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Corrigendum

Novel use of in-stream microchip readers to monitor wild platypuses

J.W. Macgregor, C.S. Holyoake, S. Munks, J.H. Connolly, I.D. Robertson, P.A. Fleming and K.S. Warren

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The Editor-in-Chief regrets that elements of Figure 5 were omitted in the original publication. The correct version of Figure 5 is given below.

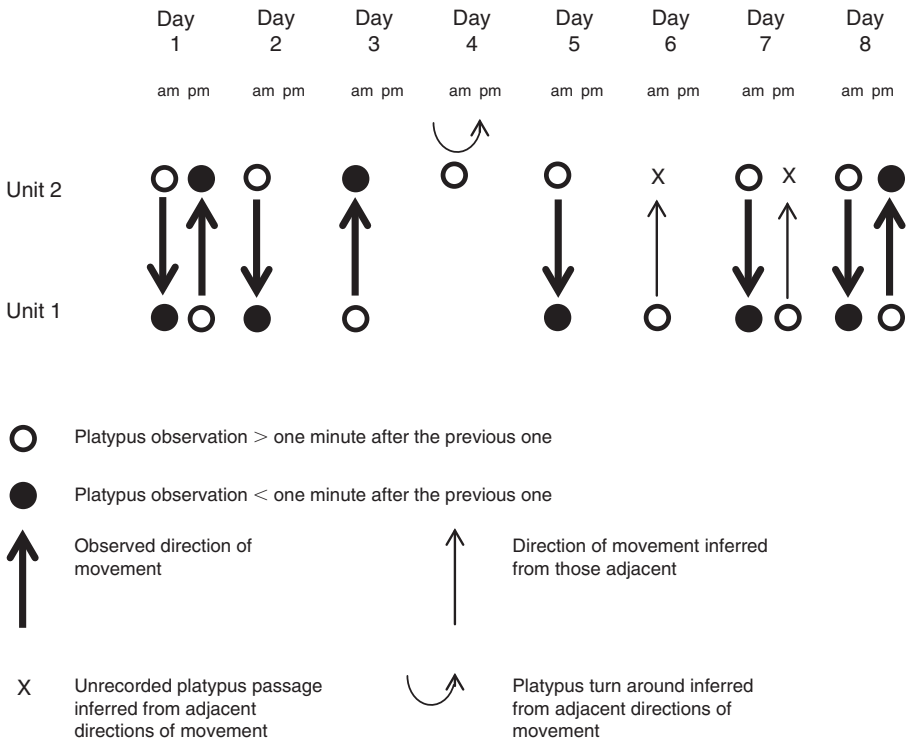

Fig. 5. Direction of movement of platypus 26 over eight days at site D.

Novel use of in-stream microchip readers to monitor wild platypuses

J. W. MACGREGOR[1], C. S. HOLYOAKE[1], S. MUNKS[2,3], J. H. CONNOLLY[4], I. D. ROBERTSON[1], P. A. FLEMING[5] and K. S. WARREN[1]

A variety of techniques have been used to monitor platypus populations to assess the impacts of the threats they face, but each technique has limitations. In this study we investigated the novel use of in-stream microchip readers, to remotely monitor the movements of microchipped wild platypuses. Over 13 months, we recorded movements of 18 microchipped individuals past nine fixed locations in the Inglis Catchment in northwest Tasmania, using three units of which all were capable of detecting Trovan® unique microchips and two were additionally capable of detecting ISO microchips. Each site was monitored one or two times, for durations of 8–39 days. We undertook direction of movement investigations during two monitoring periods, by placing the antennas from two systems in the same creek within 3 m of each other. In a total of 264 days of monitoring, 528 platypus observations were made from 18 individual platypuses, consisting of 13 of 18 (72%) platypuses captured at the monitoring sites within 16 months prior to monitoring, two platypuses captured at other sites in the same time period, and three of seven (43%) individuals microchipped 3–5 years previously. This number of platypus observations, in combination with the stable number of platypuses observed per day, the range of movement behaviours recorded and the results of the direction of movement investigations, indicates that at appropriate sites, in-stream microchip readers are an effective method of monitoring the movements and survivorship of microchipped wild platypuses.

Key words: *Ornithorhynchus anatinus*, home range, freshwater wildlife monitoring, aquatic animals.

