The Environmental and Socio-economic Impacts of Changing Agri-Environment Payments in Queens Sedgemoor, Somerset Levels.

A Report to the Somerset Wildlife Trust.

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1. Introduction

1.1 Need for the Study

Instigated in 1987, the Environmentally Sensitive Areas (ESA) scheme was the UK's first governmental scheme aimed at encouraging farmers and landowners to adopt environmentally friendly management practices. A total of 22 ESAs were designated in England between 1987 and 1994, with the Somerset Levels and Moors amongst the first to be chosen. The Somerset Levels and Moors are an extensive area of 35,000 ha which comprise one of the UK's largest remaining wetlands. They are internationally recognised for their biodiversity and archaeological interest and include 16 Sites of Special Scientific Interest (SSSIs), of which a subset are also designated under the Ramsar Convention and as Special Protection Areas under the European Union Directive on the Conservation of Birds. The aims of the Somerset Levels and Moors ESA were: *to protect and, where possible, enhance the wet permanent grassland character of the area, and its special landscape, wildlife and historical interests, by encouraging the maintenance and adoption of extensive pastoral farming systems*.

Farmers within the boundaries of the ESA were eligible to sign up to voluntary ten-year agreements which provided payments on a profits-foregone basis. The scale of the payments increased with the extent of 'conservation' management intervention. Initially agreements were banded into two distinct levels, or tiers, but this was later expanded to three tiers. Tier 1 represented the least intensive requirements for change and Tier 3 the greatest (see Armstrong and Bradley 2007 for more detail). The ESA scheme was superseded in 2005 by the Environmental Stewardship scheme, however, the majority of ESA agreements within the Somerset Levels and Moors only came to an end in 2012 or 2013.

The Environmental Stewardship scheme, now also superseded by the new Countryside Stewardship scheme, was also designed to offer farmers the choice of opting into voluntary environmentally-sensitive management agreements. Low impact management options were covered by the Entry Level Stewardship (ELS) tier and were paid a flat rate while higher intensity interventions were covered by a wide range of options offered within the Higher Level Stewardship (HLS) tier. In the Somerset Levels and Moors, ELS payments were considerably less than those available through the ESA Tier 1, but the payments available via HLS had the potential to provide greater remuneration per hectare than the ESA Tier 3 payments. Whilst the schemes were designed to be open to all land managers, restraints on public funding imposed since 2010 have led to HLS payments for the Somerset Levels and Moors only being made available, in all but a handful of cases, within areas designated as Sites of Special Scientific Interest (SSSIs). On the expiry of their ESA agreements, the

majority of farmers and landowners in the Somerset Levels and Moors had only the option of signing up for an ELS scheme or opting out of agri-environment schemes altogether. For those who had been in ESA schemes, the move from ESA to ELS represented a substantial drop in payments per hectare. In 2010 Tier 1 payments were £125 per hectare while ELS offered £30 per hectare in reward for carrying out similar actions. Payment levels are likely to decrease further under the new Countryside Stewardship schemes.

This drop in farm income may have important implications for the intensity of management within large areas of the Somerset Levels and Moors ESA. If farmers are responding to the loss of income by increasing the intensity of agricultural management operations, there may be a corresponding loss of environmental quality, biodiversity and ecosystem services (e.g. Reidsma *et al*. 2006; Stoate *et al*. 2009; Power 2010; but cf Boatman *et al.* 2010). Environmental degradation within upstream areas of the ESA has the potential to adversely affect not only the local area but also areas further downstream, including SSSIs, particularly via degraded water quality.

The Wildlife Trusts' 'Living Landscapes' initiative involves identifying, protecting, enlarging, improving and reconnecting key areas for wildlife. The restoration of healthy landscapes can also help alleviate flooding, control pollution and help wildlife and people adapt to our changing climate. Working with local partners and communities, the creation of inspirational, accessible, wildlife rich landscapes also provides opportunities for learning, better health and sustainable economic development. There are currently more than 100 Living Landscapes across the UK, two projects are based in Somerset: the Mendip Hills, and the Brue Valley. The need was identified, through the Somerset Wildlife Trust's Brue Valley Living Landscape Project, to assess the impacts of changes to agri-environment payments in the non-SSSI areas of the Somerset Levels and Moors.

The results will feed into the European Interreg IVb WOW (Value of Working Wetlands) project. WOW is a cross border project on sustainable wetland management with ten UK / French partner organisations.

1.2 Research Aims

The aim of the study was to characterise the current environmental quality of Queen Sedgemoor, particularly with respect to water quality, and assess whether changes to agri-environment payments are causing local farmers to intensify their agricultural operations.

1.3 Objectives of the Study

- Develop a baseline environmental description of the site, particularly with respect to water quality.
- Characterise the agricultural businesses and determine the reported impact of changes in agri-environment schemes on agricultural management practices in Queens Sedgemoor.
- Identify where current or proposed changes to agricultural management regimes may have implications for environmental quality.

2 Methods

2.1 Study Area

The research focussed this study on Queens Sedgemoor, a 679 hectare area located in the north east (landward) part of the Somerset Levels and Moors (ST5341). The area was chosen as it represents a microcosm of the wider Levels and Moors landscape. Lower, wetter land which contains areas of relatively high biological (particularly botanical) diversity gives way to more intensively farmed areas in the comparatively higher, drier areas. Furthermore, a risk-mapping exercise carried out by Somerset Wildlife Trust highlighted the peat soils of Queens Sedgemoor as being particularly at risk from changes in land management brought about by decreased agri-environment payments (appendix 1). The area does not contain any designated sites (SSSI, SPA, Ramsar) but 23 fields (73.5 ha, 11% of project area) were, and still are, of sufficient botanical interest to garner Tier 2 payments under the ESA scheme. One hundred and twenty two fields (397 ha, 58%) within the project area were entered into ESA Tier 1 agreements while a further two fields (9.6 ha, 1%) were entered into Tier 1A. The remaining 49 fields (199 ha, 29%) of the area was not part of the ESA scheme.

The project area is a shallow bowl, with lower regions towards the west of the area (lowest point 4m AOD) rising approximately 6 metres to a maximum height of 10m AOD to the north and east. The project area is bounded to the south by the Redlake and Hartlake rivers and to the west by the A39 (figure 1). In keeping with the landscape of much of the Levels and Moors, the area is characterised by grass fields surrounded by ditches. The majority of the area (521 ha) is underlain by deep fen peat. There are no dwellings within the project area and very few agricultural buildings. The area comprises 196 fields with an average size of 3.5 ha.

The project area lies within the upper reaches of the Somerset Levels are Moors and water drains from this basin through the northern section of the Brue Valley, through areas important for both agriculture and nature conservation.

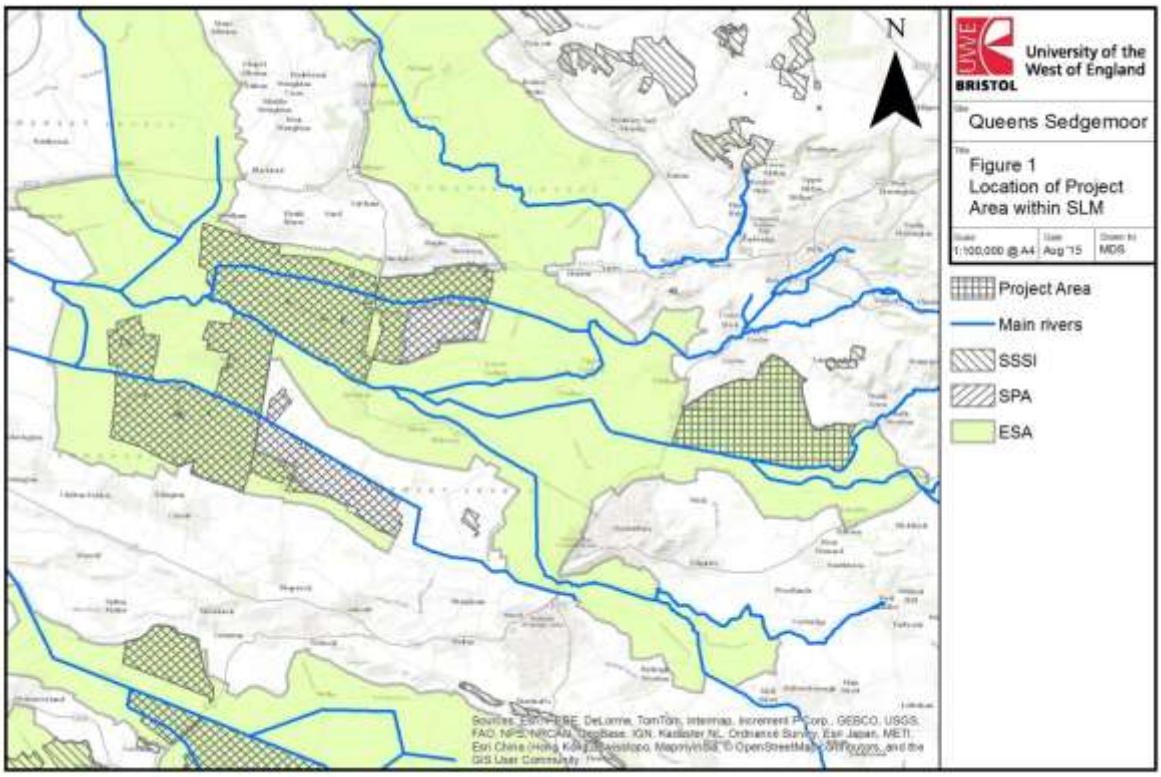

Figure 1: Location of project area within the context of the Somerset Levels and Moors Environmentally Sensitive Area (ESA), Special Protections Areas (SPA) and Sites of Special Scientific Interest (SSSI).

Water enters the south of the moor predominantly from a single entry point from the Redlake River (ST53654073), the north section of the moor is fed from a number of smaller water-bodies and direct run off from surrounding land. There is a single outfall into the Hartlake River (ST51314115) (Figure 2).

The financial impact of changed agri-environment payments was estimated by comparing the ESA history (ESA tier in 2007) and current ES options for each field using data supplied by Natural England. The total value of agri-environment payments were calculated for each field, allowing the variance between ESA and ES payments to be summed to provide an overall estimate of the change in agri-environment payment.

2.2 Water Quality Monitoring

Four metrics of water quality were measured every 15 minutes at three sites within the moor between 17th April and 29th June 2014. Two sites were situated in the upper waters of the moor, the third was located at the single outfall site (figure 2). Dissolved oxygen, conductivity, turbidity and temperature using a Eureka Environmental Manta 2™ Water Quality Multiprobe. Water depth was

measured (17/04/14 – 01/06/14) using Solinst Levelogger Junior® Model 3001 with a Solinst Barologger® Model 3001 used to compensate for variation in barometric pressure. Daily precipitation totals were obtained from Yeovilton airbase, approx. 17 km south of the project area.

Spot sampling of anion (Nitrate, Phosphate, Sulphate, Fluoride, Chloride, Bromide) concentrations were carried out on three occasions (1/5, 15/5 and 13/6) and cations (Lithium, Sodium, Ammonium, Potassium, Calcium, Magnesium) on two occasions (1/5 and 15/5). Water samples were taken at the site of each sonde and seven auxiliary sites (figure 2). Samples were kept refrigerated for a maximum of 48 hours before being analysed via ion chromatography using a Metrohm model 850 Pro-IC unit combined with a conductivity detector and fitted with a Metrosep A Supp 5 column.

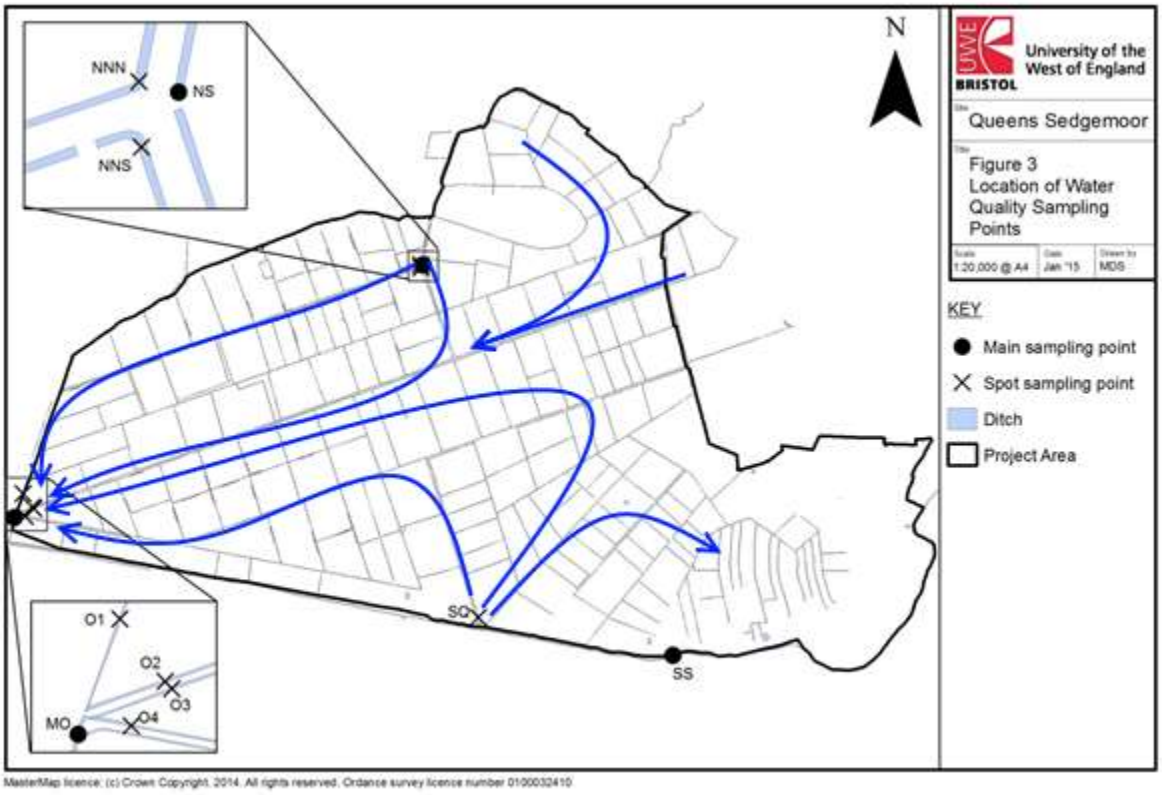

Figure 2: Location of main- and spot-sampling points. Blue lines are a simplified representation of water movement patterns through Queens Sedgemoor. Under high rain conditions, water movements can be very different, with water moving into the system from the west.

