Collaboration for Environmental Evidence

Systematic Review CEE 08-012
(SR 49)

HOW DO DRAINING AND RE-WETTING AFFECT CARBON STORES AND GREENHOUSE GAS FLUXES IN PEATLAND SOILS?

Supplementary material

Lead Reviewer: *James Bussell*

Postal Address: *Centre for Evidence-Based Conservation*
School of Environment, Natural Resources and Geography
Bangor University
LL57 2UW, UK

E-mail Address: *a.s.pullin@bangor.ac.uk*
Telephone: *+44 (0)1248 382953*
Fax: *+44 (0)1248 354997*

10.3 Appendix III

Data extraction sheet for studies included in meta-analysis

Reference	Alm, Saarnio, Nykanen, Silvola, Martikainen 1999.
Location	Bog: Ahvensalo (65°47'N 30°53'E). Fen: Salmisuo (62°47'N 30°56'E)
Subject	CO2 in dark with veg but snow removed. (g m-2 d-1) CH4 (mg m-2 d-1) N20 (ug m-2 d-1) on fen and bog
Intervention	Drained
Methodology	Site comaprison Closed chamber and gradient measures. Done over winter period of snow cover.
Sources of bias	No before data, presumably no randomisatioin in sampling procedure and repeat measures. Sinlgle site comparrisons only.
Reasons for heterogeneity	Peat depth, water table, N%, pH (Table 1). Microsite (hollow, lawn hummock). Time since intervention
Extraction	Cannot extract data for one year only so will need to extract all available. Used fig 6 to extract data. Generate mean and S SD from this data. Use n=2 from page 166 as conservative estimate as using n from graph will bias sample. Site information from table 1 on p167. BD from Silvola et al 1996 Table2.
Notes	Figures not totally clear
References	Laine et al 1996 describes the sites. Silvola et al 1996
Reference	Andersen, Francez, Rochefort 2006. The physicochemical and microbiological staus of a restored bog in Qubec
Location	Bois-des-Bel 47°58'N 69°26'W
Subject	Microbial biomass C (mg g-1)
Intervention	Rewet (with added veg and fertiliser) choice of comparator, prisitne site or non rewetted site
Methodology	Restored site has added plant fragments, blocking of drainage, add fertliser. Soil was removed from three depths, roots removed, and stored in dark bags. Only two depths used for CO2 and one for CH4. Gas done by CFE or SIR method incubation with glucose - see refs.
Sources of bias	Sinlge site comparison done at one time therefore poor quality low external validity. Low replication (n=6) and may be pseudoreplicated at the site level so n=3?. Plant cover different in control and intervention
Reasons for heterogeneity	See table 1 on p. 1379 but water table info in para 1 p 1377.
Extraction	Table 1 for het. Table 2 for microbial biomass C, extract top line of data only. use cutover as comparator as rewet is intervention and natural sites wont be rewet, must have undergone some drainage. Extract data from depths A and B u se study sample size of n=3 from section 2.2. Standard errors converted to sd
Notes	Doesn't say if fen or bog, but classified as sphagnum peatland.
References	Anderson and Domesh 1978, Sparling 1995 for SIR methods.

Reference	Basiliko et al 2007. Regulation of decomposition and methane dynamics across natural, commercially mined, and restored northern peatlands
Location	Riviere du Loup, Qubec and Shipagan, New Brunswick
Subject	DOC, microbial biomass C (mg -g peat). (CO2 and CH4 are measured as potential aerobic and anaerobic lab productions therefore exclude these outcomes).
Intervention	Drain blocking
Methodology	Site comparion at two locations at different peat depths. DOC by colour, microbial C by CHCl3 fumigation, CO2 and CH4 in lab by GC
Sources of bias	No beofre data so baseline confounded. Reading from graph decreases accuracy. Combined data from graphs.
Reasons for heterogeneity	Diff in water table, and all listed in table 1 = ph, moisture, NO3, NH4, ON, Mic N C:N PO4 P Na K Ca Mg SO4
Extraction	Site info, water depth time since intervention on p1151 in text. Figure 2 to extract DOC, microbial biomass peat. Extract data from each depth and retain study level n=3.
Notes	Extract both locations as separate data points. Abandoned sitesare control versus restored as intervetion.

Reference	Bellisario, Bubier, Moore 1999. Controls on CH4 emissions from a northern peatlnad
Location	Manitoba, Canada - 55°40'N 97°52'W
Subject	CH4 mg CH4C m-2 d-2) and CO2 in dark and across range of light PAR presumably with vegetation (NEP g Co2C m-2 d-1) flux, CH4 potential (lab).
Intervention	Natural
Methodology	Closed chamber for field measures and anaerobic and aerobic incubations on lab for CH4 potential
Sources of bias	No intervention as natural experiment. Water table changes are small and best comparable sites are fen and bog - Data is presented as averages and would combine these to get measures over a year therefore pseuodoreplicated
Reasons for heterogeneity	Water table, air temp, peat temp, cations, pH, vascualr biomass.
Extraction	Extract methane in field only as CO2 is modelled and measured values not given. Also, lab incubations measure potentials.

Reference	Best and Jacobs 1997. The influence of raised water table levels on carbon dioxide and methane production in ditch-dissected peat grasslands in the Netherlands
Location	Waginegen, NL - 51°54'N 5°38'E
Subject	CO2 possibly in ambient conditions over 24 hours so NEE? (production kg CO2-C ha-1 day-1) and CH4 (production kg CH4-C ha-1 day-1)
Intervention	Re wet of drained field by subsurface irrigation through drains from two artesian wells
Methodology	Site comparison study looking at rewet field and adjacent drained field seven years after rewetting over a period of one year in ditches, banks and fields. Top 15 cm soils extracted, acetylene inhibition method. Gas production is between 0.5 and 24 hr incubation. pH TN TC and water were measured from soils after incubation.
Sources of bias	Soil removed ten times over year from same spots so repeat measures. No before drainage measure so confounded baseline.
Reasons for heterogeneity	time since intervention (7 years), pH, Temeprature, C:N ratio, OM content, moisture content
Extraction	Data from fig 1 and fig 2. Average means and sd over years and use study sample size n =5. Extract from ditch, bank and field seperately. Table 2 for ph and C:N. Figure 4 was used to get an avergae annual air temperature.
References	Parsons et al 1991 and Berendese etal 1994 for methods of gas measurement Weshoff and Den Held 1969, Best 1995 and van der Hoek and van der Schaaf 1988 for more site info
Reference	Best and Jacobs 2001. Production, nutrient availability, and elemental balances of two meadows affected by different fertilization and water table-regimes in The Netherlands
Location	Waginegen, NL - 51°54'N 5°38'E
Subject	C in yield g C / kg AFDW-1, C mineralisation g/ha/d
Intervention	Re wet of drained field by subsurface irrigation through drains from two artesian wells
Methodology	Site comparison study looking at rewetted field and adjacent drained field seven years after rewetting.
Sources of bias	Done at the same time as Best and Jacobs 1997 so will be correlated. Fields were harvested differently for yield measures. Soil removed ten times over year from with repeat measures. No before drainage measure so confounded baseline.
Reasons for heterogeneity	Water table, bulk density, ph, air temp.
Extraction	Carbon as yield from table 1. C mineralistion from table 2. BD pH -page 63 Temp not reported, water table and air temp as for Best and Jacobs 2007.

