend to some degree on the biological and ecological characteristics of the species involved. The introduction of a new species, and in this case its offspring, carries with it a number of issues which need due consideration, including the potential for the introduced species to

1. impact on the genetic diversity of existing crayfish stocks;
2. introduce disease; and,
3. impact on the natural environment or the biodiversity of native species.

These issues are considered in further detail below, and in relation to the risks associated with either *C. rotundus* or all-male hybrid yabbies becoming established in natural water bodies in section 3.2.

3.1.1 Biological/Ecological Description of C. rotundus *and all-male hybrid yabbies*

Morphological description

C. rotundus is similar to *C. albidus* but distinguishable by the presence of setae (hairs) on the ventral (bottom) side of their claws. However, *C. rotundus* is smaller than *C. albidus*, with a reported maximum size of 107 mm and weight of 140 g (Clark, 1941), compared to 350 mm and 290 g for *C. albidus* (J. Bellanger pers. obs.).

The all-male hybrid yabbies are an intermediate form of *C. rotundus* and *C. albidus* and hence have an appearance similar to both. The maximum size of hybrids has not been recorded, although it is possible that under the appropriate conditions it may become as large as *C. albidus*.

Reproduction

In *C. rotundus* the sexes are separate, and the female lays relatively undeveloped eggs (oviparous), which is followed by a phase of maternal care of embryos on modified abdominal appendages, until they hatch as almost independent pre-juveniles. A female is estimated to produce approximately 200 offspring, although fecundity is likely to be proportionate to body size as for other yabby species. There is no information available on natural triggers for breeding in *C. rotundus* in its natural habitat, however preliminary observations in aquaria indicate that breeding is temperature related with reproduction occurring during the warmer spring/summer period. The sexes of *C. rotundus* are obvious, with the external penne (males) and oviducts (females) easily distinguishable when the yabbies are approximately 20 mm in length.

All-male hybrid yabbies are reported to be sterile (Lawrence *et. al.*, 1998). Extensive backcrosses with *C. albidus* and preliminary crosses with *C. rotundus* have not produced viable offspring. Although crosses have not been attempted with native Western Australia crayfishes, given that crosses with other yabby species have proven

unsuccessful it is very unlikely that hybrids would be able to breed with native species, which are genetically divergent from yabbies.

The issue of hybridisation of *C. rotundus* and all-male hybrid yabbies with native crayfish species is addressed in more detail in Section 3.2.

Feeding

No trophic studies have been published for *C. rotundus*, but it is likely to be similar to other yabbies and many other crayfish species which feed on a variety of detritus, algae, and benthic and swimming aquatic invertebrates.

It is very likely that the all-male hybrid yabby would adopt a similar feeding habit. Hybrids grew and survived very well in model ponds (Lawrence, 1999) using a feeding regime which has proven successful for *C. albidus* (Lawrence *et. al*, 1998).

Physical, Chemical and Habitat Preferences

All crayfish including *C. rotundus* use similar habitats, such as the banks of dams and streams to live and feed. Yabbies are able to use most areas where there are permanent or semi-permanent water bodies.

The natural distribution of *C. rotundus* is restricted to a small coastal area in New South Wales. The physical and chemical conditions of the location where the *C. rotundus* stock in consideration were collected from (temperature 18°C, pH 6.7, salinity 41 mg/L, dissolved oxygen 5.05 mg/L) (Lawrence *et al.*, 1998) may exist in some areas in WA. However, given the limited natural home range of *C. rotundus* and the narrow range in conditions likely to be experienced by yabbies living there, it is unlikely to be successful in a vast number of regions in WA. Furthermore it is unlikely to be as successful as *C. albidus*, which has a very wide natural distribution within Western Australia (Morrissy and Cassells, 1992).

The habitat preferences and tolerable limits for various physical and chemical conditions for the all-male hybrid yabby are unknown at this stage, although they are likely to be similar to those for *C. rotundus* and *C. albidus*.

Burrowing

Yabbies have some ability to survive periods of drought by burrowing into the bottom of dams or waterways. Different species of crayfish have different burrowing tendencies, and the burrowing behaviour of *C. rotundus* will be compared to that reported for *C. albidus* (Lawrence *et al.*, 2001) prior to commercial release. Based on preliminary observations in earthen ponds (J. Bellanger, pers. obs.) it is unlikely that *C. rotundus* is a prolific burrower. However as burrowing would be contained to farm dams, or otherwise in environments where other burrowing crayfish are already present, it is unlikely that *C. rotundus* would be any more problematic than the burrowing crayfish species already present.

Burrowing has been suggested to be associated with reproduction behaviour in *C. albidus* (Lawrence *et al.*, 2001) and *Procambarus clarkii* (Correia and Ferreira, 1995). Given the all-male hybrid yabbies are sterile, burrowing activity associated with reproduction is less likely to occur.

Aggression

Yabbies can be quite aggressive towards one another and recently moulted animals can be cannibalised by other yabbies. Both *C. rotundus* and the all-male hybrid yabby, however, are unlikely to pose any greater aggressive risk than *C. albidus* which is already present in Western Australia. Based on observations in aquaria (J. Bellanger pers. obs), *C. rotundus* are not unusually aggressive compared to *C. albidus*, and should not pose a greater risk than *C. albidus* if they unintentionally enter natural waterways.

3.1.2 Potential impact on genetic diversity (of existing crayfish stocks)

In assessing the potential impact of *C. rotundus* or all-male hybrid yabbies on the genetic diversity of existing crayfish stocks, the following issues have been addressed:

1. Is the proposed translocation a localised extension of its natural range? Do similar species occur within Western Australia?
2. What cross-breeding occurs? What is the likelihood that the introduced species will mate with endemic species?
3. If cross-breeding can occur, what is the likely outcome?

C. rotundus is not present in Western Australia and hence its introduction is not an extension of its natural home range. *C. albidus*, however, which is a similar species has been present in WA since 1932 (Morrissy & Cassells, 1992). *C. rotundus* is only found in a small temperate region of coastal NSW where it inhabits temporary and permanent freshwater waterways (Lawrence *et al.*, 1998). Although there is some debate over whether *C. albidus* and *C. rotundus* are sub-species of a greater '*C. destructor* complex' (Sokol, 1988, Campbell, 1994, Austin, 1996), for the purposes of the risk assessment undertaken in this discussion paper *C. rotundus* has been considered a separate species to that which is present in WA.

Female *C. rotundus* cross-breed with male *C. albidus* to produce all-male hybrid yabbies (Lawrence *et al.*, 1998). Extensive backcrossing of all-male hybrid yabbies with *C. albidus*, and preliminary back-crossing with *C. rotundus*, have not produced viable offspring, which effectively limits potential alterations to genetic diversity to hybrid yabbies. Male *C. rotundus* will mate with female *C. albidus* to produce a 'normal' sex ratio of 1 male:1 female (Lawrence *et al.*, 1998).

It is not known whether *C. rotundus* cross breeds with any of the species of freshwater crayfish present in Western Australia, however within the yabby species complex cross species reproductive capability is not complete, as is evident through the production of male hybrid yabbies from crossing *C. rotundus* with *C. albidus*, and *C. rotundus* with *C. destructor* (Lawrence *et al.*, 1998). Viable crosses between *C. rotundus* and freshwater crayfish outside of the yabby species complex are much less likely, based on genetic divergence.

