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Short Communication

A silent demise: Historical insights into population changes of the iconic platypus (*Ornithorhynchus anatinus*)

Tahneal Hawke*, Gilad Bino, Richard T. Kingsford

Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, UNSW, Sydney, NSW, 2052, Australia

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ABSTRACT

Platypus (*Ornithorhynchus anatinus*) are evolutionarily distinct monotremes, endemic to creeks and rivers of eastern Australia. Given recent evidence of a contracting distribution and local extinctions, the species was listed as 'Near-Threatened' in 2016. The magnitude of decline remains unknown, given little quantitative evidence of historical abundance and distribution. From data over 258 years (1760–2018), distribution declines surpassed previous estimates, with 41.4% and 12.8% of sub-catchments having no records over the past 10 and 20 years, respectively. Additionally, 44% of sub-catchments within the potential range were lacking data. Further, historic accounts of platypus numbers during the 19th century far exceeded contemporary numbers, likely reflecting the impacts of the fur trade, exacerbated by recent synergistic threats of river regulation and habitat destruction. Improved monitoring is essential to increase understanding and inform effective management of this enigmatic and iconic mammal for which Australia has a global responsibility.

1. Introduction

Long-term changes in populations of wild animals are difficult to estimate, given comprehensive and systematic monitoring of many species only began recently with adequate data available from the 1970s (Collen et al., 2009). Not all extinctions happen quickly, even when accelerated by anthropogenic impacts (Kuussaari et al., 2009), often extending beyond temporal windows of reliable data collection (Thurstan et al., 2015). When quantitative data are lacking, there can be an intergenerational loss of information on historical baselines of abundance, distribution and even morphology ("shifting baselines") (Pauly, 1995). This shifting baseline phenomenon compounds assessment of declines and conservation status, as modern ecological patterns and conditions are perceived as natural and less altered than they actually are (Bilney, 2014; Lindenmayer and Likens, 2009; McClenachan et al., 2012). Historical data is increasingly used to identify and track changes beyond contemporary ecological monitoring, highlighting shifting baselines and consequent priorities for conservation management (Bilney, 2014; McClenachan et al., 2012). For example, detection of declines in abundance of global populations of southern right whales (*Eubalaena australis*) and Caribbean Sea turtles (*Chelonia mydas, Eretmochelys imbricata*) were only possible using historical data (McClenachan et al., 2006).

The platypus (*Ornithorhynchus anatinus*) is a unique semi-aquatic monotreme, endemic to rivers and creeks of eastern Australia, spanning from Cooktown to Tasmania, with a small introduced population on Kangaroo Island. The mammal is

* Corresponding author.
E-mail address: t.hawke@student.unsw.edu.au (T. Hawke).

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evolutionarily distinct, being the only extant member of the Ornithorhynchidae family and one of five monotreme species worldwide (Grant, 2007). Despite their iconic status, knowledge of distribution and abundance remain poor (Woinarski and Burbidge, 2016). Its predominantly nocturnal and cryptic habits have hindered research, with few long-term monitoring studies, focused at relatively fine spatial scales (Bino et al., 2015; Serena et al., 2014). Evidence for a declining distribution primarily relied on one assessment of range decline more than two decades ago (Grant, 1992), concluding minimal change, except extirpation from South Australia. In 2016, the risk of extinction for platypus was raised to 'Near Threatened', given evidence of fragmentation, local declines and extinctions, and increasing extent and severity of threats (Woinarski and Burbidge, 2016). The historical information base remains poor, with no systematic platypus surveys prior to 1970.

In this paper we investigated past and present distribution and numbers of platypus by collating all available historical and contemporary data (1760–2018, 258 years). The use of historical records is a novel approach for platypus, providing valuable insights on societal shifts in baseline conditions after European colonization of Australia. With mounting anecdotal evidence of declines, and increasing threats, this information is critical for assessing the magnitude of decline for this iconic and evolutionarily unique species.

