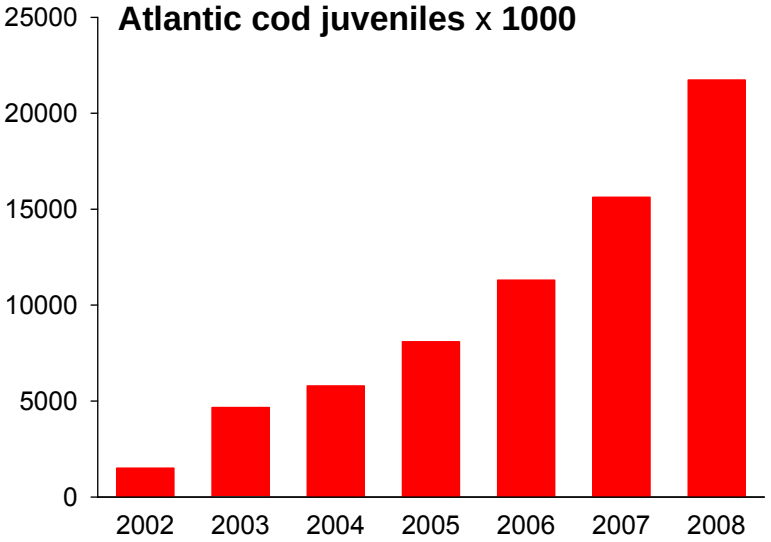
Recirculation as a microbial control strategy in intensive aquaculture of marine larvae

K. Attramadal, G. Øie, O. Vadstein, Y. Olsen

Production of marine juveniles rapidly increasing, but still the bottleneck

Atlantic cod production in Norway

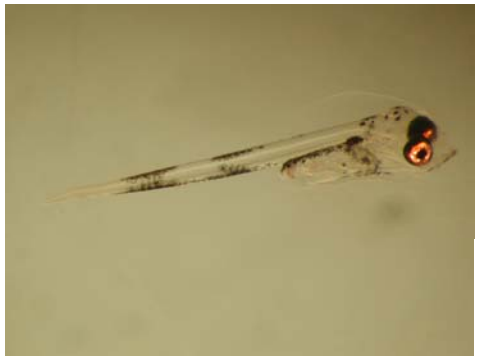


Similar with halibut, turbot, lobster, scallop..

The challenges

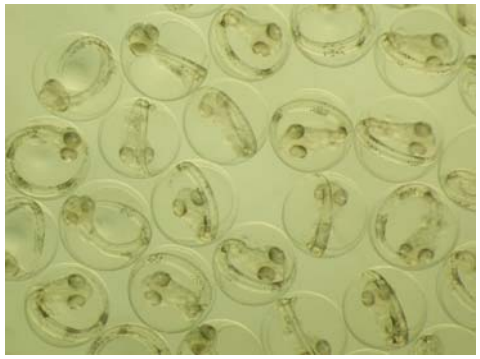
1. Bad performance

- Survival
- Growth
- Development
- First feeding



2. Lack of reproducibility

- Same temperature
- Same feed
- Full sibling groups



The causes?

→ Not nutrition

→ Not genetics or egg quality

Detrimental microbial relationships?

Efforts improving juvenile production is worth while

Costly period of production
(live feed)

Sensitive larvae

Quality at later stages affected

Large growth potential

→ **A need for microbial control strategies**

General characterisation of bacteria:
Ecological r/K-theory

Carrying capacity (CC)
= Maximum sustainable biomass
= # bacteria
that can be maintained in a system

Determined by:
physical/density dependent restrictions
= Supply of nutrients
= Dissolved organic matter supply
(heterotrophic bacteria)

Characteristics	Environment	Substrate supply per capita	Favoured ability
r-selection	Unstable or unpredictable, empty niches	High	Reproduce quickly, fast growing
K-selection	Stable or predictable, crowded	Low, close to CC	Compete for limited resources

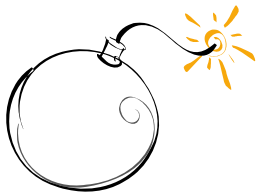
What is a 'detrimental' fish - microbe relationship?

- Type, composition *and* total amount

- Larvae rely on the general immune system
- Most diseases caused by opportunists becoming pathogenic when host's resistance is lowered by environmental stress

