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Report of the Second Workshop on the Impact of Ecosystem and Environmental Drivers on Irish Sea Fisheries Management (WKIrish2)

26–29 September 2016

Belfast, Northern Ireland

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Conseil International pour l'Exploration de la Mer

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Executive summary

WKIrish 2 is the second in a series of meetings leading to a regional ecosystem assessment for the Irish Sea. The series comprises WKIrish1 (September 2015: Information sharing and scoping), WKIrish2 (September 2016: Data evaluation; WKIrish3 (January 2017: Single-species stock assessment development; and WKIrish4 (date to be confirmed: Development of an integrated ecosystem assessment and advice).

WKIrish2 reviewed data and parameters for use in full benchmark stock assessments of Irish Sea whiting, cod, haddock and plaice. Herring was included mainly to evaluate a new industry–science acoustic survey dataset. The ToRs for WKIrish2 follow the guidelines for ICES benchmark data evaluation meetings drawn up in 2015 by the ICES Planning Group on Data Needs for Assessments and Advice (PGDATA). These covered stock identification, biological parameters (natural mortality, growth, maturity), fishery catch and length/age composition data, and survey data on relative abundance. The Workshop compiled and evaluated information on the historical national fishery sampling schemes and sampling achievements, to support decisions on inclusion and weighting of dataseries. A particular issue for Irish Sea whiting, haddock and plaice is high discard rates for which estimates are only available since the mid-2000s. WKIrish2 reviewed sampling levels by country and gear and identified years with sufficient samples (given the national fleet contributions to total discards) to compute fleet-raised discards. Time-series of discard ogives were compiled to help inform modelling approaches that can extrapolate historical discarding where there are few data. Very large changes in demersal fleet structure and effort have occurred in the Irish Sea which can lead to large changes in selectivity. WKIrish2 evaluated the potential to develop fleet-disaggregated landings and discard estimates, and associated length/age compositions for use in statistical fleet-disaggregated models. The WK drew up a time line of management measures that can affect quality, interpretation and use of fishery data for the stocks, and changes in selectivity.

Previous assessments of the demersal species have used age-invariant natural mortality values set at historically assumed values such as 0.2 for gadoids. Irish Sea cod, haddock and whiting have exhibited steep age profiles interpreted as very high F for the full history of the fisheries, and it has proved difficult to identify assessments that explain why F does not respond as expected to reductions in fishing. This may partly be due to underestimation of M, and WKIrish2 addressed this in some detail. Given the focus on multispecies models in WKIrish4, it was desirable to specify age-specific M (using Lorenzen and Gislason methods, compared with North Sea multispecies assessments), and ranges of M consistent with life-history theory. Methods were applied using the most robust data available on size-at-age, growth and maturity. The resultant M estimates are mostly larger than used at present, across all ages, and more similar to multispecies model estimates. Nonetheless, M remains a key uncertainty for assessments and reference points.

Clear trends in maturity were observed from survey time-series for cod, haddock and whiting covering the stock range, and WKIrish2 recommended including the trends with smoothing to minimise effects of sampling error. Also, the WK recommended using female-only maturity ogives (even with combined sex assessments) so that temporal effects of large recruitment anomalies on annual spawning output (egg production, or SSB as proxy) can be correctly interpreted. Plaice was an exception as there is considerable sexual dimorphism in growth leading to some issues with using female maturity ogives without disaggregating the stock abundance and weights-at-

age by sex. WKIrish2 provides sex-aggregated and female-only maturity ogives, which can be used by WKIrish3 for sensitivity analysis.

Existing survey series used in the demersal fish assessments were reviewed and were considered appropriate to use by WKIrish3. A new Cefas beam trawl survey index for 0-gp and 1-gp haddock was supplied which appears to show similar year-class tracking to the AFBI MIK net index for 0-gp haddock. WKIrish2 agreed that the series should be tested in the assessment. The MIK net series for cod, whiting and haddock is potentially useful for 0-gp fish and should be tested again.

The new AFBI fishery–science partnership herring acoustic survey, which takes place in the same area and time frame as the AFBI RV acoustic survey, was presented but will be reviewed by the ICES International Pelagic Survey WG prior to the next herring assessment WG. Therefore, WKIrish2 did not make specific comment on this survey.

1 Background and terms of reference for the meeting

1.1 Background to meeting

WKIrish 2 is the second in a series of meetings leading to a regional ecosystem assessment for the Irish Sea. The series comprises:

- WKIrish1 (September 2015): Information sharing and scoping;
- WKIrish2 (September 2016): Data evaluation;
- WKIrish3 (early 2017: date to be confirmed): Single-species stock assessment development;
- WKIrish4 (date to be confirmed): Development of an integrated ecosystem assessment and advice.

WKIrish 1 (ICES, 2015a) was a scoping workshop to enable information exchange between management stakeholder groups, fishermen, scientists, regulators and other interested parties to improve understanding of the key issues involved and questions to be addressed. Three main subject areas were discussed at WKIrish1, covering ecosystem processes, fisheries issues, and management and policy issues. The group also identified data and tools that could assist the benchmarking process, and set priorities for future work. Priorities for action included a) improving the quality of the existing analytical single-stock assessments, b) documenting the special features of the Irish Sea that need to be reproduced by models, including the lack of response to massive effort reduction in the TR1 otter trawl fleet, strongly truncated age structure, spawning areas, and impact of gyre circulation changes on fish stocks, c) ascertaining how long the truncated age structure has persisted, d) improving our understanding of the level of migration of mature fish north and south out of the Irish Sea, perhaps using the ^{14}C signature of Sellafield as a suitable "tag", e) developing a multispecies model framework that can reconcile/integrate the (improved) analytical stock assessments, and f) honestly representing uncertainties using a combination of ensemble and multi-model investigation.

The first priority identified by WKIrish 1 is addressed by WKIrish 2 and WKIrish 3 which are part of the ICES process for peer-reviewed benchmarking of the single-stock assessments forming the basis for ICES advice on fishing opportunities. WKIrish2 is a data evaluation meeting, and its objective is to review all fishery-dependent and fishery-independent data that could be used in the assessments for stocks covered by the meeting, propose which datasets or components of data are or appropriate quality, provide advice on data quality metrics that could be used in stock assessment models or for interpreting results, propose values of parameters such as natural mortality that are needed for the assessments and associated development of biological reference points, and consider other relevant information such as stock identity and mixing. The stocks covered are Irish Sea whiting, haddock, plaice, cod and herring. Other than herring, these are all stocks that have been identified by ICES as requiring a full peer-reviewed benchmark assessment process to address issues with the current data and stock assessments. Herring was added to the list as there was a need to evaluate the quality and utility of an industry–science partnership acoustic survey of herring around the Isle of Man.

The benchmark data evaluation process is intended to ensure that ICES assessments are based on data of known and acceptable quality, and ensuring transparency in the assessment process. To ensure this is done as rigorously as possible, a detailed set of guidelines was developed in 2015 by the ICES Planning Group on Data Needs for Assessments and Advice (PGDATA: ICES, 2015b). It was intended to trial the guidelines on Irish Sea whiting (which has not previously been benchmarked) but was available to guide the evaluation of data for the other stocks where appropriate.

The goal of WKIrish3 will be to develop the most appropriate single-stock analytical methods for estimating trends in abundance and exploitation rate and current stock status in relation to reference points for sustainability, particularly in the context of Maximum Sustainable Yield (MSY), and taking into account the information content and quality of the available datasets.

WKIrish4 and any subsequent meetings in the series will then focus on human impacts at the ecosystem scale, and how ecosystem processes such as predation and productivity at lower trophic levels affect our perception of exploited populations and how best to manage fisheries to meet long-term goals for sustainability. The results of the single-species stock assessments from WKIrish3, and assessments of other stocks in the Irish Sea carried out by ICES, will provide information for "tuning" the types of ecosystem model (e.g. LeMans and Ecopath/Ecosim) that will be explored in WKIrish4.

1.2 WKIrish2 process

The WKIrish2 data compilation and evaluation process took place over most of 2016. Two web meetings took place in June and September prior to the physical meeting in Belfast in late September, to look at progress and plan further tasks. Two web meetings then took place in October [and December] to evaluate work still needed to complete the process. The web meetings involved the chairs, the main people responsible for each stock, and the ICES Secretariat. Stakeholders attended the meeting in Belfast but not the web meetings.

1.3 Terms of reference

The **Second workshop on the impact of ecosystem and environmental drivers on Irish Sea fisheries management** (WKIrish2), chaired by Mike Armstrong, UK, will meet in at AFBI in Belfast, UK, 26–29 September 2016, to carry out the following tasks for Irish Sea whiting, cod, haddock, plaice and herring to provide input data and parameters for the WKIrish3 benchmark meeting:

a) Explain the basis for existing assumptions on stock structure and mixing rates between stock areas, or proposed new assumptions which form the basis for spatial aggregation of fishery and survey data and/or adjustments to datasets to account for stock mixing.

b) Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length.

c) Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of relevance for the scientific assessment of the stocks and provision of advice.

d) Develop time-series of (commercial and recreational) fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision.

e) Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision.

f) Develop recommendations for addressing fishery selectivity (pattern of catchability at-length or age) in the assessment model.

g) Recommend values for discard mortality rates, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values.

h) Review all available and relevant fishery-dependent and -independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision.

i) Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts.

j) Review progress on existing recommendations for research to develop and improve the input data and parameters for assessments, and develop and prioritise new proposals.

k) For each stock, develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the data evaluation workshop.

l) Prepare the data evaluation workshop report providing complete documentation of workshop actions, decisions, list of working documents, other information used by the workshop, and a list of any additional tasks to be completed following the workshop with dates and responsibilities for completion.

WKIrish2 will report by 14 October for the attention of ACOM, SCICOM, BSG and the WKIrish3.

Supporting information

Priority	The current activities of this workshop are in line with the ICES strategic plan to progress towards integrated ecosystem assessments.
Scientific justification	At the ICES WGCHAIRS 2015 meeting the scope of the Irish Sea Benchmark was extensively discussed. It was agreed that the Irish Sea would be a good test bed for ICES to develop an integrated ecosystem benchmark. The fisheries components to the ecosystem are relatively well understood. Several recent projects have looked at ecosystem models and reviewed the Irish Sea ecosystem in general. What has been missing thus far is how we integrate these new types of information and data into and improve the current stock assessments and management advice. Irish Sea fisheries have changed from a cod, whiting and herring dominated fishery in the 1960s to one which is dominated by *Nephrops* and other shellfish stocks today. Since the early 2000s, ICES has been advising zero catch for cod and whiting. Despite strong effort reductions and other measures to recover the cod stock, there is little evidence of any stock response, suggesting ecosystem aspects (e.g. various sources of natural mortality) may be playing a role. The work plan for WKIrish is a 2-year process, and focuses on improving single-species stock assessments (principally cod, haddock, whiting, plaice, herring), incorporating a mixed fisheries model, and developing the integration of ecosystem aspects and working towards an integrated assessment and advice. There is a strong link PGDATA to develop guidelines for data compliation and evaluation. There are four main workshops, but work needs to be coordinated and progressed intersessionally. The four workshops address: WKIrish1 (September 2015): Information sharing and scoping; WKIrish2 (September 2016): Data compilation; WKIrish3 (Early 2017): Stock assessment benchmark; WKIrish4 (tbc): Towards development of an integrated ecosystem assessment and advice. It would be beneficial to identify co-chairs for the whole process, which could, but must not necessarily also co-chair the workshops
Resource requirements	The research programmes which provide the main input to this group are already underway.
Participants	Experts on integrated assessment, fish stock assessment models and Irish Sea ecosystem, stakeholders (industry, administrations, NGOs).
Secretariat facilities	Professional assistance by the ICES Secretariat.
Financial	No financial implications.
Linkages to advisory committee	There are close links with ACOM and SCICOM.
Linkages to other committees or groups	ACOM/SCICOM Benchmarking Steering Group (BSG), ACOM/SCICOM Steering Group of Integrated Assessments (SSGIEA), ACOM/SCICOM Steering Group on Integrated Ecosystem Observation and Monitoring (SSGIEOM), WGCSE, HAWG, WGEF, PGDATA, WGEAWESS, BEWG, WGZE, WGMME, WGSFD, WGSAM, WGMIXFISH, WGISUR, WGECO, WGBIOP.
Linkages to other organizations	NWWAC, OSPAR

2 Structure of the report

The Irish Sea is a relatively small, enclosed sea, and the data for a wide range of stocks come from the same national fishery data collection schemes and fishery-independent surveys. Also, fishery management regulations such as gear restrictions and other measures associated with cod recovery plans affect many species taken by the fisheries. The report therefore commences with a description of the regional data collection schemes (with links to more detailed existing descriptions where available), and a summary of the history of management regulations. A stock-by-stock evaluation of datasets is then presented, along with recommendations for future studies or changes to data collection that have the potential to significantly improve the quality of the assessments and advice as cost-effectively as possible.

3 History of management regulations (ToR c)

The main changes in Irish Sea fisheries and the main management measures implemented in the Irish Sea are summarized since the 1950s are in Figure 3.1 below. As with most fisheries there has been a gradual creep in efficiency over time interspersed with step changes associated with the introduction of various technological and gear developments. Further descriptions of the main management measures and changes are given in the various text sections. Details of the main regulations are provided in Table 3.1.

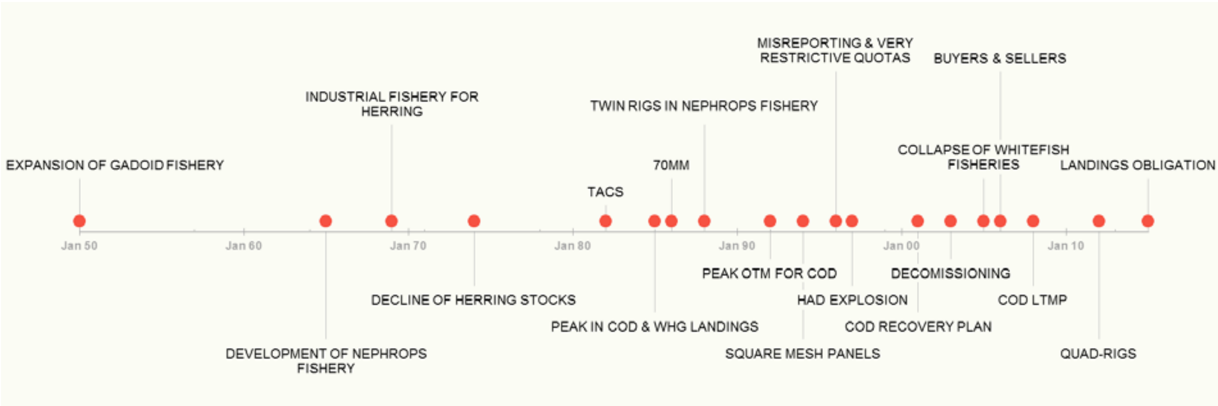

Figure 3.1. Timeline if the main changes in Irish Sea fisheries since 1950.

3.1 The expansion of the gadoid fishery

Irish Sea gadoid fisheries expanded rapidly post World War II. This fishery was mainly an unselective trawl fishery with mesh sizes of 50 or 60 mm most common. There was also some seine netting. Initially the fishery was mainly targeting whiting but by the late 1960s cod was becoming more important. The main bycatch species landed were *Nephrops* and plaice. Gear improvements and increased fishing power probably contributed to this change. Vessels typically targeted gadoids seasonally and also fished herring and *Nephrops* at other times. Landings of whiting and cod were mainly >10 000 t/year throughout the 1970s and late 1980s (Figure 3.2). The minimum mesh size in 1968 was 60 mm (Hillis, 1968). Hillis (1968) provides some information on the selection patterns of the gear.

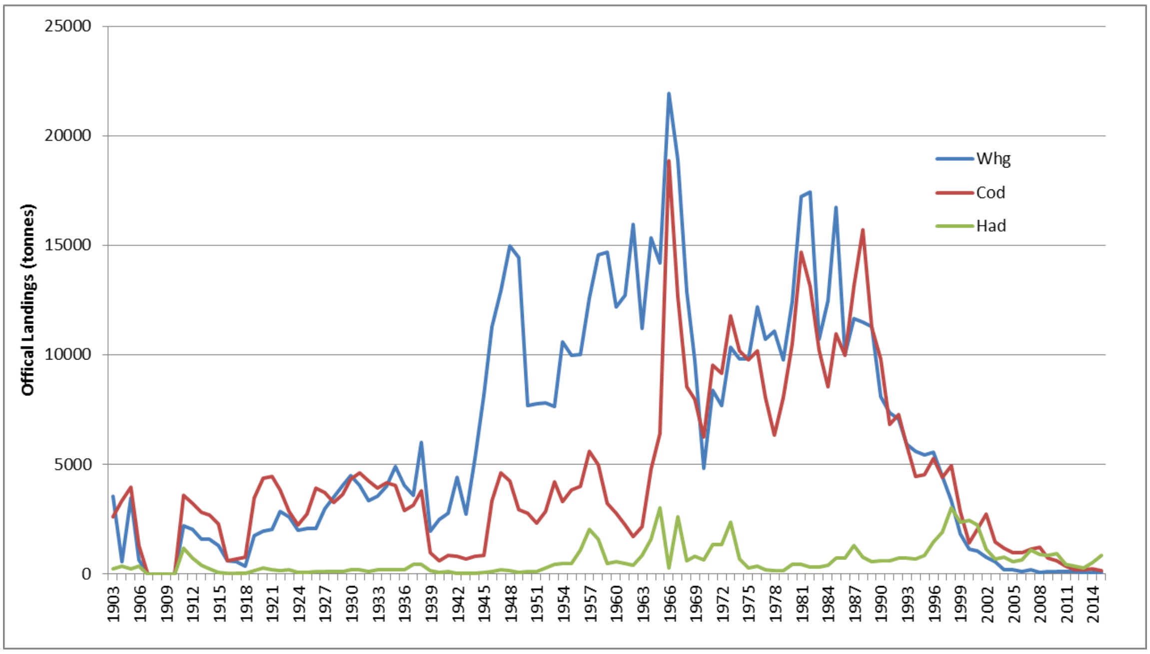

Figure 3.2. Official landings of cod, haddock and whiting from 1950 to 2015.

3.2 Development of *Nephrops* fishery

The Irish Sea *Nephrops* fishery primarily developed as new markets were found for the bycaught *Nephrops* in the whiting fishery. Small mesh, low head-line trawls with good ground contact increase catching efficiency for *Nephrops*. In the 1950s and 1960s groundgear was made of natural fibres (grass rope) and a codend of 50 mm. The landings in the western Irish Sea FU15 increased almost linearly from 1960 to the mid-1980s and catches since then have fluctuated around 10 000 t. As the fishery expanded there were gradual improvements in catching efficiency with improved rubber footropes and polyethylene netting. The introduction and widespread adoption of twin-rigs in the *Nephrops* fishery in the late 1980s resulted in a big efficiency increase. The minimum codend mesh size was also increased to 70 mm around 1986.

3.3 Development of herring fishery

The development and subsequent decline of the herring fishery in the Irish Sea is documented by Molloy, 2006. The short-lived herring boom served to increase capacity and power in the Irish Sea fishing fleet in the late 1960s and early 1970s. When the herring stock declined the fleet concentrated more whitefish and *Nephrops*.

3.4 Development of the pelagic trawl fishery for cod

In the mid-1980s, vessels in Northern Ireland developed a semi-pelagic trawl fishery to catch cod in the midwater. The main mesh used was 100 mm. This gear proved very efficient and probably resulted in a large change in selection for cod in particular. The midwater trawlers targeted spawning cod and haddock in spring, and cod, hake and haddock in summer and autumn. The summer/autumn fishery increased in importance through the 1990s. Fishing took place in the deeper offshore waters, and effort is split between the western Irish Sea and the North Channel (6.a/7.a boundary). The pelagic trawl (OTM) fishery peaked in the early 1990s and declined to only a couple of vessels by 2010. Since then the fishery has expanded again now targeting haddock.

3.5 Square mesh panels

Square mesh panel legislation was introduced for both the UK and Irish vessels in 1994 specifically to reduce the fishing mortality on juvenile whiting in the *Nephrops* fishery. This may have changed the selectivity for whiting but probably had lesser impacts on cod and haddock. Experimentally the SMPs had been shown to reduce whiting bycatches (Briggs, 1992). Despite the introduction of these measures discarding of whiting has been a persistent problem in the *Nephrops* fishery.

3.6 Restrictive cod quotas

Although TACs were introduced in the Irish Sea in 1982 they were unrestrictive until 1991, when the Council first started to reduce them significantly. Misreporting of cod, haddock and whiting in the Irish Sea occurred during extensively the 1990s due to restrictive quotas. Initially this was misreporting of species compositions (both over- and underreporting) (WGNSDS, 2003). There was also some area misreporting between 7.a and surrounding regions (mainly from the Celtic Sea into the Irish Sea). WGNSDS, 2003 reported that official landings data from one country taking a significant part of the international catch have in the past been adjusted at source for area-misreporting based on local knowledge of fleet activities. WGNSDS, 2003 also stated that "species-misreporting by another important national fleet has been estimated using a sampling method based on observations made by scientists taking length measurements in the ports. The mean observed weights of the three gadoid species per landing were calculated by port and gear type in 2002, and raised to the total number of landings for each port and gear in which at least one of the three species was recorded".

A time-series of the TACs by species is provided in the summary sheets for all the 7.a stocks. Further information and links to recent TAC regulations can be found at:

http://ec.europa.eu/fisheries/cfp/fishing_rules/tacs_en

3.7 Technical measures

Council Regulation (EC) No. 850/98 was one of the first major international regulations that had an impact on the Irish Seas as it attempted to adapt technical measures. It included new measures to improve the selectivity of towed gears by applying detailed rules on the construction of fishing gears (e.g. codend circumference, twine thickness), making the use of square mesh panels mandatory in certain fisheries, additional closed areas/seasons and gear restrictions as well as maintaining the legal architecture for emergency measures and the development of local measures for inshore fisheries within MS territorial waters, (STECF, 2012). Council Regulation (EC) 850/1998 is still applicable and has been amended numerous times since its introduction.

Council Regulation (EC) 850/1998 also established the minimum landings sizes of 27 cm for whiting, 35 cm for Cod, 30 cm for haddock and 27 cm for plaice.

3.8 Cod recovery plan and effort control

Council Regulation (EC) No. 304/2000 and Regulation (EC) No. 2549/2000 introduced area closures on the cod spawning grounds for ten weeks from mid-February till the end of April . These area closures now occur annually. There are derogations for gears not targeting cod e.g. *Nephrops* trawls.

There have been a number of regulations detailing measures to protect the cod stock in the Irish Sea. Council Regulation (EC) No 300/2001 further established measures to be applied in 2001 for the recovery of the stock of cod in the Irish Sea. It was followed with Council Regulation (EU) No. 1456/2001 which amended Regulation (EC) No. 2549/2000 establishing additional technical measures for the recovery of the stock of cod in the Irish Sea and Council Regulation (EU) No. 254/2002.

Council Regulation (EC) No 423/2004 establishing measures for the recovery of cod stocks was introduced in 2004. The regulation included a harvest control rule, measures for restriction of fishing effort, technical measures, control and enforcement, accompanying structural measures and market measures, (SGMOS, 2007).

Direct control of fishing effort has been a key aspect of cod recovery plans. Monthly effort limitation was extended to the Irish Sea (and other “cod recovery” areas) under Annex V to Council Regulation (EC) No 2287/2003. This Regulation and subsequent amendments (e.g. Council Regulation (EC) No 27/2005) restrict the number of allowable days fishing per month according to gear type, mesh size band and various derogations.

3.9 Buyers and Sellers and sales notes

In 2006 and 2007 buyers and sellers and sales notes regulations were introduced in the UK and Ireland. These regulation are expected to have improved the accuracy of the landings data because they make the landings offered for sale traceable back to vessels.

3.10 Cod long-term management plan

The introduction of the Long-Term Management Plan (Regulation (EC) No 1342/2008) has had one of the most dramatic impacts on Irish Sea fisheries. The main aim of this regulation was to reduce cod catches. The plan has resulted in effort for specific cod catching gear groupings and significant cod TAC reductions. Two articles in the plan (articles 11 and 13) provide the possibility for vessels to avoid effort restrictions provided that catch rates of cod are demonstrated to be below certain thresholds. Under article 13 of the regulation, gear groups using TCMs or engaged in cod avoidance behaviours can claw back the stringent effort reductions set out in the plan if their cod catch is less than 5% cod. Vessels using gear that catch <1.5% cod can be exempted altogether from effort reductions set out in the plan under article 11. The impact of this has been very substantial declines in effort for cod catching gears especially TR1 (Trawls and seines using >100 mm) and BT2 (Beam trawlers). Effort in TR2 which is mainly the *Nephrops* directed fishery shows a small decline. Effort in dredge fisheries has increased but these will have negligible catches of whiting (Figures 3.2 and 3.3). An overview of the catch by main demersal gear type in the Irish Sea is given in Figure 3.4.

To avail of effort claw backs both the UK and Ireland have introduce national management measures.

For example in Ireland since 2010 special conditions on the permitted types of gear have been attached to effort authorisations for TR2 vessels fishing in 7.a. The list of authorised gears has expanded from two to the four below over time.

i) A 'Swedish' Sorting Grid. The Sorting Grid must be in accordance with points (2) (3) (4) (5) of Annex XIVa of Council Regulation (EC) 850/1998 as amended by Council Regulation (EC) 227-2013. By way of derogation, the 'Swedish' sorting grid may be constructed with the inclusion of a lower horizontal gap inserted along the base of the grid being no more than 150 mm in height.

ii) An Inclined Separator. The Inclined Separator must be in accordance with the annex to Council Regulation (EC) No 254/2002.

iii) A SELTRA "300" Sorting Box. The SELTRA 300 must be in accordance with the specification contained in Annex 2 of this Authorisation.

iv) A 300 mm Square Mesh Panel. The 300mm Square Mesh Panel must be in accordance with the specification contained in Annex 3 of this Authorisation.

In trials these gears have very different selective and catchability properties for whiting (http://www.bim.ie/our-publications/fisheries/). In practice catch sampling programmes show that discard volumes have remained at a similar level to before their introduction and the length distribution of the catch have not changed significantly.

Council Regulation (EC) No 1288/2009 ensures that the temporary technical measures would remain in place by providing for continuation of the temporary measures on a transitional basis for 18 months until 30 June 2011. These measures were then further extended for another 18 months under Regulation (EU) No 579/2011 until 31 December 2012. Council Regulation (EU) No. 227/2013 forwarded a proposal to incorporate these measures into Regulation (EC) 850/98.

3.11 Decommissioning

Decommissioning is responsible for displacement and reduction of effort in the Irish Sea since its introduction. In 2003 the UK NI fleet removed 19 out of 237 UK vessels that operated in the Irish Sea, representing a reduction of 8% of the fleet by number and 9.3% by tonnage. Of these vessels, 13 were vessels that used demersal trawls with mesh size >=100 mm. The previous round of decommissioning in 2001 removed 29 UK (NI) *Nephrops* and whitefish vessels and four UK(E&W) vessels Ireland introduced a decommissioning scheme in 2005 and again in 2008 with the aim of removing 11 140 GT from the fleet register. This was targeted at vessels over ten years of age and >18 m in length. STECF (2008) reported that the fishing effort of trawlers using 100–119 mm mesh declined by 83% between 2003 and 2007, and by 86% for vessels with a track record of <5% cod in their landings. This was as a consequence of a combination of factors restricting the activities of these vessels where some whitefish vessels switched to *Nephrops* gears to take advantage of the additional days at sea and the high value of *Nephrops* and some other vessels were removed from the fleet through decommissioning.

Because the decommissioning scheme targeted whitefish vessels this would have led to changes in selectivity for the gadoids since more of the remaining catches were from *Nephrops* vessels using smaller mesh.

3.12 Landings obligation

The reform of the Common Fisheries Policy (CFP) of 2013 aims at gradually eliminating the wasteful practice of discarding through the introduction of the landing obligation. The landings obligation has been phased in in demersal fisheries since 2016 with the introduction temporary regional discard plans by means of delegated acts. Further information is available at: https://ec.europa.eu/fisheries/cfp/fishing_rules/discards_en

The delegated acts are:

Commission Delegated Regulation (EU) 2015/2438 of 12 October 2015 establishing a discard plan for certain demersal fisheries in northwestern waters.

Commission Delegated Regulation (EU) 2016/2375 of 12 October 2016 establishing a discard plan for certain demersal fisheries in northwestern waters

In the initial phase only fisheries targeting haddock and *Nephrops* in 7.a are subject to the landings obligation and only for those species. By 2019 all TAC species will be covered and the regulation could potentially have a major impact on data quality, fisheries behaviour, selectivity, etc. in the coming years.

Table 3.1. Overview of the main regulations pertaining to management of Irish Sea fisheries.

Year	International	Reason	Comments
1998	COUNCIL REGULATION (EC) No. 850/98	for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms.	Introduction of Square Mesh Panels, minimum mesh sizes and Minimum Landing Sizes
2000	COMMISSION REGULATION (EC) No. 304/2000	establishing measures for the recovery of the stock of cod in the Irish Sea (ICES Division 7.a)	
2000	COMMISSION REGULATION (EC) No. 660/2000	amending Regulation (EC) No 304/2000 establishing measures for the recovery of the stock of cod in the Irish Sea	
2000	COUNCIL REGULATION (EU) No. 2459/2000	establishing additional technical measures for the recovery of the stock of cod in the Irish Sea (ICES Division 7.a).	two closed areas in the eastern and western Irish Sea to provide the maximum possible protection during the spawning season
2001	COUNCIL REGULATION (EC) No. 300/2001	establishing measures to be applied in 2001 for the recovery of the stock of cod in the Irish Sea	
2001	COUNCIL REGULATION (EU) No. 1456/2001	amending Regulation (EC) No 2549/2000 establishing additional technical measures for the recovery of the stock of cod in the Irish Sea	
2002	COUNCIL REGULATION (EU) No. 254/2002	establishing measures to be applicable in 2002 for the recovery of the stock of cod in the Irish Sea	
2004	COUNCIL REGULATION (EC) No 423/2004	Cod Recovery Plan	

Year	International	Reason	Comments
2004	COUNCIL REGULATION (EU) No.1415/2004	fixing the maximum annual fishing effort for certain fishing areas and fisheries	
2008	COUNCIL REGULATION (EC) No. 1342/2008	Cod Recovery Plan	Swedish Grid/Inclined Separator Panel, Articles 11 & 13
2009	COUNCIL REGULATION (EC) No. 43/2009	fixing for 2009 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks	Transitional Technical Measure
2009	COUNCIL REGULATION (EC) No. 1288/2009	establishing transitional technical measures from 1 January 2010 to 30 June 2011.	Transitional Technical Measure
2011	COUNCIL REGULATION (EU) No. 579/2011	Transitional Technical Measure	
2012	COUNCIL REGULATION (EU) No. 1243/2012	amending Regulation (EC) No 1342/2008 establishing a long-term plan for cod stocks and the fisheries exploiting those stocks	
2013	COUNCIL REGULATION (EU) No. 227/2013	Irish Sea Cod Box	
2013	COUNCIL REGULATION (EU) No. 227/2013	Transitional Technical Measure/ amending Council Regulation (EC) No 850/98	
2014	COUNCIL REGULATION (EU) No.43/2014	TACs	
2015	Commission Delegated Regulation (EU) 2015/2438	establishing a discard plan for certain demersal fisheries in northwestern waters	Applies to had & nep in 7.a
2016	Commission Delegated Regulation (EU) 2016/2375	establishing a discard plan for certain demersal fisheries in northwestern waters	Applies to had & nep in 7.a

Year	International	Reason	Comments
Year	National		Comments
2003	Decommissioning	United Kingdom	
2005	Decommissioning	Ireland	
2006	SEA-FISHERIES AND MARITIME JURISDICTION ACT	Ireland	Introduced Sales notes
2008	Decommissioning	Ireland	
2013–present	Quota management	Ireland	http://www.sfpa.ie/Sea-FisheriesConservation/Legislation/FisheriesManagementNotices.aspx

3.13 References

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4 Regional data collection schemes for the Irish Sea

This section provides descriptions of the sampling schemes that have been in place in each country for collection of data to estimate discards and length/age compositions of commercial fishery catches, focusing on cod, whiting, haddock, and plaice. Historical sampling achievements are given for each stock. An overview of fishery-independent surveys providing data for demersal species and herring is also given. Further detail and interpretation of the data are given in the individual stock sections.

4.1 Port sampling and at-sea sampling achievements in England and Wales

4.1.1 Onshore demersal sampling

4.1.1.1 History of the sampling scheme

A sampling scheme to collect length and age compositions of species landed by UK vessels into England and Wales, from fishing trips in the Irish Sea, has been in place for the full period covered by the WKIrish stock assessments. Up to 2009, the sampling programme was conducted mainly by fishery inspectors working to targets of numbers of fish to measure and age by area, fishery and time period. Additional samples to meet specific targets were collected by Cefas. Since 2010, Cefas took over the full programme and began to revise the sampling designs to follow recommendations of ICES WKMERGE (ICES, 2009) and subsequent WKPICS meetings. A major change in 2010 was that sampling in Welsh ports was no longer possible, leading to a missing stratum of ports until more recent years when a Memorandum of Understanding has been agreed with the Welsh Government for Cefas to sample Welsh vessels. A large part of the Welsh fleet is inshore shellfish vessels, with larger Anglo-Spanish vessels operating from Milford Haven but operating outside the Irish Sea.

Prior to 2010, the port sampling design involved specifying targets for collection of length and age data by species and port. The intention was for inspectors to spread the sampling out over time to achieve good coverage, working to guidelines provided by Cefas. However the sampling was opportunistic rather than random, probability based. Since 2010, Cefas has adopted a more formal stratified sampling scheme, as summarised below.

4.1.1.2 Sampling frame

The population being sampled is the landings of all species covered by the scheme, within defined sea areas of capture such as 7.a. The landings are accessed through a sampling frame comprising ports and days. Each port on a day is the primary sampling unit (PSU), and sampling staff visit the selected PSUs throughout the year to sample landings of vessels for length and age composition.

The current onshore sampling design in England and Wales specifies a number of different sampling frames for sampling of different types of fleets. For example there is a separate frame for pelagic trawlers/seiners targeting species such as mackerel and herring, where there are a limited number of ports of landing and sale. For cod, haddock, plaice and sole in the Irish Sea, a frame is used covering landing sites for demersal fleets using trawls, seines, beam trawls, nets, and lines.

Demersal fish landings are accessible on shore at fish auctions and at fish merchants, but for port sampling are more accessible at fish auctions which are situated at the major landing ports. Some catches will have been landed at ports other than those where the market is situated and driven to the market by lorry. This means that landings into some small ports not included as PSUs in the sampling design are sampled *de facto* at the port of sale.

Typically, at auctions, the landings from a vessel are graded ashore by market staff and laid out in fish boxes on the floor of the market. The vessel is often identified with paper tallies laid on the fish or stuck on the side of the boxes. In some markets the vessels landings are laid out together and on other markets the vessels landings components are laid out in different parts of the market depending on the value or species. The fish will have been sorted into species or species groups (anglerfish; gurnards; cephalopods) and often market-sized categories, and iced. Boxes are weighed by the market staff and will have a weight ticket on them. The auctions take place usually in the early morning and once the landings from a particular vessel have been sold the boxes will be removed. The name and pln number of the landing vessel are known and the landing composition can usually be determined from the laid-out catch. However some species or size categories can be sold privately and will be missing from the market.

4.1.1.3 Stratification design

The onshore demersal sampling frame is stratified by geographical area, size of port (port-class), gear group and quarter. The areas are separated into NW, NE, SE, SW. The Irish Sea is covered mainly by ports in the NW stratum although vessels fishing in 7.a can also land into ports in other area strata. For several years since 2010, the NW stratum has had incomplete coverage due to no sampling being done in Wales.

The Port Class strata are determined by ranking the ports based on sales data from the reference period within a geographical area by gear group:

Major1: The ports that account for the 1st 50% of the sales/effort.

Major2: The ports that account for the next 35% of the sales/effort.

Minor: The ports that account for the remaining 15%.

If the number of active ports within a port group is <10 then the Major1 ports are the top 75% by landings/sales/ trips and the next 15% are Major2 ports and the rest are Minor ports.

Quarter is also used as a stratum to account for seasonal patterns.

Sampling effort is allocated to strata based on landings and sales for the previous year and expert knowledge as to how many samples could be expected to be taken on that day.

4.1.1.4 Sample selection

Within each stratum (Area x Port Class x Quarter) the primary sampling unity (PSU) is the market *day. To ensure a spread of sampling across the quarter and across the ports in the port class, the market trips required are allocated systematically to a biweek period and port. Each port has an OrderID based on their geographical position clockwise round the coast. This is used with the sequential number for the biweek period to randomly select a start point. See the schematic below.

Example: Overall target of twelve sampling events. Port2 Week 3 is the randomly selected start point:

Qtr1

Biweek period

	1	2	3	4	5	6
Port 1		1 + 1			1 + 1	
Port 2			1 + 1			1 + 1
Port 3	1 + 1			1 + 1		

Each market trip is conducted by a team of up to three observers. The selection of the vessel for sampling is currently at the discretion of the observer as often time is the limiting factor. Opportunities to randomly select the landings from a vessel, on a market, are limited. Currently, the selection of the fish species and the number of the samples is at the discretion of the observer. Total boxes/volumes/weight and the number of boxes/volumes/weight sampled are recorded for each sampled species and the catch composition recorded for incomplete concurrent samples. Guidelines on the numbers of fish required are provided but all the fish in one or more boxes are sampled. A "throw rate" is used to ensure sufficient numbers are measured over the total volume sampled i.e. measure 1 throw 1. When collecting otoliths, up to three otoliths are collected for each cm length class in the length sample.

Sampling at merchants

Sampling at an auction

4.1.1.5 Sampling hierarchy and probabilities

The hierarchical cluster sampling design, and the sampling probabilities (P) used for raising, is summarised below for a given sampling frame (demersal fisheries in this case). The design is subject to improvements over time, for example protocols for selecting sampling units at each stage.

The sampling hierarchy is: 1) Market*day, 2) Vessel*trip, 3) Species, 4) Box in a category, 5) fish in the box (length), 6) fish at-length (age).

1) Day selected is *ad hoc* within the bi-week period, at the observer's discretion.

P (include a market*day in the sample) = number of market days sampled in the stratum/ total of number market days in the stratum = n_{sm} / N_{sm}

2) On a particular market*day, select a sample of vessel landings from available landings. Currently vessel is selected at the observer's discretion.

P (sample a particular trip t on that day) = number of vessel trips sampled on the market day from that fleet/ total number of trip available trips from that fleet that market day

3) From a particular trip select the species. The selection is currently made at the observer's discretion based on overall targets.

4) For each species, sample all the sales categories (commercial size categories).

P (sample a particular box within a category) = number of boxes sampled in sales category / total number of boxes in sales category

Currently, landed weights and sample weights are recorded which provides the ratio.

5) Fish in the boxes are sampled and measured for length to achieve a minimum of 30–50 fish.

P = (sample for length a particular fish in the box) = number of fish sampled in the box / total number of fish in box

However, for large numbers of fish (when the throw rate is used), this is approximated by the throw rate.

6) Age sampling.

P = number of fish sampled for age-at-length l in trip t / total number of fish sampled at length l in trip t

4.1.1.6 Port sampling achievements

The numbers of port visits in the Irish Sea where a species was sampled from beam trawls, otter trawls (the main gears used for cod, whiting, haddock and plaice) is given in Tables 4.1.1–4.1.3. Very few haddock were sampled and no information for this species is shown. Prior to 1994 for plaice and whiting, and prior to 2000 for cod, the sampling data for length compositions are archived in a way that already includes some raising or aggregated over a series of sampling trips, and no information is presented. Only the landings sampled for age, and numbers aged, can be given.

Table 4.1.1. Plaice: Market sampling achievements in UK (England & Wales) ports in 7.a. No. port visits = number of visits where plaice were measured from beam or otter trawlers. "All gears" includes other gears along with beam and otter.

GEAR	BEAM TRAWL			OTTER TRAWL			ALL GEARS	
Year	No. Port visits	No. landings sampled	No. fish measured	No. Port visits	No. landings sampled	No. fish measured	No. landings sampled	Total aged
1983	NA	NA	NA	NA	NA	NA	98	1745
1984	NA	NA	NA	NA	NA	NA	117	1902
1985	NA	NA	NA	NA	NA	NA	111	2038
1986	NA	NA	NA	NA	NA	NA	72	1340
1987	NA	NA	NA	NA	NA	NA	68	1260
1988	NA	NA	NA	NA	NA	NA	66	1025
1989	NA	NA	NA	NA	NA	NA	81	1284
1990	NA	NA	NA	NA	NA	NA	115	1366
1991	NA	NA	NA	NA	NA	NA	87	1146
1992	NA	NA	NA	NA	NA	NA	42	756
1993	NA	NA	NA	NA	NA	NA	54	956
1994	11	11	1837	43	45	7119	38	805
1995	9	10	1562	39	45	7013	69	1292
1996	6	6	1141	43	43	6393	59	1203
1997	5	5	795	42	45	7939	67	1120
1998	27	28	3716	42	46	7093	71	1299
1999	8	8	1137	54	61	8077	71	1403
2000	20	22	3297	33	35	4641	66	1211
2001	10	13	1988	56	67	10763	87	1974
2002	14	14	1898	42	50	8712	66	1502
2003	13	13	2443	45	51	7534	80	1128
2004	8	8	1376	27	32	5042	41	729
2005	29	31	5430	14	15	3187	43	1077
2006	9	10	1991	11	13	1589	20	500
2007	10	11	1663	34	50	5639	40	988
2008	2	2	353	59	81	12133	43	1669
2009	0	0	0	57	82	11093	43	2388
2010	0	0	0	12	14	1558	20	944
2011	5	5	1273	16	20	2271	17	591
2012	0	0	0	14	20	3054	18	668
2013	0	0	0	15	18	2904	17	477
2014	0	0	0	13	28	1556	17	412
2015	0	0	0	15	34	1381	17	372

Table 4.1.2. Cod: Market sampling achievements in UK (England & Wales). No. port visits = number of visits where cod were measured from beam or otter trawlers. "All gears" includes other gears along with beam and otter.

GEAR	BEAM TRAWL			OTTER TRAWL			ALL GEARS	
Year	No. Port visits	No. landings sampled	No. fish measured	No. Port visits	No. landings sampled	No. fish measured	No. landings sampled	Total aged
1983	NA	NA	NA	NA	NA	NA	141	2022
1984	NA	NA	NA	NA	NA	NA	130	1911
1985	NA	NA	NA	NA	NA	NA	139	2134
1986	NA	NA	NA	NA	NA	NA	121	1773
1987	NA	NA	NA	NA	NA	NA	120	1780
1988	NA	NA	NA	NA	NA	NA	105	1430
1989	NA	NA	NA	NA	NA	NA	122	1768
1990	NA	NA	NA	NA	NA	NA	58	869
1991	NA	NA	NA	NA	NA	NA	62	850
1992	NA	NA	NA	NA	NA	NA	47	626
1993	NA	NA	NA	NA	NA	NA	48	738
1994	NA	NA	NA	NA	NA	NA	27	574
1995	NA	NA	NA	NA	NA	NA	45	964
1996	NA	NA	NA	NA	NA	NA	34	846
1997	NA	NA	NA	NA	NA	NA	28	646
1998	NA	NA	NA	NA	NA	NA	41	877
1999	NA	NA	NA	NA	NA	NA	33	660
2000	3	3	244	36	36	4385	42	726
2001	2	2	316	58	64	7285	58	989
2002	3	3	121	41	45	5676	40	662
2003	6	6	312	38	41	4680	35	656
2004	4	4	244	31	33	3609	24	454
2005	3	3	215	20	21	2539	21	319
2006	0	0	0	13	13	1447	13	214
2007	4	4	204	9	12	626	21	478
2008	0	0	0	17	19	745	12	248
2009	0	0	0	21	24	1296	12	91
2010	0	0	0	4	7	1623	6	299
2011	1	1	40	5	5	254	7	114
2012	0	0	0	6	7	383	8	186
2013	0	0	0	5	5	21	6	71
2014	0	0	0	3	5	35	11	298
2015	0	0	0	3	6	168	9	271

Table 4.1.3. Whiting: Market sampling achievements in UK (England & Wales). No. port visits = number of visits where whiting were measured from beam or otter trawlers. "All gears" include other gears along with beam and otter. Since 2006, whiting have been excluded from the sampling scheme due to extremely low catches.

GEAR	BEAM TRAWL			OTTER TRAWL			ALL GEARS	
Year	No. Port visits	No. landings sampled	No. fish measured	No. Port visits	No. landings sampled	No. fish measured	No. landings sampled	Total aged
1983	NA	NA	NA	NA	NA	NA	135	1851
1984	NA	NA	NA	NA	NA	NA	138	1683
1985	NA	NA	NA	NA	NA	NA	146	1573
1986	NA	NA	NA	NA	NA	NA	133	1411
1987	NA	NA	NA	NA	NA	NA	62	772
1988	NA	NA	NA	NA	NA	NA	0	0
1989	NA	NA	NA	NA	NA	NA	7	99
1990	NA	NA	NA	NA	NA	NA	11	130
1991	NA	NA	NA	NA	NA	NA	0	0
1992	NA	NA	NA	NA	NA	NA	0	0
1993	NA	NA	NA	NA	NA	NA	0	0
1994	6	6	544	55	56	5796	0	0
1995	5	5	438	53	58	5563	0	0
1996	5	5	492	57	60	6374	0	0
1997	1	1	134	49	51	6040	0	0
1998	9	9	693	49	52	5142	0	0
1999	4	4	401	52	54	5936	0	0
2000	3	3	317	56	61	6187	4	183
2001	0	0	0	50	60	5723	12	417
2002	1	1	41	39	47	4084	13	318
2003	4	4	423	58	64	5789	0	0
2004	0	0	0	23	30	2626	0	0
2005	1	1	145	9	9	755	0	0
2006	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0

4.1.2 At-sea sampling programme

4.1.2.1 History of the sampling programme

Some *ad hoc* observer trips took place in the Irish Sea prior to the inception of the EU Data Collection Regulation in the early 2000s. The programme was re-designed to meet DCR/DCF needs, and was re-designed further to be more statistically robust from around 2010 onwards following advice on sampling designs coming from ICES expert groups such as WKMERGE, WKPICS and SGPIDS.

4.1.2.2 Sampling frame

The population being sampled is the catch of all species covered by the scheme, within defined sea areas of capture such as 7.a. The catches are accessed through a sampling frame comprising a list of fishing vessels, from which vessels are selected at random to take an observer. A trip on a vessel is treated as the primary sampling unit (PSU) although all the trips of a vessel during a quarter are not known in advance.

The frame coverage is not complete, as vessels under 7 m are currently considered unsuitable for taking observers. Prior to around 2010, no vessels under 10 m were sampled at sea by observers. Also, since devolution of Wales, Cefas has not had an observer programme in Wales and has only recently started again through the MoU with the Welsh Government.

4.1.2.3 Stratification scheme

The vessel lists are currently stratified by area (coastline from which they operate), quarter, vessel size (<10 m; 10 m+) and predominant fishing type. The stratification has varied over time, generally reducing to avoid low sample sizes per stratum. The fishing type strata relevant to WKIrish assessments of cod, whiting, haddock and plaice are: i) otter trawls, seines, nets, lines and ii) beam trawls.

Planned number of trips per stratum is defined using information on previous fishing effort, discard rates and catches. There is a minimum of three trips per stratum.

4.1.2.4 Sample selection

A randomised vessel list is developed for each area x quarter x vessel type x vessel size stratum. The observers contact skippers in sequence until a sampling trip can be arranged. Refusal rates have been recorded since 2013.

At sea, the observers follow a detailed sampling protocol to ensure that catches are sampled following statistically sound practices, within the practical constraints of the working conditions encountered. This includes selection of hauls to sample, and how to subsample individual hauls to quantify discards and collect samples for length and age. It has been the practice to only collect age samples from the discard portion, as ALKs for the landed component are derived from port sampling.

4.1.2.5 Data analysis

In most cases a ratio estimator is used, with the landed catch weight of the species as the auxiliary variable. Trip-raised estimates are summed for sampled vessels in stratum, and then raised to total fleet using reported total fleet landings of the stock and reported landings of stock by sampled vessels. When no landings are reported, a sampling probability is derived using numbers of trips sampled and total number of fishing trips in the stratum, to raise the discard data. To obtain estimates for gear groups or métiers, the sampling frame is post-stratified provided there are sufficient observations.

4.1.2.6 Sampling achievements

The numbers of at-sea observer trips in the Irish Sea where a species was sampled from beam trawls, gillnets, otter trawls and seines (gears that can catch cod, whiting, haddock and plaice) is given in Tables 4.1.4–4.1.7. The large number of plaice measured compared to the other species is due mainly to sampling on beam trawlers where there are many hauls in a trip. These are clusters of samples, and the effective sample size for length composition is likely to be much smaller than the number of fish measured due to intra-cluster correlation. The effective sample size for length may in fact be closer to the number of fishing trips sampled.

Table 4.1.4. Plaice: At-sea observer sampling achievements in UK (England & Wales). Age samples are generally only collected for discards.

Numbers of trips where fish lengths were recorded												
	Beam trawl		Gillnet		Otter trawl		Seine		Grand Total		total fish measured	total fish aged
Year	Dis	Ret	Dis	Ret	Dis	Ret	Dis	Ret	Dis	Ret	Dis&Ret	Dis
2000	1	1			19	19			20	20	11402	
2001					15	15			15	15	6324	613
2002	1	1			7	7	1	1	9	9	15198	269
2003					6	6			6	6	2453	88
2004					13	13	1	1	14	14	6946	90
2005	2	2			5	5			7	7	2603	69
2006	1	1			3	3	1	1	5	5	4758	61
2007	1	1			29	27			30	28	11362	320
2008					31	30			31	30	9456	201
2009					12	12			12	12	3374	95
2010					10	10			10	10	2701	57
2011					10	10			10	10	2425	0
2012			1	1	10	9			11	10	2046	108
2013			4	3	7	7			11	10	1733	82
2014			2	2	10	10			12	12	2859	121
2015			2	3	10	10			12	13	2610	87

Table 4.1.5. Cod: At-sea observer sampling achievements in UK (England & Wales). Age samples are generally only collected for discards.

NUMBERS OF TRIPS WHERE FISH LENGTHS WERE RECORDED										
	Beam trawl		Gillnet		Otter trawl		Grand Total		total fish measured	total fish aged
Year	Dis	Ret	Dis	Ret	Dis	Ret	Dis	Ret	Dis&Ret	Dis
2000	1	1			12	16	13	17	532	
2001					9	15	9	15	1705	50
2002	1	1			3	6	4	7	594	22
2003					2	5	2	5	1500	36
2004					9	10	9	10	1922	12
2005		2			1	5	1	7	445	5
2006	1	1					1	1	18	7
2007	1	1			8	9	9	10	221	6
2008					3	13	3	13	55	1
2009							0	0	0	0
2010					2	2	2	2	7	1
2011				1		2	0	3	13	0
2012			1	2	1	5	2	7	150	5
2013			2	2			2	2	31	4
2014			1	2	1	2	2	4	131	5
2015			2	2		4	2	6	239	0

Table 4.1.6. Haddock: At-sea observer sampling achievements in UK (England & Wales). Age samples are generally only collected for discards.

NUMBERS OF TRIPS WHERE FISH LENGTHS WERE RECORDED								
	Beam trawl		Otter trawl		Grand Total		total fish measured	total fish aged
Year	Dis	Ret	Dis	Ret	Dis	Ret	Dis&Ret	Dis
2000		1		1	0	2	4	
2001			3	7	3	7	1098	15
2002		1	1	3	1	4	130	14
2003			3	3	3	3	1345	0
2004			7	6	7	6	3190	0
2005	1	2	1	1	2	3	1281	0
2006	1		2		3	0	27	0
2007			4	3	4	3	14	0
2008			4		4	0	6	0
2009					0	0	0	0
2010					0	0	0	0
2011			1		1	0	1	0
2012				2	0	2	186	0
2013					0	0	0	0
2014					0	0	0	0
2015					0	0	0	0

Table 4.1.7. Whiting: At-sea observer sampling achievements in UK (England & Wales). Age samples are generally only collected for discards.

Numbers of trips where fish lengths were recorded										
	Beam trawl		Gillnet		Otter trawl		Grand Total		total fish measured	total fish aged
Year	Dis	Ret	Dis	Ret	Dis	Ret	Dis	Ret	Dis&Ret	Dis
2000	1	1			19	13	20	14	1594	
2001					15	11	15	11	2461	293
2002	1	1			7	5	8	6	1666	206
2003					5	3	5	3	2025	106
2004					13	6	13	6	2297	91
2005	2	2			4	2	6	4	843	17
2006	1	1			2		3	1	635	0
2007	1				22	6	23	6	2159	0
2008			1		23	3	24	3	2128	0
2009					9		9	0	250	0
2010					6		6	0	394	0
2011					7		7	0	126	21
2012			2	1	4	2	6	3	17	3
2013			2		6	1	8	1	53	0
2014			1		7	1	8	1	492	0
2015			1		7	1	8	1	74	0

4.2 Port sampling and at-sea sampling achievements in Belgium

4.2.1 Port sampling

Sampling for length and age compositions of the whole catch, and estimation of discards, is conducted primarily by observers at sea. Some additional samples are collected in port (Table 4.2.1).

4.2.2 At-sea sampling

4.2.2.1 Sampling frame

The sampling frame is a list of beam trawlers. The beam trawl fishery is by far the most important fishery for Belgium (in 2015 TBB covered 84% of the total Belgian fishing hours) and comprises of a beam trawl fleet targeting crustaceans (TBB_CRU covers 10% of the total Belgian fishing hours) and a beam trawl fleet targeting demersal species (TBB_DEF covers 74% of the total Belgian fishing hours). The TBB_DEF fleet comprises of two fleet segments: the TBB_DEF_>221 kW fleet segment and the TBB_DEF_<=221 kW fleet segment.

The TBB_DEF_>221 kW fleet segment comprises beam trawl vessels with a capacity of more than 221 kW, operating in North Sea, the English Channel, the Irish Sea, the Celtic Sea, South of Ireland and the inner part of the Bay of Biscay (referred to as "all regions" - 4, 7.d, 7.e–h, 7.a, 8.ab in Table 4A). The TBB_DEF_>221 kW trip duration is on average 8–10 days and one trip can cover several areas.

The TBB_DEF_<=221 kW fleet segment comprises beam trawl vessels with a maximum power of 221 kW (coastal vessels and "euro cutters"), operating in the Southern North Sea and the Eastern English Channel (4 and 7.d respectively). In contrast to TBB_DEF_>221 kW, this fleet segment has also access to the 12 mile zone. A coastal vessel has a trip duration of less than 24 hours and a euro cutter of approximately four days.

4.2.2.2 Sampling design and stratification

In accordance with the recommendations from STECF-EWGs and RCMs following the preparation of the new DCF, Belgium started from 2011 onwards to redesign and develop the catch sampling schemes to move from a 'métier-based' to a 'statistically sound' sampling scheme in order to apply at random sampling of the trips. Considering the importance of the beam trawl fleet targeting demersal species in the Belgian fisheries, Belgium focuses on the collection of fishery-dependent data for this fleet (both fleet segments). The two fleet segments (TBB_DEF_>221 kW and TBB_DEF_<=221 kW) are treated as two separate strata in the Belgian at-sea sampling programme. Catch information (all catch fractions are covered) is obtained through on-board observation or 'at-sea sampling'. Four ILVO observers assure a sampling coverage of on average 1% of all fishing hours (i.e. approximately 40 trips). The sampling effort targets for one year are set at eight trips for the TBB_DEF_<=221 kW fleet segment and 32 trips for the TBB_DEF_>221 kW fleet segment.

The primary sampling unit (PSU) in the Belgian at-sea sampling programme is vessel x trip (as a proxy for trip) so the sampling design class is defined as 'type A'[1]. A haul (within a trip) is defined as the secondary sampling unit (SSU).

4.2.2.3 Sample selection

A vessel x trip (PSU) for the TBB_DEF_>221 kW fleet segment is selected by means of a random draw from a vessel list (with replacement; as described in the Belgian AR 2015[2]). Only the vessels that are willing to take observers on board and those that are suited, from a logistic point of view, to have an observer on board are included in the vessel list (sampling frame):19 vessels out of 28 vessels in total. Non–responses and refusals are documented.

A vessel x trip (PSU) for the TBB_DEF_<=221 kW fleet segment is selected *ad hoc*. The vessel list (sampling frame) has been steadily decreasing and proved too small to ensure random PSU selection. This was the result of vessels being taken out of service, but also logistic issues on board facilitated this decrease. Therefore, an *ad hoc* selection from a list containing two euro cutters and four coastal vessels out of 36 in total is done (Note that these 36 vessels include both TBB_DEF and TBB_CRU.)

For the TBB_DEF_>221 kW fleet segment, every second haul (systematic sampling of SSU) is sampled by an observer. Sampling takes place around the clock to reflect typ-

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[1] : ICES. 2013. Report of the second Workshop on Practical Implementation of Statistical Sound Catch Sampling Programmes, 6–9 November 2012, ICES Copenhagen. ICES CM 2012 / ACOM:52 71 pp.

[2] Belgian Annual Report 2015 as accepted by DG MARE 21 September 2016. Ares(2016)5475305 - BE - Acceptance of Annual Report for 2015 - Data Collection Framework.

ical working conditions on board. For the TBB_DEF_<=221 kW fleet segment, all hauls are sampled by an observer (only when large amounts of small fish are caught, the next haul might be skipped for sampling in order to be able to process the entire catch). The crew is sorting the marketable fish from the conveyor belt and stores the marketable fish per species for the observer to sample later on. In the meantime, the observer is sampling the discarded fraction of the catch by sorting all commercially important species, i.e. selected set of species. The total weight per species in each haul is determined and lengths are measured. When a species is extremely abundant, a smaller representative subsample (TSU) is measured. The marketable part of the catch (landings) is sampled in the same way as the discarded part of the catch.

During each trip, otoliths from minimum 3 fish per cm-size class per species per area, are collected (except for cod one fish per cm-size class) for age estimations. Otoliths are collected throughout the whole trip (several hauls) until the quota of otoliths is achieved. For the discarded part of the catch, otoliths are being removed on board. For the retained part (landings) of the catch, the fish are purchased for age determination. For each fish the weight, sex and maturity (from December until April) are determined. In the former Belgian AR[2], the sampling of those individual parameters was referred to as 'on shore sampling'.

All the at sea sampling data are stored in a national database called 'SmartFish'. For quality assurance and analyses (e.g. raising) of the catch data, R packages (COST) and Excel applications are being used.

4.2.2.4 Sampling strategy optimization

In the upcoming years, Belgium will invest in the further optimization of the design of the at-sea sampling programme. The ultimate goal is to make the most efficient use of sampling resources and collect unbiased and precise catch data. This stepwise optimization process will be executed during the period 2017–2019 and involves running a series of statistical analyses (random effects analysis using the at-sea sampling data from the last decade), and including investigating self-sampling options in the Belgian fleet.

4.2.2.5 Sampling achievements

The following data have been supplied for ICES data calls:

WHG 7.a: (2012–2014) Raised length–frequency distribution; raised discards by auxiliary variable whiting landings.

HAD 7.a: (2012–2014) Raised length–frequency distribution; Raising discards by auxiliary variable landings of haddock.

PLE 7.a: (2004–2014) Raised length and age frequency distribution; Raising discards by auxiliary variable landings of plaice.

COD 7.a: (2004–2014) Raised length and age frequency distribution; raised discards: using auxiliary variable effort (number of hauls) up to 2014 and cod landings from 2014 onwards.

Sampling achievements for at-sea sampling are given for plaice, cod, whiting and haddock in Tables 4.2.1 to 4.2.4. Additional market sample collections for plaice are given in Table 4.2.5.

Table 4.2.1. Irish Sea plaice: At-sea sampling achievements for the Belgian beam trawl fleet.

Year	(a) No. trips by total fleet in VIIa	(b) No. trips sampled in VIIa (observers)	(c) No. sampled trips where discards data are recorded (even if zero)	(d) No. sampled trips with observed plaice discards (i.e. excluding zero discards)	(e) No. sampled trips with plaice length data (at sea sampling)		(f) No. sampled trips where plaice age samples collected (at sea sampling)		(g) No. individual plaice aged over all trips (at sea sampling)	
					DIS	LAN	DIS	LAN	DIS	LAN
2004	153	5	5	5	5	5	5	2	387	100
2005	196	3	3	3	3	3	3	1	228	40
2006	118	4	4	4	4	4	4	2	271	184
2007	103	10	10	10	10	10	10	4	646	371
2008	60	6	6	6	6	6	6	3	363	278
2009	66	5	5	5	5	5	5	2	332	220
2010	69	8	8	7	7	7	7	5	461	524
2011	78	6	6	6	6	6	6	5	400	402
2012	67	3	3	3	3	3	3	2	210	197
2013	48	10	10	10	10	10	11	8	649	498
2014	33	8	8	8	8	8	8	7	478	350
2015	26	6	6	6	6	6	6	6	367	430

Table 4.2.2. Irish Sea cod: At-sea sampling achievements for the Belgian beam trawl fleet.

Year	(a) No. trips by total fleet in VIIa	(b) No. trips sampled in VIIa (observers)	(c) No. sampled trips where discards data are recorded (even if zero)	(d) No. sampled trips with observed cod discards (i.e. excluding zero discards)	(e) No. sampled trips with cod length data (at sea sampling)		(f) No. sampled trips where cod age samples collected (at sea sampling)		(g) No. individual cod aged over all trips (at sea sampling)	
					DIS	LAN	DIS	LAN	DIS	LAN
2004	153	5	5	5	5	5	5	5	321	414
2005	196	3	3	3	3	3	3	3	233	284
2006	118	4	4	4	4	4	4	4	203	271
2007	103	10	10	10	10	10	10	10	623	698
2008	60	6	6	3	3	3	3	3	79	187
2009	66	5	5	5	5	4	5	4	171	95
2010	69	8	8	7	7	7	7	7	540	208
2011	78	6	6	6	6	6	6	6	604	397
2012	67	3	3	3	3	3	3	3	178	228
2013	48	10	10	8	8	9	8	8	176	252
2014	33	8	8	8	8	8	8	7	313	286
2015	26	6	6	4	4	6	4	5	9	416

Table 4.2.3. Irish Sea whiting: At-sea sampling achievements for the Belgian beam trawl fleet.