Reference	Boeckx and Van Cleemput 1997 Methane emissions from freshwater wetlands in Belgium
Location	Ghent 51°04'N 3°41'e
Subject	CH4 (flux in mg m-2 d-1)
Intervention	Natural
Methodology	Closed chamber site comparison
Sources of bias	Only done on two grassland sites at one time. No water table info, compares site with bad natural drainage (site 1) and fairly bad natural drainage (site2)
Reasons for heterogeneity	pH, OM, Reduction horizon
Extraction	Extract site 1 and 2 from fig 3. Data read direct from hard copy of graph and not scanned. Errors are SE so convert to sd. n = 6 from methods. Date from p 1251 ph from table 1.
References	Marchal and Tavernier 1997 for info on drainage classification.
Reference	Bubier et al 1993 Methane emissions from wetlands
Location	Northern Ontario Canada
Subject	CH4 (mg m-2 d-1)
Intervention	Natural
Methodology	Chamber and gc from mid May to August 1991
Sources of bias	Repeat measures of same sites but some random allocation to different parts of each site each time.
Reasons for heterogeneity	water table, soil temperature at 20cm, vegetation
Extraction	Table 2 and 3 for heterogeneity, Table 4 for data. Fix n at 12 for hummocks or 36 for site level as repeat sampling of sites leads to high value of n reported in table 4. Compare sites 2 and 8 (Swamps) , 3 and 13 (Open low shrub fen) 7 and 15 (open low shrub bog). 9 and 14 (treed low shrub bog) not extracted as both very dry and unsuitable.
Notes	Extract like with like only from table 2. Extract data separately for hummock hollow and lawns.
Reference	Chapman and Thurlow 1996. Influence of climate on CO2 and CH4 emissions from organic soils
Location	Glensauh (NO655810) and Bad a Choo (ND167497) Scotland
Subject	Gross dark CO2 flux (Total respiration) (mg C m-2 h-1) CH4 (mg C m-2 h-1)
Intervention	Naturally wet and dry areas at two sites, one afforested
Methodology	Closed chamber and gas analyser and gc. Bimonthly but from same location so repeat measures.
Sources of bias	Repeat measures, low sample size as n=2 until April 1992.
Confounding	No water table info given.
Reasons for heterogeneity	Ph, location. Soil temperature at 1ocm
Extraction	Cannot extract CH4 data as no comparator data is presented. Heterogeneity from table 1 and section 2.1. CO2 from fig 1 and 2 Extract means of means and standard error and use lowest study level value of n=2. Extract from a year only to avoid bias so from Dec 1991 to Nov 1992 in Fig 1 and Jan 1992 Nov 1992 in Fig 2. Get temperature info from here also.

Reference	Chimner and Cooper 2003 Influence of water table levels on CO2 emissions in a Colorado sub alpine fen: an in situ microcosm study
Location	Moose Fen Rock Mountains Colorado
Subject	CO2 in dark with veg (mg C-CO2 m-2 h-1)
Intervention	Drain
Methodology	In situ mesocosm lower water level. Gas measured by dark chamber and mobile analyser
Sources of bias	Repeat measure of same chamber over time. Only one relatively small location therefore low external validity. Water levels are variable within treatments and replication is low. Data not presented well so need to take averaged of all data set to extract, use n=3 to be conservative
Reasons for heterogeneity	Water table level, soil temperature
Extraction	Use Fig 4 to extract temperature data. Use Fig 5 to extract CO2 data and water level data and average over all values from both years as not presented better anywhere else (like Alm 1998). Use lowest study level of n=3 to be conservative

Reference	Davidsson, et al 2002 Denitrification in drained and rewetted minerotrophic peat soils in Northern Germany
Location	N Germany (Kiel)
Subject	N20
Intervention	Rewet
Methodology	Solid cores taken but randomly and in good number so reasonable internal validity. Acetylene inhibition and gc four outcome.
Sources of bias	No info on water table or time since intervention. Only a single site comparison at two times so low external validity, several different measures of N2O so choice made on which to extract
Confounding	pH at rewet is .5 higher or 9%. Spring summer measures only.
Reasons for heterogeneity	ph, soil temp at 3cm. Water filled pore space is only measure of wetness
Extraction	Extract soil N20 from Fig 2 for data and Table 1 for heterogeneity
Notes	Average water filled pore space is 89% for drained and 100% for rewet

Reference	Davidsson and Leonardson 1997 Production of nitrous oxide in artificially flooded and drained soils
Location	Kristianstad in southern Sweden
Subject	N20
Intervention	Drain
Methodology	Solid cores taken but randomly and in good number so reasonable internal validity. Acetylene inhibition and gc for outcome.
Sources of bias	No info on water table. Time since intervention only seven days and repeat measures. Only a single site comparison. Several different measures of N2O so choice made on which to extract
Confounding	Not enough data to see confounding of other factors but no before data
Reasons for heterogeneity	pH and temperature measured but not reported.
Extraction	Table 2. Average across seasons and use study level of n from page 112. SD calculated from 95% CI's

Reference	Fiedler et al 1988 CO2 und CH4 Emissionnen aus boden entlang eines Feuchtegradienten im sudwestdeuschen Alpervorland
Location	Alpenvorland SW Germany
Subject	CO2 g m-2 d-1 CH4 mg m-2 d-1
Intervention	Drain
Methodology	Site comparison with closed chambers
Sources of bias	In German so could have misunderstood. No before data. Data and SD calculated from one years data points. Repeat measures. Presume it is total respiration.
Confounding	Temperature seems ok but no other variables shown.
Reasons for heterogeneity	Temperature, water table
Extraction	Temp from Abb1 data from Abb3
Reference	Freeman et al 2002 Contrasted effects of simulated drought on the production and oxidation of methane in a mid-Wales wetland
Location	Cerrig yr Wyn Plynlimon mid Wales
Subject	CH4 ng g h-1
Intervention	Drain
Methodology	BACI Bypass water supply, soil extraction and incubation then GC in lab
Sources of bias	Repeat measures of same two sites. No variance for each depth. Temperature not reported.
Confounding	Before measures not confounded extract CI data
Reasons for heterogeneity	Peat depth
Extraction	Data from Fig 2 drought production September 140 days since intervention, average over depth and calculate SD from this data, use study level n=3.

Reference	Glatzel et al 2003 Dissolved organic matter properties and their relationship to carbon dioxide efflux from restored peat bogs
Location	Riviere du Loup, Quebec 47°48'N 69°28'W
Subject	DOC
Intervention	Rewet as restoration
Methodology	Water sampled by piezometer over summer 2000 from abandoned and harvested peat and rewet by closing ditches.
Sources of bias	Unclear sample size, presume repeat measure of 1 piezometer at each site. Data over summer only. Block cut site has no true comparator as all sites have undergone some re-wetting. Compare AS with BC. No before data
Reasons for heterogeneity	Water level, vegetation, time since intervention
Extraction	Extract from Fig 1 and other stuff in 2.1and 2.2. Presume n=1 A59 and A vs. BC as not enough info to extract I
Notes	Checked sample size with author

Reference	Glenn et al 1993 Carbon dioxide and methane fluxes from drained peat soils, Southern Quebec
Location	Napier, Quebec 45°08'18''N and 73°26'12''E
Subject	CH4 (mg m-2 d-1) (not enough data on CO2 presented)
Intervention	Drained
Methodology	Drained by ditches, static chamber possibly opaque and then GC
Sources of bias	Only extract data from site 4and 5 as only comparable ones. Repeat measures
Reasons for heterogeneity	water table, vegetation
Extraction	Site 4 and 5 only comparable ones. Fig1 for CH4 and water table only. Not enough info to extract CO2
Reference	Heyer et al 2002 Methane emissions from different ecosystem structures of the sub arctic tundra in Western Siberia during midsummer and during the thawing period
Location	Yamal, Northwest Siberia 68°08'N 71°42'E
Subject	Methane (mg m-2 d-1)
Intervention	Natural
Methodology	Static chamber and gc
Sources of bias	Repeat measures, data only extractable from a few days in August, low sample size. Not all data presented.
Reasons for heterogeneity	Water table, peat depth, thawing depth, air temp
Extraction	Extract temperature and CH4 from Fig 1. Heterogeneity from Table 1
Notes	Not the best reporting of data restricts amount of extraction.
Reference	Hughes et al 2002 Temporal trends in bromide release following rewetting of a naturally drained gully mire
Location	Plynlimon (Mid Wales), SN820886
Subject	DOC (mg/l)
Intervention	Rewetting
Methodology	BACI but essentially without replication. Diversion of stream flow from adjacent gulley. DOC by autoanlyser using UV digestion and colorimetric detection.
Sources of bias	Only one treatment gulley and one control gulley. Repeat measures of the same five locations over time. Standard error not reported therefore need to calculate annual SD.
Confounding	No data on water table. But there is baseline data on DOC
Reasons for heterogeneity	pH
Extraction	Extract from Fig 2. Data on pH and site in alternate Hughes reference (Hughes et al 1996) attached to hard copy
Notes on quality	Has BA but very little sources of heterogeneity, essentially low replication and no SD reported.

