10. Future importation status of species on the DEWHA live import list

10.1 Introduction

Of the 23 species reviewed in this report, ten are currently listed under Part 1 of the DEWHA live import list (i.e. the schedule entitled 'List of specimens taken to be suitable for live import' - Environment Protection and Biodiversity Act 1999). This means they can be imported to Australia without a permit. Part of the brief for this report was to examine what is currently known about these ten species and to make recommendations to the DEWHA as to whether they should remain on the Part 1 list (i.e. the do nothing option) or, because of any unacceptable potential environmental cost, be shifted to the Part 2 list of the schedule (i.e. species which do require an import permit from the DEWHA). A third option would be to remove the species from both lists on the basis that no further stocks should be imported.

The ten species on the Part 1 list are shown in Table 10.1. There is no ornamental species currently on the Part 2 list. There are also many species of ornamental fish in Australia that do not appear on the live import list. Some of these species have been proposed for listing under the Noxious Species and Grey Species list established by the Strategic Approach to the Management of Ornamental Fish in Australia (NRMMC 2006). Confirmation of species on the noxious species list would result in a ban on future importation.

In this chapter of the report, we draw upon the results of the species reviews and knowledge of the known distributions of these species in Australia to assess their relative potential for creating widespread impacts. This 'potential ecological cost' is then contrasted with the relative value of the species to the ornamental fish industry and the consequences of any restriction on imports to determine whether their importation status should be changed. It should be noted that listing on the live import list is independent of any listing under the Quarantine Act. The latter is designed to reduce risks of introducing pathogens and parasites into Australia.

10.2 Approach taken

An alien species becomes a nuisance to society when it causes an unacceptable ecological impact that requires a management action to ameliorate it, or would require such action if it were technically possible to provide it at an acceptable cost. However, nuisance species only become pests when they spread widely and such management requirements escalate. To assess the potential risk of an alien ornamental species becoming a pest fish species in Australian waters we examined firstly the risk that a species will cause a decline in native fauna, especially native fish, and secondly the extent to which it might be expected to spread (i.e. its potential invasiveness).

Table 10.1: Current listing of the 23 ornamental fish species in relation to their importation status (no ornamental fish species are currently listed under Part 2 of the schedule of fish allowed to be imported). Proposed noxious and grey list species as in Tilzey (2005).

Common name	Scientific name	Current listing		
		Live import list-Part 1 species	Proposed noxious species	Proposed grey list species
Family Cichlidae				
Hybrid cichlid	*Labeotropheus/Pseudotropheus*			
Jewel cichlid	*Hemichromis bimaculatus*			
Victoria Burton's haplochromis	*Haplochromis burtoni*			
Black mangrove cichlid	*Tilapia mariae*		yes	
Redbelly tilapia	*Tilapia zillii*		yes	
Mozambique tilapia	*Oreochromis mossambicus*		yes	
Oscar	*Astronotus ocellatus*	yes		
Three-spot cichlid	*Cichlasoma trimaculatum*			
Jack Dempsey	*Cichlasoma octofasciatum*			
Red devil	*Amphilophus labiatus*			yes
Midas cichlid	*Amphilophus citrinellus*			yes
Convict cichlid	*Archocentrus nigrofasciatus*			
Blue acara	*Aequidens pulcher*	yes		
Family Poeciliidae				
Green swordtail	*Xiphophorus hellerii*	yes		
Platy	*Xiphophorus maculatus*	yes		
Sailfin molly	*Poecilia latipinna*	yes		
Guppy	*Poecilia reticulata*	yes		
Caudo	*Phalloceros caudimaculatus*			
Family Osphronemidae				
Three-spot gourami	*Trichogaster trichopterus*	yes		
Family Cobitidae				
Oriental weatherloach	*Misgurnus anguillicaudatus*		yes	
Family Cyprinidae				
Goldfish	*Carassius auratus*	yes		
Rosy barb	*Puntius conchonius*	yes		
White cloud mountain minnow	*Tanichthys albonubes*	yes		

The former assessment requires some knowledge of fish size, habitats (e.g., river, stream, lake) and feeding ecology (e.g., piscivory, omnivory, herbivory) and whether it displays aggression to other fish species. This assessment also includes any observations of the outcome of interactions with native fauna either in other countries or in Australia. The information for this assessment is taken from chapter 4 of this report.

The latter assessment requires an appraisal of the species capacity to spread unaided once established in the wild. This too requires some assessment of habitats that can be occupied (e.g., still versus flowing waters, fresh versus brackish waters) and it involves consideration of its likely tolerances of water temperature, salinity and oxygen as these have a bearing on its potential geographic range. However, invasiveness also needs to account for spread by vectors such as anglers, aquarists, birds etc. The information for this assessment is also taken from chapter 4.

Removal of a species from the live import list on the basis of its potential ecological impact would make little sense if it was already widespread in the wild, especially if its continued importation was of high value to the ornamental fish industry. It would only be considered if its continued importation presented an unacceptable disease risk to the Australian Quarantine Investigation Service. Conversely, removal of a species from the list should be seriously contemplated if its risk of becoming a pest is high, its value to the industry is low, and a reduction in its importation would reduce the risk of it becoming more widespread (i.e. propagule pressure is reduced such that the risk of spread and establishment declines). The assessment of whether a species should stay on the live import Part 1 list therefore needs to contrast the potential loss to the industry of removing it from this list against the loss to society if it proves to be a pest species and subsequently results in widespread, irreversible ecological damage. To assess the overall cost/benefit of removing it from Part 1 of the live import list (i.e. of reducing its rate of importation) we took into account the number of fish imported by the industry and the overall value of these (see chapter 7). We also examined the extent to which a curb on imports might restrict its current distribution within the wild (chapter 2) and whether it could be artificially bred in large numbers in Australia should imports be restricted.

These factors are weighed for each species below and our recommendations are based on a judgement of the overall cost-benefit of retaining each species on the Part 1 list.

10.3 Species assessments

Oscar (*Astronotus ocellatus*): Under the right conditions, oscars can grow to a large size (40 cm) and have been shown to be capable of feeding on other small fish as well as on invertebrates. The males display aggressive behaviour to other fish during spawning and this species is known to 'burrow' into the substrate (probably during nest preparation). These attributes collectively indicate a relatively high behavioural potential for impact on native fish and invertebrates.