2. Methods

We systematically collated information on the platypus from 1760 to 2018 (258 years, since beginning of available records), using digitized newspaper articles (sourced from Trove, a database of the National Library of Australia), natural history books and explorer journals (Project Gutenberg, Haiti Trust), and museums records (Victorian Museum, Queensland Museum, The Australian Museum and the Smithsonian National Museum of Natural History). To find records, we used all six known names for the species: platypus; watermole; duckmole; duckbill; mallangong; and tambrit. For each record we recorded the date, location and name of source, the activity (i.e. sighting), and observations related to platypus (i.e. number) and general comments/adjectives about social attitudes towards the species.

For platypus distribution, we assessed 25,968 records (1760–2018) from digitized newspaper articles (n = 11,974), Atlas of Living Australia (n = 4734), relevant state and Australian Capital Territory Atlas data (n = 8296; Atlas of Living Australia, 2018; ACT Government, 2017; Tasmanian Government, 2017; OEH, 2017; Queensland Government, 2017; Victoria State Government, 2017), museums (n = 155), platypusSPOT data (n = 804), explorer journals (n = 28) and natural history books (n = 4). From these, we identified 14,162 records with location data from state atlas data (58.5%), the Atlas of Living Australia (33.4%), platypusSPOT (5.7%), digitized newspaper records (1.3%) and museums (1.1%). We assigned each data point to a HydroBASIN Level 7 sub-catchment (Lehner et al., 2008) unit, using ArcMap (ESRI, 2017). For each sub-catchment with a record, we calculated the number of years since the last platypus record. We plotted records $\leq$10 years (2009–2018), >10 years ($\leq$2008) and >20 years ($\leq$1998) in sub-catchments (Fig. 1). We also summarized the number of sub-catchments and area without records, within each of the major river basins (Lehner et al., 2008), within the distribution of the platypus (IUCN, 2016).

We mapped the current assumed distribution (IUCN, 2016) and potential pre-European distribution for the platypus, outside those with existing records. We used the following criteria for the latter, within each drainage basin (Fig. 1): 1. East Coast basin, all sub-catchments without platypus records included, except for those in western Victoria where platypuses were historically uncommon (Grant, 2007); 2. South Australian Gulf, no additional sub-catchments included, as historically uncommon (Grant; Denny, 1991), records from Kangaroo Island population included after introductions in 1928; 3. Murray-Darling Basin, only sub-catchments that included the headwaters of western flowing rivers were included as lower reaches were likely not suitable habitat (Grant; Denny, 1991) and; 4. Gulf of Carpentaria, only headwater sub-catchments of western flowing rivers in Queensland were included and all sub-catchments of Queensland eastern flowing rivers.

To source information on platypus numbers, we assessed a total of 12,006 records (1777–2006) from digitized newspaper articles (n = 11,974), explorer journals (n = 28) and natural history books (n = 4). Platypus numbers were recorded from 179 records from digitized newspapers (99.5%) and natural history books (0.5%). In addition, we systematically reviewed contemporary publications on population estimates and capture rates. We searched the Google Scholar, Scopus, Web of Science and UNSW Library databases using the search terms: platypus population estimate, platypus population size, platypus population dynamics, platypus dynamics, platypus abundances, platypus life history, platypus mark-recapture, platypus tracking, and platypus density. We also obtained historical information on the fur trade during our review of digitized newspaper records of the Sydney Wool and Produce Journal and Sydney Wool and Stock Journal (1820–2006).

3. Results

Platypus were recorded in 268 sub-catchments (832,968.6 km^2), over the past 258 years (1760–2018) (Fig. 1, Supplementary data S1). Only 58.6% of sub-catchments had platypus records between 2009 and 2018, indicating almost half (41.4%, n = 111, 35.8% of distribution) had no records in the last 10 years. Of this, 12.7% (n = 34) have not had a record for at least 20 years (1999–2018), representing 9.2% of the distribution. In the last 10 years, declines occurred across all major drainage basins of the mainland (% of sub-catchments and area): South Australian Gulf (50% of two sub-catchments, 57.2% of area), Gulf of Carpentaria (42.9% of seven, 45.3%), Murray-Darling Basin (50% of 106, 41.7%), and East Coast Basin (37.8% of 143, 31.1%). In the past two decades, platypuses have not been recorded from many of the sub-catchments in the South Australian Gulf (50% of sub-catchments, 57.2% area), East Coast basin (14.7%, 9.5%), and Murray-Darling Basin (11.3%, 9.9%). No declines were

