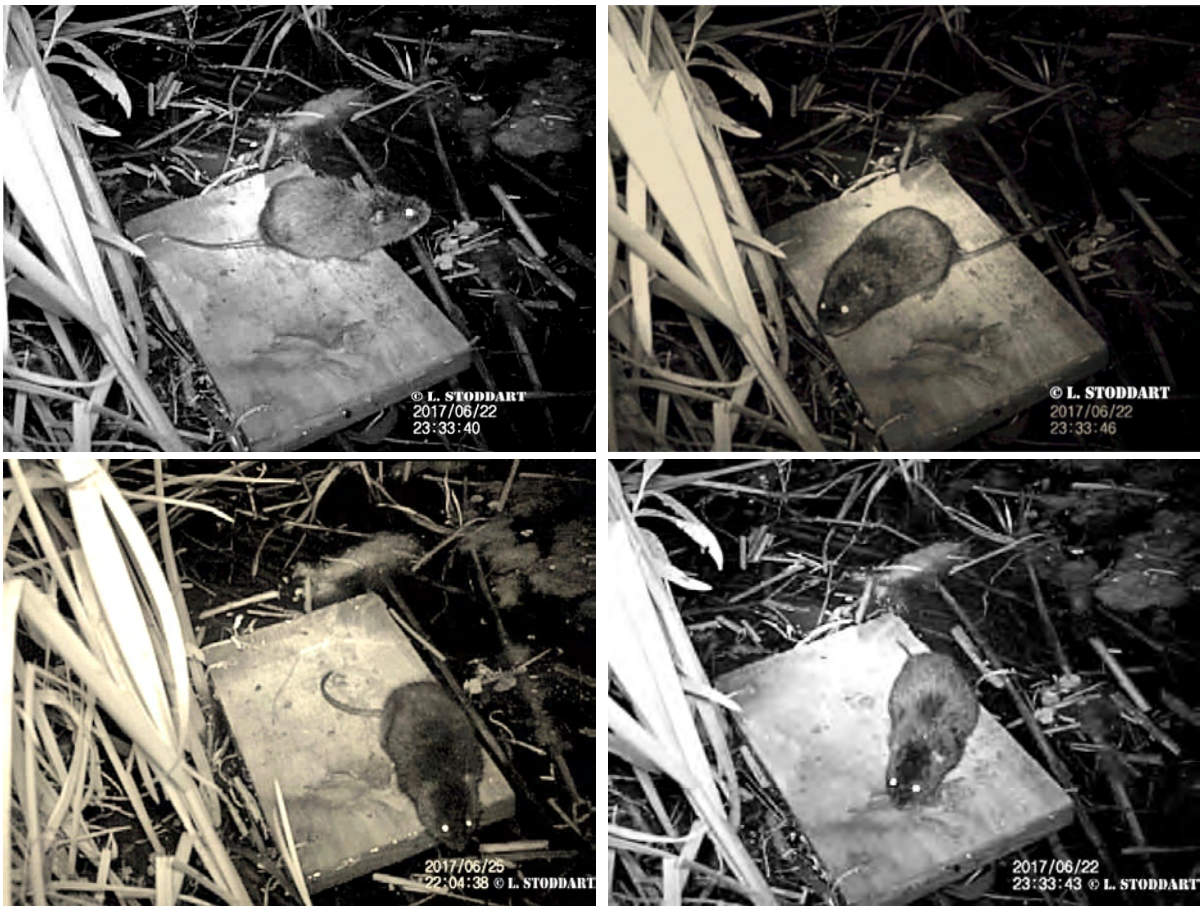
middle level commissioners

The effectiveness of installing coir roll revetments to improve riparian habitats for water voles (*Arvicola amphibius*) along Fenland drains.

Lucy Stoddart



Photos: One of the 110 survey rafts (acting as an artificial latrine and feeding platform) being used by a water vole at the edge of a Fenland drain (L. Stoddart, 2017).

Executive summary

This report examines the effectiveness of installing coir rolls (a type of organic living revetment) in comparison with four other riparian management types to improve habitats for breeding water voles. Between mid-May and early July 2017, water vole surveys were undertaken at 110 sites (22 assigned to each of the five management types) in the Cambridgeshire and Norfolk Fens. Survey work at each of these sites involved recording water vole droppings, latrines and feeding signs on floating wooden rafts (which acted as artificial latrine and feeding platforms) and on the adjacent bank. The latrine data were used to quantify water vole occupancy at the different management types, and the feeding signs data enabled food plant preferences to be studied. The latter section of this report focuses on a coir roll revetment case study to examine the efficacy of coir roll revetments to mitigate development by encouraging water voles to previously unoccupied sites.

The key findings outlined in this report are that water voles appear to favour coir roll revetments over other management types, and that the abundance of sedge (which is particularly prevalent in coir roll revetments) is an important factor influencing water vole occupancy. The success of coir roll revetments may stem from their ability to reduce bank erosion and thus allow riparian vegetation, including pre-established plant plugs within the rolls themselves to persist and thrive. It appears that a balance is needed between having enough infrastructure to prevent bank erosion, but not too much as to prevent water voles from being able to burrow into the bank, and coir roll revetments appear to fit these criteria.

Prior to this study, only unquantified observations existed concerning the use of coir roll revetments to improve water vole habitats. The findings from this novel study strongly suggest that the installation of coir roll revetments is an effective means to encourage water voles to previously unoccupied sites, and thus mitigate the negative effects of human development. Developers and water management bodies should continue to use coir roll revetments for the benefit of water voles, as well as biodiversity more generally.

1. Background

As partial fulfilment of the requirements for an MSc in Conservation Science at Imperial College London, research was undertaken to quantify the effect of riparian management strategies on riverbank occupancy by breeding water voles (*Arvicola amphibius*). Data collection was undertaken in the Cambridgeshire and Norfolk Fens with particular focus placed on examining the effectiveness of coir roll revetments (a soft bioengineering approach) to improve habitats for water voles.

The European water vole is Britain's fastest declining native mammal, and is thus listed as a Biodiversity Action Plan (BAP) Priority Species (Powell & Milburn, 2011). According to the Wildlife and Countryside Act 1981, waterway management and maintenance must be kept to a minimum in areas occupied by water voles in order to avoid disturbance (HMSO, 1981). Furthermore, the Natural Environment and Rural Communities (NERC) Act 2006, section 40 obliges Internal Drainage Boards (IDBs) to create suitable habitats to benefit wildlife, whilst carrying out flood prevention duties in their districts (Cook, 2006). Regardless of whether or not water voles are detected in the vicinity of proposed development, local waterway management bodies may require that developers consider and mitigate potentially negative impacts to suitable habitats.

This report seeks to answer the following research questions:

1. Does water vole occupancy differ between coir roll revetments and four other management types?
2. To what extent have the coir roll revetments and their pre-established plant plugs persisted since their installation?
3. Are the pre-established plant plug species embedded in the coir roll revetments suitable food plants for water voles?
4. How effective is the mitigation strategy of installing coir roll revetments to encourage water voles to previously unoccupied sites (Fillenham's Drain development case study)?

Please note that this report has been summarised from a lengthier dissertation and therefore much of the finer detail (particularly of the methods and results) has been excluded.

2. Methods

2.1 Study location

Fieldwork was undertaken along the banks of the Middle Level Commissioners (MLC) main drains and Internal Drainage Board drains in the MLC catchment (Cambridgeshire and Norfolk Fens) between the 12th April and 7th July 2017. This fieldwork involved the selection and subsequent surveys of 110 survey sites which extended between 52°27'17"–52°36'29"N and 00°00'04"W–00°19'04"E (Figure 2). Of these 110 survey sites, 22 were assigned to each of the following five distinct riparian management types (see also Figure 1 for photos):

1) *Bare bank*: Devoid of any management (hard engineering or bioengineering) and partially eroded (<50% of the bank toe's length was vegetated).
2) *Natural sedge bank*: >50% of the water's edge vegetation was comprised of sedge species (Cyperaceae). Devoid of bank management, other than annual or biannual mowing.
3) *Sedge plug ledge*: A circa 30 cm wide soil shelf (also known as a berm) installed just above the summer water level and planted with pre-established lesser pond sedge plugs (*Carex acutiformis*).
4) *Coir roll revetment*: A type of organic living revetment consisting of a series of 3 m long by 30 cm diameter cylindrical meshed nets containing coir (coconut husk material) and five pre-established riparian plant species (lesser pond sedge (*Carex acutiformis*); purple loosestrife (*Lythrum salicaria*); yellow flag iris (*Iris pseudacorus*); reed canary grass (*Phalaris arundinacea*); soft rush (*Juncus effusus*)). Coir rolls are secured against the bank at the water's edge using wooden posts. Section lengths needed to measure >21 m for statistical purposes.
5) *Hard engineering*: Corrugated metal sheets and wooden boards enclosing flint stones at the water's edge.

