Productive riparian buffer harvesting impact trials

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Executive summary

In agricultural landscapes, plantings of productive species in riparian buffers have potential to provide socio-economic benefits to farm systems as well as contributing to improved environmental performance.

This report is one of several arising from the Sustainable Farming Fund (SFF) Productive Riparian Buffers (PRBs) project. The project aims to assess the operational, financial, and environmental performance of PRBs. This report describes the results of two PRB harvesting trials where biomass yield, nutrient recovery, and potential environmental impacts were assessed.

Trials were carried out in March-April 2021 at two dairy farms in Waikato, at Walton and Tatuanui. The riparian buffer plantings were willow and poplar cultivars (1 or 2-year old coppice regrowth). Harvesting was done manually by 3-4 person teams. Plants were coppiced from marked plots, weighed to determine fresh matter yield and then chipped. Bulk, chipped material was fed out to stock to qualitatively gauge palatability. Chipped samples were also analysed in the laboratory to calculate dry matter yield and to measure standard feed profile constituents and nutrient content.

Measurements undertaken during the trials enabled assessment of the impacts of PRB harvesting on riparian/floodplain soil compaction, water quality, habitat, and aquatic insect populations in the adjacent drain (where this was possible). Fragment dispersal from the harvested plants was also evaluated because the introduced species have invasive potential (willow cultivar in particular). Pre-harvest surveys and instrument deployments were carried out 5-13 days prior to harvest. Surveys were repeated immediately after harvest (same day) and again three weeks later. Water quality variables in the adjacent drain were measured continuously over the entire four- to five-week trial period using automated monitoring equipment (multiparameter data sondes).

Harvest yields ranged from 1.1 to 16.1 tDM/ha (see Table i below). Yields from 1-year old plants were higher at Walton than at Tatuanui and were higher for poplar than willow. However, metabolizable energy (ME) of the willow and poplar chipped biomass was relatively low at both farms. Nutrient recovery rates were moderate, up to 77 kg N/ha/yr and 9.4 kg P/ha/yr.

Table i: Summary of results from field trials.

Farm	Harvest yield (t/DM)			Metabolizable energy (MJ/kg)			Nutrient recovery (kg N,P/ha/yr)		
	1-year old poplar	1-year old willow	2-year old willow	1-year old poplar	1-year old willow	2-year old willow	1-year old poplar	1-year old willow	2-year old willow
Walton	8.5	4.5	16.1	5.7	5.8	4.7-5.6	77.2, 9.4	36.4, 5.9	58.6, 8.4
Tatuanui	2.7	1.1	-	4.4-5.0	5.3	-	56.8, 5.7	19.2, 1.4	-

Farm stock did consume the chipped biomass, but not immediately, and only after mixing with their regular feed at Tatuanui. Time estimates for a three-person team to manually harvest a hectare of willow or poplar, with sickle, loppers or chainsaw, range from 16-33 hours.

No significant impacts of the harvesting activities on riparian/floodplain soils or the adjacent drain (assessed only at Tatuanui) were detected. However, plant fragments were produced by the (larger) manual harvest operation at Walton, with some short-distance dispersal noted. Aquatic conditions in the adjacent drain at Tatuanui were generally poor, especially dissolved oxygen levels, which failed to achieve bottom line status in terms of the National Policy Statement for Freshwater Management 2020.

These trials have shown that willow and poplar can be successfully cultivated and manually coppiced to provide fodder for farm livestock. These riparian buffers are also able to trap and recycle nutrients from runoff on-farm. No or little adverse impact on adjacent drains is anticipated, but care should be taken to limit fragment dispersal from these introduced species. Potential adverse impacts from larger-scale mechanical harvesting of PRB plantings, and effects of water availability and nutrient availability on plant yields, warrant evaluation in future.

1 Introduction

In agricultural landscapes, productive riparian buffers (PRBs) have potential to improve stream water quality, ecology and biodiversity while also providing socio-economic benefits to farm systems.

This report is one of several produced as outputs for the Sustainable Farming Fund (SFF) Productive Riparian Buffers project, funded by Ministry for Primary Industries. The project aims to assess the operational, financial and environmental performance of PRBs. It is a collaborative initiative co-led by DairyNZ and NIWA, working with farmer groups based in Northland (Waitangi) and Waikato (Hauraki Plains), and involving representatives from other organisations (e.g., Regional Councils, Plant and Food Research, Northland Totara Working Group) and independent experts.

For Milestone 9 of the SFF project, NIWA was contracted to carry out a trial to assess impacts from harvesting of a productive riparian buffer on the adjacent aquatic environment. The contract required the following:

(1) pre- and post-harvest assessments of stream habitat and aquatic insects,

(2) deployment of water quality monitoring sondes to measure stream water turbidity and dissolved oxygen for the duration of the trial.

Pre-harvest assessment and instrument deployment were to take place, ideally, at least one week prior to harvest, with repeat assessments the day after harvest, and three weeks later.

Trials were carried out in March-April 2021 at two dairy farms in Waikato – Bruce Fawcett Ltd Farm at Walton (hereafter Fawcett Farm) and Berry Farm at Tatuanui. The productive buffer plantings were willow and poplar cultivars at both locations.

Both harvests were done manually. The intent was to use a self-propelled forage harvester with maize header at Berry Farm, but farmer concerns about damage to the only recently established poplar and willow root network, and operator concerns about possible tyre punctures, meant this did not go ahead. At Fawcett Farm there was no water in the adjacent drain at time of harvest, negating any aquatic assessment. In lieu of this, riparian/floodplain soil compaction and fragment dispersal were included in the assessments at both farms.

2 Methods

2.1 Fawcett Farm

At Fawcett Farm, the area to be harvested was situated in a low-lying area of the farm adjacent to several drains that fed into the Waitoa River (Figure 2-1). This area is part of a flood plain, which can flood regularly and extensively in wet years. However, the drain closest to the area of harvest was dry in the month of March, when the farmer planned to carry out the harvest.

Figure 2-1: View of Fawcett Farm productive buffer from stock paddock above. Poplar plantings in the foreground, willow behind.

The main area to be harvested consisted of 490 m^2 (7 m x 70 m) of 2-year old Tangoio (*Salix matsudana* x *alba*) willow cultivar planted in 2019. In addition, three 20 m^2 plots (2 m x 10 m) within a larger area of 1-year old Tangoio willow coppice (planted in 2014 but most recently harvested in 2020), and a single 20 m^2 plot of 1-year old poplar (within a larger stand planted in 2020), were harvested. The harvested areas comprised 8 rows of 1-year old willows and 9 rows of 2-year old willows at 0.75 m spacing. Soils in the planted area had been deep ripped to 60 cm and broadcast weed sprayed with herbicide prior to planting.

Figure 2-2: Willow and poplar plantings at Fawcett Farm. Left: 2-year-old willows planted in 2019; Right: Jim Carle with 1-year old poplars. Photos: J. Carle.

On 10 March 2021, five days before harvest, six sampling transects were laid out starting at a fence line that ran across the drain and through the rows of 1- and 2-year old willows (Figure 2-3). Three were control transects where the area closest to the drain and the rows of 1-year old willows were not harvested, and three were impact transects where both the 1- and 2-year old willows were subject to harvest.

There were six sampling points on each transect labelled A-F, with point A lying between the drain and the 1-year old willows, points B-C within the 1-year old willow rows, and points D-F within the 2-year old willow rows.

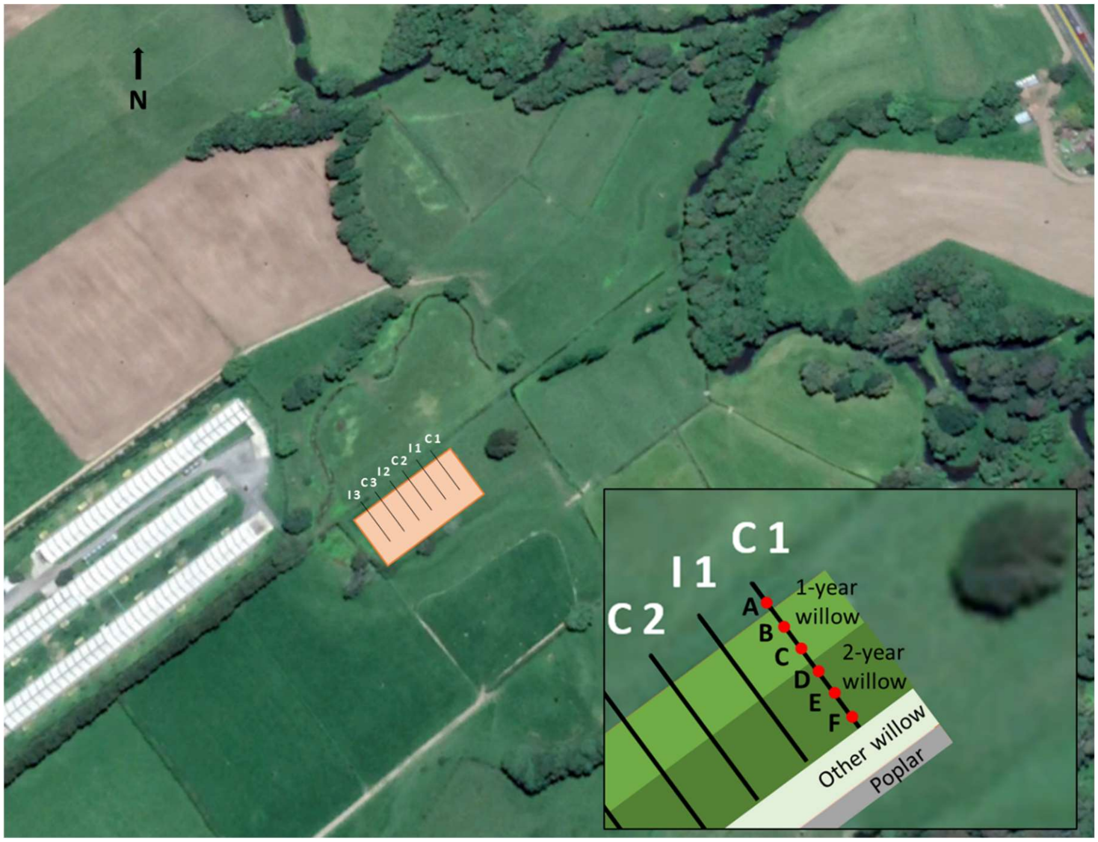

Figure 2-3: Location of productive riparian plantings and sampling transects at Fawcett Farm. Area of productive plantings shaded orange. Black lines indicate the sampling transects. "C indicates control transect, and "I" indicates impact transect. Inset (bottom right) shows detail of the planting layout and transect sampling points. Aerial image sourced from Google Earth, date 18 October 2018.