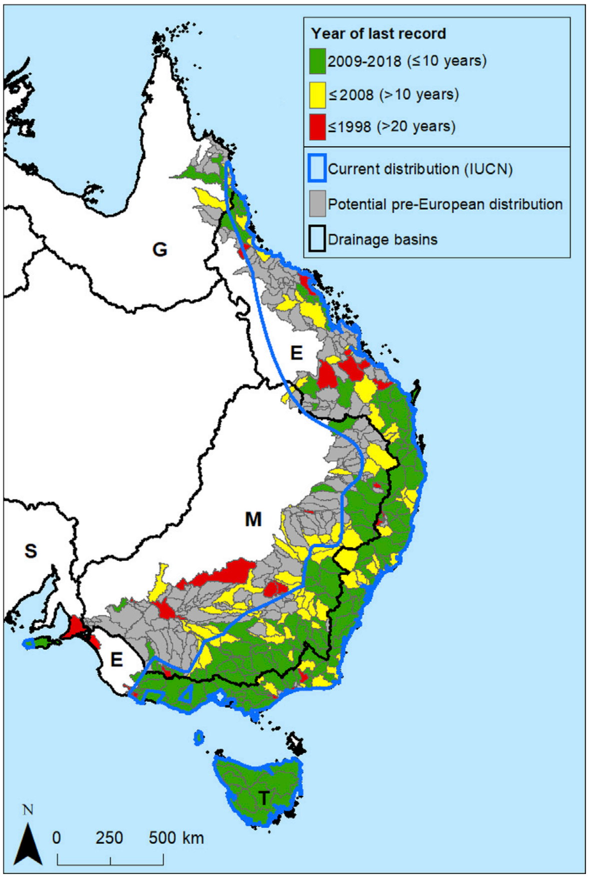

Fig. 1. Years since platypus records in sub-catchments (1760–2018), for major drainage basins (bold lines, Gulf of Carpentaria (G), Murray-Darling Basin (M), East Coast Basin (E), Tasmanian (T), South Australian Gulf (S)). Current estimated IUCN distribution of platypuses in Australia (blue line) and sub-catchments with no platypus records (grey), within potential historical distribution. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

reported in sub-catchments throughout Tasmania. Highlighting a severe knowledge gap, an additional 215 sub-catchments, within inferred historical distribution, had no records of platypus (Fig. 1).

Of 220 collated historical records associated with historical platypus numbers, 179 provided quantitative observations (Supplementary data S2). Although there are some uncertainties surrounding the exact river extent and location of historical events, many suggest historical numbers were far greater than reported today (Tables 1 and 2). An average nightly capture rate of 1.9 platypuses from 40 survey nights, and a maximum nightly capture of seven in the Border Rivers, including the Severn River (Bino, 2016, unpubl. data), was considerably lower than 18 platypuses shot in 1881 on the Severn River. Similarly, in the Snowy River, average nightly capture rate of 2.0 platypuses from 70 survey nights, and a maximum nightly capture of seven (Hawke et al., 2019; unpubl. data) were lower than historical numbers (Table 1). Recent captures in streams and rivers in Victoria were also low (Table 2), suggesting likely declines (cf. 22 platypuses in Melbourne in 1908). Historical qualitative literature further supported numerical evidence of declines (Table 3, Supplementary data S3) but also highlighted population

Table 1
Quantitative historical records of platypus numbers (>10) from digitized newspaper articles (1865–1968, All data available in Supplementary material S2).

