A sustainability assessment of marine fish species collected in the Queensland marine aquarium trade

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Front cover image: Fire coral with damselfish, Elford Reef, Queensland (photograph courtesy of A. Roelofs).

INTRODUCTION

The Queensland Marine Aquarium Fish Fishery

The Marine Aquarium Fish Fishery (MAFF) is a diver based, hand harvest fishery that has commercial and recreational fishers collecting a diverse suite of marine fish species for use in either private or public aquaria.

Operating since the 1970s, the MAFF supports 49 collection licences (in 2007) and occupies a vast area along the east coast of Queensland within the bounds of the Australian Fishing Zone (AFZ) (Figure 1). It is a predominantly commercial fishery, with most collection occurring in coastal and reef waters off Cairns and in South East Queensland. The total annual number of fish and invertebrate specimens collected in the MAFF was around 170 000 individuals in 2006 (Department of Primary Industries and Fisheries 2008). Although this is not an insignificant amount, the MAFF is small when compared to the global aquarium trade which ranges from 20 to 24 million individuals annually (Wabnitz et al. 2003). While a diverse assemblage of fish species are targeted for the aquarium trade, much of the trade tends to be centred on a limited number of individual species (e.g. blue green chromis, humbugs).

The Department of Primary Industries and Fisheries (DPI&F) manages the MAFF for sustainability, under the *Fisheries Act 1994* and *Fisheries Regulations 1995*. This legislation provides a variety of management controls to regulate the level of take within the fishery (e.g. regulating the species that may be taken, applying bag limits to commercial and recreational operators, fishing gear restrictions for commercial and recreational operators, limited entry, limited number of divers per licence, Special Management Areas and closed waters during spawning season) (Ryan & Clarke 2005). Permanent spatial closures across the fishery (e.g. Great Barrier Reef Marine Park) also offer protection from harvest and provide refuges for biodiversity and recruits.

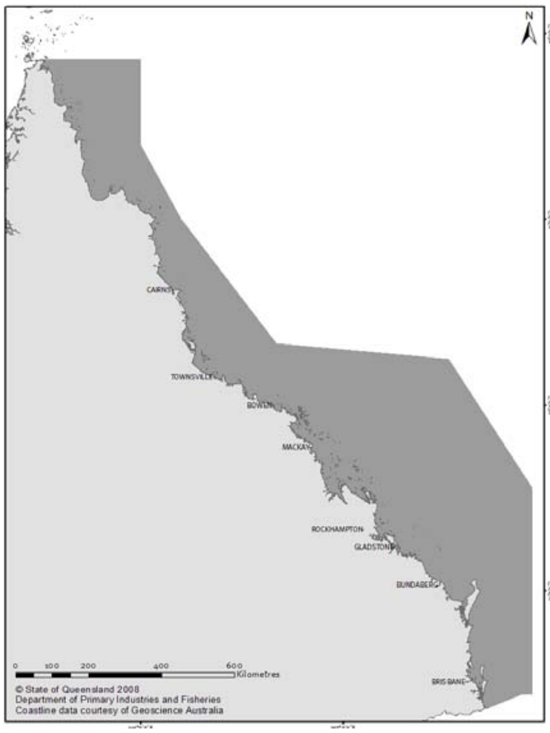

Figure 1: Map of the Queensland Marine Aquarium Fish Fishery

Effort in the fishery is further restricted by the number of active divers allowed per licence, diving safety limits (depth and duration of dive) and environmental factors such as weather and water turbidity. Together, these factors are used to assess site access and catch rates. Notably, not all fish species are equally valuable or attractive to the industry, and collection of a particular species is not always governed by simple factors such as whether a fish is abundant and easily caught.

This Study

Our assessment provides a simple and flexible structure for evaluating species sustainability within the MAFF. By quantifying the level of risk to species sustainability from collection activities in the fishery, specific management measures to mitigate fishing impacts can be developed for those fish species evaluated at medium to high risk. The sustainability assessment is intended to foster consistent approaches to ecological risk assessments of the MAFF, by identifying key issues, and defining terms used in these assessments.

This study comprises two separate processes to evaluate marine aquarium fish species sustainability: a vulnerability assessment and a susceptibility assessment. The framework for this study is conceptually similar to the approach taken by Ponder & Grayson (1998) to assess the risk posed to Marine gastropods by collection activities. First, a vulnerability assessment was conducted, with a defined set of ecological values regarding distribution & accessibility, market value and ecological niches. Additionally, our study included an evaluation of a species' ability to recover from unregulated collection. The approach is similar to that taken for assessing sustainability of shark and ray species in northern Australia (Salini et al. 2007). This susceptibility assessment considered the capacity of individual species to recover populations, the foundation of which lies within their life history traits. The susceptibility assessment recognised several issues that are integral to, but separate from, the vulnerability assessment process, including fecundity, longevity and development.

