Report of the Coastal States Working Group on the distribution of Northeast Atlantic Mackerel

28th February 2022

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1 Introduction

At the Coastal States meeting (19-21st and 27th October 2021) the delegations (the European Union, the Faroe Islands, Greenland, Iceland, Norway, the United Kingdom, the Fishing Party, and the Russian Federation) agreed to establish a Working Group and its Terms of Reference to collect and collate information on the geographical distribution of the mackerel stock in the North-East Atlantic, based on internationally recognised data collection methods and on the distribution of catches from this stock.

A first meeting of the scientific working group was held on a Teams platform in November 2021. During that meeting an approach to deal with the terms of reference was agreed. Due to the short time period between the formation of the Working Group and the required submission date for the report it was also agreed to utilise the catch data (annual by month and rectangle) which is currently held by the ICES Working Group WIDE (WGWIDE).

A number of other 'in-person' and virtual meetings were held, with the last virtual meeting on the 28th February 2022. This report contains the results of these meetings.

1.1 Terms of Reference

A. Present available fishery independent data on the geographical distribution on an annual, quarterly and/or monthly/survey basis for all life stages of Northeast Atlantic mackerel (biomass and abundance or their appropriate proxies) by the respective zones of fisheries jurisdiction and in international waters since 1977. Assess the utility of available data for the purposes of assessing the distribution of the stock in time and space.

B. For each Coastal State/Fishing Party, present total annual catch data by month and ICES statistical rectangle from 1977-2020, and by the respective zones of fisheries jurisdiction and international waters. In the event the data offers lower precision, data can be presented by quarter and/or ICES subdivision. Describe the quality and utility of the catch data for the purposes of assessing the distribution of the stock in time and space.

The Working Group should present a report by 28 February 2022.

1.2 Approach of the present group

The present WG relies on standardised information in the form of output from nationally and internationally coordinated surveys. The primary data sources are considered to be those which are internationally coordinated, with common databases and where data are reported to ICES. Secondary data sources are considered to be data that are collected nationally with well documented and approved data collection protocols but are often limited in spatial or temporal extent. Many of the secondary data sources have a relatively short time-series, are discontinuous and/or not currently undertaken. The group also considered whether surveys were specifically designed for estimating mackerel distributions and abundance or whether the mackerel was incidental in the survey i.e., the principal target was a different species or suite of species.

For temporal distribution among zones the present Working Group followed a direct observation approach.

Surveys provide snapshots of distribution of biomass/abundance of the different life stages. Due to the limited number of primary survey data sources, the WG chose to provide a detailed report on the following stages: juveniles age 0, spawning distributions, and adults age 3+ on the summer feeding grounds. The juvenile distribution constitutes surveys which were not specifically targeted on mackerel whereas the spawning and summer distributions were surveys targeted on mackerel. Visualisation of the data are given in the form of maps and when the data allowed, tables showing proportions by zones. The surveys only provide information about biomass or abundance at specific points in time and space, but the integrated nature of their analysis will give distribution maps within the survey period. Due to the lack of systematic information the WG chose to avoid interpolation between survey periods or combining surveys with different survey designs or strategies. The maps and tables provide some guidance as to the within year rate of change in distribution among zones.

Catch distributions are based on the data held by the ICES Working Group on Widely Distributed Stocks (WGWIDE) which emanates from an annual data call. The catch data span the period 1998 to 2020. Most of the data from 2006 to 2020 are by ICES statistical rectangle and month, whereas for the period 1998 - 2005 much of the data are by rectangle and quarter. To obtain a complete data set by rectangle and month would require a data call, which was not possible in the time between the conception of the mackerel distribution WG and the submission of the report. The data held by ICES did not designate the EEZ in which the catches were taken, so this information was gleaned from a process of apportioning catches as a proportion of the statistical rectangle area in each EEZ. Notwithstanding regulation effects, national agreements on zonal access, misreporting etc., the distribution of the mackerel fishery by month may provide some guidance as to the within year rate of change in distribution among zones.

Much of the data reported to date with respect to Zones and/or EEZs refers to the European Union (EU) and this includes many reports relating to the distribution and catches of Northeast Atlantic Herring (*Clupea harengus*) (Norwegian Spring Spawning (NSSH)/Atlanto-Scandian (ASH)) and Northeast Atlantic Blue whiting (M*icromesistius poutassou*). In this report the data are reported for the UK and the EU separately and to ensure there is no confusion with any previously published reports, the EU without the UK is referred to within this report as EU27.

2 Background

There has been a considerable amount of research undertaken on mackerel in the Northeast Atlantic and the fisheries have been reasonably well described since the early 1900s. Much of the information on mackerel biology, ecology (including migrations), and the fisheries in this area from 1905 to 1984 is documented on the book by Lockwood (1988). Prior to the beginning of the 1960s the fishing and landings were dominated by herring with relatively low catches of mackerel. However, in the early to mid-1960s there were substantial increases of mackerel catches, primarily by the Norwegian fleet (Iversen 2002; Tøsdal 2021).

A comprehensive, more recent summary of the available data and ecology of the Northeast Atlantic mackerel stock is documented in an ICES report examining its distribution and migration (ICES 2013a). An annual assessment of the stock status and abundance is carried out by ICES Working Group on Widely Distributed Stocks (WGWIDE). The current assessment method utilises data from sampling of the commercial catch, three internationally coordinated surveys and the Norwegian coordinated tagging study (see ICES 2021a). The distribution of spawning and an estimate of the spawning stock size is available from the triennial Mackerel and Horse Mackerel Egg Survey (reporting to the ICES WGMEGS). The summer stock (feeding) distribution is estimated by the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) and coordinated by the ICES Working Group for International Pelagic Surveys (WGIPS). The distribution of juvenile mackerel is estimated by members of WGWIDE (see Jansen et al. 2015) utilising data from a number of bottom trawl surveys on the north European western shelf in the fourth and first quarters of adjacent years. These surveys are coordinated and reported on through ICES in the International Bottom Trawl Survey Working Group (IBTSWG).

2.1 Main characteristics of the migration patterns of the stock

In general terms the life history and thus the spatial distribution of the mackerel stock can be considered within the framework of the various life history stages/phases and seasonal distributions. For the purposes of a brief summary of the current information available on the spatial distribution of the stock, four phases in the annual cycle and life history are considered (as documented in ICES (2013 AGDMM Report)):

- Spawning (adults)
- Summer (adults)
- Overwintering (adults)
- Juveniles

2.1.1 Adults

The overall annual migration patterns of northeast Atlantic mackerel are reasonably well known (Lockwood 1988; Godø et al. 2004; Uriarte and Lucio 2001; Uriarte et al. 2001). Changes in the migration patterns over the years have been also reported (Iversen 2002), however, the drivers of the timing of migration or the interannual variability in locations are less known. This lack of information and/or understanding results in a large uncertainty with respect to predicting any future shifts in spatial pattern or interpolating past distributions of the stock.

In general terms much of the Northeast Atlantic stock over-winters in the vicinity of the shelf edge around the northern part of the North Sea (ICES Division 4a) and onto the shelf in the North Sea (Uriarte and Lucio 2001; Uriarte et al. 2001; Jansen et al. 2012). The extent of adult fish overwintering along the eastern portion of the Norwegian Trench (along the Norwegian coastline) and to the west of the British Isles (ICES Sub Areas 6 and 7) has not been thoroughly investigated.

In February/March part of the stock aggregates and then starts to migrate southward toward spawning grounds in the Cantabrian Sea and Bay of Biscay. Spawning generally progresses from the south to the northern grounds, starting in around February/March and culminating in June/July (see Lockwood 1988 and ICES MEGGS reports). Spawning does occur in the North Sea and this tends to be later in the season, around June/July (ICES 2021b). The cues for where a fish may spawn are also unknown and since the centres of spawning are changing over time there must be interannual variability in the location of optimal spawning habitats (Hughes et al. 2014).

Adult mackerel migrates northward from the spawning areas to the feeding grounds. The principal feeding migration is north and west into Nordic Seas, Iceland Basin and Irminger Sea, in some years as far west into Greenland waters and also as far north into the vicinity of Svalbard (see Fig. 4.2.1 and 4.2.2). Some fish from the furthest south spawning grounds might move into the North Sea for feeding rather than migrating northward into the Nordic Sea (Uriarte et al. 2001). The drivers of the interannual variations in the location of the feeding grounds are still not properly understood (Nøttestad et al. 2016a; ICES 2020), however, there is research suggesting that this may be partially due to thermal regimes, prey availability and stock size (Nikolioudakis *et al.* 2019; Ólafsdóttir *et al.* 2019).

In the period September/October the majority of the stock departs from the feeding grounds, migrating back to the over-wintering grounds. The timing and details of this migration have not been a focus of any scientific studies and as such any quantitative assessment cannot be undertaken.

2.1.2 Early life stages

The spawning locations of mackerel and the nursery grounds are relatively well known and documented. However, there does not appear to have been any detailed studies on the dynamics of the eggs and/or larvae nor the connectivity between the spawning locations and the nursery grounds. Likewise, there is little or no available detailed information on the locations (abundances) of age 1 and 2 mackerel prior to them joining the adult feeding migrations. It is known that juveniles occur in the North Sea, Hebridean Shelf, eastern Celtic Sea/Western Channel but what proportion of the juveniles in the stock that these constitute is unknown.

2.2 Mixing and interactions with other stocks

There is spatial and temporal overlap between Northeast Atlantic mackerel and Norwegian spring-spawning herring, especially at the periphery of the mackerel distribution (northern Faroese, Icelandic and Jan Mayen waters) in the summer feeding months. This may result in competition between mackerel and herring for preferred food such as *Calanus finmarchicus* (Debes et al. 2012; Huse et al. 2012; Langøy et al. 2012; Óskarsson et al. 2012). Mackerel may outcompete herring during summer because mackerel are generally larger, faster, more enduring when migrating and more effective plankton eaters, including a wider food niche (wider diet breadth) than herring (Nøttestad et al. 2012). In a correlative study undertake on the survey data from the IESSNS, Nikolioudakis et al. (2019) indicated that herring abundance was one of the main factors which influenced both the mackerel occurrence and its density in the survey.

There is evidence of mackerel predation on other species such as in the North Sea on 0-group herring as well as 0-group Norway pout and all ages of sandeel (ICES 2008). Mackerel has also been noted to prey on Norwegian spring-spawning herring larvae along the continental shelf coast of Norway (Skaret et al. 2015; Allan et al. 2021). The full extent of this predation on herring, along with any inter-annual variability is as yet unknown.

3 Methods

3.1 Zonal database

For the purpose of the present report, the definitions of national EEZs were taken from the MarineRegions website (https://www.marineregions.org/). We used the version Intersect_EEZ_IHO_v4_2020 that presents the intersections between the EEZs and International waters (Fig. 3.1.1). Note that the MarineRegions database does not contain the special arrangement between Norway and Russia on the Russian access to the southern part of the international waters (Anon., 2010). This will be remedied in a future version.

The method to allocate the area proportion of a zone within each rectangle was carried out with R software. The results were included in a similar database as was prepared at the Blue whiting meeting in 2013 (Anon. 2013). The database holds estimates of:

- The area of sea in each ICES rectangle in the Northeast Atlantic
- The proportion of the sea area of each ICES rectangle that lies within the EEZ of each of the contracting parties, as well as in international waters outside national jurisdiction.

The database covers the area from 36.25 to 84.75N and 43.5W to 68.5E (Fig. 3.1.1). Some examples of how the area of the ICES rectangles was divided between adjacent EEZs are shown in Figures 3.1.2-3.1.4.

The codes used in this report for each of the EEZs or jurisdictional zones are as follows:

Economic Exclusive Zone (EEZ)	Code
European Union	EU27
Faroe Islands	FO
Greenland	GR
Iceland	IS
International waters	INT
Norway	NO
Russia	RU
Jan Mayen	SJM
Svalbard	SVA
United Kingdom	UK

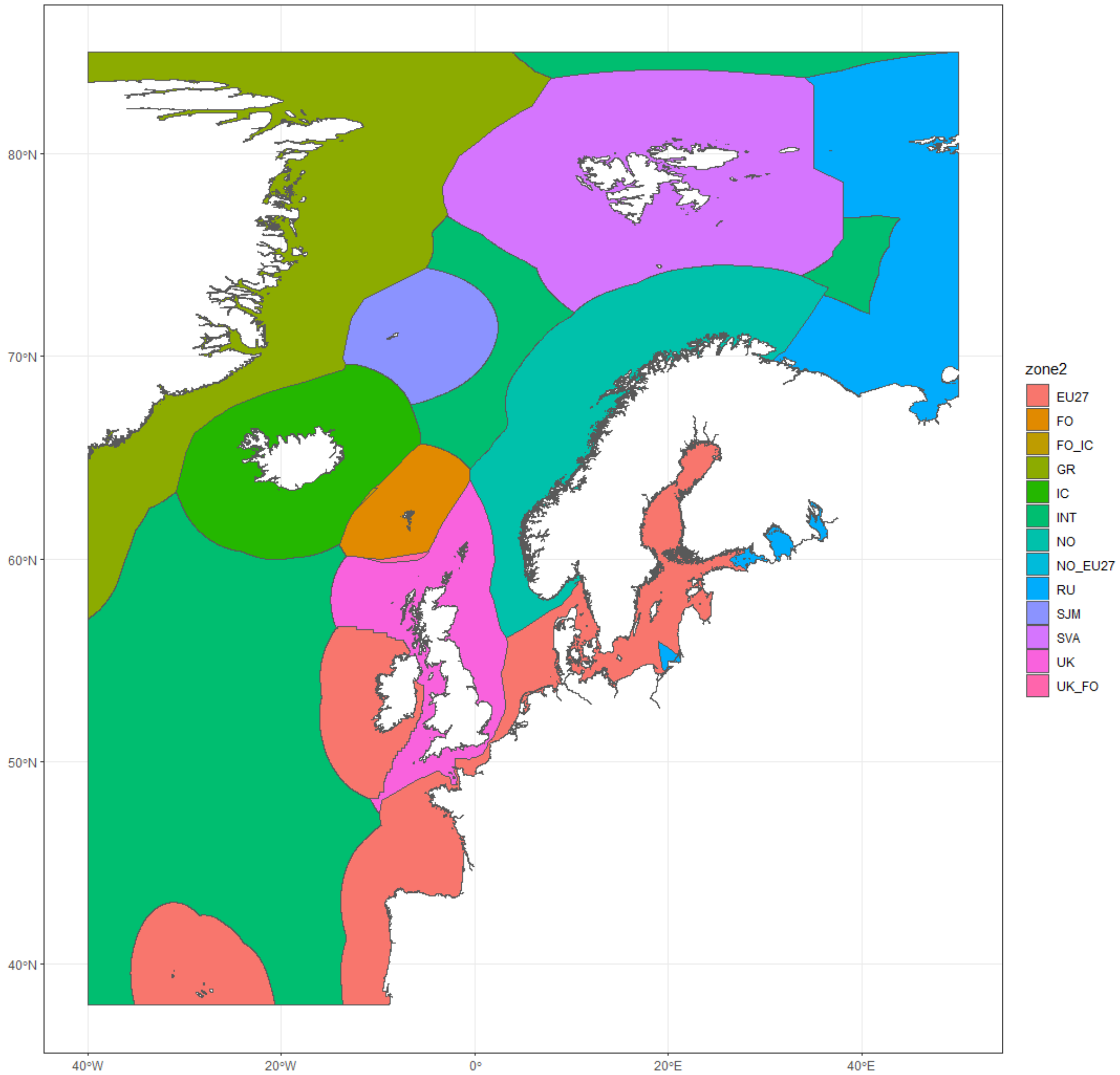

Figure 3.1.1. Overview map of Exclusive Economic Zones (EEZ) in the Northeast Atlantic used in the report.

