Fiskens mestringsevne for eksponerte forhold

Ole Folkedal, Malthe Hvas og Frode Oppedal

Oppstart 2015: Kan laksen gå mer eksponert?

- ***Svømmekapasitet****?*
- *Hva med* ***bølger****?*
- *Hvordan* ***måle laksens mestringsevner****?*
    - Fysiologi og atferd: I lab og merder

Etter hvert andre spørsmål:

- *Hva med rensefisken?*
- *Påvirker fasting/sulting mestringsevnen?*
- *Merdstørrelse?*

Oversikt

Publikasjoner og rapporter. Side 1.

Remen, M., Solstorm, F., Bui, S., Klebert, P., Vågseth, T., Solstorm, D., Hvas, M., Oppedal, F., 2016. *Critical swimming speed in groups of Atlantic salmon Salmo salar*. Aquaculture Environment Interactions 8, 659-664

Hvas, M., Folkedal, O., Solstorm, D., Vågseth, T., Fosse, J.O., Gansel, L.C., Oppedal, F., 2017. *Assessing swimming capacity and schooling behaviour in farmed Atlantic salmon Salmo salar with experimental push-cages*. Aquaculture. 473, 423-429.

Hvas, M., Folkedal, O., Imsland, A., Oppedal, F. 2017. *The effect of thermal acclimation on aerobic scope and critical swimming speed in Atlantic salmon* (*Salmo salar* L.). J. Exp. Biol. 220, 2757-2764

Hvas, M., Oppedal, O. 2017. *Sustained swimming capacity of Atlantic salmon.* Aquacult. Env. Interact. 9, 361-369.

Hvas M, Karlsbakk E, Mæhle S, Wright, D., Oppedal, F. 2017. *The gill parasite Paramoeba perurans compromises aerobic scope, swimming capacity and ion balance in Atlantic salmon.* Conservation Physiology 5. 10.1093/conphys/cox066

Hvas, M., Folkedal, O., Imsland, A., Oppedal, F. 2018. *Metabolic rates, swimming capabilities, thermal niche and stress response of the lumpfish, Cyclopterus lumpus.* Biology Open, 7, DOI: 10.1242/bio.036079

Hvas, M., Nilsen, T.O., Oppedal., F. 2018. *Oxygen Uptake and Osmotic Balance of Atlantic Salmon in Relation to Exercise and Salinity Acclimation.* Frontiers in Marine Science, 5, DOI: 10.3389/fmars.2018.00368

Jonsdottir, K. E., Hvas, M., Alfredsen., J. A., Føre, M., Alver, M. O., Bjelland, H., Oppedal, F. 2019. *Fish welfare based classification method of ocean current speeds at aquaculture sites*. Aquacult. Env. Interact.

Yuen, J.W., Dempster, T., Oppedal, F. & Hvas, M. (2019). *Physiological performance of ballan wrasse (Labrus bergylta) at different temperatures and its implication for cleaner fish usage in salmon aquaculture*. Biological Control 135, 117–123.

Oldham, T., Nowak, B. F., Hvas, M., Oppedal., F. 2019. *Metabolic and functional impacts of hypoxia vary with size in Atlantic salmon*. Comp. Biochem. Physiol. Part A. 231.

Hvas, M., Oppedal, F. 2019. *Influence of experimental set-up and methodology for measurements of metabolic rates and critical swimming speed in Atlantic salmon Salmo salar.* Journal of Fish Biology 95, 893–902.

Hvas, M., Oppedal, F. 2019. *Physiological responses of farmed Atlantic salmon and two cohabitant species of cleaner fish to progressive hypoxia*. Aquaculture. 512 734353.

Hassan, Waseem; Føre, Martin; Urke, Henning Andre; Kristensen, Torstein; Ulvund, John Birger; Alfredsen, Jo Arve. 2019. *System for Real-Time Positioning and Monitoring of Fish in Commercial Marine Farms Based on Acoustic Telemetry and Internet of Fish (IoF)*. The 29th International Ocean and Polar Engineering Conference.

Hassan, Waseem; Føre, Martin; Ulvund, John Birger; Alfredsen, Jo Arve. 2019. *Internet of Fish: Integration of acoustic telemetry with LPWAN for efficient real-time monitoring of fish in marine farms*. Computers and Electronics in Agriculture. vol. 163 104850.

Hassan, Waseem; Føre, Martin; Pedersen, Magnus Oshaug; Alfredsen, Jo Arve. 2019. *A Novel Doppler Based Speed Measurement Technique for Individual Free-Ranging Fish*. The 18th IEEE Sensors.

Hvas, M., Folkedal, O., Oppedal, F. 2019. *Havbasert oppdrett – Hvor mye vannstrøm tåler laks og rensefisk?*. Rapport fra Havforskningen. 2019. ISSN: 1893-4536.

Hvas, M., Folkedal, O., Oppedal. 2020. *Heart rates of Atlantic salmon Salmo salar during a critical swim speed test and subsequent recovery*. J. Fish Biol.

Hvas, M., Folkedal, O., Oppedal. 2020. *Fish welfare in offshore salmon aquaculture*. Reviews in Aquaculture.

Hvas et al. 2020. *The metabolic rate response to feed withdrawal in Atlantic salmon post-smolts*. Aquaculture, 529.

Hvas, M., Folkedal, O., Oppedal, F. 2020. *Heart rate bio-loggers as welfare indicators in Atlantic salmon (Salmo salar) aquaculture*. Aquaculture, 529.

Hvas, M., Stien, L.H., Oppedal, F. 2020. *The metabolic rate response to feed withdrawal in Atlantic salmon post-smolts*. Aquaculture, 529.

Johannesen, A., Patursson, Ø., Kristmundsson, J., Dam, S. P., Klebert, P. 2020. *How caged salmon respond to waves depends on time of day and currents*. PeerJ, 8.

Måløy, H. 2020. *EchoBERT: A Transformer-Based Approach for Behavior Detection in Echograms*. IEEE Access. 0.1109/ACCESS.2020.3042337

Hassan, W., Føre, M., Pedersen, M. O., Alfredsen, J. O. 2020. *A new method for measuring free-ranging fish swimming speed in commercial marine farms using Doppler principle*. IEEE Sensors Journal.

Oversikt

Publikasjoner og rapporter. Side 2

Hvas, M., Folkedal, O., Oppedal, F. 2021. *What is the limit of sustained swimming in Atlantic salmon post smolts?* Aquacult. Env. Interact.

Hvas, M., Stien, L.H., Oppedal, F. 2021. *The effect of fasting period on swimming performance, blood parameters and stress recovery in Atlantic salmon post smolts.* Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 255.

Risholm, P., Mohammed, A., Kirkhus, T., Clausen, S., Vasilyev, L., Folkedal, O., Johnsen, Ø., Haugholt, K. H., Thieleman, J. 2021. Automatic length estimation of free-swimming fish using an underwater 3D range-gated camera. Aquacult. Eng. https://doi.org/10.1016/j.aquaeng.2022.102227

Føre, M., Svendsen, E., Økland, F., Gräns, A., Alfredsen, J. A., Finstad, B., Hedger, R. D., Uglem, I. 2021. Heart rate and swimming activity as indicators of post-surgical recovery time of Atlantic salmon (*Salmo salar*). Anim Biotelemetry **9,** 3. https://doi.org/10.1186/s40317-020-00226-8

Warren-Myers, F., Hvas, M., Vågseth, T., Dempster, T. Oppedal, O. (2021). Sentinels in salmon aquaculture: Heart rates across seasons and during crowding events. Frontiers in Physiology 12, 755659. https://doi.org/10.3389/fphys.2021.755659

McIntosh, P., Barrett, L. T., Warren-Myers, F., Coates, A., Macaulay, G., Szetey, A., Robinson, N, White, C., Samsing, F., Oppedal, F., Folkedal, O., Klebert, P., Dempster, T. 2022. *Supersizing salmon farms in the coastal zone: A global analysis of changes in farm technology and location from 2005 to 2020*. Aquaculture. 553.

Hvas, M., Nilsson, J., Vågseth, T., Nola, V., Fjelldal, P.G., Hansen, T.J., Oppedal, F., Stien, L.H., Folkedal, O. 2022. *Full compensatory growth before harvest and no impact on fish welfare in Atlantic salmon after an 8-week fasting period*. Aquaculture, 546.

Johannesen Á, Patursson Ø, Kristmundsson J, Dam SP, Mulelid M, Klebert P (2022) *Waves and currents decrease the available space in a salmon cage*. PLoS ONE 17(2):e0263850.

