Frog Population Monitoring of Mulloon Creek

Report on December 2021 surveys

Report prepared for The Mulloon Institute

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Executive Summary

Frog monitoring surveys were undertaken at pre-determined sites along Mulloon Creek in December 20221. The surveys represent a third season of monitoring frogs along the creek that commenced initially in 2017 and were undertaken again in 2020 (although at fewer sites than were surveyed for this 2021 survey). The surveys were conducted by a team of people using audio-recording techniques that were later analysed by an experienced herpetologist.

The surveys found that the section of the Mulloon Creek catchment covered by this study continues to support a relatively healthy frog community along the creek and at select dams/wetland sites adjacent to the creek (but within the Mulloon Creek Home Farm property only). A total of 11 frog species were recorded during this study. This result represents a notable increase in the total number of species recorded in the study area from the previous 2020 survey of 8 species, and the initial 2017 survey of 7 species.

The three additional (new) species recorded included Lesueur's Tree Frog, Southern Leaf Green Tree Frog and the Screaming Tree Frog. The latter was commonly recorded in the study area, having not been previously detected in 2017 or 2020, whereas the former two species were recorded in a new study site location in the upper reaches of Mulloon Creek, not previously surveyed in 2017 or 2020.

The species richness of frogs at sites during the 2021 survey averaged 3.8 species/site, including an average of 3.67 species per stream site and 4.75 species per dam/wetland site. This represents an increase in the species richness on the previous (2020) year's results of 2.55 species per site including an average of 2.44 species per stream site and 3 species per dam/wetland site). The 2021 results are however, relatively identical to the 2017 of (an average of) 3.68 species per site (dam/wetland site surveys were not completed in the original 2017 study). The higher detection rate (and assumed species richness) of the 2021 results compared with the preceding 2020 study may be attributable to a number of factors including an increase in overall survey effort (including increased audio recording time) and/or observer skill, as well as potentially the affects of two previous years of very dry/drought conditions leading up to the 2020 survey, whilst there had been very good rainfall over the preceding 12 months and immediately leading up to the 2021 survey.

Notwithstanding the positive results, two species of frog may possibly be suffering from a decline in local population size as observed by a notable downward trend in detection frequency within the study area. These species may also be suffering from more widespread declines across its range. Further research may be required to confirm what the status of these species actually is.

A number of both land management and further research recommendations have been made that are drawn out by the findings of this monitoring work and are described in detail in the full report.

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1 INTRODUCTION

1.1 Summary overview of project

This report provides a summary of the amphibian population surveys undertaken at Mulloon Creek near Bungendore NSW in December 2021

The Mulloon Institute (TMI) has been working with landholders at a catchment scale to rehydrate the landscape and improve functionality and land use management along a section of Mulloon Creek near Bungendore, NSW. In 2006, the Mulloon Institute, with backing from the Southern Rivers Catchment Management Authority, and through the Mulloon Creek Natural Farms (MCNF) business, began a Natural Sequence Farming rehydration pilot project at degraded sections of Mulloon Creek. The work has included the installation of numerous weirs within the creek to reinstate more natural 'pool and riffle' sequences.

The primary aim of this work was to slow the movement of water through the creek to recharge the groundwater system within the floodplain. The targeted benefits of slowing the movement of water and recharging the groundwater was to reduce erosion and improve the productivity of the landscape, including the overall biodiversity values of the aquatic and terrestrial systems in the area.

Based on the success to date of the project at a property scale, a multi-faceted scientific research program to collect hydrological, soil, and biological data to assess the impact of the catchment scale approach, is being undertaken (Peel *et. al.*, 2022).

Part of the biodiversity surveys has included assessing the existing amphibian populations in the area to determine how they might respond to or benefit from the rehydration project. A preliminary survey was completed by Luke Peel in November 2017 with analysis and reporting by Frogwatch (Hoefer 2017) and a second follow-up survey was completed last season in December 2020 (Patmore, 2021). The recent survey completed in December 2021 (and which are the focus of this report) was undertaken to increase the extent of baseline data on the existing frog community present within the defined study area of Mulloon Creek. For this survey, all the previous years' sites were revisited and an additional 12 transects (24 sites) were added to the study incorporating new properties/landholders involved with the project not previously surveyed. This December 2021 survey also for the first time provides back-to-back years of sampling (in the hope that these frog surveys will become an ongoing annual event).

The data from these frog surveys will facilitate part of a broader project to monitor the effectiveness of the Mulloon Rehydration Initiative to regenerate the waterways and associated riparian corridor and floodplains over time.

The study area, survey methods including dates and timing of the surveys, as well as survey conditions, and results of the 2021 frog surveys are provided below.

1.2 Aims and objectives of this assessment

The broad aim of this project is to provide baseline data on the frog populations present within the defined sections of Mulloon Creek to allow for future comparisons of

population numbers and assemblages to aid in the assessment of the benefits and effectiveness of the rehydration project. Baseline data is an important tool to measure key conditions (indicators) and is commonly gathered before a project begins, to be used to monitor and evaluate a project's progress.

The key factors included in the baseline data collection are broadly in relation to the following:

- Habitat features and values including certain water variables and vegetation characteristics
- Frog species (and general estimates of abundance) present within the defined sections of Mulloon Creek in the study area.

The Frog surveys along Mulloon Creek will assist in identifying areas of high(er) diversity in frog species composition at sites which may also indicate the availability of high-quality habitat for various frog species. Identifying sites with higher quality habitat values will therefore assist in future decision-making, priority setting, planning and management of the area.

1.3 Study area - The Mulloon Creek

The study area is situated along Mulloon Creek which is situated in the Southern Tablelands of New South Wales between Braidwood and Bungendore (Figure 1). The specific location of this study includes a total of 30 monitoring transects.

The 30 transects are located between the Landtasia property in the southern/upstream parts of the Mulloon Creek catchment, approximately 5.5km due south of the MCNF Home Farm property and the Duralla – Sandhills properties, including sites on Sandhills Creek that confluence with Mulloon Creek to where it becomes Reedy Creek, as well as site in the far upper reaches of Sandhills Creek, about 3km north of the Kings Highway (Figure 2). This study area represents a total distance of almost 20km of stream length between the upstream and downstream sites (with an additional approx. 6km of stream length of Sandhills Creek from the most upstream sites to the confluence with Mulloon/Reedy Creek).

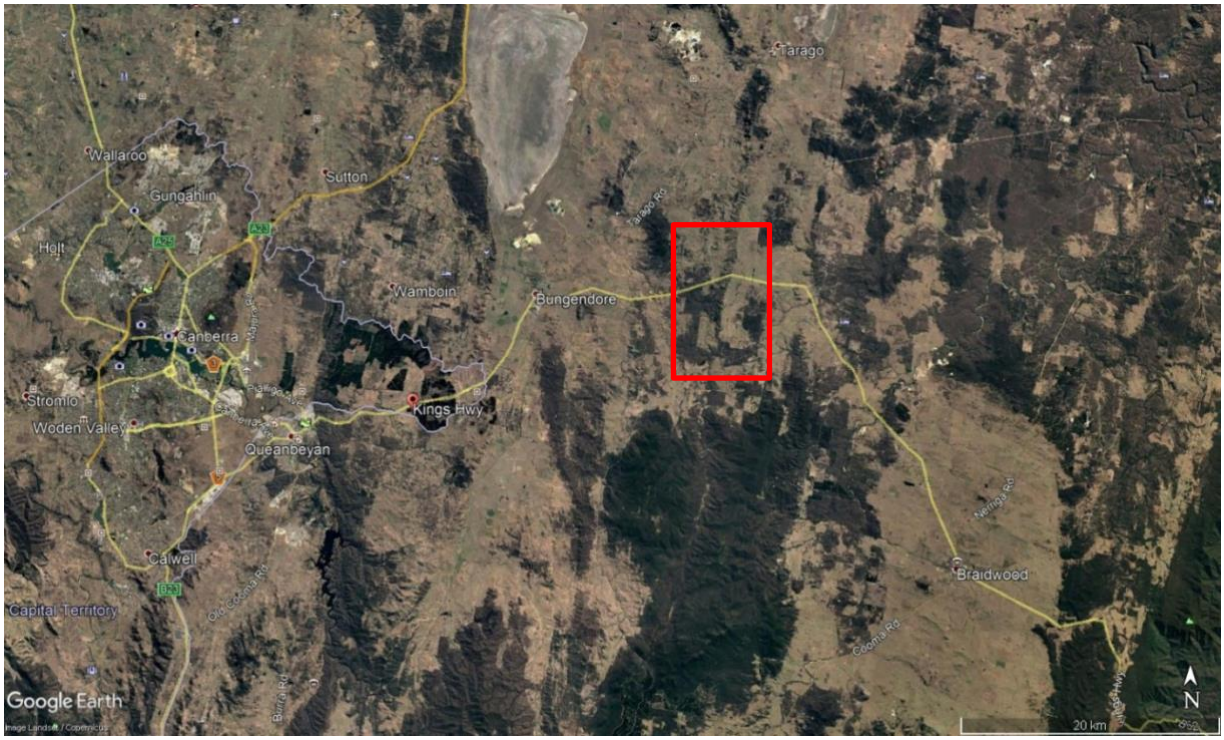

Figure 1. Location of study area on the Mulloon Creek, Southern Tablelands, NSW

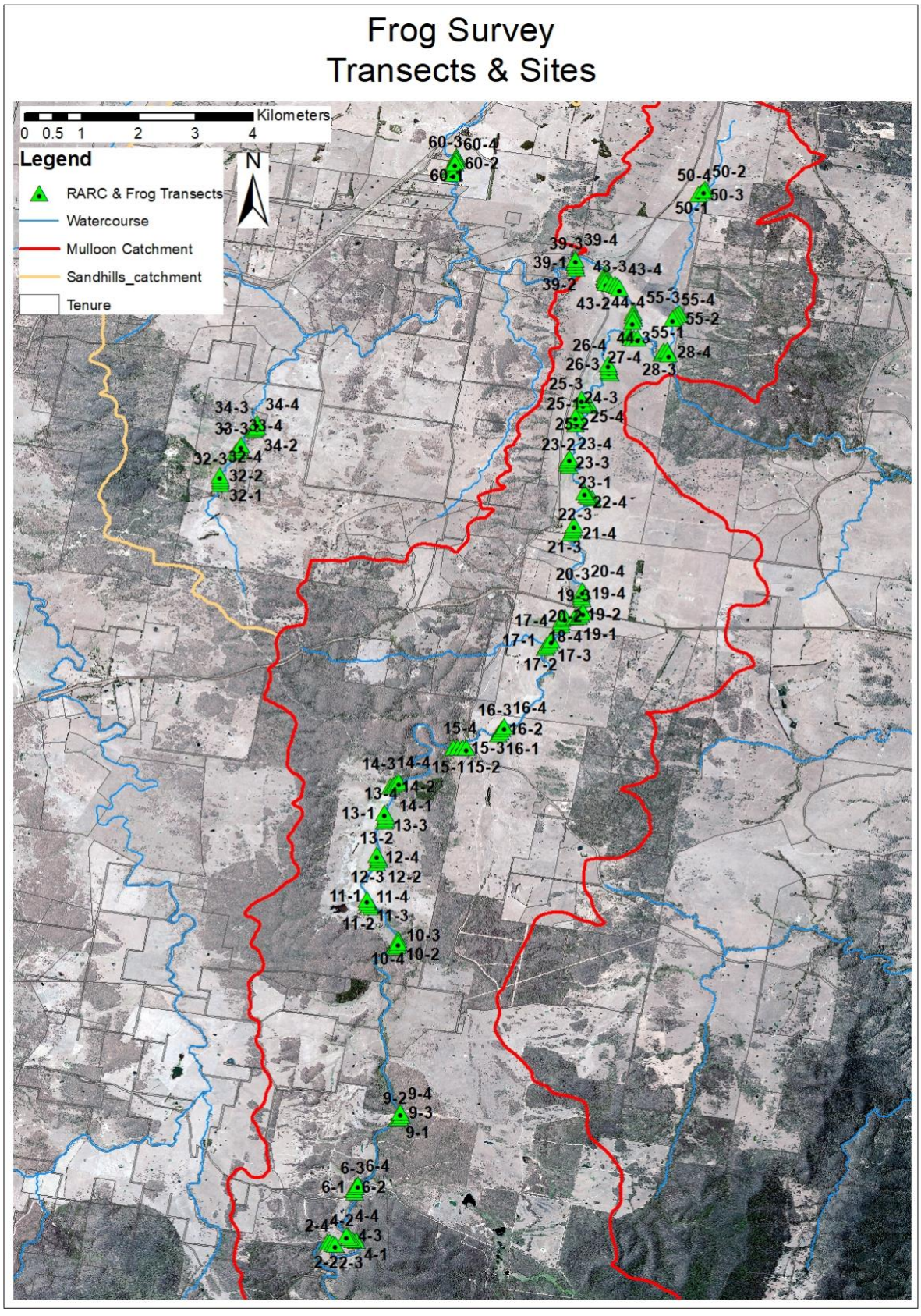

Figure 2. Study area – Mulloon Creek 2021 Frog Monitoring Transects

(image courtesy the Mulloon Institute, 2021. Note: refer to results below for summary of which (n=30) of the 60 shown transects were surveyed)