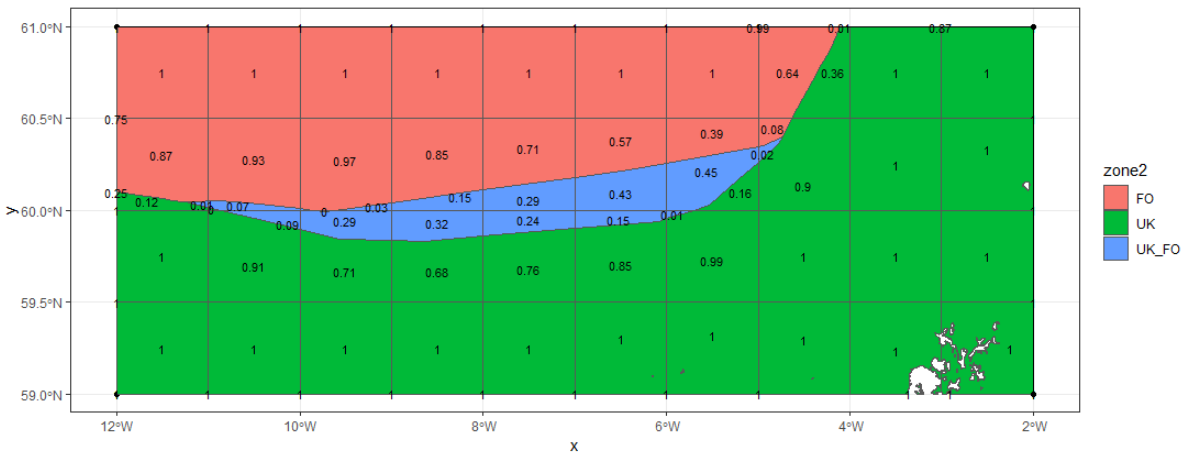

Figure 3.1.2. Proportions of Exclusive Economic Zones (EEZ) within the contested zone between the UK and Faroe Islands.

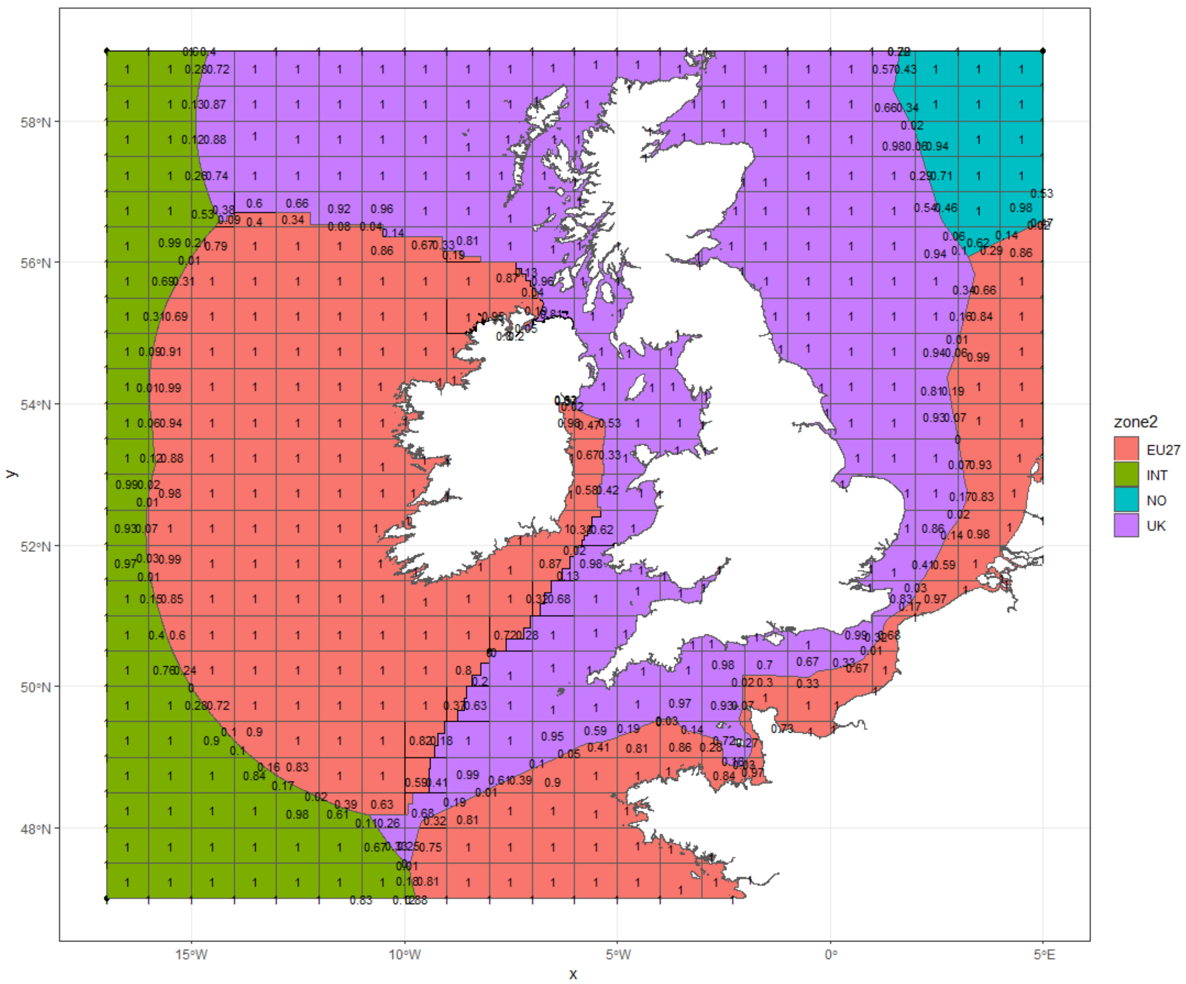

Figure 3.1.3. Proportions of Exclusive Economic Zones (EEZ) between the UK, EU27, Norway and International waters.

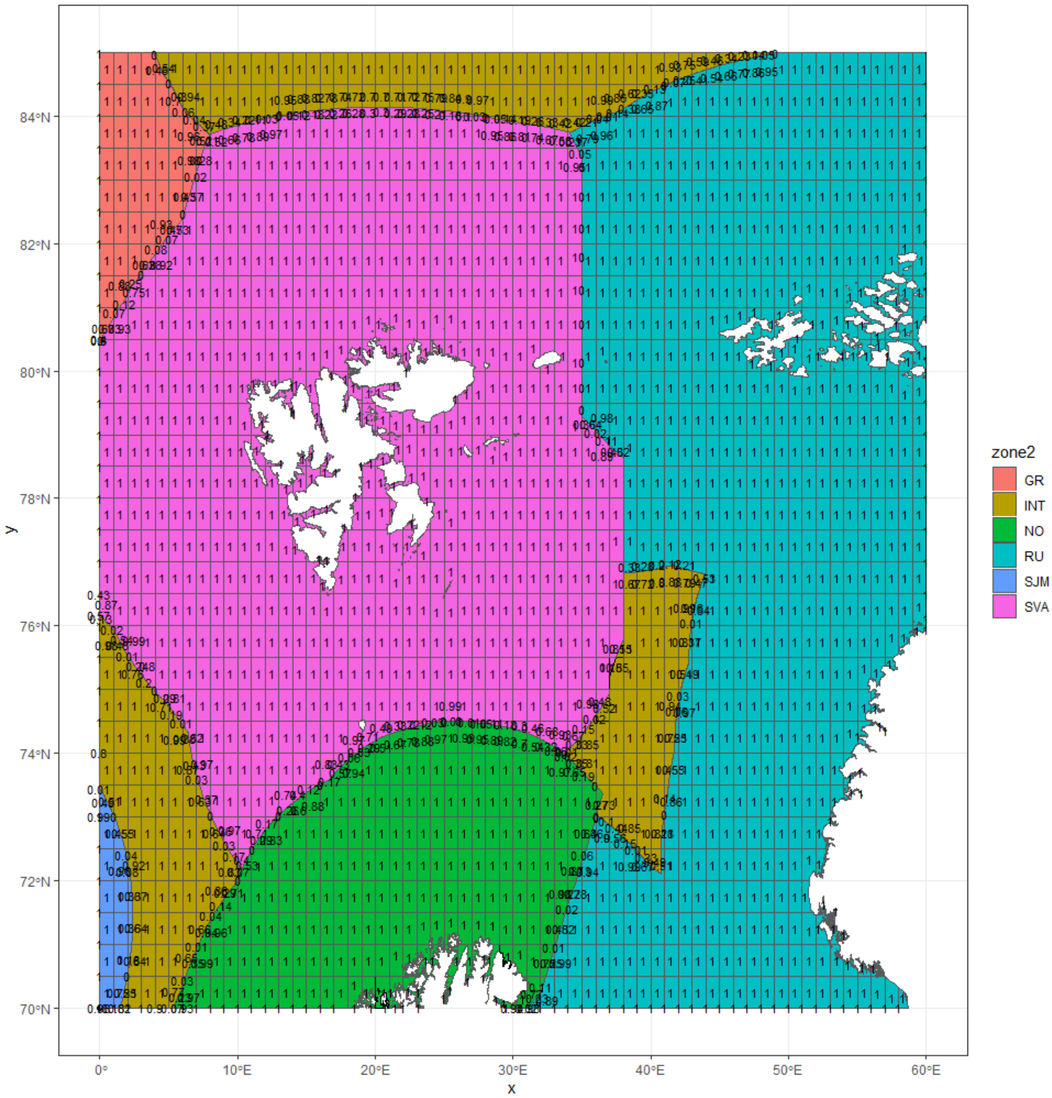

Figure 3.1.4. Proportions of Exclusive Economic Zones (EEZ) in the Barents Sea. Note that the special area between Norway and Russia has not yet been included.

3.2 Surveys

There are a number of surveys and data sources that provide information on the distribution of mackerel in the Northeast Atlantic (Table 3.2.1). However, currently no single methodology or survey strategy is capable of providing data on all life stages (i.e., from eggs to adults), over a complete annual cycle and the entire spatial distribution of the stock.

Table 3.2.1. Overview of surveys in the northeast Atlantic where mackerel occur. The survey listing and summaries include those used to quantitatively estimate the proportion of the mackerel stock in each of the Exclusive Economic Zones (EEZ) and additional surveys which contain information on the distribution of mackerel. While this list is comprehensive, it is not an exhaustive list. The electronic version of this table contains links to each section which contains more complete details and descriptions of the surveys.

	Survey acronym	Name	Time of year	Life stage	Frequency	Area	Year range	Survey type	Section report
Surveys analysed in this report	IESSNS	International Ecosystem Summer Survey of the Nordic Sea	July–August (Q3)	Adults	Annual	2, 5a–b, 14b	2010–	Swept area pelagic trawl survey	3.2.1.1
	IESSNS (North Sea)	International Ecosystem Summer Survey of the Nordic Sea	July (Q3)	Adults	Annual	4a–b	2018–	Swept area pelagic trawl survey	3.2.1.1
	MEGS	Mackerel and Horse Mackerel Egg Survey	March–July (Q1–Q2)	Adults	Annual	5–8, 12	1992–	Gulf and bongo sampling	3.2.1.2
	MEGS (North Sea)	Mackerel and Horse Mackerel Egg Survey	May–June (Q2)	Adults	Annual	3a, 4	1999–	Gulf sampling	3.2.1.2
	EVHOE	French Southern Atlantic Bottom Trawl Survey	Q4	Adults/juveniles	Annual	7e–h, 8a–b	1997–	Bottom trawl	3.2.1.3
	FRCGFS	French Channel Ground Fish Survey	Q4	Adults/juveniles	Annual	7d	1988–	Bottom trawl	3.2.1.3
	SWC-IBTS	Scottish West Coast International Bottom Trawl Survey	November–December (Q4)	Adults/juveniles	Annual	6a	1990–2009	Bottom trawl	3.2.1.3
	SCOWCGFS	Scottish West Coast Ground Fish Survey	Q4	Adults/juveniles	Annual	6a	2011–	Bottom trawl	3.2.1.3
	NS-IBTS	North Sea International Bottom Trawl Survey	Q1	Adults/juveniles	Annual	4	1965–	Bottom trawl	3.2.1.3
	SWC-IBTS	Scottish West Coast International Bottom Trawl Survey	February–March (Q1)	Adults/juveniles	Annual	6a	1986–2010	Bottom trawl	3.2.1.3
	WCGFS	Western Celtic Sea Ground Fish Survey	Q1	Adults/juveniles	Annual	7f–j	1998–2013	Bottom trawl	3.2.1.3
	FO-GFS-Q1	Faroese Bottom Trawl Survey	February-March (Q1)	Adults/juveniles	Annual	5b1	1996–	Swept area trawl survey	A1.10
	IS-GFS-Q1	Icelandic Bottom Trawl Survey (SMB)	March (Q1)	Juveniles	Annual	5a	2001–	Bottom trawl	A1.11
	PELACUS	Pelagic Acoustic in North-western Spanish Waters	March–April (Q1-Q2)	Adults/juveniles	Annual	8c, 9aN	1984–	Acoustic	A1.7

Additional surveys	PELAGO	Pelagic Acoustic Survey in Portuguese waters	March–April (Q1-Q2)	Adults/juveniles	Annual	9aS,W	1995–	Acoustic	
	IBWSS	International Blue Whiting Spawning Stock Survey	March–April (Q1-Q2)	Adults	Annual	6–7, 12	1998–	Acoustic	
	PELGAS	Pélagiques Gascogne	Q2	Adults/juveniles	Annual	8a–b,8d	2000–	Acoustic	
	IESNS	International Ecosystem Survey in the Nordic Sea	May (Q2)	Adults	Annual	2, 4a, 5a–b	1995–	Acoustic	A1.4
	IMR Tagging (NOR) RFID	Mackerel tagging survey	May–June (Q2)	Adults	Annual	Northeast Atlantic	2011–	Tagging and recapture	A2
	HERAS	Herring Acoustic Survey	June-July (Q2–Q3)	Adults/juveniles	Annual	3–7	1989–	Acoustic	A1.9
	WESPAS	Western European Shelf Pelagic Acoustic Survey	June-July (Q2–Q3)	Adults/juveniles	Annual	6–7	2016–	Acoustic	A1.5
	IBTSQ3	North Sea International Bottom Trawl Survey	Q3	Adults/juveniles	Annual	4	2007–	Bottom trawl and acoustic	A1.9
	FO-GFS-Q3	Faroese Bottom Trawl Survey	August (Q3)	Adults/juveniles	Annual	5b1	1983–	Swept area trawl survey	A1.10
	Lidar	PINRO Aerial Lidar survey	July–August (Q3)	Adults	Annual	Norwegian Sea	1997–2005	Aerial	A1.2
	IMR trawling survey (NOR)	Mackerel Survey	July–August (Q3)	Adults	Annual	Norwegian Sea	1995–2007	Swept area pelagic trawl survey	A1.1
	PT-GFS-Q4 WIBTS	Portuguese Groundfish Survey	Q4	Adults/juveniles	Annual	9a	1990–	bottom trawl	A1.6
	IS-GFS-Q3	Icelandic Bottom Trawl Survey (SMH)	October (Q4)	Adults/juveniles	Annual	5a	2001–	Bottom trawl	A1.11
	CSHAS	Celtic Sea Herring Acoustic Survey	October (Q4)	Adults/juveniles	Annual	7	2004–	Acoustic	
	PELTIC	Pelagic Ecosystem Survey in the Western Channel and the Celtic Sea	October (Q4)	Adults/juveniles	Annual	7	2012–	Acoustic	A1.8
	NSAMS	North Sea Acoustic Mackerel Survey	October–November (Q4)	Adults	Annual	4	1999–2007	Acoustic	A1.3

Highlights of many of the survey methodologies that are currently used are given below.

Acoustic Surveys

-Widely used in the assessment of pelagic stocks such as herring and blue whiting but less well developed for mackerel which does not have a swim bladder and weakly reflects acoustic energy.

-The development of a target strength model for the estimation of mackerel biomass from acoustic data, especially in relation to the horizontal orientation of the fish and behaviour in shoals is still ongoing.

-The most appropriate frequency for the acoustic mackerel detection is 200 kHz which may not be available on all vessels.

- Acoustics are a potentially rich source of information, with broad coverage throughout the distribution area although usual issues with synoptic coverage exist given the extremely wide stock distribution.

Bottom trawl Surveys

-Bottom contacting gear primarily samples demersal species but will also capture pelagic fish (e.g., recruits) close to the seabed. Mackerel at age 0 school near the bottom during winter, especially in high density areas (Jansen, et al. 2015).

Currently used to provide an index of recruits (age 0) for the mackerel assessment.

-The North Sea 3rd Quarter IBTS (summer) is not considered informative of age 0 abundance because a significant proportion of the fish are too small to be sampled.

Egg and Larval Surveys

- Uses the egg abundance as a proxy for the adult spawning distribution.

- The spawning period is protracted (Feb-Jul) so estimations of spawning distribution by month are not feasible.

- The survey coverage has changed over time to try and reflect the observed perceived changes in the timing and locations of spawning

LIDAR (Light Detection and Ranging)

- Airborne LIDAR surveys have the advantage of potentially covering large areas in a short time and an absence of vessel avoidance.