There are no similar studies conducted for marine aquarium fish in Australia. The Western Australian Marine Aquarium Fishery was assessed using an Ecological Risk Assessment framework developed by Fletcher et al. (2002). However, Fletcher et al.'s (2002) study used working groups to determine the scope of issues requiring an assessment of risk at a qualitative level. This study provides a quantitative approach to define issues at the species level (i.e. vulnerable species) before a risk assessment with management responses is developed.

Marine aquarium fish vulnerability

A species' vulnerability to collection depends on a number of life history traits, in particular growth, lifespan, reproduction and recruitment (Shuman et al. 2005). Many of the species collected for aquaria are small, brightly-coloured and have high survival rates in captivity. However, there is also a demand for larger 'showy' individuals and for 'curiosities' such as the frogfish. Often, the males of many reef species are targeted due to their distinctive colouration and patterns. Male damsel and wrasse species are preferred to plain-looking females, and regularly attract higher prices on the market.

Life history strategies underpin demography and population dynamics, and therefore are a key factor for determining a species intrinsic vulnerability to decline, recovery potential and ultimately extinction risk (Jennings et al. 1999; Dulvy et al. 2004). The selective removal of males from particular populations may ultimately lead to an increased risk of reproductive failure within the community and, in time, a population collapse due to a biased sex ratio (Wabnitz et al. 2003).

Age at maturity, sex selection, habitat requirements, fecundity and diet may all alter the way fish species interact and recover from intensive harvesting pressures. Life history studies of certain fish species have revealed close relationships between maturation and growth parameters (Pauly 1998). These correlations suggest that the maximum size may be a useful surrogate for a species' life histories, therefore predicting a species vulnerability to intensive harvesting practices (Jennings et al. 1999). Individuals in the families Lutjanidae (snappers), Scaridae (parrotfish), and Epinephelinae (groupers) exhibit a range of life history strategy combinations, such as large size and late maturity, that make them vulnerable to overexploitation and reduce their capacity to recover populations (Dulvy et al. 2004).

Coral reef fish exhibit a wide variety of mating strategies, ranging from mass spawning events to established nests and paternal mouth brooding. Just as mating systems differ amongst species (Wabnitz et al. 2003), fish also display unusual plasticity in their sexuality. For some species sex is not set and is determined through various social interactions during their lifespan (Hobbs et al. 2004). Anemonefish, for example, all commence life as males (protogyny), with the largest individual within the anemone being the dominant female (Richardson et al. 1997). Should the female be removed from the anemone, the largest male changes sex and becomes the dominant female. When a fishery is selectively removing larger animals from the environment, individuals will be forced to change sex at a smaller size, thus possibly leading to a decrease in reproductive fitness, whilst making hermaphroditic stock more vulnerable to overfishing (Emata 2003).

The greatest threats posed to the aquarium fishery are destructive and unsustainable fishing practices. The use of sodium cyanide and other chemicals to stun and catch fish for the aquarium marine trade are still being used to some extent within many undeveloped nations (Kolm & Berglund 2003). This type of harvest, which is highly destructive and devastates vast areas of reef, is banned in Queensland. The MAFF uses non-destructive methods such as hand nets and barriers, which rarely result in damage to fish, corals or reef structure.

Improving technologies and greater efficiency in fish collecting are likely to increase the exploitation of coral reef species from isolated or deep water reefs. A few divers in the MAFF are experimenting with rebreathers and mixed-gas diving to access deeper habitats for longer collecting periods. Many sought after species use deep water drop-offs and bommies as spatial refugia (Best 2002). As very little is known about the ecology of these deeper reefs and the potential impacts from exploitation, it is difficult to monitor and manage these species effectively.

Other impacts on fish sustainability

Although there are extensive management measures in place to support a sustainable fishery, other external pressures on aquarium fish species (e.g. life history strategies and habitat preferences) may affect their sustainability and are beyond management control. For example, many fish species in the MAFF have critical associations with coral reefs for habitat and food. Factors negatively affecting coral habitat are likely to have transferred effects on coral reef fish species dependent on that habitat. This study aims to understand and quantify the risk to sustainability associated with a wide variety of external factors on aquarium fish species in Queensland.

