Towards improved public confidence in farmed fish quality: a Canadian perspective

Tony Farrell[1,2,3],
Research Chair in Sustainable Aquaculture
University of British Columbia
Vancouver, Canada

Erin Friesen[1],
Steve Tang[2],
David Higgs[1,3] &
Michael Ikonomou[4]

[1]Faculty of Land & Food Systems, UBC
[2]Department of Zoology, UBC
[3]Fisheries & Oceans Canada, Centre for Aquaculture & Environmental Research, W.Van.
[4]Fisheries & Oceans Canada, IOS, Sidney, BC

Hawaii, Oct 2007

Some basic facts: Demand & supply

- Global demand for a healthy protein source is ever increasing
- Exploitation of wild fish stocks has plateaued
  Especially true of marine fish for fish feed oils
- World aquaculture is growing at 1% per annum
- Salmon feed prices are increasing
  - Atlantic salmon is Canada's major farmed fish species
  - More than 50% of Canadian salmon farms are in BC
  - BC is the 4th largest salmon producer

Salmonid dietary & welfare research in Canada

Dr. Murray Drew et al., Univ. Saskatchewan

Replacing fish meal & fish oils with canola protein & oils to reduce contaminant levels in rainbow trout

Dr. Grant Vandenberg et al., Univ. Laval

Replacing fish oils with canola & soy oils to reduce contaminant levels in rainbow trout

Dr. David Higgs et al., Fisheries & Oceans Canada & UBC

Replacing fish meal & oils with plant oils & poultry fat to ensure fish growth & health, as well as to reduce contaminant levels in Atlantic salmon

Dr. Michael Ikonomuo et al., Fisheries & Oceans Canada

Measuring contaminant levels in farmed & wild salmon

Current Canadian issues: Conflicting claims?

1. Sustainability

Feeding wild fish to farmed salmon is non-sustainable

vs

Alternative feeds are being used & further refined

2. Food quality

Farmed salmon contain carcinogens (chlorinated dioxins, PCBs, etc.)

vs

Eat salmon to prevent death from cardiovascular disease

3. Fish welfare

Farming practices negatively impact salmon welfare

vs

Farmed salmon are healthy & are treated well

Marine fish consumption is recommended worldwide (WHO, NIH, AHA, CHSA, EFSA)

Source of highly unsaturated fatty acids (HUFAs)

Marine fish oils: ≥20 carbon chain; 4+ double bonds

eicosapentaenoic acid (EPA 20:5n-3)

docosahexaenoic acid (DHA 20:6n-3)

Proven human health benefits

Cardiovascular health (anti-inflammatory, blood thinning, cholesterol lowering)

Natal & neonatal neural development

Type I diabetes (auto-antibodies)

1 g EPA+DHA per day for 70 y

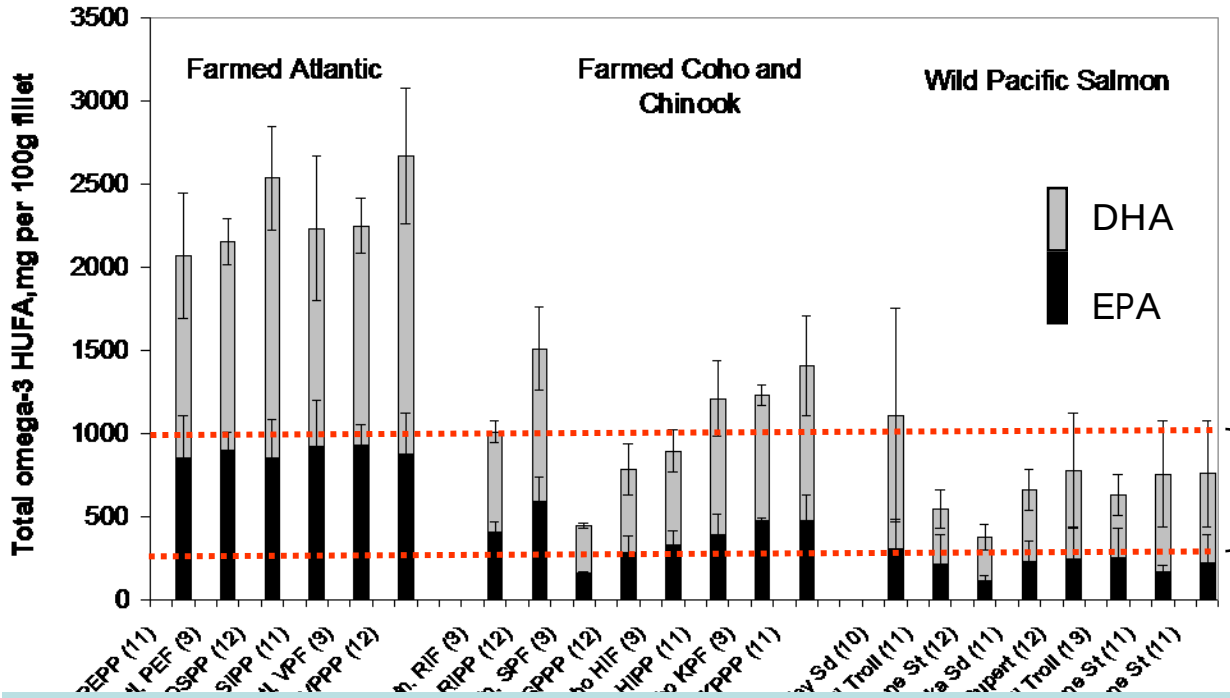
→ 7,100 fewer deaths from coronary heart disease per 100,000

(Risk analysis based; Foran et al. 2005 Environ Health Perspec)

Recommended intakes of EPA+DHA = 0.2 – 4.0 g per day

EPA + DHA content of BC-farmed salmon

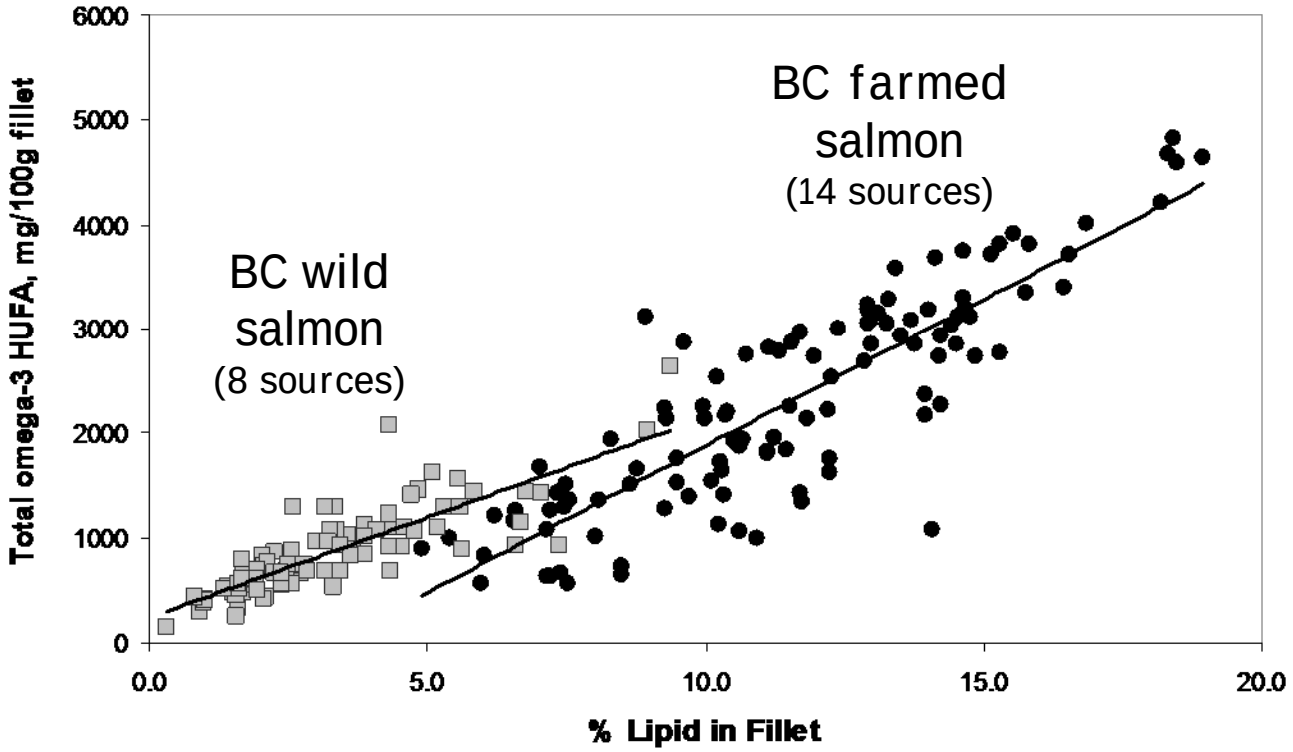
Farmed BC salmon typically have 3-times more HUFAs than wild BC salmon



A 100 g salmon fillet more than meets the daily recommended intake for a healthy individual

