

Paper III

Joensen, J.S., Steingrund, P., Henriksen, A., and Mouritsen, R.:

Migration of cod (*Gadus morhua*): tagging experiments at the Faroes 1952-65.

Migration of cod (*Gadus morhua*): tagging experiments at the Faroes 1952-1965

Merkingarroyndir við færoyiskum toski 1952-1965

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Úrtak

Í tíðarskeiðinum 1952-65 vórðu tilsamans 6512 toskar (í miðal 50,7 cm langir) merktir á færoyska landgrunninum. Tilsamans 1043 toskar (í miðal 59,1 cm langir) vórðu fiskaðir aftur (16%), ofta longu tað fyrsta árið eftir merking. Úrslitini vístu, at toskur av øllum landgrunninum savnaðist á Norðhavinum at gýta, og toskur av økinum vestan fyri Sandoy/Suðuroy, umframt Norðhavinum, eisini fór í Vágahavið at gýta. Tað tók toskinum ikki meira enn fáar vikur at koma til ella frá gýtingarøkjunum. Ferðingin uttan um gýtingartíðina var rættiliga avmarkað, og var ofta minni enn 10 fjórðingar frá staðnum, har merkt varð. Tað vóru tó altíð summir toskar, sum fóru til nýggj og meira fjar øki á landgrunninum. Positivt samband var millum ferða- og fiskilongd, og eisini var ferðalongdin ymisk fyri merkingarøkini og hvat ár, sum merkt varð. Sera sjáldan fóru toskar av færoyiskum øki til onnur havøki.

Abstract

During the period 1952-65, 6512 cod (on average 50.7 cm) were tagged on the Faroe Plateau. In total 1043 cod (on average 59.1 cm) were recaptured (16%), often during the first year after tagging. The results showed that cod from all areas of the Faroe Plateau aggregated on

the main northerly located spawning site “Norðhavið” whereas cod south-west of Faroe Islands, in addition to “Norðhavið”, also migrated to a spawning area located west of Faroe Islands (“Vágahavið”). The duration of the spawning migration to or from the spawning areas only lasted a few weeks. The migration, that was not associated with spawning was quite limited, often less than 10 nautical miles from the tagging locality. There were, however, some fish, that moved to new and distant areas on the Faroe Plateau. Migration distance was positively correlated with fish length and varied between tagging areas and years. Extremely few cod moved out of Faroese waters.

Introduction

Knowing the migration pattern of fish populations and fish stocks is a basic requirement in many respects. In commercial fishing, fishing is most profitable when the fish are aggregated, *e.g.* during the spawning season, and Faroese fishing vessels have historically exploited the valuable spawning places south of Iceland (Tåning, 1943). In ecology, the distribu-

tion (a result of the migration pattern) of predators and preys is affecting the structure and trophic importance of food webs (Steingrund and Gaard, 2005). In fisheries management, the migration pattern of commercial fish stocks is often used as a guideline when defining management areas and management units, for example in the Baltic sea (Bagge and Steffensen, 1989). When protecting local fish populations by defining areas closed for fishing (temporarily or permanently), it is crucial to have sufficient information about the migration pattern of the fish populations in question. There are several closed areas in Faroese waters (ICES, 2004).

During its life the cod normally occupies several different areas and habitats. The larvae normally drift with the current from the spawning area to the nursery area for fry or juvenile fish. The juvenile fish migrate to the feeding grounds of adult fish when they are large enough. When sexually mature the adult cod migrate to the spawning area in spring and return to the feeding area after spawning. Some Canadian cod stocks occupy an overwintering area after the feeding season in summer/autumn and the spawning season in spring (Chouinard and Swain, 2005). Some populations of cod may not occupy all these three (or four) different areas, since the nursery area sometimes is the more or less the same as the feeding area, as is the case in *e.g.* the Barents Sea (Ottersen and Sundby, 2005). The feeding area may also be more or less the same as the spawning area (*e.g.* close to the spawning area “Norðhavið” on the Faroe

Plateau, unpubl.). Some cod stocks occupy the same area regardless of individual size or season, *e.g.* on the Faroe Bank (unpubl.).

The migration pattern of cod may not be constant versus time. Nursery areas may change as observed in the North Sea where the German Bight gradually lost its importance as nursery area for juvenile cod (age 1) from 1971-2002 (Blanchard *et al.*, 2005). Spawning areas may also change as observed for West Greenland offshore cod (Wieland and Storr-Paulsen, 2005) and Arcto-Norwegian cod (Ottersen and Sundby, 2005). Feeding areas may also change as observed for West Greenland offshore cod in 1989-1991 that moved to East Greenland waters (Wieland and Storr-Paulsen, 2005). On a broad scale, the migration pattern seems to be more robust for north-east Atlantic cod stocks compared to the north-west Atlantic (Robichaud and Rose, 2004).

On a broad scale, the migration pattern of cod groups may be grouped into four: sedentary, accurate homers, inaccurate homers and dispersers (Robichaud and Rose, 2004). Sedentary groups had lower biomass than the others confirming that migration/dispersal begets abundance (Robichaud and Rose, 2004). The authors also hypothesised that the migration pattern was dependent on hydrographic conditions (“oceanographic regimes”). In the north-east Atlantic the environment is characterised by predictable oceanographic conditions leading to fairly stable migration patterns whereas the opposite is the case in the north-west Atlantic. Cod on

the Faroe Plateau were classified as “accu-rate homers” according to Robichaud and Rose (2004).

The first tagging experiments with cod at the Faroes were conducted between 1909-13 (Strubberg, 1916), and additional taggings were performed in the 1920s (Strubberg, 1933). The majority of the fish were small (35-45 cm, 2 years) and were recaptured very near the tagging site, *i.e.* very limited migration. The fishing intensity in the tagging area was very high, and thus very few tagged fish reached sexual maturity, thus leaving little information about spawning migration.

Spawning migration was investigated in tagging experiments during 1927-37, when large cod (average size 80 cm) were tagged at the main spawning site “Norðhavið” during spawning in March-May (Tåning, 1940). The results showed that cod left the spawning area after spawning and were fully dispersed around the Faroe Plateau during summer and autumn. They aggregated again at the same spawning location in subsequent years, and the migration distance ranged between almost zero to about 120 nautical miles. No tagging was performed on the western spawning site “Vágahavið” (Tåning, 1940; Jákupsstovu and Reinert, 1994).

The tagging experiments in Strubberg (1916; 1933) also showed that small, immature cod usually were distributed in shallow waters (< 100 m depth) whereas mature cod (> 70 cm) frequently were found down to 200 m depth (Tåning, 1940), *i.e.* cod moved to deeper waters when they grew larger.

The goal of the tagging experiments in 1952-65 was to get more information about spawning migration and to investigate the migration pattern of cod, that was not associated with spawning. A small part of the material was published in Joensen (1956), but the rest of the 1952-65 material had to wait 40 years before it was published in the current article. The reader may wonder why so old results should be worth publishing, but as stated earlier, the migration pattern may change with time and a thorough understanding of migration patterns requires studies during different time periods. When publishing other tagging experiments (initiated in 1997, see later), the 1952-1965 material may be very valuable. In the interest of space, fish growth is not dealt with in this article.

After the tagging experiments in 1952-1965 (the current article), extensive English tagging experiments with cod were performed during the period 1961-1967. In total 11442 cod were tagged and 2141 recaptured. A part of the material is published in Jones (1966), but migration was only briefly dealt with.

In the period 1994-95, sea ranching experiments were conducted with pen-reared cod on Faroe Plateau and Faroe Bank (Fjallstein and Jákupsstovu, 1999). About 50000 individuals were released on Faroe Bank, but only about 200 were recaptured. On the Faroe Plateau, about 8000 individuals were released and about 1200 have been recaptured up to 2004. They were released in shallow waters (< 50m) in a sound between the two largest islands. They dispersed from the sound

to deeper waters (50-100m) close to the islands (Fjallstein and Jákupsstovu, 1999). When they reached commercial size (> 50 cm), they were recaptured on traditional cod fishing grounds at depths between 50-150 m (unpubl.).

From 1997 to present, extensive tagging experiments have been performed with cod (Steingrund, 1999; unpubl.). In these experiments, cod were larger (50-70 cm) and usually tagged in deeper waters (90-400 m) than in the 1952-65 material. The results from these experiments are only dealt with if they have direct relevance to the 1952-65 material.

Materials and methods

Tags

Cod during many of the experiments (see Appendix 1) were tagged with ebonite discs as described in Strubberg (1933). Lea's hydrostatic tag was otherwise used (Anon., 1953; Jónsson, 1996). The ebonite discs were attached to the operculum and the Lea tags in front of the first dorsal fin.

Tagging procedure

The tagging experiments were normally performed twice a year, during spring and autumn. In the period 1952-64, small open boats or cutters were hired, whereas the research vessel "Svabo" was used during 1964-65.

The fish were mainly caught by hand-line, using natural bait, and sometimes by hand-jigging, using artificial bait. Longline or trawl was used in a few cases. Only fish in excellent condition were

tagged. The length was recorded (usually rounded down to whole centimeters) and the fish released.

When catch rates became too low in a particular place, the boat moved to another place. Weather conditions sometimes determined which places were selected for tagging experiments.

Publicity and rewards

There was a regular communication with fishermen both by articles in local newspapers and personal communication. The reward was usually 5 DKK per tag, corresponding to about 100 DKK today (about \$17). We assume that the reward, personal contact and communication to Faroese fishermen has been sufficient in order to keep the interest in the project on a high level. It is possible, however, that foreign fishermen (from England and Scotland) may not have had the same interest.

Recaptured fish

We tried to collect as much information about recaptured fish as possible, *i.e.* date, position, fish length, weight, sex, maturity and age (from otoliths).

The position of recapture was often reported as a distance from one or two landmarks, or as a name of a fishing site, and coordinates (latitude and longitude) were set later by the first or fourth author. No coordinates were set if the description was too imprecise, *e.g.* when two far-away locations were equally likely. The positions near land reported mainly by Faroese fishermen were normally considered to be accurate. This was not always the case for

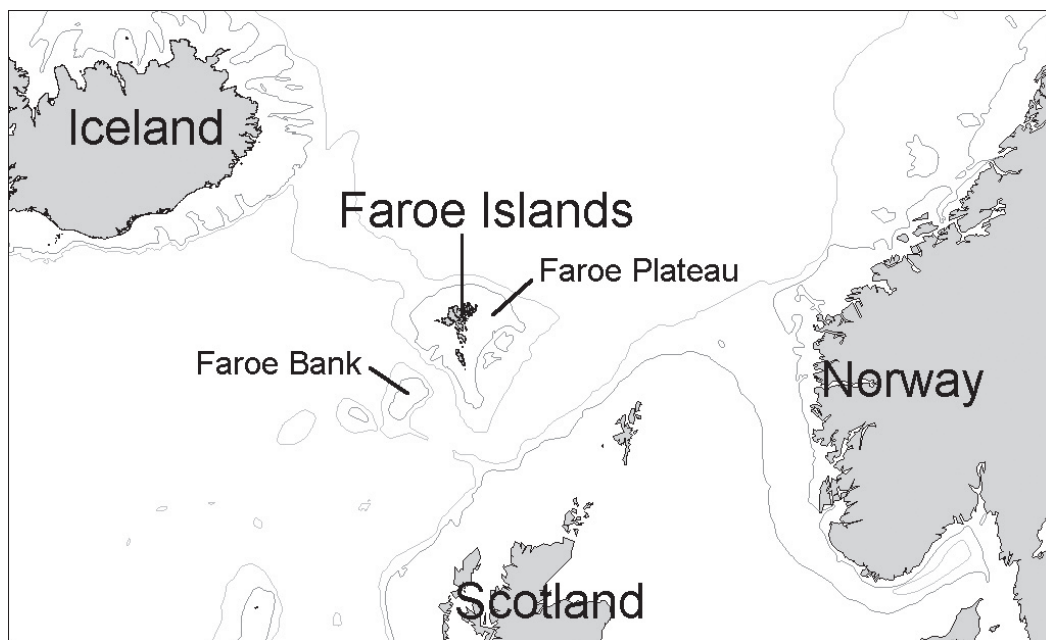


Figure 1. The study area in the waters off Faroe Islands (located at approximately 62°N 7°W), more precisely on the Faroe Plateau (ICES statistical rectangle Vb1). Faroe Bank (ICES statistical rectangle Vb2) is a shallow area south west of Faroe Islands. The 200 and 500 m depth contours are shown.

English and Scottish trawlers who sometimes used rather imprecise locations like “off Mykines” (a large area south, west and north of the westernmost island Mykines). In these occasions the most likely position was set, partially based on the present abundance and distribution of cod. Depth at recapture was often recorded and may in some cases not correspond perfectly to the position of recapture. No attempt has been made to correct position or depth. When assessing fish age, otoliths were broken at the middle and the yearly rings counted. Data about tagged and recaptured fish were written by hand. The fourth author punched the data into an electronic format. The second author looked over all

data and corrected obvious errors, in cooperation with the fourth author.

Statistics

Mann-Whitney U-test (Sokal and Rohlf, 1995) was used to test whether migration distance depended on food.

