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

Amphibian, Reptile & Mammal Vulnerability Assessments

Attachment (3) to the Final Report
June 2011

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Scientific Name:	*Crinia parinsignifera*	Common Name:	Murray Valley Froglet/ Eastern Sign-bearing Froglet

	Question	Comments/ Reference	Vul Rating
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change 'I would say a Low, they have good breeding success in both flood and rain fed wetlands (S. Wassens pers. comm. 2011)'.	Broad range of breeding habitats (Hazell et al 2004); Highly adaptable, occurring in rain fed depressions, ditches, semi-permanent wetlands, oxbow lagoons, creeks and rivers, farm dams, irrigation canals and urban ponds (Wassens 2011); Usually breed in temporary water bodies but can also use shallow permanent sites with abundant vegetation (Wassens & Maher 2010). 'The lack of a landscape-type effect may reflect a much-winnowed fauna, in which only the most resilient of species (the *Crinia* species and *Limnodynastes tasmaniensis*) have persisted through the many changes wrought over the past 200 years (McNally et al 2009)'. ***Though has a preference for breeding sites with diverse aquatic vegetation or submerged grasses, these can be inundated terrestrial plants, and species is described as highly adaptable and resilient and requires only a very short hydro-period for tadpole development so is less reliant on river flooding and able to exploit highly ephemeral shallow rain fed sites. Habitat is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change '…not as widespread through flooded or rain fed wetlands that had been subject to extended drying…more limited dispersal (S. Wassens pers. comm. 2011).	It is not clear whether they burrow or move into newly flooded wetlands from the associated river systems during flooding (Wassens 2011); Found not to be *as* widespread as some other species through flooded or rain fed wetlands that that had been subject to extended drying (S. Wassens pers. comm.); During 2010-11 flooding within the study region *C. parinsignifera* was *not* one of the several species observed moving around/ dispersing in large numbers (A. Scott pers. obs.); More limited dispersal (S. Wassens pers. comm. 2011). ***Mobility & Dispersal is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? '*Crinia sp*. adults may be quite sensitive to predation by larger frogs so this might be an impact particularly if larger species are pushed into smaller areas of habitat or increasingly use rainfed waterbodies due to reduced flooding; tadpoles are extremely cryptic however we have certainly seen spikes in recruitment when carp are removed which would indicate	Generally, smaller frogs consume smaller prey. *Crinia signifera* and *C. parinsignifera* in Victoria, found to eat mostly prey species that were considerably smaller than the frog's mouth gape even though larger items were present and larger frogs often also eat large numbers of small prey (MacNally 1983) [therefore small frogs may have a more restricted prey choice]. Diet appears to be opportunistic and non-selective dominated by representatives of the Insecta (e.g. Collembola, Coleoptera and Diptera)(SAAB 2001); '*C. parinsignifera* actively displaced males of *C. signifera* from preferred calling sites, and advertisement calls may be an important mechanism for that displacement (Littlejohn et al)'; Tadpoles are bottom dwellers and are very well camouflaged [may reduce predation]. They are not very active unless disturbed, when they dart under cover among leaf litter or vegetation (Anstis 2002). 'Tadpoles are generalist detritivores and herbivores, feeding on biofilms, algae and detritus [generalist feeder] (Wassens 2011)'; *Crinia* adults may be quite sensitive to predation by larger frogs	M

	that competition/predation may also limit tadpole recruitment in riverine/flood fed systems. I would keep it as a Medium (S. Wassens pers. comm. 2011)'.	and spikes in recruitment seen when carp are removed indicate competition/ predation by carp limits tadpole recruitment in riverine/ flood fed systems (S. Wassens pers. comm.). ***Small size = increased predation & restricted to eating small prey; generalist feeder; tadpoles cryptic & fast swimmers; short development time =can take advantage of highly ephemeral sites with reduced predators but indications are that carp are a limiting factor in flood fed systems. C. signifera can be displaced by C. parinsignifera and may be less competitive. Competition is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? '…not as widespread through flooded or rain fed wetlands that had been subject to extended drying, short life span…might increase sensitivity to severe drought (S. Wassens pers. comm.)'.	There is limited information on the capacity of these species to aestivate during dry conditions and it's not clear whether they burrow or move into newly flooded wetlands from the associated river systems during flooding. During the 2009 winter watering of wetlands in the Lowbidgee floodplain. *C. parasignifera* was common in wetlands that had been dry since 2006 (Wassens 2011); Healy et al (1997) found positive association of adults with vegetation and along the River Murray in SA; Tyler (1994) found them to only occur among dense aquatic vegetation at the water's edge; Not as widespread [e.g. as some other species] through flooded or rain fed wetlands that had been subject to extended drying and short life span, might increase their sensitivity to severe drought (S. Wassens pers. comm.); Males found to lose about 36% of their body weight during mating and related post-breeding activities (Mac Nally 1981in SAAB 2001). ***Small size; breeding activities cause loss of body condition; found to be common but not as wide spread as other species when wetlands re-wetted after extended dry periods, unknown mode of survival. More common than C. signifera in more arid parts of study region. Survival is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	In southern Queensland found to occupy coastal acid swamps with pH less than 4.9 (Straughan and Main 1966 in SAAB 2001); *C. signifera*, can tolerate warm and cool water temps observed to occur in shallow pools of 32.6oC and also 12 o C (Straughn & Main 1966) – similar tolerances expected for *C. parinsignifera;* For successful tadpole development wetlands should retain water for 6 weeks if flooded in Spring-Summer or 3 months if flooded in Winter (Wassens 2011); In salinity field study in the Victorian Wimmera (Smith et al 2007) *C. signifera* appeared to have a moderate salinity tolerance (e.g. less than several other species) detected at salinity levels up to ~4000uS/cm (~ 8% SW) - similar tolerance levels are expected for *C. parinsignifera.* ***Wide temperature tolerance; tolerant of relatively acidic waters; moderate salinity tolerance. short tadpole development time = can exploit highly ephemeral sites and escape deteriorating conditions.'Growth' is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **reproduction** limit the ability of the regional population of the	Eggs very small, laid singly, well separated and attached to grass stems or the substrate in shallow, often muddy water (Anstis 2002); *C. signifera* and *C. parasignifera* will breed successfully in a range of	L

	species to tolerate climate change? ‘…short development time, relatively opportunistic breeding (S. Wassens pers. comm. 2011)’.	waterbodies and at different times of the year. As a result they appear to be less sensitive to alterations in wetland hydrology than other wetland-dependent species. Usually breed in spring and summer but will also breed in autumn and winter following flooding or heavy rain. Tadpole development time is 6 weeks to 3 months depending on environmental conditions. Wetlands should retain water for a minimum of 6 weeks if flooded during spring and summer, and three months if flooded in winter. Preference for sites with diverse aquatic vegetation or submerged grasses. (Wassens 2011); Short development time, relatively opportunistic breeding (S. Wassens pers. comm.); Calling noted at Kingston on Murray (SA) when the air temperature was 16.5oC (Littlejohn and Martin 1965b in SAAB 2001). ***Although show preference for diversely vegetated sites (can be inundated terrestrial veg); described to be less sensitive to alterations in wetland hydrology, are able to take advantage of very short hydro-periods and can breed through most of the year. Reproduction is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Common and widespread through river and wetland systems of the Murray darling basin in warmer inland regions of the MDB in both northern and southern basins (Wassens 2011); During the 1998 SA "frog census" Walker et al (1999) described population of species to be 'large and healthy; In BDBSA there are records of *C. parinsignifera* from 96 wetland sites (post 1990) within the study region (DENR 2010); Recent surveys indicate species is common and widespread within the study region (SA MDB NRM unpublished data). ***Species is restricted to the Murray Corridor in South Australia but within the upper Murray section of the study region species is considered common and widespread. Gene pool expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	‘Range extends from the Murray River valley (in south-eastern SA) to south-eastern Queensland, through central Victoria and throughout the central west of NSW (Barker et al. 1995, Cogger 2000) [in SAAB 2001]’; Recent surveys indicate species is common and widespread within the Upper Murray section of the study region (SAMDBNRM unpublished data); More limited dispersal (S. Wassens pers. comm.). ***Species considered common and widespread within the study region but it is restricted to the Murray Corridor in SA and dispersal ability is thought to be limited. Gene flow is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	‘Crinia signifera tadpoles responded to declining water by accelerating development and so reduced time to metamorphosis. However, the resulting metamorphs were smaller and survival rate in the terrestrial stage was significantly lower. This is a clear demonstration of the benefit and cost of phenotypic plasticity in metamorphic traits…Crinia signifera reached metamorphosis comparatively synchronously and demonstrated the classic response observed for phenotypically plastic species: Metamorphs in the declining water treatment emerged earlier, at the expense of size. The cost was	L (all species ‘M’- unknow n for final

		reduced survivorship in the terrestrial phase. (Lane & Mahoney 2002)'. ***Other species of Crinia, e.g. C. parinsignifera expected to display similar phenotypic plastic traits. Phenotypic plasticity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change***	score)
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	During the 1998 SA "frog census" Walker et al (1999) described population of species to be 'large and healthy'; In the BDBSA there are records of *C. parinsignifera* from 96 wetland sites (post 1990) within the study region (DENR 2010). ***Recent surveys indicate species is common and widespread within the study region(SA MDB NRM unpublished data) and although the recent the Murraylands (SA) regional status of C. parinsignifera is 'Near threatened' highlighting its dependence on the river (Gillam & Urban 2010), population size is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Average of 130 eggs deposited at a time (39-234)…C. signifera are described as 'frequent breeders' with eggs laid throughout the year (Anstis 2002) – Similar biology is assumed for *C. parinsignifera*. ***Low-moderate number of eggs deposited per breeding event but indications are species can breed several times a year and through most of year if conditions suitable. Reproductive capacity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Similar recruitment rates as those documented for C. signifera could be inferred but even though much research has been undertaken on certain populations of C. signifera quantifying recruitment rates remains difficult; Spikes in recruitment have been observed when carp are removed from a system indicating competition/ predation by carp limits tadpole recruitment in riverine/ flood fed systems (S. Wassens pers. comm.). The short development period *C. parinsignifera* allows it to also breed in highly ephemeral rain fed water bodies and escape fish predators. ***Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to tolerate climate change***	M

Scientific Name:	*Crinia signifera*	Common Name:	Common Froglet

Question		Comments/ Reference	Vul Rating
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	Broad range of breeding habitats (Hazell et al 2004; Cogger 1992); Highly adaptable, occurring in rain fed depressions, ditches, semi-permanent wetlands, oxbow lagoons, creeks and rivers, farm dams, irrigation canals and urban ponds (Wassens 2011); Crinia signifera are well known for using open environments including human modified environments (Anstis, 2002); Usually breed in temporary water bodies but can also use shallow permanent sites with abundant vegetation (Wassens & Maher 2010); 'C. signifera is especially noted for its frequent use of highly ephemeral sites following spells of wet weather, such as wheel ruts or even footprints around ponds (Lane & Mahoney 2002)'; 'The lack of a landscape-type effect may reflect a much-winnowed fauna, in which only the most resilient of species (the *Crinia* species and *Limnodynastes tasmaniensis*) have persisted through the many changes wrought over the past 200 years (McNally et al 2009)'. ***Though has a preference for breeding sites with diverse aquatic vegetation or submerged grasses, these can be inundated terrestrial plants, and species is described as highly adaptable and resilient and requires only a very short hydro-period for tadpole development so is less reliant on river flooding and able to exploit highly ephemeral shallow rain fed sites. Habitat is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change***.	L
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change '…not as widespread through flooded or rain fed wetlands that had been subject to extended drying…more limited dispersal (S. Wassens pers. comm.).	'There is limited information on the capacity of these species to aestivate during dry conditions and it is not clear whether they burrow or move into newly flooded wetlands from the associated river systems during flooding (Wassens 2011)'; Unknown dispersal ability for *C. signifera*, though being less common in low rainfall areas than *C. parinsignifera*, and as a small frog with higher water loss and reduced temp tolerance than other small frogs (Warburg 1965) dispersal ability is expected to be low. ***Mobility & Dispersal is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? '*Crinia sp*. adults may be quite sensitive to predation by larger frogs so this might be an impact particularly if larger species are pushed into smaller areas of habitat or increasingly use rain fed water bodies due to reduced flooding; tadpoles are extremely cryptic however we have	Generally, smaller frogs consume smaller prey. *Crinia signifera* and *C. parinsignifera* in Victoria, found to eat mostly prey species that were considerably smaller than the frog's mouth gape even though larger items were present and larger frogs often also eat large numbers of small prey (MacNally 1983) [therefore small frogs may have a more restricted prey choice]. Diet appears to be opportunistic and non-selective dominated by representatives of the Insecta (e.g. Collembola, Coleoptera and Diptera)(SAAB 2001). '*C. parinsignifera* actively displaced males of *C. signifera* from preferred calling sites, and advertisement calls may be an important mechanism for that displacement (Littlejohn et al)'; Tadpoles are bottom dwellers and are very well camouflaged [may reduce predation]. They are not very active unless disturbed, when they dart under cover among leaf litter or vegetation (Anstis 2002); 'Tadpoles	M

	certainly seen spikes in recruitment when carp are removed which would indicate that competition/predation may also limit tadpole recruitment in riverine/flood fed systems. I would keep it as a Medium (S. Wassens pers. comm. 2011)'.	are generalist detritivores and herbivores, feeding on biofilms, algae and detritus [generalist feeder] (Wassens 2011)'; *Crinia* adults may be quite sensitive to predation by larger frogs and spikes in recruitment seen when carp are removed indicate competition/ predation by carp limits tadpole recruitment in riverine/ flood fed systems (S. Wassens pers. comm.). ***Small size = increased predation & restricted to eating small prey; generalist feeder; tadpoles cryptic & fast swimmers; short development time =can take advantage of highly ephemeral sites with reduced predators but indications are that carp are a limiting factor in flood fed systems. C. signifera can be displaced by C. parinsignifera and may be less competitive.Competition is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? : '…not as widespread through flooded or rain fed wetlands that had been subject to extended drying, short life span…might increase sensitivity to severe drought (S. Wassens pers. comm.)'.	There is limited information on the capacity of *Crinia* to aestivate during dry conditions and it is not clear whether they burrow or move into newly flooded wetlands from the associated river systems during flooding. During the 2009 winter watering of wetlands in the Lowbidgee floodplain *C. parasignifera* was common [though not as widespread as other species] in wetlands that had been dry since 2006 (Wassens 2011); A study found males lost about 36% of their body weight during mating and related post-breeding activities (Mac Nally 1981 in SAAB 2001); Described as highly adaptable (Wassens 2011) and one of most resilient species (McNally et al 2009); *C. signifera* shown to lose water more readily and have lower temperature tolerance than other small frogs; Thought to be non-burrowing (Warburg 1965). ***Breeding activities cause loss of body condition; found to be common but less wide spread then other species at wetlands after extended dry periods, unknown mode of survival. Poor water conserving ability indicated; Described as highly adaptable and resilient. Less common than C. parinsignifera in more arid parts of study region. Survival is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	In southern Queensland found to occupy coastal acid swamps with pH less than 4.9 (Straughan and Main 1966 in SAAB 2001); *C. signifera*, can tolerate warm and cool water temps observed to occur in shallow pools of 32.6oC and also 12 o C (Straughn & Main 1966); For tadpole development wetlands should retain water for 6 weeks if flooded in Spring-Summer or 3 months if flooded in Winter (Wassens 2011); In salinity field study in the Victorian Wimmera (Smith et al 2007) *C. signifera* appeared to have a moderate salinity tolerance (e.g. less than several other species) detected at salinity levels up to ~4000uS/cm (~ 8% SW). ***Wide water temperature tolerance; tolerant of relatively acidic waters; moderate salinity tolerance. short tadpole development time = can exploit highly ephemeral sites and escape deteriorating conditions. 'Growth' is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **reproduction** limit the	*C. signifera* and *C. parasignifera* will breed successfully in a range of waterbodies and at different times	L

	ability of the regional population of the species to tolerate climate change? : '…short development time, relatively opportunistic breeding (S. Wassens pers. comm.)'.	of the year. As a result they appear to be less sensitive to alterations in wetland hydrology than other wetland-dependent species. Usually breed in spring and summer but will also breed in autumn and winter following flooding or heavy rain. Tadpole development time is 6 weeks to 3 months depending on environmental conditions. Wetlands should retain water for a minimum of 6 weeks if flooded during spring and summer, and three months if flooded in winter. Preference for sites with diverse aquatic vegetation or submerged grasses. (Wassens 2011); Species that deposit their eggs loosely on the pool bottom (e.g. C. signifera), or lay eggs on the water surface that subsequently sink will be least susceptible to fluctuations in pond level. Species with rapid tadpole development (42 to 51 days) are able to use ponds that dry up quickly. (Hazell et al 2003); C. signifera prefers cooler temperatures and generally breeds through winter autumn and spring but will breed at anytime depending on the availability of habitat and temperature (Anstis 2002). ***Although shows preference for vegetated sites (can be inundated terrestrial veg); described to be less sensitive to alterations in wetland hydrology, are able to take advantage of very short hydro-periods and can breed through most of the year; No requirements for egg attachment. Reproduction is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	No genetic studies are known; Common and widespread in the Murray Darling basin. Very common in the cooler regions of the Murray-Darling Basin (Wassens 2011); The most common anuran species recorded in the SA "Frog Census" from 1994-1998 (Walker et al. 1999); Largely restricted to the Lower Murray section of study region (rare in the SA upper Murray) and recent surveys indicate species is common (SA MDB NRM 2011); In BDBSA there are records of *C. parinsignifera* from 69 wetland sites (post 1990) within the study region (DENR 2010). ***Common and widespread within the Lower Murray section of the study region. Large gene pool expected. Gene pool expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Common and widespread in the SA Lower Murray region (SA MDB NRM 2011; Walker et al 1999; Wassens 2011); Limited dispersal (S. Wassens pers. comm.); Females capable of producing up to three (and as many as four) clutches a year (Lembeck and Shine 1993). ***Species common and widespread within Lower Murray though capacity to disperse to new sites may be lower than for other species decreasing gene flow within regional population; Frequent breeding enhances gene flow. Gene flow is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'Crinia signifera tadpoles responded to declining water by accelerating development and so reduced time to metamorphosis. However, the resulting metamorphs were smaller and survival rate in the terrestrial stage was significantly lower. This is a clear demonstration of the benefit and cost of phenotypic plasticity in metamorphic traits…Crinia signifera reached metamorphosis comparatively	L (all specie s 'M'- unkno

		synchronously and demonstrated the classic response observed for phenotypically plastic species: Metamorphs in the declining water treatment emerged earlier, at the expense of size. The cost was reduced survivorship in the terrestrial phase. (Lane & Mahoney 2002)'. ***Phenotypic plasticity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change***	wn for final score)
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Common and widespread in the Murray Darling basin. Very common in the cooler regions of the Murray-Darling Basin (Wassens 2011); The most common anuran species recorded in the SA "Frog Census" from 1994-1998 (Walker et al. 1999); Largely restricted to the Lower Murray section of study region (rare in the SA upper Murray) and recent surveys indicate species is abundant (SA MDB NRM 2011); In BDBSA there are records of *C. parinsignifera* from 69 wetland sites (post 1990) within the study region (DENR 2010). ***Population Size is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Average of 216 (125-394) eggs deposited; 'Mortality rates may be high as eggs are often deposited in smaller ephemeral pools which may dry up, but the frogs are frequent breeders (Anstis 2002)'; Females in a study at Darkes Forest NSW produced a mean of 1.43 clutches a year, were capable of producing up to three (and as many as four) clutches a year (Lembeck and Shine 1993 in SAAB 2001]. ***Low- moderate number of eggs produced per clutch but able to produce several clutches a year and breed throughout the year. Reproductive capacity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Long lived and iteroparous, with some individuals participating in at least four consecutive breeding seasons (Williamson & Bull 1996); Capable of producing up to three (and as many as four) clutches a year (Lembeck and Shine 1993 in SAAB 2001]; Some individuals mature about one year post-metamorphosis, but the time to sexual maturity was more typically in second breeding season following metamorphosis (Williamson and Bull 1996); Embryonic mortality of in one study (69-98%) is in the high end of reported ranges of embryonic mortality in other anuran (Williamson & Bull 1994); Average survival values of 7-27% for the larval phase of hatching to metamorphosis …Recruitment to the terrestrial phase ranged from an estimated 0 to 7% of estimated total number of eggs laid (Williamson & Bull 1999); Is only species where recruitment rates have been studied, although survival percentage low is within normal documented range for anurans overseas; rapid metamorphosis and regular year round breeding indicate recruitment is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change; Significant predation by Carp/ Gambusia on tadpoles of *C. parinsignifera* is indicated in riverine/ flood fed wetlands (S. Wassens pers. comm.). ***Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Scientific Name:	*Limnodynastes dumerili*	Common Name:	*Eastern Banjo Frog*

Question		Comments/ Reference	Vul Rating
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change '…responds to flooding, but will also breed in permanent water bodies and dams, response may be rain fall dependant so altered seasonality, frequency or intensity of rain fall might impact species response, requires long hydroperiod (S. Wassens pers. comm. 2011)'.	Found in all habitats except alpine areas, rainforest and extremely arid zones (Barker et al. 1995). Recorded to breed in a range of permanent and temporary water bodies including swamps, slow moving streams, farm dams, lakes, urban and garden ponds, seasonally flooded wetlands (Barker et al. 1995; Cogger 2000, Wassens 2011, Tyler 1977), *though* 'There have been no studies on the specific habitat requirements of this group' (Wassens 2011); Broad range of breeding habitats (Hazell et al (2004); Emergent vegetation or stones are necessary to anchor the foam nest of eggs (Tyler 1977). Responds to flooding but will also breed in permanent water bodies and dams. Requires long hydro-period (S. Wassens pers. comm. 2011). ***A habitat generalist breeding in permanent and temporary water bodies but within the study region most permanent wetlands are poor breeding habitat due to the abundance of introduced fish, and a considerable loss of temporary wetlands with long hydro-periods is expected with reduced flood frequency and duration. Habitat is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change '…response may be rainfall dependant so altered seasonality, frequency or intensity of rain fall might impact species response…(S. Wassens pers. comm. 2011)'	Males migrate as far as 1 km to reach the breeding sites which are typically dams, small lakes, marshes and slow flowing streams (Barker et al. 1995 [in SAAB 2001]). Response may be rainfall dependant (S. Wassens pers. comm. 2011). ***Although species is known to make extended movements to breeding sites this is thought to be dependent on rain events of which the seasonality, frequency and intensity is forecast to be altered under climate change, and with an overall rainfall decline in the study region (REF). Mobility & Dispersal is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Large size: Female frogs up to 83 mm in length and males 70 mm (Barker et al. 1995); Reportedly eaten by Tiger Snakes (Notechis scutatus) and Black Snakes (Pseudechis porphyricanus) in captivity; observed being preyed upon by adult *L. raniformis* and recorded as a gut component of owls (Crook and Tyler 1981). Specimens of adult *Limnodynastes dumerilii* have been found in the stomachs of foxes (Marks, DNRE,Victoria, pers. comm.. [Gillespie & Hines in Campbell 1999]); Captive rats eat frogs of this species but avoid the tibial glands and the small strip of skin which unites the glands (Crook and Tyler 1981). Tibial glands secret a substance which is believed to afford some protection against predation (Turner 1998), though this secretion does not appear to be toxic to many of the predators of this species	M

		(Crook 1976); Tadpoles are largely bottom dwellers and feed on sediment and vegetation. In captivity they also feed at the surface. They are capable of swimming fairly fast and using the entire tail for motion, but are generally rather sedentary unless disturbed (Anstis 2002); A medium to very long larval stage within a range of 4-15months documented (Barker et al, Tyler 1994, Anstis 2002, Lane & Mahoney 2002, Wassens 2011). ***Large size and generalist diet, likely to be competitive with most smaller frog species; tadpoles usually sedentary but capable of fast swimming; increased risk of competition and predation expected with long larval stage; tibial gland secretions are thought to afford some defence mechanism but does not appear to be toxic to a number of known predators. Competition is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? '…sensitive to desiccation…distribution may be restricted by soil type…it is possible that dispersal capability and use of refuges might be more important than burrowing ability in terms of recovery following extended dry periods (S. Wassens pers. comm. 2011)'.	Lives in a small hole beneath damp wood or stones; aestivates in a sealed burrow during summer (Tyler 1977); 'There has been no research on the water requirements of this group or how long individuals can persist between floods' and is not known to significantly slow metabolism during dry periods. Instead it is likely to burrow further down through the soil profile as water tables decline in order to maintain its moisture balance. Frogs often emerge from their burrows and forage during heavy rains, these foraging opportunities may extend the length of time they can persist between floods. Successful recruitment may require wetlands to be flooded for around 6 months (Wassens 2011). Sensitive to desiccation, distribution may be restricted by soil type. It is possible that dispersal capability and use of refuges might be more important than burrowing ability in terms of recovery following extended dry periods (S. Wassens pers. comm. 2011). ***Burrowing frog though not known to significantly slow metabolism like some other burrowing species. Sensitive to desiccation and may be restricted by soil type. Unknown for how long can persist between floods but emergence to forage during rain events may prolong persistence. Survival is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change? 'Requires long hydro-period (S. Wassens pers. comm. 2011)'.	Highly variable tadpole development stage of 4 – 16 month range documented (Barker et al 1995, Tyler 1994, Anstis 2002, Lane & Mahoney 2002, Wassens 2011; Hazell et al 2003); 'Species with tadpoles that develop slowly, such as *L. dumerilli,* may no longer successfully reach metamorphosis in incised systems (Hazell et al 2003)'; 'Requires long hydro-period (S. Wassens pers. comm. 2011)'; In a salinity field study in the Victorian Wimmera tadpoles of *L. dumerilli* had a greater probability of occupancy at higher salinities compared to other species but tadpoles were not present above 6000uS/cm (Smith et al 2007). ***Tadpoles of L. dumerillii reported to have a higher salinity tolerance than other species, but with a medium to very long tadpole life span, 'growth' is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does **reproduction** limit	'Martin (1969) reported that emergence from hibernation in *Limnodynastes dumerilii* was dependent	H

	the ability of the regional population of the species to tolerate climate change? '…responds to flooding, but will also breed in permanent waterbodies and dams, response may be rain fall dependant so altered seasonality, frequency or intensity of rain fall might impact species response, requires long hydroperiod (S. Wassens pers. comm. 2011)'.	on high soil temperatures (>12.5°C), provided that some critical, high (possibly saturation) level of soil moisture was reached. If soils were dry, emergence was not synchronous and breeding was absent or spasmodic. In this species, breeding activity in years of mass emergence was highly skewed, and most breeding occurred immediately after emergence, but tailed off over the next five weeks (Littlejohn et al...)'; Calling is most intense after heavy rains and mass spawning can occur on the same one of two nights (Anstis 2002)'; Breeding is most likely to occur in Spring and Summer but species can be active at anytime of the year (Tyler 1977; Wassens 2011; Ulkrin 1980). Emergent vegetation or stones are necessary to anchor foam nests; normally at the edge of water bodies (Tyler 1977); Due to extended tadpole phase successful recruitment may require temporary wetlands to be flooded for around 6 months (Wassens 2011); Responds to flooding, but will also breed in permanent waterbodies and dams, response may be rain fall dependant so altered seasonality, frequency or intensity of rain fall might impact species response, requires long hydro-period (S. Wassens pers. comm..). ***Requires extended hydro-period (many permanent pool level wetlands unsuitable for breeding -see above); normally seasonal breeder; requires an anchor for foam nests; sufficient rainfall and other 'cues' appear to be required to trigger emergence to breed and breeding can be on-mass but short lived and sporadic or absent if the right conditions don't coincide. Reproduction is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Presently common and widespread; the fourth most common species recorded during 1998 in the SA "Frog Census" (Walker et al. 1999). Widespread along the Murray River to south Australia (Wassens 2011). In BDBSA recorded at 117 wetland sites after 1990 within study region. ***Common and widespread (though highly variable within study region); Large gene pool expected within study region. Gene pool expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Common and widespread along the river Murray (Walker et al 1999; Wassens 2011) and within the study region though distribution and abundance is variable (SA MDB NRM 2011); Males known to migrate considerable distance to breeding sites (Barker et al. 1995), though emergence to disperse and breed appears linked to a certain intensity and timing of rainfall (Martin 1969 in Littlejohn et al...S. Wassens pers. comm. 2011). ***Considerable dispersal ability observed, though a decline in rainfall and change of seasonality may play a role in restricting mobility and therefore gene flow. Gene flow expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***phenotypic plasticity*** limit the ability of the regional	'The duration of tadpole stage is temperature dependent and may be as long as 12-15 months under cool conditions but take as little as 4-5 months under warmer conditions (Barker et al. 1995).	M

	population of the species to tolerate climate change?	Tadpole development times [all species] are often faster in the warmer parts of a species range and reliance on seasonal flooding is more important, however I am not sure if this type of phenotypic variation across a species range should be used to imply a high level of phenotypic plasticity in the species per se, as some of the more aquatic species in SA are probably at the limit of their tolerance ranges in terms of tadpole development times and resistance to drying. As such these species may not have a lot of room to move given predictions of increasing severity of droughts and increased evaporation leading to more rapid drying times (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	The fourth most common species recorded during 1998 in the SA "Frog Census" (Walker et al. 1999). Widespread along the Murray River to South Australia (Wassens 2011); Recent surveys indicate species is common & widespread within the study region (though high variability between sites) (SA MDB NRM unpublished data); In the BDBSA is recorded at 117 wetland sites after 1990 within study region and recently conservation listed as 'Least concern' (Murray Mallee, South Australia) (Gillam & Urban 2010). ***Population Size is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Martin (1969) reported breeding activity in years of mass emergence was highly skewed, and most breeding occurred immediately after emergence, but tailed off over the next five weeks (Littlejohn et al...)'; 'Spawning is typically communal with large numbers of individuals breeding simultaneously at a site, usually on warm, wet nights (Ulkrin 1980 in SAAB 2001)'; Calling is most intense after heavy rains and mass spawning can occur on the same one of two nights (Anstis 2002); Anstis (2002) found an average of 2348 eggs per eggs mass, range 1000-3900 (Anstis 2002; Martin 1967; Barker et al.1995; Tyler 1977). ***Breeding can be sporadic and occurring over just one or two nights but a large number of eggs can be laid on- mass during a breeding event. Reproductive capacity is expected to be a minor?/ moderate limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Survival rate of offspring and overall population recruitment unknown. Predation by introduced fish species expected to be high for most species in more permanent wetlands. Below factors <u>may</u> give some indication of recruitment success of species within study region. <u>Known:</u> Moderate-slow metamorphosis; relatively large population size; large individual size; mass spawning; normally spr-sum breeder. <u>Unknown:</u> Re- clutching (but not expected with mass spawning), time to maturity, life span, specific predation and survival rate of metamorphs. ***Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to***	M

		tolerate climate change.	

