

Myxidium gadi (Georgévitch, 1916) and *M. oviforme* (Parisi, 1912) in the Gall Bladder of Cod (*Gadus morhua* L.)

Myxidium gadi (Georgévitch, 1916) og *M. oviforme* (Parisi, 1912)
í Gallbløðruni á Toski (*Gadus morhua* L.)

Magnus Gaard

Museum of Natural History, Debesartrøð, FO-100 Tórshavn, Faroe Islands; Email: magnusg@ngs.fo

Úrtak

Við tífyri eyga at kannan móguleikar fyri nýtslu av fiskasnfikum til lívfrøðilig merki á fiskastovnum, vórðu 256 gallbløðrur úr toski kannaðar fyri myxosporidiir. Á 7 ymsum støðum á landgrunninum, og á einari støð á Føroya banka vórðu royndir tiknar við Magnus Heinasyni á sumri 1998.

Um hugt verður eftir snfikum í toski á Føroya Banka í mun til sníkar í toski á landgrunninum, bæði í hesum kanningunum og í kanningum framdar frammanundan, er væl móguligt, at skilja stovnarar at við at hyggja eftir snfíkunum.

Tvey sløg av myxosporidium, *Myxidium oviforme* og *Myxidium gadi*, vórðu funnin í gallbløðrum í toskinum á landgrunninum. *Myxidium oviforme* var, allastaðni á landgrunninum, í 10-34% av gallbløðrunum. *Myxidium gadi* var einans funnin í 4 toskum av Munkagrunninum, og 4 yngri toskum av Nólsoyarfirði.

Abstract

With usage of parasites as biological indicators in mind, 256 gall bladders from cod were examined for myxosporidian infections. On seven different locations on the Faroe Plateau, and one on the Faroe Bank samples were taken with the research vessel Magnus Heinason in the summer of 1998. Parasites can be used as indicators of the Faroe Bank cod in relation to the cod on the Faroe Plateau.

Two species of myxosporidians were found in the

cod from the Faroe Plateau, *Myxidium oviforme* and *M. gadi*. *Myxidium oviforme* occurred on all stations with a prevalence from 10% to 34%. *Myxidium gadi* was only found on one station south west of the Faroes, and in young cods in Nólsoyarfjørður.

Introduction

Parasites as biological tags.

On different locations in the North Atlantic ocean parasitological investigations of cod (*Gadus morhua* L.) have been made in attempts to find suitable parasites for stock delimitation and as indicators of migration of cod stocks. In the New Foundland area Khan *et al.* (1980) used differences in prevalence of *Trypanosoma murmanensis* on different locations to map migration and intermingling of different stocks in the autumn season. Khan *et al.* (1986) also investigated myxosporidians in the gall bladder of 28 different fish species, amongst other cod. On Flemish Cap, where cod is believed to be relatively isolated, 92% of the

examined cod were infected with *Myxidium gadi*. In other areas around New Foundland the prevalence was 23%-48%. Other parasites have been found suitable as biological indicators of migration and stock delimitation of cod in the New Foundland area (Khan and Tuck, 1995).

In the New England area the copepod *Lernaecera branchialis* was investigated for its potential as a biological indicator of cod stocks (Sherman and Wise, 1961).

Comparisons between the parasite fauna of cod in the Barents Sea and Balsfjord in North Norway showed that many parasites were potential biological tags (Hemmingsen *et al.*, 1991). Especially *Myxidium* sp. was thought to have a large potential as a biological indicator because of the long duration of the infection. *Myxidium* sp. was later found to comprise two species *Myxidium bergense* and *Myxidium oviforme* (Larsen *et al.*, 1997). The duration of the infections of the digeneans in the digestive tract of cod is less than a year, and this single fact makes the digeneans less suitable as biological indicator. Nevertheless Hemmingsen *et al.* (1991) find *Hemiuris levinseni* suited because of the high prevalence in the fjords. Kjøie (1984) also argues that digeneans might be useful biological indicators because of their high intermediate host specificity. This narrows down the area where the cod can get infected. Thus migration can be determined more precisely.

