Stock Annex: Saithe (*Pollachius virens*) in subareas 4-5 and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)

Stock specific documentation of standard assessment procedures used by ICES.

Stock: Saithe

Working Group: Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)

Created:

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A. General

A.1. Stock definition

The saithe stock is defined to be a single stock in ICES Subarea 4 (North Sea), 6 (west of Scotland and Rockall), and Subdivision 3.a.20 (the northern section of 3.a; Skagerrak). Within this area, there is some evidence that Rockall may be a genetically distinct subpopulation (Saha et al. 2015). Catches from Rockall are low, which may mean there is limited risk in ignoring subpopulation structure within the stock management area.

The 2016 benchmark meeting (ICES-WKNSEA 2016) briefly explored the question of saithe stock structure. Genetic and tagging studies provided some evidence that the geographical range for North Sea saithe extends north of 62° N (the northern management boundary) and may actually lie as far north as 65° N. Surveys of O-group gadoids conducted by Norway showed a clear mixing of stocks across management boundaries for the North Sea and North-east Arctic stock units. While there appears to be evidence that the North Sea stock boundary might lie north of the current management boundary (62° N), no trials using alternate stock definitions were attempted. This was noted as being worth exploration and should be revisited in the future.

A.3. Fishery

Saithe in subareas 4, 6, and Subdivision 3.a.20 (referred to as *North Sea saithe* for brevity) are mainly taken in a directed trawl fishery in deeper water along the Northern Shelf edge and the Norwegian Trench. Norwegian, French, and German trawlers take the majority of the quota. A small proportion of the total catch was taken in a limited purse seine fishery along the west coast of Norway targeting juveniles (ages 2–4); catches from this fishery had become negligible by 2012.

The main fishery developed in the beginning of the 1970s. Historically, the fisheries in the first quarter of the year are directed towards mature fish in spawning aggregations, while concentrations of immature fish (age 3-4) often are targeted during the rest of the year. The fishery in Subarea 6 consists largely of a directed French, German, and Norwegian deep-water fishery operating on the shelf edge, and a Scottish fishery operating inshore.

There have been small changes in the exploitation pattern over time. The French fishery has typically fished along the northern shelf and west of Shetland (Figure 1). The French trawl fleet shifted southwards 2008–2011, but by 2012, returned to the northern saithe fishing ground (Figures 1 and 2). French industry representatives noted increased competition over fishing grounds between trawlers and gillnetters in Division 6, particularly in 2009 and 2010, which may explain the shift for those years. The German fleet also shifted its efforts 2008, where it concentrated almost all of its effort along the Norwegian Trench off southern Norway and also fished deep inside the Skagerrak, near Sweden (Figures 1 and 2). The EU cod management plan (1342/2008) was thought to have contributed to the southern shift for the German fleet. In 2012 and 2013, some effort was again directed in along the northern part of the shelf. Most of the catch and effort were again in the south in 2014 and 2015 (Figures 1 and 2). The Norwegian fleet has always fished along the entire shelf edge, from west of Shetland to the Skagerrak; however, in some years, more of the catch and effort was in the south (Figures 1, 2). In 2014, the EU-Norway negotiations were delayed; quota was not assigned until March and Norway was not allowed to fish in EU waters until the agreement was in place. Norway could, therefore, not take advantage of fishing on the spawning aggregations closer to Shetland; this is reflected slightly in the catch and effort figures for that year.

Changes in the dynamics in the fishery is partially reflected in changes in the catchability of age 3. In the 1980s in Subarea 4, the Norwegian trawler fleet used mesh sizes around 90 mm, while the German and French fleet used mainly 85-90 mm mesh. In 2002, minimum mesh size was increased to 110 mm, while Norway used 120 mm.

Since the fish are distributed inshore until they are about 3 years old, discarding of young fish is assumed to be a small problem in the offshore fishery, except in areas around Shetland. Discarding by Scottish vessels is high, but these fleets also do not have quota allocations. Low prices and mixed catches may lead to high grading. In trawler fleets that are targeting saithe, the quota is less limiting and the problem may be less in these fleets. In 2016, the trawler fleets will not be allowed to discard saithe. Some areas of the North Sea had large amounts of smaller saithe in the past and factory trawlers also used to operate west of Shetland, both of which could have contributed to high discard rates in the past.

Conservation schemes and technical conservation measures

Management of saithe is by TAC and technical measures. The available kw-days at sea for community vessels are restricted via the cod management plan (Council regulation 1342/2008). Only some vessels were exempted from these effort restrictions in 2009 due to low bycatch (<1.5%) of cod. In the Norwegian zone (south of 62°N) the current minimum landing size is 40 cm, while in the EU zone it is 35 cm. Discards are not allowed in the Norwegian zone. Minimum mesh size in the in the Norwegian zone is 120 mm for Norwegian trawlers and 110 mm for EU vessels.

Norwegian legislation requires the Norwegian trawlers to move out of the area when the boat quotas are reached and the fishery is closed if the seasonal quota is reached. Norwegian trawlers are regulated by a total discard ban and restrictions on bycatch allowances. The Skagerrak agreement, which previously regulated the fisheries in part of this area, has been terminated. Precautionary area closures where mixed fisheries are observed, off southern Norway and in northern Danish waters, have been problematic to enforce.