Year	Location	Number of platypus	Time/area	Event	Supplementary Index
1865	Shoalhaven River	16–18	"in a few hours"	Shooting	S2.5
1881	Severn River	18	"on an expedition"	Shooting	S2.13
1894	Murrumbidgee River	10	"in one day"	Spearing	S2.19
1908	Yarra River	22	"in a day"	Capture	S2.35
1933	Georges River	8-10 & 15	"at once"	Sighting	S2.84, S2.85
1934	Morwell River	13	"in two pools"	Sighting	S2.91
1937	Snowy River	15–20	"at once"	Sighting	S2.108
1954	Gloucester River	40	"at once"	Sighting	S2.162

Table 2
Contemporary platypus population estimates (1973–2018) from systematic capture surveys.

Year	State	Location	Estimate/captures	Reference
1973–2014	NSW	Shoalhaven River	2.8/km entire study area (19.3/km good habitat)	Bino et al. (2015)
1981, 88/89	NSW	Thredbo River	10.8/km (n = 27, 2.5 km)	Grant et al. (1992)
1989–92	VIC	Badger Creek	1.3–2.1/km	Serena (1994)
1991–93	NSW	Thredbo River	2.5/km (n = 76, 30 km)	Goldney (1995)
1992	VIC	Watts River	1.3/km	Gardner & Serena (1995)
1993	VIC	Badger Creek	1.75/km	Gardner & Serena (1995)
1993	VIC	Watts River	1.25/km	Gardner & Serena (1995)
1995	NSW	Goulburn River	16 individuals tagged over 3.5 km of river and 1.5 km billabong	Gust & Handasyde (1995)
1998	VIC	Yarra River Catchment (Yarra River, Mullum Creek, Diamond Creek)	0.64 platypuses/site night. (29 individuals from 45 site nights)	Serena et al. (1998)
2000	TAS	Upper South Esk River catchment	78 individuals captured in study area (total 5229 trapping hours across 29 streams)	Koch et al. (2006)
2001	VIC	Lake Eildon National Park	0.1–0.3/km	Serena et al. (2001)
2012	SA	Kangaroo Island population	110 individuals on island	Furlan et al. (2012)
2016	NSW	Border Rivers Catchment	Average nightly capture rate (n = 40) 1.9 ± 1.8se, Max nightly capture: 7 Max sighted at once: 4	(Hawke et al., 2019)
2017	NSW	Snowy Rivers Catchment	Average nightly capture rate (n = 70) 2.0 ± 1.7se, Max nightly capture: 7 Max sighted at once: 3	(Hawke et al., 2019)
2018	VIC	Upper Murray Rivers Catchment	Average nightly capture rate (n = 59) 0.64 ± 0.9se, Max nightly capture: 3 Max sighted at once: 1	(Hawke et al., 2019)

fluctuations from the late 19th-mid 20th centuries. Platypus were described as highly abundant before the 1890s, when records began to suggest rapid declines. By the late 1920s, a number of records suggested platypus numbers were increasing in some regions (Table 3). Evidence for historically high numbers of platypus were also supported by the large numbers of platypus shot for their fur. In the Sydney markets, skins were common in the late 19th century, with 754 to 2356 sold annually between 1891 and 1899 (1164 ± 230se traded annually, total 9315, no records for 1897). Additionally, 2000 skins were seized in Victoria in 1931 prior to overseas export.

Tracking these historical changes in abundance, public perception of platypus dramatically changed over the 19th and 20th centuries (Supplementary data S4). In the late 19th century, although some curiosity existed, platypuses were described as destructive and an ‘unwelcome intruder’, believed to have fed on fish eggs and were readily shot. By the early 20th century, there was concern about declining platypus numbers and calls for increasing awareness of protection and nation-wide banning of fur trade, even though hunting continued into the 1920s. In 1927, Tasmania fisheries commissioners admitted to destroying platypus ‘pests’ in salmon ponds. Advocacy for protection emerged in the 1930s, with increasing admiration of the species' natural history and by the mid-20th century, there was a shift in historical articles, previously dominated by skin advertisements and accounts of shootings to sightings and accidental captures (Fig. 2). In 1946 the Chief Secretary of NSW promised to take stricter action on those caught trafficking platypus skins. Platypus were permanently protected nationwide in 1952, after state by state protection, and advocacy for the species continued, with protests against opening rivers to netting. The platypus engraving on the Australian twenty cent coin in 1964 highlighted societal transformation, culminating in the march against damming of the Franklin and Gordon River in 1982, headed by a 12-m model platypus.