Ikonomou et al. 2007 Environ Sci Technol

High HUFAs in farmed salmon:
Lipid content reflects what is eaten



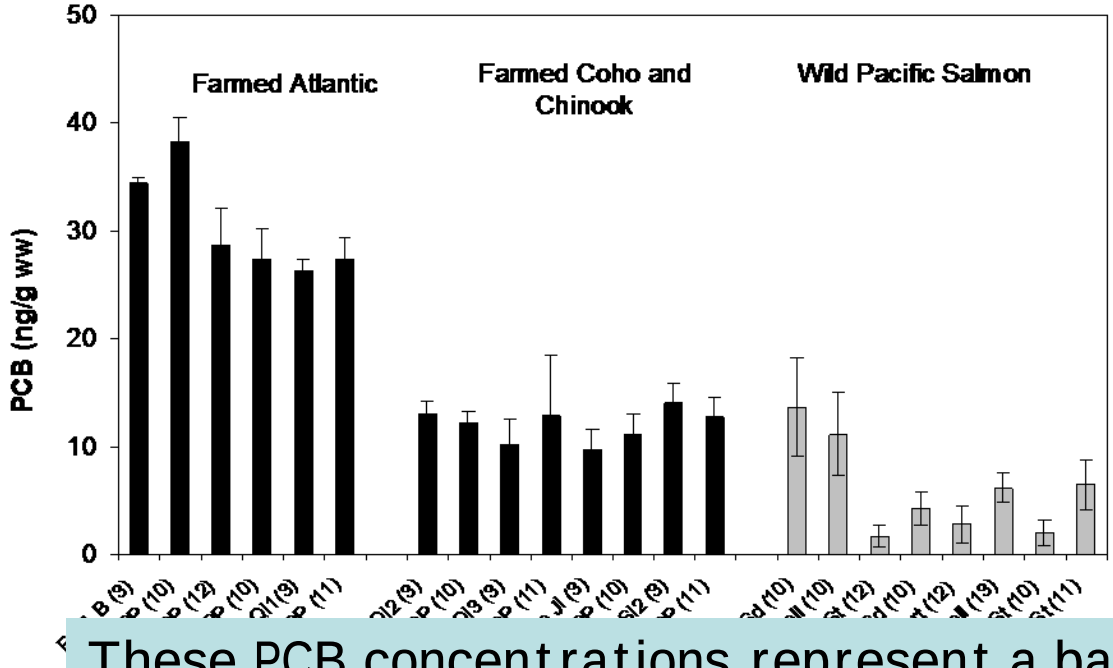
Farmed fish possess more lipid in their tissues due to the marine fish oil supplement in feed

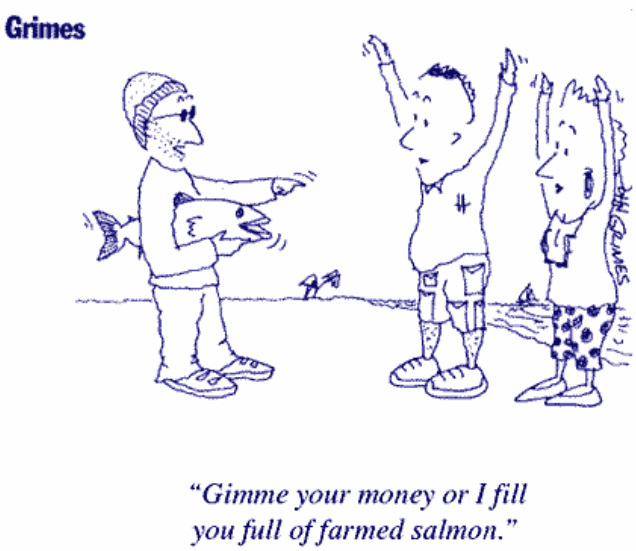
Ikonomou et al. 2007 Environ Sci Technol

Highly lipophilic contaminants are “dissolved” in animal lipids

eg, polychlorinated dibenzo-dioxins (PCDD), furans (PCDF) & biphenyls (PCBs)

PCB levels in salmon fillets





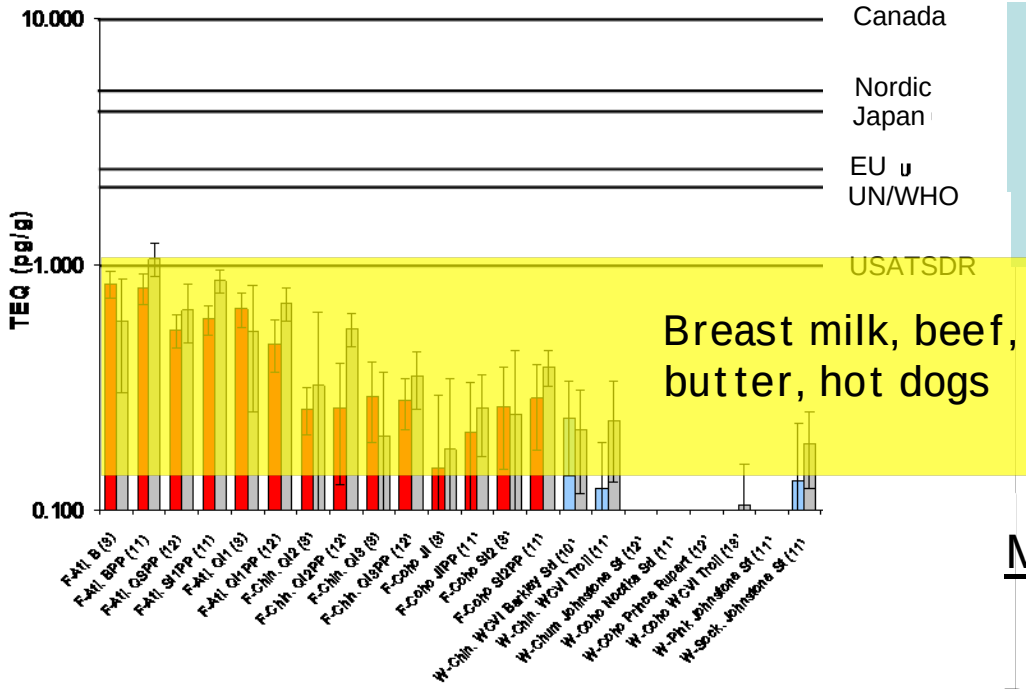
“Gimme your money or I fill you full of farmed salmon.”

These PCB concentrations represent a background level:
50-150 times lower than level of concern for human consumption (2,000 ng/g Health Canada & US-FDA)

Ikonomou et al. 2007 Environ Sci Technol

Wild & farmed salmon from BC are safe to eat

TEQ PCDD/F levels in salmon fillets



Ikonomou et al. 2007 Environ Sci Technol

Below all tolerable daily intake recommendations, except US-EPA (0.001 pg/g)

50% lower than Hites et al. 2004

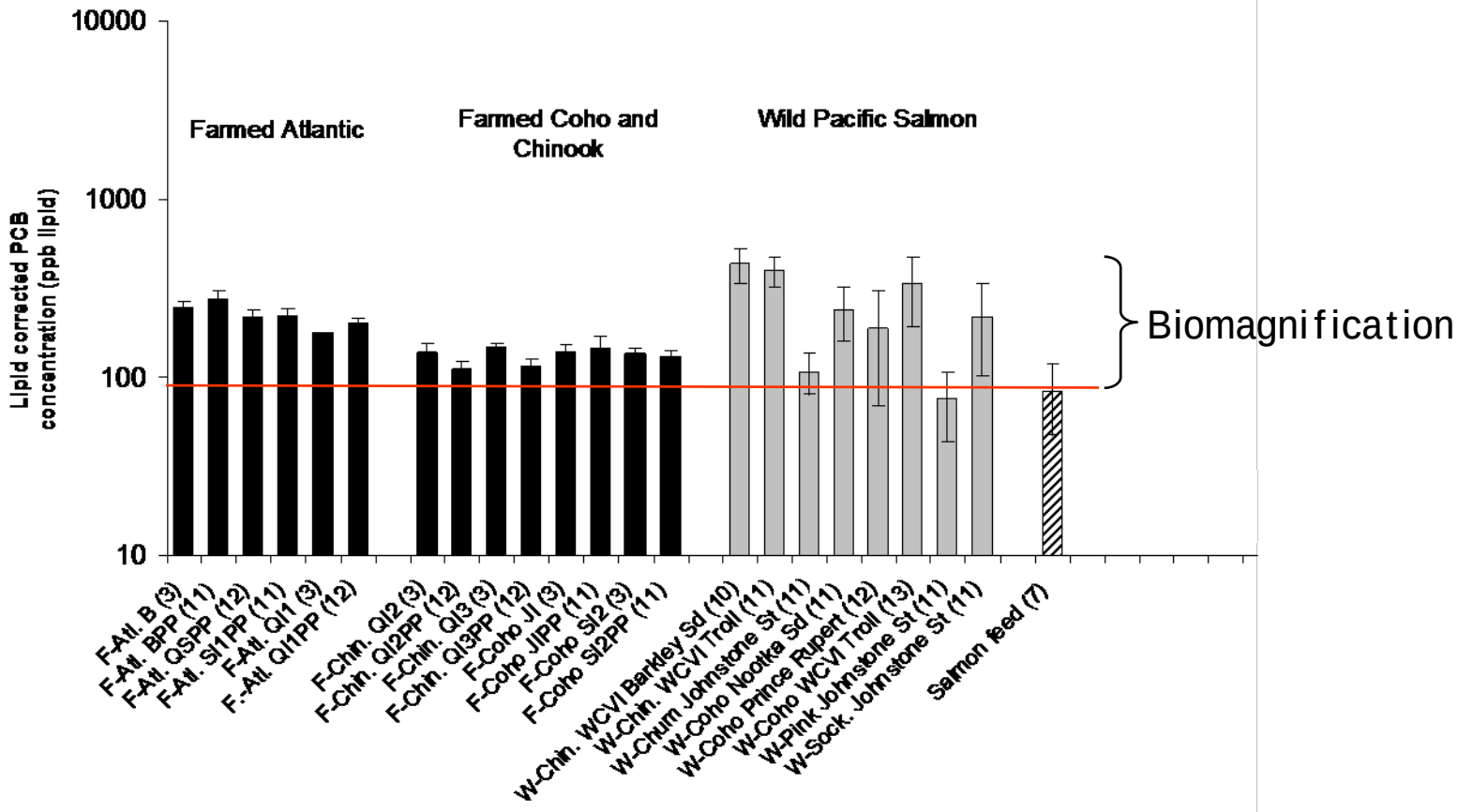
Major USA dietary sources for PCDD/F + PCB exposures

