The Gametogenic Cycle and Spawning in *Mytilus edulis* in the Faroe Islands

Kynskyknu-búning og -gýting hjá kræklingi (*Mytilus edulis*) í Føroyum

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Úrtak

Tann árliga ringrásin í búningini av kynskyknunum í kræklingi, *Mytilus edulis* L. í Eysturoy í Føroyum varð kannað tíðarskeiðið juni 1996 til juni 1997. Vevnaðurin av kynsgøgnunum vísti tekin um at búningin av kynskyknum fór fram alt árið, tó var meginbúningin í tíðini frá novembur til mars. Gýtingin fór fram yvir eitt longri tíðarskeið, frá mai til tíðliga á vetri, tó við eini høvuðsgýtingartíð í mai og juni, tá ið sjóvarhitan er um 7-8°C. Eitt búningarskeið av kynskyknum, sum líkist tí í Føroyum, er fyrr sæð í eini rød av kræklingastovnum í útsynningspartunum av Evropa, men er hetta nakað annarleiðis enn tað, sum er sæð bæði í landsynnings- og útsynnings-partunum av Íslandi.

Abstract

The annual gametogenic cycle in the blue mussel, *Mytilus edulis* L. on Eysturoy in the Faroe Islands was investigated from June 1996 to June 1997. Histological preparations of the gonads showed evidence of gonad development throughout the year with the main development period between November and March. Spawning was protracted lasting from May until early winter with the main spawning in May and June at a sea temperature of 7 and 8°C, respectively. A gametogenic cycle similar to the one in the Faroe Islands has been observed in a number of populations in Western Europe but is somehow different from those observed both in western and eastern Iceland.

Fróðskaparrit 51. bók 2004: 270-279

Introduction

Available information on the reproduction and seasonality of the gametogenic cycle of *Mytilus edulis* L. in the Atlantic is particularly extensive reflecting its commercial importance. However, in the Faroe Islands the information on reproduction in blue mussels until now is limited (Gaard, 1986).

The gametogenic cycle of *M. edulis* varies, both spatially and temporally and the timing and duration of the cycle probably results from complex interactions between several exogenous and endogenous factors. Of the exogenous factors, sea temperature, which varies seasonally and latitudinally, and food supply seem to be the most important (Seed and Suchanek, 1992).

The present paper describes the annual gametogenic cycle and spawning in *Mytilus edulis* in the Faroe Islands in relation to sea temperature. Furthermore, comparisons are made with other populations of *M. edulis* in the North Atlantic.

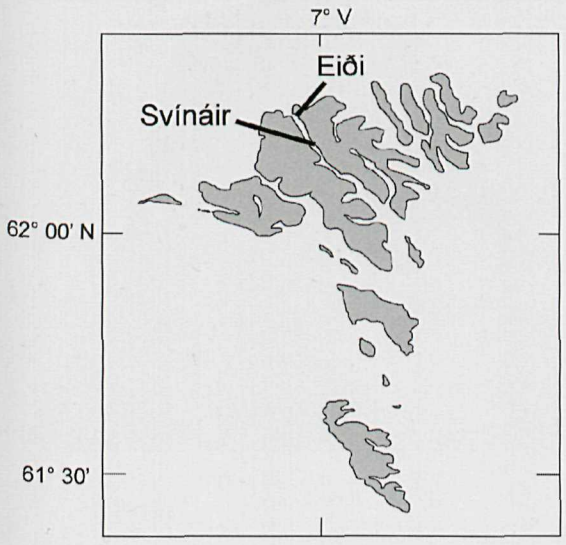

Fig. 1. Faroe Islands, showing the study site at Svínáir and the site of temperature measurements at Eiði.

Material and methods

From a *Mytilus edulis* population in the lower part of the littoral zone at Svínáir on Eysturoy in the Faroe Islands, about 30 mussels larger than 2 cm were collected (Fig. 1). The sampling was made at approximately monthly intervals, between June 1996 and June 1997.