Scientific Name:	*Limnodynastes fletcheri*	**Common Name:**	Long-thumbed Frog

Question		**Comments/ Reference**	**Vul Rating**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change '*L. raniformis* and *L. fletcheri* are high risk, specifically because they are highly dependent on wetlands and require fairly frequent flooding which means they are likely to be sensitive to declines in flood frequencies. This agrees with some of our resent work in Lowbidgee which shows *L. raniformis* and *L. fletcher*i dropping out from wetlands that have had significantly reduced flooding frequencies…known sensitivity to reduced flood frequency…Maintaining good refuges during droughts can probably increase the resilience of these species (S. Wassens pers. comm. 2011)'.	Known to occupy a range of habitats including dams, rice bays, creeks and wetlands. It appears to be most common in seasonally flooded wetlands with long hydroperiods of approximately 6 months (Wassens 2011). Breeding sites are usually temporary, shallow and containing abundant aquatic vegetation (Wassens & Maher 2010; Wassens 2011; Healey et al (1997). Can be widespread through permanent reaches, but these areas are less likely to support breeding than temporary reaches (Wassens & Maher 2010). An aquatic species always found in water or sheltering in moist places (Amey & Grigg 1995) and only occurs among dense aquatic vegetation at the water's edge along the River Murray (Tyler 1994). Highly dependent on wetlands and require fairly frequent flooding which means they are likely to be sensitive to declines in flood frequencies. Maintaining good refuges during droughts can probably increase the resilience (S. Wassens pers. comm. 2011). ***Can use a range of aquatic habitats for refuge, but highly sensitive to declines in flood frequency requiring seasonally flooded temporary wetlands for breeding and most common in temporary wetlands with long hydro-periods & strong preference for sites with abundant aquatic vegetation. Habitat is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	They actually are quite mobile, I often observe them between 500 and 1000m from the water and they will follow flood water into new habitats. *L. raniformis and L. Fletcheri* are highly dispersive and in the event of a large flood event are able to recolonise wetlands during these events. Known sensitivity to reduced flood frequency and reduced dispersal opportunities (S. Wassens pers. comm. 2011). ***Highly mobile but only during flooding and a reduction in flood frequency reduces dispersal opportunities. Mobility & Dispersal is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Tadpoles are large around 70mm (Tyler 1977; Anstis 2002). Frogs: Sexual dimorphism in size; females reach 38-55 mm in length; males attain lengths of 37-46 mm (Barker et al. 1995); The time for tadpoles to reach metamorphosis is four to five months in the Lowbidgee floodplain when wetlands are flooded through spring and summer (Wassens et al 2008 in Wassens 2011); Tadpoles largely bottom-dwellers, but	M

		range throughout most parts of the water body and feed at the surface. They are capable of strong fast swimming when disturbed (Anstis 2002); Egg and tadpole stages may be susceptible to predation by carp (Cyprinus carpio) and Eastern Gambusia (Gambusia holbrooki), particularly in billabong habitats (Healey et al. 1997 in SAAB 2001). ***Medium size adult; large tadpole; diet not described but likely to be a generalist feeder; med length larval stage; tadpoles largely bottom dwellers (e.g. may reduce detection by predators) and capable of strong swimming. Predators not documented but likely to be similar to those documented for other species including larger frogs, snakes, wading birds and introduced fish. Competition is a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? This agrees with some of our resent work in Lowbidgee which shows *L. raniformis* and *L. fletcheri* dropping out from wetlands that have had significantly reduced flooding frequencies (S. Wassens pers. comm. 2011)'.	Experimentally *L. fletcheri* appears to tolerate high ambient temperatures without sign of injury though at high temperatures also found to have high rates of cutaneous water loss (Amey & Grigg 1995); An aquatic species always found in water or sheltering in moist places (Amey & Grigg 1995). Associated with water this species only occurs among dense aquatic vegetation at the water's edge along the River Murray (Tyler 1994); Shelter during the day under large rocks, logs and other debris and in cracks and in ground crevices including yabby burrows (Barker et al 1995; Cogger 2000); Often aggregate in large groups in dry weather (Barker et al. 1995), presumably to reduce evaporative water loss; do not appear to have a water-proofing mechanism to reduce evaporative water loss (Amey and Grigg 1995 in SAAB 2001); Limited tolerance for wetland drying, excluded if no permanent refuge sites nearby (Wassens 2011). ***Med size; non-burrower; described to tolerate high ambient temperatures though not thought to possess water proofing mechanism. As a more 'aquatic species' salinity may have increased impact on adults and with limited tolerance for wetland drying is excluded if no permanent refuges sites close by.Survival is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	The time for tadpoles to reach metamorphosis is four to five months in the Lowbidgee floodplain when wetlands are flooded through spring and summer (Wassens et al 2008 in Wassens 2011); Sites occupied by *Limnodynastes fletcheri* had a significantly higher percentage cover of tall emergent vegetation and higher conductivity (Wassens & Maher 2010); Has reproductive flooding requirements similar to those of the southern bell frog (Wassens 2011). ***Med length larval stage; no specific salinity tolerance reported though indications are it may be at the higher end of the range e.g. similar to other regional Limnodynastes species.'Growth' is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	While some species identified in this study such as *Limnodynastes fletcheri and Litoria peronii* are widespread through permanent reaches of the creek systems, these results suggest that these areas are less likely to support breeding than temporary reaches (Wassens & Maher 2010); Most likely to	H

		breed in Spring and summer but can also be active during warmer late winter weather and into Autumn (Anstis 2002; Barker et al 1995; Wassens 2011); Has flooding requirements similar to those of the southern bell frog, Appears most common in seasonally flooded wetlands with long hydroperiods of approx. 6 months and strong preference for sites with abundant submerged vegetation. Require vegetation to attach foam egg masses (Wassens 2011); Males call while afloat among grasses and vegetation near the edge of water bodies (Anstis 2002); Usually breeds in grassy areas which have been inundated following rain; males characteristically call from hidden sites within floating clumps of debris, typically burr-bearing grasses (Cogger 2000 in SAAB 2001). ***Highly reliant on seasonal flooding of temporary wetlands with extended hydroperiod (in the study region this would be riverine/ flood fed sites); preference for breeding sites with abundant submerged/ inundated vegetation and generally a seasonal breeder. Reproduction is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	A common frog in seasonally flooded and permanent water bodies throughout the Murray Darling Basin (Wassens 2011); Restricted to the Murray River floodplains of north-western Victoria and extending a small way into south-eastern SA (Cogger 2000)…Recorded in the lower reaches of the River Murray during 1998 (Walker et al. 1999). Recent surveys indicate species is relatively widespread but of low-moderate abundance (SA MDB NRM 2009-2011). ***Restricted to the River Murray Corridor in South Australia. Widespread within study region but usually in low-moderate abundance and not occurring at every survey site. A moderate gene pool is expected within study region. Gene pool expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	'They actually are quite mobile, I often observe them between 500 and 1000m from the water and they will follow flood water into new habitats…Both these species [*L. raniformis and L. fletcheri*] are highly dispersive and in the event of a large flood event are able to recolonise wetlands during these events…known sensitivity to reduced flood frequency and reduced dispersal opportunities (S. Wassens pers. comm.)'; An 'aquatic species (Amey & Grigg 1995). ***Highly dispersive but only during flood events and described as a more aquatic species. Gene flow expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Under laboratory conditions minimum tadpole stage was 60 days at a water temperature of 30oC (Davies 1992) and in the field 4-5 months (in the Lowbidgee floodplain when wetlands flooded through spring/ summer)(Wassens 2011); 'Tadpole development times are often faster in the warmer parts of a species range and reliance on seasonal flooding is more important, however I am not sure if this type of phenotypic variation across a species range should be used to imply a high level of phenotypic plasticity in the species per se, as	M

		some of the more aquatic species in SA are probably at the limit of their tolerance ranges in terms of tadpole development times and resistance to drying. As such these species may not have a lot of room to move given predictions of increasing severity of droughts and increased evaporation leading to more rapid drying times (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	A common frog in seasonally flooded and permanent water bodies throughout the Murray Darling Basin (Wassens 2011); Restricted to the Murray River floodplains of north-western Victoria and extending a small way into south-eastern SA (Cogger 2000) – Restricted to the River Murray corridor in SA; Recent call surveys indicate *L. fletcheri* is relatively widespread within wetlands of the study region but occurring in low-moderate abundance (increasing with subsequent years of inundation (SA MDB NRM unpublished data). ***Population Size is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	No information found on the number of eggs deposited per egg mass or overall fecundity of the species (Anstis 2002; SAAB 2001). ***Reproductive capacity was not found documented (Likely similar to other Limnodynastes) and is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	'*Limnodynastes tasmaniensis* juvenile frogs take approximately 12 to 16 weeks to reach sexual maturity and... Similarly, Limnodynastes fletcheri rapidly reach sexual maturity after metamorphosis (Hyne et al 2009)'; Predation on *L. fletcheri* tadpoles by introduced fish, e.g. carp and gambusia is not specifically documented but is *expected* to be high for most frog species. Known: medium tadpole development time; moderate population size; rapid maturity; normally seasonal breeder. Unknown: Reproductive capacity, life span, predation rates and survival rate of tadpoles/ metamorphs. ***Many factors/ traits are expected to influence recruitment rates but due to a general scarcity of information and research 'recruitment 'is an unknown limitation on the ability of the regional*** *population* ***of the species to tolerate climate change.***	M

Scientific Name:	*Limnodynastes tasmaniensis*	Common Name:	Spotted Grass Frog

	Question	Comments/ Reference	Vul Rating
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change '… wide range of habitat tolerances (S. Wassens pers. comm. 2011)'.	Wassens & Maher (2010) found occupancy of sites by adult *Limnodynastes tasmaniensis* was not related to any of the measured habitat or water quality variables but breeding sites (similar for all species) were shallow, containing abundant aquatic vegetation and most often temporary, although shallow, well vegetated permanent sample sites were also used; Healey et al (1997) found, in contrast to *L fletcheri*, individuals of *L. tasmaniensis* occurred in a range of microhabitat types but frequently in beds of Cyperus spp, and Paspalum distichum; Readily colonise any wet freshwater area including temporary depressions, semi-permanent and permanent wetlands, creeks, dams, irrigation canals and urban ponds. It does not have specific requirements in terms of aquatic vegetation, although tadpoles are generally more abundant in areas with aquatic vegetation (Wassens 2011]'; 'It will colonise almost any area where there is a temporary or permanent pond, flooded ditch or grassland soak...(Anstis 2002)'; Wide range of habitat tolerances (S. Wassens pers. comm.)'; Wide range of habitats from wet coastal areas to arid zones (Watson et al 1995); Typically marshy areas; where streams and ponds are grass-lined, or paddocks/ grasslands are flooded (Barker et al. 1995; Tyler 1994; Davies 1992) [in SAAB 2001] or where aquatic vegetation such as *Myriophyllum* sp forms a dense mat at the water surface (A. Scott pers. obs.). '...only the most resilient of species (the Crinia species and Limnodynastes tasmaniensis) have persisted through the many changes wrought over the past 200 years (McNally et al 2009)'; ***Though like most species prefers to breed in temporary sites with abundant aquatic vegetation, is widely described as a habitat generalist, resilient, with a wide range of habitat tolerances and requires only a short hydro-period for tadpole development.*** ***Habitat is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change 'highly dispersive (S. Wassens pers. comm. 2011)'.	'This species is very common in south-eastern Australia and is often the first frog to colonise new habitats (Mokany 2007)'; 'highly dispersive (S. Wassens pers. comm.)'; During 2010-11 flooding within study region *L. tasmaniensis* was observed moving around/ dispersing in abundance between wetlands (A. Scott pers. obs.). ***Described as highly dispersive and often the first species to colonise new habitats. Mobility & Dispersal is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***competition*** limit the	Eggs and tadpoles are predated on by carp (*Cyprinus carpio*) and eastern gambusia (*Gambusia*	M

	ability of the regional population of the species to tolerate climate change? '…recruitment success is limited by predation by carp and gambusia (S. Wassens pers. comm. 2011)'.	*holbrooki* (S. Wassens pers. comm., Healey et al. 1997; Hazell et al 2004); Tadpoles are most often bottom dwellers when feeding and resting, but also feed in any area of the water body (Anstis 2002); Length of tadpole stage 2.5-5 months (Anstis 2002, Wassens 2011, Hazell et al 2003, Cogger 2000); Females reach lengths of 32-47 mm; males attain lengths of 31-42 mm (Barker et al. 1995). Tadpoles can obtain a length of 60mm but more often 54mm (Anstis 2002); Gut contents of feeding tadpoles were found to include desmids, diatoms, colonial and filamentous green algae and fragments of higher plant material (Martin 1967b) [in SAAB 2001]'. An adult frog was observed attempting to ingest a baby brown snake (Pseudonaja textilus) (Tyler 1994). ***Above factors/ traits are expected to influence the species competitiveness: e.g. small-med size; short-med tadpole stage; tadpoles often bottom dwellers (may reduce detection by predators) but feed in all of water column; generalist feeder and adults appear to be relatively competitive or capable of taking large prey items. Predators include introduced fish and may include those documented for other species e.g. larger frogs, snakes, wading birds and foxes. Competition is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? '…in our resent assessment of breeding following the drought breaking rain in Feb and March 2010- *L. tasmaniensis* really dominated these rain fed wetlands even though some were quite isolated and had not filled for a number of years, likewise in our Riverine wetlands study (ongoing), *L. tasmanensis* and *L. peronii* appear to be the most resilient species following extended drying and were present at wetlands that had been dry for 10 years… wide range of habitat tolerances (S. Wassens pers. comm. 2011)'.	'*Limnodynastes tasmaniensis* exhibited resistance to infection by chytridiomycosis (Woodhams et al 2007)'; 'This frog is extremely adaptable (Anstis 2002)'; 'It has limited capacity to burrow. Adults congregate around permanent water during droughts and distribution is restricted to areas with some permanent water (Wassens 2011)'; 'They are found under stones and debris on the beds of dry creeks, pools and dams during summer (Tyler 1977)' ; Usually found in or near water, and in dry periods they shelter in cracks in the ground and under large rocks on the edge of permanent or temporary swamps, lagoons and creeks (Cogger 2000) [in SAAB 2001]'; Found to dominate isolated rain fed wetlands even though some had not filled for a number of years and, together with *L. peronii*, appear to be the most resilient species following extended drying present at wetlands that had been dry for 10 years; wide range of habitat tolerances (S. Wassens pers. comm. 2011). ***Limited capacity to burrow but congregate around permanent water during drought and shelter in cracks and under debris in dry water bodies; described as extremely adaptable and appears to be most resilient species (with L. peronii) following extended drying.Survival is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	In a field study in the Victorian Wimmera Smith et al (2007) found *L. tasmaniensis* tadpoles present at a salinity level of up to approximately 5000 uS/cm. Of 6 species in the study *L. tasmaniensis* appeared to have the second highest salinity tolerance after *L. dumerilli ;* Laboratory studies show variable salinity tolerance but appear to concur with the field study- decreased growth rates/ survival above 5.5% SW (Quincy 1991 in Lane et al 2000) but no apparent effect on tadpoles with a gradual salinity increase up to 11.4% SW (Flower 2004); 'Tadpoles take two and a half to four months to reach metamorphosis,	L

		depending on water temperature (Anstis 2002); Tadpoles require water to remain pooled for a at least 3 months (Wassens 2011). ***Short-medium tadpole development time and field studies indicate a higher salinity tolerance than most other species within the study region.'Growth' is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? '…in our resent assessment of breeding following the drought breaking rain in feb and march 2010- *L. tasmaniensis* really dominated these rain fed wetlands…short tadpole development times, opportunistic breeding (wide breeding window so less likely to be impacted by altered seasonally of rainfall), present in wetlands that have been subject to reduced flooding (S. Wassens pers. comm. 2011)'.	Asynchronous development times to metamorphosis for siblings reported and 'may be regarded as an insurance against a prolonged dry spell resulting in loss of the water body (Lane & Mahoney 2002)'; 'Species that produce foam nests are able to use ponds that have fluctuating water levels and can take advantage of flooding after rain that recedes rapidly *Limnodynastes tasmaniensis* is one such species (Hazell et al 2003)'; 'Males call while afloat or sitting in shallow water, often among vegetation, through spring, summer, autumn, and mild winter weather, especially after rain. Breeding is opportunistic but usually peaks in summer and autumn (Anstis 2002)'; Wassens & Maher (2010) found breeding sites were shallow with abundant aquatic vegetation, majority were temporary, although permanent sites with similar characteristics also used. Breeding occurs late winter, spring and summer but may breed opportunistically at any time of year; egg masses laid on water surface (Wassens 2011). '…in our resent assessment of breeding following the drought breaking rain in Feb and March 2010- *L. tasmaniensis* really dominated these rain fed wetlands…short tadpole development times, opportunistic breeding (wide breeding window so less likely to be impacted by altered seasonally of rainfall), present in wetlands that have been subject to reduced flooding (S. Wassens pers. comm. 2011)'. ***Preference for shallow, vegetated temporary or permanent breeding sites; opportunistic breeder; no requirements for egg attachment; short tadpole development; asynchronous development; found to dominate rain fed sites so less reliant on river flooding. Reproduction is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	The second most common species recorded during 1998 in the SA 'Frog Census' (Walker et al 1999); One of the most common and widespread frogs in the Murray-Darling basin (Wassens 2011); Species is very common within the study region, recorded at 130 wetland sites (BDBSA) post 1990, and recent surveys indicate species remains currently widespread and very common (SA MDB NRM unpublished data). ***Common, abundant and widespread within study region. Large gene pool expected within study region. Gene pool expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***gene flow*** limit the	'This species is very common in south-eastern Australia and is often the first frog to colonise new	L

	ability of the regional population of the species to tolerate climate change?	habitats (Mokany 2007)'; Highly dispersive (S. Wassens pers. comm. 2011). ***Common, abundant and widespread within study region and highly dispersive. Gene flow expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'In contrast [to *C. signifera] L. tasmaniensis* metamorphosed asynchronously. Though metamorphs were smaller in declining water, there was no evidence that they reached metamorphosis more quickly and no differences were detected in survival rates as frogs. Consequently an adaptive plastic response cannot be inferred (Lane & Mahoney 2002)'. 'Tadpole development times are often faster in the warmer parts of a species range and reliance on seasonal flooding is more important, however I am not sure if this type of phenotypic variation across a species range should be used to imply a high level of phenotypic plasticity in the species per se, as some of the more aquatic species in SA are probably at the limit of their tolerance ranges in terms of tadpole development times and resistance to drying. As such these species may not have a lot of room to move given predictions of increasing severity of droughts and increased evaporation leading to more rapid drying times (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	The second most common species recorded during 1998 in the SA 'Frog Census' (Walker et al 1999); One of the most common and widespread frogs in the Murray-Darling basin (Wassens 2011); Species is very common within the study region, listed as 'least concern in Murrayland regional status (Gillam & Urban 2010) & recorded at 130 wetland sites in the BDBSA (post 1990). ***Recent surveys indicate species remains very common & widespread within the study region (SA MDB NRM data unpublished data). Population Size is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Average of 394-854 eggs per egg mass (174-794 in Sutton and 335-1550 in Sydney) (Anstis 2002); Between 88-1,359 eggs. Females capable of producing multiple clutches throughout the year (Ulkrin 1980). ***Moderate- large number of eggs per egg mass, multiple clutches and mass spawning events documented. Reproductive capacity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Predation by introduced fish species expected to be high for most species; Newly metamorphosed *Limnodynastes tasmaniensis* juvenile frogs take approximately 12 to 16 weeks to reach sexual maturity and, except for a short midwinter period, breed following rain throughout the year (Hyne et al 2009)'. Females capable of producing multiple clutches throughout the year (Ulkrin 1980); Species is common	M

		and widespread (Walker et al 1999; Wassens 2011; SA MDB NRM data 2009-2011); Short-medium tadpole development time; opportunistic breeder (Anstis 2002; Wassens 2011). *<u>Known:</u> Capable of rapid metamorphosis; large population size; rapid maturity; opportunistic breeder, multiple re-clutching.* *<u>Unknown:</u> Life span, specific predation; overall survival rate of tadpoles/ metamorphs.* ***Many factors/ traits are expected to influence recruitment rates but due to a general scarcity of information and research 'recruitment 'is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	

Scientific Name:	*Litoria ewingii*	**Common Name:**	Brown Tree Frog

Question		**Comments/ Reference**	**Vul Rating**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	A widespread, common species and a habitat generalist recorded in a range of temporary and permanent water bodies including flooded grassland, marshes, ponds, dams, lakes, wetlands, flooded roadside ditches coastal swamps and lagoons, and documented from a range of habitat types such as wet and dry sclerophyll forest, farmland, heathland, semi-arid areas, alpine regions and suburban gardens (Cogger 2000; Barker et al 1995; Anstis 2002; Mallee CMA 2009). Able to exploit highly ephemeral rain fed sites due to short larval phase (Lauck et al 2005). ***A habitat generalist that utilises and breeds in a range of temporary and permanent water bodies, common in urban areas. Able to exploit highly ephemeral sites with short larval phase. Its absence from the most arid areas of the study region may indicate a range contraction with increased aridity reducing habitat for this species. Habitat is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	Can be found far from water when not breeding (Mallee CMA 2009; SAAB 2001) indicating good mobility, and the ability to disperse and escape deteriorating habitat conditions. ***Mobility & Dispersal is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Medium size adult and tadpoles (to 56mm) (Anstis 2002); Short tadpole phase: 1.5 - 2 months (Lauck et al 2005); Tadpoles frequent surface of water bodies [may be more detectable to predators] but are fast agile swimmers (Anstis 2002); Laboratory study found tadpoles to suffer heavy predation from	M

		odonates (Peterson et al 1992); Described as an agile climber and jumper and voracious insectivore capable of leaping and catching prey in mid-air (Mallee CMA 2009; SAAB 2001). ***Above factors provide an indication of the species competitive ability but with a number of unknown factors competition is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***	
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Medium size frog; Non-burrowing (Warburg 1965); There has been some laboratory research on its water conserving ability and temperature tolerance but results appear conflicting or non-conclusive regarding its survival abilities. Warburg (1965) describes it to have a low temperature tolerance but Cree (1985) describes it to have a lower rate of dehydration (than other species in study) and well developed water balance response and rapid rehydration; Sufficiently freeze tolerant to survive sub zero temperatures (Bazin et al 2007); Can be found far from water (Mallee CMA 2009) but not found in more arid parts of study region. ***Overall L. ewingi appears to have moderate survival ability. Survival is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Short tadpole phase: 1.5 - 2 months documented (Lauck et al 2005); The salinity tolerance of tadpoles is unclear with some conflicting results between field and laboratory studies: In a field study in the Victorian Wimmera *L. ewingi* appeared to have a low-moderate salinity tolerance with tadpoles detected at salinity levels up to ~3000uS/cm (~ 6% Sea water (SW)) (Smith et al 2007) but laboratory studies show it surviving in higher salinities of 12% SW without apparent negative effects (Chinathamby et al 2006; A. Scott unpublished data). Squires et al (2008) found at 15% SW tadpoles were less active and prone to increased predation. ***Moderate salinity tolerance (conflicting research) but the very short tadpole phase would allow individuals to escape more quickly from increasing saline conditions as temporary water bodies evaporate. 'Growth' is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	Short larval phase (Lauck et al 2005); '…the relatively short life-span of *L. ewingi* larvae at warm temperatures may assist the species to breed in both permanent and temporary waters (Cree 1984)'; Flexible life history strategies of L. ewingii enables this species to colonise a range of breeding sites exhibiting different conditions (Lauck et al 2005)'; Does not have a distinct breeding season; calls and breeds at any time of the year (Cogger 2000; Tyler 1977; Barker et al. 1995; Anstis 2002). ***Species able to take advantage of short hydro-periods and breed in range of sites; opportunistic breeder throughout year. Reproduction is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	No known genetics studies; *L. ewingii* was the second most common species recorded during 1998 in the SA 'Frog Census' (Walker et al 1999); Currently considered common and widespread within Lower Murray wetlands (SA MDB NRM 2010); Within South Australia it is found in the lower south-east and on the River Murray (Tyler 1977). The BDBSA (2010) has records of *L. ewingii* at 31 wetland sites (post 1990) within the study region - low record numbers thought due to its restriction to the Lower Murray area. ***Considered common, abundant & widespread in Lower Murray section of study region. Large gene pool likely. Gene pool expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Can be found far from water when not breeding (Mallee CMA 2009; SAAB 2001); Observed crossing roads in abundance on wet nights 'presumably migrating to spawning sites (Gill 1973)'. ***Common and widespread in Lower Murray and considered relatively mobile with ability to disperse to new sites. Good gene flow likely. Gene flow is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'To avoid larval mortality due to pond desiccation, L. ewingii laid eggs and metamorphosed earlier in smaller ponds...Flexible life history strategies of L. ewingii enables this species to colonise a range of breeding sites exhibiting different conditions (Lauck et al 2005). This result is consistent with literature relating to the effect of hydro-period on larval traits. To reduce the risk of mortality as a result of complete pond drying, some species of amphibian larvae are able to accelerate the rate of development to metamorphose earlier into a terrestrial environment that is less harsh than the aquatic habitat (Lauck et al 2005)'. This may be assumed as a phenotypically plastic response but see comments by S. Wassens 'Tadpole development times are often faster in the warmer parts of a species range and reliance on seasonal flooding is more important, however I am not sure if this type of phenotypic variation across a species range should be used to imply a high level of phenotypic plasticity in the species per se, as some of the more aquatic species in SA are probably at the limit of their tolerance ranges in terms of tadpole development times and resistance to drying. As such these species may not have a lot of room to move given predictions of increasing severity of droughts and increased evaporation leading to more rapid drying times (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	*L. ewingii* was the second most common species recorded during 1998 in the SA 'Frog Census' (Walker et al 1999); Currently considered common and widespread within Lower Murray wetlands (SA MDB NRM 2010); Within South Australia it is found in the lower south-east and on the River Murray (Tyler 1977). The BDBSA (2010) has records of *L. ewingii* at 31 wetland sites (post 1990) within the study region [low record numbers thought due to its restriction to the Lower Murray area]; No formal conservation concerns within SA or Australia (Robinson *et al* 2000). ***Recent surveys indicate species is common and widespread within the Lower Murray. Population size expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'… field studies around Adelaide reporting a mean clump size of 44.13 +/- 12.6 (SE) eggs (range 9-112 eggs) (Ulkrin 1980); 'Four clusters contained 17-33 eggs (Anstis 2002)'; 'During the main periods of spawning, eggs were laid in clumps of about 25-50, but late in the season (November and December) clumps contained only 7-14 eggs (Gill 1978)'. ***Field observations document low number of eggs per 'clump' or 'cluster' though it is not clear many clumps/ clusters are deposited per breeding event. Multiple clutching not documented but species has capacity to breed through most of the year. Reproductive capacity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Survival rate of offspring and overall population recruitment is unknown. Predation by introduced fish species expected to be high for most species in flood fed/ riverine wetlands. Species such as *L. ewingi* able to breed in highly ephemeral rain fed pools will have reduced predation from fish but potentially increased predation from odonates. Below factors may influence 'recruitment' of *L. ewingi*: <u>Known:</u> Capable of rapid metamorphosis; Large population (in lower Murray); Small - medium frog/tadpole size; Year round opportunistic breeding but small clutch sizes; Observed high predation from odonates in lab study (Peterson et al 1992). <u>Unknown:</u> Re-clutching frequency, life span, time to maturity and survival rate of metamorphs. ***Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Scientific Name:	*Litoria peronii*	Common Name:	Peron's Tree Frog

Question		Comments/ Reference	Vul Rating
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change : '…breeding is not exclusively flood dependent, will breed in declining and permanent water bodies…(S. Wassens pers. comm.)'.	Utilises a wide range of permanent, semi-permanent and temporary water bodies, including dams, creeks, ponds and seasonally flooded wetlands. It prefers deeper open ponds and rarely breeds in very shallow well vegetated water bodies. During the day it shelters in tree hollows and under loose bark most abundant in river red gum forests. Occupies a range of habitats and appears to be relatively unaffected by moderate reductions in flood frequency. Able to breed successfully in permanent water bodies and small residual pools (Wassens 2011), though permanent floodplain reaches have been found less likely to support breeding than temporary reaches (Wassens & Maher 2010); Preference for sites with emergent vegetation and larger trees at water margins(Hazell 2004; Anstis 2002; Lemckert et al 2006). ***Occupies range of habitats, breeds in temporary and permanent water bodies and less affected by reduction in flood frequency than other species. Preference for vegetated margins and loss of Mature Red gums will reduce refuge habitat. Habitat is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change '*L. tasmainensis* and *L. peronii* appear to be the most resilient species following extended drying and were present [after re-wetting] at wetlands that had been dry for 10 years (S. Wassens pers. comm. 2011)'.	Documented as able to occur in terrestrial environments a considerable distance from water (Cogger 2000) - good dispersal ability/ mobility expected. ***Dispersal is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Medium size; generalised food source; med larval period: ~3.5 months (Anstis 2002); tadpoles very agile and can rapidly change direction, frequent deep & shallow water (Anstis 2002); adults able to utilise vertical landscape. ***Competition is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M

Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? '*L. tasmainensis* and *L. peronii* appear to be the most resilient species following extended drying and were present at wetlands [after re-wetting]that had been dry for 10 years (S. Wassens pers. comm. 2011)'.	Med size; Very resistant to water loss even at temperatures as high as 40oC, assumes water conserving posture and cutaneous lipid layer acts as a waterproofing barrier (Amey & Grigg 1995); good water absorbant/ rehydration abilites (Tyler 1994). Present in more arid parts of study region. Can occur considerable diatance from water (Cogger 2000). ***Survival is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Med (to long) tadpole phase: approx. 3.5 months (Anstis 2002) maybe longer- described to breed most likely in wetlands with long hydroperiods (Wassens 2011). *Litoria peronii* apparently avoids even mildly saline conditions [not in ponds >0.28% salinity] (Lane et al 2007). ***'Growth' is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? '…breeding is not exclusively flood dependent, will breed in declining and permanent waterbodies, seasonal breeding, may be sensitive to altered seasonality of rain fall (S. Wassens pers. comm. 2011)'.	Occupies a range of habitats and appears to be relatively unaffected by moderate reductions in flood frequency. Its abundance has increased in river red gum wetlands within the Lowbidgee floodplain following significant reductions in wetland flooding, probably because it is able to breed successfully in permanent water bodies and small residual pools. Although calling and spawning are restricted to spring and summer, tadpoles may linger within water bodies until April. As a result the species is most likely to breed successfully in wetlands with longer hydroperiods (Wassens 2011). Distribution closely linked to the availability of standing timber, in particular *Eucalyptus camaldulensis* forests (Wassens 2011; Healey et al 1997) Greater vegetation diversity has been found to be a predictor of the presence of *Litoria peronii* (Lane et al 2007). ***Although described to be unaffected by moderate reductions in flood frequency, significant reduction in flood frequency and increasing dry periods predicted under climate change would reduce the length of wetland hydroperiods and lead to a decline in river red gums and other vegetation in the study region. Reproduction is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	'Widespread throughout the Murray-Darling Basin (Barker et al. 1995). The River Murray in SA is the only habitat within this state where this species is found (Tyler 1994). Within study region recorded at 118 wetland sites (BDBSA) post 1990 (DENR 2010). ***Considered common and abundant within the study region but distribution in SA is restricted to River Murray Corridor (e.g. study region) indicating reduced heterogeneity of gene pool. Gene pool expected to be moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Widespread throughout the Murray-Darling Basin (Barker et al. 1995). The River Murray in SA is the only habitat within this state where this species is found (Tyler 1994). ***Considered common and widespread within the study region but distribution in SA is restricted to study region. Species considered relatively mobile as being documented to occur at distance from water (Cogger 2000) increasing opportunity for gene flow. Gene flow is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'There appears to be little plasticity in response to accelerated drying which we see in species like *L. peronii* (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L (all specie s 'M'- unkno wn for final score)
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 (Barker et al. 1995). The River Murray in SA is the only habitat within this state where this species is found (Tyler 1994). Within study region recorded at 118 wetland sites (BDBSA) post 1990 (DENR 2010). ***Recent surveys indicate species is relatively common and widespread within the study region (SA MDB NRM unpublished data), though within SA is restricted to the Murray corridor. Population size expected to be moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'Number of eggs laid found to average 1777 (1303-2391) (Anstis 2002)'. ***Large number of eggs laid per clutch. Increase in Summer rains in some years predicted under climate change has potential to increase summer-autumn river flooding in study region potentially benefiting L. peronii that peak breeds in Summer. Reproductive capacity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L

	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Survival rate of offspring and overall population recruitment unknown. Predation by introduced fish species expected to be high for most species (REF?) Below factors may give some indication of recruitment rate of species within study region. Documented: moderate time to metamorphosis (temp/perm wetlands); large population; medium individual size; Spr-sum breeding. Not Documented: Re-clutching frequency, life span, time to maturity and survival rate of metamorphs. ***Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Scientific Name:	*Litoria raniformis*	**Common Name:**	Southern Bell Frog