A general linear model (GLM) – multiple regression (Sokal and Rohlf, 1995) – was used when testing which factors (or variables) influenced migration distance. In multiple regression, one variable (in this case migration distance, termed the dependent variable) is explained by two or more variables (in this case fish length, tagging area etc.) which are termed the independent variables. A basic assumption

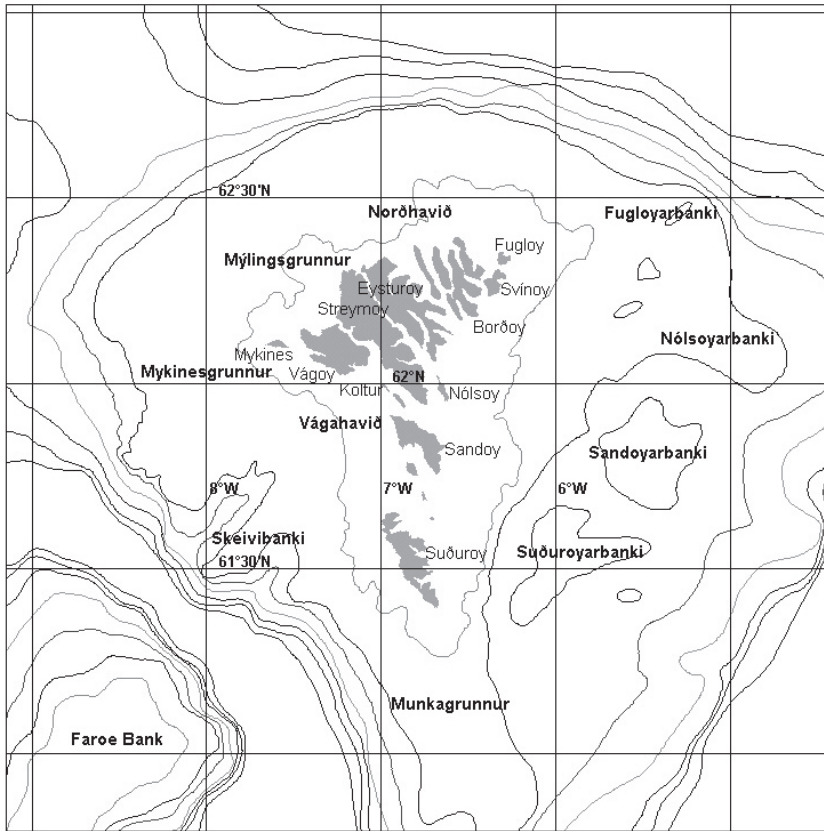


Figure 2. Map showing names of some of the islands and important fishing grounds (in bold).

in multiple regression is that the independent variables are not correlated, *i.e.* they are independent of each other.

Migration distance was calculated as linear distance in nautical miles between tagging and recapture positions. Migration distance was typically small (less than 10 nautical miles), but there were frequent outliers (more than *e.g.* 30 nautical miles). There was a need to reduce the influence of these outliers, because some of them could be due to error in the recapture positions.

Thus we used the log of the values instead of the actual values (log-transformation): 1 nautical mile corresponds to 0, 10 nautical miles to 1, 100 nautical miles to 2 and 0.1 nautical miles to -1 . When tagging and recapture positions were equal (*i.e.* the logarithmic value was not defined), we used the value -1 .

The independent variables used were: area, depth, fish length, season, year, and time since tagging. Many of these variables could be quantified in two ways (at

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

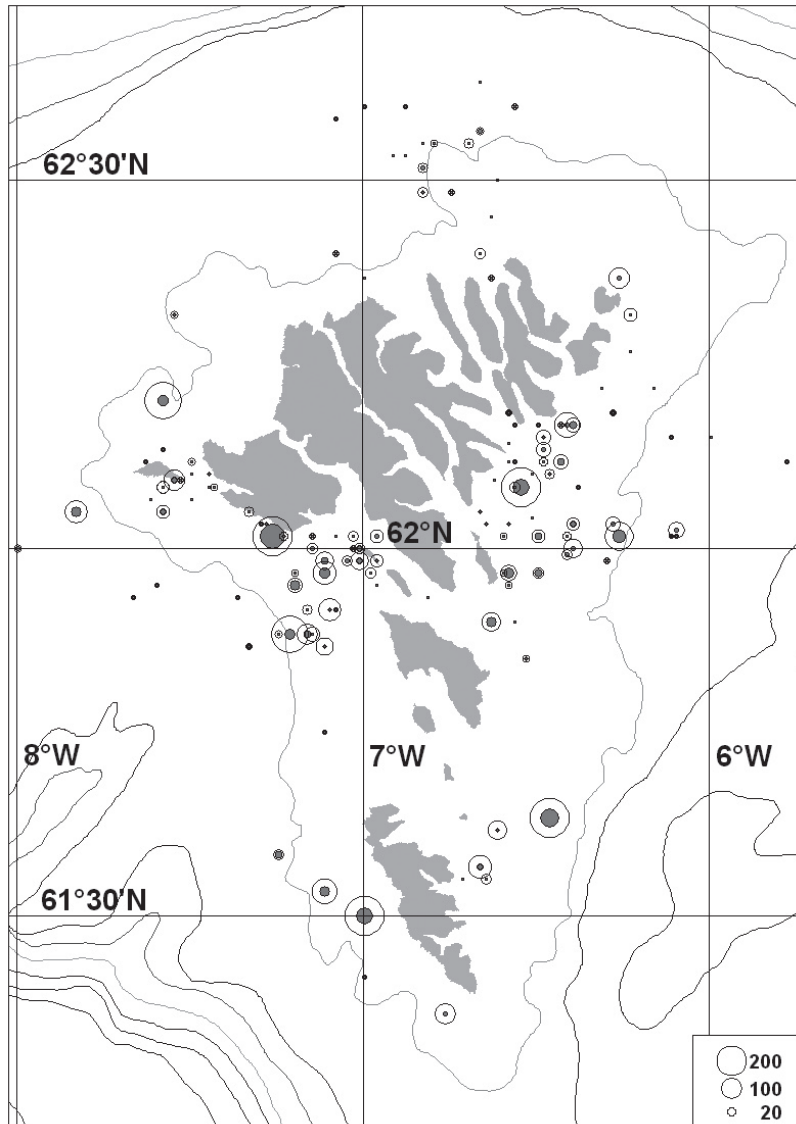


Figure 3. Positions of the various tagging experiments and corresponding number of tagged (open circles) and recaptured fish (grey circles).

tagging and at recapture), thus giving several possible combinations. We did not run

too many of these combinations in order to avoid to select the “best” result. The

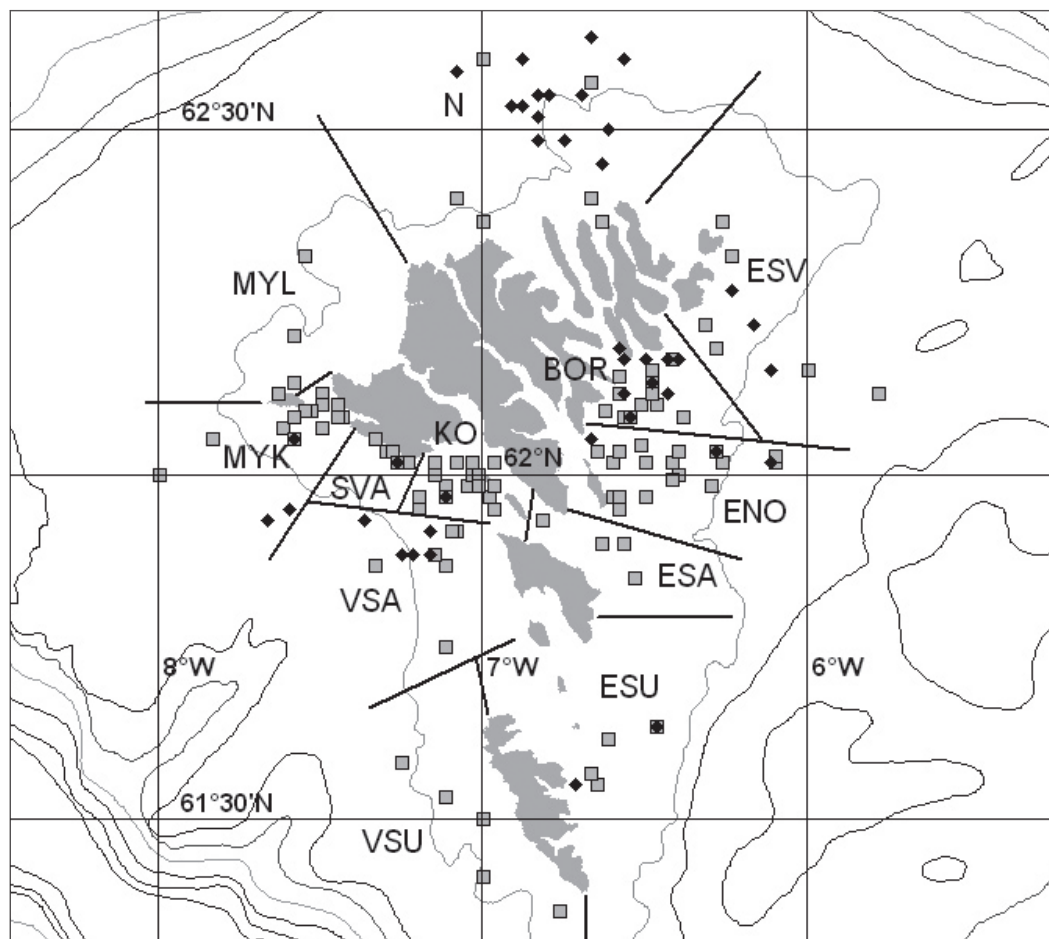


Figure 4. Tagging positions grouped by area. The abbreviations are the same as in Appendix 1. Black squares indicate taggings during spawning time in March-April whereas grey squares indicate other taggings.

statistical program “SYSTAT”, version 11 (SYSTAT, 2004) was used.

Also, it was not possible to run all combinations because some of the independent variables were correlated (*i.e.* they expressed the same signal, see “multicollinearity” in Wonnacott and Wonnacott, 1985). Thus only one of the correlated variables was used. For example, either

year of tagging or year of recapture was used. We did not use recapture depth in the regressions because migration distance and recapture depth were highly correlated (long distance – deep water). The correlation was only a result of bottom topography and had no relevance to fish migration.

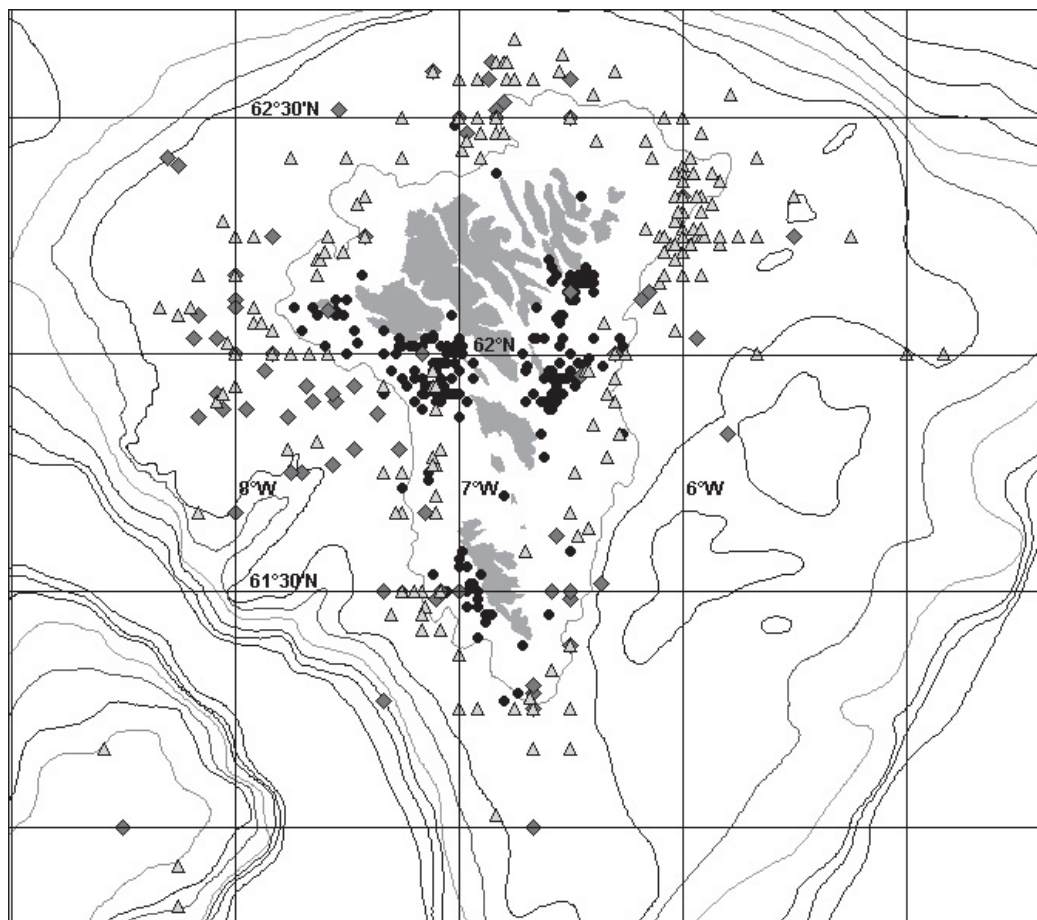


Figure 5. Recaptures grouped by fishing gear: Hand line (dots), long line (squares) and trawl (triangles). Other fishing gears (e.g. jigging) were of minor importance and are not shown.

Results

Overview

The tagging experiments were performed on the Faroe Plateau (Figure 1-2), ICES sub-division Vb1. The tagging sites were spread over a large area (Figure 3) and were grouped into 12 areas (Figure 4, Appendix 1). The number of tagged fish was high (200-500 fish) on six localities, but

was usually less than 100 fish. The taggings were performed in the spring (Figure 4, Appendix 1) on the spawning areas “Norðhavið” and “Vágahavið” (Figure 2) as well as in the feeding period during autumn.