Reference	Huttunen et al 2002 Fluxes of nitrous oxide on natural peat lands in Vuotos, an area projected for a hydroelectric reservoir in northern Finland
Location	Vuotos Finland
Subject	N2O ug m-2 d-1
Intervention	Natural
Methodology	Site comparison using static chamber and GC
Sources of bias	Repeat measure so keep n=3 at study level, single sites. Measurements June to October only
Confounding	Not sure of drainage level in plots, choice of sites based on subjective decision of reviewer. Sites 1 and 10, Pine in intervention but not control, Peat thickness (25%), Air temp (26%) soil temp (18%) may be confounded between sites. Sites 7 and 9, pine in intervention but birch in control peat thick (85%) is confounded but temperatures are not.
Reasons for heterogeneity	Water table, Air temp, peat temp, bog type
Extraction	Heterogeneity from Table 1, data from Table 2. keep n=3 due to repeat measure and not well reported (3-6). Compare sites 3 and 10 and 7 and 9 only as they seem to be similar from Table 1.
Notes on quality	Single sites. Repeat measures and maybe some drainage
Reference	Komulainen et al 1998 Short-term effect of restoration on vegetation change and methane emissions from peatlands drained for forestry in southern Finland
Location	Southern Finland - Konilamminsuo mire (fen site) 61°48'N24°17'E and Viheriaisenneva mire (Bog site) 61°51'N24°14'E)
Subject	Methane mg m-2 d-1
Intervention	Re-wetting
Methodology	Static chamber and gc. Block ditches with control BACI-esque design but low replication
Sources of bias	Repeat measures, sites not randomly chosen, site was clear cut as part of intervention
Confounding	In fen site vegetation was removed in one of the two plots in the second year making comparison here impossible. BACI design so can comment well on confounding of heterogeneity variables. Water tables ok at start of expt and intervention has desired effect. Soil temp not confounded in fen (6%) or bog (8%).
Reasons for heterogeneity	Water table, air temp, soil temp, precipitation
Extraction	BACI design but extract as site comparison and comment on levels of confounding. Extract soil temps (by average across depths) and water table from Table 2. Air temp and precipitation from p 403. Extract CH4 from Table 3. For fen extract from 1995 as 1996 is confounded by vegetation removal.
Notes on quality	Not bad, BACI so ok but low reps, only two sites with two chambers and not randomly allocated. Only two years after as well and is confounded in fen site

Reference	Laine et al 1996 Effect of water-level drawdown on global climatic warming: northern peatlands
Location	Lakkasuo central Finland 61°48'N 24°19'E
Subject	CO2 soil and root respiration (mg C02 m-2 h-1) CH4 (mg m-2 d-1) N2O (ug m-2 h-1)
Intervention	Draining
Methodology	Single site comparisons. Drain by ditches in 1961. CO2 by dynamic dark chamber and auto analyser, CH4 and N2O by static chamber and GC
Sources of bias	Data only presented well from sites 1 and 4 so reporting bias. Only n=1 on CO2 with repeat measure. Only n= 2 on CH4 and N2O so generate variances from yearly data. Measured in summer only as frozen and samples not taken at equal periods through out the year therefore biased yearly average.
Confounding	Site 1: many more trees in treatment section, pH is 1.1 lower in treatment (20%), BD is 37% higher. Site 4 is not as bad as site 1 but BD is 36% higher in treatment.
Reasons for heterogeneity	Tree stand, pH, water level ,temperature, precipitation
Extraction	Extract heterogeneity from Table 1 and bottom of p179. Data from Fig 2 include temperature data. Do not include data from tall sedge fen as extracted from Martikainen 1993.
Notes on quality	Low replication and repeat measures. Not all data presented.
Reference	Martikainen et al 1993 Effect of a lowered water table on nitrous oxide fluxes from northern peatlands
Location	Lakkasuo Mire Finland 61°47'N 24°18'E
Subject	N2O ug m-2 d-1
Intervention	Drain
Methodology	Single site comparison. Static chamber and gc. Drain by ditches in 1961.
Sources of bias	Some of this data may have been extracted already (sites 3 and 4 this paper) in Laine et al 1996.Data presented mainly when no snow cover with only one or two measures in winter so biases towards summer values. There are repeat measures and low sample size n=2.
Confounding	No before data so cannot comment on base line confounding. Ph and temp between sites seems ok
Reasons for heterogeneity	Soil temp, water table, tree cover, pH, plant cover, data for Lakkasuo can be found in Laine et al 1996
Extraction	Extract from Fig 1 sites 2-5 only as no comparator for site 1. Table 1 has extra heterogeneity data. Did not extract site 4 as have it better extracted from Laine et al 1996. Site 3 is also in Laine et al 1996 but use this data as includes se measure.
Notes on quality	Graphs are low quality to extract from.

Reference	Martikainen et al 1992 The effect of changing water table on methane fluxes at two Finnish mire sites
Location	Lakkasuo Mire Finland 61°47'N 24°18'E
Subject	CH4 mg m-2 d-1
Intervention	Drain
Methodology	Single Site comparison. Static chamber and gc. Drain by ditches in 1961.
Sources of bias	This data may have been extracted already in Laine et al 1996. Data presented mainly when no snow cover with only one or two measures in winter so biases towards summer values. There are repeat measures and low sample size n=2.
Confounding	Data may have already been presented. No before data so cannot comment on base line confounding. Ph and temp between sites seems ok
Reasons for heterogeneity	Soil temp, water table, tree cover, Ph, plant cover, data for laaksuo can be found in Laine et al 1996
Extraction	Extract from Fig 1. Extra heterogeneity data in text and in Laine 1996. use this paper over Laine as SE presented in figures and heterogeneity is more representative of measures
Notes on quality	Only a site comparison
Reference	Martin et al 1997 Water table effects on Histosol drainage water carbon, nitrogen, and phosphorus
Location	Everglades, S. Florida
Subject	TOC
Intervention	Natural
Methodology	2 x 4 factorial design, essentially site comparison with 3 replicates. TOC by wet oxidation APHA method
Sources of bias	Mean calculated from 4 repeat runs on same expt.
Confounding	pH fine no other estimates of confounding possible
Reasons for heterogeneity	ph, bulk density, site type
Extraction	Data from table 3 use depths 0 and 35 cm and extract both sites separately (Field A and D). BD averaged from Table 1
Notes on quality	Small scale study without a clear intervention done in lab, relevance low but does fit our criteria
Reference	Melling et al 2005 Soil CO2 flux from three ecosystems in tropical peatland of Sarawak, Malaysia
Location	Sarawak Malaysia
Subject	CO2 total respiration mg C m-2 h-1
Intervention	Drain
Methodology	Static chamber and GC. Site comparison
Sources of bias	Repeat measures, no before data. Measured every month so no bias towards season
Confounding	No before data. The intervention is 12% more rain, 13% thicker peat, 5% more acidic and 25% more bulk density
Reasons for heterogeneity	Wt, rainfall, peat thickness, ph, bulk density, c:n, air temp, soil temp,
Extraction	Fig 3 for CO2, temps from Fig 1other heterogeneity from Table 1, wt from Melling in soil biology.
Notes on quality	Only a site comparison with repeat measure

Reference	Melling et al 2005 Methane fluxes from three ecosystems in tropical peatland of Sarawak, Malaysia
Location	Sarawak Malaysia
Subject	CH4 ug C m-2 h-1
Intervention	Drain
Methodology	Static chamber and GC. Site comparison
Sources of bias	Repeat measures, no before data. Measured every month so no bias towards season
Confounding	No before data. The intervention is 12% more rain, 13% thicker peat, 5% more acidic and 25% more bulk density
Reasons for heterogeneity	wt, rainfall, peat thickness, ph, bulk density, can, air temp, soil temp,
Extraction	Fig 1 wt, Fig 2 CH4, Melling in tellus for rest
Notes on quality	Only a site comparison with repeat measure
Reference	Melling et al 2005 Global warming potential from soils in tropical peatland of Sarawak, Malaysia
Location	Sarawak Malaysia
Subject	Cumulative N20 mg m-2 (CO2 and CH4 extracted from previous Melling papers)
Intervention	Drain
Methodology	Static chamber and GC. Site comparison
Sources of bias	Repeat measures, no before data. Cumulative measures so take values from last month of 12 month period
Confounding	No before data. The intervention is 12% more rain, 13% thicker peat, 5% more acidic and 25% more bulk density
Reasons for heterogeneity	wt, rainfall, peat thickness, ph, bulk density, can, air temp, soil temp,
Extraction	Fig 1 c, rest from previous papers
Notes on quality	Only a site comparison with repeat measure
Reference	Meissener et al. 2003 Re-wetting of fen soils and changes in water quality - experimental results and further research needs
Location	Droemling NE Germany
Subject	DOC mg/l
Intervention	Rewet
Methodology	Single site comparison
Sources of bias	Repeat measures, no before data, several different measures of the same thing, all extracted do SA, no water table measures,
Confounding	No before measure, pH and BD look ok
Reasons for heterogeneity	pH BD
Extraction	Digitise Fig 2.
Notes on quality	Means extracted from 3 years but n=3 for repeat measure. Single site so not great