A.4. Ecosystem aspects

The distribution of juvenile (< age 3) and adult saithe differ; juveniles are found in inshore nursery grounds, while adults are oceanic and highly migratory. Juvenile saithe are mainly distributed along the coast and in the fjords of western and southern Norway, the coast of Shetland, and the coast of Scotland (Jakobsen 1976, Mente et al. 2008, Heino et al. 2012). Saithe migrate from nursery areas to the North Sea within the ages of 2-5; the mechanism driving the migration is unclear, but thought to be partially due to feeding. Because of the highly migratory behaviour, saithe provide a trophic link across several ecosystems.

When saithe exceed 60-70 cm in length, the diet changes from plankton (krill, copepods, fish larvae) to fish (mainly Norway pout, blue whiting, haddock, and herring). Large saithe (>70 cm) have a highly migratory behaviour and the feeding migrations extend from coastal areas into the Norwegian Sea, the Faroe Islands, and to Iceland. Although diet information suffers from poor spatial and temporal coverage, saithe is a top predator in the trophodynamics of the North Sea. Information on predation on other species is evaluated through the stochastic age-length structured multispecies model (SMS; Lewy and Vintner 2004) provided by ICES WGSAM.

A.4. Management considerations

Saithe has had growing importance for both the Danish and Scottish fleets. The fishers' survey (Napier, 2014) shows a perception of an increasing stock, especially in more northern areas. Reports from Norwegian fishers show concerns about increased landings from pelagic trawling and a possible change in exploitation pattern towards younger year classes. French and German industry representatives confirmed changes in fishing pattern for trawlers due to effort management and conflicts with gillnetters, especially in 2009 and 2010.

According to a RAC-meeting between scientist and fishers in Hanstholm in April 2012, the industry reported it is worried about conflicting data-sources and suggests that fishermen's knowledge should be used in the interpretation of the data.

B. Data

B.1. Commercial catch

Landings

Landings-at-age data by fleet are currently supplied by Denmark, Germany, France, Norway, and UK-Scotland. The amount of catch sampling is an issue for saithe. An attempt was made at the benchmark to collate how samples are done by each of the countries; however, because the request was made after the data call, countries were not obliged to answer. Information that was received can be found in WD 6 (National sampling; ICES-WKNSEA 2016).

Discards

Discards-at-age data are currently supplied by Denmark, France, Germany, and UK-Scotland. Norwegian discards (sampling and amounts) are an issue for further exploration, as raised at the benchmark (2016) and subsequent external review. The amount of information is sparse, but it was acknowledged that because Norway takes approximately 50% of the quota, information must be supplied. For the Norwegian industrial fleet, discards of saithe are only specified when saithe is delivered separately, and therefore bycatch of saithe that has not been separated from the bulk catch are not reported as saithe. The number of Norwegian trawlers that have been granted this exception was increased in 2016/2017.

Discards have been raised for the Norwegian fleets. For the OTB_DEF métier, Norwegian discards were raised using data from the French and German trawler métier (discarding rates were very low). Other métiers were raised using data from all other métiers (all countries) combined. Only in years with very poor coverage were there possible issues with estimates being high; otherwise, Norwegian discards ranged from 1-2% of the landings for all years except 2012 (a poor sampling year), when they were 5% of the landings.

Compilation of international catch at age

International catch data (landings, discards) have been compiled in InterCatch from 2002. Data 2002-2014 were updated (or added for the first time) as a result of the 2016 WKNSEA benchmark data call. The revision/first time addition of catch and the allocation of age samples in InterCatch resulted in large changes to the age distribution of the catch (see WD-5 in ICES-WKNSEA 2016). Some of the discrepancy was because age 10 was not included as a plus group prior to 2010; however, this could not explain all the changes. There is no documentation of how ages were allocated to the catch prior to the use of InterCatch.

Currently, age samples for the landings (and discards, if enough information exists) are allocated using a stratification by area and quarter. Subareas 4 and 6 are combined due to the paucity of age samples in Subarea 6. Division 3.a is kept separate because different mesh size regulations exist for some fisheries in the Skagerrak; in addition, smaller/younger fish are found in the Skagerrak compared to Subareas 4 and 6. Stratification is by quarter because quarters 1 and 2 are typically directed on spawning aggregations (i.e., larger/older fish).

For those years where age samples for the discards are limited, no stratification has been used. A constant ratio landings/discards by age was applied to obtain discard weights and landings prior to 2002. Discard weights for age 8+ were set to 1. Average landings (2002-2014) to average discards (2002-2014) ratios for discard weight- and number-at-age were:

	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10+
Weight	1.32	1.27	1.16	1.07	1.05	1	1	1
Number	1.72	3.46	10.77	33.56	58.24	26.19	28.10	30.35

Details are in ICES-WKNSEA (2016; WD 5).

B.2. Biological

Weight at age

Weights at age in the landings are measured weights from the various national observer programs, reference fleet, and market sampling programs. These weights are also used as stock weights. There has been a decreasing trend in mean weights from the mid-1990s for ages 4 and older, but the decline now seems to be largely halted and has reversed.

Weights-at-age from the NS-IBTS and SWC-IBTS surveys were explored for use in the assessment during the benchmark (ICES-WKNSEA 2016). They are not currently used in the assessment because of concerns over limited coverage of some of the surveys.

