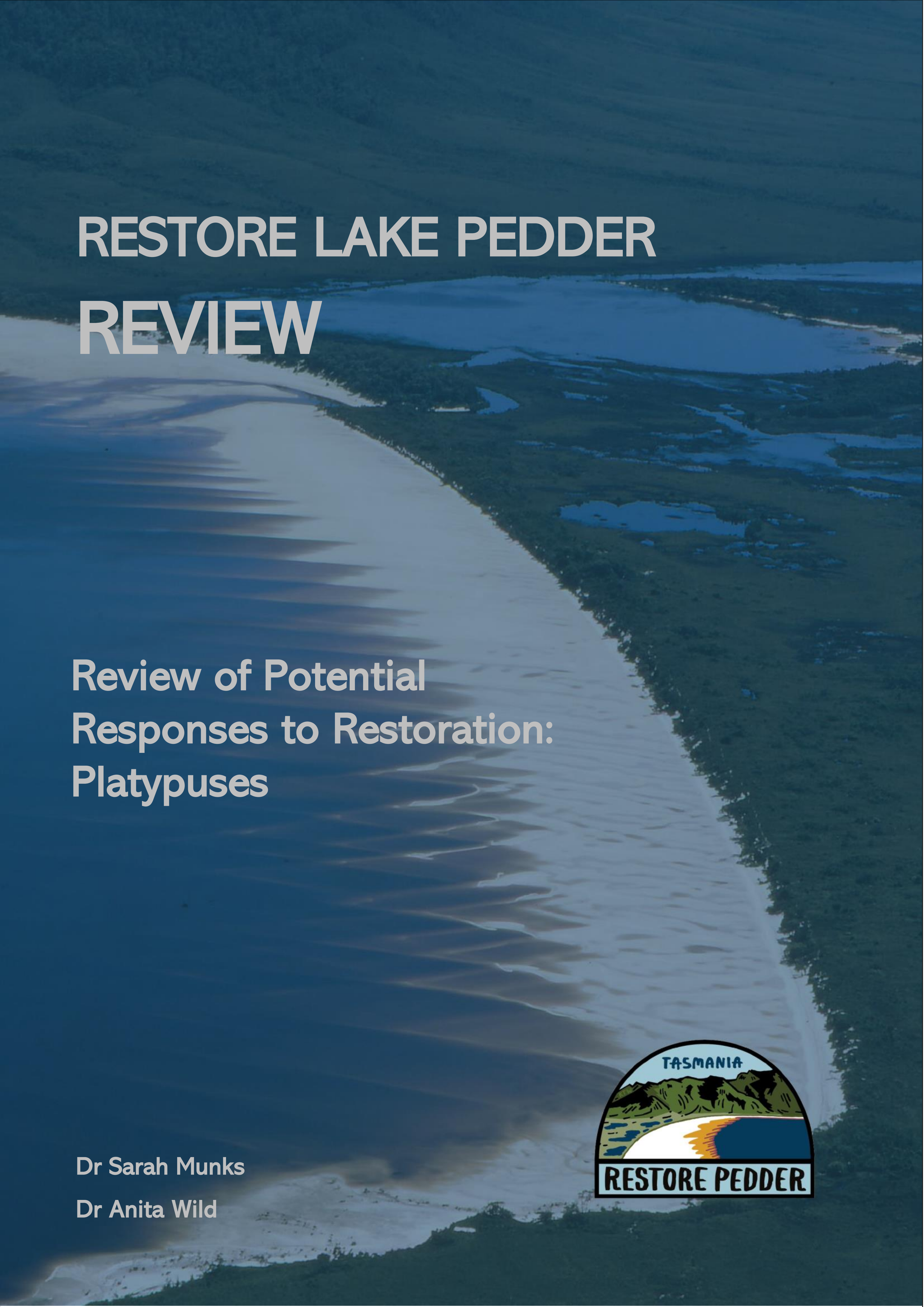

RESTORE LAKE PEDDER REVIEW

Review of Potential Responses to Restoration: Platypuses

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TASMANIA
RESTORE PEDDER

Background

The platypus (*Ornithorhynchus anatinus*) is the last surviving member of the family Ornithorhynchidae. It is widely regarded as an integral part of the freshwater ecosystems throughout its range in south-east Australia and is one of only two mammals found in freshwater systems in Australia (Grant, 2007). Platypus are known to occur in the majority of the major river catchments in Tasmania including the Gordon-Franklin and Huon catchments where the Huon-Serpentine Impoundment is located (Figure 1)(Gust and Griffiths, 2011, Otley, 2001, Connolly and Obendorf, 1998, Davies and Cook, 2001).

An early biological survey of the original Lake Pedder reported observations of platypuses in the narrow waterway with sandy banks draining Lake Maria into the northeast corner of Lake Pedder (Andrews, 1968). Subsequent observations reported that a healthy platypus population appears to have persisted in the area following the flooding of Lake Pedder in 1972 (Stewart et al., 2002) and this population attracted considerable public attention during the 1995 enquiry into the restoration of the original glacial lake (Standing Committee on Environment Recreation and the Arts, 1995). The draining of the lake was considered in one submission to the 1995 enquiry committee to present risks to an estimated large population of platypuses that inhabited the new lake, although this was not substantiated by scientific evidence. Platypus scientist, Dr Tom Grant stated in his submission that it was important for scientific work to be carried out on the platypus population at Huon-Serpentine Impoundment before any useful conclusions could be drawn on the possible impact of the proposed restoration on the species (Standing Committee on Environment Recreation and the Arts, 1995).

Platypuses were sampled briefly in the Huon-Serpentine Impoundment as part of a 2002 study into accumulation of organic pollutants in platypuses (Munday et al., 2002). They were also surveyed briefly by scientific officers from the Department of Primary Industries, Parks, Water and Environment in 2008 in tributaries of the Gordon-Franklin catchment as part of a broader study of platypus distribution in Tasmania and the impact of the disease, mucormycosis (Gust and Griffiths, 2011). While the survey data confirm the persistence of healthy individuals of platypus in the area there have been no systematic, scientific studies of the population at Huon-Serpentine Impoundment to date.

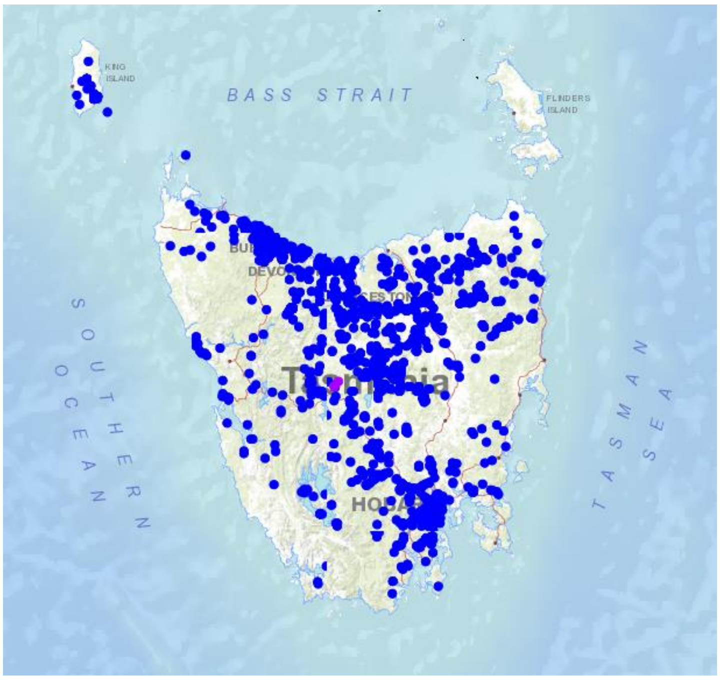


Figure 1 Platypus observations in Tasmania recorded in the DPIPWE Natural Values Atlas showing 2401 records current in 2020, indicating presence records for Gordon, Huon and Serpentine catchments.