During the period of the tagging experiments, three main fishing gears prevailed. Small Faroese boats operated in shallow

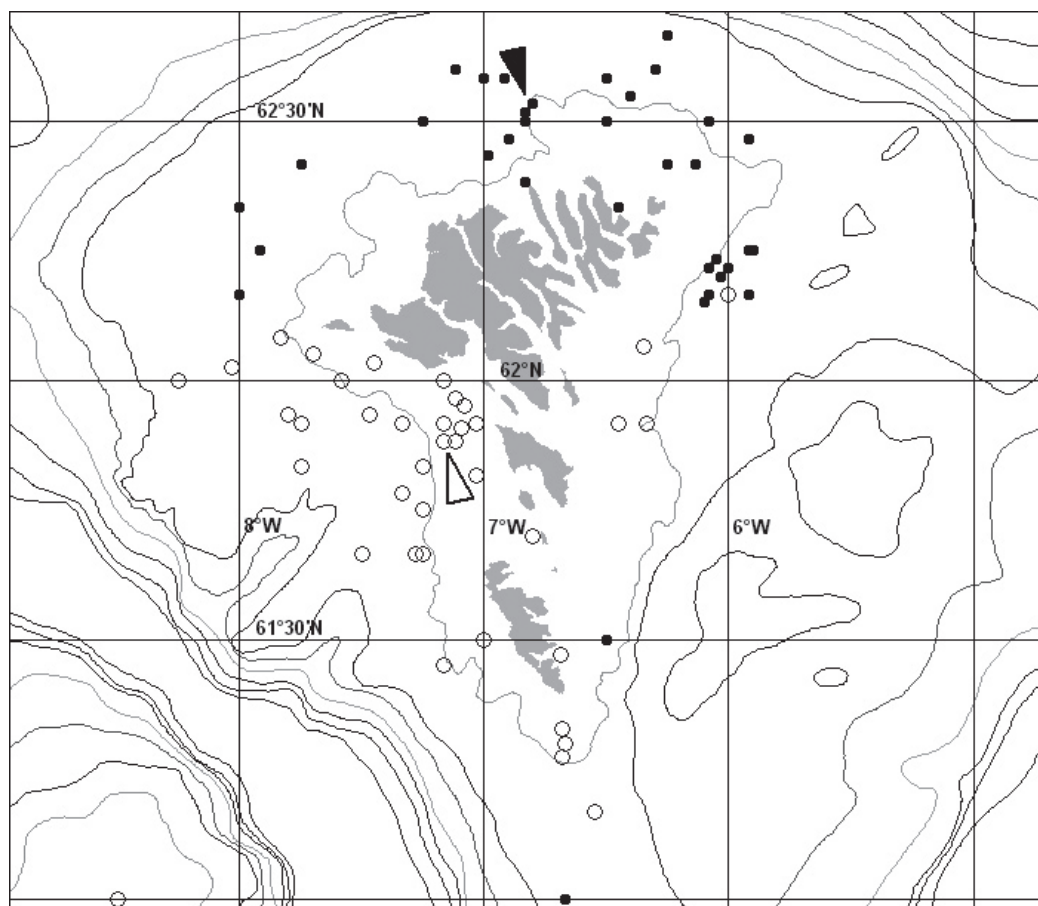


Figure 6. Taggings on the spawning grounds “Norðhavið” north of Faroe Islands and “Vágahavið” in the west. Arrowheads indicate roughly the position of tagging and dots recaptured fish. 100-700 m depth contours are shown.

waters using baited handlines (Figure 5). English and Scottish trawlers operated in deeper waters as well as Faroese longliners (Figure 5). In some areas, *e.g.* east of the Faroes, the trawlers apparently dominated completely.

In total 6512 fish were tagged and 1043 recaptured (16%) (Appendix 1). About 33% of the fish were recaptured more

than one year after tagging. The size of the tagged fish ranged between 24 and 104 cm, on average 50.7 cm (Appendix 1). The recaptured fish ranged between 34 and 90 cm, in average 59.1 cm.

Spawning migration

Cod moved mainly eastwards from the northern spawning area “Norðhavið” after

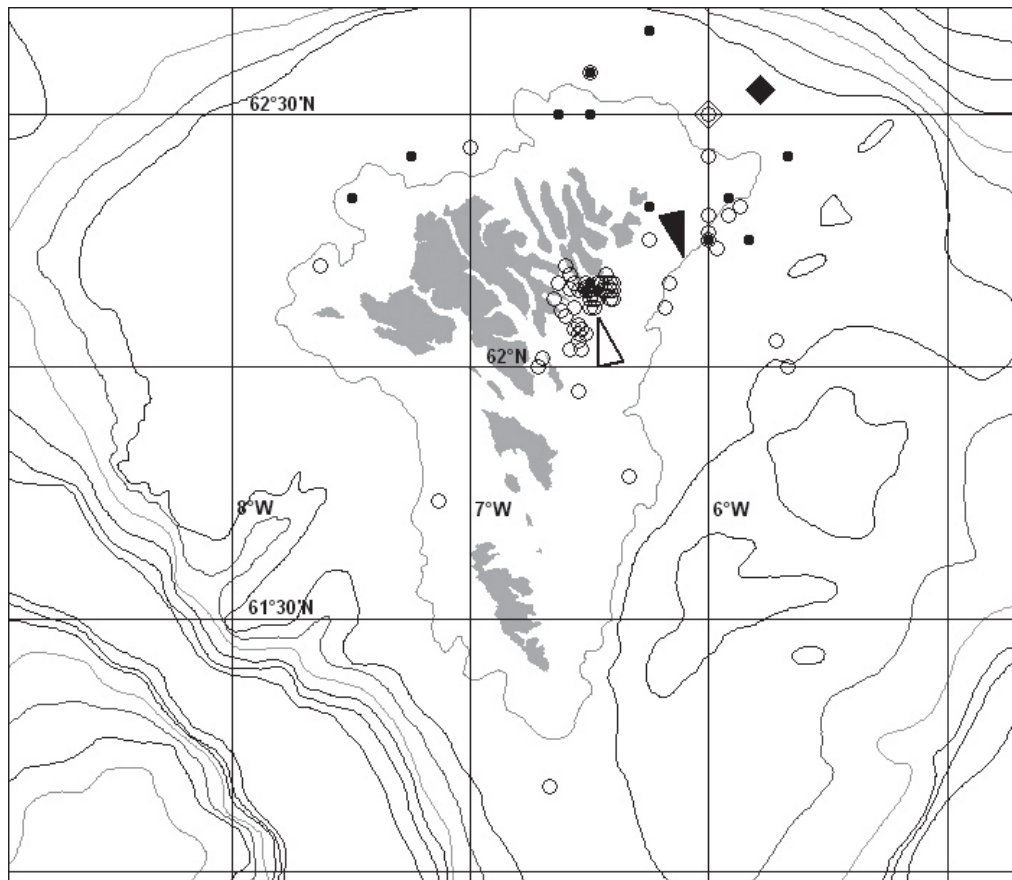


Figure 7. Taggings east of Svínoy (ESV: black symbols) and south of Borðoy (BOR: open symbols) of immature fish or outside the spawning season. Arrowheads indicate roughly the tagging positions and dots recaptured fish. Diamonds indicate fish, that may have been spawning (larger than 65 cm during March-April).

spawning in March-April, although some cod (in this case presumably immature fish) moved westwards (Figure 6). Cod tagged on the western spawning area “Vágahavið” spread all over the southern and western part of Faroe Plateau and a few were recaptured east of the Faroe Islands (Figure 6).

The migration pattern to the spawning

areas was observed in the tagging experiments that were performed other times of the year. Although few sexually mature cod were recaptured during spawning time, there were indications that cod tagged in the areas north and east of Faroe Islands spawned in the northern spawning area “Norðhavið” (Figure 7-9 and 11). Cod tagged south and west of Faroe Is-

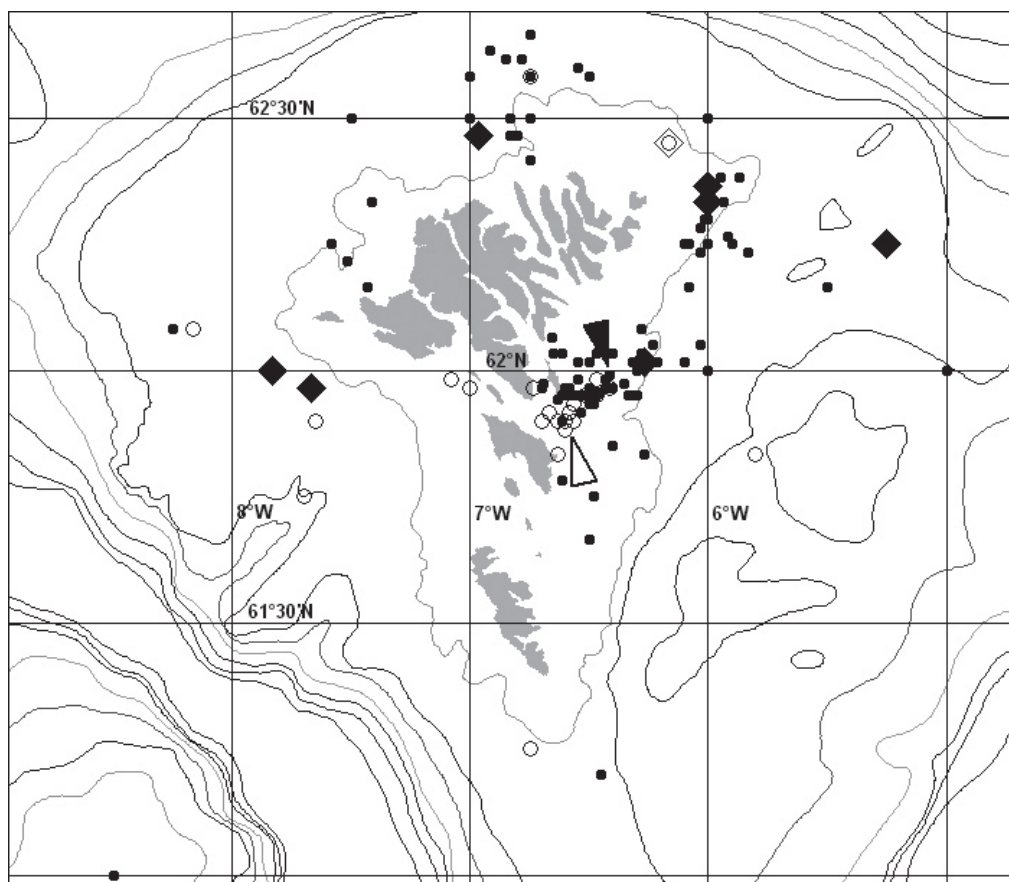


Figure 8. Taggings east of Nólsoy (ENO: black symbols) and east of Sandoy (ESA: open symbols) of immature fish or outside the spawning season. Arrowheads indicate roughly the tagging positions and dots recaptured fish. Diamonds indicate fish, that may have been spawning (larger than 65 cm during March-April).

lands seemed to spawn in “Norðhavið” or “Vágahavið” (Figure 9-11) and probably other places as well (see Figure 12).

The population of cod spawning at the “Norðhavið” seemed to be distributed over the entire Faroe Plateau other times of the year whereas the population of “Vágahavið” seemed to be restricted to the south-western part of the Faroe Pla-

teau. These two populations seemed to overlap in the south-western part of the Faroe Plateau.

The duration of the spawning migration (to or from the spawning areas) was short. Already in May-June and also in July-December, mature cod were found all around Faroe Plateau and it was hard to see any aggregation near, or on, the spawning ar-

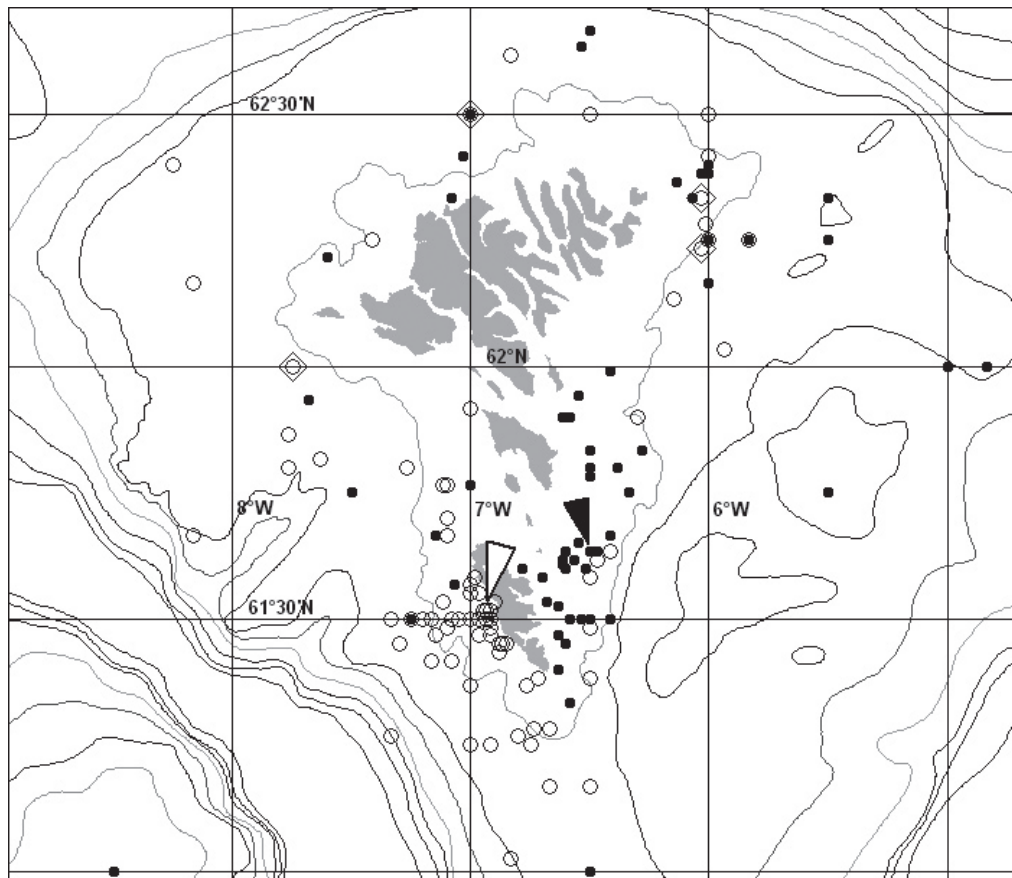


Figure 9. Taggings east of Suðuroy (ESU: black symbols) and west of Suðuroy (VSU: open symbols) of immature fish or outside the spawning season. Arrowheads indicate roughly tagging positions and black symbols recaptured fish. Diamonds indicate fish, that may have been spawning (larger than 65 cm during March-April).

east as late as in January-February (Figure 12-13). Thus, cod on the Faroe Plateau – which is a small area – only needed a few weeks to migrate to (or from) the spawning areas.