The proposed distribution plan (see Section 4) seeks to protect native crayfish species by prohibiting holding *C. rotundus* in the south-west corner of Western Australia (Zone 1, see Figure 2) which is the principal home range for most native crayfish (e.g. *C. tenuimanus*, *C. plebejus, C. glaber*, *C. quinquecarinatus* and *C. crassimanus*)

(Coy, 1979). Further, the plan restricts the location of facilities used to house *C. rotundus* if they occur in catchments which drain into the 'marron zone' (see Section 4).

3.1.3 Potential for the introduction of pathogens and diseases

The main disease issue for yabbies in Australia is a species of *Thelohania*, which is a spore-forming protozoan that infects the flesh of marine and freshwater crustaceans. The endemic *Thelohania* species found in Australian freshwater crayfish has been recorded from a number of yabby properties in WA (Jones and Lawrence, 2000).

However, to restrict the movement of *Thelohania*, the *C. rotundus* (and *C. albidus*) supplied to be used to produce all-male hybrid yabbies in Western Australia will be tested for *Thelohania* species and certified as being disease free. Additionally, hatchery operators licenced to hold mixed-sex populations of *C. rotundus* will be required to under go regular disease testing to confirm their disease – free status. Hence, the development of an all-male hybrid yabby industry using *C. rotundus* will not result in spreading of *Thelohania* in Western Australia.

The other diseases of yabbies that have been reported, including bacteria such as *Pseudomonas* spp. and flat worms like *Temnocephalus* spp. are already present in the natural environment in Western Australia, and it is only poor management practices in culture conditions that make these diseases more prevalent.

3.1.4 Potential effect on ecosystems and native aquatic species

The introduction of some aquatic organisms may affect the composition of the local community either directly through predation, competition or by altering the existing environment (Lawrence, 1993).

Given the similar attributes of *C. rotundus* and *C. albidus*, the potential for *C. rotundus* to have any greater impact on aquatic ecosystems or other aquatic species than *C. albidus* is considered to be remote. Furthermore, given that *C. rotundus* is only found in a small area of NSW where the environmental aspects differ to many of the areas in WA where *C. albidus* occurs, it is unlikely that it could be as broadly successful in WA as the yabbies already present.

This does imply that there may be areas unsuitable for holding *C. rotundus* for the commercial production of all-male hybrid yabbies. Accordingly, some caution should be exercised by hatchery operators and yabby producers seeking to obtain *C. rotundus*, so as to ensure that the conditions in which these animals are placed are suitable. In practice this can be assisted by ensuring that facilities used to house *C. rotundus* are of a high quality (well aerated, well fed, of sufficient volume to ensure temperatures are relatively stable, low densities of stocked animals).

It is possible that if *C. rotundus* was to be introduced to natural waterbodies with established populations of *C. albidus*, some crossbreeding will produce fast growing sterile all-male hybrid yabbies, which may out-compete *C. rotundus* and *C. albidus* in the short term. This may provide a mechanism for reducing yabby populations in areas where they are not wanted.

It is possible that fast growing all-male hybrid yabbies present in a waterbody containing native crayfish species may have some negative impacts, however as hybrids cannot establish (by virtue of being sterile), their long term effects are likely to be reduced.

3.2 Summary of risk assessment of establishing populations of *C. rotundus* and all-male hybrid yabbies in Western Australian water bodies

The attributes of *C. rotundus* and all-male hybrid yabbies detailed in Section 3.1 dictate the success at which these animals may establish populations outside of the suggested conditions in Section 4. The following risk assessment identifies where the level of risk is greatest, following a stepwise process which addresses:

1. the potential for *C. rotundus* or hybrids to escape or to be introduced into an unintended waterbody,
2. the potential for *C. rotundus* or hybrids to become established if they enter a waterbody,
3. the potential for *C. rotundus* or hybrids to spread if they become established in a waterbody, and,
4. the potential environment, ecological and disease impacts if *C. rotundus* or hybrids become established and spread into the greater environment.

The following risk analysis has been provided to give stakeholders an understanding of the risks associated with introducing *C. rotundus* and all-male hybrid yabbies into Western Australia.

3.2.1 The potential for escape or introduction of yabbies into a natural water body.

The potential for escape or introduction of *C. rotundus* or all-male hybrid yabbies to an unintended water body may occur through one of three mechanisms:

1. the deliberate sale of male and female *C. rotundus* to, or theft by, a person not licensed to hold mixed-sex populations of *C. rotundus*, and subsequent uncontrolled translocation;
2. escape of male and female *C. rotundus* from licensed producers' facilities; or
3. deliberate or accidental stocking of purchased all-male hybrid yabbies into a natural waterbody.

The risk of *C. rotundus* being deliberately sold to an unlicensed producer is mitigated by the commercial advantage of producing all-male hybrid yabbies and/or female *C. rotundus* within a restricted market. Additionally, the risk of cancellation of the aquaculture licence on the basis of unfit or improper behaviour would discourage such activities.

The risk of deliberate sale of male *C. rotundus* to unlicensed persons would increase as additional hatchery operators entered the industry, if this caused the commercial advantage of producing hybrids of female *C. rotundus* to decrease through market

saturation. Accordingly, there may be some benefits with respect to translocation of operating a restricted entry industry for hatchery operators.

The risk of theft of *C. rotundus* would be greater from farm dams or drainable ponds than enclosed sheds with aquaria or tanks (see Section 5.1.2). However, hatchery operators will be required to show means of reducing the risk of theft of stock, regardless of their methods producing hybrids or female *C. rotundus*. Persons convicted of theft of stock can be prosecuted under the Western Australian Criminal Code.

The risk of active escape of *C. rotundus* from a breeding facility is reduced by ensuring, by way of site inspections and licence conditions, that suitable prescribed structures are established and maintained to prevent escape. The risk of *C. rotundus* escaping from a breeding facility by way of flooding is lessened by prohibiting hatchery operators from using facilities to contain mixed sex populations in areas shown to be affected by flooding or large rainfall events. The risk of flooding affecting *C. rotundus* held in a shed with tanks or aquaria is extremely low, whilst for dams or ponds the risk may be greater. The risk of establishment of *C. rotundus* following active escape or flooding is higher where the original waterbody is near to lakes, dams or river systems.

It is feasible that legally acquired hybrids or female *C. rotundus* may be translocated into natural water bodies other than farm dams, given there are currently no licence or legislative controls on hybrids or *C. rotundus* after the point of sale. To prevent intentional translocation of all-male hybrid yabbies into waterbodies such as lakes or river systems, it is proposed to supply hatchery operators with information pamphlets to be given to purchasers on suitable systems in which to place hybrids or female *C. rotundus*. Additionally aquaculture licensees will be required to retain records of all persons supplied with hybrids and their location.

It is the intent of the Department of Fisheries to legislate the prohibition of commercial farming of hybrids and *C. rotundus* within Zone 1 (see figure 2).

3.2.2 The potential for yabbies to become established if they enter a water body

If *C. rotundus* or all-male hybrid yabbies are introduced to a natural water body the possibility of establishment will relate to:

1. the particular biological and ecological attributes of the species, and
2. the particular attributes of the water body.