Platypus ecology

Habitat

The semi-aquatic platypus is found in a wide variety of water bodies and their associated riparian areas in a range of environments, including forests, agricultural land, urban areas, mountainous areas, estuaries and cave systems (Connolly and Obendorf, 1998, Grant, 2007, Goldney, 1995, Otley et al., 2000, Otley, 2001, Rakick et al., 2001, Macgregor, 2015, Munks et al., 2004, Bethge et al., 2004). They are generally less common in upper reaches of rivers (Koch et al., 2006, Olsson Herrin, 2009, Turnbull, 1998, Rohweder and Baverstock, 1999) and this has been attributed to more optimal platypus habitat being available in the larger rivers and pools in the mid- and lower reaches of river catchments (Koch et al., 2006, Ellem et al., 1998, Macgregor, 2015, Serena et al., 2001).

Habitat characteristics found to be important for platypuses include consolidated earth banks, vegetation overhanging the stream channel, wide streams with in-stream organic matter, shallow pools, coarse woody debris and coarse channel substrates (Bryant, 1993, Ellem et al., 1998, Rohweder, 1992, Serena et al., 2001, Milione and Harding, 2009), but they can still occur in water bodies without these features. Recent work in a Tasmanian river catchment has found that the degree to which local habitat characteristics influence whether a particular stream is used by platypuses varies according to the position of the stream in the river catchment. In small headwater streams, ‘finer-scale’ features (e.g., substrate, in-stream barriers) are more useful indicators of platypus presence. However, in larger, higher order streams where platypuses are more likely to move along the entire stretch of the stream, catchment-scale factors, such as proximity to the nearest large stream and the size of the catchment, are more useful in predicting stream-use by platypuses (Lunn, 2015). This highlights the importance of considering multiple spatial scales when considering the effect of ecological disturbance on platypuses.

Platypus burrows are typically located in the banks of waterbodies (Grant, 2007) but can be found some distance away from water bodies (Otley et al., 2000). Platypus construct burrows for resting and nesting and individuals will use multiple burrows. The microhabitat of platypus burrows is of importance for energy conservation with the insulation of layers of earth providing a buffering effect against outside ambient temperature changes both in winter and in summer (Bethge et al., 2004, Grant and Dawson, 1978). Nesting burrows are more complicated than burrows used for resting, with multiple long passages and chambers. Platypuses will use a variety of microhabitats for 'resting' but nesting burrows are generally found in areas with consolidated, well drained earth banks. Otley et al. (2000) reported that 25 % of platypus burrows located during a radio-tracking study at a sub-alpine lake in northwest Tasmania, Lake Lea, were located within dense vegetation, such as sphagnum and button grass. They suggested that this was because of the lack of consolidated earth banks around the lakeshore; although a lactating female was tracked to a burrow in dense riparian vegetation (*Richea scoparium*) at Lake Lea (Otley et al., 2000), the use of such 'vegetation' burrows for nesting has not been confirmed. The insulation properties of such burrows would be expected to be poor compared to the typical underground earth burrows (Bethge et al., 2004). Other studies have recorded platypus burrows in non-earth structures including stream debris, log piles and tree roots (Grant, 2007) and platypuses are also known to construct nests in cave systems (Munks et al., 2004). Flexibility in burrow selection enables platypuses to inhabit waterbodies in nearly all lotic and lentic environments.

Movements and activity patterns

The platypus spends most of its time either resting in burrows or feeding in water. Platypus activity patterns follow a circadian rhythm, with light as a behavioural cue (Bethge, 2002, Bethge et al., 2009). While the platypus is predominantly nocturnal, some individuals are diurnal, particularly during the winter or lactation (Grant et al., 1992, Gust and Handasyde, 1995, Grigg, 1992, Bethge et al., 2009, Serena, 1994, Grant, 1983). Others have been found to have activity patterns related to the lunar cycle, synchronizing their activity to moonrise and moonset (Bethge, 2002, Bethge et al., 2009). The platypus can spend between 8–16 hours in the water foraging for food (Bethge et al., 2009, Gust and Handasyde, 1995, Serena, 1994, Otley et al., 2000). One individual at Lake Lea was recorded foraging for more than 30 hours continuously during winter (Bethge, 2002).

Platypuses appear to adjust their activity patterns in relation to other individuals within the population (Bethge et al., 2009, Hawkins, 1998). Both in captivity and in the wild, they have been demonstrated to shift their temporal activity pattern when in the presence of another individual, creating a dominance relationship where the subdominant platypus has more spread out activity periods extending more into day-light hours compared to the dominant individual (Hawkins, 1998, Bethge et al., 2009, Gust and Handasyde, 1995). Radio-tracking studies have found that platypus activity levels can vary throughout the year. In a sub-alpine lake (Lake Lea) in northern Tasmania platypuses were found to be more active between late winter and early spring, and least active in mid-summer. This was attributed to the increase in time spent searching for mates during the breeding season and an increase in foraging activity by the females in preparation for lactation which began in late spring/early summer (Bethge, 2002).

Home-range size of the platypus varies greatly with habitat characteristics and between individuals, with some individuals being more sedentary than others (Grant and Carrick, 1978, Grant et al., 1992, Otley et al., 2000). Home-range sizes of between 2.45 and 15.45ha (Gust and Handasyde 1995) and distances of 2.9 and 7.0 km (Gardner and Serena, 1995) have been reported for platypuses caught in larger rivers. Home ranges of 0.33 to 2.28km were reported for a small creek (Serena, 1994). A study of the movements in a river catchment found a large difference in the estimated distance that individuals travelled, reporting up to 10.4km for males and 4.0km for females in a single overnight period (Serena et al., 1998). This study also found that the mean home range length of adult/subadult animals was significantly greater than that of juveniles (1.4-1.7km). Foraging range of individuals in a sub-alpine Tasmanian lake system (Lake Lea) varied between 2 and 58ha (Otley et al., 2000). In general, individual platypuses in the lake system kept quite constant home ranges, at least on a small temporal scale of a few months (Bethge, 2002). Some platypuses, particularly in Tasmania, are known to move significant distances overland between catchments, water bodies or from burrows to water bodies (Taylor et al., 1991, Scott and Grant, 1997, Otley et al., 2000, Munks and Nicol, 2000, Furlan et al., 2013, Kolomyjec et al., 2009, Kolomyjec et al., 2013).