Reference	Minkinnen et al 1999 Post-drainage changes in vegetation composition and carbon balance in Lakkasuo mire, Finland
Location	Lakkasuo central Finland 61°48'N 24°19'E
Subject	Total Carbon (%)
Intervention	Drain
Methodology	Site comparison at three depths at 4 different sites
Sources of bias	Same study times as the Laine papers above. Data aggregated from transect so will have gradients in them
Confounding	Drained ditches have more trees on them. No before data so cannot comment on base line
Reasons for heterogeneity	Trees, thickness bulk density wt ph other Lakkasuo variables extracted from other studies
Extraction	Table 1 for heterogeneity Table 2 for data and ph
Notes on quality	Only site comparison at diff depths.
Reference	Minkkinen and Laine 2006 Vegetation heterogeneity and ditches create spatial variability in methane fluxes from peatlands drained for forestry
Location	Lakkasuo central Finland 61°48'N 24°19'E
Subject	CH4 mg m-2 d-1
Intervention	Drain
Methodology	Site comparison with static chamber on different vegetation types
Sources of bias	Can only extract data from bog as fen comparator data not separated in some way as intervention. Repeat measure, more measures in summer therefore biasing mean extracted.
Confounding	No before data. More trees on drained sites
Reasons for heterogeneity	Trees, peat thickness wt soil and air temp
Extraction	Table 1 for heterogeneity, Fig 3 and 6 for data. Cannot extract vegetation types separately as comparator is presented as single point so average all three types to get value
Reference	Moore et al 1990 Spatial and temporal variations of methane flux from sub arctic/northern boreal fens
Location	Scheferville Qubec Canada 54°48N 66°49W
Subject	CH4 mg m-2 d-1
Intervention	Natural
Methodology	Site comparison, static chamber
Sources of bias	Repeat measure, no before data
Confounding	Soil temperature is higher in margin (drier site)
Reasons for heterogeneity	air temp, soil temp, water table, mean annual temp, mean annual precipitation
Extraction	Fig 3 for heterogeneity Fig 4 for data
Notes on quality	Flooded site is wettest but could impact measure and CH4 seems lower here than at middle sites

Reference	Moore and Dalva 1993 The Influence of temperature and water-table position on carbon dioxide and methane emissions from laboratory columns of peatland soils
Location	Quebec
Subject	CO2 g m-2d-1 and CH4 mg m-2 d-1
Intervention	Natural (drain) in lab
Methodology	Triplicate columns at two water levels at two temperatures, orthogonal. From three different peatlands
Sources of bias	Measures taken over time but reported averaged over six weeks. Repeat measure from columns
Confounding	No before data. pH seems OK, no other data presented.
Reasons for heterogeneity	pH
Extraction	Table 2
Notes on quality	Repeat measure and low rep with low amount of heterogeneity explained plus it is in lab.
Reference	Moore and Knowles 1989 The influence of water table levels on methane and carbon dioxide emissions from peatland soils
Location	Scheferville Fen (54°47'N66°47'W, Mte St Hialaire Swamp 45°33'n73°08'w and Ste Julie bog, 45°35'n 73°20'W all Québec
Subject	CO2 CH4
Intervention	Drain or natural
Methodology	Lab comparison no before measures. GC
Sources of bias	Repeat measure from same columns over 7 weeks
Confounding	Baseline?
Reasons for heterogeneity	pH temp, wt, pd
Extraction	Heterogeneity from p 34 and Table 1 data from Fig 1
Reference	Moore2007 preliminary study of the effects of drainage and harvesting on water quality in ombrotrophic bogs near Sept-Iles, Qu
Location	Sept Iles Québec 50°15N 66°20'W
Subject	DOC mg/l
Intervention	Drain
Methodology	Spec
Sources of bias	Lack of info on heterogeneity. No replication other than that over time with repeat measure. Only for summer months
Confounding	No before, no other data
Reasons for heterogeneity	None reported
Extraction	Fig 1 only

Reference	Moore and Clarkson 2007 Dissolved organic carbon in New Zealand peatlands
Location	Waikato NZ, 37°19's176°27'e
Subject	DOC mg l-1
Intervention	Restore (rewet?)
Methodology	Samples collected in various ways. Shimadzu TOC analyser
Sources of bias	No water table info, short communication so little info on sampling and heterogeneity
Confounding	No before and no data to make decisions
Reasons for heterogeneity	None reported
Extraction	Table 3 only as no sensible choice of comparator from Table 1
Notes on quality	Lack of info makes appraisal difficult.
Reference	Moosavi et al 1996 Controls on CH4 flux from an Alaskan boreal wetland
Location	Lemeta Bog, Fairbanks Alaska, 64°53'n 147°30'w
Subject	CH4 mg m-2 d-1
Intervention	Natural field
Methodology	Static chambers, single site comparison
Sources of bias	Sample size not well reported so fixed at two based on Fig 3 legend. Repeat measure. Only sampled in summer. Variance based on annual mean and not sampling date mean as type of error not reported.
Confounding	Not enough info to comment
Reasons for heterogeneity	water table, temperature, mean annual precipitation
Extraction	Fig 3 and p288 for heterogeneity.
Notes on quality	Only a single site and sample size is difficult to extract, also variance is permuted.
Reference	Nykanen et al 1998 Methane fluxes on boreal peatlands of different fertility and the effect of long-term experimental lowering of the water table on flux rates
Location	Lakkasuo 61°47'N 24°18'e and Mekrijarvii (Ilomantsi) 62°46'N 29°50'e
Subject	CH4 mg m-2 d-1 CO2 Total respiration including vegetation mg m-2 d-1
Intervention	Drain
Methodology	Ditches. Closed chamber and GC. Site comparison with repeat measures over mainly summer period
Sources of bias	Timing of measures bias mean towards summer. Repeat measures.
Confounding	No before data. Soil temp at site 12 and 17 is higher in control. Peat depth is thicker in intervention on site 7 BD is higher on intervention on site 12.
Reasons for heterogeneity	tress, bulk density, ph pd temps map wt
Extraction	Some sites don't have comparator. Some sites already extracted in Minkinen et al 1992. Extract sites 1, 6, 7, 8, 12 and 17 from tabel2 and heterogeneity from table 1
Notes on quality	Usual standard site comparison repeat measures and few chambers

Reference	Nykanen et al 1995 Emissions of CH4, N2O and CO2 from a virgin fen and a fen drained for grassland in Finland
Location	Ilomantsi E Finland 62°45'N 3°3'E
Subject	CH4 mg m-2 d-1, N20 mg m-2 d-1, CO2 mg m-2 h-1 (Soil and root respiration vegetation removed)
Intervention	Drain
Methodology	Site comparison with repeat measure, closed chamber and gc. CO2 winter static chamber and analyser
Sources of bias	Repeat measure, small sample size, more data in summer, different measures of CO2
Confounding	Peat in control is much thicker
Reasons for heterogeneity	pH, temperature, water table, bulk density.
Extraction	Fig 1, heterogeneity in methods text. Extract data from 1991 as no 1992 N20 data
Reference	Oechel et al 1998 The effects of water table manipulation and elevated temperature on the net CO2 flux of wet sedge tundra ecosystems
Location	Prudhoe Bay Alaska 70°22'n148°34'w
Subject	CO2 (net flux, ecosystem respiration and gross ecosystem photosynthesis)
Intervention	Drain
Methodology	Factorial randomized design with good controls. Chamber and gc
Sources of bias	Repeat measures of same plots. Chamber makes better seal in wet conditions, assume no flux in snow period.
Confounding	No before info. Temp looks ok, little other heterogeneity given
Reasons for heterogeneity	Water table, soil temp, mat
Extraction	Fig 2 for water table, Fig 3 for soil temperature and Fig 5 for data. Extract all three measures, decide which to use later
Notes on quality	Usual site comparison stuff but good controls in a small scale manipulation and honest about potential biases.
Reference	Regina et al 1996 Fluxes of nitrous oxide from boreal peatlands as affected by peatland type, water table level and nitrification capacity
Location	Lakkasuo and Salmisuo at Ilomantsi 61°47N 24°18'e and 62°46'n 30°58'e
Subject	N2O ug m-2 d-1
Intervention	drain
Methodology	Site comparison, chamber and gc
Sources of bias	Some data published elsewhere like Alm and martikainen. Repeat measures, no before data.
Confounding	No before data. pH generally seems OK, little heterogeneity data presented. May be able to get some from other studies as they share sites
Reasons for heterogeneity	water table, ph,
Extraction	Table 1 for heterogeneity. Table 2 for data. Exclude site 1 and 7 as already in Alm, site 6 an 9 in Martikainen. Site 3, 4, 10, 11, 12 have no comparators. Extract from 1992 except for site 8 data for 1991 only.
Notes on quality	Usual stuff but low as not clear on heterogeneity data and need to cross ref with other studies

