Simulation and Optimization of Recirculating Aquaculture Systems

Simon Pedersen

Chalmers University of Technology

Simulation

Why simulate?

- Operator training
- RAS development
- Prediction
- ...?

History

A brief history of RAS modelling/simulation

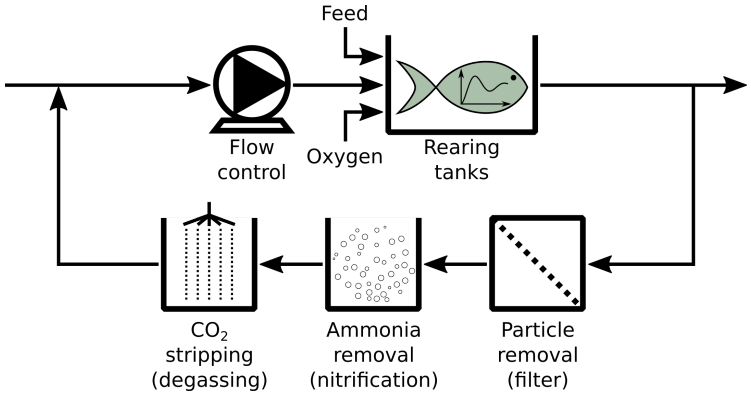
- Losordo and Westers (1994): Basic principles for design
- Losordo and Hobbs (2000): Computerized version (Excel)
- Wik et al. (2009): Dynamical models, integrated fish & WT
- Pedersen et al. (2012): Steady-state, evaluated against replicated RAS, nitrogen focus
- More?

LibRAS

2018: LibRAS – A Modelica **Lib**rary for **R**ecirculating **A**quaculture **S**imulation

Direct successor to FishSim (Wik et al. 2009).

A basic RAS



- Fish growth
- Feeding, Digestion, Evacuation
- Water flow
- Microbiology
- Chemistry

Fish

Fish calculations

- How much fish?
- How much growth? (TGC)
- FCR?

$\Longrightarrow$ Optimal feed amount

Fish calculations

- How much fish?
- How much growth? (TGC)
- FCR?

$\Longrightarrow$ Optimal feed amount

Optimal feed amount

\+ Overfeeding/loss

\+ Digestion dynamics

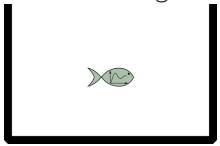
\+ Chemical waste distribution

$=$ Waste production (incl. lost feed)

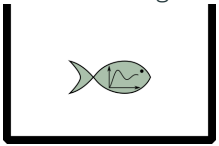
Fish density

Four tanks with $V = 10\,\mathrm{m}^3$, max density $\rho = 40\,\mathrm{kg/m}^3$, grading period 30 days, $IBW = 20\,\mathrm{g}$, 2 % death per month.

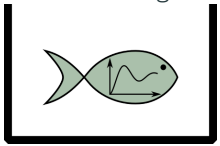
30 days
$BW = 35\,\mathrm{g}$



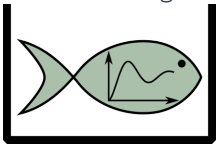
60 days
$BW = 60\,\mathrm{g}$



90 days
$BW = 90\,\mathrm{g}$



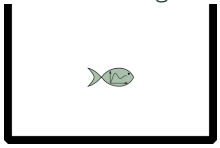
120 days
$BW = 125\,\mathrm{g}$



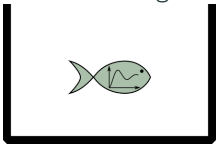
Fish density

Four tanks with $V = 10\,\text{m}^3$, max density $\rho = 40\,\text{kg/m}^3$, grading period 30 days, $IBW = 20\,\text{g}$, 2 % death per month.

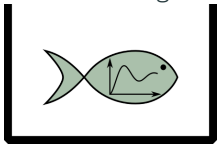
30 days
$BW = 35\,\text{g}$



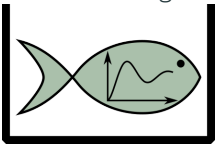
60 days
$BW = 60\,\text{g}$



90 days
$BW = 90\,\text{g}$



120 days
$BW = 125\,\text{g}$

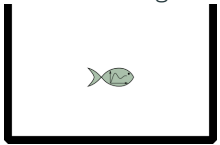


$$\rho = 40\,\text{kg/m}^3$$
$$m_4 = 400\,\text{kg}$$
$$n_4 = \frac{400}{0.125} = 3200$$

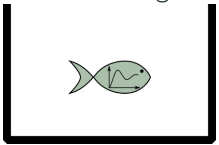
Fish density

Four tanks with $V = 10\,\text{m}^3$, max density $\rho = 40\,\text{kg/m}^3$, grading period 30 days, $IBW = 20\,\text{g}$, 2 % death per month.