This species also has a high propensity to spread. It has an oval-shaped, laterally compressed body form and is reported to occur mainly in slow-flowing waters such as occur in the lower regions of rivers and in lakes and reservoirs. Its temperature tolerances indicate a broad potential geographic range but this can be expected mainly in the warmest and hence northernmost regions of Australia. It can inhabit degraded waters such as swamps, ponds, canals and ditches where oxygen levels can be low at times. It is regarded as a good food fish and a sport fish in some parts of the world, so can be expected to be spread by humans. This, together with its wide 'potential' geographic distribution and propensity to cause an impact mean that it has a high risk of becoming a pest species.

Even though the number of oscars imported to Australia is relative low (in the order of tens of thousands) the overall value of importations to the ornamental fish industry is

rated as high. Given its limited known distribution in Australia at present (i.e. Ross River and Cairns), but its high potential for both impact and spread by human vectors, its future distribution needs to be more tightly controlled and in this respect controls over importation would be useful. It can be artificially bred in warm-water aquaria so its transfer from the Part 1 to Part 2 list of the live import schedule should be seriously considered so long as this will restrict rather than promote its spread in the wild. Its long-term future importation status in Australia will depend on clarification of its potential to create impacts.

Blue acara (*Aequidens pulcher*): The blue acara is a small fish (maximum size 16 cm) and it is reported to be an omnivore, but is also capable of feeding on small fish. It too is a bottom disturber. Like the oscar it has an oval-shaped, laterally compressed body form but it is more elongate and hence tends to occur in faster flowing waters as well as in still-water environments such as ponds and canals. It occurs over a wide range of temperatures but because of its ability to occupy flowing water habitats can be expected to have a wider potential distribution in northern Australia than the oscar. Its propensity for spread by human vectors is potentially lower because of its lower utility.

Currently the number imported is relatively low (e.g., low tens of thousands) and its overall value is not as high as the oscar. Given this and its current limited distribution in the wild (i.e. heated water from the Hazelwood Power station near Melbourne, Brisbane creeks and a dam) it should also be considered for transfer from Part1 to Part 2 of the live import list schedule and require a permit before importation. It is readily bred in captivity.

Green swordtail (*Xiphophorus hellerii*): The green swordtail is a small-sized fish (maximum size 14 cm) and it has been shown to feed on small native fish in Australia. Although it is generally peaceful in aquaria, it can be aggressive towards other fish and has been associated with the decline of native fish in several Australian studies so is capable of impacting on the native freshwater fauna of Australia.

It has an elongate, cylindrical body form and occupies more rapidly flowing streams and rivers than the blue acara, but also occurs in still water environments. It tolerates a similar range of water temperatures to the blue acara, but can cope with degraded environments where oxygen levels are often low as well as slightly brackish water environments. It is therefore likely to have a similar distributional range to the oscar, but can be expected to occupy a much wider range of habitats within this. For example swordtails have become established in several small Brisbane streams that are likely to be too cold for the oscar but which contain gambusia (pers comm., Brett Herbert). Although it is used for genetics research in scientific laboratories, it has little other utility than in the ornamental fish industry and so its spread in the wild is likely to be slow and related mainly to releases by aquarists or escapes from ornamental ponds.

Nevertheless, it already occurs sporadically along a wide length of the Queensland coast and this probably reflects its greater use in aquariums and ponds.

It is of high value to the industry primarily because of the large number imported (high hundreds of thousands). Despite this high value, its potential for impact across a wide swathe of Australia is high. Given its current limited distribution in Queensland, it too should be considered for transfer from Part 1 to Part 2 of the live import schedule.

Platy (*Xiphophorus maculatus*): The platy is a smaller fish (maximum size 6 cm) than the swordtail or blue acara and unlike these species is not reported to prey on other fish or to exhibit aggressive behaviour to other species of fish. However, it does eat small invertebrates and so may compete with other fish for food if population densities are high. This could result in the exclusion of other fish from habitats frequented by platys and hence a reduction in the distribution of the native fauna. Although there are reports warning of impacts by platys in other countries, we could find no data to either confirm or deny these. At present, the platy is widely distributed in many waters in coastal Queensland and so it should be possible to test such concerns about its potential impact.

This species is of high value to the industry and has a wide geographic distribution along the Queensland coast. A curb on imports would have little benefit in terms of restricting its future spread in this State but would adversely affect the industry. For this reason, removal of this species from the Part 1 list would be of little use in restricting its spread within this State. Should studies of field populations in Queensland indicate that impacts are occurring, the importation status of this species would then need to be reviewed, particularly as this applies to the potential spread of platy within the Northern Territory and Western Australia.

Sailfin molly (*Poecilia latipinna*): The sailfin molly can grow up to 15 cm in length and is adapted to occupy still or slow-flowing shallow waters. Although there are few studies of its diet in the wild, it appears to be mainly herbivorous and to feed on algal material. It is also non-aggressive and so any impacts on native fauna can be expected to be mainly indirect (i.e. through changes mainly in food webs). Concerns about its potential impact are therefore low but with the caveat that there are few studies of its feeding in the wild to confirm its herbivorous nature.

Its risk of spread is somewhat higher than that for the platy because wild fish are reported to have larger 'sailfins' and this may encourage its release into the wild by some aquarists to create harvestable populations. It is also tolerant of a broad salinity range which increases the risk of it establishing in inland brackish-water lakes. Nevertheless, it is only reported from a few locations along the Queensland coast to date and is less widespread than the platy.

At present, it is a highly valued species with imports ranging in the high hundreds of thousands and, apart from the fact that it is currently known from few locations in the wild (i.e. its distribution in the wild is probably very limited), there is no good reason to justify its removal from Part 1 of the live import list.

Guppy (*Poecilia reticulata*): The guppy is, like the platy, a small fish (maximum size 6 cm) and has not been reported to prey on other fish (apart from its fry). It is omnivorous and is known to be an egg eater, so could affect native fish that spawn on the substrate in shallow waters. There are several reports of impacts in other countries but as yet no evidence has been produced to substantiate these reports.

Like the platy it is already widespread, occurring in coastal waters along the coast from northern Queensland to New South Wales. It prefers warm waters but has a wide tolerance of water temperature and copes with a range of salinities. Its potential geographic distribution is therefore large, but within this it would tend to occupy still or slow-flowing waters rather than faster-flowing waters.

