# Carbon storage by intestinal solid carbonate formation in salmonid aquaculture.

Kristensen, T[1]., Schauer, K[2]., Heuer, R[2,3]. and Grosell, M[2].

[1]Faculty of Biosciences and Aquaculture, Nord University, Bodø, Norway
[2]Rosenstiel School of Marine & Atmospheric Science, University of Miami, Miami, USA
[3]Department of Biological Sciences, University of North Texas, Denton, USA

## Background:

Norwegian salmonid aquaculture production is currently at record volumes, with >300 million smolt put to sea and 1,3 million metric tons produced annually. As for any other industry, aquaculture has a substantial (albeit lower than other animal-based products) carbon footprint (Winter et al., 2009). Current calculations do not include carbon storage as organic and inorganic carbon deposited on the seafloor below production sites. Especially inorganic carbon excreted by the fish as particulate $CaCO_3$(s) and $MgCO_3$(s) in the form of calcite and aragonite minerals may be an important and permanent carbon storage mechanism.

## Mechanism:

Bicarbonate excretion in fish intestine by binding to $Ca^{2+}$ and $Mg^{2+}$ ions ingested by drinking seawater, results in formation of particulate $CaCO_3$(s) and $MgCO_3$(s) (Wilson et al., 2002). This process is facilitated both by transport from blood across the intestinal epithelium ($Cl^-/HCO_3^-$, SLC26a6 anion exchanger) and a suite of proteins facilitating Ca/Mg $CO_3$(s) formation in the digestive tract.