Reference	Riutta et al 2007 Sensitivity of CO2 exchange of fen ecosystem components to water level variation
Location	Lakkasuo tree lees fen 61°47'N 24°18'E
Subject	CO2 NEE mg m-2 h-1
Intervention	Drain
Methodology	Site comparison with different vegetation. NEE in transparent chamber and infra red analyser. Respiration measures taken but not presented in extractable form
Sources of bias	No before measure, repeat measures. Data presented as individual points over growing season so mean biased to summer
Confounding	No baseline for soil and root NEE. No difference in water level in 2001 and baseline NEE similar, Fig 2d 2001. No other data presented to assess pH etc.
Extraction	Fig 1b for water level, Fig 2a and d for NEE. Extract vegetated and bare soil but only use once in MA .
Notes on quality	Only site comparison again
Reference	Roulet et al 1993 Methane flux from drained northern peatlands - effect of a persistent water table lowering on flux
Location	Wally Creek Ontario Canada 49°3'N80°40'W
Subject	CH4 mg m-2 d-1
Intervention	Drain
Methodology	Site comparison chamber and gc
Sources of bias	Repeat measure, measures only taken in growing season (treed and forested bog) or snow free period (treed fen). Assumed errors are standard deviations due to Table 1 but not clear.
Confounding	No baseline data
Reasons for heterogeneity	Plants pH, mean annual precipitation, mean annual temperature, trees, water table.
Extraction	Table 3 for effects, Table 2 for heterogeneity and methods.
Notes on quality	Site comparison only but not bad sample sizes
Reference	Sigua, G. C. 2004 Wetland conversion to beef cattle pasture: Changes in soil properties
Location	Hillsborough county Florida 28.07°N82.12°W
Subject	Total Organic Carbon g kg-1
Intervention	Drain
Methodology	Site comparison, TOC CHN Analyzer
Sources of bias	Only done at one time in one place so low external validity. Uneven sample sizes so better estimate of treatment
Confounding	Reference is much more acidic
Reasons for heterogeneity	Bulk density, mean annual precipitation, ph
Extraction	Table 1

Reference	Strack and Waddington 2007 Response of peatland carbon dioxide and methane fluxes to a water table drawdown experiment
Location	Charles de Ebelle peatland Québec 46°40'n 71°10'w
Subject	CH4 g C m-2 and CO2 g C m-2 as NEE at range of PAR. Total ecosystem respiration with vegetation cover and calculated Gross ecosystem photosynthesis. As GEP is not measured exclude it.
Intervention	Drain
Methodology	Before after and Site comparison at different microsites but in only one site. Chamber and gc for methane chamber and analyser for CO2
Sources of bias	repeat measures, done only in summer
Confounding	Not confounded at baseline.
Reasons for heterogeneity	water table, soil temperature, air temperature, precipitation
Extraction	Table1, 2 and 3 has most of what you need, convert se to sd
Notes	Good design but only one site.
Reference	Strack et al 2004 Effect of water table drawdown on northern peatland methane dynamics: Implications for climate change
Location	Charles de Ebelle peatland Québec 46°40'n 71°10'w
Subject	CH4
Intervention	Drain
Methodology	Site comparison with repeat measure, static chamber and gc
Sources of bias	No before data, more measures in summer. No variance presented so calculated from overall mean of means
Confounding	No baseline, little heterogeneity reported but soil warmer at drained site
Reasons for heterogeneity	water table, soil temperature
Extraction	p.2 and 3 for heterogeneity Fig 1 for CH4
Reference	Strack et al 2008 Effect of water table drawdown on peatland dissolved organic carbon export and dynamics
Location	Charles de Ebelle peatland Québec 46°40'n 71°10'w
Subject	DOC mg/l
Intervention	Drain
Methodology	Piezometer nest in single site comparison. DOC by total carbon analyser
Sources of bias	Sample size not obvious therefore fix at three. Repeat measures and use of nest leads to correlated results
Confounding	No before data for site d but site e was different to control before draining so baseline probably confounded.
Reasons for heterogeneity	water table
Extraction	Fig 2

Reference	Strack et al 2006 Response of vegetation and net ecosystem carbon dioxide exchange at different peatland microforms microforms following water table drawdown
Location	Charles de Ebelle peatland Québec 46°40'n 71°10'w
Subject	CO2 exchange NEE and respiration g m-2 d-1
Intervention	Drain
Methodology	Site comparison using chamber and portable gas analyser
Sources of bias	No baseline data, only one site and sample size is not entirely clear. Repeat measure and more measures done in summer. Same bog but different sites at other Strack studies, controls maybe same though
Confounding	Lack of heterogeneity data and no baseline
Reasons for heterogeneity	water table, vegetation, soil temperature.
Extraction	Fig 1 for data, p.2 and 3 for heterogeneity. Fig 3 for soil at 5cm
Notes on quality	Only single site and sample size not clear
Reference	van den pol-van dasselar et al 1997 Effects of grassland management on the emission of methane from intensively managed grasslands on peat soil
Location	Zegveld Netherlands 52°8'N 4°48'E
Subject	CH4 mg m-2 d-1
Intervention	Natural?
Methodology	Single site comparison with repeat measure. Closed chamber flux
Sources of bias	Done on differently managed soils. Single site
Confounding	No before data and no heterogeneity reported, not even water level.
Reasons for heterogeneity	ph, water table, mean annual precipitation, vegetation.
Extraction	Extract all data for different treatment and averaged values but make clear in meta analysis sheet
Notes on quality	Single site with repeat measures. Suspect both drained, not natural, therefore could be excluded as no true comparator
Reference	van den pol-van dasselar 1999
Location	Nieuwkoopse Plassen western part of the Netherlands (52°8' N, 4°48' E).
Subject	CH4 mg m-2 d-1
Intervention	Natural esque - drainage involved but different levels
Methodology	Site comparisons with 6 chambers on each. Natural so no before data. Closed chamber and gc
Sources of bias	No variance at each time point so average over year measurements but is a whole year
Confounding	pH is quite diff in dbz to koole and there are more grasses at dbz
Reasons for heterogeneity	Water table, pH, vegetation.
Extraction	Table 2 (use 1995 data as represents a whole year) for data, Table 1 for heterogeneity
Notes on quality	Good amount of chambers, still single site. Not sure of drainage history which could be cause for rejection.

Reference	von Arnold 2005 Fluxes of CO2, CH4 and N2O from drained organic soils in deciduous forests
Location	(57°08'N, 14°45'E)
Subject	CH4 ug m-2 h-1, CO2 mg m-2 h-1(total respiration), N2O ug m-2 h-1
Intervention	Drain
Methodology	site comparison with dark closed chamber and gc
Sources of bias	no before data. Repeat measure.
Confounding	Peat depth thinner in drained, higher bd in drained, ph OK. No before data for baseline
Reasons for heterogeneity	water table, peat depth, bulk density, C:N, pH
Extraction	Table 1 for heterogeneity. Fig 3 and 4 - alder sites only
Notes on quality	Only a site comparison but at least 5 chambers used and possibly ten, fix n at 5 though.
Reference	Wallage Z 2006 Dissolved organic carbon and colour dynamics in drained and restored blanket peat
Location	Oughtershaw Beck (54°14'N; 21°14' W)
Subject	DOC mg cl-1
Intervention	Drain and rewet
Methodology	Peat dams. DOC extract with piezometer from two transects at 14 points (n=28 on each site). Repeat measures sampled over whole year.
Sources of bias	Repeat measures, only one site really. Drained is intervention in drained extraction, but control in rewet extraction and rewet. SD calculated from n=28 and not reported n so probably biases estimate.
Confounding	Averaged across depths and months
Extraction	Extract from table
Reference	Zhu et al 2007 Methane emissions from two tundra wetlands in eastern Antarctica
Location	Station Antarctica
Subject	CH4 ug m-2 h-1
Intervention	Natural
Methodology	Site comparison, static chamber and gc
Sources of bias	Repeat measures therefore mean and sd based on higher n than used in meta analysis. Only one chamber at each site to a max of n=2. Maybe some differences in microsites and maybe not much peat.
Confounding	Soil temp may be confounded
Reasons for heterogeneity	Soil temperature, mean annual temperature, mean annual precipitation, vegetation , water table.
Extraction	All data in Table 1, extract wettest and driest sites form each of the two locations

10.4 Appendix IV – Funnel plots

Funnels plots are used in the assessment of potential publication bias. The effect size (standardised mean difference) is plotted against the standard error of that effect size. Less precise studies with small sample sizes are more affected by chance and therefore scattered around the graph. Larger studies are expected to better estimate the pooled effect and have smaller variances. This results in a funnel or triangular shape to the plot. Publication bias may be present if the funnel plot is asymmetrical indicating that result in a certain direction of effect may be preferentially published. Funnel plot asymmetry does not, however, mean publication bias is present, it is an indication of its potential. The following funnel plots are those produced from the meta-analyses in the systematic review.