Year	(a) No. trips by total fleet in VIIa	(b) No. trips sampled in VIIa (observers)	(c) No. sampled trips where discards data are recorded (even if zero)	(d) No. sampled trips with observed whiting discards (i.e. excluding zero discards)	(e) No. sampled trips with whiting length data (at sea sampling)		(f) No. sampled trips where whiting age samples collected (at sea sampling)		(g) No. individual whiting aged over all trips (at sea sampling)	
					DIS	LAN	DIS	LAN	DIS	LAN
2004	153	5	5	5	5	1	5	1	379	22
2005	196	3	3	3	3	3	3	3	224	77
2006	118	4	4	4	4	4	4	3	265	64
2007	103	10	10	10	10	9	10	9	658	237
2008	60	6	6	6	6	3	6	3	342	84
2009	66	5	5	5	5	5	5	5	319	141
2010	69	8	8	7	7	6	7	6	400	211
2011	78	6	6	6	6	6	6	6	401	245
2012	67	3	3	3	3	3	3	3	215	93
2013	48	10	10	10	10	10	0	0	0	0
2014	33	8	8	8	8	7	0	0	0	0
2015	26	6	6	6	6	5	0	0	0	0

Table 4.2.4. Irish Sea haddock: At-sea sampling achievements for the Belgian beam trawl fleet.

Year	(a) No. trips by total fleet in VIIa	(b) No. trips sampled in VIIa (observers)	(c) No. sampled trips where discards data are recorded (even if zero)	(d) No. sampled trips with observed haddock discards (i.e. excluding zero discards)	(e) No. sampled trips with haddock length data (at sea sampling)		(f) No. sampled trips where haddock age samples collected (at sea sampling)		(g) No. individual haddock aged over all trips (at sea sampling)	
					DIS	LAN	DIS	LAN	DIS	LAN
2004	153	5	5	5	5	2	5	2	349	93
2005	196	3	3	3	3	3	3	3	262	183
2006	118	4	4	4	4	4	4	4	278	243
2007	103	10	10	10	10	10	10	10	551	468
2008	60	6	6	3	3	2	3	2	149	158
2009	66	5	5	5	5	5	5	5	320	226
2010	69	8	8	7	7	6	7	6	467	305
2011	78	6	6	6	6	6	6	6	420	280
2012	67	3	3	2	2	1	2	1	98	53
2013	48	10	10	7	7	5	0	0	0	0
2014	33	8	8	7	7	7	0	0	0	0
2015	26	6	6	4	4	5	0	0	0	0

Table 4.2.5. Market sampling for plaice in Belgium. Trips refers to fishing trips sampled.

Market sampling		
Year	No. sampled trips where plaice age samples collected	No. individual plaice aged over all trips
2004	1	50
2005	5	285
2006	7	427
2007	2	137
2008	1	172
2009	4	421
2010	0	0
2011	3	370
2012	2	246
2013	0	0
2014	0	0
2015	0	0

4.3 Port sampling and at-sea sampling achievements in Northern Ireland

4.3.1 Port sampling

4.3.1.1 Sampling frame

The sampling frame for port sampling in Northern Ireland is the three main harbours (Kilkeel, Portavogie and Ardglass; Figure 4.3.1) which account for over 90% of the total catch of the fleet. Following the recommendations of WKPRECISE, WKMERGE and PGCCDBS 2009 and 2010, shore-based sampling of landings in Northern Ireland is based on randomised selection of vessel landings during port sampling. Dates of visits are not preselected by a randomised design due to the low level and infrequency of market events, but are responsive to the markets occurring. A minimum of 15 port visits are carried out per annum.

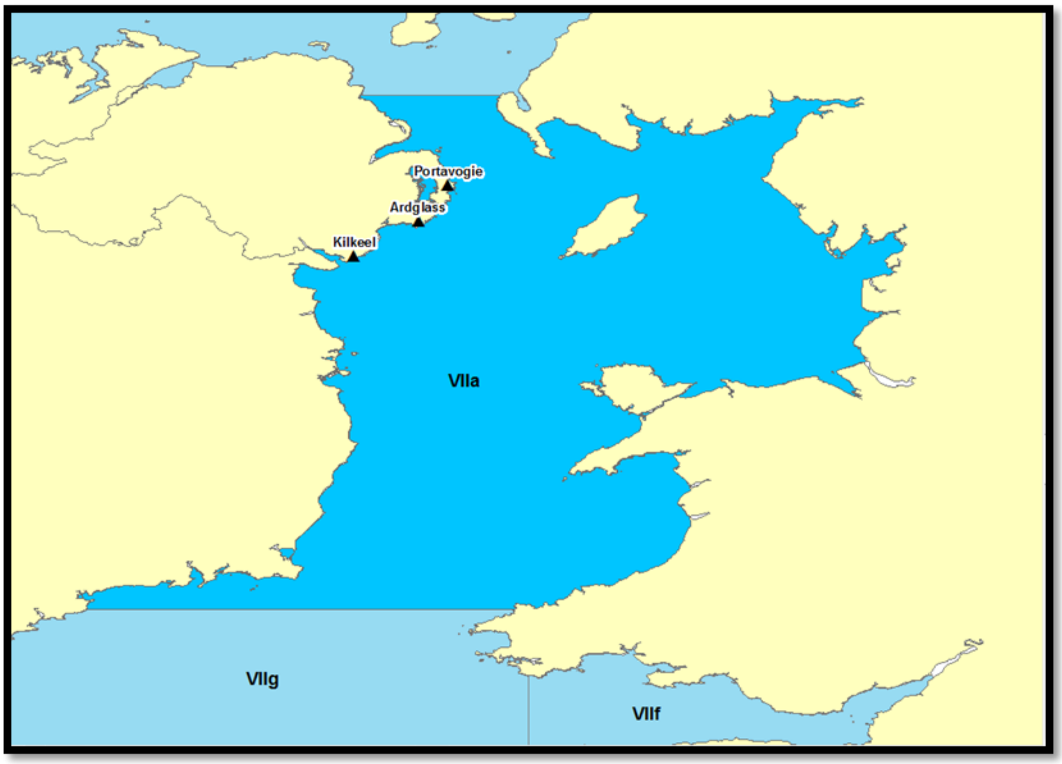


Figure 4.3.1. Ports sampled in Northern Ireland.

4.3.1.2 Sample selection

For each vessel randomly selected during a port visit, the total weight of each species caught is recorded by commercial size category (including mixed categories). For the main commercial species (cod, haddock, whiting, herring, plaice, hake) the length frequency is recorded from all boxes within a commercial size category or an appropriate subsample of boxes is taken. The total weight of subsample is recorded to give the raising factor. Length frequencies are recorded per centimetre class.

Sampling of fish to collect otoliths at the three Northern Ireland markets is not feasible due to the short time period between fish being landed and processed for sale. Samples are therefore selected from the available landings and purchased for processing at the lab. During periods of reduced fishery activity purchase of samples is not feasible when there is high demand for fish from buyers.

4.3.1.3 Sampling achievements

Collection of age (and length) samples of landings is becoming more problematic due to the poor availability of fish with low TACs at markets. In recent years, there has been a general reduction in fish catches, and alterations to the way the fleets operate. This has an implication on trips/métier and the sampling of affected métiers in Northern Ireland. Fish landings from the *Nephrops* fleet have also decreased dramatically. Numbers of fishing trips sampled for cod, haddock, plaice and whiting are given in Table 4.3.1.

Table.4.3.1. Number of fishing trips sampled from 7.a at port visits in Northern Ireland where length–frequency data were obtained. Numbers aged are from separate samples purchased at auctions. Data have been collected for a longer period but are only shown from 2005.

Year	Number of fishing trips				Number of fish aged			
	COD	HAD	WHG	PLE	COD	HAD	WHG	PLE
2005	45	14	0	0	445	283	0	0
2006	16	9	0	0	341	158	0	-0
2007	19	10	0	0	328	429	0	-0
2008	92	58	0	2	174	227	0	-0
2009	149	122	6	8	482	287	0	-0
2010	89	80	7	18	367	204	0	-0
2011	39	23	3	5	101	144	0	-0
2012	128	127	11	59	0	592	2	-0
2013	119	122	8	13	1257	344	2	-0
2014	127	93	18	49	301	0	0	-0
2015	62	87	19	25	21	301	0	-0
2016	6	10	1		17	103	0	-0

Data correct as of 29th September 2016.

4.3.2 Discards sampling

Northern Ireland operates a self-sampling scheme for *Nephrops* trawlers since 1996, as well as a more recent observer scheme.

4.3.2.1 Self-sampling scheme; Northern Ireland

A reference fleet of vessels for *Nephrops* catch sampling through fisher self-sampling. Selected vessels are from main Northern Irish ports. The reference vessels selection is designed to be representative of the entire fleet with systematic rota sampling. The reference fleet contain vessels using both single and twin rig gears, with a composition to reflect the make-up of the national fleet. . It is stratified by quarter. Samples of retained and discarded fractions from a single haul are left by the skippers of the vessel selected for the self-sampling scheme. The sample received to the laboratory is a small sample of the full catch, thus it is extremely necessary that is fully representative of the catch as a whole.

The discards samples contain the heads of *Nephrops* tailed at-sea. Using a length–weight relationship, the live weight of *Nephrops* that would have been landed as tails only is calculated from the carapace lengths of the discarded heads. Discard estimates of fish species is estimated by summing the discard weight, by species, for all samples in a quarter and expressed as a ratio of the summed live weight of *Nephrops* in the discard samples (i.e. those represented as heads only in the samples). The reported live weight of *Nephrops* landed as tails only is then used to estimate the quantity of cod or haddock discarded using the cod or haddock:*Nephrops* ratio in the discard samples. The length frequency of cod in the discard samples is then raised to the fleet estimate. To provided international estimates this is raised to the by the ratio of Northern Irish *Nephrops* landings to international *Nephrops* landings. In years prior to the self-sampling scheme the ratio of numbers-at-age of discarded cod and haddock:*Nephrops* landings in the unsampled year is used to provide an estimate of discards. In years where sampling of other fisheries has occurred these are added to the international discard estimates of the *Nephrops* fleet.

Table 4.3.2. Number of trips providing samples of discards in the NI self-sampling scheme. Numbers of fish aged are shown

	Quarter				Number of fish aged			
	1	2	3	4	Cod	Haddock	Whiting	Plaice
2006			9					
2007			27					
2008	0	3	29	20				
2009	11	47	72	46	0	0		
2010	55	9	9	16	4	61	65	
2011	34	13	11	20	6	151	165	35
2012	31	30	33	14	30	649	831	443
2013	12	6	16	23	56	509	599	219
2014	27	37	32	29	88	442	580	305
2015	39	26	36	16	64	163	251	68

4.3.2.2 Fleet observer trips

4.3.2.2.1 Sampling frame

The sampling frame providing observer data for cod, haddock, whiting and plaice is a list of vessels in the *Nephrops* and whitefish fleet operating from the three ports in Northern Ireland.

4.3.2.2.2 Stratification and sample selection

Following the recommendations of WKPRECISE, WKMERGE and PGCCDBS 2009 and 2010, new sampling schemes for demersal fisheries were set up by AFBI in 2013 implemented from 2014 onwards.

Selection of vessels for at-sea sampling in Northern Ireland is based on a target of trips that can be sampled by a fixed number of observers per quarter with random sampling of vessels within given métiers. The vessels selected for sampling are stratified by the number of vessels within strata defined by area and gear and mesh size. Selection of sample sizes is designed to provide highest possible levels of precision of sampled catches based on observed variance within strata.

The adoption of this probability-based sampling should provide representative and unbiased data for the various fisheries active during the year. An important consequence of the move away from quota sampling is that the achieved sampling of Level 6 métiers should more closely reflect their relative occurrence in the fleet activities in the current sampling year.

Whilst the theory behind statistically sound fishery sampling is well established, the practical implementation faces many logistical difficulties, and the current scheme is designed to mitigate against many of these. However, it remains difficult to overcome short-term changes in behaviour such as fishing area decisions of skippers.

From 2005 to present length frequencies from NI (AFBI) observer trips in specified fleet métiers are raised to the trip level, summed across trips during each year or by quarter, then raised to the annual number of trips per year in the NI fleet in 7.a to give raised annual LFDs for discards. An age–length key from discards trips is then applied to give annual discards by age class and métier.

4.3.2.2.3 Sampling achievements

As a result of reducing sampling opportunities at the ports, the sampling effort for biological samples has shifted to at-sea observation, which dramatically increased sampling levels of length and age information. As planned, permanent recruitment of observers has reduced subcontracting costs. The increasing shift to observer sampling also resulted in a significant increase in the observer sample cost (skipper fees similar to England).

A combination of changes in fleet behaviour and TAC restrictions was limiting sampling opportunities for some métiers. There is only a small number of vessels involved in directed whitefish fleet (OTM_DEF métier), targeting haddock, operating in 7.a due to severe TAC restrictions. These vessels operate under specific criteria with 100% observer coverage. The activity of the OTM_DEF vessels targeting haddock with complete observer coverage has enabled a high level of sampling of haddock landings. There is no OTM_DEF targeting other species resulting in almost non-existent sampling opportunities for other demersal species. As concerns FPO_CRU, there are no onshore markets for this métier in Northern Ireland that would facilitate sampling of landings, and sampling of this métier can only be done at sea, which makes it logistically difficult due to the small size of the vessels.

Table 4.3.3 shows the number of trips sampled by observers for otter and beam trawl fleets and other gears, together with the total number of recorded trips in 7.a.

Table 4.3.3. Number of trips in Northern Ireland fleet sampled by observers for otter and beam trawl fleets and other gears, together with the total number of recorded trips in 7.a.

	Number of trips from Northern Irish vessels sampled by discard observers in 7.a						Total number of triops from Northern Irish registered vessels in the 7.a fleet				
YEAR	OTB	OTB_CRU	OTB_DEF	OTM_DEF	TBB_DEF	OTHER	OTB*	OTB_CRU	OTB_DEF	OTM_DEF	TBB_DEF
2005	1	58	0	0	0	0		9095	435	482	22
2006	0	9	0	0	0	0		8242	281	419	32
2007	0	22	0	0	0	0		7911	230	194	42
2008	0	65	0	0	0	0		8503	147	298	30
2009	2	49	0	1	0	0		8451	124	232	25
2010	1	54	0	3	0	4		7322	101	204	30
2011	0	37	0	1	0	4		6978	180	95	24
2012	7	174	1	0	0	7		7147	260	19	27
2013	5	197	1	14	0	10		6675	663	18	26
2014	0	200	0	27	0	3		6236	319	60	
2015	0	128	0	26	0	5		5977	513	61	19

*** Target species unknown.**

Table.4.3.4. Number of fishing trips on which cod, haddock, plaice and whiting were observed and age samples taken.

	Cod			Had			Plaice			Whiting		
Year	Retained	Discard	Age	Retained	Discard	Age	Retained	Discard	Age	Retained	Discard	Age
2005	7	52	0	15	59	0	21	2	0	59	59	0
2006	4	3	0	4	9	0	2	1	0	9	8	0
2007	15	12	0	10	21	0	12	5	0	21	20	0
2008	41	16	0	31	58	0	15	10	0	66	58	0
2009	31	22	0	26	40	0	18	12	0	49	38	0
2010	28	32	0	26	53	0	20	22	0	58	50	0
2011	26	12	0	26	37	0	13	10	0	38	35	0
2012	68	101	30	82	147	23	78	32	23	171	150	28
2013	81	107	33	115	189	30	62	53	29	205	180	34
2014	106	92	80	123	213	63	85	65	50	217	199	72
2015	65	64	60	99	142	30	41	38	24	146	123	57
2016	29	36	8	69	97	3	22	22	2	102	93	7

4.4 Port sampling and at-sea sampling achievements in Southern Ireland

4.4.1 Description of the port sampling programme

Since 2016: Sampling of 7.a fish mainly takes place in three ports on the east coast of Ireland as well as one port in the southeast where some 7.a fish are also landed. The target number of trips for the east coast ports is around 14 per year. Since 2016 the targets are set by quarter and port and are based on the landings of demersal fish species in the previous two years. The selection of which species are sampled on port visits is based on target number of samples per stock. For 7.a cod, haddock, whiting and plaice these targets are five samples per quarter. For some of these stocks landings occur sporadically and the targets can be difficult to achieve. The targets for age sampling are one fish per cm per sample for cod, haddock and whiting and two fish per cm for plaice. These targets may be increased of the overall number of age samples is low.

Prior to 2016 the sampling design was driven mainly by otolith targets by quarter and division. The targets for 7.a cod and haddock were 500 per quarter, plaice 250 per quarter and for whiting no targets were set; these were sampled opportunistically due to their sporadic availability.

Samples of the landings from the ports are supplemented by landings samples taken at-sea. For these samples no age data are collected.

4.4.2 Sample numbers

WGIrish2 agreed to provide estimates of the age distributions in the landings for the following fleets: OTB_CRU, OTB_DEF, TBB_DEF and OTM_DEF (Ireland has no OTM_DEF fleet). The number of landings samples by fleet are given below. Note that these are the total number of sampling events; the sample numbers for each species are considerably lower.

	Market samples 7.a				At-sea landings samples 7.a				Total
Year	OTB*	OTB_CRU	OTB_DEF	TBB_DEF	OTB*	OTB_CRU	OTB_DEF	TBB_DEF	
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000									
2001	37	0	0	37	0	0	0	0	74
2002	52	0	0	34	0	0	0	0	86
2003	21	16	8	72	0	0	0	0	117
2004	17	10	7	30	0	0	0	0	64
2005	9	15	15	49	0	0	0	0	88
2006	15	26	7	45	0	0	0	0	93

	Market samples 7.a				At-sea landings samples 7.a				Total
Year	OTB*	OTB_CRU	OTB_DEF	TBB_DEF	OTB*	OTB_CRU	OTB_DEF	TBB_DEF	
2007	19	19	18	54	7	6	0	3	126
2008	37	19	9	43	5	10	0	3	126
2009	19	16	13	8	0	7	1	3	67
2010	11	15	7	17	1	9	0	3	63
2011	3	24	4	15	0	8	3	3	60
2012	2	6	12	15	1	9	5	1	51
2013	2	5	17	8	1	8	4	2	47
2014	0	12	5	1	0	6	2	0	26
2015	0	8	3	2	0	9	5	0	27

*** Target species unknown.**

4.4.3 Quality indicators

None.

4.4.4 At-sea sampling

4.4.4.1 Sampling frame

The sampling frame is a list frame of all national registered vessels using towed demersal otter trawls, beam trawls and seines as well as gillnets. For Irish Sea gadoids and plaice, vessels in the frame with activity in the following métiers are relevant to Ireland: GNS_DEF_>=220_0_0; OTB_CRU_70-99_0_0; OTB_CRU_70-99_0_0; OTB_DEF_70-99_0_0; SSC_DEF_70-99_0_0 and TBB_DEF_70-99_0_0.

4.4.5 Description of the sampling programme

The Irish demersal observer programme was described in the Annex 2 table to WGCSE 2015 and in Anon (2011). Up to now the programme has been stratified by métier and quarter; sampling plans are based on recent fishing patterns and available resources. In recent years the annual targets of observer trips in 7.a was as follows:

Métier	Annual target
OTB_CRU	16
OTB_DEF	4
TBB_DEF	6
GNS_DEF	2

Within the sampling frame there is non-random selection of vessels on opportunistic basis to meet sampling quotas by métier. Cooperation with sampling programmes is not universal with some vessels refusing to take observers. The primary sampling unit can be described as the trip. There does not seem to be a spatial difference between sampled hauls and fleet hauls.

Generally one box of discards is sampled per haul. The total volume of discards per haul is estimated from the difference of the estimated weight of the catch and the weight of the landings. For relatively rare species that can be sorted from the total discards, like cod, the total discards for the haul may be sampled.

The majority of observer trips take place on vessels targeting *Nephrops* (defined as landings of >30% *Nephrops*). Sampling of the other fleets is very variable, and it is not possible to provide estimates for other fleets in most years. An analysis of Irish discard data from 2003–2009 (Anon, 2011) showed that the *Nephrops* fleet accounts for 71% of the haddock discards, 89% of whiting discards, 72% of plaice discards and 58% of cod discards (the remainder of cod discards were estimated to come from the beam trawl fleet; this fleet has now mainly moved to the Celtic Sea). **WKIrish2 decided that Ireland would only provide discard estimates for the *Nephrops* fleet.** It may be possible to provide a rough estimate of the discard rate of the remaining fleets by combining data for all years and checking whether there is a relationship between the landings and discards. If this relationship exists, it may be possible to estimate the discards as a ratio of the landings. This is one of the approaches used in InterCatch. WKIrish2 did not have sufficient time to explore this, but as mentioned above, the majority of the discards result from the *Nephrops* directed fleet, which has by far the most effort.

Due to the relatively small number of trips in each quarter, WKIrish2 decided to pool the annual data without stratifying by quarter.

The primary sampling unit of this sampling programme is the trip, so the default raising variable would be the total number of trips in the fleet. **However WKIrish2 decided to use effort (hours fished) as raising variable for the discards** for the following reasons:

- The number of trips is not available from the logbooks prior to 2003. The effort in hours fished is available for the full time-series (1995 onwards). Effort and number of trips correlate well and there is no trend in the average effort per trip over time.
- The fleet is increasingly mobile and in recent years 5–10% of the trips that fish in 7.a also fish in other divisions. Using effort automatically accounts for any discrepancies between the proportion of sampled trips that also fish in multiple divisions and the total proportion of trips that fish in multiple divisions.
- Using effort as raising variable would also account for any differences in the trip duration of the sampled trips vs. the total population of trips.

4.4.6 Sample numbers

The achieved sampling trips are given below. These trips typically represent around 1% of the total number of trips.

	Sampled trips					Total number of trips in the fleet				
Year	OTB_CRU	OTB_DEF	TBB	GNS	SSC	OTB_CRU	OTB_DEF	TBB	GNS	SSC
1996	4	6	1	0	1	1154	780	303	243	77
1997	3	6	2	0	1	1265	508	214	121	71
1998	4	6	2	0	1	1260	437	231	80	33
1999	2	2	2	0	1	1364	353	154	91	61
2000	6	2	0	0	0	1492	677	230	168	122
2001	2	0	2	0	0	1342	303	146	174	94
2002	1	0	0	0	0	959	313	129	210	33
2003	7	3	0	0	0	1048	334	124	178	18
2004	10	3	0	0	0	1168	257	120	102	54

	Sampled trips					Total number of trips in the fleet				
Year	OTB_CRU	OTB_DEF	TBB	GNS	SSC	OTB_CRU	OTB_DEF	TBB	GNS	SSC
2005	8	0	0	0	0	1459	208	109	86	109
2006	5	1	0	0	0	1155	262	64	55	82
2007	15	0	3	0	1	1248	291	100	33	57
2008	17	1	3	0	1	1120	271	131	14	70
2009	10	1	3	0	0	1154	780	303	243	77
2010	17	1	3	1	0	1265	508	214	121	71
2011	10	3	3	3	0	1260	437	231	80	33
2012	13	6	1	0	0	1364	353	154	91	61
2013	11	4	2	0	0	1492	677	230	168	122
2014	12	2	0	0	0	1342	303	146	174	94
2015	10	7	0	0	0	959	313	129	210	33

WKIrish2 decided that sample numbers prior to 2003 were insufficient to provide discard estimates.

4.4.7 Quality indicators

WKIrish examined the spatial distribution of the sampled trips and compared it with the VMS data from total population of trips. Figure 4.4.7 shows that the distribution of the sampled trips in the western Irish Sea is not obviously different from the total population of trips. The number of trips in the eastern Irish Sea is negligible.

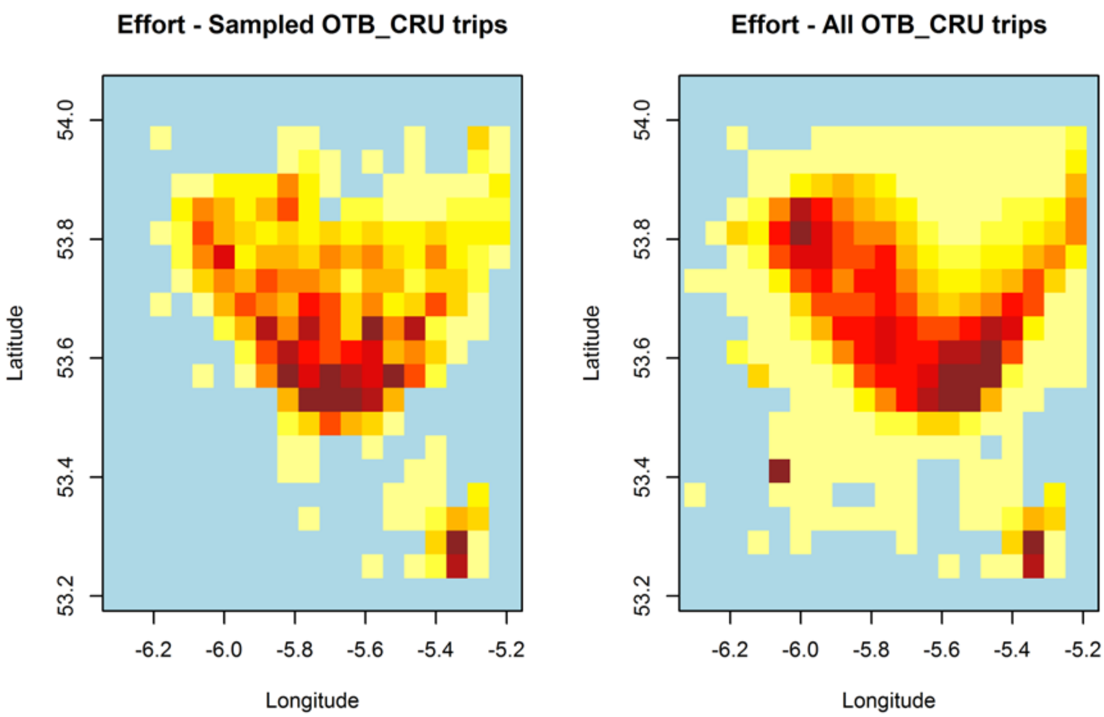


Figure 4.4.7. Spatial distribution of fishing effort of the sampled *Nephrops* trips (2003–2015; left) and the total population of trips from the VMS data (2008–2012).

Other characteristics of the sampled trips are explored in Figure 4.4.7.1, which shows a comparison of some of the characteristics of the total population of *Nephrops*-targeted trips in 7.a with the sampled trips. In general, the sampled trips appeared to be reasonably representative. Day trips and smaller vessels were slightly under-sampled. The sampled vessels appeared to have similar histograms of the landings per trip to the total population, suggesting they are representative of the fleet.

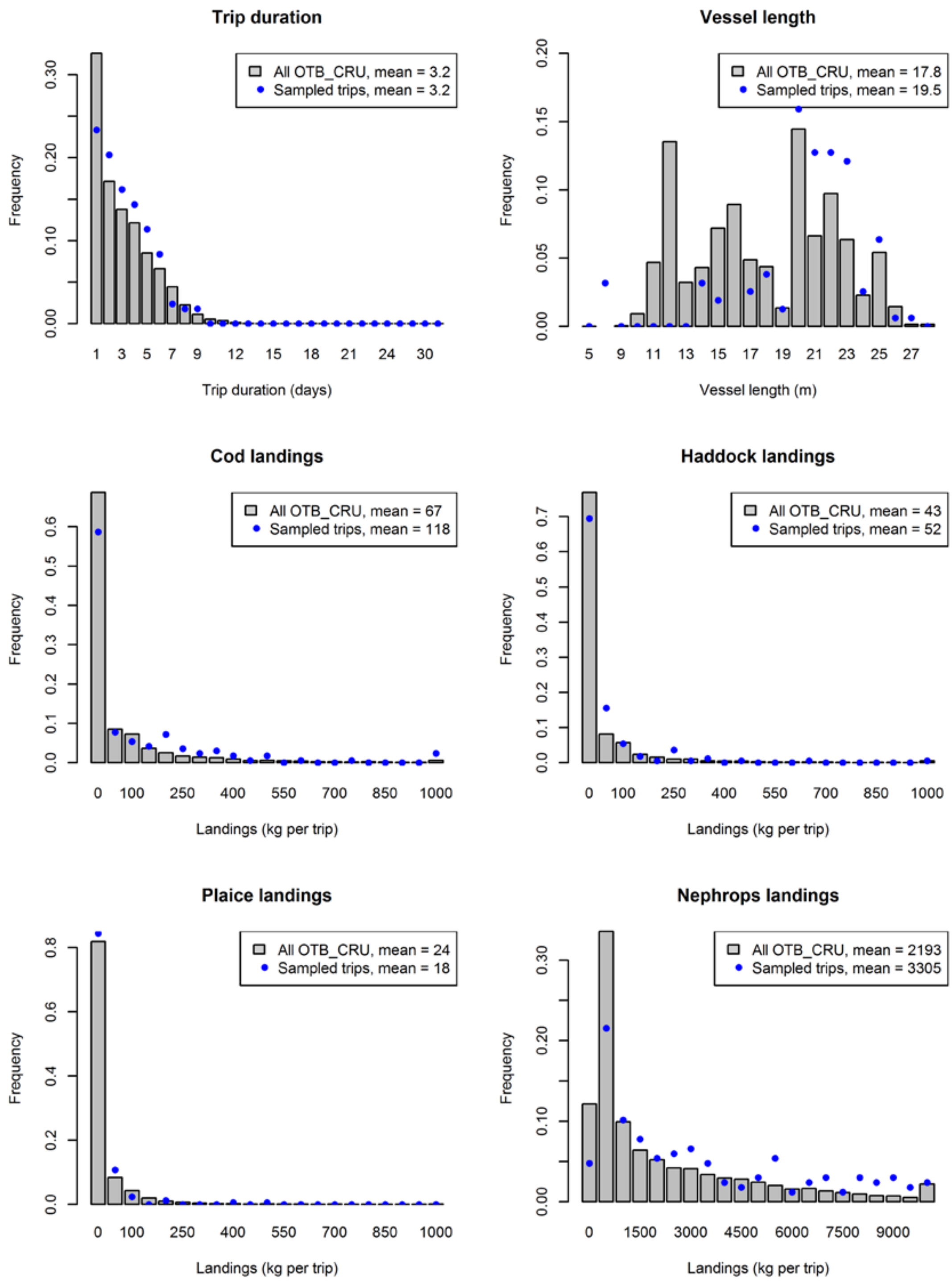


Figure 4.4.7.1. Comparison of the logbook data of *Nephrops*-targeted OTB trips in 7.a (2003–2015) with the sampled trips. It appears that day-trips were slightly undersampled, however the mean trip duration of the sampled trips was the same as that of the total population of logbook trips (top-left). Trips on 10–15 m vessels were somewhat undersampled (top-right). The sampled trips had similar distributions of cod, haddock, plaice and *Nephrops* landings to the total population of trip but note that the mean landings per trip were somewhat different between the sampled trips and the total population of trips, particularly for cod and *Nephrops*.

One further quality indicator is how well landings can be estimated from the observer programme (Figure 4.4.7.2). For cod, the estimated landings were of the same order of magnitude as the logbooks data. For haddock and plaice the estimated landings were quite close to the logbooks, showing similar trends as well as absolute values. The sampling programme did not appear to be able to estimate the whiting landings very well, though.

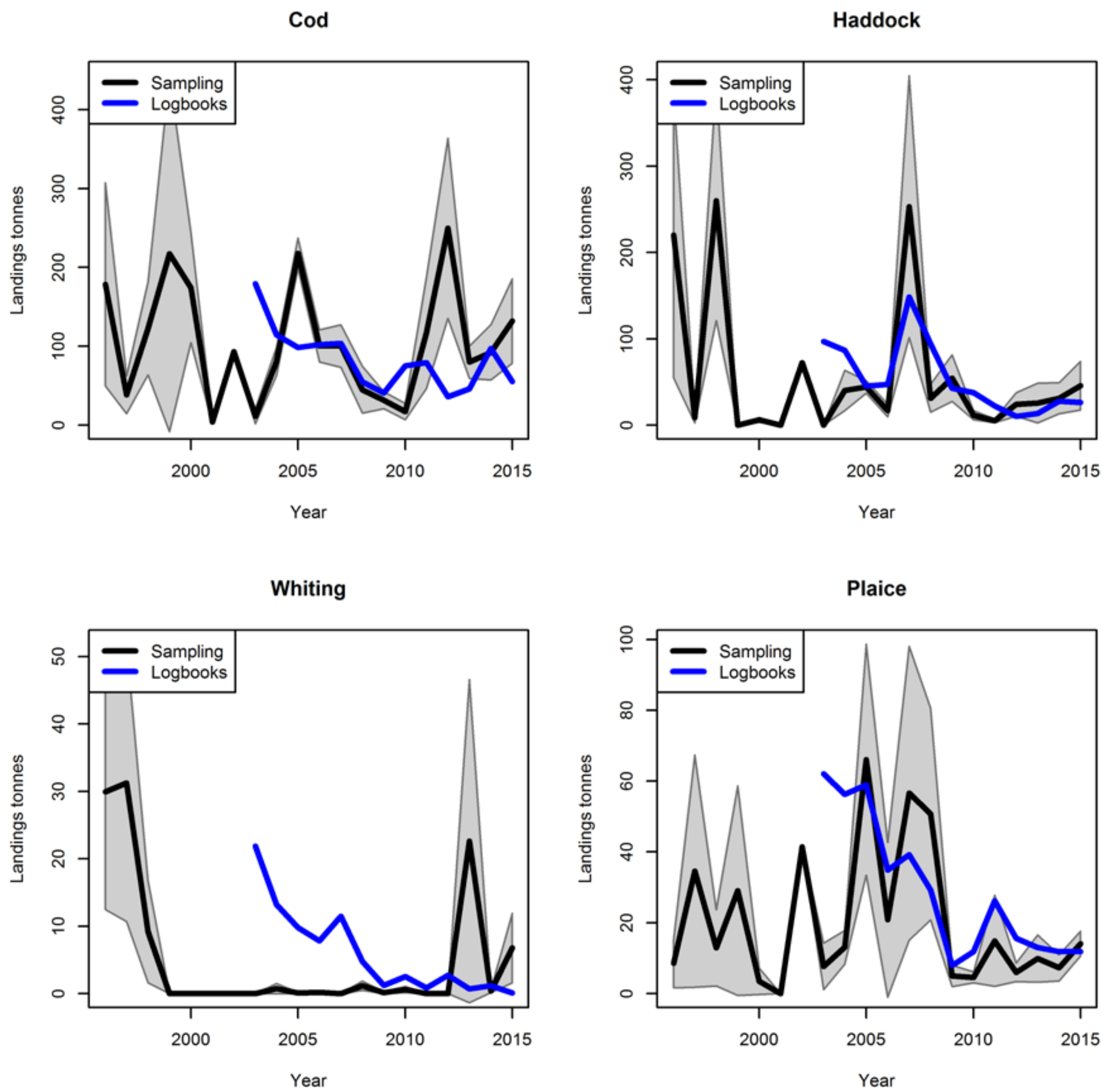


Figure 4.4.7.2. A comparison of landings recorded in logbooks (blue) to landings estimated from the at-sea sampling programme for cod, haddock, whiting and plaice in the Irish Sea.

4.4.8 Reference

Anon. 2011. Atlas of Demersal Discarding, Scientific Observations and Potential Solutions, Marine Institute, Bord Iascaigh Mhara, September 2011. ISBN 978-1-902895-50-5. 82 pp.

5 Data evaluation for Irish Sea whiting

5.1 Explain the basis for existing assumptions on stock structure and mixing rates between stock areas, or proposed new assumptions which form the basis for spatial aggregation of fishery and survey data and/or adjustments to datasets to account for stock mixing

The stock annex outlines the current stock structure for whiting in 7.a (Ref). Previously the 7.a whiting stock structure was the subject of a meeting and Working Document to WGNSSK (WD 10, Armstrong *et al.*, 2005). In summary, whiting spawn in the Irish Sea in spring in the eastern Irish Sea and in the coastal waters of the western Irish Sea, recruitment grounds are in the same general area as the spawning grounds. Historical tagging studies in the 1950s show some seasonal dispersal of larger whiting into the Clyde, eastern Irish Sea and Celtic Sea with evidence of return migrations. The age structure in the eastern Irish Sea is normally broader than in the west. This is possibly due to lower mortality in the east and incomplete mixing. However, up to now all catches in 7.a, except the two ICES rectangles in the very south of 7.a off Dunmore East (33E2 and 33E3) have been considered part of the Irish Sea stock.

WKIrish examined the following information at the meeting:

1) Age and growth data of whiting from Irish commercial sources.
2) Landings by rectangle information for 7.a and adjacent areas.
3) Spatio-temporal recruitment patterns on groundfish surveys available in DATRAS.
4) Correlations between groundfish surveys indices in 6.a, 7.a and 7.e–k.
5) Correlations between different strata on the two UK-NIGFs.

The age and growth data shown in Figure 5.1.1 from Irish commercial sources (market and observer trips) indicate whiting in 7.a on average have a consistently and significantly lower length-at-age compared with other areas around Ireland from age 1 to age 5. Observations over age 5 would be very sparse and unreliable. When the data are plotted by cohort (Figure 5.1.2) it is apparent that the asymptotic length in 7.a for most cohorts is around 35 cm. The asymptotic length in 6.a is slightly higher (~38 cm) whereas in other areas is significantly higher with the highest asymptotic lengths in 7.b (~52 cm) since 2008. These data appear to suggest significantly different growth rates in 7.a compared with other areas. This is a strong indicator that 7.a can be considered a different stock.

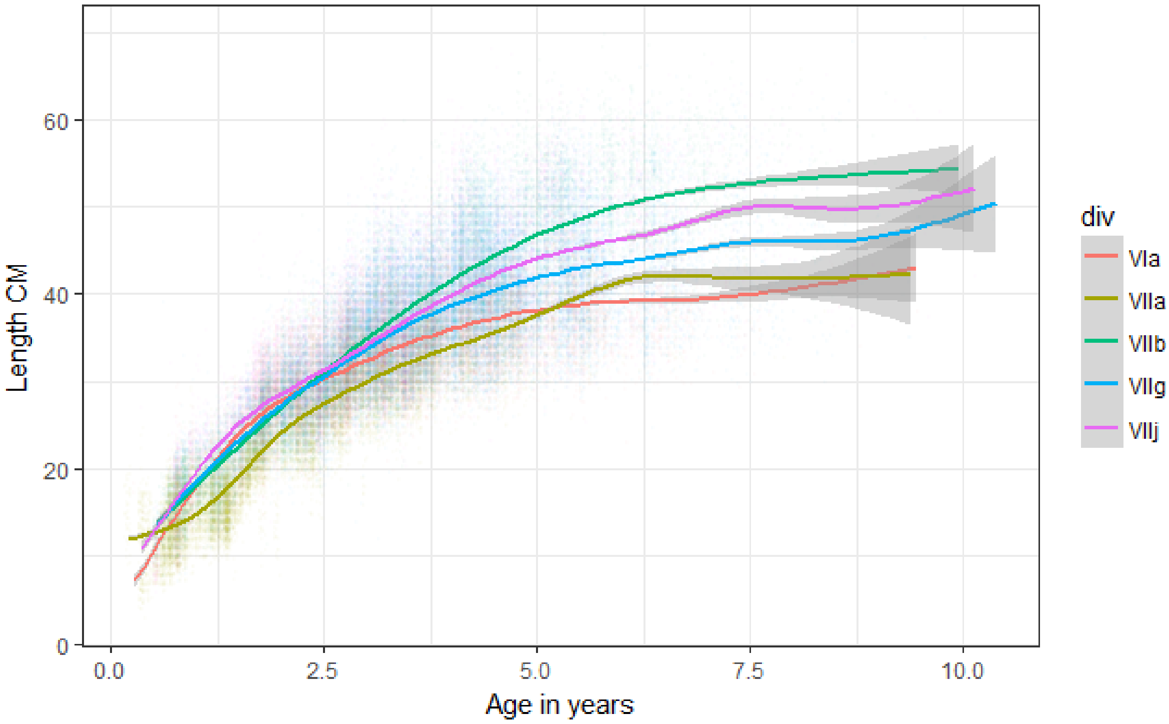


Figure 5.1.1. Scatterplot of length-at-age by month from Irish commercial sources from 1993–2016. A gam smoother with standard error shading is also shown.

International landings by rectangle and year available from STECF between 2003 and 2015 are plotted in Figures 5.1.3 and 5.1.4. In Figure 5.1.3 it is apparent that landings in 7.a are negligible compared with adjacent areas especially the Celtic sea. In Figure 4 focused on 7.a the declining trend in landings can be seen in most rectangles. Landing are higher in the western Irish Sea compared with the east. There is a discontinuity in landings by rectangle towards the south with low landings in the “34” rectangles. Landings along the southern boundary of 7.a in 33E3 and 33E4 have been reassigned to the Celtic Sea whiting stock in recent years. Landings along the northern boundary in the south of 6.a also show a declining trend. In the most recent years landings are negligible just north of 7.a. Landings data are not particularly informative about the distribution of the stock given the high discards particularly in the *Nephrops* fisheries in 7.a and 6.a.

Survey information for the various IBTS were downloaded from DATRAS and mapped by year in Figures 5.1.5 and 5.1.6 as part of the WKIrish investigations. Figure 5.1.5 shows the distribution of juveniles. What is interesting about this is that the *Nephrops* ground in the western Irish Sea and eastern Irish Sea account for the largest numbers juvenile whiting caught on all IBTS surveys around Ireland. There are relatively few juveniles caught in the Celtic Sea, west of Ireland and west of Scotland. The biomass maps (Figure 5.1.6) show a very different spatial pattern with high biomass in the Celtic Sea around the Smalls *Nephrops* ground and in the North Irish Sea in most years. There are occasional high biomasses in the Minches in early years and around the Stanton Bank in more recent years. There is apparent discontinuities in abundance in the south Irish Sea and in the North Channel area supporting the assumption that the main stock in the Irish Sea occurs east and west of the Isle of Man with lesser abundance in other areas.

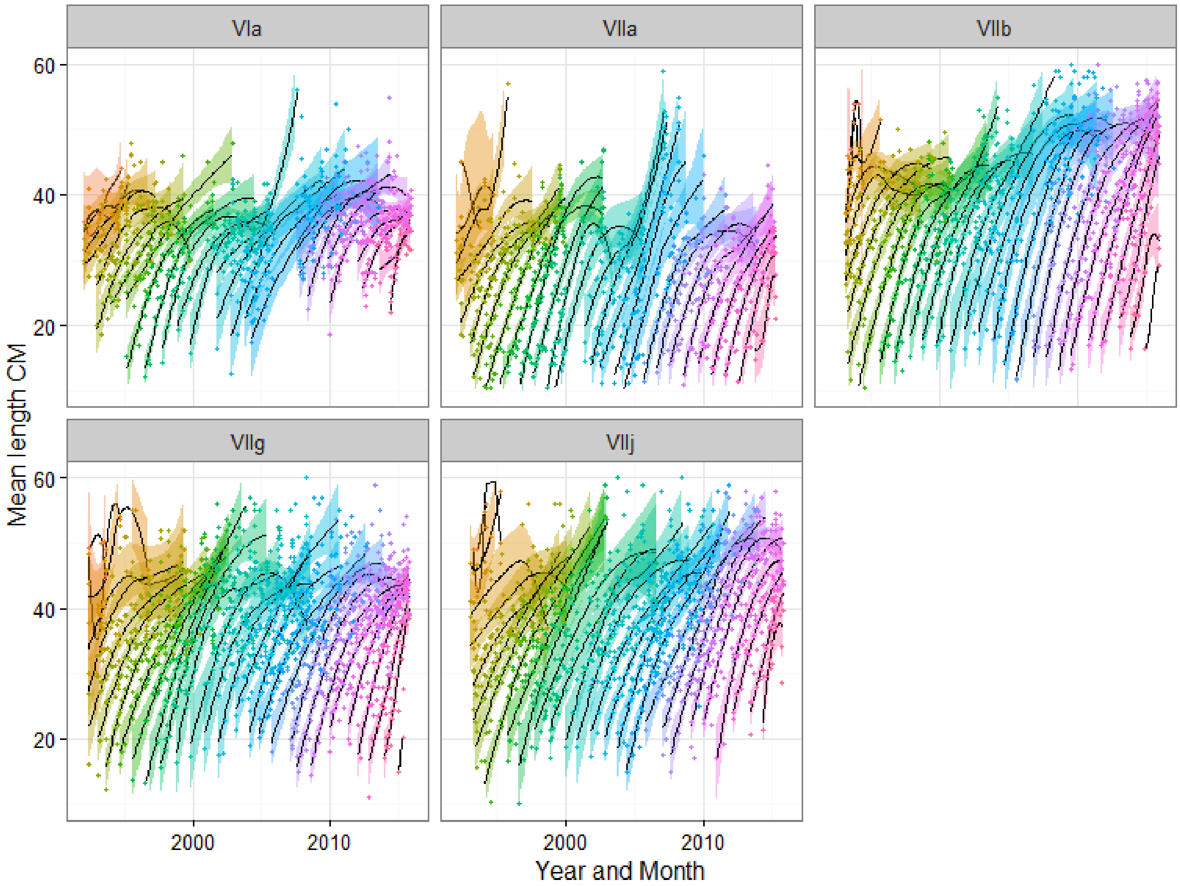


Figure 5.1.2 Scatterplot of mean length-at-age by month and cohort from Irish commercial sources from 1993–2016. A loess smoother with standard error shading is also shown.

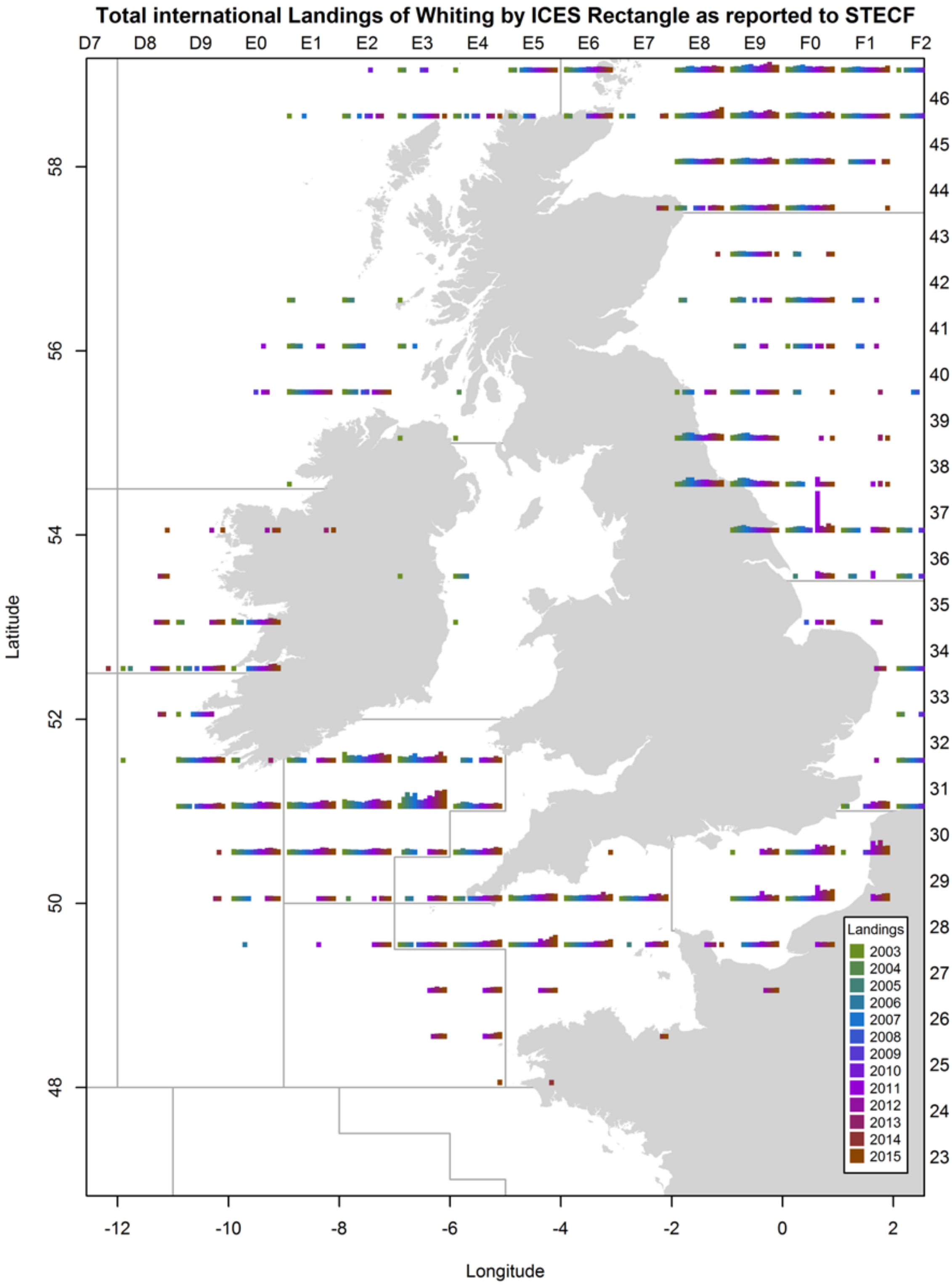


Figure 5.1.3. Time-series of international landings by rectangle from 2003 to 2015.

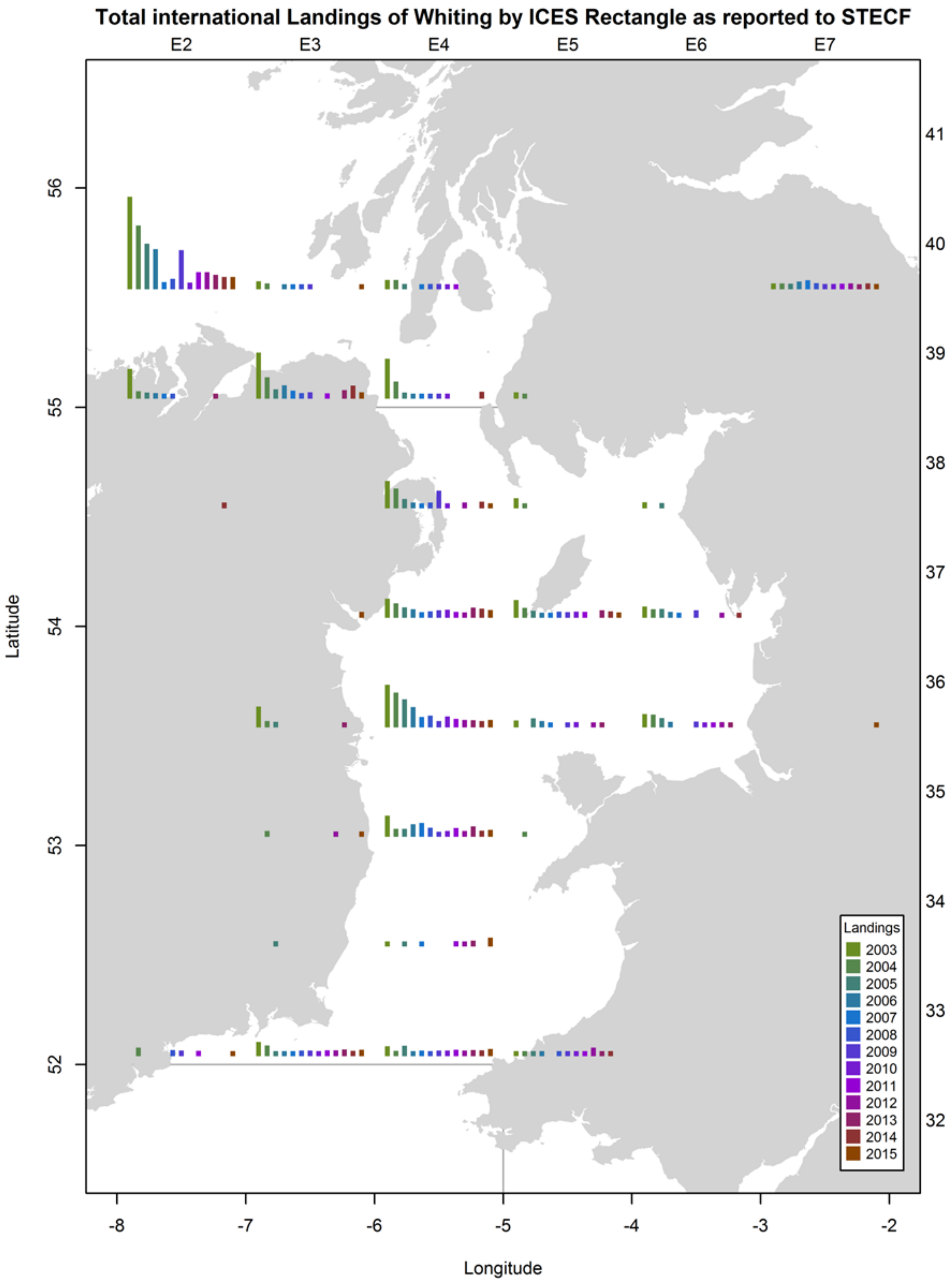


Figure 5.1.4. Time-series of international landings by rectangle from 2003 to 2015.

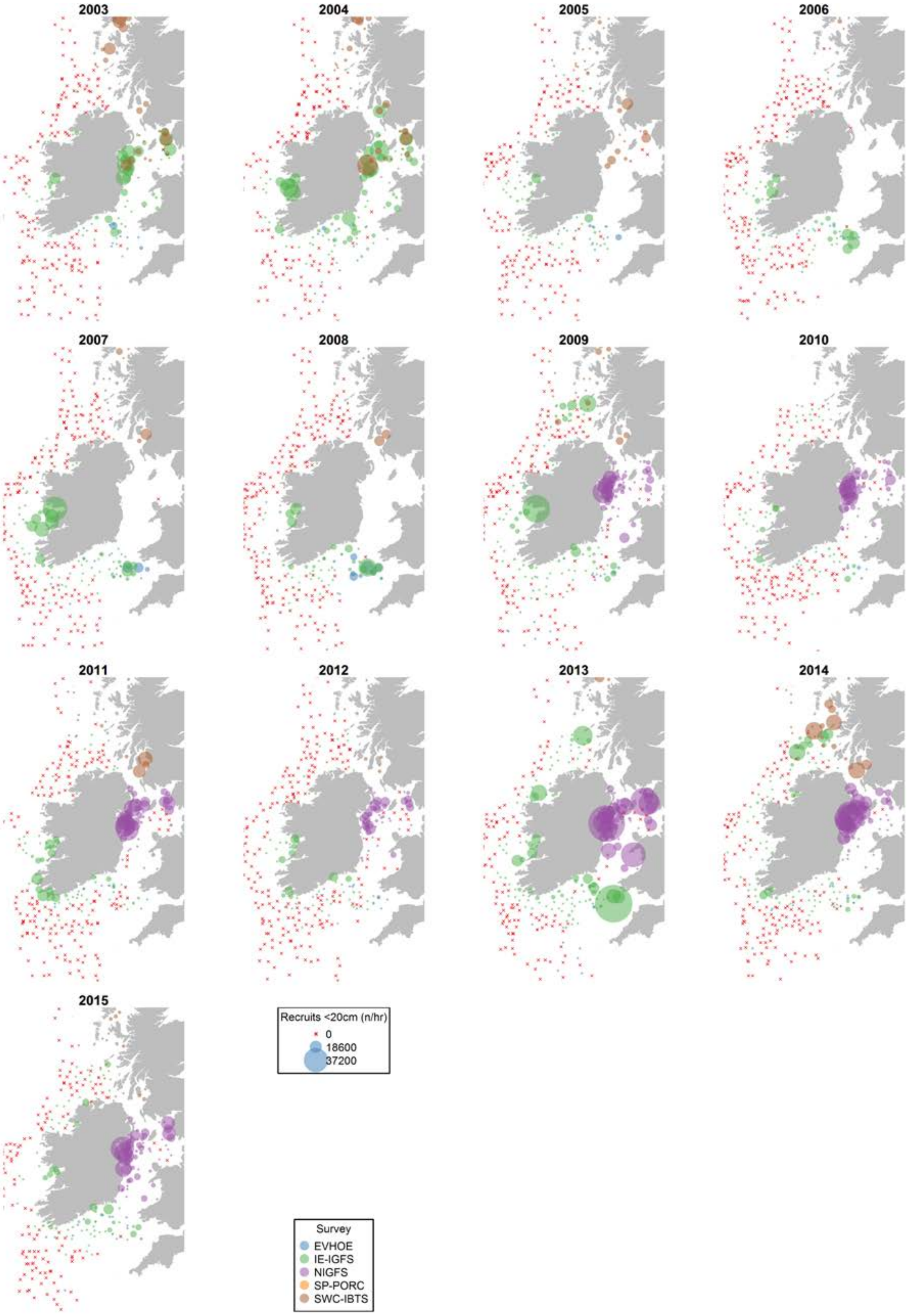


Figure 5.1.5. Whiting numbers of recruits (<20 cm) by haul from IBTS survey in DATRAS around Ireland.

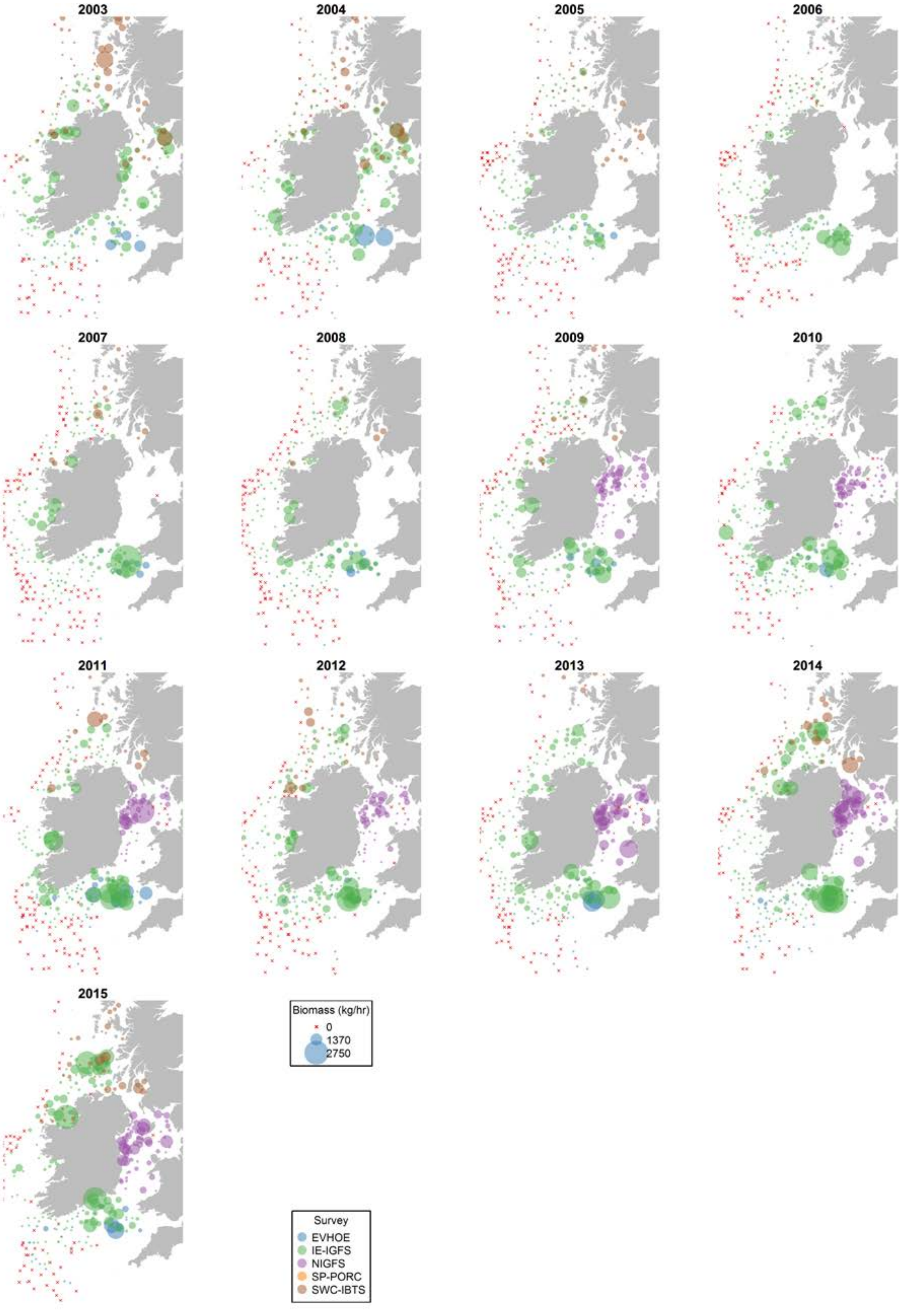


Figure 5.1.6. Whiting biomass by haul from IBTS survey in DATRAS around Ireland.

WKIrish also investigated correlations between various survey and assessment recruitment time-series in 7.a and adjacent areas. Figure 5.1.7 shows that there is a positive correlation between the recruitment in the NI-Q1-GFS and the IRGFS survey in 6.a. On closer inspection this correlation is driven by two points and is likely to be a spurious result. There is no correlation between recruitment in the NI-Q1-GFS and the NI-Q4-GFS or between both NI-GFS and recruitment indices in other adjacent areas. The strongest correlations were between recruitment in surveys in the respective areas and the assessments in 6.a and 7.b–k. These data suggest that the recruitment dynamics in 7.a are not correlated with that in adjacent areas, however, the lack of correlation between the Q1 and Q4 NI-GFS is a concern.