The larvae of the nematodes *Anisakis simplex*, *Pseudoterranova decipiens* and *Phocascaris* sp. are found useful as biological indicators because of a long duration of

the infection. Adult stages of nematodes such as *Cucculanus cirratus* and *Hysterothylacium aduncum* are not found useful because of the short duration of the infection (Hemmingsen *et al.*, 1991).

Further north in the West Murman part of the Barents Sea in the Kislaya inlet and the Ura inlet Karasev *et al.* (1996) examined 165 cod specimens and found 36 parasite species. In these studies *Echinorhynchus gadi* and *Anisakis simplex* were found the most suitable biological indicators. In Greenland Boje (1987) did use the parasites *Hemiuris levinseni* and *Hysterothylacium aduncum* to separate the cod into fjord and ocean stocks. In the area around Bornholm, Buchmann (1986) finds the prevalence of the metacercarian stage of *Cryptocotyle lingua* to be very low 0-3.5%. Two different cod stocks in the Baltic Sea are separated at the Bornholm area, and Buchmann (1986) explains the low infection frequency as a result of intermingling between the highly infected cod to the west, and the non infected cod to the east of Bornholm.

The use of parasites as biological indicators, and the criteria that have to be set when choosing parasites for fish stock investigations are best reviewed in Kabata (1963), MacKenzie (1987), Lester (1990), Moser (1991), Williams *et al.* (1992) and MacKenzie and Abauza (1998).

The parasite fauna of the Cod of the Faroe Plateau and the Faroe Bank

Several studies have been made on the parasite fauna of the Faroe Plateau and the Faroe Bank cod. Only very few of these investigations were intended for finding para-

Table 1. Investigations made on the parasite fauna of cod, with the intention of finding suitable biological indicators for delimitating stocks or finding migration routes.

PARASITE	REFERENCE
Protozoa, <i>Trypanosoma murmannsis</i> <i>Myxidium oviforme/gadi</i>	Khan <i>et al.</i> (1980) (Newfoundland) Larsen <i>et al.</i> (1997) (Barents Sea), Khan <i>et al.</i> (1986) (New Foundland)
Digenea, <i>Cryptocotyle lingua</i> (metac.) <i>Hemiuris levinseni</i> .	Buchmann (1986) (Baltic Sea) Boje (1987) (Greenland)
Nematoda, <i>Hysterothylacium aduncum</i>	Boje (1987) (Greenland)
Copepoda, <i>Lernaeocera branchialis</i>	Sherman and Wise (1961) (New England)

sites suitable as indicators of cod stocks, and are usually based on a relatively low number of cods examined.

Køie (1993) has made a host-parasite list for all nematodes occurring in 43 different fish species in the Faroe Islands. Køie (1984) examined digeneans in 40 cods. Køie (2000) publishes a complete list of all parasites, except protozoans, in the 43 examined fish species. Højgaard (1998) investigated prevalence of *Lernaeocera branchialis* in cod to find out whether the infected cod had a significantly lower condition factor (cf) than the non-infected cod. Kreiss (1952) examined and described the nematode *Contraecum clavatum*. According to Køie (1993) *C. clavatum* (Kreiss 1952) is *Hysterothylacium aduncum*.

Kreiss also described *Echinorhynchus gadi* from cod. Platt (1975) comes closest to making quantitative investigations of a relatively large number of cod, with the intention of using the parasites as biological indicators. Stephenson (1929) found four different copepod species in cod from the Faroe Islands. These are *Lernaeocera branchialis*, *Clavella adunca*, *Caligus curtus* and *C. rapax*.

Another investigation should also be mentioned although cod was not the examined fish. Kabata (1963), examined myxosporidians in the gall bladder of whiting (*Merlangus merlangus*) and haddock (*Gadus aeglefinus*) in the North Sea and the Faroe Islands. This is one of the first studies where parasites were considered as biological indicators.

Table 2. Platt's investigations, which are based on a reasonably large number of cod specimens, *P. decipiens* is clearly suited as a indicator for migrations between the investigated localities, and as a delimitator of the stocks.