Beef, chicken & pork	34%
Dairy products	30%
Vegetables	22%
Fish & shellfish	9%
Eggs	5%

Schecter et al. 2001 J Toxicol Environ Health

Contaminant levels in fish fillets largely track lipids

Oils from wild marine fish are the largest source of contaminants in salmon feeds



Ikonomou et al. 2007 Environ Sci Technol

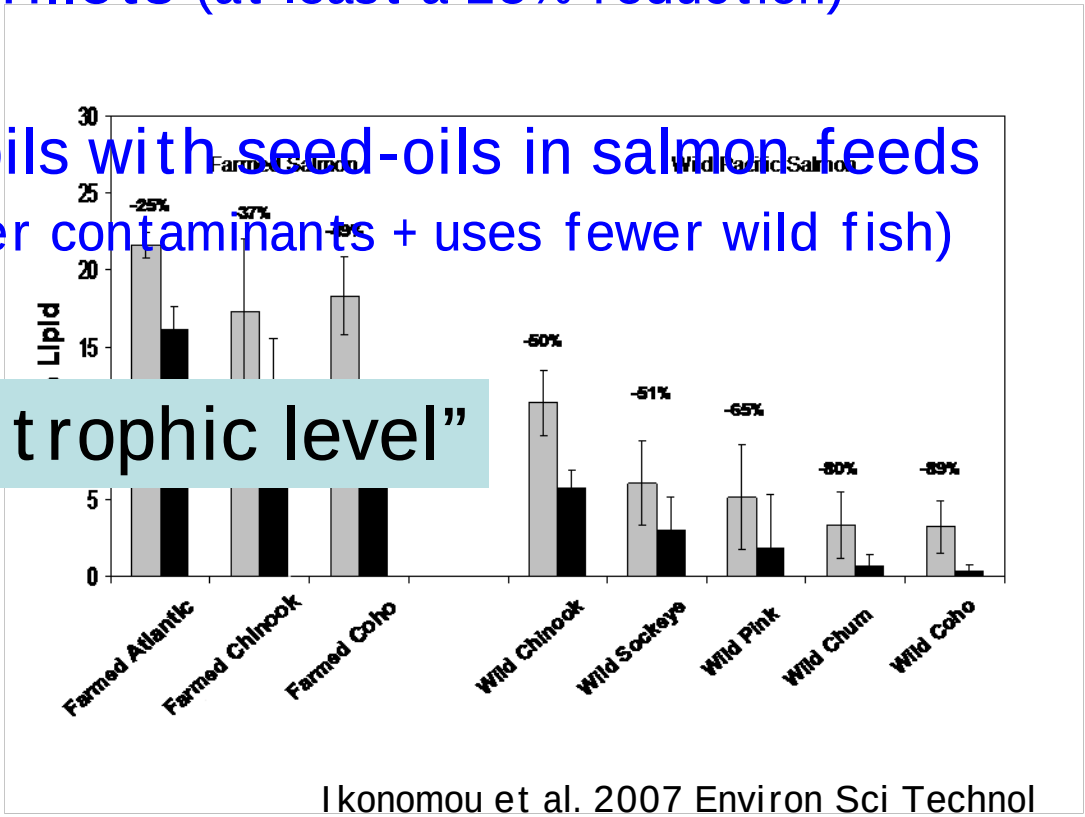
Reducing contaminant levels in salmon fillets

1. Pacific *vs* Atlantic fish

2. Market only skinless fillets (at least a 25% reduction)

3. Replace marine fish oils with seed-oils in salmon feeds
   (double benefit: lower contaminants + uses fewer wild fish)

"skipping a trophic level"



Ikonomou et al. 2007 Environ Sci Technol

Seeking balanced alternatives to using marine fish oils in salmon feeds

Traditional salmon feed

40% fish meal

20-30% marine fish oils (MFOs) (anchovy, menhaden, sardine, herring, capelin)

Fish feed: 30-60% cost of salmon farming

cheaper, healthy alternatives are welcomed by industry

Seed-based oils

20 years of research on salmon diets ➔

Like humans, salmon have an essential dietary HUFA requirement

50-80% of MFOs can be replaced plant-derived lipids

Canola

Sunflower

Soy

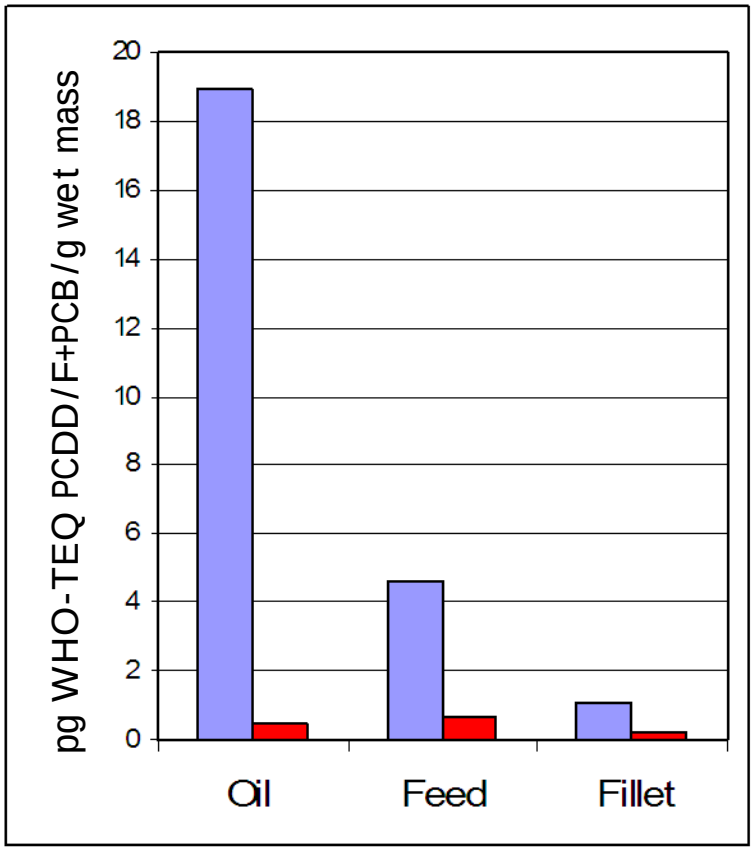
Flax

- Cheaper
- Sustainable
- Low in contaminants
- Increase local economy

Canada enjoys 80% of global trade flaxseeds

Plant-based fish feeds reduce contaminant levels

PCDD/F + PCB levels



Fish meal + 27% MFO (menhaden)

Canola protein concentrate + 27% vegetable oil (65:35 canola oil:linseed oil)

6-times reduction in contaminant levels in rainbow trout fillets

Atlantic salmon 6-times reduction
(Bell et al. 2002 Aquaculture)

Atlantic salmon 8-12 times reduction
(Berntssen et al. 2005 Aqua Nutr)

What about fish health & HUFA levels for fish fed seed-oils?

Drew et al. 2007 Aquaculture

Replacing marine fish oils:
fish health, HUFAs & contaminants

36-week trial with Atlantic salmon (80 g)

