Forestry Corporation NSW

Koondrook-Perricoota Monitoring Project

Frog Monitoring 2016

October 2017

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1. Introduction

1.1 Background and ecological objectives

Flood enhancement works were undertaken prior to 2014 by the Forestry Corporation of New South Wales to allow for the implementation of a managed flow regime through Koondrook-Perricoota Forest. Infrastructure (regulators/levies/berms) was established to divert water from the Torrumbarry Weir into the forest and control outflows from the forest. The purpose of this is to improve the condition of the vegetation and other ecosystem components of this Living Murray Icon site. This work forms part of an ongoing condition-monitoring program aimed at providing a long-term indication of the condition of the forest and forms part of The Living Murray (TLM) Program.

Frogs constitute one forest ecosystem component that is likely to depend on watering regime. Frogs occur across the forested area and are dependent on water for survival and for breeding. The flood enhancement project provides an opportunity to experimentally test and understand the response by frogs to flooding. Do frogs show large, little or no response to artificial flood events, compared with their responses to natural weather variation (e.g., rainfall and temperature). Insights into this can be gained by comparing frog responses in areas that are subject to artificial floods and areas that are not.

The inaugural delivery of managed flood water (environmental watering) to Koondrook-Perricoota Forest occurred in July 2014, and acoustic sampling of frogs (using six Songmeters) commenced in September 2014 at forest locations that corresponded to the expected flooded areas or provided suitable non-flooded controls (GHD 2015).

A second managed flood was delivered in late 2015, but with a smaller extent and scale than in 2014. Between October and December 2015, water was added to the Pollack at the far northern end of the forested area. Accordingly, frogs at the Pollack were acoustically sampled at two sites during that time, with comparative acoustic assessment of four dry sites (where Songmeters were already established for the 2014 flood event) at Koondrook-Perricoota Forest, to record frog activity (or confirm inactivity) in the absence of water, and to check for the presence of other species that may call at different seasons (GHD 2016).

In 2016, despite plans to again deliver a managed flood to the forest, no managed floodwater was delivered to the Koondrook-Perricoota Forest area. However, due to above-average rainfall across much of south-eastern Australia, Murray River flows during the latter half of 2016 were sufficiently high and sustained to result in a large overbank event through Koondrook-Perricoota Forest. Hydrographic indicators suggest that the 2016 flood was the largest through the forest since 1993.

The hydrograph for the 2016 forest flooding is shown in Figure 1. While this graphical representation is more complex than needed here (it indicates water levels for the three outflow creek systems also: Barbers Creek, Thule Creek, Wakool Creek), it shows clearly the period when water entered the forest throughout August, then again in September until mid-November (lighter blue area, above darker blue), peaking at more than 57,000 ML/day in late October. For comparison, the water delivered to the Pollack in 2015 peaked at just under 30 ML/day.

The graph for river flow at Torrumbarry Weir from 2006 – 2016 is shown in Figure 2, with the Koondrook-Perricoota inflow threshold (river level at which water begins to breach the banks and enter the forest) of approximately 18,000 ML/day. This shows the historical context and scale of the 2016 overbank event, relative to previous years during which frog sampling was conducted (2014 and 2015).

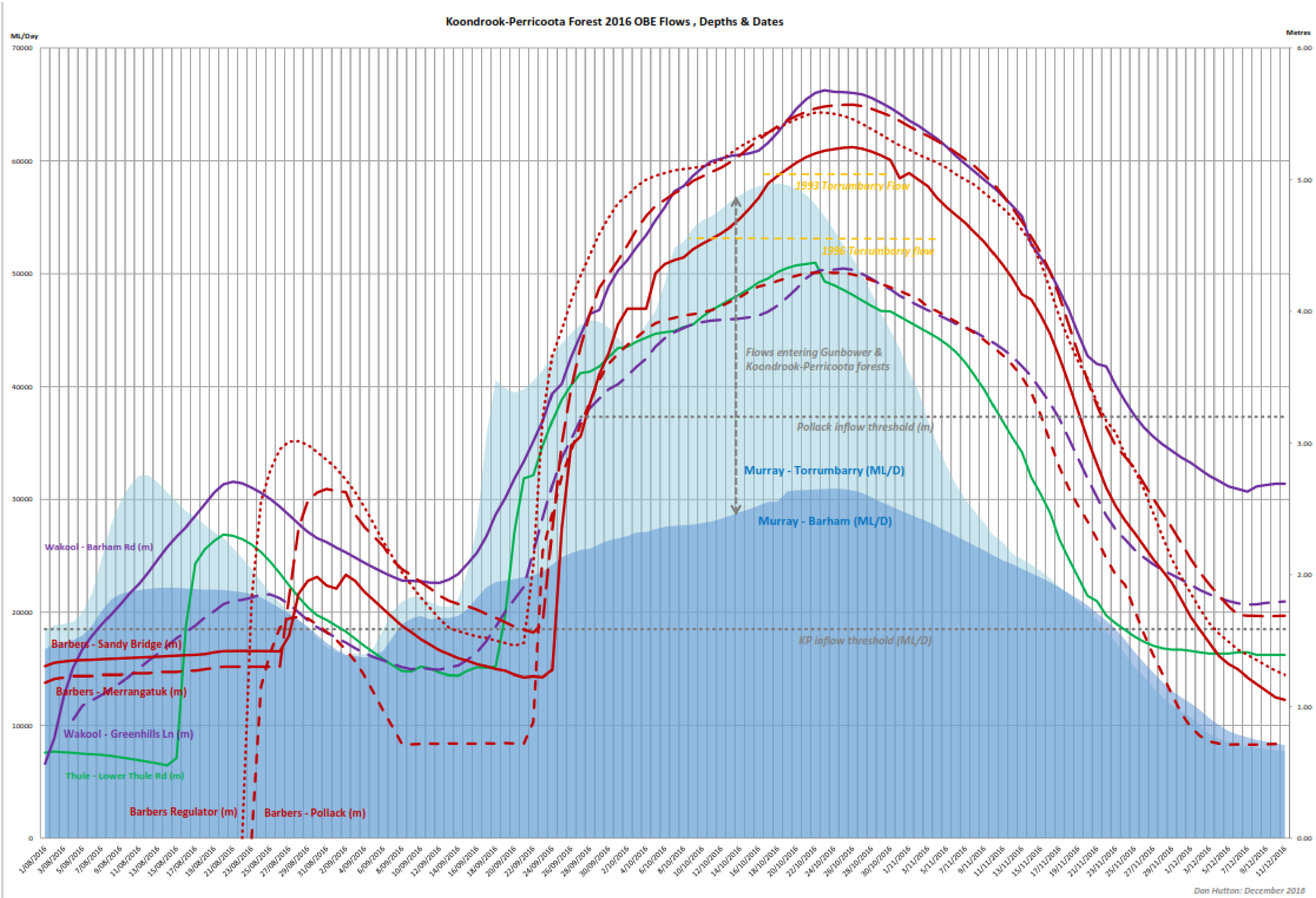


Figure 1 Hydrograph for the forest flooding in 2016 (courtesy of FCNSW)

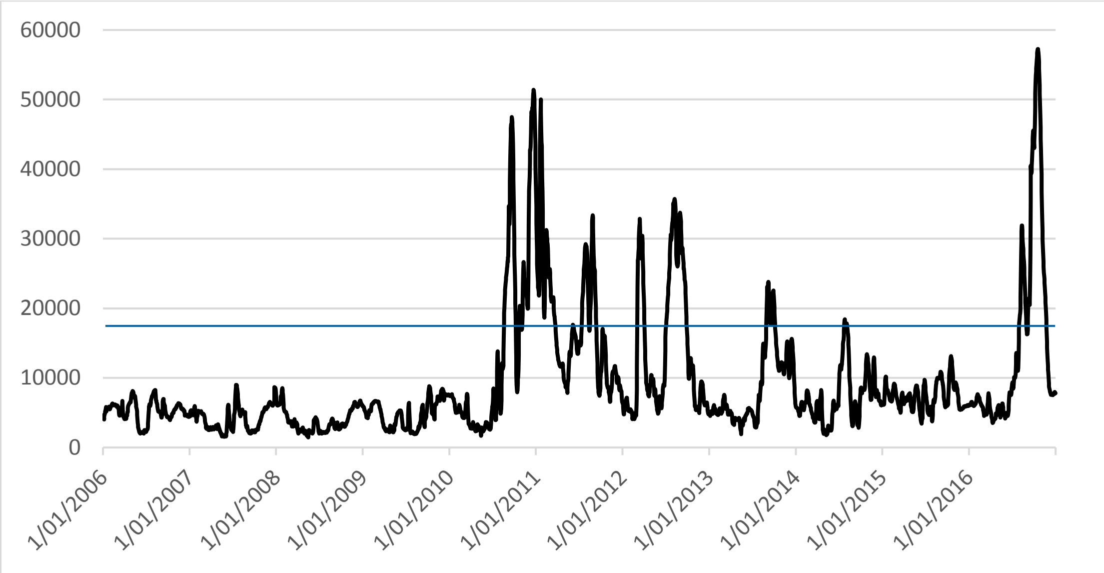


Figure 2 Flow at Torrumbarry Weir 2006-2016 (courtesy of FCNSW). The Y-axis represents average daily flow (ML/day), and the reference line indicates the KP inflow threshold of approximately 18,000 ML/day

Figure 3 shows the extent of flooding through the Koondrook-Perricoota forest at 25 October 2016. It is clear from this image that almost the entire forest system was inundated. It is clear, too, that the banks of the river are the highest locations in the forest system.

Figure 3 Satellite image of flood extent through the Koondrook-Perricoota forest on 25 October 2016 (courtesy of FCNSW). Dark shading indicates presence of water

Monitoring of frogs in 2014 and 2015 showed a pronounced response by frogs to the arrival of flood water, and little to no response to natural changes in local weather (e.g., rain). However, with small numbers of Songmeters, it was difficult to determine the strength of patterns in the data, and numerous questions arose that could not be answered with so few replicated sites.

Therefore, by chance just prior to the 2016 overbank flood, an additional 14 Songmeters (total now 20) were established through the Koondrook-Perricoota Forest, and all 20 were coupled with time-lapse cameras and water depth indicators. This provided the opportunity to hear, see and measure robust data on frog responses to flooding at 20 sites. On-ground assessment of the 20 sites during the flood would add information on breeding success (tadpoles only) for at least some of the species.

