Anglerfish (*Lophius* spp) in Nordic waters

Trond Thangstad, Otte Bjelland, Kjell H. Nedreaas
Institute of Marine Research (IMR), Bergen, Norway

Einar Jónsson
Marine Research Institute (MRI), Reykjavik, Iceland

Chevonne H. Laurenson
NAFC Marine Centre, Scalloway, Shetland

Lise Helen Ofstad
Faroe Fisheries Laboratory (FFL), Tórshavn, Faroe Islands

Anglerfish (*Lophius* spp) in Nordic waters

TemaNord 2006:570

© Nordic Council of Ministers, Copenhagen 2006

ISBN 92-893-1416-8

Print: Ekspresen Tryk & Kopicenter

Copies: 150

Printed on environmentally friendly paper

This publication can be ordered on www.norden.org/order. Other Nordic publications are available at www.norden.org/publications

Printed in Denmark

Nordic Council of Ministers

Store Strandstræde 18

DK-1255 Copenhagen K

Phone (+45) 3396 0200

Fax (+45) 3396 0202

Nordic Council

Store Strandstræde 18

DK-1255 Copenhagen K

Phone (+45) 3396 0400

Fax (+45) 3311 1870

www.norden.org

Nordic fishery co-operation

The first Nordic Fisheries Conference was established in 1949. Since then, a comprehensive co-operation has been established involving politicians, management, scientists, trades and industries and other interest groups. The fishery sectors of the Nordic countries have numerous features in common. Fishery co-operation within the Nordic area involves co-operation, financed by the Council of Ministers, on issues and problems of broad interest in the Nordic countries. The steady flow of knowledge and information characterising Nordic fishery co-operation thus becomes a vital tool in ensuring a balanced development of fisheries. The motive of co-operation is thus to contribute to a sustainable and rational use of the living, marine resources.

Nordic co-operation

Nordic co-operation, one of the oldest and most wide-ranging regional partnerships in the world, involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Co-operation reinforces the sense of Nordic community while respecting national differences and similarities, makes it possible to uphold Nordic interests in the world at large and promotes positive relations between neighbouring peoples.

Co-operation was formalised in 1952 when *the Nordic Council* was set up as a forum for parliamentarians and governments. The Helsinki Treaty of 1962 has formed the framework for Nordic partnership ever since. The *Nordic Council of Ministers* was set up in 1971 as the formal forum for co-operation between the governments of the Nordic countries and the political leadership of the autonomous areas, i.e. the Faroe Islands, Greenland and Åland.

Contents

Preface	7
Summary	9
Sammendrag	11
Samandráttur	14
Íslenskt ágríp	16
1. Introduction	21
1.1 Background and objective.....	21
1.2 Recent research on anglerfish in Nordic waters	22
Denmark.....	22
Faroes.....	22
Iceland.....	23
Norway.....	27
Shetland	30
2. Biology and ecology of anglerfish.....	31
2.1 Occurrence and distribution.....	32
General distribution.....	32
Depth distribution	32
Migratory behaviour	33
Morphological and genetic variation.....	36
2.2 Life history	39
2.3 Age and growth.....	43
Growth structures and ageing methods	43
Age validation.....	45
Growth rates.....	47
Age and length at first maturity.....	49
2.4 Sex composition.....	55
2.5 Reproduction.....	56
Sexual maturation and female fecundity	56
Spawning	58
2.6 Natural mortality.....	61
Predation	61
Cannibalism	62
2.7 Food and feeding	62
2.8 Parasite and disease studies.....	63
3. Fisheries, assessment and management of anglerfish stocks	65
3.1 Commercial anglerfish fisheries in the North Atlantic.....	65
Denmark.....	66
Faroe Islands	67
Iceland.....	69
Norway.....	71
Shetland	73
Northern and Southern Shelf.....	74
3.2 Fishing gears and methods.....	76
3.3 Fisheries statistics	77
Denmark.....	77
Faroe Islands	77
Iceland.....	77
Norway.....	77
Scotland/Shetland.....	78
3.4 Biological sampling	78
Denmark.....	78

Faroe Islands.....	78
Iceland	78
Norway	79
Scotland/Shetland	79
3.5 Stock assessment and management	80
Iceland	80
Northern and Southern Shelf	81
3.6 Mortalities and fishing pattern.....	83
Estimation of total mortality by the linear catch curve method	83
Faroe Islands.....	84
Estimation of fishing mortality and fishing pattern from population dynamics.....	86
Summary	87
3.7 Yield and spawning stock per recruiting fish	88
Faroe Islands.....	88
Iceland	89
Norway	90
Concluding remarks.....	91
4. Future research.....	93
5. References.....	95
Annex A Tagging of anglerfish during the Nordic project.....	101
Annex B Investigation into the Suitability of Internal Data Storage Tags (DST) for Studies Involving Monkfish <i>Lophius piscatorius</i>	113
Annex C Verification of anglerfish (<i>Lophius piscatorius</i>) age estimation through comparison of length modes of age read fish (<i>illicia</i>) to length modes of big year-classes appearing in the Icelandic stock	121
Annex D A note on the development of the embryos of anglerfish	139
Appendix tables and figures.....	143

Preface

The Nordic Working Group on Fisheries Research (NAF) financed a two-year research project called “Anglerfish (*Lophius* spp) in Nordic waters” during the period 2003-2004¹. The project aimed to coordinate a synoptic collection and analysis of anglerfish data in large parts of the species’ Nordic area of distribution. The initial project phase was in 2002, and was also financed through a grant from NAF. Research status on anglerfish in Nordic and European waters to the end of 2002 was presented in a preliminary project report (Thangstad *et al.* 2003), published electronically on the website of the Nordic Council of Ministers (<http://www.norden.org>).

The background for the project was the dramatic increase in directed fisheries aimed at anglerfish in Nordic and European waters during the last decade. At present, Nordic anglerfish stocks are managed mainly through gear regulations, except in ICES Division IV (the North Sea) where a total allowable catch (TAC) has been in place since 1998. The fishery in the other areas ideally needs to be limited through quotas (TACs), but necessary stock assessment is difficult to conduct because of the lack or incompleteness of fisheries and biological data on anglerfish in these waters.

During the project, meetings were held at the Faroese Fisheries Laboratory (FFL) in Tórshavn 23-25 May 2002, at the North Atlantic Fisheries College (now NAFC Marine Centre), Scalloway, Shetland, 16-19 July 2003, and at the Institute of Marine Research (IMR), Bergen, Norway, 4-6 August 2004. With the participation of scientists from Norway, Iceland, the Faroe Islands and Shetland, project status and progress on the report were discussed.

The present report describes the status with regard to research and knowledge about anglerfish in the participating Nordic countries including Shetland, and presents new results achieved during the two-year project. The report also discusses areas of research that need to be prioritised.

The authors would like to thank NAF for providing financial support. Many thanks go to Merete Fonn and Olav Sigurd Kjesbu for preliminary analysis and presentation of gonad histology, Knut Jørstad for screening of DNA sequences from genetic samples, and Hjalte í Jakopstovu at the FFL in Tórshavn for his support and hospitality during the first project

¹ Preceding and parallel with the NAF project, two Faroese anglerfish projects have been funded by the Faroese Fisheries Research Fund: “Anglerfish - Fishery and biology” (2001-2004) and “Tagging of anglerfish” (2004-2006).

meeting. Thanks also go to the NAFC in Scalloway, and the IMR in Bergen for hosting later project meetings.

Summary

The demand for anglerfish (also called monkfish; *Lophius* spp.) for human consumption has increased in the last couple of decades because of the delicate consistency of its meat. In Nordic waters anglerfish are primarily caught by large-meshed gillnets, except in parts of the North Sea where the Scottish and Danish fisheries are mainly by different trawls and regulated by days-at-sea and/or catch quotas, and at Iceland and the Faroes where trawl also is an important gear. Trawls may be designed for catching anglerfish as target species, or as an important bycatch when targeting *Nephrops*. The gillnet fisheries are regulated chiefly through restrictions on gear use, i.e. mesh size, number of nets, soak time, etc.

So far relatively little is known about the biology and ecology of anglerfish. Two quite similar species (*Lophius piscatorius* and *L. budegassa*) are commonly distributed along the European continental shelf. *L. piscatorius* is by far the most common species in near-coastal Nordic waters, where it is a regular predator upon a wide variety of prey types. It reaches maturity from an age of 5-8 years, males earlier than females. At maturation it weighs over 3 kg and is from 50 to 100 cm long in Nordic waters. *L. piscatorius* can reach a length of up to 2 m when fully grown, but are usually much smaller. It is assumed that they spawn in deeper water, but this has never been directly observed. The spawning behaviour is unusual in that the eggs are released in up to 10 m long veils, which hatch in open water. Eggs and larvae drift with ocean currents and the juveniles eventually settle on the seabed when they reach about 5 cm in length.

Answers to questions regarding the spawning behaviour, migratory behaviour and juvenile drift, as well as more knowledge about growth, sexual maturation, diet and natural mortality, will thus form crucial contributions to present and future management of Nordic anglerfish stocks.

This report presents a review of the status of current knowledge and research on the biology, ecology, fisheries and stock management of anglerfish in Nordic and European countries, including results and publications from a three-year Nordic cooperative anglerfish research project (2002-2004). An important achievement during the project has been the development of a common maturation scale between the participating countries and regions. Visual presentations of the sexual maturation process have also been prepared. Fruitful discussions on improving and standardising current ageing methodologies were held, while not yielding any definite consensus on which bony structure is optimal for ageing.

Biological sampling efforts in all participating countries were intensified during the project, and have produced better data on growth rates,

age and growth verification, maturation, age and length at first maturity, oocyte and egg development, as well as diet composition of anglerfish. Stomach contents consist mainly of various bony fishes, but diet generally seems to depend on prey availability. Sampling programmes and egg mass observation campaigns have resulted in a more precise determination of the time of spawning, but the exact locations where spawning occurs remain somewhat elusive, perhaps because of the unusual nature of the female spawning. Preliminary DNA analysis on Icelandic and Norwegian muscle tissue samples did not reveal any apparent genetic differences between the two areas. As yet the number of genetic analyses and results has been too limited to disclose any stock or population structuring of anglerfish in Nordic waters.

Tag-and-release programmes to study the migratory behaviour of anglerfish, mainly conducted with conventional spaghetti tags, have to date shown the horizontal movement of recaptured individuals to be mostly localised to the same grounds in which they were tagged, limited to straight distances within a 100 km radius. Three individuals had, however, made more extensive migrations; one fish tagged at Shetland and another tagged at the Faroes were recaptured at Iceland, while a third was after release at Shetland recaptured at the Faroes. The suitability of the use of internal data storage tags (DSTs) that log temperature and depth was investigated in tank survival experiments in Shetland. While post-operative mortality involved in this tagging procedure may be high, a small number of DSTs was used in tagging of anglerfish at Iceland and the Faroes. One Icelandic tag has so far been recovered, however only after a few weeks at sea. This is thought to be the first known successful international recovery of a DST revealing the behaviour of anglerfish. The recorded data show interesting vertical movement of the anglerfish, e.g. where it had made several trips from the bottom at 118 m depth to close to the surface.

As a first step towards an assessment of Nordic anglerfish populations/stocks, preliminary attempts were made in Faroe Islands, Iceland and Norway at estimating the current level of fishing mortality, and the yield and spawning stock per anglerfish recruit. The preliminary conclusion is that the current fishing mortality is too high to secure a sustainable and stable long-term yield, at least for the anglerfish fishery in the Faroe Islands and Norway. There will be no long-term gain in yield by increasing the current fishing effort. On the contrary, the preliminary analyses show that the long-term yield may increase if the fishing effort is reduced by 50-60% if the current exploitation pattern is kept. Some of this increase in yield and yield stability can, however, be achieved by letting a greater part of the catch be taken by large-meshed gillnets. In Norwegian waters, a change from today's exploitation pattern (both trawl and gillnets) towards only using large-meshed gillnets could increase the long-term yield by 20-25%.

Sammendrag

(Summary in Norwegian)

Etterspørselen etter breiflabb (*Lophius* spp.) for konsum har økt betraktelig de siste tiårene på grunn av kjøttets delikate konsistens. Fisket i nordiske farvann foregår hovedsakelig med stormaskede garn, bortsett fra i deler av Nordsjøen, hvor de skotske og danske fiskeriene stort sett foregår med trål og er regulert gjennom antall fiskedøgn og/eller fangstkvoter, og ved Island og Færøyene hvor trål også er et viktig redskap. Trålene kan være konstruert for et direktefiske mot breiflabb, eller som en viktig bifangst i trålfisket rettet mot *Nephrops*. Garnfisket er stort sett regulert gjennom restriksjoner i bruk av redskap, for eksempel tillatt maskevidde, antall garn, ståtid osv.

Foreløpig er relativt lite kjent omkring breiflabbens biologi og økologi. To arter som er ganske like i utseende (*Lophius piscatorius* og *L. budegassa*) er utbredt langs den europeiske kontinentalsokkelen. *L. piscatorius* er den vanligste av de to i kystnære nordiske farvann, hvor den er en vanlig predator som beiter på et variert utvalg av byttedyr. Den blir kjønnsmoden ved en alder på ca 5-8 år, hanner tidligere enn hunner. Ved kjønnsmodning veier den over 3 kg og er 50 til 100 cm lang i nordiske farvann. *L. piscatorius* kan bli over 2 m lang når den er fullt utvokst, men er vanligvis mye mindre. Den antas å gyte i dypere farvann, men dette er aldri blitt direkte observert. Gyteatferden er spesiell i og med at eggene gytes i lange rognband (opptil 10 m) og klekkes i det åpne hav. Egg og larver driver med havstrømmene og breiflabben bunnslår seg etter hvert ved en lengde på ca. 5 cm.

Besvarelse av spørsmål vedrørende gyteatferd, vandring og juvenil drift, samt mer viten om vekst, kjønnsmodning, diett og naturlig dødelighet, vil således gi avgjørende bidrag til den nåværende og fremtidige forvaltningen av nordiske bestander av breiflabb.

Denne rapporten inneholder status for viten og forskning omkring biologi, økologi, fiskerier og bestandsforvaltning av breiflabb i Norden og Europa for øvrig, samt resultater og publikasjoner fra et treårig nordisk samarbeidsprosjekt om breiflabbforskning (2002-2004). En milepæl under prosjektet har vært utviklingen av en felles modningsnøkkel mellom deltagerlandene og -regionene. Visuelle presentasjoner av seksuell modning ble også utarbeidet. Det ble holdt produktive diskusjoner omkring forbedring og standardisering av eksisterende metoder for aldersbestemmelse, men det ble ikke nådd definitiv enighet om hvilken beinstruktur hos breiflabb som er optimal til aldersbestemmelse.

Biologisk prøvetaking i alle deltagende land ble intensivert i prosjektperioden, og har resultert i bedre data på vekstrater, alders- og vekstverifisering, modning, alder og lengde ved førstegangs modning, oocytt- og eggutvikling, så vel som diettsammensetning hos breiflabb. Mageinnhold bestod for det meste av forskjellige beinfisker, men diett synes generelt å avhenge av byttedyrtilgjengelighet. Utvidet prøvetaking og kampanjer for innrapportering av eggbåndobservasjoner har resultert i en mer nøyaktig bestemmelse av gyteperioden, men det er fortsatt noe uklart hvor gytingen egentlig foregår, kanskje på grunn av breiflabbhunnens noe uvanlige gyteatferd. Foreløpige DNA-analyser av islandske og norske muskelvevsprøver viste ikke noen entydige genetiske forskjeller mellom disse områdene. Hittil har antallet genetiske analyser og resultater vært for begrenset til å påvise noen bestands- eller populasjonsstrukturering hos breiflabb i nordiske farvann.

Merke- og gjenfangstprogrammer for å studere vandringsatferden hos breiflabb, hovedsakelig gjennomført ved hjelp av konvensjonelle spagetimeker, har hittil vist at den horisontale forflytningen av gjenfangede individer for det meste er lokalisert til de samme områdene som de var merket og satt ut i, begrenset til rettlinjete distanser innenfor en radius av ca. 100 km. Tre individer hadde allikevel utført mer omfattende vandringer; en fisk merket ved Shetland og en annen merket ved Færøyene ble begge gjenfanget ved Island, og en tredje ble gjenfanget ved Færøyene etter utsetting ved Shetland. Hensiktsmessigheten av bruken av innvendige datalagringsmerker (data storage tags, DST) som logger temperatur og dybde ble testet i overlevningsforsøk i kar på Shetland. Selv om postoperativ dødelighet ved bruk av denne metoden kan være høy, ble et lite antall DST brukt i merking av breiflabb ved Island og Færøyene, hvor ett islandsk merke hittil har blitt gjenfanget, men kun etter et par uker i sjøen. Dette tror man er den første vellykkede internasjonale gjenfangsten av en DST som viser atferden til breiflabb. Lagrede data fra dette merket viser interessante vertikale forflytninger hos breiflabbindividet, hvor det for eksempel hadde gjennomført flere turer fra bunnen på 118 meters dyp opp til nært overflaten.

Som et første skritt på veien til en bestandsvurdering av breiflabbpopulasjoner i nordiske farvann, ble det gjort foreløpige forsøk på Færøyene og Island og i Norge på å estimere fiskedødelighet, og utbytte og gytebestand per breiflabbrekrutt. Den foreløpige konklusjonen er at den nåværende fiskedødeligheten er for høy til å sikre et bærekraftig og stabilt langtidsutbytte, i hvert fall for breiflabbfiskeriene ved Færøyene og i norske farvann. Det vil ikke gi noen gevinst i utbytte på lengre sikt ved å øke den nåværende fiskeinnsatsen. Tvert imot viser foreløpige analyser at langtidsutbyttet i fiskeriene kan øke hvis innsatsen reduseres med 50-60 % om det nåværende beskatningsmønsteret blir beholdt. Noe av denne økningen i utbytte og utbyttestabilitet kan allikevel oppnås ved å la en større andel av fangsten bli tatt med stormaskede garn. I norske farvann

kunne et skifte fra dagens beskatningsmønster (med både trål og garn) til bruk av kun stormaskede garn øke langtidsutbyttet med 20-25 %.

Samandráttur

(Summary in Faroese)

Eftirspurningurin eftir havtasku (*Lophius* spp) til matna er øktur seinnu árinum orsakað av góða konsistensinum í kjøtinum. Havtaska í Norðrhøvum verður fyrst og fremst veidd við gørnum við stórum meskum. Undantíknir eru teir partar av Norðsjónum, har skotar og danir serliga royna eftir henni við trolí. Hesin fiskiskapurin verður reguleraður við fiskidøgum og/ella kvotum. Við Ísland og Føroyar er trol eisini eitt týðningarmikið amboð. Trolini kunnu vera evnaði beinleiðis til havtaskuveiðu ella til veiðu eftir *Nephrops*, og tá er havtaska týðningarmikil hjáveiða. Garnaveiðan verður í høvuðsheitum regulerað við avmarkingum í reiðskapsnýtsluni, t.d. meskavídd, garnatal, tíðin gørnini standa o.a.

Lívfrøðin og vistfrøðin hjá havtasku er framvegis rættuliga ókend. Á europeiska landgrunninum liva tvey havtaskusløg, sum í útsjón eru rættuliga lík (*Lophius piscatorius* og *L. budegassa*). *L. piscatorius* er nógv tann vanligara í strandarøkjunum í Norðrhøvum, og føðin hjá henni har er fjølbroytt. Havtaska er kynsbúgvinn tá hon er um 5-8 ár, siljafiskar fyrr enn rognafiskar. Tá havtaskan er kynsbúgvinn vigar hon oman fyri 3 kg og er 50 til 100 cm til longdar. *L. piscatorius* kann gerast meira enn 2 m til longdar, tá hon er fullvaksin, men er vanligar nógv minni. Tað verður hildið at havtaska gýtir á djypri leiðum, men hetta er ongantíð beinleiðis staðfest. Gýtingaratferðin er sjáldsom, við tað at rognini verða gýtt í longum rognabondum (upp til 10 m) og klekjast á opnum havi. Rogn og yngul ferðast við streymunum og ungu havtaskurnar fara so hvørt til botns, tá tær verða um 5 cm til longdar.

At fáa spurningar um gýting, ferðing og yngulferðing svaraðar, saman við øktari vitan um vøkstur, kynsbúning, føði og náttúrligan deyða, fer at geva avgerandi ískoyti til núverandi og framtíðar umsiting av norðurlandsku havtaskustovnunum.

Henda frágreiðing vísir, hvør vitan og gransking í lötuni finst um lívfrøði, vistfrøði, fiskiskap og stovnsumsiting av havtasku í Norðurlondum og Europa annars, m.a. granskingarúrslit og publikatiónir frá eini trý ára langari norðurlandskari samstarvsverkætlan um havtaskugransking (2002-2004). Eitt avgerandi úrslit í hesi verkætlan hevur verið, at luttakarlondini og -økini hava ment ein felags búningarlykil. Myndatilfar av ymsum búningarstigum varð eisini gjørt í hesum sambandi. Fruktagóðar samrøður hava verið um at betra og standardisera nýttar hættir til aldursgreining, men ongin endalig felags niðurstøða var gjørd um hvør beinbygnaður hjá havtasku er best egnaður til aldursgreining.

Í verkætlanartíðini hava lívfrøðiligar royndir verið tiknar í størri mun enn annars í øllum luttakaralondunum. Hetta hevur ført við sær betri tilfar um vøkstur, aldurs- og vakstrarstaðfesting, búning, aldur og longd við fyrstu kynsbúning og føðisamanseting hjá havtasku. Magainnihaldið var fyrst og fremst ymsir fiskar, men føðin tykist sum heild at vera tengd at teimum føðidjórum, sum eru tøk. Víðkað royndartøka og átøk fyri at fáa fráboðanir um sædd rognabond hava ført við sær, at gýtingartíðin er nágreiniligari ásett, men tað er framvegis heldur ógreitt júst hvar havtaskan gýtir, kanska orsakað av heldur óvanligu gýtingaratferðini hjá rognafiskunum. Tær DNA-greiningar, sum eru gjørdar av íslenskum og norskum royndum av vøddavevnaði, vísa ikki nakrar eintýðugar arvaligar munir millum økini. Enn eru genetisku greiningarnar og úrslitini ov fá í tali til at ávísa stovns- ella poplutiónsbygnað hjá havtasku í Norðurhøvum.

Merkingarroyndir fyri at hyggja at ferðingini hjá havtasku, fyrst og fremst við spaghettimerkjum, hava higartil víst, at horisontala ferðingin hjá afturfingnum havtaskum fyri tað mesta er avmarkað til somu øki, sum tær vóru merktar og útsettar í, innan fyri ein radius upp á 100 km. Tríggjar havtaskur høvdu tó ferðast meiri víða. Ein havtaska merkt í Hetlandi og ein onnur við Føroyar vóru afturfingnir við Ísland, meðan tann triðja, sum var merkt í Hetlandi var fingin aftur við Føroyar. Kannað varð í yvirlivlisisroyndum í kørum í Hetlandi, um tað loysir seg at nýta inno-pereraði talgild goymslumerki (Digital Storage Tags, DST) til at máta hita og dýpi. Hóast deyðatalið eftir hesa skurðviðgerð kann vera høgt, vóru nakrar fáar havtaskur merktar við DST við Ísland og Føroyar. Av teimum er higartil eitt íslenskt merki afturfingið eftir einans tvær vikur í sjónum. Hildið verður, at hetta er fyrstu ferð í altjóða høpi at eitt DST er fingið aftur, sum vísir atferðina hjá havtasku. Tilfarið frá hesum merkinum vísti á áhugaverda vertikala ferðing, t.d. var hon fleiri ferðir farin av botni á 118 metra dýpi og næstan upp undir vatnskorpuna.

Sum eitt fyrsta stig til stovnsmeting av havtaskupoplutiónum/-stovnum í Norðurhøvum, vóru gjørdar fyribils royndir við Føroyar, Ísland og í Noregi til at áseta núverandi fiskideyðatal, úrtøku og gýtingarstovn fyri hvønn havtaskurekrutt. Fyribils er niðurstøðan, at núverandi fiskideyðatal er ov høgt til at tryggja eina burðardyggja og haldgóða langtíðarúrtøku, í hvussu so er fyri havtaskufiskiskapin við Føroyar og í norsku økjum. Ongin langtíðar vinningur er við at økja veiðitrýstið. Tvørturímóti vísa fyribils greiningar, at langtíðarúrtøkan kundi økt, um veiðitrýstið verður minkað eini 50-60% við verandi veiðihátti. Nakað hægri úrtøka og úrtøkujavnvág kann tó eisini fáast við at størri partur av veiðuni verður tikin við gørnum við størri meskum. Í norskum øki kundi langtíðarúrtøkan økt eini 20-25%, um skift var frá veiðiháttinum í dag (við troli og gørnum) til einans at nýta gørn við stórum meskum.

Íslenskt ágrip

(Summary in Icelandic)

Á síðustu tíu árum hefur eftirspurn eftir skötusel (*Lophius* spp.) aukist mjög sem aftur má þakka því hversu góður matfiskur og mikið kostgæti þessi fíkitegund þykir nú á dögum. Á því svæði sem í skýrslu þessari er mest til umfjöllunar og hér er kallað Norðursvæði - nær frá Noregi um Hjaltland, Færeyjar til Íslands - er skötuselur aðallega tekinn með stórmöskva netum og veiðunum mest stjórnað með ýmsum reglugerðar-takmörkunum varðandi gerð og notkun veiðarfæra. Á Íslandi er þetta reyndar gert með kvótasetningu og geta má þess að þar veiðist skötuselurinn töluvert sem meðafli í vörpur, sérstaklega humarvörpu.

Þekking á líf- og vistfræði skötuselsins er tiltölulega takmörkuð. Meðfram evrópsku landgrunnsbrúninni eru þekktar tvær tegundir skötusels sem eru næsta líkar í útliti, þ.e. *Lophius piscatorius* og *L. budegassa*. Sú fyrirnefnda er miklu algengari norðantil við strendur álfunnar og er þar einnig að finna á landgrunninu sjálfu allt upp undir strendur og þá stundum á tiltölulega grunnu vatni. Skötuselurinn er dæmigerður ránfiskur og bráð hans er ekki einsleit heldur legst hann á ýmsar tegundir fiska sem hafast við eða koma inn á búsvæði hans. Hann nær kynþroska 5-8 ára gamall og hængarnir þroskast nokkuð fyrr en hrygnur. Á þessum norðlæggu slóðum er fiskurinn milli 50 til 80 cm langur þegar kynþroska er náð og vegur þá um og yfir 3 kg. *L. piscatorius* getur fullvaxinn náð allt að 2 m lengd en stærstu fiskar í veiðunum í dag eru þó vanalega miklu minni. Álitid er að skötuselurinn hrygni á nokkuð djúpu vatni á og við landgrunnsbrúnir en fátt er um beinar athuganir þessu til staðfestingar. Hrygning skötuselsins er annars mjög sérstæð þar sem hrygnan setur frá sér afurð sína í allt að 10 m löngum hrognaborða sem rekur um uns hrognin klekjast út. Egg og lirfur eru svíflæg og berast með hafstraumum þar til seiðin leita botns þegar þau eru um 5 cm á lengd.

Enn er mörgu ósvarað varðandi skötuselinn svo sem um hrygningu, far hans milli landa, rek seiða, erfðafræðilegan skyldleika milli stofna á svæðinu og þörf er á frekari vitneskju um vöxt, kynþroska, fæðu og náttúrulega dánartölu. Aukin þekking um þessa þætti getur skipt sköpum um hvort hægt er að veita trausta ráðgjöf varðandi stjórnun veiða í skötuselsstofninn og þá um leið skynsamlega nýtingu hans. Þessi skýrsla er afrakstur liðlega þriggja ára samvinnu Noregs, Hjaltlands, Færeyja og Íslands um rannsóknir á skötusel sem styrkt er af Norræna ráðherraráðinu. Í henni eru bæði reynt að draga saman í einn stað kjarna núverandi þekkingar og vitneskju hvað varðar skötusel, þ.e. um líffræði, vistfræði veiðar og stjórnun þeirra á umræddu hafsvæði sem tilheyrir þessum lön-

dum en einnig er tínt til töluvert af upplýsingum um báðar skötuselstegundirnar sem finnast við Evrópustrendur. Þá eru einnig kynntar í skýrslunni niðurstöður og áfangar þeirra rannsókna á skötusel sem fram hafa farið á áðurnefndum tíma undir merki þessa norræna samstarfs.

Hér er af mörgu að taka. Tímamótaáfangi náðist þegar samin var nýr greiningarlykill fyrir kyn- og kynþroskastig skötusels sem byggður er á vitneskju frá öllum hafsvæðum og þáttakendum sem að samvinnuverkefninu stóðu. Með þessum lykli voru útbúnar litmyndir af kynkirtlum hænga og hrygna á mismunandi kynþroskastigum svo greiningarlykillinn komi að sem mestum notum því sjón er sögu ríkari. Fram fór mikil umræða um aðferðir og samræmingu á viðteknum aðferðum við aldursgreiningu sem var mjög gagnleg enda þótt ekki hafi endanlega verið kveðið upp úr með það hvort væri betra í þessum tilgangi kvörn eða veiðistöng.

Á þeim tíma sem samvinnuverkefnið stóð yfir var skötuselssýnataka hjá öllum þátttakendum stóraukin frá því sem verið hafði. Afraksturinn af því eru betri og meiri gögn varðandi ýmsa líffræðilegu þætti svo sem aldur, vaxtarhraða, sannreyningu á aldurslestri, kynþroska, kynþroskaaldri, kynþroskalengd, eggjamyndun, eggjaþroska og fæðu. Skötuselurinn leggur sér að mestu til munns aðra beinfiska og er matseðillinn allmjög háður framboði og aðgengileika bráðarinnar á hverjum tíma og stað. Hrygning skötusels er mjög sérstæð þar sem hrygnan setur frá sér egginn í löngum glærum borða sem svífur um í sjónum og margt er reyndar á huldu um allt þetta ferli. Reynt var að ná sýnum af eggjaborðum skötuselsins og auglýst eftir vitneskju sjómanna um slíka borða sem bar nokkurn árangur þannig að aflað var aukinnar þekkingar hvað þetta varðar. Safnað var vefjasýnum til erfðagreiningar (DNA) og fyrstu niðurstöður benda til mikils skyldleika milli skötusels við Ísland og Noreg. Þetta verður að teljast góður áfangi í rannsóknum á þessu sviði því áður höfðu hliðstæðar rannsóknir verið reyndar sem tóku til nokkurra af umræddum stofnum en umfang og gæði sýna var of lítið til þess að niðurstöður fengjust sem eitthvað væri byggjandi á.

Fram fóru töluvert umfangsmiklar merkingar á skötusel á rannsóknarsvæðinu í heild. Merking með venjulegum örvamerkjum hafa sýnt að skötuselurinn heldur sig að mestu á sama svæði og nær öll merkin endurheimtust innan 100 km frá merkingarstað. Á þessu voru þó þrjár mikilvægar undantekningar sem sýna að skötuselur á það til að ganga milli landa. Fiskur merktur við Færeyjar endurheimtist við suðurströnd Íslands og þar endurheimtist og annar merktur við Hjaltland. Úr Hjaltlandsmerkingunni fékkst einnig fiskur við Færeyjar. Þá var merkt með rafeindamerkjum (DST) sem skrá dýpi (þrýsting) og hita þar sem fiskurinn er staddur hverju sinni. Byrjað var að gera tilraunir í kerum á Hjaltlandi með það hvernig skötuselur þýldi þá aðger að rafeindamerki væri komið fyrir í honum innvortis og hvernig væri best að standa að slíku. Þótt ljóst sé að einhver afföll geti orðið í slíkri merkingu voru nokkrir tugir fiska merktir

með rafeindamerkjum við Ísland og Færeyjar. Eitt nothæft merki endurheimtist við Ísland eftir tæpar tvær vikur og mun þetta vera í fyrsta sinni sem upplýsingar fást um hegðan og far skötusel frá rafeindamerkjum. Þótt fiskurinn hefði verið stuttan tíma í sjó sást að hann hafði lyft sér nokkrum sinnum frá botni á 118 m dýpi og synt langleiðina upp til yfirborðs.