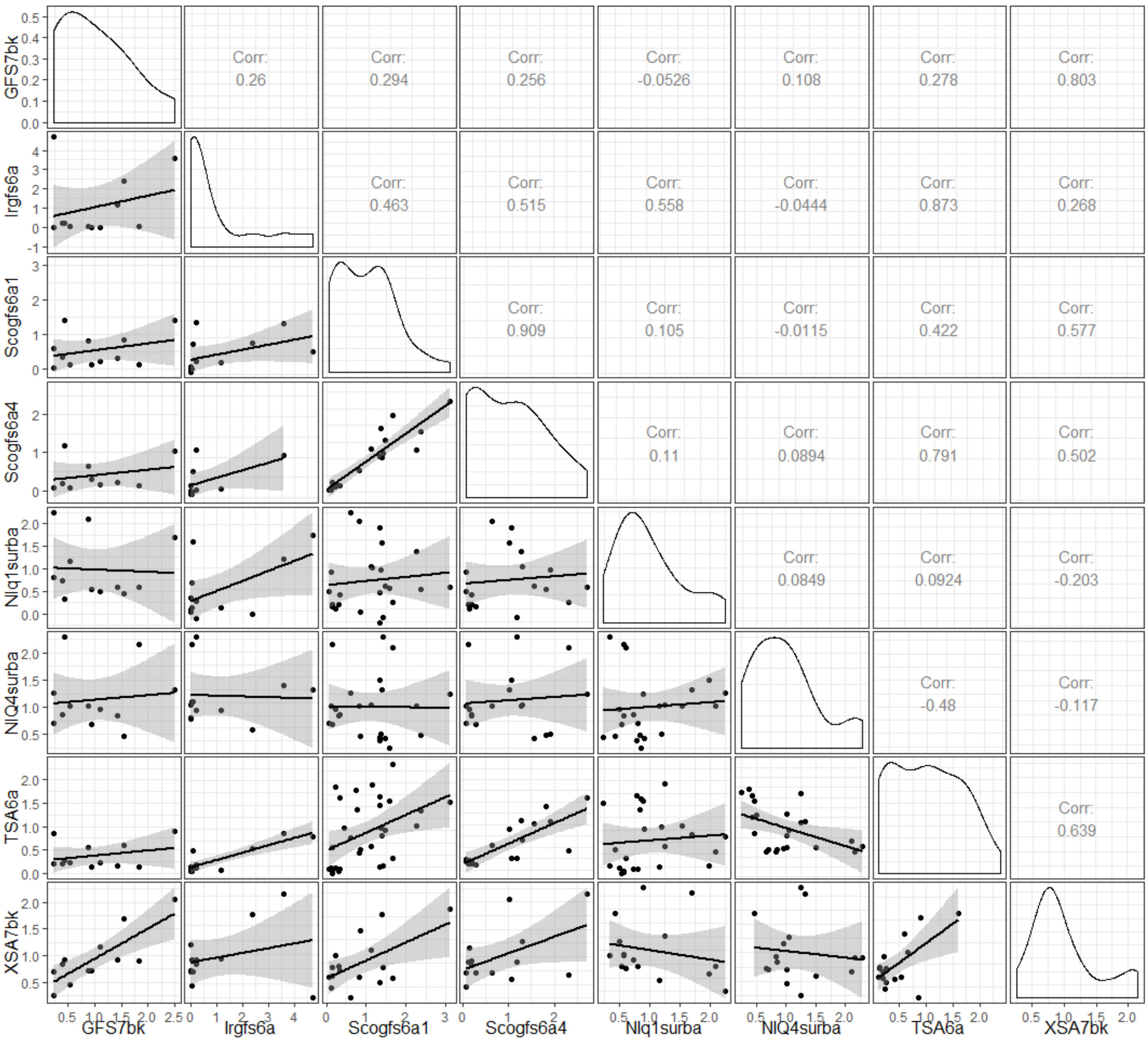
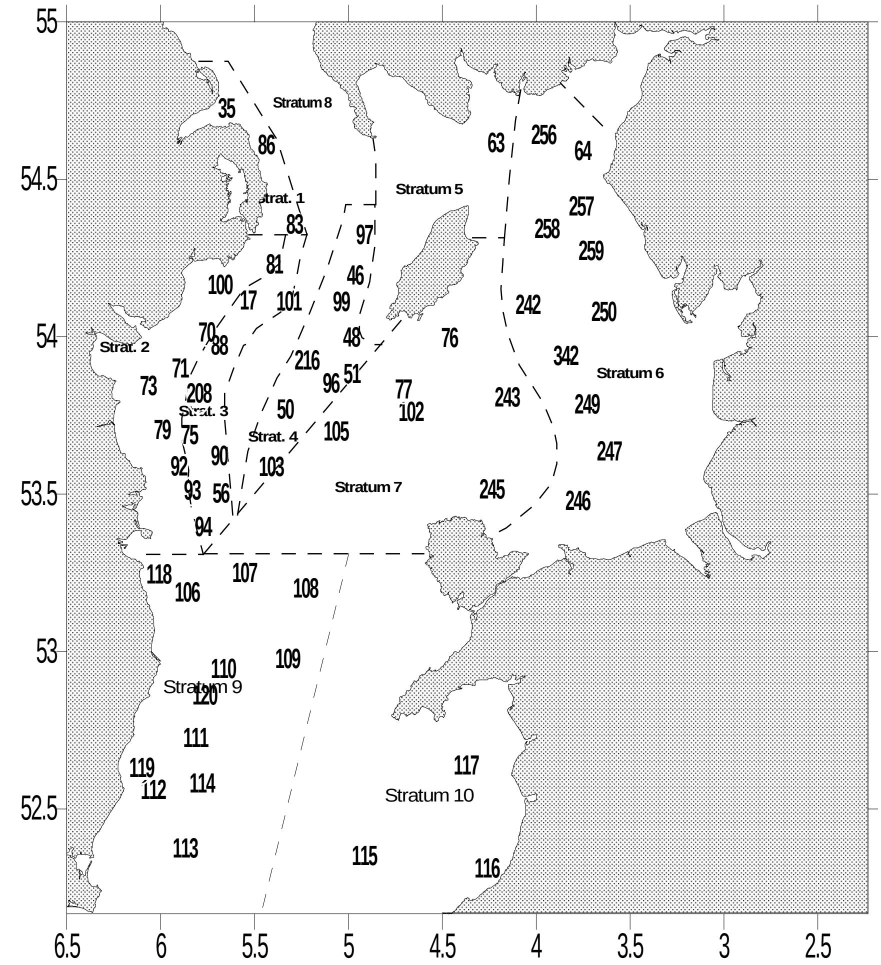


Figure 5.1.7. Correlation plots between various recruitment time-series from surveys and assessment time-series in 7.a and adjacent areas.

Having reviewed various new information WKIrish concluded that the current stock definition remains appropriate. Various future research questions do arise: why is growth so poor in 7.a compared with other adjacent areas, why are catches of recruits in 7.a on surveys so much higher than in other areas, are there genetic or other tools that might be useful to define the stock structure of whiting better in future?

5.2 Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length

The life-history parameters of whiting in the Irish Sea were estimated from NIGFS-WIGFS Q1 survey data, which includes sampling coverage from 1991–2015.



Key to strata:
1. Irish Coast (N), <100m, Mixed sediments
2. Irish Coast, < 50m, sand and finer sediments
3. Irish Coast, 50 - 100m, Muddy sediments
4. W and SW Isle of Man, 50 - 100m, mud and muddy sand
5. N Isle of Man, <50m, gravel sediments
6. Eastern Irish Sea, <50m, sand and finer sediments
7. S. Isle of Man, <100m, gravel sediments
8. Deep western channel and North Channel >100m
9. St George's Channel west; sandy/mixed sediments; <100m
10. St George's Channel east; sandy/mixed sediments; <100m

Figure 5.2.1. Map showing UK (Northern Ireland) March Groundfish Survey (NIGFS-WIBTS_Q1_East and West) stations and strata.

5.2.1 Growth parameters

To estimate parameters of growth a typical von Bertalanffy growth model was fitted to the survey data (growth{fishmethods}). The model is described by the equation: $L_t = L_\infty\left(1 - e^{-K(t-t_0)}\right)$, where $L\infty$ is the mean asymptotic total length (cm), K is the growth coefficient (yr^{-1}), t is age in years and $t0$ is the theoretical age (yr) at zero length. The function was fitted using a non-linear least of squares regression (nls{nlstools}). Confidence intervals were estimated by bootstrapping the model (nls-Boot{nlstools}). It was not possible to estimate with confidence the growth parameters of whiting in the Irish Seas using this method due to the truncated age range (age 0–5). This truncated age range resulted in whiting growth not reaching an asymptote. Therefore growth functions, such as von Bertalanffy, incorrectly estimated asymptotic fish lengths (L_∞) by more than 30% of the maximum observed length, which is considered unusable (Pauly, 1984). It is recommended that other avenues be explored for the estimation of these important parameters.

5.2.2 Natural mortality

Previous stock assessments of whiting within the Irish Sea have assumed a constant rate of natural mortality (M) at 0.2, which was applied across all ages and years. However M is a dynamic parameter and in order to improve the current single-species stock assessment M was estimated across a number of ages, along with a measure of variability of order to develop a range of M for this stock. The Lorenzen method (Lorenzen, 1996) was selected to estimate M as it does not require the input of life-history correlates (L_∞, K, t_0) or maximum age (t_{max}),thus avoiding the issue of the truncated age range present in the Irish Sea. Due to this truncated age range, estimators of M based on maximum age had the potential to introduce extreme sampling error and instability as they focus on a single old fish, ignoring all other observed ages (Kenchington, 2014). The oldest observed age for whiting in the North Atlantic is 20 (Muus and Nielsen, 1999) however the t_{max} observed in this dataset was five years. The Lorenzen method is defined by the following equation: $M = 3(W_{wet}^{-0.288})$, where W_{wet} refers to the mean wet weight of the fish.

A range of M was estimated for the mean weight-at-age (± the standard deviation) of whiting sampled on the NIGFS survey data. This survey has a sampling coverage spanning from 1991–2015, covering quarters 1, 3 and 4, and 0–5 year age classes (Table XX, Figure XX). M for whiting in 7.a was then compared to that of M for North Sea whiting which is calculated using an SMS multispecies model that incorporates predation (ICES, 2014/Figure X.X). The newly estimated values for 7.a indicate that M is potentially much higher than the previously assumed level of 0.2. The estimated levels of M in 7.a are lower than those identified for whiting in the North Sea where predation was included in the estimation process. However, the estimation of M for whiting from both areas/methodologies follows a similar trend with a high rate of M for young age class, which continues to steadily decline with age.

Table 5.2.1. Lorenzen (1996) estimates of M for NIGFS survey data (1991–2016) of whiting in 7.a using for the mean wet weight ((wt)̅) and standard deviation (sd).

Age	M at $\overline{wt}$	M at $\overline{wt} + sd$	M at $\overline{wt} - sd$
0	1.078	1.375	0.946
1	0.803	0.946	0.724
2	0.718	0.852	0.646
3	0.608	0.709	0.551
4	0.554	0.663	0.496
5	0.518	0.685	0.451

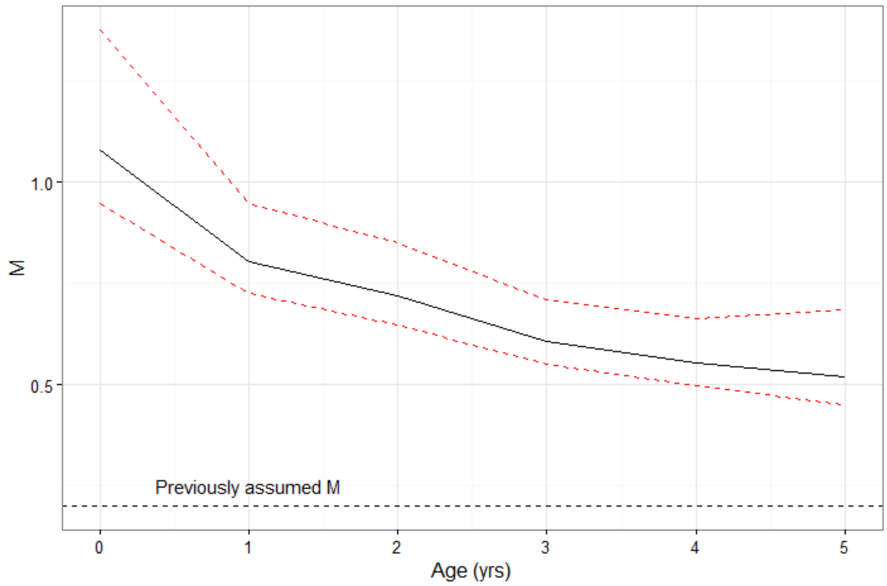


Figure 5.2.2. Plot of estimated rate of M at-age for whiting in 7.a using mean wet weight-at-age (solid black line). Ranges of M (red broken line) were estimated for the mean ± s.d. wet weight. The previously assumed level of M for 7.a whiting is shown (black broken line).

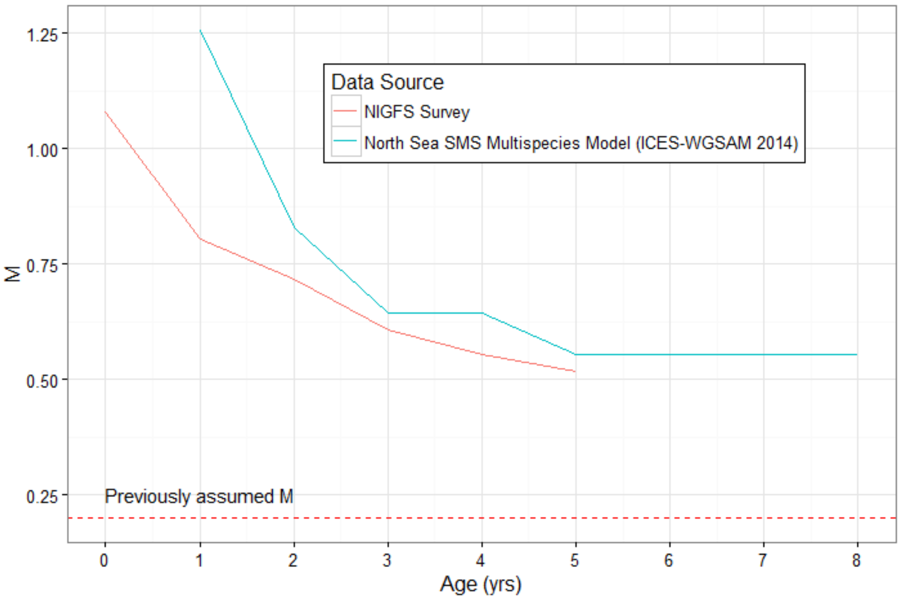


Figure 5.2.3. Plot of estimated rate of M at age for whiting in 7.a using mean wet weight-at-age (solid red line) and estimated M for whiting from the SMS multispecies model for North Sea (upper solid blue line). The previously assumed level of M for 7.a whiting is shown (black broken line).

Due to the varying weights-at-age in the catch it was decided to also look at time varying natural mortality estimates. This was done using a five year smoothed catch weight for the Lorenzen method. Comparisons between the Lorenzen method, M set at a constant of 0.2, the North Sea Multispecies model derivation of M and the Time varying natural mortality are presented in Figure 5.2.4 below. Time varying M may well be more biologically realistic, especially for the younger ages. WKIrish2 concluded that the various options should be investigated in the stock assessment models by WKIrish3.

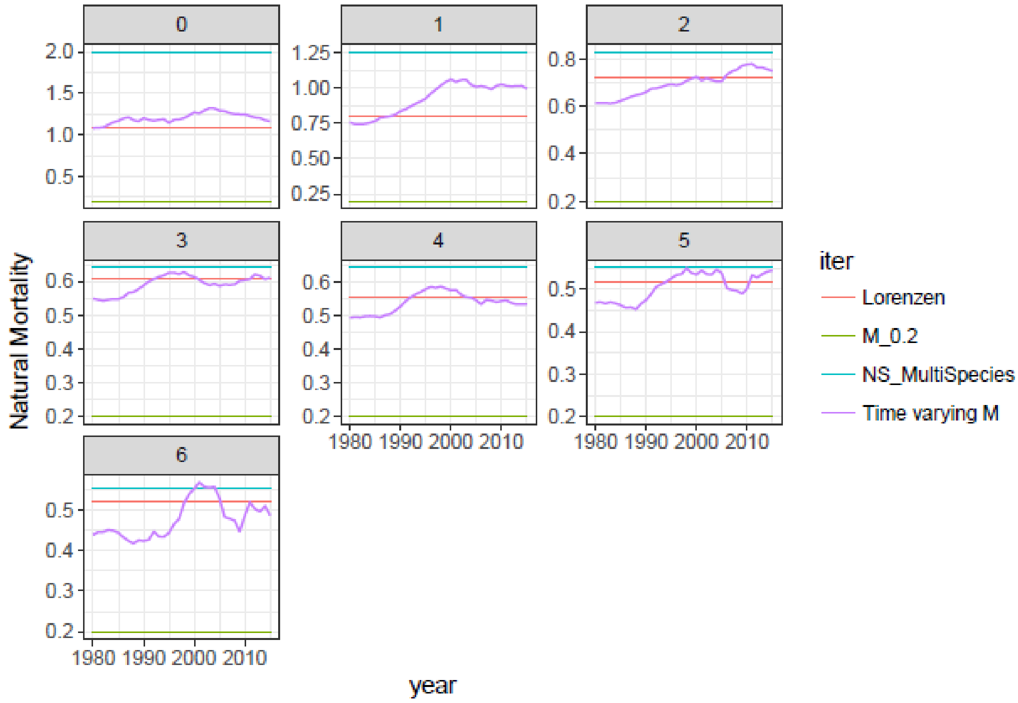


Figure 5.2.3. Plot of the various M-at-age options for whiting in 7.a.

5.2.3 Maturity

Maturity staging of whiting was carried out during the NIGFS-WIBTS_Q1 survey. The survey is stratified (Figure 5.2.1). Sampling is length stratified, with two individuals from each 1 cm length class sampled. Maturity-at-length was described using the methods outlined by Armstrong *et al.* (2003). To avoid any biases in estimating the proportion mature at-age using length-stratified samples, data on sex, age and maturity from each length class were weighted by the total catch in that length group (Morgan and Hoenig, 1997) using:

$PM_{a,s} = [\sum_j C_j P(s|j) \cdot P(a|j,s) \cdot P(m|a,j,s)] / [\sum_j C_j P(s|j) \cdot P(a|j,s)]$. The length at which 50% of fish were mature (L_{50}) was estimated using a maximum likelihood method:

$PM_j = [1 + \exp(-b \cdot (j - L_{50}))] - 1$. Maximum likelihood estimates of L_{50} and b were found by minimising the negative log-likelihood, using the Nelder-Mead method.

Interannual variability of L_{50} for males was greater than that observed in females (Figure 5.2.1). Both sexes followed a similar downward trend in L_{50} in until 2008, where upon L_{50} was steady or increasing. The trend in males co-varied significantly with the average *SST (lag-1)* as observed over a shorter time-series by (Armstrong *et al.*, 2003). The mean L_{50} for all years (1992–2015) was estimated at 17 cm for males and 20 cm for females (Figure 5.2.2). At the current MLS (27 cm) all whiting are mature.

Table 5.3.1. LOWESS smoothed proportion of female and male whiting mature at-age 1–3 from quarter 1 NIGFS surveys.

	Female			Male		
Year	Age1	Age2	Age3	Age1	Age2	Age3
1994	0.01	0.86	0.99	0.28	0.99	0.99
1995	0.01	0.92	0.93	0.24	0.95	0.97
1996	0.00	0.95	0.99	0.22	0.95	0.98
1997	0.01	0.95	1.00	0.31	0.97	0.98
1998	0.15	0.95	0.99	0.65	0.96	0.98
1999	0.16	0.99	1.00	0.67	0.98	0.99
2000	0.13	0.93	0.99	0.72	0.99	1.00
2001	0.06	0.99	0.99	0.49	0.98	1.00
2002	0.16	0.89	1.00	0.63	0.93	1.00
2003	0.14	0.97	0.98	0.57	0.97	0.92
2004	0.20	1.00	0.98	0.70	0.99	1.00
2005	0.18	0.98	0.99	0.64	0.96	0.97
2006	0.18	0.97	1.00	0.67	1.00	1.00
2007	0.33	0.99	1.00	0.77	0.99	1.00
2008	0.36	1.00	1.00	0.84	0.97	1.00
2009	0.15	0.98	1.00	0.71	0.99	1.00
2010	0.07	0.99	1.00	0.46	0.99	0.97
2011	0.17	0.98	1.00	0.54	0.96	0.91
2012	0.26	0.96	0.99	0.49	0.96	1.00
2013	0.11	0.98	1.00	0.63	0.99	1.00
2014	0.13	0.91	0.99	0.31	0.90	0.97
2015	0.14	0.95	1.00	0.57	0.98	0.97

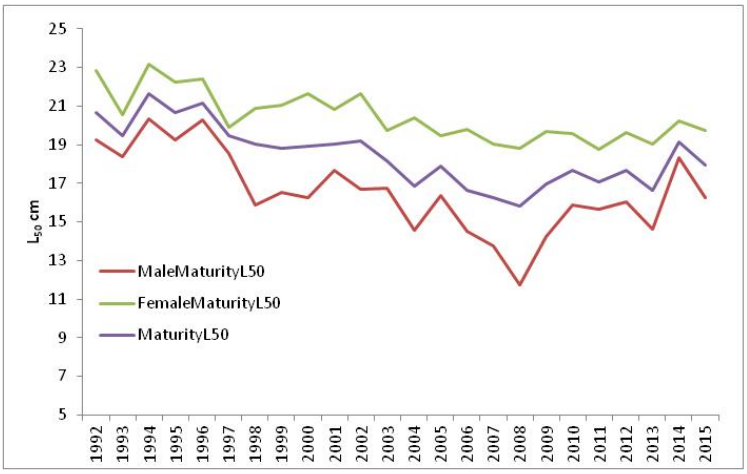


Figure 5.2.1. Annual (1992–2015) estimates of sex specific and mean population length at 50% maturity (*L_{50}*).

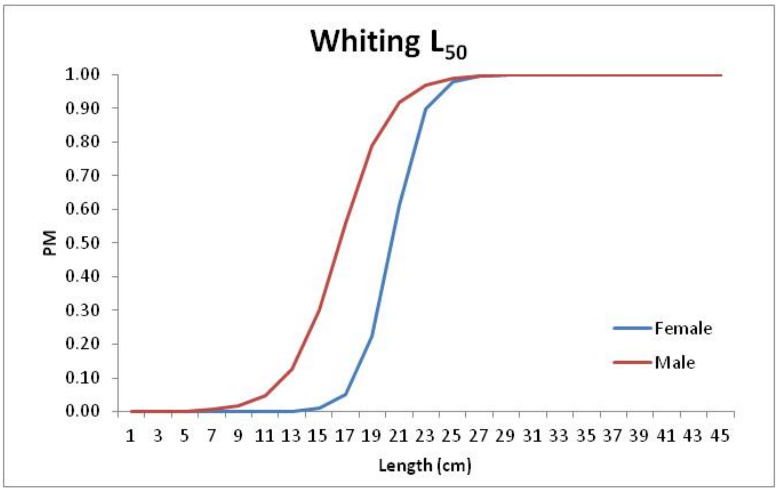


Figure 5.3.2. Estimated length at 50% maturity from complete time-series (1992–2015) for male (17 cm) (and female (20 cm) Irish Sea whiting.

5.2.4 Stock weights-at-age

Stock weights are derived from the catch weights using a procedure first described in the 1998 Working Group report. To derive stock weights for the start of the year for year i and age j the following formula is adopted:

(CW i,j + CW i+1,j+1)/2 = SW at start of year.

These values are then smoothed using a three year moving average. Linear interpolation was used in a few instances where there were zero observations of catch mean weight-at-age.

The raw and smoothed stock weights are shown in Figure 5.2.6. WKIrish2 also investigated Rivard corrected mean weights using the NOAA toolbox Calculation Utility Program version 2.1 (http://nft.nefsc.noaa.gov/Download.html). The Rivard procedure is very close to the usual WG approach.

WKIrish2 considered using the NIGFSQ1 survey mean weights. In theory the mean weights from a properly designed survey would provide a more accurate estimate of the population mean weights-at-age. The NIGFSQ1 time-series starts in 1992. The numbers sampled at-age are fairly sparse (<10 individuals) for ages 5 and 6 during the last decade (Table 5.2.2.). The survey mean weights show broadly similar trends to the catch, however the drop in mean weights the start of the series and upturn in survey mean weights at the end of the series for ages 3, 4, 5 and 6 is notable. The upturn is not yet apparent in the catch data. The survey mean weighs-at-age for three year olds are significantly less than the catch derived estimates for most of the 1990s and 2000s. At older ages 4 and 5 the survey mean weights are less than the catch derived ones mainly in the 2000s.

WKIrish2 decided to maintain consistency with the previous approach although the survey mean weights should be looked at annually to see if the upturn trend persists.

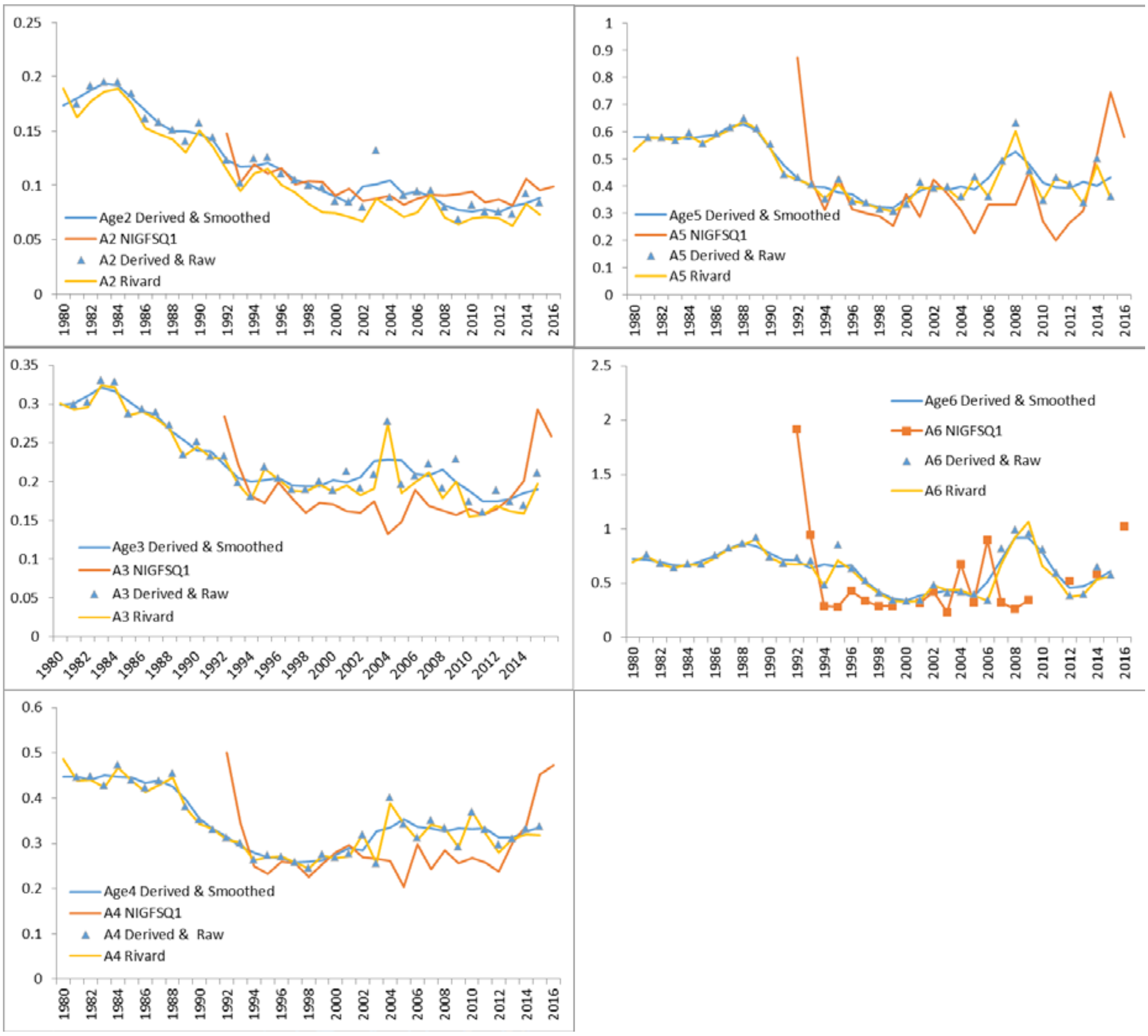


Figure 5.2.6. Raw stock weights as derived from the catch weights, smoothed catch weights according to the previous procedure, NIGFSQ1 survey mean weights and Rivard correction mean weights.

Table 5.2.2. Numbers of fish sampled for mean weight on the NIGFSQ1.

Year	A1	A2	A3	A4	A5	A6
1992	190	223	145	52	19	2
1993	151	658	289	87	18	9
1994	321	173	410	86	14	5
1995	410	348	92	161	22	5
1996	311	242	253	46	101	14
1997	167	462	216	147	17	37
1998	236	457	285	62	28	3
1999	230	414	223	123	19	3
2000	362	359	230	123	18	0
2001	319	538	188	46	19	9
2002	367	475	259	57	17	2
2003	365	509	164	82	15	2
2004	324	412	293	29	13	2
2005	393	384	105	34	7	1
2006	413	380	134	32	5	1
2007	395	444	147	42	4	1
2008	408	403	181	30	2	1
2009	427	410	143	23	3	2
2010	393	457	172	31	8	0
2011	422	337	253	29	3	0
2012	500	325	184	68	8	1
2013	352	425	221	49	7	0
2014	489	327	250	44	9	2
2015	394	491	241	50	3	0
2016	298	388	260	55	3	1

5.3 Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of relevance for the scientific assessment of the stocks and provision of advice

See Section 3.

5.4 Develop time-series of (commercial and recreational) fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision

A summary overview of the fishery-dependent data available to WKIrish and used for whiting 7.a is provided in Table 5.4.1. The data are discussed in more detail below. There are no recreational catch estimates for whiting in 7.a and although recreational catches exist they are likely to be negligible compared with the commercial fishery. The providence of historic data prior to 1996 is less certain because after that year electronic data compilation spreadsheets were available to WKIrish stock coordinators. Since 2012, national data have been submitted to InterCatch but to date InterCatch has not been use to compile the international data. WKIrish2 has re-aggregated the international data from 2003 based on reworked data available to the meeting. In future these data should be uploaded to InterCatch using the stratification agreed at WKIrish2 and documented in the revised Stock Annex.

Table 5.4.1. Time-series of fishery-dependent data types by country available and used to construct the whiting 7.a assessment inputs.

	Northern Ireland				Ireland				England, Wales, Scotland, Isle of Man			
Year	Landings (t)	Discards (t)	LNAA	DNAA	Landings (t)	Discards (t)	LNAA	DNAA	Landings (t)	Discards (t)	LNAA	DNAA
1980	Yes	Yes	Market	Self sampling	Yes				Yes			
1981	Yes	Yes	Market	Self sampling	Yes				Yes			
1982	Yes	Yes	Market	Self sampling	Yes				Yes			
1983	Yes	Yes	Market	Self sampling	Yes				Yes			
1984	Yes	Yes	Market	Self sampling	Yes				Yes			
1985	Yes	Yes	Market	Self sampling	Yes				Yes			
1986	Yes	Yes	Market	Self sampling	Yes				Yes			
1987	Yes	Yes	Market	Self sampling	Yes			SS Provided but not used	Yes			
1988	Yes	Yes	Market	Self sampling	Yes			SS Provided but not used	Yes			
1989	Yes	Yes	Market	Self sampling	Yes			SS Provided but not used	Yes			
1990	Yes	Yes	Market	Self sampling	Yes			SS Provided but not used	Yes			
1991	Yes	Yes	Market	Self sampling	Yes			SS Provided but not used	Yes			
1992	Yes	Yes	Market	Self sampling	Yes	Obs Provided but not used	Market	Obs Provided but not used	Yes			
1993	Yes	Yes	Market	Self sampling	Yes	Obs Provided but not used	Market	Obs Provided but not used	Yes			
1994	Yes	Yes	Market	Self sampling	Yes	Obs Provided but not used	Market	Obs Provided but not used	Yes			
1995	Yes	Yes	Market	Self sampling	Yes	Obs Provided but not used	Market	Obs Provided but not used	Yes			
1996	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Used	Yes		Provided but not used	
1997	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Used	Yes		Provided but not used	
1998	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Used	Yes		Used	
1999	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Used	Yes		Used	
2000	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Used	Yes		Used	
2001	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Not used	Yes		Used	
2002	Yes	Yes	Market	Self sampling	Yes	Yes	Market	Not used	Yes		Used	
2003	Yes	Yes	Insufficent data	Insufficent data	Yes	Yes	Market	Observer	Yes			
2004	Yes	Yes	Insufficent data	Insufficent data	Yes	Yes	Market	Observer	Yes	Provided but not used	Provided but not used	
2005	Yes	Yes	Insufficent data	Insufficent data	Yes	Yes	Market	Observer	Yes		No	No
2006	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2007	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2008	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2009	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2010	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2011	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes		No	No
2012	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes	Observer	No	No
2013	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes	Observer	No	No
2014	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes	Observer	No	No
2015	Yes	Yes	Market	Observer	Yes	Yes	Market	Observer	Yes	Observer	No	No

LNAA = Landings numbers-at-age, DNAA = Discard Numbers-at-age, SS = self-sampling, Obs = Observer trips.

Table 5.4.1. Continued. Time-series of fishery-dependent data types by country available and used to construct the whiting 7.a assessment inputs.

	Belgium		France		Historic	WKIRISH2
Year	Landings (t)	Discards (t)	Landings (t)	Discards (t)	Data comilation	Data compilation
1980	Yes		Yes		?	Taken from WGNSDS 2003
1981	Yes		Yes		?	Taken from WGNSDS 2003
1982	Yes		Yes		?	Taken from WGNSDS 2003
1983	Yes		Yes		?	Taken from WGNSDS 2003
1984	Yes		Yes		?	Taken from WGNSDS 2003
1985	Yes		Yes		?	Taken from WGNSDS 2003
1986	Yes		Yes		?	Taken from WGNSDS 2003
1987	Yes		Yes		?	Taken from WGNSDS 2003
1988	Yes		Yes		?	Taken from WGNSDS 2003
1989	Yes		Yes		?	Taken from WGNSDS 2003
1990	Yes		Yes		?	Taken from WGNSDS 2003
1991	Yes		Yes		?	Taken from WGNSDS 2003
1992	Yes		Yes		?	Taken from WGNSDS 2003
1993	Yes		Yes		?	Taken from WGNSDS 2003
1994	Yes		Yes		?	Taken from WGNSDS 2003
1995	Yes		Yes		?	Taken from WGNSDS 2003
1996	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
1997	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
1998	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
1999	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
2000	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
2001	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
2002	Yes		Yes		Spreadsheets	Taken from WGNSDS 2003
2003	Yes		Yes		Spreadsheets	Re-aggregrated
2004	Yes		Yes		Spreadsheets	Re-aggregrated
2005	Yes		Yes		Spreadsheets	Re-aggregrated
2006	Yes		Yes		Spreadsheets	Re-aggregrated
2007	Yes		Yes		Spreadsheets	Re-aggregrated
2008	Yes		Yes		Spreadsheets	Re-aggregrated
2009	Yes		Yes		Spreadsheets	Re-aggregrated
2010	Yes		Yes		Spreadsheets	Re-aggregrated
2011	Yes		Yes		Spreadsheets	Re-aggregrated
2012	Yes	Observer	Yes	No	Intercatch	Re-aggregrated
2013	Yes	Observer	Yes	No	Intercatch	Re-aggregrated
2014	Yes	No	Yes	No	Intercatch	Re-aggregrated
2015	Yes	No	Yes	No	Intercatch	Re-aggregrated

LNAA = Landings numbers-at-age, DNAA = Discard Numbers-at-age, SS = self-sampling, Obs = Observer trips.

5.4.1 Landings data

Landings data have been supplied (annual quarterly landings) by the UK (N. Ireland), UK (E&W), UK (Scotland), Ireland, Belgium, and the IOM from databases maintained by national Government Departments and research agencies. The landings figures may be adjusted by national administrations or scientists to correct for known or estimated misreporting by area or species. To avoid double counting of landings data, each UK region supplies data for UK landings into its regional ports, and landings by its fleet into non UK ports.

Working group estimates of landings are partially corrected using sample-based estimates of landings at a number of Irish Sea ports in the period 1991–1999. During that period the officially reported landings of whiting were thought to be inaccurate due to misreporting. Due to the low level of whiting landings since 2003 this correction has not been carried out.

As for 7.a cod and haddock, the whiting landings taken or reported in ICES rectangles 33E2 and 33E3 by Ireland have been reassigned from 7.a to the 7.e–k whiting stock since 2003.

Landings or catch data in the past have not been available dis-aggregated by gear type. Since, 2003 disaggregated catches by cod plan gear types have been available from STECF (Figure 3.5). The Irish Sea whiting stock is primarily caught by otter trawlers and to a lesser extent, Scottish seines, beam trawls and gillnets. Otter trawlers utilize two main mesh size ranges, TR2 70–89 mm and TR1 100–119 mm. Effort of trawlers utilizing the larger mesh range, traditionally targeting whitefish (cod, haddock, whiting), has seen a large declined since 2003, partially as a result of effort management restrictions (Figure 3.3). The TR2 effort has also decline by around 20% between 2003 and 2015. The primary target species of this smaller mesh TR2 fleet is *Nephrops* from which whiting is discarded at a high rate.

5.4.2 Discards estimates

Between 1980–2002, the quantity of whiting discarded from the UK (NI) *Nephrops* fishery was estimated on a quarterly basis from samples of discards and total catch provided by skippers. This "self-sampling" methodology is elaborated more in the Stock annex. UK (NI) *Nephrops* fishery discard estimates were then scaled up using international *Nephrops* landings by quarter. The accuracy and precision of this method is unknown and was not investigated by WKIrish2.

WKIrish2 focused on the methodologies and quality of discard data since 2003. A description of the discard observer programmes in UK (NI) and Ireland are provided in Sections 4.3.2.2 and 4.4.4 respectively.

Ireland

Numbers of trips sampled and for the fleet are dis-aggregated by the métiers in Tables 4.3.3 and 4.4.2. The general quality indicators for the Irish observer programme are given in Section 4.4.7. The spatial distribution of cpue for Irish Sea whiting on Irish otter trawl fishing trips since 2003 are shown in Figure 5.4.1. WKIrish2 agreed to stratify by gear and target species and that there were only sufficient samples for the OTB_CRU fleet. Even for this fleet there is a large variability of dpue and discard volumes by trip (Figure 5.4.2). The total discard estimates raised either using trip or effort as agreed at WKIrish2 are broadly similar and show large interannual fluctuations. The relative standard error for the discard volume estimates range from 17–54% (average 33%) between 2003 and 2015 (Table 5.4.1).

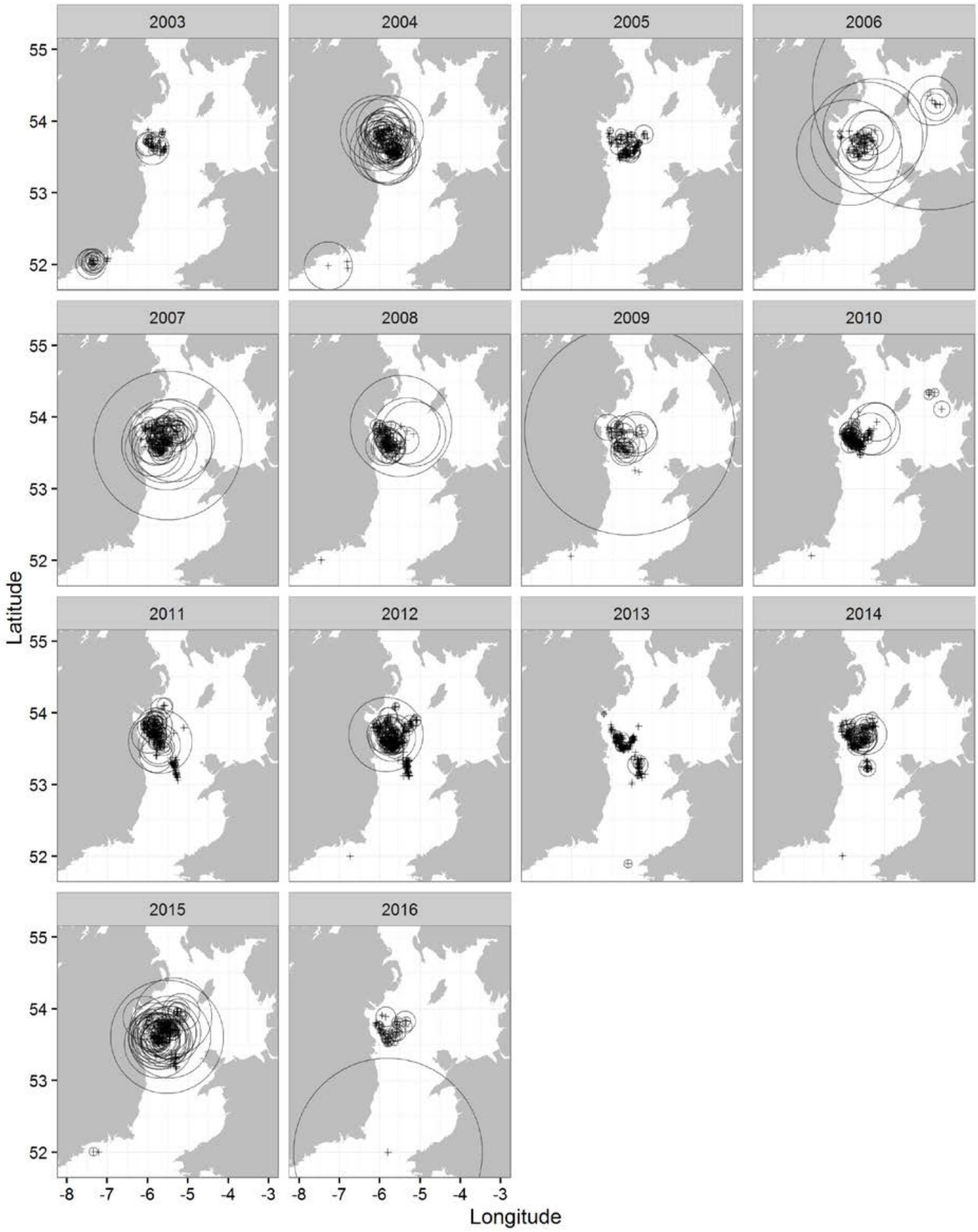


Figure 5.4.1. Catch of Whiting in Irish Sea showing concentration of hauls in the Eastern Irish Sea on the *Nephrops* Grounds.

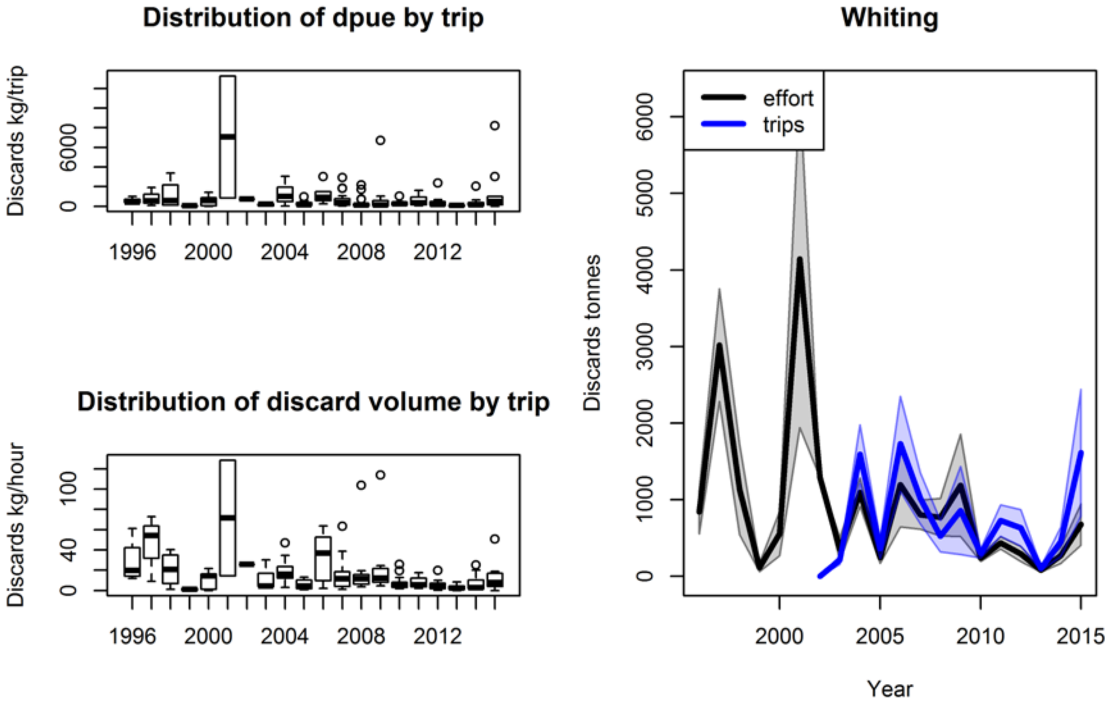


Figure 5.4.2. Discards per unit of effort (dpue) by year for Irish OTB_CRU trips (top left panel) and total discard volumes by trip (bottom left). The right panel shows total discard estimates by year of whiting from the Irish OTB_CRU métier raised using effort (as agreed by WKIrish2) with 95% confidence intervals shown as the shaded areas.

Table 5.4.1. Irish OTB_CRU métier numbers of trips sampled, total discard estimates and their relative standard errors. Only data from 2003–20015 were used by WKIrish2.

Year	Number of Trips Sampled	Discard estimate (t)	Discard Relative Standard Error
1996	4	841.8	0.343
1997	3	3020.1	0.244
1998	4	1133.4	0.519
1999	2	115.5	0.488
2000	6	558.4	0.520
2001	2	4144.9	0.531
2002	1	1289.6	0.000
2003	7	353.5	0.434
2004	10	1097.2	0.170
2005	8	245.3	0.323
2006	5	1195.5	0.461
2007	15	805.6	0.238
2008	17	771.9	0.315
2009	10	1188.3	0.564
2010	17	240.5	0.204
2011	10	435.9	0.183
2012	13	292.6	0.338
2013	11	80.8	0.333
2014	12	273.4	0.391
2015	10	677.1	0.398

Northern Ireland

A density distribution of the catch rates for the main gears sampled by Northern Ireland are shown in Figure 5.4.3. The plots show well resolved density plots of catch rates for the single rig (OTB), twin rig otter trawls (OTT) and midwater trawls (OTM) across the sampling period. For most gears the discard rates overlap significantly. The overall CV on the Northern Ireland Discard volume estimates are given in Figure 5.4.4 the total discard volumes for Northern Ireland are given in Figure 5.4.5. The total estimates and there CVs are given in Table 5.4.1. The numbers of trips sampled by fleet is shown in Table 4.3.3.

CV values vary between 10% and 40% for the Northern Irish time-series. There are large CV estimate at the beginning of the time-series but then seem to plateau at 10% with the exception of 2013. The discard volumes appear to have increased over time, with a decrease in 2015. Discard volumes vary from ~200t to ~1700 t over the time-series.

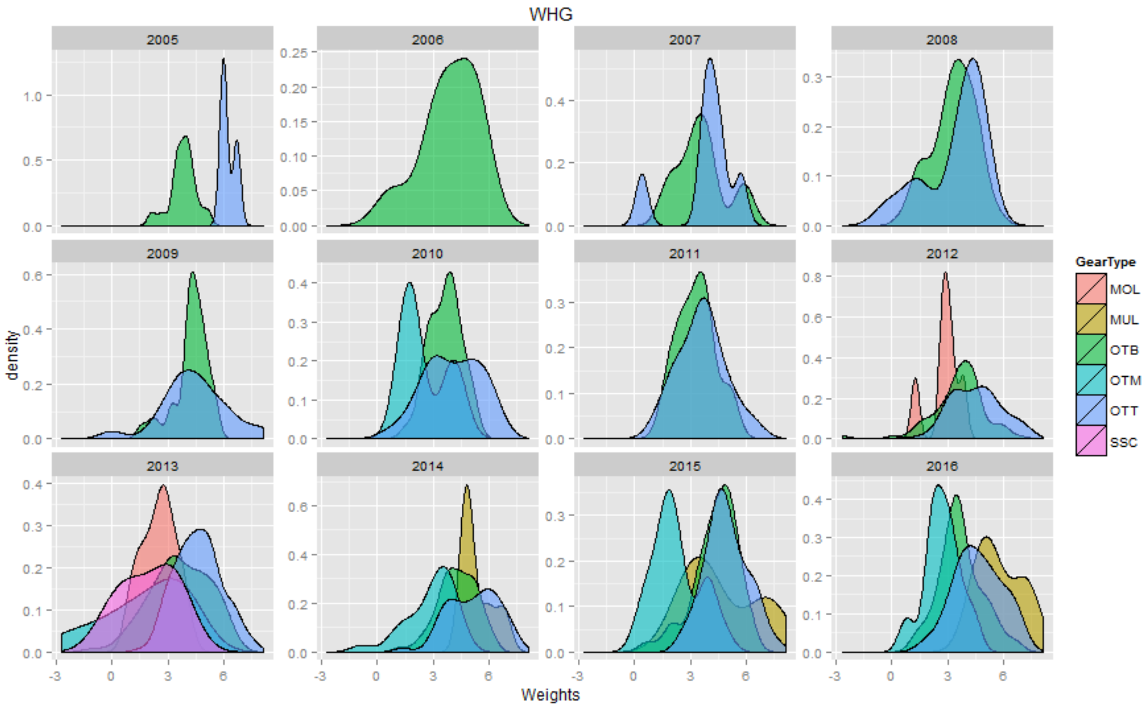


Figure 5.4.3. Irish Sea whiting catch rates of main gears sampled by Northern Irish at-sea sampling.

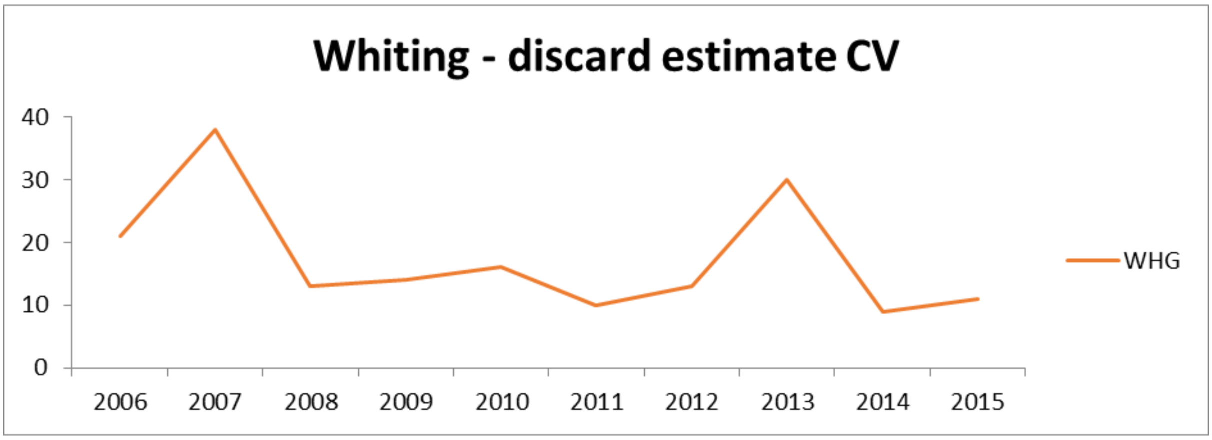


Figure 5.4.4. Time-series of CV estimates for total discard volumes from UK (NI) métiers.

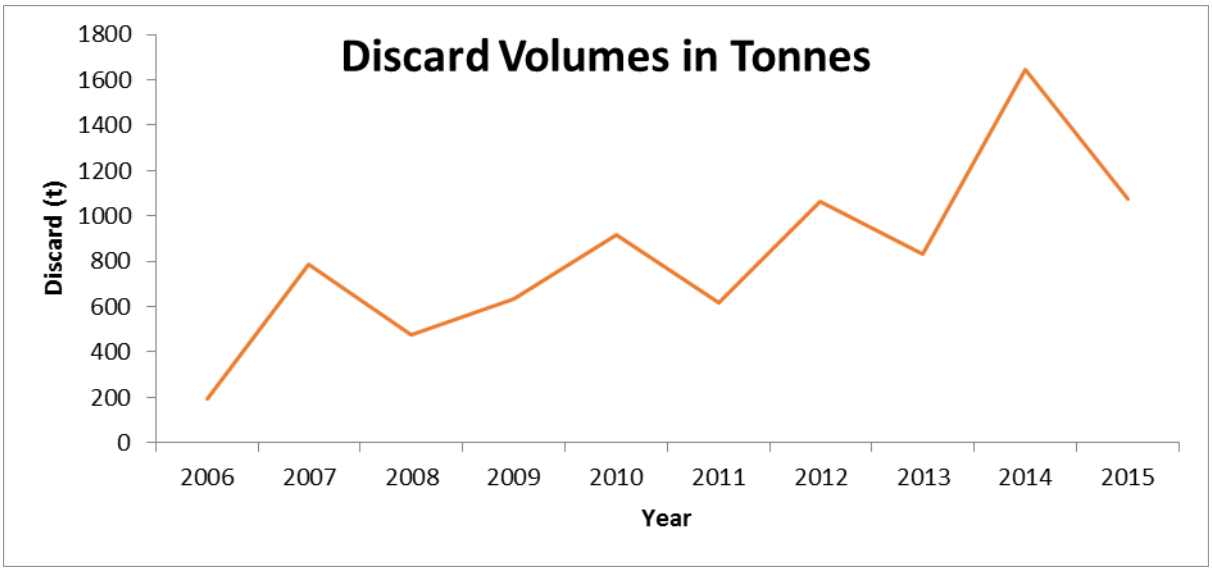


Figure 5.4.5. Time-series total discard volumes from UK (NI) métiers.

Table 5.4.2. Nominal Discards (t), Landings (t) and Catch (t) of whiting in Division 7.a, 1988–2015, as officially reported to WGCSE Expert Group (EG) and as officially reported to ICES. Landings taken or reported in rectangles 33E2 and 33E3 which are not considered part of the 7.a stock are also presented in the table below.

Year	Official landings	ICES landings	ICES Discards	ICES catch	Landings taken or reported in rectangles 33E2 and 33E3
1988	11,492	10,245	1,611	11,856	
1989	11,328	11,305	2,103	13,408	
1990	8,183	8,212	2,444	10,656	
1991	7,411	7,348	2,598	9,946	
1992	7,094	8,588	4,203	12,791	
1993	5,977	6,523	2,707	9,230	
1994	5,637	6,763	1,173	7,936	
1995	5,465	4,893	2,151	7,044	
1996	5,581	4,335	3,631	7,966	
1997	4,472	2,277	1,928	4,205	
1998	3,355	2,229	1,304	3,533	
1999	1,989	1,670	1,092	2,762	
2000	1,130	762	2,118	2,880	
2001	1,066	733	1,012	1,745	
2002	714	747	740	1,487	
2003	554	517	480	996	159
2004	204	133	905	1,038	51
2005	164	125	272	397	33
2006	85	64	1,773	1,837	22
2007	197	35	1,512	1,547	161
2008	84	37	1,169	1,206	44
2009	100	39	1,321	1,360	63
2010	121	30	1,154	1,184	91
2011	118	31	946	977	75
2012	86	60	1,339	1,399	43
2013	68	33	948	981	33
2014	73	23	1,951	1,974	50
2015	59	28	1,521	1,549	34

5.5 Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision

5.5.1 Estimating discard numbers-at-age for Ireland

Whiting are fast-growing, particularly at the ages that are discarded. This means that annual age–length keys would not be appropriate. At the same time, Irish sample numbers are insufficient to apply quarterly or monthly ALKs.

Fortunately, the cohorts can be identified quite easily once the data are presented on a monthly basis, aggregated overall years. Therefore a monthly knife-edge monthly ALK was constructed. The cut-off points were based on an examination of the length–frequency distributions (Figure 5.5.1) as well as the age data of the discard and landings samples. The following age–length split was applied:

Table 5.5.1. Size range of whiting (cm) by age class and month, applied to all years.

Month	Age 0	Age 1	Age 2	Age 3	Age 4
Jan	-	0-20	21-29	30-37	38+
Feb	-	0-20	21-29	30-37	38+
Mar	-	0-20	21-29	30-37	38+
Apr	0-10	11-20	21-30	31-37	38+
May	0-10	11-22	23-30	31-37	38+
Jun	0-12	13-23	24-30	31-37	38+
Jul	0-13	14-24	25-33	34-41	42+
Aug	0-15	16-26	27-33	34-41	42+
Sep	0-17	18-27	28-33	34-41	42+
Oct	0-19	20-29	30-35	36-41	42+
Nov	0-20	21-29	30-35	36-41	42+
Dec	0-20	21-29	30-35	36-41	42+

Figure 5.5.1 shows the monthly length distributions after applying the age–length split. Figure 5.5.2 shows the annual length distributions by age (aggregated over all months).

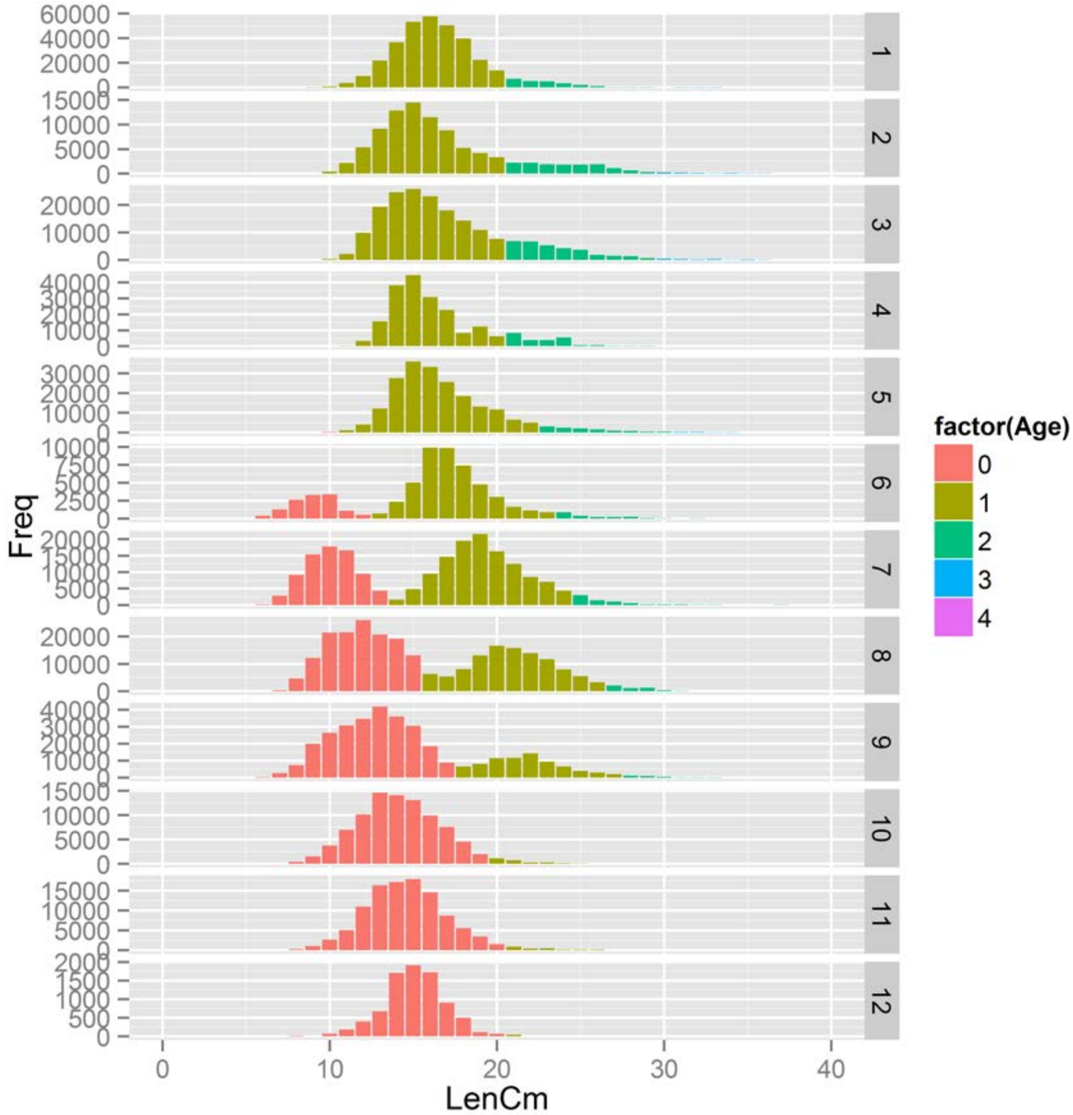


Figure 5.5.1. Length–frequency distribution of whiting Irish discard samples by month (all years combined).

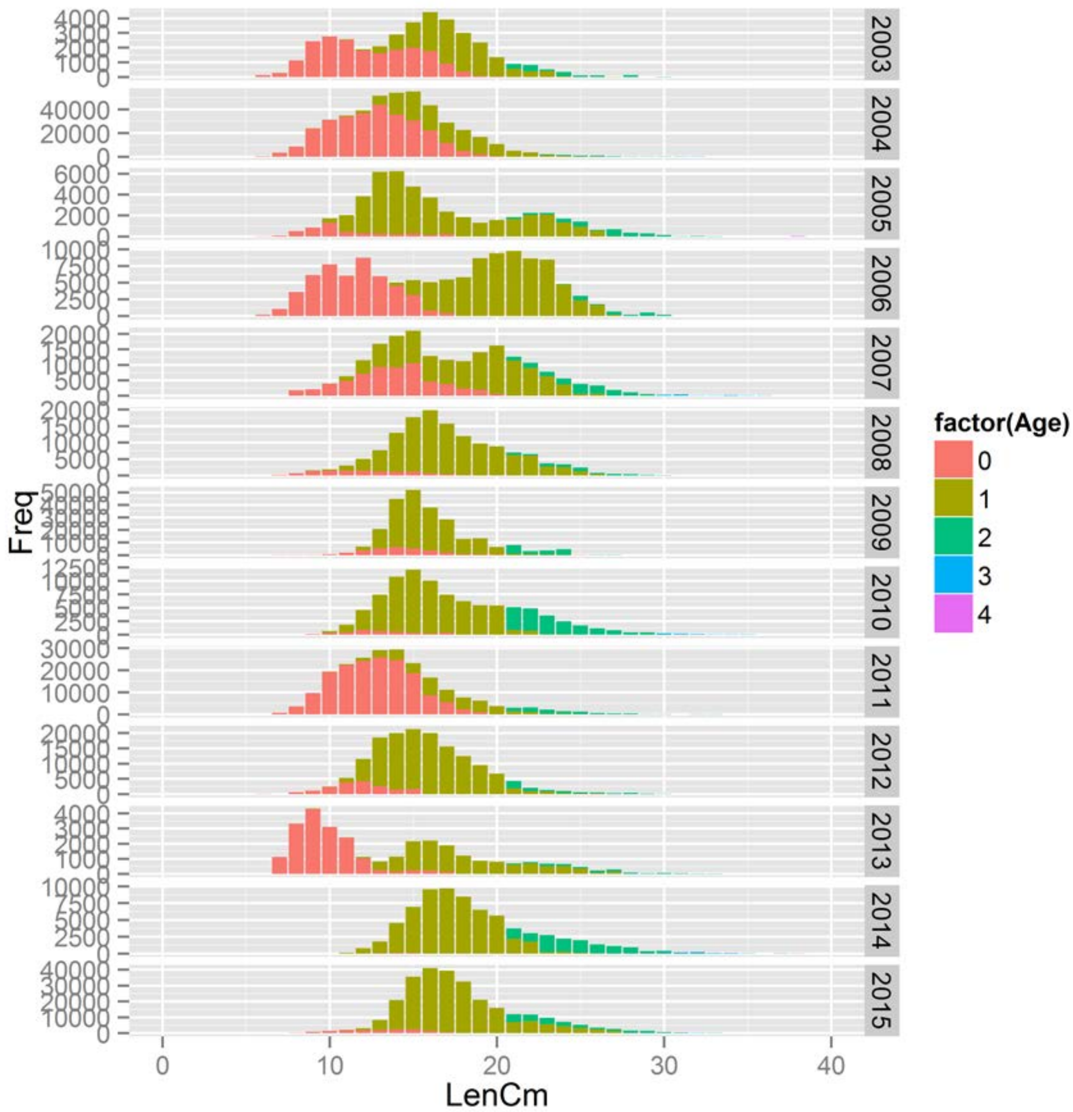


Figure 5.5.2. Length–frequency distribution of whiting Irish discard samples by year (all months combined).