As a result of the far greater volume of water entering the forest in 2016, a far broader area of forest was flooded in 2016 than in 2014 or 2015. In 2016, all but the highest (i.e., elevation) parts of the forested area were inundated. Flood water reached all 20 sites, which provided the opportunity to monitor frog responses across a far broader area than was possible in previous years.

1.2 Purpose of this report

The purpose of this report is to present the results of:

- Acoustic sampling in the Koondrook-Perricoota Forest (including the Pollack) during a >65-day period in the 2016 overbank flood
- One on-ground site visit to 20 sites across Koondrook-Perricoota Forest (including the Pollack)

With water through the entire forest in 2016, there is an opportunity to:

- Demonstrate frog response to water arrival as per 2014 and 2015, but with far more rigour and confidence in the conclusion, and with more information on variation in the response
- Assess the consistency in: i) frog diversity and ii) species' relative abundance in different habitats
- Interpret frog responses alongside information on fish and habitat characteristics (e.g., water duration, depth, extent, vegetation)

2. Methods

2.1 Acoustic monitoring – methods

In early September 2014, six Songmeters (Model SM3+) were established across six sites in the Koondrook-Perricoota forest. Since then, some of those units have been relocated (one or more times) to maximise their effectiveness with respect to localised flooding in the forest. In July 2016, a further 14 Songmeters (Model SM4+) were established across additional sites in the forest. Locations for the 20 Songmeter units since July 2016 are shown in Figure 4.

A Songmeter is an electronic device specifically designed for the purpose of detecting and recording sounds [sounds may be audible to the human ear (e.g., frogs) or inaudible to the human ear (e.g., ultrasonic calls of insectivorous bats)]. Songmeters can be programmed to automatically record sounds for pre-determined periods (e.g., one minute, five minutes, one hour, 10 hours) and at pre-determined intervals (e.g., hourly, daily, weekly). Sound files are recorded digitally (WAV files) onto SD cards. For this project, five minutes of audio file were recorded at each site every day, commencing one hour after sunset (which is generally considered to be the peak frog calling window).

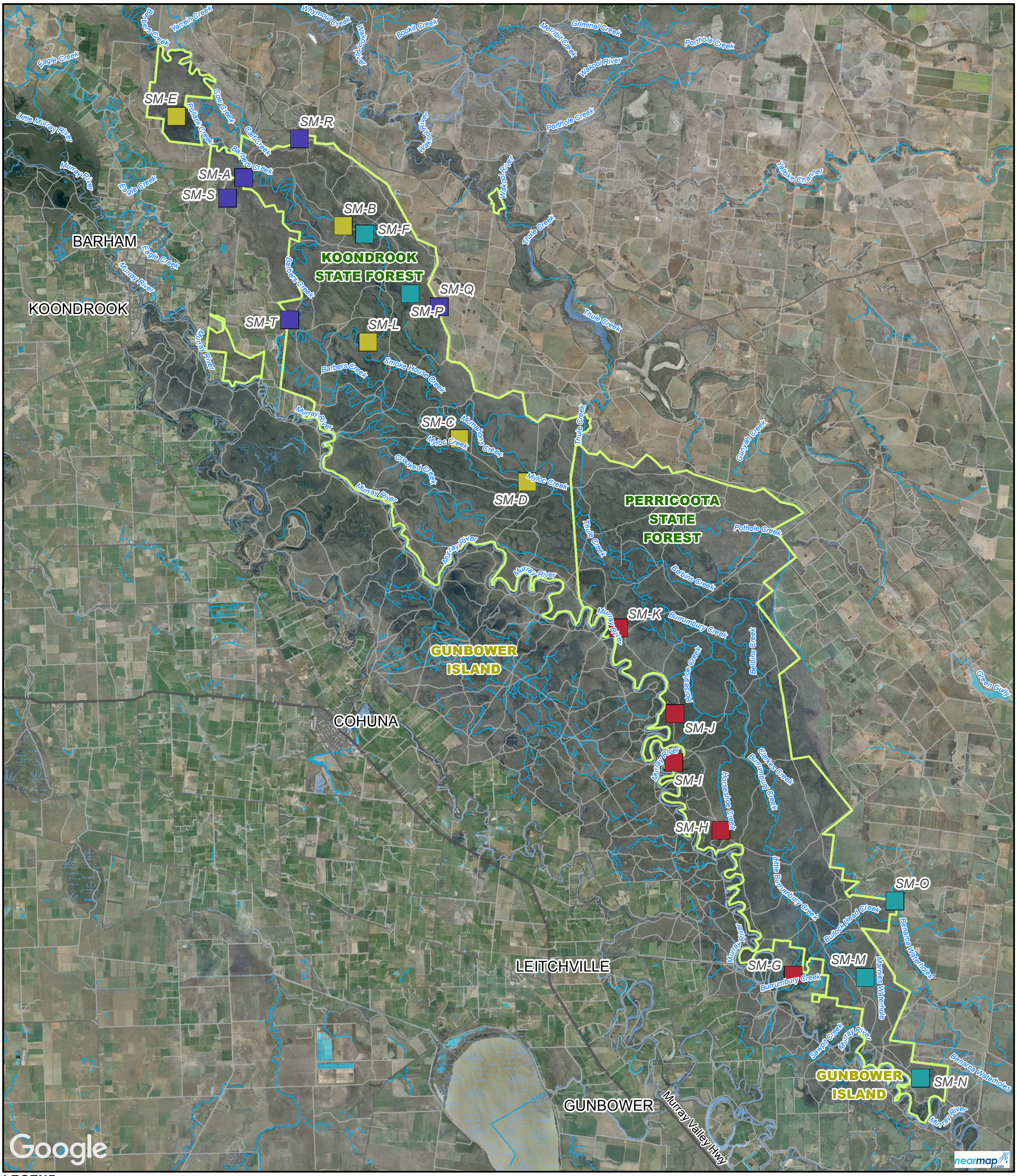
Frogs tend to have discernible acoustic calls, so species generally can be readily identified from sound recordings. It is also possible (albeit with limitations) to gauge at least some information on relative abundance from sound recordings – not actual numbers of frogs, but categories of abundance per species (e.g., one frog, two frogs, three frogs, 5-10 frogs, 10+ frogs). The data obtained through the use of Songmeters for this project is intended to provide information on changes in diversity (i.e., numbers of species calling), activity patterns (whether frogs were calling or not), and relative abundance (as a surrogate for breeding effort).

All species of frogs were 'listened for', including the two NSW threatened frog species (i.e. listed as threatened under the *Threatened Species Conservation Act 1995* and/or the *Environment Protection and Biodiversity Conservation Act 1999*) relevant to the Koondrook-Perricoota area: Sloane's Froglet (*Crinia sloanei*) and Southern Bell Frog (*Litoria raniformis*) and three additional species considered rare or threatened in nearby localities[1]: Giant Bullfrog (*Limnodynastes interioris*), Rugose Toadlet (*Uperoleia rugosa*), and Bibron's Toadlet (*Pseudophryne bibronii*).

For 2016 monitoring, each Songmeter was coupled with a time-lapse camera, which in turn was directed towards a water-level indicator pole. This allowed a comparative measure of frog activity with water arrival, water duration and water depth.

Automated software (e.g., SongScope Bioacoustics Software Version 4.0; 2011) was not used to listen to frog call data for this report.

[1] Listed under the Victorian Flora and Fauna Guarantee Act 1988



LEGEND

Frog Sites

Habitat

- Borrow pit (B)
- Primary wetland (PW)
- River lagoon (RL)
- Secondary wetland (SW)
- Koondrook-Perricoota Forest

- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Forestry Corporation

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Job Number 31-31878
Revision C
Date 19 Apr 2017

Frog habitat types and Songmeter locations

Figure 4

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Data source: DEPI, VicMap, 2014; Imagery, NearMap, extracted 16/10/2014, Image Date 27/8/2011; Google Earth Pro, extracted 26/02/2015. Created by: mjahanshahi

2.2 Site selection

The 20 Songmeter sites were chosen for their frog habitat attributes. Four habitats were selected (primary wetlands, secondary wetlands, river lagoons, and borrow pits) each with five replicates. Primary wetlands (e.g., Long Lagoon) tended to be major waterholes along defined waterways (e.g., Myloc Creek), known to fill and hold water for extended periods, even with small floods. Secondary wetlands (e.g., Benarca Creek) tended to be off-channel areas between major waterholes and waterways, likely to fill only with moderate to large floods. River lagoons (e.g., Swan Lagoon) were oxbow lakes beside the Murray River, likely to fill during overbank events, and when filled, expected to retain water for extended periods. Borrow pits are unnatural wetlands, peripheral to the forested area, that occur along the inside of the outer levy at the northern end of the forest, and are the result of excavations for material used to make the levy. Borrow pits are typically filled by floodwater only during the largest floods, and therefore, during small and moderate floods, the borrow pits were considered to provide a non-flooding, frog-habitat control.

Locations for the 20 Songmeter units for the data presented here are shown in Figure 4 and details are presented in Appendix A.

2.3 Data analysis

2.3.1 Data assessed

Songmeter data presented previously

GHD (2015) included Songmeter data from six Songmeter units at Koondrook-Perricoota Forest between the dates: 1 September 2014 and 8 December 2014

GHD (2016) included Songmeter data collected since 8 December 2014, up to 19 January 2016.

Songmeter data presented in this report

For this report, data are presented for at least 65 days of sampling for each songmeter, with the first day (at most sites) being at least 10 days before the flood water arrives at that site (as determined by the time-lapse camera images). For sites where no flood occurred or where water was already present at the commencement of the sampling (e.g., borrow pits and some river lagoons), a common 60-day period was chosen to best fit with the timing of sampling at other nearby sites. Outside dates for the Songmeter sampling in 2016 are 18 July to 20 November 2016. Assessed dates for each location are shown in Table 1.

The ten-day pre-flood period was used to establish the frogs' calling pattern prior to water arrival. The subsequent 55+ days of sampling was used to determine the intensity, timing and duration of the frogs' response.

This approach did not work for all sites. At some sites, the timing of water arrival was unknown, or was not as obvious or defined as expected. Sites that differed from the expected pattern were:

- Four of the borrow pit sites (SMQ, SMR, SMS, SMT), where the camera showed that there was already water present at the commencement of the sampling period (most likely from local rainfall), followed by a marked increase in water level on a subsequent date (according to camera results), which represented the arrival of the overbank flood event.