2.3 Characterisation of farms and reported impacts of AES on farm management

All landowners were contacted by letter and follow-up telephone call requesting a face-to-face interview. Semi-structured, face-to-face interviews were conducted between November 2013 and April 2014 to assess responses towards changing agri-environment payments. Four versions of the interview template were created to accommodate differences in farmers' previous and current experience of agri-environment schemes (participant within ESA scheme and/or ES). All interviews were carried out by an experienced farmer liaison officer (Catherine Mowat, Somerset Wildlife Trust) on site at each farm. Interviews lasted approximately one hour. Templates of each interview variant can be found in appendix 2.

Ethical approval for the study was given by the University ethics panel which examined the proposal, information sheets, main interview questions, and consent forms that would be provided to the volunteers prior to their agreement to participate. Participants were assured of anonymity, their right to withdraw, and the secure storage of all research materials such as transcripts.

3 Results

3.1 Description of Baseline Water Quality

3.1.1 Continuous Data

The data collected appears to represent a complex interplay of factors affecting water quality parameters in the project area. Water temperature increased relatively steadily throughout the study period at each monitoring station, gaining approximately four degrees Celsius over the course of the study period (fig 3). An ephemeral, but noteworthy, increase in water temperature was apparent in mid-May (peak 18th, 19th May); this corresponded with a period of significantly warmer weather.

Dissolved oxygen (DO) levels at the South Input (Redlake River) were high throughout the study, although exhibited a gradual decline (fig 4). By contrast, DO at the Northern Input showed a marked decline into hypoxic conditions (<30% saturation); by mid-May mean DO levels were relatively constant at just 6-7% and daily maxima never increased above 30%. The Outfall site also exhibited prolonged periods of hypoxic conditions punctuated by a transient recovery in mid- to late-May (fig 4, table 1).

Conductivity levels were relatively high (700 – 1000 µS) at all sites and, in general, remained relatively constant (fig 5). The North Input exhibited a sharp rise (+340 µS) between 26th-28th June which coincided with a substantial decrease in conductivity at the Outfall, which had undergone a

sustained increase during the previous three weeks, with the conductivity almost doubling to a peak daily average of 1777 µS. This pattern coincided with a period of relatively warm, dry weather followed by a heavy precipitation on 27/28th May.

Highly increased periods of conductivity at the North Input also coincide with increased turbidity and are suggestive of a significant input of nutrients via runoff within the local catchment, particularly as the precipitation event on 25/7 was the largest during the study: 22 mm falling in the day. This is not the case at the Outfall where increased conductivity coincided with a significant drop in turbidity (fig 6), which may suggest that run off is not occurring within the vicinity of the outfall and that larger particles from the run off are settling out from the water column before the water reaches the outfall. Dissolved ions (as measured by conductivity), however, remain at higher concentrations as water moves through the system, with average concentrations being higher near the outfall than at either of the inputs.

Table 1: Baseline statistics for four measures of water quality in Queens Sedgemoor: temperature, dissolved oxygen (DO), conductivity and turbidity. Minimum and maximum values are given for each measure along with median values or, for DO, the percentage of recordings under 30% saturation (hypoxic conditions)

	S_Input	N_Input	Outfall
Temp Min (°C)	7.89	9.74	7.08
Temp Med (°C)	12.85	14.68	16.75
Temp Max (°C)	18.92	19.66	20.69
DO Min (%Sat)	38.50	4.40	6.50
DO Max (%Sat)	146.70	67.10	139.50
Hypoxia	0%	84%	67%
Cond Min (µS)	5.20	481.20	444.60
Cond Med (µS)	847.40	657.90	972.30
Cond Max (µS)	934.90	1842.00	1777.00
Turb Min (NTU)	0.00	0.00	0.00
Turb Med (NTU)	43.90	8.20	13.70
Turb Max (NTU)	1640.00	1564.00	4784.00

Turbidity levels are highly variable. Periods of high turbidity are often related to precipitation events (fig 6), but not in every case. The most obvious, prolonged increase in turbidity occurred at the outfall in early- to mid-May. The cause of this increase is unclear. It may have been caused by water back-filling into the system from the Hartlake River, a process which can occur at times of high flow, but it is not associated with a significant rainfall event, so this seems unlikely. The close correlation between turbidity spikes and precipitation events may suggest that rain-created turbidity is a local phenomenon which doesn't travel far throughout the catchment before the suspended solids drop out of the water column.

3.1.2 Spot samples

Differing patterns of nutrient concentrations were apparent between nitrates and phosphates. Nitrate input is high at the southern intake and low in the northern system. Nitrates appear to decrease in concentration as water moves through the moor, suggesting that it is a nitrate-limited system (figure 7) although the apparent increase in ammonium concentrations suggests that some nitrates may be being converted to other forms of nitrogen inorganically. In general nitrates levels in the ditches adjoining the outfall (O1-O4) were greater in the ditches which drain the southern half of the moor (see appendix 3). This may be due to nitrate loading from the southern input, however, a single series of nitrate levels taken on 15/05/14 along a ditch running away from the input (SQ, see figure 2) indicated that nitrate levels dropped rapidly within the ditch system (see appendix 4)

Phosphate levels, by contrast, are relatively low at the southern intake (Redlake) and higher in the northern sections (table 2); they appear to increase as water moves through the moor and have reached a high enough concentration by the outfall for the water to be classed as poor according to revised WFD standards (figure 9). This is consistent with a nitrate-limited system where phosphate is either entering the system via fertiliser runoff or being released from the soil via chemical processes.

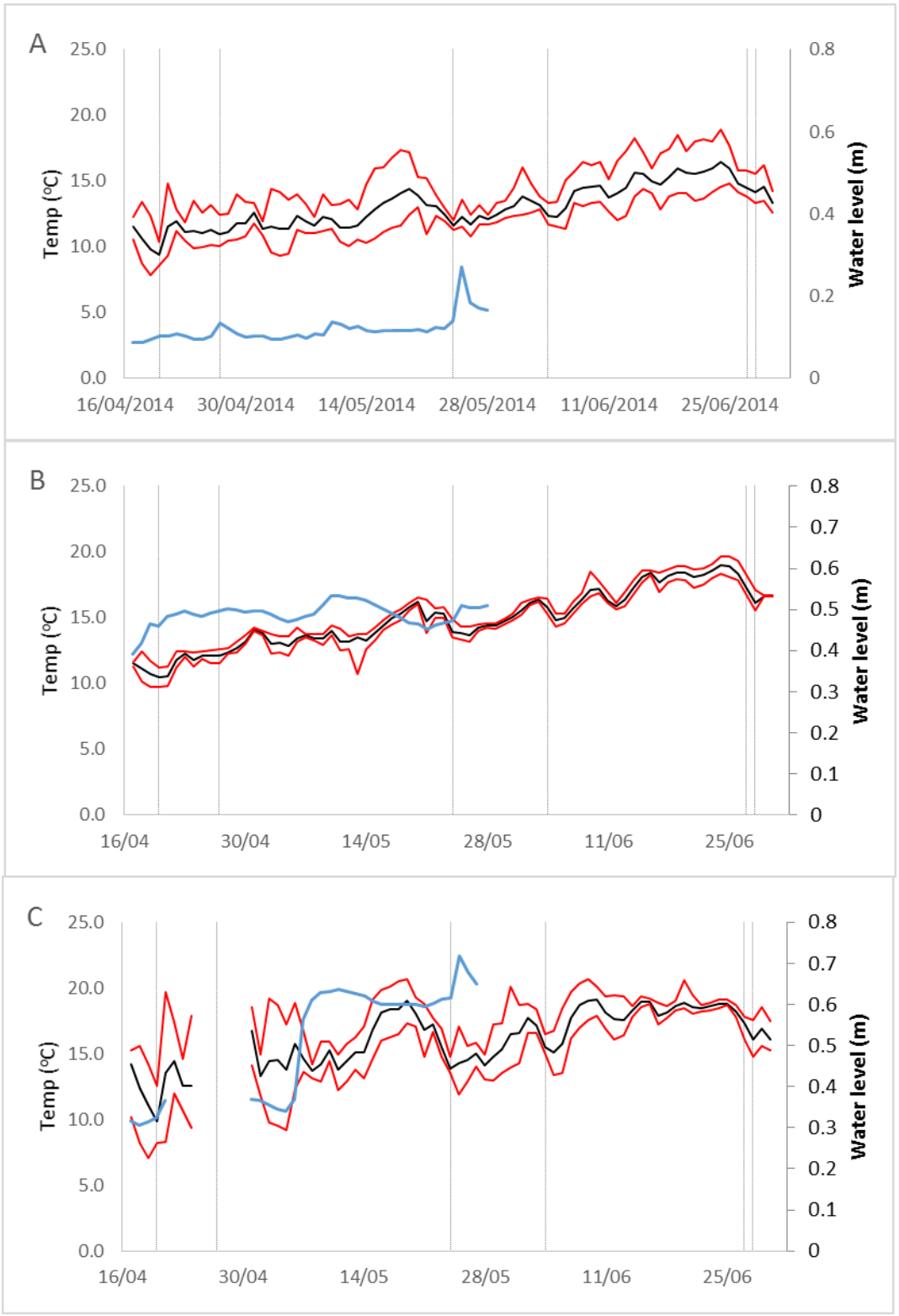

Figure 3: Mean (black), maximum and minimum (red) daily water temperatures at each main sample point over the duration of the study. A = redlake input, B = northern input, C = main outfall. Blue line denotes mean daily water level and vertical lines indicate significant precipitation event (>5mm).

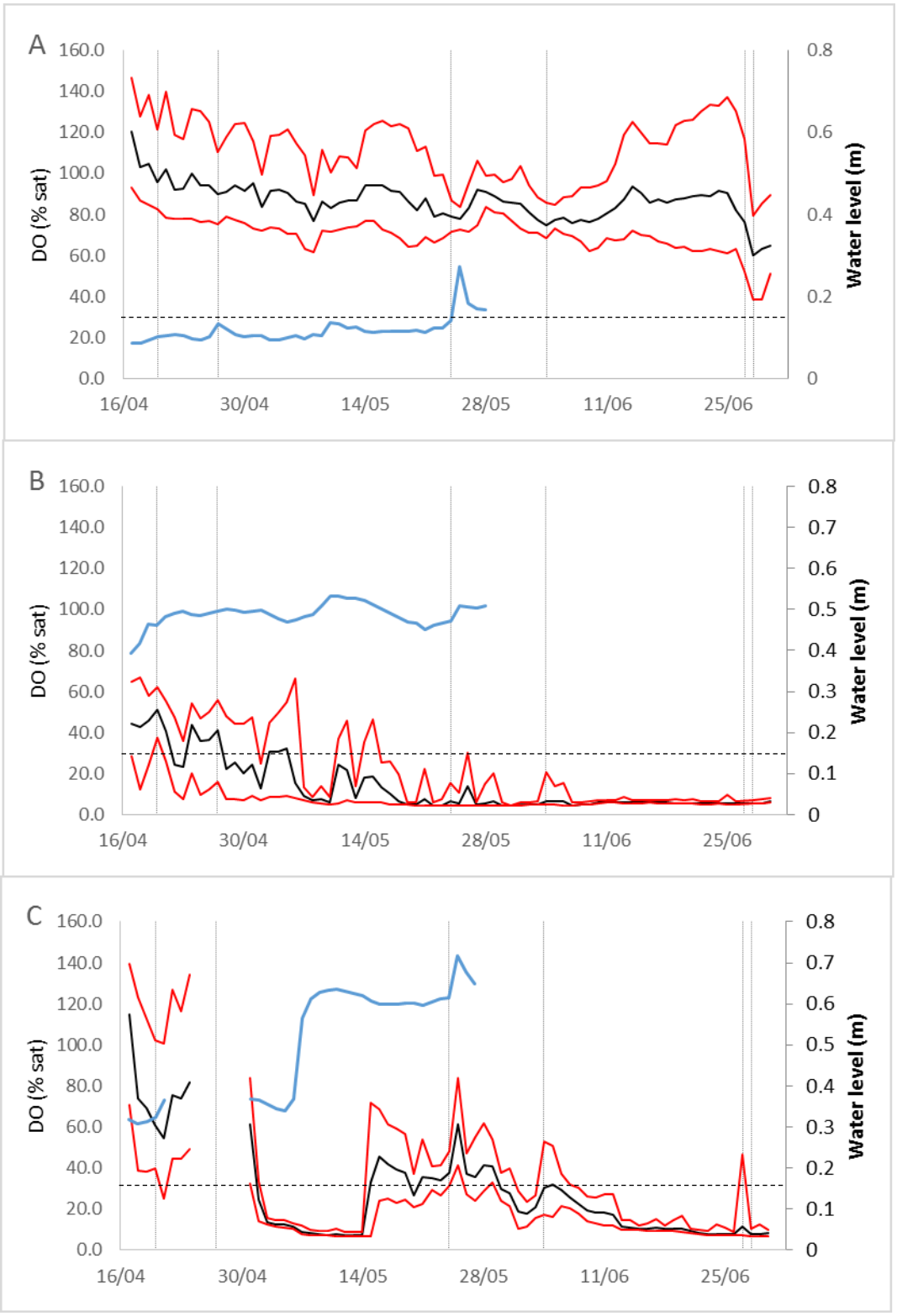

Figure 4: Mean (black), maximum and minimum (red) daily dissolved oxygen levels at each main sample point over the duration of the study. A = redlake input, B = northern input, C = main outfall. Blue line denotes mean daily water level and vertical lines indicate significant precipitation event (>5mm). The dashed line denotes the levels beneath which a water body is classed as hypoxic (< 30% saturation).