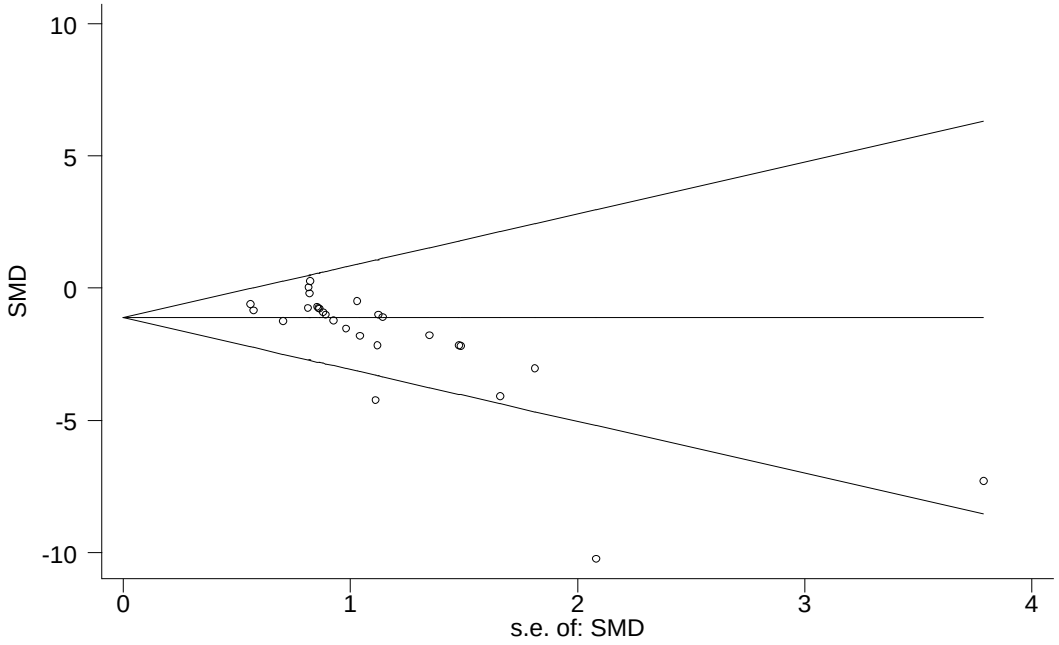

Figure A1. Begg's funnel plot for publication bias in studies investigating CH_4 emissions on drained peatlands. The standardised mean difference (SMD) is plotted against the standard error of the standardised mean difference (s.e of SMD). The funnel indicates 95% confidence intervals and horizontal line indicates the pooled effect size.

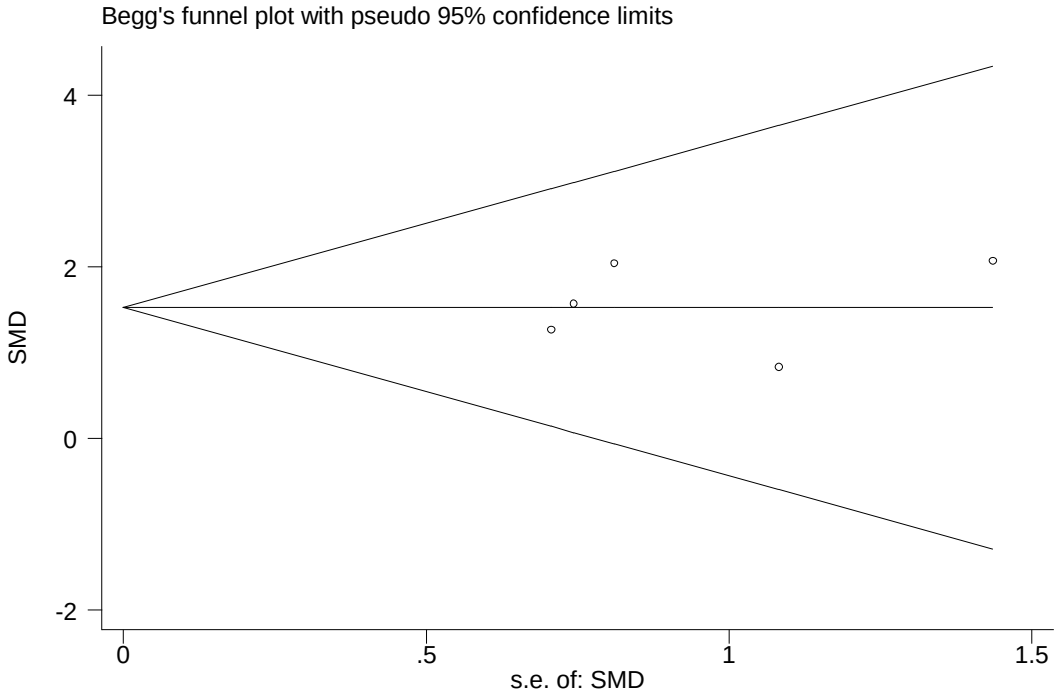

Figure A2. Begg's funnel plot for publication bias in studies investigating CH_4 emissions on re-wet peatlands. The standardised mean difference (SMD) is plotted against the standard error of the standardised mean difference (s.e of SMD). The funnel indicates 95% confidence intervals and horizontal line indicates the pooled effect size.

.

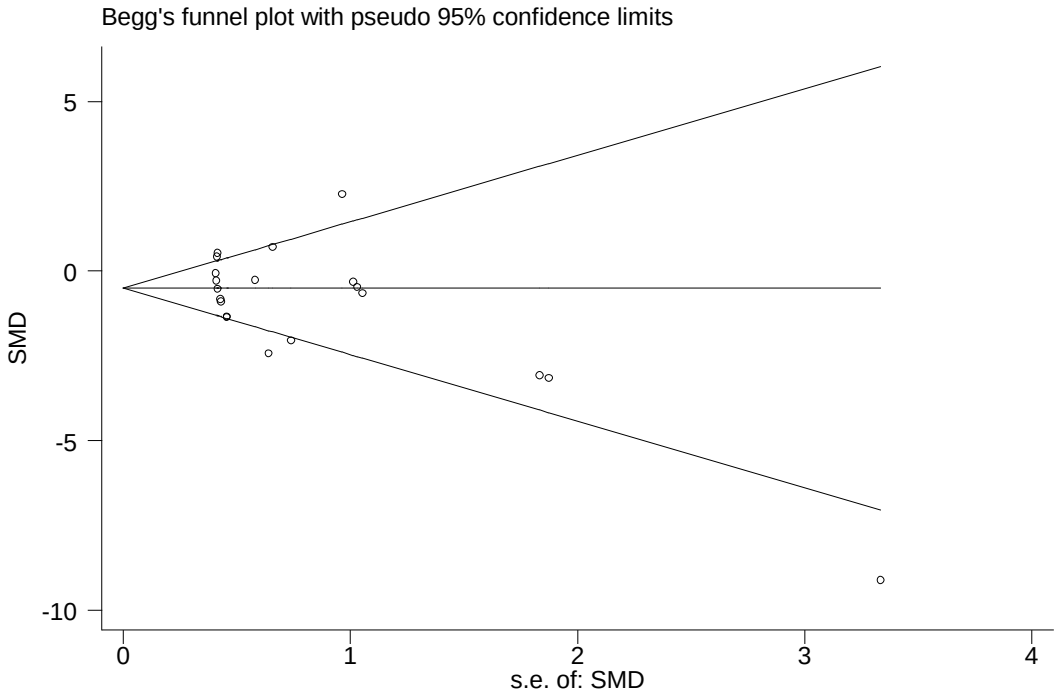

Figure A3. Begg's funnel plot for publication bias in studies investigating methane emissions comparing naturally wet and dry areas of peatlands. The standardised mean difference (SMD) is plotted against the standard error of the standardised mean

difference (s.e of SMD). The funnel indicates 95% confidence intervals and horizontal line indicates the pooled effect size.