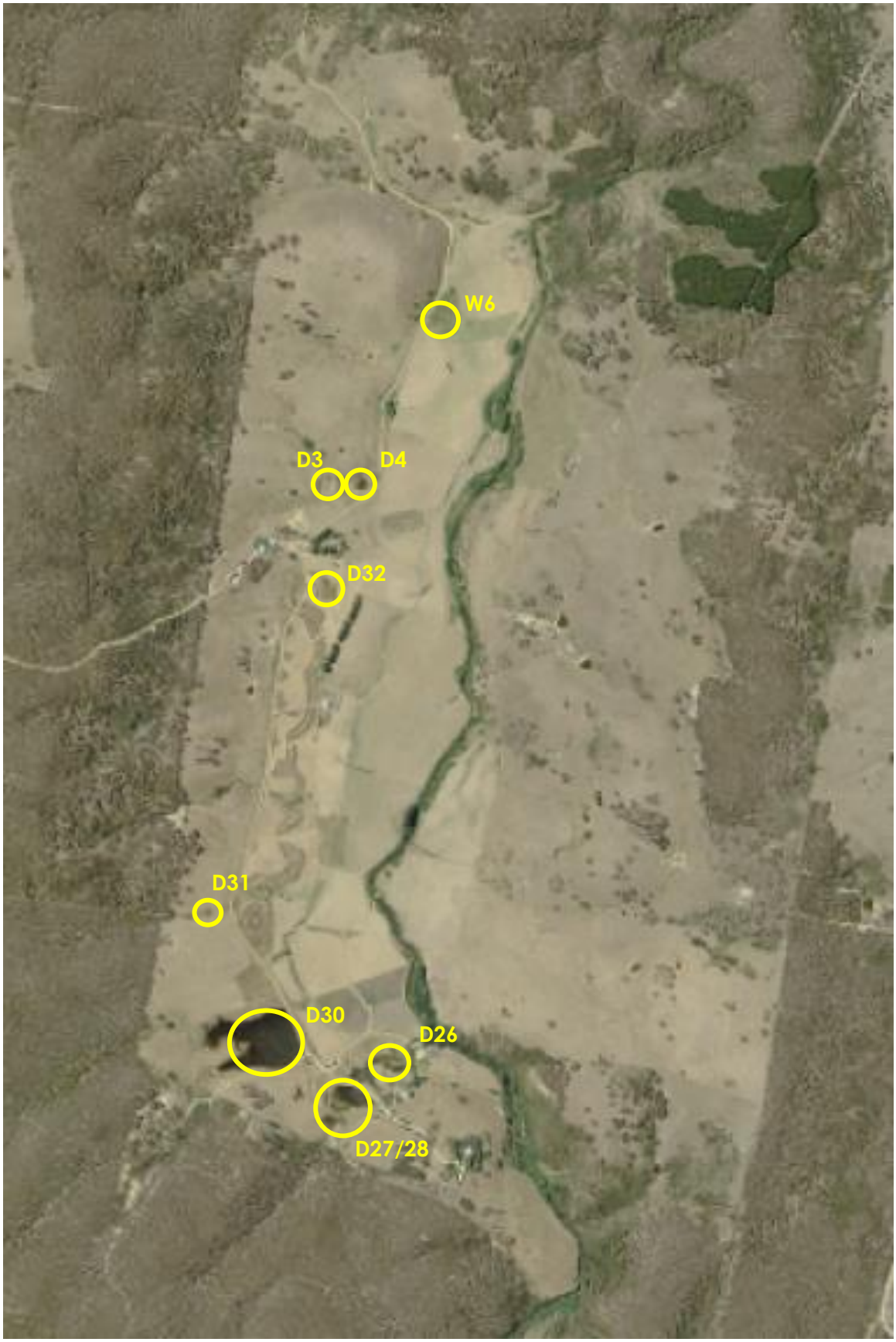

Figure 3. Location of (additional) farm dam/wetland monitoring sites at MCHF

2 Survey methods, effort, timing, and conditions

2.1 Survey methods and effort

A total of 60 survey sites were included in the December 2020 frogs surveys along Mulloon Creek. The 60 survey sites were pre-established by TMI and involved 30 stream "transects" originally established for the RARC monitoring project (see Figure 2). Each RARC transect is approximately 200m long with the survey sites located at each end of the transect (i.e. 200m apart). Each transect was spaced approximately 1km (in stream length) apart. An additional eight farm dam/wetland sites were also included in the survey program as described further below.

The 30 stream transects are located between the Landtasia property in the south of the catchment (starting at Transect No. 2) to the Sandhills Creek property in the northern parts of the catchment at the confluence of Mulloon and Reedy Creeks (Transect No. 44). This represents a total distance of more than 19km of stream length between the furthest upstream and downstream monitoring transects/sites. An additional three transects (32, 33 and 34) are located towards the upper reaches of Sandhills Creek, more than 4km southwest of the confluence of Sandhills Creek and Mulloon/Reedy Creek.

At each survey site, a combination of habitat and weather variables were collected as well as records of frog observations, including both direct visual and call recording. For this survey, the habitat variables were collected separately during the daytime, while the weather variables collected at the same time the frog surveys were being conducted.

During the daytime habitat survey the observer recorded the water depth, pond level (as being on a scale between dry and full), water flow rate (on a scale of still to fast flowing), vertical water level drop (distance from top of bank to water level) and area of exposed soil (vertical distance from the High Water Mark (HWM) to the water's edge) was also recoded. Vegetation characteristics recorded at each site included the extent of emergent as well as fringe/edge vegetation, the extent of pond shaded by trees, evidence of mowing/slashing, as well as the width of the (unmown) buffer strip (if applicable).

For the frog surveys[1], a timed (minimum) 5-minute observation period was undertaken at each site and involved primarily a call-based census of the frogs species present. This included attempts at 'on-the-spot' identification of species, including estimating the total numbers of frogs calling, by the observers (depending on observer skill level; see below). The air and water (where possible) temperature, sky (i.e. cloud cover) and wind conditions were also recorded at each frog survey site/occasion.

Given the large number of sites and area covered by the survey and the requirement to complete the surveys in a short period of time (on the same night), it was necessary to bring in help to complete the work. For this survey, a number of TMI staff and volunteers were enlisted, some of whom had little experience in frog (call) species identification. For this reason, the use of (minimum 5-minute) audio file recording was employed. The call files were subsequently assessed, and the frog species recorded by an experienced herpetologist (Sam Patmore). It is acknowledged that whilst not all frogs may have been

[1] Note: only 58 nocturnal frog surveys were completed (at 29 of the RARC transects)

captured during each audio recording, given the large total number of recordings made along the same stream and generally within close proximity and timing of each other (i.e. <200m apart for sites on the same transect and less than 1km (generally) for sites between transects), it is expected that a sufficiently comprehensive assessment of the overall amphibian community along Mulloon Creek was completed.

In addition to the (58/60) stream sites, additional frog and habitat surveys were undertaken at eight (8) of the 'farm dam' sites within MCHF (which includes a "wetland" site located in the lower floodplain valley floor – "Wetland 6"; see Figure 3).

The procedures described above are the same as for the 2020 survey and which generally follow the ACT Frogwatch protocol and is similar in manner to the 2017 survey (Hoefer 2017) (except for the increased overall survey area and effort, being extended call recording period). This repetition of methodology therefore allows for good comparison between the findings of this survey season and the previous 2017 and 2020 survey findings.

2.2 Survey timing and conditions

The surveys (both habitat and frog surveys) were completed on the 1st December 2021. Generally, the habitat variables were collected during the daytime to facilitate observations of vegetation condition and stream flow features, although in some circumstances, due to timing constraints, some of the habitat assessments were conducted at night at the same time as the frog surveys. All the frog surveys were completed at night, with surveys commencing no earlier than 20.00 hours once it was sufficiently dark and most frog species had become active/started calling.

The weather conditions for the surveys were generally ideal for frog surveys. The air temperature on the evening of 1/12/21 was warm, ranging from about 21^{0}C at the start of the survey (8pm) and dropping to about 14^{0}C at the end of the survey (about 12am in some circumstances). The sky conditions were mostly recorded as being clear, but occasionally as cloudy/overcast. Wind was mostly recorded as being still to occasionally a light breeze. Water temperature was measured/recorded at 31 (of the 58 completed) frog survey sites with recorded temperatures ranging between 17 and 22 degrees Celsius (at an average of 19.1^{0}C). This (moderately warm) water temperate would also have been relatively ideal for frog activity levels.

It is also noted that there was extensive rainfall in the late-Spring period leading up to this with (record) high rainfalls for the month of November 2021 experienced in several locations throughout the region. Specifically, for the Bungendore region, a total of 231mm of rain fell throughout November 2021 which is the highest recorded (since 2006 BoM records) and is significantly higher than the mean monthly rainfall for November in this region of 79mm (and notably higher than the 95th %ile of 170mm). This high level of rainfall further added to the suitable timing of the surveys with lots of water present in the system including both the creek and adjacent waterbodies (farm dams and wetlands).

Table 1. Timing and conditions for the 1st December 2020 Mulloon Ck frog surveys

Wetland Site No.	Survey Time	Air Temp (⁰C)	Water Temp (⁰C)	Sky (1 to 6)	Wind (1 to 4)
Mulloon RARC Sites					
T_2_1	21.50	17.4	17.1	3	1
T_2_4	22.09	NR	NR	2	1
T_4_1	22.41	NR	NR	1	1
T_4_4	22.54	NR	NR	1	1
T_6_1	23.21	NR	NR	1	1
T_6_4	23.34	NR	NR	1	1
T_9_1	20.44	NR	NR	3	1
T_9_4	20.56	NR	NR	3	1
T_10_1	20.15	19.2	NR	3	1
T_10_4	20.25	19.1	NR	3	1
T_11_1	20.01	22.5	NR	3	1
T_11_4	20.11	21	18	3	1
T_12_1	20.40	17	NR	3	1
T_12_4	21.18	15	16	3	1
T_13_1	23.33	13	20	3	1
T_13_4	23.24	13	NR	1	1
T_14_1	22.34	16	NR	3	1
T_14_4	NR	NR	NR	NR	NR
T_15_1	20.40	18	19	3	1
T_15_4	20.50	18	19	2	1
T_16_1	21.17	19	19	2	1
T_16_4	21.24	18	19	2	1
T_17_1	20.05	19	19	1	1
T_17_4	20.17	19	19	1	1
T_18_1	23.30	18	19	1	1
T_18_4	23.45	14	18	1	1
T_19_1	00.15	14	19	1	1
T_19_4	00.01	14	19	1	1
T_20_1	20.45	20	NR	3	1
T_20_4	20.55	16	NR	2	2
T_21_1	23.53	15	NR	1	1
T_21_4	00.04	14	NR	1	1
T_22_1	23.35	13	NR	1	2
T_22_4	23.37	NR	NR	2	1
T_23_1	23.04	NR	NR	2	2
T_23_4	23.02	14	NR	1	1
T_24_1	22.40	NR	19	2	1
T_24_4	22.25	NR	19	2	1
T_25_1	22.05	15	19	2	
T_25_4	22.03	NR	NR	2	1
T_26_1	21.34	NR	NR	2	1
T_26_4	21.31	16	NR	2	1
T_27_1	20.34	17	19	2	1
T_27_4	20.53	17	19	2	
T_28_1	NR	NR	NR	NR	NR
T_28_4	NR	NR	NR	NR	NR
T_32_1	20.30	24	22	1	1
T_32_4	20.40	19	22	1	1
T_33_1	21.15	20	20	1	1
T_33_4	21.43	20	20	NR	NR

T_34_1	22.06	19	20	NR	NR
T_34_4	22.22	20	20	NR	NR
T_39_1	21.42	17	NR	3	1
T_39_4	21.40	17	NR	3	1
T_42_1	22.18	18	19	3	1
T_42_4	22.27	17	19	3	1
T_43_1	22.45	17	19	3	1
T_43_4	22.55	17	19	3	1
T_44_1	23.24	16	19	3	1
T_44_4	23.27	16	19	3	1
MCHF Dam/Wetland Sites					
D3	22.05	18	23	2	1
D4	21.55	18	23	2	1
W6	22.20	17	24	1	1
D26	20.45	20	24.5	3	1
D27/28	21.00	20	24	3	1
D30	21.10	19	23.5	3	1
D31	21.25	19	23	3	1
D32	21.40	19	23	3	1

NR= not recorded

Note: A habitat assessment only was completed for Transect 28; no nocturnal frog survey.