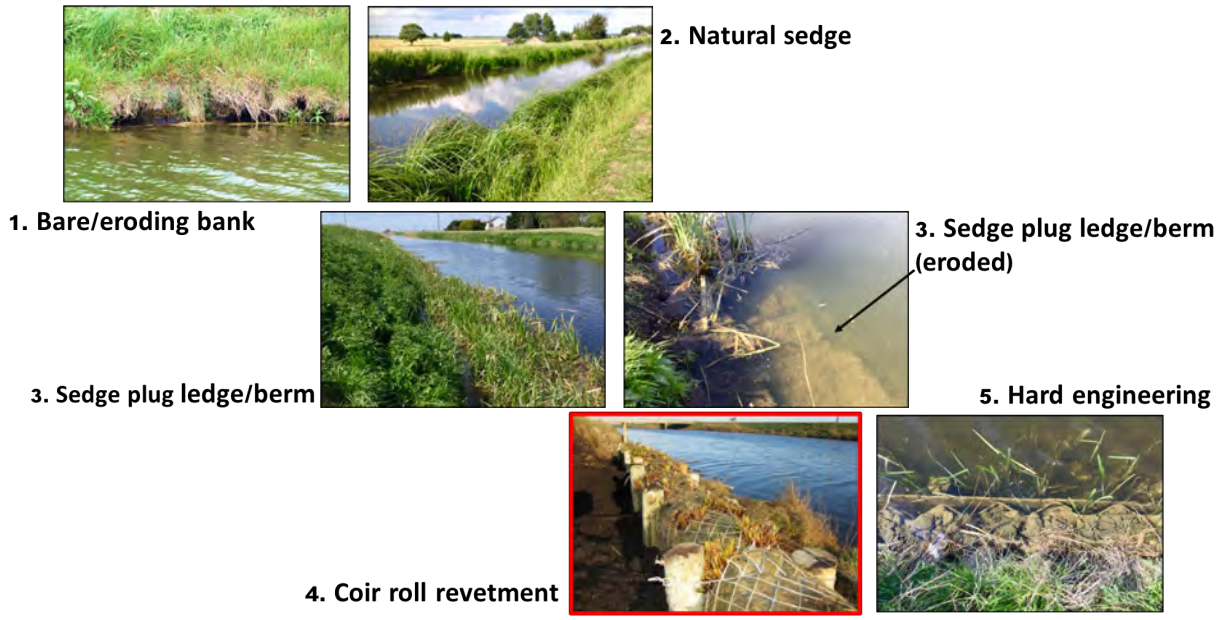


Figure 1. The five management types surveyed for water voles during the study, with coir roll revetment outlined in red (C. Carson, 2009; L. Stoddart, 2017).

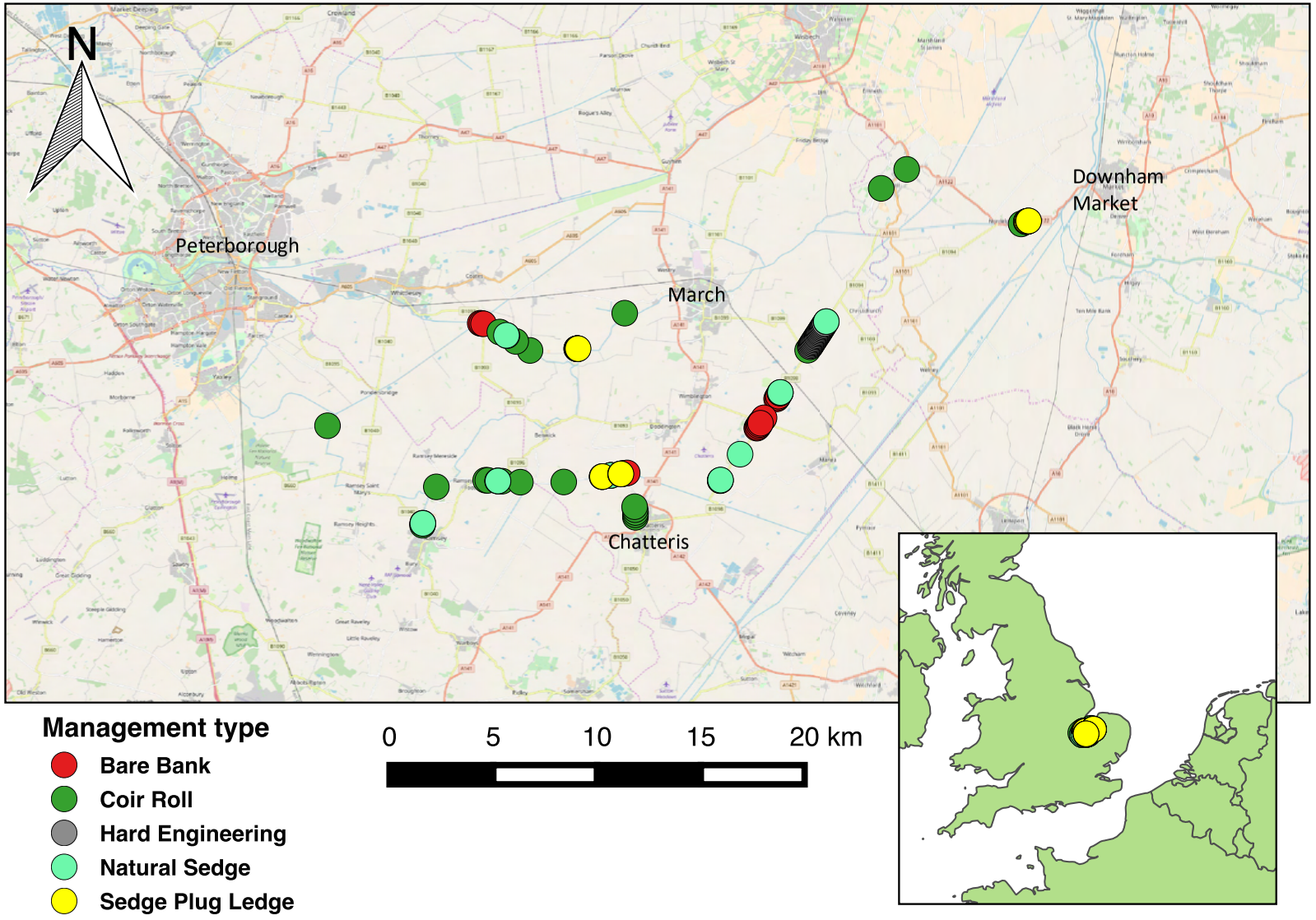


Figure 2. Locations of the 110 survey sites (22 within each management type) situated along the Fenland drains (created using QGIS with an OpenStreetMap basemap, 2017).

2.2 Field data collection

At each of the 110 survey sites (Figure 2), a wooden raft measuring 40x20 cm was installed by tethering it to the bank using string and bamboo canes. These rafts acted as artificial latrine and feeding sites allowing the presence of water voles to be easily recorded (following Richards et al., 2014).

One week after installation, each raft and the 4 m of adjacent bank up/down stream was surveyed for the presence of water vole latrines, droppings and feeding remains (prior to their removal). Three subsequent surveys at each site were carried out at two-week intervals. Latrines differ from droppings in that they are indicative of territorial breeding individuals at occupied sites. For the purpose of this study, latrines were described as an aggregation of >6 droppings which had been flattened by the 'drumming' of water voles' hind feet during scent marking (Strachan & Jefferies, 1993; Neyland et al., 2010).

The estimated abundances of four of the five pre-established coir roll plant species (lesser pond sedge, purple loosestrife, yellow flag iris and soft rush) were recorded during each survey visit using the DAFORN scale (Dominant, Abundant, Frequent, Occasional, Rare and None) (Kent & Coker, 1992), to assess their survival rates since coir roll installation. One of the five plant plug species (reed canary grass) was not surveyed, since its identification was difficult.

2.3 Data analysis

The number of survey sites at which water vole latrines were detected (during at least one of the four survey visits) was calculated for each management type. This enabled the construction of pie charts showing the percentage of sites occupied by water voles for each management type. Only latrine data were used in analysis, since latrines are indicative of permanent occupancy, unlike droppings or feeding remains which could be left by transient individuals (Neyland et al., 2010). For simplicity, this report only refers to the raw and percentage data, excluding the more in-depth dissertation statistical analysis. For details regarding this more in-depth analysis and the results that it produced, please contact the author.

DAFORN vegetation abundance scores were converted to numeric values (Dominant = 5 to None = 0) in order to present the data as figures.