INTRODUCTION

PLATYPUSES are semi-aquatic mammals that are found in association with lakes, rivers and streams in Eastern Australia (Grant and Temple-Smith 2003; Grant 2009). Numerous observed and potential threats to platypus conservation have been reported, including habitat degradation, river flow alteration and disease (Grant and Temple-Smith 2003; Gust and Griffiths 2010, Serena & Williams 2010), highlighting the importance of monitoring this cryptic species to assist with the development of conservation management plans. Platypuses have been monitored using live capture-release studies, radiotelemetry, data loggers and, to a lesser extent, remote observational studies, camera traps and acoustic transmitters (Serena 1994; Bethge *et al*. 2003; Grant 2009; Gust and Griffiths 2010; Griffiths *et al*. 2013). At the time of writing the use of acoustic transmitters has not been reported in detail, however, each of the other listed methods of monitoring platypuses has limitations (Grant 2009; Gust and Griffiths 2010). For instance, while live capture studies provide detailed information on individuals, they are very labour intensive and often have low recapture rates — 36% of 271 males and 51% of 429 females over ~30 years in the Upper Shoalhaven River reported by Grant, (2004), and 58% of males and 73% of females over ~12 years near Melbourne and 38% of males and 31% of females over 8 years in the Wimmera River reported by Serena and Williams (2013). Low recapture rates make it difficult to follow individuals through time and may in part be a result of net avoidance (Griffiths *et al*. 2013). Similarly, while radiotelemetry and dataloggers provide detailed information on activity patterns, their use is limited by battery life, problems associated with application of the device and difficulties of recapture for device retrieval (Serena 1994; Serena *et al*. 1998; Bethge, 2009). Devices are most commonly applied by glueing them to the fur which can cause skin irritation (S.Munks, unpublished data), and although Bethge *et al* (2001) found that data loggers did not significantly increase platypus foraging metabolic rate in a captive situation, potential adverse effects of attaching a device of up to 4.4% bodyweight to a platypus remain unknown (Bethge 2003). Camera traps can only be used to monitor animals when they move across land, not in water (Olsson Herrin, 2009) and, like observational studies and public surveys, do not enable individuals to be identified.

The platypus is legally protected throughout its distribution (Gust and Griffiths, 2010) and is listed as Endangered in South Australia where it had a limited distribution at the time of European settlement (Grant 2009). It is not listed under any other Australian state or federal threatened species legislation, is a species of "Least Concern" on the International Union for the Conservation of Nature and Natural Resources (IUCN) red list of threatened species and continues to have a similar distribution to that at the time of European settlement (Grant

[1] College of Veterinary Medicine, School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch, Western Australia, 6150.
[2] Tasmanian Forest Practices Authority, 30 Patrick Street, Hobart, Tasmania, Australia, 7000.
[3] University of Tasmania, School of Zoology, Private Bag 5, Hobart, Tasmania, Australia, 7001.
[4] School of Animal & Veterinary Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, Australia, 2678.
[5] Environmental and Conservational Sciences, School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch, Western Australia, 6150.

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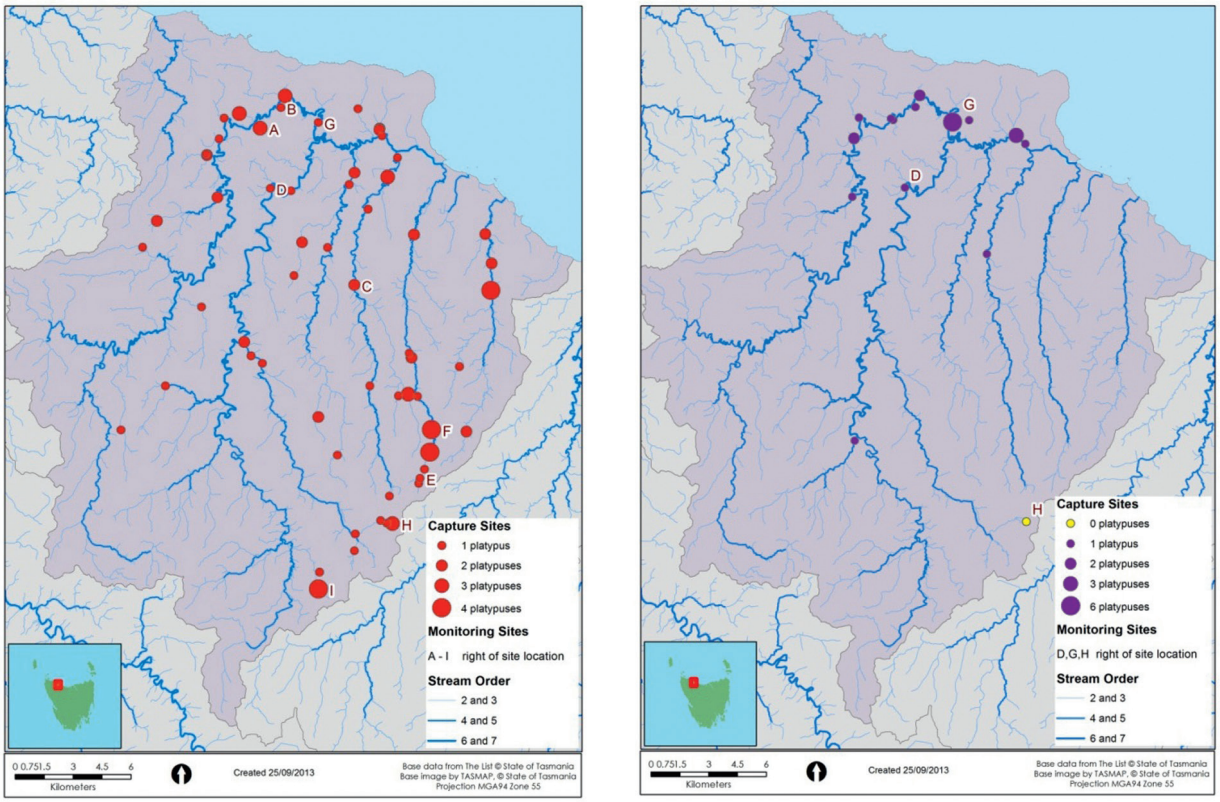