- However, there are depth-range limitations (maximum 50m depth) and they are dependent on good weather (no fog or clouds below the flight altitude).

- Present LIDAR indices for mackerel have limited temporal coverage (are underdeveloped).

Swept Area Trawl Surveys

- Primarily useful in summer when shoals disperse during feeding and the majority of the fish are dispersed and in the upper 30m of the water column.

- The swept area estimation (which samples a very large area) is an accepted methodology for the estimation of abundance and distribution of mackerel in the summer north of 60^{o}N in the Nordic Seas.

Tagging Studies

- A very large potential data source which encompasses scientific survey protocol in the location and timing of the tagging and then is fishery dependent in relation to timing and location for the capture of tagged fish.

- Many of the earlier studies were targeted at identifying the migration routes, stock size estimates etc (Hamre 1978; Iversen 2002; Tenningen et al. 2011).

3.2.1 Methods used when calculating abundance/biomass and proxies

This report analyses in detail the biomass or biomass proxies obtained from IESSNS, MEGS, and IBTS surveys. These surveys are used in the assessment of NEA mackerel and are considered to accurately cover in time and space the distribution of at least one of the life stages of mackerel.

There are additional relevant surveys which can potentially provide spatial information on mackerel and they are listed in Table 4.1. However, mainly due to time limitation, the working group did not work on the data (or provided methodologies to quantify the distributions per zone) of these surveys, and thus only a qualitative description is provided (Annex A1). Further work would be needed to infer quantitative distributions and due to the current data format and time available it was not possible to present these results in the current report. Nevertheless, these surveys can provide valuable information too, and if requested, additional analysis could be made to translate the survey data into zonal distributions.

3.2.1.1 International Ecosystem Summer Survey of the Nordic Sea (IESSNS)

The International Ecosystem Survey in the Nordic Seas (IESSNS) is a swept area trawl survey which provides age segregated abundance index for mackerel age 3+ as measured during the summer feeding season in Nordic Seas, Iceland Basin and Irminger, annually since 2010 (Figure 3.2.1). The North Sea has been included into the survey area since 2018. The precursor to this survey is documented in Annex A 1.1. IESSNS coverage varies between years as the survey tracks the variable distribution range of the stock. Due to these changes in the survey area, results are presented for the original survey area (ICES divisions 5a, 5b, 14b and Subarea 2) and the North Sea (ICES Divisions 4a-b) separately and only for the whole survey area for 2018 to 2020. ICES Working Group of International Pelagic Surveys (WGIPS) coordinates the survey.

IESSNS uses a specially designed pelagic trawl, called Multpelt832, to catch mackerel in the surface, trawl headline visible in surface and foot rope at approximately 35 m depth (ICES 2013b; Valdemarsen et al. 2014; Nøttestad et al. 2016b; ICES 2017, 2020). This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. Over the years there have been many discussions and refinements of Multpelt832 trawl, standardized trawling operation, survey design (ICES 2013a, ICES 2013b, ICES 2014a, ICES 2017). These were all considered and implemented into the IESSNS survey in July-August 2017 and remain in place (Nøttestad et al. 2017, 2019, 2020; Ólafsdóttir et al. 2018). The current survey protocol is detailed in ICES (2014b).

Calculations of mackerel age segregated IESSNS index for EEZ´s was done using StoX software package for years 2017 - 2020. EEZ boundaries are implemented within StoX and index is calculated per EEZ. A description of StoX can be found in Johnsen et al. (2019) and here: www.imr.no/forskning/prosjekter/stox. EEZ calculations for IESSNS in 2010 to 2016 were done in R software using degree rectangles calculations allocated to EEZs, see annual IESSNS cruise reports for details.

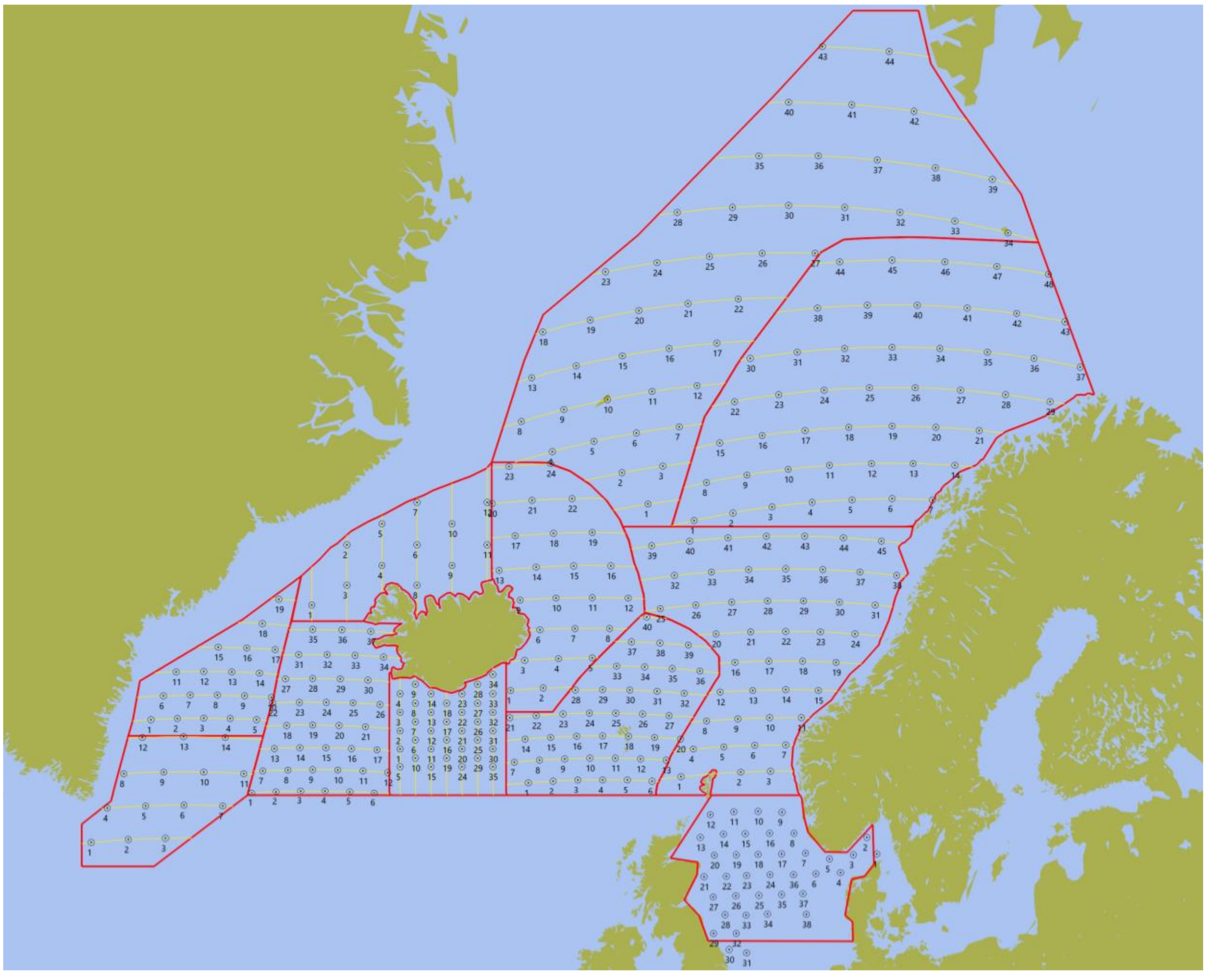

Figure 3.2.1. Survey coverage for IESSNS (Planning in WGIPS 2022, survey manual ICES 2015). Red lines indicate survey strata. Numbers indicate trawl stations in each stratum – 2022 survey plan.

Evaluation and caveats

The southern extent of the stock is not covered by the survey due to the available survey resources. In addition, the survey protocol depends on the majority of the mackerel being in the upper 30-35m of the water column. The survey does not capture the southern extent of the stock distribution as there are other surveys e.g., WESPAS (see section A1.5) that indicate mackerel is deeper in the water column which would not be sampled with an extension of this survey using the current methodology and protocols.

At present the northern extent of the stock distribution is generally within the survey area, however, as environmental conditions change, this may not be the case in the future unless the survey area is adaptive and moves with the stock.

The southern extent of the stock in the North Sea is also not well represented. The southern and eastern limit is imposed by the water depth since the trawls have too large a mouth opening for the southern North Sea.

3.2.1.2 Triennial Mackerel and Horse Mackerel Egg Survey (MEGS)

The working group on mackerel and horse mackerel egg surveys (WGMEGS) coordinates the Mackerel and Horse Mackerel Egg Survey in the Northeast Atlantic and the Mackerel Egg Survey in the North Sea with the purpose of estimating the spawning stock biomass (SSB) of mackerel since 1977 (Lockwood et al. 1981). The Annual Egg Production Method (AEPM) has been used for the estimation (Lockwood et al. 1981; Lockwood

1988), under the assumption that mackerel has a determinate fecundity. These surveys are carried out triennially, although the survey in the North Sea is usually carried out one year after the surveys in the western and southern areas.

Estimation of NEA mackerel SSB in the Northeast Atlantic is used as an SSB index in the NEA mackerel assessment process. The North Sea component is currently not incorporated in the SSB index. The main reason is that the North Sea egg survey is carried out one year after the egg survey of the Western and Southern components. Given the relatively small size of the North Sea component, the exclusion of the North Sea in the survey is considered not to have a great impact on the assessment.

The spatial and temporal distribution of sampling is designed to ensure an adequate coverage of both mackerel (*Scomber scombrus* L.) and horse mackerel (*Trachurus trachurus* L.) spawning areas. The aim of the triennial egg survey is to determine the annual egg production (AEP). This is calculated using the mean daily egg production rates per pre-defined sampling period for the complete spawning area of the Northeast Atlantic mackerel and horse mackerel stocks. To achieve this, one plankton haul is completed per half ICES rectangle with surveys conducted on transects covering the complete spawning area. Sampling effort aims to produce estimates of stage 1 egg production. The entire mackerel spawning season is divided into different sampling periods. The amount of ship time available and the size of the area to be covered determine the spacing and omission of sampling transects within the sampling periods.

<u>Northeast area survey</u>

The NEA mackerel egg survey (MEGS) has been running triennially since 1977 and since 1992 has incorporated both the southern and western areas of the NEA mackerel stock. The core area for the western and southern area surveys are presented in Figure 3.2.2. The 'southern' area is regarded as being from 36º N to 44º N in the east and 45º N in the west. It extends from Cape Trafalgar in the Gulf of Cadiz, around the coast of Portugal to 11º W, the Cantabrian Sea and southern Biscay. Sampling often begins in January in this area and continues until June in the Cantabrian Sea.

The 'western' area for mackerel is from 44º N (45º N in the west) to 63º N. It includes Biscay, the Celtic Sea and the shelf edge to the northwest of Scotland. Sampling is focussed along the shelf edge (200m isobaths) but also occurs from the French and Irish coasts out to Rockall and Hatton Bank. Sampling in this area usually begins in February and continues to the end of July.

In most of the western area plankton samplers are deployed at the centre of half standard ICES rectangles, which are 0.5º latitude, by 0.5º longitude. To the north of Spain (Cantabrian Sea) in general three sampler deployments are undertaken (in an east-west direction) in each 0.25º latitude by 1.0º longitude rectangle because of the proximity of the shelf edge to the coast.

Since the surveys began in 1977, considerable changes have been made to the “standard” sampling area and some of these were described in ICES (1994). Based on the expansion of the “standard area” since 1977, it was agreed (ICES, 2002) that the existing “standard area” should be retained only as a guide to the core survey area for cruise leaders, and that the extent of coverage should be decided based on finding the edges of the egg distribution only (adaptative sampling).

In 1992 and 1995 the standard sampling area was used for the calculation of the survey index. During the 2017 benchmark (WKWIDE) a comprehensive re-analysis of the survey time-series was carried out utilising all the station data available going beyond the boundaries of the old standard area. Due to the expansion of the spawning area which has been observed since 2007 the emphasis was even more focused on full area coverage and delineation of the spawning boundaries.

The standard plankton samplers for use on these surveys are mainly national variants of Bongo or 'Gulf type high-speed' samplers (Nash et al., 1998). Portugal (IPMA) continues to use a vertically deployed CalVET-net. All of the samplers and the sampling protocols are detailed in ICES (2019). The primary data available from each survey consists of the abundance of Stage 1 mackerel eggs per square metre of sea surface at the sampling location.

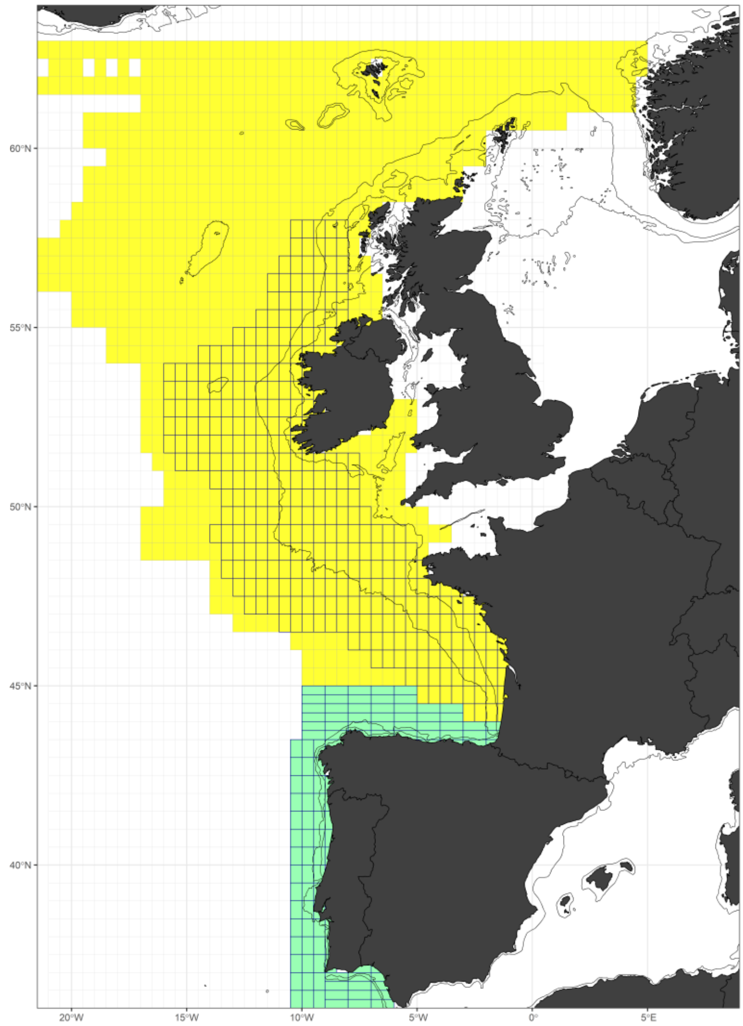

Figure 3.2.2. Survey area for the mackerel egg survey in the Northwest Atlantic for 1992-2019. The western area is shown in yellow and the southern area is shown in green. Bold rectangles show the core survey area.

<u>North Sea area survey</u>

The North Sea Mackerel Egg Survey is designed to estimate the SSB of mackerel of the North Sea spawning component of the NEA mackerel stock on a triennial basis. The core area for the North Sea survey is presented in Figure 3.2.3. Until 2017 this survey was done utilizing the AEPM, but it was agreed to switch to the Daily Egg Production Method (DEPM) for the North Sea mackerel survey in 2021 (ICES 2018). Survey design is similar to northwest Atlantic area: one plankton haul per each half ICES rectangle is conducted on transects covering spawning area 53ºN – 59ºN into different sampling periods. In 2021 a single period (peak spawning time) and bigger area (53ºN-62ºN) was sampled to adapt the survey to the DEPM.