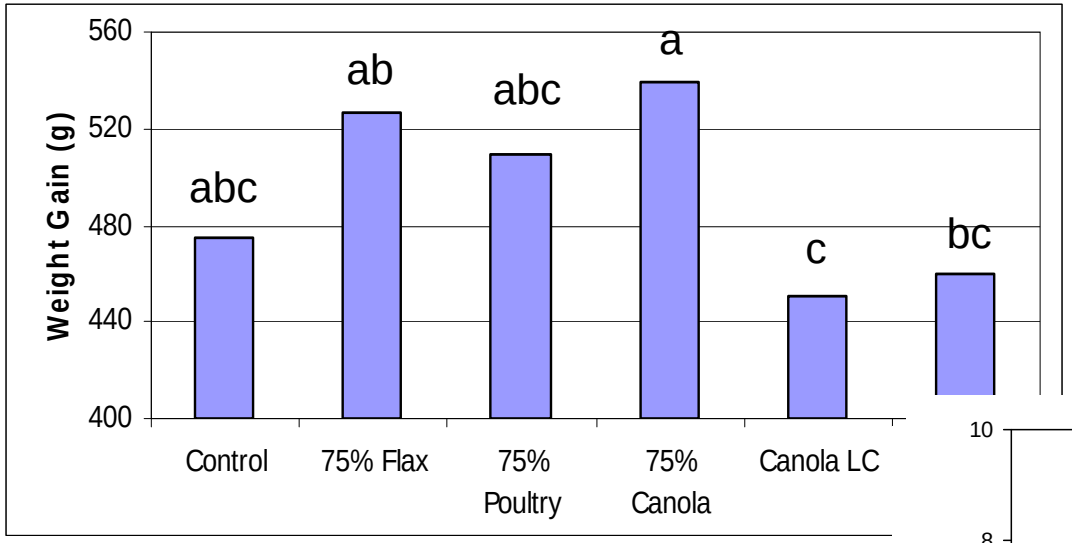
24-week phase I + 12-week phase II

Phase I diets

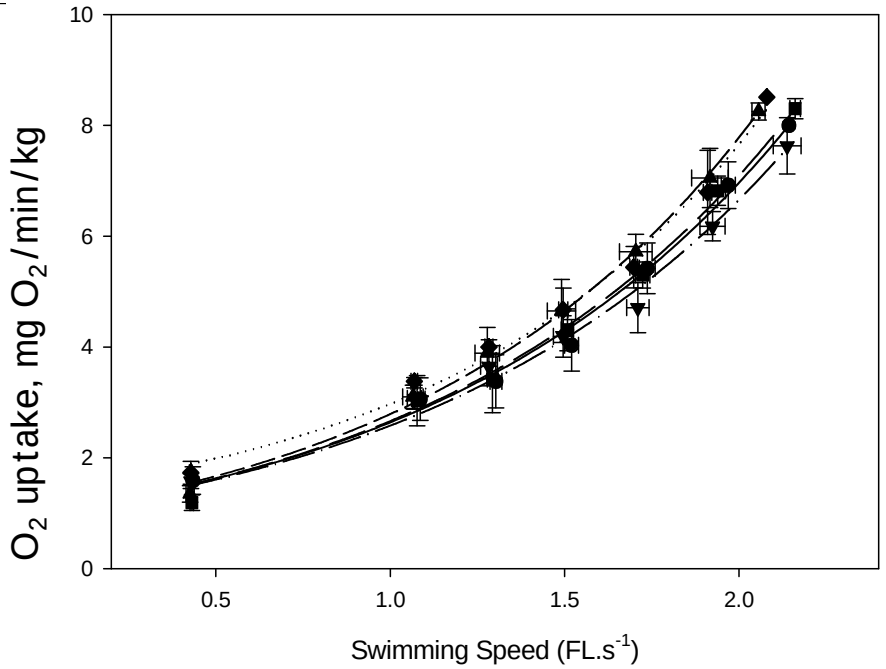
PROTEIN	LIPID	
Fish Meal	Anchovy Oil (AO)	Control
Fish Meal	AO / Flaxseed Oil	75%FO
Fish Meal	AO / Poultry Fat	75%PF
Fish Meal	AO / Canola Oil	75%CO
Fish Meal / Canola CM	CT AO / Canola Oil	Canola Low C
Fish Meal / Soy CM	CT AO / Canola Oil	Soy Low C

Friesen et al., unpublished

Plant-based lipids are healthy for salmon



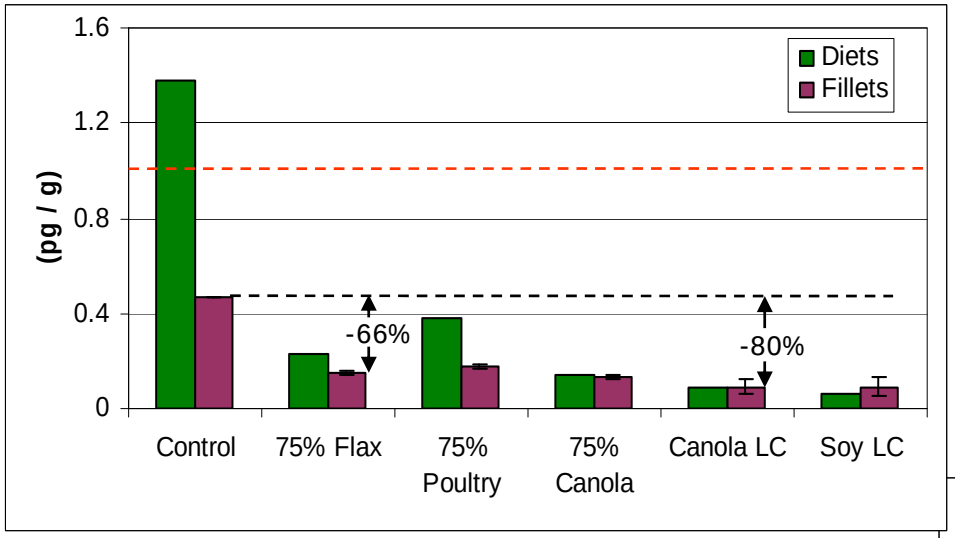
Growth rates & food conversion efficiency almost identical
(Friesen et al., submitted)



Integrated fish health
Metabolic rates & swimming performances are identical
(Wilson et al. in press, Aquaculture)

Fish fillet composition reflects what was eaten

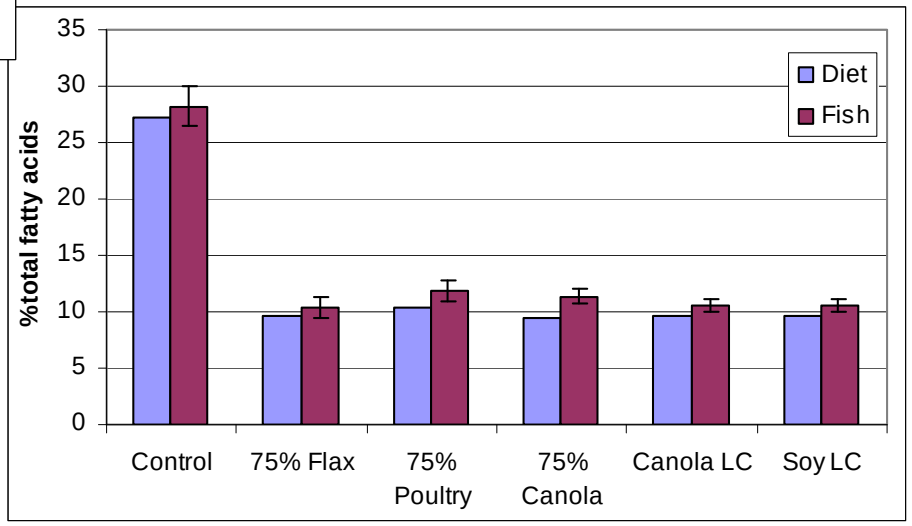
TEQ PCDD/F in diets & fish fillets



Contaminants in the fillet reduced to at least ~1/3rd of the MFO value, ie, about the same as wild BC salmon

Uptake efficiency of contaminants varies with diets

EPA+DHA in diets & fish fillets



EPA+DHA in the fillet reduced to ~1/3rd of the MFO value

Friesen et al., unpublished

Finishing diets to improve HUFA levels

Phase II diet: Restore 100% anchovy oil for 12 weeks

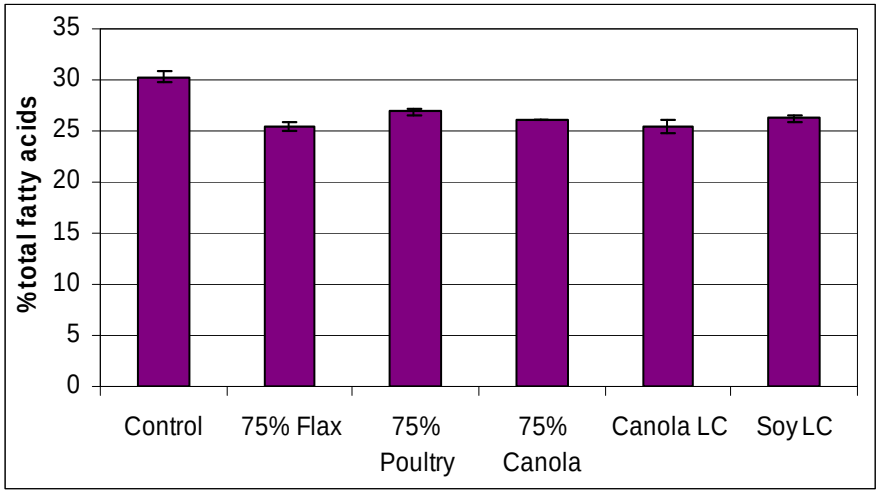
PROTEIN	LIPID	
Fish Meal	Anchovy Oil (AO)	Control
Fish Meal	Anchovy Oil (AO)	75% FO
Fish Meal	Anchovy Oil (AO)	75% PF
Fish Meal	Anchovy Oil (AO)	75% CO
Fish Meal + Canola CM	Carbon Treated AO	Canola Low C
Fish Meal + Soy CM	Carbon Treated AO	Soy Low C

Net effect on dietary use of MFOs:

halved for this expt (maybe ¼ for a full production cycle)

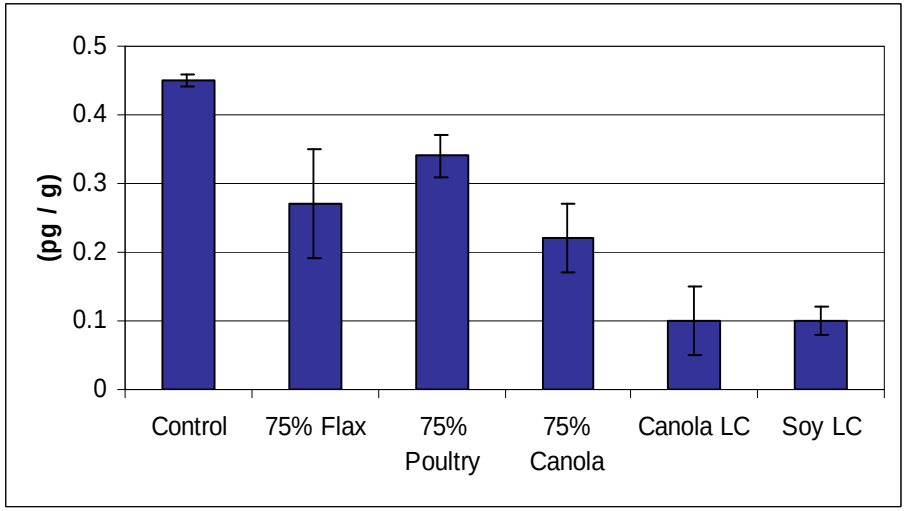
Finishing diets improve HUFA levels

EPA+DHA in diets & fish fillets



EPA+DHA in the fillet restored to 86% of the MFO value

TEQ PCDD/F in diets & fish fillets



Contaminants in the fillet still at least 60% of the MFO value, ie, similar to wild BC salmon & 7-18x lower than Hites et al.