3. Results and discussion

3.1 Effect of management type on water vole occupancy

The latrine presence/absence data revealed that 21/22 (95.45%) of the coir roll revetment survey sites were occupied by breeding water voles (latrines recorded during at least one of the four survey visits) (Table 1, Figure 3). More coir roll revetment sites were occupied than sites of any other management type, with their occupancy being even higher than natural sedge, which had 19/22 (86.36%) of occupied sites. Bare bank was the least occupied management type, with only 9/22 (40.91%) of sites being occupied (less than half the number of occupied sites than that of coir roll revetments).

Hard engineering and sedge plug ledge management types both yielded a moderate site occupancy (13/22 or 59.09%) (Table 1, Figure 3). Occupancy of hard engineering sites was perhaps higher than expected considering the impenetrable materials from which the management type is formed, and the comparatively low plant diversity. On the other hand, occupancy of sedge plug ledge sites (a much softer management approach) was perhaps lower than expected. This could partly be attributed to the fact that the ledges offered limited protection for the young sedge plugs, which were therefore eroded and failed to become established. Consequently, the vegetation cover in this management type was generally relatively low. There is an indication that erosion protection is an important and pivotal factor in determining vegetation cover of banks, and therefore suitability for water voles. It is possible that a trade-off between the effective erosion protection offered by harder engineering options, and preferential bank/vegetation characteristics offered by softer approaches must be met in order to achieve the highest occupancy. Coir roll revetments possibly meet this compromise effectively, as the dense, protective coconut husk material and meshed netting, supported by wooden posts may absorb the hydraulic power of the river. These features have likely allowed the plants within the coir rolls, and the surrounding bank vegetation to avoid erosion damage and become established, whilst simultaneously still offering a bank which is penetrable to burrowing water voles. Another explanation for the success of coir roll revetments (and indeed natural sedge banks), is that they both have a high abundance of sedge (Figure 6), a key provider of food and shelter for water voles (Bonesi et al., 2002; Strachan et al., 2011). Bare bank and hard engineering sites were distinctly lacking in sedge, whilst the sedge which had been planted at sedge plug ledge sites had largely been eroded away or replaced by common reed (*Phragmites australis*). The lack of sedge (and the reduced vegetation diversity in general) at bare bank sites is likely due to the lack of protection from erosion.

Table 1. Water vole occupancy (indicated by the presence of latrines observed during at least one of the four survey visits) for each of the management types.

Management type	*No. of sites occupied by water voles (/22)*	*Percentage of sites occupied by water voles*
Bare bank	9	40.91
Natural sedge	19	86.36
Sedge plug ledge	13	59.09
Coir roll revetment	**21**	**95.45**
Hard engineering	13	59.09

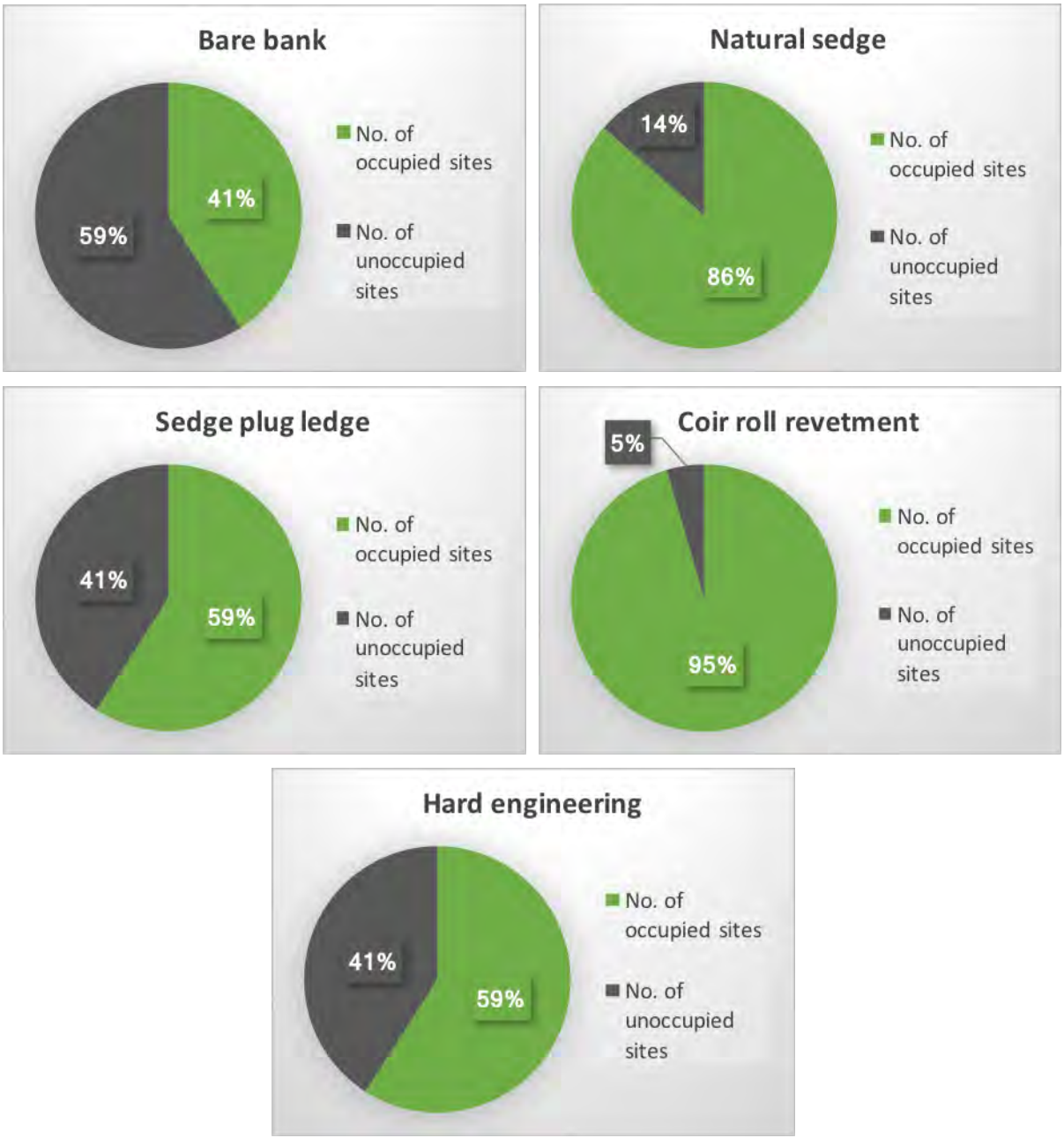


Figure 3. Percentage of the 22 survey sites occupied by water voles for each management type.

3.2. Water vole signs summary across management types

Following the trends displayed in Figure 3, Table 2 reveals that not only did coir roll revetments and natural sedge have the most occupied sites (as indicated by latrines), but they also had the greatest mean number of droppings recorded per survey visit (12.33 and 11.89 respectively). Additionally, the number of survey visits during which feeding remains were found was highest for coir roll revetments (averaging 1.36/4 survey visits), again indicating high water vole activity. Bare bank sites were second most likely to have feeding remains recorded during survey visits (averaging 1.22/4 survey visits). The high occurrence of feeding remains on bare banks may simply be due to the fact that they were easier to see on the eroded and less vegetated banks.

Table 2. The overall mean number of droppings recorded per survey visit, and the mean number of surveys (/4) during which latrines and feeding remains were recorded for each of the five management types.

Management type	Mean no. of droppings recorded per survey visit	Mean no. of surveys visits (/4) during which latrines were recorded	Mean no. of survey visits (/4) during which feeding remains were recorded
Bare bank	7.125	1.00	1.22
Natural sedge	11.89	2.00	0.64
Sedge plug ledge	10.78	1.05	0.68
Coir roll revetment	12.33	2.18	1.36
Hard engineering	8.89	1.00	0.68

Some form of water vole sign (droppings, latrines or feeding remains) were found at every coir roll revetment site (Table 3), further suggesting that coir roll revetments provide suitable habitats for water voles. The mean number of droppings recorded during survey visits was 12.33, with particularly high dropping prevalence at sites 1, 5, 7, 19, 21, and notably FIllenham's Drain sites 8, 9, 10 and 12. Feeding remains were recorded during all four visits at coir roll revetment sites 2 and 15.

Table 3. Water vole survey raft and bank signs data (droppings, latrines and feeding remains) for the 22 coir roll revetment survey sites (data collected May – July 2017).