Í þessu samvinnuverkefni voru stigin fyrstu skref í átt að stofnmati á skötusel. Í Noregi, Færeyjum og Íslandi var gerð fyrsta tilraun til þess að meta heildardánartölu stofna og afrakstur á nýliða. Fyrstu niðurstöður benda til að í tveim fyrstnefndu löndunum sé fiskveiðidauði of mikill til þess að sjálfbær nýting geti átt sér stað og aukning á núverandi sókn muni ekki skila auknum afla á land sé til langs tíma litið. Vísbendingar eru um að langtíma afrakstur stofnsins verði aðeins aukin með því að minnka sókn um 50-60% frá því sem nú er ef fiskveiðimynstur helst óbreytt. Árangursríkt skref til þess að ná betri nýtingu út úr stofnunum er að sótt sé sem mest í skötuselinn með stórmöskva netum. Þannig hafa verið leiddar líkur að því að auka megi langtímaafrakstur norska skötuselsstofnsins um 20-25% frá því sem nú er með því að breyta fiskveiðimynstrinu og stunda veiðarnar eingöngu með stórmöskva netum í stað blandaðra vörpu- og netaveiða eins og þekkist í dag.

1. Introduction

1.1 Background and objective

During the last decade trawl and gillnet fisheries targeted on anglerfish (*Lophius* spp.) in Nordic waters (Figure 1.1) have increased considerably in catch and effort. A general shortage of fisheries and biological data concerning anglerfish in these waters has made an appropriate stock assessment difficult to achieve. The considerable fishery that is pursued by UK (mainly Scottish) vessels in Area IV, particularly around the Shetland Isles, has been the subject of EU TAC regulations since 1998. This fishery is mainly by trawl and is also subject to regulations relating to the fishing gear i.e. minimum mesh sizes and also days-at-sea. Of the other countries in the region² only Iceland has so far set a precautionary TAC³. Elsewhere, regulations have mostly been limited to gear specific measures, relating to e.g. minimum gillnet mesh size, number of nets allowed per boat/setting, maximum soak time of the nets, a limited moratorium (Norway), and no directed trawl fishery (Norway).

With these limitations in mind, fisheries scientists at the Marine Research Institutes in Faroe Islands, Iceland, Norway, and Shetland have undertaken efforts to coordinate a synoptic collection and analysis of anglerfish data in large parts of its Nordic area of distribution. Research areas of particular interest in the project have been:

- Investigation of anglerfish species composition in the Nordic areas
- Description of the fisheries and catches/landings of anglerfish in the Nordic areas
- Mark and recapture of individuals to investigate distribution areas and possible migration patterns
- Collection of biological data in order to describe sexual maturation in anglerfish, localise spawning areas and determine the time of spawning
- Investigation of the age and length at first-time sexual maturation, in order to determine an optimal minimum fish size in commercial catches
- Genetic analysis of biological samples with the aim of describing stock and population structure of anglerfish

² Denmark, Faroe Islands, Iceland, and Norway

³ Total Allowable Catch, 2 500 t (2 200 t recommended by MRI based on previous years' catches), in effect from September 2005 until August 2006.

- Further research with regard to time of hatching, growth, and duration of the pelagic phase, as well as describing length and age structure of anglerfish in the distribution area, e.g. to define its nursery grounds

The objective of the project has primarily been to review and add new data and knowledge concerning the biology and ecology of European anglerfish, especially with regard to future assessment of the size and distribution of the fishable stock(s) in Nordic waters. The review includes recent studies (from 1990 and onwards) relating to *Lophius piscatorius* and *L. budegassa*, which are the only occurring anglerfish species in the Northeast Atlantic, both of which are commercially exploited. The work has mostly been financed by the Nordic Working Group on Fisheries Research, while the research on anglerfish conducted at the Faroes was also funded by other means (see footnote on p. 3).

1.2 Recent research on anglerfish in Nordic waters

This section briefly outlines previous research on anglerfish, and research efforts and publications in the participating Nordic countries during the project. These and other results pertinent to the biology, ecology and management of anglerfish are discussed in later sections.

Denmark

There has been little directed research on anglerfish in Danish waters (S. Reeves, pers. com.). However, length compositions of landings and discards have been measured during observer trips since 1995, and market sampling of landed fish commenced in 2002.

Faroes

Research at the Faroese Fisheries Laboratory (FFL) in Tórshavn has thus far focused on biological sampling of commercial trawl and gillnet landings. Data on length, weight (round, gutted, gonad, and liver), sex and maturation were collected, as well as otoliths and *illicia* (first dorsal fin ray) for ageing purposes. In addition a number of stomach samples were collected and analysed. Anglerfish samples were taken every fourth week from November 2001 to March 2002 from a trawler fishing on Skeivabanka southwest of the Faroe Islands ($n = 470$ samples) (Figure 1.2). 250 samples were taken in late August 2001 onboard a gillnetter, and 48 samples were collected from landings in the Faroes in June 2002. During a 10-day pilot anglerfish survey in February 2002 in near-Faroese waters 540 anglerfish were sampled. Some anglerfish have also been registered during regular bottom trawl surveys (Figure 1.3) (see section 3.4).

Iceland

Until 1999 anglerfish were only landed as bycatch in Iceland, and research at the Marine Research Institute (MRI) in Reykjavik was limited to length measurements from areas where anglerfish were found during annual bottom trawl surveys around Iceland (Figure 1.4) and during *Nephrops* surveys off the south coast (Figure 1.5). However, since the same trawl gear has been used since 1985, these data provide valuable information on the dynamics of anglerfish stocks in Icelandic waters. After the initiation of a directed fishery with gillnets and special anglerfish trawls in 1999, research efforts have intensified. Data on individual length and weight (round and gutted), sex, gonad weight, and maturation were collected with increased effort in 2000 ($n = 1\,624$) and 2001 ($n = 2\,924$). Liver samples are planned taken in the near future. *Illicia* have also been collected and efforts at age reading from these have been undertaken. This research is expected to be fruitful for future stock management. Some results from Icelandic age validation research were presented in a working document to the report from the Anglerfish *Illicia*/Otoliths Ageing Workshop, held in Lisbon in November 2004 (Jónsson 2004) (see also Annex C).

Figure 1.2

Length distribution of anglerfish ($n = 470$) from commercial trawl samples taken at 300-380 m depth on Skeivabanka west of the Faroes, November 2001-March 2002.

Figure 1.3

Distribution of anglerfish on the Faroe Plateau, from autumn bottom trawl surveys (1996-2002). Left plot: catch in numbers per hour; right plot: catch in kg per hour

Figure 1.4

Annual distribution and abundance of anglerfish in the Icelandic bottom trawl survey 1986-2004.

Figure 1.5

Length distribution of L. piscatorius in bottom trawl and Nephrops surveys in Icelandic waters March and May 1999-2002, respectively. A strong year class, probably hatched in 1998, can be followed during this period.

Norway

As a result of increased fishing pressure on Norwegian anglerfish, cooperative investigations by the Institute of Marine Research in Bergen and the Møre Research Foundation in Ålesund (Woll *et al.* 1995a,b) were started in 1992 in order to aid in stock assessment and regulations. A survey of the biology of Norwegian anglerfish was presented in a cand.scient thesis at the University of Bergen (Staalesen 1995), in which age determination and validation, length-weight relationship, growth, maturity stages and yield-per-recruit of anglerfish sampled monthly between November 1992 and October 1994 ($n = 1\,796$) from commercial gillnet landings on the Norwegian west coast were considered. In another cand. scient thesis at the University of Bergen, Dyb (2002) analysed the size distribution of North Sea anglerfish, among others to investigate possible anglerfish migration. Dyb's thesis was based on data from the International Bottom Trawl Survey (IBTS) (Figure 1.6 A, 1.7a,b) and the Norwegian shrimp and *Nephrops* surveys (Figure 1.6 B). Other information on Norwegian anglerfish includes catch data from commercial gill-netting and from demersal fish, shrimp and *Nephrops* surveys in the North Sea, as well as sporadic samples of bycatch from the trawl and Danish seine fisheries.

Figure 1.6

Distribution of anglerfish catches: (A) International Bottom Trawl Survey (IBTS) 1980-2000; (B) Norwegian Institute of Marine Research (IMR) shrimp and Nephrops surveys 1989-2000. Circles represent total abundance within quadrants of $0.1^{\circ} \times 0.1^{\circ}$. (Dyb 2002)

Figure 1.7a

Length distribution (5 cm length intervals) of anglerfish in IBTS samples by quarters 1991-1994. Greek letters indicate year classes that can be followed through the time series (Dyb 2002).

Figure 1.7b

Length distribution (5 cm length intervals) of anglerfish in IBTS samples by quarters 1995-2000. Greek letters indicate year classes that can be followed through the time series (Dyb 2002).

Shetland

At the NAFC Marine Centre in Shetland anglerfish data have been collected since late 1997. This started with market sampling of landed fish, however the main sources of data have been through observer trips on-board commercial vessels and through gear selectivity trials using chartered trawlers. Fish have been aged using otoliths, sex and maturation have been determined macroscopically, and a diet study has been completed. In addition a tagging programme was undertaken during 2001. A paper based on some of the data collected and describing aspects of the life history of the species (Laurenson *et al.* 2001) was presented at the ICES conference in 2001. A PhD thesis on the biology of and fishery for monkfish in the waters around the Shetland Isles was produced (Laurenson 2003) and several publications arising from the thesis have been made: Laurenson *et al.* (2004); Laurenson *et al.* (2005); Laurenson & Priede (2005). A short note on the egg development of *Lophius* was published in Laurenson (2006). Notes based on the published papers that are intended for general public readership have been produced in the NAFC Development Note series: Development Notes 9, 15, 16 & 18 and are freely available at www.nafc.ac.uk.

2. Biology and ecology of anglerfish

Anglerfish⁴ (Teleostei: Lophiidae) belong to a family of bathydemersal, dorsoventrally depressed fishes (Caruso 1986). Two European anglerfish species of the genus *Lophius* are distributed in the Northeast Atlantic including Nordic waters: white (or white-bellied) anglerfish (*L. piscatorius* L.) and black (or black-bellied) anglerfish (*L. budegassa* Spinola). The two species are very similar, the main distinguishing feature being the darker colouration of the mouth and peritoneum (body wall) of *L. budegassa* (Figure 2.1). The latter is also somewhat smaller than *L. piscatorius*.

Figure 2.1

The main difference between *Lophius piscatorius* (above) and *L. budegassa* (below) is easily seen, but only when the fish are gutted to reveal their white and black “bellies”, respectively. (Photo: L. H. Ofstad)

⁴

English
anglerfish
monkfish
goosefish

Danish
havtaske
bredflab

Faroese
havtaska

Icelandic
skötuselur

Norwegian
breiflabb
havtaske
marulk

French
baudroie
lotte

2.1 Occurrence and distribution

General distribution

Both anglerfish species occur on muddy to gravelly, occasionally rocky bottoms along the European continental shelf. *L. piscatorius* is distributed from Gibraltar to the southwestern Barents Sea, and around the Faroe Islands and at Iceland. *L. budegassa* appears to be more prevalent in warmer water, occurring mostly in the southernmost parts of this range, from the North Sea to south of Gibraltar, and including the Mediterranean Sea (Caruso 1983).

Lophius budegassa are rarely caught in Nordic waters. Out of 2 500 samples of anglerfish from Faroese waters only one specimen of *L. budegassa* was found (0.04 %) (Ofstad, pers. obs.), while Faroese fishermen have reported observing only 10 individuals of this species in the period 2002-2004. In Norway, respectively 1 out of about 2 600 and 1 out of about 1000 anglerfish landed from the Møre coast and from the North Sea proved on closer inspection to be *L. budegassa* (Dyb 2003; K. Nedreaas, pers. obs.). Around Shetland this species appears to be somewhat more common, with a frequency of occurrence of approximately 3-5 % of landed anglerfish (Laurenson, pers. obs.). At the west of Scotland the frequency of occurrence of *L. budegassa* appears to be quite patchy with some areas producing catches with around 5% *L. budegassa* while other areas may have up to 20% *L. budegassa* (Laurenson, unpubl. data).

Depth distribution

In the general literature (e.g. Caruso 1986) anglerfish are said to occur eurybathically to depths of about 1 000 m. In pelagic trawl surveys conducted in the North Sea north of 56°, the Atlantic coast of the British Isles, the Norwegian Sea and the south-western Barents Sea large *L. piscatorius* specimens >40 cm were found from 90 to 2 600 m, whereas smaller individuals were captured in shallower water (53-316 m) (Hislop *et al.* 2000). Most of the fish were caught in the northern North Sea. Around the Shetland Isles Laurenson *et al.* (2001) likewise found a trend of increasing *L. piscatorius* size with depth. On the banks west of Portugal *L. piscatorius* was found to be one of the most important deep water community species at 650-1 200 m depth (Piñeiro *et al.* 2001). However, depth appeared to have no statistically significant effect on the abundance of *L. piscatorius* and *L. budegassa* in trawl samples from the coastal regions north of Spain and Portugal (ICES Division VIIIc). Similar numbers of anglerfish were observed from the continental shelf at 30 m depth to the shelf edge at 500 m depth (Azevedo & Pereda 1994). In Division IXa west of Portugal *L. budegassa* showed differential depth distribution patterns (Azevedo 1995), which are suggested to be related to differences

in substratum, bathymetry and/or behaviour. During Icelandic trawl surveys very few anglerfish were recorded below 500 m, probably because of low temperature (Jónsson, unpubl. data). Each year in spring along the Norwegian coast, big mature female *L. piscatorius* are reported observed in very shallow water or even stranded on the beach.

Migratory behaviour

Horizontal displacement and tag-and-release studies

Displacement over some distance horizontally is observed in anglerfish, and is suggested to be related to spawning. Spanish scientists have since 1995 tagged and released some 400 individuals of both *L. piscatorius* (Landa *et al.* 2001a) and *L. budegassa* (Landa *et al.* 2001b) in the Celtic Sea, Bay of Biscay and west of Portugal (ICES Divisions VIj,k, VIIIb and IXa). Conventional external spaghetti T-bar type tags were inserted in the dorsal area of the fish as shown in Figure 2.2. A dose of oxytetracyclin, which forms deposits visible under UV light in the hard parts of the fish, was also injected (50 mg/kg) anteriorly of the anal opening. The preliminary recovery index is considered good at an overall rate of 3.4-5 %. Highest displacement was observed after 15 months in the sea at about 300 km in a straight line from the release site (estimated overall mean c. 600 m day⁻¹). The migration routes taken by many adult fish, from deeper to shallower areas during the first quarters of the year, coincide with temporal variability in commercial catches in the same areas. It is suggested that they follow the same route back during the following months, a displacement pattern which would fit a general spawning migration.

Figure 2.2

Tag placement on dorsal area of anglerfish, shown here with harpoon/dart-style tag (A) used in Laurenson *et al.* (2003, 2005) and T-type tag (B) used in Landa *et al.* (2001a,b). Anglerfish drawing taken from Bauchot (1987).

Experience at marine laboratories in Norway and Scotland from capture and handling of fish prior to tagging has shown anglerfish to be particularly vulnerable to skin abrasions (Holm *et al.* 1999; Laurenson in Annex B). Danish seine captured fish survived longer than trawl-caught fish, while only diver-caught fish seemed to survive for any period of time. Landa *et al.* (2001a), however, concluded that manipulation during the catch did not have a drastic effect on survival. Anglerfish do not have a gas bladder and thus seem resilient to being brought to the surface from large depths. Tagging of anglerfish caught by commercial trawling of long duration is not recommended due to the frequently deteriorated condition of these individuals. Best tagging results by the Faroese Fisheries Laboratory (FFL) were obtained from gillnet-caught individuals (for tagging methods and experiences see Annex A). It should however be noted that only specimens were tagged that were still fresh and vigorous when taken on board (Ofstad, pers. obs.).

Holm *et al.* (1999) and Holst & McDonald (2000) present an alternative trawling method for capturing viable specimens of delicate species like anglerfish, using a towed metal cage connected to the trawl cod-end, into which the fish are lifted through a net funnel. In principle the fish then remain in low turbulence until removal after hauling, resulting in less skin damage and/or scale loss, and consequently a higher survival rate.

Tag retention and mortality were investigated using the Marine Hatchery facilities at the NAFC Marine Centre in Shetland during 2000 and following favourable results (60 % tank survival after 72 days) a tag release programme was conducted on 22 inshore grounds around the Shetland Isles during the summer of 2001 (Laurenson 2003, 2005b). Fish were trawl-caught using short duration tows (<1hour) in shallow waters (<100m).

1 768 fish were tagged and released with conventional dart tags (type small plastic tipped dart PDS/PDT, Hallprint⁵ tags; see Figure 2.2), and to the end of May 2004 a total of 79 tags had been returned (4.5%) (Laurenson *et al.* 2005). Since then a further three recaptures were reported, two in January and one in February 2005 (Laurenson 2005b). Some recaptures indicated movements between inshore areas while those during the first autumn and winter since release generally indicated an offshore movement, mainly northwards and westwards. Two of the recaptures indicated that movements of significant distances are possible. These were shown by one recapture at the south east of Iceland, a displacement of 876 km after 1 078 days and another that was recaptured close to the Faroe Islands, a displacement of 320 km after 840 days.

A total of 526 anglerfish were tagged from 2003 to 2005 with spaghetti tags, using small Danish seine equipped boats off the northern part

⁵ 27 Jacobson Crescent, Holden Hill, Australia 5088

of the Norwegian west coast (Møre) and using a research trawl during the IBTS⁶ surveys further south in the North Sea (see annex A for procedures and experiences). To date 20 recaptures have been made (3.8 %), most within a radius of 10-80 km from the tagging grounds at Møre. One individual showed a displacement of 270 km after 551 days at sea.

The suitability of the use of data storage tags (DSTs) that are surgically inserted into the body cavity of anglerfish was tested at NAFC in 2003 (see Annex B). Experience showed that post-operative mortality may be substantial. Nevertheless, a number of anglerfish were also tagged using this method at the Faroes and Iceland.

Five tag-and-release surveys were made by the FFL in 2004 and 2005 (see annex A for procedures and experiences), where 784 anglerfish, 35-116 cm in length, were tagged with conventional Floy t-bar tags, and 30 of these also had DSTs surgically inserted into the body cavity. 19 recaptures have been made to the end of 2005, all in Faroese waters, except one individual that was recaptured south of Iceland after 183 days at sea.

In April 2004, 20 anglerfish were tagged in an area off the southwest coast of Iceland with DSTs (see Annex A for procedures and experiences), using trawl-caught individuals in the length range 35-78 cm. A *Nephrops* bottom trawl was towed for 30-60 minutes by a small research vessel. Due to poor anglerfish catches in the area and limited project-time, only an additional 14 individuals (25-40 cm) could be tagged with conventional t-bar spaghetti tags.

Two Icelandic DSTs have been recovered so far. The record from the first one, recovered after 12 days at sea, showed that the tagged anglerfish had died shortly after release. The second recovery was made 13 days after tagging, in shallower grounds (75 m) some 14 nautical miles north-east of the tagging locality (depth 118 m). This DST is probably the first successfully recovered data tag from a live anglerfish. The recording (see Figure 2.3) provides interesting data on the vertical movements of this fish; this is described in more detail in the next section.

Vertical displacement

Although anglerfish are mainly bottom dwellers, the occurrence of anglerfish in the pelagic layers has previously been reported, e.g. Hislop *et al.* (2000) reported 34 well-grown individuals (length range 24-103 cm) close to the surface at widely scattered locations in the North-east Atlantic, some over considerable depths (to 2 600 m). The authors concluded that even though the body form of the anglerfish and its high percentage liver weight would give it enough hydrodynamic lift to make vertical migrations from the bottom possible, these individuals must have drifted or strayed from their normal habitat. Single *Lophius* specimens have also been caught on Japanese tuna longlines in the mid Atlantic, as well as in herring drift nets off Scotland and Shetland (H. í Jakopstovu, pers.

⁶ International Bottom Trawl Survey, see also section 1.2

comm.). During both the annual Faroese and Norwegian herring surveys in recent years adult anglerfish have been caught by pelagic trawl. Laurenson *et al.* (2005) suggested that anglerfish are likely to be lifting from the bottom in order to use selective tidal stream transport to assist in migration and movements.

The DST recording from the recaptured anglerfish at Iceland mentioned in the last section shows that the 75 cm long anglerfish had stayed mainly on the bottom (Figure 2.3). The local tidal waves on the location are clearly expressed in the depth (pressure) data as even diurnal curves. However, the data also showed that it had made four trips up into the water column: two short ones only a few metres up, and two longer ones lasting for several hours on two separate evenings. On one occasion it had risen up from the bottom (depth about 118 m) up to some 20 m depth and then dived down again. During these vertical trips the water temperature is recorded as rising slightly and then dropping again, but during the rest of the tagging time the ambient temperature remained relatively stable (Figure 2.3).

Figure 2.3

Data from Icelandic digital storage tag (DST no. 6267) showing depth, temperature and time elapsed. Notice trips up into pelagic water and regular pressure curves corresponding to local tidal waves.

Morphological and genetic variation

Generally, in most species of *Lophius* and *Lophiomus* meristic variation appears to reflect temperature variability rather than molecular phylogeny. Patterns of morphometric variability on the other hand seem to reflect convergence in body shape between distantly-related species (Leslie & Grant 1994). Morphometric and gene-diversity analysis has been used to study the geographic stock structure of the southern African anglerfish *Lophius vomerinus*, which is regarded as a geographic isolate of *L. piscatorius*. It was found that populations of *L. vomerinus* differed with regard

to morphology, but that only a minor fraction of the total genetic variation could be attributed to geographic differences (Leslie & Grant 1990). With regard to allozyme phylogeny, cladistic analysis has shown *L. piscatorius* and *L. litulon* (Japan) to be sister taxa, whereas a link found between *L. budegassa* and *L. vomerinus* is not as clear (Grant & Leslie 1993).

In the late 1980s a comparative genetic analysis was conducted on the two European anglerfish species. The study was based on allozymes, and diagnostic differences were revealed in several loci (Crozier 1988). Although the material was small, only 17 specimens of *L. piscatorius* and 19 of *L. budegassa*, several enzyme loci were detected that should be better tested in a greater material if aiming at describing any stock structure.

Several laboratories have recently also started doing DNA analyses on the two anglerfish species, but few results have so far been published. Some results are available from the project "Population structure of the anglerfish, *Lophius piscatorius*" by Martha O'Sullivan at the Marine Laboratory in Aberdeen (see O'Sullivan *et al.* 2005). A similar project is currently being conducted in Spain and Portugal by Fariña *et al.* (2004). An Italian group of scientists has developed genetic primers for microsatellite analyses, and information (primer sequences, PCR conditions etc.) of about 6 loci has recently been published (Garoia *et al.* 2003). It is, however, not clear to what extent these have been used in any large-scale population studies so far.

Despite small economic resources allocated to genetic analysis during the Nordic project, some tissue samples of *L. piscatorius* from the Faroe Islands, Iceland and Norway were collected for further analysis at the genetic laboratory of the Institute of Marine Research in Bergen under the supervision of Knut Jørstad. The samples consisted of white muscle tissue frozen at -80° C for allozyme analysis, or muscle tissue stored in alcohol for DNA analysis (for sampling procedures see Appendix 1a). Lack of time and resources only allowed for the analysis and comparison of the Icelandic and Norwegian samples.

It was not possible to conduct expensive microsatellite analyses. However, a sub-sample was tested with regards to established DNA extraction procedures. Running a check on agarose gel showed DNA of a promising good quality compared with other species worked on by the laboratory. In addition, introductory analyses have been done to reveal the genotypes of the most common allozymes (proteins). 96 individuals from Møre (Norway) and 96 samples from Iceland were analysed on standard starch-gel electrophoresis and developed for 8 allozymes.

The frozen samples from Møre consisted of too much skin, different tissues and too little pure white muscle tissue. Unfortunately this led to poor enzymatic reaction, so that the samples were not good for allozyme analysis. However, these samples could probably be used for DNA

analysis. The samples from Iceland consisted of clean-cut muscle bits and produced good enzyme activity when analysed on starch gel. The gel was developed for the 8 allozymes GPI, PGM, CK, FBALD, MDH, ME, GPD, LDH. FBALD gave too weak enzymatic reaction to be useful for making any conclusions. CK and LDH gave good enzymatic activity, but showed no genetic variation among the 96 individuals. GPD produced some blurred band patterns on the gel, but despite this a clear heterozygote was detected. Also in PGM and MDH, a few different band patterns observed on the gel were probably heterozygotes.

All in all, these introductory analyses lead us to believe that the above listed allozymes contain/reveal low polymorphism. However, it cannot be excluded that there may be higher polymorphism in populations from other geographic areas. Most genetic variation was found within the GPI allozyme. Band patterns were detected on the gel, which may be both homo- and heterozygotes, and with a considerable higher genetic variation compared with the other allozymes. The patterns observed in the extract from white muscle suggest that another GPI locus is present in another tissue, probably liver. In order to get a proper overview of the GPI system, and concluding on the usefulness of this system in revealing population structure of *L. piscatorius*, both white muscle and liver from the same individuals should be collected and analysed.

Comparison of the current results with previous allozyme analyses is difficult, especially because of the low number of fish analysed by Crozier (1988). In addition, Crozier analysed other tissues, especially liver, which, although liver samples were collected at the Faroes, was not used for the present analyses. A preliminary evaluation of the conducted allozyme analyses is a general low polymorphism within the allozymes analysed, except GPI. It must, however, be underlined that only material from Iceland has been analysed so far in the Nordic project.

The results from the different allozyme analyses so far seem to be of limited use for greater studies of population structure of *Lophius piscatorius*. When the present Nordic project started in 2002, nobody had developed any microsatellite analyses designed for anglerfish. The present situation and knowledge is fortunately better, as the first useful primers have already been published (Garoia *et al.* 2003). It is expected that more information about new and more suitable primers will be available in near future.

Based on the current experience with regards to sample collection, transport of samples etc., for the purpose of allozyme analysis, it will probably be more advantageous to base future genetic work on DNA (especially microsatellite analysis). Samples for this purpose may be conserved in alcohol, and may be stored for later DNA extraction and analyses without reducing the quality of the samples to any measurable extent. In order to conduct such microsatellite analyses, a higher and sufficient

economic budget is necessary as such DNA analyses are much more expensive than allozyme analysis.

2.2 Life history

Laurenson *et al.* (2001) summarised the assumed life-history pattern of *Lophius* in a Harden-Jones type triangle as shown in Figure 2.4. Following migration of mature, adult anglerfish to deeper water, spawning occurs close to the seabed, whereupon the egg ribbons rise slowly towards the surface, the eggs hatching underway. Newly emerged anglerfish larvae are about 4 mm long, drift pelagically with surface currents for some time, then settle on the inshore seabed when they reach a length of 50–120 mm as post-larval stage juveniles (Hislop *et al.* 2000). The duration of the pelagic phase is not known with certainty, but may vary from weeks to several months. From otolith daily increment analysis Hislop *et al.* (2001) concluded that *L. piscatorius* larvae and juveniles from northern British waters drift for up to 120 days before settlement. Recruits may settle on the seabed hundreds of kilometres from the spawning grounds. For example, juveniles > c. 50 mm were caught by pelagic trawl in the upper 50 m on the northern Hatton Bank area during a survey for redfish in the mid-Atlantic in June 2001 (Figure 2.5) (Nedreaas, pers. obs.). These could possibly have drifted northwards with the North Atlantic Current from spawning grounds west of the British Isles.

Figure 2.4

Harden-Jones triangle showing the general life-history pattern of L. piscatorius (adapted from Laurenson et al. 2001).

Figure 2.5

Juvenile Lophius caught near the surface on Hatton Bank in 2001. (Photo: K. H. Nedreaas)

Using a particle tracking model driven by hydrodynamic data, Hislop *et al.* (2001) simulated the dispersal of *Lophius* eggs and larvae, using guestimates of the spawning depth and the ascent rate of egg ribbons towards the surface. Based on temperature and depth the potential spawning range of anglerfish was defined as the continental slope west of Ireland north to 63°N, the northern perimeter of the North Sea, and the Rockall Plateau. These regions were used as a start grid in the model. Model runs showed that 60-120 days old post-larvae caught north west of the Hebrides could originate from an extensive area of the continental slope (from the northern border of the North Sea at about 60°N to the shelf edge west of Ireland at about 50°N), as well as from the Rockall Plateau (Appendix 2a). In contrast, 80-120 days old post-larvae caught in the northern North Sea seemed to have originated far more locally, although some could have come from the continental slope west of Scotland (Appendix 2b).

Time series of 0-group survey data exist in all Nordic countries, which, when fully analysed, should provide valuable information on the distribution on the juvenile stages of anglerfish in these waters. Occurrences of larvae/juveniles in survey catches are, however, generally scarce. In Iceland, where 0-group surveys extend back to 1970, juvenile *Lophius* were recorded in only 8 out of 32 survey years, mostly one or two individuals (E. Jónsson, pers. obs.). Records of anglerfish were made partly outside the main fishing and spawning grounds on the south and southwest coast (Figure 2.6), where the predominating currents cause eggs and larvae to drift west- and northwards.

Figure 2.6

Occurrences of *L. piscatorius* in 0-group surveys at Iceland 1970-2002

During regular Faroese 0-group surveys⁷ in the 100-200 m depth range June/July 1984-2004 a total of only 73 *Lophius* juveniles was recorded (Figure 2.7), in the length range 7-130 mm (Figure 2.8) (Ofstad, unpubl. data). Most were caught on the Faroe Bank, while the remainder were found on the shelf west of the Faroes. In the upper layers, these areas are dominated by the warm northward-bound North Atlantic Current, which forms anticyclonic circulation cells around the shallow bank and shelf areas surrounding the Faroes (Hansen *et al.* 1998). This results in large retention times in the shallow areas. Presumably most recruits that aggregate by advection in these areas originated from local spawning grounds, but a number of juveniles may also have drifted northward with the Atlantic current from southern spawning areas.

⁷ A good description of Faroese 0-group surveys is given in Gaard & Reinert (2002).

Figure 2.7

Observations of anglerfish larvae ($n = 73$) from the 0-group survey in Faroese waters in June/July 1984-2004. Depth contours per 100 m.

Figure 2.8

Examples of anglerfish larvae and juveniles caught during 0-group surveys in Faroese waters. Clockwise from bottom left: larvae in spawn jelly, 7 mm long larva from spawn jelly under light microscope, and juveniles, 32 and 105 mm in length. (Photos: L. H. Ofstad)

Depending on the recruitment variability level, variation in catch-per-unit-effort due to strong and weak year classes would be expected. Some evidence of variation in year class abundance can be seen in data from Iceland (see Figure 1.5) and Shetland (Laurenson, pers. obs.). In 1998, 5 specimens ranging in length from 6.4 to 12.8 cm, presumably originating from a strong 1998 year class, were recorded in the 0-group survey in Icelandic waters. An abundance of juveniles in the 18-28 cm length range in May/June 2002 seems to point to a new strong year class in 2001 (Jónsson, pers. obs.).

2.3 Age and growth

Growth structures and ageing methods

Three calcified bone structures that show annual growth increments have been used for ageing purposes in anglerfish: the sagittal otoliths (ear bones), *illicium* (first dorsal fin ray) and the first to third vertebrae. Microstructures in the lapilli otoliths of anglerfish have been used for daily growth estimation and for validation of age estimates obtained from macrostructures.