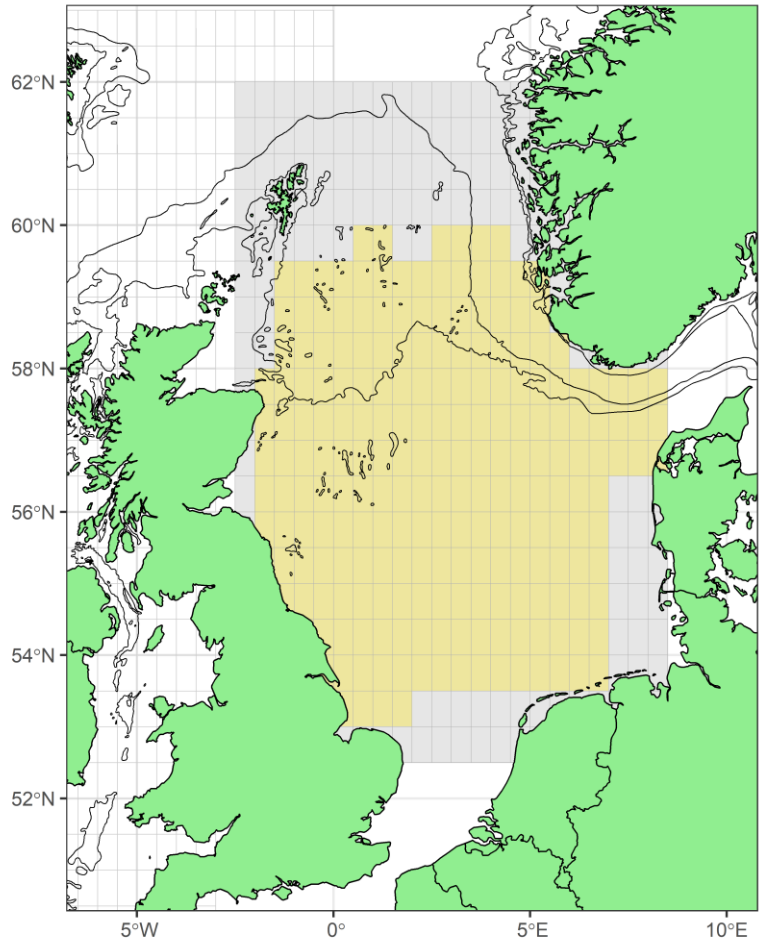

Figure 3.2.3. Survey area for the mackerel egg survey in the North Sea. The core area for the surveys 1999-2017 is shown in yellow. The survey area in 2021 (in grey) was modified to adapt to the daily egg production method.

Maps of mackerel egg production (stage I eggs / m^2) by half ICES statistical rectangle in each survey year has been estimated as follow:

1. Egg production of half ICES rectangle in each survey period: Daily egg production (stage I eggs. m^{-2}. Day^{-1}) of ICES half rectangle in each survey period multiplied by number of days of period
2. Egg production of half ICES rectangle in survey year is then estimated as a sum of egg production on each half rectangle in all survey periods

The total egg production in a survey year has used both sampled and interpolated rectangles (as used by MEGS in their estimations of egg production). Details of Daily egg production estimation and survey design can be found in Manual for mackerel and horse mackerel egg surveys, sampling at sea (ICES 2019).

The egg production by EEZ was estimated using the same methodology as for the maps. Then, the egg production of half ICES rectangle was summed at rectangle level, and then at EEZ level. Estimates for statistical rectangles straddling two or more EEZ were split in proportion to the area of each EEZ falling in that rectangle.

Evaluation and caveats

The triennial egg survey is currently the only indicator of the distribution of the stock at spawning time. Firstly, the triennial nature of the survey means that the distributional information is not annual so short-term variability in spawning locations cannot be followed. In regard to the spatial coverage, primarily for logistical reasons, the North Sea spawning area has generally been sampled one year later than the western and southern area. This results in an incomplete coverage of the whole spawning area in one survey period.

The survey protocol for the two areas has been similar, using the Annual Egg Production Method (AEPM) up until the 2021 North Sea survey. Currently the North Sea uses the Daily Egg Production Methodology (DEPM) which involves a single survey coverage at peak spawning time (rather than multiple coverages over the spawning period). The consequence of this is that the results inside and outside of the North Sea are probably not directly comparable with respect to a quantitative comparison of proportions of the spawning in each of the areas.

To the west of the British Isles and south into the Cantabrian Sea, the spawning area covers a very large area and spawning occurs over time both at relatively small ranges of latitude and over the full extent of the latitudinal extent. The survey normally takes place over a six-month period with the coverage generally progressing from south to north. For various reasons the data are not conducive to presenting spawning distributions by month or even by quarter.

It is apparent from the time series of the survey that there have been inter-annual variations in the locations and centres of spawning over the years. The survey has tried to be adaptive, and the coverage has varied somewhat over the years to try and encapsulate the spawning distribution in the area. The consequence is that the spatial coverage has varied. There has been criticism that often the zero eggs boundaries are not reached in all the surveys and that the spawning is not fully represented in the survey. Cursory studies have indicated that these very low egg abundances/densities do not contribute very much with respect to the overall annual egg production of the stock and would not make any significant contribution to the perception of the stock biomass.

In this report the annual egg production is used as a ‘proxy’ for the spawning stock biomass. To convert the egg production to a fish biomass requires an understanding of the relationship between the biomass of a female fish and the number of eggs each produces (fecundity dynamics and relationships). Unfortunately, there is a large amount of debate surrounding the fecundity relationship and the spawning dynamics of individual mackerel which has not been resolved and as such the decision was made not to utilise any relationship to covert egg production into fish biomass.

It is assumed that the annual egg production is a proxy for biomass of females that spawn, the sex ratio approximates to 50:50 and the males an equivalent biomass to the females.

3.2.1.3 International Bottom Trawl Surveys (IBTS)

The dataset consists of observations from a number of IBTS (bottom trawl) surveys (see Table 3.2.1) conducted between October and March from 1998 to present (Figure 3.2.4). Trawl operations during the IBTS have largely been standardized through the ICES IBTS Working Group. A single gear design, known as the GOV (Grande Ouverture Verticale) is used with some modifications (e.g., ground gear, overall gear dimensions) to suit the conditions in the respective survey areas. Modifications are either not considered to result in significant changes to catchability or have been accounted for in the analysis. Trawling speed is generally 3.5-4 knots with fishing operations undertaken during the hours of daylight. The majority of trawl stations are in depths of less than 220m (Figure 2).

IBTS data are stored in the ICES trawl survey repository (http://datras.ices.dk) and in some cases supplemented by data from national databases.

A geostatistical log Gaussian Cox (LGC) process model which includes spatiotemporal correlations is fit to the survey observations each year by WGWIDE and used to describe the catch rates of mackerel recruits (age 0) over space and time. The model formulation is fully described in Jansen *et al.* (2015).

The recruitment index estimated from the model is used in the annual stock assessment by ICES and in this report as an indicator of relative biomass of mackerel at age 0. For the purposes of estimating relative proportions by EEZ, model estimates were assigned to ICES rectangles and then summed for each EEZ to calculate the proportion of age-0 biomass resident in the area. Estimates for statistical rectangles straddling two or more EEZ were split in proportion to the area of each EEZ falling in that rectangle.

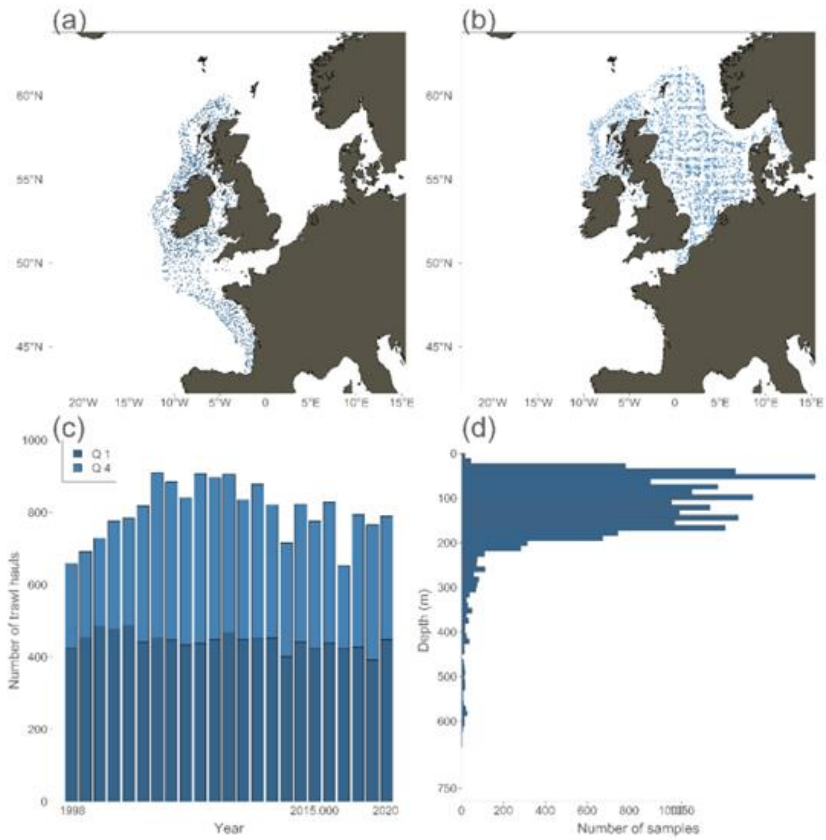

Figure 3.2.4. Demersal trawl survey data used to derive the abundance index of age-0 mackerel. (a) Trawl sample locations in the fourth quarter (Q4, October - November); (b) trawl sample locations in the first quarter (Q1, January - March); (c) number of samples by year and quarter; and (d) by depth.

Evaluation and caveats

The available surveys do provide complete coverage of the stock distribution. The quarter 4 surveys cover the north and west of Scotland, west of Ireland and the Bay of Biscay and quarter 1 the North Sea, north and west of Scotland (figure 2a-b). However, the Irish Sea and the western part of the Channel and the adjacent Celtic Sea is not covered. In addition, the shelf area southward along the southern Spanish and Portuguese coast (Cantabrian Sea and Iberian Coast) is also not included. There are however, survey data from IBTS Quarter 4 and Quarter 1 in this area (see section A1.6).

There are also additional shelf areas where juvenile mackerel do occur, often periodically and are present in ongoing national surveys. These include the Norwegian Coastal area, the Faroese Plateau, and the Icelandic Shelf. Some of these are documented in sections A1.10 and A1.11.

4 Results derived from Surveys

4.1 International Ecosystem Summer Survey of the Nordic Sea (IESSNS)

Nordic Seas have been the most important feeding ground for millions of tonnes of predominantly adult (> 3 years) mackerel in summer (June-August), particularly during the last 10 years from 2010 to 2020 (Figure 4.1.1 and 4.1.2) (Nøttestad et al. 2016a; 2020; ICES 2020).

The mackerel expanded fast from 2007 onwards, into northern parts of the Norwegian Sea as well as north along the Norwegian coast (Nøttestad et al. 2007; 2010-2017), and westward into East Icelandic waters in 2007 (Astthorsson et al., 2012). Furthermore, the mackerel expanded westward into Southeast Greenlandic waters and north to Svalbard (78°N) from around 2013 (Figure 4.1.1 and 4.1.2).

There have been rapid and large changes in mackerel abundance, distribution, and migration patterns in the Nordic seas in summers 2007-2014 (Nøttestad et al. 2016a). Quantitative results from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) demonstrate that the NEA mackerel stock has experienced a large-scale northward and westward expansion in the Nordic seas, particularly from 2010 to 2019 (Nøttestad et al. 2016a; Nøttestad et a. 2016, 2020; Olafsdottir et al. 2018).

From 2018 onward there has been a reduction in abundance of mackerel in the western area (Figure 4.1.2) compared to the years from 2010 to 2017 (ICES 2020, Nøttestad et al. 2010-2017; Olafsdottir et al. 2018). This major shift in distribution of mackerel consisted of a substantial decline of mackerel in the Icelandic and Greenland waters from 2018-2020 (Figure 4.1.2, Table 4.1.1). The central and northern part of the Norwegian Sea, on the other hand, experienced increased distribution, and abundance of mackerel from 2018 to 2020 (ICES 2020). Mackerel distribution had the highest densities recorded in the central and northern Norwegian Sea during summer 2020 (Figure 4.1.2) and high mackerel abundance was documented as far north as the Fram Strait west of Svalbard (78°N) in July-August 2020 (ICES 2020; Nøttestad et al. 2020).

The North Sea has been covered from 2018 onwards during IESSNS. The results from IESSNS 2018 to 2020 (Figure 4.1.1 and 4.1.2) quantify mackerel caught in all areas covered, deeper than about 50 m depth, within the North Sea. Predominantly juvenile mackerel, dominated by 1- and 2-year-olds was caught in the North Sea from 2018 to 2020 (Nøttestad et al. 2020). Most of the mackerel in the North Sea reside in Norwegian and UK waters, with a lower proportion in the EU waters (Table 4.1.2).

The proportions of mackerel biomass by EEZ estimated from the entire survey area (i.e., ICES Subarea 2, and divisions 5a, 5b, 14b, 4a and 4b) are shown in Table 4.2.3. Only the proportions for the three last years have been estimated because the North Sea has not been surveyed before 2018. The proportion of the survey area (approximately 2.9 million km^2) encompassed by the North Sea (0.27 million km^2) is 8.5%. Within the surveyed area, the highest abundances are found in Norwegian waters, followed by international waters in the Norwegian Sea, and Faroe Islands waters. The abundance of mackerel in Icelandic waters considerably decreased in 2020 (table 4.1.3, figure 4.1.1 and 4.1.2)

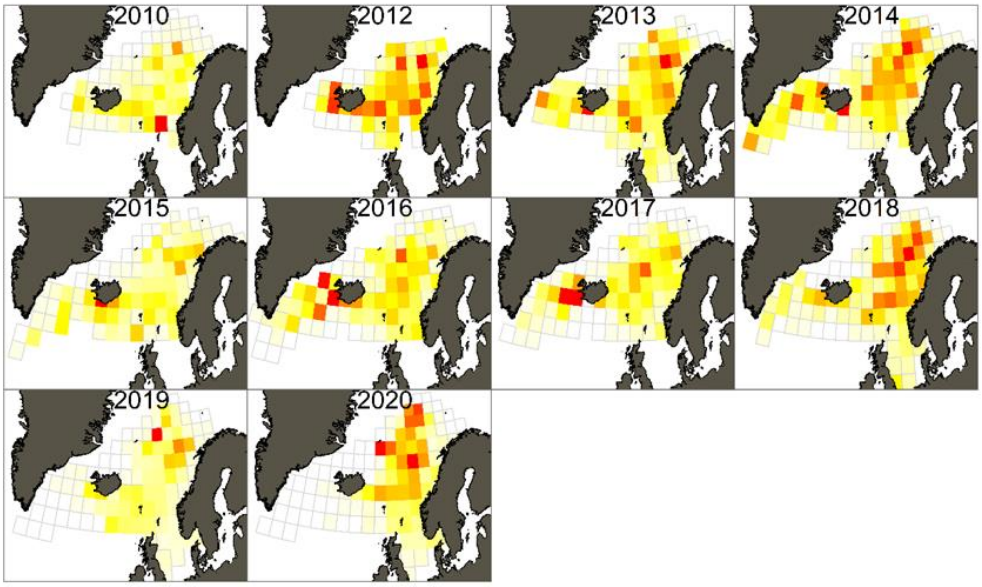

Figure 4.1.1. Annual distribution of mackerel from IESSNS 2010, 2012-2020 proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the highest year). The distribution of mackerel from the 2011 is not included due to incomplete spatial coverage in northern part of the Norwegian Sea, and it is not included in the assessment.

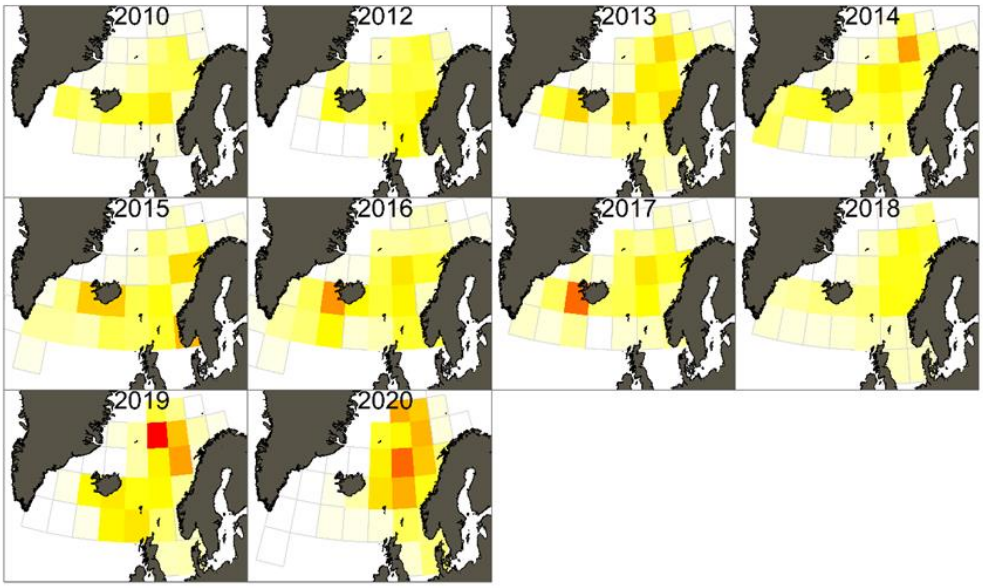

Figure 4.1.2. Annual distribution of mackerel from IESSNS 2010, 2012-2020 proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the given year). The distribution of mackerel from the 2011 is not included due to incomplete spatial coverage in northern part of the Norwegian Sea, and it is not included in the assessment.