Coral reef structures, as fish habitat, are subject to many threatening processes (Williams et al. 1990; Brown 1997; Munday 2004; Munday et al. 2008; Pratchett et al. 2008). Tropical coral reefs are affected by frequent, often catastrophic disturbances such as severe tropical storms, freshwater plumes and sedimentation from floods, as well as unseasonal temperature extremes (Pratchett et al. 2006b). Changes to the physical and biological structure of reef habitats often have detrimental effects on reef-associated organisms, particularly coral reef fishes (Wilson et al. 2006; Munday et al. 2008). Several studies have documented significant declines in the abundance of coral reef fishes, and even localised extinctions, following extensive depletion of hard coral, especially among fish species that rely on coral for food or shelter (Kokita & Nakazono 2001; Munday 2004; Pratchett et al. 2006a). Among coral reef fishes, the species most likely to be affected by coral disturbances are obligate coral-dwelling or coral-feeding species, including numerous Damselfishes (Pomacanthidae), Gobies (Gobiidae), and Butterflyfishes (Chaetodontidae)(Kokita & Nakazono 2001; Pratchett et al. 2008).

There are also new challenges to coral reef fish sustainability. The increased magnitude and frequency of coral bleaching in response to global warming has caused rapid changes in the community structure of coral reefs on a global scale (Williams et al. 1990; Brown 1997; Munday et al. 2008). These changes involve both declines in the abundance of scleractinian corals, and changes within the community composition of many corals (Munday 2004). The loss of live coral on the central Great Barrier Reef from widespread bleaching events has been shown to have negative effects on some small coral reef fish species (Pratchett et al. 2006b; Pratchett et al. 2008).

Although marine reserves can be an effective management strategy for protecting marine biodiversity, there is growing recognition that such areas cannot protect reefs from large-scale coral bleaching events. Marine reserves are necessary to control the top-down impact of harvesting; however, they must also be combined with management strategies that fundamentally address bottom-up processes such as sedimentation and coral bleaching (Jones et al. 2004).

METHODS

We ranked 587 fish species for their vulnerability and susceptibility to collection activities carried out in the MAFF. The species list was collated using stock and species lists provided by a selection of MAFF operators ranging from the south, central and north regions of the fishery. The species list therefore does not represent the entire suite of species that potentially may be collected (approximately 2000); however the list comprehensively represents those that are presently collected. A database was created in Microsoft Access® to store information related to the ranking criteria for each of the 587 aquarium fish species considered in this study.

The overall vulnerability and susceptibility risks for each fish species were determined from the cumulative score of the rankings from each criterion.

Vulnerability Criteria

A set of criteria were developed to categorise targeted taxa in terms of vulnerability from collecting by the MAFF. The methodology was based on the conceptual model for vulnerability risk assessment developed for specimen marine molluscs by Ponder & Grayson (1998). All vulnerability criteria were given the same weighting, indicating that each criterion were equally important in determining the overall risk. Rankings were scaled in increasing order of risk (i.e. 5 = higher level of risk).

Distribution

1. Widespread – Found widely throughout the Indo-Pacific. Very few spatial restrictions to distribution
2. Spread – Found widely throughout the West Pacific
4. Restricted – Found within the MAFF area with limited distribution elsewhere in Australian waters
5. Very restricted – Found only in a small area (e.g. reef complex) within the MAFF area and not elsewhere, unless near the fishery boundary and the species has a restricted distribution on the other side of that boundary e.g. Coral Sea reefs, New South Wales

A species' ability to sustain heavy collection pressure and localised depletion is likely related to its potential to repopulate and recolonise. We consider that fish species with widespread distributions are more resilient to aquarium harvesting pressures than spatially restricted or endemic species. This is due to their success at occupying a broader range of habitats and their greater ability to repopulate from areas beyond the collection sites.

Accessibility

1. Very limited accessibility – >60m; very deep water
2. Limited accessibility – 30—60m; specialist diving (inc. difficult to capture species at all depths)
3. Accessible – 10—30m; diving only (limited by dive tables)
4. Readily accessible – 5—10m; diving (no limits)
5. Readily accessible – 0—5m; free diving

As the MAFF is based on hand collection by divers, the amount of harvest effort is mostly limited by time and depth, although the type and location of collection habitat, weather conditions, turbid water and strong tidal currents also influence the amount of effort in some cases.

'Accessibility' refers to the level of effort that can be potentially applied to the collection of aquarium fish species. Consequently, shallow waters can receive more effort than deep water habitats because of increased dive times, increasing the vulnerability/exposure of shallow water species to collection (i.e. no time limits for free diving, very long dive periods for shallow water (5—10 m) SCUBA or hookah diving). Fish that are distributed predominantly below 30 metres (beyond safe dive depths) are considered to be at lower risk from over-collection. Fish species with depth ranges that extend below 30 metres are also at less risk, as these deeper areas are likely to act as refugia from harvesting.