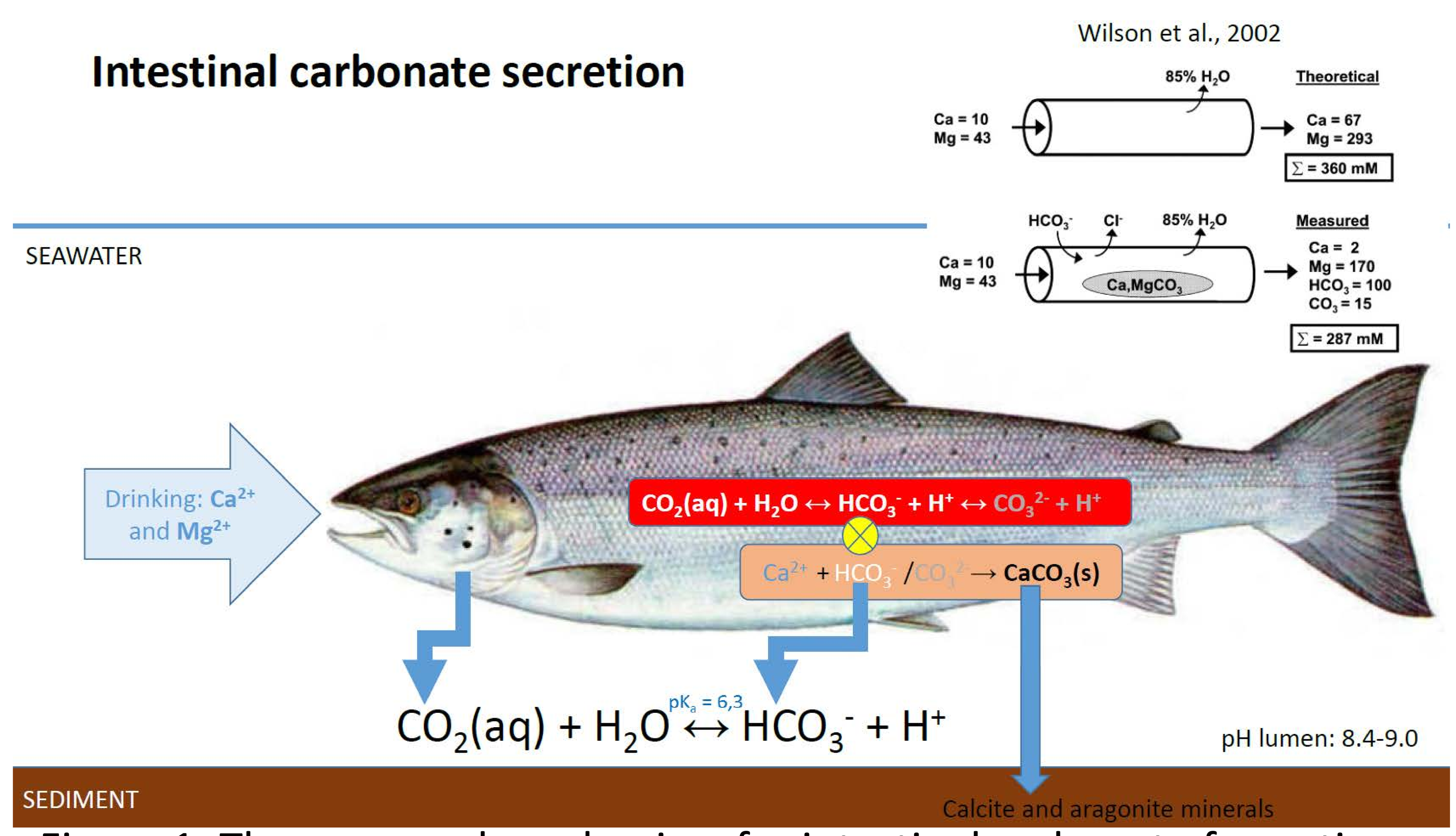


Figure 1: The proposed mechanism for intestinal carbonate formation

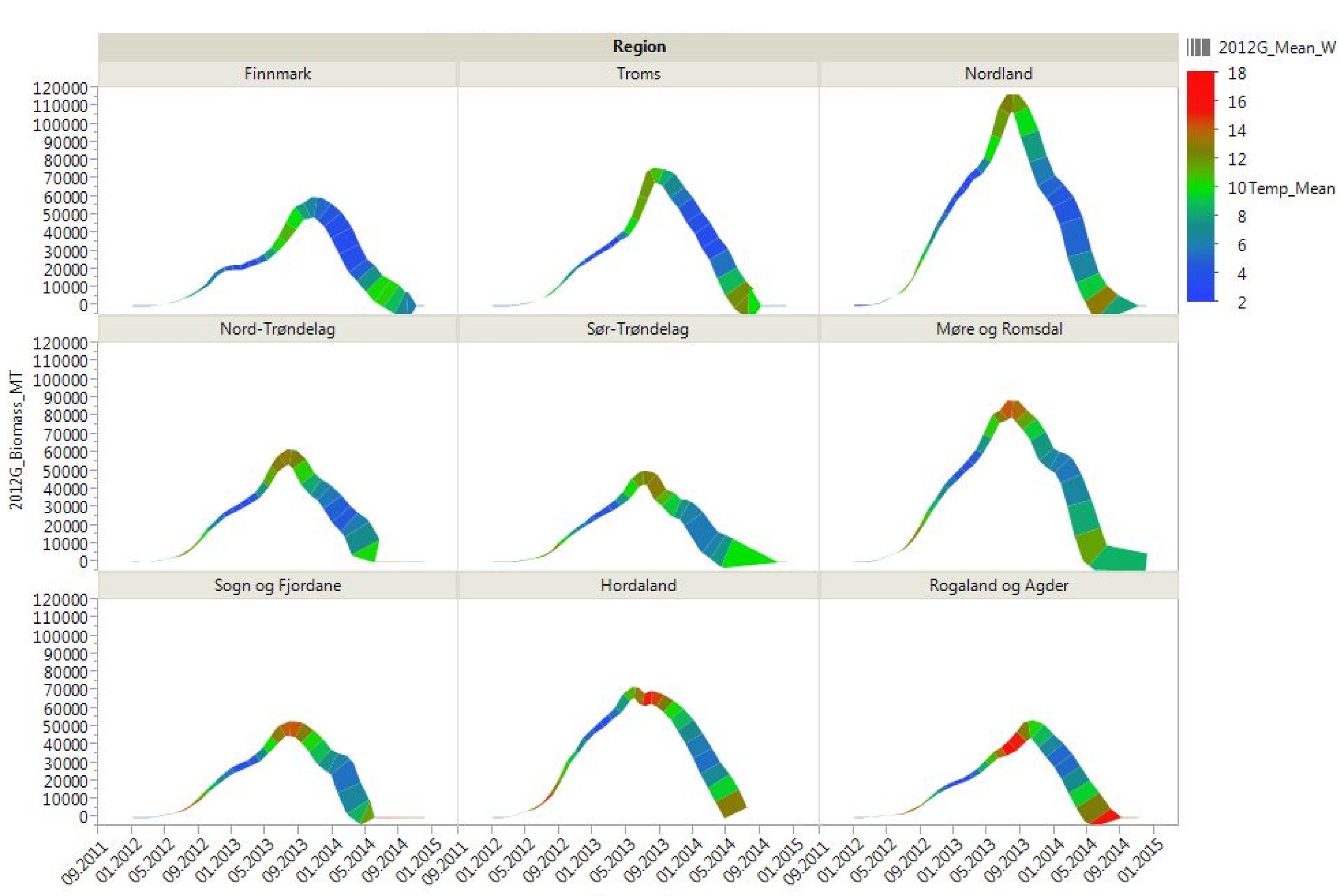


Figure 2: 2012 G monthly regional data on biomass, mean weigth (width of line) and temperature (color)

## Calculations:

The magnitude of (solid) inorganic carbonate excreted from the total biomass of Atlantic salmon in aquaculture in Norway was calculated using regional monthly reported biomass, fish cohort (2012-2014G) body weight and temperature.

Two different approaches using published literature data were used:

1) seawater drinking rate (5 ml $kg^{-1}$ $h^{-1}$ (Usher et al., 1988) and Ca (97%) and Mg (42%) precipitation rates (modified from Wilson et al., 2002)
2) Metabolic rate and measured solid carbonate excretion rates (Genz et al., 2008)

For both calculation methods, scaling effects of size and water temperature were applied to correct for variable excretion rates. The reported data represents a first effort to quantify the process of solid carbonate formation through intestinal processes.

## Results:

Both calculation-approaches gave relatively similar results. Annual $CO_2$ binding as inorganic carbonates in Norwegian salmonid aquaculture was 26±2,9 k mt and 11±1,2 k mt, respectively, for the period 2013-2015 (mean ± SD).

**Funding:** The Research Council of Norway, 254891/E40

References:

Genz, J., Taylor, J.R. and Grosell, M. (2008): Effects of salinity on intestinal bicarbonate secretion and compensatory regulation of acid-base balance in Opsanus beta. J.Exp.Biol. 211, 2327-2335.
Usher, M.KL., Takbot, C. and Eddy, F.B. (1988). Drinking in Atlantic salmon smolts transferred to seawater and the relationship between drinking and feeding. Aquaculture. 73, 237-246.
Winter, U., Ziegeler, F., Skontorp Hognes, E., Emanuelsson, A., Sund, V. and Ellingsen, H. (2009). Carbon footprint and energy use of Norwegian seafood products. SFH80 A096068. ISBN: 978-82-14-04925-1. 91pp.
Wilson, R.W., Wilson, J.M. and Grosell, M. (2002). Intestinal secretion by marine teleost fish- why and how?. Biochimica et Biophysica Acta. 1566, 182-193.

NORD universitet