The impact of the 2019/20 fires on platypus populations in the MidCoast region

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Executive summary

The platypus is an iconic Australia mammal, facing numerous anthropogenic-driven processes impacting long-term population viability across much of its distribution. During the extreme drought (2017 -2019) across much of eastern Australia, in some places the worst in over 120 years of records, incidences of platypus distress and mortality were reported through private communications with WIRES, zoos, landholders and platypus conservation groups. The fires of 2019-20, which followed the severe drought, raised concerns over the condition of platypuses in impacted rivers, estimated to cover more than 13% of its distribution. Although previous research in Victoria suggested little impacts of fires to platypuses, the extreme antecedent conditions were possibly more serious.

In this report we examine the impacts of the extreme 2019-20 fires on the MidCoast of New South Wales, preceded by a severe drought. We surveyed platypuses in fire-impacted Manning River catchment in Dingo, Bulga, and Bobin Creeks, and the un-impacted Hastings River catchment in the Thone River.

Capture rates in the fire-impacted Manning River were extremely low, at the lower end of known densities, whereas those recorded on the unimpacted Thone River were within average ranges. Platypus numbers were higher in pools on Dingo Creek, downstream of the areas directly impacted by fires, highlighting the importance of larger and deeper pools as critical refugia for platypuses during the drought and fires. Additionally, the timing of the droughts (and fires) may have also impacted breeding as no juveniles were captured in the area.

Findings suggest that platypuses were impacted by the synergistic impacts of severe droughts and fires. The full extent of this impact needs to be understood to identify direct and indirect mechanisms such as if individuals perished in fires, or if secondary impacts to water quality and macroinvertebrate prey immediately after the fire.

The platypus

Species description

The platypus (*Ornithorhynchus anatinus*) is a semi-aquatic native Australian monotreme. The species is evolutionarily and morphologically unique, being the only living species of the Ornithorhynchidae family and one of only five extant species of monotremes (Grant and Fanning 2007). Modern platypuses are endemic to eastern Australia, with the platypus lineage estimated to have originated at least 120 million years ago (Johnson 2006). Defining platypus features include its duck-like bill, waterproof fur, webbed feet, and their use of electroreception to detect prey. Females are also unique for egg laying, while males have calcaneus, venomous spurs on their hind ankles (Grant and Fanning 2007). These features make the platypus evolutionarily and morphologically unique, making it one of the most distinct and iconic mammals alive.

Distribution

Platypuses are found in eastern Australia from Cooktown in northern Queensland to Tasmania (Figure 1). Platypuses are typically distributed in eastern flowing rivers and waterways in Queensland, although data are limited for the state. Platypuses are found in western-flowing rivers of the Murray-Darling Basin in New South wales, but are more common on the eastern side of the Great Diving Range (Grant and Fanning 2007). Platypuses occupy 26 of the 31 river systems in Victoria, although there is evidence that their distribution may be declining in the state, and declines in metropolitan areas are of concern (Grant and Denny 1991b). Platypuses are reasonably widespread throughout Tasmania, found in 15 of 19 river systems. Platypuses are considered vulnerable in South Australia, with sporadic records throughout the Mount Lofty Ranges, Adelaide Hills, and the Yorke Peninsula (**Error! Reference source not found.**). There is also an introduced population on Kangaroo Island (Grant and Denny 1991b).

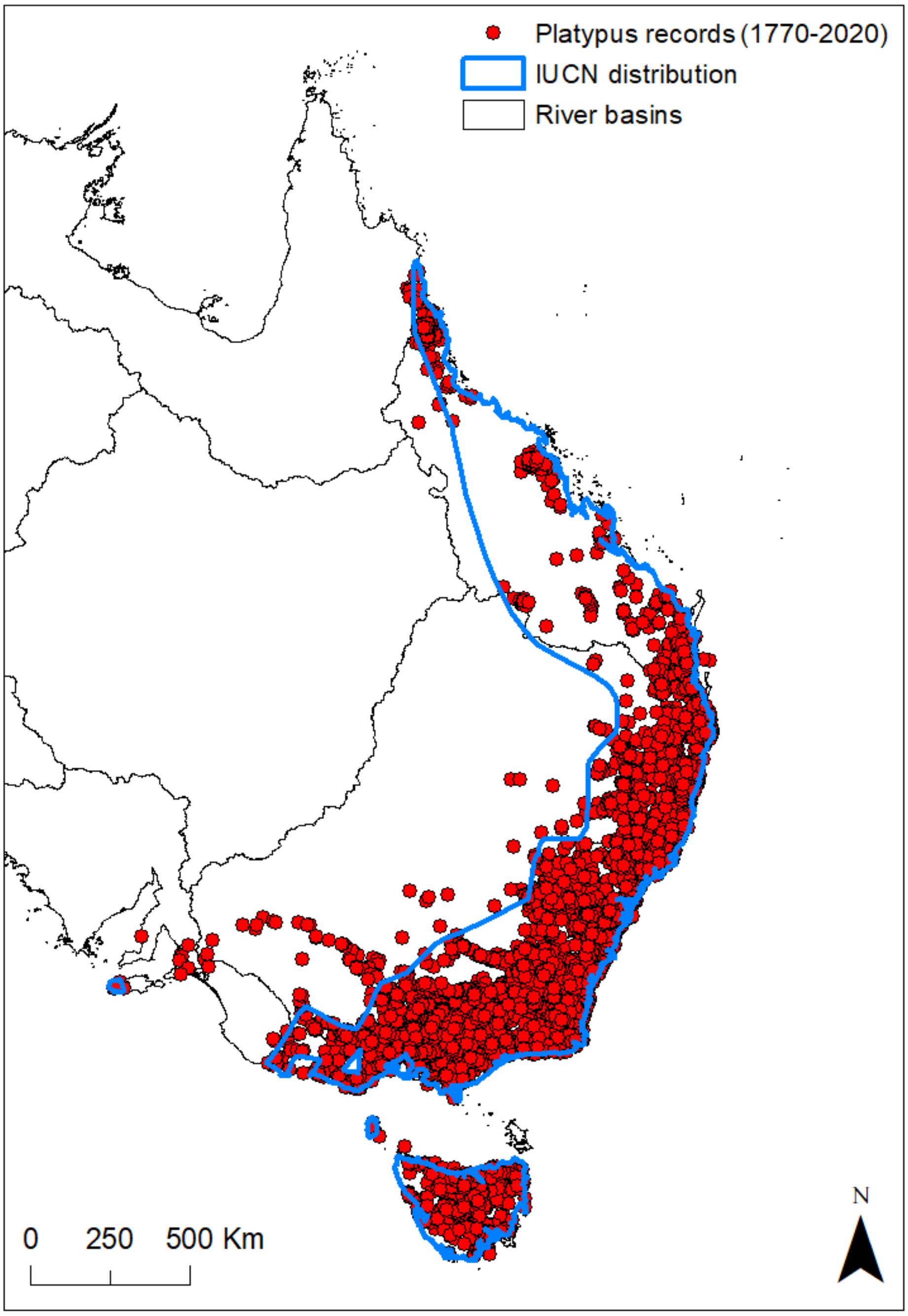

Figure 1. The distribution of the platypus based on reported observations in the Atlas of Living Australia (https://www.ala.org.au; red circles) and the current IUCN distribution for platypus.