Home range appears to be separated both spatially and temporally, particularly during the breeding season, probably as a result of competition between individuals with different positions in the social hierarchy (Serena, 1994, Gust and Handasyde, 1995, Bethge, 2002, Bethge et al., 2009). However, overlap in home ranges and sharing of burrows has been observed (Otley et al., 2000, Grant et al., 1992, Gust and Handasyde, 1995, Serena, 1994, Serena et al., 1998, Bethge, 2002).

Diet and foraging

Studies have found that platypuses forage continuously for between 8-16hours per day (Otley et al., 2000, Gust and Handasyde, 1995, Serena, 1994, Bethge et al., 2009, Bethge et al., 2003) with longer foraging bouts recorded in the winter months. In general they feed opportunistically on a wide range of benthic macroinvertebrates (Faragher et al., 1979, Grant 1882, McLachlan-Troup et al., 2010, McLachlan-Troup et al., 2020, Marchant and Grant, 2015, Bino et al., 2019). Analysis of the cheek pouch samples from individuals caught at Lake Lea show that platypuses in the lake primarily feed on a range of benthic macroinvertebrates with caddis fly larvae (*Trichoptera*) and the endemic burrowing crayfish (*Parastacoides tasmanicus tasmanicus*) forming a major part of the diet (Munks et al., 2000, Bethge, 2002, McLachlan-Troup et al., 2020). Evidence of fish forming part of the diet of the platypus has also been found at Lake Lea and at other locations (Grant, 2007, Olsson Herrin, 2009).

Platypuses were recorded feeding in all available aquatic habitats at Lake Lea during radio-tracking studies (Otley et al., 2000, Bethge et al., 2009). These ranged from the lake itself, small pools in the wetland associated with the lake, permanent and ephemeral streams and the flooded grassy plains. The majority of individuals tracked, however, preferred feeding in the lake itself and closer to the lake shore than the lake centre (Otley et al., 2000). Ellem and McLeod (1998) also noted that platypuses used shallow parts of a weir pool in the Duckmaloi River in NSW. Platypus feed during short dives and prefer water depths of 1- 5m (eg., Bethge et al., 2003, Grant, 2004b, Serena et al., 2001). At Lake Lea the mean dive depth was 1.28m, with a maximum of 8.77m (Bethge et al., 2003). Energetic efficiency of feeding and diversity of prey item are factors influencing this preferred dive depth (Bethge et al., 2003). A preference for a minimum water depth for foraging, as noted by Grant (2004), is potentially related to predator avoidance. Both the wedge-tailed eagle (*Aquila audax*), sea eagle (*Haliaeetus leucogaster*) and the grey goshawk (*Accipter novaehollandiae*) are known to predate on the platypus (Grant, 2004b, Rakick et al., 2001, Richards, 1986, Searle, 2008)(N. Mooney, pers. comm.). Studies have shown that platypuses prefer to forage in substrates that provide a range of habitats for benthic invertebrates (e.g. gravels, pebbles and cobbles) rather than sand, silt and fine sediment (Serena et al., 2001, Grant, 2004b).

Breeding season

The breeding season in platypus is later at increasing latitudes (Jabukowski et al., 1998). In Tasmania, mating peaks around October, two months later on average than in mainland populations (Connolly and Obendorf, 1998, Munks et al., 1998, Munks et al., 2000, Macgregor, 2015) with lactating females and their young in burrows between November and April after which the young emerge from the burrow between April and the beginning of June (Macgregor, 2015, Munks et al., 2000, Connolly and

Obendorf, 1998) (Figure 2). Female platypuses construct a nest in the burrow where they lay one to three eggs and then suckle the nestlings for around 4 months (Thomas et al., 2018, Grant et al., 2004, Hawkins and Battaglia, 2009).

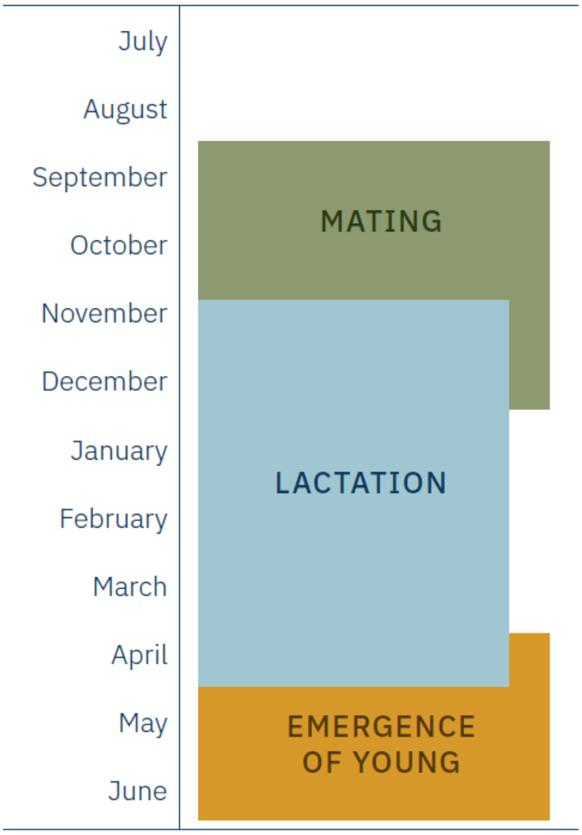


Figure 2 Approximate timing of breeding events in platypuses in Tasmania

Population size and structure

The abundance of platypuses in a particular river system or lake system is extremely difficult to quantify (Woinarski and Burbridge, 2016). The net-mark-release method traditionally used to estimate platypus numbers may not reliably assess the number of platypuses at a site and trends over time (Macgregor, 2008).This is mainly due to the substantial effort required to capture a platypus and the low and variable recapture rates (Grant, 2004a, Griffiths et al., 2013).

Existing estimates of platypus densities in lotic waterbodies range from 1.3-2.1 per kilometre for creeks in Victoria (Serena, 1994) to 3-7 per kilometre in the upper catchment tributaries of the South Esk River in Tasmania (Koch et al., 2006). Bino et al. (2015) estimated 19.3 platypuses/km, using data collected over 40 years for the most consistently surveyed large pools (~2 km) but only 2.8 platypuses/km along 16.4 km studied in the Shoalhaven River in NSW. These authors note that survey technique, sampling season, habitat type and unexplained variability in capture rates (e.g. net avoidance in intensively studied areas) may all contribute to variation in population estimates between studies and sites.

Annual estimates of the size of the platypus population in Lake Lea (142ha and associated tributaries from preliminary population modelling using mark-recapture data collected between 1996-2001 are 150-170 individuals, with more males than females (Munks, Corkrey et al, unpublished data). These figures from the preliminary modelling, however, should be treated with caution until further analysis is completed. One individual tagged as a juvenile in 1998 was estimated to be 16 years old from the results of monitoring at the Lake in 2014 using in-stream microchip readers (Macgregor and Munks, unpublished data). The maximum recorded longevity for a platypus in the wild is 21 years (Grant, 2007).