Site no. (site name)	**Mean no. of droppings recorded per survey**	**No. of surveys (/4) during which latrines were recorded**	**No. of surveys (/4) during which feeding remains were recorded**
1 (Bedlam Bridge)	20.75	3	0
2 (Betty's Nose Pumping Station)	10.5	3	4
3 (Burnt House Bridge)	8.5	1	1
4 (Cock Fen Pegs 135-137)	6.5	4	1
5 (Cock Fen 93-95)	21.25	2	2
6 (East of Nordelph)	9	1	0
7 (Engine Farm)	28.25	1	1
8 (Fillenham's Drain 1)	22	3	2
9 (Fillenham's Drain 2)	36.5	2	2
10 (Fillenham's Drain 3)	14	4	2
11 (Fillenham's Drain 4)	9.25	3	1
12 (Fillenham's Drain 5)	16.25	3	2
13 (Hollow Road 1)	1.75	0	0
14 (Hollow Road 2)	8.75	2	0
15 (Lowside Outwell 1)	8	2	4
16 (Nene Golf Course)	8.25	1	1
17 (Puddock Bridge)	0	1	1
18 (Ramsey Forty Foot)	4.5	3	2
19 (Ramsey High Lode 1)	15.25	3	2
20 (Ramsey High Lode 2)	6	3	1
21 (Top Hake's Farm)	15.25	2	0
22 (Upwell Cemetery)	0.75	1	1
Overall mean	**12.33**	**2.18**	**1.36**

3.3 Plant feeding remains across all management types

Across all 440 survey site visits, 13 plant groups were identified from feeding remains (Figure 4). Of these plant groups, reed sweet-grass was recorded 44 times (10% of all visits), making it the most commonly recorded food plant. The second mostly frequently recorded food plant was sedge (during 38/440 or 8.64% of survey visits) and the third was grass (during 25/440 or 5.68% of survey visits). The feeding remains data suggest that sedge was the preferred food source, however when sedge was not readily available, reed sweet-grass was the main substitute (compare Figure 5 with Figure 6). For example, at bare bank sites (which incidentally, had the lowest water vole occupancy), reed sweet-grass was recorded on 20/33 occasions (over half of all feeding remains recordings) (Figure 5). Conversely, coir roll revetment sites (which had the highest occupancy) were dominated by sedge and subsequently had the most sedge feeding remains.

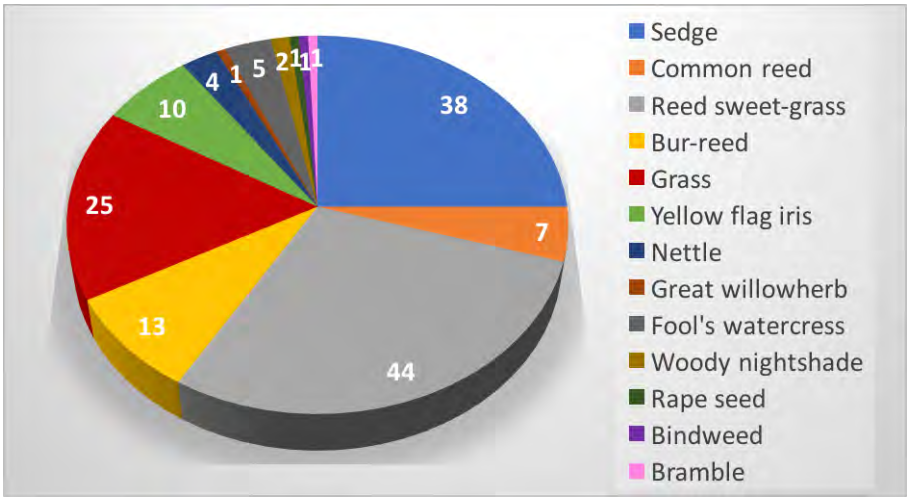


Figure 4. The number of all 440 site survey visits during which plant groups were identified from feeding remains across all management type survey sites.

Generally, water vole occupancy appears to be positively correlated with the number of survey visits during which sedge feeding remains were found (compare Figure 5 with Figure 6). This is especially true for coir roll revetment (n = 17) and natural sedge sites (n = 8), which had the most occupied sites. However, sedge feeding remains were also found during a relatively high number of sedge plug ledge survey visits (n = 10), which was among the least occupied of the management types; this exception may be explained by the fact that vegetation was relatively sparse at these sites and the sedge plugs (although mostly eroded away) provided one of the few food sources. Even if sedge is a particularly important feature defining habitat suitability for water voles, it seems likely that, in its relative absence, water voles are able to (at least partially) compensate by feeding on a range of other plant groups. The highest diversity of plant groups identified from feeding remains (9) was recorded at bare bank and sedge plug ledge (8) sites (Figure 5), where the abundance of sedge was relatively low compared with coir roll revetment and natural sedge sites (as shown in Figure 6).

Thirty (34.09%) of the 88 coir roll revetment survey visits (four visits to each of the 22 sites) revealed the presence of water vole feeding remains (more than at any other management type. Of these feeding remains, sedge was the most commonly occurring plant group, recorded 17 times (19.32% of all feeding remain records) (Figure 5). Reed sweet-grass (*Glyceria maxima*) (n = 10), closely followed by yellow flag iris (n = 8), were the next most frequently recorded food plants (11.36% and 9.09% of all feeding remain records respectively). Sedge and yellow flag iris were both incorporated in the original coir roll as pre-established plant plugs; their popularity as water vole food sources (as indicated by the feeding remains) is encouraging, and it would therefore be advisable to include these plants in future coir roll revetments. Although reed sweet-grass was the most frequently occurring plant in feeding remains across management types, and the second most frequently occurring plant in feeding remains at coir roll revetment sites, it is inadvisable to include plugs of the species in future coir roll revetments. Reed sweet-grass is often considered invasive owing to its tendency to block channels and displace other native plants, and thus requires frequent management (Carson, 2011; Weiss & Dugdale, 2017).

Of the five pre-established plant plug species incorporated in the coir rolls, only sedge and yellow flag iris (and possibly reed canary grass) appear to have been eaten by water voles (according to feeding remains) (Figure 5). No feeding remains were found for purple loosestrife nor soft rush across all five management types, despite their inclusion as pre-established plant plugs in the coir rolls. It is possible that these two species could have been eaten without feeding remains being left. Reed canary grass (the fifth pre-planted plug species incorporated in the coir rolls) could not reliably be identified from other grasses in the feeding remains, but may well have been present.