In the laboratory small samples of the gonads were removed from the mussels and preserved in 10% formaldehyde. Later histological preparations were made by dehydration of the gonad samples through an ascending alcohol series, clearing in toluene and embedding in paraffin. Sections were cut about 7 µm in thickness and stained with haematoxylin and eosin.

The stained gonad preparations were classified into different developmental stages, under a microscope, using 80 x magnification. The classification system consisted of four main stages, two of which (developing and spawning) were further divided into four sub stages, resulting in a total of ten stages, developing (1-4), ripe (5), spawning (4-1) and spent (0) (Seed, 1969). In stage 0 (spent) it is difficult to determine the sex of the animals but in some cases eggs were visible even though the spawning was over. In these cases the samples were classified as spent and the sex was given.

The reproductive condition of the population was assessed by calculating a mean gonad index. This was done by multiplying the number of mussels in each stage by the numerical ranking of that stage and dividing the resulting value by the total number of mussels in the sample. The mean gonad index for each sampling date was then calculated by adding together the scores for all stages (Seed, 1969). If all individuals were spent, the gonad index would be 0 (minimum) and if all individuals were fully ripe the index would be 5.0 (maximum).

The gametogenic cycle is discussed in relation to the sea temperature at Eiði, a few kilometres north of the mussel sampling station. The sea temperature was measured at Eiði at 1.5-2 m depth by a self registering thermometer at 10 min. interval and monthly averages were calculated. As temperature measurements are lacking from the middle of February to the middle of June 1997, sea temperatures for the period June 1993 to June 1994 (Office of Public Works, Tórshavn, unpublished data) is used for comparisons. The year to year variations in mean monthly sea temperatures during the period 1993 to 1997 were relatively small with standard deviation within 3 to 5% during the

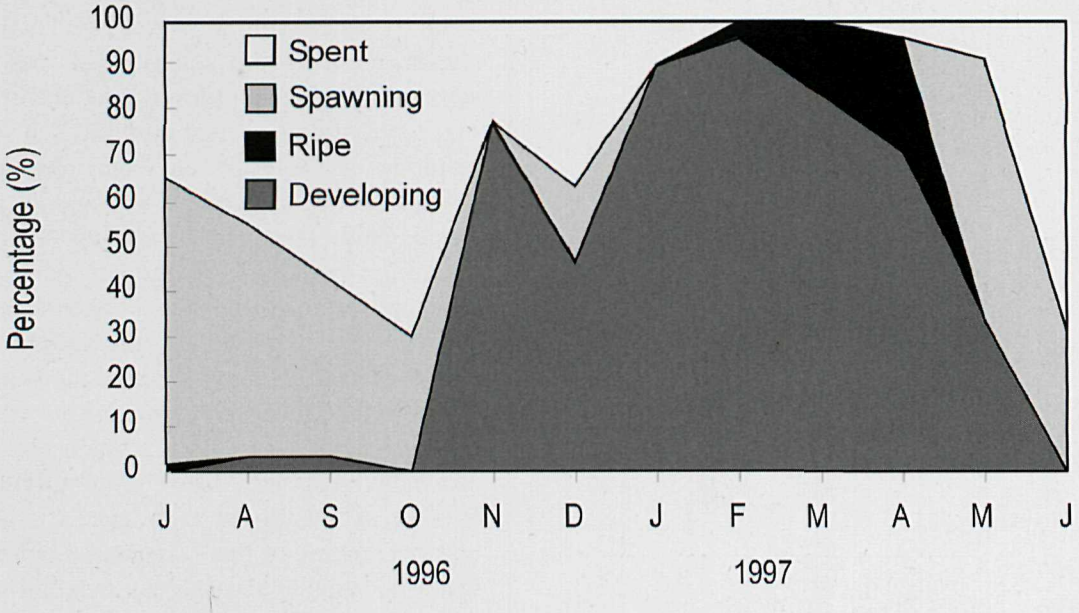

Fig. 2. Percentage of Mytilus edulis *in each phase of the gametogenic cycle during the study period.*

summer months and 2 to 11% during the colder season (Office of Public Works, Tórshavn, unpublished data).

