Erythrocyte size and genome size in Arctic charr; a linkage to temperature and body size?

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DWARF

"How will the climate warming effect the size of Arctic biota?"

DWARF is an Polish-Norwegian project which aims to provide a basic understanding of the effects of the global warming on the size of the Arctic organisms of terrestrial, limnetic and marine ecosystems.

Background and study design (Arctic charr)

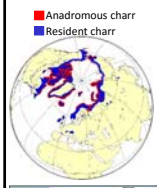
Bergman's rule/clines
- patterns of increasing size with declining temperatures
- often observed along thermal or geographical clines (climate gradients)
- may reflect evolutionary adaptations or interaction with phenotypic plasticity?

Temperature- size rule (TSR)
- repeatedly been documented that developmental temperature may affect the body size
- often leading to enlarged mature size at cold rearing temperatures = **TSR**
- so in addition to Bergman's and TSR, several correlative "rules"/"laws" have emerged, describing size scaling at various organizational levels with temperature and/or metabolic rates. Many of these share some basic predictions:
  - size decreases with increasing temperature
  - growth rate and metabolic activity is inversely correlated with cell or body size

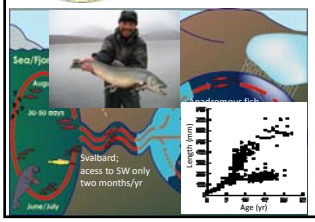
This study (Arctic charr)
Assessing linkage between temperature, food ration, body size, erythrocyte cell volume and genome size (C-value), both experimentally and by field sampling, with Arctic charr;
- raised at equal temperatures, showing different growth rates (varying food rations)
- raised at varying temperatures, showing similar growth rates (varying food rations)
- living along thermal/geographical climate gradients (latitudes; 57-81 °N)
- experiencing equal temperatures (same lake), but showing different growth rates

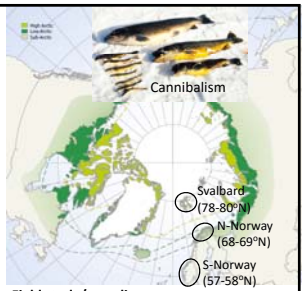
Arctic Charr (*Salvelinus alpinus*)

The northernmost freshwater fish on earth



- Northernmost freshwater fish species on earth
- Only FW-fish species on Svalbard, Novaya Zemblja, Northern Greenland etc.
- Anadromous form only in "northern" areas
- Resident charr found as far south as mid-Europe (Alps)



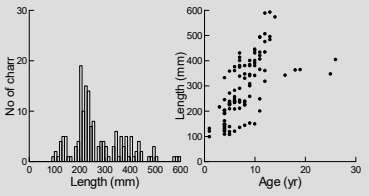


Field study/sampling:
Arctic charr was sampled in 12 lake systems: S-Norway (4), N-Norway (4) and Svalbard (4), where summer water temperatures varied from 2 °C in some Svalbard lakes to more than 25 °C in lakes in southern Norway

Experimental study:
Kårvika research station; raising Arctic charr at different temperatures and food rations

Arctic Charr; sampling and analyses

Locations	Latitude	No of lakes	No of fish: C-value	No of fish: Cell columne
Southern-Norway	57-58 °N	4 (1)	33	4
Northern-Norway	57-58 °N	4	49	49
Svalbard	57-58 °N	4	26	
Total ("wild")		**12**	**108**	**53**
Lab. experiments			54	54
TOTAL			**162**	**107**

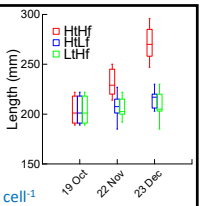


Cell volume and genome size (C-value) was analysed by flow cytometer (Jalal 2013).

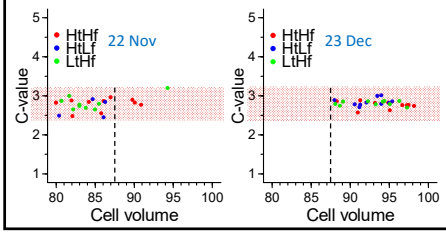
The lab. experiment was conducted at the Kårvika Research Station, located close to Tromsø, North-Norway.