Natural mortality

A natural mortality rate of 0.2 is used for all ages and years. An alternate mortality rate, based on longevity (Then et al. 2014), was investigated during the benchmark, but the expert group, due to lack of time, decided to not explore alternate methods of estimating M. Exploration of alternate natural mortality rates was noted as needing exploration before the next benchmark.

Maturity

Following maturity ogive is used for all years:

	1	2	3	4	5	6	7	8	9+
Proportion mature	0.0	0.0	0.0	0.20	0.65	0.84	0.97	1.00	1.00

	1	2	3	4	5	6	7	8	9+
Proportion mature	0.0	0.0	0.0	0.20	0.65	0.84	0.97	1.00	1.00

The maturity at age ogive was modelled during WKNSEA 2016, where age and cohort were treated as factors with maturity state (immature or mature) as a proportion, weighted by the number-at-ALK. After much discussion, it was agreed that the ogive including cohort showed too much variability that was unlikely over such a short time period, even after smoothing was applied. The newly estimated static ogive was used, with some modification based on expert knowledge within the group. This modification was because the proportions mature at age estimated from the survey data showed large fluctuations between years for ages 3 and 4, which was assumed to be due to variability in the amount of fish that migrate into the survey area. Proportions of age 3 and 4 year old fish that migrate from coastal areas to the North Sea varies annually and it is generally assumed that larger (and thus faster maturing) fish migrate out earlier. The proportion of 3/4 year olds can be low, such that using observed proportions mature without correcting for the large amount of immature fish outside the survey area will introduce a bias in the ogive. The discussion at this benchmark meeting concluded that using a slightly conservative approach was best. Proportions mature at age 3 were set to zero and proportions at age 4 to half of the estimated average proportion mature. A yearly update of the maturity ogives may give a more accurate assessment of SSB; the implications for realised spawning potential are not known.

B.3. Surveys

Only the IBTS Q3 survey is currently used in the assessment for ages 3-8, 1992 to the present year. The IBTS Q1 survey is not used because it covers only the fringe of the stock at this time of year. In addition, a large amount of movement in and out of the survey area unrelated to abundance creates too much uncertainty in the index.

The DATRAS standard index is used in the assessment. The delta-GAM method of Berg et al. (2014) was explored, but deemed inappropriate for saithe because one standard ALK is used between all years for a species that is displaying large year effects (the ALK is inappropriate). The year effects within the DATRAS standard Q3 index are partially dealt with by including the correlation between ages within years in the assessment model (Berg and Nielsen 2016).

B.4. Commercial CPUE

One "standardized" commercial tuning series is available for the period 2000-present. The index combines catch and effort information for the French, German, and Norwegian target bottom trawlers.

A single combined index was estimated to avoid using the same information twice (information in the catch-at-age matrix and in the three individual cpue fleets) in the assessment. There were concerns that using the information twice gave too much weight in the tuning.

The combined index uses information from the commercial logbooks on single trawl operations. Only trawl operations catching at least 50% saithe are include in the target fishery, thereby removing catches with accidental levels of bycatch. In periods where saithe spread to areas not fished heavily, there is a chance of losing information. All horsepower groups were included. To be included, the number of observations in a rectangle and quarter combination had to be above ten.

The model includes spatial and temporal resolution, and groups vessels by engine power intervals (to avoid the potential to identify single vessels). While variables initially explored in the model were nation, year, month, engine power group, mesh size, special coordinates (center of ICES rectangle), effort, landing, quarter, and area, based on roundfish areas), the final model included only nation, year, quarter, kW group, and area. The year effects from this "standardization" are included in the assessment model, which is then tuned to the exploitable (fishable) biomass within the assessment model. Information from the catch-at-age matrix is not used.

There is concern that a trend in the use of engine power may explain a trend in abundance over the same time period; the time series of the data is too short to be certain this is not the case. Changes in mesh size preference may have the same effects.

B.5. Other relevant data

The North Sea Fishers' Survey presents fishers' perceptions of the state of several species including whiting. The survey covers the years 2003 to the present.

C. Assessment: data and methods

A state-space assessment model (SAM, Nielsen 2010, Nielsen and Berg 2014) was used. SAM allows for objective estimation of important variance parameters, leaving out the need for subjective ad-hoc adjustment numbers, allows error in input data and provides estimates of uncertainty in summary statistics. WKNSEA 2016 (ICES-WKNSEA 2016) explored various configurations to determine the most appropriate settings. The model includes the correlation between ages within years in the survey data in the assessment model, following the method of Berg and Nielsen (2016).

Final model configuration

Min Age: 3

Max Age: 10

Max Age considered a plus group (Yes)

The following matrix describes the coupling of fishing mortality STATES, where rows represent fleets and columns represent ages:

1	2	3	4	5	6	7	7
0	0	0	0	0	0	0	0

Use correlated random walks for the fishing mortalities: AR1

Coupling of catchability PARAMETERS

0	0	0	0	0	0	0	0
1	2	3	4	5	6	0	0

Coupling of power law model EXPONENTS (if used)

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Coupling of fishing mortality RW VARIANCES

1	2	2	2	2	2	2	2
0	0	0	0	0	0	0	0

Coupling of log N RW VARIANCES

1	2	2	2	2	2	2	2

Coupling of OBSERVATION VARIANCES

1	1	1	1	1	1	1	1
2	2	2	2	2	2	0	0

Stock recruitment model code (random walk)

Years in which catch data are to be scaled by an estimated parameter

0

Fbar range: 4 to 7

Observation correlation coupling (0 = uncorrelated). Rows represent fleets, columns represent adjacent age groups, i.e. the first column is the correlation between the first and 2nd age group. An NA in all non-empty age groups for a fleet specifies unstructured correlation. NA's and positive numbers cannot be mixed within fleets.