Compared to e.g. codfish (Gadidae), anglerfish otoliths are small and the growth zones are often indistinct and difficult to discern from the hyaline (winter) zones (Woll *et al.* 1995a). Transverse sections of the *illicium* show ring (annulus) patterns where the different growth bands are often more easily counted (Figure 2.9). Under microscopy with transmitted light and under scanning electron microscopy (SEM) the surfaces of the growth rings show up as alternating light and dark areas and as high and low areas, respectively (Quincoces *et al.* 1999, Quincoces *et al.* 1999).

Figure 2.9

Examples of light microscopic images of sectioned illicia used for ageing of anglerfish caught in Norwegian waters. (Images courtesy of Jan Erik Dyb)

Staalesen (1995) found the *illicium* to be the most suitable structure for age determination of anglerfish caught in Norwegian waters, because of the low variation and high reproducibility of the readings. *Illicium* readings were also found to have a low average percent error in ageing of

Lophius vomerinus in Namibian waters (Maartens *et al.* 1999). On the other hand, Woodroffe *et al.* (2003) found otoliths to provide more consistent age estimates than *illicia* in a comparative study of age structures in *Lophius piscatorius*. Duarte *et al.* (2005), however, suggest that this result could be explained by the authors' low experience in age reading from *illicia*, rather than by any true differences in ageing precision.

Growth studies from northern British waters have more routinely used age reading from otoliths, because otolith removal does not cause external damage to the fish and thereby does not affect its market value (Hislop *et al.* 2001, Laurenson 1999, Laurenson *et al.* 2001, Laurenson 2003). Daily otolith increment analysis was found particularly useful in determining the duration of the pelagic phase (Hislop *et al.* 2001). Vertebral annuli have been used for age determination in *Lophius americanus* (Armstrong *et al.* 1992), and in *Lophius litulon* (Cha *et al.* 1998, Yoneda *et al.* 1997) and *Lophiomus setigerus* from the East China Sea (Yoneda *et al.* 1998a).

A demonstration of ageing methods on sectioned *illicia* given at the Nordic project meeting in Tórshavn in 2002 highlighted several problems encountered: determining the first annulus; large differences in the width of the first annulus between different fish were also reported, as were the presence of false rings in some samples. These problems are also encountered in the reading of otoliths (Laurenson, pers. obs.). Wright *et al.* (2002) present a method to distinguish between false rings and annuli: whereas false rings are characterised by an abrupt check in otolith formation followed by increments similar in width to adjacent opaque material, annuli appear as a sequence of gradually declining increment widths. Figure 2.10 shows the percentage throughout the year of otoliths sampled off Shetland showing opaque marginal growth.

Figure 2.10

Percent of otoliths from anglerfish sampled in Shetland/Scotland showing opaque marginal growth. Data pooled across 1998-2000.

Several European conferences (Peronnet *et al.* 1992) and workshops (Anon. 2000, Duarte *et al.* 2005, Dupouy 1997) have been held during

the last decade with the aim of achieving a consensus on anglerfish ageing criteria. *Illicium* ageing methods developed at these workshops have been adopted in most growth studies pertaining to southern European anglerfish stocks (Anon. 2001, Duarte *et al.* 1994, Duarte *et al.* 1997, Landa & Pereda 1997, Landa *et al.* 1998, Landa *et al.* 2001c, Quincoces *et al.* 1998, Quincoces *et al.* 1998). In recent years Icelandic researchers have also undertaken efforts at age reading from *illicia* (see (2004)). The Faroese Fisheries Laboratory started out collecting both *illicia* and otoliths, but decided to proceed with the *illicium* as the preferred ageing structure.

Two of the authors of the present report also participated at the most recent Anglerfish *Illicia*/Otoliths Ageing Workshop, which was held in Lisbon in November 2004 (Duarte *et al.* 2005), and which in particular addressed problems in age reading precision due to the different age reading structures. Agreement between experienced *illicium* and otolith readers was only 8 and 27 % for black and white anglerfish, respectively. Within each structure, between-reader agreement was higher in *illicia* than in otoliths, because of the higher precision and lower bias in *illicium* readings. These results show that standardisation of otolith ageing criteria is necessary before further analysis of discrepancies in age interpretation between structures.

Age validation

In mark-recapture studies Landa *et al.* (2001a,b) injected anglerfish with oxytetracyclin in an attempt to validate growth observed from *illicium* readings. Comparisons of growth rates do not yet appear to be conclusive, because of the small number of recaptured individuals that have been long enough in the sea to show significant growth. Oxytetracyclin was however observed deposited over half the width of a year zone in a *L. budegassa* specimen recovered after a little over half a year. Duarte *et al.* (2005) discuss two specimens with total lengths (TL) of 35 and 69 cm, recaptured after 13-22 months at sea, where the smallest individual had a similar growth compared to a predicted annual *illicium*-based age-length key, whereas the larger individual had a much slower growth.

Wright *et al.* (2002) used microincrements in the lapilli otoliths of *L. piscatorius* (see Hislop *et al.* 2001) to verify age estimates of specimens <27 cm TL. These were found to be either 0- or 1-group, in contrast to estimates of small size at age by Dupouy *et al.* (1984) and Duarte *et al.* (1997). These differences may have been caused by earlier misinterpretation of the time of first formation of the translucent zone, which appears in autumn in the *illicium* of most 0-group individuals, but not in the sagittal otoliths.

Validation of age estimates through length modes, as in the length distribution shown in Figure 1.5, is also often used. For example, Jónsson

(2004) (see Annex C) used length modes of big year-classes appearing regularly in the Icelandic *Lophius* stock to validate *illicium* age reading efforts. The length modes of these year-classes, of which at least 3 prominent ones have lately characterised the Icelandic anglerfish stock, can be followed as peaks in the length distributions for several years, and thus their actual age can be assumed accurately. Length distribution modes in age-read and non age-read sample were compared visually (scaled together) and statistically. The results show that there is a fairly good agreement between the length modes of the big year-classes and the corresponding length modes established through *illicium*-based age reading, indicating that age reading of the youngest individuals is based on true interpretation of year-rings.

Laurenson (2003) also investigated length frequency distributions for the presence of modes that could represent year classes. Modes were fitted using the MIX program. It was found that modes at similar length were present in length frequency distributions collected from different locations (but within a short period of time), indicating that the modes were likely to represent similar cohorts of fish. Several modes could be followed as they progressed through the quarterly time series of data over the four-year period studied. However, modes were found to be obscured, particularly in the upper halves of length distributions, and often the fit was thought to represent more than one cohort of fish at the larger lengths. This is a common problem when analysing length-based data for the presence of cohorts. From following the cohorts the growth rates estimated were compared to those estimated from both otolith analysis and tagging data.

Comparison of results from validation studies as described above with results from *illicium* readings obtained during the November 2004 Anglerfish *Illicia*/Otoliths Ageing Workshop further suggests (Duarte *et al.* 2005) that white anglerfish growth may be faster and black anglerfish growth may be slower than that estimated by *illicia*.

Figure 2.11 shows the age distribution in the landings or catch at age in the Icelandic *Nephrops*-fishery for 4 consecutive years (2000-2003), for which extensive age readings were undertaken, as described earlier. The catches include up to 12-13 years old anglerfish individuals, but chief abundances are found in the younger age groups, even down to 1 year old fish. The big 1998 year-class is dominant in the catches, and can be seen as 2 year old fish in 2000, 3 year old fish in 2001, etc. Obviously this pattern of very young fish seen in this kind of fishery is by no means representative for the rest of the anglerfish fishery, particularly the gillnet fishery.

Figure 2.11

Age distribution of anglerfish in Icelandic Nephrops surveys 2000-2003.

Growth rates

Growth in anglerfish is described as fast, particularly during the first year (Hislop *et al.* 2001). Figure 2.12 shows length-at-age estimates from different age readers. Length-at-age analysis on *L. piscatorius* from Norwegian waters (Staalesen 1995) showed a growth rate until maturation of approximately 11.5 cm per year, and 8.4 cm per year afterwards. The relatively large variation in estimates of growth curve parameters (Table 2.1) may partly be ascribed to differences in growth rates between northern and southern areas, and partly to differences in sampling gear selectivity. Table 2.1 also shows the much smaller asymptotic maximum length for males compared to females of both species. Few males above 90 cm are found, the largest fish are therefore predominantly female.

Figure 2.12

Length at age from different age readers. All readings based on illicia, except Laurenson (2003), which was based on otolith reading.

Table 2.1

Reference	No. of ind.	Age		Length (cm)		L_{inf}		k		t_0	
		Min	Max	Min	Max	Female	Male	Female	Male	Female	Male
<u><i>L. piscatorius</i></u>											
Staalesen (1995)		6	14			320	148	0.038	0.102	-0.342	-0.067
Landa & Pereda (1997)						132.05		0.1086		0.664	
Landa <i>et al.</i> (1998, 2001c)	844			14	140	140.5	110.5	0.08	0.11	0.09	0.23
Quincoces <i>et al.</i> (1998a)	1 385	1	25			150	100	0.0882	0.1517	-0.2961	0.1051
Duarte <i>et al.</i> (2001a)	1 297			11	129						
Ofstad (unpubl. data)	4 728	0	14	12	142	233.2	130.2	0.05	0.10	-1.04	-0.88
<u><i>L. budegassa</i></u>											
Landa et al. (1998, 2001c)	1 049			5	93	110.1	72.9	0.08	0.13	0.39	0.36
Quincoces et al. (1998b)	2 006	1	18	14.5	85.5	100	100	0.1113	0.1001	1.4772	1.1015
Duarte et al. (2001a)	1301			5	89						

Some growth parameters of anglerfish. L_{inf} , k and t_0 are parameters of the von Bertalanffy growth curve equation.

Faroese ageing data are mostly from trawl-caught individuals, but length-at-age estimates from gillnetting show the same trend. Over 4 700 *illicia* from the period 2000-2005 are age-read. The results from mean length-at-age in Faroese waters show the same trend as in the other Nordic countries for the youngest age groups. The females are bigger than males after about age 5, and there are no males older than 11 years.

Although the Icelandic growth curves in Figure 2.11 are based solely on data from surveys where a different gear is used than in the commercial fishery, it should, however, be more or less representative for the whole stock, due to the number of samples ($n = 948$) and their extent in time and area. If so, it can be stated that the growth of anglerfish in Icelandic waters is very fast during its first life years, and quite similar to the growth of anglerfish in neighbouring stocks in the North Atlantic.

Annual mean lengths-at-age were calculated from direct age readings of otoliths from 2 489 anglerfish at Shetland (Laurenson 2003). From these, von Bertalanffy parameters of both sexes combined were given as: $L_{\infty} = 205.7$ cm, $t_0 = -1.994$ and $k = 0.046$. This equates to a growth rate of 8-12 cm/yr during the first three years of life, which further equates well with the 8-10 cm/yr that was estimated for the first three years of life based on the previously mentioned analysis of length frequency data. The results of the tagging study indicated a mean growth rate of 9.4 cm/yr in recaptured fish. However, when the von Bertalanffy parameters were used to predict the growth in the released tagged fish over the time period between release and recapture, the actual lengths at recapture tended to be higher than those predicted by the equation (Laurenson 2003).

Age and length at first maturity

L. piscatorius usually mature when they are 4-6 years old (Woll *et al.* 1995a). At this age they may be from about 40 cm up to 80 cm long in Norwegian waters, and weigh 3-6 kg. Males tend to mature at an earlier age and smaller size than females. Data from Faroese waters show that females are nearly twice as old as males at the onset of first maturity, at 7.5 years old compared to 3.5 years (Ofstad, unpubl. data). Staalesen (1995) detected maturation as a distinct change in the appearance of the growth zones on all three growth structures (*illicium*, otoliths, or vertebrae) between the third and the fifth year zone; this finding is to date however not validated.

For *L. piscatorius* around Shetland Laurenson *et al.* (2003) estimated the mean length at maturity ($L_{50\%}$) at 98 cm for females and 58 cm for males (Table 2.2, Figure 2.14). Data collected to the west of Scotland give similar values to the Shetland estimates (Gordon 2001b). Preliminary data indicate $L_{50\%}$ for anglerfish from the Norwegian west coast and the northern North Sea (Dyb, unpubl. data) (Figure 2.14) and from Faroese waters (Ofstad, unpubl. data) (Figure 2.14) to be respectively 61 and 83 cm for females and 57 cm for males (Table 2.2). Similar, slightly lower estimates are given in Afonso-Dias & Hislop (1996), Duarte *et al.* (2001) and Quincoces *et al.* (1998) (Table 2.2). The differences in $L_{50\%}$ estimates may be due to sample size or to variability resulting from the low proportion of mature fish in the samples. *L. budegassa* do not grow as large as *L. piscatorius*, and thus have a lower $L_{50\%}$ (Table 2.2). The maturity stages assigned macroscopically by Laurenson *et al.* (2001) were determined using the scale given by Afonso-Dias (1997) (Appendix 3a). The scale used by Duarte *et al.* (2001) is essentially the same. The $L_{50\%}$ given by all three authors are determined on the basis that Stages I & II are immature and Stages III-V are mature. The calculation has been done in this manner, as it would appear that especially females are in stage II for an extended period of time (from about 40 cm in length) before moving into stage III (from about 60 cm in length) (Laurenson, pers. obs.). Similar five-stage maturation scales for anglerfish have been used in Iceland (Appendix 3b) and the Faroe Islands (Appendix 3c). Maturity ogives for anglerfish obtained by the MRI in Iceland formerly showed lower $L_{50\%}$ compared to Laurenson *et al.* (2001), because Icelandic estimates were based on the assumption that also stage II fish are mature (Appendix 3b). The maturity scale used in the Faroe Islands is for the most part based on Duarte *et al.* (2001), but with some additional gonad description from Staalesen (1995). The IMR in Norway has used the maturation scale described in the latter (Appendix 3d), which is a four-stage key modified from Armstrong *et al.* (1992), with one stage describing both maturing and pre-spawning individuals.

Table 2.2 Some estimates of anglerfish length (L50%) and age (A50%) at first maturity.

Reference	Length (cm) at first maturity		Age (yr) at first maturity	
	Female	Male	Female	Male
<i>L. piscatorius</i>				
Afonso Dias & Hislop (1996)	73.5	48.9		
Duarte et al. (2001)	93.9	50.3	14	6
Dyb (2003)	61	57		
Gordon (2001b)	92	56		
Laurenson et al. (2003)	98	58		
Ofstad (unpubl. data)	82.7	57.3	7.5	4.5
Quincoces et al. (1998a)	73.2	52.7		
<i>L. budegassa</i>				
Azevedo (1996a)	56	37.6		
Duarte et al. (2001)	54.8	38.6	9	7
Quincoces et al. (1998a)	64.5	34.5	10.4	6

The participants at the Nordic project meeting in Tórshavn in May 2002 agreed on developing a common macroscopic maturation scale between the countries. Accordingly, at their second annual meeting in Scalloway, Shetland, in July 2003, the project group decided on a description of maturation in *Lophius* as shown in Table 2.3 with regard to gonad differences between the sexes, and as shown in Table 2.4 with regard to macroscopic stages in maturation, based on the maturity scales presented above. Macroscopic images of the different stages of maturation in anglerfish relative to this new scale are shown in Figures 2.15 and 2.16. Icelandic and Faroese maturity ogives presented in Figure 2.14 have also been updated with the new scale in mind for the years following its establishment.

Table 2.3 Gonad differences between female and male anglerfish (*Lophius piscatorius*).

Female	Male
The ovaries are generally long, flat and band-shaped. The membrane connecting the ovaries extend further out than that in the testes, so that the gonads stretch further away from the vertebrae than in the males.	Testes are tube-like and more rounded than the ovary, running almost parallel to the vertebral column.
In immature females the ovaries are flat, transparent, and wider than the testes in male fish of similar length.	In immature males the testes looks like a round "thread" just beside the vertebra.

Figure 2.14

Maturity ogives for female and male L. piscatorius. Faroe Islands: data from 2000-2005, maturity at stages 3-5 (2000-July 2003: maturity scale as in Appendix 3c; August 2003-2005: maturity scale as in Table 2.4); Iceland: data from 2000-2004, maturity at stages 3-5 (Table 2.4); Norway: data from North Sea (IBTS, 1983-2000) and off Møre (1992-1997), maturity at stages 2-4 (Appendix 3d); Shetland: plots left are based on maturity at stages 3-5, plots right at stages 2-5 (maturity scale as in Appendix 3a).

Table 2.4 Macroscopic maturity scale for anglerfish *Lophius piscatorius*, as agreed on by the Nordic project group to be used as standard for their work. The scale is based on previously used scales shown in Appendices 1-4.

Maturity stage		Females	Males
I	Virgin/ immature	The ovaries are very narrow (< 2cm broad), thin and ribbon-like. They are translucent and no individual oocyte-clusters (eggs) and vascularization can be seen. Veins can though be seen in the connecting tissue/membrane running to the ovaries. The volume of the ovaries is negligible compared with that of the other internal organs.	The testes are long, narrow (<5 mm broad) and have a tube-like structure. The medial seminiferous duct is distinct, being very pale with no visible vascularization. Their volume is negligible compared with that of the other internal organs.
II	Developing	The ovaries increase in length and, particularly, in width (~2 – 4 cm broad). They become less translucent and there is visible vascularization. There are still no visible individual oocyte clusters (eggs), but the texture is almost grainy when rubbed. The volume occupied by the ovaries is roughly the same as that occupied by the intestine.	The flattened tubular shaped testes increase in length and, especially, in width. Blood vessels become visible around the medial seminiferous duct. The volume is roughly half that occupied by the intestine. Milt not visible when cutting the gonad.
III	Maturing	The ovaries increase considerably in width (>4cm) and, particularly, in length. They are highly vascularised. Individual opaque oocyte clusters (eggs) are visible, and at the end of the stage embedded in a gelatinous matrix. The ovaries occupy most of the abdominal cavity.	The testes have a very firm texture and moderate to large amounts of milt are produced when they are dissected, but no milt extrudes when pressure is applied. The seminiferous duct is now highly vascularised.
IV	Ripe or spawning	The ovaries are extremely long (>6m) and wide (20-30 cm) and occupy most of the body cavity. The bright orange oocyte clusters (1-2mm eggs) have darker centres, and are embedded in a transparent gelatinous matrix. The ovaries are highly vascularised.	Milt runs from the genital pore on slight pressure. The testes appear swollen and large amounts of milt are produced when dissected.
V	Spent or resting	The ovaries are shrunk and flaccid, with longitudinal striations. They are still wide (6-15cm) and highly vascularised when newly spent. When resting the ovaries are opaque and less vascularised. When newly spent, a few remaining oocytes (eggs) may occur.	The testes are very flaccid, and look bruised red or blotchy. In newly spent males, milt may be present in the seminiferous duct when dissected, but no milt extrudes when pressure is applied. The posterior edge is sometimes narrower than the anterior part of the gonad. At this stage, the testes are still highly vascularised in the vicinity of the seminiferous duct, and the edges of the testes are sometimes transparent.

Figure 2.15

Maturation stages in female *Lophius piscatorius*, according to scale as described in Table 2.4. (Photos: L. H. Ofstad)

Figure 2.16

Maturation stages in male *Lophius piscatorius*, according to scale as described in Table 2.4. (Photos: L. H. Ofstad)

2.4 Sex composition

Because of the higher growth rate in females, virtually all large anglerfish are female. Thus a comparison between samples obtained by 180 mm and 150 mm meshed gillnets in Norwegian waters showed that female *L. piscatorius* greatly outnumbered males (ratio 3:1) in the larger-meshed gillnets, while this difference was somewhat reduced at a 2:1 ratio in the 150 mm gillnet (Staalesen 1995). In trawl samples from Faroese waters both sexes occurred in roughly equal proportions in the length interval 30–55 cm (Ofstad, unpubl. data) (Figure 2.17). In the 55 to 75 cm length interval males were slightly more numerous than females. This predominance may be explained by sexual differences in growth and maturation. Male growth slows down after maturation is reached (at about 57 cm according to data from this area), causing an accumulation of males in this length group. Females continue to grow at the same rate until reaching a length of about 83 cm, so that after 85 cm females outnumber males, and above 107 cm all fish are females. Correspondingly, off the northwest coast of Scotland (Afonso-Dias & Hislop 1996), and around Shetland (Laurenson *et al.* 2001) (Figure 2.17) the sex ratio was about 1:1 up to lengths of 70 and 58 cm, respectively, after which females outnumbered males; above approximately 100 cm all fish were female.

Figure 2.17

Sex ratio (proportion of females) for *L. piscatorius* caught by trawl off the Faroe Islands (n female = 1 453, n male = 1 522) (Ofstad, unpubl. data), and around Shetland (Laurenson 2003).

In Portuguese and Spanish waters male *L. piscatorius* were slightly more numerous than females in the 60 to 75 cm length interval, after which the proportion of females increased until reaching 100 % above 100 cm (Duarte *et al.* 1998). For *L. budegassa* in the same area (Duarte *et al.* 1998, Duarte *et al.* 2001) no sex was predominant for individuals less than 40 cm in length, between 40 and 52 cm males were over-represented, and above 52 cm females were predominant. Individuals over 70 cm were all female.

2.5 Reproduction

Sexual maturation and female fecundity

From samples taken on the Norwegian west coast Woll *et al.* (1995a,b) found that the gonadosomatic index (GSI) of anglerfish in this area gradually increases from January and peaks in June. In their study only females larger than 90 cm contained maturing eggs. Females as small as 60–70 cm had blood-rich ovaries, which is usually a sign that spawning has taken place. No females were found in which the eggs had started forming yolk substance as a preparation to spawning. Figure 2.18 shows the GSI as a function of length in male and female *Lophius* from Faroese waters. Some large females > 90 cm showed signs of maturation with $GSI > 10\%$. All anglerfish with a $GSI > 20\%$ were caught in February and April. Male GSI increased after a length of about 55 cm, which seems to confirm male length at first maturity (see chapter 2.3).

Figure 2.18

Gonadosomatic indices (GSI, % of round weight) of (a) and (b) female ($n = 1682$) and (c) male *L. piscatorius* ($n = 1412$) caught in Faroese waters March – September 2002. Note different y-axes for females in plots (a) and (b).

Detailed light and electron micrographs have been presented for both male and female *Lophius* caught off northwest Scotland (Afonso-Dias & Hislop 1996), as well as for a related species, *Lophiomus setigerus*, found in the East China Sea (Yoneda *et al.* 1998b,c). Yoneda *et al.* (1998b) also reported fecundity data (number of eggs per specimen). To our knowledge, no such information, at least not accurate and comprehensive, has so far been presented for European *Lophius* species. Hislop (2001) does however state that *L. piscatorius* egg ribbons contain in excess of 1 million eggs. Fecundity data are considered important in understanding the

reproductive investment in species and their capacity to withstand fishing pressure.

A better understanding of the reproductive cycle of anglerfish in Nordic waters would require a dedicated sampling programme (e.g. at a monthly rate) combined with histological (microscopic) examinations. Preliminary analysis on gonads collected in Faroese waters (for sampling procedures see Appendix 1b) on several occasions in 2002 has shown some discrepancies between macroscopic and microscopic gonad classification (Appendix 4), but a larger material is needed to clarify the level of precision in using the macroscopic scale. Interestingly, some of the ovaries containing only immature oocytes (perinucleolar) showed examples of mucus, indicating that there are spent specimens. There was also an example of a maturing specimen in late autumn (migratory). Generally, larger specimens showed larger oocytes (Figure 2.19). Light microscopic images of oocyte development in anglerfish are shown in Figure 2.20. Our preliminary studies on oocyte development exemplify once more the unusual nature of anglerfish gonads (see also Afonso-Dias & Hislop 1996).

Figure 2.19

Relative oocyte diameter (B) of L. piscatorius caught in Faroese waters March – September 2002.

Figure 2.20

Light micrographs of oocyte development in *L. piscatorius*: from immature (a) to close to prior to spawning (f). Red: mucus. (Images courtesy of O. S. Kjesbu & M. Fonn)

Spawning

Little is known about when and where anglerfish spawn in northern European waters (Hislop *et al.* 2001). A reason for this lack of knowledge is undoubtedly the unusual way in which the spawning occurs. Whereas the eggs of most other marine fish are dispersed individually over a wide range, anglerfish eggs are produced in single gelatinous and buoyant, reddish to purple ribbons or tubes, which may be in excess of 10 m long and up to 1 m wide (Figure 2.21). In a mature female such a ribbon may amount to up to half of its total weight and contain more than 1 million eggs. The distribution of the eggs and newly emerged larvae is consequently highly aggregated, explaining why egg and larval surveys have provided little information about the time of spawning and the location of the spawning grounds (Hislop *et al.* 2001).

Figure 2.21

Examples of female egg veils and male testes from *L. piscatorius* caught at Iceland. Numbers refer to maturation stages as in Appendix 3b. (Photo: E. Jónsson)

In 2004 a campaign was started in Faroe Islands, Iceland and Norway to encourage fishermen and others to report observations of egg masses. Earlier observations include two recordings at Iceland by a longliner in August/September 2003, and 2-3 possible observations from April-June between 59° and 65° N on the Norwegian coast. Egg ribbons were also observed in Faroese waters on board the research vessel Magnus Heinason in March 2002, as well as on the Faroe Bank during the July 2003 0-group survey, where gelatinous egg mass was seen to contain 7 mm long larvae (see Figure 2.8).

At Shetland, a sample from an *L. piscatorius* egg ribbon was obtained from a crab-fisherman who got it entangled in his fishing gear on 19 May 2004, 10 nm south of Lerwick. Laurenson (2006) (Annex D) managed to keep the embryos from this rare find alive for 5 days while observing and describing their development. Sub-optimal water quality made it impossible to keep the embryos alive longer than this 5-day period. Photos taken of the embryonic development show one egg per chamber. Only one oil droplet was present in the eggs, which appears to be in disagreement with Tåning's (1923) observation that one or two small globules remain after fusing of the rest into one, large globule. Laurenson concludes that any smaller globules fuse to form one large prior to the stages shown in Figures 1 and 2 of Annex D.

Spawning period

Taken together, several findings suggest that the spawning season in *L. piscatorius* extends from late winter to summer in northern areas. In samples from the Norwegian coast mature males were found from March until October (Staalesen 1995). Mature females were found between June and August, but numbers were low and the sampling irregular. Egg ribbons have been found along the Norwegian coast in May-June, making it likely that spawning occurs during this period. Around the Faroes spawning female anglerfish have been observed from January to April (L. Ofstad, pers. obs.). At Iceland spawning anglerfish were observed from end April - beginning of June, while spent anglerfish were found in July/August. However, observations and reports from fishermen indicate that spawning can take place as late as September (Jónsson, unpubl. data). North-west of Scotland maturing females occurred most months, but mature females were only found between November and May (Afonso-Dias & Hislop 1996). The largest number of spent females was found between April and July. Maturing and mature males were found in every month of the year; spent males were most frequent between April and August. In waters around Shetland seasonal occurrences of maturing and spent anglerfish are similar to those reported by Afonso Dias and Hislop (Laurenson 2003). In the Bay of Biscay the reproductive period for *L. piscatorius* was by macroscopic and histological studies observed to extend from May to August with a peak in May-June (Quincoces *et al.* 1998). For *L. budegassa* the season appeared to last from April to July with a peak in May-July (Quincoces *et al.* 1998).

In the Norwegian material the majority of females were in the spent/resting stage throughout the year, whereas most males were maturing (Staalesen 1995). These broad periods of gestation suggest either that gonadal development is long or that spawning is non-synchronous. The large number of spent/resting females in the catches may indicate that individuals do not spawn every season (Staalesen 1995).

Spawning area

Spawning in anglerfish is believed to occur in deeper water. West of the British Isles spawning grounds have been reported at depths of 1 000-1 800 m. No observations exist to indicate whether Nordic stocks of anglerfish migrate to such depths to spawn. However, large mature females with a GSI of up to 32 % were reported at 350 m depth far off the coast of western Norway in June 1994 (Woll *et al.* 1995a). In deeper waters off the Faroes observations were made of four female anglerfish with a GSI > 25 % (Ofstad, unpubl. data). Two were caught in February, one at 350 m depth at Skeivabanka southwest of the Faroes, and the other at 200 m depth at the Faroe Bank. The other two were caught in April north of the Faroes at about 250 m depth. Together with observations of larvae and juveniles in the same areas, this makes it likely that spawning occurs

around the Faroes, but the exact locations have yet to be pinpointed. Egg ribbons have been caught in cod gillnets off Norway in May-June, making it likely that spawning does occur in Norwegian waters during this period. From the absence of spawning females and the low number of mature females of both species in a Southern Shelf⁸ study Duarte *et al.* (2001) suggested a reproductive migration to other areas or depths. From the distribution of demersal stages of British *L. piscatorius* and using a particle tracking model Hislop *et al.* (2001) suggested that this spawning occurs in deep water. This is also indicated by the increasing percentage of mature anglerfish which was found with increasing depth in the waters around Shetland (Laurenson *et al.* 2001, Laurenson 2003).

2.6 Natural mortality

No specific research on natural mortality in European anglerfish is at present known to the authors. For *L. americanus* Armstrong *et al.* (1992) found indications that males in the oldest age groups suffer a heavier mortality rate than females, possibly because of behavioural differences that cause higher predation or fishing mortality, or simply because of higher senescence in males. For stock assessment purposes the ICES uses a natural mortality rate of 0.15 yr^{-1} for all ages and lengths of *L. piscatorius*, adopted from earlier hake (*Merluccius merluccius*) assessments. Fishing mortality is further discussed in Section 3.5.

Predation

Apart from a study concerning cormorant birds (*Phalacrocorax* sp.) preying on *L. piscatorius* (Choisy & Jones 1983), there are no reports of predators that specifically target adult anglerfish in European waters. Indirect predation through tail removal of netted fish by seals (*Phocini*) has been described from the south coast of Ireland. According to Best (1999), male sperm whales (*Physeter macrocephalus*) may sometimes move into continental slope waters off Namibia to feed on benthic species, including the anglerfish *Lophius upsicephalus*. Examination of the stomach contents of seven sperm whales stranded on the coast of the Netherlands revealed mainly cephalopods, but anglerfish remains were found in one animal (Santos *et al.* 2002). In Faroese waters a few observations have been made of juvenile anglerfish in stomach contents of big cod (*Gadus morhua*) (Ofstad, pers.obs.). It is likely that during the pelagic phase anglerfish larvae and juveniles are heavily preyed upon by other species, but no studies are available to confirm this assumption.

⁸ See Figure 1.1

Cannibalism

There is no clear evidence of conspecific predation (cannibalism) in European anglerfish (Crozier 1985), but some stomach samples from Faroese (Ofstad, pers. obs.) and Shetland waters (Laurenson & Priede 2005) did contain remains of conspecifics. A diet study in the Shetland area showed one incidence of cannibalism in 1 054 samples, where a 74 cm long monkfish had consumed a 42 cm individual (Laurenson 2003, 2005c). Large individuals of *Lophius americanus* from the Northwest Atlantic are known to prey on smaller members of their own species (Armstrong *et al.* 1996). Being opportunistic feeders it seems likely that anglerfish do occasionally prey on members of their own species, as do the above observations confirm, but more research is needed to provide conclusive evidence as to the extent of cannibalism.

2.7 Food and feeding

Anglerfish are lie-and-wait predators, usually lying half-buried on muddy to gravelly bottoms, using their modified first dorsal fin ray as a “fishing rod” to lure prey (fish and sometimes seabirds) closer (Caruso 1986, Gordo & Macpherson 1990, Laurenson 2005a). They further have a wide, cavernous mouth with numerous sharp, backward pointing teeth to prevent the prey from escaping.