Arctic charr raised at Kårvika Research Station

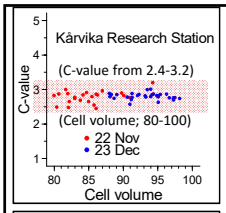
HtHf = High temperature (14 °C) High food ration
HtLf = High temperature (14 °C) Low food ration
LtHf = Low temperature (2 °C) High food ration



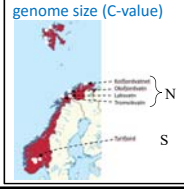
- Cell volume increased with increasing fish size
- Small changes in genome size (C-value); avg 2.8 pg DNA cell^{-1}
- No influence from temperature (p>0.5) or food ration (p>0.2)

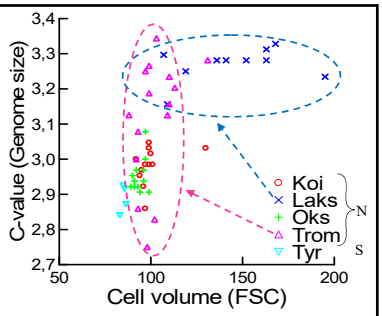


Suggesting a "relaxed" relationship between genome size (and probably also nucleus size) and cell volume?



Five of the 12 wild populations where analysed for both cell colume and genome size (C-value)



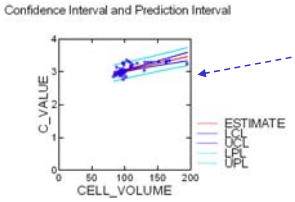


Large interpopulation variation?

- **Laks** show large variation in cell colume (100-200) and low variation in genome size/C-value (3.1-3.3)
- **Trom** show low variation in cell volume (95-105) and large variation in genome size/C-value (2.7-3.4)
- Koi/Oks/Tyr; cell volume (85-100), C-value (2.9-3.1)

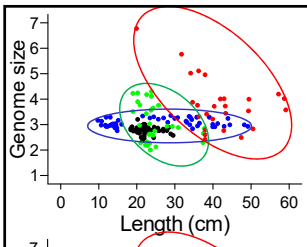
Is genome size (C-value) a proxy for cell volume?

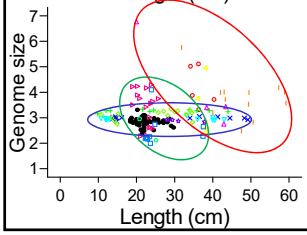
(well; yes, based om linear regression, LSR ……)

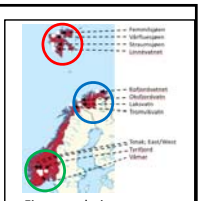


Pooling all fish:
r^2 = 0.42, p<0.01

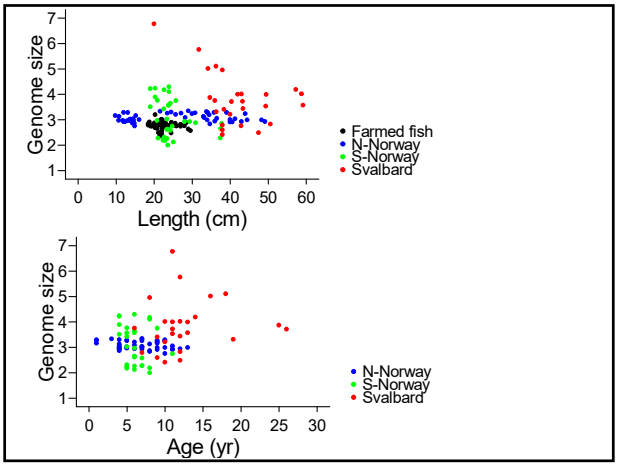
Dependent Variable	C_VALUE
N	107
Multiple R	0,653
Squared Multiple R	0,426
Adjusted Squared Multiple R	0,421
Standard Error of Estimate	0,158