- Another borrow pit site (SMA), where the camera failed to operate so the water arrival date was unknown. However, geographically, SMA is at the far northern end of the forest, nearest to and midway between nearby SMR and SMS (where water arrived 28 Sept and 26 Sept respectively), so water arrival at SMA was likely to have been around that date, and perhaps a few days prior given that SMA is near to the Barber Creek channel, which is a main water delivery channel through and beyond the northern end of the forest. There was a slight increase in frog activity at SMA on 16 September, which is likely to have represented the arrival of flood water.
- Swan Lagoon (SMG), which is a river lagoon site, where the camera failed to operate so the water arrival date was unknown. On the basis of water arrival timing at nearby RL sites (SMH, SMI, SMJ – all river lagoons downstream from SMG, and all with flood water that arrived on or before 10 August), the date was chosen as 28 July. The greatest increase in frog activity at SMG was on 15 September, but that is considered too late to have been a response to the flood water arrival.
- Benarca Ck (SMN) – where the camera showed that there was already water present at the commencement of the sampling period. This site has a direct connection to the Murray River, and is likely to hold water during all but the driest times.

Table 1 Sampling dates for Songmeters

For each row, the first black number is the first sampling date, the red number is the date of water arrival at that site (according to camera image, or determined through other means), and the third (black) number is the end date of sampling. Green shading roughly indicates the period over which calls were sampled for each Songmeter.

B – Borrow pit; PW – Primary wetland; SW – Secondary wetland; RL – River lagoon

Songmeter	Habitat	July	August	September	October	November
SM-A	B	22		16	5	
SM-B	PW		16 26		20	
SM-C	PW		7 17		11	
SM-D	PW		4 14		8	
SM-E	PW		1		1	1
SM-F	SW		15 25		19	
SM-G	RL	18 28			1	
SM-H	RL	22	1	25		
SM-I	RL	28	7		1	
SM-J	RL	31	10		4	
SM-K	RL		2 12		6	
SM-L	PW		10 20		14	
SM-M	SW		1 11		5	
SM-N	SW	18	10		14	
SM-O	SW		8 18		12	
SM-P	SW		11 21		15	
SM-Q	B		28	21		1
SM-R	B			3 28		1
SM-S	B			16 26		20
SM-T	B			5 15		1

2.3.2 Listening method

Sound files were listened to in real time. The first and last nights of recording at each site were listened to in full (i.e., all five minutes). For most of the other samples in between, the first minute or half-minute of sound was listened to. If sound quality was poor during that initial sampling period (e.g., due to wind or rain), or the pattern of frog activity during that minute was unclear or variable (e.g., intermittent calling), then additional time was listened to until an assessment of that sampling period could be made (usually an additional minute, but sometimes the full five-minute sample), or until the full five minutes had been heard. Because the frog species in the Koondrook-Perricoota area, when calling, tend to call at regular short-term intervals (i.e., multiple calls per minute), this variation in sampling period was not considered to influence the results for frogs.

While listening to the samples, a spreadsheet was completed, with an estimate made of the number of frogs calling of each species per sample. Using subtle differences in calling behaviour, sound quality and call characteristics (e.g., distant versus near calls, sequence order of calls in chorus, dominant frequency (Hz) of calls, how often individuals call), it was generally possible to quantify small numbers of frogs, at least categorically (e.g., 1, 2, 3, 4, 5-10, 10+). Counting larger numbers of frogs was almost impossible, and the likelihood of considerable error in larger estimates is acknowledged. Abundance estimates are intended to provide relative levels of activity rather than exact counts of frogs.

Strong wind, loud frog choruses and particularly close and loud individuals (particularly *Litoria peroni* close to the microphone) made it difficult to hear subtle sounds in some samples. Thus, some species (e.g., *Crinia sloanei*) are likely to be less detectable than others.

In quiet samples, loud frogs could be heard in the distance. This is an inherent bias in acoustic sampling; loud calls travel further and thus are detectable at a greater distance. For this study, distant frogs were included where identifiable, but not included where they were just a cacophony of sound. The focus was on frogs that were clearly identifiable.

2.4 On-ground assessment

Between 30 October and 2 November 2016, one GHD zoologist visited all Songmeter sites once, with assistance and logistical support from FCNSW staff members and the use of specialised FCNSW equipment (boat and amphibious vehicle). One purpose of the site visit was to refresh the SD cards and batteries in the Songmeters units, to download existing data and to ensure that they continued to operate for the duration of the flood.

Given the time required to access sites each day, time spent at each site was limited to one hour or less. At each of the 20 sites, the following was undertaken:

- Quantitative tadpole sampling, using a hand-held dipnet (6 x 10-second dips per site in best-available tadpole habitat). All tadpoles captured were identified to genus or species (some species of tadpoles are not distinguishable in the field – e.g., *Limnodynastes tasmaniensis* and *L. fletcheri*; *Crinia signifera* and *C. parinsignifera*) measured (mm) and staged (developmental stage) then retuned alive to the water. Fish and other fauna (e.g., notable invertebrates) captured were noted and identified to species as far as possible.
- Habitat assessment, with respect to frog breeding potential at and around the site, with reference to specific attributes where possible (e.g., water depth and extent, vegetation characteristics, openness, connectivity to main flood channels, etc…).
- Opportunistic observations of other signs of frog breeding activity (frogs calling, egg masses, metamorphs, adult frogs).
- Representative photographs at every site.

Due to safety considerations, no work was undertaken at night. Therefore, targeted metamorph searches (after dark) were not undertaken. Metamorphs were not seen during the daytime visit.

By visiting the 20 sites during the height of the flood, there was a rare opportunity to assess the forest conditions for frogs during a large-scale flood across an entire flooded forest, and then to compare findings from previous years of assessment, where the flood extent was far smaller.

3. Environmental conditions

Temperature and rainfall data were obtained from the Bureau of Meteorology (BOM) website for weather station 080023 (Kerang). Figure 5 shows that the weather during the sampling period followed the expected seasonal pattern, with gradual warming from July to the end of the year. Sampling began at or near the coolest part of the year. Frequent short-term temperature fluctuations are evident (i.e., the weather tends to warm up for a few days, then cool off for a few days).

The maximum temperature experienced during the sampling period was 36.0ºC (20 November), but the three-day average maximum temperature peaked at 33.4ºC in November (Figure 5). The minimum temperature experienced during the sampling period was 1.3ºC (25 August), but the three-day average minimum temperature was 1.6ºC in late August 2016 (Figure 5).

A total of 215.1 mm of rain fell in Kerang during the sampling period, which is approximately 24% above average conditions (the 30-year average rainfall for Kerang for 1 July to 30 November (five months) is 174 mm). Measureable rain (i.e., > 0.2 mm in a 24-hour period) was recorded at Kerang 46 times during the sampling period, ranging from 0.2 mm to 22.8 mm at a time. For periods when rain fall, seven-day rainfall aggregates ranged from 0.2 mm to 54.2 mm (Figure 5). On nine occasions during the sampling period, substantial rainfall (i.e., 10 mm or more) was recorded over a seven-day period; these occasions were considered likely to represent sufficiently wet periods that would typically result in frogs calling.

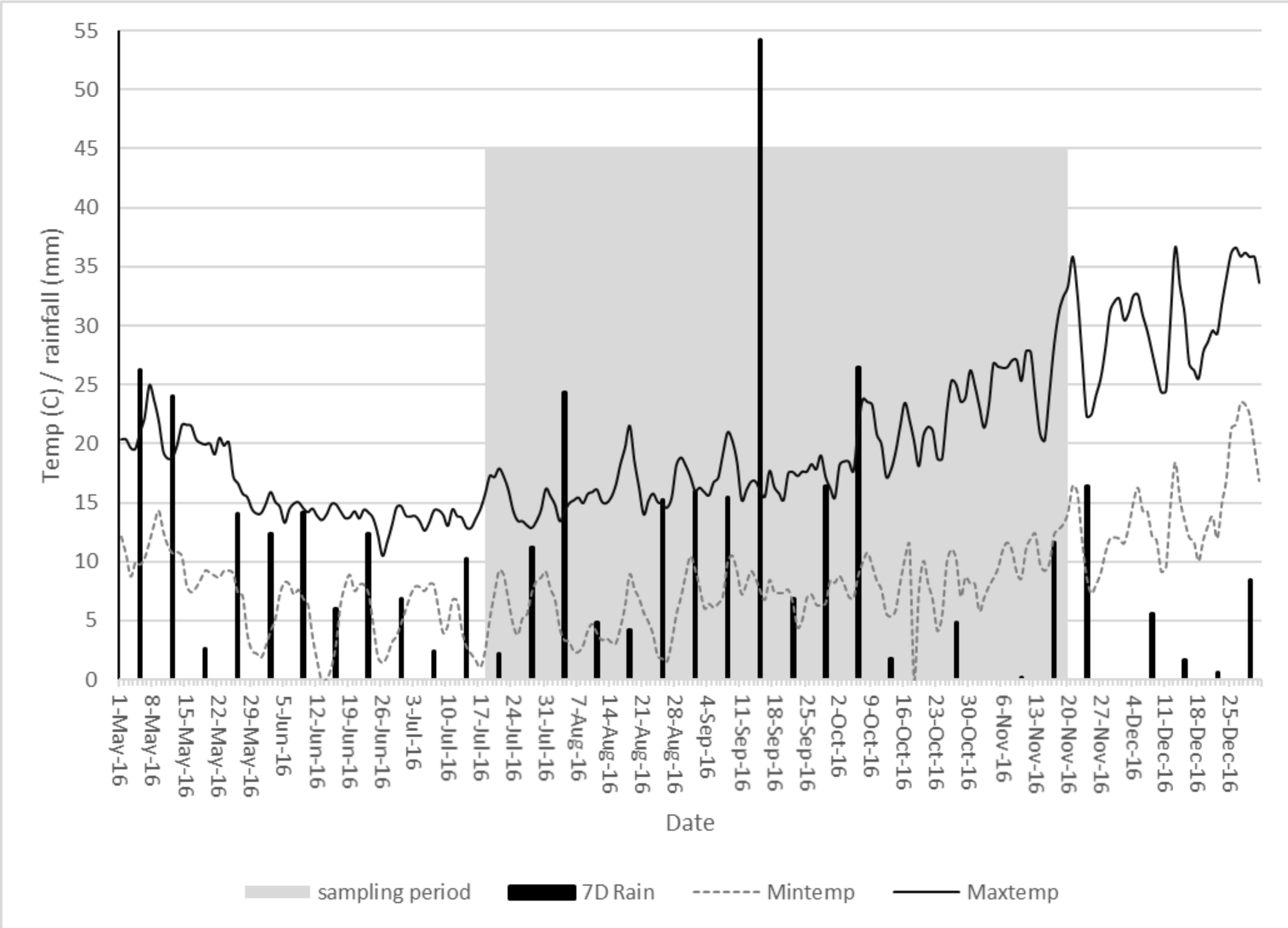


Figure 5 Temperature and rainfall data before and during the sampling period (source: Kerang; BOM station 080023)

Temperature data (minimum and maximum temperatures) are three-day averages (up to date shown) and rainfall data are seven-day aggregates (up to date shown).

