

To reference this article:

Browne RK. 2006. Saving Inshore Fish. Seadragon Foundation Articles.

This article discusses different approaches to saving inshore fish.

SAVING INSHORE FISH

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Management changes are needed to assure the sustainability of marine biodiversity into the 21st century. Traditional approaches to conservation will be overwhelmed by the ubiquitous transformations of marine and terrestrial environments. Global climate change alone will dramatically transform the marine environment. The paradigm shift in conservation must include greater encouragement of private institutions and individuals in conservation programs (Browne 2007a). The strict protection of threatened groups of inshore demersal (bottom dwelling) fish from exploitation is necessary (Hall 2006). However, in general policy should support captive breeding and other programs that engage the public in the conservation of inshore demersal fish. An increasing amount of marine biodiversity will also depend on genetic resource banks and other biotechnologies for its perpetuation. To further public support of captive breeding programs regulations must assure the highest standards of husbandry and include research components (Browne 2007b).

A hotspot for marine biodiversity is the southern coast of Australia (Baker, 2004; in press, a,b). In southern Australia small inshore demersal fish are under particular threat. These fish demand special conservation policies and programs. Fortunately, many of these species will be amenable to sustainable management practices. These practices include captive breeding with gene banks in conjunction with biodiversity surveys and monitoring, and education programs in dedicated facilities such as public aquariums (Browne 2003). Aspects of these practices for the sustainable management of biodiversity are already widely used in aquaculture and commercial fisheries, and their use should not be denied to other species (Browne and Zippel 2007).



This panel at the syngnathid (seadragons, seahorses, pipefish) exhibit at the Audobon Aquarium, New Orleans, USA, has a strong conservation message. Image Robert Browne.

As traditional conservation methods fail the plight of biodiversity appears grim. In 2006 of 40,177 species assessed 16,119 are now listed as threatened with extinction. These include one in three amphibians, one quarter of the world's coniferous trees, one in eight birds, and one in four mammals. Fortunately 65 species extinct in the wild have been saved through

captive breeding, and unfortunately another 784 are now gone forever (IUNC 2006). Freshwater fish have suffered some of the most dramatic declines: for instance 56% of the 252 endemic freshwater Mediterranean fish are threatened with extinction. In East Africa, human impacts on the freshwater environment threaten over one in four (28%) freshwater fish.

The freshwater fish of southern Australia suffer from increasing aridity and the unsustainable management of freshwaters. Under traditional management non-commercial freshwater fish from this region are already suffering from loss of genetic biodiversity and the threat of extinction. Fortunately, of all vertebrates fish are the most easily to sustainably manage using captive populations supported by genetic resource banking (Carolsfeld 2003; Holt 2003). Sperm from more than 80 other fishes has now been cryo-preserved in conservation programs (Bart 2000; Suquet et al. 2000). Programs using biotechnologies to support fish conservation should concurrently include both inshore demersal and freshwater fish.



This panel at the syngnathid exhibit at the Audobon Aquarium, New Orleans, USA, highlights the diversity of seahorses. Image Robert Browne.

The interaction between society and public and private aquariums in the maintenance of biodiversity can generate wonderful opportunities for tourism, education and conservation. Cultural identity with species is maintained where they are kept for display, and so easily lost through restrictive policy measures. For example the success of aquarium enthusiasts in rearing many species of seahorses has sustained these species, reduced stress on wild populations, and encouraged popular support for their conservation (SASMS 2007; Koldewey 2004).

If wild stocks fail rehabilitation projects using the genetic biodiversity of captive populations with diversity from genetic resource banks could be used in rehabilitation programs (Carolsfeld 2003; Holt et al. 2003). Numbers of commercial marine and freshwater fish are already subject to rehabilitation programs relying on captive breeding and genetic resource banking to preserve their biodiversity (Harvey 1998; ICAR 2007).

Genetic resource banking is used extensively for the benefit of humans and ethically its use should be extended to threatened species. Already in a global effort to secure amphibian biodiversity, captive breeding programs supported by artificial reproduction and genetic resource banking are being implemented for hundreds of amphibian species (Browne and Zippel 2007). As species inevitably become extinct due to the uncontrollable proliferation of disease and climate change their survival in controlled environments is their only hope. Efforts to maintain amphibian biodiversity will increasingly depend on amphibians kept in controlled environments by both institutions and in private. For instance in the terrestrial sphere more than 30% of amphibians are immediately threatened with extinction by all causes, and several hundred species are already extinct because of one pathogen (Skerratt et al. 2007). Unfortunately, hundreds of amphibian species have not been managed sustainably and their biodiversity is lost to future generations. When future generations acquire the capabilities for the rehabilitation of these species these species will not be available.

Trends of habitat modification which threaten amphibians and freshwater fish show that a similar situation will probably soon threaten many marine fish (Worm 2006), particularly inshore resident fish (Baker in press, a,b; Hobday et al. 2006).