C. rotundus shares similar biological and ecological attributes to *C. albidus* with the exception of that its tolerances to most environmental conditions appear to be lower. Accordingly, it is most likely that *C. rotundus* would occupy less diverse and less widespread habitats, than the already introduced *C. albidus*.

The natural habitat of *C. rotundus* is a coastal area of a similar latitude to Perth. It is unlikely that the climatic conditions within the south-west corner of Western Australia, where the ecological impacts on native crayfish are of most concern, would be suitable for *C. rotundus*. It is feasible that if *C. rotundus* was to be introduced to a

natural waterway within catchment 616 (see Figure 2) it may become established, but this area is generally within the Zones 2 and 3 where other yabbies are permitted to be commercially farmed.

It is more difficult to accurately predict where, and with what success, all-male hybrid yabbies may become established if they were released into an natural water body. Whilst a degree of risk is apparent from the lack of knowledge of this intermediate species, given that all-male hybrid yabbies are sterile the risk for long-term establishment is eliminated.

3.2.3 The potential for spread of yabbies if they become established in a water body

If *C. rotundus* became established in a natural waterway which was not intended for its use, it is likely that some degree of spread would occur within the narrow tolerance limits of this species. However, it is very unlikely that *C. rotundus* would become as widespread as *C. albidus*. If *C. rotundus* did become established in similar water bodies as *C. albidus*, the outcome of cross-breeding would be sterile all-male hybrid yabbies, which may out-compete *C. rotundus* and *C. albidus*, before eventually dying out itself.

The opportunity for all-male hybrid yabbies to become widespread is extremely low, given the sterility of these animals.

3.2.4 The potential environment, ecological and disease impacts if yabbies become established.

The risk of impacts of a ecological, environmental or disease nature associated with an established population of *C. rotundus* in a natural waterbody are likely to be less than those already observed for *C. albidus*. This is supported in that *C. rotundus* is likely to be less widespread, generally smaller, and extremely unlikely to introduce diseases into the environment.

If *C. rotundus* was introduced into a natural water body where *C. albidus* was already established, the former species will cause some slightly different impacts than caused by *C. albidus*. However, given that natural habitats with established populations of *C. albidus* are likely to already be modified, and given that both species compete for similar resources, it is unlikely that there would be a significant cumulative impact of having both species present.

The potential impact of all-male hybrid yabbies is considerably low given that the animal is sterile and hence will not become established. As with *C. rotundus* there are negligible risks of introducing problematic diseases. If all-male hybrid yabbies were to be introduced to a natural waterway containing other native crayfish species, the ecological and environmental impacts are likely to be low given the small number of hybrids that would be introduced and the impossibility of establishment.

4.0 MANAGEMENT OPTIONS

The DOF is committed to ensuring the most stringent conditions possible are met and maintained to ensure the protection of ecosystems and native species, whilst fostering profitable industry development. The proposed management options detailed below seek to meet both the ecological and economic obligations of the DOF.

4.1 Management options of the introduction of C*. rotundus* and establishment of a sustainable all-male hybrid yabby industry

A number of models and conditions have been proposed to develop and regulate an all-male hybrid yabby industry. These are detailed below.

4.1.1 Proposed models for establishing an all-male hybrid yabby production industry

Three models have been suggested for establishing an all-male hybrid yabby production industry.

Model 1. An open industry for hatchery operators producing hybrids for sale to yabby producers,

Model 2. A 'restricted entrant industry' for hatchery operators producing hybrids for sale to yabby producers, or;

Model 3. A 'restricted entrant' industry for hatchery operators producing female *C. rotundus* (only) and all-male hybrid yabbies for sale to yabby producers.

Model 1 proposes that any potential hatchery operator who is able to meet the specified conditions for holding a mixed-sex population of *C. rotundus* (see sections 4.1.2 – 4.1.4) is able to proceed with making an application for an aquaculture licence.

Model 2 would restrict the number of aquaculture licences available for potential hatchery operators to a predetermined number, on the basis of reducing potential ecological impacts. If this model was shown to be effective, an additional set of licences may be made available at some later date.

A proposed addition to Models 1 and 2 is approving hatchery operators to sell **female** *C. rotundus* (only) to any unlicensed yabby producers. These yabby producers would be able to use *C. rotundus* to establish breeding dams to produce their own hybrids. hatchery operators, and unregulated yabby producers, would not be restricted from selling all-male hybrid yabbies to other unregulated yabby producers. This model advocates the distribution of female *C. rotundus* into unregulated dams, on the basis that there is no greater risk of *C. rotundus* becoming established if sales are restricted to females only.

The same degree of compliance with the conditions specified in sections 4.1.2 – 4.1.4 would need to be shown by potential hatchery operators regardless of the model adopted by the DOF.

4.1.2 Proposed Distribution of C. rotundus *and all-male hybrid yabbies*

It is proposed to permit the holding of mixed sex populations of *C. rotundus* on approved commercial farms located in Zones 2 and 3 of Figure 2. It is proposed that potential Hatchery Operators with facilities located within specific catchments in Zones 2 and 3 comply with different requirements to become aquaculture licensees, in recognition of the greater potential ecological impacts within specific catchments. The proposed distribution of *C. rotundus* and requirements for specific catchments are detailed in Table 1.

Conditions	**Zone 2: A Category Catchments**	**Zones 2,3: Category B Catchments**	**Zone 1**
Relevant Catchments	All shaded catchments in Zone 2, as shown in Figure 2	All unshaded catchments in Zones 2 & 3, as shown in Figure 2	Any catchment in Zone 1
Permitted to hold *C. rotundus*	Approved, subject to meeting prescribed conditions	Approved, subject to meeting prescribed conditions	Not approved
Flood status of facilities used to house ♀ & ♂ *C. rotundus*	Safe from 1 in 25 yr. flood, supported by documented evidence from qualified person	Safe from 1 in 25 yr. flood, supported by historical evidence	Not Applicable
Rainfall runoff status of facilities used to house ♀ & ♂ *C. rotundus*	Facilities shown to be safe from immersion from rainfall in catchment above facility	Facilities shown to be safe from immersion from rainfall in catchment above facility	Not Applicable

Table 1. Proposed distribution of C. rotundus and requirements for facilities used to house mixed sex (♀ & ♂) populations of C. rotundus within specific catchments in Western Australia.

It is proposed that yabby producers who purchase female *C. rotundus* (under Model 3; see section 4.1.1) would not have to provide details on the flood-status of dams used to house these animals.