At each transect point a 0.7 m x 0.7 m square plot was marked out in the plantings using metal pins, flagging tape and string (Figure 2-4). At each point the overhead canopy cover of the plantings was assessed (at chest height) using a densiometer (Forestry Suppliers Model C). The number of willow fragments present in each plot was also recorded (all zero prior to harvest). At points A, C, D and F a corer (10 cm diameter and 7 cm deep) was used to collect surficial soil samples for bulk density determination. On the third impact transect, soil sampling was carried out at point E rather than D to avoid a wasp nest.

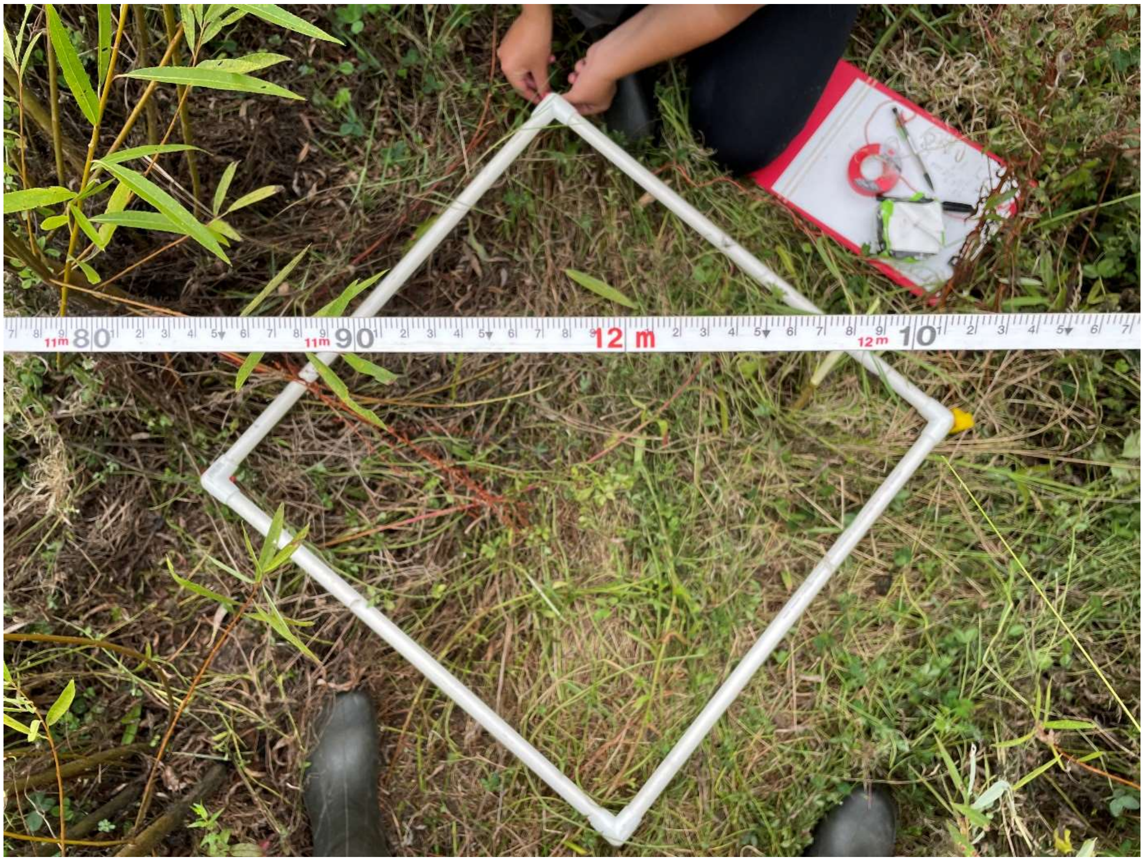

Figure 2-4: Example transect sampling point. White quadrat is 0.7 m x 0.7 m.

In the laboratory, soil samples were weighed to determine wet weight, then dried at 105°C for 24 hrs to determine dry weight. Soil bulk density (g/cm^3) was calculated by dividing the dry weight (in grams) by volume sampled.

The PRB harvest took place on 15 March 2021. Harvesting was carried out by a team of four people. Two electric chainsaws were used to coppice plants approximately 20-25 cm above the ground.

Within the area of 2-year old willows, five 2 m x 2 m plots were marked out (Figure 2-5). Plants coppiced within each plot were gathered in a basket and weighed using a mechanical hanging spring scale to determine the wet (fresh) weight of harvested plant biomass per m^2.

Figure 2-5: Harvest of 2-year old willows.

Within the area of 1-year old willows, three 2 m x 10 m plots were marked out along each of the three-harvest impact transect lines. These three areas and a 20 m^2 plot of 1-year old poplar (4 rows at 0.75m spacing) on the other side of the 2-year old willow plantings were harvested and weighed as above.

Figure 2-6: Harvest of 1-year old willows. Photo: J. Kleinmans.

Harvested plants were gathered by hand and transported to eastern end of the plantings using a quadbike and trailer. Here, they were passed through a tractor PTO driven disk-type Hansa C21 differential chipper. The bulk of the harvested material was chipped into the back of a feed-out wagon for subsequent in-paddock feeding to stock. However, a sample of each plant type corresponding to one of the plots mentioned above was run separately through the chipper and captured in a sack. A 0.5-1 kg subsample of this chipped material was placed in a large paper bag and prepared for routine laboratory analysis of feed value and nutrient content. Further subsamples were taken by Mr J. Kleinmans from NutriAssist Ltd for ensilage testing (results are described in a separate report).

The bulk of the chipped material was fed to the farms dairy herd immediately after the harvest was completed (Figure 2-7).

Figure 2-7: Feeding out of chipped willow and poplar biomass to the dairy herd at the Fawcett Farm.

Shade measurement, fragment counts, and soil sampling along transects was repeated immediately after harvest (same day) and three weeks later, on 9 April 2021.

Harvested and chipped willow and poplar biomass subsamples were dried in a laboratory oven at 62°C for 24 hrs. They were then analysed for feed value and nutrient content using wet chemistry methods at Hill Laboratories, Hamilton.

2.2 Berry Farm

At Berry Farm, the area to be harvested was located next to a permanently flowing headwater drain that feeds into a tributary of the Piako River. The plantings, established in 2020, covered an area of 77 m long and 7 m wide (Figure 2-8). They consisted of 2 rows of 1-year old willows closest to the drain and 6 rows of 1-year old poplars further back, all spaced 0.75 m apart. Plants had been sourced from Fawcett Farm stock and had been planted the previous spring. Two rows of *Carex* sedges were planted between the drain and willows. These were not harvested. All plantings had been separated from the adjacent grazed pasture using a temporary electric fence.

Figure 2-8: View of Berry Farm productive buffer. Looking upstream, the sequence of plantings is poplar (field edge on left), to willow to *Carex* (drain edge), drain is centre-right, with stock on far right in paddock on the other side of drain.

On 11 March 2021, two weeks before harvest, three transects were laid out starting from a fence line along the drain, passing through the drain, *Carex*, willow and poplar plantings and into the adjacent area of pasture on the opposite bank of the drain (Figure 2-9). Transects were placed equidistantly to dissect (perpendicularly) the rows of plantings to be harvested and were located away from the upstream and downstream edges of the planted area. There were 4 sampling points on each transect. Point A lay within the unharvested area of *Carex*, Point B within willow, Point C within poplar and Point D in grazed pasture.

Three additional transects of the same length and point spacing and distance apart were laid out through the unplanted, pasture grazed area immediately upstream of the harvested area to serve as controls.

Figure 2-9: Location of productive riparian plantings and sampling transects at Berry Farm. Area of productive plantings shaded orange. Black lines indicate the sampling transects. Inset (top right) shows detail of the planting layout and transect sampling points. Aerial image sourced from Google Earth, date 9 July 2010.

At each sampling point along the six transects, a plot (0.7 m x 0.7 m) was marked out and assessed for overhead canopy cover, fragment count and soil sampling, using the same process employed at Fawcett Farm.

