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SOUTH AUSTRALIAN RESEARCH & DEVELOPMENT INSTITUTE
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Oriental Weatherloach, *Misgurnus anguillicaudatus*, in the River Murray, South Australia: A Risk Assessment

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June 2014

Report to Biosecurity SA

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

SOUTH AUSTRALIA

Government of South Australia
Primary Industries and Regions SA

SARDI
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EXECUTIVE SUMMARY

Until the recent drought breaking floods throughout eastern Australia (2010/11) there was only one anecdotal report (1987) of the fish species Oriental weatherloach, *Misgurnus anguillicaudatus*, within the South Australian section of the River Murray. However, post-flood sampling of wetlands and floodplains confirms the species distribution has extended into South Australia with a total of 46 reported captures. The species is currently established across two Australian states (Victoria and New South Wales) and one territory (Australian Capital Territory) and is listed as noxious across all jurisdictions. Although there have been reported catches in South Australia there is currently no data to suggest the species has established. Due to this recent incursion and unknowns associated with the establishment/spread of the species, the screening software, Fish Invasiveness Scoring Kit (FISK v.2.0) followed by the Non-native species APplication based Risk Analysis (NAPRA v.2.61) were used to assess, rank and score the environmental, economic and social impacts/costs associated with the species within South Australia. The results indicate a high risk of establishment and suggest several potential impacts including: competition for spawning sites with native fish; disturbance or predation of both fish and frog eggs; competition for food and shelter; alteration of habitat; and decreased water quality. However, these impacts are largely speculative and several knowledge gaps regarding the species ecological impacts and interactions with native flora and fauna exist. Further research is required to quantify potential impacts and determine the most appropriate management/control strategies for Oriental weatherloach in South Australia.

1. INTRODUCTION

1.1. Background

The Oriental weatherloach (*Misgurnus anguillicaudatus*) is a fish species native to Asia (subtropical to cold temperate latitudes; 27-53^{o}N) (Koster *et al.* 2002). It was first imported into Australia in 1964, however, the first wild breeding population was not recorded until 1984 (Yarra River, Victoria) (Lintermans and Burchmore 1996). Until the recent drought breaking floods throughout eastern Australia (2010/11) there was only one anecdotal report (1987) of Oriental weatherloach in the South Australian section of the River Murray. However, post-flood sampling confirms the species distribution has extended into South Australia with 46 reported captures to date. Oriental weatherloach is currently distributed across two States (Victoria and New South Wales (NSW)) and one Territory (Australian Capital Territory (ACT)) and is listed as noxious across all jurisdictions.

The presence of Oriental weatherloach in South Australia is cause for concern as it displays several characteristics which indicate it may be a successful and high impact invader. Oriental weatherloach can tolerate a wide range of environmental conditions (i.e. temperature 2-42^{o}C, high turbidity, deoxygenated water and moderate salinity) (Lintermans and Burchmore 1996, Burchmore *et al.* 1990, Lintermans *et al.* 1990b, Clunie *et al.* 2002, Koster *et al.* 2002). Oriental weatherloach create shallow burrows in the substrate where it can hide with only its head protruding (predator avoidance) (Clunie *et al*. 2002). The species has the ability to crawl out of water, survive in damp soil and even move across land (Lintermans *et al.* 1990b). During drought conditions it can burrow into the sediments to avoid desiccation (Clunie *et al.* 2002). Oriental weatherloach is omnivorous and feeds on detritus, worms, small crustaceans, insects, insect larvae and potentially fish and frog eggs (Lintermans *et al.* 1990b, Lintermans and Burchmore 1996). Spawning is linked to the warmer months of the year and preferred spawning habitats i.e. slow-flowing water bodies (Chen and Su 1980, Lintermans *et al*. 1990b, Swales 1992, cited in Koster *et al.* 2002). The species reaches sexual maturity at 100 mm and grows to a maximum of 250 mm (Lintermans 2007). They are multiple spawners and lay approximately 4000-8000 eggs per event (eggs hatch within 2-3 days) (Lintermans and Burchmore 1996, Lintermans 2007). Oriental weatherloach is considered to have a medium level of resilience with a minimum population doubling time of 1.4-4.4 years (www.fishbase.org).

The impacts of Oriental weatherloach are still largely unknown, however, they can generally be related to habitat preference, burrowing behavior, disturbance and predation of eggs, habitat alteration, potential transmission of diseases and parasites and competition with native species for food resources and shelter (Lintermans *et al.* 1990b, Clunie *et al.* 2002, Koster *et al.* 2002). Preliminary risk assessments indicate that Oriental weatherloach represents a high risk and has a moderate to high probability of establishment, however, these assessments were based on simplified methods and a more rigorous assessment is required (Beyer and Fredberg 2010). In this regard, Biosecurity SA engaged SARDI to conduct a rigorous risk assessment which incorporates up-to-date information and determines the likely risks, impacts and hazards associated with the establishment and management/control of the species within a South Australian context.

1.2. Objectives

1. Determine the risks, hazards, impacts and knowledge gaps associated with the establishment and management/control of the Oriental weatherloach in South Australia.

2. Evaluate the effectiveness, cost-benefit, feasibility and potential impacts on non-target species of management/control mechanisms.

3. Provide a report detailing the reviewed literature, risk assessment protocol, and the risks, hazards and impacts associated with the species establishment. This report will also highlight identified knowledge gaps, evaluate potential management/control mechanisms and provide future research directions.

2. METHODS

To comprehensively and rigorously assess Oriental weatherloach's risks and potential impacts to the River Murray, South Australia, two risk assessment software programs were used. The first of these assessments was the Fish Invasiveness Scoring Kit (FISKv.2.0; Copp *et al.* 2005a), which is a pre-screening tool used to numerically categorise and rank potential invasive freshwater fish as a low, medium or high risk species. The second assessment, Non-native species APplication based Risk Analysis (NAPRAv.2.61), in parallel to the European and Mediterranean Plant Protection Organistation (EPPO) and CAPRA software programs (Mumford *et al.* 2010), is a more detailed, non-numerical, assessment that covers both risks and impacts on an environmental, social and economic level. This assessment, although originally devised for Great Britain, can be applied to any risk assessment area worldwide.

2.1. FISK v2.0 assessment

FISK is an Excel based program which consists of 2 main sections: 1) Biogeography and History which incorporates the 3 categories of domestication, climate/distribution and invasive history; and 2) Biology and Ecology which incorporates the 5 categories of undesirable traits, feeding guild, reproduction, dispersal mechanisms and persistence attributes (Copp *et al.* 2005a, Vilizzi *et al.* 2012). The user can assess an existing species (i.e. previously assessed) or create a new entry. Once this choice is made, the user is presented with a total of 49 sequential questions which require a "yes", "no", "don't know", "high", "moderate" or "low" style response. The user then defines a confidence level (i.e. very uncertain-1, mostly uncertain-2, mostly certain-3, very certain-4) and provides justification for the response (i.e. bibliographic source, background information, etc.). Once all 49 questions are completed, a total score is generated and compared to the critical values in the threshold levels to determine the overall risk outcome. For FISKv.2.0, the critical values in the threshold levels to determine the overall risk outcome are; 1) Low (scores ≤ 0), 2) Medium (1–18), or 3) High (≥19) (from Copp *et al.* 2009). For detailed methods of the FISK assessment please refer to section FISK v2.0.

2.2. NAPRA v2.61 Assessment

The Great Britain Non-Native Species Risk Assessment (NAPRA; Mumford *et al.* 2010), is a software program developed from the template used as a part of the UK risk assessment scheme for all non-native species (Baker *et al.* 2008). This software has then been developed by EPPO for agricultural quarantine of pests and modified for all non-native organisms in the natural environment (Mumford *et al.* 2010). NAPRA v2.61 is free to download, and can be found at http://napra.eppo.org/index.php (accessed 19/09/2011).

Unlike FISK v2.0, NAPRA v2.61 does not have a numerical scoring system for each question which in turn is totaled to produce an overall score and then directly correlated to critical values in the threshold levels. Instead the assessment is split into two main sections: Stage 1) Organism information and screening which is essentially a literature review on the species addressing general background information such as basic biological and ecological characteristics and current distribution status; and Stage 2) A detailed assessment which is the backbone of the assessment and is comprised of four main components plus an overall conclusion. The four components of Stage 2 are listed as: 1) Entry, 2) Establishment, 3) Spread, and 4) Impacts. The conclusion is the overall risk of the organism based on the answers given in the previous four components.

Each question of the four components in Stage 2 has either a five-point or magnitude (log10) scale, correlating to the response given. The following depicts this 'scoring' system based on each individual component.

Entry and Establishment

A five-point scale is used to describe the likelihood and probability of entry and establishment by the organism in the risk assessment area over a five year period (Table 1) (Mumford *et al.* 2010).

Table 1. A five-point scale used to describe the likelihood of entry and establishment of Oriental weatherloach in South Australia, over a five year period.

Response	Scale	Weighting
Very Unlikely	1	0-10% over 5 years
Unlikely	2	11-33% over 5 years
Moderately Likely	3	34-66% over 5 years
Likely	4	67-90% over 5 years
Very Likely	5	91-100% over 5 years

Spread

A five-point scale is used to describe the spread of the organism as a proportion of the risk assessment area that could be colonised over a five year period (Table 2) (Mumford *et al.* 2010).

Table 2. A five -point scale used to describe the proportion of spread of Oriental weatherloach in South Australia, over a five year period.

Response	Scale	Weighting
Minimal	1	0-10% over 5 years
Minor	2	11-33% over 5 years
Moderate	3	34-66% over 5 years

Table 2. Continued.

Response	Scale	Weighting
Major	4	67-90% over 5 years
Massive	5	91-100% over 5 years

Impacts

Impact covers a wider range and follows an order of magnitude (log10) scale, with parallel definitions in economic, social and environmental terms as described in Baker *et al.* (2008) (Tables 3 and 4).

Table 3. Magnitude (log10) scale of potential economic and social impacts associated with Oriental weatherloach in South Australia.

Response	Magnitude (log10) Scale	Weighting
Minimal	1	≥ $1000 with no social impact over a year
Minor	10	≥$10,000 with little social impact over a year
Moderate	100	≥ $100,000 with moderate social impact over a year
Major	1000	≥ $1,000,000 with high social impact over a year
Massive	10 000	≥ $10,000,000 with major social impact over a year

Table 4. Magnitude (log10) scale of potential environmental impacts associated with Oriental weatherloach in South Australia.

Response	Magnitude (log10) Scale	Weighting
Minimal	1	Local, short-term population loss with no significant ecosystem effect
Minor	10	Local, short-term population loss with little significant ecosystem effect
Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect
Major	1000	Widespread, long-term population loss with high significant ecosystem effect

Associated with each response, the assessor also gives a confidence rating on a four-point scale (Table 5) (Mumford *et al.* 2010). Where possible, justification (i.e. references, background information, etc) are filled out in the justification box provided, as to support or reveal knowledge gaps associated with the confidence and certainty in answering the question.

Table 5. A four point scale used to describe the confidence ratings of each answered question in all Stage 2 components of the NAPRA risk assessment.

Confidence	Scale	Certainty
Low	1	35%
Medium	2	50%
High	3	80%
Very High	4	90%

Upon completion of the risk assessment, the assessor is then asked to produce a summary score and confidence rating for each of the four individual components, as well as an overall risk and confidence score for the entire assessment (Mumford *et al.* 2010). This was done by calculating the Mode of the scores given for both the responses (five-point and magnitude (log10) scale separately) and confidence scores (four-point scale), respectively (Baker *et al.* 2008).

The assessment is then given to an independent reviewer and/or panel for review, whereby validation of summary scores for both responses and confidence in all four components and the conclusion is conducted. A sample from uncertainty (confidence) distributions around the agreed scores has to all be agreed upon to produce an overall risk distribution (John Mumford, pers. Comm. 15/05/14).

3. RESULTS

Oriental weatherloach are already in occurrence in the River Murray, South Australia. This along with numerous factors such as suitable habitat for establishment, suitable water quaility for reproductive purposes (e.g. water temperature and quality), invasive biological and ecological attributes and widespread dispersal by natural means (e.g. high flow events) have caused this species to be rated as high risk in both the FISK and NAPRA risk assessments.

3.1. FISK Assessment

The overall score obtained for Oriental weatherloach was 23 (Table 7). Therefore, when compared to critical values in the threshold levels, Oriental weatherloach was deemed as a high risk species (≥19 = high risk). The overall confidence level for responses was 3 (mostly certain), however each question for each category had varying degrees of confidence (Table 6). In total, 10 questions out of the possible 49 responses were answered 'Don't Know' which is represented as a "?" in Table 6, and in turn had a low confidence level (mostly uncertain-2) highlighting knowledge gaps associated with the species that requires future research.

Fish Invasiveness Scoring Kit (G.H. Copp, R. Garthwaite & R.E. Gozlan, 2005a)

Latin name: *Misgurnus anguillicaudatus*

Common name: Oriental weatherloach

Assessor: Josh Fredberg, Leigh Thwaites and Jason Earl

Table 6. The FISK risk assessment on Oriental weatherloach, Misgurnus aguillicaudatus, for the River Murray, South Australia.

Question ID	Risk Query	Response	Certainty	Comments & References
Domestication				
1.01	Is the species highly domesticated or widely cultivated for commercial, angling or ornamental purposes?	Yes	4	(Refer to NAPRA Stage 1; Section B; Q. 16)
1.02	Has the species established self-sustaining populations where introduced?	Yes	4	(Refer to NAPRA Stage 1; Section A; Q. 7 and Q.8)
1.03	Does the species have invasive races/varieties/sub-species?	?	2	(Refer to NAPRA Stage 1; Section A; Q.3)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Climate and Distribution				
2.01	Is the species reproductive tolerance suited to climates in the risk assessment area (1-low, 2-medium, 3-high)?	3	3	(Refer to NAPRA Stage 1; Section B; Q.13)
2.02	What is the quality of the climate match data (1-low, 2-medium, 3-high)?	3	3	(Refer to NAPRA Stage 1; Section B; Q.14)
2.03	Does the species demonstrate broad climate suitability?	Yes	3	(Refer to NAPRA Stage 1; Section B; Q. 11 and Q.13)
2.04	Is the species native to, or has established self-sustaining populations in, regions with similar climates to the RA area?	Yes	4	(Refer to NAPRA Stage 2; Section B; Q.2.02)
2.05	Does the species have a history of being introduced outside its natural range?	Yes	4	(Refer to NAPRA Stage 1; Section A; Q.7)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Invasive elsewhere				
3.01	Has the species established one or more self-sustaining populations beyond its native range?	Yes	4	(Refer to NAPRA Stage 1; Section A; Q.7 and 8)
3.02	In the species' introduced range, are there impacts to wild stocks of angling or commercial species?	Yes	2	(Refer to NAPRA Stage 2; Section D; Q.4.06 and 4.13)
3.03	In the species' introduced range, are there impacts to aquacultural, aquarium or ornamental species?	?	2	(Refer to NAPRA Stage 2; Section D; Q.4.03)
3.04	In the species' introduced range, are there impacts to rivers, lakes or amenity values?	?	2	(Refer to NAPRA Stage 2; Section D; Q.4.06)
3.05	Does the species have invasive congeners?	No	1	(Refer to NAPRA Stage 1; Section A; Q.2)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Undesirable traits				
4.01	Is the species poisonous/venomous, or poses other risks to human health?	No	3	(Refer to NAPRA Stage 2; Section D; Q.4.13)
4.02	Does the species out-compete native species?	?	2	(Refer to NAPRA Stage 2; Section D; Q.4.08)
4.03	Is the species parasitic of other species?	No	4	Oriental weatherloach are not parasitic, however they do act as important secondary hosts to diseases and parasites (Koster *et al.* 2002)
4.04	Is the species unpalatable to, or lacking, natural predators?	No	2	(Refer to NAPRA Stage 2; Section B; Q. 2.06)
4.05	Does the species prey on a native species previously subjected to low (or no) predation?	?	2	Oriental weatherloach is omnivorous and feeds on detritus, worms, small crustaceans, insects, insect larvae and potentially fish and frog eggs (Lintermans *et al.* 1990b, Lintermans and Burchmore 1996). However there is no supporting literature to determine whether any of these food items are subjected to low or no predation

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
4.06	Does the species host, and/or is it a vector, for one or more recognised non-native infectious agents?	Yes	3	(Refer to NAPRA Stage 2; Section D; Q.4.16)
4.07	Does the species achieve a large ultimate body size (i.e. >15 cm total length)?	Yes	3	The species grows to a maximum of 250 mm, but in Australia they are commonly found at 200 mm or less (Lintermans and Burchmore 1996, Lintermans 2007)
4.08	Does the species have a wide salinity tolerance or is euryhaline at some stage of its life cycle?	No	2	It has been suggested that in Australia salinity may pose as a physiological barrier to Oriental weatherloach (Koster *et al.* 2002)
4.09	Is the species able to withstand being out of water for extended periods (e.g. minimum of one or more hours)?	Yes	4	(Refer to NAPRA Stage 1; Section B; Q. 11)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
4.10	Is the species tolerant of a range of water velocity conditions (e.g. versatile in habitat use)?	Yes	3	(Refer to NAPRA Stage 1; Section B; Q. 13)
4.11	Does feeding or other behaviours of the species reduce habitat quality for native species?	Yes	2	(Refer to NAPRA Stage 1; Section B; Q. 17)
4.12	Does the species require minimum population size to maintain a viable population?	Yes	3	Oriental weatherloach is considered to have a medium level of resilience with a minimum population doubling time of 1.4- 4.4 years (fishbase.org)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Feeding guild				
5.01	If the species is mainly herbivorous or piscivorous/carnivorous (e.g. amphibia), then is its foraging likely to have an adverse impact in the RA area?	No	3	(Refer to NAPRA Stage 1; Section B; Q. 17)
5.02	If the species is an omnivore (or a generalist predator), then is its foraging likely to have an adverse impact in the RA area?	Yes	2	(Refer to NAPRA Stage 1; Section B; Q. 17)
5.03	If the species is mainly planktivorous or detritivorous or algivorous, then is its foraging likely to have an adverse impact in the RA area?	Yes	2	(Refer to NAPRA Stage 1; Section B; Q. 17)
5.04	If the species is mainly benthivorous, then is its foraging likely to have an adverse impact in the RA area?	Yes	2	(Refer to NAPRA Stage 1; Section B; Q. 17) (Refer to NAPRA Stage 2; Section B; Q. 2.06)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Reproduction				
6.01	Does the species exhibit parental care and/or is it known to reduce age-at-maturity in response to environment?	No	2	There is no supporting literature to suggest that Oriental weatherloach exhibit parental care or is known to reduce age-at-maturity in response to the environment
6.02	Does the species produce viable gametes?	Yes	2	(see Koster *et al.* 2002)
6.03	Is the species likely to hybridize with native species (or use males of native species to activate eggs) in the RA area?	No	2	There are no members of the Cobitidae family native to Australia, however Suzuki (1955) suggests that short lived (max 20 days) diploid Oriental weatherloach fry can be artificially produced by fertilizing the eggs with crucian carp (*Carassius carassius*) or goldfish (*Carassius auratus*) spermatozoa
6.04	Is the species hermaphroditic?	Yes	3	Hermaphrodism in Oriental weatherloach is rare, but has been reported (Kobayashi 1963; cited in Koster *et al.* 2002)
6.05	Is the species dependent on the presence of another species (or specific habitat features) to complete its life cycle?	No	2	(Refer to NAPRA Stage 1; Section B; Q. 13)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
6.06	Is the species highly fecund (>10,000 eggs/kg), iteropatric or has an extended spawning season relative to native species?	Yes	3	(Refer to NAPRA Stage 1; Section B; Q. 11)
6.07	What is the species' known minimum generation time (in years)?	2	3	(Refer to NAPRA Stage 1; Section B; Q.11)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Dispersal mechanisms				
7.01	Are life stages likely to be dispersed unintentionally?	Yes	3	(Refer to NAPRA Stage 2; Section A; Pathway 1: Q. 1.03-1.09)
7.02	Are life stages likely to be dispersed intentionally by humans (and suitable habitats abundant nearby)?	Yes	2	(Refer to NAPRA Stage 1; Section B; Q. 16)
7.03	Are life stages likely to be dispersed as a contaminant of commodities?	No	3	(Refer to NAPRA Stage 1; Section B; Q. 16)
7.04	Does natural dispersal occur as a function of egg dispersal?	?	2	This may or may not be a form of natural dispersal for Oriental weatherloach in South Australia. No information could be sourced to validate this question