Fig. 1. Locations of platypus capture and monitoring sites in the Inglis Catchment, Tasmania, a) red dots: animals identified with Trovan Unique® microchips (August 2011–December 2012), letters: sites monitored using in-stream antennae between November 2011 and December 2012; b) purple dots: animals identified with ISO microchips (December 2007–August 2008), letters: sites monitored using in-stream antennae capable of detecting ISO microchips between November 2011 and December 2012.

2009). However, because of the difficulties of monitoring platypuses described above, population declines are hard to identify and Grant (2009) suggested that the species could be more appropriately placed in the "Data Deficient" category by the IUCN.

In-stream antennas capable of remotely detecting implantable animal transponders (microchips) are commonly used to monitor individuals within wild fish populations (Zydlewski *et al*. 2006). Similarly, antennas are used out of water to monitor other species of wildlife such as penguins and bats which either pass through or can be directed to pass through a small aperture (e.g. cave openings, fence apertures) (Kerry *et al*. 1993; O'Donnell *et al*. 2011).

Platypuses rest in burrows on land which they typically leave once a day to forage (Serena, 1994; Bethge, *et al*. 2009). While out of their burrows platypuses tend to display foraging behaviour, diving to the water body floor to find prey interspersed with time on the water surface (Gust and Handasyde 1995). Gust and Handasyde (1995) and Bethge *et al*. (2003) found a mean foraging durations of ~10 hr/day and 11.5 hr/day respectively. During foraging trips, platypuses have been observed to move distances of a few hundred metres to several kilometres along rivers and/or streams and have been known to move over land to avoid obstructions such as waterfalls, culverts or meanders in rivers (Serena 1994; Gardner and Serena 1995; Gust and Handasyde 1995; Munday *et al*. 1998; Mooney and Spencer 1999). In this study, we investigate the novel use of in-stream microchip readers as a remote, long-term and relatively non-labour intensive method of monitoring microchipped wild platypuses as they move along waterways during foraging.

MATERIALS AND METHODS

A field study was performed between November 2011 and December 2012, using in-stream microchip reader units to monitor the movements of wild platypuses past nine specific sites (A–I) in the Inglis Catchment in northwest Tasmania (Fig. 1). Each micro-chip reader unit (Units 1–3) consisted of an antenna capable of detecting microchips connected to a decoder (Trovan® LID 650; Trovan Ltd., Microchips Australia Pty. Ltd., Keysborough, Victoria) that stored microchip numbers and the date/time they were detected for subsequent download.

Unit 1 used a Trovan®ANT612 antenna, which is a 475 × 400 × 35 mm panel capable of detecting Trovan®Unique microchips passing within 250 mm of its flat surface. The antenna was placed on the floor of small waterways with the aim of detecting platypuses moving over the top of it (Fig. 2a). Units 2 and 3 used Trovan®ANT C600 antennas, which are open-ended cylinders (used as a swim-through tunnel) 600 × 300 × 10 mm (diameter × depth × thickness). These antennas were placed with part of their circumference resting on the floor of small waterways, partly out of the water and with the water flowing through it, with the aim of detecting platypuses passing through the antenna (Fig. 2b). Unit 2 was configured to optimally detect Trovan®Unique microchips (but also capable of detecting ISO microchips) while Unit 3 was configured to optimally detect ISO microchips (but also capable of detecting Trovan®Unique microchips). At most sites, rocks and/or pieces of wood found nearby were placed around the antenna in an attempt to discourage platypuses from moving around it. Each unit was powered by a 12 Volt battery. In the early stages of the study, these batteries were changed

