Review of grey listed non-native ornamental fish species

Kathleen Beyer and Josh Fredberg

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PO Box 120 Henley Beach SA 5022

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Report to the Ornamental Fish Management Implementation Group (OFMIG)

Government of South Australia

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

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Cover pictures: Top left- Koi carp (*Cyprinus carpio carpio*) (www.redclawlobster.net), Top right- Oscar fish (*Stronotus ocellatus)* (www.yourfishinfo.blogspot.com), Bottom left- Leopard ctenopoma *(Ctenopoma acutirostre)* (www.fish-keeper.net), Bottom right- Asian arowana *(Scleropages formosus)* (www.sharesinv.com.).

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

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Author(s):	Dr Kathleen Beyer and Josh Fredberg
Reviewer(s):	Dr Leigh Thwaites and Dr Jason Nicol
Approved by:	Dr Qifeng Ye Program Leader – Inland Waters & Catchment Ecology
Signed:	
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Table of Contents

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1 Executive summary

A total of 806 non-native ornamental fish species are (at the time of this study) contained in the grey list of potentially noxious fish species in Australia. As part of the national strategy, all species on the grey list are to be allocated a potential preliminary risk rating. Of the 806 species a total of 681 grey listed species have already been reviewed using the BRS Grey List Review methodology.

The aim of the present project was to populate the review matrix for the remaining 125 non-native ornamental grey listed fish species using the BRS Grey List Review methodology. For each species a total risk score was allocated using the review matrix provided by PIRSA.

Of the remaining 125 non-native ornamental fish species, 18 species (14.4 %) were allocated an overall 'low risk' − score, 25 species (20 %) were 'Borderline' and 82 species (65.6 %) were allocated a 'high risk' score. The 'high risk' species will be undergoing closer examination by the Ornamental Fish Management and Implementation Group (OFMIG), and will be assessed as to whether they are to undergo a rigorous risk assessment (RA). Such RA is essential to more robustly identify the ecological and economical risk associated with the respective species and the potential implications for native Australian ecosystems.

2 Introduction

At a global scale, the introduction of non-native species is recognised as a major threat to biodiversity (Diamond, 1985; Mooney and Hobbs, 2000; Bøhn *et al.*, 2004; Dudgeon, 2005) and can have great economic implications (Perrings *et al.,* 2000; Pimental, 2002). Live fish trade is of great importance to the Australian economy ($65 Million), and this includes the domestically bred fish (60%) and live fish imports from overseas (40%) (ABARE, 2004; DAFF, 2006). Of all non-native freshwater fishes that have established in Australian ecosystems (34), 64% were associated with the live fish trade (Lintermans, 2004; DAFF, 2006).

To minimise biosecurity risks associated with the live fish trade, a strategic approach to the management of ornamental fishes was developed (DAFF, 2006). In 2007, the Ornamental Fish Management Implementation Group (OFMIG) was created to address recommendations made by the Department of Agriculture Fisheries and Forestry (DAFF) to minimise the potential risks associated with the importation of live fish for the ornamental fish trade. OFMIG developed the 'grey list' presently containing 'potentially noxious' non-native fish species. The Bureau of Rural Sciences (BRS) developed a preliminary assessment process for the grey-listed species involving the compilation of biological and ecological data. A matrix was developed to enable grouping of ornamental fish species into 'high', 'borderline' or 'low risk' categories using a series of scores and ratings (grey list species review process, 2008; see Appendix 1 for details). The collated information would be used to assess the overall risk that these 'grey listed' species may pose to native ecosystems in Australia.

A total of 806 non-native ornamental fish species are (at the time of this study) contained in the grey list of potentially noxious fish species in Australia. As part of the national strategy, all species on the grey list are to be allocated a potential preliminary risk rating. Of the 806 species, a total of 681 grey listed species have already been reviewed by BRS (447) and SARDI (234) using the BRS Grey List Review methodology. The remaining 125 non-native ornamental fish species currently contained in the grey list underwent review during the present project.

The aims of the current project were:

- To populate the grey list review matrix for the remaining 125 grey listed non-native ornamental fish species; and
- To allocate each of those 125 fish species to a risk category.

3 Methods

The review of the 125 fish species was carried out as per BRS Grey List review methodology (Bureau of Rural Sciences, 2008; OFMIG/DAFF, 2008; Appendix 1; see also Fredberg and McNeil, 2010). For each species a total risk rating was allocated using the grey list species review matrix provided by PIRSA. The matrix consists of a series of pivot tables with answer options of 'yes', 'no' or 'unknown'. Each answer is allocated a representative score to enable calculation of a final overall rating (Appendix 2). Based on the final rating each species can then be categorised as:

1) 'high risk' (≥13),
2) 'low risk' (≤12); or
3) 'borderline' (between 12 and 13).

During the review, SARDI consulted information from additional sources including the Institute for Scientific Information (ISI-Web of Knowledge), and other peer-reviewed scientific literature. This was recorded in the review matrix as a separate column.