Question/ Criteria		**Comments/ References**	**Vul Rating**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	Strong preference for temporary water bodies with large areas of lignum (Schultz 2006); Reduction in flood frequency will significantly reduce the area of available breeding habitat (Schultz 2005)'; 'The results of this study indicate that L. raniformis is more sensitive to changing flooding frequency and to drought periods than was previously thought. Annual flooding of key sites is essential if *L. raniformis* is to persist within the Lowbidgee region…The probability of occupancy by *L. raniformis* increased with increasing cover of emergent and submerged vegetation… (Wassens et al 2008b)'; 'The Lowbidgee population is immediately threatened with extirpation due to a lack of flooding in core habitat in recent years (Clemann & Gillespie 2010)'; Occupancy is highest in seasonally flooded wetlands; known sensitivity to reduced flood frequency (<2 years in 5). Recent work in Lowbidgee shows *L. raniformis* dropping out from wetlands that have had significantly reduced flood frequencies (Skye Wassens pers. comm. 2010); 'Maintaining good refuges during droughts can probably increase the resilience of these species (Skye Wassens pers. comm. 2010)' ***Although permanent wetlands provide refuge, species is reliant on flooding of temporary wetlands for breeding. Reduced incidence of flooding and increased evaporation rates will result in a significant decrease of temporary wetland breeding habitat and loss of known important aquatic vegetation such as Tangled Lignum (Muehlenbeckia florulenta). Habitat is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	'Highly mobile in the landscape (Schultz 2007)'; At Lake Littra on the Chowilla floodplain moved at least 350m overland to newly inundated sites from the nearest permanent water and related species *L. aurea* recorded moving up to 1.25km (DEH 2004 & Goldingay & Newell 2005 in Schultz 2006); As well as reducing the availability of breeding habitats across both space and time, reduced flooding has the potential to limit dispersal and recolonisation opportunities thereby threatening the long-term viability	M

		of floodplain populations (Wassens et al 2008a)';Highly dispersive and in the event of a large flood event are able to recolonise wetlands during *these* events, known sensitivity to reduced flood frequency and reduced dispersal opportunities…We radio tracked frogs moving around 200m per night. They are highly mobile but this is strongly linked to flooding (that is they move on the flood pulse) (S. Wassens pers. comm. 2011)'. **Known to move considerable distances to newly inundated wetlands but dispersal strongly linked to flooding. *Mobility & dispersal is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? Competition is a major factor for *L. raniformis* (S Wassens pers. comm. 2011)'.	Large frog up to 10cm, generalist carnivore and opportunistic forager, feeding on range of aquatic and terrestrial invertebrates and vertebrates including other frogs (Pyke & White 2001; Schultz 2005). ; Tadpoles are agile swimmers diving straight to deep water if disturbed; large tadpoles observed swimming among small red fin fish that made no attempt to attack (Anstis 2002); Adults active during day increased risk of predation but also reduced competition; Wassens (pers. comm.) records fastest metamorphosis as 3 months in Lowbidgee but only under ideal conditions and high water temperatures. but usually metamorphs not observed until late march/April for wetlands flooded in October (e.g. 5-6 months); '*L. raniformis* is highly sensitive to competition/predation by carp and gambusia. Recruitment frequently fails at wetlands with high carp abundances and removal of carp has been shown to produce a large spike in recruitment…While the situation may be somewhat different for SA I would err on the side of caution and put this as a High. Competition is a major factor for *L. raniformis* (S Wassens pers. comm. 2011)'. ***Though L. raniformis is expected to be a good competitor as an adult frog, research indicates tadpoles are very sensitive to competition/predation by carp and gambusia. Competition is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H (all spps. 'M' for final score)
	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	The presence of permanent water is important for *L. raniformis* populations in semiaridlandscapes, because they lack water-conserving adaptations such as burrowing, and the low rainfall combined with high evaporation rates limits the availability of moist terrestrialhabitats (Pyke 2002 in Wassens et al 2008a)'; Wassens (2011) documents a very limited capacity to survive dry periods and must move to permanent refuge sites; Adults quite 'aquatic' and described to have moderate tolerance to salinity but 'does not occur in water bodies where salinity levels exceed 7.0 ms/cm for lengthy periods and numbers decline rapidly as salinity approaches these levels (M. Smith pers.comm. in Clemann & Gillespie 2010);'Our experience with the 2005-2010 drought in Lowbidgee is that this species is highly sensitive to drying and drought (particularly in semi-arid areas). Mass mortality of adults was common in 2006 -2007 when core permanent water bodies dried and this should be taken into account when considering climate change impacts as most climate models predict and increase in the frequency and severity of severe droughts (S. Wassens pers. comm. 2011)'. ***Though species may be able to persist in permanent wetlands and tolerate moderate salinity, species***	H

		lacks water conserving adaptations and mass mortality is documented under drought conditions, particularly in semi-arid areas (such as the study site) and drying of permanent wetlands, events expected under climate change scenarios. Survival is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.	
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Short-moderate tadpole phase in temporary wetlands: approximately 3 months in study region (Schultz 2007); Wassens (pers. comm. 2011) records minimum metamorphosis at 3 months in the Lowbidgee region but only under ideal conditions and high water temperatures, and usually metamorphs not observed until late March/April for wetlands flooded in October (e.g. 5-6 months); Does not occur in water bodies where salinity levels exceed 7.0 ms/cm for lengthy periods and numbers decline rapidly as salinity approaches these levels (M. Smith pers.comm. in Clemann & Gillespie 2010). **Requires medium hydro period for successful tadpole development (variable and season dependant) and species appears to display a moderate tolerance to salinity. *Growth tolerances are expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	Populations in Northern Murray region of SA are reliant on flooding of temporary wetlands for breeding (Clemann & Gillespie 2010; Schultz 2007); A reduction in flood frequency will significantly reduce the area of available breeding habitat (Schultz 2005); 'The Lowbidgee population is immediately threatened with extirpation due to a lack of flooding in core habitat in recent years (Clemann & Gillespie 2010)'; Breeding is strongly flood dependant, relatively narrow breeding window so may be affected by altered seasonality of flooding/ rainfall (S. Wassens pers. comm. 2011)'. **Species reliant on flooding of temporary wetlands for breeding which is expected to decline in frequency and duration under climate change. May also be affected by a change in seasonality of flooding. *Reproductive tolerances expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Has suffered a dramatic decline throughout its distribution since the early 1990s (Schultz 2007)' Locally abundant in some areas of the SA Murray River corridor such as Chowilla Game Reserve (Schultz 2006; SA MDB NRM unpublished data). ***Restricted distribution but locally abundant in some parts of study region indicating a moderately sized gene pool. Gene pool expected to be moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Has suffered a dramatic decline throughout its distribution since the early 1990s but is locally abundant in areas of the SA Murray River corridor (Schultz 2006); 'As well as reducing the availability of breeding habitats across both space and time, reduced flooding has the potential to limit dispersal and recolonisation opportunities thereby threatening the long-term viability of floodplain populations (Wassens et al 2008a)'; '…highly dispersive and in the event of a large flood event are able to	M

		recolonise wetlands during these events…known sensitivity to reduced flood frequency and reduced dispersal opportunities…They are highly mobile but this is strongly linked to flooding (that is they move on the flood pulse) (S. Wassens pers. comm..)'; Restricted distribution but locally common in some parts of study region. Highly mobile but strongly linked to flooding with reduced dispersal opportunities with a decline in flood frequency and extent. ***Gene flow is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	The larval period is highly variable for *L. raniformis* across its distribution (2-12 months), with shorter tadpole phases generally exhibited in temporary wetlands (Clemann & Gillespie 2010). This *could* be an indication of phenotypic plasticity in response to increasing unfavourable conditions e.g. a drying wetland or increasing water temperatures, as documented for other amphibian species (Denver 1997). Also shown to breed over a protracted season, i.e. Aug-Feb, in response to flooding (M. Schultz pers.comm..); '*L. raniformis* tadpoles are less flexible then other wetland species and I have recorded significant mortality in wetlands that were flooded from October to January. Development times are likely to be driven more by water temperature and food availability then plasticity per se- that is the temporary water bodies studied tend to be warm, shallow and highly productive but this is not really the norm. There appears to be little plasticity in response to accelerated drying which we see in species like *L. peronii*- I would put this as a Medium/High…(S. Wassens pers.comm.)'. ***Some differing expert opinions but indications are that tadpole development is less flexible than for other species in the study region. Phenotypic plasticity is expected to be a moderate/high limitation on the ability of the regional population of the species to tolerate climate change.***	M
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	'The Southern Bell Frog (*Litoria raniformis*) is a vulnerable (EPBC Act 1999) wetland species that has undergone significant range declines over the past 30 years (Wassens et al 2008)'; '...has suffered a dramatic decline throughout its distribution since the early 1990s (Schultz 2007)'; 'In NSW the decline was first noted in the 1970's and probably started in some areas during the 1960's…But given that the distribution is more limited in SA it may have occurred later there (S. Wassens pers. comm..)'; Locally abundant in some areas of the SA Murray River corridor and study region (Schultz 2006; SA MDB NRM unpublished data); Population size expected to be moderate limitation on the ability of the regional population of the species to tolerate climate change. ***Overall population within former range is considered small and distribution limited but it is locally common in some areas of the study region after flooding and environmental watering, Population Size is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.*** .	M
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate	Approximately 2000 eggs are laid in a loose clump (Gillespie et al 2004; ARC 2005); Two females laid 1885-3893 eggs (Anstis 2002); Large numbers of tadpoles recorded in artificially watered temporary wetlands of SA Upper Murray (Schultz 2007; A. Scott pers.obs. 2010).	L

	climate change	**Capacity for high reproductive capacity during inundation of temporary wetlands. *Reproductive capacity is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change*.**	
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	'High densities of European Carp are likely to have contributed to poor recruitment outcomes… (Wassens et al 2008)'; *L. raniformis* is highly sensitive to competition/predation by Carp and gambusia. Recruitment frequently fails at wetlands with high carp abundances and removal of carp has been shown to produce a large spike in recruitment… (S. Wassens pers. comm. 2011); Population rate of increase would likely depend on repeated flooding of temporary wetlands after long dry periods (M. Schultz pers. comm. 2010); 'The long-term persistence of this species depends on regular flooding events to promote recruitment. At this stage, annual flooding over a number of years may be required in order to re-establish population numbers (Wassens et al 2008a)'; *L. raniformis* tadpoles are less flexible in development time then other wetland species and significant mortality was recorded in wetlands flooded from October to January. Development times are likely to be driven more by water temperature and food availability (S. Wassens pers. comm. 2011). ***Species has high reproductive potential but only during flooding of temporary wetlands. Increased evaporation rates would likely result in higher mortality of tadpoles if not able to successfully disperse before wetlands dry or salinity tolerances are exceeded. Predation by introduced fish is implicated in frequent recruitment failures and with a reduction in temporary wetlands the proportion of wetlands without fish will decline. Recruitment is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***	H (all spp. 'M' for final score)

Scientific Name:	*Neobatrachus pictus/ N. sudelli*	**Common Name:**	Painted/ Burrowing Frog & Sudell's Frog

Question		**Comments/ Reference**	**Vul Rating**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change '…breeds in flooded wetlands along the Murray and in rain fed wetlands but is not widely distributed through rain fed wetlands, distribution may be limited to areas with specific soil types suitable for burrowing…moderate tadpole development times so sensitive to reduced flooding (S. Wassens pers. comm.)'. [*N. Sudelii*]	'Recorded in a range of habitat types (Walker et al. 1999). Occur in a wide range of arid and semi-arid areas including mallee, shrublands, woodlands and heathlands; found in open grassland and woodland (Barker et al. 1995)…Flooded grassy marshes, temporarily inundated roadside ditches and clay pans, and lagoons (Cogger 2000)…Require heavy rains to allow young toads to disperse from the breeding sites; require sufficient water at breeding sites to allow time for the eggs and tadpoles to develop to the toad stage (Tyler 1977)…breeding can be adversely affected by drought and a lack of heavy rains; a lack of enough free standing water to enable the tadpoles to complete their development would also pose a threat to the long term viability of populations of this species [in SAAB 2001])'. Limited habitat information for *N. Pictus*- assumed similar to *N. Sudellii.* ***Although is not considered dependent on riverine habitat (Gillam & Urban 2010, Wassens 2011) reduction in flooding of the River Murray is expected to reduce breeding habitat. Habitat is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? '…does not appear to be highly dispersive (S. Wassens pers. comm. 2011)'.	Frogs can be found wandering on moist evenings, far from permanent water (Cogger 2000). [N. Pictus] Require heavy rains to allow young toads to disperse from the breeding sites (Tyler 1977). ***Dispersal may be limited by a reduction in rain events. Dispersal is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Adult size med; tadpole large; massive jaw sheaths facilitate feeding on large plant and animal food items-voracious when protein source available, e.g. dead tadpole/insects; mostly bottom dwellers/ sedentary but can move rapidly; *N. Sudellii*: Med tadpole phase 4.5-7months (Martin 1965; Barker et al. 1995). *N. Pictus*: Short tadpole phase (Tyler 1977) (some conflicting refs). ***Competition is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	'Med size; aestiviates and forms a coccoon in response to a lack of free water, considerable reduction in evaporative water loss (Withers 1995). Showed combined reduced water loss and increased water uptake at high temperatures only exceeded by *N. centralis* (Warburg 1965). Prolonged dormancy facilitate long-term survival in arid habitats (Roberts…, Littlejohn…)'. ***Survival is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***	L
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	*N. sudellii*: Med tadpole phase: 4.5-7months (Martin 1965; Barker et al. 1995). In salinity field study (Smith et al 2007). *N. sudelli* appeared to have a moderate salinity tolerance detected at salinity levels up to ~4200uS/cm (~ 8.5% SW). The duration of the tadpole stage [N. Pictus] is approximately 2 months (Tyler 1977 in SAAB 2001)'. ***Moderate salinity tolerance and short-moderate tadpole development time. 'Growth' is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? '…[N. Sudelli] breeds in flooded wetlands along the Murray and in rain fed wetlands but is not widely distributed through rain feed wetlands… moderate tadpole development times so sensitive to reduced flooding, appears to have a restricted breeding window- winter/spring (S. Wassens pers. comm. 2011)'.	Rains are required to trigger breeding and provide enough temporary freestanding water for tadpole development. Breeding can be adversely affected by drought and a lack of free standing water (SAAB 2001). Breeding following summer rain episodes in grassy marshes, lagoons, flooded clay pans and temporarily inundated roadside ditches) (Cogger 2000). The male calls while floating in shallow, still water; eggs are spawned in long attached strands which become entangled in submerged vegetation (Barker et al. 1995). '…[N. Sudelli] breeds in flooded wetlands along the Murray and in rain fed wetlands but is not widely distributed through rain feed wetlands… moderate tadpole development times so sensitive to reduced flooding, appears to have a restricted breeding window- winter/spring (S. Wassens pers. comm. 2011)'. ***Although it may not be entirely dependent on riverine habitat (Gillam & Urban 2010, Wassens 2011), it requires temporary wetlands for breeding and may have moderate tadpole development times. With a reduction in flood frequency and rainfall, 'reproduction' is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Tyler (1997) advocates research into the conservation of this and other poorly known genera which inhabit arid areas of Australia. Due to confusing taxonomy and limited research of *Neobratrachus* species (M. Tyler pers. comm. 2011) the extent and diversity of the gene pool within the study region is unknown ***Gene pool expected to be unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Frogs can be found wandering on moist evenings, far from permanent water (Cogger 2000); Require heavy rains to allow young toads to disperse from the breeding sites (Tyler 1977). '…does not appear to be highly dispersive (S. Wassens pers. comm. 2011)'. Tyler (1997) advocates research into the conservation of this and other poorly known genera which inhabit arid areas of Australia. **Does not appear highly dispersive and dispersal is linked to rain events but may be able to travel considerable distance under the right conditions. Knowledge on the distribution and abundance of this genera is limited (see 'gene pool'). Gene flow is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.**	M
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Conflicting information (regarding species taxonomy and larval phase) but variable larval phase described for N. sudelli & N. pictus between 2 - 7 months (Anstis 2002; Tyler 1977; Martin 1965; Barker et al 1995). As a species of arid environemnts phenotypic responses may occur due to highly ephemeral habitats. Tadpole development times are often faster in the warmer parts of a species range and reliance on seasonal flooding is more important, however I am not sure if this type of phenotypic variation across a species range should be used to imply a high level of phenotypic plasticity in the species per se, as some of the more aquatic species in SA are probably at the limit of their tolerance ranges in terms of tadpole development times and resistance to drying. As such these species may not have a lot of room to move given predictions of increasing severity of droughts and increased evaporation leading to more rapid drying times (S. Wassens pers. comm. 2011)'. ***Phenotypic plasticity is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Tyler (1997) advocates research into the conservation of this and other poorly known genera which inhabit arid areas in Australia. Within study region Neobatrachus spp. Is recorded at 16 wetland sites (BDBSA) post 1990 (DENR 2010). [*N. Pictus]* Described as 'Common in areas of south Australia (frogs.org.au)'. ***There are few records of Neobatrachus species within the study regionbut this may not be a good indication of population size due to their reduced dependence on the Murray Corridor and habitat of the study region (Gillam & Urban 2010). Population size is expected to be an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Approximately 1,000 eggs are produced (Tyler 1977) [in SAAB 2001]'. Anstis (2002) doesn't document number of eggs for *N. sudellii* 'Over one thousand individuals of Limnodynastes tasmaniensis bred in one year in a single pond of 20 m diameter, compared to only one or two individuals at the same site for Neobatrachus pictus (Roberts?)'. 'Two females laid 560 and 935 eggs (Anstis 2002)'. – *N. sudellii* ***Moderate-high number of eggs laid in a clutch; and although other Neobatrachus are known to mass spawn information on mass spawning events or multiple clutching for N. sudelli or N. pictus specifically was not found. Reproductive capacity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***	M
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	***Survival rate of offspring and overall population recruitment unknown. Many factors influence recruitment and due to a general lack of information and research for all species recruitment is an unknown limitation on the ability of the regional population of the species to tolerate climate change.***	M

FROG REFERENCES

Amey, A.P. & Grigg, G.C. (1995). Lipid-reduced evaporative water loss in two arboreal hylid frogs. Comp. Biochem. Physiol. 111a(2): 283-291.

Anstis, M. (2002) *Tadpoles of South-eastern Australia: A Guide with Keys*. Reed New Holland Pty Ltd. Sydney.

Barker, J., Grigg, G. and Tyler, M. (1995). 'A Field Guide to Australian Frogs.' (Surray Beatty & Sons: Chipping Norton, NSW.)

Chinathamby, K., Reina, R. D., Bailey, P. C. E. & Lees, B. K. (2006). Effects of salinity on the survival, growth and development of tadpoles of the brown tree frog, Litoria ewingi. Australian Journal of Zoology 54: 97–105.

Clemann, N. & Gillespie, G.R. (2010). *National Recovery Plan for the Growling Grass Frog Litoria raniformis*. Department of Sustainability and Environment, Melbourne.

Cogger, H.G. (2000). ‘Reptiles and Amphibians of Australia.’ Sixth Edition. (Ed. P. Hutton.) (Reed New Holland, an imprint of New Holland Publishers (Australia) Pty Ltd: Sydney.)

Department of Environment and Heritage (2004a) *Lake Littra Draft Management Plan*. Department for Environment and Heritage, Berri, South Australia.

Denver, R. J. (1997). Proximate Mechanisms of Phenotypic Plasticity in Amphibian Metamorphosis. *American. Zoologist* **37**:172-184.

Gillam, S. and Urban, R. 2010. Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region. Department of Environment and Natural Resources, South Australia.

Goldingay, R.L. and Newell, D.A. 2005b. Population estimation of the Green and golden bell frog *Litoria aurea* at Port Kembla. *Australian Zoologist* **33**: 210-216.

Pyke, G.H. 2002. A Review of the Biology of the Southern Bell Frog, *Litoria raniformis* (Anura: Hylidae) *Australian Zoologist* **32**: 32-48.

Healy, M., Thompson, D. & Robertson, A. (1997). Amphibian communities associated with billabong habitats on the Murrumbidgee floodplain Australia. Australian Journal of Ecology. 22: 270-278.

Lauck, B,. Swain, R. & Barmuta, L. (2005) Breeding site characteristics regulating life history traits of the brown tree frog, Litoria ewingi. Hydrobiologia 537: 135–146

Mac Nally, R., Horrocks, G., Lada, H., Lake, P.S., Thomson, J.R. and Taylor, A.C. (2009). Distribution of anuran amphibians in massively altered landscapes in south-eastern Australia: effects of climate change in an aridifying region. Global Ecology and Biogeography. 18: 575-585.

Pyke, G.H. & White, A.W. (2001). A Review of the Biology of the Green and Golden Bell Frog Litoria aurea. *Australian Zoologist* **31** (4): 563-598.

Schultz, M.A. (2005) *Draft Recovery Plan for the Golden Bell Frog Litoria raniformis in the South Australian River Murray Corridor*. Department for Environment and Heritage, Adelaide, South Australia.

Schultz, M.A. (2006) Distribution and Detectability of the Golden Bell Frog Litoria raniformis in the South Australian River Murray Corridor: Implications for Conservation and Management. Department for Environment and Heritage Adelaide, South Australia. Report to South Australian Murray Darling Basin Natural Resources Management Board.

Schultz, M.A. (2007), Response of the Golden Bell Frog Litoria raniformis to Environmental Watering Programs on the Chowilla Floodplain, Department for Environment and Heritage, Murraylands Region. Report prepared for the Department of Water Land Biodiversity and Conservation.

SA MDB NRM unpublished data. South Australian Murray Darling Basin Natural Resources Management Board wetland monitoring data (ongoing). Aquatic Biodiversity, SAMDBNRM Board.

Smith, M.L., Schreiber, E.S.G., Scroggie, M.G., Kohout, M., Ough, K., Potts, J., Lennie, R., Turnbull, D., Jin, C. & Clancy, T. 2007. Associations between anuran tadpoles and salinity in a landscape mosaic of wetlands impacted by secondary salinisation, Freshwater Biology, 52: 75–84.

Squires, Z.E., Bailey, P.C.E., Reina, R.D. & Wong, B.B.M. (2008). Environmental deterioration increases tadpole vulnerability to predation. *Biology Letters* 4: 392-394.

Tyler, M.J. (1994). *Australian Frogs: A Natural History*. Reed New Holland Publishers (Australia) Pty Ltd: Sydney.

Tyler, M.J. (1977), Frogs of South Australia. (2nd ed). South Australian Museum, Adelaide.

Warburg, M.R. (1965). Studies on the water economy of some Australian frogs. *Australian Journal of Zoology* **13**: 317-30

Wassens, S. (2010), Frogs. In Rogers, K & Ralph, T.J. (eds), *Floodplain Wetland Biota in the Murray-Darling Basin Water and Habitat Requirements*, pp. 253-274. CSIRO Publishing, Collingwood, Australia.

Wassens, S. & Maher, M. (2010). River Regulation Influences The Composition and Distribution of Inland Frog Communities. *River Research & Applications.*

Wassens, S., Watts, R. J., Jansen, A. & Roshier, D. (2008a) Movement patterns of Southern Bell Frogs (Litoria raniformis) in response to flooding. *Wildlife Research* **35**: 50 - 58.

Wassens, S., Arnaiz, O., Healy, S., Watts, R. and Maguire, J. (2008b) *Hydrological and habitat requirements to maintain viable Southern Bell Frog (Litoria raniformis) populations on the Lowbidgee floodplain- Phase 1*. Final Report DECC. Queanbeyan

Scientific Name:	*Chelodina expansa*	Common Name:	Broad Shelled Turtle

Question		Comments/ Reference
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change?	Appears restricted to deep, permanent water; favours still waters. Inhabits lagoons, lakes, rivers & swamps throughout the Murray Darling drainage (Cann 1998). Despite their description as a riverine turtle they are more often represented in permanent lakes and billabongs reflecting their preference for slow flowing waters (D. Bower unpublished review). Chessman (1983, 1988) found it to occur in waters that were relatively deep (>2-3m), often turbid and within 600m of the Murray River. Prefers habitats with structural complexity (D. Bower unpublished review) and majority of habitat use described in emergent reeds, aquatic macrophytes and submerged logs, dead trees and root systems. Without structured aquatic habitats the food resources that *C. expansa* rely on may decrease (Ercolano unpublished report). Able to tolerate short periods of high salinity (Scheltinga 1991). 'Persistence of *C. expansa* relies on the health of freshwater systems in south eastern Australia; large scale river regulation degrading the health of the river and development of adjacent land can threaten the persistence of species reliant on freshwater systems (D. Bower unpublished review)'. *Chelodina expansa* appear to have tolerated the initial regulation of the Murray Darling Basin (Chessman 1978). ***With a reduction in river flow and its preference for deep, permanent still waters the habitat suitability of some areas of the river channel and large anabraches may increase, but complex habitat structure, water quality and abundance of specialized prey items are likely to decline with reduced flood frequency. 'Habitat' is expected to be a moderate-major limitation on the ability of the regional population to tolerate climate change.***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Dependence on permanent waters is most likely associated with its higher rate of evaporative water loss under desiccating conditions, infrequent emigration between water bodies, and lack of terrestrial (or aquatic) aestivation (Chessman 1988). Radio-telemetry has revealed that female turtles occupy discrete home ranges 2.64 ± 1.73 km, whilst males have larger home ranges 11.18 ± 0.91 and are capable of movements > 25 km up stream D. Bower unpublished review). 'Immigration and emigration was assumed to be low because both *E. macquarii* and *C. expansa* are considered lacustrine species and are not mobile (Chessman 1978; Cann 1998) [in Spencer & Thompson 2005]'. ***A lacustrine species with restricted mobility on land and infrequent overland emigration between permanent water bodies. Instream barriers such as weirs are likely to restrict aquatic movements within the River Murray. 'Mobility and dispersal' is expected to be a major limitation on the ability of the regional population to tolerate climate change.***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Some conflicting information regarding its diet possibly to do with resource availability: Chessman (1983) describes it as a wholly carnivorous turtle and a selective and specialised predator feeding on highly motile prey with decapod crustaceans, aquatic bugs and small fish predomiant and diet includes some carrion.

		However, Meathrel *et al* (2002) found 80% of gut contents of individuals in an isolated billabong to be comprised of plant debris suggesting vegetation may be significant during periods of low resource availability; In Brisbane's urban lakes, *C. expansa* represents 11.1% of the total turtle assemblage, whilst abundance correlates *positively* with both introduced fish abundance and level of disturbance (De Lathouder et al. 2009). *C. expansa* appears the least cold-adapted of the three species, and was not trapped below 18°C (Chessman 1988b) indicating inactivity at moderate-low water temperatures that would occur for several months of the year within the study region. ***Described as a selective and specialised predator which may reduce its competitiveness though it appears able to expand diet to vegetation at times of low resource availability; large turtle; nest and adult predation appears lower than for E. macquarii; evidence for positive correlation with introduced fish & disturbance in some locations; not active at moderate-low water temperatures. 'Competition' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Dependence on permanent waters is described to be most likely associated with its higher rate of evaporative water loss under desiccating conditions, infrequent emigration between water bodies, and lack of terrestrial aestivation (Chessman 1988). The physiology of *C. expansa* is linked to their highly aquatic existence. Their resistance to desiccation is intermediate between the more terrestrial *C. longicollis* and the highly aquatic *E. macquarii* (Chessman 1984). Able to tolerate short periods of high salinity (Scheltinga 1991). The internal surface area of cloacal bursae is comparatively smooth; suggesting they do not undergo a high level of cloacal respiration (Legler and Georges 1994 in D. Bower unpublished review). ***Moderate-high evaporative water loss; intermediate resistance to desiccation compared to sympatric turtles; lack of aestivation; highly aquatic existence; can exist in highly saline waters for short periods. 'Survival' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Growth patterns of *C. expansa* demonstrate slow growth for the first two years followed by rapid growth between three and five years of age, after which grow slows (Spencer 2002); *C. expansa* appears the least cold-adapted of the three species, and was not trapped below 18.4°C in Spring and 20°C in autumn (Chessman 1988b); Able to tolerate short periods of high salinity (Scheltinga 1991). ***Not enough information was found to determine limitations to growth under climate change. 'Growth is' is an unknown limitation to the ability of the regional population of the species to tolerate climate change***

	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	Females documented to construct nests between; 1.5m & 1 km from water (Cann 1998 [in SAAB 2001]); 42.1 ± 12.8 m (±SD) (Spencer and Thompson 2005) and 9-750 m from water (Georges, 1984 [in Greer 2003]). Females nest from mid-March to 20 August (Greer 2003). 'Emydura macquarii and C. expansa respond strongly to rain and air temperature changes associated with rain, usually emerging to nest during or after storms (Bowen et al 2005)'. If soil is too dry females may not deposit eggs because they can't excavate a suitable nest and hatchling emergence can be unsuccessful (Goode & Russell 1968). 'The decreasing occurrence of storms and rain may adversely affect E. macquarii and C. expansa by delaying nesting, making nest construction more difficult and nests more conspicuous to predators (Bowen et al 2005)'. Terrestrial areas with substantial vegetative cover were found to be preferred nesting sites (Ercolano unpublished report). '*Chelodina expansa* eggs tolerate a wide temperature range from 4.9–29.6oC (Goode and Russell 1968). Higher nest temperatures can reduce incubation time (Goode and Russell 1968; Greer 2006 in Ercolano unpublished report, Booth 2002). However in the laboratory, eggs incubated at 30° C had only 5 percent survival (Legler, 1985), surprising, as 30° C seems to be a favoured and successful incubation temperature for other Australian turtles (in Greer 2003)'. 'Climate change may be problematic for C. expansa because nesting, diapauses and possibly hatching, rely on climatic cues (Bowen et al. 2005, Booth 2002a). Additionally, the morphology of hatchlings is influenced by the hydric environment experienced throughout incubation (Booth 2002b) and may cause further vulnerability to populations of *C. expansa* if aridity or salinisation increases in south eastern Australia (in D. Bower unpublished review)'. Average incubation time is 324 - 360 days (range 192 and 522 days) (Good and Russell, 1968; Georges, 1984). Long incubation is due to hatchlings overwintering in the nest and emerging the following spring. The 522 day incubation appears due to an additional over-summering during an unusually dry summer/autumn, followed by a second over-winter (Goode and Russell 1968). The autumn laying and over-wintering may have evolved to ensure young emerge at the 'right time' to have the best survival chance e.g. at commencement of growing season to have a full season to feed and grow before winter (Greer 2003). ***Increased evaporation rates, receding water, reduced rainfall in autumn/winter and increasing salinity may result in preferred vegetated sites and soils close to the water becoming increasingly unsuitable for nesting and may increase mortality rates of females; eggs tolerant of wide temperature range but not of temperatures ≥30oC which may occur more commonly under climate change and with a reduction in vegetative cover; long incubation times can benefit hatchlings but may increase exposure time of eggs to potential extremes of climate and predation. 'Reproduction' is expected to be a major limitation to the ability of the regional population of the species to tolerate climate change.***

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	*Chelodina expansa* have lower population densities than sympatric turtle species, which may increase their vulnerability to threatening processes. It is distributed throughout the inland rivers of south-eastern Australia's Murray Darling Basin, and in the Paroo drainage in inland eastern Australia. In the Murray Darling Basin it does not extend south of the Murray River, except for a population in the Goulburn River drainage (Cann 1998). Low numbers of *C. expansa* make populations highly susceptible to perturbations in particular life stages (Spencer & Thompson 2005). 'Three species of tortoise inhabit the Murray in South Australia…The first two species occur in large numbers, *C. expansa* being less common (Thompson 1993)'. 'To conform to the precautionary principle, due to a paucity of information, *C. expansa* is listed as 'Vulnerable' in South Australia under the National Parks and Wildlife Act (1972) and 'Threatened' in Victoria under the Flora and Fauna Guarantee Act (1988). However, these listings may reflect their cryptic nature rather than their population vulnerability (Spencer and Thompson 2005). They are not listed under the EPBC and are classified as 'Near Threatened' under the IUCN red listing (D. Bower unpublished review)'. ***Species has been previously documented to have a low population density but relatively broad distribution through most of Murray Darling Basin but low recorded abundance may be due to species' cryptic nature. 'Gene pool' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	'Immigration and emigration was assumed to be low because both *E. macquarii* and *C. expansa* are considered lacustrine species and are not mobile (Chessman 1978; Cann 1998) [in Spencer & Thompson 2005]'. Infrequent emigration between water bodies (Chessman 1988) but capable of movements > 25 km up stream (D. Bower unpublished review). ***Species has been historically documented to have a low population density but with a relatively broad distribution through most of Murray Darling Basin. However, low recorded abundance is thought to 'reflect their cryptic nature rather than their population vulnerability (Spencer and Thompson 2005)'. Species documented to infrequently emigrate between water bodies but can travel considerable distance 'in-stream'. 'Gene fowl' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	*Phenotypic* influence of incubation temperature can affect post hatch behaviour and growth and may be an important determinant of hatchling survival and therefore reproductive fitness (Booth 2002). Booth (2000) found that eggs at 24°C absorbed more water during incubation than did eggs at 28°C. Eggs at 28°C had a larger yolk reserve and presumably this enabled hatchlings to survive longer under conditions of starvation that may occur when food in the aquatic environment is scarce. On the other hand hatchlings from 24°C had larger heads that may provide a feeding advantage over hatchlings from 28°C because the larger head width results in a larger mouth size, which may enable these individuals to tackle a larger variety of prey. Booth (2002) found time to hatching was shorter under higher temps (e.g. at constant 28C 164 days & fluctuating 192 days).

		'The reproductive biology of C. expansa set them apart from other turtles; in response to temperature, embryos enter a secondary diapause, which enable them to overwinter in the nest, resulting in a year long incubation period (D. Bower unpublished review)'. 'The two observations made of September-deposited eggs showed that hatching was about the same time as that for eggs deposited 5 months earlier (Goode & Russell 1968)'. ***C. expansa appears to have the most variable embryo development rates of the turtles. Onset of secondary diapause in response to cooling temperatures and increased rate of embryo development with increased nest temperature indicates a plastic response to variable environmental conditions.***
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	*Chelodina expansa* have lower population densities than sympatric turtle species, which may increase their vulnerability to threatening processes. It is distributed throughout the inland rivers of south-eastern Australia's Murray Darling Basin, and in the Paroo drainage in inland eastern Australia (Cann 1998). Described as being in 'low numbers' (Spencer & Thompson 2005)'. 'Three species of tortoise inhabit the Murray in South Australia…The first two species occur in large numbers, *C. expansa* being less common (Thompson 1993)'. '…*C. expansa* is listed as 'Vulnerable' in South Australia under the National Parks and Wildlife Act (1972)… However, these listings may reflect their cryptic nature rather than their population vulnerability (Spencer and Thompson 2005) (D. Bower unpublished review)'. ***Documented to have low population density but with a relatively broad distribution through most of Murray Darling Basin. However, low recorded abundance is thought to 'reflect their cryptic nature rather than their population vulnerability (Spencer and Thompson 2005)'. Population size' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Clutches of 5-28 eggs documented (D. Bower unpublished review); average clutch size of 15.4 eggs (Goode & Russell 1968) and 15.5 (autumn) and 11.0 (Spring) (Booth 1998). '… it is not known whether spring nests represent a second clutch (Booth 1998a)'. ***Average clutch size is less than E. macquarri but higher than C. longicollis; re-clutching not confirmed. 'Reproductive capacity' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Spencer & Thompson (2005) found that *C. expansa* had relatively more juveniles in the population and was less reliant on adult survival. Despite its vulnerable status, *C. expansa* is relatively more stable than *E. macquarii*, primarily because there were proportionally more juveniles in the population… *C. expansa* matures later and has lower adult survival and elasticity value than *E. macquarii.* Generation times were between 50 and 60 years for E. macquarii but were<30 years for *C. expansa. C. expansa*, however, had lower rates of nest predation and higher rates of juvenile survival than *E. macquarii* …Foxes have been well established in the area since the mid to late 1800s and nest predation rates have been known to be <90% for

		at least 20 years (Thompson 1983) [in Spencer & Thompson 2005])'. A closed population of *C. expansa* that has been studied in detail demonstrates that survivorship is high (Females 0.92, male 0.88 and juveniles 0.84); and does not vary temporally or between lagoons (Spencer and Thompson 2005). Female *C. expansa* mature at approximately 14 years, later than *C. longicollis* or *E. macquarii* (Spencer 2002). 'The diurnal nesting habits of *C. expansa* result in predation rates much lower (50–70%) than sympatric species (*E. macquarii*) which are heavily predated by foxes (Spencer and Thompson 2005)…After entering aquatic habitats, hatchlings may be predated by large fish such as saratoga (Scleropages leichardti; Phillott and Parmenter 2000 in D. Bower unpublished review)'. Survivorship of adult C. expansa is high and most mortality occurs in adult females during nesting forays (Spencer and Thompson 2005). The propensity to nest far from shore increases the probability of harmful encounters with vehicles and predators (Spencer and Thompson 2005). ***Lower nest predation rates, relatively more juveniles, and higher productivity (than E. macquarii) (Spencer & Thompson 2005); late female maturity; shorter generation time/ longevity; high adult mortality. 'Recruitment' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***

Scientific Name:	*Chelodina longicollis*	**Common Name:**	Common Long-necked Turtle

	Question	**Comments/ Reference**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	A habitat generalist occurring in a range of water bodies (Chessman 1988). Chessman (1988) found water bodies in which *C. longicollis* greatly dominated were either, shallow, ephemeral or remote from the Murray River and noted that *C. longicollis* does seem to be scarce in large, stable water bodies where *Emydura spp.* are present. 'Changes in the flow pattern of the Murray River as a result of river regulation have probably been to the advantage of *E. macquarii* and the detriment of *C. longicollis*…Migration of *C. longicollis* between water bodies also results in large numbers being crushed by vehicles while crossing roads (B. C. Chessman, personal observations) or trapped by fences (Chessman 1988)'. ***Although is a habitat generalist occurring in both permanent and ephemeral waters it is described as scare in large stable, water bodies and a strong preference for ephemeral, shallow waters that have declined under river regulation and predicted to decline further with reduced flooding under climate change scenarios. Habitat preference is expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	Often undertakes extensive overland migrations. When water bodies dry out the turtles move to more permanent water. Conversely, when wet conditions return and ephemeral water bodies fill, the turtles quickly return. Documented to move 2.5 km within four days to an ephemeral wetland that commenced filling (Kennett and Georges, 1990). That is an average rate of movement of 26 m per hour. The turtles have been found as far away as 3 km from the nearest water (Parmenter 1976 [in Greer 2003]). The widespread distribution of this species stems from its ability to move long distances over land and thereby inhabit temporary waters (Chessman 1988; Thompson 1993). 'The capacity of C. longicollis for colonising and surviving in small, remote and ephemeral ponds and pools relates to its ability to aestivate and resist desiccation and its propensity for overland migration (Chessman 1988)'. The eastern snake-necked turtle can move up to 8 km in 24 hours (Goode 1967). ***Species has good mobility and disperses readily in comparison to other freshwater turtles though may be limited by increasing distances between suitable water bodies. Mobility & dispersal is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	'In ephemeral water bodies on the island, not containing *Emydura krefftii* or *C. expansa, C. longicollis* does better (Georges et al 1986)'.One distinct advantage of ephemeral water bodies is that they generally lack a major group of competitors for the turtle's invertebrate prey: fish (Chessman 1988; Kennett & Georges 1990 [in Greer 2003])'. Opportunistic carnivore (Kennet & Georges 1990). 'Disturbance by dense fish populations in drying pools may also contribute towards prompting migration (Chessman 1978)'.

