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Effects of predation from juvenile herring on mortality rates of capelin larvae in the Barents Sea

by

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ABSTRACT

In this study, we examine whether predation from juvenile herring has a significant effect on mortality rates of capelin larvae in the Barents Sea, which in turn might affect the year class strength in the capelin stock. Surveys were carried out in summer 2001, 2002, 2003 and 2004. Juvenile herring were sampled by pelagic trawl, and a Gulf III was used to sample capelin larvae and other zooplankton. Hydrographical and acoustic data were also collected. The stomach contents of herring and the zooplankton samples were dominated by *Calanus finmarchicus* and euphausiids. Capelin larvae with lengths in the range 7-25 mm dominated the ichthyoplankton. In 2001, juvenile herring were widely distributed and overlapped with capelin larvae over a wide area. At 11 of 24 stations where herring was caught, capelin larvae were observed in the herring stomachs. Average frequency of occurrence for capelin larvae was 7% (n = 612 herring stomachs). In 2002 and 2004, herring was almost absent from the trawl catches. Herring abundance in 2003 appeared to be higher than in 2002, but lower than in 2001. Large schools of herring were observed in one area, and analysis of three trawl samples from these schools revealed that the herring had been feeding intensively on capelin larvae. Five hundred nine capelin larvae were found in 330 herring and 39.7 of the herring stomachs contained capelin larvae. The effects of abundance of herring and capelin larvae and drift patterns on mortality rates were analysed and are discussed. A total estimate of 7.3% and 9.9% of the capelin larvae were eaten by herring per day in 2001 and 2003, respectively. This refers to stations where herring was presented in the trawl catches.

Keywords: predation, capelin larvae, herring, mortality

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1. Introduction

It has been suggested that juvenile herring (*Clupea harengus*) is an important predator on capelin larvae and a main cause of poor capelin recruitment in years with high herring abundance in the Barents Sea (Hamre, 1994; Hamre, 2003). Herring juveniles drift from the spawning grounds in the south into the Barents Sea as 0-group fish during their first summer and stay for 2-3 years in the southern part of the Barents Sea (Røttingen, 1990; Gjøsæter, 1998). Predation from juvenile herring on capelin larvae has been observed (Huse and Toresen, 2000), but it has been uncertain whether predation mortality is the main cause of the herring impact on capelin recruitment (Gjøsæter and Bogstad, 1998; Mikkelsen and Pedersen, 2004). Huse and Toresen (1995 and 2000) suggested that the predation imposed by juvenile herring on capelin larvae during their investigation in 1992 and 1993 was an important mortality factor in those years. Due to limited knowledge of digestion rates of capelin larvae in herring, it has been difficult to estimate the predation mortality.

The present investigation is a part of the BASECOEX (<u>Ba</u>rents <u>Se</u>a Capelin and Herring-<u>Co</u>existence or <u>Ex</u>clusion) programme. We attempt to investigate whether herring significantly influence mortality rates of capelin larvae in the Barents Sea by sampling capelin larvae and herring in the area and time of the year that is hypothesised to be the main area of predatory interactions between the two species.

2. Material and methods

2.1 Investigation area and trawl sampling

Data were collected on surveys with RV "Johan Ruud" and RV "Jan Mayen" during surveys in June-August 2001 and June-July in 2003 (Table 1), respectively. The survey area was planned to cover the areas based on prior information about abundance of capelin larvae and herring from a survey in June by the Institute of Marine Research.

Herring and other pelagic fish were sampled using a pelagic trawl. The trawl used was a "Harstad" trawl with a 12x12 m opening and an inner net with 10 mm mesh size in the cod end. If no distinct aggregated registrations of fish were observed on the echo sounder, the trawl was hauled with the headline in the surface using buoys. If aggregations were observed, we attempted to trawl at the depth of the aggregations. Each haul lasted 20 minutes, except for the trawling on aggregations.

