DOCTOR OF PHILOSOPHY

The use of constructed treatment wetlands for water quality amelioration in conservation scenarios

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Record of Corrections

The use of constructed wetlands for water quality amelioration in conservation scenarios

Mike West

The following general and specific changes have been made following the suggestions of Peter Randerson and James McDonald. We appreciate the time and effort put in to this work and feel that the thesis has been improved greatly as a result.

General changes

All spellings and references corrected throughout the thesis significant removal of redundant phraseology and correction of figures. Additionally, most headings changed to provide additional information on the section.

Page numbers refer to original text.

Specific changes

Chapter 1

Page 2 – modification of introduction title

3. Apostrophe added to the word on ‘site’s’, degree of territorialisation explained, Moffatt reference spelled correctly
4. Title change Section 1.3
5. Modification of figure legend, ‘liable to’ replaced with ‘subject to’
6. Addition of Fill and Drain tidal wetland system
7. No additional or current data on CW numbers found in current literature, VF changed to include ‘compact’ VF systems
8. Inclusion of the discussion of anaerobic zones in predominantly aerobic FWS systems,
9. Inclusion of nitrogen cycling and reaction process diagrams, integration of this research with the study
10. Spelling of *Shoenus nigricans*
11. Removal of the word ‘said’ with regards to DOC
12. – 14. Reference list removed and placed at the end of the thesis

Chapter 2

Page 16 – introductory section entirely re-written, removal of FCW benefits and inclusion into more relevant section, removal of prejudicial statements regarding success of FCWs

17. 2 spelling mistake corrections
18. Combination of 3 titles into one section heading, phosphorus point sources re-phrased
19. Past tense, ‘this compound was’ changed to ‘these compounds were’
20. Removal of capital letter in ‘Hydroxy hydroquinone’, removal of phenol characterisation and inclusion in relevant sections. Modification of Title 2.8
21. –
22. Additional rationale for hypotheses paragraph, spelling corrected, reiteration of organic materials used. Explanation of experiment duration and general clarification of method
23. Section title changed to reflect scale by volume inclusion, 300ml of cultured algae. Fourty millilitres to 40ml
24. Explanation included of FCW replaced by barley straw. Rewording of enzymic latch phase. Rewording of substrate to organic material. maturation time of *Juncus effusus* included
25. Condensing of nutrient concentrations table, inclusion of FCW system diagram and explanation of construction
26. Significant addition of methods for parameter collection phenolics, DOC, SUVA, Ion Chromatography, statistical methods. In vitro phenol release graph legend reworded. Discussion removed and replaced into overall discussion to aid flow.
27. ANOVA method removed from results, figure legend rewritten
28. Tittle altered to ‘Effect of’, y-axis adjusted discussion points removed and included in relevant section. Figure legend rewritten
29. –
30. Discussion removed and placed into relevant section. Also reworded to discuss temperature effect. Discussion point added that Phenolics may not effect Algal biomass but rather it may be due to temperature alone with further testing required
31. SUVA method added to method section as specified in notes. Figure number corrections (throughout)
32. Addition of barley straw clearly indicated on graphs, delete repeated word, Phosphate dynamics reworded, figure 2.7 removed due to prior figure modification
33. Discussion removed and included in relevant section, barley straw addition clearly labelled. Description of more rapid NO3 removal in treatment clarified.

34. Nitrite and chlorophyll data labels corrected. Explanation and linking of algal decline following nitrate decline added
35. Page entirely rewritten and corrected
36. Referral to CW1 included, species name corrected, termination date of nutrient addition and maturity of the Juncus treatment now valid as included in methods
37. Conclusions modified to include referenced to hypotheses listed earlier in the chapter. Explanation of knowledge gained in the chapter and how it applies as a preliminary to the following chapter.
38. – 40, References removed and placded at the end of the thesis.

