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Department of the Environment and Energy



Department of
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Draft National Recovery Plan for the Macquarie Perch (*Macquaria australasica*)

March 2017



The Species Profile and Threats Database pages linked to this recovery plan is obtainable from:
<http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

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Images credits

Cover page: Macquarie perch (*Macquaria australasica*).

Luke Pearce, New South Wales Department of Primary Industries.

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1 SUMMARY

Macquarie perch (*Macquaria australasica*)

Family: Percichthyidae

IBRA Bioregions: Sydney Basin, South Eastern Highlands, Australian Alps, NSW South Western Slopes, Riverina, Victorian Midlands

Conservation status: Statutory

Environment Protection and Biodiversity Conservation Act 1999:
Endangered

Fisheries Management Act 1994 (New South Wales):
Endangered

Flora and Fauna Guarantee Act 1988 (Victoria): Threatened

Nature Conservation Act 2014 (Australian Capital Territory):
Endangered

Non-statutory

Action Plan for South Australian Freshwater Fishes 2009 list:
Extinct

Advisory List of Threatened Vertebrate Fauna in Victoria 2013 list: Endangered

IUCN Red List of Threatened Species: Data Deficient

Distribution and habitat: Remaining viable, self-sustaining populations occur in
(also refer to Figure 3) New South Wales in the:

- upper reaches of Lachlan River catchment, including: the Abercrombie and Lachlan River upstream of Lake Wyangala;
- upper Murrumbidgee River below Tantangara Dam upstream of Gigerline Gorge;
- Hawkesbury-Nepean river system and Georges River on the east coast.
- Adjungbilly Creek in the Tumut River catchment, part of the upper Murrumbidgee River catchment.

A remaining viable, self-sustaining population occurs in the Australian Capital Territory in the Cotter River above the Cotter Dam and below Bendora Dam, including in the lacustrine waters of Cotter Dam.

Distribution and habitat: Remaining viable, self-sustaining populations occur in Victoria in cont...

(also refer to Figure 3)

- upper reaches of Mitta Mitta river catchment above Dartmouth Dam, including in Lake Dartmouth (where it is also stocked);
- Ovens River catchment in the Buffalo River;
- upper tributaries of the Goulburn River catchment, including in King Parrot, Hughes and Holland's creeks.

Translocated populations occur in New South Wales in the:

- Mongarlowe River in the upper Shoalhaven River catchment;
- Cataract Dam in the upper Hawkesbury-Nepean system.

Translocated populations occur in Victoria in the:

- Campaspe River catchment in the Upper Coliban Reservoir and tributaries;
- Yarra River catchment;
- Ovens River catchment in the lower and middle reaches of the Ovens River itself (along with stocked individuals) and in Lake William Hovell on the King River.

Stocked populations occur in New South Wales in the:

- Retreat River in the upper Abercrombie River catchment;
- upper Tumut River catchment (part of the Murrumbidgee River catchment) in Talbingo Reservoir;
- Swampy Plain River catchment (part of the upper Murray River catchment) in Khancoban Pondage.

Stocked populations occur in Victoria in the:

- Expedition Pass Reservoir in the upper Loddon River catchment;
- Lake Dartmouth in the Mitta Mitta River catchment (where there is a natural population of the species);
- Ovens River catchment in the lower and middle reaches of the Ovens River itself (along with translocated individuals), between Oxley Flats and Rocky Point;
- Goulburn River, in the middle reaches of the Goulburn River itself between Molesworth and Trawool.

Habitat critical for survival:

Habitat critical to the survival of the Macquarie perch is described as:

- all areas within the species' range which are characterized by flowing runs or riffles and small complex rock piles;
- the current area of occupancy of the species;
- any newly discovered locations which hold populations that extend the area of occupancy for the species;
- unoccupied habitat throughout the Murray-Darling Basin into which the species could disperse or be translocated.

Recovery plan objective and strategies:

The overarching objective of this recovery plan is to –

Ensure the recovery and ongoing viability of Macquarie perch populations throughout the species' natural range.

The recovery plan sets out six recovery strategies that build toward this overarching objective:

1. Conserve existing Macquarie perch populations.
2. Protect and restore Macquarie perch habitat.
3. Investigate threats to Macquarie perch populations and habitats.
4. Establish additional Macquarie perch populations.
5. Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance.
6. Increase participation by community groups in Macquarie perch conservation.

Recovery team:

Recovery teams provide advice and assist in coordinating actions described in recovery plans. They include representatives from organisations with a direct interest in the recovery of the species, including those involved in funding and those participating in actions that support the recovery of the species. The Macquarie Perch Recovery Team has the responsibility of providing advice, and coordinating and directing the implementation of the recovery actions outlined in this recovery plan. The recovery team has had input from the New South Wales, Australian Capital Territory and Victorian governments, independent researchers and community groups; recovery team membership may change over time.

Criteria for success:

This recovery plan will be deemed successful if, within 10 years, all of the following have been achieved:

- Populations of Macquarie perch have increased at each known location.
- Self-sustaining populations of Macquarie perch have been established at locations where it once historically occurred but no longer occurs.
- A long-term population monitoring strategy has been implemented and is ongoing for the Macquarie perch in the Australian Capital Territory, New South Wales and Victoria.
- There is improvement in understanding of what threat mitigation is required to recover the Macquarie perch.
- There is implementation of threat mitigation measures to protect known Macquarie perch populations.
- There is increased success in closed life-cycle breeding within hatcheries for the Macquarie perch.

Criteria for failure:

This recovery plan will be deemed to have failed if; within 10 years, any of the following have occurred:

- The number of self-sustaining populations of Macquarie perch has decreased.
- No population monitoring has been conducted for the species and population trends are not known in any or all of the Australian Capital Territory, New South Wales or Victoria.
- No further understanding of threat mitigation has been achieved to recover the Macquarie perch.
- No further advancement in success of closing life-cycle breeding within hatcheries.
- The conservation status of the Macquarie perch has declined during the life of the plan.

2 INTRODUCTION

This document constitutes the Australian National Recovery Plan for the Macquarie Perch (*Macquaria australasica*). The plan considers the conservation requirements of the species across its range and identifies the actions to be taken to ensure the species' long-term viability in nature, and the parties that will undertake those actions. This is the first National Recovery Plan for Macquarie perch.

The Macquarie perch is a moderate sized, large eyed, secretive freshwater fish native to the cooler middle-upper reaches of the Murray-Darling Basin (MDB). The species was originally described from specimens collected from the Macquarie River in New South Wales, but has long since disappeared from that part of the MDB. Museum records also exist for Macquarie perch from the Murray River in South Australia but the species is now presumed extinct from the lower Murray River. Macquarie perch are now found as far north as the Abercrombie River in the Murray Darling Basin, as well as the eastern coastal, Hawkesbury-Nepean, Georges and Shoalhaven river systems in New South Wales (Harris & Rowland 1996; Lintermans 2007). In Victoria, populations are known from the Mitta Mitta, Ovens and Broken river catchments and several tributaries in the Goulburn River catchment, in addition to a translocated population in the Yarra River (Lintermans 2007).

The Macquarie perch was once an important and valued species for recreational fishing. However, the Macquarie perch has undergone a long-term decline in abundance; populations have become fragmented and the species is now absent from much of its former range. The Macquarie perch is listed as 'endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Australian Society of Fish Biology Threatened Fishes List, the Australian Capital Territory *Nature Conservation Act 2014* (NC Act), and the New South Wales *Fisheries Management Act 1994* (FM Act). The Macquarie perch is also listed as 'threatened' in Victoria under the *Flora and Fauna Guarantee Act 1988* (FFG Act) and 'presumed extinct' in South Australia under the *National Parks and Wildlife Act 1972* (NPW Act).

The draft national recovery plan summarises the current state of knowledge of the Macquarie perch and contains detailed information on the threats being faced by this species. The draft plan also provides a list of actions and strategies to assist in the recovery and viability of wild Macquarie perch populations throughout their natural range by focusing government, community and Indigenous groups support and involvement.

An accompanying Species Profile and Threats Database (SPRAT) page provides additional information on the Macquarie perch. The SPRAT page is available at:
<http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

3 SPECIES INFORMATION

3.1 Names

Common name: Macquarie perch

Other historical and current common names: mountain perch, Murray perch, Macquarie's perch, black perch, black bream, Goulburn bream, silver-eye or white-eye, goggle eyes, humpy back, butterfish and snub-nosed perch.

Scientific name: *Macquaria australasica* (Cuvier 1830)

3.2 Stock structure

There is a high level of genetic diversity in Macquarie perch across its range. Morphological and genetic differences between Murray-Darling and eastern Macquarie perch continue to hold the taxonomic status of this species in question (Faulks et al., 2010). However, this recovery plan covers the currently accepted taxon for the Macquarie perch, which is the species listed as endangered under the EPBC Act.

Investigations into morphological and genetic differences between populations of Macquarie perch east and west of the Great Dividing Range in New South Wales were carried out by Duffy (1986). Duffy (1986) concluded it was probable that the eastern and western populations were separate species and that there were at least two sub-species in the eastern population. Eastern and western populations were identified as apparently distinct species using morphological differences alone, and this conclusion was further supported after electrophoretic analysis. Weaknesses of the study included small sample sizes (due to difficulties finding fish) and only a small number of sampling sites (three sites west and two sites east of the Great Dividing Range). Conclusions of the study recommended further sampling with increased replication of sites and number of fish sampled.

The electrophoretic techniques used by Duffy (1986) to draw conclusions about the genetic structure of Macquarie perch populations are likely to be dated. There have been significant advances in the techniques used to investigate genetic issues since 1986 and the use of mitochondrial and microsatellite DNA in current research has provided greater insight into the genetic complexities associated with the Macquarie perch.

Research by Faulks et al. (2010) on the phylogeography of the Macquarie perch shows the species originated in the eastern drainages and is thought to have migrated to the Murray-Darling system approximately 675 000 years ago through a low point in the Great Dividing Range or a stream capture event. Genetic divergence and diversity of the populations of Macquarie perch has been encouraged through geographical isolation within catchments and across the Great Dividing Range. Faulks et al. (2010) concludes that there are six major lineage groups of Macquarie perch in New South Wales, those being the: Kangaroo River (Shoalhaven River system), Webbs Creek, Colo River, Nepean River, Murray-Murrumbidgee rivers and Lachlan River.

Genetic material from the specimen of the Kangaroo River is distinctly different from others in the eastern drainages and may in fact be a separate species. As there was only one sample available from the Kangaroo River this is inconclusive and requires further taxonomic investigation (Faulks et al., 2010). However, the Kangaroo River population (i.e. the relict Shoalhaven River system) is likely extinct.

Research in Victoria has shown that there are two distinct genetic clusters in Macquarie perch populations in the state; one group being fish in the Buffalo River (tributary of the Ovens River), Holland's Creek (tributary of the Goulburn-Broken river system) and Hughes Creek (a tributary of the Goulburn River), and one group being fish in Lake Dartmouth (on the Mitta Mitta River) (Nguyen et al., 2012).

The Macquarie perch recently had its complete mitochondrial genome sequenced so that further studies can be undertaken into the species' evolution, population genetics, conservation and taxonomy (Gan et al., 2014). The species was the first of its genus *Macquaria* to be sequenced (Gan et al., 2014).



Figure 1: Typical adult Macquarie perch from the Murray-Darling Basin.

Photo – Luke Pearce, NSW Department of Primary Industries.



Figure 2: Typical adult Macquarie perch from the Hawkesbury-Nepean system.

Note the substantially smaller adult size of the Hawkesbury/Nepean specimen (~17 cm) compared to the MDB specimen (~30 cm).

Photo – Andrew Bruce, NSW Department of Primary Industries

3.3 Description

The Macquarie perch is a moderate sized, elongated, oval shaped, laterally compressed fish with large silvery-white eyes, a small mouth and a rounded tail. The snout is tapered and the upper jaw slightly overhangs the lower jaw. There are conspicuous pores on the lower jaw. Macquarie perch have a concave nape similar to, but not as distinct as, golden perch. They are similar in appearance to golden perch, Australian bass and estuary perch. Juveniles closely resemble several pygmy perch species found in eastern Australia (*Nannoperca* spp.) (Family Percichthyidae).

The colour of Macquarie perch within the Murray-Darling Basin varies from almost black or dark silvery-grey, dark bronze to pale bluish grey or green-brown above, with off-white below. Fins sometimes have a purplish or yellowish tinge. Coastal drainage fish often have grey-brown, buff and dark grey patches.

Size varies greatly between Murray-Darling Basin and coastal drainage populations, with Murray-Darling fish reaching up to 495 mm and 4 kg (but are uncommon today over 1.5 kg), while coastal drainage fish rarely reach over 190 mm (Lake 1959; Battaglione 1988; Harris & Rowland 1996; Douglas et al., 2002; Bruce et al., 2007).

4 BIOLOGY AND ECOLOGY

4.1 Age and growth

The growth rate of Macquarie perch largely depends on location, climate, water temperature, habitat type, and food resources (Battaglione 1988).

Size varies greatly between Murray-Darling Basin and native coastal populations, with the Basin specimens reaching larger body size and weight than those collected from eastern drainage systems (Harris & Rowland 1996). Murray-Darling Basin populations have been reported to grow from 7 – 10 mm (hatched larvae) to 370 mm in length in the first five years of life (Harris & Rowland 1996; Lintermans 2002; 2007; Kearns et al., 2012). In eastern drainage populations mature individuals greater than 190 mm in length are rare (Harris & Rowland 1996; Bruce et al., 2007).

Size at first sexual maturity varies between lake and river populations, with a study comparing fish from selected riverine tributaries in the Murray-Darling Basin and resident fish from Lake Dartmouth finding that both males and females of river populations tend to mature at a much smaller size than fish resident in the lake (Appleford et al., 1998).

The maximum age potential for Macquarie perch is currently unknown. Estimates of maximum age will be useful when considering management of the species into the future and should be a focus of future research. While the maximum age is still uncertain, it appears the species is relatively long-lived, with reports of fish from Victoria aged up to 26 years (Tonkin et al., 2014). Detailed age and growth studies of Macquarie perch from Lake Dartmouth were undertaken by Cadwallader (1984), Douglas et al. (2002) and Tonkin et al. (2014). The initial research by Cadwallader (1984) found after eggs hatch, growth can be rapid, with a five-year-old fish being 380 mm. Males can mature at two years of age and up to 210 mm; females at three years of age are up to 300 mm (Cadwallader 1984; Harris & Rowland 1996).

However it has become evident through later research that size is not a reliable indication of age because local conditions may induce the species to breed at smaller or larger sizes. Estimates of mature females as small as 100 mm total length have been made based on the length-at-age relationships formulated by Douglas et al. (2002). In the Cotter River in the Australian Capital Territory, males mature at about 140–150 mm and in Lake Dartmouth mature males have been recorded as small as 117 mm (Lintermans 2007).

4.2 Habitat

Historically, the Macquarie perch was abundant in the upland zones of rivers, sometimes extending into the montane zone. The species was usually abundant in slope zones; and occurred sporadically in lowland habitats, generally at the start of the lowland sections. The species was also locally abundant in the Barmah Lakes and the Edward River, on the New South Wales/Victoria border. However, evidence indicates it was rare in the Murray River, downstream of Barmah Lakes, and almost unknown in the South Australian reaches of the Murray River (Cadwallader 1979; Lintermans 2007; Trueman 2011). Overall, the historical evidence and the breeding biology of the Macquarie perch indicate it was a species primarily of the upland zones and slope zones (Trueman 2011).