Results

At the start of the sampling period in June 1996, 64% of the *Mytilus edulis* population investigated was spawning (Figs. 2, 3C and 4C) and 35% was spent (Figs. 2, 3D and 4D). In June the mean sea temperature was 8.4°C and still increasing, reaching a maximum, 9.5°C, in September (Fig. 5). The number of spawning individuals decreased gradually through autumn and no spawning was observed from November until May except in December when about 16% of the population was spawning (Fig. 2). In November the development of the gonads (Figs. 3A and 4A) started and the highest number of developing individuals was observed in February about 97% (Fig. 2, Table 1). Fully ripe (Figs. 3B and 4B) individuals were only observed in April and May but developing gonads were observed in the samples until June (Fig. 2, Table 1). In 1997 spawning started intensively in May at a mean sea temperature of 7.3°C and in June 70% of the population had finished spawning and was in spent condition (Fig 2, Table 1).

Some individuals were found with developing gonads throughout most of the year but the major period of development was from November through February corresponding with increasing gonad index and decreasing sea temperature (Figs. 2 and 5, Table 1). The gonad index reached its maximum in March and April when most of the

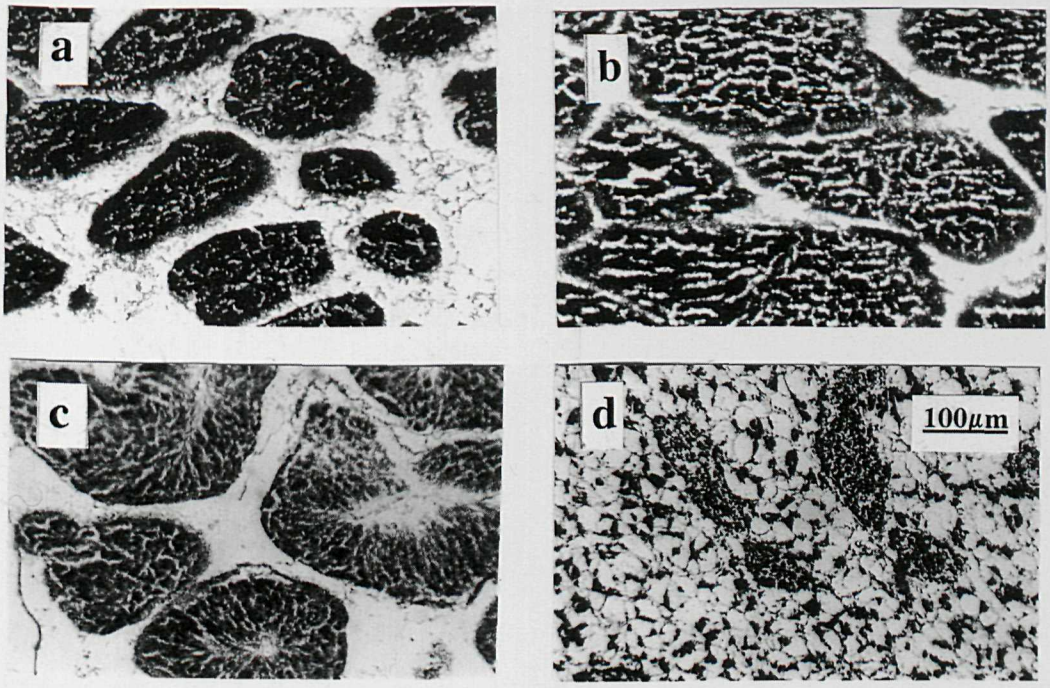

Fig. 3 A-D. *Photomicrographs of transverse sections through male gonads of* Mytilus edulis *at various stages in the gametogenic cycle. A. Stage 3, developing. B. Stage 5, fully ripe. C. Stage 4, partially spawned. D. Spent phase.*

individuals were developing but some had mature gonads (Fig 2, Table 1). At this time of the year the minimum sea temperature, 4.7°C, was observed (Fig. 5).