Chapter 3

Page 42 – rewording of introductory paragraph, clear addition of Hypotheses, clarification of levels of nutrient and inclusion into randomised block of total treatments, explanation of triplicate treatments occurring at both trophic levels

43. Rewording of tittle 3.2.2, correction of dates. Explanation of macronutrient constituents at each trophic level
44. Effective explanation of pseudo control treatment (matured system), rewording of 'ensuring equality of biomass between treatment species'.
45. Alteration of title 3.2.5 – increased detail of sampling methods. Pore water sampling methods explained in greater detail. Chlorophyll method clarified with reference to solvent addition, storage, experiment duration and analysis.
46. Page flow restructured to introduce topics logically; summarised in a single section as opposed to 'Water column and rhizosphere Enzyme Activity Analysis'
47. Statistical methods included and explained. Stats package detailed. Explanation of dual function; between AND within treatments, methods and discussion removed from figure legends. **Note – All figures from 3.2 to 3.22 have been converted to identical y-axis to ensure ease of comparison between hypertrophic and mesotrophic parameters measured.**
48. -64 all figure legends substantially reworded. Removal of any references to methodology or discussion points. Removal of double reporting of significance values
65. Phenol oxidase activity corrected to 2 d.p. clarification of benthos in supporting literature compared to no benthos sediment in experiment
66. Dissolved CO_2 consumption during algal photosynthesis tense correction. Clarification of pH rise due to CO_2 consumption. Clarification regarding water movement between the water column and rhizosphere

67. 2 spellings corrected
68. Rephrasing of degree to which statistical significance was detected. ' the original spelling of algaecide was retained since it appears in the Oxford Dictionary as such. Logical sentence structure of algal phenolic production used
69. Rephrasing of natural abundance of phenolics to include algal production of phenolics. Explanation of high phenolics in the control – only observed in the initial stages of the experiment
70. Spelling correction of split plot Anova. Explanation of phenolics as a result of algal bloom colonisation
71. The reference referred to was already provided earlier. Total nitrogen analysis altered to gaseous nitrogen analysis in order to quantify denitrification SUVA method reiteration removed and included in methods section
72. Title 3.4.3 adjusted. Entire page rewritten for clarity regarding primarily nutrient removal processes. Inferences made regarding removal rates between trophic levels added
73. Two spelling corrections
74. Replacement of ‘delineations’ with ‘type’. ‘Presence of oxidising and reducing conditions within the same reactor’ rephrased. Removal of redundant nitrite reduction paragraph. Additional description of system replicates added
75. DIN acronym explained at first use as dissolved organic nitrogen, scale added to figure 3.23. figure numbers corrected for chapter 3
76. Five spellings and hyphenated acronym correction. ‘a number of weeks’ replaced by ‘4 weeks’
77. Removal of colloquialism ‘far’ lower. Clarification of homogenous sub sets formed by the data
78. Support of biological significance although statistical significance may not exist. ($P<0.054$). Multiple referencing errors corrected in opening paragraph of the conclusion
79. Three referencing errors corrected, removal of colloquialisms/vague statement ‘fairly conclusive’
80. Algaecide retained as above
81. -83 references removed and placed at the end of the thesis.

Chapter 4

Page 85 – Three words corrected

86. Alteration of paragraph flow, nutrient pressure causes included and clarified in section regarding habitat quality. Map illustrating conservation site location included
87. Duplicated section removed, title adjustment of 4.4, spelling corrected and clarification of progressively accurate design tool utilisation