Figure 5.5.3 shows the on-board retention ogives for Irish observer trips. Due to minimal retention of catch it is not possible to estimate a retention ogive in most years. For the few years where some retained catch of whiting was observed the L_{50} appears to be well above the MLS (27 cm).

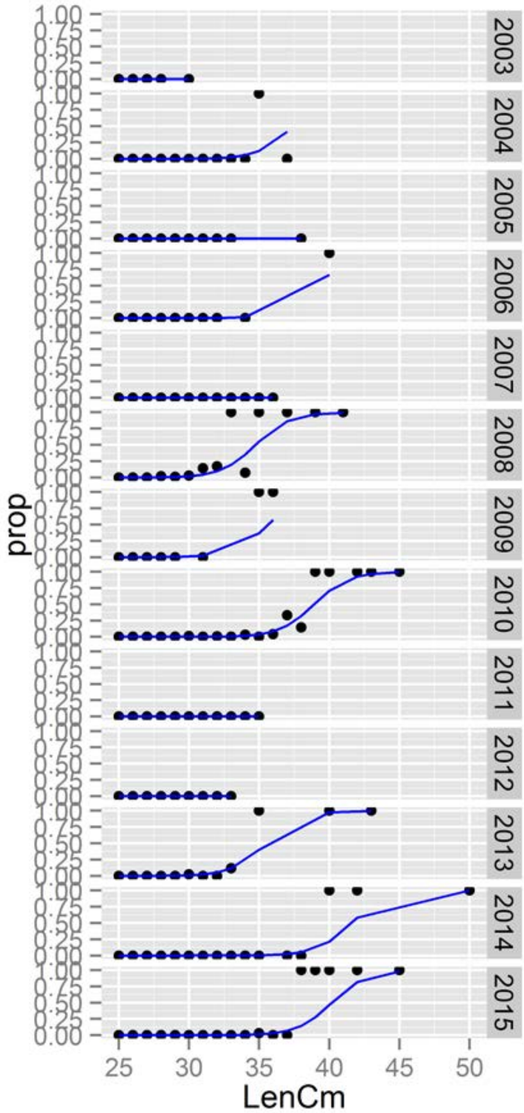


Figure 5.5.3. Shows the Irish 7.a whiting retention ogive by year from 2003–2015.

5.6 Catch selectivity

The figure below shows the log-ratios of the catch numbers-at-age. The log-ratios for ages 1–2 dramatically increase in the late 1990s (indicating the numbers decline much faster in the second half of the time-series). The log-ratios at ages 1–3 also show some increase, while for the older fish, there is mainly an increase in noise but no obvious trend.

This could indicate a change in selectivity of the fleet (catching more young fish) but there is no evidence of any changes in gear that can explain this. Alternatively it may reflect changes in the way discards were sampled or estimated or it can reflect a change in natural mortality or migration.

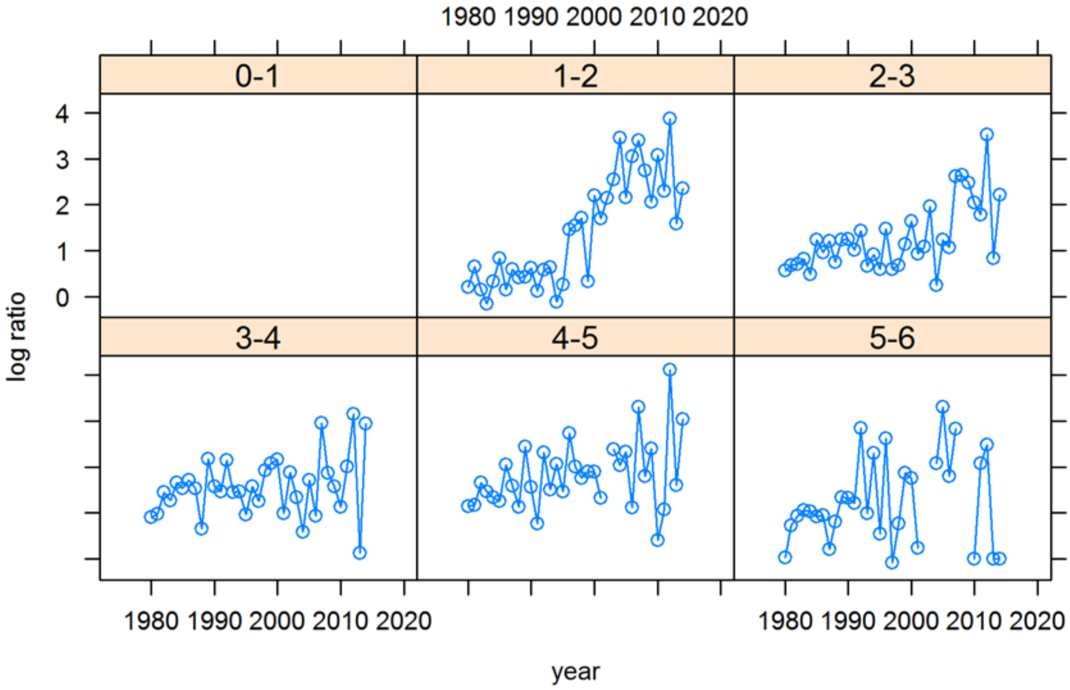


Figure 5.6.1. Log catch-at-age ratios over time for 7.a whiting.

The Figure 5.6.2 below shows the catch curves in the period up to 1999 and from 2000 onwards. After 2000 the catch curves are considerably steeper, this could be a change in natural mortality/migration or change in selectivity of the fleet.

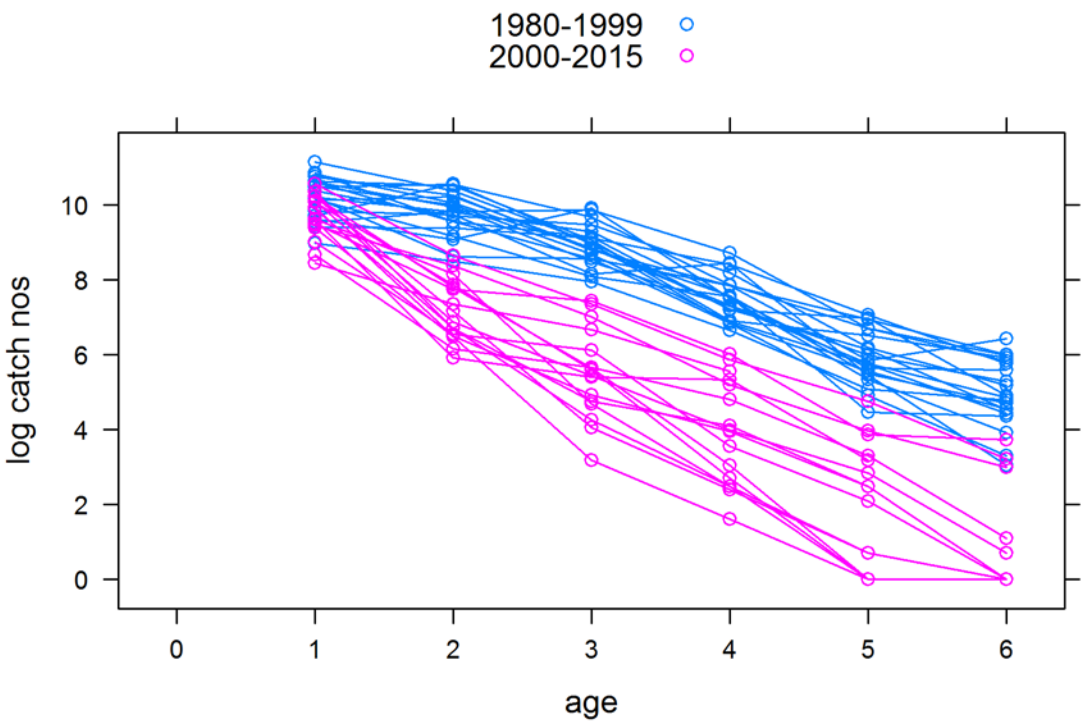


Figure 5.6.2. Catch curves based on the commercial catch-at-age data for 7.a whiting.

Figure 5.6.3 below shows the catch curves by year. The slopes throughout the time-series are very steep. The slopes appear slightly shallower at the start of the time-series compared with the end where the numbers are very low especially for older ages.

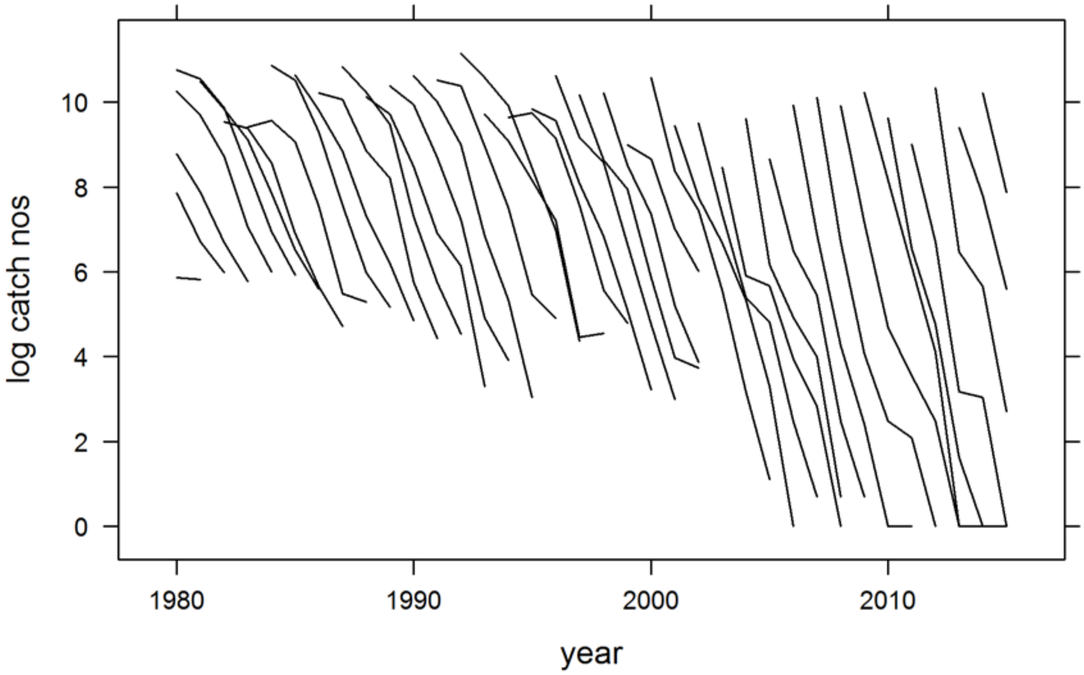


Figure 5.6.3. Catch curves by cohort based on the commercial catch-at-age data for 7.a whiting.

Conclusion

- It is probably necessary to have at least two selectivity blocks in ASAP.
- Full selectivity can be assumed from age 3, allowing the model to estimate it for ages 1 and 12.

5.7 Recommend values for discard mortality rates, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values

No data relating to discard survival rates of whiting were available. However it is very likely that discard mortality is very high, most whiting on observed board commercial trips are dead, a precautionary estimate of 1 is assumed.

5.8 Review all available and relevant fishery-dependent and -independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision

5.8.1 Fisheries-independent data

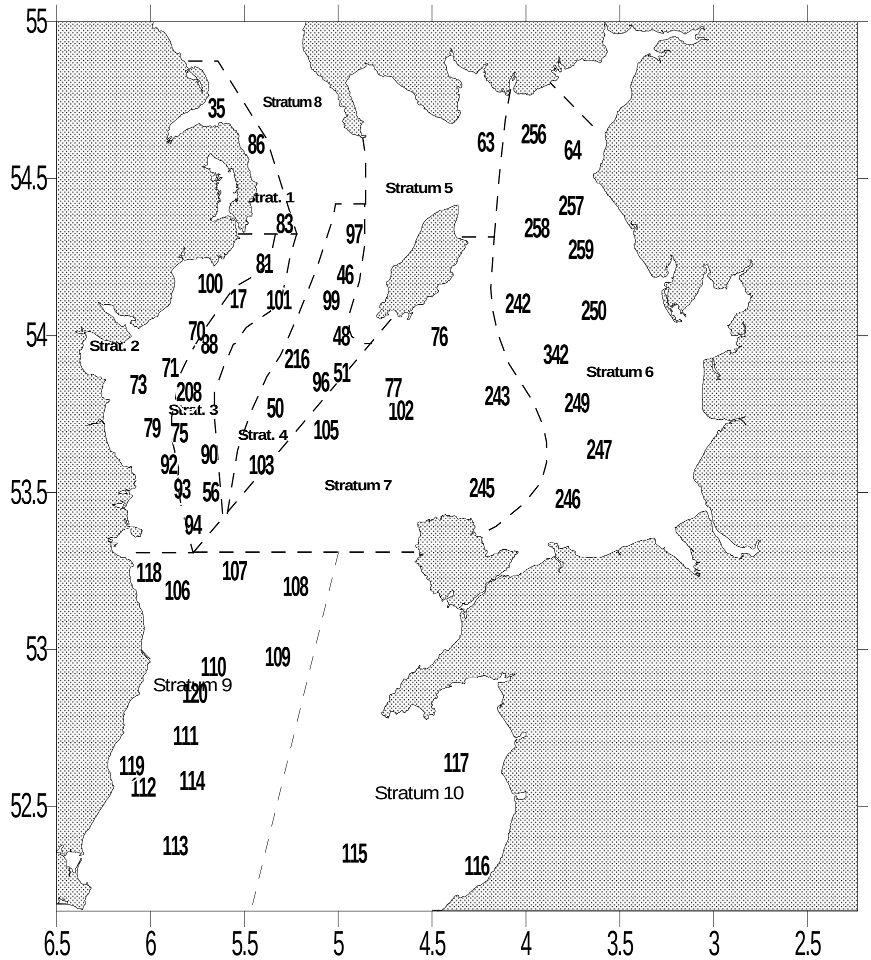
Five survey tuning series were considered by WKIrish2 for Whiting in 7.a. These are summarised in the table below:

Index ID	Vessel	Gear	Year Range	Age Range	Time of year	Coverage	Design
NIGFS-Q1	1992–2004 R.V. Lough Foyle	Rock-hopper otter trawl with a 17 m footrope fitted with 250 mm non-rotating rubber discs.	1992-presnet	1–6	March	North Irish Sea (Strata 1–8 Figure 5.6.1)	Stratified Fixed stations within strata
NIGFS-Q4	2005–Present RV Corystes		1993-Present	0–6	October		
NIMIK			1994-present	0	May	North Irish Sea	
UK-BTS-Q3	RV Corystes	Beam Trawl	1988-Present	0–1	September	Mainly east	Fixed prime stations
EIS-FSP	FV Isadale	Boris rock-hopper otter trawl with 118 ft headline and 160 ft groundgear comprising 100 ft of 14-inch hoppers and 2 × 30 ft ground chains.	2005-2013	1-6	February–March	East	Stratified by rectangle with a minimum number of tows requested in each rectangle

The UK (Scotland) groundfish survey in spring (ScoGFS-WIBTS-Q1) and autumn (ScoGFS-WIBTS-Q4) were not reconsidered by WKIrish as previous investigations have shown these surveys not to be useful for whiting. These surveys finished more than a decade ago (2007) and would have no influence on current stock perception. There is also no egg production estimate for whiting and the other FSP surveys do not catch whiting in sufficient number to generate an index.

NIGFS-WIBTS-Q1 (East & West)

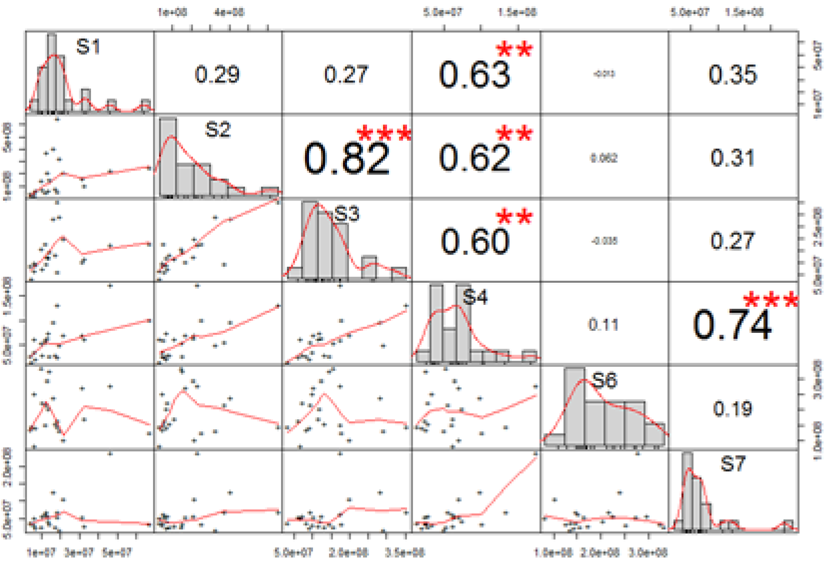
- UK (Northern Ireland) October Groundfish Survey (**NIGFS-WIBTS-Q1-EAST & WEST**): ages 1–6, years 1992–present: The survey series commenced in its present form in 1992. It comprises 45 3-mile tows at fixed station positions in the northern Irish Sea, with an additional 12 1-mile tows at fixed station positions in the St George's Channel from October 2001 (the latter are not included in the tuning data). The surveys are carried out using a rock-hopper otter trawl deployed from the R.V. *Lough Foyle* up 2005 and from 2005 the R.V. Corystes has been used. The survey designs are stratified by depth and seabed type (Figure 5.6.1). The mean numbers-at-length per 3-mile tow are calculated separately by stratum, and weighted by surface area of the strata to give a weighted mean for the survey or group of strata. The strata are grouped into western Irish Sea and eastern Irish Sea, and a separate age–length key is derived for each area to calculate abundance indices by age class. The survey design and time-series of results including distribution patterns of whiting are described in detail in Armstrong *et al.*, 2003. There are seven strata in this survey. Figure 5.6.2 below examine the correlation between strata for different ages caught in the NIGFSQ1 survey. They indicate that for the younger ages (1–3) there are strong correlations between most of the strata. The weakest correlations are between stratum 6 (the most eastern strata) and the remaining strata.



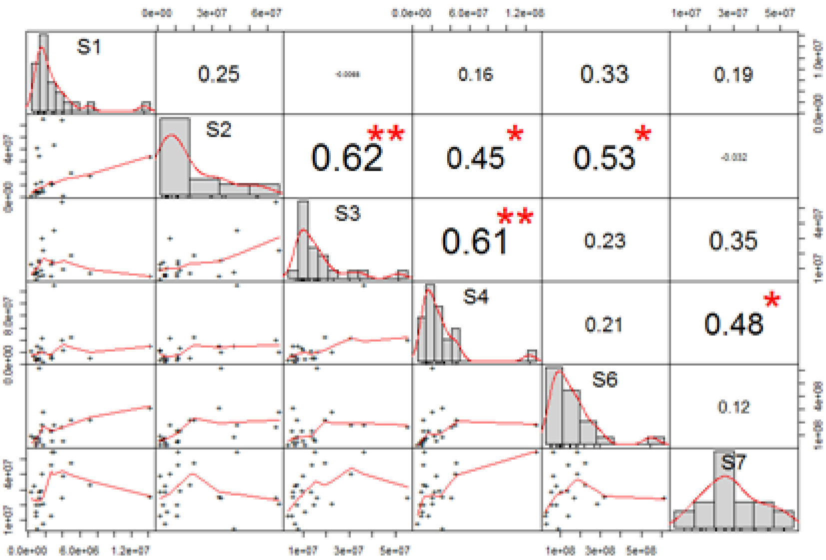
Key to strata:
1. Irish Coast (N), <100m, Mixed sediments
2. Irish Coast, < 50m, sand and finer sediments
3. Irish Coast, 50 - 100m, Muddy sediments
4. W and SW Isle of Man, 50 - 100m, mud and muddy sand
5. N Isle of Man, <50m, gravel sediments
6. Eastern Irish Sea, <50m, sand and finer sediments
7. S. Isle of Man, <100m, gravel sediments
8. Deep western channel and North Channel >100m
9. St George's Channel west; sandy/mixed sediments; <100m
10. St George's Channel east; sandy/mixed sediments; <100m

Figure 5.6.1. Map showing UK (Northern Ireland) March Groundfish Survey (NIGFS-WIBTS_Q1_East and West) stations and strata.

Q1 – Age1



Q1 – Age2



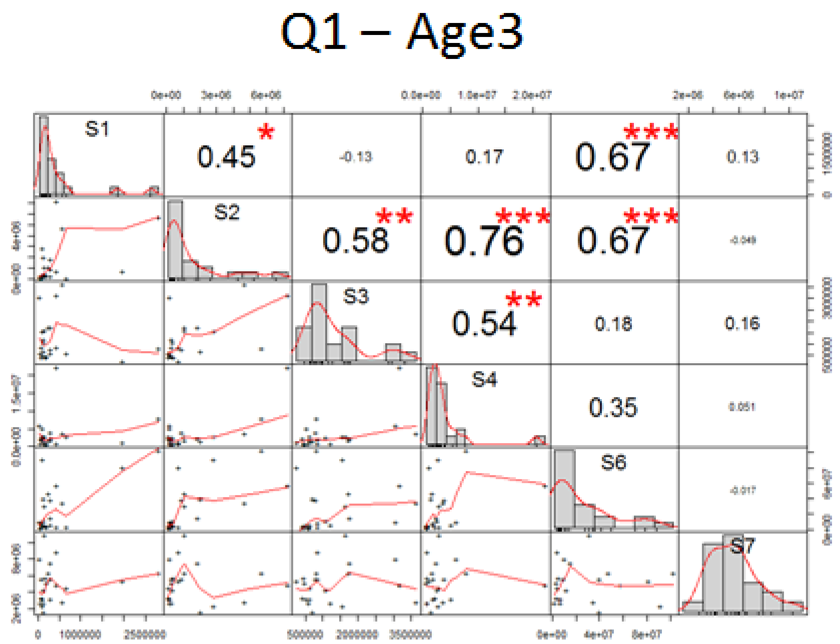


Figure 5.6.2. Between strata cpue correlation plots for UK (Northern Ireland) March Groundfish Survey (NIGFS-WIBTS_Q1).

Figure 5.6.3 looks at the numbers-at-ages 1–3 caught on the survey and shows that Strata 6 accounts for the steep decline in survey catch rates from the beginning of the time-series to 2005.

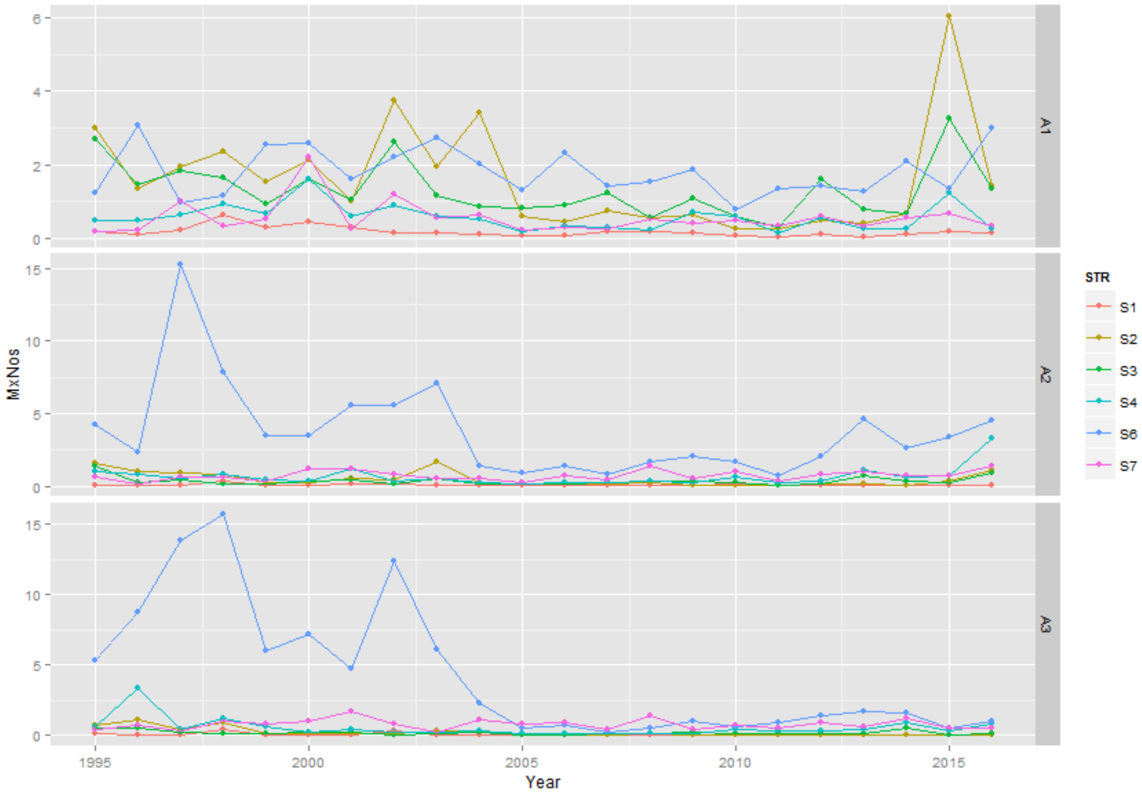
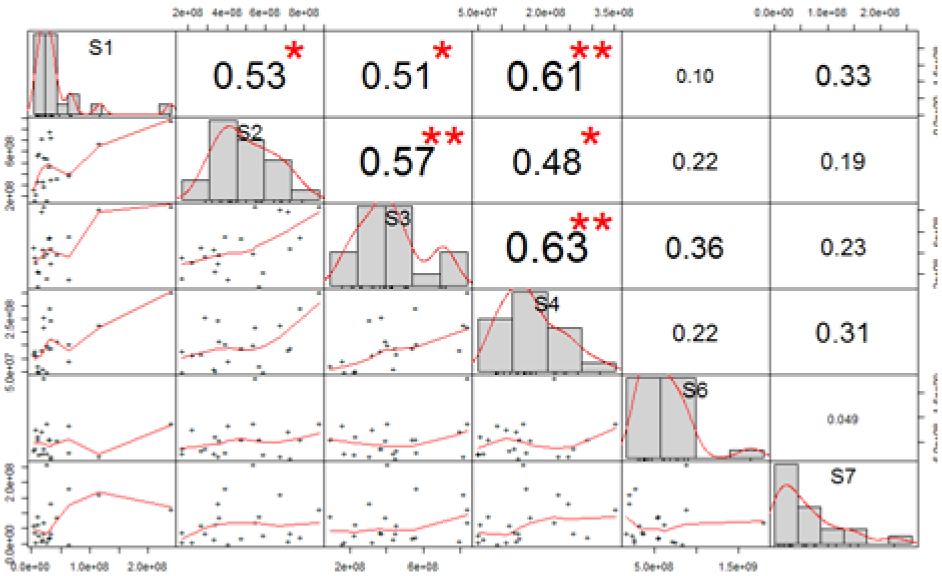


Figure 5.6.3 Catch of whiting in numbers by strata for ages 1, 2 and 3 on the NIGFS-WIBTS-Q1.

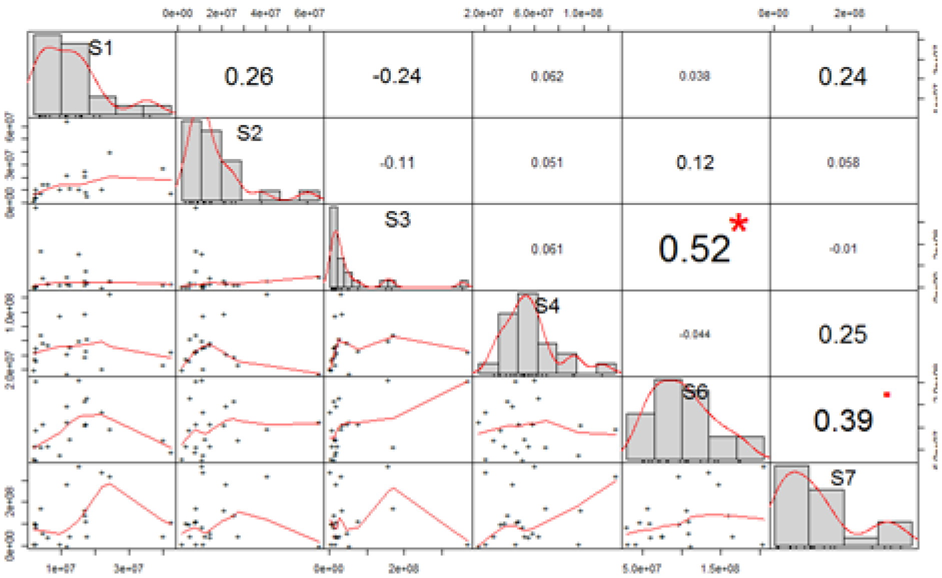
NIGFS-WIBTS-Q4 (East & West)

General description as for October Surveys above, except that 3-mile stations have been retained in all strata other than in the St Georges Channel. The survey series commenced in its present form in 1993. Figure 5.6.4 shows the correlations between strata for ages 0–2. The correlations are also stronger between strata in the western Irish Sea.

Q4– Age0



Q4– Age1



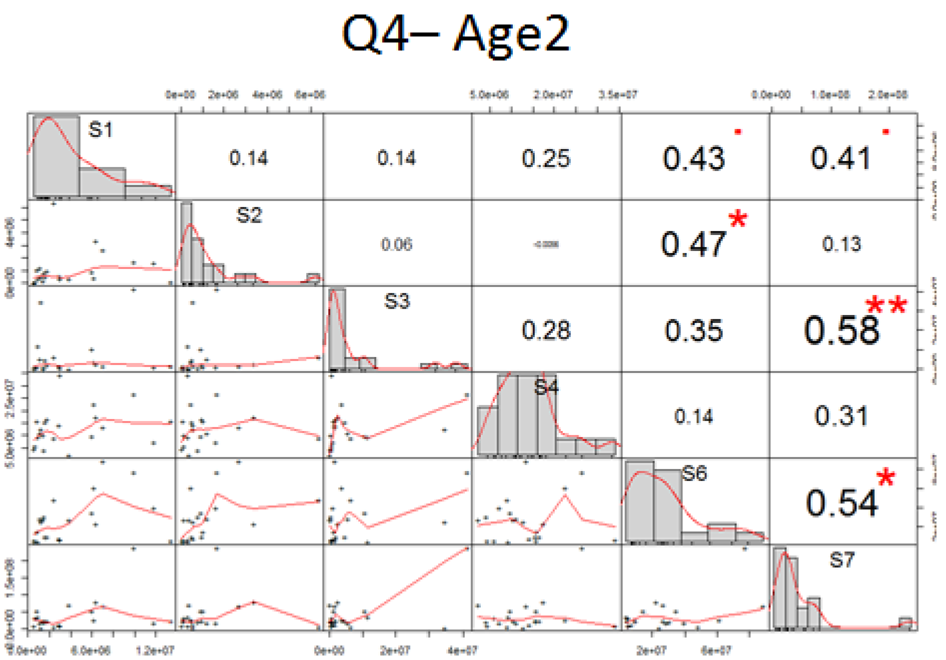


Figure 5.6.4. Between strata cpue correlation plots for UK (Northern Ireland) October Groundfish Survey (NIGFS-WIBTS_Q4).

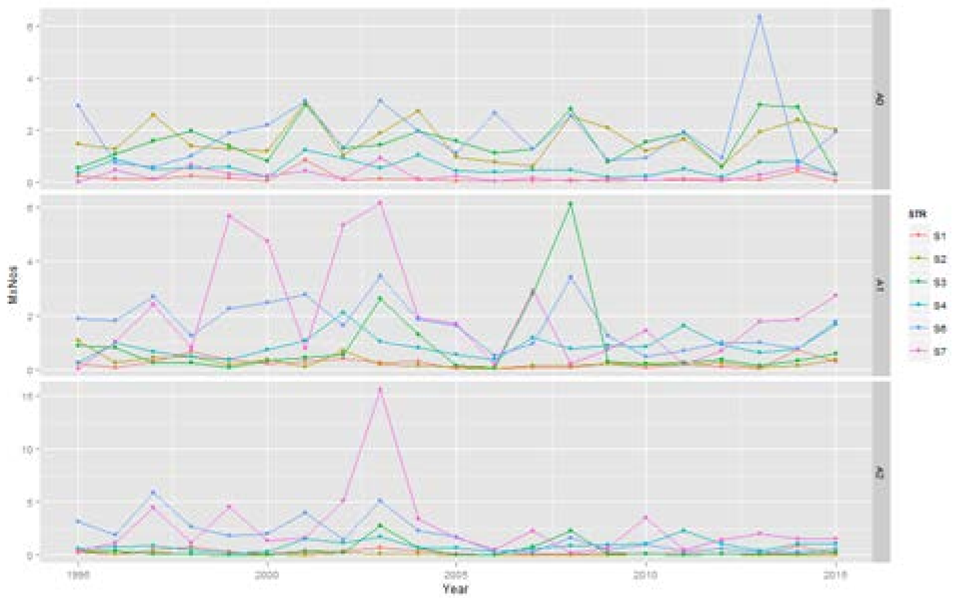


Figure 5.6.5. Catch of whiting in numbers by strata for ages 0, 1 and 2 on the NIGFS-WIBTS-Q4.

Northern Ireland MIK Net Survey

UK (Northern Ireland) Methot-Isaacs–Kidd Survey (NIMIK): age 0, years 1994–2015: The survey uses a Methot-Isaacs–Kidd frame trawl to target pelagic juvenile gadoids in the western Irish Sea at 40–45 stations. The survey is stratified and takes place in June during the period prior to settlement of gadoid juveniles. Indices are calculated as the arithmetic mean of the numbers-per-unit sea area.

FSP Surveys

The Irish Sea roundfish survey was carried out between 2004–2013 as a fully collaborative project between the fishing industry and Cefas scientists (Armstrong *et al.*, 2013). It formed part of the UK Fisheries Science Partnership funded by the UK's Department for Environment, Food and Rural Affairs (Defra). The main objective of the Irish Sea roundfish survey was to develop a time-series of data to track year-on-year changes in abundance, population structure and distribution of the target species (cod, haddock and whiting). The survey used a stratified design to allow additional trawling effort in areas expected to have the greatest densities of cod, haddock or whiting. Whiting were most abundant in the southern part of the eastern Irish Sea and it is the data from this survey that is used in t the whiting 7.a assessment. The vessel that carried out the survey was the MFV Isadale using an otter trawl. Catch rates throughout out the time-series were low and were dominated by young fish less than five years old.

Data screening

Each of the survey series were examined to look their ability to track cohorts. Figure 5.6.6 shows log standardized indices by age for the NIGFSQ1, NIGFSQ4 and Eastern Irish Sea FSP surveys. There is weak evidence of cohort tracking, e.g. strong 2008 and weak 2009 year classes. However throughout the time-series of these indices there hasn't been much contrast in the cohort strength.

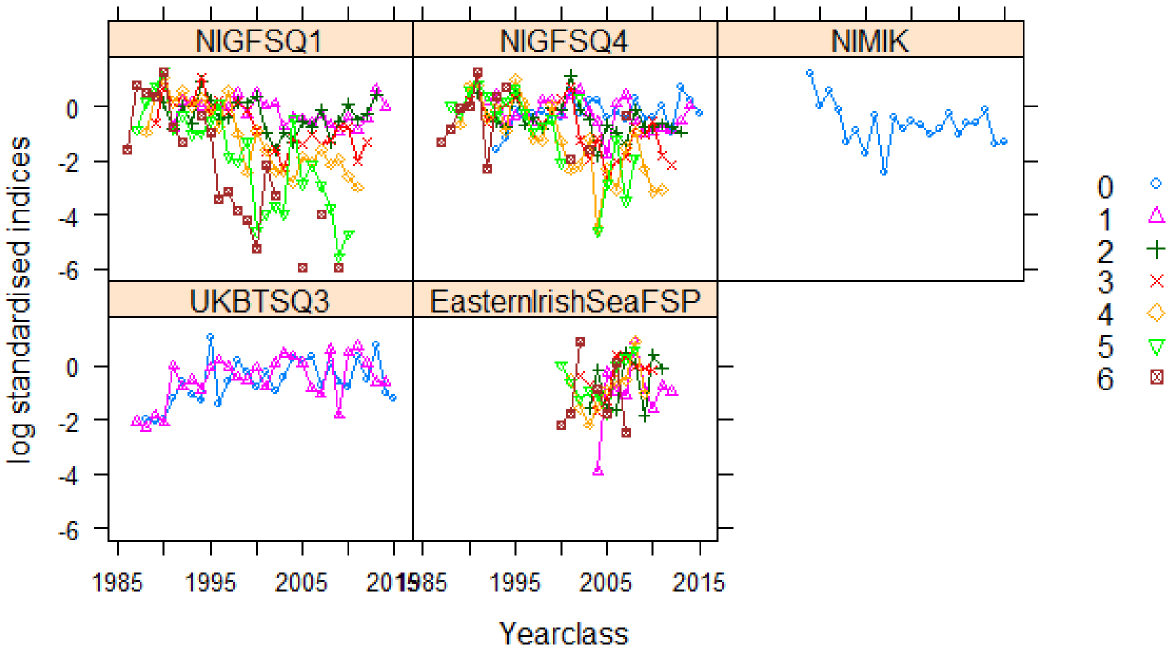


Figure 5.6.6. Log Standardized Indices of whiting catch numbers-at-age in the NIGFSQ1, NIGFSQ4, NIMIK, UKBTSQ3 and the Eastern Irish Sea FSP.

Figure 5.6.7 shows the log standardized indices per age to examine consistency across the surveys for each age group. For age 0, there is evidence that the NIMIK and NIGFSQ4 track this age class well. Beyond that there is little strong evidence to show that that other surveys track any of the other age classes.

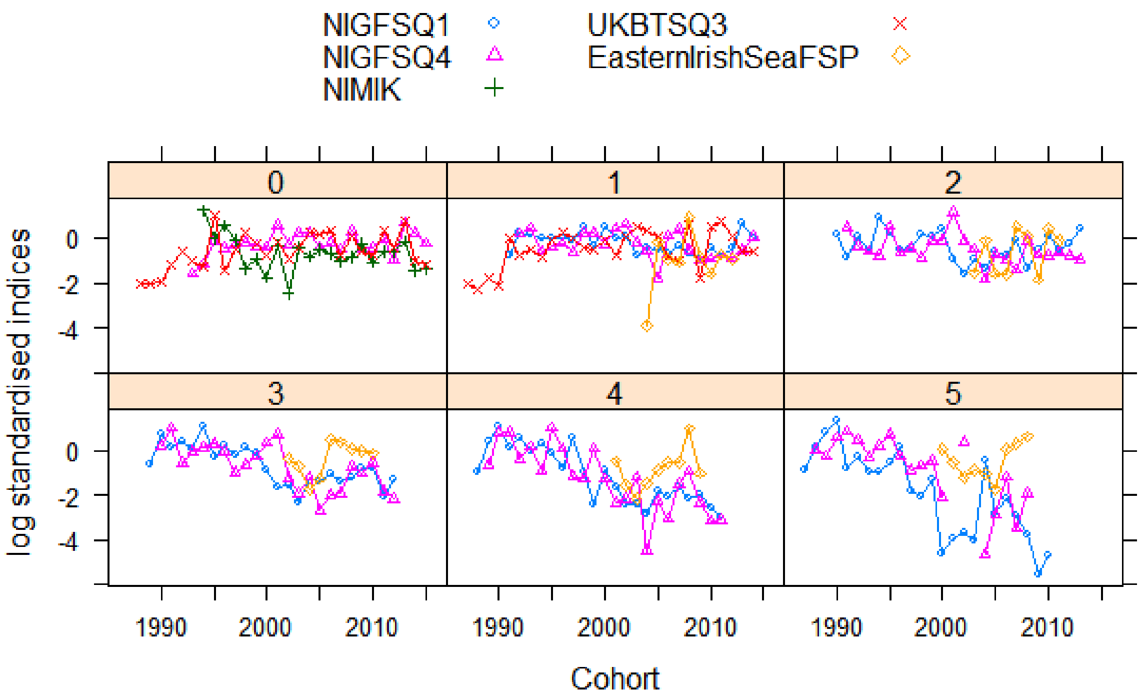


Figure 5.6.7. Log standardised indices of whiting catch numbers-at-age for the five surveys by age.

The most noticeable feature of Figure 5.6.6 is spreading out of the log-standardised index for the older ages on the two Northern Ireland surveys. This implies an increase in total mortality. Figure 5.6.8 shows the log indices of the NIGFSQ1, NIGFSQ4 and the Eastern Irish Sea FSP. These catch curves shows steep decline in the catches across years for all surveys. The catch curves post-2004 show a steeper slope than those before 2004. The catch curve for the eastern Irish Sea FSP survey show a more domed shape reflecting the selection pattern of the 100 mm gear used.

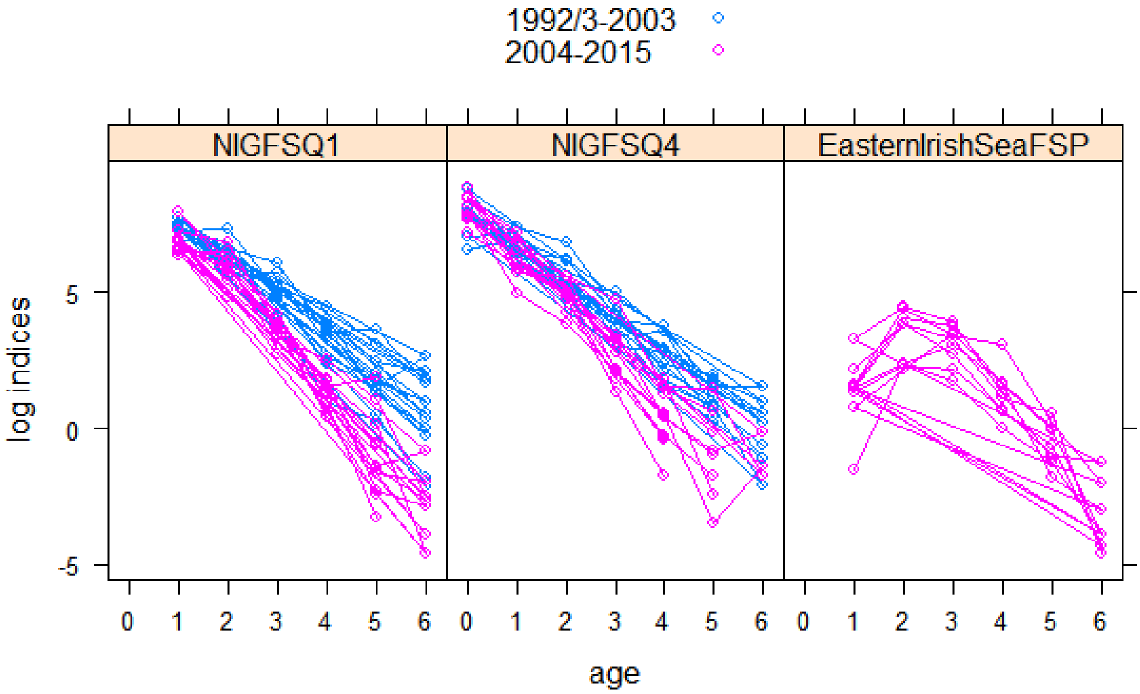


Figure 5.6.8. Catch curves for NIGFSQ1, NIGFSQ4 and the eastern Irish Sea FSP.

Figure 5.6.9 looks at the internal consistency within Surveys. The NIGFSQ1 seems to track ages well as correlations are stronger with the younger ages (Figure 5.6.9a). The NIGFSQ4 shows little correlation amongst younger ages and negative correlations for age 0 and some of the older ages (Figure 5.6.9b). The eastern Irish Sea FSP survey is based on few datapoints (Figure 5.6.9c) and it is difficult to determine any patterns.

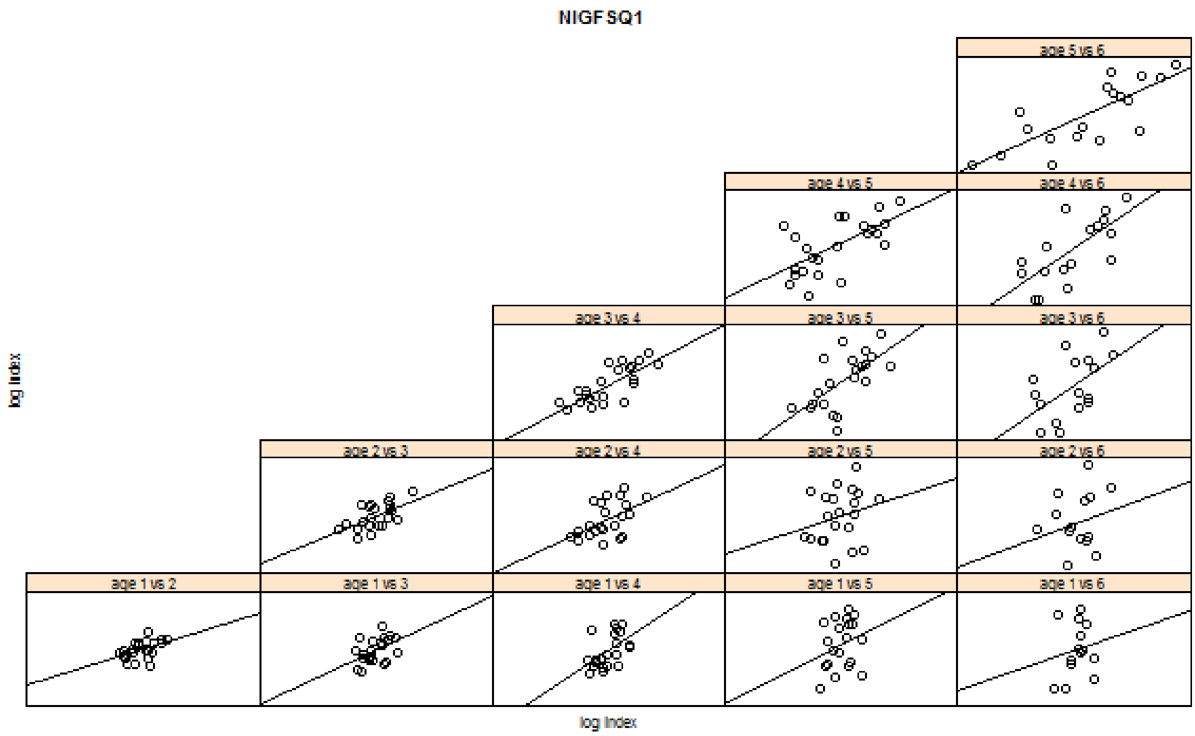


Figure 5.6.9a. Scatterplots of log index-at-age with correlation line for NIGFS-Q1.

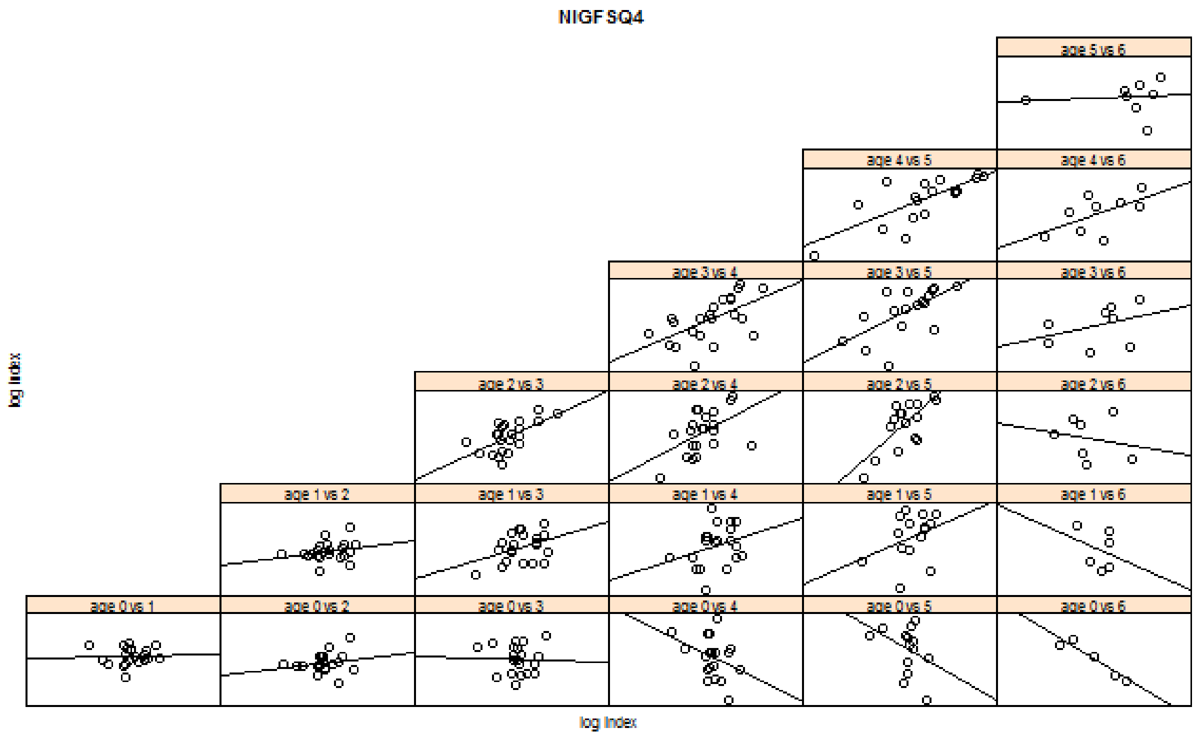


Figure 5.6.9b. Scatterplots of log index-at-age with correlation line for NIGFSQ4.

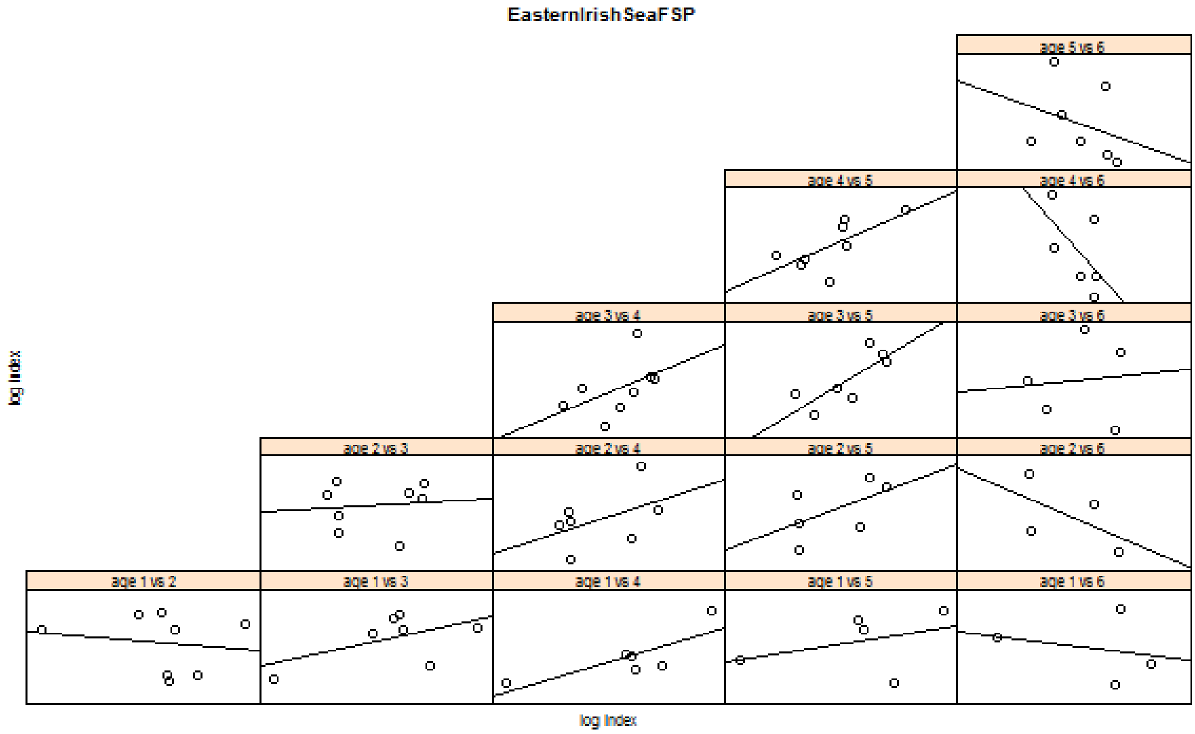


Figure 5.6.9c. Scatterplots of log index-at-age with correlation line for the eastern Irish Sea FSP.

Conclusions

- There is no particular reason to exclude any of the survey indices, based on the data; however it seems unlikely that a beam trawl can catch whiting in a quantitative way (considering their vertical distribution). Therefore the beam trawl survey will be excluded a-priori. Additionally, the NIGFSQ1 survey takes place during the spawning season, when the adults congregate on the spawning grounds; it may therefore be better to use this index only for age 1 fish, which are immature.
- There is no obvious explanation for the step-change in the NIGFS surveys around 2004 (like changes in gear, vessel, etc.).

5.8.2 Fisheries-dependent data

No fishery-dependent tuning data were considered by WKIrish2 for this stock.

5.9 Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts

a) Review progress on existing recommendations for research to develop and improve the input data and parameters for assessments, and develop and prioritise new proposals.

b) For each stock, develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the data evaluation workshop.

c) Prepare the data evaluation workshop report providing complete documentation of workshop actions, decisions, list of working documents, other information used by the workshop, and a list of any additional tasks to be completed following the workshop with dates and responsibilities for completion.

5.10 References

Armstrong, M. J., Gerritsen, H. D., Allen, M., McCurdy, W. J., and Peel, J. A. D. 2003. Variability in maturity and growth in a heavily exploited stock: Cod (*Gadus morhua* L.) in the Irish Sea. ICES Journal of Marine Science, 49: 69–82.

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6 Data evaluation for Irish Sea haddock

6.1 Explain the basis for existing assumptions on stock structure and mixing rates between stock areas, or proposed new assumptions which form the basis for spatial aggregation of fishery and survey data and/or adjustments to datasets to account for stock mixing

At WKIrish2 the current stock boundary of Irish Sea haddock was explored though comparison of stock trends between adjacent areas and plotting commercial catch, effort data and survey records.

Catch weights from IBTS surveys 2003–2015 were plotted (Figure 6.6.1). The plot demonstrates distich area related pulses of recruitment and supports the current stock area definition. Exploration of survey indices from current assessments also suggests distinct stock dynamics for 7.a, 4&4.a and 7.g. At present landings in rectangles 33E2 and 33E3 are considered to be fish from the northern extreme of the 7.g haddock stock. These rectangles have historically been removed from the landing series of 7.a haddock. At WKIrish2 no data contrary to this perception were found to suggest that this was not a valid assumption.

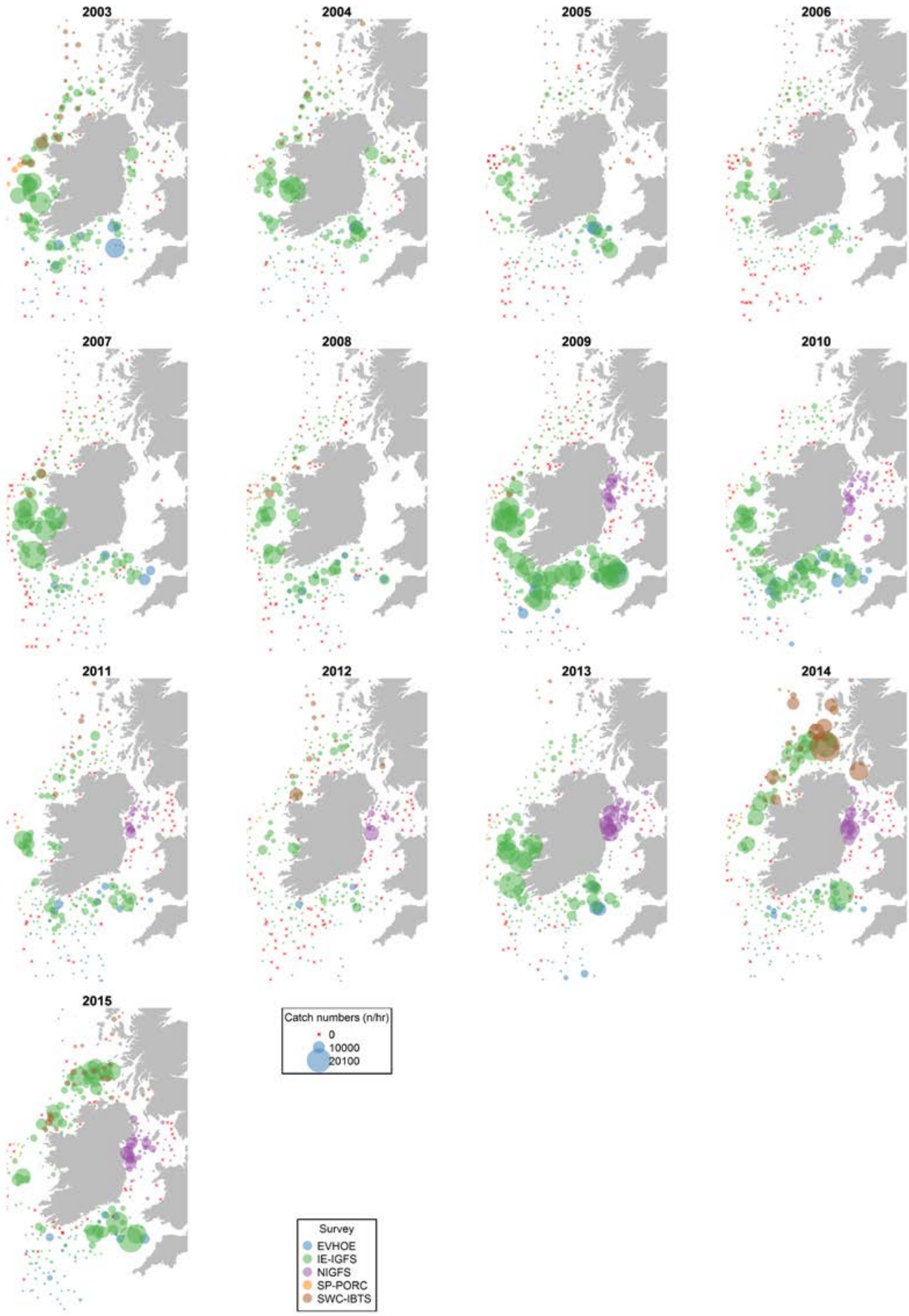


Figure 6.1.1. Catch numbers of haddock from IBTS surveys 2003–2015.

6.2 Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length

6.2.1 Growth parameters

There is evidence of trends in mean length-at-age over time (Figure 6.3.1), which needs to be reflected in the stock weights-at-age. Since 2001 the WG calculated stock weights by fitting a von Bertalanffy growth curve to all available survey estimates of mean length-at-age in March, described in the Stock Annex 6.3. The procedure was updated this year using NIGFS-WIBTS-Q1 (2016) and quarter one commercial landings data for 2015. The time-series of length–weight parameters indicate a reduction in expected weight-at-length since 1996 although this strength of this decline has reduced in recent years (see stock annex for historical data):

Table 6.2.1.

	Length–weight parameters		Expected weight-at-length	
Year	A	B	30 cm	40 cm
2006	0.00506	3.165	239	595
2007	0.00469	3.194	244	612
2008	0.00523	3.159	242	601
2009	0.00431	3.224	249	629
2010	0.00413	3.238	250	635
2011	0.00457	3.207	250	629
2012	0.00499	3.174	243	606
2013	0.00451	3.208	247	622
2014	0.00591	3.121	241	591
2015	0.00423	3.232	251	637
2016	0.00420	3.233	250	634

6.2.2 Natural mortality

Natural mortality M was calculated using a number of different approaches. The following approaches were considered: Pauly (1980) length equation; Hoenig (1983) joint equation; Alverson and Carney (1975); Then *et al*. (2015) age and growth equation; Gislason *et al*. (2010) and Lorenz (1996) (package fishmethods in R). Parameters Linf and K were calculated from commercial catch samples collected in observer programs, self-samples and market samples were estimated by Francis (1988) re-parameterized von Bertalanffy growth equation using non-linear least squares (package fishmethods in R). For further details on equations please refer to Section x.x.

Table 6.2.2. Empirical mortality estimates by Pauly, Then *et al.*, Hoenig and Alverson and Carney and the parameters used in the calculation: Linf, growth parameter K, maximum age and temperature.

	Linf	K	Max age	Temperature	M
Pauly	76.9	0.197		12	0.320
Hoenig			8		0.548
Alverson and Carney		0.197	8		0.721
Then *et al.* (maximum age)			8		0.729
Then *et al.* (growth equation)	76.9	0.197			0.3

Gislason *et al*. and Lorenz assume that M changes over the lifetime of a fish with their length/weight. M decreases with size, as the risk of predation decreases. Lorenz bases his estimation on wet weight alone, while Gislason *et al*. use body length-at-age, L_{inf} and growth parameter K.

Table 6.2.3. Estimates for M as calculated by Gislason *et al*. and Lorenz for mean wet weight-at-age.