In the Seven Creeks system in Victoria, Cadwallader (1979) noted that the Macquarie perch was found where aquatic vegetation was usually present with additional cover provided by large boulders, debris and overhanging banks; and where steep rock faces, well vegetated banks and open eucalypt woodland typically provided shade. Brumley et al. (1987) found that Macquarie perch habitat sites in rivers consisted of a rubble substrate of small boulders, pebbles and gravel. Additionally, water depth was between 0.2 and 0.9 m (usually 0.4 – 0.6 m) and water velocity was between 0.3 and 0.6 m/sec. Brumley et al. (1987) also found that habitat areas often have a pool (usually 15 – 30 m long and at least 1.5 m deep) immediately upstream and fast-flowing broken water immediately downstream. In the Seven Creeks system, the species still occurs in the middle reaches from below Polly McQuinns Weir downstream to Gooram Falls, and individuals were thought to be in good condition in areas where deep refuge habitat, from predators, was accessible. There are reports that redfin have been liberated into this stretch of waterway, adding another threat to this population. Upstream of Polly McQuinns Weir, the species is likely to be extinct (Stoessel 2009). Until recently, adults in the Cotter River catchment in the Australian Capital Territory principally resided within Cotter Reservoir rather than the river (Ebner & Lintermans 2007; Ebner et al., 2008) but that was probably due to the lack of riverine habitat available to the species given the barrier posed by Vanitys Crossing. Within the Cotter Reservoir adults use emergent macrophytes for shelter and juveniles are associated with rock piles (Ebner & Lintermans 2007).

Preferred juvenile habitat in rivers is not well documented; 30 – 40 mm juveniles have been found in riffle habitat and 80 – 100 mm juveniles have been found in pools amongst debris and overhanging vegetation in the Mongarlowe River. Juveniles of 10 – 30 mm length inhabit pools in the Cotter River and are benthic or semi-pelagic during the day and inactive at night (Ebner & Lintermans 2007; Ebner et al., 2008; 2009).

Macquarie perch can tolerate relatively cold water temperatures as would be expected from a fish inhabiting upland parts of the southern Murray-Darling Basin. It has been measured to be living in temperatures as low as at least 9°C in Lake Eildon, Victoria. The species requires a temperature rise in spring months, generally to at least 16°C for spawning to occur, but it is possible that they can spawn at lower temperatures (Cadwallader & Rogan 1977; Harris & Rowland 1996; Lintermans 2007; Koster et al., 2014). Winter (June) temperatures of Victorian streams where Macquarie perch exist, such as King Parrot Creek, can range between 10 and

14 C (Ayers 2009). A recent study of the species' population in Lake Dartmouth found that growth and recruitment were highest during years of refilling, when amongst other variables, water temperature were low. The study considered the influence of low water temperatures on high growth not surprising given the species' natural occupancy of cool, upland streams (Tonkin et al., 2014). Observational evidence indicates that the Macquarie perch in aquaria show signs of severe illness or stress once temperatures reach 26°C or above.

Historical records indicate that Macquarie perch inhabited many types of riverine habitat that have now been extensively modified. However, Gilligan et al. (2010) summarising research in the Lachlan River proposed that Macquarie perch are –

“... riverine fish most abundant in reaches > 200m altitude. The species is heavily dependent on the availability of flowing mesohabitats (runs and/or riffles) and small complex rock piles (aggregations of 0.5 – 1 m diameter boulders) to provide cover. Extensive lengths of undercut banks in reaches with low coverage of flowing mesohabitats or limited small complex rock cover are detrimental. Depth, substratum type, riparian vegetation cover and aquatic macrophyte cover have little influence on the probability that Macquarie perch will occupy a reach.”

The removal of rock and woody snags, introduction of aquatic pests, siltation and degraded water quality have likely contributed to the loss of quality habitat for Macquarie perch. Few native species require silt-free coarse spawning substrates, however this is essential for the Macquarie perch. Alien fish species, brown and rainbow trout, also require such substrates (Harris 1995).

Habitat critical to the survival of the Macquarie perch can therefore be described as all areas within the species' range which are characterized by flowing runs or riffles and small complex rock piles.

4.3 Reproductive biology

In Murray-Darling Basin rivers, Macquarie perch tend to spend most of their time in deep holes and probably move upstream to spawn during spring and early summer (from September through to mid-January) when water temperatures range between 16 and 20°C (Koehn & O'Connor 1990a; Ingram et al., 2000; Gilligan 2005). Fish in lakes or impoundments tend to aggregate at the mouths of suitable feeder streams awaiting appropriate water temperatures (>16.5°C). When the water reaches the required temperature the fish move upstream into appropriate riffle habitat to spawn and then return to the lake or impoundment upon completion of spawning activities or when water temperatures fall below 16.5°C (Wharton 1968; Cadwallader & Rogan 1977; Cadwallader, 1977; 1979).

Cadwallader (1979) found that Macquarie perch once reproduced in the upper reaches above Polly McQuinns Weir in the Sevens Creek river system in Victoria, but there was no evidence that the population in the lower reaches reproduced there. This is concerning, given that the species is considered to be now locally extinct upstream of Polly McQuinns Weir (Stoessel 2009). Bishop (1979), who studied Macquarie perch in the Shoalhaven River, also found no evidence of populations reproducing in the lower reaches and suggested that specimens occurring in these reaches may be outriders from the self-maintaining populations upstream. Running ripe Macquarie perch were collected from the Barmah Lakes area during studies in 1937 suggesting that the species may be able to spawn in some circumstances in lowland conditions (Cadwallader 1977), though the requirement for silt-free substrates probably remains.

Murray-Darling Basin Macquarie perch have estimates of age and size at sexual maturity varying from 1–2 years and 117–210 mm for males and 3–4 years and 100–300 mm for females

(Cadwallader 1984; Douglas et al., 2002; Lintermans 2007; Tonkin et al., 2009). Fish from the coastal eastern drainages tend to have a smaller size at sexual maturity. Ripe females of 100 mm total length have been reported from the Hawkesbury-Nepean and Shoalhaven river systems in New South Wales (Dufty 1986) and ripe males as small as 80 mm total length have been captured in the Georges River (Knight 2010).

Fecundity is estimated at 32 000 eggs per kilogram of fish (Wharton 1973) hence a large (3.5 kg) female may produce up to 110 000 eggs. Eggs are cream coloured, approximately 1–2 mm in size and adhesive, and are usually found amongst gravel and stones in riffle areas approximately 50–75 cm deep with a flow rate of less than 1 m/s. Hatching usually occurs after 10 – 11 days at water temperatures ranging from 15 – 17°C (Lintermans 2007). Newly hatched yolk sac larvae shelter amongst pebbles (Cadwallader & Rogan 1977).

Macquarie perch larvae in the Cotter River above Cotter Reservoir in the Australian Capital Territory have been observed during snorkelling surveys schooling in deep sections of river pools which have little to no surface flow along steep rock faces in the upper water column (at depths less than 1 m) (Broadhurst et al., 2012). As they grew and became juvenile fish, they developed strong associations with the benthic substrates of boulders, cobbles or large woody debris at the head and tail of pools in relatively shallow water, where some surface flow is present (Broadhurst et al., 2012).

Macquarie perch have been particularly problematic to breed in captivity, requiring flowing water (Farrington et al., 2014). However, there has been some recent success for captive breeding programs of the species by the New South Wales Narrandera Fisheries Centre hatchery, using a new approach employing an artificial stream to coax both males and females into breeding condition (NSW DPI 2010). Until this development, hatchery programs for the species have relied on capturing spawning-run fish from the wild (NSW DPI 2010), inducing individuals to spawn through the injection of artificial hormones to collect the eggs and sperm.

4.4 Behaviour

While anglers regularly capture the species during daylight, it is thought that Macquarie perch search for food more actively at night (Lintermans 2006a, Ebner & Lintermans 2007, Ebner et al., 2009; Thiem et al., 2013). Nevertheless, whilst the species is generally regarded as quite cryptic and docile (Lintermans 2007), during reproduction fish form dense aggregations at the base of pools and within riffles (Cadwallader & Rogan 1977). During such times fish also become quite aggressive, making the species particularly vulnerable to predation and anglers (Tonkin et al., 2009).

In the Cotter Reservoir, Australian Capital Territory, Macquarie perch have been shown to inhabit deeper water depths during the warmer summer months in comparison with other seasons (Thiem et al., 2013). Diel geographical range movements were significantly higher in winter than other seasons, probably due to having to move larger distances to encounter the same quantity of prey items, such as decapods which are in lower abundance during winter (Thiem et al., 2013).

A study on Macquarie perch in Lake Eildon, Victoria, found that as water temperatures rose in spring months towards 16°C, fish began migrating to upstream regions of the lake ready to move into inflowing streams once the water temperature rose above this level (Cadwallader & Rogan 1977). However, unlike the abovementioned impoundment population, a recent study involving the radio-tagging of fish from the riverine Yarra River population found no synchronised migratory behaviour or movement of multiple fish (Koster et al., 2014). However, two individuals were recorded moving between 5 and 6 km upstream shortly after their release in the month of

May (Koster et al., 2014). The Yarra River findings are in contradiction to a number of oral history recordings on the species, in which schooling and migration was recognised, including by Indigenous groups such as the Yorta Yorta people, as a general trait of the species (Trueman 2011). Many people in their oral history recordings described a strong, but not unpleasant, odour produced by the species that signified to some fisherman the presence of these large aggregations of the species in waterways (Trueman 2011). Given the uncertainty created by the conflicting historical and recent research, the migratory nature of the species is likely to require further investigation.

4.5 Diet

Macquarie perch and trout cod (*Maccullochella macquariensis*) are the only two Australian species of the Family Percichthyidae, which exhibit a relatively sub terminal mouth. A sub terminal mouth typically indicates benthic feeding habits in fish species. Laboratory observations have shown that Macquarie perch feed using a sucking action; evidenced by the frequent occurrence of sand grains, gravel and detritus in stomach analyses of the species (Cadwallader & Eden 1979). Macquarie perch predominantly feed upon benthic aquatic insects and insect larvae, particularly beetles, mayflies, caddis flies and midges. Decapod crustaceans (shrimp and crayfish) are also an important food source with other known prey including dragonfly larvae, molluscs and small fish (McKeown 1934; Butcher 1945; Cadwallader & Eden 1979; Battaglione 1988; Lintermans 2006a). In lakes and impoundments cladocerans (water flea crustaceans) can also be a significant dietary item (Cadwallader & Douglas 1986; Lintermans 2007). The cladoceran, *Moina* spp., followed by calanoids, chironomids and cyclopoids were the most abundant prey in the stomachs of juvenile Macquarie perch reared in fertilised earthen aquaculture ponds (Ingram & De Silva 2007).

The composition of diet for Macquarie perch in impoundments fluctuates depending on water level, and feeding activity is known to increase in times of flooding when fresh ground is made available (McKeown 1934; Cadwallader & Douglas 1986; Battaglione 1988). Macquarie perch have been found to feed on terrestrial invertebrates, such as arthropods and annelids, when the water levels of Lake Dartmouth rose rapidly over areas which had previously not been inundated (Cadwallader & Douglas 1986). There has been little evidence of feeding on terrestrial items from other studies focussing on riverine populations (Cadwallader & Rogan 1977; Cadwallader & Eden 1979; Lintermans 2006b).

The abovementioned study of the Lake Dartmouth population found that there was no obvious relationship between size of Macquarie perch and size of food items (Cadwallader & Douglas 1986). This is in contradiction to riverine populations of the species in the Canberra region, where ontogenetic changes in diet have been observed: as individuals mature, the importance of decapods increases and the importance of dipterans (true flies) decreases (Lintermans 2006b). Macquarie perch prey in riverine populations in the Canberra region is dominated by the shrimp (*Paratya australiensis*) and freshwater prawn (*Macrobrachium australiense*) (Lintermans 2006b).

5 DISTRIBUTION AND POPULATIONS

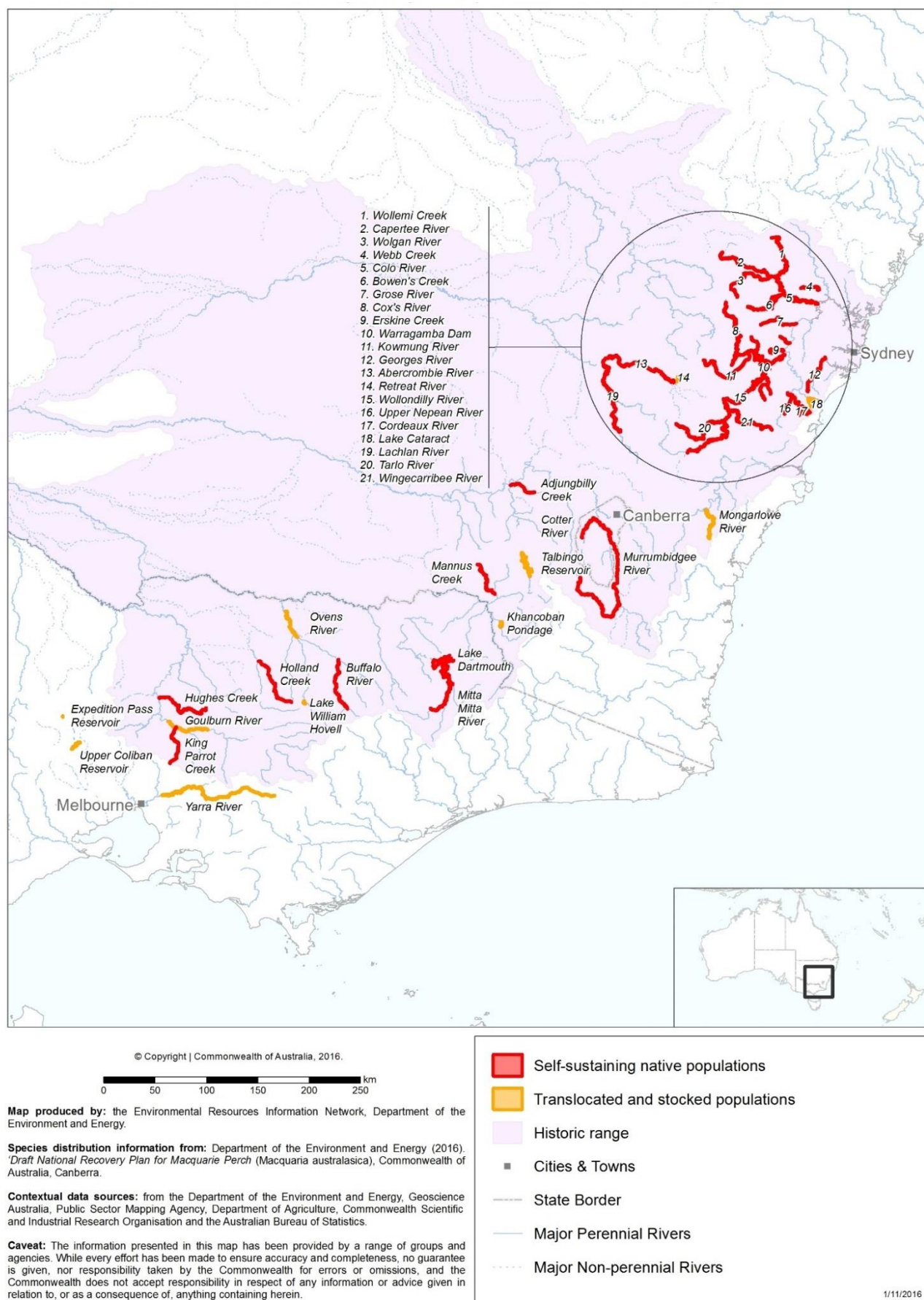


Figure 3: Current and historical distribution of *Macquarie perch* (*Macquaria australasica*) in south-eastern Australia.