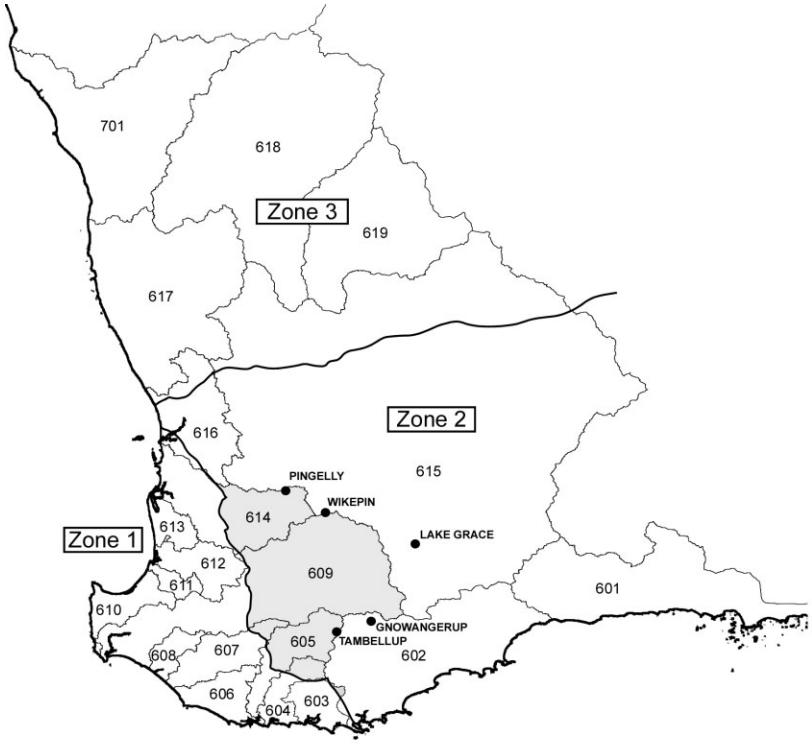

Figure 2. Proposed distribution of C. rotundus for use to commercially produce all-male hybrid yabbies (Note – Zones 2 and 3 are the areas where commercial yabby farming is permitted; as delineated by the yabby boundary – see Appendix 2).

4.1.3 Proposed selection criteria for potential hatchery operators

It is proposed that potential hatchery operators applying to hold mixed-sex populations of *C. rotundus* for the purposes of producing all male hybrids and/or female *C. rotundus* demonstrate the ability to meet the following selection criteria to the satisfaction of the Executive Director of the DOF. It is proposed that only those potential hatchery operators meeting **all** of the following requirements to the satisfaction of the Executive Director of the DOF would be likely to be issued an aquaculture licence.

1. ***Prevention of uncontrolled translocation***

It is proposed that potential hatchery operators provide details of a site in which mixed sex populations of *C. rotundus* and all-male hybrid yabbies will be secure from escape, theft or flood or any other type of inadvertent translocation.

It is proposed that the site must be shown to be:

1. Predator and escape proof (using exclusion netting and/or fences).

Facilities (dams, ponds, tanks) which contain male and female *C. rotundus* must exclude any predators (birds, water rats, etc.) which may result in inadvertent loss/translocation of yabbies. It is suggested that facilities other than sheds must be completely surrounded by a solid fence of durable material which is extends at least 0.5 m vertically from ground level, and netting which is used to prevent avian predators is to have a mesh size of no greater than 100 mm. If sheds are used to

contain *C. rotundus* is it suggested that they be constructed of durable material of which at least 0.5 m of the walls must extend vertically from ground level.

2. Flood proof.

Facilities must be sufficiently protected from flooding to prevent inadvertent loss/translocation of mixed-sex populations of *C. rotundus*. Potential hatchery operators must provide the DOF with a topographic map of the area where the site is proposed. The map must detail the size of the catchment above the site and the location of any temporary or permanent waterways in the vicinity. Potential hatchery operators must provide a history of flooding of the area, and describe means of preventing runoff from summer thunderstorms from flooding any facilities which contain mixed-sex populations of *C. rotundus*. Proposed specific requirements for evidence of the flood status for facilities located in difference catchments is presented in Table 1.

3. Protected from theft.

Potential hatchery operators must describe the means by which theft will be prevented.

2. *Technical competence to sex animals and produce all-male hybrid yabbies.*
It is proposed that potential hatchery operators provide the DOF with an outline of the means by which they plan to produce all-male hybrids and female *C. rotundus*, and provide evidence of their experience in sexing, handling and producing yabbies.

3. *Provision of a distribution plan for sale of hybrids and/or female* C. rotundus.
It is proposed to require potential hatchery operators to describe their plans to advertise and distribute hybrids and/or female *C. rotundus* to the yabby industry. It is suggested that a distribution plan be developed which incorporates the existing yabby and marron zones (Zones 2 and 3, see Figure 2).

It is proposed that if Models 1 or 2 (see section 4.1.1) are adopted, the sale of live male or live female broodstock *C. rotundus* would only be permitted to another licensed hybrid producer, and would be conditional on approval from the DOF. If Model 3 is adopted, it is proposed that for the purposes of accurately sexing yabbies, the sale of female *C. rotundus* **less than** 25 grams (live body weight) to anyone other than another person licensed to hold mixed populations of *C. rotundus* (that is, a yabby producer) would be prohibited. If Model 3 is adopted it is proposed that the sale of live male *C. rotundus* to anyone other than another person licensed to hold mixed sex populations of *C. rotundus* would be prohibited.

To safeguard the WA yabby industry from diseases, hatchery operators will be supplied with *Thelohania*-free *C. rotundus* and *C. albidus* stock subject to translocation approval being given. However, in order to further protect the '*Thelohania*-free' status of Zone 3, it is proposed that the movement of all-male hybrid yabbies and female *C. rotundus* from Zone 2 into Zone 3 would be prohibited. It is advised that Hatchery Operators deciding to use farm dams to house *C. rotundus* and produce all-male hybrid yabbies construct new dams to lessen the risk of introducing *Thelohania*.

It is proposed to permit hybrids produced within Zone 3 to be sold in Zone 3 or Zone 2, but not Zone 1.

Commercial yabby farming, hybrid production and the holding of *C. rotundus* is prohibited within Zone 1.

4. ***Liaison with Industry***
Hatchery operators must display a history or ability to liaise effectively with yabby farmers to enable sale of hybrids and/or female *C. rotundus*.

5. ***Maintenance of disease free stock***
It is proposed to subject hatchery operators who are licensed to hold mixed sex populations of *C. rotundus* to annual disease testing for *Thelohania* species and other certified aquatic diseases. The identification of a certified disease within a facility used to house mixed sex populations of *C. rotundus* may result in cancellation of the aquaculture licence. It should be noted, however, that the DOF Fish Health Unit works constructively with the aquaculture industry to overcome disease problems.

6. ***Display the financial resources to operate a business***.
Hatchery operators must provide a business plan.

It is proposed that hatchery operators licensed to hold mixed-sex populations of *C. rotundus* must provide a bond to the DOF, which will be set aside in an interest bearing account, for the purposes of removing all mixed-sex populations of *C. rotundus* in the event of a business failure.

7. ***Outward sale of all-male hybrid yabbies***

The intent of the DOF in supplying *C. rotundus* to licensed hatchery oerators (subject to translocation approval) is to enable benefits to the whole of the WA yabby industry through the supply of all-male hybrid yabbies to broad growout markets (farm dams). Accordingly, it is proposed to require that potential hatchery operators demonstrate the ability to produce hybrids or female *C. rotundus* (if Model 3 is adopted) in excess of their own requirements (i.e. those used for growout of juveniles for sale to food markets). Furthermore it is proposed that hatchery operators who are successful in gaining an aquaculture licence would be required to provide the DOF with an annual estimate of hybrids destined for external growout markets, and those used internally for growout to supply food markets.