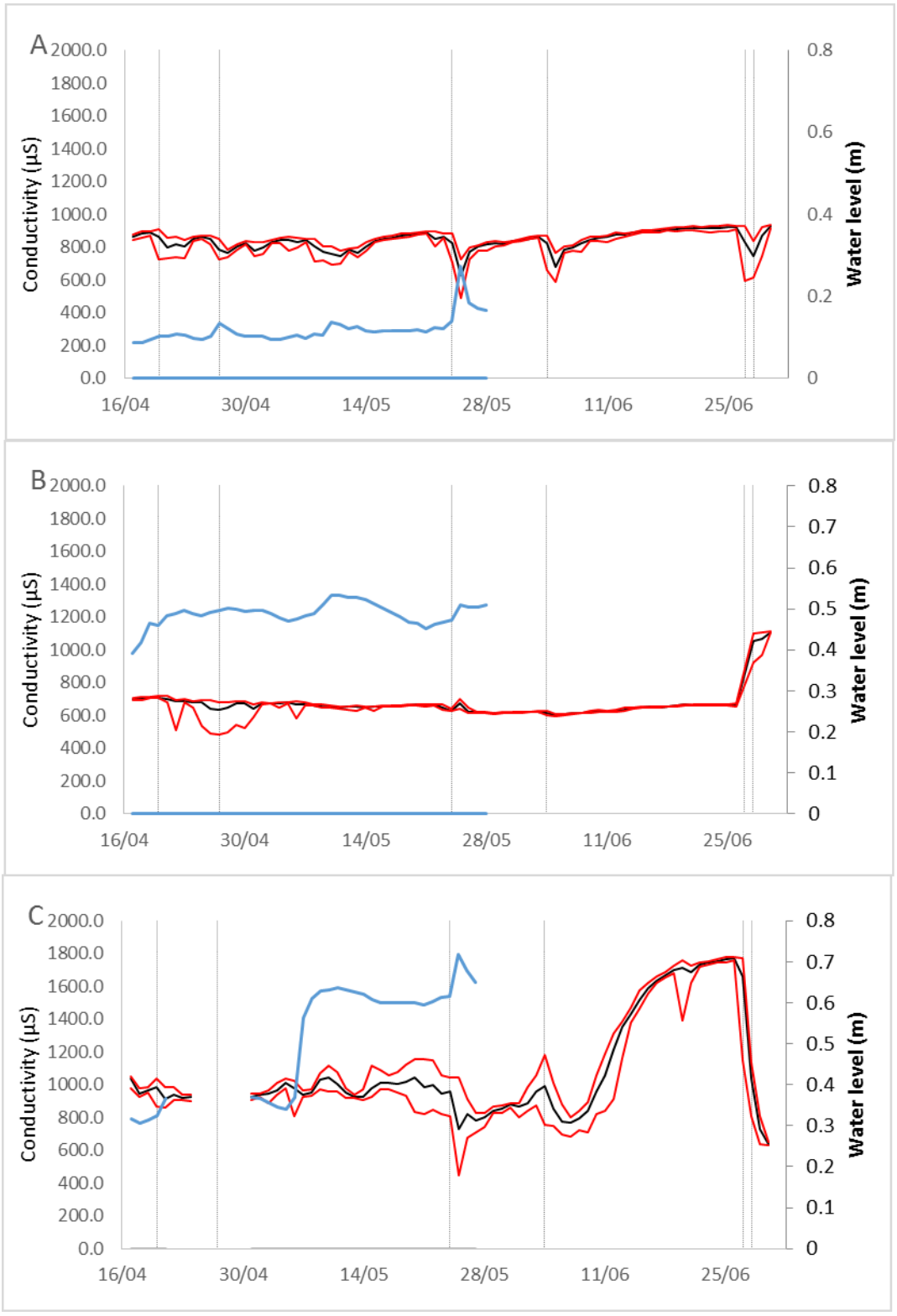

Figure 5: Mean (black), maximum and minimum (red) daily conductivity levels at each main sample point over the duration of the study. A = redlake input, B = northern input, C = main outfall. Blue line denotes mean daily water level and vertical lines indicate significant precipitation event (>5mm).

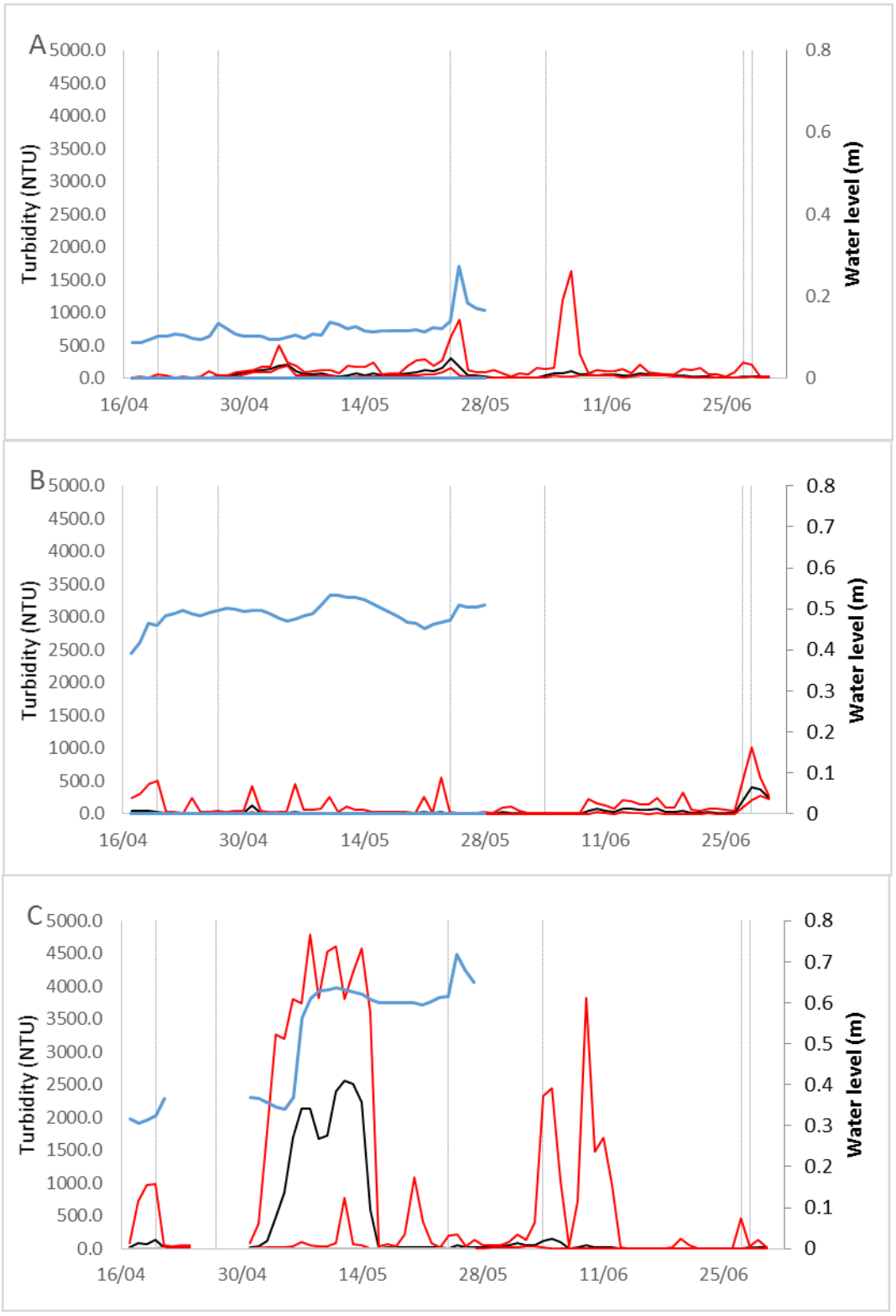

Figure 6: Mean (black), maximum and minimum (red) daily turbidity levels at each main sample point over the duration of the study. A = redlake input, B = northern input, C = main outfall. Blue line denotes mean daily water level and vertical lines indicate significant precipitation event (>5mm).

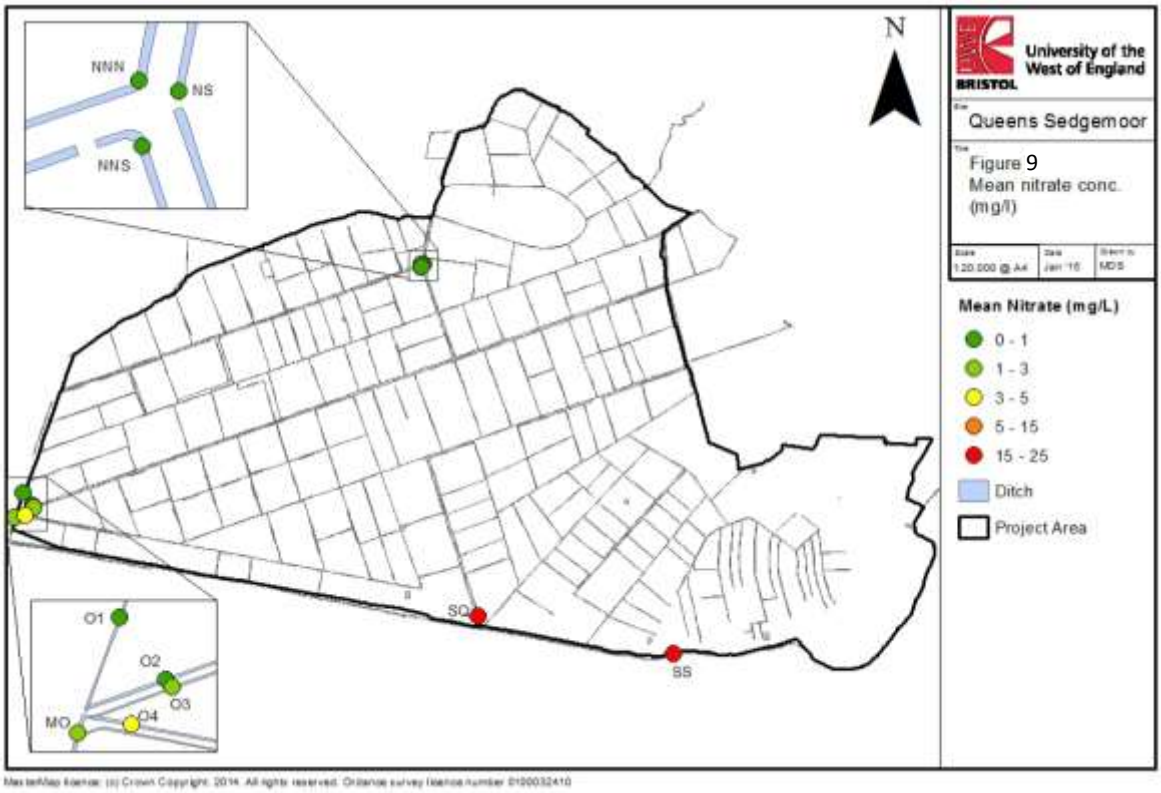

Figure 7: Mean nitrate levels recorded around Queens Sedgemoor May-June 2014.

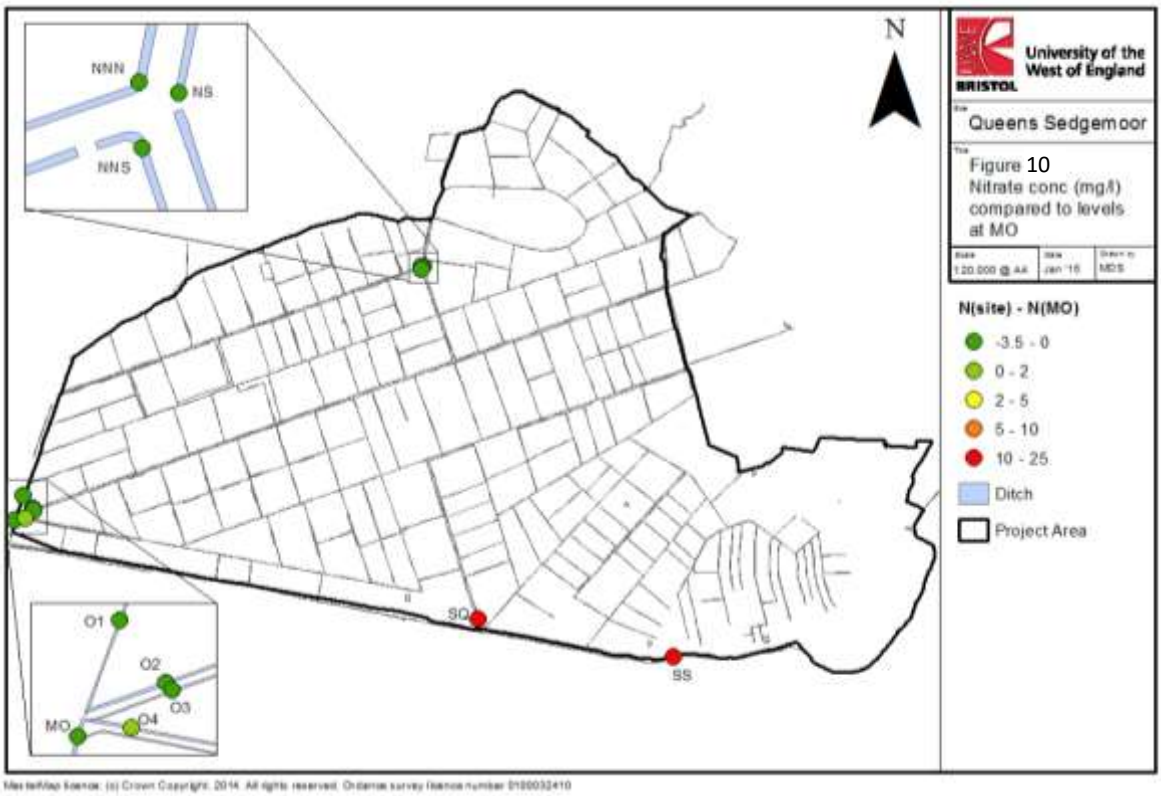

Figure 8: Mean nitrate levels recorded around Queens Sedgemoor May-June 2014 standardised to the level recorded that day at MO. See figure 2 for explanatory notes of locations.

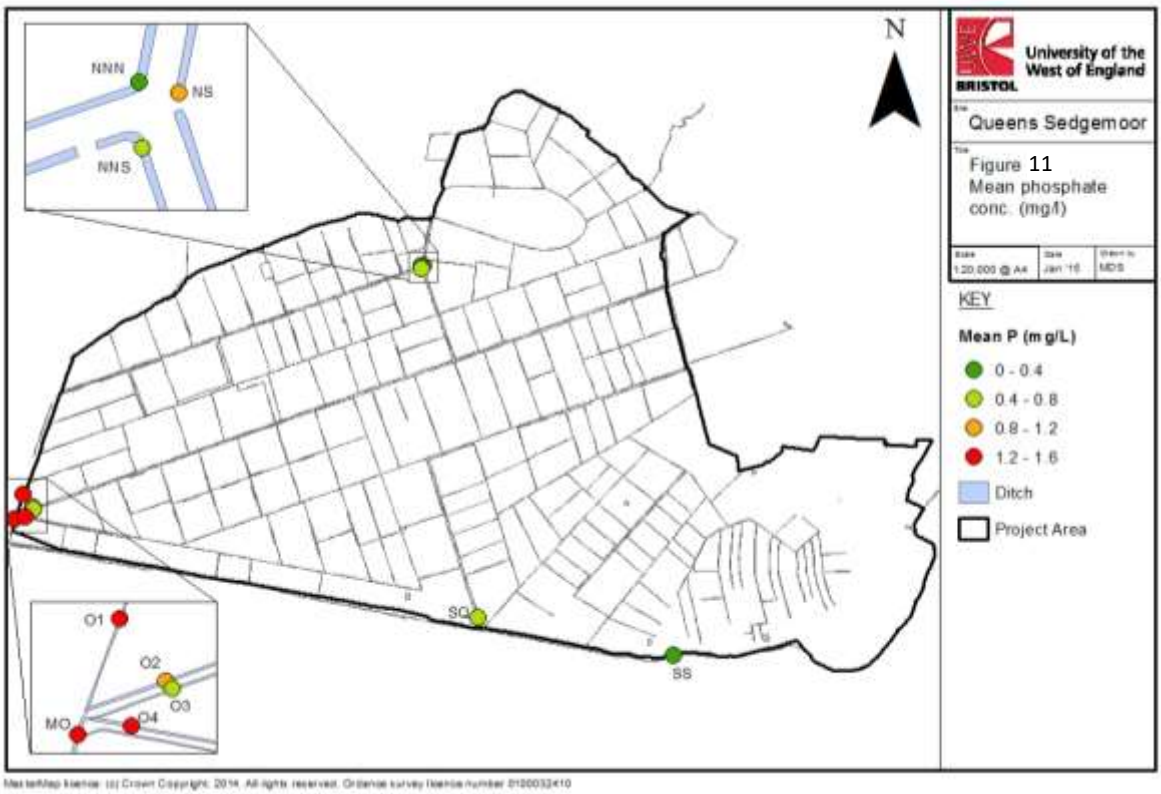

Figure 9: Mean phosphate levels recorded around Queens Sedgemoor May-June 2014.