		Occupation of ephemeral waters is probably of ecological advantage to C. *longicollis* because it permits feeding on dense populations of aquatic invertebrates which develop in the absence of predation by fish. Chessman (1984b) found that the average volume of stomach contents of C. *longicollis* was nearly eight times as great in ponds and pools without fish as in waters where fish were present (Chessman 1988). 'Perhaps the combined effect of competition from fish and other turtle species makes water bodies such as Lake Boga, and to a smaller extent the Murray River, a less suitable habitat for C. longicollis (Chessman 1988)'; '*C. expansa* and *E, macquarii* were caught only from October to April, while *C. longicollis* was taken in all months but June and July. Minimum water temperatures at capture were highest for *C. expansa* and lowest for *C. longicollis*…By comparison, C. longicollis appears to have a low feeding threshold, being trapped at temperatures down to 12°C (Chessman 1988b)'. ***Competitors include fish and potentially other turtle species and a reduction in ephemeral water bodies may increase competition. However as a generalist carnivore with high mobility, the effects of competition may be reduced. Competition is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Kennett & Georges (1990) observed many emaciated turtles in permanent lakes after a long drought when temporary wetlands did not flood. Observations also suggest though that C. *longicollis* is capable of withstanding long periods with limited food and may inhabit water bodies in which the productivity is so low that the animals cannot put on enough condition to allow them to reproduce (Kennett and Georges 1990); They are much less prone to desiccation than the broad-shelled river turtle (*Chelodina expansa*) or the Murray turtle (*Emydura macquarii)*, and have a low rate of evaporative water loss. Further, they can rehydrate by drinking or immersion of the cloaca (Chessman 1984a in SAAB 2001). Documented to occur in wetlands of study region with moderate salinity levels (Suter et al. 1993 in SAAB 2001, SAMDBNRM unpublished data). ***Capable of withstanding long periods without food; least prone to desiccation of 3 Murray turtle species; low evaporative water loss; mechanisms for re-hydration; tolerant of moderately saline habitats. Survival tolerances are expected to be a minor (to moderate) limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Kennett & Georges (1990) found high population densities in lakes coupled with low productivity led to a sharp decline in growth and a close relationship between turtle growth and rainfall. '…*C. longicollis* in temporary wetlands exploit abundant prey resources in the absence of competitors, grow faster and have substantially higher reproductive output than in permanent lakes (Kennett & Georges 1990). ***A decrease in productive temporary wetlands with reduced flooding is expected to significantly impact on growth and development of C. longicollis. Growth tolerances are expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does **reproduction** limit the ability of the regional population of the species	Kennett & Georges (1990) found high population densities in lakes coupled with low productivity led to a sharp decline in growth and reproduction. '…*C. longicollis* in temporary wetlands exploit abundant prey

	to tolerate climate change?	resources in the absence of competitors, grow faster and have substantially higher reproductive output than in permanent lakes (Kennett & Georges 1990). ***A decrease in temporary wetlands with reduced flood frequency duration and extent is expected to significantly impact on reproduction of C. longicollis. Reproductive tolerances are expected to be a major limitation on the ability of the regional population of the species to tolerate climate change.***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Typically widely distributed and abundant (Georges 1993). The most widespread of Australian chelid turtles (Parmenter 1985 in Greer 2003). ***Historically widespread and abundant but limited genetic information available. Gene pool is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Typically widely distributed and abundant (Georges 1993). The most widespread of Australian chelid turtles (Parmenter 1985 [in Greer 2003]). Often undertakes extensive overland migrations (Kennet & Georges 1990)'. agree ***Widespread, abundant and with relatively high mobility, but limited genetic information available. Gene flow is expected to be a moderate/ unknown limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Incubation time varies from year to year depending on local weather conditions and nest position (Parmenter 1985, Beck 1991in Greer 2003);'With the three species of the Chelidae investigated, incubation at 30°C resulted in much more rapid development of embryos and earlier hatching than at temperatures closer to 20°C. Furthermore, the influence of temperature on incubation periods was shown by comparisons between nests deposited in locations open to all available sunlight and those wholly in shade (Goode & Russell 1968)'. Temperature influences embryonic development of turtles and other reptiles. Turtle eggs incubated at higher temperatures have shorter incubation periods and this has consequences for the pattern of embryonic growth and oxygen consumption. Phenotypic influence of incubation temperature can affect post hatch behaviour and growth and may be an important determinant of hatchling survival and therefore reproductive fitness (Booth 2002). ***Although research by Booth is not specific for C. longicollis, plastic embryo development in response to changing environmental conditions/ nest temperature is known for this species. Phenotypic plasticity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Typically widely distributed and abundant (Georges 1993). The most widespread of Australian chelid turtles (Parmenter 1985 [in Greer 2003]). ***Population size is considered large within the study region. Population size is expected to be a minor limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'…lay one clutch of eggs annually of between 6 and 23 eggs (Greer 2003) but potential to produce 'more than one clutch per season (Kennett & Georges 1990)'. 'Females probably produce every year (Parmenter 1985 [in Greer 2003])'. At a Canberra site, between 5% - 100% of 28 egg clutches were infertile, and the number of infertile eggs appear to increase for clutches laid in the second half of the season (Vestjens 1969 [in SAAB 2001). A pair of Chelodina longicollis produces 8-24 eggs per clutch (Cann 1978 [in Thompson 1993])'. ***Species appears to have moderate reproductive capacity. Reproductive capacity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Mean incubation period for eggs of *Chelodina longicollis* in population of Victorian Murray River valley was 138 days and 10.7 eggs per nest (Goode & Russell 1968). Lay one clutch of eggs annually of between 6 and 23 eggs (Greer 2003) but potential to produce 'more than one clutch per season (Kennett & Georges 1990)'. Male *C. longicollis* mature at approximately 7 years and females around 10-11 years of age (Parker 1999). Extensive predation of nests by *Vulpes vulpes*. In captivity there are records of species living to 36 & 37+ years (Parmenter 1976). However, based on conservative estimates of growth rates, maximum longevity for the largest size obtained by the species could be in the order of 150 years (Parmenter, 1985 [in Greer 2003]); 'Regular inspection of tortoise nesting sites along the Murray River in South Australia showed that over 96% of eggs were taken by predators. Endemic predators accounted for less than 3% of this total. Foxes took the rest…populations contained a disproportionately large number of old individuals; this difference was attributed to egg losses. As these old animals die recruitment of juveniles into the population will probably fall even further. As a result tortoise populations in the Murray will decline (Thompson 1993)'. ***Moderate reproductive capacity; moderate time to maturity but long life span; high predation rate. Recruitment is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***

Scientific Name:	*Emydura macquarii*	Common Name:	Macquarie (Murray Short-necked) Turtle

Question		Comments/ Reference
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	Chessman (1988) found *E. macquarii* was the species most often caught in the river itself and river Backwaters. Relative abundance of E. macquarii was significantly positively correlated with water body depth, transparency, persistence during dry conditions and flow speed, and negatively correlated with remoteness from the river; In Lake Boga, a formerly natural, 900 ha lake in northern Victoria now regulated and kept at near constant level for water supply, nearly 500 *E. macquarii* but only four *C. longicollis* (and no *C. expansa*) were taken (Chessman 1988)'; 'Changes in the flow pattern of the Murray River as a result of river regulation have probably been to the advantage of *E. macquarii* and the detriment of *C. longicollis* (Chessman 1988)'. **It is thought that river regulation and the creation of permanent stable wetlands has increased habitat for *E. macquarii* within the Murray Valley however declines in water level and loss of permanent wetlands, increased turbidity and reduced flow is expected to reduce habitat quality for this highly aquatic species. *'Habitat' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	'Confined to large permanent waters (Thompson 1993). Rarely found far from permanent water, and apparently only come on to dry land to nest, bask and occasionally move between water bodies (Chessman 1978 [in SAAB 2001])'; 'However, they showed that *E. macquarii* is strongly attached to a home range and that specimens captured at a specific location and then released more than a mile away returned to the original location within 3 months. Furthermore, there were indications that some tortoises come ashore to nest in the same location each year (Goode & Russell 1968)'. ***Has capacity to move considerable distances in water but only to return 'home' after being translocated, otherwise described to have a strong attachment to home range and to rarely move out of permanent water. 'Mobility & Dispersal' is expected to be a major limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Species has been described to be more active and aggressive than *C. longicollis* (Chessman 1988b); Species is an opportunistic omnivore eating plant and animal material but stomach analysis revealed plant material makes up majority of diet. Plant material includes periphyton, filamentous algae, aquatic macrophytes, terrestrial plants, blue green algae, various microorganisms and fungi. Animal material includes mostly carrion (fish and some bird) plus aquatic and terrestrial invertebrates (Chessman 1986); *Emydura macquarii* is described as 'the most versatile of the 3' turtle species occurring in the River Murray (Legler 1978); 'Nest predation is greater than 90% (Thompson 1983; Spencer 2002[a]) and birds are a major source of hatchling mortality (Spencer et al 2001) in *E. macquarii* on the Murray River. Predation pressures on two year old *E. macquarii* with a plastron length of over 100mmis much lower than on a hatchling that is

		only one third of the size (Spencer 2002)'. Hatchling *E. macquarii* grow relatively rapidly in the first year and potentially obtain a size where predation pressures are reduced (Spencer 2002). ***Species' generalist diet allows it to utilise other food sources in times of low resource availability increasing its competitiveness as a species. Nest predation is high, but fast hatchling growth reduces period of high predation risk. 'Competition' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	'The Murray turtle has a relatively high rate of evaporative water loss, and it is unlikely that aestivation occurs in this species (Chessman 1978 [in SAAB 2001])'. Confined to large permanent waters (Thompson 1993); *E. macquarii* is highly aquatic and documented to have the lowest resistance to dessication of the 3 turtle species occurring within the Murray Valley study region (Chessman 1984). 'Changes in the flow pattern of the Murray River as a result of river regulation have probably been to the advantage of E. macquarii and the detriment of C. longicollis (Chessman 1988)'. It has a broad omnivorous diet and is described as 'the most versatile of the three' species occurring in the River Murray (Legler 1978). ***E.macquarii has a low resistance to dessication but relateively broad diet and habitat tolerances. 'Survival tolerances' are expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Females are presumed to grow periodically only when conditions are favourable and if resources are low growth and reproduction can be reduced and age of maturity may be delayed (Spencer 2002);'The lowest temperature at which turtles have been caught in baited traps is 16.3° C in the spring and 16.9° C in the autumn (Chessman 1988b) which may be an indication of the lowest temperature at which they are likely to feed; Species is omnivorous and diet changes with size. Small turtles tend to eat more microorganisms and the substrate on which they grow (detritus) than do large turtles (Chessman 1986 in Greer 2003). ***Reduced growth and delayed maturity under low resources but maybe offset by generalist diet; active at moderate minimum temperatures. Salinity tolerances not found documented. Not enough information was found to determine limitations to growth under climate change. 'Growth is' is an unknown limitation to the ability of the regional population of the species to tolerate climate change***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	Nesting occurs on evenings following rains and thunderstorms associated with warm to hot days. During drought the turtles nest whenever rain does fall, even during the day. Gravid females may leave the water at about the same time, leading to crowded conditions on the nesting ground. Nest sites are usually in the open and from 2 to 40 m from the water. The same areas seem to be used for nesting by the population year after year (Green 1996 in Greer 2003). 'Nests are located 5-250 yards from water (Goode 1965a in SAAB 2001)'. 'The close coupling of the nesting of Australian turtles with rainfall events suggests that a decrease in rainfall may adversely affect the reproduction of these animals. This finding is important considering that El Nino–

		Southern Oscillation (ENSO) events result in dry conditions in Australia. If the frequency and intensity of ENSO events continue to increase (Trenberth & Hoar, 1997), the decreasing occurrence of storms and rain may adversely affect *E. macquarii* and *C. expansa* by delaying nesting, making nest construction more difficult, or making nests more conspicuous to predators (Bowen et al 2005)'; Moisture does not appear to have more than a minor influence in the incubation of eggs of the species studied, though many hatchlings remain in the nest, often out of the egg, until a shower of rain occurs to soften the sun baked surface (Goode & Russell 1968); *Emydura macquarii* and *C. expansa* respond strongly to rain and air temperature changes associated with rain, usually emerging to nest during or after storms (Bowen et al 2005); 'With the three species of the Chelidae investigated, incubation at 30°C resulted in much more rapid development of embryos and earlier hatching than at temperatures closer to 20°C. Furthermore, the influence of temperature on incubation periods was shown by comparisons between nests deposited in locations open to all available sunlight and those wholly in shade (Goode & Russell 1968)'. An incubation period of 66-85 days under natural conditions and 44 days at controlled conditions of 30 °C. Eggs are deposited in Spring and emerge in late summer. Position of *E. macquarii* embryo in shell facilitates rapid ingestion of yolk sac and emergence compared with *C. longicollis* (Goode and Russell 1968). ***Short period of incubation and rapid emergence by hatchlings decreases exposure time to extreme climatic conditions and predators; incubation time decreased by increasing temperature (44 days at 30oC); rainfall triggers nesting and hatchling emergence and overall increase in aridity in study region may affect nesting success and competition for sites however expected increased summer rains in some years may benefit spring-summer nesters; strong nest site fidelity may lead to reproductive failure at sites that become unsuitable due to salinisation &/or declining water levels; documented to nest in open areas with no apparent vegetation requirements. 'Reproductive tolerances' are expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	'Three species of tortoise inhabit the Murray in South Australia, the common short necked tortoise Emydura macquarii (Gray), the common long-necked tortoise Chelodina longicollis (Shaw), and the broad-shelled tortoise C. expansa Gray. The first two species occur in large numbers… (Thompson 1993)'; 'The presence of large numbers of animals, as with *E. macquarii*, can be deceptive because it implies robustness… (Spencer & Thompson 2005)'.Turtle catches from the Murray River and its backwaters were greatly dominated by *E. macquarii*, but the relative abundance of this species there may be overestimated (Chessman 1988)'; In a study at Lake Boga nearly 500 *E. macquarii* but only four *C. longicollis* (and no *C. expansa*) were caught(Chessman 1988); Through its range *E. macquarii* is generally described as abundant though some caution is indicated suggesting abundance and population robustness may be overestimated (Spencer & Thompson 2005; Chessman 1988). ***Its abundance and distribution, within the study area is not clear and there is limited genetic information available. 'Gene pool' is expected to be a moderate/ unknown limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***gene flow*** limit the ability of the regional population of the	'Confined to large permanent waters (Thompson 1993). Rarely found far from permanent water, and apparently only come on to dry land to nest, bask and occasionally move between water bodies

	species to tolerate climate change?	(Chessman 1978 in SAAB 2001)'; Described to be strongly attached to a home range and specimens captured at a specific location and then released more than a mile away were found to return to the original location within 3 months. There were also indications that some tortoises come ashore to nest in the same location each year (Goode & Russell 1968). ***Has strong attachment to home range and high nest site fidelity weirs are likely barriers to movement; Its abundance and distribution, within the study area is not clear and there is limited genetic information available. 'Gene flow' is expected to be a moderate/ unknown limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'With the three species of the Chelidae investigated, incubation at 30°C resulted in much more rapid development of embryos and earlier hatching than at temperatures closer to 20°C. Furthermore, the influence of temperature on incubation periods was shown by comparisons between nests deposited in locations open to all available sunlight and those wholly in shade (Goode & Russell 1968)'. Eggs have an incubation period of 66-85 days under natural conditions and 44 days at controlled conditions of 30 °C (Goode & Russell 1968)'. Temperature influences embryonic development of turtles and other reptiles. Turtle eggs incubated at higher temperatures have shorter incubation periods and this has consequences for the pattern of embryonic growth and oxygen consumption. Phenotypic influence of incubation temperature can affect post hatch behaviour and growth and may be an important determinant of hatchling survival and therefore reproductive fitness (Booth 2002). ***Although research by Booth is not specific for E. macquarii, plastic embryo development in response to changing environmental conditions/ nest temperature is known for this species. Phenotypic plasticity is expected to be a moderate limitation on the ability of the regional population of the species to tolerate climate change.***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	'The presence of large numbers of animals, as with *E. macquarii,* can be deceptive because it implies robustness…(Spencer & Thompson 2005); 'Turtle catches from the Murray River and its backwaters were greatly dominated by *E. macquarii*, but the relative abundance of this species there may be overestimated (Chessman 1988); 'Three species of tortoise inhabit the Murray in South Australia, the common short necked tortoise Emydura macquarii (Gray), the common long-necked tortoise Chelodina longicollis (Shaw), and the broad-shelled tortoise C. expansa Gray. The first two species occur in large numbers, C.' expansa being less common (Thompson 1993)'; Through its range E. macquarii is generally described as abundant though some caution is suggested indicating abundance and population robustness may be overestimated (Spencer & Thompson 2005; Chessman 1988). ***It is listed as 'vulnerable' in South Australia (NPW 1972) and 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and in 'probable decline' (Gillam and Urban 2010), indicating that abundance within the study region may be lower than in other parts of its range. 'Population size' is expected to be a moderate limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'High nest predation is a life history trait to which E. macquarii has adapted, given the species' reliance on adult survival for population stability and high annual reproductive output (Spencer & Thompson 2005)'; Clutch size in this species ranges from 6 to 30 with recorded means of 15.7 (Goode and Russell 1968), 24.6 (Green 1996 [in Greer 2003] and 23.0 (Thompson 1993); A pair of *E. macquarii* produces an average of 23 eggs per clutch at Lake Bonney. High fecundity and a long reproductive life. Has a relatively low incidence of multiple clutches (Thompson 1993)';'Female *E. macquarii* delay maturity until 9-12 years of age because clutch size is positively related to body size and they can produce only one large clutch per year. Large female *E. macquarii* in the Murray River can produce at least 36 eggs and their average clutch size is far greater than northern *E. macquarii* in Queensland (Spencer 2002). ***Although usually only produces one clutch per year E. macquarii within the study region is documented to have high fecundity, producing a large number of eggs/ clutch. 'Reproductive capacity' is expected to be a minor limitation to the ability of the regional population of the species to tolerate climate change.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Spencer & Thompson (2005) found that *E. macquarii* populations had low productivity and are declining under predation pressure from foxes; *E. macquarii* mature at 10 years or more (Spencer 2002b); low incidence of multiple clutches (Thompson 1993); Thompson (1993) found that on the Murray River in South Australia >96% of eggs were taken by predators (>93% by foxes). The Murray population of *Emydura macquarii* contained a disproportionately large number of old individuals; this difference was attributed to egg losses and Thompson (1993) said 'as these old animals die recruitment of juveniles into the population will probably fall even further and as a result tortoise populations in the Murray will decline'; Fecundity and a long reproductive life would normally offset high losses of eggs and hatchlings. However, the present rate of recruitment of juveniles into the population on the Murray may not be adequate to balance the adult mortality (Thompson 1993); Despite high densities, life-history traits can make a species more susceptible to predation by foxes than a similar species that occurs in low densities (Spencer & Thompson 2005).

		Long generation time and high fecundity but high predation and low recruitment of juveniles into the population.

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Scientific Name:	*Eulamprus quoyii (Sphenomorphus group)*	**Common Name:**	Eastern (Golden) Water Skink

Question		**Comments/ Reference**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? <u>Critically water dependent especially in arid environments. Must have access to water, adequate cover and a cool, moist environment to avoid dehydration (D. Armstrong pers. comm. 2011).</u>	Confined to river and threatened by river degradation (Gillam & Urban 2010). Considered a mallee fringe dweller in Victoria and generally do not penetrate into arid areas. Usually found along tributaries and floodplains in River Red Gum and eucalypt woodlands and grasslands and often bask in moist areas of riverine habitat along the Murray River (Swan and Watharow 2005). 'Sclerophyll forests, costal and inland wetlands and riverine vegetation along larger inland rivers (Cogger 2000). Occurs along creek, river and swamp margins, and near the edges of wet and dry sclerophyll forests to woodlands and heathlands (Wilson and Knowles 1992). A study found that moist, open rocky habitats support higher densities than cool, closed forests with few rocks. Apart from water, rocks were the most useful predictor of presence or absence. The availability of suitable basking conditions (e.g. rocky, open areas) in a particular habitat may be a main factor influencing the population density in a location (Law and Bradley 1990). Occurs in some suburban areas, living in stormwater drains (Swanson 1987). In a study near Armidale, New South Wales, no lizards were found among vegetation, but rocks and open habitats had high frequencies of usage. They appear to have a clear preference for emergent streamside sites rather than for the water itself. The preferred microhabitat for basking are sunlit rocks, especially those on a soil substrate suitable for burrowing (Daniels and Heatwole 1990)' (all as cited in SAAB 2001). Appears to have extended its range into otherwise unsuitable arid environments through use of Murray River mesic riparian corridor (Hutchinson and Rawlinson 1995). *Largely restricted to creek margins and riparian areas with extensions into more arid areas facilitated by presence of water bodies. Uses emergent vegetation for foraging and feeds at or near waters surface and population densities dependent on suitable open areas with basking sites (rocks, logs) near water. Climate change is expected to reduce the extent and quality of these habitats posing a threat to the species.* ***MAJOR FACTOR/S: WATER AVAILABILITY, RIPARIAN HABITATS, RIVERBANK EROSION THROUGH DRYING/FLOODING CYCLES AND LOSS OF STABILISING VEGETATION, WEED INVASION AND SHADING***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? <u>Not mobile to extent of being able to relocate if conditions become unsuitable e.g. dry. Habitat fragmentation and</u>	No information. Similar species (*S. kosciuskoi*) is one of the most aggressive and territorial of the Australian Skinks but this is usually against conspecifics of same sex e.g. males (Heatwole and Taylor 1987). *Difficult to assess due to lack of studies. Similar species are known to be strongly territorial and defend home/nest sites but spatial scale is not described. As a small semi-aquatic skink, movement over large enough scales to escape unfavorable local conditions is probably limited but confidence is very low.* ***MAJOR FACTOR/S: INABILITY TO ESCAPE UNFAVOURABLE CONDITIONS; HABITAT FRAGMENTATION AND HYDROLOGIC DISSCONNECTION WILL PREVENT GRADUAL SHIFT OF POPULATIONS TO SUITABLE HABITATS UNDER CLIMATE CHANGE***

	<u>hydrologic disconnection will prevent gradual relocation of populations e.g. along riparian corridors (D. Armstrong pers. comm. 2011).</u>	
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? <u>Lower in the food chain than other larger reptiles assessed in this study and therefore probably suffer increased predation. Lack of cover/water will increase predator susceptibility (D. Armstrong pers. comm. 2011).</u>	Moderately sized skink with an SVL to around 9.5cm (Swan and Watharow 2005), although other sources suggest around 28cm (DEH 2008) and up to 30cm (Worrell 1966; Griffiths 1985; Swanson 1987 all as cited in SAAB 2001). 'Has the ability to loose its tail as a method of escaping predator - 47% of 349 museum specimens had no tail, with a higher frequency of tail loss in mature individuals compared with juveniles (Wilson and Booth 1998)… When diving to escape a predator, the lizard descends to the bottom and remains motionless in leaf litter or rock crevices, usually for several minutes. However, when approached, lizards usually escaped by running rather than diving, with rocks the preferred cover sought regardless of the escape route or mode of locomotion used (Daniels and Heatwole 1990)' (SAAB 2001). Predation usually a major factor in determining mortality in reptile populations, 102 potential predators of *S. quoyii* (aka. *E. quoyii*) identified of which 14% believed to have significant impact. Similar species (*S. kosciuskoi*) is one of the most aggressive and territorial of the Australian Skinks but this is usually against conspecifics of same sex e.g. males (Heatwole and Taylor 1987). *While moderately sized compared to other skinks and geckos, species is very small compared to other reptile species assessed in this study. Risk increased as high number of known predators and probably has high mortality due to predation. Frequently uses water to escape predators so reduction and fragmentation of these habitats under climate change will probably increase competition. Tail loss is a defensive strategy but has deleterious consequences e.g. reduced fecundity. Species is probably at moderate to high risk of limitation through competition.* ***MAJOR FACTOR/S: SMALL SIZE, HIGH PREDATION, LACK OF COVER/WATER***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? <u>Extremely prone to dehydration with exposure to heat and/or lack of water/cover and perish quickly if stranded from moist, shaded habitat especially during warmer months (D. Armstrong pers. comm. 2011).</u>	'Omnivorous. Stomach analysis showed aquatic animals represent 26% of diet - insects, spiders, crustaceans, snails, frogs and fish (Daniels 1987a)… An opportunistic feeder, eating mainly diurnal insects. Large prey included grasshoppers, crickets and dragonflies (< 3-5 cm long), medium prey included most larvae, beetles, spiders and damselflies (between 0.5-4 cm long), and small prey included ants, beetles and bugs (< 0.5cm) (Veron 1969)' (SAAB 2001). 'Dinural, usually seen basking on rocks and logs near streams and rivers (Wilson and Knowles 1992)' (SAAB 2001). 'The reduction in basking behaviour when deprived of water may affect fitness and thus its success in dry habitats (Law and Bradley 1990)' (SAAB 2001). 'There was a significant difference between body temperature when water was absent (24°C) or present (28°C) suggesting a physiological dependence on water, however, it is hypothesised that this species is a substrate thermoregulator as non-random utilisation of substrate temperature appears to play a role in basking site selection (Law and Bradley 1990)' (SAAB 2001). 'The reduction in basking behaviour when deprived of water may affect fitness and thus its success in dry habitats (Law and Bradley 1990)' (SAAB 2001). 'Readily enters water to forage among waterside vegetation (Wilson and Knowles 1992; Cogger 2000). In laboratory feeding trials, the eastern water skink caught prey by waiting at the waters edge before lunging at prey near the surface. In the wild it probably takes all its prey from near the water or from still pools (Daniels 1987)' (SAAB 2001). Skinks have relatively low survival times in high temperatures compared to other reptiles (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: PRESENCE OF WATER, RIPARIAN VEGETATION, MORE SENSITIVE TO EXTENDED PERIODS OF HIGH TEMP***
	To what extent does **growth** limit the ability of the regional population of the	Live-bearing (Griffiths 1985 as cited in SAAB 2001). 'Omnivorous. Stomach analysis showed aquatic animals represent 26% of diet - insects, spiders, crustaceans, snails, frogs and fish (Daniels 1987a)… An opportunistic

	species to tolerate climate change?	feeder, eating mainly diurnal insects. Large prey included grasshoppers, crickets and dragonflies (< 3-5 cm long), medium prey included most larvae, beetles, spiders and damselflies (between 0.5-4 cm long), and small prey included ants, beetles and bugs (< 0.5cm) (Veron 1969)' (SAAB 2001). Similar species (*E. tympanum*) matures at 3-4 years (Heatwole and Taylor 1987) so may be a slow-grower. Slow growing reptiles are more drought and heat resistant but are more susceptible to cold particularly in first year (Heatwole and Taylor 1987). Skinks have relatively low survival times in high temperatures compared to other reptiles (Heatwole and Taylor 1987). *Live-bearing so young are relatively well-developed at birth although probably take a relatively long time to reach maturity (3-4 years) suggesting a slow growth rate. This may mean species is more drought and heat resistant compared to fast-growers. Broad diet opportunistic feeder unlikely to be limiting.* ***MAJOR FACTOR/S: SLOW GROWTH BUT MAY BE MORE DROUGHT/HEAT RESISTANT THAN COMPARABLE FAST GROWING SMALL REPTILES***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? Viviparity is an adaptation to breeding in cooler climates, difficult to say whether is advantage or disadvantage under climate change as many confounding factors e.g. predation, food availability etc. (D. Armstrong pers. comm. 2011).	'Viviparous, giving birth to up to eight young, but the usual brood number is five (Davey 1970). Litters of two to five young (Wilson and Knowles 1992)… Mating in spring, with litters of two to five young born in summer (Wilson and Knowles 1992)… Mean diameter of the largest ovarian follicle in tailed lizards was more than twice that of those with tails removed (whole-tail autotomy), resulting in a 75% reduction in clutch size in the tail-less lizards (Wilson and Booth 1998)' (SAAB 2001). More vulnerable to predation when gravid through restricted movement (reduced running speed) and increased basking time (Heatwole and Taylor 1987). Females ovulate in late spring and give birth in summer (Jan-Feb), also observed mating in spring (Hutchinson and Rawlinson 1995). ***MAJOR FACTOR/S: LIVE BEARING SO HIGH COST OF REPRODUCTION FOR FEMALE, PREDATION OF GRAVID FEMALES, REDUCED FECUNDITY THROUGH TAIL LOSS***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Listed status as 'Near Threatened' under regional IUCN criteria in the Murray Scroll Belt with a stable trend (Gillam & Urban 2010). Held at near-threatened conservation status in Victoria (Swan and Watharow 2005). Distribution within the AMLR region is classified as 'extremely restricted' and AMLR regional conservation status as 'vulnerable' (DEH 2008). Statewide in SA 71 records, in SAMDB 44 and in floodplain and study area 39 records since 1990 (BDBSA 2010). ***MAJOR FACTOR/S: LOW ABUNDANCE, PATCHY DISTRIBUTION***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Low number of recent (post-1990) records widely distributed across study area (BDBSA 2010). Listed status as 'Near Threatened' under regional IUCN criteria in the Murray Scroll Belt with a stable trend (Gillam & Urban 2010). Held at near-threatened conservation status in Victoria (Swan and Watharow 2005). Distribution within the AMLR region is classified as 'extremely restricted' and AMLR regional conservation status as 'vulnerable' (DEH 2008). ***MAJOR FACTOR/S: LOW ABUNDANCE, PATCHY DISTRIBUTION***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	'Subjected to 40.5°C for 3 hours, individual females collected near Sydney died, where those from Townsville survived, suggesting that acclamation may be a factor determining CTmax (Schwarzkoff 1998)' (SAAB 2001). Part of the *E. quoyii* species complex, displays morphological differences in scale patterns (Hutchinson and Rawlinson 1995) but spatial scale or driving mechanisms for differences are not described. Only nominate species listed in BDBSA, no subspecies of any *Eulamprus* species (BDBSA 2010). ***MAJOR FACTOR/S: ADAPTS TO DIFFERENT TEMP REGIMES, MORPHOLOGICAL VARIATION***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Listed status as 'Near Threatened' under regional IUCN criteria in the Murray Scroll Belt with a stable trend (Gillam & Urban 2010). Held at near-threatened conservation status in Victoria (Swan and Watharow 2005). Distribution within the AMLR region is classified as 'extremely restricted' and AMLR regional conservation status as 'vulnerable' (DEH 2008). 71 records in SA since 1990, 44 in SAMDB and 39 records in study area (BDBSA 2010). ***MAJOR FACTOR/S: LOW ABUNDANCE BUT MANY MORE THAN SOUTHERN OR YELLOW-BELLIED WATER SKINK IN STUDY AREA, PATCHY DISTRIBUTION NORTH OF MYPOLONGA TO BORDER; PROPOSED REGIONAL THREAT LISTING 'NEAR THREATENED' IN STUDY AREA***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'Viviparous, usually producing two or three young in a litter (Cogger 2000). Viviparous, giving birth to up to eight young, but the usual brood number is five (Davey 1970). Litters of two to five young (Wilson and Knowles 1992)' (SAAB 2001). 'Mating in spring, with litters of two to five young born in summer (Wilson and Knowles 1992)' (SAAB 2001). Clutch size 2-7, only one clutch per year (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: SINGLE CLUTCH PER YEAR, LOW FECUNDITY COMPARED TO OTHER SPECIES ASSESSED***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Mean diameter of the largest ovarian follicle in tailed lizards was more than twice that of those with tails removed (whole-tail autotomy), resulting in a 75% reduction in clutch size in the tail-less lizards (Wilson and Booth 1998)' (SAAB 2001). Proposed status as 'Near Threatened' under regional IUCN criteria in the Murray Scroll Belt but with a stable trend (Gillam & Urban 2010). Statewide in SA 71 records, in SAMDB 44 and in floodplain and study area 39 records since 1990 (BDBSA 2010). Similar species (*E. tympanum*) lives for between 8-15 years (Tilley 1984, as cited by Schwarzkopf 1996 in SAAB 2001). Similar species (*E. tympanum*) matures at 3-4 years (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: PREDATION/REDUCTION OF FECUNDITY, LOW POPUALTION BASE, PROBABLY LONG TIME TO MATURE***

Scientific Name:	*Eulamprus tympanum (Sphenomorphus group)*	**Common Name:**	Southern Water Skink
Question		**Comments/ Reference**	
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? <u>Critically water dependent especially in arid environments. Must have access to water, adequate cover and a cool, moist environment to avoid dehydration (D. Armstrong pers. comm. 2011).</u>	Terrestrial and occurs in alpine woodland and forests both wet and dry and wetlands. 3 *Eulamprus* species occurring in MDB occupy moist areas e.g. stream sides. Southern species occurs mainly in mid-zone elevations. Management recommendations include preservation of wetlands and waterways used for foraging and sheltering through fencing to prevent grazing and soil erosion. Allowing flooding of wetlands to prevent system disconnection from main channels and retaining snags and fallen trees in waterways that provide basking sites. Retention and provision of surface rocks and dead trees (good thermal properties) for basking but also nesting and sheltering (Michael & Lindenmayer 2010). 'Occur in well timbered areas, usually along creek, river or swamp margins (Wilson and Knowles 1992). Found in the vicinity of water (Griffiths 1985). Frequents small creeks, and is usually observed basking on rocks and logs (Cogger 2000)' (SAAB 2001). Restricted to margins of water courses in the low rainfall part of its range. Rock-dwelling streamside populations and log-dwelling forest populations (Hutchinson and Rawlinson 1995). ***MAJOR FACTOR/S: WATER AVAILABILITY; LOSS OF RIPARIAN HABITATS; RIVERBANK EROSION THROUGH DRYING/FLOODING CYCLES AND LOSS OF STABILISING VEGETATION; WEED INVASION AND SHADING***	
	To what extent does ***mobility and dispersal*** limit the ability of the regional population	No information. Similar species (*S. kosciuskoi*) is one of the most aggressive and territorial of the Australian Skinks but this is usually against conspecifics of same sex e.g. males (Heatwole and Taylor 1987).	