Threats and Conservation status

The platypus is endemic to Australia. Their numbers are thought to have declined sharply during the days of trade in their furs, before their legal protection in all states in 1912 (Burrell 1927, Grant and Temple-Smith 2003, Hawke et al., 2019). Data from trapping surveys and observations indicate more recent population declines and extinctions in some river systems which has led to the species being currently listed as 'Near-Threatened' under the IUCN Red List due to declines and dependence on adequate water (Woinarski and Burbridge, 2016). Recent estimates of the impact of threatening processes on platypus populations using population viability analysis indicate increased risk of extinction across around 40% of its range (Bino et al., 2020) qualifying the platypus for IUCN Red Listing as 'Vulnerable'.

Platypuses are not listed on Australian national legislation (i.e. *Environment Protection and Biodiversity Conservation Act 1999*). However, platypus are currently listed as 'endangered' in South Australia (*National Parks and Wildlife Act 1972*) and have been nominated for listing as 'vulnerable' in Victoria (*Flora and Fauna Guarantee Act 1988*) by the Victorian Scientific Advisory Committee in a preliminary recommendation dated July 2020.

Tasmania is considered a stronghold for the platypus (Hawke *et al.*, 2019, Munks and Nicol, 2000). Platypuses in Tasmania are genetically distinct from platypuses in mainland Australia (Furlan et al., 2010, Gongora et al., 2012) reflecting the long-term isolation of Tasmanian populations. The platypus is protected in Tasmania under the *Nature Conservation Act 2002*. This state legislation may also provide some protection for known platypus burrows since they are deemed platypus products, which places conservation obligations on riparian zone developments (Gust and Griffiths, 2010). The trapping and handling of platypuses is also regulated under the *Inland Fisheries Act, 1995* and the *Animal Welfare Act 1993 (amended in 2008)*.

Potential threats to platypus populations in general, including urban development, agriculture, forestry, in-stream dams, pollution, disease, introduced species and climate change, are reviewed in Grant and Temple-Smith (2003), Bino et al. (2019) and Klamt et al. (2011) . The impact of these processes may be significant for some populations, however there have been few studies on the effects of human activities on platypus populations (Grant and Temple-Smith, 2003). Grant and Temple-Smith (2003) observe that '*in spite of these threatening processes, the species has continued to inhabit and reproduce in considerably degraded environments*'. Quantifying the effects of potential threatening processes on the platypus is extremely difficult and this hampers risk assessments required for the development of effective conservation actions (Bino et al., 2019).

The most significant current threats to the Tasmanian platypus population are considered to be habitat loss and modification (associated with a variety of human activities), disease (e.g. mucormycosis), introduced predators (particularly dogs and cats), pollution and other forms of direct mortality such as road-kill and fishing by-catch (Gust and Griffiths, 2010, Grant and Temple-Smith, 2003). Klamt et al. (2011) found that projected climate change will likely affect platypuses distribution and numbers, particularly in the northern and inland parts of its range, through reducing the availability of thermally suitable habitat. These authors emphasise the importance of maintaining and restoring potential thermal refugia throughout the range of the species.

The ulcerative fungal disease mucormycosis has been present in platypus populations in Tasmania for over 30 years, with adult males being most affected (Gust and Griffiths, 2011). The disease caused some concern in the mid-90s due to observations of significant morbidity and mortality of platypuses in some catchments (Connolly and Obendorf, 1998). The results of subsequent studies indicate, however, that platypuses are currently not threatened by this disease although it may play an ongoing role in the health of infected populations (Gust and Griffiths, 2011, Macgregor, 2008, Macgregor, 2015, Macgregor et al., 2010, Macgregor et al., 2017).

Potential changes from restoration and implications for the platypus

The construction of the current reservoir in 1972 changed a relatively shallow lake, wetland and stream system into a deep, less productive lentic environment. This would have impacted the platypus population present in the area at that time in a variety of ways. Platypuses in the Serpentine and Huon river reaches downstream would have experienced changes in water temperature, water flow rates and sediment levels, altering foraging habitat and potentially impacting on reproductive success (Serena and Grant, 2017, Grant and Temple-Smith, 2003). The impoundment may have fragmented populations in the catchment and impeded movements of platypuses (Bino et al., 2020). Creation of the deep areas of water storage undoubtedly caused increased mortality rates, flooding of burrow sites and reduction in the availability of optimal foraging habitat and disrupted breeding (Grant and Temple-Smith, 2003). However, despite these significant changes to its environment, some of which may be ongoing, a platypus population appears to have persisted in the area.

While removal of dams is gaining momentum in other jurisdictions there is limited scientific information concerning the effects of dam removal on biota (Stanley and Doyle, 2003). The major changes relate to sediment exposure, erosion and redistribution, water flow and barrier removal (Stanley and Doyle, 2003). Consideration of the potential effects of these changes in the environment on the platypus is further complicated by limited scientific information on the effects of human activities in general on the platypus (Grant and Temple-Smith, 2003). The effects on platypuses may be inferred, however, from an understanding of the relationships between platypus habitat requirements and factors that affect these requirements, especially changes in food and shelter. Most of the current information on platypus habitat requirements comes from studies of platypuses inhabiting narrow lotic habitats (river and stream systems) although there are a handful of studies from lentic habitats (e.g. weirs, reservoirs, and lakes). The results from studies of the ecology of platypuses inhabiting a Tasmanian sub-alpine lake, Lake Lea may be relevant when considering the Huon-Serpentine Impoundment population (e.g.Munks et al., 2000, Bethge et. al., 2003, Munks et al., 1998). This dystrophic lake with karst features has an elevation of 816m and a surface area of 142 ha. However, similar to the original Lake Pedder, Lake Lea is largely shallow (average depth of 2-3m) with a connecting network of permanent and ephemeral streams, pools and wetlands and is surrounded by diverse vegetation communities including buttongrass, moorland, rainforest, native grasslands, eucalypt forest, woodland scrub and alpine heath (Otley, 1996, Otley, 1998).

The potential impacts of the restoration on platypus population size, survival rates and other population parameters has not been attempted in this consideration of potential changes resulting from the restoration. This is largely because there have been no systematic studies of the platypus population in the Huon-Serpentine Impoundment and platypus abundance and population trends are extremely difficult to determine even with decades of mark-recapture data. It may be feasible to explore the impacts on the platypus population inhabiting the planned restoration site through population size and viability modelling using data collected from another lentic system (eg.,Bino et al., 2020, Bino et al., 2015), however such work is beyond the scope of this current report.

Habitat extent and type

The draining of the existing Huon-Serpentine Impoundment would significantly change the habitat utilised by the current population of platypuses from a large deep waterbody, with connectivity with other waterbodies potentially impeded by dams, to a freshwater environment characterized by a complex network of connecting multiple-order streams, rivers, wetlands and shallow lakes and ponds (Figure 3).