4 Results

Of the 125 grey listed non-native fish species reviewed during this project, 139 (59.4%) were allocated 'high risk', 48 (21%) 'low risk' and 46 (19.7%) 'borderline' ratings. The results of the review (the populated review matrix) including the total allocated scores and associated categories are presented in Appendix 2.

5 Discussion

The grey list review methodology is policy-focused and was developed to act as an initial screening tool to assess the invasive potential of exotic ornamental fish species. It performs to quickly assess non-native fish species and allocate them to one of the following categories: 'high risk' (≥13), 'low risk' (≤12); or 'borderline' (between 12 and 13) (see also Appendix 1; Fredberg and McNeil, 2010). Grey listed species which have been allocated a 'high risk' score should undergo a further science-focused, rigorous risk assessment process. Such assessment is essential to more robustly identify the ecological and economic risks associated with the respective fish species and the potential implications for Australian ecosystems. This will further provide a more comprehensive tool for the management of ornamental fish species associated with the live fish trade in Australia.

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7 Appendices

Appendix 1: Grey list species review method

This document outlines the grey list review method as developed following OFMIG's meeting in April 2008 and through consultation with the Australian Centre for Excellence in Risk Assessment (ACERA).

Review Process

The review matrix and how it would be applied was discussed and accepted in principle at the 3rd OFMIG meeting as a screening method to apply to the grey list and as an alternative to more costly risk assessment of individual species.

Representatives of DEWHA, BRS and ACERA have worked together to develop the approach and matrix for collating information to allow a transparent review of species on the grey list. The approach could be used for species that may require review in the future. The review matrix has been refined to include an appropriate threshold score to determine potentially high and low risk species and to address further comments provided by OFMIG members (WA and PIAA) and as a result of suggestions from an expert workshop to review grey listed species held 16 October 2008.

The review matrix uses climate matching (as used in the Bomford risk assessment models (Bomford 2006)), the assessment criteria considered in the original noxious list assessment, and other criteria. A criterion for hardiness was added following suggestions at the expert workshop in October 2008. The criteria are grouped according to the key policy areas relevant to government consideration of the potential pest and invasiveness of a species: biodiversity; impacts; and trade. The definitions section below provides explanations of the terms for categories used in the matrix. BRS has populated the matrix with information for grey list species with the exception of several genera which were considered by an expert group based on 'example' species. The expert workshop involved nominated experts and members of the aquarium industry.

The outputs of each tranche are reported to OFMIG for consideration and review at its regular meetings. OFMIG then reports these outcomes to MACC, who develops recommendations for additions to the noxious list. These are provided to the NRMSC who consider and endorse any additions to the national noxious list.

Species classified as low risk through this process could be considered for further assessment as species suitable for live import into Australia under Federal legislation and processes e.g. if the Industry chose to make an application to amend the live import list for individual species. A requirement of this legislated process is for a comprehensive environmental assessment of the proposed amendment on the Australian environment. The Bomford risk assessment model for freshwater fish would be applied in this process to contribute to the environmental assessment and information for the decision. The work done in reviewing the grey list under the OFMIG process could be used as an initial source of information if a live import list amendment application was made.

The review matrix and method as outlined provide a repeatable process for reviewing further species that may be added to the grey list for the purpose of recommending whether they be considered potentially noxious in Australia. To ensure consistent and

repeatable results, future users outside this process will need to be mindful to apply the review matrix in an appropriate context using relevant and reliable information sources.

Review matrix categories

- Climate match
- Biodiversity
    - Established in Australia
    - Eradication effort
    - Established beyond natural range
    - CITES listing
    - Hardiness
    - Resilience
- Impact
    - Current noxious status in Australia
    - Impact on habitat
    - Impact on other species
    - Genetic risk to native species
    - Genetic risk of non-native hybridisation
    - Known carrier of high risk disease
    - Direct threat to humans
- Trade
    - Restricted trade elsewhere
    - Multiple use species
    - Captive status in industry

Review matrix definitions

Climate Match and impacts

A two staged approach was utilised to assess the outputs of the risk matrix. If a species received a moderate to high climate match using the software package 'Climatch' (four or above) and was assigned the highest score (score of two or 2.1) for any of the 'impact' categories apart from 'current noxious status in Australia' or 'genetic risk of non-native hybridisation', then it was automatically deemed high risk. If it did not meet both of these criteria, the scores for each category were summed to give a relative risk score (see Application of the Threshold Score below). The relative risk score was calibrated against exotic species known to be present and established in Australia to determine a threshold score.

The threshold score of 12 as the threshold for potentially high risk species has been determined by calibrating the matrix with a number of fish species know to have established in Australia and have been shown to have clear impacts on other species or habitats. These species include European carp and Gambusia. A similar system has been used widely in New Zealand and Great Britain. The ranking criteria have been applied to differentiate between those species that are high risk (to be considered for addition to the noxious list) and those that are lower risk.