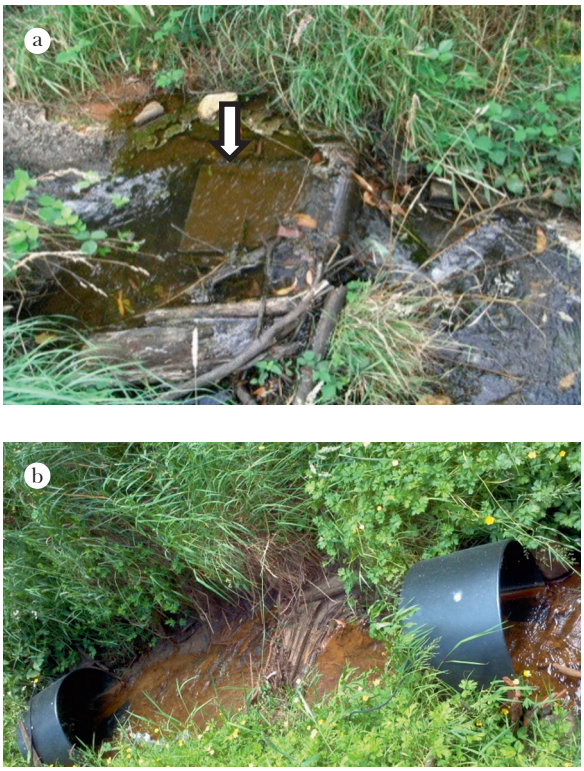

Fig. 2. Showing the three Units placed in the field. a) Unit 1, the ANT612 flat panel antenna (arrow) in the creek at Site A, and b) Units 2 and 3 (C600 swim-through tunnels) placed in line at Site G.

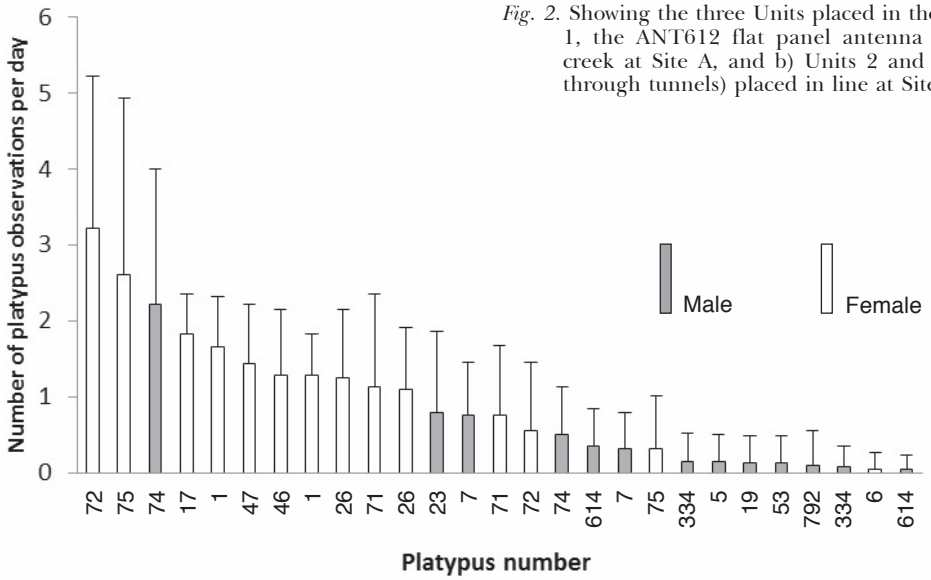

Fig. 3. Mean number of platypus observations/day for each platypus organised from largest to smallest with positive standard deviation error bars.

and recharged daily; later the charge was maintained using a 135W Kyocera® Solar Panel and Plasmatronic® Dingo 20/20 Solar Regulator.