4. Songmeter results and discussion

4.1 Species richness and abundance across the sites

Seven frog species were heard across the sites (Table 2), but no species was heard at all sampled locations. Sites had either five or six species recorded at them.

Five species were almost ubiquitous among the sites, being found at 19 or all of the 20 sites: Plains Froglet (*Crinia parinsignifera*), Common Froglet (*Crinia signifera*), Peron's Tree Frog (*Litoria peroni*), Spotted Marsh Frog (*Limnodynastes tasmaniensis*) and Southern Bullfrog (*Limnodynastes dumerili*). Two species were less widespread (Barking Marsh Frog, *Limnodynastes fletcheri*; Southern Spadefoot Toad, *Neobatrachus sudellae*), being found at eight and five sites respectively (Table 2).

Calling activity was dominated by three species (*Crinia parinsignifera*, *Crinia signifera*, *Limnodynastes tasmaniensis*), which on average called on ≥51% of nights during the sampling period. Two species (*Litoria peroni* and *Limnodynastes dumerili*) had intermediate calling activity (called on 27 – 38% of nights) during the sampling period, and two species (*Limnodynastes fletcheri* and *Neobatrachus sudellae*) had considerably less activity overall, calling on <10% of nights (Table 2).

Comparison of calling activity at the different sites and habitats (standardised for number of sampling nights at each site) showed that there was no strong pattern among habitats or sites with regard to frog activity or species richness (Figure 6). The greatest frog calling activity was at SMA (borrow pit) and SMD (primary wetland), while the least activity was at SMR (borrow pit) and SMM (secondary wetland).

All habitat types had a range of levels of frog calling activity (i.e., sites with low, medium and high activity) (Figure 6). Primary wetlands had the smallest difference between high activity and low activity – PW sites tended to have relatively high frog calling activity.

The frog community at SMM appears to differ most from frogs at other sites. Unlike other sites, SMM had very few *Crinia parinsignifera* calling and unusually high calling activity by *Neobatrachus sudellae*.

Maximum counts of individuals of each species at the different sites varied greatly (Figure 7). It is important to note that not all of these individuals were necessarily heard simultaneously. The Pollack (SME) had the highest aggregate maximum count of individuals, with more than 75 frogs across six species. Two river lagoon sites (SMI and SMG) had the lowest counts of individuals, with 20 or fewer individuals across six or five species, respectively. Overall, the maximum counts of frogs at the primary and secondary wetland sites tended to be higher (combined mean = 7.12 per species) than at river lagoons and borrow pits (combined mean = 4.92 per species).

It is also important to note that abundance as a measurement from Songmeter files has limitations, as discussed in Section 2.3.2.

Table 2 Number of nights that each species was heard at each site

Habitat type	Songmeter	# nights sampled	# species	*Crinia parinsignifera*	*Crinia signifera*	*Litoria peroni*	*Limnodynastes tasmaniensis*	*Limnodynastes dumerili*	*Limnodynastes fletcheri*	*Neobatrachus sudellae*
Primary wetlands	SMB	66	6	58	51	32	38	34	0	2
	SMC	66	6	65	25	24	45	42	2	0
	SMD	66	6	66	56	16	50	37	0	1
	SME	117	6	81	67	31	66	36	26	0
	SML	66	6	63	21	22	37	12	0	3
Secondary wetlands	SMF	66	5	62	19	22	38	37	0	0
	SMM	66	6	1	13	9	55	1	0	31
	SMN	66	5	0	65	18	18	30	10	0
	SMO	66	5	47	19	19	51	24	0	0
	SMP	66	6	60	4	27	51	47	1	0
River lagoons	SMG	76	6	12	64	10	34	19	0	1
	SMH	66	6	41	39	6	34	5	2	0
	SMI	66	5	5	52	16	29	42	0	0
	SMJ	66	5	40	32	23	40	47	0	0
	SMK	66	5	58	33	22	49	53	0	0
Borrow pits	SMA	76	5	76	76	38	63	0	18	0
	SMQ	82	5	59	10	18	64	25	0	0
	SMR	81	5	53	2	0	57	2	22	0
	SMS	66	6	56	40	9	46	10	16	0
	SMT	66	5	55	37	27	50	39	0	0
TOTAL	ALL	1422	7	958	725	389	915	542	97	38
ACTIVITY (% of total)				67.4%	51.0%	27.4%	64.3%	38.1%	6.8%	2.7%
# sites				19	20	19	20	19	8	5

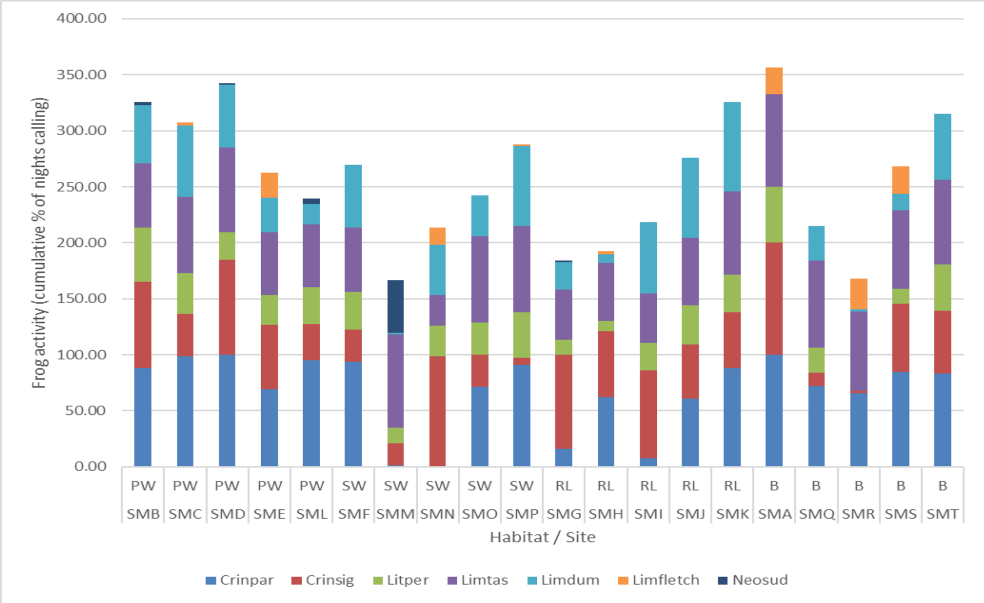


Figure 6 Calling activity by different species of frogs at the 20 sites, grouped by habitat type, and standardised for number of nights sampled at each site

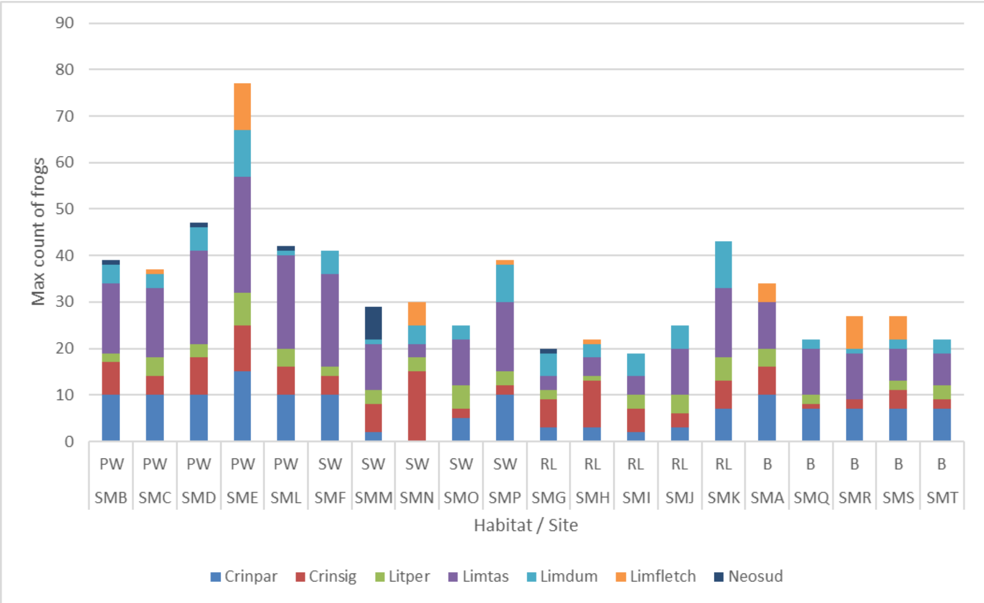


Figure 7 Maximum counts of each species at each site during the calling period

4.2 Frog responses to weather patterns

Figure 8 presents weather information (daily maximum temperature, daily minimum temperature, daily rainfall) and mean frog calling activity per site (total numbers of frogs heard that day, divided by the numbers of sites sampled that day) for a period that covers the sampling period at all sites. The standardisation per site (rather than total frog calling activity) is done in an effort to remove a potentially misleading increase in frog calling activity from July onwards as sites are added incrementally to the sampling (i.e., as flood water arrives). However, there is still a pronounced increase in calling activity to a peak in early September, then a gradual decrease by the end of October.

At a coarse level, frog activity in this graph does not appear to respond to seasonal temperatures or rainfall. The main increase in frog calling activity during August occurs at a time when maximum and minimum temperatures remain fairly consistent, albeit with short-term fluctuations, and the peak rainfall events are not matched by peaks in frog calling activity. Frogs are likely to have responded to other cues also, such as moon phase and changes in atmospheric pressure. These are not investigated here.

