Quantifying natural GHG sources and sinks: The role of regional small water bodies

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Key Findings

Ponds located in Seqwater catchment areas occupy a surface area over 120 km^2 which is in excess of the largest raw water storage, Lake Wivenhoe.

Over 67,000 individual ponds were identified in SEQ region with annual methane emissions over 280,000 t CO_2 eq y^{-1}.

Weir emission rates were significantly higher compared with all other pond types suggesting Seqwater owned weirs should be included in future greenhouse gas monitoring programs.

Seqwater has the opportunity to develop whole of catchment mitigation strategies that will be relevant to all artificial water bodies within the catchment area.

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1 Introduction

Freshwater storages are usually sources of greenhouse gases (St Louis et al 2000), as accumulation of organic matter in the sediment zone and the highly anoxic conditions found there favour the production of methane (CH_4) in particular (Fig. 1). CH_4 escapes the water surface following two major pathways, either via diffusion or bubbling, and then can be emitted from the water surface. Diffusive emissions are greatly reduced via the consumption by methanotrophic microbes primarily located at the oxycline of the water column (Fig. 1). CH_4e bubbles allow rapid transport of CH_4, usually bypassing methantrophs, to the water surface and this results in greatly increased emission rates in zones where bubbling occurs. The raw water storages owned by Seqwater are, therefore, a potential liability in a future carbon economy as sources of greenhouse gases (Grinham et al 2010).

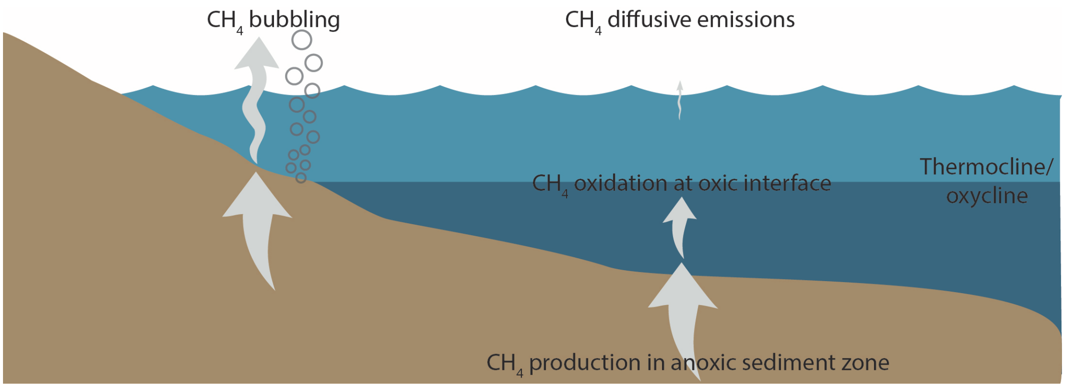

Figure 1. Conceptual model highlight two major pathways of methane (CH_4) emissions from stratified freshwater systems.

However, what is often overlooked in greenhouse gas assessments are the smaller artificial water bodies (ponds) located within the catchment areas of Seqwater raw water storages. These ponds are less than 0.1 km^2 in surface area and perform a number of important functions in rural and urban catchment areas. These include stock watering for cattle and sheep, irrigation for agriculture, stormwater management, streamflow gauging weirs, recreation and aesthetic uses (Fig. 2).

Figure 2. Examples of different pond types with left-hand panel showing a stock watering dam and right hand panel showing an irrigation dam.

In Queensland, there are over 200,000 ponds and are located throughout the state, however, they are heavily concentrated in the state's south east (Fig. 3 A). Ponds (< 0.1 km^2) cover almost 50% of the total surface area of water bodies in Queensland (Fig. 3 B) with just 198 larger water bodies accounting for the other 50%. This is an important consideration for Seqwater as the ponds located within catchment areas have been shown to intercept large quantities of sediment and organic matter (Verstraeten and Prosser, 2008) and reduce loading into downstream receiving water bodies such as raw water storages.