Table 1 Overview of surveys

Date	Vessel	No trawl hauls	No Coverage	No hauls with herring	No stomachs investigated
31/7-10/8-2001	"Johan Ruud"	54	1	24	674
23/6 - 29/7 2003	"Jan Mayen"	37	1	8	87
29/6 - 6/7 2003	"Jan Mayen"	40	2	8	335

2.2 Acoustical abundance estimation of herring

Abundance of herring was estimated using acoustical echo integration and using the data from the pelagic trawl hauls to allocate the integration values to species and age groups within species. The echo sounder frequency was 38 kHz. To calculate the density of herring for each station, the S_A values were averaged for the nearest 10 nm^2 before and after the station. The target strength (TS) of the herring was estimated using the average length (L) at each station following the relation given by Foote 1987 ($TS = 20 \cdot \log L - 71.9$). For 2001, length at stations where herring was not present in the trawl catches was the length at the nearest station with herring, and for 2003, average length of the total catches of herring that year was used. Total length was converted from standard length as $TL = 1.1507 \cdot SL$ (www.Fishbase.org). The weight of herring was estimated by the function $W = 0.008 \cdot SL^{3.135}$, based on the weight and standard length relation from the 2001 data.

2.3 Abundance of capelin larvae and zooplankton

Shortly before or after each trawl haul, capelin larvae and zooplankton were sampled as close as possible to the trawl trajectory using a GULF III high-speed plankton sampler with mesh size 375 µm (Alvheim 1984). The gear was lowered to about 60 m depth and then hauled up again with a vessel speed of 5 knots and a wire speed of 0.5 m sec^{-1}. Except for in 2001, the exact depth of the GULF III was monitored using a Scanmar depth sensor. A flow meter was used to measure the water velocity through the net in the GULF, and the water volume filtered was subsequently calculated and used in the calculation of abundance. In 2001, 250 m wire was lowered from the gear, which should correspond to approximately 60 m depth.

Capelin larvae and other fish larvae were counted, and larvae and zooplankton were conserved in 96% ethanol in separate bottles. Abundance estimates of the zooplankton taxa were estimated by counting from sub-samples, and copepods were identified to species and stages. Carapax lengths of sub-samples of euphausiids were measured.

2.4 Stomach content analysis

Most of the herring were frozen immediately after hauling the trawl and kept at -18 ^{o} C until analysis at the laboratory. In 2003, 30 stomachs from each haul, if available, were analysed onboard the vessel. The stomachs analysed onboard were kept cool on ice prior to stomach analysis, and stomachs analysed in the laboratory were individually thawed. The length and body wet weight of the herring were measured and the stomachs were dissected. Presence of the characteristic double ventral row of melanophores was used as a secure identification of capelin larvae. Presence of a small vertebrae eye with lens (< 1 mm in diameter) was taken as a secure identification of a fish larva. The numbers of capelin larvae were counted. For most of the stomachs, the presences of the different zooplankton taxa were noted.

Stomachs from 330 herring caught at three stations in 2003 were worked up following the procedure described in Godiksen (2003). These stomachs were divided into five sections and the occurrence of capelin larvae and the volume of different prey occurring in each of the sections were recorded.

2.5 Mortality rates

The number of capelin larvae eaten per herring per day at a given station was calculated by the formula given by Munk (2002): Neaten = Nstomach·D·24h, where Nstomach is the average number of capelin larvae found in the herring at a given station. D is the time of 50% prey recognition and was estimated from a stomach evacuation experiment to be 0.3 larvae per hour (Hallfredsson unpublished). Neaten multiplied with numbers of herring per m^2 as estimated by the acoustics gave numbers of capelin larvae eaten per day per m^2. The numbers of capelin larvae eaten per m^2 as percent of the numbers of capelin larvae per m^2 estimated from the GULF III samples gives mortality of capelin larvae per day.

Spearman Rank Correlation was calculated between density of capelin larvae and percent of capelin larvae occurring in herring stomachs.