(Platt 1975)	FAROE PLATEAU	FAROE BANK
<i>P. decipiens</i>	61% (n: 104)	1% (n: 278)
<i>A. simplex</i>	86% (n: 104)	73% (n: 278)

Materials and methods

Choice of parasites

The choice of *Myxidium gadi* and *M. oviforme* is based on former investigations, and the criteria set up by Kabata (1963), Mackenzie (1987), Lester (1990), Moser (1991), Williams *et al.* (1992) and Mackenzie and Abaunza (1998). The weakness of

using these parasites as indicators is, that their lifecycle is poorly understood. Their greatest advantage is that they are highly tissue specific, and are believed to stay in the fish for several years.

Sampling and species identification

The cod was caught by trawl on seven different stations with the fisheries research vessel Magnus Heinason. On each station 30-38 cods were sampled. Length and

weight was measured, and otoliths and gall bladders kept for laboratory investigations. On one station in Nólsoyar fjord the cods were caught with line and the gallbladders examined for myxosporidians while still fresh, to get correct size measurements.

In the laboratory a drop of bile was taken from each gall bladder and examined under the microscope at a magnitude of 400X and in some cases 1000X. Some specimens were mounted in DPX, and are deposited at

Table 3. A list of all the parasite species found in/on cod from the Faroe Islands.

Myxozoa	<i>Myxidium oviforme</i> Parisi (1912)	This study
Myxozoa	<i>Myxidium gadi</i> Georgévitch (1916)	This study
Digenea	<i>Prosorhynchoides graciliscens</i> (Rudolphi, 1819) Stunkard (1976)	Køie (2000; 1984)
	<i>Prosorhynchus squamatus</i> Odhner (1905)	Køie (2000; 1984)
	<i>Podocotyle reflexa</i> (Creplin, 1825) Odhner (1905)	Køie (2000; 1984)
	<i>Lepidapedon elongatum</i> (Lebour, 1908) Nicoll (1910)	Køie (2000; 1984)
	<i>Lepidapedon rachion</i> (Cobbold, 1858) Stafford (1904)	Køie (2000; 1984)
	<i>Hemiuris leviseni</i> Odhner (1905)	Køie (2000; 1984)
	<i>Lechitochirium rufoviride</i> (Rudolphi, 1819) Luhe (1901)	Køie (2000)
	<i>Dero genes</i> sp.	Køie (2000; 1984)
Nematoda	<i>Capillaria gracilis</i> (Bellingham, 1840) Travassos (1915)	Køie (1993)
	<i>Anisakis simplex</i> (Rudolphi, 1845) Dujardin (1845)	Køie (1993); Sørensen (1988); Platt (1975)
	<i>Pseudoterranova decipiens</i> (Krabbe, 1878) Gibson and Colin (1982)	Køie (1993); Sørensen (1988); Platt (1975)
	<i>Contracaecum osculatatum</i> (Rudolphi, 1802) Baylis (1920)	Køie (1993); Sørensen (1988)
	<i>Contracaecum</i> sp.	Køie (1993); Kreiss (1952)
	<i>Hysterothylacium aduncum</i> (Rudolphi, 1803) Deardorff and Overst (1981)	Køie, (1993); Sørensen (1988)
	<i>Hysterothylacium rigidum</i> (Rudolphi, 1809) Deardorff and Overst (1981)	Køie (1993)
	<i>Cucullanus cirratus</i> Müller (1777)	Køie (1993)
	<i>Ascarophis morhua</i> van Beneden (1871)	Køie (1993)
	<i>Ascarophis crassicollis</i> Dollfus and Campana-Rouget (1956)	Køie (1993)
Achantocephala	<i>Echinorhynchus gadi</i> Zoega in O.F. Müller (1776)	Køie (2000); Kreiss (1952)
	<i>Corynosoma</i> sp.	Køie (2000)
Copepoda	<i>Holobomolochus confusus</i> (Stock, 1953) Vervoort (1969)	Køie (2000)
	<i>Lernaecera branchialis</i> (Linnaeus, 1767) Wilson (1917)	Køie (2000); Stephenson (1929) and Højgaard (1998)
	<i>Clavella adunca</i> (Strøm, 1762) Dollfus (1953)	Stephenson (1929); Køie (2000)

the Faroese Museum of Natural History, Tórshavn. The procedure for the species identification is according to Lom and Dýkova (1992), and the size measurements are compared to MacKenzie and Kalavati (1995).

