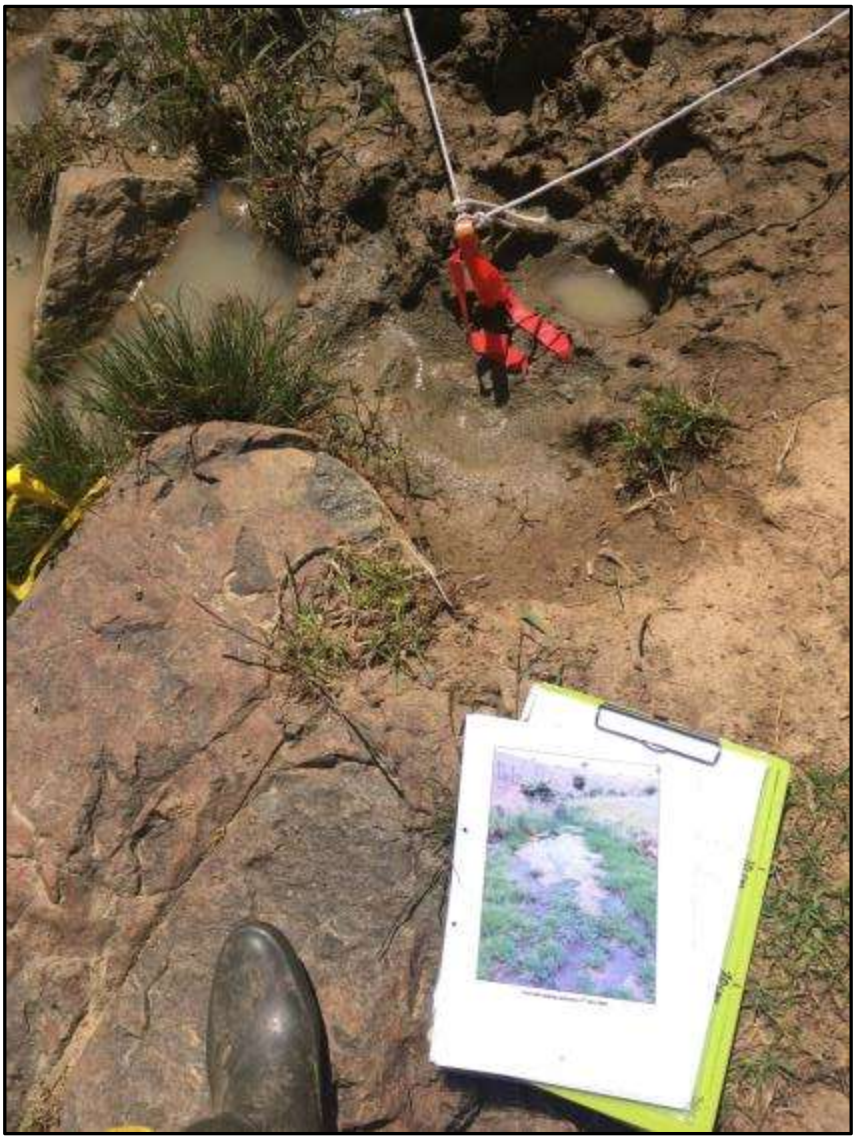
Pool and Bench Vegetation of Stream E, Ginninderry

Monitoring Results: spring 2020



Jane Roberts and Alice Bauer

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For further Information on Stream E and the Conservation Corridor, contact:

Steve Harding, Riverview Developments

Jason Cummings, Ginninderry Conservation Trust

Ange Calliess, Program Director, Conservation Corridor

For further information on Ginninderry:

check the website: https://ginninderry.com/about/

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Executive Summary

Vegetation of pools and benches was re-surveyed in November 2020. The survey followed the protocols and methods described in *Pool and bench vegetation of Stream E, Ginninderry, ACT. Baseline in Spring 2018 (*Roberts and Sharp 2019). Minor updates to the methods are the inclusion of an 'impact gradient' for reporting on Bench condition; and calculating the Nativeness indicator for only forbs (formerly forbs and shrubs). This was the second repeat survey since the Baseline was established in spring 2018. The winter-spring months preceding the survey were very different from the previous year, being milder and wetter, and so providing favourable growing conditions, whereas the previous spring had been cooler and drier. Pulses of reddish sediment-rich water passed down Stream E on the first day of the field survey.

Reporting follows a standard format comprising a General Description, presentation of quantitative Indicators for Pools (Indicators A, B and C) and Benches (Indicators D, E, F and G), followed by an Evaluation which compares results for 2020 with a set of targets for Stream E. Indicators are selected to give feedback on water and land management in the Stream E and its catchment.

Stream E in November 2020 was improved relative to previous year. Vegetation was taller, denser and with slightly different array of species, and benches and pool edges were much less affected by livestock (grazing, pugging). Two sites where this was not the case are both stream crossing places.

Pools: The two vegetation indicators (area of tall emergent macrophytes; area of submerged macrophytes) both increased relative to previous year, but these increases were not statistically significant, so there was no evidence these had changed. However, the third indicator, which is pool depths measured at the deepest point (water depth; sediment depth) did change significantly: water depth increased, virtually doubling, from 29.7 to 64.0 cm whereas sediment depth decreased by an order of magnitude, from 30.9 to 3.3 cm.

Benches: The four vegetation indicators for bench quadrats (bare ground; Annuals cover; grasses cover; Nativeness of forbs) increased or decreased relative to their values in 2019 but none were significant except Annuals, and only marginally so. Bare ground remained low, with 5.3% (10.4% in 2019); Annuals had 31.6% cover (from 1.8% in 2019); Grass cover was 55.6% (from 77.1%); and Nativeness of Forbs species and forbs cover remained low, 11.7% and 5.1%.

Evaluation: Stream E meets 3 of the 4 targets for pools, an improvement from 2019 when 2 of 4 pool targets were met. The target for submerged macrophytes has not been met since the first year. Stream E meets just one of 3 targets for benches, Target G to do with shrub cover: this is satisfactory as this target is a land management alert for particular weedy species. Even more benches fail the other two targets in 2020 than in 2019 (perennial cover; grass cover).

A comparison of indicator values in different years (2019 v 2019 v 2020) found no real change in the vegetation: values for 2020 were statistically similar to 2018. The only significant change in this 3-year period was in the pools: these accumulated deep deposits of sediment in 2019, and then underwent a scouring in 2020.

The finding that there has been no real change in the vegetation between 2018 and 2020 suggests Stream E may be more resistant to change than originally anticipated. However, the finding of 'no

change' is driven by high variability in the data. This variability constrains the analysis, making it difficult to detect small changes.

Bench floristics: Two analyses were done on bench floristics (forbs and shrubs), a small data set of 11 sites x 3 years. One analysis found that 'site' explained some of the variability but not the year of when sampling was done. The other found that site and year were both important influences on floristics and, and hence both contributed to variability in bench floristics. These findings were for bench floristics (mainly forbs) and are not directly transferable to pool vegetation: nonetheless, the insight that variability is driven by a combination of site and year is valuable.

1: Vegetation Monitoring of Stream E

1.1: Background

This is the second repeat survey of vegetation of Stream E, one of several short steep streams in the Ginninderry Conservation Corridor, flowing down into the Murrumbidgee River.

Design and rationale for this monitoring program, and results of the Baseline Survey in October-November 2018, are given in *Pool and Bench Vegetation of Stream E, Ginninderry: Baseline in Spring 2018* (Roberts and Sharp 2019). The survey was repeated the following year, in spring 2019, using the methods set out in the Baseline Survey, and findings are in *Pool and Bench Vegetation of Stream E, Ginninderry: Monitoring Results: Spring 2019* (Roberts and Sharp 2020).

Monitoring Program: Vegetation is monitored on two geomorphic features of Stream E, pools and benches, as these are where vegetation changes are likely to occur in response to upstream development. For practical reasons, runs[1] which are a third geomorphic feature of Stream E, were not included. The monitoring program uses four qualitative indicators and seven quantitative indicators: three for Pools, and four for Benches (Table 1). The seven quantitative indicators were chosen because they are expected to respond to urbanisation effects on stream hydrology (increased discharge, faster flows, fewer dry spells) and water quality (higher sediment load, more nutrients).

After completing the Baseline survey in spring 2018, it became apparent that large (hoofed) animals, principally livestock (cattle) but also feral deer, were affecting vegetation and banks and edges of Stream E. Such animals can have a considerable effect on in-stream and riparian zones through grazing and trampling, and so potentially confound interpretations of change, if any. To accommodate this, the monitoring program now routinely reports on grazing effects and physical damage to pool and bench edges. Qualitative observations are considered adequate for this monitoring program: the time required for a quantitative assessment of herbivory and damage is large, and disproportionate to its usefulness in this instance.

Table 1: Structure of Vegetation Monitoring Program

	Pools	Benches
General Description	Reference Photos	Vegetation Height Impact Gradient Dominant Species
Quantitative Indicators	Tall emergent macrophytes (area) Submerged macrophytes (area) Pool depths – water, sediment (cm)	Bare ground (cover %) Annuals (cover %) Grasses (cover %) Nativeness (%)

[1] **Runs**: the narrow faster-flowing sections between pools

1.2: Implementation & Conditions in Spring 2020

Timing: Field work was done on two days, each from morning to mid-afternoon, on 7 and 9 November 2020. These dates conform to the mid-spring timeframe recommended in the Baseline report (Section 5.1, Roberts and Sharp 2019): they are two weeks later than the first repeat survey which was on done on three half days on 21, 22 and 23 October 2019.

Conditions: Weather conditions preceding the 2020 survey, as indicated by the rainfall and temperature record for Canberra Airport (Station 070351, Bureau of Meteorology), were considerably wetter and milder than the previous year (Figure 1), as well as in comparison with the long-term average (not shown). Rainfall in August and October (106 mm, 134 mm) was well above the long-term average of 46 and 49 mm respectively. The high number of rainy days and the intensity and volume of rainfall in October pushed field work into early November, including on a Saturday (with special permission of Ginninderry). Monthly average temperatures for 2020 were higher than the long-term average for all minimum winter-spring months and nearly all maximum except June.

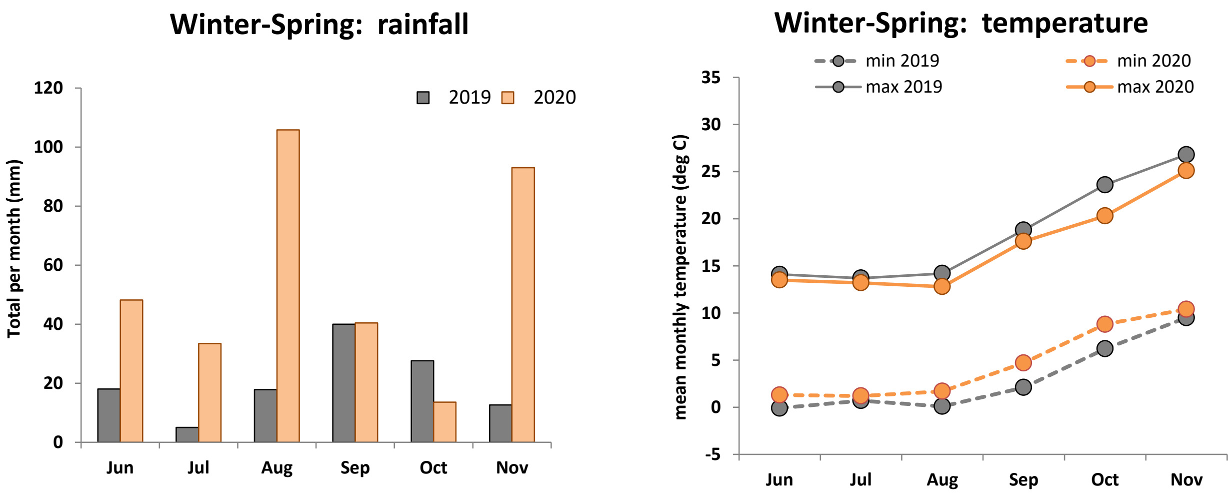


Figure 1: Winter-Spring weather in 2020 v 2019
Left: Total rainfall per month (mm) from June to November in 2019 and 2020 (dark grey and orange colours). Right: mean maximum (solid line) and minimum (dashed line) temperature per month from June to November in 2019 and 2020 (dark grey and orange colours).

The temperature plot (Figure 1: Right) is a reminder of how rapidly growing conditions improve from winter to spring. Both mean maximum and mean minimum are low and change little over winter but increase steadily after August.

Completeness: One of the sites, rc1, was not sampled. This site is in a deep cleft in one of the steeper parts of Stream E, hence its name 'rc1' standing for rocky cascades 1. Access to this site was somewhat overgrown with blackberries, and with no gloves, pruners or shears, the team was unprepared to hack their way in and out again. Thus the number of sites reported here is 10 for Benches, rather than 11. However because all plots show the sites in downstream sequence, rc1 is retained in the bottom axis of the plots but with no data given (not zero data).

Survey Team: The survey team in 2020 comprised Jane Roberts (Pools; overall project, reporting) and Alice Bauer (Benches), who replaced Sarah Sharp, team member in 2018 and 2019. To ensure consistency, the new team had a training session and practice beside Ginninderra Creek in October 2020, with the assistance of Sarah Sharp (Figure 2).