Hvas, M. 2022. Influence of photoperiod and protocol length on metabolic rate traits in ballan wrasse *Labrus bergylta*. Journal of Fish Biology, 1-10. https://doi.org/10.1111/jfb.14981

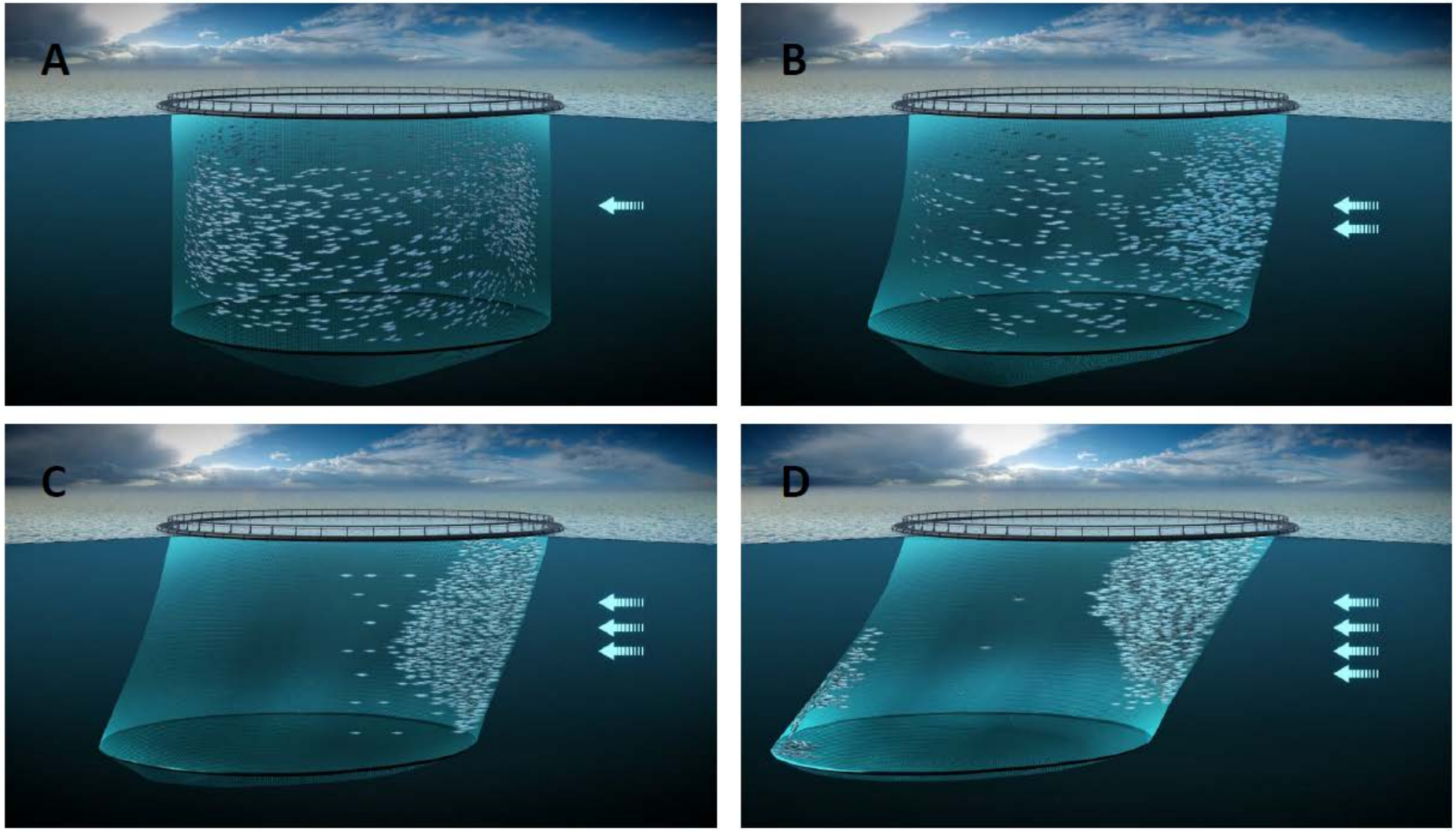
Hvas, M., Bui, S. 2022. Energetic costs of ectoparasite infection in Atlantic salmon. Journal of Experimental *Biology* 225(1), jeb243300. https://doi.org/10.1242/jeb.243300

Hassan, W., Føre, M., Urke, H. A., Ulvund, J. B., Bendiksen, E., Alfredsen, J. A. 2022. New concept for measuring swimming speed of free-ranging fish using acoustic telemetry and Doppler analysis. Biosystems Engineering. https://pubag.nal.usda.gov/catalog/7785894

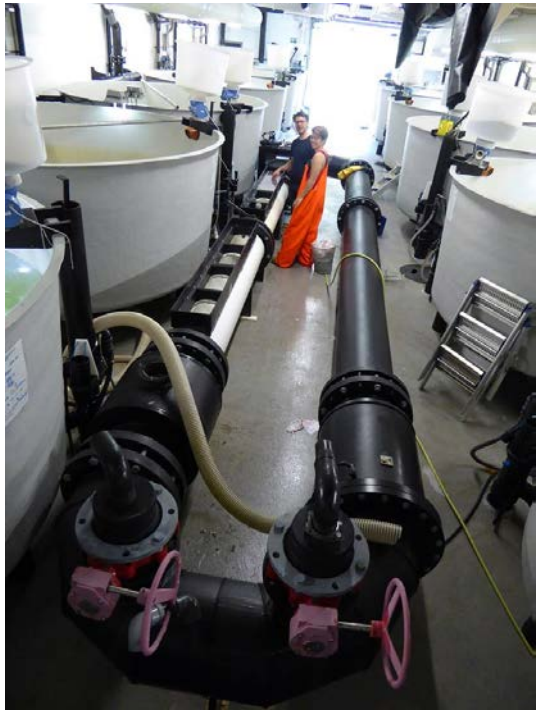
Hvas, M. 2022. Swimming energetics of Atlantic salmon in relation to extended fasting at different temperatures. Conservation Physiology. 10.1093/conphys/coac037

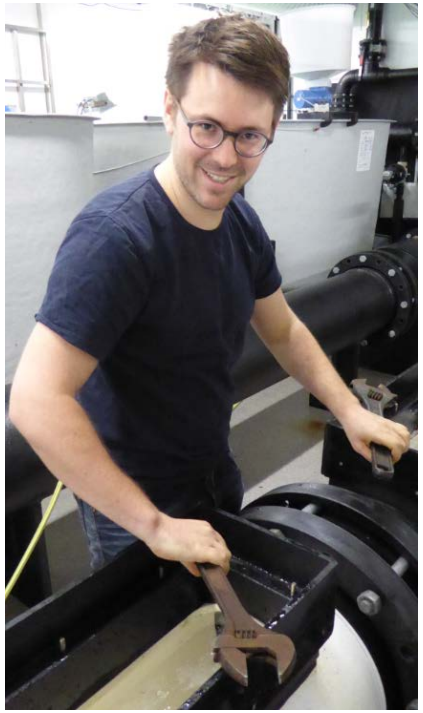
Kalananthan, T., Folkedal, O., Gomes, A. S., Lai, F., Handeland, S., Tolås, I., Gelebart, V., Rønnestad, I. 2023. Impact of long-term fasting on the stomach-hypothalamus appetite regulating genes in Atlantic salmon postsmolts. Aqauculture https://doi.org/10.1016/j.aquaculture.2022.738917

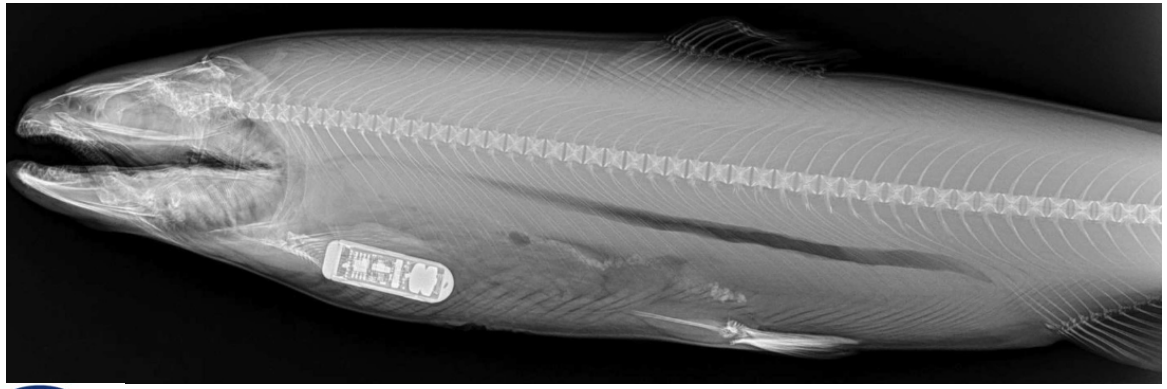
Hva gjør laksen ved høy vannstrøm?!



Hvas et al. 2020 Reviews in Aquaculture







HAVFORSKNINGS INSTITUTTET

EXPOSED

REVIEWS IN Aquaculture

Reviews in Aquaculture, 1–17 doi: 10.1111/raq.12501

Fish welfare in offshore salmon aquaculture

Malthe Hvas, Ole Folkedal and Frode Oppedal

Animal Welfare Research Group, Institute of Marine Research, Matre, Norway

Correspondence
Malthe Hvas, Animal Welfare Research Group, Institute of Marine Research, Matre 5, 5984 Matredal, Norway. Email: malthe.hvas@imr.no

Received 25 December 2019; accepted 18 August 2020.