Similar results emerging for feeding expts with sablefish

Friesen et al., unpublished

Fish welfare: live-hauling of adult salmon for processing

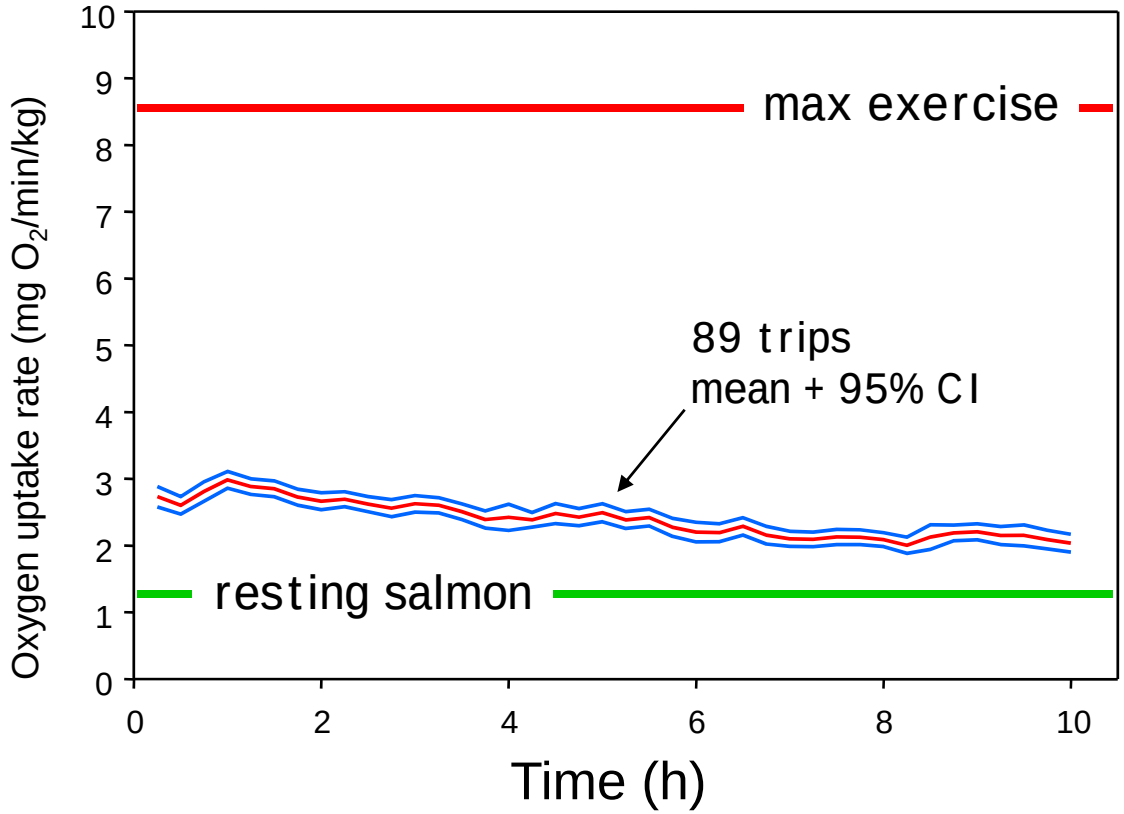
Good welfare = better product = economic value

- occurs year round in BC
- >60,000 kg fish per trip (~10,000 fish @ ~5 kg)
- >$300,000 per trip
- >3 million fish per year
- 2 to 12 h ocean journeys

Bulk respirometry

On-line O_2 & temperature electrodes

Adult salmon swim calmly during livehaul



Other studies:

- CO_2 build up of fillet pH & rigor
- Smolt welfare during transport

Farrell 1986, Aquaculture; Tang & Farrell, in prep.

Summary



24 potential cancer deaths vs 7,000 CHD-deaths prevented

1. BC-farmed [illegible] y safe to eat:

Close the door on contaminant issues

- 6 potential can[illegible] 2006, JAMA)

2. Seed-oils partially replacing marine fish oils can:

Quantify environmental benefits

- retain human[illegible]
- reduced PCD[illegible]
- 0.2-1 potent[illegible]
- greatly reduced dependence on wild fish for feeds

3. Fish welfare

Growing issue

"Only actions that reduce contaminants in the tissues of farmed salmon while maintaining elevated n-3 fatty acids will reduce the influence of contaminant-associated risk on the benefit-risk ratio, and only in that case will all farmed salmon become a highly desirable, low risk source of beneficial n-3 fatty acids." Foran et al. 2005

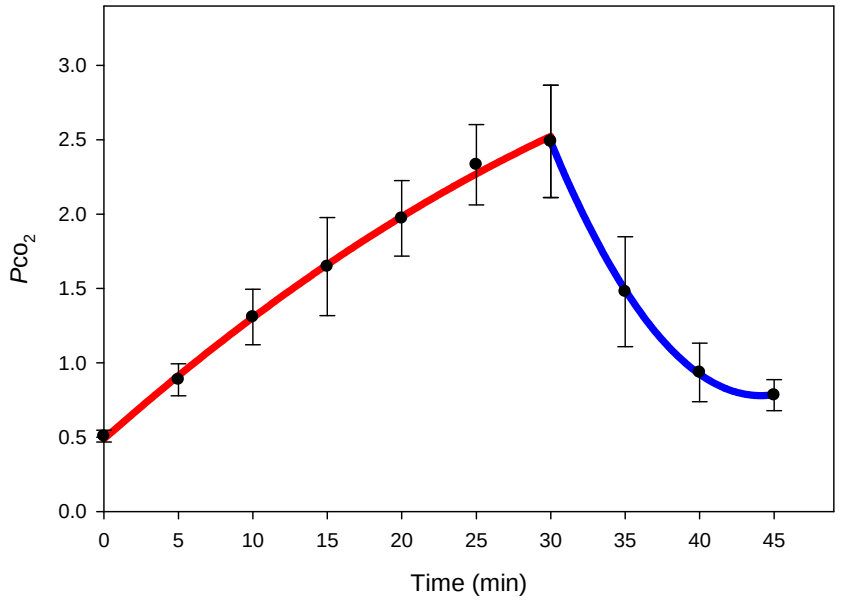


Fig. 1. Water Pco_2 during 30 min re-circulated transport followed by 15 min recovery (n=3, means ± SE).

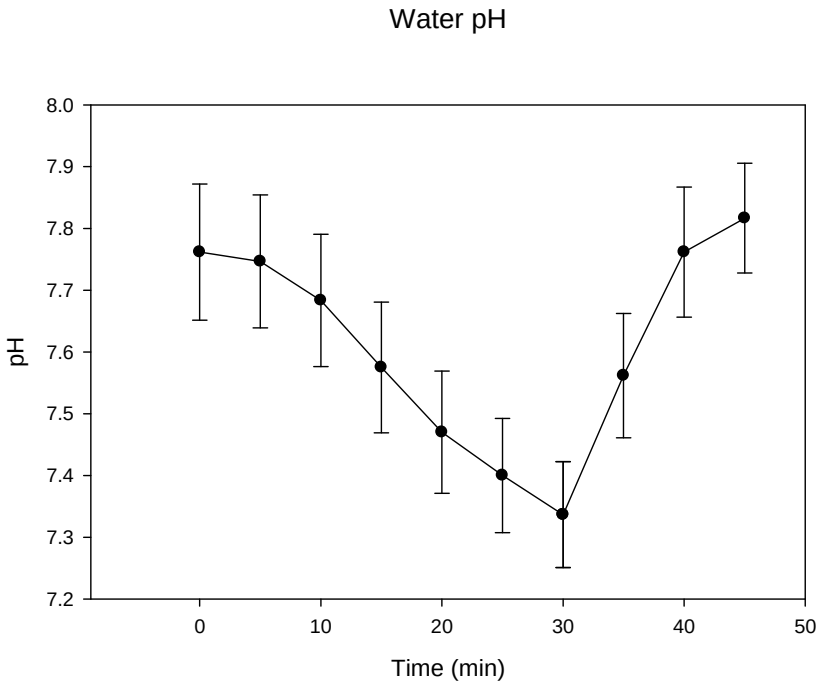


Fig. 2. Water pH during 30 min re-circulated transport followed by 15 min recovery (n=6, means ± SE).