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
7.05	Does natural dispersal occur as a function of dispersal of larvae (along linear and/or 'stepping stone' habitats)?	?	2	In larval studies conducted by SARDI between 2005-2010 in the River Murray of South Australia, Oriental weatherloach was absent from all sampling rounds. However, this was mainly in periods of low to no flows, therefore larvae would have not been able to be dispersed into the risk assessment area from established populations upstream. Larval sampling post 2010 has been undertaken, however, the samples have yet to be identified, therefore the presence of Oriental weatherloach larvae in South Australia is still unknown (Bucater, pers. Comm. 3/02/12)
7.06	Are juveniles or adults of the species known to migrate (spawning, smolting, feeding)?	?	2	No literature could be found to answer this question decisively
7.07	Are eggs of the species known to be dispersed by other animals (externally)?	?	2	No literature could be found to answer this question decisively
7.08	Is dispersal of the species density dependent?	No	3	(Refer to NAPRA Stage 2; Section A; Q. 1.04)

Table 6. Continued.

Question ID	Risk Query	Response	Certainty	Comments & References
Persistence attributes				
8.01	Are any life stages likely to survive out of water transport?	Yes	3	(Refer to NAPRA Stage 1; Section B; Q.11)
8.02	Does the species tolerate a wide range of water quality conditions, especially oxygen depletion and temperature extremes?	Yes	4	(Refer to NAPRA Stage 1; Section B; Q.11)
8.03	Is the species readily susceptible to piscicides at the doses legally permitted for use in the risk assessment area?	Yes	2	(Refer to NAPRA Stage 2; Section B; Q. 2.09)
8.04	Does the species tolerate or benefit from environmental disturbance?	Yes	3	(Refer to NAPRA Stage 2; Section B; Q. 2.11)
8.05	Are there effective natural enemies of the species present in the risk assessment area?	?	2	(Refer to NAPRA Stage 2; Section B; Q. 2.06)

Table 7. Summary results of the FISK (V2.0) risk assessment. Scores < 0 = low risk, 1–18 = medium risk, ≥19 = high risk (from Copp *et al.* 2009).

Score Summary	
Total questions:	**49**
Answered:	**49**
Unanswered:	**0**
Overall Score:	**23**
Outcome User-defined:	**High Risk**

3.2. NAPRA Assessment

The full version of the NAPRA risk assessment, as generated by the NAPRA v2.61 software program, and conducted by SARDI on Oriental weatherloach in the River Murray, South Australia can be found in NAPRA v2.61 of this report.

The results from the NAPRA risk assessment are summarised in Table 8. This table represents only the Stage 2 (detailed assessment) component of the risk assessment as it incorporates the scaling and confidence scores for each question given by the primary assessor. Stages 1 and 3 can be viewed in the full version of the risk assessment in NAPRA v2.61.

The overall risk associated with Oriental weatherloach in the River Murray, South Australia, was calculated as High in Section E- Conclusion (Q. 5.01) (Table 8). This was due to the five-point and magnitude (log10) scale scores of all four components being collated and the Mode calculated to give a combined scale score of four and one, respectively. This gave a combined weighting of 67-90% over 5 years for future entry, establishment and spread of Oriental weatherloach in the River Murray, South Australia. Environmental impacts were weighted as local, short-term population loss with no significant ecosystem effect, and ≥ $1000 with no social impact over a year for future economic and social impacts (Table 8).

Each individual component's scale scores were also summarised in the same manner. Section A- Entry, estimated that the overall likelihood of Oriental weatherloach entering into the River Murray, South Australia based on all pathways described, was rated as four (likely) in the five-point scale, giving the weighting of a 67-90% chance of entry over the next 5 years (Table 8). Given that Oriental weatherloach are already present in the risk assessment area it is reasonable to assume that the likelihood of entry should have been rated as five (very likely), however, some pathways of entry were rated lower than others i.e. 1) Use as bait by recreational anglers and 2) The aquarium trade; hence lowering the mode scores when calculated. Section B- Establishment was rated similarly (likely), as too with Section C- Spread (major), both rating four in the five-point scale and weighted as a 67-90% chance of establishment and a 67-90% proportion of the risk assessment area (River Murray) being colonised in the next 5 years, respectively (Table 8).

Section D- Impacts, consisted of potential economic, social and environmental impacts caused by Oriental weatherloach in the River Murray, South Australia. The potential impacts were found to be minimal (Table 8); with a magnitude (log10) scale rating of one and therefore the weighting of ≥ $1000 with no social impact over a year and local, short-term population loss with no significant ecosystem effect (Table 8).

The overall confidence level for the NAPRA assessment (Section E- Conclusion (Q.5.01)) was derived from the Mode taken from the four-point scale used in all questions from all four components. The overall confidence associated with these responses was rated High (3) with a weighting of 80% certainty (Table 8). In three out of the four components (Entry, Establishment and Spread), the confidence level was also rated as High (Table 8); however, for Section D- Impacts, confidence levels were found to be low (1) with only 35% certainty (Table 8). This suggests that large knowledge gaps are associated with the potential impacts Oriental weatherloach may have on the River Murray in South Australia.

Table 8. Invasive Non-Native Species Risk Assessment (NAPRA v. 2.61) results summary table (Mumford *et al.* 2010).

Stage 2-Detailed Assessment				
Section A-Entry				
	Response	**Scale**	**Weighting**	**Confidence**
1.01 How many active/future pathways are relevant to the potential entry of this organism?	Few	-	-	High- 80%
1.02 List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	-	-	-	-
1.02b Select a pathway to assess.	-	-	-	-
Pathway: Natural Dispersal				
1.03 Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	-	-	High- 80%
1.04 How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Moderately likely	3	34-66% over 5 years	Medium- 50%
1.05 How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?	Unlikely	2	11-33% over 5 years	High- 80%
1.06 How likely is the organism to survive during passage along the pathway?	Very Likely	5	91-100% over 5 years	High- 80%
1.07 How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	4	67-90% over 5 years	High- 80%
1.08 How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Likely	4	67-90% over 5 years	High- 80%
1.09 Estimate the overall likelihood of entry into South Australia based on this pathway?	Very Likely	5	91-100% over 5 years	High- 80%

Table 8. Continued.

Stage 2-Detailed Assessment Section A-Entry	Response	Scale	Weighting	Confidence
Pathway: Water Regulation				
1.03 Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Accidental	-	-	Medium- 50%
1.04 How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	2	11-33% over 5 years	Medium- 50%
1.05 How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?	Unlikely	2	67-90% over 5 years	High- 80%
1.06 How likely is the organism to survive during passage along the pathway?	Likely	4	67-90% over 5 years	High- 80%
1.07 How likely is the organism to arrive during the months of the year appropriate for establishment?	Likely	4	67-90% over 5 years	Medium- 50%
1.08 How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Moderately likely	3	34-66% over 5 years	Medium- 50%
1.09 Estimate the overall likelihood of entry into South Australia based on this pathway?	Moderately Likely	3	34-66% over 5 years	Low- 35%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section A-Entry				
	Response	**Scale**	**Weighting**	**Confidence**
Pathway: Use as Bait by Recreational Anglers				
1.03 Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Intentional	-	-	High- 80%
1.04 How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	2	11-33% over 5 years	High- 80%
1.05 How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?	Likely	4	67-90% over 5 years	High- 80%
1.08 How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Moderately likely	3	34-66% over 5 years	Medium- 50%
1.09 Estimate the overall likelihood of entry into South Australia based on this pathway?	Moderately likely	3	34-66% over 5 years	Medium- 50%
Pathway: Aquarium Trade				
1.03 Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	Intentional	-	-	Medium- 50%
1.04 How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	Unlikely	2	11-33% over 5 years	High- 80%
1.05 How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?	Likely	4	67-90% over 5 years	High- 80%
1.08 How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Likely	4	11-33% over 5 years	Medium- 50%
1.09 Estimate the overall likelihood of entry into South Australia based on this pathway?	Unlikely	2	11-33% over 5 years	Medium- 50%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section A-Entry				
	Response	**Scale**	**Weighting**	**Confidence**
1.11 Estimate the overall likelihood of entry into South Australia based on all pathways.	**Likely**	**4**	**67-90% over 5 years**	**High- 80%**

Table 8. Continued.

Stage 2-Detailed Assessment				
Section B- Establishment				
	Response	**Scale**	**Weighting**	**Confidence**
2.01 "Is the organism well established in South Australia (if there is any uncertainty answer 'unsure')?	Unsure	-	-	-
2.02 "How likely is it that the organism will be able to establish in South Australia based on the similarity between climatic conditions in South Australia and the organism's current global distribution?	Very likely	5	91-100% over 5 years	High- 80%
2.03 "How likely is it that the organism will be able to establish in South Australia based on the similarity between other abiotic conditions in South Australia and the organism's current global distribution?	Very likely	5	91-100% over 5 years	High- 80%
2.04 "How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in South Australia?	Likely	4	67-90% over 5 years	High- 80%
2.05 "How likely is it that establishment will occur despite competition from existing species in South Australia?	Likely	4	67-90% over 5 years	Medium- 50%
2.06 "How likely is it that establishment will occur despite predators, parasites or pathogens already present in South Australia?	Likely	4	67-90% over 5 years	High- 80%
2.07 "How likely is it that establishment will occur despite existing management practices in South Australia?	Likely	4	67-90% over 5 years	High- 80%
2.08 "How likely is it that management practices in South Australia will facilitate the establishment of the organism?	Moderately likely	3	34-66% over 5 years	Medium- 50%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section B-Establishment				
	Response	**Scale**	**Weighting**	**Confidence**
2.09 “How likely is it that biological characteristics of the organism would allow it to survive eradication campaigns in South Australia?	Likely	4	67-90% over 5 years	High- 80%
2.10 "How likely is it that the biological characteristics of the organism will facilitate its establishment?	Likely	4	67-90% over 5 years	High- 80%
2.11 "How likely is it that the organism's capacity to spread will facilitate its establishment?	Likely	4	67-90% over 5 years	High- 80%
2.12 "How likely is it that the organism's adaptability will facilitate its establishment?	Likely	4	67-90% over 5 years	High- 80%
2.13 "How likely is it that the organism could establish despite low genetic diversity in the founder population?	Moderately likely	3	34-66% over 5 years	Low- 35%
2.14 "Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in South Australia? (If possible, specify the instances of invasion elsewhere in the justification box.)	Very likely	5	91-100% over 5 years	High- 80%
2.15 If the organism does not establish, then how likely is it that transient populations will continue to occur?	Likely	4	67-90% over 5 years	Medium- 50%
2.16 "Estimate the overall likelihood of establishment (mention any key issues in the justification box).	**Likely**	**4**	**67-90% over 5 years**	**High- 80%**

Table 8. Continued.

Stage 2-Detailed Assessment				
Section C-Spread				
	Response	**Scale**	**Weighting**	**Confidence**
3.01 "In what proportion (%) of 10km squares in South Australia could the organism establish?	Major	4	67-90% over 5 years	Medium- 50%
3.02 "How important is the expected spread of this organism in South Australia by natural means? (Please list and comment on the mechanisms for natural spread in the justification box)	Major	4	67-90% over 5 years	High- 80%
3.03 "How important is the expected spread of this organism in South Australia by human assistance? (Please list and comment on the mechanisms for human-assisted spread in the justification box.)	Moderate	3	34-66% over 5 years	High- 80%
3.04 "Within South Australia, how difficult would it be to contain the organism?	Major	4	67-90% over 5 years	High- 80%
3.05 "What proportion (%) of the area in South Australia suitable for establishment, if any, has already been colonised by the organism?	Moderate	3	34-66% over 5 years	Medium- 50%
3.06 "What proportion of the area in South Australia suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	Major	4	67-90% over 5 years	Medium- 50%
3.07 "What other timeframe would be appropriate to estimate any significant further spread of the organism in South Australia? (Please comment on why this timeframe is chosen.)	10 Years	-	-	High- 80%
3.08 "In this timeframe, what proportion of the endangered area (including any currently occupied areas) is likely to have been invaded by this organism?	Massive	5	91-100% over 5 years	Medium- 50%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section C-Spread				
	Response	**Scale**	**Weighting**	**Confidence**
3.09 "Based on the answers to questions on the potential for establishment and spread in South Australia, define the area endangered by the organism. Be as specific as possible (if available, provide a map showing the area most likely to be endangered).	All wetlands, floodplains, lakes, backwaters and off-channel habitats found along the River Murray.	-	-	High- 80%
3.10 "Estimate the overall potential for future spread for this organism in South Australia (using the justification box to indicate any key issues).	**Major**	**4**	**67-90% over 5 years**	**High- 80%**

Table 8. Continued.

Stage 2-Detailed Assessment				
Section D- Impacts				
	Response	**Scale**	**Weighting**	**Confidence**
4.01 "How great is the economic loss caused by the organism within its global distribution (excluding South Australia), including the cost of any current management?	Minor	10	≥$10,000 with little social impact over a year.	Low- 35%
4.02 "How great has the economic cost of the organism been in South Australia from the time of introduction to the present? Exclude any costs associated with managing the organism from your answer.	Minimal	1	≥ $1000 with no social impact over a year.	High- 80%
4.03 "How great is the economic cost of the organism likely to be in the future in South Australia? Exclude any costs associated with managing the organism from your answer.	Minimal	1	≥ $1000 with no social impact over a year.	Low- 50%
4.04 "How great have the economic costs of managing this organism been in South Australia from the time of introduction to the present?	Minimal	1	≥ $1000 with no social impact over a year.	High- 80%
4.05 "How great is the economic cost of managing this organism likely to be in the future in South Australia?	Moderate	100	≥ $100,000 with moderate social impact over a year.	Low- 35%
4.06 "How important is environmental harm caused by the organism within its global distribution?	Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect.	Low- 35%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section D-Impacts				
	Response	**Scale**	**Weighting**	**Confidence**
4.07 "How important has the impact of the organism on biodiversity* been in South Australia from the time of introduction to the present?*e.g. decline in native species, changes in community structure, hybridisation	Minor	10	Local, short-term population loss with little significant ecosystem effect.	Low- 35%
4.08 "How important is the impact of the organism on biodiversity likely to be in the future in South Australia?	Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect.	Low- 35%
4.09 "How important has alteration of ecosystem function* caused by the organism been in South Australia from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	Minor	10	Local, short-term population loss with little significant ecosystem effect.	Medium- 50%
4.10 "How important is alteration of ecosystem function caused by the organism likely to be in South Australia in the future?	Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect.	Low- 35%
4.11 "How important has decline in conservation status* caused by the organism been in South Australia from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	Minor	10	Local, short-term population loss with little significant ecosystem effect.	High- 80%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section D-Impacts				
	Response	**Scale**	**Weighting**	**Confidence**
4.12 “How important is decline in conservation status caused by the organism likely to be in the future in South Australia?	Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect.	Medium- 50%
4.14 "How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within South Australia?	Minimal	1	≥ $1000 with no social impact over a year	Medium- 50%
4.15 "How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	Minimal	1	Local, short-term population loss with no significant ecosystem effect	Low- 35%
4.16 "How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	Moderate	100	Widespread, short-term population loss with moderate significant ecosystem effect	Medium- 50%
4.17 "How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the justification box)	Minimal	1	≥ $1000 with no social impact over a year	High- 80%
4.18 "How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in South Australia?	Major	1000	Widespread, long-term population loss with high significant ecosystem effect	Low- 35%

Table 8. Continued.

Stage 2-Detailed Assessment				
Section D-Impacts				
	Response	**Scale**	**Weighting**	**Confidence**
4.19 "Indicate any parts of South Australia where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible, where possible include a map showing vulnerable areas).	Figure 3A indicates vulnerable area's in South Australia that impacts of Oriental weatherloach are likely to occur and hold the highest significance.	-	-	High- 80%
4.20 "Estimate the overall potential impact of this organism in South Australia (using the justification box to indicate any key issues)	**Minimal**	**1**	**≥ $1000 with no social impact over a year. Local, short-term population loss with no significant ecosystem effect**	**Low- 35%**

Table 8. Continued.