Abstract

To accommodate further growth in the Atlantic salmon aquaculture industry, new production sites may well be established at more exposed locations along the coast or even offshore. Here, fish will encounter strong currents and powerful waves, which are avoided at traditional sheltered locations. Exposed locations offer several advantages and necessitate new technological advancements. However, the most crucial question is whether Atlantic salmon are able to thrive in

HAVBASERT OPPDRETT – HVOR MYE VANNSTRØM TÅLER LAKS OG RENSEFISK?

fiskevelferd og grenseverdier

Malthe Hvas, Ole Folkedal og Frode Oppedal (HI)

EXPOSED

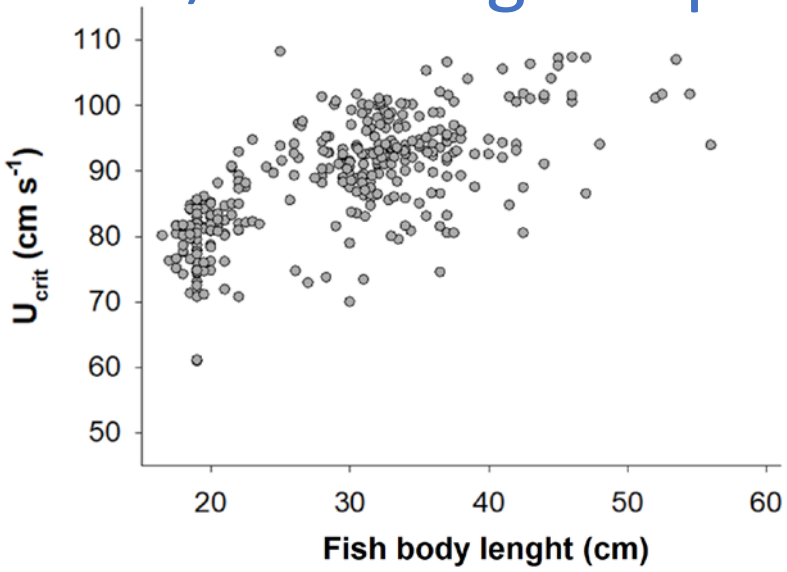
“Ulike” svømmekapasiteter hos laks, avhengig av stryke av vannstrøm og varighet, og ulike konsekvenser dersom grenseverdiene overstiges

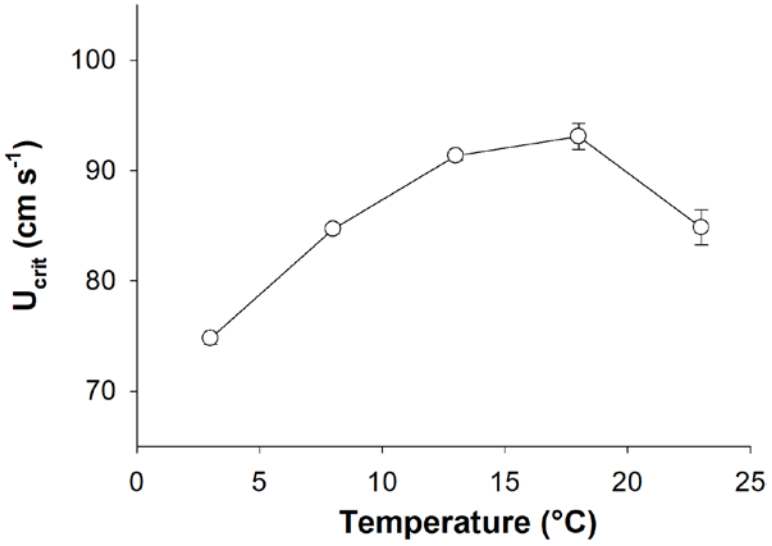
Welfare indicator	Speed	Duration	Consequence
U_{crit}	Extreme	Minutes	Fatigue, injuries, death
Sustained	High	Hours	Fatigue, injuries, death
Preferred	Moderate	Days / Weeks	Involuntary behaviour, reduced growth

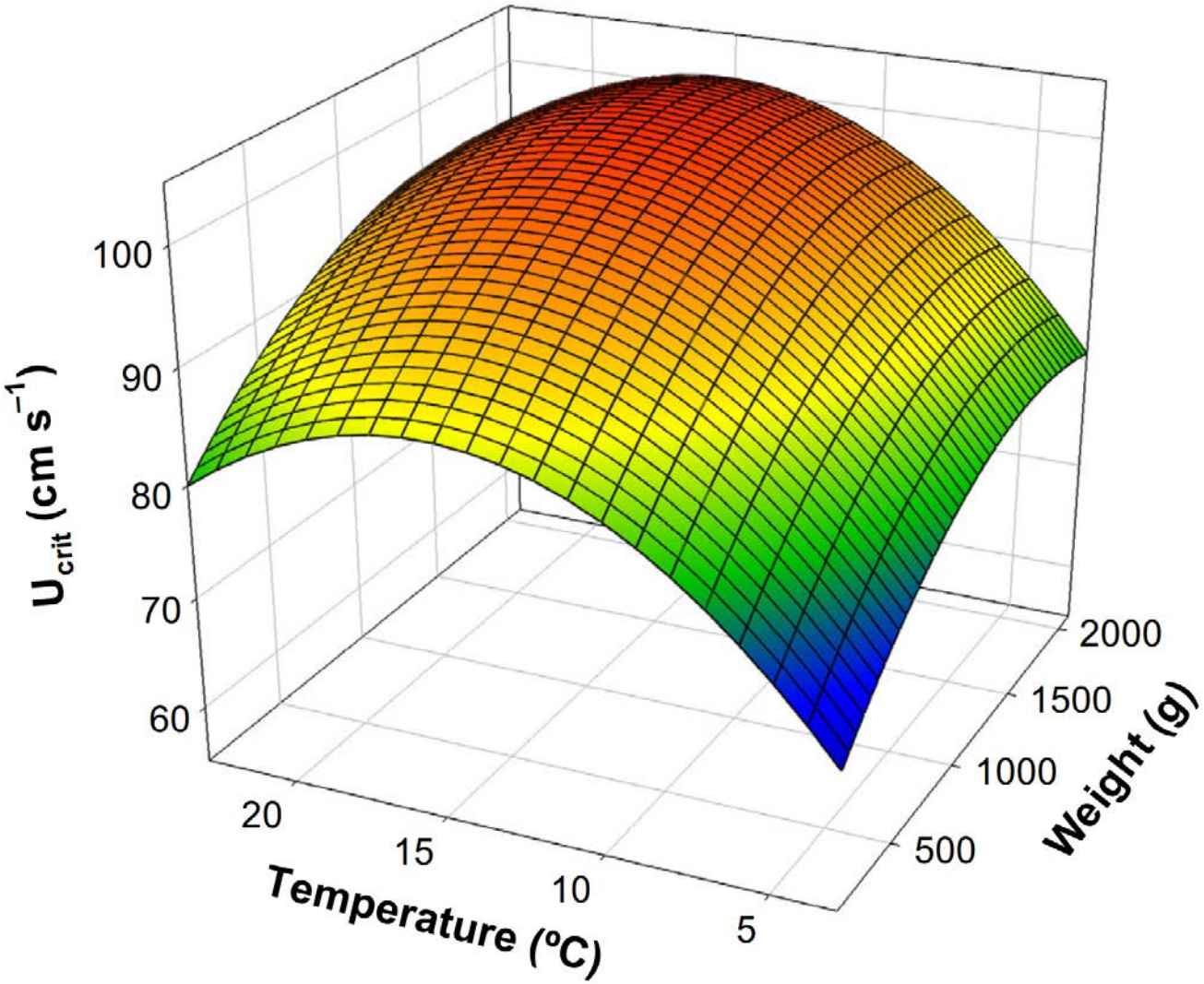
Hvas et al. 2020 Reviews in Aquaculture

Kritisk hastighet (akutt):

Fiskestørrelse og temperatur



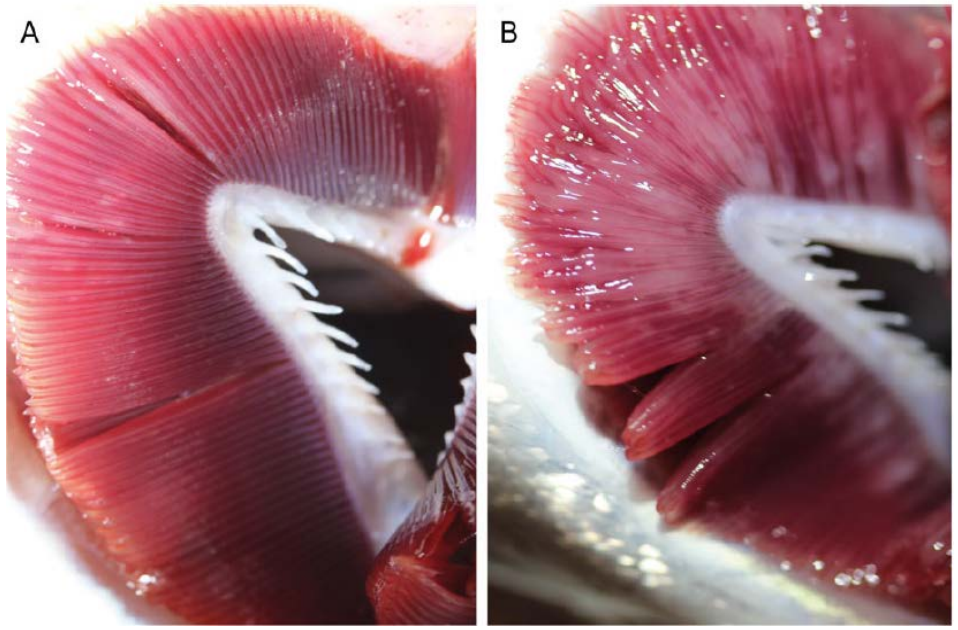




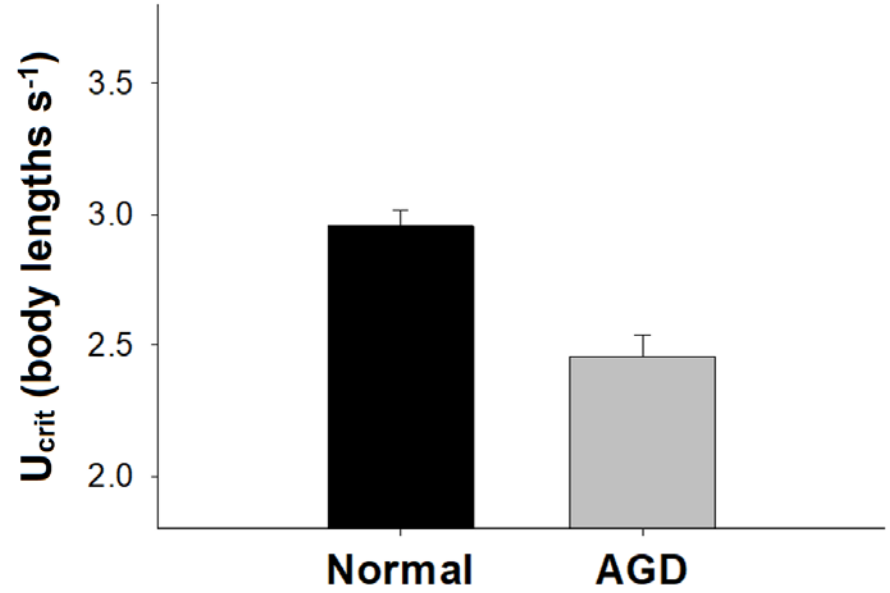
Modified from Remen et al., 2016; Hvas et al., 2016, 2017a, 2017b, 2017c, 2018a; Hvas and Oppedal, 2017