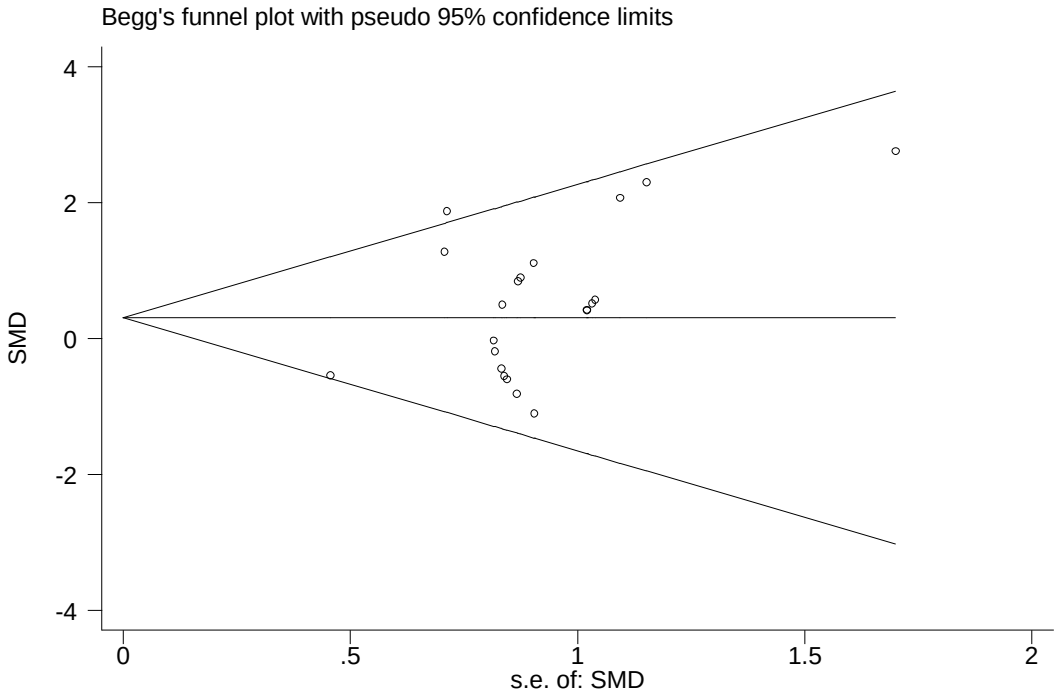

Figure A4. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies measuring CO_2 flux as total respiration from drained peatlands. The funnel indicates 95% confidence intervals and horizontal line indicates the pooled effect size.

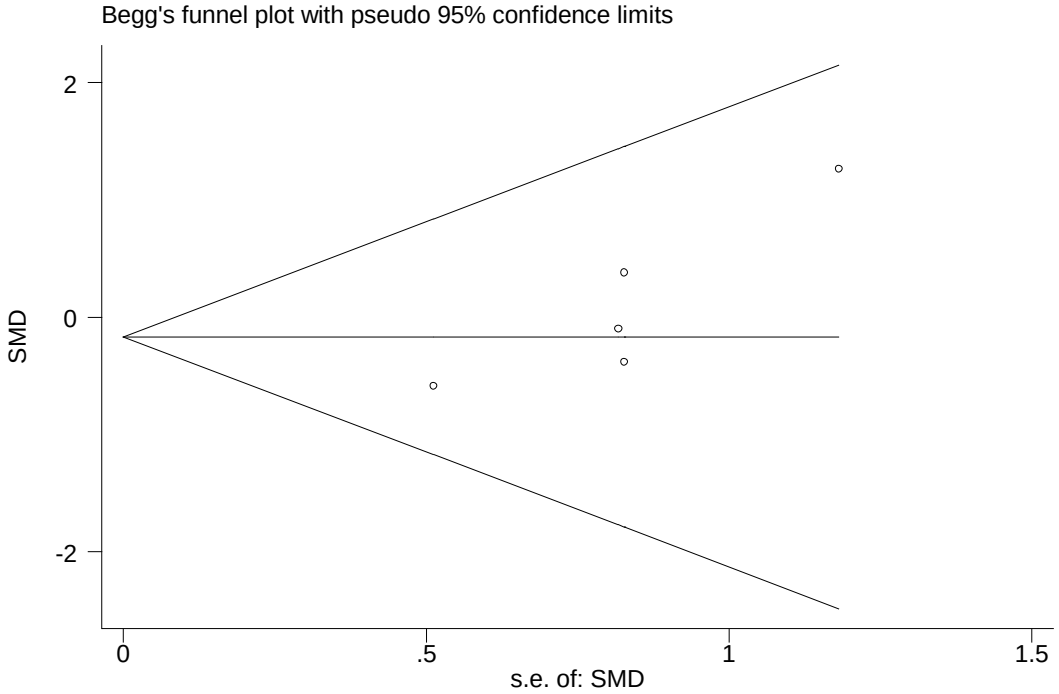

Figure A5. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies

measuring CO_2 flux as net ecosystem exchange from drained peatlands. The funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.

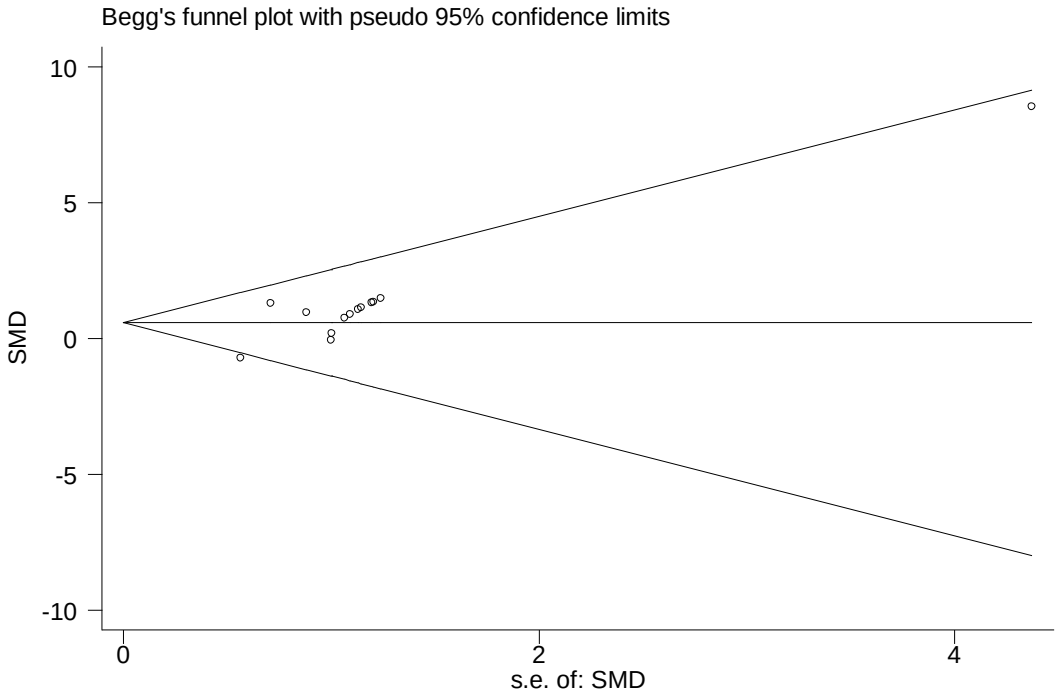

Figure A6. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies measuring N_2O flux from drained peatlands. Funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.

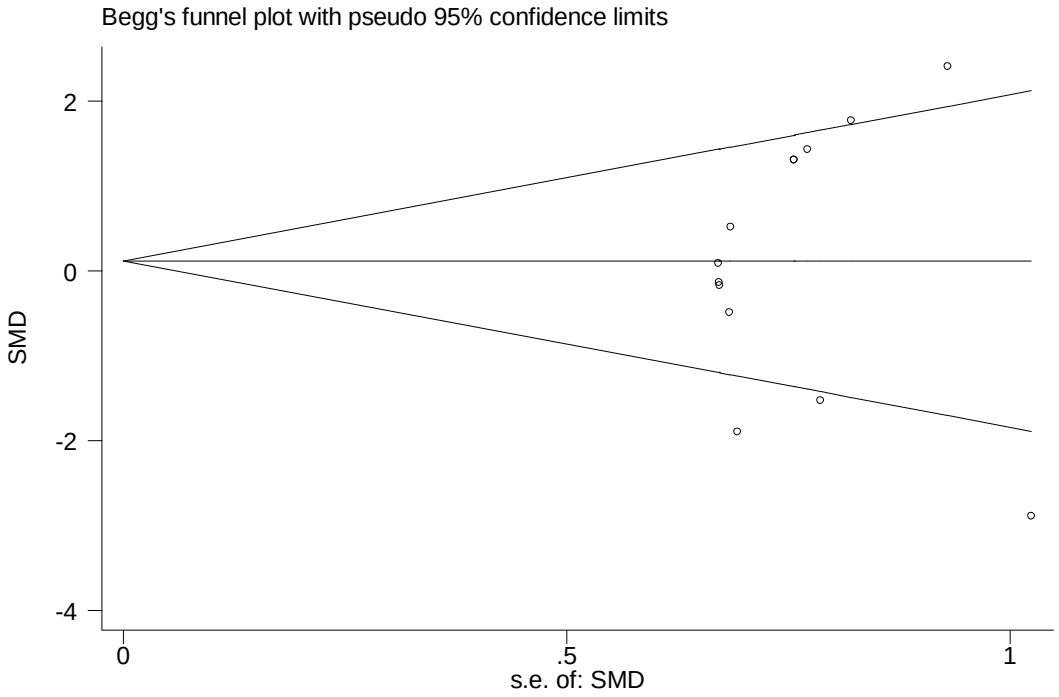

Figure A7. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for effects sizes in Minkkinen et al. (1999) and Sigua et al. (2004) measuring total C content of

drained peatlands. The funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.