88. Maximum fen restoration for minimum CW footprint reworded to balancing conservation space with treatment achieved. Corrections of figure numbers referred to in the text nHRT calculation to include assumptions of a fully mixed system.
89. Table included to clarify formula components of the P-k-C* equation. Rewording of 'encroachment' changed to 'balancing of CW treatment area versus conservation site space'. Explanation of area computations included q=HLR=Q/A. NRW action replaced with Aim.
90. Capital letters removed from pollutant names. Listing of chapter and section numbers for nitrogen cycling processes previously described
91. C* explained to be a modifier of the equation as a system specific value for pollutant cycling within the system. Ground water fed systems – emerge as springs therefore flow volumes and lag times can be calculated. Explanation of within site harvesting for CW plants and species used included
92. Year added to 4.10 title. Inflow to systems properly characterised, volume modified to include/day.
93. Figure of FWS system deleted and referred to FWS explanation earlier in the thesis. Clarification of system short circuiting prevention methods
94. Location of HSSF discussed and characterised– separate inflow point to the same fen. Discussion of design development with EA Wales. Removal of HSSF diagram
95. HSSF systems scaling significantly rephrased. HSSF diagram clarification of distribution channel for short circuiting prevention. Explanation of standing water caused by water table elevation in the receiving fen. Figure numbers adjusted.
96. Two spellings corrected. Volumetric and flow rate notations corrected. 2 d.p. used in parameters for Cae Gwyn FWS. Units added to table and explanation of terms removed due to inclusion earlier.
97. Rephrase of practitioners to contractors
98. Dates added to figure. Removal of redundant phrases in figure legend. Denitrification processes occurring in primarily aerobic FWS system included in discussion. Maximum nitrate inputs clarified. Previously it was unclear that a max of 22mg was for Cae gwyn rather than Bodeilio.
99. Series labels corrected, temperature effects of P removal and soil absorbance included in discussion
100. Discussion of Calcium phosphate formation
101. Correction of Y-axis titles, system inlets and outlets explained. Inclusion of summer growth as explanation for NO_3^- removal

102. Removal of reference to FWS system ammonium, rephrased to include description of ammonium inflow to the system
103. Removal of estimates for Ca storage capacity included in discussion
104. Cae gwyn FWS Nitrate discussion points included regarding flow rates in addition to temperature effects
105. Five spelling mistakes corrected. Rephrasing of design tools used in discussion 'despite the use of basic scaling methods'. Rephrasing of denitrification process to include potential denitrification in future in the anaerobic zones of biofilms
106. Figure number corrected. Inclusion of potential PO_4 binding with Calcium. Removal of riverine sediments as a PO_4 source. Calcium maintenance reworded to minimal removal
107. Table adjusted to 2 significant figures. Clarification of back calculation from P-k-C* to nHRT method used. Figures indicate similar response. Observed Denitrification process reduction dates altered. Removal of redundant phraseology
108. Independent and dependant variable axis swapped on figure. Two spelling mistakes corrected. 'Flow path surface area' rephrased.
109. Methods detail added referring to Calcium gravel addition this relates to the discussion also. Cae Gwyn discussion reference to planting level replaced by planting density. Further clarification that the streams supplying the Cae gwyn system emerge as springs, fed by groundwater
110. 24mg/L changed to 22, 'biomass building' changed to 'plant growth'. SAV acronym removed and replaced with Submerged Aquatic Vegetation
111. Calculation of estimates total nitrogen removed from the system clarified, based on average flow average inflow concentration and average outflow concentration across the 14 month period averaged across the 3 systems
112. –
113. -114 references removed and placed at the end of the thesis.

Chapter 5

Page 115 – chapter title corrected. 'Into' replaced by 'to'

116. Section 5.1 title spelling correction, rephrasing of 'readily used technology', deletion of 'amount of' potential, spelling of watershed corrected
117. Microbial community respiration rates clarified
118. Supporting research defined and included, removal of speculative removal pathway, rephrased to refer to calcium as a micronutrient, removal of 'regularly' in 'experiments previously untaken'.

119. Reference correction and 2 word alterations. Microbial respiration rephrased.
120. Methods stated in past tense throughout
121. Explanation of equilibrium mechanism, title correction and corrections of tense
122. Correction to NitraBar, correct use of tense, correction of stage 2 method general clarification and explanation of remaining LMW within the dialysis tube. Correction of tense in stage 3, clarification of experiment duration and ratio of organic material specified.
123. Chlorophyll spelling correction. Modification of figure legend to clarify graph.
124. Removal of reference to calibration curve, explained in methods in more detail. Figure title correction
125. Experiment duration clarified in methods. Clarification of SEC analysis with regard to individual analyses of DOC released from organic matter
126. And SEC results following organic matter derived DOC as a mixture pre and post dialysis.
127. Correction of figure number 5.6. Acronym now appropriate due to earlier explanation.
Clarification of DOC-phenolics relationship observed in Peacock et al.
Conclusion developed to summarise findings and justify the experiments undertaken. Also explained is the rationale for further experiments using chapter 5 as a basis for further work.
128. -129 references removed and placed at the end of the thesis.