4. Discussion

The platypus was previously considered to have experienced limited range contraction with little evidence of any change in abundance, since European settlement (Grant and Denny, 1991). Our analyses, using the novel approach of rigorously tracking historical accounts, strongly indicates considerable range reduction (Fig. 1) and serious declines in numbers (Tables 1 and 2). Impacts of the historic fur trade were a likely cause of substantial declines in platypus abundances, with populations continuing to be affected because its range coincides substantially with ongoing threats (Woinarski and Burbidge, 2016).

Declines in distribution were consistent across the range, except for Tasmania. The Murray-Darling Basin had the greatest number of sub-catchments with no records in the last 10 years, potentially reflecting water resource development and increased drying. Concerningly, 12.3% of sub-catchments had no records for the last 20 years. Given platypus survive 6–15 years in the wild (maximum reported life span of 21 years (Grant, 2004)), possible localised extinctions may have occurred. We acknowledge potential uncertainties of public sightings in wildlife databases, but these are the only available data for the species, highlighting the need for more research and monitoring. Additionally, the absence of records from some sub-

Table 3
Qualitative historical records of platypus numbers from digitized newspaper articles (1865–1968, data available in Supplementary material S3).

Year	State	Location	Observations	Supplementary Index
1865	QLD	Pike's Creek	"Platypus found in nearly every water hole"	S3.1
1865	NSW	Yass River	"The platypus is also found in the banks of the stream in very large numbers"	S3.2
1875	NSW	Campbell's River	"Immense numbers of platypus are found"	S3.4
1879	NSW	Not reported	"Still common in most rivers and creeks of NSW and in some districts found in considerable numbers"	S3.5
1890	NSW	Hay	"platypus are now nearly extinct"	S3.6
1893	SA	Not reported	"formerly found in some of the few permanent streams of SA, has disappeared from this country, and in other exists in rapidly diminishing numbers"	S3.7
1900	NSW	New England Region	"he has not seen in his district a wallaroo or platypus for fifteen years … where they once abounded in thousands"	S3.8
1904	TAS	Not reported	"numbers are steadily decreasing, and if they continue to do so there is danger of extermination at no very distant date"	S3.9
1905	NSW	Not reported	"They were numerous, and now they are only a few to be seen"	S3.10
1909	NSW	Not reported	"but the platypus and the opossum are rapidly becoming extinct"	S3.11
1910	VIC	Moorabool River	"becoming almost extinct, and is rarely met within the vicinity of large towns"	S3.12
1910	NSW	Not reported	"these animals are being slaughtered every day and their skin sold". "these animals are very scare"	S3.13
1912	NSW	Not reported	"still very scare, and in some districts quite extinct"	S3.14
1923	QLD	Not reported	"the platypus is all but extinct"	S3.18
1924	NSW	Not reported	"become almost extinct"	S3.19
1926	NSW	Not reported	"once so common in some of our creeks and rivers, is also becoming a rarity"	S3.20
1927	QLD	Not reported	"the platypus is nearly extinct"	S3.21
1927	TAS	Not reported	"The platypus is not a disappearing species but an increasing one"	S3.22
1928	VIC	Not reported	"they are far more numerous than they were ten years ago"	S3.24
1929	QLD	Cooroy	"It has been many years since one of these animals has been seen locally"	S3.25
1930	NSW	Wyong	"For the first time in 20 years a platypus has been caught"	S3.26
1932	QLD	Eumundi	"This is the first one seen in the locality for a full decade, though at one time they were numerous"	S3.27
1936	NSW	Macquarie River	"it is years since a platypus has ever been caught in any of the western rivers; it is a long time since a platypus has been seen on the Macquarie, although in days gone by they were to be found there in hundreds"	S3.29
1937	NSW	Murrumbidgee River, Wagga	"This is the first platypus seen in the district for a great many years"	S3.30
1940	VIC	Murray River, Echuca	"This must be one of the very few left in the country"	S3.34
1942	VIC	Not reported	"Platypus are not particularly rare in the rivers and streams of south-eastern Australia, thanks to protection"	S3.37
1954	NSW	Not reported	"They exist in hundreds in the 40–50 miles of the river"	S3.40
1968	ACT	Not reported	"platypus has responded so well to legal protection as to become common again although it was once an endangered species"	S3.41