Section E- Conclusion	Response	Scale	Weighting	Confidence
5.01 "Estimate the overall risk of this organism in South Australia.	**High**	**4**	**67-90% over 5 years, ≥ $1000 with no social impact over a year. Local, short-term population loss with no significant ecosystem effect**	**High- 80%**

4. DISCUSSION AND RECOMMENDATIONS

The overall risk of the Oriental weatherloach to South Australia across both FISK and NAPRA risk assessments is considered high (NAPRA confidence: High-80%). The results of the FISK assessment (23) is consistent with results obtained for other highly invasive species found in the Murray-Darling Basin; including common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and eastern gambusia (*Gambusia holbrooki*) which scored 40, 40 and 34, respectively (Vilizzi *et al.* 2012). Given that this is the first application of NAPRA within Australia there is no scope for direct comparison with other Australian invasive species. Furthermore, international applications of the NAPRA have not assessed any species that will provide meaningful comparisons with Oriental weatherloach within an Australian context. Notwithstanding, Oriental weatherloach scored a high risk in the entry, establishment and spread sections of the NAPRA risk assessment. Although it is currently unknown if the species has established in South Australia, it has successfully established populations in over 80% of countries in which it has been introduced (Lever 1996, Arthington *et al.* 1999, Koster *et al*. 2002). This is primarily due to the species opportunistic life history strategy (Winemiller and Rose 1992), ability to survive in modified and/or degraded habitats (Burchmore *et al.* 1990, Lintermans *et al.* 1990b, Clunie *et al.* 2002), tolerance to a wide range of water temperatures (2-42°C; Koba 1942, Lintermans and Burchmore 1996 cited in Koster *et al*. 2002) and moderate salinities (Koster *et al*. 2002), ability to survive temporarily out of water via aestivation and gulping air through hind gut (Allen 1984, Lintermans and Burchmore 1996, Clunie *et al.* 2002) and relatively broad dietary niche (Yamamoto and Tagawa 2000). Indeed, the species meets all three factors proposed by Arthington *et al.* (1999) for a successful invader; *i*) previous successful invasions, *ii*) large and abundant populations (within upstream “seed” stocks), and *iii*) specific habitat matching to areas at risk (e.g. Murray-Darling Basin).

The results of the current risk assessment indicate that Oriental weatherloach could potentially have a significant detrimental influence on the structure of aquatic assemblages, ecosystem function, commercial and recreational fishing, as well as the conservation status of some key areas in South Australia. Maciolek (1984) reported that the species had an intermediate stream impact in Hawaii and suggests that this is a result of competition associated with habitat preference, food habits and abundance. Yamamoto and Tagawa (2000) report that Oriental weatherloach consume a diverse array of small benthic-dwelling aquatic organisms including worms, small crustaceans, insects and insect larvae across their natural range. Keller and Lake (2007) conducted a series of mesocosm experiments to determine the density-dependent impacts of Oriental weatherloach on macroinvertebrate numbers/biomass and water quality (control=0, 1 fish, 3 fish). The authors reported that the higher density experiments caused significant reductions in macroinvertebrate abundance and biomass, as well as elevated ammonia, nitrate/nitrite and turbidity levels through re-suspension of sediments. While these impacts may carry social and economic cost associated with the management of erosion and water quality, particularly for water that may be used for stock and irrigation, the authors stated that because of issues involved in scaling up mesocosm experiments, they were unable to conclusively determine if Oriental weatherloach would have a large scale impact in the natural environment. Within Australian ecosystems, Lintermans *et al.* (1990b) speculate that the species impacts may be associated with competition for spawning sites with native fish, predation or disturbance of fish and frog eggs, competition for food and shelter and alteration of native habitats. Further, Dove and Ernst (1998) report that at least one monogenean parasite, *Gyrodactylus macracanthus*, has been introduced into Australia (only one stream in the ACT) via the importation of Oriental weatherloach. These impacts may potentially carry economic and social costs associated with a reduction in the abundance of economically-important fish species that support commercial and recreational fisheries.

Although some authors have reported these potential impacts, it is important to note they have been derived from small scale experiments (i.e. Keller and Lake 2007), international studies (Maciolek 1984, Yamamoto and Tagawa 2000) and observations/speculation (Lintemans *et al.* 1990b). They are yet to be quantified within the Australian context and this is reflected in the overall NAPRA response of “minimal impact” with a confidence level of “low” or “35%”. Indeed, due to the lack of information on the species’ ecology, biology and environmental, social and economic impacts both on a national and international scale, the actual impacts/costs of Oriental weatherloach remain poorly understood. Thus, a future research strategy which aims to provide a comprehensive assessment of these impacts is required. This will aid in refining the current risk assessment and in determining the level of resources (if any) that are required to manage the species.

4.1. Recommendations - Monitoring and Evaluation

To address the above knowledge gaps it is recommended that a targeted monitoring program be implemented. This program should aim to provide a comprehensive assessment of the species biology and ecology within South Australia and include diet, habitat preference, reproductive biology and age structure (to assess establishment), as well as the potential to carry and transmit diseases and parasites. This program should also aim to determine the most effective sampling strategy that targets Oriental weatherloach but also samples the entire fish assemblage as this will aid in determining niche overlap and competition with native species.

Sampling strategies

To determine the most effective Oriental weatherloach sampling techniques it is recommended that the following be trialled within and adjacent to sites where the species has previously been captured:

- Omni-directional small single winged fyke nets - 5 m wing, 70 cm drop, with 70 cm high 'D' and 3 compartments (funnels), 6 hoops with 6 mm mesh with exclusion grills.
- Multi-directional fyke/box nets: 2 cm stretched mesh, 6 chambers (80 cm x 80 cm) with alternating 25 cm funnels, two cod ends, 9.5 m total length.
- Box traps - 400 mm in length with two square ends (250 x 250 mm) with 70 mm openings at each end, brown in colour and targeted.
- Larval drift and tow nets - 500 µm mesh, 0.5 m diameter opening, 1.5 m length.
- Backpack electrofishing (Smith Root® LR-24).
- Experimental trap techniques including heat traps and flow traps.

All netting techniques should be trialled in combination with various baits (i.e. detritus berley, cat food, bait/berley mixtures, blood-worms, benthic invertebrates, etc.) and all sampling techniques should be trialled across a wide variety of habitats including macrophytes, snags, open water, littoral zones, wetland inlets/outlets, inundated flood-plains, irrigation channels, main river channel, etc. In addition, nets and traps should be set in close proximity (composite set) to determine which is most effective for a given habitat type.

Monitoring program

The Oriental weatherloach monitoring program should aim to systematically target sites that encompass the current and potential distribution of Oriental weatherloach within South Australia. The program should also target sites where the species has previously been captured (i.e Nelwood wetland, Portee wetland complex, Chowilla anabranch system;

NAPRA v2.61). All nets/traps within a composite should be set for a minimum of 24 h within relatively close proximity and target all habitat types to ensure the most reliable description of the fish community. In addition, the monitoring program should employ surveillance techniques such as environmental DNA (eDNA; Mahon *et al*. 2013) to assist in detection.

Sample processing

All captured fish within each composite set should be identified to species level, counted and bulk weighed to determine relative abundance and total weight. Native fish should be measured for length (TL, mm) and weight (g). Captured Oriental weatherloach should be measured for length (TL, mm), width/depth (mm) and weight (g). Each specimen should be sexed, their gonads weighed, eggs staged and gut contents analysed. In addition, each specimen should be inspected for disease and parasites and their otiliths should be removed for aging and to permit determination of their natal origin (microchemistry). Finally, captured Oriental weatherloach larvae should be counted and staged. Environmental parameters should also be collected including habitat type and water quality (temperature, salinity, dissolved oxygen, pH, turbidity).

5. CONCLUSION

The overall risk of the Oriental weatherloach spreading and establishing within South Australia is considered high. However, there is an overall lack of information regarding the species' ecology, biology and environmental, social and economic impacts. A future research strategy which aims to provide a comprehensive assessment of the species biology and ecology within South Australia is required. This will aid in refining the current risk assessment and in determining the level of resources (if any) that are required to manage the species.

6. FISK V2.0

The following information outlines the background and protocols used in the Cefas developed, FISK risk assessment (Lorenzo Vilizzi, David Cooper, Andy South and Gordon H. Copp). This document has not been produced by SARDI Aquatic Sciences; however some formatting changes have been performed to allow continuity throughout this report.

Decision support tools

Invasive species identification kits

Background and guidance in the use of these tools for identifying potentially invasive non-native species of marine and freshwater fauna: fish, invertebrates and amphibians.

Adaptations of the Pheloung, Williams & Halloy (1999) Weed Risk Assessment tool kit.

Salmon & Freshwater Fisheries Team

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These tool kits were developed by Cefas, with VBA for Excel and computational programming by Lorenzo Vilizzi, David Cooper, Andy South and Gordon H. Copp, based on VisualBasic code in the original Weed Risk Assessment (WRA) tool kit of P.C. Pheloung, P.A. Williams & S.R. Halloy (1999). http://www.daff.gov.au/ba/reviews/weeds/system

We are grateful to Pheloung *et al.* (1999) for providing an open version of the original WRA as well as for their permission to adapt the original code for the tool kits made available here:

* FISK – Freshwater Fish Invasiveness Scoring Kit (v2 Calibrated) [Excel, 1.80 MB]

* S-FISK – Spanish language version of FISK (v1.19 Calibrated) [Excel, 1.71 MB]

* MFISK – Marine Fish Invasiveness Scoring Kit (v1.19) [Excel, 1.64 MB]

* MI-ISK – Marine Invertebrate Invasiveness Scoring Kit (v1.19) [Excel, 1.71 MB]

* FI-ISK – Freshwater Invertebrate Invasiveness Scoring Kit (v1.19 Calibrated) [Excel, 1.66 MB]

* AmphISK – Amphibian Invasiveness Scoring Kit (v1.19) [Excel, 1.65 MB]

Historical background

FISK was originally adapted from the WRA during the development of a two-part risk analysis scheme for non-native freshwater fishes in the UK (see Copp et al. 2005a, 2005b). Funded by Defra contract no. SF0238, this scheme consisted of a risk identification protocol (FISK, adapted from the WRA) and a risk assessment protocol adapted from European Plant Protection Organisation standards PK5/1-4 (EPPO, 2000). Subsequently, FISK was incorporated into the GB non-native risk assessment scheme as a tool for identifying potentially invasive species (Baker *et al.* 2008).

As part of a contract to develop the GB scheme, FISK was adapted for marine fish, marine invertebrates and amphibians. These initial versions were all still nested within the original WRA package. The original WRA code was re-drafted to create the current versions of FISK and its 'sister' tool kits as contributions to a variety of research contracts:

• UK Defra contract SF0248 on non-native fish species (Contract Leader: Prof. Gordon H. Copp, Cefas)

• EC project 'IMPASSE' on the use of alien species in Aquaculture (Contract Leader: Prof. Ian G. Cowx, HIFI, Hull), http://www.hull.ac.uk/hifi/IMPASSE/

• Scottish Executive contract to finalize the GB Non-native Species Risk Assessment Scheme (Contract Leader: Prof. John Mumford, Imperial College, London).

Toolkit overview

The questions in these tool kits were adapted from the Pheloung *et al.* (1999) original by Cefas with contributions from the persons indicated below:

FISK: Gordon H. Copp (Cefas), Rachel Garthwaite (formerly Cefas, now the Royal Society, London) & Rodolphe E. Gozlan (University of Bournemouth, England).

S-FISK: As above for FISK, with the translation of FISK text elements into Spanish language by Roberto Mendoza (Universidad Autónoma de Nuevo Leon, Mexico).

MFISK: Jim Ellis (Cefas) & Gordon H. Copp (Cefas).

MI-ISK: Jim Ellis (Cefas), Anna Occhipinti (UNIPV, Pavia, Italy), Dario Savini (UNIPV, Pavia, Italy) & Gordon H. Copp (Cefas).

FI-ISK: Elena Tricarico (UNIFI, Florence, Italy), Francesca Gherardi (UNIFI, Florence, Italy) & Gordon H. Copp (Cefas).

AmphISK: Matthew Ellis (CCW, Mold, Wales), Liz Howe (CCW, Bangor, Wales) & Gordon H. Copp (Cefas).

The finalisation of these tool kits benefited from comments and suggestions received form a number of individuals besides those mentioned above, including: Becky Cudmore (DFO, Canada), Gemma Fenwick (formerly of Cefas), Michael J. Godard (Cefas), Stephan Gollasch (GoConsult, Germany), Vladimír Kováč (Comenius University, Slovakia), Nick Mandrak (DFO, Canada) and Hugo Verreycken (INBO, Belgium). Apologies to anyone whose name has been overlooked.

The front menu was designed by Irene Gooch (Cefas) using photos kindly provided by:

• Background: Gordon H. Copp

• Photos from left to right:

–Upper row: The Herpetological Conservation Trust (HCT, UK), Rodolphe E. Gozlan (University of Bournemouth, UK), The HCT (UK), Gordon H. Copp (Cefas);

–2nd row: Gordon H. Copp (Cefas), Riccardo Innocenti (UNIFI, Florence, Italy), Gordon H. Copp (Cefas);

–3rd row: Jim Ellis (Cefas), Luis Zamora (University of Girona, Spain); 4th row: Riccardo Innocenti (UNIFI, Florence, Italy).

Toolkit description

The tool kits are designed to be as self-explanatory as possible. The main menu has four main options.

<u>Using the Toolkits:</u>

• Run Assessment – Clicking this button starts the risk identification assessment and brings up the Species Assessment Menu:

• The assessor is offered the opportunity to create a new record (i.e. start a New species), Edit or Delete an existing record. In the Setup New Species Record dialog, the assessor must give a Latin name, common name (or 'n/a' when a common name does not exist), and his/her name. If either field is left blank upon committing the changes, the user is notified accordingly.

• The total number of species in the list is displayed along with the total number of selected species. Holding Ctrl whilst clicking the left mouse button will individually select multiple species in the list; holding Shift whilst clicking the left mouse button will select multiple adjacent species in the list; checking or unchecking boxes will select or unselect individual species in the list.

• Species in the list can be sorted by ascending order by clicking on the combobox based on any of the column headings in the list (except for the unique ID).

• User-defined thresholds can be set by pressing the UD Thresholds button. This brings up a dialog where new Medium and High thresholds can be defined or previous UD thresholds can be cleared.

• A report can be generated for one or more selected species in the list by clicking on the Report button.

• The Open Q & A button brings up the species assessment dialog. For each of the 49 questions, the assessor is asked to provide the Response, level of Certainty, and a Justification. For each question, a detailed explanation (Question Help) is provided and Advice for the Certainty level can be accessed by clicking on the corresponding button. To facilitate navigation, the Go to Question combobox lets the user jump to any question in the list, which can be otherwise navigated through by pressing the basic navigation buttons. Responses for any question can be cleared by pressing the Clear button. The total number of completed questions is also indicated. Editable fields for completed questions are displayed in light green, for unaswered questions in light red, and for questions being edited in light yellow. Finally, the user can choose either to quit the species assessment dialog without saving any of the changes made since opening (Close no Save) or to commit the changes made (Save and Close).

• Simple Species Sort – By clicking this button the database of assessments will be sorted in alphabetical order by Latin name (first by Genus name and then by species name).

Advanced Functions:

• Unprotect – This button (password protected) is for accessing the internal workings (programming) of the tool kit.

• Export Data – Click this button will output your database of species assessments as an Excel file.

Toolkit Help:

Clicking any of the buttons (Overview, Scoring, Exporting Data, Credits) will provide the relevant information. The secondary menu allows the user to move between these four help screens.

Exit Excel:

• Save and Close – Click this button will save all changes made and close Excel.

• Close No Save – Click this button will close Excel without saving changes.

Undertaking a risk identification assessment

The risk identification tool kits consist of six worksheets, which are linked through VBA for Excel programming. Access to these worksheets is password protected. The general user is able to sort and output the database of assessments they create.

Clicking the "Run Assessment" button allows the user to select an existing species or to create a new entry.

The user is presented sequentially with 49 questions in sequential ‘question menus’. In each of the 49 question menus, the assessor must:

1) Answer the question (yes, no, don't know),

2) Provide a confidence level for that response (very uncertain, mostly uncertain, mostly certain, very certain)

3) Provide a justification for that response (i.e. bibliographic source, background information, etc.).

Constraints when moving forword or backward through the question menus:

With any given question menu, a consistent response is required for the assessor to proceed to the next question menu. In other words, all three queries (question, certainty, justification) must be answered (or all three left unanswered) for the assessor to proceed to the next (or back to the previous, or any other) question menu.

A question is counted as unanswered if any of these items is not completed.

The responses and scores are stored to the workbook 'database' as the assessor moves through the question menus. From the responses, a numerical score is calculated using the following threshold levels:

For FISK, which has been calibrated (see Copp *et al.* 2009): Low (scores < 0 = low risk), Medium (1–18 = medium risk), or High (≥19 = high risk).

For FI-ISK, which has been calibrated (Tricarico et al. 2009): accept (scores < 0 = low risk), evaluate (1–15 = medium risk), or reject (≥16 = high risk).

For MFISK, MI-ISK and AmphISK, which have not yet been calibrated, the original score thresholds of Pheloung *et al.* (1999) are used pending calibration: accept (scores < 0 = low risk), evaluate (1–6 = medium risk), or reject (>6 = high risk).

These thresholds can be modified once calibration and validation has been undertaken and the relevant documentation is provided.

The certainty response is only stored if both the question response and justification are completed. A question is counted as unanswered if any of these items is not completed – in such a case, a default (precautionary) score is given (i.e. the highest possible value).

The tool kit compiles all of the responses for a species in one data line (row) and these 'assessment reports', i.e. the database of assessments, can be organised alphabetically by Genus/species name ('Sort Species List' button). The database can be exported ('Export' button) as a new Excel workbook. The new workbook is only retained if the user selects 'Save and Close', and the user will be prompted to provide the workbook with a file name.

Existing entries may be exported or amended by using the navigation controls.

Note that changes to the database (i.e. new entries, changes to existing entries) are not saved until the assessor leaves the Excel using the 'Save and Close' button.

Scoring

The responses are translated into a numerical score, with positive values (1 or 2) allocated to reflect an elevated risk, a zero given to reflect intermediate risk, and a negative value (-1) given to reflect low or negligible risk. The scoring table is defined in the yellow columns under the heading 'Response' and the values are the same as those given in Pheloung *et al.* (1999), with deviations thereof described in Copp *et al.* (2005a).

The 'climate' and 'invasive elsewhere' sections generate a score using a weighting system: a better climate match decreases the climate weight (because of the increased certainty of a reliable climate matching assessment) and a poorer quality of match increases the weight (because of the greater uncertainty associated with the climate matching assessment, and thus the increase in potential risk).

The species elsewhere responses, as defined in the Response column, are multiplied by the climate weight to generate the final score for each question.

The total score is compared to the critical values in the threshold levels to determine the outcome. These values can be modified by the toolkit authors upon request.

In addition to the score, the number of questions answered in each section is tallied. More information is required if the minimum criteria in the 'Questions answered' table are not met: The minimum numbers of questions required per section are (as per Pheloung *et al.* 1999); Biogeography = 2, Undesirable attributes = 2, Biology/Ecology = 6.