Recent studies identify cephalopods (Velasco *et al.* 1998) and gadoids, particularly blue whiting (*Micromesistius potassou*) (Azevedo 1996, Silva *et al.* 1997) as the most important forage for anglerfish on the Southern Shelf⁹. Gadoid fish were likewise the main food for *L. piscatorius* from the Irish Sea (Crozier 1985) and Norwegian waters (Woll *et al.* 1995a). Stomach samples from Faroese waters contained mainly bony fish prey such as Norway pout, blue whiting, small redfish, flatfishes, haddock and cod. Remains of various other fish species were also found, as well as some decapods and cephalopods (Ofstad unpubl. data). Laurenson and Priede (2005) found that stomachs of anglerfish collected on sandeel fishing grounds at the Shetland Islands contained a wide variety of mainly fish prey, of which the most important species were Norway pout (*Trisopterus esmarkii*) and lesser sandeel (*Ammodytes marinus*). Bony fishes as well as cephalopods were also the dominant prey groups in stomach samples of Lophids from other parts of the world (Armstrong *et al.* 1996, Cha *et al.* 1997, Gordo & Macpherson 1990, Macpherson 1985a,b).

Anglerfish are essentially opportunistic feeders, displaying a low degree of prey selectivity. In tank experiments anglerfish nevertheless refused to take dead whitefish species (Laurenson 2003). Stomach contents

⁹ See Figure 1.1

reflect spatial and/or temporal prey availability or abundance (Crozier 1985). Thus, in addition to codfish, Woll *et al.* (1995a) found large amounts of migrating herring (*Clupea harengus*) in stomach samples from commercial anglerfish catches off the coast of Norway, February 1994. Bruno *et al.* (2001) suggest movement associated with feeding or reproduction as a likely cause of seasonality in Portuguese gillnet catches. Lordan (2000) describes a new project seeking among others to better describe the diet of both anglerfish species in the Irish Sea. No results appear as yet to have been published. From the prey items recorded in anglerfish stomach samples at various times and at various location around Shetland it was concluded that anglerfish were opportunistic, taking whatever of a manageable size was available. It was also speculated, on the basis of both diet and tagging studies, that anglerfish may undertake feeding migrations onto areas where prey, such as sandeels, are seasonally or temporarily abundant (Laurenson 2003).

2.8 Parasite and disease studies

Only a limited number of studies is available that deal with parasitology and diseases of anglerfish in European waters. Most research involves *Lophius* as host species for a variety of nematode and trematode parasites. Kie (1993) investigated occurrences of nematodes in teleosts including *Lophius* to 1 540 m depth off the Faroes. Other parasite studies from northern European waters include Crozier (1987) and Petter & Cabaret (Petter & Cabaret 1995). A study relating to the prevalence of parasites (*Anasakis* and *Pseudoteranova* nematodes) and the effect of their occurrence on monkfish flesh quality is currently being undertaken at the FRS Marine laboratory in Aberdeen, Scotland.

3. Fisheries, assessment and management of anglerfish stocks

3.1 Commercial anglerfish fisheries in the North Atlantic

Nordic fisheries directed at anglerfish take place on the continental shelf areas around the Faroes and Iceland and west and south of Norway, specifically in ICES Divisions IIa, IIIa, IVa,b and Va,b (see Figure 1.1). For the purposes of the present report these areas are defined as Nordic waters. Northern and Southern Shelf refer to areas defined in reports prepared by the ICES Demersal Stocks Assessment Working Groups for these areas (e.g. Anon. 2006) (see Figure 1.1), and may basically be characterised as the continental shelf north and south of the English Channel, respectively.

Anglerfish are usually not sorted by species in commercial landings in Northern Europe; consequently the TAC, where appropriate, is set for both species combined (e.g. for Northern Shelf divisions). The stock status of each species is, however, assessed separately on the basis of species composition in samples collected from the various fisheries. Catch and survey data from the North Sea, west of Scotland and Norway indicate that the large majority of catches on the Northern Shelf and in Nordic waters consist of *L. piscatorius* (Anon. 2005a, Staalesen 1995, Woll *et al.* 1995a,b). On the Southern Shelf the proportion of *L. piscatorius* in the catches has since 1990 varied from 44 to 67 % in southern parts, and from 61 to 78 % in northern parts (Appendix 5). Official landings in tonnes for each fishing area from 1990 to 2004 are shown in Figure 3.1.

Figure 3.1.

Annual anglerfish landings from different regions in the Northeast Atlantic (see Figure 1.1) 1990-2004 (in tonnes). In this figure, Nordic waters includes Iceland (ICES Division Va), Faroe Islands (ICES Div. Vb) and Norwegian waters north of 62°N (ICES Div. Ila). Source: ICES Fisheries Statistics. (*) preliminary data.

Factors used by the Nordic countries for converting fish product weight to round weight and length to weight are given in Appendix 6.

Denmark

In Denmark anglerfish are largely taken as bycatch in demersal fisheries in the North Sea and Skagerrak (S. Reeves, pers. comm.). However, these bycatches can form a relatively high proportion of the total value of the catch, so the species is important, particularly to the fishers of the ports in West Jutland. Reported Danish landings of anglerfish from the North Sea varied between 1 404 t and 2 254 t over 1990 to 2002 (Figure 3.2), making Denmark the second most important exploiter of this stock after the UK. Denmark also takes the majority of catches of anglerfish reported from ICES Division IIIa (Skagerrak & Kattegat). Danish landings from this area have varied between 312 t and 658 t over 1990 to 2002.

Figure 3.2

Annual landings (tonnes) of anglerfish in Denmark 1990-2004. Source: ICES Fisheries Statistics. () preliminary data.*

Faroe Islands

During the 1990s directed trawl and gillnet fishing efforts for anglerfish in Faroese waters intensified, resulting from 1997 onwards in a marked increase in landings (Figure 3.3, Appendix 7). In 2001 some 2 200 t of anglerfish were landed, about half of which was caught by gillnets, mainly on the Faroe Plateau and the banks off the Faroes. The presently well-established Faroese deep-water tangle net fishery for anglerfish is described in Reinert (1995). Appendix 8a shows typical length-frequency distributions of anglerfish caught by trawl and gillnet.

Figure 3.3

Annual anglerfish landings (tonnes) in the Faroes, Iceland and Norway, proportionally by gear type.

Since 1993 when the gillnet fishery started, it has been managed as a licensed fishery, without any TAC constraint. Five vessels are currently licensed for fishing anglerfish. The gillnet fishery is furthermore restricted by area, depth, mesh size, number of nets, soaking time, and bycatch rules. The fishery is allowed in a small area east and in a larger area southwest of the islands. The closed area restrictions for the demersal fishery is also in force for the gillnet fishery, and gillnetting is only allowed at depths greater than 380 m. Minimum mesh size permitted is 280 mm (stretched), but most gillnetters uses 300 mm mesh size. The maximum soaking time is 72 hours. Bycatch regulation of cod, haddock, saithe and redfish is in order; catches of these species may not exceed 20 % of the total catch in weight for the whole year.

Small trawlers (<400 hp) have a direct fishery for anglerfish. During the summer season these are allowed to fish in specified areas inside the 12 nautical miles limit. The fleet is regulated through numbers of fishing days, permanent and temporary area closures, and bycatch restrictions.

Anglerfish are also caught as bycatch by larger trawlers (>1 000 hp) and in the longline fishery.

Anglerfish fishing grounds for two gillnetters in 2004 are shown in Figure 3.4.

Figure 3.4

Anglerfish gillnet fishing grounds for two gillnetters in Faroese waters in 2004.

Iceland

In the relatively warm waters off the south coast of Iceland, anglerfish were previously mainly taken as trawl bycatch. Total annual catch during the last 30 years was usually between 600 and 700 t, equally proportioned between *Nephrops* and conventional trawls (Figure 3.3, Appendix 7). In 1999 a directed fishing effort on *Lophius* began, conducted by boats equipped with specially designed trawls, after which the annual catch increased to about 1 000 t. In 2000 a large-scale gillnet fishery with special wide-meshed nets was initiated, similar to the net fisheries in Norwegian and Faroese waters which were started some years earlier. During 2000 gillnet landings grew from about zero to 764 t, and the total *Lophius* catch in Icelandic waters rose to a record high of 1 503 t. During the same period the share of the catch in *Nephrops* and conventional trawls decreased 25 and 31 %, respectively, compared with the previous year. In 2001 gillnet landings were 150 t less than the previous year, while trawl landings remained stable, ending with a total catch of 1 350 t. This reduction in net landings seems not to be caused by a change in fishing effort, but rather by a decrease in CPUE (kg/net) from the high virgin catches in the large-mesh net fishery initialised in 2000. A slight decline in the fishable stock is also indicated at the same time in the March survey indices.

However, the net-catches dropped drastically in 2002 but this drop was due to drastic decrease in effort, which again was due to the introduction of the quota system for the species that year. The original shares (quotas) distributed to each boat were so many and small that this thwarted the effort – a situation which was later mostly removed by the fishing industry itself through buying and uniting quotas so a profitable fishery could be conducted.

In Iceland, gillnets with different mesh sizes are allowed, but 241-330 mm is mostly used. The gillnet fishery is partly conducted in much deeper water than on conventional trawling grounds, but anglerfish caught at these depths appear to migrate to shallower water during parts of the year. The net fishery therefore does not seem to be exploiting any new stock component. The main anglerfish grounds were concentrated off the south coast (Figure 3.5). However, during the last 4-5 years the species has migrated strongly onto the grounds west off Iceland where formerly it was almost nonexistent, as clearly seen by the annual distribution and abundance of anglerfish in the Icelandic bottom trawl survey (see Figure 1.4). This development is undoubtedly due to the increasing water temperatures in Icelandic waters during the same period. In accordance with this invasion of the species into new territories the importance of the anglerfish fishing-grounds west off Iceland have grown more important every year. Appendix 8b shows some typical length-frequency distributions of anglerfish caught by trawl and gillnet.

Figure 3.5

Anglerfish fishing grounds in Icelandic waters (gillnet fishery 2001). Catch size indicated by circle diameter.

Norway

In 1992 a new fishery with specially designed anglerfish gillnets started on the shelf off the northern part of the Norwegian west coast (Møre) (Woll *et al.* 1995a,b). Anglerfish were previously mainly taken as by-catch in gillnets, and in shrimp and groundfish trawls. Total annual catch quickly reached a peak in 1993 with 4 452 t (Appendix 7). From a period of decline in reported landings since 1994, catches increased to a preliminary record high of 4 996 t in 2001 (Bjelland 2006). Contributing factors for this increase may have been an illegal fishery using smaller gillnet mesh sizes (300 instead of 360 mm; for length-frequency distributions see Appendix 8c), an increase in the number of nets, increased soak times, as well as an extension of the fishing areas to the north. The majority of the landings (Figure 3.3, Appendix 7) presently come from small gillnetters less than 17 m in length and carrying from 100 to 500 nets per boat.

The fishery is mainly concentrated on the western coast off Møre, inside 12 nautical miles (Figure 3.6). For most of the 1990s anglerfish landings from northern Norway were limited, varying between 2 and 5 % of the total anglerfish catch. In recent years, catches originating from northern regions have increased dramatically, so that at present (2005) about 34 % of all Norwegian anglerfish is caught north of Halten.

Figure 3.6

The majority of anglerfish landings from Norwegian waters come from gillnetting north of 62° N (Halten Bank). Circles in the maps show proportional landings by statistical square in Norwegian statistical areas 5-7 from 1996-2004. Circles enclosed in squares denote landings unallocated to locations within the statistical areas.

The gillnet fishery is regulated through a smallest permitted mesh size (360 mm stretched mesh), a limit to the number of nets per boat, and a

maximum soak time of two days to limit effort and to ensure good fish quality. No bycatch regulations exist for the trawl fishery. No annual quotas are presently set.

Since 2004 there has been a moratorium on the anglerfish fishery north of 62° N during March-June. Legally permitted bycatch of anglerfish by other gears than gillnets is restricted to maximally 25 % of the total catch in weight. A directed trawl fishery is, however, conducted by EU countries in the Norwegian Economic Zone south of 62° N, limited by a total quota of 1 750 tonnes (2006).

Shetland

At Shetland the majority of anglerfish are caught by trawl, only a small percentage comes from seining (<5 %), while none come from gillnetting. The Shetland trawl fleet started to target anglerfish during the mid-eighties and the catch became important almost overnight. Compared to whitefish nets, the nets used to target anglerfish have got longer wings, a mouth in a tighter “V” rather than “U” shape, and hoppers that are smaller. The anglerfish *net* also does not stand as high in the water. Appendix 8d shows the length-frequency distribution of anglerfish caught by this type of gear. Data on anglerfish landings at Shetland ports are available from 1981. These are shown in relation to the other whitefish landings over the time period (Figure 3.7). During the early development of the fishery the anglerfish landings show an increase from 533 t to over 2 100 t in 1990 (Figure 3.7). During the peak landings in 1996 anglerfish accounted for 15 % weight and 40 % value of demersal landings in Shetland (Figure 3.7).

Figure 3.7

Annual landings (tonnes and value in GBP (thousands)) of anglerfish and whitefish species in Shetland 1981-2003. (NB. a small percentage of landings into Shetland is from non-Shetland registered vessels and a small percentage of catches by Shetland vessels is made into non-Shetland ports).

Following fleet redevelopment during the 1990s most of today's demersal fleet are designed to target anglerfish. The main anglerfish fishing

grounds are to the north of Shetland and along the shelf break to the west. During the late 1990s and at the start of the 2000s there were concerns over the ability of the anglerfish stock to withstand the fishing pressure that it was under during the peak of the fishery. However, during 2000 and 2001 there was evidence of a large year class recruiting into the fishery, and this is still evident today. During 2003 69 Scottish vessels were accepted into a decommissioning scheme (as part of a cod recovery plan). In places such as Shetland up to 30 % of the whitefish fleet was decommissioned, and this has dramatically reduced the fishing effort on whitefish stocks, including anglerfish. Today fishermen report that catch rates for anglerfish are as high as they have ever been.

Anglerfish landings for the UK are shown in Figure 3.8. From 1973-1983 they remained constant. Since 1984 it is seen that most of the increase in UK landings is from Scottish (including Shetland) vessels.

Figure 3.8

Catches (live weight) by UK vessels (by country) between 1973 and 2000. (source: ICES Catch data 1973-2000).

Northern and Southern Shelf

On the Northern Shelf (ICES Divisions IIIa, IV and VI), anglerfish were until the 1980s mainly taken as bycatch during bottom trawling for other groundfish. Following TAC restrictions on other species, fishing pressure on anglerfish increased, specifically in new fisheries where they now also were targeted. Landings from Northern Shelf areas increased sharply during the early 1990s, peaking at about 34 000 t in 1996, but have since fallen back to approximately the same levels as before 1990 (Figure 3.1, 3.). No reduction in fishing effort seems to be in evidence to explain the recent decline, but the earlier sharp rise in catch-per-unit-effort indicates

the expansion and increasing efficiency of a new, directed anglerfish fishery.

According to the latest official landing statistics reported to the ICES, the total annual outtake of anglerfish on the Northern Shelf in 2004 was about 11 500 t. The bulk of the landings (about 9 000 t in 2004) are from the northern North Sea (IVa) (Figure 3.9), where a Scottish directed trawl fishery is responsible for most of the catch. Following the drop in catch-per-unit-effort, the fishery has since the mid-nineties expanded into deeper water where large, mature anglerfish are believed to aggregate. For example, a fishery involving French and Scottish vessels has since the late 1980's developed in deeper water (1 000-1 500 m) west of the British Isles, targeting a variety of species, including *Lophius* (Blasdale & Newton 1998). Anglerfish are also an important target species in the bottom trawl fisheries on the upper ridge slopes to the west of the Hebrides and Shetland (Gordon 2001a). Together with the high fishing mortality rates anglerfish prior to first maturity are subjected to, the new deepwater fisheries targeting adult fish have raised the level of concern about over-fishing in northern areas considerably.

Figure 3.9

Spatial distribution (by statistical rectangle) of official landings of anglerfish within ICES Divisions IIIa, IVa, and VIa for the period 1995-2004 (source: Anon. 2005)

On the Southern Shelf, anglerfish are an important component of mixed species trawl fisheries taking gadoids, flatfish and *Nephrops* from the west of the British Isles to the northern parts of the Bay of Biscay. These fisheries developed in the 1970s, and annual landings increased steadily until 1986. Even though the fishing effort increased until 1990, anglerfish catches declined until 1993. Previous heights were reached again in 1996, but landings have until recent years been falling again. Annual landings reported to the ICES for 2004 present a preliminary record high of nearly 39 000 t, compared to 20 000 t in 1990. French, Spanish and Irish trawlers take most of this catch, with UK trawlers and gillnetters taking the remainder. In Northern Spain, specially designed anglerfish nets (280 mm mesh size) are used in a medium to deep-water (100-800 m) gillnet fishery (Pereda *et al.* 1998). Anglerfish make up 97 % of the total catch landed by this gear type.

On the shelf areas west of Portugal and north of Spain both species are caught in mixed fisheries by Spanish and Portuguese fleets. A directed small-scale artisanal fishery has also existed in the region since the 1970's. Annual outtake of both species combined has over the last 20 years fluctuated between some 2 000 and 6 000 t.

3.2 Fishing gears and methods

The most common fishing methods for anglerfish are trawling and gill-netting, but in certain areas Danish seines are also used. Appendix 8 shows some typical examples of length distributions from these different gear types. Sangster & Breen (1998) compared the fishing and engineering performance of single and twin rigged scraper trawls during trials aboard a commercial fishing boat. The twin trawl significantly out-fished the single trawl for *L. piscatorius*, even over the same swept area. Analysis of bridle herding efficiency demonstrated that anglerfish and flatfish may have been herded more effectively by the twin trawl bridles, which had the smaller angle of attack. Shetland trawlers now commonly use a twin rigger set-up. Madsen & Hansen (2001) describe a flexible grid system for reducing bycatch in the Danish trawl fishery targeting shrimps on the Fladen Ground in the North Sea, while still retaining marketable catches of roundfish like anglerfish. A similar grid system was previously tested in the groundfish trawl fishery in the Celtic Sea and the Bay of Biscay (Meillat *et al.* 1994). The authors have also been informed that commercial trawls have been equipped with so-called "tickler chains" to increase the catchability of anglerfish. The use of tickler chains is restricted to more sandy or muddy bottoms due to obvious snagging problems on rough ground. Their use can considerably increase the catch rate of anglerfish on a given ground (Laurenson, unpubl. data).

3.3 Fisheries statistics

Data on catches and landings of commercial fish species, as well as vessels and fishing gears are registered and published regularly by public offices in each country. Data are also compiled by ICES and available for use with the FishStat Plus program from:

<http://www.ices.dk/fish/statlant.asp>.

Denmark

Danish official statistics are administered by the Fiskeridirektorat of the Danish Ministry for food, land use and fisheries (Ministeriet for Fødevarer, Landbrug og Fiskeri). Fisheries statistics can be found online at <http://www.fd.dk> (English version available).

Faroe Islands

The Faroese statistical office (Hagstova Føroyar) (<http://www.hagstova.fo>) has data on Faroese catch statistics. The Faroe Islands Fisheries Inspection (Fiskiveiðieftirlitið) (<http://www.fve.fo>) reports annual landings and official catch statistics (only in Faroese).

Iceland

Data on annual catches in Iceland are gathered and registered by the office of Fiskistofa. Information about landings on an annual and/or a daily basis is public and accessible by all under <http://www.fiskistofa.is> (English version available).

Norway

The Norwegian Directorate of Fisheries (Fiskeridirektoratet, <http://www.fiskeridir.no>) publishes weekly and monthly Norwegian catch statistics as tables in PDF and Excel format (Norwegian language only). English language tables of annual landings in previous years, as well as preliminary statistics for the current year, can also be found here.

Scotland/Shetland

The Scottish Executive publishes an annual report of fisheries statistics; the 2001 publication “Scottish Fisheries Statistics 2000” may be found at <http://www.scotland.gov.uk>. On the same website the Shetland Islands Council publishes an annual report “Shetland in Statistics”, which contains information on the Shetland fleet and includes landings into Shetlands ports.

3.4 Biological sampling

Biological data on many fish species, including anglerfish, are collected on a regular basis in all countries, either from market sampling or specific research surveys, where also pertinent non-biological data are gathered.

Denmark

There are no directed surveys for anglerfish in Danish waters (S. Reeves, pers. comm.). However, length data are available for anglerfish caught during the Danish surveys in the North Sea, Skagerrak and Kattegat. Length data are also available from commercial catches, as noted in Section 1.2.

Faroe Islands

There are no directed surveys for anglerfish in Faroese waters. However, in the annual bottom trawl surveys for cod, haddock and saithe around the Faroe Islands in February/March (spring survey since 1983) and August/September (summer survey since 1996) some anglerfish are also caught (see Figure 1.3). From these, length and round weight data exist. From 2002 anglerfish length, weight, sex, maturity stage and age data have been routinely sampled in the annual bottom survey for cod, haddock and saithe. There are also some length data from other surveys with the research vessel, and from commercial vessels hired for special investigations by the Fisheries Laboratory. In 2002 a regular length and age (*illicia*) sampling programme was established to get sufficient data on anglerfish from the landings.

Iceland

The Marine Research Institute (MRI) in Reykjavik collects biological data on a regular basis from commercial landings. Monthly samples of landed, gutted fish are taken at 2-3 ports within driving distance of MRI.

Further biological data are collected during an annual *Nephrops* survey that also covers the anglerfish fishing grounds. Length measurements of anglerfish have also been taken during Icelandic bottom trawl surveys in March and October for a number of years, since these surveys cover the anglerfish fishing grounds. Anglerfish surveys are also conducted twice yearly by MRI staff going out with commercial vessels 2-4 days at a time sampling biological data.

Norway

Biological data from commercial anglerfish landings were collected from the northwest coast of Norway (Møre) during the period 1992-1997 (33 stations, $n = 2\,639$ individuals). Most of the samples were taken from catches by gillnet vessels using nets with 300 and 360 mm mesh size; only one station was carried out on anglerfish landed by a Danish seine equipped vessel. Most of the sampling was performed on landed catch, therefore most of the sampled fish were gutted. In order to get complete biological data, some samples were also taken at sea from round anglerfish, and in some cases the fishermen agreed to deliver round fish on-shore. In the beginning, otoliths were collected for age determination, but later the *illicium* became the preferred ageing structure, and sampling was concentrated on *illicia* instead. The commercial catch sampling was restarted in the beginning of 2002. About 60 specimens from 1-2 samples are sampled each month. In 2004 further efforts were undertaken to establish a network of fishermen along the coast in order to collect samples from their catches. In addition, fishermen on board each of 9 open sea vessels that form part of the Norwegian Reference fleet take up to one length sample per day on a maximum of 60 fish.

The Institute of Marine Research has since the early eighties sampled anglerfish during annual bottom trawl surveys, including the IBTS, and during shrimp and *Nephrops* surveys in the North Sea. Systematic sampling of anglerfish, which are regarded as bycatch in these surveys, was not performed before the late 1980s (O. Smedstad, pers. comm.), causing a lack of data in parts of the time series. From 1989 to 2000 Norwegian scientists sampled 1 834 anglerfish collected on 3 336 stations.

Scotland/Shetland

Since late 1997 data and biological samples have been collected at Shetland mainly from trips onboard commercial trawlers and during various gear selectivity trials. Some biological data have been collected from market sampling. Otoliths are collected from various ports throughout Scotland as part of a market-sampling programme run by the Marine Laboratory in Aberdeen.

An anglerfish tagging programme was conducted in Shetland during the summer of 2001, during which length frequencies and catch rates were recorded from each ground surveyed. During the last few years the Marine Laboratory in Aberdeen has conducted several anglerfish research surveys, mainly to the west of Scotland.

3.5 Stock assessment and management

With the exception of the Nordic stock component in the northern North Sea (ICES Divisions IIIa, IVa,b), no assessments are carried out on anglerfish stocks in Nordic waters¹⁰. Management of these stocks is achieved exclusively through regulations concerning minimum fish size, through restrictions on fishing gear (Norway), and by imposing precautionary TACs (Iceland). The Faroese gillnet fishery for anglerfish is managed solely as a licensed fishery without a quota constraint.

Iceland

No proper stock assessment has yet been done due to the fact that general age reading from all gears and years is not available yet. The data series that has been collected spans only 4 years from 2000-2004. General age reading is now underway, and once this is established, modelling of the stock size will be attempted. However, it has been clear from the fishery itself and from the March and October bottom trawl surveys and the *Nephrops*-survey in May, that the stock is in an upward swing (Figure 3.10).

Although total catches have been increasing annually, indices of higher catch-per-unit-effort that point to a stock increase are not very clear when looking at series of years, probably due to the fact that the bulk of the catches has been brought ashore as bycatch until quite recently. Other indicators from the catch data, such as the extension of the fishery onto new grounds (see Figure 3.5), and the very high proportion of young fish in some years (see catch length distributions, Figure 1.5 and Figure 1 in Annex C), have furthermore been positive signs of a very prolific stock.

These same signs are, however, much better recorded in the surveys. Thus recruitment indices from the March survey of 1 and 2 years old fish indicate very low recruitment from 1985 to 1998 when a strong year-class appears in the stock. Two other big year-classes appear to develop in 2001 and 2003, and in the most recent survey (2005) the survey records a new strong year-class from 2004. Indices of recruitment expressed as fish

¹⁰ Although evidence to link the stocks is still inconclusive, the 2005 report from the ICES Working Group on the Assessment of Northern Shelf Demersal Stocks (Anon. 2006a) for the first time also includes a section reporting on the Nordic anglerfish stock component in the Norwegian Sea (Division IIa).

in the size range 40-60 cm are accordingly on the rise in the survey, mainly since 2000 (Figure 3.10). The good state of the fishable stock is finally well demonstrated in the survey as indices of fish >60 cm which have been rapidly increasing since 2003 (Figure 3.10)

Figure 3.10 Iceland

March survey anglerfish indices of fishable stock (> 60 cm) and juveniles (40-60 cm) during the period 1985-2005.

After having advised a TAC of 1 500 tonnes for several years on a precautionary basis (in spite of increasing total landings which exceed the proposed TAC), the MRI in 2005 recommended a TAC of 2 200 tonnes, corresponding to previous years' catches. This increase in the recommended TAC is mainly based on the increase in the fishable stock indices of the March survey, which is interpreted as a true sign of stock increase. At the same time it is obvious that the stock has responded positively to increased effort and catches, as seen in regular and good recruitment.

Northern and Southern Shelf

The ICES Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNDS) carries out annual assessments of stocks in the North Sea (IVa-c), Skagerrak/Kattegat (IIIa), and north and west of Scotland (VIa,b) (e.g., Anon. 2006a). Similar assessments are performed by the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrin (WGHMM) on anglerfish stocks in Divisions VIIb-k, VIIId-d and IXa (e.g., Anon. 2006b,c). TAC regulations are now set in all the above ICES areas. These TACs were formerly based on average landings in previous years, but have since 2000 been subjected to a precautionary approach in response to increased levels of fishing mortality as well as uncertainty about levels of recruitment and spawning stock biomass (SSB). Until recently, the lack of a TAC in Division IVa encour-

aged misreporting of landings from other areas on the Northern Shelf into that area, causing allocation uncertainty and undermining management efforts.

The Advisory Committee on Fishery Management (ACFM) is responsible, on behalf of the ICES, for providing scientific information and advice on living resources and their harvesting¹¹. For anglerfish in the Northern Shelf divisions the ACFM considers the stock status at present (2005) to be unknown, due to “major uncertainties about catch and effort data for anglerfish, as well as limited knowledge about population dynamics and distribution”. ACFM further states that the available information is inadequate to evaluate spawning stock or fishing mortality relative to risk, and that a reliable assessment presently (2005) therefore is not possible. The development of commercial CPUE from logbook data from the Scottish anglerfish fishery does however suggest that the stock is not in decline (Anon. 2005a). ICES recommends that the “effort in the fishery should not be allowed to increase and the fishery must be accompanied by mandatory programmes to collect catch and effort data on both target and by-catch fish”. For anglerfish in the northern divisions on the Southern Shelf the ACFM classifies both *L. piscatorius* and *L. budegassa* stocks as being at full reproductive capacity, but considers that the *L. piscatorius* stock is at risk of being harvested unsustainably. Fishing mortality should therefore be kept within precautionary limits. In the southernmost divisions on the Southern Shelf the size of the stock of both species combined is considered to be well below the level associated with harvesting at maximum sustainable yield. Measures should be taken to assure that the TAC (set at 2 000 t in 2005) is restricting the fishery, landings from which have been well above the TAC in later years. If this objective is not met, setting the fishing mortality equal to zero in 2006 could be required to ensure full recovery of the SSB on a short-term basis.

Discarding of anglerfish is known to occur in all areas, but data are not routinely collected. Recent Scottish survey data do, however, indicate that discard levels are probably low on the Northern Shelf. For Southern Shelf stocks, where no minimum mesh size restrictions are in effect, there is probably an even lower level of discards. For example, anglerfish caught by the multi-métier French trawler fleet operating in the Celtic sea were discarded in negligible numbers compared to numbers that were landed (Rochet *et al.* 2002). Anglerfish are almost always retained as a valuable commercial fish, like in the multi-species trawl fisheries. Nevertheless, the ICES Study Group on Unaccounted Mortalities in Fisheries does conclude that *L. piscatorius* is a species of concern in the Eastern North Atlantic fisheries, particularly with regard to unaccounted discard and escape mortality (Anon. 1995).

Because of uncertainties in age reading, as well as the concern that the age-based separability assumption in catch-at-age analysis may be vio-

¹¹ Available at <http://www.ices.dk/iceswork/acfm.asp>

lated in the rapidly growing fisheries on the Northern Shelf, the WGNDS has since 1999 instead explored a length-based approach to stock assessment. Yield per recruit was estimated from a modified catch-at-size analysis (CASA), using the size transition matrix model of Sullivan *et al.* (1990). Use of this method gave qualitatively similar results to catch-at-age analysis. For Southern Shelf anglerfish stocks the WGHMM has used a separable age-based VPA with XSA tuning, although ageing problems have also here been suspected.

3.6 Mortalities and fishing pattern

No attempts have been done in this project to estimate the natural mortality, M (for natural mortality causes see section 2.7). The value of this has hence been set to 0.15 for all age groups, i.e., the same as used by ICES for anglerfish further south in the northeast Atlantic.

Estimation of total mortality by the linear catch curve method

An approximation of the total mortality, Z , may be estimated for the fully recruited (to the fishery or survey) age groups by a linear catch curve method (e.g., Baranov 1918, Sparre 1998). This has been done by Faroe Islands, Iceland and Norway, based on age and length sampling of the commercial catches and/or research surveys covering anglerfish. The amount and completeness of data which these estimations have been based on differ from country to country, e.g. at Faroe Islands the mortality estimation and result are presented for commercial catches in 2004, at Iceland from the annual 2000-2003 research surveys (targeting *Nephrops*, but believed to provide a reliable abundance index of anglerfish, and also representing the commercial anglerfish catches taken by the *Nephrops* trawlers), and in Norway from commercial catches in 2002. Similar estimations of Z have also been done using anglerfish data from the international bottom trawl survey (IBTS) in the North Sea (Dyb 2002). However, in addition to fishing mortality (F), these IBTS estimations of total mortality (Z) are influenced by the emigration of anglerfish from the North Sea. Emigration, immigration, and recruitment variability, are all factors that must be taken into account when discussing the mortality estimations done for the different areas using this method. Nevertheless, the aim of the present project report has been to show the possibilities for estimating total mortality by using the catch curve method, and to show the level of this mortality in some example years. Routine monitoring and advice based on this method is, however, dependent on a much more regular and better coverage of the biological sampling. The catch curve method is not suitable for estimating fishing pattern.