0	0	0	0	0	0	0
NA	NA	NA	NA	NA	0	0

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1967-present	3-10+	Yes
Canum	Catch at age in numbers	1967-present	3-10+	Yes
Discards	Discards in tonnes	1967-present	3-10+	Yes
Landing fraction	Percent landed	1967-present	3-10+	Yes – from 2002; constant by age 1967-2002
Weca	Weight at age in the commercial catch	1967-present	3-10+	Yes

Stock weights	Weight at age in the commercial catch	1967-present	3-10+	Yes
Mprop	Proportion of natural mortality before spawning	0		No
Fprop	Proportion of fishing mortality before spawning	0		No
Matprop	Proportion mature at age	1967-present, See section B2 - maturity		No
Natmor	Natural mortality	1967-present, See section B2 – Natural mortality		No

Tuning data:

Type	Name	Year range	Age range
cpue index	cpue; combined cpue, tuned to the exploitable biomass	2000-present	NA
Survey index	IBTS-Q3; International bottom trawl survey in the North Sea, 3th quarter	1992-present	3-8

D. Short-term Projection

The short term projection is run in SAM in the form of short-term stochastic projections. These projections are carried out using estimates and the covariance matrix of those estimates from the final year. A total of 1000 samples are generated from the estimated distribution of the final year's estimates. These 1000 replicates are then simulated forward according to model and forecast assumptions and subject to different scenarios. Intermediate year assumptions are the TAC constraint (landings, without adjustment, but this may change as the total discard ban is phased in). The basis (assumptions) for the forecast is in the table below, where *Yi* is the intermediate year.

Variable	Notes
F ages 4–7 (Yi)	TAC constraint *
SSB (Yi)	SSB in the intermediate year
SSB (Yi+1)	SSB at the beginning of the TAC year
Rage3 (Yi)	Median recruitment re-sampled from 2003-present
Rage3 (Yi+1)	Median recruitment re-sampled from 2003-present
Total catch (Yi)	Assuming landings fraction by age in assessment year
Commercial landings (Yi)	TAC in year assessment year
Discards (Yi)	Assuming discard fraction by age in assessment year

* TAC without adjustment

E. Medium-Term Projections

No medium-term projections are done for this stock.

F. Long-Term Projections

No long- term projections are done for this stock.

G. Biological Reference Points

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY Btrigger	150000 t	Bpa	ICES (2016a)
	FMSY	0.36	Stochastic simulation using hockey-stick stock–recruitment.	ICES (2016a)
Precautionary approach	Blim	107000 t	Bloss	ICES (2016a)
	Bpa	150000 t	Bpa =1.4 * Blim * exp(1.645 σB); σB = 0.20	ICES (2016a)
	Flim	0.56	Flim gives the 50% probability to fall below Blim in the stochastic EqSim simulations	ICES (2016a)
	Fpa	0.40	Fpa = Flim * exp(-1.645 σF); σF = 0.20	ICES (2016a)
EU–Norway management strategy	SSB trigger	200000 t	Old Bpa	ICES (2016a)
	FMGT	0.3	Ages 3-6	

Reference points were estimated after WKNSEA 2016 and refer to an F_{bar} for ages 4 to 7. ICES was requested to update other reference points in light of the change from F_{MSY} as a single reference point to F_{MSY} as a range, where the range is derived to deliver no more than a 5% reduction in long-term yield compared with MSY. Two estimates of $F_{MSY\ upper}$ were given, where one conforms to the ICES MSY advice rule (AR; with $B_{trigger}$) and the other uses a constant F without an advice rule (for details, see ICES 2015).

Reference point	Value
FMSY without Btrigger	0.36
FMSY lower without Btrigger	0.21
FMSY upper without Btrigger	0.498
New FP.05 (5% risk to Blim without Btrigger)	0.419
FMSY upper precautionary without Btrigger	0.403
FP.05 (5% risk to Blim with Btrigger)	0.492
FMSY with Btrigger	0.395
FMSY lower with Btrigger	0.213
FMSY upper with Btrigger	0.647
FMSY upper precautionary with Btrigger	0.403
MSY (without HCR)	89 305
Median SSB at FMSY (without HCR)	206 513
Median SSB lower precautionary (median at FMSY upper precautionary; without HCR)	179 497
Median SSB upper (median at FMSY lower; without HCR)	368 806