Migration pattern not associated with spawning

Cod were usually very stationary as more

than 50% moved less than 10 nautical miles away from the tagging locality and only about 10% migrated more than 40 nautical miles (Table 1).

The migration pattern was quite variable and depended on locality. The migration distance seemed to be higher in the areas off Suðuroy (ESU and VSU) compared to other areas (ignoring areas where $N < 30$)

Area Code	Length tag. (cm)	Length rec. (cm)	Increase (cm)	0-1 nm	1-5 nm	5-10 nm	10-20 nm	20-40 nm	40-80 nm	>80 nm	Sum	< 10 nm (%)	> 20 nm (%)
N	61.6	62.5	0.9	1	2	5	9	14	5	1	37	21.6	54.1
ESV	47.6	54.7	7.1	0	1	5	9	2	0	1	18	33.3	16.7
BOR	47.1	53.8	6.7	52	38	6	6	11	1	0	114	84.2	10.5
ENO	54.5	60.1	5.6	23	35	11	15	38	8	2	132	52.3	36.4
ESA	53.0	61.4	8.4	6	8	4	2	6	2	0	28	64.3	28.6
ESU	44.8	53.3	8.5	6	11	8	17	7	20	0	69	36.2	39.1
VSU	51.7	60.6	8.9	10	20	15	23	20	17	2	107	42.1	36.4
VSA	56.4	63.5	7.1	4	8	5	11	12	3	0	43	39.5	34.9
KO	50.6	58.2	7.5	28	43	14	13	10	1	0	109	78.0	10.1
SVA	53.3	61.6	8.2	52	11	16	10	29	13	0	131	60.3	32.1
MYK	59.4	62.5	3.2	10	11	6	11	7	6	1	52	51.9	26.9
MYL	52.2	63.7	11.4	0	3	2	6	8	3	1	23	21.7	52.2
Total	52.1	59.1	7.0	192	191	97	132	164	79	8	863	55.6	29.1

Table 1. Mean length of recaptured cod when tagged (Length tag.) and when recaptured (Length rec.) grouped by area. Distance travelled (nautical miles) is also shown as well as the percentage of fish that had travelled less than 10 nautical miles (nm) or more than 20 nautical miles. Taggings on the spawning areas during spawning time are highlighted in bold. Area codes are shown in Figure 4.

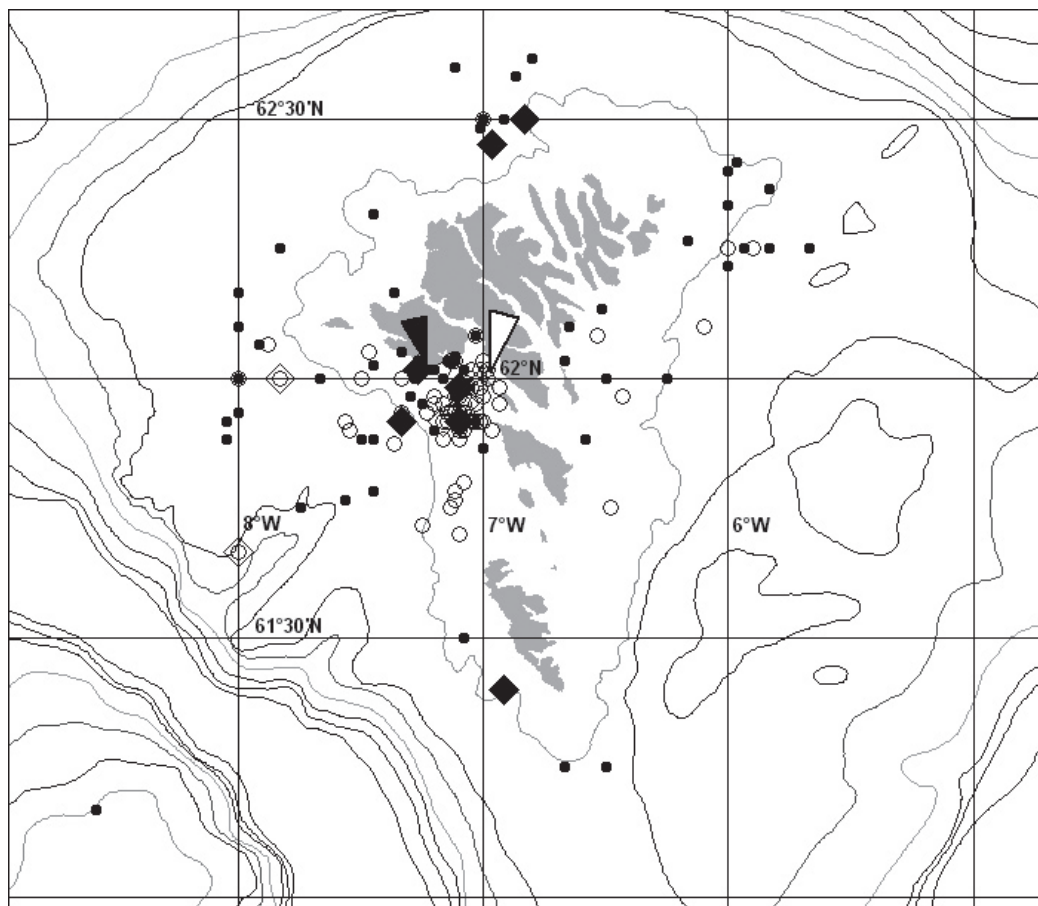


Figure 10. Taggings off Koltur (KO: open symbols) and south of Vágoy (SVA: black symbols) of immature fish or outside the spawning season. Arrowheads indicate roughly tagging positions and dots recaptured fish. Diamonds indicate fish, that may have been spawning (larger than 65 cm during March-April).

(Table 1). There was, however, great variation between areas. For example, the proportion of fish migrating more than 20 nautical miles was 10.5% for the area off Borðoy (BOR) and 36.4% for the area east of Nólsoy, ENO (Table 1).

Cod tended to migrate towards deeper waters in the vicinity of – *i.e.* outside – the tagging area, although there was great indi-

vidual variation. Thus, as a rule of thumb, cod in deep waters (> 100 m) originated from shallower waters in the same main area, *e.g.* east or west of Faroe Islands.

There were, however, exceptions to this pattern since cod in some cases moved to new areas. For example, cod tagged east of Nólsoy (area ENO) often were recaptured north of Faroe Islands (Figure 8).

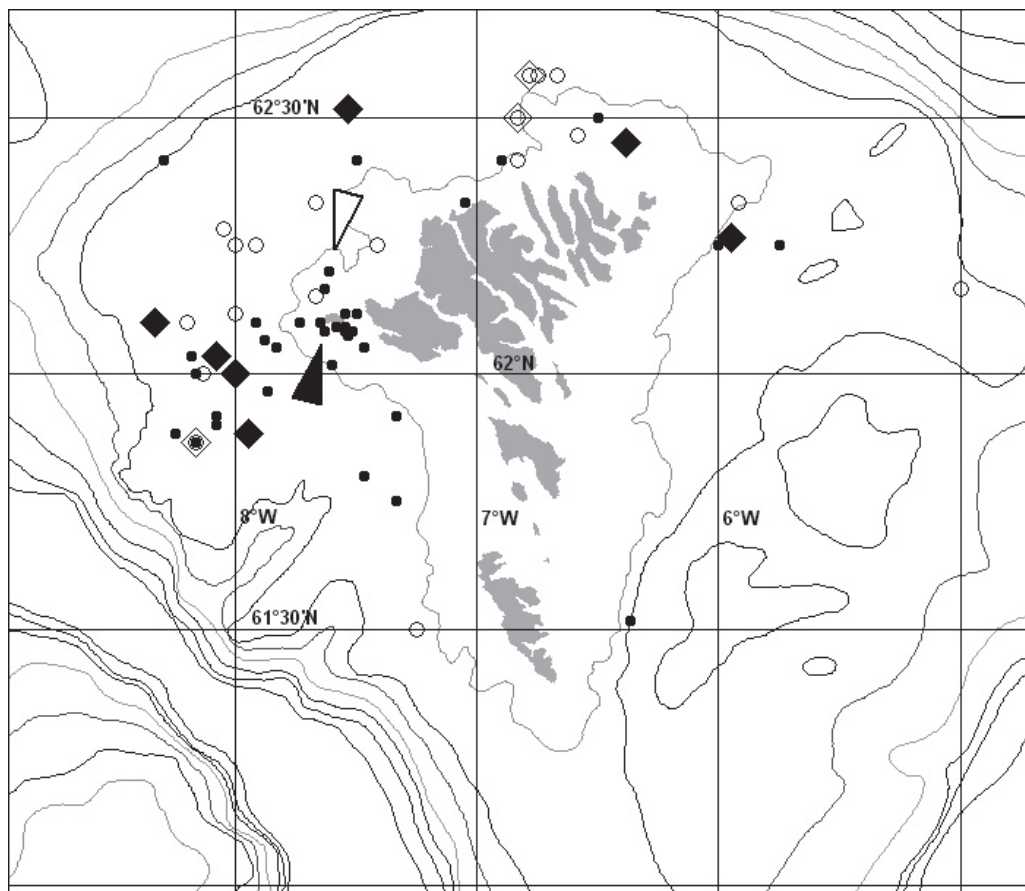


Figure 11. Taggings close to Mykines (MYK: black symbols) and on Mýlingsgrunnur (MYL: open symbols) of immature fish or outside the spawning season. Arrowheads indicate roughly tagging positions and dots recaptured fish. Diamonds indicate fish, that may have been spawning (larger than 65 cm during March-April).

Although some of the distant recapture positions could be wrong, it seems clear that these “straying” cod in principle could move to any area of similar depth on Faroe Plateau as was observed for the tagging experiments in the area west of Suðuroy and south of Vágoy (areas VSU – Figure 9 and SVA – Figure 10).

In order to investigate which factors in-

fluenced migration distance, a part of the material was selected according to following criteria: 1) the migration should not be associated with spawning, *i.e.* fish larger than 55 cm tagged or recaptured during the period February-May were excluded and 2) information about fish length and position at recapture should be available and 3) the tagging was conducted during

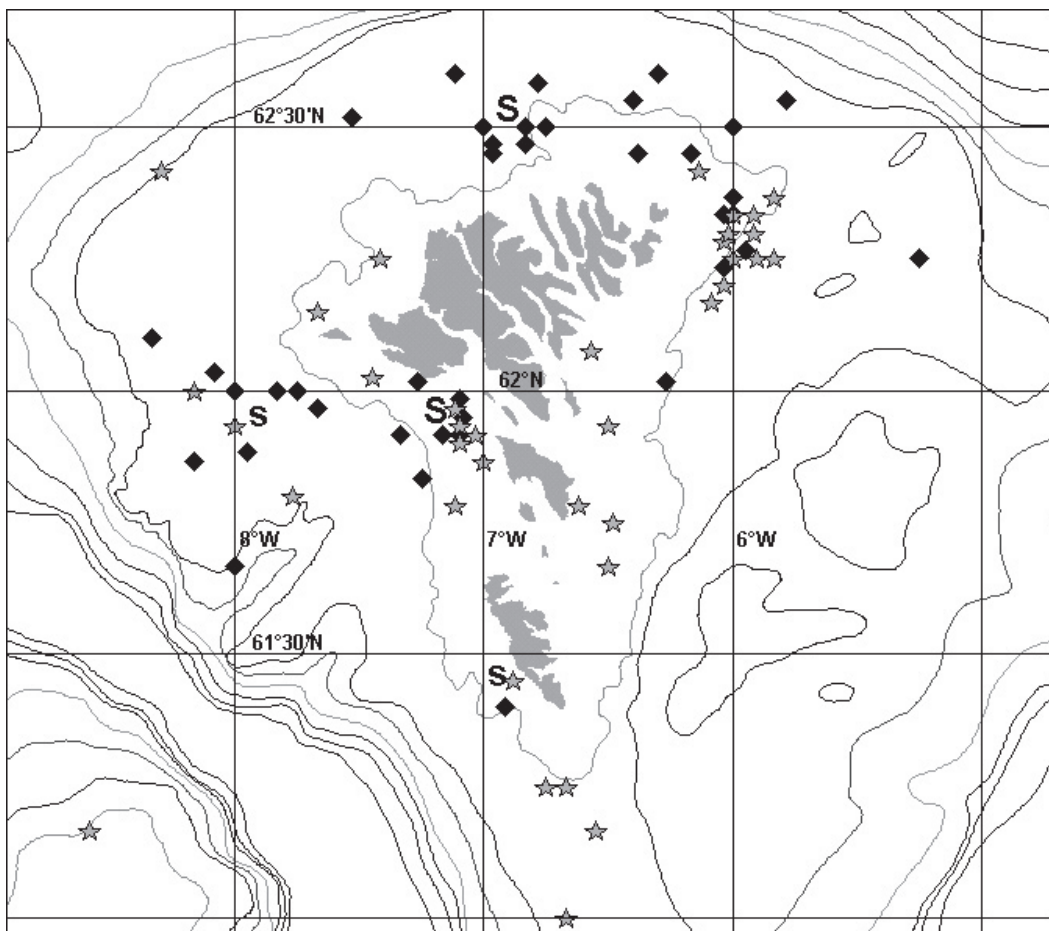


Figure 12. Cod larger than 65 cm recaptured during the spawning season in March-April (black diamonds) and during May-June (stars). Major spawning areas (“Norðhavið” and “Vágahavið”) are denoted by “S” and minor spawning areas by “s”.

the same period of the year, *i.e.* during November-December and 4) the number of observations should usually be larger than five when grouped by area and year. In total 131 recaptures fulfilled these criteria and covered three areas (ENO, KO and SVA) and six years (tagging years 1952-1957 and recapture years 1953-1958).