Age	Length	Weight	M (Gislason)	M (Lorenz)
0	6.306264	2.05752	9.165	2.44
1	18.86225	61.02887	1.576	0.918
2	29.24511	237.0379	0.743	0.621
3	37.83096	525.6647	0.53	0.494
4	44.93081	894.9961	0.401	0.424
5	50.80186	1308.702	0.326	0.38
6	55.65678	1735.73	0.272	0.35
7	59.67144	2153.132	0.243	0.329

6.2.3 Maturity

Maturity staging of haddock carried out during the NIGFS-WIBTS_Q1 survey. The survey is stratified (Figure 5.6.1). Sampling is length stratified, with two individuals from each 1 cm length class sampled. We used the methods described in (Gerritsen et al., 2003) to fit a model to maturity-at-length data. To avoid any biases in estimating the proportion mature-at-age using length-stratified samples, data on sex, age and maturity from each length class were weighted by the total catch in that length group using:

We estimated L50 (lengths at which 50% of fish are mature) using a maximum likelihood method:

$$PM_j = \left[1 + \exp\left(-b \cdot (j - L_{50})\right)\right] - 1$$

Maximum likelihood estimates of L50 and b were found by minimising the negative log-likelihood, using the Nelder-Mead method.

Interannual variability of L_{50} for males and females appears to be similar. (Figure 6.2.1). There is downward trend in L_{50} in until 1993–2008, where upon L_{50} has been steady, although interannual variability is high.

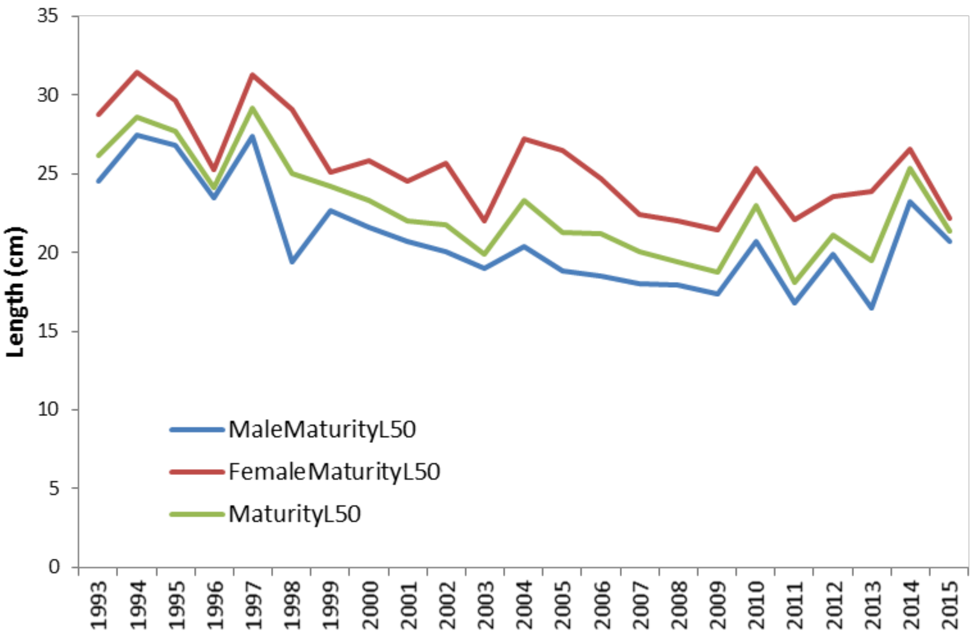


Figure 6.2.1. Length at which 50% of Irish Sea haddock are mature for males, females and combined from quarter 1 NIGFS survey data.

6.2.3.1 Proportion mature-at-age

The proportions mature-at-age was recalculated based mean proportion of females observed during the NIGFS-WIBTS-Q1 survey (Figure 6.2.2). A LOWESS smoother was fitted to the proportion mature-at-age data, weighted by strata contribution to the survey area. A smoother span of $^2/_3$ was used. It was proposed that this could be reapplied to update the series; the analysis is applied at-age 1–3 to provide a temporally dynamic estimate of proportion of female haddock mature-at-age (Table 6.2.4).

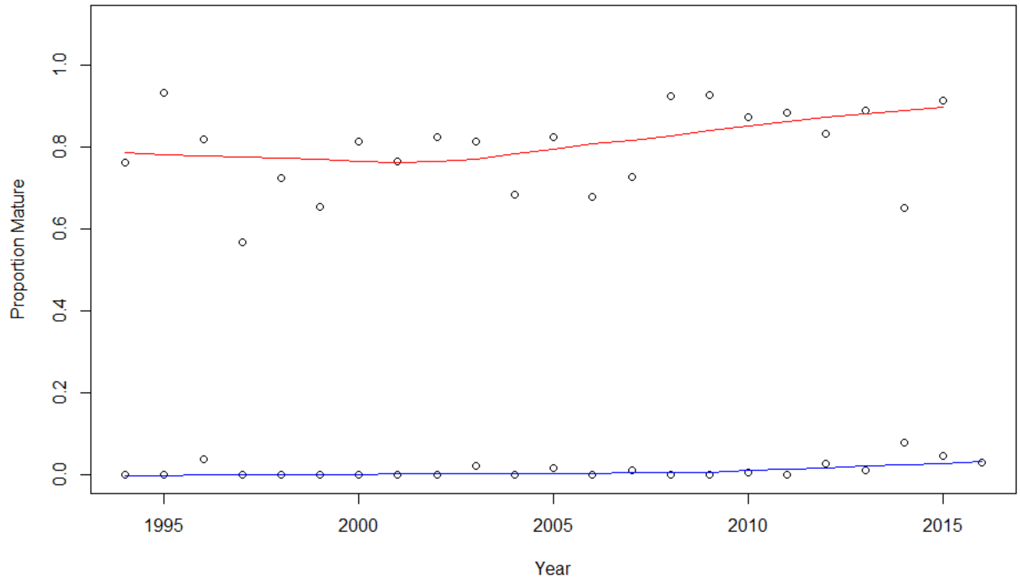


Figure 6.2.2. Proportion of female haddock mature-at-age; Lines are LOWESS smoothed with span = ²/₃ for age 1 (blue) and age 2 (red) haddock.

Table 6.2.4. LOWESS smoothed proportion of female haddock mature-at-age 1–3 from quarter 1 NIGFS surveys.

Year	Age -1	Age -2	Age - 3
1994	0	0.79	1
1995	0	0.78	1
1996	0	0.78	1
1997	0	0.77	1
1998	0	0.77	1
1999	0	0.77	1
2000	0	0.76	1
2001	0	0.76	1
2002	0	0.76	1
2003	0	0.77	1
2004	0	0.78	1
2005	0	0.79	1
2006	0	0.81	1
2007	0	0.82	1
2008	0	0.83	1
2009	0	0.84	1
2010	0	0.85	1
2011	0	0.86	1
2012	0	0.87	1
2013	0	0.88	1
2014	0	0.89	1
2015	0	0.90	1

6.3 Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of relevance for the scientific assessment of the stocks and provision of advice

See Section x.x.

6.4 Develop time-series of (commercial and recreational) fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision

6.4.1 Commercial fishery landings

Landings data have been supplied (annual quarterly landings) by the UK(N. Ireland), UK(E&W), UK(Scotland), Ireland, Belgium, and the IOM from databases maintained by national Government Departments and research agencies. The landings figures may be adjusted by national administrations or scientists to correct for known or estimated misreporting by area or species. To avoid double counting of landings data, each UK region supplies data for UK landings into its regional ports, and landings by its fleet into non-UK ports.

An international landing series for registered landings is available. This is updated annually, along with landings numbers-at-age at WGCSE. Landings data for this stock are uncertain because of species misreporting, which has been estimated from quayside observations in one country only. The landings since 1993 have been revised and exclude landings from the southern rectangles in the Irish Sea as they not are believed to be part of this stock. Restrictive quotas for some countries caused extensive misreporting during the 1990s prior to the introduction of a separate TAC allocation for the Irish Sea. Estimates of misreporting have been included in the estimates of landings, except for 2003. The recent implementation of buyers and sellers legislation has improved the quality of the landings data since 2006.

Table 6.4.1. Haddock in 7.a. Total international landings of haddock from the Irish Sea, 1972–2015, as officially reported to ICES. Working Group figures (WGCSE) , assuming 1972–1992 official landings to be correct, are also given. The 1993–2005 WG estimates include sampled-based estimates of landings at a number of Irish Sea ports. Sample-based evidence confirms more accurate catch reporting since 2006. Landings in tonnes live weight. Since 1993 the landings have been corrected to exclude catches from the southernmost rectangles, which are not considered part of this stock.

Year	Official landings	WG landings	ICES discards**	ICES catch	% Discard	Landings taken or reported in rectangles 33E2 and 33E3
1972	2204	2204				
1973	2169	2169				
1974	683	683				
1975	276	276				
1976	345	345				
1977	188	188				
1978	131	131				
1979	146	146				
1980	418	418				
1981	445	445				
1982	303	303				
1983	299	299				
1984	387	387				
1985	728	728				
1986	726	726				
1987	1287	1287				
1988	747	747				
1989	560	560				
1990	582	582				
1991	616	616				
1992	703	656				
1993	730	813				
1994	681	1042				
1995	841	1736	780	2516	31%	16
1996	1453	2981	709	3690	19%	33
1997	1925	3547	895	4442	20%	36
1998	3015	4874	1015	5889	17%	28
1999	2370	4095	634	4729	13%	34
2000	2447	1357	802	2159	37%	11
2001	2229	2246	269	2515	11%	74
2002	1115	1817	387	2204	18%	82
2003	674	659	-	-	-	64
2004	761	1217	392	1609	24%	53
2005	547	666	551	1217	45%	35
2006	655	633	306	939	33%	26
2007	1078	886	722	1608	45%	222

Year	Official landings	WG landings	ICES discards**	ICES catch	% Discard	Landings taken or reported in rectangles 33E2 and 33E3
2008	879	786	643	1429	45%	194
2009	846	581	579	1160	50%	285
2010	939	679	508	1187	43%	267
2011	813	446	307	753	41%	374
2012	n/a	343	599	942	64%	473
2013	654	254	283	537	53%	410
2014	953	518	488	1006	49%	444
2015	1154	833	652	1451	44%	322

The input data on fishery landings and age compositions are split into four periods:

1968–1990. Landings in this period, provided to ICES by stock coordinators from all countries, are assumed to be un-biased and are used directly as the input data to stock assessments.

1991–1999. TAC reductions in this period caused substantial misreporting of landings, primarily cod but associated with this was the misreporting as/of other species, into several major ports in one country. Landings into these ports were estimated based on observations of landings by different fleet sectors during regular port visits. For other national landings, the WG figures provided to ICES stock coordinators were used.

2000–2005. Cod recovery measures were considered to have caused significant problems with estimation of landings. The ICES WG landings data provided by stock coordinators for all countries are considered uncertain and estimated within an assessment model. Observations of misreported landings were available for 2000, 2001, 2002 and 2005. However, they have generally not been used to correct the reported landings but have been used to evaluate model estimates in those years.

2006–2015. The introduction of the UK buyers and sellers legislation is considered to have reduced the bias in the landings data but the level to which this has occurred is unknown. Consequently comparisons were made between the fit of the model to recorded landings under an assumption of bias and unbiased information.

In addition to the above, Irish landings of haddock reported from ICES rectangles immediately north of the Irish Sea/Celtic Sea boundary (ICES rectangles 33E2 and 33E3) have been reallocated into the Celtic Sea as they represent a combination of inaccurate area reporting and catches of haddock considered by ICES to be part of the Celtic Sea stock.

6.4.2 Discards estimates

At WKROUND 2013 collation of recent discard information provided by Member States for the stock was carried out for future trialling stock assessment models and the provision of catch advice. Up to 2003, estimates of discards are available only from limited observer schemes and a self-sampling scheme. Observer data are collected using standard at-sea sampling schemes. Results have been reported to ICES. Discards data (numbers-at-age and/or length frequencies) are have been supplied for

7.a haddock by Ireland, UK(Northern Ireland) and UK(E&W) and Belgium. The data were supplied raised to the appropriate fleet/métier level by the Member States. These methods have been applied annual since WKROUND 2013, using 'InterCatch' protocols with comparison to existing spreadsheet based methods.

Northern Ireland

The catch rates for the Northern Irish at-sea sampling scheme are shown in Figure 6.4.1, the plots show well resolved density plots of catch rates for the single rig (OTB), twin rig otter trawls (OTT) and midwater trawls (OTM) across the sampling period.

As an indication of confidence in the discard estimates derived from sampling schemes coefficients of variation were calculated. These have been provided the assessment working groups (WGCSE 2015) however; the series was extended to cover the entire time-series of catch sampling. Coefficients of variation were calculated for individual national schemes. The coefficients of variation for the Northern Irish at-sea sampling scheme were calculated to take into consideration the contribution of fleet segments to total fleet activity, by quarter (Cochran, 1977). Discard estimates were also calculated for haddock from the fisher self-sampling scheme, used to provide samples for *Nephrops* discards (Table 6.4.2). Comparison of these provides confidence in the ability of these schemes to provide robust estimates of discards. The CVs calculated for discard estimates of haddock show a reduction in the estimated CVs in recent years 2012–2015, this is considered to be related to higher sampling levels and also high stock abundance in this period.

The sampling coverage of fleets was also assessed by comparing the observed and reported landings values. Figure 6.4.2 shows the observer (raised to sampled fleets) and reported (from sampled fleets) landings from the Northern Irish at-sea sampling scheme. It considered that there is consistent agreement in the estimate derived from at-sea sampling that that reported providing confidence in the design of the sampling scheme to provided estimates of catch for the sampled fleets.

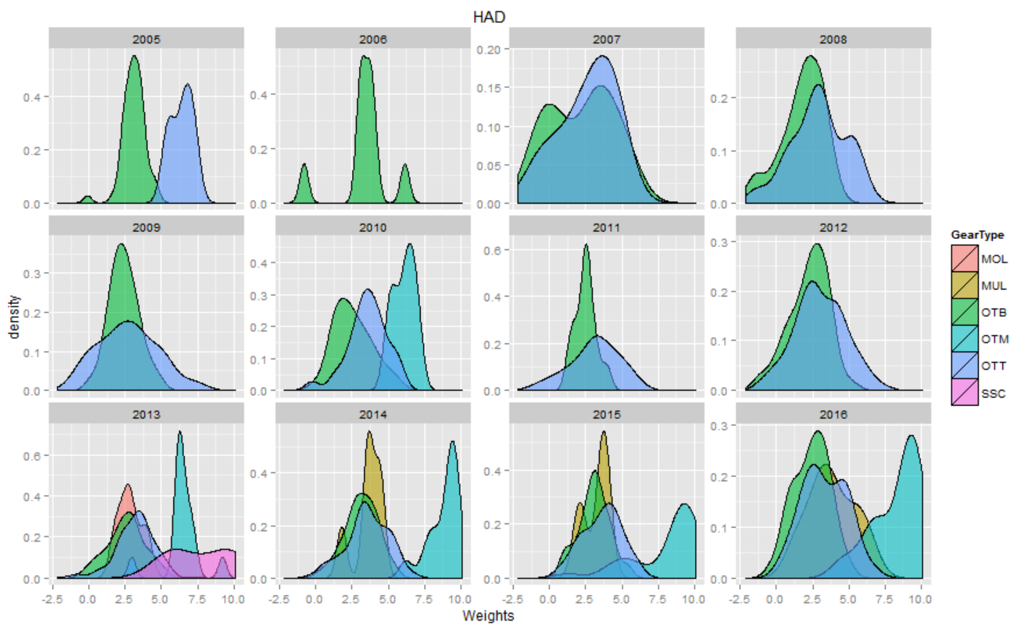


Figure 6.4.1. Irish Sea haddock catch rates of main gears sampled by Northern Irish at-sea sampling.

Table 6.4.2. Haddock in 7.a. Discard(t) estimates for haddock from the Irish Sea, 2006–2015, as derived through at-sea catch sampling and fisher self-sampling schemes. Coefficients of Variation (CV) are shown for discard estimates as a measure of error.

	At - sea sampling					Self-sampling
	OTB	OTT	OTM	Total	CV	
2006	109.3	8.0	0.0	117.3	30	
2007	290.4	27.7	0.0	318.1	42	
2008	57.1	38.6	0.1	95.8	20	197.7
2009	61.3	215.7	13.2	290.2	51	302.0
2010	149.6	187.0	9.6	346.2	19	196.6
2011	72.0	127.6	0.0	199.6	29	136.1
2012	89.1	143.5	0.1	232.7	12	155.2
2013	88.5	53.9	0.5	142.9	14	428.7
2014	298.6	143.1	7.2	448.9	10	261.3
2015	398.5	90.3	14.9	503.7	17	144.4

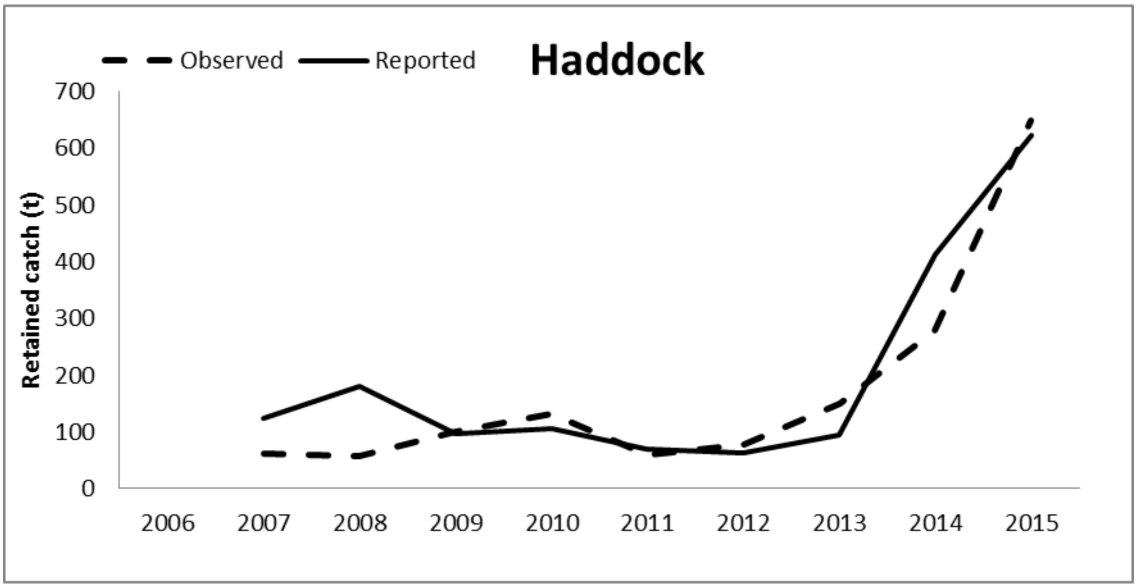


Figure 6.4.2. Irish Sea haddock observed and reported landings from NI fleet. Observed landings are derived from the Northern Ireland at-sea sampling and raised using by quarter & gear as used to obtain estimates of discards.

Ireland

Numbers of trips sampled and for the fleet are dis-aggregated by the métiers in Tables 4.3.3 and 4.4.2. The general quality indicators for the Irish observer programme are given in Section 4.4.7. The spatial distribution of cpue for Irish Sea haddock on Irish otter trawl fishing trips since 2003 are shown in Figure 6.4.2. WKIrish2 agreed to stratify by gear and target species and that there were only sufficient samples for the OTB_CRU fleet. Even for this fleet there is a large variability of dpue and discard volumes by trip (Figure 5.3.3). The total discard estimates raised either using trip or effort as agreed at WKIrish2 are broadly similar and show large interannual fluctuations. The relative standard error for the discard volume estimates range from 17–54% (average 33%) between 2003 and 2015 (Table 5.3.1).

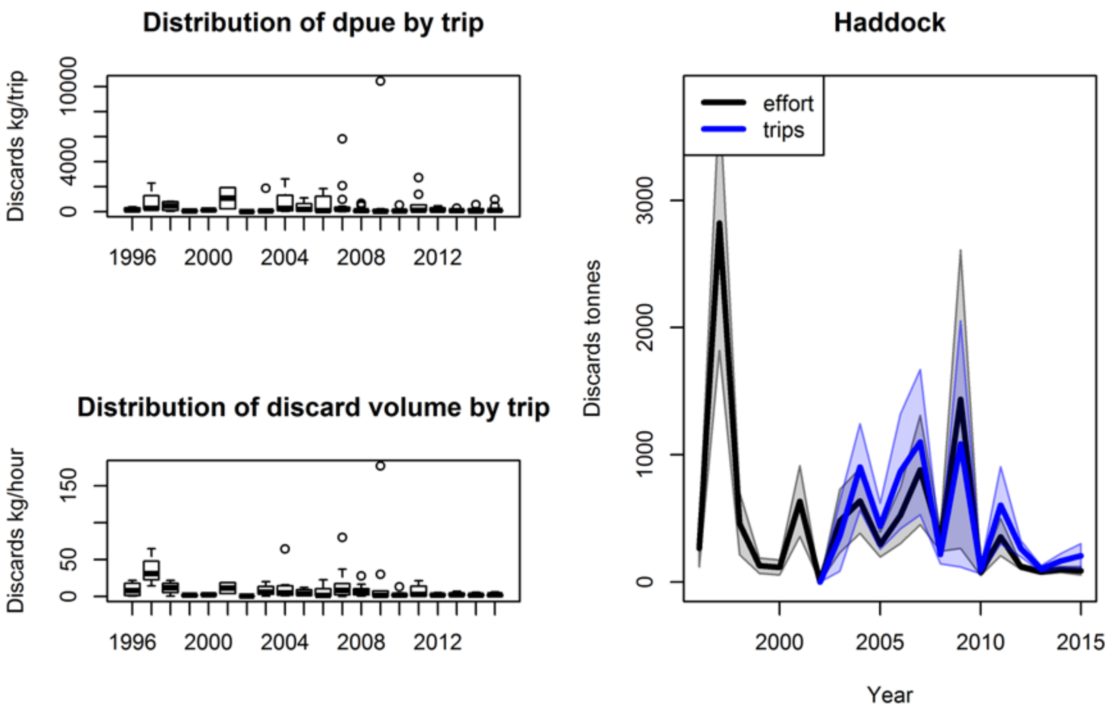


Figure 5.3.3. No difference was found in discard levels raised by trip or by effort. The plots on the left indicate that the raising of the sampled discards by effort and trip followed similar trends and were both effected by a few trips/days which contained inconsistently high levels of discarding. The plot on the right describes a historically similar trend in discards raised by effort and by trip.

6.5 Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision

Member States that have collected length and age composition data for 7.a haddock as required by the EU Data Collection Framework entered quarterly and annual landings-at-age data on InterCatch. Quarterly and annual estimates of landings-at-age are provided by the UK(E&W), UK(NI), Belgium and Ireland. These have been raised to include landings by the other countries, then summed over quarters to produce the annual figures for input to stock assessment.

In addition, the stock coordinator compiles the international landings and catch-at-age data and maintains a time-series of such data with any amendments; since 2013 this has applied using 'InterCatch' protocols and compared with existing spreadsheet based methods. These methods have been evaluated and provide similar results with negligible differences.

Since 2005 an at-sea sampling scheme has been in place for Northern Irish vessels. Observations are conducted across all trawling vessels, including otter trawls targeting *Nephrops*, otter trawling for Queen scallop, midwater demersal vessels targeting white fish, under recent management restriction mainly targeting haddock and hake, midwater pelagic vessels targeting herring, and also vessels using dredge gear to catch scallops. The sampling effort on board vessels during the period 2005–2011 was on average 45 trips per year, in the period 2012–2015 the sampling effort has increased to 230 fishing trips per year.

On-board observers conduct a range of sampling producers whilst at sea. This sampling includes taking length measurements of species retained and discarded, recording the total catch weights (retained and discarded) and collection of other biological samples such as otoliths used for aging. From the length frequencies collected and catch volume estimates fleet level discard estimates can be estimated. Total weights discarded on observer trips are calculated and summed across all trips using the same gear type. These estimates are then raised to the total number of trips made by vessels in the Northern Irish fleet using that gear. Where sufficient observation are achieved, estimates are raised to fleet level based on annual quarterly time periods; however, in some cases trips are aggregated to annual totals.

Ageing error and Age–Length Key quality was assessed by means of a fitting a multinomial logistic regression of age with length as explanatory variable (Ogle, 2016). Individual models of age were constructed for each year and quarter for the NIGFS and combined first and second quarter commercial catch samples and third and fourth quarter commercial catch samples. The model is used to predict the age of each sample using length as the predictor. The error is calculated as absolute difference between the observed age and the predicted age. A mean ageing error is calculated for the ALK in each year and quarter.

The mean ageing error for haddock from NIGFS surveys derived from use of the multi-nominal logistic regression of age using length as a predictor was 0.16 years in quarter 1 and 0.14 years in quarter 4. Over time there is a trend toward increased error rates observed. This considered to be related to the development of the stock with older age fish tending to allow greater absolute error rates, as ageing error will have an asymmetrical error profile bias in younger ages.

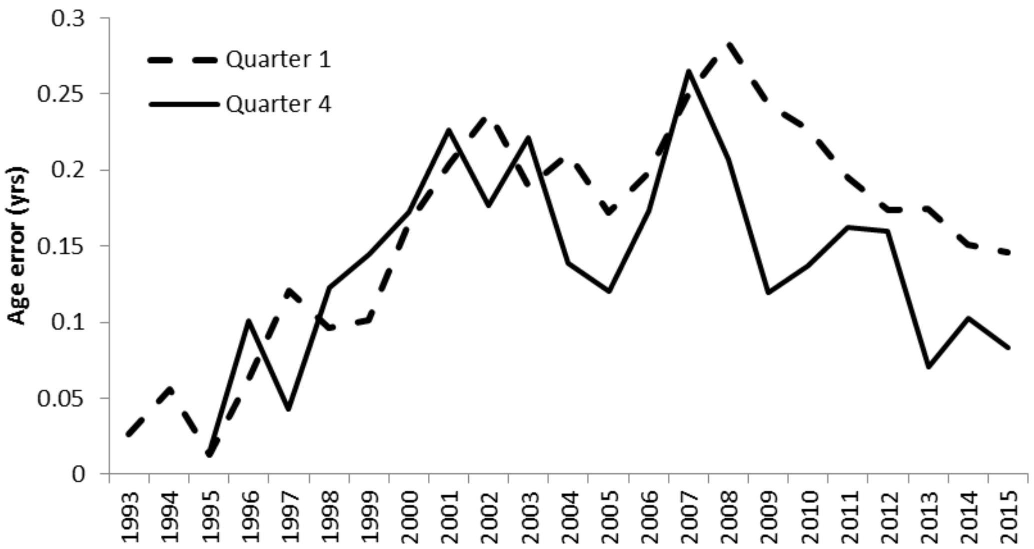


Figure 6.5.1. Ageing error for haddock from NIGFS quarter 1 and quarter 4 surveys.

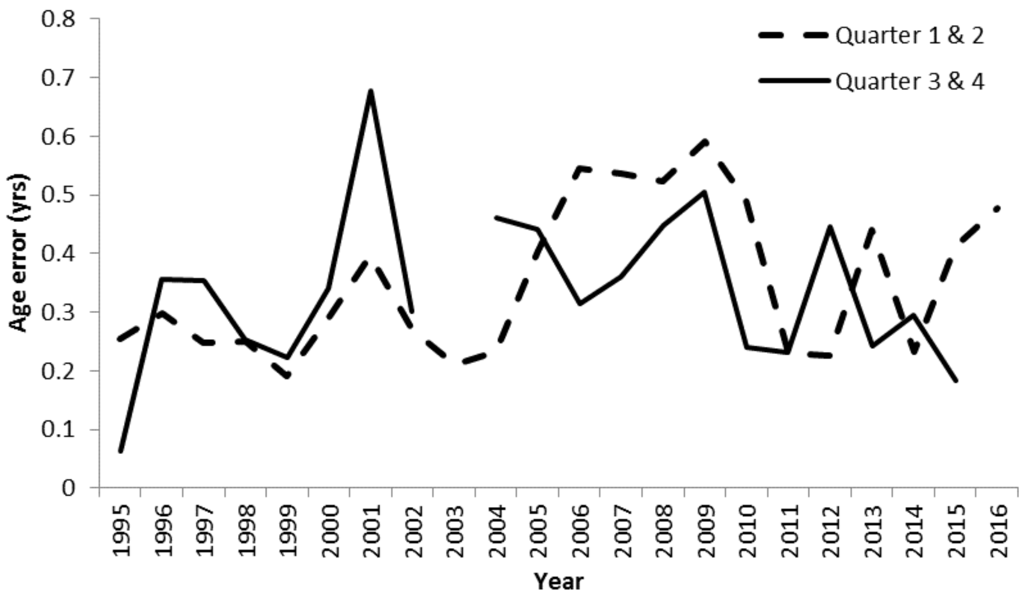


Figure 6.5.2. Ageing error for haddock from NI commercial catch samples with combined quarter 1 & 2 and quarter 3 & 4.

The mean ageing error for haddock from commercial samples was 0.35 years in quarter 1 & 2 and 0.34 in quarter 3 & 4. These rates are higher than those observed in the survey acquired samples. This is likely to reflect the longer time period of sample collection and potentially greater prevalence of older fish in commercial catches and the asymmetrical error profile bias. Compared to the survey error trend over time this is not as obvious in the commercial sampling ALK error likely as result of the samples coming from starting when the stock was established.

Table 6.5.1. Haddock in 7.a: landings numbers-at-age.

	LANDINGS NUMBERS-AT-AGE					NUMBERS*10**-3																	
YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AGE																							
0	0	0	0	0	0	0	924	1	0	0	n/a	0	0	0	0	0	0	0	0	0	0	0	0
1	94	30	1329	108	1272	601	287	548	13	290	n/a	72	69	13	23	129	33	18	44	9	38	30	0
2	1250	123	1310	4568	693	8353	916	575	2741	697	n/a	220	473	519	911	336	451	430	550	232	210	642	971
3	18	861	106	727	2387	252	4773	438	1074	2036	n/a	753	226	519	495	718	549	409	148	170	125	176	321
4	1	3	220	16	201	488	25	457	30	142	n/a	46	193	63	60	242	121	309	97	27	41	17	63
+gp	1	2	5	30	16	42	57	418	89	18	n/a	78	34	51	47	36	36	59	52	28	18	10	5

	DISCARDS NUMBERS-AT-AGE					NUMBERS*10**-3																	
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AGE																							
0	790	16857	95	15171	347	4209	4020	286	7883	2105		10797	6048	5334	2282	2158	4327	3933	5669	6235	4525	1392	518
1	1474	791	6750	1272	7556	4041	2913	10570	412	7939		1984	4273	2958	3514	4440	2457	4040	2280	2790	1123	3823	1892
2	816	135	277	942	835	2179	2520	1196	505	92		201	943	137	2460	1716	1570	404	392	542	348	628	2116
3	1	61	1	1	1	0	0	28	0	27		74	59	5	176	119	80	55	91	31	31	13	3
4	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
+gp	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0

6.6 Develop recommendations for addressing fishery selectivity (pattern of catchability at length or age) in the assessment model

The catch characteristics of the main fleet segments where explored at WKIrish2. Comparing length composition, discard rates and age selectivity patterns. The characteristics of the catches at length for single rigs, twin rigs, multi-rig and midwater gears are shown in Figure 6.5.1. Similar length composition of catches is seen in single (OTB) and twin (OTT) rig otter trawl fleets whilst the catches achieve in the midwater trawl vessels are of greater length.

From at-sea observations retention selectivity patterns of the main fleets catching haddock is shown in Figure 6.5.2. The retention ogives for these fleets however, are shown to be of similar character across years and gear types. With retained fish being selected based on a minimum landing size of 30 cm. At WKIrish2 fleet disaggregated discard estimates were presented and discard ogives for Northern Irish OTB, OTT and OTM fleets.

Age–length selective characteristics of the main fisheries were explored by means of modelling mean length-at-age, with gear type and quarter. The variation in length-at-age was explored and compared using multi-nominal regression. The prediction error rates were compared from Age–Length Keys of fleet disaggregated age data. Figure 6.5.3 shows the mean ageing error at-age for the Northern Irish OTB_CRU and OTM_DEF fleets. The model suggests small difference in the mean length-at-age of haddock caught by these gears types. These differences are not considered to represent significant selectivity of different population fractions but reflected the shorter temporal character of the OTM_DEF fishery and its targeted nature.

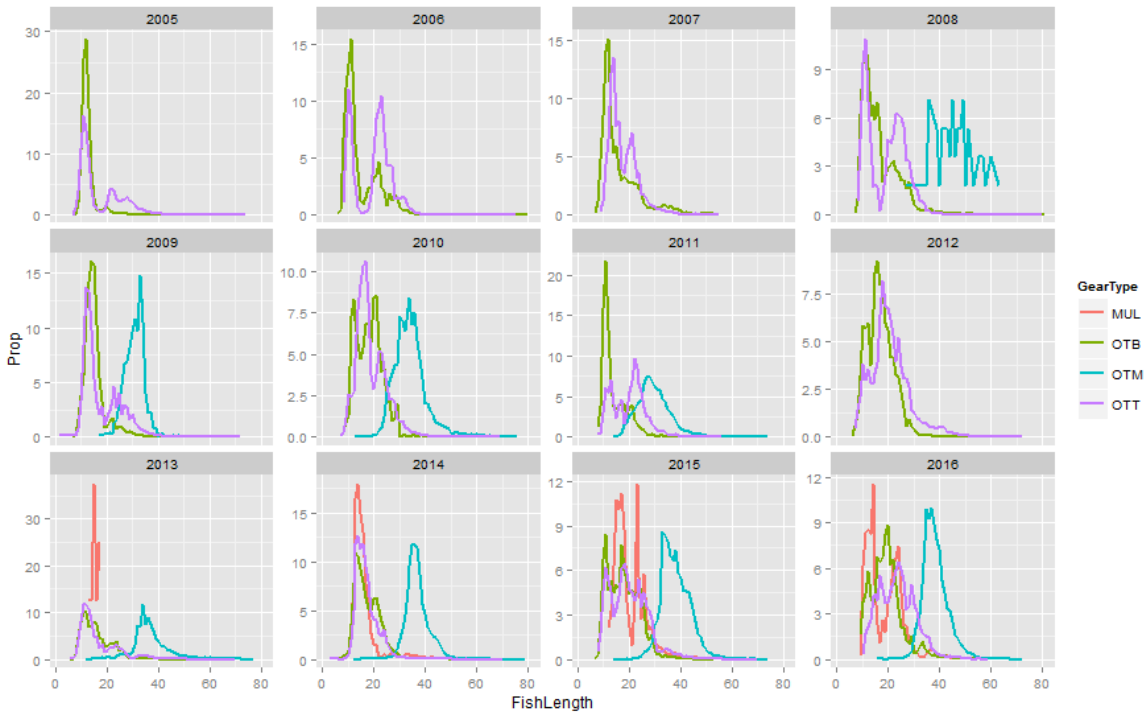
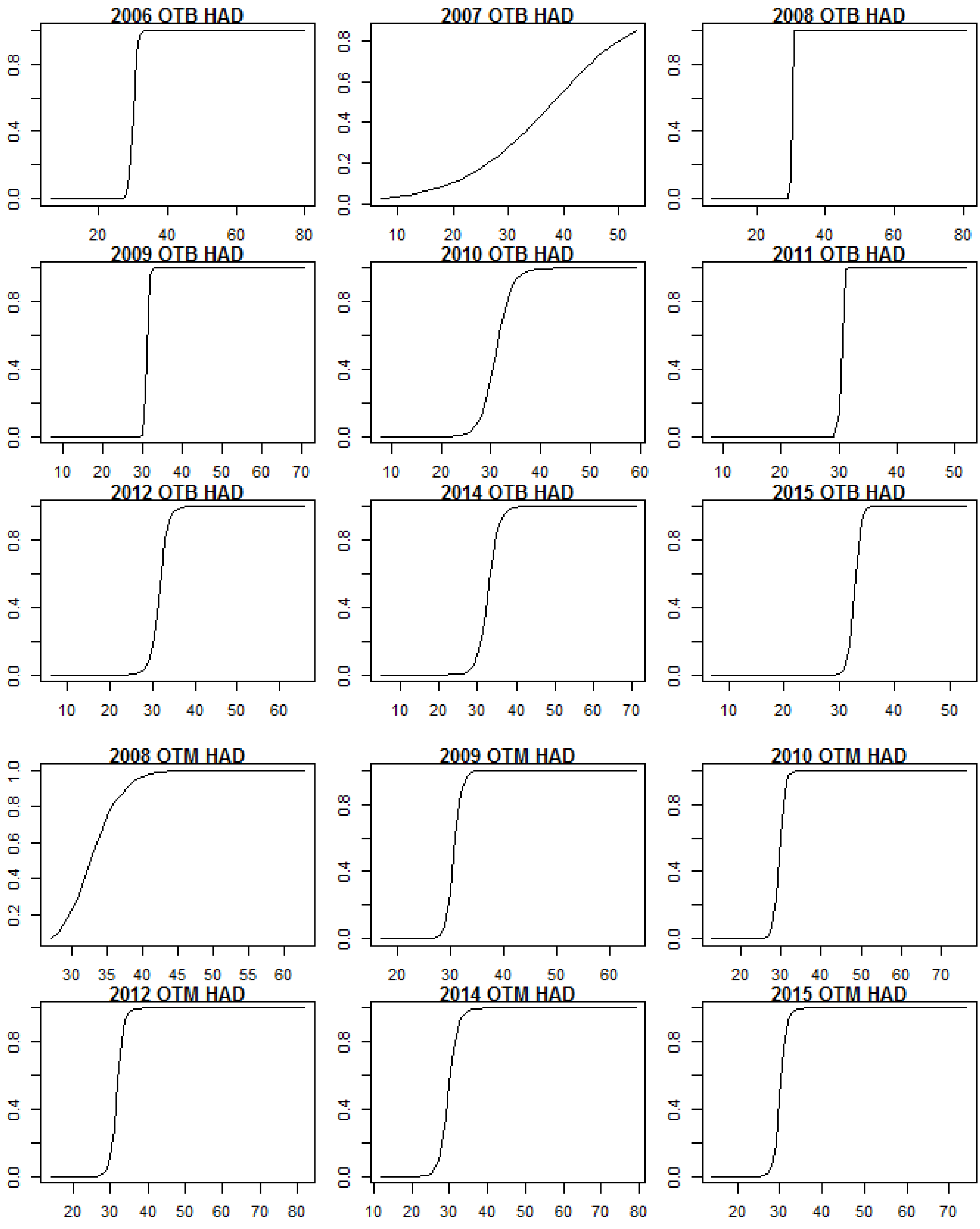


Figure 6.5.1. Length characteristics of the haddock catches observed in at-sea sampling of the Northern Irish fishing fleet.


2006 OTB HAD
2007 OTB HAD
2008 OTB HAD
2009 OTB HAD
2010 OTB HAD
2011 OTB HAD
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2014 OTB HAD
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2015 OTM HAD

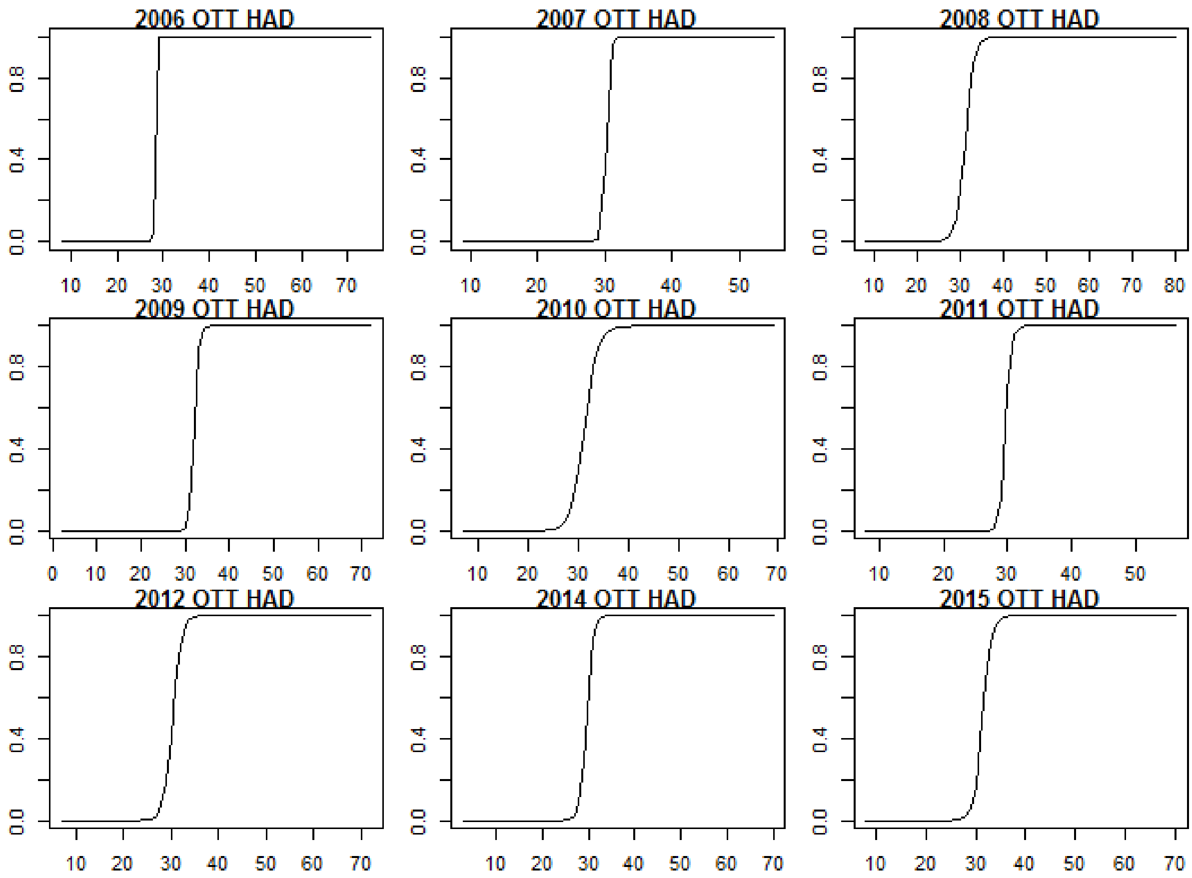


Figure 6.5.2. Discard ogives for haddock observed in at-sea sampling for single rigs (OTB), twin rigs (OTT) and midwater trawling (OTM).

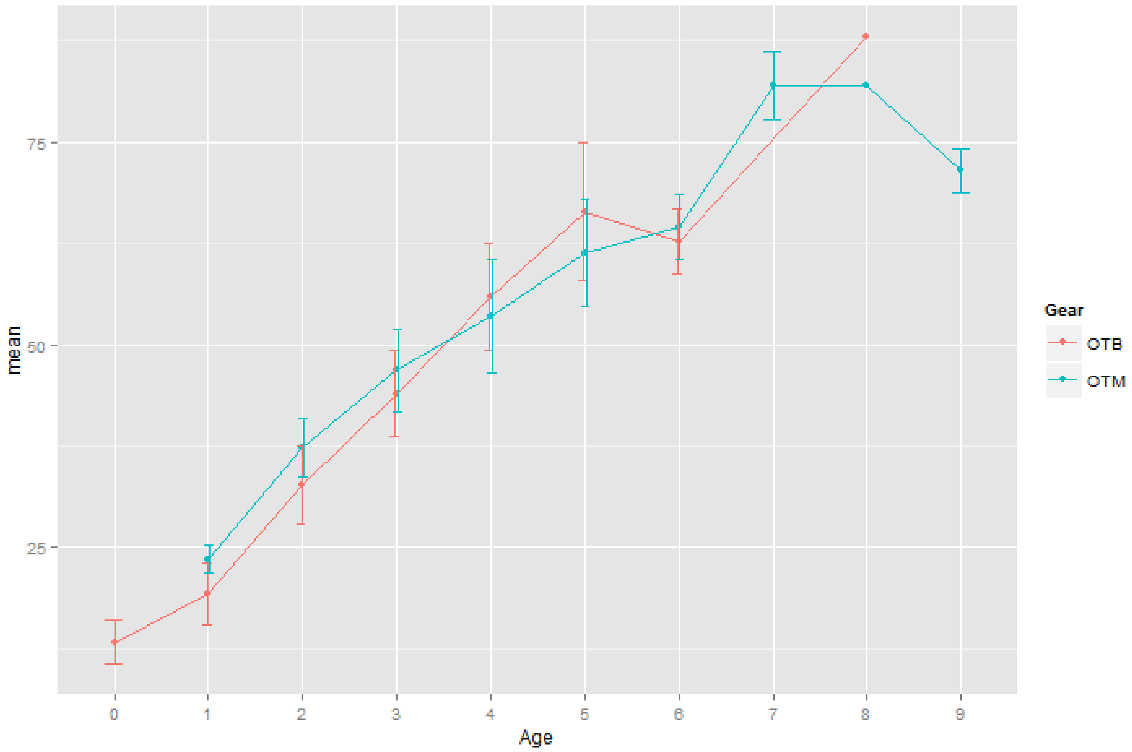


Figure 6.5.3. Mean length-at-age of haddock caught by Northern Irish otter trawls (OTB) and midwater demersal trawling.

6.7 Recommend values for discard mortality rates, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values

No data relating to discard survival rates of haddock were available. It assumed that discard mortality is high and a precautionary estimate of 1 is assumed.

6.8 Review all available and relevant fishery-dependent and -independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision

6.8.1 Fisheries-independent data

At present the assessment model for haddock uses the NIGFS-Q1 survey. As additional indicators the NIGFS-Q4 and NI-MIK surveys are also presented annually. Across these indices there is a high level of agreement and cohort tracking (Figure 6.8.1).

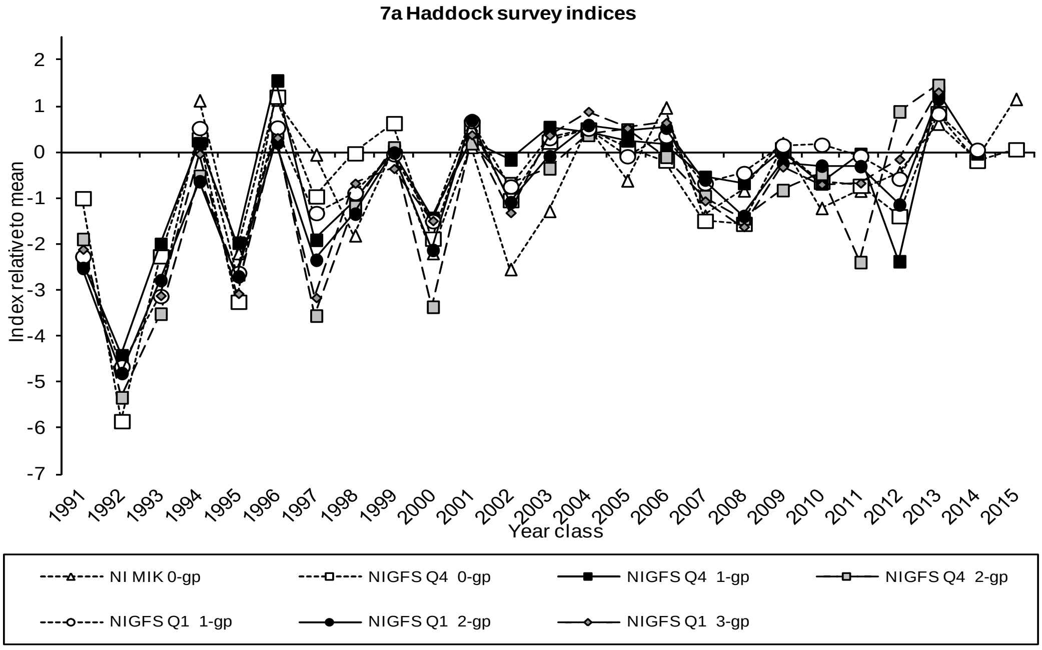


Figure 6.8.1. Haddock in 7.a: Time-series plots of the logarithms of survey indices at-age by year class, after standardising by dividing by the series mean for years from 1991. Data have only been illustrated for the most abundant ages for comparison of year-class signals.

Nine research vessel survey series for haddock in 7.a are available and are described and evaluated below. The two Irish groundfish surveys (IR-GFS and IR-ISCS GFS) in autumn were not considered because of the short series. Coverage of the Irish Sea in the IR-GFS survey (2003–2004) has been terminated. The IR-ISCS GFS is also excluded on the basis of changes in survey design and the method of calculating the indices not allowing for the changes in spatial coverage.

Table 6.8.1: Summary of available surveys.

Index ID	Vessel	Gear	Year Range	Age Range	Time of year	Coverage	Design
NIGFS-Q1	1992–2004 R.V. Lough Foyle	Rock-hopper otter trawl with a 17 m footrope fitted with 250 mm non-rotating	1992–present	1-5	March	North Irish Sea (Strata 1–8 Figure 5.6.1)	Stratified Fixed stations within strata
NIGFS-Q4	2005–Present RV Corystes	rubber discs.	1992–Present	1-3	October		
NIMIK			1994–present	0	May	North Irish Sea	
UK-E/W BTS-Q3	RV Corystes	Beam Trawl	1994–Present	0	September	Mainly east	Fixed prime stations
ScoGFS-WIBTSsta	RV Scotia	GOV trawl	1996–2006	1-5	Spring	Northern limit of the Irish Sea to around 53°30′	two fixed-position stations per ICES rectangle
ScoGFS-WIBTSsit	RV Scotia	GOV trawl	1997–2007	1-2	Autumn	Northern limit of the Irish Sea to around 53°30′	two fixed-position stations per ICES rectangle
UK-FSP		Boris rock-hopper otter trawl with 118 ft headline and 160 ft groundgear comprising 100 ft of 14 inch hoppers and 2 × 30 ft ground chains.	2005–2013 2015–2016	1-5	March	Western Irish Sea	Stratified by rectangle with a minimum number of tows requested in each rectangle

6.8.1.1 UK (England and Wales) Beam Trawl Survey (E/W-BTS-Q3): ages 0 (1994)–2015

This series has not previously been used in stock assessment of Irish Sea haddock. The survey covers the entire Irish Sea excluding the North Channel and is conducted in September. The survey uses a 4 m beam trawl targeted at flatfish. The survey is stratified by area and depth band, although the survey indices are calculated from the total survey catch in the eastern Irish Sea, and without accounting for stratification except for ALKs. Numbers of 0-gp and 1-gp haddock at-age per 100 km towed are provided for prime stations only (i.e. those fished in most surveys). An automated data extraction and analysis routine in r is now used, and the series was revised in 2008 using this routine. The 2009 assessment used data for years 1993 onwards. The survey series was compared with the NIGFS-Q4 '0-group' index and NI-MIK net index to assess concordance with the existing indices (Figure 6.8.2).

At WKIrish2 it was agreed that the survey may provide useful input into the haddock assessment model.

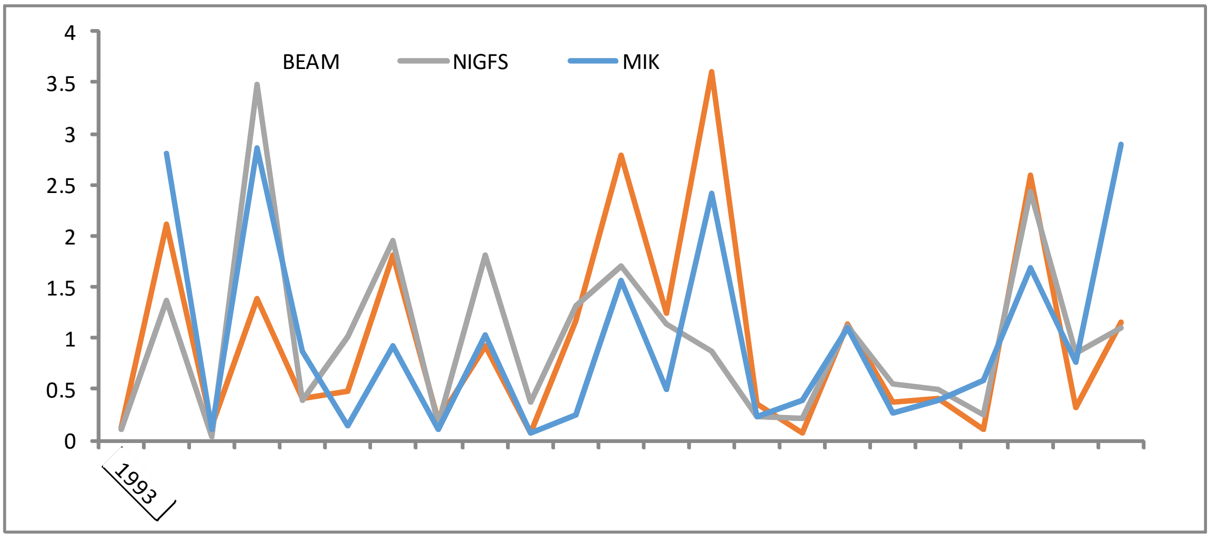


Figure 6.8.2. Comparison of E/W-BTS-Q3 age 0, NI-MIK age 0 and NIGFS-q4 age 0 indices.

6.8.1.2 UK (Northern Ireland) October Groundfish Survey (NIGFS-WIBTS-Q4): ages 1-3, years 1992-2015

The survey-series commenced in its present form in 1992. It comprises 45 three mile tows at fixed station positions in the northern Irish Sea, with an additional twelve one mile tows at fixed station positions in the St George's channel from October 2001 (the latter are not included in the tuning data). The surveys are carried out using a rock-hopper otter trawl deployed from the RV Lough Foyle. The survey designs are stratified by depth and seabed type. An ALK for the whole survey is used for filling in for any length groups with no ages at a station. The effects of using strata specific and all area age–length keys were explored at WKIrish2 (Figure x.x). The effects of this are agreed to be negligible, with greatest effect in older ages 3+, but it is agreed that strata specific ALKs are more appropriate.

Mean numbers-at-age per 3-mile tow are calculated separately by stratum, and weighted by surface area of the strata to give a weighted mean for the survey or group of strata. Coefficients of variation are calculated at-age across strata and for numbers of individuals between stations. From 2002 onwards, all stations in the survey have been reduced to 1 nautical mile, with comparative tows of 1 and 3 nm conducted to use a reference calibration dataset. Analysis of this dataset has shown no effect of tow duration on the, weight or lengths of haddock catches (Figure x.x). A high degree of agreement is observed in age tracking of the NIGFS-WIBTS-Q1, NIGFS-WIBTS-Q4 and NI-MIK survey series, providing confidence in the ability of the surveys to track stock changes and inform the assessment.

Since 2005, the RV Lough Foyle used for all surveys since 1992 has been replaced by the larger RV *Corystes*. The trawl gear and towing practices have remained the same.

6.8.1.3 UK (Northern Ireland) March Groundfish Survey (NIGFS–WIBTS-Q1): ages 1–5, years 1993–2016

General description as for October Surveys above, except that 3-mile stations have been retained in all strata other than in the St Georges Channel. Since 2005, the RV Lough Foyle used for all surveys since 1993 has been replaced by the larger RV Corystes. The trawl gear and towing practices have remained the same. The 1992 survey had only partial coverage of the western Irish Sea and is no longer used in the assessment. An ALK for the whole survey is used for inferring age from length. The effects of using strata specific and all area age–length keys were explored at WKIrish2 (Figure x.x). The effects of this are agreed to be negligible, with greatest effect in older ages 3+, but it is agreed that strata specific ALKs are more appropriate. A high degree of agreement is observed in age tracking of the NIGFS-WIBTS-Q1, NIGFS-WIBTS-Q4 and NI-MIK survey series, providing confidence in the ability of the surveys to track stock changes and inform the assessment.

6.8.1.4 UK (Northern Ireland) Methot–Isaacs–Kidd Survey (NIMIK): age 0 (brought forward to obtain indices of age1), years 1994 (1995)–2015 (2016)

The survey uses a Methot–Isaacs–Kidd frame trawl to target pelagic juvenile gadoids in the western Irish Sea at 40–45 stations. The survey is stratified and takes place in June during the period prior to settlement of gadoid juveniles. Indices are calculated as the arithmetic mean of the numbers-per-unit sea area. The survey is considered informative as an index of recruitment with and displays consistent patterns with indices from other series.

6.8.1.5 UK (Scotland) groundfish survey in spring (ScoGFS–WIBTS-Q1): ages 1–5, years 1996–2006

This survey represented an extension of the Scottish West Coast groundfish survey (Area 6), using the research vessel Scotia. The survey gear is a GOV trawl, and the design is two fixed-position stations per ICES rectangle from 1997 onwards (17 stations) and one station per rectangle in 1996 (nine stations). The survey extends from the Northern limit of the Irish Sea to around 53°30′. This ScoGFS-Spring was excluded due to the limited survey coverage in the western Iris Sea, where haddock is most abundant.

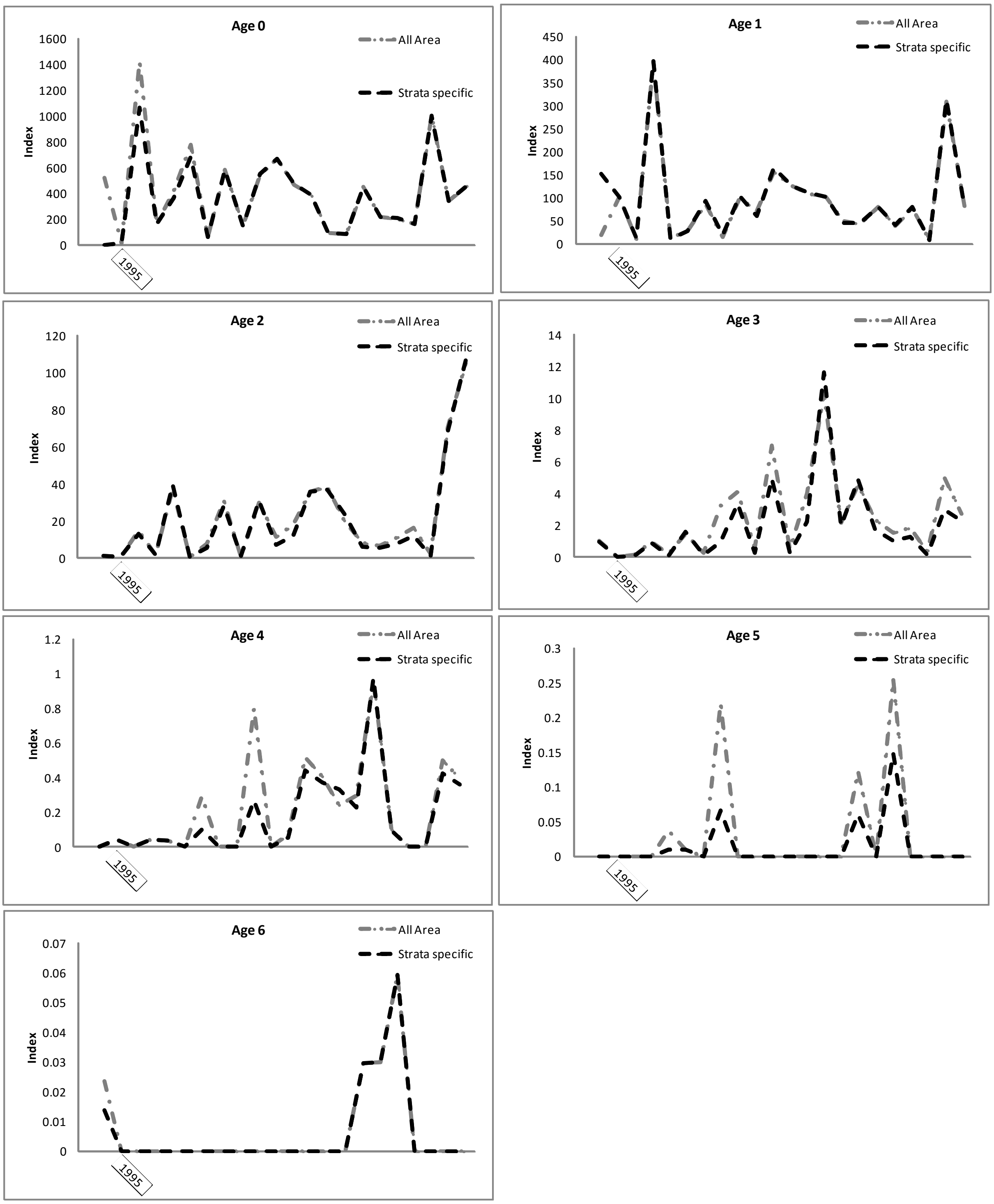
6.8.1.6 UK (Scotland) groundfish survey in autumn (ScoGFS–WIBTS-Q4): ages 1–2, years 1997–2007

This survey represented an extension of the Scottish West Coast groundfish survey (Area 6), using the research vessel Scotia. The survey gear is a GOV trawl, and the design is two fixed-position stations per ICES rectangle from 1997 onwards (17 stations) and one station per rectangle in 1996 (nine stations). The survey extends from the northern limit of the Irish Sea to around 53°30′. The ScoGFS-Autumn survey was also excluded due to the small number of stations in the western Irish Sea where haddock are most abundant, and the poor internal consistency and consistency with other fleets.

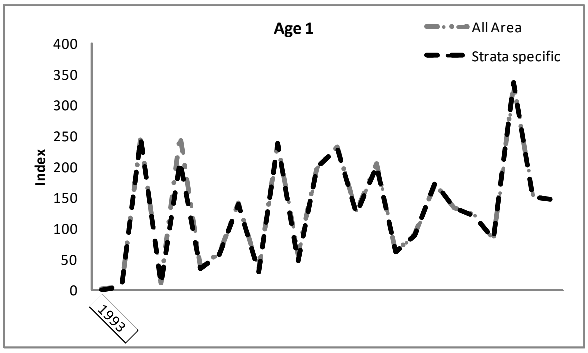
6.8.1.7 UK Fishery Partnership Surveys (UK–FSP), Western Irish Sea, in March: ages 1–5, years 2005–2013, 2015–2016

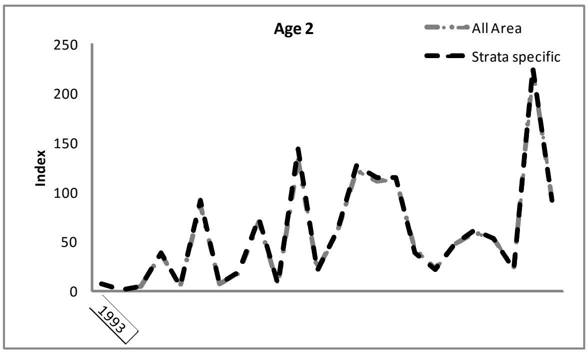
The Irish Sea roundfish survey was initiated in 2003 as a fully collaborative project between the fishing industry and Cefas scientists. It forms part of the UK Fisheries Science Partnership funded by the UK's Department for Environment, Food and Rural Affairs (Defra). The main objective of the Irish Sea roundfish survey is to develop a time-series of data to track year-on-year changes in abundance, population structure and distribution of the target species (cod, haddock and whiting). The results of the surveys provide information supporting the scientific assessment of the stocks and the management of the fisheries in the Irish Sea. The surveys were designed to achieve full coverage of potential cod, haddock and whiting habitats within the area of the main roundfish fisheries of the Irish Sea, using a stratified design to allow additional trawling effort in areas expected to have the greatest densities of cod, haddock or whiting. The survey is conducted on board a commercial fishing vessel. Fishing gear and survey methods are kept constant. In the most recent year of the highest index value in the series was observed. This coincided with a vessel change after a period of consistent vessel selection. The potential for a vessel effect to generate this high index value was explored by plot mean standardised index values, by year and age, to evaluate if there was a step-change (Figure x.x). The plot suggests that the recent index value is a true reflection of stock development with index values at year -1 and age-1 appearing to correspond in the penultimate year and final year of the survey and reflecting the 2013 year class observed in other survey series.