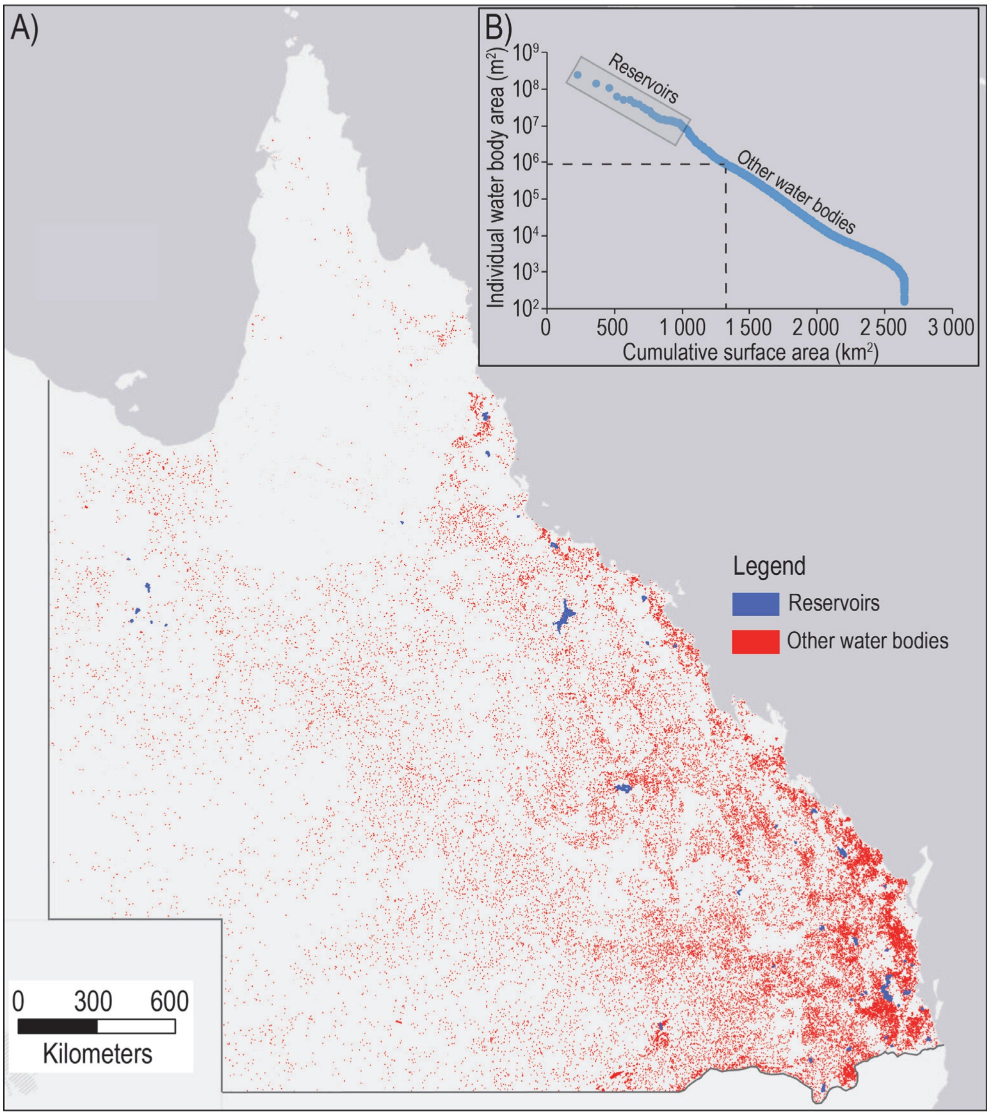

Figure 3. A) Location of artificial water bodies across Queensland showing the reservoirs relative to all the other systems. B) Cumulative surface area of all artificial water bodies relative to individual water bodies highlighting the size class range of Queensland reservoirs. Dotted line indicates the water body area corresponding to the 50th percentile of cumulative surface area.

This report details recent work undertaken quantifying emissions from ponds primarily within the state's south east region and will be accompanied by an additional review of greenhouse gas sources and sinks within Seqwater's natural asset portfolio. Together these will be used to develop a monitoring approach to allow a regional understanding of greenhouse gas dynamics across all Seqwater's natural assets.