A general linear model was used to investigate the effect of area, depth, fish length, season, year, and time at liberty on migration distance (log-transformed values), see “Materials and methods”. We have presented one run in Appendix 2 where we included following independent variables: area of tagging, fish length

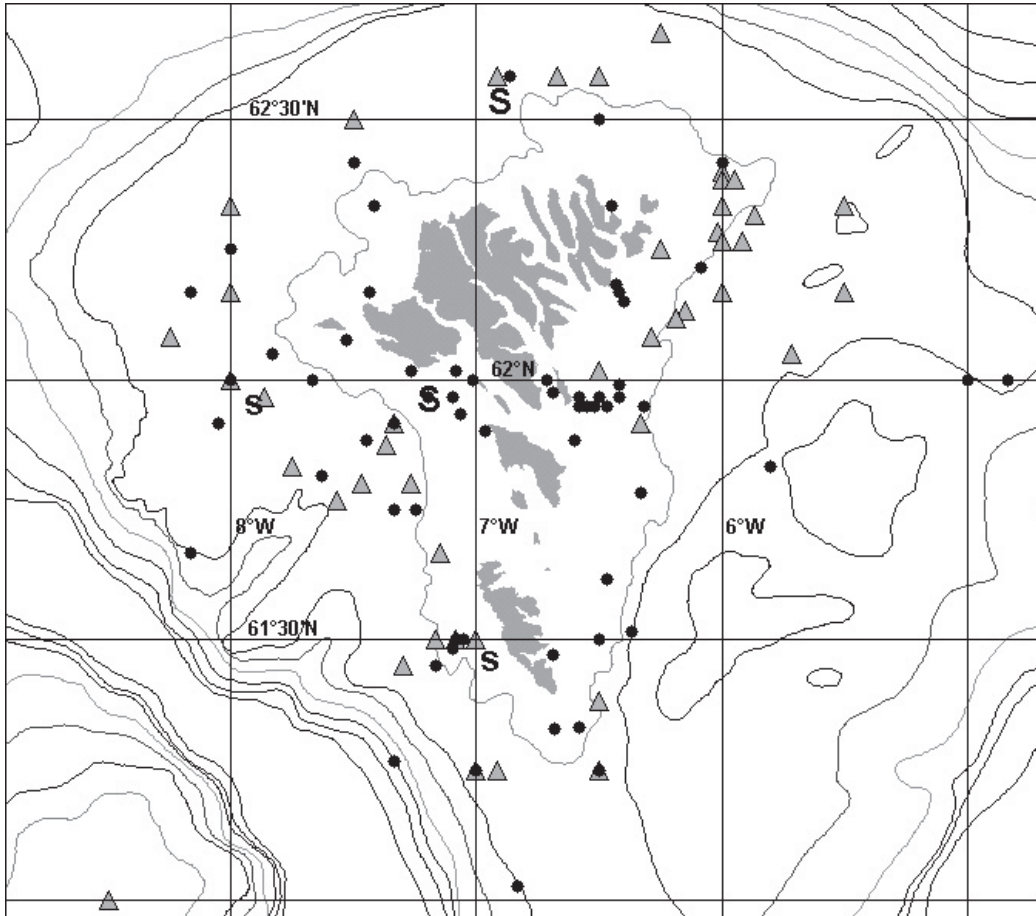


Figure 13. Cod larger than 65 cm recaptured outside the spawning season, i.e. July-December (dots) and prior to the spawning time, i.e. in January-February (triangles). Major spawning areas (“Norðhavið” and “Vágahavið”) are denoted by “S” and minor spawning areas by “s”.

at recapture, season at recapture (periods of two months) and year of tagging. Time after tagging (days at liberty) and tagging depth were excluded from the model because these variables were highly insignificant. The model explained 29 % of the variance and showed that area, fish length and year were statistically significant ($p < 0.05$) whereas season also had

a low, but insignificant p-value. A closer look revealed in the first hand that cod tagged in the area SVA migrated less than cod tagged in the other areas (Figure 14). Secondly, that migration distance increased with increased fish length (Figure 15) and that cod tagged in 1955-1956 migrated less than cod tagged in 1957 (Figure 14).

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

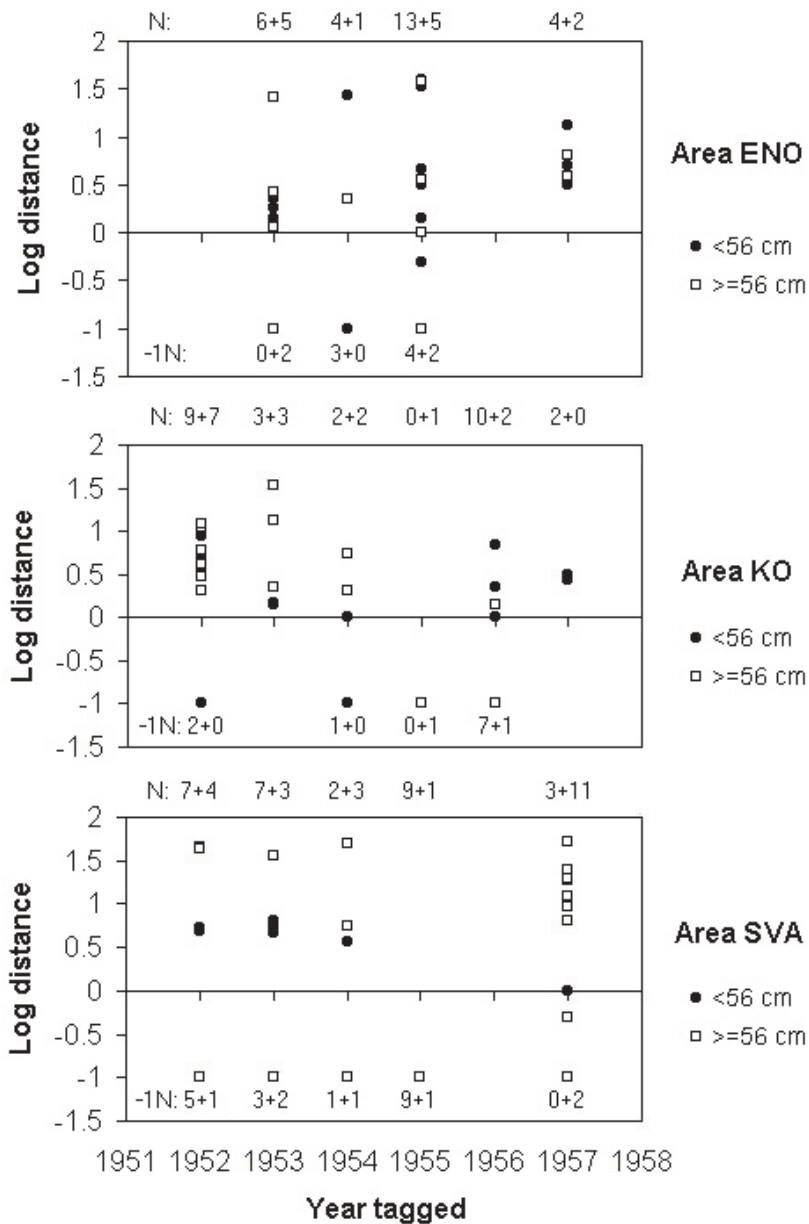


Figure 14. Migration distance (log-transformed) grouped by year of tagging and size of cod for three areas: east of Nólsoy (ENO), off Koltur (KO) and south of Vágoy (SVA). -1N denotes number of fish having migration distance of -1 (no migration) and N the total number of fish. The values are presented as number of fish less than 56 cm plus fish larger or equal to 56 cm.

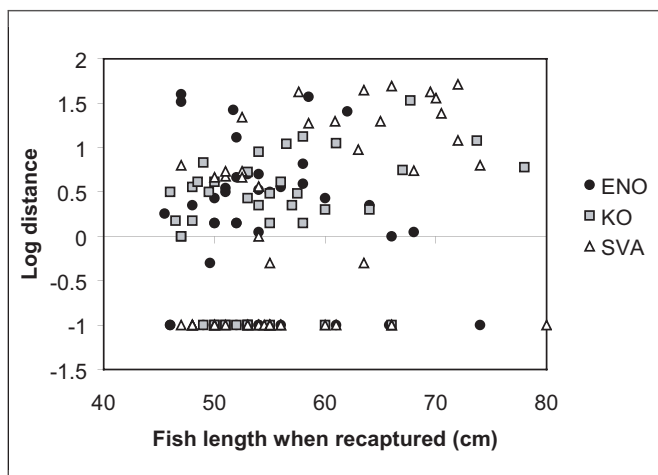


Figure 15. Migration distance (log-transformed) versus fish length (when recaptured) for the following areas: east of Nólsoy (ENO), off Koltur (KO) and south of Vágoy (SVA).

Cod moving long distances

Three cod were reported to be recaptured on Faroe Bank (south-west of Faroe Islands) (Figures 8-10). We had no extra information that could tell whether these reports were correct or not. One of them was, when tagged 21 November 1952 south of Vágoy (SVA), characterised as “sand-eel preying cod that was caught off bottom” (see discussion).

Two cod were reported to be recaptured in Icelandic waters. One was caught 15 July 1966 south of Iceland (63°40'N 16°30'W) by a Faroese vessel and is considered to be reliable. It was tagged west of Suðuroy 16 June 1952 – 14 years earlier at 61°30'N 7°00'W (area VSU). The other was caught east of Iceland by an English trawler and we were not able to verify whether this report was correct.

One cod was reported to be recaptured 27 September 1955 in the North Sea (ca. 53°30'N 2°30'E). This report is supposed to be correct. The cod was also tagged

west of Suðuroy 16 June 1952 at 61°30'N 7°00'W (area VSU – Figure 9).

Finally one cod was reported to be caught 24 January 1966 north of Scotland (ca. 53°30'N 2°30'E). This report is also supposed to be correct. The cod was tagged 16 June 1965 at 62°12'N 7°35'W (in area MYL – Figure 11).

Thus three fish were caught outside Faroese waters: one at Iceland, one north of Scotland and one in the North Sea, and by coincidence all were tagged 16 June.

Discussion

Main results

Cod spawning on the northern spawning area “Norðhavið” came from the entire Faroe Plateau – especially from the areas north and east of Faroe Islands. Cod spawning on the western spawning area “Vágahavið” came from a more limited area west and south of Faroe Islands. Immature cod were fairly stationary and tended to move to deeper waters (> 100

m) in the vicinity of the tagging area when they grew larger. A varying proportion of immature fish migrated to new areas of similar depth on the Faroe Plateau. Migration to other places than the Faroe Plateau was very seldom observed. The migration pattern, that was not associated with spawning, was dependent on area of tagging, fish length and year.

Fishery induced biases

During the period of the tagging program, there were changes in the Faroese fishery limit (Nolsøe, 1963; 1965). During the period 1952-1955, the Faroese fishery limit was 3 nautical miles from land. In 1955, it was extended in some areas west of Faroe Islands. It was extended in 1959 to 12 nautical miles, except for British fishermen who were allowed to fish 6 nautical miles from land. The spawning area "Norðhavið" was closed to all gears, except longlines and handlines. In 1964, the fishing limit was extended to 12 nautical miles, measured from straight baselines. Foreign fleets (*i.e.* English, Scottish and a few German trawlers) formally operated outside the fishery limit. Inside the fishery limit, the fishery was dominated by small Faroese boats or cutters. The larger Faroese vessels usually operated in Icelandic or Greenlandic waters, but occasionally in Faroese waters. Thus many of the small cod were recaptured by Faroese fishermen and the larger cod by English or Scottish fishermen, *e.g.* on the spawning grounds "Norðhavið" and "Vágahavið" (Jákupsstovu and Reinert, 1994).

We expect that the results are biased

towards small fish caught by Faroese fishermen operating inside the fishery limit, as seems to be the case for the tagging experiments conducted during 1909-13 and published in Strubberg (1916). Taken into account the aggregations of spawning cod in the "Norðhavið" and "Vágahavið" (Tåning, 1940; Jákupsstovu and Reinert, 1994) during March-April, it is noteworthy, that so few cod were recaptured at these places during spawning time.

A varying fishing effort by area (*i.e.* some areas are fished harder than others) may have influenced the results. We do not know how the fishing effort varied by area, but it may have been highest where it was possible to use small boats (*e.g.* east of Nólsoy - ENO, Figure 5) or where the trawlers dominated (*e.g.* east of the Faroe Islands). The migration distance of cod tagged in these fishery-intensive areas may have been underestimated (too many fish recaptured near the tagging locality) whereas the migration distance may have been overestimated for taggings in areas with less fishing effort.

Spawning migration

There is no reason to believe that there was any major difference in the spawning migration to and from the northern spawning area "Norðhavið" compared to the results in Tåning (1940) even though the westward migration from the spawning area was hard to see in the present study. The material in this study was much smaller and the fishing intensity in the areas west of "Norðhavið" may have been less than in the east, as judged from Figure

5. Tåning (1940) demonstrates convincingly the existence of the westward migration, probably because Faroese fishermen at that time claimed that the fish moved towards the east after spawning. Thus, cod disperse both eastwards and westwards from “Norðhavið” after spawning and eventually all over the Faroe Plateau (Tåning, 1940). These findings are confirmed by taggings on the spawning area “Norðhavið” in March 2000 (unpubl.).

The results from the taggings on the western spawning area “Vágahavið” represent new knowledge, because no tagging had been performed there previously. They showed that cod spawning in “Vágahavið” in March were dispersed in the south-western part of Faroe Plateau other times of the year. These findings are confirmed by taggings in March 2004 (unpubl.).

The duration of the spawning migration only lasted a few weeks. It is not surprising because the distance to (or from) the spawning areas is very short (ranges from zero to 150 nautical miles, but is typically 30 nautical miles). The typical minimum swimming speed of cod migrating from the Icelandic spawning areas has been estimated to 3-8 nautical miles per day (Jónsson, 1996). Assuming a similar swimming speed for Faroese cod, the duration of the spawning migration to (or from) the spawning areas might be between zero and 50 days, but should more typically be between 4 and 10 days.

The location of the spawning areas “Norðhavið” and “Vágahavið” may not be constant (Jákupsstovu and Reinert, 1994). The spawning area “Norðhavið”

seems to have been more westerly distributed during 1994-2004 (ICES, 2004) than in the 1930s (Tåning, 1940) and in the present tagging study (Figure 12). The spawning area “Vágahavið” seems to be in approximately the same location during the present study compared to 1994-2004 (ICES, 2004).