The indices from the UK FSP survey in the western Irish Sea also show similar year-class signals to the other survey series, but are noisy with strong year effects. The survey is considered informative as an index of older age classes.


Age 0
All Area
Strata specific
Index
1600
1400
1200
1000
800
600
400
200
0
1995
Age 1
450
400
350
300
250
200
150
100
50
Age 2
120
100
80
60
40
20
Age 3
14
12
10
8
6
4
2
Age 4
1.2
1
0.8
0.6
0.4
0.2
Age 5
0.3
0.25
0.2
0.15
0.1
0.05
Age 6
0.07
0.06
0.05
0.04
0.03
0.02
0.01

Q1


Age 1
All Area
Strata specific
Index
400
350
300
250
200
150
100
50
0
1993


Age 2
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Strata specific
Index
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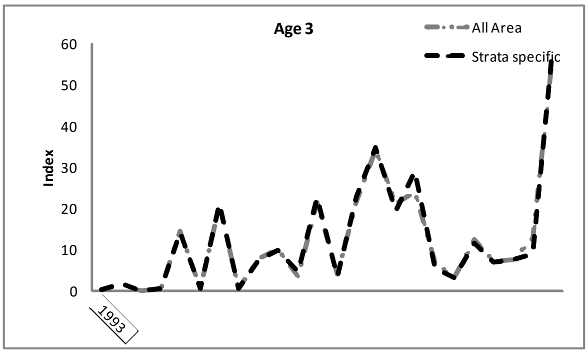
150
100
50
0
1993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Strata specific
Index
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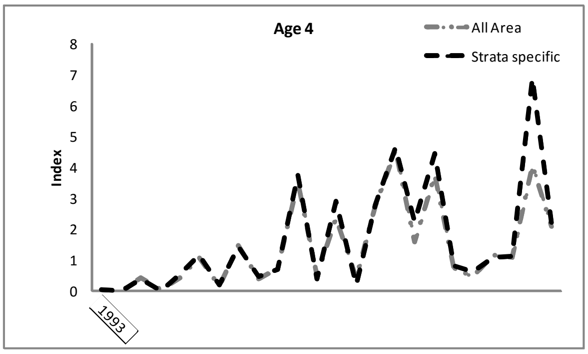
50
40
30
20
10
0
1993


Age 4
All Area
Strata specific
Index
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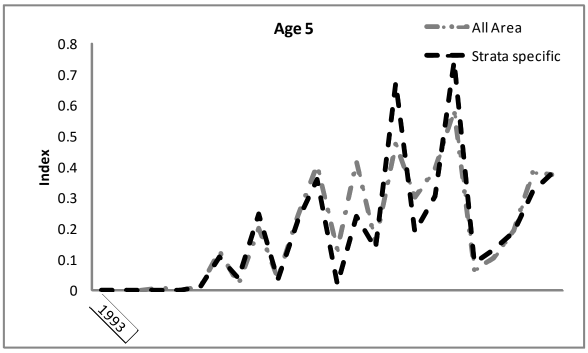
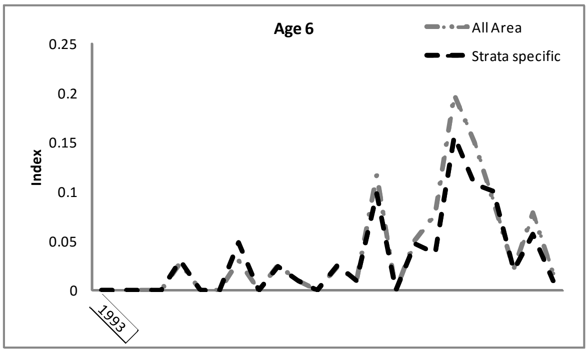
7
6
5
4
3
2
1
0
1993


Age 5
All Area
Strata specific
Index
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1993


Age 6
All Area
Strata specific
Index
0.25
0.2
0.15
0.1
0.05
0
1993

Q4

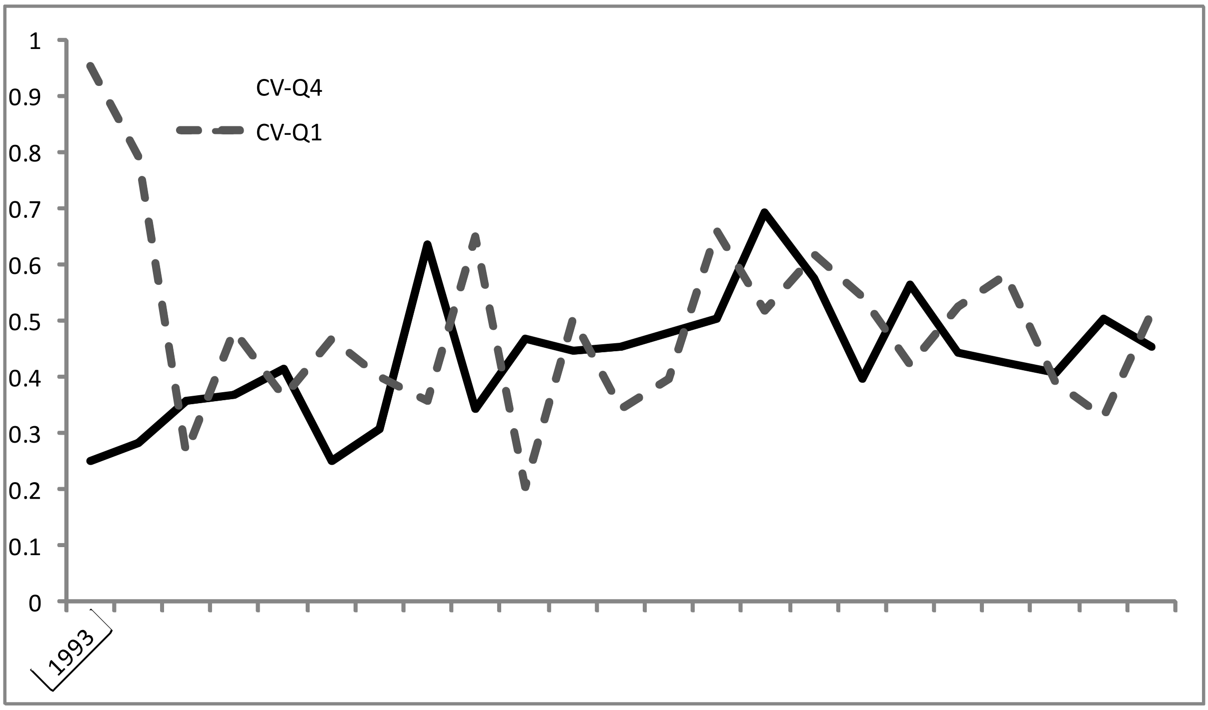


Figure x.x. NIGFS haddock catch numbers coefficient of variation (CV).

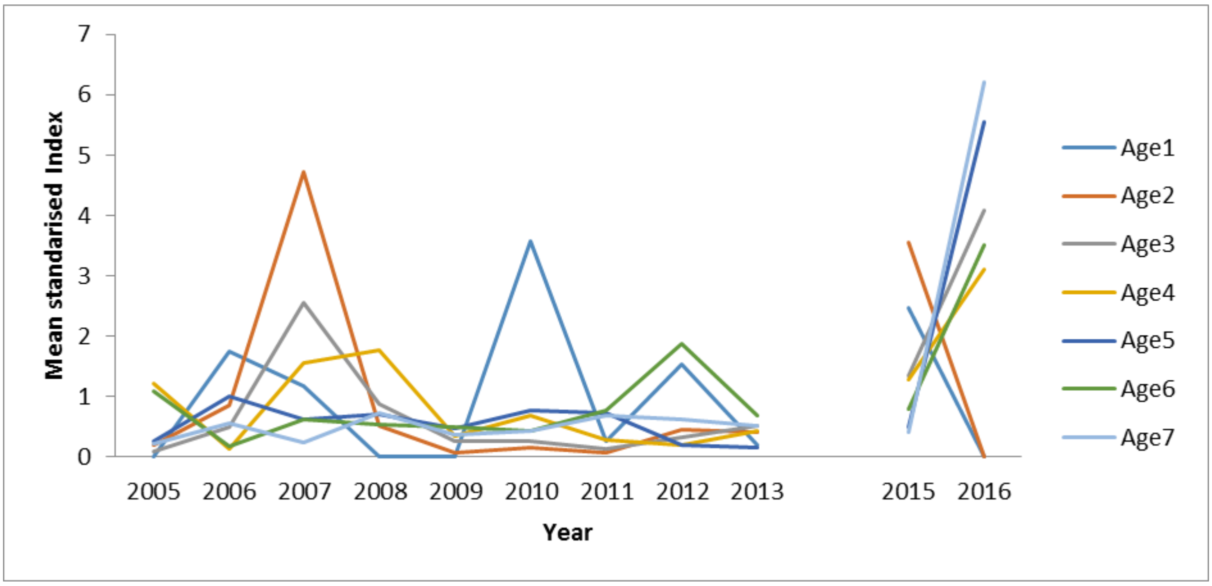


Figure x.x. Mean standardised indices of haddock catch rates at-age positive values (red) negative values (black) from UK Fishery Partnership Surveys (UK-FSP), Western Irish Sea.

6.9 Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts

As with cod in the Irish Sea haddock recruitment variability is thought to originate in processes occurring during the early life-history stages (eggs, larvae, pelagic juveniles). Similarly these processes co-vary with SST, whereby stronger recruitment occurs during colder temperatures.

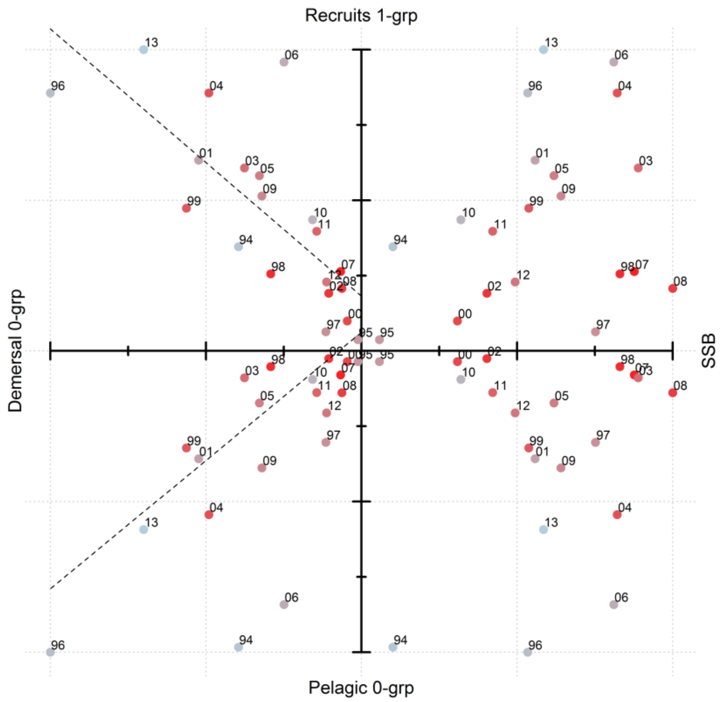


Figure 6.9.1. Paulik diagram for Irish Sea haddock. Trend lines are given for significant regressions between life-history stages. SSB, spawning–stock biomass from survey based analysis (SURBA), Pelagic 0-grp, abundance indices from MIK net survey, Demersal 0-grp, abundance indices from October groundfish survey, Recruits, recruitment at-age 1 from survey based analysis (SURBA). All data (1994–2013) standardised by mean. Axis values are index values and are for illustrative purposes only, therefore no numbers given. Years donate year class and colours represent average temperature February to May, blue cooler and red warmer.

A significant negative relationship ($p<0.01$) between recruitment success (log(R/SSB)) and SST during the egg and larval drift period (March to June) was observed.

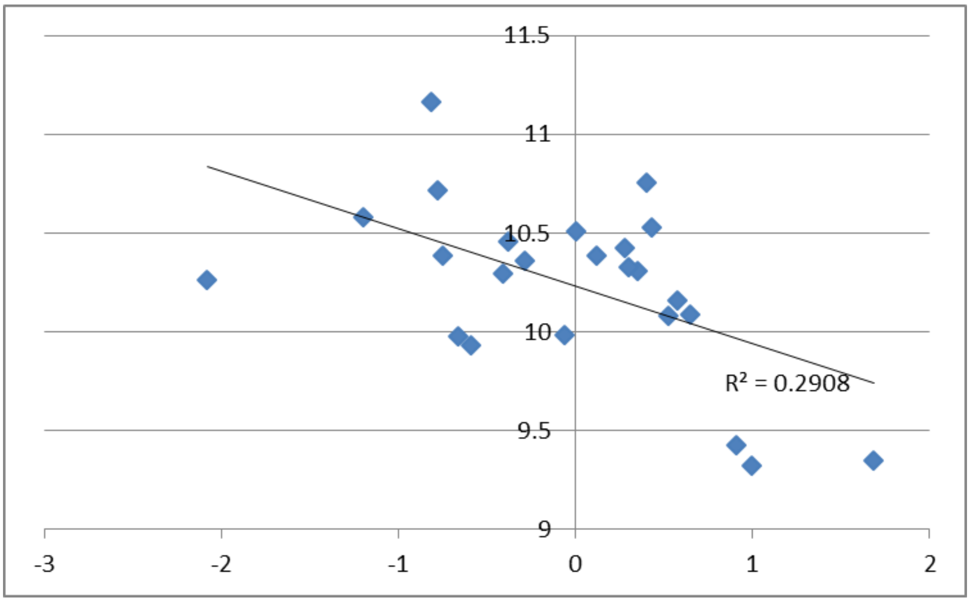


Figure 6.9.2. Relationship between SST and Irish Sea Haddock recruitment success.

As with the cod example we fit haddock recruitment data into an environment dependent Ricker-type stock–recruitment relationship based on observed SST time-series. The results suggest that including a SST term in the Ricker-type stock–recruitment relationship significantly improved recruitment predictions over the observed time-series (ANOVA p<0.05).

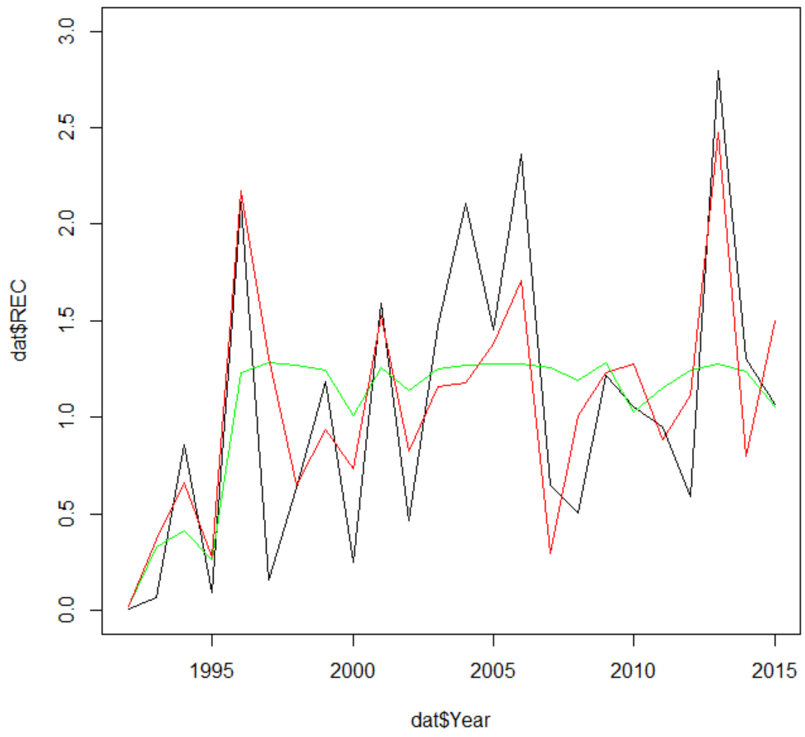


Figure 6.9.3. Time-series of recruitment estimates from SURBA 1 (black line), Ricker recruitment estimates with no SST term (green line) and Ricker recruitment estimates with SST term (red line).

6.10 References

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7 Data evaluation for Irish Sea cod

7.1 Explain the basis for existing assumptions on stock structure and mixing rates between stock areas, or proposed new assumptions which form the basis for spatial aggregation of fishery and survey data and/or adjustments to datasets to account for stock mixing

All catches and survey data from within ICES Division 7.a are assumed to come from a unit stock. Irish landings of cod reported from ICES rectangles immediately north of the Irish Sea/Celtic Sea boundary (ICES rectangles 33E2 and 33E3) have been reallocated into the Celtic Sea as they represent a combination of inaccurate area reporting and catches of cod considered by ICES to be part of the Celtic Sea stock.

Recent egg surveys in 2006 and 2008, using DNA probes to distinguish early stage eggs of cod from other gadoids, confirm the location of distinct cod spawning grounds in the western and eastern Irish Sea (Goodsir *et al*., 2008). Historical tagging studies indicated spawning site fidelity but varying degrees of mixing of cod between the Irish Sea, Celtic Sea and west of Scotland/north of Ireland (see Lordan *et al*., 2011). Studies based on meristic characteristics, allele frequencies and micro-satellite markers genetics and population structure have not provided unequivocal evidence of genetically isolated stocks in the Irish Sea and surrounding waters.

A tagging programme during 1997–2000, in which over 2200 cod were tagged using external and data storage tags revealed that although there was some movement of cod between the Irish and Celtic Seas, the component of Irish Sea cod in the Celtic Sea was low. Furthermore, no cod tagged in the Celtic Sea were recovered from the Irish Sea (Connolly and Officer, 2001). One problem with interpreting this evidence is that the overall stock sizes in both areas have declined significantly in recent years. There may therefore have been changes in geographic range and movement patterns making comparison of recent results with earlier studies problematic.

Tagging of cod off Greencastle on the north coast of Ireland (Ó Cuaig and Officer, 2007), and limited tagging on UK Fisheries Science Partnership surveys, have demonstrated movements of cod between Division 6.a and 7.a. Most recaptures in 7.a from cod tagged in 6.a have come from the North Channel and in or near the deep basin in the western Irish Sea that is a southward extension of the North Channel. The research surveys used for tuning the 7.a cod assessment cover only the western and eastern Irish Sea, and do not extend into the deeper water of the North Channel, where large catches of cod were made by midwater trawlers in the 1980s and 1990s.

Recovered data storage tags from 25 of 33 cod tagged in the Irish Sea showed migratory behaviour (Neat *et al*., 2014). Five individuals moved north, which could have brought them into contact with cod from the southern part of the Scottish west coast and the firth of Clyde. Four individuals moved sufficiently far south to bring them into contact with cod from the Celtic Sea, and one individual migrated into the western section of English Channel during the spawning season. Latitudinal range was 53°, and the migratory distance of this group of cod was amongst the highest, relative to cod from other areas, the home range area of Irish Sea cod during the spawning season or feeding season was quite restricted.

Recent Irish Sea cod tagging in the western Irish Sea and North Channel conducted in March 2016 tagged 976 individual fish with passive external tags. As of July 2016 seven recoveries have been achieved with seven fish showing high levels of capture site fidelity, with all recaptures occurring in the western Irish Sea and North Channel.

Although some movements and migratory patterns are thought to occur in Irish Sea cod at present, the data to estimate rates of emigration/immigration are not sufficient to confidently define a rate of movement. It is not considered that at present there is sufficient evidence to suggest a positive or negative movement of a significant portion of the stock into/out of the current stock area.

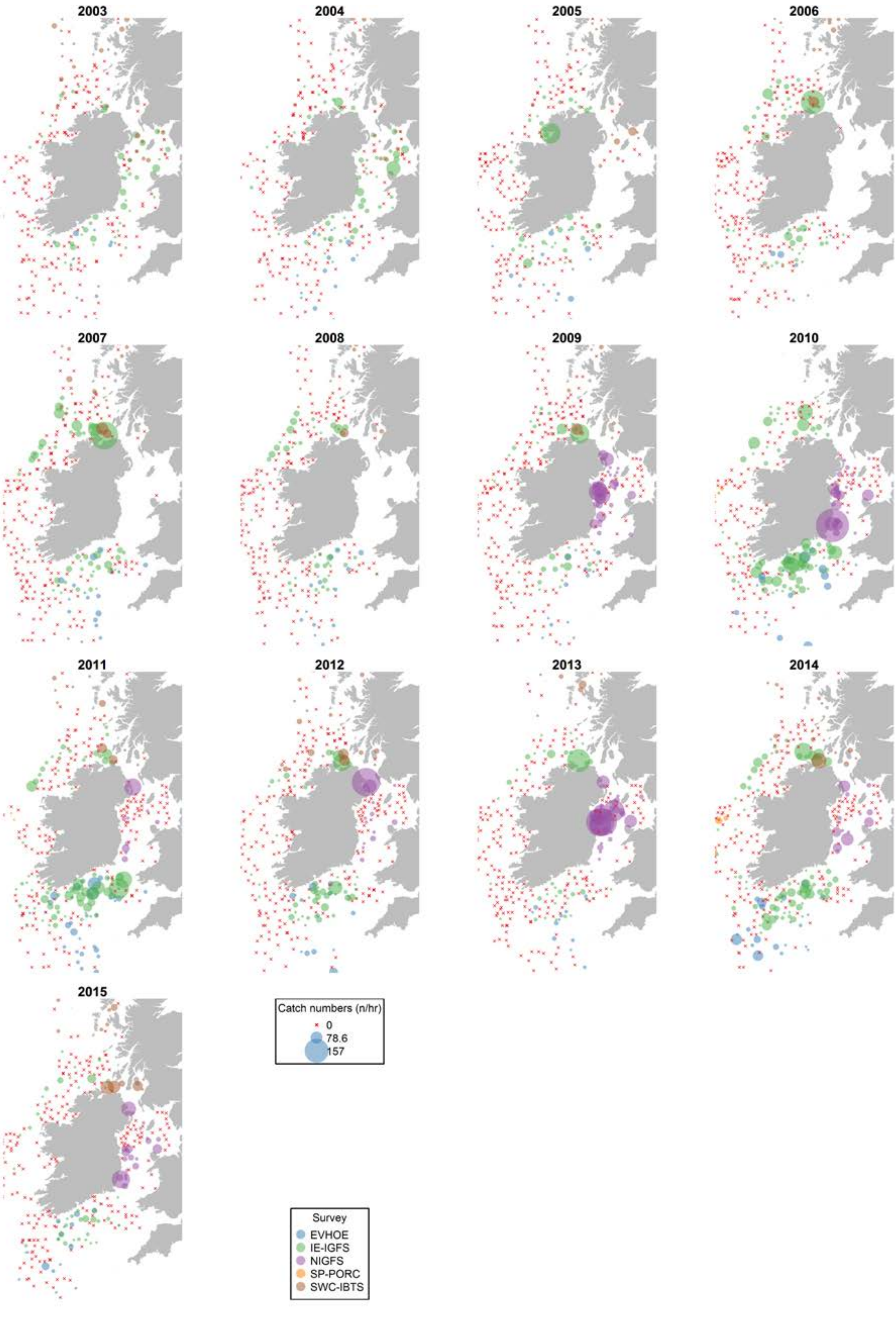


Figure 7.1.1. Catch numbers of cod from IBTS surveys 2003–2015.

7.2 Review and recommend life-history parameters (e.g. growth parameters, maturity ogives, fecundity, natural mortality), for use in assessments. Where applicable, provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length

7.2.1 Growth

Biological parameters for cod were estimated from combined survey data. All available survey data were combined as numbers were otherwise non-sufficient. Growth parameters were estimated by Francis (1988) re-parameterized von Bertalanffy growth equation using non-linear least squares using all available age/length data from surveys, observer discard sampling programmes, self-sampling programmes and port sampling from 1993 to 2015.

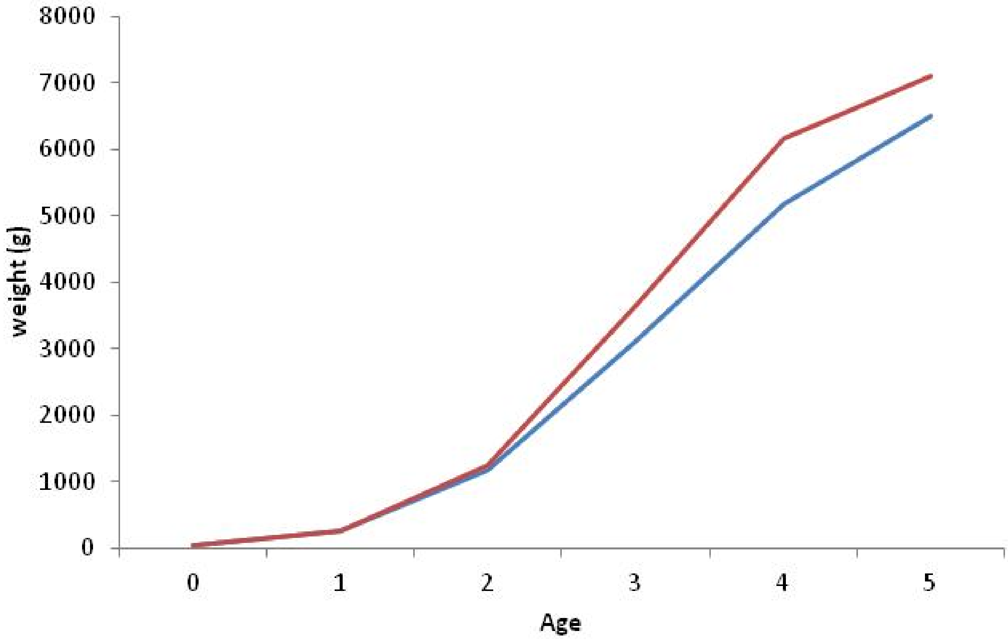


Figure 7.2.1. Mean observed weight of male (blue) and female (red) cod at-age from 2000–2015.

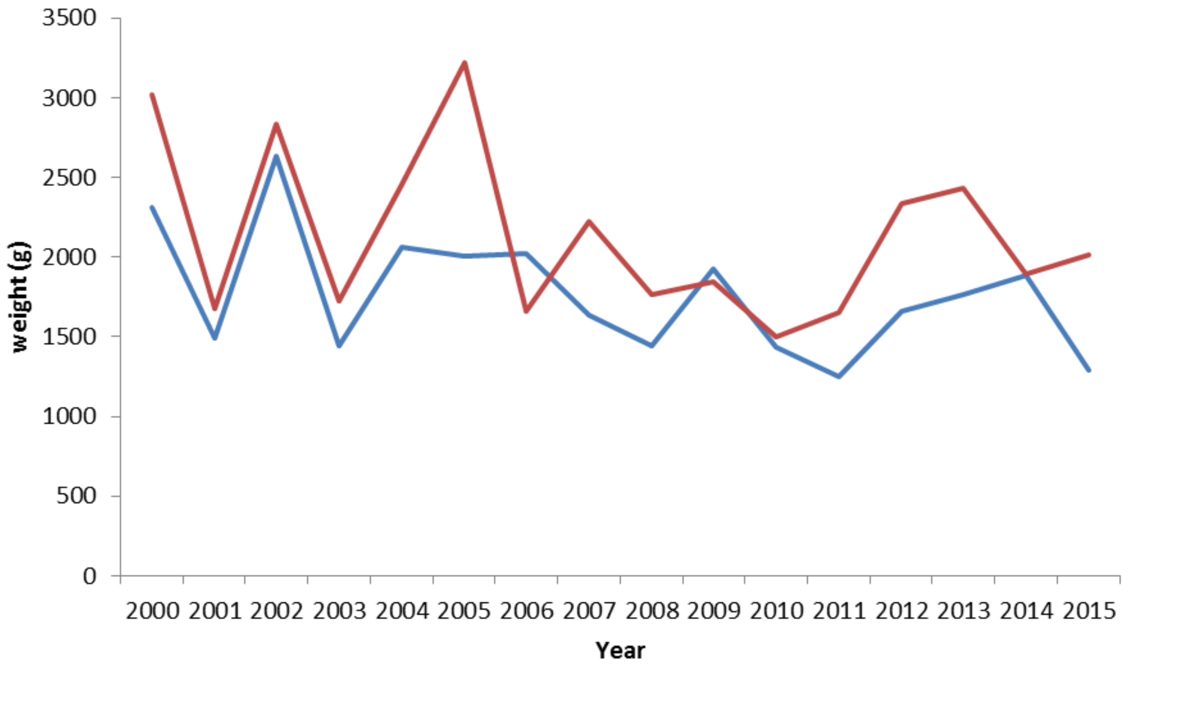


Figure 7.2.2. Mean observed weight of mature (2+ years) male (blue) and female (red) cod from 2000–2015.

Length–weight parameters were calculated for males and females combined for years 2006–2015 using the length–weight relationship.

$$W = a * L^b$$

There were not enough data available for 2008 to estimate the parameters.

Table 7.2.1. Length–weight parameters *a* and *b* and expected weights at 30 and 40 cm. There were not sufficient numbers in 2008 to conduct the calculations.

	Length–weight parameters		Expected weight–at–length (g)	
Year	a	b	30cm	40cm
2006	0.0090169	3.0394488	278	667
2007	0.0048458	3.1923327	251	630
2008				
2009	0.008683	3.0605533	288	694
2010	0.0115297	2.9920692	303	716
2011	0.0121691	2.9694043	296	695
2012	0.0099143	3.0141358	280	668
2013	0.0052105	3.1768	257	640
2014	0.0119519	2.9753436	297	698
2015	0.0063796	3.1342741	272	670

7.2.2 Natural mortality

Total mortality rates for the stock have been high throughout the time period for which information is available. Even when the stock was considered abundant and recruitment levels supported high levels of catch the gradient of the catch curve was in the range 0.8–1.0. Year classes rapidly disappeared from the commercial landings data. The increase in the negative slope indicates that total "mortality" rates have increased over time and now are double that recorded in the historic data during the period when the stock was abundant. M in cod has been historically set to 0.2. Due to recent study and research it appears that natural mortality is higher in cod and very likely dependent on temperature. A range of different methods (implemented in R package fishmethods (2016)) were investigated to estimate M with a range of values.

Pauly (1980) using Linf, K and temperature T, using a range of temperatures:

$$10^{-0.0066-0.279*\log10(\mathrm{Linf})+0.6543*\log10(\mathrm{K})+0.4634*\log10(\mathrm{T})}$$

Hoenigs Joint equation (Hoenig, 1983)

$$4.22/\mathrm{tmax}^{0.982}$$

and Hoenigs Fish Equation (Hoenig, 1983), both using maximal age tmax

$$e^{1.46-1.01*\log(\mathrm{tmax})}$$

Alverson and Carney (1975), using K and maximum age tmax

$$3\mathrm{K}/e^{\mathrm{k}*0.38*\mathrm{tmax}}-1$$

Lorenzen (1990) using weight-at-age, calculated for each age

$$3*\mathrm{weight}^{-0.288}$$

Gislason *et al*. (2010) using Linf, length L at-age and growth coefficient K, calculated across ages.

$$e^{0.55-1.61*\log(\mathrm{L})+1.44*\log(\mathrm{Linf})+\log(\mathrm{K})}$$

Then *et al*. (2015) using maximum age tmax

$$4.899*\mathrm{tmax}^{-0.916}$$

Then *et al*. (2015) using Linf and K

$$4.118*\mathrm{K}^{0.73}*\mathrm{Linf}^{-0.33}$$

Growth parameters were estimated by Francis (1988) re-parameterized von Bertalanffy growth equation using non-linear least squares.

Data from surveys, observer discard sampling programmes, self-sampling programmes and port sampling from 1993 to 2015 were used to estimate the following values:

L_{inf}	115.6
K	0.4
t_0	0.39

Maximum age was assumed as either eight years (observed in Irish Sea) or 13 years.

Table 7.2.2. Empirical mortality estimates by Pauly, Hoenig, Then and Alverson and Carney for maximum age eight (as observed in Irish Sea) and 13 years.

	M (8 YEARS)	M (13 YEARS)
Then (tmax)	0.729	0.469
Then (growth)	0.44	(no age included)
Hoenig (Joint equation)	0.548	0.340
Hoenig (fish equation)	0.527	0.323
Alverson and Carney	0.504	0.193

Table 7.2.3. Empirical natural mortality estimates by Gislason and Lorenz (mean wet weight) for each age.

AGE	LENGTH (CM)	WEIGHT (G)	M (GISLASON)	M (LORENZ)
1	25	149	3.651	0.714
2	55	1,660	1.031	0.355
3	75	4,338	0.625	0.269
4	88	7,218	0.479	0.232
5	97	9,740	0.41	0.213
6	103	11,727	0.374	0.202
7	107	13,203	0.352	0.195

Table 7.2.4 Empirical mortality estimates by Pauly for different temperatures and different years.

	TEMPERATURE (C)		
year	9	11	13
1996–1999	0.306	0.336	0.361
2000–2008	0.31	0.345	0.362
2009–2014	0.383	0.42	0.454

There is also a concern of cod mortality increasing with temperature due to physiological and respiratory insufficiencies, especially at a higher age (e.g. Holt and Jørgensen (2014); Pörtner and Knust (2007)). This will have to be investigated in a separate project.

7.2.3 Maturity

Maturity staging of cod carried out during the NIGFS-WIBTS_Q1 survey. The survey is stratified (Figure 5.6.1). Sampling is length stratified, with two individuals from each 1 cm length class sampled. We used the methods described in (Gerritsen et al., 2003) to fit a model to maturity-at-length data. To avoid any biases in estimating the proportion mature-at-age using length-stratified samples, data on sex, age and maturity from each length class were weighted by the total catch in that length group using:

We estimated L50 (lengths at which 50% of fish are mature) using a maximum likelihood method:

$$PM_j = \left[1 + \exp\left(-b \cdot (j - L_{50})\right)\right] - 1$$

Maximum likelihood estimates of L50 and b were found by minimising the negative log-likelihood, using the Nelder-Mead method.

Interannual variability of L_{50} for males and females appears to be similar. (Figure 7.3.1). There is downward trend in L_{50} in since 1993, although interannual variability is high.

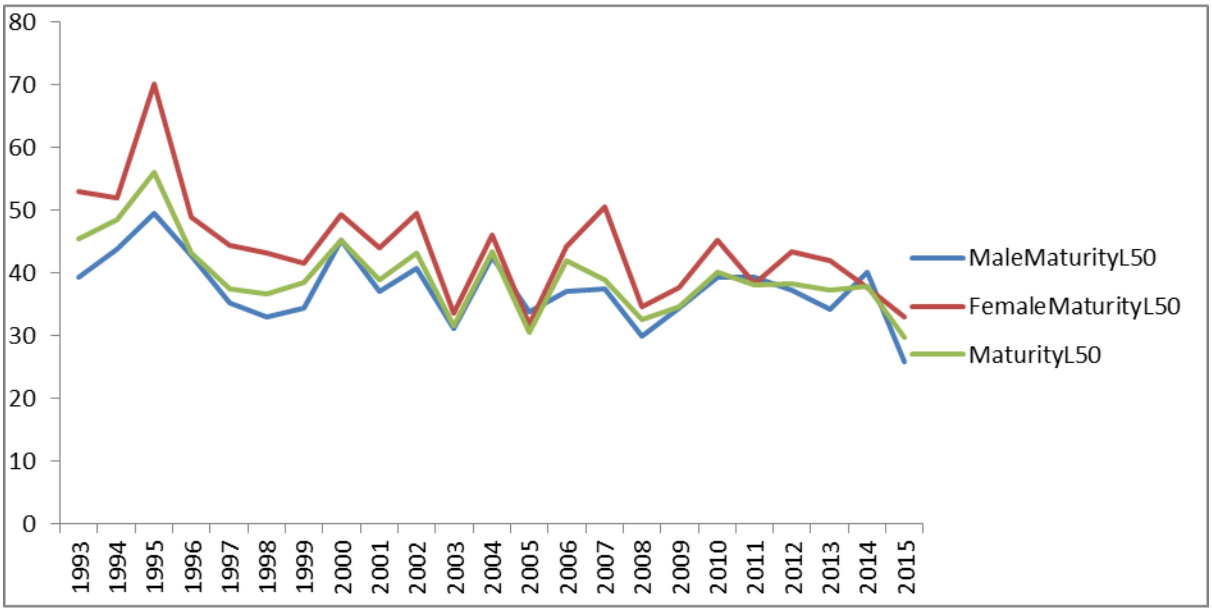


Figure 7.3.1. Length at which 50% of Irish Sea cod are mature for males, females and combined from quarter 1 NIGFS survey data.

7.2.3.1 Proportion mature-at-age

The proportions mature-at-age was recalculated based mean proportion of females observed during the NIGFS-WIBTS-Q1 survey (Figure 7.3.2). A LOWESS smoother was fitted to the proportion mature-at-age data, weighted by strata contribution to the survey area. A smoother span of 2/3 was used. It was proposed that this could be reapplied to update the series; the analysis is applied at-age 1–3 to provide a temporally dynamic estimate of proportion of female cod mature-at-age (Table 7.2.3.1).

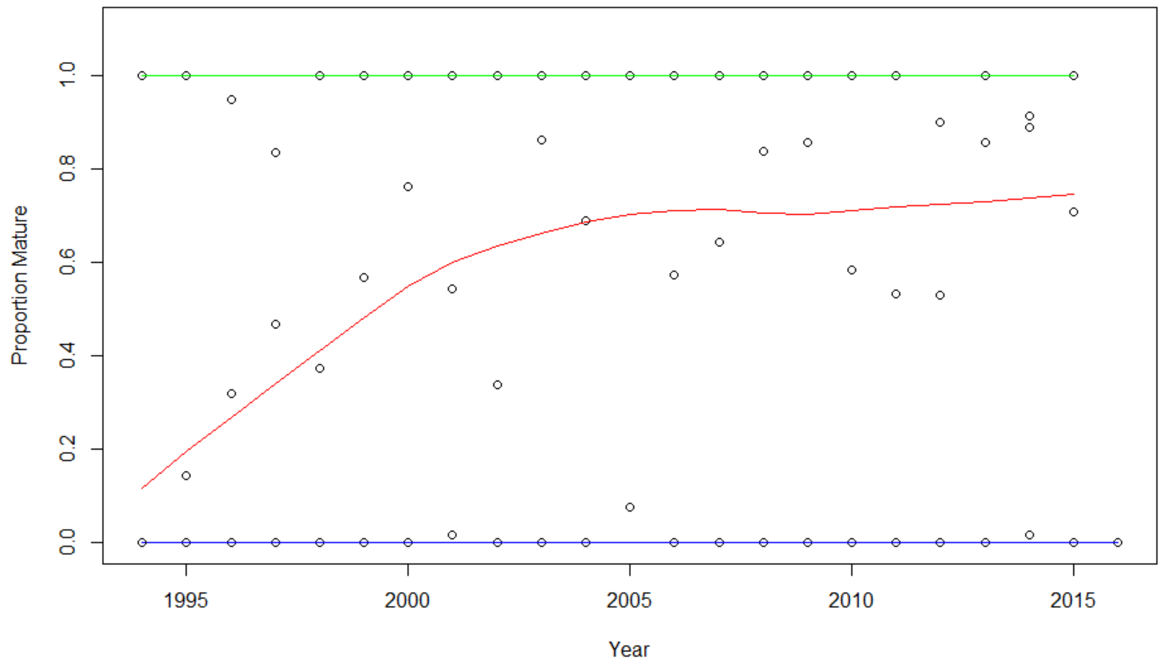


Figure 7.3.2. Proportion of female cod mature-at-age; Lines are LOWESS smoothed with span = 2/3 for age 1 (blue) and age 2 (red) and age 3 (green) cod.

Table 7.2.3.1. LOWESS smoothed proportion of female cod mature at age 1–3 from quarter 1 NIGFS surveys.

YEAR	AGE -1	AGE -2	AGE - 3
1994	0	0.12	1
1995	0	0.19	1
1996	0	0.27	1
1997	0	0.34	1
1998	0	0.41	1
1999	0	0.48	1
2000	0	0.55	1
2001	0	0.60	1
2002	0	0.63	1
2003	0	0.66	1
2004	0	0.69	1
2005	0	0.70	1
2006	0	0.71	1
2007	0	0.71	1
2008	0	0.71	1
2009	0	0.70	1
2010	0	0.71	1
2011	0	0.72	1
2012	0	0.72	1
2013	0	0.73	1
2014	0	0.74	1
2015	0	0.75	1

7.3 Describe the history of fishery management regulations and actions that are expected to have caused changes in the quality of fishery catch data or the selectivity patterns of fisheries that are of relevance for the scientific assessment of the stocks and provision of advice

See Section x.x.

7.4 Develop time-series of (commercial and recreational) fishery catch estimates, including both retained and discarded catch, with associated measures or indicators of bias and precision

7.4.1 Landings

Landings data have been supplied (annual quarterly landings) by the UK(N. Ireland), UK(E&W), UK(Scotland), Ireland, Belgium, and the IOM from databases maintained by national Government Departments and research agencies. The landings figures may be adjusted by national administrations or scientists to correct for known or estimated misreporting by area or species. To avoid double counting of landings data, each UK region supplies data for UK landings into its regional ports, and landings by its fleet into non-UK ports.

In addition, the stock coordinator compiles the international landings and catch-at-age data and maintains a time-series of such data with any amendments, since 2013 this has applied using 'InterCatch' protocols and compared with existing spreadsheet based methods. These methods have been evaluated and provide similar results with negligible differences.

7.4.1.1 Historic adjustments to official landings data

The input data on fishery landings and age compositions are split into four periods:

1968–1990. Landings in this period, provided to ICES by stock coordinators from all countries, are assumed to be un-biased and are used directly as the input data to stock assessments.

1991–1999. TAC reductions in this period caused substantial misreporting of cod landings into several major ports in one country, mainly species misreporting. Landings into these ports were estimated based on observations of cod landings by different fleet sectors during regular port visits. For other national landings, the WG figures provided to ICES stock coordinators were used.

2000–2005. Cod recovery measures were considered to have caused significant problems with estimation of landings. The ICES WG landings data provided by stock coordinators for all countries are considered uncertain and estimated within an assessment model. Observations of misreported landings were available for 2000, 2001, 2002 and 2005. However, they have generally not been used to correct the reported landings but have been used to evaluate model estimates in those years.

2006–2015. The introduction of the UK buyers and sellers legislation is considered to have reduced the bias in the landings data but the level to which this has occurred is unknown. Consequently comparisons were made between the fit of the model to recorded landings under an assumption of bias and unbiased information.

In addition to the above, Irish landings of cod reported from ICES rectangles immediately north of the Irish Sea/Celtic Sea boundary (ICES rectangles 33E2 and 33E3) have been reallocated into the Celtic Sea as they represent a combination of inaccurate area reporting and catches of cod considered by ICES to be part of the Celtic Sea stock.

Table 7.4.1. Cod (*Gadus morhua*) in Division 7.a. History of ICES advice, the agreed TAC, and ICES estimates of landings and discards. Weights are in thousand tonnes.

Year	Official landings	ICES landings	ICES discards	ICES catch	% Discard
1987	13.2	12.9		12.9	
1988	15.8	14.2		14.2	
1989	11.3	12.8		12.8	
1990	9.9	7.4		7.4	
1991	7	7.1**		7.1	
1992	7.4	7.7**		7.7	
1993	5.9	7.6**		7.6	
1994	4.5	5.4**		5.4	
1995	4.5	4.6**		4.6	
1996	5.3	4.96**		4.96	
1997	4.44	5.86**		5.86	
1998	4.96	5.31**		5.31	
1999	2.96	4.78**		4.78	
2000	1.42	1.27**		1.27	
2001	2.03	2.25		2.25	
2002	2.7	2.69		2.69	
2003	1.5	1.28		1.28	
2004	1.1	1.07		1.07	
2005	0.97	0.91		0.91	
2006	0.95	0.84		0.84	
2007	1.12	0.7	0.15	0.85	18%
2008	1.22	0.66	0.06	0.72	8%
2009	0.75	0.47	0.06	0.53	11%
2010	0.59	0.46	0.38	0.84	45%
2011	0.48	0.37	0.04	0.41	10%
2012	0.33	0.2	0.66	0.86	77%
2013	0.28	0.21	0.12	0.33	36%
2014	0.23	0.21	0.15	0.36	42%
2015	0.2	0.16	0.22	0.38	58%

**** Includes sample-based estimates of landings into three ports.**

7.4.2 Discards

At WKROUND 2012 collation of recent discard information provided by Member States for the stock was carried out as a scoping exercise ready for future modelling and the provision of advice. Up to 2003, estimates of discards are available only from limited observer schemes and a self-sampling scheme. Observer data are collected using standard at-sea sampling schemes. Results have been reported to ICES. Discards data (numbers-at-age and/or length frequencies) are have been supplied for 7.a cod by Ireland, UK(Northern Ireland) and UK(E&W) and Belgium. The data were supplied raised to the appropriate fleet/métier level by the Member States. These methods have been applied annual since WKROUND 2012, using InterCatch protocols with comparison to existing spreadsheet based methods. The catch rates for the

Northern Irish at-sea sampling scheme is shown in Figure 7.4.2, the plots show well resolved density plots of catch rates for the single rig (OTB), twin rig otter trawls (OTT) and midwater trawls (OTM) across the sampling period.

As an indication of confidence in the discard estimates derived from sampling schemes coefficients of variation were calculated. These have been provided the assessment working groups (WGCSE 2015) however; the series was extended to cover the entire time-series of catch sampling. Coefficients of variation were calculated for individual national schemes. The coefficients of variation for the Northern Irish at-sea sampling scheme were calculated to take into consideration the different of contribution of fleet segments to total fleet activity, weighted by quarterly contribution of gears to entire fleet activity (Cochran, 1977). Discard estimates were also calculated for cod from the fisher self-sampling scheme, used to provide samples for *Nephrops* discards (Table 7.4.2). Comparison of these provides confidence in the ability of these schemes to provide robust estimates of discards. The CVs calculated for discard estimates of cod show a high level of inter annual variation although no temporal trend or relationship with total discard volume is apparent. The sampling coverage of fleets was also assessed by comparing the observed and reported landings values. Figure 7.4.2.1 shows the observer (raised to sampled fleets) and reported (from sampled fleets) landings from the Northern Irish at-sea sampling scheme. It considered that there is consistent agreement in the estimate derived from at-sea sampling that that reported providing confidence in the design of the sampling scheme to provided estimates of catch for the sampled fleets.

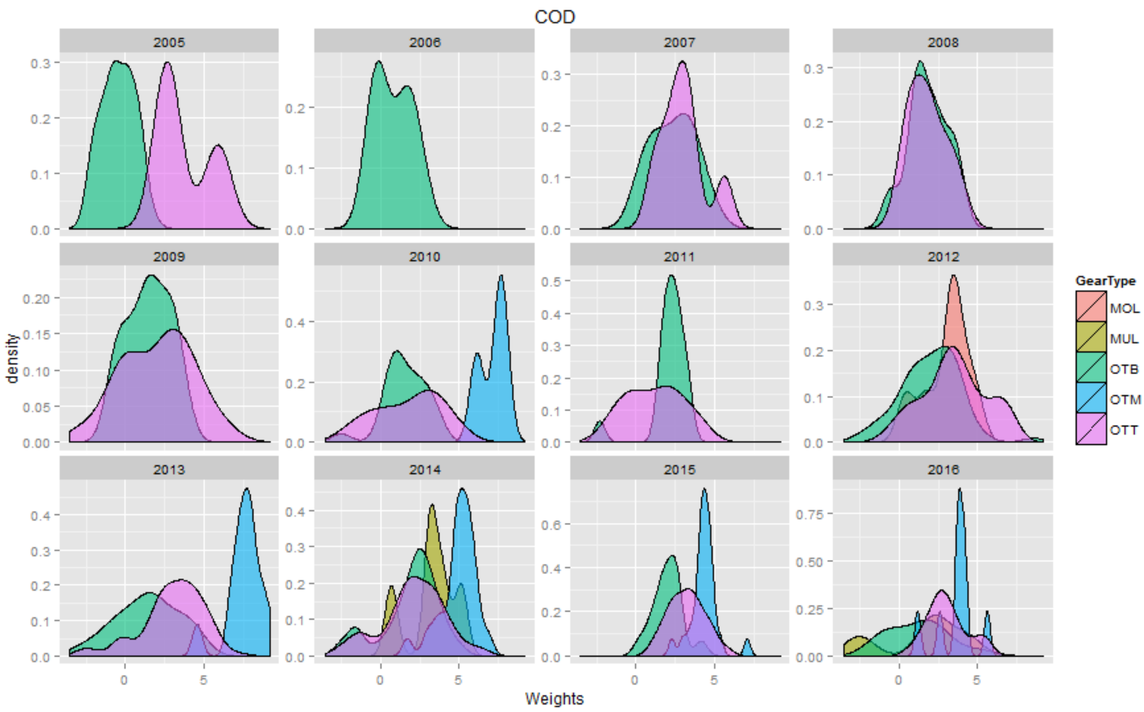


Figure 7.4.2. Irish Sea cod catch rates of main gears sampled by Northern Irish at-sea sampling.

Table 7.4.2. Cod in 7.a. Discard estimates for cod (t) from the Irish Sea, 2006–2015, as derived through at-sea catch sampling and fisher self-sampling schemes. Coefficients of Variation (CV) are shown for discard estimates as a measure of error.

	At - sea sampling					Self-sampling
	OTB	OTT	OTM	Total	CV	
2006	0.6	0.0	0.0	0.6	12	
2007	5.6	1.4	0.0	7	9	
2008	1.0	1.6	0.1	2.7	37	10.1
2009	2.5	3.2	0.0	5.7	13	9.4
2010	7.5	65.7	0.7	73.9	36	6.9
2011	0.7	1.0	0.0	1.7	14	10.9
2012	320.9	346.9	0.0	667.8	49	22.8
2013	36.1	85.6	0.0	121.7	30	53.8
2014	42.4	12.6	0.1	55.1	26	27.1
2015	34.8	50.4	2.1	87.3	41	12.3

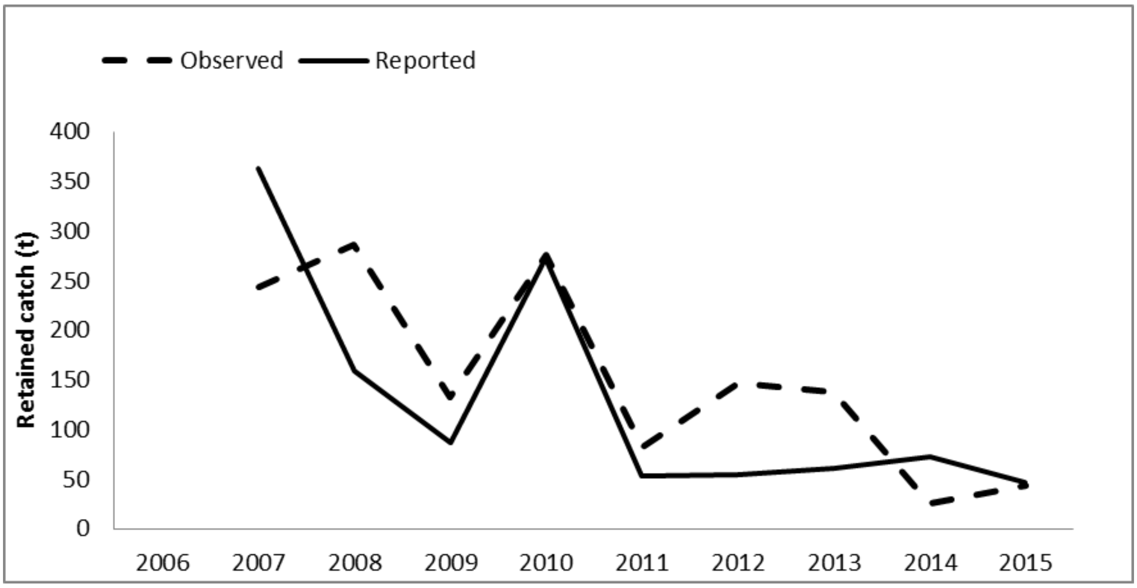


Figure 7.4.2.1. Irish Sea cod observed and reported landings from NI fleet. Observed landings are derived from the Northern Ireland at-sea sampling and raised using by quarter & gear as used to obtain estimates of discards.

7.5 Estimate the length and age distributions of fishery landings and discards if feasible, with associated measures or indicators of bias and precision

Member States that have collected length and age composition data for 7.a cod as required by the EU Data Collection Framework entered quarterly and annual landings-at-age data on InterCatch. Quarterly and annual estimates of landings-at-age are provided by the UK(E&W), UK(NI), Belgium and Ireland. These have been raised to include landings by the other countries, then summed over quarters to produce the annual figures for input to stock assessment.

Ageing error and Age–Length Key quality was assessed by means of a fitting a multinomial logistic regression of age with length as explanatory variable (Ogle, 2016). Individual models of age were constructed for each year and quarter for the NIGFS and combined first and second quarter commercial catch samples and third and fourth quarter commercial catch samples. The model is used to predict the age of each sample using length as the predictor. The error is calculated as absolute difference between the observed age and the predicted age. A mean ageing error is calculated for the ALK in each year and quarter.

The mean ageing error for cod from NIGFS surveys derived from use of the multinominal logistic regression of age using length as a predictor was 0.07 years in both quarter 1 and quarter 4. Over time there does not appear to be a trend in the error rates observed, however, in 1999 quarter 1 and 2002 quarter 4 the error rates exceed a level of the mean error + 2*sd.

The mean ageing error for cod from commercial samples was 0.19 years in quarter 1 & 2 and 0.20 in quarter 3 & 4. These rates are higher than those observed in the survey acquired samples. This is likely to reflect the longer time period of sample collection and potentially greater prevalence of older fish in commercial catches and the asymmetrical error profile bias.

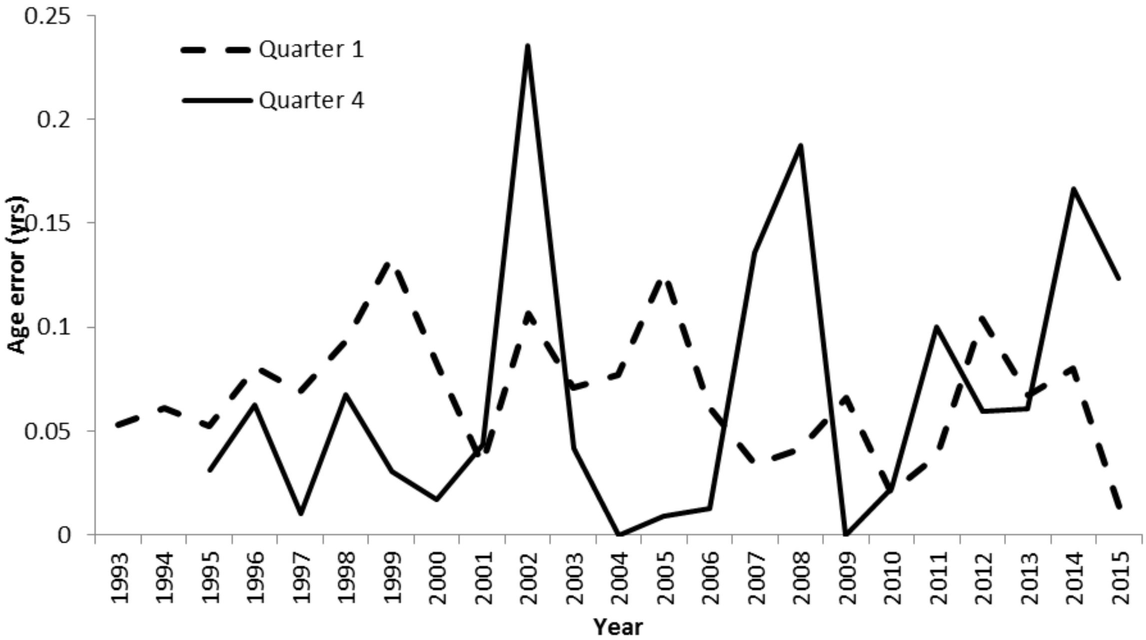


Figure 7.5. Ageing error for cod from NIGFS quarter 1 and quarter 4 surveys.

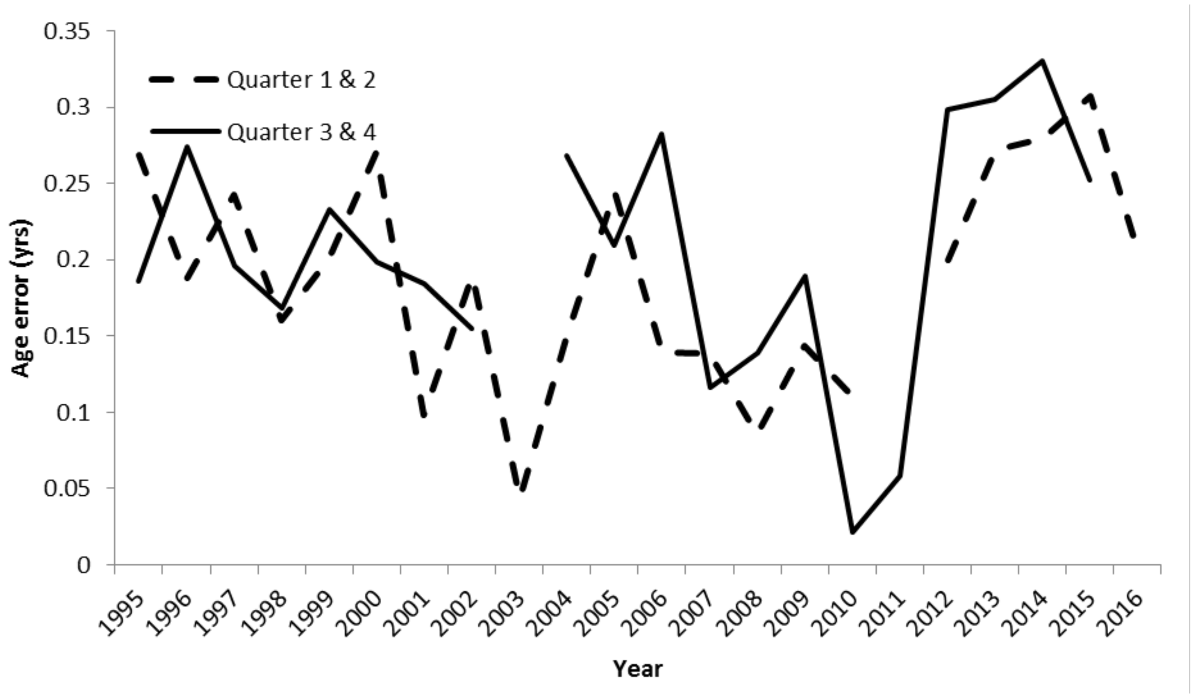


Figure 7.5.1. Ageing error for cod from commercial catch samples with combined quarter 1 & 2 and quarter 3 & 4.

Table 7.5. Cod in 7.a: landings numbers-at-age.

CATCH NUMBERS-AT-AGE			NUMBERS *10**-3													
Age\Year	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	364	882	1717	2739	789	2263	530	1699	1135	816	687	1762	2533	1299	345	814
2	1563	1481	1385	2022	3267	1091	3559	642	3007	511	1092	1288	2797	3635	2284	932
3	1003	1050	352	904	824	1783	557	1407	363	1233	310	608	729	1448	1455	751
4	456	269	204	144	250	430	494	294	500	163	311	127	243	244	557	499
5	177	186	163	67	58	173	131	249	61	218	39	164	49	99	102	154
+ gp	30	113	71	51	59	81	74	117	104	71	65	71	55	47	79	46
Age\Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	1577	1218	974	4323	2792	582	710	1973	1375	223	749	498	318	523	204	70
2	1195	2105	2248	1793	4734	2163	1075	1408	1243	2907	569	1283	1113	1149	1926	843
3	439	703	699	841	702	1886	545	442	664	403	848	180	700	501	335	871
4	240	158	203	252	263	231	372	127	132	119	68	163	38	213	80	66
5	161	84	64	75	71	86	70	98	42	16	20	7	39	17	28	21
+ gp	75	77	65	43	38	37	30	22	49	13	10	6	6	16	8	7
Age\Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	289	338	196	45	68	42	14	49	14	20	40	11	4	6	6	0
2	176	841	564	439	101	224	142	205	166	53	128	105	35	32	44	34
3	107	53	405	93	158	62	112	56	87	66	15	36	32	19	16	19
4	50	13	7	35	21	33	16	11	9	17	7	2	4	7	4	3
5	4	9	2	1	6	5	8	1	3	3	2	1	0	1	1	1
+ gp	1	2	3	0	3	1	3	0	0	0	1	1	0	0	0	0

Table 7.5.1. Cod in 7.a: discard numbers-at-age.

Age\Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	16	5.5	329.3	48.7	9.7	7.5	36.1	1.08612	0
1	167	63.4	39.8	180	42.7	79.9	31	34.661549	37.3
2	4.6	3.4	4.4	60.3	0.9	100.2	26.5	41.931801	45.8
3	0	0	0.1	1.4	0	112.9	11	10.304373	6.8
4	0	0	0	0.5	0	5.9	2	1.52931	1.3
5	0	0	0	0.1	0	0.2	0.5	0.1	0.3
+ gp	0	0	0	0	0	0	0	0	0

7.6 Develop recommendations for addressing fishery selectivity (pattern of catchability at-length or age) in the assessment model

The catch characteristics of the main fleet segments where explored at WKIrish2. Comparing length composition, discard rates and age selectivity patterns. The characteristics of the catches at length for single rigs, twin rigs, multi-rig and midwater gears are shown in Figure 7.6. Similar length composition of catches is seen in single (OTB) and twin (OTT) rig otter trawl fleets whilst the catches achieve in the midwater trawl vessels are of greater length.