Calculations

Definition of prevalence of infection in this study is defined by Margolis *et al.* (1982) as fish examined divided by fish sampled.

The condition factor is calculated as $\text{Weight (g)} \times 100 / \text{length (cm)}$. The condition factor is a measure of the state the fish is in. In Højgaard (1998), the condition factor is significantly higher in fish infected with *Lernaecera branchialis* than in uninfected fish. If a fish is negatively affected by an infection, the infecting parasite loses value as a biological indicator.

The average measures of the polar capsules and the spores are given with Standard errors at 68% confidence limits.

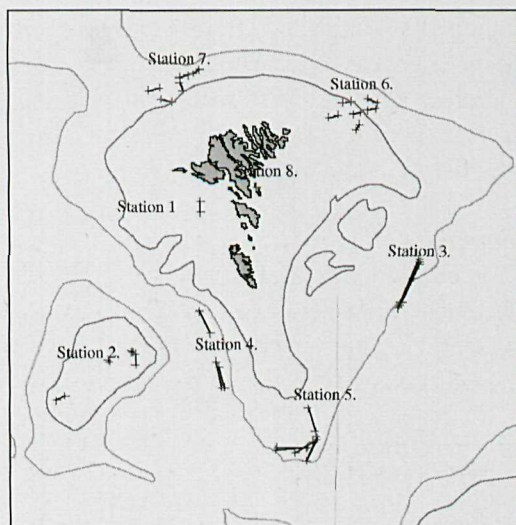


Fig. 1. Map of the Faroe Islands with 200 and 500 m depth curves, showing the geographical position of the stations.

Results

Condition factor

Since a pathogenic parasite would be unsuited as a biological indicator I decided to test pathogenity indirectly by comparing the condition factor of uninfected fish with the condition factor of the infected fish. It is clear from Table 5 that the parasites have no

Table 4. Size measures of the spores and the polar capsules in μm .

	<i>Myxidium oviforme</i>				<i>Myxidium gadi</i>			
	The spore		Polar capsule		The spore		Polar capsule	
	Length	Width	Length	Width	Length	width	Length	width
My own	12.75	8.40	3.85	3.35	13.05	5.90	3.45	2.50
S. E.	+/- 0.977	+/- 0.68	+/- 0.67	+/- 0.67	+/- 0.94	+/- 0.72	+/- 0.60	+/- 0.69
MacKenzie and Kalavati (1995)	14.86	8.93		4.85	14.00	6.35	3.90	3.23
S. E.	+/- 1.45	+/- 0.38		+/- 0.72	+/- 0.95	+/- 0.73	+/- 0.42	+/- 0.54