2 Methods

2.1 Study region

To quantify the range of emission rates from ponds, a monitoring program was undertaken across a wide spectrum of ponds including: farm dams (irrigation and stock watering), urban lakes, small weir systems (i.e. small dams leading to widening and slowing of river flows) and rural residential water supplies (Table 1). The majority of sites were located in coastal catchments in south east Queensland, Australia as well as one urban lake and three stock dams in Central Queensland (Table 1).

2.2 Methane emissions monitoring

CH_4 emission rates were measured by deploying between 3 and 16 floating chambers per water body, capturing both peripheral and central zones. Chamber design followed the recommendations of Bastviken et al (2015), as these lightweight chambers (diameter 40 cm, 12 L headspace volume and 0.7 kg total weight) were ideally suited to deployment in ponds where both site access and on-water deployments can be challenging. Where possible 24 hour measurements were undertaken, however in three water bodies this was not possible (Table 1) and here measurements lasted between 6 and 8 hours. After each deployment a chamber headspace gas sample was collected following the Exetainer method described in Sturm et al (2015). CH_4 emission rates were calculated from the change in headspace concentration over time and normalised to areal units (Grinham et al 2011).

2.3 Estimating surface area of ponds

The number and relative surface area of ponds in South East Queensland was derived from the most recent assessment of land use for the region (QLUMP, 2018) as well as two additional databases from a high resolution assessment of artificial water bodies across the state published in 2014 and 2015. One database contains water bodies greater than 625 m^2 at full supply (Reservoirs – Queensland; http://qldspatial.information.qld.gov.au/catalogue/) and the other contains water bodies less than 625 m^2 (Water storage points - Queensland; http://qldspatial.information.qld.gov.au/catalogue/). Ponds were then categorised into three size classes (0.0001 to 0.001 km^2; 0.001 to 0.01 km^2; and, 0.01 to 0.1 km^2) as per the Global Reservoir and Dam (GRanD) assessment (Lehner et al 2011)

3 Study findings

3.1 Pond methane emission rates

All 22 water bodies monitored were shown to be emitters of CH_4, and emission rates ranged from a minimum of 1 mg m^{-2} d^{-1} to a maximum of 5,425 mg m^{-2} d^{-1} (Table 1). Only one water body (Mt Larcom 3) had a maximum rate below the reported upper range (50 mg m^{-2} d^{-1}) for diffusive fluxes found in Seqwater reservoirs (Grinham et al 2011). Mean flux rates of only four individual water bodies were below 50 mg m^{-2} d^{-1} (Table 1) suggesting ebullition to be the dominant emission pathway in these systems.

Table 1: Selected characteristics from individual ponds showing: primary use of each system; surrounding land-use type; location of system latitude (Lat) and longitude (Long); average surface area (SA) in m^2; arithmetic mean (Arth), geometric mean (Geo), median, minimum (Min) and maximum (Max) methane emission rates (mg m^{-2} d^{-1}). Primary uses included the following: irrigation for cropping; stock watering for cattle and horses; urban uses included stormwater management and aesthetic purposes; weirs for water supply and stream flow monitoring. * indicates water bodies where repeat sampling was conducted; # indicates water bodies where deployments of less than 24 hours were conducted.

