

LEGACY EFFECTS OF EUTROPHICATION ON MODERN METHANE DYNAMICS IN A BOREAL ESTUARY

Online Resource

Estuaries and Coasts

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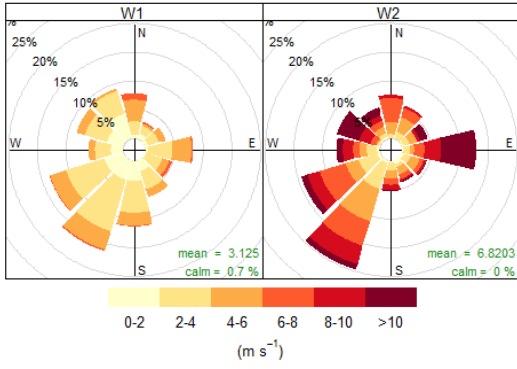


Fig. S1 Frequency of counts by wind direction (%) in June 2016 and distribution of average windspeeds in m s^{-1}

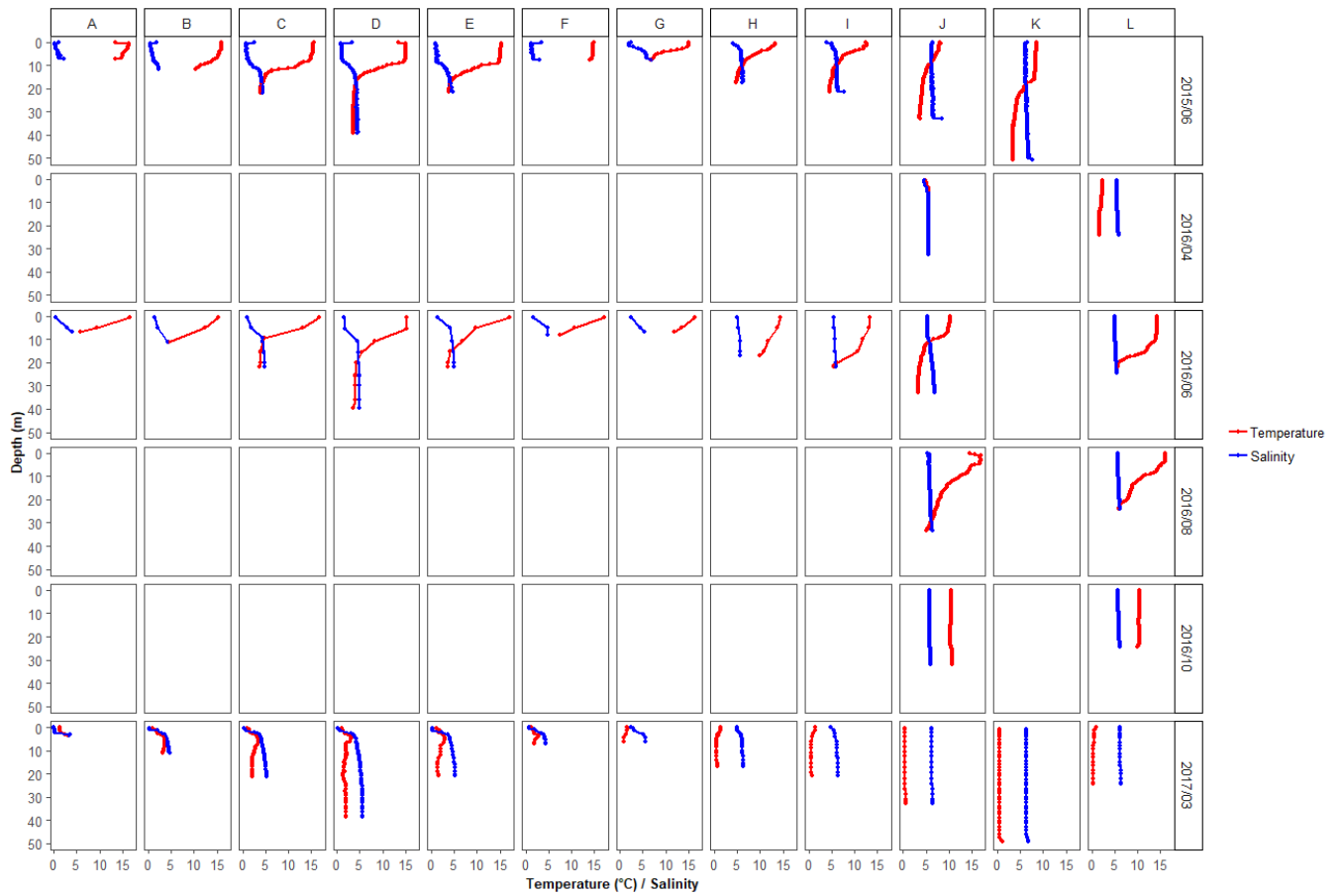


Fig. S2 Salinity and temperature profiles of all sites measured with hand-held CTD devices

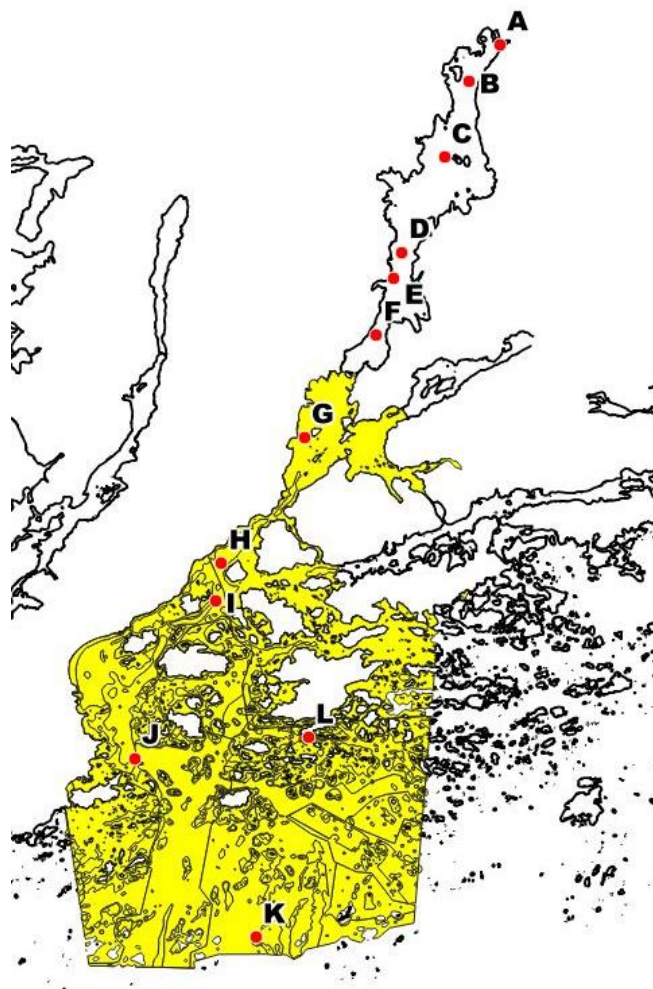


Fig. S3 Map of the area used for calculating the budget for the archipelago in Fig 7

Table S1 The parameters, their values and derivations used in calculation of the budget in Fig 7