A total of 31 platypuses had been microchipped in the Inglis Catchment before commencement of the in-stream microchip monitoring: 23 (10 adult males, two juvenile males and 11 adult females) between December 2007 and August 2008 with ISO microchips (Macgregor *et al.* 2010) and 8 (six adult males and two adult females) between August 2011 and November 2011 with Trovan Unique® microchips. During the period of in-stream monitoring, a further 80 platypuses (39 adult males, three juvenile males, 36 adult females and two juvenile females) were microchipped with Trovan Unique® microchips bringing the total number of animals microchipped in the study area to 111 by the end of this study (Fig. 1). Sites to locate the micro-chip readers were selected where at least one platypus had been captured and microchipped since August 2011 and where a section of the creek was a similar

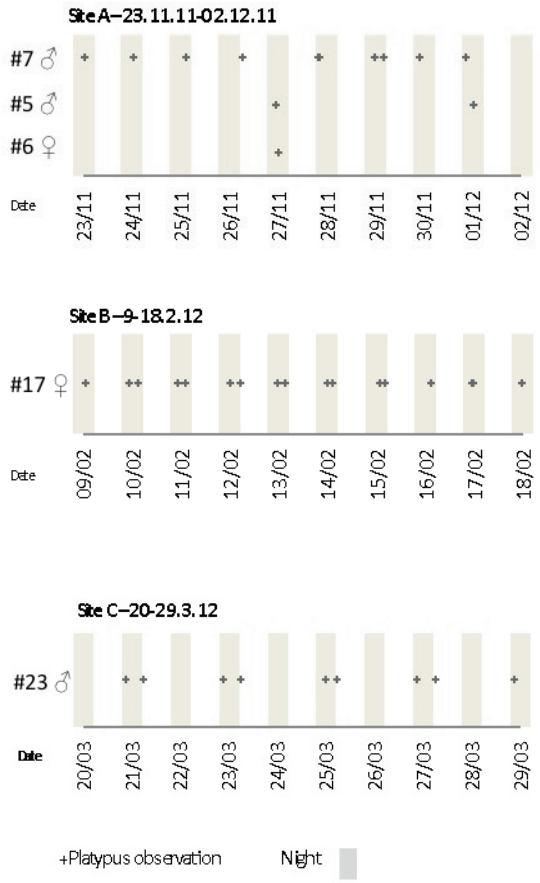

Fig. 4. Observations over 10 days at three sites (A–C) showing three individuals (platypus #7, #17 and #23) that were recorded regularly and two that were recorded only once or twice (platypus #5 and #6).

width to that of the antennas and less than 25cm in depth. Each site was monitored for one or two periods of 8–31d duration; the exact length of each monitoring period depended on the logistics involved in transport of equipment, stock rotation through paddocks (where fieldwork sites were adjacent to pasture), and periods of flood.

Direction of movement investigations were performed in two 3-week monitoring periods (one at site D, one at site G) by placing the antennas from two monitoring units in the same creek within 3 m of each other (Fig. 2b). A recording of the same microchip from two units within 1 min of each other was considered to reflect movement of a platypus along the creek. Comparison of the time of recordings from the two units allowed us to determine the direction of movement of platypuses each time they were recorded. When only one of the two units recorded a microchip, examination of the direction of movement on previous and subsequent recordings allowed us to determine if the recording missed was due to the platypus turning around when it encountered the first antenna, or whether the passage of a platypus went undetected by one of the units.

The microchip reader units monitor constantly until a microchip is detected, after which monitoring is suspended for a pre-set wait time before continuous monitoring is recommenced. During the two first monitoring periods (which were at Site A), wait times of 0.1, 1 and 5 s were tested on different days. Subsequently, at the other sites, the wait time was set at 10 s.

Data from the microchip readers were used to determine two parameters. The first parameter was a 'microchip recording', which was defined as a single record of a microchip where one unit was in place, or a record of the same microchip from the two units and within 1 min during the direction of movement investigation. In order to avoid over-representation of observations of any platypuses that might backtrack briefly for any reason as they move along a creek and be recorded more than once in a particular passage, a second parameter of "platypus observation" was used. Any two microchip recordings of the same platypus separated by <30 min (from a single unit or from two units in the same creek) were classed as a single platypus observation. The same principle was applied to any number of microchip recordings for the same platypus where consecutive intervals were <30 min. So when a platypus observation consisted of multiple microchip recordings, the total duration of the event may have been >30 min.

A day of monitoring was defined as an in-stream microchip reader unit monitoring one waterway for 24 h, or two units monitoring the same waterway within 3 m of each other for 24 h.

A type III mixed-model ANOVA test (with day of monitoring period and site as random factors) was carried out to test for an effect of time and monitoring site on the daily number of platypus observations. A second type III mixed-model ANOVA test (with day of monitoring period and platypus identity as random factors) tested for daily and individual platypus differences in activity patterns. Statistical analysis of results was performed using Statistica 8.0 (Stat Soft Inc. Tulsa OK, USA).

RESULTS

In a total of 264 days of monitoring, 528 platypus observations were made of 18 individual platypuses (9 males, 9 females) (Table 1). Three of the seven platypuses (43%) originally captured in 2007–2008 and identified with ISO microchips, were detected at sites monitored in this study by units 2 and 3 (all at

Table 1. Numbers of microchipped platypuses in the study area and detected in this study.