	of the species to tolerate climate change? Not mobile to extent of being able to relocate if conditions become unsuitable e.g. dry. Habitat fragmentation and hydrologic disconnection will prevent gradual relocation of populations e.g. along riparian corridors (D. Armstrong pers. comm. 2011).	*Difficult to assess due to lack of studies. Similar species are known to be strongly territorial and defend home/nest sites but spatial scale is not described. As a small semi-aquatic skink, movement over large enough scales to escape unfavorable local conditions is probably limited but confidence is very low.* ***MAJOR FACTOR/S: INABILITY TO ESCAPE UNFAVOURABLE CONDITIONS; HABITAT FRAGMENTATION AND HYDROLOGIC DISSCONNECTION WILL PREVENT GRADUAL SHIFT OF POPULATIONS TO SUITABLE HABITATS UNDER CLIMATE CHANGE***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? Lower in the food chain than other larger reptiles assessed in this study and therefore probably suffer increased predation. Lack of cover/water will increase predator susceptibility (D. Armstrong pers. comm. 2011).	Snout-vent length (SVL) of around 93mm (Michael & Lindenmayer 2010). 'Grows to 250 mm (Griffiths 1985)… Olive-brown on top, and grows to 80 mm in length (SVL)… 'Diurnal. Found along creeks basking on rocks and logs, and flees to water when alarmed (Cogger 2000)' (SAAB 2001). ***MAJOR FACTOR/S: : SMALL SIZE; HIGH PREDATION; LACK OF COVER/WATER***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? Extremely prone to dehydration with exposure to heat and/or lack of water/cover and perish quickly if stranded from moist, shaded habitat especially during warmer months (D. Armstrong pers. comm. 2011).	Diurnal activity patterns. Feeds on a range of arthropods and sometimes small lizards (Michael & Lindenmayer 2010). Omnivorous (SAAB 2001) and subspecies *E. t. marnieae* is known to feed on fruit and may form an important food source (DSEWPC 2011). Small size allows more activity in cooler months as can warm more efficiently than larger species. Small size also leads to higher ET rates as function of larger surface area to weight ratio and also not able to tolerate higher temps as well as larger species (Heatwole & Taylor 1987). 'Upper lethal limit of 41.2°C (Veron and Heatwole 1970). Preferred body temperature of 32°C (Schwarzkopf and Shine 1991)' (SAAB 2001). Generalised invertebrate carnivore, takes small proportion of plant matter (Brown 1991 as cited in Hutchinson and Rawlinson 1995). Skinks have relatively low survival times in high temperatures compared to other reptiles (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: MORE HEAT SENSITIVE THAN LARGER REPTILES; FLEXIBLE DIET OF INVERTEBRATES, SMALLER LIZARDS AND SOME VEGETATION; MORE SENSITIVE TO EXTENDED PERIODS OF HIGH TEMP***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Feeds on a range of arthropods and sometimes small lizards (Michael & Lindenmayer 2010). Matures at 3-4 years (Heatwole and Taylor 1987) so may be a slow-grower. Slow growing reptiles are more drought and heat resistant but are more susceptible to cold particularly in first year (Heatwole and Taylor 1987). Typically have low juvenile survivorship (Hutchinson and Rawlinson 1995). Skinks have relatively low survival times in high temperatures compared to other reptiles (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: JUVENILE MORTALITY THOUGH DRIVER UNDESCRIBED (POSSIBLY PREDATION); SLOW GROWTH BUT MAY BE MORE DROUGHT/HEAT RESISTANT THAN COMPARABLE FAST GROWING SMALL REPTILES***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? Viviparity is an adaptation to breeding in cooler climates, difficult to say whether is	Viviparous (Michael & Lindenmayer 2010) like most skinks and can bear young around 1 month earlier than similar oviparous species (Heatwole & Taylor 1987). Skinks can develop gametes over winter so more advanced going into spring and some can develop quickly at the onset of warmer weather while others can store sperm over winter without loss of viability (Heatwole & Taylor 1987). 'Survival was reduced in gravid females when compared to males (Schwarzkopf 1996)' (SAAB 2001). Thought to mate in autumn but lacks

	advantage or disadvantage under climate change as many confounding factors e.g. predation, food availability etc. (D. Armstrong pers. comm. 2011).	observation, may be late autumn-winter or spring as in similar species *E. quoyii* and *E. heatwolei* (Hutchinson and Rawlinson 1995). '… A low-diet regime gave a significantly smaller total offspring mass and smaller litters' (Rohr 1997 as cited in SAAB 2001). ***MAJOR FACTOR/S: LIVE BEARING SO HIGH COST FOR REPRODUCTION ON FEMALE; BREEDING/MATING SEASON VARIABLE (GAMETE PRODUCTION/STORAGE); LOWER SURVIVAL OF GRAVID FEMALES***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Conservation status in NSW is 'common' (Michael & Lindenmayer 2010). Conservation status is 'secure in South Australia (Robinson et al. 2000)' (SAAB 2001). Classed as 'rare' under the NPW Act (Gillam & Urban 2010). No recent records (since 1990) in SA, only 1 record in study area and 19 in SA prior to 1990 (BDBSA 2010). 'Isolated populations occur in the Fleurieu Peninsula (Cogger 2000)' (SAAB 2001). ***MAJOR FACTOR/S: VERY LOW ABUNDANCE; SMALL ISOLATED POPUALTIONS LIKELY; PROBABLY RESTRICTED GENETIC DIVERSITY***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Conservation status in NSW is 'common' (Michael & Lindenmayer 2010). Conservation status is 'secure in South Australia (Robinson et al. 2000)' (SAAB 2001). Classed as 'rare' under the NPW Act (Gillam & Urban 2010). No recent records (since 1990) in SA, only 1 record in study area and 19 in SA prior to 1990 (BDBSA 2010). 'Isolated populations occur in the Fleurieu Peninsula (Cogger 2000)' (SAAB 2001). ***MAJOR FACTOR/S: VERY LOW ABUNDANCE; SMALL ISOLATED POPUALTIONS LIKELY; PROBALY LOW GENE FLOW***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Polytypic with at least 2 known subspecies. Geographic variation between subspecies and slight variation within subspecies. Rock-dwelling streamside populations and log-dwelling forest populations noted to vary in colouration. Scale size and tail length also vary e.g. between Otway Ranges and Grampians populations. Subspecies *E. t. marnieae* displays behavioural differences; is much shyer. Subspecies known to intergrade with *E. tympanum* (Hutchinson and Rawlinson 1995). Only nominate species listed in BDBSA, no subspecies of any *Eulamprus* species (BDBSA 2010). ***MAJOR FACTOR/S: SUBSPECIATION/GEOGRAPHIC VARIATION/BEHAVIOURAL DIFFERENCES EVIDENT; UNCERTAINTY AS TO WHICH SUBSPECIES (IF ANY) OCCUR IN STUDY AREA***
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change? Unlikely to have a distribution within study area, more likely to be *E. quoyii* and *E. heatwolei* (D. Armstrong pers. comm. 2011).	Conservation status in NSW is 'common' (Michael & Lindenmayer 2010). Conservation status is 'secure in South Australia (Robinson et al. 2000)' (SAAB 2001). Classed as 'rare' under the NPW 1972 Act (NPW 1972). No recent records (since 1990) in SA, only 1 record in study area and 19 in SA prior to 1990 (BDBSA 2010). 'Isolated populations occur in the Fleurieu Peninsula (Cogger 2000)' (SAAB 2001). ***MAJOR FACTOR/S: LOW ABUNDANCE; REGIONAL THREAT LISTING; NO RECORDS IN BDBSA; UNLIKELY TO HAVE DITRIBUTION WITHIN STUDY AREA***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Viviparous and gives birth to 2-6 young (Michael & Lindenmayer 2010). 2-5 young and only 1 clutch per year (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: SINGLE CLUTCH PER YEAR; LOW FECUNDITY COMPARED TO OTHER SPECIES ASSESSED***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	'Lives for between 8-15 years (Tilley 1984, as cited by Schwarzkopf 1996)' (SAAB 2001). Males live for around 11 years and females live around 13 years and typically have low juvenile survivorship (Hutchinson and Rawlinson 1995). Matures at 3-4 years (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: LOW JUVENILE SURVIVORSHIP; LOW FECUNDITY; LONG TIME TO MATURITY***

Scientific Name:	*Morelia spilota*	Common Name:	Carpet (Diamond) Python

	Question	Comments/References
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? More general habitat requirements compared to Lace Monitor as is arboreal and forages in trees but also uses cliff lines, rocky outcrops and burrows for shelter and foraging. Less critical dependence on narrow habitat requirements i.e. large trees, hollows etc. found in close proximity to water as Lace Monitor (D. Armstrong pers. comm. 2011).	Arboreal, saxicolous (lives amongst rocks) and terrestrial; inhabits dry forest, grassy box/sandhill/black box/mallee woodland and red gum forest. In some areas restricted to granite outcrops where suitable food and shelter exists. In west of MDB restricted to river red gum forests and well vegetated creeks (Michael & Lindenmayer 2010). At least 2 forms of *M. spilota* are known to use buildings (commonly in attics and rafters) (Greer 1997). Management recommendations include the retention and provision of surface rocks and dead trees (good thermal properties) for basking but also nesting and sheltering, conservation of large mature trees used for foraging, basking, sheltering, preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees). Provision of leaf litter and fine woody debris e.g. beneath trees important for food source and nest chamber construction; fire management needs t o be applied carefully to avoid 'blackout burns' and preserve some areas of native vegetation. Also control of exotic animals that prey on eggs, young and sometimes adults and introduced herbivores e.g. feral goats and sheep that degrade soil and land through grazing. Rabbit control should be considered as also provide good food source for larger reptiles in some areas and use of burrows for shelter. Invasive exotic plants also need to be controlled through removal or grazing to avoid shading and blockage of basking and sheltering sites and reduction of foraging areas (Michael & Lindenmayer 2010). Subspecies *M. s. variegata* has been recorded in mangroves (Storr & Smith 1975 as cited in Greer 1997). Another subspecies *M. s. mcdowelli* has been recorded spending up to 45% of its time in trees (Shine & Fitzgerald 1996 as cited in Greer 1997). ***MAJOR FACTOR/S: BROAD HABITAT REQUIREMENTS; NOT STRICTLY ASSOCIATED WITH IMMEDIATE PROXIMITY TO WATER; DISTRIBUTION IN AREAS OF MDB RESTRICTED TO VULNERABLE RIPARIAN RED GUM FORESTS AND WELL VEGETATED WATER BODIES; USES ARTIFICIAL HABITATS AND AT LEAST MILDLY SALINE MANGROVE AREAS; EXOTIC ANIMALS MAY INCREASE PROVIDING ADDITIONAL BURROWS AND FOOD***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Pythons are basically sedentary animals, Slip & Shine (1988) as cited in Greer (1997) found that *M. s. spilota* spent up to 85% of its time immobile and only 15% of time moving. Like most large terrestrial reptiles, pythons are restricted to a strict and well-known home range (Greer 1997). Average daily movements of pythons is probably very low, *M. s. mcdowelli* found to move only 11-12m even during active period in spring/summer (Greer 1997). ***MAJOR FACTOR/S: LARGELY SEDENTARY; SMALL HOME RANGE; RELUCTANT OR UNABLE TO MOVE IF LOCAL CONDITIONS DETERIORATED***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Large non-venomous snake, mainly an ambush predator and carnivorous taking only vertebrate prey through striking and constriction (Greer 1997). Adult prey includes mice, rabbits, possums and nestling birds (Michael & Lindenmayer 2010). Juveniles often prey on small lizards, typical of juvenile snake diets consisting of small ectothermic prey (Greer 1997). Management recommendations include control of exotic animals that prey on eggs, young and sometimes adults and introduced herbivores e.g. feral goats and sheep that degrade soil and land through grazing. Rabbit control should be considered as also provide good food source for larger

		reptiles in some areas and use of burrows for shelter (Michael & Lindenmayer 2010). Large goannas and monitors are known to take eggs from brooding pythons also causing nest abandonment. Defense strategies in pythons usually involves hiding first, then fleeing and finally to biting, some *Morelia* species are known to become more aggressive when older e.g. after first shed. Occurrence of parasites (internal protozoans e.g. namatodes) in pythons while well studied, effects on health in the wild is unknown (Greer 1997). ***MAJOR FACTOR/S: LARGE SIZE SNAKE SO PROBABLY LIMITED PREDATION PRESSURE AS ADULT; DOCUMENTED PREDATION BY EXOTIC ANIMALS WHEN SMALL OR AS EGGS; SHY AND FLIGHTY CREATURE AND RELUCTANT TO STRIKE UNLESS HEAVILY PROKED; PARASITES ARE KNOWN BUT EFFECT ON HEALTH IN WILD IS UNKNOWN***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Nocturnal but often basks in early morning or late afternoon sun. Preys on rats, mice, rabbits, possums and nestling birds. Juveniles prey on small lizards. Decline thought to be related to decreased food availability mainly of rabbits where are almost exclusive food source but also habitat loss (Michael & Lindenmayer 2010). As a large python over 2m in length it will take prey commonly over 50% of it body weight and recorded up to 62% in one case. Voluntary maximum body temp tolerated is around 35°C (Greer 1997). ***MAJOR FACTOR/S: REQUIRES LARGE SIZE PREY AS ADULT; DECREASED FOOD AVAILABILTY OF SOME NATIVE FOOD ITEMS MAY BE OFFSET BY INCREASES IN EXOTIC ANIMALS FAVOURED UNDER CLIMATE CHANGE EG RABBITS; BROAD HABITAT REQUIREMENTS; NOT STRICTLY ASSOCIATED WITH IMMEDIATE PROXIMITY TO WATER***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change? <u>Habitat/cover is critical for juveniles as they are more secretive presumably to avoid predation. Small juveniles are rarely seen in the wild (D. Armstrong pers. comm. 2011).</u>	Juveniles prey on small lizards (Michael & Lindenmayer 2010). Pythonids may lay their eggs in a more advanced development state than other snakes. Advanced embryonic stage through egg retention may be precursor to live birth as in close relative boids. Hatching usually occurs in Dec-Feb timed to coincide growth with optimum productivity (temperature, food availability etc.) of summer ahead of cooler months. Growth rates for *M. s. spilota* is 0.22 and up to 0.36 for *M. s. cheynei* is 0.36 which are low compared to most elapids. *M. s. cheynei* has a low growth rate (around 0.11g/day) even when compared with other pythonids (Greer 1997). ***MAJOR FACTOR/S: NARROW JUVENILE DIET OF MAINLY ECTOTHERMIC PREY; RELATIVELY WELL DEVELOPED AHTCHLINGS; VERY SLOW GROWTH RATE EVEN FOR PYTHONS SO MORE VULNERABLE FOR LONGER***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? <u>Fertilisation to oviposition plus egg incubation time in oviparous species is generally about the same as fertilisation to birth in viviparous species. The advantage/ disadvantage of either reproductive mode will have a more complex relationship with climate change than just the immediate climate effect. Egg predation, nest mortality and mortality of pregnant females will also vary as the distributions of predator, prey and habitat species change (M. Hutchinson pers. comm. 2010).</u>	Oviparous, incubation period of around 70 days (Michael & Lindenmayer 2010) but is highly variable ranging from 32-102 days (subspecies *M. s. variegata*) (Greer 1997). Probably mates in late spring polygamously with several (3-5) different partners in either sex. Nest site is usually in tree hollows or burrows. Among climatic/environmental factors thought to trigger breeding are a long period of low temperature and a sudden rise in humidity. Day length and temperature are also probably important in timing of breeding (Greer 1997). Length of gravid stage is poorly studied for pythons but can be up to 111 days in another *Morelia* species and represents 60-70% of total development time (Greer 1997). This means that incubation may take as long as 44 days for a total time to hatching from fertilization of around 155 days. When brooding, may curtail or cease feeding and when gravid may spend more time basking and may also become terrestrial and not climb trees. Oxygen consumption and metabolic demand also increase when brooding. Obvious large energy drain on females as will consistently only breed once every 2-3 years (Greer 1997). Natural brooding site for species is typically in and under vegetation (Greer 1997). Provision of leaf litter and fine woody debris e.g. beneath trees important for nest chamber construction; fire management needs t o be applied carefully to avoid 'blackout burns' and preserve some areas of native vegetation (Michael & Lindenmayer 2010). ***MAJOR FACTOR/S: LONG GRAVID PERIOD AND INCREASED BASKING AND METABOLIC DEMANDS AND CANNOT BREED EVERY YEAR AS RESULT OF HEAVY INVESTMENT; LIMITED MOVEMENT AND RESTRICTED TO TERRESTRIAL HABITATS; SEASONAL TEMP REGIMES MAY CHANGE AND AFFECT TIMING AND SUCCESS OF BREEDING***

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Widespread but patchy distribution in floodplain forests of the western MDB. Conservation status in NSW is 'uncommon' and populations have severely declined across the Murray catchment. Local extinctions in upper part of MDB system are thought likely (Michael & Lindenmayer 2010). Pythons are basically sedentary animals, Slip & Shine (1988) as cited in Greer (1997) found that *M. s. spilota* spent up to 85% of its time immobile and only 15% of time moving. Like most large terrestrial reptiles, pythons are restricted to a strict and well-known home range (Greer 1997). Average daily movements of pythons is probably very low, *M. s. mcdowelli* found to move only 11-12m even during active period in spring/summer. Probably mates in late spring polygamously with several (3-5) different partners in either sex (Greer 1997). ***MAJOR FACTOR/S: PATCHY DISTRIBUTION AND ABUNDANCE AND SEDENTARY NATURE REDUCES CHANCE OF DIVERSE EFFECTIVE GENE POOLS IN REGIONAL POPULATIONS WITHIN THE STUDY AREA; POLYGAMOUS MATING INCREASES CHANCE OF GENETIC DIVERSITY BUT PROBABLY AT SMALL SPATIAL SCALES***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Widespread but patchy distribution in floodplain forests of the western MDB. Conservation status in NSW is 'uncommon' and populations have severely declined across the Murray catchment. Local extinctions in upper part of MDB system are thought likely (Michael & Lindenmayer 2010). Pythons are basically sedentary animals, Slip & Shine (1988) as cited in Greer (1997) found that *M. s. spilota* spent up to 85% of its time immobile and only 15% of time moving. Like most large terrestrial reptiles, pythons are restricted to a strict and well-known home range (Greer 1997). Average daily movements of pythons is probably very low, *M. s. mcdowelli* found to move only 11-12m even during active period in spring/summer. Probably mates in late spring polygamously with several (3-5) different partners in either sex (Greer 1997). ***MAJOR FACTOR/S: PATCHY DISTRIBUTION AND ABUNDANCE AND SEDENTARY NATURE REDUCES CHANCE OF GOOD GENE FLOW BETWEEN REGIONAL POPULATIONS WITHIN STUDY AREA SCALE; POLYGAMOUS MATING INCREASES CHANCE OF GENE FLOW BUT PROBABLY AT SMALL SPATIAL SCALES***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Widespread but patchy distribution in floodplain forests of the western MDB. Conservation status in NSW is 'uncommon' and populations have severely declined across the Murray catchment. Local extinctions in upper part of MDB system are thought likely (Michael & Lindenmayer 2010). Species is polytypic (*M. spilota* species complex) featuring several subspecies and is known to hybridize with other subspecies, species and in some cases genera e.g. *Liasis* commonly where ranges contact or overlap (Banks & Schwaner 1984 as cited in Greer 1997). Subspecies of *M. spilota* are generally divided into geographic ranges with the Murray-Darling or Victorian form named *M. s. metcalfei*, with other subspecies in eastern, western and northern parts of Australia and southern New Guinea (Greer 1997). *M. spilota* is only species recorded in BDBSA with no subspecies listed (BDBSA 2010). ***MAJOR FACTOR/S: POLYTYPIC SPECIES WITH SEVERAL SUBSPECIES AND KNOWN TO HYBRIDISE; DISTRIBUTION OF SUBSPECIES MAY BE AT LARGER SCALES THAN STUDY AREA; ONLY ONE SPECIES LISTED IN BDBSA; PATCHY DISTRIBUTION AND ABUNDANCE AND SEDENTARY NATURE INCREASES CHANCE OF GEOGRAPHIC VARIATION***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Widespread but patchy distribution in floodplain forests of the western MDB. Conservation status in NSW is 'uncommon' and populations have severely declined across the Murray catchment. Local extinctions in upper part of MDB system are thought likely (Michael & Lindenmayer 2010). Classed as rare under the NPW Act 1972 and 'near threatened' under regional IUCN criteria for the Murray Scroll Belt sub-region but with a stable trend. Listed as 'rare in the Murray Mallee and South Olary Plain IBRA sub-regions and in 'probable decline' (Gillam & Urban 2010). Highest number of BDBSA records within study area since 1990 of all reptiles assessed in this study (BDBSA 2010). ***MAJOR FACTOR/S: THREAT LISTED AT NATIONAL AND SUBREGIONAL LEVELS WITHIN STUDY AREA; LOCAL EXTINCTIONS IN UPPER MDB; MOST NUMBER OF RECORDS IN BDBSA OF ALL REPTILES ASSESSED***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change?	Largest clutch size of Australian pythons of 9-54 with a mean of 27.4 from 11 clutches (Greer 1997). Produces around 20 eggs per clutch and incubated for around 70 days (Michael & Lindenmayer 2010). Temperate *M. s. spilota* species consistently does not breed every year, usually every 2-3 years (Slip & Shine 1988 as cited in Greer 1997). ***MAJOR FACTOR/S: LARGE CLUTCH SIZE COMPARED TO OTHER AUST PYTHONS AND OTHER REPTILES ASSESSED IN THIS STUDY; PRESUMABLY SINGLE CLUTCH PER SEASON AND INDIVIDUAL FEMALES CANNOT BREED EVERY YEAR***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Reproduces around once every 3 years (Michael & Lindenmayer 2010). Temperate *M. s. spilota* species consistently does not breed every year, usually every 2-3 years (Slip & Shine 1988 as cited in Greer 1997). Age at sexual maturity for large pythons is probably 18-24 months (16-24 for females for another *Morelia* species) and longevity of species is thought to be 10-17 years, but may be over 20 as for *M. viridis* (green tree python) and probably most medium to large pythons (studies cited in Greer 1997). Classed as rare under the NPW Act 1972 and 'near threatened' under regional IUCN criteria for the Murray Scroll Belt sub-region but with a stable trend. Listed as 'rare in the Murray Mallee and South Olary Plain IBRA sub-regions and in 'probable decline' (Gillam & Urban 2010). Highest number of BDBSA records within study area since 1990 of all reptiles assessed in this study (BDBSA 2010). ***MAJOR FACTOR/S:INDIVIDUAL FEMALES CAN ONLY REPRODUCE EVERY 2-3 YEARS; LONG-LIVED SPECIES AND REACHES MATURITY RELATIVELY SOON COMPARED TO OTHER REPTILES ASSESSED IN THIS STUDY; PROBABLY LIMITED POPUALTION BASE FORM WHICH TO RECRUIT FROM***

Scientific Name:	*Notechis scutatus (ater, ater ater)*	Common Name:	(Eastern /Black /Krefft's) Tiger Snake

	Question	Comments/ Reference
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? Highly water dependent within study area as is primarily frog-eater. Requires wet, swampy areas and populations in study area (and in SA) are isolated by need for cooler (or wetter) environments (D. Armstrong pers. comm. 2011).	Occurs in open woodland and riparian habitats and rocky isolates. Found only along margins of watercourses typically lined with Eucalypt species including River Red Gums. Shelter in flood debris in creek beds and rocky screes on slopes and shrubland undergrowth on plains (Cogger et al 1993). Some snakes take refuge in water when disturbed (Mirtschin & Bailey 1990 as cited in DEHWA 2010d). *Notechis* genera shows 'occasional arboreality' and may climb to 5m up trees but is mainly terrestrial. *Notechis spp* are known to enter freshwater to forage and are able to stay submerged for several minutes (Greer 1997). Flow diversion and eutrophication of water bodies e.g. through aerial fertilizer spraying and runoff combined with vegetation clearing and overgrazing are reasons for decline. Bush fires have also lead to recorded declines in numbers (Cogger et al 1993). Inhabit alpine and grass box woodland, montane, wet, dry and river red gum forests and wetlands. Management recommendations include preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees). Wetland protection is also important to prevent over-grazing and soil erosion and allowing natural flow/flooding regimes to prevent wetland disconnection, preservation and planting/distribution of native vegetation to improve water quality and snags and fallen trees in waterways. Changes to flooding regimes have significantly reduces its range and abundance but some parts have seen recoveries where irrigated farming e.g. rice has provided additional habitat. Environmental water delivery is critical to provision of suitable habitat and prey (Michael & Lindenmayer 2010). Almost certain that combination of land clearing/draining for agriculture has resulted in reduced populations (Greer 1997). ***MAJOR FACTOR/S: FLOW DIVERSION/EXTRACTION FOR IRRIGATION ESPECIALLY IN DROUGHTS, INCREASE IN BUSH FIRE FREQUENCY AND EXTENT, NATIVE RIPARIAN VEGETATION LOSS ESPECIALLY RIVER RED GUM FORESTS, SOIL/BANK EROSION, WETLAND DISCONNECTION***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? Fragmentation of habitats is main limitation to species ability to adapt to different climates. Not mobile at landscape scale so continuous habitat may allow gradual relocation but gaps will cause die-off at boundaries (D. Armstrong pers. comm. 2011).	*Notechis* genus shows 'occasional arboreality' and may climb to 5m up trees but is mainly terrestrial. *Notechis spp* are known to enter freshwater to forage and are able to stay submerged for several minutes (Greer 1997). 'Known to move considerable distances during the active season and may use several different homesites within an area (Fearn 1993 as cited in Greer 1997). The sedentary nature of gravid females may be related to their vulnerability to predators (Shine 1979). Distances from water were an average of 71 m for gravid and 185 m for non-gravid females (n = 34) (Shine 1979). Home range of two individual males was 0.75 ha and 0.78 ha (Shine 1979)' (all as cited in SAAB 2001). 'Often congregates into large colonies at swampy areas' (Gow 1976 as cited in SAAB 2001). 'Active for eight months of the year in natural conditions' (Softly 1971 as cited in SAAB 2001). ***MAJOR FACTOR/S: MOVEMENT CAPACITY APPEARS HIGH FOR REPTILES BUT STILL LOW COMPARED TO OTHER GROUPS EG BIRDS, FISH; SCALE OF MOVEMENT UNLIKELY TO PERMIT EVACUATION IF CONDITIONS BECOME UNSUITABLE; GRAVID FEMALES ARE EVEN MORE SEDENTARY***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Highly venomous and large elapid growing to around 2m. Takes mainly frogs and lizards, although birds and mammals are also taken (Michael & Lindenmayer 2010). A reason for decline is competition for food (frogs) with introduced species e.g. trout. Trout introductions to several streams within the species' range resulted in noted disappearance of frogs from that area (Cogger et al 1993), though it is unlikely that this applies to the

	<u>Well known for having under-skin worm infections (nematode) but net effect on health in wild is unknown as is effect of climate change (D. Armstrong pers. comm.. 2011).</u>	lower reaches of the MDB in the study area. Live bearing species have a reproductive cycle time around twice as long as oviparous elapids. Costs may include decreased feeding capacity and ability to replenish energy stores for subsequent broods and increased predator susceptibility. Main predators of elapids in Australia are birds of prey e.g. raptors, storks, ibises, gulls, kingfishers and some mammals e.g. introduced cats. Common ticks and mites and a variety of protozoan endoparasites are known to infect elapids (Greer 1997). Parasites include Cryptosporidium, Eimeria, Sarcocystis, Caryospora, Capsulotaenia, Renifer, ascarids and oxyurids (O'Donoghue 1993 as cited in SAAB 2001). 'A study of 23 specimens from the Western Australia Museum found 13 infected with the nematode (Ophidascaris pyrrhus), with 25% being heavily infected. Worms were found in the oesophagus and stomachs, usually threaded through the stomach mucosa so that both ends of the worm protruded into the lumen, and it is possible that frogs (a large part of the snakes diet) are the intermediate host for the nematode' (Jones 1980 as cited in SAAB 2001). ***MAJOR FACTOR/S: LARGE ANAIMAL AND HIGHLY VENOMOUS SO COMPETITIVE ADVANTAGES PROBABLE; NOTED PREDATION BY NATIVE AND INTRODUCED SPECIES; PREDATION HIGHER WHEN GRAVID; VARIOUS PARASITIC INFECTIONS***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Actively searches for its prey (Greer 1997) and forages in water, perhaps utilising its black colouration to quickly gain heat when out of the water before reentering to forage (Mirtschin and Bailey 1990 as cited in DEHWA 2010d). Not observed to swallow prey on or below waters surface (Greer 1997). They have been observed to muzzle under submerged rocks, flipping their tails on the surface, in search of tadpoles. Individuals have been observed to stay submerged for up to nine minutes. The diet of wild individuals includes frogs, tadpoles and ducklings. Captive specimens will readily take mice, rats and chickens (Mirtschin and Bailey 1990 as cited in DEHWA 2010d). Recent work shows that Australian elapids take vertebrate prey almost exclusively and invertebrates are a very minor part (if at all) part of their diet. Accepts lizard, snake, fish, frog/tadpole, bird and mammal food offerings, generally rejects fish and insects (Greer 1997). Subspecies *N. s. ater*, begin entering the water in Nov. when water temperatures average between 16.5°C and 18.5°C. No observations of snakes in the water made after January (Mirtschin and Bailey 1990 as cited in DEHWA 2010d). Diurnal species but may shelter in the mid-day on very hot days and may come out at night when temperatures moderate. Preferred body temp, voluntary thermal maximum and critical thermal maximum for species is low compared to other Aust. elapids (Greer 1997). ***MAJOR FACTOR/S: STRONG RELIANCE ON FRESHWATER AQUATIC PREY EG FROGS, TADPOLES, DUCKLINGS;***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change? <u>Diurnal and very active as juveniles due to need to feed regularly to sustain growth rate. Trade-off between high fecundity and fast growth and high mortality as juvenile (D. Armstrong pers. comm. 2011).</u>	Live bearing. Mean size and weight of hatchlings are SVL of 189.4mm and 4.6g (n=21) and first shedding is at <1 day (Greer 1997). Growth rate in subspecies *M. a. serventyi* is very high (1.55 to 5.94g/day) compared to other elapids and to most pythons (Greer 1997). ***MAJOR FACTOR/S: LIVE BEARER SO JUVENILES HAVE ADVANTAGES; VERY FAST GROWTH RATE COMPARED TO MOST AUST SNAKES***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? <u>Running speed in gravid females is</u>	Viviparous (Michael & Lindenmayer 2010), mating occurs in spring (Mirtschin & Bailey 1990 as cited in DEHWA 2010d) but other authors state autumn mating in various subspecies (studies cited in Greer 1997) and generally birthing in autumn (Greer 1997). Viviparous species with spring sperm production while in most other live-bearing elapids occurs in spring-autumn. Live bearing species have a reproductive cycle time (from

	negatively affected but by being more sedentary a female reduces her exposure to predators. Fertilisation to oviposition plus egg incubation time in oviparous species is generally about the same as fertilisation to birth in viviparous species. The advantage/ disadvantage of either reproductive mode will have a more complex relationship with climate change than just the immediate climate effect. Egg predation, nest mortality and mortality of pregnant females will also vary as the distributions of predator, prey and habitat species change (M. Hutchinson pers. comm. 2010).	fertilization to birth) of around 100-160 days compared to 50-60 days for oviparous elapids. Costs may include decreased feeding capacity and ability to replenish energy stores for subsequent broods and increased predator susceptibility. Gravid females will often bask for longer than normal, curtail feeding and reduce range of movements (Greer 1997). ***MAJOR FACTOR/S: LIVE BEARING SO HIGH COST OF REPRODUCTION FOR FEMALE; INCREASED PREDATIONAND METABOLIC DEMAND WHEN GRAVID; LONG REPRODUCTIVE CYLE TIME COMPARED TO OVIPAROUS ELAPIDS***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Subspecies (*N. scutatus ater*) is listed under EPBC as vulnerable (DEHWA 2010d). Present patchy distribution of similar species (*N. ater*) in Flinders Ranges combined with anecdotal evidence suggest tiger snake was more common in early part of 1900's and have suffered declines. Current distribution confined to several stream systems in Southern Flinders Ranges where average annual rainfall is above 600mm (Cogger et al 1993). Once abundant along the Murray floodplain and adjacent wetlands. Conservation status in NSW is 'uncommon' and reported to have declined in the Riverinna bioregion (Michael & Lindenmayer 2010). Proposed IUCN status as 'vulnerable' in the Murray Scroll Belt with a declining trend (Gillam & Urban 2010). Only 6 records within study areas since 1990, 34 within SAMDB floodplain (BDBSA 2010). 'Often congregates into large colonies at swampy areas' (Gow 1976 as cited in SAAB 2001). ***MAJOR FACTOR/S: LOW ABUNDANCE; PATCHY DISTRIBUTION; NATIONAL AND REGIONAL THREAT LISTING WITH DECLINING TREND; MAY FORM COLONIES BUT DRIVERS NOT DESCRIBED AND MAY NOT BE FOR BREEDING***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Once abundant along the Murray floodplain and adjacent wetlands. Conservation status in NSW is 'uncommon' and reported to have declined in the Riverinna bioregion (Michael & Lindenmayer 2010). Listed as 'vulnerable' in the Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the Lowan Mallee and in 'probable decline' (Gillam & Urban 2010). Only 6 records within study areas since 1990, 34 with SAMDB floodplain (BDBSA 2010). 'Often congregates into large colonies at swampy areas' (Gow 1976 as cited in SAAB 2001). ***MAJOR FACTOR/S: MAJOR FACTOR/S: LOW ABUNDANCE; PATCHY DISTRIBUTION; NATIONAL AND REGIONAL THREAT LISTING WITH DECLINING TREND; MAY FORM COLONIES BUT DRIVERS NOT DESCRIBED AND MAY NOT BE FOR BREEDING***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change? Fragmentation of habitats is main limitation to species ability to adapt to different climates. Not highly mobile so continuous	All *Notechis* species in Australia are now recognized as one binomial *N. Scutatus* (M. Hutchinson pers. Comm. 2010). No hybridization is known for any Australian elapid species except the *Hoplocephalus* genera. Some colour differences have been noted for populations restricted to Chappell Island in Bass Strait compared to mainland populations. Island populations can be different size to mainland e.g. smaller on Roxby Is. off the Eyre Penn and larger on Chappell Is. in Bass Strait. Many southern tiger snakes are darker (almost all black, previously referred to as *N. ater*) whereas northern populations are often lighter (brownish, previously referred to as *N. scutatus*). Head scale differences are also noted for previous subspecies of tiger snakes (Greer 1997).