3 RESULTS

3.1 Habitat Assessments

3.1.1 Stream Transect Sites

The results of the habitat assessments completed for the 60 stream (only) monitoring sites are described below, including a brief comparison with last season's (2020) results (note that habitat assessment data was not provided for the 2017 survey findings, and therefore comparisons cannot be made for that year).

The full results of the habitat descriptions and water quality measurements are provided at Appendix B and separately as a Microsoft Excel spread sheet.

Water levels and stream banks

Generally, water depth category estimates at most sites were >30cm (n=52/60 sites), with only eight sites recorded at <30cm (and no sites recorded as 'unknown' or dry; see Figure 4). Similarly, the 'Pond' (or stream) levels were recorded mostly as being 'nearly full' (n= 55/60), with only two sites recorded as "full' (T_11_1 & T_12_1) and three sites recorded as 'bank very exposed' (T_32_4, T_33_1 & T_33_4; see Figure 5). Water flow rates was recorded at most sites as 'slow' (n=36/60) to occasionally 'moderate' (n=22), with a 'fast' flow rate recorded at only two sites ((T_2_4 & T_14_4)). No sites recorded a 'still' water flow rate (Figure 6).

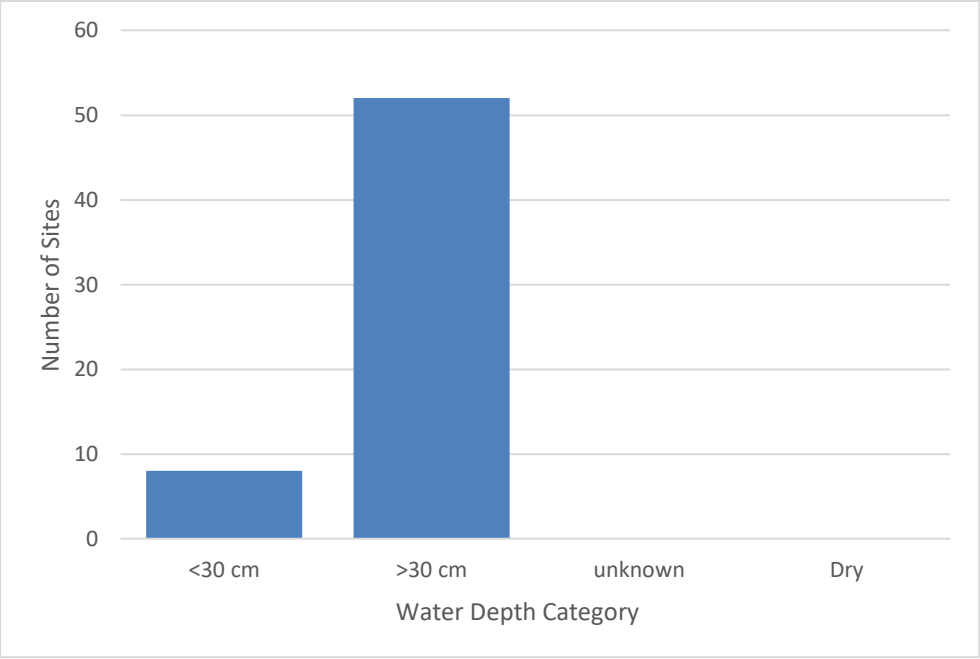

Figure 4. Water depth estimates at sites during the 2021 frog surveys

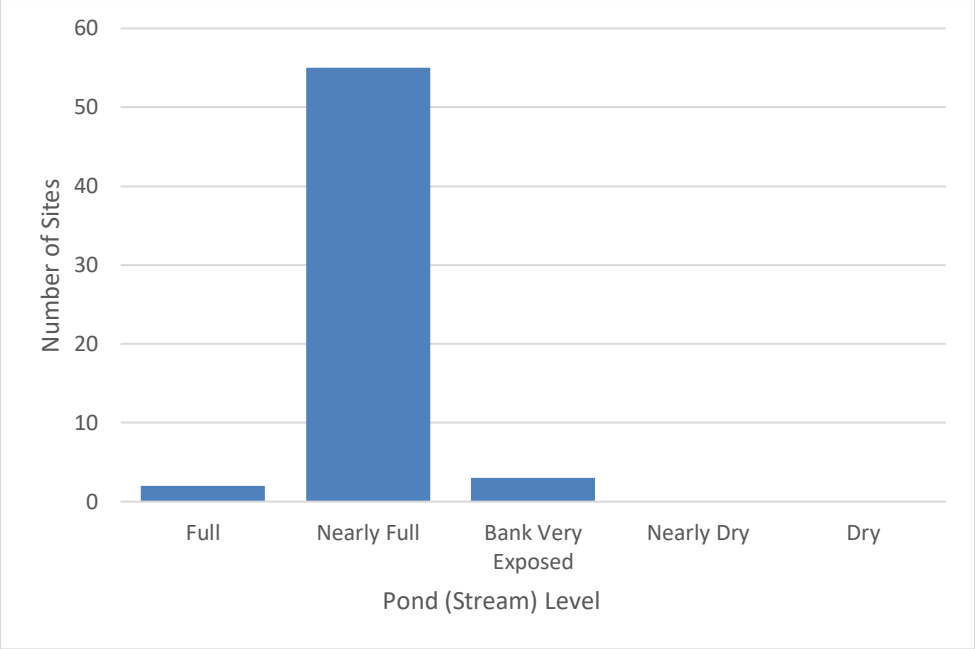

Figure 5. Pond (stream) level estimates at sites during the 2021 frog surveys

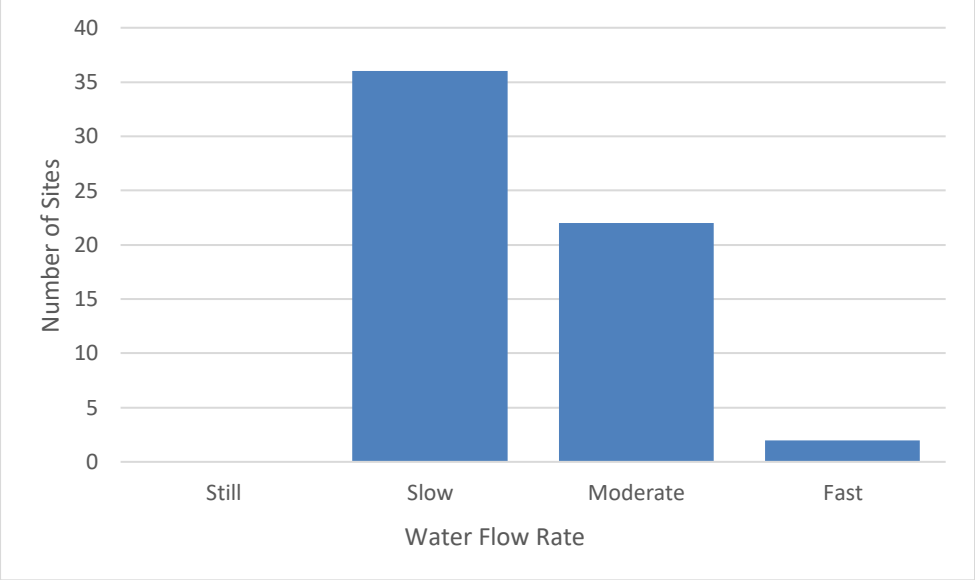

Figure 6. Water flow rate estimates at sites during the 2021 frog surveys

The vertical water level drop across sites ranged from 0.0-0.5m with an average drop across sites of 0.32m. Similarly, the area of exposed soil ranged from a minimum (average across sites) of 0.0m to a maximum (average across sites) of 0.36m, with the highest maximum recorded value for area of exposed soil being 1.5m at site T_44_1.

Overall, these measures indicate that there was quite a reasonable amount of water in the system with all sites having moderate to high water levels and (on average) moderate flow rates with minimal exposed banks. Given the relatively high rainfalls in the region through November 2021, these higher water levels were expected which

combined with the warm weather, provided good conditions for frog surveys with expected high activity levels.

Compared with last year's (2020) survey season, the measurements indicate that there was substantially more water in the system this season. While there was no substantial difference in the recorded water depths between the two seasons (2020 = 11% of sites with <30cm and 2021 = 13% sites with <30cm water depth), there was a notable difference in the "pond levels", with 21/36 (58%) of sites recorded as having "banks very exposed" during the 2020 season surveys compared with 3/60 (5%) of sites during the 2021 season surveys recorded as having "banks very exposed" with the remainder (57/60) of sites recorded as being either "full" or "nearly full", indicating that there was more water (and greater water depth) compared to the 2020 season. Additionally, there was a notable (but relatively minor) difference in the estimated water flow rates between the two seasons with 26/36 (72%) of sites recorded as having a "slow" water flow rate and 9/36 (25%) of sites recorded as having a "moderate" water flow rate for the 2020 season, compared with 36/60 (60%) of sites recorded as having a "slow" water flow rate and 22/60 (37%) of sites recorded as having a "moderate" water flow rate for the 2021 season (both seasons recorded 3% of sites as having a "fast" water flow rate). This also suggests that water flow rates were slightly faster in 2021 compared to 2020, indicating that there was more water in the system during the 2021 survey.

There was a notable difference in the range of values for the vertical water level drop across sites and compared between the two survey seasons, with the 2020 season recording a range of drop heights between 0.25-10m (at an average of 2.4m) while the 2021 season values ranged from 0.0-0.5m with an average drop across sites of 0.32m. However, this difference is considered likely to be attributable to differences in observer estimates as opposed to any real difference in actual conditions between the two seasons. Of note, during the 2020 survey season, the habitat assessments were conducted by a number of different people/observers while for the 2021 survey season, all of the habitat assessments were conducted by the same (single) observer. Given there was some possible confusion as to how to appropriately record this value, the differences in the seasons are therefore likely attributable to the observer. As an example, Transect 10 (Sites T_10_1 and T_10_4) at the southern end of MCHF which has a relatively high bank, had a recorded vertical water level drop of 10m during the 2020 season, and only 0.25m during the 2021 survey season. Given the likely variation due to observer bias, no effective comparison can be made with the data for this variable between the two survey seasons.

Vegetation

Emergent aquatic vegetation cover (recorded at 59/60 sites) at ponds varied greatly across sites, although it was noted that only one site (T_34_1) recorded emergent vegetation cover as covering the entire pond. Otherwise there was a relatively broad spread of scores across the various cover range categories, although the majority (n=31/59 sites) recorded a cover value of "just localised". After this, five sites recorded a cover value of between 75–99%, six sites recorded a cover value of between 50–74% as well as six sites recording a cover of between 25–49%, and eight sites recorded a cover of <25%. Two sites recorded no emergent vegetation cover (T_4_4 & T_11_4; see Figure 7).