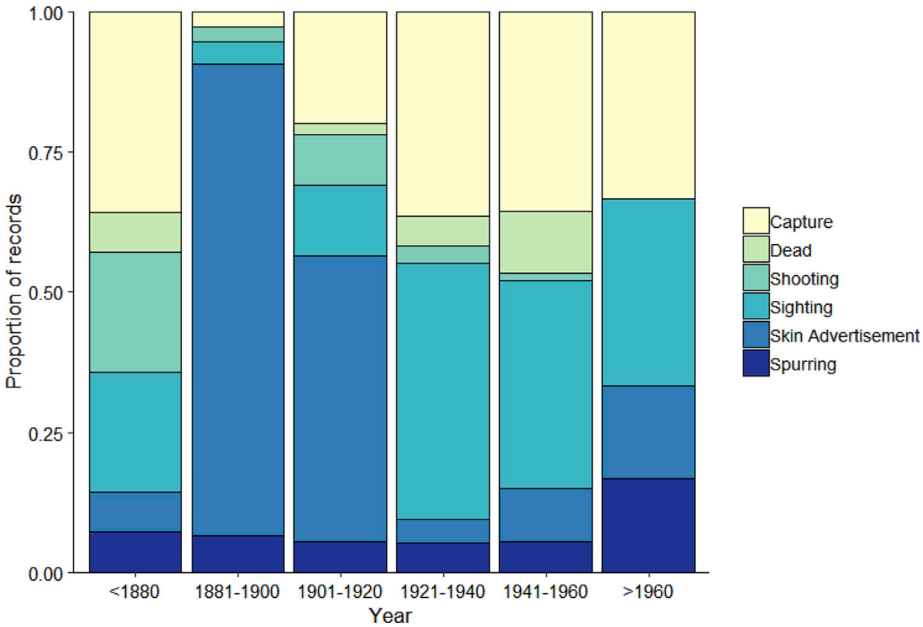

Fig. 2. Proportion of recorded platypus events for year groups throughout the 19th and 20th centuries (spurring refers to injury sustained from calcaneus spurs present on male platypuses), (Data available in Supplementary data S4).

catchments may result from low sighting records, rather than localised extinctions, further supporting the need for increased monitoring.

This study provides the first reported historical quantitative data for the platypus, showing consistent observations which indicate high platypus numbers (1859–1964, Tables 1 and 3). It is clearly not possible to make direct comparisons due to differences in data collection techniques and the nature of anecdotal data, but the size of reported differences likely exceeds observational and methodological biases. Despite over 1000 collective trapping nights, using rigorous netting techniques, contemporary systematic surveys have never captured more than 20 in a single trapping night of 6–12 h and over 10 captures is considered very rare (T. Grant, pers. comm; Table 2). Historical observations or shootings probably did not occur at night when platypus are most active (Grant, 2007), but conservatively assuming historical observations represent the entire local population, numbers still far exceed current population estimates, reported sightings or capture rates (Table 2). While historical records could be exaggerated, records were consistent across temporal and spatial scales. Additionally, while observers may overestimate platypus numbers from sightings by counting the same individual more than once, most historical quantitative accounts were made simultaneously (Table 1), reducing the likelihood of overestimation. Further, recent systematic surveys suggest capture rates generally exceed observations (Table 2), further supporting high densities.