Figure 2: Practice run in October 2020 at Umbagong Park: Sarah Sharp and Alice Bauer

Field observations: Incidental observations were made on a bank slump, a pulse of poor water quality, and some interesting wildlife.

While walking between sites, the team found a bank slump (Figure 3: next page), located at 35deg 13m 45.69s S and 148deg 58m 26.4 E, which was apparently recent. This was a steep bank, about 4 m tall which is fairly high (for Stream E). Rhizomes of *Phragmites australis* protruding from the bare face of the slump indicated this was probably an area of groundwater seepage that had become unstable under the above-average wet seasonal conditions. There was no trace of any slumped material at the base of the bank, and no deposits of material noticed further downstream. The implications are that the slumped material had mostly washed through to the end of Stream E (the Murrumbidgee River) or been partly deposited in pool e32, which had noticeably more sediment than other pools.

Flow down Stream E increased while the team was at pool e07 on 7th November 2020: water levels rose and became thick and near orange-coloured. This is evident in the reference photographs for this site.

Sightings of the Perunga grasshopper *Perunga ochracea* and a Yellow-bellied waterskink *Eulamprus heatwolei* were uploaded to Canberra Nature Map.

1.3: This report

This report uses the same lay-out as previous monitoring reports (Roberts and Sharp 2020). Results are in two sections (Section 2: Pools; Section 3: Benches). This is followed by an evaluation of Stream E against pre-determined targets (Section 4) and, new to reporting in 2020, a multi-year comparison looking at indicators over three years (2018 v 2019 v 2020). Bulky, technical or reference material is in the Appendices, also copies of Field Sheets.

Two modifications are made in this report: one is to do with presenting Methods; and the other is to do with cover data for forbs in Bench quadrats.

Methods: Sections 2 and 3 of this report now have a short description of the Method, immediately before each set of Results. This is a slightly unconventional structure for a technical report but is done to make this a stand-alone document and easier to follow. The short description is not comprehensive and is intended to inform the results.

Nativeness Indicator: In the benchmark report and first re-survey report (Roberts and Sharp 2019, 2020), the Nativeness indicator is forbs plus shrubs, and referred to as 'non-grassy' (rather clumsy). With results from three consecutive years to hand, it is now apparent that shrubs contribute very little to this indicator, either in terms of species or cover. To simplify reporting and interpretation, the Nativeness indicator is revised to be forbs only. In order to align with this, the values for species nativeness and cover nativeness in 2018 and 2019 have been retrospectively re-calculated to be forbs only. These re-calculated values are used in plots in Section 3.

Re-calculating the Nativeness indicator for 2018 and 2019 made very little difference to the actual values. For example, the re-calculated values for 2018 are 12.9% for species nativeness (instead of 11.9%) and 11.7% for cover nativeness (previously 10.5%); and for 2019 the recalculated values are 8.1% for species nativeness (instead of 7.8%) and 9.1% for cover nativeness (previously 8.8%).

In this report and henceforward, shrubs will be included under Bench vegetation in Section 3.1 General Description.

Analyses: Comparison of indicators at three points in time (in 2018, 2019 and 2020) is done using General Linear Model to determine if 'year' has a significant effect on indicator values; and if so, then pairwise comparison between years is done using Tukeys HSD. Part of this analysis was used for a two-year analysis, comparing 2010 with 2019.

The following convention is used for reporting statistical outcomes from Tukeys HSD: NS (not significant) if p =>0.1; marginal if p =>0.05 to 0.1; significant * if p = 0.01 to 0.05; moderately significant if p = >0.001 to 0.01; highly significant *** if p = <0.001.

These analyses were done in the statistical analysis package SYSTAT 13 (Systat Software Inc).

Additional analyses: In spring 2020, it was very evident that plant growth was more vigorous and further advanced, and that species richness was higher than in previous years, especially when compared to spring 2019. This lead to speculation about how to disentangle the effect of seasonal conditions on vegetation indicators from the effects of upstream development on flow regime and water quality. Accordingly, a detailed examination was done of bench floristics (predominantly forbs), and is presented in Appendix D. The findings help in understanding the variability in species richness and cover of forbs on benches.

Figure 3: Alice Bauer at top of bank slump, 9th November 2020

2: Pools in 2020

2.1: General Description

Reference Photographs

METHOD

Two reference photos are taken at each site: one looking downstream, one looking upstream. The observer is positioned so that the angle and scope of the photograph match the baseline photograph taken in 2018, the baseline year: a set of laminated 2018 photographs is taken into the field for this purpose (cover photograph). A second set of laminated photographs is taken in to the field, showing the positon of the marker pegs: the pegs define the upstream and downstream boundary of each pool. Quality of the reference photographs (shadow intensity, light saturation) is affected by light intensity and sun angle, and back scattering makes many photographs dark. When necessary, dark photographs are adjusted (increased lightness, increased contrast) using a photo-editor, however this sometimes results in slightly lurid colours.

RESULTS

Copies of reference photographs for each pool, looking upstream and downstream (except rc1 which is upstream only) on 7th and 9th November 2020, are in Appendix A.

The photographs show a rather different Stream E in spring 2020 than in spring 2019, the two principal differences being high and turbid water flows, and the vigorous and abundant appearance of the vegetation. These are illustrated for a selection of sites (Appendix B).

High and turbid flows: Flow down Stream E was higher, faster in spring 2020 compared with spring 2019 when the flow was a gentle trickle and relatively clear. This difference was particularly noticeable on 7th November, when sediment gave Stream E a bright orange appearance, making the reference photographs rather lurid.

Vigorous and abundant vegetation: Vegetation on mudflats, benches, and the hillside beside Stream E was more vigorous and more abundant than in 2019: this was not true for submerged macrophytes in the pools. This vigorous and abundant growth is attributed to seasonal conditions in spring 2020 which were conducive to plant growth in contrast to cooler and drier conditions in spring 2019 (Figure 1), and to the timing of spring survey, which was approximately 2-3 weeks later in 2020.

The high and turbid flows, and the vigorous and abundant vegetation affected field work in the following ways.

Positioning marker pegs: Precise positioning of marker pegs was challenging at some sites, due to tall grass obscuring visual cues such as rocks and boulders, and concealing the soil surface.

Aligning reference photographs: Aligning reference photographs to correspond to 2018 benchmark photographs was a little tricky at some pools. Visual landmarks such as rocks and large boulders were obscured by taller denser vegetation, and standing mid-stream at the top of a boulder-step waterfall was a little hazardous in flowing water. This affected the alignment of reference photographs at some boulder-step pools.

Pool size: Several pools appeared smaller (narrower) in 2020 than they had been. This was due to lush growth of mudflat plants on pool margins, and extending out into the pool.

Submerged macrophytes: The very turbid water made it impossible to see if submerged macrophytes were present, so visual appraisal was replaced by poking around and making grabs under the water.

2.2: Indicators

Tall Emergent Macrophytes

METHOD

Three species of tall emergent macrophytes are used as ecological indicators: *Phragmites australis*, *Schoenoplectus tabernaemontani*, and *Typha domingensis*, henceforward referred to as *Phragmites*, *Schoenoplectus* and *Typha* respectively. Two metrics are used: abundance and occurrence.

Abundance, as area of each species in the marked out pool, is measured in the field, by treating each species as one or more simple geometric shapes (rectangle, circle, ellipse, equilateral triangle) and measuring its critical dimensions (height, length, or diameter) as relevant. Area of each shape, of each species and of all tall emergent macrophytes is calculated on return.

Occurrence, meaning the number of pools where a species is recorded, is derived from the area data.

RESULTS

All three species of tall emergent macrophytes were present in Stream E in spring 2020: no additional species were recorded.

Combined area: Combined area of tall emergent macrophytes in spring 2020 averaged 3.61 m^2 per pool (s.d. = 3.74). This is higher than it was in 2019 (mean = 2.79 m^2) but the difference is not statistically significant. As in previous years, the area of tall emergent macrophytes per pool is highly variable, ranging from trace amounts (0.01 m^2 in e01, 0.15 m^2in e07, and 0.225 m^2 in rc2) to 11.9 m^2 in pool e19 (Figure 3). The change from 2019 to 2020 is not uniform along Stream E: out of ten pools, five showed a clear increase to 2020, three were similar and two decreased (Figure 4).

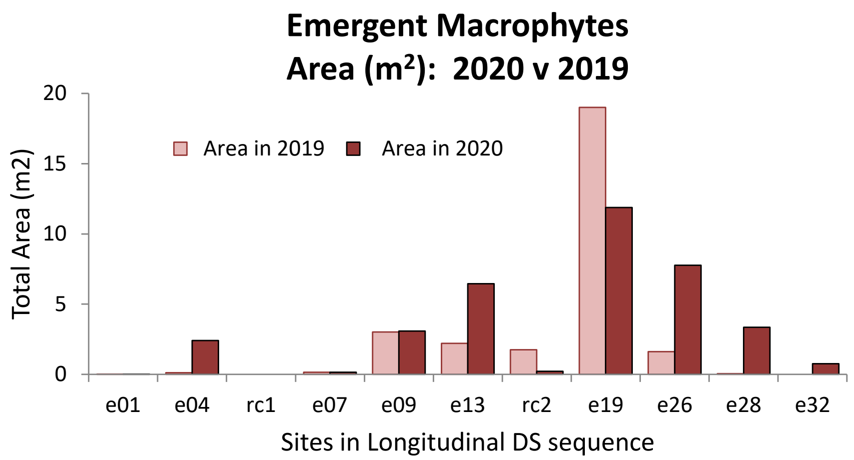


Figure 4: Area per pool of tall emergent macrophyte in spring 2020 v spring 2019
Note: there is no pool at Site rc1.

The decrease at pool rc2, evident in Reference Photos (Appendix B), is attributed to scouring effect of persistent high flows. The decrease at pool e19 is not credible. Reference photographs for e19 (Appendix A) show no change in the extent of *Phragmites*, which occupied most of the pool in 2018, 2019 and 2020. This decrease therefore has to be attributed to observer error, probably in re-positioning the two marker pegs that define pool length.

Individual species: Area of individual emergent macrophytes was only slightly higher in 2020 for two species, *Phragmites* and *Typha*, and slightly lower for *Schoenoplectus* (Table 2). Occurrence was higher than in 2019 for all three species, being 5, 6 and 5 pools for *Phragmites*, *Schoenoplectus* and *Typha* respectively compared with 3, 4 and 3 respectively in 2019.

Table 2: Individual species: mean area and occurrence

		Phragmites	*Schoenoplectus*	*Typha*
Species Area (m^2) Mean (s.d.) per pool	**2020**	2.48 (3.93)	0.41 (0.76)	0.8 (2.01)
	2019	2.06 (5.67)	0.50 (0.98)	0.23 (0.66)
Number of pools present	**2020**	5	6	4
	2019	3	4	3

Submerged Macrophytes

METHOD

Three species of submerged macrophyte are used as ecological indicators, *Chara australis*, *Nitella pseudoflabellata* and *Potamogeton crispus*, henceforward referred to as *Chara*, *Nitella* and *Potamogeton* respectively. Two metrics are used: abundance (mean area) and occurrence.

Area of each species is recorded in the field, by interpreting its area within the marked-out pool as one or more simple geometric shapes (rectangle, circle, ellipse, equilateral triangle) and measuring the dimensions critical for that shape (height, length, radius) as required. The area per shape, per species, and per pool is calculated later, using standard geometric area formulae.

Occurrence, meaning the number of pools where a species is recorded, is derived from area data.

RESULTS

Only one indicator species, *Potamogeton*, was present in pools in spring 2020.

Combined area: Area of submerged macrophytes averaged 3.31 m^2 per pool (s.d. = 6.45) in spring 2020. Although this is higher than in 2019, when it averaged 1.20 m^2, the increase is not significant. Occurrence of submerged macrophytes in 2020 is the same as in 2019, being present in 3 pools in both years. However, in 2019, submerged macrophytes were present only in trace amounts in two pools (e09, e19) that are barely visible when plotted (Figure 4).

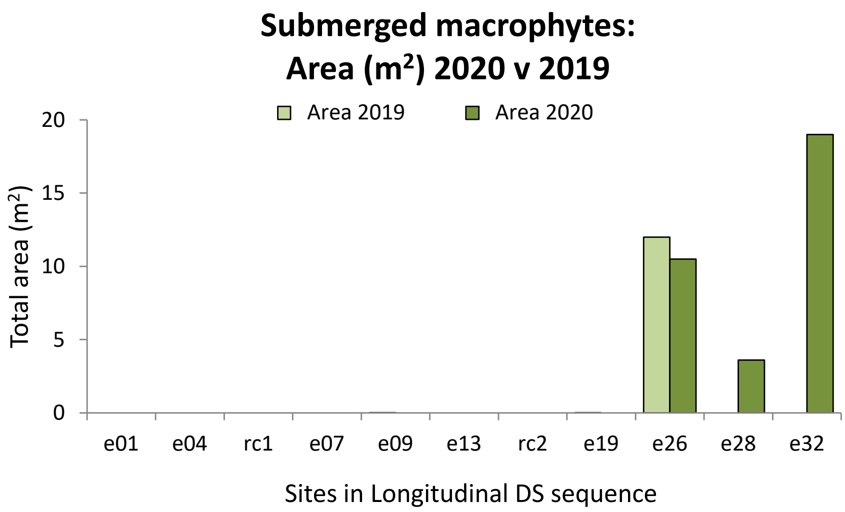


Figure 5: Area per pool of submerged macrophytes in spring 2020 v spring 2019
Note: there is no pool at Site rc1.