At the coast of Norway there are several local cod stocks, termed “Norwegian coastal cod”, that are more reddish in appearance than north-east Arctic cod (Rollefsen, 1934; Jakobsen, 1987). Reddish coloured cod (“reyðfiskur” in Faroese) are also common at the Faroes in shallow waters (< 100 m) near land. The material in this study is not able to tell whether they belong to local spawning stocks or spawn together with other cod at “Norðhavið” or “Vágahavið”. In the present study 43 of them were tagged south of Mykines and five recaptured, all near the tagging place. Tagging experiments in December 2002 and November 2003 indicate that reddish coloured cod have very limited migration (unpubl.).

Migration pattern not associated with spawning

The stationary habit of cod is in good agreement with the earlier studies of cod in Faroese waters (Strubberg, 1916; 1933) and more recent experiments (Fjallstein and Jákupsstovu, 1999). It is often observed for juvenile cod in other areas, e.g. on the Swedish west coast (Pihl and Ulmestrand, 1993), on the southern coast of Norway (Danielssen and Gjørseter, 1994), and in western Norway fjord areas (Godø

et al., 1986). Large cod (35-100 cm) north of Scotland moved somewhat more than cod in this study (Easey, 1987). The reader is referred to Robichaud and Rose (2004) for a comprehensive comparison of all cod stocks in the Atlantic ocean.

Migration distance depended on tagging location (Figure 14) and several factors may have been involved. The bottom topography sets the limits what is possible, and the topography is different between areas, which again may influence the abundance of food or hiding places. Stomach investigations at the time of these tagging experiments indicate that there were differences in food organisms between areas (Rae, 1967) and stomach analyses during the period 1997-2004 show that both species composition and abundance may vary considerably between areas (unpubl.). The deciding factor (or factors) is, however, not known.

The movement of cod to deeper waters is likely related to fish size and abundance of suitable food organisms. Results from the summer groundfish survey on Faroe Plateau (ICES, 2004) show that the mean size of cod increases with increasing depth (unpubl.) and stomach analyses show – on a broad scale – that prey size increases with increasing depth (unpubl.). Thus the relation between predator and prey size (Floeter and Temming, 2003) seems to be an important factor that is influencing the distribution of cod on Faroe Plateau.

The swimming capacity of cod is limited (Soofiani and Priede, 1985) and may affect migration. In order to minimise swimming, cod may select the shortest

way to deeper waters, which normally can be achieved by moving a few nautical miles farther from land. This is one way of keeping the populations of cod east (Figure 7-9) and west of Faroe Islands (Figure 9-11) separated. The Faroe Plateau is, on the other hand, a small area compared to other areas (*e.g.* Icelandic waters) suggesting that other factors than energy minimisation could control the migration pattern to deeper waters.

It is interesting that there always were some cod that moved to new and distant areas. The size of these fish was quite similar to local cod, but we have indications, that diet played a role. On 21 November 1952, 75 cod were tagged south of Vágoy (SVA), that were characterised as “sand-eel preying cod that were caught off bottom”. Seventeen of them were recaptured, and the average distance to the tagging locality was 22 nautical miles. The next day 31 cod were tagged on the same locality and they were “not sand-eel preying cod and caught close to bottom”. Eight of them were recaptured, and the average distance was only one nautical mile. The difference was statistically significant (Mann-Whitney U-test, $p < 0.05$). Faroese fishermen have told the first author that sand-eel preying cod move much more than cod eating benthic food. Migrants to new areas may play an important role by enhancing local populations of cod that for some reason, for example high fishing intensity, are on a low level.

Migration distance differed between years and one reason may be a variable fishing pattern (*i.e.* the observed differ-

ence between years is an artefact), but there are no data available to confirm this hypothesis. On the other hand, the actual migration pattern may have differed between years. Tagging experiments during 1997-2004 indicate that cod may some years migrate into shallow water close to land when food abundance on the typical fishing grounds is low (unpubl.). We are, however, not able to decide whether this may have happened during the period 1952-1957 (that was selected for the analysis).

The general linear model also indicated that time of the year (season) may play a role (although $p > 0.05$). We investigated the material in Strubberg (1916), *i.e.* the appendix with information on individual recaptured fish, in the same way as in this study. It indicated a clear effect of season. It is not surprising, because a number of factors, *e.g.* food availability (unpublished material), vary on a seasonal basis (Rae, 1967). Tagging experiments on the southern coast of Norway have also shown an effect of season: juvenile cod in those areas migrate to deep water (about 75 m) during summer (Danielssen and Gjørseter, 1994).

Cod moving long distances

Only three out of about 1000 cod were caught outside Faroese waters (*i.e.* Faroe Plateau and Faroe Bank). Previous tagging experiments have also shown that such highly migrating cod are extremely scarce. When considering all recaptured cod in Strubberg (1916; 1933) and Tåning (1940), only one out of about 2100 cod was

recaptured outside Faroese waters (in the Barents Sea). Tagging experiments during 1997-2004 have also indicated a very low frequency (about 5 of 6000). These cod were recaptured in Shetland waters (one specimen), off the coast of Norway – close to Trondheim – (two specimens) and in the Barents Sea (two specimens). Thus – when including this study – cod from Faroese waters have been recaptured in the whole area from Iceland, North Sea to the Barents Sea.

It is also very seldom observed that cod migrate to Faroese waters from distant areas. Icelandic tagging experiments during 1948-1986 showed that only four out of about 11000 recaptured cod were recaptured in Faroese waters (Jónsson, 1996). It should be mentioned, however, that tagging experiments indicate that cod on the Faroe-Icelandic ridge are mainly, or at least partially, of Icelandic origin (unpubl.). Immigration of cod from the areas north of Scotland/Shetland is also on a very low level since no cod out of 430 recaptured cod came from Faroese waters during the late 1970s (Easey, 1987).

Implications for fisheries management

The fact that cod move to deeper waters when they grow larger, and that they tend to stay in the same main area has important implications for fisheries management. The fishing mortality has been high in recent years (ICES, 2004). If the fishing mortality should be reduced by introducing new closed areas, they should be located close to land if the young fish should be protected. If the adult fish should be

protected by closed areas, there should be many small closed areas scattered around Faroe Islands in order to protect local groups or populations of cod rather than a few large areas. The 1952-65 material shows that it may take some time to recolonise areas with low density of cod, especially if they are far from high density areas, which could be the case if only a few closed areas were introduced.

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MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

Appendix 1. Information about tagging experiments 1952-65 grouped by tagging locality. The tagging locality is denoted by name, latitude, longitude and depth in meters. Area codes are as follows: N: North, ESV: East of Svínø, BOR: South of Borðø, ENO: East of Nólsoy, ESA: East of Sandø, ESU: East of Suðuroy, VSU: West of Suðuroy, VSA: West of Sandø, KO: Off Koltur, SVA: South of Vágø, MYK: South of Mykines, MYL: North of Mykines – or Mýlingsgrunnur. Abbreviations for boats: A: “M/S Akranes”, E: “M/B Ennið”, G: “M/B Gjógvarenni”, K: “M/S Kúrberg”, B: “Brimnes”, N: “Núpur” and S: “Svabo”. The

Tagging locality	Area code	Depth (m)	Boat	First date	Last date	Days	Earliest month	Latest month	Season	Tag type
N Haraldssund 6222 638 84	N	84	N	20/09/1963		1	9			L
N Kunoy 6224 640 85	N	85	N	26/10/1964		1	10			L
Norðhavið 6227 638 85	N	85	G	19/04/1952		1	4		Sp.	D
Norðhavið 6230 637 85	N	85	G	19/04/1952		1	4		Sp.	D
Norðhavið 6229 645 95	N	95	G	22/04/1954		1	4		Sp.	D
Norðhavið 6231 650 100	N	100	G	22/04/1952		1	4		Sp.	D
Norðhavið 6233 642 100	N	100	G	18/04/1952		1	4		Sp.	D
Norðhavið 6233 648 100	N	100	G	19/04/1952		1	4		Sp.	D
Norðhavið 6235 705 105	N	105	G	24/04/1954		1	4		Sp.	D
Norðhavið 6222 700 110	N	110	K	27/11/1958		1	11			L
Norðhavið 6233 650 110	N	110	G	10/03/1953		1	3		Sp.	D
Norðhavið 6236 700 112	N	112	K	26/11/1958		1	11			L
Norðhavið 6229 650 115	N	115	G	18/03/1952	20/03/1952	2	3	3	Sp.	D
Norðhavið 6232 653 115	N	115	G	11/03/1952		1	3		Sp.	D
Norðhavið 6232 655 115	N	115	G	21/04/1954		1	4		Sp.	D
Norðhavið 6224 705 117	N	117	K	27/11/1958		1	11			L
Norðhavið 6234 640 117	N	117	K	27/11/1958		1	11			L
Norðhavið 6236 634 120	N	120	G	21/04/1952		1	4		Sp.	D
Norðhavið 6236 653 130	N	130	G	21/04/1952		1	4		Sp.	D
Norðhavið 6238 640 130	N	130	G	12/03/1952		1	3		Sp.	D
Whole area		107		11/03/1952	26/10/1964	1.1	3	11		
E Fugloy 6219 614 64	ESV	64	S	17/12/1964		1	12			L
Skarðsvík 6222 616 73	ESV	73	S	15/12/1964		1	12			L
Um Húsagrynnu 6211 617 74	ESV	74	N	11/09/1963		1	9			L
Svínøyarvík 6216 614 77	ESV	77	A	16/04/1958		1	4		Sp.	L
S Svínø 6213 610 78	ESV	78	A	16/04/1958		1	4		Sp.	L
S Svínø 6213 619 80	ESV	80	K	25/11/1958		1	11			L
NE Húsagrynnna 6209 607 113	ESV	113	A	16/04/1958		1	4		Sp.	L
SV Svínø 6209 600 119	ESV	119	K	24/11/1958		1	11			L
SV Svínø 6207 547 147	ESV	147	K	25/11/1958		1	11			L
Whole area		92		16/04/1958	17/12/1964	1.0	4	12		
Við Mjóvanes 6207 634 28	BOR	28	E	16/03/1960		1	3		Sp.	D
Út fyri Mjóvanesi 6207 635 30	BOR	30	E	04/02/1960		1	2			D
Við Mjóvanes 6207 635 30	BOR	30	E	12/01/1960		1	1			L
Høgnaboði 6205 633 43	BOR	43	E	10/01/1961	30/01/1961	2	1	1		L
Gøtuvík 6208.5 635 47	BOR	47	E	13/02/1960		1	2			D
Høgnaboði 6205 633 50	BOR	50	E	12/01/1960	08/11/1960	8	1	11		D &

tagging experiments usually lasted one day, but sometimes several taggings were done on the same locality. In those cases the period of tagging (first and last date) and earliest and latest month of the year (1: January, 12: December) were given. Experiments during the spawning season in March-April were denoted "Sp.". Two types of tags were used: Disc (D) and Lea tags (L). Not all tagged nor recaptured fish were length measured, and average length, Standard Deviation (S.D.), minimum (Min) and maximum (Max) thus refer to fish where length was available.

No. tagged	No. of lengths	Avg. length	S.D.	Min	Max	No. of recapt.	No. of lengths	Avg. length (tagging)	Avg. length (recapt.)	S.D.	Min	Max	Recapt. %
11	11	38.8	7.6	30	55	0	0						0.0
34	33	49.1	11.3	27	77	1	1	72.0	72.0		72	72	2.9
2	2	50.0	7.1	45	55	0	0						0.0
3	3	50.0	7.0	45	58	0	0						0.0
11	11	64.1	15.5	45	83	2	1	63.0	55.0		55	55	18.2
27	27	65.3	16.9	46	104	6	5	60.7	64.6	15.5	51	90	22.2
25	25	61.8	12.2	46	83	2	1	79.5	76.7		77	77	8.0
13	13	67.3	17.9	47	94	2	1	67.5	62.5		63	63	15.4
7	7	69.4	12.7	45	80	2	1	75.0	80.0		80	80	28.6
2	2	72.0	7.1	67	77	1	1	67.0	68.6		69	69	50.0
2	2	69.5	26.2	51	88	1	1	51.0	64.0		64	64	50.0
7	7	54.1	4.6	49	60	2	1	56.5	60.6		61	61	28.6
30	30	78.0	8.9	63	101	5	3	76.8	77.7	7.8	69	84	16.7
1	1	80.0		80	80	0	0						0.0
2	2	75.0	14.1	65	85	0	0						0.0
10	10	45.8	8.3	33	60	2	1	50.0	47.0		47	47	20.0
16	16	57.7	13.6	42	85	8	6	50.5	50.5	6.9	44	60	50.0
11	11	64.5	17.2	45	90	1	1	45.0	53.0		53	53	9.1
9	9	66.7	18.8	47	103	2	2	51.5	58.8	8.8	52	65	22.2
3	3	69.3	9.1	61	79	1	1	68.0	72.0		72	72	33.3
226	225	61.3	16.5	27	104	38	27	61.6	62.5	12.6	44	90	16.8
50	50	45.3	5.8	34	61	3	2	46.3	45.3	3.9	42	48	6.0
104	102	45.9	7.0	31	68	9	7	49.1	60.3	8.2	48	71	8.7
12	12	37.2	5.8	29	45	4	3	35.5	40.2	1.3	39	42	33.3
1	1	59.0		59	59	0	0						0.0
1	1	61.0		61	61	0	0						0.0
1	1	38.0		38	38	0	0						0.0
8	8	48.6	9.3	35	58	2	1	57.0	58.2		58	58	25.0
2	2	63.0	11.3	55	71	1	1	55.0	55.0		55	55	50.0
8	8	65.0	9.7	51	78	2	2	55.5	64.4	7.6	59	70	25.0
187	185	46.4	8.5	29	78	21	16	47.6	54.7	10.7	39	71	11.2
7	7	44.0	3.8	40	51	0	0						0.0
2	2	41.5	3.5	39	44	0	0						0.0
1	1	42.0		42	42	0	0						0.0
140	140	46.9	4.2	39	61	11	8	47.9	49.3	1.8	46	51	7.9
2	2	41.5	0.7	41	42	0	0						0.0
377	376	46.5	4.8	34	65	54	36	46.9	50.8	7.8	42	67	14.3