Chapter 6

Page 130 – correction of spelling in title page from onto to into

131. Introductory section completely rewritten from paragraph 3. Completely rephrased and restructured.
132. Complete re-write of the page. Addition of section titles; hypothesis development with regard to Phenolics and DOC, achieving molecular weight variability, achieving phenolic concentration variability and inclusion of hypotheses.
133. Reference year for Kadlec and Wallace corrected to 2008. Complete re-write of plant selection methods and details given regarding gravel type used. Re-write of experimental in-flowing water chemistry and inflow control. Addition of experimental design flow diagrams and tables explaining levels of hypothesis testing
134. Explanation of in parallel experiment set up. Electric water pump spelling correction. Re wording of ‘combination o’ changed to ‘use of’.
135. Addition of appropriate figure legend for mesocosm pictures.
136. Adequate account of system design, layout, pictures and hypothesis testing structure now provided. Correction of degrees C sign.

137. Subscript for all chemical formulae, ions analysed now listed. Matrix addition method clarified and reworded. Samples are ‘carried’ by a mobile phase retained.
138. Rephrasing of determination of SEC HMW LMW process. Figure spelling correction of *pseudacorus*
139. Statistical methods sufficiently explained in method section. Removal of double reporting of statistical figures. Removal of figure tittle in figure correction not required.
140. Interaction term of statistical analysis explained. Dissolved oxygen included in the method and explained in further detail.
141. Rephrasing of ‘replicate’ to ‘represent’. Future tense removed. P-values reported correctly
142. Rephrasing of pattern observed in nitrite concentrations
143. Phrasing changed to ‘greater than’ rather than ‘increased’. DOC varies with treatment. Condensing of statistical reporting
144. Ambiguity of SEC retention time removed. Figure X-axis units added (min)
145. 2 redundant words removed 1 spelling correction.
146. Figure legend rephrased. Relationship described no longer phrased as ‘replicates’, altered to ‘is similar to’
147. Wave lengths described accurately in methods. Degree of aromaticity and humicification index properly clarified in methods
148. –
149. Legend rephrased. Interaction effect removed.
150. –
151. –
152. –
153. Highlighted that percentage differences are very small. Basic parameters significantly condensed and rephrased
154. Linking of pH to denitrification optimum ranges specified in the literature. Rephrasing that pelagic algal colonisation can only occur in FWS. Removal of second basic parameter phrase
155. DO analysis significantly rephrased
156. Past tense used regarding phosphorus supply, spelling correction
157. Rephrased such that denitrification is classed as the main pathway for N removal from dissolved to gaseous state, plus figure number correction
158. Replacement of ‘greater than’ and ‘larger than’. Free floating denitrifiers removed. Number of papers altered to list the specific references explicitly

159. Explanation included regarding the production of root exudates that do not contain bound metals and are therefore capable of binding. Restructuring of paragraphs and flow regarding DOC and acid mine drainage systems in relation to Fe^{2+}.
160. Additional explanation of DOC LMW characterisation. Rephrasing of phenolic production in mesocosm systems. Rephrasing from 'varied' to 'changed' over time with regard to biomass.
161. Discussion of microbial biomass colonisation with relevance to this study. Added that microbial biomass may not be significantly different in field scale systems. Description of the effect of carbon characterisation with direct reference to Ca effect added. Condensing of links to preliminary experiments. Additional justification for HSSF, higher Aromatic for Ca plus lower total DOC therefore advantageous do to aforementioned effect on local drinking water reservoir although *Phragmites* produced significantly more total. Rephrasing of organic matter particle sorption in literature.
162. Description of humic metal binding facilitation. Implications of humic formation addressed with reference to the field sites. Rewording of C_{13} carbon labelling process
163. Application of E2:E3 ratio to SUVA and HMW humic compounds. Removal of contradictory section. UV-Vis DOC summary rewritten, now accurate due to hypotheses before method section.
164. Calcium chelation with DOC added and rephrasing of DO, pH and Calcium interactions linking to carbonate formation
165. Matrix Calcium addition section removed as covered in earlier pages
166. Inference regarding plant tissue calcium demands as a result of stomatal density removed
167. Conclusion section rewritten balancing primary aims of the CWs of the LIFE sites with additional secondary benefits regarding calcium mobility
168. -171 References removed and placed at the end of the thesis.