Table 4.1.1. Percentages of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) from the International Ecosystem Summer Survey in the Nordic Sea (IESSNS) in June–August 2010, 2012–2020. Only data from the original survey were used in the estimations (ICES Subarea 2, and Divisions 5.a, 5.b, and 14.b). IESSNS 2011 is not included due to incomplete spatial coverage in northern part of the Norwegian Sea and it is not included in the assessment. * Indicates when a zone was unsampled during a survey. Note that Jan Mayen is included in the Norwegian EEZ.

Survey year	FO	GR	INT	IC	NO	SVA	UK
2010	15.8	0	11.6	22.9	40.8	0.5	8.4
2012	14.7	0	13	29.5	40.9	*	2
2013	17.2	5.7	11.1	17.2	43.5	1.6	3.7
2014	6.1	13	20.5	17.7	33.4	6.8	2.5
2015	10.3	4.2	10.4	37.3	30.6	1.3	5.8
2016	9.3	10	20.4	30.6	24.5	1.2	3.9
2017	8.8	5	20.7	37.4	25.4	1	1.8
2018	12.4	4.7	12.0	18.1	47.6	4.0	1.2
2019	13.6	0.1	11.4	16.9	49.4	3.1	5.5
2020	12.5	0	22.2	4.4	47.2	10.5	3.3

Table 4.1.2. Annual proportion of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone from the swept area survey (IESSNS) undertaken in the North Sea for 2018–2020.

Survey year	EU27	NO	UK
2018	9.1	47.9	43
2019	8.8	29.2	62
2020	6.1	55.6	38.3

Table 4.1.3. Percentages of Northeast Atlantic (NEA) mackerel biomass by Exclusive Economic Zone (EEZ) from the International Ecosystem Summer Survey in the Nordic Sea (IESSNS) in June–August 2018–2020. Data from the original survey area and North Sea was used in the estimations. Note that both Jan Mayen and Svalbard are included in the Norwegian EEZ.

Survey year	EU27	FO	GR	INT	IC	NO	UK
2018	0.9	11.7	4.4	11.3	17	51.6	3.2
2019	0.8	13.6	0.1	11.4	16.9	49.4	4.7
2020	0.5	12.5	0	22.2	4.4	57.5	2.8

4.2 Triennial Mackerel and Horse Mackerel Egg Survey (MEGS) Gersom, Brendan, Fin

4.2.1 Western and southern

In 2019 mackerel eggs were found distributed from the southern tip of Spain (30°) to the southern coast of Iceland (65°) (Figure 4.2.1). The highest densities of eggs were distributed along the shelf edge around NW of Scotland, Ireland, Celtic Sea, and into the Bay of Biscay and the Cantabrian Sea. Throughout the time series presented in Fig 4.2.1 and table 4.2.1 (1992-2019), the shelf edge has remained the area with highest densities of eggs. However, the distribution of mackerel eggs has expanded North and west since 2007 where eggs have been found up to 65 °N. In the most recent years (2016 and 2019) the maximum egg densities found were lower than in previous years (indicated by lighter colours along the shelf edge Fig. 4.2.1).

The estimates by EEZ shows that eggs are mostly found in the European Union and UK waters (Table 4.2.1). The temporal patterns in the distribution of Mackerel eggs (Fig 4.2.1) explain the changes observed across years in the proportions by EEZ.

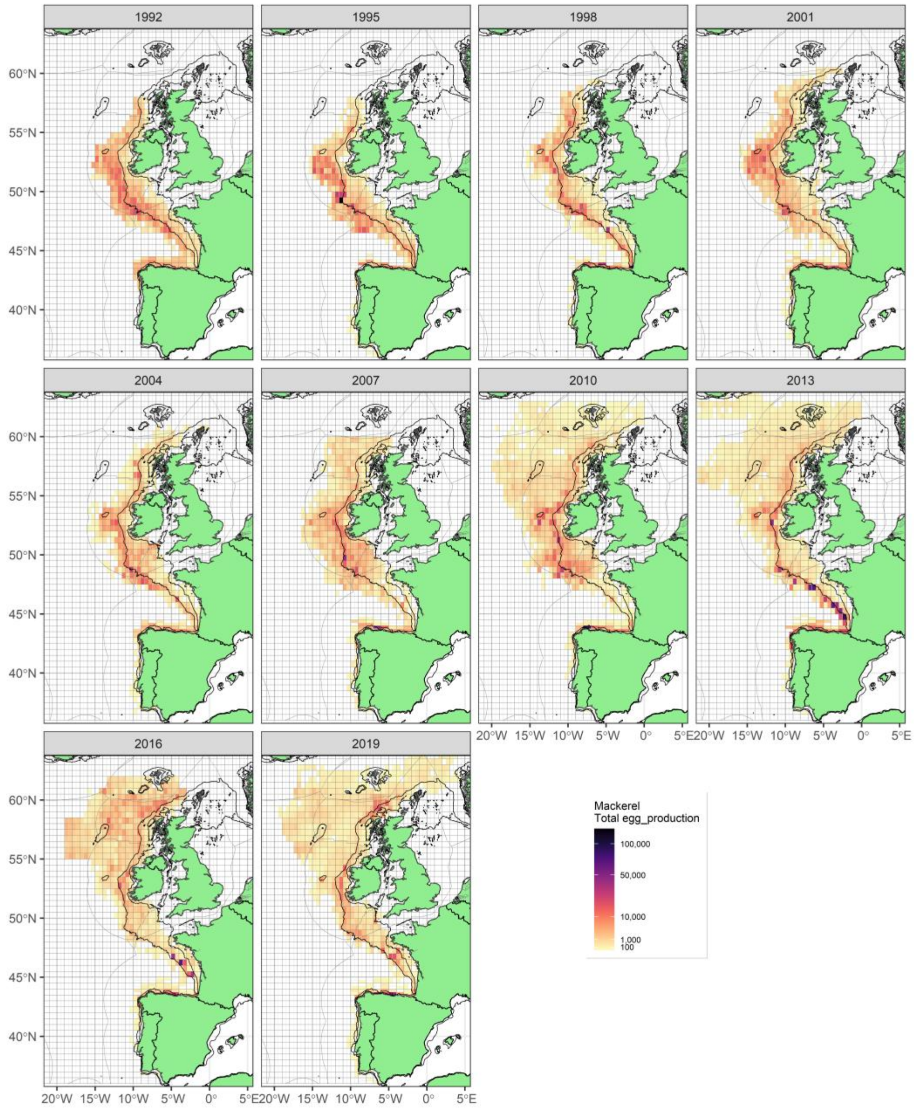

Figure 4.2.1. Distribution of egg production (stage 1 eggs/m2) by half ICES rectangle and survey year. The EEZ boundaries are shown.

Table 4.2.1. Triennial proportion of Northeast Atlantic (NEA) mackerel eggs by Exclusive Economic Zone (EEZ) from the Mackerel and Horse Mackerel Egg Survey (MEGS) undertaken to the south and west of the British Isles. The abundance of mackerel eggs for the whole spawning period (January–early July) is a proxy for biomass of spawners. * Indicates when a zone was unsampled during a survey.

Survey year	EU27	FO	FO_IC	INT	IC	NO	UK	UK_FO
1992	88.28	*	*	1.45	*	*	10.28	*
1995	92.48	*	*	1.88	*	*	5.63	*
1998	87.63	*	*	0.05	*	*	12.32	*
2001	89.36	0.02	*	0.53	*	*	10.08	0.02

2004	83.56	0.05	*	1.47	*	*	14.9	0.03
2007	83.72	0	*	1.83	*	*	14.27	0.18
2010	78.88	0.59	0	5.65	0.22	*	14.52	0.14
2013	89.2	0.86	0	1.36	0.2	*	8.23	0.15
2016	56.04	6.32	*	7.1	0.36	*	28.95	1.24
2019	66.4	2.34	0	5.02	1.22	0.36	23.53	1.13

4.2.2 North Sea

In 2021 there was a change in survey design to a single period (peak spawning time) and bigger area (see section 3.2.1.2). In this new survey design mackerel eggs were found distributed in the North Sea (53.5-62N°) with the highest densities of eggs found off the northeast coast of England, which is consistent with the pattern seen throughout the time series presented (Figure 4.2.2 and table 4.2.2 [1999-2021]). The change in 2021 survey design may have resulted in some differences in the distribution of eggs when compared with the previous years presented. Crucially, the larger survey area in 2021 survey revealed high densities of eggs off the coast of Norway in areas which have previously not been included in the survey. The newly designed 2021 survey found a more sporadic distribution of the highest densities of mackerel eggs across the North Sea that differed from the more concentrated high-density areas seen in previous years surveys (Figure 4.2.2).

The estimates by EEZ shows that eggs are mostly found UK waters followed by Norway and then the European Union (Table 4.2.2). The temporal patterns in the distribution of Mackerel eggs (Figure 4.2.2) explain the changes observed across years in the proportions by EEZ.

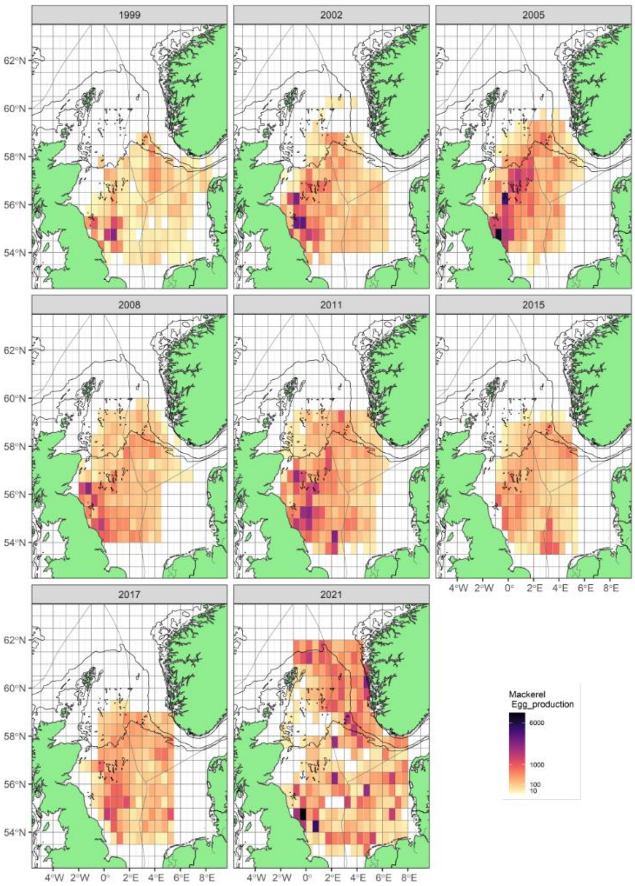

Figure 4.2.2. Distribution of egg production (stage 1 eggs/m2) by half ICES rectangle and survey year. The EEZ boundaries are shown. Note that egg production was estimated by means of AEPM between 1999 and 2017, and by means of DEPM in 2021.

Table 4.2.2. Triennial proportion of Northeast Atlantic (NEA) mackerel eggs by Exclusive Economic Zone (EEZ) (Note that both Jan Mayen and Svalbard are included in Norwegian EEZ) from the Mackerel and Horse Mackerel Egg Survey (MEGS) undertaken in the North Sea. The abundance of mackerel eggs for the whole spawning period (May–July) is a proxy for biomass of spawners in this area. * The 2021 survey utilised the Daily Egg Production Methodology and as such only constitutes one survey period, differing from previous surveys.

Survey year	EU27	NO	UK
1999	12.3	23.11	64.59
2002	10.53	12.66	76.8
2005	5.09	13.98	80.93
2008	7.09	17.92	74.99
2011	10.87	13	76.12
2015	27.08	21.66	51.26
2017	16.36	21.57	62.07
2021*	20.5	35.39	44.11

4.3 International Bottom Trawl Surveys (IBTS)

Mackerel recruits (age 0) are distributed in a band that runs from the southern Bay of Biscay, west of the British Isles, north of Scotland, and into the northern North Sea (Figure 4.3.1). Overall, the shelf around Ireland and Scotland and the northern North Sea are the most important nursery areas, although some changes have been observed over the years. At the beginning of the timeseries, the highest densities of recruits were found to the northwest of Ireland and the northern North Sea. However, since 2005 the nursery area has expanded and covered from the northwest of Ireland to the east of Orkney Islands. Between 2011 and 2018 the recruitment index in the North Sea decreased while increasing west of Ireland, in the Celtic Sea and the Bay of Biscay. The recruitment levels in the North Sea increased again in 2019 and 2020 (Figure 4.3.1).

The estimates by EEZ indicate that mackerel recruits reside in both European Union and UK waters, and to a lower extent in Norwegian waters (Table 4.3.1). The temporal patterns in the distribution of recruits explain the changes observed across years in the proportions by EEZ.

Figure 4.3.1. Spatial distribution of mackerel juveniles at age 0 from October to March and from 1998 to 2020. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km^2) overlaid on modelled squared catch rates per 10 x 10 km rectangle. Each rectangle is coloured according to the expected squared catch rate in percent of the highest value for that year (white=0%, red=100%). See Jansen *et al.* (2015) for details.

Table 4.3.1. Annual proportion of age-0 Northeast Atlantic (NEA) mackerel abundance by Exclusive Economic Zone (EEZ) from International Bottom Trawl Surveys (IBTS) undertaken on the western European continental shelf. Data are taken from surveys undertaken in Quarter 4 (Q4) and the following Quarter 1 (Q1) and are identified as the year class (the year in which eggs were spawned). * Indicates negligible percentages in all years.

Year class	EU27	FO	INT*	NO	NO_EU27*	UK	UK_FO*
1998	42.93	0.1	0	14.37	0	42.46	0.12
1999	47.79	0.1	0	12.06	0	39.93	0.12
2000	44.82	0.08	0	13.07	0	41.93	0.1
2001	46.49	0.08	0	11.9	0	41.43	0.1
2002	53.63	0.07	0	8.15	0	38.05	0.09
2003	52.33	0.09	0	9.47	0	37.99	0.12
2004	40.65	0.18	0	8.38	0	50.54	0.25
2005	28.65	0.21	0	8.75	0	62.07	0.31
2006	33.49	0.22	0	7.26	0	58.7	0.32
2007	38.63	0.13	0	8.97	0	52.08	0.18
2008	38.58	0.12	0	5.84	0	55.27	0.19
2009	39.01	0.09	0	13.48	0	47.29	0.12
2010	38.83	0.10	0	13.48	0	47.46	0.13
2011	46.61	0.09	0	11.39	0	41.81	0.1
2012	61.18	0.05	0	6.69	0	32.01	0.06
2013	56.66	0.09	0	6.74	0	36.39	0.12
2014	47.89	0.11	0	8.58	0	43.25	0.16
2015	62.34	0.06	0	5.75	0	31.77	0.08
2016	45.68	0.12	0	16.16	0	37.89	0.15
2017	51.89	0.06	0	13.82	0	34.16	0.07
2018	55.18	0.1	0	9.87	0	34.71	0.13
2019	37.01	0.16	0	17.43	0	45.18	0.22
2020	37.11	0.13	0	12.88	0	49.71	0.16

5 Results derived from catches

5.1 Overview of submitted data and methodology for partitioning catches to zones

Data source – data currently held by the ICES WGWIDE. A new data call was not submitted at this time due to the short time period between the set-up of the Working Group and the required submission of the report.

The data consisted of catch by nation state, by ICES statistical rectangle and by month. The available data consisted of monthly catches between 2006 and 2020 and for some nation states by quarter for the years 1998 to 2005. Some updates to the data were requested and supplied to correct for missing data or to replace quarterly data by monthly data 2006-2020:

- UK England: catches by quarter to catches by month and errors corrected to agree with the annual catches.
- France: added catch by rectangle data for 2015 (only available by quarter).
- Portugal: catches by quarter to catches by month 2010-2020.
- Greenland: catches by quarter to catches by month 2019.
- Ireland: full revision of the data to address missing years 2000-2020.
- Faroes: catches by quarter to catches by month 2008.
- Russia: catches by quarter to catches by month 2008.