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

Tagging locality	Area code	Depth (m)	Boat	First date	Last date	Days	Earliest month	Latest month	Season	Tag type
Rituvíksgrynnan 6205.5 637.5 50	BOR	50	E	12/01/1960		1	1			L
Toftamangrynnna 6205 634 50	BOR	50	E	08/11/1960		1	11			D
Uttan fyri Gøtuvík 6210 634 50	BOR	50	G	11/03/1953		1	3		Sp.	D
E Borðoyarnes 6210 624 60	BOR	60	G	12/04/1954		1	4		Sp.	D
Lorvíksfjørður 6211 635 60	BOR	60	G	21/03/1952		1	3		Sp.	D
S Borðoy 6207 626 60	BOR	60	G	11/03/1953		1	3		Sp.	D
S Borðoy 6210 626 60	BOR	60	G	28/03/1952		1	3		Sp.	D
S Borðoy 6210 630 60	BOR	60	G	28/03/1952		1	3		Sp.	D
S Borðoyarnes 6207 626 60	BOR	60	G	28/04/1954		1	4		Sp.	D
SE Borðoyarnes 6210 625 64	BOR	64	S	10/12/1964	16/12/1964	2	12	12		L
Borðoyarnes 6208 629 65	BOR	65	N	10/09/1963	17/09/1963	2	9	9		L
Høgnaðøi 6206 631 65	BOR	65	E	20/01/1960		1	1			D
Lorvíksgrýnna 6207 629 65	BOR	65	E	20/01/1960		1	1			D
SE Borðoyarnes 6209 629 66	BOR	66	N	20/10/1964	21/10/1964	2	10	10		L
Borðoyarnes 6208 629 69	BOR	69	N	18/09/1963		1	9			L
S Borðoy 6208 629 70	BOR	70	G	29/03/1952		1	3		Sp.	D
Borðoyarnes 6206 628 74	BOR	74	N	12/09/1963		1	9			L
Whole area		55		21/03/1952	16/12/1964	1.5	1	12		
E Borðan 6158 636 30	ENO	30	A	28/10/1954		1	10			L
Fyri Urðini, Nólsoy 6158 636 35	ENO	35	E	08/11/1960		1	11			D
Húsagrýnna 6202 617 36	ENO	36	A	18/04/1958		1	4		Sp.	L
E Borðan 6158 635 40	ENO	40	A	19/11/1955	07/12/1955	3	11	12		D &
E Nólsoy 6158 635 40	ENO	40	A	03/11/1954	04/11/1954	2	11	11		L
NE Nólsoy 6202 639 40	ENO	40	A	02/11/1954		1	11			L
E Borðan 6157 635 50	ENO	50	E	05/01/1961		1	1			D
E Stongin 6201 636 50	ENO	50	E	05/01/1961		1	1			D
Húsagrýnna 6159.5 625 56	ENO	56	E	14/01/1960	20/01/1961	4	1	1		D &
E Borðan 6158 630 60	ENO	60	A	13/11/1953		1	11			D
E Nólsoy 6202.5 631 61	ENO	61	E	13/02/1960		1	2			D
“Moskva” 6201 630 65	ENO	65	A	09/11/1957		1	11			D &
Við Eystnes 6203 640 65	ENO	65	E	16/03/1960		1	3		Sp.	D
E Nólsoy 6201 607 80	ENO	80	A	18/04/1958		1	4		Sp.	L
E Nólsoy 6201 625 84	ENO	84	E	11/01/1960		1	1			L
E Nólsoy 6202 624 84	ENO	84	E	14/01/1960	15/01/1960	2	1	1		D &
Eysturi í Holinum 6201 625 84	ENO	84	E	11/01/1960		1	1			L
Nólsoyargrýnna 6202 635 85	ENO	85	E	30/01/1961		1	1			L
Høkilin 6200 624 93	ENO	93	E	20/01/1961		1	1			L
Larvasagrýnna 6202 617 93	ENO	93	E	26/01/1960	24/10/1960	3	1	10		D
Reynsendagrýnna 6200 624 93	ENO	93	E	30/01/1961		1	1			L
V Húsagrýnna 6202 624 93	ENO	93	E	30/01/1961		1	1			L
Glyvramannagrýnna 6205 623 94	ENO	94	E	24/10/1960		1	10			D
Holið 6201 616 106	ENO	106	E	26/01/1960	20/01/1961	5	1	1		D &
Kíkagrýnna 6201 606 112	ENO	112	E	28/10/1960		1	10			D
Kíkagrýnna 6201.5 606 112	ENO	112	E	05/02/1960		1	2			D
E Nólsoy 6159 618 117	ENO	117	K	25/11/1958		1	11			L

No. tagged	No. of lengths	Avg. length	S.D.	Min	Max	No. of recapt.	No. of lengths	Avg. length (tagging)	Avg. length (recapt.)	S.D.	Min	Max	Recapt. %
1	1	48.0		48	48	0	0						0.0
34	34	46.4	3.3	40	55	1	0	43.0					2.9
6	6	47.3	1.4	45	49	3	1	46.7	48.0		48	48	50.0
59	58	51.1	4.7	44	62	18	12	52.5	63.2	8.2	52	76	30.5
12	12	48.6	4.0	44	58	5	4	47.4	53.6	2.9	50	57	41.7
44	44	50.4	5.8	44	70	10	6	50.5	63.6	13.9	48	81	22.7
12	12	50.5	5.0	44	59	2	1	45.0	46.0		46	46	16.7
7	7	47.7	2.5	45	51	1	1	45.0	50.0		50	50	14.3
10	10	50.2	6.0	45	65	3	2	52.7	64.5	17.7	52	77	30.0
144	143	40.0	5.6	27	60	9	6	42.9	56.9	13.9	42	74	6.3
21	21	39.0	8.0	27	56	4	3	43.8	46.8	2.8	44	50	19.0
3	3	43.0	3.0	40	46	1	0	46.0					33.3
22	22	46.1	3.7	40	54	2	1	52.5	54.0		54	54	9.1
54	54	46.7	13.6	28	85	4	3	47.0	56.2	15.1	40	69	7.4
35	35	39.5	9.9	27	64	4	3	35.5	40.7	6.1	34	46	11.4
5	5	46.4	6.7	41	58	1	1	45.0	63.0		63	63	20.0
26	25	40.1	9.0	28	68	4	1	37.3	47.0		47	47	15.4
1024	1020	45.6	6.8	27	85	137	89	47.1	53.8	10.1	34	81	13.4
9	9	48.7	4.4	45	59	3	3	47.7	49.8	3.3	46	53	33.3
6	6	45.5	4.7	39	52	0	0						0.0
5	5	38.2	6.0	31	47	0	0						0.0
45	45	51.4	7.0	45	78	23	22	50.5	55.8	8.6	46	80	51.1
21	21	48.7	3.6	44	56	8	5	49.3	52.9	7.5	43	64	38.1
4	4	46.3	1.9	45	49	1	1	46.0	46.0		46	46	25.0
13	12	44.9	3.2	40	51	1	1	46.0	48.0		48	48	7.7
14	14	45.2	4.6	40	56	0	0						0.0
29	29	45.3	5.8	37	65	6	0	45.2					20.7
34	34	50.1	4.8	44	64	19	13	49.8	57.5	8.3	45	71	55.9
2	2	41.0	1.4	40	42	0	0						0.0
49	49	57.4	8.7	44	84	15	11	57.7	63.7	11.4	52	82	30.6
4	4	45.8	5.7	42	54	2	0	43.5					50.0
8	8	44.5	7.3	32	51	1	1	50.0	57.7		58	58	12.5
3	3	46.7	4.0	43	51	0	0						0.0
40	39	55.0	7.3	41	69	10	8	57.7	64.2	8.6	52	78	25.0
17	16	65.4	10.8	52	93	2	0	64.0					11.8
4	4	41.5	1.9	40	44	0	0						0.0
51	51	61.3	8.9	45	86	5	4	61.2	66.5	12.1	51	80	9.8
57	57	45.9	4.4	39	57	7	5	44.7	55.1	13.7	44	78	12.3
39	39	47.0	5.0	40	63	3	2	45.7	51.0	9.9	44	58	7.7
4	4	46.3	6.3	40	55	0	0						0.0
6	6	49.8	12.7	40	75	0	0						0.0
179	179	61.5	11.2	40	100	43	30	61.8	65.0	10.2	44	79	24.0
8	8	55.1	16.5	44	91	1	0	45.0					12.5
64	63	49.8	8.7	40	93	6	4	54.7	62.0	6.5	56	69	9.4
10	10	66.3	10.6	54	88	1	1	54.0	70.5		71	71	10.0

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

Tagging locality	Area code	Depth (m)	Boat	First date	Last date	Days	Earliest month	Latest month	Season	Tag type
Whole area		73		13/11/1953	30/01/1961	1.5	1	12		
E Nólsoy 6154 638 50	ESA	50	A	03/11/1954		1	11			L
SV Bórðan 6154 638 50	ESA	50	A	05/11/1954	16/11/1955	2	11	11		D &
Skálvíksgrynnna 6151 632 60	ESA	60	A	18/11/1955	07/12/1955	2	11	12		D
Skálhøvdi 6154 634 66	ESA	66	K	28/11/1958		1	11			L
Á Røðini 6156 649 70	ESA	70	E	25/10/1960		1	10			D
Whole area		59		03/11/1954	25/10/1960	1.4	10	12		
NE Frøðbiarnípa 6133 643 56	ESU	56	B	29/04/1963		1	4		Sp.	L
E Frøðbiarnípu 6134 640 68	ESU	68	B	30/05/1963		1	5			L
E Litlu Dímun 6137 637 68	ESU	68	B	28/05/1963	13/06/1963	6	5	6		L
E Tvøroyri 6133 639 68	ESU	68	B	27/05/1963		1	5			L
E Frøðbiarnípu 6134 640 75	ESU	75	B	30/05/1963	08/06/1963	6	5	6		L
E Litlu Dímun 6137 637 75	ESU	75	B	30/05/1963		1	5			L
Rankin 6138 628 75	ESU	75	B	29/04/1963	06/05/1963	5	4	5		L
Whole area		69		29/04/1963	13/06/1963	3.0	4	6		
V Famjin 6130 700 80	VSU	80	A	16/06/1952		1	6			D
V Famjin 6132 707 100	VSU	100	A	18/11/1952	19/11/1952	2	11	11		D
Sumbiargrynnna 6122 646 103	VSU	103	B	06/05/1963		1	5			L
V Famjin 6125 700 110	VSU	110	A	18/11/1952		1	11			D
V Suðuroy 6135 715 130	VSU	130	K	09/12/1958		1	12			L
Whole area		105		16/06/1952	06/05/1963	1.2	5	12		
Vágahavið 6155 710 70	VSA	70	G	27/04/1954		1	4		Sp.	D
Guttagrynnna 6153 710 74	VSA	74	E	28/03/1960	30/03/1960	2	3	3	Sp.	D
Sandshavið 6145 707 78	VSA	78	K	05/12/1958		1	12			L
Guttagrynnna 6152 707 80	VSA	80	E	25/10/1960		1	10			D
Guttagrynnna 6153 709 84	VSA	84	E	31/01/1961		1	1			L
Hestgrynnna 6155 706 84	VSA	84	E	09/01/1961		1	1			D &
Hestgrynnna 6155 706 85	VSA	85	E	31/01/1961		1	1			L
V Høvdanum 6155 705 85	VSA	85	E	25/10/1960		1	10			D
Vágahavið 6156 722 100	VSA	100	A	31/03/1955		1	3		Sp.	D
Guttagrynnna 6153 715 112	VSA	112	E	28/03/1960		1	3		Sp.	D
Vestur av Guttagrynnnu 6153 713 112	VSA	112	E	28/03/1960	30/03/1960	3	3	3	Sp.	D
Tindarnir 6152 720 113	VSA	113	K	06/12/1958		1	12			L
Whole area		90		27/04/1954	31/01/1961	1.3	1	12		
Vágafjørður 6159 658 55	KO	55	A	26/10/1954		1	10			L
Koltur 6200 701 60	KO	60	A	19/10/1954		1	10			L
NV Koltur 6201 702 60	KO	60	A	13/11/1952	14/11/1953	2	11	11		D
Uttan fyri Koltursnakk 6200 701 65	KO	65	A	02/11/1956		1	11			L
V Koltur 6159 701 65	KO	65	A	08/11/1957		1	11			L
Vestan fyri Koltursnakk 6200 701 65	KO	65	A	03/11/1956		1	11			L
Koltur 6200 702 70	KO	70	A	01/11/1954		1	11			L
V Koltur 6159 701 70	KO	70	A	06/11/1954		1	11			L
V Koltur 6200 702 70	KO	70	A	10/12/1955		1	12			D
V Koltur 6158 659 75	KO	75	A	13/11/1952		1	11			D
V Koltur 6159 701 75	KO	75	A	20/11/1953		1	11			D