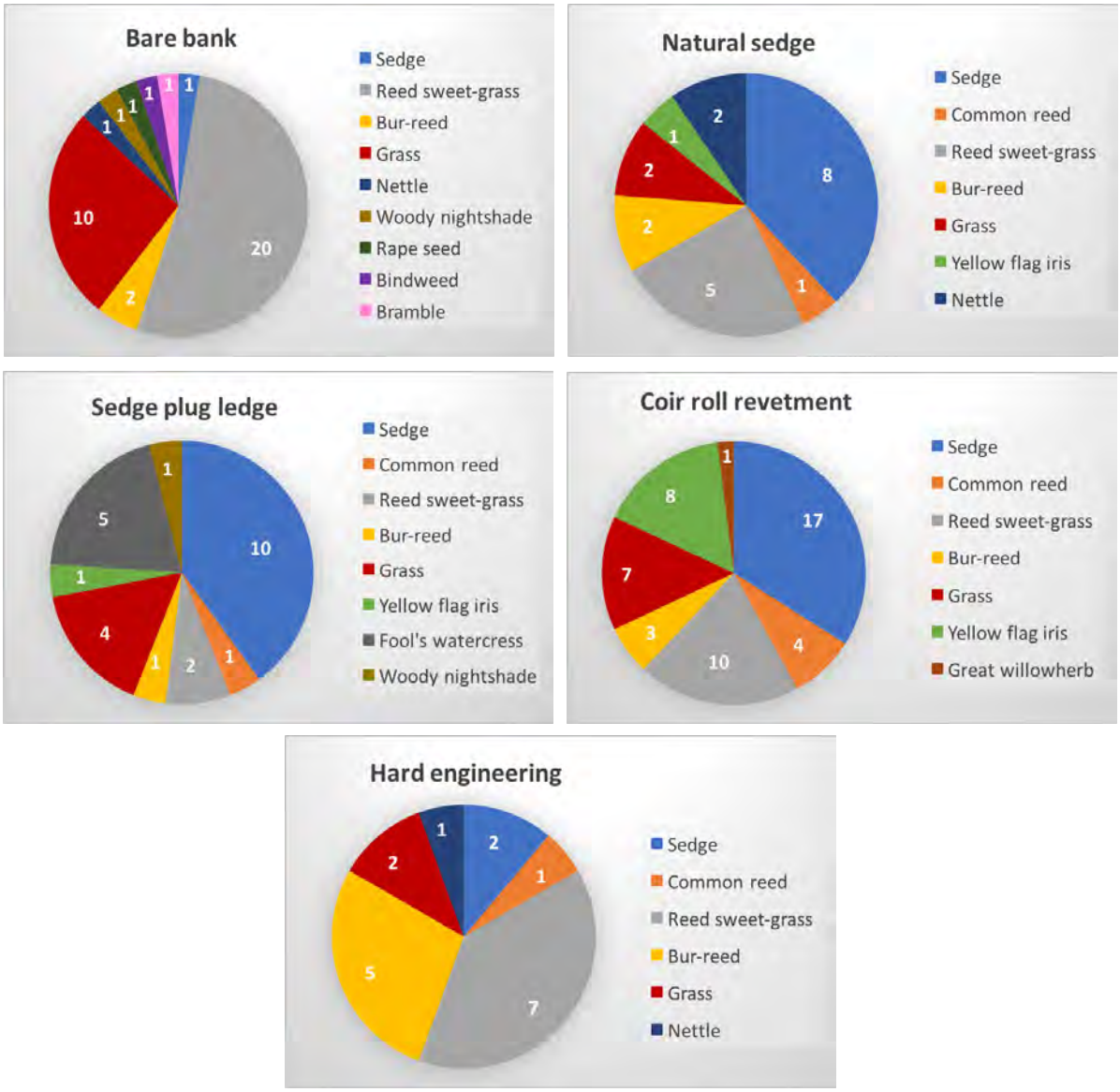


Figure 5. The number of survey visits during which plant groups were identified from feeding remains at each management type (four visits at each management type's 22 sites).

3.4 Reed sweet grass and sedge abundance according to DAFORN scores

As previously alluded to, the same general trend can be seen in Figures 5 as in Figure 6, in that more sedge and reed sweet grass feeding remains were found where these species were more plentiful. In particular, sedge was especially abundant at coir roll revetment and natural sedge sites (DAFORN scores 3.43 and 3.41 respectively). Reed sweet grass was most abundant at bare bank and hard engineering sites (DAFORN scores 2.06 and 1.57 respectively).

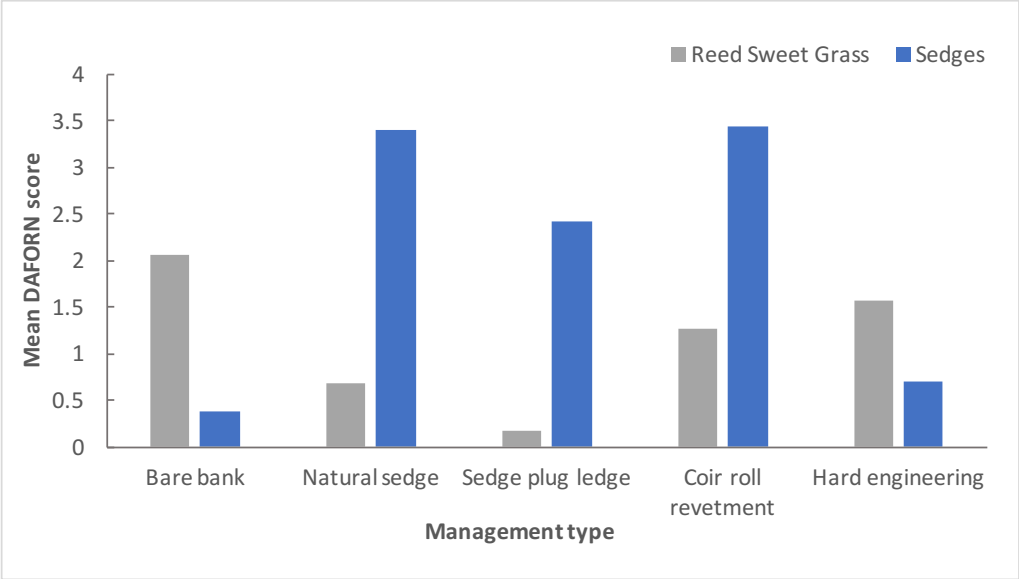


Figure 6. Mean DAFORN abundance scores (5 = Dominant; 4 = Abundant; 3 = Frequent; 2 = Occasional; 1 = Rare; 0 = None) for the two most dominant food plants (reed sweet grass and sedge) across the five management types.

3.5 Survival of coir roll revetment plant plug species since installation

Of the five pre-established plant plug species incorporated in the coir rolls, reed canary grass was not recorded during survey visits since it could not reliably be identified from other grass species. Considering the other four species, lesser pond sedge was by far the most abundant, with a DAFORN abundance score of 3.43 (Figure 7), indicating that it has persisted and established well. The second most abundant plant plug species was yellow flag iris, with an abundance score of 1.28, less than half that of the sedge. Purple loosestrife and soft rush were the least abundant plant plug species within the coir rolls, with abundance scores of 0.83 and 0.14 respectively; these low abundance scores indicate that these species did not establish as successfully, possibly due to species competition.

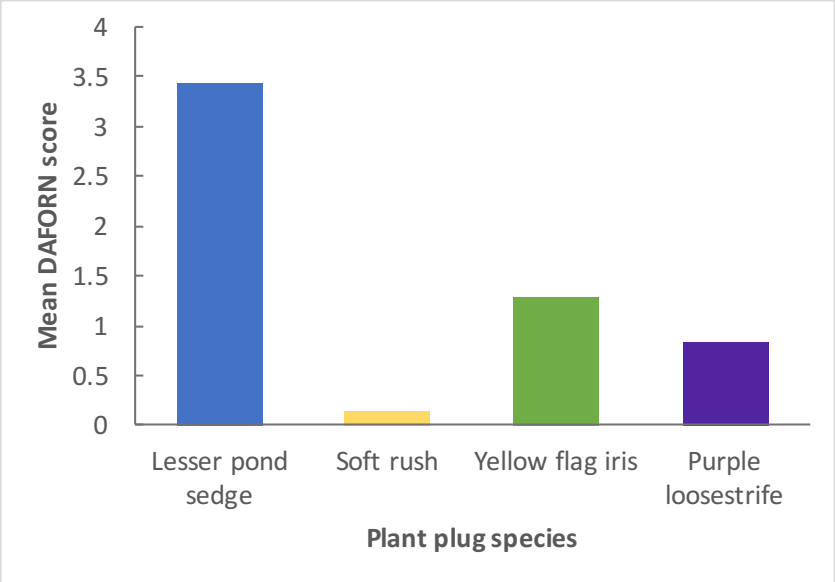


Figure 7. Mean DAFORN abundance scores (5 = Dominant; 4 = Abundant; 3 = Frequent; 2 = Occasional; 1 = Rare; 0 = None) for four of the five pre-established coir roll revetment plant plug species.

3.6. Effect of vegetation height on water vole occupancy

At each of the 110 survey sites, the mean vegetation height at the water's edge was measured at approximately 4 m up/down stream from the raft. This was done using a sward stick consisting of a 40x40 cm polystyrene board with a central hole, through which a pole marked with height gradations was inserted. Statistical analysis revealed that there was a height threshold of approximately 60-70 cm (below the average vegetation height of 90.18 cm across management types) at which water vole occupancy rapidly increased. These findings are important for informing waterway management bodies; to encourage water voles, a margin of at least 50 cm should be left unmown at the water's edge. However, if

mowing at the water's edge is unavoidable, a minimum vegetation height cut of 65 cm would be best practice to maintain optimum cover for water voles.

3.7 Coir roll revetment case study: Fillenham's Drain, Chatteris

In addition to the more general research findings, this section examines the effectiveness of installing coir roll revetments as a pro-wildlife mitigation technique in response to human development. The case study in question is a section of the Fillenham's Drain located in Chatteris which was diverted in 2014 to enable the development of a Tesco supermarket. The Middle Level Commissioners (who manage the watercourse) gave planning consent for the diversion, under the condition that five sections of coir rolls (each 42 m long, totalling 210 m) were installed in the newly created channel to encourage water voles. Water voles were previously absent in this location, as ascertained from a 2014 survey (pers. comm. C. Carson, 2017), however mitigation was commissioned in order to replace the suitable habitat which had been lost.

The five coir roll revetment sites were located along the Fillenham's Drain in Chatteris, North Cambridgeshire (Figure 8), (Raft 1: 52.45821667, 0.039458024; Raft 2: 52.45929408, 0.039442233; Raft 3: 52.46028152, 0.039527962; Raft 4: 52.46153838, 0.039250368; Raft 5: 52.46277552, 0.038887282).