Habitat

Platypuses are semi-aquatic mammals, primarily inhabiting rivers and waterways. They occasionally move overland between water bodies and river catchments to disperse (Scott and Grant 1997, Kolomyjec et al. 2009, Furlan et al. 2013). Platypuses prefer rivers and streams with pool and riffle sequences of 1-5 metres depth (Rohweder 1992, Bryant 1993, Ellem et al. 1998, Grant 2004). Presence of riparian vegetation is important for habitat complexity, as it provides stable banks for construction of burrows and in-stream organic material (Rohweder 1992, Bryant 1993, Serena et al. 2001). Riverbed substrate is also an important habitat quality, with platypuses preferring a combination of gravel, pebbles, cobbles, and larger rocks for foraging (Rohweder 1992, Serena et al. 2001, Grant 2004). While all these factors are important habitat characteristics, platypuses are also found in a variety of environments, including in degraded agricultural areas (Grant and Denny 1991a, Rohweder and Baverstock 1999).

Platypuses use riverbanks for construction of both resting and nesting burrows, typically preferring vegetation consolidated banks greater than 0.95 m (Brunt et al. 2018). Resting burrows can be up to three metres long, with entrances mainly occurring above the surface of the water. Their nesting burrows, which are up to 30m long, are constructed by females over one or more breeding seasons to house dependent offspring until emergence (Burrell 1927).

Ecology

Platypuses have lived up to 21 years in the wild and 25 years in captivity, although most survive between 6-15 years (Bino et al. 2019). They are seasonal breeders, with breeding beginning earlier in the year in lower latitudes. In NSW, breeding begins in August and juveniles emerge between January and March, while in Tasmania breeding begins around two months later (Connolly et al. 1998, Temple-Smith and Grant 2001). During courtship, male and female platypuses engage in courting behaviour where the male grabs hold of the females tails with its bill, before he is lead through a series of slow twists and turns prior to mating (Bino et al. 2019). Females will then construct or utilise an existing nesting burrow where they typically lay 1-3 eggs, hatching to dependent nestlings (usually 1 or 2). Nestlings are suckled in the burrow for 120-140 days in captivity (Hawkins and Battaglia 2009, Thomas et al. 2018), but probably for a shorter period in the wild (Grant et al. 2004).

Platypuses are opportunistic predators, feeding on a variety of benthic macroinvertebrates, foraging for food in pool and riffle habitats of rivers and streams for up to 16 hours a day. Platypuses normally utilize between 0.5-15 km of rivers, with males moving greater distances than females, especially during the breeding season (Bino et al. 2019). Juvenile males are also reported to move distances of greater than 40 km from their natal sites during dispersal (Serena and Williams 2012).

Conservation status

Limited by a poor knowledge base, the platypus is currently listed as ‘Near Threatened’ under the IUCN Red List, but not currently listed at risk under Australia’s *EPBC Act 1999*. In South Australia, the platypus is currently listed as Endangered (*National Parks and Wildlife Act 1972*), while in Victoria it was recently recommendation for listing as Threatened.

Threats

The platypus is facing numerous threats right across the species’ distribution. Increases in agriculture and urbanisation have resulted in land clearing, which has reduced riparian vegetation and impacted instream organic matter and habitat availability (Bradshaw 2012, Evans 2016). The species is particularly vulnerable to urbanisation and has disappeared from Melbourne’s CBD, now rarely sighted within 15 km of the city (Serena and Pettigrove 2005). The building of dams and extraction of water also poses a significant threat to platypuses, given the distribution of the species’ overlaps significantly with Australia’s most regulated rivers. Alterations to flow regimes, including the timing and temperature of flows, can significantly impact platypus abundances downstream of these regulatory structures (Hawke et al. 2020a). There is also evidence that dams can restrict lifetime dispersal of platypuses (Mijangos et al. unpublished data). In the short term, reduced dispersal will limit the ability of one part of the river to recolonize another part that has experienced adverse effects. In the medium term, dividing the river into two separate populations, that must be smaller than the entire pre-dam population, is expected to lead to loss of genetic diversity which in-turn reduces survival and breeding, as well reducing the ability of populations to respond to environmental change (Frankham et al. 2002, Allendorf and Luikart 2007).

Platypuses are susceptible to predation by red foxes (*Vulpes vulpes*) and dogs (*Canis familiaris*), (Grant and Fanning 2007), with anecdotal evidence of predation by feral cat (*Felis catus*). Closed topped yabby traps (e.g. Opera house style), can drown platypuses which become trapped inside and cannot escape. In Victoria, where mortality was tracked and could be assigned, 56% of 186 platypus mortalities (1980–2009) were caused by drowning in illegal nets or enclosed traps (Serena and Williams 2010). The Victorian Fisheries Authority announced a state-wide ban on enclosed traps in 2019, but they can still be used in private waters in NSW and QLD and are still used illegally in some public waters where platypuses occur. The nature of platypus foraging also makes them particularly susceptible to entanglement around their neck and torso by plastic, fishing line, and rubber bands.

Climate change is predicted to significantly contract the species' climatic niche (Klamt et al. 2011), likely to be further impacted by increasing severity and frequency of droughts (Bino et al. 2020a). During the recent (2017 -2019) extreme drought across much of eastern Australia (in some areas the worst in over 120 years of records; BOM Webinar 18 July 2019), many incidences of platypus distress and mortality were reported in the media as well as through private communications with WIRES, zoos, and platypus conservation groups. Reductions to river flows due to increased dry periods and increases in temperature are predicted to have a significant impact to the future survival of the species in its northern extent (Klamt et al. 2011). Drying of streams and refuge pools will increase overland movements that make platypuses more susceptible to predation and air temperatures in excess of their upper thermal tolerance of over 30°C (Robinson 1954). Increases in drought frequency and severity are predicted to reduce the total population abundance of platypuses by up to 73% within the next 50 years (Bino et al. 2020). Increasing human water demands during drought conditions will increase stress on water sources with regulation of rivers with dams likely exacerbating these impacts (Klamt et al. 2011).

Increased severity and occurrence of fires is also likely to significantly impact platypus populations due to loss of riparian vegetation and reduced water quality, through deposition of ash and sediment into streams. Previous research on the impacts of fires to platypuses suggest mixed impacts of the fires, and more research is needed to determine how platypuses respond to fires.

Fires

Fire impacts

Fire is a natural disturbance ubiquitous to almost all vegetative terrestrial ecosystems, interacting with the landscape across complex spatiotemporal and evolutionary scales (McKenzie et al. 2011). Fire is driven and regulated by both abiotic and biotic factors alike, representing an interactive process which shapes landscapes and the ecosystems within (Falk et al. 2007, Kelly et al. 2017). At fine spatial scales, fire extent and intensity are driven by ignition properties, fuel load, and climate, while at larger scales, fire is influenced by topographic characteristics such as elevation, slope, and aspect.

