The Minister approved this conservation advice and included this species in the Vulnerable category, effective from 13/04/*2021*

Conservation Advice

Nannoperca australis Murray-Darling Basin lineage

Southern Pygmy Perch-MDB

Taxonomy

Species remains accepted as *Nannoperca australis* Günther 1861.

Three subspecies, *Nannoperca australis australis* Günther 1861*, Nannoperca a. tasmaniae* (Johnston 1883) and *Nannoperca a. flindersi* Scott 1971 were previously recognised (Llewellyn 1974; Cadwallader & Backhouse 1983; Unmack et al., 2013). However, the subspecific designations were poorly characterised and are not commonly used (Unmack et al., 2013).

Australian pygmy perches, of which there are currently six formally recognised species within the genus *Nannoperca* and one within *Nannatherina*, represent a group of species with confusing taxonomy and the potential for cryptic species (Buckley et al., 2018). Genetic analysis has suggested the presence of two species within *Nannoperca australis*, one occurring in the coastal drainages in Tasmania, King Island, western Victoria, South Australia and the Murray-Darling Basin and the second species occurring in coastal drainages in eastern Victoria, Flinders Island and in one river catchment, the Anson River, in northeast Tasmania (Unmack et al., 2013; Buckley et al., 2018). Recent analyses also identified that there could be as many as three evolutionarily significant units (ESUs) within the 'western' species: one within the Murray-Darling Basin; one within the South Australian and western Victorian coastal drainages; and one in the Darby River on Wilson's Promontory in Victoria. A further two ESUs are indicated within the 'eastern' species: one in eastern Victoria coastal drainages; and one in the Anson River and catchments on Flinders Island (Unmack et al., 2013; Buckley et al., 2018).

For the purposes of this assessment, the conservation status of only the Murray-Darling Basin lineage of the species *Nannoperca australis* will be considered. Unmack et al. (2013) described this component as the Murray-Darling Basin ESU within the western species. Under Section 517 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), a determination can be made that a "distinct population of biological entities is a species" for the purposes of the EPBC Act. In this assessment, this "distinct population" will be referred to as *Nannoperca australis* Murray-Darling Basin lineage (Southern Pygmy Perch-MDB).

Summary of assessment

Conservation status

Vulnerable: Criterion 1 A2,(a),(c) and Criterion 2 B2,(a),(b),(ii),(iv),(v)

The highest category for which *Nannoperca australis* Murray-Darling Basin lineage is eligible to be listed is Vulnerable.

Nannoperca australis Murray-Darling Basin lineage has been found to be eligible for listing under the following categories:

Criterion 1: A2 (a)(c): Vulnerable
Criterion 2: B2,(a),(b),(ii),(iv),(v): Vulnerable

Species can be listed as threatened under state and territory legislation. For information on the listing status of this species under relevant state or territory legislation, see http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Reason for conservation assessment by the Threatened Species Scientific Committee

This advice follows assessment of information provided by the New South Wales Government as part of the process to systematically review species that are inconsistently listed under the EPBC Act and relevant New South Wales legislation/lists.

Public consultation

Notice of the assessment and a consultation document was made available for public comment for 36 business days between 14 June 2019 and 2 August 2019. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

Species/sub-species information

Description

The Southern Pygmy Perch-MDB is a small, laterally compressed fish which grows to a maximum size of 85 mm (Kuiter et al., 1996; Allen et al., 2002; Lintermans 2007). Southern Pygmy Perch-MDB differ from the closely related *Nannoperca obscura* (Yarra Pygmy Perch) by having a smooth, non-serrated lower edge of the preoribital bone (Lintermans 2007). Morphologically, Southern Pygmy Perch-MDB appear the same as other lineages of Southern Pygmy Perch, and range in colour from cream to gold-orange to greenish-brown mottling on its back and sides, to a silver white belly (Allen et al., 2002; Lintermans 2007). Fins are generally clear to dusky, but for males turn bright red to black in the breeding season (Allen et al., 2002; Lintermans 2007).

Distribution

The natural distribution of Southern Pygmy Perch-MDB once extended across the southern Murray-Darling Basin, from the lowland to the upland zones (0–580 m a.s.l.) of New South Wales and Victorian catchments (Cadwallader 1979; ALA 2020). In New South Wales the species was once found within the Lachlan, Murrumbidgee and Murray river catchments (ALA 2020). In New South Wales, remnant populations remain in a tributary of the Lachlan River, and two tributaries of the Murray River (Gilligan et al., 2010; Gould & Pearce 2012; Pearce 2015a; Pearce et al., 2018). In Victoria, the species can be found within the Mitta Mitta, Kiewa, Ovens, Goulburn-Broken, Campaspe, Avoca and Wimmera river catchments (Lintermans 2007; Davies et al., 2008; 2012; Rose 2018; Whiterod et al., 2019). The species is also present in the tributaries draining into the lower Murray River in the Mount Lofty ranges in South Australia and the Lower Lakes (Lintermans 2007; Whiterod et al., 2019). Within the Murray-Darling Basin, the species has been shown to have a strong and hierarchical population structure (differentiation much greater among, than within, catchments) and no migration is evident between most catchments (Brauer et al., 2016). Genetic studies indicate that the currently observed isolated and fragmented nature of populations across the Murray-Darling Basin has resulted from the anthropogenic development of region post-European settlement (Cole et al., 2016).

The Southern Pygmy Perch-MDB, has been observed to prefer habitats in low-gradient waterways and floodplains with slow-flowing or still water, and aquatic macrophyte cover or wood at shallow depths, with little or no flow in summer (Cadwallader 1979; Humphries 1995; Woodward & Malone 2002; Unmack et al., 2011; 2013; Hammer et al., 2013; Price et al., 2016). The species has a limited tolerance of salinity and prefers waters with salinity less than 3.3 ppt (Chessman & Williams 1974), however it can tolerate a broad range of temperatures and extremely low dissolved oxygen levels (McNeil & Closs 2007).

Observations made by J.O. Langtry in his 1949 and 1950 surveys noted that Southern Pygmy Perch-MDB "…appear to abound throughout the whole Murray system" (Cadwallader 1977). J.O. Langtry noted in his 1949-50 observations that "pigmy perch (*Southern Pygmy Perch*) are known to exist in the creeks in the Narrandera area" in reference to its presence in the Murrumbidgee River catchment (Cadwallader 1977). The species is still considered locally extinct in the Murrumbidgee River catchment (Wassens et al., 2017), after reports from over a decade ago that this was the case (Gilligan 2005a).

Declines in Southern Pygmy Perch-MDB abundance in the lower Murray River in South Australia were being reported as early as the mid-1980s where the species was thought to have disappeared from the main river channel itself (Lloyd & Walker 1986). Records of the species were reported, in sampling occurring over 1982–1984, for two streams flowing into Lake Alexandrina at the Murray River's mouth (Lloyd & Walker 1986). Declines in Victorian tributaries of the Murray River were reported by the early-1990s (Unmack 1992).

Cultural significance

Trueman (2011) reports that the Jari Jari name for Southern Pygmy Perch-MDB was Collundera, however Blandowski (1857) reports Collundera as a name used by the Nyeri Nyeri for *Hypseleotris* spp. (Carp Gudgeon). Therefore, Traditional names for the species require further investigation.

Relevant biology/ecology

Southern Pygmy Perch-MDB spawning seems to occur when water temperatures rise above 19°C and can occur as early as September (Llewellyn 1974). As a recent example, spawning was recorded from the Barmah-Millewa Forest wetland on the Murray River in October (Tonkin et al., 2008).

Spawning likely occurs in macrophyte beds, as running-ripe and spent fish have been found in this habitat (Humphries 1995). Males display courtship behaviour involving rapid vibrations of the body, with fins erect, and nudging and swimming rapidly around the female (Cadwallader & Backhouse 1983). Floodplains are likely to be utilised by various Pygmy Perch species as nursery grounds (Woodward & Malone 2002).