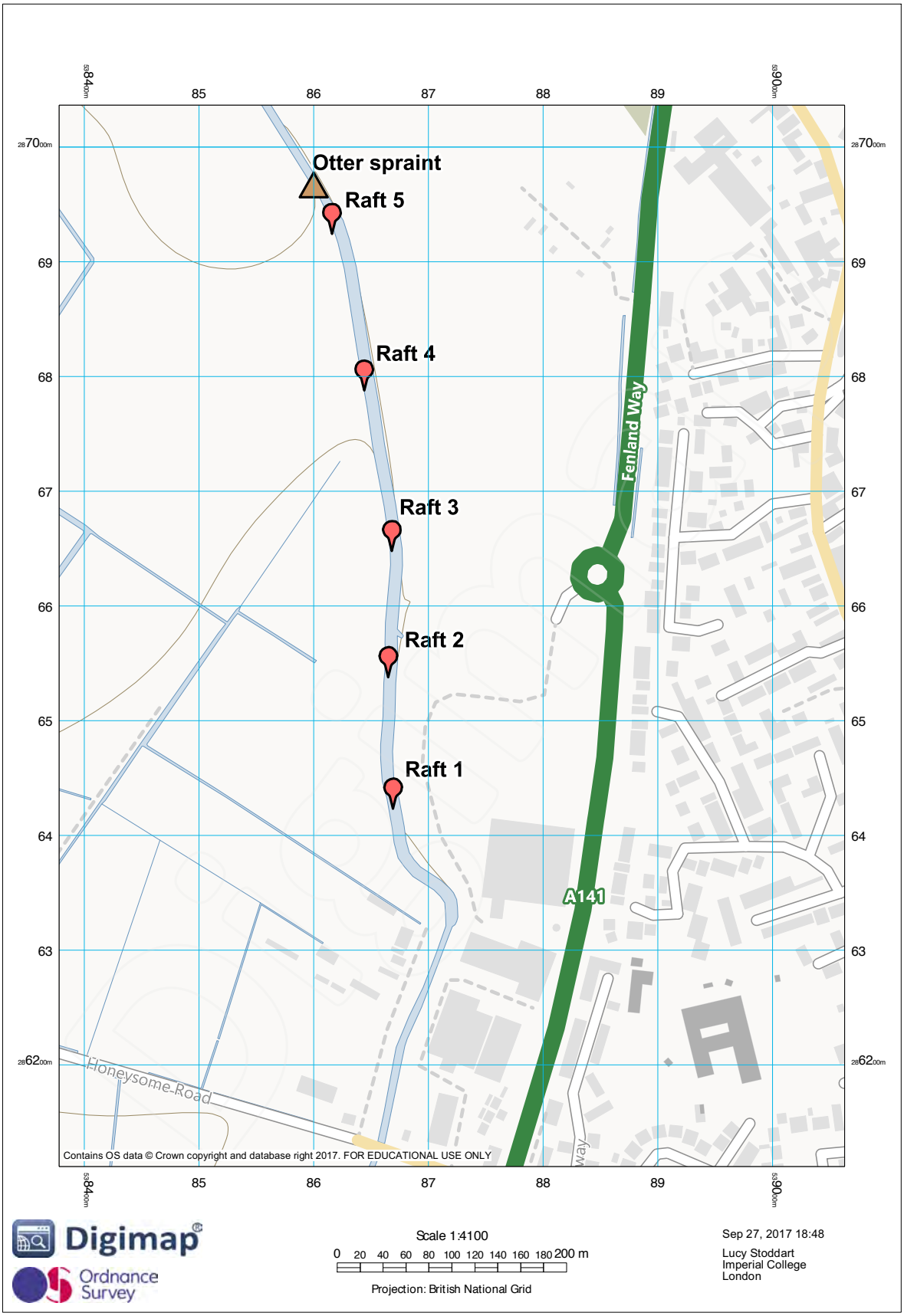


Figure 8. Locations of the five coir roll revetment survey sites along Fillenham's Drain, each marked by the placement of a water vole survey raft (Ordnance Survey, 2017). Also note the otter spraint located near raft 5 (See Figure 12e for photo).

3.7.1 Survival of Fillenham's Drain coir roll revetments and plant plugs

The 210 metres of coir roll revetments (installed in 2014) along the banks of the diverted section of Fillenham's Drain appear to be well established in terms of vegetation growth (compare Figure 9d from 2017 with Figures 9a and 9b from 2014). The growth of the pre-established plants within the coir rolls and the natural vegetation extending in front of the rolls themselves (Figure 9c) have created a densely vegetated and species-rich margin that has become self-sustaining. Of the five pre-planted coir roll species, lesser pond sedge appears to have colonised the rolls and surrounding bank particularly well (Figure 9d). Lesser pond sedge was present at all five survey sites and earned the highest mean DAFORN abundance score of 4.55 (Table 4). The next most abundant of the pre-planted species was soft rush, which was present at three of the five sites, but earned a DAFORN abundance score of just 0.60. The presence of yellow flag iris was not recorded at any of the five survey sites (possibly crowded out by other, more dominant plants), thus resulting in a DAFORN score of 0.00. The difference between these scores highlights just how successful pre-planted sedge plants have been at colonising the banks, compared with other species. Short grasses were the most abundant non-pre-planted species, earning a DAFORN abundance score 3.15.

The vegetated coir rolls appear to have prevented any potential erosion from the channel current, and fluctuations in water level. The wooden posts securing the coir rolls at the water's edge are still in place and the coir roll structure (netting and coconut husk material) is still intact, as shown in Figure 9c.

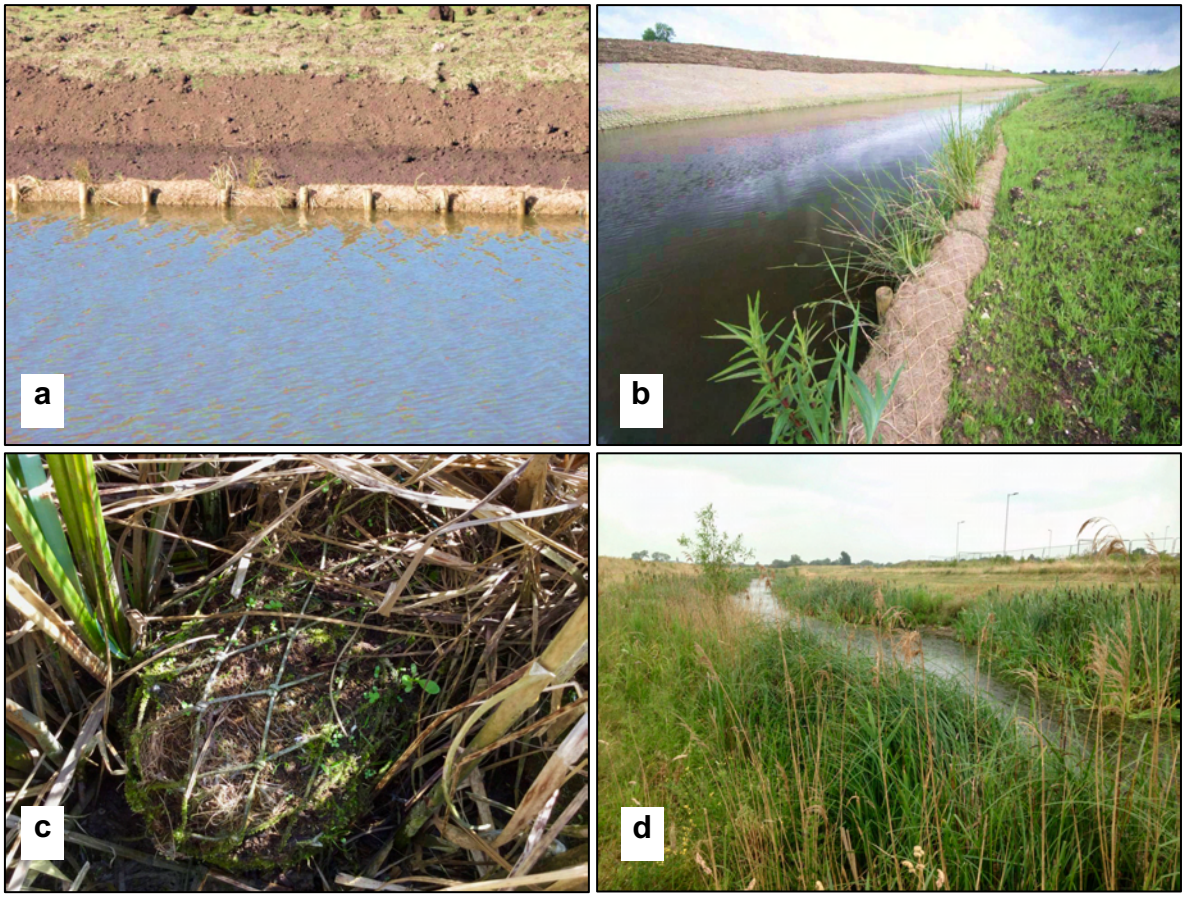


Figure 9. Fillenham's Drain coir roll revetments: (a) The bank just after installation (March 2014); (b) The bank two months after the installation showing pre-established plants beginning to thrive (C. Carson, May 2014); (c) The end of a section of coir roll located near raft 2 (L. Stoddart, 19th April 2017) (d) Site location of raft 2 (L. Stoddart, 6th July 2017).