4.1.4 Proposed aquaculture licence conditions for hatchery operators

(Conditions relating to the Fish Resources Management Act 1994)

1. Hatchery operators must meet the requirements of, and be issued an, aquaculture licence to "Hold a mixed sex population of *C. rotundus* for the purposes of producing all male yabby hybrids and female *C. rotundus*". Note: This condition may change depending on the model adopted for the industry (see section 4.1.1).
2. Hatchery operators must display compliance with all relevant conditions specified under the *Fish Resources Management Act, 1994.*
3. Hatchery operators must be open to regular bi-annual compliance checks by DOF officers for stock security evaluation.
4. Hatchery operators must provide monthly returns for the number of hybrids produced.

Specific Conditions

1. Hatchery operators must prepare sites to the conditions set down in Section 4.1.3, to the satisfaction of the Executive Director of the DOF.
2. Hatchery operators producing all-male hybrid yabbies in non-drainable farm dams must house breeding pairs of *C. rotundus* and *C. albidus* in secure breeding cages.
3. Hatchery operators are to provide annual samples of *C. rotundus* and all-male hybrid yabbies to the DOF Fish Health Section for annual disease testing.
4. Hatchery operators must provide the exact location (Latitude and Longitude) of enclosures used to hold *C. rotundus* and all-male hybrid yabbies.
5. In the exception of the adoption of Model 3 specified in section 4.1.1, the sale or delivery of *C. rotundus* females to any person other than a licensed hatchery operator, will result in the cancellation of the aquaculture license. Regardless of the model adopted in section 4.1.1, *C. rotundus* males may only be sold commercially to another licenced *C. rotundus* hatchery operator, or otherwise only as a non-living product processed in Department of Health approved processing facilities.
5. Hatchery operators will be charged an annual fee to help cover compliance and administrative costs.
4. Mature all male hybrids (>20 grams live body weight) may not be held in the same enclosure as female *C. rotundus*.

5. *C. rotundus* or all male hybrid yabbies may not moved from Zone 2 to Zone 3.
6. All-male hybrid yabbies or *C. rotundus* may not be sold into Zone 1.
7. Licensees must retain records of persons sold all-male hybrid yabbies and/or female *C. rotundus*, and their locations, for a period of seven years, or until notified otherwise by the Department of Fisheries.
8. Licensees must not sell female *C. rotundus* of a size <25 g (live whole body weight) to anyone other than another person licenced to hold mixed-sex populations of *C. rotundus*.

5.0 POTENTIAL ECONOMIC BENEFITS

A consideration of the economic benefit of establishing populations of *C. rotundus* and an all-male hybrid yabby industry in Western Australia has been included in this document to indicate the benefits that may flow from the associated risks.

An appraisal of the potential economic potential of producing and growing all-male hybrid yabbies is presented in Appendix 3, and a summary of these figures is provided below. It should be noted that whilst the data presented are inferred from actual figures of production and survival, the appraisal is purely hypothetical. The DOF takes no responsibility of the accuracy of these figures, and the relative success of pursuing a form of aquaculture presented in Appendix 3.

5.1 Local benefits

5.1.1 Economic benefits to yabby producers

It is estimated that an average sized dam (1300 m^2) used exclusively to grow all-male hybrid yabbies from juvenile to a market sized 50 gram yabby would yield approximately 1280 kg/ha/year. This equates to 166 kg of harvested product worth approximately $1500, based on current market prices.

By comparison, a normal mixed-sex *C. albidus* dam on average produces 700 kg/ha/year (Lawrence *et al.*, 2001), or 91 kg from a 1300 m^2 dam, which is worth approximately $813 (based on current market prices).

It is estimated that after expenses that a yabby producer growing all-male hybrid yabbies in a 1300 m^2 dam would have a net margin of $778 for purchasing hybrids. This equates to a maximum purchase price of $0.20 per hybrid (Models 1 or 2, see section 4.1) or $29.92 per female *C. rotundus* (Model 3, see section 4.1.1).

If 200 dams are conservatively estimated to be used in the first year that hybrid yabbies become available, approximately 33,200 kg of marketable product would be produced at a gross value of $298,800.

5.1.2 Economic benefits to hatchery operators

The three following alternative methods for hatchery operators producing either all-male hybrid yabbies or female *C. rotundus* have been appraised.

1. Drainable breeding ponds.
2. Farm dams.
3. Aquaria production.

The estimated hypothetical cost of producing all-male hybrid yabbies or female *C. rotundus* from each of systems are presented in Table 2.

Production System	Production cost per hybrid	Production cost per female *C. rotundus*
Drainable breeding pond	$0.08	$0.16
Farm dam	$0.08	$0.16
Aquaria	$0.27	$0.54

Table 2. Hypothetic cost of producing all-male hybrid yabbies or female* C. rotundus *from drainable breeding ponds, farm dams or aquaria. See Appendix 3 for the derivation of figures.

If 200 dams are used to grow hybrids in the first year they become available, approximately 780,000 hybrids or 5,200 female *C. rotundus* would be required (see Appendix 3). 780,000 hybrids sold at $0.20 each would return a gross profit of $156,000. Alternatively, 5,200 female *C. rotundus* sold at $29.92 each would return a gross profit of $155,584, however, this falls to $51,861 when it is considered that each female only needs to be replaced once every three years and not annually.

5.1.3 Economic benefits to yabby processors

The DOF does not record data on the profit margins gained from processing yabbies, and hence it is difficult to estimate what increase in turnover may be gained from processing all-male hybrid yabbies. However, if a hypothetical profit margin of $2.50 per kg of processed product is assumed, 33,200 kg of processed hybrids would increase turnover by approximately $83,000.

5.2 State benefits

5.2.1 Economic benefits to Western Australia

Based on the conservative figure of 200 new farm dams being used to produce all-male hybrid yabbies per year, an increase in annual turnover in the WA yabby industry may be between $0.43 – 0.54 M.

6.0 REFERENCES

Austin, C.M., 1996. Systematics of the freshwater crayfish genus *Cherax* Erichson (Decapoda: Parastacidae) in northern and eastern Australia: electrophoretic and morphological variation. *Australian Journal of Zoology*, 44: 259-296.

Campbell, N.J.H., Geddes, M.C. and Adams, M., 1994. Genetic variation in yabbies *Cherax destructor* and *C. albidus* (Crustacea: Decapoda: Parastacidae), indicates the presence of a single highly sub-structured species. *Australian Journal of Zoology*, 42: 745-760.

Clark, 1941. New Species of Australian freshwater and land crayfishes (Family Parastacidae) *Memoirs of the Natural Museum of Victoria*, 12: 31-41.

Correia, A.M. and Ferreira, O. 1995. Burrowing behaviour of the introduced red swamp crayfish *Procambarus clarkii* (Decapoda: Cambaridae) in Portugal. *Journal of Crustacean Biology* 15(2): 248-257.

Coy, N.J. (1979) *Freshwater Fishing in South Western Australia*. Jabiru Books, Perth, Western Australia, p.216.

Jones B.J. & Lawrence, C.S. (2001) Diseases of yabbies (*Cherax albidus*) in Western Australia. *Aquaculture* 194(3-4) pp.221-232.

Lawrence, C., 1993. *The introduction and translocation of fish, crustaceans and molluscs in Western Australia.* Fisheries Management Paper No. 58. Fisheries Department of Western Australia. 36 pp.