Discussion

In the present study of a *Mytilus edulis* population in the Faroe Islands one long spawning period was observed lasting from spring to early winter. In June 1996, when the sampling began, over 60% of the population was spawning. Spawning decreased gradually through autumn but started intensively again in May 1997. The main spawning period was probably in May both the years investigated at sea temperature of about 7°C. No resting phase was observed as the spent period was not very marked. Onset of gametogenesis started immediately after spawning in November at a sea temperature of about 7°C lasting through May. In November the gonad index increased with increasing activation of the gonads reaching its maximum in March and April when only developing and ripe individuals were observed. The gonad index was lowest in October 1996 and June 1997 when the highest percentage of spent individuals was observed.

Sexual maturity in *Mytilus edulis* is at-

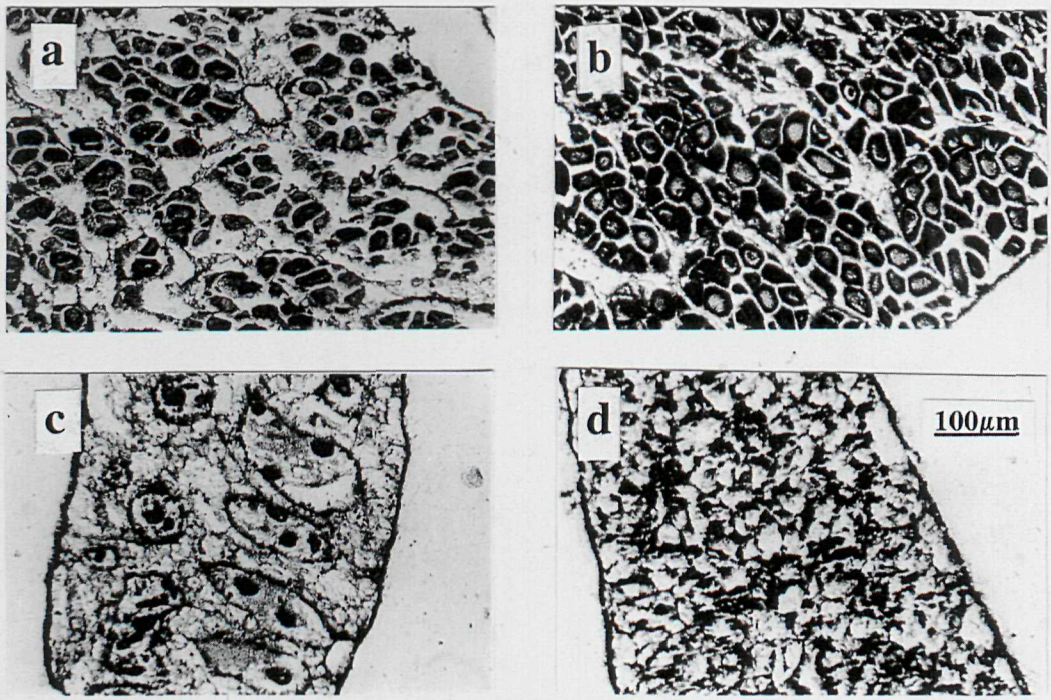

Fig. 4 A-D. *Photomicrographs of transverse sections through female gonads of* Mytilus edulis *at various stages in the gametogenic cycle. A. Stage 3, developing. B. Stage 5, fully ripe. C. Stage 4, partially spawned. D. Spent phase, traces of sexuality evident.*

tained in the first year of life, but the size at which this occurs depends largely on local growth rates (Seed, 1976; Sprung, 1983). In an investigation on exposed rocky shore in Britain, Seed (1969) found no marked or consistent differences in the spawning periods of mussels from different local habitats or among animals of different size. In the present study all the investigated individuals are considered over one year old and sexually mature, as they are all >2 cm in shell length and sampled from a location where the growth rate might not be very high. In a suspended mussel culture in the Faroe Islands the mean growth during the first year was only 0.9 mm (Gaard, 1986).

In a wild population it is difficult to demonstrate a simple causal relationship between a single environmental variables and reproduction as the variables may cover each other or interact synergistically.