Independent data from the fur trade support historical observations of high abundance. Thousands of furs were processed through the Sydney markets between 1891 and 1899. However, numbers reported in the Sydney markets still appear to underestimate the numbers hunted. Sportsmen were making a living off the fur trade, shootings hundreds and sometimes thousands of platypuses for rugs and garments, typically requiring more than 50 skins (Grant; Denny, 1991). One furrier sold over 29,000 skins before 1914 (The Nowra Leader, 1938). Low numbers of platypus furs were also reportedly exported to London, but many more were likely smuggled out of Australia disguised as rabbits and other small skins (Burrell, 1927). It was assumed that the 1912 protection and ban on hunting allowed populations to recover (Grant; Denny, 1991). However, these conclusions lack information on historical numbers and fur sales. Current population estimates are 30,000–300,000 (50,000) individuals (Woinarski and Burbidge, 2016). Between 1891 and 1899, 7500 furs were recorded sold in the Sydney market, suggesting written records from one market account for 15% of current population estimates. Furs were undoubtedly also sold in other markets, with the seizure of 2000 skins by Victorian fisheries suggesting a prominent Melbourne market (Western Age, 1931). Subsequently, it is likely that most platypus populations never fully recovered from hunting, given their slow reproductive rate (1.5 young per year, 50% of females breeding in a given year), and high juvenile mortality rates (Bino et al., 2015).

Today, platypus populations continue to face increasing pressure from habitat destruction, river regulation, netting and pollution (Bino et al., 2019). Between 1960 and 1980, the building of dams and water diversions dramatically increased across rivers, coinciding with the distribution of the platypus. River regulation has severely altered the natural flow regime, degrading productivity and habitat availability and exacerbating impacts of dry periods, further threatening platypus populations (Scott and Grant, 1997). During dry periods, platypus disperse overland to seek refugia, making them susceptible to predation by red foxes (*Vulpes vulpes*), feral dogs (*Canis familiaris*), and feral house cats (*Felis catus*). Large dams also restrict movements between platypus populations on the same river, increasing likelihoods of local extinctions and restricting gene flow, reducing population sizes (Furlan et al., 2012). Land clearing has also increased significantly since the 1970s across eastern Australia (Australian Department of Environment, 2015), increasing erosion of riverbanks and sedimentation of stream beds, reducing suitable habitat for platypuses (Scott and Grant, 1997). Platypus are under ongoing threat from drowning in enclosed nets used for catching fish and crustaceans, and frequently suffer detrimental impacts from discarded fishing line, rubber and plastics (Bino et al., 2019).

Limited baseline data were available for the platypus before this study. We argue this has hindered assessment of the magnitude of decline, given a shift in collective memory of abundance over time. Platypus numbers undoubtedly declined during the fur trade, likely briefly recovering with protection and changing societal appreciation but likely then continuing to decline as anthropogenic development and habitat degradation increased in the mid-1900s. Poorly documented historical observations and more appreciation may have resulted in the belief populations had recovered, setting new baselines and ultimately resulting in the underestimation of the severity of declines. A shifting baseline phenomenon is evident today, with a sighting or capture of just a few platypuses considered indicative of a healthy population, when historical records suggest today's numbers are likely only a fraction of what once occurred, similar to many cases globally (McClenachan et al., 2006).

Our evidence for decline in abundance and distribution is critical, possible only through the inclusion of historical information. This decline in distribution and numbers of platypus is of increasing concern to governments and scientific communities but the seriousness of the decline outlined requires more urgent conservation attention. As there are no data for 44% of sub-catchments across its inferred range, investment in surveys of this cryptic animal is urgently needed to identify where platypus still occur. Given anticipated continual declines due to ongoing threatening processes (Bino et al., 2019), outcomes of such surveys may provide information to warrant reassessment of the platypus' conservation status. Australia has a global obligation to rapidly increase understanding of this unique species, including improved monitoring, matched with effective conservation strategies that include mitigation of key threatening processes.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2019.e00720.

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