Drain habitat was assessed at each transect by placing two wooden pegs at approximately the same elevation close to the top on opposite banks, and a string was run across the drain from peg to peg. Peg heights were adjusted so that the string was level. These were left in place for the duration of the trial. For all transects the drain was relatively uniform in width so total distance between pegs was approximately 3 m.

Figure 2-10: Drain at Berry Farm. Level string across the drain is visible beginning bottom left of photo.

At 0.1 m intervals along the string, the vertical distance from string down to bank/drain bed and water level (if applicable) was measured. At five equidistant intervals across the string a visual assessment of percent cover of bare soil, riparian and aquatic plant types was made. On each transect, two assessments were of the banks, two were at the intersection of bank and wetted channel, and the fifth in the centre of the channel. Wetted width of the drain was recorded, and overhead canopy cover was assessed in the centre of the channel using a densiometer.

A 1 m wide band across the channel, and directly upstream of the string (at 0-1 m distance) was sampled for aquatic insects. The stream banks with overhanging vegetation were targeted just below the waterline and an area of approximately 0.8 m^2 was sampled with a hand net – 4 agitations with the net each side of the channel. Samples were transferred into 1 L opaque, rigid plastic bottles and preserved with 70% isopropyl alcohol. In the laboratory, each sample was split into quarters, and a 200-specimen fixed count with scan for rare taxa was performed on one or more quarters as required. Specimens were identified to taxon level.

Two multiparameter water quality data sondes (Model: EXO2 - YSI Inc., USA) were deployed in the waterway to measure water turbidity and dissolved oxygen at 15 min intervals for the duration of the trial. One was deployed at the downstream end of drain section adjacent to the harvested area, and the other was deployed at the downstream end of the drain section adjacent to the pasture area with the control transects. The sondes also logged water temperature, pH and conductivity at 15 min intervals for the duration of the trial.

Harvest of the PRB biomass took place on 25 March 2021 using a team of three people. Harvesting efficiency using a chainsaw versus loppers or a sickle was compared. The six rows of poplars were divided into three sections, working from downstream to upstream: 1) 25 m x 4.5 m, 2) 25 m x 4.5 m and 27 m x 4.5 m. Plot 1 was harvested by chainsaw and Plots 2 and 3 with loppers. The two rows of willows were divided into two sections of 38.5 m x 1.5 m. Working from upstream to downstream, the first plot was harvested using a sickle and the second section using a chainsaw.

Figure 2-11: Harvesting poplars at Berry Farm. Left photo: Coppicing trees one by one; Right photo: Cut stumps from which new growth will emerge.

Time taken to harvest each plot was recorded. The fresh weight of material in each willow plot was determined using a basket and mechanical hanging spring scale, after which the material was chipped. All poplar material was chipped into a 1 m^3 (clean) fertilizer bag and this was transported by tractor to the dairy shed for weighing on the cow scales. Subsamples of freshly chipped willow and poplar biomass were taken for laboratory analysis as at Fawcett Farm.

The chipped willow and poplar biomass was fed out to the dairy herd at the farms' feed pad later that day, with qualitative observations made by the farmer of preference and consumption (Figure 2-12).

Figure 2-12: Feed out of chipped poplar (left) and willow (right) to Berry Farm dairy herd. Photos: W Berry.

Overhead canopy cover analysis, fragment counts, soil sampling, waterway habitat and aquatic insect assessments were repeated immediately after the harvest was completed (same day), and three weeks later, on 15 April 2021. For aquatic insect sampling, the same 1 m band of channel cross-section was not re-sampled because of concerns that insects might not have had time to re-colonise these areas. Instead, a 1 m band at distance 2-3 m upstream of the string was sampled on 25 March, and then a band at distance 3-4 m upstream of the string was sampled on 15 April.

2.3 Data analysis

For aquatic insect data, six common metrics were calculated, applying scoring factors specific to soft-bottom waterways. These metrics were the Macroinvertebrate Community Index (MCI), Quantitative MCI (QMCI), the total abundance/number of specimens in each sample, the total number of taxa in each sample, the percentage of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) specimens in each sample (%EPT abundance) and the percentage of mayfly, stonefly and caddisfly taxa in each sample (% EPT taxa).

A repeated measures analysis of variance (RM ANOVA) was applied to the impact monitoring data gathered at each farm. This analysis was used to identify significant differences that might be attributable to impacts from harvesting, or other factors. We compared results from the different transect types (control vs. impact), planting zones (willow, poplar vs. unharvested) and sampling dates (before vs. after harvest) as appropriate.

3 Results

3.1 Fawcett Farm

3.1.1 Harvest yield and feed value

Biomass yield was relatively high, especially for the 1-year old poplar and 2-year old willow (Table 3-1). However, metabolizable energy of the chipped material, both willow and poplar, was relatively low, ranging from 4.7 to 5.8 MJ/kg DW. The full feed profile results are provided in Appendix A.

Nutrient content of the chipped material ranged from 0.7 to 0.9% for nitrogen and 0.10 to 0.13% for phosphorus. Combined with biomass yield data this equates to nutrient uptake rates for the plantings ranging from 36 to 77 kg N/ha/yr. and 5.9 to 9.4 kg P/ha/yr.

Annual nutrient uptake rates were highest for 1-year old (2020) poplar, followed by the 2-year old (2019) willow, then the 1-year old (2014) willow.

Table 3-1: Yield and feed value of harvested and chipped plants at Fawcett Farm.

Planting	Biomass yield (± std err.)		Metabolizable Energy	N content (%)	N uptake (kg/ha/yr)	P content (%)	P uptake (kg/ha/yr)
	(kg FM/ha)	(kg DM/ha)[1]	(MJ/kg DW)				
1-year old willow	9283 (±1547)	4549 (±835)	5.8	0.8	36.4	0.13	5.9
2-year old willow plot	34150 (±6737)	16734 (±3638)	4.7	0.7	58.6	0.10	8.4
2-year old willow general	ND	ND	5.6	0.7	ND	0.10	ND
1-year old poplar	19500	8580	5.7	0.9	77.2	0.11	9.4

[1] assumes 51% water content for willow, 56% for poplar based on Berry Farm results, wet weight of Fawcett samples not determined before oven drying. n = 3 plots for 1-year old willow, n = 5 plots for 2-year old willow, n = 1 for poplar. FM is Fresh matter, DM is dry matter.

3.1.2 Feed-out observations

Upon feed-out, the dairy cows followed the feed-out wagon with interest, but only a few cows initially sampled the chipped willow biomass. The stock had been in the feed-out paddock for some time and were due to be moved to a new paddock, so the farmer suspected that this might be the reason for their reluctance to feed. However, approximately half of the PRB biomass was consumed by stock later that day, with calves released into the paddock the following day to finish the rest.

Figure 3-1: Remaining willow woodchip for calves to consume at Fawcett Farm the day after harvest. Photos: J. Carle.

3.1.3 Soil bulk density

Soil bulk density ranged from 0.6 to 0.8 g/cm^3 in the riparian zone soils of Fawcett Farm (Table 3-2). Statistical analysis indicated that soil bulk density tended to be slightly higher in the zone adjacent to the drain, and slightly lower for all samples collected three weeks post-harvest (RM ANOVA, Date: F value 5.3, $p<0.01$, Zone: F value 5.3, $p<0.01$). There was no evidence for an increase in soil bulk density and, therefore, increased riparian soil compaction, resulting from the manual harvesting operation.

Table 3-2: Soil bulk density (g/cm^3) at Fawcett Farm.

Timing in relation to harvest	Transect type	Soils bulk density (g/m^3)		
		Adjacent to drain (A)	1 year old willow (B,C)	2 year old willow[1] (D,E,F)
Before	Control	0.72 ± 0.02	0.65 ± 0.03	0.71 ± 0.04
	Impact	0.75 ± 0.02	0.64 ± 0.04	0.66 ± 0.03
After (same day)	Control	0.68 ± 0.08	0.68 ± 0.09	0.68 ± 0.03
	Impact	0.80 ± 0.08	0.67 ± 0.09	0.69 ± 0.05
After (3 weeks)	Control	0.72 ± 0.04	0.60 ± 0.02	0.63 ± 0.04
	Impact	0.65 ± 0.02	0.62 ± 0.03	0.62 ± 0.05

[1]Control plots of 2-year old willow were harvested.

3.1.4 Fragment generation

Following harvest at Fawcett Farm the number of willow stem fragments left behind in the harvested areas ranged from 0 to 26/m^2. Virtually all fragments were found in the 2-year old willow zone. This is unsurprising given the much larger biomass harvested from this area compared to the 1-year old willow zone. A small number of fragments were found in the unharvested zone lying between the drain and 1-year old willows. They were not detected three weeks later suggesting that they may have decomposed in this period. A reduced number of fragments in the 2-year old willow plots were observed between 0 and 3-weeks post-harvest, also suggesting a gradual decomposition of fragments. However, the appearance of fragments in the 1-year old willow plot three weeks post-harvest is curious, but might indicate that some fragments had been moved from the 2-year old willow zone into the adjacent 1-year old willow zone by birds, animals or wind gusts.

Table 3-3: Fragment generation from harvest (n/m^2) at Fawcett Farm.

Timing	Transect type	Fragment occurrence (n/m^2)		
		Adjacent to drain (A)	1-year old willow (B,C)	2-year old willow[1] (D,E,F)
Before	Control	0 ± 0	0 ± 0	0 ± 0
	Impact	0 ± 0	0 ± 0	0 ± 0
After (same day)	Control	0 ± 0	0 ± 0	14 ± 4[1]
	Impact	2 ± 2	0 ± 0	26 ± 8
After (3 weeks)	Control	0 ± 0	0 ± 0	6 ± 2[1]
	Impact	0 ± 0	12 ± 10	16 ± 8

[1]Control plots of 2-year old willow were harvested.