Below 30 metres, ‘Limited accessibility’ refers to specialist diving activities using mixed-gases and rebreathers, which allows greater lengths of dive and therefore access to fish populations at depths to 60 metres. Only one MAFF operator has experimented with this diving capacity. Fish species that are particularly difficult to capture while diving or are only available at restricted times of year (e.g. clear water, low wind periods on weather faces of reefs, high tidal range areas) are also included in the ‘Limited accessibility’ criterion. Where a species occurred over a range of depths or accessibility criteria (not including species that are difficult to capture), each category was recorded and an average taken for the overall ranking.

Ecological niche

2. Generalist – Demersal, No specific ecological niche — broad range of habitats used
2. Generalist – Pelagic, No specific ecological niche – broad range of habitats used
3. Restricted – Reliant on 3D structure (non-living) for any part of its life history
4. Restricted – Restricted to a habitat (obligate coralivores, coral dwellers reliant on 3D structure, restricted to habitats associated with coral reefs) for any part of its life history
5. Very restricted – Species specific host/food corals or anemones, species restricted coralivores

‘Ecological niche’ emphasises the critical interconnections between fish species and habitats. The more specific an ecological connection and the more restricted that species is, then the more likely it is to be sensitive to collection activities causing localised depletion. This criterion also emphasises the health of critical habitats in ensuring species survival e.g. climate change and coral bleaching are likely to have a greater impact on obligate coralivores and coral dwellers. The two ‘Generalist’ categories are ranked at Level 2 owing to the potential impacts of line, net and trawl fisheries on these fish assemblages. We also considered that, although it is important to identify pelagic and demersal generalist species, the level of vulnerability is likely to be similar for the two categories and they have been ranked the same.

Market value

1. $0—10
2. $10—99
3. $100—999
5. >$1000

The driving forces behind market prices for aquarium fish species are complex. Market value may not always be a reflection of demand or rarity and may simply be a product of the costs associated with the collection of that species. For example, costs attributed to the accessibility, handling, transport and husbandry of high price individual species can limit their attractiveness to collectors, as the profit margins may be small and not worthwhile from a business sense. Collectors may also limit the number of expensive fish they collect and provide to the market to artificially maintain exclusivity and therefore high prices.

We make some assumptions about the market value criteria provided here. Generally the value criteria are based on price groupings determined by a frequency analysis of pricelists for fish species in the MAFF. Low value species are generally easy to collect and plentiful and are considered a low vulnerability risk. A higher market value may be related to the rarity of a species or may simply reflect costs associated with its collection. It is the rarity aspect of high value species that determined the high risk ranking of 5 for ‘>$1000’ criterion.

Market value can range to thousands of dollars for some species; however, fish species at this upper end of the value quotient are often large, difficult to catch and transport, and probably destined for public aquaria. Many of the valuable, large species in the MAFF are species for which harvest is regulated for sustainability reasons (e.g. Queensland groper) and require DPI&F permits to collect. Consequently, harvest of these species is controlled and generally, few individuals are collected overall. We do not believe that these species warrant further differentiation beyond the rank of 5.

Susceptibility ranking criteria

Fish species determined to be at greater than a medium vulnerability risk (n = 56; see Table 2) were further evaluated for their capacity to recover from, or, their susceptibility to heavy collection pressure. We developed Susceptibility ranking criteria to score each medium to high vulnerability risk species. All Susceptibility criteria were given the same weighting, indicating that each criterion were equally important in determining the overall risk. Rankings were scaled in increasing order of risk (i.e. 5 = higher level of risk).

The recovery capacity of individual species was determined from biological data extracted from the literature. Susceptibility ranking criteria emphasise life history strategies that are likely to work in combination to affect overall population sustainability.

Fecundity (number of eggs produced at each spawning event)

1. >15000
2. 2500—15000
3. 1000—2499
4. 200—999
5. <200

Development

1. Planktotrophic (larval stage feeds on plankton)
3. Lecithotrophic (larval stage feeds on yolk reserves)
5. Direct development

Fecundity and types of natal development are linked in their influence on the recovery abilities of fish species. Very generally, the more eggs that are produced, the better the chances of recovery success, especially if adjoining or nearby reef areas are considered as potential refugia, or if the random dispersal of planktonic larvae via ocean currents mean an inexhaustible supply of recruits. Of course, there are always exceptions. Some recent work is challenging the passive genetic panmixis associated with dispersal on ocean currents and the source/sink reefs paradigm, with the larvae of some fish species being shown to smell and swim their way home – see Discussion. Some fish species rely on parental care and egg nesting areas (e.g. anemonefish and mouth brooding cardinalfish) to promote successful reproduction, however the number of eggs cared for is usually small and, if parents are removed, they are at a greater risk of being consumed.