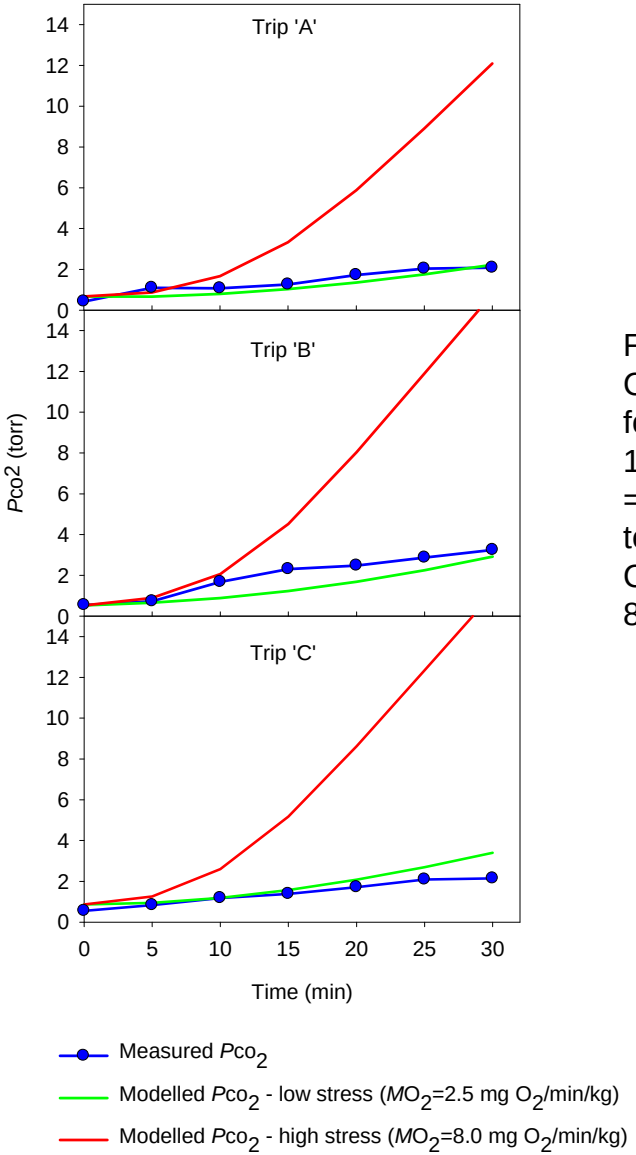
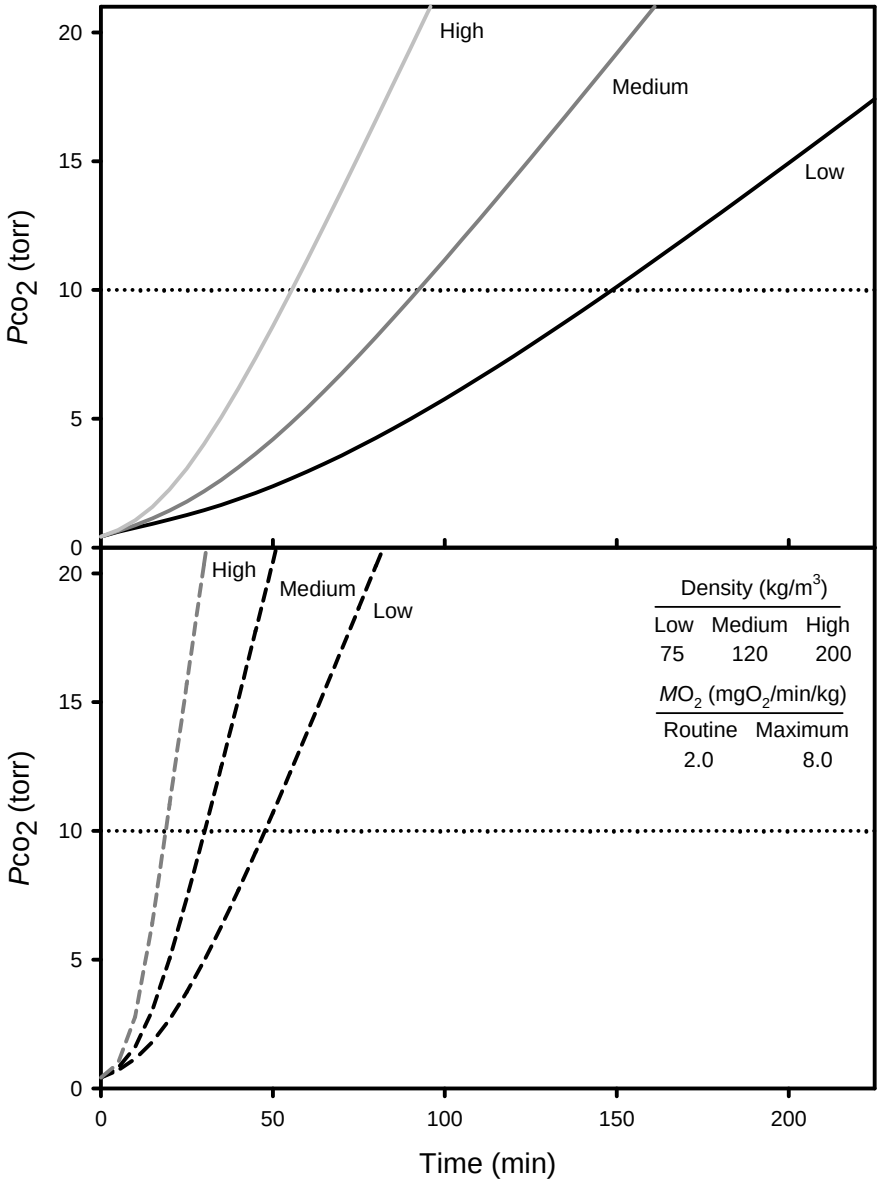


Figure 4. Com
CO2 levels an
for 3 individual
144 kg/m3, ter
= 7.63. Trip B:
temperature =
C: density = 1(
8.6 ºC, pH = 7



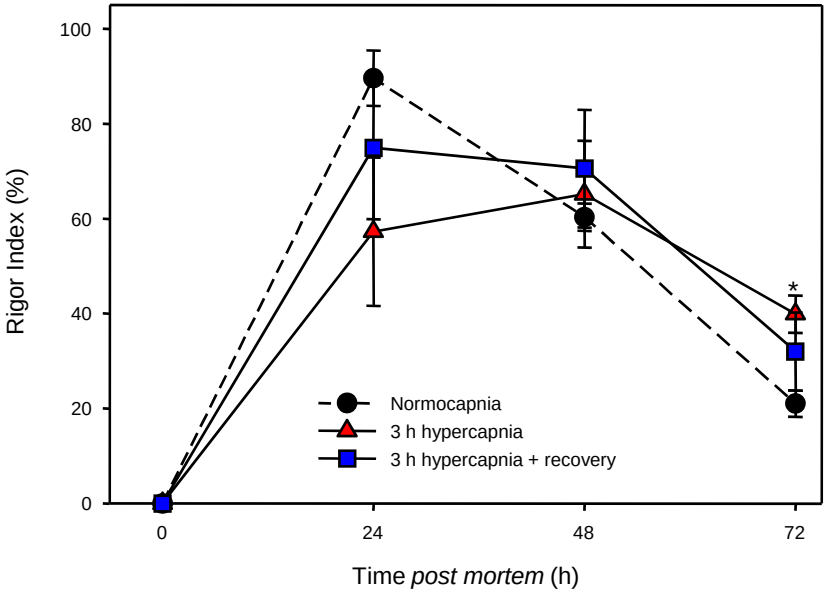


Fig. Y-1. Rigor progression in Atlantic salmon exposed to 10 torr hypercapnia for 3 h (n=7), 10 torr hypercapnia for 3 h followed by 24 h recovery period in normocapnic water (n=5) , and control treatment (normocapnia, n=5). Rigor index (RI) is measured as percent change from time 0. Means ± SEM, means significantly different from control means are indicated with an * ($p<0.05$), recovery treatment means significantly different from hypercapnia means are indicated with an † ($p<0.05$).

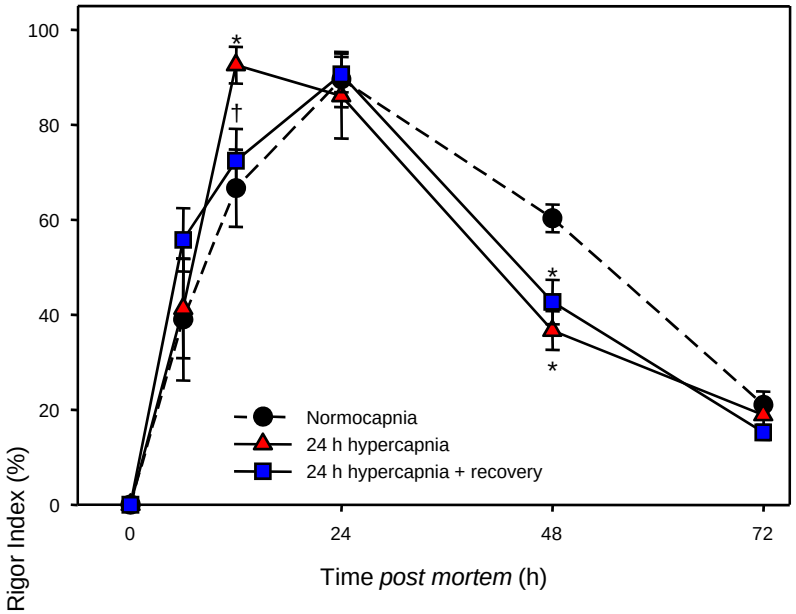
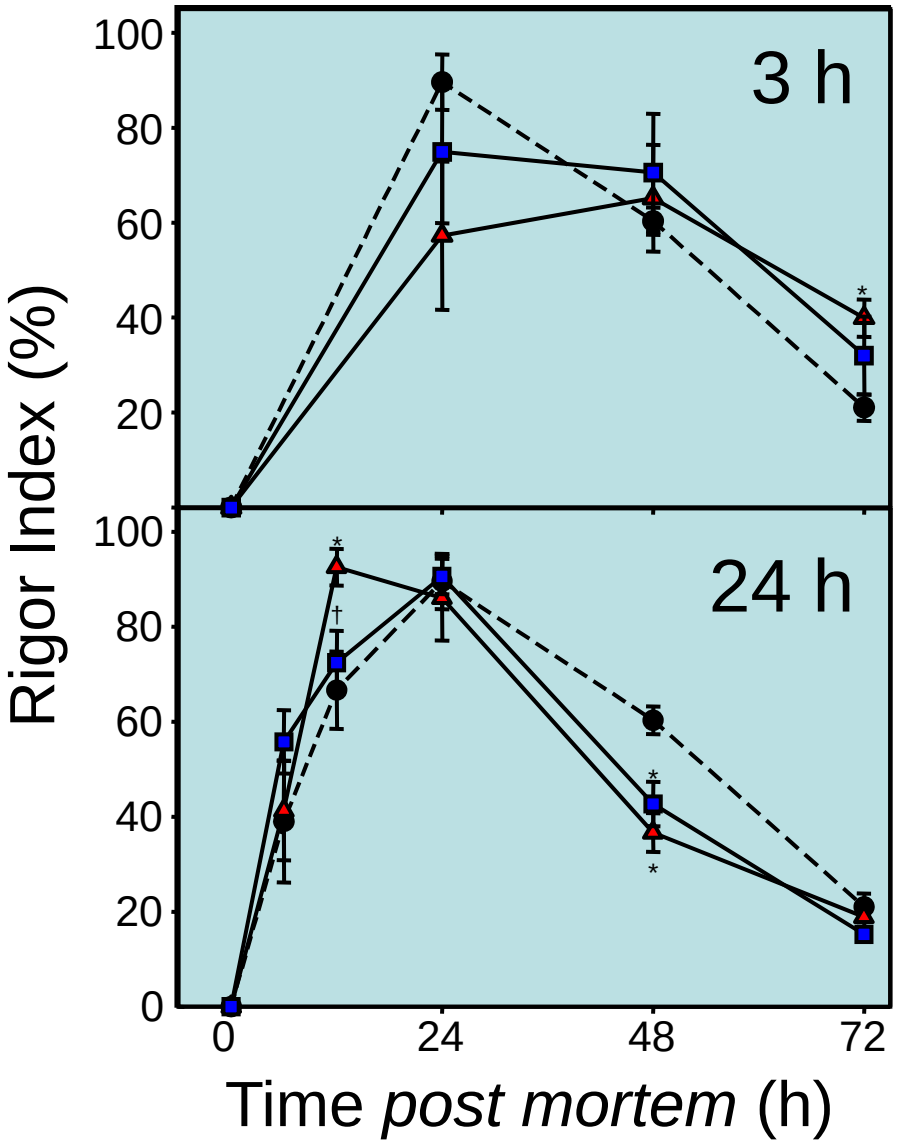