7. NAPRA V2.61

NAPRA Risk Assessment v2.61
Guideline on Pest Risk Analysis
Decision-support scheme for quarantine pests Version N°5

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Stage 1 - Organism Information and Screening Section A - Organism Information

1 - What is the reason for performing the risk assessment?

Wild populations of introduced Oriental weatherloach (*Misgurnus anguillicaudatus*) were first discovered in Victoria in 1981 (Koster *et al.* 2002). However, it was not until the recent drought breaking floods throughout eastern Australia (2010/11) that the distribution of Oriental weatherloach extended into South Australia. The presence of Oriental weatherloach within South Australia is cause for concern as it displays several characteristics which indicate it has the potential to be a successful invader. Biosecurity SA is currently developing an Oriental weatherloach control plan in response to the recent incursion. As part of this plans development, Biosecurity SA engaged SARDI Aquatic Sciences to conduct a rigorous risk assessment which incorporates up-to-date information and which determines the likely risks, costs and impacts associated with the establishment and spread of Oriental weatherloach within the South Australian context. This knowledge will aid in focusing resource allocation for future research and management/control efforts.

2 - Name organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

Oriental weatherloach (*Misgurnus anguillicaudatus*).

There is currently limited genetic information and no accurate identification keys to clearly separate specific species of Oriental weatherloach (Joanne Kearns, PhD candidate, pers. comm. 23/2/12, Koster *et al.* 2002). Notwithstanding, it is reported that at least four *Migurnus* spp. exist across subtropical and cold temperate latitudes of the Asiatic continent (27-53^{o}N); *M. anguillicaudatus, M. mizolepis, M. bipartitus* and *M. cestoideus* (Koster *et al.* 2002). Evidence suggests the Oriental weatherloach was imported to Australia from Japan, Hong Kong, and Singapore but the specific source locations remain unknown (Koster *et al.* 2002). While it is possible that all four species may have been introduced, Koster *et al.* (2002) suggest there is a greater likelihood that the majority of imported fish are *M. anguillicaudatus* and to a lesser extent *M. mizolepis*. It is reasoned that these two species have the broadest distributions within their natural range and therefore carry a greater likelihood of collection for importation (Koster *et al.* 2002). Although there is some doubt over species classification for Oriental weatherloach, Australian researchers typically refer to the species as *Misgurnus anguillicaudatus* (see, Lintermans 1993, Clunie *et al.* 2002, Koster *et al.* 2002, Raadik and Koster 2004; Keller and Lake 2007). This classification has been somewhat supported by recent preliminary research into the genetic structure of Oriental weatherloach within Australia. This work indicates that specimens collected from Barmah (River Murray, Victoria,

≈400 km upstream of South Australia) may be one haplotype, which most likely suggests that the South Australia invasion is by one species only. A voucher sample of the Barmah specimens was morphologically identified as *M. anguillicaudatus* by an international taxonomic expert; however, the expert also indicated the specimen was not completely identical to other types of specimens (Joanne Kearns, PhD candidate, pers. comm.23/2/12). It must be noted that this genetic research is not yet conclusive and further work is required to definitively distinguish individual species. Notwithstanding, given the above information, this risk assessment will consider the species which is most likely to be present in South Australia, *Misgurnus anguillicaudatus*.

3 - If not a single taxonomic entity, can it be redefined? (If necessary use the justification box to re-define the organism and carry on)
Possibly

Although this risk assessment focuses on *Misgurnus anguillicaudatus*, further genetic research may determine that other species of Oriental weatherloach are present within the risk assessment area. The uncertainty surrounding the taxonomic identification of Oriental weatherloach within Australia represents a key knowledge gap.

4 - Does a relevant earlier risk assessment exist? (Give details of any previous risk assessment)
Yes

The species was declared noxious and allocated a high risk score in all Australian jurisdictions as a part of the 2006 "Strategic Approach to the Management of Ornamental Fish in Australia", a report to the Natural Resource Management Ministerial Council (DAFF 2006). This classification was based the Bureau of Rural Sciences (BRS) grey list species review method (DAFF 2006).

5 - If there is an earlier risk assessment is it still entirely valid, or only partly valid?
Partial

The Bureau of Rural Sciences (BRS) grey list species review method was policy based and developed to act as preliminary screening tool (Beyer and Fredberg 2010). It was applied to hundreds of different ornamental fish species and did not specifically address issues and regions affected by Oriental weatherloach. In concluding their assessment, Beyer and Fredberg (2010) recommended that all high risk grey listed species should undergo a more rigorous science-focused risk assessment. As such, this assessment represents the first comprehensive scientific risk assessment of Oriental weatherloach within Australia.

Although no scientifically rigorous risk assessments have been conducted, studies addressing the potential impacts, distribution, spread, biology and ecology of Oriental weatherloach have been conducted in all invaded Australian states and territories with the exception of South Australia and Queensland (see list of Australian studies below). Despite this, large knowledge gaps still exist in regard to the actual impacts of Oriental weatherloach on native fish, habitats and general ecological processes in these areas.

References:

Koster, W. M., T. Raadik, *et al.* (2002). Scoping Study of the Potential Spread and Impact of the Exotic Fish Oriental weatherloach in the Murray-Darling Basin, Australia: A Resource Document. Freshwater Ecology, Arthur Rylah Institute for Environmental Research, 123 Brown St Heidelberg, Victoria, Australia.

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Lintermans, M. (1993). Oriental Weatherloach, *Misgurnus Anguillicaudatus*, In The Cotter River: A New Population In The Canberra Region L. a. P. Department of the Environment. ACT, ACT Parks and Conservation Service.

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Clunie, P., I. Stuart, *et al.* (2002). A Risk Assessment of the Impacts of Pest Species in the Riverine Environment in the Murray-Darling Basin. Department of Natural Resources and Environment, Arthur Rylah Institute,123 Brown Street, Heidelberg, Victoria, Australia: 77-80.

Raadik, T. A. and W. Koster (2004). "Potential spread and impact of a little known alien fish introduced into Australia: the Oriental weatherloach (Misgurnus anguillicaudatus)." New Zealand Journal of Marine and Freshwater Research 38(3): 562.

6 - Where is the organism native?

Oriental weatherloach is endemic to the eastern Indian sub-continent and Asia. They are indigenous to Mongolia, the eastern portion of Russia and Siberia (from Tugur and Amur Rivers, including Sakhalin Island), Japan, North and South Korea, China (including Hainan and Hong Kong), Taiwan, northern Vietnam, north-eastern Burma (Myanmar), Cambodia, India, Thailand and Laos (Rendahl 1922, 1936, 1937, 1943, 1944, Fowler 1934, Chu 1931, Nichols 1943, Orsi 1974, Yen 1978, 1985, Jayaram 1981, Kochetov and Kochetov 1986, cited in Koster *et al.* 2002; Keller and Lake 2007).

7 - What is the current global distribution of the organism (excluding Australia)?

In addition to the species' endemism throughout the eastern Indian sub-continent and Asia, the current reported global distribution of Oriental weatherloach, encompasses the Rhine (Germany) and Tincino (Italy) drainages and also the Aral sea basin (Freyhof and Korte 2005, Razzetti *et al.* 2001, Nico *et al.* 2009, cited in fishbase.org), North America (including Hawaii) (Welcomme 1998, Yamamoto 1992, cited in fishbase.org), Mexico (Contreras and Escalante 1984), Philippines (Juliano *et al.* 1989, cited in fishbase.org), Pacific (Palau Islands)(Bright 1979, Bright and June 1981) the United Kingdom (Lever 1996), Spain (Franch *et al.* 2008), Brazil (Abilhoa *et al.* 2013 cited in Wegener and Suitor 2013) and the Netherlands (van Kessel et al. 2013 cited in Wegener and Suitor 2013).

8 - What is the current distribution of the organism in Australia?

Established reproducing populations of the Oriental weatherloach were first recorded in Morses Creek, a tributary of the Ovens River in northeast Victoria in 1981 (Department of Ichthyology, Victoria 1981, cited in Koster *et al*. 2002). Since that time, the species' distribution has expanded into many parts of New South Wales, Victoria and the Australian Capital Territory (Lintermans 2007). There has been known occurrence of a self-sustaining population in Burpengary Creek north of Brisbane (Queensland), however this population was successfully eradicated (J. Johnson pers. comm.1989, cited in Koster *et al.* 2002). Most recently, the species was found in wetlands and floodplains in the lower River Murray, South Australia, where numerous individuals were captured as a part of non-targeted wetland and floodplain monitoring program from 2011 to 2013 (see Table A1). To date, the southern-most reported sighting in the Lower River Murray was near Blanchetown, i.e. approximately 270 km from the Murray Mouth. It is currently unknown if this incursion into South Australia is self-sustaining. To date, there has been only one unconfirmed report of Oriental weatherloach in Western Australia, and no reported sightings of the species in the Northern

Territory, Tasmania or any of Australia's offshore islands. A more comprehensive overview of the distribution of this species within Australia is given below.

<u>Summary of Oriental weatherloach distribution in Australia- (adapted from Koster *et al.* 2002)</u>*except for South Australia*

***South Australia-** The first report of Oriental weatherloach within the South Australian section of the River Murray occurred during 1987. However, this initial report was unconfirmed and no further reports were recorded until 2011-13 when 46 individuals were captured during non-targeted wetland and floodplain monitoring across the South Australian section of the River Murray (Table A1). It is believed that the individuals captured within South Australia were displaced downstream during the 2010/2011 high flow events that were prevalent in the Murray-Darling Basin. It remains unknown if self-sustaining populations have established and targeted monitoring is required. There have been no records of Oriental weatherloach in any other drainage systems within South Australia.

Victoria- Oriental weatherloach were first recorded in north-east Victoria in 1981. Since then, individuals have been recorded in seven river basins in the Murray-Darling drainage division (Morses Creek, River Murray floodplains, Barmah floodplain, Campaspe River, Broken Creek, a drain near Shepperton, irrigation drain near Cohuna and an irrigation dam near Tyntynder) and five river basins in the South-east Coast drainage divisions (Yarra River, Corhanwarrabul Creek, Dandenong Creek, Skeleton Creek, La Trobe River, Maribyrnong River, Patterson River and an irrigation drain, near Maffra). Numerous established populations have been recorded throughout these areas, and there is a high potential for further expansion.

NSW- Found in seven streams in south-east inland NSW (MDB) (Murrumbidgee River, Queanbeyan River, River Murray, Tuppal Creek, Wakool River, Edwards River and Peak River) and the Hawkesbury and Snowy River Systems in coastal NSW (Wingecarribee River, Lake Eucumbene tributary, Wollondilly River, Coxs River, Lake Burragorang and an unnamed creek in the Royal National Park). The species is established in the eastern and southern regions of NSW and it is anticipated that further rapid expansion will occur.

ACT- Found in four river systems in the Murrumbidgee River Basin (Lake Burley Griffin, Ginninderra Creek, Tuggeranong Creek, Cotter River, Paddys River and the Molonglo River). Well established populations and widespread, with a high potential for more rapid expansion.

Queensland- Recorded on three occasions near Brisbane (Kedron Brook, Burpengary Creek and Logan River). However the Burpengary Creek population has been successfully eradicated and the others are not believed to be established.

Western Australia- A single unconfirmed report of Oriental weatherloach from Buchmore *et al.* 1990, however no other information is given about the incident, therefore the species is presumed absent.

Tasmania- No records of Oriental weatherloach being collected from the wild.

N.T- No records of wild catches, however, several specimens have been confiscated from the aquarium trade by NT Fisheries.

9 - Is the organism known to be invasive anywhere in the world?
Yes

See Q7 above (current global distribution). Australia is also included in this list of countries where Oriental weatherloach are considered an invasive species.

<u>Stage 1 - Organism Information and Screening Section B - Organism Screening</u>

10 - Have you been asked to carry out a screening assessment?
<u>Yes</u>

11 - Does the organism have intrinsic attributes that indicate that it could be invasive?
<u>Yes</u>

This species has successfully established populations in over 80 per cent of countries in which it has been introduced (Lever 1996, Arthington *et al.* 1999, Koster *et al*. 2002). Oriental weatherloach prefer still and/or slow flowing freshwater systems that are characterised by muddy or sandy substrates in which they can burrow and therefore possibly escape predation (Clunie *et al.* 2002). They can also survive in modified and/or degraded habitats and are semi tolerant to pesticide contamination (Lintermans *et al.* 1990b, Burchmore *et al.* 1990, cited in Clunie *et al.* 2002). They are eurythermal, thriving in a wide range of water temperatures from 2 - 42°C (Lintermans and Burchmore 1996, Koster *et al*. 2002) and can survive in moderate salinities (Koster *et al*. 2002). They can respire and survive temporarily out of water where they burrow into the sediments and aestivate (Clunie *et al.* 2002). The species can also respond to reduced oxygen availability by gulping air and passing it through a highly vascularised hind gut, thus being able to survive in severely degraded/de-oxygenated water bodies (Allen 1984, Lintermans and Burchmore 1996). Despite a scarcity of information on the dietary niche of this species, anecdotal observations indicated that they consume a diverse array of small benthic-dwelling aquatic organisms including worms, small crustaceans, insects and insect larvae (Yamamoto and Tagawa 2000). Oriental weatherloach display an opportunistic live history strategy (after Winemiller and Rose 1992). They are capable of rapid population expansion, reach sexual maturity at 100 mm (total length) or two years of age (Kochetov and Kochetov 1986), and are able to spawn up to 150 000 eggs per year. These eggs are released in batches (up to 8 000 eggs per batch) throughout each reproductive season which generally occurs over a prolonged period during the warmer months of each year (Kimura and Koya 2011). The eggs are adhesive and once released, attach to aquatic vegetation or muddy substrates (Allen 1984, Lintermans and Burchmore 1996). The species meets two of the three factors proposed by Arthington *et al.* (1999) for a successful invader, *i*) previous successful invasions, and *ii*) large and abundant populations, however, knowledge gaps still exists in regards to the third factor of specific habitat matching to areas at risk (e.g. Murray-Darling Basin) (Clunie *et al.* 2002).

12 - Is the organism present in the Risk Assessment Area in containment from which it is likely to escape?
<u>Yes</u>

Oriental weatherloach are present within the risk assessment area (i.e. the River Murray, South Australia), with unconfirmed reports occurring from as far back as 1987 and with the first confirmed report by Lara Suitor (DEWNR) in 2011. To date, 46 individuals have been captured from at least 18 locations throughout the risk assessment area between 2011 and 2013 (Table A1). Unfortunately, due to the scale of the risk assessment area and its connection to area's upstream where populations have been established for over a decade, it is highly likely that containment to certain areas of the risk assessment area will not be possible. It is also possible that Oriental weatherloach will spread to other South Australian river catchments through vectors which include illegal use as live bait by anglers and transportation within flood control and irrigation systems (Clunie *et al.* 2002).

Table A1. Dates, sites, abundance and the relative sampling agencies involved in the collection of Oriental weatherloach in South Australia from 1987-present.

Date	Site	Species	No. of Fish	Sampling Agency
1987	Lower River Murray	Mis ang	1	Lloyd & Walker pers.comms. 2002
Feb-11	Katarapko Floodplain	Mis ang	5	Wegener & Suitor 2013
Feb-11	Chowilla Floodplain (Werta wert)	Mis ang	3	Wegener & Suitor 2013
Mar-11	Chowilla Floodplain (Werta wert)	Mis ang	4	Wegener & Suitor 2013
Mar-11	Chowilla Floodplain (Lake Littra)	Mis ang	1	SARDI
Mar-11	Chowilla Floodplain (Lake Limbra)	Mis ang	9	SARDI
Mar-11	Chowilla Floodplain (Werta wert)	Mis ang	4	SARDI
Mar-11	Kingston on the Murray (wetland)	Mis ang	1	Wegener & Suitor 2013
Mar-11	Waikerie (Hart & Ramco lagoon)	Mis ang	3	Wegener & Suitor 2013
Apr-11	Katarapko (Piggy Creek Wetaland)	Mis ang	1	SARDI
Apr-11	Katarapko (Ngak Indau Floodrunner)	Mis ang	1	SARDI
Aug-11	Cobdogla	Mis ang	1	PIRSA Biosecurity (via Fishwatch)
Sep-11	Yatco (wetland)	Mis ang	1	SARDI & DEWNR
Dec-11	Katarapko Island Horshoes (wetland)	Mis ang	1	Wegener & Suitor 2013
Mar-12	Riverland Ramsar (wetland)	Mis ang	5	Wegener & Suitor 2013
Oct-12	Noonawirra (wetland)	Mis ang	1	Wegener & Suitor 2013
Dec-12	Martin’s Bend (wetland)	Mis ang	1	SARDI
Jan -13	Overland Corner (wetland)	Mis ang	1	SARDI
Apr-13	Nelwood (wetland)	Mis ang	1	SARDI
Apr-13	Portee (wetland complex)	Mis ang	1	SARDI
Total			**46**	

13 - Are there conditions present in the Risk Assessment Area that would enable the organism to survive and reproduce? Comment on any special conditions required by the species?
Yes

Oriental weatherloach can survive and reproduce in a wide variety of habitats and environmental conditions. They can endure water temperatures ranging from 2-42°C in both still and slow flowing waters with muddy or sandy substrates (Clunie *et al.* 2002; Koster *et al*. 2002), both with and without abundant vegetation (Logan *et al.* 1996), as well as hot springs in which temperatures may constantly exceed 38°C (Lintermans and Burchmore 1996). This tolerance to a broad range of temperatures and degraded (oxygen-depleted) habitats (Lintermans *et al.* 1990) enables the species to adapt and establish in most habitats found in the River Murray, especially weir pools and off-channel habitats such as wetlands and floodplains. Moreover, the species' ability to consume a diverse array of benthic-dwelling aquatic organisms including worms, small crustaceans, insects and insect larvae (Yamamoto and Tagawa 2000) suggests that the species' distribution would not be limited to specific areas or habitat types.

Within Australia, Oriental weatherloach have been recorded in rivers, creeks, anabranches, ephemeral billabongs, wetlands (flow-through and terminal), depressions, rice paddy fields, impoundments and irrigation and concrete flood control channels (Allen 1984, Lintermans *et al.* 1990b, Swales 1992, Raadik, T. unpublished data, MacQueen 1995, Tudehope 2001, cited in Koster *et al.* 2002). In the ACT, Oriental weatherloach have been recorded over a range of different substrates (fine silt and mud, coarse sands, cobble and sand mix and even protruding bedrock overlaid with boulders and small pockets of silt) (Lintermans *et al.* 1990b, Koster *et al.* 2002).