Eggs are demersal, transparent, spherical and essentially non-adhesive (Llewellyn 1974). Observations on the number of eggs produced by females can range from 78 in a 37 mm fish to 4217 in a 57 mm fish (Llewellyn 1974; Humphries 1995), and like other small fish species, it appears capacity for egg production increases with size, with oldest age classes having the highest reproductive output (Todd et al., 2017). Observations on the species also suggest that individuals inhabiting increasingly harsh environments produce more, but smaller, eggs than those in more stable environment (Morrongiello et al., 2012).

Eggs take between 66–79 hours (~3 days) to hatch, with the larvae about 3–4 mm long (Llewellyn 1974). Individuals probably mature by the end of their first year of life, or sometime in their second year (Llewellyn 1974; Humphries 1995; Todd et al., 2017). There are suggestions that individuals can live to at least five years of age, but populations of the species are dominated by individuals aged between one and three years old, with some individuals living to 4 years (Humphries 1995; Kuiter et al., 1996; Lintermans 2007; Todd et al., 2017). Therefore, using estimates of survival and fecundity rates prescribed in Todd et al. (2017), generation length for Southern Pygmy Perch-MDB is estimated to be ~2.5 years using the IUCN Red List Guidelines prescribed formula – $G = \Sigma x l_x m_x / \Sigma l_x m_x$ [1] (Source: IUCN S&PC 2019).

The diet composition of Southern Pygmy Perch in Tasmania, and likely reflective of the diet of Southern Pygmy Perch-MDB, is insectivorous and planktivorous, consisting of crustaceans, such as amphipods and ostracods, that are benthic and/or associated with aquatic plants (Humphries 1995). The species also likely feeds on other crustaceans such as cladocerans and copepods, insects such as larval chironomids and mayflies, and adult hemipterans and other terrestrial insects which fall in water (Kuiter et al., 1996).

A genetic study of the species in the Goulburn River system in Victoria has indicated that populations occurring in different creek tributaries are genetically isolated from one another, however there is some level of genetic connectivity within streams (Cook et al., 2007). The study proposed that its findings could translate to other major lowland catchments across the species' distribution (Cook et al., 2007).

Threats

Suspected primary threats to Southern Pygmy Perch-MDB include the removal of riparian and aquatic vegetation (Lloyd & Walker 1986; Cook et al., 2007) that the species is known to rely upon (Unmack et al., 2011; 2013); the loss of connectivity between rivers and floodplains (Lyon et al., 2010; Saddlier et al., 2013); and sedimentation of water bodies (Bond & Lake 2005). The introduced fish species, Trout (Famly Salmonidae) (Cadwallader & Eden 1982; Humphries 1995) and Redfin (*Perca fluviatilis*) (Woodward & Malone 2002), are known predators of Southern Pygmy Perch in areas outside the MDB but are likely predators in MDB areas where the species co-exist; eastern gambusia is also a likely predator of eggs and juveniles (Woodward & Malone 2002). Carp destroy submerged macrophytes (Roberts et al., 1995; Roberts & Sainty 1996; Vilizzi et al., 2014), so are likely indirectly impacting upon Southern Pygmy Perch given the species' reliance on aquatic vegetation.

[1] where the summations are from age (x) 0 to the last age of reproduction; mx is (proportional to) the fecundity at age x; and lx is survivorship up to age x (i.e., $lx = S0 \cdot S1 \cdots Sx\text{-}1$ where S is annual survival rate, and $l0 = 1$ by definition). Implemented using the IUCN spreadsheet file which can be accessed at - https://www.iucnredlist.org/resources/generation-length-calculator

Table 1 – Threats impacting the Southern Pygmy Perch-MDB in approximate order of severity of risk, based on available evidence.

Number	Threat factor	Threat type and status	Evidence base
1.0	Habitat loss and fragmentation		
1.1	Removal of riparian and aquatic vegetation	Known past, current and future	Once widespread in the lower Murray River and associated tributaries in South Australia, the Southern Pygmy Perch-MDB is considered to have declined due to the removal of shaded, vegetated habitats which were often destroyed in "stream improvement" practices (Lloyd & Walker 1986). Clearing and unrestricted stock access to riparian zones has led to a reduction in riparian and aquatic vegetation levels (Belsky et al., 1999). Given nowadays that stream populations of the species can be isolated from other populations in other streams relatively close by due to anthropogenic impacts (Cook et al., 2007; Cole et al., 2016), even relatively small-scale loss and degradation of riparian and aquatic vegetation may be impacting relict populations, especially considering the likely importance of macrophytes to the spawning part of the species' life cycle. For example, there are indications that 70 percent of critical habitat for the species has become unsuitable in the north central Victoria region since European settlement (Rose 2018).
1.2	Loss of connectivity between rivers and floodplains	Suspected past, current and future	Substantial areas of shallow wetland habitat have been lost in parts of the Murray-Darling Basin and coastal drainages where the Southern Pygmy Perch-MDB occur, and reduced wetland connectivity to more permanent waterbodies such as rivers and creeks has occurred (Saddlier et al., 2013). Indications are that lateral connectivity is important for the small-bodied fish community in the Murray-Darling Basin (Lyon et al., 2010). Recruitment and dispersal of Southern Pygmy Perch-MDB in the Barmah-Millewa Forest on the Murray River has been observed to significantly increase during a floodplain

			inundation in comparison with other conditions (Tonkin et al., 2008). While recent fishway construction programmes have focussed towards restoring longitudinal connectivity in the temperate south-eastern rivers of Australia, up until 2008 no regulators controlling flow into lateral areas had had fishways installed (Jones & Stuart 2008). The trial of several potential management and engineering solutions has been recommended to improve river floodplain connectivity in lowland rivers (Jones & Stuart 2008). Recent environmental water priorities are focussed on lateral connectivity, including an emphasis that follow-up connections are established using water releases for in future years (MDBA 2019). These releases are identified as a key action under moderate and wet, to very wet, conditions and are designed to allow fish to exit off-channel habitats, and for offspring to disperse (MDBA 2019).
1.3	Sedimentation	Suspected past, current and future	Human-induced erosion delivering increased sedimentation to streams and rivers (known as sand-slugs) deplete the number of permanent refuge pools in waterways when there are drought conditions (Bond & Lake 2005). It has been proposed that restoration work in streams degraded by sand-slugs may be better directed toward restoring refuge habitat (deep pools and backwaters) rather than focussing on residential habitat (addition of wood/timber structures) to increase the resilience of species such as Southern Pygmy Perch-MDB to drought and flood (Bond & Lake 2005).
1.4	Changes to flow regimes	Suspected past, current and future	River regulation throughout the Murray-Darling Basin, which has involved the construction of thousands of dams, weirs and other structures in catchments and along waterways (Lintermans 2007) have greatly influenced natural flow regimes. Human-management of water within the Murray-Darling Basin since European Settlement has profoundly changed seasonal and inter-annual flow regimes (Kingsford et al., 2015). In general, river regulation in the Murray-Darling Basin has reduced seasonal timing and variability in flow diminished the extent and frequency of

			overbank flooding events and reduced the volume of flow of especially in downstream areas (Kingsford et al., 2015). This has likely had severe impacts on habitat characteristics important to the life cycle of the Southern Pygmy Perch-MDB.
2.0	Invasive introduced species		
2.1	Competition and predation by introduced fish species	known past, current and future	Several alien (or introduced) fish species are present in the areas where Southern Pygmy Perch-MDB occurs, including Redfin (*Perca fluviatilis*), Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (Salmo trutta), European Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*) and Eastern Gambusia (*Gambusia holbrooki*). Redfin are now widely distributed throughout the southern half of the Murray-Darling Basin (Lintermans 2007), restricted to waterways where temperatures remain less than 31°C (Weatherley 1963a; b; 1977). Redfin are known to prey on many small and juvenile native species (Clunie et al., 2002). The population collapse of Southern Pygmy Perch-MDB in Lake Alexandrina has been linked to Redfin (Wedderburn & Barnes 2016). Direct observations of predation by Redfin on Southern Pygmy Perch-MDB was determined by gut analyses in Blakney Creek in 2015 (NSW DPI pers. comm., 2019). There has been a decline in Southern Pygmy Perch-MDB numbers in Blakney Creek in New South Wales with the invasion of Redfin and European Carp (Pearce 2015a). A study of Rainbow Trout stomach contents in Lake Purrumbete in Victoria, found Southern Pygmy Perch in some samples (Cadwallader & Eden 1982). In Tasmania, a study examining gut contents from Brown Trout and Redfin indicated that Southern Pygmy Perch was an important prey item for both these introduced fish species (Humphries unpub. data., cited in Humphries 1995). This study supports findings from Seven Creeks, where both Brown Trout (no Rainbow Trout were sampled) and Redfin were found to predate on Southern Pygmy Perch-MDB (Cadwallader 1979). Current-day

