Assessing the vulnerability of native vertebrate fauna under climate change, to inform wetland and floodplain management of the River Murray in South Australia:

Fish Vulnerability Assessments

Attachment (1) to the Final Report
June 2011

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Scientific Name:	*Anguilla australis*	Common Name:	Short-finned Eel

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change.	Occupy a variety of habitats including rivers, lakes and swamps, generally with low or no flow (Lintermans 2007). Wide tolerance to environmental conditions (Bice 2010). High salinity tolerance, a period of time may be spent in brackish waters to allow acclimatisation and make the necessary physiological changes required to move from marine to freshwater. Mature adults and larval eels are found in marine environments and are therefore tolerant of marine salinities. Also tolerant of low dissolved oxygen concentrations due to their high blood affinity for oxygen (various studies cited in SAAB 2001). *Species not specifically associated with aquatic vegetation or particular bottom types. Wide salinity tolerance but need to acclimatise in brackish water before moving either to fresh or marine conditions. No major threat to species through habitat loss identified in the literature. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Can potentially disperse great distances due to a marine life phase; upstream migrants known to travel hundreds of kilometers; adults are able to move over land in damp conditions (Beumer 1996 a cited in SAAB 2001). Migrates to sea to spawn to locations in Coral Sea near New Caledonia. Larval eels are washed down the east Australian coast, metamorphose and attain the typical eel shape before entering fresh water in spring–summer and migrating upstream to the upper reaches of rivers. Adults occupy a well-defined home range of about 400m (Lintermans 2007). Migration downstream by adults triggered by high water temperature and arrested by temperatures below 12C (Sloane 1984). Downstream migration is also thought to be facilitated by flooding and occurs in response to specific temperature, pressure and salinity gradients (Beumer 1983 as cited in SAAB 2001). No specific flow requirements have been identified for upstream migrations. Upstream migration of brown or yellow elvers (juveniles) into freshwater triggered by characteristics associated with summer flows, such as reduced water flows (and increased water temperatures) (Sloane 1984), predominantly during spring and summer (Beumer 1996 as cited in SAAB 2001). Large barriers which block their passage such as weirs, dams and waterfalls are particularly problematic if water is not on the spillway. They can not negotiate "V notch type" gauging weirs under dry conditions due to the presence of the steel lip (Sloane 1984). *Strong evidence of critical migrations to and from freshwater, brackish and saline environments reliant on good connectivity of the system. Climate change is likely to increase disconnection through reduced/managed flow and lowered water levels thus exposing more fish barriers. Migrations triggered by water temperature and flow rate may also be affected by river regulation and cold water pollution. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Voracious nocturnal predator, eats a variety of fish, crustaceans, molluscs and insects (Lintermans 2007). Intra and interpsecific competition is a likely limiting factor through predation (e.g. by long-finned eels in NZ) and habitat displacement (Jellyman 1997). Potentially compete with long-finned eels in some areas, but effects unknown (SAAB 2001). Predated upon by birds, with the risk enhanced by congregation at stream barriers (Beumer	**M**	**M**

		et al 1982 as cited in SAAB 2001). Several species of protozoans are reported to infect the gills, gill arch, skin, swim and urinary bladders and stomach walls of animals in some populations. Trematodes, a cestode (tapeworm), nematode, a copepod and mussel have also been reported to infect some individuals (Beumer et al 1982 as cited in SAAB 2001). *Evidence of a degree of competition but not identified in the literature as a major threat. Long-finned eels are thought the main competitor but do not occur in study area. Nocturnal feeding may reduce potential competition. Disease is identified as a threat to species. Species should be conservatively considered at moderate risk but with medium confidence due to lack of specific studies into competition with introduced species in the study area.*		
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Tolerates salinity < 13.4ppt, low oxygen and large temperature variations (Bice 2010). High salinity tolerance, a period of time may be spent in brackish waters to allow acclimatisation and make the necessary physiological changes required to move from marine to freshwater. Mature adults and larval eels are found in marine environments and are therefore tolerant of marine salinities. Also tolerant of low dissolved oxygen concentrations due to their high blood affinity for oxygen (studies cited in SAAB 2001). Broad and flexible diet so density related food availability constraints unlikely to be a primary limiting factor (Jellyman 1997). *Species generally has wide environmental tolerances associated with survival. Most vulnerable stage may be when acclimatizing to either fresh or marine environments when species requires estuarine conditions. These areas (Lower Lakes and tributaries) are outside the study area and therefore cannot be considered but flow management at Barrages may affect species ability to acclimatize to freshwater upstream if estuarine conditions are non-existent. Due to knowledge gaps, species should be conservatively considered at moderate risk with only medium confidence*	**M**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Adults prefer low-flow or still environments, likely highly salt tolerant, wide temperature range, likely tolerates low oxygen (Bice 2010). NZ studies on *A. anguilla* reveal slower growth rates compared to other temperate eel species (Jellyman 1997). Larvae are oceanic, juveniles are estuarine and into lower reaches (Bice 2010). NZ studies have shown Water temperature to affect the length of the growing season. Other factors suggested as affecting growth rates are eel density, quantity and quality of food, and interactions between eel species (short and long finned) (Jellyman 1997). *Species generally has wide environmental tolerances associated with growth and survival. No species specific growth studies found but similar species in NZ have slow growth rate compared to other temperate eel species, this increases risk but confidence in interpretation is limited. Most vulnerable stage may be juveniles requiring estuarine conditions. These areas (Lower Lakes and tributaries) are outside the study area and therefore cannot be considered but flow management at Barrages may affect species ability to acclimatize to freshwater upstream if estuarine conditions are non-existent. NZ studies suggest species growth may be affected by changes in water temperature regimes, this is likely to occur more frequently in the study area under climate change placing the species at further risk of growth limitation. Interpretation is limited however as observations are not verified in the study region. Due to knowledge gaps, species should be conservatively considered at moderate risk with only low confidence*	**M**	**M**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Short-finned Eels move from fresh water into river estuaries from Oct - Nov. They then move out to sea from Jan-May. They spawn somewhere in the Coral Sea at depths of more than 300m, probably in groups (SAAB 2001; Lintermans 2007). Larvae are oceanic, juveniles are estuarine and into lower reaches, adults must reach sea to spawn (Bice 2010). Tropical species of *Anguilla* with shorter larval migrations have faster growth rates than temperate *A. australis* with longer migrations to higher latitudes (Kuroki et al 2008). Migration downstream by adults triggered by high water temperature and arrested by temperatures below 12C (Sloane 1984). Downstream migration is also thought to be facilitated by flooding and occurs in response to specific temperature, pressure and salinity gradients (Beumer 1983 as cited in SAAB 2001). No specific flow requirements have been identified upstream migrations in species. Upstream migration of brown or yellow elvers into freshwater triggered by characteristics associated with summer flows, such as reduced water flows (and increased water temperatures) (Sloane 1984), predominantly during spring and summer (Beumer 1996 as cited in SAAB 2001). *Barriers to connectivity are the main potential threats to the reproductive cycle of the species. Critical breeding migrations are known to be triggered by seasonal flow and temperature cycles and climate change may threaten these processes through increased river management, reduced flows and water levels. This may also lead to more fish barriers along the system affecting the species capacity to move downstream to breed. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change? <u>Species is distributed across the eastern seaboard of Aust. so effective population is probably shared with eastern states as well (D. McNeil pers. comm. 2010).</u>	No molecular evidence to support present NZ subspecies designation. It would be more appropriately merged into single classification of *A. australis.* As Australian and New Zealand populations of this species share a common gene pool, fisheries management needs to be carried out cooperatively between the two countries (Dijkstra and Jellyman 1999). *Given the small and very fragmented Australian populations, gene pool may be restricted although migration to sea to spawn and high larval dispersal at sea significantly reduces threat as effective population is shared among different regions e.g. NZ, this is verified in genetic studies. While Australian populations appear patchy and sparse, it is likely offset through sharing of genetic information with distant populations. Species should be considered at low risk but with medium confidence as is unknown exactly how much other populations contribute to gene pool or relative diversity of gene pool compared to similar species.*	**M**	**L**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change? <u>Species is distributed across the eastern seaboard of Aust. so effective population is probably shared with eastern states as well (D. McNeil pers. comm. 2010).</u>	Given the sharing of gene pool with NZ populations, gene flow is likely to be frequent. Eels from both countries must either share a common spawning ground or else, if there is partial spatial or temporal segregation during spawning there must be widespread mixing of adults originating from both countries (Dijkstra and Jellyman 1999). *Spawning and larval dispersal at sea increases chances of gene flow between regional populations. Genetic evidence from studies of Australian and NZ populations verifies this. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of	Phenotypic plasticity is a feature of many freshwater eels, *A. australis* displays size-maturity relationships associated with habitat and environmental conditions. Trade-off between small	**H**	**L**

	the species to tolerate climate change?	size and low fecundity or large size with high fecundity with the position determined by growth rate and hence subject to change (Jellyman 2001). *Compelling evidence to indicate species has a high capacity for phenotypic plasticity particularly in response to habitat and environmental conditions. This is a major asset to the species ability to cope with the increasingly variable conditions expected under climate change. Species should be considered at low risk.*		
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change? <u>Species is distributed across the eastern seaboard of Aust. so effective population is probably shared and has a reasonable population size from which to recruit from (D. McNeil pers. comm. 2010).</u>	Studies in Western South Pacific Ocean indicate *A. australis* is among most abundant eel larval species in region (Kuroki et al 2008). Females dominate the catch in freshwater environments and males are more abundant in downstream, estuarine areas (Lintermans 2007). Rare in MDB, few records scattered in Lower Murray and Lower Lakes and fringes (Bice 2010). While MDB population is low, abundance in other populations e.g. NZ, provide a potential source. As populations share a common gene pool, fisheries management needs to be carried out cooperatively between the two countries (Dijkstra and Jellyman 1999). Very few records within study area (2 since 1990 in BDBSA 2010) and no records in RMWBS 2004/7 (Smith et al 2009). *Given the small and very fragmented SA MDB populations, population size is likely to be a limiting factor to some extent. Marine larval phase reduces threat as effective population may be shared among different regions e.g. NZ, and this is verified through genetic studies. While SA MDB populations appear patchy and sparse, they may be offset through sharing individuals with distant populations e.g. NZ and eastern seaboard of Aust. Species should be considered at moderate risk but with low confidence as unknown how much other populations contribute to regional populations within the study.*	**L**	**M**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity likely to be variable between populations. Jellyman (2001) concurred with other studies finding that females adopt size-maturity strategies (small size and low fecundity or large size with high fecundity) in reaction to environmental and habitat conditions. Other studies suggest fecundity is potentially high, females between 516-933 mm total lengths have been found to carry 0.46-3.06 million eggs (Cadwallader and Backhouse 1983 as cited in SAAB 2001) and other studies quote females containing 5-10 million eggs (Beumer 1987 as cited in SAAB 2001). *While apparently highly female size dependent, fecundity in the species seems to be in the high range for fish species. Reproductive capacity is therefore high and unlikely to be exclusively limiting. Species should be considered at low risk*	**H**	**L**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change? <u>Species is distributed across the eastern seaboard of Aust. so effective population is probably shared and has a reasonable population size from which to recruit from (D. McNeil pers. comm. 2010).</u>	Long lived species whose maximum age recorded is 30 years (Sloane 1984). Sexual maturity is reached between 10-20 years (Beumer 1996 as cited in SAAB 2001). Age of mature (silver) eels during downstream migration was found in one study to be between 18-30 years, with an average age of 22.1 years (Sloane 1984). In Queensland mature males participating in the downstream spawning migration were 8-12 years old, and mature females were 10-20 years old (Beumer 1987 as cited in SAAB 2001). Other authors describe male sexual maturity at 14 years and females at 18–24 years. Adults may remain in fresh waters for 20 years or more before migrating to the sea to breed and then die (Lintermans 2007). Rare in MDB, few records scattered in Lower Murray and Lower Lakes and fringes (Bice 2010). While MDB population is low, abundance in other populations e.g. NZ, provide a potential source (Dijkstra and Jellyman 1999).	**M**	**H**

		A long lived species that has a very long time to maturity so recruitment is likely to be a major limiting factor due to a long generation time. It is also likely that high egg and larval mortality rates exist for the species given its high egg production, as a strategy to cope with high mortality. Actual fecundity is quoted in the literature as being variable to high dependent mainly on size. Further research into population age/size structures in the study area is required to make a confident assessment of species recruitment capacity. The extent to which distant population may contribute to recruitment in regional SA MDB populations is also unknown but presumed to exist to some degree given genetic evidence. Due to knowledge gaps, species should be conservatively considered at high risk but with medium confidence.		

Scientific Name:	*Bidyanus bidyanus*	**Common Name:**	Silver Perch

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Schooling fish occurs across variety of climatic types and environmental conditions, generally in flowing river habitat (Hammer et al 2007). Lowland, turbid and slow flowing reaches, main channel in Lower Murray (Bice 2010). Silver perch are found in similar habitats to Murray cod and Golden perch, i.e. lowland, turbid and slow-flowing rivers (Lintermans 2007). Juveniles and adults inhabit rivers and large tributaries as well as lakes and reservoirs, occurring predominantly in open, fast-flowing, freshwaters, especially in conjunction with rapids and races (studies cited in SAAB 2001). Can be found in warmer, sluggish waters and is also common in turbid, standing and slow flowing waters. Appears to favour areas where cover is provided by debris and aquatic plants (Cadwallader 1979) and also associated with flowing waters upriver and channel edge habitat in South Australia (Pierce 1997 as cited in SAAB 2001). Juveniles and adults will tolerate brackish salinity to 21ppt and 16ppt respectively (Bice 2010). *Species occupies fresh to brackish conditions and is associated with aquatic vegetation, debris, cover and edge habitat. Most literature refers to a preference for slow to rapid flowing systems but also found in standing, warm sluggish water. High levels of salinity and reduction in flow volumes/velocities likely to affect distribution of species within study area under climate change. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Upstream spawning migrations historically documented, adults and juveniles display active movement outside spawning period possibly stimulated by river flows, appear to be particularly sensitive to flow regulation as biological requirements rely on flows and flooding (Hammer et al 2007). Adults can move a considerable distance upstream for spawning (up to 600 km) (Merrick 1996 as cited in SAAB 2001) to areas behind the peaks of floods to spawn in inundated backwaters. Immature fish are known to move upstream during the day after small rises in water level (Merrick 1996 as cited in SAAB 2001). Migration patterns are similar to those of golden perch (Reynolds 1983). Small changes in water level trigger upstream movement of immature fish. It is likely that upstream migration of mature fish is linked to spring or summer flooding (Merrick 1996 as cited in SAAB 2001). The main threat to species is loss of access to upstream spawning areas by	**H**	**H**

		high level dams, coupled with altered thermal and flow regimes as a consequence of river regulation (Merrick and Schmida 1984 as cited in SAAB 2001). *Species clearly relies on connectivity and natural flow regimes in order to complete critical breeding migrations. Climate change is expected to lead to increased flow regulation and a general reduction in flow volumes and frequencies. This may expose further fish barriers and may affect recruitment. Species should be considered at high risk.*		
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Omnivorous, consuming aquatic plants, snails, shrimps and macroinvertebrates, competition with Carp for similar food resources (Hammer et al 2007). Interactions with alien species (Carp and Redfin perch) are suspected to be a threat (Lintermans 2007). Predation of fry by Redfin and very susceptible to foreign disease transmitted by exotic species e.g. parasitic copepods and tapeworms. The most serious threat from introduced fish species may lie in impacts of exotic disease Epizootic Haematopoietic Necrosis Virus (EHNV). Unique to Australia, ENVH is carried by Redfin perch. It is characterised by sudden high mortalities of fish displaying necrosis of the renal haematopoietic tissue, liver spleen and pancreas (ACT Government 2003). *Compelling evidence species is under significant competitive pressure for food and resources with introduced species e.g. Carp and Redfin and sufferes some predation. Most serious threat associated with increased disease risk of EHNV transmitted to species from Redfin. Climate change may increase competition with exotic species as introduced species possesses competitive advantages and may increase in abundance, also increasing disease risk to species. Species should be considered at high risk.*	**H**	**H**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Adults require salinity < 16ppt and pH > 5, provision of habitat also important factor for growth and survival of juveniles and adults. Moderate tolerance to low DO (>2mg/L) (Bice 2010). Silver perch are omnivorous. Diet contains aquatic plants, snails, shrimps and aquatic insect larvae (Lintermans 2007). Can live in very turbid conditions (Cadwallader 1979) and also occurs in slow flowing waters (Lake 1971 as cited in SAAB 2001) as well as rapidly flowing waters (Merrick 1996 as cited in SAAB 2001). Known to have a wide temperature tolerance occurring in waters between 2-38^0 C (Lake 1967 as cited in SAAB 2001). *Species has a broad diet and is unlikely to be limiting as presumably can switch when needed. Adults are moderately salt tolerant and have a wide temperature tolerance range. Apart from high levels of salinisation and stagnation and oxygen limitations, the species show little risk of being affected climate change is expected to increase the frequency of these events. Species should be considered at low risk.*	**H**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles require salinity < 21ppt (adults < 16ppt) and pH > 5 but eggs and larvae but be below 9ppt and will tolerate moderate DO levels . Provision of habitat also important factor for growth and survival of juveniles and adults. Juveniles also likely to have a narrower diet consisting mainly of zooplankton (Bice 2010). Juveniles suffered no mortality when transferred from freshwater to a salinity of 12ppt but 40% juvenile mortality experienced in salinities of 15ppt after 7 days (Guo et al 1995). Require spring (or summer) floods in order to spawn (because adults migrate up past flood peak and spawn in flooded backwaters) and to ensure the survival of newly hatched larvae. If these conditions are not met (e.g. drought conditions prevail) the animals do not spawn or	**H**	**M**

		have limited spawning success (Cadwallader 1977 as cited in SAAB 2001). *Eggs and larvae show little tolerance to salinity, likely to require moderate DO and fry require adequate habitat. Diet requirements and salinity tolerances are wider once grown to juvenile size. Species should be considered at moderate risk due to its wide temperature tolerance and ability to use brackish waters.*		
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawning requires a trigger of water level rise or flooding (Hammer et al 2009). Spawning triggered at water temperatures > 23^0 C and appear to increase during floods. Thermal pollution (cold water) is an identified threat to reproduction in the species (Lintermans 2007; Merrick and Schmida 1984 as cited in SAAB 2001). Eggs require low salinity < 9ppt and pH > 6.5 and hatching larvae have even lower tolerance to salinity (< 7.6ppt) (Bice 2010). Require spring (or summer) floods in order to spawn (because adults migrate up past flood peak and spawn in flooded backwaters) and to ensure the survival of newly hatched larvae. If these conditions are not met (e.g. drought conditions prevail) the animals do not spawn or have limited spawning success (Cadwallader 1977 as cited in SAAB 2001). However, they migrate and spawn on smaller flow rises than are needed to trigger these events in Callop and Murray cod (Pierce 1997 as cited in SAAB 2001). *The main threat to species reproduction is access to upstream spawning areas by high level dams, coupled with altered thermal and flow regimes as a consequence of river regulation. Cold water pollution is identified as a main threat in literature and system connectivity is also crucial for access to spawning areas and for breeding success. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Formerly widespread over much of the Murray-Darling Basin excluding the most upper reaches, Silver Perch has declined over most of its range. Numbers moving througha fishway at Euston Weir on the Murray River declined by 93% from 1940-1990. The species is still patchily abundant in the mid-Murray (Lintermans 2007). Only 12 records of species since 1990 within SA MDB floodplain widely distributed from Lower Lakes up to Paringa near Vic border (BDBSA 2010). Wild populations in MDB are patchy in distribution and abundance, stocking of hatchery reared Silver Perch is threat to local stocks (e.g. genetic pollution, reduced genetic diversity and disease (Hammer et al 2009). Despite some genetic studies being conducted, more information is required to properly assess the genetic structure of wild populations of Silver Perch and any potential impacts that have occurred as a result of stocking activities (Moore et al 2010). Moore et al (2010) in a comprehensive review of the genetic health of a number of key fish species in the MDB identified silver perch as requiring management units as sufficient genetic subdivision between populations was found. Adults can move a considerable distance upstream for spawning (up to 600 km) to areas behind the peaks of floods to spawn in inundated backwaters (Merrick 1996 as cited in SAAB 2001). *Strong evidence to suggest population numbers within the study area are very low with BDBSA records confirming estimated patterns in the literature. This raises risk that gene pool may be limiting. Fish stocking is also identified as a potential threat to genetic diversity and integrity although further studies are required. Management units identified in the literature did not cover the study area and appear to be at larger spatial scales than the SA MDB region and may mean that the populations in SA could be grouped into one strain. Mass spawning migrations increase potential for genetic diversity through mixing and the large spawning runs that were historically observed no longer occur. Species should be considered at high risk.*	**M**	**H**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Small fragmented wild populations (Hammer et al 2007). Many wild populations now mixed with hatchery-raised stock, may be threat to genetic variability and adaptive capacities (ACT 2003). Moore et al (2010) in a comprehensive review of the genetic health of a number of key fish species in the MDB identified silver perch as requiring management units as sufficient genetic subdivision between populations was found. Formerly widespread over much of the Murray-Darling Basin excluding the most upper reaches, Silver Perch has declined over most of its range. Numbers moving through a fishway at Euston Weir on the Murray River declined by 93% from 1940-1990. The species is still patchily abundant in the mid-Murray (Lintermans 2007). Only 12 records of species since 1990 within SA MDB floodplain widely distributed from Lower Lakes up to Paringa near Vic border (BDBSA 2010).Adults can move a considerable distance upstream for spawning (up to 600 km) to areas behind the peaks of floods to spawn in inundated backwaters (Merrick 1996 as cited in SAAB 2001). *Strong indication that gene flow is limited within the study area. Population numbers are reported to be very low and patchily distributed meaning small regional populations may be geographically or genetically isolated. Mass spawning migrations increase potential for mixing but the large spawning runs that were historically observed no longer occur. Fish stocking is also identified as a major potential threat to genetic diversity and integrity and may reduce the effectiveness of any gene flow that does occur. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Many wild populations now mixed with hatchery-raised stock, may be threat to genetic variability and adaptive capacities (ACT 2003). Moore et al (2010) in a comprehensive review of the genetic health of a number of key fish species in the MDB identified silver perch as requiring management units as sufficient genetic subdivision between populations was found. Moore et al (2010) identify at least one instance where this population subdivision manifested in heritable differences in digestive enzyme activities between different strains of Silver Perch. All studies mentioned in Moore et al (2010) suffered from the same limitation of small sample sizes of wild fish and a use of stocked populations to determine natural population subdivision so interpretations are limited as to gene flow but do provide information on stocking impacts. *Population sizes particularly of wild fish (as opposed to stocked) are extremely low and appear fragmented. A number of studies have identified distinct genetic subdivision among populations but typically at the basin scale or between wild and stocked populations. Limited sample sizes (arising from lack of wild numbers) have restricted interpretation of studies reducing confidence in assessment. All indications are that at the scale of the study area, population genetic subdivision including phenotypic differences, do not occur. Species should be considered at high risk but with low confidence due to lack of studies and limited interpretation offered by existing work.*	**L**	**H**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Was common throughout lowland river habitat in the SAMDB until 1960s, distribution is now patchy mainly of a few individuals from limited localities, some translocated populations (Hammer et al 2009). Wild populations are now small and fragmented (Hammer et al 2007). Formerly widespread over much of the Murray-Darling Basin excluding the most upper reaches, Silver Perch has declined over most of its range. Numbers moving througha fishway at Euston Weir on the Murray River declined by 93% between 1940-1990. The species is still patchily abundant in the mid-Murray (Lintermans 2007). RMWBS in 2004/7 found very few capture records patchily distributed across floodplain (Smith et al 2009). Only 11 records of species since 1990 within SA MDB floodplain (9 in study area) widely distributed from Lower Lakes up to Paringa near Vic border (BDBSA 2010). *Strong evidence to suggest population numbers within the study area are very low with BDBSA records confirming estimated patterns in the literature. Mass spawning migrations that were historically observed no longer occur. This means that effective population sizes may now be restricted (fragmented populations). Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity is potentially high (100,000's eggs) and spawn once appropriate conditions are reached in Spring-Summer (Bice 2010). Fecundity is high, varying from 300,000-500,000 eggs. More than 300,000 eggs are reported to be shed (Merrick 1996 as cited in SAAB 2001); and individuals between 1.5-2 kg have each shed 500,000 eggs (studies cited in SAAB 2001). *Reproductive capacity is in the high range for fish species assessed in this study despite single spawning. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Individuals mature at 3–5 years (males earlier than females). They spawn in spring and summer after an upstream migration (Lintermans 2007). Is a long-lived species and been recorded to 27 years of age (Merrick 1996 as cited in SAAB 2001). Spawning occurs in spring and early summer involving large numbers of small semi-buoyant eggs shed into the water column requiring a trigger of water level rise or flooding, little or no spawning occurs in drought years (Hammer et al 2007). Require spring (or summer) floods in order to spawn (because adults migrate up past flood peak and spawn in flooded backwaters) and to ensure the survival of newly hatched larvae. If these conditions are not met (e.g. drought conditions prevail) the animals do not spawn or have limited spawning success (Cadwallader 1977 as cited in SAAB 2001). However, they migrate and spawn on smaller flow rises than are needed to trigger these events in Callop and Murray cod (Pierce 1997 as cited in SAAB 2001). *Recruitment is likely to be highly limiting under climate change. Species takes a long time to reach breeding maturity and spawning is heavily influenced by hydrological regimes requiring flooding or water level rise to initiate. Drought can limit or completely stop spawning and water needs to inundate spawning areas behind flood peaks for some time to ensure larval survival. Species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Craterocephalus fluviatilis*	Common Name:	Murray Hardyhead