Lawrence C.S. 1999 *Yabby Hybrid Growout Experiment.* Final Report, FRDC Project 97/319.02: p.99.

Lawrence C.S. and Morrissy N.M., 2000 Hybridization in Australian Freshwater Crayfish: production of an all-male progeny. *Journal of the World Aquaculture Society* 31 (4), pp. 651-657.

Lawrence, C.S , Morrissy, N. M., Bellanger, J.E. and Cheng, Y.W., 1998. *Enhancement of yabby production from Western Australian farm dams*. Fisheries Research and Development Corporation Report No 94/75. p 134.

Lawrence, C.S., Cheng, Y.W., Bellanger, J.E., Cole, N.M. & Seidel, S. (2001) *Feeding and management practices to enhance yabby (Cherax albidus Clark 1936) production from farm dams*. FRDC Project 1997/319. p.213.

Morrissy, N.M. and Cassells, G., 1992. *Spread of the introduced yabbie Cherax albidus Clark, 1936 in Western Australia*. Fisheries Research Report No. 92. p 27.

Sokol, A., 1988. Morphological variation in relation to the taxonomy of the destructor group of the genus *Cherax*. *Invertebrate Taxonomy*, 2: pp.55-79.

7.0 APPENDICES

Appendix 1. Description of catchments and proposed classification relating to requirements to operate a C. *rotundus* hatchery. (note. location of yabby boundary is specified in appendix 2).

Drainage Basin	Description	Catchment Classification
601	Esperance Coast	B
602	Albany Coast	B
603	Denmark Coast – East of yabby boundary	A
603	Denmark Coast – West of yabby boundary	NP
604	Kent River – East of yabby boundary	A
604	Kent River – West of yabby boundary	NP
605	Frankland River – East of yabby boundary	A
605	Frankland River – West of yabby boundary	NP
606	Shannon River	NP
607	Warren River – East of yabby boundary	A
607	Warren River – West of yabby boundary	NP
608	Donnelly River	NP
609	Blackwood River – East of yabby boundary	A
609	Blackwood River – West of yabby boundary	NP
610	Busselton Coast	NP
611	Preston River	NP
612	Collie River	NP
613	Harvey River	NP
614	Murray River – East of yabby boundary	A
614	Murray River – West of yabby boundary	NP
615	Avon River	B
616	Swan Coastal – East of yabby boundary	A
616	Swan Coastal – West of yabby boundary	NP
617	More-Hill Rivers	A
618	Yarra Yarra	A
619	Ninghan	A
701	Greenough River	A

A: Indicates that enclosures to be used to contain mixed-sex populations of *C. rotundus* must be safe from immersion due to 1 in 25 year flood and rainfall on immediate catchment.

B: Indicates that enclosures to be used to contain mixed-sex populations of *C. rotundus* must be safe from immersion due rainfall on immediate catchment.

NP: Indicates commercial yabby farming, including possession of *C. rotundus* is not permitted.

Appendix 2. Boundary of commercial yabby farming as prescribed under section 91(d) of the *Fish Resources Management Act 1994*

All areas of Western Australia north and east of:

Perth City generally south east along Albany Highway to the intersection of Albany Highway and Bannister/Marradong Road,
Thence generally south west along that road to Boddington (Town),
Thence generally south west along that road to Marradong (location),
Thence generally south west along Pinjarra/Williams Road to Quindanning (Town),
Thence southerly along Quindanning/Darkan Road to Darkan (Town),
Thence southerly along Darkan Road south to Duranillan (Town),
Thence west along Bowelling/Duranillan Road to Capercup Road,
Thence south along Capercup Road south to Boyup Brook/Arthur Road,
Thence south west along that road to Glenorchy Road,
Thence south east along that road to Qualeup North/South Road,
Thence south along that road to Kojonup/Donnybrook Road,
Thence south west along that road to Foley Road,
Thence south west along that road to Woodenbillup Road,
Thence south west along that road to Mullidup Road,
Thence south east along that road to Wandoora Road,
Thence south and south east along that road to Kojonup/Frankland Road,
Thence south along that road to Frankland (Town),
Thence south along Frankland/Rocky Gully Road to Rocky Gully (Town) to its intersection with Muirs Highway,
Thence generally east along Muirs Highway to Mount Barker (Town),
Thence generally east along that highway to Albany townsite.

Appendix 3. Hypothetical economic appraisal of various forms of producing and growing all-male hybrid yabbies

An appraisal of the potential economic potential of producing and growing all-male hybrid yabbies is presented in Appendix 3, and a summary of these figures is provided below. It should be noted that whilst the data presented are inferred from actual figures of production and survival, the appraisal is purely hypothetical. The DOF takes no responsibility of the accuracy of these figures, and the relative success of pursuing a form of aquaculture presented in Appendix 3.

Hypothetical profit from growing all-male hybrid yabbies in farm dams for food markets.

All-male hybrid yabbies grow 83 per cent faster than mixe-sex WA yabbies in pools (Lawrence, 1999). By comparison, WA male yabbies grew 53 per cent faster than a mixed sex population of WA yabbies in ponds (Lawrence *et al.*, 1998). Therefore, although the actual benefit of hybrids lay in a simple method of controlling density, there may be additional gains in improved growth compared to WA males.

Optimal stocking densities for all-male hybrid yabbies in farm dams have not been determined, however the higher growth rates suggest that farmers may be able to stock hybrids at medium to high (3-5 yabbies/m^2) stocking rates and still experience reasonable profits compared with mixed sex dams. Farmers will undoubtedly experience further improvements with lower densities (i.e. <3 yabbies/m^2) however management techniques such as harvesting frequency, annual production from individual dams, the availability of dams on individual properties, and the number of hybrids available to stock dams will ultimately dictate the densities used by farmers. For the purposes of the following hypothetical economic assessment, a moderate stocking rate of three yabbies/m^2 has been used.

The average production of *C. albidus* yabbies from a mixed sex commercial farm dam in Western Australian is approximately 700 kg/ha/year (Lawrence *et al.*, 2001). If an 83 per cent improvement in growth using all-male hybrid yabbies stocked at three hybrids/m^2 is assumed, a dam used to produce hybrids should result in production in the vicinity of 1280 kg/ha/year. (Note. The density in a normal mixed sex dam is approximately 4.5 yabbies/m^2, however, if this could be maintained at three yabbies/m^2 the annual yield would be likely to be greater than 700 kg/ha/yr.)

The average size of a commercial dam in WA is approximately 1300 m^2 (Lawrence *et al.*, 2001).

The production of 1280 kg/ha/year of yabbies from a 1300 m^2 dam equates to an annual harvest of approximately 166 kg. This harvest is possible if 80 per cent of stocked hybrids survive, which is feasible based on the survival of stocked yabbies in experimental ponds (Lawrence *et al.*, 1998). It is reasonable to assume that production losses from small amounts of mortality would be offset by increased growth rates of the remaining stock due to reduced density. It is worth considering however that if significant deaths occur (i.e. > 50%), it is unlikely that a harvested biomass of 166 kg from an average farm dam would be possible.

A 1300 m^2 dam with a carrying capacity of 166 kg/year of all-male hybrid yabbies, should support an average harvest size of approximately 50 grams, if one cohort is stocked and harvested after 12 months have expired.

