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Introduction

Current conservation status of Australian freshwater turtles

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Globally, turtles are among the most threatened vertebrate taxa, with over 60% of all species being listed as endangered, threatened, or vulnerable (Turtle Conservation Coalition 2011). Australian freshwater turtles are not immune from this trend, and 44% (11 of 25 taxa) are currently listed as vulnerable or worse at state or federal levels, and/or by the IUCN (Table 1). Recent studies are increasingly reporting declines in Australian turtle species, either as long-term trends (Chessman 2011) driven by a variety of factors including invasive species (Spencer *et al*. 2016), drought (Bower *et al*. 2012), and/or habitat modification (Ferronato *et al*. 2016; Ocock *et al*. 2018), or as rapid crashes caused by disease events that remain poorly understood (Spencer *et al*. 2018). Accordingly, we convened a conference on freshwater turtle conservation in Canberra, ACT, in February 2017 to discuss the threats to Australian turtle populations. We also aimed to establish a dialogue among turtle biologists, indigenous stakeholders, reserve managers, zoo curators, and interested members of the public, which would facilitate the development and implementation of conservation strategies nationwide. This special issue of *Australian Journal of Zoology* is the product of that meeting.

Turtles typically experience their highest rates of mortality at early life stages due to the vulnerability of both their eggs and nests. Perhaps as a result, much of the research we highlight focussed on the biology and conservation of turtle nesting. Petrov *et al*. (2018*b*) explored the nesting ecology of the broad-shelled snake-necked turtle (*Chelodina expansa*), which is listed as endangered in Victoria and vulnerable in South Australia (Table 1). *Chelodina expansa* exhibited predictable nesting habitat preferences, which could be used to target conservation efforts to protect nests from predators, including foxes (*Vulpes vulpes*). Similarly, Espinoza *et al*. (2018) evaluated the ecohydrological rules associated with nesting behaviour in the Mary River turtle (*Elusor macrurus*), which is listed as endangered in both Queensland and at the federal level (Table 1). They used these rules to set boundaries for environmental flow management in Queensland to ensure the availability of nesting habitat during the nesting season, and that high flows do not flood *E. macrurus* nests once eggs have been laid. Rusli and Booth (2018) examined the impact of sand type on the cost of digging that hatchling Brisbane River turtles (*Emydura macquarii signata*) experienced during nest emergence. Nests constructed in fine sand were less costly to dig through, which may have consequences for hatchling bioenergetics and fitness if the soils of nesting habitat are altered. Along similar lines, Chessman (2018*a*) found that hatchling eastern long-necked turtles (*Chelodina longicollis*) experience high rates of imprisonment in nests constructed in hard soils. Delayed emergence by *C. longicollis* hatchlings may not be adaptive, but may instead be a consequence of nest construction in hard soils that hatchlings struggle to excavate (Chessman 2018*a*). Together, these studies provide important baseline information for protecting shoreline habitats ideal for turtle nesting.

Despite being aquatic, freshwater turtle populations are also vulnerable to road mortality. Santori *et al*. (2018) used citizen-science data to show that *C. longicollis* experiences high rates of road mortality during the nesting season, when females seek nesting sites on land. Near the Murray River, *C. longicollis* mortality rates are particularly high on divided highways and near populated areas, and are associated with rainfall. Baxter-Gilbert *et al*. (2018) turn the potential threat of roads into a useful method for detecting cryptic turtle species, using Canadian turtles as a model system. They report that road surveys are important sampling methods for species and/or locations where other sampling methods may not be feasible. Walking and cycling surveys were especially effective, but driving surveys allowed sampling of larger areas more rapidly. Combining citizen road surveys and geolocation-based apps like TurtleSat (www.turtlesat.org.au) leads to powerful methods for gaining baseline data on cryptic turtle populations throughout Australia.

Freshwater turtles are vulnerable to disruptions of freshwater habitat, and the studies presented here illustrate two aspects of habitat modification impacts. Clark *et al*. (2018) describe how construction of the Wyaralong Dam in south-east Queensland may have impacted the low relative abundances of both Murray River turtles (*Emydura macquarii*) and common saw-shelled turtles (*Myuchelys latisternum*). Catch-per-unit-effort of both species is variable across the new reservoir, and varies between dry and wet seasons, so long-term monitoring will be necessary to fully understand the impact the dam has on them. Petrov *et al*. (2018*a*) examined how turtle diets varied across wetlands that differ in plant and invertebrate composition in north-central

Table 1. Conservation listing of all Australian freshwater turtles, from the following species lists: Ellis and Georges (2015); Georges and Thomson (2010); ASH (2016)

IUCN, International Union for Conservation of Nature (*assessments under review*), from Rhodin *et al.* (2017); EBPC, Environment Protection and Biodiversity Conservation Act (Australia); NSW/OEH, New South Wales Office of Environment and Heritage; QLD/DES, Queensland Department of Environment and Science; SA/DEW, South Australia Department for Environment and Water; VIC/DEWLP, Victoria Department of Environment, Land, Water and Planning; WA/DPAW, Western Australia Department of Parks and Wildlife; LC, least concern; NT, near-threatened; VU, vulnerable; EN, endangered; CR, critically endangered; DD, data deficient; NE, not evaluated