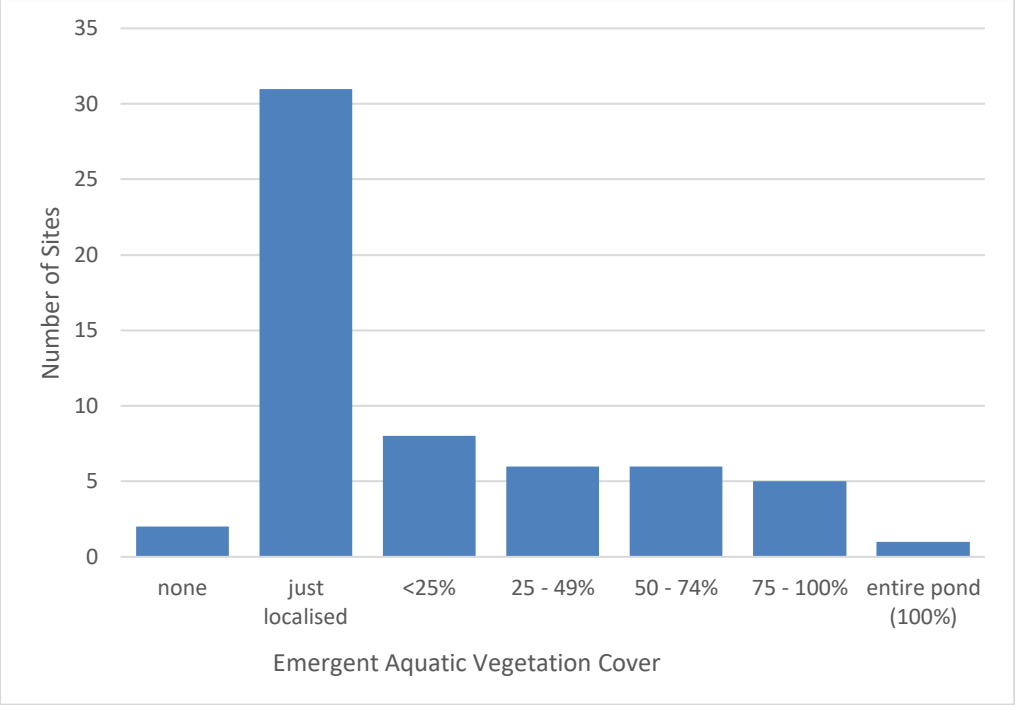

Figure 7. Emergent Vegetation Cover at sites during the 2021 frog surveys

Compared with last year's (2020) survey season results, there appeared to be a notable (but not substantial) difference in the levels of emergent aquatic vegetation across the sites, with the recent 2021 season recording slightly higher emergent aquatic vegetation cover levels (based on the spread of sites across the various cover value ranges). Broadly, for the 2020 season, all but one (35/36, or 97%) of the sites had a cover value of less than 50% (with most, 77% of sites, recording either "just localised" or <25% cover values). By comparison, for the 2021 season, 12/59 (or 20%) of sites surveyed had a cover value of more than 50%, and, with 39/59 (67%) of sites, recording either "just localised" or <25% cover values.

Fringe or edge vegetation cover (recorded at 58/60 sites) also varied greatly across sites, although it was noted that all sites recorded a cover score of at least 25%, with eight sites recording cover of between 25–49%, 25 sites recording cover of between 50–74%, 12 sites recording cover of between 75–99%, and 13 sites recording cover of the entire edge (100%) of the pond (Figure 8).

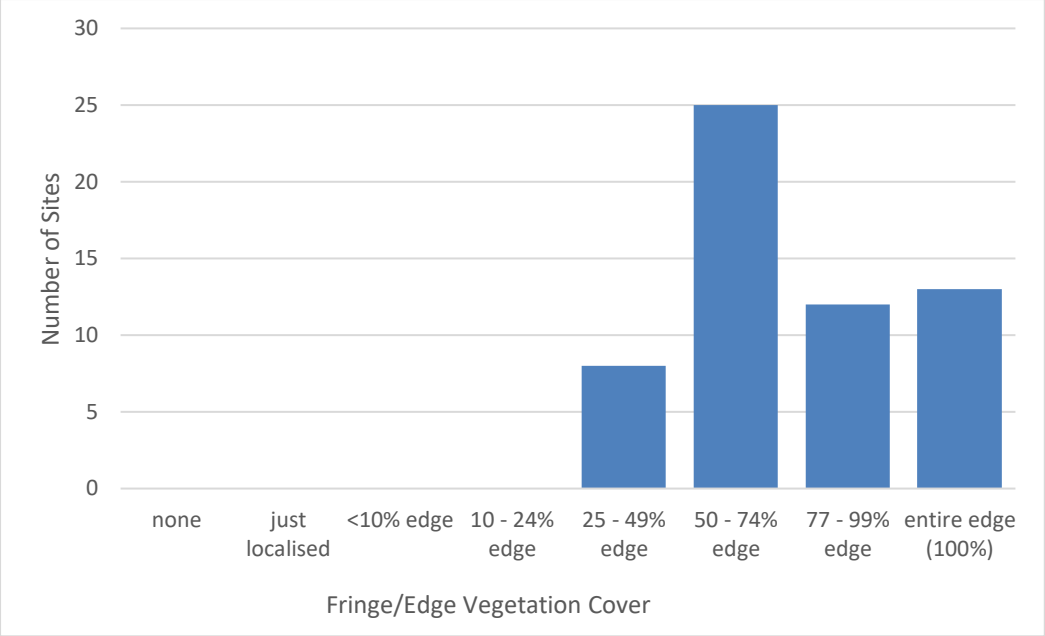

Figure 8. Fringe/Edge Vegetation Cover at sites during the 2021 frog surveys

Compared with last year's (2020) survey season results, there was a notable (but not substantial) increase in the observed/recorded levels of the fringe/edge vegetation cover levels. For the 2021 season, 50/58 (86%) of sites surveyed had fringe/edge vegetation cover levels of more than 50%, compared with 27/36 (75%) of sites having fringe/edge vegetation cover levels of more than 50% for the 2020 survey season. Additionally, 13/58 (22%) of sites surveyed during the 2021 season had observed fringe/edge vegetation cover levels of the "entire edge", compared with no (0%) sites having fringe/edge vegetation cover levels of the "entire edge" for last year's 2020 survey season. Further, no (0%) sites were surveyed as having fringe/edge vegetation cover levels of less than 25% for the 2021 season, whereas 2/36 (6%) of sites were surveyed as having fringe/edge vegetation cover levels of less than 25% for last year's 2020 survey season.

Levels of pond shading (recorded at 60/60 sites) also varied greatly across sites. Two sites (T_34_1 & T_34_4)) recorded no shading of the pond, while 10 sites recorded a shade cover score of 1-9%, six sites recorded shade cover of between 10-24%, 10 sites recorded shade cover of between 25–49%, 21 sites recorded shade cover of between 50-74%, and 11 sites recorded shade cover of 75-100% of the pond (Figure 9).

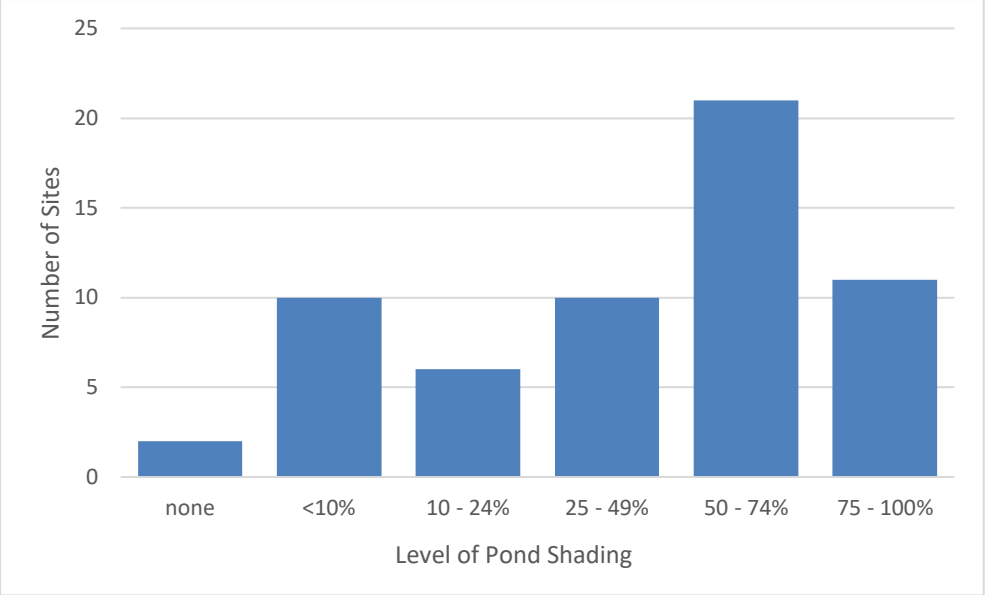

Figure 9. Level of Pond Shading at sites during the 2021 frog surveys

Compared with last year's (2020) survey season results, there was a substantial increase in the observed/recorded levels of pond shading, with 32/60 (53%) sites surveyed having pond shade levels of more than 50% compared with 8/36 (22%) of sites surveyed having pond shade levels of more than 50% for the 2020 season. Of note, 11/60 sites (18%) had pond shade levels of between 75-100% for the 2021 season, while no (0%) sites had pond shade levels of between 75-100% for last year's 2020 survey season.

There was no recorded evidence of mowing or slashing within close proximity of the creek, with all (60) sites recording no evidence of mowing within 5 m of the creek. A minimum 5m buffer was also recorded at all 60 sites. This compares with last year's (2020) survey season results whereby 33/36 of the sites recorded no evidence of mowing and a minimum 5m buffer was present.

In considering the above comparisons of vegetation cover levels between the 2020 and 2021 survey seasons, there appeared to be an overall increase in vegetation cover levels for each category/variable. However, further assessment of these results may be required to confirm whether these findings represent a real increase in vegetation cover at sites over the year, or, whether the increase in cover values is an artefact of the new/additional survey sites. In this instance, a 'within' site comparison between years would be required, or, at a simpler level, the new/additional sites could be removed from the comparisons and only those sites surveyed across both seasons are compared, this would help determine if there is an actual (notable) increase in vegetation cover "within" sites between the two surveys seasons. This level of additional in-depth comparison of habitat variables between years is beyond the scope of this current study which is primarily to assess the frog population status.

In addition to the above, it is noted that for the 2020 survey season, the habitat assessments were completed by several different observers, whereas for the 2021 season, all habitat assessments were completed by the same observer. Consequently, there may be some observer-related bias in the data that could affect the ability to accurately compare across seasons (as noted previously for the major discrepancy in

values for the vertical water level drop, which should not have changed so markedly between the two survey seasons). It is therefore recommended that for future surveys, greater emphasis is placed on accounting for observer bias by either having a single observer conduct all habitat assessments (such as for the 2021 season), or a greater level of training is provided to help calibrate how observations are recorded if different observers are used for the habitat assessments.

3.1.2 Dam/Wetland Sites

Water levels within the eight dam/wetlands included in this study were all relatively high with all sites recorded as "Full" and all sites recording a water depth of more than 30cm. Additionally, all sites had a vertical water level drop of 20cm or less and a maximum area of exposed soil of 0.5m or less.

For vegetation, most sites (7/8) recorded 'just localised' emergent aquatic vegetation cover scores, with one site (W6) recording an emergent aquatic vegetation score of 'entire pond'. This is a shallow artificially constructed wetland and is dominated by dense thickets of Typha and Phragmites. For fringing/edge vegetation, site W6 recorded a value of 75-99% while all other sites scored a value of either 50-74% (5/8 sites) or 25-49% (2/8 sites) edge vegetation cover, indicating there was relatively good cover of fringing vegetation across most sites.

Levels of pond shading across sites varied from between none (4/8 sites); some, but less than 10% (3/8 sites); and 10-24% (1/8 sites). There was no evidence of mowing around any of the dam/wetland sites, although some sites did appear to be subject to some stock access and grazing of surrounding vegetation.

Habitat assessments were not completed for the previous years' studies and so no comparisons are made with this season's results and earlier habitat assessment results.

The full results of the habitat descriptions and water quality measurements are provided at Appendix B and separately as a Microsoft Excel spread sheet.

3.2 Frog species detected during the December 2021 Surveys

The results of the frog surveys for the 58 completed (out of 60 RARC) stream transect and 8 dam/wetland monitoring sites are described below. In summary, a total of 11 species were detected across the 66 monitoring sites during the 1st December 2021 survey (Table 2). This included the following species:

- *Crinia signifera,* Common Eastern Froglet
- *Crinia parinsignifera,* Plains Froglet
- *Limnodynastes dumerelli,* Eastern Banjo Frog
- *Limnodynastes peronii,* Striped Marsh Frog
- *Limnodynastes tasmaniensis,* Spotted Grass Frog
- *Litoria lesueuri*, Lesueur's Tree Frog
- *Litoria nudidigitus*, Southern Leaf Green Tree Frog
- *Litoria peronii,* Peron's Treefrog
- *Litoria quiritatus*, Screaming Tree Frog
- *Litoria verreauxii,* Whistling Treefrog
- *Uperoleia laevigata,* Smooth Toadlet

Table 2 below shows the number/frequency of sites that each species was detected at (and includes the 8 dam/wetland sites; therefore, the total number of sites each species was recorded at, and the detection frequency is out of 66 completed frog survey monitoring sites).