High share of r-selected opportunists

Unstable, low diversity microbial community



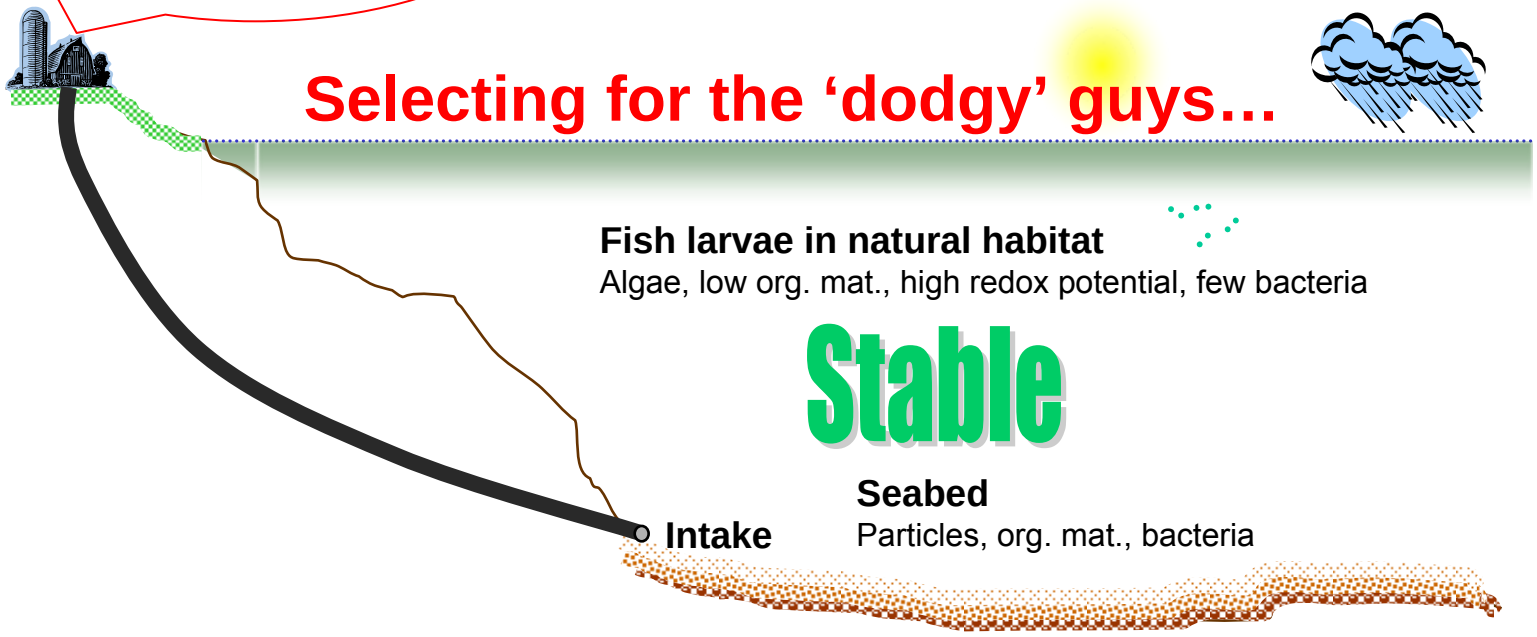
Effect of intensive fish cultivation procedures on the microbial community

Landbased fishfarm

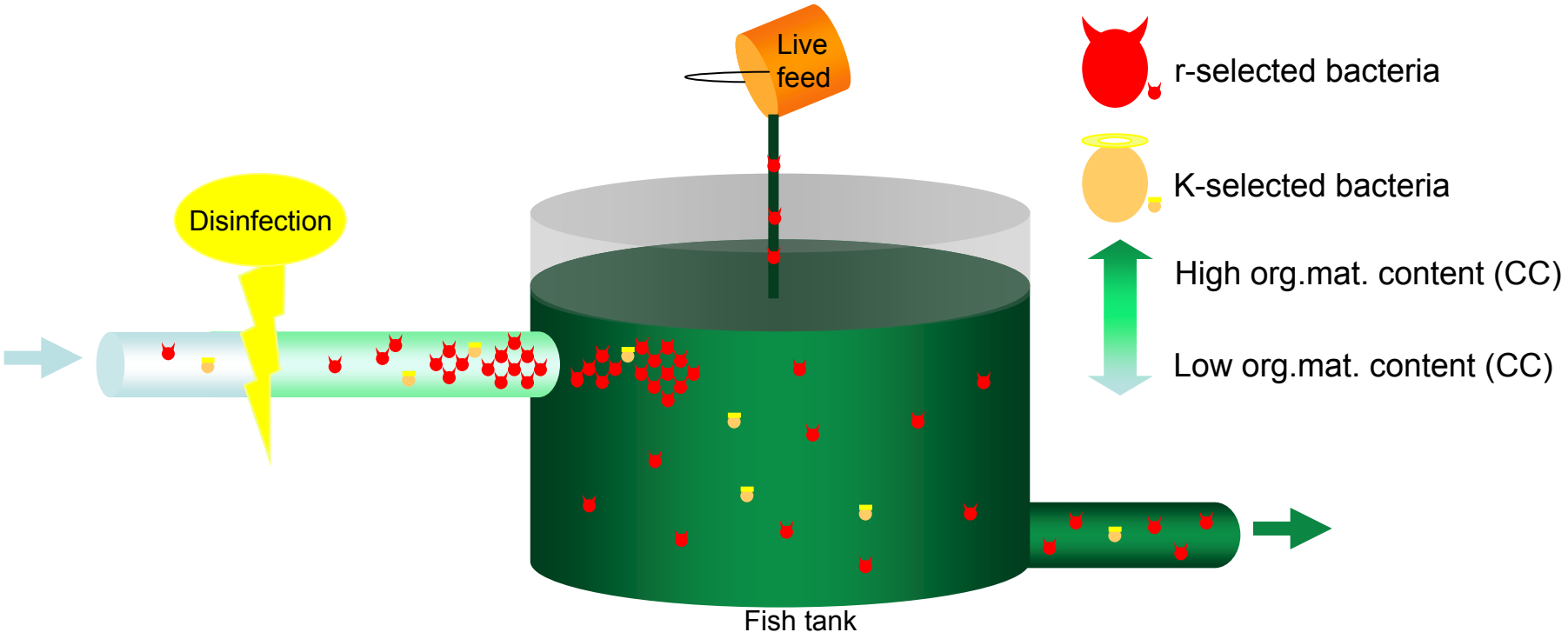
› Disinfection
› Frequent perturbations
› High and fluctuating [org. mat.]
› High densities of fish and prey with associated microflora

Destabilization r-selection

Favors proliferation of opportunistic and potentially harmful species



Flow through



Controlled recolonization: Microbial maturation of water

- Allow the microbial flora to stabilize at a given CC
- Selecting for the domination of a diverse community of slower growing specialists
- Waiting for succession and K-selection to happen