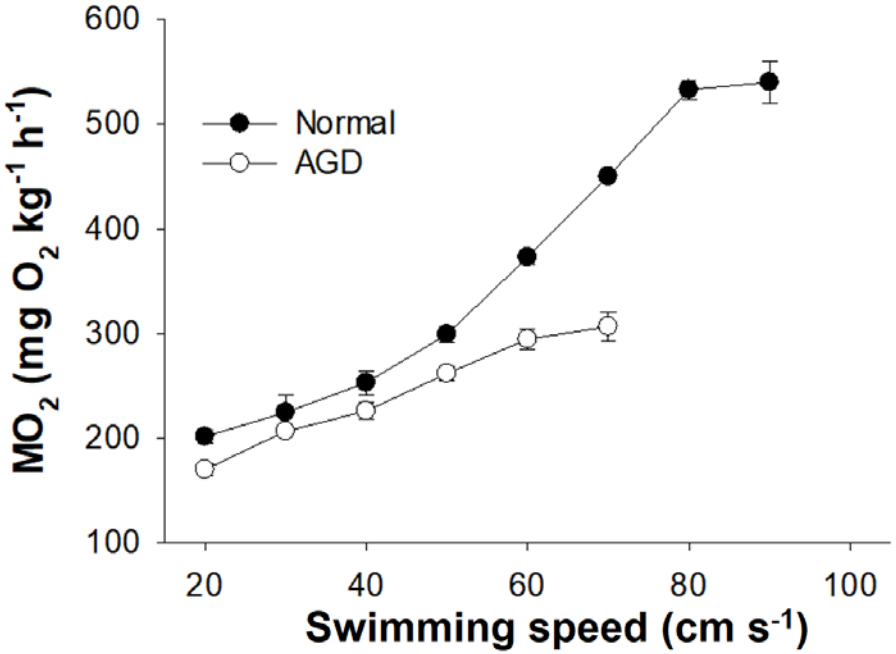
Hvas et al. 2020 Reviews in Aquaculture

Sykdom og parasitter



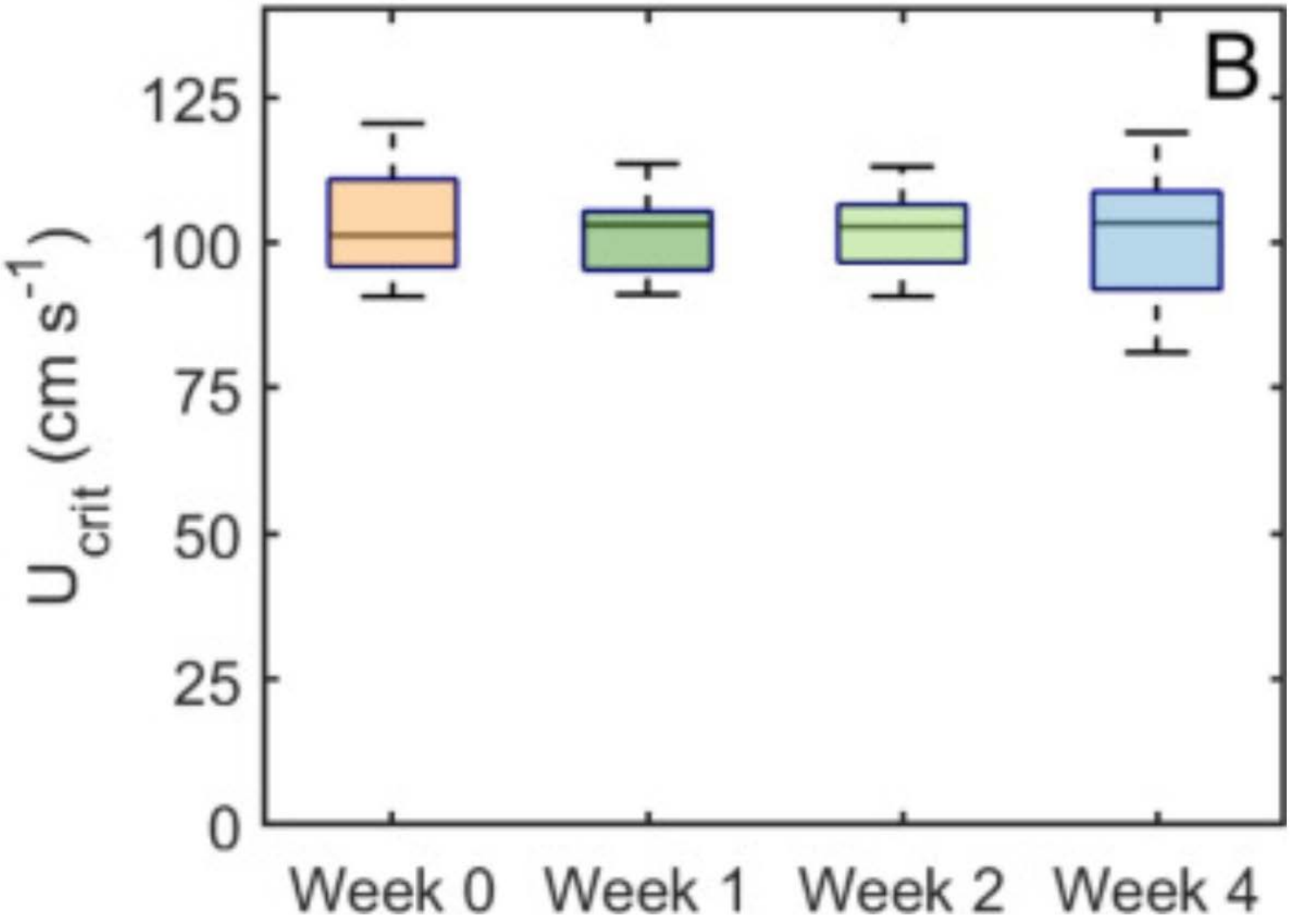
Normal AGD-score 5





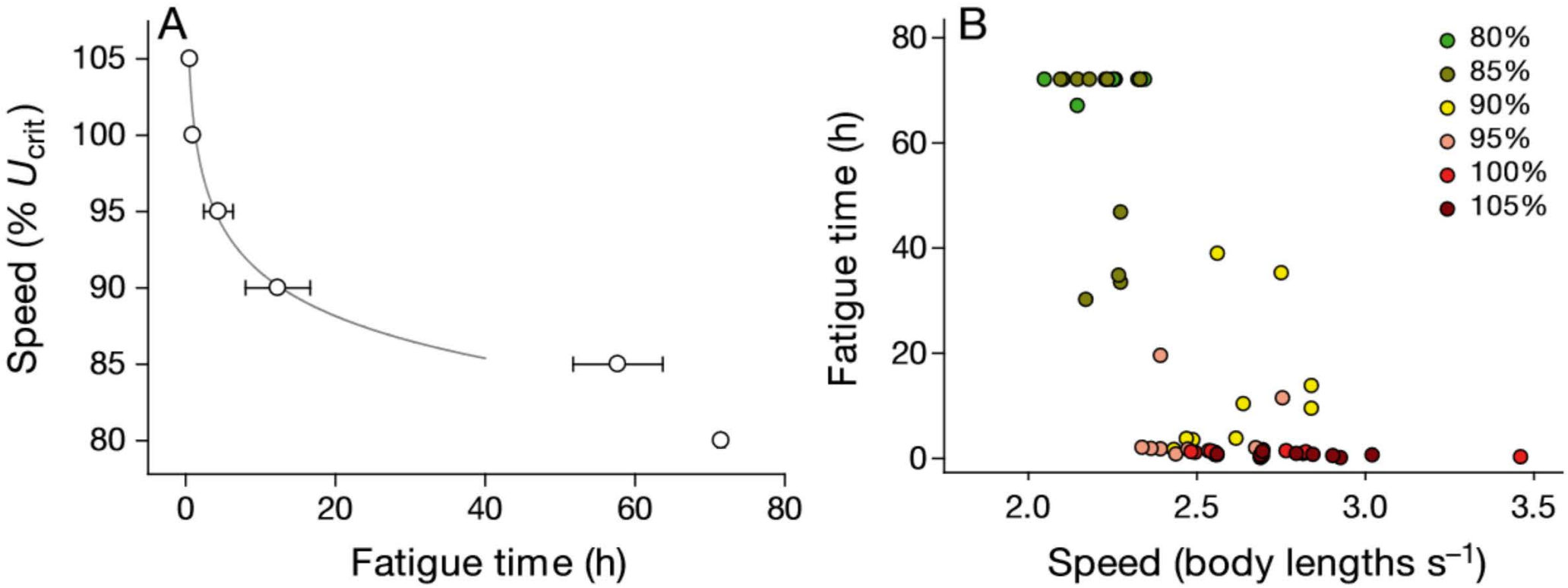
Modified from Hvas et al., 2017a

Fasting har ingen effekt!