Table 2. Species recorded and detection rates during the December 2021 Mulloon Ck frog surveys

Species Name	Common Name	Number of sites recorded at (n=66)	Detection Frequency (% of sites detected at)
Crinia parinsignifera	Plains Froglet	45 (37/58 & 8/8)	68% (64% & 100%)
Crinia signifera	Common Eastern Froglet	53 (49/58 & 4/8)	80% (84% & 50%)
Limnodynastes dumerilii	Eastern Banjo Frog	29 (28/58 & 1/8)	44% (48% & 13%)
Limnodynastes peronii	Striped Marsh Frog	18 (15/58 & 3/8)	27% (26% & 38%)
Limnodynastes tasmaniensis	Spotted Grass Frog	47 (39/58 & 8/8)	71% (67% & 100%)
Litoria lesueuri	Lesueur's Tree Frog	2 (2/58 & 0/8)	3% (3% & 0%)
Litoria nudidigitus	Southern Leaf Green Tree Frog	1 (1/58 & 0/8)	2% (2% & 0%)
Litoria peronii	Peron's Tree Frog	7 (3/58 & 4/8)	11% (5% & 50%)
Litoria quiritatus	Screaming Tree Frog	29 (23/58 & 6/8)	44% (40% & 75%)
Litoria verreauxii	Whistling Tree Frog	7 (6/58 & 1/8)	11% (10% & 13%)
Uperoleia laevigata	Smooth Toadlet	11 (8/58 & 3/8)	17% (14% & 38%)

No species was detected at every single site in this survey. The Common Eastern Froglet was the most frequently detected species during the surveys, being detected at 53 of the 66 (or 80%) sites surveyed in total (including at 49/58, or 84%, of the creek sites). This species is common and widespread across much of eastern Australia. Every species detected during either/both the previous 2017 and 2020 surveys was successfully detected during the 2021 survey.

In comparison with previous years' results, it is noted that there was an increase in the total number of species detected, with only 7 species detected in 2017 and 8 species detected in the 2020 survey season. The "new" species detected in the recent 2021 surveys include the following:

- Screaming Tree Frog
- Southern Leaf Green Tree Frog
- Lesueur's Tree Frog

Of note, the Southern Leaf Green Tree Frog and Lesueur's Tree Frog were recorded only at sites in the upper reaches of Mulloon Creek within Landtasia (sites T_6_4 for *L. nudidigitus* and sites T_2_4 and T_4_4 for *L. lesueuri*). These sites were not previously surveyed in 2017 or 2020 and therefore, they do not represent records of a new species for the parts of study area where repeated surveys have occurred. A feature of these sites is the rocky outcrops within the stream that these frog species are typically associated with.

For the Screaming Tree Frog, this species was recorded commonly throughout the survey area, including at many sites previously surveyed in 2017 and 2020, and therefore represents a "new" species for the (repeatedly sampled) study area.

In comparing the detection frequency of species across the three survey seasons *and for stream sites only* (see Table 3 below), as a surrogate measure of the distribution of each species across the study area, generally, there was an increase in the frequency of occurrence for many of the species identified in this survey, and in particular, there was a notable increase in the detection frequency for most species between the 2020 and 2021 survey seasons, although less so when compared with the 2017 surveys (see Table 3 below). The species where the highest level of frequency of detection occurred during the recent 2021 survey (and excluding the three "new" species described above) included the Plains Froglet, Eastern Banjo Frog, Spotted Grass Frog and Smooth Toadlet.

However, there were some declines in detection frequency for some species between survey seasons. The species where the highest level of frequency of detection occurred during last season's (2020) survey was the Striped Marsh Frog, and the species where the highest level of frequency of detection occurred during initial/first (2017) survey was the Common Eastern Froglet, Peron's Tree Frog and Whistling Tree Frog.

In considering the trends in the increases or decreases in detection frequency for species recorded during the three survey seasons within the study area, for many species the changes were generally minor (less than about 20%). The most notable changes in detection frequency for species across the three survey seasons included the following:

- Large increase in detection frequency of the Spotted Grass Frog (from 16% in 2017 to 19% in 2020 to 67% in 2021)
- Notable decrease in in detection frequency of the Peron's Tree Frog (from 50% in 2017 to 31% in 2020 to 5% in 2021)
- Notable and large decrease in in detection frequency of the Whistling Tree Frog (from 100% in 2017 to 31% in 2020 to 10% in 2021)

Of the above, the most noteworthy pattern of increase/decline is for the Whistling Tree Frog which over the four-year period from 2017 to 2021 decreased from 100% detection frequency to only 10% detection frequency at stream sites (and also declined at dam/wetland sites from 38% of sites in 2020 to 13% sites in 2021; see Table 4). This decline in observed occurrence (via detection frequency) could be of concern given the excellent survey conditions for the 2021 survey season, as well as to some extent last year's 2020 survey season. However, more ongoing annual surveys are required to help assess whether the local population of this species is, in fact, stable or in decline. Specifically, it is noted that this species' peak activity/calling period is from June to November (www.frogID.net.au, 2022). It is also noted that the initial 2017 survey was conducted in November while the 2020 and 2021 surveys were conducted in (mid to early) December (respectively). Therefore, the observed pattern of decline in the detection frequency could be attributable to the survey period and seasonal activity period for this species which naturally declines in December. However, the 2017 survey report also noted that this species is recovering from population declines due to the amphibian chytrid fungus disease Chytridiomycosis (Ben Scheele, ANU *pers. comms.* to Hoefer, A.M.). Given the *apparent/potential* decline in occurrence of this species in this study, further investigation of the population status of the species may be worth considering, including possibly undertaking an assessment of whether Chytrid is present in the local population.

The seemingly large decline in the detection frequency of Peron's Tree Frog at stream sites could also potentially be of concern, having declined from 50% of sites in 2017 to 31% of sites in 2020 to only 5% of sites in 2021. Additionally, the species also had a decline in the detection frequency at dam/wetland sites from 63% of sites in 2020 to 50% of sites in 2021 (Table 4).

This species is generally regarded as being locally abundant as well as being widespread with a large extent of occurrence in eastern Australia and with no known declines (AmphibiaWeb, 2022) as well as having an IUCN status of *Least Concern*. The species is reported to breed dams, ponds, creek pools, swamps, and even in abandoned swimming pools (www.frogID.net.au, 2022). It is possible that the reduced extent of occurrence within the creek may be attributable to the higher stream flow rates during the 2021 survey, with this species tending to prefer still water more than flowing streams. The decline in occurrence from 63% to 50% of (still) dam/wetland sites represent a reduction in detection of only one site (of eight) and therefore is perhaps of no notable concern.

However, Peron's Tree Frog is one of several species with recent reports of high mortality events whereby numerous sick and dying individuals have been observed by researchers as well as members of the public (Rowley and Rose, 2021). While the causes of these declines/mortality events is not fully understood, it is considered likely that it is disease related, and potentially/likely to be attributable to the amphibian chytrid fungus (Rowley and Rose, 2021). Based on the observed detection frequency of this species in this study and the reports of mortalities of this species elsewhere during 2021, further research may be required to help better understand whether: (i) there is, in fact, a real decline in occurrence, and (ii) what the causes might be, including undertaking an assessment of whether Chytrid is present in the local population.

In terms of the patterns of occurrence in the catchment for other species, the Striped Marsh Frog can be a generally uncommon but often locally abundant species in the ACT region (Hoefer 2017) and was not detected during the 2017 survey. This species was detected at 28% of stream sites during the 2020 survey and at 26% of stream sites during the 2021 survey (Table 3). Of note, the species was detected at only one wetland (13%) site during the 2020 survey and at three (38%) of the dam/wetland sites during the 2021 survey (Table 4). It would appear now to have a stable local population in the Mulloon Creek catchment. As noted by Hoefer, this species is very common in coastal regions of NSW and is typically positively associated with relatively high cover levels of emergent and riparian macrophytes and reeds. Its presence can often be seen as a relatively good indicator of good quality amphibian habitat.

The Plains Froglet is both locally abundant but also common and widespread throughout the region and much of eastern Australia more broadly and had a relatively high detection rate at both stream (64%) and dam/wetland (100%) sites during the 2021 season. This species appears to have a very stable population within the catchment having been recorded frequently at stream sites during the previous 2017 (62%) and 2020 (47%) seasons, as well as having been recorded at 100% of dam/wetland sites in 2021 and 50% of dam/wetland sites in 2020.

As noted above the Spotted Marsh Frog has had a notable increase in detection frequency over the years as mentioned above and therefore also appears to have a

stable population within the catchment. It also was recorded at 100% of dam/wetland sites in 2021 and at 63% of dam/wetland sites in 2020.

The Banjo Frog also appears to have a stable local population and was recorded at almost half (48%) of the sites surveyed in 2021. This result is similar to the result in 2017 where it was recorded at 42% of sites, and well up from last years' (2020) survey where it was recorded at only 14% of sites. As noted previously by Hoefer, the 2017 survey result was a much higher detection rate than during any FrogCensus activity in the ACT since 2002 (until 2017; no reports are known of more recent survey results). Anecdotal evidence has suggested this species has been declining over the past decade in the Capital Region (Hoefer, 2017, cited as *pers comms* with Murray Evans, ACT Government). The numbers seen at the Mulloon Creek catchment therefore appear positive, and the catchment may in fact be an important area for ensuring this species remains stable in the region.

The Smooth Toadlet was again recorded in low numbers in 2021, although it was detected at 14% of stream sites compared with 2020 where it wasn't recorded at any stream sites and 2017 where it was recorded at 11% of sites. The species was however recorded at 38% (3/8) of the dam/wetland sites during both the 2020 and 2021 surveys. There are no known reported concerns over populations declines for this species and although it is widespread it is often not locally abundant. It tends to prefer permanent ponds for breeding habitat (www.frogID.net.au, 2022), as reflected by the higher frequency of detection at the dam/wetland sites opposed to the stream sites. This species would therefore appear to have a relatively stable local population within the catchment.

The full results of the frog surveys are provided at Appendix A and separately as a Microsoft Excel spread sheet.

Table 3. Comparison of detection frequency of species between survey seasons (*stream sites only*)

Common Name	2017 survey detection frequency	2020 survey detection frequency	2021 survey detection frequency
Plains Froglet	62%	47%	**64%**
Common Eastern Froglet	**94%**	75%	84%
Eastern Banjo Frog	42%	14%	**48%**
Striped Marsh Frog	0%	**28%**	26%
Spotted Grass Frog	16%	19%	**67%**
Lesueur's Tree Frog	0%	0%	**3%**
Southern Leaf Green Tree Frog	0%	0%	**2%**
Peron's Tree Frog	**50%**	31%	5%
Screaming Tree Frog	0%	0%	**40%**
Whistling Tree Frog	**100%**	31%	10%
Smooth Toadlet	11%	0%	**14%**

**Bold text represents year with highest recorded detection frequency; underlined text represents year with the lowest recorded detection frequency*

Table 4. Comparison of detection frequency of species between (2020 & 2021 only) survey seasons (*dam/wetland sites only*)

Common Name	2020 survey detection frequency	2021 survey detection frequency
Plains Froglet	50%	**100%**
Common Eastern Froglet	38%	**50%**
Eastern Banjo Frog	0%	**13%**
Striped Marsh Frog	13%	**38%**
Spotted Grass Frog	63%	**100%**
Peron's Tree Frog	**63%**	50%
Screaming Tree Frog	0%	**75%**
Whistling Tree Frog	**38%**	13%
Smooth Toadlet	38%	38%

**Bold text represents year with highest recorded detection frequency.*

3.2.1 Species richness at sites

The species richness per site describes the total number of species detected at a single site. The average number of species detected per site/survey across all (66; 58 creek and 8 dam/wetland) sites was 3.80. This included an average of 3.67 species per creek site and an average of 4.75 species per dam/wetland site, discussed separately below.