Parameter	Value	Unit	Variable	Source / Derivation
Estuary surface volume	147.0	10 ⁻⁶ m ³	$V(surf)$	Virta 1977 ¹
Estuary bottom water volume	86.2	10 ⁻⁶ m ³	$V(bot)$	Virta 1977 ¹
Estuary area	21.8	10 ⁻⁶ m ²	$A(est)$	Virta 1977 ¹
Estuary pycnocline area (~10 m depth)	9.2	10 ⁻⁶ m ²	$A(pyc)$	Virta 1977 ¹
Estuary methanogenic bottom area (>10 m depth)	9.2	10 ⁻⁶ m ²	$A(bot_est)$	Virta 1977 ¹
River mean June discharge 2015-2016	7.06	m ³ s ⁻¹	Q	Finnish Environment Institute
Lowest monthly discharge 2015-2016	2.43	m ³ s ⁻¹	$Q(min)$	Finnish Environment Institute
Highest monthly discharge 2015-2016	17.21	m ³ s ⁻¹	$Q(max)$	Finnish Environment Institute
Diffuse flow multiplier	1.11		d	Stipa 1999 ²
River mouth mean CH ₄ concentration	557	nmol L ⁻¹	$c(riv)$	Measured June 2015 & 2016
Lowest CH ₄ concentration measured at river mouth	199	nmol L ⁻¹	$c(riv_min)$	Measured 2015-2017
Highest CH ₄ concentration measured at river mouth	1666.1	nmol L ⁻¹	$c(riv_max)$	Measured 2015-2017
Total river input	373.7	mol d ⁻¹	$J(riv)$	$J(riv) = Q \times d \times c(riv)$
Minimum total river input	46.0	mol d ⁻¹	$J(riv_min)$	$J(riv_min) = Q(min) \times d \times c(riv_min)$
Maximum total river input	2725.1	mol d ⁻¹	$J(riv_max)$	$J(riv_max) = Q(max) \times d \times c(riv_max)$
Mean atmospheric flux of CH ₄ in the estuary	-0.3	mmol m ² d ⁻¹	$F(atm_est)$	Calculated*
Low atmospheric flux	-0.1	mmol m ² d ⁻¹	$F(atm_est_min)$	Calculated†
High atmospheric flux	-0.6	mmol m ² d ⁻¹	$F(atm_est_max)$	Calculated†
Total estuary atmospheric CH ₄ flux	-5589.3	mol d ⁻¹	$J(atm_est)$	$J(atm_est) = A(est) \times F(atm_est)$
Minimum total atmospheric flux	-2548.0	mol d ⁻¹	$J(atm_est_min)$	$J(atm_est_min) = A(est) \times F(atm_est_min)$
Maximum total atmospheric flux	-12285.9	mol d ⁻¹	$J(atm_est_max)$	$J(atm_est_max) = A(est) \times F(atm_est_max)$
Mean pycnocline diffusive CH ₄ flux 2015–2016	0.00005	mmol m ² d ⁻¹	$F(pyc)$	Calculated*
Lowest calculated pycnocline flux 2015–2016	0.00001	mmol m ² d ⁻¹	$F(pyc_min)$	Calculated†
Highest calculated pycnocline flux 2015–2016	0.00014	mmol m ² d ⁻¹	$F(pyc_max)$	Calculated†
Total pycnocline CH ₄ flux	0.5	mol d ⁻¹	$J(pyc)$	$J(pyc) = A(pyc) \times F(pyc)$
Minimum total pycnocline flux	0.1	mol d ⁻¹	$J(pyc_min)$	$J(pyc_min) = A(pyc) \times F(pyc_min)$
Maximum total pycnocline flux	1.4	mol d ⁻¹	$J(pyc_max)$	$J(pyc_max) = A(pyc) \times F(pyc_max)$