Overhead canopy cover

Overhead canopy cover created by the PRB plantings ranged from 28 to 41% in the 2-year old willow zone, from 8 to 19% in the 1-year old willow zone, and from 3 to 7% in the zone adjacent to the drain. After harvesting of the willows, canopy cover was reduced to ≤4% in all zones. The small amount of canopy cover remaining was provided at the edge of each zone by adjacent plantings which were not harvested.

Table 3-4: Overhead canopy cover (%) from riparian plantings at Fawcett Farm.

Timing	Transect type	Overhead canopy cover (%)		
		Adjacent to drain (A)	1 year old willow (B,C)	2 year old willow[1] (D,E,F)
Before	Control	3 ± 1	8 ± 2	28 ± 5
	Impact	3 ± 2	10 ± 3	41 ± 12
After (same day)	Control	5 ± 1	13 ± 1	1 ± 1[1]
	Impact	0 ± 0	3 ± 3	3 ± 2
After (3 weeks)	Control	7 ± 1	19 ± 10	0 ± 0[1]
	Impact	0 ± 0	2 ± 2	4 ± 3

[1]Control plots of 2-year old willow were harvested.

3.2 Berry Farm

3.2.1 Harvest yield and feed value

At time of harvest, poplar and willow plantings were around 3 m and 2 m in height, respectively. Biomass yield was considerably higher for poplar compared to willow (Table 3-5). However, metabolizable energy of the chipped material was relatively low for both (from 4.4 to 5.3 MJ/kg DM), with slightly lower values for the poplar. The full feed profile results are provided in Appendix A.

Nutrient content of the chipped material ranged from 1.4 to 1.8% for nitrogen and 0.10 to 0.18% for phosphorus. Combined with biomass yield data this equates to nutrient uptake rates for the plantings ranging from 19 to 57 kg N/ha/yr. and 1.4 to 5.7 kg P/ha/yr. Annual nutrient uptake rates were 3-4 fold higher for 1 year old poplar, than 1 year old willow.

Table 3-5: Yield and feed value of harvested and chipped plants at Berry Farm.

Planting	Biomass yield (kg FM/ha)	Biomass yield (kg DM/ha)[1]	Metabolizable Energy (MJ/kg DW)	N content (%)	N uptake (kg/ha/yr)	P content (%)	P uptake (kg/ha/yr)
1-year old willow	2,160	1,369	5.3	1.4	19.2	0.10	1.4
1-year old poplar	6,275	3,155	4.4-5.0	1.8	56.8	0.18	5.7

[1] 46% water content willow, 55% water content poplar. FM is Fresh matter, DM is dry matter.

The estimated time required to manually harvest a hectare of willow or poplar with the three-person team ranged from 16-33 hours. Surprisingly, harvest using a chainsaw was slower than with loppers or a sickle. The farmer attributed this to a tendency for the chainsaw to get entangled in grass at the base of the trees.

Table 3-6: Harvest efficiency summary by implement type at Berry Farm.

Planting	Time to harvest (hrs required per ha)[1]			Time to chip (hrs required per ha)
	Chainsaw	Loppers	Sickle	
1-year old willow	33	NA	21	2
1-year old poplar	28	16-17	NA	8

[1] approximate, based on 3-person team

3.2.2 Feed-out observations

Upon feed-out, the farmer reported that initially only a few cows were sufficiently interested to lick or sample the chipped willow and poplar biomass. However, when the stock's usual feed of maize and palm kernel was placed on top, the chipped material was consumed, although long, thin willow stems (that the chipper struggled to process) were left behind.

3.2.3 Soil bulk density

Overall, we found no indication that the manual harvesting operation had resulted in compaction of the riparian/floodplain zone soils. In fact, on all sampling dates, soil bulk density was significantly lower in the transects that dissected the riparian plantings, indicating less soil compaction, compared to the grazed pasture control transects (RM ANOVA, F value 82.05, p value <0.001). However, soil bulk density was lower in the pasture zone adjacent to the riparian plantings as well. This suggests that the set-aside and planting of the buffer was not the reason for reduced soil compaction. The results indicate that the downstream, riparian/floodplain area that was planted with a PRB had an inherently lower soil bulk density than the upstream grazed pasture area.

Table 3-7: Soil bulk density (g/cm^3) at Berry Farm transects.

Timing	Transect type	*Carex* zone (A)	1 year old willow (B)	1 year old poplar (C)	Pasture (D)
Before	Control	0.71 ± 0.05	0.78 ± 0.04	0.77 ± 0.05	0.71 ± 0.02
	Impact	0.52 ± 0.01	0.58 ± 0.03	0.52 ± 0.04	0.57 ± 0.01
After (same day)	Control	0.74 ± 0.11	0.73 ± 0.02	0.74 ± 0.08	0.78 ± 0.01
	Impact	0.74 ± 0.07	0.57 ± 0.04	0.50 ± 0.06	0.59 ± 0.02
After (3 weeks)	Control	0.81 ± 0.08	0.79 ± 0.09	0.82 ± 0.05	0.71 ± 0.02
	Impact	0.55 ± 0.02	0.62 ± 0.03	0.61 ± 0.08	0.62 ± 0.05

3.2.4 Fragment generation

No fragments of the willow or poplar productive buffer plantings were observed in any of the transect plots at Berry Farm before or after harvest. The size of plant specimens and quantity of biomass to harvest at the Berry Farm was less than at Fawcett Farm. Consequently, it was much easier for the harvesting team to gather the harvested biomass for chipping, with few/no stray fragments left behind.

3.2.5 Overhead canopy cover

Overhead cover created by the poplar and willow plantings at Berry Farm was relatively low and ranged from 3 to 6%. All overhead canopy cover in both planting zones was removed when trees were harvested. The canopy cover was lower than that measured at Fawcett Farm, especially amongst the latter 2-year old willows, which presumably reflects the lower biomass of the Berry Farm plantings.

Table 3-8: Overhead canopy cover (%) at Berry Farm transects.

Timing	Transect type	*Carex* zone (A)	1 year old willow (B)	1 year old poplar (C)	Pasture (D)
Before	Control	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	Impact	4 ± 3	3 ± 3	6 ± 5	0 ± 0
After (same day)	Control	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	Impact	0 ± 0	0 ± 0	0 ± 0	0 ± 0
After (3 weeks)	Control	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	Impact	0 ± 0	0 ± 0	0 ± 0	0 ± 0

3.2.6 Waterway profiles and habitat

This assessment was carried out only at Berry Farm. Waterway profiles and plots showing the extent of cover of different vegetation types across the drain transects are provided in Appendix B. Drain profiles were somewhat variable through time. We attribute this variability to there being a degree of subjectivity in detecting when bank soil or stream bed base was reached with the measuring rod due to the thick bank vegetation and soft drain bed.

Maximum water depth in the drain ranged from approximately 200-700 mm, with generally shallower water in the upstream, control transect reach, especially later in the trial. Water was generally very slow flowing. Duck weed (*Lemna* spp.), green filamentous algae and swamp willow weed (*Persicaria* spp.) were the dominant aquatic plants in the channel, the latter only present in the downstream transects. Significant rainfall on the afternoon of 25 March 2021 following harvest, meant that there was surface runoff and the drain was more obviously flowing at this time, elevating the water level slightly.

Bank vegetation was dominated by dense rank grass and the drain had a layer of soft sediment, which varied in depth (although we did not specifically measure this). The taller riparian plantings were set back several metres from the drain. Consequently, shading was low (<2%) in both upstream and downstream sections. Mosquitofish (*Gambusia affinis*) were observed at the time of survey and a few specimens were subsequently found in some of the aquatic insect samples. The surveys also disturbed some other larger aquatic life that could not be identified at the time, possibly eels or frogs.

There was no evidence of any impact from the harvest operation on the drain. This is not surprising given that the operation was manual (i.e., not mechanised), all activities were at least several metres away from the drain, and that an area of unharvested *Carex* sedges lay between the drain and the harvested trees. Drain banks were fully vegetated, with no bare soil or slumping and this did not change over the trial period.

3.2.7 Aquatic insects

Aquatic insect monitoring data for the Berry Farm drain show no evidence of impact from the PRB harvest (Table 3-9). No significant differences were found between the control and impact transects across the three sampling dates for six commonly used metrics.

The MCI and QMCI scores (all <80 and <4, respectively), indicate a drain in poor biological condition, with probable severe pollution. Taxa associated with good water quality usually include mayflies, stoneflies, and caddisflies (the EPT taxa). Only one EPT individual, a caddisfly (Triplectides), was found in a single (impact) transect.

Table 3-9: Aquatic insect summary for Berry Farm drain. Values are means (± standard error, n=3). MCI=macroinvertebrate community index, QMCI=quantitative macroinvertebrate community index, total abundance=no. of specimens in each sample, no. of species=no. of species in each sample, % EPT (abundance)= percentage of mayfly, stonefly and caddisfly specimens in each sample, % EPT (taxa) = percentage of mayfly, stonefly and caddisfly taxa in each sample. The raw sample data are provided in Appendix C.

