Lit Review of Aquaculture and Lakes

Variables in our data: Alkalinity, Calcium? (CA), Chloraphyl A, Chloride? (CL), Conductivity, Dissolved Inorganic Carbon (DIC), Dissolved Organic Carbon (DOC), Potassium (K), Magnesium (Mg), MN, Nitrate (NO3), PARTC, PARTN, PARTP, PH, Sulfate (SO4), Total dissolved nitrogen (TDN), Total dissolved phosphorus (TDP), Nitrogen Dioxide (NO2), TSS, TDS, Turbidity

Not ideal data (not many records)

General aquaculture methods:

* Rainbow trout (*Oncorhynchus mykiss*, Wallaum) obtained from Linwood Trout Hatchery, Ontario, Canada (Azevedo et al., 2011)
  + 10000 female rainbow trout stocked in 2003 and 2004
  + Raised for 167 days (2003) and 155 days (2004)
  + Hand-fed to near-satiety twice a day (morning and dusk)
* “Two production trials were carried out between May and October 2003 and 2004 in Lake 375, an oligotrophic double basin (north and south basins) lake located at the Experimental Lakes Area (ELA), northwestern Ontario, Canada (49°44′43.61″N, 93°47′15.56″W). This lake was the object of frequent monitoring over two decades and long term pre-cage (1982–2002) mean TP and TN values (mean ± SD, n = 314) of 6.3 ± 4.5 μg L− 1 and 245.2 ± 92.0 μg L− 1, respectively were available. The lake has a surface area of 23.2 ha and maximum depth of 26 m (in the south basin), respectively. Fish were raised in a 10 m × 10 m cage that was anchored in the north basin of the Lake 375 over approximately 15 m of water, with the cage net extending approximately 10 m into the water column.” (Azevedo et al., 2011)
  + May through October 2003 and 2004
  + L375: Oligotrophic lake with SA 23.2 ha and max depth 26 m
  + Rainbow trout raised in 10 m x 10 m cage going 10 m deep into water column
* Fish fed a commercial trout diet (Martin Mills Profishent) (Azevedo et al., 2011)

Individual measurements:

* Dissolved phosphorus: primary nutrient of interest (Azevedo et al., 2011)

Possible ideas:

* Use the extrapolated data and time series to compared against MECP standards for waste outputs from cages
  + Can other water chemistry measurements be indicative to nutrient output and tell about the quality of systems that aquacultures are being placed in?
  + Are the MECP guidelines exceeded in the lake/are expected to be exceeded in the future if the aquaculture were to continue?

**Estimation of waste outputs by a rainbow trout cage farm using a nutritional approach and monitoring of lake water quality (Azevedo et al., 2011)**