Chapter 7

Page 173 - rephrasing of introductory paragraph and inclusion of references to prior relevant chapters. Hypotheses clearly stated. Method title adjusted. Sample volumes clearly defined
174. Root altered to rhizome
175. –
176. Calcium addition method fully re-written, spelling correction, further description of ion chromatography and reference to only ionic Ca data utilised.
177. Tittle error – removed title on figure. T-Test utilised as recommended by examiner. Recalculation with reference to biomass correction

178. Rephrasing of figure legend to clarify statistical significance. Also adjustment of total DOC per unit biomass description
179. Graph type altered, i.e. line graph for phenolics per unit biomass replaced. Clarified explanation and figure legend. Addition of potentially due to high variability in *Iris* samples
180. Figure legend entirely re-written and clarified
181. Clarification of Figure with regard to molecular weight. The LMW cut of appears at ~10 minutes. At this point the response from *Iris* is observed to be higher, compared with a higher response from *Phragmites* in the heavier weight ranges. Humic content comparisons clarified to be between species
182. Rephrasing of 'not a marked difference'. Data transformed to a more utilizable order replacing percentage ionic calcium remaining in the water column after chelation to mg/L bound Ca /mg LMW DOC. Title species names in italic. Rephrasing of discussion paragraph 1 to clarify root exudate contribution to the experiment in chapter 6. Repetitive phrases removed for clarity.
183. Clarification of potential pathways for root exudate production and links to morphological adaptations of the roots and rhizomes. Correction of the charge on calcium – formatted as superscript. 2 spellings corrected
184. Calcium binding efficiency reworded to clarify the higher binding capacity versus low total DOC. Italics and figure numbers corrected throughout paragraph. Earlier explanation of MW analysis therefore section removed. Rephrasing of plant root/rhizome preparation with regard to biofilm colonisation
185. Clarification of suitability for *in vitro* analysis to isolate plant based constituent of the chelation process in CW mesocosms in previous chapter. Ionic total and overall chelation paragraph totally rephrased and significantly condensed. Presentation of the benefit of system selection to the aims of the LIFE fens project. Past tense used throughout
186. Reiteration of phenolics as a beneficial component for calcium chelation and mobility maintenance but also in terms of inhibiting wetland decomposition and net carbon losses. Suggestions for mechanism of chelation proposed between the polar bonds of carboxylic acids.
187. References removed and placed at the end of the thesis

Chapter 8

Page 189 –

190. Floating wetland successes synthesised and significant number of references formatted. Removal of 'increased' replaced with 'greater'

191. Removal of ‘concurrent’ and replacement by ‘as described in’. removal of isolated phrase. Spelling of ‘affected’. Rephrasing of threats to sites and degradation. Change of ‘upon’ to ‘on’.
192. Spelling of ‘Cae Gwyn’. Addition of the word ‘prevention’ in calcium carbonate formation. Addition of the word ‘of’ in ‘removal of calcium’
193. Spelling of Shen et al. Clarification of DOC reduction targets now included in chapters 4,5,6 and 7. ‘Whilst DOC production is low’ phrase removed
194. ‘Number of levels’ replaced by ‘the types of experiments used’ e.g. mesocosm/in vitro etc. Change of ‘upon’ to ‘on’. Rephrase of experiments in chapter 3 ‘outside’ changed to ‘exposed to environmental inputs’. Change of ‘suggests’ to ‘suggested’
195. Figure legends to include numbers
196. Rephrase of ‘if space was available’ to ‘were available’. Challenge regarding use of ‘will be’, describing actions that ‘will be’ undertaken by NRW in the future. Removal of ‘to’ in ‘elucidates to the effect’.
197. Explanation of why tracer testing was not used included in text
198. Additional explanation of what would be achieved by undertaking a tracer test. i.e. provide a measure of the dead volume within the system as compared to the designed volume and retention time. Proposed method for Ca chelation removed and replaced into chapter 7
199. Chelation method moved to chapter 7
200. -202 references removed and placed at the end of the thesis.