			stockings of salmonids still occur in areas where Southern Pygmy Perch-MDB occur and could potentially occur in future as recovery is attempted. J.O. Langtry reported in his observations from 1949-50 that “Brown Trout have been seen feeding voraciously on shoals of Pigmy Perch (i.e. *Southern Pygmy Perch*) in the Yarrawonga area” (Cadwallader 1977). Interestingly, a dedicated Trout fishing book states that Southern Pygmy Perch is the best bait for big Trout (Wedlick 1981), leaving little doubt that Trout predate on the species in Murray-Darling Basin waterways. European Carp now dominate freshwater systems across the Murray-Darling Basin and have become the most abundant large-bodied freshwater fish in south-eastern Australia (Koehn 2005; Davies et al., 2012). Carp disturb native fish habitats by raising turbidity and destroying submerged macrophytes (Roberts et al., 1995; Roberts & Sainty 1996; Vilizzi et al., 2014) in areas which may be habitats for Southern Pygmy Perch-MDB. Pearce (2014) reported a negative correlation between Carp and Southern Pygmy Perch-MDB abundances in New South Wales populations. Goldfish are also likely to impact in a similar manner to European Carp upon Southern Pygmy Perch-MDB in areas where the two species co-exists, such as in Blakney Creek in New South Wales. Eastern Gambusia are found widely across Australia, including throughout the Murray-Darling Basin (Lintermans 2007). Eastern Gambusia are known to eat fish eggs and juveniles of other fish species and aggressively attack fish by nipping fins (Koehn & O’Connor 1990a; b; Arthington & McKenzie 1997). Woodward & Malone (2002) suggested that Eastern Gambusia are likely predators of Pygmy Perch eggs and larvae. Direct observations are reported of fin nipping by Eastern Gambusia on juvenile Southern Pygmy Perch (Tonkin et al., 2011).

3.0	Climate change associated events		
3.1	Increased intensity/frequency of wildfire/bushfire	Suspected current and future	Bushfires experienced during the 2019/20 bushfire season burnt more than 10 million hectares of land in southern Australia (CSIRO 2020). While climate change doesn't directly cause bushfire, it has caused an increase in the occurrence of extreme fire weather and in the length of the fire season across large parts of Australia since the 1950s (CSIRO 2020). In 2019, the annual national mean temperature was 1.52°C above average (BOM 2020). Climate change has driven longer, more intense fire seasons and an increase in the average number of elevated fire weather days, as measured by the Forest Fire Danger Index (FFDI) (CSIRO 2020). The highest annual accumulated FFDI was recorded in 2019 (CSIRO 2020). Bushfire can adversely affect stream habitat by increasing water temperature, altering water chemistry (Lyon & O'Connor 2008), and creating sediment/ash runoff 'slugs' that can form in waterways following rainfall on burnt areas (Lyon & O'Connor 2008; Alexandra & Finlayson 2020). Sediment slugs have been found to impact aquatic ecosystems up to 80 km downstream of burnt areas (Lyon & O'Connor 2008). While the full impact of the 2019-20 bushfires is yet to be determined, initial analysis estimates that impacts to areas where Southern Pygmy Perch-MDB occur are currently low (DAWE 2020a). Bushfire seasons of this intensity and scale are likely to increase as a result of climate change (CSIRO 2020).
3.2	Changing rainfall patterns	Suspected current and future	Freshwater ecosystems are particularly vulnerable to climate change because they are isolated and fragmented within a terrestrial landscape (Morrongiello et al., 2011). Surface water, which determines the quality and availability of aquatic habitat, depends heavily on rainfall and temperature regimes which are predicted to drastically change under climate change predictions (Carpenter et al., 1992; Hobday & Lough 2011). Climate change projections for the Murray-Darling Basin predict

			increases in temperature and evaporation and less rainfall and snowfall, which will likely result in reduced runoff to rivers and wetlands especially in the southern Basin (CSIRO 2008; Dunlop & Brown 2008; Morrongiello et al., 2011). Median runoff is predicted to decline by up to 12% and flood frequency is predicted to decrease (Balcombe et al., 2011). Extreme events such as storms (and associated floods) and droughts are projected to rise in frequency and/or intensity under climate change (Aldous et al., 2011; Hobday & Lough 2011). Given that remaining Southern Pygmy Perch-MDB populations are isolated and fragmented, there is a high likelihood that severe impacts will occur to the species as a result of changing rainfall patterns driven by climate change.

How judged by the Committee in relation to the EPBC Act criteria and regulations

Criterion 1. Population size reduction (reduction in total numbers)
Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered Very severe reduction	Endangered Severe reduction	Vulnerable Substantial reduction
A1	**≥ 90%**	**≥ 70%**	**≥ 50%**
A2, A3, A4	**≥ 80%**	**≥ 50%**	**≥ 30%**

A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(*a) cannot be used for A3*]

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation [*except A3*]

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Evidence:

Eligible under Criterion 1 A2(a),(c) for listing as Vulnerable

It should be noted that population size reduction has been assessed over the past 10 years (as prescribed above for how Criterion 1 is applied) rather than past three generations of Southern Pygmy Perch-MDB which amount to 7.5 years.

New South Wales

Only three remnant populations of Southern Pygmy Perch-MDB are currently known to exist in New South Wales excluding the Murray River. One exists in Blakney Creek, a tributary in the upper Lachlan River catchment, near Yass (Gilligan et al., 2010; Gould & Pearce 2012). A remnant population also occurs in Coppabella Creek, a small tributary (38 km long) of the Jingellic Creek which joins the upper Murray River, near Jingellic upstream of Lake Hume (Gilligan et al., 2010). Another remnant population occurs in the upper Billabong Creek catchment, a tributary of the Murray River (Billabong Creek eventually joins the Edward River at Moulamein in New South Wales) (Gilligan et al., 2010).

Lachlan River Catchment

The distribution of Southern Pygmy Perch-MDB within Blakney Creek contracted by 51 percent (in stream length) from 2007 to 2013, this is assumed to be indicative of population decline of a similar magnitude (Pearce 2015a). Follow up monitoring in 2018 recorded very low abundances of Southern Pygmy Perch-MDB and an increasing distribution of Redfin (Lintermans 2018). Both Carp and Redfin are present in Blakney Creek (Pearce 2015a), it is uncertain whether Brown or Rainbow Trout are also present. No salmonid stockings have been reported in Blakney Creek since 2009, but Trout are stocked in close-by tributaries of the Lachlan River such Grabben Gullen and Humes creeks (NSW DPI 2019).

A translocated population of Southern Pygmy Perch-MDB has been created in Pudman Creek in the upper Lachlan River catchment using fish sourced from Blakney Creek (Gilligan et al., 2010; Gould & Pearce 2012). Pudman Creek was chosen given its high abundance and diversity of aquatic vegetation, which are important habitat requirements for Southern Pygmy Perch-MDB (Gould & Pearce 2012). Surveys conducted in 2013 found that the species was surviving and recruiting in Pudman Creek (Gould & Pearce 2012; Pearce 2015a). However, an extensive survey of Pudman Creek in 2013 revealed that, while fish persisted at the location where individuals had been translocated, they had not spread (Pearce 2015a;b).

Murrumbidgee River Catchment

The species is considered locally extinct in the Murrumbidgee River catchment since at least 2005 (Gilligan 2005a; Wassens et al., 2017), indicating declines in population in this catchment occurred well before 10 years ago and thus are beyond the scope of assessment for this criterion.