In the dataset, the catch zone was not identified, so that for the purposes of this report, the zonal apportionment outlined in section 3.1 was used, using the proportion of rectangle in each zone.

A final csv (comma separated) file was produced for the years 2006-2020 containing catches by country by rectangle by month by zone. This file was then used to plot maps and create tables of catches by zone in the report.

5.2 Description of Fishery

As a widely distributed and migratory species, NEA Mackerel is exploited over a wide geographic range throughout the year. Significant fisheries extend from the Gulf of Cadiz, along the western and northern Iberian costs, through the Bay of Biscay, S, W and N of the United Kingdom and Ireland, into the northern North Sea and the Norwegian Sea and, in more recent years as far north as 72°N and west into Icelandic and east Greenland waters (Figure 5.3.3).

The fishery is international and, as such it is exploited by several nations using a variety of techniques determined by both the national fleet structure and the behaviour of the mackerel. At the onset of the spawning migration, large mackerel shoals move out of the northern North Sea initially to the west before moving south down the west coast of Scotland and Ireland. The timing of this migration is variable but generally occurs around the end of quarter 4 and the start of quarter 1. During this time, they are targeted primarily by Scottish and Irish pelagic trawlers with RSW tanks and also by freezer (factory) vessels (primarily Dutch and German). Prior to the onset of this migration the mackerel are overwintering, relatively static and are targeted by a large Norwegian purse-seine fleet. During summer, the mackerel are more widely dispersed as they feed in Northern waters. At this time Russian pelagic freezer trawlers and, in more recent times, Icelandic, Faroese and Greenlandic pelagic vessels are active. The southern fishery takes place at the start of the spawning season upon completion of the spawning migration. The Spanish fleet is comprised of both bottom and pelagic trawlers and also a large artisanal fleet. There are other smaller scale fisheries such as a

Norwegian gillnet fleet and an English handline fleet that operates in the otherwise restricted area known as the Cornwall or Mackerel box.

There are a number of national and international agreements to control the exploitation of the NEA Mackerel stock. A full description of the regulations that were in force for the mackerel fishery in each year by each of the Coastal States, including access rights, are outlined in a separate report. This information can be obtained on request from the Chair of the Coastal States Mackerel Group and will be useful for interpreting both annual and inter-annual spatial patterns in the commercial catch data.

5.3 Seasonal and interannual patterns

Interannually, relative catches of mackerel fluctuate by year for all zones (Figure 5.3.1, Figure 5.3.3, Table 5.3.1). More than 30% of the total catches are annually taken from UK waters for the studied period (2006-2020), and this proportion increased up to 53% in the last three years. Catches from international waters have also increased since 2014 (tables in A2.3), and in the last four years around 20% of the catches came from this zone. On the other side, relative catches from EEZ of Norway, EU, Iceland, and Faroe Island have recently decreased. Seasonally, catch patterns show two peaks: in January and from June-October (Figure 5.3.2) which appears the case for all assessed years. However, when pooled into five-year averages, larger portions of catches in the autumn period appear to be taken in years after 2011, whereas in years 2006-10 the relative catch forms a trough between July-October. Yet, the period 2006-10 had a greater relative catch during the January peak than the remaining time periods. On a spatial scale, when considering the months exhibiting greater relative catch, mackerel are present in more northern waters (Figure 5.3.4) during their feeding migration.

Additional figures and tables showing the spatial and temporal distribution of mackerel catches can be found in annex A3.

Table 5.3.1 Proportion of catches of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) from 2006–2020. Catch proportions of 0 were present for certain zones (NOR_EU27, RUS) across the full time series and were thus removed from the table.

Year	EU27	FO	FO_IC	GR	INT	IC	NO	SJM	SVA	UK	UK_FO
2006	24.72	1.86	0	0	4.54	0.38	36.3	0.01	0	32.16	0.03
2007	25.26	2.83	0	0	4.37	5.2	30.53	0.05	0	31.65	0.1
2008	25.88	8.53	0.01	0	4.72	10.91	18.19	0.06	0	31.66	0.04
2009	29.31	2.83	0.18	0	4.13	14.60	9.73	0.08	0	39.03	0.11
2010	27.62	7.82	0	0	5.20	14.73	13.64	0.09	0	30.89	0.01
2011	10.48	13.93	0.19	0.01	5.15	17.47	10.94	0.01	0	41.78	0.05
2012	14.07	11.64	0.13	0.61	5.65	18.45	15.45	0.15	0	33.83	0.02
2013	9.06	15.62	0.15	6.35	6.66	16.2	10.27	0.19	0.03	35.46	0.01
2014	12.75	7.42	0.06	5.91	9.48	12.08	12.21	0.12	0.03	39.63	0.32
2015	13.95	7.42	0.02	1.92	11.88	11.71	18.1	0.08	0	34.84	0.08
2016	7.87	13.7	0	2.87	10.30	7.56	19.4	0.09	0	38.13	0.08
2017	5.68	6.44	0.01	2.16	18.58	9.93	13.92	0.03	0	43.13	0.12
2018	6.91	5.27	0	4.81	19.58	8.09	4.05	0.42	0	50.79	0.09
2019	9.42	4.78	0.01	0.67	22.54	7.66	4.69	0.17	0	50.02	0.03
2020	10.48	4.25	0	0	20.93	4.43	6.54	0.2	0	53.09	0.07

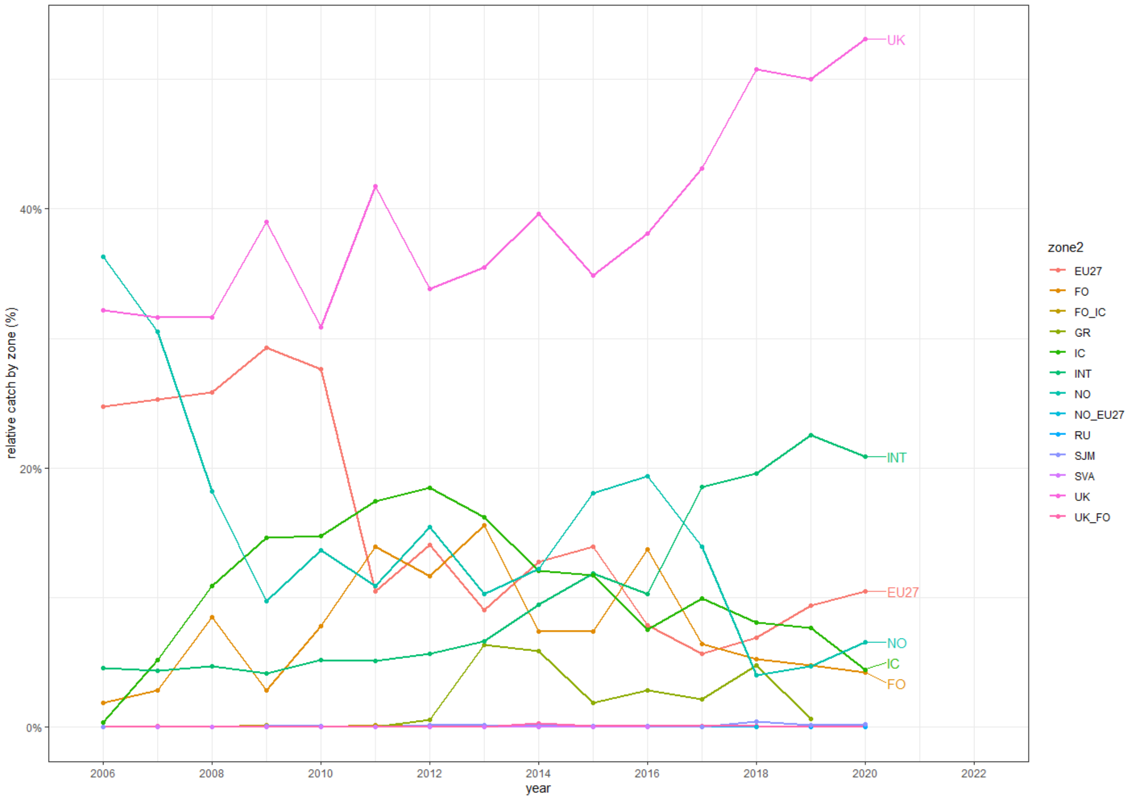

Figure 5.3.1. Relative catch (%) of northeast mackerel by exclusive economic zone.

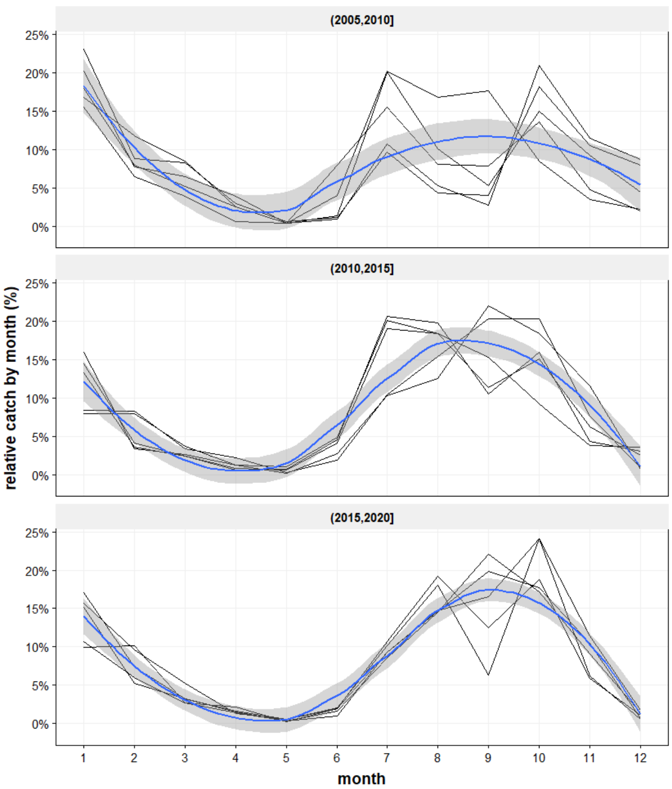

Figure 5.3.2. Relative catches by month, disaggregated in blocks of 4 (first panel) and 5 (second and third panel) years. Black lines represent individual years, whereas the blue line is the average trend of catches for the block. The grey area shows the confidence intervals of the average trend.

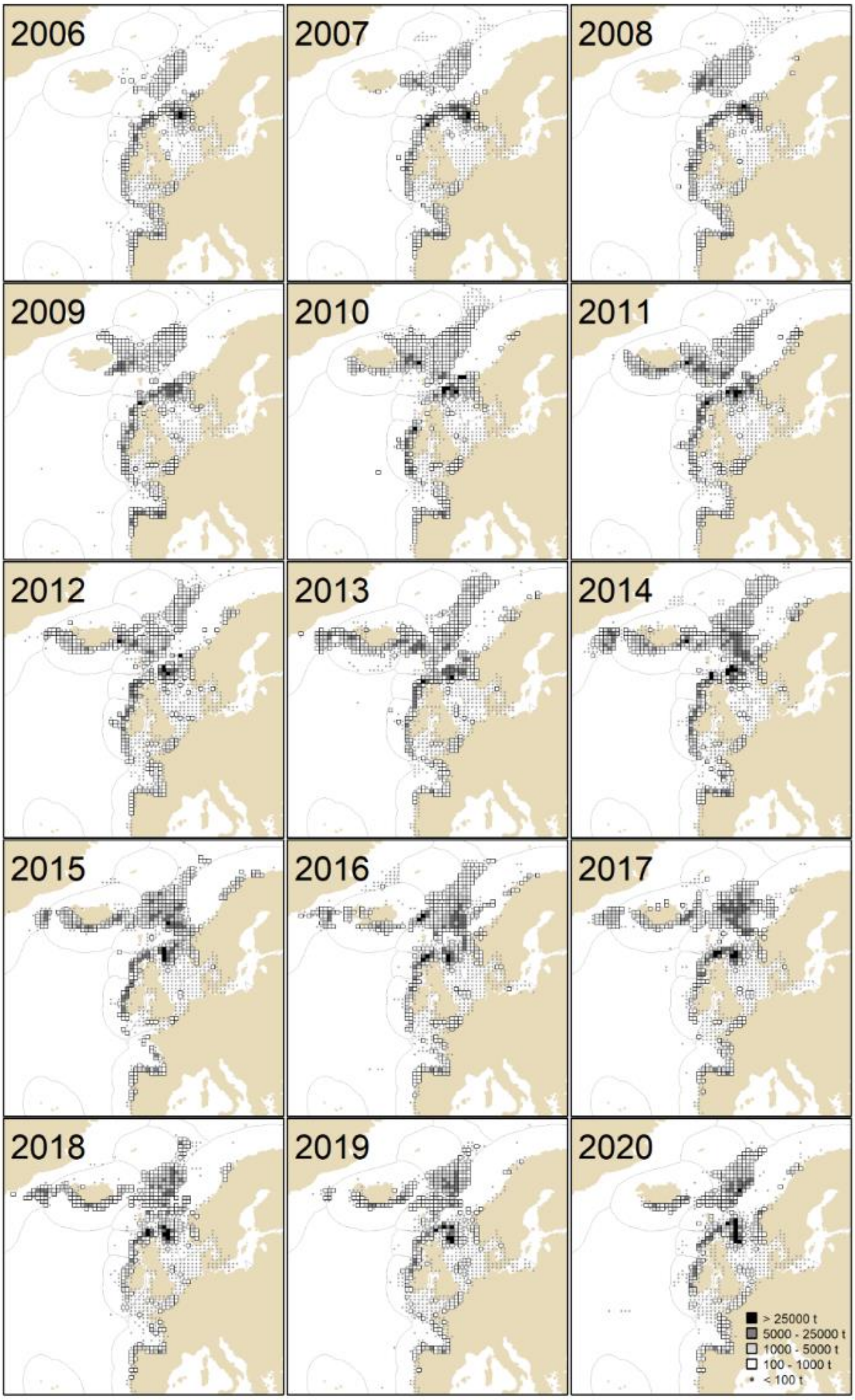

Figure 5.3.3. Annual aggregated catches of Northeast Atlantic (NEA) mackerel for individual years between 2006–2020.

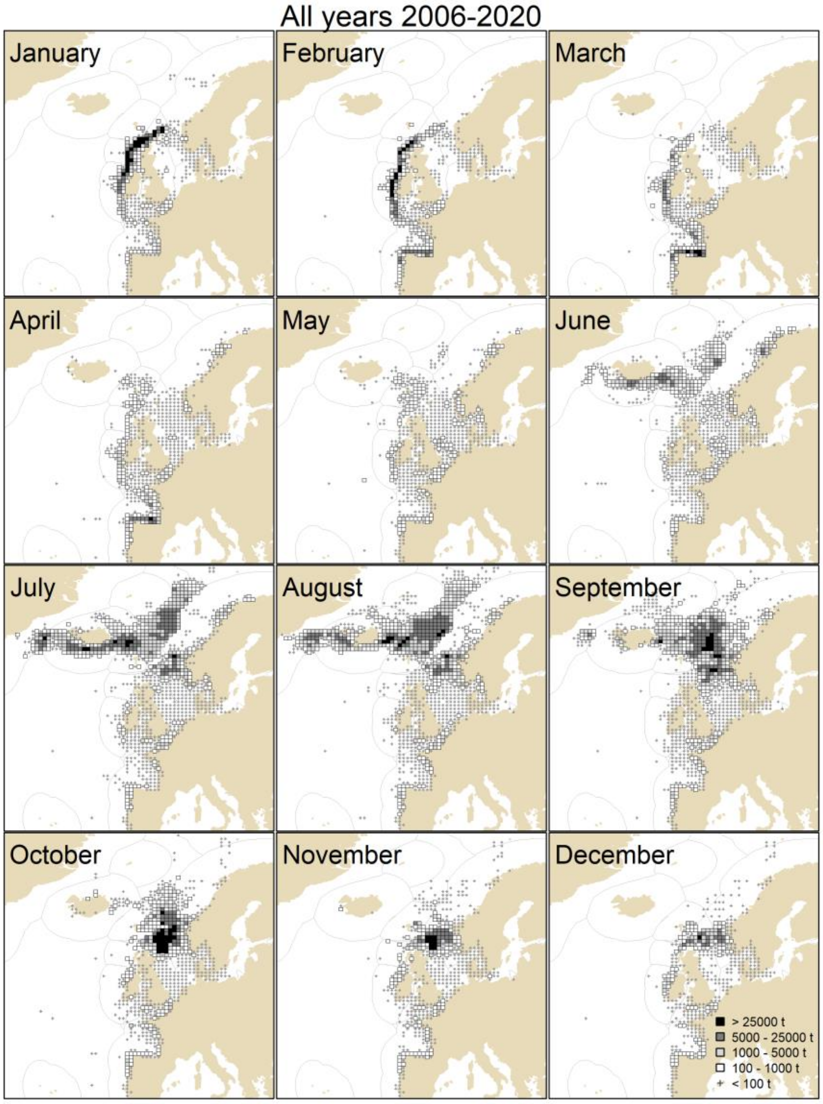

Figure 5.3.4. Cumulative catches of mackerel for individual months for all years between 2006-2020.