Timing	Transect type	MCI score	QMCI score	Total abundance	No. of taxa	% EPT (abund.)	% EPT (taxa)
Before	Control	75.7 (± 2.1)	3.67 (± 0.19)	490 (± 170)	15.3 (± 2.0)	0.0 (± 0.0)	0.0 (± 0.0)
	Impact	76.6 (± 3.8)	3.65 (± 0.17)	1273 (± 257)	15.7 (± 0.7)	0.0 (± 0.0)	0.0 (± 0.0)
After (same day)	Control	78.7 ± (1.5)	3.91 (± 0.10)	344 (± 53)	15.0 (± 1.0)	0.0 (± 0.0)	0.0 (± 0.0)
	Impact	72.1 (± 1.6)	3.49 (± 0.13)	1095 (± 385)	16.7 (± 0.9)	0.0 (± 0.0)	0.0 (± 0.0)
After (3 weeks)	Control	67.8 (± 1.2)	3.48 (± 0.10)	1163 (± 86)	13.7 (± 1.2)	0.0 (± 0.0)	0.0 (± 0.0)
	Impact	74.3 (± 3.1)	3.79 (± 0.12)	576 (± 133)	13.0 (± 0.6)	0.0 (± 0.0)	0.0 (± 0.0)

3.2.8 Water quality

Water quality monitoring for the Berry Farm drain began 13 days prior to harvest of the productive plantings, with instruments removed three weeks post-harvest.

Dissolved oxygen levels were found to be much lower, and indicating sustained low oxygen conditions (<30% saturation), at the bottom of the downstream section of the drain, adjacent to the productive riparian buffer, both before and after the harvest (Figure 3-2). Dissolved oxygen readings at the upstream section of drain, adjacent to grazed pasture, showed high diurnal variability reflecting a strong influence from aquatic plant photosynthesis. Upstream readings similarly dropped to low levels overnight but reached supersaturation (DO levels of up to 180% saturation) during the day. This pattern was also evident before and after harvesting. The sustained low oxygen readings in the downstream section are somewhat surprising, given that this section also supported aquatic plants, and there was little shading, despite the PRB plantings, to limit their growth. However, it was apparent that there was a greater abundance of floating and emergent plants (duckweed, swamp willow weed) in the downstream reach (see Figure B-3). In contrast to submerged plants, floating and emergent plants do not release oxygen into the water during daytime photosynthesis but they do continuously draw oxygen from the water and release carbon dioxide, thus their greater abundance might be contributing to the sustained low dissolved oxygen in the downstream reach. In both reaches the minimum absolute DO concentration recorded was 0.15 mg/L.

Specific conductivity, water temperature and pH were also measured during the trial (Figure 3-2, Figure 3-3). At the upstream reach, conductivity was relatively stable through time. Water temperature and pH showed regular diurnal variations, increasing during daylight hours and decreasing through the night, and were well matched to and consistent with the dissolved oxygen data.

At the downstream reach, conductivity was frequently slightly higher than upstream and showed regular fluctuations, at least in the early part of the record, suggestive of a diurnal pattern, although this became muted and less consistent over time. Water temperature followed the expected diurnal pattern, but peak temperatures were less than those measured upstream. In contrast, pH at the downstream reach showed a diurnal pattern but it was unusual, and opposite, to that which is normally expected. The data showed that pH peaked when water temperature was lowest, and vice versa. The pH was also higher at the downstream reach that the upstream reach. We have insufficient data to properly interpret this result. However, one possible explanation is that increased respiration by biota as water temperatures increase produces carbon dioxide, which lowers the pH. At the same time there is little production of dissolved oxygen to counteract this effect because of the dominance of floating and emergent plants in this reach.

Turbidity was also measured over the same period (Figure 3-4). Upstream turbidity readings were highly variable (and spurious) suggesting a fault with the probe (so this data is not shown). Downstream readings show periodic elevation of turbidity in the drain (up to 120 FNU), mostly likely due to rainfall and associated surface runoff transporting fine sediment into the drain.

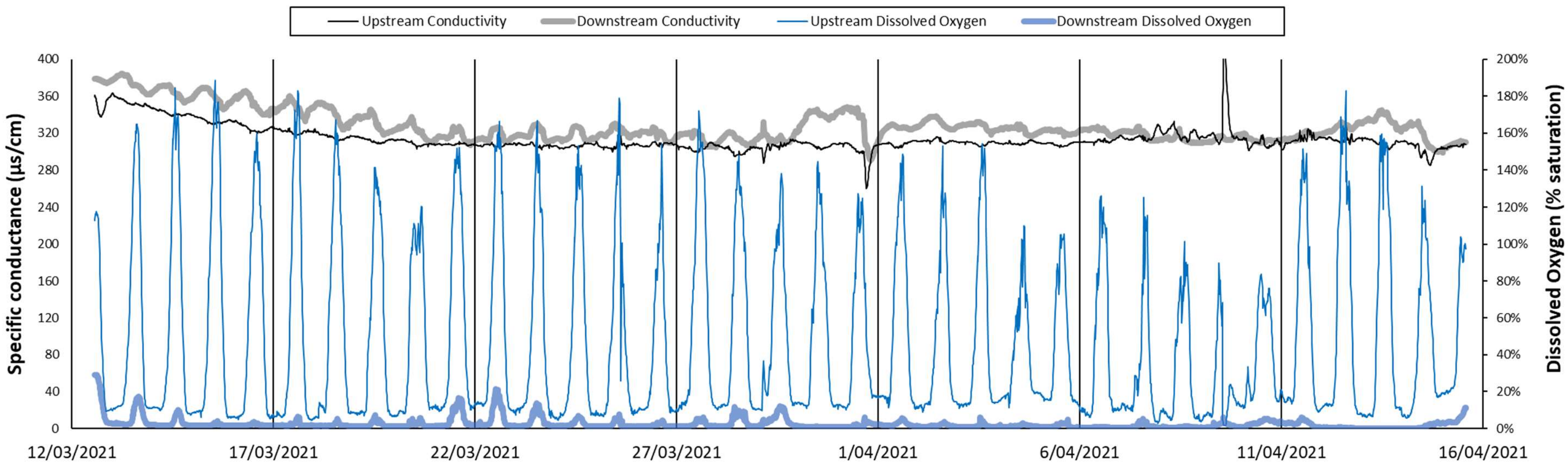

Figure 3-2: Sonde instrument data for specific conductance and dissolved oxygen from Berry Farm drain. 'Upstream' refers to sonde placed at bottom end of the control reach, 'down' refers to sonde placed at bottom end of the productive buffer harvested reach. Harvest took place on 25 March 2021.

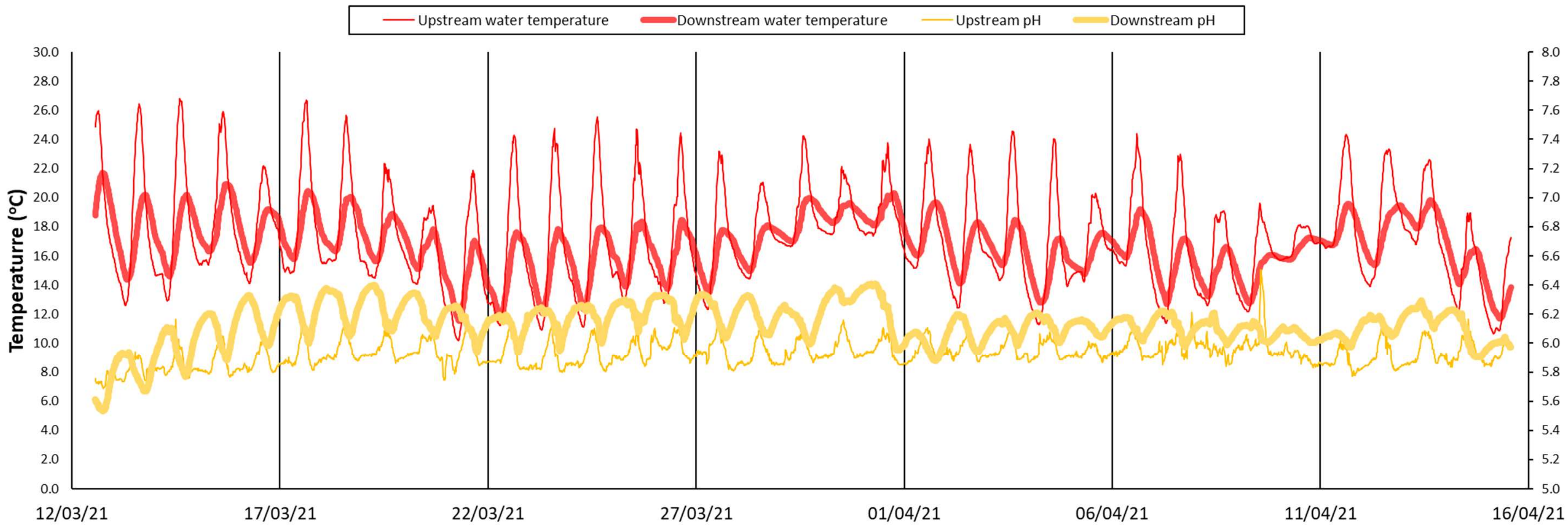

Figure 3-3: Sonde instrument data for water temperature and pH from Berry Farm drain. 'Upstream' refers to sonde placed at bottom end of the control reach, 'Downstream' refers to sonde placed at bottom end of the productive buffer harvested reach. Harvest took place on 25 March 2021.