Faroe Islands

The catch curve method was applied to the Faroese landings in 2004, using an age-length key from 2002 (see Appendix 9a). The average total mortality (Z) for ages 7-12 was estimated to 0.49 for gillnet and to 0.57 for trawl for ages 4-7, yielding a total Z (including all landings) for ages 4-12 of 0.49 (Figure 3.11).

Figure 3.11 Faroe Islands

Linear catch curves fitted to the Faroese gillnet (A), trawl (B) and all gears (C) catches of *L. piscatorius* in 2004. The total mortality, Z , estimated by this method gives $Z = 0.49$ as an average for ages 7-12 for gillnet and $Z = 0.57$ for ages 4-7 for trawl, and an overall Z for ages 4-12 of 0.49.

Iceland

Until lately the Icelandic fishery on anglerfish was conducted almost entirely on a by-catch basis, and considerations e.g. regarding yield per recruit were not in sight, as the bulk of the catch was brought ashore by *Nephrops*-boats using small mesh trawls, most likely cutting heavily into the annual recruitment, and discarding the not marketable small fish. As direct effort started, research advanced and length and age samples have been collected. However, age reading has commenced slowly. By mid-summer 2004 only some 950 age samples, all from four (2000-2003) annual *Nephrops*-surveys had been read, mainly for the special purpose of validating the age readings via the length distribution modes of big

year-classes appearing regularly in the stock since 1998 (see Figure 1 in Annex C). Samples collected from other gears, and from the commercial fleet itself have not yet been aged. Thus, the following yield calculations are all based on data from one specific gear described above, and are therefore more or less trial calculations not fully representing the general fishery on anglerfish. Based on the same age-read data, the age-disaggregated abundance indices from the *Nephrops*-survey were used to estimate the total mortality (Z) both for all data combined (Figure 3.12), and 5 year-classes separately (Table 3.1). In the former case the Z estimate is 0.496 and in the latter case the Z estimate is in the range 0.36-0.66.

Figure 3.12 Iceland

Catch-curve of anglerfish (Nephrops-survey 2000-2003, n=948) and fitted linear decline of 4 years and older indicating total mortality of $Z = 0.50$.

Table 3.1 Iceland

Year-class	Z	R^2	% survival
1994	0.655	0.659	70.1
1995	0.433	0.699	56.7
1996	0.371	0.898	69.0
1997	0.569	0.697	64.9
1998	0.356	0.805	51.9
Total	0.497	0.966	68.9

Estimate of total mortality (Z), R^2 and survival (%) of 5 anglerfish year-classes and in the total data (Nephrops-survey 2000 -2003).

Norway

The catch curve method was applied on the Norwegian landings in 2002, using the age-length key shown in Appendix 9c. This age-length key was constructed using age readings of fish collected during the Institute of Marine Research's research surveys in the North Sea and port sampling at Møre in 1994-1998. The average total mortality (Z) for ages 7-12 was estimated to 0.82 and 0.87 for gillnet and all gears, respectively (Figure 3.13). For gillnet, which comprises the greatest anglerfish fishery in Norway, it is not possible to use the catch curve method for ages younger than 7-8.

Figure 3.13 Norway

Linear catch curves fitted to the Norwegian gillnet (A), other gears (B) and all gears (C) catches of *L. piscatorius* in 2002. The total mortality, Z , estimated by this method gives $Z = 0.82$ as an average for ages 7-12 for gillnet and $Z = 0.34$ for ages 3-6 for trawl, and an overall Z for ages 7-12 of 0.87.

Estimation of fishing mortality and fishing pattern from population dynamics

By using and combining equations from the fishery population dynamics it is possible to estimate the fishing mortality for most of the harvested age groups, and thus the exploitation pattern and the number of anglerfish in the actual population:

- i. $N_{i+1} = (N_i \cdot e^{-M/2} - C_i) \cdot e^{-M/2} \Leftrightarrow N_i = e^M \cdot N_{i+1} + e^{M/2} \cdot C_i$
- ii. $N_{i+1} = N_i \cdot e^{-(F_i+M)}$
- iii. $C_i = \frac{N_i \cdot F_i}{F_i + M} \cdot (1 - e^{-(F_i+M)})$,

where N_i and N_{i+1} are the numbers of anglerfish within the harvested population at the beginning of the year, i , and at the beginning of the next year, $i+1$, respectively; C_i is the catch-in-numbers during the present year with corresponding fishing mortality F_i ; and M is the natural mortality, which has been set to 0.15 as a constant. Whether all equations are needed depends on the data available.

Equation I is the cohort analysis invented by Pope (1972) as an approximation for a virtual population analysis (VPA). Since the catch-at-age data available for anglerfish were too limited to follow a cohort through the fishery, we had to take an age distribution of catches in one particular year to represent a single cohort's development, year by year, through the fishery.

Another assumption which is necessary to make is about the population (N) at the oldest (included) age group as a starting value, N_{i+1} , to equation I. Different starting values lead only to minor differences in the F s for ages younger than 10 (see Appendix 10). This method may therefore be used as a rather robust method of estimating the fishing mortalities for most of the age groups (i.e., younger than age 10) composing the commercial landings, and hence the fishing pattern.

This method is the only way to achieve an approximate fishing pattern necessary for e.g., any yield-per-recruit calculations. It is also considered better than the catch curve method, as it may estimate the fishing mortality for each age group each year, and not only the right hand side and the fully recruited part of a catch curve.

The results from these calculations, which so far only have been applied to the Faroese and Norwegian data, are shown in Appendix 10a,b.

For the total international anglerfish fishery in the Norwegian Economic Zone (NEZ) in 2002, and given the assumptions and quality of the input data and $M=0.15$, the average fishing mortalities (F) for ages 3-9, 4-11 and 7-11 were estimated to about 0.42, 0.57 and 0.76, respectively (Appendix 10a).

Similar calculations conducted on the Faroese data show average fishing mortalities (F) of 0.35, 0.49 and 0.59, respectively, for ages 3-9, 4-11 and 7-11 in the total anglerfish fishery at Faroe Islands in 2004 (Appendix 10b).

Summary

The above estimations of mortality are founded on different biological sampling effort and age reading procedures, which currently are subject for research and improvement. The use of Pope's cohort analysis under such data poor conditions have also made it necessary to make the assumptions that recruitment to the fisheries varies from year to year in the same way over time, and that the age dependent catchability follows the same pattern over time.

- At the Faroe Islands, the current (2004) fishing mortality (F) seems to be about $F=0.35$, 0.49 and 0.59, respectively, for ages 3-9, 4-11 and 7-11.

- At Iceland, the current (2000-2003) average fishing mortality seems to be about $F=0.35$ for ages 4-11(12) (estimated by the catch curve method).
- In Norwegian waters, the current (2002) fishing mortality (F) seems to be about $F=0.42, 0.57$ and 0.76 , respectively, for ages 3-9, 4-11 and 7-11.

3.7 Yield and spawning stock per recruiting fish

With known exploitation pattern, natural mortality, maturity ogive (knife-edged) and individual mean weight-at-age, yield and spawning stock per recruiting fish may be estimated and presented for different fishing mortalities.

Using the data and information available on these parameters, tables with the necessary input data to the yield- and spawning stock per recruit calculations for Faroe Islands, Iceland and Norway are shown in Appendix 11a-c. The corresponding current fishing mortality for ages 4-11 is shown by an arrow in each figure below.

Faroe Islands

In the Faroese fisheries for anglerfish, the landings caught by trawl and gillnet are about the same, together representing almost all the landings. The first case (Figure 3.14 A) uses a knife-edged exploitation pattern at age 4, which is about the age when the anglerfish seem to be full recruited to the fishery. In the more “realistic” second case (Figure 3.14 B) the exploitation pattern is based on the estimate of fishing mortality from all landings in 2004 (Appendix 11a).

Figure 3.14 Faroe Islands

Yield- and spawning stock per two-year-old recruit when (A) based on a knife-edged exploitation pattern at age 4, and (B) based on the exploitation pattern as estimated and presented in Appendix 11a. $M=0.15$.

Iceland

Only limited data on selection in the actual Icelandic fishery are available. The actual selection in the fishery has been two-sided. Firstly, the *Nephrops*-boat fishery often fishing on medium sized and very small fish, and secondly the net fishery taking only big fish. Fortunately, the latter fishery has been growing in extent. A medium choice was made for the trial selection, assuming the anglerfish recruits (50%) into the fishery at the age of 4; firstly (A) very abruptly, and secondly (B) not very abruptly (see Figure 3.15). In both cases the maximum yield per recruit is about 4 kg. The optimal F (F_{01}) according to the yield-curves is in both cases around $F=0.24$ (Figure 3.11). As these values are not founded on a very broad basis, it serves little purpose to compare them with corresponding values in other anglerfish stocks

Figure 3.15 Iceland

Yield (Y/R) and spawning stock biomass (SSB/R) per two years old recruit at various fishing mortalities (F), and the assumption that the fish selects sharply into the fishery at the age of 4 (**A**), or gradually into the fishery, and is half (50%) recruited at the age of 4 (**B**). $M=0.15$.

Norway

Estimations analogous to those presented for Faroe Islands and Iceland are given in Figure 3.16.

Figure 3.16 Norway

Yield- and spawning stock per one year old recruit when (A) based on the exploitation pattern representative of the Norwegian gillnet (360 mm) fishery, and (B) based on the present exploitation pattern for the total fishery for anglerfish in the NEZ (incl. gillnet, trawl, Danish seine). $M=0.15$.

Concluding remarks

There is a huge difference in the weight-at-age and maturity-at-age data used by Iceland as input to the yield-per-recruit calculations compared with the similar input data used by Faroe Islands and Norway (see Appendix 10). This is the main reason for a much higher yield-per-recruit in this area compared with the others. More research is urgently needed to improve and standardise the age reading method in order to confirm or reject these differences.

The maximum yield-per-recruit is achieved at a fishing mortality of 0.2-0.4 dependent on fishing pattern and natural mortality. Delaying the start of the fishery until the anglerfish has gained more weight is clearly increasing the yield-per-recruit, and this increased harvest potential is not fully utilised in any of the areas.

Based on these preliminary analyses and yield-per-recruit estimations, the current fishing mortality in Norway and Faroe Islands seems to be too high to secure a high, sustainable and stable long-term yield, while the Icelandic fishing pressure seems to be closer to the optimum.

Table 3.2 shows the consequences for $F_{\max}$ and yield-per-recruit of using $M=0.15$ instead of $M=0.20$, and also the importance of using a likely age range. The max age should at least be 25 or 30 years to get a correct

$F_{\max}$, unless a good algorithm for a plus-group is used (e.g., 12+). By using age range 1-12 (no plus-group), a too high $F_{\max}$ is indicated. This problem is more serious for $M = 0.15$ than for $M = 0.20$.

Table 3.2

M = 0.15 per year			M = 0.20 per year		
Age range	$F_{\max}$	Max YPR	Age range	$F_{\max}$	Max YPR
1-12	0.42	2.77	1-12	0.52	1.93
1-25	0.26	2.91	1-25	0.42	1.95
1-30	0.21	2.9	1-30	0.42	1.95
1-60	0.21	2.9	1-60	0.42	1.95

Maximum fishing mortality and yield-per-recruit for different natural mortality rates and age groups (Norwegian data).

4. Future research

Although an important part of the European fisheries for anglerfish takes place in Nordic and Northern Shelf waters this report indicates that the body of work done on anglerfish in these regions is still somewhat lacking compared to research in more southern parts of Europe. More research on the biology, ecology and abundance of northern anglerfish is thus needed in order to properly manage the growing fisheries in the area.

Future research that should be prioritised:

- With the recent expansion of anglerfish fisheries into deeper water along the northern shelf-edges, an increasing fraction of both mature and immature anglerfish is being targeted. To properly address the impact of fisheries on northern anglerfish populations more basic data need to be gathered on their life-history and population dynamics. How many separate stocks do for example exist in northern waters? Mark-recapture experiments and population genetic research will to this end be useful tools.
- To achieve consistent data on length and age at first-time maturation among the participating countries it is important that a common maturation scale be constructed, and that consensus be reached over which stages represent mature fish.
- Furthermore, data on spawning time and spawning areas are still relatively scarce.
- Ageing methodology has improved over the last decade, but a standardisation of techniques as well as structures used for ageing between the participating countries is in order to ensure accurate and consistent readings.
- If expensive data storage tags are decided upon in mark-recapture studies, preliminary trials using dummy or conventional tags would be recommendable considering the vulnerability of anglerfish to traumas due to handling. Methods of capture that ensure best survival rates need also be investigated.
- Tags placed on the dorsal area of the fish may be overlooked because commercial fishermen often immediately place caught fish on their backs for processing. Extra markings or dye applied to the ventral area may increase visibility in this respect.

5. References

- Anon. (1995) Report of the Study Group on Unaccounted Mortality in Fisheries, Aberdeen (Scotland), 17-18 April 1995. *ICES Council Meeting papers* CM-1995/B:1. 27 pp.
- Anon. (2000) Third International Ageing Workshop on European Anglerfish, IPIMAR, Lisbon, 8-12 March 1999. European Fish Ageing Network, EFAN Report 2-2000.
<<http://www.efan.no/NewsAndReports/EFAN%20Report%202-2000.htm>>. 15 pp.
- Anon. (2005) Report of the *ad hoc* scientific working group on management measures for sandeel, Norway pout, anglerfish and horse mackerel in the North Sea and Skagerrak. EU-Norway working group, Charlottenlund, Denmark 23-27 May 2005.
- Anon. (2006a) Anglerfish (on the Northern Shelf and IIa). p. 280-327 in ICES (2006) Report of the Working Group on Working Group on the Assessment of Northern Shelf Demersal Stocks (WGNSDS), 10-19 May 2005, Murmansk, Russia. *ICES Council Meeting papers* CM-2006/ACFM:13. 757 pp.
- Anon. (2006b) ANGLERFISH in Divisions VIIb-k and VIIIa,b,d,e. p. 100-184 in ICES (2006) Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrin (WGHMM), 10-19 May 2005, Lisbon, Portugal. *ICES Council Meeting papers* CM-2006/ACFM:01. 881 pp.
- Anon. (2006c) Anglerfish (*L. piscatorius* and *L. budegassa*) in Divisions VIIIc and IXa. p. 302-336 in ICES (2006) Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrin (WGHMM), 10-19 May 2005, Lisbon, Portugal. *ICES Council Meeting papers* CM-2006/ACFM:01. 881 pp.
- Afonso-Dias IP (1997) Aspects of the biology and ecology of anglerfish (*Lophius piscatorius* L.) off the west-coast of Scotland (ICES Sub-area VIa). *PhD* thesis, University of Aberdeen. 192 pp.
- Afonso-Dias IP & Hislop JRG (1996) The reproduction of anglerfish *Lophius piscatorius* Linnaeus from the north-west coast of Scotland. *Journal of Fish Biology* 49(A): 18-39.
- Armstrong MP, Musick JA, & Colvocoresses JA (1992) Age, growth, and reproduction of the goosefish *Lophius americanus* (Pisces: Lophiiformes). *Fishery Bulletin* 90(2): 217-230.
- Armstrong MP, Musick JA, & Colvocoresses JA (1996) Food and ontogenetic shifts in feeding of the goosefish, *Lophius americanus*. *Journal of Northwest Atlantic Fishery Science* 18: 99-103.
- Azevedo M (1995) A statistical analysis of black monkfish catch rates in ICES Division IXa. *Fisheries Research* 24(4): 281-289.
- Azevedo M (1996) Studying the feeding habits of anglerfish (*Lophius* spp.) in Portuguese waters: A qualitative approach. *ICES Council Meeting papers* CM-1996/G:19. 9 pp.
- Azevedo M & Pereda P (1994) Comparing monkfish (*Lophius piscatorius* and *L. budegassa*) abundance in ICES Division VIIIc by year and depth strata. *ICES Council Meeting papers* CM-1994/G:22. 7 pp.
- Baranov FI (1918) On the question of the biological basis of fisheries. *Izvestiya otdela rybovodstva i nauchno-promyslovyyh issledovaniy* 1(1): 81-128. (In Russian)
- Bauchot M-L (1987) Poissons osseux. p. 891-1421 in Fischer W, Bauchot M-L, & Schneider M (eds) Fiches FAO d'identification pour les besoins de la pêche (Revision 1). Méditerranée et Mer Noire. Zone de pêche 37. Rome: Commission des Communautés Européennes & FAO. (In French)
- Best PB (1999) Food and feeding of sperm whales *Physeter macrocephalus* off the west coast of South Africa. *South African Journal of Marine Science* 21: 393-413.
- Bjelland O (2006) Breiflabbb. p. 144-145 in Iversen *et al.* (eds.) (2006) Havets Resurser 2002. Fisken og Havet, særnr 1-

2006. Bergen: Institute of Marine Research. 203 pp. (In Norwegian, summary in English)
- Blasdale T & Newton AW (1998) Estimates of discards from two deepwater fleets in the Rockall Trough. *ICES Council Meeting papers* CM-1998/O:11. 18 pp.
- Bruno I, Fariña AC, Landry J, & Morlán R (2001) The gillnet fishery for anglerfish (*Lophius piscatorius*) in deep-water in the northwest of Iberian Peninsula. *NAFO Scientific Council Research Documents* 01/99. 5 pp.
- Caruso JH (1983) The systematics and distribution of the lophiid anglerfishes: II. Revisions of the genera *Lophiomus* and *Lophius*. *Copeia* 1: 11-30.
- Caruso JH (1986) Lophiidae. p. 1362-1363 in Whitehead PJP, Bauchot M-L, Hureau J-C, Nielsen J, & Tortonese E (eds) *Fishes of the North-eastern Atlantic and the Mediterranean*. Paris: Unesco. 1473 pp.
- Cha BY, Hong BQ, Jo HS, Sohn HS, Park YC, Yang WS, & Choi OI (1997) Food habits of the yellow goosfish, *Lophius litulon*. *Journal of the Korean Fisheries Society* 30(1): 95-104. (In Korean, abstract in English)
- Cha BY, Park YC, & Huh SH (1998) Age and growth of the yellow goosfish, *Lophius litulon*. *Journal of the Korean Fisheries Society* 31(4): 529-534. (In Korean, abstract in English)
- Choisy JP & Jones R (1983) Predation of a cormorant *Phalacrocorax* sp. on an anglerfish *Lophius piscatorius*. *Oiseau et la Revue Française Ornithologie* 53(2): 181. (In French, summary in English)
- Crozier WW (1985) Observations on the food and feeding of the angler-fish, *Lophius piscatorius* L., in the northern Irish Sea. *Journal of Fish Biology* 27(5): 655-665.
- Crozier WW (1987) Occurrence of *Contracaecum clavatum* Rudolphi in anglerfish (*Lophius piscatorius* L.) from the north Irish Sea. *Fisheries Research* 5(1): 83-90.
- Crozier WW (1988) Comparative electrophoretic examination of the two European species of angler-fish (Lophiidae): *Lophius piscatorius* (L.) and *Lophius budegassa* (Spinola) and assessment of their genetic relationship. *Comparative Biochemistry and Physiology*, B 90B(1): 95-98.
- Duarte R, Azevedo M, Landa J, & Pereda P (1998) Reproduction of black and white anglerfish (*Lophius budegassa* Spinola, 1807; *Lophius piscatorius* Linnaeus, 1758) in the southern stock (ICES Divisions VIIIc and IXa). *ICES Council Meeting papers* CM-1998/O:23. 21 pp.
- Duarte R, Azevedo M, Landa J, & Pereda P (2001) Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. *Fisheries Research* 51(2-3): 349-361.
- Duarte R, Azevedo M, & Pereda P (1994) Study on the growth of black monkfish (*Lophius budegassa* Spinola) and white anglerfish (*L. piscatorius*, L.) of ICES stock in Division VIIIc+IXa. *ICES Council Meeting papers* CM-1994/G:26. 16 pp.
- Duarte R, Azevedo M, & Pereda P (1997) Study of the growth of southern black and white monkfish stocks. *ICES Journal of Marine Science* 54(5): 866-874.
- Duarte R, Landa J, Morgado C, Marçal A, Warne S, Barcala E, Bilbao E, Dimeet J, Djurhuus H, Jónsson E, McCormick H, Ofstad L, Quincoces I, Rasmussen H, Thaarup A, Vidarsson T, & Walmsley S (2005) Report of the Anglerfish *Illicia*/Otoliths Ageing Workshop, Lisbon (Portugal), 8-12 November 2004. Lisbon: IPIMAR. 47 pp.
- Dupouy H, Pajot R, & Kergoat B (1984) Etude de la croissance des baudroies, *Lophius piscatorius* et *L. budegassa*, de l'Atlantique Nord-Est, obtenue à partir de l'illicium. *Revue des Travaux de l'Institut des Pêches Maritimes, Nantes* 48(3-4): 107-131. (In French, summary in English)
- Dupouy H (ed.) (1997) Report of the International ageing workshop on European monkfish, Lorient (France), 25-28 June 1991 and 9-11 July 1997. Lorient (France): IFREMER. 34 pp.
- Dyb JE (2002) Populasjonsstudier av *L. piscatorius* langs Mørkysten og i Nordsjøen. *Cand. scient* thesis, University of Bergen. 105 pp. (In Norwegian)
- Fariña AC, Duarte R, Landa J, Quincoces I, & Sanchez JA (2004) Multiple stock identification approaches of anglerfish (*Lophius piscatorius* and *L. budegassa*) in western and southern European waters. *ICES Council Meeting papers* CM-2004/EE: 25.

- Gaard E & Reinert J (2002) Pelagic cod and haddock juveniles on the Faroe plateau: distribution, diets and feeding habits, 1994-1996. *Sarsia* 87(3): 193-206.
- Garoia F, Guarniero I, & Tinti F (2003) Polymorphic dinucleotide microsatellites for the Mediterranean angler species (Lophiidae). *Molecular Ecology Notes* 3(2): 294-296.
- Gordoa A & Macpherson E (1990) Food selection by a sit-and-wait predator, the monkfish, *Lophius upsicephalus*, off Namibia (South West Africa). *Environmental Biology of Fishes* 27(1): 71-76.
- Gordon JDM (2001a) Deep-water fisheries at the Atlantic Frontier. *Continental Shelf Research* 21(8-10): 987-1003.
- Gordon JDM (Ed.) (2001b) Distribution and biology of anglerfish and megrim in waters to the west of Scotland. Final report. European Commission - DGXIV Study Contract 98/096. Oban (Scotland): Scottish Association for Marine Science. 88 pp.
- Grant W & Leslie R (1993) Biochemical divergence and biogeography of anglerfish of the genus *Lophius* (Lophiiformes). *Journal of Zoology* 231: 465-485.
- Hansen B, Stefánsson U & Svendsen E (1998) Iceland, Faroe and Norwegian Coasts. p. 733-758 in Robinson AR & Brink KH (eds.) *The Sea, Volume 11, Regional Studies and Syntheses*. Harvard (USA): Harvard University Press. 1090 pp.
- Hislop JRG, Gallego A, Heath MR, Kennedy FM, Reeves SA, & Wright PJ (2001) A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus, 1758) in northern British waters. *ICES Journal of Marine Science* 58(1): 70-86.
- Hislop JRG, Holst JC, & Skagen D (2000) Near-surface captures of post-juvenile anglerfish in the North-east Atlantic - an unsolved mystery. *Journal of Fish Biology* 57(4): 1083-1087.
- Holm M, Arnold GP, Holst JC, & Midling KR (1999) Capture and handling of fish for electronic tagging - a review and a new non-intrusive capture method. *ICES Council Meeting papers* CM-1999/AA:03. 24 pp.
- Holst JC & McDonald A (2000) FISH-LIFT: a device for sampling live fish with trawls. Technical note. *Fisheries Research* 48: 87-91.
- Jónsson E (2004) Verification of anglerfish (*Lophius piscatorius*) age estimation through comparison of length modes of age read fish (*illicia*) to length modes of big year-classes appearing in the Icelandic stock. Working document to Duarte *et al.* (2004) Report of the Anglerfish *Illicia*/Otoliths Ageing Workshop, IPIMAR, Lisbon, Portugal, 8-12 November 2004.
- Koie M (1993) Nematode parasites in teleosts from 0 to 1540 m depth off the Faroe Islands (the North Atlantic). *Ophelia* 38(3): 217-243.
- Landa J & Pereda P (1997) Growth of white monkfish (*Lophius piscatorius* L.) in the northern Spanish Continental Shelf (ICES Divisions VIIIc and IXa). *ICES Council Meeting papers* CM-1997/CC:07. 10 pp.
- Landa J, Pereda P, Duarte R, & Azevedo M (1998) Growth study of white and black anglerfish (*Lophius piscatorius* Linnaeus, 1758; *L. budegassa* Spinola 1807) based on annual sampling in the southern stock (ICES Divisions VIIIc and IXa). *ICES Council Meeting papers* CM-1998/O:21. 41 pp.
- Landa J, Bruno I, Fariña AC, & Autón U (2001a) Movement rates and validation trials of growth of white anglerfish (*Lophius piscatorius*) in the Northeastern Atlantic based on mark-recapture experiments. *ICES Council Meeting papers* CM-2001/O:22 (Poster).
- Landa J, Duarte R, Fariña AC, Bruno I, & Castro J (2001b) Mark-recapture studies of black anglerfish (*Lophius budegassa*) in the Northeastern Atlantic: Preliminary results. *ICES Council Meeting papers* CM-2001/O:21 (Poster).
- Landa J, Pereda P, Duarte R, & Azevedo M (2001c) Growth of anglerfish (*Lophius piscatorius* and *L. budegassa*) in Atlantic Iberian waters. *Fisheries Research* 51(2-3): 363-376.
- Laurenson CH (1999) The monkfish *Lophius piscatorius* - its biology and fishery in Shetland waters. North Atlantic Fisheries College, Fisheries Development Note no. 9. 4 pp.
- Laurenson CH (2003) Aspects of the biology and fishery for monkfish *Lophius piscatorius* Linnaeus 1758, in waters around the Shetland Isles, North-eastern Atlantic. *PhD thesis*, University of Aberdeen, Dept. of Zoology. 306 pp.

- Laurenson CH (2005a) Behaviour of the monkfish, *Lophius piscatorius* recorded using a remotely operated vehicle (ROV). North Atlantic Fisheries College, Fisheries Development Note no.15, 4 pp.
- Laurenson CH (2005b) Movement and growth of monkfish tagged and released at Shetland. North Atlantic Fisheries College, Fisheries Development Note no. 16, 4 pp.
- Laurenson CH (2005c) A summary of the diet of monkfish, *Lophius piscatorius* caught at Shetland. North Atlantic Fisheries College, Fisheries Development Note no.18, 4 pp.
- Laurenson CH (2006) A note on the development of the embryos of anglerfish *Lophius piscatorius*. *Journal of Fish Biology* 68: 1287-1290.
- Laurenson CH & Priede I (2005) The diet and trophic ecology of anglerfish *Lophius piscatorius* at the Shetland Islands, UK. *Journal of the Marine Biological Association of the United Kingdom* 85: 419-424.
- Laurenson CH, Priede IG, Bullough LW, & Napier IR (2001) Where are the mature anglerfish? The population biology of *Lophius piscatorius* in northern European waters. *ICES Council Meeting papers* CM-2001/J:27 . 15 pp.
- Laurenson CH, Hudson I, Jones D, & Priede I (2004) Deep water observations of *Lophius piscatorius* in the north-eastern Atlantic Ocean by means of a remotely operated vehicle. *Journal of Fish Biology* 65: 947-960.
- Laurenson CH, Johnson A, & Priede I (2005) Movements and growth of monkfish *Lophius piscatorius* tagged at the Shetland Islands, northeastern Atlantic. *Fisheries Research* 71: 185-195.
- Leslie RW & Grant WS (1990) Lack of congruence between genetic and morphological stock structure of the southern African anglerfish *Lophius vomerinus*. *South African Journal of Marine Science* 9: 379-398.
- Leslie RW & Grant WS (1994) Meristic and morphometric variation among anglerfish of the genus *Lophius* (Lophiiformes). *Journal of Zoology* 232(4): 565-584.
- Lordan C (2000) The secret lives of monks and megrims! *Sherkin Comment* 25: 20.
- Maartens L, Booth AJ, & Hecht T (1999) The growth of monkfish *Lophius vomerinus* in Namibian waters, with a comparison of otolith and *illicia* methods of ageing. *Fisheries Research* 44(2): 139-148.
- Macpherson E (1985a) Daily ration and feeding periodicity of some fishes off the coast of Namibia. *Marine Ecology Progress Series* 26(3): 253-260.
- Macpherson E (1985b) Effect of predation by *Lophius upsicephalus* on the *Merluccius capensis* population. *Collection of scientific papers. International Commission for the Southeast Atlantic Fisheries* 12(1): 155-162. (In Spanish, summary in English)
- Madsen N & Hansen K (2001) Danish experiments with a grid system tested in the North Sea shrimp fishery. *Fisheries Research* 52(3): 203-216.
- Meillat M, Dupouy H, Bavouzet G, Kergoat B, Morandeau F, Gaudou O, & Vacherot JP (1994) Preliminary results of a trawl fitted with a selective grid for the fishery of benthic species from Celtic Sea and Bay of Biscay. *ICES Council Meeting papers* CM-1994/B:23. 15 pp.
- Nedreaas KH (2002) Breiflabb. p. 109-111 in Iversen SA (2002) Havets Ressurser 2002. Fisker og Havet, særnr 1-2002. Bergen (Norway): Institute of Marine Research. 151 pp. (In Norwegian, summary in English)
- O'Sullivan M, Wright P, Verspoor E, Knox D, & Piernsey S (2005) Microsatellite DNA polymorphism indicates an absence of population structure in monkfish *Lophius piscatorius* in its northern distribution. *ICES Council Meeting papers* CM-2005/T:18 (Poster).
- Pereda P, Punzón A, & Landa J (1998) The "rasco": A gillnet fishery for anglerfish (*Lophius piscatorius* L., 1758 and *L. budegassa* Spinola, 1807) in the Cantabrian Sea (ICES Division VIIIc). *ICES Council Meeting papers* CM-1998/O:46. 12 pp.
- Peronnet I, Dupouy H, Rivoalen JJ, & Kergoat B (1992) Methods of ageing based on caudal fin-rays for megrim (*Lepidorhombus wiffiagonis*) and on sections of *illicium* for anglerfishes (*Lophius piscatorius* and *L. budegassa*). p. 307-324 in Bagliniere J-L, Castanet J, Conand F, & Meunier F (eds) Hard tissues and individual age of vertebrates. Colloque et Séminaires. Institut Français de Recherche Scientifique pour le Déve-

- loppement en Coopération. (In French, summary in English)
- Petter AJ & Cabaret J (1995) Ascaridoid nematodes of teleostean fishes from the eastern North Atlantic and seas of the north of Europe. *Parasite* 2(2): 217-230.
- Piñeiro CG, Casas M, & Araujo H (2001) Results of exploratory deep-sea fishing survey in the Galician Bank: Biological aspects on some of seamount-associated fish (ICES Division 9b). *NAFO Scientific Council Research Documents* 01/146. 7 pp.
- Pope JG (1972) An investigation of the accuracy of virtual population analysis using cohort analysis. *Research Bulletin of the International Commission for the Northwest Atlantic Fisheries* 9: 65-74.
- Quincoces I, Lucio P, & Santurtún M (1998a) Biology of black anglerfish (*Lophius budegassa*) in the Bay of Biscay waters, during 1996-1997. *ICES Council Meeting papers* CM-1998/O:47. 28 pp.
- Quincoces I, Santurtún M, & Lucio P (1998b) Biological aspects of white anglerfish (*Lophius piscatorius*) in the Bay of Biscay (ICES Division VIIIa, b, d) in 1996-1997. *ICES Council Meeting papers* CM-1998/O:48. 29 pp.
- Quincoces I, Lucio P, & Santurtún M (1999a) The growth structures in black anglerfish, *Lophius budegassa* (Spinola 1807) *illicia*: A photographic approximation. *ICES Council Meeting papers* CM-1999/Post:08 (Poster).
- Quincoces I, Santurtún M, & Lucio P (1999b) Photographical study using scanning electron microscopy techniques of *illicia* of white anglerfish, *Lophius piscatorius* (L. 1758). *ICES Council Meeting papers* CM-1999/Post:07 (Poster).
- Reinert J (1995) Deep water resources in Faroese waters to the South, Southwest and West of the Faroes: A preliminary account. p. 201-225 in Hopper A (ed.) *Proceedings of the NATO Advanced Research Workshop on Deep-Water Fisheries of the North Atlantic Oceanic Slope*, Hull (UK), 1-4 March 1994. NATO Advanced Science Institutes Series E: Applied Sciences 296. Dordrecht (Netherlands): Kluwer Academic Publishers. 420 pp.
- Rochet M-J, Péronnet I, & Trenkel VM (2002) An analysis of discards from the French trawler fleet in the Celtic Sea. *ICES Journal of Marine Science* 59: 538-552.
- Sangster G & Breen M (1998) Gear performance and catch comparison trials between a single trawl and a twin rigged gear. *Fisheries Research* 36(1): 15-26.
- Santos MB, Pierce GJ, García Hartmann M, Smeenk C, Addink MJ, Kuiken T, Reid RJ, Patterson AP, Lordan C, Rogan E, & Mente E (2002) Additional notes on stomach contents of sperm whales *Physeter macrocephalus* stranded in the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom* 82(3): 501-507.
- Silva A, Azevedo M, Cabral H, Machado P, Murta A, & Silva MA (1997) Blue whiting (*Micromesistius poutassou*) as a forage fish in Portuguese waters. p. 127-146 in *Forage Fishes in Marine Ecosystems: Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems*, Anchorage (USA), 13-16 November 1996. Lowell Wakefield Fisheries Symposium Series 14. Fairbanks (USA): University of Alaska. 816 pp.
- Sparre P (1998) Introduction to tropical fish stock assessment. *FAO Fisheries Technical Paper*, 306/1. 397 pp.
- Staalesen BI (1995) Breiflabb (*Lophius piscatorius* L.) langs norskekysten. *Cand. scient* thesis, University of Bergen. 88 pp. (In Norwegian, summary in English)
- Sullivan PJ, Lai HL, & Gallucci VF (1990) A catch-at-length analysis that incorporates a stochastic model of growth. *Canadian Journal of Fisheries and Aquatic Sciences* 47: 184-198.
- Thangstad T, Dyb JE, Jónsson E, Laurenson CH, Ofstad LH, & Reeves SA (2003) Anglerfish (*Lophius* sp.) in Nordic and European waters: Status of current knowledge and ongoing research, December 2002. http://www.norden.org/fisk/publikationer/RAPP_Breiflabb_status.pdf. 66 pp.
- Tåning ÅV (1923) *Lophius*. In *Report on the Danish Oceanographical Expeditions 1908-1910 to the Mediterranean and Adjacent Seas*. Vol. II. Biology. 30 pp.
- Velasco F, Olaso I, & Sánchez F (1998) The role of cephalopods as forage for the demersal fish community in the Southern Bay of Biscay. *ICES Council Meeting papers* CM-1998/M:26. 15 pp.