5.1 Historical distribution and abundance

The natural, historical geographical distribution of the Macquarie perch included all major river systems in the southeastern part of the Murray-Darling Basin in New South Wales, the Australian Capital Territory and Victoria and the two eastern draining river catchments in southern New South Wales (Figure 3). Within the Murray-Darling Basin, the species once ranged from the Macquarie River catchment in New South Wales in the north, where the type specimen was caught, southwards and then west in Victoria to the Loddon River catchment in central Victoria in the south (Cadwallader 1981; Faulks et al., 2010; Trueman 2011). In between these two catchments, the species was present in the Lachlan, Murrumbidgee, Murray, Mitta Mitta, Kiewa, Ovens, Goulburn-Broken and Campaspe river catchments (Cadwallader 1981). In eastern draining river catchments in New South Wales, the species was naturally found from the Hawkesbury-Nepean in the north, south to the Shoalhaven river catchment, including the Georges River catchment which occurs between these two (Faulks et al., 2010). In South Australia, it was likely that the species was scarce in the lower Murray River (Trueman 2011).

In the Murray-Darling, the Macquarie perch is typically found in the cool, upper reaches of river catchments (Cadwallader 1981; Lintermans 2007; Trueman 2011), however recent analysis of oral history records, newspaper records and photographs has identified that in some Victorian catchments it was also once considered abundant in the mid to lower reaches (Trueman 2011). A summary analysis of these historical records made the conclusion that in New South Wales and the Australian Capital Territory, the species was most abundant in upland zones. In Victoria the species was most abundant in slopes zones of river catchments but it was also noted that the species could not reach the higher 'upland' and 'montane' elevations in some catchments due to waterfall barriers, therefore possibly influencing the analysis (Trueman 2011). In the Ovens and Goulburn river catchments in Victoria especially, the species was commonly caught in lagoons in the 'slopes' and 'lowland' zones (Trueman 2011).

While analysis of the oral history records has concluded that the species was most abundant in upland and slopes zones of river catchment in the Murray-Darling Basin, there are a number of reliable records of the species having once been common in some lowland habitats, generally in the southern parts of its range (e.g. Cadwallader 1977; 1981; Hammer & Walker 2004; Mallen-Cooper & Brand 2007; Trueman 2011).

5.2 Present natural distribution and abundance

While there are existing populations of Macquarie perch in the Murray-Darling Basin and in eastern drainage catchments in New South Wales (Figure 3), populations are often small and geographically isolated (Lintermans 2007; Faulks et al., 2010). The species is now absent from much of its former range. In New South Wales, the species still occurs in parts of the Lachlan, Murrumbidgee in the Murray-Darling Basin, and in the Hawkesbury-Nepean catchment on the east coast (Lintermans 2007; Faulks et al., 2010). In the Australian Capital Territory, the species still occurs in the Paddys and Cotter river catchments, which flow into the Murrumbidgee River, and the Murrumbidgee River itself, however it is now only in extremely low abundance in the Murrumbidgee River (Lintermans 2007; Lintermans unpub. data, cited in Lintermans 2013). In Victoria, the species still occurs in the Mitta Mitta, Ovens and Goulburn-Broken river catchments (Lintermans 2007) (Figure 3).

The populations of Macquarie perch in impoundments such as Lake Eildon, Victoria (its dam completed in 1929 in the Goulburn River catchment) and Lake Burrinjuck, New South Wales (its dam completed in 1928 in the Murrumbidgee River catchment) initially sustained significant recreational fishing pressure but ultimately declined dramatically, with the species now likely extinct from both reservoirs (Cadwallader & Rogan 1977; Douglas et al., 2002;

Lintermans 2006a; 2007; Farrington et al., 2014). The Macquarie perch population within Lake Dartmouth, Victoria (its dam completed in 1979 in Mitta Mitta river catchment) also underwent a major decline, but has shown recent signs of recovery following increased reservoir productivity and increased restrictions on recreational catch (Hunt et al., 2011, Tonkin et al., 2014). Within 12 years of the completion of the dam forming Lake Dartmouth on the Mitta Mitta River, the species disappeared downstream of the dam (Koehn et al., 1995; Copeland & Lugg 2014).

New South Wales and Australian Capital Territory

The population in Googong Reservoir (its dam completed in 1979 in the Queanbeyan River catchment) is considered to be effectively extinct, and any individuals found in the reservoir have been likely displaced from upstream areas of the impoundment in the Queanbeyan River (Lintermans pers. comm. 2015). Within the upper Murrumbidgee River catchment, barriers to fish movement such as Googong Dam on the Queanbeyan River which restricted the species moving from the upper Queanbeyan River to areas downstream of Googong Reservoir, and Scrivener Dam on the Molonglo River that restricted upstream movement of the species from the Murrumbidgee to the lower Molonglo and Queanbeyan rivers are the most likely reasons for the disappearance on the Macquarie perch in the Queanbeyan River downstream of Googong Reservoir (Lintermans 2013). There is also a significant barrier to passage created by a weir on the Queanbeyan River near the Queanbeyan town centre which greatly restricts fish passage in usual river flow. Upstream of Googong Reservoir, a population was established in the upper Queanbeyan River soon after the completion of the dam using translocated individuals from the Reservoir (Lintermans 2013). This population was considered to have declined based on observations from net surveys for the species between 2001 and 2006, and given there was no evidence of detectable recruitment since 2001 (Lintermans 2013). Monitoring of the upper Queanbeyan River since 2006 has only detected a single individual (in 2007), and it is likely that the species is now effectively extinct in this catchment (Lintermans 2013; Lintermans pers. comm. 2015).

Below the dam which forms Cotter Reservoir (its dam completed in 1915 on the Cotter River which flows into the Murrumbidgee River), Macquarie perch have only been recorded in the river rarely, and these individuals are presumed to have been displaced from the upstream reservoir (Lintermans 2002). Above the dam, Macquarie perch are now found in Cotter Reservoir and for a possible 27 km of the Cotter River upstream of the reservoir and downstream of Bendora Reservoir, now that a fishway has been installed at Vanity's Crossing since 2001 (Lintermans 2002; 2007; 2012; Broadhurst et al., 2013).

A survey undertaken in 1998 and 1999 failed to located Macquarie perch in any of the Yass, Bredbo, Numeralla, Kybean, and Big Badja rivers of the Murrumbidgee River catchment (Lintermans 2002), where they once occurred. The species was recorded in very low numbers in the Goodradigbee River and reasonable numbers of the species occur in the upper Murrumbidgee River from Cooma to Yaouk (approximately 1100 m a.s.l) (Lintermans 2002). There is also a small population of the species in the Murrumbidgee River near Michelago (Lintermans 2002).

No Macquarie perch have been reported from downstream of Wyangala Dam (dam completed in 1935 in the Lachlan River catchment) for many decades (Trueman pers. comm. cited in Gilligan et al., 2010). Sampling in the Lachlan River catchment upstream of Wyangala Dam between 2006 and 2008, reported catching no Macquarie perch in the impoundment waters itself, but found Macquarie perch to be proportionally the most common large native fish in the Abercrombie and the Lachlan rivers (Gilligan et al., 2010). Today, the species is considered to be rare at best, but probably extinct in Lake Wyangala given the rare accounts of recreational

fishers encountering the species in the lake (Gilligan et al., 2010). However, the species has not been detected in the Lachlan River above Lake Wyangala since 2008 (NSW DPI pers. comm. 2016).

Today in eastern catchments natural populations of Macquarie perch still occur in the Hawkesbury-Nepean river system and the Georges River (Faulks et al., 2010). It is likely that the natural population that once occurred in the Shoalhaven River is now extinct, with the last known population in the catchment, in the Mongarlowe River, presumed to be a result of translocated individuals from the Murray-Darling Basin (Harris & Rowland 1996; Lintermans 2008; Faulks et al., 2010). The species was once common in the Shoalhaven River catchment (Bishop & Tilzey 1978; Bishop 1979). Where Macquarie perch persist in eastern catchments, they mostly occur in waterways upstream of where Australian bass (*M. novemaculeata*) populations are located (Harris & Rowland 1996).

Faulks et al. (2010) undertook a phylogeographical study of Macquarie perch in New South Wales and found a high level of genetic diversity for the species, with some lineages extremely divergent to the level that one of the populations, an individual from the Kangaroo River population, considered to be the last known individual from the now extinct natural population that once occurred in the Shoalhaven River catchment, to have been a putative undescribed species. The study also proposed that the species originated on the coast, east of the Great Dividing Range, with subsequent colonisation of the Murray-Darling Basin (Faulks et al., 2010). The high levels of genetic diversity and divergence within the species may be due to specific habitat requirements (such as divergent lineages being isolated in upper reaches of catchments), localised recruitment and climate fluctuations (Faulks et al., 2010). Faulks et al. (2010) notes that not only are the Murray-Darling Basin and eastern populations of the species genetically divergent, but they are also morphologically different. The study noted that the major lineage groups observed were for the Kangaroo River, Webbs Creek, Colo River, Nepean River, Murray-Murrumbidgee rivers and Lachlan River.

Victoria

Recent observations have shown populations of Macquarie perch are still present in Victoria in the upper tributaries of the Goulburn-Broken river system (King Parrot, Hughes and Holland's creeks), the Ovens River catchment (including the Buffalo River tributary) and the upper Mitta Mitta River (including Lake Dartmouth) (ARI 2007; Ayers 2009; Hunt et al., 2011; Nguyen et al., 2012; Tonkin et al., 2014). While recent surveys have detected a few Macquarie perch in the Goulburn River 2.5 km downstream from the King Parrot Creek confluence (near Kerrisdale) (GBCMA 2015), adult Macquarie perch remain rare in the main channel of the Goulburn River as it is too early to see the benefits of stocking. While historical records indicated that the species was present in the Campaspe River catchment (including Axe Creek and the Coliban River) (Cadwallader 1981), indications are that they have contracted to Upper Coliban Reservoir, likely to be supported by stockings which occurred there during the mid-1990s (Vic DELWP pers. comm. 2015).

Other genetic work on Macquarie perch in Victoria has identified relatively low levels of genetic diversity within populations occurring there (Nguyen et al., 2012), which is not inconsistent with the Faulks et al. (2010) study: compared to the high level of genetic divergence between coastal and Murray-Darling Basin populations, there is low genetic divergence within the Murray-Darling Basin. Importantly, two different genetic clusters were identified in Victoria, one cluster from the Goulburn and Ovens river catchments (Buffalo River, Holland's and Hughes creeks) and another cluster from Lake Dartmouth in the Mitta Mitta River catchment (Nguyen et al., 2012).

5.3 Translocated populations

A number of translocations of Macquarie perch have occurred within and outside of its former range. Viable populations of fish believed to have been sourced from MDB populations exist in several coastal catchments, most notably in the Yarra River in Victoria and in Cataract Dam in New South Wales.

New South Wales and the Australian Capital Territory

Macquarie perch were translocated from the Murray-Darling Basin, probably the Murrumbidgee River, to the Mongarlowe River in the Shoalhaven River catchment in the late-1800s (likely to be the 'perch' referred to in the *Goulburn Evening Penny Post*, 1 June 1897, p. 4; Harris & Rowland 1996; Lintermans 2008; Faulks et al., 2010). The species was translocated to Cataract Dam (Nepean River catchment) and the Nepean River itself near Sydney using fish captured from the Berembed Weir area of the Murrumbidgee River in around 1916 (SFD 1914; 1923). A number of other New South Wales coastal populations are believed to have been translocated from the Murray-Darling Basin (Lake 1971; Cadwallader 1981), however there are no written records to support this assertion, with the exception of Cataract Dam and the Nepean River.

Macquarie perch have also been translocated within catchments where it naturally occurred such as within the Queanbeyan River to the area upstream of Googong Reservoir in New South Wales and the Cotter River to the area upstream of Vanitys Crossing before a fishway was installed at this barrier (Lintermans 2006a; 2006b).

In addition, Macquarie perch were translocated from the upper Murrumbidgee River near Cooma to two locations in the Snowy River (Stead 1913). The species has not since been recorded from the Snowy River.

Victoria

In the past, Macquarie perch were translocated, most likely in batches containing a mixture of other 'perch species' such as golden perch (*M. ambigua*) and silver perch (*Bidyanus bidyanus*), widely within and outside its natural distribution in Victoria (Cadwallader 1981). It is considered that the species was introduced to the Yarra River catchment in 1857 from upper parts of King Parrot Creek via the upper Plenty River which ultimately flows into the Yarra River (Wilson 1857) and further translocations took place in the early twentieth century from the Goulburn-Broken river system, one of the source locations being recorded as Goulburn Weir (Cadwallader 1981; Barnham 1989) for recreational fishing opportunities. Given the findings of a recent genetic study that showed that the Yarra River population has genetic traits from Lake Dartmouth (Mitta Mitta River catchment) cluster as well as the cluster for the Goulburn-Broken and Ovens rivers, it appears likely that some translocations (or stockings) of Macquarie perch into the Yarra River catchment occurred from fish (or broodfish) sourced from the Mitta Mitta River catchment (Nguyen et al., 2012).

Macquarie perch were naturally found in the Seven Creeks near Euroa up to a natural barrier in the form of the Gooram Falls. During 1921/22 juvenile Macquarie perch were translocated upstream of the falls to near Strathbogrie from the Seven Creeks itself and from the Goulburn River at Cathkin and have persisted as a self-sustaining population. Other translocated populations were established in the Barwon, Latrobe and Wannon rivers but in the first two are now considered extinct (Cadwallader 1981).

In western Victoria, still within the Murray-Darling Basin and to the west of the its natural, historical distribution, Macquarie perch were translocated into the Wimmera River catchment and into the Loddon River catchment, which likely represented the most western catchment containing natural populations at the time of European settlement, but these populations were likely supplemented with translocated Macquarie perch as early as 1873 (Trueman 2011). Fish sourced from the Goulburn River were translocated into the Bet Bet Creek, Tullaroop Creek and Lake Daylesford in the Loddon River catchment in the 1930s (Cadwallader 1981). Fish sourced mainly from the Goulburn River were also translocated into waterways within the Wimmera River catchment between about 1910 and the 1930s (Cadwallader 1981). Until recent stockings into Expedition Pass Reservoir (Loddon River catchment), the species was considered not to have been completely extirpated in the Loddon or Wimmera rivers catchments (Lintermans 2007; Vic DELWP pers. comm. 2015).

Recently, there has been translocation of sub-adult individuals from the Lake Dartmouth population in the Mitta Mitta River catchment to the middle reaches of the Ovens River in addition to stocked fingerlings (see below under 5.4 for more detail on the stockings) with the aim of establishing a range of age and developmental stages that are similar to those which exist in natural populations (Vic DEPI 2014a). There have also been individuals translocated from Lake Dartmouth to Lake William Hovell, a dammed reservoir on the King River (Ovens River catchment) in Victoria (Vic DEDJTR 2015a).

5.4 Breeding and stocking

Attempts made to breed Macquarie perch in captivity up until 2009 had not been successful, as mature fish were not able to reach breeding condition (NSW DPI 2010). Until recently, hatchery programs for the species relied on capturing spawning-run fish from the wild (NSW DPI 2010), inducing individuals to spawn through the injection of artificial hormones to collect the eggs and sperm. While the species can live in impoundments, as a truly riverine species it requires fast-flowing water with gravel-cobble substrates to breed (Cadwallader & Rogan 1977; Appleford et al., 1998; Lintermans 2007; 2013).

The requirement for flowing water conditions to stimulate breeding in Macquarie perch is supported by the many failures of impoundment populations to be self-sustaining. Research on the now likely extinct Queanbeyan River population of the species found evidence of recruitment until 2001 but not thereafter, and this may have been the effect of the millennium drought (between 1997 and 2010) (Lintermans 2013). The millennium drought would have reduced the frequency of available fast-flowing conditions in the waterway available to the species, and this could explain the persistent breeding failure since 2001 (Lintermans 2013).

