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GROWTH RATE RELATED TO GENOTYPE OF 0-GROUP COD AT THREE ENVIRONMENTAL TEMPERATURES

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Growth rates of cod of an initial weight of about one gram were studied at three environmental temperatures (6, 10, and 14° C) for about 70 days. Samples of all three groups of fish were genotyped for haemoglobin and several tissue enzymes by agar or starch gel electrophoresis. Size at termination of the experiment, regarded to represent individual growth rate, was studied separately for frequent genotypes within temperature groups. No clear associations between mean growth rate and genotypes of the enzymes LDH or PGI were found at any temperature. However, fish of the genotype *Hb-I(2/2)* showed the highest mean growth rate regardless of environmental temperature, and fish of genotype *Hb-I(1/1)* grew on average slowest at the two higher temperatures. This observation was partly in contrast to earlier findings indicating that the performance of the different genotypes is temperature dependent, with *Hb-I(2/2)* as the more efficient at lowest temperatures.

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INTRODUCTION

Biochemical genetic variations of commercially important fishes have now been studied for three decades. Much information on fish population biology has been obtained by studies on the geneotypes of individual fish or fish populations by relatively simple methods such as electrophoresis and isoelectric focusing. However, use of genotype distributions, or gene frequencies, as population parameters requires that the involved genes are either selectively neutral, or at least so unaffected by selective forces that the gene frequencies may be regarded as practically stable over several generations. This again is related to the biological significance of biochemical genetic variation which by and large still is unknown.

However, KARPOV & NOVIKOV (1980) reported specific temperature dependence of oxygen dissociation curves for cod with the different haemoglobin types, and also the reports by MORK, GISKEØDEGÅRD & SUNDNES (1984a,b) on genotype growth differences have contributed to the discussion on the dynamics of the genetic variation.

The present report is part of more extensive studies on coastal cod in culture and in nature. Cod which had been kept at different environmental temperatures for two and a half months during their first summer in order to study temperature effects on growth rate, were used for studies on possible genotype influence on this trait. The hypothesis was that the large individual variation and large variation due to temperature itself, was not expected to be associated with the genotypes analysed here.

MATERIAL AND METHODS

The juveniles used in this study were raised in an enclosed pond (small isolated fjord) called Parisvatnet in Øygarden northwest of Bergen (BLOM & al. 1990). The main aim of these culture activities is to produce 0-group cod for sea ranching in nearby fjords and coastal areas. The eggs were spawned naturally in two spawning pens at the Austevoll Aquaculture Research Station (belonging to the Institute of Marine Research, Bergen), and released in Parisvatnet as 5 days old larvae. The larvae were raised on natural zooplankton until after metamorphosis, and then fed formulated feed as supplement. They were caught by sinking nets in mid-summer and transferred to net pens in the pond for subsequent tagging and release in nearby fjords and costal areas.

The parent fish in one of the spawning pens were genetically tagged. They were all offspring of fish of the homozygote *Pgi-1(30/30)*, a genotype of the enzyme phosphoglucose isomerase (PGI) which is extremely rare in nature. The genetic tagging process has been described by SKAALA & al. (1990). The purpose of developing geneticallly tagged fish for sea ranching experiments is to study the relation between released cultured fish and the 'natural' fish in the release area, and to develop reliable tagging methods for studies on survival and recapture of the released fish.

On 13 June, 1991 about 3800 young fry, with a mean weight about one gram, were transported to the wet laboratory at the University of Bergen where they were used for growth studies. The fish were graded, about 100 small and 400 large fish were removed, and the rest were divided into three main groups of similar sized fish

(1.27 g ± 0.31). The groups were raised at 6, 10, and 14° C. The fish were fed in excess with dry feed until 26 August when the experiment was terminated. At that time the variation in size was high both within and between the experimental groups. Survival during the experimental period averaged 93 %.

About 100 cod from each group were collected for blood and muscle sampling as described by MØLLER (1968) and JØRSTAD (1984). Individual length and weight were recorded.

The methods described by JØRSTAD (1984) were applied for analysis of haemoglobins and tissue enzymes. The tissue enzymes stained for are those found by initial screening to be the most informative about cod (see JØRSTAD & NÆVDAL 1989), including lactate dehydrogenase (LDH), phosphoglucomutase (PGM), glucose-6-phosphate dehydrogenase (GPD), phosphoglucose isomerase (PGI) and isocitrate dehydrogenase (IDH).

RESULTS AND DISCUSSION

Table 1 presents gene frequencies. The frequencies of the haemoglobin genes are very close to those found in samples from western Norway more than 25 years ago (FRYDENBERG & al. 1965). The gene frequencies for the tissue enzymes, with the exception of PGI, are also very similar to those earlier found among samples from Norwegian waters (JØRSTAD & NÆVDAL 1989). The PGI frequencies clearly reflect that about half of the cod sampled belonged to the genetically tagged fish, consisting of the homozygote genotype *Pgi-1(30/30)*.

Growth rate in general increased with increasing temperature. Tables 2–4 show the mean lengths at termination of the experiments. No significant differences in genotype distributions were found in any of the genetic systems ($P > 0.4$, one-way ANOVAs).