Hvas et al., 2021

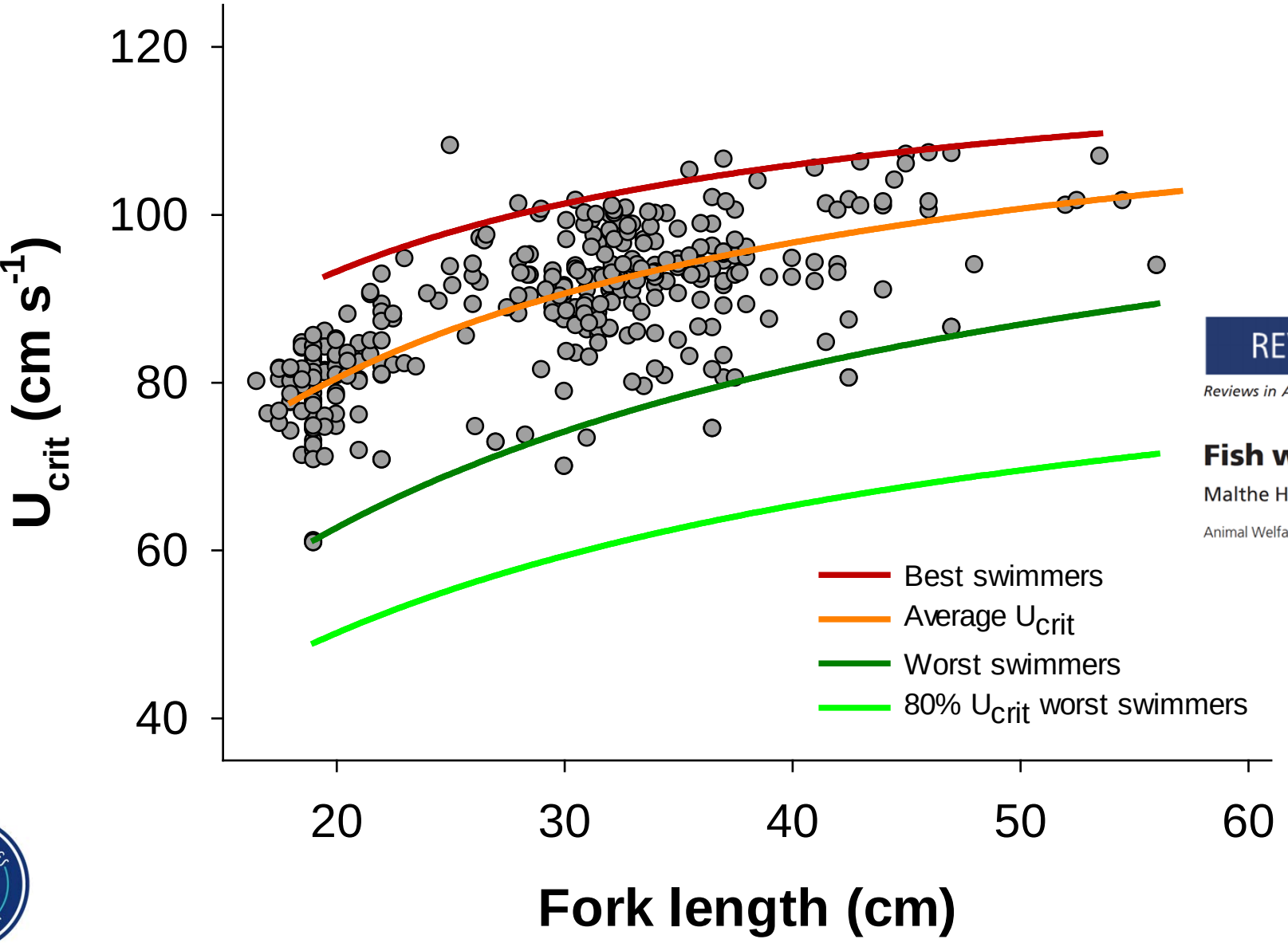
Vedvarende høy hastighet (timer til dager)



De fleste holdt ut >72 timer på 80 og 85% av gjennomsnittlig Ucrit (107 cm s^{-1}; 2.8 fiskelengder s^{-1})

Hvas et al., 2021b

Anbefalte grenseverdier gitt fiskestørrelse



REVIEWS IN Aquaculture

Reviews in Aquaculture, 1–17

Fish welfare in offshore salmon aquaculture

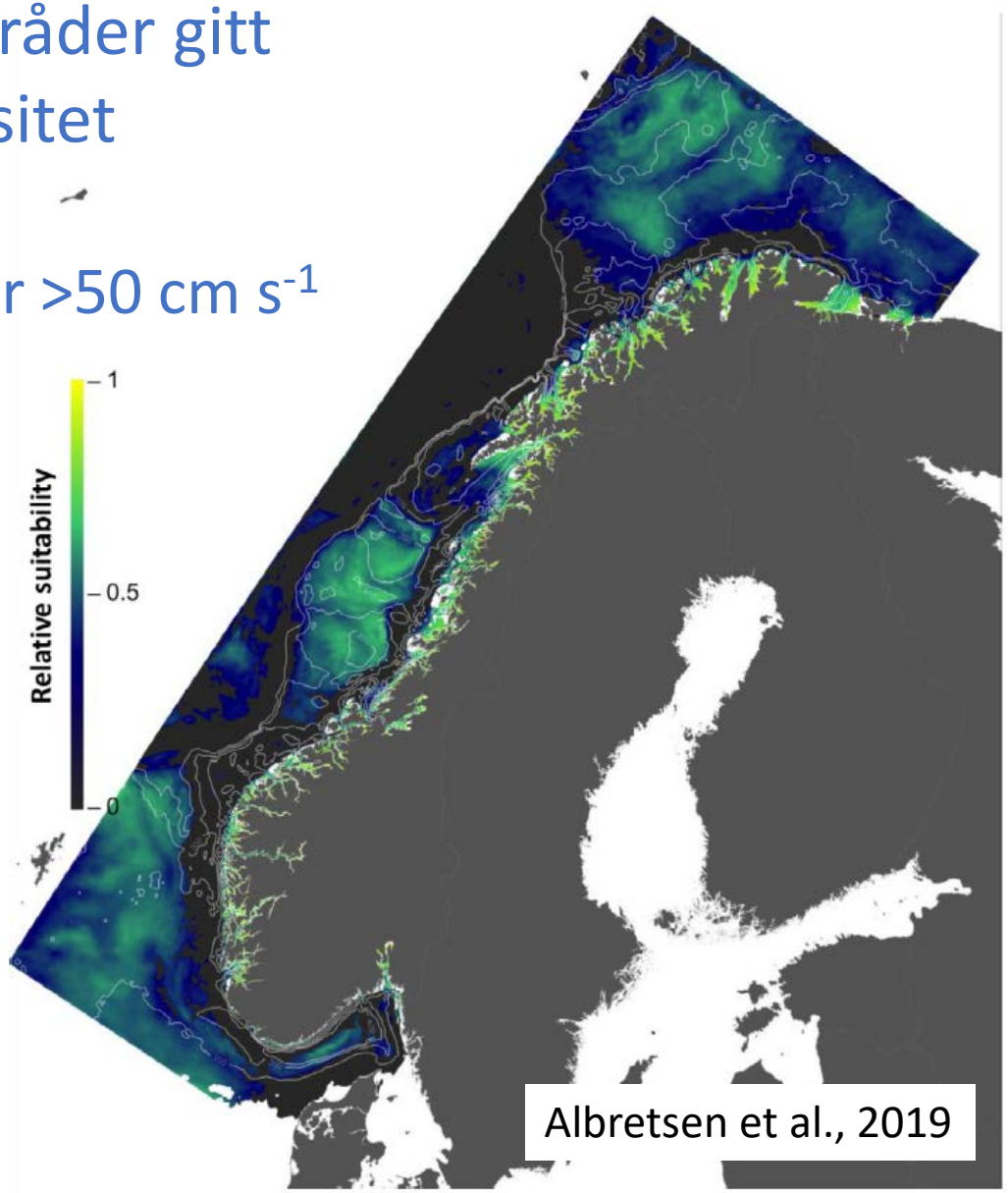
Malthe Hvas, Ole Folkedal and Frode Oppedal