	habitat may allow gradual relocation but gaps will cause die-off at boundaries (D. Armstrong pers. comm. 2011).	***MAJOR FACTOR/S: MARKED GEOGRAPHIC VARIATION IN SIZE, COLOUR AND SCALE PATTERNS, REVISED TAXONOMY NOW GROUPS PREVIOUSLY SEPERATED NOTECHIS SPECIES AND SUBSPECIES***
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	All *Notechis* species in Australia are now recognized as one binomial *N. Scutatus* (M. Hutchinson pers. Comm. 2010). Subspecies (*N. scutatus ater*) is listed under EPBC as vulnerable (DEHWA 2010d). Present patchy distribution of similar species (*N. ater*) in Flinders Ranges combined with anecdotal evidence suggest tiger snake was more common in early part of 1900's and have suffered declines. Current distribution confined to several stream systems in Southern Flinders Ranges where average annual rainfall is above 600mm (Cogger et al 1993). Once abundant along the Murray floodplain and adjacent wetlands. Conservation status in NSW is 'uncommon' and reported to have declined in the Riverinna bioregion (Michael & Lindenmayer 2010). Listed as 'vulnerable' in the Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the Lowan Mallee and in 'probable decline' (Gillam & Urban 2010). Only 6 records within study areas since 1990, 34 with SAMDB floodplain (BDBSA 2010). ***MAJOR FACTOR/S: LOW ABUNDANCE; PATCHY DISTRIBUTION; NATIONAL AND REGIONAL THREAT LISTING WITH DECLINING TREND***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change? Fertilisation to oviposition plus egg incubation time in oviparous species is generally about the same as fertilisation to birth in viviparous species. However, oviparous species can produce multiple clutches and so their reproductive potential may be several times greater than for related viviparous species (M. Hutchinson pers. comm. 2010). Diurnal and very active as juveniles due to need to feed regularly to sustain growth rate. Trade-off between high fecundity and fast growth and high mortality as juvenile (D. Armstrong pers. comm. 2011).	Mating occurs in spring, with two females held in captivity giving birth to 15 and 8 young in April (Mirtschin & Bailey 1990 as cited in DEHWA 2010d). Produces up to 40 live young (Michael & Lindenmayer 2010). 'Mean brood size around 23-28 (n=40) birthing in autumn (Greer 1997). Produce from five to 12 living young (Worrell 1966). Livebearing, producing about 30 young in a litter, with litters of 17-109 reported (Cogger 2000). Usually litters of around 30 young, although litters of over 100 are reported (Wilson and Knowles 1992). Produces more than 40 young in a litter (Gow 1976)' (all as cited in SAAB 2001). Unable to reproduce annually even in captivity with the abundance of food (Greer 1997). ***MAJOR FACTOR/S: HIGH FECUNDITY COMPARED TO OTHER REPTILES ASSESSED IN THIS STUDY ALTHOUGH REPORTS VARY FROM MODERATE TO HIGH NUMBERS; MANY OVIPAROUS SPECIES THAT CAN HAVE MULTIPLE CLUTCHES PROBABLY STILL ABLE TO PRODUCE SEVERAL TIMES THE NUMBER OF OFFSPRING***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change? Diurnal and very active as juveniles due to need to feed regularly to sustain growth rate. Trade-off between high fecundity and fast growth and high mortality as juvenile (D. Armstrong pers. comm. 2011).	Unable to reproduce annually even in captivity with the abundance of food. Sexually mature at 20-24 months and may live to over 13 years (Greer 1997). ***MAJOR FACTOR/S: LONG-LIVED BUT SLOW TO REPRODUCE; GROWS QUICKLY SO JUVENILE MORTALITY MAY BE REDUCED; MATURES RELATIVELY QUICKLY; INDIVIDUALS PROBABLY CANNOT BREED EVERY YEAR DUE TO HIGH REPRODUCTION COST***

Scientific Name:	*Pseudechis porphyriacus*	**Common Name:**	Red-bellied Black Snake

Question	**Comments/ Reference**	
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? Highly water dependent within study area as is primarily frog-eater. Requires wet, swampy areas and populations in study area (and in SA) are isolated by need for cooler (or wetter) environments (D. Armstrong pers. comm. 2011).	Terrestrial and semi-aquatic, inhabits grass box woodland, dry forests and river red gum forests and wetlands. Management recommendations include preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees). Wetland protection is also important to prevent over-grazing and soil erosion and allowing natural flow/flooding regimes to prevent wetland disconnection, preservation and planting/distribution of native vegetation to improve water quality and snags and fallen trees in waterways (Michael & Lindenmayer 2010). Species is known to enter freshwater to forage and able to stay submerged for several minutes (Greer 1997). Species is associated with wet environments and often seen foraging beneath water for tadpoles, frogs or fish (Michael & Lindenmayer 2010). Almost certain that combination of land clearing/draining for agriculture has resulted in reduced populations (Greer 1997). 'Favours swamp, riverbank or wet sclerophyll forests margins' (Wilson and Knowles 1992 as cited in SAAB 2001). 'Associated with streams, swamps and lagoons, although sometimes range extends well beyond these areas' (Cogger 2000 as cited in SAAB 2001). 'Widespread in relatively moist environments, including marshlands' (Weigel 1990 as cited in SAAB 2001). ***MAJOR FACTOR/S: FRESHWATER AVAILABILITY FOR FORAGING FOR FROGS, TADPOLES ETC; HEALTH OF RIPARIAN HABITATS INCLUDING RIVER RED GUM FOREST AND NATIVE WETLAND VEGETATION; FLOW REGIMES/CONNECTIVITY OF SYSTEM***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? Fragmentation of habitats is main limitation to species ability to adapt to different climates. Not mobile at landscape scale so continuous habitat may allow gradual relocation but gaps will cause die-off at boundaries (D. Armstrong pers. comm. 2011).	Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Appears to have strict home ranges within definite geographic areas but the size of these ranges varies considerably but broadly correlated with snakes size (Greer 1997). 'A study found that activity (home) ranges of radio-tracked snakes varied between locations from 0.02-46.0 ha for males, and 0.02-14.7 ha for females' (Shine 1987c as cited in SAAB 2001). 'The sedentary nature of gravid females may be related to their vulnerability to predators… Distances from water were an average of 17 m for gravid and 130 m for non-gravid females (n = 57)' (Shine 1979 as cited in SAAB 2001). 'An active searching forager, with a home range among the largest recorded for snakes' (Shine 1987d as cited in SAAB 2001). ***MAJOR FACTOR/S: AMONG LARGEST HOME RANGES FOR AUST ELAPIDS BUT STILL REASONABLY SMALL SCALE COMPARED TO OTHER TAXA; INDIVIDUALS MAY BE ABLE TO MOVE IF CONDITIONS BECOME UNFAVOURABLE BUT PROBABLY TO LIMITED EXTENT***

	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Highly venomous and large elapid growing to around 2m although typically placid and reluctant to bite unless severely provoked (Michael & Lindenmayer 2010). Increased activity of males in breeding season may expose it to more predation as it more exposed for longer and has more variable body temperatures (Greer 1997). Live bearing species have a reproductive cycle time around twice as long as oviparous elapids. Costs may include increased predator susceptibility. Main predators of elapids in Australia are birds of prey e.g. raptors, storks, ibises gulls and kingfishers and some mammals e.g. introduced cats. Common ticks and mites are known in elapids and a variety of protozoan endoparasites (Greer 1997). ***MAJOR FACTOR/S: LARGE, VENOMOUS ALTHOUGH GENERALLY PLACID; LIMITED POTENTIAL PREDATORS ALTHOUGH SOME NOTED; MORE VULNERABLE TO PREDATION WHEN BREEDING AND GRAVID; KNOWN TO CARRY DISEASE AND PARASITES BUT EFFECTS UNKOWN***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change? <u>Lower tolerance to high temp than suggested in literature possibly due to comparison with nocturnal elapids. If stranded in hot area with no cover/water will probably die quite quickly (D. Armstrong pers. comm. 2011).</u>	Actively searches for its prey and forages in water for tadpoles, frogs and fish (Greer 1997; Michael & Lindenmayer 2010). Observed 'fishing' or hunting fish underwater and will take prey on or below the surface (Greer 1997). Recent work shows that Australian elapids take vertebrate prey almost exclusively and invertebrates are a very minor part (if at all) part of their diet. Accepts mostly ectothermic food e.g. lizards, snakes, fish and frogs/tadpoles and fish scented mammal food items. Unscented mammal food offerings are generally rejected (Greer 1997). Preferred body temp, voluntary thermal maximum and critical thermal maximum for species is higher compared to other Aust. elapids (PBT ~33°C, VTMax 32.5°C, TCrit~40°C) (Greer 1997). ***MAJOR FACTOR/S: VERY NARROW DIET OF MAINLY ECTOTHERMIC PREY; RELIANCE ON FRESHWATER HABITATS FOR AVAILIABILTY MAJOR PREY ITEMS; HIGH TEMP TOLERANCE***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Mean size and weight of hatchlings are SVL of 237.6mm and 11.1g (n=9) and first shedding is at 10-15 days (Greer 1997). Growth rate is very slow (0.16 and 0.23g/day) in the species compared to other elapids and even slow-growing pythons (Greer 1997).). Recent work shows that Australian elapids take vertebrate prey almost exclusively and invertebrates are a very minor part (if at all) part of their diet. Accepts mostly ectothermic food e.g. lizards, snakes, fish and frogs/tadpoles and fish scented mammal food items. Unscented mammal food offerings are generally rejected (Greer 1997). ***MAJOR FACTOR/S: VERY SLOW GROWTH RATE SO MORE VULNERABLE FOR LONGER; VERY NARROW DIET OF MAINLY ECTOTHERMIC PREY; RELIANCE ON FRESHWATER HABITATS FOR AVAILIABILTY MAJOR PREY ITEMS; HIGH TEMP TOLERANCE***

	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? Running speed in gravid females is negatively affected but by being more sedentary a female reduces her exposure to predators. Fertilisation to oviposition plus egg incubation time in oviparous species is generally about the same as fertilisation to birth in viviparous species. The advantage/ disadvantage of either reproductive mode will have a more complex relationship with climate change than just the immediate climate effect. Egg predation, nest mortality and mortality of pregnant females will also vary as the distributions of predator, prey and habitat species change (M. Hutchinson pers. comm. 2010).	Viviparous species with spring sperm production while in most other live-bearing elapids occurs in spring-autumn and birthing in summer. Occasional winter occurrence of embryos also seen but reasons are unknown; studies and data are lacking onto this phenomenon (Greer 1997). Live bearing habits appear to have evolved in response to cooler temperate environments. Live bearing species have a reproductive cycle time (from fertilization to birth) of around 100-160 days compared to 50-60 days for oviparous elapids. Costs may include decreased feeding capacity and ability to replenish energy stores for subsequent broods and increased predator susceptibility. Gravid females will often bask for longer than normal, curtail feeding and reduce range of movements (Greer 1997). During extreme droughts, species may not breed at all e.g. drought of 1981 in Macquarie Marshes (Shine 1987 as cited in Greer 1997). 'Mating occurs in spring and young emerge from membranous sacs from January to March' (Wilson and Knowles 1992 as cited in SAAB 2001). '… Numbers basking were higher in gravid females' (Shine 1979 as cited in SAAB 2001). 'In South Australia, birth usually takes place in February and March' (Waite 1993 as cited in SAAB 2001). Distances from water were an average of 17m for gravid and 130m for non-gravid females (n = 57)' (Shine 1979 as cited in SAAB 2001). ***MAJOR FACTOR/S: LIVE BEARING SO HIGH COST OF REPRODUCTION FOR FEMALE; INCREASED PREDATIONAND METABOLIC DEMAND WHEN GRAVID; LONG REPRODUCTIVE CYLE TIME COMPARED TO OVIPAROUS ELAPIDS; MAY NOT BREED DURING DROUGHTS; MOVES LESS AND PREFERS TO BE CLOSER TO WATER WHEN GRAVID***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Not listed under EPBC, NPW Act, listed as 'vulnerable' in DENR Murraylands region and Murray Mallee IBRA sub-region and in 'probable decline' (Gillam & Urban 2010). Only 1 BDBSA record within study area since 1990, 14 in SAMDB and 54 statewide (BDBSA 2010). ***MAJOR FACTOR/S: BDBSA RECORDS IMPLY VERY LOW ABUNDANCE IN STUDY AREA AND FEW STATEWIDE RECORDS ALSO; HOWEVER NOT THREAT LISTED AT STATE, NATIONAL OR REGIONAL LEVELS; POPUALTION LIKELY TO BE SMALL AND FEATURE RESTRICTED GENE POOL ACROSS THE STUDY AREA***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Not listed under EPBC, NPW Act, listed as 'vulnerable' in DENR Murraylands region and Murray Mallee IBRA sub-region and in 'probable decline' (Gillam & Urban 2010). Only 1 BDBSA record within study area since 1990, 14 in SAMDB and 54 statewide (BDBSA 2010). ***MAJOR FACTOR/S: BDBSA RECORDS IMPLY VERY LOW ABUNDANCE IN STUDY AREA AND FEW STATEWIDE RECORDS ALSO; HOWEVER NOT THREAT LISTED AT STATE, NATIONAL OR REGIONAL LEVELS; POPUALTION LIKELY TO BE SMALL AND FEATURE RESTRICTED GENE FLOW EVEN AT SMALL SPATIAL SCALES***

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	No hybridization is known for any Australian elapid species except the *Hoplocephalus* genera. Ventral hues seem to vary geographically (southern versus northern populations) but the significance of this variation is unknown. Trend for snakes in highland areas to be larger than populations in lowlands (Greer 1997). Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Not listed under EPBC, NPW Act, listed as 'vulnerable' in DENR Murraylands region and Murray Mallee IBRA sub-region and in 'probable decline' (Gillam & Urban 2010). ***MAJOR FACTOR/S: GEOGRAPHIC VARIATION IN COLOUR AND SIZE BUT UNCLEAR IF EVIDENT WITHIN STUDY AREA; LIMITED POPUALTION SIZE AND PATCHY DISTRIBUTION INCREASES CHANCE OF DELINEATION OF PHENOTYPIC/GEOGRAPHIC VARIATION AS LESS MIXING***
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Not listed under EPBC, NPW Act, listed as 'vulnerable' in DENR Murraylands region and Murray Mallee IBRA sub-region and in 'probable decline' (Gillam & Urban 2010). Only 1 BDBSA record within study area since 1990, 14 in SAMDB and 54 statewide (BDBSA 2010). ***MAJOR FACTOR/S: BDBSA RECORDS IMPLY VERY LOW ABUNDANCE IN STUDY AREA AND FEW STATEWIDE RECORDS ALSO; HOWEVER NOT THREAT LISTED AT STATE, NATIONAL OR REGIONAL LEVELS; POPUALTION LIKELY TO LIMITING DESPITE LACK OF THREAT LISTING GIVEN SPARSENESS OF RECORDS***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change? <u>Oviparous species can produce multiple clutches and so their reproductive potential may be several times greater than for related viviparous species (M. Hutchinson pers. comm. 2010).</u>	Viviparous, produces an average of 20 live young (Michael & Lindenmayer 2010). Mean brood size around 12.3 (n=60) birthing in summer (Greer 1997). Produces 5-40 young (various studies cited in SAAB 2001). 'Clutch size was positively correlated with female body size, and over 80% of adult females reproduced every year' (Shine 1977a as cited in SAAB 2001). Maximum of 1 clutch per year with 5-16 offspring (Heatwole and Taylor 1987). ***MAJOR FACTOR/S: VARIABLE CLUTCH SIZE REPORTED LOW TO MODERATE AND HIGH NUMBERS POSSIBLE; SINGLE CLUTCH PER YEAR; PROBABLY POOR TO MODERATE RELATIVE REPRODUCTIVE CAPACITYCOMPARED TO MANY OVIPAROUS SPECIES***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Sexually mature at 19-31 months (male/female) and may live to over 6 years of age, females may not be mature until their 3rd or 4th season. Records indicate that large elapids can live for at least 10 years (Greer 1997). Males reach sexual maturity at 19 months, but some delay for another year. Females first mate at 31 months and give birth at 36 months (Shine 1978 as cited in SAAB 2001). Maximum of 1 clutch per year with 5-16 offspring (Heatwole and Taylor 1987). Localised distribution mainly along the Murray river system and it creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010). Not listed under EPBC, NPW Act, listed as 'vulnerable' in DENR Murraylands region and Murray Mallee IBRA sub-region and in 'probable decline' (Gillam & Urban 2010). Only 1 BDBSA record within study area since 1990, 14 in SAMDB and 54 statewide (BDBSA 2010). ***MAJOR FACTOR/S: LARGE AND PROBABLY LONG-LIVED SPECIES WITH LONGER GERATION TIMES; SINGLE CLUTCH AND INDIVIDUALS MAY NOT BREED EVERY YEAR OR DURING DROUGHTS; PROBABLY VERY LOW POPUALTION BASE WITHIN STUDY AREA FROM WHICH TO RECRUIT FROM***

Scientific Name:	*Varanus varius*	Common Name:	Lace Monitor (Tree Goanna)

Question		Comments/ Reference
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change? Critical dependence on narrow habitat requirements i.e. large trees, hollows etc. Will use terrestrial movement to relocate but forages for nestling birds almost exclusively in trees. Not as dependent on water as Carpet Python but requires trees found almost only near water especially in arid areas (D. Armstrong pers. comm. 2011).	Arboreal and terrestrial, inhabit dry forests, grassy box woodland, sandhill woodland, black box woodland, river red gum forest and mallee woodland. Shelter in hollow logs and trees and uses rabbit burrows. Management recommendations include preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees), conservation of large mature trees used for foraging, basking, sheltering and nesting and control of exotic animals that prey on eggs, young and sometimes adults. Also introduced herbivores e.g. feral goats and sheep that degrade soil and land through grazing. Rabbit control should be considered as also provide good food source for larger reptiles in some areas and use of burrows for shelter (Michael & Lindenmayer 2010). 'Monitor lizards are generally good runners, climbers, and/or swimmers. This repertoire in movement suggests an ability to move through variable habitats' (Arida 2008). ***MAJOR FACTOR/S: REASONABLY BROAD HABITAT PREFERENCES AND NOT EXPLICITLY ASSOCIATED WITH PROXIMITY TO WATER BODIES; MAIN THREAT THROGUH REMOVAL OF LIVE AND DEAD TREES INCLUDING VULNERABLE RIVER RED GUM FORESTS ALONG RIPARIAN AREAS***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change? While relatively mobile, may still be limited by habitat fragmentation (riparian woodland forests) as will tend to avoid travelling across open areas. Reptiles more able to cope than warm-blooded animals if conditions deteriorate as can hide in cover, lower metabolism and hibernate for extended periods (D. Armstrong pers. comm. 2011).	Found to move several kilometers over a 5-day period and over 1km within a few hours. Varanids have a very large home range and are 'cruising' foragers that slowly move around their territory (Heatwole & Taylor 1987). 'In southeastern Australia, lace monitors are active between Sept and May (spring, summer, and autumn) and generally inactive between June and August… The movement frequency (and distance) of monitors was significantly higher during summer, intermediate during spring and autumn, and lowest during winter' (Guarino et al 2002). Food availability is given as a main driver of reduced activity in late summer concurring with other studies of Varanids (Guarino et al 2002). 'We observed some males moving over 1km in 1 day in search of females' (Guarino et al 2002). ***MAJOR FACTOR/S: MOST MOBILE OF TERRESTRIAL REPTILE SPECIES ASSESSED IN THIS STUDY (APART FROM THE CHELUIDAE) WITH LARGE HOME RANGE; MOVES IN RESPONSE TO FOOD AVAILABILITY; HABITAT FRAGMENTATION LIKELY TO LIMIT ABILITY TO RELOCATE AS WILL USUALLY AVOID OPEN AREAS; SEARCH FOR FEMALES OVER KMS***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? Apex predator, almost exclusively arboreal and feeds on nestling birds (D. Armstrong pers. comm. 2011).	Very large lizard (2nd largest in Aust.) to over 2m length possessing toxin secreting glands in lower jaw. Venom thought to aid disabling of prey as shown in experiments with lab rats and human experience of bites (Michael & Lindenmayer 2010). Management recommendations include control of exotic animals e.g. red foxes, feral cats; that prey on eggs, young and sometimes adults. Rabbit control should be considered as also provide good food source for larger reptiles in some areas and use of burrows for shelter (Michael & Lindenmayer 2010). '… mortality in lizards is generally at its highest during the hatchling and juvenile stages of the life cycle (Auffenberg 1981; Civantos 2000; Civantos and Forsman 2000; Pianka and Vitt 2003); therefore, for any given population of varanids, survival of most adults within any 2-year period is highly probable' (Smith et al 2009). Varanids can sustain high levels of aerobic activity in order to capture active prey. Most large lizards lack this ability and are herbivourous after a certain size (Pough 1973 as cited in

		Heatwole and Taylor 1987). ***MAJOR FACTOR/S: LARGE SIZE LIMITS POTENTIAL PREDATORS; VENOM AIDS PREY CAPTURE AND PRESUMABLY HELPS IN DEFENCE STRATEGY; PROBABLY HIGH JUVENILE AND EGG MORTALITY BUT HIGH ADULT SURVIVORSHIP; AEROBIC CAPACITY HELPS IN PREY CAPTURE AND PRESUMABLY PREDATOR ESCAPE***
Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Diurnal activity patterns (Michael & Lindenmayer 2010). Varanids appear to have very high tolerance to extended periods of high temperature although extreme temperatures have not been tested (Heatwole and Taylor 1987). Varanids can sustain high levels of aerobic activity in order to capture active prey. Most large lizards lack this ability and are herbivourous after a certain size (Pough 1973 as cited in Heatwole and Taylor 1987). Food availability is given as a main driver of reduced activity in late summer concurring with other studies of Varanids (Guarino et al 2002). 'This pattern of behaviour (e.g., adjusting outputs) is consistent with the hypothesis that lizards can change their activity in a manner that ultimately enhances their survival' (Merker and Nagy 1984 as cited in Guarino et al 2002). A 'water efficient' lizard with similar water intake to energy output rates as some desert reptiles. Observed to adjust behaviour and use non-food water intake to reduce energy expenditure (Guarino et al 2002). 'It has been suggested that during periods of low food acquisition, increased water influx through nonfood sources may be advantageous because it presumably reduces metabolic expenditure associated with water conservation via solute linked reabsorption by the kidneys and cloaca' (Green et al 1997 as cited in Guarino et al 2002). '… mortality in lizards is generally at its highest during the hatchling and juvenile stages of the life cycle (Auffenberg 1981; Civantos 2000; Civantos and Forsman 2000; Pianka and Vitt 2003); therefore, for any given population of varanids, survival of most adults within any 2-year period is highly probable' (Smith et al 2010). ***MAJOR FACTOR/S: TOLERANT OF HIGH TEMPS; HIGH AEROBIC CAPACITY HELPS IN PREY CAPTURE; ADJUSTS ACTIVITY LEVELS IN ACCORDANCE WITH FOOD AVAILABILITY; USES NON-FOOD WATER INTAKE WHEN PREY IS SCARCE REDUCING ENERGY EXPENDITURE; PROBABLY HIGH JUVENILE AND EGG MORTALITY BUT HIGH ADULT SURVIVORSHIP***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	'… mortality in lizards is generally at its highest during the hatchling and juvenile stages of the life cycle (Auffenberg 1981; Civantos 2000; Civantos and Forsman 2000; Pianka and Vitt 2003); therefore, for any given population of varanids, survival of most adults within any 2-year period is highly probable' (Smith et al 2009). Varanids appear to have very high tolerance to extended periods of high temperature although extreme temperatures have not been tested (Heatwole and Taylor 1987). Varanids can sustain high levels of aerobic activity in order to capture active prey (Pough 1973 as cited in Heatwole and Taylor 1987). Food availability is given as a main driver of reduced activity in late summer concurring with other studies of Varanids (Guarino et al 2002). 'This pattern of behaviour (e.g., adjusting outputs) is consistent with the hypothesis that lizards can change their activity in a manner that ultimately enhances their survival' (Merker and Nagy 1984 as cited in Guarino et al 2002). A 'water efficient' lizard with similar water intake to energy output rates as some desert reptiles. Observed to adjust behaviour and use non-food water intake to reduce energy expenditure (Guarino et al 2002). ***MAJOR FACTOR/S: TOLERANT OF HIGH TEMPS; HIGH AEROBIC CAPACITY HELPS IN PREY CAPTURE; ADJUSTS ACTIVITY LEVELS IN ACCORDANCE WITH FOOD AVAILABILITY; USES NON-FOOD WATER INTAKE WHEN PREY IS SCARCE REDUCING ENERGY EXPENDITURE; PROBABLY HIGH JUVENILE AND EGG MORTALITY BUT HIGH ADULT***

		SURVIVORSHIP
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change? Widely thought to lay eggs in termite nests particularly in trees but also on ground as provides a stable temperature environment for incubation (D. Armstrong pers. comm. 2011).	Oviparous (Michael & Lindenmayer 2010). '… mortality in lizards is generally at its highest during the hatchling and juvenile stages of the life cycle (Auffenberg 1981; Civantos 2000; Civantos and Forsman 2000; Pianka and Vitt 2003); therefore, for any given population of varanids, survival of most adults within any 2-year period is highly probable' (Smith et al 2009). A review of reproductive data on Australian varanids suggested that some large-bodied species (e.g., *V. varius*) had relatively small clutches' (James et al 1992). 'Body size has an influence on clutch sizes, with females of larger species having larger and more variable clutch sizes than those of smaller species. This implies that larger species have higher reproductive output, although low offspring survival seems to counterbalance' (Arida 2008). 'We observed some males moving over 1km in 1 day in search of females' (Guarino et al 2002). Various reports of egg-laying in termite mounds on ground and in trees associated with provision of stable temperature environment for incubation (Hose 1998). ***MAJOR FACTOR/S: NO INFO ON BREEDING TRIGGERS OR TOLERANCES; HIGH MORTALITY OF EGGS AND JUVENILES; LARGER VARANIDS MAY HAVE LARGER CLUTCHES TO OFFSET LOW SURVIVAL; MALES MAY BE MORE EXPOSED TO PREDATION AND HIGHER METABOLIC DEMAND WHEN SEARCHING FOR FEMALES***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Classed as 'rare' under the NPW Act 1972 and 'near threatened' in the Murray Scroll Belt and 'rare' in the Murray Mallee IBRA sub-regions under regional IUCN criteria with a stable trend (Gillam & Urban 2010). Only 17 BDBSA records within study area since 1990 with majority above Lock 3 and a small grouping above Lock 6 (BDBSA 2010). ***MAJOR FACTOR/S: VERY FEW RECORDS IN BDBSA; NATIONALLY LISTED AS RARE AND NEAR THREATENED AT REGIONAL LEVEL WITHIN STUDY AREA; PROBABLY LIMITED GENE POOL IN EXTANT POPULATIONS IN STUDY AREA***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Classed as 'rare' under the NPW Act 1972 and 'near threatened' in the Murray Scroll Belt and 'rare' in the Murray Mallee IBRA sub-regions under regional IUCN criteria with a stable trend (Gillam & Urban 2010). Only 17 BDBSA records within study area since 1990 with majority above Lock 3 and a small grouping above Lock 6 (BDBSA 2010). 'We observed some males moving over 1km in 1 day in search of females' (Guarino et al 2002). ***MAJOR FACTOR/S: VERY FEW RECORDS IN BDBSA; NATIONALLY LISTED AS RARE AND NEAR THREATENED AT REGIONAL LEVEL WITHIN STUDY AREA; MALES MAY MOVE TO BREED; PAIR BONDS UNKNOWN; PROBABLE LIMITED FLOW AT SCALE OF STUDY AREA***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Classed as 'rare' under the NPW Act 1972 and 'near threatened' in the Murray Scroll Belt and 'rare' in the Murray Mallee IBRA sub-regions under regional IUCN criteria with a stable trend (Gillam & Urban 2010). Only 17 BDBSA records within study area since 1990 with majority above Lock 3 and a grouping above Lock 6 (BDBSA 2010). Two colour morphs are present in the Murray Catchment differing in size and colour of body bands and both colour morphs can occur in a single clutch of eggs (Michael & Lindenmayer 2010). ***MAJOR FACTOR/S: MONOTYPIC SPECIES; SLIGHT VARIATION IN COLOURATION BUT NOT ASSOCIATED WITH GEOGRAPHIC OR ENVIRONMENTAL VARIABLES; PROBABLY NO PLASTICITY PROVIDING ADDED TOLERANCE TO CLIMATE CHANGE***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Common and secure status with widespread distribution in NSW except far eastern part of catchment (Michael & Lindenmayer 2010). Classed as 'rare' under the NPW Act 1972 and 'near threatened' in the Murray Scroll Belt and 'rare' in the Murray Mallee IBRA sub-regions under regional IUCN criteria with a stable trend (Gillam & Urban 2010). Only 17 BDBSA records within study area since 1990 with majority above Lock 3 and a small grouping above Lock 6 (BDBSA 2010). ***MAJOR FACTOR/S: VERY FEW RECORDS IN BDBSA; NATIONALLY LISTED AS RARE AND NEAR THREATENED OR RARE AT SUB-REGIONAL LEVEL WITHIN STUDY AREA; PROBABLY LIMITED POPULATION SIZE IN STUDY AREA***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Oviparous (Michael & Lindenmayer 2010). Data from captive specimens give clutch size around 5 (Carter 1990; Weavers 2004 both as cited in Arida 2008). Varanid 'clutch sizes ranged from 1-7 eggs. Regression slopes of maternal SVL and clutch size seemed to be higher for the smaller-bodied species compared to the larger-bodied species, but sample sizes were too low to compare them statistically. A review of reproductive data on Australian varanids suggested that some large-bodied species (e.g., *V. varius*) had relatively small clutches' (James et al 1992). 'Small varanids seem to lay multiple clutches over a year… Large species tend to lay one clutch per year within total deposition time of a few weeks' (Arida 2008). ***MAJOR FACTOR/S: PROBABLY SINGLE CLUTHING; PROBABLY SMALL TO MODERATE CLUTCH SIZE COMPARED TO OTHER REPTILES ASSESSED IN THIS STUDY***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Although the demography and life history of most varanids in Australia is unknown, varanids in general are thought to be long-lived' (various studies cited in Smith et al 2009). '… mortality in lizards is generally at its highest during the hatchling and juvenile stages of the life cycle (Auffenberg 1981; Civantos 2000; Civantos and Forsman 2000; Pianka and Vitt 2003); therefore, for any given population of varanids, survival of most adults within any 2-year period is highly probable' (Smith et al 2009). Data from captive specimens suggest species matures at 3 years (Carter 1990; Weavers 2004 both as cited in Arida 2008). Conservative estimates of recruitment suggest a quarter of original clutch size may survive to reproductive age due to predation and cannibalism (Arida 2008). ***MAJOR FACTOR/S: PROBABLY A LONG LIVED SPECIES; TAKES MODERATE LENGTH OF TIME TO REACH MATURITY COMPARED TO OTHER REPTILES ASSESSED IN THIS STUSY; QUITE HIGH EGG/JUVENILE MORTALITY AND ONLY ¼ OF CLUTCH SIZE MAY REACH ADULTHOOD; PROBABLY SINGLE CLUTCHING BUT REPRODUCING EVERY YEAR***

Reptile References

Turtle References

Beck, R.G. (1991), The common long necked tortoise *Chelodina longicollis* (Shaw 1802) (Testudinata: Cheildae): A comparative study of morphology and field behavior of disjunct populations. Victorian Naturalist **66**, 4-22.

Booth DT (1998), Egg size, clutch size, and reproductive effort of the Australian broad-shelled river turtle, Chelodina expansa*, Journal of Herpetology,* 32 (**4**): 592-596

Booth, D. 2002a. The breaking of diapause in embryonic broad-shelled river turtles Chelodina expansa. Journal of Herpetology 36:304-307.

Booth, D. 2000. Incubation of eggs of the Australian broad-shelled turtle, Chelodina expansa Testudinata: Chelidae at different temperatures: effects on pattern of oxygen consumption and hatchling morphology. Australian Journal of Zoology 48:369-378.

Bowen, K. D., Spencer R. J. & Janzen F. J. 2005. A comparative study of environmental factors that affect nesting in Australian and North American freshwater turtles. Journal of Zoology 267:397-404.

Cann, J. 1998. Australian Freshwater Turtles. Beaumont Publishing, Singapore [in Spencer & Thompson 2005 & SAAB 2001].

Chessman BC (1983), Observations on the diet of the Broad-Shelled Turtle, Chelodina expansa (Testudines: Chelidae), Australian Wildlife Research, 10: 169-172.

Chessman, B. C. (1986). Diet of the Murray turtle, Emydura macquarii (Gray) (Testudines: Chelidae). Aust. Wildl. Res. 13, 65-9.

Chessman, B. C. (1984a). Evaporative water loss from three south-eastern Australian species of freshwater turtles. *Australian Journal of Zoology* **32**, 649-655.

Chessman, B. C. (1984b). Food of the snake-necked turtle, Chelodina longicollis (Shaw) (Testudines: Chelidae) in the Murray Valley, Victoria and New South Wales. Aust. Wildl. Res. 11, 573-8.

Chessman, B. C. (1988). Habitat preferences of freshwater turtles in the Murray Valley, Victoria and New South Wales. *Australian Wildlife Research* **15**, 485-491.

Chessman, B. 1988b. Seasonal and diel activity of freshwater turtles in the Murray Valley, Victoria and New South Wales. Wildlife Research 15:267-276.

De Lathouder, R., Jones, D. N. & Balcombe, S. R. 2009. Assessing the abundance of freshwater turtles in an Australian urban landscape. Urban Ecosystems 12:215-231.

Ercolano, E. unpublished report, Aquatic & terrestrial habitat use of the Australian freshwater turtle, *Chelodina expansa* (SIT study abroad student project).

Georges, A. 1984. Observation on the nesting and natural incubation of the longnecked tortoise Chelodina expansa in south-east Queensland. Herpetofauna 15:27-31.

Georges, A. (1993). Setting conservation priorities for Australian freshwater turtles. In: *Herpetology in Australia: a diverse discipline* (Eds D. Lunney and D. Ayers.) pp. 49-58. (Royal Zoological Society of New South Wales: Mossman.)

Georges. A., Norris, R.H., & Wensing, L. (1986), Diet of the Freshwater Turtle Chelodina longicollis (Testudines: Chelidae) from the Coastal Dune Lakes of the Jervis Bay Territory, *Aust. Wildl. Res*, **13**, 301-8

Goode, J. & Russell, J. 1968. Incubation of eggs of three species of chelid tortoises and notes on their embryological development. Australian Journal of Zoology 16:749-61.

Green, D. 1996. Observations of grooming in some captive Australian chelid turtles. Herpetofauna 26:46 [in Greer 2003].