When fires move through the landscape, nutrients are released (e.g., nitrogen and phosphorus) (Sherson et al. 2015), also promoting runoff and erosion, significantly increasing inputs into freshwater habitats that can extend long past the actual fire (Gresswell 1999, Benda et al. 2003, Coombs and Melack 2013). Increased inputs have both rapid and long-lasting impacts to water quality, reducing dissolved oxygen and increasing turbidity, pH, and dissolved organic compounds (Dahm et al. 2015; Harris et al. 2015) as well as the long term water yield in some areas (Lane et al. 2010). Fires can also open up riparian vegetation and influence light penetration, increasing temperature and microbial activity (Rodríguez-Lozano et al. 2015). Fire's effect on the freshwater fauna is equally complex, dependant on the cause and effect interactions throughout the food web, able to alter freshwater communities following changes to habitat and resources.

Fires in Australia

Australia's fire history began approximately 30 mya following the breakup from Gondwanaland and the northerly drift of the continent (Bear 1977). Charcoal records suggest changing fire activity in response to climate, predominantly increasing during the late Pleistocene and Holocene (Murphy et al. 2011) but may have been enhanced by Aboriginal activity (Kershaw et al. 2002), peaking during the late 19th century (Bradstock et al. 2002). Since European colonisation, fire regimes have dramatically changed, with an overall decrease as a result of fire suppression on account of land use change and agricultural expansion (Marlon et al. 2008). At the same time, fires have intensified and even changed in timing in more natural areas (Russell-Smith et al. 2007).

In areas experiencing increased fire frequency and intensity, species declines have been documented, often interacting with anthropogenic threatening processes (Woinarski et al. 2010, Chia et al. 2015, McLean et al. 2018, Hradsky 2020). A changing climate towards hotter and drier climates is already increasing fire frequencies and intensities around the world (Flannigan et al. 2013, Abatzoglou et al. 2019) including Australia (Di Virgilio et al. 2019, Dowdy et al. 2019). The 2019/20 fire season in Australia was exceptionally prolonged, extensive, and severe, burning almost 19 million hectares in over 15,000 fires (Filkov et al. 2020), costing the economy as much as AUD$40 billion (Wilkie 2020), and killing an estimated 3 billion animals (van Eeden et al. 2020).

Fires and platypus

Increased severity and occurrence of fires is likely to significantly impact platypus populations due to loss of riparian vegetation and reduced water quality resulting from deposition of ash into streams. Previous research in the species' southern extent (Victoria) found no effects of fire (Williams and Serena 2006, Serena and Williams 2008, Armistead and Weeks 2009, Griffiths and van Rooyen 2015). However, lack of pre-fire surveys to provide information on abundances and recruitment rates, limit conclusions from these studies. It is anticipated that in some areas, severe fires, in combination with drought and reduced water availability, will have a significant effect on platypuses.

The fires which occurred in 2019 and 2020, which were preceded by a severe drought in many parts of the platypus' range, have likely had significant impacts to platypus populations. The timing of the fires may have also increased the impact of the fires, occurring and having a legacy impact during late breeding stages and juvenile emergence in some regions (Grant et al. 2004). To estimate the extent to which platypuses were exposed to fires, we used the predicted probability of occurrence derived from the developed habitat suitability model. Following examination of model accuracy, we removed probabilities lower than P = 0.25. We then summed probabilities (cell size 250 m × 250 m) across all Australian bioregions that intersected with the predicted platypus distribution. Within each bioregion, we then calculated the sum of probabilities that overlapped with the extent of the recent fires (Environmental Resources Information Network 2020) and calculated their proportion from the sum of probabilities across the entire bioregion. We estimate that 13.56% of available platypus habitat was impacted during the 2019-20 fires (van Eeden LM et al, unpublished).

Fire impacts on platypus – Case study, MidCoast NSW

Study area

The Manning and Hasting River systems are located in the mid-north coast of eastern Australia and are part of the North Coast biogeographic region (Figure 2). The area supports sub-tropical and warm temperate rainforests and wet sclerophyll forests (NSW DPIE 2020b). We surveyed platypuses in the Manning River catchment (Dingo, Bobin, and Bulga Creeks) and the Hastings River catchment (Thone River), (Figure 3).

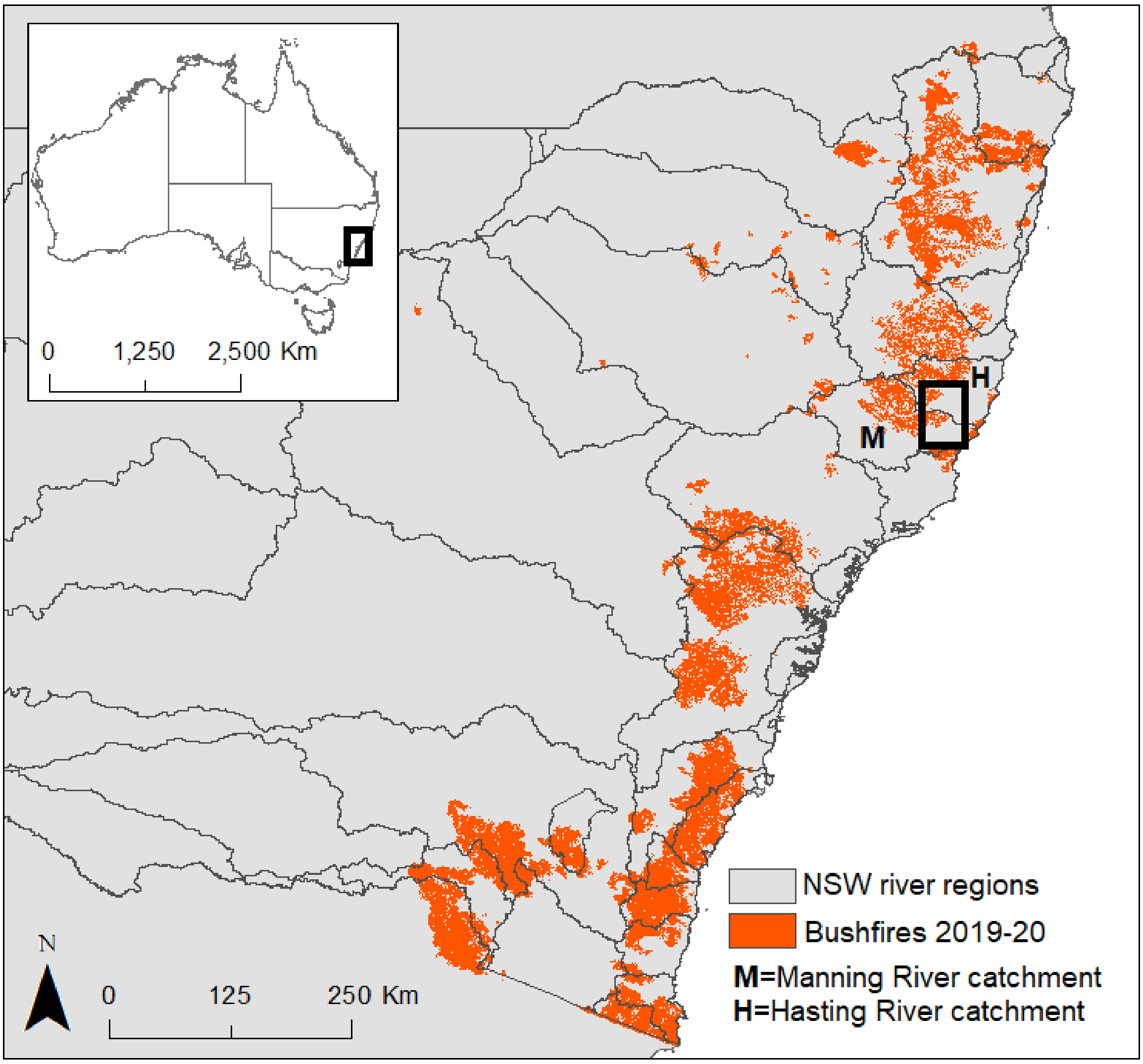

Figure 2. Location of the Manning (M) and Hastings (H) River catchments and the extent of the fires in NSW in 2019-20.