H. References

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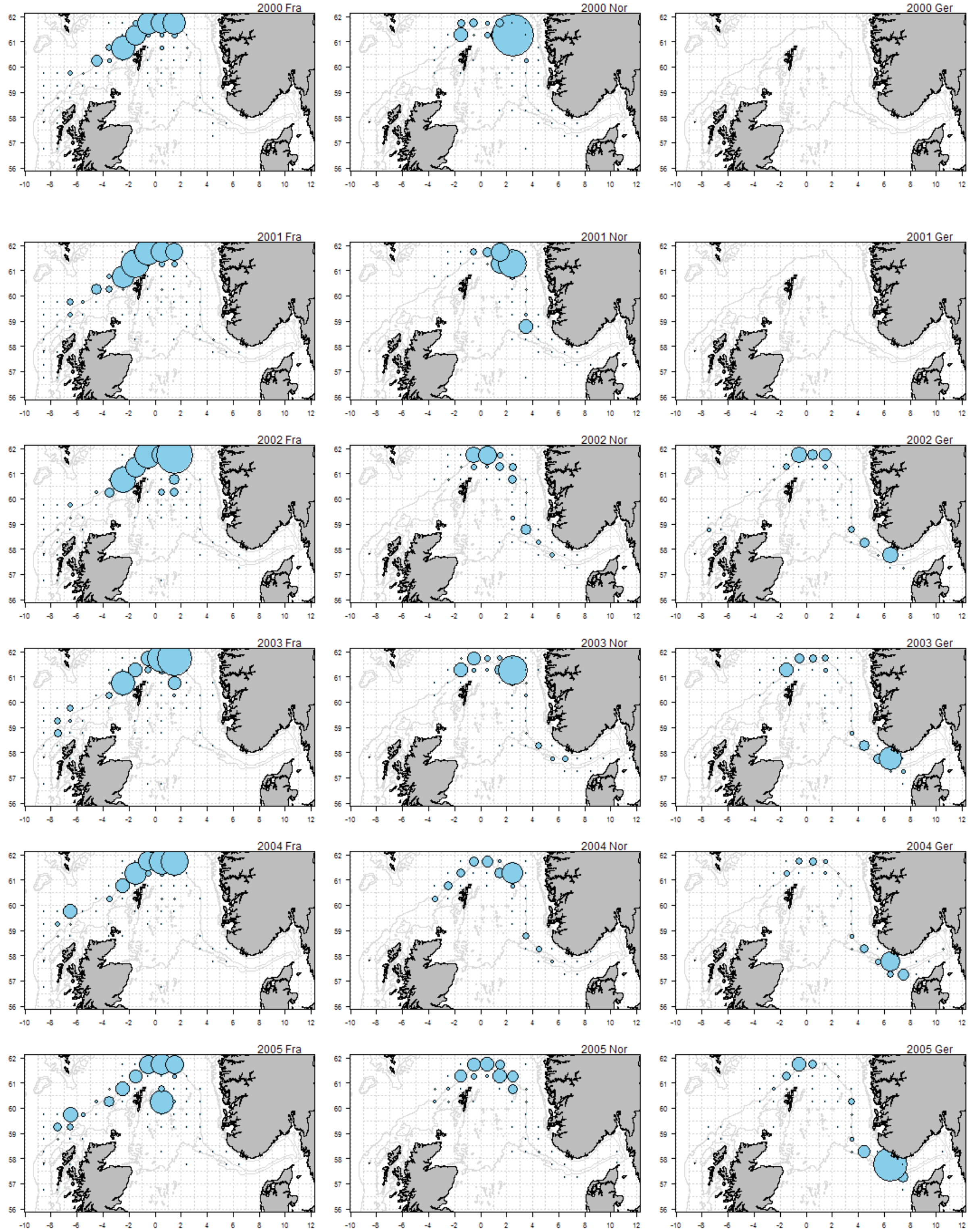

Figure 1. Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of landings for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015. Germany did not provide catch data for 2000 and 2001. Catch for each nation in each year has been scaled by dividing by mean catch for that nation in that year.