Murray River Catchment

The remnant population of Southern Pygmy Perch-MDB occurring in Coppabella Creek was reported to have been decimated by the flooding between 2010 and 2012 which ended the Millennium Drought (Pearce 2015b). Recent indications are that the population in Coppabella Creek declined again in 2017 for an unknown reason (Pearce et al., 2018). The species remains in a stretch of Coppabella Creek where both Carp and Redfin presence is excluded due to Clearsprings Weir blocking their incursion upstream (Pearce et al., 2018). The remnant

population that occurs in the upper Billabong Creek catchment has declined in abundance and geographic distribution and now no longer occurs in Ten Mile Creek, but still remains in the tributaries of Mountain and Spring creeks (Pearce 2015b; NSW DPI pers. comm., 2020) near Holbrook in New South Wales.

Southern Pygmy Perch-MDB has not been recorded in recent monitoring for the Edward-Wakool system in the middle Murray River region (Watts et al., 2017). Surveys in 2004 failed to detect the species in the lower Murray River in New South Wales, in the river stretch between the Murrumbidgee River confluence downstream to the South Australian border (Gilligan 2005b). Surveys which detected Southern Pygmy Perch-MDB in the Barmah-Millewa Forest wetland on the Murray River up until 2007, failed to detect any individuals of the species in late-2007/early-2008 primarily due to most wetland sites being completely dry (Tonkin et al., 2008), near the end of the millennium drought, and this population is now considered to be locally extinct. Populations which existed at Normans Lagoon and Barmah-Millewa Forest are likely locally extinct given that recent extensive targeted surveys at these locations failed to detect the species (Sharpe & Wilson 2012; Sharpe et al., 2012, both cited in Pearce 2015a).

Victoria

Prior population reductions in the Victorian tributaries of the Murray River were being reported by the early-1990s (Unmack 1992), these occurred however outside the time period to be considered under this criterion.

Mitta Mitta River Catchment

Southern Pygmy Perch-MDB were recorded in the slopes zone (200-400 m a.s.l) of the Mitta Mitta River catchment in 2011 as part of the Sustainable Rivers Audit (SRA) surveys, and more specifically in 2011 at a location in Tallangatta Creek at the Crossing of Soldiers Settlers Road (ALA 2020). It is unclear how many targeted surveys for Southern Pygmy Perch-MDB have occurred in the past 10 years in the Mitta Mitta River catchment, therefore it is difficult to make inference about declines in species abundance in this catchment over the past 10 years.

Kiewa River Catchment

Southern Pygmy Perch-MDB were recorded in SRA surveys in the lowland zone of the Kiewa River catchment in 2012 (ALA 2020), interestingly after not being detected in the lowland zone (0-200 m a.s.l) in 2009 but being detected in 2006 (Davies et al., 2008; 2012). Another observation of the species being present was made in 2015 at Bight Creek, near its confluence with the Kiewa River (ALA 2020). It is unclear how many targeted surveys for Southern Pygmy Perch-MDB have occurred in the past 10 years in the Kiewa River catchment, therefore it is difficult to make inference about declines in species abundance in this catchment over the past 10 years.

Ovens River Catchment

A survey in the lower Ovens River found the species in low numbers at sites from Peechelba northwards to Bundalong South in 2009 and 2010 (Macdonald et al., 2012). One individual was sampled in SRA surveys in the slopes zone of the Ovens River catchment in 2010 (ALA 2020).

The species was sampled in parts of the catchment in 2009 in a King River Billabong under the bridge of the King Valley Road at Cheshunt and in Happy Valley Creek at the Carrolls Road crossing (ALA 2020). It is unclear how many targeted surveys for Southern Pygmy Perch-MDB

have occurred in the past 10 years in the Ovens River catchment, therefore it is difficult to make inference about declines in species abundance in this catchment over the past 10 years.

Goulburn-Broken Rivers Catchment

In 2011, Southern Pygmy Perch-MDB were recorded in low numbers in the lowland zone of the Broken River catchment (ALA 2020). The species was recorded in Hollands Creek in 2011, and several observations of the species were detected in Sam Creek, a tributary of Hollands Creek via Ryans Creek, up until 2009 (ALA 2020). In the Broken River itself, there are records up until 2009, where the species was sampled downstream of Nillahcootie Dam in the area of Lima South (ALA 2020). In 2015 the species was recorded in Swanpool Creek, at the crossing of Castle Hill Road (ALA 2020).

In the Upper Goulburn River catchment upstream of Lake Eildon, Southern Pygmy Perch-MDB was recorded in parts of Merton and Brankeet creeks in 2016 (Lieschke & Ayres 2016). The species was recorded in Seven Creeks in 2013, west of Strathbogie (ALA 2020). In the same year, it was also recorded in a small creek tributary of Seven Creeks (ALA 2020). It was recorded in 2013 and 2015 in Castle Creek (ALA 2020). The species was recorded in Creightons Creek upstream of the Creightons Creek area (ALA 2020). It is unclear how many targeted surveys for Southern Pygmy Perch-MDB have occurred in the past 10 years in the Goulburn-Broken Rivers catchment, therefore it is difficult to make inference about declines in species abundance in this catchment over the past 10 years.

Campaspe River Catchment

Southern Pygmy Perch-MDB were detected in SRA surveys in the upland zone (400-700 m a.s.l.) of the Campaspe River catchment in 2012 (ALA 2020). The species was sampled in Jews Harp Creek in 2012 west of Pastoria East, an upper tributary of the Campaspe River (ALA 2020). The species was also surveyed in the Campaspe River itself in 2009 at the Tylden-Woodend Road crossing (ALA 2020). Sampling between April and August 2018 indicate that the species is strongly persisting in the Campaspe River catchment (i.e. likely stable or increasing), especially in the Jews Harp Creek catchment but also in the Campaspe River itself around Kyneton and upstream from there (Rose 2018).

Loddon River Catchment

Given the lack of records for Southern Pygmy Perch-MDB in the past 20 years in the Loddon River catchment despite surveys being undertaken (Davies et al., 2008; 2012; Rose 2018; ALA 2020), it would appear due to that the species is locally extinct in this catchment, but it appears that this extinction occurred well before 10 years ago.

Avoca River Catchment

There are multiple records of the species in SRA surveys in the slopes zone for the Avoca River catchment in 2011, namely in the tributary Mountain Creek (Rose 2018; ALA 2020). Sampling in 2018 indicate that the species is persisting in the Avoca River catchment, in Mountain and Middle creeks (Rose 2018).

Wimmera River Catchment

There are multiple records of the species in SRA surveys from 2012 in the slopes zone, namely from within Mount William and Mount Cole creeks, but also in the Mackenzie River near Wartook (ALA 2020). 2014 MDB fish monitoring surveys detected the species in upper Mount Cole Creek near Warrak (ALA 2020). Records from 2011 also found the species in Glenlofty and

Glenpatrick creeks northeast of Ararat (ALA 2020). It is unclear how many targeted surveys for Southern Pygmy Perch-MDB have occurred in the past 10 years in the Wimmera River catchment, therefore it is difficult to make inference about declines in species abundance in this catchment over the past 10 years.

South Australia

Populations of the species in the lower Murray River in South Australia 10 years ago, at the height of the Millennium Drought conditions, were probably the lowest to date (PIRSA pers. comm., 2019). Monitoring since then has detected gradual increases in abundance and geographic distribution in the Lower Lakes (PIRSA pers. comm., 2019). There are multiple occurrence records for the species in the past 10 years from the Angas, Finniss, Tookayerta and on Hindmarsh Island (e.g. Hunters) river and creek catchments which drain into the Lower Lakes (Cole et al., 2016; ALA 2020) where strong subpopulations persist (Whiterod et al., 2019). However, Wedderburn et al (2017) reports that the species is locally extinct within the Lower Murray River channel itself from upstream of the Lower Lakes to Mannum. The species has likely been locally extinct in this stretch of the Murray River since the early 1980s (Lloyd & Walker 1986), outside the time period for consideration under this criterion.