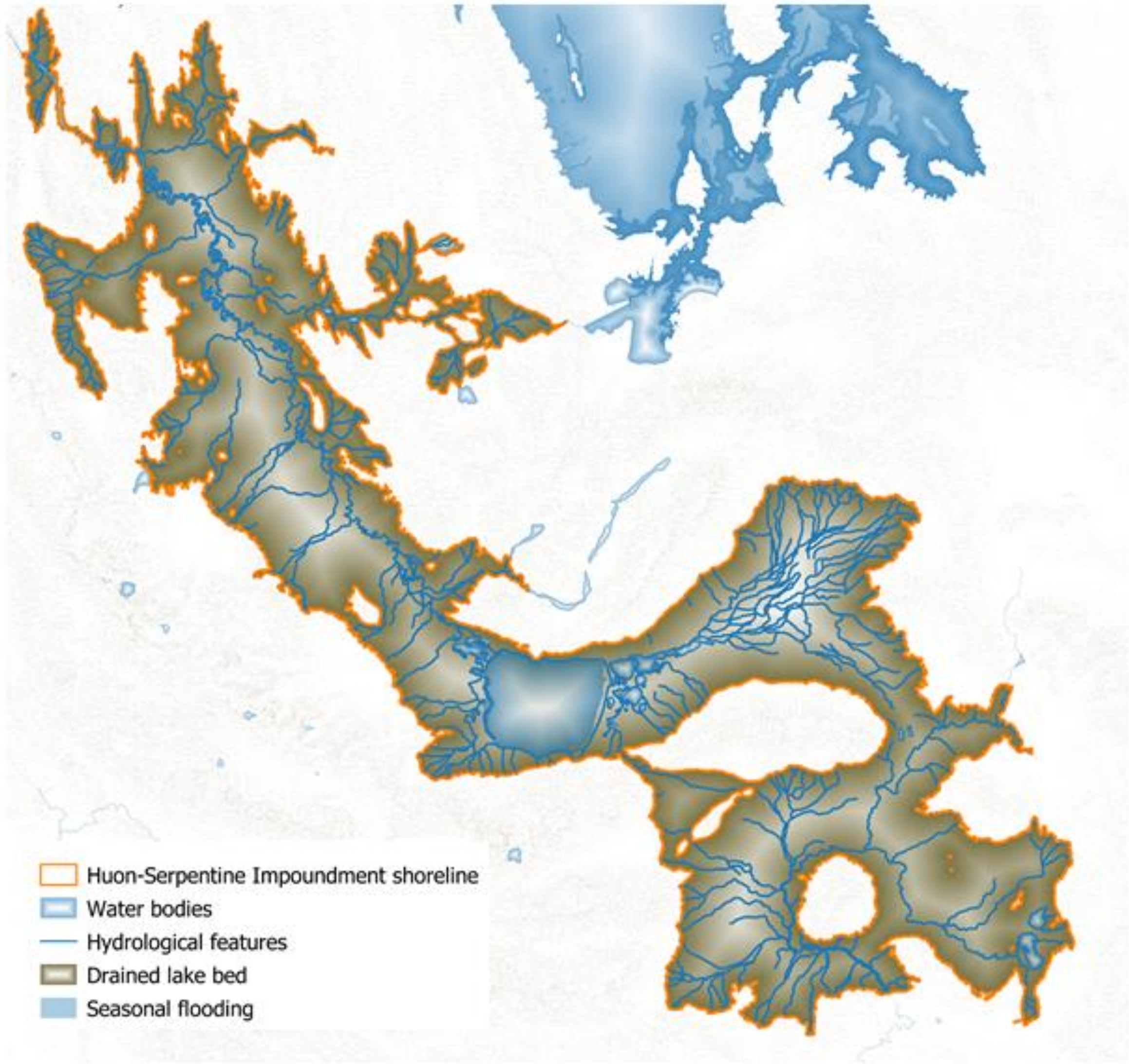


Figure 3 Overlay of pre-flooding water features as mapped from the initial topographic maps illustrating the complex network of wetlands, streams, rivers, ponds and lakes providing potential platypus habitat. The boundary of the current reservoir is indicated by the orange outline and the extent of the exposed lakebed immediately following restoration is shaded in brown.

The current Huon-Serpentine Impoundment is reported to be 242 km2 (approx. 24,200ha) with an average depth of 13-16m (43m maximum depth). This 'new' lake has been in existence since the damming in 1972. In contrast, the area of the original Lake Pedder, when full, was 9.7 km2 (approximately 1000ha) but in summer the shallow sand bed of the lake facilitated considerable lateral contraction of the lake margins, and the exposure of wide beaches. Under these conditions the maximum depth of Lake Pedder was reported to be approximately 3 m (Kiernan, 2001). This shallower habitat (<5m) is preferred by the platypus for foraging.