<https://doi.org/10.1016/j.aquaculture.2010.12.001>

* Solid and dissolved P and N could lead to environmental degradation
  + Env compliance of cage culture operations generally assessed by measuring nutrient concentrations in water to ensure that target water quality criteria are met (set by gov – MECP in ON)
    - ON: take depth-integrated water samples for total P 30 m from each side of the cages and at two remote reference stations eleven times during ice-off period (Boyd et al., 2001)
    - However, these measurements may not be sufficient
* It’s difficult to differentiate bw farm-loaded, natural, and other anthropogenic nutrients
* Dissolved phosphorus: primary nutrient of interest
  + Taken up rapidly by bacteria and phytoplankton and removed to sediments
  + ~ 7.3 kg of P released into the env for every tone of fish produced in rainbow trout production
  + Over 60% of waste P is particulate and settles quickly ( > 6 cm/sec)
    - Most fecal matter that is generated in the epilimnion (where cage is) will settle to the sediments so it’s unavailable for algae or detected by epilimnetic water monitoring (our data) until thermal mixing occurs
* This project looked at relationship bw predicted waste outputs (Fish-PrFEQ model) and measured water chemistry parameters
* No significant differences in N and P measured in epi or metalimnion near the cage vs 400 m away (fig 6)
* Fish-PrFEQ models predicted: ammonia should inc from less than 10 ug/L before aquaculture to more than 250 ug/L in 2003 and over 300 ug/L in 2004
  + Not detected
  + Inc in nitrite/nitrate from less than 2 ug/L to more than 19 ug/L
    - At least part of ammonia added as fish waste was converted into nitrite/nitrate
* Models predicted: TDP (total dissolved phosphorus) should inc from less than 5 ug/L before to 25 ug/L in 2003 and over 35 ug/L in 2004
  + Not detected
* Discussion: 4.2 Water chemistry and nutrient status of the lake
  + Fish-PrFEQ model predicted an inc of NH4 and TDP by more than 10x background levels
    - Not confirmed by measurements
    - Lower ammonia likely due to Nitrogen transformations
      * Inc in nitrite/nitrate suggests that excreted fish waste (ammonia) converted into nitrate
  + Sig change in SUPN but also observed in reference lake (L373)
  + Dissolved N and P and suspended N and P lower than expected
    - Likely bc of immediate sedimentation of solid waste and uptake of dissolved N and P by algae and bacteria (High inc in Chl A due to lots of primary productivity?)
      * Look at Findlay et al., 2009 (<https://doi.org/10.1139/F09-121>)
  + Reflux of nutrients form sediments: some TDP inc in water were higher than TDP added as fish waste due to internal loading of P in sediments and settled solid waste
  + Expected to have an inc in nutrient concentrations in lake due to aquaculture, but not measured or observed
    - Nutrients don’t behave conservatively (as the model predicts) but is rapidly taken up and transformed
    - Ecological effects related to nutrient loading were observed
      * Inc in phytoplankton biomass and chlorophyll A (Bristow, 2006 and Findlay et al., 2009)

**Aquaculture impacts on the agal and bacterial communities in a small boreal forest lake (Findlay et al., 2009)**

* Nice map that is put in folder: L375\_map (fig. 1)
* 10 tonne fish capacity aquaculture stage stocked with rainbow trout
* N inc 15x in 4 years
* P inc 4x in 4 years
* Phytoplankton biomass inc 4x in 4 years
  + Blooms of chrysophytes and dinoflagellates inc biomass by 12x in fall/winter following the dimictic mixing events
* Bacteria biomass inc in late fall
* Inferred to phytoplankton and bacterial communities would be similar to other forms of eutrophication
  + Predicted that effects of aquaculture would parallel L227 (phosphorus lake) and L302 (phosphorus added at thermocline)
  + L373 reference lake
* Phytoplankton:
  + June 2003 (start): no immediate response from phytoplankton with biomass compared to previous years
  + 2004: biomass in both basins inc 2.3x over precage and reference lake
  + New species (*Pseudoanabaena galeata*) in north bason of L375
  + Mean epilimnetic ice-free total phytoplankton biomass elevated compared to the reference lake in 2005 and 2006
  + Inc biomass and shift in species composition and altered size structure for algae in both basins of L375
  + Edible phytoplankton biomass dec from 60% before cage to 40% after cage in 2006
* Bacteria:
  + No observed difference in bacterial biomass due to aquaculture, but seasonal fluctuations were greater
* Discussion:
  + Excess nutrients from aquaculture cage in L3785 significantly impacted phytoplankton community
    - Inc epilimnetic nutrient concentrations optimized by phytoplankton during spring and fall turnover
      * Less nutrient concentrations in epi during thermal stratification
    - 66% of solid form of feed waste
  + Over the 4 years, 109 kg P/year and 693 kg N/year contributed
    - 4 x inc in N loading and 15 x inc in P loading to the lake
      * BUT only 8% of N and 10% of P remained in water column for a result of 2.5 x inc P
        + Because most of the waste was sedimented and isolated before the thermocline hence the lower changes to N and P as showing with L302 N when nutrient loading was done below the thermocline
  + Suggest that effects on phytoplankton and bacterial communities from cage aquaculture are cumulative over time
  + Chloryphyl A as a surrogate for algae biomass (MacIsaac and Stockner, 1995)
    - Inverse relationship bw periphyton biomass and distance from culture cage (max biomass next to cage)