Animal Welfare Research Group, Institute of Marine Research, Matre, Norway

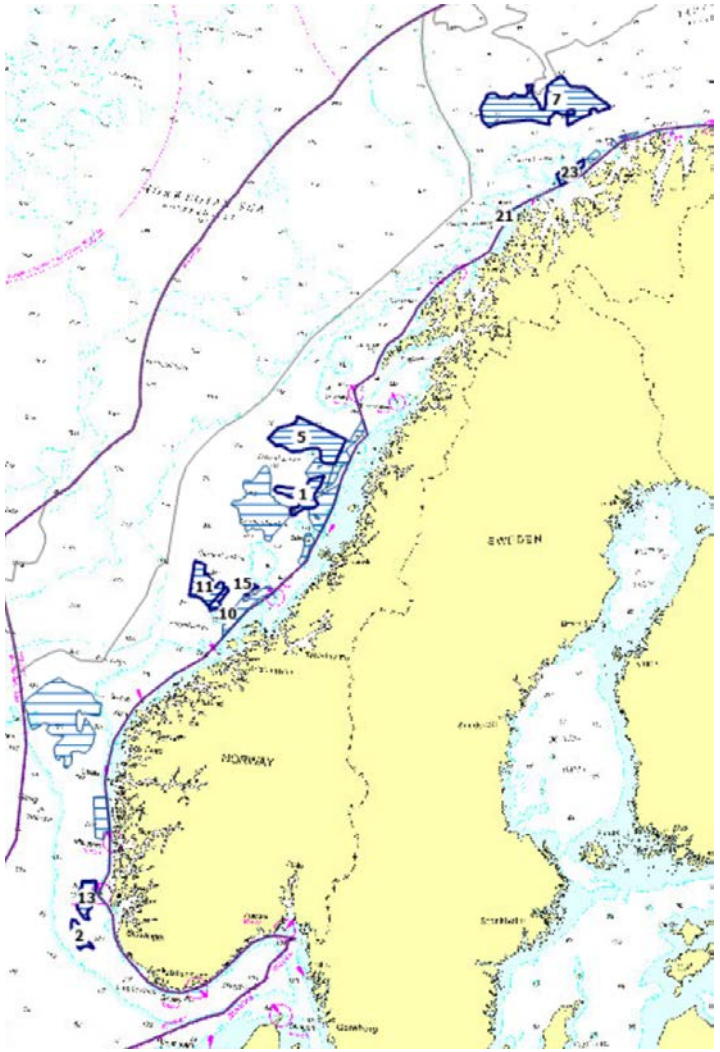
Hvas et al. 2021a Reviews in Aquaculture

Kartlegging av havområder gitt laksens svømmekapasitet

Sort areal representerer >50 cm s^{-1}



Albretsen et al., 2019



Hvas et al. 2020 Reviews in Aquaculture

Lokalitetsvurdering basert på svømmekapasitet

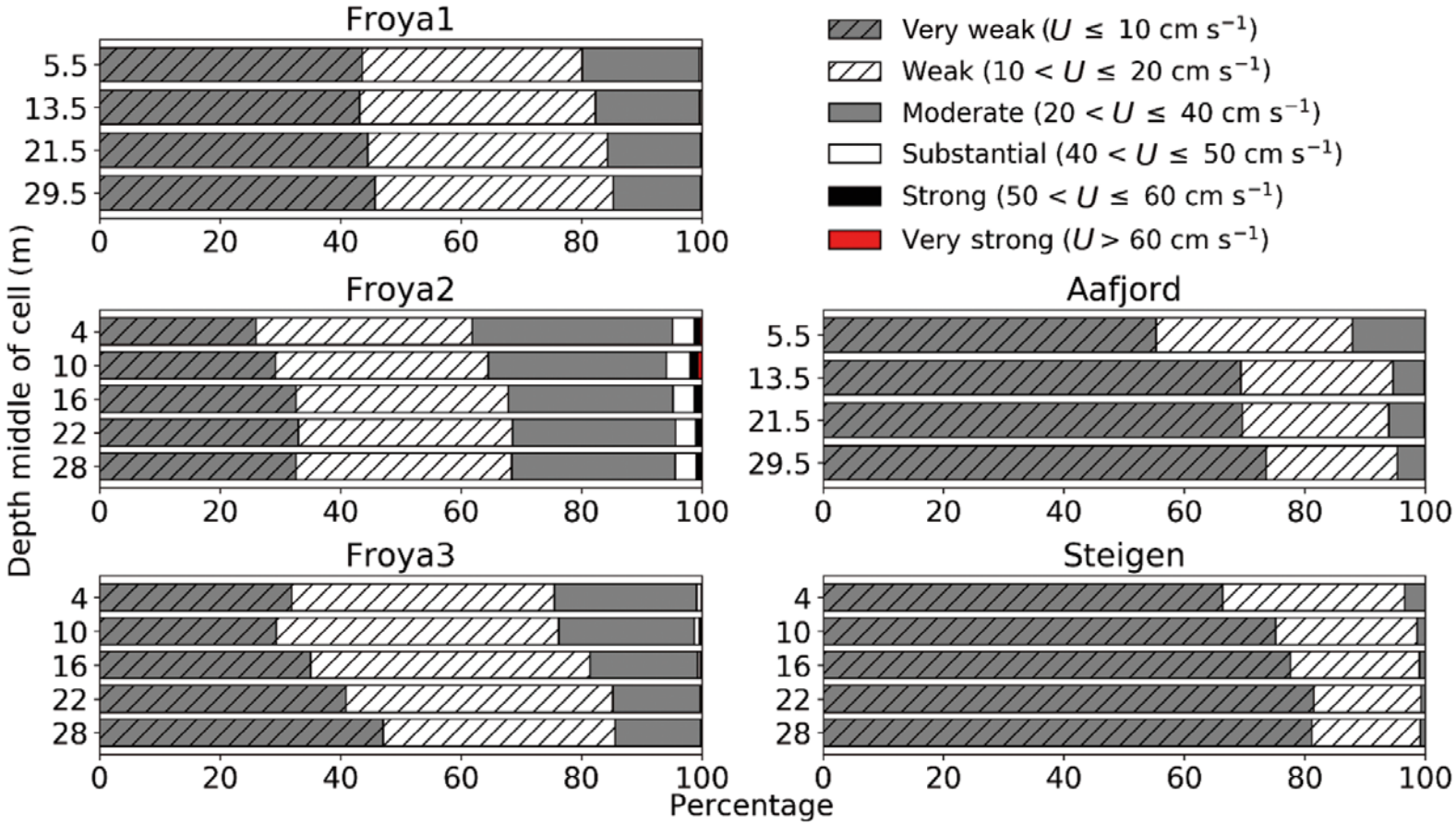
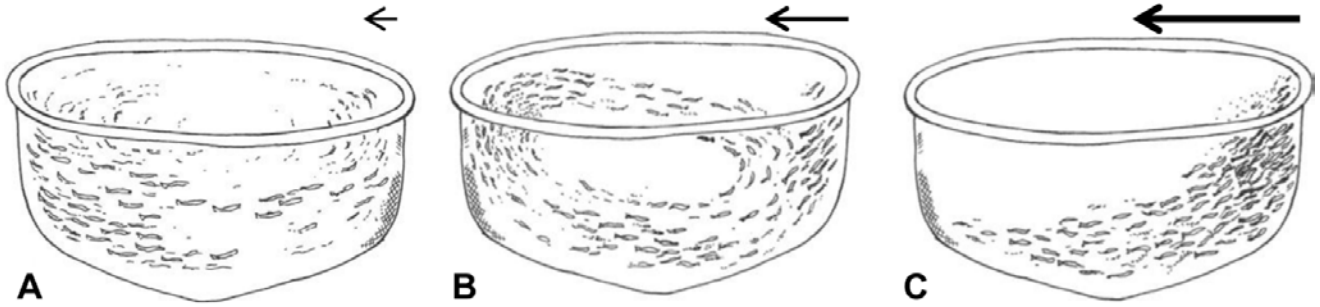


Fig. 4. Total distribution of current classes over the entire duration of deployment for selected depths at each location. U: current speed. See Fig. 1 for site locations