The results from the present study showed, that the gonad development started after spawning in November with decreasing sea temperature and the fastest development was observed from December to January when the sea temperature was still decreasing. The population reached the highest gonad index in March and April just after the minimum sea temperature was ob-

Date	No.	Male									Spent	Female									Gonad index
		Developing					Spawning					Developing					Spawning				
		I	II	III	IV	V	IV	III	II	I	0	I	II	III	IV	V	IV	III	II	I	
1996																					
June	58						5	5	6	7	20	1				1	3	6	2	3	1,6
August	29						1	1	3	6	13	1								4	0,8
Sept	28								6	4	16	1								1	0,6
Oct	30								3	6	21										0,4
Nov	18	5	1	2							4	6									1
Dec	30	7	2						2	3	11	5									0,8
1997																					
Jan	31		2	1	3						3	8	4	6	4						2,2
Feb	29	1	5	3	3	1							8	3	5						2,8
March	31			5	2	2						6	4	2	7	3					3,1
April	28			2	4	5					1	4	6	2	2	2					3,1
May	24	1					1	2			2	1	2	3	1		3	4	4		2,7
June	29							1	1	5	20									2	0,4

Table 1. *Distribution of gonad stages of* Mytilus edulis *from the Faroe Islands from June 1996 to June 1997*

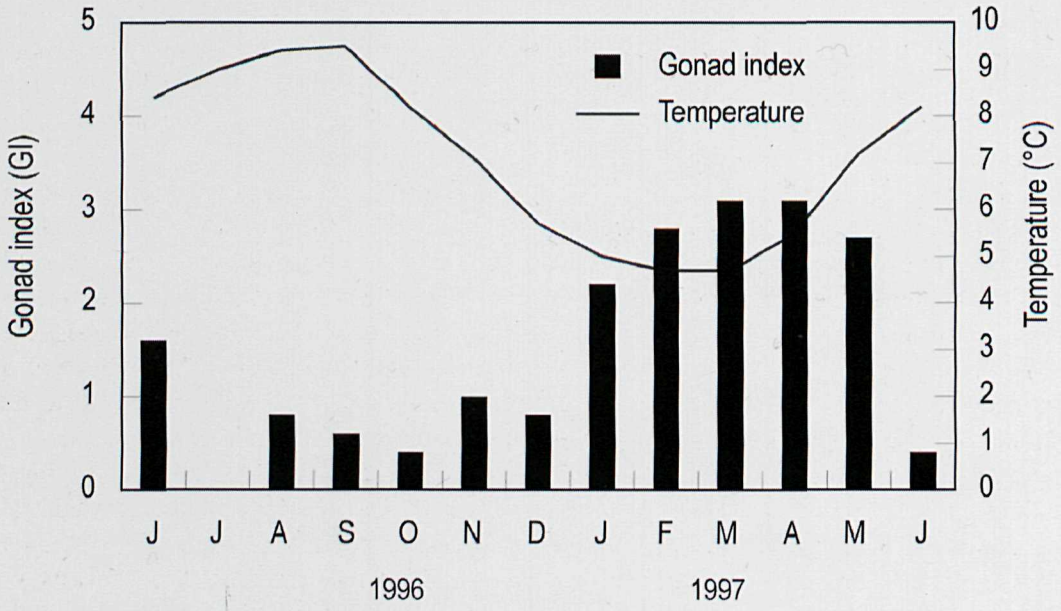

Fig. 5. *Seasonal changes in mean monthly sea temperature at Eiði a site close to the study area at Svínáir and the gametogenic cycle in* Mytilus edulis *from the study site, shown as the mean gonad index (temperature records, courtesy of the Office of Public Works, Tórshavn).*

served (February and March) and spawning began in May when sea temperature was increasing but had not reached its maximum. Similar results were found in a study of farmed blue mussels on Suðuroy in the Faroes in 1984 and 1985, with maximum gonad index during the period late March to early May (Gaard, 1986).