At all three temperatures the genotype *Hb-I(2/2)* showed the highest growth rate. The lowest mean growth rates at the two higher temperatures were found for the genotype *Hb-I(1/1)*, whereas the heterozygotes were intermediate between the two homozygotes (Table 2). At the lowest temperature the mean growth rates were similar for *Hb-I(1/1)* and *Hb-I(1/2)*.The effects of temperature and genotype were significant ($P < 0.001$ and $P = 0.049$ respectively), while no significant interaction ($P = 0.61$) was found (two-way ANOVA) between these two variables. The mean lengths of the two homozygotes were significantly different, while none of them differed significantly from the heterozygote (Tukey HSD test, $P < 0.05$).

For LDH genotypes no clear differences or tendencies were seen (Table 3). At the higest temperature heterozygote superiority was indicated, although not statistically significant ($P = 0.67$, two-way ANOVA).

Table 1. Allele frequencies in samples of 0-group cod raised at three environmental temperatures. * = rare alleles included.

	Hb-I		*Ldh-3*		*Gpd*			*Pgi-I*			*Pgm*		*Idh-2*	
T° C	*1*	*2*	*70*	*100*	*90*	*100*	*120*	*30*	*100*	*150*	*30*	*100*	*70*	*100*
6	0.60	0.40	0.34	0.66	0.01	0.88	0.11	0.45	0.42*	0.13	–	1.00	–	1.00
10	0.56	0.44	0.39	0.61	0.01	0.87	0.12	0.53	0.33	0.14	–	1.00	0.01	0.99
14	0.59	0.41	0.39	0.62	0.01	0.84	0.15	0.54	0.38	0.08	0.01	0.99	0.02	0.98

Table 2. Mean lengths (l) in mm of haemoglobin genotypes in cod raised at different temperatures. s = standard deviation, n = numbers.

T° C	*Hb-I(1/1)*			*Hb-I(1/2)*			*Hb-I(2/2)*		
	l	s	n	l	s	n	l	s	n
6	91.6	12.8	33	89.8	12.7	50	95.0	12.6	14
10	109.0	12.5	29	115.0	14.5	46	120.0	20.7	18
14	123.2	18.0	33	126.1	17.7	43	129.0	18.2	16

Table 3. Mean lengths (l) in mm of LDH genotypes in cod raised at different temperatures. s = standard deviation, n = numbers.

T° C	*Ldh-3(70/70)*			*Ldh-3(70/100)*			*Ldh-3(100/100)*		
	l	s	n	l	s	n	l	s	n
6	90.7	15.8	10	90.0	13.3	47	90.9	12.2	41
10	118.0	15.9	12	114.5	17.7	50	112.2	13.0	33
14	120.1	14.5	12	127.3	18.2	50	123.2	18.7	34

Table 4. Means lengths (l) in mm of PGI genotypes in cod raised at different temperatures. s = standard deviation, n = numbers.

T° C	*Pgi-1(30/30)*			*Pgi-1(100/100)*			*Pgi-1(100/150)*		
	l	s	n	l	s	n	l	s	n
6	91.0	13.2	43	90.6	14.1	30	89.7	12.3	15
10	114.1	15.9	48	113.4	15.1	22	114.7	18.7	18
14	125.7	19.7	50	121.9	16.0	30	121.3	11.3	11

The genetically marked fish (*Pgi-1(30/30)* tended to grow on average somewhat faster than the other fish at the highest temperature, while no genotypic dependent growth rate was indicated among the other groups (Table 4). This does not necessarily reflect the performance of the genotype itself because the batch of genetically marked larvae originally released in the pond, were on average larger than the rest of the larvae, and this difference has been tracked throughout the production cycle in spring and summer (Geir Blom and Ole Ingar Paulsen, pers. commn). In the present study no significant genotype effects on lengths were observed ($P = 0.70$, two-way ANOVA).

The weight data showed the same tendencies as the length data. Two-way ANOVA tests revealed significant effects of haemoglobin genotype ($P = 0.026$) as well as of rearing temperature ($P < 0.001$) on growth, while no significant interaction between genotype and temperature effects were revealed ($P = 0.70$). The Fulton's condition factor was not significantly influenced by any of the studied genotypes.

This work has indicated an association between haemoglobin genotype and growth rate in cod, which is in accordance with the results of MORK & al. (1984a,b) obtained from studies on cod from Trondheimsfjorden. These authors concluded that the genotype *Hb-I(2/2)* performed best in that particular environment. This genotype is the most common in northern areas, but in more southern localities the two haemoglobin alleles occur with about equal frequencies or with a surplus of the gene *Hb-1(1)* (FRYDENBERG & al. 1965; MØLLER 1968). Thus it might seem surprising that the genotype *Hb-I(2/2)* should perform best at the highest temperatures. However, high growth rate by itself does not necessarily mean selective advantages. Natural selection works on the total phenotype, and haemoglobin type is only a small part of the total individual genotype. The results indicate that biochemical genetic variation have some biological significance. However, at present it seems difficult to draw conclusions about the adaptive significance and thus the selection potential the individuals may be subjected to on basis of such significance. Since the cod in this study, in contrast to most wild-caught cod, were fed in excess and had high growth rates, the results may reflect differences in metabolic capacity rather than metabolic efficiency.

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