Summary

An overall population reduction in the Southern Pygmy Perch-MDB over the past 10 years can be inferred or suspected from the above available information. There is evidence of as much as a 51 percent contraction in distribution in catchments in New South Wales, with associated inferred population decline. Evidence from several other New South Wales locations, such as Ten Mile Creek, part of the Billabong Creek catchment, and in Coppabella Creek, also indicate significant population decline. The Victorian component is considered the dominant portion of the species' range and it is known to have experienced historic localised population extinctions in this portion longer than 10 years ago. A lack of targetted survey effort in Victoria since 2009 prevents definitive assessment of population trends over this period. The species has however been shown to be persisting in several catchments within Victoria at very low numbers. Despite the population reductions observed in some areas of the Murray-Darling Basin, it appears that in the Lower Lakes in South Australia the species has been recovering and increasing in abundance in the past 10 years, since the end of the Millenium Drought (PIRSA pers. comm., 2019).

Therefore, across the entire Murray-Darling Basin, the Committee infers a population reduction greater than 30 percent over the past 10 years and that the causes of reduction have not ceased. It is also highly likely that substantial population declines occurred across the Murray-Darling Basin before 10 years ago (i.e. 2010), outside consideration of this Criterion. The Committee's assessment against the relevant elements of Criterion 1 finds the Southern Pygmy Perch-MDB is eligible for listing as Vulnerable.

Criterion 2.	Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy			
		Critically Endangered Very restricted	**Endangered Restricted**	**Vulnerable Limited**
B1.	Extent of occurrence (EOO)	**< 100 km^2**	**< 5,000 km^2**	**< 20,000 km^2**
B2.	Area of occupancy (AOO)	**< 10 km^2**	**< 500 km^2**	**< 2,000 km^2**
AND at least 2 of the following 3 conditions:				
(a)	Severely fragmented OR Number of locations	**= 1**	**≤ 5**	**≤ 10**
(b)	Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Evidence:

Eligible under Criterion 2 B2(a),(b),(ii),(iv),(v) for listing as Vulnerable

The extent of occurrence (EOO) is estimated to be 168 398 km^2, and the area of occupancy (AOO) is estimated to be 636 km^2 (unpublished report, DAWE 2020b). The EOO was calculated using a minimum convex hull while the AOO was based on the mapping of point records since 1999, obtained from state governments, museums and CSIRO (unpublished report, DAWE 2020b). Therefore, the AOO is classified as limited.

The geographic distribution of Southern Pygmy Perch-MDB is severely fragmented, given that river regulation throughout the Murray-Darling Basin has involved the construction of thousands of barriers to fish movement throughout the system (Lintermans 2007) and recent genetic analysis on the 578 individuals of Southern Pygmy Perch-MDB across 45 localities detected strong and hierarchical population structure, very low genetic diversity and a lack of contemporary gene flow across the Murray-Darling Basin species indicating that there is limited movement between creek catchments of the same river catchment (Cole et al., 2016). The absence of pronounced or long-term phylogeographic structure suggests that observed population divergences generally do not reflect deeply historic natural fragmentation, but rather the contemporary isolation of populations partly explained by the severe modification of the Murray-Darling Basin following European settlement (Cole et al., 2016). Continuing decline in the area of occupancy, the number of locations or subpopulations and the number of mature individuals is inferred, given that most of the putative threats are still active and may be still negatively impacting on the species into the future within the Murray-Darling Basin.

In this context, the Committee considers that the species' AOO is limited, and the geographic distribution is precarious for the survival of the species because its occurrence is severely fragmented and continued decline in area of occupancy and number of locations and subpopulations may be inferred. Therefore, the species has been demonstrated to have met the relevant elements of Criterion 2 to make it eligible for listing as Vulnerable.

Criterion 3. Population size and decline				
		Critically Endangered Very low	**Endangered Low**	**Vulnerable Limited**
Estimated number of mature individuals		**< 250**	**< 2,500**	**< 10,000**
AND either (C1) or (C2) is true				
C1	An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	**Very high rate 25% in 3 years or 1 generation (whichever is longer)**	**High rate 20% in 5 years or 2 generation (whichever is longer)**	**Substantial rate 10% in 10 years or 3 generations (whichever is longer)**
C2	An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(a)	(i) Number of mature individuals in each subpopulation	**≤ 50**	**≤ 250**	**≤ 1,000**
	(ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b)	Extreme fluctuations in the number of mature individuals			

Evidence:

Insufficient data to determine eligibility

The Committee considers that there is insufficient information to determine the eligibility of the species for listing in any category under this criterion.

Criterion 4. Number of mature individuals			
	Critically Endangered Extremely low	**Endangered Very Low**	**Vulnerable Low**
Number of mature individuals	**< 50**	**< 250**	**< 1,000**

Evidence:

Insufficient data to determine eligibility

The Committee considers that there is insufficient information to determine the eligibility of the species for listing in any category under this criterion. However, while numbers are likely to continue to decline for the Southern Pygmy Perch-MDB, the Committee considers that it is highly likely that the number of mature individuals in the wild is greater than 1000. Therefore, it is also highly likely that the species is not eligible for listing under this criterion.

Criterion 5. Quantitative Analysis			
	Critically Endangered Immediate future	**Endangered Near future**	**Vulnerable Medium-term future**
Indicating the probability of extinction in the wild to be:	**≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)**	**≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)**	**≥ 10% in 100 years**

Evidence:

Insufficient data to determine eligibility

While a population viability analysis was undertaken for Southern Pygmy Perch-MDB by Todd et al. (2017), its primary purpose was to develop a stochastic population model to inform management strategies for establishing new populations of Southern Pygmy Perch-MDB rather than estimating the probability of extinction for the species across the Murray-Darling Basin or the national extent. Therefore, there are currently insufficient data to determine the eligibility of the species for listing in any category under this criterion.

Conservation actions

Recovery plan

Many of the threats to the Southern Pygmy Perch-MDB are threats to other EPBC Act-listed threatened fish species that occur within the Murray-Darling Basin. Actions and mechanisms that are being implemented through a variety of other existing programs (including in other species recovery plans, a national native fish recovery strategy, water management plans, actions being undertaken by relevant catchment management authorities) are likely to be of benefit to this species. In particular, with regard to the threat posed by riparian vegetation removal and degradation, river regulation and its associated negative impact on lateral connectivity, an objective of the Basin Plan 2012 (paragraph 8.06(3)(b)) is “to protect and restore connectivity within and between water-dependent ecosystems, including by ensuring that ecological processes dependent on hydrologic connectivity laterally between watercourses and their floodplains (and associated wetlands)”. This approved Conservation Advice provides sufficient direction, especially for the immediate term under ‘Information and research priorities’, and it is unlikely sufficient extra direction would be provided to necessitate a recovery plan for the species. Prioritisation of recovery actions under a recovery plan to address these threats may be a little premature until there is a greater understanding of the current population trends across the Murray-Darling Basin, which can be gained from targeted research that can be undertaken outside the confines of species-specific recovery plan.

Primary conservation actions

Halt decline and stabilise populations of Southern Pygmy Perch-MDB by protecting the species from habitat degradation and introduced fish species, including salmonids, and then recover its range to its historical extent and rebuild populations.

Conservation and management priorities

- Habitat loss and fragmentation
    - Revegetate and protect riparian vegetation in river catchments where Southern Pygmy Perch-MDB are found or have been known to occur. Focussed, small-scale restoration projects may prove useful given that populations may be isolated.
    - Implement, or supplement existing programs to include a seeding program of native aquatic plants (such as *Vallisneria* spp.) in waterbodies known to contain Southern Pygmy Perch-MDB. Focussed, small-scale restoration projects may prove useful given that populations may be isolated.
    - Improve river floodplain to channel lateral connectivity by investigating and trailing management and engineering solutions to establish the best methods.
    - Implement management and engineering solutions to physical barriers, such as dams, weirs, levees, culverts, to improve river-floodplain connectivity, targeting areas where Southern Pygmy Perch-MDB are found, or have been known to occur.
    - Explore the use of larger environmental flow events to improve lateral connectivity, particularly the use of environmental water to “top-up” natural flood events, so that off-channel billabongs, lagoons and wetlands receive sufficient watering at appropriate times to encourage Southern Pygmy Perch-MDB to breed/spawn, move and recruit.
    - Restore habitat to provide refugia, including the re-establishment of deep pools and backwaters in degraded waterbodies, to increase the resilience of Southern Pygmy Perch-MDB to drought and flood.
- Introduced species
    - Implement, or supplement existing programs to include a targeted control program for introduced fish species, including Redfin (*Perca fluviatilis*), Trout (Family Salmonidae), Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*) and Eastern Gambusia (*Gambusia holbrooki*), in areas known to contain Southern Pygmy Perch-MDB.