Table 4. Presence and mean abundance of four of the five pre-planted coir roll plant plug species (5 = Dominant; 4 = Abundant; 3 = Frequent; 2 = Occasional; 1 = Rare; 0 = None). Note that these results are calculated from four visits to each of the five sites (May – June 2017).

Species	Lesser pond sedge	Purple loosestrife	Yellow flag iris	Soft rush
No. of survey sites where species was present (/5)	5	2	0	3
Mean DAFORN abundance score	4.55	0.45	0.00	0.60

3.7.2 Water vole occupancy at Fillenham's Drain coir roll revetment sites

Although water voles were not physically seen during any of the survey visits between May and June 2017 (they are predominantly crepuscular animals), their presence was frequently recorded through the observation of signs (droppings, latrines and feeding remains), both on survey rafts and on the banks (see Figure 10). Some form of sign was recorded during each of the sites' four survey visits. On average, approximately 20 droppings were recorded per survey visit and latrines were found during three out of every four survey visits (Table 5). The fact that latrines were recorded so frequently is a good indicator that the Fillenham's Drain coir rolls are occupied by breeding water voles, and not just visited by transient males looking for mates. It is also important to note that water voles were previously absent when the drain was newly constructed in 2014 (pers. comm. C. Carson, 2017). This shows that coir rolls are not only valuable as an option to improve habitats for existing water vole populations, but can also allow water voles to colonise new locations in a relatively short time period.

Table 5. Water vole survey raft and bank signs data (droppings, latrines and feeding remains) for the five Fillenham's Drain survey sites (data collected May – June 2017).

Site/Raft no.	Mean no. of droppings recorded during surveys	No. of surveys during which latrines were recorded (/4)	No. of surveys during which feeding remains were recorded (/4)
1	22	3	2
2	36.5	2	2
3	14	4	2
4	9.25	3	1
5	16.25	3	2
Mean	**19.6**	**3**	**1.8**

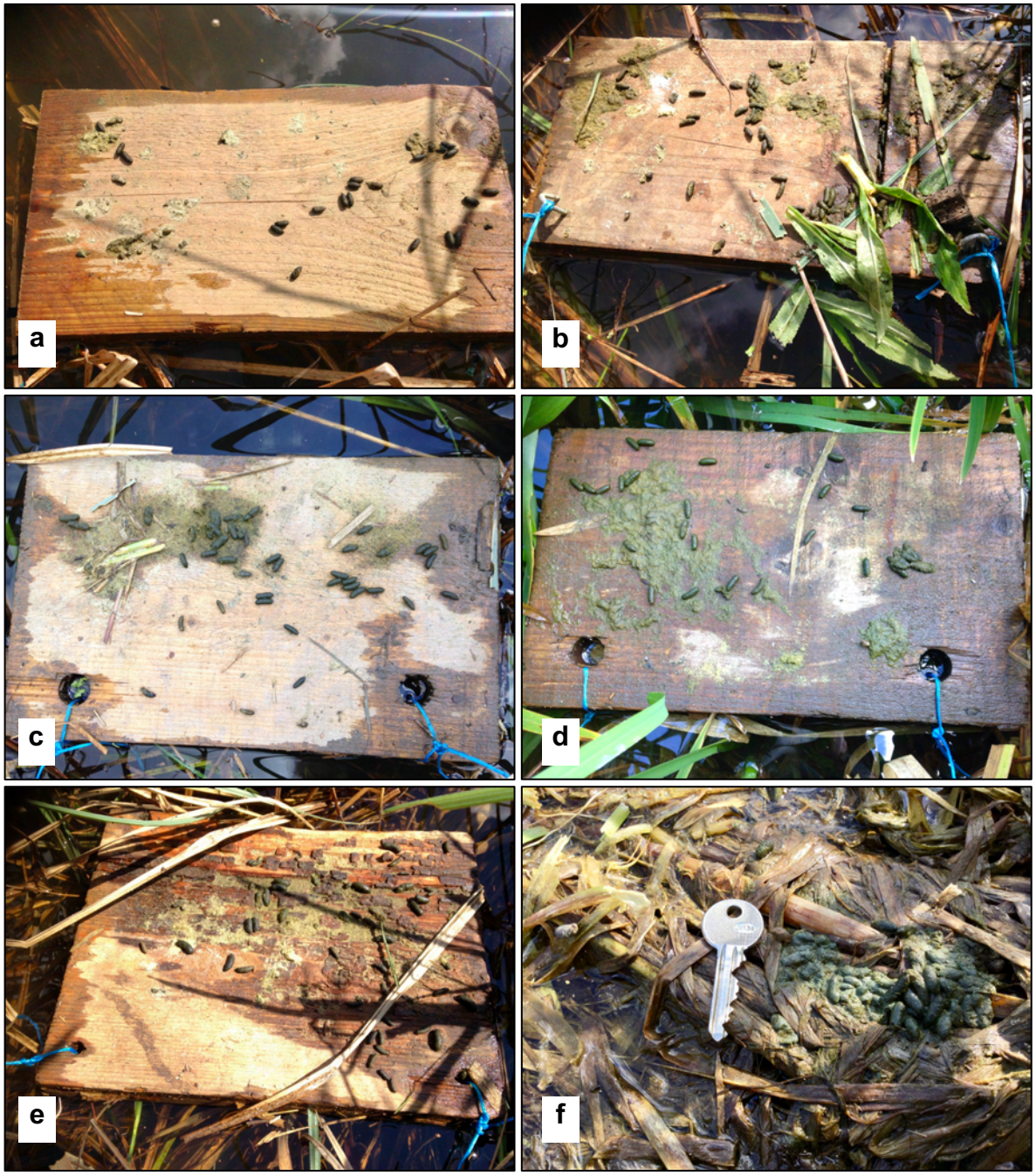


Figure 10. The five survey rafts acting as artificial latrine sites along the diverted section of Fillenham's Drain: (a) Raft 1; (b) Raft 2; (c) Raft 3; (d) Raft 4; (e) Raft 5 (L. Stoddart, 18th May 2017); and (f) A natural bank latrine site, with key for scale (L. Stoddart, 19th April 2017).

3.7.3 Water vole feeding remains at Fillenham's Drain coir roll revetment sites

The probability of finding feeding remains at Fillenham's Drain coir roll revetment sites was 1.8/4 (Table 5), i.e. feeding remains were found during almost half (45%) of the 20 survey visits (9% higher than at the 22 overall coir roll revetment survey sites).

As recorded for coir roll revetment sites more generally (Figure 5), sedge was the most frequently recorded plant from feeding remains at Fillenham's Drain sites (Figure 11). Sedge feeding remains were recorded during seven of the Fillenham's Drain survey site visits, making up 50% of all visits during which feeding remains were found. This finding indicates that sedge was perhaps proportionally even more important a primary food source at Fillenham's Drain sites than at coir roll revetment sites more generally. Aside from sedge, none of the other four pre-established coir roll plant species (yellow flag iris, soft rush, purple loosestrife and reed canary grass) were recorded from feeding remains, thus emphasising the importance of sedge. Common reed was the second most popular food plant at the Fillenham's Drain sites (n = 3), constituting 22% of feeding remains. Despite the relative popularity of common reed and reed sweet-grass as food plants, it is inadvisable to incorporate these plants in coir rolls for the benefit of water voles since they are deemed invasive for reasons previously mentioned for reed sweet-grass (Carson, 2011; Weiss & Dugdale, 2017). In addition to the feeding remains recorded during the survey visits, Bulrush (*Typha latifolia*) feeding remains were also recorded (on one occasion) outside of the survey period.