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Wetland and sheltered lake edge habitat, often in areas with high densities of submerged aquatic plants including Milfoil *(Myriophyllum* spp.*)*, Foxtail *(Ceratophyllum)* and Eel Grass *(Ruppia* spp.*)* (Hammer et al 2009). Found in shallow, vegetated areas in standing to slow-flowing, fresh waters in rivers, streams, creeks, backwaters, water-holes, billabongs, lagoons, swamps, and lakes (Ivantsoff and Crowley 1996 as cited in SAAB 2001). Prefers open water, shallow, slow flowing or still habitats, with sand or silt substrates (Lintermans 2007). Appears to thrive in ephemeral deflation basin lakes and can survive in highly saline environments (Hammer et al 2009), found in waters up to 62ppt (SAAB 2001). Dry conditions occurring throughout the Murray-Darling Basin, have dried up many sites. While some sites may still hold water, salinity, temperature, dissolved oxygen and pH may reach lethal levels with compounding effects (Backhouse et al 2008). In addition, littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and, although water conditions may continue to be suitable for the species, there is no breeding or feeding habitat, and lack of cover renders the fish more exposed to predatory fish and birds (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). *Shows ability to tolerate a variety of conditions including brackish and saline/hypersaline water and occupies silt/sand bottom types. However littoral aquatic vegetation habitats relied on for feeding and breeding may suffer under climate change. Compounded effects of degraded water quality (salinity, pH, DO, eutrophication etc.) is also identified as a major threat to habitat suitability. Species should be considered at moderate risk*	**H**	**M**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Data suggests the species distribution is severely fragmented, some evidence for small-scale movements as fish have been observed to colonise freshly inundated habitat on Hindmarsh Island. Disconnections e.g. with floodplain lakes and drying of some wetlands attributed for population extinctions in Vic (Hammer et al 2009). The Murray Hardyhead is not known to be a migratory species, and is able to complete its life cycle in isolated lakes. However, barriers to movement may affect recolonisation after local extinction of populations. River regulation, construction of levee banks, barriers and weirs have almost certainly reduced the ability of the Murray Hardyhead to disperse along river systems and across floodplains. The largest, most diverse remaining population in the Lower Lakes region (South Australia) is effectively isolated from the rest of the Murray River (except in high flows) by Lock 1 (B. Zampatti n.d., pers. comm. cited in Backhouse et al 2008). *Species does not rely on connectivity for large scale spawning migrations but dispersion may be limited under an increasingly regulated system with lower water level as expected under climate change. Some movement between ephemeral wetlands and main channel evident and increased drought and drying of these habitats may be limiting and has been the cause of localised extinctions. Species should be considered at moderate risk*	**H**	**M**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Interaction with predatory Redfin needs to be assessed as they may limit populations and be a biological barrier to movement. Aggressive interactions from Gambusia in shallow habitat may also be a threat under some conditions (Hammer et al 2009). Dry conditions occurring throughout the Murray-Darling Basin, have dried up many sites (Backhouse et al 2008), in addition, littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and a lack of cover renders the fish more exposed to predatory fish and birds (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). Several introduced fish species, including Carp, Goldfish , Redfin and Eastern Gambusia occur with Murray Hardyheads. Precise impacts are unknown, but its small size, pelagic habit and requirement for aquatic vegetation in which to spawn, renders it susceptible to predation and habitat degradation, often through the very high densities some introduced species e.g. Carp, can reach (MDBC 2003). Stocking of native fish e.g. Murray Cod and Callop are also identified as raising predation pressure (Backhouse et al 2008). Fish in captive breeding programs appear to be free of disease and in good genetic health (DEHWA 2010). *Strong evidence for significant competition and predation pressure. Further loss of suitable habitats is likely under climate change and may force even greater competition for resources and increase predation pressure as introduced species with wider tolerance and flexible life strategies have competitive advantages. Species should be considered at high risk.*	**H**	**H**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Physiological and/or competitive advantage in estuarine or salt affected habitats due to high salt tolerance throughout life stages (Bice 2010; Hammer et al 2009). Tolerant of high salinities, being found in waters up to 62ppt (SAAB 2001). While some sites may still hold water, salinity levels are likely to increase to lethal levels (Backhouse et al 2008). In addition, littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and, although water conditions may continue to be suitable for the species, there is no breeding or feeding habitat, and lack of cover renders the fish more exposed to predatory fish and birds (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). The impact of reduced water levels may also be felt through a combination of high salinity, high water temperatures, low dissolved oxygen and fluctuating pH levels having synergistic or compounding effects (Backhouse et al 2008). McNeil et al (2009) suggest a low resistance to limited DO, in line with limited tolerance to high temperatures e.g. >28°C (Bice 2010). *Good evidence for a degree of tolerance to a wide range of water quality and habitat types for survival particularly of adults perhaps except low DO. Likely to directly tolerate some degradation of water quality expected under climate change but associated littoral habitats may not fare as well. Compounding effects of degraded water quality poses additional threats. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Appears to thrive in ephemeral deflation basin lakes and can survive in highly saline environments (Hammer et al 2009). Adults have been recorded in waters with a salinity of up to 85ppt, but whether they can survive and reproduce in such high salinities is not known. While some sites may still hold water, salinity levels are likely to increase to lethal levels (Backhouse et al 2008). In addition, littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and, although water conditions may continue to be suitable for the species, there is no breeding or feeding habitat, and lack of cover renders the fish more exposed to predatory fish and birds (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). The impact of reduced water levels may also be felt through a combination of high salinity, high water temperatures, low dissolved oxygen and fluctuating pH levels having synergistic or compounding effects (Backhouse et al 2008). While adults may be relatively salt-tolerant, the early life stages, particularly eggs and fry, may be more sensitive to high salinity levels (Backhouse et al. 2008; T.A. Raadik 2002, pers. comm. as cited in DEHWA 2010). *Good evidence for a degree of tolerance to a wide range of water quality and habitat types for survival particularly of adults. Early life stages may be more susceptible to habitat/water quality degradation but is not quantified thus reducing confidence in assessment. Likely to directly tolerate some degradation of water quality expected under climate change but is dependent on littoral habitats that may not fare as well. Compounding effects of degraded water quality e.g. acidification of saline lakes poses additional threats. Species should be considered at high risk but with medium confidence*	**M**	**H**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Reproductive biology poorly understood but maybe similar to other Hardyhead species (Lintermans 2007). Adhesive eggs require aquatic vegetation for attachment (Bice 2010). While adults may be relatively salt-tolerant, the early life stages, particularly eggs and fry, may be more sensitive to high salinity levels (Backhouse et al. 2008; T.A. Raadik 2002, pers. comm. as cited in DEHWA 2010). Short spawning season occurring late summer and early autumn, triggered at water temperatures above 23-25^0 C (SAAB 2001). The stimulus for spawning is unknown but may, like most fish, correspond with increasing water temperature and photoperiod (Ellis 2005). *Lack of specific studies into reproduction in species reduces confidence in assessment. Suggestion that early life stages are not as tolerant to degraded water quality as adults and clear reliance on aquatic vegetation for eggs to attach raises threat under climate change. Short breeding season and high temperature to trigger breeding. Seasonal temperature regimes likely to alter under climate change posing a threat to reproduction. Species should be considered at moderate risk but with medium confidence.*	**M**	**M**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Need to undertake a genetic assessment of population structure throughout the range of the Murray hardyhead to determine presence and limits (Moore et al 2010). Present populations in the MDB are patchy in distribution and abundance (Hammer et al 2009). The Lower Lakes region holds the largest, and probably most genetically diverse of all Murray Hardyhead populations, in South Australia (MDBA 2009). River regulation has almost certainly reduced the ability to disperse along river systems and across floodplains. The Lower Lakes comprise several more-or-less isolated populations (Backhouse et al 2008) that show high genetic diversity and are effectively isolated from the rest of the Murray River (except in high flows) by Lock 1 (B. Zampatti n.d., pers. comm. as cited in Backhouse et al 2008). Known populations of the species exist (in South Australia) in two salt evaporation basins near Berri (Disher Creek and Berri) in the Rocky Gully wetland near Murray Bridge and in the Lower Lakes (Bice et al 2008). Outside the Lower Lakes, all populations (including the three known locations in Victoria) are effectively isolated from one another (Backhouse et al 2008). *Patchy distribution and abundance and lack of large-scale movements increase the chances of genetically homogenous regional population structures. Good evidence to suggest existing regional populations within study area are geographically and genetically isolated and contain limited gene pools. Lower Lakes populations (outside the study area) show higher diversity. Additional research into population genetics required and reduces confidence in assessment. Species should be considered at high risk but with medium confidence*	**M**	**H**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Regional populations in the MDB thought to be fragmented (Hammer et al 2009). Population genetics and phylogeography are identified knowledge gaps, other Hardyhead species show restricted gene flow e.g. Fly-specked Hardyhead (Moore et al 2010). The Lower Lakes comprise several more-or-less isolated populations (Backhouse et al 2008) that show high genetic diversity and are effectively isolated from the rest of the Murray River (except in high flows) by Lock 1 (B. Zampatti n.d., pers. comm. as cited in Backhouse et al 2008). Outside the Lower Lakes, all populations (including the three known locations in Victoria) are effectively isolated from one another (Backhouse et al 2008). *Patchy distribution and abundance and lack of large-scale movements. Good evidence to suggest existing regional populations within study area are geographically and genetically isolated and feature low (or no) gene flow between regional populations. Additional research into population genetic structures identified as being required thus reducing confidence in assessment. Species should be considered at high risk but with medium confidence*	**M**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Unknown but may be similar to other Hardyhead species, similar species *C. stercusmuscarum fulvus* form monophyletic clades (Moore et al 2010), it is likely Murray Hardyhead shows similar pattern of phenotypic homogeny. Population genetics and phylogeography are identified knowledge gaps (Moore et al 2010). *Patchy abundance, restricted distribution and low movement capacities increase chance of delineation of different phenotypes. Similar species however show phenotypic homogeny and it is likely Murray Hardyhead follows this pattern. Species should be considered at high risk but with low confidence due to lack of specific studies.*	**L**	**H**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Nationally listed as vulnerable (EPBC Act 1999), endangered in SA (NPW Act 1972) and critically endangered in NSW under the Fisheries Management Act 1994 (DEHWA 2010). Known SA populations exist in two salt evaporation basins near Berri (Disher Creek and Berri), in the Rocky Gully wetland near Murray Bridge and in the Lower Lakes (Bice et al 2008). The Lower Lakes holds the largest populations (Backhouse et al 2008). Once considered widespread and common to abundant throughout the mid and lower reaches of the Murray-Darling River system, it has suffered an extensive decline in range and abundance throughout its distribution. Up to 16 populations have become extinct in the past 50 years, including at least five populations since 2000 (studies cited in DEHWA 2010). Some locations, particularly those in the Murray River main channel, records were of a few, or single fish only, possibly indicating low numbers of fish in these locations (Backhouse et al. 2008). *No specific population data exists for species but considerable evidence for significant declines in range and abundance within the study area is given in the literature. National and state threat listing also raises confidence that population size may be limiting. Species should be considered at high risk*	**H**	**H**

	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity is poorly documented but likely to be in the low range similar to other Hardyhead species (Lintermans 2007), The SAAB (2001) database records fecundity reaching 2000 eggs per female. Species may exhibit protracted, serial or repeat spawning over an extended period independently of flow (Bice 2010). Thought to be an annual species, most of the fish reach maturity, spawn and die within a year (SA DEH 2008) though some individuals survive into their second year (Lintermans 2007). The stimulus for spawning is unknown but may, like most fish, correspond with increasing water temperature and photoperiod (Ellis 2005). *Research into reproductive capacities in species is limited thus reducing confidence in assessment. Fecundity is documented as being low, analogous to similar Hardyhead species. Species appears reliant on raised water temperature and increased light cycle for spawning but this is not quantified however cold water pollution e.g. dam water releases, in an increasingly managed system under climate change, conceivably poses a threat. As an annual species, reproductive capacity relies on recruitment success of previous year. Species should be considered at high risk but with medium confidence due to lack of specific studies*	**M**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Studies suggest species is primarily annual (i.e. most fish reach maturity, spawn and die within a year) (SA DEH 2008; Hammer et al 2009) though some individuals survive into their second year (Lintermans 2007). Hence, any failure in recruitment could be catastrophic for a population (Hammer et al 2009). Reproductive biology poorly understood but adhesive eggs require aquatic vegetation for attachment (Bice 2010) and early life stage may be more susceptible to variations in water quality (Backhouse et al 2008). Littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and, although water conditions may continue to be suitable for the species, there is no breeding or feeding habitat (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). *Strong evidence to suggest recruitment could be a major limiting factor for species as any disturbance in recruitment in one year may severely affect success and recovery of populations in subsequent years. Reproductive biology of species is poorly understood reducing confidence in assessment but aquatic vegetation (e.g. Eelgrass) is identified as critical for successful breeding. These habitats are under threat of degradation under climate change thus raising risk. Species should be considered at high risk but with medium confidence*	**M**	**H**

Scientific Name:	*Craterocephalus stercusmuscarum fulvus*	Common Name:	Unspecked (Fly-specked) Hardyhead

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Occurs in large, relatively fresh deep pools fringed with emergent vegetation of reeds (*Typha* and *Phragmites*), commonly in edges or shallow areas of rock, algae or pond weed (*Potamogeton crispus).* Margins of large, slow-flowing, lowland rivers, and in lakes, backwaters and billabongs. It prefers slow-flowing or still habitats with aquatic vegetation and sand, gravel or mud substrates (Lintermans 2007). Weedy areas are preferred for spawning with some flow and correct water temperature (SAAB 2001). High levels of stock grazing may be detrimental to water quality and edge habitat condition (Hammer 2009). Suspected reasons for decline of species include increased salinisation (which affects macroinvertebrate and aquatic vegetation structure) and habitat degradation (Lintermans 2007). *Appears to have similar environmental tolerances to that of other small bodied native fish but relies on specific habitat that is at higher risk of degradation under climate change. Prefers freshwater, saline usually occupies by Lake Eyre Hardyhead species instead. Pastoral practices, salinisation and habitat degradation are identified in the literature as main potential threats. Species should be considered at high risk*	**H**	**H**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Mobile within sections of stream systems but not reliant on long distance migration for reproduction, records spread throughout Murray floodplain (Hammer et al 2009). Schooling fish but little is known of its movements. Recent research in the Murray and Murrumbidgee rivers has recorded it attempting to move upstream through fishways, with most movement in the afternoon or dusk periods (Lintermans 2007). *Some diurnal movement evident but apparently not reliant on large scale migrations for reproduction. Increased river regulation and reduced water levels are expected under climate change and may result in more barriers to movement. Species should be considered at moderate risk but with medium confidence due to gaps in knowledge of specific movements*	**M**	**M**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Competition, disease and aggressive behaviour from exotic Gambusia and translocated native species which do not naturally occur in the region (e.g. predation and disease from larger angling species) (Hammer 2009). Fed on by large birds and fish e.g. Golden Perch, impacts of alien species such as Eastern gambusia and Redfin perch are identified as main threats to the species (Lintermans 2007). *Identified threats through competition with alien species (exotic and native). This may increase as conditions deteriorate favouring species with competitive advantages and removing suitable habitat forcing greater competition. Species should be considered at high risk*	**H**	**H**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Seems to prefer fresher pools whereas more saline areas inhabited by Lake Eyre Hardyhead (Lintermans 2007). Adults have high salt tolerance (<44ppt) and wide temperature tolerance (9-36^0 C) (Bice 2010). Appears to be tolerant of a wide range of salinities (recorded at between 8.8-61.9ppt), 4 day LC50 of 43ppt (studies cited in SAAB 2001). Temperature: reported to occur at water temperatures as low as 9.3oC; found in water temperatures as high as 28oC (Merrick and Schmida 1984 as cited in SAAB 2001); tolerant of water temperatures of 36+/-0.5oC (Semple 1985 as cited in SAAB 2001). *Adults show tolerance to a wide range of conditions, preference for freshwater but survive up to very high salinity and wide temperature range. Species should be considered at low risk*	**H**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Species is carnivorous, adults consume aquatic insects and zooplankton, juveniles and larvae likely feed on microcrustaceans and rotifers (Bice 2010). Seems to prefer fresher pools (Lintermans 2007), but adults can tolerate high salinity (43.7ppt) and wide temperature range and pH > 5 (Bice 2010). No information on egg, larvae or juvenile physiological tolerances but larvae is well developed at hatching and takes food immediately (SAAB 2001). *Adults show a wide tolerance to range of conditions, preference for freshwater but survives up to very high salinity and wide temperature range. Larvae are given a good chance as they well developed upon hatching. Early life stages could be more vulnerable to poor water quality but no specific studies. Species should be considered at moderate risk but with low confidence as no information exists on larval and juvenile physiological tolerances or growth requirements*	**L**	**M**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawns from October to February, with a peak in spring when water temperatures are above 24°C, and is capable of multiple spawnings (Lintermans 2007). Peak spawning when water temperature > 24^0 C, require vegetation for adhesive eggs to attach (Bice 2010). NSW studies indicate spawning requires a water temperature above 23.6°C in conjunction with some water flow (SAAB 2001). *Specifically requires aquatic vegetation, seasonal water temperature regime and some flow to initiate successful breeding. Climate change expected to alter seasonal temperature regimes and reduced flows are likely with increasing drought frequency and magnitude. Adults tolerate wide salinity range and even low pH, no information on egg/larval/juvenile tolerances but likely to be reduced but still high. Species should be considered at moderate risk but with low confidence due to lack of data on egg, larval and juvenile tolerances.*	**L**	**M**

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Generally now found only in lowland areas of Basin but more common in northern Basin, formerly abundant but has suffered significant reduction in distribution and now considered rare in the southern part of its range (Lintermans 2007). Listed in SA and NSW as vulnerable and threatened in Victoria (Hammer 2009). Moderately common in Lower Murray and Lower Lakes (Bice 2010), 2nd most abundant native fish in RMWBS 2004/7 with widespread distribution from Vic border to Lower Lakes (Smith et al 2009). High abundance and throughout study area (187 records since 1990 within SAMDB, majority above Wellington) (BSBSA 2010). Some movement within stream sections and diurnally through fishways noted in Hammer (2009) and Lintermans (2007) but range is unclear, no long-distance migrations noted. Gene flow is restricted between regional populations and clades are monophyletic across large drainage scale e.g. east and west of Great Dividing Range (McGlashan and Hughes 2001). *Current population status in SA listed as vulnerable, noted severe declines in southern part of range however BDBSA records and RMWBS indicate a wide distribution with high abundance. Movement capacity not well known and unclear whether regional populations are geographically isolated. Likely that gene pool is limiting given abundance and fragmented distribution evidenced by genetic studies. Species should be considered at low risk*	**H**	**L**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Moderately common in Lower Murray and Lower Lakes (Bice 2010), 2nd most abundant native fish in RMWBS 2004/7 with widespread distribution from Vic border to Lower Lakes (Smith et al 2009). High abundance and throughout study area (187 records since 1990 within SAMDB, majority above Wellington) (BSBSA 2010). Some movement within stream sections and diurnally through fishways noted in Hammer (2009) and Lintermans (2007) but range is unclear, no long-distance migrations noted. Patterns of large and significant pairwise population diversity values imply that restriction of gene flow occurs between many populations regardless of geographic position. Gene flow is restricted between regional populations and clades are monophyletic across large drainage scale e.g. east and west of Great Dividing Range (McGlashan and Hughes 2001). *Strong evidence to suggest gene flow is restricted between regional populations but at scales larger than study area. High abundance and widespread distribution across study area coupled with at least small scale movements reduces risk. Species should be considered at low risk*	**H**	**L**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	The 2 sub-species in Australia form monophyletic clades, this may be a preliminary indication that coastal populations of the two sub-species in south-eastern Australia have been independently derived (McGlashan and Hughes 2001). Moderately common in Lower Murray and Lower Lakes (Bice 2010), 2nd most abundant native fish in RMWBS 2004/7 with widespread distribution from Vic border to Lower Lakes (Smith et al 2009). High abundance and throughout study area (187 records since 1990 within SAMDB, majority above Wellington) (BSBSA 2010). *Formation of only 2 monophyletic clades indicates a lowered capacity for different phenotypic expressions. Any variation is likely to be at larger scales than the study area and independently derived. Wide, continuous distribution across study area also reduces chance of development of different phenotypes. Species should be considered at moderate risk.*	**H**	**M**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Generally now found only in lowland areas of Basin but more common in northern Basin, formerly abundant but has suffered significant reduction in distribution and now considered rare in the southern part of its range (Lintermans 2007). Listed in SA and NSW as vulnerable and threatened in Victoria (Hammer 2009). Moderately common in Lower Murray and Lower Lakes (Bice 2010), 2nd most abundant native fish in RMWBS 2004/7 with widespread distribution from Vic border to Lower Lakes (Smith et al 2009). High abundance and throughout study area (187 records since 1990 within SAMDB, majority above Wellington) (BSBSA 2010). *Current population status in SA listed as vulnerable, noted severe declines in southern part of range however BDBSA records and RMWBS indicate a wide distribution with high abundance. Species should be considered at low risk but with medium confidence due to conflicting abundance reports.*	**M**	**L**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity is low, with only 20–107 eggs laid , spawns in spring-summer when water temperature reach >24^0 C and is capable of multiple spawnings (Lintermans 2007). Fecundity is low and could be between 16-680 eggs over the month assuming 2-85 eggs are released over 2 days followed by a rest period of 3 days and this pattern is repeated 4 times within the month (SAAB 2001). *Species has a low reproductive capacity and should be considered at high risk*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Annually spawns from October to February peaking in spring and early summer when water temperatures reach above 24°C, species capable of multiple spawning (Lintermans 2007). Fecundity is low and could be between 16-680 eggs over the month assuming 2-85 eggs are released over 2 days followed by a rest period of 3 days and this pattern is repeated 4 times within the month (SAAB 2001).Spawning occurs on submerged and edge vegetation opportunistically over an extended period depending on temperatures and rainfall. Fish mature quickly but are relatively short lived (~2 years) (Hammer 2009). NSW studies indicate spawning requires a water temperature above 23.6°C in conjunction with some water flow (SAAB 2001). *The low fecundity and short longevity of species reduces recruitment potential although it has a short time to maturity. Population base appears quite strong despite threat listing reducing risk. Species should be considered at moderate risk but with medium confidence due to conflicting abundance reports.*	**M**	**M**