Survey and monitoring priorities

- Implement a targeted monitoring program for Southern Pygmy Perch-MDB across the Murray-Darling Basin, to assess the current extent of occurrence, area of occupancy and population abundance and to detect population trend/trajectory.
- Utilise a combination of eDNA techniques and conventional monitoring to improve monitoring for all introduced fish species in areas where Southern Pygmy Perch-MDB occur, as Bylemans et al. (2016) describes for use in Redfin detection.

Information and research priorities

- Resolve and publish taxonomy of the Southern Pygmy Perch species complex.
- Priority given to research on the relative impacts of introduced species on Southern Pygmy Perch-MDB, including Salmonids (as specified by Cadwallader (1996) for pygmy perches), Redfin, Carp, Goldfish and Eastern Gambusia.

- Develop a strategic captive breeding program for Southern Pygmy Perch-MDB. Hatchery-bred individuals should be used for conservation stocking activities. Such program should factor in considerations about increasing variation in gene expression to strengthen the ability of reintroduced populations to persist in variable environments (Attard et al., 2016a;b; Brauer et al., 2017).
- Develop a translocation program for Southern Pygmy Perch-MDB which investigates the benefits and potential risks of translocating individuals between catchments to increase variation in gene expression.

Recommendations

(i) The Committee recommends that the Minister declare *Nannoperca australis* Murray-Darling Basin lineage to be a species for the purposes of the EPBC Act, under Section 517 of the Act.

(ii) The Committee recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the Vulnerable category:

Nannoperca australis Murray-Darling Basin lineage

(iii) The Committee recommends that there not be a recovery plan for this species.

Threatened Species Scientific Committee

02/06/2020

References cited in the advice

Aldous, A., Fitzsimons, J., Richter, B., & Bach, L. (2011). Droughts, floods and freshwater ecosystems: evaluating climate change impacts and developing adaptation strategies. *Marine and Freshwater Research 62*, 223-231.

Alexandra, J., & Finlayson, C.M. (2020). Floods after bushfires: rapid responses for reducing impacts of sediment, ash, and nutrient slugs. *Australasian Journal of Water Resources 19*, 1-3.

Allen, G.R., Midgley, S.H., & Allen, M. (2002). *Field Guide to the Freshwater Fishes of Australia*. Western Australian Museum, Perth.

Arthington, A., & McKenzie, F. (1997). *Review of impacts of displaced/introduced fauna associated with inland waters.* Australia: State of the Environment Technical Paper Series (Inland Waters), Department of the Environment, Canberra.

Atlas of Living Australia (ALA) (2020). *Records provided for* Nannoperca australis*, accessed through the Atlas of Living Australia website.*
Viewed: 30 April 2020.
Available on the Internet at:
https://www.ala.org.au

Attard, C.R.M., Brauer, C.J., Van Zoelen, J., Sasaki, M., Hammer, M.P., Morrison, L., Harris, J.O., Möller, L.M., & Beheregaray, L.B. (2016a). Multi-generational evaluation of genetic diversity and parentage in captive southern pygmy perch (*Nannoperca australis*). *Conservation Genetics 17*, 1469-1473.

Attard, C.R.M., Möller, L.M., Sasaki, M., Hammer, M.P., Bice, C.M, Brauer, C.J, Carvalho, D.C, Harris, J.O, & ,Beheregaray, L.B. (2016b). A novel holistic framework for genetic-based captive breeding and reintroduction programs. *Conservation Biology 30*, 1060-1069.

Balcombe, S.R., Sheldon, F., Capon, S.J., Bond, N.R., Hadwen, W.L., Marsh, N., & Bernays, S.J. (2011). Climate-change threats to native fish in degraded rivers and floodplains of the Murray-Darling Basin, Australia. *Marine and Freshwater Research 62*, 1099-1114.

Belsky, A.J., Matzke, A., & Uselman, S. (1999). Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation 54*, 419-431.

Blandowski, W. (1857). Recent discoveries in natural history on the lower Murray. *Transactions of the Philosophical Institute of Victoria 2*, 124-137.

Bond, N.R., & Lake, P.S. (2005). Ecological restoration and large-scale ecological disturbance: the effects of drought on the response by fish to a habitat restoration experiment. *Restoration Ecology 13*, 39-48.

Brauer, C.J., Hammer, M.P., & Beheregaray, L.B. (2016). Riverscape genomics of a threatened fish across a hydroclimatically heterogeneous river basin. *Molecular Ecology 25*, 5093-5113.

Brauer, C.J., Unmack, P.J., & Beheregaray, L.B. (2017). Comparative ecological transcriptomics and the contribution of gene expression to the evolutionary potential of a threatened fish. *Molecular Ecology 26*, 6841-6856.

Buckley, S.J., Domingos, F.M.C.B., Attard, C.R.M., Brauer, C., Sandoval-Castillo, J., Lodge, R., Unmack, P.J., & Beheregaray, L.B. (2018). Phylogenomic history of enigmatic pygmy perches: Implications for biogeography, taxonomy and conservation. *Royal Society Open Science 5*, 172125.

Bureau of Meteorology (BOM) (2020). *2019 annual climate facts and events*. Australian Government Bureau of Meteorology, Viewed: 26 June 2020 Available on the Internet at: http://www.bom.gov.au/climate/current/annual/aus/

Bylemans, J., Furlan, E.M., Pearce, L., Daly, T., & Gleeson, D.M. (2016). Improving the containment of a freshwater invader using environmental DNA (eDNA) based monitoring. *Biological Invasions 18*, 3081-3089.

Cadwallader, P.L. (1977). *J.O. Langtry's 1949–50 Murray River Investigations*. Fisheries and Wildlife Paper No. 13. Fisheries and Wildlife Division, Victoria.

Cadwallader, P.L. (1979). Distribution of native and introduced fish in Seven Creeks river system. *Australian Journal of Ecology 4*, 361-385.

Cadwallader, P.L. (1996). *Overview of the Impacts of Introduced Salmonids on Australian Native Fauna*. Report prepared for the Australian Nature Conservation Agency.

Cadwallader, P.L., & Backhouse, G.N. (1983). *A Guide to the Freshwater Fish of Victoria*. Victorian Government Printing Office, Melbourne.

Cadwallader, P.L., & Eden, A.K. (1982). Observations on the food of rainbow trout, *Salmo gairdneri* Richardson, in Lake Purrumbete, Victoria. *Australian Society of Limnology Bulletin 8*, 17-21.

Carpenter, S.R., Fisher, S.G., Grimm, N.B., & Kitchel, J.F. (1992). Global change and freshwater ecosystems. *Annual Review of Ecology and Systematics 23*, 119-139.

Chessman, B.C., & Williams, W.D. (1974). Distribution of fish in inland saline waters in Victoria, Australia. *Australian Journal of Marine and Freshwater Research 25*, 167-172.

Cole, T.L., Hammer, M.P., Unmack, P.J., Teske, P.R., Brauer, C.J., Adams, M., & Beheregaray, L.B. (2016). Range-wide fragmentation in a threatened fish associated with post-European settlement modification in the Murray-Darling Basin, Australia. *Conservation Genetics 17*, 1377-1391.

Cook, B.D., Bunn, S.E., Hughes, J.E. (2007). Molecular genetic and stable isotope signatures reveal complementary patterns of population connectivity in the regionally vulnerable southern pygmy perch (*Nannoperca australis*). *Biological Conservation 138*, 60-72.

CSIRO (2008). *Water Availability in the Murray-Darling Basin*. A report from CSIRO to the Australian Government. CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. 67pp.