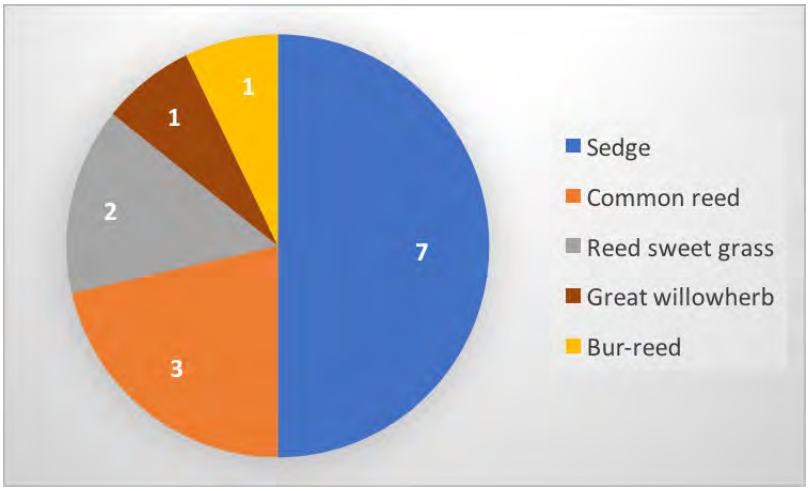


Figure 11. Number of the 20 Fillenham's Drain coir roll revetment survey visits (4 visits at each of the 5 sites) during which plant groups were identified from feeding remains.

3.7.4. Use of Fillenham's Drain coir roll revetment sites by other wildlife

As well as water voles, a variety of other species appear to have benefited from the creation of habitats, by the introduction of coir roll revetments at Fillenham's Drain, including those pictured in Figure 12. A suite of insects was observed during survey visits, including dragonflies and pollinators taking advantage of the biodiverse riparian flora (e.g. Figures 12a, 12b and 12d). Birds observed using the Fillenham's Drain riverbanks include moorhens (*Gallinula chloropus*) (Figure 12f), reed warblers *(Acrocephalus scirpaceus*), mute swans (*Cygnus Cygnus*) (as pictured in Figure 12c) and on one occasion, a grey heron (*Ardea cinerea*). Common buzzards (*Buteo buteo*) were also seen circling above the river on two occasions (possibly searching for water voles or other bank rodents). Perhaps the most interesting wildlife observation (other than water vole signs) was an otter spraint (Figure 12e), indicating that the Fillenham's Drain lies within an otter's territory.

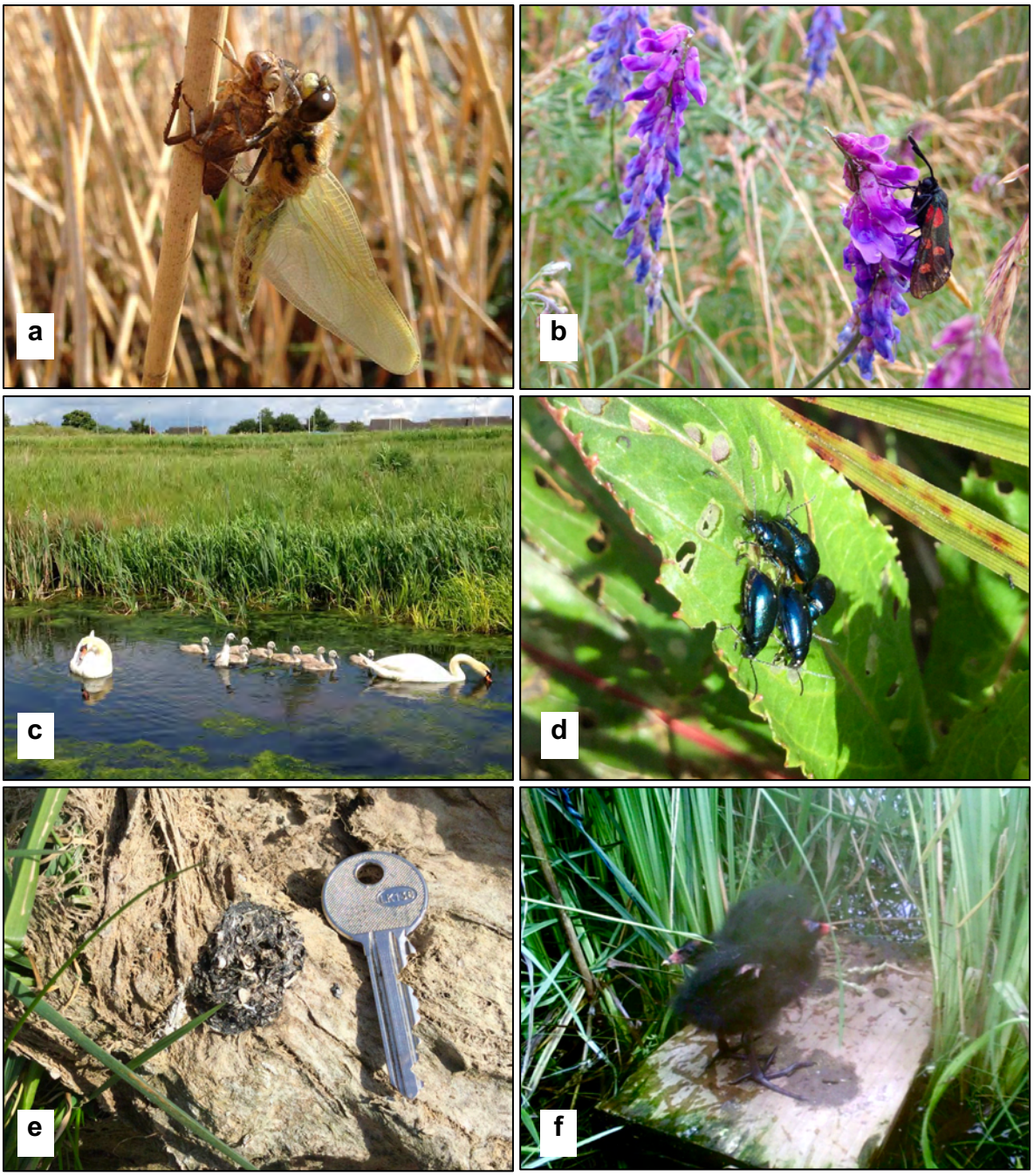


Figure 12. Other sympatric species benefiting from the coir roll installations at Fillenham's Drain: (a) An emerging female broad bodied chaser (*Libellula depressa*) (L. Stoddart, 18th May 2017); (b) A six-spot burnet moth (*Zygaena filipendulae*) extracting nectar from a tufted vetch (*Vicia cracca*) plant (L. Stoddart, 27th June 2017); (c) A pair of mute swans and nine cygnets (*Cygnus cygnus*); (d) Blue leaf beetles (*Altica sp*.) on a willowherb leaf (*Epilobium sp.*); (e) An otter (*Lutra lutra*) spraint located near raft 5 (L. Stoddart, 19th April 2017); (f) Two moorhen chicks (*Gallinula chloropus*) standing on a survey raft (C. Carson (trail camera), 25th July 2017).

4. Concluding statement

The results summarised in this report strongly suggest that water voles are more likely to occupy coir roll revetments than the other four management types surveyed in this study. The success of coir roll revetments in terms of water vole occupancy is likely due, at least in part, to the high abundance of sedge (a key provider of food and shelter). In general, management types characterised by more sedge appear more likely to be occupied by water voles. Where sedge is lacking, reed sweet grass appears to be eaten as a substitute.

Another possible explanation for the success of coir roll revetments is that they provide enough infrastructure to prevent the erosion of plants, thus allowing them to become established quickly, but not so much infrastructure as to prevent bank penetrability to water voles. The materials from which the coir roll revetments are made appear to withstand erosion very well, and of the pre-established plant plugs, sedge has survived the most successfully, followed by yellow flag iris. Incidentally, sedge and yellow flag iris were also identified from the most feeding remains found at coir roll revetment sites, indicating that they are suitable food plants for water voles. Two of the other pre-planted plug species (soft rush and purple loosestrife) were never recorded from feeding remains; it is of course possible however, that these species were consumed without the creation of food detritus. Regardless of whether or not these species were eaten by water voles, they may provide important habitats for other riparian species. In addition to incorporating suitable food plant species into the bank, vegetation height was found to be another important factor influencing water vole occupancy. Where possible, bank mowing should be avoided at the water's edge.

In terms of using coir roll revetments as a mitigation strategy in response to human development, the five survey sites along Fillenham's Drain have demonstrated marked success. These survey sites reveal particularly high water vole occupancy, just three years after the installation of the coir rolls along the newly created drain, where water voles were previously absent.

Finally, this study shows that the use of survey rafts is an effective, accessible, relatively cheap and reliable means by which to measure the presence of breeding water voles. The success of coir roll revetments to increase riverbank occupancy by water voles is quantifiably demonstrated for the first time, and previous unquantified observations are now supported. As well as the clear benefits to biodiversity, partly due to their ability to reduce erosion, coir roll revetments are an unobtrusive feature, which may appeal to developers wishing to install a riparian revetment with high aesthetic value. As a result, the implementation of coir roll revetments is strongly encouraged for future projects.

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