In terms of their reproduction strategy, Oriental weatherloach need to lay their eggs on aquatic vegetation (Kochetov and Kochetov 1986) preferably in shallow water (Okada 1960, cited in Koster *et al.* 2002) or on mud substrate between plant roots (Allen 1984, cited in Koster *et al.* 2002); all of which are habitat types prevalent in the River Murray. Kubota and Matsui (1955c) observed that larval hatching occurred between 12°C to 31°C, with 25°C being the optimal temperature for growth and survival. Such temperatures are very similar to those occurring in the lower River Murray in South Australia (Avg. summer temp-24.4°C, Avg. winter temp-12.3°C) (e-nrims.dwlbc.sa.gov.au).

14 - Does the global distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment Area or sufficiently similar for the organism to survive and thrive?
Yes

The ecoclimate of the South Australian risk assessment area is similar to regions where the species has been introduced and successfully established populations, including North America, Mexico, Germany, Italy, Pacific Island and the U.K as well as other areas of the Australia (Victoria, NSW and the ACT) (www.fishbase.org, Koster *et al.* 2002). This is further supported by climate matching that occurred as part of the OFMIG risk assessment conducted by BRS which also indicated that the climate of the risk assessment area is suitable for the species (Beyer and Fredberg 2010). As such, the ecoclimate of the risk assessment will not inhibit the survival or establishment of the Oriental weatherloach.

15 - Has the organism established viable (reproducing) populations anywhere outside of its native range?
Yes

This species has established populations in over 80 per cent of countries in which it has been introduced (Lever 1996, Arthington *et al.* 1999, Koster *et al.* 2002), including 2 states and 1 territory in Australia (NSW, Victoria and the ACT). See Q.7 and Q.8 of this risk assessment for further detail.

16 - Can the organism spread rapidly by natural means or by human assistance?
Yes

There are numerous natural and human vectors which have assisted the rapid spread of Oriental weatherloach both in Australia and internationally. These include (Koster *et al.* 2002);

- Aquarium trade
- Water Diversion
- River regulation
- Use as live bait
- Natural Dispersion
- Fish Stocking
- Aquaculture
- Mosquito control

Aquarium trade- Dumping or accidental release of fish from the aquarium trade is suggested to be one of the key vectors for the establishment of wild populations within Australia (Koster *et al.* 2002). Indeed, Lintermans *et al.* (1990b) suggests that populations of Oriental weatherloach found in the ACT are likely a result of the deliberate release of unwanted fish from the aquarium trade. Allen (1984) reports that the presence of the species within the Ovens River in Victoria may be due to flooding of ornamental ponds close to the river that were initially stocked with Oriental weatherloach. Although importation of the species into Australia has been banned since 1986, there are anecdotal reports that Oriental weatherloach are still being sold through the aquarium trade and new infestations of the species within residential creeks continue to be reported (e.g. Maribyrnong River, Melbourne) (Koster *et al.* 2002).

Water Diversion- Logan *et al.* (1996) suggests that dispersal of the species through flood control and irrigation systems is likely to be an influencing factor within Australia and refers to several reports of this dispersal mechanism in three states of North America (California, Idaho and Oregon). Indeed, there have been numerous reports by rice farmers in Victoria and NSW of the presence of Oriental weatherloach within their irrigation drains and channels (Koster *et al.* 2002). Rice paddys, a habitat commonly used by the species in its natural range, are prevalent throughout these areas (Saitoh *et al.* 1988, Katano *et al.* 1998, Lane and Fuijioka 1998, cited in Koster *et al.* 2002).

River Regulation- The role of river regulation in the dispersal of Oriental weatherloach is still largely unknown (Koster *et al.* 2002). However, altering key hydrological processes such as flow regimes, which commonly occurs in the lower River Murray, is likely to benefit the species by creating slow flowing areas which are preferred by the Oriental weatherloach (Clunie *et al.* 2002). Further, in periods of drought, the South Australian section of the River Murray is commonly reduced to a series of large weir pools (Cheshire and Ye 2008), which may also assist the establishment of the species in the risk assessment area. The managed inundation of wetlands and floodplains will also increase the availability of the preferred habitat for the species, i.e. shallow muddy or sandy habitats with submerged and fringing vegetation (Logan *et al.* 1996, Clunie *et al.* 2002).

Use as Live Bait- Oriental weatherloach is ideal live bait as it is hardy, easily transported and quite active on the hook (Koster *et al.* 2002). They have been used as live bait in countries including Japan (Suzuki 1983) and the US (St. Amant and Hoover 1969) for many years and there is evidence to suggest that this practice also occurs in Australia. Lintermans (1993) concluded that it is likely that populations in the Cotter River and Lake Eucumbene (ACT, NSW) may have established as a result of fishing practises using Oriental weatherloach as live bait (i.e. escapee’s or dumped as left over bait).

Natural Dispersal- Oriental weatherloach are capable of natural dispersal throughout river systems (Lintermans 1993), although little is known regarding the species movement patterns in Australia. Lintermans *et al.* (1990b) reported observations of the species moving overland (due to their ability to aestivate and air breathe), which suggests that weirs and dams may not present a barrier to their dispersal. Koster *et al*. (2002) suggests that downstream dispersal following high flows is a key mechanism for the species' spread. Given the magnitude of the high flows throughout the Murray-Darling system in 2010/11, and the presence of upstream populations of Oriental weatherloach, this mechanism represents the most likely explanation for the South Australian incursion.

Fish Stocking- Fish stocking programs may be contaminated with Oriental weatherloach but this mechanism is considered highly unlikely in Australia. However, it may represent a future vector of accidental spread (Koster *et al.* 2002).

Aquaculture Trade- Although commercially caught and cultured for aquaculture purposes overseas (i.e. Japan, Korea and the Phillipines as a food source, Phillipines and Mexico as an aquaculture pond cleaner fish), it is not utilised here in Australia for aquacultural purposes (Koster *et al.* 2002).

Mosquito Control- It has been considered overseas, but has not been deliberately introduced into areas of Australia for this purpose (Koster *et al.* 2002).

17 - Could the organism as such, or acting as a vector, cause economic, environmental or social harm in South Australia?
Yes

The environmental effects and impacts of Oriental weatherloach are not well known and there is limited information regarding the potential economic and social impacts (Bright and June 1981, Maciolek 1984, Welcomme 1984, Contreras and Escalante 1984, Courtenay *et al.* 1987, Koster *et al.* 2002). Keller and Lake (2007) conducted a series of mesocosm experiments to determine the density dependant impacts of Oriental weatherloach on macroinvertebrate numbers/biomass and water quality (control=0, 1 fish, 3 fish). The authors reported that the higher density Oriental weatherloach experiments caused significant reductions in macroinvertebrate abundance and biomass as well as elevated ammonia, nitrate/nitrie (NOx) and turbidity levels. However, the authors also stated that because of issues involved in scaling up mesocosm experiments, they were unable to conclusively determine if Oriental weatherloach would have a large scale impact in the natural environment. Although no intensive *in-situ* research has been conducted to specifically investigate the potential impacts; Maciolek (1984) reports that the species has had an intermediate stream impact in Hawaii and suggests that this is a result of habitat preference, food habits and abundance. Within Australia, Lintermans *et al*. (1990b) proposes that the environmental impacts caused by Oriental weatherloach may include the following;

- Competition for spawning sites with native fish
- Disturbance or predation of both fish and frog eggs
- Competition for food and shelter, and
- Alteration of habitat

Determining the economic, environmental and social harm of Oriental weatherloach represents a significant knowledge gap that requires further research.

Stage 2 - Detailed assessment Section A – Entry

1.01 - How many active/future pathways are relevant to the potential entry of this organism?
Few
Confidence: high

The main pathway for the current incursion and for future entry of Oriental weatherloach into the South Australian risk assessment area is considered to be natural dispersal i.e. established populations found in the upper Murray-Darling Basin will either be displaced downstream during high flow events or actively engage in downstream migrations to colonise suitable habitat (Koster *et al.* 2002). Other less likely pathways may include dumping of unwanted fish through the aquarium trade (although importation of the species was banned in 1986), river regulation (human induced flow events such environmental flows) and the use of Oriental weatherloach as live bait by recreational anglers.

1.02 - List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.

- Natural Dispersal
- Aquarium Trade
- River Regulation
- Use as bait by Recreational Anglers

1.02b - Select a pathway to assess.

Natural dispersal

Pathway 1: **Natural Dispersal**

1.03 - Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?
Accidental
Confidence: high

Oriental weatherloach were first imported into Australia for the aquarium trade, however this was banned in 1986 (Koster *et al.* 2002). It is thought that this pathway is the original source of introduction into Australian waterways due to the dumping of unwanted fish into nearby creeks and rivers (Allen 1984, Lintermans 1990b). However, in regards to the South Australian River Murray incursion, the pathway of entry is most likely through natural dispersion of individuals by downstream migration (Koster *et al.* 2002) or displacement from upstream populations during high flow events.

1.04 - How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?
Moderately likely
Confidence: medium

There is a moderate likelihood that large numbers of Oriental weatherloach could move into the South Australian section of the River Murray over the course of one year through two possible mechanisms of natural dispersion, 1) active downstream migration (Koster *et al.* 2002) and, 2) passive migration or entrainment in high flow. Given that the first recorded captures of Oriental weatherloach in SA were immediately following high flow events (2010/2011) (Figure A1), entrainment of upstream "seed" stocks during similar events is thought to be the most likely pathway for Oriental weatherloach to enter South Australia. Established populations of Oriental weatherloach were recorded ≈300 km upstream of the South Australian border at Swan Hill (Victoria) during 2003 (MDFRC unpublished data in Wegener and Suitor, 2013). However, the extent of this "seed" stock and the rates of downstream dispersal have increased since 2003, with documented reports of Oriental weatherloach being caught between Robinvale (VIC) and Lock 7 (SA,VIC and NSW Border) in 2009-2011 (MDFRC unpublished data in Wegener and Suitor 2013). Given the recent SA incursion it is reasonable to assume that Oriental weatherloach are now dispersed throughout the entire Victoria section of the River Murray and, as a result, the relative contribution from this upstream "seed" stock through active and passive migration is likely to increase. While little is known of the migratory behaviour of Oriental weatherloach, it is believed that dispersal tends to be in a downstream direction (Koster *et al.* 2002).

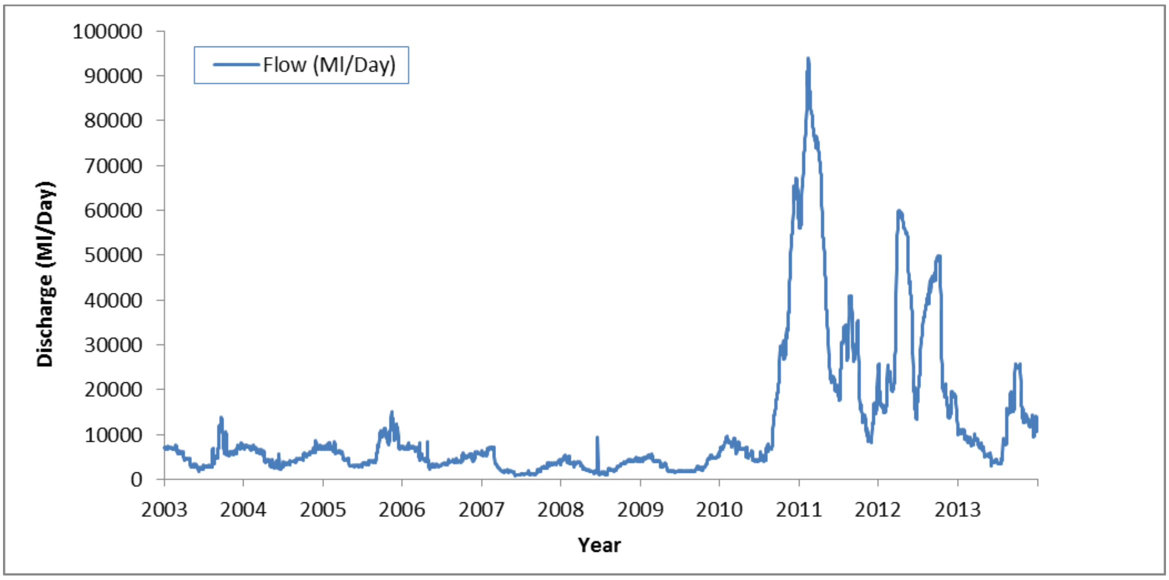

Figure A1. Flow into South Australia from 2003-2013.

1.05 - How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?
Unlikely
Confidence: high

Considerable off-channel and within-channel monitoring is conducted regularly by multiple agencies along the lower River Murray, South Australia. While these monitoring programs do not specifically target Oriental weatherloach, the species was first recorded as part of this monitoring in February 2011 and has been recorded regularly since that time between the SA border and Lock 1 (Blanchetown) (see Table A1). Thus, even though the monitoring was not Oriental weatherloach specific it did detect the species quite quickly. Notwithstanding, given that little is known regarding the rates of the dispersal and the full extent of the incursion throughout SA, targeted monitoring is warranted and needed.

1.06 - How likely is the organism to survive during passage along the pathway?
Very Likely
Confidence: high

The presence of Oriental weatherloach as far down as the South Australia township of Blanchetown (≈270 km from Victorian/NSW border) indicates that the species is highly likely to survive passage along this pathway. This is further supported by the fact that Oriental weatherloach is a robust species that is tolerant to a wide range of environmental conditions (See 11 & 13 in Stage 1 - Organism Information and Screening Section B - Organism Screening). In addition, floodplains, wetlands, weir pools and anabranches, e.g. the preferred habitats of Oriental weatherloach (Koster *et al.* 2002), are prevalent throughout the South Australia section of the River (Cheshire and Ye 2008) which is likely to enhance key processes of the species' life cycle such as reproduction, recruitment and feeding.

1.07 - How likely is the organism to arrive during the months of the year appropriate for establishment?
Likely
Confidence: high

Oriental weatherloach are most likely to enter the risk assessment area by natural dispersion processes during periods of elevated flows to South Australia. Since 2010 there have been a number of high unregulated flow events in the South Australian section of the River Murray (Figure A1). Spawning for Oriental weatherloach in Australia occurs during summer (Lintermans 2007) and in their natural range between spring and summer (Chen and Su 1980). They are multiple spawners, capable of laying up to 8,000 eggs each spawning event (Lintermans 2007) with larval hatching occurring between 12°C to 31°C, with 25°C being the most optimal temperature for survival (Kubota and Matsui 1955c, cited in Koster *et al.* 2002). The period during which natural dispersion is most likely to occur in the River Murray in South Australia is during the summer months of each year (avg. water temperature of 24.4°C. (www.e-nrims.dwlbc.sa.gov.au)), coinciding with the time when temperatures are most suitable for the hatching and survival of eggs and subsequently the establishment of populations. Despite the scarcity of information on the movement patterns of Oriental weatherloach into the risk assessment area, it seems likely that the species arrived at a time that is appropriate for establishment. Provided summer and spring flows continue and water temperatures remain at the summer average, further entrained Oriental weatherloach may enter South Australia during periods which are appropriate for establishment.

1.08 - How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?
Likely
Confidence: high

Oriental weatherloach prefer habitats associated with slow-flowing or still waters with a sand, mud or detritus substrates (Lintermans 2007). As the South Australian section of the River Murray is characterised by these habitats (i.e. floodplains, wetlands, weir pools and anabranches) (Cheshire and Ye 2008), it is likely that transfer from natural dispersal pathways (i.e. main river channel) into these habitats will be common.

1.09 - Estimate the overall likelihood of entry into South Australia based on this pathway?
Very likely
Confidence: high

Recent sampling confirms that the Oriental weatherloach is present in the River Murray, South Australia. However, it is yet to be confirmed if the species has established a self-sustaining population. Lintermans (2007) states that "it is only a matter of time" before populations are established in SA.

1.10 - Do other pathways need to be considered?
Yes

Pathway 2: **Water Regulation**

1.03 - Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?
Accidental
Confidence: medium

River regulation alters natural flow regimes and is quite prevalent in the South Australian section of the River Murray with the presence of 6 locks/weirs from the Victorian border (Lock 6) to Blanchetown (Lock 1) (Cheshire and Ye 2008). Little is known about the role of river regulation in facilitating the incursion, establishment and spread of Oriental weatherloach. However, if areas of slow flowing water are created through regulation it may assist the entry of this species by providing suitable habitat (Koster *et al*. 2002). In addition, the provision of environmental flows may assist the dispersal of Oriental weatherloach in a manner similar to natural high flow conditions.

1.04 - How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?
Unlikely
Confidence: medium

Little is known regarding the role of river regulation on the dispersal rates of Oriental weatherloach. While river regulation may not be directly responsible for the dispersal of large numbers of Oriental weatherloach over the course of a year, it may aid existing populations (established or not) by creating suitable habitat due to reduced flow rates, and by maintaining the inundation of, and subsequent access to, suitable wetland habitats (slow flow areas) (Cheshire and Ye 2008). However, the provision of environmental flows (or piggyback flows) may assist the dispersal of Oriental weatherloach in a manner similar to natural high flow conditions. (Refer to Natural Dispersion above).

1.05 - How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?

Unlikely
Confidence: high

(Refer to Natural Dispersion 1.05 above).

1.06 - How likely is the organism to survive during passage along the pathway?
Likely
Confidence: high

As water regulation creates slow flowing areas or weir pools (Cheshire and Ye 2008), which are optimal habitat for Oriental weatherloach, survival of the species will be likely along this pathway. Koster *et al.* (2002) also suggests that if high flows are delivered as part of River regulation management process, Oriental weatherloach could persist in colonised areas by burying themselves in the substrate to avoid being entrained. In addition, high flows could disperse Oriental weatherloach downstream as seen in the recent high flow events of 2010/2011. Since Oriental weatherloach are not diadromous or potamodromous i.e. undertaking large migrations to complete their life-cycle requirements, water regulators such as weirs, locks and barrages will not impede reproduction.

1.07 - How likely is the organism to arrive during the months of the year appropriate for establishment?
Likely
Confidence: medium

Water regulation will likely assist the establishment of Oriental weatherloach that are already present in the risk assessment area, more so than aiding the spread of the species outside this range due to the creation of suitable habitat. This would be particularly pronounced in periods of drought or low flows i.e. summer months, whereby weir pools formed by water regulators are more likely to occur (Cheshire and Ye 2008).

1.08 - How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?
Moderately likely
Confidence: medium

Water regulation may benefit Oriental weatherloach by creating suitable habitat via reduced flows and the creation of weirpools. However, the role of water regulation in facilitating the presence, dispersal and establishment of the species remains unknown.