The development method a fish species utilises is important in understanding its ability to recover at a discrete local geographical scale (e.g. reef) from localised depletions cause by high levels of collecting activity or by natural disaster. Fish species that passively disperse planktonic larvae via currents may re-establish populations from beyond their home range following depletion events. Fish that have egg nests may not recover if the parent population is removed. Many shark species use direct development or live birth to maintain populations. The number of young that are produced is usually small but juveniles are very well developed and equipped for survival at birth. Obviously, there are sustainability issues if too many of the adult breeding population of direct developers are harvested, as recovery is likely to be much slower compared with highly fecund planktonic spawners.

Longevity

1. Up to one year
3. 1—10 years
5. >10 years

Age at first maturity

1. Few months
2. 1 year
3. 2 years
4. 20 to 30 years
5. >30 years

It is generally understood that long lived species have longer reproductive spans and lower annual reproductive output (Jennings & Beverton 1991). Species with slow, long life histories are intrinsically more vulnerable to exploitation as there is less capacity for recovery (Jennings & Beverton 1991). Longevity may also be important for the persistence of highly fecund fish species (Dulvy et al. 2004). Although a fish species may live for a relatively short time, the little time it spends as a reproductive adult is critical for species continuity. This life history strategy is usually balanced by high abundance levels, ensuring that at least some of the population can reproduce future generations.

Consultation

Critical to the success of this study was the engagement and consultation with fishery operators, science community and conservation agencies (e.g. GBRMPA). At all stages of the study, we asked these stakeholders and experts to provide comment and feedback on the species/taxa being assessed and the criteria and rationale used in the ranking process. Stakeholder input and acceptance of this work ensured the end results were accurate and relevant.

Other recovery strategies (not used in the overall assessment)

Other data collected by this project included information that may be important in subsequent analyses of risks in the fishery (e.g. an ecological risk assessment). Information about life history characteristics, such as the ability for some species to change sex either through a natural ageing process or through social hierarchy cues, was recorded because of its potential importance in understanding a species ability to recover. However, this information was not used in the Susceptibility risk assessment.

I.e. Sex change ability

1. Gonochoristic (remains same sex throughout lifespan)
2. Polygyny (dominant male, resides over harem of females)
3. Protandry (male to female, sex reversal)
4. Protogyny (female to male, sex reversal)
5. Induction (Changes sex due to lack or removal of other dominant sex, social or environmental effects)

Aquarium suitability

Many marine fish species have been assessed for the suitability for housing in aquariums (Michael 2001). We have included this ranking in the database where information exists in the literature. The aquarium suitability index is a rating, ranging from 1 to 5, that gives an indication of the durability, hardiness, and/or adaptability of each species to captive conditions. Many factors such as dietary breadth, competitiveness, tolerance of sudden changes, and habitat requirements all need to be taken into account. Michael (2001) assessed aquarium suitability by the following ranking. Aquarium suitability is unlikely to affect a species ability to recover, but it may influence the targeting behaviour of collectors knowing that fish are hardy and likely to survive capture, transport and living in aquaria. The rankings used by Michael (2001) are:

1. Fish species are almost impossible to keep, and should be left on the reef.
2. Most individuals of these species do not acclimate to the home aquarium, often refusing to feed and wasting away in captivity.
3. These individuals are moderately hardy, with most individuals acclimating to the home aquarium if special care is provided.
4. These species are generally durable and hardy, with most individuals acclimating to the home aquarium.
5. These species are very hardy with almost all individuals readily acclimating to aquarium confines.

Database structure

TAXA: Family, Genus, Species, Common names, List of synonyms

VULNERABILITY INFORMATION:
Ranking criteria:

- Distribution & Abundance: Very restricted, restricted, spread, widespread.
- Accessibility: Highly accessible (0–5 m) Accessible by diving only (5–30 m), limited accessibility (30–80m), very limited accessibility (>80 m).
- Ecological niche: Very restricted (species specific host/food), restricted (habitat restricted), Generalist (no specific ecological niche), Pelagic (very generalised)
- Market value: given as a range in Australian dollars.

Distribution & Abundance: The geographical distribution of each of the species covered within the vulnerability assessment is given in fairly general terms. Species are categorised into four main areas. Indo-pacific, comprising Indian and Pacific Oceans from the coast of East Africa to the easternmost islands of Oceania. Western Pacific, ranging from southern Japan through the Philippines, Indonesia, and the islands of Melanesia to the Great Barrier Reef. Restricted, refers to species found within the MAFF area, however may also exhibit a limited distribution elsewhere in Australia. Very restricted refers to the species distribution being confined to the MAFF area perhaps specific reef(s).

Endemicity: The endemicity of species is noted as either rare, endemic to a region or endemic to specific reefs.

Life History: Life history refers to information regarding the reproductive biology at the species or family level. Notes on spawning type (demersal, pelagic, parental/maternal mouth brooders), paternal pairing, nest guarding, spawning site requirements, spawning behaviour, and larval stages.