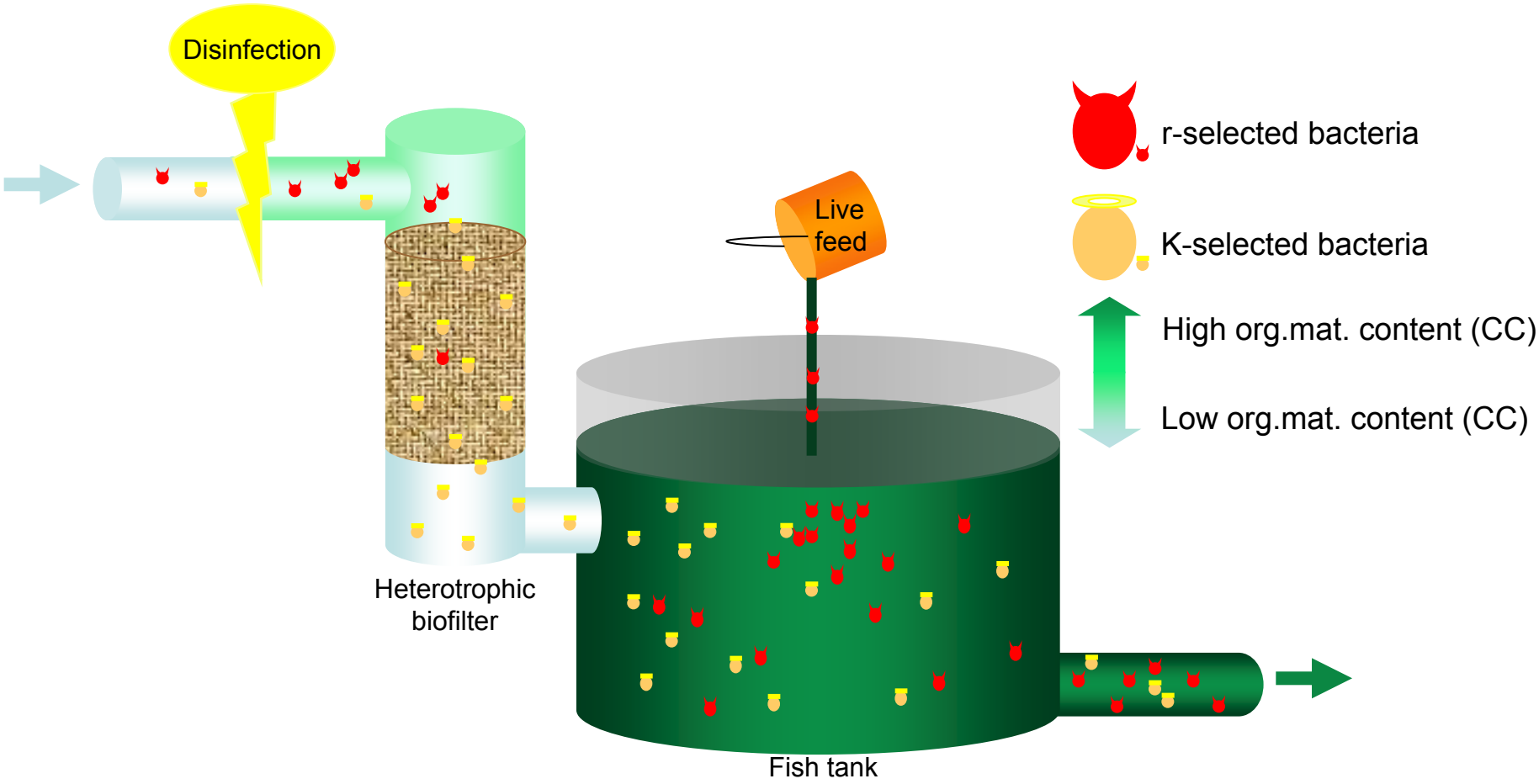
- Shown to benefit marine fish larvae (survival, growth)

  (Vadstein *et al*., 1993, Skjermo *et al*., 1996, Skjermo *et al*., 1997 Salvesen *et al*., 1999)