From at-sea observations retention selectivity patterns of the main fleets catching cod is shown in Figure 7.6.1. In some years the retention ogives for these fleets are not well resolved. This is considered to reflect 'over quota' discarding of fish above the MLS (35 cm). In years with clear discard / retention selection fish are retained based on a minimum landing size of 35 cm. At WKIrish2 fleet disaggregated discard estimates were presented for Northern Irish OTB, OTT and OTM fleets.

Age–length selective characteristics of the main fisheries were explored by means of modelling mean length-at-age, with gear type and quarter. The variation in length-at-age was explored and compared using multi-nominal regression. The prediction error rates were compared from Age–Length Keys of fleet disaggregated age data. Figure 7.6.2 shows the mean ageing error at-age for the Northern Irish OTB_CRU and OTM_DEF fleets. The model suggests small difference in the mean length-at-age of cod caught by these gears types. These differences are not considered to represent significant selectivity of different population fractions but reflected the shorter temporal character of the OTM_DEF fishery and its targeted nature.

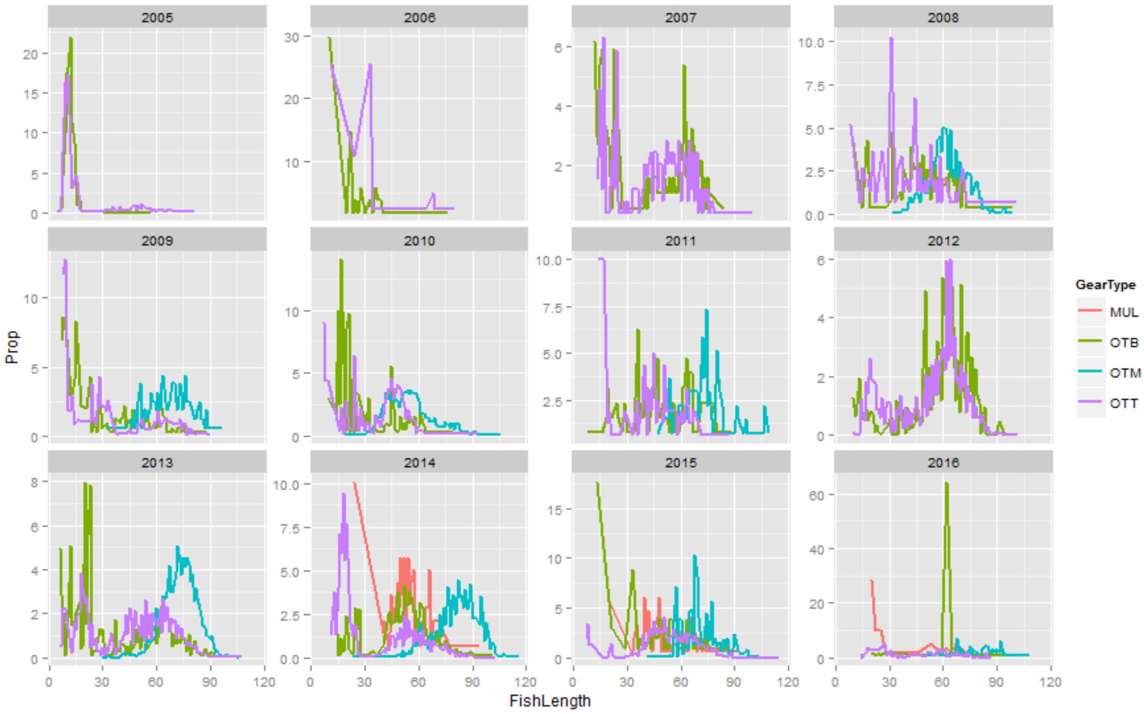
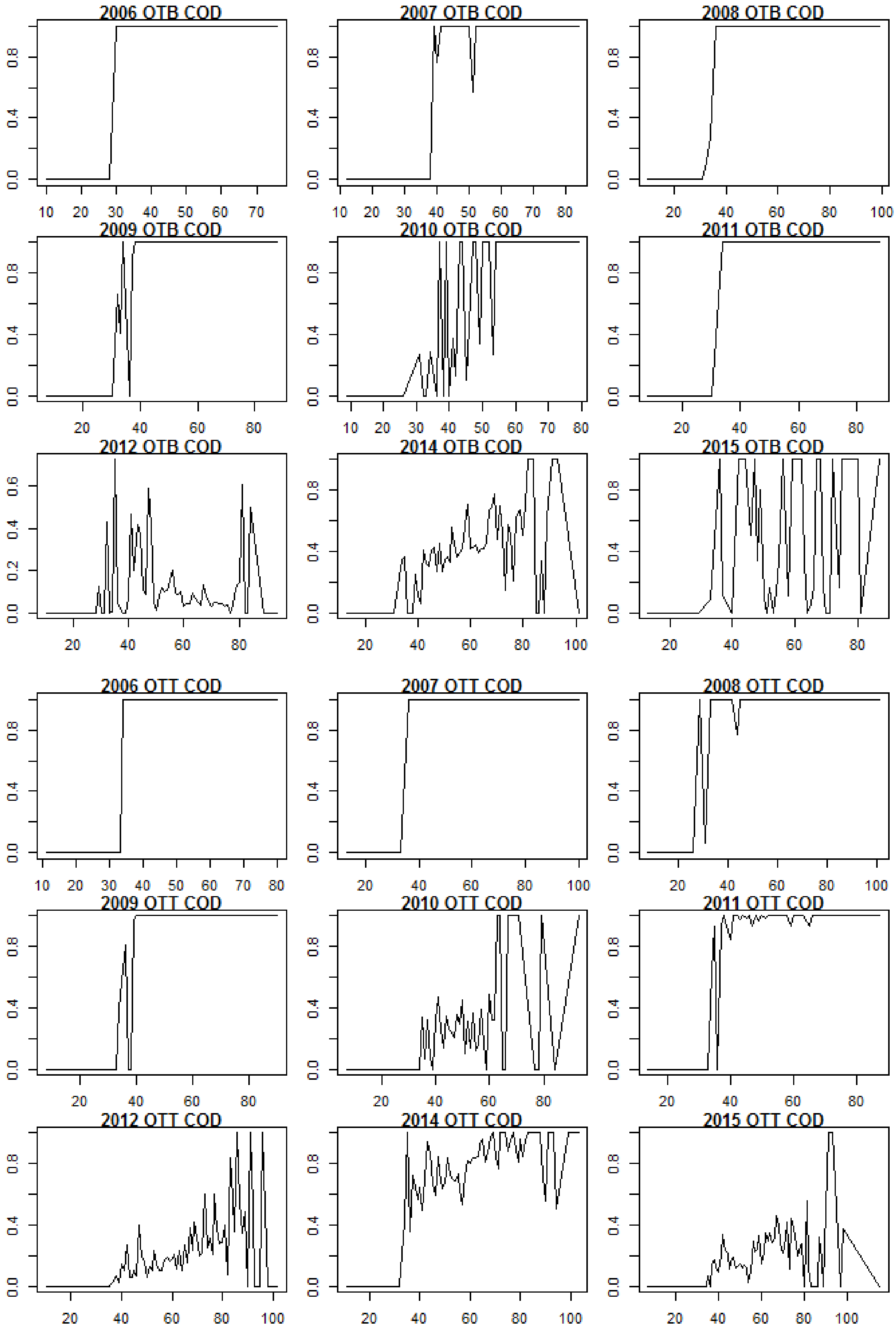


Figure 7.6. Length characteristics of the cod catches observed in at-sea sampling of the Northern Irish fishing fleet.


2006 OTB COD
2007 OTB COD
2008 OTB COD
2009 OTB COD
2010 OTB COD
2011 OTB COD
2012 OTB COD
2014 OTB COD
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2015 OTT COD

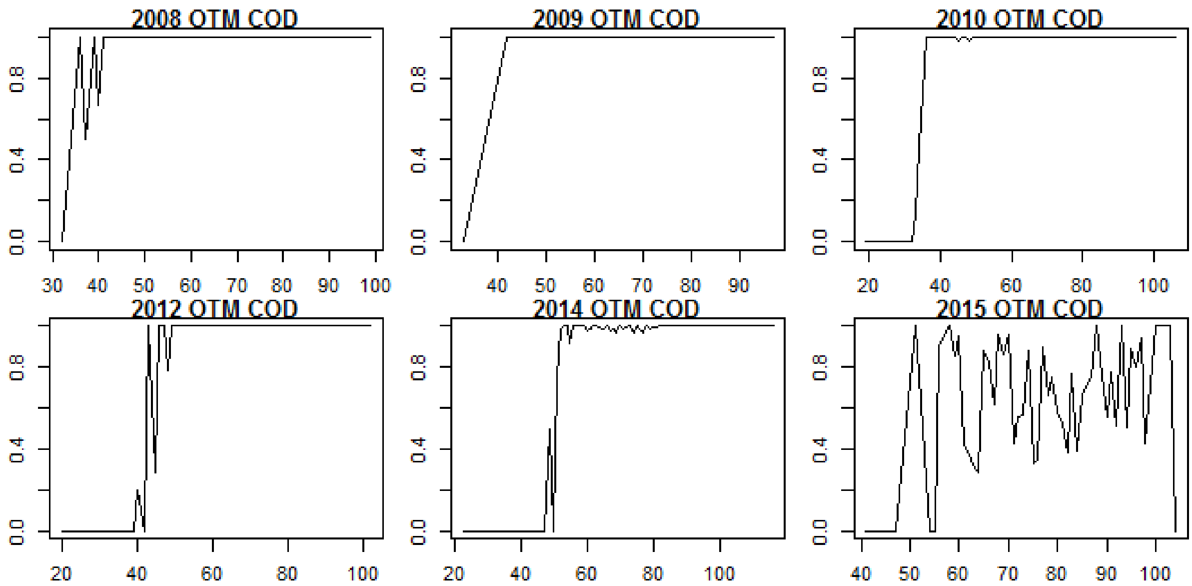

Figure 7.6.1. Discard ogives for cod observed in at-sea sampling for single rigs (OTB), twin rigs (OTT) and midwater trawling (OTM).

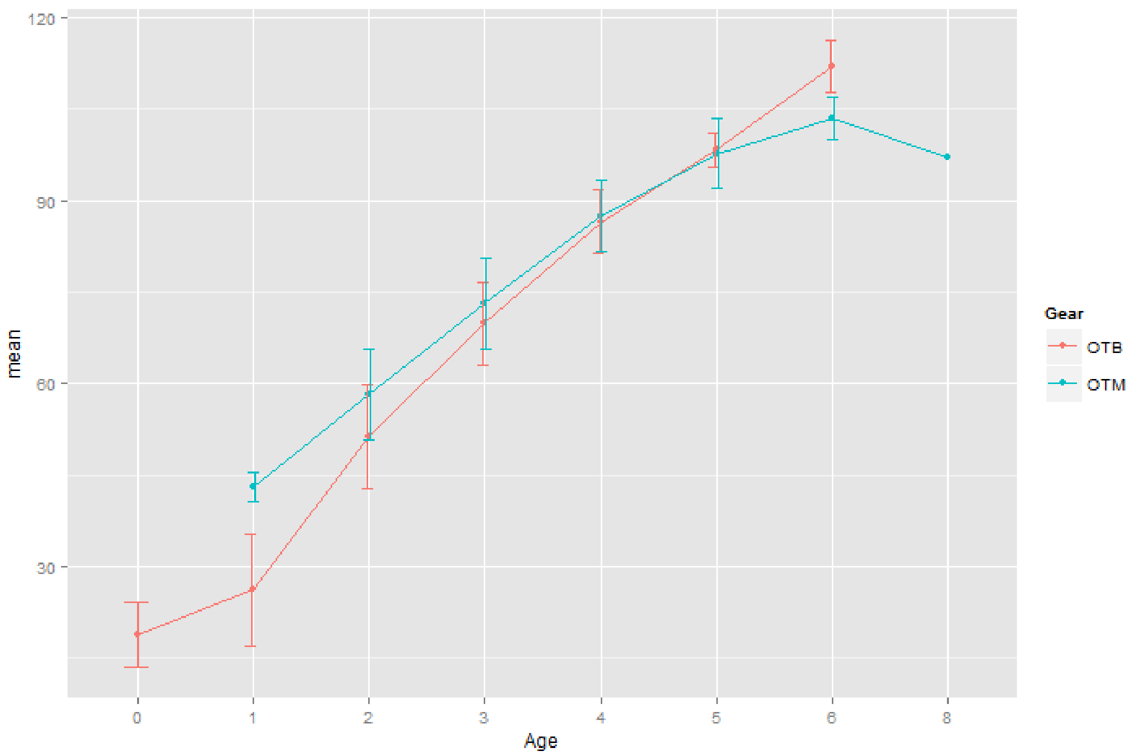

Figure 7.6.2. Mean length-at-age of cod caught by Northern Irish otter trawls (OTB) and midwater demersal trawling.

7.7 Recommend values for discard mortality rates, if required, following the guidelines provided by ICES WKMEDS and indicate the range of uncertainty in values

No data relating to discard survival rates of cod was available. It assumed that discard mortality is high and a precautionary estimate of 1 is assumed.

There is a Cefas FSP project still being finalised suggesting good survivability:

Randall, P. 2016. In prep. North East Coast Discards Survivability: February 2015 (A scoping study on gadoid survival). Final report: UK Fisheries Science Partnership MF059.

This study demonstrated that after observation periods of 5–22 hours for cod held in tanks after capture by trawling (normal commercial tows around 4 hours in 44–64 m of water off NE England), there was a 16–21% increase in the “excellent” vitality category of cod while 23–34% of cod exhibited a decline in vitality to moribund status. For whiting in captivity for 5 hours, there was a 12% increase in the excellent vitality category while 56% of whiting exhibited a decline in vitality to moribund status. The immediate mortality of cod at the point they arrived on deck was 7%. The immediate mortality of whiting was 39%. The mortality observed in captive fish after a period in on-board tanks was 22% for cod and 65% for whiting. An effective health assessment for cod was developed. The health assessment includes reflex testing as well as scoring both barotrauma and injury. A small increase in fishing depth saw an overall reduction in vitality in cod. When held for short period of up to 5 hours in holding tanks on board, the overall survival of cod was 67% (excellent vitality), for 17–22 hours survival of cod was 79%.

7.8 Review all available and relevant fishery-dependent and -independent data sources on relative trends in abundance or absolute fish abundance, and recommend which series are considered adequate and reliable for use in stock assessments. Provide measures or indicators of bias and precision

7.8.1 Fisheries-independent data

Nine research vessel survey series for cod in 7.a are available:

Index ID	Vessel	Gear	Year Range	Age Range	Time of year	Coverage	Design
NIGFS-Q1	1992–2004 R.V. Lough Foyle 2005–Present RV Corystes	Rock-hopper otter trawl with a 17 m footrope fitted with 250 mm non-rotating rubber discs	1992–present	1–5	March	North Irish Sea (Strata 1–8 Figure 5.6.1)	Stratified Fixed stations within strata
NIGFS-Q4			1992–Present	1–3	October		
NIMIK			1994–present	0	May	North Irish Sea	
UK-E/W BTS-Q3	RV Corystes	Beam Trawl	1994–Present	0	September	Mainly east	Fixed prime stations
ScoGFS-WIBTS-Q1	RV Scotia	GOV trawl	1996–2006	1–5	Spring	Northern limit of the Irish Sea to around 53°30′	two fixed-position stations per ICES rectangle
ScoGFS-WIBTS-Q4	RV Scotia	GOV trawl	1997–2007	1–2	Autumn	Northern limit of the Irish Sea to around 53°30′	two fixed-position stations per ICES rectangle
UK-FSP		Boris rock-hopper otter trawl with 118 ft headline and 160 ft groundgear comprising 100 ft of 14 inch hoppers and 2 × 30 ft ground chains.	2005–2013 2015–2016	1–5	March	Western Irish Sea	Stratified by rectangle with a minimum number of tows requested in each rectangle
UK IS-AEMP		Egg production survey	1995, 2000, 2006, 2008, 2010	SSB	March	Irish Sea	

7.8.1.1 UK (England and Wales) Beam Trawl Survey (E/W-BTS-Q3): ages 0 (brought forward to obtain indices of age 1), years 1993 (1994)–2014 (2015)

The survey covers the entire Irish Sea excluding the North Channel and is conducted in September. The survey uses a 4 m beam trawl targeted at flatfish. The survey is stratified by area and depth band, although the survey indices are calculated from the total survey catch in the eastern Irish Sea, and without accounting for stratification except for ALKs. Numbers of 0-gp and 1-gp cod at-age per 100 km towed are provided for prime stations only (i.e. those fished in most surveys). An automated data extraction and analysis routine in r is now used, and the series was revised in 2008 using this routine. The 2009 assessment used data for years 1993 onwards. The survey provides an important recruitment index and has been observer to closely follow the recruitment signals from the NIGFS-WIBTS-Q4 and NIMIK survey series.

7.8.1.2 UK (Northern Ireland) October Groundfish Survey (NIGFS-WIBTS-Q4): ages 1-3, years 1992-2015

The survey series commenced in its present form in 1992. It comprises 45 three mile tows at fixed station positions in the northern Irish Sea, with an additional twelve one mile tows at fixed station positions in the St George's channel from October 2001 (the latter are not included in the tuning data). The surveys are carried out using a rock-hopper otter trawl deployed from the R.V. Lough Foyle. The survey designs are stratified by depth and seabed type. Virtually all cod are aged apart from 0-gp and 1-gp fish when particularly abundant. An ALK for the whole survey is used for filling in for any length groups with no ages at a station. The effects of using strata specific and all area age–length keys were explored at WKIrish2 (Figure 7.8.1). The effects of this are agreed to be negligible, but it is agreed that strata specific ALKs are more appropriate.

Mean numbers-at-age per 3-mile tow are calculated separately by stratum, and weighted by surface area of the strata to give a weighted mean for the survey or group of strata. Coefficients of variation are calculated at-age across strata and for numbers of individuals between stations. From 2002 onwards, all stations in the survey have been reduced to 1 nautical mile, with comparative tows of 1 and 3 nm conducted to use a reference calibration dataset. Experimental tows were of 20 minute duration (1 nm) and standard 1 hour (3 nm). There were 42 tows completed during 2002–2006; 2002 (9), 2003 (9), 2004(8), 2005 (7), 2006 (9). A Generalised linear mixed models (GLMM) with log catch weight were applied with Variables duration (factor), order (factor), Station (random effect), Strata (factor) and year (factor). The GLMM showed no effect of tow duration on the, weigh or lengths of cod catches (Figure 7.8.1.1).

The survey picks out the year classes consistently from year to year especially at the youngest ages (0–2) age 3 is poorly correlated with age 2, and it would be appropriate not to include the series in the assessment model fit. The survey is consistent with other autumn surveys in not catching older fish consistently. More recently, at lower stock abundances, the noise in the time-series has increased but the survey still appears to be picking up a consistent signal from across ages 0–2.

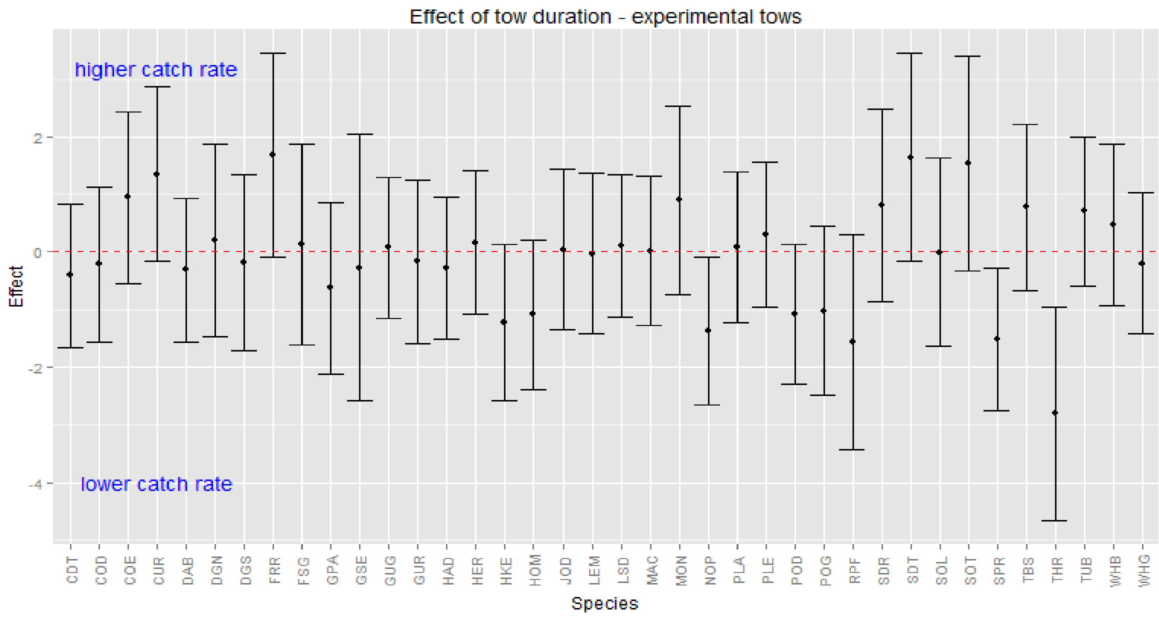

Figure 7.8.1. Catch weigh effects derived from GLMM of catch weights with tow duration from comparative 1 nm and 3 nm paired tows.

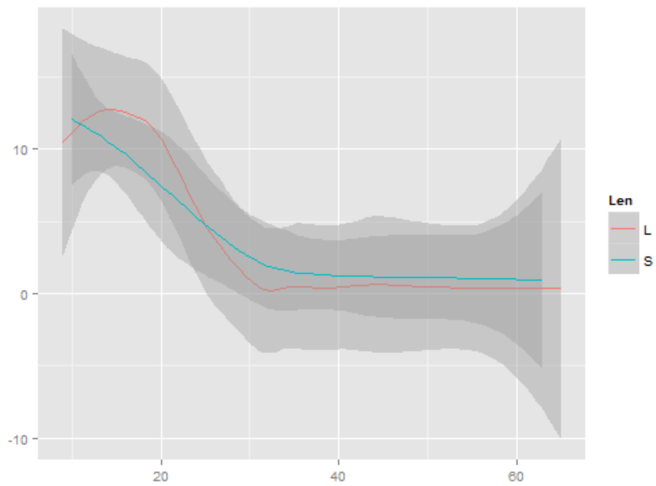

Figure 7.8.1.2. Length–frequency distribution raised to 3 nm from comparative 1 nm and 3 nm paired tows for L - 3nm tows and S - 1nm tows.

Since 2005, the RV Lough Foyle used for all surveys since 1992 has been replaced by the larger RV Corystes. The trawl gear and towing practices have remained the same.

7.8.1.3 UK (Northern Ireland) March Groundfish Survey (NIGFS-WIBTS-Q1): ages 1–5, years 1993–2016

General description as for October Surveys above, except that 3-mile stations have been retained in all strata other than in the St Georges Channel. Since 2005, the RV Lough Foyle used for all surveys since 1993 has been replaced by the larger RV Corystes. The trawl gear and towing practices have remained the same. The 1992 survey had only partial coverage of the western Irish Sea and is no longer used in the assessment. The survey picks up the year classes consistently from year to year across all ages. There is a rapid, relatively constant decline in the age classes with time.

7.8.1.4 UK (Northern Ireland) Methot-Isaacs-Kidd Survey (NIMIK): age 0 (brought forward to obtain indices of age1), years 1994 (1995)-2015 (2016)

The survey uses a Methot–Isaacs–Kidd frame trawl to target pelagic juvenile gadoids in the western Irish Sea at 40–45 stations. The survey is stratified and takes place in June during the period prior to settlement of gadoid juveniles. Indices are calculated as the arithmetic mean of the numbers-per-unit sea area. The survey provides an important recruitment index and has been observer to closely follow the recruitment signals from the NIGFS-WIBTS-Q4 and E/W-BTS-Q3 survey series.

7.8.1.5 UK (Scotland) groundfish survey in spring (ScoGFS-WIBTS-Q1): ages 1-5, years 1996-2006

This survey represented an extension of the Scottish West Coast groundfish survey (Area 6), using the research vessel Scotia. The survey gear is a GOV trawl, and the design is two fixed-position stations per ICES rectangle from 1997 onwards (17 stations) and one station per rectangle in 1996 (nine stations). The survey extends from the Northern limit of the Irish Sea to around 53°30′. The survey picks up the year classes consistently for ages 2–4 with reasonable consistency at-age 1 and noisier signal at-age 5.

7.8.1.6 UK (Scotland) groundfish survey in autumn (ScoGFS-WIBTS-Q4): ages 1-2, years 1997-2007

This survey represented an extension of the Scottish West Coast groundfish survey (Area 6), using the research vessel Scotia. The survey gear is a GOV trawl, and the design is two fixed-position stations per ICES rectangle from 1997 onwards (17 stations) and one station per rectangle in 1996 (nine stations). The survey extends from the Northern limit of the Irish Sea to around 53°30′. The survey only has a consistent time-series of data for age 2 and considerable noise ages 1 and 3. The survey is consistent with other autumn surveys in not catching older fish consistently. If only providing information at-age 2, it may be that this survey should be omitted from the assessment.

7.8.1.7 UK Fishery Partnership Surveys (UK-FSP), Western Irish Sea, in March: ages 1-5, years 2005-2013, 2015-2016.

The Irish Sea roundfish survey was initiated in 2003 as a fully collaborative project between the fishing industry and Cefas scientists. It forms part of the UK Fisheries Science Partnership funded by the UK's Department for Environment, Food and Rural Affairs (Defra). The main objective of the Irish Sea roundfish survey is to develop a time-series of data to track year-on-year changes in abundance, population structure and distribution of the target species (cod, haddock and whiting). The results of the surveys provide information supporting the scientific assessment of the stocks and the management of the fisheries in the Irish Sea. The surveys were designed to achieve full coverage of potential cod, haddock and whiting habitats within the area of the main roundfish fisheries of the Irish Sea, using a stratified design to allow additional trawling effort in areas expected to have the greatest densities of cod, haddock or whiting. The survey is conducted on board a commercial fishing vessel. Fishing gear and survey methods are kept constant. In the most recent year of the highest index value in the series was observed. This coincided with a vessel change after a period of consistent vessel selection. The potential for a vessel effect to generate this high index value was explored by plot mean standardised index values, by year and age, to evaluate if there was a step-change (Figure 7.8.1.7). The plot suggests that the recent index value is a true reflection of stock development with index values at year -1 and age-1 appearing to correspond in the penultimate year and final year of the survey and reflecting the 2013 year class observed in other survey series.

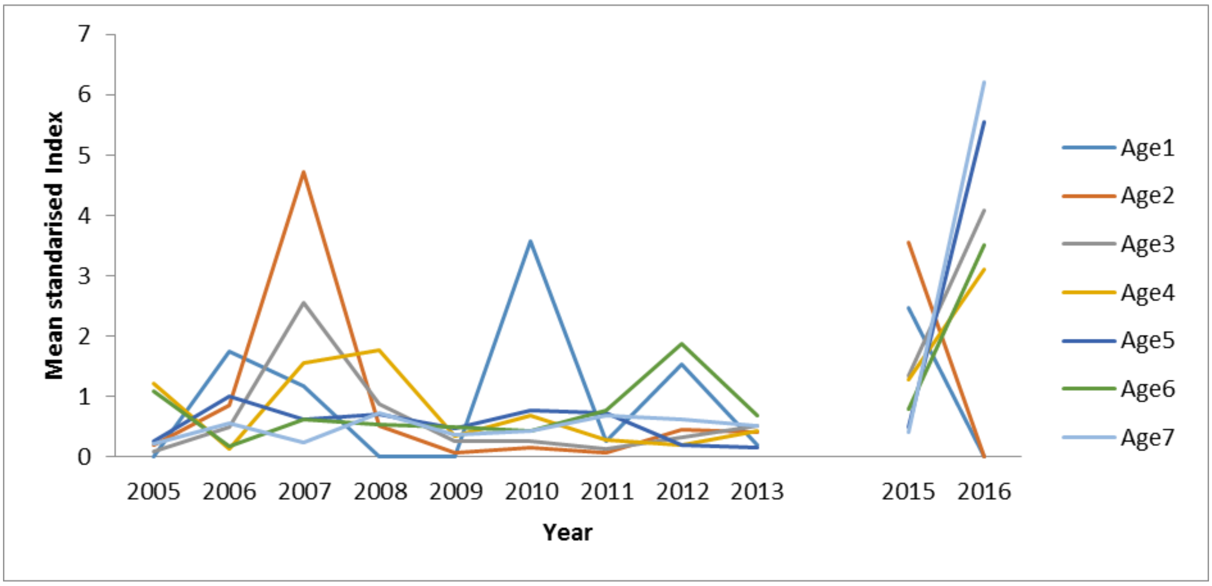

Figure 7.8.1.7. See haddock comment about year/year-class plots.

7.8.1.8 UK Fishery Partnership Surveys (UK-FSP), Eastern Irish Sea, in March: ages 1-5, years 2005-2013

The Irish Sea roundfish survey was initiated in 2003 as a fully collaborative project between the fishing industry and Cefas scientists. It forms part of the UK Fisheries Science Partnership funded by the UK's Department for Environment, Food and Rural Affairs (Defra). The main objective of the Irish Sea roundfish survey is to develop a time-series of data to track year-on-year changes in abundance, population structure and distribution of the target species (cod, haddock and whiting). The results of the surveys provide information supporting the scientific assessment of the stocks and the management of the fisheries in the Irish Sea. The surveys were designed to achieve full coverage of potential cod, haddock and whiting habitats within the area of the main roundfish fisheries of the Irish Sea, using a stratified design to allow additional trawling effort in areas expected to have the greatest densities of cod, haddock or whiting. The area coverage of survey is consider to over a small proportion of the main stock area and therefore may provide only limited information for the entire stock.

7.8.1.9 UK IS-AEMP, Irish Sea, in March: SSB index, years 1995, 2000, 2006, 2008, 2010

The Annual Egg Production Survey has been used to obtain estimates of cod spawning–stock biomass in the Irish Sea.

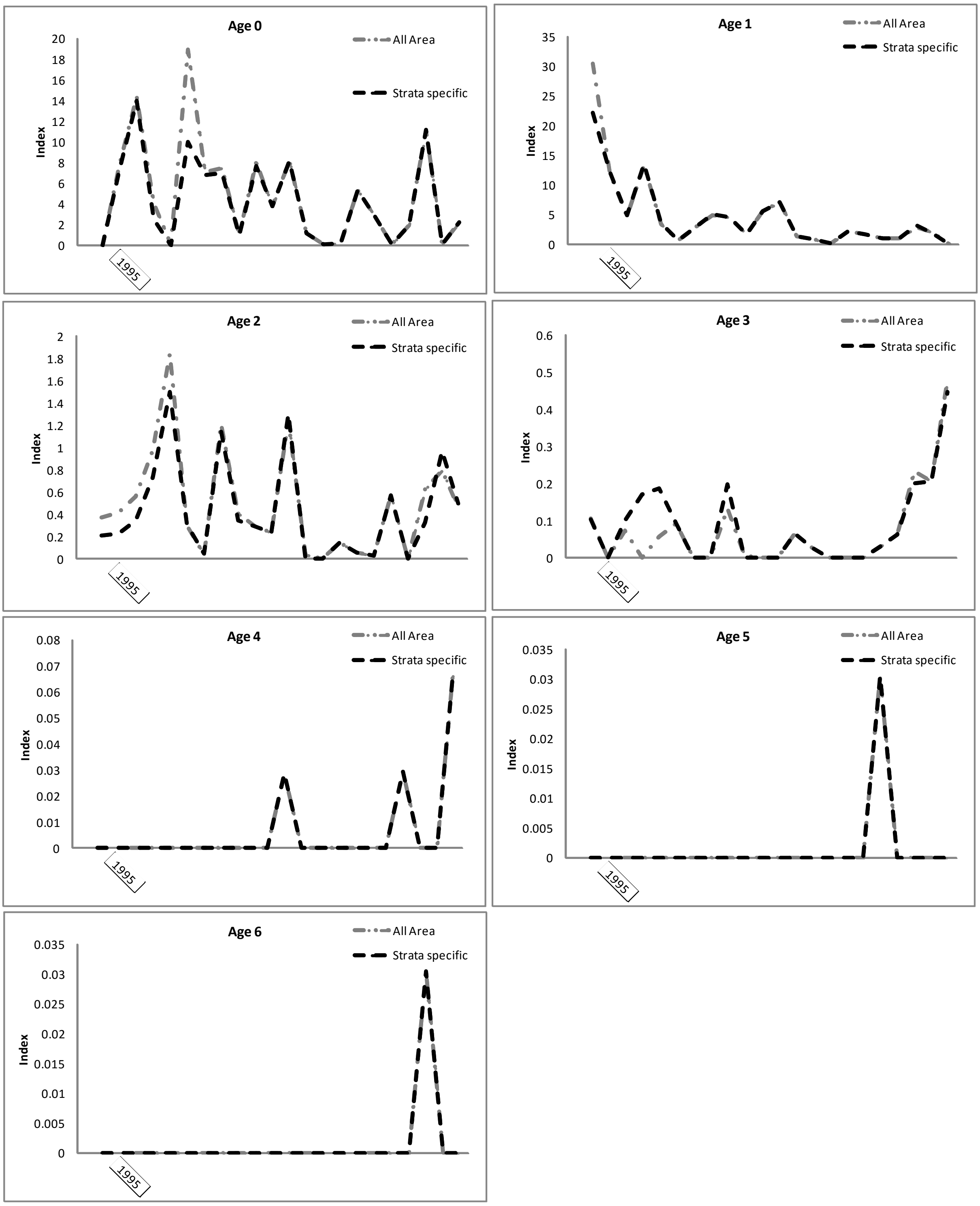

Figure 7.8.1.9.1. NIGFS Q1 survey indices for cod derived through strata specific age–length key application and generalised all areas age–length key.

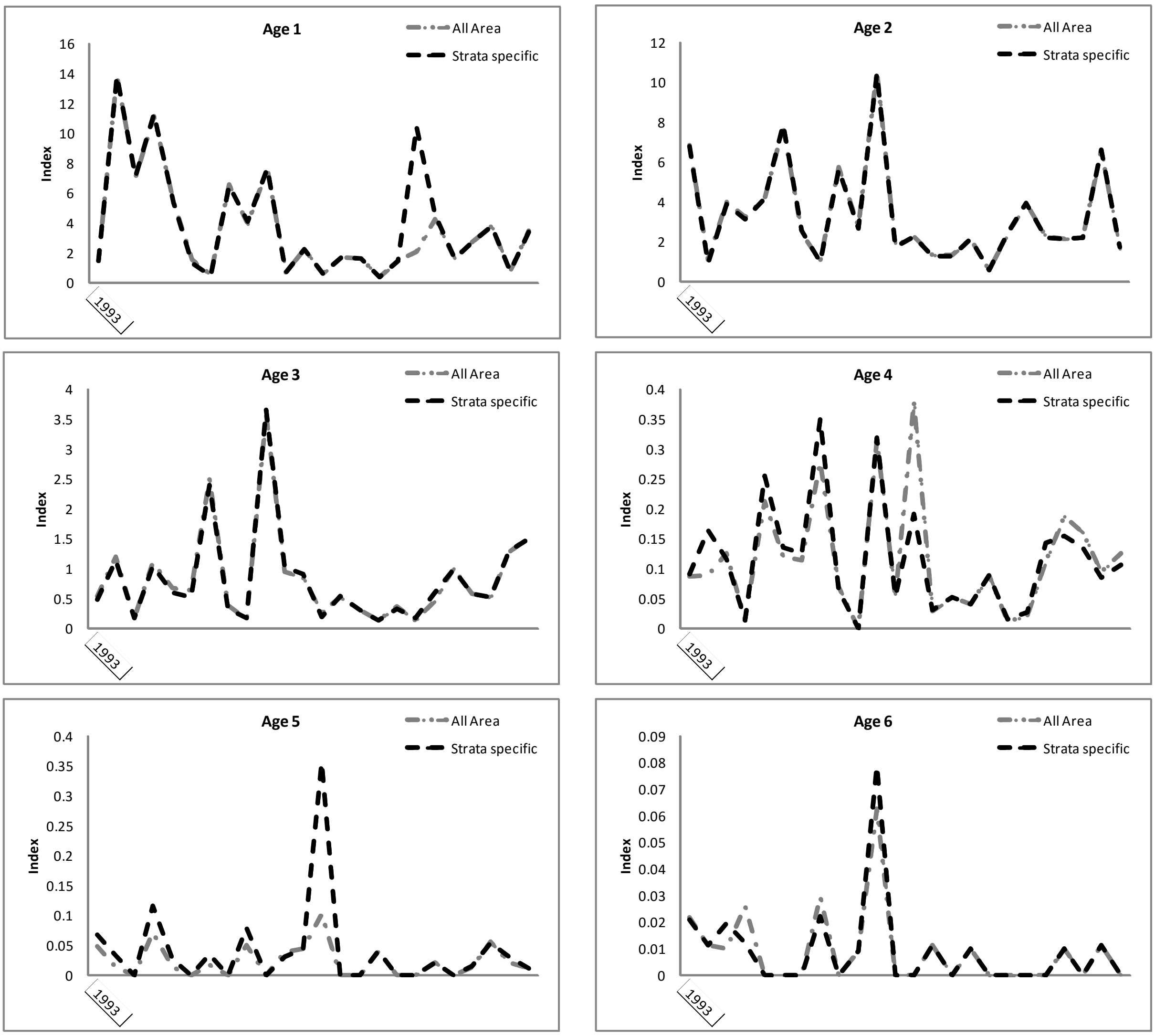

Figure 7.8.1.9.2. NIGFS Q4 survey indices for cod derived through strata specific age–length key application and generalised all areas age–length key.

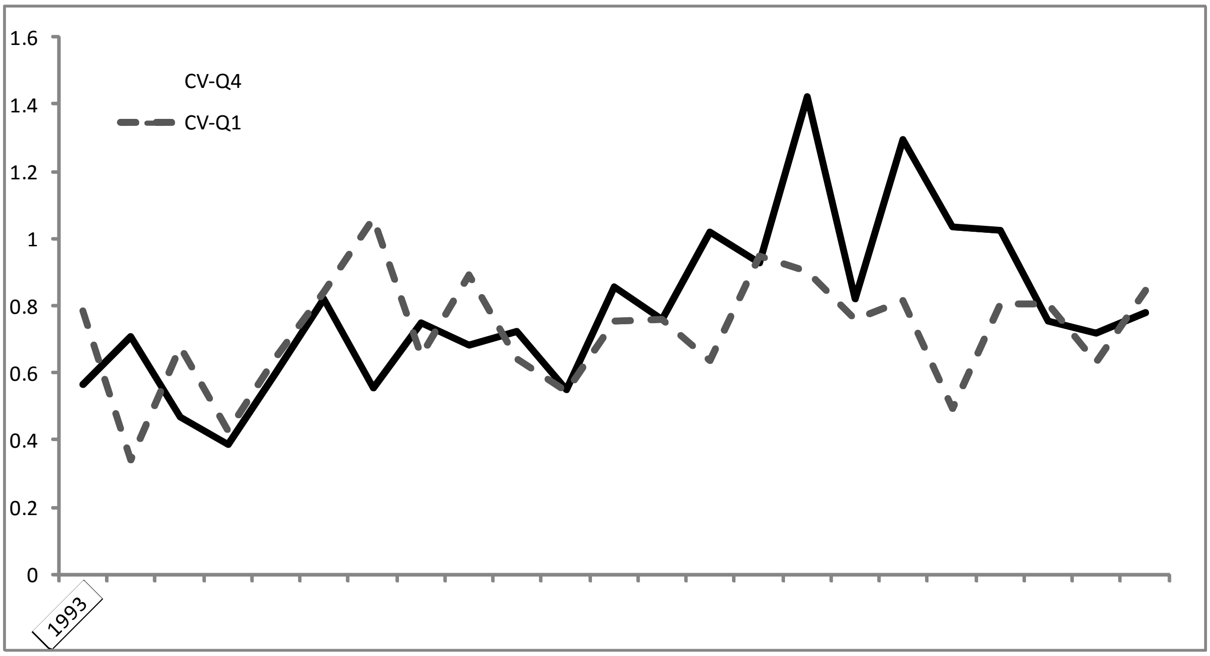

Figure 7.8.1.9.3. NIGFS cod catch numbers coefficient of variation (CV).

7.9 Identify any longer term or episodic/transient changes in environmental drivers known to influence distribution, growth, recruitment, natural mortality or other aspects of productivity and which are relevant to assessments and forecasts

SST time-series from the waters surrounding Ireland exhibit a warming trend over the period 1900–2007. The rate of warming since the late 1990s is unprecedented in the 150-year observational time-series, with 2005–2007 the warmest years on record (Cannaby and Hüsrevoğlu, 2009).

A negative relationship between Irish Sea cod recruitment and temperature is well documented (Planque and Fox, 1998; Planque and Frédou, 1999), with the species living close to its southern limit of distribution in the Irish Sea.

There is evidence that the reduction in cod recruitment observed in the Irish Sea since the 1990s may be as a consequence of a combination of small spawning–stock biomass and poor environmental conditions, coinciding with a shift towards above-average sea temperatures (ICES, 2006). Cod recruitment has been shown to be more sensitive to SST variability during the present low SSB regime (Beggs *et al.*, 2014).

The link between temperature and recruitment is thought to originate in the early life-history stages (eggs, larvae, pelagic juveniles).

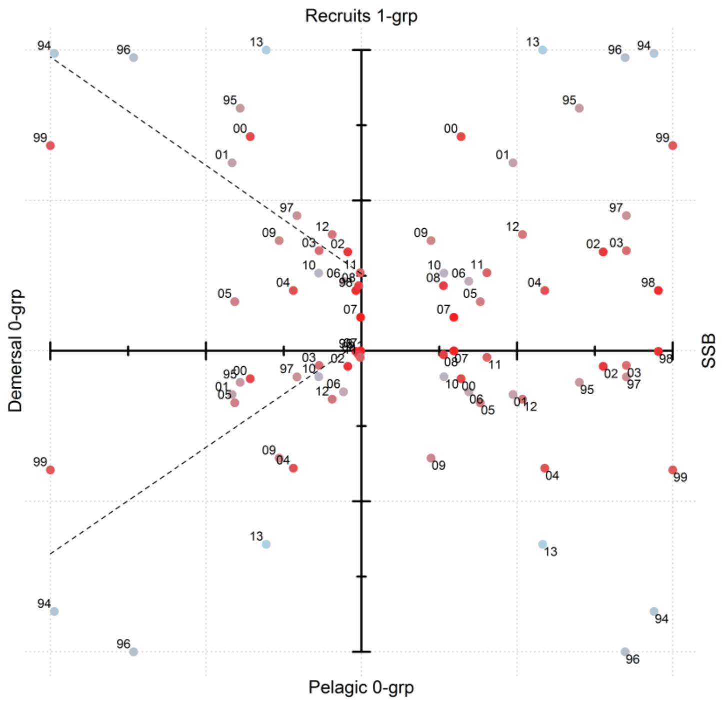

Figure 7.9.1. Paulik diagram for Irish Sea cod. Trend lines are given for significant regressions between life-history stages. SSB, spawning–stock biomass from Virtual Population Analysis (VPA), Pelagic 0-grp, abundance indices from MIK net survey, Demersal 0-grp, abundance indices from October groundfish survey, Recruits, recruitment at-age 1 from VPA. All data (1994–2013) standardised by mean. Axis values are index values and are for illustrative purposes only, therefore no numbers given. Years donate year class and colours represent average temperature February to May, blue cooler and red warmer.

Irrespective of the mechanisms involved the productivity of early life-history stages of cod have shown marked variation with many southern stocks, including the Irish Sea, at historically low productivity levels (Minto *et al*., 2014).

Disentangling the effects of spawning–stock biomass and environmental variability on recruitment can be difficult, however ignoring trends between recruitment and environmental drivers can be detrimental to advice precision especially in scenarios of rapid warming (Pershing *et al*., 2015). Taking into account environmental variability may improve the precision of advice in these situations.

Constructing environmentally sensitive stock–recruitment relationships has been highlighted as a useful way to incorporate environmental information into advice such as short-term forecasts (ICES, 2016). As an example we fit Irish Sea cod recruitment data into an environmental dependent Ricker-type stock–recruitment relationship based on observed SST time-series. The results suggest that including a SST term significantly improved recruitment predictions over the observed time-series (ANOVA $p<0.05$).

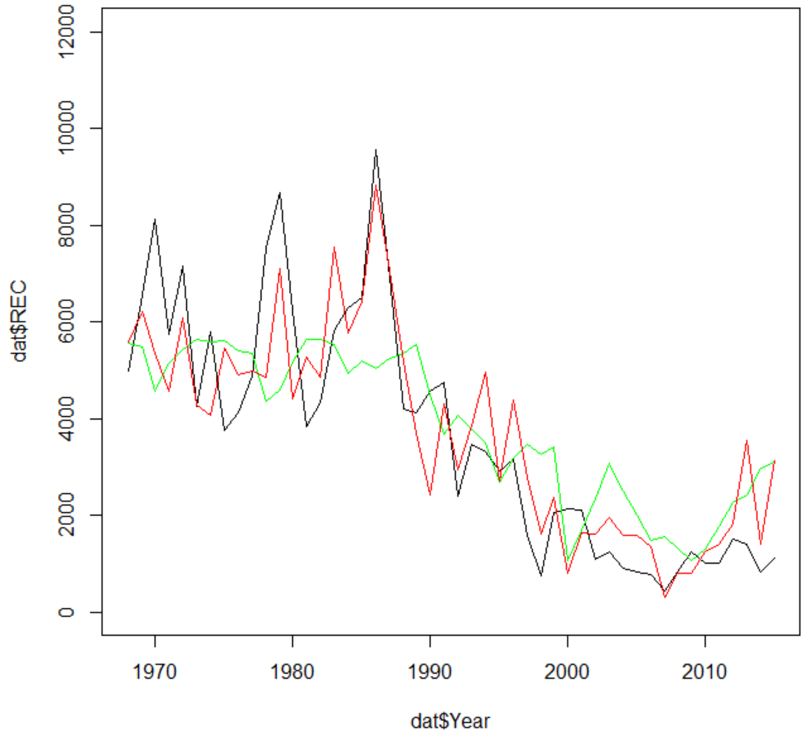

Figure 7.9.2. Time-series of recruitment estimates from VPA model (black line), Ricker recruitment estimates with no SST term (green line) and Ricker recruitment estimates with SST term (red line).

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7.10 Review progress on existing recommendations for research to develop and improve the input data and parameters for assessments, and develop and prioritise new proposals

7.10.1 References

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8 Data evaluation for Irish Sea plaice

8.1 Stock Structure

From WKFLAT 2011.

There are three principle spawning areas of plaice in the Irish Sea: one off the Irish coast, another northeast of the Isle of Man towards the Cumbrian coast, and the third off the north Wales coast (Nichols *et al.*, 1993; Fox *et al.*, 1997; Figure A1). Cardigan Bay has also been identified as a spawning ground for plaice in the Irish Sea (Simpson, 1959).

The level of mixing between the east and west components of the Irish Sea stock appears small (Dunn and Pawson, 2002). Length-at-age measurements from research surveys as well as anecdotal information from the fishing industry suggests that plaice in the western Irish Sea grow at a much slower rate than those in the eastern Irish Sea. Earlier studies have suggested that the east and west components of the stock are distinct (Brander, 1975; Sideek, 1981). Morphometric differences have been observed between the east and west components of the stock; the 2004 WG indicated that the UK(E&W) beam trawl survey in September (from 1989) catches plaice off the Irish coast that are smaller at-age than those caught in the eastern Irish Sea.

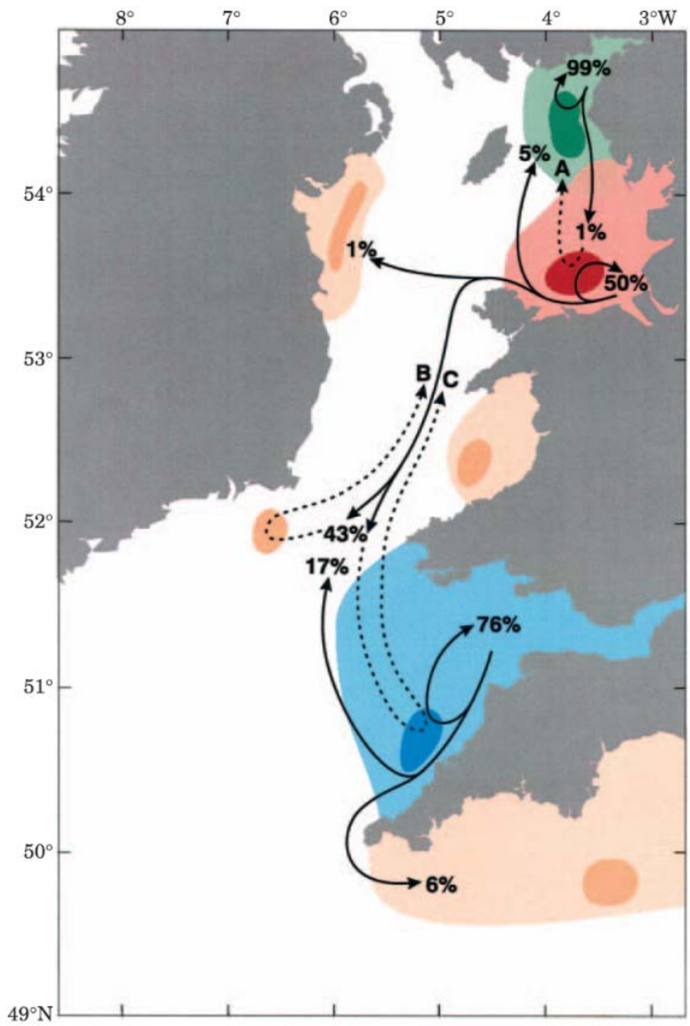


Figure 8.1. Principal substock areas and movements of plaice on the west coast of England and Wales. Percentages are the recaptures rates of tagged plaice <25 cm total length when released, and >26 cm when recaptured in English and Welsh commercial fisheries. Tagging exercises in 1979–1980 and 1993–1996 were combined based on the assumption that the dispersal patterns of plaice were consistent over time. For each substock, the main feeding area (derived from tag recaptures during April–December; light shading), and the main spawning area (derived from tag recaptures during January–March, and ichthyoplankton surveys; dark shading) are indicated. The substocks tagged have been coloured green, red and blue. The substocks coloured orange are less well determined, with the feeding area around southeast Ireland unknown. Letters represent return migrations, where A ≈ 6%, and B+C ≈ 46%. Reproduced from Dunn and Pawson (2002).

Although considered separate stocks for management, the stocks of plaice in the Irish Sea and the Celtic Sea do mix during spawning. Tagging studies have indicated a southerly movement of mature fish (or fish maturing for the first time) from the southeast Irish Sea, off North Wales, into the Bristol Channel and Celtic Sea during the spawning season, such that 43% of the new recruits are likely to recruit outside the Irish Sea (Figure 8.1). While some of these migrant spawning fish will remain in the Bristol Channel and Celtic Sea, the majority (≥70%) are expected to return to summer feeding grounds in the Irish Sea (Dunn and Pawson, 2002).

Very little mixing is considered to occur between the Irish Sea and Channel stocks or between the Irish Sea and North Sea (Pawson, 1995). Nevertheless, time-series of recruitment estimates for all stocks in waters around the UK (Irish Sea, Celtic Sea, western and eastern Channel, North Sea) show a significant level of synchrony (Fox *et al.*, 2000). This could indicate that the stocks are subject to similar large-scale environmental forces and respond similarly to them, or alternatively that there are subpopulations that share a common spawning.

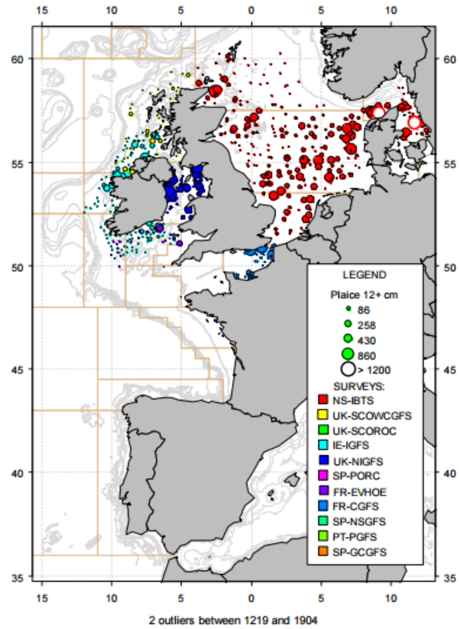


Figure 8.2. Catches in numbers per hour of 0-group plaice, *Pleuronectes platessa* (<12 cm), in summer/autumn 2014 IBTSurveys. The catchability of the different gears used in the NeAtl surveys is not constant; therefore, the map does not reflect proportional abundance in all the areas but within each survey. From ICES IBTSWG REPORT (2015).

8.2 Life-history parameters

8.2.1 Growth

Stock weight-at-age estimates used in the assessment were initially based on a separate sex basis up to 1983. The stock weights used in the current assessment are based on landings weights up to 2003, after this, catch weights derived from landings and discards are used, but historic data were not re-estimated. The catch weights show a decreasing trend over the most recent period since 2000.

Length-at-age from the UK beam trawl survey (Figure 8.2) shows a decreasing trend for the stock across all areas that the survey covers, and both sexes.

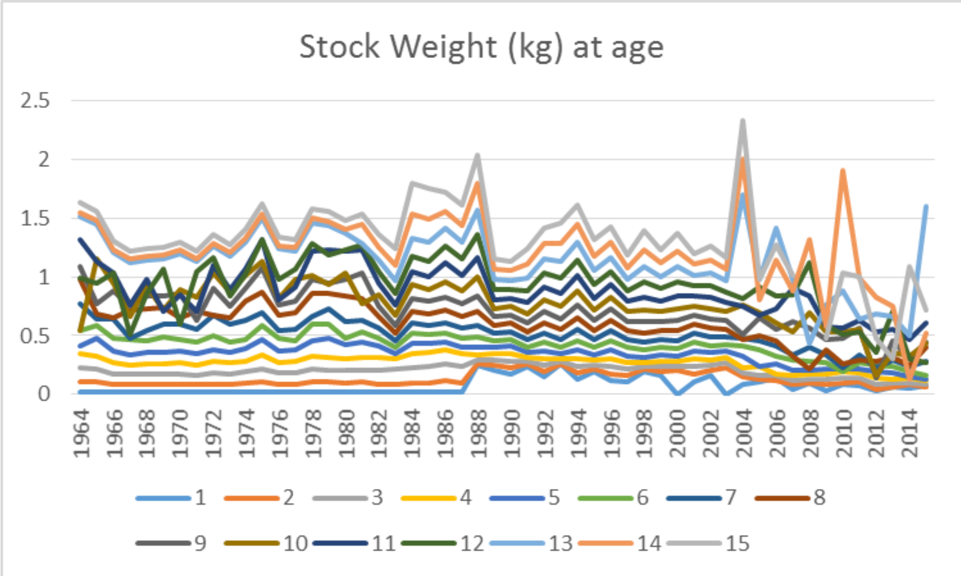


Figure 8.3. Plaice in 7.a stock weight-at-age.

Figure 8.4. Plaice 7.a mean length-at-age by year for each sex and area from UKBTS.

8.2.2 Maturity

Prior to 1983, maturity was estimated as sex-specific ogives (Sideek, 1981). In 1983, a single sex ogive was calculated by taking the weighted mean of the sex-specific ogive. The maturity ogive was revised again in 1992 based on the results of an EU project. WKFLAT 2011 was unable to update the maturity ogive due to time restraints.

The most recent data on maturity-at-age are from Gerritsen (2015) compiled from Q1 groundfish surveys between 2004 and 2009, and since 2010 from commercial vessel and port sampling. Data from these samples were compiled to give combined ogives for all of ICES Area 7, broken down by sex. The ogives are shown in Table 8.1, along with the ogives used by the working group. Length at 50% maturity was also calculated, and is shown in Figure 8.5; there is little evidence of a trend in the length-at-maturity.

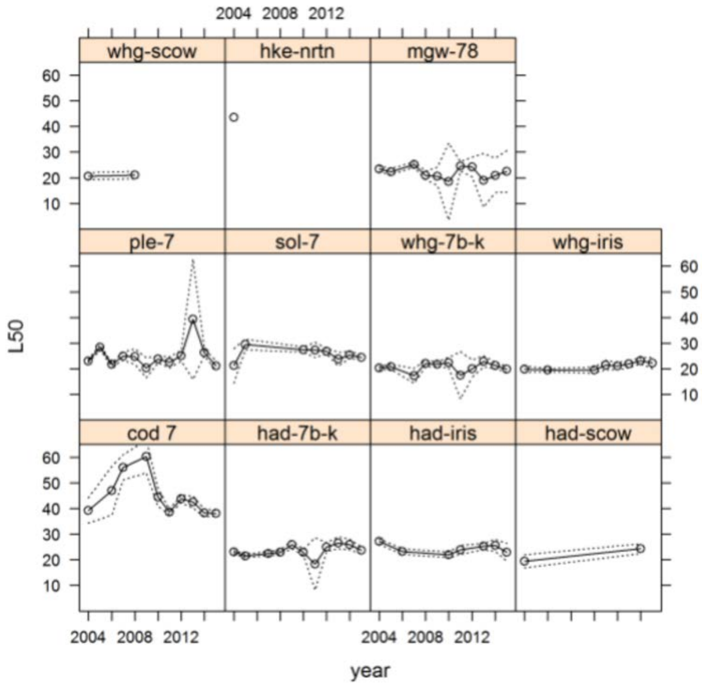


Figure 8.5. Length at 50% maturity (cm) for females by stock and year (Gerritsen, 2015).

Table 8.1. Estimated proportions mature (sample numbers in brackets) by stock, sex and age. Maturity ogives used by the WG are also given (Gerritsen, 2015; WGCSE 2015)

Stock	Sex/WG	1	2	3	4	5	6	7	8	9	10+
ple-7	Gerritsen F	0.00 (13)	0.15 (199)	0.45 (604)	0.64 (458)	0.80 (339)	0.97 (116)	0.94 (75)	0.93 (35)	1.00 (10)	0.97 (21)
	Gerritsen M	0.00 (13)	0.30 (226)	0.53 (438)	0.72 (314)	0.80 (168)	0.85 (86)	0.88 (44)	0.89 (34)	0.76 (10)	1.00 (5)
ple-7a	WGCSE (1992-2015)	0.00	0.24	0.57	0.74	0.93	1.00	1.00	1.00	1.00	1.00
ple-7a	WGCSE (1983-1992)	0.00	0.15	0.53	0.96	1.00	1.00	1.00	1.00	1.00	1.00
ple-7a	WGCSE (1978-1982) F	0.00	0.04	0.40	0.94	1.00	1.00	1.00	1.00	1.00	1.00
ple-7a	WGCSE (1978-1982) M	0.00	0.30	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ple-7fg	WGCSE	0.00	0.26	0.52	0.86	1.00	1.00	1.00	1.00	1.00	1.00

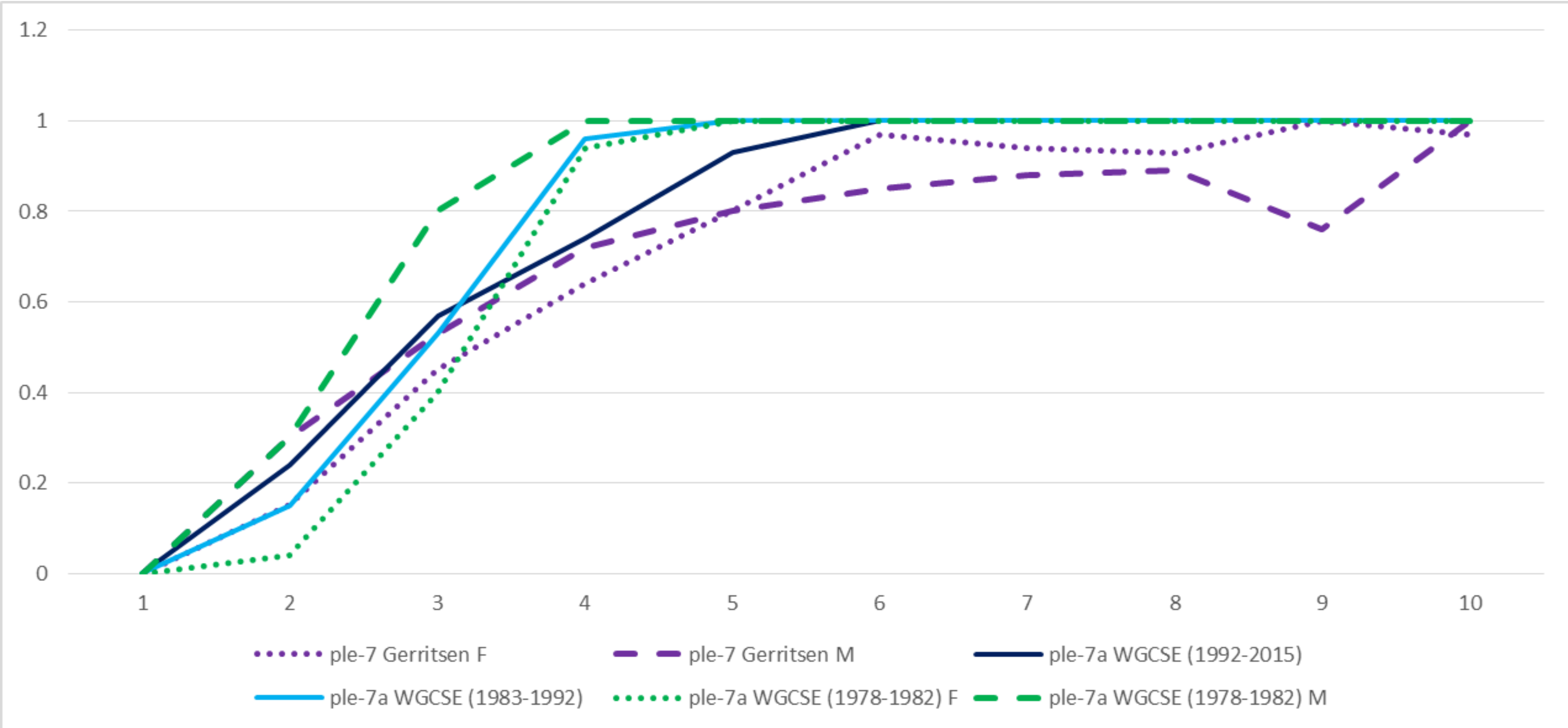


Figure 8.6. Estimated proportions mature (sample numbers in brackets) by stock, sex and age. Maturity ogives used by the WG are also given (Gerritsen, 2015, WGCSE 2015).