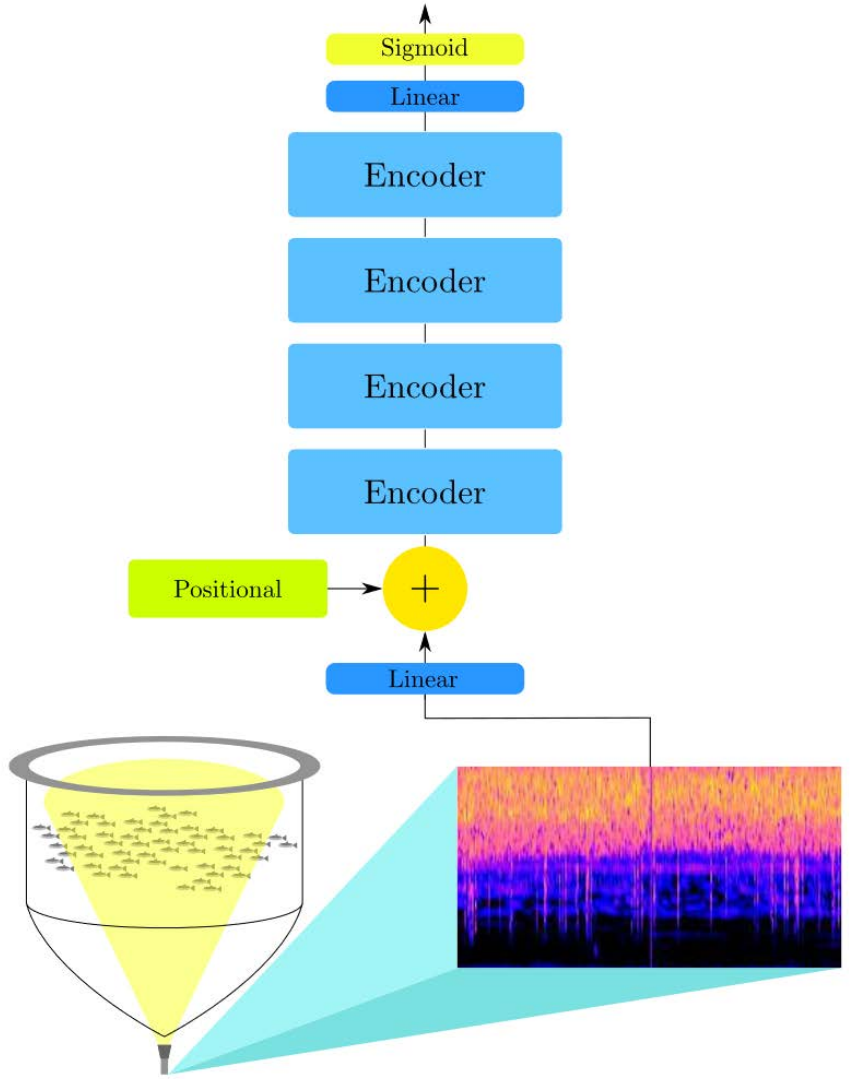
Jonsdottir et al., 2019

Velferdsindikatorer – Gruppeatferd

Visuell/kamera-observasjon



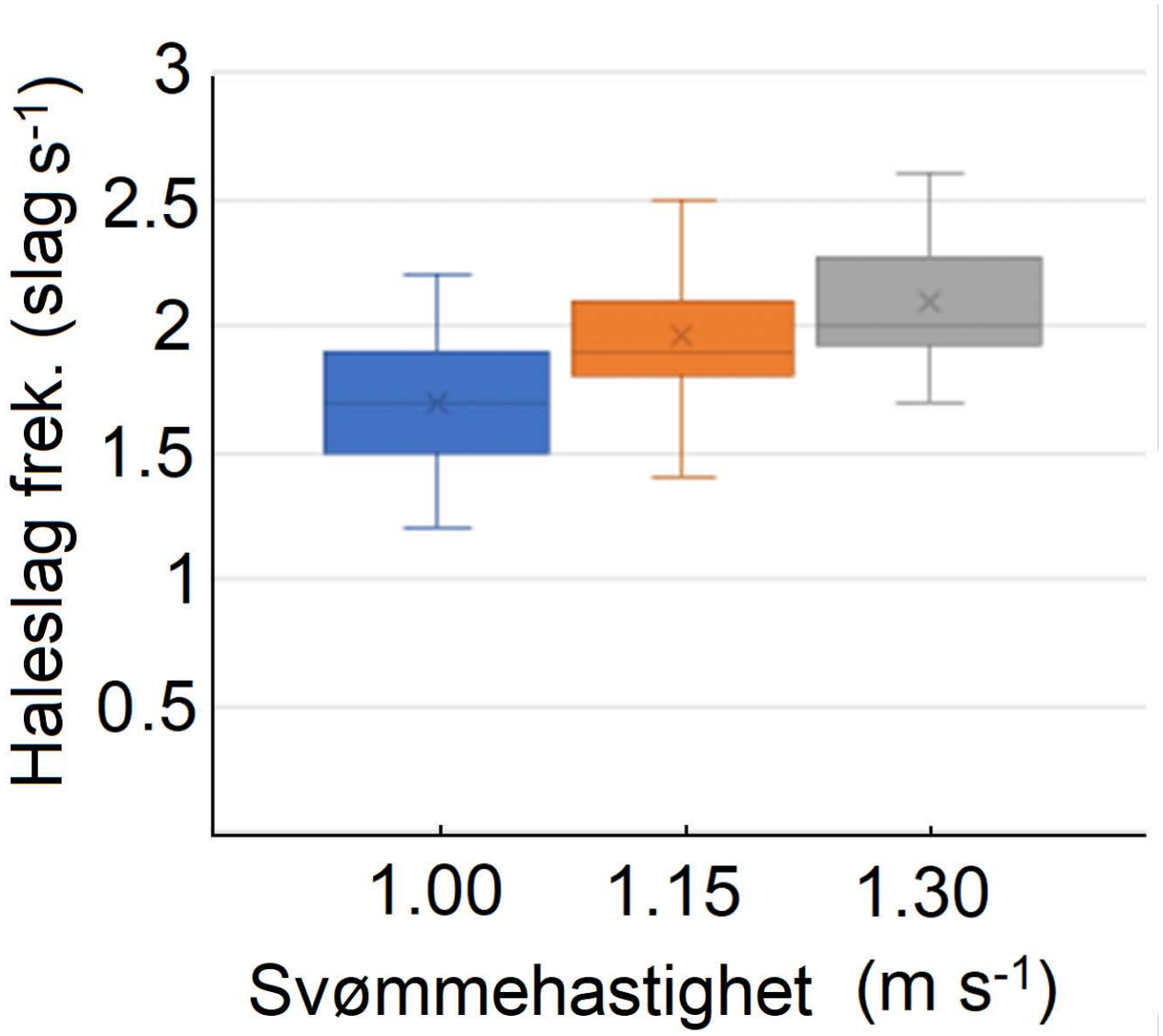
Johansson et al., 2014



Automatisk tolkning av ekkolodd-data

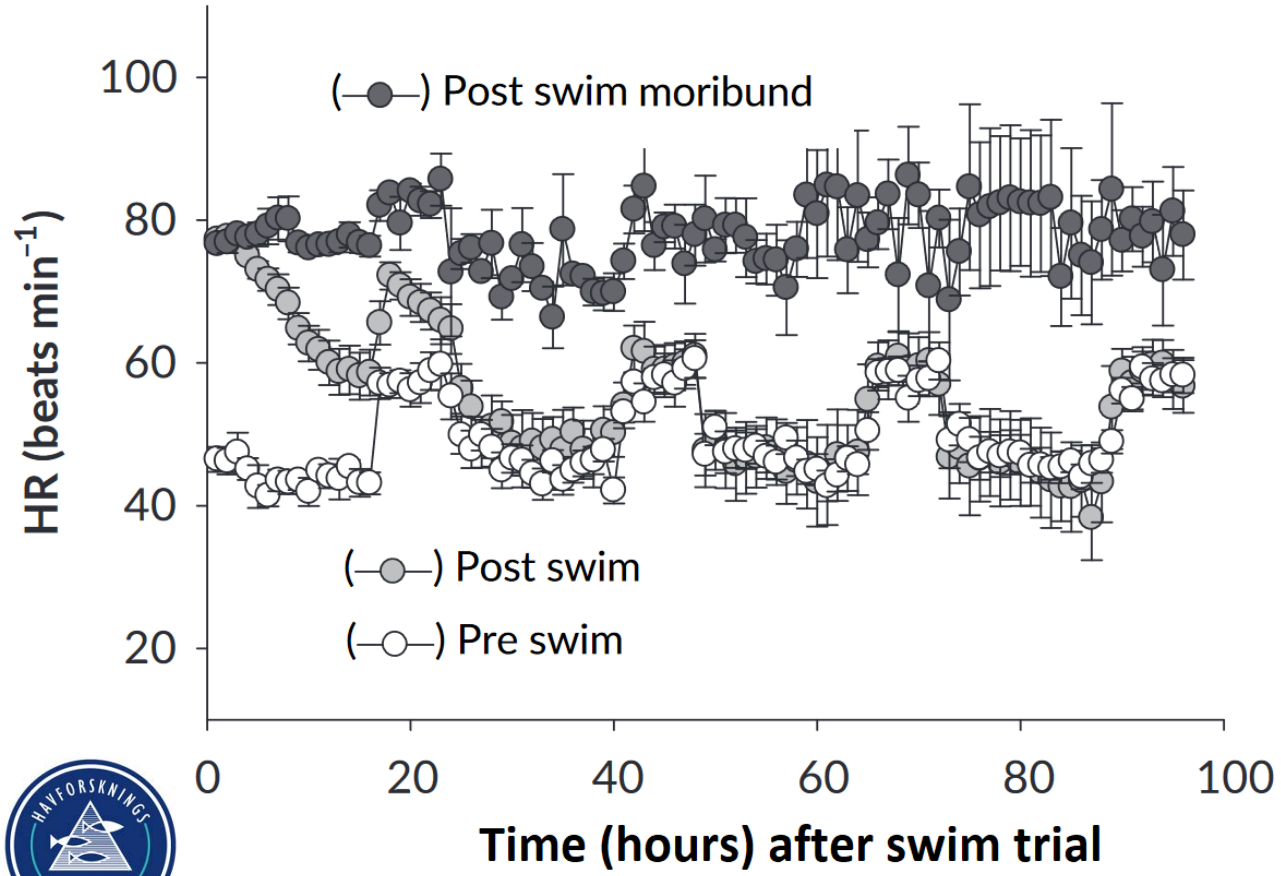
Måløy, 2020

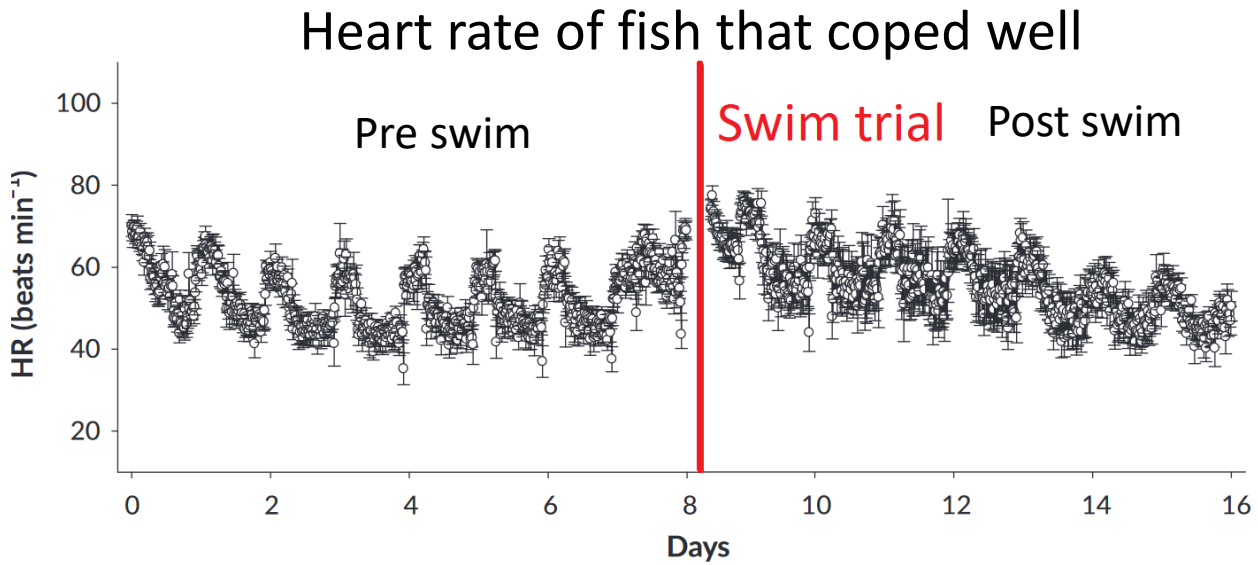

SALMA


Haleslag frek. (slag s-1)
3
2.5
2
1.5
1
0.5
1.00
1.15
1.30
Svømmehastighet (m s-1)

Hjerterate som indikator for stress og restitusjon

- Etter svømming til utmattelse: 4 av 12 individer klarte ikke “lande” og døde





Hva med bølger???

- Fisken kan stikke ned og bak i merden (Ása forteller mer om litt!)
- Tåler fisk opphold i bølger?
  - Nytt prosjekt er i gang!

Fremtidens eksponerte oppdrett?

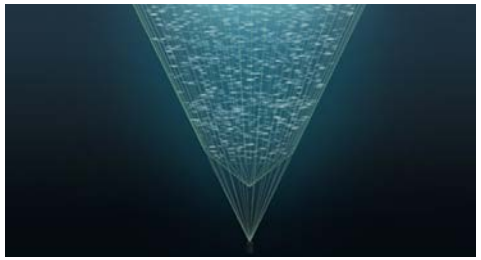
Overflatemerder?

Nedsenket?

Lukket?

Kombinasjoner?

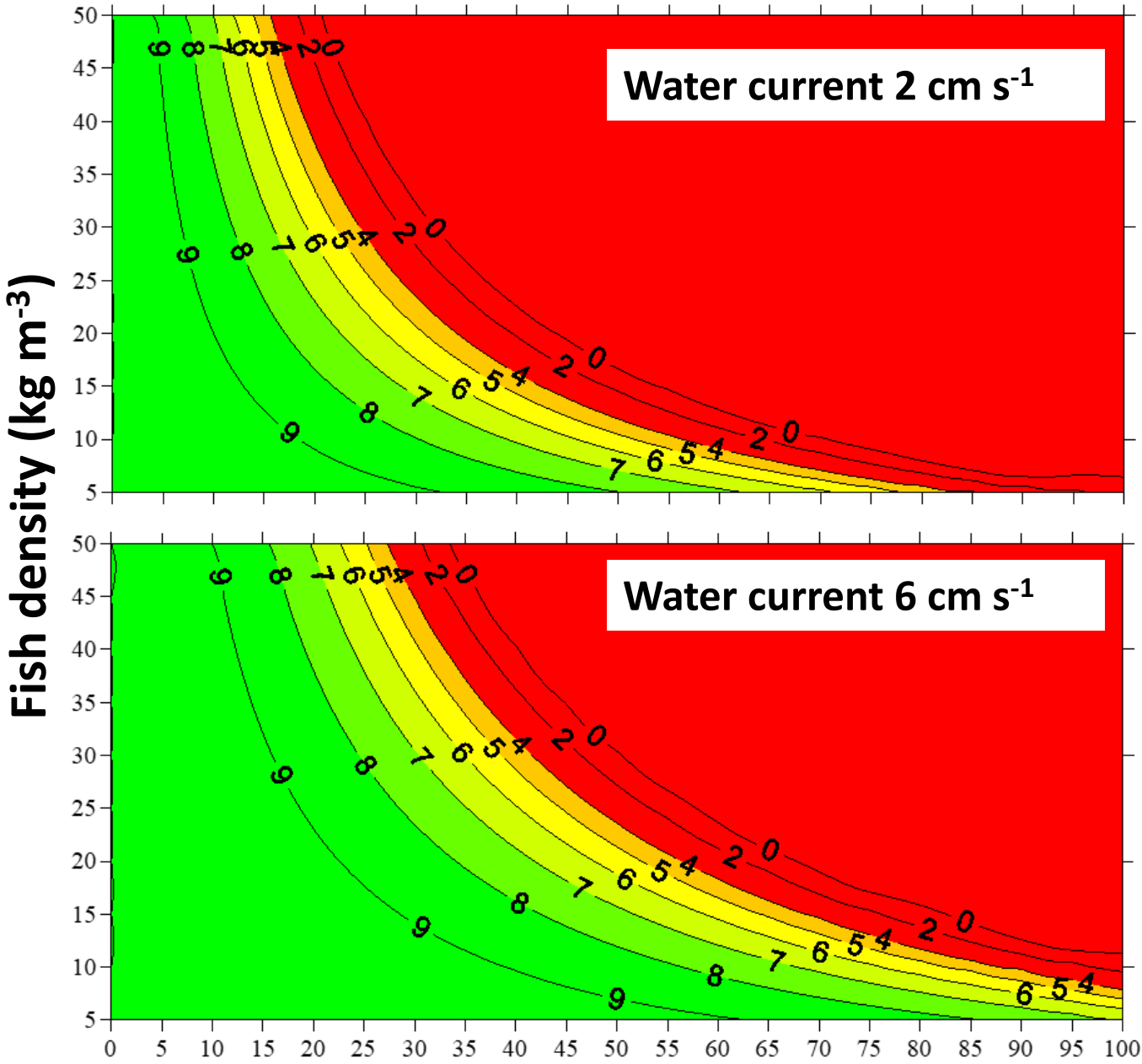