Its widespread distribution in coastal Queensland and New South Wales provides plenty of scope to determine its impact on other fish in the wild in Australian waters and means that there is little point in curbing imports to restrict its spread here, especially as it has high value to the industry. As with the platy, removing this species from the Part 1 of the live import list is not warranted at present. However, should studies of field populations in Queensland indicate that impacts are significant, the importation status of this species may need to be reviewed to restrict its future spread within the Northern Territory and Western Australia.

Three spot gourami (*Trichogaster trichopterus*): The three spot gourami is a medium sized fish (maximum length 15 cm) and is omnivorous. There are no reports of it preying on other fish or displaying aggression and no reports of it affecting native fish in other countries where it has been introduced. This may be taken to indicate a lack of impact potential, but there are few studies of this species in the wild and so it is characterised by a distinct lack of information.

It is found mainly in still or slow-flowing freshwater habitats and can tolerate low oxygen levels. There are no anthropogenic factors known to enhance its risk of spread and it currently has a very restricted known distribution within Australia. However, in its natural habitat, it is reported to undertake seasonal migrations between standing waters and flood plains. This migratory behaviour would enhance its spread within a river system once it is established there.

This species has a high value to the ornamental fish industry because of the high number of imports and a curb on importation would harm the industry. At present there is too little known about it to warrant a recommendation on its importation status.

Goldfish (*Carassius auratus*): The goldfish is a ubiquitous species found in many parts of the world and is not known to directly affect other fish species. It is primarily a detritivore. There is some concern about high densities of this species increasing turbidity levels and promoting blue-green algal blooms in shallow, eutrophic waters. There is also concern about its impact on trout cod (*Maccullochella macquariensis*) presumably as a result of habitat modification. These concerns have not been substantiated to date, and if so, are likely to be limited to habitats where population densities are high.

The goldfish has a wide distribution within south-eastern Australia, mainly occurring throughout New South Wales, ACT and Victoria. This geographic distribution is not expected to change greatly and a curb on importation is unlikely to affect its distribution in the wild. The species is of high value to the ornamental fish industry and therefore there is no ecological justification to remove it from Part 1 of the live import. However, the disease burden is high in goldfish (see chapter 5) and there may well be a strong epidemiological and pathogenic justification for removing it from this list. This aspect of environmental risk is the responsibility of the Australian Quarantine and Investigation Service.

White cloud mountain minnow (*Tanichthys albonubes*): This species is very small (maximum size 4 cm) and does not prey on the adult stage of other fish, although it may consume fry at times. It is likely to be mainly carnivorous, feeding on small insect larvae and zooplankton in small streams. It is a schooling fish and can be aggressive to other species in aquaria, but there is a distinct lack of information on its ecology in the wild.

Although its potential impact on other fish is unknown, its potential to spread is very high because of its tolerance of low water temperatures, its ability to cope with flowing waters, and its promotion (albeit misguided) as an alternative to gambusia for mosquito control. In this sense, its potential geographic distribution could be expected to match and even exceed that of goldfish. Its spread is likely to occur mainly as a consequence of its deliberate but misguided introduction into waters for mosquito control and/or its escapement from garden ponds. But its current known distribution is limited to three sites indicating that, compared with some other ornamental fish species, its introduction into the wild is either rare or that its survival after introduction is very low.

Although this species may not have a major impact on native fish, or be spread rapidly, its potential to spread and likely geographic range is wide. Hence, it could be argued that a curb on importation is needed to help restrict its further spread until its potential to create an impact or not can be better established. However, this species is of high value to the ornamental fish industry because of the high number imported. A curb on importation could harm the industry and if this species can be readily bred

from existing stocks within Australia (e.g., because of its low temperature requirements), then a curb on importation may instead encourage more breeding within Australia and this may then escalate its spread. Clearly, there is an urgent need to better establish the potential environmental effects of this species in Australian waters in order to guide its management.

Rosy barb (*Puntius conchonius*): The rosy barb is a small-sized fish with a maximum length of 14 cm. Although it is not reported to prey on other fish it is omnivorous and in aquaria has a reputation as a 'spawn robber'. In aquaria, rosy barbs are reported to swim near the bottom and a barb can be aggressive if no others are present. Rosy barbs are capable of tolerating moderate water velocities and are likely to form schools. There are no reports of impacts on native fish in the wild, but this reflects a lack of study as against a lack of impacts.

Its ability to cope with moderate water velocities (e.g., fast-flowing hill streams) and its tolerance of relatively low water temperatures means that like the white cloud mountain minnow and goldfish, it can be expected to have a wide geographic distribution in southern Australia if it is allowed to spread. In this sense, its potential invasiveness is high but its potential impact is unknown.

It is a high value- high volume species for the ornamental fish industry and its known wild populations in Australia are currently limited to two locations. A restriction on importation would possibly disadvantage the ornamental fish industry and lead to more breeding within Australia with a consequent greater risk of spread.

10.4 Recommendations

Our assessment of the cost/benefit of allowing continued importation without permit of the species reviewed and currently on the Part 1 list of the live import schedule indicates that three species could be considered for transfer to the Part 2 list (i.e. require an import permit). These are the oscar, blue acara, and green swordtail. Transfer to the Part 2 list implies control over importation by the DEWHA through conditions on importation permits (e.g., more stringent health certification to be applied by AQIS, restriction on where importation is allowed to restrict spread). However, the aim and feasibility of such conditions would need to be more fully explored on a species-by-species basis. Such a transfer would need to be justified by consideration of the wide range of factors involved, including not only the disease risk but also the potential for environmental impacts on native species (see Chapter 4) and the regulatory implications for both DEWHA and AQIS. The aquarium supply industry would be opposed to such a list transfer because it would not restrict the spread of these species within Australia, and would make importation potentially more difficult. Consequently, justification for such a transfer would be required more on the risk of disease importation than on ecological impact grounds.

There is insufficient justification in terms of ecological cost/benefit to remove the other species from the Part 1 list at present. This aside, more information is clearly required on the effect that platys and guppies may currently be having on the native fauna in Queensland waters. These species are already widespread in freshwaters down the Queensland coastline and so it may be possible to obtain such information. If an impact can be demonstrated, then their future spread to freshwater habitats in the northern territory and Western Australia would need to be prevented and a restriction on importation to these States (if administratively feasible) may be warranted.

There was too little information to make any recommendation on the three-spot gourami.