Size: We have listed the maximum length in centimetres (cm) attained by each of the species, this frequency however, is just an approximation with literature often unclear on specific measurements. Length measurements are generally taken from the end of the snout to the tip of the tail.

Diet: Marine fish vary dramatically in their feeding preferences and requirements. Fish diets can range from herbivore, carnivore, generalist feeder, parasite (mucus and scales) or cleaning station, to restricted obligate coralivores.

Habitat:
Information about the habitat in which the species is found, including where possible, the type of substrata and depth of water.
Depth range is given in metres (m) for each of the species listed within the sustainability assessment. Where a species occurred over a range of depths, each category was recorded and an average taken for the overall ranking.
Habitats; sandy bottoms—digging burrows, pelagic—deep water, coral reef associated, reef slopes, channels, lagoons, seaward reefs, caves, ledges, drop-offs, and a reliance on coral structure for habitat and protection.

SUSCEPTABILITY INFORMATION:
Information regarding the susceptibility of marine aquarium fish was collated for species with a ranking of 12.5 or higher on the vulnerability scale.
Ranking criteria:

- Fecundity: very low (<200 eggs), low (200–999 eggs), medium (1000–2499 eggs), high (2500–15,000) and very high fecundity (>15,000)
- Longevity: short lived species up to 1 year, between 1 and 10 years, and long lived species, living greater than 10 years.
- Development: Planktotrophic larval stage (plankton feeding), Lecithotrophic larval stage (feeds on yolk reserves) and direct development, e.g. parental mouth brooding or brood pouches.
- Age at first maturity: The mean age at which 50% of a cohort spawn for the first time.

Development: Marine larval development can be broadly classified into three categories; Planktotrophic, Lecithotrophic and direct development. Planktotrophic larvae generally have prolonged pelagic larval stages; Feeding directly on zooplankton and phytoplankton within the water column.

Lecithotrophic larvae feed from yolk reserves within the egg, many demersal spawner are know to have this method of egg development, along with some sort of parental care by either the male of the female of the pair. Direct development is a term often referring to the lack of larval and metamorphism stages.

Fecundity: Marine Fishes exhibit great diversity in reproductive strategies and associated traits, such as breeding systems, numbers of partners, gender role, spawning habit, spawning season and fecundity. Reproductive potential is a measure of the capacity of a population to produce viable eggs and larval. Several factors have been identified which influence reproductive output, adult age structure and biodiversity, the proportion of first time and repeat spawners, nutritional condition as well as age and size at sexually maturity. Fecundity is described as the number of eggs produced by a female. The fecundity of each species was considered as either, very low (<200 eggs), low (200–999 eggs), medium (1000–2499 eggs), high (2500–15,000) and very high fecundity (>15,000)

Longevity: The longevity of fish is referred to in either months or years

Age at Maturity: The age of marine fish at maturity is given in years. Age at maturity is given as an approximation, often with literature being unclear on specific ages. Age at maturity is given for each of the species as either, a few months (gobies), 1 year, 2 years, and as seen in many of the long lived species 20-30 years and greater.

Size at Maturity: We have listed the size at maturity in centimetres (cm) attained by each of the species, this frequency however, is just an approximation with literature often unclear on specific measurements. Length measurements are generally taken from the end of the snout to the tip of the tail.

Sex Change Ability: Information regarding the ability of some species to change sex either through a natural ageing process or through social interactions. We have listed five stages of sex change within this study. The ability to change sex is an important characteristic, often determining many life history traits. Many marine fish species remain the same sex throughout their lifespan (gonochoristic). However some species start of live as males and turn into females with age (protandry), whereas some do the opposite changing from female to male (protogyny). Induction refers to the species ability to change sex due to a lack or removal of the other dominant sex (as seen in clown fish), social or environmental effects can also cause species to change sex. Polygyny is the term used to define a dominant male, which resides of a harem of females.

RESULTS

Vulnerability risk categories are shown in Table 1. We ranked 587 fish species for their vulnerability and susceptibility risks. Ranking results for species with vulnerability rankings higher than 12.5 are shown in Tables 2 & 3.

Table 1: Vulnerability and Susceptibility risk categories for fish species collected in the Marine Aquarium Fish Fishery

Vulnerability Risk	Cumulative score from criteria	Description
Very Low	0—8	Average ranking across each criterion is 2 or below. These species are not vulnerable/susceptible to collection activity in the MAFF.
Low	8.5—12	Average ranking is between 2 and 3. These species are at low risk from MAFF collection activity.
Medium	12.5—16	Average ranking is between 3 and 4. These species have characteristics that make the moderately vulnerable/susceptible to over collection by the fishery.
High	>16	Average ranking is >4. These species have characteristics that make them highly vulnerable/susceptible to over collection by the fishery.