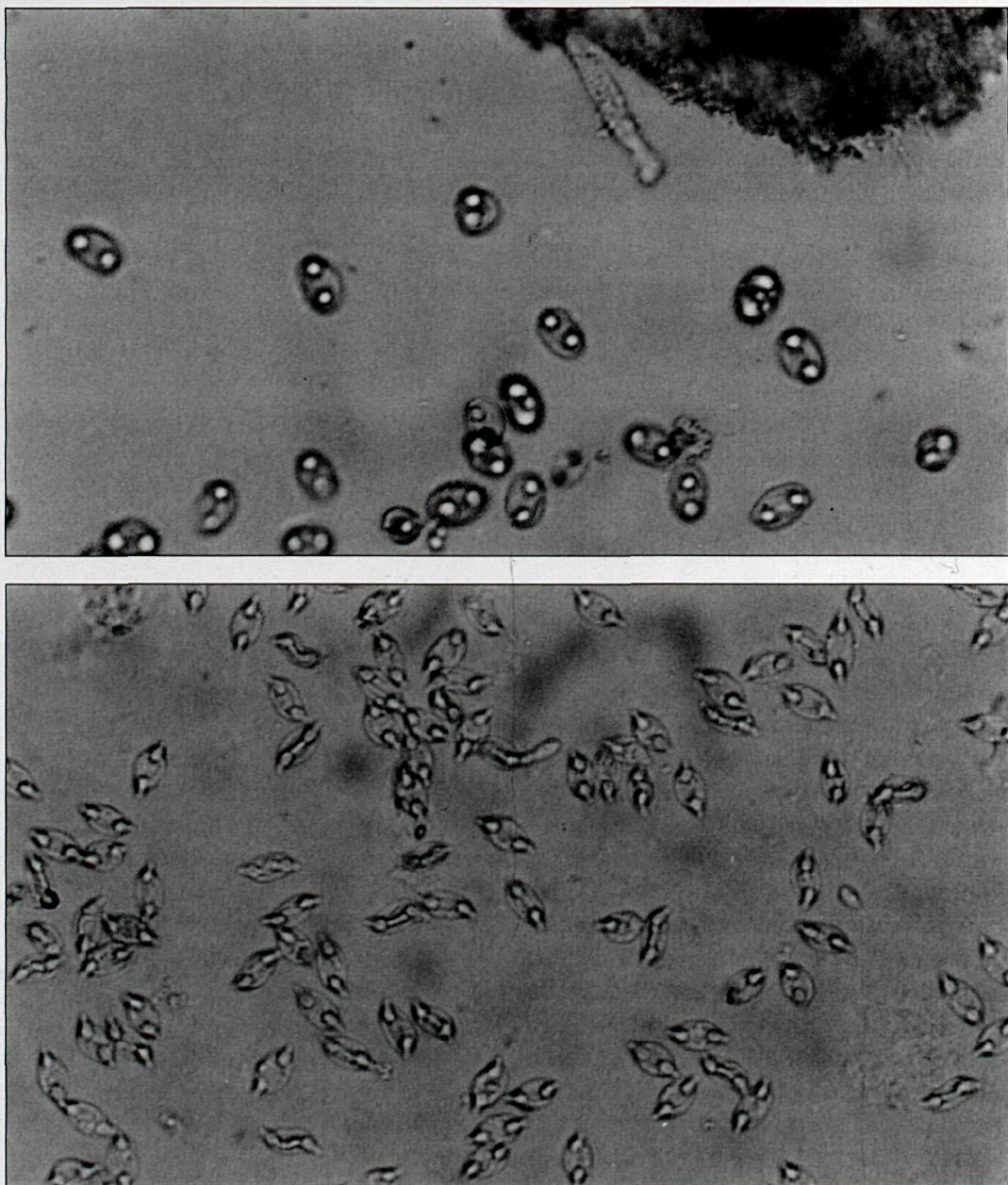


Fig. 2. On top is a picture of the spores of *Myxidium oviforme*, and below are the spores of *M. gadi*.

significant negative effect on the condition factor of the fishes.

Difference in prevalence between age groups

To make sure that a difference in prevalence between localities is real, a good picture of the infection of different age groups can exclude the possibility that the differences in prevalence at different localities are caused by unequal distribution of different agegroups samples at the different stations (Table 6).

It looks as if the the older fishes are more frequently infected with *Myxidium oviforme*, while it is hard too say wether the same pattern accounts for *Myxidium gadi* because of the low number of fish infected.

Table 5. The myxosporidians in this study have no pathogenic effects on cod

Cf.	Uninfected	Myxidium oviforme	Myxidium gadi
Average	0.93	0.90	0.95
+ / - S. E.	0.01	0.01	0.04

Geographical differences in prevalence

The basic criteria that must to be fulfilled before a parasite can be used as an indicator, is that there are statistically significant

differences in prevalence of infection between the geographical areas where the cod is studied (Table 7).

There is a significant difference in the prevalence of *Myxidium gadi* χ^2 (P=0.005) between localities. Besides from station 2 (Faroe Bank) there is no significant difference in prevalence of *Myxidium oviforme* between stations. None of the parasites were found on the Faroe Bank.

Discussion

The Faroe Bank cod

None of the examined cods from the Faroe Bank were infected with *Myxidium gadi* nor *Myxidium oviforme*. In Højgaard (1998) 1 out of 52 examined fishes was infected with *Lernaeocera branchialis* while the cod from the Faroe Plateau had a prevalence from 30-90%. Platt (1975) showed that the prevalence of *Pseudoterranova deceptiens* was significantly higher on the Faroe Plateau than it was on the Faroe Bank.