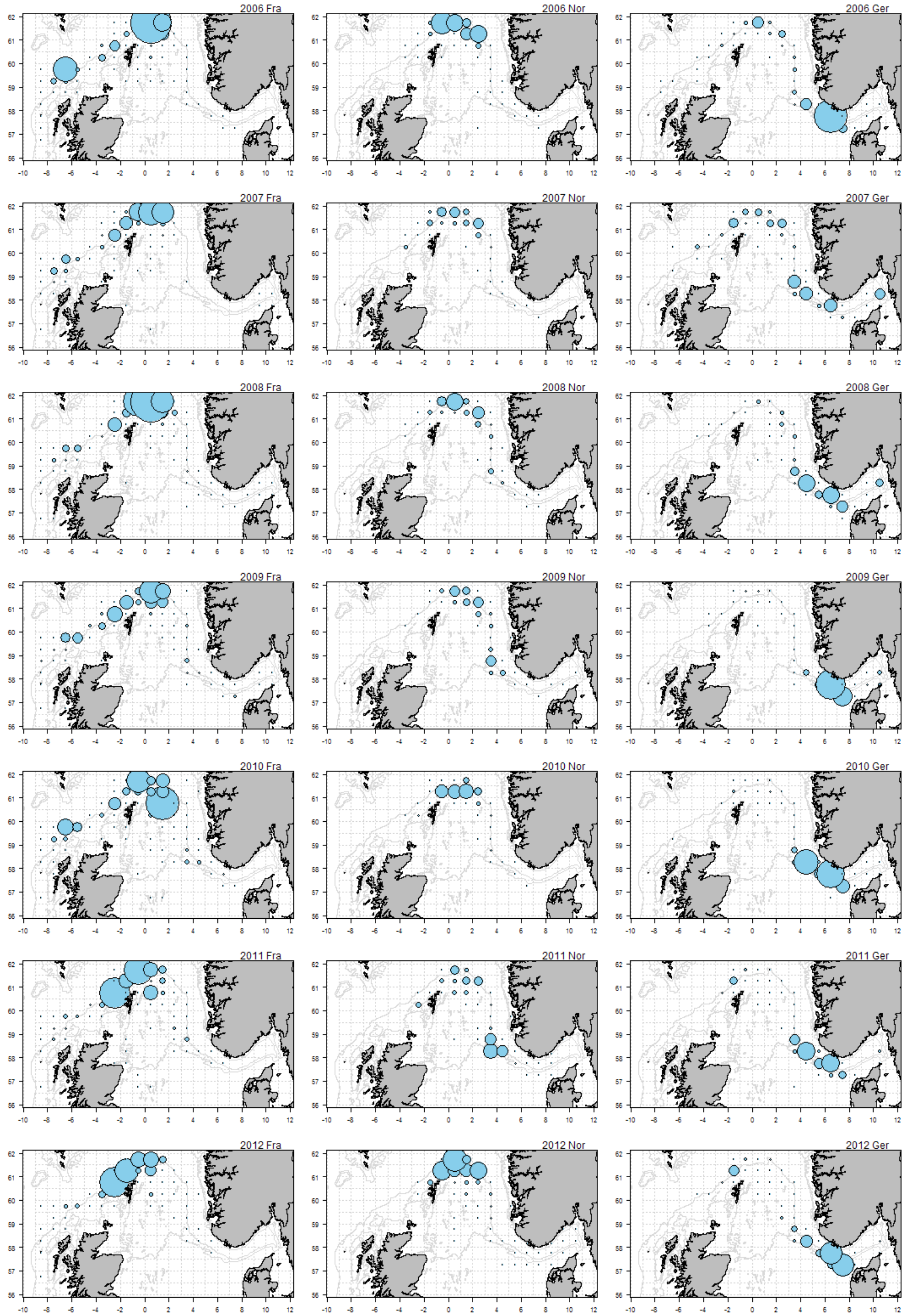

Figure 1. (cont). Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of landings for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015.

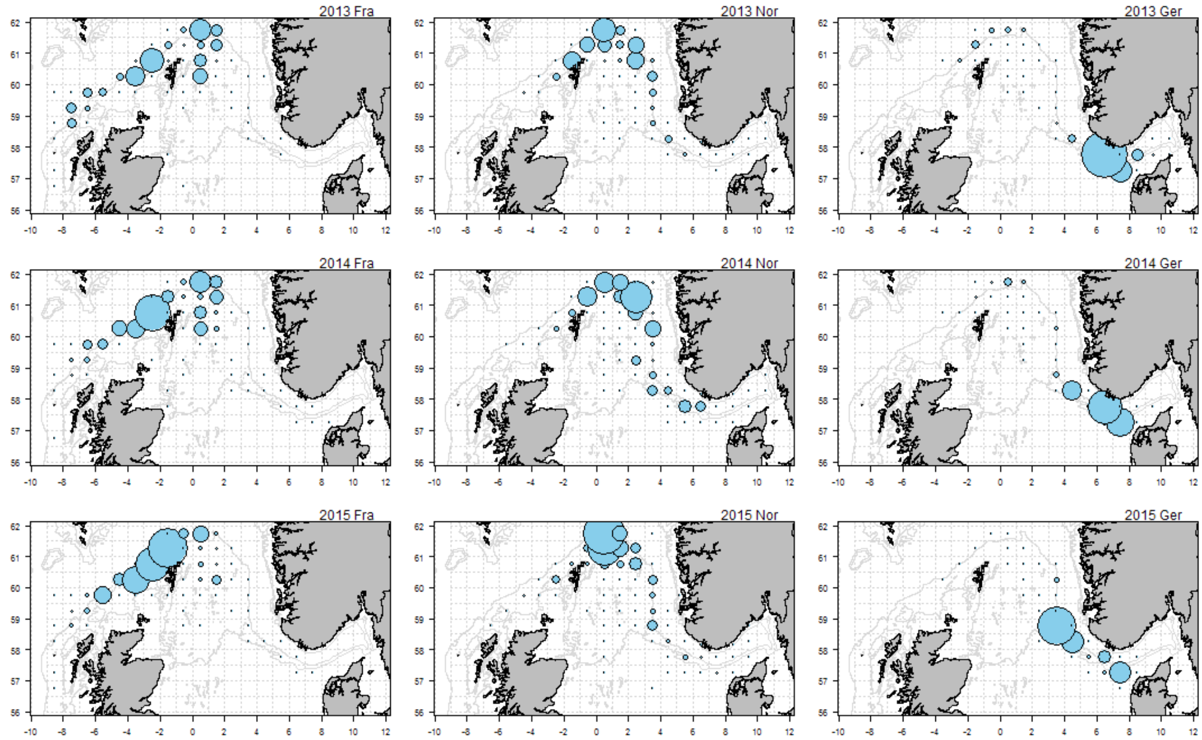

Figure 1. (cont). Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of landings for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015.