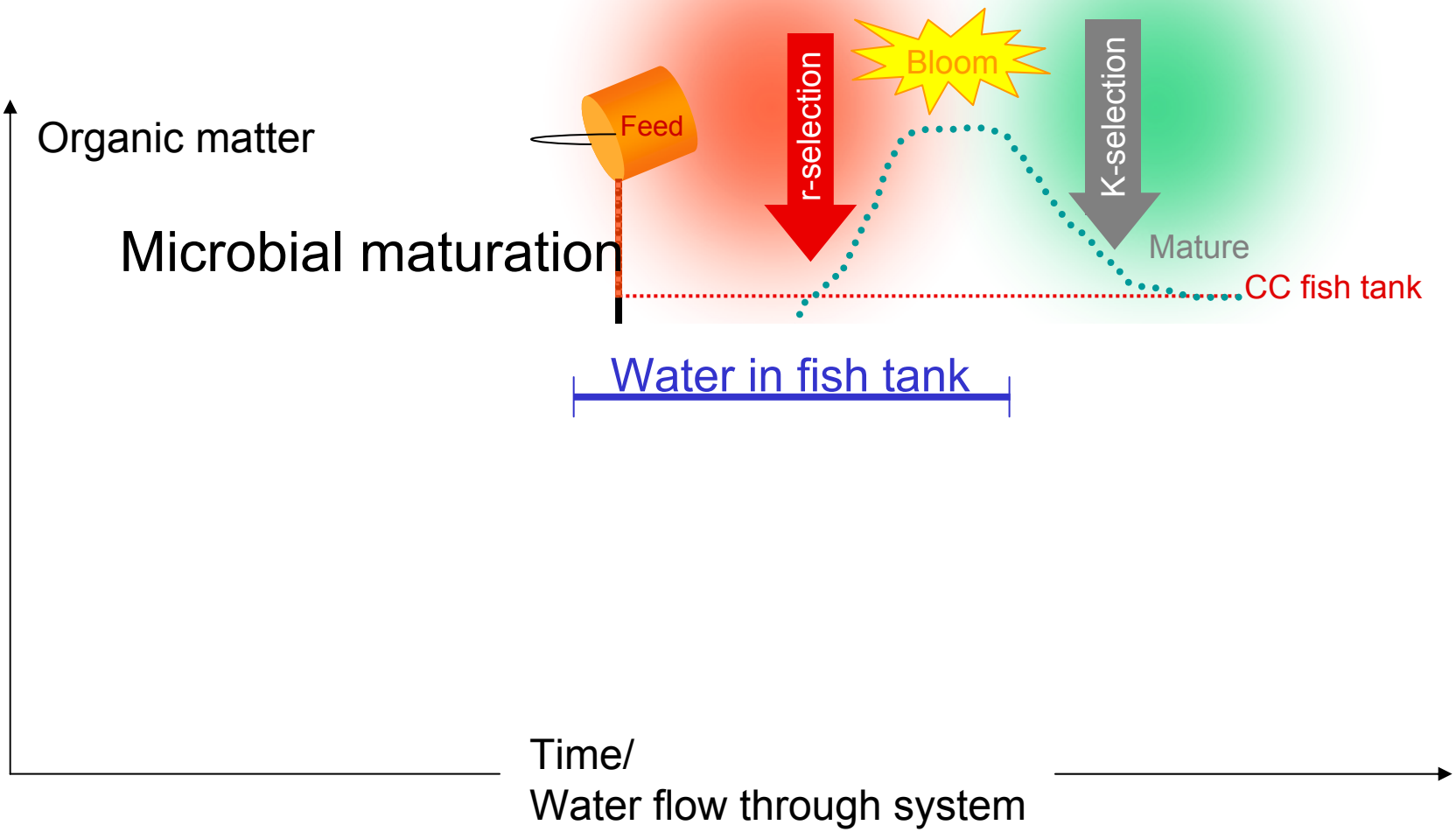
- Maturing unit = biofilter = large surface area to maintain a heterotrophic biofilm influencing the intake water

Microbial maturation, flow through

..but there is a shortage:



..a challenge to maintain the mature situation in the rearing tanks with low water exchange rates



Improved microbial maturation

To promote and maintain a stable and beneficial bacterial community

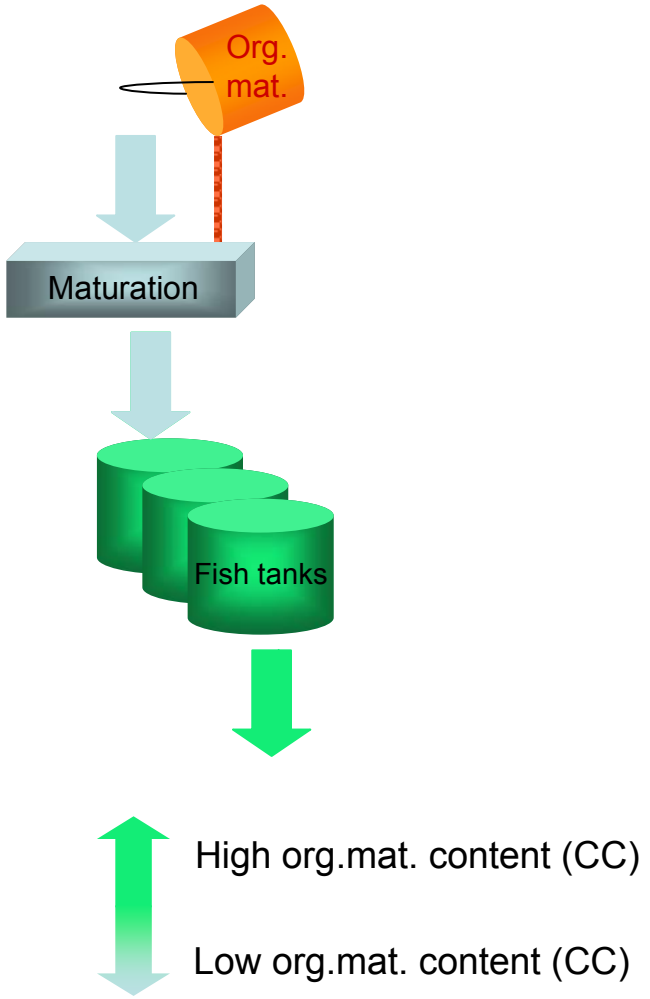
selection should be carried out at a CC similar to CC in the rearing tanks