Individual species: Two of the three indicator species had zero area in 2020, *Chara* and *Nitella.* Strictly speaking, zero area is a decrease relative to 2019, but the actual change is very small as these had been present only in trace amounts (Table 3). Mean area of the third indicator species, *Potamogeton*, was higher in 2020. Occurrence was 0, 0 and 3 for *Chara*, *Nitella* and *Potamogeton* respectively in 2020 (Table 3). This was lower than in spring 2019 for the two charophytes, *Chara* and *Nitella*, but up for *Potamogeton*.

Table 3: Individual species of submerged macrophytes: mean area and occurrence

		Chara	*Nitella*	*Potamogeton*
Species Area (m^2) Mean (s.d.) per pool	**2020**	0	0	3.31 (6.45)
	2019	0.002 (0.003)	0.001 (0.003)	1.2 (3.60)
Number of pools where present	**2020**	0	0	3
	2019	2	1	1

Pool Depths

METHOD

The monitoring program uses three metrics for pool depths, all measured with a metre rule in the deepest part of the pool: total depth, which is the depth from firm substrate to water surface; water depth, which is distance from the sediment surface to the water surface; and sediment depth, which is the depth of sediment, and is obtained by subtracting water depth from total depth. All measurements are made at least three times, in the deepest part of the pool that can be located by probing with a 1 metre metal rule, and the mean of the three (or more) measurements is used.

The type of substrate (rock, gravel, sand, silt, unconsolidated clay) is noted for each measurement, based on probing with the metal rule.

RESULTS

Total Depth: Total depth in spring 2020 averaged 67.3 cm (s.d. = 21.73). This was slightly deeper than in spring 2019 (mean = 60.8 cm) but the difference is not significant. Individually, pools were quite variable, ranging from 39.7 cm for pool e19, to 102.3 cm for pool e13 (Figure 5). As noted in previous reports, the three boulder-step pools on the steep mid-slope of Stream E (e07, e09 and e13) are noticeably deeper than pools further upstream and further downstream. Only four of the ten pools showed a clear increase relative to 2019 (e01, rc2, e26 and e28); most pools were roughly similar and one (e09) decreased (Figure 6).

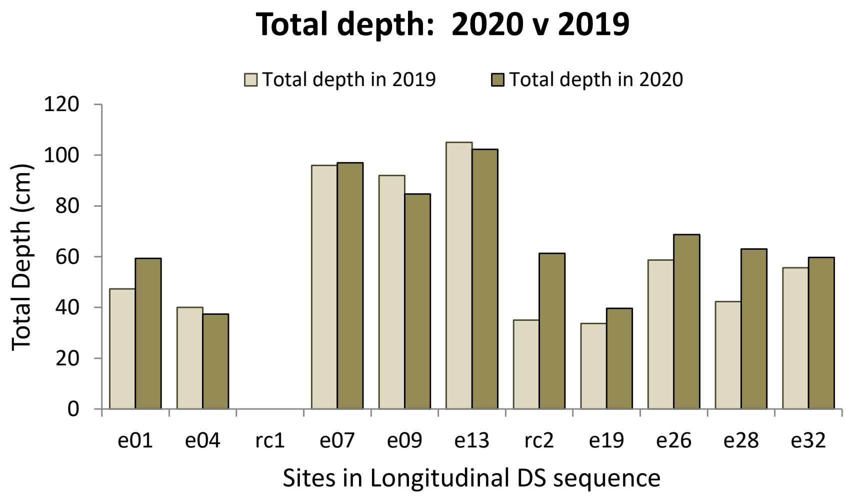


Figure 6: Total depth per pool along Stream E in 2020 and 2019
Note: there is no pool at Site rc1.

Water depth: Water depth in spring 2020 averaged 64.0 cm (s.d. = 22.3 cm). This was considerably deeper than in spring 2019 (mean = 29.7 cm) and the difference is statistically significant. Water depth in pools was quite variable, ranging from just under half a metre (39.0 and 43.3 cm in e19 and e32) to nearly a metre (96.7 and 98.0 cm in e07 and e13). Water depth increased in all ten pools (Figure 7), indicating a whole-of-system change.

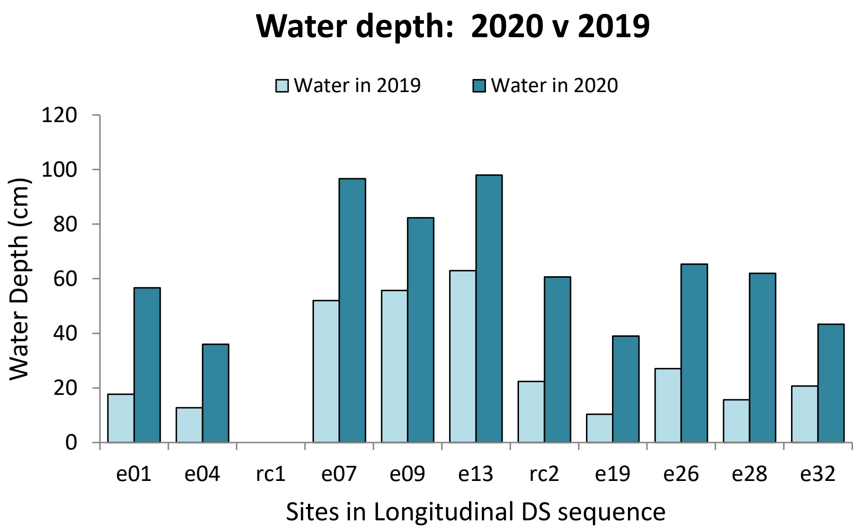


Figure 7: Water depth per pool along Stream E in 2020 and 2019
Note: there is no pool at Site rc1.

Sediment depth: The depth of unconsolidated sediment (uncompacted mud, silt or sand) in spring 2020 averaged 3.3 cm (s.d. = 4.76). This was quite shallow, and was an order of magnitude less than in spring 2019 when it averaged 30.9 cm: the difference between 2020 and 2019 is highly significant. Sediment depth was less than 5 cm in all pools along Stream E, except the very lowest one along Stream E, pool e 32, where it was 16.3 cm. Sediment depth decreased in all ten pools (Figure 8), indicating that, as with water depth, this has been a whole-of-system change.

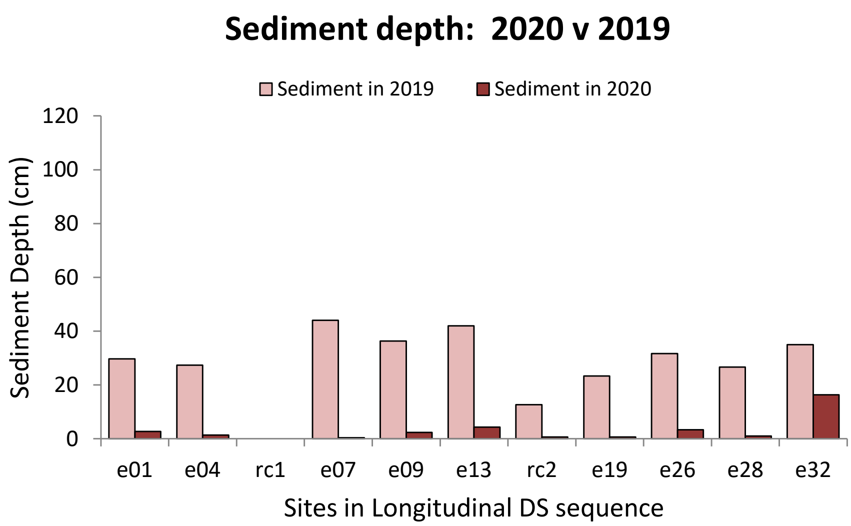


Figure 8: Sediment depth per pool along Stream E in 2020 and 2019
Note: there is no pool at Site rc1

2.3: Summary for Pools

METHOD

Pool indicators are used to determine if there have been ecological changes; and if so, then in what direction (increase ? decrease ?), and the observed change can then be interpreted for Stream E.

RESULTS

Changes in the indicators for pools are summarised below (Table 4), along with a break-down of each indicator into Trend & Pattern and, for the vegetation indicators, into ecological types. For this, invasive species are compared with non-aggressive species (tall emergent macrophytes) and robust species are compared with sensitive species (submerged macrophytes): these comparisons are qualitative as the data does not lend itself to a statistical analysis such as analysis of variance.

Table 4: Pool Indicators: Summary

Indicator	Change / Trend from 2019 to 2020
Tall emergent macrophytes	Mean area per pool: in 2020 was 3.61 m^2 and in 2019 was 2.79 $m^{2.}$, but 2020 and 2019 are not significantly different. Trend & Pattern: Area increased in 5 pools (ie half). Invasive species (*Typha Phragmites*): mean area and occurrence of both species increased slightly *(significance not known)* Non-aggressive species (*Schoenoplectus*): mean area decreased slightly, and occurrence increased *(significance not known)*
Submerged macrophytes	Mean area per pool: in 2020, was 3.3 m^2 and in 2019 was 1.2 m^2, but 2020 and 2019 are not significantly different. Trend & Pattern: Area increased in two pools. Robust species (*Potamogeton*): Area and occurrence increased *(significance not known)* Sensitive species (*Chara, Nitella*): Area decreased but was already very low in 2019. Occurrence decreased to zero.
Water Depth (cm)	Mean water depth per pool: in 2020 was 64.0 cm and significantly different from 2019 when it was 29.7 cm Trend & Pattern: All pools had more water depths, indicating a system-wide change
Sediment Depth (cm)	Mean sediment depth per pool: in 2020 was 3.3 cm, and was significantly different from 2019 when it was 30.9 cm, much deeper Trend & Pattern: All pools had less sediment, indicating a system-wide change.

Tall emergent macrophytes: Although the mean area was higher in 2020 than in spring 2019, it was not statistically different, meaning no detectable change in this indicator from 2019 to 2020.

This outcome (no detectable change) was contrary to expectations which were that tall emergent macrophytes would be extensive in spring 2020 and show a significant increase in area relative to spring 2019. This expectation was based on growing conditions for emergent macrophytes being so much better in winter-spring 2020 (saturated soils; warmer temperatures) and on field work being done 2-3 weeks later.

Submerged macrophytes: Although mean area was higher in 2020 than in spring 2019, it was not statistically different, meaning no detectable change from 2019 to 2020.

Again, this outcome was contrary to expectations, which were that submerged macrophytes would be very sparse to negligible in spring 2020, and likely show a decrease in area relative to spring 2019. This expectation was based on the likelihood that submerged macrophytes (which have flimsy leaves and stems) would be damaged and swept away by high-energy and turbulent flows down Stream E in the winter months. High and turbulent flows are assumed to have happened, driven by above-average rainfall (Figure 1) and possibly upstream releases. It is notable that only the robust species, *Potamogeton crispus*, was present in spring 2020 (Figure 5, Figure 9). Regrettably, it was not possible to determine if *Potamogeton* had resisted winter conditions or recovered faster, possibly the latter. It has been reported that *Potamogeton crispus* "grows rapidly when water temperatures reach c.15deg C" (Sainty and Jacobs 2003).

Water depth: Water above the sediment surface in the deepest part of each pool was significantly deeper in 2020, by about 34-35 cm. This increase is too big to be accounted for by high flows such as noticed on 7th November 2021, as water levels on that day were likely only about 10-15 cm higher (Appendix B: Site e07 and accompanying notes). The probable reason for water being deeper is that sediment has been removed from the bottom of all pools.

Sediment depth: The depth of unconsolidated sediment decreased substantially from 30.9 cm in 2019 down to 3.3 cm in 2020, a highly significant difference. The only way that relatively large amounts of unconsolidated sediment can be removed out of pool, often down to underlying bedrock, is by being entrained by high energy flows; such flows would need to be sustained or repeated in order to remove unconsolidated sediment out of Stream E altogether. Loss of sediment helps to account for the significant increase in water depth.

Overall: The overall finding is that from 2019 to 2020, vegetation abundance is unchanged but pool characteristics (and hence the pool as habitat) did change. There are indications that invasive and more robust species may be doing slightly better than non-aggressive or sensitive species.

Figure 9: Potamogeton crispus in pool e28

3: Benches in 2020

3.1: General Description

Bench vegetation

METHOD:

Vegetation on the bench is checked to record if it is a grassland (dominated by grasses), sedgeland, rushland or forbland. Vegetation height is estimated as an average of erect culms.

RESULTS

All benches were short, only 15 to 30 cm tall, except for two (rc2 and e28) where vegetation reached 60 cm and 110 cm respectively. This was taller than in spring 2019 when grassland was only 10 cm tall. The bench at rc2 is in a steep part of Stream E, that is not readily accessed by livestock and feral herbivores and so has less grazing pressure. This bench was noticeably taller than others in 2019. The bench at e28 was water-logged, which had the dual effect of boosting the growth of mudflat plants, and of being avoided by herbivores. Plants here were so tall that the quadrat had to be marked out using yellow flagging tape instead of pegs (Figure 10).

