The spawning migration of capelin (*Mallotus villosus*) in Icelandic waters

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Summary
Capelin (*Mallotus villosus*) have adapted to the sub-arctic environment by migrating north (67–72°N) to feed during summer in deep cold waters (>500m; 1–3°C) before migrating south (63–65°N) in winter to spawn in warmer shallow waters (<100m; 5–7°C) on the south and west coasts of Iceland. To examine mechanisms regulating location and timing of the spawning migration, acoustic recordings were analyzed from capelin winter acoustic assessment surveys between 1992 and 2007. The southward migration (from 63-67°N) utilized a consistent route within southward flowing cold sub-arctic waters (1–3°C) off the east coast of Iceland. Migration was active and followed the outer shelf edge (>200m bottom depth). Further south (<65°N), after the front with warmer Atlantic waters (>4.5°C) was encountered, the migration route veered inshore (<200m bottom depth) towards coastal spawning grounds. The annual spawning migration moved southward across latitude 67°N between December 23 to January 20 in all years. Both increased spawning biomass and colder summer feeding temperatures resulted in earlier migration. Migration was not continuous but staged. Staging occurred offshore in the transition zone between the offshore and the inshore phase of the migration (63.8-65.8°N). Capelin amassed in the staging area until roe content reached 12–14%.

Introduction
Capelin is one of the most important commercial fish stocks in Icelandic waters and a major forage species as important prey for predatory fish, sea birds and marine mammals (Vilhjálmsson 1994). This small (< 20 cm), pelagic, plankton-feeding, schooling coldwater fish has circumpolar distribution in northern oceans. Capelin migrate between geographically separated spawning, nursing, over-wintering and feeding grounds (Vilhjálmsson, 1994). Every winter pre-spawning capelin migrate 500 to 1000 km from their offshore (>200m bottom depth) northern feeding areas (67–71°N) to inshore (<200m bottom depth) southern spawning areas (63–65°N) (Vilhjálmsson, 1994). Scientists have long been fascinated by the guiding mechanisms of fish migrations. Despite years of study, the sensory organ(s) and mechanisms used for navigation remain largely unknown. However, numerous factors have been linked to location of migration routes and timing of movement. We explore several aspects of the timing and route of the spawning migration of the Icelandic capelin stock.

Materials and Methods
We analyzed digitized acoustic data on abundance and distribution of migratory maturing capelin from the winter (January to March) acoustic assessment surveys of the Marine Research Institute, Reykjavik, Iceland. In total, acoustic recordings were analyzed from thirteen cohorts spawning in 1992-3, 1995, and 1998 to 2007. The survey region was the northwest, north and northeast of Iceland (63 – 68 °N and 8 – 28 °W). As the present study addressed migration of the mature part of the stock, bins having > 50 % juvenile capelin were not used in these analyses. Sea surface temperature (SST) was assumed to be an appropriate proxy for ambient temperature within the epipelagic layer (<200 m in winter) because the thermocline was sufficiently strong between 200 – 300 m that the epipelagic layer was thought to be thermally isolated from deeper waters. We used a daily optimum interpolation SST provided by the National Oceanic and Atmospheric Administration of the United States.

Results and Discussion

Acoustic data revealed a consistent southward route along which capelin migrated actively (ground velocity faster than current velocity) off the east coast of Iceland (and a lesser used route off the west coast) (Olafsdottir and Rose, 2012). North of 65 ºN, the dominant eastern route followed the bathymetry, skirting the shelf edge (> 200 m bottom depth) within a funnel of near constant temperatures (ca. 2.5 ºC). Further south, between 65 and 64 ºN, as temperatures warmed to 4.5 ºC (reaching 7.9 ºC at 63.5 ºN), capelin abruptly moved onto the shelf and towards the coastal spawning areas. Capelin spawning migrations appear to be an innately based southward search for appropriate spawning locations, guided by bathymetry and temperature. We suggest that the extended eastern migration route minimizes exposure to cod predation, and that resent warming conditions north of Iceland may result in a northward shift in migrations and spawning locations, as occurred in 1920s and 1930s.

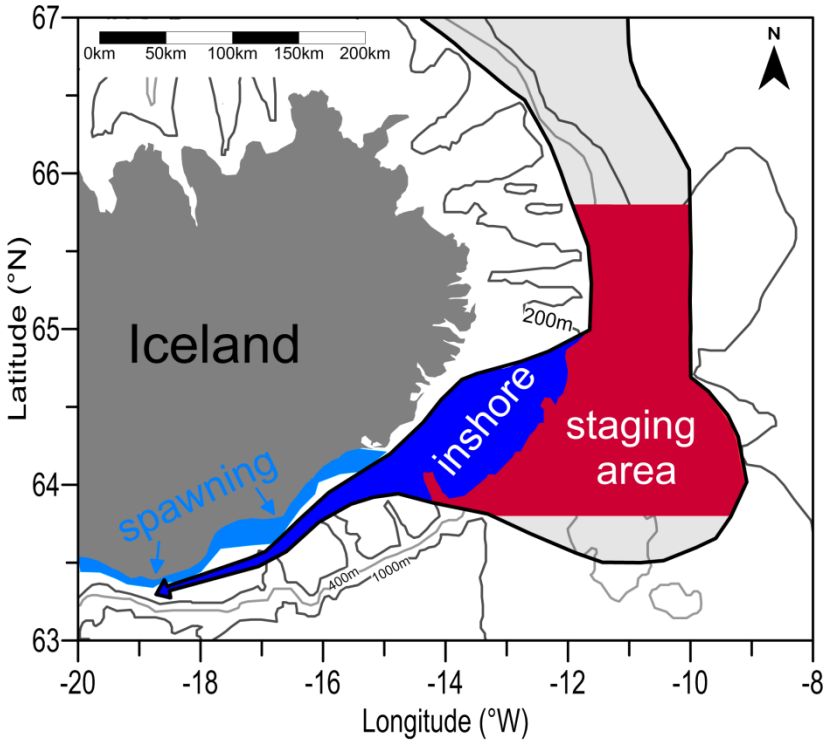

Figure 1. Spawning migration route (within thick black line) of the Icelandic capelin stock displaying staging area and inshore phase.

The major migration route east of Iceland consists of both offshore and inshore phases (Olafsdottir and Rose, 2013). The migration begins (50% of spawning stock biomass passed latitude 67°N) offshore as capelin skirt the shelf edge north of 65°N then veer inshore between latitudes 64–65°N. For the offshore phase, migration timing varied by as much as one month, from December 22 to January 21. A combination of larger spawning stock biomass and colder feeding ground temperatures (August to December) corresponded to earlier offshore migration. The timing of the inshore migration phase was not dependent on the offshore migration timing, and never began prior to the first week of February. Many cohorts arrived at latitudes 64–65°N in early January but staged offshore at latitudes 63.8–65.8°N until early February. The longest observed delay in the staging area was five weeks before the inshore phase was initiated. Timing of the inshore migration was controlled by gonad maturity, with migration beginning when roe content attained 12–14%. Staging limited the time capelin spent on the continental shelf before spawning to three weeks. We suggest offshore staging evolved to minimize temporal overlap with predatory cod.

References

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