No. tagged	No. of lengths	Avg. length	S.D.	Min	Max	No. of recapt.	No. of lengths	Avg. length (tagging)	Avg. length (recapt.)	S.D.	Min	Max	Recapt. %
725	721	53.9	10.8	31	100	157	111	54.5	60.1	10.4	34	82	21.7
26	26	51.3	3.8	45	61	8	4	51.3	55.8	3.0	52	59	30.8
65	65	50.5	4.8	44	65	18	11	50.6	57.3	10.4	47	80	27.7
14	14	61.5	11.4	47	92	4	4	63.5	75.4	5.7	69	82	28.6
1	1	67.0		67	67	1	1	67.0	73.0		73	73	100.0
2	2	45.5	2.1	44	47	0	0						0.0
108	108	52.2	7.0	44	92	31	20	53.0	61.4	11.3	47	82	28.7
2	2	48.0	2.8	46	50	1	1	46.0	47.0		47	47	50.0
17	17	41.8	5.0	35	52	0	0						0.0
91	90	41.3	6.4	26	57	5	3	42.0	50.0	10.4	43	62	5.5
28	28	43.6	7.1	28	59	0	0						0.0
109	108	42.4	7.6	26	75	10	7	44.8	55.2	7.0	46	65	9.2
1	1	38.0		38	38	0	0						0.0
520	519	44.2	8.3	24	79	85	71	45.0	53.4	9.2	38	84	16.3
768	765	43.5	7.9	24	79	101	82	44.8	53.3	9.0	38	84	13.2
373	371	53.1	11.6	37	92	68	46	52.0	62.2	11.3	45	87	18.2
146	146	54.8	7.0	44	81	27	19	52.0	60.0	6.5	50	78	18.5
99	97	42.5	6.5	31	60	8	5	43.4	48.4	7.0	39	55	8.1
6	6	49.2	1.7	47	51	3	2	50.0	52.5	2.1	51	54	50.0
29	29	53.4	10.0	39	83	13	12	55.2	62.1	12.8	47	85	44.8
653	649	51.8	10.7	31	92	119	84	51.7	60.6	10.7	39	87	18.2
26	25	53.8	11.2	45	90	3	2	49.0	56.6	13.4	47	66	11.5
97	95	50.3	6.9	39	75	14	6	49.5	56.3	6.0	50	65	14.4
6	6	67.8	5.7	63	79	1	1	67.0	69.7		70	70	16.7
75	75	45.1	4.1	39	56	5	2	45.0	52.9	4.4	50	56	6.7
59	58	44.5	3.7	39	56	0	0						0.0
114	113	47.2	4.9	39	73	3	1	48.3	60.0		60	60	2.6
8	8	42.8	3.2	40	50	1	0	40.0					12.5
7	7	59.6	4.9	52	66	1	0	65.0					14.3
6	6	49.7	3.2	47	55	2	2	49.5	54.0	4.2	51	57	33.3
19	19	55.9	7.9	44	78	1	1	53.0	61.0		61	61	5.3
294	294	58.5	9.1	41	87	31	23	61.4	66.9	7.3	55	79	10.5
12	12	66.6	5.2	60	77	5	2	67.2	72.9	7.2	68	78	41.7
723	718	52.9	9.6	39	90	67	40	56.4	63.5	8.7	47	79	9.3
42	42	50.3	4.7	44	64	5	4	53.2	56.9	14.1	38	72	11.9
4	4	49.8	4.5	46	56	1	0	50.0					25.0
30	30	52.3	4.6	45	62	3	3	55.7	67.2	13.0	54	80	10.0
14	14	48.7	4.3	45	59	3	3	52.0	53.7	5.5	50	60	21.4
13	13	52.7	6.3	45	70	2	0	55.5					15.4
14	14	49.3	3.0	45	55	6	4	48.8	56.0	8.0	47	66	42.9
10	10	50.6	4.3	45	58	2	1	53.5	56.5		57	57	20.0
61	61	49.6	5.2	44	80	9	4	48.3	56.3	9.0	47	67	14.8
2	2	50.5	0.7	50	51	0	0						0.0
34	34	48.6	4.4	39	59	3	2	48.7	54.5	9.2	48	61	8.8
12	12	49.9	3.9	45	57	1	1	53.0	58.0		58	58	8.3

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

Tagging locality	Area code	Depth (m)	Boat	First date	Last date	Days	Earliest month	Latest month	Season	Tag type
Vágafjørður 6201 658 75	KO	75	A	21/11/1953	27/11/1953	3	11	11		D
Á Barminum 6200 709 80	KO	80	A	02/11/1956		1	11			L
Á Barminum 6201 709 80	KO	80	A	06/11/1957		1	11			L
Grynnan 6158 707 80	KO	80	A	25/10/1954	01/11/1956	3	10	11		L
Hestgryнна 6158 707 80	KO	80	A	13/11/1952	08/11/1957	3	11	11		D &
Hestgryнна 6159 707 80	KO	80	A	14/11/1952		1	11			D
Út fyrri Sandavági 6201 705 80	KO	80	A	01/11/1956		1	11			L
Vágafjørður 6159 703 80	KO	80	A	26/10/1954		1	10			L
Vágahavið 6158 707 80	KO	80	A	31/03/1955	11/05/1955	2	3	5	Sp.	D
V Koltur 6157 712 90	KO	90	A	07/05/1955		1	5			L
Vestan fyrri Grynuna 6158 712 90	KO	90	A	15/11/1955		1	11			L
Vesturhavið 6157 712 90	KO	90	A	04/05/1955		1	5			L
V av Trøllhøvda 6157 658 94	KO	94	E	21/01/1961		1	1			L
Whole area		75		13/11/1952	21/01/1961	1.3	1	12		
Geldisskórðabarmur 6202 717 50	SVA	50	A	10/12/1955		1	12			D &
Undir Vágabjörgum 6202 718 50	SVA	50	A	22/11/1952		1	11			D
Nípubarmur 6201 714 70	SVA	70	A	07/11/1957		1	11			L
Trælanípan 6201 716 70	SVA	70	A	14/11/1953	11/11/1957	7	11	11		D &
Undir Trælanípu 6201 716 70	SVA	70	A	21/11/1952	22/11/1952	2	11	11		D
Undir Vágabjörgum 6201 716 70	SVA	70	A	22/10/1954	23/10/1954	2	10	10		L
Undir Vágabjörgum 6203 720 70	SVA	70	A	21/11/1952		1	11			D
Vágahavið 6201 716 70	SVA	70	G	26/04/1954		1	4		Sp.	D
Trælanípan 6201 716 75	SVA	75	A	30/10/1954	03/11/1956	7	10	11		L
Vágahavið 6201 716 75	SVA	75	A	03/05/1955		1	5			D
Whole area		67		21/11/1952	11/11/1957	2.4	4	12		
Kálvanesboði 6205 726 30	MYK	30	A	29/11/1955	09/12/1955	2	11	12		D &
Urðarboði vestur á Víkina 6205.5 733 40	MYK	40	A	01/12/1955		1	12			L
Mykinesfjørður 6206 727 40	MYK	40	A	21/11/1955	24/11/1955	2	11	11		D &
N av Gáshólmi 6205 727 40	MYK	40	A	05/11/1956		1	11			L
Urðarboði 6205.5 733 40	MYK	40	A	15/11/1952	12/11/1957	2	11	11		D
Álabergsbuktin 6206 730 50	MYK	50	A	21/11/1955		1	11			L
Urðarboði 6205.5 732 50	MYK	50	A	21/11/1955		1	11			L
Mykinesfjørður 6207 730 60	MYK	60	A	20/11/1952		1	11			D
Sunnan fyrri Mykines 6204 737 60	MYK	60	A	23/10/1954		1	10			L
S Mykines 6205 735 80	MYK	80	A	13/11/1957		1	11			D &
SV Dragasund 6204 730 80	MYK	80	A	21/11/1952		1	11			D
Undir Mykinesi (S) 6205 735 80	MYK	80	A	14/11/1957		1	11			D
Guttamið 6203 735 85	MYK	85	A	23/04/1955	02/05/1955	3	4	5		D &
Á Pollinum 6203 750 110	MYK	110	A	03/05/1955	14/11/1957	4	5	11		D &
Vágahavið 6157 736 125	MYK	125	G	26/03/1952		1	3		Sp.	D
Vágahavið 6156 740 130	MYK	130	A	29/03/1955		1	3		Sp.	D
VSV Mykines 6200 800 130	MYK	130	K	08/12/1958		1	12			L
Whole area		72		26/03/1952	08/12/1958	1.5	3	12		
Havnaflæs 6207 738 50	MYL	50	A	20/11/1957		1	11			D
V Barðið 6207 738 50	MYL	50	A	20/11/1952		1	11			D

No. tagged	No. of lengths	Avg. length	S.D.	Min	Max	No. of recapt.	No. of lengths	Avg. length (tagging)	Avg. length (recapt.)	S.D.	Min	Max	Recapt. %
50	50	50.2	4.4	44	62	7	6	48.3	56.3	8.9	46	71	14.0
34	34	50.5	8.7	44	84	7	5	48.3	52.1	4.8	46	57	20.6
12	12	53.6	7.4	46	73	2	1	56.0	60.0		60	60	16.7
57	57	49.4	6.2	44	79	19	12	48.9	55.5	7.6	47	73	33.3
56	56	51.2	4.8	44	65	12	10	51.8	58.2	9.0	46	78	21.4
87	87	51.9	5.2	44	67	14	12	50.9	58.6	8.9	48	74	16.1
2	2	50.0	1.4	49	51	0	0						0.0
29	28	52.0	5.3	45	68	6	2	52.7	63.5	20.5	49	78	20.7
17	17	50.6	4.6	45	61	1	0	51.0					5.9
51	50	49.8	5.3	44	64	19	16	51.4	63.0	8.2	50	73	37.3
15	15	53.7	5.8	45	63	2	2	51.5	60.0	0.0	60	60	13.3
11	11	49.5	4.4	45	60	6	3	49.7	55.3	6.1	50	62	54.5
1	1	59.0		59	59	0	0						0.0
658	656	50.6	5.4	39	84	130	91	50.6	58.2	8.7	38	80	19.8
5	5	50.2	3.7	46	56	0	0						0.0
9	9	50.7	6.6	44	65	0	0						0.0
22	22	51.7	5.6	45	71	4	3	49.5	57.5	5.2	54	64	18.2
348	348	52.8	5.8	42	79	73	53	54.4	61.6	9.6	47	82	21.0
106	106	53.9	5.9	44	71	25	21	54.0	61.1	9.0	48	82	23.6
45	45	51.2	5.5	44	69	7	4	50.0	60.8	11.1	52	76	15.6
24	24	50.7	5.2	43	61	1	1	51.0	55.0		55	55	4.2
2	2	63.0	18.4	50	76	0	0						0.0
132	130	51.4	5.6	44	78	33	17	52.1	63.2	11.1	49	85	25.0
25	25	49.6	6.6	44	77	3	3	48.3	62.6	9.2	52	69	12.0
718	716	52.4	5.9	42	79	146	102	53.3	61.6	9.5	47	85	20.3
13	13	50.5	4.2	45	57	0	0						0.0
33	33	52.6	4.4	45	63	2	1	52.5	57.0		57	57	6.1
4	4	49.5	5.4	45	56	1	1	56.0	70.0		70	70	25.0
2	2	46.5	0.7	46	47	0	0						0.0
70	70	56.2	8.3	46	97	8	8	53.9	58.3	4.8	51	66	11.4
1	1	51.0		51	51	0	0						0.0
10	10	56.0	4.7	49	62	0	0						0.0
17	17	51.5	4.9	46	65	3	3	50.3	66.7	9.0	61	77	17.6
1	1	58.0		58	58	0	0						0.0
33	33	53.7	5.1	47	73	2	1	59.0	70.0		70	70	6.1
2	2	52.0	4.2	49	55	1	1	55.0	61.0		61	61	50.0
4	4	58.3	5.4	52	65	0	0						0.0
48	48	62.8	8.5	48	87	10	5	57.8	61.7	9.3	52	77	20.8
121	121	61.1	9.5	46	97	24	17	63.0	62.4	9.3	51	88	19.8
7	7	56.6	12.0	47	82	1	1	82.0	83.0		83	83	14.3
9	9	62.0	11.5	52	87	0	0						0.0
16	16	57.2	8.4	44	73	6	6	59.0	62.5	10.8	51	78	37.5
391	391	57.7	8.9	44	97	58	44	59.4	62.5	8.9	51	88	14.8
1	1	66.0		66	66	0	0						0.0
8	8	57.4	5.3	52	65	0	0						0.0

MIGRATION OF COD (*GADUS MORHUA*):
TAGGING EXPERIMENTS AT THE FAROES 1952-1965

Tagging locality	Area code	Depth (m)	Boat	First date	Last date	Days	Earliest month	Latest month	Season	Tag type
N av Mykinesi 6208 735 70	MYL	70	A	17/11/1956		1	11			L
Grynnan N Mykines 6212 735 75	MYL	75	S	15/06/1965	16/06/1965	2	6	6		L
V Mýling 6219 733 102	MYL	102	K	07/12/1958		1	12			L
Whole area		69		20/11/1952	16/06/1965	1.2	6	12		
All areas combined		77		11/03/1952	16/06/1965	1.5	1	12		

Appendix 2. Statistics.

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:

AREA\$ (3 levels)

ENO, KO, SVA

MONTHSRECAP\$ (6 levels)

01-02, 03-04, 05-06, 07-08, 09-10, 11-12

YEARTAGGED (6 levels)

1952, 1953, 1954, 1955, 1956, 1957

Dep Var: LOGDISTANCE N: 131 Multiple R: 0.533 Squared multiple R: 0.285

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
<i>AREA\$</i>	5.473	2	2.737	4.079	0.019
<i>LENGTHRECAPT</i>	5.572	1	5.572	8.305	0.005
<i>MONTHSRECAP\$</i>	5.524	5	1.105	1.647	0.153
<i>YEARTAGGED</i>	19.349	5	3.870	5.768	0.000
<i>Error</i>	78.498	117	0.671		

Durbin-Watson D Statistic 1.661

First Order Autocorrelation 0.169

No. tagged	No. of lengths	Avg. length	S.D.	Min	Max	No. of recapt.	No. of lengths	Avg. length (tagging)	Avg. length (recapt.)	S.D.	Min	Max	Recapt. %
8	7	55.1	9.6	47	76	1	1		65.0		65	65	12.5
296	296	52.1	6.6	28	77	32	27	52.9	65.0	9.7	48	90	10.8
18	18	46.6	6.9	33	56	5	4	47.8	54.5	5.0	48	61	27.8
331	330	52.0	6.9	28	77	38	32	52.2	63.7	9.7	48	90	11.5
6512	6484	50.7	9.8	24	104	1043	738	52.1	59.1	10.4	34	90	16.0