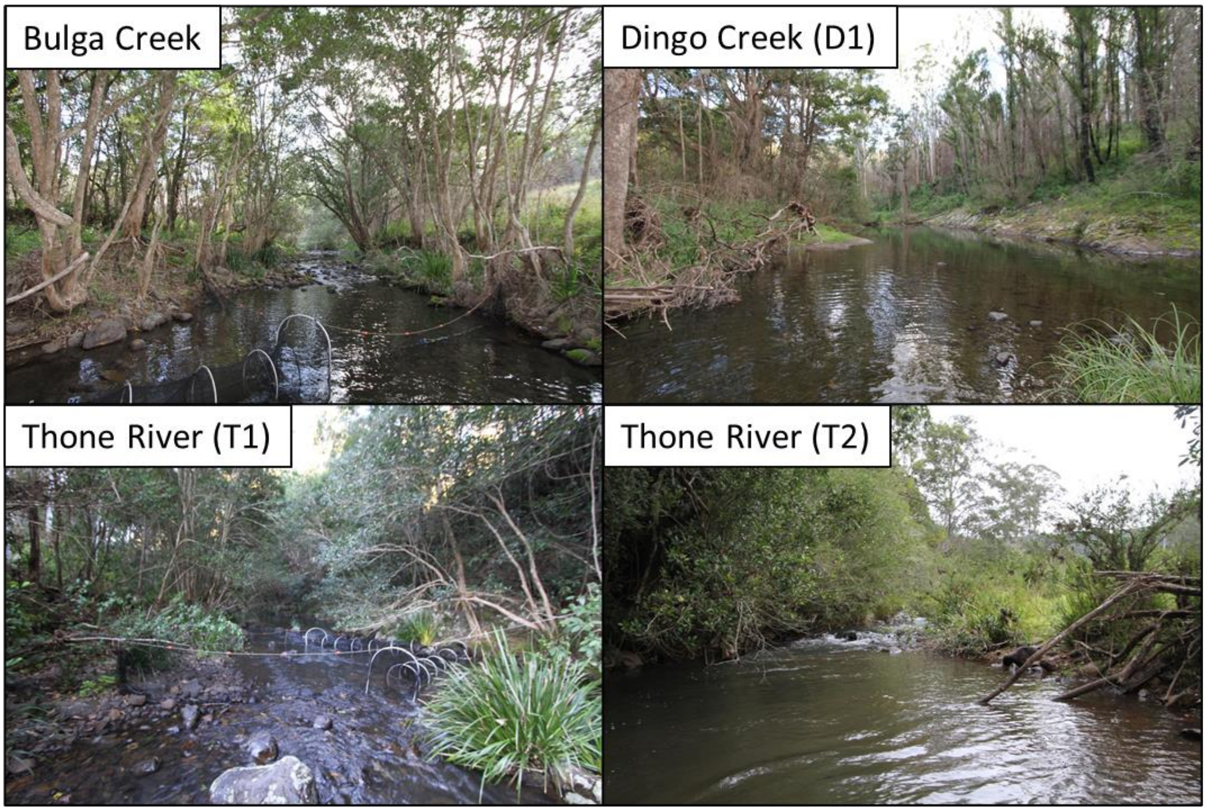

Figure 3. Representative photographs of burnt (Bulga and Dingo Creek) and unburnt (Thone River) sites at time of surveys

Over the summer of 2019-20, both river catchments experienced a severe drought, with water levels significantly diminishing. Dingo Creek ceased to flow between November and December 2019 and the Thone River neared cease to flow during the same period (Figure 4). In early 2020, significant rainfall increased discharge and water levels to pre-drought levels.

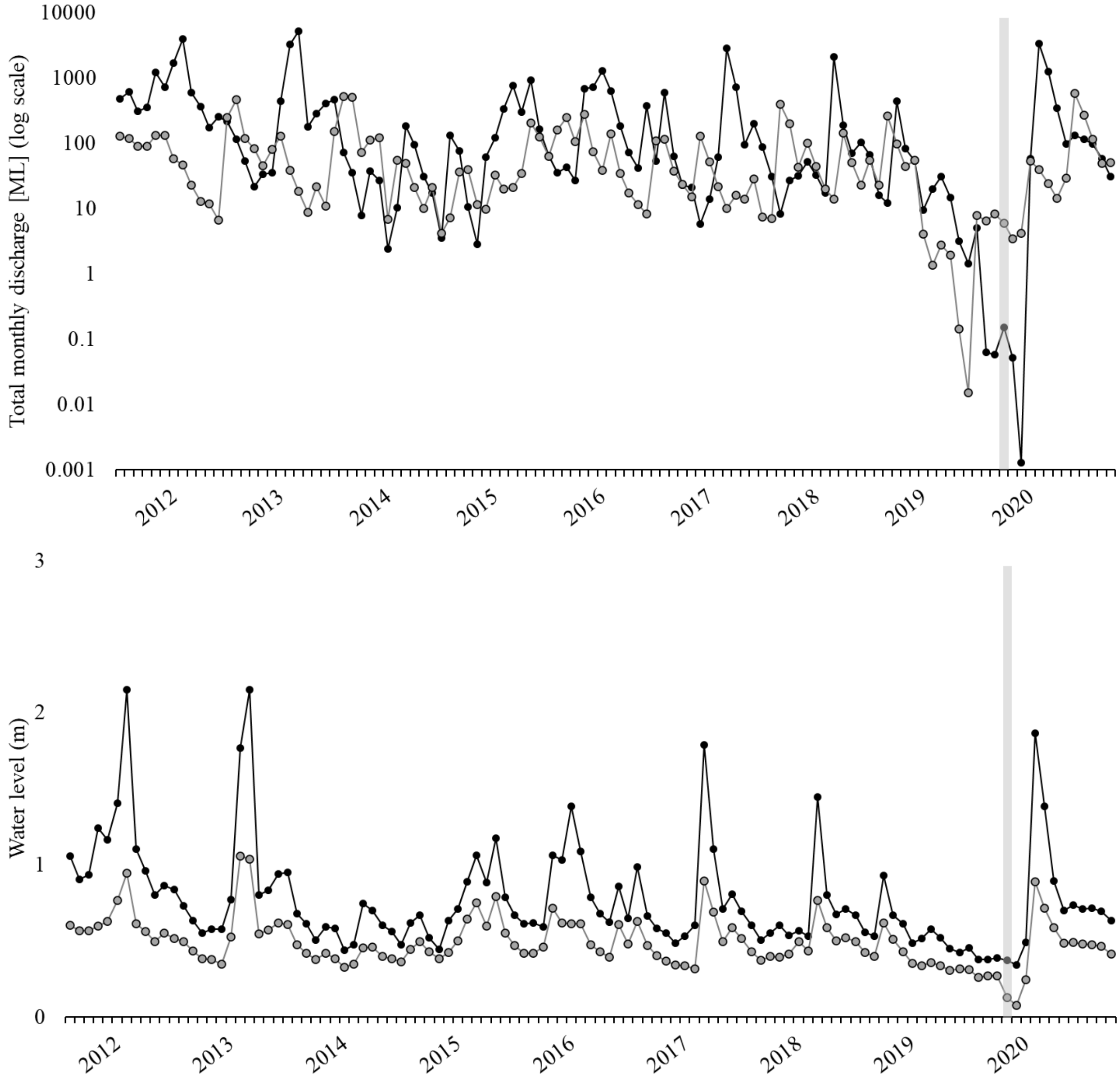

Figure 4. Average monthly (top) discharge [ML] and (bottom) water level (m) in Dingo Creek (black) and Thone River (grey) between July 2011 and October 2020 with the timing of the fires around Dingo Creek over November 2019 marked (grey bar).