Scientific Name:	*Galaxias maculatus*	Common Name:	Common Galaxis (Jollytail)

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change.	Commonly found in coastal habitats, in still or slow-flowing streams and the margins of lagoons and lakes, spawning sites are terrestrial vegetation along shallow margins of streams and estuaries (Lintermans 2007). Larvae and juveniles are marine (if not land locked) occurring in shallow coastal areas amongst submerged vegetation. Typically occur amongst aquatic vegetation in standing to slow-flowing waters in pools and at stream, lagoon and lake margins, as well as in the lower reaches of streams in estuaries (SAAB 2001). *Preference for coastal and estuarine environments with aquatic vegetation and slow flow conditions but generally wide salinity and temperature tolerance. Estuarine tolerance lowers risk to species and may actually benefit from range extension under climate change as more temporary, saline wetlands are expected to form. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	In coastal streams, adults migrate downstream to brackish areas to spawn. Larvae disperse to sea for six months before returning to streams the following spring. In landlocked populations in lakes, breeding occurs in late winter-early spring on rising water levels, with adults making a short migration into tributaries to spawn. The larvae are washed down into lakes to spend several months amongst the shallow shoreline vegetation. The barrages on the Lower Lakes may be depressing larval whitebait returns (Lintermans 2007). *Clear reliance on spawning migrations and movement between wetlands and main channel for breeding. Lowered water levels, reduced flows and barriers threaten fish passage placing species at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Shown to out-compete the common exotic species *Gambusia holbrooki* in feeding trials, far out-weighed by intra-specific competition (Becker et al 2005). Provide a food source for eels, introduced salmonids, and other predatory fish. Believed to be a significant food resource for brown trout and other predatory fishes in lowland rivers and estuaries during spring and summer. Free swimming larvae are vulnerable to predation particularly by introduced trout and Redfin (SAAB 2001). Galaxids (minnows), particularly the Common Galaxias, are often infected by the tapeworm Ligula (DPI Vic 2008). *While species shows ability to out compete Gambussia, conspecific competition and larval predation are main competitive pressures on species and disease is an identified threat. Species is also a small bodied fish and susceptible to added pressure and should be considered at high risk.*	**H**	**H**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Early life stages show a high tolerance to salinity (up to 45ppt) but require neutral pH (> 6.5), adults have an even higher tolerance to salinity (up to 62ppt) and pH > 5 (Bice 2010). Adults are powerful osmotic regulators and can tolerate salinities well in excess of sea water (recorded in waters ranging from 1-50 ppt). Tolerates very high turbidity but moderate temperatures from 10-24.5°C (SAAB 2001). Capable of adapting itself to the most readily available food in the environment in which it lives e.g. crustaceans in lake and estuarine environments and insects in rivers and streams (Pollard 1973). *Physiologically tolerant of wide range of salinities but limited high water temperature tolerance may reduce available habitat through drying and heating of small, temporary pools under climate change. DO requirements are unknown but probably moderate as larvae and juveniles can survive lentic water but only to ~24°C. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	A euryphagic carnivore capable of adapting itself to the most readily available food in the environment in which it lives e.g. crustaceans in lake and estuarine environments and insects in rivers and streams (Pollard 1973). Some authors describe eggs and larvae occurring in fresh to almost pure seawater, tolerating salinities up to 30 ppt (Cadwallader and Backhouse 1983 as cited in SAAB 2001), and others at least as high as 10-20 ppt (Hortle 1989 as cited in SAAB 2001). Growth relies on tolerable water quality and availability of habitat. Juveniles (and adults) have been observed in the MDB at salinities above 25ppt (Bice 2010). *Growth is unlikely to be limited through climate change as species has wide tolerance to salinity, turbidity and temperature. Migration upstream required for juveniles to complete life cycle and if land locked, rely on intermittent flowing creeks and flooding for hatching, growth and dispersion of young. Connectivity, flow and flooding regimes may be altered under climate change possibly limiting growth. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Rely on migration to downstream tributaries/lakes to spawn in riparian vegetation above the water line, either in flooded shallow margins of streams or above the normal tideline in estuaries. Eggs are able to survive up to 8 weeks non-immersed and hatching is stimulated by high tide or flooding, reduced flows may be reducing spawning opportunities for landlocked recruitment and migration (Lintermans 2007). Newly hatched larvae are transported to the sea where they remain during winter, often travelling long distances. They migrate back up into estuaries and rivers in spring where they occupy adult habitats, and mature over summer. Lunar and tidal cycles appear to trigger spawning migrations (SAAB 2001). Marine *Clear reliance on water level, flow, flooding and or passage to estuary/sea using high tides for completion of reproductive cycle. River and wetland interconnection and flow are expected to reduce and become more variable threatening the health of the species. Species should be considered at high risk.*	**H**	**H**

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Meristic and morphological data combined with allozyme data support concept of a single species that has dispersed around the Southern Hemisphere. Gene flow via dispersal tends to maintain a gene pool with low interpopulation differentiation. Analysis of genotypes and allele frequencies from east and west South Pacific populations indicate all are from same gene pool with gene flow occurring via larval dispersal at sea (Berra et al 1996). *Gene pool unlikely to be limited unless land locked evidenced by sharing of genetic profile with species form other parts of the South Pacific but this assumes connectivity to the sea is maintained and is a risk under climate change. Land locked populations more likely in study area and under climate change where flow regulation and lowered water levels are likely to result in more disconnection. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Analysis of genotypes and allele frequencies from east and west South Pacific populations indicate all are from same gene pool with gene flow occurring via larval dispersal at sea (Berra et al 1996). Adults form small to large spawning shoals, releasing their eggs haphazardly among grasses (Pollard 1966, Benzie 1968c, Lake 1971 as cited in SAAB 2001) and vegetation on river estuary margins inundated by a high spring tide (Burnet 1965, McDowall 1968b, McDowall 1969, Andrews 1976, McDowall and Fulton 1996 as cited in SAAB 2001). *Studies show evidence of significant gene flow between regional populations through oceanic dispersion. Risk if populations get land locked by flow or connectivity disruption and can no longer disperse. In this respect the species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Studies have found little allozymic variation between landlocked and diadromous species. Considerable differentiation in mitochondrial DNA however was found. The differences are attributed to reproductive isolation of landlocked populations. MtDNA analysis in progress may shed more light on genetic divergence among geographic populations (Berra et al 1996). While dispersal clearly influences biogeography, presence of highly divergent haplotypes within and among locations indicates the evolution of this species may be very complex (Waters & Burridge 1999). In the Murray-Darling Basin it is known from the Lower Lakes (Alexandrina and Albert), extending up to approximately Mannum on the Lower Murray, abundance in Lower Basin has decreased but is still high in Lower Lakes (Lintermans 2007). Historically common in the lower reaches of the River Murray, currently often seen but massed spawning migrations no longer occur implying a considerable reduction in abundance (SAAB 2001). 141 records within SA MDB floodplain since 1990 distributed mainly in Lower Lakes and extending to Mannum (BDBSA 2010). Smith et al (2009) showed moderate abundance but mainly concentrated in Lower Lakes outside of study area with few records above Wellington. Uses estuarine and marine environment but can also maintain populations if land locked (Bice 2010). *Presence of highly divergent haplotypes with regional populations although further research is required and a degree of allopatric speciation is evident in land locked populations. High variation within groups suggests a complex evolution of genetic structures. Capacity to adjust breeding strategy is an example of adaptive capacity. Species spawns in large shoals thus decreasing potential for phenotypic delineation, more so if diadromous. Limited population size within study area also reduces potential for phenotypic expression. Species should be considered at moderate risk.*	**M**	**M**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	One of the world's most widespread freshwater fish found on the east and west sides of the Pacific Ocean (Waters & Burridge 1999). In the Murray-Darling Basin it is known from the Lower Lakes (Alexandrina and Albert), extending up to approximately Mannum on the Lower Murray, abundance in Lower Basin has decreased but is still high in Lower Lakes (Lintermans 2007). Historically common in the lower reaches of the River Murray, currently often seen but massed spawning migrations no longer occur implying a considerable reduction in abundance (SAAB 2001). 141 records within SA MDB floodplain since 1990 distributed mainly in Lower Lakes and extending to Mannum (BDBSA 2010). Smith et al (2009) showed moderate abundance but mainly concentrated in Lower Lakes outside of study area with few records above Wellington. *All indications that the once highly abundant population is declining and majority are recorded in lower reaches and Lakes. Major threat if populations become isolated (land locked) upstream due to flow/water level reductions under climate change. This aspect greatly influences assessment as the effective population would be severely reduced. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity potential is moderate and variable, each female produces several thousand eggs (up to 13,500) (Lintermans 2007). Spawn once a year in Autumn-Spring over a short period (Bice 2010). *Moderate to low number of eggs produced compared to other species assessed in this study. Variable reproductive potential and only spawns once a year. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Individuals are mature at the end of their first year, (90 mm length), although some do not breed until their second year. Very few survive until the end of their third year and a substantial proportion of adult fish die after spawning (Lintermans 2007; SAAB 2001). Juveniles of diadromous populations rely on connection to sea for upstream migration and recruitment to adulthood (Bice 2010). If populations are land locked recruitment relies on intermittent flow s and flooding to immerse eggs laid on banks of intermittent streams (SAAB 2001). *Recruitment relies on either connection to sea/estuary or passage between intermittent water ways and flows/flooding to allow eggs to hatch and dispersal of larvae and young. Being a short lived species with a relatively short life and long time to maturity raises risks. Species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Hypseleotris spp. (complex)*	Common Name:	Carp Gudgeon (carp gudgeon complex)

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change.	Study shows significantly more larvae in slow anabranch macrohabitats than in fast-flowing systems (Leigh et al 2008). Strongly associated with dense aquatic vegetation, snags and cover and required in spawning sites for egg adherence (Bice 2010). This group of species is found in slow-flowing or still waters, normally associated with macrophyte beds or other aquatic vegetation (Lintermans 2007). Salinity not thought to be directly toxic to adults or larvae, most species in MDB are relatively tolerant due to hydro-geomorphic history of the Basin. Adults show experimental tolerance to high salinity (<50ppt) and hypoxia (Bice 2010) and have been found in brackish water to 8.8ppt in the wild (Chessman and Williams 1974). Other experiments show an LC50 of 38ppt after 4 days (studies cited in SAAB 2001). Widespread and abundant throughout its range, occurs inland in the Murray-Darling drainages throughout SA (Larson and Hoese 1996 as cited in SAAB 2001). Availability of high quality food e.g. chironomids, dependent on presence of dense macrophyte stands that support biofilm assemblages representing significant benthic production (Balcombe and Humphries 2006). *Species appears to have a wide geographic range across the study area and occupies a variety of habitats ranging from fresh to brackish conditions. Usually associated with dense aquatic vegetation and slow-flowing reaches. Reported in fresh to mildly brackish waters but experiments show species does not tolerate high salinity e.g. close to marine, for very long and suffers mortalities. Preference for lentic water concurs with experiments suggesting good tolerance for low DO. Species is unlikely to be dramatically affected through habitat limitations unless water quality drops below levels required for aquatic plant/biofilm assemblage health as a result of flow/water level reductions, drought and/or drying under climate change. As a moderately salt tolerant species its range may even extend slightly under climate change with a move form permanent freshwater to more temporary saline wetlands. Species should be considered at moderate risk.*	**H**	**M**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Originally thought to be a relatively sedentary species, recent investigations have demonstrated that large numbers of carp gudgeons attempt to move through fishways on the Murrumbidgee and Murray rivers. Whether these attempted movements reflect local dispersal or foraging movements is unknown (Lintermans 2007). Evidence for lateral migration between main channel and billabongs/wetlands. Recent drought (8+ years) has resulted in the complete drying of many off-channel habitats and lateral re-population of billabongs from the Murray River is likely to be an important aspect of drought recovery. Hence, the exchange of fish between river and floodplain is likely important in maintaining biodiversity (Lyon et al 2010). Generally as water levels rise, fish leave main channel and move into newly flooded off-channel habitats; bidirectional movement as water levels peak; on falling levels fish move back to the permanent riverine habitats. The high degree of lateral movement indicates the importance of habitat connectivity for the small-bodied fish community. Wetlands adjacent to the Murray River are becoming increasingly regulated by small weirs and ensuring lateral fish movement will be important in maintaining riverine-wetland biodiversity (Lyon et al 2010). *Strong indication that species relies on river connectivity with adjoining wetlands and tributaries for foraging or spawning (in flooded backwaters) and movements are associated with rises and falls in river height. Climate change is expected to lead to general reductions of flow volumes and lower water levels throughout the system and may increase disconnection. Drought magnitude and frequency is also expected to rise under climate change putting further pressure on access to suitable resources and may result in lower diversity of wetlands including the small-bodied fish community including Carp gudgeons. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Studies from a River Murray billabong in Victoria found that low water levels may increase aggregation and predation, competition and disease transmission (Balcombe & Humphries 2006). In the ACT, significant kills of Western carp gudgeon have occurred as a result of infestation with the introduced tapeworm *Bothriocephalus acheilognathi* thought to have been sourced from introduced Carp or Eastern Gambussia. Also suffers predation pressure from Callop, Redfin and Brown trout where it can form a substantial part of their diet (Lintermans 2007). Also reported to be predated on by Murray cod, Freshwater catfish and wading birds (SAAB 2001) and may form a critical dietary component for juvenile Murray Cod (Bertozzi et al 2000). *Lower river heights are expected under climate change and this increases risk to species through higher levels of competition and disease transmission when fish are highly aggregated. Species is particularly susceptible to parasitism with introduced tapeworm (studies from ACT catchments) and also reported to suffer predation from cold-water exotic species e.g. Brown trout and Redfin perch. These species may be favoured due to competitive advantages under climate and may increase predation pressure and disease risk. Also an important diet component of larger predatory native fish and wading birds. Species suffers significant competitive pressures and should be considered at high risk.*	**H**	**H**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Salinity not thought to be directly toxic to adults and juveniles at salinities below 30ppt, most species in MDB are relatively tolerant due to hydro-geomorphic history of the Basin. Adults show a high tolerance to salinity (<50ppt) and hypoxia and juveniles survive up to 30ppt (Bice 2010). ACT studies found important dietary items include copepods, aquatic insects, cladocerans and ostracods, and chironomids are the most frequently consumed aquatic insect (Lintermans 2007). Small macroinvertebrates (food source) may be more succeptible and pose threat of indirect impact (Leigh et al 2008). Balcombe & Humphries (2006) in a study on a billabong in Victoria, found that unstable water levels prior to sampling led to significantly poorer quality diet (more detritus, less invertebrates) but not stomach fullness. Water level fluctuations were driven by releases for irrigation purposes and did not reflect natural patterns which would be more gradual. Water level stability thus may have a profound effect on resources for the species (*H. klunzingeri*), it is possible that impacts on natural river flows through the irrigation season could override natural patterns of food supply to resident fish and ultimately affect survivorship (Balcombe & Humphries 2006). *Species shows wide environmental tolerance to salinity and DO and is not likely to be limited by these factors directly. Food availability is thought to be the most important factor in determining ultimate survivorship. Studies give compelling evidence for reduced food quality and availability when artificial fluctuations in water level occur in a system. Further alteration of natural flows is expected under climate change with a more managed system. This will lead to the transition to more temporary wetlands with fluctuating levels in the study area. Omnivorous diet of species means that it is able to switch to alternate food sources (e.g. detritus) when better quality food is scarce. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Adults show tolerance to high salinity (<50ppt) and hypoxia but hatching larvae can only survive fresh to mildly brackish conditions (6.3ppt) (Bice 2010). Diet quality affected by fluctuating water levels (more detritus, less invertebrates) but not stomach fullness. If water level stability has such a profound effect on resources available to fishes it is possible that the impacts on natural river flows through the irrigation season could override natural patterns of food supply to the resident fishes. Such changes would then be expected to impact on other natural processes, such as larval and juvenile recruitment, and ultimately survivorship (Balcombe & Humphries 2006). *Species shows wide environmental tolerance to salinity and DO and is not likely to be limited by these factors directly at juvenile or adult life stages. Species is more vulnerable in egg and larval stage only surviving in fresh to mildly brackish conditions but food availability is thought to be the most important factor in determining larval and juvenile recruitment. Studies give compelling evidence for reduced food quality and availability when artificial fluctuations in water level occur in a system resulting in poorer diets. Further alteration of natural flows is expected under climate change with a more managed system. This will lead to the transition to more temporary wetlands with fluctuating levels in the study area. Omnivorous diet of species means that it is able to switch to alternate food sources (e.g. detritus) when better quality food is scarce. Species should be considered at moderate risk.*	**H**	**M**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Published information on breeding in this species complex often relates to a particular species and may not necessarily represent the complex as a whole. The spawning site is typically in quiet flooded but shallow backwaters. The eggs are deposited in a mass on the bottom, usually on vegetation and rocks or other instream biotic material, such as twigs or grasses. Eggs are vulnerable to desiccation and low oxygen levels but are aerated (fanned) and protected by adults (various studies cited in SAAB 2001). Spawning is triggered at water temperatures >22^{0} C, larvae have some tolerance to mild brackish salinity (<6.3ppt) (Bice 2010). Adhesive eggs need structure (e.g. submerged aquatic vegetation or twigs) (Lintermans 2007). Larvae require slow anabranch macrohabitats (Leigh Zampatti & Nicol 2008). *While not documented as a major threat, species is triggered to spawn by warm water. This may be affected by increased flow regulation under climate change and alterations to seasonal temperature regimes that may affect spawning. Availability of suitable spawning sites with aquatic macrophytes and or benthic structure may also be degraded if water quality deteriorates beyond tolerance levels or if reduced flows cause silting of broken bottom types used as nesting sites. Use of flooded backwaters for spawning also raises threat as frequency and magnitude of floods is expected to decrease under climate change. Main threat to recruitment success identified in literature concern instability of water levels reducing quality of available food for early, planktivorous life stages. Larvae also are vulnerable to raised salinity above 6.3ppt which may further reduce viable sites as a transition to more temporary, saline wetlands is expected under climate change. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Taxonomy and nomenclature of sub-species remains unclear, three distinct taxa in the Lower Murray, and imply the presence of a fourth taxon, hybridization is common (Bertozzi et al 2000). Widespread distribution and abundant numbers (Leigh Zampatti & Nicol 2008). Present and abundant in River Murray and Lower Lakes, absent form Coorong (Bice 2010). Widespread and abundant throughout its range. Occurs inland in the Murray-Darling drainages throughout SA, no formal conservation concern within Australia or SA (Larson and Hoese 1996 as cited in SAAB 2001). BDBSA records indicate widespread distribution across the study area with the highest number of records than any other species assessed in this project (1148), within the SA MDB floodplain since 1990 (BDBSA 2010). *Wide agreement in the literature of widesdpread and abundant distribution throughout study area, this pattern is confirmed by BDBSA records. Taxonomy for this species complex is incomplete and reduces confidence in assessment however the presence of 3-4 taxa within group and evidence of extensive hybridization suggests a diverse potential gene pool. Coupled with high abundance and distribution, species is unlikely to be limited by gene pool and should be considered at low risk.*	**H**	**L**

Scientific Name:	*Maccullochella peelii peelii*	Common Name:	Murray Cod

	Question	Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Generally occur in river channels, larger flowing anabranches, in or near deep holes with cover (rocks, fallen timber or tree stumps), threats from extensive snag removal (i.e. fallen trees) to aid navigation and recreation, general habitat transformation and flow regulation/stoppage (Hammer et al 2009). Generally associated with deep holes in rivers, the Murray cod prefers habitats with in-stream cover such as rocks, stumps, fallen trees or undercut banks (Lintermans 2007). An overarching and continuing threat however, is reduced and altered flow patterns from massive upstream regulation and abstraction which appears to interfere directly in Murray Cod ecology or impact ecological processes (e.g. food resources and appropriate habitat for juveniles). The River Murray now receives on average only a third of natural flow volumes and the frequency, magnitude and timing of floods have been dramatically altered. Reduced flows and related poor water quality may also lead to fish kills as seen interstate recently (Hammer 2009). *Species is under severe threat from habitat degradation and water quality deterioration, alteration of flow regimes and channel clearing. Increased disconnection from critical remaining habitat in off-channel environments with flow and structure is a major threat through flow diversion and barriers. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Often have defined local home range or territory however long distance migrations have been noted at certain times especially around spawning period and high flow thought to relate to upstream migration to spawn followed by a return to home (Hammer et al 2009). It has only recently been discovered that Murray cod make an upstream migration to spawn. This movement can be up to 120km and generally occurs in late winter/early spring when river levels are high. After spawning the fish move downstream again, returning to the same area they occupied before the migration, usually to exactly the same snag (Lintermans 2007). *Strong evidence for migratory and dispersal movement for success of species. This capacity that may be severely restricted through lower flows and water levels and altered flood frequency, timing and magnitude under climate change. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Consumes larger prey including yabbies, shrimp and fish. Competition for food or modification of habitat by introduced fish, (e.g. Redfin and Carp) are identified as main threats (Hammer et al 2009). *Likely that species undergoes some competition for food with other apex predators (e.g. large fish and birds) but extent is unclear. Higher threat of habitat modification and nest disturbance e.g. by Carp/Redfin. Species should be considered at high risk.*	**H**	**H**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Larvae feed on microcrustaceans and insects, juveniles consume larger prey and adults are apex predators of large fish, frogs and crustaceans. Adults suffer mortality at salinities above 15.7ppt and pH <5 (Bice 2010). An overarching and continuing threat however, is reduced and altered flow patterns from massive upstream regulation and abstraction which appears to interfere directly in Murray Cod ecology or impact ecological processes (e.g. food resources and appropriate habitat for juveniles) (Hammer 2009). *Main threat surrounds damage to ecosystem through increased regulation and consequent lowered water levels and altered flow regimes. Rainfall, drought and flooding frequency, timing and magnitude are expected to vary under climate change posing a major risk to survival. Low tolerance to salinity also raises threat significantly. Species should be considered at high risk.*	**H**	**H**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Availability of zooplankton of appropriate size, type and abundance is critical for success of early life stages. Eggs and larvae have low tolerance to salinity over 7.6ppt and juveniles suffer mortality at salinities > 10ppt and pH < 5. Adults have a moderate salinity tolerance (14ppt) and species has wide temperature range of 10-37°C (Bice 2010). Cold water release from dams is known to lower the overall water temperature of a river by 15 °C, this typically extends 100–150 km downstream from the dam wall. Surveys have shown that juvenile Murray Cod raised in 24°C grow twice as long and 3.5 times as heavy as those found in 13°C water over a 3 month period (Ryan et al 2003). It has been suggested that spring flooding and the emergence of pelagic zooplankton associated with newly inundated floodplain habitat may play an important role in the survival of Murray cod during first feeding in lowland river habitats, and that mortality has increased due to flow alteration and severing of the connection between the river channel and floodplain (Kaminskas & Humphries 2009). *Main threats to growth of species includes low and/or regulated flows, salinity problems and cold water pollution. Early life stages even more susceptible to degraded water and environmental conditions than adults. These problems are expected to increase under climate change so the species should be considered at high risk.*	**H**	**H**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawns once a year in spring and early summer over a short season, independently of flow when water temperatures exceed 15°C (Bice 2010). Eggs are laid in guarded nest on hard substrates (e.g. rocks, logs), success heavily reliant on presence of suitable nesting habitat. Water quality must meet requirements (salinity <9ppt, pH <6.5) for successful egg and larvae development (Bice 2010). Channel clearing (removal of structural woody habitat) is considered among the main threats to reproduction in the species (Lintermans 2007). *Main threats to reproduction concern removal of suitable nesting habitat (snags), salinity problems and cold water pollution. These factors are expected to become increasingly significant through climate change so the species should be considered at high risk.*	**H**	**H**