As a result of difficulties in securing sufficient resources to undertake individual risk assessment OFMIG agreed to the involvement of a small group of experts to consider

borderline species, or species evaluated as having insufficient information. Borderline species are those species that have scores of 11 or 12. Species evaluated as not having sufficient information have a lack of information on 3 or more criteria.

Application of the Threshold Score

The review matrix has been used to identify grey listed species that are high risk (relative risk score >13), and species that are low risk (relative risk score <12). Any species considered borderline (relative risk score 12 or 13) were deemed to warrant expert technical input at the review workshop, as were species where information is limited (more than 3 criteria do not have sufficient supporting literature).

Precautionary Principle

Many animal species (including fish) when assessed in terms of their potential impact on the environment or invasiveness may have limited scientific or other information to support views on their potential impacts or noxious status. It is accepted practice in Australia to apply a precautionary approach (e.g. the precautionary principle is taken into account in statutory decision making in some jurisdictions) when there is little or no scientifically based evidence or information, and where other information available is not science based. In circumstances where there was either conflicting information from reliable sources or no information available, the precautionary principle was used. To identify where the precautionary principle was used, 0.1 was added to the score for that category; for instance, instead of a score of 2 for 'impact on other species' it would be assigned 2.1. This does not impact on the final threshold score but allows easy identification of where the precautionary principle was used, and how many times it was used for any species or category.

BIODIVERSITY

The following criteria relate to the distribution and abundance of a species. A species is more likely to establish itself in Australia if introduced if it is: widely distributed; can tolerate a wide range of climatic conditions; lives in a region with closely matching climatic conditions to Australia; or previously has established itself outside its natural range, either in Australia or elsewhere.

Climate match

The climate score is derived from the risk assessment climate matching model Climatch; the revised model used for previous risk assessments (e.g. Bomford, 2006).

Risk assessment models have been developed by BRS to assess the risk of exotic vertebrates establishing in Australia. An integral part of these models is climate matching between each species' natural geographic distribution and similar environments in Australia.

Species which have a high Climatch score show attributes which are likely to make them successful colonisers in Australia. Conversely species with a low climate score will have a lower probability of establishment. The climate match score ranges from 1-8 with the following scoring system:

Table 1. **Climate match scoring system.**

Climate match score	PC Climatch score
1	0
2	1-40
3	41-150
4	151-400
5	401-1000
6	1001-1500
7	1501-2500
8	>2500

NB: *where no geographical information is available, the species is assigned a precautionary score of 4.1 for the Climate Match category.*

The Climate Match score is the single highest possible score in the review matrix, reflecting its importance as the key criteria in determining if a species is likely to establish itself in Australia if introduced. The 'World stations' database was generally used in Climatch for climate matching, however due to the paucity of data, it was sometimes necessary to use the 'Worldclim' dataset as this infers the likely climate in an area where there are no weather stations from which to take data. For some species there was no data available on distribution and in these cases a precautionary score of 4.1 was assigned based on the initial subsample of 132 species. It was agreed that these species were the most appropriate to use as a subsample as they represented species from over 80% of genera and 95% of families on the grey list and were therefore the most representative sample taken.

Established in Australia

Indicates if the species has previously established populations or currently has populations in Australia. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= Not established in Australia
- 1= Recorded occurrence in Australia
- 2= Reproducing population or widespread in Australia

Eradication effort

Indicates if there is, has been, or will be an eradication effort of any scale in Australia for the species. Accurate data for this category is difficult to obtain. For this reason this category is used for information purposes only and does not contribute to the overall score. This category has the following rating system:

- Ongoing- An eradication program is currently in place and eradication efforts are ongoing
- Eradicated- An eradication program has been implemented previously and the species has been successfully eradicated from Australia.
- Not at this time - An eradication program within Australia has yet to be implemented for this species.

- Not required - The species has not established in Australia and so an eradication effort is not currently contemplated or required for this species.

Established internationally

Indicates if the species has established populations outside their natural range in any other country. This information is taken primarily from FishBase (http://www.fishbase.org/search.php) and other web based fish sites (see website list section). This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= No established populations outside their natural range
- 1= Limited distribution outside its natural range, typically in the same continental region
- 2= Widespread distribution outside its natural range
- 2.1= No information available (2.1 precautionary principle)

CITES listing

Indicates if the species is listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This criteria is of limited value in determining whether a species is likely to establish itself if introduced to Australia and so is used here for information purposes only and does not contribute to the overall relative risk score. It follows a simple yes/no scoring system. Listing information is gathered from CITES (http://www.cites.org/).

Hardiness

Hardiness is used as an indicator of the species' ability to tolerate, or survive, or adapt to a wide range of temperatures, pH, salt or freshwater aquatic environments, or the ability to survive out of water for periods of time. Information for this criterion was gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological and aquarium sites (see website list section) and through an expert technical panel.