3. Results

3.1 Abundance of predators and prey

Herring were mainly distributed in the eastern part of the investigation area in both 2001 and 2003, but closer to shore in the Varangerfjord area in 2001 (Figure 1A). The average standard length of the herring in 2001 was 14.0 cm and the average weight was 33.5g. In

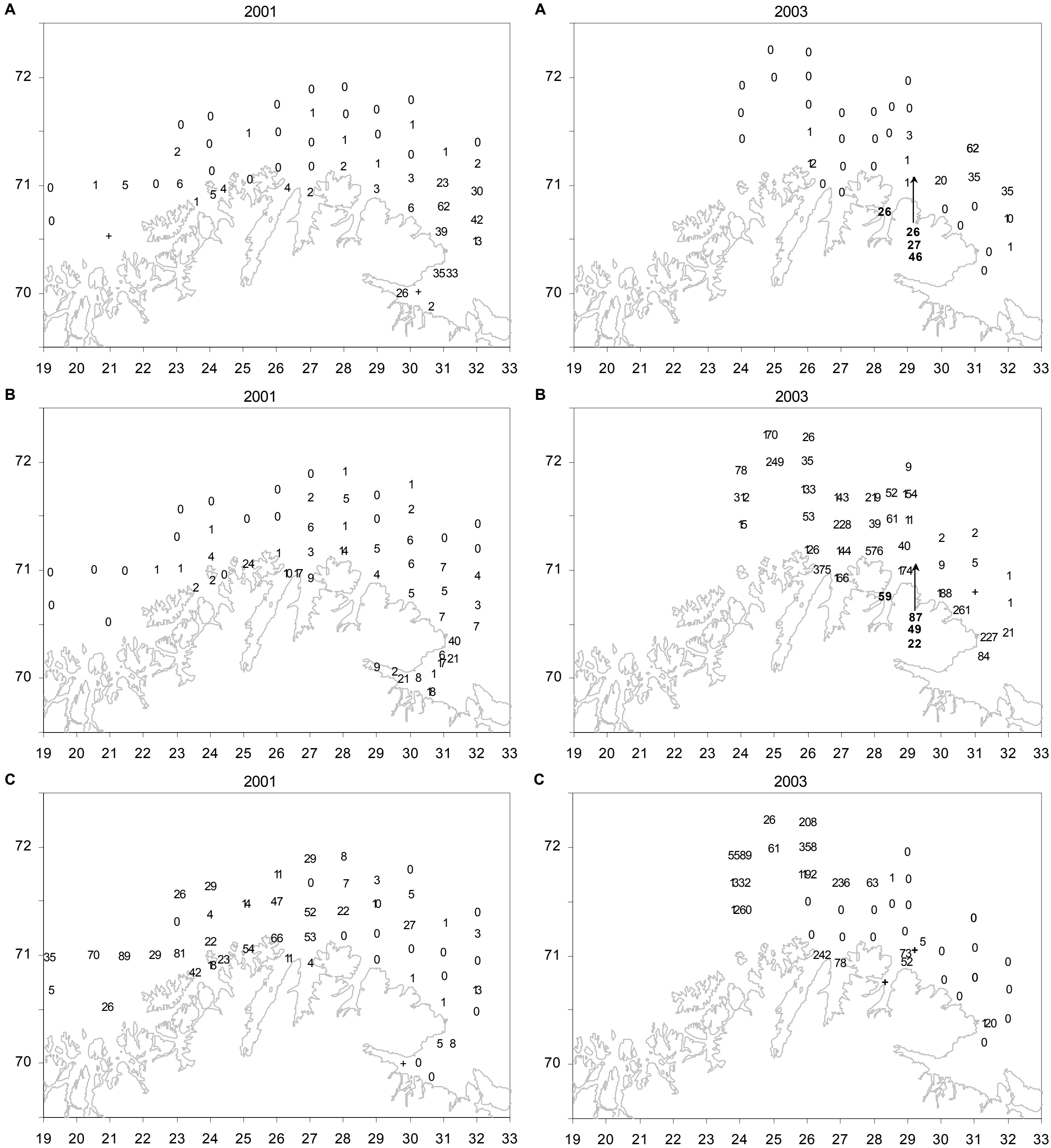

Figure 1. Maps of (A) herring abundance (tons km^{-2}), (B) capelin larvae abundance (ind. m^{-2}), (C) Capelin larvae catches in the pelagic trawl (numbers). The notation + indicates stations with no observations. The arrow indicates the position where three hauls were taken in 2003.