Fig. Y-2. Rigor progression in Atlantic salmon exposed to 10 torr hypercapnia for 24 h (n=5), 10 torr hypercapnia for 24 h followed by 24 h recovery period in normocapnic water (n=6) , and control treatment (normocapnia, n=5). Rigor index (RI) is measured as percent change from time 0. Means ± SEM, means significantly different from control means are indicated with an * ($p<0.05$), recovery treatment means significantly different from hypercapnia means are indicated with an † ($p<0.05$).

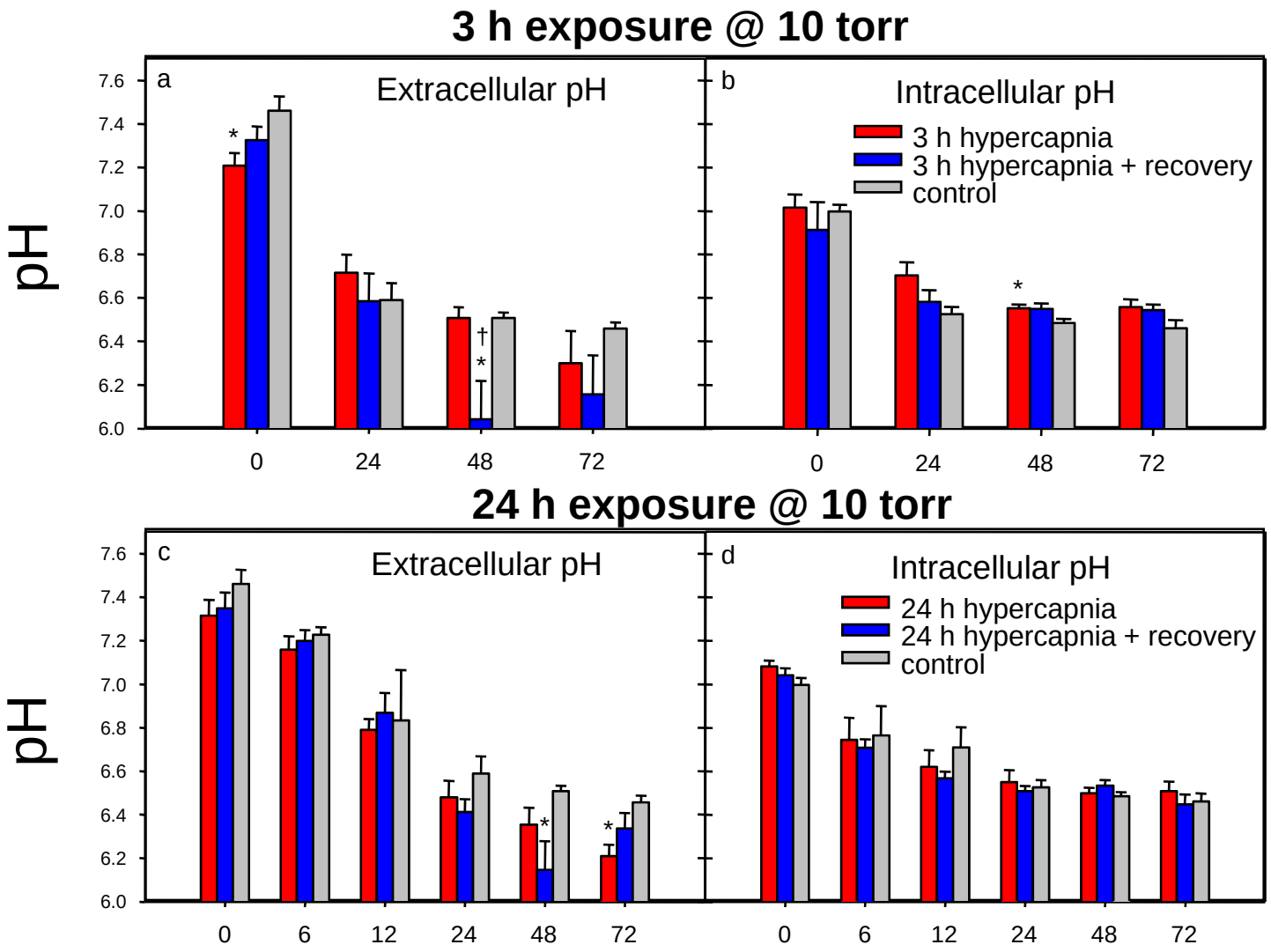
10 torr Pco_2 vs. *rigor mortis*



O h

24 h

10 torr Pco_2 vs. muscle pH



Surface plot of loading density vs. MO_2 over time

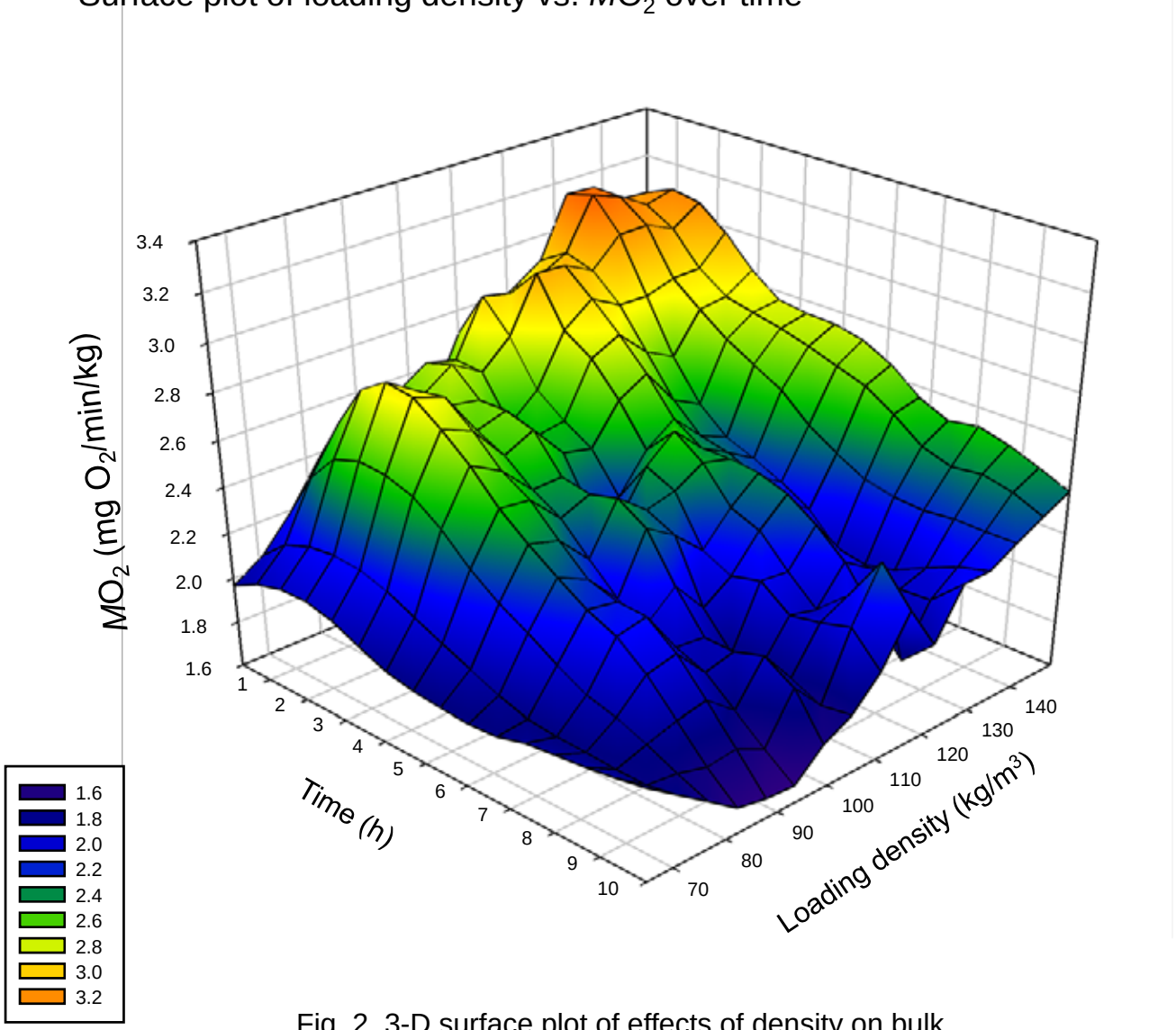


Fig. 2. 3-D surface plot of effects of density on bulk MO_2 during transport (n=89, Loess smoothing)