6 Discussion and conclusions

The 'Terms of Reference' set the time frame for the fishery independent and fishery dependent data as starting in 1977. The original reason for starting in 1977 was because the first fishery independent survey occurred in that year (the first Mackerel and horse mackerel egg survey). A subsequent examination of the quality controlled available data indicated that the readily available time series was shorter (started in 1992). In regard to the other two surveys where quantitative distributional data were available the start of the time series were later, 1998 for the IBTS and 2010 for the summer survey (IESSNS), although large-scale distributional mackerel data are also available from 1995 in the Norwegian Sea. The last set of data readily available were the catch data which were only available from 2006 at the level of catch per ICES statistical rectangle, per month in each year. Whilst this report gives the complete time series for each data set, the core data set currently available, where there are quantitative distributional data on the spawning, summer feeding, juvenile and catch distributions are for 2006 to 2020. An extension of a quantitative time series of the distribution of mackerel to earlier years will entail further analyses of survey and catch data and a consideration of the additional survey data not analysed here (see Annex 1).

The ’Terms of Reference’ also required data to be presented on an annual, quarterly and/or monthly/survey basis. Unfortunately, the fishery independent data did not fit into just one of these categories for a variety of reasons. The way that the spawning survey (MEGS) was conducted meant that it was only feasible to present a single spawning distribution covering a period of approximately 6 months (Quarters 1 and 2). The adult summer distribution (IESSNS), from late June to August, could be considered as representative of the distribution in Quarter 3. The juvenile (age 0) distribution can be considered as indicative of the distribution over the periods Quarter 4 and 1. All the distributions from survey data, therefore, are not easily lined up within the framework or either a monthly or a quarterly distribution. On the other hand, the catch data from 2006 to 2020 is compatible with investigations at the monthly, quarterly or annual level of resolution.

The ’Terms of Reference’ also made reference to all life stages. It is apparent that the available survey data on the quantitative distribution of the stock is currently not able to provide information on at least two ages in the life history (age 1 and 2) nor the spatial distribution of the stock during the winter period (Quarter 4 and period before occurring on the spawning grounds in Quarter 1). The report is able to provide both the currently available survey and catch data by zones (EEZ) and thus provide the proportion of the surveyed or captured stock in each of the Coastal State EEZs.

As stated above, there are other survey data sources that could be explored. The catch data can be also extended, but possibly not at the same level of resolution presented here (by ICES statistical rectangle and month). During the analyses of the catch data, it came to light that since the catch data held by ICES did not identify the zone but the ICES rectangle, there was potential for bias from the allocation methodology used. The reason is that the licence of the vessel determines in which zone it is allowed to fish. The majority of the catches are not an issue since 80.3% occur in a single rectangle which can be identified to a zone. However, 17.4% the catches occur in rectangles covering two zones and 2.3% in rectangles covering three zones. As an illustration of the problem, an investigation of the 2015 the catches from one party could have been misrepresented by zone using the approach used on the WGWIDE data. The perceived change was probably less than 5%. This was not further investigated for all years so this remains as simply an illustration of a potential bias. In regard to these data, uncertainties should always be considered and specifically in regard to the current data set this may be one source of uncertainty. The extension of the catch data will require a new data call which will also need the data submitters to also designate the zone of the catch to correct any bias or inaccuracies generated in the present data set.

The surveys cover much of the stock over the spawning period, the summer feeding period and the age 0 nurseries. Unfortunately, as is to be expected of the surveys, they do not, and mostly probably never will, encompass the whole distributional area of a particular stage in the life history. The Working Group is of the opinion that each of the surveys provides a representative, overall, view of the stock distribution at the time of the survey. The principal caveat is that there will be an unknown proportion of the stock which is elsewhere and this must be considered when utilising the results presented in this report.

The data presented here also indicate that the distribution of the mackerel stock is dynamic with change occurring at short (inter-annual) and longer-term (decadal) temporal scales. Unfortunately, the drivers of the change are largely not fully understood.

In summary: The working group has compiled and systematized the available data from different surveys on the distribution of the mackerel stock and the catch statistics from the fishery. Although much of the survey data is not designed to cover the total stock, and the catch data often are results of quota and access agreement, the working group is of the opinion that overall the report gives a relevant general picture of the temporal and spatial (zonal) distribution of the mackerel stock in the recent period, even though it cannot be quantified in proportions of biomass per life-stage and per zone.

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Annexes

A1. Additional surveys which provide incomplete spatial or temporal coverage

A1.1 Precursor survey to the current IESSNS

This targeted mackerel survey during summer was initiated in 1995 and conducted by the Institute of Marine Research (IMR) in Norway with two vessels and since its inception was gradually expanded in geographical coverage due to the expansion of the mackerel stock (Iversen & Holst 1998; Nøttestad et al. 2007, 2011, 2014; Utne et al. 2012; ICES 2013a, b). Annual dedicated scientific surveys by Norway with targeted focus on abundance and spatial distribution of NEA mackerel have been conducted almost every year in the Norwegian Sea and surrounding waters in July-August (3rd Quarter) from 1995-2007. This mackerel survey came prior to the later extended international cooperation of IESSNS 2010 onward (see section 3.2.1.1).

The distribution of mackerel between 1995 and 2007 are shown in Figure A1.1. As with the IESSNS this survey used swept area calculations from pelagic trawl catches (kg/nmi) of NEA mackerel to estimate total swept area biomass index in tonnes.

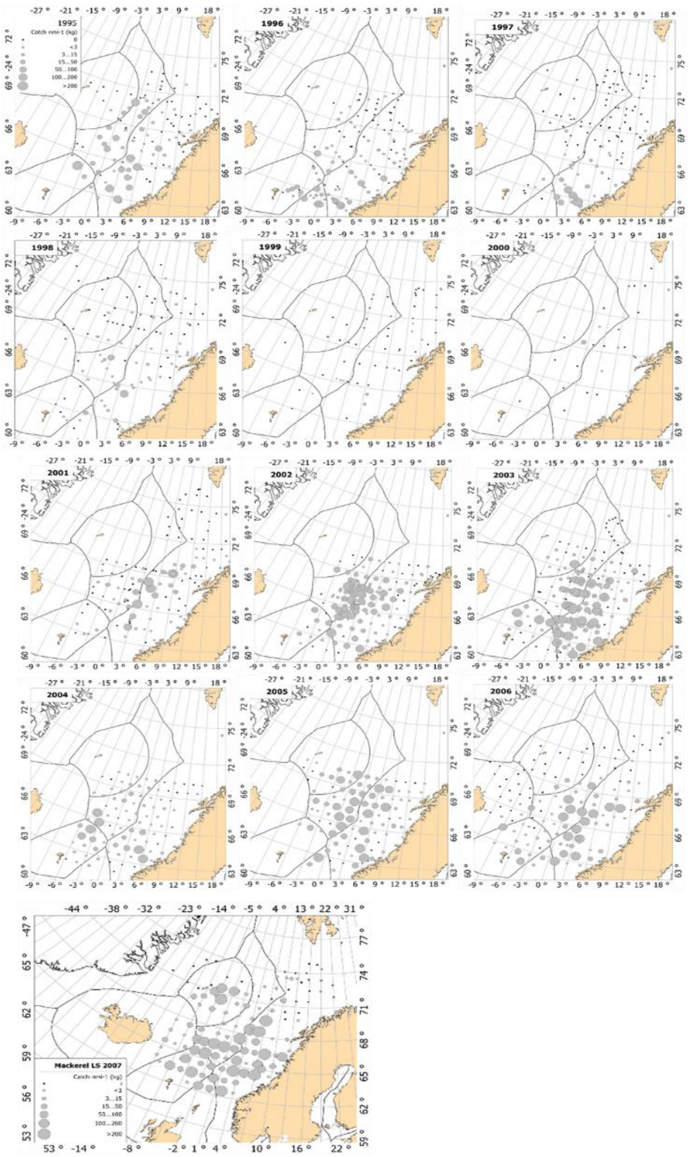

Figure A1.1. Mackerel distribution and abundance for the years 1995-2007. Mackerel catches from annual scientific surveys conducted by the Institute of Marine Research in Norway in the Norwegian Sea and surrounding waters in July-August (3rd Quarter). Catch rates are illustrated by grey circles where size/diameter represents catches (kg/nmi) of mackerel from the standardized pelagic trawling close to the surface. The national EEZs (including international waters) are shown on all of the maps.

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A1.2 Russian aerial surveys by PINRO on feeding mackerel in the Norwegian Sea (discontinued)

PINRO carried out annual aerial surveys on feeding mackerel in the Norwegian Sea in July in the years 1997 to 2005. All these surveys were carried out in the framework of ecosystem surveys also collecting oceanographic data, which describe current conditions and phenomenon at the sea surface and subsurface layers. Data on marine mammals and seabird distribution and abundance were collected as well to assess their potential predation pressure on fishes, specifically on mackerel.

For all surveys the aircraft AN- 26 # Arktika # was used with the following equipment onboard: IR- Radiometer and Scanner, Lidar system, synthetic aperture Radar, digital and analog photo-and video equipment. All measured and observed data, effects and parameters were stored on a computer in real time together with their geographical GPS positions.

Calibration and confirmation of fish concentrations were carried out by Russian and Norwegian research and commercial vessels. Mackerel spatial distribution in the Norwegian Sea in from 1997 to 2005 is presented in figures A1.2.1 & A1.2.2.

Mackerel biomass was calculated using LIDAR for 1998 and 1999.

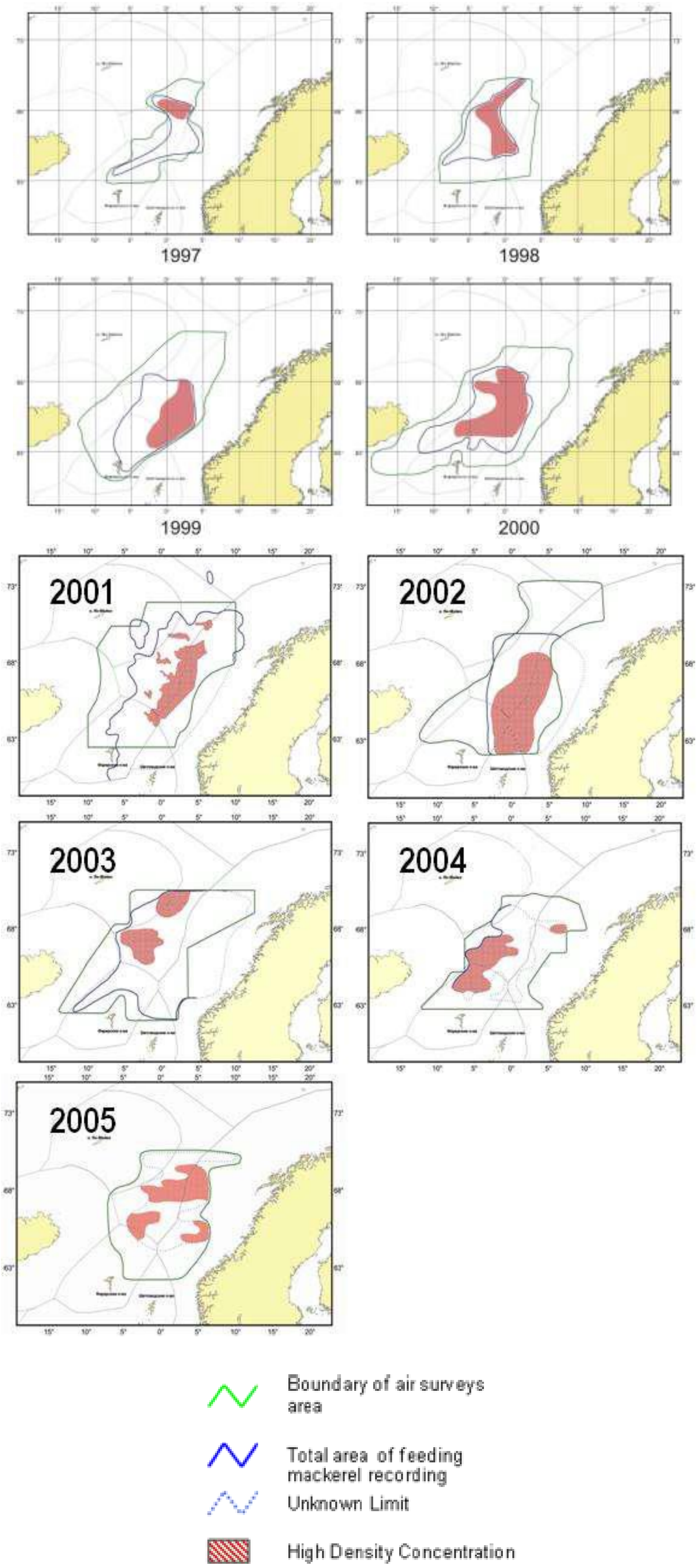

Figure A1.2.1 & A1.2.2. Spatial distribution of mackerel in the Norwegian Sea 1997-2005.

A1.3 Winter acoustic surveys on distribution and abundance of NEA mackerel in the northern North Sea (Quarter 4)

The Institute of Marine Research (IMR) in Norway initiated acoustic estimates of abundance and mapping of NEA mackerel with multifrequency echosounder combined with pelagic trawling on acoustic registrations in the northern parts of the North Sea annually during the overwintering period in October-November from 1999 to 2007 (Korneliussen and Ona, 2004; ICES 2005, 2006, 2007, 2013; Gorska et al. 2007; Slotte et al. 2007; Korneliussen 2010; Nøttestad et al. 2014), as well as in with two chartered Norwegian vessels in October 2012 (Peña et al. 2012). During October-November (4th Quarter) for the years 2000-2007 the acoustic surveys were conducted as a scientific collaboration between Norway and United Kingdom (UK).

Methodology

Over the years the overwintering distribution of NEA mackerel both in Norwegian and UK waters to a variable extent was covered during the acoustic surveys from October-November in 2000-2007. The overwintering distribution of NEA mackerel was only covered in Norwegian waters in October-November 1999. The methods used are described and documented in detail by Korneliussen and Ona (2004), ICES (2005, 2006, 2007, 2013), Gorska et al. (2007), and Korneliussen (2010). The scrutinized acoustic data were validated by biological data from repeated trawl samples of NEA mackerel.

Discussion

Maps of the mackerel distribution and abundance based on acoustic NASC (s_a) values (38 kHz) for each 5 nmi from dedicated acoustic scientific surveys in the North Sea in October-November (4th Quarter) from 1999-2007 are shown in Figure A1.3. It should be noted here that normally mackerel are assessed acoustically using 200 kHz rather than the 38kHz used here and there are still some unresolved issues with respect to the acoustic quantification of the signal, especially when large schools are encountered (Paul Fernandes, University of Aberdeen, *Pers. comm.*).

The main commercial fishery was concentrated in this general geographic area during the late autumn season (ICES 2013), indicating the spatial coverage of the acoustic surveys on NEA mackerel between 2000 and 2007 covered the area where the fishing fleet was concentrating their efforts. These studies show that multi-frequency acoustic surveys combined with pelagic trawl sampling are applicable for collecting data on the distribution of mackerel in the overwintering/pre-spawning phase (ICES 2013). The uncertainties in the conversion of acoustic data into biomass estimates have resulted in these data not being considered as quantitative as yet.