1.09 - Estimate the overall likelihood of entry into South Australia based on this pathway?
Moderately likely
Confidence: Low

Overall, the likelihood of Oriental weatherloach entering the River Murray, South Australia through water regulation remains unknown.

Pathway 3: **Use as bait by Recreational Anglers**

1.03 - Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?
Intentional
Confidence: high

It is thought that a significant factor contributing to the spread of Oriental weatherloach between drainage systems in south-eastern Australia is through recreational anglers illegally using the species as live bait (Lintermans 2007). Indeed, established self-sustaining populations within the Cotter River and Lake Eucumbene (ACT, NSW), have been attributed to live bait escapees or dumped excess live bait (Lintermans 1993). However, there is no evidence to date to suggest that this pathway contributed to the entry of the species into the risk assessment area.

1.04 - How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?
Unlikely
Confidence: high

It is unlikely that large numbers of Oriental weatherloach will enter the risk assessment area via this pathway over the course of a year. Notwithstanding, if populations continue to establish in Victoria and South Australia, the use of the species as live bait may increase and this may assist in their broader dispersal both within and among catchments. Live baiting with Oriental weatherloach is popular in countries including Japan and the USA, as the species is hardy, easily transportable and remains active on the hook (St Amant and Hoover 1969, Suzuki 1983, cited in Koster *et al.* 2002) and there is evidence to suggest that this practice may be occurring in Australia (Lintermans 1993).

1.05 - How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?
Likely
Confidence: high

If Oriental weatherloach are brought into the risk assessment area for live bait, it is likely they would enter undetected as there is no specific task force designed to monitor or regulate this pathway. Notwithstanding, PIRSA Fisheries do monitor catches obtained by recreational anglers (species, bag limits, legal lengths, gear types) within the upper reaches of the risk assessment area (Blanchetown to Victorian border). Monitoring is conducted monthly to bi-monthly during the winter months and more intensely during summer. To date, no reports of live baiting with Oriental weatherloach have been recorded (David Grant, PIRSA Fisheries Compliance Officer, pers. comm.). However, the risk of species entering undetected downstream of Blanchetown to the Lower Lakes is greater as this reach is relatively unregulated. Also, the vast expanse of the risk assessment area further decreases the probability of detection by the relevant authorities.

1.08 - How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?
Moderately likely
Confidence: medium

The risk assessment area is characterised by habitat that is suitable for the survival and establishment of Oriental weatherloach (Cheshire and Ye 2008). While live bait escapees may have a limited chance of survival due to injuries and infections associated with hooking wounds, anglers may release excess or unwanted bait and this could pose more of a threat due to increased survival rates of uninjured fish.

1.09 - Estimate the overall likelihood of entry into South Australia based on this pathway?
Moderately likely
Confidence: medium

It is moderately likely that Oriental weatherloach will enter the River Murray in South Australia through recreational anglers using the species as live bait. As the species becomes more available and the popularity of this illegal fishing method increases, as in Japan and the USA, then the likelihood of entry via this means will increase. Indeed, evidence suggests live baiting using Oriental weatherloach has occurred in the ACT and NSW (Lintermans 1993).

Pathway 4: **Aquarium Trade**

1.03 - Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?
Intentional
Confidence: medium

The importation of Oriental weatherloach into Australia for the aquarium trade has been banned since 1986 (Burchmore *et al.* 1990). Further, Oriental weatherloach were declared noxious in all Australian jurisdictions as a part of the 2006 "Strategic Approach to the Management of Ornamental Fish in Australia", a report to the Natural Resource Management Ministerial Council (DAFF 2006). Notwithstanding, little is known of the current extent of the residual and illegal aquarium trade of Oriental weatherloach within Australia and the intentional, illegal dumping of unwanted fish throughout SA may still occur.

1.04 - How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?
Unlikely
Confidence: high

1.05 - How likely is the organism to enter South Australia undetected or without the knowledge of relevant competent authorities?
Likely
Confidence: high

Due to importation bans and the noxious species listing, dumping of unwanted Oriental weatherloach from the aquarium trade is unlikely to occur in the risk assessment area (see Q. 1.03). However, if dumping does occur, there is a high probability that the species will enter undetected due to the vast expanse of the risk assessment area and challenges associated with effectively monitoring this area.

1.08 - How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?
Likely
Confidence: medium

(Refer to Pathway 1-3: Natural Dispersal 1.08, Water Regulation 1.08, Use by Recreational Anglers 1.08).

1.09 - Estimate the overall likelihood of entry into South Australia based on this pathway?
Unlikely
Confidence: medium

1.11 - Estimate the overall likelihood of entry into South Australia based on all pathways (comment on the key issues that lead to this conclusion).
Very likely
Confidence: high

As the species is already present within South Australia, the overall likelihood of Oriental weatherloach entering the risk assessment area must be considered very high. Natural dispersal and water regulation are considered to be the most likely causes of current and future incursions of the species, however other potential pathways (i.e. aquarium trade, live baiting, etc.) should not be discredited.

Although it is currently unknown if the species has established a self-sustaining population, other researchers have suggested that "it is only a matter of time before Oriental weatherloach become established in SA" (see Lintermans, 2007). Supporting this is the rate of spread and establishment of the species in other states such as Victoria, NSW and the ACT. Between 1980 and 2003, the species colonised 12 river basins in Victoria, nine streams in NSW and four river systems in the ACT (Figure A2) (Raadik, 2003). Further spread has also recently been documented (2009-2013) in the River Murray, Victoria at the township of Robinvale and upstream of Lock 7 (SA/VIC/NSW border) (Figure A2) (MDFRC unpublished data in Wegener and Suitor, 2013).

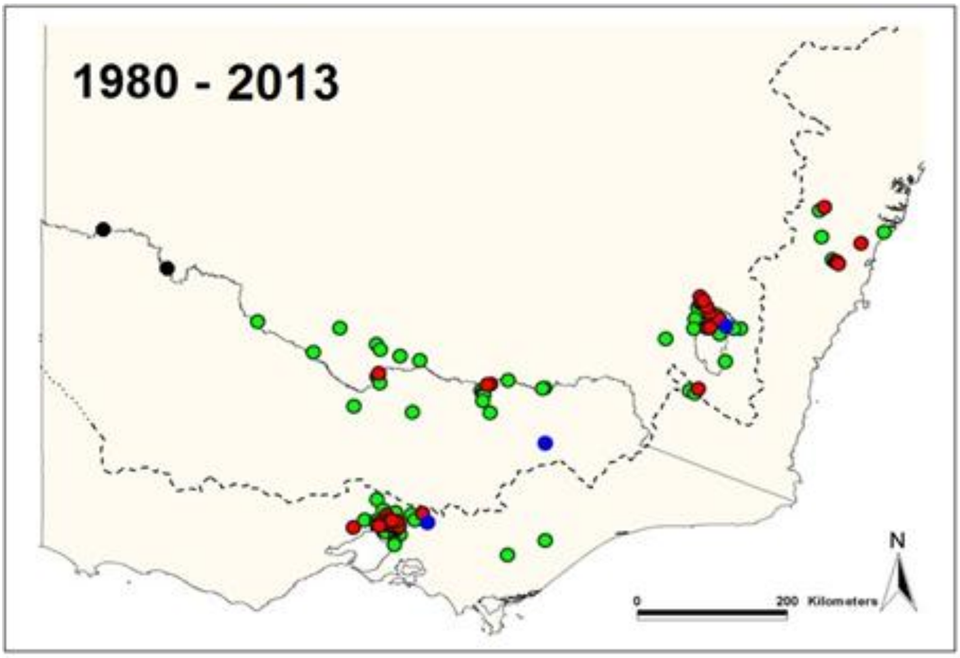

Figure A2. Spread of Oriental weatherloach in Victoria, NSW and the ACT from 1980-2013. (● = Spread from 1980-1983, ● = Spread from 1983-1993, ● = Spread from 1993-2003 and ● = 2009-2013 (adapted from Raadik, 2003 and MDFRC unpublished data in Wegener and Suitor, 2013).

<u>Stage 2 - Detailed assessment Section B - Establishment</u>

Important instructions:

For organisms which are already well established in South Australia there is no need to complete this section - move straight to the Spread section. If it is unclear whether the organism should be considered 'well established' contact the Non-native Species Secretariat.

Notes:

- **Establishment is defined as the perpetuation, for the foreseeable future, of an organism within an area after entry.**

2.01 -

Is the organism well established in South Australia (if there is any uncertainty answer 'unsure')?

<u>Unsure</u>

It is currently unknown if Oriental weatherloach have established in the lower River Murray in South Australia. While a total of approximately 46 individuals have been recorded in 18 different sites within the upper reaches since 1987 (see Table A1 and Figure A3), abundances at each site have been low and no young of year have been captured. Thus, there is insufficient data to confidently determine if the species is established in South Australia and this represents a significant knowledge gap.

2.02 -

How likely is it that the organism will be able to establish in South Australia based on the similarity between <u>climatic conditions</u> **in South Australia and the organism's current global distribution?**

<u>Very likely</u>

<u>Confidence: high</u>

Given that Oriental weatherloach have established in 2 states and 1 territory of Australia (Victoria, NSW and the ACT) (Koster *et al.* 2002), including sections of the Murray-Darling Basin, as well as in countries such as North America, Mexico and the United Kingdom (www.fishbase.org) (all of which have similarities in climatic conditions to South Australia), it is very likely that the species will establish in South Australia. (See Stage 1; Section A; Questions 7 & 8 for more details)

2.03 -

How likely is it that the organism will be able to establish in South Australia based on the similarity between other <u>abiotic conditions</u> **in South Australia and the organism's current global distribution?**

<u>Very likely</u>

<u>Confidence: high</u>

Oriental weatherloach are a hardy species and are able to tolerate a wide range of abiotic conditions. Throughout their global distribution, the species can thrive in water temperatures ranging from 2-42°C. It can be found in stagnant (oxygen-depleted), moderately saline, detritus-filled waters with muddy substrates (Koba 1942, Lintermans *et al.* 1990b, Lintermans and Burchmore, 1996, Logan *et al.* 1996, Clunie *et al.* 2002, Koster *et al.* 2002). The species' broad tolerance levels may enable it to establish in most habitats found in the River Murray, especially weir pools and off-channel habitats such as wetlands and floodplains.

2.04 -
How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in South Australia?
Likely
Confidence: high

The risk assessment area in South Australia is characterised by habitats suitable for the survival and establishment of Oriental weatherloach (Cheshire and Ye 2008). The species is most suited to muddy or sandy substrates in which they can burrow and avoid predation (Clunie *et al.* 2002). They also utilise modified and/or degraded habitats and are semi tolerant to pesticide contamination often occurring in rice paddy fields and irrigation channels (Lintermans *et al.* 1990b, Burchmore *et al.* 1990, Clunie *et al.* 2002). Despite a lack of information on the diet of this species, anecdotal observations indicate an opportunistic feeding mode and a diet comprised of small benthic-dwelling aquatic organisms including worms, small crustaceans, insects and insect larvae (Yamamoto and Tagawa 2000). This non-specialised dietary niche suggests that the species is likely capable of adapting its diet to exploit the trophic resources within South Australia.

In other regions of Australia, Oriental weatherloach have been recorded in rivers, creeks, anabranches, ephemeral billabongs, wetlands (flow-through and terminal), depressions, rice paddy fields, impoundments and irrigation and concrete flood control channels (Allen 1984, Swales 1992, Raadik, T. unpublished data, MacQueen 1995, Tudehope 2001, Lintermans *et al.* 1990b, cited in Koster *et al.* 2002). In the ACT, the species has been recorded over a range of different substrates including fine silt and mud, coarse sands, cobble and sand mix and even protruding bedrock overlaid with boulders and small pockets of silt (Lintermans *et al.* 1990b, Koster *et al.* 2002).

In addition, Oriental weatherloach are capable of rapid population expansion. They reach sexual maturity at 100 mm (total length) or two years of age (Kochetov and Kochetov 1986), and are able to spawn up to 150 000 eggs per year. These eggs are released in batches (up to 8 000 eggs per batch) throughout each reproductive season that generally occurs during the warmer months of each year (Kimura and Koya 2011). The eggs are adhesive and once released, attach to aquatic vegetation or muddy substrates (Allen 1984, Lintermans and

Burchmore 1996). Kubota and Matsui (1955c) indicated that the optimal temperature for larval hatching was 25°C, , which correlates with water temperatures found in the River Murray in South Australia (Avg. summer temp-24.4°C, Avg. winter temp-12.3°C)(e-nrims.dwlbc.sa.gov.au).

The South Australia section of the River Murray is characterised by floodplains, wetlands, weir pools and anabranches that provide ideal habitat for the Oriental weatherloach (Cheshire and Ye 2008). This coupled with the species high fecundity and tolerance to broad range environmental conditions suggests that it is highly likely that the species will encounter habitats necessary for the survival, development and recruitment within South Australia. (See Stage 1; Section B; Question 11 & 13 for more information)

2.05 -
How likely iit that establishment will occur despite competition from existing species in South Australia?
Likely
Confidence: medium

Very little is known regarding the interactions between Oriental weatherloach and native and non-native fish species in the Murray-Darling Basin or other catchments within Australia. Notwithstanding, as Oriental weatherloach are a benthic species there is potential for competition with both native and non-native species with similar ecological traits. These include flatheaded/dwarf flatheaded gudgeons (*Philypnodon grandiceps, Philypnodon macrostomus*) and congolli (*Pseudaphritis urvillii*) all of which are benthic species (Lintermans 2007) that consume similar food resources; carp gudgeons (*Hpseleotris spp.*) which also consume similar food items (Lintermans 2007); and possibly common carp (*Cyprinus carpio*) due to similarities in their benthic foraging behaviour (Lintermans 2007). However, as Oriental weatherloach have established populations upstream of the risk assessment area, where the majority of these species exist, it is likely that the potential for competitive exclusion is limited and establishment will likely occur.

2.06 -
How likely is it that establishment will occur despite predators, parasites or pathogens already present in South Australia?
Likely
Confidence: high

Little is known regarding native fish predation on Oriental weatherloach in Australia. However, as part of their primarily benthic existence, Oriental weatherloach have the ability to bury and/or burrow into mud or fine sediment to avoid predation (Clunie *et al.* 2002). Furthermore, with the exception of common carp, benthic predators within the Murray-

Darling Basin are rare and given Oriental weatherloach populations have established further upstream among existing fish assemblages which are similar to those in South Australia, fish predation is considered unlikely to inhibit establishment. Notwithstanding, predation from piscivorous birds such as the white-faced heron (*Egretta novaehollandiae*) and cormorants (*Phalacrocorax spp.*) may occur within the risk assessment area, as this behavior has been observed by the Japanese crested ibis (*Nipponia Nippon*), which exclusively feeds on Oriental weatherloach, in its natural range (Kano *et al.* 2011).

Significant knowledge gaps exist regarding the impact of pathogens and parasites on Oriental weatherloach in Australia and specifically the Murray-Darling Basin. Notwithstanding, as Oriental weatherloach have been within the Murray-Darling Basin since the early-1990s, there is high probability that the species has been exposed to the majority of endemic and introduced parasites and pathogens. Given the species has established populations in the Murray-Darling Basin, it appears unlikely that naturally occurring parasites and pathogens will inhibit the establishment of the species within South Australia. Conversely, Oriental weatherloach provide natural vectors for numerous diseases and parasites, and are thought to act as important secondary hosts (Koster *et al.* 2002). According to Dove and Ernst (1998) at least one monogenean parasite, *Gyrodactylus macracanthus*, has been introduced into Australia (only one stream in the ACT) via the importation of Oriental weatherloach. The potential impacts associated with this and other parasites on native species require further investigation.

2.07 -
How likely is it that establishment will occur despite existing management practices in South Australia?
Likely
Confidence: high

Currently, there are no formal species specific management strategies for Oriental weatherloach in South Australia. Notwithstanding, it has been listed as a noxious species in SA and is therefore governed by regulations set out in the Fisheries Management Act 2007 (i.e. no translocation, no live baiting, reporting of findings, etc.). In addition, since the species was discovered in South Australia, Biosecurity SA have established an Oriental weatherloach online reporting system and database, whereby members of the public can report a capture of the species online;
(http://www.pir.sa.gov.au/biosecuritysa/forms/Oriental_weatherloach_online_reporting_form) or by contacting Fishwatch. Biosecurity SA also commissioned this risk assessment in order to identify interstate and international management practices and knowledge gaps which will

assist in the development of a cost-effective state specific management strategy for the species.

2.08 -
How likely is it that management practices in South Australia will facilitate the establishment of the organism?
Moderately likely
Confidence: medium

Modifications to natural flow regimes through river regulation and water diversion schemes may help facilitate the establishment of Oriental weatherloach in South Australia. The alteration of key hydrological processes such as flow regimes, whereby reducing flow velocity, will likely improve habitat quality for Oriental weatherloach and maintain access to weir pools and wetlands and ultimately facilitate the establishment of reproducing, self-sustaining populations. (see Stage 2, Section A, Pathway 2: Water Regulation). Further research is required to better inform managers about the influence of these management practices on Oriental weatherloach.

2.09 -
How likely is it that biological characteristics of the organism would allow it to survive eradication campaigns in South Australia?
Likely
Confidence: high

Oriental weatherloach possess several biological characteristics that may limit the effectiveness of an eradication program in South Australia including; 1) their ability to bury/burrow into sediment to escape predation (Clunie *et al.* 2002) and in-turn certain physical control techniques such as electro-fishing (Koster *et al.* 2002), 2) their semi tolerance to pesticide contamination (Burchmore *et al.* 1990, Lintermans *et al.* 1990b, Clunie *et al.* 2002), 3) their ability to survive in severely degraded/de-oxygenated water bodies by gulping air (Allen 1984, Lintermans and Burchmore 1996) and 4) their ability to aestivate and survive temporarily out of water (Clunie *et al.* 2002). Notwithstanding, rotenone has been successfully used to eradicate an established population from Burpengary Creek, a small isolated creek north of Brisbane (J. Johnson pers. comm. 1989 cited in Koster *et al.* 2002), however the actual dosage rates implemented in this eradication were not reported. While this strategy may be successful in isolated water bodies, the identification of large scale control/eradication techniques remains a significant knowledge gap in the management of the species and this requires further research.

2.10 -
How likely is it that the biological characteristics of the organism will facilitate its establishment?
<u>Likely</u>
<u>Confidence: high</u>

Oriental weatherloach possess numerous biological characteristics which will help facilitate its establishment within the risk assessment area, including;

1) Tolerance to a wide range of water temperatures (2°C - 42°C) (Koba 1942, Lintermans and Burchmore 1996, cited in Koster *et al*. 2002).