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Wild populations have patchy distribution and abundance and species is listed as nationally threatened (Lintermans 2007). Stocking of hatchery reared Murray Cod is additional threat to genetic health of wild SA populations (e.g. genetic pollution and reduced genetic diversity) (Hammer et al 2009). A review of stocking impacts on genetic diversity of almost three decades of stocking on populations in 5 catchments of the southern MDB found that stocking had not significantly impacted genetic structure. Current genetic diversity was moderately high and had not changed over the period of stocking (Rourke et al 2010). When river connectivity is high, fish are moderately migratory. Murray cod in the southern MDB may have avoided a genetic bottleneck through a combination of gene flow from other populations, long lifespan and only gradual demographic decline (Rourke et al 2010). Rourke et al (2009), revealed unexpected incidences of polygamous spawnings (both polygyny and polyandry) within a season and repeated matings between pairs of fish across multiple seasons. Only 38 records since 1990 within SA MDB floodplain, patchy distribution and abundance, majority of records north of Mannum (BDBSA 2010). *Gene pool of wild populations is likely to be highly limited due to patchy distribution and very low abundance of individuals. Genetic pollution from stocking is another identified threat although studies show efforts to be successful and current genetic diversity is high (although relative comparison with other species is lacking). Due to very low wild population numbers species however, species should be considered at high risk.*	**H**	**H**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Wild populations have patchy distribution and abundance, listed as nationally threatened (Lintermans 2007). Gene flow between populations likely to be limited due to low numbers, studies of other *Maccullochella* species show genetic segregation. The pattern of genetic variation among remnant populations of *M. ikei* is consistent with restricted dispersal and isolation by distance. It is likely that human activities including habitat alterations, overfishing and stocking have acted on and amplified the effects of these natural processes to the detriment of the species (Nock 2009). Rourke et al (2010) found current genetic diversity was moderately high across 5 catchments and 3 decades of stocking in the southern MDB and had not changed over the period of stocking. Murray cod in the southern MDB may have avoided a genetic bottleneck through a combination of gene flow from other populations, long lifespan and only gradual demographic decline (Rourke et al 2010). Rourke et al (2009), revealed unexpected incidences of polygamous spawnings (both polygyny and polyandry) within a season and repeated matings between pairs of fish across multiple seasons. *Gene flow is likely to be highly restricted in the species if observations of similar species are analogous. Small, fragmented populations of endangered species run a much high risk of suffering gene flow limitations. Rourke et al 2010 indicated high genetic diversity and attributed it partially to gene flow between regional populations in the southern MDB but the relative extent of genetic diversity may be low when compared to other species. Rourke et al 2009 also found polygamous spawning in the species and this increases chances of gene flow throughout populations. Species should be considered at high risk but with medium confidence due to studies indicating good gene flow in populations in the southern part of the study area.*	**M**	**H**

Resilience	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Some evidence of plasticity in the genus as eastern species, *M. Ikei,* and *M. p. mariensis* shows phenotypic differences between regional populations e.g. upper and lower reaches (Nock 2009). Genetically distinct populations or 'management units' of Murray cod exist in the wild (Rourke 2007 as cited in Rourke et al 2009). Therefore, supplementing these populations will require the use of broodfish sourced from the same management unit to avoid disrupting the original population structure, and also to ensure that any local adaptation between genetically distinct populations is maintained (Rourke et al 2009). *Reasonably convincing evidence for plasticity certainly within the genus and evidence of genetically distinct populations in the wild that affect management of stocking efforts to maintain genetic integrity and diversity. Phenotypic plasticity in terms of adaptive capacities are not mentioned in literature so not clear whether genetically different populations is artifact of geographic isolation/drift or responses to local/regional conditions. Conservatively, the species should be considered at moderate risk but with low confidence.*	**L**	**M**
	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Low number of mainly large individuals from a few specific cohorts (i.e. individuals from a particular spawning event), slight catch increases in 2000-2002 following a successful recruitment event but further declines likely if poor flow and related habitat conditions continue to limit recruitment (Hammer et al 2009). Wild populations have patchy distribution and abundance (Lintermans 2007) and species is nationally listed under the EPBC Act as 'vulnerable' (Gillam and Urban 2010). Only 38 records since 1990 within SA MDB floodplain, patchy distribution and abundance, majority of records north of Mannum (BDBSA 2010). *BDBSA records concur with literature in describing very patchy distribution extremely low abundance. Likely that species is highly limited by low regional population numbers so should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Annual spawning is typically once over a short season and fecundity is moderate (1000's-10000's of demersal eggs) (Bice 2010). Fecundity depends on size; females have been recorded with between 10000 and 90000 eggs (Harris and Rowland 1996 as cited in SAAB 2001), and other authors describe up to 200000 eggs for very large fish (Lake 1967d as cited in SAAB 2001). Rourke et al (2009), in a study on captive broodfish, revealed unexpected incidences of multiple spawnings by both sexes within a season. This concurred with previous studies (Rowland 1998; Newman et al 2007 both as cited in Rourke et al 2009) of captive Murray cod, repeat spawnings may have occurred because a fish was disturbed while spawning and subsequently spawned in another nest. Breeding behaviour of wild fish still needs to be explored to see if it is similar to that of captive broodfish (Rourke et al 2009). *Reproductive capacity is variable depending on size of female but is in low-moderate range for fish species assessed in this study. A study by Rourke et al 2009 concurred with previous studies finding high incidence of multiple spawning in captive broodfish which may increase species reproductive capacity however, this requires validation against breeding behaviour of wild fish. Species should be considered at moderate risk but with medium confidence due to lack of knowledge of reproductive capacities of wild fish.*	**M**	**M**

	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Adult condition and recruitment appears to benefit from flooding (especially sequential flood years in SA), with important small breeding areas at the Chowilla anabranch system where there is in-channel flow. Slight increases in catch occurred in 2000-2002 following a successful recruitment event, but further declines are likely through if poor flow and related habitat conditions continue to limit recruitment (Hammer et al 2009). Flow thought to be important for recruitment success (but not spawning). Lack of significant flows in last 20 years has resulted in limited recruitment evidenced by populations dominated by large, old individuals primarily >15 years old (Bice 2010). Lotic environment (flow) helps to disperse larvae (Kaminskas & Humphries 2009). Fish mature after around 4 years (variable in size) and the species is long lived with fish aged 20-50 years old recorded (Hammer 2009) and estimated that it may live to 50-60 years of age (SAAB 2001). *Reduced flows, drought and lowered water levels are expected to become more common through climate change and the literature suggests this may significantly affect recruitment success in species. Species also has a very long generation time maturing at 4 years of age and fecundity is low particularly in young/small fish. The species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Macquaria ambigua ambigua*	**Common Name:**	Callop (Golden Perch)

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Golden perch are predominantly found in the lowland, warmer, turbid, slow flowing rivers, shown to prefer deep, slow flowing pool habitats and often associated with snags and other cover. Cold water pollution (e.g. below dams), and channel clearing of suitable habitat are recognised threats (Lintermans 2007). Prefer permanent wetlands (Smith et al 2009), able to grow well in lentic and shallow water but well adapted to different flow regimes (SAAB 2001). *Reliance on benthic aquatic vegetation and slow flowing, warmer conditions. Preference for permanent wetlands but adapted to cope with a variety of flow conditions. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Adult and immature fish are migratory and extensive upstream movements of more than 1000 km have been recorded for some adult fish, outside the breeding season home ranges are about 100 m for weeks or months before relocating to another. Upstream movements by both immature and adult fish are stimulated by small rises in streamflow and most movement in the Murray occurs between October and April. Recent research in the Murray River has also suggested that some fish may move downstream to spawn (Lintermans 2007). Well adapted to widely variable stream flow conditions with dispersal and migration being aided by flooding and high stream flows. Movements of juveniles during minor rises in water levels are likely to be impeded by the presence of even low weirs. In-stream barriers inhibit migration and reduce the amount of upstream habitat the fish are able to access (SAAB 2001). *Ability to move unrestricted along the river is critical to the reproductive life stage of the species undertaking spawning migrations and post breeding dispersion. Reduced flows and drought, fish barriers, low water levels and weirs may affect this capacity. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Opportunistic carnivore, diet of adults consists mainly of shrimps, yabbies, small fish and benthic aquatic insect larvae. Juveniles consume smaller items e.g. aquatic insect larvae and microcrustaceans (Lintermans 2007). *Little information. No mention of direct competition for food or resources in literature but some likely with other large fish and birds with similar diets. Conservatively the species should be considered at moderate risk but with low confidence.*	**M**	**M**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Prefer warm water, slow-flowing water, cold water pollution, barriers to migration and relocation are threats, cold-water pollution has eliminated some populations below large dams (Lintermans 2007). Adults will tolerate salinities up to 33ppt and pH not <5 (Bice 2010). Prefers very high turbidities, favours water temperatures of 25-27°C, but is well adapted to fluctuating temperatures, young fish survive temperatures of 4-37°C (SAAB 2001). *Wide tolerance to salinity and turbidity and adapted for varying flow regimes. Prefers warmer, slower flowing and turbid waters and has suffered elimination through cold-water pollution although this is not a risk within study area. Main threat through connectivity preventing access to habitat. Species should be considered at moderate risk.*	**M**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Slow growing fish compared to other large-bodied freshwater species, mouth gape and feeding ability of larvae and fry is limited, growth and survival relies on high density of available plankton of the right size. Zooplankton succession needs to be in early stages e.g. recently inundated floodplain for success of larvae. Fry growth and survival may also rely on availability of cover (Arumugam & Geddes 1987). Juveniles will die or emigrate when salinity exceeds 21ppt or pH drops below 5, adults will tolerate salinities up to 33ppt and pH > 5 (Bice 2010). Young fish survive temperatures of 4-37°C (SAAB 2001). *Growth of young dependent on food availability and provision of cover, juveniles have moderate tolerance to salinity but wide temperature and flow regime requirements. Slow-growing species are also more at risk as they are vulnerable for longer. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawning triggered by temperatures above 20^{0} C and possibly linked to increased flow and floods (Bice 2010). Release of cold water from dams or reservoirs into areas where fish are spawning (during spring or summer) is likely to stop spawning or result in an incomplete spawning event, either of which could have severe negative impacts on the long term viability of local populations (SAAB 2001). River regulation has disrupted migrations and spawning behaviour (Lintermans 2007). *Alteration of natural flow and water temperature regimes as a consequence of river regulation and construction of dams and weirs threatens reproduction. Connectivity of system also likely to decline under climate change. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Patchy distribution and abundance (Smith et al 2009) means gene pool of regional populations may be limited. Studies show regional populations have little genetic diversity and gene pools are isolated (Musyl & Keenan 1992). *Gene pool likely to be limiting given distribution and abundance of species, this is supported by genetic studies. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Gene-flow statistics indicate that the regional populations from both sides of the Great Dividing Range can be regarded as separate gene pools that have been isolated for different and considerable periods of time. Within the Murray-Darling drainage basin there is little indication of genetic heterogeneity (Musyl & Keenan 1992). *Little indication of gene flow as regional populations show genetic homogeneity. This may be as a result of a degree of allopatric speciation (regional divergence). Species should be considered at high risk.*	**H**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Genetic divergence of regional populations indicates species ability to evolve allopatric subspecies although within the Murray-Darling drainage basin there is little indication of genetic heterogeneity. Within the Murray-Darling basin, three populations of golden perch have been distinguished by morphological differences with >95% accuracy (Musyl 1990 as cited in Musyl & Keenan 1992). However, there was little evidence for population subdivision among samples. Only small differences in allele frequencies were seen but it could not be concluded that the fish sampled are part of a single gene pool due to insufficient sample size to detect statistically significant subdivisions (Musyl & Keenan 1992). *Indication of population subdivisions based on morphologies and genetic differences but not within study range. Species should be considered at high risk.*	**H**	**H**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Widespread throughout the Murray-Darling Basin in the lower and mid reaches but has declined in some areas (Lintermans 2007). Patchy abundance and distribution in the River Murray in SA (Smith et al 2009). Now rare or absent from large areas in Murray-Darling tributaries and higher reaches of the main channels (SAAB 2001). 133 records within SA MDB floodplain since 1990 in BDBSA, low abundance and widely distributed across all reaches including Lower Lakes but not Coorong (BDBSA 2010). *All indications are that species has small regional populations according to literature and verified by pattern in BDBSA records. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Highly fecund, adult female can hold up to 500,000 eggs, water-hardened eggs are large (~3–4 mm diameter) semi-buoyant and drift downstream (are demersal) (Lintermans 2007). *High potential reproductive capacity, species should be considered at low risk.*	**H**	**L**

	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Long-lived (maximum validated age for an individual of 26 years) although most live less than 12 years, males are reproductively mature at 2 years and females at 4 years. Spawn during spring and summer when water temperature exceeds about 20°C, recent evidence from Murray River suggests ability to spawn during stable irrigation flows, spawning was significantly increased during the 2005 environmental water release in mid-Murray (Lintermans 2007). Prolonged absence of flooding flows appears to have severely affected recruitment in a 2004 study (Smith et al 2009). *Compelling evidence that high flows/flooding are responsible for triggering large spawning events and significantly influence recruitment success. Alteration of natural flow regimes and water temperature as a consequence of river regulation and construction of dams and weirs threatens recruitment. A long-lived species but long time to maturity so long generation time and increased risk. Species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Maquaria colonorum*	**Common Name:**	Estuary Perch

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Typically in tidally influenced estuaries but will penetrate into fresh waters. Associated with structure (Bice 2010). Essentially a fish of coastal drainages from the Murray mouth in SA and is rare in the Basin and recorded only from the Lower Murray, Lower Lakes and Coorong (Lintermans 2007). Prefers estuarine environments and migrates to spawning habitat in lower river reaches, primary reason for its decline in the SAMDB relates to a continuing decline in the area and quality of suitable habitat the Barrages combined with a 2/3 reduction in River Murray flow. The Barrages have acted as a physical barrier to dispersal between freshwater and the sea. Reduced flow to the Coorong has resulted in the habitat on the seaward side of the barrages often being purely marine (almost exclusively so in the last 10 years), and purely fresh on the upstream side, providing no area of true estuarine conditions (Hammer et al 2009). Tolerant of a range of salinities from fresh to salt water; breeds in seawater at estuarine mouths or in the sea and able to adapt to a freshwater environment (Allen 1989; McCarraher 1986 both as cited in SAAB 2001). *Specialist estuarine dependent species whose habitat in the study area is under severe threat through altered flow regimes and river regulation, flow barriers and seawater intrusion. The magnitude and frequency of intervention and regulation is set to increase with climate change. Some authors however, also identify the species as having wide salinity tolerances and adaptable to freshwater. Species is not likely to benefit from a range extension (as more saline wetlands are expected under climate change) as connectivity is likely to decline. Species should be considered at high risk but with medium confidence due to conflicting reports on the species salinity tolerances/preferences but it is likely that the optimal habitat range in the study are will decline under climate change.*	**M**	**H**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Must have downstream access to estuaries for spawning migrations. Juvenile growth to adulthood may take place in estuary but upstream migrations also occur (Bice 2010). Specimens have been recorded in recent years from as far up the Murray as Swan Reach (Lintermans 2007). Dispersal capacity unknown, but tagged fish have traveled between 14-29 km on spawning migrations (McCarraher 1979). *The species critically relies on passage and access to estuaries and/or sea for spawning migrations. While the Lower Lakes, Coorong and Murray Mouth are outside the study area, fish in the lower reaches rely on unrestricted passage to sea. Careful management of water levels to minimize impacts of fish barriers throughout the study area is required. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Species probably suffers from competition and predation with high numbers of Redfin in the Lower Lakes and lower River Murray, and is also susceptible to fishing pressure across its range when they congregate in areas for spawning (Hammer et al 2009). Recreational fishing has been linked to an apparent decline in its abundance (SAAB 2001). *Exotic fish (Redfin) that have competitive advantages in preferred habitats, occur in abundance in the lower part of the study area. Fishing pressure is also identified as a major threat in the literature. Species should be considered at high risk.*	**H**	**H**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Very little information on physiological tolerances of adults. The composition of the diet from freshwater environments in the MDB is unknown (Lintermans 2007). Tolerant of a range of salinities from fresh to salt water; breeds in seawater at estuarine mouths or in the sea and is able to adapt to a freshwater environment (Allen 1989; McCarraher 1986 both as cited in SAAB 2001). A study from the Hopkins River showed diet varies seasonally with terrestrial insects becoming prominent in November but otherwise, an opportunistic carnivore and a mid-water feeder (mainly fish and crustaceans) (Lintermans 2007), but consumes quantities of molluscs, and terrestrial insects and worms when available (SAAB 2001; Lintermans 2007). *Various literature indicating broad salinity tolerances and estuarine habitation that reduces risk as can tolerate raised salinity levels. Opportunist carnivore diet and a mid-water feeder (fish and crustaceans) but will switch according to seasonal availability e.g. insects in summer also an advantage. Likely to be at low risk but lack of knowledge of adult physiological tolerances reduces confidence. Species should be considered at low risk but with medium confidence.*	**M**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Larvae moderately developed at time of first feeding, feed on micro-crustaceans, juveniles eat crustaceans and aquatic insects and adults are opportunistic carnivores feeding on crustaceans, aquatic insects and fish (Bice 2010). Species seems to be primarily piscivorous (mid-water) but eat quantities of crustaceans, molluscs, and worms when available (SAAB 2001; Lintermans 2007). Hatching larvae have a wide salinity tolerance but very little specific information on juvenile and adult physiological tolerances (Bice 2010). *Species relies on brackish, estuarine conditions for spawning and growth of larvae and fry, larvae tolerate high salinity but unknown if young will survive extended saline conditions. Within the study area, climate change may actually provide added habitats (temporary saline wetlands) and conversely render others*	**M**	**M**

		unsuitable (drying, hypersalinisation). Juveniles are reasonably well developed so wide planktivorous diet reduces risk as has presumably fast growth. Species should be considered at moderate risk with medium confidence.		
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Migrates to estuaries to spawn once water temperatures reach 14-19°C. Can delay spawning until conditions suit, usually in winter. Pelagic, non-adhesive semi-buoyant eggs and no parental care. Spawning may be linked to increased flow and floods (Bice 2010). Breeding in waters where salinities are typically 10-24 ppt, over areas with submerged aquatic vegetation, submerged reefs or both. The duration of the spawning season depends on the presence of water at optimal salinities, the ambient temperature and the availability of the preferred spawning habitat (McCarraher and McKenzie 1986). *Relies on strict set of environmental conditions to successfully spawn and reproduce. Access to and health of breeding areas is threatened under climate change (reduced water levels, managed flows) so species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Very few recent records in Lower Lakes and Coorong, common before construction of barrages, now absent from River Murray Lower Lakes and Coorong. State threat listed in SA as endangered (Bice 2010). *Gene pool is likely to be highly restricted as numbers are very scarce. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Estuarine breeding so not genetically structured within Basin, i.e. gene flow dependent on spawning in estuarine and oceanic environments (Moore et al 2010). *If connectivity to estuaries and/or mouth of River Murray is lost, breeding and gene flow will be affected and this is an issue affecting the study area above Wellington to Lock 1. Non-estuarine conditions induced in the Lower Lakes, Coorong and Murray Mouth region through altered flow regimes and fish barriers pose threats to the breeding and genetic health of the species. This species should be considered at high risk.*	**H**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Insufficient data to identify genetically distinct populations (Moore et al 2010). Very few recent records in Lower Lakes and Coorong, common before construction of barrages, now absent from River Murray Lower Lakes and Coorong. State threat listed in SA as endangered (Bice 2010). 3 records within SA MDB floodplain since 1990 (BDBSA 2010). *Difficult to assess due to lack of data, very limited populations in SA MDB so likely to be susceptible to any pressure and to posses weak genetic capacities to mitigate effects. Specialist environmental requirements for breeding and general preferences but tolerates a range of salinities as adult so cannot be called niche specialist per say. While patchy distribution increases chance of development geographic variation, very low abundance and mass spawning migrations reduce this chance to large extent. Species should be considered at high risk but with medium confidence as population genetic/phenotypic structures are not defined in the literature.*	**M**	**H**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Very few recent records in Lower Lakes and Coorong, common before construction of barrages, now absent from River Murray Lower Lakes and Coorong. State threat listed in SA as endangered (Bice 2010). 3 records within SA MDB floodplain since 1990 (BDBSA 2010). *Population size according to literature and departmental records are extremely sparse and is likely to be highly restrictive. Species should be considered at high risk.*	H	H
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Highly fecundity potential, 100000's eggs spawned at a time (Bice 2010) Fecundity is high and increases with fish length up to +500000 (Lintermans 2007). *Species is capable of producing many offspring and should be considered at low risk.*	H	L
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Adults mature after 2-3 years and migrate downstream to near the mouth of estuaries to spawn (Hammer et al 2009). It breeds in seawater at the entrance of estuaries in winter when water temperatures are from 14 to 19°C.Breeding occurs annually in warmer months of spring and summer, typically Aug-Dec (McCarraher and McKenzie 1986 as cited in SAAB 2001). No information on longevity but large fish to 10kg have been recorded but more commonly <3kg (Harris and Rowland 1996 as cited in SAAB 2001). Very few recent records in Lower Lakes and Coorong, common before construction of barrages, now absent from River Murray Lower Lakes and Coorong. State threat listed in SA as endangered (Bice 2010). 3 records within SA MDB floodplain since 1990 (BDBSA 2010). *Moderate time to maturity so recruitment is limited compared to species that mature earlier although has a high potential fecundity. Probably a long lived species given recorded weights. Not triggered to breed by flow but rather water temperature, seasonal temp regimes may alter under climate change. Recruitment events also rely heavily on downstream connectivity to estuaries. Very low population base from which to recruit from in study area. Species should be considered at high risk.*	H	H

Scientific Name:	*Melanotaenia fluviatilis*	**Common Name:**	Crimson-spotted Rainbow Fish