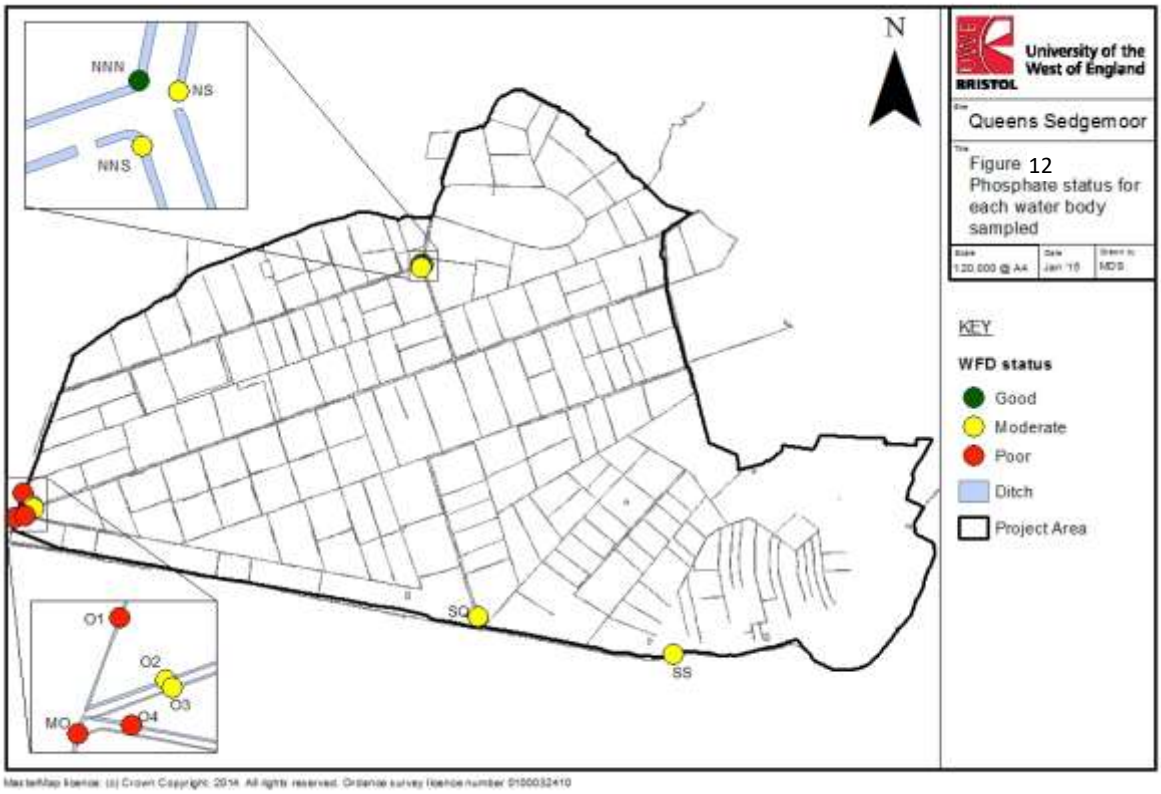

Figure 10: Mean phosphate levels recorded around Queens Sedgemoor May-June 2014 expressed in terms of WFD status. See figure 2 for explanatory notes of locations.

Sulphate ion concentrations are generally high (table 2) and appear to increase as water moves through the moor. This may be due to sulphides being oxidised as peat soils are dried and rewetted (see Eimers *et al*. 2003). Sulphate concentrations are highly correlated with conductivity readings (Pearson correlation: r = 0.750, p = 0.020; table 3), suggesting that they are the principle factor in determining conductivity. Chloride ion concentations are co-correlated with sulphate concentrations, but they are less likely to be a significant factor in conductivity readings due to their considerably lower concentration. Anti-correlation between conductivity and water levels / precipitation events are apparent at both the Redlake input and main outfall, indicating that sulphate is not being imported into the site via rainfall or higher concentrations in inflowing water.

A full list of ions and their measured concentrations is provided in appendix 3.

Table 2: Summary of ion concentrations from three samples (NH^{4+}: n = 2) taken at the location of each sonde. Values show the mean, minimum and maximum concentrations recorded in mg/L. Results for PO_4^{3-} also indicate waterbody status according to Water Framework Directive standards

	Redlake		N_Input		Outfall	
NO_3^-	23.15	22.16 24.78	0.09	0.07 0.17	2.72	0.17 5.85
PO_4^{3-}	0.27 (Good)	0.23 0.30	0.96 (Moderate)	0.82 1.16	1.31 (Poor)	1.16 1.40
SO_4^{2-}	176.04	160.22 184.38	142.47	112.30 165.63	244.72	220.48 282.68
NH^{4+}	0.07	0.00 0.14	0.08	0.00 0.15	1.37	0.69 2.05

Table 3. Correlation matrix for water quality measures. Values indicate Pearson correlation coefficient (above) and p-value. Significant positive correlations are highlighted in green and significant negative correlations in orange. DO = dissolved oxygen, cond = conductivity, turb = turbidity

	Fluoride	Chloride	Bromide	Nitrate	Phosphate	Sulphate	Temp	DO	Cond
Chloride	0.375								
	0.321								
Bromide	0.970	0.401							
	0.000	0.284							
Nitrate	-0.092	0.204	-0.181						
	0.814	0.598	0.642						
Phosphate	0.332	0.231	0.435	-0.851					
	0.383	0.550	0.242	0.004					
Sulphate	0.517	0.931	0.567	-0.032	0.437				
	0.154	0.000	0.111	0.935	0.239				
Temp	0.470	-0.098	0.320	-0.144	0.231	0.067			
	0.201	0.802	0.401	0.712	0.550	0.863			
DO	-0.342	0.159	-0.406	0.913	-0.843	-0.065	-0.303		
	0.367	0.682	0.278	0.001	0.004	0.869	0.428		
Cond	0.397	0.741	0.344	-0.018	0.308	0.750	0.302	-0.174	
	0.290	0.022	0.365	0.964	0.420	0.020	0.429	0.655	
Turb	-0.618	-0.404	-0.542	0.190	-0.470	-0.467	-0.515	0.279	-0.485
	0.076	0.281	0.131	0.625	0.201	0.205	0.156	0.467	0.186

3.2 Farmer Interviews

Calculations based on reported engagement with ESA and ES schemes suggests that over agri-environment investment within Queens Sedgemoor has decreased by £50,300 due to the change in payment scheme.

Twenty four farmers and landowners were contacted. Of these, four no longer manage land on Queens Sedgemoor and were excluded from the interview process; seven declined an interview while thirteen (65% of active farmers) agreed to be interviewed. Interviews were declined mainly due to a lack of time (n = 5) while two did not want to engage with a conservation organisation. The land managed represented by the interviewed farmers represents 71% of the fields on the moor (72% of the area), spread evenly across the area (figure 11).

Figure 11: Spatial distribution of respondents' land.

3.2.1 Characterisation of Farm Businesses

Ten of the interviewees identified themselves as the main or joint main decision-maker on the farm while three identified family members as the joint decision-maker, and all farms were classified as private agricultural businesses. All respondents owned some or all of the land that they managed, two had additional full agricultural tenancies, a further six rented fields in from other landowners and one rented land out. Six farms (46%) are predominantly dairy farms, five (38%) predominantly beef with the remaining two farms identifying as mixed beef and dairy or mixed beef and arable. Farms employed an average of 2 FTE people (range 1 – 4; table 4), which suggests that the moor supports a maximum of 40 FTE jobs, although the true figure will be considerably lower than this since few farmers farm solely on the moor and the reported figures include contracting work which some farm businesses undertake. In general dairy farms reported that a greater proportion of their total income was derived from agriculture with four farms reporting that it comprised their entire income and the remaining two stating it comprised most of their income. By contrast only one of the beef farms reported that all of the income was derived from agriculture, three reported that it constituted less than half of their income and one was unsure (although this is highly likely to be less than 100%). Other income streams recorded were agricultural contracting (two respondents),

building, holiday rentals and pension (one respondent each). Both farms which reported a mixed system derived 100% of their income from agriculture. Two farms stated the intention to grow or intensify their business within the next five years whilst the majority planned to maintain their level of farming with few changes.

Table 4: Summary of farm businesses*.

Farm	QSM ha	Farm Type	Grassland management	FTE	% Income Agriculture	AES experience	Five year plan
F1	30 - 49	Mixed dairy and beef	Permanent grassland	3	All	YN	Maintain with no major changes
F2	≥ 80	Mainly dairy	Short leys	4	Most	NY	Maintain with no major changes
F3	30 - 49	Mainly beef	Permanent grassland	1	All	YY	Maintain with no major changes
F4	10 - 29	Mainly beef	Permanent grassland	1	Less than half	YY	Maintain with no major changes
F5	10 - 29	Mainly beef	Permanent grassland	1	Less than half	YY	Plan to grow / intensify business
F6	10 - 29	Mainly beef	Permanent grassland	1	Unknown	YN	Maintain with no major changes
F7	10 - 29	Mainly dairy	Permanent grassland	1	All	NN	Maintain with no major changes
F8	10 - 29	Mainly beef	Permanent grassland	1.6	Less than half	YY	Maintain with no major changes
F9	< 10	Mainly dairy	Permanent grassland	2	All	YN	Maintain with no major changes
F10	< 10	Mainly dairy	Short (drier) and long (wetter) leys	2.5	All	YN	Plan to grow / intensify business
F11	≥ 80	Mainly dairy	Short leys	2	All	YN	Maintain with no major changes
F12	50 - 79	Mixed beef and arable	Short ley, long ley and permanent pasture.	4	All	YY	Maintain with no major changes
F13	50 - 79	Mainly dairy	Long leys; permanent grassland	2.5	Most	YY	Maintain with no major changes

*QSM ha is the number of hectares farmed on the moor, FTE relates to the number of full time equivalent posts employed on the farm, % income agriculture relates to the percentage of the farmer's income which comes directly from agriculture. AES experience is the farmer's history in agri-environment schemes: Y indicates the farmer opted into the scheme, N that they didn't; the first letter refers to their experience of ESA and the second their experience of ES.

The ages of the principle decision-makers ranged from >36 to <75 years old (table 5). A single respondent had been managing the land for 5-10 years while the rest had been working the land for more than twenty years. Eight (62%) of the thirteen farms in the study reported that the eventual

inheritance of the farm was secure within the family, while four (31%) reported that the farm definitely wouldn't, or was unlikely to, pass to a family successor. Only one of the three farms where the principle decision maker was identified as being over 65 had an uncertain inheritance.

Table 5: Age structure of principle decision makers

Age bracket	Number of respondents
< 36	1
36 – 45	1
46 – 55	3
56 - 65	5
66 – 75	2
> 75	1

3.2.2 Experience of Agri-Environment Schemes

Only two of the respondents had not entered into ESA agreements, one of these had subsequently joined the Entry Level Environmental Stewardship scheme while the other had not. Of the eleven respondents who had previously entered into ESA agreements, six had continued into Environmental Stewardship while five (45% of respondents who had been in the ESA) had opted out.

The farmers who hadn't joined the ESA scheme did so to maintain flexibility of management, particularly with reference to silage cutting and reseeding. Reasons given for not joining Environmental Stewardship were varied: three respondents reported that they didn't feel the monetary gains were sufficient to warrant the loss of flexibility to reseed or spray rushes; one cited a lack of knowledge about ELS and one that the rewards weren't worth the paperwork. Only one of the farmers who hadn't opted into an Environmental Stewardship agreement suggested that there weren't conditions under which they would consider moving into the scheme.

None of the farmers questioned had been offered HLS agreements and decided against them.

3.2.3 Reported Changes during ESA period

In general farmers reported relatively little environmental change over the past twenty years, however, some patterns did appear to emerge, notably increases in rush cover and land wetness were more commonly reported than decreases (table 6). Only one respondent reported both increased rush cover and field wetness.

Table 6: Summary of reported changes to key environmental parameters between 1994 and the end of the ESA period*.