Woody species were noted only twice in bench quadrats, and these were seedlings of *Acacia* species. In previous years, juveniles of introduced shrubs such as hawthorn *Crataegus monogyna*, Sweet Briar *Rosa rubiginosa* and Blackberry *Rubus fructicosus* have been recorded in bench quadrats, but not in spring 2020.

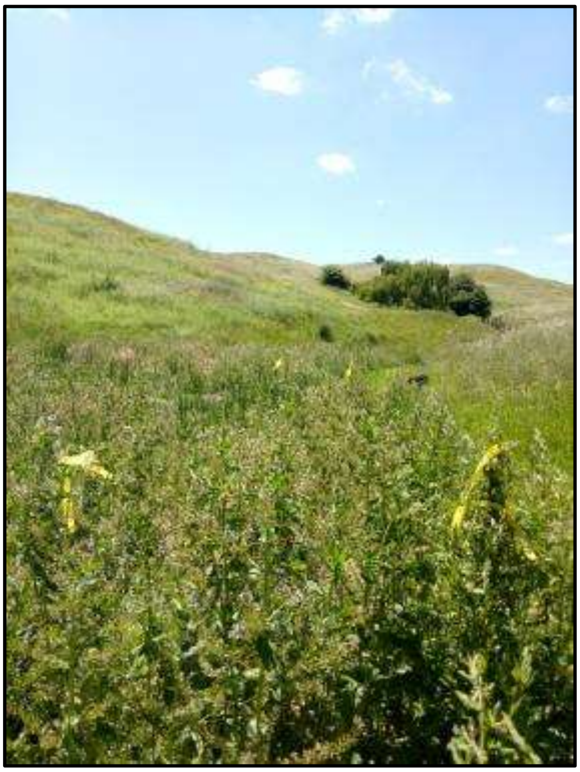


Figure 10: Flagging tape marks out the quadrat at Site e28 where plants are nearly one metre tall

Bench Condition

METHOD

Extent and severity of grazing and of physical damage (such as pugging, slumping and erosion) to soil surface or bank are noted at each site, and subsequently categorised as ***none***, ***little***, ***some*** or ***lots***. Each site is then positioned on the impact gradient, colour-coded from light (= ***none***) to dark (= ***lots***). The impact gradient used here is an updated version of the impact gradient used and presented in last year's report (Roberts and Sharp 2020).

RESULTS

The intensity of grazing and of physical damage varied along Stream E (Table 5). At three sites, there was no sign of grazing or of physical damage to the benches (rc2, e26, e28): these are all in the lower sections of Stream E. Conversely, two sites were quite impacted, with light grazing and considerable physical damage (e04, e09): both these are in the mid to upper part of Stream E. Livestock have their preferred places to cross Stream E, including at e04 and e09. As long as they continue to cross at these sites, these sites will continue to show grazing and physical damage.

Benches and bench vegetation were in better condition than in 2019 (Table 5). In 2020, most benches were positioned towards the lower (left) end of the impact gradient, whereas in spring 2019 they were distributed across the gradient and three benches were severely affected by grazing and physical damage.

Table 5: Bench condition arranged as an impact gradient.

Grazing	**none**	**none**	**little**	**some**	**some**	**little**	**lots**
Pugging	**none**	**little**	**little**	**none**	**some**	**lots**	**lots**
Spring 2020	3 sites rc2, e26, e28	2 sites e19, e32	3 sites e01, e07, e13			2 sites e04, e09	
Spring 2019	2 sites rc1, rc2		1 site e07	3 sites e13, e26, e32	2 sites e09, e19		3 sites e01, e04, e28

Dominant species

METHOD

The species that dominate (ie that are visually most abundant) in the bench quadrat are recorded. Dominant may mean from one to five species per quadrat, as suits.

RESULTS

Fourteen species were noted as dominant in spring 2020 (Table 6); nearly all were introduced species (13) and just under half (6) were grasses. The two species most frequently recorded as a dominant are both grasses: kikuyu *Cenchrus clandestinus* and ryegrasses *Lolium* spp. Eight of these 14 species were 'new' as dominants in 2020, (although would have been present in previous years): this included three clovers (*Trifolium arvense, T. campestre*, and *T. subterraneum*), and three mudflat species (*Paspalum distichum*, *Nasturtium officinale*, and *Veronica anagallis-aquatica*). This shift in dominant species is probably driven by growing conditions being warmer and wetter in 2020.

Table 6: Species Dominant on benches

Key: Occurrence = number of benches where a species was noted as dominant (max = 11).

For Origin: X = introduced to Australia, For Life-span: A = annual or short-lived, P = perennial.

Dominant Species	Common name	Occurrence in 2020	Occurrence in 2019	Origin	Life Span	
Avena spp	Wild Oats		**2**	X	A	Grass
Bothriochloa macra	Red Leg Grass		**1**	Native	P	Grass
Bromus diandrus	Great Brome		**1**	X	A	Grass
Bromus hordeaceus	Soft Brome	**2**	**1**	X	A	Grass
Carthamus lanatus	Saffron Thistle	**1**		X	A	
Cenchrus clandestinus	Kikuyu	**7**	**10**	X	P	Grass
Eragrostis curvula	African Lovegrass		**1**	X	P	Grass
Holcus lanatus	Yorkshire Fog	**3**	**2**	X	P	Grass
Lolium spp	Ryegrasses	**4**	**8**	X	A & P	Grass
Paspalum distichum	Water Couch	**1**		X	P	Grass
Nasturtium officinale	Water Cress	**1**		X	P	
Themeda triandra	Kangaroo Grass	**1**		Native	P	Grass
Trifolium arvense	Hare's Foot Clover	**1**		X	A	
Trifolium campestre	Hop Clover	**1**		X	A	
Trifolium repens	White Clover	**2**		X	P	
Trifolium subterraneum	Subterraneum Clover	**1**	**1**	X	A	
Veronica anagallis-aquatica	Blue Water Speedwell	**1**		X	P	
Vulpia spp	fescues	**1**	**1**	X	A	Grass
Number of Dominants =		**14 species**	**10 species**			

Compared with spring 2019, more forbs and fewer grasses were dominant in 2020 (Table 6). This was the first year that thistles were dominant at any site (Site e32). The list of dominants includes three mudflat species (*Paspalum distichum*, *Nasturtium officinale*, *Veronica anagallis aquatica*). As in 2019, there is one native grass species dominant, but in 2020 it is *Themeda triandra* instead of *Bothriochloa macra* as in 2019. The pest species African Love grass *Eragrostis curvula* is no longer a dominant species.

3.2: Indicators

Bare Ground

METHOD

Percentage cover of perennials, annuals, shrubs, litter (loose dead material not attached to a plant, bare ground and rocks is recorded in each 5 x 1 m bench quadrat. Quadrats are set out to correspond to their position in previous years, using laminated photographs as a guide.

Site e04 is a special case. It was severely trampled sometime between benchmarking in spring 2018 and the first repeat survey in spring 2019. Damage was so severe that part of the bench effectively became part of the mudflat in the pool, leaving the other part still elevated. At this site, cover is recorded for both the lower and upper part of the quadrat, but only the upper part is relevant and used as an indicator.

Bare ground means unvegetated soil with no plants growing.

RESULTS

Bare ground averaged 5.3% of bench quadrats (s.d. =7.3): this is lower than in 2019 (10.4%), but is not statistically different. Bench bare ground was highest, 19.4% and 15.0%, at sites e04 and e01, which are the two most upstream sites (Figure 11). Four benches were fully vegetated with no bare ground (sites e13, e26, e28 and rc2), and two benches had very low amounts of bare ground, only 0.5% (sites e07 and e32).

Considered individually, the benches showed a variable response from 2019 to 2020 (Figure 11). Bare ground decreased at 3 sites (rc2, e28, e32); increased at 3 sites (e01, e09, e19) and at the remaining 4 sites was either similar or unchanged.

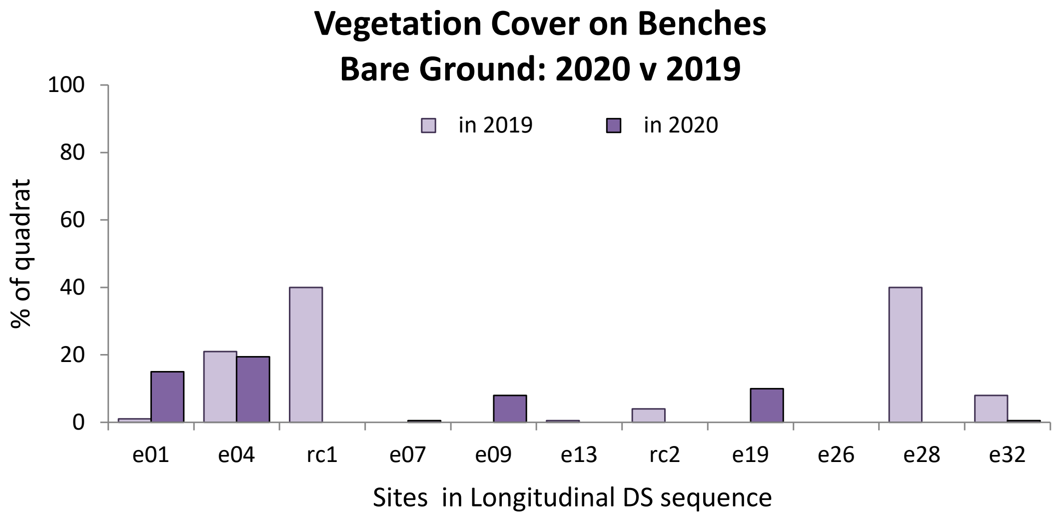


Figure 11: Bare ground (%) per bench quadrat in spring 2020 and spring 2019.
Note: there is no data for Site rc1 in 2020

Annuals

METHOD

The cover of annuals (meaning annuals and short-lived species) is recorded in each 5 x 1 m bench quadrat as described for Bare Ground.

RESULTS

Annual cover averaged 31.6% of bench quadrats (s.d. = 24.6) in spring 2020. This was more than double what annual cover had been in spring 2019 (mean = 12.8%) but was only marginally significant. Annual cover was quite variable, ranging from 5% or less (benches at e04 and e28) to just over 60% (at e01 and e26) (Figure 10).

This increase in annual cover was evident at most benches (7 out of 10), suggesting a near system-wide change; two benches showed no real change; a decrease was evident at only one site (e09), and this was fairly small, from 12% in 2019 down to 10%. Two benches had big increases in annual cover (60% and 59% at sites e01 and e26) and two had moderately large increases (41.5% and 33% at e32 and e13) (Figure 12).

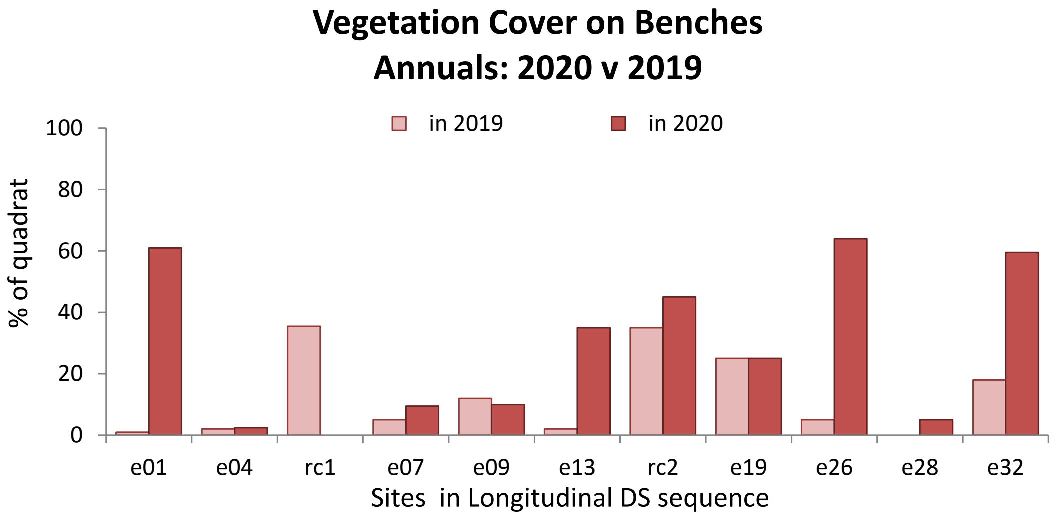


Figure 12: Annuals cover (%) per bench quadrat in spring 2020 and spring 2019
Note: there is no data for Site rc1 in 2020

Nativeness of Forbs

METHOD

Nativeness is the percentage of forb species in the bench quadrat that is native; and the percentage of forb cover that is native. For this, the bench quadrat is scrutinised: all species of forbs present and their %cover recorded. Species that cover less than 1% of the 5x1 m quadrat are recorded as 0.05%.

In the Baseline Survey of spring 2018 and repeat survey of spring 2019, nativeness was for forbs and shrubs combined. As explained above (Section 1.3), the Nativeness indicator is now revised to be only forbs.

RESULTS

A total of 50 forb species were recorded in spring 2020, of which half (26) were short-lived species, and only 10 were native species. The total number is considerably higher than in 2019, when 33 species were recorded. The most frequently occurring species were: *Trifolium repens* (in 8 quadrats): *Hypochaeris radicata*, *Plantago lanceolata, Trifolium campestre* and *Trifolium subterraneum* (each in 6 quadrats); and *Centaurium erythraea, Rumex crispus, Trifolium angustifolium* and *Juncus bufonius* (each in 5 quadrats). All these are introduced species: most were the most frequent species in other years.