The common weedfish is widely distributed. However, there are several known weedfish with limited distribution that would be particularly threatened by climate change. Image David Muirhead.

Commercial fish have received the bulk of all marine management funding. Even without the growing stress of climate change in commercial species the inability of traditional fisheries management alone to manage the conservation of marine fish is shown. Currently 30% of commercial species have been decimated until less than 10% of their population remains. If current trends continue within 40 years all commercial species will have reached this crisis stage. It has been shown that with many species remaining populations of 10% often fail to recover even when fishing ceases and the species is effectively ecologically extinct (Worm 2006; Hutchings and Reynolds 2004).

With fish harvested for food, slow growing and late maturing species are particularly vulnerable to extinction. Of the 547 species of sharks and rays assessed in 2006, 20 % are threatened with extinction. For instance the angel shark and common skate, once common in European markets are now critically endangered. Even the deep bottom-dwelling gulper shark has local population declines of up to 95% due to unsustainable fishing. Besides the regulation of fishing pressure Marine Parks and Marine Protected Areas are particularly valuable to protect commercial species (Musick et al. 2000).

However, marine reserves or protected areas will not assure the survival of many inshore demersal fish. These small often resident species will be very vulnerable to habitat changes even at quite small geographical scales. For example some species appear dependent on particular seaweeds, which are very susceptible to changes in temperature, nutrients, or sedimentation.

Until recently, except for commercial fish, dramatic and accelerating rates of the extinction of marine life have not been widely recorded, and there is no proof of the extinction of any marine fish. However, populations of most inshore demersal fish are not monitored, and the limited recent studies of species and populations show that a growing number of extinctions in the wild are imminent. These extinctions will occur through changes in water temperature, vegetation structure; introduced diseases, competitors and predators, and the general restructuring of marine ecosystems (Browne et al. 2007a; Musick et al. 2000).

With anticipated climate change, the future of close inshore marine environment of southern Australia promises warmer water temperatures, changes in dominant currents, increased acidity, nutrients and silt. Clearly these stressors have the capacity to threaten many inshore fish (Browne et al. in press; Browne et al. 2007a).

Temperature rises along Australia's coastline are already occurring with south-east Australia among the most affected region in the world. Temperature along Tasmania's east coast has already increased by almost 2°C due to climate change. The CSIRO has already predicted dramatic changes in the range of species and the disruption of reproductive cycles for the fish of south-east Australia as the eastern Australian current warms and moves further south. The United Nations climate panel stated that the Tasman Sea is suffering the greatest ocean warming in the southern hemisphere. The most affected marine groups are predicted to include inshore demersal fish.

"Sub-tropical migrations to the Tasmanian east coast where the waters have warmed in recent years are already altering the habitat of a whole range of species, and introducing new species such as the sea urchin," Dr Hobday from the CSIRO says. "Climate projections indicate that temperate Australian fisheries will be more vulnerable than tropical fisheries." (Hobday et al. 2006). Ocean waters east of Tasmania have had surface temperatures rise nearly two degrees, coinciding with a southward shift in South Pacific zonal winds which has strengthened the warm, pole-ward flowing East Australian Current (Thresher et al. 2007).



The weedy seadragon is found on the southern coast of Australia. The future looks threatening for this and many other inshore fish. Image Terri Renee.

Fish from warmer southern waters are already moving northward in the Atlantic. In the Bay of Biscay many fish species are at the southern or northern limit of their distribution range: large hydroclimatic changes have recently occurred. Warming of the bay has increased the abundance of mainly subtropical

species that have a wide distribution range in latitude, whereas the abundance of temperate and the least widely distributed species decreased (Poulard and Blanchard 2005).

Genner et al. 2007 also showed dramatic changes in species composition, including the non-commercial inshore species due to ocean warming in the English Channel of 1°C.

The warm water Atlantic triple fin has recently been captured off Britain, and numerous other warm water species including swordfish, shoals of sunfish, and jelly fish are proliferating in British waters (IOL e-news 2006). In addition the sensitivity of inshore marine fish to temperature was shown in the Europe flounder which migrate months earlier to spawning grounds even with only a 2°C water temperature change (Sims et al. 2007).

Although the United Nations climate panel and CSIRO have emphasised the south-east coast of Australia and Tasmania as a critical area for the affects of climate change on fish and marine ecosystems, the east-west coastline of southern Australia would appear to be equally threatened or more so. Two major and biologically important current systems of the east-west coastline of southern Australia are influenced by global climate. In addition the region has a very high diversity of unique inshore demersal fish. Many of these species have biological characteristics that make them particularly vulnerable to environmental change (Foster and Vincent 2004).