For the (58) *stream* sites along Mulloon Creek, the greatest number of species found at any one site during the surveys was 7 species, recorded at two sites (T_26_1 & T_33_1). Four sites recorded six (6) species, eight sites recorded five (5) species, 17 sites recorded four (4) species, 16 sites recorded three (3) species, eight sites recorded two (2) species and three sites recorded only one (1) frog species (see Figure 10 below).

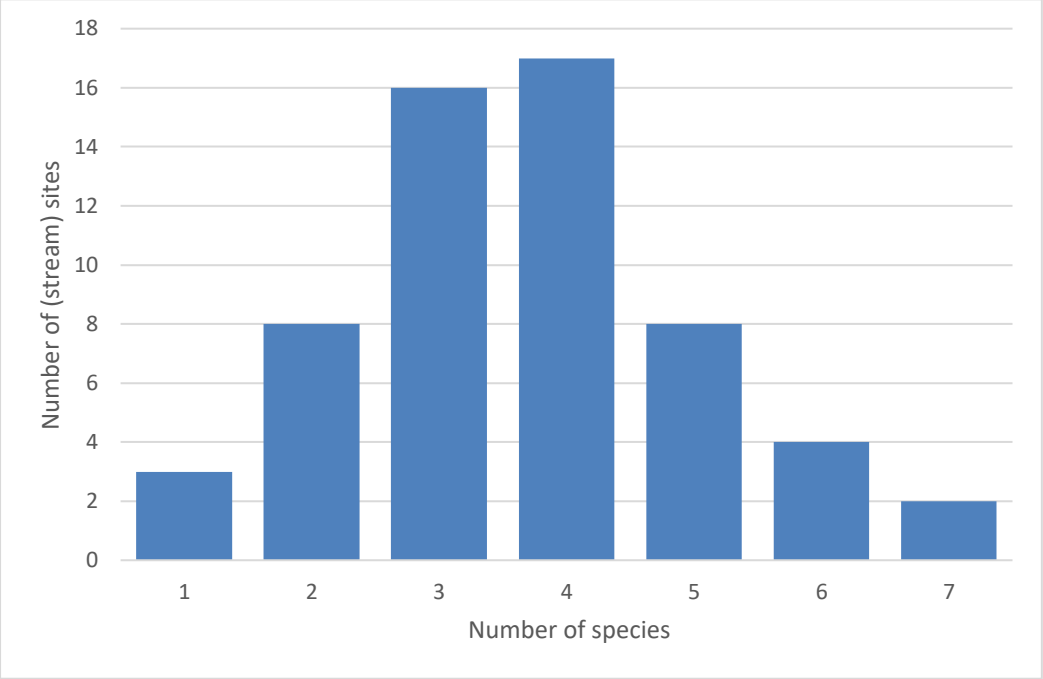

Figure 10. Species richness at stream sites along Mulloon Creek during the 2021 frog surveys

The average species richness (3.67 per site) of stream sites recorded in this year's (2021) survey represents a notable increase in the average species richness of stream sites compared to the previous 2020 survey (2.67 species per site) but is almost identical to the result from the 2017 survey (3.68 species per site), although the 2017 did record a maximum of only 6 species at a single site, compared with 7 species this year (and only 5 species in 2020).

For the (8) *dam/wetland* sites, the greatest number of species found at any one site during the surveys was 6 species that were recorded at two of the dam/wetland sites (W6 and D26). Of the remaining six dam/wetland sites, three sites recorded five (5) species, two sites recorded four (4) species, and only one site (D30) recorded three (3) species, with no dam/wetland sites recording fewer species than this (Figure 11).

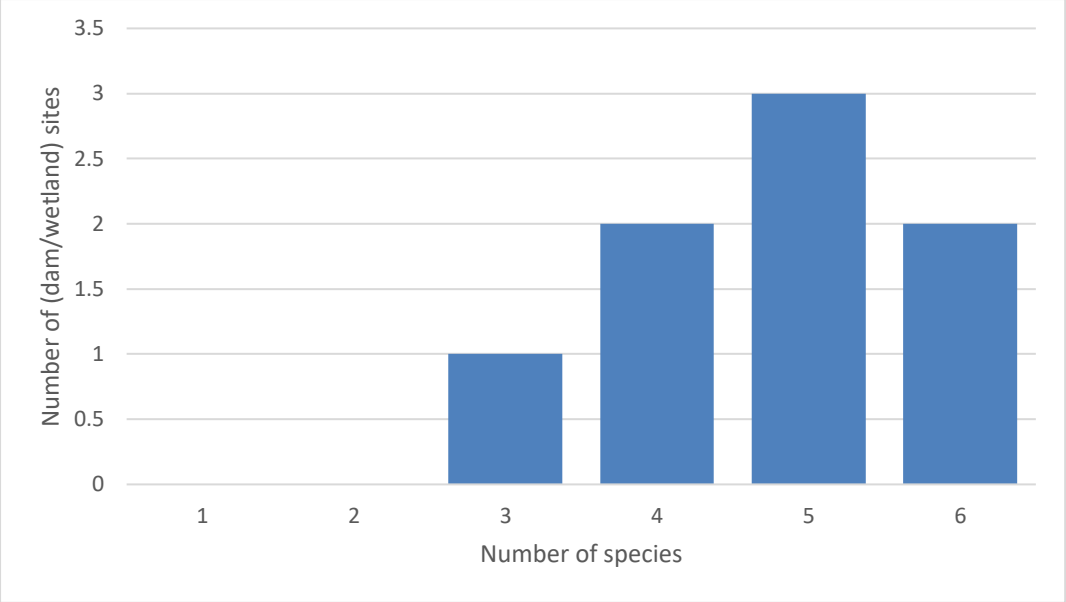

Figure 11. Species richness at dam/wetland sites at MCHF during the 2021 frog surveys

This year's findings represent a notable increase in species richness per dam/wetland site from the 2020 survey (the dam/wetland sites were not included in the original 2017 survey) which reported an average of only 3.0 species per dam/wetland site, as well as a maximum number of species for a single site of only four (4) species.

3.2.2 Species richness at transects

The species richness at transects describes the total number of species detected at each transect (i.e. total species recorded combined for both sites T_x_1 & T_x_4). For this assessment, the dam/wetland sites were discounted as these sites did not involve a transect with two survey sites.

For the transects along Mulloon Creek, an average of 4.9 species per transect were detected across the 29 transects completed in the frog survey. The greatest number of species found at any single transect during the surveys increased to 8 species (compared to the highest single *site* score of 7 species) but was recorded at only one transect (T_4). Four transects recorded 7 species, three transects recorded 6 species, 11 transects recorded 5 species, five transects recorded 4 species, four transects recorded 3 species and one transect (T_43) recorded only a single species ((*C. signifera*; no transects recorded a total of 2 species; see Figure 12).

Just over half (15/29) of the transects completed had an increased combined number of species for the transect than for one the (i.e. the highest) individual site species count (for example, each site may have recorded three species, but with a different composition of species at each site, the combined species count for the transect was higher at 4, or possibly more, species).

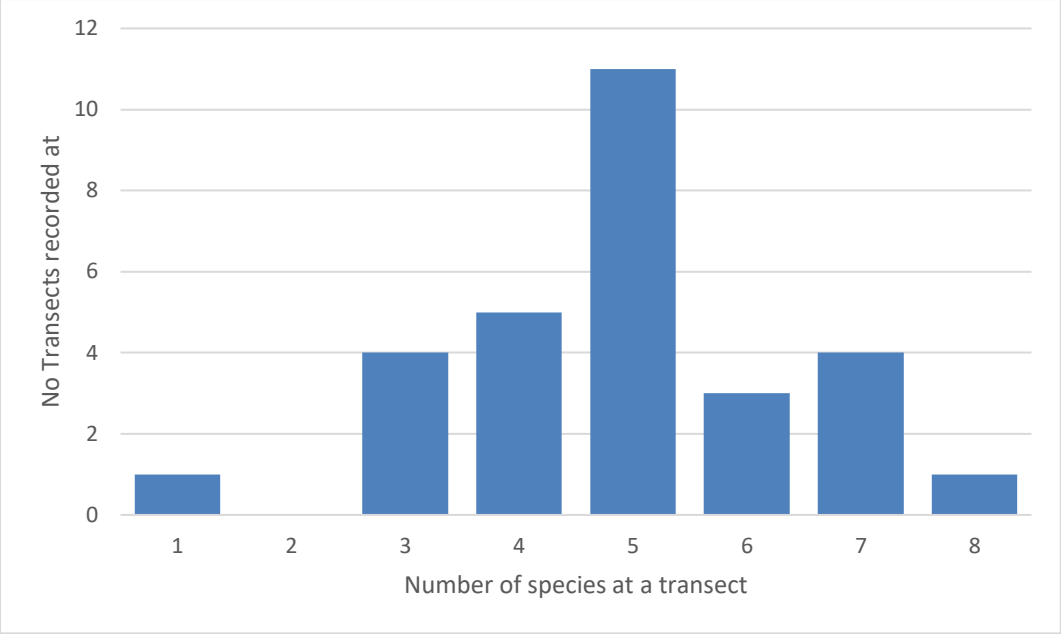

Figure 12. Species richness at stream transects along Mulloon Creek during the 2021 frog surveys

The average species richness recorded per transect (4.9) in this year's (2021) survey represents a notable increase in the average species richness of stream transects compared to the previous 2020 survey (3.56 species per transect) and again is similar to the result from the 2017 survey (5 species per transect), although the 2017 did record a maximum of only 7 species at a single transect, compared with 8 species this year (and only 5 species in 2020).

4 DISCUSSION AND MANAGEMENT RECOMMENDATIONS

4.1 Discussion

The December 2021 frog surveys conducted at Mulloon Creek were undertaken at 60 stream sites being located within (at either end of) 30 existing RARC transects, as well as at 8 dam/wetland sites. These sites were also surveyed during the previous 2020 December surveys although only 38 sites/19 transects were completed in the 2020 study, with 11 new transects (22 sites) added to this December 2021 survey.

The survey was conducted on a single night (1/12/2021) and during relatively ideal conditions. The habitat conditions for frogs were also observed to be quite good, with the region having experienced very high rainfall through November. Consequently, water levels and flow rates within the creek were quite good (for frog habitat conditions). Similarly, all the dams/wetlands were full during the time of the survey. Given the rainfall and water levels, emergent aquatic and riparian fringe/edge vegetation levels were also quite good (for frog habitat conditions). Compared with the previous year's (December 2020) survey, there was notably more water in the system (in terms of depth/flow) this season, as well as slightly higher levels of aquatic and riparian vegetation cover.

The surveys found that the section of the Mulloon Creek catchment covered by this study continues to support a relatively healthy frog community along the creek and adjacent dams/wetlands (within MCHF only), with a total of 11 frog species recorded during the study. This represents a notable increase in the total number of species recorded in the study area from the previous 2020 survey of 8 species, and 7 species in the 2017 survey. The three additional (new) species recorded included Lesueur's Tree Frog, Southern Leaf Green Tree Frog and the Screaming Tree Frog. The latter was commonly recorded in the study area, having not been previously detected in 2017 or 2020, whereas the former two species were recorded in a new study site location in the upper reaches of Mulloon Creek, not previously surveyed.

No survey site within the study failed to record at least one species of frog. The species richness of frogs at sites, being the total number of species detected at a single site, averaged 3.8 species/site, including an average of 3.67 species per stream site and 4.75 species per dam/wetland site. This represents an increase in the species richness on the previous (2020) year's results (of 2.55 species per site including an average of 2.44 species per stream site and 3 species per dam/wetland site). The 2021 results are however, relatively identical to the 2017 of (an average of) 3.68 species per site (dam/wetland site surveys were not completed in the original 2017 study). It was noted though that the maximum number of species detected at single site in the 2017 study was 6 species, compared with 7 species in the 2021 study and 5 species in the 2020 study.

A similar pattern was found when looking at species richness at survey transects (i.e. the total number of individual species combined from both sites at a stream transect; this count excludes dam/wetland sites). For the 2021 survey, an average of 4.9 species per transect were detected across the 29 transects completed in the frog survey, which is

again similar to the result from the 2017 survey (5 species per transect), and more than the 2020 result (3.56 species per transect). For the 2021 survey, a maximum of 8 species was detected at any one single transect, compared to maximum of only 7and 5 species at a single transect for the 2017 and 2020 surveys respectively.