2) Tolerance to desiccation (Clunie *et al.* 2002).

3) Tolerance to poor water quality (Allen 1984; Lintermans and Burchmore 1996).

4) Ability to occupy a wide variety of habitats (Allen 1984, Lintermans *et al.* 1990b, MacQueen 1995, Tudehope 2001, Koster *et al.* 2002).

5) Multiple batch spawning strategy to ensure some, if not all of their eggs are released in environmental conditions most favourable for the survival and hatching of eggs (Kimura and Koya 2011).

6) Moderate fecundity (4000-8000 eggs/batch) of up to 150 000 eggs per year (Kochetov and Kochetov 1986, Lintermans 2007).

7) Sexually mature at approximately 10 cm or 2 years of age (Kochetov and Kochetov 1986).

8) Larval hatching can occur in a wide range of temperatures (12°C to 31°C), but occurs optimally at 25°C (Kubota and Matsui 1955c), i.e. the approximate mean water temperature during summer in the River Murray in South Australia (e-nrims.dwlbc.sa.gov.au).

9) Capable of feeding on a diverse array of small aquatic organisms and is likely to be able to adapt depending on the availability of food resources (Yamamoto and Tagawa 2000).

2.11 -
How likely is it that the organism's capacity to spread will facilitate its establishment?
<u>Likely</u>
<u>Confidence: high</u>

It is likely that further Oriental weatherloach will enter South Australia from upstream populations during future natural and regulated high flow events similar to those witnessed during 2010-2013. The increased abundance of the species, and increased floodplain/wetland inundation associated with ongoing regulation and management of elevated flows associated with the release of environmental water, will aid in the species survival and increase the probability of establishment in these areas. Once a successful spawning event occurs in South Australia, dispersal and establishment of new populations is more likely, however, little is known about the movement and longevity of the larval phase of Oriental weatherloach. Future research into the larval ecology of the species is required to help predict the species' capacity to spread and establish self-sustaining populations in South Australia.

The rate of spread and establishment of the species in other states of Australia provides some evidence to suggest that the species has a high capacity to establish itself within the South Australian risk assessment area. (Refer to Stage 2; Section A; Question 1.11).

2.12 -
How likely is it that the organism's adaptability will facilitate its establishment?
Likely
Confidence: high

Oriental weatherloach are highly adaptable to a range of temperatures, water qualities, trophic needs and habitat types (Refer to Stage 1; Section B; Question 13 for more details), which will facilitate their establishment in the risk assessment area.

2.13 -
How likely is it that the organism could establish despite low genetic diversity in the founder population?
Moderately likely
Confidence: low

There is currently limited genetic information for Oriental weatherloach inhabiting freshwater systems in Australia (Joanne Kearns, PhD candidate, pers. comm., Koster *et al.* 2002). However, given that the initial seed populations of Oriental weatherloach were most likely established by a small number of discarded fish from the aquarium trade, there is a high probability that the Oriental weatherloach occurring in Australia lack genetic diversity. Despite this, the species has still managed to spread and establish reproducing populations, suggesting that low genetic diversity is unlikely to inhibit establishment within South Australia. Alternatively, a lack of genetic diversity may limit the species ability to survive if a biological virus or disease is contracted, or environmental conditions suddenly become unfavourable (e.g. increased salinities), whereby all fish in the population may be vulnerable. However, it must be noted that genetic research is not yet conclusive and further work is required before such scenarios can be considered.

2.14 -
Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in South Australia? (If possible, specify the instances of invasion elsewhere in the justification box.)
Very likely
Confidence: high

Oriental weatherloach has successfully invaded at least eight countries outside of its natural range (Lever 1996, Arthington *et al.* 1999, Koster *et al.* 2002). The current reported global distribution of the species encompasses the Rhine (Germany) and Tincino (Italy) drainages (Razzetti *et al.* 2001, Freyhof and Korte 2005, cited in www.fishbase.org), North America (including Hawaii) (Yamamoto 1992, Welcomme, 1998, cited in www.fishbase.org), Mexico (Contreras and Escalante 1984), Philippines (Juliano *et al.* 1989, cited in www.fishbase.org), Pacific (Palau Islands)(Bright 1979, Bright and June 1981; cited in www.fishbase.org) the United Kingdom (Lever 1996) and Australia (Koster *et al.* 2002).

Due to the species high fecundity and their ability to tolerate extreme environmental conditions and to survive in wide variety of habitat types, it is very likely that Oriental weatherloach will establish reproducing populations within the risk assessment area. Indeed, the spread and establishment of the species in other Australian states and territories has been rapid and expansive (Koster *et al.* 2002).

2.15 -
If the organism does not establish, then how likely is it that transient populations will continue to occur?
Likely
Confidence: medium

If Oriental weatherloach are unable to establish a reproducing population here in South Australia, it is likely that transient populations will continue to occur provided high flow events continue to occur. Given that the first recorded captures of Oriental weatherloach in SA were immediately following high flow events (2010/2011; 90,000+ ML/day), entrainment of upstream “seed” stocks during similar events is thought to be the most likely pathway for transient populations to enter South Australia. Unless such “seed” stocks are naturally or artificially depleted, it is likely that transient populations will continue to occur

2.16 -
Estimate the overall likelihood of establishment.
Very likely
Confidence: high

Overall, the likelihood of establishment of Oriental weatherloach in South Australia is very high. While Oriental weatherloach are already present in the risk assessment area, these fish were all adult/sub-adult fish and to date, no young-of-the-year fish have been captured. Nevertheless, the South Australia section of the River Murray is characterised by floodplains, wetlands, weir pools and anabranches that provide ideal habitat for the survival and spawning traits of Oriental weatherloach. This coupled with the species high fecundity and tolerance to a broad range environmental conditions suggest that it is highly likely that the species will encounter habitats and resources to facilitate the establishment of the species within South Australia.

Stage 2 - Detailed assessment Section C - Spread

Notes:

- **Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.**

3.01 -
In what proportion (%) of 10km squares in South Australia could the organism establish?
67% - 90% (of the River Murray)
Confidence: Medium low

It is likely that further Oriental weatherloach will enter South Australia from upstream populations during natural and regulated high flow events similar to those witnessed during 2010-2013. As such, the incursion of Oriental weatherloach will be most likely limited to the risk assessment area and other off-channel habitats of the River Murray, such as small tributaries, irrigation channels, weir pools, wetlands etc, unless the species is translocated to other water bodies by recreational fishers or through the aquarium trade. It is possible that the species could establish in suitable habitats along the entire length of the river system in South Australia, including off-channel habitats (as mentioned above). Given the South Australian section of the River Murray is approximately 650 km from the SA border to the Murray Mouth (Baker and Reschke 1996), the total river kilometres where Oriental weatherloach could establish is between 435-585 km.

3.02 -
How important is the expected spread of this organism in South Australia by natural **means? (Please list and comment on the mechanisms for natural spread in the justification box)**
Major
Confidence: high

Given that the first recorded captures of Oriental weatherloach in SA were immediately following high flow events (2010/2011; 90,000+ ML/day), natural dispersal from established upstream 'seed' populations is considered to be a key mechanism driving the spread of the species into and throughout South Australia. Established populations of Oriental weatherloach were recorded ≈300 km upstream of the South Australian border at Swan Hill (Victoria) during 2003 (MDFRC unpublished data in Wegener and Suitor 2013). Recent reports have suggested that this has now has expanded to upstream of Lock 7 and Robinvale, both of which are in Victoria but are close to the SA border (Wegener and Suitor 2013). Notwithstanding, given the recent SA incursion it is reasonable to assume that Oriental weatherloach are now dispersed throughout the entire Victoria section of the River Murray and, as a result, the relative contribution from this upstream "seed" stock through active and passive migration is likely to increase. (See Stage 2, Section A, Pathway 1 for a more detailed explanation of the potential influence of dispersal via natural means).

3.03 -

How important is the expected spread of this organism in South Australia by <u>human assistance</u>? (Please list and comment on the mechanisms for human-assisted spread in the justification box.)
<u>Moderate</u>
<u>Confidence: high</u>

Human assisted spread of Oriental weatherloach may occur in South Australia however, in comparison to natural spread, this mechanism is considered to be of moderate importance. Human mechanisms that may assist in the spread of Oriental weatherloach include;

1) River regulation

3) Live baiting by recreational anglers, and

4) Aquarium trade

(See Stage 1; Section B; Question 16 and Stage 2; Section A for more details)

3.04 -
Within South Australia, how difficult would it be to contain the organism?
<u>Major</u>
<u>Confidence: high</u>

Due to the length of the South Australian section of the River Murray (≈ 650 km; Baker & Reschke 1996), the area of off-channel habitat (i.e. wetlands/floodplains), the successful invasive and survival qualities of Oriental weatherloach (see above) and the current lack of effective species specific management strategies (Koster *et al.* 2002) it will be extremely difficult to contain the species. Indeed, efficient and cost-effective containment/control/eradication strategies represent a significant knowledge gap in the management of Oriental weatherloach and this requires further research.

3.05 -
What proportion (%) of the area in South Australia suitable for establishment, if any, has already been colonised by the organism?
<u>34% - 66%</u>
<u>Confidence: medium</u>

The incursion of Oriental weatherloach into South Australia will most likely be limited to the risk assessment area and other off-channel habitats of the River Murray. It is possible that the species could establish in suitable habitats along the entire length of the river system in South Australia. To date, Oriental weatherloach have been recorded as far downstream as the South Australian township of Blanchetown (≈270 km downstream from the NSW-SA border, Figure A3) (Thwaites and Fredberg, 2014). This area represents approximately 50 per cent of the South Australian section of the River Murray (See Figure A3).

Figure A3. A map showing wetlands and floodplains on the River Murray, South Australia, that have recently been sampled (2010-2013) during non-targeted monitoring programs. Markers in green represent areas (*n*= 61) sampled with <u>NO</u> recorded catches of Oriental weatherloach, while markers in red represent areas (*n*= 18) where Oriental weatherloach <u>HAVE</u> been caught.

3.06 -
What proportion of the area in South Australia suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?
67% - 90%
Confidence: medium

It is likely that Oriental weatherloach will continue to enter South Australia from upstream 'seed' populations during future natural and regulated high flow events in the next 5 years. As such, further invasion of Oriental weatherloach in the risk assessment area and other off-channel habitats of the River Murray, such as small tributaries, irrigation channels, weir pools, wetlands etc, are likely to continue during this period. Since 2010, the species' has been recorded from near the SA border, to as far downstream as the South Australian township of Blanchetown (≈270km downstream from the NSW-SA border, Figure A3) (Thwaites and Fredberg, 2014). This colonisation area represents approximately 50per cent of the South Australian section of the River Murray (See Figure A3). Since 2010, fish assemblage monitoring programs have recorded a gradual increase in distribution range of Oriental weatherloach into South Australia (see Figure A3). As such, it is highly likely that the range of the species will continue to increase over the next 5 years. Furthermore, the rate of increase in range is also likely to increase if the species establishes reproducing populations in the upper reaches of risk assessment area where individuals have been recorded since 2010.

Despite the lack of information on dispersal and establishment rates, the magnitude of the incursion will be largely dependent on the magnitude of flows to South Australia and the species' establishment in the risk assessment area during this period. If flow conditions continue as they have in the past 3 years, the availability of suitable habitats and environmental conditions remains at current levels, and optimal water temperatures for reproduction continue during the summer months, it is realistic to suggest that up to 80 per cent of the risk assessment area could be invaded by Oriental weatherloach over the next five years. Further research and informed modelling that considers various flow scenarios and environmental conditions is required to more accurately predict future incursions.

3.07 -
What other timeframe would be appropriate to estimate any significant further spread of the organism in South Australia? (Please comment on why this timeframe is chosen.)
10 years
Confidence: high

Given the scarcity of information on dispersal and establishment rates for Oriental weatherloach, our ability to predict further spread of the species into the risk assessment area is limited. The rate of incursion in SA during the past 3 years (i.e. 50 per cent of the SA section of the River Murray in 3 years) provides some evidence to the rate at which incursion can occur under relatively high flow conditions. If these conditions continue over the next 5-10 years, thus maintaining access to the large amount of suitable habitat for the species and optimal environmental conditions for survival and reproduction, it is likely that that the species will spread and extend its range throughout the majority of the risk assessment area. Furthermore, the rate of increase in range is also likely to increase if the species is able to establish reproducing populations in the risk assessment.

3.08 -
In this timeframe, what proportion of the endangered area (including any currently occupied areas) is likely to have been invaded by this organism?
91% - 100%
Confidence: medium

If suitable environmental conditions and relatively high flow conditions are maintained throughout this period, it is likely that the majority of the endangered area will be invaded during the next 5-10 years. However, there are many other factors that will influence the rate of invasion. See Stage 2 for more detailed explanation of the factors that will influence the rates of spread and establishment of Oriental weatherloach in the risk assessment area.

3.09 -
Based on the answers to questions on the potential for establishment and spread in South Australia, define the area endangered by the organism. Be as specific as possible (if available, provide a map showing the area most likely to be endangered).
Confidence: high

The area endangered by potential incursion and establishment of Oriental weatherloach is widespread and includes all wetlands, floodplains, weir pools, irrigation channels, backwaters and small tributaries along the entire length of the River Murray in SA (see Figure A4 for a detailed map of the risk assessment area). Provided water levels in the main channel of the River Murray are maintained at pool level and the present climatic conditions prevail, all these habitats are endangered by Oriental weatherloach.

Figure A4. The areas endangered by potential incursion and establishment of Oriental weatherloach including all wetlands, floodplains, weir pools, irrigation channels, backwaters and small tributaries along the entire length of the River Murray in SA.

3.10 -
Estimate the overall potential for future spread for this organism in South Australia (using the justification box to indicate any key issues).
Major
Confidence: high

The overall potential for the future spread of Oriental weatherloach in South Australia is major. There are several key factors that will influence the rate of the spread including:

- The magnitude of flow into South Australia. High flow events have the capacity to displace individuals from established upstream populations. Moreover, high flow conditions create and maintain access to habitats suitable for the establishment of reproducing populations through the prolonged inundation of wetlands, floodplains and backwaters and increased productivity.
- The availability of suitable habitat types which occur throughout the entire length of the risk assessment area (e.g. wetlands, floodplains, backwaters, weir pools, off-channel habitat and lakes, spanning from the Chowilla floodplains in the upper reaches to the Lower Lakes near the Murray Mouth).
- River regulation - the likelihood of Oriental weatherloach establishing a population in the River Murray, South Australia as a result of water regulation remains unknown. If slow flow areas and weir pools are created by river regulation, which in turn creates suitable habitat for the species, then establishment of populations from individuals already present in the risk assessment area may eventually occur, and this would increase the potential for future spread of the species in SA.
- The use of Oriental weatherloach as live bait by recreational anglers or dumping of unwanted aquarium fish. While it is thought to be uncommon practice in South Australia, if this illegal fishing method increases in popularity then this pathway will increase the potential for the species to further spread in SA.
- Larval hatching occurring between 12°C to 31°C, with 25°C being the optimal temperature for growth and survival. Such temperatures are very similar to those occurring in the lower River Murray in South Australia (Avg. Summer temperature 24.4°C, Avg. Winter temperature 12.3°C).

<u>Stage 2 - Detailed assessment Section D – Impact</u>

Important instructions:

- **When assessing potential future impacts, climate change should <u>not</u> be taken into account. This is done in later questions at the end of the assessment.**
- **Where one type of impact may affect another (e.g. diseases associated with the organism may also cause economic impact) the assessor should try to separate the effects (e.g. in this case discuss the economic impact of disease under the disease question only).**

Notes:

- **The initial questions in this section are provided in groups relating to economic impact, environmental impact and social impact. The first question in each group related to evidence of impacts anywhere in the world. Following questions relate to impacts in SA and are usually grouped into questions about impacts that have happened (up to the present day) and potential future impacts.**

4.01 -
How great is the economic loss caused by the organism within its global distribution (excluding South Australia), including the cost of any current management?
<u>Minor</u>
<u>Confidence: low</u>

Despite the broad distribution of Oriental weatherloach, the economic loss associated with the species invasion and subsequent establishment has received little attention and remains poorly understood in all countries throughout its distribution.

4.02 -
How great has the economic cost of the organism been in South Australia from the <u>time of introduction to the present</u>**? Exclude any costs associated with managing the organism from your answer.**
<u>Minimal</u>
<u>Confidence: high</u>

The first anecdotal report of Oriental weatherloach in the South Australia section of the River Murray occurred during 1987, yet there were no further reports of the species until 2011. Since that time 46 individuals have been recorded. Although no species-specific monitoring has been conducted to determine the density and distribution of the species in SA, the low abundances recorded in numerous wetland monitoring programs suggests that the economic cost of the species' invasion has more than likely been minimal.

4.03 -
How great is the economic cost of the organism likely to be in the <u>future</u> **in South Australia? Exclude any costs associated with managing the organism from your answer.**
<u>Minimal</u>
<u>Confidence: low</u>

The likely future economic cost of Oriental weatherloach to SA is difficult to assess as there is a lack of information on the biology and ecology of this species, its interactions with other species and the ecosystems of which they would be a part. As such, it is difficult to estimate the impact of the species' competition for resources (e.g. for food resources and critical habitats with other species) on other economically-important fish species that support commercial and recreational fisheries. The capacity of Oriental weatherloach to impact on such species through predation or as a vector for parasites and/or diseases also remains unknown. The primarily benthic existence of Oriental weatherloach and its ability to burrow and bury into the soft sediments of irrigation channels may contribute to some economic cost associated with the management of erosion and the quality of water that may be used for stock and irrigation purposes (by elevating ammonia, nitrate/nitrite and turbidity levels) (Keller and Lake 2007). Given the large knowledge gaps, the economic cost of the species is purely speculative and more research is required to accurately establish such estimates.

4.04 -
How great have the economic costs of managing this organism been in South Australia from the time of introduction to the present**?**
Minimal
Confidence: high

Fish monitoring programs conducted throughout the risk assessment area have indicated that Oriental weatherloach are currently present in very low numbers in SA. While sightings of the species have increased since 2010, no species-specific management strategies have been developed for this species in South Australia. This risk assessment provides the first step in assessing the need for the development of future management strategies to minimise the spread and establishment of Oriental weatherloach in South Australia.

4.05 -
How great is the economic cost of managing this organism likely to be in the future **in South Australia?**
Moderate
Confidence: low

Given the lack of information on potential impacts of Oriental weatherloach in SA, it is difficult to estimate the economic cost of managing the species in South Australia. Such an estimate requires greater knowledge of the scale of the incursion and the potential rate of establishment, an evaluation of the impacts of the species' existence (e.g. whether the incursion warrants specific management strategies), and the development and implementation of an effective management strategy. Given these knowledge gaps, the likely economic cost of managing the species is unknown, but could be significant.