- Woll A, Nedreaas KH, & Staalesen BI (1995a) Breiflabb langs norskekysten: Fiske, biologi og bestandsgrunnlag. *Fiskets Gang* 2: 19-26. (In Norwegian)
- Woll A, Staalesen BI, & Nedreaas KH (1995b) The development of a new gill-net fishery for anglerfish (*Lophius piscatorius*) in Norwegian waters: Biological parameters, selectivity in size and sex ratios for gillnets with 300 and 360 mm mesh sizes. *ICES Council Meeting papers* CM-1995/G:12. 11 pp.
- Woodroffe D, Wright P, & Gordon J (2003) Verification of annual increment formation in the white anglerfish, *Lophius piscatorius*, using the *illicia* and *sagitta* otoliths. *Fisheries Research* 60: 345-356.
- Wright PM, Woodroffe DA, Gibb FM, & Gordon JDM (2002) Verification of first annulus formation in the *illicia* and otoliths of white anglerfish, *Lophius piscatorius* using otolith microstructure. *ICES Journal of Marine Science* 59: 587-593.
- Yoneda M, Tokimura M, Fujita H, Takeshita N, Takeshita K, Matsuyama M, & Matsuura S (1997) Age and growth of anglerfish *Lophius litulon* in the East China Sea and the Yellow Sea. *Fisheries Science* 63(6): 887-892.
- Yoneda M, Tokimura M, Fujita H, Takeshita N, Takeshita K, Matsuyama M, & Matsuura S (1998a) Age and growth of the anglerfish *Lophiomus setigerus* in the East China Sea. *Fisheries science* 64(3): 379-384.
- Yoneda M, Tokimura M, Fujita H, Takeshita N, Takeshita K, Matsuyama M, & Matsuura S (1998b) Ovarian structure and batch fecundity in *Lophiomus setigerus*. *Journal of Fish Biology* 52(1): 94-106.
- Yoneda M, Tokimura M, Fujita H, Takeshita N, Takeshita K, Matsuyama M, & Matsuura S (1998c) Reproductive cycle and sexual maturity of the anglerfish *Lophiomus setigerus* in the east China Sea with a note on specialized spermatogenesis. *Journal of Fish Biology* 53(1): 164-178.

Annex A

Tagging of anglerfish during the Nordic project

I. Useful guidelines for anglerfish tagging

Discussed and decided upon as acceptable during the August 2004 anglerfish project meeting in Bergen:

- Use *internal* data storage tags (DST) because of the reduced risk of losing tags
- Agree on the best position where to anchor and sew the DST tag, using e.g. sutures and surgical glue or superglue (for usage and experience from tagging at the Faroes and Iceland see sub-sections below)
- Avoid damage to the *Lophius* tail, which heals very slowly, even with the antibiotics used so far
- Trawls should be deployed in shallow water; Norway: max 185 m, Shetland: 100 m, Iceland: 120 m
- Short tows should be used, preferably less than 1 hour
- Towing speed should be low, maximally 1.8-2.0 knots
- Longer sweeps may give better catch rates, preferably with the use of a tickler chain
- Avoid areas with great bycatch of other species, since these cause injury to the anglerfish
- Work in calm weather to avoid rolling of the boat and the tank
- Oxytetracycline hydrochloride (OTC) dosage used so far is 50 mg/kg (Landa *et al.* 2001a,b) injected in the tail muscle of each fish. A scheme including total fish length, round weight and OTC dose has been made, providing a suitable OTC dosage for a given fish length
- It can be discussed whether to inject the OTC in the stomach cavity (Iceland: including vitamins) or the muscle (Faroes, Shetland)
- Possible side effects are a concern, e.g. from increased handling time

In general, however, we are awaiting more results in order to gain experience through trial and error before concluding on the best tagging procedure.

II. Experiences from tagging fieldwork in Faroese waters

Lise H. Ofstad

Faroese Fisheries Laboratory (FFL), Tórshavn, Faroe Islands

The FFL made five tag-and-release surveys in 2004 and 2005, where 784 anglerfish between 35 and 116 cm in length were tagged with conventional Floy t-bar tags, and 30 of these also got an internal DST operated into the body cavity (Table 1).

Table 1 Overview of the number of tagged fish in each survey, whether the fish was injected with OTC, gear used, and number recaptured to the end of 2005.

Survey	Number tagged with Floy tag	Number tagged with DST	OTC used	Gear	Number recaptured
Spring 2004	235	10	+	Trawl	0
Autumn 2004	145	20	+	Trawl	1
Spring 2005	260	0	-	Trawl	3
Summer 2005	104	0	-	Gillnet	13
Autumn 2005	40	0	-	Gillnet	2

a. Methods

Onboard the trawler, viable anglerfish were immediately transferred to a tank with running seawater and kept there for at least 10 minutes in order to judge if they were fit for tagging. After tagging, the fish was released into the tank again and observed for some time. If the fish did not behave normally, the tag was removed and used in another individual. Fish that were successfully tagged were released carefully into the sea. Onboard the gillnetter the fish were not put into tanks, but all fish that were alive were gently removed from the gillnet, after which length measurements were taken, tags were fitted and the fish released into the sea again. Almost all anglerfish dived at once, indicating that they were in good condition. A few anglerfish remained floating with their mouth open, but after some seconds they closed their mouth and disappeared in the sea. All tagged fish that were floating were noted.

Information was sent to newspapers and radio, so that the public knew what to do when they caught a tagged anglerfish. Information was also sent to all boats fishing anglerfish in Faroese waters.

Floy tag

Each fish was, after being taken from the tank, laid on a table, where total length was measured and a purple Floy tag was anchored in the anterior dorsal part of the tail muscle (see Chapter 5 “Tagging Study” in Laurenson 2003).

Data Storage Tag

The DST milli tags used in this study have temperature and depth (pressure) sensors, and are produced by Star-Oddi in Iceland (www.star-oddi.com). During the first survey the DSTs were programmed to log in intervals of two days with registrations every 10 minutes followed by 12 days with registrations every 3 hours. During the second trip the 20 DST tags were programmed to log in intervals of two days with registrations every 15 minutes followed by 4 days with registrations each hour.

After tagging with a Floy tag, each fish was laid upside down in order to fit the DST in the body cavity. We tried to put a tube with running seawater into the mouth in order to secure oxygen supply, but this didn't work well because the mouth was too big for the seawater to pass through the gills. No anaesthetics were used. A slit was made with a scalpel through the body wall on the right side, allowing the DST to be placed into the peritoneal cavity. In the beginning there were problems with air trapped in the body cavity after the operation, resulting in the fish floating upside down. The solution was to not penetrate the innermost skin. The DST was attached to the body wall by absorbable sutures, and the slit closed by sutures. With some experience, the DST tagging procedure took about 2-5 minutes.

Oxytetracycline hydrochloride (OTC)

An OTC dose of 50 mg/kg (Landa *et al.* 2001a,b) was injected in the tail muscle of all anglerfish in the two first tag-and-release surveys. A correlation scheme was made between length and OTC dose, in order to secure the right OTC dose for all fish.

Comments and results

To the end of 2005 the FFL has received tags from 19 recaptured anglerfish (Table 1). All recaptures were in Faroese waters, except one that was recaptured south of Iceland (Figure 1 and 2).

Nine individuals were caught by gillnet in the same area and from the same boat from which they were tagged and released. Four individuals had moved 12-23 km southwards inshore and were recaptured after 17-35 days (Figure 1). One anglerfish had moved 84 km southeasterly in a straight line and was recaptured after 77 days, thus averaging a distance of about one km each day.

Figure 1

Map with the movement of the recaptured anglerfish around the Faroe Islands. Red circles: tagging position; white circles: recapture position.

Figure 2 Anglerfish tagged in Faroese waters, recaptured 183 days later south of Iceland. Red circle: tagging position March 6, 2005; white circle: recapture position September 5, 2005.

At the end of 2005 the FFL received a message from the MRI in Iceland regarding the recapture of a tagged Faroese anglerfish. This is the first anglerfish tagged in Faroese waters that has been recaptured in other fishing areas. This 43 cm long individual was tagged in the spring of 2005, and was measure at 44 cm at recapture south of Iceland 183 days later. The straight-line distance from release to recapture position is about 635 km (Figure 2), which equals a travelling distance of at least 3.5 km per day (4 cm/s). This is faster than expected for a fish species like anglerfish, which normally is said to lie on the bottom and “fish” for most of the time. In comparison a cod of equal size usually travels less than 10 nautical miles a day (Joensen *et al.* 2005), whereas an equally sized halibut can travel the same distance with the same speed as an anglerfish (P. Steingrund, pers.com.).

The percentage recapture of anglerfish tagged by a small gillnetter was 10.4 %. On-board the gillnetter handling time was minimal, the fish were out of the water for only a few minutes, and were not put in holding tanks before or after tagging. Average depth at the catch-and-release positions was about 200 m.

Recapture of anglerfish tagged using trawlers was less than expected, at only 0.6 %. The reason for the low recapture from the first two surveys could be a combination of long handling time, bad weather (a lot of waves) and greater depth (some hauls had an average depth deeper than 300 m). In 2005 a smaller trawler was used, the weather was more satisfactory and the handling time of the fish was less. However, the recaptures during this survey indicate that there may be some problems with the tagging procedure. One reason may be that the anglerfish, which are covered with protective slime on the outside of the skin, suffered heavy slime losses during the tagging procedure. This may affect osmotic regulation and could be the cause of death for these fish (Holm *et al.* 1999). It was observed that the seawater in the tank got muddy with this slime.

References

- Holm M, Arnold GP, Holst JC, & Midling KR (1999) Capture and handling of fish for electronic tagging - a review and a new non-intrusive capture method. *ICES Council Meeting papers* CM-1999/AA:03. 24 pp.
- Joensen JS, Steingrund P, Henriksen A & Mouritsen R (2005) Migration of cod (*Gadus*

morhua): Tagging experiments at the Faroes 1952-1965. Fróðskaparrit 53. bók 2005: 100-135.

Landa J, Bruno I, Fariña AC, & Autón U (2001a) Movement rates and validation trials of growth of white anglerfish (*Lophius piscatorius*) in the Northeastern Atlantic based on mark-recapture experiments. *ICES Council Meeting papers* CM-2001/O:22 (Poster).

Landa J, Duarte R, Fariña AC, Bruno I, & Castro J (2001b) Mark-recapture studies of black anglerfish (*Lophius budegassa*) in the Northeastern Atlantic: Preliminary results. *ICES Council Meeting papers* CM-2001/O:21 (Poster).

Laurenson CH (2003) Aspects of the biology and fishery for monkfish *Lophius piscatorius* Linneaus 1758, in waters around the Shetland Isles, Northeastern Atlantic. *PhD thesis*, University of Aberdeen, Dept. of Zoology. 306 pp.

III. Experiences from tagging fieldwork in Icelandic waters

Einar Jónsson

Marine Research Institute (MRI), Reykjavík, Iceland

On April 19 2004, 20 anglerfish were tagged in Icelandic waters with internal data storage tags (DST), and an additional 14 were tagged with T-bar tags.

Tags used and programming of DST tags

Data Storage Tags (DST milli) were used, with temperature and depth (pressure) sensors, produced by Star-Oddi in Iceland (www.star-oddi.com). The tags were programmed to log in intervals of 7 days with registration every 10 minutes, followed by 2 days with registration every 3 hours. Conventional tags were of T-bar type with a red colour.

Methods of sampling and procedures in fieldwork

The fish were caught by *Nephrops*-bottom trawl (mesh size 40 mm), by a small research vessel (GRT 155). The tagging area north of the Eldey island southwest off the Reykjanes peninsula (Figure 3) had been picked with several aspects in mind. The grounds had to be fairly smooth so as to be able to apply the *Nephrops*-trawl, which is designed for muddy smooth bottom. Due to heavy fishing effort on the main *Nephrops* ground during spring and summer, it was decided to pick the tagging spot at the edge of the *Nephrops* area in order to avoid too quick recapture. However, these turned out to be rather poor anglerfish fishing grounds. Thus anglerfish catches were rather poor, with only 3- 9 individual fishes in each 1-hour haul. Water depth in the tagging tows was 130-140 m. The tagging operation lasted one day from early morning until late at night with 7 tows, 30-60 minutes in duration.

Figure 3

Tagging location at the SW coast of Iceland in the anglerfish tagging project of the Marine Research Institute Reykjavik, April 19th 2004, and location of recapture of anglerfish with DST tag nr 6267.

The size of the DST tagged anglerfish ranged from 35-78 cm, while those tagged with T-bar tags were between 24 and 40 cm in length, i.e. mainly fish less than one year old, considered to small to carry a DST tag.

Bycatch was considerable, mainly flatfish species. As the research vessel is a double decker and all facilities are on the lower deck, the cod-end was lowered carefully through the upper deck-hatch onto the lower deck where the cod-end was opened, to avoid fish falling onto the deck. The anglerfish were immediately transferred to tanks with running seawater and kept there for at least 15 minutes in order to judge if they were suitable for tagging. Only two individuals were not considered suited for tagging due to floating upside down in the tanks. As the tagging took time some of the fishes were in the tank for up to 45 minutes.

Insertion of DST tags

Each fish was taken from the tank and length measured and tagged with a T-bar tag on the dorsal side. Thereafter it was laid upside down on a trough-like table. No anaesthetic drugs or tranquillisers were used; instead a wet, dark towel was wrapped around the head to calm the fish. A tube with running seawater was held in the mouth in order to secure oxygen supply. A slit was cut with a scalpel through the body wall or the skin on the posterior ventral side, allowing the DST to be placed slightly into the peritoneal cavity or just under the skin (Figure 4). Thus penetration into the buccal cavity, leading to trouble with air or gas trapped in the cavity, as experienced by FFL, was purposely avoided. The end of the DST was attached to the body wall by absorbable sutures, and the slit closed by sutures. The procedure of internal tagging normally took about 3-5 minutes.

Figure 4 DST tag insertion and placement under the skin.

Administration of drugs and OTC

After insertion of a DST tag each fish received a 50-mg/kg dose of oxytetracycline hydrochloride (OTC) injected in the body cavity. The OTC solution deposits in bone tissues (marker) and can be detected and measured under UV light if the fish is recaptured, so that individual growth can be studied. An amount of 50 mg/kg B-vitamin complex dose was also injected simultaneously into the fish. After the insertion of the DST tag the wound was sprayed with antibiotic fluid. All tools used in the operation - scalpel, syringe, etc - were kept in trays filled with disinfecting fluid.

After tagging, the fish were left to recover in a tank with running seawater and observed for some time (at least 30 minutes). All tagged fish behaved normally and were believed fit for release. Each tagged fish was then released carefully through a side hatch where it could be dropped at a height of less than 1 m to the sea surface. The tagged anglerfish all dived and were out of sight instantly or within half a minute after being dropped.

Information on the DST tagging was spread in fishing newspapers to inform fishermen of the new tag device and secure tag returns in case of recapture.

Comments and results

Only two recoveries, both DSTs, have been made so far. The data record from one of these, recovered after 13 days at sea, is discussed in section 2.1. The other recovery took place only 12 days after tagging, in the same area as where the tagging had taken place. This fish was reported dead and rotten, and the data stored in the data tag indicated little or no movement of the tagged fish, i.e. it must have died shortly after tagging. This shows mortality due to handling during the process of sampling and tagging. Mortality due to handling is common in most tagging operations, either instantly or some time after release. However, this somewhat unique record of instant tagging mortality indicates merely that that mortality occurs but by no means at what rate.

Effort concerning the cheap non-electric T-bar tags is very small; it has therefore been a standing plan of the MRI to tag at least several hundred anglerfish with these conventional types of tags, but this has for various reasons not been carried out yet.

IV. Experiences from tagging fieldwork in Norwegian waters

Otte Bjelland

Institute of Marine Research, Bergen, Norway

Anglerfish were tagged during two IBTS surveys in the North Sea and five one-day trips using a small (15 m) Danish seiner off the Norwegian coast at around 62°40'N (Møre). A total of 526 individuals were tagged with conventional Floy dart type tags, 118 in the North Sea and 408 at Møre (Table 2). The commercial fleet has so far made twenty recaptures (Figure 5) and a diver has caught one. Only a few recaptures have been reported directly by the fishermen and most tags have been discovered after landing. In many cases this resulted in poor information about the geographical position of the recapture. Most recaptures were made close to the release sites, but some individuals had performed extensive horizontal migrations, among these one anglerfish tagged at Møre which was recaptured in the North Sea, a displacement of some 270 km after 551 days at sea (Figure 5).

Table 2 Tagging efforts in Norwegian waters 2003-2005.

Date	Number of individuals tagged		Tag	Gear
	Møre (Norway)	IBTS (North Sea)		
19.09.03	14		Floy	Danish seine
30.09.03	138		Floy	Danish seine
16.01.04	62		Floy	Danish seine
09.10.04		5	Floy	Research trawl
10.10.04		53	Floy	Research trawl
11.10.04		39	Floy	Research trawl
12.10.04		5	Floy	Research trawl
20.10.04	109		Floy	Danish seine
21.10.04	85		Floy	Danish seine
12.07.05		1	Floy	Research trawl
13.07.05		1	Floy	Research trawl
16.07.05		14	Floy	Research trawl
	408	118		

Material

The Floy tags used during the Norwegian tagging were the same type as used at Shetland (Laurenson 2003, see section 2.1), but the colour used was bubble gum pink (Figure 6).

Methods

Danish seining was performed at known anglerfish grounds off the coast of Møre (Figure 6). An experienced fisherman, who had been fishing these grounds for a few years with his one-man Danish seiner, was hired for one-day trips. Anglerfish were also tagged during the third-quarter IBTS surveys (Norwegian part) of 2004 and 2005, using R/V Håkon Mosby. The standard IBTS research trawl (GOV trawl) was then used in the areas with highest catch rates of anglerfish, mostly in the western part of the Norwegian Deep (Figure 6). The catches made by Danish seine comprised mostly anglerfish, 10-50

Figure 5 Anglerfish tagging locations 2003-2005 on the northwest coast of western Norway (Møre, with more detailed inset map) and during IBTS surveys, and recapture locations with number of days at sea.

Figure 6 Tag were placed in the dorsal part of the tail muscle for maximum visibility.

individuals per haul, while the catches in the North Sea yielded mostly saithe and other gadids, and only small numbers (1-15 individuals) of anglerfish.

In both cases all live anglerfish were transferred as fast as possible to tanks of running seawater. The fish were then carefully scrutinised for skin damage and abnormal behaviour indicating poor suitability for tagging experiments. Most of the fish caught by Danish seine were of good quality for tagging, while on average only every second fish caught by trawl could be tagged. Lengths and minor skin damages were recorded for the tagged individuals, and they were handled and released as fast as possible on the same location as the tagging hauls. The tag was placed in the anterior dorsal part of the tail muscle, following Laurenson (2003) (Figure 6). The tagged anglerfish were lowered into the sea in a basket with ropes attached to the handles and the bottom. The basket was turned around in the sea surface by pulling the latter rope, enabling a careful release of the anglerfish. A few fish remained in the surface up to ten seconds before they descended, while most fish descended within a couple of seconds.

Comments and results

The recapture rates (4.9 %) from the experiments carried out using Danish seine at Møre are quite good compared to similar studies. A relatively high number of anglerfish could be tagged during each of these one-day trips and one fisherman and two scientists carried out seining and tagging. This made the cost per tagged individual much lower than by using a research vessel for tagging, as catch rates for IBTS surveys were lower and the need for manpower much higher. Recapture rates for the IBTS tagging experiments have so far also been much lower. For future tagging experiments on anglerfish in Norwegian waters it would therefore be recommendable to focus on Danish seining instead.

The problem in getting a finer spatial resolution on the recapture positions might be due to poor visibility of the chosen tags, preventing them from being seen by the fishermen at the fishing grounds. Although some efforts were made to present the project in media (newspapers etc.) and within the fishing industry, there might have been recaptures observed at sea that were not reported due to lack of knowledge about the project. There are still reports about recaptures coming in, and there will be some more tagging trips in Norwegian waters during 2006.

References

- Laurenson CH (2003) Aspects of the biology and fishery for monkfish *Lophius piscatorius* Linnaeus 1758, in waters around the Shetland Isles, Northeastern Atlantic. *PhD thesis*, University of Aberdeen, Dept. of Zoology. 306 pp.

Annex B

Investigation into the Suitability of Internal Data Storage Tags (DST) for Studies Involving Monkfish *Lophius piscatorius*

Chevonne Laurenson

Date: December 2003

Introduction

The use of tagging studies has become standard practice in the field of fisheries science. Studies using conventional tags (e.g. dart, T-bar, disc, Carlin) allow the collection of data on, for example, movement, verification of growth parameters and estimation of exploitation levels. The recent development of Data Storage Tags (DSTs), where data on external parameters can be logged (depth, temperature and now also light intensity) has resulted in the value of tagging studies becoming more pronounced.

Tagging studies using DSTs have been successful on species such as cod (Godø & Michalsen, 2000; Stensholt, 2001; Righton & Metcalfe, 2002; Turner *et al.*, 2002), plaice (Solmundsson *et al.*, 2003), tunas (Block *et al.*, 2001; Schaefer & Fuller, 2002) and salmonids (Walker *et al.*, 2000) and have yielded important information relating to, for example, migration and spawning behaviour and behavioural differences between stocks. Aspects of the information obtained can be directly related to both stock assessment and fisheries management.

DSTs have not previously been used on *Lophius*. Before a viable field study can be undertaken it is important to investigate the extent to which the tagging process may cause, for example, post-tagging infection and mortality or effects on behaviour. This is due to both animal welfare reasons and the costs of the tags involved. If the effects of tagging are minimal then there is a greater likelihood that: any tagging study would be successful; that results relating to the movement and behaviour of tagged fish would be typical of that exhibited by untagged fish, and factors such as growth and reproduction are less likely to be affected.

A successful tagging project using conventional dart tags was initiated during 2001, at the North Atlantic Fisheries College (NAFC), as part of a PhD study, (Laurenson, 2003). Prior to the fieldwork in that study a tank-based study was undertaken using facilities at NAFC. During this, valuable experience was gained in the handling and husbandry of the species.

There has recently been increased interest in the developing fisheries for *Lophius* in Nordic countries and there are concerns over recent fishing intensity in areas to the west of Scotland and in the northern North Sea. However, relatively little is known about the biology of the species and the study by Laurenson (2003) provides the only information on movements of *Lophius* in the area. Technological advances in the field of DSTs has resulted in tags being available that are both increasingly small and with larger data capacities. The following report details attempts undertaken at NAFC to investigate the suitability of DSTs for tagging studies using monkfish.

Work Planned

The experimental design is summarised as follows:

Lophius piscatorius were to be caught by trawl on grounds close to NAFC. They would be kept alive in a holding bin on a flow-through system on deck during transfer to tank facilities at NAFC.

The fish would be allowed an acclimatization period to allow for post-capture mortalities and the resumption of feeding. Based on previous experience, it was estimated that this would require a period of 8 – 14 days.

After the acclimatization period it was planned that 30 individuals would be selected for the experiment: two experimental tank groups of 10 each and a control tank group also of 10. The dummy tags chosen were LOTEK 1200-1000 tags that weigh 6 g in seawater and are cylindrical (23 x 64 mm). Due to the size of the tag and because one of the main objectives of a field study would be to investigate movements in larger fish, a minimum length of 40 cm, depending on body condition, was chosen.

The process of tagging was to be as follows:

Individual fish would be removed and anaesthetised using MS-222. To insert the tag, an incision would be made in the abdominal wall, approximately 3 cm long and at a position approximately 5 cm forward of the vent and approximately 3 cm from the mid-line of the individual. To close and seal the incision it was planned to use a combination of sutures and surgical glue.

The individual would then immediately be transferred to a recovery tank and observed until it had regained consciousness. It would then be transferred to an experimental group tank.

Experience at FRS (Aberdeen) using an identical method to tag cod, has shown that the duration of the procedure is short enough that aeration of the gills is not required during the time on the operating table.

Post-operative monitoring would include monitoring of behaviour, resumption of feeding, and occurrences of tag extrusion.

Humane endpoints would be employed at all times.

Work Undertaken

In the UK, as the work planned would involve procedures “which may cause pain, suffering, distress or lasting harm”, the work was designated as “regulated procedures” under the UK Animals (Scientific Procedures) Act 1986. As such the procedures must: (1) only occur at UK Home Office (HO) designated establishments, (2) have a Project Licence issued by the HO and (3) only be undertaken by personnel licensed specifically for that project.

Relevant Licences were awarded during late August 2003.

2. Fish Capture

All fish were trawl caught using the NAFC fishing vessel MFV *Atlantia* LK328 (10 m, 120 hp). The first capture dates were the 1st and 2nd October 2003 when 43 monkfish of a suitable size and condition were captured and transferred to tank facilities at NAFC. Following concerns over difficulties in getting the monkfish to start feeding and mortality rates a further 15 monkfish were captured on 29th October. Following further problems 19 monkfish of a suitable size and condition were captured on the 20th of November. The fishing areas for all trawls are shown in Figure 1. Transfer times between hauling and reaching NAFC were under one hour.

Figure 1 Locations of tows for capture of monkfish.

General Husbandry

Five tanks each measuring 2 x 2 x 0.75 m with a water depth of 0.7 m (volume 3 m³) on a filtered seawater flow-through system were available for holding the monkfish. A separate tank was used for maintaining fish that were to be sacrificed for foodstuffs, these included Gadidae spp., gurnard spp., scorpion fish and flatfish spp.. Monkfish were found to accept freshly killed prey items, but not items that had been frozen then thawed. Pellet feeds and fish pastes made into sausages, which are used as feed for other species at the facilities, were always rejected by the monkfish despite repeated attempts

of offering these. Any fish that had not started feeding by the fourth week post-capture were removed for humane reasons.

Only fish with no or very minor visible skin damage were accepted. At around two-three days post-capture bruising and skin damage associated with the capture process generally became more visible. To assist with recovery and prevent further infection monkfish were routinely administered an antibiotic injection after being transferred to the tank facilities.

Fish were checked daily, any mortalities removed and any deemed unfit were removed. Food was offered from day 4 post-capture. Feeding never occurred until after nine days post-capture although lure flicking was initiated in a number of individuals from 6 days post-capture.

Problems Encountered

Based on past experience there were higher than expected mortality rates and longer recovery times from any damage associated with capture (Figure 2). The caudal fins of the monkfish were particularly prone to infection and even with the administration of antibiotics recovery was slower than expected. This accounted for the removal of nine individuals. There were also four unexpected instances of mortality in individuals that had previously initiated post-capture feeding.

The other main problems were associated with getting the monkfish to start feeding and to continue feeding once started. Individual fish generally accepted food intermittently, often with periods of several days between meals. On the basis of past experience, it was expected that the introduction of prey items into a tank would initiate a lure flicking response in most individuals, even if no feeding actually occurred. However the introduction of prey often did not result in any response.

The cumulative number of monkfish that had initiated feeding (minus mortalities) is illustrated in Figure 3. The period from the second week of November when feeding fish seemed to lose their appetite and stop feeding is indicated. At this time there were no signs of a resumption of feeding, although two of the fish from those captured in late November did start feeding. During this time, although there were enough fish being held, it was not advisable to undertake the tag implantation procedures, as it is likely that any results would have been negatively impacted by the prior non-feeding status of the fish.

For humane reasons the remaining fish were removed on 10 December 2003.

Figure 2 Number of monkfish in tanks.

Figure 3 Number of monkfish that had initiated feeding (minus mortalities).

Discussion

It was expected that there would be post-capture mortalities and some individuals that would not start feeding. However, the problems that were encountered regarding the continuation of feeding once it had been initiated, and the subsequent maintenance of body condition, were more severe than had been anticipated. The cessation of feeding that was recorded from the 9th November onwards was unexpected and with no obvious cause. Increasing numbers of individuals appeared uninterested in food items during that time and the incidences of lure flicking responses upon the introduction of food into the tank diminished. There were increasing concerns about the maintenance of body condition during this time and subsequently three individuals were removed.

When the monkfish were transferred into the tanks there were no obvious signs of caudal fin damage, however there must have been some degree of damage to the skin to allow the infections to start. Antibiotics were routinely administered to fight infections. The infections in the caudal fins healed slowly and could have contributed to some of the problems relating to the initiation of feeding. The lack of feeding would also have slowed down the healing process. In aquaculture situations the fins of fish are accepted as being more prone to infection and the poorer blood supply to peripheral areas may delay the healing process. The infections that appeared in the caudal fins resulted in the removal of nine individuals for humane reasons.