Family	Genus	Species	Common name	Conservation listing(s)
Carettochelydidae	*Carettochelys*	*Carettochelys insculpta*	Pig-nosed turtle	IUCN-EN
Chelidae	*Chelodina*	*Chelodina burrungandjii*	Sandstone snake-necked turtle	IUCN-LC
		Chelodina canni	Cann's long-necked turtle	IUCN-NT
		Chelodina colliei	South-western long-necked turtle	IUCN-NT
		Chelodina expansa	Broad-shelled snake-necked turtle	IUCN-NT; SA/DEW: VU; VIC/DELWP: EN
		Chelodina longicollis	Eastern long-necked turtle	IUCN-LC; VIC/DELWP: DD
		Chelodina oblonga (formerly *rugosa*)	Northern snake-necked turtle	IUCN-NT
		Chelodina steindachneri	Steindachner's long-necked turtle	IUCN-DD
	Elseya	*Elseya albagula*	White-throated snapping turtle	IUCN-VU; EBPC-CR; QLD/DES: EN
		Elseya dentata	Northern snapping turtle	IUCN-LC
		Elseya flaviventralis	Yellow-bellied snapping turtle	IUCN-NE
		Elseya irwini	Irwin's snapping turtle	IUCN-DD
		Elseya lavarackorum	Gulf snapping turtle	IUCN-DD; EBPC-EN; NT: LC; QLD/DES: VU
	Elusor	*Elusor macrurus*	Mary River turtle	IUCN-EN; EBPC-EN; QLD/DES: EN
	Emydura	*Emydura macquarii*	Murray River turtle	IUCN-LC; SA/DEW: VU; VIC/DELWP: VU
		Emydura subglobosa subglobosa	New Guinea painted turtle	IUCN-LC
		Emydura s. worrelli	Worrell's short-necked turtle	IUCN-LC
		Emydura tanybaraga	Northern yellow-faced turtle	IUCN-DD
		Emydura victoriae	Northern red-faced turtle	IUCN-LC
	Myuchelys	*Myuchelys bellii*	Bell's sawshelled turtle	IUCN-EN; EBPC-VU; NSW/OEH: EN; QLD/DES: VU
		Myuchelys georgesi	Bellinger River sawshelled turtle	IUCN-CR; EBPC-CR; NSW/OEH: CR
		Myuchelys latisternum	Common sawshelled turtle	IUCN-LC
		Myuchelys purvisi	Manning River sawshelled turtle	IUCN-NT; NSW/OEH: EN
	Pseudemydura	*Pseudemydura umbrina*	Western swamp turtle	UCN-CR; EBPC-CR; I WA/DPAW: CR
	Rheodytes	*Rheodytes leukops*	Fitzroy River turtle	IUCN-VU; EBPC-VU; QLD/DES: VU

Victoria. Although *E. macquarii* is often considered a generalist omnivore, filamentous green algae are such an important part of their diet that turtles often had empty stomachs at sites where it is scarce. Thus, green algae may be a limiting food source for *E. macquarii* in some wetlands. This is an important result because *E. macquarii* is currently listed as vulnerable in Victoria and South Australia (Table 1). In contrast, *C. expansa* and *C. longicollis* exhibited carnivorous diets, but capture rates for these species were too low to allow among-wetland comparisons.

Chessman (2018*b*) presents an analysis of growth rates of *C. longicollis* from a population from the southern and altitudinal limits of the species' distribution, near Gippsland, Victoria. Growth and maturation rates of *C. longicollis* were slower than those reported from other systems, and may reflect the direct effects of low temperatures and shorter growing seasons compared with elsewhere in the species' range. Interestingly, adult growth rates were erratic, which may reflect periods of fast growth during wet years and slow growth during dry years, and may provide a baseline for future studies of climate change effects.

An important issue facing Australian conservation biologists is inconsistent nomenclature. The need for consistency is essential to facilitate communication among researchers, managers and policy-makers. Australian turtles are a good example of this problem: the genus names *Myuchelys* and *Wollumbinia* are used to describe the same species by the New South Wales Office of Environment and Heritage and by the Australian Environment Protection and Biodiversity Conservation Act, respectively. Thus, our issue concludes with a point-counterpoint: Georges' (2018) review of Cann and Sadlier's recent volume, *Freshwater Turtles of Australia* (Cann and Sadlier 2017) indicates certain differences with their taxonomy and Sadlier and Cann (2018) give their reasons for the differences in their response. Future turtle meetings should ensure that turtle taxonomies used resolve some of these problems to try to avoid future conflicts.

Our conference and special issue have highlighted some of the major threats Australian freshwater turtles face. An important, yet relatively neglected, area of research is the ecological roles Australian turtles play. Thus, the impacts of their declines on the broader ecosystem are not well understood. In producing this issue, we aim to push turtle conservation forward at state and federal levels so that the causes and consequences of turtle declines can be mitigated before they become extinct. To that end, we aim to continue the dialogue established in this first

meeting in a biennial workshop under the banner of the Australian Freshwater Turtle Advisory Group (AFTAG). Our mission will be to facilitate communication among researchers, managers, landowners, traditional indigenous caretakers and other stakeholders, and advocate for improved awareness and conservation of declining turtles throughout Australia.

Conflicts of interest

The authors declare no conflicts of interest.

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