= no free niches for opportunists

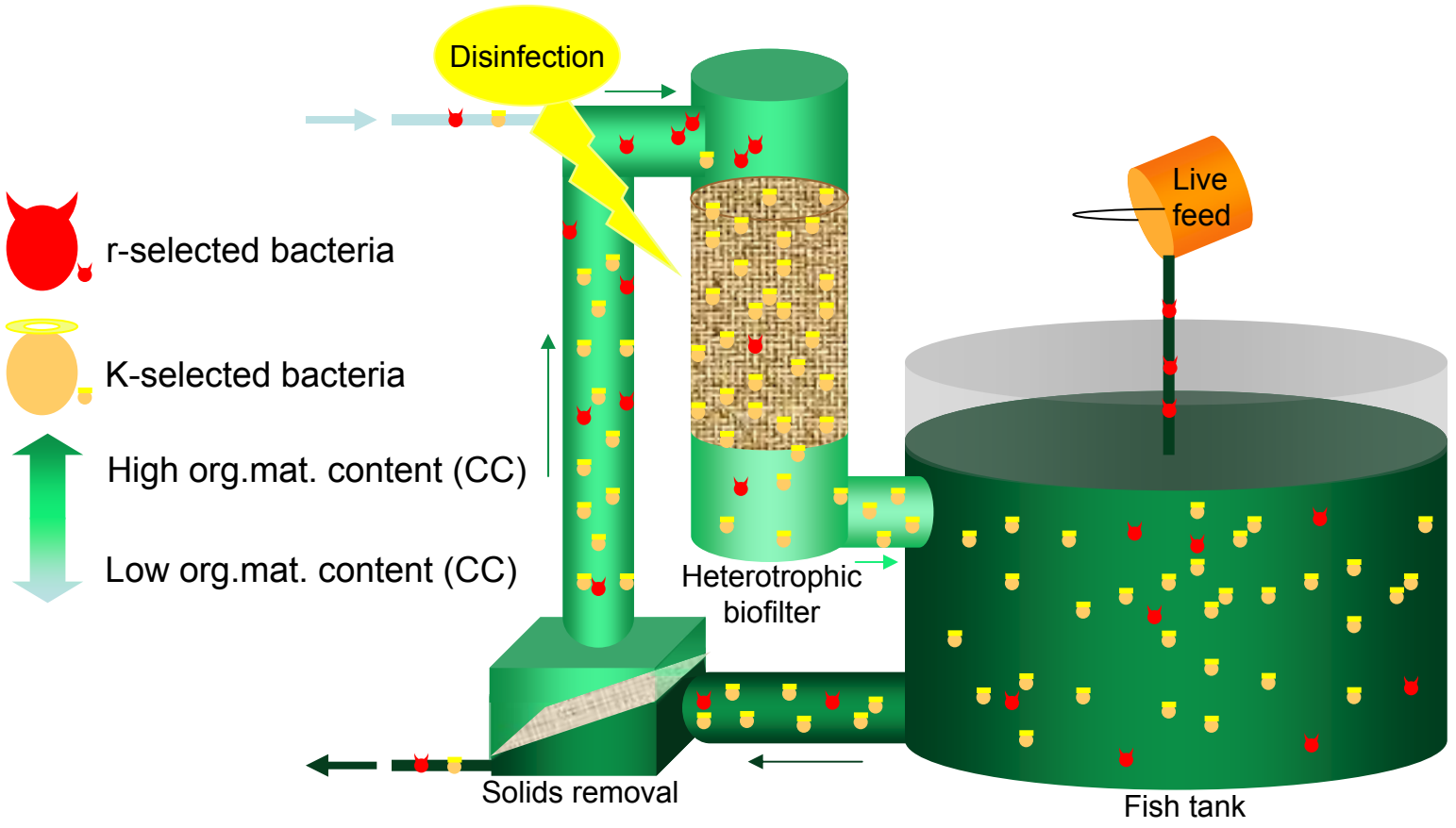
1. Feed the maturing water with organic matter
2. Reuse water from the fish tanks
   = organic matter source
   to raise CC in the maturing unit
   = biofilter

Simplest way to secure a quantitatively and qualitatively similar mix of nutrients to that found in the fish tanks

Better resource management



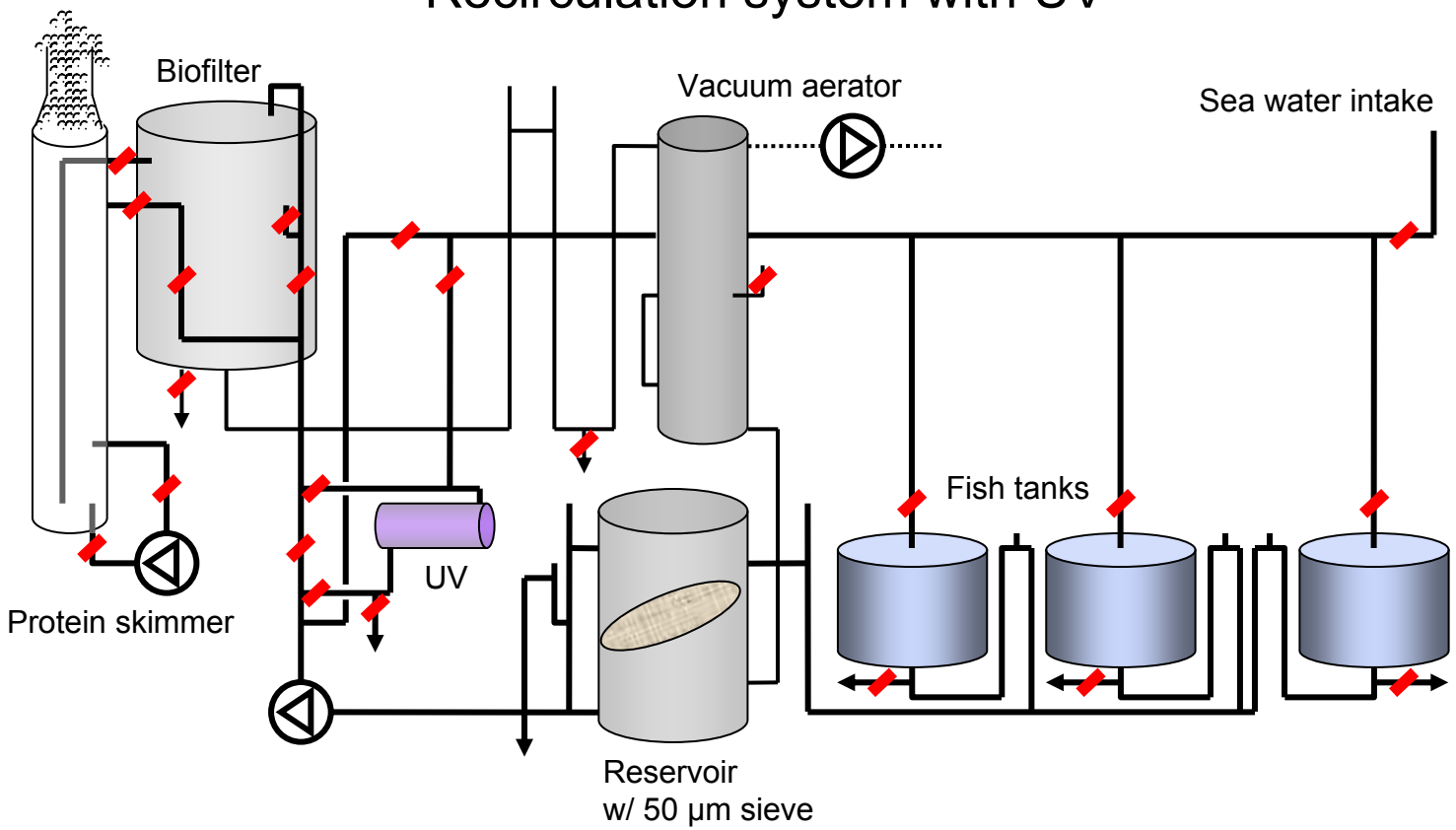
Recirculation as a microbial control strategy