Nativeness of forb species averaged 11.2% (s.d. = 9.0%) per quadrat, which was not significantly different from 8.1% in spring 2019. At three sites, the benches (e04, e07 and e09) had no native species at all. This was well down from spring 2019 when there were 7 sites with no native species. Only about half the sites (5 out of 11) showed an increase in nativeness (Figure 13).

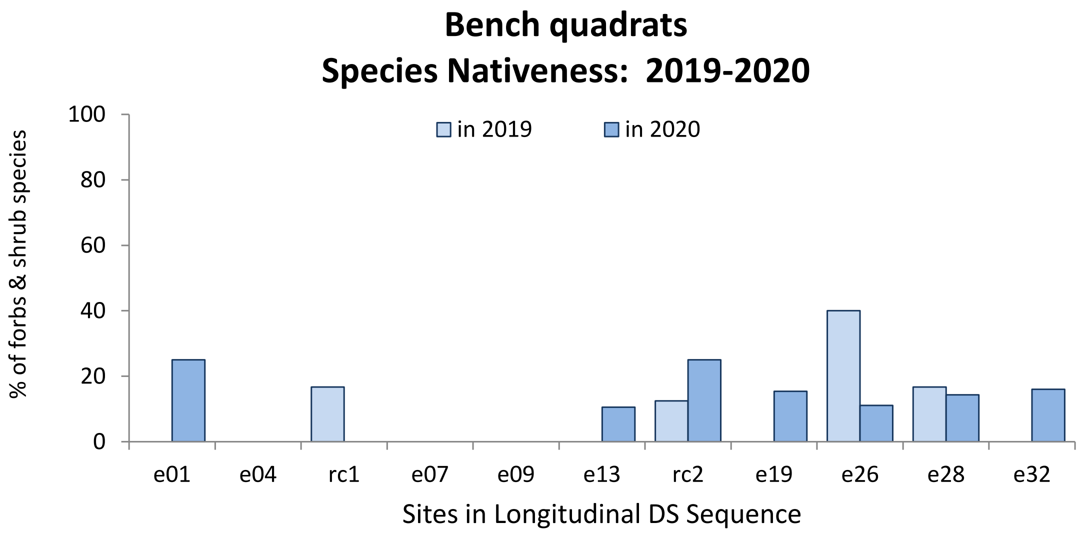


Figure 13: Nativeness of Forbs Species on each bench along Stream E in 2020 and 2019
Note: no data for Site rc1 in 2021

Cover nativeness averaged 5.1% (s.d. = 5.8) per quadrat, which is very low, however it has always been low. There is no statistical difference between cover nativeness in 2020 and 2019 (8.2%). Cover nativeness is low at all sites (Figure 14), showing this is a general not localised characteristic. The two sites where it was highest, rc2 and e26, were also highest in 2019.

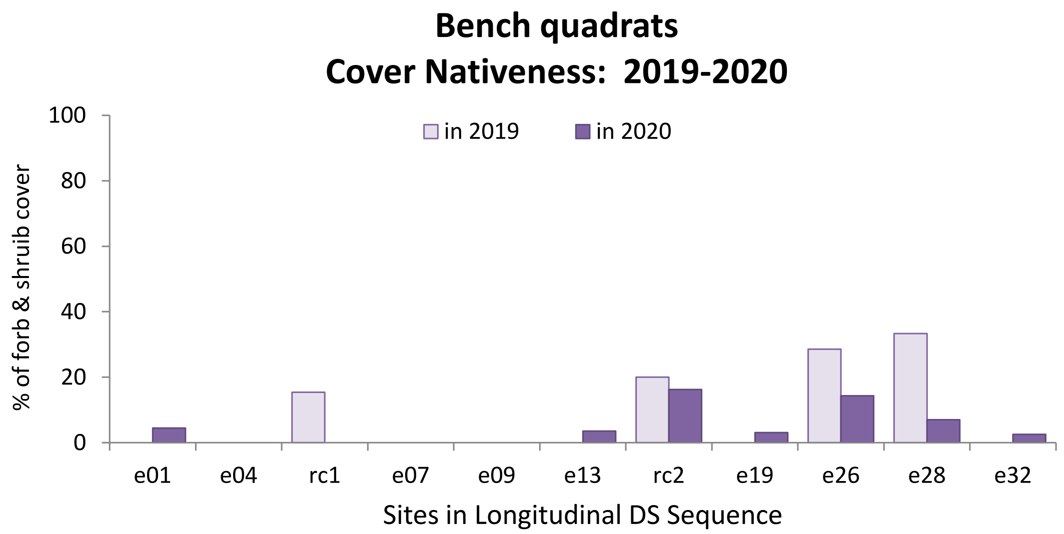


Figure 14: Nativeness of Forbs Cover on each bench along Stream E in 2020 and 2019
Note: no data for Site rc1 in 2021

Grasses

METHOD

The extent of grasses per quadrat is calculated from other data, not estimated directly.
Grass cover = (Annuals + Perennials + Shrubs cover) *minus* (Forbs cover).

Note that Grasses cover for 2019 has been re-worked.

RESULTS

Grass cover in spring 2020 averaged 55.6% (s.d. = 33.49) per quadrat and was highly variable ranging from 0% at e28 to 97.5% at e07 (Figure 15). This is not significantly different from spring 2019, when it averaged 77.1%. Grass cover decreased at most sites (7 out of 10), increased marginally at two sites (e04 and e07) and was unchanged at one site (e26) (Figure 12). At two sites (rc2 and e32), grass cover dropped by 60%.

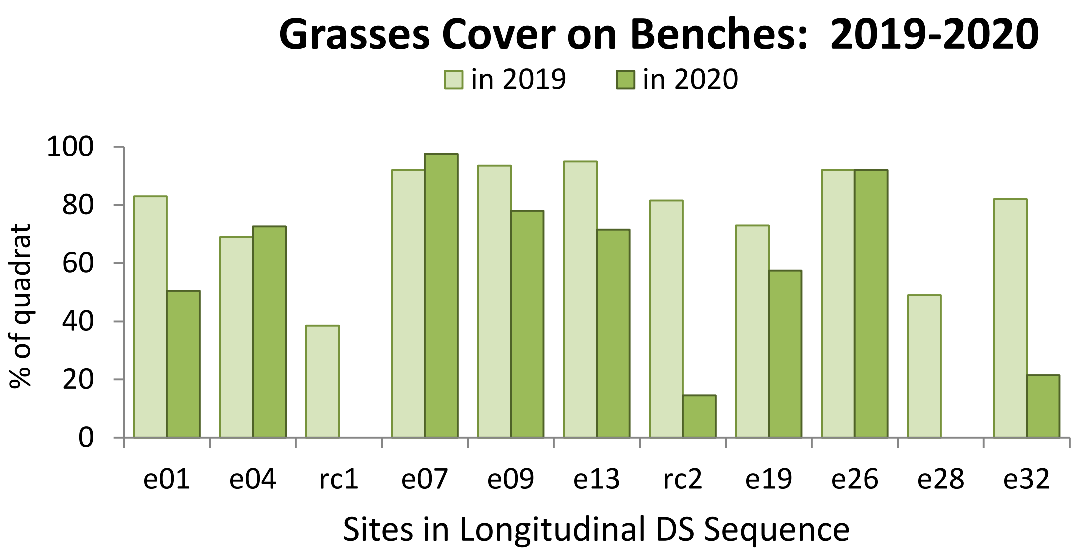


Figure 15: Grass cover (%) per bench quadrat in spring 2020 and spring 2019.
Note: there is no data for Site rc1 in 2020

3.3: Summary for Benches

METHOD

As with Pools, bench indicators are used to determine if there has been any change, and if so, then in what direction (increase, or decrease, and then the observed change can be interpreted.

RESULTS

Changes in the bench indicators are summarised below (Table 7). This includes a break-down into individual sites, and their pattern. This breakdown is observational, and is not a definitive test.

Table 7: Bench Indicators: Summary

Indicator	Change / Trend from 2019 to 2020
Bare ground (mean %)	Mean cover per quadrat = 5.3% (2020) and 10.4% (2019). Low in both years. No significant difference between 2020 and 2019, so no change detected. Individual sites: four had no bare ground in 2020 (e13, rc2, e26, e28) compared with four in 2019 (e07, e09, e19, e26). Same pattern in 2020 and 2019., but differing sites
Annuals (mean %)	Mean cover per quadrat = 31.6 % (2020) and 12.8 % (2019). More than doubled from 2019 to 2020, with 2020 being significantly different from in 2019, making this a significant increase Individual sites: Five sites had more than 30% annual cover in 2020 (e01, e13, rc2, e26, e32) compared with only 2 sites in 2019 (rc1 and rc2). Pattern suggests a general increase.
Grasses (mean %)	Mean cover per quadrat = 55.6% (2020) and 77.1% (2019). No significant difference between 2020 and 2019, so no change detected. Individual sites: Five sites had more than 70% grass cover in 2020 (e04, e07, e09, e13, e26) compared with eight in 2019 (e01, e07, e09, e13, rc2,e19, e26, e32) Pattern suggests a widespread decrease.
Nativeness of forb species (mean %)	Mean % of forb species that are native per quadrat = 15.2% (2020) and 8.1% (2019) Low in both years. No significant difference between 2020 and 2019: No change detected. Individual sites: three sites had no native forb species in 2020 (e04, e07, e09) compared with seven sites in 2019 (e01, e04, e07, e09, e13, e19, e32). Pattern suggests a widespread decrease in 'zero' native species.
Nativeness of forb cover (mean %)	Mean % cover of forbs that is native per quadrat = 9.3% (2020) and 9.1% (2019) Low in both years No significant difference between 2020 and 2019: No change detected. Individual sites: three sites had more than 10% forb cover being native in 2020 (e04, e07, e32) compared with four sites in 2019 (rc1, rc2, e26, e28). Pattern suggests a decrease and shift in some sites.

Bare ground: Mean area of bare ground was lower in 2020 than it had been in 2019, but not statistically different, meaning no detectable change in this indicator. Values for bare ground are low, showing that the benches are generally well-vegetated, regardless of seasonal conditions.

Annuals: Mean cover of annuals more than doubled from 2019 to 2020, from 12.8% to 31.6%, but was only marginally statistically significant. This large increase in cover of annuals is attributed to seasonal conditions in 2020, which were moister and warmer than in 2019.

Grasses: Mean grass cover per quadrat was lower in 2020 than in 2019, being 55.6% compared with 77.1%. Despite the large difference of 21.5%, there was no significant difference between the two years, an outcome attributable to the very diverse values, ranging from 0% to 97.5%.

Nativeness of forb species: Nativeness of forb species was low, averaging 15.2% but not statistically different from 2019 when it averaged 8.1%, which is also low.

Nativeness of forb cover: The nativeness of forb cover was also low, averaging 9.3% and similar to 2019, when it averaged 9.1%.

Section 4

4.1: Evaluation against targets

Seven targets (coded A to G) were proposed in the Baseline Survey (Section 5.4 in Roberts and Sharp 2019): four for pools, and three for benches. Two of the targets for pools are for specific types of pools. These seven targets cover a number of processes likely to result from a 'wetter' or higher flow regime and altered water quality: sediment deposition and pool in-filling; erosion; expansion of competitive species of tall emergent macrophytes; loss of habitat diversity; bench water-logging; loss of in-stream plant diversity (ie the sensitive submerged macrophytes). If all these eventuate, this will result in a radical change in the ecological character of Stream E, along with a very real risk of periodic bank erosion should tall emergent macrophytes expand to occupy an entire pool. The targets give feedback on trajectory of Stream E.

Evaluation against targets is summarised below for pool indicators (Table 7), and further below for bench indicators (Table 8).

Pools: Stream E meets three of the four targets for pools. This is an improvement on 2019 when only two pool targets were met (B and C). The improvement is driven by the dramatic reduction in sediment depth from 2019 to 2020 evident in all ten pools (Figure 8) which means the four boulder-step (BS) pools no longer fail Target A.

Stream E continues to fail Target D about the occurrence of submerged macrophytes. The gap between actual and target is the same in 2020 as in 2019, with occurrence being only 3 pools though not the same three pools: pools e26, e28 and e32 (all at the bottom of Stream E) in 2020 but pools e09, e19 and e26 in 2019. In spring 2020, the only species of submerged macrophyte present was *Potamogeton crispus*, a relatively robust species: the area and occurrence of the two sensitive species, *Chara* and *Nitella*, have declined since 2018, the benchmark year (Table C2, Appendix C).

To date, none of the three emergent macrophytes has expanded to occupy a whole pool (Target C). One pool, e19, is nearly completely occupied by *Phragmites* but does not appear to be expanding. More telling, however, is that in most pools, the area of emergent macrophytes is little different in 2020 from what it was in 2018. Scrutinising the area data for individual pools and individual species reveals there are just three instances of net increase from 2018 to 2020: *Phragmites* in pool e26 (from 4.5 to 7.75 m^2), *Phragmites* in pool e28 (from 0.5 to 3.35 m^2), and *Schoenoplectus* in pool e04 (from 0.2 to 2.41 m^2).