A gross income of approximately $1500, based on current market prices will be returned by 166 kg of 50 gram yabbies This compares to a gross income of $813 for an average normal mixed-sex farm dam containing WA yabbies (based on the percentages of each size grades received from commercial farm dams in a processing facility).

The cost of managing a 1300 m^2 dam is approximately $722 per annum (Table 1).

Item	**Description**	**Cost**
Feed	Lupins at $0.20 using the DoF recommended rates for different seasons*	$80
Harvesting	8 harvests per season: pilchards, 10% depreciation on 9 traps	$50
Fuel	Based on a 10 km round trip per week, @ 5 km/litre @ $1/litre fuel cost	$112
Harvest labour	8 harvests @ 1 hour each @ $20/hr	$160
Feeding labour	48 trips @ 20 minutes each @ $20/hr	$320
Total Costs		$722
Net Profit (not including purchase price of all-male hybrid yabbies)		**$778**

* Note: greater growth rates will occur using freshwater crayfish pellets

Table 1. Costs for managing a 1300 m^2 dam for 1 year

The net margin therefore for purchasing all-male hybrid yabbies (Models 1 or 2, see section 4.1), or female *C. rotundus* for producing hybrids (Model 3, see section 4.1), is approximately $778 (Table 1). This compares to a net margin (after expenses) in a normal mixed sex *C. albidus* farm dam of $91 per year.

A yabby producer therefore has hypothetically $778 per year to purchase 3,900 all-male hybrid yabbies to stock a 1300 m^2 dam. This equates to a **maximum** purchase price of $0.20 per animal, assuming all other costs are zero and no profits other than wages are generated from harvesting yabbies from the dam.

Alternatively, if the sale of female *C. rotundus* to yabby producers is adopted (see section 4.1), approximately 26 female *C. rotundus* would be required to produce 3,900 hybrids per annum in a farm dam situation. This equates to a **maximum** purchase price of each female *C. rotundus* of $29.92. This cost may be significantly reduced by spreading the cost of each female over 3 years (on the basis that a female *C. rotundus* will produce hybrids at least until the age of three years old) and by using each female to produce two crops of hybrids per year. Note: This assessment assumes all other costs for managing a dam are zero, there is no extra costs associated with maintaining breeding pairs of *C. rotundus* and *C. albidus* in farm dams, and that no profits other than wages are generated from harvesting yabbies from the dam. This model also does not account for the difference in growout period associated with producing hybrids from juvenile recently released from the mother, as opposed to purchased hybrids which would be approximately 8 – 12 weeks of age.

Hypothetical market capacity for all-male hybrid yabbies destined for growout in farm dams?

An average dam size of 1300 m^2 stocked at three hybrids/m^2 requires 3,900 yabbies per dam (Model 1 or 2), or 26 female *C. rotundus* (Model 3). It is conservatively estimated that approximately 200 × 1300 m^2 farm dams would be stocked at one cohort per year and at three hybrids/m^2 in the first year of availability. This equates to a demand of approximately **780,000** all-male hybrid yabbies or **5,200** female *C. rotundus* (Table 2).

No. of 1300m^2 dams used	**No. hybrids required for 1 crop per year @ 3 hybrids/m^2**	**No. ♀ *C. rotundus* required to produce 1 crop per year @ 3 hybrids/m^2**
50	195,000	1,300
100	390,000	2,600
200	**780,000**	**5,200**
300	1,560,000	7,800
400	3,120,000	10,400
500	6,240,000	13,000

Table 2. Number of all-male hybrid yabbies or female (♀) C. rotundus required to stock 1300m^2 commercial farm dams.

Requirement for breeding pairs of C. rotundus and C. albidus

The following tables provide an estimate of how many female *C. rotundus* and male *C. albidus* breeding pairs would be required to produce 780,000 all-male hybrid yabbies (in order to stock 200 dams).

Style of production	**Fecundity**	**Survival**	**Infra-structure Costs**	**# hybrids produced**	**# hybrids recovered ***	**# of ♀ *C. rotundus* produced**	**# of ♀ *C. rotundus* recovered ***
100 m^2 drainable breeding ponds	150 offspring per adult	~80%	$1000 ea	120	120	60	60
1000 m^2 farm dam	150 offspring per adult	~85%	$850 ea	128	103	64	51
Hatchery Production in 80 L aquaria	150 offspring per adult	~10%	$800 ea	15	15	8	8

*Recovery from drainable stock breeding dams and aquaria is 100%. Recovery from dams using traps is approximately 80% resulting in a net recovery of approximately 100 AMH per breeding pair.

Table 3. Estimated production rates and costs of producing all-male hybrid yabbies or female (♀) C. rotundus in different systems.

On an individual unit basis the cheapest form of producing all-male hybrid yabbies, based on infrastructure costs alone, is likely to be using aquaria. However, the extremely low recovery of yabbies from these systems compromises the cost effectiveness of this system (Table 3). Whilst the drainable ponds are the most expensive option (Table 3) based on infrastructure costs, high retrieval rates of yabbies, low maintenance costs and ease of management make them an extremely attractive option.

Style of production	No. of successful matings and pairs required	No. of breeding units required to produce 780,000 hybrids
100 m^2 Drainable stock breeding ponds	6,500 matings. 2 matings per pair per year require 3,250 breeding pairs	16-17 (assuming 200 breeding pairs per pond)
Production in a 1000 m^2 dam	7,573 matings. 2 matings per pair per year require 3,786 breeding pairs*	7-8 (assuming 1000 breeding pairs/dam)
Hatchery Production in 80L aquaria	52,000 matings. 2 matings per pair per year require 26,000 breeding pairs.	6,500 (assuming 1 breeding pair per tank [which is used 4 times/year]*)

* assumes juveniles are removed soon after release from female so that tank can be reused.

Table 4. Breeding pairs and units required to produce 780,000 hybrid yabbies.

The most effective form of producing all-male hybrid yabbies is likely to be using 100 m^2 drainable ponds (Table 4).

Style of production	No. of successful matings and pairs required	No. of breeding units required to produce 5,200 ♀ *C. rotundus*
100 m^2 Drainable stock breeding ponds	87 matings. 2 matings per pair per year require 44 breeding pairs	1 (assuming 200 breeding pairs per pond)
Production in a 1000 m^2 dam	102 matings. 2 matings per pair per year require 51 breeding pairs*	1 (assuming 1000 breeding pairs/dam)
Hatchery Production in 80L aquaria	650 matings. 2 matings per pair per year require 325 breeding pairs.	163 (assuming 1 breeding pair per tank [which is used 4 times/year]*)

Table 5. Breeding pairs and units required to produce 5,200 ♀ C. rotundus.

The hatchery production of female *C. rotundus* for use by yabby producers to produce their own hybrids, requires far less infrastructure than required for producing hybrids (Table 5).

Hypothetical cost of producing all-male hybrid yabbies

The following hypothetical economic appraisal of the costs of establishing different types of facilities (sufficient to produce 780,000 all-male hybrid yabbies) is intended as a guide only. The DOF takes no responsibility for the accuracy of the information provided below.

Drainable breeding ponds

Drainable breeding ponds have been used successfully in other forms of crayfish aquaculture for producing large numbers of juveniles at minimal costs. For example a single 150 m^2 pond can be used to produce in excess of 25,000 juvenile marron (*C. tenuimanus*) in a single cycle (G. Cassells, pers. comm.).