Mean sediment to water CH ₄ flux 2016	-0.6	mmol m ² d ⁻¹	$F(sed_est)$	Calculated*
Lowest calculated sediment flux 2016	0.0	mmol m ² d ⁻¹	$F(sed_est_min)$	Calculated†
Highest calculated sediment flux 2016	-0.9	mmol m ² d ⁻¹	$F(sed_est_max)$	Calculated†
Total sediment CH ₄ flux	-5233.9	mol d ⁻¹	$J(sed_est)$	$J(sed_est) = A(bot_est) \times F(sed_est)$
Minimum total sediment flux	-284.6	mol d ⁻¹	$J(sed_est_min)$	$J(sed_est_min) = A(bot_est) \times F(sed_est_min)$
Maximum total sediment flux	-8092.9	mol d ⁻¹	$J(sed_est_max)$	$J(sed_est_max) = A(bot_est) \times F(sed_est_max)$
Mean water CH ₄ concentration at sill	80.0	mol d ⁻¹	$c(sill)$	Measured June 2015 & 2016
Mean - 1SD concentration at sill 2015–2016	64.4	nmol L ⁻¹	$c(sill_min)$	Measured June 2015 & 2016
Mean + 1SD concentration at sill 2015–2016	96.5	nmol L ⁻¹	$c(sill_max)$	Measured June 2015 & 2016
Total CH ₄ outflow removal	-48.8	mol d ⁻¹	$J(out)$	$J(out) = Q \times d \times c(sill)$
Minimum total outflow removal	-13.5	mol d ⁻¹	$J(out_min)$	$J(out_min) = Q(min) \times d \times c(sill_min)$
Maximum total outflow removal	-143.5	mol d ⁻¹	$J(out_max)$	$J(out_max) = Q(max) \times d \times c(sill_max)$
Mean estuary surface water CH ₄ concentration	87.4	nmol L ⁻¹	$c(surf)$	Measured June 2015 & 2016
Mean - 1SD estuary surface water CH ₄	23.5	nmol L ⁻¹	$c(surf_min)$	Measured June 2015 & 2016
Mean + 1SD estuary surface water CH ₄	151.3	nmol L ⁻¹	$c(surf_max)$	Measured June 2015 & 2016
Mean estuary bottom water CH ₄ concentration	48.8	nmol L ⁻¹	$c(bot)$	Measured June 2015 & 2016
Mean - 1SD estuary bottom water CH ₄	19.2	nmol L ⁻¹	$c(bot_min)$	Measured June 2015 & 2016
Mean + 1SD estuary bottom water CH ₄	78.5	nmol L ⁻¹	$c(bot_max)$	Measured June 2015 & 2016
Estuary surface water CH ₄ pool	12852.7	mol	$C(surf)$	$C(surf) = V(surf) \times c(surf)$
Estuary surface water CH ₄ minimum pool	3461.2	mol	$C(surf_min)$	$C(surf_min) = V(surf) \times c(surf_min)$
Estuary surface water CH ₄ maximum pool	22244.3	mol	$C(surf_max)$	$C(surf_max) = V(surf) \times c(surf_max)$
Estuary bottom water CH ₄ pool	4209.5	mol	$C(bot)$	$C(bot) = V(surf) \times c(bot)$
Estuary bottom water CH ₄ minimum pool	1654.4	mol	$C(bot_min)$	$C(bot_min) = V(surf) \times c(bot_min)$
Estuary bottom water CH ₄ maximum pool	6764.6	mol	$C(bot_max)$	$C(bot_max) = V(surf) \times c(bot_max)$
Archipelago volume	2414.6	10 ⁻⁶ m ³	$V(arc)$	GIS (Fig. S3)
Archipelago area	165.5	10 ⁻⁶ m ²	$A(arc)$	GIS (Fig. S3)
Archipelago methanogenic bottom area	100.1	10 ⁻⁶ m ²	$A(bot_arc)$	GIS (Fig. S3)
Mean atmospheric flux of CH ₄ in the archipelago	0.3	mmol m ² d ⁻¹	$F(atm_arc)$	Calculated*
Lowest atmospheric flux of CH ₄ in the archipelago	0.1	mmol m ² d ⁻¹	$F(atm_arc_min)$	Calculated†