There have been a number of breeding investigations for Macquarie perch to support a hatchery production source. Initial research on developing hatchery produced Macquarie perch began in 1978 at the Narrandera Fisheries Centre (formerly the Inland Fisheries Research Station (IFRS)) in New South Wales (Ingram et al., 1994). It was followed by trials in 1983 at Snobs Creek Fish Hatchery in Victoria, which involved catching running-ripe females from Lake Dartmouth during their annual spawn run (Gooley & McDonald 1988). The New South Wales Government halted its captive breeding research on the species between 1990 and the early-2000s, due to lack of success (Ingram et al., 1994; NSW DPI 2010). However, the Narrandera Fisheries Centre has had recent success in breeding the species in captivity, using a new approach employing an artificial stream with flowing water and coarse substrates to coax both males and females into breeding condition (NSW DPI 2010). The Victorian program at Snobs Creek Fish Hatchery was halted in the mid-1990s, primarily due to difficulties in attaining mature fish in spawning condition

captured from Lake Dartmouth (Gray et al., 2000; Ingram et al., 2000). Fingerling production for stocking recommenced in 2010 (Vic DEDJTR 2015b). Note that the breeding of captive-held fish at Snobs Creek Fishery Hatchery has been occurring since 2010, however results are still inconsistent and further research is needed to refine the methods (Ho & Ingram 2012). Between 1986 and 1997 approximately 456 000 juveniles, sourced from production at the Snobs Creek Fish Hatchery, were released into nine sites throughout the Murray-Darling Basin (Ingram et al., 2000).

New South Wales and the Australian Capital Territory

Captive breeding trials in 2010 and 2011 proved successful at the Narrandera Fisheries Centre in New South Wales, and the product of these trials, 137 (2010) and 7500 (2011) Macquarie perch fingerlings were released into the Retreat River, in the upper Lachlan River Catchment (Pearce 2013). This waterway, as it provided a suitable refuge area, protected from predation and competition by alien fish species due to a waterfall acting as effective natural barrier from alien redfin migrating upstream, from parts lower in the Lachlan River catchment (Pearce 2013). These stockings were followed up with a release of 10 000 fingerlings into the same stretch of the Retreat River in late-2013 (NSW DPI 2013b).

Juvenile, hatchery-produced Macquarie perch have been stocked into a number of impoundments in New South Wales, including Talbingo and Khancoban reservoirs on the western side of the Snowy Mountains in southern New South Wales and Cataract Reservoir in the Hawkesbury-Nepean catchment (Lintermans 2007).

Victoria

Recent stockings of Macquarie perch fingerlings into Victorian waters as part of the Victorian Fish Stocking Program include:

- 2015 – 5000 in February into Expedition Pass Reservoir (Farraday); 12 750 in February into the Goulburn River (Molesworth to Trawool), and; 13 600 in February into the Ovens River (Oxley Flats to Rocky Point).
- 2014 – 5000 in February into Expedition Pass Reservoir (Farraday); 27 500 in February into the Goulburn River (Molesworth to Trawool), and; 40 500 in February into the Ovens River (Myrtleford area).
- 2013 – 5000 in January into Dartmouth Dam (Dartmouth); 5000 in January into Expedition Pass Reservoir (Farraday); 6320 in January into the Goulburn River (above Nagambie Lake to Seymour), and; 6320 in January into the Ovens River (Myrtleford area)
- 2012 – 3620 in January into Expedition Pass Reservoir (Farraday).
- 2011 – 3000 in February into Expedition Pass Reservoir (Farraday); 1325 into the Ovens River at Rocky Point and 1325 at Whorouly Bridge, and; 2650 into William Hovell Lake (Cheshunt South).
- 2010 – 2800 in February and 500 in March into Expedition Pass Reservoir (Farraday) and 250 into Holland's Creek (Tatong) in February (Gray 2010; Vic DEPI 2014a; 2014b; Vic DEDJTR 2015b).

Fingerlings have also been previously stocked in the Upper Coliban Reservoir near the town of Tylden (Lintermans, 2007).

6 DECLINE AND THREATS

6.1 Decline

There was a lack of focussed scientific studies when the main declines for Macquarie perch occurred between the 1920 and 1960. The best known work of early accounts of the fish fauna of the Murray-Darling Basin was conducted by Colonel John O. Langtry between 1949 and 1950 (Cadwallader 1977). Langtry's study focussed on lowland habitats and, as Langtry notes, followed significant changes to the native fish compositions in the system already (Cadwallader 1977; Trueman 2011).

However, the research of oral histories, newspaper records and photographs undertaken by Trueman (2011), obtained more records in the Murray-Darling Basin of Macquarie perch than for any other individual species, which suggests that its abundance was 'prolific' in the first 100 years of European settlement of Australia. Trueman (2011) uses an approach referred to as 'historical triangulation', which is becoming increasingly accepted in documenting environmental change in ecological studies. Triangulation refers to the practice of using two or more sources to verify observations, and its use is well established in the social sciences and is used by doctors when evaluating patient history (Robertson et al., 2000). Oral histories are particularly powerful for river management in Australia, in that they provide information that precedes formal agency or research institution records (Boulton et al., 2004). Trueman (2011) utilised photographs, newspaper stories and supporting accounts to verify oral recollections of lay observers (oral histories). For Macquarie perch, this historical research uncovered, and also confirmed that significant declines in the species' populations were evident by the early twentieth century in some areas, and that widespread population extinctions occurred between 1920 and 1960 (Trueman 2011).

By the end of the 1960s, endemic populations in New South Wales and the Australian Capital Territory were largely restricted to the upper Lachlan and Murrumbidgee river catchments (Trueman 2011). In Victoria by the end of the 1960s, relict populations were restricted to the slopes and upland zones of the Mitta Mitta, Ovens and Goulburn-Broken river catchments (Trueman 2011).

New South Wales and the Australian Capital Territory

The Macquarie perch was captured regularly in the Macquarie River catchment in New South Wales until the 1950s but historical research indicates that the species had disappeared and become extinct in the catchment by the 1960s (Trueman 2011). The species was not recorded, when it was predicted to be commonly sampled, in the Sustainable Rivers Audit sampling of the catchment (Davies et al., 2008). Estimates of Macquarie perch abundance in the Macquarie River catchment at the time of European settlement were rated as: rare in lowland zone of the Macquarie River catchment; common in the slopes zone, and; abundant in both the upland and montane zones of the catchment (Trueman 2011).

For the Lachlan River catchment, historical research indicates that the Macquarie perch initially flourished in Wyangala Dam in the 1930s soon after its construction. However, the species experienced a decline in the Abercrombie and Lachlan rivers above Wyangala Dam in the 1950s and 1960s, while below the dam decline was noted in the 1930s (Trueman 2011). While the species was not caught in Sustainable Rivers Audit surveys of the Lachlan River catchment (Davies et al., 2008), it has been caught in other surveys and is considered to still persist in the upper parts of the catchment where it is the most common large native freshwater fish

(Lintermans 2007; Gilligan et al., 2010; Faulks et al., 2011). It is also considered to be likely migrating unidirectionally between the Abercrombie and upper Lachlan rivers based on recent estimates of gene flow (Faulks et al., 2011). There have been recent stockings of the species into the Retreat River, which flows in the Abercrombie River, the major tributary of the upper Lachlan River catchment (Pearce 2013). Estimates of Macquarie perch abundance in the Lachlan catchment at the time of European settlement were rated as: absent from the lowland zone; common from the slopes zone, and; abundant from both the upland and montane zones (Trueman 2011).

For the Murrumbidgee River catchment, historical research indicates that for the majority of the catchment the Macquarie perch declined in abundance between the 1930s and 1960s and by the 1980s had become rare in many parts of the catchment (Trueman 2011). Initially, the species flourished in Lake Burrinjuck after its construction in the early-1900s until the 1950s, but then declined to the point that by the 1970s it could only be caught during spawning migrations into upstream areas and by the 1980s it was rare (Trueman 2011). Similar patterns of decline in the 1980s were observed for the Australian Capital Territory section of the Murrumbidgee River (Lintermans 2002). A relict population of the species continues to remain strong in the Cotter Reservoir on the Cotter River in the Australian Capital Territory (Farrington et al., 2014). In New South Wales, the species is now considered to be effectively extinct in the Queanbeyan River upstream of Googong Reservoir (the Queanbeyan River flows into the Molonglo River, which in turn flows in the upper Murrumbidgee River) (Lintermans pers. comm. 2015), where a translocated self-sustaining population had persisted recruiting until the early 2000s but has since declined (Lintermans 2013). Three individuals were caught in the Sustainable Rivers Audit surveys in the montane zone of the Murrumbidgee River catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Murrumbidgee River catchment were rated as: common from the lowland zone, and; abundant from three zones, the slopes, upland and montane (Trueman 2011).

For the upper parts of the Murray River catchment, historical research indicates that the Macquarie perch declined in abundance from the time of World War One to the 1930s (Trueman 2011). The species was abundant in the Upper Murray River upstream of the area near Khancoban in New South Wales until the 1930s when they became sparse and the last reported capture of the species in this region was in the Tooma River in 1999 (Harris et al., 2006; Trueman 2011). The species is likely to have disappeared from the upper Cudgewa Creek catchment in Victoria, which flows into the Upper Murray River, after about 1920 (Trueman 2011). This trend appears to be consistent with records further downstream, on the Upper Murray River and nearby creeks near Burroweye and Towong, where recordings of Macquarie perch seem to decline until the 1930s (Trueman 2011). Downstream on the Upper Murray River near Albury, the species was common in the late-1920s but underwent a dramatic decline shortly after that time (Trueman 2011). Very few historical records exist of native fish in general for the montane zone of the Upper Murray River (upstream of the Tom Groggin campground which is close to the New South Wales-Victoria border within the New South Wales' Kosciuszko National Park) (Trueman 2011). Surveys undertaken as part of the Sustainable Rivers Audit did not record the species in the Upper Murray River catchment (Davies et al., 2008). Much of the Upper Murray River occurs within the slopes zone. Macquarie perch abundance has been estimated at the time of European settlement for the Upper Murray River catchment as: abundant in the slopes zone, and; common in both the upland and montane zones (Trueman 2011).

The middle or central Murray River catchment stretching from Wentworth in the west, at the confluence of the Murray and Darling rivers, to Albury-Wodonga in the east, is unusual for

assessment of Macquarie perch abundance, as this part of the river is entirely zoned as lowland for purposes of Trueman's 2011 analysis. For the Central Murray River catchment, historical research indicates that there seemed to be a consistent trend of the species decline in abundance, with few exceptions, occurring during the 1930s and becoming severely 'depleted' by the 1950s, to the point where the species had completely disappeared from most of the Central Murray River catchment by the 1970s (Trueman 2011). The stretch of Murray River between Tocumwal eastwards to Yarrawonga was an exception where the species was common until about 1950, then declined in abundance until they had disappeared in this area by the end of the 1980s (Cadwallader 1977; Trueman 2011). The Sustainable Rivers Audit surveys did not catch any individuals in the Central Murray River catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Central Murray River catchment were rated as: rare in the Murray River between the Wentworth eastwards to the Wakool River confluence; common between the Wakool River confluence eastwards to Echuca (Campaspe River confluence); abundant between Echuca eastwards to Albury-Wodonga in these lowland zones of the Murray River (Trueman 2011).

Out of the catchments of the Hawkesbury-Nepean, Georges and Shoalhaven rivers, where Macquarie perch historically occurred at the time of European settlement and for some time afterwards (Faulks et al., 2010; 2011), it is still present in fragmented populations in the upper Hawkesbury-Nepean catchment, in tributaries of the Warragamba Dam/River and tributaries of the Nepean River (Knight 2010) and tributaries of the Colo River, which flows into the Hawkesbury River (Faulks et al., 2011). The natural population in the Shoalhaven River catchment declined rapidly during the late-1990s. Recent intensive sampling efforts have found no individuals in the wild since 1998. Therefore, it is considered that the natural population is extinct from the catchment except for a population remaining in the Mongarlowe River which genetic analysis has been found to be derived from a translocation of individuals from the Murray-Darling Basin (Faulks et al., 2010; 2011). Recent declines are reported for the translocated population of the species in the Mongarlowe River (Lintermans 2008). Cataract Dam near Bulli Tops on the Cataract River, a tributary of the upper Nepean River, is also home to a population of Macquarie perch, which also has been shown to be derived from a translocation from the Murray-Darling Basin, and there has been some interbreeding with the naturally occurring population in the Cataract River downstream of the dam wall (Faulks et al., 2011).

Victoria

For the Mitta Mitta River catchment, historical research indicates that for the majority of the catchment, Macquarie perch declined in abundance between in the 1930s and by the end of the World War II the species was rare in the catchment above the Larsens Creek confluence (before Lake Dartmouth was made) and by the 1950s had become scarce throughout the catchment and until the 1970s had contracted to the area of the Dart Creek/River confluence (also now swamped by Lake Dartmouth) and had become rare in many parts of the catchment (Trueman 2011). Soon after Lake Dartmouth was constructed and flooded in the 1970s, the population of Macquarie perch initially flourished becoming reasonably abundant and supporting a recreational fishery (Hunt et al., 2011; Trueman 2011). Below the Lake Dartmouth dam wall, Macquarie perch disappeared in the Mitta Mitta River within twelve years of its completion in 1979 (Koehn et al., 1995; Copeland & Lugg 2014). A decline in the species' abundance then was observed for Lake Dartmouth between the mid-1980s and 2000 (Douglas et al., 2002; Hunt et al., 2011). Recreational fishing of the species is currently permitted in Lake Dartmouth, with a daily bag limit of one fish, but the Victorian Government has tightened regulations associated with catching the species by increasing the legal minimum length from 250 mm to 300 mm in

Draft National Recovery Plan for the Macquarie Perch (Macquaria australasica)

2000, and then to 350 mm in 2004 (Hunt et al., 2011, Vic DEDJTR 2015c). There have been recent indications that the Lake Dartmouth population is recovering following years of higher rainfall that have resulted in greater inflows to the lake between 2008 and 2013, leading to increased biological productivity in the impoundment (Tonkin et al., 2014). Surveys undertaken as part of the Sustainable Rivers Audit did not catch any individuals, even though they were predicted to be common in the catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Mitta Mitta River catchment were rated as: abundant from both the slopes zone and upland zones, and; common from the montane zone (Trueman 2011).

For the Kiewa River catchment, historical research indicates that for the slopes zone of the catchment, Macquarie perch were abundant until a massive fish kill in 1939 in the catchment, initiated by extensive bushfires in the catchment in February (Rhodes 1999; Trueman 2011). The steep gradient between the slopes zone and the upland and montane zones of the Kiewa catchment is thought to have prevented access of Macquarie perch, and other native fish species, to these higher areas (Trueman 2011). It is now considered that the species is extinct in the Kiewa River catchment. Recent sampling as part of the Sustainable Rivers Audit did not detect the species at all in the catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Kiewa River catchment were rated as: abundant from the slopes zone, and; absent from the upland and montane zones (Trueman 2011).

For the Ovens River catchment, historical research indicates that, for the upland zone, Macquarie perch and other native fish were scarce since the early-1900s, with the exception of the Buffalo River where the species remained in good populations until fish kills following extensive bushfires in 1939 (Trueman 2011). For the slopes area of the catchment, Macquarie perch declined during the 1920s and 1930s and had disappeared from many areas by the 1940s (Trueman 2011). In the lowland areas of the catchment, the species declined during the 1930s and 1940s to the point where they were scarce during the late-1940s (Trueman 2011). The montane zone in the Ovens River catchment is essentially isolated from lower elevations of the catchment by steep gradients and waterfalls at the base of Mount Buffalo and the Wabonga Plateau, and given that there is no information for larger native species in this zone, it is considered that Macquarie perch and other native species were prevented access to it (Trueman 2011). The species was not detected in the Sustainable Rivers Audit surveys of the catchment, even though it was predicted by the study to be common (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Ovens River catchment were rated as: abundant from the lowland, slopes and upland zones, and; absent from the montane zone (Trueman 2011).