Area	Primary use	Land-Use	Lat	Long	SA	Arth Mean	Geo Mean	Median	Min	Max
Gatton 1*	Irrigation	Grazing	-27.5541	152.3412	25,903	785	590	527	238	1,648
Gatton 2*	Irrigation	Grazing	-27.5548	152.3394	3,450	581	170	140	17	2,261
Gatton 3*	Stock	Grazing	-27.5615	152.3434	1,041	1,149	905	980	314	2,007
Gatton 4*	Stock	Grazing	-27.5625	152.3447	1,893	63	55	63	20	109
Gatton 5	Irrigation	Cropland	-27.5537	152.3503	30,458	129	122	110	89	186
Gatton 6	Stock	Cropland	-27.5546	152.3488	446	1,229	724	844	93	3,635
Port precinct#	Urban	Settlement	-27.3917	153.1676	38,285	144	57	68	8	357
St Lucia 1*	Urban	Settlement	-27.4996	153.0163	22,727	632	282	279	36	3,558
St Lucia 2	Urban	Settlement	-27.4984	153.0173	4,291	92	83	76	51	148
St Lucia 3	Urban	Settlement	-27.4981	153.0167	1,755	56	49	43	27	115
Pinjarra 1*	Irrigation	Grazing	-27.5372	152.9139	56,782	34	15	20	2	122
Pinjarra 2	Stock	Grazing	-27.5294	152.9242	1,943	205	59	277	2	335
Pinjarra 3	Stock	Grazing	-27.5294	152.9227	210	193	143	107	67	404
Oxenford	Urban	Settlement	-27.8924	153.2997	36,938	97	94	81	76	133
Mt Larcom 1	Stock	Grazing	-23.8008	150.9558	5,025	574	37	18	1	2,051
Mt Larcom 2	Stock	Grazing	-23.806	150.9574	1,256	48	45	49	26	70
Mt Larcom 3	Stock	Grazing	-23.8015	150.9446	16,093	17	17	18	14	19
Fig Tree Park	Urban	Settlement	-27.5394	152.9682	8,357	709	301	289	19	1,850
Greenbank#	Stock	Settlement	-27.7249	152.9779	575	290	166	188	29	755
Lake Alford#	Urban	Settlement	-26.2152	152.6848	21,689	49	29	62	5	79
Mt Cootha*	Weir	Forest	-27.4763	152.9642	580	2,493	1,405	2,337	368	5,425
Indooroopilly	Weir	Settlement	-27.5027	152.988	436	413	274	314	77	947

Grouping ponds according to their primary use resulted in no significant differences in emissions rates between irrigation dams, stock dams and urban lakes, however, weirs were significantly higher ($p < 0.001$) than all other categories (Fig. 4). Mean emission rates were however higher in stock water bodies (168 mg m^{-2} d^{-1}) compared with irrigation and urban bodies (84 and 129 mg m^{-2} d^{-1}, respectively). Weir water bodies had mean emission rates of 730 mg m^{-2} d^{-1}, more than four times higher those of any other category (Fig. 4).

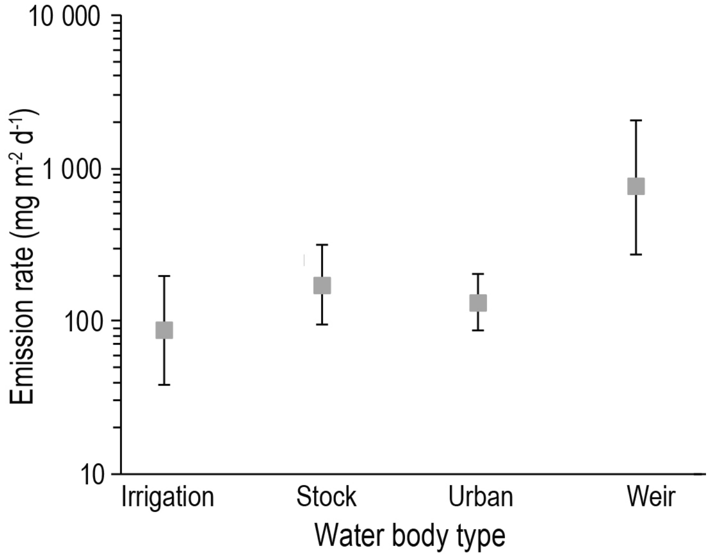

Figure 4. Mean CH4 emissions across four categories of small water bodies (irrigation dams, stock dams, urban lakes and weirs). Values indicate geometric mean emission rates and 95% confidence intervals (± 95% CI).

3.2 Surface area of SEQ ponds

Over 67,000 ponds were identified in SEQ and covered almost the entire Seqwater raw water storage catchment area (Fig. 5). Ponds were heavily concentrated in the agricultural areas of the central, western and southern parts of SEQ and relatively few ponds were located in the steep, mountainous areas (Fig. 5).