8.2.3 Natural mortality

Natural mortality was initially determined on a separate sex basis and taken as 0.15 for males and 0.1 for females independent of age. In 1983 when a combined sex assessment was undertaken a sex weighted average value of 0.12 was used as an estimate of natural mortality. This estimate of natural mortality has remained unchanged since 1983.

8.3 Fishery management

NA.

8.4 Catch data

National landings data reported to ICES and Working Group estimates of total landings are given in Table X. The working group procedures used to determine the total international landings numbers and weights-at-age are documented in the stock annex. As a result of increased rates of discarding, landed numbers-at-age for the younger ages (ages 2 to 4) have declined more rapidly over the last two decades than landings of older fish (Figure x).

In 1986, the UK fleet was restricted to a 10% bycatch of plaice for almost the entire year. Estimates were made of the increased quantity of plaice that would have been discarded based on comparisons of lpue values for 1985–1986 with those for 1984–1985. The estimated quantity of 250 tonnes was added to the catch. A similar situation arose the following year and 250 tonnes was added to the catch for 1987.

The 10% plaice bycatch restriction was enforced again in 1988 to all UK(E&W) vessels in the 1st quarter and to beam trawlers in the 2nd and 3rd quarters. However, this time the landings were not corrected for discard estimates.

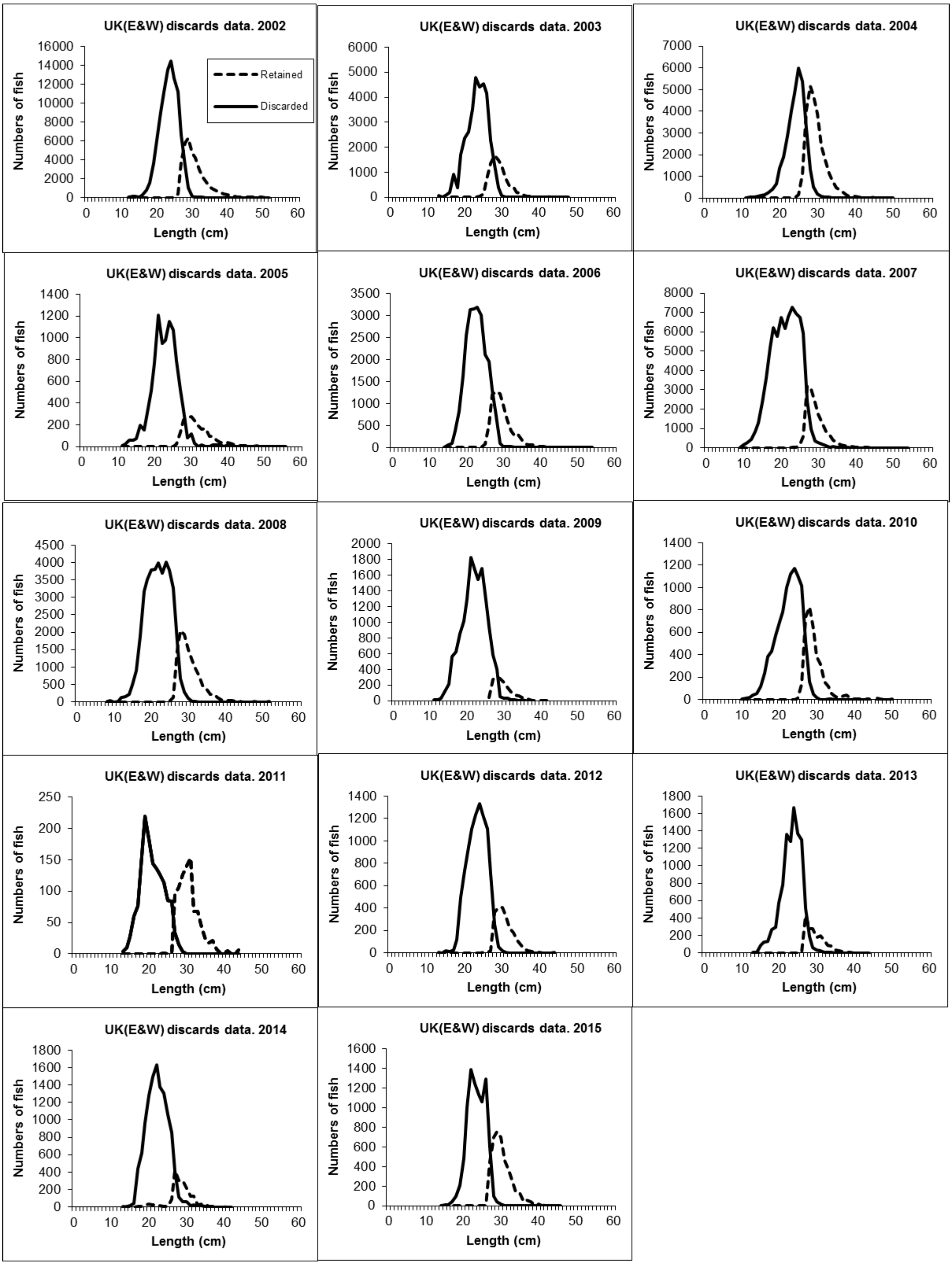
Discard information was not routinely incorporated into the assessment prior to benchmarking by WKFLAT in 2011.

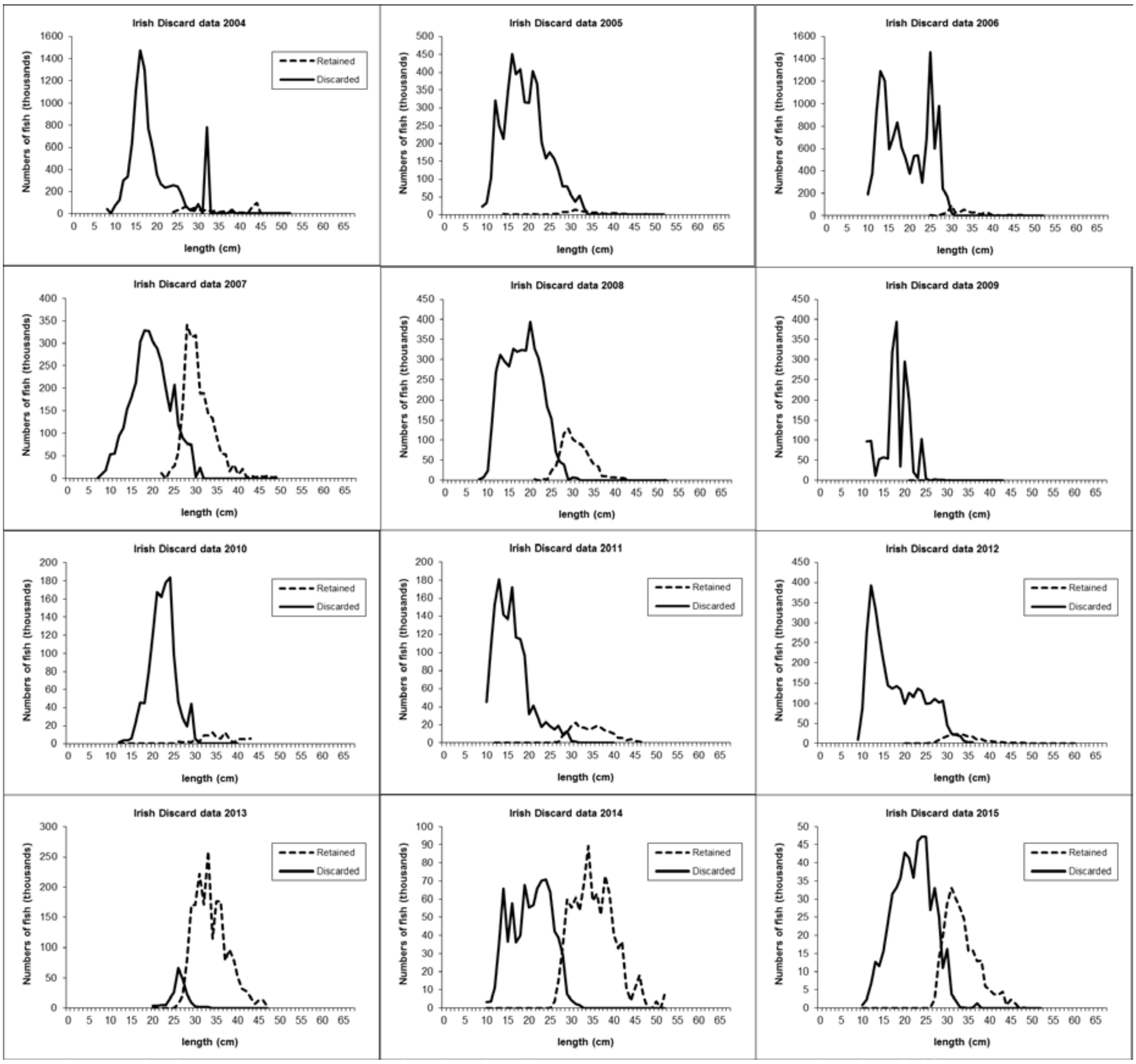
Discard sampling has been conducted by the UK(E&W) since 2002 and by Ireland since 1993; Northern Ireland has collected data from 1996 (but not between 2003 and 2005), and Belgium since 2003. Length distributions (LD) of landed and discarded fish estimates are presented for all UK(E&W) gears in Figure 6.7.2.3, for Irish otter trawls in Figure 6.7.2.4 and Belgian beam trawl fleets in Figure 6.7.2.5 (ICES, WKFLAT 2011). For all of the fleets illustrated the discarding pattern is dominated by discarding of small fish, below the MLS of 27 cm.

WKFLAT 2011 first estimated total international discards-at-age and introduced them to the assessment of the stock for the first time. Due to limitations in the data available by gear type, discards for Ireland, France and Northern Ireland, for the years 2004–2011 were raised using UK estimates on the basis of equivalent gear types. A raising factor based on tonnages landed for these countries was calculated and applied to the UK(E+W) estimates of discard numbers. Finally, these estimates were added to those calculated for Belgium to give estimates of total international discard numbers-at-age.

In 2012–2015 landings and discard estimates for UK(E&W), Ireland, Northern Ireland and Belgium were available by gear type and used to raise discards for France, Scotland and UK(IOM).

8.5 Length and age distributions for landings and discards

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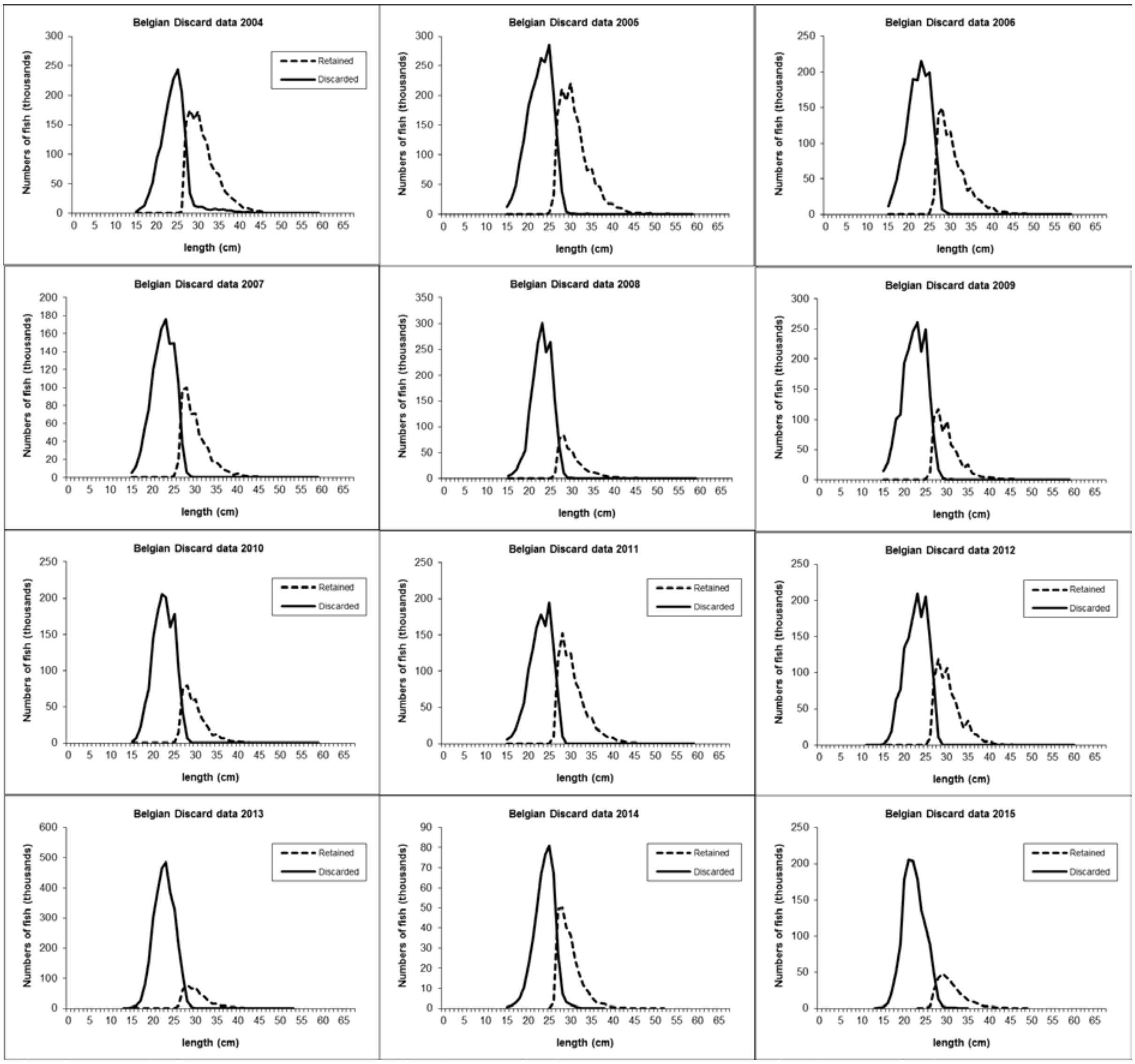
Retained
Discarded
Numbers of fish (thousands)
length (cm)


Belgian Discard data 2004
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Retained
Discarded
Numbers of fish (thousands)
length (cm)

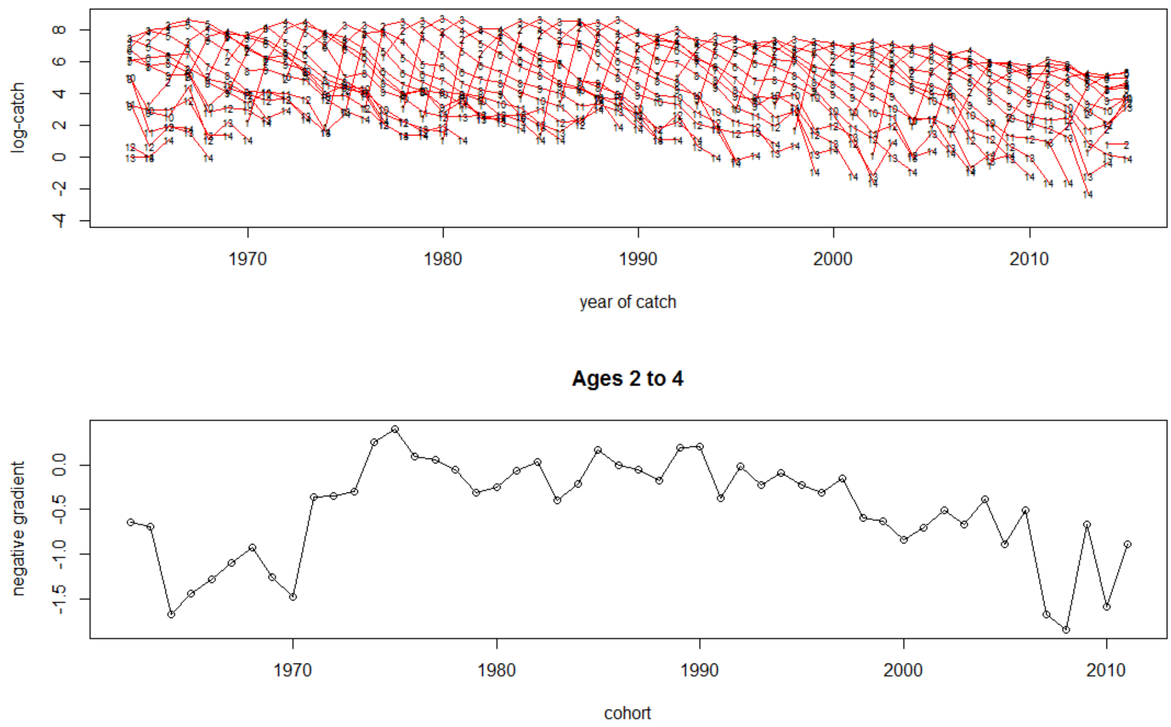


Figure 8.7. Plaice in 7.a catch curves from landings data, with average gradient between ages 2 and 4.

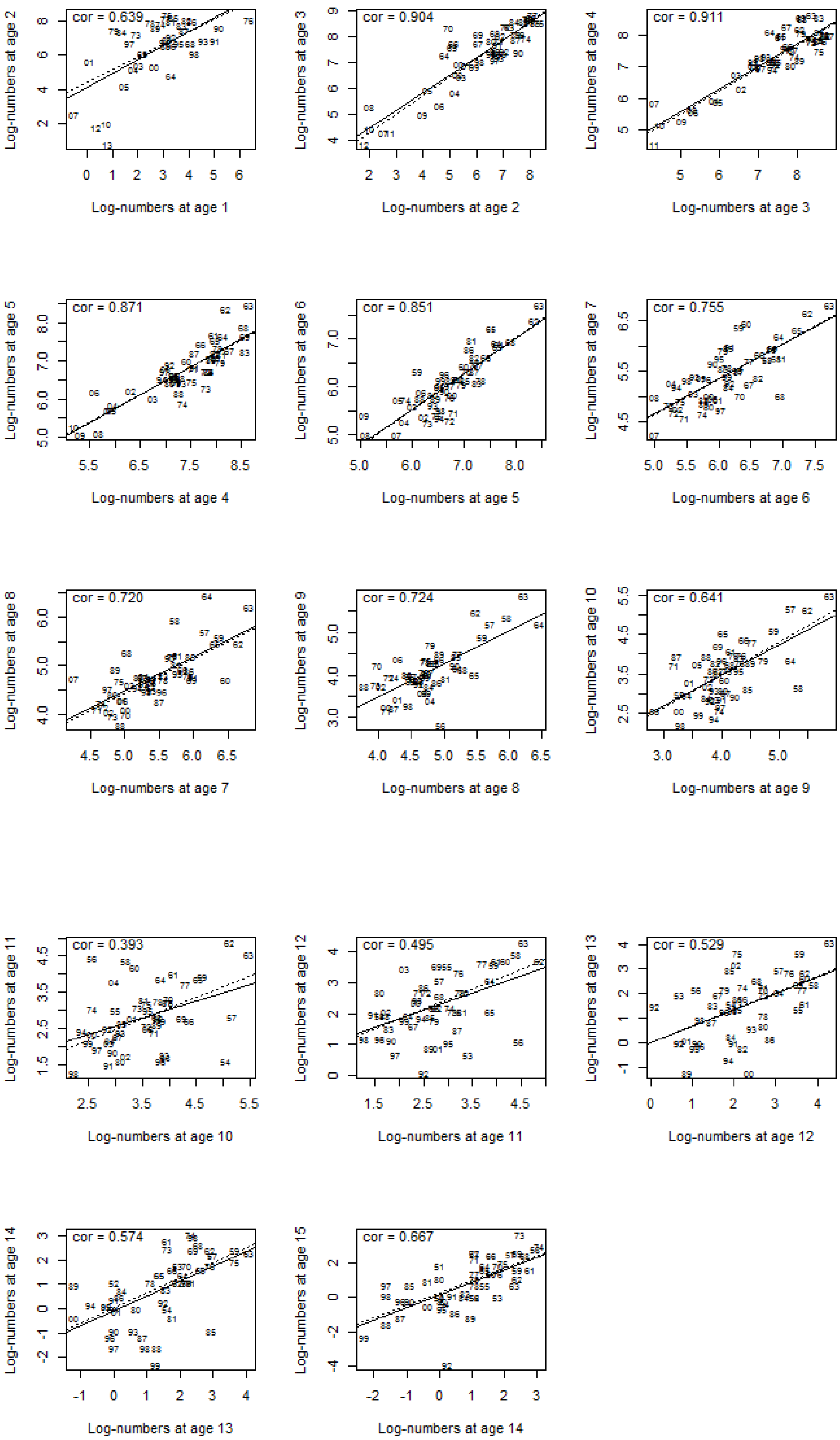


Figure 8.8. Plaice in 7a, correlation between consecutive ages in landings data.

8.6 Recommendations for addressing fishery selectivity

8.7 Discard mortality rates and range of uncertainty

There is no known data on mortality rates within the Irish Sea; a fisheries–science partnership in the UK is currently gathering data on this. Data from nearby areas are reported in a study of English Channel beam Trawlers (Revill *at al*., 2007 and Enever *et al*., 2007), and for four case studies in the North Sea and English Channel (Catchpole *et al*., 2015).

The case studies in the North Sea and English Channel showed a variety of survival rates, ranging from 18.8–20.0% for the North Sea otter trawl to 71.1–71.9% in the Eastern Channel trammelnet. In contrast to the North Sea otter trawl, the otter trawl in the Western Channel had a much higher survival at 47.1–62.8%.

8.8 Fisheries-independent and -dependent data sources on fish abundance

8.8.1 UKBTS survey

In 1993, the UK(E&W) beam trawl survey series that began in 1988 was considered to be of sufficient length for inclusion in the assessment. Since 1991, tow duration has been 30 minutes but prior to this it was 15 minutes. In 1997, values for 1988 to 1990 were raised to 30 minute tows. However, data for 1988 and 1989 were of poor quality and gave spurious results: thus, the series was truncated to 1990. A similar March beam trawl survey began in 1993 and was made available to the WG in 1998. The March beam trawl survey ended in 1999 but continued to be used as a tuning index in the assessment until 2003.

In 2011, the UK(E&W) beam trawl survey was re-examined and additional stations sampled in the western Irish Sea and St Georges Channel (Cardigan and Caernarfon Bays) since 1993 were included in the index. The extended index replaced the earlier 'prime stations' index since it was considered more representative of the entire stock (WKFLAT 2011).

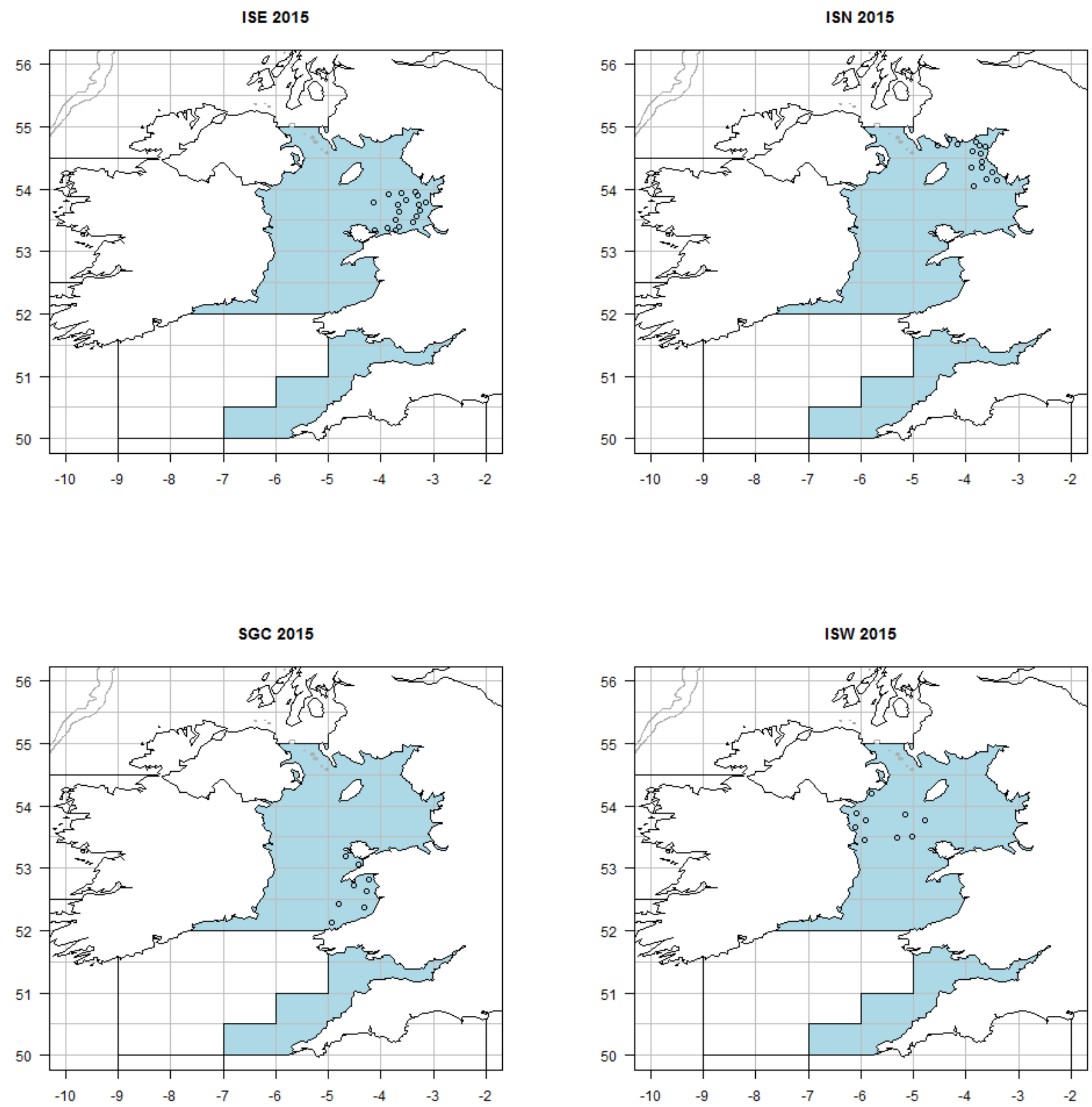


Figure 8.9. Locations of hauls in 2015 by strata, showing the strata included in the prime stations (top) and all stations added in to create the extended survey (bottom).

```
Plaice in VIIa, 2015  # TJE 02/05/2016

101

UK BT SURVEY (Sept) - all stations Rcode

1993 2015

1 1 0.75 0.85

0 7

1       0.197763463    4.636682219    4.026996933    0.904110338
        0.428658282    0.024706201    0.046110652    0.127515877

1       0.575941068    4.125238962    2.483375561    1.422338489
        0.31795772     0.083932938    0.051814947    0.01995681

1       1.121036192    5.55901104     1.964290614    0.841512161
        0.413895927    0.084309108    0.056596266    0.028012293

1       0.280586906    5.794657312    2.174401871    0.526173772
        0.191131498    0.197877316    0.072020565    0.003747676

1       1.594332337    5.465255609    2.910991795    1.262268241
        0.276747303    0.160070248    0.166930401    0.076033368

1       0.562532586    4.504834121    4.262442032    1.090764404
        0.403034017    0.21037804     0.085751919    0.072603291

1       2.61218922     3.963749372    3.907921916    1.991179262
        0.683886335    0.293094144    0.11271225     0.1091173

1       1.56868843     8.739835539    2.796655904    1.474932999
        1.111344864    0.471063873    0.175869389    0.144063223

1       0.832759551    5.98749465     3.621806204    1.114222975
        0.597819007    0.541991551    0.107002624    0.073114935

1       0.395222942    6.457375737    4.943055995    2.270316542
        0.876956287    0.532686975    0.520474719    0.102350336

1       3.358707075    6.118574905    5.846375247    2.610749756
        1.583491919    0.582270571    0.53763659     0.259575905
```

1	1.086309247	8.069393528	5.359435771	3.942814076
	1.881850494	1.151441279	0.20935296	0.277531133
1	2.073451302	3.75635527	4.748108804	1.981140114
	1.420172125	0.804764204	0.50948675	0.133377832
1	3.563652604	5.010514171	3.451997692	2.458734205
	1.095613823	0.790888959	0.358226176	0.197140704
1	1.688199006	7.967043192	4.466196475	1.65854067
	1.195638015	0.646668031	0.251572473	0.294257216
1	1.85959705	4.679598649	5.706461994	2.026243729
	1.151785893	0.365773221	0.203124063	0.146159381
1	1.225877887	4.740681467	3.396170237	3.303124477
	0.986285055	0.655972607	0.634455775	0.16283008
1	2.014277464	6.22272086	4.312589352	2.04504786
	1.44384166	0.658013085	0.545977284	0.37397866
1	1.024890883	6.731615872	4.281818956	1.749178667
	1.003588302	1.079330815	0.485817214	0.272199657
1	1.404990975	6.515529337	6.368982265	1.714368126
	1.025829503	0.474533376	0.529779295	0.290768
1	2.037702142	4.326627836	5.054710907	3.079814653
	1.595734782	1.067700095	0.482093344	0.421032064
1	0.645410656	9.163372763	7.883490614	4.094893598
	2.909817535	1.210600779	1.028281384	0.605300389
1	0.360992401	3.792243404	8.864368956	3.270809936
	2.308163533	1.217893555	0.940768075	0.514140692

UK BT SURVEY (Sept-Trad) - Prime stations only

1989 2015

1 1 0.75 0.85

1 8

129.710	309	441	530	77	13	44	3	0
128.969	1688	405	176	90	54	30	3	1
123.780	591	481	68	47	4	4	24	3
129.525	1043	470	267	23	19	14	14	3
131.192	1106	812	136	101	16	8	21	4
124.892	815	608	307	68	33	12	17	8
126.004	1283	387	179	84	16	18	0	1

126.004	1701	601	124	74	49	9	11	1
126.004	1363	668	322	65	50	23	8	7
126.004	1167	767	212	95	34	23	14	3
126.004	1189	965	344	113	38	17	7	7
126.004	2112	659	298	141	73	22	7	3
126.004	1468	663	218	130	89	28	10	7
126.004	1734	1615	647	243	79	51	16	17
126.004	1480	1842	827	296	122	62	39	10
126.004	1816	1187	1184	404	261	57	57	14
122.298	869	1295	666	499	297	111	17	17
126.004	1120	840	722	411	178	83	59	16
126.004	2667	1255	525	417	196	95	45	37
122.298	1293	1893	628	339	243	76	55	33
126.004	1460	1083	1225	310	189	251	65	31
126.004	1823	1413	670	505	184	155	98	60
122.298	2168	1440	646	324	379	137	121	87
122.298	1941	1844	661	312	158	145	124	72
126.004	1493	1662	973	580	376	151	161	82
126.004	2763	2189	921	759	331	256	191	79
126.004	1126	2594	724	554	344	264	119	71

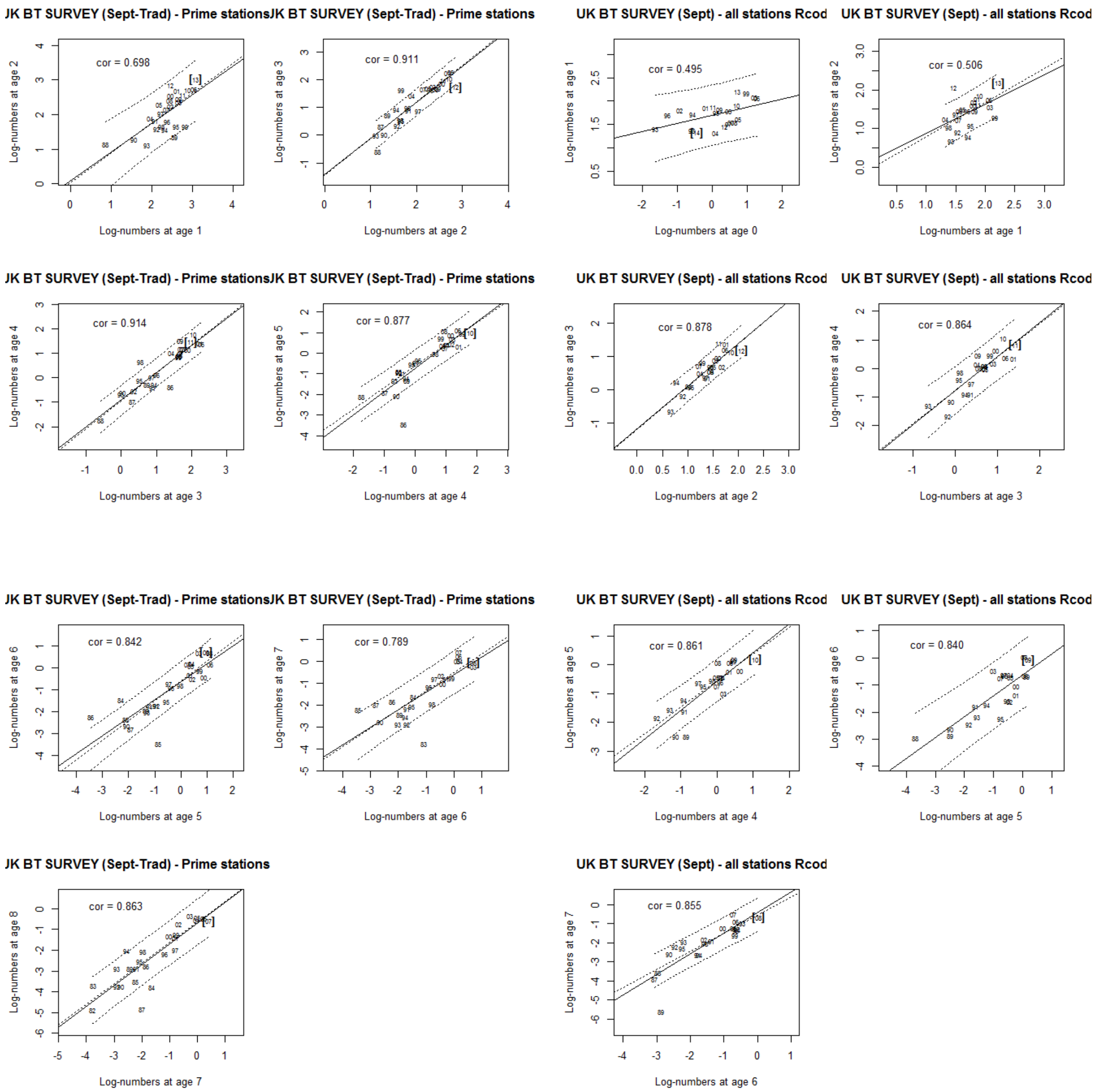


Figure 8.10. Plaice in 7.a, Survey internal consistency for prime stations (left) and extended (right).

8.8.2 Northern Irish Groundfish survey

The NIGFS-WIBTS survey strata can be disaggregated into eastern (Strata 4–7) and western (Strata 1–3) subareas, where the subareas are divided by the deep trench that runs roughly north–south to the west of the Isle of Man (Figure 8.11, Table 8.11). The notable difference in mean biomass between spring and autumn in the western area (Strata 1–3) suggests either that spawning fish migrate into the area during spring or that catchability of plaice increases during spawning.

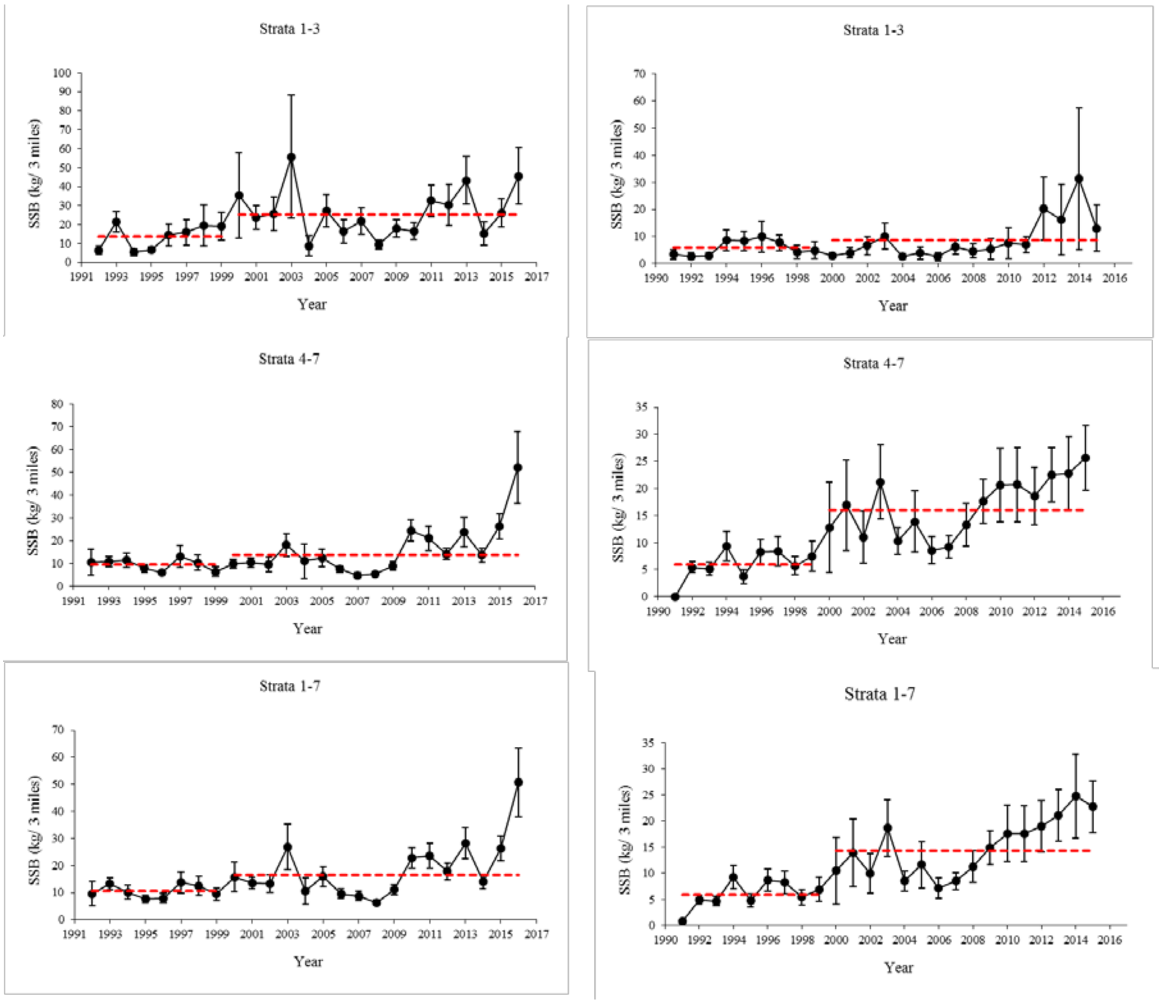


Figure 8.11. Northern Irish groundfish survey SSB indices split into spring (left hand panels) and autumn (right hand panels) sampling by western strata (1–3), eastern strata (4–7) and total survey area (strata 1–7) with confidence intervals (± 1 standard error, vertical lines) and mean biomass (kg/3 miles, dashed horizontal lines) for periods identified by statistical breakpoint analysis (see WGCSE, 2010).

8.8.3 AEPM

The SSB of plaice can be estimated using the Annual Egg Production Method (AEPM) (Armstrong *et al.*, 2002 and WD 9, WGCSE 2011). This method uses a series of ichthyoplankton surveys to quantify the spatial extent and seasonal pattern of egg production, from which the total annual egg production can be derived. The average fecundity (number of eggs spawned per unit body weight) of mature fish is estimated by sampling adult females immediately prior to the spawning season. Dividing the annual egg production by average fecundity gives an estimate of the biomass of mature females. Total SSB can be estimated if the sex ratio is known. Although substantial discrepancies between absolute estimates of SSB from the Annual Egg Production method (AEPM) and the ICES catch-based assessments were observed, they do confirm that SSB of plaice in the Irish Sea is currently at high levels.

AEPM estimates of SSB for plaice (RSE = relative standard error, as %), based on production of Stage 1 eggs) are shown below (note 1995 and 2000 estimates were revised in 2010 and 2006 and 2008 estimates revised in 2011 see WD 9, WGCSE 2011):

Table 8.11. AEPM estimates of SSB for Irish Sea plaice. All estimates from stratified mean (design-based) estimates.

	TOTAL		WEST		EAST	
Year	SSB(t)	RSE	SSB(t)	RSE	SSB(t)	RSE
1995	9081	21	3411	42	5670	22
2000	13 303	19	5654	36	7649	19
2006	14 417	16	3885	29	10 532	19
2008	14 352	19	4639	43	9713	18
2010	15 071	14	3435	20	11 636	18

Splitting the SSB estimate by substrata (Figure 8.12 below) suggests that the perceived increase in plaice SSB is limited to the eastern Irish Sea. This finding agrees with an analysis of NIGFS-WIBTS data and UK(E&W)-BTS-Q3 by substrata, which also indicate increases in biomass limited to the eastern Irish Sea.

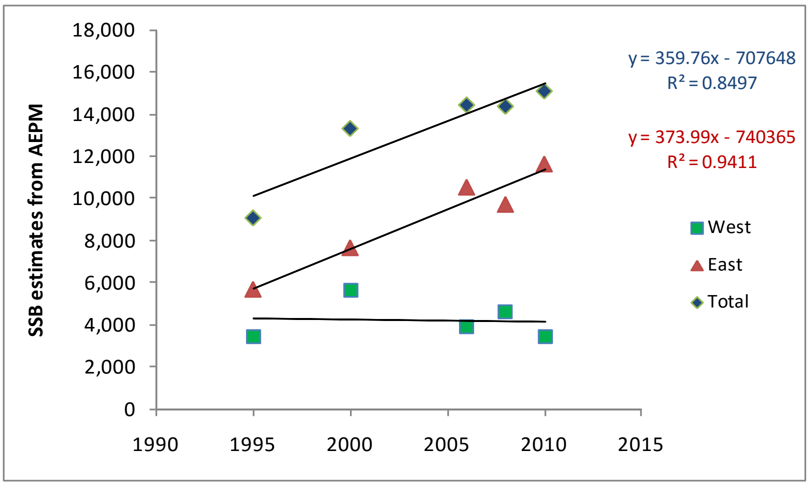
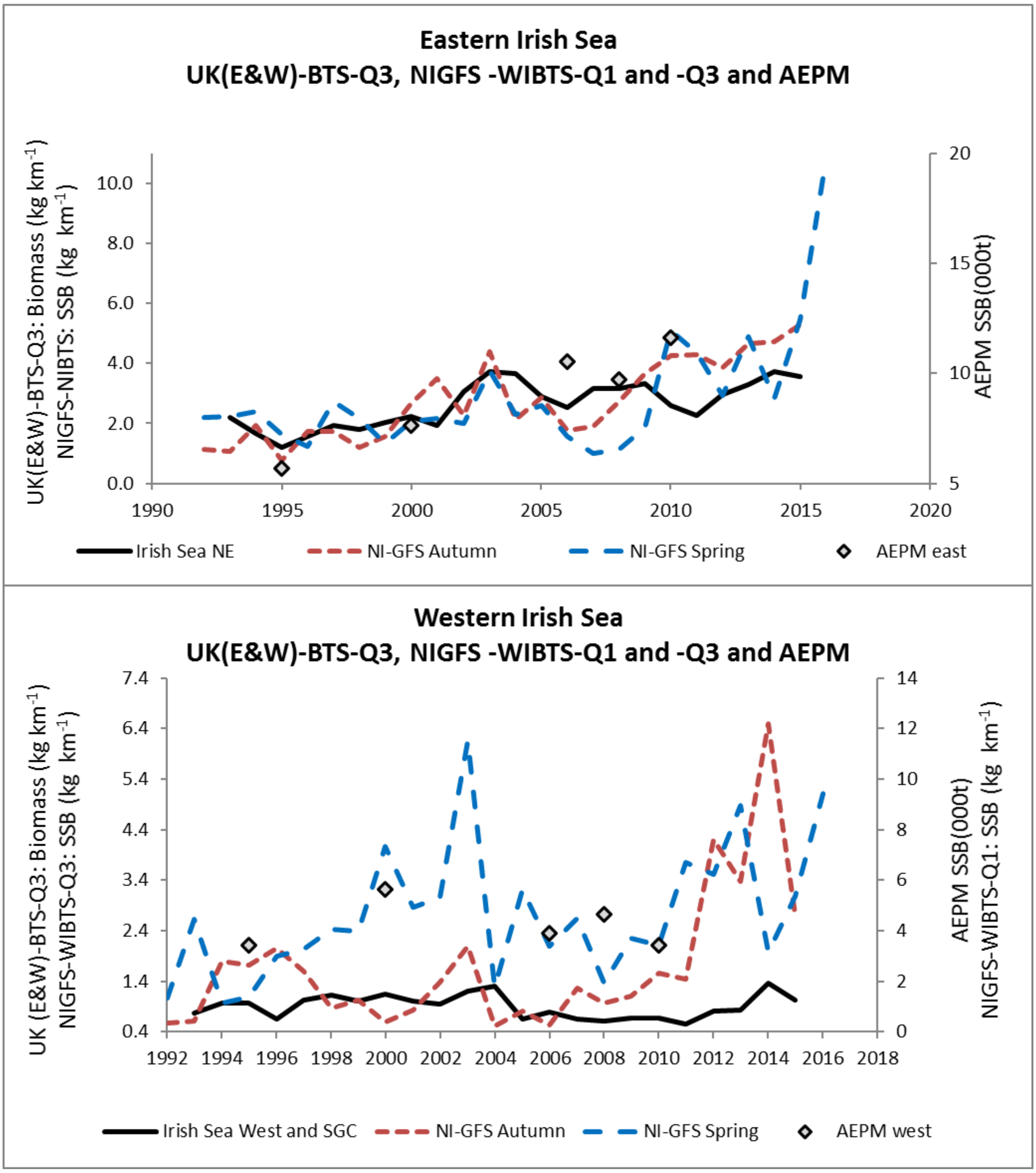


Figure 8.12. AEPM estimates by year and substrata.



8.8.4 Other fisheries-independent indices

An Irish juvenile plaice survey index was presented to the WG in 2002 (1976–2001, ages 2–8). Between 1976 and 1990 this survey had used an average ALK for that period. Serious concerns were expressed regarding the quality of the data for this period and the series was truncated to 1991. The stations for this survey are located along the coast of southeast Ireland between Dundalk Bay and Carnsore Point and there was some concern that this localised survey series would not be representative of the plaice population over the whole of the Irish Sea. Numerous tests were conducted at the 2002 WG to determine the validity of this and other tuning indices and it was concluded that this survey could be used as an index of the plaice population over the whole of the Irish Sea. This survey is no longer used in the assessment.

8.8.5 Commercial lpue indices

Prior to 1981 tuning data were not used in the assessment of this stock. A separable assessment method was used and estimates of terminal S and F were derived iteratively based on an understanding of the recent dynamics of the fishery.

In 1981 the choice of terminal F was determined from a regression of exploited stock biomass on cpue. Catch and effort series were available for the UK(E&W) trawl fleet and the Belgian beam trawl fleet for the period 1964 to 1980. In 1994 the Belgian and UK cpue series were combined to provide one mean standardised international index. The UK(E&W) trawl series was revised in 1986 (details not recorded) and in 1987 was recalculated as an age-based cpue index enabling the use of the hybrid method of tuning an *ad hoc* VPA.

The UK(E&W) trawl tuning series was revised in 1999 and separate otter trawl and beam trawl tuning series were produced using length samples from each gear type and an all gears ALK. Since the data could only be separated for 1988 onwards the two new tuning series were slightly reduced in length. In 1996 UK(E&W) commercial effort data were re-scaled to thousands of hours so as to avoid numerical problems associated with low cpue values and in 2000 the UK(E&W) otter trawl series was recalculated using otter trawl age compositions only rather than combined fleet age compositions as previously.

Two revised survey indices for the Lough Beltra were presented to the WG in 1996 though they were considered too noisy for inclusion in the assessment. They were revised again for the following year and found to be much improved but were again not included because they ended in 1996 and the WG felt that they would add little to the assessment. An Irish otter trawl tuning index was made available in 2001 (1995–2000, age 0 to 15). While this fleet mainly targets *Nephrops*, vessels do on occasion move into areas where plaice are abundant. Landings of plaice by this fleet were approximately 15% of total international landings in 2000 and the WG considered that this fleet could provide a useful index of abundance for plaice.

The effects of vessel characteristics on lpue for UK(E&W) commercial tuning series was investigated in 2001 to investigate the requirement for fishing power corrections due to MAGP IV re-measurement requirements. It was found that vessel characteristics had less effect on lpue than geographic factors and unexplained noise and concluded that corrections were not necessary. However, vessels of certain size tended to fish in certain rectangles. This confounding may have resulted in the underestimation of vessel effects.

At WKFLAT 2011, age-based tuning data available for this assessment comprise three commercial fleets; the UK(E&W) otter trawl fleet (UK(E&W)OTB, from 1987), the UK(E&W) beam trawl fleet (UK(E&W)BT, from 1987) and the Irish otter trawl fleet (IR-OTB, from 1995). However, as a consequence of inconsistencies in these commercial tuning fleets and surveys in the Irish Sea no commercial tuning information is used in the assessment. The area and HP-correction employed to calculate the UK(E&W) commercial effort indices require re-evaluation since vessels have changed greatly since the relationship was modelled. In recent years, the proportion of the fleet recording effort data has dropped to zero for the UK fleets, and so these data sources are no longer considered useful.

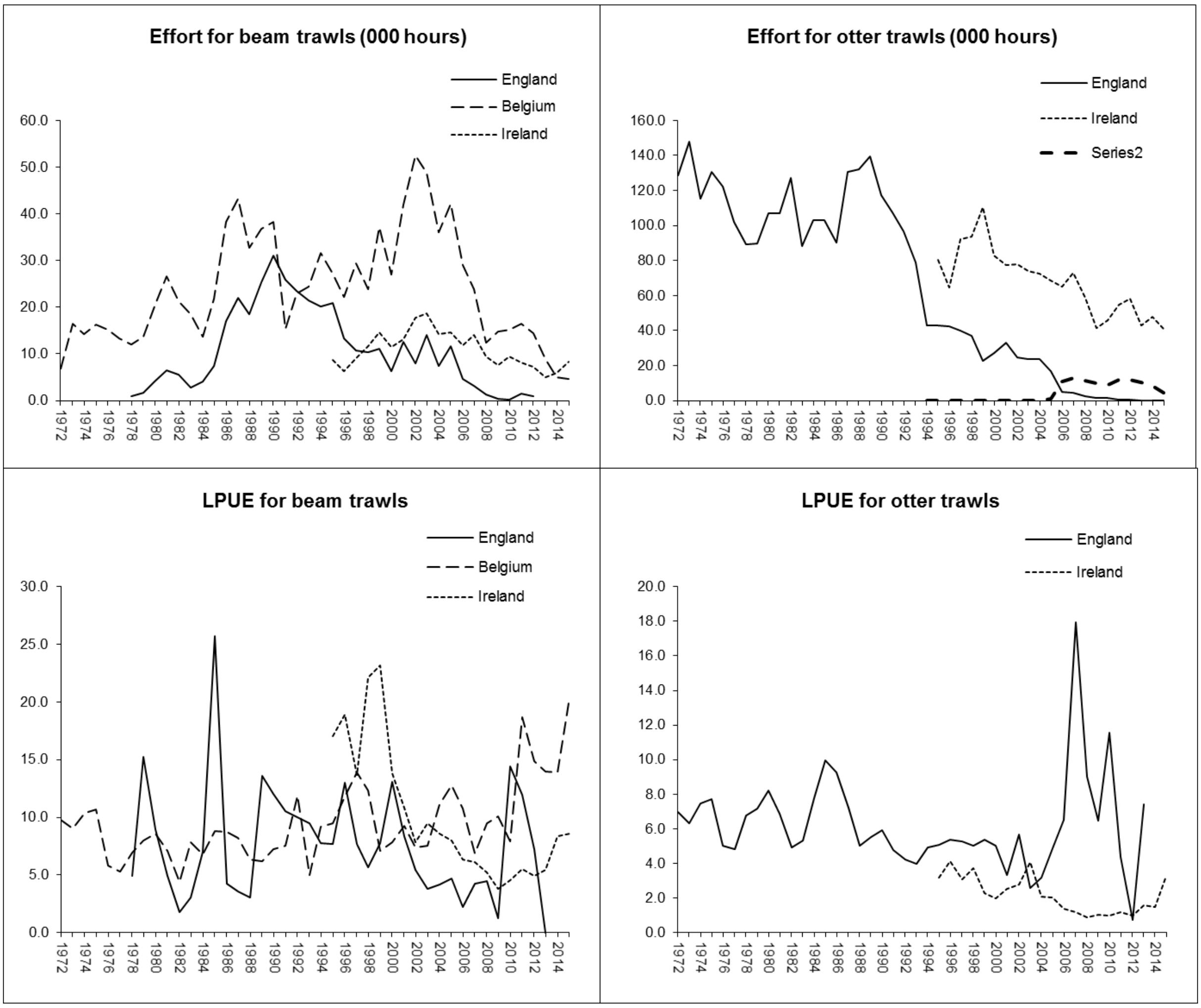


Figure 8.13. Plaice in 7.a effort and landings per unit effort for commercial fleets.

8.9 Long-term changes in environmental drivers

No known information.

8.10 Progress on recommendations from WKFLAT 2011

Recommendation	Progress
WKFLAT recommends that future assessments are carried out following the methodology proposed during this meeting and described in the Stock Annex.	WKIrish3 will make new recommendations about future assessments
WKFLAT recommended that the AP model should be tested against a stock for which there was a time-series of discarding available.	No known progress, may become irrelevant to this stock after WKIrish3
Biological reference points will need to be reinvestigated once an assessment has been agreed for this stock from which terminal estimates of population abundance and exploitation rate are considered sufficiently well estimated. This cannot be achieved at present.	Reference points for this stock will be considered at WKIrish3
Estimates of variability of the UK(E&W) discard estimates should be determined through a bootstrapping approach. Estimates of variability of the Belgian discard estimates are provided by the COST package but require further analysis. The discard estimates from N. Ireland require evaluation and alternative raising procedures for the Republic of Ireland data should be investigated.	Estimates of variability of UK(E&W) discard estimates have been calculated to lie in the range 35–55%. Discards sampling from Ireland and N. Ireland have improved, and a summary of the sampling programme is included in this work.
Discard weights-at-age should be reinvestigated in order to incorporate data more representative of all fleets active in the fishery.	Discards sampling has been improved
Procedures for including limited discard information into stock weights-at-age should be evaluated.	
Temporal and spatial patterns in the maturity ogive and length–weight relationships should be fully addressed and any differences identified should be incorporated into the raising of the length frequencies from the NI-GFS, which currently assumed time and spatial invariance in these components.	
The procedure for updating the UK-BTS to include the extended area should be further evaluated and the proportions of available habitat in the various sectors should be determined to more accurately combine data from the sectors.	
The spatial structure in the discarding if plaice in the Irish Sea should be further investigated using data from all relevant nations.	
A sex-separated assessment methodology for this stock, which can incorporate the complex spatial issues regarding this stock, would merit further study.	

9 References

van Beek, F.A., van Leeuwen, P.I., Rijnsdorp, A.D. 1990. On the survival of plaice and sole discards in the otter-trawl and beam trawl fisheries in the North Sea. Neth. J. Sea Res. 26, 151–160.

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Kaiser, M.J., Spencer, B.E. 1995. Survival of by-catch from a beam trawl. Mar. Ecol. Prog. Ser. 126, 31–38.

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ICES. 2015. Report of the Working Group for the Celtic Seas Ecoregion (WGCSE), 12–21 May 2015, Copenhagen, Denmark. ICES CM 2015/ACOM:12. 1432 pp.

10 Data evaluation for Irish Sea herring

This section is not available.

11 Stakeholder views

The meeting was attended by Jenni Grossman (Client Earth); Alan McCulla (ANIFPO); Hugo Boyle (Irish South & East Fish Producers' Org) and John Ward (IFPO – Dublin), and they are thanked for their input to the meeting.

The industry stakeholders confirmed the increasing use of multiple-rig *Nephrops* trawls such as low-headline quad rigs. Together with selectivity devices these appear to have low discard rates. Northern and Southern Irish vessels are using different selectivity devices; most NI vessels use 300 mm mesh panels whereas separator panels have been more common in the southern Irish fleet.

The explosion in abundance of haddock was noted.

Alan McCulla expressed a strong view that the construction of windfarms has an impact on fish species such as plaice and sole spawning in the areas of the eastern Irish Sea where windfarms are located, and that this should be considered in future integrated ecosystem assessments.

12 References

ICES. 2015a. Report of the Benchmark Workshop on sharing information on the Irish Sea ecosystem, stock assessments and fisheries issues, and scoping needs for assessment and management advice (WKIrish1). 14–15 September 2015, Dublin, Ireland. ICES CM 2015/BSG:01.

ICES. 2015b. Report of the Planning Group on Data Needs for Assessments and Advice (PGDATA). ICES CM 2015/SSGIEOM:06.

See references in separate sections as well.

Annex 1: List of participants

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Annex 2: Agenda

Date	Time	Stock	Topic	General outputs expected, & additional notes	Person presenting / responsible
26 Sept	09:00		Overview of work for meeting and what has been completed		
	09:30	all	ToR 3 – management regulation history for fisheries and fleets	Agreed information common to all or most of the stocks that is useful for how the assessment models are constructed and interpreted.	
	10:00	Whiting	ToR 1	Stock area map; brief text; links & refs; evidence of mixing with neighbouring stock areas	
	10:15		ToR 2	Agreed M and documentation of source of information; what is known about predators? age accuracy (ICES exchanges, etc.); other bio inputs: maturity ogives, stock weights, etc. and changes over time; sources of data, quality.	
	10:45		ToR 3 stock specific	List of relevant species-specific measures	
	11:10		ToR 4	Agreed landings and discards series; how misreporting has been calculated; discards survey design and achievement, quality indicators. Expect large focus on discards.	
	11:40		ToR 5	Agreed time-series of fishery age compositions; data sources / design & sampling achievement; quality indicators; consider needs for fleet disaggregated models	
	12:10		ToR 6	If needed for potential assessment models: known or expected selectivity-at-length/age by gear and expected changes over time due to gear changes, etc.	
	12:25		ToR 7	Not likely to be relevant to whiting	

Date	Time	Stock	Topic	General outputs expected, & additional notes	Person presenting / responsible
	12:30		Tor 8	Agreed survey inputs – abundance indices, compositions and quality indicators. Documentation of survey design (coverage; gears; data analysis including age compositions if appropriate; quality including outliers etc.) and documentation of reasons for excluding dataseries.	
	14:00		ToR 9	Any environmental signals relevant to assessment	
	14:10		ToR 10	Ongoing studies and future research needs	
	14:30		Data compilation / revision	Compile dataseries in Excel file; collate bits of text, figures, etc. for report.	
	17:30		End of day		
ToR details for other species as for whiting but at appropriate level of detail depending on previous recent benchmarks. See additional notes below					
27 Sept	09:00	Plaice	ToR 1		
	09:10		ToR 2	May need to consider east–west differences in growth, maturity, weights-at-age, etc. Is also sexual dimorphism in growth which will affect selectivity at age by sex.	
	09:30		ToR 3 stock specific		
	09:35		ToR 4	Expect large focus on discards	
	10:00		ToR 5	Consider needs for possible fleet disaggregated models (TR1 & TR2; BT?)	
	10:30		ToR 6	Consider potential effects of changes in fleets and needs of possible fleet disaggregated models	
	10:40		ToR 7	See recent Cefas studies re. Landings obligation	
	10:50		Tor 8	Cefas BTS age comps; NIGFS – consider need for length data for statistical models?	
	11:30		ToR 9		

Date	Time	Stock	Topic	General outputs expected, & additional notes	Person presenting / responsible
	11:40		ToR 10		
	12:00		Data compilation / revision		
	14:00	Haddock	ToR 1		
	14:10		ToR 2	Trends in weights-at-age and maturity……	
	14:25		ToR 3 stock specific		
	14:30		ToR 4	Accuracy of landings data; large focus on discards estimates	
	15:00		ToR 5	Consider potential needs for fleet disaggregated models (TR1 & TR2)	
	15:30		ToR 6	Consider potential effects of changes in fleets and needs of possible fleet disaggregated models	
	16:00		ToR 7	Any studies elsewhere?	
	16:10		Tor 8	NIGFS	
	16:40		ToR 9		
	16:50		ToR 10		
	17:00		Data compilation / revision		
	17:30		End of day		
28 Sept	09:00	Cod	ToR 1	Is total 7.a fishery catch history representing same stock coverage and mixing as GFS surveys?	
	09:20		ToR 2	Trends in weights-at-age and maturity……	
	09:40		ToR 3 stock specific		
	09:45		ToR 4	Accuracy of landings data; misreporting corrections; discards estimates; highgrading	

Date	Time	Stock	Topic	General outputs expected, & additional notes	Person presenting / responsible
	10:15		ToR 5	Consider potential needs for fleet disaggregated models (TR1 & TR2)	
	11:00		ToR 6	Consider potential effects of changes in fleets and needs of possible fleet disaggregated models	
	11:30		ToR 7	Any studies elsewhere?	
	11:40		Tor 8	NIGFS Q1 – high male component due to spawning behaviour – check that is not changing over time biasing trend?	
	12:10		ToR 9	Temperature effects on recruitment (cold winter/spring)?	
	12:20		ToR 10		
	12:30		Data compilation / revision		
Herring – probably least data evaluation – refer to previous benchmark, stock annex, for each ToR unless new data; update existing dataseries.					
	14:00	Herring	ToR 1		
	14:10		ToR 2		
	14:25		ToR 3 stock specific		
	14:30		ToR 4		
	15:00		ToR 5		
	15:30		ToR 6		
	15:35		ToR 7		
	15:40		Tor 8	Focus on new commercial survey series. Is larva survey still useful as SSB index?	
	16:00		ToR 9		
	16:05		ToR 10		
	16:15		Data compilation / revision		

Date	Time	Stock	Topic	General outputs expected, & additional notes	Person presenting / responsible
	17:30		End of day		
29 Sept.	09:00	All	ToR 11: check through tables in plenary and agree		
	10:00	All	ToR 12: draft text for report		
	17:30	All	Close of meeting		