For the Goulburn-Broken river catchments, historical research indicates that, for the majority of this major river system, Macquarie perch had declined during the 1920s and had disappeared from most of the Goulburn-Broken river catchments by the 1950s (Trueman 2011). There were a few exceptions though, such as the Yea River and King Parrot Creek, in the Goulburn River catchment, and the lower Broken River near Benalla and Nalinga, where populations remained at least until the 1970s. A relict population has remained in the lower reaches of King Parrot Creek downstream of Flowerdale, but the species had disappeared from its upper reaches in the early 1900s, this population having been the source for the 1857 translocation to the Yarra River catchment (Wilson 1857; Trueman 2011). In Lake Eildon, which was initially filled by the construction of the Eildon Weir on the Goulburn River in 1929 and then expanded in 1956, the Macquarie perch population initially flourished but subsequently declined and had disappeared by the late-1960s (Cadwallader & Rogan 1977; Trueman 2011). After the construction of

Lake Nillahcootie on the upper Broken River in 1967, a population of Macquarie perch continued until probably the late-1970s or early-1980s, given observations in the upper Broken River, near the Bridge Creek locality, but is now likely extinct (Trueman 2011; Vic DEDJTR 2015d). Populations in Ryan and Holland's Creeks declined until the 1960s and became scarce (Trueman 2011). Self-sustaining populations still exist in Holland's Creek near the township of Tatong in the Broken River catchment and in the lower to middle reaches of Hughes Creek, upstream of the township of Avenel, in the Goulburn River catchment (ARI 2007; Raymond et al., 2008). The Sustainable Rivers Audit caught two individuals from sites sampled in the upland zone of the Goulburn River catchment, but none from the Broken River catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Goulburn-Broken rivers catchments were rated as: abundant from the lowland and slopes zones; common in the upland zone, and; rare from the montane zone (Trueman 2011).

For the Campaspe River catchment, historical research indicates that, for the lowland and slopes zones, Macquarie perch had declined in the years leading up to the early-1940s, such that translocations to the Coliban River (a tributary of the Campaspe River) from the Broken River were made in 1936 and 1962 (Cadwallader 1981; Trueman 2011). Only a very small percentage of the catchment is classified in the montane zone and waterfalls, such as Mitchells and Coliban falls, are considered to have blocked access of larger native fish species, including Macquarie perch, to upland zones and higher (Trueman 2011). Surveys undertaken as part of the Sustainable Rivers Audit did not catch any individuals, even though they were predicted to be common in the catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Campaspe River catchment was rated as common from the lowland zone and abundant in the slopes zone; and absent from the upland and montane zones, probably as a result of the presence of Mitchells and Coliban falls (Trueman 2011).

For the Loddon River catchment, historical research indicates that, for the lowland and slopes zones, Macquarie perch had declined in the late-1800s until they were virtually extinct by the 1930s (Trueman 2011). The Loddon River catchment is considered to have undergone the most severe environmental disturbance of all Victorian catchments during the Victorian Gold Rush years (circa 1850 – 1900), due to its proximity to the Victorian goldfields and the consequences of mining sludge and tailings being discharged into its waterways, and the impacts from increased siltation from the introduction of hydraulic sluicing of alluvium loosing massive quantities of topsoil in the Castlemaine district (Scott 2001). Surveys undertaken as part of the Sustainable Rivers Audit did not catch any individuals, even though they were predicted to be common in the catchment (Davies et al., 2008). Estimates of Macquarie perch abundance at the time of European settlement for the Loddon River catchment was rated as rare from the lowland zone and abundant in the slopes zone; and rare from the upland zone which is probably a result of the presence many waterfalls in the upper Loddon River catchment (Trueman 2011). Only a few small streams penetrate into the montane zone of the Loddon River catchment and there are no records of larger native fish being present in this zone (Trueman 2011).

6.2 Threats

6.2.1 Habitat degradation

Habitat degradation can include processes such as sedimentation and destruction and/or removal of woody and rock habitats (snags) essential for the important life cycle stages of the Macquarie perch.

Native fish fauna in the upper reaches of Murray-Darling Basin catchments, such as the Macquarie perch, which lay adhesive eggs on the silt-free coarse substrate, have probably been the most directly affected by increased sedimentation (Cadwallader 1978; Harris 1995). Sedimentation is considered to be one of the most important reasons for the decline of Macquarie perch populations (Cadwallader 1978; 1979).

While sediment and other suspended materials in the water column are natural components of rivers and streams, as erosion and decay processes will deliver sediment to streams even in pristine landscapes, land-use changes (especially poorly-managed agricultural practices, forestry, road construction and maintenance, mineral extraction, construction activities and increased fire frequency or catastrophic bushfires) have resulted in an increase in anthropogenic fine sediment deposition in Australia (Walker et al., 1986; Waters 1995; Burkhead et al., 1997; Wood & Armitage 1997). Sedimentation is one of the most widespread physical disturbances degrading the habitats within Australian rivers (Commonwealth of Australia 1996, in Harris & Silveira 1999). Since European settlement, river sediment loads are estimated to have increased by 10 to 50 fold, with gully, riverbank and sheet erosion delivering, on average, over 120 million tonnes of sediment to Australian streams each year (NLWRA 2001). Increased levels of sediment can adversely affect many aspects of freshwater ecosystems by reducing water quality, modifying the morphology, ecology and physical form of streams and altering the physical, physiological and behavioural responses of aquatic flora and fauna (Edwards 1969; Nuttall 1972; Beschta & Jackson 1978; Brookes 1986; Jones & Clark 1987; Wright & Berrie 1987; McDonnell & Pickett 1990; Doeg & Koehn 1994; Waters 1995; Delong & Brusven 1998; Jones et al., 1999; Dudgeon 2000; Sutherland et al., 2002; Mol & Ouboter 2004).

Catastrophic bushfires are of particular concern to remaining Macquarie perch populations. Direct impacts of bushfire on freshwater environments are increased temperatures (Hitt 2003), increased pH (Cushing Jr. & Olson 1963) and increases in nutrients from smoke and ash inputs (Bayley et al., 1992; Earl & Blinn 2003). A study in Montana recorded water temperature rises of nearly 10°C caused by a high-severity wildfire (Hitt 2003). pH increased in a stream in Washington State from 7.8 to 11.1 with temperature increase immediately following weed burning on its banks (Cushing Jr. & Olson 1963). Potassium, and phosphorus and nitrogen compounds such as ammonium, nitrate, soluble reactive phosphorus, all increase in concentration within streams immediately following a fire (Bayley et al., 1992; Earl & Blinn 2003). Mortalities of freshwater fish from these direct impacts following bushfire have been generally confined to smaller order streams, such as the ones which Macquarie perch are known to inhabit (Cushing Jr. & Olson, 1963; Lyon & O'Connor 2008).

A secondary, or indirect, impact following bushfire is the increased sediment load (often referred to as a 'sediment slug') which can follow rainfall events and subsequent run-off from recently burnt ground and is often more widespread (Benda et al., 2003; Meyer & Pierce 2003; Smith et al., 2011; Goode et al., 2012). A sediment slug following large bushfires in 2003 in the southern Murray-Darling Basin had major negative impacts to freshwater fish in streams in the region, including native fish (Lyon & O'Connor 2008), and while no Macquarie perch were sampled in the study despite being known from surveyed catchments, it is plausible that the species also was negatively affected as recorded for other native species in the study.

Gravel beds are important habitat areas for Macquarie perch spawning, feeding and as refuge areas for juvenile fish (Lintermans 2007). Berkman & Rabeni (1987) found that fish species requiring clean cobble/gravel for spawning, such as the Macquarie perch, declined as fine sedimentation of substrates increased. For Salmonid species which rely on cobble/gravel for spawning, fine sediment was also found to impair the gas exchange of developing eggs by

adhering to the surface of the egg (Chapman 1988). Overseas studies have found high concentrations of fine sediment increases exposure of fish to predators and physical disturbance through destruction of shelter, physical structures and hiding places, for example smothering of aquatic macrophytes (Brookes 1986; Mol & Ouboter 2004).

Deposited coarse sediment can fill deep holes, create barriers and alter stream morphology leading to wider, shallower profiles. Infilling of deep holes removes thermal refuges that many Australian native fish species, such as the Macquarie perch, rely upon during the summer and autumn months, and reduces their ability to withstand drought events (Cadwallader 1978; Coats et al., 1985). Furthermore, the nutrients and toxic substances attached to sediment particles also pose a threat to Australian native fish species (Cadwallader 1978; 1979; Lintermans 1991a; ACT Government 1999a; Horner 2000; Burton et al., 2004). Silt and clay particles can absorb, transport and store metal contaminants (Stone & Droppo 1994) so that deposited sediments act as a sink for heavy metals, with contaminated sediment potentially continuing to pose a pollution problem long after land disturbances first occurred (Trimble 1981; Mol & Ouboter 2004).

High levels of suspended sediment will reduce light penetration leading to reduced primary productivity, submergent macrophytes, food and habitat availability for fish (Edwards 1969; Petts 1984; Power 1984; Brookes 1986; Van Nieuwenhuysen & LaPerriere 1986; Schälchli 1992; Davies et al., 1992; Richards & Bacon 1994). Suspended sediments may impact fish directly by clogging gill rakers and gill filaments leading to death (Bruton 1985). Suspended sediment will also affect the efficiency of hunting, particularly in the case of visual feeders (Vinyard & O'Brien 1976; Bruton 1985; Ryan 1991) and may also affect spawning success of fish by rendering visual courtship signals less effective (Burkhead & Jelks 2001).

Following extensive bushfires in Victoria in early 2009, a portion of the Macquarie perch population occurring in King Parrot Creek were temporarily moved to the Snobs Creek Fish Hatchery to allow water quality to improve (Kearns et al., 2012). There was concern that the fires, which burnt up to the water edge of King Parrot Creek in a number of sections, would cause a sediment slug, amongst other direct and indirect effects, to form in King Parrot Creek (Kearns et al., 2012). It appears that Macquarie perch do not spawn evenly across habitats and have preference for specific sites within King Parrot Creek (Kearns et al., 2012). Sedimentation, loss of riparian vegetation and bank erosion are all evident in King Parrot Creek, and for recovery of the species to occur, protection of spawning habitats will be greatly assisted if there is focussed action on riparian restoration and bank stabilisation to reduce sediment loads into this waterway (Kearns et al., 2012).

In addition to sedimentation, snags (woody and rocky) have a critical role to play in the ecological functioning of rivers. Snag structures can consist of whole trees, limbs, root masses, boulders and rocks that are partly or totally submerged. Snag structures provide complex and diverse habitat for native fish and invertebrates including cover from predation, refuge from high velocity flows and feeding sites (Bilby & Likens 1990; O'Connor 1991; Crook & Robertson 1999; Treadwell et al., 1999). Snags also play a significant role in promoting different habitat elements including scour pools, bars, islands, and side-channels. Conversely removal of snags can lead to a range of detrimental effects on stream morphology including increased flow velocity, bed degradation, channel enlargement and direct loss of fish habitat (Erskine & Webb 2003).

Since the mid nineteenth century, thousands of snags have been removed from Australian streams and rivers, especially within the Murray-Darling Basin, in an effort to stabilise rivers (Erskine 1990; 1992; 2001) and to increase river navigability, flood mitigation and increase channel efficiency (Gippel 1995, Erskine & Webb 2003). While there is limited data on the

current extent of snag removal, snag management and current snag loads in Australian rivers, estimates of the extent and scale of historical 'desnagging' works indicate widespread and major snag removal was carried out in many coastal and inland rivers (Erskine & Webb 2003). Given the objectives of such works, including navigation, flood mitigation and channel efficiency, it seems likely that the most intensive snag removal programs concentrated on lowland and slope reaches, likely within stretches of rivers in the southern Murray –Darling Basin where Macquarie perch were present.

Therefore in the short term resnagging is necessary in specific areas, while in the longer term the restoration of riparian vegetation is essential to ensure future supplies of snags. Resnagging some areas of riverine habitat has been recommended as an action under other National threatened species recovery plans (Brown et al., 1998; NMCRT 2010).

6.2.2 Alien fish

Alien fish species may impact on native species in a number of different ways such as: predation (particularly on eggs and larvae); competition for habitat and food resources; habitat degradation; spread of diseases and parasites. Interactions with alien fish species such as trout (brown and rainbow) and redfin have been identified as likely causes in the decline of the Macquarie perch (Cadwallader 1978; 1996; Gilligan 2005; Lintermans 2007). Furthermore, alien fish species may bring new parasites and diseases which could potentially threaten native species (Cadwallader & Lawrence 1990; Arthington 1991; Abramovitz 1996; Cadwallader 1996; Arthington & McKenzie 1997; Horwitz et al., 1998; Lintermans 2007). For more information on this threat refer to section 6.2.5 below. Alien fish have also been implicated in the local extinction and altered community structure of macroinvertebrates which are major food resources for native fish (Bruton 1995, Horwitz et al., 1998, Lintermans 2007).

Stocking alien fish species for recreational fisheries, including trout (brown and rainbow) and redfin, has occurred widely in Macquarie perch range states and territory of New South Wales, the Australian Capital Territory, Victoria and South Australia during the past 100 years (Arthington & McKenzie 1997). Brown trout (*Salmo trutta*) rainbow trout (*Oncorhynchus mykiss*), brook char (*Salvelinus fontinalis*), Atlantic salmon (*Salmo salar*), tench (*Tinca tinca*), roach (*Rutilus rutilus*), redfin (*Perca fluviatilis*) were all originally introduced to Australia for acclimatisation so the species could be recreationally fished (Lintermans 2004).

Brown trout, a species native to Europe and North Africa, was first introduced to Australia from the United Kingdom to Tasmania in 1864 and soon afterwards eggs were brought to Victoria from Tasmania, and by 1888 brown trout had been introduced into New South Wales streams (Wilson 1879; Nicols 1882; Lake 1957; 1967; Cadwallader 1996). Rainbow trout, a species native to the Pacific coast of the North American continent, was introduced into New Zealand waters from the United States of America in 1883 (Cadwallader 1996). The species was first introduced to Australia from New Zealand as fertilised eggs in 1894 (Cadwallader 1996; Arthington & McKenzie 1997; Lintermans 2004). Populations soon became established in New South Wales and were subsequently distributed to Victoria and other states and formed self-sustaining populations, which persist (Cadwallader 1996; Arthington & McKenzie 1997).

From as early as 1934, observations of stomach contents from fish in New South Wales showed that the both rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) preyed upon items very similar to the items which Macquarie perch prey upon (McKeown 1934), indicating the risk of competition for food resources (Butcher 1945; Butcher 1967; Cadwallader 1978). And from as early as the mid-1940s, there were reports of brown trout eating small Macquarie perch

(Butcher 1945; 1967). The dietary overlap that has been observed between Macquarie perch, European carp and rainbow trout is now well recognised (Butcher 1945; Cadwallader 1978; 1979; Jackson 1981; Battaglione 1988; Koehn & O'Connor 1990b; Lintermans 2006a). There is a range overlap between trout and Macquarie perch in south eastern Australia (Butcher 1967; Crowl et al., 1992), with clarifications being made since the late-1960s that Macquarie perch occur in the highland and colder waters as versus other native fish species that are lowland, "warm water species" (Butcher 1967). Observations such as those made by J.O. Langtry during his 1949 and 1950 surveys (Cadwallader 1977) seem to support this, and the concern was expressed by Langtry at this time about the ability for native fish and trout to coexist.