CSIRO (2020). *The 2019-20 bushfires: a CSIRO explainer*. February 2020.
Viewed: 26 June 2020
Available on the Internet at:
https://www.csiro.au/en/Research/Environment/Extreme-Events/Bushfire/preparing-for-climate-change/2019-20-bushfires-explainer

Davies, P.E., Harris, J.H., Hillman, T.J., & Walker, K.F. (2008). *SRA Report 1: A Report on the Ecological Health of Rivers in the Murray–Darling Basin, 2004–2007*. Prepared by the Independent Sustainable Rivers Audit Group for the Murray– Darling Basin Ministerial Council.

Davies, P.E., Stewardson, M.J., Hillman, T.J., Roberts, J.R., & Thoms, M.C. (2012). *Sustainable Rivers Audit 2: The ecological health of rivers in the Murray–Darling Basin at the end of the Millennium Drought (2008–2010).* Prepared by the Independent Sustainable Rivers Audit Group for the Murray-Darling Basin, Murray-Darling Basin Authority, Canberra.

Department of Agriculture, Water and the Environment (DAWE) (2020a). *Revised provisional list of animals requiring urgent management intervention*. Australian Government Department of Agriculture, Water and the Environment, Canberra.
Viewed: 29 June 2020
Available on the Internet at:
https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-animals

Department of Agriculture, Water and the Environment (DAWE) (2020b). *Area of Occupancy and Extent of Occurrence for* Nannoperca australis Murray-Darling Basin lineage *(Southern Pygmy Perch-MDB) 1999 – 2019*. Unpublished report, Australian Government Department of the Environment and Energy, Canberra.

Dunlop, M., & Brown, P.R. (2008). *Implications of climate change for Australia's National Reserve System: A preliminary assessment*. Report to the Department of Climate Change, February 2008. Department of Climate Change, Canberra, Australia.

Gilligan, D. (2005a). *Fish Communities of the Murrumbidgee catchment: Status and trends*. Fisheries Final Report Series No.75. New South Wales Department of Primary Industries.

Gilligan, D. (2005b). *Fish Communities of the Lower Murray-Darling catchment: Status and trends*. Fisheries Final Report Series No. 83. New South Wales Department of Primary Industries.

Gilligan, D., Rodgers, M., McGarry, T., Asmus, M., & Pearce, L. (2010). The distribution and abundance of two endangered fish species in the NSW Upper Murray Catchment. A report to the Murray Catchment Management Authority and Murray-Darling Basin Authority, September 2010. Industry & Investment NSW – Fisheries Final Report Series No. 127.

Gould, L., & Pearce, L. (2012). Community efforts to save a small native fish. *RipRap 34*, 58-59.

Günther, A. (1861). On a new genus of Australian freshwater fishes. *Proceedings of the Zoological Society of London 1861*, 116-117.

Hammer, M.P., Bice, C.M., Hall, A., Frears, A., Watt, A., Whiterod, N.S., Beheregaray, L.B., Harris, J.O., & Zampatti, B.P. (2013). Freshwater fish conservation in the face of critical water shortages in the southern Murray–Darling Basin, Australia. *Marine and Freshwater Research 64*, 807-821.

Hobday, A.J., & Lough, J.M. (2011). Projected climate change in Australian marine and freshwater environments. *Marine and Freshwater Research 62*, 1000-1014.

Humphries, P. (1995). Life history, food and habitat of southern pygmy perch, *Nannoperca australis*, in the Macquarie River, Tasmania. *Marine and Freshwater Research 46*, 1159-1169.

Jones, M.J., & Stuart, I.G. (2008). Regulated floodplains – a trap for unwary fish. *Fisheries Management and Ecology 15*, 71-79.

Johnston, R.M. (1883). General and critical observations on the fishes of Tasmania. *Papers and Proceedings of the Royal Society of Tasmania 1882*, 53-144.

Kingsford, R.T., Mac Nally, R., King, A., Walker, K.F., Bino, G., Thompson, R., Wassens, S., & Humphries, P. (2015). A commentary on 'Long-term ecological trends of flow-dependent ecosystems in a major regulated river basin' by Matthew J. Colloff, Peter Caley, Neil Saintilan, Carmel A. Pollino and Neville D. Crossman. *Marine and Freshwater Research 66*, 970-980.

Koehn, J.D. (2005). Threats to Murray cod. In: Lintermans, M. & Phillips, B. (eds.) (2005). *Management of Murray cod in the Murray-Darling Basin – Canberra Workshop, June 2004*. Murray-Darling Basin Commission, Canberra, pp. 30-37.

Koehn, J.D., & O'Connor, W.G. (1990a). *Biological Information for Management of Native Freshwater Fish in Victoria*. Department of Conservation and Environment, Freshwater Fish Management Branch, Arthur Rylah Institute for Environmental Research, Victoria.

Koehn, J.D., & O'Connor, W.G. (1990b). Threats to Victorian native freshwater fish. *Victorian Naturalist 107*, 5 – 12.

Kuiter, R.H., Humphries, P.A., & Arthington, A.H. (1996). Family Nannopercidae: Pygmy perches. In: McDowall, R.M. (1996). *Freshwater Fishes of South-Eastern Australia*. Reed Books, Chatswood, New South Wales.

Lieschke, J, & Ayres, R. (2016). *Merton and Brankeet Creek Fish Surveys 2016*. Arthur Rylah Institute for Environmental Research, Victoria.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*. Murray-Darling Basin Commission Publication No. 10/07.

Lintermans, M. (2018). *Monitoring for Southern Pygmy Perch in the Gunning district 2018*. Consultancy report to Gunning District Landcare.

Llewellyn, L.C. (1974). Spawning, development and distribution of the southern pygmy perch *Nannoperca australis australis* Günther from inland waters in eastern Australia. *Australian Journal of Marine and Freshwater Research 25*, 121-149.

Lloyd, L.N., & Walker, K.F. (1986). Distribution and conservation status of small freshwater fish in the River Murray, South Australia. *Transactions of the Royal Society of South Australia 110*, 49-57.

Lyon, J.P., & O'Connor, J.P. (2008). Smoke on the water: Can riverine fish populations recover following a catastrophic fire-related sediment slug? *Austral Ecology 33,* 794-806.

Lyon, J., Stuart, I., Ramsey, D. & O'Mahony, J. (2010). The effect of water level on lateral movements of fish between river and off-channel habitats and implications for management. *Marine and Freshwater Research 61*, 271-278.

Macdonald, J.I., Tonkin, Z.D., Ramsey, D.S.L., Kaus, A.K., King, A.K., & Crook, D.A. (2012). Do invasive eastern gambusia (*Gambusia holbrooki*) shape wetland fish assemblage structure in south-eastern Australia? *Marine and Freshwater Research 63*, 659-671.

McNeil, D.C., & Closs, G.P. (2007). Behavioural responses of a south-east Australian floodplain fish community to gradual hypoxia. *Freshwater Biology 52*, 412-420.

Morrongiello, J.R., Beatty, S.J., Bennett, J.C., Crook, D.A., Ikedife, D.N.E.N., Kennard, M.J., Kerezsy, A., Lintermans, M., McNeil, D.G., Pusey, B.J., & Rayner, T. (2011). Climate change and its implications for Australia's freshwater fish. *Marine and Freshwater Research 62*, 1082-1098.

Morrongiello, J.R., Bond, N.R., Crook, D.A., & Wong, B.B.M. (2012). Spatial variation in egg size and egg number reflects trade-offs and bet-hedging in a freshwater fish. *Journal of Animal Ecology 81*, 806-817.

Murray–Darling Basin Authority (MDBA) (2019). *Basin environmental watering priorities 2019–20: Overview and technical summaries*. Murray–Darling Basin Authority, June 2019, Canberra. CC BY 4.0.

New South Wales Department of Primary Industries (NSW DPI) (2019). *Fish stocking*. Viewed: 7 May 2019
Available on the Internet at:
https://www.dpi.nsw.gov.au/fishing/recreational/resources/stocking

New South Wales Department of Primary Industries (NSW DPI) (2019). *Personal communication by email, 28 February 2019*. New South Wales Government Department of Primary Industries.

New South Wales Department of Primary Industries (NSW DPI) (2019). *Personal communication by email, 6 August 2020*. New South Wales Government Department of Primary Industries.