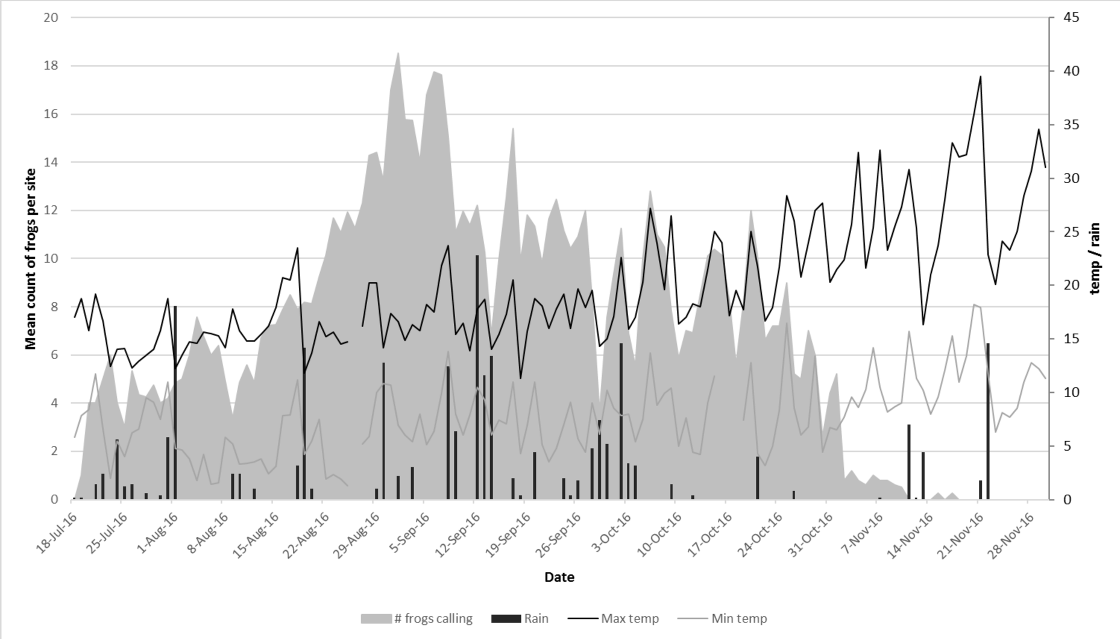


Figure 8 Frog calling activity (mean count of frogs heard per site) relative to temperature and rainfall during and around the sampling period

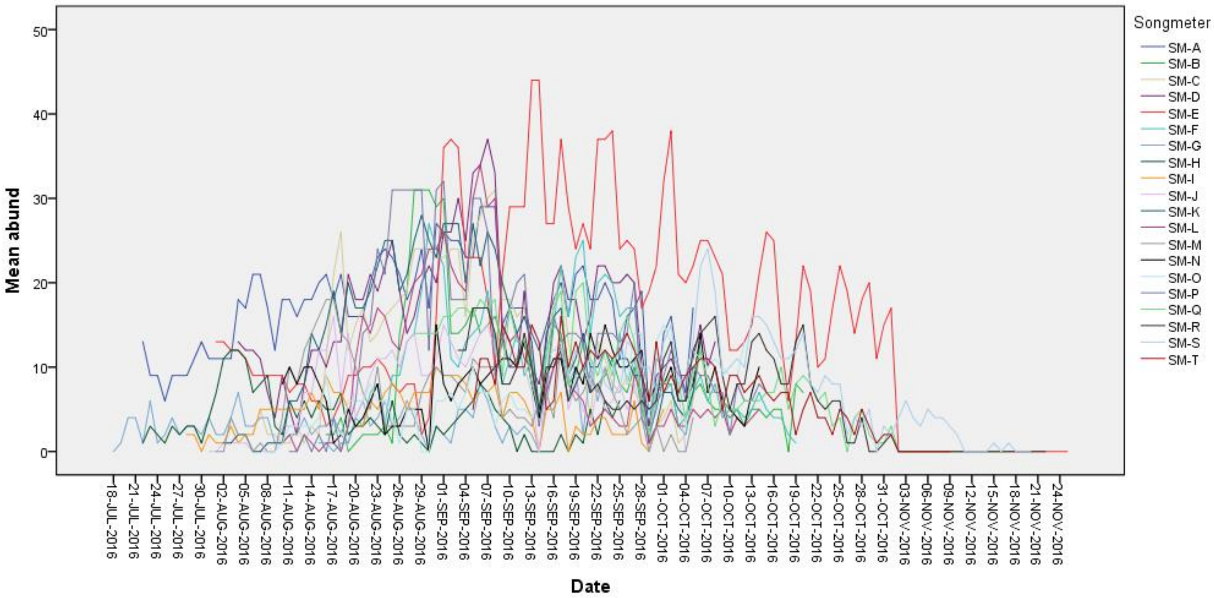


Figure 9 Mean frog abundance by date at sites during the 2016 sampling period

4.3 Frog responses to arrival of flood water

Figure 9 shows the mean count of frogs (all species combined) calling at each site during the 2016 sampling period. This graph shows that no two sites were the same, with respect to frog responses. However, this graph masks patterns that may be there, because the water did not arrive at sites at the same time.

On the basis of camera photos, the day of water arrival at most sites could be determined accurately (see example in Figure 10). The days of water arrival at a site were given a reference value of zero, and then site data were plotted against day number.

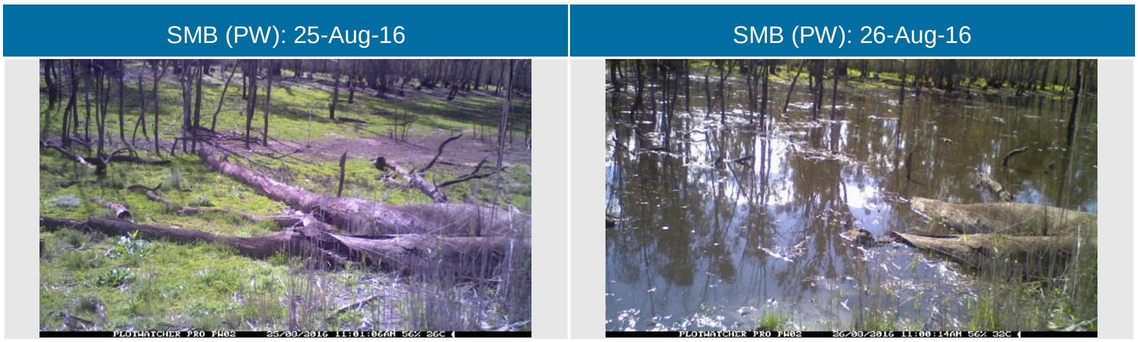


Figure 10 Example of water arrival within 24 hours at a site (SMB), as recorded by the time-lapse camera

A clearer pattern begins to emerge when the water arrival dates (t = 0) at sites are aligned (Figure 11). This shows that many sites, but not all, had little frog calling activity in the days immediately prior to water arrival. Some sites had considerable frog calling activity prior to water arrival, and one site (SME – The Pollack) was notably different from all other sites. It is important to note here that the water arrival date at some sites was uncertain, due to cameras failing (SMA, SMG) or due to water already being present prior to flood water arriving (SMN, SMQ, SMR, SMS, SMT). For those sites, a guestimate of water arrival day was made on the basis of water arrival at nearby sites, or the day the water level increased markedly and rapidly.

When sites are grouped by habitat type, the pattern strengthens further (Figure 12). For three habitats (primary wetlands, secondary wetlands, river lagoons), pre-water frog activity is low, then increases markedly at or around the known/proposed time of water arrival. For the fourth habitat (borrow pits), frogs appear to be calling prior to flood water arrival and there is no apparent change in their calling activity. It is notable that four of the five borrow pit sites held water prior to the arrival of flood water – thus, there was frog habitat present already.

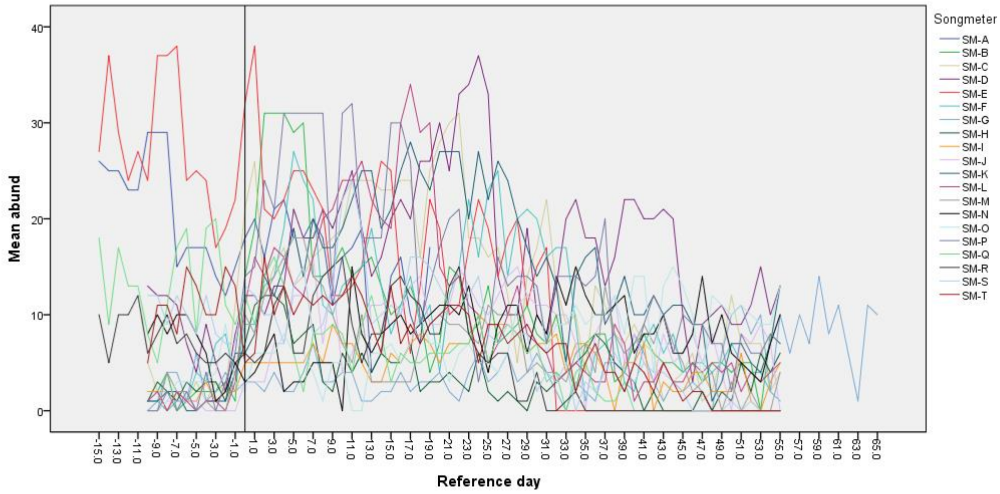


Figure 11 Mean frog abundance at sites during the 2016 sampling period, standardised for day of water arrival (reference day = 0)