Earthen ponds used to produce juvenile crayfish have the advantage improved survival and production compared to aquaria or tanks, due possibly to the presence of natural sources of food (aquatic flora and fauna) and the capacity for some natural removal of metabolic wastes. Depending on the rates at which drainable breeding ponds are stocked for the production of all-male hybrid yabbies, aerators may be required. It is estimated that the stocking, harvesting and maintenance of drainable breeding ponds used to produce all-male hybrid yabbies would require an annual 0.75 time position.

Item	Description	Cost
Enclosures	17 × 100 m^2 ponds @ $1000 ea. (see table 4)	$17,000
Stock	Purchase *C. rotundus*	$2,500
Operating	Maintenance/Electricity/fuel	$1,500
Feed	Crayfish pellets using DoF feeding recommendations	$273
Aerators	Pumps and venturis: 17 @ $300 each	$5,100
Misc items	Refuges, trays, buckets, etc.	$1,000
Labour	0.75 FTE @ $30,000 p.a. (+ 12% on-costs)	$25,200
Packing boxes etc.	Foam boxes with soft foam and ice	$500
Aquaculture Licence	Once off application fee and annual renewal fee	$340
Compliance costs	Cost recovered DoF compliance costs	$1,000
Capital Depreciation	8% per annum	$1,848
Interest on business loan	8% per annum	$4,420
Total*		**$60,681**

*excludes business management costs, advertising costs and cost recovery of disease testing and compliance.

Table 6. Hypothetical establishment and annual costs associated with hatchery production using 100 m^2 drainable breeding ponds.

Based on capital establishment and operating costs, the use of drainable breeding ponds to produce all-male yabby hybrids would result in a production cost in the order of $0.08 per juvenile in first year of production (excluding business management and advertising costs). Once the capital establishment costs had been met this cost may reduce to $0.05 per juvenile.

The unit cost of producing female *C. rotundus* for sale to yabby producers is likely to be approximately double the cost of producing hybrids, given that only half of the crop would be female and saleable.

Farm dams

The use of newly constructed farm dams provides a ready means for applicants wishing to produce all-male hybrid yabbies, and are very successful for breeding *C. albidus*. Dams, like drainable breeding ponds, contain natural food resources and have the potential to absorb a certain amount of metabolic wastes. In order to separate adult broodstock from hybrids, it would be necessary for applicants pursuing this method to construct breeding cages from which *C. rotundus* and *C. albidus* pairs could be removed once juvenile release has occurred. The retrieval of hybrids from undrainable dams would require trapping which represents an additional cost, and may result in a portion of hybrids which may not be easily removed. Applicants licensed to produce all-male hybrids would be permitted to sell hybrids that have grown to marketable sizes in breeding dams to food markets.

Item	Description	Cost
Enclosures	8 × 1000 m^2 ponds @ $1,500 ea.(see table 4)	$12,000
Stock	Purchase *C. rotundus*	$2,500
Operating	Maintenance/Electricity/fuel	$500
Feed	Crayfish pellets using DoF feeding recommendations	$1,014
Breeding Cages	2,500 cages @ 5$ each	$10,000
Harvesting traps	50 traps at $10 each	$500
Bait	50kg of pilchards @ $3.50/kg	$175
Labour	0.75 FTE @ $30,000 p.a. (+ 12% on-costs)	$25,200
Packing boxes etc.	Foam boxes with soft foam and ice	$500
Aquaculture Licence	Once-off application fee and annual Licence fee	$340
Compliance costs	Cost recovered DoF compliance costs	$1,000
Misc items	Refuges, trays, buckets, etc.	$1,000
Capital Depreciation	8% per annum	$1,760
Interest on business loan	8% per annum	$4,378
Total*		**$59,107**

*excludes business management costs, advertising costs and cost recovery of disease testing and compliance.

Table 7. Hypothetical establishment and annual costs associated with hatchery (cage) production of 780,000 all-male hybrid yabbies in 1000m^2 farm dams.

Based on capital establishment and operating costs, the use of farm dams to produce all-male yabby hybrids in farm dams would result in a production cost in the order of $0.08 per juvenile in first year of production. Once the capital establishment costs had been met this cost may reduce to $0.05 per juvenile.

The unit cost of producing female *C. rotundus* for sale to yabby producers in farm dams is likely to be double the cost of producing hybrids, given that only half of the crop would be female and hence saleable.

Aquaria production

The use of aquaria or tanks for breeding and producing hybrids, whilst useful as a research tool, are likely to be inadequate for producing commercial quantities of yabbies for stocking growout dams. Whilst such systems afford a greater degree of control over breeding cycles and the harvesting of juveniles, typically they experience extremely high levels of mortality of juveniles and hence require large numbers of aquaria at significant capital costs.

If hatchery operators however were able to incorporate an all-male hybrid yabby production facility into an existing facility (such as a shed used for processing yabbies for export) this may enable significant cost savings. Furthermore, if a yabby processor was licensed to produce all-male hybrid yabbies and adopted a policy of selling hybrids to farmers at nominal costs, with profits gained once those adult hybrids are bought back and processed for export, the capacity for all-male hybrid yabby production in aquaria or tanks may be feasible.

One distinct benefit of using aquaria to produce all-male hybrid yabbies is the ability to secure both *C. rotundus* and hybrids against losses from flooding, theft or predation.

Item	Description	Cost
Enclosures	Shed, 6,500 × 80 L aquaria @ $20.00 ea. and assoc. equip.	$145,000
Stock	Purchase *C. rotundus*	$2,500
Operating	Maintenance/Electricity/fuel	$5000
Feed	Crayfish pellets	$273
Labour	1 FTE @ $30,000 p.a. (+ 12% on-costs)	$33,600
Packing boxes etc.	Foam boxes with foam and ice	$500
Misc items	Trays, buckets, etc.	$1000
Aquaculture Licence	(once-off application fee and annual Licence fee)	$340
Compliance costs	Cost recovered DoF compliance costs	$1000
Capital Depreciation	8% per annum	$11,680
Interest on business loan	8% per annum	$15,671
Total*		**$211,564**

*excludes business management costs, advertising costs and cost recovery of disease testing and compliance.

Table 8. Hypothetical establishment and annual costs associated with hatchery production of 780,000 all-male hybrid yabbies in 80 L aquaria

Based on capital establishment and operating costs, the use of aquaria to produce all-male yabby hybrids would result in a production cost in the order of $0.27 per juvenile in first year of production. If however significant portions of the capital costs were already met in an existing facility these costs may reduce to as much as $0.08 per juvenile.

The unit cost of producing female *C. rotundus* for sale to yabby producers is likely to be double the cost of producing hybrids, given that only half of the crop would be female and hence saleable.

Appendix 4. Issues submission sheet

Issue	**Comment/Strategy**
Translocation of *C .rotundus* within Western Australia	
Translocation of all-male hybrid yabbies within Western Australia	
Hybrid yabbies production methods	
Aquaculture facility site constraints	
Social and economic benefits	
Models for establishing an all-male hybrid yabby industry	
Impact on the environment and native species	
Competition with and/or predation on native species	
Genetic diversity	
Introduction of diseases and parasites	