2003, the average standard length was 11.6cm and the average weight was 19.0g. The densities of capelin larvae captured by the GULF were generally low in 2001 with maximum of 40 larvae per m^2 in the Varangerfjord area (Figure 1B). In 2002, the density of capelin larvae was considerably higher than in 2001, with a maximum of 576 larvae per m^2 near the Nordkyn Peninsula. Larvae were noticeably scarce in the northeast part of the investigation area in 2003, an area where herring were abundant that year (Figure 1A). The catches of capelin larvae in the pelagic trawl were more westerly distributed in 2001 compared to the densities estimated from the GULF III samples that year (Figures 1B and 1C). As the GULF III density estimates, the catches of capelin larvae in the trawl in 2003 reflect higher abundances of capelin larvae in 2001 than in 2003 (Figure 1C).

3.2 Occurrence of predation and numbers eaten

Occurrence of capelin larvae in the herring stomachs ranged from 0% to 42% at the stations in 2001 and from 0% to 62% at the stations in 2004 (Figure 2A). The highest

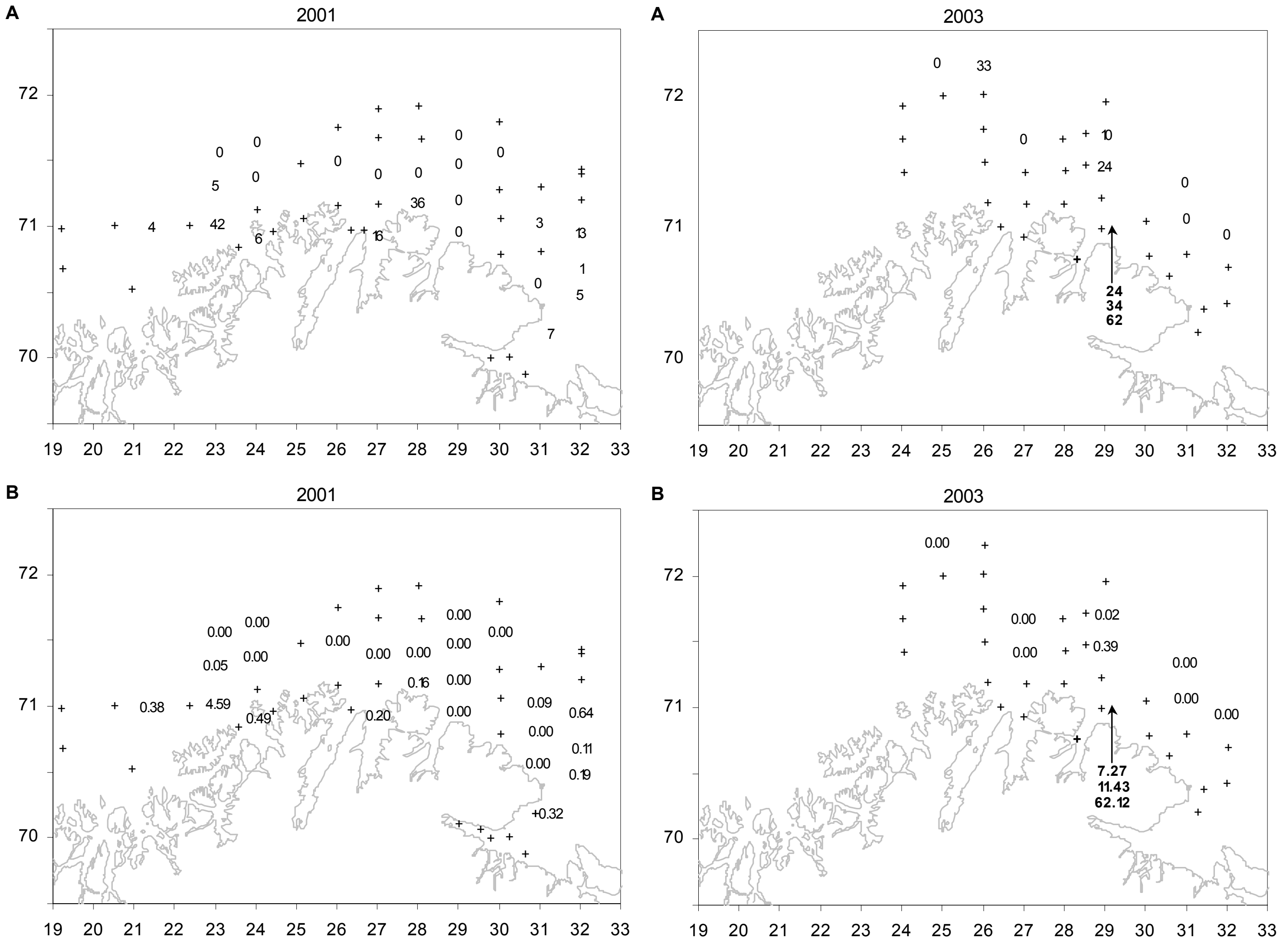

Figure 2. Occurrence in percent of capelin larvae in herring stomachs (A), and estimated numbers of capelin larvae eaten by herring per m^2 per day (B). The notation + indicates stations with no herring caught. The arrow indicates the position where three hauls were taken in 2003.