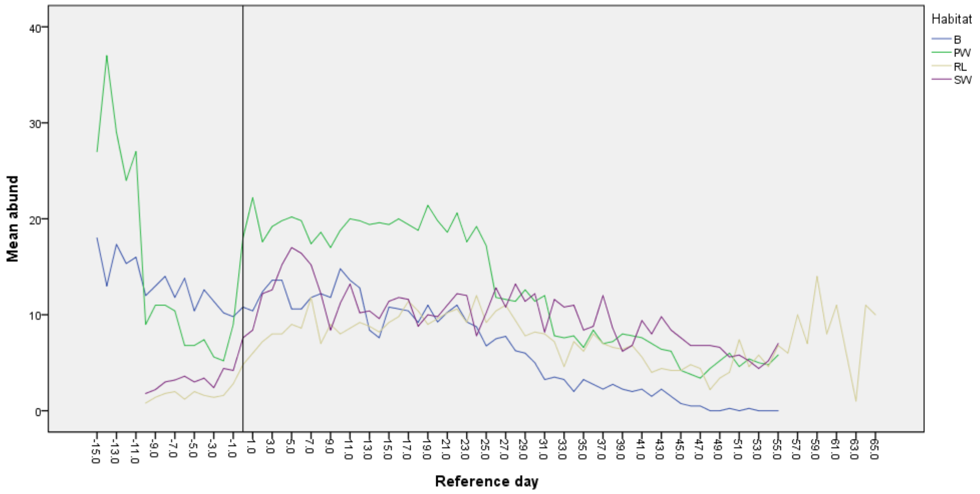


Figure 12 Mean frog abundance by habitat type during the 2016 sampling period, standardised for day of water arrival (reference day = 0)

B – Borrow pits; PW – Primary Wetlands; RL – River Lagoons; SW – Secondary Wetlands

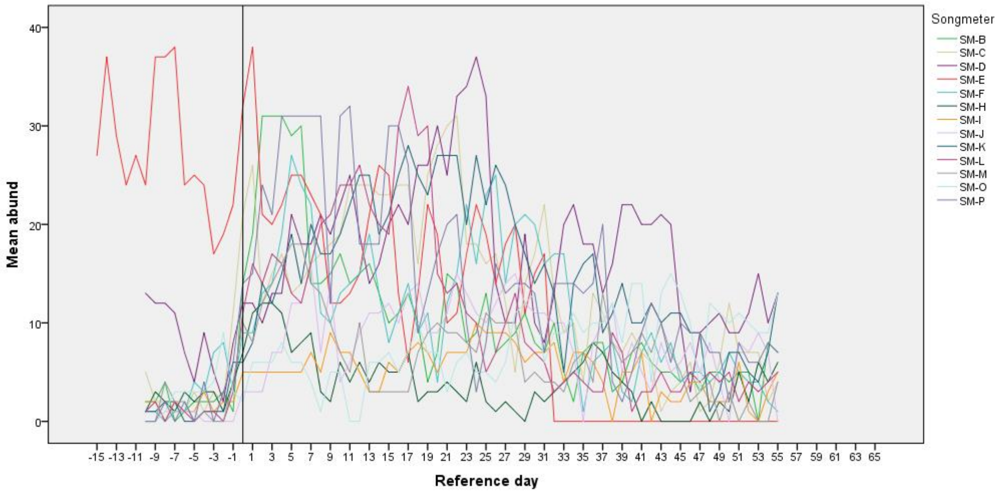


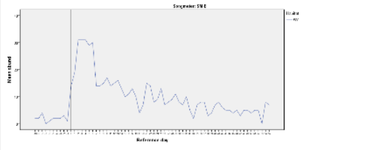
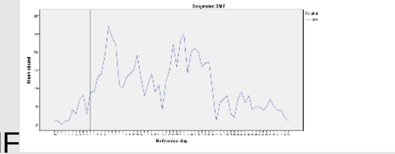
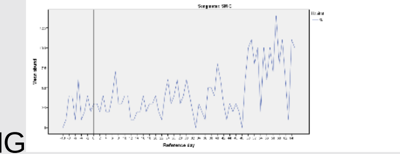
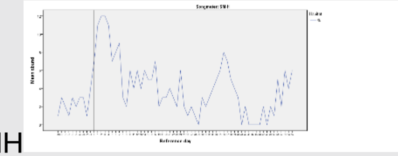
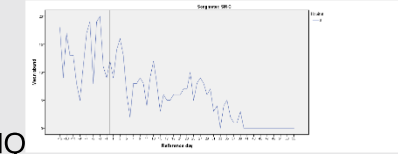
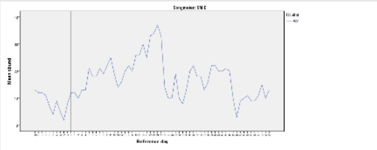
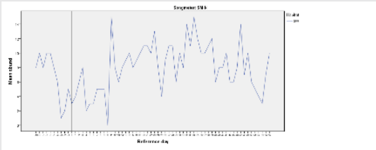
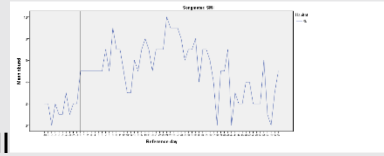
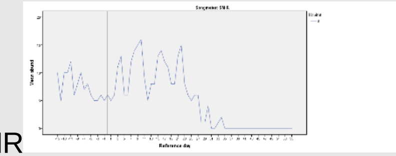
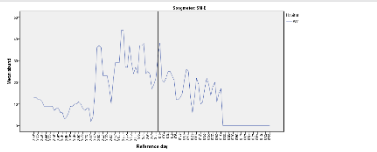
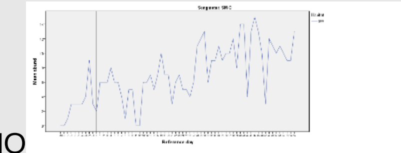
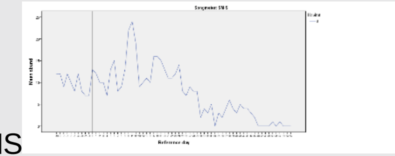
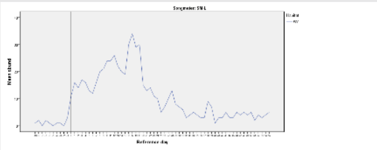
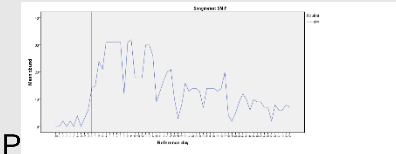
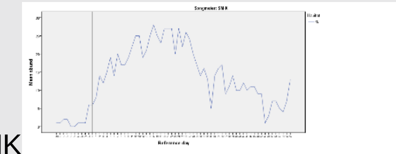
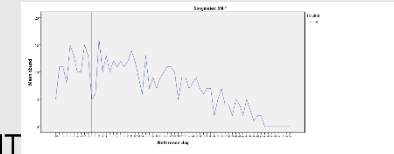
Figure 13 Mean frog abundance by site, standardised for day of water arrival (reference day = 0), and with uncertain sites removed

When the uncertain sites (SMA, SMG, SMN, SMQ, SMR, SMS, SMT) are removed from the graph (see Figure 13), it is clear that all but one of the sites showed the same response: frogs were silent or near silent the day before water arrived, then began calling on the day of arrival. Frog calling activity at the Pollack (SME) during the sampling period was notably different from all other sites. SME is the northern-most site of all, and was the last site to have received flood water (1 October). However, frog activity at that site was high well prior to the arrival of the flood, and there was no obvious increase in activity on or after that date.

At SME, there was a large increase in frog activity approximately 30 days prior to the arrival of the flood water (which was approximately 31 August – see SME in Table 3). This increase was similar to the pattern seen at other sites upon arrival of flood water. According to the hydrograph presented earlier (Figure 1), the timing of the increase in frog activity at SME corresponds with the arrival of water at Barbers Creek (Pollack) in late August. The frog calling activity recorded by the Songmeter suggests that water reached the Songmeter at SME during that period, and a rapid increase in frog activity that occurred was in response to that water, rather than the subsequent arrival of water in early October.

It is also noteworthy that the Pollack was flooded artificially in the latter part of 2015. It is possible that there was water remaining at the site prior to flood water arrival, and that seasonal conditions and/or time-of-year encouraged the frogs at that site to call prior to the arrival of the main flood event. It is also possible that there were more frogs at that site in response to successful breeding the year before, but that information is unlikely to be picked up by Songmeter acoustic analysis.

Table 3 Mean frog abundance for individual sites, relative to the arrival of water (reference line at x = 0)

Primary wetlands	Secondary wetlands	River lagoons	Borrow pits
SMB 	SMF 	SMG 	SMA 
SMC 	SMM 	SMH 	SMQ 
SMD 	SMN 	SMI 	SMR 
SME 	SMO 	SMJ 	SMS 
SML 	SMP 	SMK 	SMT 

5. On-ground assessment - results and discussion

Dipnetting was undertaken at 16 of the 20 sites visited. During the dipnetting, 48 tadpoles of potentially six species were captured (Table 4). Identification of tadpoles to species level at Koondrook-Perricoota is fraught with challenges – many of the species present have tadpoles that are extremely similar to tadpoles of closely related species. Thus, in the field, distinguishing between tadpoles of *Crinia signifera* and *C. parinsignifera*, and *Limnodynastes tasmaniensis* and *L. fletcheri* is near impossible. Some larger and more developed *Limnodynastes* tadpoles may develop dorsal patterns that indicate one species or another, but this was not commonly seen. Even for some of the smaller *Limnodynastes* tadpoles, it was difficult to distinguish between *L. tasmaniensis*, *L. fletcheri*, and *L. dumerili*.

Limnodynastes tadpoles were the most commonly captured tadpoles, accounting for 26 of the 48 tadpoles captured. *Crinia* tadpoles were the next most common (21 individuals), and one *Neobatrachus* tadpole was captured at site SMM.

Interestingly, no tadpoles of *Litoria peroni* were captured in 2016, despite this being one of the most ubiquitous species of frog heard by Songmeters. In 2015, 41 of the 42 tadpoles captured at the Pollack were of *Litoria peroni*, and one was *Limnodynastes dumerili*. This difference between years (2016 versus 2015) is likely to reflect time of year. The tadpole sampling at the Pollack was done in January 2016, while the sampling for this 2016 flood event was done in late October/early November. By January, rapidly developing tadpoles (e.g., *Crinia* spp.) are likely to have reached metamorphosis and departed the aquatic habitat, and at least some of the Limnodynastes tadpoles may have metamorphosed also. At the Pollack in January 2016, numerous *Crinia* and *Limnodynastes* metamorphs were observed at night.

No sampling was undertaken at four sites (SMD, SME, SMF, SMO; two primary wetlands and two secondary wetlands) because the surrounding water was too deep, and the nearest available habitat suitable for dipnetting was deemed too far from the Songmeter to be easily linked with the acoustic results at that Songmeter. Note that effective dipnetting (with a hand-held net) in deeper water is more difficult than in shallow water, because it is more difficult to move the net fast enough to capture tadpoles, and balance is more difficult, and submerged logs and woody debris are more concealed.