The results indicate that the Mulloon Creek supports a relatively healthy frog population. The apparent dip in species richness numbers in last year's 2020 survey could be attributed to a number of factors, including both habitat conditions and/or survey bias (inconsistencies). As noted in the report on the 2020 survey (Patmore, 2021), the lower detection rate and species richness in that survey (compared to the 2017 survey) may have included either or a combination of overall survey effort and/or observer skill, and notably, the audio recording was less than 2 minutes in length. It was also noted that for the 2020 survey period, although there was some good rainfall leading up to the surveys, there had been two previous years of very dry/drought conditions which may have reduced overall abundances of various frog species in the area. Therefore, despite the good rainfall/conditions immediately leading up to and during the 2020 surveys, there would not have been sufficient time for population numbers (and distribution across the study area) have built up again.

For the 2021 surveys, the audio recording time per site was more than doubled from two to five minutes. This, combined with the full year since the (apparent) good breeding conditions of 2020, and good conditions immediately leading up to and during the 2021 surveys, may explain to a large degree the noted increase in species richness at sites from the 2020 to the 2021 surveys.

Despite the increase in species richness, and apparent good health of the overall frog community in the catchment, when looking at the patterns of detection rates of individual species, there may be some evidence that certain species are not doing as well as others, with a potentially concerning decline in detection rates. This decline in detection rate may be an indicator of a decline in either or both the abundance and the distribution of these frogs. The main species of concern where there has been a noted decline in the detection rate include the Whistling Tree Frog and Peron's Tree Frog.

For the Whistling Tree Frog, the decline in detection rates could potentially be attributed to survey timing as this species' peak activity is June – November, with the 2017 survey being conducted in November compared with the December timing for the 2020 and 2021 surveys, where activity levels would be starting to decline. However, this species is also reported to be recovering from population declines due to the amphibian chytrid fungus disease. Further surveys would therefore be required to help determine the health of this population, which may include earlier timing (in November) as well as potentially seeking to assess the presence/levels of Chytrid in the population.

The seemingly large decline in the detection frequency of Peron's Tree Frog at stream sites could also potentially be of concern. While this species is generally regarded as being abundant and widespread (and regularly recorded at many sites in eastern Australia, pers. obs), the pattern of decline at the stream sites (from 50% in 2017 to 31% in 2020 to 5% in 2021) is worrying. It is noted that this species tends to prefer breeding in still water and was recorded at half (4/8) of the dam/wetland sites, although this is still down from 5/8 dam/wetland sites in the 2020 survey. It is possible that the reduced extent of occurrence within the creek may also be attributable to the higher stream flow rates

during the 2021 survey, with this species tending to prefer still water more than flowing streams. However, Peron's Tree Frog is one of several species with recent reports of high mortality events, likely attributable to the amphibian chytrid fungus. Further research may be required to help better understand whether there is a real decline in the occurrence of this species, and whether that may be attributable to the chytrid fungus.

From these surveys and combined with now two previous years of surveying for frogs in 2017 and 2020, an early picture can begin to be drawn on the overall status of the frog community within the study area of the Mulloon Creek catchment. The result of these surveys indicates that there is a relatively diverse suite of frog species within the catchment, with moderate levels of species richness/diversity and that the community overall appears relatively healthy with populations of most species seeming to be stable (noting this does not incorporate any direct abundance measures and relies on detection frequency as a measure of distribution across the study area, which can be used as a basic measure for population size). Notwithstanding these positive results, two particular species may be suffering from a decline in local population size as observed by a notable downward in detection frequency within the study area and may also be suffering from more widespread declines across its range. Further research may be required to confirm what the status of these species are

Possible management and further research recommendations to ensure the ongoing health and future potential increase in the frog community within the catchment are discussed below.

4.2 Recommendations

4.2.1 Land and habitat management

The land/habitat management recommendations related to ensuring the maintenance of a viable (sustainable and diverse) frog community at Mulloon Creek are relatively unchanged from those proposed in the previous 2020 survey (Patmore, 2021). As indicated in that report, these are primarily for consideration (not mandatory or otherwise urgently required) and include the following:

1. Continue to maintain in good repair all existing fencing along the creek to exclude/control livestock access.
2. Consider constructing additional fencing along sections of the creek that are currently unfenced.
3. Reduce/manage degradation of in-stream and riparian habitat through addressing any active sediment and erosion inputs.

As also noted in the 2020 report, a strategy for the longer-term management/removal of Blackberry along creek banks should be considered. However, this removal needs to be balanced against its current role in maintaining bank stability, thus, some form of replacement planting would be required. This combined with the difficulty of removal of the Blackberry could become a prohibitively costly exercise. Consequently, this factor is mentioned for consideration only, but not a specific recommendation for implementation.

As also noted in the 2020 report, it is recommended consideration be given to future possible longer-term habitat creation, enhancement, or expansion for frogs in the catchment. These include:

- Construction/establishment of further artificial wetlands within MCHF (as discussed and recommended in the *Habitat Assessment & Translocation Strategy for the Green and Golden Bell Frog* report prepared by PATH Co (2019).
- Consider further riparian revegetation along sections of the creek where natural/native riparian vegetation species are limited.

4.2.2 Further research

Recommendations for further/ongoing research and monitoring to assist with managing the site for the benefit and maintenance of frog communities include mainly the recommendation for the continuation of this current monitoring program, although with some possible additions/alterations, including:

- Depending on time/budget constraints for continuing this monitoring program, consideration could be given to changing the monitoring to a two-yearly event. Monitoring only every second year would obviously save some funds which may allow the project to continue, and over a longer duration, but also, budget savings could potentially be re-deployed to other parts of the project to allow some increased survey efforts to increase the scope of the overall amphibian assessment, discussed below. It is believed that monitoring every second year would still provide for good long-term monitoring results, particularly if conducted over a longer period of time, especially given the site/habitats are not currently known to be subject to any proposed major land use changes that might result in a sudden change in the frog community status. Ideally however, annual seasonal monitoring is best as this will capture short (and long) term changes and can be more responsive to detecting seasonal conditions and changes in frog community composition and status.
- If time/budgets permit, consider increasing the survey period to include two separate nights of survey. This will not only improve the overall chances of detection of species (and is more in-line with amphibian survey guidelines for many species) but will allow the surveys to be spread out which can help account for potential inclement weather, but also, can allow for an earlier (November) survey occasion, discussed below.
- If two separate surveys are not achievable, bring forward the survey timing to about mid-November (ideally at the latest). This earlier timing will help increase the likelihood of detection of the Whistling Tree Frog as part of a further detailed assessment of this species' status (see below), while also being generally suitable for adequately surveying the other species likely to be encountered in the area
- Consider further detailed investigations into the potential declining occurrence of the Whistling Tree Frog and Peron's Tree Frog. As noted above, earlier survey timing, including potentially second additional survey occasion, would help increase the likelihood of detection. Therefore, if detection rates of these species remains low despite the increased effort, this may be a sign of actual (local) population decline. Although it is likely that if there is a decline in these species,

the amphibian chytrid fungus would be responsible, this is not definite. Further assessment of the causes of decline may be warranted, including possibly undertaking a chytrid assessment of the population (likely through a swab analysis of frogs although other assessment techniques may be available).

- Consider adding some additional parameters such as more water chemistry variables (e.g. pH, Conductivity etc). Note that water chemistry variables along a continuous aquatic system like Mulloon Creek may only need to be assessed at a smaller sub-set of sites/transects.
- Consider also increasing information on vegetation parameters, including noting dominant species of emergent aquatic and fringe/edge vegetation. Tracking any changes in the vegetation composition and structure over time would be useful for comparisons with any potential changes in frog species richness (and abundance) over time that could be attributable to these vegetation changes.
- If time/budgets permit, consider undertaking additional surveys of other non-stream habitats (i.e. additional dams/wetlands) within not only MCHF, but other properties within the study area.
- For future surveys, it is recommended that the habitat assessment component of the study, typically undertaken diurnally and separate to the frog survey (undertaken nocturnally), should be completed either by a single observer (as was the case for the 2021 survey), or, if undertaken by multiple observers, that some initial training be held to 'calibrate' their estimates. This is necessary to ensure consistency of data collection to enable more effective comparisons between sites and between seasons.

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Appendix A. Frog Survey Records

The table below provides the species recorded as present (i.e. heard calling) at each site as well as the estimated number of individuals of each species present at the site. The estimated number of individuals present at a site has been grouped into size class categories as per the Frowatch survey data sheet and as follows:

- 1-5 frogs
- 6-20 frogs
- 21-50 frogs
- 51-99 frogs

Table A1. Frog species records at 58 survey sites (29 RARC Transects) along Mulloon Creek during the December 2021 Frog Surveys

SITE	*Cri. par*	*Cri. sig*	*Lim. dum*	*Lim. per*	*Lim. tas*	*Lit les*	*Lit. nud*	*Lit. per*	*Lit. qui*	*Lit. ver*	*Upe. lae*	***Sp. total***
T_2_1		x (1-5)	x (1-5)									*2*
T_2_4		x (1-5)				x (1-5)						*2*
T_4_1	x (6-20)		x (1-5)		x (6-20)				x (1-5)	x (1-5)	x (1-5)	*6*
T_4_4		x (6-20)	x (1-5)			x (1-5)						*3*
T_6_1	x (1-5)	x (1-5)										*2*
T_6_4	x (1-5)				x (6-20)		x (1-5)			x (1-5)	x (1-5)	*5*
T_9_1	x (1-5)	x (6-20)										*2*
T_9_4		x (6-20)							x (1-5)			*2*
T_10_1	x (1-5)	x (1-5)			x (1-5)							*3*
T_10_4		x (1-5)		x (1-5)								*2*
T_11_1		x (1-5)										*1*
T_11_4	x (1-5)				x (1-5)				x (1-5)			*3*
T_12_1	x (1-5)	x (1-5)	x (1-5)					x (1-5)		x (1-5)	x (1-5)	*6*
T_12_4	x (1-5)		x (1-5)		x (1-5)				x (6-20)			*4*
T_13_1		x (1-5)		x (1-5)	x (1-5)				x (1-5)			*4*
T_13_4		x (1-5)	x (1-5)						x (1-5)			*3*
T_14_1				x (1-5)				x (1-5)	x (1-5)			*3*
T_14_4		x (1-5)		x (1-5)	x (1-5)							*3*
T_15_1	x (1-5)		x (1-5)		x (1-5)							*3*
T_15_4		x (1-5)	x (1-5)					x (1-5)		x?		*4*
T_16_1	x (1-5)	x (1-5)			x (1-5)				x (1-5)	x (1-5)		*5*
T_16_4	x (1-5)				x (1-5)					x (1-5)		*3*
T_17-1	x (1-5)	x (1-5)	x (1-5)		x (1-5)							*4*
T_17_4			x (1-5)		x (1-5)							*4*
T_18_1	x (1-5)	x (1-5)	x (1-5)		x (6-20)							*4*
T_18_4		x (6-20)	x (1-5)		x (1-5)							*3*
T_19_1		x (6-20)	x (1-5)	x (1-5)	x (1-5)							*4*
T_19_4	x (6-20)	x (6-20)										*2*
T_20_1		x (6-20)	x (1-5)	x (1-5)	x (1-5)							*4*
T_20_4		x (6-20)	x (1-5)		x (1-5)						x (1-5)	*4*
T_21_1	x (1-5)	x (6-20)	x (1-5)									*3*
T_21_4	x (6-20)	x (6-20)	x (1-5)	x (1-5)								*4*
T_22_1	x (1-5)	x (6-20)	x (1-5)		x (1-5)				x (1-5)			*5*
T_22_4	x (1-5)	x (6-20)			x (1-5)							*3*
T_23_1		x (1-5)		x (1-5)	x (6-20)				x (1-5)			*4*
T_23_4	x (1-5)	x (1-5)			x (1-5)				x (1-5)			*4*
T_24_1	x (6-20)	x (1-5)	x (1-5)	x (1-5)	x (6-20)				x (1-5)		x (1-5)	*7*
T_24_4	x (6-20)	x (1-5)			x (1-5)				x (1-5)			*4*
T_25_1	x (1-5)	x (1-5)	x (1-5)		x (1-5)				x (1-5)			*5*
T_25_4	x (1-5)	x (1-5)		x (1-5)	x (1-5)				x (1-5)			*5*
T_26_1	x (1-5)	x (1-5)	x (1-5)									*3*
T_26_4	x (1-5)	x (1-5)	x (1-5)		x (1-5)				x (1-5)			*5*
T_27_1	x (1-5)	x (1-5)			x (1-5)				x (1-5)			*4*
T_27_4	x (1-5)	x (6-20)	x (1-5)		x (1-5)				x (1-5)			*5*
T_32_1	x (1-5)	x (1-5)		x (1-5)	x (6-20)				x (6-20)		x (1-5)	*6*
T_32_4		x (6-20)		x (6-20)	x (21-50)				x (1-5)			*4*
T_33_1	x (1-5)	x (6-20)	x (1-5)	x (1-5)	x (6-20)				x (6-20)		x (1-5)	*7*
T_33_4	x (6-20)		x (1-5)	x (21-50)	x (21-50)							*4*
T_34_1	x (1-5)	x (6-20)		x (1-5)	x (6-20)				x (1-5)		x (1-5)	*6*
T_34_4	x (1-5)	x (1-5)	x (1-5)		x (6-20)							*4*
T_39_1	x (1-5)	x (1-5)										*2*
T_39_4	x (1-5)	x (6-20)			x (1-5)							*3*
T_42_1		x (6-20)	x (1-5)		x (1-5)							*3*
T_42_4	x (1-5)	x (1-5)	x (1-5)		x (1-5)				x (1-5)			*5*
T_43_1		x (6-20)										*1*
T_43_4		x (6-20)										*1*
T_44_1	x (6-20)	x (6-20)			x (1-5)							*3*
T_44_4	x (1-5)	x (1-5)			x (1-5)							*3*