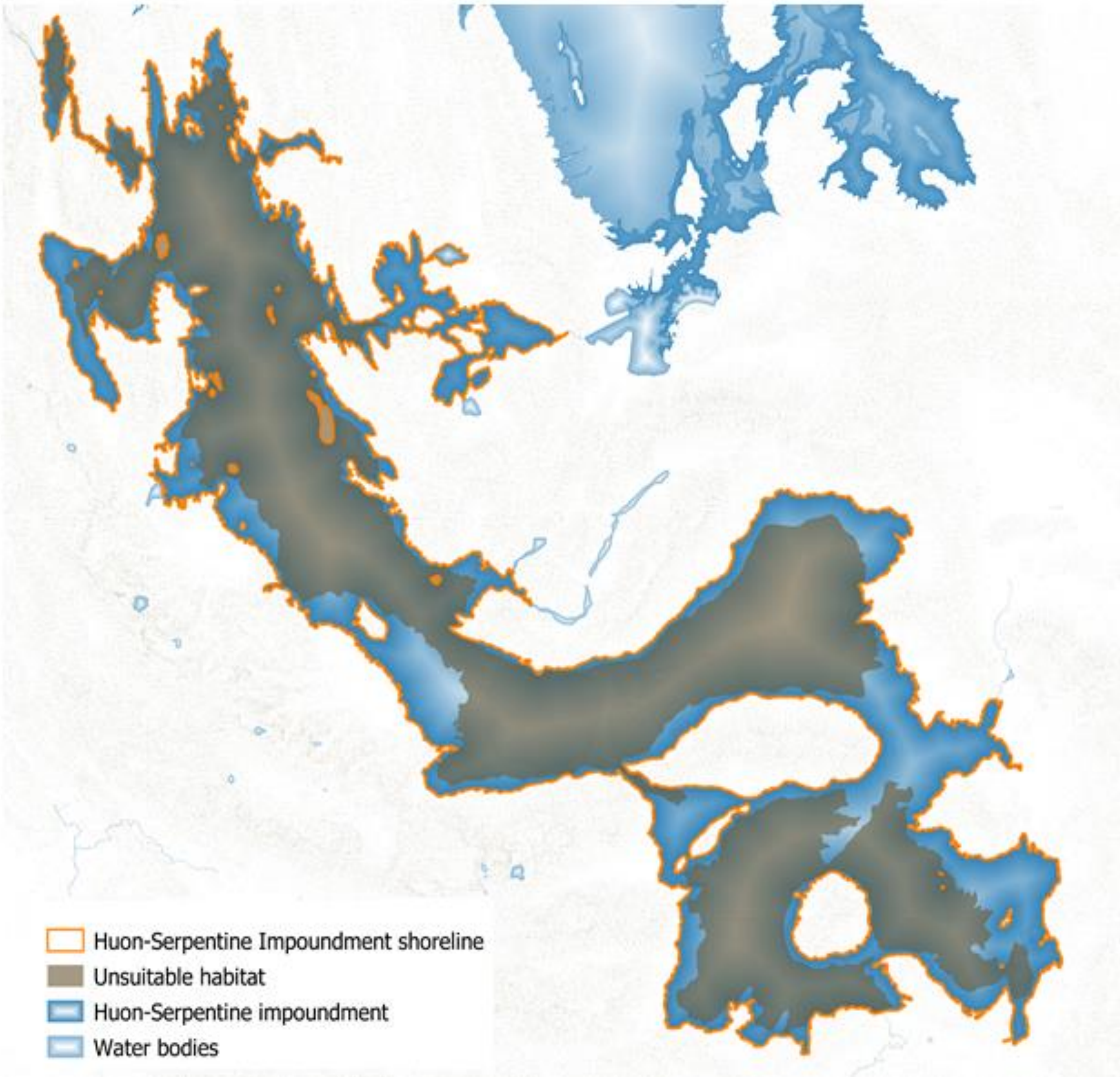


Figure 4 Areas within the current reservoir that may be within and the preferred dive depth of the platypus (Light blue<5m deep) and those areas greater than 5m deep at the lowest operating level.

It should be noted, however, that although the average depth of the majority (153km^2) of the existing reservoir is generally greater than the preferred dive depth of a platypus, a substantial proportion of the reservoir is still <5m in depth (89km^2) (Table 1, Figure 4). The drowned trees in the current reservoir may also provide foraging habitat for the platypus in the existing reservoir. The area of this drowned tall scrub and forest mapped and estimated from aerial photography and topographic map interpretation is 640ha (Figure 5 and Figure 6). Restoration to the original Lake Pedder with breaching (or removal) of the dams and the subsequent increased connectivity of water bodies could benefit the platypus population in the long term through reducing barriers to dispersal and movement. However, in the early stages of restoration considerable disruption to the shape and dimensions of home ranges and increase competition would be expected. Platypus home range is known to be influenced by the depth and size of a waterbody and is inversely related to the occurrence of relatively fine inorganic benthic material (Grant, 2004b, Serena et al., 2001, Ellem and McLeod, 1998). The increased connectivity could also increase the risk of disease, although there are no known records of mucormycosis in the adjacent catchments (Gust and Griffiths, 2011).

Table 1 Area of the current reservoir and the original lakes that is estimated to be within the preferred dive depth (<5m) for the platypus as illustrated in Figure 4.

Feature	Area (km^2)
Huon-Serpentine Impoundment	
Current Huon-Serpentine Impoundment	242
Current Huon-Serpentine Impoundment <5m depth	89
Current Huon-Serpentine Impoundment >5m depth	153
Restored Pedder	
Original Lake Pedder	10
Maria Lakes Complex	2

Figure 5 Exposed forest remnants in Ragged Basin of neighbouring Lake Gordon after water levels receded in 2014. (Image Dr David Bluhdorn)

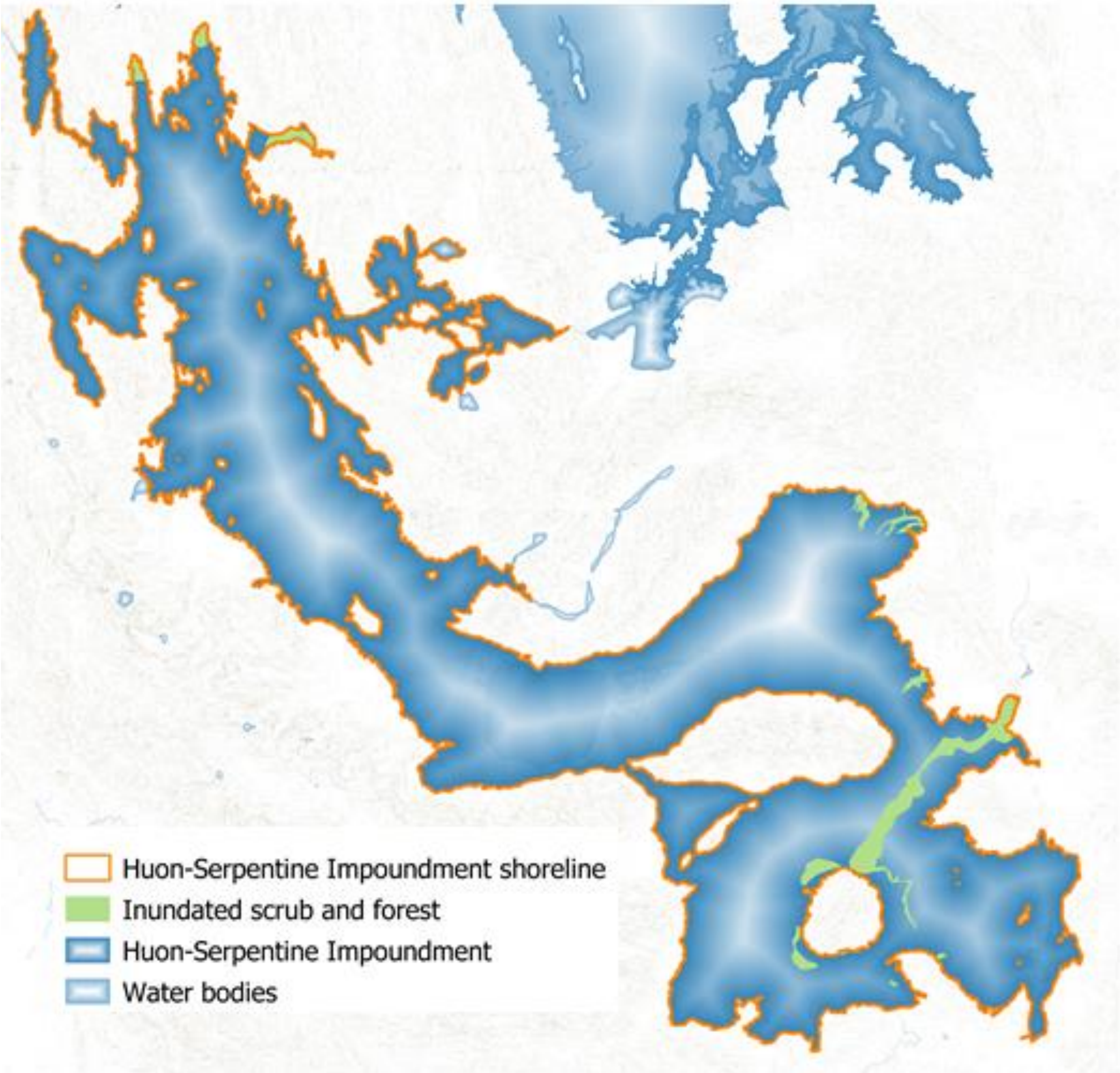


Figure 6 Areas of 'drowned tall scrub and forest' within the boundary of the existing reservoir (orange outline) estimated from pre-flooding aerial photography and topographic map interpretation

Habitat quality

Platypuses are known to be sensitive to changes in stream flow (Serena and Grant, 2017). Fluctuations in flow conforming to variations in power requirements may impact on foraging behaviour and reproduction in the platypus (Serena and Grant, 2017). Dam removal in other jurisdictions has resulted in restoration of natural flow regimes, increasing the density and diversity of aquatic species through the restoration of a diversity of freshwater micro-habitats downstream (Bednarek, 2001). This restoration of natural flows might also increase the connection between riparian and aquatic habitats and result in the return of small ephemeral pools and coarse woody debris in downstream reaches (Bednarek, 2001) which are important for platypuses foraging and movement. Small pools and backwaters created by the exposed forest remnants in the receding waters may also provide foraging habitat (Figure 5).