It is suspected that the time of year may have played a role in the husbandry problems encountered. It is known that feeding rates are lower in the winter than in the summer (Crozier, 1985; Laurenson, 2003). This naturally lower feeding rate may have contributed to the problems encountered with respect to the initiation and continuation of feeding. The cessation of feeding that was observed during this study was not recorded during previous work (Laurenson, 2003). The main difference between that study and the current one is that that study occurred during the summer and early autumn. The decreasing water temperature during the autumn period may have contributed to a generally slower metabolic rate and hence less feeding, longer healing times on skin abrasions and this could have contributed to the problems associated with the caudal fins. To summarise, the husbandry problems that were encountered did not allow that the dummy DSTs could safely be implanted. The reduction and cessation of feeding during the period when there were sufficient numbers of fish to undertake the experiment was both unexpected and unfortunate. The work undertaken serves to demonstrate that the species is not an easy species to hold in captivity and previous accomplishments (Laurenson, 2003) are not a guarantee of continued success. The skin, particularly the caudal fins, can be prone to infection. A surgical wound would also be an infection concern and it would be expected that the routine administration of antibiotics would likely be necessary. On the basis of the experiences gained during this study, it would be expected that post-operative mortality following the implantation of DSTs could be substantial.

Acknowledgements

This study was funded by the Nordic Council of Ministers.

References

- Block, B. A., Dewar, H., Blackwell, S. B., Williams, T. D., Prince, E. D., Farwell, C. J., Boustany, A., Teo, S. L. H., Seitz, A., Wallis, A. & Fudge, D. 2001 Migratory movements, depth preferences, and thermal biology of Atlantic bluefin tuna. *Science* **293**, 1310-1314.
- Crozier, W. W. 1985 Observations on the food and feeding of the angler-fish, *Lophius piscatorius* L. in the northern Irish Sea. *Journal of Fish Biology* **27**, 655-665.
- Godø, O. R. & Michalsen, K. 2000 Migratory behaviour of north-east Arctic cod, studied by use of data storage tags. *Fisheries Research* **48**, 127-140.
- Laurenson, C. H. (2003). Aspects of the biology and fishery for monkfish *Lophius piscatorius* Linnaeus 1758, in waters around the Shetland Isles, Northeastern Atlantic. PhD. Department of Zoology. University of Aberdeen. pp. 306.
- Righton, D. & Metcalfe, J. 2002 Multi-torsking: simultaneous measurements of cod behaviour show differences between North Sea and Irish Sea stocks. *Hydrobiologia* **483**, 193-200.
- Schaefer, K. M. & Fuller, D. W. 2002 Movements, behaviour, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial Pacific, ascertained through archival tags. *Fishery Bulletin* **100**, 765-788.
- Solmundsson, J., Karlsson, H. & Palsson, J. 2003 Sexual differences in spawning behaviour and catchability of plaice (*Pleuronectes platessa*) west of Iceland. *Fisheries Research* **61**, 57-71.
- Stensholt, B. K. 2001 Cod migration patterns in relation to temperature: analysis of storage tag data. *ICES Journal of Marine Science* **58**, 770-793.
- Turner, K., Righton, D. & Metcalfe, J. D. 2002 The dispersal patterns and behaviour of North Sea cod (*Gadus morhua*) studied using electronic data storage tags. *Hydrobiologia* **483**, 201-208.
- Walker, R. V., Myers, K. W., Davis, N. D., Aydin, K. Y., Friedland, K. D., Carlson, H. R., Boehlert, G. W., Urawa, S., Ueno, Y. & Anma, G. 2000 Diurnal variation in thermal environment experienced by salmonids in the North Pacific as indicated by data storage tags. *Fisheries Oceanography* **9**, 171-186.

Annex C

Verification of anglerfish (*Lophius piscatorius*) age estimation through comparison of length modes of age read fish (*illicia*) to length modes of big year-classes appearing in the Icelandic stock

Einar Jónsson, Marine Research Institute, Reykjavík, Iceland

Abstract

In order to validate age readings of white anglerfish (*Lophius piscatorius*) length modes of large year-classes that have characterised the Icelandic stock since 1998 were compared with length modes from age read samples. The length modes of these year-classes can be followed as peaks in the length distributions for several years and thus their actual age assumed accurately. The results show that there is a fairly good agreement between the non age-read length modes and the corresponding length modes established through age readings (of the *illicia*) indicating that the age readings are based on true interpretation of year-rings.

Introduction

Age estimation of anglerfish has always been somewhat problematic. Various authors have described the difficulties arising, which are due to multiple zones (rings) in the calcified hard structures used, i.e. *sagittae* (otoliths) and *illicia* (from the first dorsal fin-ray) and their interpretation. It appears that otoliths were the first hard structures used for age reading of anglerfish as commonly done for other demersal species. However, difficulties in reading and interpreting the otolith as many author have described (Tsimendis and Ondrias 1980, Griffith and Hech 1986; Crozier 1989) led to use of other structures such as the *illicia* which some authors have found more reliable mean of age estimation (Dupouy *et al.*, 1986, Maartens *et al.*, 1999) than the otoliths. Thus, this new approach has become a standard method in some ICES countries while other stick to the old method of otoliths. According to Wright *et al.*, (2002) the growth estimates derived from the two structures differ, particularly with regard of the first few year of life. According to those authors this is due to different understanding of what to count as the first year ring. Therefor they have tried to verify the first annulus formation by using microstructure of the otolith.

Age-reading workshops have been held on behalf of ICES (Anon. 2000, Duarte *et al.*, 2005) and calibration and validation of the two methods is still in process.

In trying to draw some additional information of different type into this problematic a verification of *illicia* age estimation is attempted in this work by comparing age-read and non age-read length modes. This is possible as distinct year-class length modes are available in the Icelandic anglerfish stock where at least 3 big year-classes have characterised the stock since 1998, Fig. 1, 2.

Methods

Sampling

Samples were obtained from the Icelandic *Nephrops*-survey conducted annually in the month of May on the *Nephrops* grounds S and SW of Iceland with 40 mm mesh *Nephrops* bottom trawl. These grounds also happen to be the most abundant anglerfish grounds. Length measurements of anglerfish in the survey have taken place since 1995 but collection of *illicia* for age estimation was not started until in the year 2000.

Age reading

An effort was made to read all available *illicia* collected in the survey during 4 consecutive years (2000-2003) consisting of samples from 947 individual fishes (293 in 2000, 289 in 2001, 230 in in 2002 and 135 in 2003). Only about half of these age readings (427) are, however, taken into close consideration since only 7 distinct age group modes occur in the length distributions fit for comparison. The length mode of the big year-class (2003), observed in the 2004 survey is not included in the study as age readings had not been done.

The age reading was done by a scientist from the age reading department of the Marine Research Institute (MRI) in Reykjavik; an experienced reader of other demersal species (otolith) but with no prior experience of anglerfish nor *illicia*. The basic knowledge on the *illicia* age reading of anglerfish was obtained from various literature on the subject (Peronnet *et al.* 1992, Duarte *et al.* 1997) and also from the Norwegian scientist J E Dyb through personal communication, lending of photo-samples as well as his thesis on an anglerfish stock off the Norwegian coast, at the University of Bergen, 2003. Furthermore, Dyb's approach and interpretation in age reading as well as those of others have been thoroughly discussed during the annual meetings of the Nordic anglerfish study-group of which the author of this article is a participating member.

The age group length modes compared

The total length distributions of the *Nephrops*-survey for the years 2000-2003 used in the study consist of some 2744 length measured fishes (554 in 2000, 569 in 2001, 833 in 2002 and 788 in 2003). Less than 2000 of these measurements are, however, taken into close consideration (see Table 1) since only the distinct age group modes of the outstanding big year-classes are mainly looked at.

In the data of the 4 years included in the study, two distinguished age group modes of 1 and 2 years old are looked at but one of these is most likely not belonging to a big year-class (1 year old 2002). Furthermore distinct age group modes of 3, 4 and 5 years old fish (one for each age group) are studied. Thus 7 assumed age group modes in the length distributions are compared with corresponding length modes of fish that have been age-read through *illicia*. The former consist of some 165-320 measured fish per mode and survey year versus 30 -141 age-read fish per mode and survey year, (see Table 1).

March- and May-surveys

In Fig. 1 length distributions of anglerfish from the Icelandic bottom trawl survey in March (1999-2000) are also included as well as those from the *Nephrops*-survey in May. Since no age estimation samples are collected in the March survey the March data cannot be used directly as mean of age verification as the *Nephrops*-survey data. However, the length modes from the March survey are useful as comparison to the May sur-

vey modes in establishing age groups of big year-classes and their pattern as they can be detected and followed from year to year and months of the year. Thus, the March survey data strengthens the assumption of age group modes and which age group they belong to. Data on anglerfish, i.e. length measurements from the March survey are available since 1985 and since the year 1995 from the May survey. However, little or no distinctive age group length modes can be seen or traced in the data prior to the year 1999 when a big year-class (from 1998) appeared in the stock. The data in Fig. 1, covering the years 1999-2004 consist of 1185 length measurement of anglerfish in the March survey and 5360 in the May survey. In Fig. 2 the anglerfish length distributions of the May-survey 1999-2004 are also presented and the age group modes appear as smoothed means of every 3 cm in order to spell out the character and the ageing of the modes.

Age assumption of the non age-read length modes.

The length range (TL) of the smallest mode (1 year old fish?) is 24-27 cm. The mean length of the next age group (2 years old fish?) is about 40 cm and for the third group (3 years old?) ca 52 cm. This suggests an annual growth rate of 13-14 cm for the assumed 1 year old and at least 12 cm for the 2 years old. The assumed 1 year old length modes (24-27 cm in May) can hardly be interpreted as anything else than being of age one and the next peak 2 year old etc. This assumption is based on the fact that the few small (0-group?) anglerfish that have been sampled during the 0-group pelagic trawl survey conducted annually (1970-2003) in Icelandic waters in the month of August have the length-range (TL) of only some 5-15 cm, (see table 2). These small anglerfish are therefore with little doubt an 0-group as the main spawning season of anglerfish in Icelandic water is mainly in spring (April-June) with some exceptional females spawning through out the summer, even as late as September, according to the findings of the author of this paper.

Statistical analysis

To analyse statistically the comparison of age group length modes the following was done: Mean length and median length of the age group modes were calculated for both age-read and non age-read modes. As the age group modes in the total length distributions (non age-read) overlap with modes of other age groups the lowest value at the side of each mode was used to define the edges and hence each age group mode studied. Secondly a model called MIX (Macdonald and Pitcher 1979) was applied and used to analyse and define each age group mode in question and calculate its' mean length. This is an interactive program for fitting mixtures of distributions of age groups by fitting them to normal distributions. It also estimates the accuracy of the mean length (standard error, Table 1) and can be applied to analyse one defined distribution. Hence, this model was also used to fit and calculate the mean length of the age-read modes and the accuracy of the mean lengths of the two different modes (age-read and non age-read) could be compared. Other statistical diagnostic values such as Chi-square and Probability are also calculated in the MIX model and listed in Table 1. These are, however, not referred to in the text, as they are believed to have less value in comparing age-read and non age-read modes. This is due to the fact that these values describe how well the data can be fitted to a normal distribution. Two modes that are being compared might not be in the same phase, i.e. have different mean length and thus be quite different even though they fit quite well to a normal curve.

In fitting mixtures of distributions with the MIX model it was found out that the model could not in all instances cope with some small age groups modes as they are so poorly

represented in the data. These had to be “fixed” according to options in the model and were given the same mean length as age group modes of the same age group from different survey-year, which were more distinct and had been successfully fitted.

Results

In Fig. 3, 9 and 10 the age-read length mode of 2-year-old fish in the survey in 2000 is matched with the assumed 2-year-old mode in the total length distribution of the same survey. These modes are believed to represent the big year-class of 1998, which is 2 years old in the year 2000. Looking at the two modes when they have been scaled together (Fig. 3) the match can be said to be almost complete. This is also reflected in the diagnostic in Table 1 where the mean lengths are almost the same and the standard error low. Furthermore, Fig. 7 verifies that the length distribution of the age-read samples matches very well the total length distribution and Fig. 8 shows that the mode of the 2 years old is fairly little influenced by the 1 and 3 years old modes through overlapping.

In Fig. 4 and 11 the age-read length modes of 1 and 3 years old fish in the 2001 survey are matched with the corresponding length modes in the total distribution of the same survey. The modes of the 3 years old belongs to the big 1998 year-class and the modes of 1 year old fish to the 2000 year-class. It should be pointed out that the latter is not considered to be a big year-class as it is only discernible as a distinct age group mode this one year and then only in the *Nephrops*-survey but not in the March-survey.

The general match of the length modes of both one and three years old can be said to be fairly good in Fig. 4. However, the non age-read length mode of the 3 years old tends to stretch slightly further to the right (toward bigger fish) than the age-read mode and vice versa for the 1-year-old modes. This is also reflected in Table 1 where the mean length of age-read 1 year old is somewhat higher than in the non age-read mode (of the same age) and vice versa for the 3 years old modes. This discrepancy can hardly be blamed to poor sampling of *illicia* according to Fig 7 but Fig. 8 shows that the mode of 4 years old is heavily overlapping the 3-year-old mode in question. Looking at the statistical diagnostic (Table 1) the standard error of the MIX mean tends to be higher in the age-read modes of younger fish which most likely reflects scarce data in this category versus the modes in the total distributions (non age-read). The exception from this rule is the mode of age-read 2 years old in 2000 where the standard error is lower than in the corresponding non age-read mode but the former has the best (in number) age reading samples available (141). Furthermore, the standard error tends to increase with higher age groups and is obviously higher in the 3-year-old modes than in the modes of 1 and 2 years old.

In Fig. 5 the length modes of 1 and 4 years old anglerfish in the 2002 survey are matched with the corresponding age group length modes of the total distribution of the same survey, i.e. the big year-classes of 2001 and 1998. The general match of the scaled length modes of both ages is again fairly good. However, here the non age-read modes of both age groups are stretch slightly further to the left (toward smaller fish) than the corresponding age-read modes. This is also reflected in Table 1 but the difference in mean length is slight. According to Fig. 7 the goodness of the age reading sampling might here be questioned, as the match of the lengths to the total length distribution is poorer than in other instances. Fig. 8 shows much overlapping of other age groups into the mode of the age group 4 but their influence should be minor as their abundance compared to the 4 years old is little. The highest standard error of mean length (0.923) occurs here in the non age-read mode of the 4 years old in spite of more than 300 length

measurements and the overlapping towards modes of older age is here most likely causing some problems.

In Fig. 6 the length modes of 2 and 5 years old fish in the 2003 survey are matched with the corresponding length modes in the total distribution of the same survey, i.e. the big year-classes of 2001 and 1998.

The general match of the scaled length modes of both two and five years old is once again fairly good. In looking at Fig. 5 it is difficult to state that the two modes, which are being compared, are not in the same phase. This is also reflected in the diagnostic in Table 1 where mean lengths of the 2 year old are the same in age-read and non age-read modes but somewhat higher for the latter in the case of 5 years old. Standard error of the 5 years old is high in both age-read and non age-read modes. Fig. 7 shows a fairly good match in the length distributions of age-read and non age-read samples although this survey (2003) has the lowest number of age readings (135). The match, however, is questionable when it comes to the mode of 5 years old and Fig. 8 shows that this mode is heavily overlapped by other age groups but their influence is most likely limited due to their low abundance compared to the main mode (5) in question.

Discussion

Different factors in this study might be biasing the results to some extent. It is obvious that the distributions of younger age groups are more suited for comparison than the ones of older groups since overlapping of age groups increases with growing age. This can clearly be seen in Fig. 11 where available distributions of age-read age groups (1-5, same survey and time period) are set up in one graph. It is clear that fish older than 3 years old is heavily overlapping in length and the fact that length modes of age groups can be traced beyond age 2 seems only to be due to big year-classes which become more distinct as small year-classes (age groups) are on both sides. Therefore the MIX model is very important in defining an age group in overlapping distributions. The length distributions of age groups in Fig. 11 are based on data from 4 years. This increases the range of length-classes each age group is spanning (in Fig. 11) since annual growth or mean length of each age group is obviously not always the same in different years. This can be seen in Fig. 13 where the length modes of 1 year old in 4 surveys are compared. The mode of the year 2002 is obviously more to the right than the modes of the years 1999, 2001 and 2004 and hence with lower mean length. This is also verified in the age readings in Table 1 where one year olds are 3 cm smaller in the survey 2002 than in the survey 2001. The reason for different mean length of the same age group in different years (as seen above for one year olds) is not quite clear but it might be due to different spawning time from year to year. The Icelandic anglerfish seems mainly to spawn in the spring, however, there is evidence of spawning individuals during the summer months and even in autumn (Jonsson E., unpublished material). Some fluctuations of mean length of age groups from year to year as seen in the *Nephrops*-survey in May should not, however, obscure the results of this study as length-modes from the same year are always being compared.

The poor sampling for age estimation compared to the non age-read sampling where as few as 135 age-read fishes are available for the year 2003 might of course be a source of

bias as already mentioned. However, as seen in Fig. 7 the length distributions of the age-read samples follow fairly good the same pattern as the total non age-read distributions. This is true for all the 4 survey years and the exceptions are minor indicating identical length distributions.

The overlapping of age group modes is another factor, which is bound to obscure the true length modes in the non age-read distributions. This is looked at in Fig. 8 (through age-read samples) where a heavy overlapping in the older age group modes is seen. However, as the age group modes of the big year-classes which are here in focus are so dominant in the total distributions the effects due to overlapping of neighbouring age groups is probably far less than the range of the overlapping might indicate.

A source of bias might also be the age reading itself. The reading was not “blind” (information of the size of the fish were available to the reader) but performed by a person with great experience in age reading of various species, mainly otoliths and scales. If the knowledge of the size of the fish has been a biasing factor it is no way to estimate its effect except to repeat this study with blind reading which was not within the scope of this work.

The comparison of modes for age verification can hence be summed up as follows. It is assumed in the statistical study that the age group distributions (modes) have normal distributions. The fact that the standard error is low in the non age-read length modes of young age groups (1 and 2) where overlapping is negligible and also (low) in age-read length modes of age groups where many (141) age readings are available seems to reflect that this assumption (normal distribution) is correct and applicable in the MIX analysis used.

All but one age-read modes, however, seem to suffer somewhat from scarce data when it comes to statistical tests and so do the non age-read modes of 4 and 5 years old in the total length distributions due to heavy overlapping. Regardless of this it can, however, be concluded that the compared modes are more than less matching each other. Difference in length (mean, median and/or MIX mean) of some compared modes in the size of 0.5, 1 or 2 cm does not seem to disprove the match. More age readings could undoubtedly lower the statistical discrepancy seen in Table. In general, however, it can be stated that there is a fairly good agreement between the non age-read length modes and the corresponding length modes established through age readings (of the *illicia*) strongly indicating that the age readings are based on true interpretation of year-rings.

References

- Anon. (2000). Third International Ageing Workshop on European Anglerfish, IPIMAR, Lisbon, 8-12 March 1999 European Fish Ageing Network, EFAN Report 2-2000 <<http://www.efan.no/NewsAndReports/EFAN%20Report%202-2000.htm>> 15 pp.
- Crozier, W. W. 1989. Age and growth of angler-fish (*Lophius piscatorius* L.) in the North Irish Sea. Fisheries Research, 7: 267 – 278.
- Duarte R., Azevedo, M., and Pereda, P., 1997 Study of the growth of southern black and white monkfish stocks. ICES Journal of Marine Science, 54: 866-874.
- Duarte, R., Landa, J., Morgado, C., Marcal, A., Warne, S., Barcala, E., Bilbao, E., Dillemeit, J., Djurhus, H., Jónsson, E., McCormic, H., Ofstad, L., Quincoces, I., Rasmussen,

H., Thaarup A., Vidarsson, T., and Walmsley, S., 2005. Report of the Anglerfish *Illicia*/Otoliths Ageing Workshop, IPIMAR, Lisbon, 47 pp.

Dupouy, H., Pajot, R., and Kergoat, B. 1986. Etude de la croissance des baudroies, *Lophius piscatorius* et *L. budegassa*, de L'Atlantique Nord-Est obtenue à partir de l'*illicium*. Revue des Travaux de l'Institut des Pêches Maritimes, 48(3 et 4): 107 –131.

Dyb, J. E. (2003). Bestandsstudier av breiflabb *L. piscatorius* langs kysten av Möre og i Nordsjøen. *Cand scient.* thesis, University of Bergen (In Norwegian).

Griffiths, M. H., and Hecht, T. 1986. A preliminary study on age and growth of the monkfish (*Lophius upsicephalus* (Pisces: Lophiidae) on the Agulhas Bank, South Africa. South African Journal of Marine Science, 4: 51 – 60.

Maartens, L., Booth, A. J., and Hecht, T. 1999. The growth of monkfish *Lophius vomerinus* in Namibian waters, with a comparison of otolith and *illicia* methods of ageing. Fisheries Research, 44: 139 – 148.

Peronnet, I., Dupouy, H., Rivoalen, J., J., and Kergoat, B., 1992. Methods of ageing based on caudal fin-rays for mergrim (*Lepidorhombus wiffiagonis*) and sections of *illicium* for anglerfishes (*Lophius piscatorius* and *L. budegassa*). In hard tissues and individual age of vertebrates. Ed. by J. L. Bagliniér, J. Castanet, F. Condon and F. J. Meunier. Colloque national, Boundy, France, 4-6 Mars 1991. ORSTOM/INRA: 307 –324.

Tsimenidis, N., C., and Ondrias, J., C., 1980. Growth studies of angler-fishes *Lophius piscatorius* L., 1758 and *Lophius budegassa* Spinola, 1807 in Greek waters. Thalassographica, 3: 63-94.

Wright, P. J., Woodroffe, D. A., Gibb, F. M. and Gordon, J. D. M. 2002. Verification of first annulus formation in the *illicia* and otoliths of white anglerfish, *Lophius piscatorius* using otolith microstructure. ICES Journal of Marine Science, 59: 587 – 593.

Fig. 1. Length distributions and assumed age group modes, and/or year-class modes of Icelandic anglerfish in *Nephrops*-survey 1999-2004 in the month of May ($n=5360$) and Icelandic bottom trawl survey in the month of March ($n=1185$).

Fig. 2. Length distributions of anglerfish in May *Nephrops*-survey 1999-2004 and assumed modes of age groups in year-classes 1998, 2001 and 2003. Smoothed as mean of every 3 cm.

Fig. 3. Length distribution of 2 years old (age-read) in *Nephrops*-survey 2000 versus assumed mode of the same age group in the total length distribution of anglerfish in the survey the same year. Smoothed values as mean of every 3 cm.

Fig. 4. Length distributions of 1 and 3 years old (age-read) in *Nephrops*-survey 2001 versus assumed modes of the same age groups in the total length distribution of anglerfish in the survey the same year. Smoothed values as mean of every 3 cm.

Fig. 5. Length distribution of 1 and 4 year old (age-read) in *Nephrops*-survey 2002 versus assumed modes of the same age groups in the total length distribution of anglerfish in the survey the same year. Smoothed values as mean of very 3 cm.

Fig. 6. Length distributions of 2 and 5 years old (age-read) in *Nephrops*-survey 2003 versus assumed modes of the same age groups in the total length distribution of anglerfish in the survey the same year. Smoothed values as mean of every 3 cm.

Fig. 7. Length distributions of anglerfish in *Nephrops*-surveys 2000-2003 as total non age-read distribution versus distribution in age-read samples. Smoothed values as mean of every 3 cm.

Fig. 8. Length distributions (modes) of age groups 1-7 in age-read samples of anglerfish in *Nephrops*-surveys 2000-2003. Smoothed values as mean of every 3 cm.

Fig. 9. MIX length-frequency analysis of assumed 2 years old mode in the length distribution, anglerfish in *Nephrops*-survey the year 2000. Thin un-curved line: original data distribution, thin curved lines: normal distribution, thick line: mixture distribution (sum of normal distributions). The triangles mark the mean lengths of age groups. Mode of age group 2 (in the middle): mean length 40.1 cm (standard error = 0.327).

Fig. 10. MIX length-frequency analysis of age-read 2 years old length distribution; anglerfish in *Nephrops*-survey the year 2000. Thin un-curved line: original data distribution, thin curved lines: normal distribution (falls within the thick line), thick line: mixture distribution (sum of the two former). The triangle marks the mean length of the age group; 40.1 cm (standard error = 0.287).

Fig. 11. MIX length-frequency analysis of assumed 1 and 3 years old in the length distribution of anglerfish in *Nephrops*-survey the year 2000. Thin un-curved line: original data distribution, thin curved lines: normal distribution, thick line: mixture distribution (sum of normal distributions). The triangles mark the mean lengths of age groups. Mode of age group 1 (left): mean length: 26.8 cm (standard error = 0.397). Mode of age group 3 (middle), mean length 52.3 (standard error = 0.492)

Fig. 12. Length distribution of anglerfish age groups, 1-5, in all age-read samples in the *Nephrops*-survey 2000-2003. Smoothed values as mean of very 3 cm.

Fig. 13. Modes of assumed 1-year-old (non age-read) anglerfish in the total length distributions from May *Nephrops*-survey of the years 1999, 2001, 2002 and 2004. Smoothed values as mean of every 3 cm.

Table 1. Mean and median lengths and values of statistical diagnostic according to MIX analysis of compared age group modes (age-read and non age-read): Anglerfish data in *Nephrops*-survey 2000-2003.

year	age			mean le.	median le.	MIX	MIX	MIX	MIX	n
						mean le.	standard error	Chi-square (Freedom de.)	Probability	
2001	1	age-read		27.7	28.0	28.2	0.561	14.7 (14)	0.399	45
2001	1		non age read	26.3	26.0	26.8	0.397	43.6 (49)	0.690	165
2002	1	age-read		25.6	24.0	25.8	0.669	11.7 (9)	0.233	34
2002	1		non age read	24.0	24.0	24.4	0.291	61.3 (67)	0.675	340
2000	2	age-read		39.6	40.0	40.1	0.287	20.4 (13)	0.086	141
2000	2		non age read	39.5	40.0	40.1	0.327	40.1 (40)	0.466	301
2003	2	age-read		39.9	40.0	40.3	0.585	7.4 (8)	0.500	30
2003	2		non age read	40.5	40.0	40.3	0.325	50.2 (63)	0.878	261
2001	3	age-read		51.8	51.0	52.5	0.706	29.1 (23)	0.176	63
2001	3		non age read	51.6	52.0	52.3	0.492	43.6 (49)	0.690	235
2002	4	age-read		61.2	61.5	61.7	0.567	20.5 (17)	0.251	73
2002	4		non age read	60.0	61.0	61.2	0.923	61.3 (67)	0.675	320
2003	5	age-read		67.3	67.0	67.3	0.849	17.1 (154)	0.312	41
2003	5		non age read	65.5	67.0	68.8	0.851	50.2 (63)	0.878	287

Table 2. Sampled anglerfish in the 0-group survey conducted annually from 1970-2003 in Icelandic waters with pelagic trawl, length range 4.7-15 cm, mean 8.1 cm.

Survey year	length cm	n
1977	15,5	1
1994	6,3	1
1997	4,7	1
1998	6,4 8,5 8,5 9,3 12,8	5
1999	8,0 12,0	2
2000	9,8	1
2001	5,7 8,5 11,2	3
2002	14,0 6,3	2
2003	5,8 6,5	2

Annex D

Journal of Fish Biology (2006) **68**, 1287–1290

doi:10.1111/j.1095-8649.2006.01001.x, available online at <http://www.blackwell-synergy.com>

BRIEF COMMUNICATIONS

A note on the development of the embryos of anglerfish *Lophius piscatorius*

C. H. LAURENSEN*

North Atlantic Fisheries College, Port Arthur, Scalloway, Shetland, UK

(Received 2 June 2005, Accepted 5 October 2005)

Embryo development over a 5 day period are shown and described from a rare find of anglerfish *Lophius piscatorius* spawn that was obtained at the Shetland Islands, U.K. The stage of development shown is earlier than that previously available for the species.

© 2006 The Fisheries Society of the British Isles

Key words: anglerfish; development; eggmass; *Lophius piscatorius*; monkfish; reproduction.

Anglerfish *Lophius piscatorius* L. release their eggs embedded in a large buoyant gelatinous matrix commonly known as an 'eggmass', 'ribbon', 'raft' or 'veil'. The ribbon floats in surface waters as the embryos develop (Bowman, 1920) but ribbons are reported infrequently and they are rarely obtained for study. Descriptions of developing *L. piscatorius* embryos in the ribbon are limited to those given by Prince (1891), Fulton (1903) and Bowman (1920).

A 1.2 l sample from a ribbon was obtained on 18 May 2004 from an inshore location at the Shetland Islands, U.K. (c. 60°00' N; 01°10' W). The ribbon from which the sample was obtained had become entangled in a rope attached to shellfish creels (pots). The sample was c. 40 × 20 cm and was maintained for 7 days in a 12 l tank with ambient filtered sea water on a flow-through system (c. 1 l min⁻¹).

The long edges of the ribbon were smooth and rounded in cross-section. The ribbon consisted of polygonal chambers and inside each chamber there was one developing embryo [Fig. 1(a)]. Along the short edges, where the sample had been removed from the main ribbon, many of the chambers had been ruptured. Eggs belonging to ruptured chambers escaped, floated to the water surface then gradually died and sank over a period of c. 24 h. Over the 7 day period much of the matrix gradually disintegrated, releasing increasing numbers of eggs which also floated free then sank as they died.

When the sample was obtained, all of the embryos were at a similar stage of development to each other and none of the eggs appeared to be either

*Author to whom correspondence should be addressed. Tel.: +44 (0)1595 772306; fax: +44 (0)1595 772010; email: chevonne.laurenson@nafo.uhi.ac.uk

FIG. 1. *Lophius piscatorius* embryos photographed on 20 May 2004: (a) embryos inside individual egg chambers and (b) melanophores concentrated over head (left) and along developing neural area, single oil globule at right. Scale bar: 500 μ m.

unfertilized or dead. Photographs of developing embryos were taken on 20 May 2004 (Fig. 1). Each egg filled approximately half the volume of its chamber, was free floating inside its chamber and floated with the amber coloured oil globule uppermost [Fig. 1(a)]. This concurs with a previous description by Bowman (1920). The cephalic area of the developing embryo and the oil globule were on opposite sides of the egg. Embryos had numerous dendritic shaped melanophores concentrated around the head region and this pigmentation extended

EMBRYO DEVELOPMENT IN ANGLERFISH

1289

back for approximately one quarter the circumference towards the oil globule. Towards the oil globule the melanophores were fewer in number and were largely absent from the area covering the yolk [Fig. 1(b)]. This stage of development (Fig. 1) is similar to stage 12, the late gastrula stage described and shown by Everly (2002) for *Lophius americanus* Valenciennes. This is an earlier stage of development than figures shown in previous references for *L. piscatorius*. The stage of development reached on 25 May 2004 (Fig. 2) appeared similar to the

FIG. 2. *Lophius piscatorius* embryos photographed on 25 May 2004: (a) distribution of pigment around the head and development of the brain, and (b) development of the tail. Scale bar: 500 μ m.

development stage shown by Bowman (1920) but the embryos shown in Fig. 2 are less developed than the advanced embryos shown by Prince (1891).

By 25 May 2004 surviving embryos had a noticeable increase in the density of pigmentation which had also developed around the oil globule, however, the yolk was still mostly unpigmented. In all of the 50 embryos sampled the eyes and the main divisions of the brain showed a more advanced development [Fig. 2(a)], the caudal fin of each embryo had formed and was becoming detached from the yolk posteriorly [Fig. 2(b)]. The developing caudal fin was free from any pigment. The embryos shown in Fig. 2 correspond to stage 14 embryos as described and shown for *L. americanus* by Everly (2002).