Table 4 Results of habitat assessment and tadpole dipnetting during the on-ground assessment in peak-flood (Oct-Nov 2016)

Site	Habitat category	Date	Habitat notes	Tadpoles captured	Tadpole species	Notes
SMA	B	2 Nov	Shallow water near SM, deep water close by. Small extent of fringing vegetation, along immediate edge of borrow pit	1	*Limnodynastes tasmaniensis/fletcheri*	Deep borrow pit, with steep grassy edge beneath Songmeter
SMB	PW	1 Nov	Shallow water near SM only, deep water close by. Small fringe of vegetation in shallow water.	1	*Limnodynastes dumerili? L. tasmaniensis/fletcheri*	Good tadpole habitat present.
SMC	PW	1 Nov	Water level varies, deep water and shallow water, dry ground near SM	5	*Limnodynastes tasmaniensis/fletcheri*	Tadpole shrimps captured also
SMD	PW	1 Nov	Deep water only. No fringing vegetation. Trees standing in deep water.	NA	-	No dipnetting done – too deep for dipnet
SME	PW	2 Nov	Deep water only. No fringing vegetation. Trees standing in deep water.	NA	-	No dipnetting done – too deep for dipnet
SMF	SW	1 Nov	Trees standing in deep water only. No fringing vegetation. Flowing water, too swift for most frogs/tadpoles. 50 m to nearest veg, 25 m to rushes	NA	-	No dipnetting done – too deep for dipnet
SMG	RL	31 Oct	Like lake edge, deep water with no veg, narrow fringe 1 - 2 m wide of vegetation with shallow to deep pretty quickly. 1 - 50 cm depth in approx 2 m from edge.	1	*Limnodynastes tasmaniensis/fletcheri*	Tadpole shrimps captured also
SMH	RL	31 Oct	Edge of lagoon near road, grassy meadow with big trees along edge, drops off to depth quickly. Not much fringing veg., like a beach, larger trees in water, not much egg-laying or tadpole shallow water protection, large RRG, smaller RRG in water	0	-	-
SMI	RL	31 Oct	Nice lagoon, with veg through water, and expanse of shallow water. Good egg-laying habitat at edge, rushes growing. Apparently good tadpole habitat.	0	-	Tadpoles likely to be present, but difficult to catch in vegetation
SMJ	RL	31 Oct	Fringing habitat shaded and smothered by duck-weed. Deep water to one side, with trees in water, then behind SM is flooded grassland, good frog/tadpole habitat.	0	-	Tadpoles likely to be present, but difficult to catch in vegetation. Tadpole shrimps captured
SMK	RL	31 Oct	Edge of lagoon. Narrow band of fringing veg with seemingly good tadpole habitat, then drops to depth quickly. Some shallow water tadpole habitat west of SM.	0	-	-

Site	Habitat category	Date	Habitat notes	Tadpoles captured	Tadpole species	Notes
SML	PW	1 Nov	Good edge habitat, other side has deeper water flowing slightly towards Barber Ck. Good frog habitat	2	*Limnodynastes tasmaniensis/fletcheri*	-
SMM	SW	3 Nov	Expansive shallow water with veg growing through it, Connected water, with hummocks - good habitat. Not much shelter for frogs during day - perhaps tree frogs but less so for ground frogs. Sparse ground veg. Turbid shallow water (20 cm generally, but with deeper holes. Seems as though cattle have been through, but apparently not too many here. Not too many logs, but some sticks and litter. Not much understorey, no mid-storey.	4 1 1	*Limnodynastes tasmaniensis/fletcheri* *Neobatrachus sudellae* *Crinia parinsignifera/signifera*	Tadpole shrimps captured also. Lots of life in this water - damselflies, snails, tadpoles, tadpole shrimps, etc…
SMN	SW	3 Nov	Extensive shallow water around SM, water ribbon, rushes, duckweed (smothering light), less good for tadpoles. Away from creek channel, drier, grassy, not much mid-storey, trees, not so good for frogs. Towards and within channel, good water, aquatic plants.	5 1	*Crinia parinsignifera/signifera* *Limnodynastes dumerili*	
SMO	SW	3 Nov	Deep water only	NA	-	no tadpoling done - too deep, and tadpole habitat too far away
SMP	SW	2 Nov	Typha along edges. Varied habitat. Large deep water areas, lots of fringing veg near SM, good for tadpoles. Tadpole habitat likely to stay with water edge as water rises or drops.	6 12	*Limnodynastes tasmaniensis/fletcheri* *Crinia parinsignifera/signifera*	-
SMQ	B	2 Nov	Dark, smelly, black water. But with good life forms. Water boatmen, damselflies, 2+ tadpole spp. Borrow pit full, veg all around perimeter, good egg laying habitat along edge, deep water in middle, no water flow. Habitat for all types of local tadpoles.	1 3 1	*Limnodynastes tasmaniensis/fletcheri* *Crinia parinsignifera/signifera* *Limnodynastes fletcheri?*	L. fletcheri tadpoles was large and mottled (80 mm total length).
SMR	B	2 Nov	Extensive shallow water at edge of borrow pit, and deep water nearby. Shallow water has dead grass in it, rather than new, lush green grass. Looks, smells anoxic.	1	*Limnodynastes tasmaniensis/fletcheri*	-

Site	Habitat category	Date	Habitat notes	Tadpoles captured	Tadpole species	Notes
SMS	B	2 Nov	long continuous borrow pit, v deep in middle, vegetated sides, trees in water with dead grass, but further in towards forest are veg areas with daisies etc. Mediocre habitat for frogs and tadpoles. Dipped in shallow water (to knee depth) where there was and wasn't veg.	1 1	*Limnodynastes dumerili* *Limnodynastes dumerili? L. tasmaniensis/fletcheri*	
SMT	B	2 Nov	very deep water and also inundated grassy areas on forest side.	0	-	-

6. Conclusions

As in 2014 and 2015, this work demonstrates a dramatic response by frogs to the arrival of flood water in 2016, and in the absence of rainfall. The results here are more rigorous than those in previous years, aided by larger numbers of Songmeter units. However, the results showed unexpected variation also. Assessment of the frog responses in the different habitats in the forest (PW, SW, RL and B) suggest that habitat may play a role in responses by frogs. The different habitats tended to support the same assemblages of frog species, but sites that already held water at the time of flooding had less pronounced responses by the local frogs than sites that were dry prior to flooding. This has implications for the benefits to frogs of timing and scale of artificial floods. If small artificial floods simply add water to sites where water already lies, then there may be minimal benefit to frogs. However, if water is added to dry sites, then the benefit may be maximised.

7. Recommended next steps

As in previous years, this work demonstrates a dramatic response by frogs to the arrival of flood water, and in the absence of rainfall. Assessment of the frog responses in the different habitats in the forest (PW, SW, RL and B) suggest that habitat also plays a role in responses by frogs. Sites that already held water at the time of flooding had less pronounced responses by the local frogs than sites that were dry prior to flooding. This has implications for the benefits to frogs of timing and scale of artificial floods. If small artificial floods simply add water to sites where water already lies, then there may be minimal benefit to frogs. However, if water is added to dry sites, then the benefit may be maximised.

Further work could take many directions. Some ideas are outlined below, with the aims of: i) maximising the benefit and learnings that result from artificially-delivered floods, which are expected to be generally of a small scale and extent, and ii) maximising the cost-efficiencies of unmanned use of the 20 Songmeters. Some of these ideas are interrelated, and can be combined or amalgamated as required.

Ideas that could be factored into future investigations are:

- <u>Understand microhabitats used by frogs</u> There is probably no need to sample frogs at borrow pits or river lagoons any more – we know enough about the frog species that occur in the forest, and their responses to flood water and natural environmental conditions (rainfall, temperature). The project can now switch efforts to investigate differences (in frog responses and frog breeding success) between primary wetlands and secondary wetlands. Primary wetlands are those that will always receive water during a flood, regardless of flood scale, and secondary wetlands are those that will receive water during larger floods only. Primary and secondary wetlands may differ in their habitat characteristics, and some of those habitat characteristics may influence the breeding success of frogs. This has implications for relative benefits of the scale of artificial floods.

  Place multiple Songmeters near each other at a range of predicted water depths (i.e., prior to arrival of water – use existing models and LIDAR?) in consistently good frog wetlands, so that timing of frog responses can be measured as the water level rises and new areas become available. Tie in information on frog calling with water depth changes (water depth gauges were present for some sites in this project, but the data have not been extracted here due to time constraints). Then couple that with appropriately timed on-ground surveys to quantify the habitat characteristics (water depth, water quality, fringing vegetation, flow, shadiness, etc) and tadpole surveys to assess breeding locations and tadpole preferences. **This would help to provide information on the relative benefits (to frogs) of small-scale floods (i.e., those that remain within channels) and larger floods (i.e., those that spread onto the flood plains).**

- Understand frog population dynamics along waterways Place Songmeters at regular intervals along waterway reaches during small flood events. Are the numbers of frogs consistent along the flooded reach, or are there preferred frog locations? How do flooded grassy wetlands compare with deeper pools? Does frog breeding success vary between habitats? Do frogs move with the water front, or do 'new' frogs commence calling as the water moves through the forest (like a Mexican wave)? These questions can be tackled by placing multiple Songmeters (each with a camera and a water level indicator) at staged locations along stretches of waterway that receive floodwater during a small flood, and out (perpendicular direction) from the waterway to measure the frogs' response as the water spreads beyond the waterway channels. **The idea of this would be to understand more about what attributes of the water/habitat frogs are responding to – is it the water depth, the vegetation, etc.?**
- Establish transects Now that flood extent is relatively well known for small and large events, FCNSW could establish repeatable transects across the flooded area, to use for breeding success surveys (frog counts, egg mass count and distribution, tadpole counts and distributions, habitat characteristics). These transects can be assessed year after year and during/after floods to assess changes in frog population sizes. LIDAR imagery could be used to predict locations for transects, to maximise benefit. **The use of repeatable transects would allow year-to-year comparisons in the consistency of frog responses and breeding success.**
- Assess spread of frogs from population breeding source – do frog populations expand radially from breeding areas, or do they remain localised to flooded areas? i.e., does flooding small parts of the forest allow frogs to recolonise the remaining parts of the forest, or is a large flood required? **Does a small flood benefit frogs throughout the entire forest, or just those nearest the waterways?**
- Time of year Does a managed flood at one time of year influence the success of species that are active at other times of the year? For example, winter floods may lead to longer-lasting soil moisture during spring/summer, such that breeding locations can fill more easily with summer rains, or such that individuals may not need to disperse so far from potential breeding locations during their off-season. **This would provide information on how important time of year for flooding is to frogs.**
- Tadpole success at a local scale If shallow flood water contracts quickly to deeper waterholes (with low area-to-fringing-edge ratio), then tadpoles in that deeper habitat may be less able to find and occupy warmer, shallower water for more rapid development, and less able to escape predators (e.g., large-bodied fish and yabbies/crayfish). Therefore, if those tadpoles can develop and metamorphose prior to the water contracting, the breeding effort may be more successful. **To most benefit frogs, should artificial floods be managed to keep shallow water for as long as possible, or just to fill deeper pools?**
- Fish Review comparable information on habitat use and timing of arrival by small and large bodied fish (as predators of amphibian eggs and tadpoles) in the various habitats. Does the timing of calling and habitat preference by frogs match the movements and habitat use by fish? **Try to gain an understanding of some of the other influences on frog breeding success.**