Study: RAS microbial development

- Atlantic cod (*Gadus morhua*)
- Experiment I: FTS *vs.* RAS w/ O_3
- Experiment II: FTS *vs.* RAS w/ O_3 *vs.* RAS w/ UV

Recirculation system with UV



Study: RAS microbial development

- **Characteristic markers for mature water:**
  - a more stable microbial community composition over time
  - less variability between parallel tanks
  - higher species richness
  - lower fraction of opportunists

- **Better performance of fish larvae?**

Result 1:
Selection by water treatment is a significant force

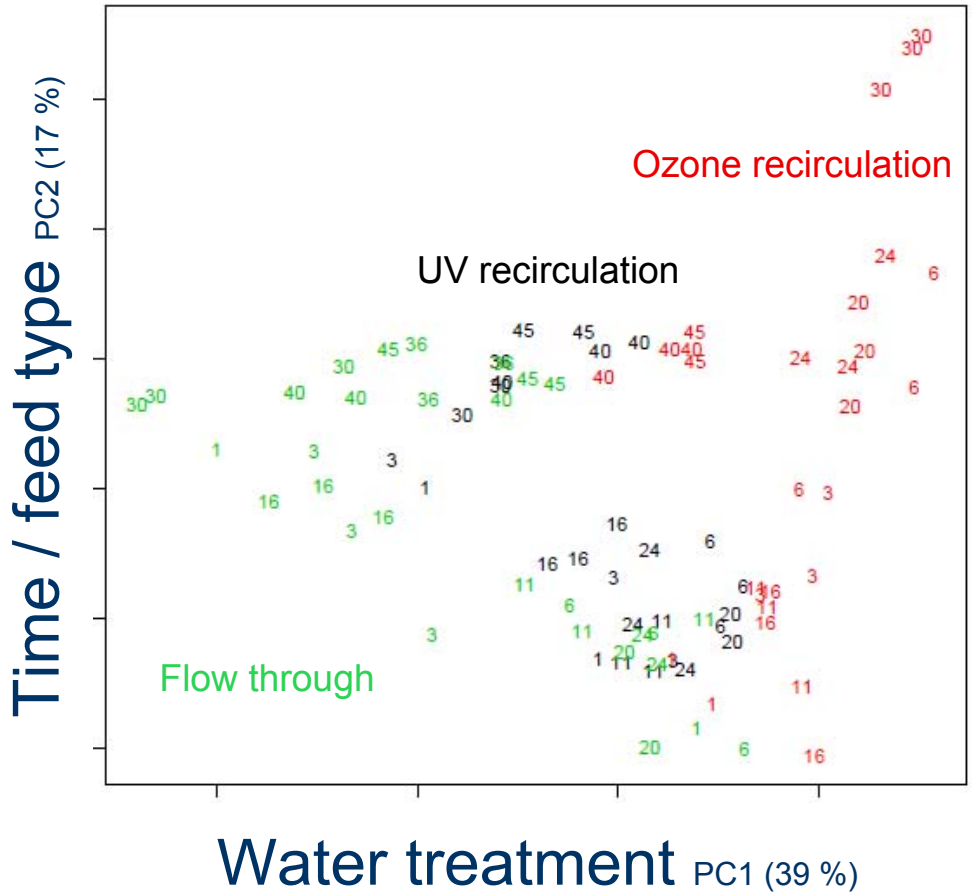
DO develop different microbial community compositions
despite significant contributions of bacteria from the same feed and algae

Principal component analysis of DNA fingerprints (TRFLP) of the microbial community

Water treatment regime explained more of the variation than change of feed type

- Recirculation with ozonation
- Recirculation with UV
- Flow through

Numbers = days post hatching



Result 2:
More mature microbial environment in RAS

- **RAS developed and maintained a more mature, diverse and stable microbial community**
  - Higher and more stable species richness and diversity
  - Lower share of opportunists
  - More stable microbial community composition over time
  - Lower variation between parallel tanks

