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Modelling nutrient emissions from a net-cage aquaculture system in Northeastern Brazil

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Abstract
Aquaculture has been encouraged in Brazil in the past five decades, mainly for tilapia production. Nowadays this production rises at a rapid pace of 7.5% a year. In Brazilian reservoirs, aquaculture is permitted to occupy 1% of a lake's surface, but this intensive fish production in net cages rises concerns about water quality. Besides, this activity is responsible for a significant biological oxygen demand, due to nutrient load, which promotes water eutrophication. In this study, four cases were investigated according to different water levels and flows, considering a 10-day production period. TELEMAC-2D was used as processor, to compute hydrodynamics and transport, and ParaView was used to visualization application. We observed higher concentrations of Nitrogen and Phosphorus (44,3 and 3,32 µg L^{-1} respectively), for the low water level and flow case, which were 58% higher than for high flow, and the nutrients emitted from the source favored their increase in the downstream aquacultures. For the future it is possible to evaluate the aquaculture emissions to quantify the total nutrient accumulation for different reservoir areas, and use projections in various scenarios for decision-making and carrying capacity limit studies.

Keywords: Aquaculture, Eutrophication, Itaparica reservoir, Tilapia.

Introduction
Fish culture is a worldwide practice, motivated by the demand for food. Nowadays this production rises at a rapid pace of 7.5% a year in comparison with 1.4% a year in the yield of commercial fishery in Brazil. Aquaculture has been encouraged in Brazil in the past five decades, and has been presenting significant growth since the 80s (FAO, 2013).
In Brazil, aquaculture is permitted to occupy 1% of a lake's surface, but there are concerns about the sustainability of this regulation, mainly regarding the high input of nutrients (Gunkel et al., 2013; Canocico et al., 2015). In this context, understanding the consequences through modelling tools is important for supporting the management of fishery resources, once it has not currently achieved its main purpose, which is to guarantee the economic growth of the activity and the sustainability of the use of the resources at the same time.

Methods
The Itaparica reservoir, located in the semiarid Brazilian region, has a storage capacity of $10,7\times10^9$ m^3 and a surface area of 828 km^2. The water level variation is 299 - 304 m (CHESF, Companhia Hidro Elétrica do São Francisco).
The study cases were investigated according to different water levels (299.5 m - 302.8 m) and different flows (900 $m^3 s^{-1}$ - 2060 $m^3 s^{-1}$ mean flow observed), considering a period of ten days. An unstructed grid with high resolution was obtained by Broecker et al. (2014). TELEMAC-2D was used as

processor, to compute hydrodynamics and transport, and ParaView, a multi-platform data analysis and visualization application, was used as post-processor. For all cases a mean wind of 5.5 ms^{-1} blowing from South-East (140°) was taking into account. The nutrient inputs set in the model are measured data of dissolved Phosphorus and Nitrogen (13.67 kg d^{-1}, 178.2 kg d^{-1}, respectively) (Table 1).

Results

The environmental impact of aquaculture net cage in the Itaparica reservoir was investigated in one aquaculture in Itacuruba municipality. In this aquaculture tilapia (*Oreochromis niloticus*) is produced in 65 net cages (200-400 m^2). The total annual tilapia production amounts to 1320 t, which made it necessary the use of 1848 t feed (Table. 1).

Parameter	Calculation factor	Value
Fish production		1320 t y^{-1}
Feed used	Conversion factor 1,4	1848 t y^{-1}
P input	1,2% P in feed	22.176 t y^{-1}
Dissolved P emission	22% P dissolved excretion	13.67 kg d^{-1}
N input	40% protein content	118.27 t y^{-1}
Dissolved N emission	55% excretion (NH_4^+)	178.2 kg d^{-1}

Table 1. Feed used and nutrient emission rates at the upstream net cage system.

We observed higher concentrations of Dissolved Nitrogen (DN 44,3 µg L^{-1}) and Phosphorus (DP 3,32 µg L^{-1}) for the low water level and low water flow case. The values obtained were already higher than 10% of the critical permitted concentration, equal to 25 µg P L^{-1} (Table 2).

Condition		Concentration	
Water level (m)	Flow (m^3 s^{-1})	DP (µg L^{-1})	DN (µg L^{-1})
Low (299.5 m)	Low (900 m^3 s^{-1})	3,32	44,3
	Mean (2060 m^3 s^{-1})	1,37	18,3
Mean (302.8 m)	Low (900 m^3 s^{-1})	2,60	34,6
	Mean (2060 m^3 s^{-1})	1,08	14,4

Table 2. High concentrations computed for different conditions.

The nutrients emitted from the source favored the increase of nutrient concentrations in the downstream aquacultures (0,053 - 1,86 µg L^{-1}) (Fig. 1-2).

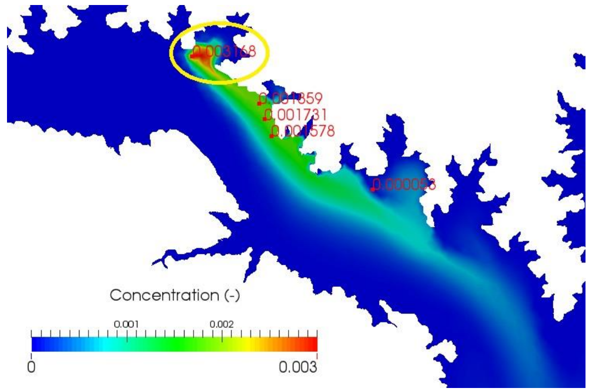

Fig. 1. Concentration of DP in the aquaculture systems (Flow: 900 m^3 s^{-1}), after a 10-day production period.

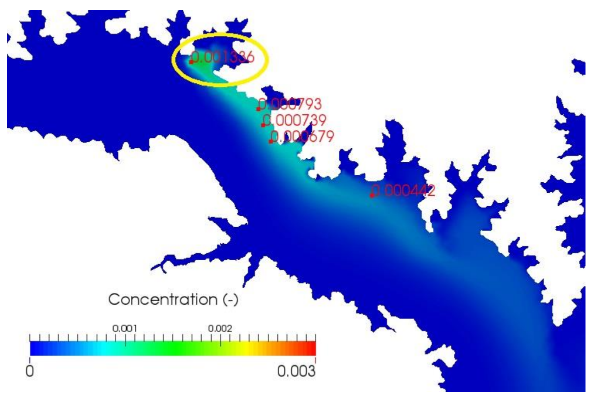

Fig. 2. Concentration of DP in the aquaculture systems (Flow: 2060 m^3 s^{-1}), after a 10-day production period.

Discussion and Conclusions

Taking into account that the Itaparica reservoir has multiple water uses, including human consumption, the influence of nutrients, as well as their long-term effects, are an important issue for the management of water resources.

The increase of nutrients in downstream aquaculture represents an important aspect, due to nutrient accumulation processes. The nutrient concentrations are highly dependent on flow conditions. For low flow in both cases, we obtained values 58% higher than for high flow.
Besides, the high increase of DP due to aquaculture emissions becomes a more complicated issue if it occurs in the bays located in the reservoir, which have low water exchange rate with the main stream (Matta el al., 2016).
For the future it is necessary to evaluate the aquaculture emissions to quantify the total nutrient accumulation for different reservoir areas and under different flow through conditions in the reservoir. The modelling tool can be used in various scenarios for decision-making and carrying capacity limit studies.

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