	Adult male	Juvenile male	Adult female	Juvenile female	Total
Number of platypuses with ISO microchips implanted at monitored sites(2007–2008)	4	0	3	0	7
Number of platypuses with ISO microchips detected at the site of their capture in this study	3	0	0	0	3
Number of platypuses with Trovan® Unique microchips implanted at monitored sites (Aug 2011–Dec 2012)	8	0	10	0	18
Number of platypuses with Trovan® Unique microchips detected at the site of their capture in this study	5	0	8	0	13
Number of platypuses with Trovan® Unique microchips implanted away from monitoring sites (Aug 2011–Dec 2012)	37	3	28	2	70
Number of platypuses with Trovan® Unique microchips detected away from their capture site in this study	1	0	1	0	2

Table 2. Percentage of platypus observations that were classified as single or multiple microchiprecordings for different reader wait times.

Wait time	n observations	Single recordings	Multiple recordings	Duration of multiple microchip recordings*
0.1 s	17	0 %	100 %	2 – 7 s
1 s	1	0 %	100 %	2 – 7 s
5 s	7	57 %	43 %	5 – 33 s
10 s	503	92 %	8 %	10 s – 110 min

* Although the minimum interval between two platypus observation was set at 30 min, where consecutive intervals were <30 min, consecutive recordings were not considered independent and were classed as one platypus observation. The longest total duration of a single platypus observation was 110 min and consisted of ten sequential microchip recordings.

site G). Of the 18 platypuses captured since August 2012 at Sites A–I, and identified with a Trovan®Unique microchip, 13 (72%) were detected at the site of their capture. Two other platypuses microchipped in the associated health study were also detected: one at Site E ~200 m from the site of its capture in the same creek but separated by a small farm dam, and one at Site A, ~11 km by waterway from the site of its capture.

The mean number of times that individual platypuses were observed per day over the duration of each monitoring period is shown in Fig. 3 (the nine platypuses detected over two monitoring periods are each represented twice). In general, female platypuses were observed more frequently than males. Fig. 4 shows examples of the patterns of observations that were recorded. Two platypuses showed a very regular pattern of observation timings, one female with a 24 h cycle and one male with a 48 h cycle; other individuals showed less regular patterns. Mixed-model ANOVA (with day of monitoring period and site as random factors) showed that the number of platypus observations varied between sites ($F_{8,225} = 34.07$, $p<0.001$); there was a noticeably greater number of platypus observations at site I where four microchipped individuals were monitored. However, there was no effect of length of time that the sites were monitored ($F_{30,225} = 0.44$, $p>0.99$). Mixed-model ANOVA (with day of monitoring period and platypus identity as random factors) showed that the number of platypus observations varied between individual platypuses ($F_{17,497} = 11.39$, $p<0.001$), but importantly there was no effect of length of time that the sites were monitored ($F_{30,497} = 0.68$, $p = 0.90$).

Table 3. Percentage of platypus observations that were single or multiple microchip recordings for different antenna(s) when the wait time was set at 10 s.

Antenna(s) in creek	n observations	Single recordings	Multiple recordings
Flat panel only	400	91%	9%
Circular only	52	94%	6%

The incidence of multiple microchip recordings was reduced from 100% at the two shortest wait times (0.1 s and 1 s), to only 8% when the wait time was set at 10 s (Table 2). For those multiple observations that occurred when the wait time was set at 10 s, both the swim-over panel and the swim-through tunnels recorded similar incidences (Table 3).

Data from eight days of one of the direction of movement investigations is shown in Fig. 5 to illustrate how the results have been

interpreted. As shown in Table 4, of 48 passages of a platypus in the direction of movement investigations, 41 (85%) were detected by both antennas and seven were only detected by one of the antennas (six by the flat panel antenna and one by the swim through antenna). On one occasion a platypus turned around after encountering the antenna (swim through antenna). The minimum time between two passings of a platypus in opposite directions during the two monitoring periods where direction of movement could be determined was 1 h 15 min 24 s.

DISCUSSION

Results of this study indicate that in-stream microchip readers are an effective method of detecting microchipped wild platypuses at appropriate sites. Importantly, during the 13 months of the study, the detection rates of platypuses microchipped at the monitoring sites (72% of the platypuses microchipped in 2011–2012 and 43% of those microchipped in 2007–2008) were similar to the recapture rates achieved during repeated live capture studies performed by Grant (2004) over ~30 years and Serena & Williams (2013) in two areas over ~8 and 12 years. The results of the direction of movement investigations, the absence of a significant effect of length of monitoring on the number of platypus observations at each site and for each individual platypus, and the regular and frequent observations from two platypuses further reinforce our conclusion.