Table 7: Evaluation of 2020 findings against targets: Pools

Target	Evaluation
A: Sediment depth in boulder-step (BS) pools does not exceed 10% of total depth *There are 4 BS pools* *Information Source Table C3*	For 2020: no BS pool fails None of the four BS pools has sediment that is more than 10% of total depth when measured at the deepest point. For 2019: FAIL for all four BS pools For 2018: FAIL for one BS pool (e26)
B: Sediment depth in Downstream-Control Pools (DSC) and in No	For 2020: no DSC or NOC pool fails None of the two DSC pools and none of the three NOC pools has

Target	Evaluation
Obvious Control (NOC) pools does not exceed 80% of total depth *There are 2 DSC pools and 3 NOC pools* *Information Source Table C3*	sediment that is more than 80% of total depth at the deepest point. For 2019: no DSC and no NOC pool failed For 2018: no DSC and no NOC pool failed
C: Area of emergent macrophytes does not expand to occupy the whole pool *Information Source: Reference photos*	For 2020: no pool fails. None of the ten pools is completely covered by tall emergent macrophytes) For 2019: no pool failed For 2018: no pool failed
D: Submerged macrophytes continue to be present at 7 out of 10 pools *Information Source Table C2*	For 2020: FAIL Submerged macrophytes are present in only 3 out of 10 For 2019: FAIL For 2018: no fail

Benches: Stream E meets only one of the three bench targets (Table 8), Target G to do with shrub cover, and fails two targets (Target E for perennial cover; and Target F for grass cover). This is the same as in 2019.

Target G is intended as an early alert to land managers that prickly sprawling exotic species (Sweet Briar *Rosa rubiginosa*, Blackberry *Rubus fructicosus*, and Hawthorn *Crataegus monogyna*) may be expanding. To date however, there is no evidence that any of these species is expanding or even persisting. All three species were recorded in trace amounts in 2018 and 2019, then were not recorded at all in spring 2020. Instead, in a welcome shift, in 2020 there were trace amounts of native species, *Acacia rubida* and *Acacia* sp, which are treated here as shrubs. This is the first evidence of native woody regeneration, and may be due to the unusual seasonal conditions.

Ostensibly the 2020 outcome (fail for Target E and Target F) is the same as in 2019, however there does seem to be an intensification of the 'fail' as the gap between target and actual condition is now wider. In 2020, six benches failed Target E compared with three in 2019; and five benches failed Target F compared with three in 2019. It is likely that the drop in grass and perennial cover is due to the abundant annuals and short-lived species, for example by over-topping them.

Table 8: Evaluation of 2020 findings against targets: Benches

Target	Evaluation
E: Perennial cover on benches does not fall below 70% *Information Source Table C5*	For 2020: six benches fail Perennial cover was less than 70% in e01 (12.0%), in e13 (65.0%), rc2 (25.0%), e19 (65.0%), and e32 (40.0%). For 2019: three benches fail For 2018: two benches fail

Target	Evaluation
F: Grass cover on benches does not fall below 70% *Information Source C5*	For 2020: five benches fail Grasses cover was less than 70% in e01 (50.5%), rc2 (14.5%), e19 (57.5%), e28 (0%), and e32 (21.5) For 2019: three benches fail For 2018: five benches fail
G: Shrub cover on benches does not exceed 5% *Information Source Table C5*	For 2020: no bench failed Shrub cover ranged from 0 to 0.5% on the eleven benches. For 2019: no benches fail For 2018: no benches fail

4.2: A 3-year perspective

A short-term perspective on changes in Stream E was given above when indicator values for the current year were compared with the previous year (Tables 4 and 7, in Sections 2.3 and 3.3). Here there is a slightly longer perspective on changes in Stream E, and three years are compared (Benchmark 2018, 2019 and 2020). The outcomes of this comparison for pool and bench indicators A to G are shown below (Table 9). Methods are given in Section 1.3.

Two things are immediately apparent. First, all pool indicators and some bench indicators have fluctuated over this 3-year period, either rising then falling or vice versa. Despite these considerable fluctuations, only a very few indicators actually changed from one year to the next. These were: Water depth increased from 2019 to 2020; Sediment depth increased from 2018 to 2019, then decreased from 2019 to 2020; Annuals may have increased from 2019 to 2020.

Second, indicator values for 2020 are statistically indistinguishable from Benchmark values in 2018: cells in the right-hand column (2018 v 2020) are all NS.

Table 9: A three year overview

Indicator	Mean (s.d) Values			Comparison between years		
	Bench-Mark 2018	2019	2020	2018 v 2019	2019 v 2020	2018 v 2020
Tall Emergent macrophytes area: in m^2	**4.2** (5.9)	**2.8** (5.5)	**3.6** (3.7)	NS	NS	NS
Submerged macrophytes area: in m^2	**4.5** (7.5)	**1.2** (3.6)	**3.3** (6.5)	NS	NS	NS
Water depth in cm	**47.5** (33.1)	**29.7** (19.5)	**64.0** (22.3)	NS	*	NS
Sediment depth in cm	**11.1** (11.0)	**30.9** (9.2)	**3.3** (4.8)	***	***	NS

Indicator	Mean (s.d) Values			Comparison between years		
	Bench-Mark 2018	2019	2020	2018 v 2019	2019 v 2020	2018 v 2020
Bare Ground **cover, as % of quadrat**	**11.2** (15.8)	**10.4** (15.9)	**5.3** (7.3)	NS	NS	NS
Annual **cover, as % of quadrat**	**21.1** (14.8)	**12.8** (13.6)	**31.6** (24.6)	NS	marginal	NS
Grasses **cover, as % of quadrat**	**70.0** (27.2)	**77.1** (18.6)	**55.6** (33.5)	NS	NS	NS
Forbs Species Nativeness **number as % of quadrat**	**12.9** (12.7)	**8.1** (13.1)	**11.2** (9.0)	NS	NS	NS
Forbs Cover Nativeness **cover, as % of quadrat**	**11.7** (17.3)	**9.1** (13.2)	**5.0** (5.7)	NS	NS	NS

4.3: Conclusions

Both the evaluation against pre-determined targets (Tables 7 and 8) and the 3-year comparison (Table 9) show there is very little evidence of Stream E changing; and that the few changes that have occurred (water depth, sediment depth) have self-corrected. At one level, this is a 'good news' story, along with other positive findings and observations (such as the slight evidence of native tree regeneration). At another level, it is clear that the lack of significant changes is driven by highly variable values for indicators. For example, grass cover in 2020 ranged from 0% at bench e28 to 97.5% at bench e07.

The exploration into bench floristics (Appendix D) found no single factor was driving similarities and differences in species composition: for some benches it was site, for others it was environmental factors (the year of being sampled), and for others it was a mix of these. It is likely this applies also to pools. Hence having targets related to pool types (such as Targets A and B, Table 7) is a sensible strategy.

For Stream E, variability is a given, and likely to continue being a characteristic, at least in the near future. With this comes another realisation; that comparing mean values of indicators will tend to return conservative answers, because of being insensitive to small changes.

References

Roberts J and Sharp S (2020). *Pool and bench vegetation of Stream E, Ginninderry, ACT. Monitoring results: Spring 2019.* Report Number JR 40/2020, Canberra ACT 2602.

Roberts J and Sharp S (2019). *Pool and bench vegetation of Stream E, Ginninderry, ACT. Baseline in Spring 2018.* Report prepared for Riverview, ACT. Report Number JR 39/2020, Canberra ACT 2602.

Sainty GR and Jacobs SWL (2003). *Waterplants in Australia*. Sainty and Associates Pty Ltd, Potts Point, Sydney.

Appendix A: Reference photos of pools in November2020

Pool e01 looking DOWNstream: 7 November 2020

Pool e01 looking UPstream: 7 November 2020

Pool e04 looking DOWNstream: 7 November 2020

Pool e04 looking UPstream: 7 November 2020

Pool e07 looking DOWNstream: 7 November 2020

Pool e07 looking UPstream: 7 November 2020

Pool e09 looking DOWNstream: 7 November 2020

Pool e09 looking UPstream: 7 November 2020

Pool e13 looking DOWNstream: 7 November 2020

Pool e13 looking UPstream: 7 November 2020

Pool e19 looking DOWNstream: 9 November 2020

Pool e19 looking UPstream: 9 November 2020

Pool e26 looking DOWNstream: 9 November 2020

Pool e26 looking UPstream: 9 November 2020

Pool e28 looking DOWNstream: 9 November 2020

Pool e28 looking UPstream: 9 November 2020

Pool e32 looking DOWNstream: 9 November 2020

Pool e32 looking UPstream: 9 November 2020

Appendix B: Selected comparisons 2020 v 2019

e07 looking DOWNstream

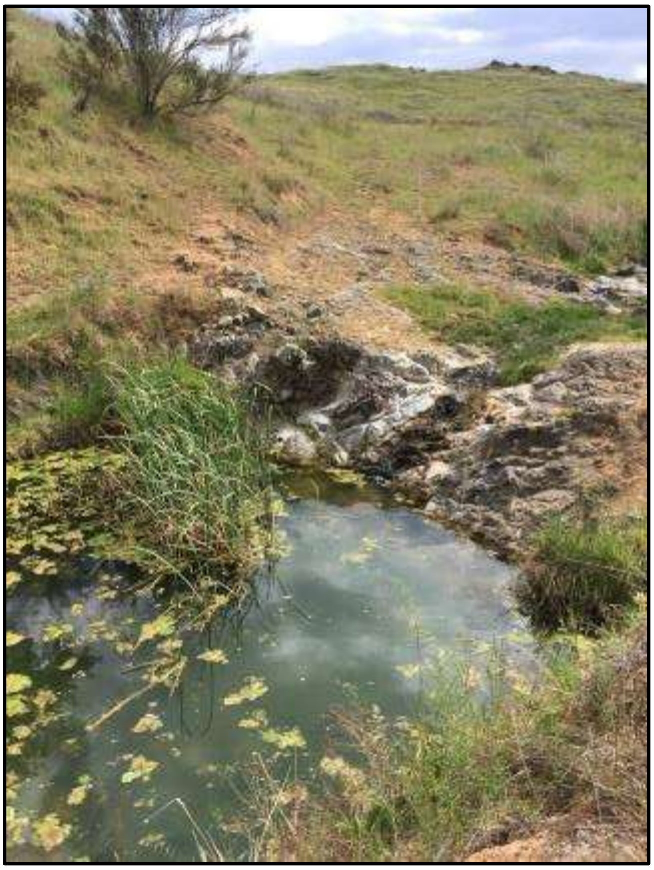
Site e07 on 7 November 2020 (left) and 21 October 2019 (right)

Water level is higher up boulder in 2020 and looks approx 10-15 cm lower in 2019

Stream E flowing strongly over boulder step in 2020 and barely trickling in 2019

Water is sediment rich, reddish-orange in colour in 2020, and clear with algal growths in 2019

e13 looking UPstream

Site e13 on 7 November 2020 (left) and 25 October 2019 (right)

Stream is flowing, forming a waterfall in 2020 but not in 2019

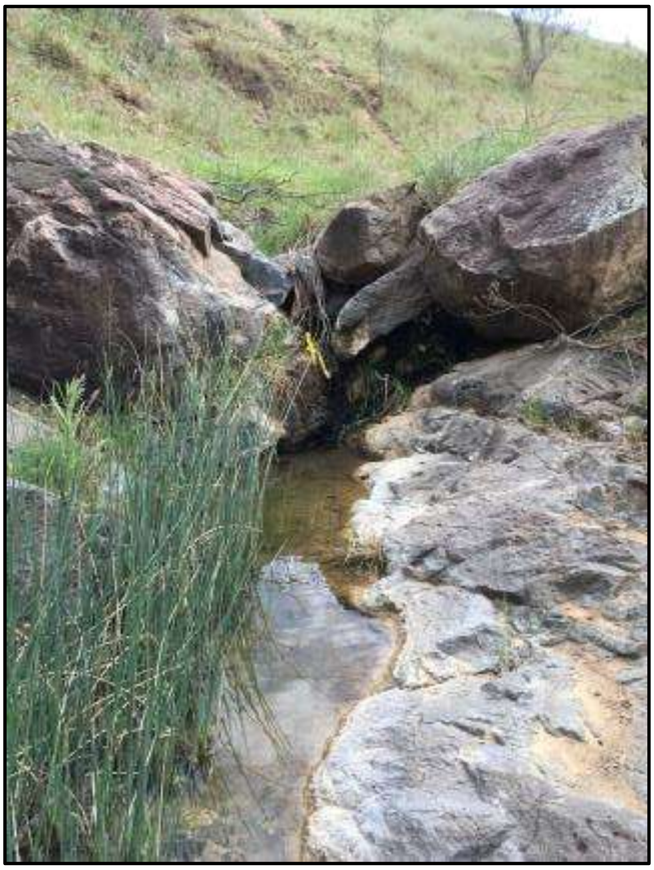
Upstream of waterfall is a pool in 2020 but only ground cover in 2019

Water is very turbid and orange-red in 2020 but is clear with algal scuds in 2019

Typha is tall near full height forming a medium-sized patch in 2020 but is shorter and smaller patch in 2019