	Productivity	Hay Quality	Rush Cover	Land Wetness	Standing Water	No. gripes	Water quality	Botanical richness	Faunal richness
F1	↔	↑	Minor ↓	↔	↓	n/a	↔	↔	↔
F2	↔	↔	↔	↔	↔	n/a	↔	↓	↔
F3	↔	↔	Minor ↑	↔	↔	↔	↓	?	?
F4	↓	↓	↑	↔	↔	n/a	↔	↔	↓
F5	↔	↔	↔	↔	↔	n/a	↑	↔	↑
F6	↔	↔	↑	↔	↔	↓	↔	↔	↓
F7	↔	↔	↔	↑	↔	n/a	↔	↔	↑ ↓
F8	↓	↓	↑	↑	↑	↔	↓	↑	↑
F9	↔	↑	↔	↔	↔	n/a	↔	↔	↓
F10	↔	↓	↔	↔	↔	n/a	↑	↔	↔
F11	↔	↔	↔	↑	↔	↔	↔	↔	↔
F12	↑	↔	↔	↑	↔	↔	↔	↓	↔
F13	↔	↔	↑	↔	↔	n/a	↑	↑	↑

*↑ = reported increase; ↓ = reported decrease; ↔ = reported no change; n/a = not applicable; ? = not known

The three reports of increased water quality all related to Hartlake and Redlake rivers indicating that the quality of the water inputting the southern hydrological system may have increased, but there doesn't appear to have been a noticeable change in the water quality within the rhyne network despite two reports of occasional agricultural discharges from farms higher in the catchment (beyond QSM). Five farmers reported that a decrease in floral abundance and richness wasn't possible on their land since all botanical diversity had already been sprayed off or lost to reseeding. Responses concerning changes to faunal composition suggested a changing species assemblage with an increase in mesopredators particularly badger (*Meles meles*) and buzzard (*Buteo buteo*). Three respondents reported declines in skylark (*Alauda arvensis*) numbers and two suggested declines in the lapwing (*Vanellus vanellus*) population. Other species recorded as having increased were mute swan (*Cygnus olor*), sparrowhawk (*Accipiter nisus*), deer (presumably roe deer, *Capreolus capreolus*), rabbit (*Oryctolagus cuniculus*), little egret (*Egretta garzetta*), moorhen (*Gallinula chloropus*), grey heron (*Ardea cinerea*), cormorant (*Phalacrocorax carbo*), pheasant (*Phasianus colchicus*) ducks, dragonflies and frogs. Other species mentioned as having decreased were hedgehog (*Erinaceus europaeus*), brown hare (*Lepus europaeus*), partridge (*Perdix perdix*), robin (*Erythacus rubecula*), finches, ducks and bees.

Fifty percent (6 of 12) of respondents reported that the amount of fertiliser used on the moor has decreased substantially since the start of the ESA. It is noteworthy that this decline was reported by

both of the farmers who had not been in the ESA scheme, while the others reported no change (of these, three said that they had never used artificial fertilisers). Two farmers had moved to organic production since the start of the ESA. Five farmers reported that grazing intensity had decreased while two reported increases. Four farmers reported that their stocking densities had decreased by 25-50%. None of the farmers reported a change in the dates of hay cutting and only one reported that they had converted grassland to arable (and they were planned to convert back to a long ley due to the risks inherent in growing arable crops).

When asked how the ESA had altered management practices four farmers reported that they had decreased fertiliser use, three that they had ceased to spray herbicides, two that they had decreased levels of reseeding and one that they had reverted maize fields back to grassland. Where no changes were reported, this doesn't necessarily mean that the land is not intensively farmed.

Table 7: Summary of reported changes to key management parameters between 1994 and the end of the ESA period*.

	AES experience	Fertiliser use	Grazing intensity	Date of hay cut	Grassland conversion to arable
F1	YN	↓	↓	n/a	None
F2	NY	↓	↑	↔	None
F3	YY	↓	↔	↔	None
F4	YY	↔	↓	↔	None
F5	YY	↔	↓	↔	None
F6	YN	↔	↔	↔	None
F7	NN	↓	↓	↔	None
F8	YY	↓	↓	↔	None
F9	YN	↔	↔	↔	None
F10	YN	nr	nr	n/a	None
F11	YN	↔	↔	↔	Yes
F13	YY	↓	↑	↔	None

*AES experience is the farmer's history in agri-environment schemes: Y indicates the farmer opted into the scheme, N that they didn't; the first letter refers to their experience of ESA and the second their experience of ES. Nr indicates that no response was made. F12 not included as interview had terminated.

Farmers were asked whether they thought that the ESA and ES schemes were been effective at protecting the quality of soils and water and populations of wild animals and plants. There was no clear consensus with approximately half of the farmers thinking that the schemes had been successful with the other half disagreeing. Perceptions of the efficacy of the schemes did not appear

to have generally affected farmers' choices to enter ES or not with around half of both YN (two of five) and YY (three of six) farmers stating that the schemes provided environmental benefits.

Table 8: Reported comments in response to the question "Do you think that the ESA and ES schemes have been effective at protecting the quality of soils and water and populations of wild animals and plants?"

Generally positive comments

F8	YY	Yes
F10	YN	Yes, reduced intensity of farming
F11	YN	yes - shifted the holding as not intensive
F12	YY	Yes is useful e.g. spreading manure more responsibly More likely to be positive than negative
F13	YY	Environmentally good because reduced too much fertiliser, so wildlife better BUT badly policed e.g. tier 2 not really farmed yet still got payments e.g. ditches not maintained etc. So land gone down in quality. ESA payments are worth the restrictions especially re rolling and cutting dates

Generally negative comments

F1	YN	No - a lot of landowners ignored it, or they farmed that same as they would have without the ESA
F2	NY	ESA - don't know - not seen and difference. Not seen anyone spray rushes off as a result of ESA ending - though he says his neighbours said that they'd do this
F3	YY	Doesn't agree with ploughing land ESA didn't have much effect - didn't take much notice
F4	YY	Did no good whatsoever Cutting date rules promote damage - not in tune with nature. Doesn't think the artificial fertiliser damages flowers - no-one ever forced the ground before ESA, moor grass doesn't respond well to artificials - just grows long, leggy and stalky
F5	YY	ESA good because of financial gain good incentive; ELS not enough - not enough to stop farmers ploughing land he sold
F6	YN	No - people couldn't plough ground anyway. Should stay as a grass moor. Wants birds back - too many predators now. Dog walkers - loose dogs a problem for birds
F7	NN	Up to individual farmers. QSM hasn't changed over 20 years, only change due to wetter weather Moor prevents you from farming intensively etc.
F9	YN	No difference to … family, but must have made a difference elsewhere

When asked if there were ways in which agri-environment schemes could have been made more effective at protecting the environment, four farmers replied that it the felt it couldn't be improved – of these three were generally positive about how the scheme was run while one stated that the scheme was of no use because no-one was abusing the ground prior to the ESA. Four farmers stated that the schemes could have been improved by providing more money (F5), offering incentives for trapping vermin (F6), providing more management flexibility (F8) and better policing (F13). The remaining five farmers expressed no opinion either way (table 8).

3.2.4. Reported Changes since the End of ESA Agreements

Most farmers didn't report any major changes to their management systems since the end of the ESA period (table 9). One reported that since the cessation of their ESA agreement their grazing levels and fertiliser use had increased and another stated that their moorland fields were now more important agriculturally because they have the freedom to manage them exactly as they wish, however, it is unclear what the change of management might be. One respondent, since leaving the ESA scheme (group YN), had decided to expand dairy operations which included sowing arable break crops.

Table 9: Summary of reported changes to key management parameters since the end of the ESA period. See table 7 for explanations.

	AES experience	Importance of wet fields	Fertiliser use	Grazing intensity	Date of hay cut	Grassland conversion to arable
F1	YN	↔	↔	↔	↔	↔
F2	NY	↔	↔	↔	↔	↔
F3	YY	↔	↔	↔	↔	↔
F4	YY	↔	↔	↔	↔	↔
F5	YY	↔	↔	↓	↔	↔
F6	YN	↑	↔	↔	↔	↔
F7	NN	↔	↔	↔	↔	↔
F8	YY	↔	↔	↔	↔	↔
F9	YN	↔	↔	↔	↔	↔
F10	YN	↔	↑	↑	n/a	↔
F11	YN	↔	↔	↔	↔	Reversion to grassland
F13	YY	n/a	n/a	n/a	n/a	n/a

However, the comments related to the questions indicated that at least four of the five farmers who had left ESA and not joined ES had started spraying herbicide, while none of the other farmers mentioned significant changes in their herbicide regimes.

When asked about the financial implications of the move from ESA to ES three of the eleven affected farmers (27%) stated that it had been a severe loss, two (18%) reported a minor loss, five (45%) reported no impact and one felt that it had had either no impact or a minor loss. Notably, farmers who had moved from ESA to ES tended to report a more severe impact on their agricultural business that those who opted not to join ES (table 10).

Table 10: Reported impact of change to agri-environment scheme on farm finances. Number in brackets indicates number of respondents who selected more than one option.

	No change	Minor Loss	Severe Loss	N/A
NN	.	.	.	1
NY	.	.	.	1
YN	4	1	.	.
YY	1 (1)	1 (1)	3	.

All three of the farmers who reported severe losses are predominantly beef farmers who farm relatively small amounts of amounts of land on the moor.

4. Discussion

Queens Sedgemoor supports a range of ecosystem services including food production, carbon storage, nitrate removal and maintenance of biodiversity (RPA *et al*., 2011). It is a stable agricultural area, dominated by beef and dairy, However, we estimate that recent changes to agri-environment schemes has led to a net loss of £50,300 per annum in agri-environment investment from the project area, and this may be compromising the provision of some of the non-food ecosystem services. However, we suggest that it is likely that some elements of the environment were in decline prior to the change from ESA to ES schemes.

4.1 Baseline Water Quality

Water quality in Queens Sedgemoor is generally poor, but does exhibit noteworthy patterns. Dissolved oxygen levels, while remaining high in the faster-flowing Redlake River, dropped to hypoxic levels (i.e. levels where most aquatic life cannot persist) for significant periods of time at both the north input (84% of total time) and the main outfall (63% of total time). This is likely to be linked in large part to a lack of submersed vegetation in the ditches which, in turn, is most likely caused by eutrophication and ditch maintenance works. The impact of low dissolved oxygen levels on fish is well characterised. Assuming that the sample ditches are representative of the ditches in the project area as a whole, these findings suggest that Queens Sedgemoor, and by extension many other non-designated areas of the Somerset Levels and Moors, are not suitable habitat for fish including species for which the levels were once famed such as European Eel (*Anguilla anguilla*). The extent of habitat available to eels in the Levels and Moors is of particular interest given the species' international classification as Critically Endangered due to a decline of over 90% in recent decades (Jacoby & Gollock 2014). The presence of submerged aquatic vegetation in particular positively influences the amount of dissolved oxygen throughout the growing season. However, floating aquatic vegetation can have the opposite effect (Caraco *et al*. 2006). The occurrence and distribution of submerged and emergent vegetation in the project area is thought to have undergone a

substantial decline in recent decades (Haslem *pers comm*.) suggesting that low dissolved oxygen levels within the ditch network may be an increasing problem.

The moor appears to provide a service in stripping nitrates from the water. Water inputting from the Redlake River is relatively high in nitrate levels (~20 mg/L). This level is within guidelines for safe nitrate levels in the environment, but is much higher than is likely to have been the case pre-industrialisation. Mapping of the broad patterns indicates that nitrate levels drop by around 15 mg/L while transiting between the southern input and the outfall. However, the situation is probably more complex. Data taken along the ditch running N from the Redlake River input suggests that nitrate levels were rapidly expunged, dropping from >19 mg/L to <0.2 ml/L within 900 m (see appendix 4). If this rapid decrease in nitrate levels is a general trend, then it would suggest that nitrate concentrations, having been reduced, are being replenished as water moves through the system near the outfall. This could be an indication of significant run off from improved fields.

The fact that nitrate levels decrease as water moves through the moor, while phosphate levels increase, suggests that Queen Sedgemoor is a nitrate-limited system with excess phosphate availability. Relatively small amounts of nitrate appear to be being reduced to ammonium, but this cannot account from the magnitude of changes observed in the nitrate levels.

Phosphate concentrations increase to such an extent that the water leaving the system, having been rates of good or moderate quality within the framework of the WFD, is ranked as poor. Increases in ion concentrations may be linked to evapo-concentration within the water body. However, the increases are such that it is feasible that concentrations are being increased by run off from fields and/or the oxidation of other phosphorus-containing compounds as the peat soils dry out. Similarly sulphate levels, which also appear to increase within the moor to high levels, have been shown to be increased by oxidisation of sulphides within peat caused by drought (Bayley *et al*. 1987). Sulphate concentrations, which correlate strongly with conductivity levels, have been shown to mobilise the release of phosphate from biologically inaccessible forms of phosphorous (Lamers *et al*. 2001). It has been suggested that phosphorous release in peat wetlands is strongly associated with soil chemical processes, and that high release rates may be due to the high sulphate content of the water. (Koerselman *et al*. 1993). Therefore high sulphate levels may be part of the cause for phosphorous being released from peat soils.

Differential responses to major precipitation events are apparent at the different monitoring stations. Conductivity is strongly anti-correlated with water levels at the southern output and outfall. This indicates that precipitation events are diluting the amount of sulphate in the water at these

locations and therefore, rainwater is not the source of increasing concentrations. The north input, by contrast, indicates a strong correlation between conductivity levels and precipitation. The most likely explanation for this would seem to be that increased run off from the fields is increasing the ionic concentration of the water.

4.2 Reported Impact of the Change in Agri-environment Schemes

There has not been a singular response from the farming community to the changing schemes, nor should we expect one due to different farming systems present on the moor. In general, despite losses in income, the majority of farmers interviewed who had joined ES from ESA did not report a significant need to try and intensify agricultural operations. However, some respondents have not entered into the new schemes, having been in the ESA, in order to gain independence over reseeding and spraying regimes. This suggests that these areas might be undergoing agricultural intensification. Since intensification is often correlated with decreased provision of non-food ecosystem services (e.g. see Tscharntke *et al*. 2005 and citations within), we can assume that the change from ESA has directly led to loss of ecosystem service provision on a minimum of 30% of farms in the project area.

The change in agri-environment scheme funding appears to have affects smaller beef farms disproportionately hard.

Possible impacts of increased herbicide spraying

It is likely that there is an increased use of herbicides, such as MCPA which is often used to control soft rush *Juncus effusus* (McCorry & Renou, 2003). This may well be a direct consequence of changing payment structures on Queens Sedgemoor and elsewhere. Four (30%) farmers in our study reported an intention to increase spraying, rather than weed-wiping, as have farmers in other areas of the Somerset Levels and Moors (R. Bradford *pers comm*). The impacts of commonly used herbicides such as MCPA and mecoprop are generally short-lived within the environment; under aerobic conditions they have very short half-lives (approx. two days). However, in low oxygen conditions these herbicides can persist for up to a year (Vink & Van Der Zee, 1997) which suggests that increased herbicidal spraying could lead to a build-up within the ditch network particularly during periods when oxygen levels are very low. Herbicide spraying tends to be most effective in June and July (McCorry & Renou, 2003), when ditch oxygen levels are likely to be very low. If herbicides remain effective at low oxygen conditions then the growth of submerged vegetation within the ditches may be compromised, further exacerbating likelihood of dissolved oxygen levels dropping below levels required for the persistence of most animals and all UK fish. Furthermore,

there could be downstream implications of herbicide persistence if oxygen-poor, herbicide-rich waters travel through the ditch network. Whilst it is likely that increased oxygen levels resulting from water movement would decrease herbicide levels before they reach areas of notified botanic interest within the Brue Valley, this possibility may be deserving of future study.