Although information on the potential for impacts was sparse for the white cloud mountain minnow and rosy barb, the ability of these three species to cope with lower water temperatures means that breeding is likely to be much easier in Australia than for the other ornamental fish species. Consequently, the collection of information on the biology and ecological interactions of theses species in the wild is a priority.

The recommendations above are based on ecological cost/benefit considerations and not on threats to fish health posed by introduced pathogens (see Chapter 5). When threats to fish health alone are considered, it is apparent that the goldfish, guppy and three-spot gourami pose a greater risk than other species of introducing pathogens into the wild that could prove damaging to native fish health as well as to other fish resources such as salmonid fisheries and freshwater aquaculture industries. However, there is too little scientific information on the pathogens and parasites present in ornamental fish in the wild in Australia to fully assess these risks. Because of a shortage of funds at present, there is no surveillance and monitoring to determine their prevalence and distribution. In the absence of such funding, there is scope for more public education to reduce the frequency of escapes from garden ponds and of hobbyists releasing aquarium fish into the wild.

AQIS imposed new measures on the importation of live ornamental fish to Australia in 1999 including official health certification, pre-export quarantine of two weeks, and post-arrival quarantine for up to three weeks. The quarantine risk management measures for the importation of ornamental finfish may be reviewed when relevant scientific information becomes available that demonstrates that current risk management measures are not effective.

11. Summary and recommendations

This review of the impacts of ornamental fish species currently established in Australian waters was not intended to provide an analysis of the regulatory structures for alien fish in Australia or to provide comprehensive recommendations for the management of such species. However, it is inevitable that some recommendations will arise from such a review of impacts. The following recommendations are therefore intended to complement those provided by individual states (e.g., DPIQ 2001) as well as those developed for application throughout Australia (e.g., Koehn and MacKenzie 2004; DAFF 2005).

11.1 Distribution and spread of ornamental fish

Thirty species of alien fish used as ornamental pets in either freshwater aquariums or ornamental ponds are now known to have established feral populations in the wild in Australia. Clearly, only a small proportion of the total ornamental fish species present in Australia have wild populations as the total number of species kept in aquaria and ponds is likely to number in the many hundreds. Nevertheless, the addition of 30 alien fish species to the Australian fish fauna represents a potentially large change that could have major implications for native biodiversity in the future.

Some families of fish appear to be over-represented in the wild populations. In particular, 19 of these 30 species are cichlids. In addition, there are 5 poeciliid species, 4 cyprinids, 1 cobitidid and 1 osphronemid species. However, no species in the families Characidae, Cyprinodontidae or Callichthyidae are known to be present in the wild despite the high number of species within these families that are kept in aquaria. Reasons for this apparent disparity are not yet known.

The establishment of ornamental fish in the wild has accelerated over the past decade in Australia and, if nothing is done, it is inevitable that in the future more species will become established and those already present will spread to other areas. Apart from the historic reasons for alien fish introductions (e.g., escapees from fish farms, sport fish enhancement, bait fish, aquatic insect control, flooding of ornamental fish ponds, live discards from aquaria) society is now less tolerant of 'killing' fish and animal ethics considerations will increasingly result in more unwanted ornamental fish being released alive into the wild. This trend is no doubt exacerbated by films such as 'Finding Nemo' which popularize and humanize small, colourful fish. Many aquarium fish species are now widely established in many of the warmer, southern States of the USA, particularly Florida. If northern Australian states such as Queensland are to avoid a similar dilution of the native fish fauna by alien species, then urgent action is required to halt the introduction and spread of more ornamental fish species.

The brief for this investigation required the assessment of 23 of the 30 species known to be present in the wild. In general, most of these 23 species are utilised in tropical

(i.e. warm water > 20ºC) aquaria or garden ponds and can be expected to occur mainly in the more northern regions of Australia. But three species thrive in colder waters and so are likely to occur mainly in the south.

The mapping of the known locations of wild populations for the 23 species reviewed illustrates their current geographical range in Australia and their prevalence within this (Chapter 2). In addition, we provide maps for the known distributions of another four species, known to occur in the wild. It should be noted that for many of these 27 species, this geographic distribution depends to a large extent on sampling coverage and there are many gaps in this. Hence, the maps record only the known presence of wild populations, not where the species is known to be absent, or where its presence/absence is unknown because of a lack of sampling. No distributional data were obtained for three of the 30 species reported to occur in the wild and their status needs to be determined.

Some trends in species distributions are noted in more detail in Chapter 2. In particular, most species occur in freshwaters along the Queensland coastline between Brisbane and Cairns and the highest concentration of species occurred in the vicinity of Townsville. This may well reflect a much higher level of sampling in these areas, but without accompanying data on the number of sites or length of stream sampled in the various regions or States this cannot be determined. Another trend was that the wild populations of many species occurred close to major human population centres. Again this may reflect sampling coverage (close to main centres) as against the release of such fish close to major population centres, but the available data do not permit such a comparison. Nevertheless, it is apparent that ornamental fish species are increasingly being released into the wild in the often mistaken belief that this is a humane way of disposing of unwanted fish and will cause no harm. The overall extent of ornamental fish populations in the wild clearly makes a compelling case for public education programmes to rapidly debunk this false paradigm.

Limitations in sampling coverage aside, it is apparent that some species of ornamental fish are both widespread and relatively common (e.g., goldfish) whereas others, while being widespread, have highly localised distributions (i.e. only a few wild populations occur, but these occur over a wide latitudinal or longitudinal range). Other species are highly localised and are currently known to be present in only one location.

Mapping provides a useful tool for the management of alien fish species and where accurate can be used to monitor spread, determine priorities for management and help identify optimal management strategies (e.g., containment versus control). It should be noted that mapping is also a key tool for the management of native fish species. The mapping exercise undertaken for this investigation revealed an urgent need for coordination and control over the recording of fish species occurrence in Australian

waters and the need for integration and/or coordination of such efforts between States and Territories.

We therefore propose the following recommendations:

1. Explore the feasibility of adopting a national freshwater fish database through consultation with the Australian Society of Fish Biology (ASFB), the Australian New Guinea Fish Association (ANGFA) and the relevant state, territorial and national agencies.

2. In the interim, set up a national database on the distribution of ornamental fish species in the wild to collate all records of both presence and absence from across Australia. In conjunction with this, encourage further field surveys to fill in the gaps in sampling coverage.