Vegetation on adjacent hillside and foreground is taller, and denser with almost no bare ground showing in 2020, and much shorter, sparser and with more bare ground evident in 2019

rc2 looking UPstream



Rc2 on 7 Nov 2020 (left) & 25 Oct 2019 (right)

High energy & fast flows in 2020, barely a trickle in 2019

Water levels higher up covering rocks in 2020, and rocks exposed in 2019

Turbid water in 2020, clear and still in 2019

Traces of *Schoenoplectus* in 2020, band of *Schoenoplectus* lining the pool in 2019

e28 looking UPstream

Site e28 on 9 November 2020 (left) and on 23rd October 2019

Ground cover on adjacent hillside is lush and tall in 2020 and obscuring hillside rocks: and is short and some still senescent in 2019

Water quality is turbid in 2020, but clear and with algal scuds in 2019

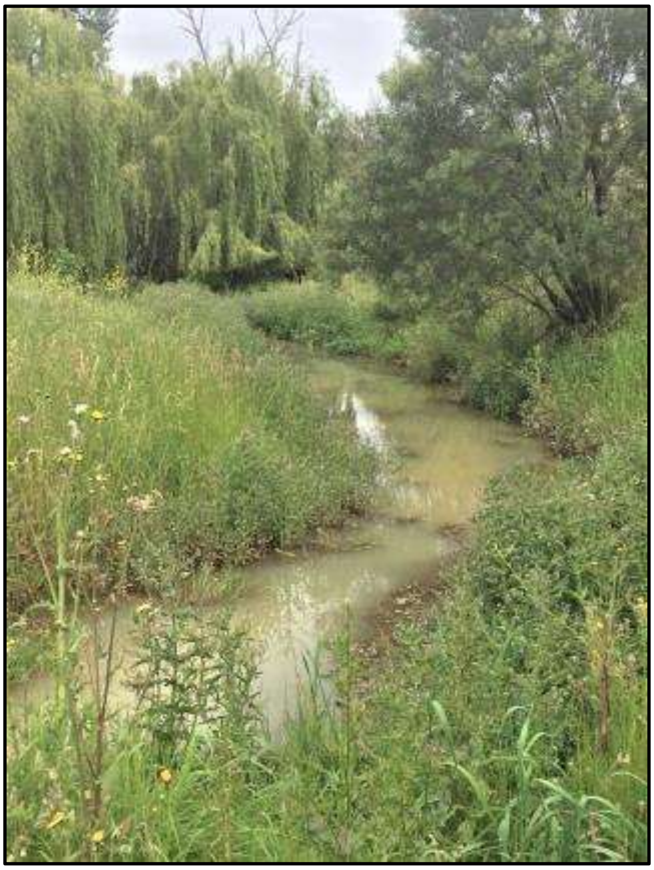
No evidence of recent pugging or trampling in 2020 but pool edges extensively pugged in 2019

Early growth of tall emergent macrophytes (Typha) in 2020 near centre of channel, but no tall emergent evident in 2019

Mud flat forbs forming large cushions and extending into stream channel in 2020 but present as patches and trampled in 2019

Submerged macrophyte *Potamogeton crispus* is abundant and dense in pool in 2020, but completely absent in 2019.

e32 looking DOWNstream



Site e32 on 9 November in 2020 (left) and 23 October in 2019 (right)

Water quality is slightly turbid in 2020 but clear with extensive algal scuds in 2019

Bench vegetation is tall in 2020 but short with boulders evident in 2019

No sign of pugging in 2020 but pugging is extensive in 2019

Appendix C: Summary 2018 to 2020

Table C1: Species of tall emergent macrophytes: abundance and occurrence

		Phragmites	*Schoenoplectus*	*Typha*
Species Area (m^2) Mean (s.d.) per pool	**2020**	2.5 (3.93)	0.4 (0.76)	0.8 (2.01)
	2019	2.1 (5.67)	0.5 (0.98)	0.2 (0.66)
	2018	2.8 (6.23)	0.7 (1.04)	0.8 (1.68)
Number of pools where present	**2020**	5	6	5
	2019	3	4	3
	2018	4	7	4

Table C2: Species of submerged macrophytes: abundance and occurrence

		Chara	*Nitella*	*Potamogeton*
Species Area (m^2) Mean (s.d.) per pool	**2020**	0	0	3.3 (6.45)
	2019	0.002 (0.003)	0.001 (0.003)	1.2 (3.60)
	2018	1.3 (1.58)	0.012 (0.04)	3.4 (7.57)
Number of pools where present	**2020**	0	0	3
	2019	2	1	1
	2018	6	1	4

Table C3: Sediment depths as % of total depth at deepest point for different pool types

Pool Type	**DSC downstream control**		**BS Boulder Step**		**RP Rock pool**		**NOC no obvious control**	
2020	e01 e04	4.5% 3.6%	e07 e09 e13 e26	0.3% 2.8% 4.2% 4.9%	rc2	1.1%	e19 e28 e32	1.7% 1.6% 27.4%
2019	e01 e04	62.7% 68.3 %	e07 e09 e13 e26	45.8 % 39.5 % 40.0 % 54.0 %	rc2	36.2 %	e19 e28 e32	69.3 % 63.0 % 62.9 %
2018	e01 e04	31.3 % 73.3 %	e07 e09 e13 e26	0 % 0.6 % 3.0 % 20.0 %	rc2	0 %	e19 e28 e32	25.0 % 60.0 % 43.1 %

Table C4: Dominant bench species and their occurrence as dominants per year

Species	2018	2019	2020	Family
Avena sp	2	3	0	Poaceae
Bothriochloa macra	1	1	0	Poaceae
Briza minor	2	0	0	Poaceae
Bromus diandrus	1	1	0	Poaceae
Bromus hordeaceus	6	1	2	Poaceae
Carthamnus lanatus	0	0	1	Asteraceae
Cenchrus clandestinus	6	10	7	Poaceae
Eragrostis curvula	1	1	0	Poaceae
Holcus lanatus	6	2	3	Poaceae
Juncus articulatus	1	0	0	Juncaceae
Lolium spp	7	8	4	Poaceae
Paspalum dilatatum	1	0	0	Poaceae
Paspalum distichum	0	0	1	Poaceae
Rorippa nasturtium-aquaticum	0	0	1	Brassicaceae
Themeda triandra	0	0	1	Poaceae
Trifolium arvense	0	0	1	Fabaceae
Trifolium repens	0	0	2	Fabaceae
Trifolium spp	1	1	2	Fabaceae
Veronica anagallis-aquatica	0	0	1	Plantaginaceae
Vulpia spp	2	1	1	Poaceae

Table C5: Cover of perennials, grasses and shrubs as % of bench quadrat

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Perennials in 2020	12.0	78.2		90.0	81.0	65.0	25.0	65.0	35.0	95.0	40.0
Perennials in 2019	87.5	76.0	9.0	94.5	85.5	97.0	58.0	73.0	90.5	55.0	72.5
Perennials in 2018	44.0	40.0	18.5	80.0	59.5	55.0	34.0	82.0	94.5	85.0	84.5
	e01	**e04**	**rc1**	**e07**	**e09**	**e13**	**rc2**	**e19**	**e26**	**e28**	**e32**
Grasses in 2020	50.5	72.6		97.5	78.0	71.5	14.5	57.5	92.0	0.0	21.5
Grasses in 2019	83.0	69.0	38.5	92.0	93.5	95.0	81.5	73.0	92.0	49.0	82.0
Grasses in 2018	63	46.5	56.0	98.0	91.5	93.5	59.0	79	90.5	7.5	86.0
	e01	**e04**	**rc1**	**e07**	**e09**	**e13**	**rc2**	**e19**	**e26**	**e28**	**e32**
Shrubs in 2020	0.0	0.0		0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5
Shrubs in 2019	0	0	1	0	0	0	0	0	0	0	0
Shrubs in 2018	1	0	0.5	0	0.5	0	1	0	0	0	0

Appendix D: Bench Floristics

Context

As part of Stream E vegetation monitoring program, forbs and shrubs on benches are recorded in spring of each year in a 5 x 1 m quadrat. Quadrats are positioned on each bench as best corresponds to reference photos. Reference photos are used because geo-co-ordinates derived from a hand-held GPS generally have a +/- 5 m error margin, so do not have the spatial precision needed. Benches are small geomorphic features, not much bigger than the quadrat, so the monitoring is effectively a repeated measures exercise. In terms of their vegetation, benches are assumed to be homogeneous for grasses (the dominant species) with forbs randomly scattered through.

Forbs and shrubs are identified to species, and species abundance is recorded as cover. The cover of individual forb and shrub species is typically small to tiny: some are about 2% of the quadrat but most are usually recorded as 0.5%. For pragmatic reasons, species with cover less than 1% of the 5 x 1 m quadrat (ie less than 500 cm^2) are treated as 'trace' and assigned a value of 0.5%.

Spring 2020 was the third year of monitoring the benches, and this meant there was now a small data set on bench floristics comprising three consecutive years of abundance from eleven bench sites. In practice, there are 32 samples in the data set rather than 33 as one bench (rc1) was not re-sampled in spring 2020. The data set is just large enough to do some analyses, exploring the spatial and temporal patterns in bench floristics. A particular point of interest was understanding whether floristic composition was determined by site characteristics or by seasonal conditions. This question was triggered by field observations in November 2020 that vegetation of pools and benches appeared rather different from previous years.

Analysis

Two analyses were done using the package PRIMER 7 (copyright Quest Research Limited). The first analysis, an analysis of factors, tests the assumption that variation in floristic composition of bench quadrats is due to year-year differences in seasonal conditions. This analysis also tests the counter assumption that floristic composition is determined by the site, in particular to bench as a habitat. The second analysis, on floristic similarity, determines which samples are floristically similar to each other and makes it possible to infer what they have in common.

A sample means the species (forbs and shrubs) recorded at a particular site in a particular year: for example, the sample *rc1_18* means the data for site rc1 in spring 2018.

Prior to analyses, abundance (%cover) data were transformed to Presence-Absence data: other transformations were tried (square root, log(x + 1)) but did not give clear outcomes. A sample-sample resemblance matrix was constructed using the Bray-Curtis measure of similarity.

Analysis of factors: Assumptions about the drivers of floristic variability were tested using YEAR and SITE as factors. An nMDS ordination plot was overlain with each factor as a visual guide to its likely influence. This graphical approach treats the proximity of samples in ordination space as a measure of their similarity. The influence of each factor was then tested using the ANOSIM routine, with Global R statistic set to 0.1%. If found to be statistically significant, then the SIMPER routine was used to determine how strongly similar the levels of each factor are, and which species are driving this.

Floristic similarity: Similarity between samples was determined by cluster analysis using group average linkage, with the number of clusters and the samples per cluster identified using SIMPROF. This routine uses an iterative procedure of 999 permutations to test each cluster for heterogeneity, with a significance level set to 5%. The SIMPROF routine provides a statistical definition of clusters that is objective and sound, as opposed to an observer drawing a line across a dendrogram.

Results

General: A total of 68 species/taxa were recorded in the bench quadrats from 2018 to 2020. These are nearly all forbs (63 taxa), the five woody species being mostly single occurrences of seedlings and juveniles of *Rosa rubiginosa*, *Rubus fructicosus*, *Crataegus monogyna*, *Acacia rubida* and *Acacia* sp. These woody species are included in the analyses but as they did not persist and are a very minor component, the analyses are effectively about forbs on the benches. Overall, the six most frequently recorded species were: *Trifolium dubium* (10 samples), *Rumex crispus* (12 samples), *Vicia sativa* (13 samples), *Hypochaeris radicata* (14 samples), *Plantago lanceolata* and *Trifolium repens* (24 samples each). These are all common introduced species.

The list of species recorded per year was fairly stable for the first two years with 28 forbs and 2 shrubs in spring 2018, and 33 forbs and 2 shrubs in 2019, then increased quite dramatically to 50 forbs and 2 shrubs in 2020. High numbers in 2020 are attributed to favourable growing and germinating and establishment conditions preceding the spring survey.

Mean number of species per quadrat shows a similar trend over 3 years, averaging 5.7 and 7.3 in 2018 and 2019, then rising sharply to 13.9 in 2020. The highest number of species per quadrat really boomed in 2020, reaching 25 and 36 at sites rc2 and e32 respectively, whereas in earlier years this had been a modest 8 and 16.

Analysis of factors: The nMDS ordination in 2-dimensions had a stress level of 0.15 which is acceptable. Overlaying the factors YEAR (three years: 2018, 2019, 2020) and SITE (eleven sites) shows each of these appears to have *some* influence on floristic variability but does not account for all of it (Figure D1). With YEAR, for example, samples for three years are distributed in different parts of ordination space (2018 mostly in the upper area, 2020 samples mostly in lower half, and 2019 samples in-between), however the years overlap and are not clearly separated. It is a similar story of mixed patterns with the factor SITE. There are tight clusters well-separated from other sites (examples: e13, rc1), tight clusters that overlap with other tight clusters (examples: e26, e07), and sites that form loose open clusters (examples: e04, e32) that overlap with others. Results from ANOSIM showed that YEAR was not statistically significant in explaining floristic variation between samples (Global R = 0.08, probability = 5.6%, Not Significant) whereas SITE was significant (Global R = 0.562, probability = 0.1%, Significant).