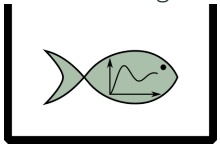
30 days
$BW = 35\,\text{g}$



60 days
$BW = 60\,\text{g}$

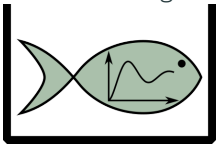


90 days
$BW = 90\,\text{g}$



$n_3 = 3265$
$m_3 = n_3 \times 90\,\text{g} = 294\,\text{kg}$
$\rho = 29\,\text{kg/m}^3$

120 days
$BW = 125\,\text{g}$

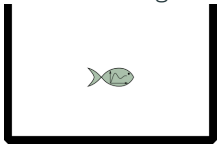


$\rho = 40\,\text{kg/m}^3$
$m_4 = 400\,\text{kg}$
$n_4 = \frac{400}{0.125} = 3200$

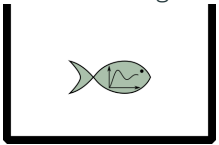
Fish density

Four tanks with $V = 10\,\mathrm{m}^3$, max density $\rho = 40\,\mathrm{kg/m}^3$, grading period 30 days, $IBW = 20\,\mathrm{g}$, 2 % death per month.

30 days
$BW = 35\,\mathrm{g}$

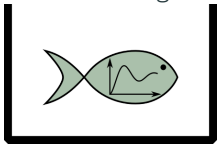


60 days
$BW = 60\,\mathrm{g}$



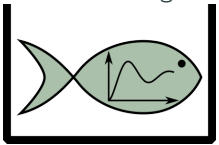
$n_2 = 3331$
$m_2 = n_2 \times 60\,\mathrm{g} = 200\,\mathrm{kg}$
$\rho = 20\,\mathrm{kg/m}^3$

90 days
$BW = 90\,\mathrm{g}$



$n_3 = 3265$
$m_3 = n_3 \times 90\,\mathrm{g} = 294\,\mathrm{kg}$
$\rho = 29\,\mathrm{kg/m}^3$

120 days
$BW = 125\,\mathrm{g}$

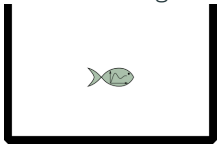


$\rho = 40\,\mathrm{kg/m}^3$
$m_4 = 400\,\mathrm{kg}$
$n_4 = \frac{400}{0.125} = 3200$

Fish density

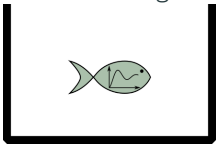
Four tanks with $V = 10\,\mathrm{m}^3$, max density $\rho = 40\,\mathrm{kg/m}^3$, grading period 30 days, $IBW = 20\,\mathrm{g}$, 2 % death per month.

30 days
$BW = 35\,\mathrm{g}$



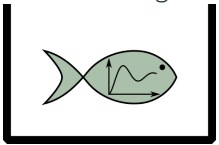
$n_1 = 3399$
$m_1 = n_1 \times 35\,\mathrm{g} =$
$119\,\mathrm{kg}$
$\rho = 12\,\mathrm{kg/m}^3$

60 days
$BW = 60\,\mathrm{g}$



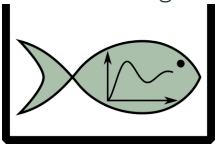
$n_2 = 3331$
$m_2 = n_2 \times 60\,\mathrm{g} =$
$200\,\mathrm{kg}$
$\rho = 20\,\mathrm{kg/m}^3$

90 days
$BW = 90\,\mathrm{g}$



$n_3 = 3265$
$m_3 = n_3 \times 90\,\mathrm{g} =$
$294\,\mathrm{kg}$
$\rho = 29\,\mathrm{kg/m}^3$

120 days
$BW = 125\,\mathrm{g}$

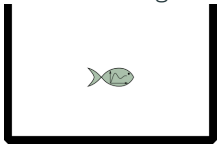


$\rho = 40\,\mathrm{kg/m}^3$
$m_4 = 400\,\mathrm{kg}$
$n_4 = \frac{400}{0.125} = 3200$

Fish density

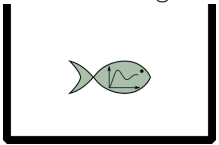
Four tanks with $V = 10\,\mathrm{m}^3$, max density $\rho = 40\,\mathrm{kg/m}^3$, grading period 30 days, $IBW = 20\,\mathrm{g}$, 2 % death per month.

30 days
$BW = 35\,\mathrm{g}$



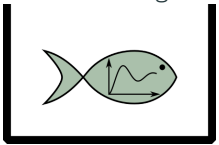
$n_1 = 3399$
$m_1 = n_1 \times 35\,\mathrm{g} =$
$119\,\mathrm{kg}$
$\rho = 12\,\mathrm{kg/m}^3$

60 days
$BW = 60\,\mathrm{g}$



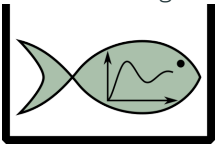
$n_2 = 3331$
$m_2 = n_2 \times 60\,\mathrm{g} =$
$200\,\mathrm{kg}$
$\rho = 20\,\mathrm{kg/m}^3$

90 days
$BW = 90\,\mathrm{g}$



$n_3 = 3265$
$m_3 = n_3 \times 90\,\mathrm{g} =$
$294\,\mathrm{kg}$
$\rho = 29\,\mathrm{kg/m}^3$