Highest atmospheric flux of CH ₄ in the archipelago	0.8	mmol m ² d ⁻¹	$F(atm_arc_min)$	Calculated†
Total archipelago atmospheric CH ₄ flux	45778.2	mol d ⁻¹	$J(atm_arc)$	$J(atm_arc) = A(arc) \times F(atm_arc)$
Minimum total archipelago atmospheric flux	17162.6	mol d ⁻¹	$J(atm_arc_min)$	$J(atm_arc_min) = A(arc) \times F(atm_arc)$
Maximum total archipelago atmospheric flux	124326.2	mol d ⁻¹	$J(atm_arc_max)$	$J(atm_arc_min) = A(arc) \times F(atm_arc)$
Mean archipelago sediment CH ₄ flux	-1.5	mmol m ² d ⁻¹	$F(sed_arc)$	Calculated*
Lowest calculated archipelago sediment flux	-0.1	mmol m ² d ⁻¹	$F(sed_arc_min)$	Calculated†
Highest calculated archipelago sediment flux	-6.2	mmol m ² d ⁻¹	$F(sed_arc_min)$	Calculated†
Total archipelago sediment CH ₄ flux	-148082	mol d ⁻¹	$J(sed_arc)$	$J(sed_arc) = A(arc) \times F(sed_arc)$
Minimum total archipelago sediment flux	-6033.6	mol d ⁻¹	$J(sed_arc_min)$	$J(sed_arc_min) = A(arc) \times F(sed_arc)$
Maximum total archipelago sediment flux	-623111	mol d ⁻¹	$J(sed_arc_max)$	$J(sed_arc_min) = A(arc) \times F(sed_arc)$
Archipelago mean water CH ₄ concentration	71.6	nmol L ⁻¹	$c(arc)$	Measured June 2015 & 2016
Mean - 1SD archipelago water CH ₄	23.7	nmol L ⁻¹	$c(arc_min)$	Measured June 2015 & 2016
Mean + 1SD archipelago water CH ₄	119.5	nmol L ⁻¹	$c(arc_max)$	Measured June 2015 & 2016
Total archipelago CH ₄ pool	172885.2	mol	$C(arc)$	$C(arc) = V(arc) \times C(arc)$
Minimum total archipelago CH ₄ pool	57261.5	mol	$C(arc_min)$	$C(arc_min) = V(arc) \times C(arc_min)$
Maximum total archipelago CH ₄ pool	288508.9	mol	$C(arc_max)$	$C(arc_max) = V(arc) \times C(arc_max)$

¹ Niemi, Å. 1977. Hydrography and oxygen fluctuations in Pojoviken, southern Coast of Finland, 1972-1975. *Meri* 4: 23–35.

² Stipa, Tapani. 1999. Water exchange and mixing in a semi-enclosed coastal basin (Pohja Bay). *Boreal Environment Research* 4: 307–317.

Note on the calculations:

* Atmospheric fluxes were calculated using Eq. 6 in the main text. The estuary and archipelago areas were subdivided latitudinally between the sampling stations in GIS software and the areas were used as weights in calculating a single weighted average flux from the point values shown in Fig. 4 of the main text. Sedimentary fluxes were calculated with Eq. 1 using the similar area weights as the atmospheric fluxes, except applied only to water areas deeper than 10 m. Hence, sediment flux calculations do not account for shallower than 10 m depth methanogenesis, riparian inputs or diffuse flow in the archipelago. Mean pycnocline diffusive flux was calculated using eq. 1 without porosity, i.e. $J = -D_s \frac{\partial C}{\partial x}$, where ∂C is the average concentration difference between concentrations

immediately above and below the steepest temperature gradient at sites C, D and E (i.e. the only sites with a properly defined thermocline in June 2016, Fig. S2).

† The minimum and maximum values for atmospheric fluxes were calculated as described above, with the exception that the flux point values used were the ± 1 SD monthly wind speed fluxes presented in Fig. 4 (i.e. the upper and lower limits of the grey bands). For sediment and pycnocline fluxes, minimum and maximum absolute values across all sites during the period reported in Table S1 were used.