Water quality changes expected to occur during drawdown and the initial recovery period include increase in temperature, turbidity and sedimentation. The water temperature increases expected for all waterbodies, particularly shallower first to third order streams with lack of shading until riparian vegetation has regenerated (5-10 years), could result in some thermal stress for the platypus. The platypus is known to be intolerant of water temperatures greater than 25^{o}C (Grant, 2007) and significant increases in water temperature in the shallow creeks and ponds may impact on activity patterns, restricting foraging activity to the nighttime and hence increasing competition between individuals. It is probably unlikely, however, for water temperatures to get high enough for long enough to affect platypuses directly.

There is some evidence that there is a lack of widespread, deep accumulation of sediment in the current reservoir from underwater videography in 2020 supplementing studies by Tyler in 1996. Nevertheless, there is likely to be some sediment movement and re-distribution throughout the lake and associated water bodies, streams and rivers downstream following dam removal. Such sedimentation could decrease the diversity of food and foraging habitat for the platypus with fine particles filling in valuable coarse sand and cobble substrates preferred by the platypus.

An increase in lotic (stream) habitats is expected after dam removal (Figure 6). This will result over time in a change to the benthic macroinvertebrate communities in the catchment, potentially increasing the diversity and possibly abundance of prey items for platypuses. Although in the initial recovery phase the macroinvertebrates may be dominated by silt-loving species (Figure 6) platypuses are opportunistic in their diet and although not preferred, they are known to tolerate silty habitats (Koch et al., 2006, LaGrandeur, 2012).

It is expected that the restoration of a network of small rivers, creeks, ponds and wetlands would increase the extent of riparian habitat (Table 2) available to the platypus. Over time, this could potentially provide an increase in available burrow locations; although it is not clear how much of this 'riparian' habitat would comprise 'consolidated earth banks' preferred by platypuses for nesting burrows. At Lake Lea platypus burrows are located on lake, creek and pool edges with many being located in dense vegetation, with some individuals travelling up to 20 m overland to burrows on sloping banks of the lake shore (Otley et al., 2000).

Table 2 Estimated change in the perimeter of water bodies following dam removal and restoration to past water course features

Post-impoundment Feature	Perimeter/length (km)
Huon-Serpentine Impoundment at full supply level (FSL)	423.2
Pre-impoundment features	
Lake Pedder perimeter	20.4
Lake Maria complex perimeter	22.4
Huon River	18.6
Serpentine River	39.2
Mapped tributaries & drainage lines	471.2
Total wetted perimeter	571.7

The proximity of foraging habitat from existing burrow sites around the perimeter of the current reservoir is expected to change as the water level drops. However, observations from Lake Lea (where the water edge fluctuates significantly seasonally) suggests that they may adapt by moving along small restored drainage lines and tributaries (Figure 7) and overland to the lake shore. Anecdotal observations from work done at Lake Lea and in the upper reaches of the South Esk River suggest that the platypus may also forage in the exposed wetland areas, preying on burrowing crayfish that persist in the area (Lake, 2001). The Tasmanian platypus is known to spend more time moving overland than mainland individuals, possibly due to reduced predation risk from introduced predators (Munks and Nicol, 2000, Furlan et al., 2013). However, this increased exposure may make the platypus more vulnerable to predation by native predators (e.g. raptors) in the dewatered area.

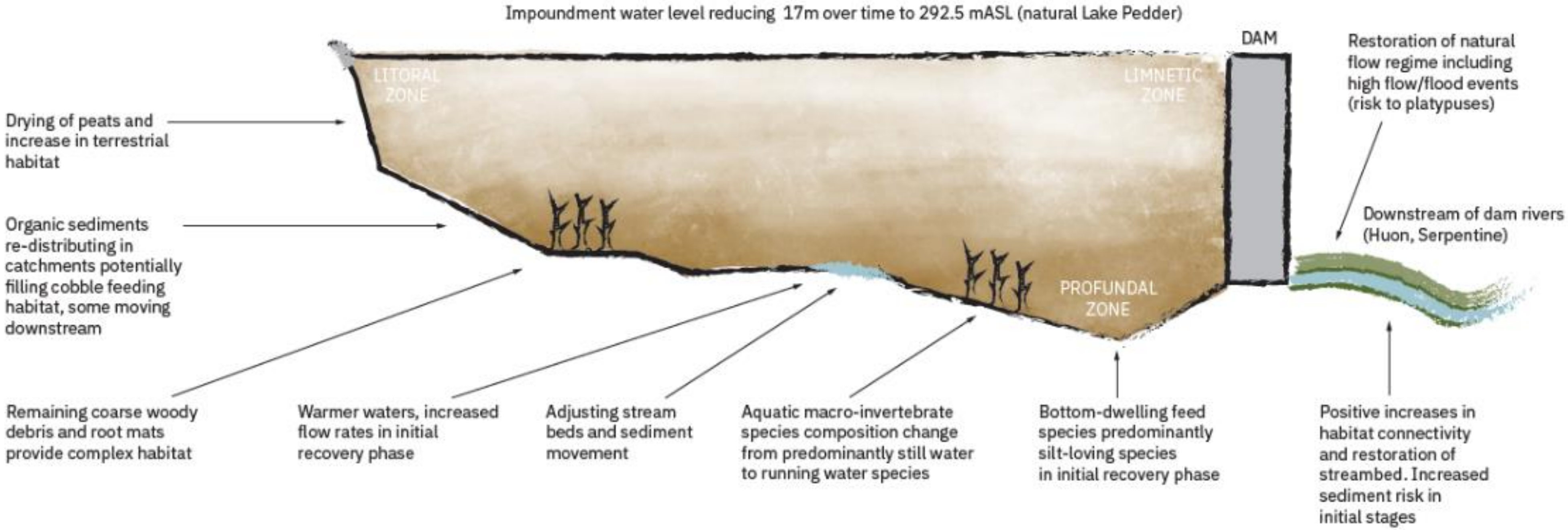


Figure 6a Predicted changes to aquatic habitats and forage sources for platypuses during, and immediately following, dewatering of the impoundment.