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Occurs in the inland Murray Darling system in S.A in the lowland parts of the Basin, and prefers slow-flowing rivers, wetlands and billabongs. Tend to avoid fast, murky water in favour of still, clear water near thick vegetation. Currently its abundance is much reduced and it is now mainly found in association with dense riparian vegetation. Aquatic plants are also required as attachment sites for eggs and may also be necessary for larval attachment for the first 2 days after hatching. Salinity tolerant but disease risk if exposed to cold water (SAAB 2001). Loss of aquatic vegetation (spawning sites and cover) and cold-water pollution are main threats (Lintermans 2007). *Relatively narrow habitat preferences although short term tolerance of wide range of environmental conditions. Main threat identified as loss of suitable vegetated habitats through clearing and ecological degradation. Species should be considered at high risk*	H	H
	To what extent does ***mobility and dispersal***	Until recently it was not known that this species migrated, but individuals as small as 21 mm	H	M

	limit the ability of the regional population of the species to tolerate climate change?	have been recorded moving through a fishway on the Murrumbidgee River, most commonly in the afternoon and dusk (Lintermans 2007). They may prefer clearer water for movements associated with courtship displays and breeding (Hutchinson et al 2008). Species has low dispersal ability (McNeil et al 2009). *Some diurnal movement suggested in literature but no significant long-distance spawning migrations noted. Increased habitat fragmentation e.g. stranding of wetlands or tributaries, may limit ability to reach ideal habitats. Larval dispersive capacity is considered low adding to risk. Species should be considered at moderate risk.*		
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Predation of adults by Redfin perch and larvae by Eastern gambusia are among the main potential threats to species (Lintermans 2007). *Distribution and abundance of exotic species e.g. Eastern gambusia, is expected to rise through climate change as they have significant competitive advantages, e.g. environmental tolerance, high fecundity etc. Predation identified as a major threat in literature. Species should be considered at high risk.*	**H**	**H**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	All life stages are tolerant to a wide range of salinities. Favours still or slow flowing waters, preferred temperature range is 18-28°C but highly susceptible to protozoan and bacterial infection at low temperatures. It is thought that low winter temperatures restrict its range and limit population sizes. Also appears to be at risk of population depression under drought conditions (SAAB 2001). Loss of aquatic vegetation and cold-water pollution are main threats (Lintermans 2007). They may prefer clearer water for movements associated with courtship displays and breeding (Hutchinson et al 2008). *Wide tolerance to salinity and cold water pollution is not likely to be an issue within study area. Drought, turbidity and loss of aquatic vegetation habitat threaten survival. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Little known of juvenile life stage requirements other than attatchment to vegetation for 2 days after hatching. Juvenile and eggs are tolerant of only mildy brackish conditions (<12ppt) and neutral ph (Bice 2010). Favours still or slow flowing waters, preferred temperature range is 18-28°C but highly susceptible to protozoan and bacterial infection at low temperatures. It is thought that low winter temperatures restrict its range and limit population sizes. Also appears to be at risk of population depression under drought conditions (SAAB 2001). Loss of aquatic vegetation and cold-water pollution are main threats (Lintermans 2007). *Loss of habitat required for (food availability and cover) and drought are identified as major threats. Early life stages are susceptible to mild salinity and species has a narrow temperature preference. Species should be considered at high risk but with medium confidence as little is known of juvenile growth requirements*	**M**	**H**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Breeding is seasonal, generally spring-summer when water temperature exceeds 20°C (Lintermans 2007). Male spawning triggered at water temperatures >20°C, adhesive eggs require structure or vegetation (Bice 2010) and hatched larvae also attach to aquatic vegetation for 2 days following hatching (SAAB 2001). Spawning follows rapid warming of shallow floodwaters to temperatures between 20-25°C, but an increase in water level is not a necessary spawning trigger (SAAB 2001). Loss of aquatic vegetation spawning sites and cold-water pollution are major threats (Lintermans 2007). They may prefer clearer water for movements associated with courtship displays and breeding (Hutchinson et al 2008). *Main threats to reproduction of species concern loss of suitable spawning habitats through environmental degradation and disruption of water temperature regimes associated with triggering breeding. Turbidity may also be a threat to breeding in species. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change? <u>Medium-paced recoloniser and probably moves throughout study area to a reasonable extent. Populations probably shared across floodplain (D. McNeil pers. Comm. 2010).</u>	Patchy abundance and distribution throughout MDB and has disappeared from Lower Lakes. Still localised in wetlands and vegetated edges of main channel in Lower Murray River SA (Lintermans 2007). Some daily movement noted through fishways but scale unknown (Lintermans 2007). Relatively common over the majority of its range, although numbers can fluctuate widely, and fell dramatically in Victoria after the 1982/83 drought (no specimens being recorded at a number of Victorian sites following this event) (Allen 1996 as cited in SAAB 2001). Reasonably abundant and widespread according to RMWBS 2004/7 (Smith et al 2009). 109 records since 1990 within SA MDB floodplain, patchy distribution from Wellington to Vic border (BDBSA 2010). *Diurnal migratory movement is noted and probably moves throughout study area reasonably well. Populations across floodplain probably share gene pool through good mixing. BDBSA records suggest a patchy abundance and distribution in SA MDB although RMWBS studies found it to be relatively abundant and widely distributed across the study area. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change? <u>Medium-paced recoloniser and probably moves throughout study area to a reasonable extent. Populations probably shared across floodplain (D. McNeil pers. Comm. 2010).</u>	Crowley et al (1986) in a study of populations from coastal and inland drainages, suggest geographic isolation as a mechanism for restricting gene flow. In lab conditions, different rainbowfish species interbreed producing viable young whereas in the wild, despite their sympatry, different rainbow fish species retain their integrity, suggesting that other isolating mechanisms restrict gene flow (Crowley et al 1986). *Diurnal migratory movement is noted and probably moves throughout study area reasonably well. Populations across floodplain probably share gene pool through good mixing. Geographic isolation is a suggested mechanism for restricting gene flow but at large spatial scale scales e.g. coastal/inland drainage systems. Unlikely those populations within the study area are genetically segregated. Species should be considered at low risk.*	**H**	**L**

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Shows intra-species morphological and meristic variation but unclear as to whether it translates into alteration of phenotype based on genetic analyses. Morphology and meristics often vary within species as much as variation between species of *Melanotaenia*. When combined with genetic cluster analysis species they form more distinct groups. *M. fluviatilis* shows homozygosity for at least one loci, other species are homozygous or have high frequency for alleles at other loci (Crowley et al 1986). *Reasonable evidence for separation of Melanotaenia species based on morphological and meristic data however remains unclear on different gene expression within species. Genetic variation is a feature of genus so it is likely some occurs. Conservatively the species should be considered at moderate risk but with low confidence.*	**L**	**M**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change? <u>Medium-paced recoloniser and probably moves throughout study area to a reasonable extent. Populations probably shared across floodplain (D. McNeil pers. Comm. 2010).</u>	Formerly widespread across the Basin but has declined in the Murray region, still patchily recorded from the middle and lower sections of the Murray but appears to have disappeared from the Lower Lakes in SA. It is still common but localised in wetlands and vegetated edges of the main channel of the Lower Murray River in SA (Lintermans 2007). Relatively common over the majority of its range, although numbers can fluctuate widely, and fell dramatically in Victoria after the 1982/83 drought (no specimens being recorded at a number of Victorian sites following this event) (Allen 1996 as cite din SAAB 2001). Reasonably abundant and widespread according to RMWBS 2004/7 (Smith et al 2009). 109 records since 1990 within SA MDB floodplain, patchy distribution from Wellington to border (BDBSA 2010). *BDBSA records suggest a patchy abundance and distribution in SA MDB although RMWBS studies found it to be relatively abundant and widely distributed across the study area. Populations can be highly variable e.g. with drought, but is a good recoloniser. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity is low (average 130 eggs, range 35–333) with females laying 5–20 eggs per batch in 3–4 batches per day for several days (Lintermans 2007). *Very low reproductive capacity compared to other fish assessed in this study. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change? <u>Medium-paced recoloniser (D. McNeil pers. Comm. 2010).</u>	Individuals mature at 10–12 months old and live for around 3 years (McNeil et al 2009). Breeding is seasonal, generally in spring-summer (Lintermans 2007). It is thought that low winter temperatures restrict its range and limit population sizes (SAAB 2001).). Numbers fell dramatically in Victoria after the 1982/83 drought (no specimens being recorded at a number of Victorian sites following this event) (Allen 1996 as cited in SAAB 2001). Loss of aquatic vegetation spawning sites and cold-water pollution are major threats (Lintermans 2007). *Matures within its first year but is relatively short lived. Cold water pollution is not a major risk within study area. Loss of spawning sites may be a threat. Drought frequency and magnitude is also expected to increase and may threaten recruitment. A medium-paced recoloniser, it is able to repopulate areas well after a disturbance. Species should be considered at moderate risk*	**H**	**M**

Scientific Name:	*Mogurnda adspersa*	Common Name:	Purple-spotted gudgeon

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Specific habitat requirements of larvae unknown. Juveniles and adults: typically found in slow-flowing or still waters, among weed. Breeding habitat requires areas with hard substrate for spawning such as rocks, wood and broad-leafed aquatic plants (SAAB 2001). Decline likely due to progressive reduction in the suitability of local habitats from a combination of reduced flows, increases in turbidity along the River Murray, decreased water quality, and loss of submerged and emergent macrophytes (Hammer et al 2009). Habitat alteration has dramatically reduced the size and the range of Murray–Darling Basin populations (Faulks et al 2008). The restricted distribution and unique habitat occupied by this species suggests a limited dispersal capability (SAAB 2001). *Evidence for strong reliance on health of suitable habitats, identified in literature as one of main limiting factors to abundance and distribution of species. While species has relatively wide survival tolerances, its habitat is characteristically at high risk under climate change (i.e. freshwater habitats with dense vegetation). Further habitat alteration and degradation is expected and it is likely that further declines/pressure on species will occur as optimal habitats are lost. Species should be considered at high risk.*	**H**	**M**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Boxall et al (2002), found between pool movement was a prominent feature of population behaviour, male gudgeons moved significantly more than females suggesting an association with reproductive cycles, e.g. searching for nesting sites. Large scale migrations have not been identified in the literature, localised drying and disconnection of wetlands may threaten population through disease (Hammer et al 2009) or disruption of breeding (Boxall et al 2002). The continued lowering of River levels has caused drying of a wetland with a related crash in its local abundance, this is likely to result in the loss of this remaining population in South Australia and hence the southern Murray-Darling Basin (Hammer et al 2009). *Clear link between increased habitat fragmentation and degradation and disruption of breeding, dispersal and distribution and increased disease risk. Lowered water and further disconnection of the system is expected under climate change. Species does not rely on long-distance migrations and so is less at risk than highly migratory species e.g. Callop, Silver Perch or diadromous fish. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Interaction with introduced fishes is likely to be significant, especially Redfin predation and aggressive interactions, competition and predation of fry by Eastern Gambusia. There is a casual link between the arrival of Carp in the River Murray and the disappearance of Southern Purple-spotted Gudgeon (i.e. potential habitat modification through loss of aquatic vegetation or transmission of disease). Disease incidence was high just prior to wetland drying of the last known wild site (Hammer et al 2009). *Species undergoes significant competition with exotic fish with competitive advantages and may be subject to biological barriers to its range. Species should*	**H**	**H**

		be considered at high risk.		
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Found in freshwater as well as in waters with salinities as high as sea water (SAAB 2001) but Bice (2010) quotes an adult LC50 of 17ppt. Appears to favour clear water and is reported to tolerate waters ranging from soft to hard and acid to alkaline (SAAB 2001). Prefers still, slow-flowing (Larson and Hoese 1996b as cited in SAAB 2001) or almost stagnant water (Blewett 1929 as cite din SAAB 2001) which may imply a tolerance for low levels of water oxygenation. Considerable declines likely due to progressive decline in the suitability of local habitats from a combination of reduced flows, increases in turbidity, decreased water quality, and loss of submerged and emergent macrophytes (Hammer et al 2009). *While declines are attributed to reductions in water quality, the species shows a high tolerance to a range of conditions. Demonstrates a clear preference for lentic, clear water and may tolerate low oxygen and survives wide temperature and pH ranges. Declines likely to be result of habitat degradation rather than direct impact although this is still a survival requirement. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles require vegetated off channel habitat and salinity < 21ppt and pH > 5, adults suffer mortalities at salinities > 17ppt, but larvae tolerate only <12ppt (Bice 2010). Availability of microcrustaceans, suitable water quality and off channel habitat important for growth larvae and juveniles (Bice 2010). Decline likely due to reduced flows, increased turbidity, decreased water quality (Hammer et al 2009). In addition, littoral habitat areas, with aquatic vegetation become exposed when water levels drop too low and, although water conditions may continue to be suitable for the species, there may be no suitable habitat, and lack of cover renders small-bodied fish (e.g. Murray Hardyhead) more exposed to predation pressure (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). *While declines are attributed to reductions in water quality, the species shows a moderate tolerance to a range of conditions although susceptible to salinisation particularly in breeding sites. Demonstrates a preference for lentic, clear water but seems to tolerate low oxygen and wide temperature and pH ranges but turbidity may be a threat under climate change due to reduced flows and silting. Compounding effects of water quality parameters may threaten growth particularly at more vulnerable early life stages. Declines also likely to be result of habitat degradation rather than direct impact however habitat is still required for successful growth. Species should be considered at high risk.*	**H**	**H**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Utilizes hard substrates for spawning during summer (Hammer et al 2009). Spawning occurs in summer when water temperature exceeds 20°C (Lintermans 2007). Eggs and hatching larvae have low-moderate tolerance to salinity (< 12ppt) and pH > 6.5 (Bice 2010). Flooding is not believed to trigger spawning, believed to be by increasing day length and rising water temperatures (Hansen 1988 as cited in SAAB 2001). Studies cited in SAAB (2001) report spawning occurring at water temperatures reach 19-30^0 C during spring and summer (Dec-Feb). Their requirement for water temperatures of 20-34^0 C within Dec-Feb for spawning to occur means that summer water management activities which result in water temperatures outside of this range could severely retard spawning success or prevent spawning from occurring at all. Any local habitat degradation which	**H**	**M**

		adversely affects water quality, decreases the amount of water plants or decreases the number of suitable spawning sites (such as removal of logs and wood debris) could also seriously impact on the viability of this species (SAAB 2001). *While not relying on hydrological regime (rainfall, flow, flooding), breeding may be affected by changes to seasonal temperature regimes under climate change. River management is expected to increase under climate change and will need to be applied carefully so as not to affect spawning. Removal of suitable spawning habitat (aquatic vegetation loss) through water quality degradation and lowered water heights are also identified in the literature as a significant threat. This includes connectivity with wetlands containing adequate spawning sites (snags etc). Species should be considered at moderate risk.*		
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Limited gene pool of wild and re-stocked populations, ill-planned reintroductions could cause genetic problems (Hammer et al 2009). Murray–Darling Basin populations are characterised by lineages with highly localised endemism and very low genetic diversity (Faulks et al 2008). Low abundance in localised populations in Lower Murray and Murray Bridge (Hammer et al 2009). Has undergone a significant decline in Basin and is now presumed extinct in SA (where a single translocated population occurs) and Vic (Lintermans 2007). No records shown for 2004/7 RMWBS (Smith et al 2009). Very few records within study area since 1990 (14) with no records below Wellington (BDBSA 2010). *Compelling evidence of very limited gene pools particularly in populations within the study area in SA. Low abundance to the point of regional extinctions and fragmented distribution in SA means remaining regional populations are isolated and feature very low genetic diversity. Further pressure is likely under climate change so species should be considered at high risk.*	**H**	**H**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Low abundance in localised populations in Lower Murray and Murray Bridge. Native population in Lower Murray different to translocated population from Qld MDB (Hammer et al 2009). Murray–Darling Basin populations are characterised by lineages with highly localised endemism, very low genetic diversity and restricted gene flow (Faulks et al 2008). *Strong evidence of restricted gene flow in regional populations of the species throughout its range and particularly within the study area. Extremely low abundance to the point of regional extinctions within the study area means any existing populations are likely to be fragmented and genetically isolated. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Phylogenetic reconstructions show that Murray–Darling Basin populations comprise a monophyletic clade that possibly originated by range expansion from the coast around 1.6 million years ago. It is proposed that the divergent Murray–Darling Basin clade is of high conservation priority and requires separate management (Faulks et al 2008). *Strong evidence of genetically distinct, monophyletic MDB populations requiring careful management and high conservation priority to improve chances of survival/recovery of species. Species should be considered at high risk.*	**H**	**H**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Low abundance in localised populations in Lower Murray and Murray Bridge (Hammer et al 2009). Has undergone a significant decline in Basin and is now presumed extinct in SA (where a single translocated population occurs) and Vic (Lintermans 2007). Currently classified as endangered in S.A. (Robinson et al 2000 as cited in SAAB 2001). A recent study has described this species as regionally extinct in the Murray drainage of South Australia (Wedderburn 2000 as cited in SAAB 2001). Listed as 'critically endangered' and in 'definite decline' in the DENR Murraylands region and Murray Mallee IBRA sub-region under IUCN criteria and is considered regionally extinct in the Murray Scroll belt sub-region (Gillam and Urban 2010). *Significant evidence for severely limited regional population sizes especially within the study area. Species is listed as endangered in SA and has suffered regional extinctions. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity is relatively low, 280–1300 eggs are deposited in a single batch on a rock, log or aquatic plants (Lintermans 2007), mean around 500 eggs (McNeil et al 2009). Females are multiple spawners (Larson and Hoese 1996b as cited in SAAB 2001; McNeil et al 2009). *While species is capable of multiple spawning, it typically lays a very low number of eggs per batch. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Summer seasonal spawning, may display protracted, repeated or serial spawning over an extended period, may spawn independently of flow e.g. flat-headed gudgeon (Bice 2010; Lintermans 2007). Flooding is not believed to trigger spawning, believed to be triggered by increasing day length and rising water temperatures (Hansen 1988 as cited in SAAB 2001). Any local habitat degradation which adversely affects water quality, decreases the amount of water plants or decreases the number of suitable spawning sites (such as removal of logs and wood debris) could also seriously impact on the viability of this species. Requirement for water temperatures between 20-34^{0} C within December-February for spawning to occur means that summer water management activities which result in water temperatures outside of this range could severely retard spawning success or prevent spawning from occurring at all (SAAB 2001). Species takes 6 months to reach breeding maturity and likely to breed in their first year and may live over 3 years (McNeil et al 2009). *Species has a moderate fecundity potential but is restricted to spawning over the summer months when water temperature reach a suitable range. River management is expected to increase under climate change and will need to be applied carefully so as not to affect water temperatures and spawning. Connectivity with wetlands off the main chanel containing suitable breeding habitat (snags, debris etc) is critical to recruitment as river is cleared of much structure. Species grows to maturity quickly and also thought to live over 3 years which is relatively long for a small-bodied native fish but has a very small population base within the study area. Species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Mordacia mordax*	Common Name:	Short-headed Lamprey

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Marine/estuarine when adult, fresh when juvenile requiring permanent flow and shade. Reduced stream and river flows (e.g. farm dams and water storage) are affecting amount of wetted habitat available and quality of remaining habitat (e.g. less dissolved oxygen and increased temperatures with decreased flows (Hammer et al 2009). Most of the adult life is spent at sea or in estuaries. Young adults migrate upstream from the sea in spring and summer to breed in rivers. Ammocetes are sedentary and live in slow-flowing streams, burrowing in silt or mud, for about 3 years before metamorphosing (at around 100–140 mm length) and migrating down to the sea, usually in spring (Lintermans 2007). *Habitat requirements of adults are not assessable as they occur outside the study area. Freshwater benthic habitats of ammocetes within the study area are vulnerable to degradation and drying out through climate change. Reduced flows under increased management of the system are likely and this may affect the amount and quality of available habitat for young of the species. Species should be considered at high risk as it spends around half its life in the freshwater larval phase*	H	M
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Diadromous species switching between fresh and marine habitat, migration up-river in spring for spawning, down in high-flow winter conditions (Hammer et al 2009). Can climb up wet vertical surfaces but weirs are still migration barriers (Lintermans 2007). Downstream migrants need characteristics associated with winter flows (e.g. increase in flow and decrease in water temperature) to trigger downstream migration. Upstream migrants require characteristics associated with summer flows, (e.g. decrease in flow and increase in water temperature). Ammocoetes remain in freshwater until they metamorphose into the downstream migrating form. They then spend time in estuarine waters and can move out into the ocean in search of prey. Later, they migrate upstream into freshwater to mature and breed. During upstream migrations they have the capacity to move large distances and negotiate fish barriers and vertical rock faces beside weirs (Sloane 1984; SAAB 2001). *Clear reliance on connectivity and natural flow patterns in the system for the successful breeding and migratory requirements of the species. Climate change may lead to increasingly managed flows and reduced water levels and may reveal more fish barriers (higher and drier). Species should be considered at high risk*	H	H
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Probably predated on by birds and piscivorous fish (McNeil et al 2009). Filter feeding ammocetes and parasitic marine adult life stages (Hammer et al 2009). Most of the adult life is spent at sea or in estuaries. Ammocetes are sedentary and live in slow flowing streams, burrowing in silt or mud, for about 3 years before metamorphosing (at around 100–140 mm length) and migrating down to the sea, usually in spring (Lintermans 2007). *Adult phase of life in estuaries and sea and outside study area but unlikely to suffer much competitive pressure due to its parasitism. No competition/interaction with exotic species noted. Ammocetes have a wide planktonic diet and unlikely to suffer food competition. Ammocetes are small and may suffer more predation pressure as are benthic and sedentary in freshwater habitats within the study area. Some predation may occur (birds and fish) and some competition but little known. Species should be conservatively considered at moderate risk but with medium confidence.*	M	M

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles are filter feeders and require permanent flow and shade (rarely found in stagnant or eutrophic waters. Adults are parasitic and occupy marine or estuarine waters (Hammer et al 2009). Ammocetes found only in freshwater, parasitic stage only found at sea so it is possible that these lifestages cannot survive outside of their usual environment. The occurrence of upstream migrants in fast-flowing waters suggests a preference for moderate to high dissolved oxygen levels, or a need for eggs to be spawned in this type of environment (Potter 1970; Potter 1996 both cited in SAAB 2001). *Clearly tolerant of saline water as part of life cycle spent at sea but speculative evidence of young being freshwater specialists and adults being strictly confined to marine/estuarine environments is given by inference of distribution. Adults migrating upstream show preference to fast flowing water indicating it may require high levels of DO or needed for spawning. These conclusions are not supported by studies into physiological tolerances/preferences and reduce confidence in assessment. Adult of species within study area are probably at moderate risk through the reduction/increased management of flows under climate change but confidence is reduced to a medium level due to lack of quantitative studies*	**M**	**M**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Long larval and juvenile life stages (~3yrs) relying on filter feeding in fresh water with consistent flow (Hammer et al 2009). Ammocetes are sedentary and live in slow-flowing streams, burrowing in silt or mud, for about three years before metamorphosing (around 100–140 mm length) and migrating down to the sea, usually in spring. The ammocetes are toothless, feeding on algae, detritus and micro-organisms filtered from the water. After metamorphosis to adulthood, they become parasitic on other fish, rasping a hole in the side and feeding on blood and/or muscle. Adults cease feeding prior to their spawning migration (Lintermans 2007). *Adults migrating upstream show preference to fast flowing water indicating it may require high levels of DO or needed for spawning and egg/larvae survival. Ammocetes and juveniles appearing to require fresh, well aerated water (i.e. some flow) is potentially highly limiting under climate change. These conclusions are not verified by studies into physiological tolerances/preferences of early life stages and reduce confidence in assessment. Young of species within study area is probably at high risk through salinisation of freshwater habitats and reduced/managed flows under climate change affecting feeding and habitat quality. Species should be considered at high risk as larval phase within study area is long. Confidence is reduced to a medium level due to lack of quantitative studies*	**M**	**H**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawning migration upstream to freshwater reaches is required. Barriers and increased salinity may pose threat (Lintermans 2007). Critical Lower Lakes/Coorong connection with river for upstream migration of adults to spawning sites and downstream migration to sea of juveniles (Bice 2010). Young adults migrate upstream from the sea in spring and summer to breed in rivers. The spawning run lasts for about a year. Ammocetes are sedentary and live in slow flowing streams, burrowing in silt or mud, for about 3 years before metamorphosing (at around 100–140 mm length) and migrating down to the sea, usually in spring (Lintermans 2007). *Clear reliance on connectivity and natural flow patterns in the system for the successful migratory breeding requirements of the species. Increasingly managed/reduced flows and lower water levels expected under climate change may result in more fish barriers (higher and drier) and also remove suitable spawning habitat. Study area plays a critical role in the rearing of benthic freshwater larval stage and the quality and range of this environment is under threat through salinisation and stagnation through reductions in magnitude and frequency of flows through the system and drought under climate change. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change? <u>Populations have probably declined throughout study area and SA MDB generally. Some ammocetes recently found downstream of study area below Goolwa Barrage (D. McNeil pers. comm. 2010).</u>	Current distribution and abundance difficult to ascertain without targeted investigations as species is cryptic as both adult and juvenile. Opportunistic records have diminished since the 1970s despite increased levels of sampling. A few records near Murray Mouth with recent intensive and temporally repeated sampling and two single individuals were recorded along the River Murray channel (Hammer et al 2009). In recent times adults are rarely seen, but formerly they could be seen in large numbers in the lower Murray on their spawning run at migration barriers such as weirs. There are recent records of this species from below the Goolwa Barrage and ammocetes are reasonably common in suitable silty habitats (Lintermans 2007) but it has not been recorded in Lower Lakes or Murray Estuary since 2007 (Bice 2010). Historically not well known in the River Murray, but was apparently common although not overly abundant. Currently moderately abundant in some rivers within its range (SAAB 2001). *Difficult to assess due to a lack of confirmed records and cryptic nature of species. Indication that species was never highly abundant within study area and seems to have undergone significant decline as the mass spawning runs in the Murray are no longer seen. Ammocetes are still reportedly found in reasonable numbers in suitable habitats but downstream from the Goolwa Barrage outside the study area. Population size within study area appears very low. Study area probably shares effective population with other areas due to marine life phase but extent of sharing is unknown and also relies on connectivity that is expected to reduce under climate change. Gene pool is likely to be highly restricted given recent abundance data and presence of fish barriers preventing upstream migration to spawning areas. The species should be conservatively considered at high risk but with low confidence due to lack of specific knowledge of population genetic structures and effective population size.*	**L**	**H**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Current distribution and abundance difficult to ascertain without targeted investigations as species is cryptic as both adult and juvenile. In recent times adults are rarely seen, but formerly they could be seen in large numbers in the lower Murray on their spawning run at migration barriers such as weirs. There are recent records of this species from below the Goolwa Barrage. Ammocetes are reasonably common in suitable silty habitats (Lintermans 2007). Historically not well known in the River Murray, but was apparently common although not overly abundant. Currently moderately abundant in some rivers within its range (SAAB 2001). *Difficult to assess due to a lack of confirmed records and cryptic nature of species. Population size indicates very low abundance reducing chances of good gene flow. Formerly seen in mass migrations to spawn upstream that would have increased chances of genetic mixing but this is no longer seen in the SAMDB. The species should be considered at high risk but with low confidence due to lack of specific knowledge of population genetic structures and size of effective population.*	**L**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	No specific studies on phylogeny within species, some evidence of species specific evolution of trypsin inhibitor (would help protect the cellular lining of its highly folded internal walls from its own proteolytic secretion) different in *M. mordax* compared to other southern hemisphere species (Gillet et al 1996). Current distribution and abundance difficult to ascertain without targeted investigations as species is cryptic as both adult and juvenile. There are recent records of this species from below the Goolwa Barrage. Ammocetes are reasonably common in suitable silty habitats (Lintermans 2007). Historically not well known in the River Murray, but was apparently common although not overly abundant. Currently moderately abundant in some rivers within its range (SAAB 2001). *Difficult to infer from current knowledge of population dynamics and no specific studies into genetic structuring of populations within study area. Indication of evolution of certain traits within the species but drivers are unknown and do not suggest phenotypic plasticity within the species per say. No indication of any geographic or other variation in species and so is probably at high risk but with low confidence due to lack of specific studies.*	**L**	**H**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change? <u>Populations have probably declined throughout study area and SA MDB generally. Some ammocetes recently found downstream of study area below Goolwa Barrage (D. McNeil pers. comm. 2010).</u>	Generally restricted to the lower to mid Murray River in the Basin, in recent times adults are rarely seen, formerly they could be seen in large numbers in the Lower Murray on their spawning run at migration barriers such as weirs (Lintermans 2007). Historically not well known in the River Murray, but was apparently common although not overly abundant. Currently moderately abundant in some rivers within its range (SAAB 2001).There are recent records of this species from below the Goolwa Barrage and ammocetes are reasonably common in suitable silty habitats (Lintermans 2007) but has not been recorded in Lower Lakes or Murray Estuary since 2007 (Bice 2010). Very few BDBSA records within SAMDB floodplain (4) since 1990 and only 2 within study area (BDBSA 2010). *Difficult to assess due to a lack of confirmed records and cryptic nature of species. Indication that species was never highly abundant within study area and seems to have undergone significant decline as the mass spawning runs in the Murray are no longer seen. Ammocetes are still reportedly found in reasonable numbers in suitable habitats but not clear whether this applies to study area. Population size within study area appears very low and showing some signs of stress. Study area possibly shares effective population with other areas due to marine life phase but extent of contribution unknown and relies on connectivity that is expected to reduce under climate change. The species should be considered at high risk but with medium confidence.*	**M**	**H**