We used mapped extent and severity of the 2019-20 fires, derived from Sentinel 2 satellite imagery (NSW DPIE 2020a) and a Random Forest classification approach based on a number of indices (Collins et al. 2018). We calculated the proportion of burnt area classified as: 1. burnt grassland; 2. burnt understory with unburnt canopy; 3. partial canopy scorch; 4. complete canopy scorch; and 5. complete canopy consumption, within a 500 m buffer around surveyed sites, using ArcMap (ESRI 2019). We also reviewed historic (1988 – present) fire extent in the areas (NSW DPIE 2020c) to evaluate possible long term impacts of fires in the areas.

At the height of the drought (November 2019), a severe and extensive fire swept through the area, burning over 2623 km^2 in the Manning River catchment (31.9% of 8219.8 km^2) and 1825 km^2 in the Hastings River catchment (40.1% of 4548.8 km^2), (Figure 5). Within 500m buffer around burnt surveyed sites along Dingo Creek, the total proportion of burnt area generally declined with elevation with varying intensities, declining from 100% in the upper reaches of the burnt Dingo Creek sites to 14% and none in the lower reaches of Dingo Creek (Figure 6). Since 1988, there was only one other small (~500ha) fire in 2002 in Dingo Creek area (Appendix 1). None of sites along the Thone River or its upper reaches were impacted by fires, either in 2019 or within the historical record (Figure 5).

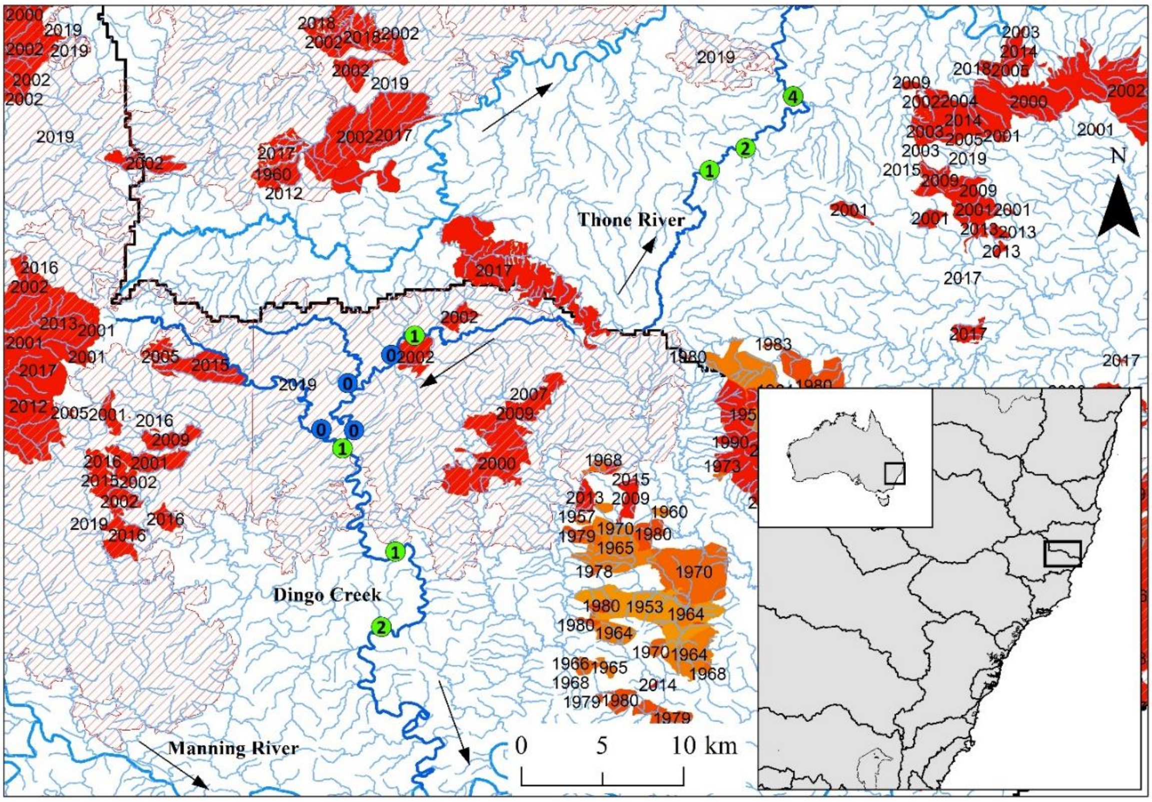

Figure 5. Fire boundaries for every year for which there is data since 1988. The 2019-20 fire is outlined in black rather than filled (https://datasets.seed.nsw.gov.au/dataset/fire-history-wildfires-and-prescribed-burns-1e8b6).

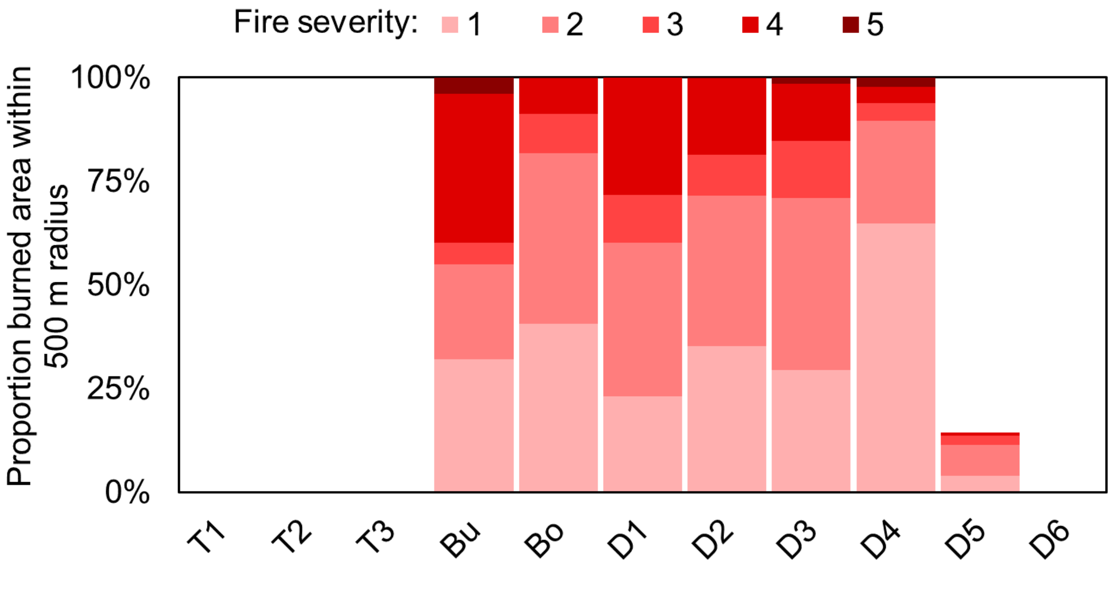

Figure 6. Proportion of burned area within one km radi around each site assessed based on fire extent and severity of the 2019-20 fires measured using sentinel 2 satellite imagery (NSW DPIE 2020a), classified as 1. burnt grassland; 2. burnt understory with unburnt canopy; 3. partial canopy scorch; 4. complete canopy scorch; and 5. complete canopy consumption.