Other recommendations stemming from the mapping exercise include:

3. Support taxonomic studies to confirm the identification of species where there is potential for confusion and uncertainty (e.g., hybrid crosses, oriental weatherloach, cichlids) and more particularly, ensure that there are good keys available to all field biologists to aid in the identification of all ornamental fish species in the wild.

4. Confirm the presence in the wild for the three species reported to be present, but for which no geographic data could be obtained (i.e. blue tilapia, redhead cichlid, Sumatra barb).

5. Confirm the limited presence of breeding populations for species currently known from just 1 or 2 locations and assess their risk of spread along with the feasibility of containment and/or eradication.

6. Investigate the causes of 'hot spots' for species incursions in northern Queensland and develop targeted public relations campaigns to counter the release of ornamental fish species in these places, as well as in Queensland and nationwide.

11.2 Reviews of impact assessments

The review of impact assessment methodologies (Chapter 3) revealed that a wide range of approaches and methods are used, extending from quick (and therefore relatively inexpensive) desk-top risk assessments to a multi-year, triple-bottom-line impact assessments incorporating hypothesis-based field studies of both the nature and mechanism of impact across a range of both ecosystems and geographic regions, together with economic and social analyses of the costs of these impacts. In practice, most assessments are carried out with limited funds and time and are therefore of limited extent and predictive value. The ecological impact assessments carried out for ornamental fish species in Australia to date are limited to few species and are limited in scope, probably because of funding and time constraints. The huge gap between the information actually required for good decision-making and the information available does not reflect a lack of good scientific methodology. Rather, it reflects the fact that

resource managers and hence researchers rarely have the time and resources for full impact evaluation.

Where limited resources and cost/benefit considerations occur, a judgement needs to be made as to the level of impact that is acceptable given the type of assessment that is affordable. In the case of ornamental fish species, where such 'proof of impact' may trigger management actions and costs, this would be best achieved by prior agreement among stakeholders and biologists as to what is an acceptable level of proof (i.e. establishing the 'burden of proof'). This is a social approach to this issue, not a scientific one and it increases the risk of 'Type 1 and II errors'. In particular, accepting that there is no significant impact from an alien species and being wrong can result in an expensive problem for society that may be irreversible and everlasting. Conversely, accepting that there is an impact and being wrong, may involve a high initial economic cost, but this would not be ongoing, so will be cheaper in the long term. Such temporal economic considerations support a precautionary approach.

The literature search and review of impacts for the 23 aquarium species now in the wild in Australia indicated how little is known of the ecology of these species in their natural range, let alone in Australia (Chapter 4). This lack of information severely limits the quality and predictive power of the assessments and indicates that there is an urgent need to fill the main information gaps.

This aside, it is apparent that a number of the species have the potential to become widespread pests. In particular, species that are relatively large and carnivorous and which are capable of direct impacts on a wide range of native fish through predation are a major concern. These include the oscar, three spot cichlid, Jack Dempsey, red devil tilapia and Midas cichlid. These species can all be expected to inhabit still or slow-flowing, fresh-water habitats in the warmer northern regions of Australia. Of these five species, the oscar and Jack Dempsey can tolerate low oxygen levels and so can inhabit degraded waters. At present, the oscar is only reported from two locations in Australia which means that any future ecological impact assessment would be limited in scope. However, the red devil is reported from three locations, two of which are enclosed, still-water environments and these may therefore present a better opportunity for an ecological impact assessment of this species than the others.

The smaller carnivorous fish that can also prey on smaller native fish are also a concern, especially if they are also aggressive towards other fish species. Such species include the convict cichlid, blue acara and the green swordtail. These three species all tolerate higher water velocities than the species listed above so can be expected to occur in rivers and streams as well as in standing waters. The convict cichlid occurs over a wider temperature range than the other species but the green swordtail, while likely to be confined to warmer waters can also tolerate saline waters and low oxygen habitats. These two species therefore have a greater invasive potential than the blue

acara. Of these species, the green swordtail currently has the widest distribution in Australia with populations in the Northern Territory, Queensland, New South Wales and Western Australia. In addition it is a livebearer so can rapidly establish large populations from relatively few individuals. It should be a major priority for investigations focused on impacts.

Some of the species that are not predators of other fish also need to be considered as threats. Although impacts on other fish are indirect, they can nevertheless displace native fish species from key habitats through aggression, competition for food, disruption of reproduction and habitat modification. The black mangrove cichlid, redbelly tilapia and Mozambique tilapia fall into this category. They are all relatively large fish (up to 40 cm long), and although they are primarily herbivorous as adults, they may have the potential to displace native fish through aggressive behaviour during the spawning season. Similar behavioural traits have been attributed to the jewel cichlid. Although it is a much smaller fish, such traits can also be expected to result in negative interactions with small native fish. Both the redbelly tilapia and Mozambique tilapia have also been reported to be aggressive to other fish and are substrate diggers. They have a wider temperature range than the black mangrove cichlid, can tolerate brackish water conditions and are more likely to be spread because of their aquaculture and sport fish values. The Mozambique tilapia also tolerates low oxygen levels. Given its slightly greater invasive potential and the greater number of wild populations in Australia it is clearly a priority species for research to determine the nature and scope of such indirect impacts on other fish.

The platy, sailfin molly, guppy and caudo are all livebearers which can establish from relatively few individuals and are closely related to gambusia which is a known pest fish. However, the caudo has been reported to displace gambusia and so may present an even greater threat. It tolerates brackish waters and has been used for mosquito control so may well spread more readily. It is now present in three locations in Australia (two in New South Wales, one in Perth) and is also a priority for impact assessment in both states, as environmental conditions and native fish populations differ between them and may influence the scope for impacts.

The remaining five species (oriental weatherloach, goldfish, rosy barb, sumatra barb and white cloud mountain minnow) all occur naturally in colder waters than the other species and thus have a greater potential distribution within the southern regions of Australia than most other ornamental fish reviewed. Although there is little known about the oriental weatherloach it has been associated with the decline of small galaxiid fishes in Australia so is also a high priority for research into impacts.

Of the remaining species, the rosy barb and white cloud mountain minnow occur in streams as well as in still water environments. The former species is reported to be an egg eater whereas the latter can be aggressive to other species and is a carnivore.

These two species also need urgent investigation to determine whether they pose a threat in Australian waters.