The development time from stages 12 to 14 was 120 h at 7° C. This development rate broadly supports the speculation by Fulton (1903) that the embryonic stage of *L. piscatorius* could be 3 weeks in duration in May in Scottish waters. Development times recorded by Everly (2002) for an *L. americanus* ribbon maintained at 20° C were more rapid with a development time from stages 12 to 14 of c. 27 h.

The mean $\pm$ s.d. diameter of the eggs was $2998 \pm 81 \mu\text{m}$, $n = 25$ on 20 May 2004. This is towards the upper end of the range of 2040–3110 μm given by Bowman (1920). Each egg contained only one oil globule and globules were either spherical in appearance or slightly oval in shape with a mean $\pm$ s.d. diameter on the longest axis of $748 \pm 30 \mu\text{m}$, $n = 25$. Tåning (1923) states that in both *L. piscatorius* and *L. americanus* there are multiple small oil globules that fuse to form one larger one as the embryos develop but often one or two small globules are left. No smaller additional globules were recorded in the present sample. From this sample it is concluded that any smaller oil globules that may be present fuse to form one larger globule prior to the stage shown in Fig. 1.

Although there have been some recent publications regarding the reproduction and early life stages of the anglerfish, there are still aspects of these subjects where details are scant.

N. Smith is thanked for donating the ribbon sample. This work was supported in part by project number 661045-20282 from the Nordic Council of Ministers.

References

- Bowman, A. (1920). The eggs and larvae of the angler *Lophius piscatorius* L. in Scottish waters. *Reports of the Fishery Board for Scotland, Scientific Investigations for 1919* **11**, 1–55.
- Everly, A. W. (2002). Stages of development of the goosefish, *Lophius americanus*, and comments on the phylogenetic significance of the development of the luring apparatus in Lophiiformes. *Environmental Biology of Fishes* **64**, 393–417.
- Fulton, T. W. (1903). The distribution, growth, and food of the angler, *Lophius piscatorius*. *Twenty-first Annual Report of the Fishery Board for Scotland (Part III)*, 186–217.
- Prince, E. E. (1891). Notes on the development of the angler-fish (*Lophius piscatorius*). *Ninth Annual Report of the Fishery Board for Scotland (Part III)*, 343–348.
- Tåning, Å. V. (1923). *Lophius*. *Report on the Danish Oceanographical Expeditions 1908–10 to the Mediterranean and Adjacent Seas* **2** (Biology A10), 1–30.

Appendix tables and figures

Appendix 1a,b Procedures used in biological sampling during the Nordic project.

a) Preservation of gonads for histological analysis.

Measurements	Gonad sample	Fixation liquid
The length of the anglerfish is measured in mm and its weight is measured to the nearest gram. Gonad, liver, and viscera are also measured to the nearest gram.	<p>Cut a one cm section from the middle of one of the gonad sides as shown in the picture below. Similarly for the other side, so that two samples are obtained for each fish. The sections are then weighed to the nearest 0.001 g and placed in a plastic bottle (e.g. <i>Kartell</i> make). Finally the tissues are covered by fixation fluid in a 1:10 ratio.</p>	<p>Buffered formaldehyde made from:</p> <ul style="list-style-type: none"> • 2-3 litres of distilled water • 20.35 g of sodium dihydrogen phosphate, monohydrate ($\text{Na}_2\text{H}_2\text{PO}_4 \cdot \text{H}_2\text{O}$) • 41 g of disodium hydrogen phosphate, dihydrate ($\text{Na}_2\text{HPO}_4 \cdot 2\text{H}_2\text{O}$) • 486 ml 37% formaldehyde (p.a.) <p>Fill with distilled water up to 5 litres.</p>

b) Preservation of anglerfish muscle and liver tissue for genetic analysis.

Measurements	Liver sample	Muscle sample
The length of the anglerfish is measured in mm and its weight is measured to the nearest gram. Weight of the gonads, liver and viscera is also measured to the nearest gram.	A section the size of the smallest fingernail is cut from the liver. The sample is put into a plastic bag, which is marked with a pen and frozen.	Cut two smallest fingernail-sized sections. One is put into a marked bag and frozen; the other is put into a marked vial and preserved in ethanol.

Appendix 2a

Simulation of the dispersal of *Lophius* eggs and larvae using a particle tracking model (Hislop *et al.* 2001): particles originating in the Rockall source box. (a) Age 0; (b) age 30 days; (c) age 60 days; (d) age 90 days; (e) age 120 days. Source: Figure 10 from Hislop *et al.* (2001).

Appendix 2b

Simulation of the dispersal of *Lophius* eggs and larvae using a particle tracking model (Hislop *et al.* 2001): particles originating in the Rockall source box. (a) Age 0; (b) age 30 days; (c) age 60 days; (d) age 90 days; (e) age 120 days. Source: Figure 11 from Hislop *et al.* (2001).

Appendix 3a Macroscopic maturity scale for *L. piscatorius* (Afonso-Dias 1997), as used by the NAFC, Shetland.

Maturity stage	Female	Male
I Virgin	The ovaries are very narrow (~ 2 cm broad), thin and ribbon-like. They are translucent and no individual oocyte-clusters or vascularization can be seen. Their volume is negligible compared with that of the other internal organs.	The testes are long, narrow (~ 1 cm broad) and have a tubular-like structure. The medial seminiferous duct is distinct, being very pale with no visible vascularization. Their volume is negligible compared with that of the other internal organs.
II Developing or re-covering/resting	The ovaries increase in length and, particularly, in width (~ 2 to 4 cm broad). They become less translucent and there is visible vascularization. There are still no visible individual oocyte clusters. The volume occupied by the ovaries is roughly the same as the one occupied by the intestine.	The flattened tubular shaped testes increase in length and, especially, in width. Blood vessels become visible around the medial seminiferous duct. The volume occupied is roughly half that occupied by the intestine.
III Maturing	The ovaries increase considerably in width (> 4 cm) and, particularly, in length. They are highly vascularised. Individual opaque oocyte clusters are visible, embedded in a gelatinous matrix. At this stage the ovaries occupy most of the abdominal cavity.	The testes have a very firm texture and moderate to large amounts of milt are produced when they are dissected. The seminiferous duct is now highly vascularised. Stage III testis still occupy less volume than the intestine.
IV Ripe	The ovaries are extremely long (> 6 m) and wide (30 cm) and occupy most of the body cavity. The bright orange oocyte clusters (1 to 2 mm) are embedded in a transparent gelatinous matrix. The ovaries are highly vascularised.	Milt runs from the genital pore on slight pressure. The testes are extremely turgid in texture and large amounts of milt are produced when dissected. Even at this stage the testis still occupy less volume than the intestine (except in very large fishes, where the volume are similar).
V Spent	The ovaries are opaque and flaccid, with longitudinal striations. They are still very wide (10-15 cm) and highly vascularised.	The testes are very flaccid. Frequently, there are roseate/salmon areas in the beige surface of the testis. Milt is often present in the seminiferous duct and also when dissected. The posterior edge is sometimes narrower than the anterior part of the gonad. At this stage the testis still are highly vascularised in the vicinity of the seminiferous duct.

Appendix 3b Macroscopic maturity scale for *L. piscatorius*, as used by the MRI, Iceland (source: Mike Pawson, Lowestoft, UK).

Maturity stage	Female	Male
I	Ovaries flat and transparent, wider than the testes in male fish of similar length. The membrane connecting the ovary extends further out than that in the testes, so that gonad stretches further away from the vertebrae than in the males. In larger fish the ovary looks frilly. No eggs.	Testes pink, taking up an insignificant part of the body cavity. Slightly more rounded than the female, running almost parallel to the vertebral column. 1-2 mm in width.
II	Taking up a larger proportion of the body cavity. The ovary is broader, flat, ribbon like and longer. Egg follicles are visible as white specks and are densely packed giving the ovary a creamy appearance.	Taking up a larger proportion of the body cavity. Not transparent, firm, yellow creamy pink. No ripe milt visible in sperm ducts.
III	Thickening, becoming more orange but still flat and ribbon like. Eggs much larger and densely packed edges of the ovary beginning to curl and veins on membrane running to the ovary are more prominent. The ovary may be up to 9 m in length.	Testes larger in diameter and comprise a significant proportion of the body cavity. Creamy and firm. Sperm ducts are more pronounced but no milt extrudes when pressure applied.
IV	Eggs round and gelatinous with yellow brown centres and look similar to frog spawn. Eggs not in obvious ribbons as with the earlier stages, but appear free flowing within the ovary membrane and occupy most of the body cavity.	Milt is present in the sperm ducts of the testes or the testes contain running milt. The testes feel quite spongy and are a greeny cream colour when very ripe.
V	The ovaries have shrunk back to the size they were when maturing and the membrane appears loose and flabby. The remaining oocytes are yellow red in colour, of different sizes and breaking down as they are reabsorbed.	The testes look bruised, red and blotchy. They are not as firm as they were when maturing and there is no milt present in the sperm ducts.

Appendix 3c Macroscopic maturity scale for *L. piscatorius*, as used by the Faroese Fisheries Laboratory. Modified from Duarte *et al.* (2001) and Staalesen (1995).

Maturity stage	Female	Male
I Immature	Band-shaped ovaries Very transparent No visible oocytes	Very small tube-shaped testicles Transparent/pink/brown colour No sperm visible
II Maturing	Ovaries take up a little part of the visceral cavity Brown/orange colour Small oocytes visible Not gelatinous	Testicles take up a greater proportion of the visceral cavity White/creamy coloured Sperm not visible by cutting the gonad
III Mature	Ovaries taking up a part of the visceral cavity Ovaries orange coloured Visible oocytes Gelatinous	White/creamy colour with some red areas Sperm visible by cutting the gonad Strong blood vessel in mesentery Testes have a very firm texture
IV Spawning	Orange/yellow coloured ovaries Enormous gelatinous mass wraps the hyaline oocytes	White/creamy colour with some red areas Sperm is easily freed by applying pressure to the abdomen, A lot of sperm visible by cutting the gonad Strong blood vessels in mesentery Testes have a very firm texture
V Spent/resting	Soft or retracted ovaries Grey/orange colour No visible oocytes	Grey/red stained testicles Little sperm visible by cutting the gonad Edge area sometimes transparent Testes very flaccid

Appendix 3d Macroscopic maturity scale for *L. piscatorius*, as used by the IMR, Norway. From Staalesen (1995), modified from Armstrong *et al.* (1992).

Female (ovaries)

Maturity stage	Colour	Size/form	Eggs (ova)	Vascularisation	Period
I Immature	Greyish-pink	Small, ribbon-like ovaries, appearing almost empty	No visible eggs	No	All year
II Developing	Pink	Ovaries increased in size, abdominal cavity slightly bulging	Ova discernible by eye	High	January-October
III Ripe	Straw-coloured to almost clear	Abdominal cavity greatly bulging	Distinct ova present		March-August
IV Spent/resting	Grayish or orange	Ovaries extremely flaccid. Appear almost empty. Larger than in Stage I	No visible eggs/atretic ova appear as black or white dots	Moderate/little	All year (spent from March-August)
V Immature/spent (uncertain)					

Male (testes)

Maturity stage	Colour	Size/form	Milt	Texture	Period
I Immature	White to tan	Medial groove less distinct. Similar in shape to mature testes, but very small	No		All year
II Developing	Blotchy cream to tan	Ring of creamy testes. Enlarged blood vessels in mesentery.	Moderate to large amount of milt produced when dissected	Very firm	January-June
III Ripe	Blotchy cream to tan with areas of pink		Milt produced from genital pore when pressure is applied to abdomen, copious amounts present when dissected	Extremely firm	March-August (until October)
IV Spent/resting	Grayish-tan with pink areas. Edges appear translucent.	Extremely flaccid. Larger than Stage I. Medial groove distinct.	Small amount of milt present when dissected	Flaccid	July-October (spent from October-January-)
V Immature/spent (uncertain)					

Appendix 4

Data from preliminary analyses of the maturation cycle in anglerfish, from gonad samples collected in Faroese waters in 2002. Macroscopic scale after Appendix 3 (Faroese maturity scale). GSI = gonadosomatic index (gonad weight/whole body weight); chorion = egg shell, yolk granules = yolk-containing structures found in cytoplasm; atretic = resorbing oocytes.

Date	Fish no.	Total length (cm)	GSI (%)	Maturity scale		Rel. oocyte diam.	Oocyte stage	Chorion	Yolk granules	Mucus	Cytoplasmic activity	Cell packing	Atretic
				Macroscopic	Microscopic								
8.3.02	52	62	0.56	1	1	26.0	Perinucleolar	no	no	no	low	high	-
8.3.02	24	77	0.66	Uncert.	1	38.0	Perinucleolar	no	no	no	med	high	-
8.3.02	61	75	0.52	1	1	39.0	Perinucleolar	no	no	no	low	high	-
2.9.02	16	91	0.76	2	1	53.0	Perinucleolar	no	no	no	low	high	-
8.3.02	36	88	0.82	5	1	56.5	Perinucleolar	no	no	no	low	high	-
2.9.02	5	71	0.70	1	1	27.5	Perinucleolar	no	no	no	low	high	-
2.9.02	10	81	0.48	5	1	32.0	Perinucleolar	no	no	no	high	high	-
5.6.02	29	87	0.64	1	1	41.0	Perinucleolar	no	no	no	low	high	-
2.9.02	11	91	0.61	5	1	43.5	Perinucleolar	no	no	no	low	med	-
2.9.02	7	90	0.65	1	1	45.0	Perinucleolar	no	no	no	low	high	yes
5.6.02	44	89	0.80	1	1	46.0	Perinucleolar	no	no	no	med	med	-
8.3.02	23	95	0.99	5	1/2	50.5	Perinucleolar	no	no	no	med	high	-
2.9.02	18	83	0.86	2	1/2	52.0	Perinucleolar	no	no	some	med	high	-
2.9.02	8	81	0.58	1	1/2	52.5	Perinucleolar	no	no	no	med	med	-
5.6.02	43	97	1.00	1	1/2	59.0	Perinucleolar	no	no	little	high	high	-
5.6.02	15	103	2.50	2	2	58.5	Perinucleolar	no	no	no	high	med	-
2.9.02	23	99	0.86	2	2	63.0	Perinucleolar	no	no	no	med	med	-
5.6.02	16	93	0.95	2	2	63.5	Perinucleolar	no	no	no	med	med	yes
5.6.02	40	92	1.28	2	2	64.0	Perinucleolar	no	no	little	high	high	-
5.6.02	1	119	1.54	2	2	70.5	Perinucleolar	no	no	yes	low	high	yes
2.9.02	12	118	2.24	2	2	82.0	Perinucleolar	no	no	some	high	high	-
5.6.02	37	98	1.24	2	2/3	74.0	Perinucleolar	no	no	some	high	med	-
2.9.02	14	96	1.47	2	2/3	76.0	Migratory	yes	beg.	some	high		yes
2.9.02	17	108	1.90	2	2/3	77.5	Perinucleolar	no	no	some	high	med	-
2.9.02	13	100	1.28	2	2/3	91.5	Perinucleolar	yes	no	little	high	low	-
5.6.02	36	101	1.51	2	2/3	101.0	Perinucleolar	beg.	no	no	high	low	-
5.6.02	48	112	1.72	2	2/3	108.0	Perinucleolar	yes	no	some	med	high	-
8.3.02	30	90	9.00	3	3		Migratory	yes	yes	yes	high	low	-
8.3.02	45	104	13.44	3	3		Migratory	yes	yes	yes	high	low	yes

Appendix 5 Commercial landings (tonnes) of *Lophius* and proportion of *L. piscatorius* in catches from the Southern Shelf 1990-2004.

	Southern Shelf – Northern parts (ICES Divisions VIIb-k & VIIIa,b,d)				Southern Shelf – Southern parts (ICES Divisions VIIIc & IXa)			
	Catch (tonnes)			Proportion <i>L. piscat.</i>	Catch (tonnes)			Proportion <i>L. piscat.</i>
	<i>Lophius piscatorius</i>	<i>Lophius budegassa</i>	Total		<i>Lophius piscatorius</i>	<i>Lophius budegassa</i>	Total	
1990	19 753	9 632	29 385	0.67	3 790	2 334	6 124	0.62
1991	16 229	8 840	25 069	0.65	3 640	2 163	5 803	0.63
1992	12 818	8 266	21 084	0.61	3 382	2 111	5 493	0.62
1993	13 481	6 659	20 140	0.67	2 329	2 227	4 556	0.51
1994	16 120	5 814	21 934	0.73	2 007	1 580	3 587	0.56
1995	19 502	7 053	26 555	0.73	1 834	1 831	3 665	0.50
1996	22 003	8 092	30 095	0.73	2 955	1 629	4 584	0.64
1997	21 660	8 114	29 774	0.73	3 714	1 813	5 527	0.67
1998	19 572	8 599	28 171	0.69	2 981	2 089	5 070	0.59
1999	17 186	7 325	24 511	0.70	1 932	1 885	3 817	0.51
2000	14 925	7 037	21 962	0.68	1 259	1 369	2 628	0.48
2001	16 508	5 688	22 196	0.74	788	1 013	1 801	0.44
2002	20 130	6 534	26 664	0.75	1 032	770	1 802	0.57
2003	23 591	8 134	31 725	0.74	2 278	926	3 204	0.71
2004*	27 313	7 590	34 903	0.78	3 076	924	4 000	0.77

* Preliminary data

Appendix 6 Factors used by the Nordic countries and regions to convert fish product to round weight, and length to weight.

Country/ region	Season/ month	Conversion factor (product weight to round weight)		Length-to-weight relationship ⁽¹⁾⁽²⁾ ($W = a * L^b$)	
				<i>a</i>	<i>b</i>
Faroe Islands	All	Gutted	1.2		
Iceland	All	Gutted	0.9		
		(corresponding multiplication factor:	1.1)		
		Tail including tail-fin (i.e. headed & gutted)	2.857		
		Tail without tail-fin	3.703		
Norway ⁽¹⁾	All	Gutted	1.2		
		Tail weight to round weight	3.8		
Shetland ⁽²⁾	All	Gutted	1.1952	0.0232	2.828
		Nominal to live weight	1.28		
	All			0.0232	2.828
	Jan			0.0227	
	Feb			0.024	
	Mar			0.0221	
	Apr			0.0243	
	May			0.0244	
	Jun			0.0232	
	Jul			0.0232	
	Aug			0.0235	
	Sep			0.0227	
	Oct			0.023	
	Nov			0.0221	
	Dec			0.0236	

(1) Analyses and results showing the relationships between (i) length-round weight by sex, (ii) length-gutted weight by sex, and (iii) gutted weight vs. round weight are available from Dyb (2003)

(2) Laurenson (2003) gives the conversion from gutted weight to length $GW = 0.0123 * L^{2.9865}$ based on fish market data. For comparison, Afonso-Dias (1997) gives: total length = $1.4 * \text{tail length}$ and total weight = $1.2 * \text{gutted weight}$

Appendix 7 Commercial landings (tonnes) of anglerfish per fishing gear type in Faroe Islands, Iceland and Norway, 1990-2004.

Faroe Islands	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Gillnet	1	2	3	61	252	449	353	359	475	937	1 014	1 119	764	874	1 163
Bottom trawl	680	764	751	699	651	787	1 024	1 154	1 229	1 226	1 060	827	793	1 370	2 142
<i>Nephrops</i> trawl															
Others	40	24	19	14	15	30	44	65	70	104	110	151	241	408	440
	721	790	773	774	918	1 266	1 421	1 578	1 774	2 267	2 184	2 097	1 798	2 653	3 745
Iceland	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Gillnet	43	13	14	29	25	49	37	54	69	53	764	612	239	882	1 211
Bottom trawl*	316	325	371	308	229	344	462	542	468	652	527	492	423	455	659
<i>Nephrops</i> trawl	275	384	358	348	387	155	261	213	296	282	212	246	304	349	353
Others															
	634	722	743	685	641	548	760	809	833	987	1 503	1 350	966	1 686	2 223
Norway	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Gillnet	98	304	577	3 642	2 056	1 111	1 504	1 053	2 049	2 473	3 644	4 208	2 552	2 748	3 349
Bottom trawl	519	485	656	647	539	472	456	304	423	607	481	544	426	425	485
<i>Nephrops</i> trawl			0	4	13	4	6	10	24	29	41	39	49	53	76
Others	87	94	93	159	114	142	104	79	148	130	192	201	145	160	159
	704	883	1 326	4 452	2 722	1 729	2 070	1 446	2 644	3 239	4 358	4 992	3 172	3 386	4 069

* Including Danish seine

Appendix 8a,b Typical length distributions of commercially landed catches of anglerfish in the countries participating in the Nordic project.

a) **Faroes.** Data from 2004.

b) **Iceland.** Data from 2000-2002.

Appendix 8c,d Typical length distributions of commercially landed catches of anglerfish in the countries participating in the Nordic project.

c) **Norway.** Data from the Møre coast, 1992-1997.

d) **Shetland.** Data from trawling 1997-2002 (n=18 552)

Appendix 9a **Faroe Islands.** The Faroese age-length key used for the present mortality- and Y/R calculations. This age-length key is constructed using all age material from the Faroese Fisheries Laboratory's research surveys and port sampling in 2002.

Length (cm)	Number per age group															Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
15 - 19	4	7														11
20 - 24	1	17														18
25 - 29		23	7	1												31
30 - 34			43	9												52
35 - 39			11	33	2											46
40 - 44				46	11											57
45 - 49				22	53	4										79
50 - 54				11	96	13										120
55 - 59				3	50	64										117
60 - 64					13	74	21									108
65 - 69					1	16	65	12								94
70 - 74						2	38	30	6	1						77
75 - 79							12	38	22	1	1					74
80 - 84								10	21	3	4					38
85 - 89								4	15	9	3					31
90 - 94									5	7	8	4				24
95 - 99								1	8	7	10	3	1			30
100 - 104										2	3	5	3	1		14
105 - 109										1	5	3	2			11
110 - 114											2	2	2	1		7
115 - 119											2	3				5
120 - 124													1			1
125 - 129														1	1	2
130 - 134													1			1
135 - 139																0
140 - 144														1		1
Total	5	47	61	125	226	173	136	95	77	31	38	20	10	4	1	1 049

Appendix 9b

Iceland. The Icelandic age-length key used for the present mortality- and Y/R calculations. This age key consists of all available age-read material from the MRI Reykjavik, containing samples from the years 2000-2003 collected in the annual *Nephrops*-survey off the south coast of Iceland.

Length (cm)	Number per age group															Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5 - 9	13															13
10 - 14	4															4
15 - 19	1	6														7
20 - 24		40														40
25 - 29		43														43
30 - 34		18	10													28
35 - 39		5	77													82
40 - 44			101	11	1											113
45 - 49			21	42	9	1										73
50 - 54			5	47	26	7										85
55 - 59			3	27	43	4	1									78
60 - 64			1	12	51	25	7	2	1							99
65 - 69			1	5	29	33	8	5			1					82
70 - 74				2	5	22	7	5	2	2						45
75 - 79					2	11	14	10	2	1				1		41
80 - 84						6	7	6	7	1	1	2	1			31
85 - 89					1	6	6	3	4	3	3		1			27
90 - 94						2	3	3	3	3	2	4		1	1	22
95 - 99							3	6	7	2	2					20
100 - 104							2	5	3	3	3	1	1			18
105 - 109								1	1	1			1			4
110 - 114									1	1	1	2				5
115 - 119										1	1		2			4
120 - 124																
125 - 129											1	1				2
Total	18	112	219	146	167	117	58	46	31	18	15	10	7	1	1	966

Appendix 9c **Norway.** The Norwegian age-length key used for the present mortality- and Y/R calculations. This age-length key is constructed using all age material from the Institute of Marine Research's research surveys in the North Sea and port sampling at Møre during 1994-1998.

Length (cm)	Number per age group															Total
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
5 - 9	2															2
10 - 14	4	1														5
15 - 19	1	2														3
20 - 24	1	1	6													8
25 - 29	1	1	2													4
30 - 34		5	1	8												14
35 - 39		4	3	6	1											14
40 - 44		8	9	3	7	1										28
45 - 49		1	6	2	10	2										21
50 - 54		1	4	5	10	9	2									31
55 - 59			1	5	2	14	7	1								30
60 - 64			1	8	10	11	13	4								47
65 - 69				5	15	14	11	12	2	1						60
70 - 74				2	15	12	16	25	5	4						79
75 - 79					9	12	16	23	21	6	2					89
80 - 84						8	17	34	33	7	1					100
85 - 89					1	1	8	33	39	26	7					115
90 - 94						1	8	17	30	32	11	4				103
95 - 99							2	11	16	21	19	6				75
100 - 104							1	3	14	17	8	4				47
105 - 109							1	2	5	9	9	7	6	1		40
110 - 114									3	3	5	5	4	1		21
115 - 119										2	3	7	2	1		15
120 - 124												5	6	1	1	13
125 - 129													1	2		3
130 - 134													1	1		2
135 - 139																
140 - 144														1		1
Total	9	24	33	44	80	85	102	165	168	128	65	38	20	8	1	970

Appendix 10a

Norway/NEZ. Catch in numbers and estimated fishing mortality (natural mortality $M=0.15$) for the Norwegian gillnet fishery and the total international fishery (gillnet included) in the Norwegian Economic Zone (NEZ) in 2002. An estimate of the population in NEZ is also given. The table should be used as an example of how the estimations may be done, and not treated as being accurate, given the rather poor biological sampling and age reading of the commercial landings. Note that the necessary assumption about the starting value for the population (N) at age 13 leads to only minor differences in the Fs for ages younger than 10.

Age	Norway Gillnet			All nations in NEZ All gears		
	Catch in numbers	F when N set to 1 000 at age 13	F when N set to 300 at age 13	Catch in numbers	Est. population in thousands	F when N set to 1000 at age 14
0	0	0	0	69 158	3 466	0.02
1	0	0	0	212 084	2 919	0.08
2	2 205	0	0	271 188	2 316	0.13
3	15 784	0.02	0.02	264 983	1 742	0.18
4	39 340	0.08	0.07	198 588	1 253	0.19
5	49 439	0.12	0.12	191 234	895	0.26
6	56 728	0.19	0.19	144 539	593	0.31
7	77 920	0.4	0.39	138 148	376	0.5
8	61 057	0.59	0.58	83 389	195	0.62
9	37 793	0.85	0.83	48 714	91	0.86
10	15 825	1.07	0.99	18 380	33	0.92
11	5 290	1.34	1.08	6 307	11	0.92
12	1 281	1.6	0.78	1 795	4	0.69
13	303			472	2	0.36
14				89	1	
Sum	362 967			1 648 852		
Average weight	6.98			3.04		
Landings (tonnes)	2 534			5 020		
Average F ages 3-9		0.32	0.32	Average F ages 3-9		0.42
Average F ages 4-11		0.58	0.53	Average F ages 4-11		0.57
Average F ages 7-11		0.85	0.77	Average F ages 7-11		0.76

Appendix 10b **Faroe Islands.** Catch in numbers and estimated fishing mortality (natural mortality $M=0.15$) for the Faroes fisheries in 2004. An estimate of the population at the Faroes is also given. The table should be used as an example of how the estimations may be done, and not treated as being accurate given the rather poor biological sampling and age reading.

Age	Catch in numbers				Estimated population in thousands	F when N set to 1000 at age 13
	Gillnet	Trawl	Others	Total		
0	0	0	0	0	2 443	0
1	0	644	132	776	2 102	0
2	0	17 714	3 639	21 353	1 809	0.01
3	92	154 001	31 633	185 726	1 537	0.14
4	1 756	238 887	49 069	289 712	1 151	0.32
5	8 231	129 698	26 641	164 570	722	0.28
6	35 717	77 134	15 844	128 695	468	0.35
7	41 477	42 607	8 752	92 836	284	0.43
8	33 295	27 782	5 707	66 784	158	0.61
9	9 928	7 427	1 526	18 881	74	0.32
10	11 767	8 484	1 743	21 993	46	0.72
11	6 098	3 570	733	10 401	19	0.86
12	3 633	1 542	317	5 492	7	1.81
13	1 060	589	121	1 770	1	
14	307	0	0	307		
Sum	153 361	710079	145856	1009297	Average F ages 3-9	0.35
Average weight	7.58	3.02	3.02	3.71	Average F ages 4-11	0.49
Landings (tonnes)	1 163	2 142	440	3 745	Average F ages 7-11	0.59

Appendix 11a **Faroe Islands.** Input data to the yield-per-recruit calculations based on **(A)** a knife-edged exploitation pattern at age 4, and **(B)** on the exploitation pattern as estimated and presented in Appendix 10b. The exploitation pattern **(B)** has been scaled so that the average for the age group 7-10 becomes equal to 1.0 ($F_{7-10} = 1.0$). As a simplification, a knife-edged maturity at age 8 has been used. Length distributions and weight-at-length relationship are taken from ongoing sampling from the fishery. Age-length key in Appendix 9a has been used.

Age	Natural mortality	Maturation	Individual weight in stock and catch (kg)	Exploitation pattern (A)	Exploitation pattern (B)
2	0.15	0.00	0.61	0.0	0.02
3	0.15	0.00	1.18	0.0	0.27
4	0.15	0.00	1.98	1.0	0.61
5	0.15	0.00	3.04	1.0	0.54
6	0.15	0.00	4.35	1.0	0.68
7	0.15	0.00	5.94	1.0	0.84
8	0.15	1.00	7.79	1.0	1.17
9	0.15	1.00	9.90	1.0	0.62
10	0.15	1.00	12.27	1.0	1.38
11	0.15	1.00	14.88	1.0	1.65
12	0.15	1.00	17.73	1.0	3.47

Appendix 11b **Iceland.** Input data to the yield-per-recruit calculations based on **(A)** the assumption that the fish selects sharply into the fishery at the age of 4 **(A)** or gradually into the fishery and is half (50%) recruited at the age of 4 **(B)**. Length distributions and weight-at-length relationship are taken from ongoing sampling from the fishery. Age-length key in Appendix 9b has been used.

Age	Natural mortality	Maturation	Individual weight in stock and catch (kg)	Exploitation pattern (A)	Exploitation pattern (B)
2	0.15	0.23	1.24	0.01	0.01
3	0.15	0.63	3.58	0.01	0.25
4	0.15	0.65	5.38	1.00	0.50
5	0.15	0.92	7.17	1.00	0.75
6	0.15	0.96	9.98	1.00	1.00
7	0.15	0.88	11.13	1.00	1.00
8	0.15	0.92	12.27	1.00	1.00
9	0.15	1.00	14.12	1.00	1.00
10	0.15	1.00	14.74	1.00	1.00
11	0.15	1.00	15.00	1.00	1.00

Appendix 11c **Norway.** Input data to the yield-per-recruit calculations based on **(A)** the exploitation pattern of the Norwegian gillnet (360 mm) fishery only, and **(B)** on the present exploitation pattern for the total fishery for anglerfish in the NEZ (incl. gillnet, trawl, Danish seine). In both cases the exploitation pattern has been scaled so that the average for the age group 7-10 becomes equal to 1.0 ($F_{7-10} = 1.0$). As a simplification, a knife-edged maturity at age 8 has been used. Length distributions and weight-at-length relationship are taken from ongoing sampling from the fishery. Age-length key in Appendix 9c has been used.

Age	Natural mortality	Maturation	Individual weight in stock and catch (kg)	Exploitation pattern (A)	Exploitation pattern (B)
1	0.15	0	0.53	0.0004	0.109
2	0.15	0	0.88	0.0040	0.180
3	0.15	0	1.70	0.035	0.239
4	0.15	0	3.16	0.106	0.250
5	0.15	0	3.97	0.171	0.350
6	0.15	0	5.75	0.266	0.408
7	0.15	0	7.44	0.564	0.677
8	0.15	1	9.37	0.829	0.832
9	0.15	1	11.08	1.188	1.182
10	0.15	1	13.12	1.420	1.310
11	0.15	1	17.24	1.539	1.462
12	0.15	1	21.12	1.121	1.439