120 days
$BW = 125\,\mathrm{g}$

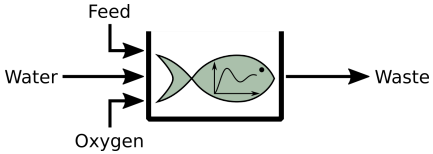


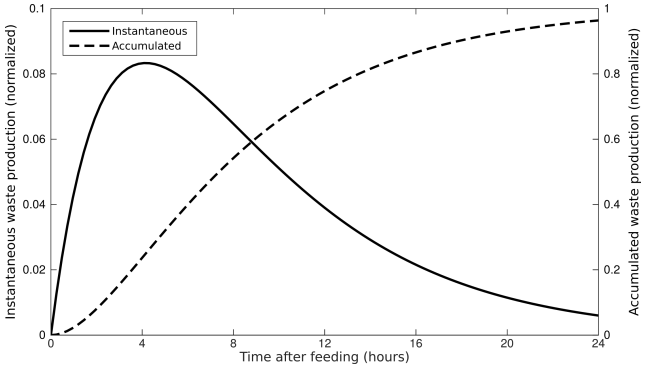
$\rho = 40\,\mathrm{kg/m}^3$
$m_4 = 400\,\mathrm{kg}$
$n_4 = \frac{400}{0.125} = 3200$

$\Longrightarrow$ Stock with $3468 \times 20\,\mathrm{g} = 69\,\mathrm{kg}$ after each grading.

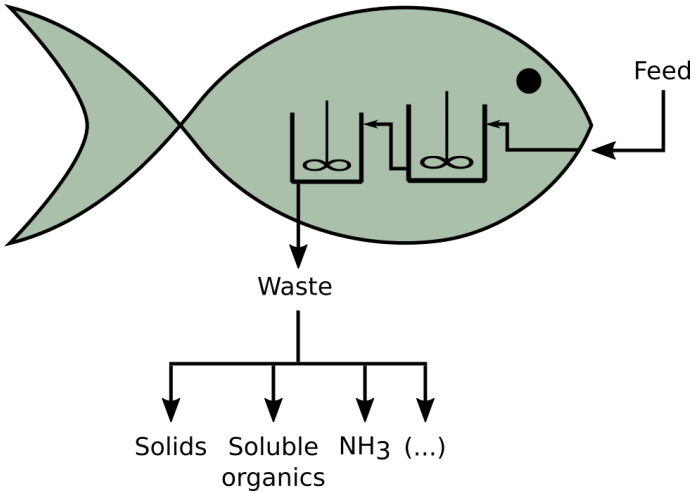
Makes sense?

Waste production

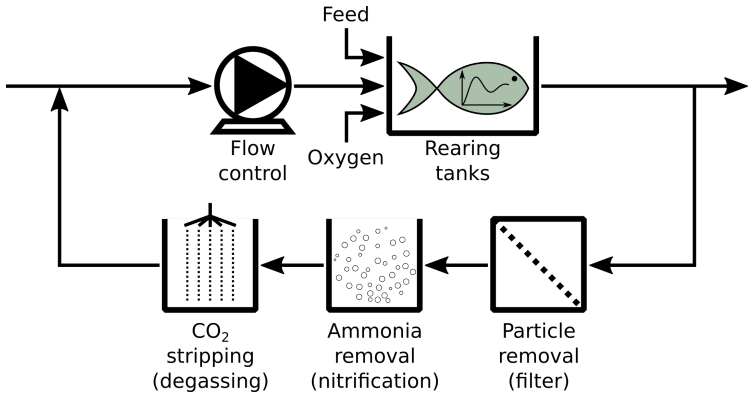




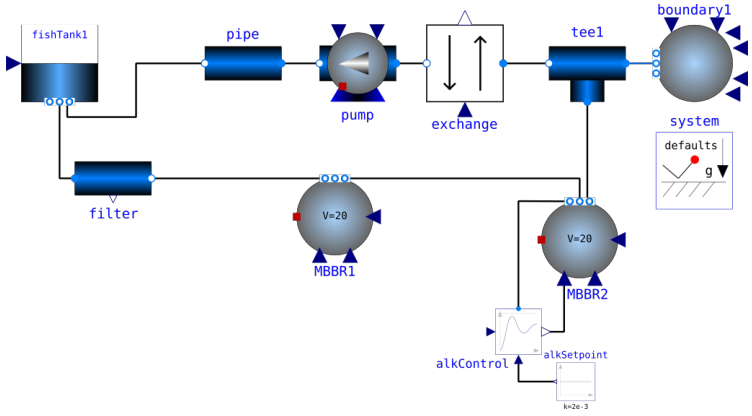
Waste production cont.



Water treatment



Water treatment



- Soluble organic components
- Oxygen
- Nitrite
- Nitrate
- TAN
- Alkalinity
- Inert matter
- Particulate organic material
- Heterotrophic bacteria
- Ammonia oxidizing bacteria (AOB)
- Nitrite oxidizing bacteria (NOB)
- Organic nitrogen

All models are wrong, but some models are useful!