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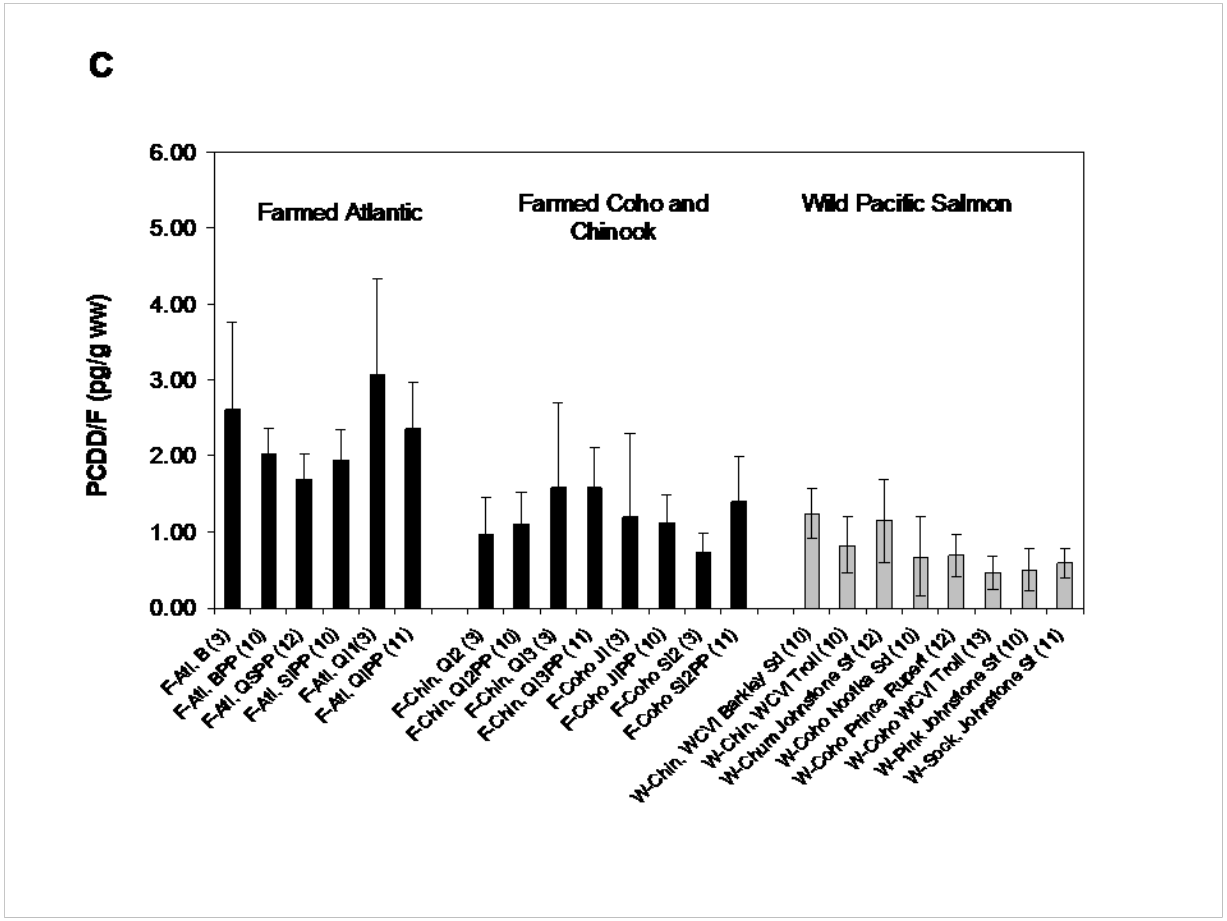
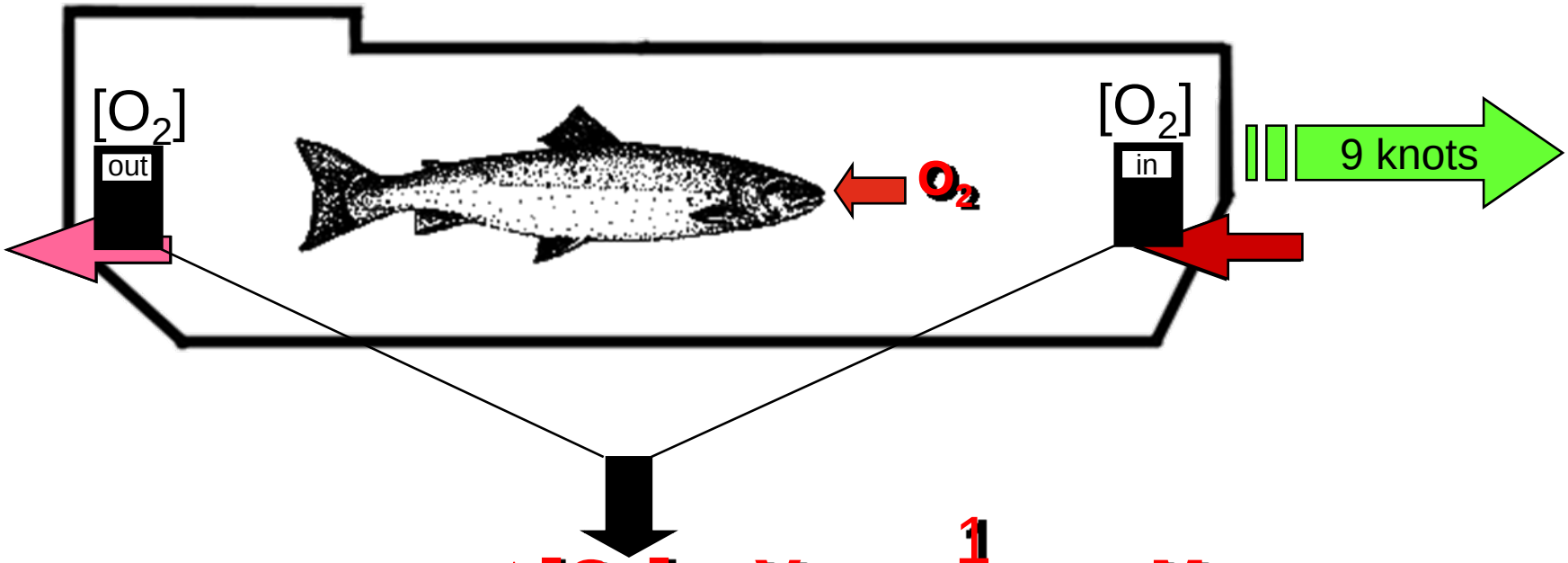


Bulk respirometry

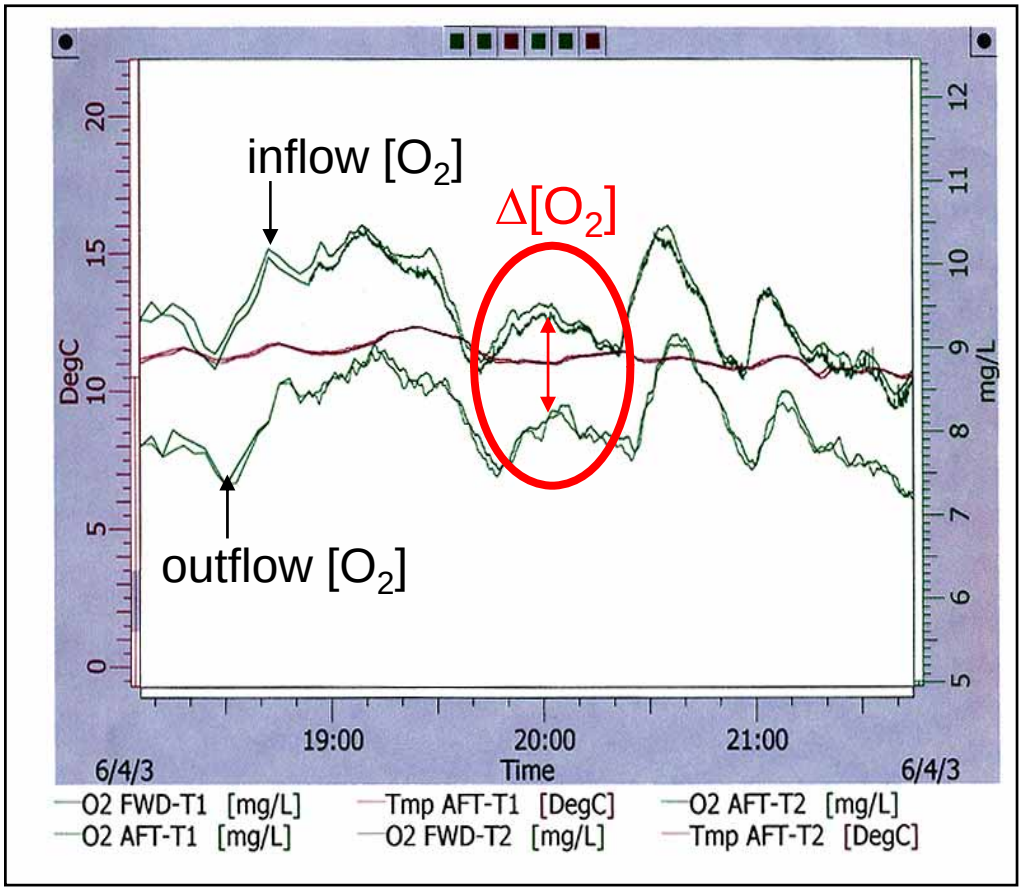
Sterling Carrier is equipped for on-line monitoring of inflow & outflow [O_2] in both fish holds



$$\Delta[O_2] \times V \times \frac{1}{mass} = Mo_{2(bulk)}$$

Water flow rate = ~40 m^3/min/hold

Assessing fish welfare with bulk respirometry



Load = 62,000 kg of salmon