Table 2: Fish species in the MAFF ranked as medium or high level of vulnerability risk.

Species group	Family	Genus	Species	Common name	Distribution	Ecological Niche	Market Value	Accessibility	VAR
Catsharks	Scyliorhinidae	*Atelomycterus*	*macleayi*	Marbled Catshark	4	4	2	5	15
Anemone fish	Pomacentridae	*Amphiprion*	*melanopus*	Tomato Anemonefish	2	5	2	4.5	13.5
Anemone fish	Pomacentridae	*Amphiprion*	*akindynos*	Brown Anemonefish	2	5	2	4	13
Anemone fish	Pomacentridae	*Amphiprion*	*chrysopterus*	Orange-fin Anemonefish	2	5	2	4	13
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*jugumus*	Collared Seahorse	5	2	2	4	13
Anemone fish	Pomacentridae	*Amphiprion*	*perideraion*	Skunk Anemonefish	2	5	2	4	13
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*colemani*	Coleman's Seahorse	5	2	2	4	13
Anemone fish	Pomacentridae	*Premnas*	*biaculeatus*	Maroon Anemonefish	2	5	2	4	13
Cardinalfish	Apogonidae	*Archamia*	*leai*	Lea's Cardinalfish	4	4	1	4	13
Butterflyfish	Chaetodontidae	*Chaetodon*	*rainfordi*	Rainford's Butterflyfish	2	5	2	4	13
Cardinalfish	Apogonidae	*Apogon*	*limenus*	Sydney Cardinalfish	5	2	2	4	13
Surgeonfish	Siganidae	*Siganus*	*corallinus*	Coral Rabbitfish	2	4	2	4.5	12.5
Blennies	Blenniidae	*Ecsenius*	*tigris*	Tiger Blenny	5	2	2	3.5	12.5
Gobies	Gobiidae	*Exyrias*	*bellissimus*	Beautiful Goby	2	4	2	4	12
Razorfish	Centriscidae	*Aeoliscus*	*strigatus*	Razor Fish	2	4	2	4	12
Gobies	Gobiidae	*Arenigobius*	*bifrenatus*	Bifrenatus Goby	2	4	2	4	12
Wrasses	Labridae	*Labroides*	*pectoralis*	Gold Cleaner Wrasse	2	4	2	4	12
Rabbitfish	Siganidae	*Siganus*	*puellus*	Bluelined Rabbitfish	2	4	2	4	12
Anemone fish	Pomacentridae	*Amphiprion*	*ocellaris*	Ocellaris Anemonefish	1	5	2	4	12
Anemone fish	Pomacentridae	*Amphiprion*	*percula*	Percula Anemonefish	1	5	2	4	12
Butterflyfish	Chaetodontidae	*Chaetodon*	*ulietensis*	Double-saddle Butterflyfish	2	4	2	4	12
Cardinalfish	Apogonidae	*Sphaeramia*	*nematoptera*	Pyjama Cardinalfish	2	4	2	4	12
Butterflyfish	Chaetodontidae	*Chaetodon*	*melannotus*	Blackback Butterflyfish	1	5	2	4	12
Butterflyfish	Chaetodontidae	*Chaetodon*	*ornatissimus*	Ornate Butterflyfish	2	4	2	4	12
Rabbitfish	Siganidae	*Siganus*	*vulpinus*	Foxface	2	4	2	4	12
Blennies	Blenniidae	*Cirripectes*	*stigmaticus*	Reticulated Blenny	2	4	2	4	12
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*procerus*	High-Crown Seahorse	4	2	2	4	12
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*bargibanti*	Pygmy Seahorse	2	5	2	3	12
Blennies	Blenniidae	*Ecsenius*	*australis*	Australian Blenny	3	3	2	4	12

Table 3: Susceptibility risk ranking for fish species in the MAFF ranked as medium or high level of vulnerability risk.