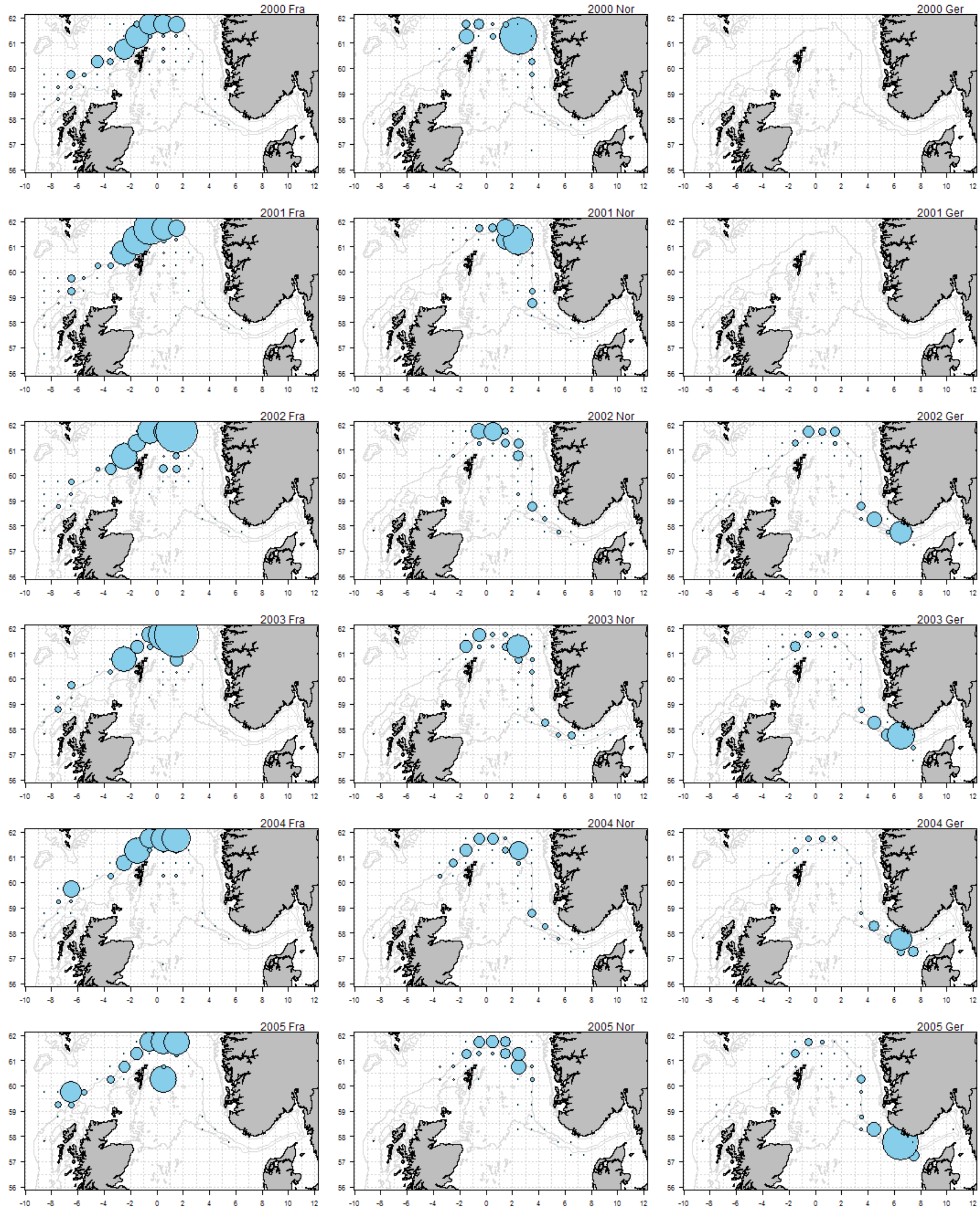

Figure 2. Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of effort for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015. Germany did not provide catch data for 2000 and 2001. Effort for each nation in each year has been scaled by dividing by mean effort for that nation in that year.