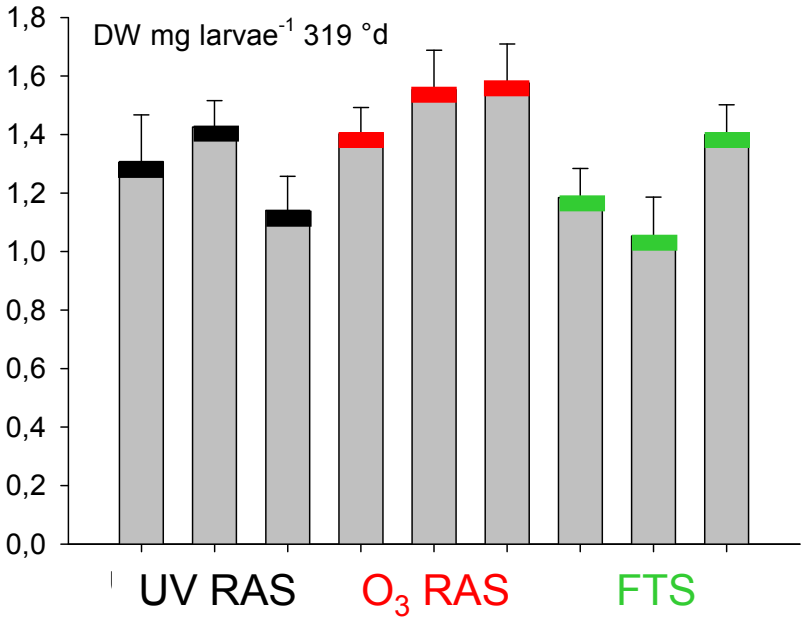
- **Qualitative microbial shifts in FTS**
- **Quantitative response in RAS**

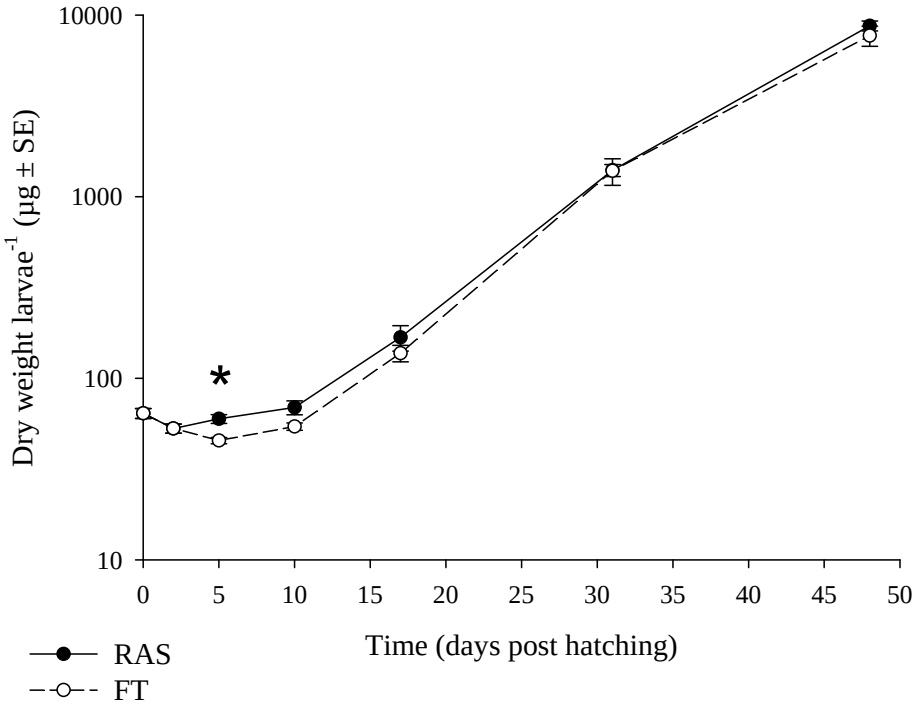
Result 3:
Slightly worse physiochemical environment in RAS

- More variation over time
- Higher concentrations of nitrogenous waste products
- More suspended particles
- Higher organic matter level
- Lower pH

This may be improved

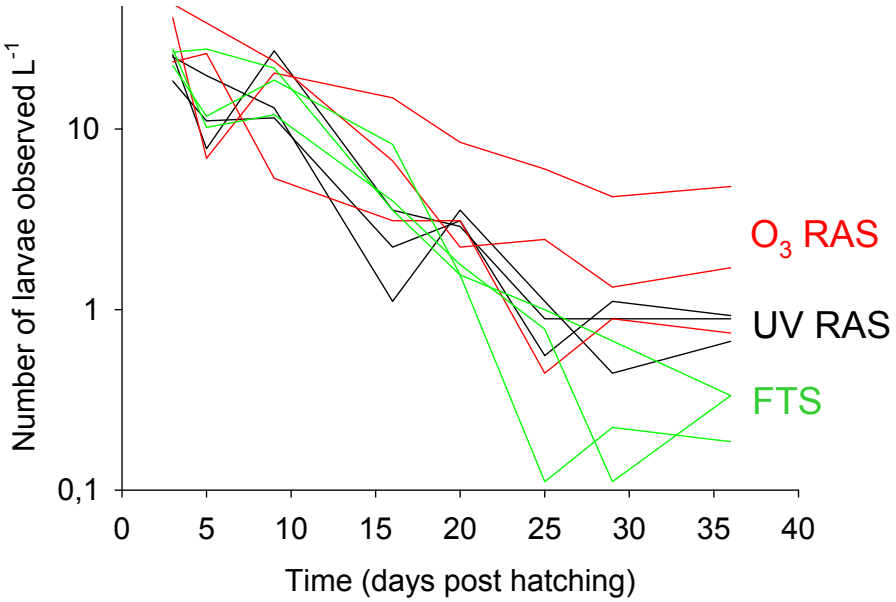
Result 4:
Equal or better fish growth in RAS