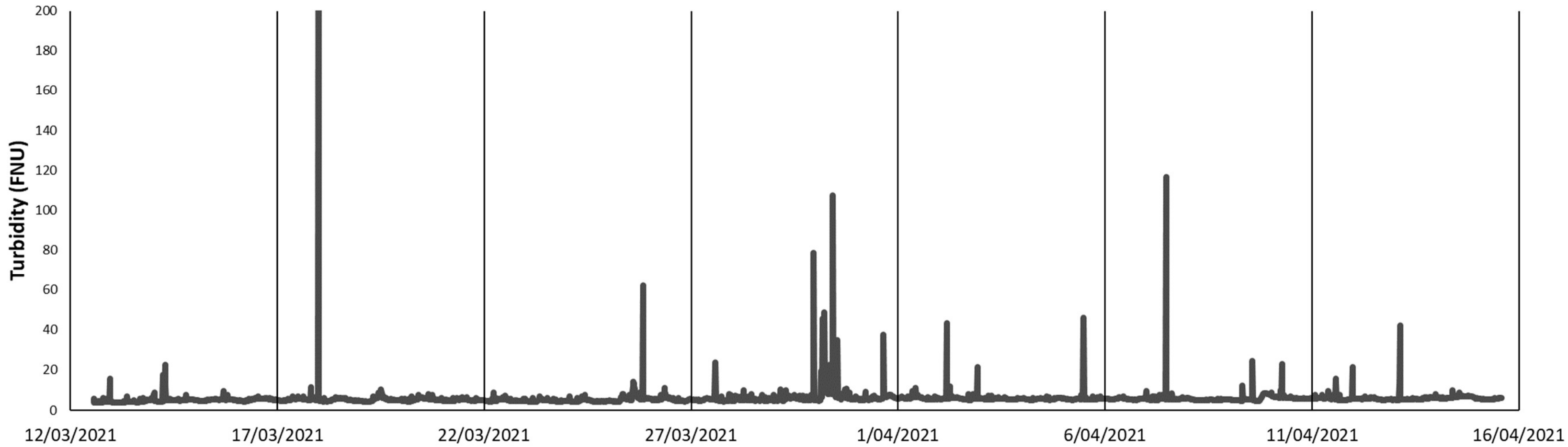

Figure 3-4: Sonde instrument data for turbidity from Berry Farm drain. The upstream turbidity data (not shown) was highly variable and spurious, possibly because of interference from aquatic plants. Consequently, only data from the sonde at the bottom end of the downstream reach are shown. Harvest took place on 25 March 2021.

4 Discussion

4.1 Harvest yield and feed value

At Fawcett Farm, harvest yield from the 2-year old willows was high (16.7 t DM/ha), with the yield from the 1-year old willow much lower, at 4.5 t DM/ha. The 2021 1-year old willow harvest yielded much less than the 2020 harvest of the same crop which generated 8.7 t DM/ha (Heubeck 2020). At Berry Farm the harvest yield of the 1-year old willows was even lower at 1.4 t DM/ha.

Despite the high biomass yield from Fawcett Farm 2-year old willows, feed value of the chipped material was relatively low, with maximum metabolizable energy (ME) of 5.6 MJ/kg, crude protein 4.7% and digestibility 38%. Values for chipped Fawcett Farm 1-year old willows were similar with ME 5.8 MJ/kg, crude protein 5.0% and digestibility 37%. The values for 1-year old willow are lower than those reported for the same block coppiced in 2020 of ME 8.4 to 9.0 MJ/kg, 11.7-13.1% crude protein, and digestibility 57-61% (Heubeck 2020), which were in line with previous reports for the Tangoio cultivar (Kemp et al. 2001). At Berry Farm, feed value of chipped 1-year old willow was also comparatively low at ME 5.3 MJ/kg, 8.4% crude protein, and digestibility 35%.

Yields of 1-year old poplar were higher than those for 1-year willow at both farms, at 3.1 t DM/ha from Berry Farm and 8.5 t DM/ha from Fawcett Farm. However, the estimate from Fawcett Farm came from a harvest a single 20 m^2 plot. Feed values for poplar were also relatively low with ME 4.4-5.7 MJ/kg, crude protein 5.5-11.3% and digestibility 30-36%.

The relatively low feed value of both chipped willow and poplar biomass from the two 2021 PRB harvest trials, appears to explain the hesitancy of livestock to consume the material, at least initially. This in contrast to findings from the March 2020 trial at Fawcett Farm where the chipped willow biomass was quickly consumed (Heubeck 2020). The 2021 material had a lower feed value than poor pasture (6.8 MJ/kg ME, DairyNZ 2021: Feed Values - DairyNZ) and/or emergency feeds such as barley straw (55% DM digestibility, 6.8 MJ/kg ME, Kirchgessner 1997). It appears that feed quality may vary between years, perhaps related to water availability. Willows, in particular, prefer moist soils. Nutrient limitation and/or mining of nutrient stocks in riparian soils through time might also explain the lower yield and feed quality of the 2021 harvests. Fertilisation might therefore increase yields, but also increase risks of nitrate/contaminant leaching to drains. Yields of Tangoio willow of up to 13 and 24 t DM/ha in first year of growth have been achieved with effluent irrigation equivalent to 250 and 500 kg N/ha/yr. (Snow et al. 2003).

The lower biomass yields of willow and poplar could also be due to infections with giant willow aphid (GWA), *Tuberolachnus salignus,* (Sopow et al. 2017), and rust (Snow et al. 2003), respectively. Willow trees at Fawcett Farm have periodically suffered from GWA infestation (see Heubeck (2020)), and releases of the parasitoid wasp *Pauesia nigrovaria*, a potential biological control agent for GWA, have been made at Fawcett Farm by researchers from Scion. At Berry Farm, rust infection was evident on the poplar plantings.

4.2 Nutrient uptake

Annual nutrient uptake rates for the 1- to 2- year old willow plantings ranged from 15-59 kg N/ha/yr. and 1.4-8.4 kg P/ha/yr. respectively, with highest annual uptake rates for the older trees. For 1-year old poplar plantings uptake rates were 50-77 kg N/ha/yr. and 5.7-9.4 kg P/ha/yr. The results therefore suggest that poplar plantings may have greater potential for on-farm nutrient interception and recycling than willow.

Uptake rates for the coppiced Tangoio willow in this study seem quite low compared to maximum potential rates of up to 440 kg N/ha/yr. reported for a dairy farm in Carterton (Snow et al. 2003, National Poplar and Willow Users Group 2007). Fertilisation with effluent can clearly increase yield and nutrient uptake substantially, but also elevates the risk of contaminant wash off and leaching into drains, especially if effluent is applied during cooler, wetter months when the likelihood of runoff is increased, and plant growth and uptake rates are reduced.

4.3 Environmental impacts

Overall, there were no obvious impacts of the PRB harvests on riparian soils and (at Berry Farm) the adjacent aquatic habitat. This was not unexpected, given the manual nature of the harvests.

Soil bulk densities were in the range of 0.5 to 0.8 g/cm^3, with slightly higher values at Fawcett Farm. Bulk densities in this range are typical of soils with moderate organic carbon- and water content. Water content was determined as a component of soil bulk density analysis and values ranged from 11-50% for Berry Farm (mean 33%) and 17-34% for Fawcett Farm (mean 27%). Bulk densities of 0.2 to 0.3 g/cm^3 were measured previously in the plough layer of peat soils developed for agriculture at nearby Torehape, also in the Hauraki Plains (McLay et al. 1992). Soil bulk densities over 1.6 g/cm^3 are considered likely to restrict plant root development.

Fragments of willow were inevitably produced from the sizeable manual harvesting operation at Fawcett Farm, although few spread beyond the harvested area. No fragments were produced at Berry Farm. Although there were indications that any fragments produced broke down quite quickly, harvest of productive plants clearly does increase the risk of spreading undesirable species, and this risk may increase with mechanisation, and upscaling, of harvest in the future. We note that the Tangoio willow cultivar trialled in this study is a female clone and is generally not recommended for planting along watercourses to prevent seed dispersal downstream (NZ Farm Forestry Association 2021). However, the farmers involved in this study were careful to manage this risk. Following trial completion at Fawcett Farm, the intent was to release stock into the harvested area for a short period of time to consume any remaining fragments. However, the farmer delayed doing this to accommodate assessment of fragment occurrence three weeks post-harvest. At this point, remaining fragments had dried out so much that they were not suitable for stock consumption.

The drain at Berry Farm is typical of many smaller watercourses across the Hauraki Plains. The water quality, habitat and aquatic insect data collected during the trial did not suggest any detrimental impact from harvest of the PRB. However, they did indicate that drains of this nature generally do not provide good conditions to support aquatic life. Aquatic insect metrics classified the conditions in the drain, both upstream and downstream sections, as poor, with probable severe water quality.

Peak daily water temperatures in the shallower, upstream section of the drain mostly exceeded 20°C during the trial period. The Cox-Rutherford index (CRI), the temperature midway between maximum and average water temperature for the five hottest consecutive days each year, was 22.6°C for the upstream section, and 19.4°C for the downstream section, of the drain.

These CRI values would classify conditions in the drain as fair (C Band) and good (B Band), respectively, if we assume that the hottest summer water temperatures occurred during the trial period. However, this may not be the case, and higher water temperatures may have occurred in January or February. The higher peak water temperatures in the upstream section of the drain likely result from the generally shallower depth of water. The PRB plantings adjacent to the downstream section were setback from the drain and very little shading was detectable in the channel with the densiometer.