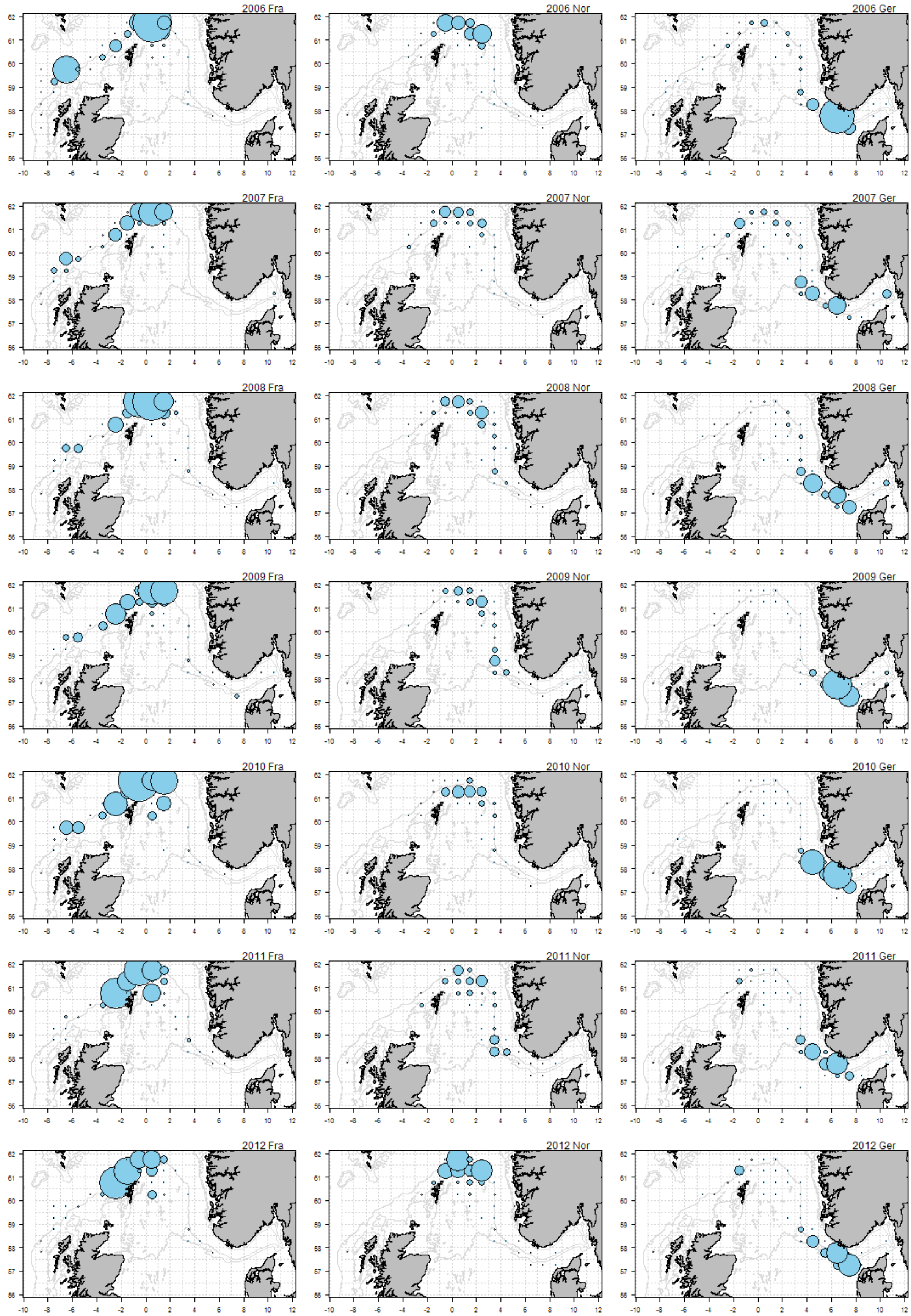

Figure 2. (cont). Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of effort for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015.

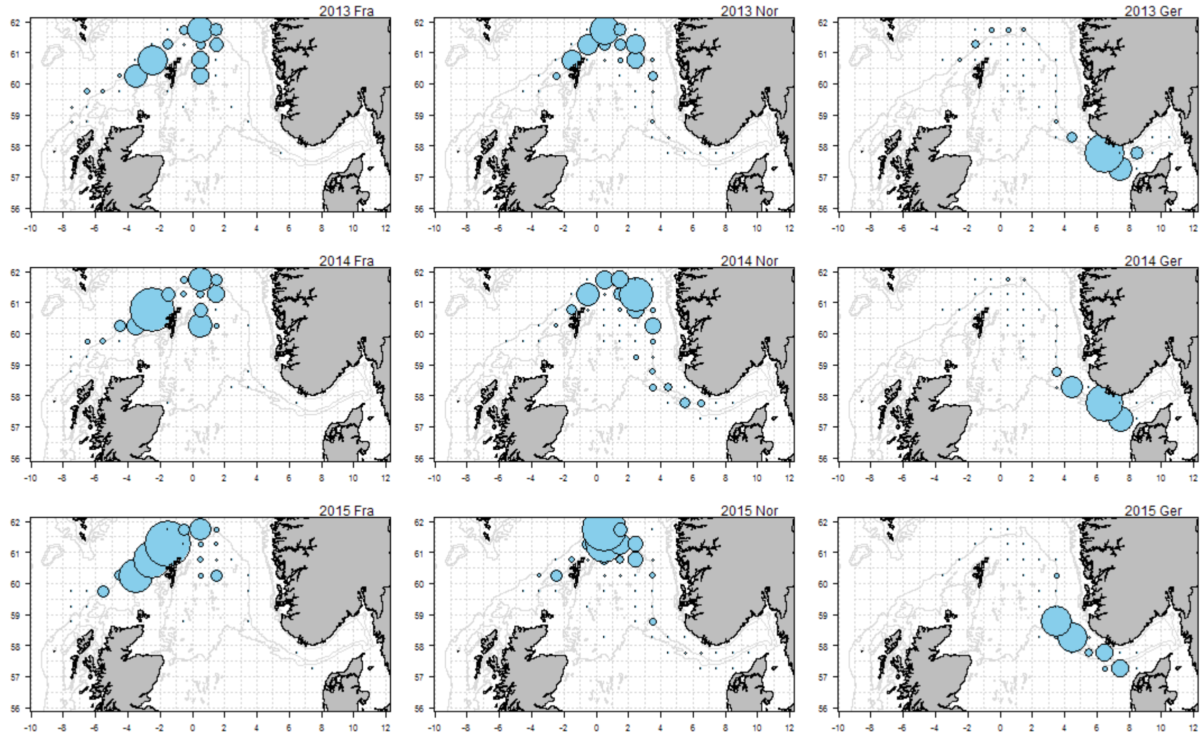

Figure 2. (cont). Saithe in Subareas 4 and 6 and Subdivision 3.a.20. Spatial distribution of effort for French (Fra), Norwegian (Nor), and German (Ger) trawler fleets, 2000–2015.