Pearce, L. (2014). *Conservation management of southern pygmy perch (*Nannoperca australis*) in NSW, in the context of climactic extremes and alien species*. MSc Thesis, Charles Sturt University.

Pearce, L. (2015a). *Surveys, monitoring and conservation status of Southern Pygmy Perch (*Nannoperca australis*) within Blakney and Pudman Creeks*. Published by NSW Department of Primary Industries. January 2015
Viewed 8 February 2018
Available on the Internet at:
https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/551927/southern_pygmy_perch_web_version.pdf

Pearce, L. (2015b). *Conservation management of Southern Pygmy Perch (*Nannoperca australis*) in NSW, in the context of climatic extremes and alien species*. (MSc thesis). A0ustralia: Charles Sturt University.

Pearce, L., Silva, L.G.M., Mabon, S., Horta, A., Duffy, D., Ning, N., & Baumgartner, L.J. (2018). *Finding forgotten fishes, the search for two endangered species in the NSW Murray Catchment*. Institute for Land, Water and Society, Charles Sturt University. 81 pp.

Price, A.E., Stoffels, R.J., Weatherman, K.A., O'Keefe, R., & Müller, W. (2016). *Structural habitat selection by southern pygmy perch (*Nannoperca australis*)*. Final report prepared for Murray Local Land Services by the Murray-Darling Freshwater Research Centre, MDFRC Publication 102/2016 May, pp. 26.

Primary Industries and Regions South Australia (PIRSA) (2019). *Personal communication by email, 22 February 2019.* South Australian Government.

Rose, P. (2018). *Prediction of Fish Assemblages in Eastern Australian Streams Using Species Distribution Models: Linking Ecological Theory, Statistical Advances and Management Applications*. PhD Thesis, Griffith University.

Roberts, J., Chick, A., Oswald, L., & Thompson, P. (1995). Effects of carp, *Cyprinus carpio*, an exotic benthivorous fish, on aquatic plants and water quality in experimental ponds. *Marine and Freshwater Research 46,* 1171-1180.

Roberts, J., & Sainty, G. (1996). *Listening to the Lachlan*. Geoff Sainty and Associates, Potts Point, NSW.

Saddlier, S., Koehn, J.D., & Hammer, M.P. (2013). Let's not forget the small fishes – conservation of two threatened species of pygmy perch in south-eastern Australia. *Marine and Freshwater Research 64*, 874-886.

Scott, E.O.G. (1971). Observations on some Tasmanian fishes – Part XVIII. *Papers and Proceedings of the Royal Society of Tasmania 105*, 119-143.

Sharpe, C., & Wilson, E. (2012). *Fish surveys at 39 sites throughout Millewa Forest, NSW, with focus on the distribution of Southern pygmy perch (*Nannoperca australis*)*. May/June 2012. Summary of Findings Report for the NSW Office of Environment and Heritage.

Sharpe, C., Wilson, E., & Healy, S. (2012). *Summary of fish surveys at Normans Lagoon NSW, with focus on the occurrence of Southern pygmy perch (*Nannoperca australis*)*. June 2012. Summary of Findings Report for the NSW Office of Environment and Heritage.

Todd, C.R., Koehn, J.D., Pearce, L., Dodd, L., Humphries, P., & Morrongiello, J.R. (2017). Forgotten fishes: What is the future for small threatened freshwater fish? Population risk assessment for southern pygmy perch, *Nannoperca australis*. *Aquatic Conservation: Marine and Freshwater Ecosystems 27*, 1290-1300.

Tonkin, Z., King, A.J., & Mahoney, J. (2008). Effects of flooding on recruitment and dispersal of the southern pygmy perch (*Nannoperca australis*) at a Murray River floodplain wetland. *Ecological Management & Restoration 9*, 196-201.

Tonkin, Z., Macdonald, J., Kaus, A., Ramsey, D., Hames, F., Crook, D., & King, A. (2011). A field based assessment of native fish responses following eastern gambusia removal: putting theory into practice. In: Jackson, P. & Bamford, H. (eds) (2011). *Gambusia Forum 2011: Small fish…big problem*, 1–2 June 2011, Crown Plaza Hotel, Melbourne, Victoria, Australia.

Trueman, W.T. (2011). *True Tales of the Trout Cod: River Histories of the Murray-Darling Basin*. MDBA Publication No. 215/11. Murray-Darling Basin Authority, Canberra.

Unmack, P. (1992). Victorian pygmy perches. *Fishes of Sahul 7*, 321-323.

Unmack, P.J., Hammer, M.P., Adams, M., & Dowling, T.E. (2011). A phylogenetic analysis of pygmy perches (Teleostei: Percichthyidae) with an assessment of the major historical influences on aquatic biogeography in southern Australia. *Systematic Biology 60*, 797-812.

Unmack, P.J., Hammer, M.P., Adams, M., Johnson, J.B., & Dowling, T.E. (2013). The role of continental shelf width in determining freshwater phylogeographic patterns in south-eastern Australian pygmy perches (Teleostei: Percichthyidae). *Molecular Ecology 22*, 1683-1699.

Vilizzi, L., Thwaites, L.A., Smith, B.B., Nicol, J.M., & Madden, C.P. (2014). Ecological effects of common carp (*Cyprinus carpio*) in a semi-arid floodplain wetland. *Marine and Freshwater Research 65*, 802 – 817.

Wassens, S., Spencer, J., Thiem, J., Wolfenden, B., Thomas, R., Jenkins, K., Brandis, K., Lenon, E., Hall, A., Ocock, J., Kobayashi, T, Bino, G., Heath, J., & Callaghan, D. (2017). *Draft Commonwealth Environmental Water Office Long-Term Intervention Monitoring project Murrumbidgee River System Selected Area evaluation report, 2014-17*. Draft report prepared for the Commonwealth Environmental Water Office. Commonwealth of Australia.

Watts, R.J., McCasker, N., Howitt, J.A., Thiem, J., Grace, M., Kopf, R.K., Healy, S., Bond, N. (2017). *Draft Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Edward-Wakool River System Selected Area Evaluation Report, 2016-17*. Draft report prepared for Commonwealth Environmental Water Office. Commonwealth of Australia.

Weatherley, A.H. (1963a). Thermal stress and interrenal tissue in the perch *Perca fluviatilis* (Linnaeus). *Proceedings of the Zoological Society of London 141*, 527-555.

Weatherley, A.H. (1963b). Zoogeography of *Perca fluviatilis* (Linnaeus) and *Perca flavescens* (Mitchill) with special reference to the effects of high temperature. *Proceedings of the Zoological Society of London 141*, 557-576.

Weatherley, A.H. (1977). *Perca fluviatilis* in Australia: zoogeographical expression of a life cycle in relation to environment. *Journal of the Fisheries Research Board of Canada 34*, 1464-1466.

Wedderburn, S.D., & Barnes, T.C. (2016). Piscivory by alien redfin perch (*Perca fluviatilis*) begins earlier than anticipated in two contrasting habitats of Lake Alexandrina, South Australia. *Australian Journal of Zoology 64*, 1-7.

Wedderburn, S.D., Hammer, M.P., Bice, C.M., Lloyd, L.N., Whiterod, N.S., & Zampatti, B.P. (2017). Flow regulation simplifies a lowland fish assemblage in the Lower River Murray, South Australia. *Transactions of the Royal Society of South Australia 141*, 169-192.

Wedlick, L. (1981). *60 Ways to Fool a Trout*. Wedneil Publications, Newport, Victoria.

Woodward, G.M.A., & Malone, B.S. (2002). Patterns of abundance and habitat use by *Nannoperca obscura* (Yarra pygmy perch) and *Nannoperca australis* (southern pygmy perch). *Proceedings of the Royal Society of Victoria 114*, 61-72.

Whiterod, N., Zukowski, S., Ellis, I., Pearce, L., Raadik, T., Rose, P., Stoessel, D., & Wedderburn, S. (2019). *The present status of key small-bodied threatened freshwater fishes in the southern Murray-Darling Basin, 2019*. A report to the Tri-State Murray NRM Regional Alliance. Aquasave–Nature Glenelg Trust, Goolwa Beach.