We can conclude, based on former and present investigations, that the cod stock on the Faroe Bank, based on parasitological investigations, can be delimited as a separate cod stock. Migrations between The Faroe Bank and the Faroe Plateau could be detected by looking at the parasite fauna of

Table 6. The prevalence of infection of different age groups of cod.

	2-year olds	3-year olds	4-year olds	5-year olds	6-year olds	7-8-year olds
M. oviforme	9	10	3	19	20	22
M. gadi	9	0	0	2	3	0

Table 7. Prevalence of infection at the different stations cod were sampled.

	Stat. 1	Stat. 2	Stat. 3	Stat. 4	Stat. 5	Stat. 6	Stat. 7	Stat. 8
<i>M. oviforme</i>	12	0	34	23	10	13	27	12
<i>Myxidium gadi</i>	0	0	0	13	0	0	0	12

a reasonably high number of cods.

Magnussen (1993) was not able to delimitate the Faroe Bank cod from the Faroe Plateau cod using isozyme markers. Recently more advanced molecular methods such as AFLP as described by Vos *et al.*, (1995) and methods using microsatellite markers have proven to be ideal tools in revealing the genetic variation amongst populations. Faroe Bank and Faroe Plateau cod would be interesting subjects to such investigations. In Iceland Jónsdóttir *et al.* (1999) were able to discriminate between to different genotypes.

Traditional tagging experiments support the delimitation of the Faroe bank cod (Tåning, 1943).

Whether the cod on the Faroe Bank stays on the bank throughout its entire lifespan is impossible to say, unless further knowledge on the parasites lifecycle and the parasites intermediate hosts geographical distribution is known.

The Faroe Plateau cod

Myxidium oviforme evidently has an equal distribution throughout the Faroe Plateau, which makes the parasite unsuitable as an indicator of any kind on the plateau. The prevalence seems to increase with age, which indicates a life long duration of the infection.

Myxidium gadi was only found in a sparse number of fish on two of the stations. Whether *Myxidium gadi* is restricted to cod in these areas, or has a clustered distribution throughout the region can only be acknowledged by examining a larger number of fish using a different sampling strategy.

Lernaeocera branchialis has an interesting geographical distribution in prevalence of infection on the Faroe Plateau (Højgaard 1998 and my own observations). The cod from the southern part of the Faroe Plateau seems to be less frequently (appr. 10%) and less severely infected than the cod on the Northern part of the plateau (appr 90%). The prevalence in samples taken on the spawning grounds in spring is somewhere in between (35%). This indicates intermingling of cod from the entire Plateau during spawning. Same migrational pattern has been shown for the Faroe plateau cod using traditional tagging (Tåning, 1943).

The North Atlantic

In the New Foundland area the prevalence of *Myxidium gadi* on different locations ranges between 23-48%. On Flemish cap the prevalence is 92% (Khan *et al.*, 1986). My own investigations indicate a much lower prevalence of *Myxidium gadi* on the Faroe Plateau, and absence on the Faroe

Bank. In the North Sea there is also an absence of *Myxidium gadi* in cod. In Norwegian waters *Myxidium gadi* also seems to be absent.

Myxidium oviforme shows an opposite pattern in distribution throughout the North Atlantic ocean. Although examining 925 specimens of cod no infection was found by Khan *et al.* (1986). My own investigations show a prevalence between 10-34%, which is approximately the same prevalence that Mackenzie and Kalavati (1995) find in the North Sea. In the Barents Sea the prevalence is 8-27%, and in two Norwegian fjords the prevalence is 47-73% (Larsen *et al.*, 1997). In the West Murman part of the Barents Sea Karasev *et al.* (1996) find the prevalence to be 3-9%. It is scientifically impossible to conclude anything on the prevalences in the entire North Atlantic ocean, because sampling procedures and laboratory procedures are not comparable in all the mentioned studies. Nevertheless a large scale study might prove very interesting especially from a phylogenetic point of view.

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