	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity is in the moderate range for the fish species assessed in this study. Females have 3,800–13,400 small eggs which are deposited in a shallow nest (Lintermans 2007). Spawning occurs in Winter and Spring once over a short period (Bice 2010). Fecundity of 5000-13400 eggs is high according to Hughes and Potter (1969) (as cited in SAAB 2001). *Moderate fecundity when compared to other species assessed in this study but some authors describe it as highly fecund. Unclear as to whether 'fecundity' in the literature refers simply to birth rate or egg production or considers survivorship and reduces confidence in assessment. Species is probably at moderate risk but with medium confidence as egg/larval success rates for species are not described*	**M**	**M**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles take around 3.5 years to mature from the benthic, freshwater larval stage and live for 5-6 years (SAAB 2001). Fecundity is in the moderate range for the fish species assessed in this study. Females have 3,800–13,400 small eggs which are deposited in a shallow nest (Lintermans 2007). Young adults migrate upstream from the sea in spring and summer to breed in rivers (Lintermans 2007). Strong reliance on migration patterns and suitable freshwater habitats for spawning and growing to maturity (Hammer et al 2009). Downstream migrants need characteristics associated with winter flows (e.g. increase in flow and decrease in water temperature) to trigger downstream migration. Upstream migrants require characteristics associated with summer flows, (e.g. decrease in flow and increase in water temperature) (Sloane 1984; SAAB 2001). Can climb up wet vertical surfaces but weirs are still migration barriers (Lintermans 2007). *Species takes a long time to reach maturity (long generation time) and has a relatively moderate fecundity potential. Species also spends around half its life in the freshwater larval phase; these aspects raise risk to species. Main threat to successful recruitment however is associated with disconnection of the river system affecting spawning migrations and this would severely affect species capacity to recruit successfully. Climate change is expected to lead to increasingly managed/reduced flows and lower water levels and may reveal more fish barriers to spawning sites. Species should be considered at high risk*	**H**	**H**

Scientific Name:	*Nematalosa erebi*	Common Name:	Bony Bream

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Most widespread of Australia's native freshwater fish species, most common in lowland river systems but largely absent from upland habitats, probably due to low water temperatures (Lintermans 2007). More abundant in permanent wetlands (Smith et al 2009). It appears to prefer weedy areas with a mud substrate and is often found in very turbid waters. Robust and able to survive under a wide range of temperatures, salinities and other habitat conditions (SAAB 2001). *Seems to prefer slow flowing or still habitats and thrives in turbid water but survives wide range of conditions. Species should be considered at low risk .*	**H**	**L**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? <u>Very high mobility, can recolonise a stretch of river up to 200km long in one week (D. McNeil pers. comm. 2010).</u>	Daytime upstream movements recorded for juveniles and adults in Murray River, these movements are possibly related to colonisation of new habitats by juveniles and reproductive movements by adults (Lintermans 2007). Migratory patterns largely unknown but upstream migrations during the day of both adult and sub-adult fish have been recorded at the Torrumbarry fishway on the Murray River (SAAB 2001). Species has pelagic, surface drifting eggs (Bice 2010). *Little information in literature but no large scale migrations known, some daily movement noted, some movement to spawning areas suggested. Reportedly has very high mobility and can recolonise large tracts of river quite quickly. Pelagic eggs would require flow and connectivity of river system to effectively disperse but this is not quantified. Conservatively the species should be considered at high risk but with low confidence due to significant knowledge gaps.*	**L**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Omnivorous, consuming algal detritus, aquatic insects and crustaceans and potentially competes with European carp which has similar food and habitat requirements (SAAB 2001). Bony Bream are consumed by other fish such as Murray cod and Golden perch, and also form a significant part of the diet of waterbirds e.g. cormorants and Pelicans (Lintermans 2007). *Direct competition for food is possible but not quantified, predated on by a number of species. Species should be considered at moderate risk but with medium confidence due to knowledge gaps and lack of empirical studies.*	**M**	**M**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Hardy fish tolerating high temperatures (up to 38°C), high turbidity and high salinity (up to at least 39ppt), however is not tolerant of low water temperatures and is considered susceptible to the effects of cold-water pollution (Lintermans 2007). Wide tolerance to pH (4.8-8.6), prefers low flows but appears to be sensitive to low oxygen concentrations. Under drought conditions as streams dry and pools stagnate they are among the first fish to die from hypoxia. Cold water e.g. release of cold water from dams or reservoirs, is likely to increase their susceptibility to parasites and potentially pose a threat to population viability (SAAB 2001). *Generally a hardy species with wide environmental tolerances to salinity and pH. Most threatened by cold water pollution (e.g. dam water releases) but not an issue in study area. Stagnation and hypoxia may be a threat. Decreased flows, lower water heights and higher water temperatures may increase stagnation of some wetlands. Species should be considered at moderate risk.*	**H**	**M**

	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Tolerant of a wide range of environmental conditions except cold water. Omnivorous, consuming algal detritus, aquatic insects and crustaceans. Juveniles diet consists mainly of microcrustaceans (Lintermans 2007). Survival is threatened by hypoxic water, slow flow conditions preferred which may be linked to the associated increases in freshwater macrophyte growth and microhabitat provision. Wide tolerance to pH (4.8-8.6) but appears to be sensitive to low oxygen concentrations. Under drought conditions as streams dry and pools stagnate they are among the first fish to die from hypoxia. Survival of bony bream larvae, which are small and have a short period of yolk nutrition, is likely to be flood dependent (SAAB 2001). Large bodied fish (Bice 2010) and likely to have slower growth rate and spend longer as vulnerable juveniles. *Resilient species as an adult with wide environmental tolerances to salinity, pH and high temperature. Juveniles however have a narrower diet and are more susceptible to low temperatures. Larvae survival likely to be flood dependent and egg dispersal is also linked to flow and connectivity of the system (pelagic eggs). May be threatened by hypoxia where water is stagnant. These events may be increased through flow regulations and reductions expected under climate change. Species should be considered at high risk.*	**H**	**H**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawning in waters of shallow, sandy bays in October–February, in lower Murray (Lintermans 2007). Spawning triggered by temperatures above 20° C (Bice 2010). Spawning has been reported between December-January in the lower River Murray at water temperatures of 21-23°C, either immediately post-flood or 2-3 months after flooding, suggesting that this is a non-essential spawning cue in this environment. Lake Alexandrina appears to be a favoured breeding site for the species. Survival of bony bream larvae, which are small and have a short period of yolk nutrition, is likely to be flood dependent (SAAB 2001). *Species shows some response to flooding but mainly triggered by warm water temperatures in spring and summer. Climate change may alter seasonal temperature regimes and may affect breeding. Hydrological connectivity with preferred breeding areas downstream of study area may also be reduced under climate change. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Widespread and abundant distribution of wild populations (Lintermans 2007). Good potential for genetically healthy and diverse populations. Widespread, prolific and abundant. Found in higher densities than other large native freshwater fish (which are tending to show severe population declines) in the highly regulated lower River Murray (SAAB 2001). *Widespread, abundant and dispersive, unlikely to be limited by gene pool. Species should be considered at low risk*	**H**	**L**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Specific studies are lacking. Given the restricted distribution in the Basin (only in lower reaches and Lakes) (Lintermans 2007; Smith et al 2009), genetic mixing between populations is likely to occur particularly given its high dispersal ability (Moore et al 2010) and high abundance (Lintermans 2007). *Species with good abundance and dispersive capacities are less threatened through gene flow limitations. While good potential for gene flow could be inferred, a lack of specific research reduces confidence. Species should be considered at low risk but with low confidence*	**H**	**L**

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Widespread and abundant distribution of wild populations (Lintermans 2007). Good potential for genetically healthy and diverse populations. Widespread, prolific and abundant. Found in higher densities than other large native freshwater fish (which are tending to show severe population declines) in the highly regulated lower River Murray (SAAB 2001). Within basin differences for the MDB suggest only minor though significant genetic differentiation. Further sampling throughout the MDB is warranted to determine the overall level of population differentiation (Moore et al 2010). *Few studies but indication of some genetic differentiation between populations. High abundance, widely distribution and dispersive nature of species reduce chance of evolution of different phenotypes. Species should be at moderate risk but with medium confidence due to lack of specific research.*	**M**	**M**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Most widespread of Australia's native freshwater fish species, largely absent from upland habitats probably due to low water temperatures (Lintermans 2007). Widespread, prolific and abundant, found in higher densities than other large native freshwater fish which are tending to show severe population declines in the highly regulated lower River Murray (SAAB 2001). *Widespread and abundant, unlikely to be limited by population size. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity potential is high, with 33,000–880,000 eggs produced, depending on fish size (Lintermans 2007). *High reproductive capacity, species should be considered at low risk.*	**H**	**L**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change? <u>At population scale, can have more than one brood (cohort recruitment) per year (D. McNeil pers. comm. 2010).</u>	Long-lived species living up to 10 years reaching maturity at 1 year (SAAB 2001). Relatively short generation time, in lower Murray males mature at 1–2 years and females at 2 years (Lintermans 2007).). It is possible that certain flood events may induce spawning and facilitate exceptional levels of recruitment, but in the lower Murray spawning is not flood-cued. Survival of bony bream larvae, which are small and have a short period of yolk nutrition, is likely to be flood dependent (SAAB 2001). Most widespread of Australia's native freshwater fish species, largely absent from upland habitats probably due to low water temperatures (Lintermans 2007). Widespread, prolific and abundant, found in higher densities than other large native freshwater fish which are tending to show severe population declines in the highly regulated lower River Murray (SAAB 2001). *High potential fecundity, time to maturity and high longevity reduces risk to species. While recruitment may be enhanced by flooding it is not explicitly dependent in lower Murray, survival of larvae may be and possibly linked to food availability. Can have more than one brood (cohort) per year and has a very large extant population base. Species should be considered at low risk.*	**H**	**L**

Scientific Name:	*Philypnodon grandiceps*	Common Name:	Flat-headed Gudgeon/Big-headed Gudgeon

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Typically a habitat generalist inhabiting a range of off-channel, lake and riverine habitats (Bice 2010). A benthic species that prefers slow-flowing areas of lowland streams or lakes and dams and is often found in weedy or muddy areas with abundant cover in the form or rocks or logs (Lintermans 2007). Most common in quiet waters, particularly lakes and dams with weedy or muddy bottoms, frequently found in estuaries and low altitude coastal streams with slow flow, mud substrate and aquatic macrophytes. Euryhaline, tolerates salinities from brackish to moderately saline (<20ppt). A relatively hardy fish as indicated by its presence in streams with poor water quality (SAAB 2001). *Like other small bodied native fish is considered a generalist but is commonly associated with structure and vegetative cover, muddy or weedy substrates but can tolerate degraded stream systems. Further habitat loss and channel clearing threatens species but species shows some resilience to water quality degradation. Species should be considered at moderate risk.*	**H**	**M**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Comprised 96% of drifting larval fish fauna in the Campaspe River between 1995 and 2001, with majority of downstream drift occurring in late spring/early summer. Flow regime appears to play little part in breeding, and the species does not routinely utilise the floodplain for larval development (Lintermans 2007). Several studies summarised by Hutchinson et al (2008), describe movement of large numbers, one study found large numbers accumulating downstream of barriers during flow increases suggesting obstruction of movement upstream. *P. grandiceps* has been recorded in mass migrations, especially between estuarine and freshwater reaches across weirs and other barriers to movement, although these movements are not associated with any specific aspect of their life history or the size class of individuals (Thacker et al 2008). *Dispersal of pelagic larvae definitely relies on connectivity and flow. Some migratory movements recorded possibly in response to flow variation. Climate change may reduce connectivity and alter flow regimes and this may affect species capacity to disperse and migrate. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Carnivorous ambush predator of aquatic insects, molluscs, tadpoles, crustaceans and small fish (Lintermans 2007). Lowered water levels force fish into open water and shallows where there may be increased aggregation and consequently predation, competition and disease transmission (Bice 2010). *Direct competition for food or resources not described. Lowered water levels and increasing drought frequency and magnitude through climate change raises threat. The species should be considered at moderate risk.*	**H**	**M**

Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Survival relies on availability of prey (zooplankton for larvae and juveniles, crustaceans , insects and fish for adults). Juveniles and adults can tolerate high salinity < 40ppt but require appropriate habitats e.g. muddy substrates with abundant vegetative or structural cover. Species has a short-term tolerance to low dissolved oxygen (<1mgL^{-1}) (Bice 2010). A relatively hardy fish as indicated by its presence in streams with poor water quality (SAAB 2001). *Juveniles and adults appear to have relatively broad survival tolerances of salinity, acidity and diet and not likely to be limiting. Shows capacity to tolerate degraded systems but requires abundant cover. Species should be considered at low risk.*	**H**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Hatching larvae require salinity < 12.3ppt and pH > 6.5 and availability of plankton. Juveniles and adults can tolerate high salinity < 40ppt but require appropriate habitats e.g. muddy substrates with abundant cover. Short-term resilience to low dissolved oxygen (<1mgL^{-1}) (Bice 2010). A relatively hardy fish as indicated by its presence in streams with poor water quality (SAAB 2001). *Larvae show vulnerability to moderate salinity and are sensitive to slightly lowered pH in early stages of life. Juveniles and adults are hardier and can withstand degraded water quality conditions including hypoxia. Young need abundant vegetation or structure for cover and food provision. Species should be considered at moderate risk.*	**H**	**M**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Breeds in spring and summer when water temperatures are between 18 and 27°C, requires parental care (male fanning eggs) (Lintermans 2007). Eggs require salinity <21ppt and pH >6.5, eggs require structure/vegetation for adhesion (Bice 2010). Their breeding biology appears to be typical for eleotrids, with the males defending a territory and guarding the eggs until hatching. Species probably reaches maturity by the end of first year, their total longevity is unknown (Thacker et al 2008). *Potential for salinisation (at high levels) and acidification to impact reproduction. Spawning habitat loss through lowered water levels (affecting connectivity) and channel clearing also a threat. Species should be considered at moderate risk.*	**H**	**M**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Thacker et al (2008), found no evidence for population genetic diversity in the MDB but interpretation of results was limited due to small sample sizes. Several studies summarised by Hutchinson et al (2008), describe movement of large numbers, one study found large numbers accumulating downstream of barriers during flow increases suggesting obstruction of movement upstream. *Current wide distribution, moderate abundance and records of movements of large numbers reduces risk of gene pool limitations. Species should be considered at low risk.*	**H**	**L**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Thacker et al (2008) found that regional populations did not differ much phylogentically or genetically. This suggests gene flow between populations. Several studies summarised by Hutchinson et al (2008), describe movement of large numbers, one study found large numbers accumulating downstream of barriers during flow increases suggesting obstruction of movement upstream. *P. grandiceps* has been recorded in mass migrations, especially between estuarine and freshwater reaches across weirs and other barriers to movement, although these movements are not associated with any specific aspect of their life history or the size class of individuals (Thacker et al 2008). Related haplotypes within *P. grandiceps* are found on either side of the Eastern Highlands in western Victoria and South Australia, although it is unclear whether populations mixed via coastal connections (between drainages adjacent to the Murray River mouth), or across the Eastern Highlands. Either is possible, as the Eastern Highlands are very subdued in this region, with little significant separation between north and south flowing drainages. Patterns are further complicated by water transfers via pumping from the MDB into Gulf of St Vincent drainages (Thacker et al 2008). *Given species distribution and capacity to move coupled with genetic evidence of mixing between regional populations at large scales reduces threat of gene flow limitations. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Thacker et al (2008) found evidence for population subdivision within the MDB however their results were poorly supported due mainly to small sample sizes. Related haplotypes within *P. grandiceps* were found on either side of the Eastern Highlands in western Victoria and South Australia. Pairwise population divergence analyses found significant differences between drainage basin boundaries but these differences did not correlate with geographical distance. Haplotype networks indicate regional population divergence and are supported by phylogenetic trees based on DNA sequence data (Thacker et al 2008). 253 records in BDBSA within SA MDB floodplain since 1990 indicating a wide current distribution with moderate abundance (BDBSA 2010). 4th most abundant native fish species in RMWBS 2004-7 with distribution from Vic border to Lower Lakes (Smith et al. 2009). *Genetic diversity measures indicate some regional population divergences though mechanisms are unclear. Geographic separation is likely to have contributed but likely that any variation is at scales larger than the study area (e.g. basin-scale). Widespread distribution and high mobility reduces opportunity for development of geographic variation. Species should be considered at moderate risk.*	**H**	**M**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Once widely distributed and abundant throughout MDB, current distribution is patchy, reasonably common in wetlands and tributaries of the Lower Murray and along the edges of the Lower Lakes in SA but absent or in decline in rest of Basin (Lintermans 2007). Bice (2010) describes presence and abundance in River Murray and Lower Lakes and largely absent from the Coorong. 253 records in BDBSA within SA MDB floodplain since 1990 indicating a wide current distribution with moderate abundance (BDBSA 2010). 4th most abundant native fish species in RMWBS 2004-7 with distribution from Vic border to Lower Lakes (Smith et al. 2009). *Records in BDBSA reflect pattern in literature of widespread abundance and distribution throughout the SA MDB floodplain region. Species should be considered at low risk.*	**H**	**L**

	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity is low and ranges from 500–900 eggs which are attached to solid objects such as rocks and wood (Lintermans 2007). Females produce between 1400 and 2300 eggs (McNeil et al 2009). *Low reproductive capacity compared to other fish assessed in this study. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Breeds in spring and summer when water temperatures are between 18 and 27°C, requires parental care (male fanning eggs). Species probably reaches maturity by the end of first year (Thacker et al 2008) and breeds in spring and summer (Lintermans 2007). Their total longevity is unknown (Thacker et al 2008). Hatching larvae require salinity < 12.3ppt and pH > 6.5 and availability of plankton, juveniles can tolerate high salinity < 40ppt but require appropriate habitats e.g. muddy substrates with abundant cover for successful recruitment to adult life stage (Bice 2010). 253 records in BDBSA within SA MDB floodplain since 1990 indicating a wide current distribution with moderate abundance (BDBSA 2010). 4th most abundant native fish species in RMWBS 2004-7 with distribution from Vic border to Lower Lakes (Smith et al. 2009). *Salinity, acidity and loss of spawning habitat are the main threats to recruitment success. Increased salinity/acidity problems are expected through climate change as is further loss of suitable habitats and connectivity through lowered water levels and flow. Reasonably good population base form which to recruit from reduces risk. Species should be considered at moderate risk.*	**H**	**M**

Scientific Name:	*Philypnodon macrostomus*	**Common Name:**	Dwarf Flathead Gudgeon