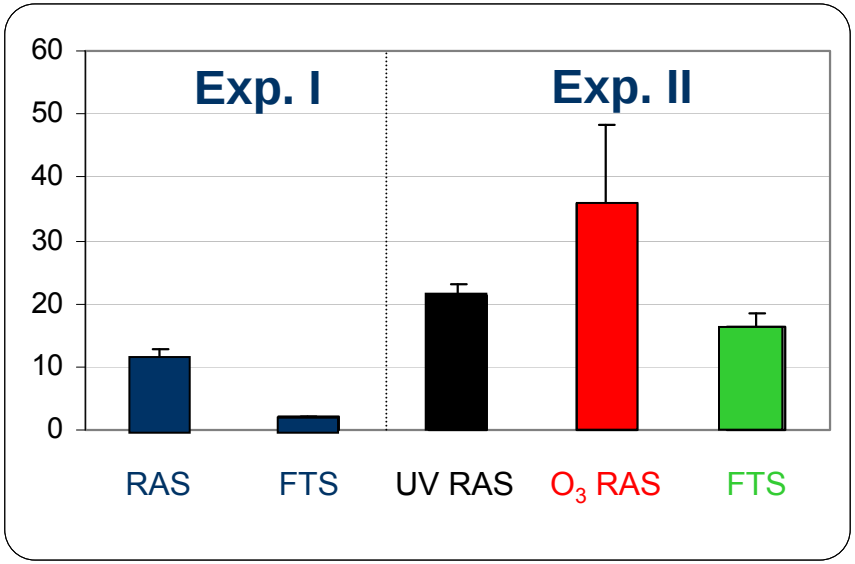


Result 5:
Equal or better fish survival in RAS

Density by photography



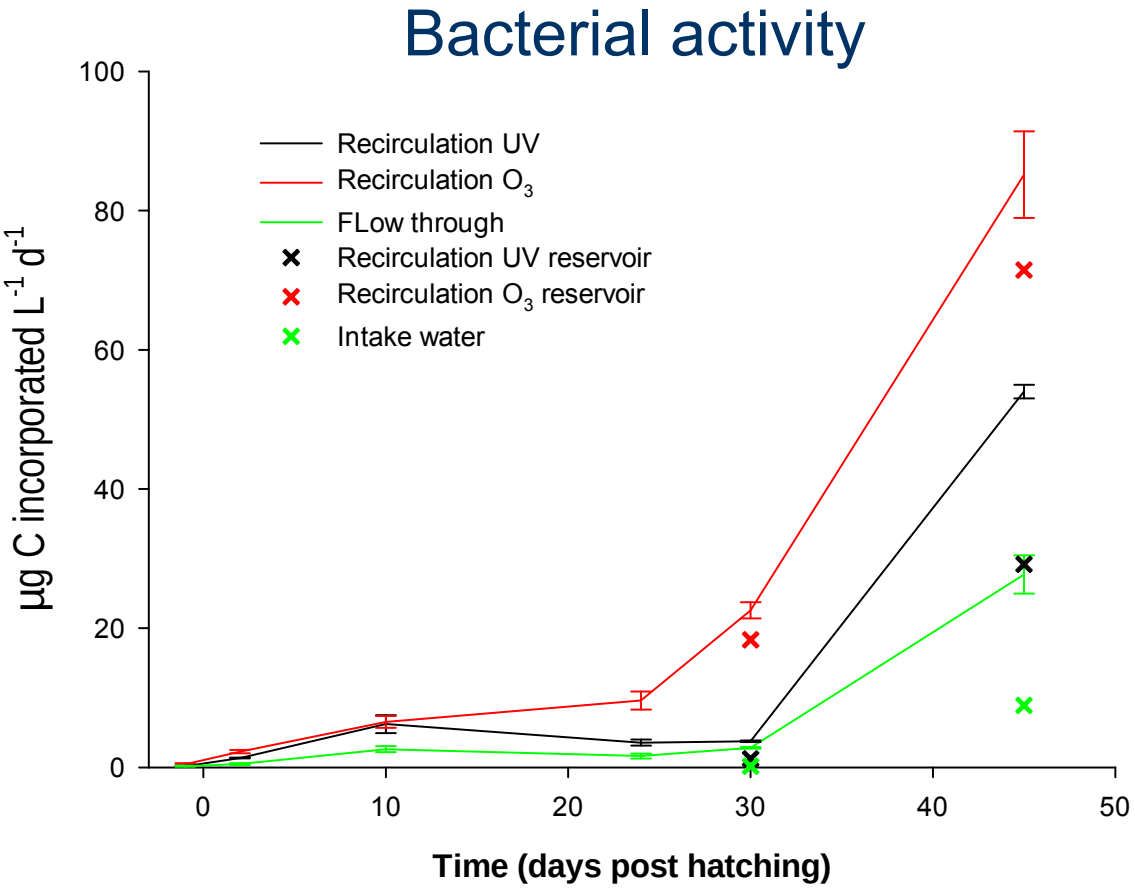
Survival through live feed period (%)



Result 6:
Less RAS disinfection - better results

Microbial activity in tanks compared to inflowing water:

O_3 RAS	1.2 × higher
UV RAS	3.0 × higher
FTS	17.5 × higher



Aknowledgement: Norwegian Research Counsel, NTNU, SINTEF