Concern was also being expressed in the late 1970s about the impacts of 'incessant' trout stocking on native fish in the Murray-Darling Basin and that little information on the composition of native fauna was available before the first trout introductions were made (Cadwallader 1978). Especially in the case of the disappearance of Macquarie perch in Lake Eildon where between 1958 and 1967 more than 750 000 rainbow trout and more than 250 000 brown trout were liberated into the lake and trout is considered as one of three factors (the other two factors were considered to be large harvests during spawning time and habitat change) in the Macquarie perch's disappearance (Cadwallader & Rogan 1977).

In recent times, the awareness of the risk that trout may pose to Macquarie perch is increasing and the New South Wales Government considers brown trout as a contributing factor in the decline of Macquarie perch (NSW FSC 2008). Ebner et al. (2007) report a lack of evidence of juveniles in the diet of trout in the "upstream" parts of Cotter Reservoir (as opposed to Cotter River itself), but importantly argued that this may have been a consequence of juvenile Macquarie perch being absent from that area. Gilligan (2005) correlates the decline of Macquarie perch in the early-1980s in the upper Murrumbidgee River with the first year of a series of very large releases of rainbow trout in the area starting in 1980.

While documented occurrences of predation on Macquarie perch are scarce, there have been almost no studies commissioned in Australia into the physical examination or DNA-assays of trout gut contents in the few remaining locations where Macquarie perch still co-occur.

Redfin (*Perca fluviatilis*) are a fast-breeding, voracious predatory fish introduced to mainland Australia in 1860s originating from stock from the United Kingdom (Weatherley 1963b; Weatherley 1977; Cadwallader & Backhouse 1983; Lintermans 2007). The species is now widely distributed through the southern part of the Murray-Darling Basin, being restricted to water temperatures less than 31°C (Weatherley 1963a; 1963b; 1977). Redfin are known to prey on many small and juvenile native species (Clunie et al., 2002; Karolak 2006). Cadwallader & Rogan (1977) noted the appearance of redfin in Lake Eildon, Victoria attributed predation on juvenile Macquarie perch by redfin as a contributing factor to their decline. A recent laboratory study did show that Macquarie perch are able to recognise and respond to the threat of predation posed by redfin (Brown & Morgan 2015).

European carp (*Cyprinus carpio*) were first introduced into Australia as early as the 1860s, but these strains showed no signs of spreading (Shearer & Mulley 1978). The 'Boolarra strain' was imported illegally into Victoria from Germany in the 1950s, and in the 1960s was illegally introduced into watercourses in the Murray-Darling Basin and quickly spread throughout (Rhodes 1999; Koehn et al., 2000). European carp now dominate freshwater systems across the Murray-Darling Basin, and it has become the most abundant large freshwater fish in southeastern Australia (Koehn 2005; Davies et al., 2012). European carp disturb native fish habitats by raising turbidity and destroying submergent macrophytes (Roberts et al., 1995;

Roberts & Sainty 1996; Villizi et al., 2014). European carp larvae feed upon similar prey items as larvae of two other species of native fish, Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua*) (Tonkin et al., 2006), so it is likely that the same competition exists for Macquarie perch.

Eastern gambusia (*Gambusia holbrooki*), native to the Gulf of Mexico, were introduced to Australia in the mid-1920s to control mosquito larvae (Cadwallader & Backhouse 1983; Lloyd & Tomasov 1985; Arthington 1991). The fish was distributed widely around Australia during the Second World War to military camps. It is now found widely across the Murray-Darling Basin (Lintermans 2007). Although there are no direct studies on the impacts of Eastern gambusia on Macquarie perch, they Eastern gambusia are known to harass and impact small native fish through fin-nipping (Koehn & O'Connor 1990a; Bayley & Li 1992; Arthington & McKenzie 1997; Tonkin et al., 2011), thus may similarly impact juvenile Macquarie perch.

The impact of alien fish species on Macquarie perch is likely to have been significant and has contributed to the widespread decline of the species. If alien fish species such as salmonids, redfin, eastern gambusia and European carp continue to increase in numbers and proliferate in areas where Macquarie perch live and breed, the species will decline further and recovery will be extremely difficult.

6.2.3 Barriers to fish movement

Human made structures such as dams, weirs and regulators are known to impede migration and prevent completion of life cycles of freshwater fish species (Cadwallader 1978; Faragher & Harris 1994; Kearney et al., 1999; Thorncraft & Harris 2000; Gilligan et al., 2005), such as the Macquarie perch. Instream barriers can prevent fish reaching spawning and feeding areas as well as interrupting gene flow and causing fish populations to fragment (NSW DPI 2013a). The fragmented range of Macquarie perch makes the species particularly vulnerable to local extinctions (Morrongiello et al., 2011). The unimpeded passage of fish throughout streams is considered crucial for migration, re-colonisation, general movement and habitat selection (Koehn & O'Connor 1990b; MDBC 2004). A high number of major barriers to fish movement exist in the Murray Darling Basin (Table 1).

Table 1: Major fish barriers by catchment

River catchment	Dam
Lachlan	Wyangala Dam
Murrumbidgee	Tantangara, Cotter, Bendora, Scrivener, Captain's Flat, Googong, Burrinjuck, Talbingo and Blowering dams
upper Murray	Khancoban pondage and Hume Dam
Mitta Mitta	Dartmouth Dam
Ovens	Buffalo Dam
Goulburn	Eildon Weir
Hawkesbury-Nepean	Cataract, Nepean, Avon and Warragamba dams
Shoalhaven	Tallowa Dam

Until 2001, the one viable population of Macquarie perch in the Australian Capital Territory found in the Cotter River catchment was restricted from accessing habitats upstream of the Cotter Reservoir by a road crossing (Vanities Crossing), which is about 6 km upstream of the reservoir (Broadhurst et al., 2013). In 2001, a rock-ramp fishway was constructed to allow Macquarie perch to another 22 km to the base of Bendora Dam (Ebner & Lintermans 2007; Ebner et al., 2008; Broadhurst et al., 2013).

The construction of Googong Dam in 1978 is considered to have caused the extirpation of the Macquarie perch from the lower Queanbeyan River (i.e. from where the Googong Dam wall is now to the weir near the centre of Queanbeyan itself) (Lintermans 2002). It is likely that Burrinjuck and Wyangala Dams had similar effects on probable populations in the Murrumbidgee and Lachlan rivers downstream of these structures.

When considering fish barriers, not only 'physical' structures should be examined but also other barriers such as 'hydraulic' (e.g. areas of high velocity flow or turbulence) and 'chemical' (areas where chemical discharge causes avoidance by fish). Barriers may also have benefits for Macquarie perch in some instances by impeding the movement of pests (e.g. redfin) and diseases (epizootic haematopoietic necrosis virus (EHNV)), from contacting 'quarantined' Macquarie perch populations. Therefore, there is a clear need to balance connectivity with the exclusion of pests and diseases and their vectors (Langdon 1989a; Lintermans 2005).

Genetic diversity has been found to be higher in the Macquarie perch populations occurring in locations with a higher river slope, which correlates to a higher frequency of the species preferred 'riffle' habitat (Faulks et al., 2011). However, man-made barriers, of which there are many in Murray-Darling Basin areas which Macquarie perch once inhabited, degrade habitat and impede dispersal, which has likely lowered the genetic diversity in the species (Faulks et al., 2011).

The impact of barriers may be local and immediate. For example, a new barrier may prevent a local population of Macquarie perch from diurnal movements to/from feeding and sheltering locations. Barriers may also introduce longer term impacts including preventing access to spawning beds or refuges on a seasonal basis or by altering flows and stream morphology and their ability to sustain a Macquarie perch population.

6.2.4 Altered flow and thermal regimes

In their natural state, inland rivers were characterised by variable flow patterns and reasonably consistent cyclic increases and decreases in temperature annually. Native species, such as the Macquarie perch, have become adapted to these flow patterns and thermal changes, and periods of low and high flows, and high and low temperatures have important ecological functions.

Flow in the coastal rivers of New South Wales where the Macquarie perch occurs, is generally more consistent however altered flow regimes as a result of large dams and impoundments also have a major impact on Macquarie perch ecology. River regulation has resulted in changes in the size of flows; seasonality of flow patterns; frequency and duration of floods; timing, variability and predictability of flows; rates of rise and fall of water levels; and surface and subsurface water levels.

Studies suggest that any impounded water body over five metres in depth can undergo thermal stratification, except those reservoirs where average yearly inflow volume exceeds the reservoir volume by a factor of 10 or more (Harleman 1982). Warm water is less dense than cooler water,

and therefore 'floats' above denser cooler water (Bayly & Williams 1973). Since most impoundments are only equipped with bottom release valves only cold water can be released downstream, causing 'cold water' or 'thermal pollution' (Koehn 2001; Ryan et al., 2001; Astles et al., 2003; Preece 2004; Sherman et al., 2007).

Regulation of flows through controlled release from storages, which is often the release of cold water, and water extraction have vastly changed the hydrology and thermal regimes of river systems, causing widespread degradation and are considered to be severely impacting upon native fish in the Murray-Darling Basin (Cadwallader 1978; Koehn & O'Connor 1990a; Kinsolving & Bain 1993; Weisberg & Burton, 1993; Faragher & Harris, 1994; Welcomme 1994; Koehn et al., 1995; Gehrke et al., 1999; Kearney et al., 1999; Lugg 1999; Koehn 2001; Phillips 2001; Astles et al., 2003; MDBC 2004).

Cold water pollution has the effect of reducing annual temperature ranges, delaying the timing of summer temperature peaks, eliminating the natural rapid temperature rise in spring and also severely reducing the difference between annual maximum and minimum temperature (Lugg 1999; Ryan et al., 2001). In Lake Eildon, it was found that Macquarie perch required the water temperature to rise to 16.5°C before spawning could occur (Cadwallader & Rogan 1977), and it was considered that the colder water of the Reservoir and extent of flooding were severely impacting the species ability to reproduce in this catchment (Cadwallader 1978).

By the end of the 1970s all of the major river catchments in New South Wales, the Australian Capital Territory and Victoria where the Macquarie perch occurs were regulated with large dams to store and control the flow of water for primary resources and domestic supply. The regulation of water flow by the operation of in-stream structures generally reduces the flow of water downstream and reduces the frequency and magnitude of natural flooding (Walker 1985; ASEC 2001; NSW FSC 2002; Magilligan et al., 2003). Water is delivered to users who depend on reliable and predictable water supplies often at the expense of the ecological needs of fish communities. This has been demonstrated specifically by studies within the Murrumbidgee catchment (Finlayson et al., 1994; Gehrke et al., 1995; Burns et al., 2001; Gehrke & Harris 2001).

While Macquarie perch populations have been considered relatively tolerant of flow regulation and diversion in the Hawkesbury-Nepean rivers (Gehrke et al., 1999) the impact of river regulation and altered flow regimes has continued over many years and periods of low flow is likely to have contributed significantly to the extirpation of Macquarie perch populations in areas of the Murray-Darling Basin, such as in the lower Queanbeyan River below Googong Dam. Impoundments can also interfere with vital factors required for Macquarie perch spawning, such as sufficient water flow and riffle or near riffle-areas (Sammut & Erskine 1996).

Seasonal variation in water temperature is an important trigger for many native freshwater fish species to spawn (Milton & Arthington 1983; 1984; 1985; Koehn & O'Connor 1990b). Although little work has been undertaken into the precise impact of cold water pollution on Macquarie perch, a study in 2002 demonstrated that the egg survival of a number of native species including Murray cod, golden perch, silver perch and freshwater catfish was reduced by temperatures below 15°C (Lyon et al., 2002). Thermal pollution affects fish populations by preventing seasonal warming to critical spawning temperatures, temperature shock to eggs and larvae following sudden high volume releases, inhibited activity, growth, and disease resistance, reduced egg and larval survival, and delayed maturity (Burton & Raison 2001; Koehn 2001; Astles et al., 2003). In Australia, the most widely recognised effect of thermal pollution is that of depressed summer temperatures on native fish populations (Ryan et al., 2001). Most native

species breed over the warmer months and require relatively warm temperatures to induce spawning (Lake 1967; Llewellyn 1971; Rowland 1983; Cadwallader & Gooley 1985).

Remnant populations of Macquarie perch in the Murray-Darling Basin generally occur either in and/or above impoundments or in unaltered catchments. However, drought and periods of low rainfall can result in low stream flow (Tonkin et al., 2014) which would likely impact upon the species. In areas upstream of impoundments, Macquarie perch need riverine habitats for spawning (Cadwallader 1981; Appleford et al., 1998). Reduced flows caused by drought and water extraction may impact by reducing size of key refuge pools in streams and access to key riffle habitats which are important for spawning.

The exceptions are small populations of Macquarie perch below Cordeaux Dam in the Cordeaux River and the upper Murrumbidgee River below Tantangara Dam, while recent anecdotal reports suggest this population is close to extirpation. If flow regulation were to mimic natural flow regimes these populations of Macquarie perch would more than likely respond positively.

Cold water pollution is likely to have had a significant impact on the distribution of the Macquarie perch. Cold water releases occur annually during critical spawning intervals and threatens the survival of Macquarie perch juveniles and eggs. Reduction of cold water pollution through strategies to reduce temperature stratification of water storages and/or to release water that more closely resembles the natural flow and temperature regime of rivers are likely to have a positive effect on the Macquarie perch.

6.2.5 Disease

Macquarie perch have been shown experimentally to be highly susceptible to Megalocytivirus infection, which is an emerging threat from the live ornamental fish trade. These viruses represent an array of closely related agents that were first recognised to cause high mortality in aquacultured food and aquarium fish in the 1990s. Megalocytiviruses have low host specificity and appear to be readily carried by freshwater aquarium fish including gouramis, poeciliids and cichlids. In 2003, Dwarf Gourami Iridovirus (DGIV) found in 'presumably' imported dwarf gourami (*Trichogaster lalius*) in retail shops in Australia was identical to the causative agent for mass mortality in intensively farmed Murray cod (*Maccullochella peelii*) (Go et al., 2006).

The susceptibility to DGIV of several other native freshwater fish species was subsequently demonstrated by experimental challenge studies (Rimmer et al., 2016). The studies indicated that naïve native fish populations, including Macquarie perch, would be vulnerable to megalocytiviruses should they enter natural waterways through infected ornamental fish (Rimmer et al., 2016).

Currently megalocytiviruses such as infectious spleen and kidney necrosis virus-like viruses (e.g. DGIV) and Red Sea Bream Iridovirus (mainly affects marine finfish species) are exotic to Australia. Limited reports of their detection relate exclusively to the imported ornamental fish industry and trade (Anderson et al., 1993; Go et al., 2006; Rimmer et al., 2015).

Import regulations and surveillance activities of domestic ornamental facilities have been designed to reduce the risk of these agents for Australia's native fish species including Macquarie perch and Murray cod. Nevertheless, historical imports of ornamental fish with minimal regulation has led to the establishment of 22 alien species with wild breeding populations (Lintermans 2004). These feral populations demonstrate a prospective exposure pathway for subclinically infected imported ornamental fish to aquatic environments, with the potential to hinder recovery efforts.

Another serious threat to the Macquarie perch may be an internationally significant disease Epizootic Haematopoietic Necrosis Virus (EHNV). EHNV was first isolated in Australia from juveniles of the alien fish species, redfin, sourced from Lake Nillahcootie in 1984, near Benalla in northeastern Victoria (Langdon et al., 1986). Potential carriers (vectors) for EHNV include the alien species redfin and rainbow trout (Whittington et al., 2007). Another disease to affect Macquarie perch is the parasitic protozoan *Chilodonella cyprini*, which was first found in Australia on brown trout in the Snobs Creek Fish Hatchery. It was likely spread to native fish, including Macquarie perch, via the stocking of infected trout into Victorian waters (Cadwallader 1996). European carp, goldfish (*Carassius auratus*) or eastern gambusia have been likely implicated as the source of, and a vector for, the introduced tapeworm *Schyzocotyle acheilognathi* which has been recorded in native fish species (Dove et al., 1997; Dove & Fletcher 2000). This tapeworm causes widespread mortality in juvenile fish overseas.