- 0= low
- 1= medium
- 2= high
- 2.1 = No information available (2.1 precautionary principle)

Resilience

Indicates rate of population doubling as an indicator of the rate of population growth. This is likely to be a good indicator of rate of population expansion once established. This attribute is also likely to provide an indication of the difficulty of eradication once established. FishBase (http://www.fishbase.org/search.php) lists a category on resilience for most species and provides information on population doubling. Information was also provided by an expert technical panel. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= Slow population growth
- 1= Moderate population growth
- 2= Fast population growth
- 2.1= Unknown rate of population growth (precautionary principle)

IMPACTS

The following criteria relate to the environmental impact a species is likely to have if it successfully establishes in Australia. Possible impacts include habitat modification or disturbance, negative interaction with native species, particularly predation or aggression, the genetic risk to the gene pool of native species through hybridisation, the genetic risk of hybridisation with established noxious species and adopting some or all of the pest characteristics of that species or increasing hybrid vigor (heterosis) to bottlenecked populations, or the potential introduction of high risk diseases.

Current noxious status in Australia

Indicates if the species has noxious status in any Australian states or territories. Currently no distinction is made between being listed as noxious in a single state or territory and being listed as noxious in multiple states or territories.

- 0=Not listed in any jurisdiction
- 1=Yes listed in at least one jurisdiction

Potential Impact on habitat

Indicates if the species has potential to significantly modify or disturb habitats in which it establishes. Information on this criteria has been gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological and aquarium internet sites (see website list section) and through an expert technical panel. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= No impact on habitat
- 1= Low impact on habitat
- 2= Medium or high impact on habitat
- 2.1= Unknown impact on habitat (precautionary principle)

Potential Impact on other species

Indicates if the species has characteristics or behaviour which could significantly impact other species in environments if it establishes. Strong negative impacts include predation and aggression which are likely to affect the distribution and abundance of other species in these areas. Information on this criteria has been gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological and aquarium internet sites (see website list section) and through an expert technical panel. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= No impact on other species
- 1= Low impact on other species
- 2= Medium or high impact on other species
- 2.1= Unknown impact on other species (precautionary principle)

Genetic risk to native species

Indicates if the species poses a significant genetic risk to native fish species through hybridization and introgression. Hybridization with native species will alter and dilute the gene pool of native species and in extreme cases may lead to the genetic extinction of the native species, particularly in cases where the introduced species is abundant and the native species is rare. Introgression is the introduction, through hybridisation, of non-native genetic information into the native gene pool, which may alter the fitness of native species. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= Low or no risk of hybridisation. Introduced species shares no or only distant phylogenetic relationship with native species
- 1= Medium risk of hybridisation. Introduced species belongs to the same phylogenetic family as native species
- 2= High risk of hybridisation. Introduced species belongs to the same phylogenetic genus as native species
- 2.1= Unknown risk of hybridisation. Introduced species has an unresolved phylogeny but may have close ancestral relationship with native species (precautionary principle)

Genetic risk from hybridisation with established noxious species

Indicates if the species poses a significant genetic risk through hybridization with established noxious species and adopting some or all of the characteristics of the noxious species or through hybrid vigor (heterosis) to bottlenecked populations. Established noxious species are defined as those listed on the national noxious fish list. This criteria is given a ranking score from 0-2, with the following scoring system:

- 0= Low or no risk of hybridisation. Introduced species shares no or only distant phylogenetic relationship with established noxious species
- 1= Medium risk of hybridisation. Introduced species belongs to the same phylogenetic Family as established noxious species
- 2= High risk of hybridisation. Introduced species belongs to the same phylogenetic Genus as established noxious species
- 2.1= Unknown risk of hybridisation. Introduced species has an unresolved phylogeny but may have close ancestral relationship with established noxious species (precautionary principle)

Known carrier of high risk disease

Indicates if the species is a known carrier of high risk disease that could pose a significant risk to native fish species. High risk disease is defined here as those listed on Australia's National List of Reportable Diseases of Aquatic Animals (2007) and included in the Import Risk Analysis on live Ornamental Finfish (1999). Information on this criterion has been gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological and aquarium internet sites (see website list section) and through an expert technical panel. This criterion is given a ranking score with the following scoring system:

- 0= Not know to carry high risk disease
- 1= May carry high risk disease
- 2= Is known to carry high risk disease
- 2.1= Unknown disease risk (precautionary principle)

TRADE

The following criteria relate to how international trade in a species might influence escape and establishment of that species, or its potential impact if it escapes. If trade in a species has been restricted elsewhere, it suggests that this species has been recognised by that country as a potential threat, for one reason or another, and so may pose a similar threat if introduced to Australia. If a species has multiple uses across sectors this relates to how widely spread the species is likely to become if it is introduced to Australia and thus how many different pathways exist to escape into the wild.

The more widespread a species is spread across activities or industries, the greater and more varied the risk of the species escaping captivity and establishing in the wild. However some pathways to escape pose a greater risk than others. For example those species commonly kept in ponds and dams are far more likely to escape than those restricted to strict research facilities. Thus the extent and type of industry use will also be a determining factor of the likelihood of escape. Together these two factors can be considered as the breadth and depth of risk of escape into the wild due to industry trade.