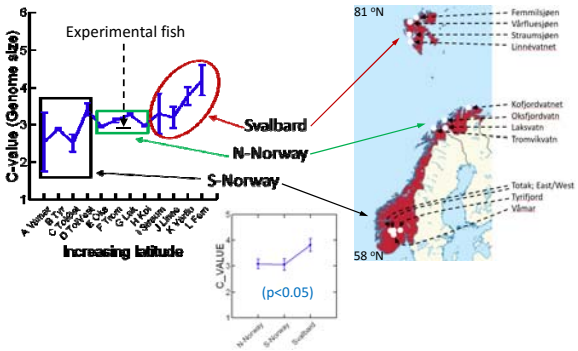




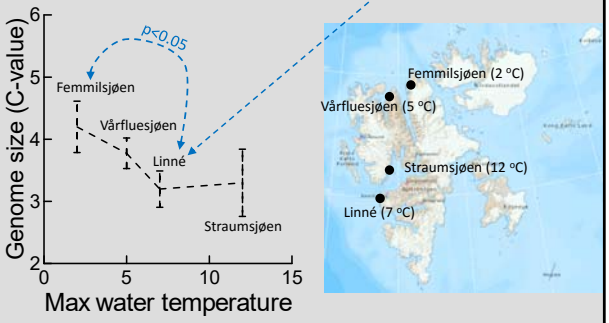
- Five populations were analysed for both genome size (C-value) and cell volume
- All 12 populationes were analysed for genome size (C-value)



Any tendency for increasing genome size with increasing latitude (decreasing temperature)?



Still a tendency, but no significant differences (unless removing an 'outlier')



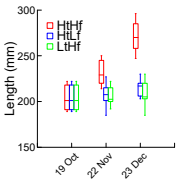
Conclusions

- Somewhat 'relaxed' relationship between genome size and cell volume
- Striking interpopulation variability (wild fish) in genome size and cell volume
- Still, pooling all populations yielded a positive correlation between genome size (C-value) and cell volume
- Tendency for increasing genome size with increasing latitude (decreasing temperature)
- Svalbard charr significant higher genome size (C-value) than populations from Southern and Northern Norway

What's next ?

In the present study we combined two approaches;

1) through a 'controlled' experimental study, where fish were exposed to different temperatures and different food rations for two months
2) by comparing wild fish populations from different latitudes, experiencing different temperature regimes

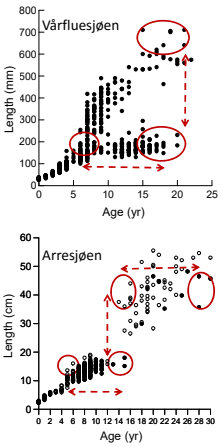


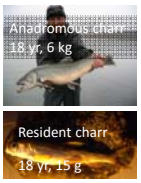
1. Experimental study

Individuals should be followed for their entire lifespan, or at least until maturity, at different temperatures and at standardized feeding regimes

2. Field study

Not only by comparing populations from different latitudes (temperature regimes), but rather focus on one or few populations, showing different life strategies

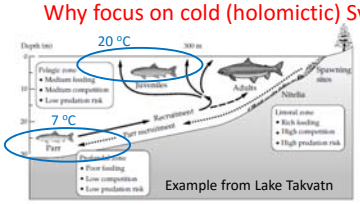




How to benfit on Arctic charr being a very "suitable" organism?

similar temperatur: age similar - and size varies
size similar - age varies

Why focus on cold (holomictic) Svalbard lakes?



- In a typical Norwegian (dimictic) lake, surface temperature may reach 20-25 °C, even in North-Norway
- While bottom temperature may be around 6-7 °C
- Fish may experience huge variations in temperature during a year, and during their life style

Segregation in summer will not be affected by temperature in Svalbard lakes