Greer, A.E. 2003. Encyclopedia of Australian Reptiles. Australian Museum Online http://www.amonline.net.au/herpetology/research/encyclopedia.pdf Version date: 25 May 2004.

Kennett, R. M. and Georges, A. (1990). Habitat utilization and its relationship to growth and reproduction of the eastern long-necked turtle, Chelodina longicollis (Testudianta: Chelidae), from Australia, *Herpetologica* **46**, 22-33.

Meathrel, C. E., Suter, P. J. & Radford, N. M. 2002. Niche segregation between three species of freshwater turtle in a large billabong during flood. Victorian Naturalist 119:160-173.

Parmenter, C. J. (1985). Reproduction and survivorship of Chelodina longicollis (Testudinata: Chelidae). Pp 53-61. In: *Biology of Australasian frogs and reptiles*. (Eds G. Grigg, R. Shine and H. Ehmann.) (Royal Society of New South Wales: Sydney.)

Scheltinga, D. 1991. Salt glands and the tolerance of Chelodina longicollis and C. expansa for saline water. Honours thesis, University of Queensland, Brisbane [in D. Bower unpublished review].

South Australian Department for Water Resources (2001), *South Australian Aquatic Biodiversity Database* (SAAB): Version 1.0, South Australian Department for Water Resources, Adelaide.

South Australian Murray Darling Basin Natural Resource Management Board (SAMDBNRM) (unpublished data), SAMDBNRM Wetland Monitoring data, SAMDBNRM.

Spencer, R. J. 2002. Growth patterns of two widely distributed freshwater turtles and a comparison of common methods used to estimate age. Australian Journal of Zoology 50:477-490.

Thompson, M. B. (1993). Hypothetical considerations of the biomass of chelid tortoises in the River Murray and the possible influences of predation by introduced foxes. Pp 219-224. In: *Herpetology in Australia: a diverse discipline*. (Eds D. Lunney and D. Ayers.) (Royal Zoological Society of New South Wales: Mosman)

Thompson, M. B. 1983. Murray River tortoise (Emydura, Chelodina) populations: the effect of egg predation by the red fox, Vulpes vulpes. Australian Wildlife Research 10:363–371 [in Spencer & Thompson 2005].

Vestjens, W. J. M. (1969). Nesting, egg-laying and hatching of the snake-necked tortoise at Canberra, A.C.T. *Australian Zoologist* **15**, 141-149.

Lizard & Snake References

Arida, E. 2008. 'An overview on the ecology of varanid lizards'. Zoo Indonesia. Vol. 17(2): 67-82.

DEH 2008. Eastern Water Skink Threatened Species Profile. Prepared as part of the Regional Recovery Plan for Threatened Species and Ecological Communities of Adelaide and the Mount Lofty Ranges, South Australia 2009 – 2014. Department for Environment and Heritage. May, 2008. [Online]. Available: http://www.environment.sa.gov.au/biodiversity/pdfs/regional_recovery/fauna/reptiles/eastern-water-skink.pdf. Accessed Thurs, 6 Jan 2011 16:31:48 +1000.

DEHWA. 2010d. Notechis scutatus ater 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 Mon, 20 Sep 2010 12:48:51 +1000.

Cogger, H.G., Cameron, E.E., Sadlier R.A. & Eggler P. 1993. 'The Action Plan for Australian Reptiles'. Australian Nature Conservation Agency. Canberra, ACT.[Online]. Available: http://www.environment.gov.au/biodiversity/threatened/action/reptiles/index.html. Accessed Mon, 20 Sep 2010 12:36:48 +1000.

Barnett, B. & Schwaner, T. D. 1985. 'Growth in captive born tiger snakes (Notechis ater serventyi) from Chappell Island: implications for field and laboratory studies. Trans. R. Soc. S. Aust. Vol. 109 (2): 31-36.

Smith, M. & Eredith, J. 1975. 'The vertebrae of four Australian elapid snakes (Squamata: Elapidae)'. Trans. R. Soc. S. Aust. Vol. 99(2): 71-84.

DECCW 2004. 'Coolibah - black box woodland as an endangered community'. Report prepared by the Department of Environment, Climate Change and Water (DECCW) NSW. May 2004. [Online]. Available: http://www.environment.nsw.gov.au/threatenedspecies/CoolibahBlackBoxWoodland.htm. Accessed Wed, 15 Dec 2010 09:19:36 +1000.

Gillam, S. and Urban, R. 2010. 'Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region'. Department of Environment and Natural Resources, South Australia.

DSEWPC 2011. Eulamprus tympanum marnieae in Species Profile and Threats Database, Department of Sustainability, Environment, Water, Population and Communities, Canberra. [Online]. Available: http://www.environment.gov.au/sprat. Accessed Fri, 7 Jan 2011 15:56:03 +1100.

Guarino, F., Georges, A., & Green, B. 2002. 'Variation in Energy Metabolism and Water Flux of Free-Ranging Male Lace Monitors, Varanus varius (Squamata: Varanidae)'. Physiological & Biochemical Zoology. Vol. 75(3): 294-304.

Smith, J. G., Griffiths, A. D., & Brook, B. W. 2010. 'Survival estimation in a long-lived monitor lizard: radio-tracking of Varanus mertensi'. Population Ecology. Vol. 52(1): 243-247.

James, C. D., Losos, J. B. & King, D. R. 1992. 'Reproductive Biology and Diets of Goannas (Reptilia: Varanidae) from Australia'. Journal of Herpetology. Vol. 26(2): 128-136.

Heatwole, H. & Taylor, J. 1987. Ecology of Reptiles. 1st Ed. Norton, NSW. Surrey Beatty & Sons Pty. Ltd.

Michael, D. & Lindenmayer, D. 2010. Reptiles of the NSW Murray catchtment. Aguide to their identification, ecology and conservation. 1st Ed. Collingwood, Victoria. CSIRO Publishing.

Swan, M. & Watharow, S. 2005. Snakes, lizards and frogs of the Victorian Mallee. 1st Ed. Collingwood, Victoria. CSIRO Publishing.

Greer, A. 1997. The biology and evolution of Australian snakes. 1st Ed. Norton, NSW. Surrey Beatty & Sons Pty. Ltd.

Scientific Name:	*Hydromys chrysogaster*	Common Name:	Eastern Water Rat

Question		Comments/ Reference
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change	'Populations are dense in some irrigation areas, particularly in drainage swamps, but appear to be sparse along rivers. Swamp mitigation practices have removed much habitat but the overall range of the water rat does not appear to have changed much since European settlement (Olsen 2008)'; Inhabiting most inland water systems, estuaries, marine beaches and islands from Queensland south to Tasmania and west to South Australia(Woollard et al 1978); 'High salinity levels are clearly not a problem for the water rat'; Found from brackish and marine habitats to upland streams (Scott and Grant 1997); Water rats do not require the flow in a river to be maintained above some minimum value but on a long term basis floods are most likely to benefit the water rat since the floodwaters result in an increase of suitable feeding habitat. The water rat can tolerate changes in flow better than many other aquatic vertebrates (Scott & Grant 1997); Reed beds (e.g *Typha* spp., *Phragmites australis)* provide habitat for water rats and reed growth and the expansion of reed beds is benefited by reduced river flows and stability of water levels (SA MDB NRM unpublished data). ***Permanent water is preferred habitat and is expected to be largely retained because of water supply requirements. Species is not normally associated with the river channel of large rivers (Olsen 2008) but with reduced river flows under climate change and increased reed growth, weir pools and associated large anabranches are likely to be more attractive to the water rat.*** ***Decreased flooding of temporary and permanent wetlands is expected to reduce food availability and decrease habitat, but as a habitat generalist, tolerant of varied water quality conditions, e.g. high salinity, the impacts are expected to be minimized.***
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change.	The water rat maintains a home range and has no migratory patterns. Dams and weirs would not inhibit the dispersal of water rats since they can move considerable distances across dry land (Scott & Grant 1997); Although normally found close to water, the rats may move considerable distances overland at night in search of food (McNally 1960); Home ranges in SE Queensland are 2-10 hectares (Olsen 2008). ***Dams and weirs are not a barrier to movement and H. chrysogaster known to move considerable distances overland in search of food. No migratory patterns and maintains a home range, but unknown if would disperse in response to deteriorating local conditions.***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	'Fish, in particular, and large aquatic insects were of primary importance in the diet in terms of constancy and biomass. Semi-aquatic spiders and fully aquatic damsel and dragonfly nymphs were of major seasonal importance. Birds, both waterbirds and small passerines, crustaceans and possibly mussels were important secondary items. Supplementary prey Included frogs, turtles and bats. Mice were readily taken during a plague. Traces of plant material, present in many guts, formed a small part of the diet increasing somewhat in importance during the winter months (Woolard et al 1978)'.

		'With the ability to capture a large range of food items, from mosquitos to ducks, the water rat appears to be an opportunist governed by changing availability and in times of abundance by preference ...Since carp are benthic feeders and water rats hunt for food across a wide range of habitats there is probably little competition for food. In fact the water rat might have benefited from the large increase in carp numbers with anecdotal evidence of water rats feeding on large numbers of carp in Barmah forest following flooding (Scott & Grant 1997)'. Young animals are preyed upon by snakes and large fish; adults and young by birds or prey, foxes and cats (Olsen 1983). ***Highly generalist and opportunistic diet reduces competition and reliance on any one particular prey item. No other mammal species would compete for food source (or habitat) but some competition may occur from piscivorous birds, diving ducks, large fish, turtles and other reptiles. Introduced fish such as the European carp are expected to provide an increasing food source. Predation rate on adults is not expected to be high due to generality cryptic nature and ability to escape to the water but predation would be higher on young.***
Physiology	To what extent does ***survival*** limit the ability of the regional population of the species to tolerate climate change?	'High salinity levels are clearly not a problem for the water rat (Scott and Grant 1997)'; Substantial declines of H. chrysogaster have been noted in southwestern Western Australia and along inlandwaterways affected by salinity and degradation (Lee 1995); Has a broad distribution inhabiting most inland water systems, estuaries, marine beaches and islands from Queensland south to Tasmania and west to South Australia (Woollard *et al* 1978); Versatility and broad resource utilization would appear to ideally suit the water rat to the dynamically changing waterways of Australia (Woollard et al 1978). ***Adaptable, a generalist and tolerant of many conditions. Appears not significantly limited by water regime, temperature or salinity, though in Western Australia declines have been linked to salinity. Highly saline waters may be limiting if main prey species and habitat vegetation are not tolerant to salinity or if there is a lack of freshwater close by.***
	To what extent does ***growth*** limit the ability of the regional population of the species to tolerate climate change?	'…their lifespan has been foreshortened by the drought…(Serena in Sullivan 2007)'. ***Unknown to what extent physical 'growth' is limited by the effects of climate change but as a forage and habitat generalist and tolerant of salinity the potential negative effects may be reduced. Their preference for permanent waters ensures that during times of extended drought within the study region pool level water bodies and stable weir pools will provide refuge.***
	To what extent does ***reproduction*** limit the ability of the regional population of the species to tolerate climate change?	'In dry years breeding is irregular and litters are smaller (Scott & Grant 1997)'. '…and so many bad breeding years caused by the drought, water rats have disappeared from some parts of their range…They have litters of between three and five young, and may have up to three litters a year, although the number of young born in a year depends very much on the availability of food (Serena in Sullivan 2007)'. Although the flooding of rivers or wetlands in spring or summer may lead to some mortality of young in burrows, the water rat is capable of producing a second and possibly even a third litter in the same

		season...'This ability to produce more than one litter per season enables the water rat to tolerate changes in flow better than many other aquatic vertebrates (Scott & Grant 1997)'. ***Under drought conditions reproduction is expected to decline but does not appear to be significantly limited by salinity or alteration of water regime***.
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	The water rat is widely distributed throughout Australia. Within the Murray Darling Basin however it is still common in areas where there is suitable habitat, such as irrigation areas and permanent wetlands (Scott & Grant 1997); 'A recent survey of the Murray River Corridor recorded the species from numerous points along the river (A. Graham and H. Stewart pers. comm..), indicating that it is secure within the region (Carthew & Reardon 2009)'. *H. chrysogaster has a broad distribution and is considered common across its range where there is suitable habitat. Recent surveys indicate the species is relatively common within the study region. Species is expected to have a large gene pool.*
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Dams and weirs would not inhibit the dispersal of water rats since they can move considerable distances across dry land (Scott & Grant 1997)'. 'It is usually found close to water but it is able to survive on dry land and may range far from water in search of prey (McNally 1960; Harrison 1962 in Woollard 1978)'. ***Gene flow does not appear to be restricted as species has ability to disperse readily within the local region and home ranges up to 3.9 river km have been recorded*****(Scott & Grant 1997).** ***Roads, fences, loss of vegetative cover may provide some limitation to overland movement, and dams and weirs are expected to provide restriction where terrestrial barriers also occur.***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	**It is unknown to what extent does *phenotypic plasticity would* limit the ability of the regional population of the species to tolerate climate change?**
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Species is not listed as threatened at the state or national level but has recently been listed as 'Near Threatened' (listing 'yabby nets and river decline' as threats) and population trends as 'Data deficient' (Gillam & Urban 2010) with only 6 records for *H. chrysogaster* within the Biodiversity Database SA (BDBSA) (DEH 2010). This is known not to reflect the true population density within the study region with a recent survey of the Murray River Corridor recording the species from numerous points along the river (A. Graham and H. Stewart pers. comm..)(Carthew & Reardon 2009) and several opportunistic observations were made at wetland locations within the study region from 2009-2011 (A. Scott pers. comm..). ***Though the population within the study region is currently considered secure and population size relatively large, it is expected that a population decline did occur with the recent drought, with drought implicated in the species disappearing from some parts of their range (Serena in Sullivan 2007).***
	To what extent does ***reproductive capacity*** limit the ability of the regional	'The fecundity of water rat is lower than normal for murid species, but fertility is high and a substantial population turnover occurs each year that conditions are favourable (McNally 1960)'; Litters are of between

	population of the species to tolerate climate change?	three and five young, and they may have up to three litters a year, although the number of young born in a year depends very much on the availability of food (Serena in Sullivan 2007); Their ability to produce more than one litter per season enables the water rat to tolerate changes in flow better than many other aquatic vertebrates(Scott & Grant 1997); Can produce up to five litters in years of abundant food and water, whereas breeding is irregular and smaller litters are produced in drier years (CSIRO 2004); Up to five litters (usually one or two) may be produced annually, each usually with 3-4 young (Olsen 2008). ***Potential for high reproductive capacity under good conditions though the fecundity of water rats is lower than for other murid species.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	With many bad breeding years caused by the drought, water rats have disappeared from some parts of their range; 'Their lifespan has been foreshortened by the drought and their numbers are declining because they can't produce enough viable young in the limited life available to them (Serena in Sullivan 2007); Females never breed in more than 3 consecutive breeding seasons even when they survived as many as 6 seasons (Olsen 1982; McNally 1960 in Scott & Grant 1997); Rainfall can influence the timing of breeding and the age at which individuals breed. Under favourable conditions a female may become sexually mature at the age of 4 months. Commonly however breeding does not commence until animals are about 8 months old (Olsen 2008); Young animals are preyed upon by snakes and large fish; adults and young by birds or prey, foxes and cats (Olsen 2008). 'In dry years breeding is irregular and litters are smaller (Scott & Grant 1997)'. ***Though fertility is considered high and H. chrysogaster is able to produce several litters a season under good conditions (McNally 1960) drought is implicated in reproduction failures, irregular breeding, smaller litters and delayed matirity and coupled with a short lifespan, low murid fecundity and predation, an increasing incidence of drought and reduced flooding predicted under climate change is expected to significantly reduce recruitment success.***

Scientific Name:	*Myotis macropus*	**Common Name:**	Southern Myotis; Large-Footed Myotis

Question		**Comments/ Reference**
	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	Roosts in caves, tunnels, mines, under bridges and culverts and known to roost regularly in tree hollows of both dead and living trees (Campbell 2009; Anderson et al 2006). '…the protection and continual recruitment of trees close to water bodies is essential to ensure that the favoured roosting sites of *M. macropus* are maintained (Campbell 2009). '…The primary force driving roost selection by *M. macropus* appears to be proximity of suitable waterways for foraging. Retention and maintenance of extensive riparian habitat, as well as the preservation of other structures used for roosting, are the most important conservation strategies for management …(Campbell 2009)'. ***The availability of suitable roost sites close to water is documented to be essential for the occurrence of M.***

		macropus* (Campbell 2009; Law et al 2001; Anderson et al 2006. Salinisation and reduced flood frequency will threaten survival of mature hollow bearing E. camaldulensis and riparian and aquatic vegetation important habitat for prey species.** Feed exclusively over water (REF). Individuals use their enlarged hind feet to capture both invertebrates (predominantly dipterans and lepidopterans) and small fish from immediately above, and directly from, the water surface (Campbell 2009). Appear to be significantly associated with larger, more permanent waterways including lakes, wetlands, streams and farm dams (Anderson et al 2006). Some indication they prefer still water habitats with Barclay et al. (2000) commenting that radio-tagged individuals were not observed foraging over streams, but made extensive use of a freshwater lake 10 km from their roost, but travelling along a stream rather than overland to get to the lake (in Anderson et al 2006). Also documented to be most likely recorded 'on large streams in the lower end of catchments (Anderson et al 2006)'. ***Dependant on a water source for foraging. Contraction of permanent water bodies and reduction in large temporary systems with reduced flooding and increased evaporation would reduce size of available foraging area in study region. Law & Anderson (1999) speculated that a low availability of the aquatic prey of *M. macropus* is one possible reason for the bat's rarity and that reductions in prey abundance may have resulted from changes to flow regimes with the Murray River. It now experiences fewer flood events and an increase in stable water levels such as in permanent pool level wetlands. Drying and subsequent flooding increases the number of invertebrates while stable water levels support relatively few invertebrates. ***Alteration to flood frequency, duration and extent under climate change is expected to reduce productivity of aquatic systems reducing the abundance and diversity of invertebrate food resources for M. macropus.*** 'Law and Urquhart (2000) found that aquatic invertebrates associated with the water surface were the main prey of M. macropus and that these insects are reasonably tolerant of low water quality (e.g. water boatmen, water striders, whirligig beetles). 'A small number of scats were also examined from *M. macropus* caught on the Murray River in South Australia (Jansen 1987). These contained fish remains and insects, particularly Chironominae (midges) and Culicidae (mosquitoes)…(Law and Urquhart 2000)' ***M. macropus do not require pristine waters for feeding and some of its main prey occurs in reduced water quality (Law 200, Law et al 2001). Chironomids and Culicidae are also tolerant of saline waters and may continue to provide a food source to M. macropus when other prey species have declined with increased salinity and declining water quality of wetlands. An increase in introduced small bodied fish such as Gambusia holbrooki that prefer stable waters and tolerate high salinity may provide an increasing component of the diet if other sources decline.***
	To what extent does ***competition*** limit the ability of the regional population of the	'The large-footed myotis *Myotis macropus*, is Australia's only trawling bat… (Campbell et al 2010)'. 'Individuals use their enlarged hind feet to capture both invertebrates (predominantly dipterans and

	species to tolerate climate change?	lepidopterans) and small fish from immediately above, and directly from, the water surface…(Campbell 2009)'. Campbell et al (2010) indicates that with the specialised feeding behaviour of M. macropus there is potential for the species to exploit a more seasonally reliable, highly nutritious, prey base (i.e., fish), and therefore remain relatively active throughout the winter. Though some studies have found diet is predominantly made up of insects including Jansen (1987) in South Australia where 99% of diet from scat analysis was identified as adult insects associated with the aquatic environment; small proportion of fish was identified (Law 2000). It is thought that fish may be more common prey in other areas (Law 2000). ***Specialised feeding behavior largely excludes competition with other bat species that generally don't forage for prey so close to the water surface.*** Law & Anderson (1999) speculated a decline in aquatic prey with river regulation and reduced flooding, as well as an increased abundance and competition with introduced fish. ***A reduction in river flows and flooding under climate change but maintenance of stable weir pools (and associated permanent wetlands) is expected to improve conditions for many introduced fish species that prefer stable conditions increasing the competition for food resources between M. macropus and fish. Some competition with water fowl may also occur.*** Campbell (2009) found that entrance dimensions of *M. macropus* roosts are not so small as to exclude other hollow-dependent fauna such as possums, birds and other microbats, and indicated the possibility of interspecific competition from other tree-roosting species excluding *M. macropus* from the older trees. Kirkley (2007) found *M. macropus* roosting in small limestone caves on the Murray River in South Australia. ***Competition for hollows with other fauna species in the study region is possible and may increase with decline in abundance of River Red gums with increased salinisaton and reduced flood frequency. Limestone caves within the study region provide additional roosting opportunities and likely less competition.***

Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	Capable of entering torpor, with bouts of eight days and three weeks recorded (Geiser 2006; Kulzer et al 1970 in Campbell et al 2010). Torpor results in considerable metabolic savings, which may be particularly important in times of reduced food supply and controlled reduction of temperature found to also reduce evaporative water loss (Campbell et al 2010). Campbell et al (2010) found that *Myotis macropus* successfully reared young in maternity roosts with divergent microclimates, suggesting a great degree of thermal tolerance in both reproductive adults and non-volant young. Small, tree-roosting microbats have high energy requirements for maintenance, thermoregulation and locomotion. The Thermal neutral zone for microbats, the range of temperatures within which basal, or resting, MR can be maintained, has been recorded as between 29.1–33.2°C (Geiser & Brigham 2000) or 28.9–36.3°C based on averages from several temperate and tropical species (Speakman & Thomas 2003). Metabolic costs increase with both increasing and decreasing environmental temperatures outside of the thermal neutral zone (Campbell et al 2010). ***Documented to have a great degree of thermal tolerance and can enter torpor for up to several weeks that will assist in conserving energy and water under cold conditions and times of food shortage. The TNZ for M. macropus is not documented but if similar to other micro bats, temperatures above 33-36oC not uncommon in the study region over summer and expected to become more frequent, may lead to increased metabolic costs and stress particularly at times of food shortage.*** Law & Anderson (1999) speculated that a low availability of the aquatic prey of *M. macropus* is one possible reason for the bat's rarity and that reductions in prey abundance may have resulted from changes to water-flow regimes within the Murray River now experiences fewer flood events and a shift from winter to summer flooding -Drying and subsequent flooding increases the number of invertebrates. In contrast, permanent flooding supports relatively few invertebrates and has increased abundance of competitive introduced fish. ***Reduced flooding and increased competition by introduced fish expected to reduce the abundance and diversity of invertebrate prey available to M. macropus*** **(Law & Anderson 1999)** ***is likely to also contribute to reducing the survival capabilities of the population within the study region.***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	Capable of entering torpor, with bouts of eight days and three weeks recorded (Geiser 2006; Kulzer et al 1970 in Campbell et al 2010). Torpor results in considerable metabolic savings, which may be particularly important in times of reduced food supply and controlled reduction of temperature found to also reduce evaporative water loss (Campbell et al 2010). ***No information on growth tolerances or factors that affect body condition was found documented on this little studied species. However the use of torpor to reduce energy and water loss in times of reduced food resources may limit loss of body condition.***
	To what extent does **reproduction** limit the ability of the regional population of the	'… limestone cliffs and caves are a feature of the locality where the species was caught on the Murray River in South Australia (Jansen 1987 [in Law & Anderson 1999])'. Roosting sites in this area are described as

	species to tolerate climate change?	groups of about 10 bats in holes within a limestone rock overhang, 2 metres above the water level , and indications are that the colony has occupied the site for 'some time (Kirkley 2007)'. '…the protection and continual recruitment of trees close to water bodies is essential to ensure that the favoured roosting sites of *M. macropus* are maintained (Campbell 2009)'. Campbell et al (2010) found that *Myotis macropus* successfully reared young in maternity roosts with divergent microclimates, suggesting a great degree of thermal tolerance in both reproductive adults and non-volant young. Warmer roosts are known to promote faster growth of young in other species (Campbell et al 2010) - too high temps are anticipated to be a negative. ***Little information is documented on reproductive tolerances and conditions required for successful breeding, but the availability of suitable roost sites close to water is essential. In the study region roosts are known in limestone caves and hollow bearing river red gums (threatened with increasing salinisation and reduced flooding) are assumed to be utilised. Young appear able to tolerate a range of thermal conditions and warmer temperatures may promote faster development but little else is documented on the development requirements of young. There is no evidence to indicate increased breeding rate under high resource availability but a decline is expected in times of drought/ reduced food resources.***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	The low detection rate recorded from different regions presumably points to the fact that bats are thinly spread throughout their preferred habitats (Anderson et al 2006). '…restricted distribution and apparently low population densities…Current estimates of population size for all populations are relatively small (range 50–250) and warrant concern for the ongoing persistence of these small populations which may be susceptible to the deleterious effects of inbreeding (Campbell et al 2009)' '…targeted surveys have revealed that this species is clearly uncommon in certain areas, such as along the Murray River (Law and Anderson 1999 [in Law et al 2001])'. ***It appears generally accepted that the population size of M. macropus across its range is low and this would indicate a relatively small gene pool.***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	In a Victorian study Campbell et al (2009) found significant genetic differentiation was detected between all populations and suggested that the movement of ***M. macropus*** throughout the landscape is constrained by the availability of permanent waterways and associated riparian habitats. They expected that gene flow would occur among populations via the movement of individuals along connective riparian vegetation, but suggest that the movement of individuals between populations is surprisingly limited. Even two geographically close populations only 15km apart had more genetic structuring than expected and may suggest that the degradation and destruction of riparian habitat in this agricultural area may severely restrict the movement of individuals along the river. Significant population structuring in Victoria implies movement of individuals along waterways and between catchments is infrequent.

		In Victoria gene flow in populations of M. macropus was found to be limited and within the study region similarly low gene flow is expected.
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Warmer roosts are known to promote faster growth of young in other microbat species (Campbell et al 2010). Though it is assumed that temperatures s above the maximum of the 'thermal neutral zone' e.g. 33.2°C (Geiser & Brigham 2000) to 36.3°C (Speakman & Thomas 2003) would have a negative effect on young. These temperatures are not uncommon in the study region in Summer but limestone cave roosts are likely to maintain a lower temperature microclimate. ***Increased rates of development with increasing temperature may be a display of phenotypic plasticity though it is unclear if M. macropus shows variable development rates. Increasing temperatures up to a point may provide benefits if, increased development rates lead to a reduced time requirement for parental care and vulnerability to predation, without a reduction in fitness.***
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	The low detection rate recorded from different regions presumably points to the fact that bats are thinly spread throughout their preferred habitats (Anderson et al 2006). '…restricted distribution and apparently low population densities…Current estimates of population size for all populations are relatively small (range 50–250) and warrant concern for the ongoing persistence of these small populations which may be susceptible to the deleterious effects of inbreeding (Campbell et al 2009)' '…targeted surveys have revealed that this species is clearly uncommon in certain areas, such as along the Murray River (Law and Anderson 1999 [in Law et al 2001])'. ***It is widely accepted that the population size of M. macropus is low across its range. Regional population size is not known but species is recorded at only site within the study region on BDBSA database, though there is suspected to be more roost sites along the Murray (Gillam & Urban 2010).***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Females from Victoria and southern New South Wales have only one young each year; from central New South Wales to South-East Queensland two young are born each year (Richards et al in Van Dyck & Strahan 2008). Colonies of 10-15 (occasionally up to several hundred). Within breeding colonies occur in relatively small clusters, where each male establishes a territory, excludes other males and forms a harem of females during the breeding period (Stathan & Van Dyck 2008). ***Colonies normally small; unknown whether one or two young are born to females in the study region but the species has low reproductive capacity.***
	To what extent does ***recruitment*** limit the ability of the regional population of the	Campbell et al (2010) identifies several potential predators for *M. macropus* in Victoria including several nocturnal aerial predators such as owls and several arboreal predators including the lace monitor V*aranus*

	species to tolerate climate change?	*varius*, which occurs in the study region. Harem formation concurrent with mating has been observed. Lactation lasts about 8 weeks and the bond between mother and young extends beyond nursing and may persist for about 3 to 4 weeks post lactation (Dwyer 1970). ***Although recruitment rates for M. macropus are unknown extended parental care and harem formation is expected to increase survival rates of young. An additional predator within the study region may be the carpet python that also inhabits limestone cliffs where bats roost.***

Scientific Name:	*Planigale gilesi*	**Common Name:**	Giles Planigale (Paucident Planigale)

Question		**Comments/ Reference**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	Strongly associated with deep cracking clay soil drainage depressions, swamps, dry lakes and creek lines (Strahan 1995 in Briggs et al 2000; Read 1987; Blacket et al 2008; Briggs 1996) and has a requirement for densely vegetated habitats associated with water though can occur within different vegetation communities e.g. tussock grassland, low shrubland, lignum (Read 1987; Blacket et al 2008). Positive association with depth and density of soil cracks, e.g. less abundant where cracks are shallower, which may contribute to the variable distribution of the species. Larger prey species may also be more abundant in deep soil cracks than shallow cracks (Read 1987). Generalist diet of invertebrates and small vertebrates (Read 1984; Read 2008). 'Need floods to open cracks in clay for habitat (Gillam & Urban 2010)'. Can occur in habitats with some disturbance such as grazed areas, e.g. 'Throughout its range Giles' Planigale is often encountered during fauna surveys whether these are undertaken in national parks and conservation reserves or habitats grazed by sheep or cattle (Read 2008)'. *Increased drought and reduced flooding may increase the availability of dry wetland beds for P. gilesi to colonise in the short term but it is unlikely to be advantageous for the species in the long term with an interruption of the natural wetting and drying cycle likely to reduce vegetation cover and prey species. It is the process of drying after floods that induces cracking in clays. Salinisation may alter soil type and contribute to a reduction of deep cracking clays.*
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	'Individuals have shifting home ranges: some travel more than a kilometer in a few days (Read 2008)'. We do know that some small mammals in arid Australia are highly mobile (Dickman et al. 1995); small mammals leave flooding lakes in inland New South Wales by ground *and on the backs of domestic sheep* (Briggs 1997 [in Briggs et al 2000])'.'Both males and females have unstable home ranges and, although juveniles move less, individuals are shifting their home ranges. Such fluid home ranges must have important implications for the social organization of this species (Read 1984)'.

