

An evaluation of the temperature dependent development rates of cod (*Gadus morhua* L.) eggs from the Irish Sea

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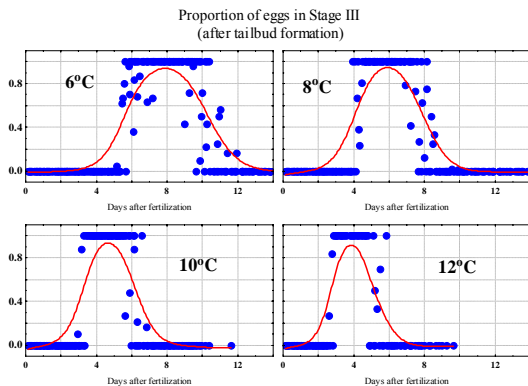
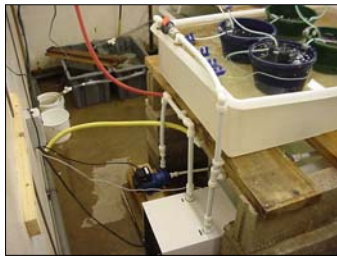
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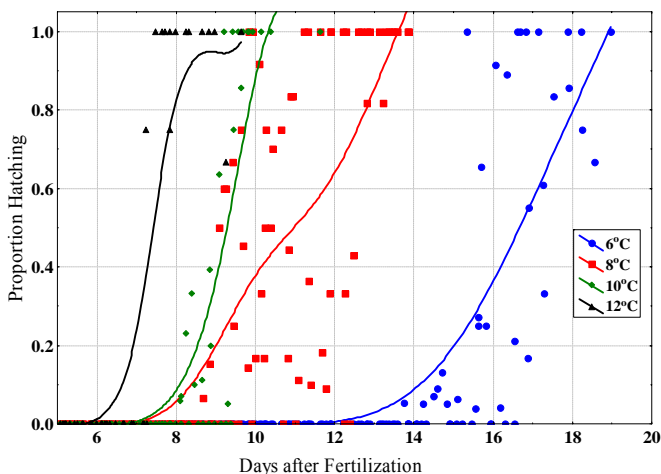


Cod spawning grounds are distributed over a wide geographic range and eggs from different populations experience a different range of incubation temperatures. Overall, incubation occurs at temperatures ranging from -2°C to 10°C, with Western Atlantic populations experiencing lower temperatures, and Irish Sea and Celtic Sea populations experiencing higher temperatures.

Embryos that develop at different temperatures are different physiologically, morphologically and behaviourally. Climate changes that alter the temperature regime can directly affect larval growth and survival.



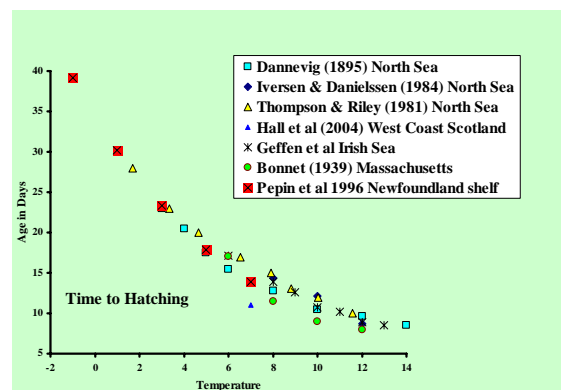
Temperature has a direct effect on embryo development, with colder temperatures leading to longer development times. Equally important is the effect that temperature has on the synchrony of development within a population. At lower temperatures, egg development is spread out over a longer period of time, with more individual variation in stage-at-age. At increasing temperatures, the transition from one stage to the next is more synchronous. Thus, for example, hatching may occur over 5 days at 3°C, but is completed in 2 days at 10°C. Reductions in the length of the hatching period could make populations more vulnerable to stochastic events, and this vulnerability could differ between cod populations.



We measured the development rates of Irish Sea cod at 6, 8, 10 and 12°C and examined the effect of temperature on development rate and synchrony of development. Five separate batches of eggs from four female Irish Sea cod were incubated from fertilisation through to the completion of hatching. The eggs were incubated in a flow-through system consisting of four, re-circulating, controlled temperature seawater baths at 6, 8, 10 and 12°C (± 0.25°C). We compared our results with those of 8 published studies of temperature development rates in cod eggs, using at least 5 different cod populations, and covering temperatures from -1 to 12°C.

	descriptor of end of stage	Markle & Frost 1985	Laurence & Rogers 1976	Thompson & Riley 1981	Bonnet 1939	von Westernhagen 1970	Hall et al 2004	Fridgerisson 1978
Cleavage	first cleavage	Stage I	Stage I	Stage IA	First Cleavage	Stage Iaα	Zygote Period	Stage 1
	2cells							
	4cells							
	8cells							
	16cells							
Blastula	32cells	Stage II	Stage II	Stage IB	Late blastula	Stage Iaγ	Blastula Period	Stage 2
	128 cells							
	blastodisc							
Gastrula	Blastula	Stage II	Stage II	Stage II	1/4 gastrula	Stage Iba	Gastrula Period	Stage 3
	germ ring							
	start of gastrulation							
	embryonic axis							
	Gastrula middle							
Embryo	epiboly	Stage III	Stage III	Stage IV	1/2 gastrula	Stage Ibb	Stage 4: closure of blastopore	Stage 4
	closure of blastopore							
	tailbud formation							
	embryo 270° round yolk							
	heart visible							
Hatch	regular heartbeat	Stage IV	Stage IV	Stage V	3/4 somites	Stage IIγ	Segmentation period	Stage 5
	embryo 270° to 360° round yolk							
	embryo 360° round yolk							
	Hatching starts							
	50% hatch							
100% hatch	Stage Vα	Stage Vβ	Stage Vγ	Stage 6				

Comparisons between studies were difficult because 7 different development staging systems were used by the different authors to define cod embryo development. By synchronising the development stages in use, we were able to directly compare stock differences in influence of temperature on developmental rates.



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