Overall, the review of impacts has revealed significant cause for concern over some, but not all, ornamental fish species in Australia. However, there is very little hard evidence to support such concern and virtually no definitive knowledge of mechanisms. This situation needs to be addressed urgently so that management of priority species is underpinned by good science. This situation led to our seventh recommendation:

7. More comprehensive impact measurement is urgently required for species identified as high priorities based on the type of impact expected, their invasive potential and existing reports of potential effects on other fish. These include the Mozambique tilapia, oscar, three spot cichlid, Jack Dempsy, red devil, Midas cichlid, convict cichlid, blue acara, green swordtail, oriental weatherloach and rosy barb and white cloud mountain minnow.

The assessment of the fish health risks associated with the spread of wild populations of ornamental fish (Chapter 5) underlined the importance of this often neglected issue. The presence of wild populations increases the risk that some pathogens and parasites associated with ornamental fish will find their way into native fish populations but, at present, this has been little investigated. There is also a lack of information on the pathogens and parasites associated with ornamental fish. An even greater gap concerned the parasites and pathogens of native fish. Ornamental species identified as posing a high risk in terms of the spread of diseases included the goldfish, three spot gourami, and all of the poeciliid species. However, the Mozambique tilapia, oriental weatherloach and rosy barb are also of concern and are rated as medium risk species. Several practical ways of filling the knowledge gaps are recommended. They are:

8. Increased surveillance of the parasites and disease agents of ornamental fish traded internationally.

9. Increased surveillance and taxonomic study of the parasites and disease agents of Australian native fishes in the wild.

10. Increased surveillance, taxonomic and epidemiological study of the parasites and disease agents of introduced fishes.

Practical ways of mitigating disease threats posed by the establishment of ornamental fish species include:

11. Increased public education to reduce the incidence of escapes of ornamental fish in ponds into the wild and of hobbyists releasing aquarium fish into the wild.

12. Providing Biosecurity Australia with relevant new scientific information to support a review of current quarantine risk

management measures when this information demonstrates that current risk management measures are not effective.

The genetic threats of hybridisation, introgression and breakdown of species boundaries associated with the spread of ornamental fish in the wild in Australia are viewed as negligible (Chapter 6). This is because the Australian freshwater fish fauna is highly endemic and it does not include the main fish families represented by the alien ornamental fish species now in the wild. However, a future risk may be posed by hybridisation among the alien species now in the wild with the resultant production of genetically different morphs with increased adaptability to the Australian environment. To minimise this risk, attention should be focused on locations in Australia where two or more closely related alien species co-occur to determine whether hybridisation occurs and whether any resultant hybrids pose a risk. Artificial mating of such species could be trialled under laboratory conditions to test the viability of hybrids. The recommendation to deal with this issue is:

13. Monitor sites where two or more closely related ornamental fish species now co-exist to determine whether hybrids develop. Test for hybridisation potential by cross-breeding these species under laboratory conditions.

11.3 Socio-economic values of ornamental fish in Australia

The economic analysis of the ornamental fish industry (Chapter 7) revealed a number of significant statistics that collectively describe the industry (Table 11.1). Because of the lack of information on the environmental impacts of wild populations of ornamental fish species in Australia, no meaningful economic or social analysis of the costs of these could be made. However, a comprehensive review of methods variously used to determine the socio-economic costs of environmental impacts resulted in the recommendation of an innovative population dynamic-based methodology. This could be readily adapted to determine the environmental costs of ornamental fish on native fish species. However, the use of such models depends on having adequate 'input' data and this will be lacking until there is a much better quantification of the actual impacts that ornamental fish are, or may be, having on other fish.

It was not possible to compare the socio-economic value or ecological impact of ornamental fish with other stressors of the native fauna, including other alien fish species, altered flow regimes, water quality decline, degradation of habitats or barriers to fish movements (Chapter 8). Comparisons have been made between a number of feral animals (e.g., fox, cat, mouse, rabbit, cane toad) and common carp (Chapter 7), but too little is known about the impacts of ornamental fish to permit even a subjective assessment. The estimated cost of the effect of common carp in Australia was approximately $16 million. This is for just one species of fish and if only a quarter of the ornamental fish species now present in the wild in Australia proved to be pests and involved a similar order of costs, then the total figure could be as high as $120 million.

Table 11.1: Statistics describing the ornamental fish industry in Australia.

Variables describing the industry	Value (A$) or number
Value of ornamental fish trade in Australia	$350 million/annum
Number of pet shops and aquarium shops	1025
Staff employed	6150
Annual turnover	$970 million/annum
Consumer expenditure on aquarium fish	$75-90 million/annum
Value of aquarium fish exported	$1.4 million/annum
Value of aquarium fish imported	$4.2 million/annum
Number (and % of total) of aquarium fish kept in New South Wales	$4.2 million (34%)
Number (and % of total) of aquarium fish kept in Victoria	$3.0 million (35%)
Number (and % of total) of aquarium fish kept in Queensland	$2.2 million (18%)
Number (and % of total) of aquarium fish kept in Western Australia	$1.2 million (10%)
Number (and % of total) of aquarium fish kept in South Australia	$1.0 million (8%)

11.4 Management of ornamental fish

The Natural Resource Management Ministerial Council (NRMMC) has produced a strategic approach to the management of ornamental fish in Australia (NRMMC 2006) and this makes a number of recommendations concerning national coordination of the regulatory framework related to ornamental fish. It proposes a noxious species list and a grey list of species and the information in our review provides information relevant to the status of species on these lists and the potential addition of other species to them.

The review of methods for the eradication and control of pest fish species (Chapter 9) revealed that a wide range of methods and combinations of methods are used to reduce populations of pest fish and that there is ongoing research to develop new methods. This review was limited to control and eradication methods and thus did not deal with the issue of containment. For many species with a limited geographical distribution, eradication may not be feasible and containment and minimisation of the risk of spread may be the most viable option. This is likely to be especially important for populations located in the higher altitude regions of catchments because flooding and subsequent downstream movement of larvae and juveniles can be expected to spread such populations downstream. One strategy for containment may be an on-going reduction in abundance to reduce the number of individuals (i.e. the potential propagules available for spread). Today containment may involve some fish control, but is based mainly on public education and monitoring of nearby waters to detect new incursions.