Table A2. Frog species records at the (8) dam and wetland sites at MCHF during the December 2021 Frog Surveys

SITE	*Cri. par*	*Cri. sig*	*Lim. dum*	*Lim. per*	*Lim. tas*	*Lit les*	*Lit. nud*	*Lit. per*	*Lit. qui*	*Lit. ver*	*Upe. lae*	***Sp. total***
D3	x (6-20)	x (6-20)			x (6-20)						x (6-20)	*4*
D4	x (6-20)				x (6-20)			x (1-5)	x (1-5)		x (6-20)	*5*
W6	x (6-20)	x (6-20)		x (6-20)	x (6-20)				x (1-5)	x (1-5)		*6*
D26	x (6-20)	x (6-20)		x (6-20)	x (6-20)			x (1-5)	x (1-5)			*6*
D27/28	x (21-50)				x (6-20)			x (1-5)	x (1-5)		x (1-5)	*5*
D30	x (6-20)	x (1-5)			x (6-20)							*3*
D31	x (1-5)			x (1-5)	x (6-20)				x (1-5)			*4*
D32	x (21-50)		x (1-5)		x (21-50)			x (1-5)	x (1-5)			*5*

Species Code:
C. par = Crinia parinsignifera
C. sig. = Crinia signifera
Lim. dum = Limnodynastes dumerilii
Lim. per. = Limnodynastes peronii
Lim. tas. = Limnodynastes tasmaniensis
Lit. les. = Litoria leseuerii
Lit. nud. = Litoria nudidigitus
Lit. per. = Litoria peronii
Lit. qui. = Litoria quiritatus
Lit. ver. = Litoria verreauxii
U. lae. = Uperoleia laevigata

Appendix B. Habitat Survey Data

Table B1. Habitat Survey Details at (19) RARC transects (n=36 sites) along Mulloon Creek during the December 2021 Frog Surveys

Site Ref No	Sky	Wind	Air Temp	Water Temp	Water Depth	Pond Level	Water Flow	Vertical Water Level Drop (m)	Area Exposed Soil (m)		Emergent Aquatic Veg Cover	Fringe/Edge Veg Cover	Pond Shading	Mowing? (Y/N)	Width of buffer
									Min	Max					
T_2_1	3	1	17.4	17.1	2	2	3	0.25	0	0.5	2	6	4	N	3
T_2_4	2	1	NR	NR	2	2	4	0.25	0	0.5	2	5	5	N	3
T_4_1	1	1	NR	NR	2	2	3	0.5	0	0.5	2	6	5	N	3
T_4_4	1	1	NR	NR	2	2	3	0.25	0	0.5	1	5	5	N	3
T_6_1	1	1	NR	NR	2	2	2	0.25	0	0.5	2	6	5	N	3
T_6_4	1	1	NR	NR	2	2	3	0.5	0	0.5	2	6	6	N	3
T_9_1	3	1	NR	NR	2	2	2	0.25	0	0.25	2	6	5	N	3
T_9_4	3	1	NR	NR	2	2	3	0.25	0	0.25	2	6	5	N	3
T_10_1	3	1	19.2	NR	2	2	3	0.25	0	0.2	2	8	5	N	3
T_10_4	3	1	19.1	NR	2	2	3	0.25	0	0.5	2	5	4	N	3
T_11_1	3	1	22.5	NR	2	1	2	0	0	0	2	6	6	N	3
T_11_4	3	1	21	18	2	2	2	0.25	0	0.25	1	6	4	N	3
T_12_1	3	1	17	NR	2	1	3	0	0	0	2	8	3	N	3
T_12_4	3	1	15	16	2	2	2	0.25	0	0.25	2	6	5	N	3
T_13_1	3	1	13	20	2	2	3	NR	NR	NR	2	6	5	NR	NR
T_13_4	1	1	13	NR	2	2	3	0.25	0	0.25	2	6	4	N	3
T_14_1	3	1	16	NR	2	2	3	0.25	0	0.25	4	NR	6	N	3
T_14_4	NR	NR	NR	NR	1	2	4	0.3	0	0.3	4	8	6	N	3
T_15_1	3	1	18	19	2	2	2	0.5	0	0.5	2	5	6	N	3
T_15_4	2	1	18	19	2	2	2	0.25	0	0.25	2	6	5	N	3
T_16_1	2	1	19	19	2	2	2	0.25	0	0.25	2	6	4	N	3
T_16_4	2	1	18	19	2	2	3	0.25	0	0.25	2	6	5	N	3
T_17_1	1	1	19	19	2	2	2	0.25	0	0.25	3	8	5	N	3
T_17_4	1	1	19	19	2	2	2	0.25	0	0.25	4	8	5	N	3
T_18_1	1	1	18	19	2	2	3	0.25	0	0.25	4	7	6	N	3
T_18_4	1	1	14	18	2	2	2	0.25	0	0.25	3	8	5	N	3
T_19_1	1	1	14	19	2	2	3	0.25	0	0.25	3	8	2	N	3
T_19_4	1	1	14	19	2	2	3	0.25	0	0.25	3	7	2	N	3
T_20_1	3	1	20	NR	2	2	2	0.25	0	0.25	5	8	6	N	3
T_20_4	2	2	16	NR	2	2	3	0.25	0	0.25	6	8	2	N	3
T_21_1	1	1	15	NR	2	2	2	0.25	0	0.25	3	8	2	N	3
T_21_4	1	1	14	NR	2	2	2	0.25	0	0.25	3	6	4	N	3
T_22_1	1	2	13	NR	2	2	2	0.25	0	0.25	2	5	3	N	3
T_22_4	2	1	NR	NR	2	2	2	0.25	0	0.25	2	7	3	N	3
T_23_1	2	2	NR	NR	2	2	3	0.25	0	0.25	2	6	5	N	3
T_23_4	1	1	14	NR	2	2	3	0.25	0	0.25	3	6	5	N	3
T_24_1	2	1	NR	19	2	2	3	0.25	0	0.25	2	7	5	N	3
T_24_4	2	1	NR	19	2	2	2	0.25	0	0.25	2	5	5	N	3
T_25_1	2	NR	15	19	2	2	2	0.5	0	0.5	2	6	2	N	3
T_25_4	2	1	NR	NR	2	2	2	0.5	0	0.5	2	7	5	N	3

T_26_1	2	1	NR	NR	2	2	2	0.25	0	0.5	2	6	2	N	3
T_26_4	2	1	16	NR	2	2	2	0.25	0	0.5	2	6	2	N	3
T_27_1	2	1	17	19	2	2	2	0.25	0	0.5	4	6	2	N	3
T_27_4	2	NR	17	19	2	2	3	0.25	0	0.5	2	6	6	N	3
T_28_1	NR	NR	NR	NR	2	2	3	0.25	0	0.5	2	7	5	N	3
T_28_4	NR	NR	NR	NR	2	2	3	0.25	0	0.5	2	6	5	N	3
T_32_1	1	1	24	22	1	2	2	0.5	0	0.1	6	7	2	N	3
T_32_4	1	1	19	22	1	3	2	0.5	0	0.1	6	7	4	N	3
T_33_1	1	1	20	20	1	3	2	0.5	0	0.5	6	6	6	N	3
T_33_4	NR	NR	20	20	1	3	2	0.5	0	0.1	5	8	2	N	3
T_34_1	NR	NR	19	20	1	2	2	0.25	0	0.1	7	7	1	N	3
T_34_4	NR	NR	20	20	1	2	2	0.5	0	0.5	5	5	1	N	3
T_39_1	3	1	17	NR	2	2	2	0.5	0	0.1	5	8	6	N	3
T_39_4	3	1	17	NR	2	2	2	0.5	0	0.1	6	8	4	N	3
T_42_1	3	1	18	19	2	2	2	0.5	0	0.5	5	7	3	N	3
T_42_4	3	1	17	19	2	2	2	0.5	0	0.5	5	7	4	N	3
T_43_1	3	1	17	19	2	2	2	0.5	0	1	2	6	3	N	3
T_43_4	3	1	17	19	2	2	2	0.5	0	0.2	NR	5	6	N	3
T_44_1	3	1	16	19	2	2	2	0.5	0	1.5	3	NR	3	N	3
T_44_4	3	1	16	19	1	2	2	0.5	0	1	4	7	4	N	3

Table B2. Habitat Survey Details at (8) Dam/Wetland sites at MCHF during the December 2021 Frog Surveys

Site Ref No	Sky	Wind	Air Temp	Water Temp	Water Depth	Pond Level	Water Flow	Vertical Water Level Drop (m)	Area Exposed Soil (m)		Emergent Aquatic Veg Cover	Fringe/Edge Veg Cover	Pond Shading	Mowing? (Y/N)	Width of buffer
									Min	Max					
D3	2	1	18	23	2	1	1	0.2	0	0.2	2	6	1	N	3
D4	2	1	18	23	2	1	1	0.2	0	0.2	2	6	1	N	2
W6	1	1	17	24	2	1	1	0	0	0	7	7	2	N	3
D26	3	1	20	24.5	2	1	1	0.2	0	0.5	2	6	3	N	1
D27/28	3	1	20	24	2	1	1	0	0	0	2	6	2	Y	2
D30	3	1	19	23.5	2	1	1	0.1	0	0.5	2	5	2	Y	1
D31	3	1	19	23	2	1	1	0.2	0	0.3	2	5	1	N	2
D32	3	1	19	23	2	1	1	0.2	0	0.2	2	6	1	N	3

Table B3. Description of score categories for habitat variables in Tables B.1 and B.2

Sky (1 to 6)	Wind (1 to 4)	Water Depth (1 to 4)	Pond Level	Water Flow (1 to 4)	Emergent Aquatic Veg Cover	Fringe/Edge Veg Cover	Pond Shading	Width of buffer
1= clear/few clouds	1 = Still	1 = <30	1 = Full	1 = Still	1 = none	1 = none	1 = none	1 = <1m
2 = Partly cloudy/variable	2 = Light Breeze	2 = >30	2 = Nearly Full	2 = Slow	2 = just localised	2 = just localised	2 = <10%	2 = 1-5m
3 = Cloudy/overcast	3 = Light Wind	3 = unknown	3 = Bank V. Exposed	3 = Moderate	3 = <25%	3 = <10% edge	3 = <25%	3 = >5m
4 = Fog	4 = Windy	4 = Dry	4 = Nearly Dry	4 = Fast	4 = <50%	4 = <25% edge	4 = <50%	
5 = Drizzle			5 = Dry		5 = <75%	5 = <50% edge	5 = <75%	
6 = Showers					6 = <100%	6 = <75% edge	6 = <100%	
					7 = entire pond	7 = <100% edge		
						8 = entire edge		