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change.	Dwarf flat-headed gudgeon reportedly prefer relatively calm waters and occur over mud and rock substrates or in weedy areas (Lintermans 2007). Coastal populations in southeastern Queensland indicates occurrence also over coarser substrates such as gravel and cobbles, and close to submerged cover such as leaf-litter accumulations, woody habitat and aquatic vegetation (Thacker et al 2008). Tolerant of brackish estuarine water to freshwater at altitudes of several hundred metres (SAAB 2001). Lowered water levels correspond to loss of aquatic vegetation habitats forcing fish into open water and shallows (Bice 2010). *Salinity requirements are from brackish to fresh but most commonly associated with structure and aquatic vegetation. Loss of habitat through lowered water levels/flows forces fish to areas where they are more vulnerable. Likely optimal habitat range will decrease under climate change. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Similar species, *P. grandiceps* comprised 96% of drifting larval fish fauna in the Campaspe River between 1995 and 2001, with majority of downstream drift occurring in late spring/early summer (Lintermans 2007). Some evidence of downstream migration on falling flows possibly to avoid desiccation (Hutchison et al 2008). *Dispersal of pelagic larvae definitely relies on connectivity and flow but this is inferred from a similar species as specific research is lacking, this reduces confidence in the assessment. Some migratory requirements also on receding water levels. Climate change may reduce connectivity and alter flow regimes and this may affect species capacity to disperse larvae and to avoid desiccation or stranding. Species should be considered at moderate risk but with low confidence due to lack of research.*	**L**	**M**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Predation (larval and adult) by alien fishes and interaction with the aggressive Eastern gambusia may be threats (Lintermans 2007). Lowered water levels force fish into open water and shallows where there may be increased aggregation and consequently predation, competition and disease transmission (Bice 2010). *Direct competition for food or resources is eluded to but not quantified in the literature. Some predation pressure and potentially negative interactions with Gambusia suggested but not verified. Lowered water levels and increasing drought frequency expected under climate change may force greater competition and disease risk. The species should be considered at moderate risk but with medium confidence due to lack of research.*	**M**	**M**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles and adults have a high tolerance to salinity (< 33ppt) and require pH > 5 (Bice 2010). Specific flow requirements unknown, but appears to favour quiet waters in association with mud or weedy bottoms. Diet not well studied but eats both live and dead food in captivity. Predominantly feeds on insects, insect larvae and crustaceans (SAAB 2001). *Juveniles and adults appear to have relatively broad survival tolerances of salinity, acidity and diet is not likely to be limiting. Species should be considered at low risk.*	**H**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Larvae have low tolerance for raised salinity (< 6.9ppt) and require habitat i.e. vegetation for refuge and feeding. Juveniles and adults have a higher tolerance to salinity (< 33ppt) and require pH > 5 (Bice 2010). Specific flow requirements unknown, but appears to favour quiet waters in association with mud or weedy bottoms. Diet not well studied but eats both live and dead food in captivity. Predominantly feeds on insects, insect larvae and crustaceans (SAAB 2001). *Eggs and larvae of species show relatively narrow growth tolerance to salinity and acidity. Larvae also require vegetation for attachment and as refuge for young and adults. Salinity and acidification are expected to become more variable under climate change. Early life stages of the species are particularly threatened, species should be considered at high risk.*	**H**	**H**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	In aquaria, breeding recorded at temperatures of 18-27°C. Do not regularly use floodplains for larval development (Lintermans 2007). Spawning independent of flow, adhesive eggs require structure/vegetation, triggered by water temperatures > 19^0 C, eggs are moderately salt tolerant to 21ppt and pH > 6.5, larvae will only tolerate mild salinity up to 6.9ppt (Bice 2010). Their breeding biology appears to be typical for eleotrids, with the males defending a territory and guarding the eggs until hatching. *Narrow temperature requirement to trigger breeding may be a threat as climate change is expected to alter seasonal temperature and flow regimes. Loss of critical spawning habitats poses additional risk as while eggs/juveniles are resilient to moderate salinity, aquatic vegetation may have tolerances well below these thresholds. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Very patchy abundance and distribution within the SA MDB (Hutchison et al 2008), regional populations show some genetic differences e.g. coastal and inland, but also variable within groups (Thacker et al 2008). 178 records in BDBSA within SA MDB floodplain since 1990, patchily distributed from Lower Lakes to Vic. Border. (BDBSA 2010). *Regular or seasonal large scale movement is not recorded for species. Genetic differentiation between regional populations suggests limited gene flow and effective gene pool may be restricted although variation within groups is noted for some regional populations. BDBSA records indicate a limited population consisting of several small regional populations. Actual range of movements is not quantified and this reduces confidence in assessment. Gene pool may be limited and species should be considered at moderate risk but with medium confidence due to knowledge gaps.*	**M**	**M**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Likely to be limited somewhat but mechanisms are poorly understood. Although regional populations in SA show considerable genetic variation (Hoese & Reader 2006), groupings do not follow obvious geographic divisions suggesting other mechanisms are influencing population genetics (Thacker et al 2008). Regional populations show some genetic differences e.g. coastal and inland, but also variable within groups (Thacker et al 2008). While the species is widely distributed, it shows considerable genetic variation over the range of the species but without any clear geographical pattern (Hoese & Reader 2006). *Genetic differentiation between regional populations from different studies suggests limited gene flow although similar variation within groups is noted for some regional populations. Gene flow is likely to be limiting but mechanisms are unclear. Species should be considered at high risk but with low confidence as further research is required.*	**L**	**H**

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Population genetic comparisons found differences between MDB and coastal populations but no evidence for population subdivision within the MDB however study sample sizes were too small for confidence in population genetics analysis (Thacker et al 2008). While the species is widely distributed, it shows considerable genetic variation over the range of the species. The intensity of coloration varies from light brown to almost black and fin ray counts vary considerably, but without any clear geographical pattern (Hoese & Reader 2006). *Appears likely that the species possesses a considerable degree of phenotypic plasticity as its morphological and genetic profile varies from one regional population to another. Populations within the study area may not be subdivided but interpretation is limited due to small sizes. Mechanisms behind morphological variation are also unclear. Species should be considered at low risk but with medium confidence due to limited specific research of MDB populations.*	**M**	**L**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	They occur in inland MDB but are patchily distributed. In the first two sampling rounds of the Sustainable Rivers Audit covering 16 river valleys encompassing 351 sampling sites, only 9 individuals were captured, all from the Lower Murray (Lintermans 2007). Very restricted distribution within the MDB, occurring in a few localities in the Murray River in SA and NSW, the upper reaches of the Macquarie River and in the lower Condamine River, as well as in coastal streams of SE Australia (Hutchinson et al 2008). 178 records in BDBSA within SA MDB floodplain since 1990, patchily distributed from Lower Lakes to Vic. Border. (BDBSA 2010). *Strong evidence for very limited regional population sizes in literature and verified by pattern in BDBSA data. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Exhibit protracted, serial or repeat spawning over extended period in late spring/summer, may have parental care/guarding (Bice 2010). Nothing is known of the reproductive biology in the wild but flatheaded gudgeon (*P. grandiceps*) fecundity is in the low range of 500-900 eggs (Lintermans 2007). *Fecundity for species not known, similar species has low fecundity and likely to be similar as similar spawning strategy. Species should be considered at high risk but with low confidence due to lack of species-specific knowledge.*	**L**	**H**

	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Hatching larvae require low salinity (<6.9ppt) and pH >6.5 to avoid mortality, juveniles can tolerate higher salinity (< 35ppt) and pH >5. Spawning triggered at warm temperature (>19°C) in spring and summer. Presence of structure is critical for spawning, egg attachment and larval development. Structure and vegetation is also important for juvenile and adult cover and influences recruitment success (Bice 2010). Species probably reaches maturity by the end of first year, their total longevity is unknown (Thacker et al 2008). Patchily distributed within the MDB. In the first two sampling rounds of the Sustainable Rivers Audit covering 16 river valleys encompassing 351 sampling sites, only 9 individuals were captured, all from the Lower Murray (Lintermans 2007). *Salinity, acidity and loss of spawning habitat are the main threats to recruitment success within the study area. Increased salinity/acidity problems are expected through climate change as is further loss of suitable habitats (through lowered water levels and degradation of aquatic vegetation). Species matures quickly (within a year) thereby reducing risk but longevity is unknown. Population base form which to recruit from, especially within the study area is also very low. Species should be considered at high risk but with medium confidence due to gaps in knowledge of fecundity and longevity of the species.*	**M**	**H**

Scientific Name:	Retropinna semoni	**Common Name:**	Australian Smelt

Question		**Comments/ Reference**	**Confid**	**Vul Ranking**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Generalist fish found in all regions of the Murray, prefers permanent wetlands (Smith et al 2009). Larvae, juveniles and adults occur amongst submerged macrophytes and debris, which affords protective cover (Cadwallader 1979). Not generally found in upland headwater streams with fast flows (Lintermans 2007) but a study by Wedderburn (2000) in the Lower River Murray found a positive association between this species and both flowing and highly turbid water. Various slow flowing or still water habitats including main channel, lakes, weir pools and wetlands (Bice 2010). Species shows a very high tolerance to raised salinity and survives pH > 5 (Bice 2010) and has also been found in very turbid waters (Cadwallader 1979). *Generalist habitats requirements. Species occupies a range of habitats throughout the study area including waters with high salinity and turbidity. Conflicting evidence suggesting preferences for lentic or lotic conditions supports theory that species is a habitat generalist. Species unlikely to be limited by habitat requirement s and should be considered at low risk.*	**H**	**L**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Present and abundant in all regions of the River Murray (Smith et al 2009). Daily upstream migration patterns observed during daylight hours (Lintermans 2007). Longitudinal movement of thousands of Australian smelt observed in new fishways on the Murray River. Occasionally managed as 'wetland specialists' but actually appear to have a more flexible movement and life history strategy including riverine habitation (Lyon et al 2010). Other species of retropinnid are anadromous, and it is possible that smelt larvae are washed downstream to the sea in coastal drainages and spend some of there life there. This is unsubstantiated but is supported by the lack of larval smelt in the lower Barwon River following a high flow (studies cited in SAAB 2001). *Fish barriers may restrict movement and prevent eggs ansd larvae from dispersing e.g. to sea if anadromous like other retropinnids. This is not quantified but implicitly supported by larval distribution studies thus reducing confidence in the assessment. Increased fragmentation of habitat and disconnection of river system is expected under climate change. Species should be considered at moderate risk but with medium confidence due to lack of empirical knowledge of dispersive capacities.*	**M**	**M**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Diet consists primarily of terrestrial insects and microcrustaceans, although a variety of small aquatic insects are also consumed (Lintermans 2007). The exotic *Gambusia holbrooki* may pose a threat as it would be especially susceptible to damage associated with fin nipping and subsequent infection (SAAB 2001). Susceptible to infestation by a protozoan and several nematode parasites. Also susceptible to fungal infections by Saprolegnia and some populations can be affected by a parasitic nematode worm which encysts in the muscle (various studies cited in SAAB 2001). Said to only exist in trout-free water bodies (McNeil et al 2009). *Direct competition for food or other resources is not mentioned in literature and varied diet requirements reduce this risk. Theoretically suffers competition with aggressive Gambusia (small-bodied fish with similar diet) for food and habitat and may be more susceptible to disease through injury. Competitive effects are not quantified thus reducing confidence in assessment. Trout predation is not a likely threat within study area. Species should be considered at moderate risk but with medium confidence due to lack of specific knowledge.*	**M**	**M**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Adults have a very high tolerance to salinity (< 59ppt) and pH > 5 (Bice 2010). Food availability is the main limiting factor to adult survival and growth, evidence of compensatory growth in line with food availability (Tonkin et al 2008). Consumes a wide range of planktonic organisms, mainly carnivorous but also thought to eat algae i.e. may be omnivorous and able to switch diets according to availability (studies cited in SAAB 2001). *Wide water quality tolerance levels in adult phase. Generalist diet means food unlikely to be limiting as can switch according to availability. Environmental degradation, e.g. water quality issues may affect food web and impact species indirectly but not identified as threat in literature. Compensatory growth is an advantage in variable climate/conditions. Species should be considered at low risk.*	**H**	**L**

	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Juveniles have moderate tolerance to salinity < 28ppt, pH > 5 and low oxygen <2mgL^{-1} (Bice 2010). Food density has greatest influence on growth, evidence of compensatory growth in line with food availability (Tonkin et al 2008). Consumes a wide range of planktonic organisms, mainly carnivorous but also thought to eat algae i.e. may be omnivorous and able to switch diets according to availability (studies cited in SAAB 2001). *Species generally shows wide environmental tolerances but early life stage may be more sensitive. The ability to compensate for setbacks in growth is important adaptation in fluctuating and unpredictable environments. Species should be considered at low risk.*	**H**	**L**
	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawning occurs when water temperatures reach about 11–15°C, generally in spring and early summer, up to 9 months of the year in some rivers (Lintermans 2007) and up to 6 months in other areas (Humphries et al 1999). Require structure for spawning sites (Bice 2010). *Relatively broad and extended spawning season and do not need high temperatures (e.g. > 20 ^{0}C) in order to start spawning. Can spawn over large part of the year. Species should be considered at low risk.*	**H**	**L**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Wide dispersal and naturally divided in inland waters, populations are exposed to isolation and significant genetic divergence. Upper Murray-Darling, Lower Murray and Tasmanian regional allele clusters form distinct groups (Hammer et al 2007). *As one of most abundant and widespread species in south eastern Australia it has a very large potential gene pool. Genetic divergence in isolated populations adds to genetic diversity. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Distinct genetic groups identified in regional populations suggests gene flow between populations is limited (Hammer et al 2007). Fish barriers thought to be fragmenting populations (Lintermans 2007). *Gene flow may be impacted severely by increasing disconnection and further fragmenting populations leading to genetic isolation and weakness. Species should be considered at high risk*	**H**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Widely dispersed but naturally divided inland waters where it breeds and is thus exposed to isolation and genetic divergence. However morphological differences in retropinnids is limited (Hammer et al 2007). *Phenotypic, geographic or morphological variation is not described in the literature. Identification of distinct genetic groups means some flexibility is apparent but drivers are unknown and may be simply genetic isolation and drift. Limited gene flow between isolated populations limits potential for different phenotypic expression as populations are more likely to be genetically homogenous. Species should be considered at high risk.*	**H**	**H**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Present and abundant in all regions of the River Murray, preference for permanent wetlands (Smith et al 2009). One of most abundant and widespread species in south eastern Australia (Lintermans 2007). Highly abundant according to RMWBS 2004/7 (Smith et al. 2009). *Large and widely distributed population increases the species resilience to climate change impacts. Species should be considered at low risk.*	**H**	**L**

	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Fecundity is low and ranges from 100 to 1000 eggs depending on fish size (Lintermans 2007). *Low fecundity and reproductive capacity lowers species ability to tolerate climate change. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Both sexes mature by end of first year and may live two or more years, although most only live for a year. In Lower Murray, smelt are multiple batch spawners and females produce discrete batches of eggs every 3–4 days (Lintermans 2007). Recruitment occurs for approximately 6 months of the year, although most successful recruitment times may be limited (Humphries et al 1999). Largely annual life cycle, recruitment failure could be catastrophic for a given population (Bice 2010). *Short generation time and short time to maturity i.e. short life cycle reduces risk of impacts of climate change. Any recruitment failure from one year to the next however may severely damage a population due to annual life cycle, this raises the threat level. Large regional population base from which to recruit from. Species should be considered at moderate risk.*	**H**	**M**

Scientific Name:	*Tandanus tandanus*	**Common Name:**	Freshwater (Eel-tailed) Catfish

Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Freshwater Catfish prefer slow flowing habitat such as rivers and wetlands with reasonable levels of structure including snags, undercut banks and aquatic plants (Hammer et al 2009). Tend to primarily be associated with benthic areas within its habitat. Spawning habitat is typically a flooded, shallow area within main rivers or quieter backwaters. Since this species does not undertake long distance movements and tends to remain within a fairly restricted location (Reynolds 1983) the adult habitat in general is likely to be the same as that selected for spawning (SAAB 2001). Long periods of low flow and subsequent settlement and build up of silt is likely to interfere with their bottom feeding behaviour (smother productive surfaces), nesting requirements (coarse particles being covered with fine silts), and general habitat requirements (loss of structure and aquatic vegetation). Hence significant river regulation and loss of flow volume (only one third or less of the natural flow now reaches SA) and flushing flows/floods on the River Murray are likely to be a long term threat (Hammer et al 2009). *Freshwater specialist associated with structure, aquatic plants and benthic environment. Increasing threat of silting of habitat and turbidity with altered/managed flows. Low tolerance to high salinity increases threat directly and through disruption of food webs based on freshwater aquatic biota. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Freshwater Catfish do not appear to undergo long-distance movements in South Australia, current distribution is patchy, recent records limited to a handful of locations from wetlands and the main Murray channel (Hammer et al 2009). Relatively sedentary species and adults show very limited movement; most individuals move less than 5 km (Lintermans 2007). Tend to remain in the same river section for most of their life (Reynolds 1983). *Species appears largely sedentary and has limited dispersal and mobility capacities/requirements. Unlikely to suffer pressure through increased fish barriers under climate change (through reduced water levels/flow) as no strict requirement to migrate. Localised threats when an area is rendered unsuitable (e.g. salinisation) as resident fish may be killed or displaced. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Overlap of diet and potential competition with Carp and direct interaction e.g. nest disturbance by Carp (Hammer et al 2009) and Redfin perch (Lintermans 2007), especially considering the high abundance of Carp in lowland river reaches including the River Murray within the study area (Hammer 2009). *Overlap in diet with Carp and nest disturbances identified as major potential threats to species. Species should be considered at high risk.*	**H**	**H**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Food availability (microcrustaceans) is important and may be affected by reductions in water quality. Adults have a low tolerance to salinity (<18ppt) (Bice 2010). Silting of riverbed in low-flow conditions interfering with bottom-feeding activity (Hammer et al 2009). Changes to natural flow regimes and elevated salinity are suspected causes of declining local populations (Lintermans 2007). Preference for still or slow-flowing waters is possibly indicative of a tolerance to low oxygen. Tolerant of a wide temperature range of (4-38°C) but does not survive well below 4°C (SAAB 2001). *Strong evidence for flow regulation (low volumes) has major effects on habitat and water quality critical for survival. Management of flows and general flow reduction is expected to increase with climate change raising threat to species. Salinity problems (more temporary saline, less permanent freshwater wetlands) expected to increase with climate change raising threat as species shows low tolerance. Species should be considered at high risk.*	**H**	**H**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Larvae have a lower tolerance to salinity than juveniles and adults (< 11.4ppt compared with 19ppt, pH needs to be > 5. (Bice 2010). Relies on availability of prey including fish, shrimps, freshwater prawns, yabbies, and other macroinvertebrates which are mostly taken from the river bottom (Hammer et al 2009). Silting of riverbed in low-flow conditions interfering with bottom-feeding activity (Hammer et al 2009). Changes to natural flow regimes and elevated salinity are suspected causes of declining local populations (Lintermans 2007). Fish mature from 2-5 years of age and probably can live for 12 or more year (Hammer 2009). *Strong evidence for flow regulation (low volumes) has major effects on habitat and water quality critical for survival. Management of flow, flow volume reductions and salinity problems are expected to increase with climate change raising threat to species. Early life stage show greater susceptibility to degraded water quality than adults. Probably slow-growing as is a large, long-lived species maturing after 2 or more years. Species should be considered at high risk.*	**H**	**H**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Spawn in spring and summer when water temperatures are 20–24°C, it has been suggested that there may be multiple spawnings in a single nest in a season, either sequentially or concurrently (Lintermans 2007). Hatching larvae have low tolerance to salinity (<11.4ppt) and pH<6.5 (Bice 2010). Long periods of low flow and subsequent settlement and build up of silt are likely to interfere with nesting requirements (coarse particles being covered with fine silts) (Hammer 2009). *Changes to natural flow regimes and elevated salinity levels threaten species at early stage of life. Salinity and silting of nesting habitats are identified as major threats to reproductive success. Cold water pollution under increased river regulation also poses threat to reproduction. Species should be considered at high risk.*	**H**	**H**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	There is no current evidence for natural genetic structuring within the MDB. Unless data becomes available to the contrary it can be thought of as a single stock within the Basin, this is not expected given the fragmentation of the system (Moore et al 2001). Current distribution is patchy. Recent records limited to handful of locations from wetlands and main Murray channel including juveniles from wetland habitat at Chowilla, Blanchetown, Mypolonga, Murray Bridge, Tailem Bend and Wellington (Hammer 2009). Most riverine populations have declined significantly since the late 1970s/early 1980s, and the species is no longer common in many areas where it was formerly abundant (Lintermans 2007). Listed as endangered in SA, vulnerable in NSW and threatened in Vic (Hammer 2009). Only 18 records since 1990 within SA MDB floodplain, widely distributed from just below Wellington to border (BDBSA 2010). Relatively sedentary species and adults show very limited movement; most individuals move less than 5 km (Lintermans 2007). Tend to remain in the same river section for most of their life (Reynolds 1983). *BDBSA records confirm patchy distribution and abundance patterns cited in literature. Population size is small and fragmented and available gene pool likely to be limiting especially given sedentary nature of species. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Phylogeographic investigations found that MDB populations clustered into a single clade derived from populations inhabiting eastern drainages. Unless data becomes available to the contrary it can be thought of as a single stock within the Basin (Moore et al 2010). Current distribution is patchy. Recent records limited to handful of locations from wetlands and main Murray channel including juveniles from wetland habitat at Chowilla, Blanchetown, Mypolonga, Murray Bridge, Tailem Bend and Wellington (Hammer 2009). Relatively sedentary species and adults show very limited movement; most individuals move less than 5 km (Lintermans 2007). Tend to remain in the same river section for most of their life (Reynolds 1983). Small population size combined with habitat fragmentation may lead to lower heterozygosity in riverine populations (Moore et al 2010). *Strong evidence for restricted gene flow among regional populations given species current distribution and abundance coupled with its lack of movement. Genetic evidence supports theory of fragmentation leading to homogeny of gene profile through inbreeding regional populations. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Phylogeographic investigations found that MDB populations clustered into a single clade derived from populations inhabiting eastern drainages. Unless data becomes available to the contrary it can be thought of as a single stock within the Basin. Small population size combined with habitat fragmentation may lead to lower heterozygosity in riverine populations (Moore et al 2010). *Species does not show any geographic variance among wild regional populations within the MDB, formation of single clade indicates species is not phenotypically flexible in this geographic range. Climate change may further fragment habitats and isolate populations and could increase homozygosity in regional populations. Species should be considered at high risk.*	**H**	**H**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Current distribution is patchy. Recent records limited to handful of locations from wetlands and main Murray channel including juveniles from wetland habitat at Chowilla, Blanchetown, Mypolonga, Murray Bridge, Tailem Bend and Wellington (Hammer 2009). Most riverine populations have declined significantly since the late 1970s/early 1980s, and the species is no longer common in many areas where it was formerly abundant (Lintermans 2007). Listed as endangered in SA, vulnerable in NSW and threatened in Vic (Hammer 2009). Only 18 records since 1990 within SA MDB floodplain, widely distributed from just below Wellington to border (BDBSA 2010). Listed as 'endangered' and in 'probable decline' in the DENR Murraylands region and in the Murray Mallee and Murray Scroll Belt IBRA sub-regions under IUCN criteria (Gillam and Urban 2010). *BDBSA records confirm patchy distribution and abundance patterns cited in literature. Population size likely to highly limit the species resilience, recovery capacity and ability to tolerate climate change. Species should be considered at high risk.*	**H**	**H**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Fecundity is size dependent; 2,800-20,600 eggs in females between 390-530 mm long; 2,000-20,600 eggs in fish weighing 0.675-2.275 kg; 18,000-26,000 in females 1.25-2.0 kg (studies cited in SAAB 2001). *Fecundity is in the low range and varies dependent on fish size. Reproduction capacity in hence limited so the species should be considered at high risk.*	**H**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Individuals are sexually mature at 3–5 years of age and spawn in spring and summer when water temperatures are 20–24°C, it has been suggested that there may be multiple spawnings in a single nest in a season, either sequentially or concurrently (Lintermans 2007). Fish mature from 2-5 years of age and probably can live for 12 or more year (Hammer 2009). *A long-lived species but takes a long time to reach sexual maturity (long generation time) that lowers the species recruitment capacity. Fecundity is in the low range and recruitment success may be also be affected by cold water pollution and salinisation that are expected to increase under climate change. Species should be considered at high risk.*	**H**	**H**

Scientific Name:	*Tasmanogobius lasti*	Common Name:	Lagoon Goby

Question		Comments/ Reference	Confid	Vul Rating
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	Really an estuarine species in areas of freshwater discharge but can also complete its lifecycle in freshwater streams and lakes. Usually recorded in still or slow-flowing habitats with mud or silty sand substrates, benthic, burrowing species (Lintermans 2007). Principally confined to the Lower Lakes and Lower Swamps regions (Smith et al 2009). Known to occasionally use freshwater habitat (Stuart et al 2005). Common in Coorong and Lower Lakes, mostly in Murray Estuary but also North Lagoon. Prefer still or slow-flowing water over silt or mud substrate with structure e.g. rocks, vegetation, in estuarine and adjacent freshwaters (Bice 2010). Classed as a habitat generalist, gobies were exclusively sampled in shallow areas with sandy or muddy habitats and moderate cover for sites below Wellington (Rowntree and Hammer 2007). *As a habitat generalist, species is not likely to be limited by habitat alterations within the study area under climate change. Possibility range of species may actually extend through increased salinity in traditionally freshwater habitats upstream of Wellington. Reduced flow volumes and velocities may also provide added silt/mud bottom types preferred by the species. Species should be considered at low risk.*	**H**	**L**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Known to migrate along river, small numbers captured at fishways at Tauwitchere barrage on downstream and upstream flows (Stuart et al 2005). Newly emergent larvae of a similar estuarine goby species (Bluespot goby *Pseudogobius olorum*) are planktonic and are swept downstream to estuaries upon hatching. They gradually migrate upstream into freshwater as they grow, although this does not occur in landlocked populations (Allen 1989 as cited in SAAB 2001). 61 of 65 records within SAMDB floodplain since 1990 are located in Lower Lakes region, remaining records distributed sparsely from Younghusband to Wellington (BDBSA 2010). *Barriers to fish movement e.g. weirs, locks and river disconnection impede the movement of the species. Hatched larvae of similar species are reliant on flow for dispersal downstream and to estuaries. Increase river and wetland disconnection and reduced flow and lower river heights are expected under climate change and would exacerbate the presence of fish barriers and restrict movement and dispersal of species. Current BDBSA records show that the system may already be affecting distribution of species due to artificial disconnection of Lower Lakes from River Murray. Species should be considered at high risk but with medium confidence due to lack of species-specific studies.*	**M**	**H**