Only some of the control and eradication methods reviewed in Chapter 9 are applicable to ornamental fish. In particular water removal by pumping, and chemical treatment using rotenone or lime, have been used to successfully eradicate small populations of some ornamental fish species in Australia. Electric fishing is also used

to reduce fish numbers and hence provided a degree of control. The review indicated that there is no standard treatment and that the best options need to be determined for each pest fish population within each ecosystem. The review also indicated that control or eradication cannot be carried out in isolation and that some methods will remove native species along with the pest fish. Consequently management of wild populations of ornamental fish species may in some circumstances require public consultation and the preparation of plans that place control within a wider socio-economic framework. In some cases there may be need to carry out cost/benefit studies for the control method and this will generally require monitoring to determine the effectiveness of control as well as its cost. Public education programmes are also necessary to prevent re-introduction. The report on a strategic approach to the management of ornamental fish in Australia (NRMMC 2006) recommended that stakeholders agree on control mechanisms to be used for noxious fish. This will be required to resolve issues concerning the safe use of piscicides and potential damage to native species.

The review of the importation status of the ten species currently on the Part 1 list of the live import list (i.e. require no permit to import) recommended the transfer of three species to the Part 2 list (i.e. require an import permit) on the basis of their overall potential cost/benefit (Chapter 10). These species are the oscar, blue acara and green swordtail. There are other species where there is concern over impact but too little is known of the ecological impact to recommend transfer from the Part 1 to Part 2 list. Several species that are already widespread in Queensland may have an impact and if proof of this is obtained then removal from the Part 1 list may help restrict their future spread to other States. Conversely, the absence of significant impact would cement their place on the Part 1 list.

Transfer of species from Part 1 to Part 2 of the DEWHA live import list may prevent introductions from overseas to states or territories where there are currently no feral populations. However, this would not affect interstate transfers. Because of this, transfer of these species to the Part 2 list would be opposed by the industry because it would be impractical and not serve the intended purpose of restricting spread within Australia. Self-regulation by the industry coupled with public education at the point-of-sale to the public may prove a more practical and effective way of restricting spread into the wild. Other forms of self-regulation by the industry may prove equally viable. Consequently, means of restricting species spread within Australia through industry self-regulation need to be explored and developed.

An analysis of the pathogenic risk posed by all 23 species recommended that the goldfish, three spot gourami and all poeciliid species be removed from the live import list and that these species be propagated by breeding in Australia.

14. On the basis of their environmental cost/benefit, the future spread of oscar, blue acara and green swordtail within Australia needs to be

restricted. The options for accomplishing this need to be identified and evaluated in consultation with the aquarium industry.

15. In order to minimise the risk of importing and spreading new fish diseases into Australia via the importation of goldfish, three spot gourami or poeciliid fish, especially the guppy, the Commonwealth consider further scientific advice from independent experts to determine whether the current quarantine measures are stringent enough to avert this risk.

11.5 Overview

This report has mapped the current known distribution of 27 species of ornamental fish that have established wild populations in Australia, and it has reviewed information on the environmental impacts of 23 species. In addition to environmental impact assessments, the risks posed by the spread of parasites and pathogens and by the introduction of alien genomes are reviewed and discussed. The report also presents an economic evaluation of the ornamental fish industry in Australia and an appraisal of the overall impact of ornamental fish in Australian waters within the context of other stressors of freshwater ecosystems. Although the evidence for negative environmental impacts is currently very limited, it is nevertheless clear that there are major causes for concern with some species, and that there is scope for a precautionary approach to their management. These concerns indicate an urgent need to obtain more information on the type and scope of impacts posed by the certain species together with the potential socio-economic costs of these impacts so that management frameworks to address the need for education and control can be developed.

In retrospect, it is perhaps fortunate that so few of the potential hundreds of ornamental fish species that could have been released into the wild in Australia have become established. However, it is also apparent that more releases will continue in the future unless action is taken to reduce the main vectors for spread. This prospect needs urgent attention because the potential environmental problems posed by even a few of the 27 species currently known to be established, let alone additional species, could be hugely significant and much greater than for other pets such as dogs, cats and birds. Experience has already shown that some native fish species inhabiting the cooler regions of Australia have been negatively affected by the introduction of sport fish such as trout and perch and by gambusia (mosquitofish). Now, ornamental fish collectively pose a similar if not greater threat to the native fauna in the warmer, northern and inland regions of Australia. Because of the greater number of species now present, the chances of at least some of these having a negative effect on the native Australian fauna is high and this risk can only increase as the number of introductions to new locations increases.

This potential problem requires the cooperation of the DEWHA and the ornamental and pet fish industry in agreeing on an acceptable way of dealing with the issues. This report makes a number of recommendations that address the main management issues and it is hoped that these will collectively form a platform from which progress can be made firstly to resolve the problem of on-going releases and secondly, to better identify the impact that existing wild populations may be having. Although progress will clearly involve a widespread and significant change in public attitude to the danger of alien fish establishing in the wild, it will also involve the formation of a sophisticated and nationally coordinated strategy to evaluate the various risks and to deal with issues at both a federal, state, territorial and local level. In this respect it is hoped that both the DEWHA and the ornamental fish industry play a leading role in developing the required initiatives.