values in 2003 were at the stations where trawling was aimed for dense shoals of herring. The estimated numbers of capelin larvae eaten by herring per m^2 ranged from 0 to 4.6 in 2001 and from 0 to 62.1 in 2003 (Figure 2B).

3.3 Correlation between capelin larvae density and occurrence of predation

At all stations with herring where density of capelin larvae was higher than 8 per m^2, capelin larvae were found in more than 7% of the herring stomachs (Figure 3). Spearman Rank Correlation between the density of capelin larvae and percent of capelin larvae occurring in the herring stomachs was 0.968 and statistically significant ($P < 0.001$).

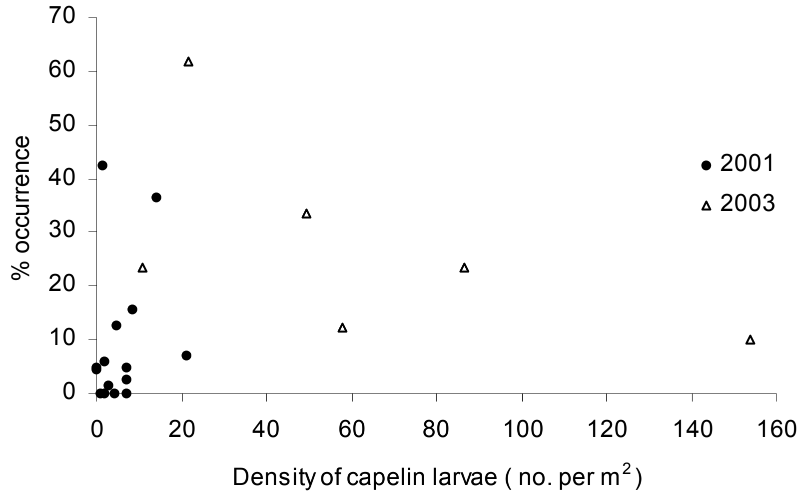

Figure 3. Relation between density of capelin larvae and occurrence of capelin larvae in the herring stomachs. Each data point refers to a single station, except for the stations where numbers of herring in the catches were less than ten, where occurrence and density were averaged for each year.

3.4 Predation mortality

In total for all stations where herring was caught, 7.3% of the capelin larvae were estimated eaten by herring per day in 2001. In 2003 for all stations with herring, 9.9% of the capelin larvae were estimated eaten by herring per day.