(a)

(b)

Figure 7 Example of 14 years of regeneration along a drainage line during low lake levels at Lake Gordon (Images: Dr David Bluhdorn)

Summary of potential risks and mitigation measures

While dam removal could benefit the platypus population in the catchment in the long-term there may also be negative impacts, particularly in the short-term. The risks include

- increased mortality rate
- loss and/or shift of home range shape and dimensions
- concentration of individuals leading to competition for suitable burrow and foraging areas (in early stages)
- increased predation (e.g. from raptors)
- increased likelihood of thermal stress
- reduction in reproductive success (at least in the early stages)
- delay in development of appropriate forage/breeding habitat
- increase in exposure to landscape-scale fire events (increase in intensity and frequency related to climate factors and increased ignitions from dry lightning strikes)

The rate of dewatering is probably the most important factor when considering ways to reduce impacts of disturbances caused by dam removal on the platypus, including those on existing populations downstream of the current dams. Studies elsewhere have found that mortality rates of populations of biota inhabiting reservoirs can be extremely high if dewatering is rapid (Stanley and Doyle, 2003, Orr et al., 2008). However, some studies have found that biota (fish and macroinvertebrates) recovered within a year of removal of in-stream dams through recolonisation from connected river reaches and successful reproduction within the drained area (Stanley *et al.*, 2002).

Taking into account the predicted rate of recovery of the physical habitat, particularly vegetation cover to facilitate shading, provide potential burrow sites and cover for the platypus, and the time of the year when individuals would be most vulnerable to disturbance, the optimal strategy for the platypus would be a gradual, winter staged dewatering over the maximum two year period although a gradual change over several years would be the optimum scenario (Tables 3 and 4). A similar slow and decremental dropping of the water level has been recommended to reduce the impacts on aquatic fauna in general (Lake, 2001). Dewatering during the winter months may disrupt mating in platypuses but would avoid change in water level and flow impacting on the period when females are lactating (and have increased food requirements), and juveniles are confined to nesting burrows in the vicinity of the lake or along the downstream reaches. Platypuses are known to be sensitive to changes in flow and significant changes can compromise reproductive success (Serena and Grant, 2017).

Active revegetation of riparian areas may also be considered to speed up habitat stabilisation and shading for platypuses in the new environment created by the dewatering. This would reduce the risk of thermal stress, provide cover, and would help in the restoration of foraging and burrow habitats.

Table 3 The likely optimum rate of dewatering for platypuses – Green represents the optimal or preferred rate with the highest chance of meeting aim, orange represents sub-optimal rate with less certainty of meeting the aim and red represents the highest risk rate with the lowest likelihood of meeting the aim. More details on the specific assessments are provided in the review document.

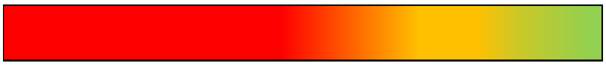
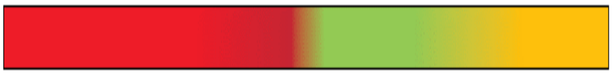
Risk mitigation aim	100 days	6 months	12 months	24 months	>24 months
Allowing retreat/movement/ establishment of burrows of platypuses					

Table 4 The likely optimum season of dewatering – time for maximum surface area exposed for platypuses (colour code as above)

Risk mitigation aim	Summer	Autumn	Winter	Spring
Allowing retreat/movement/ establishment of burrows of platypuses				

Significant knowledge gaps to assess restoration effects and studies required

Considerable uncertainty remains about the current distribution, abundance and conservation status of the platypus across its range, including Tasmania, and the direct and indirect impacts of anthropogenic disturbance (Bino et al., 2020, Grant and Temple-Smith, 2003). The effects of restoration of the Huon-Serpentine Impoundment on platypuses have cautiously been inferred here from relevant published information on the ecology of the species. However, as mentioned earlier, much of this information comes from studies of platypuses inhabiting narrow lotic habitats (river and stream systems), although some anecdotal/unpublished information from another Tasmanian lake system has also been used where relevant.

As stated by Dr Tom Grant in his submission to the 1995 enquiry, it is important for scientific work to be carried out on the platypus population in the Huon-Serpentine Impoundment before any robust conclusions can be drawn on the possible impact of the proposed restoration project on the species (Standing Committee on Environment

Recreation and the Arts, 1995). While the comments made here on restoration effects are based on the best available information currently available, they should be treated with considerable caution given the significant knowledge gaps.

The following additional work is recommended to increase the reliability of conclusions about the effects of restoration on the platypus population in the Huon-Serpentine Impoundment:

- platypus surveys with the aim of gathering data on the structure, spatial ecology and health of the platypus population in the catchment. The assessment of health of the population could follow the framework developed by Macgregor (2015);
- population viability analysis using methods similar to Bino et al. (2020), and Bekessy et al. (2004) modelling the initial changes in populations from dewatering and subsequent recovery. This study could initially be done using data from the Lake Lea studies;
- habitat suitability models similar to the approach used to assess restoration success in the US (Tomsic et al., 2007);
- modelling of the optimum drawdown rates to ensure continuity of platypus habitat over time and space;
- monitoring of the platypus population and their habitats before, during and after the dewatering and restoration (this could be done using new cost effective techniques such as eDNA[1] (Lugg et al., 2018);
- further studies of vegetation recovery, particularly along streams to determine the potential and rate of restoration of platypus habitat; and
- studies to determine how intact and stable stream and creek banks may be for burrow creation.

[1] eDNA is nuclear or mitochondrial DNA that is released from an organism into the environment. As part of their everyday activity, aquatic animals shed DNA from their bodies which is dispersed via water movement. The process of eDNA sampling involves collecting simple water samples and filtering the water. The filtrate (material that is collected in the filter) is sent to a diagnostic laboratory where the DNA is then extracted if present.

Conclusion

Restoration of Huon-Serpentine Impoundment would convert the current large, deep reservoir into a freshwater environment characterised by a complex network of connecting multiple-order streams, rivers, wetlands and shallow lakes and ponds, habitat types known to currently support viable platypus populations both in Tasmania and on mainland Australia (Grant, 2007). Based on available information it is likely that the disturbance caused by the removal of the dams will expose, erode and redistribute sediment, change water flow, depth and temperature and alter the macroinvertebrate and plant communities in the catchment. These physical consequences of dam removal will significantly alter habitat (both foraging and refuge) for the platypus present in the current reservoir and downstream river reaches. The initial disruption and changes to the physical environment would therefore be expected to have significant direct and indirect negative impacts on the platypuses inhabiting the area, possibly including lower reproductive success, increased competition, increased susceptibility to disease, thermal stress and increased mortality rates. However, it is difficult to speculate on the longer-term effects of this initial disturbance event. The predicted pattern of restoration of the physical environment following the initial dewatering may result in beneficial outcomes for the platypus population including increasing connectivity with downstream river and stream reaches, increased burrow site availability and increased foraging areas of suitable depth, macroinvertebrate diversity and abundance.

The rate and timing of dewatering is an important factor when considering ways to reduce impacts of disturbances caused by dam removal on platypuses. A slow, staged rate of dewatering and timing the dewatering to the winter months is critical to reduce impacts, particularly to minimise disruption to breeding. Some active reconfiguration and revegetation of riparian areas may be desirable to speed the recovery of riparian and in-stream habitats utilised by the platypus. Further scientific studies are recommended (e.g. surveys of the current platypus population in the Huon-Serpentine impoundment and predictive population viability analysis) to increase the reliability of conclusions about the effects of restoration of Lake Pedder on the platypus.

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Acknowledgements:

Dr Tom Grant kindly provided comment on earlier drafts of this review.