Changes in temperature have been found to stimulate initiation of gonad development (Bayne, 1975; Gray *et al.*, 1997) as well as spawning (Chipperfield, 1953; Sprung, 1983). Some authors have even suggested that a critical temperature change is needed for initiation of spawning (Kautsky, 1982; Seed, 1976) while others have found little or no evidence of this (Newell *et al.*, 1982; Seed and Suchanek, 1992). In the field reproductive activity of *M. edulis* has often been correlated with rising water temperatures (Kinne, 1970; Seed, 1976; Bayne, 1975; Hines, 1979).

Annual differences in reproductive condition and fecundity have also been connected with differences in annual food supply (Thompson, 1979; Newell *et al.*, 1982). Spawning has been considered timed such that both larvae and adults have access to abundant supplies of food (Thompson, 1979; Newell *et al.*, 1982) and direct coupling of mussel spawning with phytoplankton blooms has been observed (Starr *et al.*, 1991).

Food supply in form of phytoplank-

ton was not measured at the study site in the present study but investigations from the Faroe shelf show that the phytoplankton concentrations are highest in summer (June-July) and that phytoplankton is sparse after September (Gaard, 2000). The main spawning in the Faroe Islands was observed in early summer. Therefore both adults and larvae had probably access to abundant food during summer.

A gametogenic cycle similar to the one in the Faroe Islands with spawning during summer and developing gonads during winter has been observed in a number of populations in Western Europe e.g. in Ireland (Snooden and Roberts, 1997), Wales (Lowe *et al.*, 1982), Germany (Sprung, 1983), Portugal (Reis-Henriques and Coimbra, 1990), the Baltic (Kautsky, 1982), western Norway (Barkati, 1990) and the Wadden Sea (Pieters *et al.*, 1979). On the east coast of the United States, Brousseau (1983) observed a population with a similar pattern of gametogenesis in Long Island sound. In the Faroe Islands nutrient reserves, which have accumulated in the mantle tissue during the summer, probably have functioned as an energy source for gametogenesis during autumn and winter when food supply was limiting, a process common in bivalves (Gabbot, 1983).

Another pattern of gametogenic cycle is found when carbohydrate stores are used primarily for non-reproductive metabolic requirements during the winter and the gonads are synthesized in late winter and early spring in conjunction with the onset of phytoplankton spring growth followed by spawning in summer. This has been observed in populations in the north-west Atlantic as in Newfoundland (Thompson, 1984), off the east coast (Newell *et al.*, 1982) and the west coast of the United States (Emmet *et al.*, 1987).

Both types of gametogenic patterns occur in *Mytilus edulis* in Iceland. The initiation of gonad development has been observed in January in west Iceland at a sea temperature of 0-1.8°C while on the east coast the gonads starts developing in October at a temperature of 7°C. This is thought to be related to the fact that in autumn food supply measured as chlorophyll-a and winter temperatures are higher in the east than in the west. Spawning starts in June or July (10-11°C) and continues through November at both sites (Thorarinsdóttir, 1996; Thorarinsdóttir and Gunnarsson, 2003).

The gametogenic cycle in the mussels in Faroe Islands is more similar to the one observed on the east coast of Iceland than on the west coast. However, the onset and duration of spawning is different at the two sites and can probably be related to the difference in sea temperatures observed. The sea temperature in the Faroe Islands does not fluctuate as much as in Iceland. The maximum sea temperature is observed in August/September in Faroese waters with monthly averages at 9.4-10.7°C and in August in Icelandic waters at 9.8-11.0°C. At both sites the minimum sea temperature is observed in March which is considerably lower in Icelandic (0-2°C) than in Faroese waters (4-5°C). The spring temperature is higher in Faroe Islands and probably therefore the gametogenesis starts earlier and is followed by earlier spawning.

Mytilus edulis populations may adapt to develop gonads and spawn at different temperatures at different locations but there can also be a local variation and even year to year variations within a population (Lowe *et al.*, 1982). The present study underlines that generalizations about pattern of the gametogenic cycle and spawning in populations in the North Atlantic are difficult.

Acknowledgements

We thank Halldóra Skarphéðinsdóttir and Elena Guijarro Garcia at the Marine Research Institute in Reykjavík for their assistance in the laboratory.

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