Species group	Family	Genus	Species	Common name	VAR	Maturity	Fecundity	Longevity	Develop^{nt}	RAR
Catsharks	Scyliorhinidae	*Atelomycterus*	*macleayi*	Marbled Catshark	15	3	5	5	3	16
Anemone fish	Pomacentridae	*Amphiprion*	*melanopus*	Tomato Anemonefish	13.5	2	4	3	3	12
Anemone fish	Pomacentridae	*Amphiprion*	*akindynos*	Brown Anemonefish	13	2	4	3	3	12
Anemone fish	Pomacentridae	*Amphiprion*	*chrysopterus*	Orange-fin Anemonefish	13	2	4	3	3	12
Anemone fish	Pomacentridae	*Amphiprion*	*perideraion*	Skunk Anemonefish	13	2	2	3	3	10
Anemone fish	Pomacentridae	*Premnas*	*biaculeatus*	Maroon Anemonefish	13	2	4	3	3	12
Butterflyfish	Chaetodontidae	*Chaetodon*	*rainfordi*	Rainford's Butterflyfish	13	2	2	3	1	8
Cardinalfish	Apogonidae	*Apogon*	*limenus*	Sydney Cardinalfish	13	2	5	5	5	17
Cardinalfish	Apogonidae	*Archamia*	*leai*	Lea's Cardinalfish	13	2	5	5	5	17
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*jugumus*	Collared Seahorse	13	2	4	3	5	14
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*colemani*	Coleman's Seahorse	13	2	4	3	5	14
Blennies	Blenniidae	*Ecsenius*	*tigris*	Tiger Blenny	12.5	2	2	3	1	8
Surgeonfish	Siganidae	*Siganus*	*corallinus*	Coral Rabbitfish	12.5	3	1	3	1	8
Anemone fish	Pomacentridae	*Amphiprion*	*ocellaris*	Ocellaris Anemonefish	12	2	2	3	3	10
Anemone fish	Pomacentridae	*Amphiprion*	*percula*	Percula Anemonefish	12	2	2	3	3	10
Butterflyfish	Chaetodontidae	*Chaetodon*	*melannotus*	Blackback Butterflyfish	12	2	2	3	1	8
Butterflyfish	Chaetodontidae	*Chaetodon*	*ornatissimus*	Ornate Butterflyfish	12	2	2	3	1	8
Butterflyfish	Chaetodontidae	*Chaetodon*	*ulietensis*	Double-saddle Butterflyfish	12	2	2	3	1	8
Wrasses	Labridae	*Labroides*	*pectoralis*	Gold Cleaner Wrasse	12	3	2	5	1	11
Blennies	Blenniidae	*Cirripectes*	*stigmaticus*	Reticulated Blenny	12	3	2	3	3	11
Blennies	Blenniidae	*Ecsenius*	*australis*	Australian Blenny	12	3	2	3	1	9
Gobies	Gobiidae	*Arenigobius*	*bifrenatus*	Bifrenatus Goby	12	2	2	3	3	10
Gobies	Gobiidae	*Exyrias*	*bellissimus*	Beautiful Goby	12	2	2	3	3	10
Rabbitfish	Siganidae	*Siganus*	*puellus*	Bluelined Rabbitfish	12	3	1	3	1	8
Rabbitfish	Siganidae	*Siganus*	*vulpinus*	Foxface	12	3	1	3	1	8
Cardinalfish	Apogonidae	*Sphaeramia*	*nematoptera*	Pyjama Cardinalfish	12	2	2	5	1	10
Razorfish	Centriscidae	*Aeoliscus*	*strigatus*	Razor Fish	12	3	2	1	1	7
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*bargibanti*	Pygmy Seahorse	12	2	5	3	5	15
Seahorses/Pipefish	Syngnathidae	*Hippocampus*	*procerus*	High-Crown Seahorse	12	2	4	3	5	14

DISCUSSION

Our method for assessing sustainability risk has the following benefits:

- Provides a scientifically rigorous risk assessment of data poor multi-species fisheries where little to no stock assessment information exists.
- Can be achieved with a small team.
- Is time and resource efficient by being focused in its scope and the type of information sought.
- Is developed in consultation with fishing operators, science community and conservation agencies (e.g. GBRMPA) to ensure all significant stakeholder topics are covered and the assessment outputs supported.
- Results are logical and easily understood by a wide audience.
- Directly inputs to a wider ranging ecological risk assessment of the fishery.
- Provides a valuable tool for fisheries management. This same technique has been applied to the Queensland Coral Fishery (+100 taxa) and can easily be applied to fisheries where a wide range of species are encountered.

The generic international move to ecosystem-based fisheries management presents great challenges to the sustainable management of fisheries that are data deficient and/or comprise a large number of harvested species. Managers require solid, consistent and well-informed platforms on which to base fishery management decisions and directions, and data poor, multi-species fisheries are no exception.

There are no stock assessments and very little long-term understanding of marine aquarium fish species collected from the Great Barrier Reef Marine Park (GBRMP). Information collected through compulsory commercial fishery logbooks, although improved in recent years, still provides very limited species-specific catch data from which fishery performance and ecological sustainability can be measured. In this study, we have provided a simplified approach to understanding the level of potential impact that the conduct of a fishery can have on the ecological sustainability of the species on which it relies. This study was used to inform an Ecological Risk Assessment of the MAFF and has provided robust estimates of the sustainability risks associated with the current list of harvested species.

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