In both sections of the drain dissolved oxygen fell to low levels overnight, as a result of benthic respiration (and lack of plant photosynthesis), but it was also low, <30%, during daylight hours, in the downstream section. Dissolved oxygen levels in the drain did not meet the RMA minimum standard for aquatic ecosystems (RMA 1991) which requires ≥ 80% saturation They are also below the national bottom-line standard in the National Policy Statement for Freshwater Management (New Zealand Government 2020) which requires summer-time 1-day minimum concentrations in waterways to be >4 mg/L. pH in drain water ranged from 5.6 to 6.6. pH values <6 lie below the RMA minimum standard for aquatic ecosystems (RMA 1991), and the proposed National Policy Statement for Freshwater Management bottom line (Davies-Colley et al. 2013).

Pulses of elevated water turbidity and accumulation of fine sediments in the base of the drain indicate that sediment is frequently washed into the drain from the grazed pasture. Bank erosion does not appear to be a significant source of sediment, at least not in the drain sections surveyed during the Berry Farm trial. The dense grass and sedge growth created by the PRB is expected to intercept at least a portion of sediment runoff, and therefore lessen this impact. However, only one section and side of the drain currently has the PRB.

5 Acknowledgements

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Appendix A Feed profile results

Fawcett Farm

Planting	Crude protein (%DM)	Acid-detergent fibre (%DM)	Neutral detergent fibre (%DM)	Lignin (%DM)	Ash (%DM)	Organic matter (%DM)	Soluble sugars (%DM)	Starch (%DM)	Crude fat (%DM)	Digestibility of organic matter (DOMD, %)	Non-structural carbohydrate (%DM)	OMD in-vivo (%DM)
1-year old willow	5.0	47.7	57.9	13.7	2.8	97.2	6.5	5.7	1.3	36.0	28.4	37.0
2-year old willow plot	4.3	55.4	70.0	14.4	5.5	94.5	7.4	2.9	1.8	35.7	29.2	37.8
2-year old willow general	4.7	50.9	66.0	13.5	2.3	97.7	5.3	5.4	1.3	29.1	22.1	29.8
1-year old poplar	5.5	44.3	62.5	12.5	2.5	97.5	6.4	5.5	1.6	35.1	25.2	36.0

Berry Farm

Planting	Crude protein (%DM)	Acid-detergent fibre (%DM)	Neutral detergent fibre (%DM)	Lignin (%DM)	Ash (%DM)	Organic matter (%DM)	Soluble sugars (%DM)	Starch (%DM)	Crude fat (%DM)	Digestibility of organic matter (DOMD, %)	Non-structural carbohydrate (%DM)	OMD in-vivo (%DM)
1-year old willow	8.4	48.0	62.7	15.8	4.8	95.2	5.1	3.9	1.3	32.8	22.8	34.5
1-year old poplar, plot 1	11.3	48.2	62.8	18.6	6.7	93.3	3.5	1.3	1.4	31.5	17.7	33.8
1-year old poplar, plots 2 and 3	11.1	51.5	66.0	19.9	7.4	92.6	2.4	1.0	1.4	27.4	14.1	29.5

Appendix B Drain profiles and habitat assessment plots

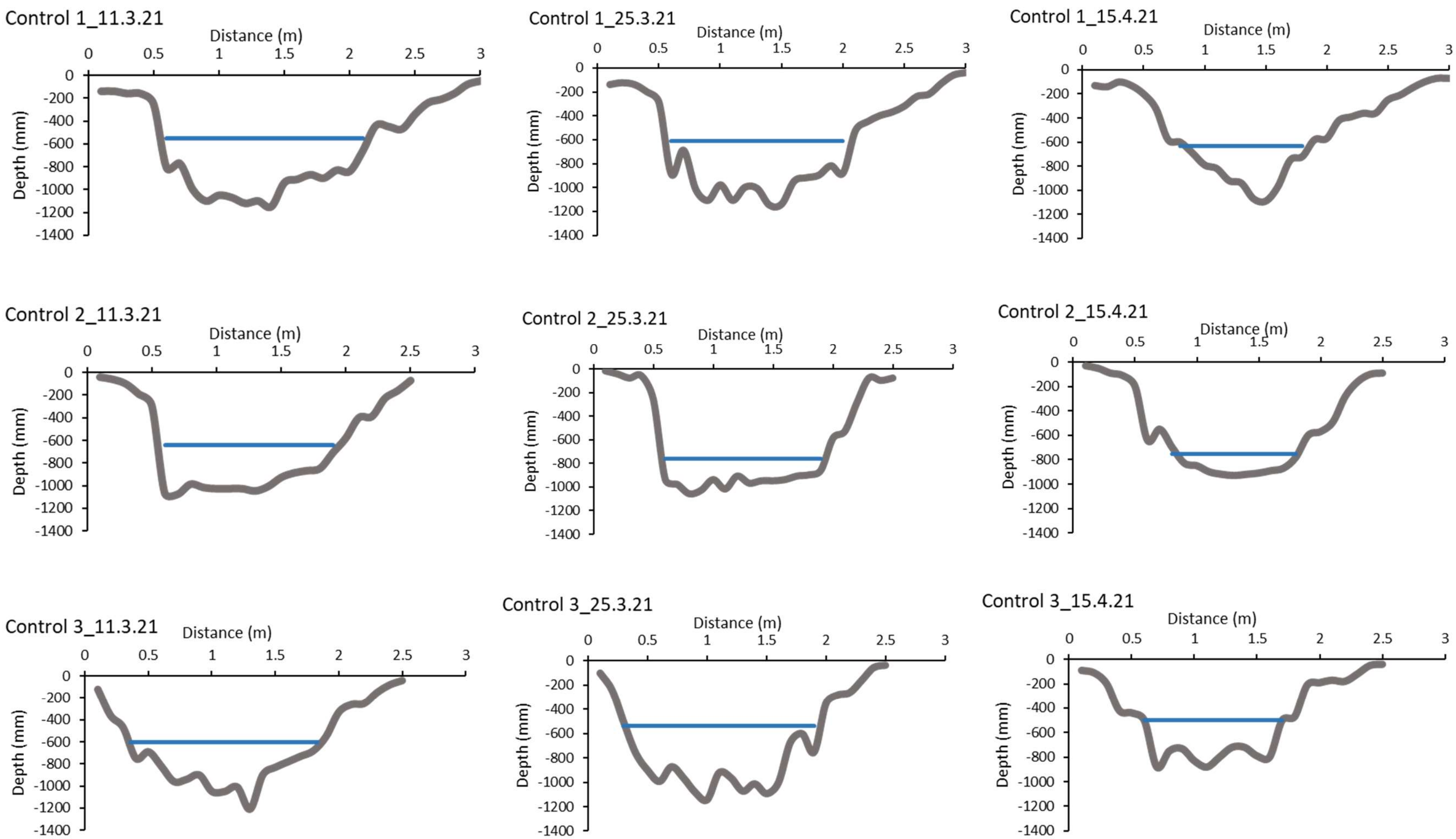

Figure B-1: Drains profiles adjacent to pasture upstream of the productive riparian buffer at Berry Farm, before and after harvest. Profiles show depth to bank or drain bed below a levelled string, before and after harvesting. Blue line indicates the water level. Harvesting took place on 25.3.21 prior to profile measurements.