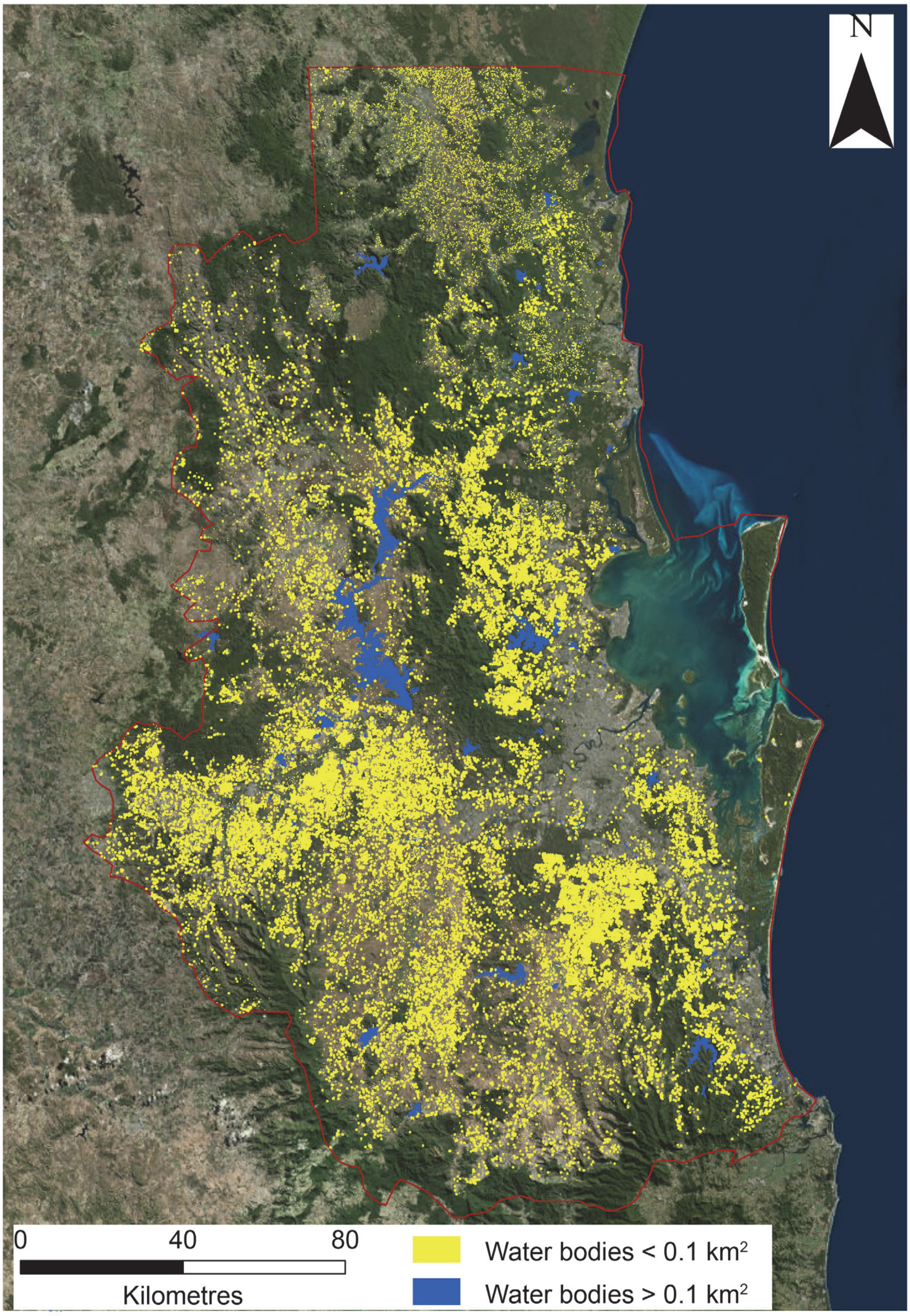

Figure 5. Location of artificial water bodies across South East Queensland within Seqwater raw water storage catchments.