Restricted trade elsewhere

Indicates if the importation or movement of the species has been limited to or within other countries. If trade in a species has been restricted elsewhere, it suggests that this species has been recognised by that country as a potential threat, for one reason or another, and so may pose a similar threat if introduced to Australia. This information is difficult to ascertain and is likely available only for a handful of countries. For this reason this category is currently used for information purposes only and does not contribute to the overall relative risk score. However, this category could help inform the decision process where the review ranking is borderline. This category has a simple rating system of yes trade in this species is restricted elsewhere, no trade in this species is not restricted elsewhere, or trade in this species is unknown.

Multiple use species

Indicates the use and benefits of the species across various sectors, including recreational fishing, aquaculture, the aquarium industry, or religious/ethnic activities. If a species has multiple uses across sectors this relates to how widely spread the species is likely to become if it is introduced to Australia and thus how many different pathways exist to escape into the wild. The more widespread a species is spread across industries, the greater and more varied the risk of the species escaping captivity and establishing in the wild. Information on this criterion has been gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological and aquarium internet sites (see website list section) and through an expert technical panel. This criterion can be considered as the breadth of risk due to industry use. This criterion is given a ranking score of 1 or 2, with the following scoring system:

- 1= Used in ≤ one industry
- 2= Used in > one industry
- 2.1= Breadth of use of this species is unknown (precautionary principle)

The score cannot equal zero because that would imply no use for this species and therefore no reason to bring it into the country.

Captive status in industry

Indicates how widely the species is kept within an industry and under what conditions. Some pathways to escape pose a greater risk than others. For example those species commonly kept in ponds and dams are far more likely to escape than those restricted to strict research facilities. Thus the extent and type of industry use will also be a determining factor of the likelihood of escape. Information on this criterion has been gathered from FishBase (http://www.fishbase.org/search.php), various ichthyological, aquarium internet sites (see website list section) and through an expert technical panel. This criterion can be considered as the depth of risk due to industry use. This criterion is given a ranking score from 0-2, with the following scoring system:

- 0= Use is restricted to a limited purpose or highly contained

- 1= Use is not restricted or contained but the species is not widely kept
- 2= Use is not restricted or contained and the species is widely kept
- 2.1= Depth of use of this species is unknown (precautionary principle)

Useful websites consulted for this review

http://animal-world.com/encyclo/fresh/fresh.htm
http://aquatic-hobbyist.com
http://aquaticpredators.com
http://aquaworld.netfirms.com
http://fisc.er.usgs.gov/afs/
http://fish.mongabay.com
http://fpcs.fish.govt.nz/
www.amonline.net.au/fishes/index.cfm
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www.arcbc.org.ph/arcbcweb/pdf/vol2no4/12-15_sr_invasive_aquatic_animals.pdf
www.cites.org/
www.defra.gov.uk
www.fishbase.org
www.fishprofiles.com
www.geocities.com
www.liveaquaria.com
www.nanfa.org
www.planetcatfish.com
www.pond-life.me.uk
www.scotcat.com
www.seriouslyfish.com
www.theaquariumwiki.com
www.thetropicaltank.co.uk
www.tropicalfishfinder.co.uk
www.wcs.org/globalconservation/Africa/madagascar/freshwaterfishconservation
www.wetwebmedia.com

Appendix 2: Populated Grey List Review matrix for the remaining 125 species

Table 2: Results for the review of 125 non-native ornamental fish species following the BRS grey list review methodology. Whereby, CM=Climate match, EA=Established in Australia, EE=Eradication Effort, EI=Established Beyond Natural Range Internationally, CT=Cites Listed, Ha=Hardiness, Re=Resilience, Nx=Noxious Status in Australia, IH=Impact on Habitat, IS=Impact on other Species, GN=Genetic Risk to Native Species, GI=Genetic Risk to Invasive Species, DS=Known Carrier of Disease, TH=Direct Threat to Humans, RT=Restricted Trade Elsewhere, MU=Multiple use Species, CS=Captive Status in Industry, TT=Threshold Total (risk score), uk=Unknown's, RC=Risk Category, HR=High Risk, LR=Low Risk and B=Borderline, Ref=References). References can be found in Table 3. [*, only if eaten; #, marine species; ", estuarine species; ^, native to northern Australia (marine/estuarine species)].