Platypus surveys and analysis

We surveyed platypuses over 11 trapping nights, 22nd July-2nd August 2020 in the Manning (Dingo Creek and two tributaries: Bobin and Bulga Creeks) and Hastings (Thone River) River catchments, seven months after the severe 2019 fire. In selected sites of small shallow (<1m) streams, we used four pairs of double winged fyke nets (30 mm knotless 20 ply nylon, 1 m x 5 m wings and 0.8 m x 5 m wings), pairing them with one facing upstream and the other facing downstream, spaced over a distance of <500m. Fyke nets were set towards 17:00 and checked every three hours until 08:00am Eastern Daylight Time (EDT). As survey effort when using fyke nets can often be uncertain, we counted the four pairs as single survey nights, also standardising Catch Per Unit Effort (CPUE) as net hours. In deep pools (>1.5m), we used unweighted mesh nets (80 mm multifilament nets 50m x 2 m). Mesh nets were set from 17:00 EDT until midnight, and checking every 2-3 minutes with a spotlight, immediately removing platypuses and non-target species. We also physically examined nets every hour to remove snags.

Where waterways were directly impacted by fires, we surveyed platypuses over a series of six nights: four (Dingo Creek), one (Bulga Creek), and one (Bobin Creek), hereafter all referred to as burnt sites on Dingo Creek, given Bulga and Bobin Creeks are tributaries of Dingo Creek (Figure 2). This equated to 20 Fyke pairs (240 net hours) and one mesh night (6 hours). We also surveyed for two nights on Dingo Creek at two sites not directly impacted by the 2019 fire (Figure 2), using 50m of mesh nets, equating to two nights and total of 12 net hours. We surveyed for three nights on the Thone River, not impacted by the 2019 fire, two nights using Fyke nets (eight Fyke nights, total of 96 net hours) and one night using 50 mesh net (total of 6 net hours).

Captured platypus were removed from the water and held in pillow cases, prior to anaesthetic induction in an induction chamber, using isoflurane (Pharmachem) (5%) in oxygen (3L/min), (Darvall DVM ISO) (Booth and Connolly 2008, Chinnadurai et al. 2016, Fiorello et al. 2016). Platypuses were then maintained under anaesthesia, via a T-piece and face mask, supplying isoflurane (1-2.5%) in oxygen (1.0L/min) (Vogelnest and Woods 2008). Blood oxygen saturation, heart rate, and body temperature were continuously monitored (Darvall H100N). All platypuses were injected with a Passive Integrated Transponder (PIT) tag (Trovan), subcutaneously between the scapulae, and weighed, measured, sexed, aged. Sex and age class were determined using spur and spur sheath morphology (Williams, Serena, & Grant, 2013). We also measured the animals Tail Volume Index (TVI), a commonly used metric for fat storage (Grant and Carrick 1978). We estimated the Packed Cell Volume (PCV) from collected blood samples, using a microhematocrit heparinized capillary tube, following centrifugation (75μL, 14000 g, 5 min). Total protein (TP) was then measured using a refractometer and the specific gravity scales (g/100ml).

We also surveyed macroinvertebrates, using a 350mm mesh sweep net (opening 33 x 26 cm) by holding the net opening upstream, flush with the substratum, and kicking and dislodging the substratum, taking three samples from random locations (Chessman 2003). We quantified abundance, identified to order, and calculated a biotic index for river macroinvertebrates using the Stream Invertebrate Grade Number Average Level (SIGNAL) score (Chessman 2003), using categories of invertebrate abundances: 1-2, 3-5, 6-10, 11-20, and >21. We also measured pH, Dissolved Oxygen (0-100%), total Dissolved Solids (ppm mg/L) and Conductivity (μS/cm), using a multiparameter water meter (HANNA HI9829) at each site. We reviewed water quality measurements undertaken by MidCoast council taken from Dingo Creek (Ashlea Bridge) between 18/1/2020 – 10/6/2020, following the fires and first flush of water (MidCoast Council 2020). We calculated monthly mean discharge and water levels on Dingo Creek (Belbourie Bridge 208032) and on the Thone River (Deep Creek Road 207018), (waterinfoNSW 2020).

We assessed three possible explanatory variables that best explained variation in platypus capture rates, macroinvertebrates, and water quality. These included whether the site was burnt, net type, and river. We used Generalized Linear Models (GLMs), with a Poisson error term for count data (platypus or macro-invertebrates) or Gaussian for SIGNAL score or water quality. Given small sample sizes, we undertook a univariable approach, modeling response variables against each explanatory variable separately, ranking model fit using the corrected Akaike Information Criterion (AICc) (Grueber et al. 2011) and assessing effect size within the R environment (R Development Core Team 2020).

Platypus Captures and demographics

On Dingo Creek's burnt sites, we trapped one platypus (male adult) over five nights (20 sites), when using Fyke nets (Figure 2), equating to 0.04 platypuses per Fyke night, and one platypus (female adult) in one night, using a mesh net (Figure 2 and Table S1). On the unburnt sites on Dingo Creek, not directly impacted by the fire, we trapped three platypuses (two male and one female adult) over two nights when using mesh nets, equating to 1.5 platypuses per mesh net night. In comparison, we trapped three platypuses (two male adults, of which one was recaptured 3 km from site of first recapture) on the unburnt Thone River, over two nights (eight sites), when using Fyke nets (0.375 platypuses per Fyke net night or 0.250, not considering recapture). We also trapped four platypuses (two male adults, one female adult, and one unknown - escaped from the net during retrieval) in one night, when using a mesh net, representing four platypuses per mesh net night, or three if the escaped fourth platypus was a recapture (Figure 1). Platypus numbers were best explained by whether sites were burnt followed by River (ΔAICc 2.3) and net used (ΔAICc 2.8), significantly lower in burnt sites (P=0.02) and on Dingo Creek (P=0.02) and higher when using mesh nets (P=0.04), (Appendix S2-S3). Platypus densities on burnt sites were low compared to other studies, although density estimates are predominantly biased towards the species' southern range (Hawke et al. 2020b).