4.3 The Future for Agri-Environment Schemes in Queens Sedgemoor

Environmental Stewardship agreements run for just five years and so farmers who are currently in these schemes will be coming to the end of their agreements within the next 2-3 years. If they want to continue receiving agri-environment payments they will need to enter a Countryside Stewardship arrangement. Countryside Stewardship provides incentives for land managers to look after their environment. The scheme is open to all eligible farmers, woodland owners, foresters and other land managers through a competitive application process. The main priority for Countryside Stewardship is to protect and enhance the natural environment, in particular the diversity of wildlife and water quality. Other outcomes include flood management; the historic environment; landscape character; genetic conservation; and educational access.

The location of Queen Sedgemoor and its relatively limited current biodiversity value, combined with ever decreasing public funds, mean that farmers in this location are extremely unlikely to be successful in gaining the highest tier of payments in the new Countryside Stewardship scheme.

Applications to the mid-tier will be assessed competitively are there is no guarantee that an applicant will be accepted on to the scheme. Therefore a partnership bid to the mid-tier, via the facilitation fund[1], may have more chance of success than individual applications. Mid Tier aims to address environmental issues in the wider countryside, such as reducing diffuse water pollution from agriculture and improving the farmed environment for farmland birds and pollinators. Multi-year management options and capital items, including the water capital grants in this Tier are designed to deliver environmental improvements in the wider countryside.

The priorities for the Somerset Levels and Moors for Mid Tier include habitat and species works which contribute significantly to improvements in water quality, air quality and flood management (see Countryside Stewardship priorities for the Somerset Levels and Moors for more information[2]).

[1] See Guide to Countryside Stewardship: facilitation fund: https://www.gov.uk/government/publications/guide-to-countryside-stewardship-facilitation-fund/guide-to-countryside-stewardship-facilitation-fund#annex1

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/412670/NCA142-Somerset-Levels-and-Moors.pdf

Applicable options will aim to maintain or enhance the condition of the coastal and floodplain grazing marsh.

5. Conclusions

The moor appears to be nitrate limited, but there is evidence that may suggest there is significant nitrate input in parts of the moor. It would be instructive to understand the flux of nitrates as water move through the ditch system in more detail. Aquatic phosphate levels increase through the moor and water leaving the site fails the ecological standards of WFD. Increasing phosphate and sulphate levels may be an indication of continuing desiccation (oxidation) of peat soils releasing nutrients into the water system. These have the potential to be transported through the drainage network which may lead to detriment of water quality within notified sites.

The change from ESA to ES appears to have had relatively little impact on the working practices of farmers on Queens Sedgemoor. However, the majority of farmers who had not engaged with ES having been in the ESA schemes reported spraying herbicides on their fields. This, particularly combined with persistently low oxygen levels and high nutrient levels, may present a persistent threat to the biological integrity of the ditch network and, potentially, impact the health of livestock drinking ditch waters.

Current funding regimes mean that future AES funding is likely to fall further, in the real terms. However, the new Countryside Stewardship scheme contains a competitive, mid-tier option that may be available to farmers in the area. Farmers are more likely to be successful with a bid to the scheme if they are in a partnership bid via the Facilitation Fund.

However, if peat degradation is found to be a major source of nutrient input into the waterways, the only solution may be to hold water levels higher, which will impact agricultural productivity and isn't currently funded through Mid Tier management options.

6. Recommendations

1. Assessment of the viability of generating a partnership of farmers within the moor to put together a bid to the Mid Tier Countryside Stewardship scheme.
2. Further work should be carried out to ascertain the source of nutrient inputs into the water column, particularly phosphate. This could be achieved using isotope analysis, comparing

phosphates in the water column with the phosphates in the peat soils and those in fertiliser inputs.

3. Studies of herbicide presence in water, particularly towards the end of the summer, tracking persistence in flood waters post-storm as they move downstream.
4. The generality of these conclusions across other areas of the SLM which are not in target areas for the higher payment management options should be assessed since significant reductions in environmental quality upstream may have significant impacts on the Somerset Levels and Moors SPA and other designated sites.

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Appendix 1: Mapping of At Risk Peat Soils in the Somerset Levels and Moors

Introduction

The change in agri-environment schemes from ESA to Environmental Stewardship in the Somerset Levels and Moors is likely to have consequences for the integrity of peat soils. Within the Brue Valley, for instance, approximately two-thirds of land parcels are not within HLS target areas and consequently are seeing their agri-environment scheme value decline from a minimum of £125 per hectare (ESA tier 1) to £30 per hectare (ELS).

We do not know what the consequences of these changes in payment levels will be, but a 2011 survey of farmer intention (R. Bradford unpub report, 2011) suggested that there may be significant shifts in land management which could affect carbon storage and biodiversity.

A need to increase agricultural productivity may lead to increased use of herbicides and inorganic fertilisers, more cutting for silage, less cutting for hay, ploughing and reseeding some fields, or, on a smaller and more local scale, converting them to arable. Conversely, in some areas management might decrease leading to under-management (e.g. e.g. less topping of soft rush, less hay/ silage making, less ditch cleaning, less pollarding of willows, less management of scrub, less maintenance of the droves) in sensitive areas)

Somerset Wildlife Trust and Natural England have undertaken a small project to map peat soils most likely to at risk from changing land management in response to the move from ESA agreements to Environmental Stewardship. The aim is to highlight areas which should be priorities for joint action via the Levels and Moors Nature Delivery Group.

Methods

Maps of peat risk, ESA tiers and current HLS and ELS extents were overlain using ArcGIS.

Individual land parcels were classified by peat wastage risk score (Medium, Medium High, High, Very High) and the extent of fields in each category calculated. Parcels were sequentially discounted from the analyses if they weren't contained within the following categories designed to correlate with increasing risk of adverse effects to peat soils and biodiversity:

- Fields have no current infield HLS, OELS or ELS options
- Fields have no current infield HLS, OELS or ELS options but were included under an ESA scheme
- Fields have no current infield HLS, OELS or ELS options but were included in ESA tiers 2 or 3

Fields which were included in the ESA scheme, especially those in tiers 2 or 3, are assumed to have experienced less peat wastage in the past and host greater levels of biodiversity than fields which weren't included. Therefore the assumption follows that those fields which were in ESA, and in particular those in tiers 2 or 3, will have most to lose in the event of agricultural intensification.

At each stage the extent of land in each peat risk category which was coded as permanent or temporary grassland by farmers in their Single Payment Schemes returns was also calculated; as was the extent of each habitat type (Brue Valley only) (see table 1).

Data	Source	Date	Notes
Extent and vulnerability of peat soils	SCC (Richard Brunning)	2010	Need to clarify methods used to develop this dataset.
ESA tiers	Natural England	2007	
In-field Environmental Stewardship options	Natural England	June 2012	Up-to-date version required
SPS land use codes	RPA	2012	
Habitats extent (Integrated Habitat System)	SWT	2008-2011	Available for the Brue Valley only

Table a1.1: Summary of data sets used in analyses

Results & Discussion

There appear to be substantial areas of the Levels and Moors which are at risk from changes in agri-environment schemes (table 2) with some obvious clusters in areas such as Butleigh Moor, Lang Moor and Queen's Sedgemoor where the risk of peat wastage is high or very high (figure 1).

Relatively small areas of land which were in tiers 2 or 3 of the ESA scheme appear to be at risk (table 2). These areas, comprising approximately 5-6% of the total extent of land in each peat wastage risk category, represent priority targets for landowner engagement. The real number of fields is likely to be even lower than shown here since more ELS and HLS applications have been approved since June 2012.

Over ninety-five percent of the land parcels which were historically within the ESA schemes were classified as permanent pasture in the 2012 SPS returns. This may serve as a useful metric for assessing future patterns of intensification in future years.

Within the Brue Valley, a range of BAP habitats have been identified as being at risk (table 3) with a total extent of 2068 hectares of ex-ESA land at risk and 361 hectares of land which was in ESA tiers 2 or 3. The peat soils of the Brue Valley represent approx 44% of the entire peat soils in the project area, therefore, if this patterns seen in the Brue Valley are repeated across the entire project area it would equate to BAP extents for 4704 hectares (ex-ESA) and 821 hectares (ex ESA tiers 2 or 3).

A.

Peat risk	Total extent of peat soils	
	Nº fields	Extent (ha)
Very High Risk	4052	11309.3
High Risk	1460	4118.5
Medium High Risk	318	881.1
Medium Risk	1462	3966.1
Total	7292	20275.1

B.

Peat risk	Fields not in ES schemes (Jun 2012)		
	Nº fields	Extent (ha)	% of total extent
Very High Risk	2492	6916.2	61%
High Risk	909	2697.3	65%
Medium High Risk	187	524.0	59%
Medium Risk	1087	3085.6	78%
Total	4675	13223.2	65%

C.

Peat risk	Fields not in ES schemes (Jun '12), ex-ESA (2007)		
	Nº fields	Extent (ha)	% of total extent
Very High Risk	1232	3412.2	30%
High Risk	382	1100.7	27%
Medium High Risk	116	312.9	36%
Medium Risk	514	1457.4	37%
Total	2244	6283.2	31%

D.

Peat risk	Fields not in ES schemes (Jun '12), ex-ESA tiers 2 or 3		
	Nº fields	Extent (ha)	% of total extent
Very High Risk	256	692.5	6%
High Risk	84	190.2	5%
Medium High Risk	16	40.8	5%
Medium Risk	86	232.0	6%
Total	442	1155.4	6%

Table a1.2: Extents of 'at risk' peat soils defined by different past and present implementation of agri-environment schemes in the Somerset Levels and Moors.

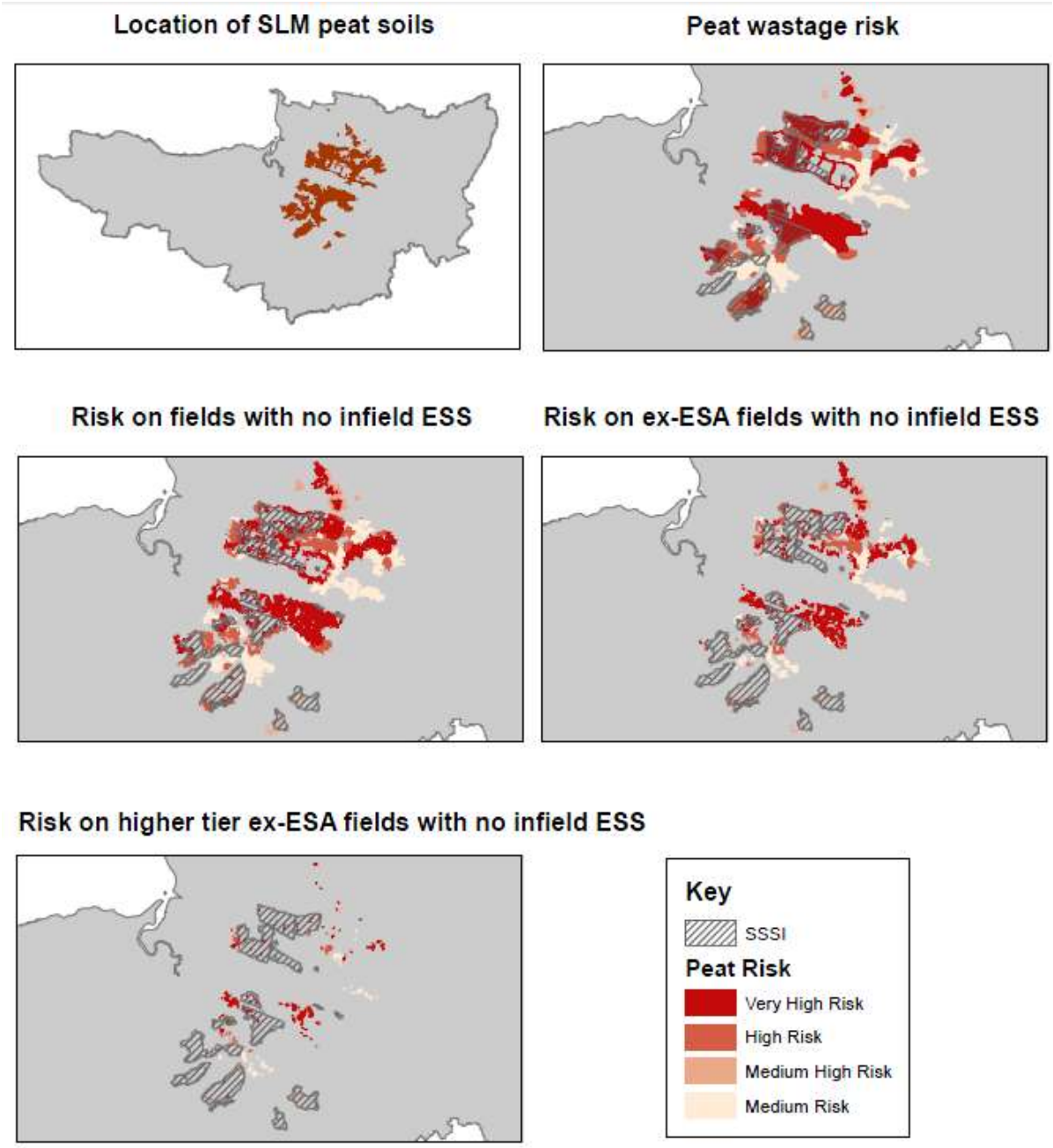

Figure a1.1: Location of peat soils and allied peat wastage risk in the Somerset Levels and Moors given increasingly strict categorisations for inclusion based on history and current engagement with agri-environment schemes.

A.

BAP habitat	No. fields	Hectares
Fen	3	5.8
Lowland Meadow	73	188.6
Purple Moor Grass & Rush Pasture	45	108.9
Wet Woodland	3	1.7
Coastal & Floodplain Grazing Marsh*	770	2060.0
Total BAP habitat at risk (adjusted for overlap with Coastal & Floodplain Grazing Marsh)	776	2067.5
Other habitats:		
Improved Grassland	176	527.0
Other arable, horticulture & non-cereal crops	2	0.4
Total	954	2594.9

B.