The SIMPER analysis confirmed that sites differ in their species dynamics, with some sites changing through time, and others remaining relatively consistent. Specifically, the results showed that seven sites had samples with low similarity (less than 60%), meaning the samples from different years were floristically different. These seven sites (sites e01, e04, e09, e13, e19, e32) are scattered along Stream E from top to bottom, in all topographic positions. One of these sites (e32) is particularly low (21.4%) indicating substantial species turnover between years. In contrast, three sites (e07, e26, e28) have high similarity in their samples (60 to 70.5%), indicating persistent species composition and no seasonal effect. Site rc1 (with just two samples) is not included in this due to low sample size.

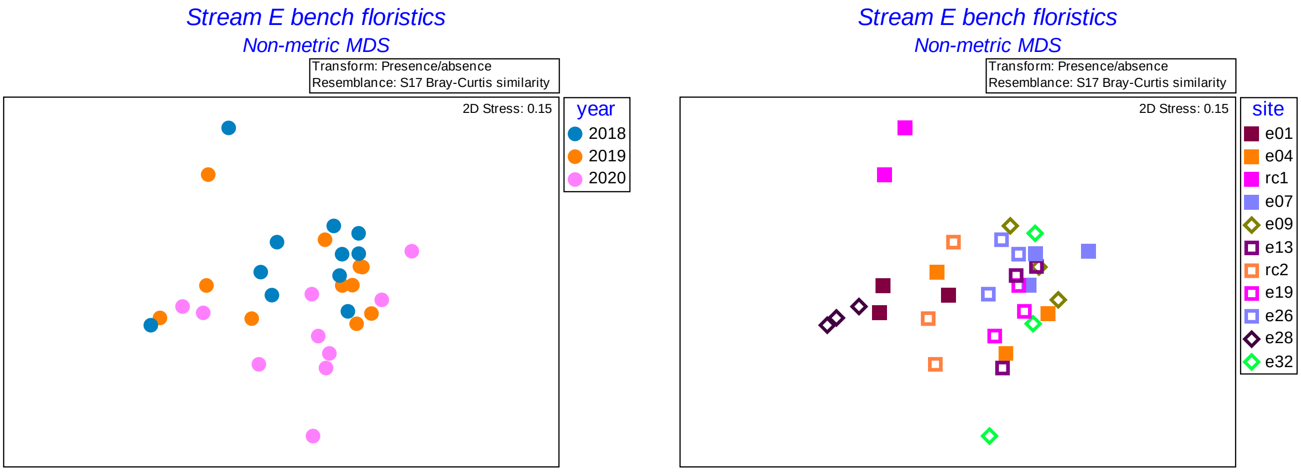


Figure D1: Ordination plots overlain by factor YEAR (left) and SITE (right)

Floristic similarity: Cluster analysis and the SIMPROF routine identified four clusters and one singleton, as indicated by the black lines (Figure D2): the parts of the dendrogram shown as dashed red lines are not statistically different from each other.

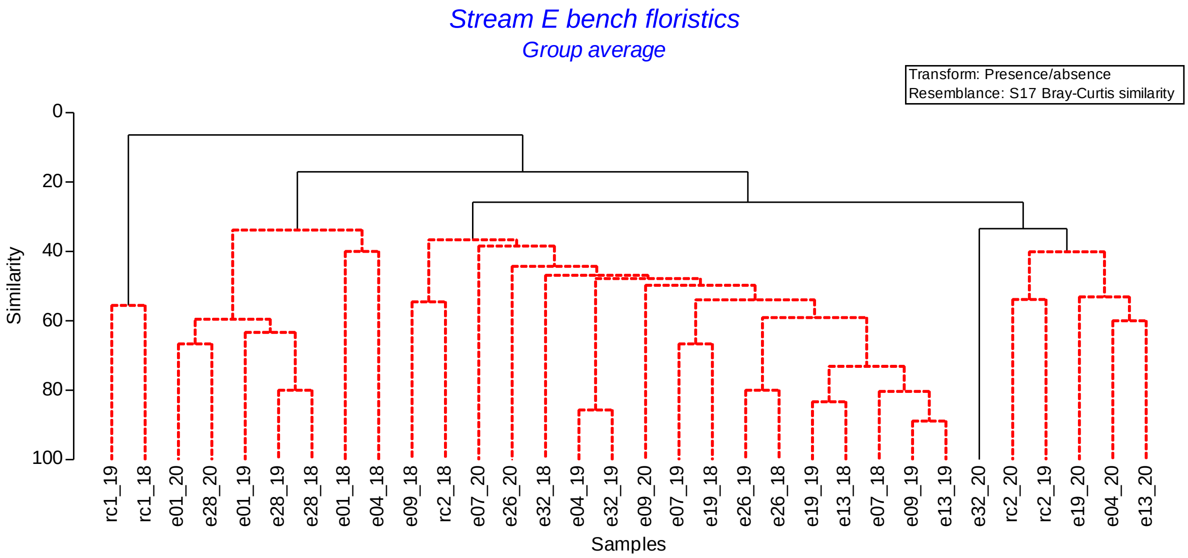


Figure D2: Dendrogram of bench forbs from 11 sites and three years

The five clusters, referred to as Cluster A to E and reading from left to right across the dendrogram (Figure D2), are.

Cluster A has 2 samples: from one site (rc1) in two years (2018 and 2019)

Cluster B has 7 samples: mostly from two sites (e01 and e28) in three years (2018, 2019 and 2020)

Cluster C has 17 samples: from 8 sites, mostly in two years (2018 and 2019)

Cluster D has 1 sample: from just one site (e32) in one year (2020)

Cluster E has 5 samples: from 4 sites (rc2, e19, e04, e13) mostly from one year (2020).

Considered overall, the composition of these five clusters is driven by a mix of site and seasonal conditions, rather than by just one or the other of these. Clusters A and B are characterised by their sites (rc1 for A; e01 and e28 for B); clusters C and E are characterised by year when sampled (2018 and 2019 for C; and 2020 for E). The largest cluster, Cluster C, does not show the same coherence as other clusters, as is evident from the 'chaining' in the dendrogram (Figure D2).

The SIMPER routine shows which species contribute significantly to cluster formation, and this can inform about the sites. In the case of Cluster B, the species defining this cluster are all amphibious or mudflat species (*Juncus articulatus*, *Veronica anagallis-aquatica*, *Rumex crispus*) tolerant of very moist or water-logged soils and of periodic inundation. Cluster D, which is actually a singleton with just one sample (Site e32 in 2020), is an outlier (see also Figure D1) that is floristically quite dissimilar to all samples. Eight of the 25 forb species in this sample were not recorded in any other sample over three years: mostly these were common pasture weeds (*Chondrilla juncea*, *Echium plantagineum*, *Malva neglecta*, *Paronchyia brasiliana*, *Tolpis* sp) but one of the eight was the native *Lomandra bracteata*.

Conclusions

The two principal findings from the analyses are as follows: these findings came from both analyses, despite their different approaches. First, both seasonal conditions and site characteristics influence floristic composition. Second, the benches along Stream E are not as similar in their forb floristics and floristic responses as initially assumed. Most of the benches (eight out of eleven) are somewhat dissimilar through time, indicating their species composition is dynamic and influenced by seasonal conditions. At one of these eight benches, the dynamic in floristics was so marked that the 2020 sample was distinct from all other samples. In contrast, three of the eleven benches (rc1, e01, e28) have high similarity between years suggesting their forb species composition is relatively stable through time.

This finding, that there appear to be two types of 'floristics behaviours', helps to explain why mean indicator values for benches show high variability (as evident by relatively high s.d. values), and why even relatively large changes in mean values are not statistically significant.

There is an important caveat on these findings, and that is to do with the size of the data set and the type of data used. With only 32 samples, the data set is not large. In the factor analysis, the finding for YEAR is probably robust, as there are eleven samples for each level of YEAR (ie for 2018, 2019 and ten for 2020). This may not be true for SITE which has eleven levels, each with only three samples. In addition, similarity matrix was computed using Presence-Absence data for species, not abundance, which with a small data set constrains the values.

In conclusion, the findings of these analyses are probably indicative of likely patterns, and food for thought. Stronger conclusions require bigger data sets.

Appendix E: Field sheets

Stream E POOLS: General Description

Site: ……………… **Date:**……………………………… **Observer:**……………………………………

Reference Photos: Record time when photo taken

	POOL looking UP	POOL looking DOWN
Time		
Notes to help interpretation ?		

General Description of POOL:

Describe each. For Grazing & Physical Damage, summarise as: none, little, some, lots

Water & Water Quality (flow ? algae ? clarity ?)	**Grazing Pressure** (on pool-side vegetation)	**Physical Damage Banks** (pugging, hoofed animal)

Stream E POOLS: Indicators

INDICATOR: Sedimentation

Total Depth (cm) Measure Firm base to water surface	**Water Depth (cm)** Measure Top of sediment to water surface	**Sediment Depth (cm)** Calculate Total Depth MINUS Water Depth
1: …………………………………… **2:** …………………………………… **3:** ……………………………………	**1:** …………………………………… **2:** …………………………………… **3:** ……………………………………	**1:** …………………………………… **2:** …………………………………… **3:** ……………………………………
NOTES:		

Stream E POOLS: Indicators

INDICATOR: Tall Emergent Macrophytes (between markers)

Phragmites australis	Schoenoplectus	Typha domingensis	
Shapes & Sizes (m)	Shapes & Sizes (m)	Shapes & Sizes (m)	Shapes & Sizes (m)
Area (m^2):	Area (m^2):	Area (m^2):	Area (m^2):

INDICATOR: Submerged Macrophytes (between markers)

Chara australis	Nitella pseudoflabellata	Potamogeton crispus	
Shapes & Sizes (m)	Shapes & Sizes (m)	Shapes & Sizes (m)	Shapes & Sizes (m)
Area (m^2):	Area (m^2):	Area (m^2):	Area (m^2):

ADDITIONAL NOTES/SKETCHES

Stream E BENCHES

Site: ……………………….. Date:……………………. Observer:…………………………………..

Time when Photos of Quadrat taken:

Looking UPstream at ………………………Looking DOWNstream at …………………………

General Description of Bench

Describe Grazing & Damage: Use: none evident, negligible, light, moderate, lots.

Foliage Height (cm) of ground cover	Grazing Pressure	Physical Damage (pugging, hoofed animal) to Bench

General Description: Bench Dominants

Tick which species are dominant, up to max 5. Add additional species if necessary

Avena sp		*Lolium perenne*	
Bothriochloa macra		*Lolium rigidum*	
Briza minor		*Lolium spp*	
Bromus diandrus		*Paspalum distichum*	
Bromus hordeaceus		*Trifolium repens*	
Cenchrus clandestinus		*Trifolium spp*	
Eragrostis curvula		*Vulpia spp*	
Holcus lanatus			
Juncus articulatus			

Quadrat Cover

Estimate %cover in the 5 x 1 m quadrat for each of the following

Bare Ground	Rocks	Litter	Shrubs	Perennials	Annuals	TOTAL
………………	………………	………………	………………	………………	………………	100%

Bare Ground = unvegetated soil : note if water-logged
Rocks = rocks, large bounders (not soil)
Shrubs: woody usually multi-stemmed plants. Most likely are Sweet briar, Blackberry
Perennials = Long lived non-woody plants (grass, sedge, rush, forb)
Annuals = short-lived or annual plants
Litter = fallen plant material or blown, no longer attached to parent plant, obscuring ground

Nativeness of Forbs in Quadrat

Only for species that are forbs (ie not grasses).

Record %cover of each species. If less than 1% of quadrat, then record as 0.5%

The table shows species recorded in 2018 and 2019. It may be necessary to add more species.

Estimating cover – a guide for a 1 x 5 m quadrat:

1% cover is equivalent to five 10 x 10 cm rectangles.

2% cover is equivalent to ten 10 x 10 cm square or five 5 x 20 cm rectangles.

A circle 10 cm in diameter (5 cm radius) is about 78cm^2 which is less than a 10 x 10 cm square.

Acaena ovina		*Lythrum hyssopifolia*	
Capsella bursa-pastoris		*Oxalis sp*	
Carthamus anatus		*Petrorhagia nanteuilli*	
Centaurium erythraea		*Phragmites australis*	
Cerastium glomeratum		*Plantago lanceolata*	
Cirsium vulgare		*Polygonum aviculare*	
Crepis vulgare		*Rorippa nasturtium-aquatica*	
Cyperus eragrostis		*Rumex crispus*	
Eleocharis acuta		*Sanguisorba minor*	
Erigeron sp.		*Schoenoplectus validus*	
Galium aparine		*Taraxacum officinale*	
Geranium solanderi		*Trifolium arvense*	
Hypericum perforatum		*Trifolium dubium*	
Hypochaeris radicata		*Trifolium repens*	
Juncus articulatus		*Trifolium subterraneum*	
Juncus filicaulis		*Trifolium sp*	
Juncus subsecundus		*Verbena incompta*	
Lysimachaia anagallis		*Veronica anagallis-aquatica*	
Lythrum hyssopifolia		*Vicia sativa*	
Oxalis sp			
SHRUBS (including woody juveniles)			
Crataegus monogyna		*Acacia rubida*	
Rosa rubiginosa		*Acacia sp*	
Rubus fruticosus			