Family	Species	CM	EA	EE	EI	CT	Ha	Re	Nx	IH	IS	GN	GI	DS	TH	RT	MU	CS	TT	UK	RC	Ref
Mastacembelidae	*Mastacembelus notophthalmus*	2.05	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	1
Mastacembelidae	*Mastacembelus oatesii*	3	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	12	1	LR	2
Mastacembelidae	*Mastacembelus ophidium*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	2	1	14	1	HR	3
Mastacembelidae	*Mastacembelus paucispinis*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	4
Mastacembelidae	*Mastacembelus plagiostomus*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	2	1	14	1	HR	5
Mastacembelidae	*Mastacembelus platysoma*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	2	1	14	1	HR	6
Mastacembelidae	*Mastacembelus polli*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	7
Mastacembelidae	*Mastacembelus praensis*	2	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	8
Mastacembelidae	*Mastacembelus robertsi*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	9
Mastacembelidae	*Mastacembelus sanagali*	2	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	10
Mastacembelidae	*Mastacembelus sclateri*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	11
Mastacembelidae	*Mastacembelus seiteri*	3	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	12	1	LR	12
Mastacembelidae	*Mastacembelus sexdecimspinus*	2.05	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	13
Mastacembelidae	*Mastacembelus shiloangoensis*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	14
Mastacembelidae	*Mastacembelus shiranus*	5	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	2	15	1	HR	15
Mastacembelidae	*Mastacembelus signatus*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	16
Mastacembelidae	*Mastacembelus stappersii*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	17
Mastacembelidae	*Mastacembelus taiaensis*	2	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	18
Mastacembelidae	*Mastacembelus tanganicae*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	2	14	1	HR	19
Mastacembelidae	*Mastacembelus traversi*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	20
Mastacembelidae	*Mastacembelus trispinosus*	2	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	11	1	LR	21

Family	Species	CM	EA	EE	EI	CT	Ha	Re	Nx	IH	IS	GN	GI	DS	TH	RT	MU	CS	TT	UK	RC	Ref
Mastacembelidae	*Mastacembelus ubangensis*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	22
Mastacembelidae	*Mastacembelus unicolor*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	23
Mastacembelidae	*Mastacembelus vanderwaali*	6	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	15	1	HR	24
Mastacembelidae	*Mastacembelus zebratus*	4	0	no	0	no	1	2	0	1	1	0	0	2.1	0	uk	1	1	13	1	B	25
Notopteridae	*Chitala borneensis*	2.05	0	no	0	no	2	1	0	1	1	0	0	2.1	0	uk	2	2	12	1	LR	26
Notopteridae	*Chitala chitala*	5	0	no	1	no	2	0	0	1	2	0	0	2.1	0	uk	2	2	17	1	HR	27
Notopteridae	*Chitala hypselonotus*	2.05	0	no	0	no	2	0	0	1	2	0	0	2.1	0	uk	2	1	12	1	LR	28
Notopteridae	*Chitala lopis*	5	0	no	1	no	2	0	0	1	2	0	0	2.1	0	uk	2	1	16	1	HR	29
Notopteridae	*Arapaima gigas*	4	0	no	2	yes (Cites 2)	2	0	0	2	2	0	0	2	0	yes	2	1	17	0	HR	30
Pangasiidae	*Pangasius bedado*	4	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	15	3	HR	31
Pangasiidae	*Pangasius bocourti*	5	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	2	1	17	3	HR	32
Pangasiidae	*Pangasius djambal*	5	0	no	0	no	2	1	0	2.1	1	0	0	2.1	0	uk	2	1	16	2	HR	33
Pangasiidae	*Pangasius humeralis*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	34
Pangasiidae	*Pangasius kinabatanganensis*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	35
Pangasiidae	*Pangasius lithostoma*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	36
Pangasiidae	*Pangasius mahakamensis*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	37
Pangasiidae	*Pangasius mekongensis*	3	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	14	3	HR	38
Pangasiidae	*Pangasius myanmar*	2	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	39
Pangasiidae	*Pangasius polyuranodon*	5	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	40
Pangasiidae	*Pangasius rheophilus*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	41
Pangasiidae	*Pangasius sabahensis*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	42
Pangasiidae	*Pangasius sanitwongsei*	6	0	no	0	no	2	2.1	0	2.1	2	0	0	2.1	0	uk	2	1	19	3	HR	43
Pangasiidae	*Pangasius tubbi*	2.05	0	no	0	no	2	2.1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	44
Pimelodidae	*Brachyplatystoma capapretum*	2.05	0	no	0	no	2	1	0	2.1	2	0	0	2.1	0	uk	2	1	14	2	HR	45
Pimelodidae	*Brachyplatystoma juruense*	3.05	0	no	0	no	2	1	0	2.1	2	0	0	2.1	0	uk	2	1	15	2	HR	46
Pimelodidae	*Brachyplatystoma platynemum*	3.05	0	no	0	no	2	0	0	2.1	2	0	0	2.1	0	yes	2	1	14	2	HR	47
Pimelodidae	*Brachyplatystoma rousseauxii*	3.05	0	no	0	no	2	0	0	2.1	2	0	0	2.1	0	uk	2	1	14	2	HR	48
Pimelodidae	*Brachyplatystoma tigrinum*	3.05	0	no	0	no	1	1	0	2.1	2	0	0	2.1	0	uk	1	1	13	2	B	49
Pimelodidae	*Leiarius longibarbis*	3.05	0	no	0	no	2.1	1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	50
Pimelodidae	*Leiarius marmortus*	3.05	0	no	0	no	2.1	1	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	51
Pimelodidae	*Sorubim cuspicaudus*	2.05	0	no	0	no	1	1	0	2.1	2	0	0	2.1	0	uk	1	1	12	2	LR	52
Pimelodidae	*Sorubim maniradii*	2.05	0	no	0	no	1	2	0	2.1	1	0	0	2.1	0	uk	1	1	12	2	LR	53
Pimelodidae	*Sorubim trigonocephalus*	2.05	0	no	0	no	1	1	0	2.1	2	0	0	2.1	0	uk	1	1	12	2	LR	54
Poeciliidae	*Alfaro amazonus*	3.05	1	no	1	no	2.1	2	1	2.1	1	0	1	2.1	0	uk	1	1	18	3	HR	55