- Tadpole sampling frequency During a flood, sample tadpoles and metamorphs more often rather than less often, to get a better indication of seasonal dynamics. To really understand breeding success, more visits are needed to capture metamorphosis times for the different species. *Crinia* species are small and are likely to metamorphose earlier than *Limnodynastes* species, and *Litoria peroni* appears to either breed later than other species or have a particularly long larval/tadpole duration. In 2015, one of the recommendations was to sample prior to end of the year to catch tadpoles of *L. tasmaniensis*, *L. fletcheri*, *C. signifera*, *C. parinsignifera* – this was done in 2016 and was successful in this aim. **More frequent sampling would allow more robust data to be collected.**
- Frog calling behaviour – environmental cues Use the history of Songmeter results to investigate frog calling patterns with other environmental cues, such as moon phase and atmospheric pressure changes.

8. Limitations (GHD)

This report has been prepared by GHD for Forestry Corporation NSW and may only be used and relied on by Forestry Corporation NSW for the purpose agreed between GHD and the Forestry Corporation NSW.

GHD otherwise disclaims responsibility to any person/entity other than Forestry Corporation NSW arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

9. References

GHD (2015) Koondrook-Perricoota Monitoring Project – Frog Monitoring 2014. Report to Forestry Corporation of New South Wales. June 2015

GHD (2016) Koondrook-Perricoota Monitoring Project – Frog Monitoring 2015. Report to Forestry Corporation of New South Wales. June 2016

Gosner, KL (1960) A Simplified Table for Staging Anuran Embryos and Larvae with Notes on Identification. Herpetologica, Vol. 16(3):183-190

Appendices

Appendix A – Songmeter monitoring locations and sampling periods since 1 September 2014

Rows with **BOLD** indicate the 2016 monitoring.

Songmeter	Location	Description	Habitat	Latitude (S)	Longitude (E)	ZoneNum	Easting	Northing	Elevation (m)	First date	Last date	# nights
SMA	SMA1	Borrow pit - east side		35.65365301	144.2764	55H	253427	6051048	88	1-Sep-14	21-Jul-15	323
	SMA2	Borrow pit - north side		35.59163396	144.182355	55H	244716	6057689	81	23-Jul-15	25-Nov-15	126
	SMA2		**B**							**22-Jul-16**	**5-Oct-16**	**76**
SMB	SMB1	sth of Myloc Creek Road		35.69172101	144.2573	55H	251819	6046776	86	1-Sep-14	9-Mar-15	189
	SMB2	Long Lagoon		35.61162338	144.2293773	55H	249039	6055592	81	10-Mar-15	25-Nov-15	261
	SMB2		**PW**							**16-Aug-16**	**20-Oct-16**	**66**
SMC	SMC1	nth of Myloc Creek Road		35.69657296	144.2788	55H	253777	6046292	89	1-Sep-14	9-Mar-15	189
	SMC2	Myloc Creek		35.7148651	144.3167057	55H	257265	6044357	90	10-Mar-15	21-Jul-15	134
	SMC1	nth of Myloc Creek Road		35.69657296	144.2788	55H	253777	6046292	89	22-Jul-15	24-Sep-15	64
	SMC3a	Pollack Swamp1		35.57125	144.16007	55H	242631	6059892	35	25-Sep-15	10-Nov-15	46
	SMC3b	Pollack Swamp2 (100m towards water)		35.5709442	144.1592176	55H	242553	6059924	34	11-Nov-15	19-Jan-16	69
	SMC1	**nth of Myloc Creek Road**	**PW**			**55H**	**254068**	**6046373**	**89**	**7-Aug-16**	**11-Oct-16**	**66**
SMD	SMD1	McMahon / Myloc Roads		35.713421	144.3139	55H	257011	6044510	79	1-Sep-14	25-Nov-15	486
	SMD1		**PW**							**4-Aug-16**	**8-Oct-16**	**66**
SME	SME1	Horseshoe Lagoon		35.85738799	144.4008	55H	265295	6028749	79	1-Sep-14	21-Jul-15	323
	SME2	Waterhole Creek Trail		35.66336202	144.267528	55H	252652	6049948	79	22-Jul-15	24-Sep-15	65
	SME3	Pollack Swamp		35.56702	144.15116	55H	241810	6060338	9	25-Sep-15	19-Jan-16	116
	SME3		**PW**							**1-Aug-16**	**1-Nov-16**	**93**
SMF	SMF1	wetland near Long Lagoon		35.61492501	144.2393	55H	249951	6055251	86	1-Sep-14	25-Nov-15	486
	SMF1		**SW**							**15-Aug-16**	**19-Oct-16**	**66**
SMG	**SMG**	**Swan Lagoon, north-east side**	**RL**			**55H**	**268542**	**6023156**		**18-Jul-16**	**1-Oct-16**	**75**

Songmeter	Location	Description	Habitat	Latitude (S)	Longitude (E)	ZoneNum	Easting	Northing	Elevation (m)	First date	Last date	# nights
SMH	**SMH**	**Horseshoe Lagoon, north-east side**	**RL**			**55H**	**265415**	**6029416**		**22-Jul-16**	**25-Sep-16**	**65**
SMI	**SMI**	**Black Box Lagoon, north-west side**	**RL**			**55H**	**263372**	**6032367**		**28-Jul-16**	**1-Oct-16**	**65**
SMJ	**SMJ**	**Black Gate Lagoon, east side**	**RL**			**55H**	**263413**	**6034479**		**31-Jul-16**	**4-Oct-16**	**65**
SMK	**SMK**	**Black Lagoon, north side**	**RL**			**55H**	**260972**	**6038183**		**2-Aug-16**	**6-Oct-16**	**65**
SML	**SML**	**Moorings Lagoon**	**PW**			**55H**	**250101**	**6050559**		**10-Aug-16**	**14-Oct-16**	**65**
SMM	**SMM**	**Bullockhead Ck**	**SW**			**55H**	**271673**	**6023055**		**1-Aug-16**	**5-Oct-16**	**65**
SMN	**SMN**	**Benarca Ck**	**SW**			**55H**	**273993**	**6018553**		**18-Jul-16**	**14-Oct-16**	**88**
SMO	**SMO**	**Cpt 6 Boundary**	**SW**			**55H**	**272951**	**6026350**		**8-Aug-16**	**12-Oct-16**	**65**
SMP	**SMP**	**The Rookery**	**SW**			**55H**	**251950**	**6052661**		**11-Aug-16**	**15-Oct-16**	**65**
SMQ	**SMQ**	**BP 13,500; east side**	**B**			**55H**	**253203**	**6052093**		**28-Aug-16**	**1-Nov-16**	**65**
SMR	**SMR**	**BP 24,500; north side**	**B**			**55H**	**247142**	**6059364**		**3-Sep-16**	**1-Nov-16**	**59**
SMS	**SMS**	**BP 32,000; north-west side**	**B**			**55H**	**244023**	**6056803**		**16-Sep-16**	**20-Nov-16**	**65**
SMT	**SMT**	**BP 36,500; west side**	**B**			**55H**	**246722**	**6051515**		**5-Sep-16**	**1-Nov-16**	**57**

Datum: GDA94; Habitats: B – Borrow Pit; PW – Primary wetland; SW – Secondary wetland; RL – River lagoon

Appendix B – Photographs of water levels at individual sites during the 2016 flood

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SMA (B)	NA	Unknown Frog activity increased on 26 Sept 2016	NA	No photos - camera failed.
SMB (PW)		 26-Aug-16		
SMC (PW)		 17-Aug-16		
SMD (PW)		 14-Aug-16		slightly wet prior to flood arrival - rain filled?

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SME (PW)		 1-Oct-16		slightly wet prior to flood arrival. End photo is 1 Nov, only 31 days after water arrival.
SMF (SW)		 25-Aug-16		
SMG (RL)	NA	Unknown. Possibly 28-Jul-16, judging from timing at nearby RL sites.	NA	No photos - camera failed (black screen each day).
SMH (RL)		 1-Aug-16		

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SMI (RL)		 7-Aug-16		Some water present prior to flood arrival - rain filled?
SMJ (RL)		 10-Aug-16		
SMK (RL)		 12-Aug-16		

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SML (PW)		 20-Aug-16		
SMM (SW)		 11-Aug-16		
SMN (SW)		 18-Jul-16	NA	Water already present prior to camera installation. Always wet here – direct connection to river.

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SMO (SW)		 18-Aug-16		Slightly wet prior to flood arrival - rain filled? Then becomes deeper flood later (18 Sep 2016).
SMP (SW)		 21-Aug-16		
SMQ (B)		 23-Sep-16		Water already present prior to camera installation. Last photo Nov 1.

site (habitat)	Day before arrival of water	Day of water arrival (date)	55 days after water arrival	notes
SMR (B)		 28-Sep-16		Water already present prior to camera installation. Water arrives slowly, then fills pit completely. Last photo Nov 2.
SMS (B)		 26-Sep-16		Water already present prior to camera installation. Water arrives slowly, then fills pit completely. Last photo Nov 2.
SMT (B)		 15-Sep-16		Water already present prior to camera installation. Water arrives slowly, then fills pit completely. Last photo Nov 2.

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