Suggested causes of failure to recapture certain individuals during longitudinal live capture studies have focussed on a likely high degree of mobility of certain individuals, including individuals with large ranges, individuals with a nomadic or roving breeding strategy, non-breeding individuals unable to find a vacant home range, and transient occupation of an area (Grant, 2004; Bethge, 2009; Serena & Williams, 2013). Such explanations would be consistent with certain platypuses not being detected in this study. The range of frequency and regularity of observations from the 18 platypuses that were detected is also consistent with the findings of previous studies. Firstly, a range of behaviour patterns have been observed using radiotracking and dataloggers — some very regular, others less so (Gardner and Serena 1995; Bethge *et al*. 2009). Secondly, radiotracking has shown platypuses using certain parts of their home ranges more frequently than others (Gardner and Serena 1995; Gust and Handasyde, 1995). Lastly, a long-term mark-recapture study found that the home ranges of male platypuses were significantly larger than those of females (Serena and Williams, 2013). The variation of frequency of observations for those individuals that were detected in this study (Fig. 3) is likely to be a result of the differing home range sizes of the individuals (affected in particular by their sex) and the position of the antenna within each platypus's home range. It should be noted that we did not attempt to determine whether platypuses ever left the water to avoid the antennas and this remains a possible explanation, at least in part, for the failure to detect certain platypuses and for the variability in detection frequency in those that were detected.

The observation at Site G of three platypuses microchipped in 2008 is of particular importance. This observation reveals that these individuals were still present at the sites, despite not being re-trapped during the associated health study (four nights of trapping at that site between August 2011 to December 2012; Macgregor *et al*., unpublished data). Without the use of the in-stream antennas, the continued presence of these animals would not have been known.

The direction of movement investigations suggested that microchipped platypuses were recorded on 93% of occasions that they passed an antenna. Of the remaining 7% of passages, it was not possible to determine if the absence of a recording was due to the equipment failing to detect a microchip that passed within its read range or due to platypuses leaving the water to move around the antennas. While comparison of Unit 1 with Units 2 and 3 may indicate that the flat panel (pass-over) antennas are more efficient than the circular (pass-through) antennas, the differences in efficacy of the two antennae designs is not great. Furthermore, the ability of the pass-through antennas to detect both ISO and Trovan Unique microchips will be important at many survey locations.

We observed signs that on some occasions the antennas appear to alter platypus behaviour. Firstly, in the six weeks of our direction of movement investigations we identified one platypus turning around after encountering an antenna. Secondly, we observed multiple microchip recordings over periods longer than would be expected for a platypus moving through the read range of the antennas. Such multiple microchip recordings may have been produced by a platypus moving very slowly past an antenna or moving up and down a short section of creek during foraging. However, it may also indicate that some platypuses spent time investigating the antennas, since sight or touch may alert platypuses to presence of the antennas. Platypus 23 appeared to investigate the antenna at Site C, despite this antenna being covered in river substrate, suggesting that platypuses may sense the electric field produced by the antenna using electroreceptors in their bill that are usually used to detect prey (Scheich *et al*. 1986).