Family	Species	CM	EA	EE	EI	CT	Ha	Re	Nx	IH	IS	GN	GI	DS	TH	RT	MU	CS	TT	UK	RC	Ref
Protopteridae	*Protopterus aethiopicus congicus*	2	0	no	0	no	2	0	0	2.1	2	0	0	2.1	0	uk	1	1	12	2	LR	56
Protopteridae	*Protopterus aethiopicus mesmaekersi*	4.05	0	no	0	no	2	0	0	2.1	2	0	0	2.1	0	uk	1	1	14	2	HR	57
Protopteridae	*Protopterus annectens annectens*	7	0	no	1	no	2	0	1	2.1	2	0	0	2.1	0	yes	1	1	19	2	HR	58
Protopteridae	*Protopterus annectens brieni*	6	0	no	1	no	2	0	1	2.1	2	0	0	2.1	0	yes	2	1	19	2	HR	59
Schilbeidae	*Schilbe angolensis*	4	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	15	3	HR	60
Schilbeidae	*Schilbe banguelensis*	5	0	no	0	no	2.1	2	0	2.1	2	0	0	2.1	0	uk	1	1	17	3	HR	61
Schilbeidae	*Schilbe bocagii*	5	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	62
Schilbeidae	*Schilbe brevianalis*	5	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	63
Schilbeidae	*Schilbe congensis*	4.05	0	no	0	no	2.1	2	0	2.1	2	0	0	2.1	0	uk	1	1	16	3	HR	64
Schilbeidae	*Schilbe djemeri*	3	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	14	3	HR	65
Schilbeidae	*Schilbe durinii*	4	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	15	3	HR	66
Schilbeidae	*Schilbe grenfelli*	4	0	no	0	no	2.1	2	0	2.1	2	0	0	2.1	0	uk	2	1	17	3	HR	67
Schilbeidae	*Schilbe laticeps*	2	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	13	3	B	68
Schilbeidae	*Schilbe mandibularis*	2	0	no	0	no	2.1	2	0	2.1	1	0	0	1	0	uk	1	1	12	3	LR	69
Schilbeidae	*Schilbe micropogon*	5	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	70
Schilbeidae	*Schilbe moebiusii*	5	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	71
Schilbeidae	*Schilbe multitaeniatus*	3	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	14	3	HR	72
Schilbeidae	*Schilbe mystus*	8	0	no	2	no	1	2	1	2.1	1	0	0	2	0	yes	2	2	23	1	HR	73
Schilbeidae	*Schilbe nyongensis*	3	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	14	3	HR	74
Schilbeidae	*Schilbe tumbanus*	4	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	15	3	HR	75
Schilbeidae	*Schilbe uranoscopus*	5	0	no	0	no	2.1	2	0	2.1	2	0	0	2.1	0	uk	1	1	17	3	HR	76
Schilbeidae	*Schilbe yangambianus*	5	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	16	3	HR	77
Schilbeidae	*Schilbe zairensis*	4.05	0	no	0	no	2.1	2	0	2.1	1	0	0	2.1	0	uk	1	1	15	3	HR	78
Tetraodontidae	*Auriglobus modestus*	5	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	15	1	HR	79
Tetraodontidae	*Auriglobus remotus*	4	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	14	1	HR	80
Tetraodontidae	*Carinotetraodon imitator*	5	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	15	1	HR	81
Tetraodontidae	*Carinotetraodon irrubesco*	1.05	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	2	12	1	LR	82
Tetraodontidae	*Carinotetraodon salivator*	1.05	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	11	1	LR	83
Tetraodontidae	*Chelonodon patoca*	6	2	no	0	no	2	2	0	1	1	2	0	2.1	0	uk	2	1	21	1	HR ^	84
Tetraodontidae	*Takifugu alboplumbeus*	5	0	no	0	no	2	2	0	1	1	1	0	2.1	0 *	uk	2	1	17	1	HR #	85
Tetraodontidae	*Takifugu bimaculatus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR #	86
Tetraodontidae	*Takifugu chinensis*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR #	87
Tetraodontidae	*Takifugu chrysops*	4	0	no	0	no	2	2	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR #	88
Tetraodontidae	*Takifugu coronoidus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0	uk	2	1	16	1	HR "	89
Tetraodontidae	*Takifugu exascurus*	4	0	no	0	no	2	2	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR #	90
Tetraodontidae	*Takifugu flavidus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR #	91