	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Similar estuarine goby species are an important prey item for a number of waders including heron and cormorant (Larson and Hoese 1996; McDowall 1996 both as cited in SAAB 2001). Diet of larvae likely to consist mainly of microcrustaceans while juveniles consume amphipods and benthic larvae. Adult diet is not described (Bice 2010). *A lack of species-specific studies limits interpretation however is likely to be analogous to similar estuarine goby species. Conspecific competition is not identified as a limiting factor. As a small-bodied species, predation may be a main factor as similar goby species are known to form a major part of the diet of a number of water birds. Diet is also reasonably narrow (zooplankton) and may suffer in limiting environments. Species should be considered at moderate risk but with medium confidence due to lack of species-specific studies.*	**M**	**M**
Physiology	To what extent do ***survival tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Classed as a habitat generalist, gobies were found in shallow areas with sandy or muddy habitats and moderate cover for sites below Wellington (Rowntree and Hammer 2007). Tolerant of a wide range of salinities (Smith et al 2009). Hatching larvae and juveniles have a high tolerance to salinity (35ppt and 72ppt respectively), and low dissolved oxygen (< 1mgL^{-1}). Observed in MDB in Coorong at salinities between 1-35ppt and tolerant of water temperatures to 26^{0} C. Diet of larvae likely to consist mainly of microcrustaceans while juveniles consume amphipods and benthic larvae. Adult diet is not described (Bice 2010). Usually recorded in still or slow-flowing habitats with mud or silty sand substrates, benthic, burrowing species (Lintermans 2007), may imply a tolerance to turbidity as suggested for other goby species (SAAB 2001). *As a habitat generalist, species shows tolerance to a wide range of environmental conditions and is unlikely to be limited by changes to these parameters within the study area under climate change. Species should be considered at low risk.*	**H**	**L**
	To what extent do ***growth tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Tolerant of a wide range of salinities (Smith et al 2009). Hatching larvae and juveniles have a high tolerance to salinity (35ppt and 72ppt respectively), and tolerate low dissolved oxygen (< 1mgL^{-1}). Diet of larvae likely to consist mainly of microcrustaceans while juveniles consume amphipods and benthic larvae. Adult diet is not described (Bice 2010). Similar goby species e.g. Bridled goby, feed on planktonic and benthic aquatic invertebrates, small fish, and algae, and also obtain food by sifting through the substrate (Harris 1995). *As a habitat generalist, adults of the species show a high tolerance to a wide range of environmental conditions and are unlikely to be limited by changes to these parameters within the study area under climate change. Early life stages also show a high degree of resilience to different conditions. Small-bodied species that probably grows quickly to maturity and has a short life-span. Species should be considered at low risk.*	**H**	**L**

	To what extent do ***reproductive tolerances*** limit the ability of the regional population of the species to tolerate climate change?	Largely not described, possibly spawns in burrows in spring and male guards nest like other goby species. Hatching larvae likely have a high salt tolerance but pH must be >6.5, eggs also possibly have high tolerance to salinity like other goby species (Bice 2010). Similar estuarine goby species (Bluespot, Bridled, Tamar River gobies), typically spawn in the upper reaches of estuaries in lower salinities, usually in areas where aquatic vegetation is thick and usually burrow under rocks or tree roots (various studies cited in SAAB 2001). However, estuarine spawning is not an obligatory part of their lifecycle and some populations are completely landlocked (Allen 1989 as cited in SAAB 2001). Spawning sites for the Lagoon goby are thought to be restricted to the estuary in the MDB (Bice 2010). *Lack of species-specific studies and uncertainty if species actually spawns in study area lowers confidence in assessment. Eggs and larvae in similar gobies, show high tolerance to a range of conditions but structure and/or dense aquatic vegetation is requirement in spawning sites and this may be at some risk of loss under climate change. Bice (2010) concluded that spawning is restricted to the Murray Estuary (i.e. outside the study area), however other authors remark that estuarine spawning is not obligatory e.g. for landlocked populations. It is unclear whether land locked populations occur in the study area but is likely given disconnection of the system and recent, though patchy, biological records. Species should be considered at moderate risk but with low confidence due to lack of regional and species-specific studies into reproduction.*	**L**	**M**
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Relatively common and widespread estuarine species in coastal streams of Vic, SA and Tas. In the Basin, is known only from the Lower Lakes (Alexandrina and Albert) and Coorong where it is widely distributed but not abundant. Its distribution extends a small distance upstream into the main channel and wetlands of the Lower Murray (Lintermans 2007). Limited number of known locations within a limited area of occupancy within South Australia (Hammer et al 2009). One of least abundant native fish species with patchy distribution confined to Lower Lakes and Swamps. Update of EPBC listing recommended for the SA MDB based on limited distribution and abundance (Smith et al 2009). 61 of 65 records within SA MDB floodplain since 1990 are located in Lower Lakes region, remaining records distributed sparsely from Younghusband to Wellington (BDBSA 2010). *Strong indication that population size, especially with study area above Wellington, is severely restricted. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Hoese (1991) identified considerable variation in several characteristics (e.g. head pore and scale patterns, and dorsal, pectoral and caudal ray counts) of the species. These variations are manifested in different geographic regions, e.g. populations on different islands, and suggest a highly variable species (Hoese 1991). Limited number of known locations within a limited area of occupancy within South Australia (Hammer et al 2009), and a limited distribution within the MDB (Rowntree and Hammer 2007). Update of EPBC listing recommended for the SA MDB based on limited distribution and abundance (Smith et al 2009). 61 of 65 records within SA MDB floodplain since 1990 are located in Lower Lakes region, remaining records distributed sparsely from Younghusband to Wellington (BDBSA 2010). *The occurrence of morphologically different examples of the same species may be interpreted as restricted gene flow between regional populations that lead to the entrainment of these differences. This conclusion however is based on studies of isolated populations on different islands and not within the study area and reduces confidence. The low abundance and patchy distribution of species within the study area also reduces chance of good gene flow. Species should be considered at high risk but with medium confidence due to lack of studies of populations within the study area.*	**M**	**H**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Insufficient data to assign separate genetic management units within the MDB (Moore et al 2010). Hoese (1991) however, identified considerable variation in several characteristics (e.g. head pore and scale patterns, and dorsal, pectoral and caudal ray counts) of the species. These variations are manifested in different geographic regions, e.g. populations on different islands, and suggest a highly variable species (Hoese 1991). *Identified in literature as a highly variable species according to meristic and morphological differences noted across several regional populations in Australia though not in the study area. This evidence of significant variation indicates the species has a high capacity for phenotypic plasticity. Species should be considered at low risk but with medium confidence as conclusions based on the work of Hoese (1991) did not include the River Murray or the study area specifically.*	**M**	**L**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Relatively common and widespread estuarine species in coastal streams of Vic, SA and Tas. In the Basin, is known only from the Lower Lakes (Alexandrina and Albert) and Coorong where it is widely distributed but not abundant. Its distribution extends a small distance upstream into the main channel and wetlands of the Lower Murray (Lintermans 2007). Limited number of known locations within a limited area of occupancy within South Australia (Hammer et al 2009), and a limited distribution within the MDB (Rowntree and Hammer 2007). Update of EPBC listing recommended for the SA MDB based on limited distribution and abundance (Smith et al 2009). 61 of 65 records within SA MDB floodplain since 1990 are located in Lower Lakes region, remaining records distributed sparsely from Younghusband to Wellington (BDBSA 2010). *Pattern of records in BDBSA reflects abundance and distribution as suggested in the literature. Population size, particularly in the study area above Wellington in likely to be highly limiting according to these data. Species should be considered at high risk.*	**H**	**H**

	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change? Species invests in parental care rather than producing large numbers of eggs (D. McNeil pers. comm. 2010).	Fecundity of a similar estuarine goby species (Bluespot goby *Pseudogobius olorum*) is reported to reach 150 eggs per female (Cadwallader and Backhouse 1983; Allen 1989 both as cited n SAAB 2001). *Fecundity of species is likely to be in line with similar estuarine goby species however this lack of specific research reduces confidence in assessment. Fecundity of similar species is definitely in the low range compared to other fish species assessed in this study and species invests in parental care (guarding/fanning). Species should be considered at high risk but with low confidence as information is derived from similar goby species.*	**L**	**H**
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	A similar estuarine goby species (Bridled goby Amoya bifrenatus) lives for 3-4 years (SAAB 2001) and probably reaches breeding maturity by its first year (McNeil et al 2009). Similar estuarine goby species (Bluespot, Bridled, Tamar River gobies), typically spawn in the upper reaches of estuaries in lower salinities, usually in areas where aquatic vegetation is thick and usually burrow under rocks or tree roots (various studies cited in SAAB 2001). However, estuarine spawning is not an obligatory part of their lifecycle and some populations are completely landlocked (Allen 1989 as cited in SAAB 2001). Spawning sites for the Lagoon goby are thought to be restricted to the estuary in the MDB (Bice 2010). *Lack of specific studies and uncertainty if species actually spawns in study area lowers confidence in assessment. Probably short lived and matures quickly (typical of small-bodied fish) so risk is reduced through short generation times. Eggs and larvae in similar gobies, show high tolerance to a range of conditions but structure and/or dense aquatic vegetation is a feature of spawning sites and this may be at some risk of loss under climate change. Bice (2010) concluded that the spawning is restricted to the Murray Estuary (i.e. outside the study area), however other authors remark that estuarine spawning is not obligatory e.g. for landlocked populations. It is unclear whether species uses study area for spawning and recruitment. If it does, there is some risk of limitation through environmental degradation particularly of dense aquatic vegetation spawning habitat. Species should be considered at moderate risk but with low confidence due to lack of regional and species-specific studies.*	**L**	**M**

FISH REFERENCES

SMITH, B.B., CONALLIN, A. & VILIZZI. 2009. 'REGIONAL PATTERNS IN THE DISTRIBUTION, DIVERSITY AND RELATIVE ABUNDANCE OF WETLAND FISHES OF THE RIVER MURRAY, SOUTH AUSTRALIA'. TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA, VOL. 33(2): 339–360

Lintermans, M. 2007, *Fishes of the Murray-Darling Basin: An introductory guide*.
MDBC Publication No. 10/07. ISBN 1 921257 20 2

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*, Vol. 61: 271–278

Bice , C. 2010. Literature review of the ecology of fishes of the Lower Murray, Lower Lakes and Coorong. Report to the South Australian Department for Environment and Heritage. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 81 pp. SARDI Publicartion No. F2010/000031-1

TONKIN, Z., KING, A. J. & RAMSEY, D. S. L. 2008. 'Otolith increment width responses of juvenileAustralian smelt Retropinna semoni to sudden changes in food levels: the importance of feeding history'. Journal of Fish Biology, Vol.73: 853–860.

Humphries, P., King, A. J. & Koehn, J. D. 1999. 'Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia'. *Environmental Biology of Fishes.Vol. 56*: 129–151.

Hammer, M. P., Adams, M., Unmack, P. J. & Walker, K. F. 2007. 'A rethink on Retropinna: conservation implications of new taxa and significant genetic sub-structure in Australian smelts (Pisces : Retropinnidae)'. *Marine and Freshwater Research*. Vol. 58: 327–341.

Moore, A., Ingram, B.A., Friend, S., King Ho, H., Robinson, N., McCormack, R., Coughran, J. & B. Hayes. 2010. *Management of genetic resources for fish and crustaceans in the Murray-Darling Basin.* Bureau of Rural Sciences, Canberra. ISBN: 9781921192364

ARUMUGAPM, T. & GEDDESM, C. 1987. 'Feeding and growth of golden perch larvae and fry (Macquaria arnbigua Richardson)'. *Transactions of the Royal Society of South. Australia.* Vol. 111(1): 59-65.

Musyl, M. K. & Keenan, C. P. 1992. 'Population Genetics and Zoogeography of Australian Freshwater Golden Perch, *Macquaria ambigua* (Richardson *1845)* (Teleostei : Percichthyidae), and Electrophoretic Identification of a New Species from the Lake Eyre Basin'. *Marine and Freshwater Research.* Vol. 43: 1585-601.

Becker, A. Laurenson, L. J. B. Jones, P. L . & Newman, D. M. 2005. 'Competitive Interactions between the Australian Native Fish *Galaxiasmaculatus* and the Exotic Mosquitofish *Gambusia holbrooki*,in a Series of Laboratory Experiments'. *Hydrobiologia.*Vol. 549 (1): 1573-5117.

Pollard, D. A. 1973. 'THE BIOLOGY OF A LANDLOCKED FORM OF THE NORMALLY CATADROMOUS SALMONIFORM FISH *GALAXIAS MACULATUS* (JENYNS) V.* COMPOSITION OF THE DIET'. *Marine and Freshwater Research.* 1973, *24,* 281-295.

Berra, T. M. Crowley, L. E. L. M., Ivantstoff & W. Fuerst, P. A. 1996. '*Galaxias maculatus:* an Explanation of its Biogeography'. *Marine and Freshwater Research. Vol.* 47:845-9.

Waters, J. M. & Burridge, C. P. 1999. 'Extreme Intraspecific Mitochondrial DNA Sequence Divergence in *Galaxias maculatus* (Osteichthys: Galaxiidae), One of the World's Most Widespread Freshwater Fish'. Molecular Phylogenetics and Evolution. Vol. 11 (1): 1–12.

Crowley, L. E. L. M., Ivantstoff, W. & Allen, G. R. 1986. 'Taxonomic Position of Two Crimson-spotted Rainbowfish, *Melanotaenia duboulayi* and *Melanotaenia fluviatilis* (Pisces : Melanotaeniidae), from Eastern Australia, with Special Reference to Their Early Life-history Stages'. *Marine and Freshwater Research. Vol.* 37: 385-98.

Hutchison, M, Butcher, A, Kirkwood, J, Mayer, D, Chikott, K & Backhouse, S. *Mesoscale movements of small and medium-sized fish in the Murray-Darling Basin.* MDBC Publication No. 41/08. ISBN 978 1 921257 81 0.

THACKER, C. E, UNMACK, P J., MATSUI, L., DUONG, P & HUANG, E. 2008. 'Phylogeography of *Philypnodon* species (Teleostei: Eleotridae) across south-eastern Australia: testing patterns of connectivity across drainage divides and among coastal rivers'. *Biological Journal of the Linnean Society*. Vol. (95): 175–192.

Hoese D.F. & Reader S. 2006. Description of a new species of dwarf *Philypnodon* (Teleostei: Gobioidei: Eleotridae) from south-eastern Australia. *Memoirs of Museum Victoria* 63(1): 15–19.

McGlashan, D. J. Hughes, J. M. 2001.' Genetic evidence for historical continuity between populations of the Australian freshwater fish *Craterocephalus stercusmuscarum* (Atherinidae) east and west of the Great Dividing Range'. *Journal of Fish Biology.* Vol. 59 (Supplement A): 55–67.

Hammer, M. Wedderburn, S. & van Weenen, J. 2009. Action Plan for South Australian Freshwater Fishes. Report to the South Australian Department for Environment and Heritage. Native Fish Australia (SA) Inc., Adelaide. ISBN978-0-9806503-7-2

BALCOMBE, S. R. & HUMPHRIES, P. 2006. 'Diet of the western carp gudgeon (Hypseleotris klunzingeri Ogilby) in an Australian floodplain lake: the role of water level stability'. *Journal of Fish Biology*. Vol. 68: 1484–1493.

Ryan, T., R. Lennie, J. Lyon & T. O'Brien (eds.) 2003. *Thermal rehabilitation of the southern Murray-Darling Basin. Department of Sustainability and Environment.* Final report to Agriculture, Forestry, Fisheries Australia. MD 2001 FishRehab program.

Nock, CJ 2010, `Conservation genetics of the endangered eastern freshwater cod, Maccullochella ikei', PhD thesis, Southern Cross University, Lismore, NSW. Thesis is posted at ePublications@SCU.
http://epubs.scu.edu.au/theses/116

Kaminskas, S & Humphries, P. 2009. Diet of Murray cod (Maccullochella peelii peelii) (Mitchell) larvae in an Australian lowland river in low flow and high flow years'. *Hydrobiologia*. Vol. 636: 449–461.

Faulks, L. K., Gilligan, D. M. & Beheregaray, L. B. 2008. 'Phylogeography of a threatened freshwater fish (*Mogurnda adspersa*) in eastern Australia: conservation implications.' *Marine and Freshwater Research*. Vol. 59: 89–96.

Sloane, R. D. 1984. 'Preliminary Observations of Migrating Adult Freshwater Eels *(Anguilla australis australis* Richardson) in Tasmania'. *Aust. J. Mar. Freshw. Res. Vol. 35:* 471-476.

Jellyman, D. J. 2001. 'The influence of growth rate on the size of migrating female eels in Lake Ellesmere, New Zealand'. *Journal of Fish Biology. Vol.* 58: 725–736.

Kuroki, M., Aoyama, J., Miller, M. J. Watanabe, S., Shinoda, A., Jellyman, D. J., Feunteun, E. & Tsukamoto, K. 2008. 'Distribution and early life-history characteristics of anguillid leptocephali in the western South Pacific'. *Marine and Freshwater Research*. Vol. 59: 1035–1047.

Dijkstra, L. H. & Jellyman, D. J. 1999. 'Is the subspecies classification of the freshwater eels *Anguilla australis australis* Richardson and *A. a. schmidtii* Phillipps still valid?' *Mar. Freshwater Res.* Vol. 50, 261-263.

GILLETT, E., CAKE, M.H., POTTER, I.C., & TMBAIMSH, M. 1996. 'Compact Exocrine Pancreas of Ammocoetes of the Southern Hemisphere Lamprey *Mordacia mordax* Contains a Trypsin Inhibitor: Putative Evolutionary Considerations'. *THE JOURNAL OF EXPERIMENTAL ZOOLOGY.* Vol. 274: 227-233.

ACT Government, 2003. Silver Perch (*Bidyanus bidyanus*)—an endangered species. Action Plan No. 26. Environment ACT, Canberra. [Online]. Available: http://www.tams.act.gov.au/__data/assets/word_doc/0008/154619/silverperchactionplan.doc. Accessed Mon, 5 Jul 2010.

Leigh, S. J., Zampatti, B. P & Nichol, J. M. 2008. Spatial and temporal variation in larval fish assemblage structure in the Chowilla Anabranch system: with reference to water physico-chemistry and stream hydrology. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2008/000051-1.SARDI Research Report Series Number 286.

Bertozzi, T. Adams, M. & Walker, K. F. 2000. 'Species boundaries in carp gudgeons (Eleotrididae : *Hypseleotris*) from the River Murray, South Australia: evidence for multiple species and extensive hybridization'. *Mar. Freshwater Res.* Vol. 51: 805–815

McCarraher, D.B. 1979. 'Estuary perch. Fisheries and Wildlife Division, Victoria'. *Freshwater Fish Newsetters.* Vol. 9: 15-20.

McCarraher, D. B. & McKenzie, J. A. 1986. Observations on the distribution, growth, spawning and diet of estuary perch (Macquaria colonorum) in Victorian waters. Arthur Rylah Institute for Enviromental Research. Technical Report Series No. 42. 21 pp. Department of Conservation, Forests and Lands, Melbourne.

Harris, J.H. and Rowland, S.J. 1996. Family Percichthyidae. Australian freshwater cods and basses. In 'Freshwater Fishes of South-Eastern Australia'. R. M. McDowall (Ed.) pp. 150-163. Reed Books, Sydney.

SAAB. 2001. South Australian Aquatic Biota Database. South Australian Department for Water Resources, 2001.

Reynolds, L.F. 1983. 'Migration patterns of five fish species in the Murray-Darling River system'. *Australian Journal of Marine and Freshwater Research*. Vol. 34: 857-871.

DEHWA. 2010d. Craterocephalus fluviatilis in Species Profile and Threats Database, Department of the Environment, Water, Heritage and the Arts, Canberra. [Online]. Available: http://www.environment.gov.au/sprat. Accessed Thu, 2 Sep 2010 14:12:16 +1000.

Backhouse, G., J. Lyon & Cant, B. 2008. National Recovery Plan for the Murray Hardyhead, Craterocephalus fluviatilis. Department of Sustainability and Environment. Melbourne, Victoria. [Online]. Available: http://www.environment.gov.au/biodiversity/threatened/publications/recovery/murray-hardyhead/index.html. Accessed Thu, 2 Sep 2010 14:22:16 +1000.

South Australia Department for Environment and Heritage (SA DEH). 2008. Adelaide and Mount Lofty Ranges South Australia, Threatened Species Profile: *Craterocephalus fluviatilis*, Murray Hardyhead. Department for Environment and Heritage. Biodiversity Conservation Unit, South Australia. [Online]. Available: http://www.environment.sa.gov.au/biodiversity/pdfs/regional_recovery/fauna/fw-fish/murray-hardyhead.pdf. Accessed Thu, 2 Sep 2010 15:20:16 +1000.

Murray-Darling Basin Authority (MDBA) 2009. The Living Murray Annual Environmental Watering Plan 2009-10. Murray-Darling Basin Authority, Canberra, Australian Capital Territory. [Online]. Available: http://www.mdba.gov.au/files/publications/MDBA_TLMWateringReport.pdf. Accessed Thu, 2 Sep 2010 15:28:16 +1000.

Ellis, I. 2005. Ecology of the Murray hardyhead, Craterocephalus fluviatilis (McCulloch), Family Atherinidae. Murray-Darling Freshwater Research Centre. Albury, NSW. [Online]. Available: http://mic.malleecma.vic.gov.au/documents/R290.pdf. Accessed Thu, 2 Sep 2010 15:33:16 +1000.

Cadwallader, P.L. 1979. 'Distribution of native and introduced fish in the Seven Creeks River system, Victoria'. *Australian Journal of Ecology*. Vol. 4: 361-385.

Guo, R., Mather, P.B. and Capra, M.F. 1995. 'Salinity tolerance and osmoregulation in the silver perch, Bidyanus bidyanus Mitchell (Teraponidae), an endemic Australian freshwater teleost'. *Marine and Freshwater Research*. Vol. 46: 947-952.

Harris, J.H. 1995. 'The use of fish in ecological assessments'. *Australian Journal of Ecology*. Vol. 20: 65-80.

Rowntree, J. and Hammer, M. 2007. 'Assessment of fishes, aquatic habitat and potential threats at the proposed location of the Wellington Weir, South Australia'. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide.

Crook, D. A., Reich, P., Bond, N., R., McMaster, D., Koehn, J., D., & Lake, P., S. 2010. 'Using biological information to support proactive strategies for managing freshwater fish during drought'. *Marine and Freshwater Research*. Vol. 61: 379–387.

McNeil, D., Gehrig, S., Sharpe, C. 2009. 'Resistance and Resilience of Murray-Darling Basin Fishes to Drought Disturbance'. Draft report to the Murray-Darling Basin Authority under Native Fish Strategy project MD/1086.

Closs, G. P., Balcombe, S. R., Driver, P., McNeil, D. G., Shirley, M. J. 2006. 'The importance of fl oodplain wetlands to Murray-Darling fish: What's there? What do we know? What do we need to know?' Keynote presentation, native fish and wetlands in the Murray-Darling Basin. Canberra Workshop, 7-8 June 2005. [Online]. Available: http://www.dpi.vic.gov.au/dpi/nreninf.nsf/v/265E265147773510CA25740F00814C63/$file/Some_Parasites_of_Freshwater_Fish.pdf Accessed Wed, 24 Nov 2010 14:31:10 +1000.

Department of Primary Industries Victoria. 2008. Some parasites of freshwater fish. Fisheries Notes. March 2008. FN0023. ISSN 1440-2254.