In New South Wales, EHNV was first detected in redfin in Blowering Dam and Lake Hume in 1986 and then was subsequently found in specimens in Burrinjuck Dam in 1990, from Lake Burley Griffin in 1991 and 1994 and from Googong Reservoir in 1994. These historical outbreaks suggest that the distribution of EHNV in redfin has extended upstream in the Murrumbidgee River system (Whittington et al., 1996). It is highly likely that the upstream Murrumbidgee River, Googong Reservoir/Queanbeyan River (now extirpated) populations of Macquarie perch were exposed to the virus (Lintermans 2006b).

The presence of EHNV is thought to be a major impediment to recovery of populations of Macquarie perch in the Australian Capital Territory (Lintermans 1991b) and it has been suggested that EHNV may have been a cause for the decline of Macquarie perch in Lake Eildon in Victoria (Langdon 1989b). Experimental work in the 1980s demonstrated that Macquarie perch was one of several species extremely susceptible to the disease with 100 per cent mortality (Langdon 1989a; 1989b). Other native fish species found experimentally to be susceptible to EHNV include silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii*), golden perch (*Macquaria ambigua*) and mountain galaxias (*Galaxias olidus*), and other alien fish species include Atlantic salmon (*Salmo salar*) and eastern gambusia (*Gambusia holbrooki*) (Langdon et al., 1986; Langdon 1989b; Gray et al., 2000).

EHNV is characterised by sudden high mortalities of fish displaying necrosis of the renal haematopoietic tissue, liver spleen and pancreas (Langdon & Humphrey 1987). EHNV is a fast spreading and robust virus. The mechanisms of spread are uncertain in redfin but are likely to include the movement of the virus on structures such as nets, boats and gear, movement of live fish or frozen bait fish by recreational fisherman, movement with migrating fish and transmission by piscivorous birds (Whittington et al., 1996). There may be an as yet undiscovered natural host that is responsible for infection of redfin, or redfin may simply amplify the infection in an ecosystem (Whittington & Hyatt 1998). Langdon (1989b) found EHNV retained infectivity after 113 days of dry storage and Whittington et al. (1996) found similar results after freezing fish carcasses for at least a year.

Given that EHNV is known to cause direct mortality to Macquarie perch and could be also causing indirect mortality by severely disabling feeding and predator evasive abilities and is apparently highly virulent, past impacts on populations have likely been immediate and catastrophic and may have not been detected adequately due to insufficient awareness. Due to EHNV appearing to impact all age classes and lifecycle phases of Macquarie perch and causing up to 100 per cent mortality, any Macquarie perch population subject to an EHNV outbreak is unlikely to exhibit significant resilience.

6.2.6 *Illegal/Incidental capture*

With the exception of Lake Dartmouth, Upper Coliban Reservoir and the Yarra River (all in Victoria), the taking of Macquarie perch in fishing activities in Australia is prohibited (Vic DEDJTR 2016). In Victoria, there is a closed season for the species between 1 October and 31 December each year, and daily bag/possession limits apply such that recreational fishing is permitted in Lake Dartmouth and tributaries (1 per day), Yarra River and tributaries (2 per day) and the Upper Coliban Reservoir (2 per day) (DEDJTR 2016). Illegal fishing is recognised as a key threat to native fish management (MDBC 2004). It is illegal to buy, sell or possess Macquarie perch in New South Wales and the Australian Capital Territory.

Historically, Macquarie perch were considered a prized table fish (Lake 1971; Trueman 2011). They were once caught in large numbers by recreational fishers targeting spawning migrations (Cadwallader & Rogan 1977). Cadwallader & Rogan (1977) make note of 2 to 3 tonnes of fish removed from Lake Eildon in a single week by targeting a spawning aggregation. With close to 1.6 million recreational fishers across New South Wales, the Australian Capital Territory and Victoria, approximately 24 per cent of whom undertake fishing in inland regions (Henry & Lyle 2003), the risk of illegal fishing remains high to Macquarie perch.

The Macquarie perch's tendency to form spawning aggregations makes the species particularly susceptible to fishing at particular times of the year and targeting of these aggregations by fishers in the past has almost certainly contributed to their decline (Cadwallader & Rogan 1977; Cadwallader 1978; Harris & Rowland 1996).

Studies undertaken on other Percichthyidae species have found that the stress of being caught and released in recreational fishing activity can cause hidden, delayed impacts such as reduced gonad development and reproductive potential (Hall et al., 2009a), and fish that are gut-hooked are more likely to die than fish that are mouth hooked (Van Der Walt et al., 2005; Hall et al., 2009b). Even if accidental capture occurs and fish are correctly identified and returned to the water, injury and stress may result (Van Der Walt et al., 2005; Hall et al., 2009a; 2009b). Conversely, there is good evidence to suggest that if fish are mouth hooked, handled carefully and returned to the water promptly they are likely to survive.

Illegal fishing removes mature adult fish from the population. At a genetic level, it is possible that persistent selective removal of larger individuals ('trophy fish') from a population will cause an evolutionary shift in population characteristics with smaller size at maturity being an advantage and hence becoming the dominant phenotype (Conover & Munch 2002). High levels of illegal fishing may constitute negative impacts to the species.

6.2.7 *Chemical water pollution*

Chemical water pollution can be derived from point source and non-point sources and may be derived from sources such as run-off from agricultural, rural and industrial development, and acid mine drainage and iron flock contaminating streams from river cracking due to long wall mining. Water pollution is related to land use; the development of intensive agriculture, mining, rural industries and urban development have contributed to water pollution across the Murray-Darling Basin and in the eastern catchments where Macquarie perch occur (MDBC 2003).

For many of the extant populations, pollution is probably of low risk given that the populations exist within national parks, wilderness areas and nature reserves such as the Lake Dartmouth and Mitta Mitta River, Yarra River, Buffalo River, Cotter River populations in the Murray-Darling Basin and Webbs Creek, Colo River, Grose River, Kowmung River, Wongawilli Creek, Cordeaux

and the Cataract River populations in the eastern drainages in the Hawkesbury-Nepean rivers catchments. Conversely, some remaining populations of Macquarie perch exist adjacent to land use types where there are livestock grazing, production and plantation forestry, perennial horticulture of vine and tree fruits, irrigated modified pastures and grazing modified pastures. These include the King Parrot Creek, Yea River, Holland's Creek, Hughes Creek, Murrumbidgee River, Adjungbilly Creek, Mannus Creek, Lachlan River and Abercrombie River populations in the Murray-Darling Basin and the Mongarlowe River and Cox's River populations in the eastern New South Wales drainages.

A further source of pollution threatening the recovery of some Macquarie perch populations includes mining and domestic effluent disposal. In particular, Macquarie perch in the Hawkesbury-Nepean catchment are at risk from current, proposed and past mining activities (NSW DoP 2008). Effluent from underground coal mining is saline and acidic and subsidence caused by longwall mining cracks river beds and releases iron floc from ground water. Disused and historic mine sites are a source of acid mine drainage and heavy metal contaminants (NSW DoP 2008).

Pollution has the potential to affect all aspects of the life history of the Macquarie perch. Of particular concern is endocrine disruption from exposure to heavy metals and organic compounds. The most prominent effect of endocrine disruption in fish is in the reproductive system affecting gonad development, potential intersex fish and elevated levels of female egg protein in male fish (Batty & Lim 1999; Pait & Nelson 2002). The introduction of chemicals and biodegradable material to water has obvious effects on fish, depleting dissolved oxygen levels resulting in fish kills. From what is known of fish at a similar trophic level a healthy level of dissolved oxygen for Macquarie perch would be in the order of 7.5mg/L and above (Davis & Cornwell 2008).

Poor water quality is also likely to affect Macquarie perch feeding, breeding and migration. Poor water quality is likely to lead to a lowered immune system in fish making them susceptible to disease (see also section 6.2.5). There are also many effects on the fish that may be unknown such as the bio-accumulation of fat-soluble chemicals. Although historically there have been no reported fish kills of Macquarie perch as a direct result of poor water quality, there is an increasing risk of fish kills in the future as human activities expand. Poor water quality is also likely to limit the expansion of Macquarie perch into other areas.

6.2.7 Climate change

Climate change projections for the Murray-Darling Basin predict increases in temperature and evaporation and less rainfall, which will likely result in reduced runoff to rivers and wetlands especially in the southern Basin (CSIRO 2008; Dunlop & Brown 2008). Additional declines in water quantity and quality will have an adverse impact on existing freshwater ecosystems (Pittock & Finlayson 2011). Reductions in flow associated with climate change will further fragment habitats and populations, leading to reduced 'fitness' (Balcombe et al., 2011). It is likely that fish species in the Murray-Darling Basin, which has rivers generally orientated in an east-west direction will be less able to follow changing thermal isolines over time (Ficke et al., 2007). Climate change, coupled with the impacts of existing land and water use, could further significantly change freshwater ecosystems in the Murray-Darling Basin unless on ground conservation actions are undertaken (Pittock & Finlayson 2011).

The general effects of climate change on freshwater systems will likely be increased water temperatures, decreased dissolved oxygen levels, and the increased toxicity of pollutants (Ficke

et al., 2007). Water temperatures are especially important to freshwater fish as all are exothermic, hence body temperatures are identical to environmental temperatures (Ficke et al., 2007). Increased water temperatures are likely, on average, to decrease dissolved oxygen levels, given that cold water has the potential to hold more dissolved oxygen than hot water (Ficke et al., 2007). Increases in the toxicity of pollutants with increased water temperatures results from the increased production of bioactivated free radicals that are more toxic than the parent compound (Nemcsók et al., 1987) or the increased uptake of the original toxin (Murty 1986).

Freshwater fish in the Murray Darling Basin have been particularly affected by the changes to flow regimes and biological connectivity associated with water-resource development and climate change will place further stress on these species (Balcombe et al., 2011). However, there is some thought that climate change may potentially benefit Macquarie perch in the southern Basin, as increased temperatures may lead to increased abundances in areas where the species has been impacted by cold-water pollution. It could be that in areas where water temperatures become too for alien salmonids and stocked populations cannot persist, Macquarie perch populations may benefit (Balcombe et al., 2011). However, increased temperatures may affect timing of zooplankton emergence which may have implications for Macquarie perch larval recruitment success (Balcombe et al., 2011).

It is considered that the conservation of free-flowing river ecosystems where maintenance of ecological processes enhances their capacity to resist climate change impacts, and where adaptation may be maximised (Pittock & Finlayson 2011). Systematic alteration of the operation of existing water infrastructure may also counter the major climate change impacts expected for regulated rivers of the Murray-Darling Basin (Pittock & Finlayson 2011).

Conservation activities for the benefit of Murray-Darling ecosystems could focus on gaining river reaches which are used for salmonids in the United States through the maintenance of water flows and temperatures (Poole & Berman 2001; Pittock & Finlayson 2011). It is expected that such activities would of benefit to Macquarie perch.

7 RECOVERY OBJECTIVES AND STRATEGIES

7.1 Recovery plan objective

The objective of this national recovery plan is to ensure the recovery and ongoing viability of Macquarie perch populations throughout the species' natural range.

7.2 Recovery plan strategies

The strategies to achieve the recovery plan objective are to:

1. Conserve existing Macquarie perch populations;
2. Protect and restore Macquarie perch habitat;
3. Investigate threats to Macquarie perch populations and habitats;
4. Establish additional Macquarie perch populations;
5. Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance; and
6. Increase participation by community groups in Macquarie perch conservation.

8 ACTIONS TO ACHIEVE THE OBJECTIVE

The recovery actions listed in this plan identify actions to address each threat. Individual jurisdictions can implement recovery actions to ensure the most effective use of available resources. Actions identified for the recovery of the Macquarie perch are described below. It should be noted that the objective are long-term and may not be achieved prior to the scheduled five-year review of the recovery plan. Priorities assigned to actions should be interpreted as follows:

Priority 1: Taking prompt action is necessary to mitigate the key threats to the Macquarie perch and also provide valuable information to help identify long-term population trends.

Priority 2: Action would provide a more informed basis for the long-term management and recovery of the Macquarie perch.

Priority 3: Action is desirable, but not critical to the recovery of the Macquarie perch or assessment of trends in that recovery.

Strategy 1 – Conserve existing Macquarie perch populations

On ground actions

Table 2: Strategy 1 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost <i>*priority 1 only</i>
1a	Protect Macquarie perch from competition with and predation by alien fish species.	1	<ul style="list-style-type: none"> Minimise stocking of salmonids or other alien fish species into areas where Macquarie perch are known to occur. Programs are being implemented to reduce the populations of alien fish in stream habitats where the Macquarie perch occurs. A management plan is developed for alien fish species that impact Macquarie perch, including European carp, eastern gambusia, redbfin and trout. 	State/territory governments and the research community	
1b	Ensure that the impacts of recreational fishing are minimised	1	<ul style="list-style-type: none"> Self-sustaining populations are listed as 'no-take' species. Where take is allowed of stocked impoundment populations, management measures are in place to protect wild, self-sustaining populations from illegal fishing (i.e. compliance measures have been implemented so that fish from stocked populations can be identified). 	State/territory governments and the research community	
1c	Protect Macquarie perch populations from outbreaks of disease and parasites	2	<ul style="list-style-type: none"> Effective development of treatment and immunisation techniques for EHNH and <i>Lernaea</i> (aka 'anchor worm') has occurred. Hygiene protocols have been developed and implemented to protect Macquarie perch populations (and populations of other threatened native fish species) from outbreaks of EHNH and <i>Lernaea</i> (aka 'anchor worm'). 	State/territory governments and the research community	

Strategy 2 – Protect and restore Macquarie perch habitat

On ground actions

Table 3: Strategy 2 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost *priority 1 only
2a	Undertake priority habitat rehabilitation, restoration and enhancement work.	1	<ul style="list-style-type: none"> Fish passage is restored to locations where Macquarie perch are currently impeded by anthropogenic fish barriers. Restore riffle habitats in areas below water storages and offtakes to promote spawning areas by concentrated effort to remove sand slugs or by enhancing environmental flows to scour sediment loads. Rehabilitate riparian vegetation. Reinstate large woody and rock snags in channels. Spawning activity is recorded following trials/installation of artificial habitat, which may include but is not limited to: <ul style="list-style-type: none"> pipes, cement blocks sand/silt excavation gravel/shale depositing 	State/territory governments	
2b	Seek to provide appropriate flow regimes in all waters where Macquarie perch occur below water storages or offtakes.	1	<ul style="list-style-type: none"> Small daily variations are returned to river flows, rather than the highly regulated stable flow state in areas where some Macquarie perch populations occur (as informed by data from Action 5c below). Re-establish the traditional spring seasonal water level rises in areas where Macquarie perch occur (as informed by data from Action 5c below). 	Australian and state/territory governments and the research community	
2c	Undertake works to minimise cold water pollution.	1	<ul style="list-style-type: none"> Modify outlet works on dams where Macquarie perch are known to occur downstream so that warm water is released downstream. 	Australian and state/territory governments	

Strategy 3 – Investigate threats to Macquarie perch populations and habitats

Research and on ground actions

Table 4: Strategy 3 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost *priority 1 only
3a	Investigate methods to promote spawning activity of Macquarie perch in naturally occurring and stocked populations.	1	<ul style="list-style-type: none"> Monitoring has been established to detect spawning activity of Macquarie perch in both naturally, self-sustaining populations and stocked populations and is correlated against the habitats available to the population. 	Australian and state/territory governments and the research community	

3b	Better understand competition and predation on Macquarie perch by alien fish species	1	<ul style="list-style-type: none"> Gut-analysis studies have been undertaken on all alien fish species in areas where they co-exists with self-sustaining populations of Macquarie perch (i.e. where Macquarie perch are reproducing and producing larvae and juveniles). Studies have been undertaken on limiting aspects of prey availability for Macquarie perch. 	Research community
3c	Increase the confidence that the viruses and pathogens impacting Macquarie perch are all identified and known.	2	<ul style="list-style-type: none"> Protocols and/or guidelines are established for identifying and/or detecting newly discovered, newly introduced, or poorly known viruses and pathogens which may be impacting this species. Greater certainty is established about the number and types of viruses and pathogens impacting this species. 	Australian and state/territory governments and the research community
3d	Increase understanding of the degree of impact parasites are having on Macquarie perch populations.	2	<ul style="list-style-type: none"> Collection and examination protocols for aquatic parasites are established. Assessments of fish kills can judge, with greater confidence, whether, and to the extent, aquatic parasitic were responsible, or partly responsible. 	State/territory governments and the research community

Strategy 4 – Establish additional Macquarie perch populations.

