Gas Transfer Velocity as a critical variable in coastal ecosystem metabolism studies

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INTRODUCTION

Net ecosystem production (NEP), the difference between organic matter production and consumption, has been estimated in the mixed-layer of the Randers Fjord (Denmark; Fig 1) during two field cruises in April and August 2001 and using two different approaches: (1) dissolved inorganic carbon (DIC) budgets based on the apparent zero end-member (AZE) method and (2) the Response Surface Difference (RSD; Swaney *et al.*, 1999) based on diel oxygen (O_2) technique. Using these approaches, an assessment of the transfer of CO_2 or O_2 across the air-water interface is needed in order to estimate the variation of either DIC or O_2 due to biological processes (gross primary production and community respiration). These fluxes depend on the air-water gradient (ΔpCO_2), the solubility coefficient (α) and the transfer velocity (k) of the considered gas ($F = \alpha\ k\ \Delta pCO_2$). While the two first variables can be easily constrained, estimating the gas transfer velocity, which depends on the surface water turbulence, is more problematic and has been, most of the time, parameterized as a function of wind speed. A generic formulation of this gas transfer velocity is often used in open-system methods to estimate NEP. In this study, we computed NEP values using the two approaches cited above and several gas transfer velocity parameterizations among which one was estimated in this estuary during the two cruises based on the floating dome technique (Borges *et al.* 2004).

Material & Methods

We evaluated these two methods using air-water O_2 or CO_2 flux calculated from several gas transfer velocity parameterizations taken from the literature (Fig. 2; Wanninkhof 1992, Raymond & Cole 2001, Kremer *et al.* 2003, Borges *et al.* 2004 for the Thames estuary) and the parametrization established in the Randers Fjord (Borges *et al.* 2004). The Wanninkhof (1992) and Raymond & Cole (2001) formulations were considered as they have been widely used in the open ocean and estuaries, respectively; the Borges *et al.* (2004; Thames estuary) and Kremer *et al.* (2003) parameterizations were included because they predict the highest and lowest k values in estuaries, respectively.

Results & Discussion

Results of CO_2 / O_2 fluxes and NEP computations using these various k parametrizations are presented in Table 1. Gas fluxes estimates and consequent NEP results (especially with the RSD method) strongly depend on the parametrization used. For instance, in April, computations using the RSD method and the parametrization of Wanninkhof (1992), Kremer *et al.* (2003) and Raymond & Cole (2001) reveal an autotrophic ecosystem. In contrast, the use of Borges *et al.* (2004) formulation for Randers Fjord and Thames estuary results in slight to high heterotrophic ecosystem estimates, respectively. Moreover, it is noteworthy that the formulation of Borges *et al.* (2004), estimated in the Randers Fjord, is the only one to provide similar NEP values using the RSD and DIC methods during both campaigns. This illustrates that the evaluation of the gas transfer velocity is of the utmost importance to measure ecosystem metabolism using open-system approaches, especially in estuaries where parameterizations as a function of wind speed have only recently been shown to be site specific (Kremer *et al.* 2003, Borges *et al.* 2004).

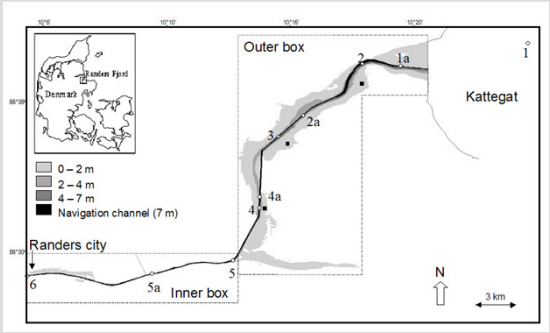

Fig. 1 Map of the Randers Fjord (Denmark)

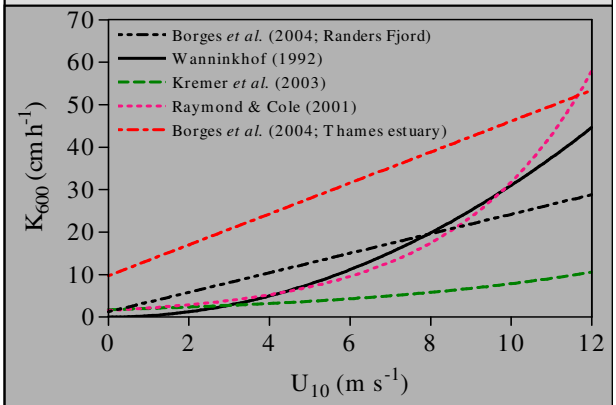

Fig. 2 Gas transfer velocity parameterizations used in this study

Table 1 Computed gas transfer velocities (k), CO_2 or O_2 fluxes and NEP estimates using the 2 methods

	DIC method						RSD method					
	April			August			April			August		
	k_{CO2}	F_{CO2}	NEP	k_{CO2}	F_{CO2}	NEP	k_{O2}	F_{O2}	NEP	k_{O2}	F_{O2}	NEP
Borges *et al.* (2004) - Randers Fjord	2.5	-5	-9	1.7	24	-53	3.1	-1	-11	1.3	-2	-69
Wanninkhof (1992)	1.7	-4	-11	0.3	4	-33	3.2	0	6	0.5	0	-31
Kremer *et al.* (2003)	0.7	-1	-13	0.5	7	-36	1.0	0	4	0.6	-1	-51
Raymond & Cole (2001)	1.5	-3	-12	0.7	9	-38	3.4	0	10	0.8	-1	-55
Borges *et al.* (2004) - Thames estuary	5.3	-11	-3	3.9	53	-82	6.5	-2	-47	4.0	-8	-216

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