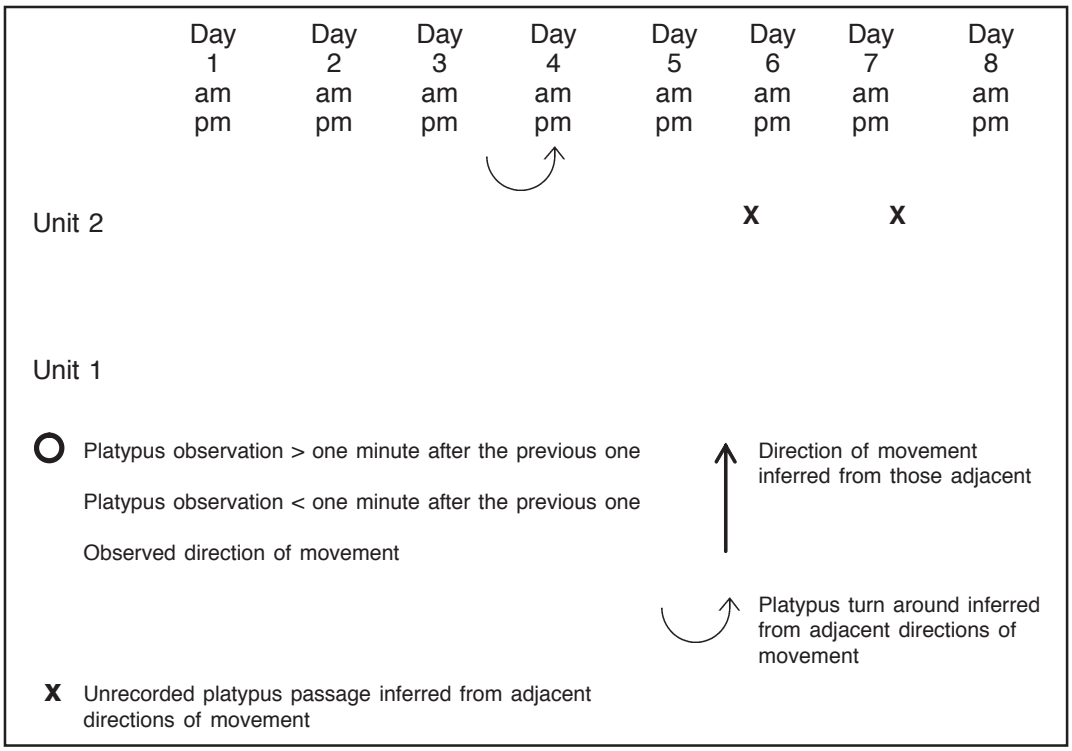

Fig. 5. Direction of movement of platypus 26 over eight days at site D.

Table 4. Number of times a platypus turned around when encountering an antenna and number of times an antenna failed to detect a platypus moving past it during direction of movement investigations.

		Number of observations		
		Unit 1	Unit 2	Unit 3
Site D	n obs	19	17*	
Platypus # 26 (20 d)	failed	1+	5	
	turned around	0	1	
Site G	n obs		28	27
Platypus #1 (22 d)	failed		0	1
	turned around		0	0
	% failures	5%	10%	3.6%
	% turn arounds	0%	2%	0%

*Excluding the first recording by Unit 2 at site D which could not be characterized.
+Excludes one occasion when the batteries were changed late and the one supplying unit 1 (which drew more power than unit 2) had run out of power.

A read-wait time of 10 s after a microchip was detected was settled on for this study, to reduce time platypuses might be aware of the electric field and reduce the number of multiple microchip readings evident when shorter wait times were tested. The time taken for a platypus to pass through the field of the antenna when moving at normal speed along a creek is likely to always be greater than 0.1 and 1 s and may even be longer than 5 s. However, it is unlikely that a platypus moving normally should take longer than 10 s to pass over/through an antenna.

We considered consecutive microchip recordings separated by <30 min as not independent to ensure that we did not overanalyse our data. The choice of any particular interval could be debated but we chose 30min as a likely maximum time that a platypus would spend either foraging in a section of a narrow creek or investigating the antenna. The use of a figure close to this is supported by the following points: 1) clusters of three or more microchip readings separated by up to several minutes were observed on several occasions, indicating that the platypuses were not simply moving in a straight line up the creek and were sometimes returning and passing back over/through antennae; and 2) the shortest interval between return journeys during apparently normal behaviour during the direction of movement investigations was 1hr 15min 24s. However, it is likely that whatever time delay is chosen, occasionally two platypus observations will be miscounted as one, or a single platypus observation will be miscounted as more than one.

The use of in-stream microchip readers does not overcome all of the obstacles facing platypus monitoring. Importantly it is only applicable in relatively small creeks; although it may be that experimentation with antenna design may allow this method to work in wider and deeper creeks. Other limitations of in-stream microchip readers are that they only provide information about platypus movements at certain locations, they provide no information on the observed individuals' health except that they are alive, and a live capture and release study is required to microchip individuals before the units can be used. Also, while the equipment is robust it is possible that the antennas could be moved or even damaged by fast flowing water if not secured adequately and there is potential for the electronics in the decoders to be damaged by waterlogging if placed in a position where floodwater may reach. However, as a platypus monitoring technique, this method comprises a unique set of advantages: it is reliable, remote and relatively non-labour intensive; requires only the routine implantation of a microchip; and can be used repeatedly or left in the field to monitor the same animal over periods of years. We believe that in-stream microchip readers will allow important new data to be gathered in many areas of platypus conservation research and assist in more reliably categorizing the species according to threatened species schedules. Because platypuses have routinely been identified in research project with microchips for over two decades, it will be possible to use the technique to study platypuses captured in previous research projects, which may not have anticipated ongoing monitoring, as well as those in prospective studies. Specifically, we think in-stream antennas will assist in gathering information on platypus short- and long-term habitat use and home ranges, population demographics, survivorship and longevity, as well as the safety of new research techniques and net avoidance during live capture studies. We also think that survivorship and movement monitoring will aid the impact assessment of disease, including mucormycosis, and human land use practices.

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