Water temperatures of the southern Australian coast are expected to warm as a consequence of climate change altering currents. There are two areas that support unique marine ecosystems in southern Australia, the SE of South Australia near Robe, and the southern coast of Kangaroo Island. These cold upwelling contain between 30 and 70 times the nitrate concentration of surrounding water and support unique marine ecosystems (Lewis 1981). These upwellings are subject to influence by ENSO events in the Pacific Ocean where El Nino events lead to enhanced upwelling (Middleton et al. 2006).

Similarly ENSO events affect the warm Leewin Current which flows strongly southwards along the Western Australian coast, before turning eastwards at Cape Leeuwin and continuing into the Great Australian Bight where its influence extends as far as Tasmania (Feng et al 2003). The Leewin Current affects commercial fish and lobsters and almost certainly affects inshore demersal fish (Clarke and Li 2004; Li and Clarke 2004). Upwellings are expected to change and the warm Leewin current to increase its eastward flow as global temperatures increase.

Unfortunately, the southern coast of Australia as it faces the southern ocean offers no chance for the southward migration of the affected fish species. Widespread reduction in the populations, the extinction of local populations, and the extinction of wild populations of species are anticipated. The species group that will suffer the greatest losses will be inshore demersal fish due to their highly specialized habitat, lack of migratory young and adults, and fragmented populations.

Compounding the challenge for the sustainable management by environmentalists of these southern Australasian threatened species is the large number of endemic species. Because more than 90% of inshore demersal fish are endemic and the number of species in the most threatened groups is over 100 there are probably tens of species that should have immediate captive breeding and gene banking programs to assure maintenance of their biodiversity. The groups most likely to be affected are syngnathids (seadragons, seahorses and their kin), gobescoides, threespines, handfish, and anglerfish. Highly threatened are some close inshore syngnathids, and many gobescoides, particularly weedfish and shore-eels, and threespines. Recent surveys have shown that even close to urban populations there remain numerous undiscovered species in these groups (Browne and Smith in press; Hammer 2006).

The effects of rapid and unpredictable changes in the environment favour the survival and predominance of generalist species that can migrate as juveniles or adults, have large numbers of young, and that do not require special habitat structures to survive. These survivors have a wide geographical range, have planktonic or nektonic larvae, and are widely distributed in different habitats. Examples of these generalists are many commercial and recreational fish which are valued for their large muscle mass supported by a high protein diet, and medium fish are Australian salmon, mullet, pike and among larger fish many rays and sharks. Because of their ecology and reproductive modes the monitoring of these species will not be a reliable method of determining the status of smaller, more specialized inshore demersal fish (Genner et al. 2007, 2004). Consequently, biodiversity surveys targeting inshore demersal fish and monitoring of some populations of select species should be instituted.

In contrast to the generalists many inshore demersal fish need specialised complex habitats and do not have migratory juveniles or adults. In addition they produce small numbers of young and are often egg and nest brooders with generally low dispersal. For example of a vulnerable group, southern Australia is the center for biodiversity of syngnathids with many species having very restricted distribution. Although the migratory habits of southern Australasian syngnathids (sea dragons, seahorses, pipefish) are poorly known, overseas species have shown high site fidelity by both adults and juveniles. High site fidelity has also been shown by species from Southern Australia. Syngnathids brood their young and produce few advanced larvae with specialized food and habitat requirements. (Browne et al. in press; Browne and Smith, in press; Browne et al. in prep).



The crested threespine. Image David Muirhead.

Other inshore demersal fish at particular risk are the egg nesters including gobies, threespines, handfish and anglerfish which need specialized nesting sites for brooding eggs. These sites include substrates such as clean rock or sponge, sometimes with crevices, to support the adults. These specialized habitats are often patchy and the corresponding fragmentation of populations greatly increases the chance of extinction.

These habitats are also very susceptible to damage from siltation, other forms of pollution, and water temperature changes.

Historic examples of Australian fish sustainably managed through captive breeding are the Lake Eacham rainbow fish and the spotted hand fish. The captive breeding program for the Lake Eacham rainbow fish involved individual aquarists, hobbyist organizations and scientists as well as the aquarium industry and government, with many captive breeding populations with numbers greater than 1000 in eastern Australia with further populations maintained in North America and Europe (Leggett and Merrick 1997).

Hopefully, many other threatened species of freshwater fish in Australia and globally can similarly be sustainably managed. The first marine fish to be listed as endangered in Australia was the spotted handfish with a known population of about 750. Spotted handfish have been subject to a limited institutional captive breeding program. Other southern Australasian examples of inshore fish with stable captive populations are the many species of seahorses.

In conclusion, the extinction in the wild of some southern Australasian inshore demersal fish appears inevitable. However, timely implementation of policies to encourage their captive breeding, especially those immediately threatened, will perpetuate these species. To enable the rehabilitation of these fish, gene banks should be established for all susceptible species before genetic biodiversity is lost during population declines.

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