Hvor eksponert – Offshore?



Må alt offshore være gedigent?

I prinsippet:
Oksygennivået beror på:

- Fisketetthet/biomasse
- Oksygenforbruk
- Vannstrømstyrke
- Merd-lengde



Aure and Oppedal, 2009

Så, hvor store bør offshore-merder være??

- teknologi for industri eller fisk?

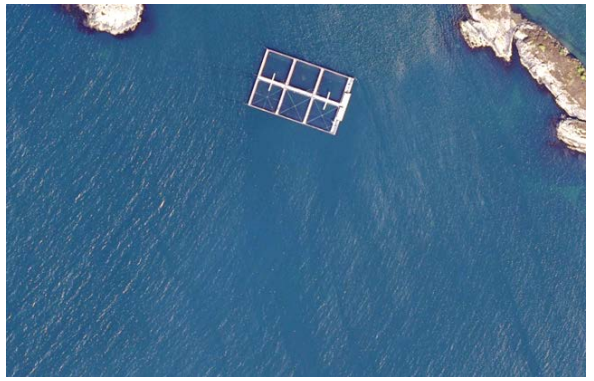
Diameter (m)	
30	
40	
50[ab]	(standard)
76[b]	(Tasmania+)
110[c]	(Ocean Farm 1)
164?	(Smart?)

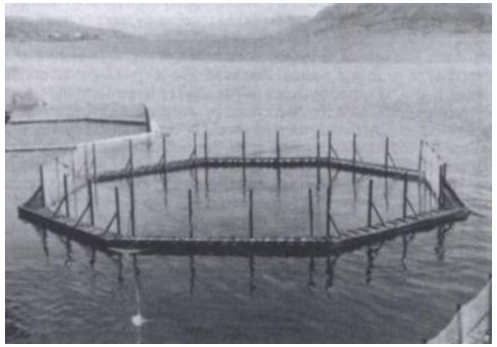
Poor oxygen observed

[a] Oldham et al 2018

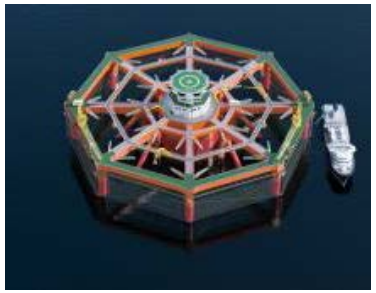
[b] Solstorm et al 2018

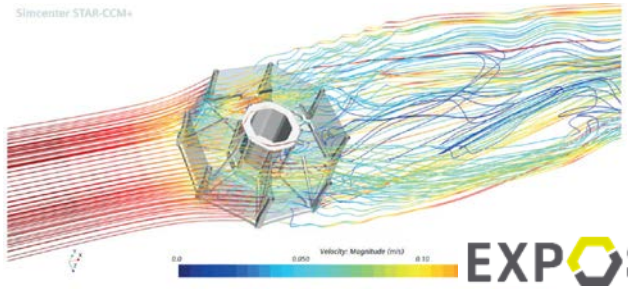
[c] Alver et al 2022





?





Oppsummert

- Laksen tåler mer enn vi trodde (i 2015)!

- Grenseverdier er etablert
  - Kortsiktig og langsiktig
  - Vi vet hva som påvirker

- Målemetoder er etablert
  - Både i lab og merder

Velferds-vennlige offshore merder?