		Considered to be highly mobile with naturally shifting home ranges and to disperse in response to reduced foraging ability, e.g. flooding of dry lakes, and/ or a decline of resources. Obviously as a small mammal long range movements, e.g. many kilometres, are unlikely so some limitation is expected where deteriorating habitat conditions and loss of resources are wide ranging though retention of micro habitat refuges are expected.
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	Diet is varied and includes beetles, locusts, spiders, centipedes, or other arthropods, even small lizards or mammals, described as an 'efficient killer (Read 2008)'. Considered primarily a generalist in respect to taxa and size of prey (Read 1984). 'I suggest that *S. crassicaudata* forages mostly on the ground surface, *P. tenuirostris* forages mostly deep in the soil cracks, and *P. gilesi* forages at the interface, both above and below the ground surface (Read 1984)'. *Some competition likely with other small mammals and reptiles, but as an 'efficient killer', a generalist forager and ability to forage both above and below ground it is expected to be minimized. Competition around wetlands expected to increase with decline in prey with interruption to normal wetting/ drying cycles and increased incidence of drought*

Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	'Denny (1975) suggested a fall in numbers of *P. gilesi* at Tibooburra, N.S.W., was in part due to drier conditions. This seems to be the only previously published report relating abundance of Planigale species to seasonal conditions and, although it is consistent with the present study, it is difficult to confirm the generality of this relationship (Read 1984)'. *Several studies suspect a decline in population size occurs under extended or unusually dry conditions.* The combination of small body size and arid habitat imposes harsh living conditions for *Planigale gilesi* but it has been found to have a comparatively high point of relative water economy and undergoing torpor was found to reduce energy expenditure by 79% and evaporative water loss by 62%. The generally low energy requirements of marsupials, as well as the planigales' behavioural strategies (e.g. semi-fossorial, crack-dwelling habits), enhanced heat dissipation of a small body mass and the use of torpor appear to suffice to reduce energy and water expenditure and secure its survival in a harsh environment (Warnecke et al 2010). Gieser & Baudinette (1988) found withdrawal of food and water further increased the incidence of torpor to about 100% even at Temperatures>20°C and suggest frequent torpor in nature, where nocturnal temperatures are low and a constant surplus of food is unlikely. 'The microclimate in soil cracks and holes is less extreme than the weather above ground, especially in temperature (Newsome 1969; Read 1986). Planigale species may be too small to be able to exploit habitats without soil cracks (Read 1987)'. Read (2008) describe *P. gilesi* as 'an accomplished survivor' in arid and semi-arid areas. *Activation of torpor found to reduce water loss and energy expenditure, and combined with living under ground and asmall body size are considered physiological adaptations for living in arid climates. Torpor also found to be activated under conditions of food shortage. Although population declines have been attributed to dry conditions P. gilesi possess physical mechanisms to survive increased temperatures, drought conditions and reduced food supply.*
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	'In good seasons with abundant prey, the tail becomes swollen and carrot shaped with stored fat; when conditions are poor it is thin and bony (Read 2008)'. Briggs et al (2000) reported strongly increased captures of *Planigale gilesi* following nights with rain. This response has been interpreted as an adaptation to increased food availability for insectivores on rainy nights. Gieser & Baudinette (1988) found withdrawal of food and water further increased the incidence of torpor to about 100% even at Temperatures>20°C and suggest frequent torpor in nature, where nocturnal temperatures are low and a constant surplus of food is unlikely. *Though not specifically documented it is expected that increased incidence of drought and interruption to*

		flood cycles of temporary wetlands would reduce prey abundance that would impact on body condition and growth in P. gilesi. The increased incidence of torpor observed with withdrawl of food and water (Gieser & Baudinette 1988) is expected to play a role in limiting the decline of body condition under low resource availability.
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	Breeding is from mid July to late January, gestation is 16 days and the young are independent at 65 days (Read 2008). *P. gilesi* young have faster growth and a shorter period of lactation than *P. tenuirostris*. Female *P. gilesi* can, potentially, rear more litters during a breeding season (Read 1987). *Extended breeding season; fast growth rate and early independence of young indicate that species has the ability to adapt breeding to changing climatic conditions and with rapid development of young can capitalize on short periods of optimum conditions.*
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	'Population densities are generally low and fluctuate widely from season to season and from year to year. It is possible that in the wild, fewer than 20 per cent of individuals survive for more than 2 years …Nationally, the species is considered secure (Read 2008)'. Occurs in arid and semiarid areas eastward from the Stuart highway in central south Australia to near Moree in New South Wales. From Boulia, Queensland, its distribution extends south to Victoria along the Murray River (Read 2008). 'Throughout its range Giles' Plaigale is often encountered during fauna surveys…(Read 2008)'. Positive association with depth and density of soil cracks, e.g. less abundant where cracks are shallower, which may contribute to the variable distribution of the species (Read 1987). *No studies on gene pool of species found. Has a relatively broad distribution through arid inland areas of eastern Australia and although not uncommon and described as often encountered during fauna surveys, distribution is described as patchy and population densities generally low. A gene pool of moderate size is expected.*
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	'Individuals have shifting home ranges: some travel more than a kilometer in a few days (Read 2008)'. We do know that some small mammals in arid Australia are highly mobile (Dickman et al. 1995); small mammals leave flooding lakes in inland New South Wales by ground *and on the backs of domestic sheep* (Briggs 1997 [in Briggs et al 2000])'.'Both males and females have unstable home ranges and, although juveniles move less, individuals are shifting their home ranges. Such fluid home ranges must have important implications for the social organization of this species (Read 1984)'. *Documented to have variable distribution (Read 1987) with generally low population densities but as 'often encountered during fauna surveys wherever these are undertaken (Read 2008)' and is considered a highly*

		mobile species with naturally shifting home ranges. Gene flow is expected to be moderate.
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	*Unclear if P. gilesi displays phenotypic plasticity in some aspects of its biology but some indications of plasticity include : Variable use of torpor to conserve energy and respond to changing climatic conditions (Gieser & Baudinette1988), fast growth rate (Read 1987), rapid ability to change behavior to capitalize on increased prey abundance(Briggs et al 2000) and relatively broad breeding season (Read 2008) that may indicate plasticity in breeding cycles.*
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	*Regional population size is not known but species is recorded at only 2 sites within study region on the BDBSA database (DENR 2011), though this is likely to be indicative of survey effort rather than population size in the study region. Species has a relatively broad distribution through arid inland areas of eastern Australia and although not uncommon and described as often encountered during fauna surveys (Read 2008), distribution is described as variable depending on the presence of soil cracks (Read 1987) and population densities generally low but fluctuating widely from season to season (Read 2008). Similar patterns of population distribution and abundance are expected in the study region.*
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Breeding is from mid July to late January with one or two litters per female in a season. The usual litter size is 6-8 young, gestation is 16 days and young are independent at 65 days (Read 2008). *P. gilesi* young have faster growth and a shorter period of lactation than *P. tenuirostris*. Female *P. gilesi* can, potentially, rear more litters during a breeding season (Read 1987). ***Large litter size and potential for 2 (or more) litters per season. Potential for high reproductive capacity particularly at times of increased resources and with an extended breeding season.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	'It is possible that in the wild, fewer than 20 per cent of individuals survive for more than 2 years (Read 2008)'. Some captive individuals have lived to 5 years of age (Strahan 1995). *Rates of recruitment are unknown but likely to be highly variable for P. gilesi. Thought to have a short life span in the wild with most females unlikely to recruit more than 4 litters in a life time. A shorter time to independence compared with other planigales (Read 1987) may compromise recruitment if a reduced period of parental care resulted in reduced fitness. Though a faster growth rate reduces the period of high vulnerability to predators and environmental extremes, and period of stress on the female. Unknown elements include survival rate of juveniles, rate of predation and age of maturity.*

Scientific Name:	*Trichosurus vulpecula*	**Common Name:**	Brush-Tail Possum

Question		**Comments/ Reference**
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change	' The occurrence of large old Eucalyptus spp. along the creek-banks may result in a large number of suitable den sites (Munks et al 1996)'. A positive relationship between the number of brushtail possums observed and the density of hollow bearing trees is documented (Harper et al 2008). ***Within the study region brushtail possums require mature red gums with hollows to provide den sites for day roosts and breeding. Survival of red gums is threatened by increased salinity, drought and reduced flood frequency.*** Studies from arid parts of Australia found the diet of T. vulpecula consisted of a range of leaves, flowers and fruits of perennial dicotyledonous species herb, shrub and tree strata. Flowers eaten were almost exclusively Acacia (Foulkes 2001; Evan 1992). Kerle & How (2008) found flowers and fruits are important and can make up half the diet. The digestive tract of the common brushtail possum is not highly specialised like that of some other possums and a more varied diet is required for adequate nutrition (Kerle & How 2008)'. Evans (1992) found Eucalypts were rarely eaten in central Australia though they were present at the study site, but said that they were found to be important in the diet in eastern Australia and Tasmania with Kerle (1984) finding *Eucalyptus camaldulensis* comprised 90% of stomach contents in Victoria (Evans 1992). ***The proportion of eucalypt and other species in diet of local population is unknown but increased salinity and reduced flooding is expected to reduce diversity of prefered ground, shrub and tree species on the floodplain and reduce production of flowers and fruits. The dominant Acacia species in study region A. stenophylla is under stress from salinisation and during recent monitoring Brushtail possums were observed predominantly feeding in A. stenophylla.If the diet of regional species is similar to the study by Evans a decline in Acacia and other shrub and ground species will have a significant impact on brushtails within the study region.*** Eucalypt leaves contain toxic compounds or 'antifeedants' (Kerle & How 2008; Le Mar & McArthur 2005; Loney et al 2006). Loney et al (2006) found brush tails to prefer juvenile foliage over adult foliage. Adult foliage contains less anti-feedants, but is significantly tougher (thicker cuticle, more fibre and lignin and higher percentage dry mass) than juvenile foliage, suggesting that leaf toughness is more significant than defensive chemistry in influencing intake by possums. Evans (1992) found species preferentially consumed at each site had significantly higher moisture content and dry matter digestibility than species not consumed. Cork et al (1990) said tree growth is probably restricted by low availability of water that in turn may result in high levels of leaf toxins (Munks et al 1996). ***A reduction in the abundance of herbs and shrubs, flowers and fruits may increase reliance on Eucalypts for food. Increased salinity and incidence of drought is expected to reduce production of new growth and make mature Eucalypt leaves less palatable further reducing food resources for possums.*** 'It has disappeared from most of the arid zone, is rare and mostly restricted to river red gums along creeks and rivers in the semi-arid country…(Kerle & How 2008)'. Rivers, creeks and drainage lines with River Red Gums (Eucalyptus camaldulensis) form the most important habitats in semiarid regions (Kerle 2001 [in Ecological Associates 2006]). ***The Murray River corridor is the only remaining habitat left within the study region and reasons for population declines are expected to be exacerbated under climate change habitat decline.***

	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change	Varying levels of dispersal are described but dispersal tends to be largely by juvenile males and is strongly seasonal (Cowan et al 1997). Most research on dispersal has been undertaken in New Zealand and Cowan et al (1997) found 25% of juvenile males dispersed 2km or more and up to 12.8km from their natal area. Stow et al (2006) described dispersal by males in urban Sydney beyond 900m as infrequent. 'Daughters typically reside beside their mothers (Clinchy 1999) and/or take up home ranges that largely overlap with those of their mothers (Cowan and Clout 2000) (in Stow et al 2006)'. 'T. vulpecula has previously been shown up to one kilometer from within forest to feed on pasture (Green and Coleman 1986 [in Le Mar & McArthur 2005]) and Stratham & Statham (1997) found average nightly movements of 411 and 315 m, for males and females respectively. Also shown to have strong homing tendencies in New Zealand after translocations, capable of homing over long distances with some return movements were quite rapid: one individual returned from 3.8 km away in two days, and another from 7 km away in 19 days (Cowan 2001). Kerle et al 1992 describes possums in arid distributions as 'not highly mobile' and 'It is probable that their movements from drought refuges occurred along drainage lines which retain moisture for longer than the surrounding sandy habitats…Emigration and the establishment of new populations would then have occurred when conditions were suitable (Kerle et al 1992)'. ***Mobility and dispersal within the study region is unknown but likely to be more limited by the arid climate and the linear nature of the River corridor with some normal seasonal movements by juvenile males expected. Strong attachment to home range may limit movement in response to deteriorating conditions.***
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	'Rabbits have occupied a great variety of habitats, altering the vegetation composition of the habitat (Foran et al. 1985) and competing directly with possums for some food species (Foulkes and Kerle 1991). The impact of rabbits on drought refuges is likely to have been most severe when plagues coincided with dry periods [in Kerle et al 1992]'. In central Australia (Foulkes) 2001 found preferred species had significantly higher moisture content and dry matter digestibility than species not consumed. Preferred species in central Australian studies included mistletoes, *Amyema* spp, *Acacia* spp., *Santalum spp*, *Marsdenia australis*, *Solarium quadriloculatum*, *Euphorbia spp.* and *Rhagodia spinescens* (Foulks 2001; Evans 1992). 'Brushtails rarely feed soley on eucalypt foliage but the few cases documented indicate there is no inherent barrier to their doing so (Wallis et al 2002)'. Recent surveys in study region observed brush-tails primarily feeding in *Acacia stenophylla* (A. Scott pers. obs.). ***Some competition likely by rabbits and possibly also kangaroos for preferred shrubs and herbs but only intra-specific competition expected for preferred large shrub and tree forage such as Acacia flowers (increasing under drought conditions). It is unknown what percentage of the diet Eucalypt leaves comprise for the regional population but if it is high, forage competition may be lower.*** 'In arid and semiarid environments, water availability and predation are probably most important factors that influence the distribution and population dynamics of the Brushtail Possums (Kerle 2001) (in Ecological Associates 2005)'.

		Likely high predation by foxes and feral cats and may be higher in arid climates as possums tend to be smaller. ***Competition for E. camaldulensis hollows is expected with a number of other bird and mammal species known to use hollows for nesting and roosting. Competition is expected to increase with declining health of Red gums with salinisaion and reduced flooding.***

Physiology	To what extent does **survival** limit the ability of the regional population of the species to tolerate climate change?	'The absence of regular rainfall has recently been strongly associated with the decline of brushtail possum populations in the south coast forests of New South Wales (Davey 1990) and in rocky outcrops in sub-tropical woodlands of north-west Queensland (R. Delaney, pers. comm.). Delaney observed that numbers and condition of possums slowly declined over six years when the wet season rains failed or were below average (Kerle et al 1992). ***Below average rainfall, predicted for the study region under climate change, has been implicated in mortality and population decline of brush-tail possums.*** 'Yom Tov and Nix (1986) found that 50-60% of the variance in body size of possums throughout their range was accounted for by the moisture index of the driest quarter, which provides a measure of available food resources. Central Australian possums are about two-thirds the size of their south-east Australian conspecifics and the unpredictable moisture regime would confer physiological limitations. Medium sized mammals are also disadvantaged by having similar relative gut sizes but larger relative metabolic rates when compared with larger mammals. A poor quality diet will not meet the metabolic requirements of a smaller species (Morton 1990). Consequently smaller herbivores must eat more digestible, nutritious and moist foods and become confined to smaller patches of optimum habitat. They are then more vulnerable when these patches become degraded (Kerle et al 1992)'. 'The water requirements of Brushtail Possums are closely related to body size, with smaller animals requiring higher mass specific water requirements than larger animals (Green 1997)….Reduced size is believed to be either adaptation to high diurnal temperatures (in summer), which can cause significant increases in evaporative water loss, or an adaptation to less predictable rainfall and primary productivity (McIlwee 2001 [in Ecological Associates 2005])'. ***The size of possums within the study region compared with other areas is unknown but below annual rainfall, increased incidence and severity of droughts and higher temperatures in an already arid climate may exceed physiological limitations of some individuals of a 'medium sized mammal', and also not maintain foraging resources with sufficient water and nutrition requirements for survival.*** Described as a 'hardy survivor with the ability to adapt to many environments' in other parts of its range (Statham and Statham 1997 [in Le Mar & McArthur 2005]) but generally documented to be declining throughout arid and semi arid parts of its range (Kerle 2001; Kerle et al 1992; Papenfus 1990). ***This may indicate that survival tolerances are already being exceeded in areas of climate similar to that of the study region.***
	To what extent does **growth** limit the ability of the regional population of the species to tolerate climate change?	'…Delaney observed that numbers and condition of possums slowly declined over six years when the wet season rains failed or were below average… [Kerle et al 1992]'. ***Below average rainfall has been linked to declining body condition (and population) of brush tail possums***

		'Flowers and fruits are important and can make up half the diet, particularly in the arid and tropical areas where these foods are essential to successful breeding. The digestive tract of the common brushtail possum is not highly specialised like that of some other possums and a more varied diet is required for adequate nutrition (Kerle & How 2008)'. 'Most plants do not reproduce during drought and so access to flowers and fruit (and seeds) cannot be guaranteed. *Trichosurus vulpecula* must therefore have drought staples and the use of flowers and fruits indicates an opportunistic use (Evans 1992)'. 'The probability of breeding declined rapidly as body condition fell below average. An index of fruitfall of hinau (Elaeocarpus dentatus), a highly nutritious food used by possums, and population density in the previous year were the most important predictors of possum condition and breeding rate. High density in the previous year coupled with low hinau fruitfall in the current year predicted below-average body condition and reduced breeding rate (Ramsey et al 2002)'. ***It is documented that a varied diet is required for adequate nutrition and a reduction in fruit and flowers in the diet of T. vulpecula is implicated in declining body condition that may occur in drought conditions when most plants don't reproduce and possums must revert to 'drought staples'.***
	To what extent does **reproduction** limit the ability of the regional population of the species to tolerate climate change?	'Flowers and fruits are important and can make up half the diet, particularly in the arid and tropical areas where these foods are ***essential to successful breeding…***(Kerle & How 2008)'. 'Most plants do not reproduce during drought and so access to flowers and fruit (and seeds) cannot be guaranteed (Evans 1992)'. '***The probability of breeding declined rapidly as body condition fell below average***. An index of fruitfall of hinau (Elaeocarpus dentatus), a highly nutritious food used by possums, and population density in the previous year were the most important predictors of possum condition ***and breeding rate***. High density in the previous year coupled with low hinau fruitfall in the current year predicted below-average body condition and ***reduced breeding rate*** (Ramsey et al 2002)'. 'Bell (1981) found Adult females that bred were significantly heavier than those that failed to breed. Females in good condition were also more likely to breed earlier in the season and to rear a pouch young successfully than females in poor condition…Successful breeding was also significantly dependent on relative body weight, with only 25% of females who were 875 g or more lower than the average body weight for the population being predicted to Breed…(Ramsey et al 2002)'. ***Successful reproduction has been linked to a varied diet and flowers and fruits are documented to be 'essential for successful breeding' and their abundance to influence breeding rate. In drought conditions most plants don't reproduce so breeding is likely to be significantly impacted under climatic scenarios of below average rainfall, increased incidence of drought and reduced flooding of floodplains.*** 'Most populations have a major autumn and a minor spring breeding season but some including those in the tropics and arid regions, breed continuously if the required food supplies are available…(Kerle & How 2008)'. Foulks (2001) in a study in central Australia found T. vulpecula to breed continuously, with births recorded in almost

		all months. Growth of the young were also more rapid than previously recorded for *Trichosurus* in Australia. This is interpreted as an adaptation for living in an arid environment, enabling the young to achieve independence before quality food supplies diminish. 'The brushtail possum shows a remarkable degree of plasticity in its habitat preference and breeding cycles… (Kerle et al 1992)'. ***Most Australian populations have a main Autumn breeding season and sometimes a minor Spring season but in more arid areas breeding has been observed as continuous if food resources are available and growth of young more rapid interpreted as an adaptation to living in arid environments. Breeding seasons and triggers in the population of the study region are unknown but as an arid region populations are expected to have some flexibility in responding to changing climatic conditions, capitalizing on times of increased resources and consequently ceasing reproduction in times of drought and low resources that are likely to increase under climate change.*** A positive relationship between the number of brushtail possums observed and the density of hollow bearing trees is documented (Harper et al 2008). ***Within the study region brushtail possums require mature red gums with hollows to provide den sites for day roosts and breeding. Survival of red gums is threatened by increased salinity, drought and reduced flood frequency.***
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Historically thought to be widespread and common in arid and semi-arid areas being described by Baldwin Spencer an early explorer in central Australia as "occurring everywhere amongst the eucalypts which border the riverbeds" (Spencer 1896, pp.16-17 [in Kerle et al 1992])'. Described as 'locally common' within the study region (DEH 2010) but generally documented to be declining throughout arid and semi arid parts of its range and populations tend to be small and widely scattered (Kerle 2001; Kerle et al 1992; Papenfus 1990). Decline is documented to have occurred over the past sixty to seventy years (How and Hilcox 2000 in Ecological Associates 2006) and populations fluctuate with climate declining with reduction in rainfall (Kerle et al 1992). ***Though described as 'locally common' (DEH 2010) populations are confined to the river corridor resulting in a linear population which also increases their detectability and possibly exagerating the appearance of a larger population. Populations are also likely to be patchy depending on local habitat suitability and fluctuating from year to year with climate, e.g. declining in dry years. A moderate gene pool is expected***
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	Historically thought to be widespread and common in arid and semi-arid areas being described by Baldwin Spencer an early explorer in central Australia as "occurring everywhere amongst the eucalypts which border the riverbeds" (Spencer 1896, pp.16-17 [in Kerle et al 1992])'. Described as 'locally common' within the study region (Gillam & Urban 2010) but generally documented to be declining throughout arid and semi arid parts of its range and populations tend to be small and widely scattered (Kerle 2001; Kerle et al 1992; Papenfus 1990). Decline is documented to have occurred over the past sixty to

		seventy years (How and Hilcox 2000 in Ecological Associates 2006) and populations fluctuate with climate declining with reduction in rainfall (Kerle et al 1992). Varying rates of dispersal are described but appears to be largely by juvenile males and strongly seasonal (Cowan et al 1997). Most research on dispersal has been undertaken in New Zealand and Cowan et al (1997) found 25% of juvenile males dispersed 2km or more and up to 12.8km from their natal area. Stow et al (2006) described dispersal by males in urban Sydney beyond 900m as infrequent. 'Daughters typically reside beside their mothers (Clinchy 1999) and/or take up home ranges that largely overlap with those of their mothers (Cowan and Clout 2000) (Stow et al 2006)'. Dispersal within the study region is unknown but likely to be more limited by climate and the linear habitat for the River corridor. Kerle et al 1992 describes possums in arid distributions as 'not highly mobile' and 'It is probable that their movements from drought refuges occurred along drainage lines which retain moisture for longer than the surrounding sandy habitats…Emigration and the establishment of new populations would then have occurred when conditions were suitable (Kerle et al 1992)'. Possums are described to have strong homing tendencies (Cowan 2001) ***Though significant dispersal has been recorded in New Zealand it is under quite different climatic conditions, local dispersal is unknown but is not expected to be significant. The population in the study region is confined to the river corridor resulting in a linear population, decreasing opportunity for gene flow.***
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	The brushtail possum shows a remarkable degree of plasticity in its habitat preference and breeding cycles (Kerle 1984 [in Kerle et al 1992]). 'During this study, T. vulpecula was found to breed continuously, with births recorded in almost all months. Growth of the young were more rapid than previously recorded for Trichosurus in Australia. This is interpreted as an adaptation for living in an arid environment, enabling the young to achieve independence before quality food supplies diminish (Foulks 2001)'. ***Plasticity in breeding cycles and more rapid growth of young documented in central Australia indicates an adaptation to variable arid climates and ability to capitalize on increased resource availability. Plasticity in the regional population is expected and may allow populations to breed when conditions allow rather than being constrained by seasons.***

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Described as 'locally common' within the study region (Gillam & Urban 2010) but widely documented to be declining throughout arid and semi arid parts of its range and populations tend to be small and widely scattered (Kerle 2001; Kerle et al 1992; Papenfus 1990). Decline is documented to have occurred over the past sixty to seventy years (How and Hilcox 2000 in Ecological Associates 2006) and populations fluctuate with climate declining with reduction in rainfall (Kerle et al 1992). ***Regional population size is not known but species is described as 'locally common*** (Gillam & Urban 2010)' ***and recorded at 56 sites within study region on BDBSA database. Populations are confined to the river corridor resulting in a linear population which increases their detectability and possibly exaggerates the appearance of a larger population. Populations are likely to be patchy depending on local habitat suitability and fluctuate from year to year with climatic conditions.***
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	'In New Zealand and Australian possum populations, most births occur in autumn, where the percentage of females that give birth (the breeding rate) is usually 80–100% (Green 1984; Kerle 1984; Cowan 1990a [in Ramsey et al 2002)'. Most populations have a major autumn and a minor spring breeding season but some including those in the tropics and arid regions, breed continuously if the required food supplies are available. A single young is born, that spends 4-5 months in the pouch and further 1-2 months suckling and riding on the mothers back before weaning (Kerle & How 2008). Foulks (2001) in a study in central Australia found *T. vulpecula* to breed continuously, with births recorded in almost all months. In New Zealand a population was found to respond to reduced density after de-population with higher proportion of females breeding, higher survival rate of young and less seasonal fluctuation in body condition (Weihong et al 2004). ***In many parts of its range, annually a single young is born in the major Autumn breeding season. However with the study region having an arid climate continuous breeding may occur under favourable conditions with capability to produce 2-3 young per year, assuming birth occurs as soon as previous young leaves the pouch. A high percentage of females are documented to breed each year. However, overall reproductive capacity is considered low due to long period of parental care and low fecundity.***
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	A single young is born, that spends 4-5 months in the pouch and further 1-2 months suckling and riding on the mothers back before weaning. Few young die in the pouch but considerable mortality can occur at 6-8 months of age when juveniles disperse (Kerle & How 2008). 'Most females raised a young to independence each year but very few bred in both autumn and spring. Many females become mature at the end of their first year but fewer males do so. Males and females are all mature at the end of their second year. Males remain continuously fertile throughout the year (Smith et al 1969)'.

		Bell (1981) found females in good condition were more likely to breed earlier in the season and to rear a pouch young successfully than females in poor condition (Ramsey et al 2002). 'Dingo, cat, fox, large pythons and large monitors are known to prey on the common brushtail and can significantly affect numbers when population size is low (Kerle & How 2008)'. 'In the riparian lowlands, the effects of rabbits and livestock together with predation were found to have the major impact on *T. vulpecula* populations (Foulks 2001)'. 'Longevity is usually less than 11 years but one wild individual is known to have lived for 13 years (Kerle & How 2008)'. ***Survival of young to independence is documented as high and likely attributed to parental care (though also dependant on mothers body condition) however considerable mortality can occur during juvenile dispersal; Females mature relatively early for a medium sized mammal and longevity is considered moderate. It is unknown at what age breeding ceases but females would likely recruit < 10 young in a life time; Predation is considered high and mother and young would likely both die as the result of an attack; Competition for food resources would impact recruitment rates. Recruitment within the study region is unknown but expected to be moderate.***

Water Rat References

Carthew & Reardon 2009....

CSIRO (2004), *Hydromys chrysogster*, *Water Rat*, Water for a Healthy Country, CSIRO http://www.csiro.au/files/files/pbzn.pdf

Gillam, S. and Urban, R. 2010. 'Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region'. Department of Environment and Natural Resources, South Australia.

McNally , J. (1960), 'The biology of the water rat, *Hydromys chrysogaster* Geoffroy (Muridae: Hydromyinae) in Victoria, *Australian Journal of Zoology*, **8**: 170-180.

Olsen, P.D. (1982), 'Reproductive biology and development of the water rat, Hydromys chrysogaster in captivity', *Australian Wildlife Research*, **9**: 39-53.

Scott, A. & Grant, T. (1997), Impacts of water management in the Murray-Darling Basin on the Platypus (Ornithorhynchus anainus) and the water rat *(Hydromys chrysogaster*), Technical Report 23/97, CSIRO Land and Water, CSIRO Australia.

Sullivan, R. (2007), 'The secret life of water rats', ABC, http://www.abc.net.au/science/articles/2007/10/04/2185999.htm

Woollard, P., Vestjens, J.M. and MacLean, L. (1978), The Ecology of the Eastern Water Rat *Hydromys chrysogaster* at Griffith, N.S.W.: Food and Feeding Habits, *Australian Wildlife Research*, **5**: 59-73.

Southern Myotis References

Anderson J., Law, B. and Tidemann, C. (2006). Stream use by the large-footed myotis *Myotis macropus* in relation to environmental variables in northern New South Wales. *Australian Mammalogy* 28: 15-26.

Barclay, R. M. R., Chruszcz, B. J., and Rhodes, M. (2000). Foraging behaviour of the large-footed myotis, Myotis moluccarum (Chiroptera: Vespertilionidae) in south-eastern Queensland. Australian Journal of Zoology 48, 385–392 [in Campbell 2009]

Campbell, S. (2009). So long as it's near water: variable roosting behavior of the large-footed myotis (Myotis macropus) *Australian Journal of Zoology* **57**: 89–98

Campbell, S., Guay, P.-J., Mitrovski, P. J. and Mulder, R. (2009). Genetic differentiation among populations of a specialist fishing bat suggests lack of suitable habitat connectivity. *Biological Conservation* 142: 2657–2664.

Campbell, S., Coulson, G. and Lumsden, L.F (2010). Divergent microclimates in artificial and natural roosts of the large-footed myotis (*Myotis macropus*). *Acta Chiropterologica* **12**(1): 173–185.

Dwyer, P.D. (1970) Social organisation in the bat *Myotis adversus*. *Science* **168**: 1006–1008.

Jansen, L. (1987). The occurrence of *Myotis adversus* confirmed on the River Murray in South Australia. *Macroderma* **3**: 14-5 [in Law & Urquart 2000].

Geiser, F. (2006). Energetics, thermal biology, and torpor in Australian bats. Pp. 5–22, in Functional and evolutionary ecology of bats (A. ZUBAID, G. F. MCCRACKEN, and T. H. KUNZ, eds.). Oxford University Press, New York, 342 pp [in Campbell et al 2010].

Geiser, F., and Brigham, M.R. (2000). Torpor, thermal biology, and energetics in Australian long-eared bats (Nyctophilus). *Journal of Comparative Physiology* **170B**: 153–162 [in Campbell et al 2010].

Gillam, S. and Urban, R. 2010. 'Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region'. Department of Environment and Natural Resources, South Australia.

Kulzer, E., Nelson, J. E., McKean, J. L. and Mothers, F. P. (1970). Untersuchungen über die Temperaturregulation australischer Fledermäuse (Microchiroptera). *Zeitschrift für ver gleich ende Physiologie* **69**: 426–451 [in Campbell et al 2010].

Kirkley, D. (1997) Large footed Myotis (Myotis macropus adversus) on the Murray River of South Australia. *The Australasian Bat Society Newsletter. 7*: 38-40

Law, B. and Anderson, J. (1999). A survey for the Southern Myotis *Myotis macropus* (Vespertilionidae) and other bat species in River Red Gum *Eucalyptus camaldulensis* forests of the Murray River, New South Wales. *Australian Zoologist* **31**(1): 166-174

Law B and Urquhart CA, 2000. Diet of the large-footed myotis Myotis macropus at a forest stream roost in northern New South Wales. Australian Mammalogy 22: 121-124.

Law, B., Chidel, M. and Towerton, A. (2001). A maternity roost of the Southern Myotis *Myotis macropus* in a rural landscape. *The Australasian Bat Society Newsletter.* **17***:* 13-15.

Richards (2008) Southern Myotis, *Myotis macropus* . In: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition, pp. **. Reed New Holland, Sydney, Australia.

Giles Planigale References

Blacket, M. J., Kemper, C. and Brandle, R.C. (2008). Planigales (Marsupialia: Dasyuridae) of eastern Australia's interior: a comparison of morphology, distributions and habitat preferences, with particular emphasis on South Australia. *Australian Journal of Zoology* **56**: 195–205.

Briggs, S.V. (1996). Native Small Mammals and Reptiles in Cropped and Uncropped Parts of Lakebeds in Semi-arid Australia. *Wildlife Research* **23:** 629-36.

Briggs, S.V. (1997). Small mammals in cropped and uncropped parts of dry lakes along the Darling Anabranch in south-western New South Wales. In: Conservation outside nature reserves (Eds P. Hale and D. Lamb) pp. 344-8. University of Queensland, Brisbane [in Briggs et al 2000]

S.V. Briggs, J.A. Seddon and S.A. Thornton (2000). Wildlife in dry lake and associated habitats in western New South Wales, *Rangel. J*. **22(2)**: 256-71.

Dickman, C.R., Haythornthwaite, A.S., McNaught, G.H., Mahon, P.S., Tamayo, B. and Letnic, M. (1995) Population dynamics of three species of dasyurid marsupials in arid central Australia: a 10-year study. *Wildlife Research* **28:** 493–506.

Gillam, S. and Urban, R. 2010. 'Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region'. Department of Environment and Natural Resources, South Australia.

Denny, M. J. S. (1975). Mammals of Sturt National Park, Tiboobuma, New South Wales. *Aust. Zool.***18**: 179-95.

Newsome, A. E. (1969). A population study of house mice temporarily inhabiting a South Australian wheatfield. *J. Anim. Ecol.* **38**: 341-59.

Read, D. G. (1984). Movements and Home Ranges of Three Sympatric Dasyurids, *Sminthopsis crassicaudata*, *Planigale gilesi* and *P. tenuirostris* (Marsupialia), in Semiarid Western New South Wales. *Australian Wildlife Research* 11: 223-34.
Read, D. G. (1987) Habitat Use by Sminthopsis crassicaudata, Planigale gilesi and P. tenuirostvis (Marsupialia : Dasyuridae) in Semiarid New South Wales. *Australian Wildlife Research* ., 1987, 14, 385-95

Read, D. G. 2008. Giles' Planigale, Planigale gilesi. In: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition, pp. 107-109. Reed New Holland, Sydney, Australia.

Warnecke, L., Cooper, C.E., Geiser, F. and Withers, P.C. (2010). Environmental physiology of a small marsupial inhabiting arid floodplains, *Comparative Biochemistry and Physiology, Part A.* **157**: 73–78.

Brushtail Possum References

Cowan, P. E., Brockie, R. E., Smith, R. N., and Hearfield, M. E. (1997). Dispersal of juvenile brushtail possums, Trichosurus vulpecula, after a control operation. Wildlife Research 24, 279–288.

Cowan, P.E. (2001). Responses of common brushtail possums (Trichosurus vulpecula) to translocation on farmland, southern North Island, New Zealand. *Wildlife Research* **28**: 277–282

Cowan, P., and Clout, M. (2000). Possums on the move: activity patterns, home ranges, and dispersal. In 'The Brushtail Possum: Biology, Impact and Management of an Introduced Marsupial'. (Ed. T. L. Montague.) pp. 24–34. (Manaaki Whenua Press: Lincoln, New Zealand.) [in Stow et al 2006]

Ecological Associates 2006, Distribution and status of Brushtail Possums on the Lower Eyre Peninsula following the January 2005 bushfire, Report CC004A.

Evans, M.C. (1992). Diet of the brushtail possum *Trichosurus vulpecula* (Marsupialia: Phalangeridae) in central Australia. *Australian Mammalogy* 15: 25-30.

Foulkes, J. 2001. The ecology and management of the common brushtail possum Trichosurus vulpecula in Central Australia. University of Canberra, Canberra -PhD thesis University of Canberra.

Gillam, S. and Urban, R. 2010. 'Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region'. Department of Environment and Natural Resources, South Australia.

Harper, M.J., McCarthy, M.A. & Van Der Ree, R. (2008). Resources at the landscape scale influence possum abundance. *Austral Ecology* **33**: 243–252

Ji, W. H., Sarre, S. D., White, P. C. L., and Clout, M. N. (2004).Population recovery of common brushtail possums after local depopulation. *Wildlife Research* **31**:543–550.

Kerle J.A. (1984). Variation in the ecology of Trichosurus: its adaptive significance. In: Possums and gliders. (Eds A.P. Smith and I.D. Hume) pp. 115-28. Surrey Beatty and Sons, Sydney.

J.A. Kerle , J.N. Foulkes, R.G. Kimber and D. Papenfus, Rangel. J. 14(2) 1992, 107-27, The Decline of the brushtail possum, Trichosrus vulpecula (Kerr 1798), in arid Australia.

Kerle, J.A. (2001) Possums: the brushtails, ringtails and geater gliders. University of New South Wales Press, Sydney [in Ecological Associates 2005].

Kerle, J.A. & How, R.A. (2008) Common Brush-tail Posum, *Trichosurus vulpecula*. In: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition, pp. PP. Reed New Holland, Sydney, Australia.

Le Mar, K. and McArthur, C. (2005). Habitat selection by common brushtail possums in a patchy eucalypt-forestry environment. *Australian Mammalogy* 27: 119-127.

Loney P. E., McArthur, C., Potts, B. and Jordan, G.J. (2006). How does ontogeny in a Eucalyptus species affect patterns of herbivory by Brushtail Possums? *Functional Ecology* **20:** 982–988.

Munks, S. A., Corkrey, R. and Foley, W.J. (1996). Characteristics of Arboreal Marsupial Habitat in the Semi-arid Woodlands of Northern Queensland, *Wildlife Research*, **23**: 185-95

McIlwee, A.P. (2001) The distribution and abundance of arboreal folivores in response to variation in soil fertility, climate and the nutritional quality of eucalpt foliage. PhD Thesis. School of Tropical Biology. James Cook University, Townsville.[in Ecological Associates 2005]

Papenfus, D. (1990). Is the common brushtail possum still common in South Australia? Unpublished Thesis, B.Appl.Sc, SACAE, Salisbury S.A.

Ramsey, D., Efford, M., Cowan, P. and Coleman, J. (2002). Factors influencing annual variation in breeding by common brushtail possums (*Trichosurus vulpecula)* in New Zealand. *Wildlife Research*, **29**: 39–50.

Smith, M.J., Brown, B.K. & Frith, H.J. (1969). Breeding of the brush-tail possum, *Trichosurus vulpecula* (Kerr), in New South Wales. *CSIRO Wildl. Res.* **14**: 181-93

Statham, M. and Statham, H. L. (1997). Movements and habits of brushtail possums (*Trichosurus vulpecula* Kerr) in an urban area. *Wildlife Research* 24: 715-726.

Stow, A. J., Minarovic, N., Eymann, J., Cooper, D. W. and Webley, L. S. (2006). Genetic structure infers generally high philopatry and male-biased dispersal of brushtail possums (*Trichosurus vulpecula*) in urban Australia. *Wildlife Research* **33**: 409–415.

Wallis, I.R., Watson, M.L. and Foley, W.J. (2002). Secondary metabolites in *Eucalyptus melliodora*: field distribution and laboratory feeding choices by a generalist herbivore, the common brushtail possum. *Australian Journal of Zoology* **50**: 507-519.

Yom Tov Y. and Nix H. (1986). Climatological correlates for body size of five Australian mammals. *Biol. J. Linn. Soc.* **29**: 245-62.