BAP habitat	No. fields	Hectares
Fen	2	3.5
Lowland Meadow	26	68.5
Purple Moor Grass & Rush Pasture	25	65.4
Wet Woodland	2	1.4
Coastal & Floodplain Grazing Marsh*	137	356.1
Total BAP habitat at risk (adjusted for overlap with Coastal & Floodplain Grazing Marsh)	141	361.0
Other habitats:		
Improved Grassland	1	1.3
Other arable, horticulture & non-cereal crops	1	0.1
Total	143	362.4

Table a1.3: Brue Valley Living Landscape BAP habitats formerly in A. ESA (all tiers) with no ESS agreement and B. ESA tiers 2 or 3 with no ESS agreement. Coastal & Floodplain Grazing Marsh figures include Lowland Meadow and Purple Moor Grass and Rush Pasture habitats

Appendix 2: Interview Templates

NN Interview

Section: You and your farm business

1	Are you the main decision maker on the farm? ***Yes / No***	
	1.1	***If no***, who is the main decision maker on the farm? Family member / non-family member
	1.2	***If yes***, what other input is there? Family member / non-family member
2	Is your farm (record one only) a. a private business b. local authority holding c. owned by a voluntary body d. other (specify)	
3	Would you describe the farm as (record one only) a. Agricultural b. Non-agricultural c. Not a commercial operation	
4	Which of the fields in your holding are: (use map) a. Owner occupied b. Rented in (full agricultural tenancy / short term let / grass let / informal let/ contract farming / share farming / other) c. Rented out (full agricultural tenancy / short term let / grass let / contract farming / share farming / other)	
5	Which best describes the farm type of the farm? (Mainly arable / mainly dairy / mainly beef / pigs & poultry / other)	
6	Please mark on the map which of your fields fall into the following categories: a. Arable crops and short leys b. Long leys c. Permanent grassland d. Rough grazing (open unenclosed hills/commons) e. Woodland f. Other	
7	How many people work on the farm – please include yourself and all family members (Full-time / part-time / casual - indicate which of these are family members).	
8	Which management tasks do you employ contractors for?	
9	Approximately how much of your business income derives from the agricultural enterprises on the farm? All of it / most of it / about half / less than half / very little/none	
	9.1	What other significant revenue streams do you have?
10	What are the main difficulties of farming on QSM?	

	10.1	Do you think that there are any solutions or schemes that could be put in place to combat these?
11	How many years have you worked on/managed this farm? Less than 5 yrs 5-10 yrs 10-20 yrs More than 20 yrs	
12	Which of these statements reflect your current plans for the future (next 5 years)? (choose one only) a. I plan to sell off the business b. I plan to reduce the size/intensity of the business c. I plan to maintain possession of the land but find other parties to manage it d. I intend to maintain my business without major changes e. I plan to grow/intensify the business f. I intend to change the business but direction of change uncertain at current time	
13	Will a member of your family take on the management of the farm after you retire? Definitely Very likely Possibly Unlikely Definitely not (not applicable)	
14	Have you noticed changes to the water quality, soil and wildlife on your holding over the years? Have land levels dropped? Has water changed in quality? Have ditch levels changed? Have the wader birds/ wildflowers changed? Has food production changed?	
	14.1	***If yes***, have these changes caused any problems for your farm system and management?
15	In your view, does any of your land have any importance for wildlife conservation, landscape character or public access? (allow farmer to respond without probing and record answer verbatim)	

Section: Interviewee's Scheme History/Experience

16	Why did you decide not to enter either the ESA or Environmental Stewardship schemes?	
	16.1	Were there any factors that might have changed your decision?
17	Have you significantly changed your farm system or management practices in the last 15-20 year period? ***Yes / No***	
	17.1	***If yes*** what are the main changes?
18	Do you think that the ESA and ES schemes have been effective at protecting the quality of soils and water and populations of wild animals and plants?	
19	In your opinion how could the ESA and ES schemes have been made more effective at protecting the quality of soils and water and populations of wild animals and plants?	
20	How significant would describe the financial implications of the end of the ESA scheme to your business? (Dramatic loss / significant loss / minor loss / little change / minor gain / significant gain / dramatic gain)	
21	Do you think that continued governmental subsidies are the right way to ensure that UK farming retains its competitiveness into the future?	
	21.1	Do you think that intervention in market support is better solution (i.e. protection from global markets or supermarket strangleholds)?
	21.2	Do you think that there a need to look at other ways of strengthening sales e.g. co-operative marketing / better local marketing / more advice on farming such as soil and stock management?

22	If a scheme was available that offered payment for protecting peat soils or improving water quality, do you think you would consider joining it?	
	22.1	***If no***t, why not?

Section: Wash-up

23	That is the end of the interview but before closing the interview do you have any other comment to make regarding agri-environment schemes that you think is relevant?	
24	Thank you very much for taking part in this survey, your contribution has been very helpful and I am grateful for your assistance. Later in the project we planning to hold a workshop looking at ways we can work in partnership to access new business opportunities. Would you be interested in taking part in this part of the project? ***Yes / No***	
	24.1	***If yes***, check contact details are most appropriate.
25	Record time interview closed …	

NY Interview

Section: You and your farm business

1	Are you the main decision maker on the farm? ***Yes / No***	
	1.1	***If no***, who is the main decision maker on the farm? Family member / non-family member
	1.2	***If yes***, what other input is there? Family member / non-family member
2	Is your farm (record one only) a. a private business b. local authority holding c. owned by a voluntary body d. other (specify)	
3	Would you describe the farm as (record one only) a. Agricultural b. Non-agricultural c. Not a commercial operation	
4	Which of the fields in your holding are: (use map) a. Owner occupied b. Rented in (full agricultural tenancy / short term let / grass let / informal let/ contract farming / share farming / other) c. Rented out (full agricultural tenancy / short term let / grass let / contract farming / share farming / other)	

5	Which best describes the farm type of the farm? (Mainly arable / mainly dairy / mainly beef / pigs & poultry / other)	
6	Please mark on the map which of your fields fall into the following categories: a. Arable crops and short leys b. Long leys c. Permanent grassland d. Rough grazing (open unenclosed hills/commons) e. Woodland f. Other	
7	How many people work on the farm – please include yourself and all family members (Full-time / part-time / casual - indicate which of these are family members).	
8	Which management tasks do you employ contractors for?	
9	Approximately how much of your business income derives from the agricultural enterprises on the farm? All of it / most of it / about half / less than half / very little/none	
	9.1	What other significant revenue streams do you have?
10	What are the main difficulties of farming on QSM?	
	10.1	Do you think that there are any solutions or schemes that could be put in place to combat these?
11	How many years have you worked on/managed this farm? Less than 5 yrs 5-10 yrs 10-20 yrs More than 20 yrs	
12	Which of these statements reflect your current plans for the future (next 5 years)? (choose one only) a. I plan to sell off the business b. I plan to reduce the size/intensity of the business c. I plan to maintain possession of the land but find other parties to manage it d. I intend to maintain my business without major changes e. I plan to grow/intensify the business f. I intend to change the business but direction of change uncertain at current time	
13	Will a member of your family take on the management of the farm after you retire? Definitely Very likely Possibly Unlikely Definitely not (not applicable)	
14	Have you noticed changes to the water quality, soil and wildlife on your holding over the years?	

	Have land levels dropped? Has water changed in quality? Have ditch levels changed? Have the wader birds/ wildflowers changed? Has food production changed?	
	14.1	***If yes***, have these changes caused any problems for your farm system and management?
15	In your view, does any of your land have any importance for wildlife conservation, landscape character or public access? (allow farmer to respond without probing and record answer verbatim)	

Section: Interviewee's Scheme History/Experience

16	Why did you decide not to enter the ESA scheme?	
	16.1	Were there any factors that might have changed your decision?
17	Which of your fields have got HLS or ELS options? (mark on map)	
18	Were you offered HLS on fields but turned it down? ***Yes / no***	

	18.1	***If yes,*** why have you kept some areas out of the new scheme? (wish to maintain autonomy / farm system doesn't fit scheme requirements / payments wouldn't cover cost of implementing scheme / too bureaucratic / other)
19	Has joining ES altered your farm management practices? (prompt for in-field management, ditches, hedgerows, archaeology)	
20	Are there other changes, not directly related to land management, that you've made to your business and farm management as a result of joining the Environmental Stewardship scheme?	
21	Do you think that the ESA and ES schemes have been effective at protecting the quality of soils and water and populations of wild animals and plants?	
22	In your opinion how could the ESA and ES schemes have been made more effective at protecting the quality of soils and water and populations of wild animals and plants?	
23	How significant would describe the financial implications of the end of the ESA scheme to your business? (Dramatic loss / significant loss / minor loss / little change / minor gain / significant gain / dramatic gain)	
24	Do you think that continued governmental subsidies are the right way to ensure that UK farming retains its competitiveness into the future?	
	24.1	Do you think that intervention in market support is better solution (i.e. protection from global markets or supermarket strangleholds)?
	24.2	Do you think that is there a need to look at other ways of strengthening sales e.g. co-operative marketing / better local marketing / more advice on farming such as soil and stock management?

25	If a scheme was available that offered payment for protecting peat soils or improving water quality, do you think you would consider joining it?	
	25.1	***If no***t, why not?

Section: Wash-up

26	That is the end of the interview but before closing the interview do you have any other comment to make regarding agri-environment schemes that you think is relevant?	
27	Thank you very much for taking part in this survey, your contribution has been very helpful and I am grateful for your assistance. Later in the project we planning to hold a workshop looking at ways we can work in partnership to access new business opportunities. Would you be interested in taking part in this part of the project? ***Yes / No***	
	27.1	***If yes***, check contact details are most appropriate.
28	Record time interview closed …	

YN Interview

Section: You and your farm business

1	Are you the main decision maker on the farm? ***Yes / No***	
	1.1	***If no***, who is the main decision maker on the farm? Family member / non-family member
	1.2	***If yes***, what other input is there? Family member / non-family member
2	Is your farm (record one only) a. a private business b. local authority holding c. owned by a voluntary body d. other (specify)	
3	Would you describe the farm as (record one only) a. Agricultural b. Non-agricultural c. Not a commercial operation	
4	Which of the fields in your holding are: (use map) a. Owner occupied b. Rented in (full agricultural tenancy / short term let / grass let / informal let/ contract farming / share farming / other) c. Rented out (full agricultural tenancy / short term let / grass let / contract farming / share farming / other)	
5	Which best describes the farm type of the farm? (Mainly arable / mainly dairy / mainly beef / pigs & poultry / other)	
6	Please mark on the map which of your fields fall into the following categories: a. Arable crops and short leys b. Long leys c. Permanent grassland d. Rough grazing (open unenclosed hills/commons) e. Woodland f. Other	
7	How many people work on the farm – please include yourself and all family members (Full-time / part-time / casual - indicate which of these are family members).	
8	Which management tasks do you employ contractors for?	
9	Approximately how much of your business income derives from the agricultural enterprises on the farm? All of it / most of it / about half / less than half / very little/none	
	9.1	What other significant revenue streams do you have?
10	What are the main difficulties of farming on QSM?	

	10.1	Do you think that there are any solutions or schemes that could be put in place to combat these?
11	How many years have you worked on/managed this farm? Less than 5 yrs 5-10 yrs 10-20 yrs More than 20 yrs	
12	Which of these statements reflect your current plans for the future (next 5 years)? (choose one only) a. I plan to sell off the business b. I plan to reduce the size/intensity of the business c. I plan to maintain possession of the land but find other parties to manage it d. I intend to maintain my business without major changes e. I plan to grow/intensify the business f. I intend to change the business but direction of change uncertain at current time	
13	Will a member of your family take on the management of the farm after you retire? Definitely Very likely Possibly Unlikely Definitely not (not applicable)	
14	Have you noticed changes to the water quality, soil and wildlife on your holding over the years? Have land levels dropped? Has water changed in quality? Have ditch levels changed? Have the wader birds/ wildflowers changed? Has food production changed?	
	14.1	***If yes***, have these changes caused any problems for your farm system and management?
15	In your view, does any of your land have any importance for wildlife conservation, landscape character or public access? (allow farmer to respond without probing and record answer verbatim)	

Section: Interviewee's Scheme History/Experience

16	Over what period of time were you part of the ESA scheme?	
17	Which of your fields did you have in ESA tiers? (mark on map)	
18	Did being in the ESA alter your farm management practices? (prompt for in-field management, ditches, hedgerows, archaeology)	
19	Since leaving the ESA scheme have you continued with the same management practices? ***Yes/No***	
	19.1	***If no*** what are the main changes?
20	Why did you decide not to enter the Environmental Stewardship scheme?	
	20.1	Are there factors that might make you reconsider?
21	Are there other changes, not directly related to land management, that you've made to your business and farm management as a result of the change in schemes?	
22	Do you think that the ESA and ES schemes have been effective at protecting the quality of soils and water and populations of wild animals and plants?	
23	In your opinion how could the ESA and ES schemes have been made more effective at protecting the quality of soils and water and populations of wild animals and plants?	

24	How significant would describe the financial implications of the end of the ESA scheme to your business? (Dramatic loss / significant loss / minor loss / little change / minor gain / significant gain / dramatic gain)	
25	Do you think that continued governmental subsidies are the right way to ensure that UK farming retains its competitiveness into the future?	
	25.1	Do you think that intervention in market support is better solution (i.e. protection from global markets or supermarket strangleholds)?
	25.2	In your opinion is there a need to look at other ways of strengthening sales e.g. co-operative marketing / better local marketing / more advice on farming such as soil and stock management?
26	If a scheme was available that offered payment for protecting peat soils or improving water quality, do you think you would consider joining it?	
	26.1	***If no***t, why not?

Section: Wash-up

27	That is the end of the interview but before closing the interview do you have any other comment to make regarding agri-environment schemes that you think is relevant?	
28	Thank you very much for taking part in this survey, your contribution has been very helpful and I am grateful for your assistance. Later in the project we planning to hold a workshop looking at ways we can work in partnership to access new business opportunities. Would you be interested in taking part in this part of the project? ***Yes / No***	
	28.1	***If yes***, check contact details are most appropriate.
29	Record time interview closed …	

YY Interview

Section: You and your farm business

1	Are you the main decision maker on the farm? ***Yes / No***	
	1.1	***If no***, who is the main decision maker on the farm? Family member / non-family member
	1.2	***If yes***, what other input is there? Family member / non-family member
2	Is your farm (record one only) a. a private business b. local authority holding c. owned by a voluntary body d. other (specify)	
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6	Please mark on the map which of your fields fall into the following categories: a. Arable crops and short leys b. Long leys c. Permanent grassland d. Rough grazing (open unenclosed hills/commons) e. Woodland f. Other	
7	How many people work on the farm – please include yourself and all family members (Full-time / part-time / casual - indicate which of these are family members).	
8	Which management tasks do you employ contractors for?	
9	Approximately how much of your business income derives from the agricultural enterprises on the farm? All of it / most of it / about half / less than half / very little/none	
	9.1	What other significant revenue streams do you have?
10	What are the main difficulties of farming on QSM?	