Whether the fires directly impacted platypuses remains undetermined, particularly given platypus body condition was similar between burnt and unburnt areas. However, the timing of the fires, as well as an extreme drought, may have also impacted their recruitment, given the fires coincided with the period of juvenile rearing in burrows and emergence (Grant et al. 2004). Unexpectedly, there was a strong male bias on the Thone River (1 female/4 males) while, on Dingo Creek, captures were more balanced (2 females/3 males). In our surveys, seven months after expected emergence of juveniles, we did not record any ues. All animals in both areas presented themselves in good condition with no apparent differences in Tail Volume Index between burnt and unburnt sites. Total protein count of platypuses on the burnt Dingo Creek sites averaged 6.74±0.40SD, compared to 6.56±0.77SD on the unburnt Thone River sites while packed cell volume was 55.6±6.9SD and 51.8±5.4SD, respectively.

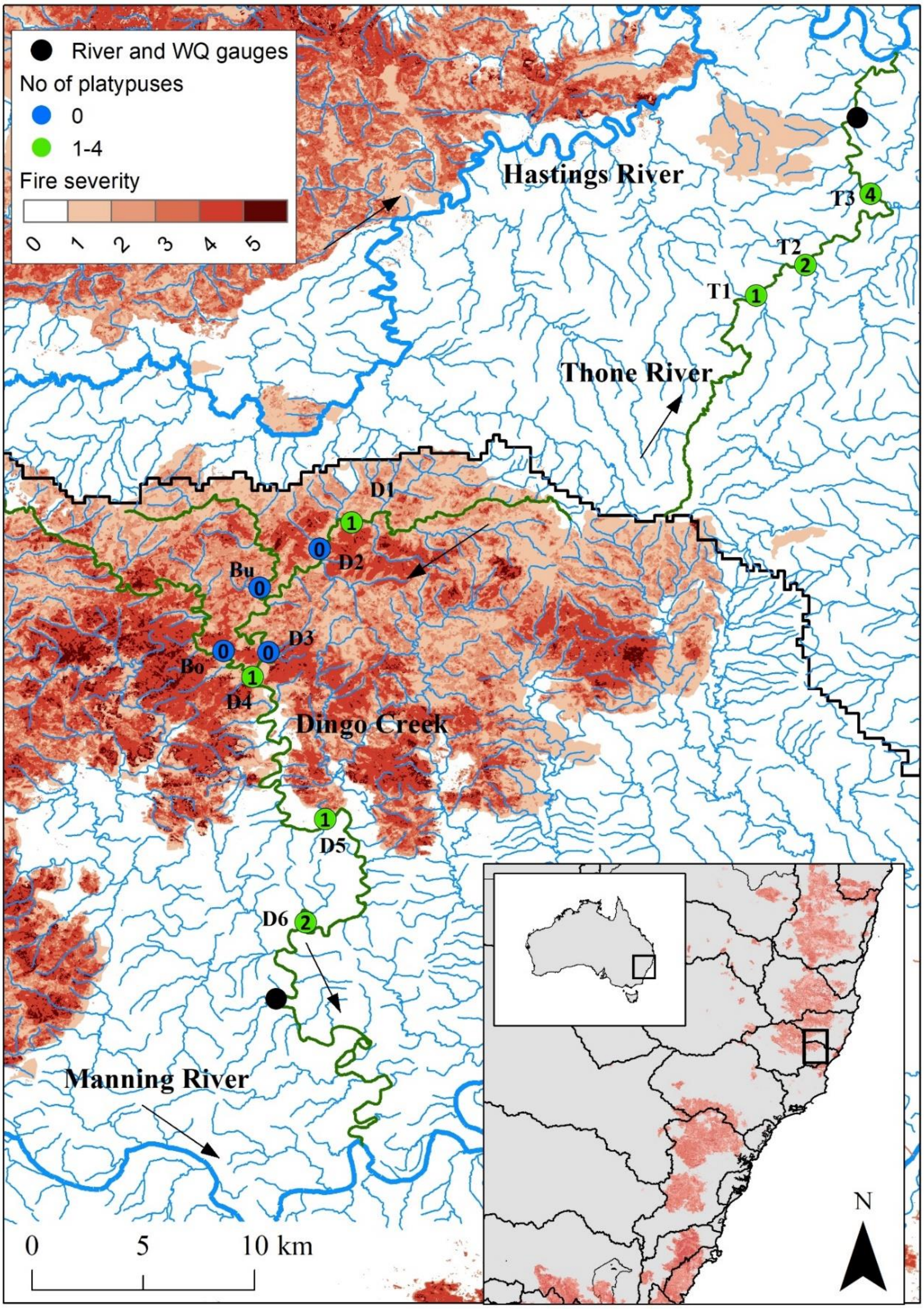

Figure 7. Number of platypuses caught in the Dingo, Bulga and Bobin Creeks (green lines) in the Manning River catchment and in the Thone River (green line) in the Hasting River catchment (catchments are delineated by black lines) along with the fire extent and severity (four classes (NSW DPIE 2020a))

Table 1. The river, site, date, net type, sex, and age of platypuses captured during surveys on Dingo Creek and the Thone River.

River	Site	Date	Net Type	Recapture	Platypus#	Sex	Age
Dingo	Dingo1	24/07/2020	Fyke (x4 pairs)	N	D1	Male	Adult
Dingo	Dingo4	27/07/2020	Gill (50m)	N	D2	Female	Adult
Dingo	Dingo5	29/07/2029	Gill (50m)	N	D3	Male	Adult
Dingo	Dingo6	2/08/2020	Gill (50m)	N	D4	Female	Adult
Dingo	Dingo6	2/08/2020	Gill (50m)	N	D5	Male	Adult
Thone	Thone1	1/08/2020	Fyke (x4 pairs)	Y	T1	Male	Adult
Thone	Thone2	28/07/2020	Fyke (x4 pairs)	N	T1	Male	Adult
Thone	Thone2	28/07/2020	Fyke (x4 pairs)	N	T2	Male	Adult
Thone	Thone3	30/07/2020	Gill (50m)	N	T3	Male	Adult
Thone	Thone3	30/07/2020	Gill (50m)	N	T4	Male	Adult
Thone	Thone3	30/07/2020	Gill (50m)	N	T5	Female	Adult
Thone	Thone3	30/07/2020	Gill (50m)	NA	NA		

Water quality

Water quality measurements from Dingo Creek on the 18th of January 2020, following the fires and first flush of water (MidCoast Council 2020), indicated high of turbidity (NTU 220), low dissolved oxygen (DO 3.43 mg/L), acidity (pH 6.6), high dissolved organic compounds (DOC 20 mg/L), and high nutrients (3.43 TN mg/L, 3.92 TP mg/L). In the following months (February – June) as flows continued, water quality metrics improved (NTU 1.5, DO 9.55 mg/L, pH 8.5, DOC 1.8 mg\L, TN 0.11 mg\L, TP 0.01 mg\L), (MidCoast Council 2020). During our platypus surveys, dissolved oxygen differed among sites, generally decreasing with increased elevation, significantly lower in burnt sites (average 38.9%±11.4SD, P=0.02, Tables S2-S3) compared to unburnt sites (59.5%±11.2SD, P=0.02) but also higher on the Thone River (65.1%±0.85SD, P=0.004) compared to Dingo Creek sites (39.5%±10.5SD), including the lowest reading at the Bulga Creek site (17.8%). Turbidity, conductivity, and pH did not significantly differ between burnt sites nor rivers.