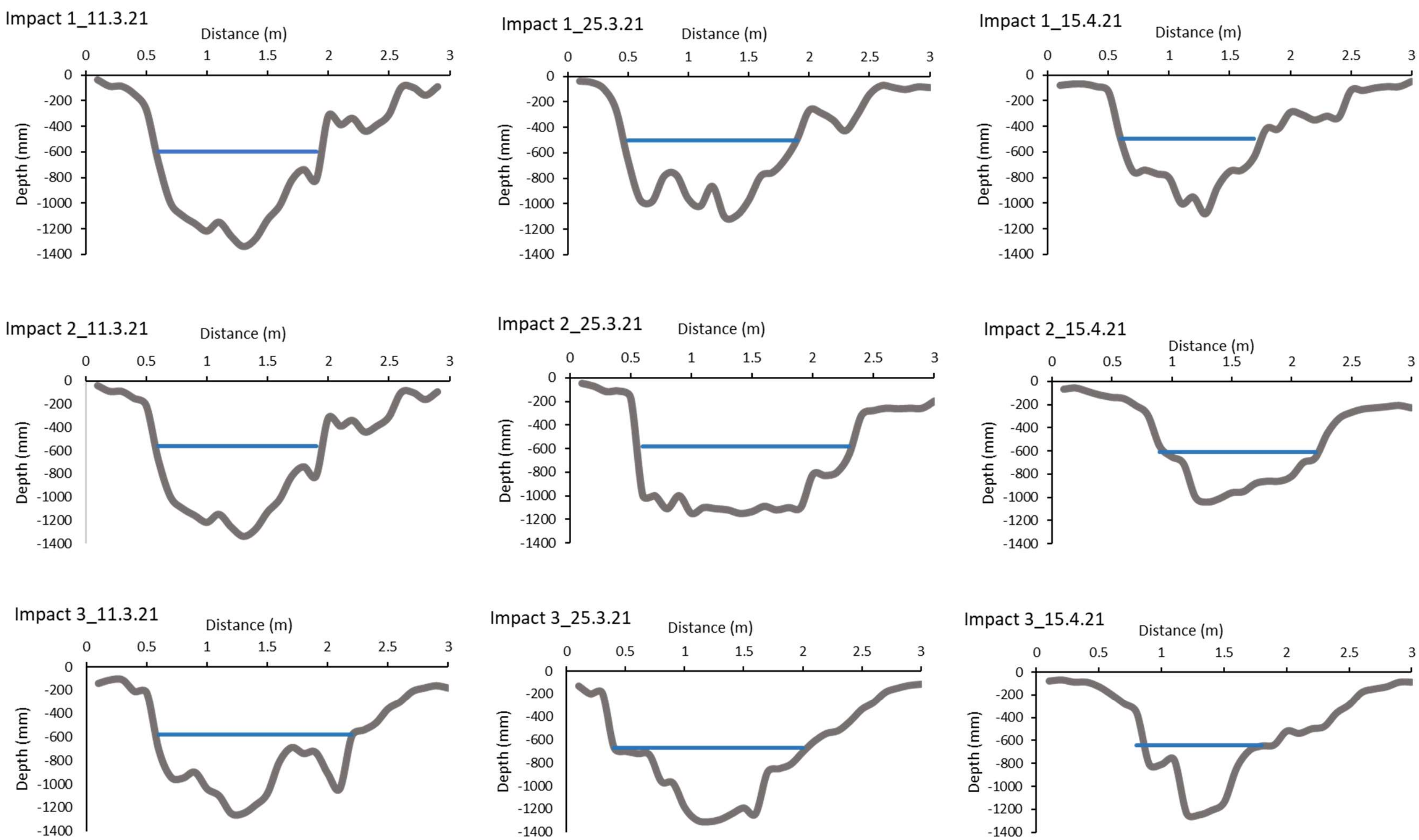

Figure B-2: Drains profiles adjacent to harvested riparian buffers at Berry Farm, before and after harvest. Profiles show depth to bank or drain bed below a levelled string, before and after harvesting. Blue line indicates the water level. Harvesting took place on 25.3.21 prior to profile measurements.

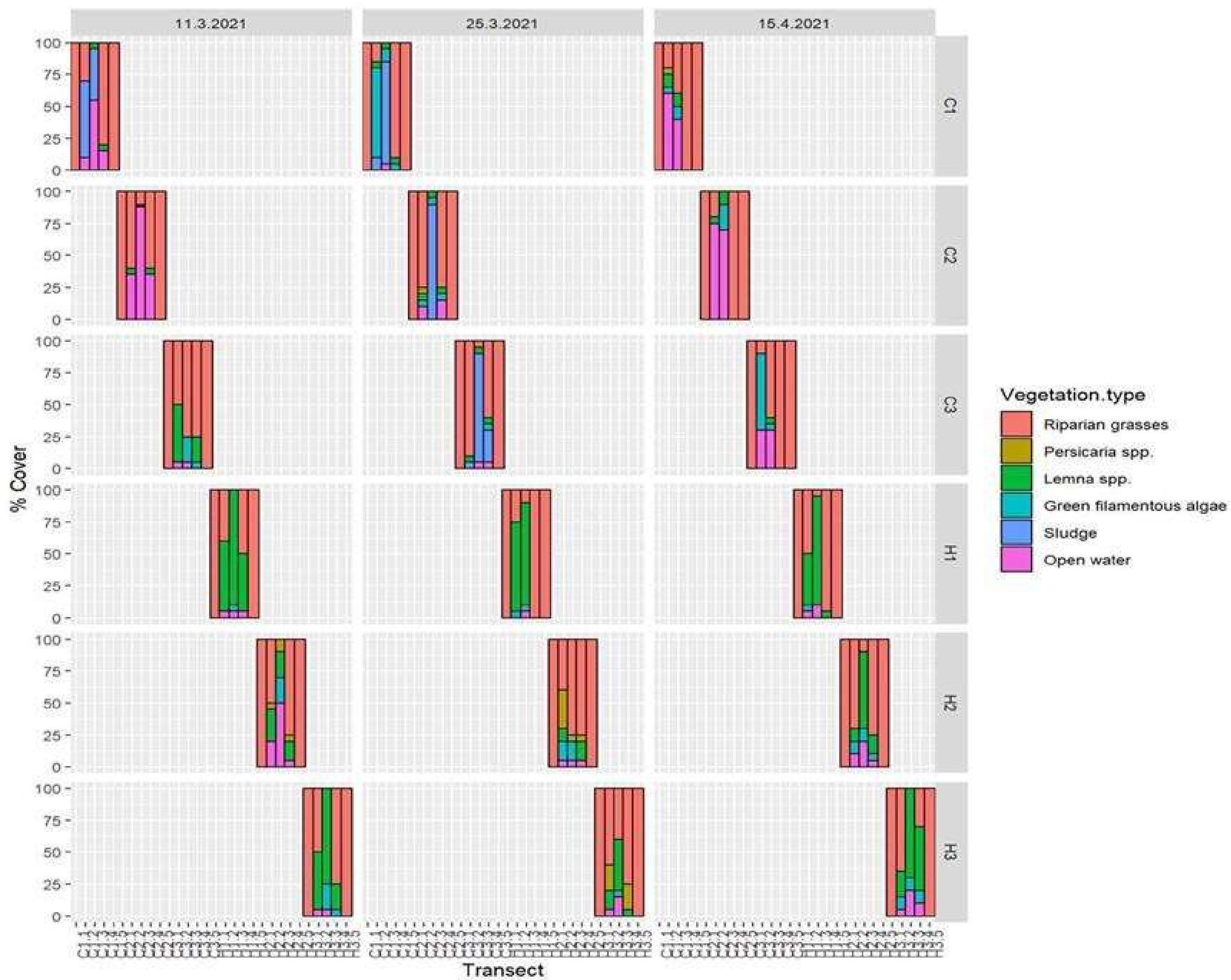

Figure B-3: Drain vegetation assessment at Berry Farm, before and after harvest. Five quadrats were assessed at equidistant intervals across the channel, including banks. Plots show cover of each vegetation type within each 0.3 x 0.3 m square quadrat. From left to right, each plot shows vegetation types across the channel from true left to true right banks (i.e. as if facing downstream).

Appendix C Aquatic insect raw data

Taxa		11 March 2021						25 March 2021						15 April 2021					
		C1	C2	C3	I1	I2	I3	C1	C2	C3	I1	I2	I3	C1	C2	C3	I1	I2	I3
	Subsample	1/4	1	1/2	1/4	1/4	1/4	1	1	1	1	1/4	1/4	1/4	1/4	1/4	1/2	1/4	1/2
Platyhelminthes	Platyhelminthes	0	14	3	6	0	8	0	0	4	22	17	13	2	9	5	0	0	0
Nematoda	Nematoda	6	1	2	1	1	0	2	6	1	2	0	0	2	0	1	1	0	0
Oligochaeta	Oligochaeta	151	90	52	139	250	84	117	196	101	86	161	111	110	93	118	112	89	82
Hirunidea	Hirunidea	1	10	3	14	38	31	36	1	5	47	36	25	7	7	9	18	1	1
Crustacea	Amphipoda	8	9	52	19	3	2	32	4	115	16	3	1	31	1	4	32	9	56
	Copepoda	9	5	0	8	21	7	8	1	41	21	57	33	14	20	12	2	3	2
	Ostracoda	0	61	7	0	4	3	19	27	100	0	2	25	0	0	19	12	33	47
Odonata	Xanthocnemis	0	1	0	4	7	7	1	0	0	9	8	9	8	0	11	0	0	1
Hemiptera	Microvelia	5	19	6	1	3	7	19	1	3	10	6	3	0	2	5	0	3	4
Coleptera	Hydraenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrophilidae (A)	8	4	2	17	13	6	11	4	20	21	5	6	0	0	3	0	1	8
	Hydrophilidae (L)	0	5	5	4	0	7	11	2	3	26	15	7	0	0	2	0	0	0
	Liodessus (A)	1	0	1	1	0	0	1	0	0	0	0	1	1	0	1	1	1	1
	Liodessus (L)	0	5	0	1	3	2	3	1	2	2	7	5	1	1	1	0	2	2
Diptera	*Chironomus*	0	0	0	31	2	75	17	0	2	41	22	36	78	125	106	19	41	0
	Chironominae	4	1	1	0	97	9	3	0	0	5	5	3	0	0	27	0	9	0
	Corynoneura	0	0	0	0	0	1	0	0	0	0	2	2	0	1	3	0	0	0
	Hexatomini	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
	Muscidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Orthocladiinae	5	3	2	2	1	6	8	0	2	9	16	7	0	1	4	2	3	3
	Psychodidae	0	0	1	0	1	0	0	0	0	0	0	18	0	0	0	0	0	0
	Stratiomyidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tanytarsus	0	0	0	0	0	0	0	6	3	0	2	63	2	9	2	1	0	0
	Tipulidae	0	0	5	0	0	0	0	0	6	0	0	0	0	0	0	5	3	1
Trichoptera	*Triplectides*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	Collembola	4	4	1	1	1	1	8	7	34	2	5	0	3	2	0	2	0	0
Acarina	Acarina	0	1	3	2	1	0	4	5	5	7	1	1	5	4	0	27	12	1
Mollusca	Gyraulus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potamopyrgus	1	0	63	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
	Austropeplea	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Total count	**203**	**233**	**213**	**252**	**447**	**256**	**315**	**269**	**447**	**326**	**370**	**370**	**264**	**275**	**333**	**235**	**210**	**209**