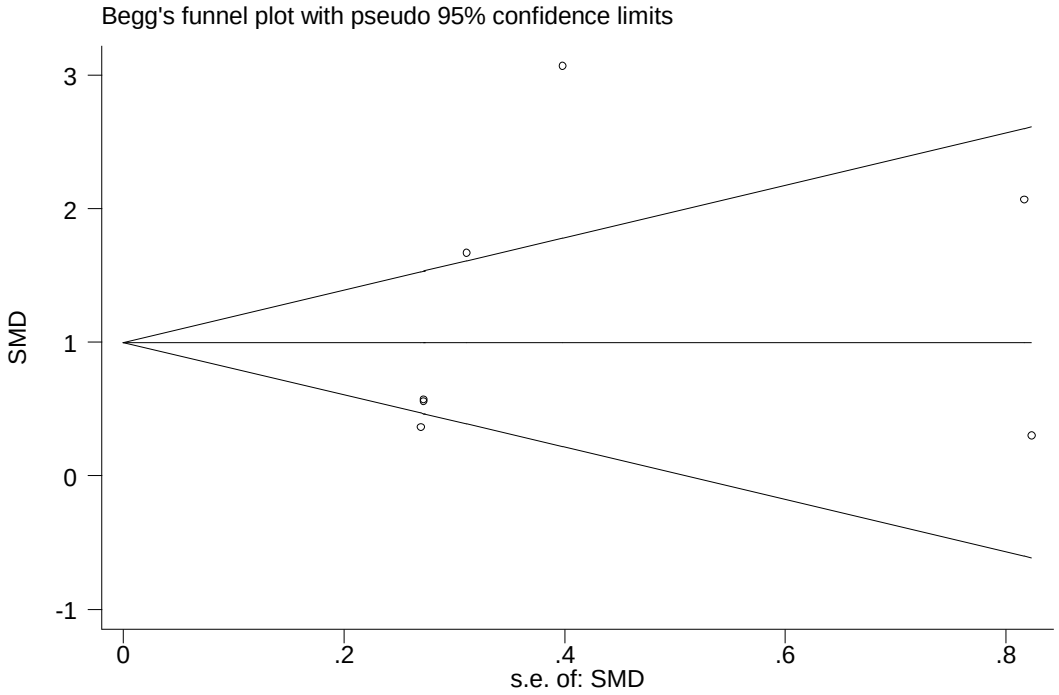

Figure A8. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies measuring dissolved organic carbon (DOC) from drained peatlands. Funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.

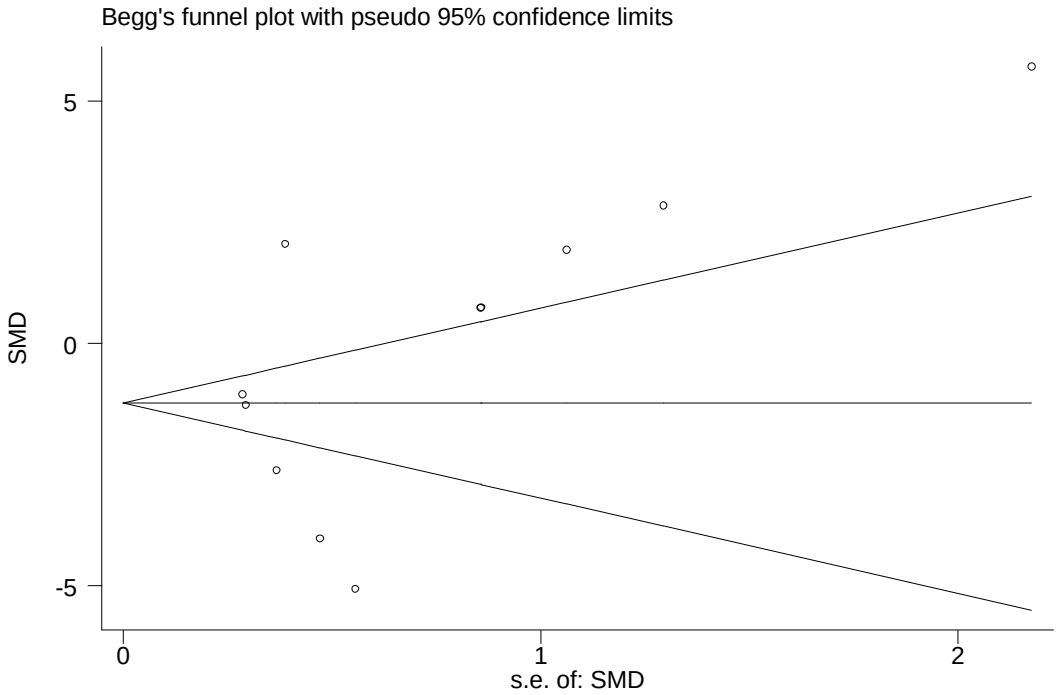

Figure A9**.** Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies measuring dissolved organic carbon (DOC) on re-wet peatlands. The funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.

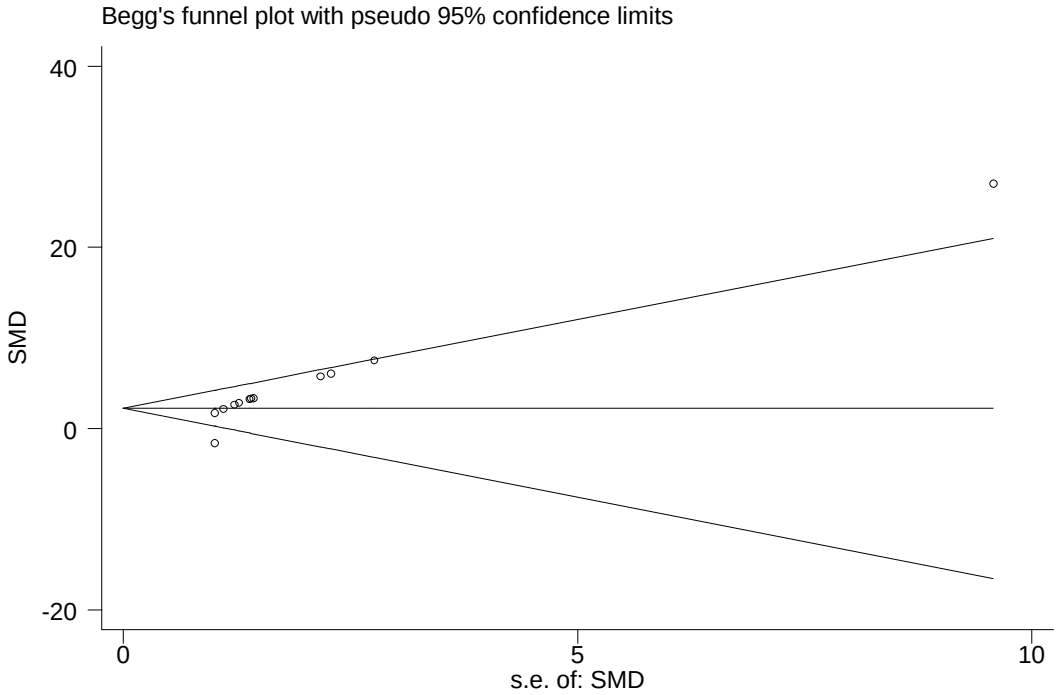

Figure A10. Begg's funnel plot for publication bias plotting the standardised mean difference against the standard error of the standardised mean difference for studies measuring microbial carbon content in re-wet peatlands. The funnel indicates 95% confidence intervals and the horizontal line indicates the pooled effect size.