Macroinvertebrates

Macroinvertebrate communities were diverse and abundant, with between four to nine taxonomic orders and a SIGNAL score between 3.72 to 5.63 (Table 1), with no significant difference between rivers (Tables S2-S3). However, there were marginally higher numbers of yabbies (Decapoda, P=0.087) and beetles (Coleptera, P=0.064) but less segmented worms in (Oligochaeta, P=0.001) in the unburnt Thone River compared to the fire impacted creeks (Table 2).

*Table 2. Macroinvertebrate survey results at different burnt (directly burnt (DB), and unburnt sites (UB), see Figure 2 for location and Figure 3 for burn severity), classified into categories of invertebrate abundances: 1-2, 3-5, 6-10, 11-20, and >21 (Chessman 2003), deep pools (>1.5m) are marked with *, see burnt impact in Figure 3.*

Type	Order	Bug grade	Bu	Bo	D1	D2	D3	D4	D5*	D6*	T1	T2	T3*
			DB	DB	DB	DB	DB	DB	UB	UB	UB	UB	UB
Mayflies	Ephemeroptera	9	>20	6-10	1-2	11-20	11-20	0	15	1-2	11-20	>20	15
Cadissflies	Trichoptera	9	1-2	>20	0	3-5	>20	11-20	0	1-2	6-10	0	11-20
Alderflies	Megaloptera	8	0	1-2	0	0	0	0	0	0	0	0	0
Mite	Trombidiformes	6	>20	0	>20	>20	11-20	0	>20	1-2	>20	0	>20
Yabbies	Decapoda	4	0	1-2	15	3-5	0	0	0	0	11-20	11-20	>20
Beetles	Coleoptera	4	1-2	1-2	1-2	3-5	3-5	1-2	6-10	3-5	>20	11-20	1-2
Dragonflies	Odonata	3	6-10	11-20	>20	>20	>20	11-20	6-10	>20	>20	6-10	>20
Fly larva	Diptera	3	0	0	0	0	0	0	0	1-2	0	0	0
Freshwater mussels	Bivalvia	3	0	0	0	1-2	0	0	0	0	0	0	0
True bugs	Hemiptera	2	>20	>20	>20	>20	>20	>20	>20	>20	>20	0	6-10
Segmented worms	Oligochaeta	2	1-2	0	11-20	>20	6-10	11-20	0	1-2	0	0	6-10

Impacts of fire and drought

Platypuses are increasingly under threat from direct and indirect human developments across much of their range. In November 2020, they were recommended for listing as vulnerable in Victoria, a stronghold for the species (SAC 2020) and listed as Endangered (*National Parks and Wildlife Act 1972*) in South Australia. Although considered ubiquitous in eastern Australia, there is increasing evidence of historically higher numbers (Hawke et al. 2019) and more recent local declines. Fires likely pose another largely unrecognised significant threat, compounded by severe droughts which are further exacerbated by river regulation and demand for fresh water (Bond et al. 2008, Griffiths et al. 2019).

Platypuses are mainly aquatic, but occasionally move across land between water bodies, particularly during dry periods (Furlan et al. 2013; Kolomyjec et al. 2009; Scott & Grant 1997), making them more susceptible to predation (Grant & Fanning 2007), as well as susceptible to exceeding their upper thermal tolerance of 30°C (Robinson 1954). During the Millennium Drought (2002-2009) severe declines in platypus numbers and distribution were observed in impacted rivers (Griffiths and Weeks 2013, Griffiths and van Rooyen 2015). During the recent (2017 -2019) extreme drought across much of eastern Australia, in some places worst in over 120 years of records (Jones and Coulton 2019)), many incidences of platypus distress and mortality were reported through private communications with WIRES, zoos, landholders and platypus conservation groups (Bino, G., Kingsford, R. pers comm) as well as in the media (Sullivan 2020). Increased frequency and severity of fires, often following severe droughts (Littell et al. 2016), will further strain the viability of platypus populations, particularly in small streams likely to dry out. Continued reductions of river flows from prolonged dry periods along with increases in temperatures (CSIRO and Bureau of Meteorology 2015) are predicted to significantly impact the future survival of the species (Klamt et al. 2011, Bino et al. 2020b).

But there are opportunities to improve conservation outcomes and the resilience of populations to both droughts and fires. These include identifying and protecting freshwater refugia during droughts, minimising sedimentation which fill up pools, ensuring sustainable diversion of water, protecting riparian vegetation structure, and development of regeneration strategies. Ensuring movement of platypuses across barriers, including dams and in-stream structures which fragment populations, will also allow access to critical freshwater refugia and recolonisation. Developing monitoring programs, utilising both systematic, as well as citizen science surveys, are needed to provide essential baseline data to better understand the impacts of threatening processes and prioritise future conservation strategies.

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Appendix

Table 3. Platypus capture, proportion of burnt area within 500m buffer (%) and morphometric [mm] details, Tail Volume Index (TVI), Packed Cell Volume [%], and Total Protein Count [g/100ml].

River	Site	Burnt [%]	Date	Net Type	Recapture	Microchip Number	Platypus#
Dingo	D1	100	24/07/2020	Fyke (x4 pairs)	N	0007A3A112	D1
Dingo	D4	100	27/07/2020	Gill (50m)	N	00079F5DFD	D2
Dingo	D5	14.4	29/07/2029	Gill (50m)	N	00079FE3D8	D3
Dingo	D6	0	2/08/2020	Gill (50m)	N	0007E0B312	D4
Dingo	D6	0	2/08/2020	Gill (50m)	N	0007E0C003	D5
Thone	T1	0	1/08/2020	Fyke (x4 pairs)	Y	0007A3C490	T1
Thone	T2	0	28/07/2020	Fyke (x4 pairs)	N	0007A3C490	T1
Thone	T2	0	28/07/2020	Fyke (x4 pairs)	N	0007A3B0FE	T2
Thone	T3	0	30/07/2020	Gill (50m)	N	0007E0CA9A	T3
Thone	T3	0	30/07/2020	Gill (50m)	N	0007E0AC69	T5
Thone	T3	0	30/07/2020	Gill (50m)	N	0007E0ADF4	T4
Thone	T3	0	30/07/2020	Gill (50m)	NA	NA	NA

Platypus#	Sex	Age	Weight [kg]	Spur length (sheath)	Bill width	Bill length w/o shield	Body length	Tail length	Tail width	TVI	PVC (%)	TPC
D1	M	A	1.27	10	49	53	505	140	80	2	68	7.0
D2	F	A	0.9	na	40	45	405	120	80	3	53	6.8
D3	M	A	1.44	13	53	54	550	151	90		53	6.2
D4	F	A	0.85	na	45	55	405	134	70	3	52	6.5
D5	M	A	1.17	14	52	55	485	140	70	3	52	7.2
T1	M	A	1.23	10	50	57	505	160	90	2	55	6.0
T1	M	A	1.23	10	50	57	505	160	90	2	55	6.0
T2	M	A	1.37	11	52	55	520	145	87		57	6.8
T3	M	A	1.22	10	50	53	474	135	76	2	52	6.0
T4	M	A	1.15	15(4)	50	55	477	133	70	4	43	6.2
T5	F	A	0.97	na	42	47	434	132	79		52	7.8