4.06 -
How important is environmental harm caused by the organism within its global distribution?
<u>Moderate</u>
<u>Confidence: low</u>

The environmental impact of Oriental weatherloach remains poorly understood for both Australian and overseas populations (Koster *et al.* 2002). Maciolek (1984) concluded that the species had an "intermediate stream impact" based on its competition with other native and invasive fish for habitat and food resources. In addition, Welcomme (1984) indicated that the species did not contribute to any significant environmental harm in freshwater systems in the Phillippines, while Courtney *et al.* (1987) suggested that the species was not a direct threat to native fish but raised concerns over potential inter-specific competition for resources with native species. In Mexico and the Palau Islands the environmental impacts of Oriental weatherloach have not been examined and remain unknown (Bright and June 1981, Contreras and Escalante 1984, Koster *et al*. 2002). Although still speculative, in Australia Oriental weatherloach may impact the local environment by competing for spawning sites with native fish, predation or disturbance of fish and frog eggs, competition for food and shelter and alteration of habitat (Lintermans *et al.* 1990b). Despite the species' prevalence as an invasive species across the world, the lack of knowledge and understanding on the species ecology and how it interacts with native flora and fauna, as well as the impact of its primarily benthic existence (e.g. burrowing, benthic foraging potentially resuspending nutrients and fine sediment) is a concern. As such, it is imperative that future research strategies are developed to provide a comprehensive assessment of the potential environmental impacts of the species' invasion to the risk assessment area and how this may affect ecosystem function, including the existence of native flora and fauna.

4.07 -

How important has the impact of the organism on biodiversity* been in South Australia from the <u>time of introduction to the present</u>?
*e.g. decline in native species, changes in community structure, hybridisation
<u>Minor</u>
<u>Confidence: low</u>

There is no information on the ecological interactions and/or the role of Oriental weatherloach in South Australian ecosystems. Hence, it is difficult to assess the impact, if any; the species has had on biodiversity in South Australia since the unconfirmed report of the species in 1987. Fish monitoring programs conducted throughout the risk assessment area have indicated that Oriental weatherloach are currently present in very low numbers and so it is highly likely that species has had a very minor (if any at all) impact. In other

Australian states and territories where Oriental weatherloach have successfully established reproducing populations, the impacts to native fish species and fish assemblage structure have not been assessed and remain poorly understood (Koster *et al.* 2002).

4.08 -
How important is the impact of the organism on biodiversity likely to be in the future in South Australia?
Moderate
Confidence: low

Due to the lack of ecological information on Oriental weatherloach in Australia, it is difficult to assess the future impact the species will have on biodiversity in South Australia. If Oriental weatherloach do establish reproducing populations in the risk assessment area, which is likely if the current high flow conditions prevail, the impacts on biodiversity may include:

- Competition for spawning sites with native fish (Lintermans 1990b)
- Disturbance or predation of fish and frog eggs (Lintermans 1990b)
- Competition with other fish species for food and shelter (Lintermans 1990b)
- Alteration of important habitat for endemic fish and invertebrate species (Lintermans 1990b)
- Modification to fish and macro-invertebrate communities through predation and the decrease in water quality (e.g. increase in ammonia, nitrate/nitrie (NOx) and turbidity levels) (Keller and Lake 2007).

4.09 -
How important has alteration of ecosystem function* caused by the organism been in South Australia from the time of introduction to the present?
*e.g. habitat change, nutrient cycling, trophic interactions
Minor
Confidence: medium

Given the lack of information on population dynamics and ecology of Oriental weatherloach, it is difficult to determine whether the species has contributed to alteration of ecosystem function in South Australia. This would require an estimate of incursion and establishment and a comprehensive knowledge of the ecological interactions and trophic niche of the species. Fish monitoring programs conducted throughout the risk assessment area have indicated that Oriental weatherloach have been present in very low numbers since the species was first allegedly recorded in 1987. While sightings of the species have increased in recent years, it is unlikely that the species' incursion has contributed to any significant alterations to ecosystem functions since its incursion.

4.10 -
How important is alteration of ecosystem function caused by the organism likely to be in South Australia in the future?
Moderate
Confidence: low

There is no knowledge of the ecological role/niche of Oriental weatherloach in South Australian ecosystems. Hence, it is difficult to estimate the impact, if any, the species will have in South Australia in future. Moreover, there is a limited understanding of localised ecological impacts of the species throughout its global distribution (Koster *et al.* 2002). Maciolek (1984) concluded that an established population in Hawaii had an "intermediate stream impact" on some aspects of ecosystem function based on the species' competition with other native and invasive fish for habitat and food resources. While Courtney *et al.* (1987) raised concerns over potential inter-specific competition for resources with native fish species. No other studies have evaluated the influence of the species on ecosystem function. Given the species prevalence as an invasive species across the world, it is imperative that future research strategies are developed to provide a comprehensive assessment of the potential impacts of this species' invasion to ecosystem function. While current numbers of Oriental weatherloach are low in SA, if incursion continues and establishment occurs over the next 5-10 years, it is likely the species incursion will alter ecosystem function in some capacity. The severity of this alteration remains unknown.

4.11 -
How important has decline in conservation status* caused by the organism been in South Australia from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.
Minor
Confidence: high

As Oriental weatherloach have yet to establish in South Australia and have only been recorded in relatively low abundance, decline in conservation status has been minor to inexistent.

4.12 -
How important is decline in conservation status caused by the organism likely to be in the future in South Australia?
Moderate
Confidence: medium

If Oriental weatherloach successfully establish reproducing populations in South Australia, the conservation status of areas in the lower River Murray may need to be reassessed. These areas include the Chowilla floodplain and anabranch system, the Katarapko floodplain and major wetland networks including Rocky Gully and the Lower Lakes (figure A5). These areas all support populations of either iconic native fish species such as Murray cod (*Maccullochella peelii peelii*), silver perch (*Bidyanus bidyanus*), golden Perch (*Macquaria ambigua ambigua*), freshwater catfish (*Tandanus tandanus*) or threatened small bodied species such as the Murray hardyhead (*Craterocephalus fluviatilis*), southern and Yarra pygmy perch (*Nannoperca australis, Nannoperca obscura*) and southern purple-spotted gudgeons (*Mogurnda adspersa*). As recent records indicate (Table A1), the majority of captures of Oriental weatherloach in South Australia occurred in these key conservation areas, specifically the Chowilla and Katarapko floodplains (Figure A5). This is cause for concern, as these areas are potentially suitable and desirable habitat of Oriental weatherloach, and also hold rich biodiversity and key habitat structures utilised by native fish in both their ecological and biological processes.

4.13 -
How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?
<u>Minimal</u>
<u>Confidence: medium</u>

Currently, there is no information available indicating that Oriental weatherloach can be physically harmful (e.g. possesses spines or are aggressive toward humans) or that the species' is harmful if consumed (e.g. toxins within the flesh). In fact, in the Philippines the species is commonly exploited for human consumption (Kim *et al.* 1987, cited in Koster *et al.* 2002).

There is some evidence to suggest that Oriental weatherloach may compete with native fish species (including recreational and commercially important species), for food resources and critical habitats (Maciolek 1984, Courtney *et al.* 1987). The loss or reduced abundances of such economically-important species may subsequently impact on social activities such as recreational fishing. However, further research is required to more confidently estimate the potential social harm caused by the species.

4.14 -
How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within South Australia?
<u>Minimal</u>
<u>Confidence: medium</u>

Currently, there is no information available indicating that Oriental weatherloach can be physically harmful (e.g. possesses spines or are aggressive toward humans) or that the species' is harmful if consumed (e.g. toxins within the flesh).

The environmental impact of Oriental weatherloach remains poorly understood (Koster *et al.* 2002). However, there is some evidence to suggest that Oriental weatherloach may compete with native species, including recreational and commercially important species, for food resources and critical habitats (Maciolek 1984, Courtney *et al.* 1987). Whilst the rate of incursion and potential establishment into SA also remains unknown, if successfully established, Oriental weatherloach may displace native species from key habitats and reduce the availability of food resources for these native species, thus influencing their distribution and abundance. A reduction in the abundance of native species such as Murray cod (*Maccullochella peelii peelii*), silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua ambigua*) and freshwater catfish (*Tandanus tandanus*) may impact on social activities such as recreational fishing throughout the risk assessment area. Further research on the potential impacts of Oriental weatherloach on native, fishery-important species is required to more confidently estimate the potential social (and economic) harm caused by the species in South Australia.

4.15 -
How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?
Minimal
Confidence: low

There is currently limited genetic information for Oriental weatherloach (Joanne Kearns, PhD candidate, pers. comm., Koster *et al.* 2002). Further genetic research is required to definitively distinguish individual species and investigate whether the species poses genetic traits that may be carried to other fish species, potentially modifying their genetic nature. Indeed, Suzuki (1955) reports that short lived (≥20 days) Oriental weatherloach fry can be artificially produced by fertilizing Oriental weatherloach eggs with crucian carp (*Carassius carassius*) or goldfish (*Carassius auratus*) spermatozoa. Further, Suzuki et al. (1985b) produced long lived (>1 year) gynogenetic diploid Oriental weatherloach using artificially irradiated spermatozoa of common carp (*Cyprinus carpio*). They also demonstrated hybridization between Oriental weatherloach (eggs) and carp (untreated spermatozoa) producing short lived (≥20 days) deformed fry. Although Suzuki et al. (1985b) utilised artificial processes to produce gynogentic Oriental weatherloach, it was largely unsuccessful in the untreated hybridization experiment, thus further research is required to determine if there is any potential for goldfish and common carp to fertilise Australian Oriental weatherloach eggs and produce viable offspring. If viable offspring are produced then this may create a genetically diverse “super strain” of the species and could potentially impact control strategies similar to daughterless carp or Koi herpes virus. Until such research is conducted it is difficult to speculate as to what the economic, environmental and social impacts may be.

4.16 -
How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?
<u>Moderate</u>
<u>Confidence: medium</u>

Oriental weatherloach are known hosts and secondary hosts of numerous parasites and diseases (Koster *et al.* 2002). Parasites such as species from Eimeriidae, Gnathostoma, Gyrodactylidae, Trematoda, Protozoa and Cestoda are commonly observed in Oriental weatherloach, while diseases including red fin, red spot, columnaris disease, gas bubble disease and crooked spine disease are also common (Liu 1979, cited in Koster *et al.* 2002). Parasitic diseases such as yellow grub, black spot and lerneosis have also been recorded in some overseas populations (Liu 1979, cited in Koster *et al.* 2002).

Despite the ban on the importation of Oriental weatherloach to Australia, there is some evidence that the monogenean parasite, *Gyrodactylus macracanthus*, was introduced to Australia via the importation of one or more infected Oriental weatherloach (Dove and Ernst 1998). This parasite was observed in the ACT; however no further research has been conducted, making it difficult to determine the extent of the spread or impact this parasite has had on the species and other native fish.

4.17 -

How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (Specify in the justification box)
<u>Minimal</u>
<u>Confidence: high</u>

The impacts covered in previous questions are the most important and are discussed in detail in this risk assessment. Due to a general lack of information on the Oriental weatherloach, it is difficult to identify other potential impacts.

4.18 -
How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in South Australia?
<u>Major</u>
<u>Confidence: low</u>

The potential impacts (as described above) of Oriental weatherloach in South Australia remain poorly understood and are somewhat speculative, due mainly to a lack of information in most areas of the species' ecology and biology. Nevertheless, observations from other countries (e.g. USA – Hawaii) suggest that the species could have a dramatic influence on the structure of fish assemblages and ecosystem function in the lower River Murray; this is despite the threat of natural control mechanisms/organisms such as predators, parasites or pathogens that could potentially limit the significance of some impacts.

4.19 -
Indicate any parts of South Australia where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible; where possible include a map showing vulnerable areas).
Confidence: high

The risk assessment area in South Australia is characterised by habitats considered suitable for the establishment and sustainability of Oriental weatherloach populations. The species is most suited to muddy or sandy substrates in which they can burrow and avoid predation (Clunie *et al.* 2002). This habitat preference combined with a non-specialised dietary niche suggests that the species is likely capable of surviving in most anabranches, ephemeral billabongs, wetlands (flow-through and terminal), impoundments and irrigation channels throughout the area, as indicated in Figure A4 (Allen 1984, Swales 1992, Raadik, T. unpublished data, MacQueen 1995, Tudehope 2001, Lintermans *et al.* 1990b, cited in Koster *et al.* 2002). As such the majority of the lower River Murray, from the SA border to the Lower Lakes, is vulnerable to the economic, environmental and social impacts (as discussed above) associated with the invasion of Oriental weatherloach. However, there are nine main areas where the suitable habitats are most prevalent and are accessible throughout the entire year (except during extreme drought periods). These areas are: Chowilla floodplain, Pike floodplain, Berri and Dishers Creek evaporation basin, Katarapko floodplain, Banrock Station wetland, Paiwalla, Rocky Gully and the Lower Lakes (see Figure A5). Each of these areas has a high conservation value and is regarded as critical habitat for iconic and vulnerable native fish species.

Figure A5. A map indicating areas of high conservation value in the risk assessment area, due to the presence of either iconic or threatened native fish species, which maybe vulnerable to Oriental weatherloach colonisation.

4.20 -
Estimate the overall potential impact of this organism in South Australia (using the justification box to indicate any key issues).
Major
Confidence: Low

The potential impacts of Oriental weatherloach in South Australia remain poorly understood due to a lack of information on the species' ecology and biology. Nevertheless, scientific studies from Hawaii, suggest that the species could potentially have a significant detrimental influence on the structure of fish assemblages and ecosystem function in the environment to which they invade or are introduced (Maciolek 1984). If Oriental weatherloach successfully establish reproducing populations in the risk assessment area, which is likely if current flow conditions prevail, the ecological impacts may include:

- Competition for spawning sites with native fish (Lintermans *et al.* 1990b)
- Disturbance or predation of fish and frog eggs (Lintermans *et al.* 1990b)
- Competition with native fish for food and shelter (Lintermans *et al.* 1990b)
- Alteration of habitat of endemic fish and invertebrate species (Lintermans *et al.* 1990b)
- Modification to macro-invertebrate communities through predation (Keller and Lake 2007).
- Decreased water quality (Keller and Lake 2007)

Given the significant potential ecological impacts of Oriental weatherloach in South Australia, there is a risk that these impacts may negatively affect economically- and socially-important activities such as commercial and recreational fishing. A reduction in the abundance of native species such as Murray cod, silver perch, golden perch and freshwater catfish could have a detrimental impact on South Australia through a range of economic, environmental and social impacts (see above for detailed description).

Stage 2 - Detailed assessment Section E – Conclusion

5.01 -
Estimate the overall risk of this organism in South Australia.
High
Confidence: medium

The potential impacts of Oriental weatherloach in South Australia remain poorly understood due to a lack of information on the species' ecology and biology, however the overall risk of the species to South Australia is considered high. The species could potentially have a significant detrimental influence on the structure of fish assemblages, ecosystem function, commercial and recreational fishing as well as the conservation status of some key areas in South Australia. These potential risks to South Australia are due mainly to the species' intrinsic invasive and survival qualities, such as their tolerance to a wide range of temperatures, water qualities, habitat variability, highly plastic feeding preferences, biological attributes (aestivation, air breathing), reproductive cycles (multiple spawners) and ecological traits (burrowing to escape predation). Observations from the examination of the fish assemblages in the lower River Murray in recent years have indicated that the species' abundance and distribution in the risk assessment area is gradually increasing. This is likely the result of increased natural dispersal, whereby high rainfall events in the past 3 years in the upper Murray-Darling Basin have contributed to high flow conditions in South Australia, thereby displacing individuals from established upstream populations to SA.

Despite a general lack of information on the potential ecological impacts of Oriental weatherloach in South Australia and Australia, evidence from other studies highlights some of the potential risks associated with the establishment of this species in an ecological context. These ecological risks/impacts include:

- Competition for spawning sites with native fish (Lintermans *et al.* 1990b)
- Disturbance or predation of fish and frog eggs (Lintermans *et al.* 1990b)
- Competition with native fish for food and shelter (Lintermans *et al.* 1990b)
- Alteration of habitat of endemic fish and invertebrate species (Lintermans *et al.* 1990b)
- Modification to macro-invertebrate communities through predation (Keller and Lake 2007).
- Decreased water quality (Keller and Lake 2007)

Given the significant potential ecological impacts of Oriental weatherloach in South Australia, there is a risk that these impacts may negatively affect economically and socially-important activities such as commercial and recreational fishing. A reduction in the abundance of native species such as Murray cod, silver perch, golden perch and freshwater catfish could have a detrimental impact on South Australia through a range of economic, environmental and social impacts (see above for detailed description).

Stage 3 - Risk management Section A - Risk management

The management of the species will require an integrated approach similar to the approach which is currently being taken toward the control of common carp i.e. identify and target weaknesses in the species biology and ecology using targeted monitoring programs and integrated control techniques.

However, it must be noted that common integrated techniques (i.e. rotenone, physical trapping, physical exclusion, electrofishing etc.) are less effective during periods of high flow and flooding which is precisely the time when further spread of the species is likely to occur.

The control of the species may rely on biological controls such as daughterless gene technology or species specific diseases/viruses similar to Koi Herpes Virus.

As Oriental weatherloach have spread rapidly since their introduction into Australia over 2 decades ago, large-scale attempts to either contain, reduce or eradicate this species are still unknown (Koster *et al.* 2002). Only one eradication attempt has been successful, this was through the use of the pesticide Rotenone, however this was conducted in a small disconnected stream north of Brisbane (Burpengary Creek), with crucial details such as fish assemblages present at the time, densities of Oriental weatherloach present and the size of the site in general being absent. Other attempts to use rotenone to eradicate or even locate Oriental weatherloach in Australia have proved to be unsuccessful or inconclusive (Burchmore *et al.* 1990, Lintermans *et al.* 1990b, Koster *et al.* 2002).

The following is a list of potential control options that maybe effective in the containment of Oriental weatherloach in South Australia (Koster *et al.* 2002);

- Targeted Monitoring Programs
- Use of Pathogens and Parasites
- Chemical Controls (e.g. rotenone, lime)
- Molecular Biology and Biotechnology (e.g. daughterless-gene technology)
- Biomanipulation (e.g. predation by native fish)
- Physical Controls (e.g. capture and removal by electrofishing, netting and trapping, exclusion methods/devices, environmental rehabilitation, environmental manipulation, electric fields, sonic barriers and bubble curtains)

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