Research and on ground actions

Table 5: Strategy 4 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost *priority 1 only
4a	Refine and improve captive breeding techniques for Macquarie perch	1	<ul style="list-style-type: none"> Hatchery production of fingerlings is able to operate as a closed system with a permanent broodstock system, rather than capturing spawning run individuals from the wild. Large numbers of fingerlings are produced each year for stocking into wild waters, comparable with other successfully bred hatchery native fish, such as Murray cod, trout cod, golden perch and silver perch. 	Australian and state/territory governments and the research community	
4b	Undertake a conservation stocking program for Macquarie perch	1	<ul style="list-style-type: none"> A population model for Macquarie perch is established across the Murray-Darling Basin incorporated regular monitoring. Sites known to have held the species previously, but where the species is now extinct, are stocked with fingerling Macquarie perch. <ul style="list-style-type: none"> Where this occurs, steps should be taken to reduce/eliminate stocking of alien fish species as per Action 1a. Self-sustaining populations are re-established at sites where the species has previously been extirpated from. 	Australian and state/territory governments and the research community	

Strategy 5 – Improve understanding of the biology and ecology of the Macquarie perch, and its distribution and abundance

Research actions

Table 6: Strategy 5 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost <i>*priority 1 only</i>
5a	Implement a long term monitoring program for the Macquarie perch which is able to record the size and importance of natural, self-sustaining populations and stocked populations.	1	<ul style="list-style-type: none"> Permanent monitoring sites are established across the Murray-Darling Basin in appropriate locations where Macquarie perch are known, or likely, to occur. Regular and effective monitoring is undertaken at permanent monitoring sites. Population trends are reported on a regular basis to detect sudden fluctuations. Identify Macquarie perch populations that are of high conservation priority, which may be identified, but not limited to, populations that are key source populations for breeding or dispersal; populations necessary for maintaining genetic diversity and/or populations that are near the limit of its range. 	Australian and state/territory governments	
5b	Increase understanding of spawning and recruitment ecology of the Macquarie perch and its relationship to habitat.	2	<ul style="list-style-type: none"> Define which factors of instream habitat are critical to important stages of the life cycle for the species successful spawning and recruitment and locate and map sites across its range where these occur. 	Australian and state/territory governments and the research community	
5c	Increase understanding of how the Macquarie perch's life cycle is related to flow and temperature.	2	<ul style="list-style-type: none"> Critical times during the year are identified when increased flow and temperature changes are important for life cycle events to occur naturally. Based on findings, environmental flow is allocated appropriately and cold water pollution is effectively managed for the species in areas where populations are being affected. 	Australian and state/territory governments and the research community	
5d	Resolve whether populations in eastern flowing drainages of coastal New South Wales are separate species or subspecies.	1	<ul style="list-style-type: none"> Published research in a scientific journal confirms whether populations in eastern flowing river systems of New South Wales are a separate species or subspecies to the Murray-Darling Basin populations. 	Australian and NSW governments and the research community	
5e	Investigate the fate of released fingerlings.	2	<ul style="list-style-type: none"> Survival rates have been approximated from tag/recapture surveys. 	Australian and state/territory governments and the research community	

Strategy 6 – Increase participation by community groups in Macquarie perch conservation

On ground actions

Table 7: Strategy 6 Actions

Action	Description	Priority	Performance Criteria	Responsible Agencies and potential partners	Indicative Cost <i>*priority 1 only</i>
6a	Raise awareness for the conservation status of Macquarie perch in the community.	2	<ul style="list-style-type: none"> Information materials are distributed, specifically targeting anglers to enhance identification of Macquarie perch. A reporting system is established for sightings of the species. Improved awareness regarding the Macquarie perch's conservation status and threats impacting the species, and the benefits of recovering the species, amongst the community, including recreational fishers, land owners and managers, natural resource management groups, acclimatisation societies. 	Australian and state/territory governments and the research community	
6b	Engage with private landholders and land managers responsible for the land adjacent to waterways which populations occur and encourage these key stakeholders to support the conservation of the Macquarie perch.	2	<ul style="list-style-type: none"> Develop education/awareness raising products. Landholders with river or creek frontage to water with Macquarie perch inhabiting are aware of the species' conservation and management requirements. Indigenous and community groups are involvement in aspects of Macquarie perch recovery including for example, habitat restoration activities, stocking; research and monitoring programs. Recreational fishers and its associated community are made aware about the historical abundance of Macquarie perch and the once sizeable fisheries it sustained. Awareness should be raised that if significant recovery is achieved, strong future economic, social and tourism opportunities are likely to arise in relation to fishing for the species. 	Australian and state/territory governments and the research community	

9 DURATION AND COST OF THE RECOVERY PROCESS

It is anticipated that the recovery process will not be achieved prior to the scheduled five year review of the recovery plan. The *Draft National Recovery Plan for the Macquarie Perch* (*Macquaria australasica*) (2016) will therefore remain in place until such time as the Australian populations of Macquarie perch have improved to the point at which the species no longer meet threatened species status under the EPBC Act.

The cost of implementation of this plan should be incorporated into the core business expenditure of the affected organisations and through additional funds obtained for the explicit purpose of implementing this recovery plan. It is expected that state and Commonwealth agencies will use this plan to prioritise actions to protect the species and enhance its recovery, and that projects will be undertaken according to agency priorities and available resources. Whilst only Priority 1 actions are costed in this recovery plan, this should not deflect from any proposal to undertake Priority 2 or 3 actions. All actions are considered important steps towards ensuring the long-term survival of the species.

Table 8: Summary of high priority (Priority 1 as identified in Section 8) recovery actions and estimated costs in (\$000's) for the first five years of implementation (these estimated costs do not take into account inflation over time).

Action	Cost					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Protect Macquarie perch from competition with and predation by alien fish species.						
Ensure that the impacts of recreational fishing are minimised.						
Undertake priority habitat rehabilitation, restoration and enhancement work.						
Seek to provide appropriate flow regimes in all waters where Macquarie Perch occur below water storages or offtakes.						
Undertake works to minimise cold water pollution.						
Investigate methods to promote spawning activity of Macquarie perch in naturally occurring and stocked populations.						
Better understand competition and predation on Macquarie perch by alien fish species						
Refine and improve captive breeding techniques for Macquarie perch.						
Undertake a conservation stocking program for Macquarie perch.						
Implement a long term monitoring program for the Macquarie perch which is able to record the size and importance of natural, self-sustaining populations and stocked populations.						
Resolve whether populations in eastern flowing drainages of coastal New South Wales are separate species or subspecies.						
TOTAL						

10 CURRENT MANAGEMENT PRACTICES

As the Macquarie perch is listed in the Endangered category of the threatened species list (Part 13) under the EPBC Act it is a considered Matter of National Environmental Significance (MNES) (Part 4), and any action that may have an impact on MNES must be referred to the Minister of the Environment for approval. The Department of the Environment and Energy, as the Australian Government department responsible for administering the EPBC Act, maintains a suite of interactive tools that allow users to search, find and generate reports on information and data describing MNES, including the Macquarie perch.

In New South Wales and the Australian Capital Territory, the Macquarie perch is totally protected. In New South Wales it is illegal to catch and keep, buy, sell, possess or harm Macquarie perch without a specific permit or licence (NSW DPI 2005), and significant penalties apply under Division 4 and 4A of the *Fisheries Management Act 1994*. In the Australian Capital Territory, it is an offence to kill, injure or endanger, take, keep, sell or offer to sell Macquarie

perch under the *Nature Conservation Act 2014*. In Victoria, fishing for Macquarie perch is still permitted in the Yarra River and Upper Coliban Reservoir where a bag limit of 2 individuals per day applies, and in Lake Dartmouth where a bag limit of 1 individual per day applies (Vic DEDJTR 2016). Fishing for Macquarie perch in all other waterways where it occurs in Victoria is prohibited (Vic DEDJTR 2016). The species is listed as threatened and protected under the Victorian *Flora and Fauna Guarantee Act 1998*, by which it cannot be taken or kept without an order, licence or permit. A Governor in Council “Flora and Fauna Guarantee (Taking, Trading In or Keeping of Listed Fish) Order” made under section 53(2) of the *Flora and Fauna Guarantee Act 1998* allows for the take of Macquarie perch in the Yarra River catchment, Lake Dartmouth (and tributaries) and the Upper Coliban Reservoir (and tributaries). A minimum size limit of 35 cm applies and a closed season to the taking of the species applies between 1 October and 31 December each year.

11 EFFECTS ON OTHER NATIVE SPECIES AND BIODIVERSITY BENEFITS

By managing south eastern areas of the Murray Darling Basin for the benefit of the Macquarie perch, many other native aquatic fauna will also benefit. Other EPBC Act listed threatened fish species that currently occur, or potentially could occur in future, in Macquarie perch habitat include the trout cod (*Maccullochella macquariensis*), Murray cod (*Maccullochella peelii*), silver perch (*Bidyanus bidyanus*), flathead galaxias (*Galaxias rostratus*) and barred galaxias (*Galaxias fuscus*). Because of the linkages between riparian and in-stream ecosystems, the protection of riparian zones will benefit riparian and in-stream fauna. Functional, intact riparian zones are directly related to high in-stream biodiversity (Boulton & Brock 1999) and contribute to the floristic diversity of off-reserve areas. The implementation of this recovery plan includes a number of potential biodiversity benefits for other species and ecological communities.

Macquarie perch in many areas of their natural distribution are part of fish communities in which several other members are under threat. Hence, recovery activities to protect and restore habitats of Macquarie perch should also make an important contribution to the conservation of other native species occupying similar habitat.

Efforts to protect and recover Macquarie perch populations will deliver a range of indirect biodiversity benefits. For example, increasing community awareness about the threatened status of Macquarie perch may assist in raising the profile of threatened species in general and may lead to increased opportunities to conserve and protect threatened species and aquatic biodiversity in the future.

12 SOCIAL, ECONOMIC AND CULTURAL CONSIDERATIONS

The presence of alien fish species in areas that the Macquarie perch was once common has likely had major impacts on extinct populations, and it is likely that alien fish species are continuing to threaten the few remaining extant populations of Macquarie perch. The halting of salmonid stocking activities in areas where there are Macquarie perch populations is likely to have some social and economic impact.

Most wild, self-sustaining populations of Macquarie perch are no longer the target of any commercial or recreational fishing activities. The species is protected from take across most of

its range, except in Lake Dartmouth (and tributaries) and the Upper Coliban Reservoir (and tributaries) where there have been periodic stockings by the Victorian Government, and the Yarra River, where the species did not exist naturally before individuals were first translocated there in 1857 (Wilson 1857).

The increased protection of the Macquarie perch prescribed in this plan is expected to result in recovery of populations, which could allow for fishing activities for the species to resume under appropriate fisheries management oversight, once the species has recovered to a level (across its entire range) in which there would be a strong case for delisting the species from its EPBC Act threatened status.

In New South Wales, Macquarie perch were a significant source of food and totemic value for Indigenous communities, specifically for the Gamilaroi. The Gamilaroi would not take pregnant or juvenile fish, or spawning run fish. Medium-sized fish were selected as part of their food supply (Phil Duncan, Industry & Investment NSW 2005 pers. comm.). The Macquarie perch was probably known as Wunnumberu (pronounced 'Wanambiyu') by the Dhudhuroa who lived along the upper Murray River and lower Kiewa and Mitta Mitta rivers (Trueman 2011). Other possible names are Nooraderri and Gubir by the Wiradjuri who lived in the area bordered by the Lachlan, Macquarie and Murrumbidgee rivers (Trueman 2011; About NSW 2013). Implementation of this plan should involve knowledge sharing, participation in education and training relevant to threatened species management and engagement in recovery actions where relevant to aboriginal land management and communities. Indigenous groups will be encouraged to take part in activities that are part of the recovery plan. Any proposal that could affect places of cultural importance will need to be discussed in direct consultation with local groups.

Strategy 4 of this recovery plan identifies the protection and restoration of Macquarie perch habitat, of which a major component is providing for appropriate flows (both quantity and quality) where the species occurs. There is a need for recovery activities to work within broader natural resource management programs at a national level as well as at a state and territory level. This recovery plan aims to encourage the adoption of flow regimes conducive to the survival of the Macquarie perch and to maintain a suitable aquatic ecosystem within the species range.

As habitats critical to the survival of the species are identified, there is potential for developments to be restricted under the EPBC Act assessment and approval process. Any measures to assist recovery of this species that involve restrictions on the use of riparian land may result in economic impacts to affected industries. A person who proposes to take an action that will have, or is likely to have; a significant impact on a matter of national environmental significance must refer that action to the Minister for a decision on whether assessment and approval is required under the EPBC Act. For further information on the environment assessment and approval process please refer to: <http://www.environment.gov.au/epbc/assessments/process.html>

Improved community awareness and support is essential to the conservation and management of Macquarie perch. Currently, there is a general lack of awareness of issues affecting the recovery and long-term conservation of the species. Some anglers may not be aware of the protected status of Macquarie perch, and the illegal take of the species may be having a detrimental impact in some areas.

13 AFFECTED INTERESTS

Continued liaison with those potentially affected by the implementation of this recovery plan should occur on an ongoing basis. Stakeholders with an interest in the actions proposed in this plan include Australian and state governments' environment and fisheries agencies, Indigenous

groups, land holders and managers, recreational fishers, irrigators, universities, researchers, conservation groups, environmental non-government organisations, local councils, regional natural resource management groups and proponents of development in the vicinity of important Macquarie perch habitat. This list, however, should not be considered exhaustive, as there may be other interest groups that would like to be included in the future or need to be considered when specialised tasks are required in the recovery process.

14 CONSULTATION

This plan should be reviewed no later than five years from when it was endorsed and made publically available. The review will determine the performance of the plan and assess:

- whether the plan continues unchanged, is varied to remove completed actions, or varied to include new conservation priorities, and
- whether a recovery plan is no longer necessary for the species' as either conservation advice will suffice, or the species' are removed from the threatened species list.

The review will likely be coordinated by Department of the Environment and Energy in association with relevant Australian and state government agencies and key stakeholder groups such as non-governmental organisations, local community groups and scientific research organisations.

Key stakeholders who may be involved in the review of the performance of the *Draft National Recovery Plan for the Macquarie Perch (Macquaria australasica)* include organisations likely to be affected by the actions proposed in this plan and are expected to include:

Australian Government

Department of the Environment and Energy(including the Commonwealth Environment Water Office)

Department of Agriculture and Water Resources

State/territory, local governments

New South Wales Department of Primary Industries

New South Wales Office of Environment and Heritage

Victoria Department of Environment, Land, Water and Planning

Victoria Department of Economic Development, Jobs, Transport and Resources

Australian Capital Territory Environment and Planning Directorate

South Australian Research and Development Institute

Natural Resource Management Groups

Local Land Services

Local Governments

Non-government organisations

Conservation Groups

Local Communities

Indigenous Groups and Traditional Owners

Experts from Universities and other organisations

Recreational Fishers and Associations

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