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14. Appendices

14.1 List of contacts who were sent the first questionnaire.

Organisation Type	State	Organisation	Contact Name	Expertise
Research	ACT	AFFA	Mary Bomford	exotic species
Research	ACT	Wildlife Research & Monitoring	Mark Lintermans	exotic fish introduction
Research	ACT	Wildlife Research & Monitoring	Brendan Ebner	native fish (vulnerability to exotics)
Government	ACT	Biosecurity Australia	Warren Vant	Contact officer for the Policy Review On The Importation Of Freshwater Ornamental Finfish: Risks Associated With Iridoviruses
Research	NSW	Southern Cross University / ASFB	Andy Moore	fish genetics / exotic fish species rep
Government	NSW	NSW Fisheries (name change)	Michael Holloway	NSW Contact Person regarding control of exotic Pest Fish
Government	NT	Northern Territory Seafood Council		Referred to in the NT aquarium fishery status report 2003 is the peak body representing the licenses of the Aquarium Fishery. The NTAA operates under the NT Seafood Council (NTSC). Member are drawn from the Aquarium Fishery and from the NTSC
Government	NT + WA	DPIF&M	Andria Marshall	Program Coordinator- Aquatic Pest Management
Government	NT	DPIF&M	Helen Cribb	Research Officer
		DPIF&M	Alex Beatty	Technical Officer
Research	Qld	Griffith University	Angela Arthington	Ecology of exotic fish risk assessment (Tilapia, Poecillidae)
Research	Qld	Griffith University	Mark Kennard	exotic species and links with disturbance
Research	Qld + NT	JCU	Damien Burrows	fish sampling in FNQ and knowledge of study in the Burdekin. Just started a major exotic pest sampling program in the NT and is keen to help us out and hear about our study.
Government	Qld	QDPIF	Amanda Dimmock	Qld Contact Person regarding control of exotic Pest Fish
Research	Qld	JCU	Alan Webb	Exotic fish ecology (particularly Tilapia and Red Devils)
Catchment Management Groups	Qld	Mary River Catchment Committee	Dale Watson	knowledge on exotics in the Mary River
Catchment Management Groups	Qld	Mary River Catchment Committee	Brad Wedock	knowledge on exotics in the Mary River
Government	Qld	Queensland Institute of Medical Research	Tim Hurst	native species for mosquito control in SEQ (translocations for residential use)
Aquarium fish stakeholder group	Qld	ANGFA	Bruce Hansen, Jeff Gunston	native aquarium fish hobbyist group
Government	SA	PIRSA	John Gilliliand	Marine Invasive Species (but covers freshwater)
Government	SA	PIRSA	Helen Croft	Compliance officer for introduced pests
Government	Tasmania	Inland Fisheries Service	Jean Jackson	Control of fish pest species
Research	Tasmania	University of Tasmania	Peter Davies	fish biologist / salmonids / fish database for Tas
Research	Tasmania	University of Tasmania	Scott Hardie	just finished PhD
Research	Tasmania	University of Tasmania	Rick Stuart-Smith	just finishing masters, plans to explore fish faunas in the Pacific
Research	Vic	Arthur Ryllah	Tarmo Raadik	exotic fish introduction
Research	Vic	Arthur Ryllah	John Koehn	exotic fish introduction
Research	Vic	Primary Industries Research Victoria	Wayne Fulton	fish biologist / risk assessment for salmonids
Commercial	Vic	Lloyd Environmental Pty Ltd	Lance Lloyd	Translocation Evaluation Panel member in Vic
Research	WA		Brad Pusey	exotic species and links with exotics and disturbance
Research	WA	Murdoch Uni	David Morgan	Introduced species in WA
Research	Fiji	Marine Studies Program, The University of the South Pacific	Patricia Kailola	exotic fish introduction

14.2 First questionnaire

We Need Your Help in understanding the current distribution of ornamental fish that have established populations in Australia's waterways.

NIWA Australia has been commissioned by the Department of Environment & Heritage (DEH) to lead an overview of the risks associated with ***established*** ornamental fish in Australia's waterways. This is a nation-wide study that will examine the ecological and socio-economic impacts associated with such species, the suitability of various control and eradication options and, which knowledge gaps require priority attention. For more details about this project, please contact Damian McRae, DEH's project officer for this study (Email: Damian.McRae@deh.gov.au; Ph: 02 6274 2524; Fax: 02 6274 1332). In order to complete our study, we require your assistance in identifying where introductions have occurred (including habitat information where possible) and how far these species have spread so far. We would be grateful if you could complete the following short questionnaire and return it to Anthony Moore at the earliest possible convenience (before 30/11/05). Anthony's contact details are:

Anthony Moore
Graduate Research College
Southern Cross University
PO Box 157 Lismore
NSW 2480
Ph: 02 66 269 437
M: 04 2826 5720
Email: amoore@scu.edu.au

Thank you in advance for your assistance.

Dr Jamie Corfield
Environmental Scientist
NIWA Australia Pty Ltd
j.corfield@niwa.com.au
www.niwa.com.au

Your name		State	

Common name of fish	Scientific name of fish	Tick if you know of any wild populations of these in your State
Red devil	*Amphilophus labiatus*	
Midas cichlid	*Amphilophus citrinellus*	
Oscar	*Astronotus ocellatus*	
Convict cichlid	*Archocentrus nigrofasciatus*	
Black mangrove cichlid	*Tilapia mariae*	
Redbelly tilapia	*Tilapia zillii*	
Three-spot cichlid	*Cichlasoma trimaculatum*	
Victoria Burton's haplochromis	*Haplochromis burtoni*	
Jewel cichlid	*Hemichromis bimaculatus*	
Mozambique tilapia	*Oreochromis mossambicus*	
Blue acara	*Aequidens pulcher*	
Jack Dempsey	*Cichlasoma octofasciatum*	
Hybrid cichlid	*Labeotropheus/Pseudotropheus cross?*	
Three-spot gourami	*Trichogaster trichopterus*	
Oriental weatherloach	*Misgurnus anguillicaudatus*	
Goldfish	*Carassius auratus*	
White cloud mountain minnow	*Tanichthys albonubes*	
One-spot livebearer	*Phalloceros caudimaculatus*	
Sailfin molly	*Poecilia latipinna*	
Guppy	*Poecilia reticulata*	
Green swordtail	*Xiphophorus hellerii*	
Platy	*Xiphophorus maculatus*	
Rosy Barb	*Barbus (Puntius) conchonius*	

Please list the contact details of anyone else you think might know of wild populations of these fish in your State.

Can we contact you again to get more detailed information **(Y/N)?**

If Yes, Anthony or myself will contact you by phone.

14.3 Follow-up questionnaire

Phone/email follow up to Questionnaire

THE KEY INFORMATION WE NEED IS:

1. Locations (GPS, or map coordinates, or sufficient info for us to get a map reference (e.g. large pond about 12 km north of Geelong, on the Watt's farm.).

2. Information on habitat (type of water –lake, pond, wetland, stream, billabong, river, maybe habitat type in running waters (e.g. pool, run riffle etc.), max. water depth, location of fish (edge/ middle), capture method/place, substrate composition (silt, sand, rock etc) , presence of plants and other cover, salinity if known, water clarity, other fish present etc.). This could be a nearly endless list. Better to keep it reasonably succinct and general to start with. Can always go back to source later if some key question not asked. In many cases knowledge of environment may be very general.

3. Evidence for the citing (who made observation, what was observed/measured, who identified species, were juveniles seen, when was observation made year and month if known).

4. Whether or not any attempts for control or eradication have been made (method, frequency and location details).

5. Whether population or distribution monitoring is taking place (method, frequency and location details).