4. Discussion

Capelin larvae drift to the north and east from the spawning areas along the coast (Gjøsæter 1998). On their drift route, they may encounter juvenile herring that migrate westward from the wintering area in the southeast Barents Sea to feed on zooplankton (op cit.). The westwards movement of herring along the coast may be a response to heavy zooplankton predation and hence decreased zooplankton abundance in areas with dense herring concentrations. Especially in 2003, it was evident that in the area with high juvenile herring abundance, zooplankton was almost absent from the GULF III samples (Hallfredsson unpubl.). High biomass of juvenile herring was observed, concentrated in the northeast part of the observation area. The estimated abundance of herring (20-60 t km^{-2}) was very high in the area northeast (2001) and north (2003) of the Varanger Peninsula (Figure 2A). Such a high abundance is far above the average density of 1-5 t km^{-2} common for the whole Barents Sea (Bogstad et al. 2000).

The predation interaction between herring and capelin larvae appears to be a very dynamic process in which both predator and prey are moving. In 2003, the predation intensity was high in the area where the "front" of high herring abundance encountered high abundance of prey (> 100 larvae m^{-2}) at about 29° E (Figures 1 and 2). In 2003, we observed heavy predation from dense concentrations of herring on capelin larvae in the area outside Tana (29° E, Figures 1A, B and C). Apparently, the herring had moved westwards during the one-week period between the two coverages in 2003, as aggregations were observed northeast of Tanafjord (E 29°12`, N 71°04`) in the second coverage where low densities were observed in the first coverage. In 2001, the survey was conducted a month later and it appeared that the herring was more spread westwards and predation was frequent over a larger area.

The predation by herring on capelin larvae seems to be correlated with the density of capelin larvae (Figure 3). High occurrence of capelin larvae in the stomachs at low GULF III estimated abundance of capelin larvae was only observed at one station. At that station, however, where occurrence was 42%, there were high numbers of relatively large capelin larvae in the trawl catches (n = 81). This may indicate that the herring is more efficient when catching larger capelin larvae. Even though it is impossible to achieve absolute densities of capelin larvae based on the trawl catches, they are useful as an indicator of presence of larger capelin larvae. Length distribution of capelin larvae showed that the trawl primarily encountered rather large capelin larva (> 20mm in length) (Hallfredsson unpubl.). Herring has been shown to predate selectively on larger capelin larvae (Huse and Toresen 2000). The catches of larger capelin larvae in the pelagic trawl were more westerly distributed especially in 2001, compared to the densities estimated from the GULF III samples that year (Figures 1B and 1C). This may reflect hatching takin place earlier in the spawning areas in the west, rather than being a consequence of predation.

It is evident that the mortality upon capelin larvae caused by predation from herring is considerable, with as much as 9.9% of the capelin larvae eaten by herring in 2003. This, however, may be an overestimate as it does not include stations without herring catches. There are several sources of errors in such an estimate: Prey and predator abundance, stomach content analysis and digestion rate estimates. For example, small shoals of herring near the surface (above ca. 10 m depth) will not be registered by the acoustics, thus the abundances of herring may be underestimated. In 2001, catches of herring in the upper 10 m were frequent in the western part of the distribution area. Some stations had low catches of herring and few herring stomach analysed. This affects the results at these stations. For instance, at 8 out of 12 stations with no occurrence of predation in 2001, the number of herring stomachs was less then 10. The same applied for all stations with no predation in 2003. At almost all stations with numbers of herring stomachs larger than 10 and high abundance of capelin larvae, a relatively high percentage of the herring had eaten capelin larvae (Figure 3).

The survival potential of capelin larvae in the absence of predators seems to be very high. In predator-free bag experiments, the capelin larvae had high survival rate, in average 55% to day 79 after hatching and a mortality rate of about 1% per day, indicating high survival potential at low growth rate in the absence of predators (Ivarjord et al 2004). Capelin larvae have low specific growth rates (ca. 2.3% per day) in the field (Pedersen 2004), and predation mortality in the order of 7-10% can consequently make a huge impact on recruitment. Despite the uncertainties discussed above, the results indicate that the estimated predation rates imposed by juvenile herring may have a considerable impact on capelin larvae mortality in years with high herring abundance.

Further work will i.a. include analysis on the effects of alternative prey on the predation mortality on capelin larvae and prey length preferences for the herring. Further, we will work on the impact of spatial distribution and drift of herring and capelin larvae.

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