	10.1	Do you think that there are any solutions or schemes that could be put in place to combat these?
11	How many years have you worked on/managed this farm? Less than 5 yrs 5-10 yrs 10-20 yrs More than 20 yrs	
12	Which of these statements reflect your current plans for the future (next 5 years)? (choose one only) a. I plan to sell off the business b. I plan to reduce the size/intensity of the business c. I plan to maintain possession of the land but find other parties to manage it d. I intend to maintain my business without major changes e. I plan to grow/intensify the business f. I intend to change the business but direction of change uncertain at current time	
13	Will a member of your family take on the management of the farm after you retire? Definitely Very likely Possibly Unlikely Definitely not (not applicable)	
14	Have you noticed changes to the water quality, soil and wildlife on your holding over the years? Have land levels dropped? Has water changed in quality? Have ditch levels changed? Have the wader birds/ wildflowers changed? Has food production changed?	
	14.1	***If yes***, have these changes caused any problems for your farm system and management?
15	In your view, does any of your land have any importance for wildlife conservation, landscape character or public access? (allow farmer to respond without probing and record answer verbatim)	

Section: Interviewee's Scheme History/Experience

16	Over what period of time were you part of the ESA scheme?	
17	Which of your fields did you have in ESA tiers? (mark on map)	
18	Did being in the ESA alter your farm management practices? (prompt for in-field management, ditches, hedgerows, archaeology)	
19	Do you think that the ESA scheme was effective at protecting the quality of soils and water and populations of wild animals and plants?	
20	Since leaving the ESA scheme have you continued with the same management practices? ***Yes/No***	
	20.1	***If no*** what are the main changes?
21	Which of your fields have got HLS or ELS options? (mark on map)	
22	Were you offered HLS on fields but turned it down? ***Yes / no***	
	22.1	***If yes,*** why have you kept some areas out of the new scheme? (wish to maintain autonomy / farm system doesn't fit scheme requirements / payments wouldn't cover cost of implementing scheme / too bureaucratic / other)

23	Has joining ES altered your farm management practices? (prompt for in-field management, ditches, hedgerows, archaeology)	
24	Are there other changes, not directly related to land mangement, that you've made to your business and farm management as a result of the change in schemes?	
25	Do you think that the ESA and ES schemes have been effective at protecting the quality of soils and water and populations of wild animals and plants?	
26	In your opinion how could the ESA and ES schemes have been made more effective at protecting the quality of soils and water and populations of wild animals and plants?	
27	How significant would describe the financial implications of the end of the ESA scheme to your business? (Dramatic loss / significant loss / minor loss / little change / minor gain / significant gain / dramatic gain)	
28	Do you think that continued governmental subsidies are the right way to ensure that UK farming retains its competitiveness into the future?	
	28.1	Do you think that intervention in market support is better solution (i.e. protection from global markets or supermarket strangleholds)?
	28.2	In your opinion is there a need to look at other ways of strengthening sales e.g. co-operative marketing / better local marketing / more advice on farming such as soil and stock management?
29	If a scheme was available that offered payment for protecting peat soils or improving water quality, do you think you would consider joining it?	
	29.1	***If no***t, why not?

Section: Wash-up

30	That is the end of the interview but before closing the interview do you have any other comment to make regarding agri-environment schemes that you think is relevant?	
31	Thank you very much for taking part in this survey, your contribution has been very helpful and I am grateful for your assistance. Later in the project we planning to hold a workshop looking at ways we can work in partnership to access new business opportunities. Would you be interested in taking part in this part of the project? ***Yes / No***	
	31.1	***If yes***, check contact details are most appropriate.
32	Record time interview closed …	

Appendix 3: Raw data from spot samples of water quality

Individual measurements of anions and cations including supplementary data gathered in Oct-Dec 2014 which are not included in main analyses. ns = no sample, values of 0 indicate that concentrations were below the detectable limit of the ion chromatograph. All values are given in mg/L.

Nitrate

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	0.695	0.141	1.138	7.214	5.174
O2	ST5137341303	ns	0.335	0.043	0.849	4.825	1.268
O3	ST5137341303	ns	5.645	0.0322	3.813	5.083	3.705
O4	ST5136941290	ns	5.769	1.994	5.813	6.62	2.721
MO	ST5133741217	2.151	5.848	0.171	3.035	6.62	3.863
NS	ST5335342520	0.069	0.174	0.029	0.402	4.243	0.117
NNN	ST5335342520	0.245	0.145	0.103	0.156	0.133	0.201
NNS	ST5335342520	0.033	0.159	0.052	0.322	0.108	21.625
SS	ST5450840586	22.157	24.783	22.495	19.278	21.695	20.6
SQ	ST5364340742	20.044	19.671	ns	18.546	21.889	22.360

Phosphate

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	1.91	1.106	0.894	0.866	0.695
O2	ST5137341303	ns	1.156	0.624	0.342	0.397	0
O3	ST5137341303	ns	1.202	0.361	1.425	0.929	1.393
O4	ST5136941290	ns	1.267	1.668	1.311	0.629	0.956
MO	ST5133741217	1.387	1.396	1.162	1.307	0.653	0.968
NS	ST5335342520	0.82	0.902	1.159	0.115	0	0.102
NNN	ST5335342520	0.084	0	0	0.535	0.366	0.175
NNS	ST5335342520	0.268	0.53	0.848	0.369	0.612	0.252
SS	ST5450840586	0.226	0.298	0.298	0.302	0.269	0.432
SQ	ST5364340742	0.174	0.642	ns	0.334	0.263	0.289

Sulphate

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	283.434	221.486	335.333	218.317	247.624
O2	ST5137341303	ns	58.503	96.613	124.506	151.51	78.909
O3	ST5137341303	ns	282.119	411.195	381.358	258.078	458.933
O4	ST5136941290	ns	283.808	200.294	253.274	218.23	223.245
MO	ST5133741217	231.01	282.68	220.48	323.49	217.403	267.669
NS	ST5335342520	149.487	165.63	112.298	330.086	269.929	319.585
NNN	ST5335342520	219.76	274.981	246.152	93.536	267.324	306.107
NNS	ST5335342520	169.961	184.308	153.875	129.909	25.018	136.516
SS	ST5450840586	160.221	184.38	183.519	246.415	93.132	25.793
SQ	ST5364340742	156.367	183.926	ns	242.802	94.416	127.835

Flouride

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	0.347	0.228	ns	ns	ns
O2	ST5137341303	ns	0.345	0.226	ns	ns	ns
O3	ST5137341303	ns	0.269	0.226	ns	ns	ns
O4	ST5136941290	ns	0.27	0.183	ns	ns	ns
MO	ST5133741217	0	0.552	0.279	ns	ns	ns
NS	ST5335342520	0	0.28	0.214	ns	ns	ns
NNN	ST5335342520	0	0.265	0.208	ns	ns	ns
NNS	ST5335342520	0	0.312	0.193	ns	ns	ns
SS	ST5450840586	0	0.237	0.206	ns	ns	ns
SQ	ST5364340742	0	0.236	ns	ns	ns	ns

Chloride

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	37.54	27.626	ns	ns	ns
O2	ST5137341303	ns	27.448	19.827	ns	ns	ns
O3	ST5137341303	ns	33.321	35.286	ns	ns	ns
O4	ST5136941290	ns	33.328	24.997	ns	ns	ns
MO	ST5133741217	30.194	33.648	27.228	ns	ns	ns
NS	ST5335342520	14.93	18.384	11.284	ns	ns	ns
NNN	ST5335342520	19.241	21.461	17.123	ns	ns	ns
NNS	ST5335342520	34.895	40.865	62.052	ns	ns	ns
SS	ST5450840586	22.607	27.392	20.824	ns	ns	ns
SQ	ST5364340742	22.171	27.36	ns	ns	ns	ns

Bromide

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	0.415	0.256	ns	ns	ns
O2	ST5137341303	ns	0.459	0.318	ns	ns	ns
O3	ST5137341303	ns	0.345	0.164	ns	ns	ns
O4	ST5136941290	ns	0.338	0.238	ns	ns	ns
MO	ST5133741217	0	0.765	0.258	ns	ns	ns
NS	ST5335342520	0	0.33	0.232	ns	ns	ns
NNN	ST5335342520	0	0.339	0.223	ns	ns	ns
NNS	ST5335342520	0	0.526	0.489	ns	ns	ns
SS	ST5450840586	0	0.2	0.15	ns	ns	ns
SQ	ST5364340742	0	0.188	ns	ns	ns	ns

Lithium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	0.058	ns	ns	ns	ns
O2	ST5137341303	ns	0	ns	ns	ns	ns
O3	ST5137341303	ns	0.051	ns	ns	ns	ns
O4	ST5136941290	ns	0.046	ns	ns	ns	ns
MO	ST5133741217	0.047	0.044	ns	ns	ns	ns
NS	ST5335342520	0.044	0	ns	ns	ns	ns
NNN	ST5335342520	0.046	0.058	ns	ns	ns	ns
NNS	ST5335342520	0.233	0.025	ns	ns	ns	ns
SS	ST5450840586	0.09	0.042	ns	ns	ns	ns
SQ	ST5364340742	0.052	0.045	ns	ns	ns	ns

Sodium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	34.151	ns	ns	ns	ns
O2	ST5137341303	ns	31.927	ns	ns	ns	ns
O3	ST5137341303	ns	24.97	ns	ns	ns	ns
O4	ST5136941290	ns	24.116	ns	ns	ns	ns
MO	ST5133741217	24.766	25.411	ns	ns	ns	ns
NS	ST5335342520	12.127	15.68	ns	ns	ns	ns
NNN	ST5335342520	20.522	26.12	ns	ns	ns	ns
NNS	ST5335342520	28.44	30.432	ns	ns	ns	ns
SS	ST5450840586	15.058	15.667	ns	ns	ns	ns
SQ	ST5364340742	14.015	15.314	ns	ns	ns	ns

Ammonium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	0.863	ns	ns	ns	ns
O2	ST5137341303	ns	0	ns	ns	ns	ns
O3	ST5137341303	ns	0.791	ns	ns	ns	ns
O4	ST5136941290	ns	0.812	ns	ns	ns	ns
MO	ST5133741217	2.054	0.686	ns	ns	ns	ns
NS	ST5335342520	0.151	0	ns	ns	ns	ns
NNN	ST5335342520	0.294	0	ns	ns	ns	ns
NNS	ST5335342520	0.398	0	ns	ns	ns	ns
SS	ST5450840586	0.135	0	ns	ns	ns	ns
SQ	ST5364340742	0.069	0	ns	ns	ns	ns

Potassium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	6.044	ns	ns	ns	ns
O2	ST5137341303	ns	0.735	ns	ns	ns	ns
O3	ST5137341303	ns	9.608	ns	ns	ns	ns
O4	ST5136941290	ns	9.665	ns	ns	ns	ns
MO	ST5133741217	6.153	9.237	ns	ns	ns	ns
NS	ST5335342520	8	8.787	ns	ns	ns	ns
NNN	ST5335342520	1.958	1.724	ns	ns	ns	ns
NNS	ST5335342520	3.853	1.393	ns	ns	ns	ns
SS	ST5450840586	4.417	4.158	ns	ns	ns	ns
SQ	ST5364340742	3.852	4.359	ns	ns	ns	ns

Calcium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	47.093	ns	ns	ns	ns
O2	ST5137341303	ns	23.034	ns	ns	ns	ns
O3	ST5137341303	ns	37.054	ns	ns	ns	ns
O4	ST5136941290	ns	37.454	ns	ns	ns	ns
MO	ST5133741217	38.444	33.719	ns	ns	ns	ns
NS	ST5335342520	16.365	20.04	ns	ns	ns	ns
NNN	ST5335342520	24.586	25.893	ns	ns	ns	ns
NNS	ST5335342520	26.24	29.038	ns	ns	ns	ns
SS	ST5450840586	37.193	38.66	ns	ns	ns	ns
SQ	ST5364340742	34.843	39.174	ns	ns	ns	ns

Magnesium

Site	Grid Ref	01/05/2014	15/05/2014	13/06/2014	29/10/2014	28/11/2014	11/12/2014
O1	ST5135841307	ns	117.122	ns	ns	ns	ns
O2	ST5137341303	ns	72.912	ns	ns	ns	ns
O3	ST5137341303	ns	132.046	ns	ns	ns	ns
O4	ST5136941290	ns	131.674	ns	ns	ns	ns
MO	ST5133741217	77.293	127.342	ns	ns	ns	ns
NS	ST5335342520	54.471	94.431	ns	ns	ns	ns
NNN	ST5335342520	66.057	100.197	ns	ns	ns	ns
NNS	ST5335342520	67.939	119.44	ns	ns	ns	ns
SS	ST5450840586	70.164	102.549	ns	ns	ns	ns
SQ	ST5364340742	66.118	102.951	ns	ns	ns	ns

Appendix 4: Nitrate consumption in one rhyne

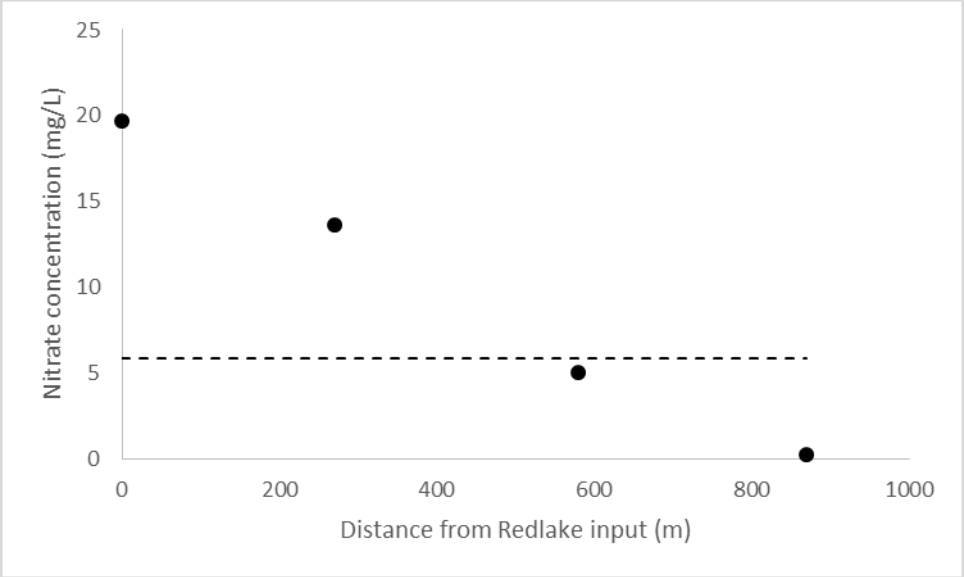

Figure A4.1: Nitrate concentrations recorded from water samples taken along the ditch running north from the Redlake input (SQ). Samples were taken on 15/05/14, the dashed line represents nitrate concentrations taken at the outfall on the same day.