Family	Species	CM	EA	EE	EI	CT	Ha	Re	Nx	IH	IS	GN	GI	DS	TH	RT	MU	CS	TT	UK	RC	Ref
Tetraodontidae	*Takifugu niphobles*	5	0	no	0	no	2	2	0	1	1	1	0	2.1	0 *	uk	2	1	17	1	HR #	92
Tetraodontidae	*Takifugu oblongus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0	uk	1	1	15	1	HR	93
Tetraodontidae	*Takifugu obscurus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	2	1	16	1	HR	94
Tetraodontidae	*Takifugu ocellatus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0	uk	1	1	15	1	HR	95
Tetraodontidae	*Takifugu pardalis*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	1	1	14	1	HR	96
Tetraodontidae	*Takifugu plagiocellatus*	5	0	no	0	no	2	2	0	1	1	1	0	2.1	0	uk	1	1	16	1	HR #	97
Tetraodontidae	*Takifugu poecilonotus*	4	0	no	0	no	2	2	0	1	1	1	0	2.1	0 *	uk	1	1	15	1	HR	98
Tetraodontidae	*Takifugu porphyreus*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	2	1	15	1	HR	99
Tetraodontidae	*Takifugu pseudommus*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	1	1	14	1	HR #	100
Tetraodontidae	*Takifugu reticularis*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	1	1	14	1	HR #	101
Tetraodontidae	*Takifugu snyderi*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	1	1	14	1	HR #	102
Tetraodontidae	*Takifugu stictonotus*	5	0	no	0	no	2	1	0	1	1	1	0	2.1	0 *	uk	1	1	15	1	HR #	103
Tetraodontidae	*Takifugu variomaculatus*	4.1	0	no	2.1	no	2	2.1	0	1	1	1	0	2.1	0	uk	1	1	17	4	HR #	104
Tetraodontidae	*Takifugu xanthopterus*	4	0	no	0	no	2	1	0	1	1	1	0	2.1	0	uk	2	1	15	1	HR #	105
Tetraodontidae	*Tetraodon abei*	5	0	no	0	no	1	2.1	0	1	2	1	0	2.1	0	uk	1	2	17	2	HR	106
Tetraodontidae	*Tetraodon barbatus*	6	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	1	17	1	HR	107
Tetraodontidae	*Tetraodon biocellatus*	5	0	no	0	no	1	2	0	1	2	1	0	2	0	uk	1	2	17	0	HR	108
Tetraodontidae	*Tetraodon cambodgiensis*	6	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	16	1	HR	109
Tetraodontidae	*Tetraodon cochinchinensis*	6	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	16	1	HR	110
Tetraodontidae	*Tetraodon cutcutia*	6	0	no	0	no	2	2	0	1	1	1	0	2.1	0	uk	1	1	17	1	HR	111
Tetraodontidae	*Tetraodon duboisi*	4.05	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	14	1	HR	112
Tetraodontidae	*Tetraodon erythrotaenia*	4	0	no	0	no	2	2	0	1	1	1	0	2.1	0	uk	1	1	15	1	HR	113
Tetraodontidae	*Tetraodon fluviatilis*	5	0	no	0	no	2	2	0	1	2	1	0	2.1	0 *	uk	1	2	18	1	HR	114
Tetraodontidae	*Tetraodon implutus*	2	0	no	0	no	2	2	0	1	1	1	0	2.1	0	uk	1	1	13	1	B #	115
Tetraodontidae	*Tetraodon kretamensis*	1.05	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	11	1	LR	116
Tetraodontidae	*Tetraodon leiurus*	5	0	no	0	no	2	2	0	1	2	1	0	2.1	0	uk	1	2	18	1	HR	117
Tetraodontidae	*Tetraodon lineatus*	7	0	no	0	no	2	1	0	1	2	1	0	2.1	0	uk	1	1	18	1	HR	118
Tetraodontidae	*Tetraodon miurus*	5	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	1	16	1	HR	119
Tetraodontidae	*Tetraodon palembangensis*	6	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	2	18	1	HR	120
Tetraodontidae	*Tetraodon pustulatus*	2	0	no	0	no	2	1	0	1	2	1	0	2.1	0	uk	1	1	13	1	B	121
Tetraodontidae	*Tetraodon sabahensis*	4	0	no	0	no	1	2	0	1	1	1	0	2.1	0	uk	1	1	14	1	HR	122
Tetraodontidae	*Tetraodon schoutedeni*	5	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	2	17	1	HR	123
Tetraodontidae	*Tetraodon suvattii*	6	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	1	17	1	HR	124
Tetraodontidae	*Tetraodon waandersii*	4	0	no	0	no	1	2	0	1	2	1	0	2.1	0	uk	1	1	15	1	HR	125

Table 3: References consulted and comments for fish species presented in Table 2.

No	References consulted
1	http://fishbase.org/Summary/SpeciesSummary.php?id=25158 http://www.discoverlife.org/20/q?search=Mastacembelus+notophthalmus&b=FB25158
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