

Cold water cod performed better than warm water cod in maximum growth trials over a wide range of temperatures: are cold water stocks better fit to face climate variability?

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Introduction

Common garden experiments are very popular as a tool to investigate the growth potential of different stocks under similar environments. Climate is changing and fishery biologists are asked to anticipate how each stock might be affected by cooling or warming in the future. Temperature and growth are of a particular interest in this respect because growth is controlled by temperature and growth performance has an impact on surplus production (Dutil and Brander, 2003).

Previous experiments compared growth performance of fish reared in the laboratory and under exactly the same conditions from the larval stage. We have proceeded otherwise. Wild Atlantic cod from two stocks and having survived the process of natural selection in their own environment were acclimated to laboratory conditions and their growth performance was compared over a wide range of temperatures. We hypothesized that the cold water stock would do better than the warm water stock at low temperatures and inversely that the warm water stock would do better at high temperatures.

Materials

The cold water Stock (CW) Southern Gulf of St. Lawrence, growth production 250 g/fish/year, caught in 4T

The warm water stock (WW) Western Scotian Shelf (Bay of Fundy), growth production 710 g/fish/year, caught in 4X

Two experiments

Treatment	Temperature	Duration	Period
Cold water	1, 3, 5, 7 °C	57 days	Mid-November to mid-January
Warm Water	7, 9, 11, 13	59	Mid-August to mid-October

Both experiments

Two stocks, four temperatures, two tanks per stock and temperature combination, 7-10 fish per tank, fish fed *ad libitum* once daily, seven days a week, with frozen capelin (5 days) and shrimp (2 days), and vitamins (once a week). The following factors were tested with ANOVAs: stock, temperature, interaction between stock and temperature, and tank effects (nested). Tank effects were never significant. Only significant factors are mentioned ($\alpha=0.05$).

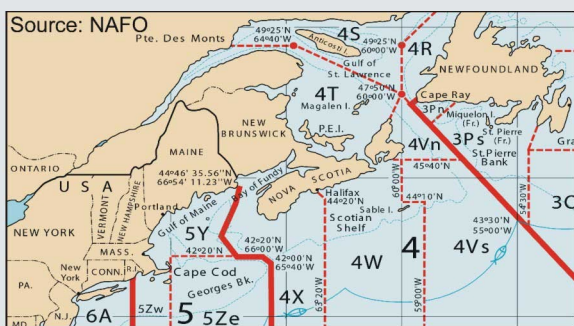
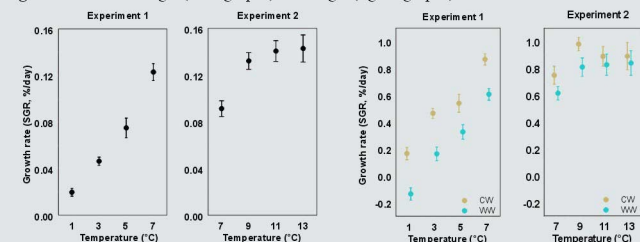


Table 1. Fork length (mean \pm SD, mm) and condition factor at the start of the 2 experiments.

	Experiment 1		Experiment 2	
	Fork length	Condition factor	Fork length	Condition factor
CW	446 \pm 38	0.81 \pm 0.10	459 \pm 32	0.76 \pm 0.06
	76	76	85	85
WW	475 \pm 50	0.97 \pm 0.11	469 \pm 41	0.83 \pm 0.09
	71	71	74	74

Figure 1. Growth in length (left 2 graphs) and weight (right 2 graphs)



Growth in length: Temperature effect was significant in both experiments ($p<0.05$); results for the two stocks are pooled.

Growth in weight: Temperature and stock effects were significant in both experiments ($p<0.05$).

Take-home message: Different stocks behave differently in similar environments and may respond differently to changing climate

Table 2. Percentage of fish with maturing gonads at the end of the experiments. Fish with gonadosomatic indices above 3.0 were considered to be maturing. The number of fish on which this number is based is shown in parentheses.

	Experiment 1			Experiment 2		
	T	CW	WW	T	CW	WW
1	21,1	6,6	7	9,1	50,0	
	(19)	(15)		(22)	(16)	
3	29,4	0,0	9	0,0	30,0	
	(17)	(18)		(22)	(20)	
5	30,0	5,6	11	0,0	31,6	
	(20)	(18)		(22)	(19)	
7	60,0	5,0	13	0,0	47,3	
	(20)	(20)		(19)	(19)	

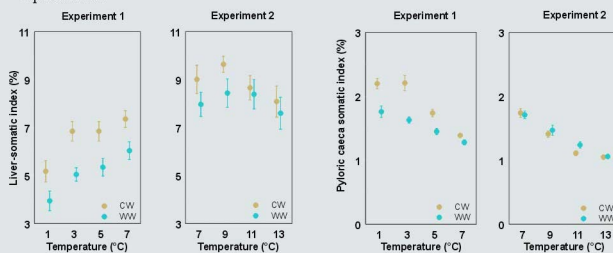
Table 3. Food consumption during the experiments. Consumption is expressed as fresh weight (kg) per kg of fish and is a mean value for two tanks.

	Experiment 1			Experiment 2		
	T	CW	WW	T	CW	WW
1	0,69	0,33	7	1,87	1,68	
3	1,45	0,67	9	2,54	2,16	
5	1,59	1,05	11	2,48	2,27	
7	2,49	1,80	13	2,76	2,21	

Table 4. Conversion efficiency during the experiments. Conversion is expressed as an increase in fresh weight (kg) per kg of food consumed (%) and is a mean value for two tanks.

	Experiment 1			Experiment 2		
	T	CW	WW	T	CW	WW
1	14,3	-23,1	7	30,0	25,6	
3	21,9	13,7	9	30,8	28,7	
5	23,0	18,2	11	28,0	28,2	
7	25,4	22,9	13	26,3	28,1	

Figure 2. Liver-somatic (LSI, %) and pyloric caeca - somatic index (CSI, %) of cod in the two experiments.



LSI: Temperature and stock effects were significant in experiment 1 ($p<0.001$) and not significant in experiment 2 ($p>0.05$).

CSI: Temperature and stock effects, and their interaction were significant in experiment 1 ($p<0.01$) and in experiment 2 ($p<0.05$).



Main points

- Growth in length and weight increased with increasing temperature up to 9°C. The cold water stock out-performed the warm water stock at all temperatures in the range 1-9 °C.
- In cold water, the cold water stock ate more food and maintained a higher conversion efficiency than the warm water stock.
- In warm water, the warm water stock did not perform better than the cold water stock. The warm water stock had a low conversion efficiency below 7°C and lost weight at the coldest temperature.
- The larger relative size of the pyloric caeca and enhanced metabolic capacities in the gut (not shown) of the cold water stock at the lowest temperatures may explain the faster growth rate of Gulf of St. Lawrence cod compared to Bay of Fundy cod. Gulf of St. Lawrence cod live at lower temperatures than Bay of Fundy cod.