Ponds in SEQ occupy a surface area of over 120 km^2 (Table 2) which is in excess of Seqwater's largest raw water storage, Lake Wivenhoe. There was an increase in pond number and decrease in total surface area with decreasing size class (Table 2). Smaller pond size classes had relatively high annual emission rates compared with the largest pond class and together these emit over 280,000 t CO_2 eq y^{-1}.

Table 2. Summary of South East Queensland ponds' surface area, number and annual emissions grouped using relative size classifications.

Size class (km2)	*Surface area (km^2)*	*Number*	*Annual emissions (tCO_2 eq y^{-1})*
0.1 to 0.01	40	1,709	48,181
0.01 to 0.001	59	24,109	127,973
0.001 to 0.0001	22	41,424	107,724
Total	**122**	**67,242**	**283,879**

4 Conclusions

There are two major findings from this study which will be highly relevant to the future Seqwater regional emissions monitoring research program:

1) Weirs have relatively high emission rates. To date efforts to monitor CH_4 emissions on Seqwater raw water storages have been limited to reservoirs. However, Seqwater has over 50 weirs within their natural asset portfolio and the findings from the pond study suggest these weirs could be an important emission source in these systems.

2) Small, artificial water bodies represent a major source of emissions within Seqwater catchment areas. These ponds likely intercept large quantities of sediment and organic matter that would otherwise likely be deposited in Seqwater raw water storages. Catchment derived mitigation strategies developed for Seqwater storages will provide a potential mitigation strategy for all artificial water bodies within this region. This, in turn, provides an opportunity for Seqwater to take a leadership role in whole catchment carbon mitigation strategies.

Bibliography

Bastviken, D., Sundgren, I., Natchimuthu, S., Reyier, H., and Gålfalk, M. 2015. Technical Note: Cost-efficient approaches to measure carbon dioxide (CO2) fluxes and concentrations in terrestrial and aquatic environments using mini loggers. Biogeosciences, 12, 3849–3859. doi:10.5194/bg-12-3849-201

Grinham A, Dunbabin M, Gale D, Udy J (2010) Quantification of daily spatial variability in storage methane efflux: Diffusive and ebullition rate estimation on Little Nerang Dam. *Seqwater internal report*, The University of Queensland.

Grinham, A., Dunbabin, M., Gale, D. and Udy, J. (2011). Quantification of ebullitive and diffusive methane release to atmosphere from a water storage. Atmospheric Environment, 45 (39): 7166-7173, doi: 10.1016/j.atmosenv.2011.09.011.

Lehner, B., Reidy Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J., Rödel, R., Sindorf, N., Wisser, D. (2011): High resolution mapping of the world's reservoirs and dams for sustainable river flow management. Frontiers in Ecology and the Environment.

QLUMP 2018 Queensland Land use Mapping Program (https://www.qld.gov.au/environment/land/vegetation/mapping/qlump/). Accessed April 2018.

St Louis VL, Kelly CA, Duchemin E, Rudd JWM, Rosenberg DM (2000) Reservoir surfaces as sources of greenhouse gases to the atmosphere: A global estimate. *Bioscience* 50, 766-775

Sturm, K.; Yuan, Z.; Gibbes, B.; Werner, U.; Grinham, A. (2014) Methane and nitrous oxide sources and emissions in a subtropical freshwater reservoir, South East Queensland, Australia *Biogeosciences* 11, 5245– 5258 DOI: 10.5194/bg-11-5245-2014

Sturm, K., Keller, B., Werner, U., Sharma, K., Grinham, A., and Yuan, Z. (2015) Sampling considerations and assessment of Exetainer usage for measuring dissolved and gaseous methane and nitrous oxide in aquatic systems. *Limnology and Oceanography: Methods* 13(7), 375-390.

Verstraeten, G., and Prosser, I. P.: Modelling the impact of land-use change and farm dam construction on hillslope sediment delivery to rivers at the regional scale, Geomorphology, 98, 199-212, 2008.