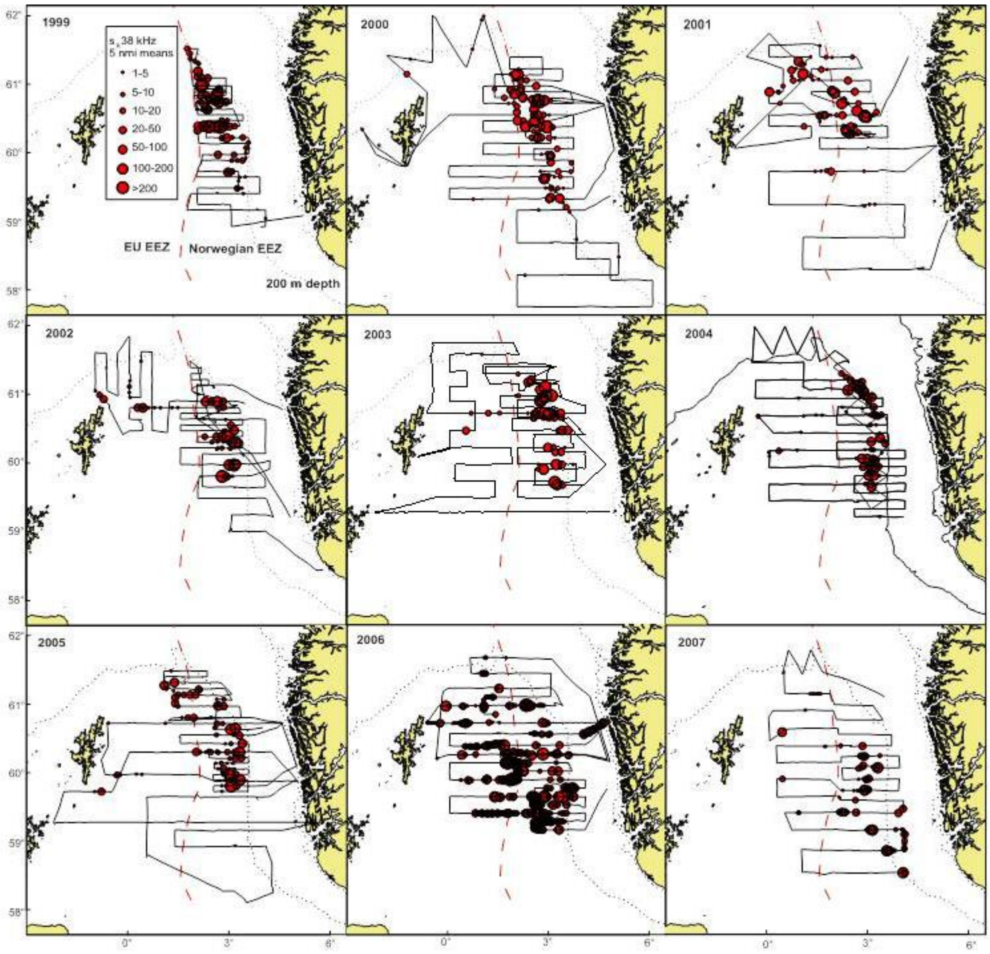

Figure A1.3. Mackerel distribution and acoustic NASC (s_a) values (38 kHz) for each 5 nautical mile from dedicated acoustic scientific surveys in the North Sea in October-November (4th Quarter) from 1999-2007. The survey lines are shown as continuous black lines on the maps. The international borders are shown with red stippled line.

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Slotte, A., Skagen, D. and Iversen S.A. 2007. Size of mackerel in research vessel trawls and commercial purse-seine catches: implications for acoustic estimation. ICES journal of Marine Science, 64:989-994.

A1.4 International Ecosystem Survey in the Nordic Seas (IESNS)

The IESNS is aimed at observing the pelagic ecosystem, focusing on herring (target species), blue whiting, zooplankton and hydrography. The survey, carried out in late April and May since 1995, is coordinated by ICES survey planning groups (PGNAPES and currently WGIPS) and is a cooperative effort by Faroes, Iceland, Norway, Russia, and since 1998 the EU (Denmark, Germany, Ireland, The Netherlands, Sweden and UK). Sampled trawl stations since 2004 are shown in Figure A1.4.1.

Although the survey is targeted on herring adult post-spawning mackerel are intercepted in the trawl samples in the southern and eastern fringe areas of the survey area.

Since mackerel is only caught a few trawl hauls in the south-eastern area during the May survey, the IESNS survey cannot be used for any zonal attachment (areal) analysis, but rather to indicate that post-spawning mackerel are on their way northwards already in May (i.e., entering the Faroese, the UK and the Norwegian zones in May). Further that since around 2008 also spawning mackerel is intercepted in the south-eastern survey areas (Fig A1.4.2).

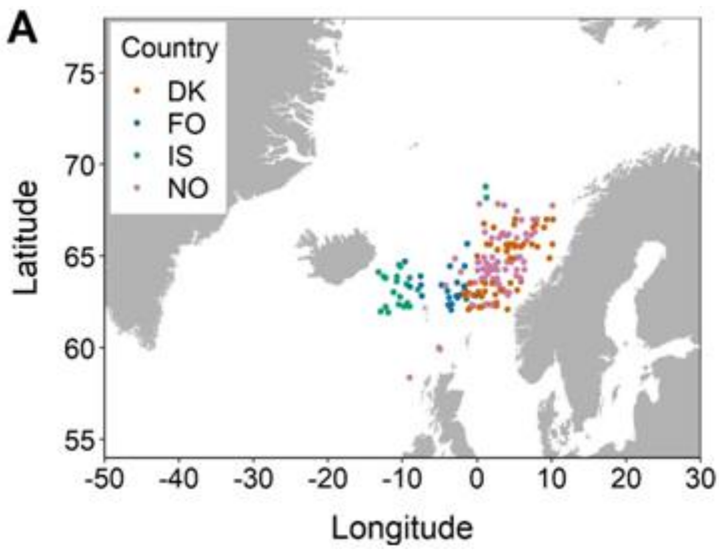


Figure A1.4.1. General overview of sampling areas covered for each country from 2004 to 2021. All stations during the IESNS survey in May.

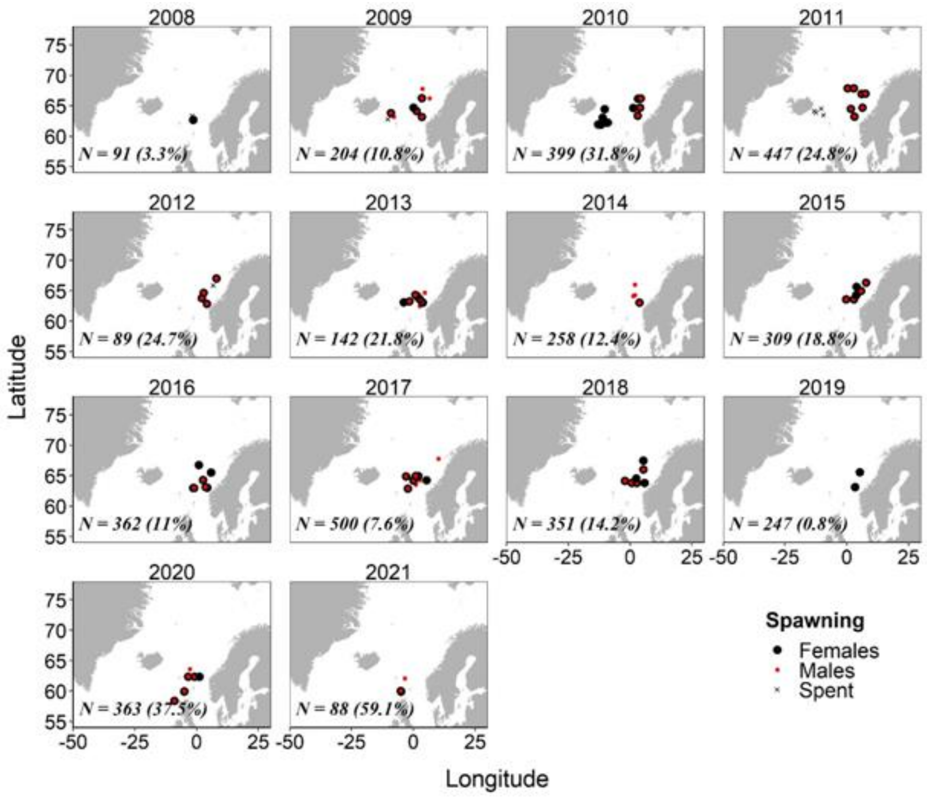


Figure A1.4.2. Long-term distribution of early maturation (A), mature (B) and, spawning and partly spent (C) females and males in Nordic waters during May. N denotes the total number of individuals and percentage the frequency males and females in each maturity stage combined. Spent fish are also present but not accounted in the percentage value (pers. comm. Thassya C. dos Santos Schmidt, IMR, Bergen, Norway).

A1.5 The Western European Shelf Pelagic Acoustic Survey (WESPAS)

WESPAS is an annual survey conducted by the Irish Marine Institute. It is an amalgamation of the Irish component of the Malin Shelf herring acoustic survey which has been carried out annually since 2008 in ICES Subreas 6a and 7bc and the boarfish acoustic survey which was first conducted in 2011 in 7hjk and the north of 8c on a commercial vessel. In 2016, these surveys were combined into the WESPAS survey and have been conducted by the *RV Celtic Explorer* since this time. The survey is conducted over 6 weeks in June and July, covering the shelf waters from 47˚30’ N to 58˚30’ N. The 2021 survey track is shown in figure A1.5.1.

In 2017, the survey design was changed and since this time it has started in the south in north Biscay and worked in a northerly direction in a series of parallel transects spaced 10-15nm apart. The western extent of the transects coincides with the shelf break and depths of approximately 300m with the exception of the Porcupine bank (400m). The easterly extent of the transects generally coincides with the land mass (min. depth 50m) with the exception of Celtic Sea transects. Transects may extend further east or west than planned as they are usually only ended once a number of miles have been completed with no acoustic detections. The survey design consists of a number of strata (species specific) with a total transect length of approximately 5000nm (9250 km) and area coverage of 65,000 nm^2 (225,000 km^2).

Acoustic data is collected by a Simrad EK60 on 4 frequencies (18,38,120 and 200kHz). Echograms are scrutinised and individual schools are identified to species level where possible.

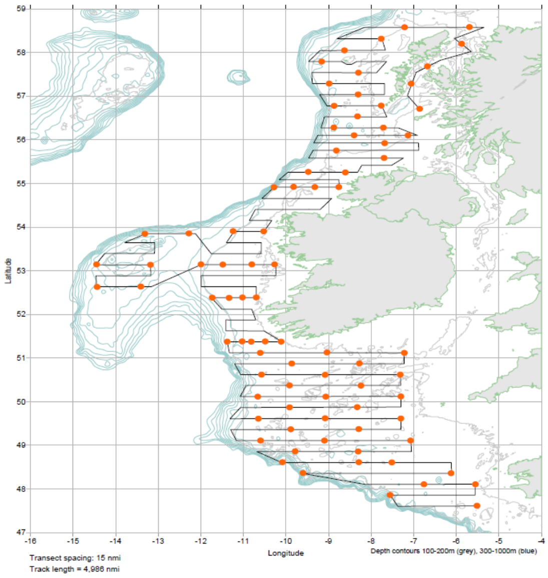


Figure A1.5.1. WESPAS 2021 survey track with CTD stations.

Biological sampling is carried out using a single midwater pelagic trawl 85m in length with a fishing circle of 420m. The mesh size in the wings is 2.4m, reducing to 10cm in the cod end. The net is fished with a vertical opening of approximately 25m and monitored via a headline transducer and door sensors.

The complete catch from each haul is separated by species and sampled for length and weight with further subsampling for age, sex, maturity for the primary survey target species (herring, boarfish and horse mackerel). Also recorded during fishing operations are a number of metrics associated with the fishing tow including tow speed, door spread, tow duration, warp length, headline depth and temperature at the headline. Tow depth varies according to the position of the target, duration is generally between 30 and 60 minutes but occasionally shorter if the headline transducer indicates a potentially large catch.

Hauls are primarily undertaken to obtain samples from acoustic registrations from the survey target species and are therefore not conducted at predetermined locations or depths. However, non-target species, most commonly mackerel, are often caught either in a mix (usually with herring) or as the sole species.

Figure A1.5.2 shows the location of the hauls from each of the surveys between 2016 and 2021. Hauls with no Mackerel, those with Mackerel present and those with 20kg or more of Mackerel are indicated.

WESPAS Hauls 2016-2021

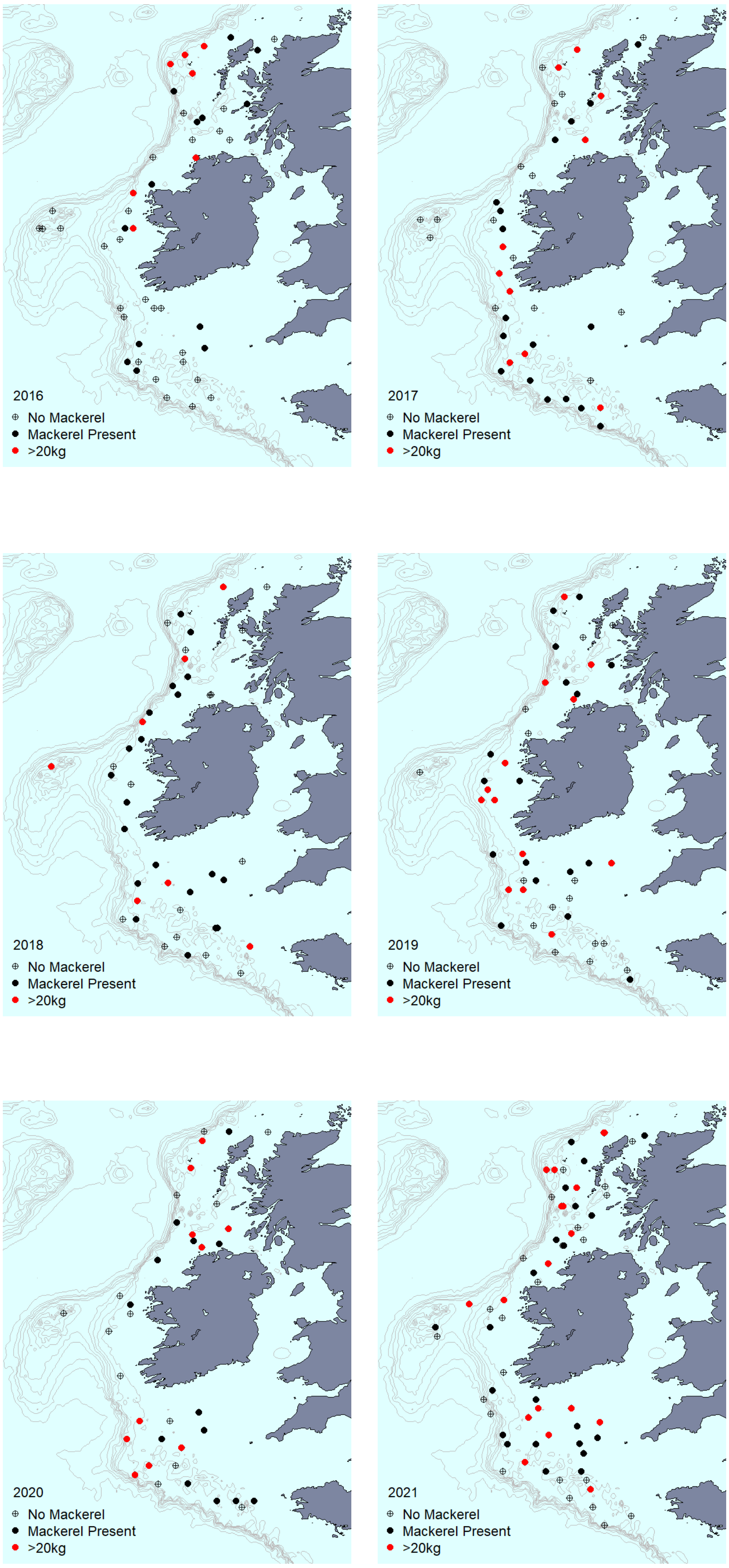


Figure A1.5.2. WESPAS survey hauls indicating those with no mackerel, those with mackerel (filled circles) and those with greater than 20kg of mackerel (red).

Since 2017, mackerel has been caught in over 60% of the survey hauls in each year. In 2016, 43% of hauls contained mackerel. Surface temperatures in 2016 were the highest in the time series, in excess of 17˚C south of 50˚N although it should also be noted that the survey was conducted from north to south in this year such that the sampling in southern waters will be several weeks later than that in surveys since 2017. The highest proportion of hauls containing mackerel was recorded in 2020, a relatively cool year. The proportion of hauls with more than 20kg of mackerel has increased in the most recent years.

Aside from the distribution noted for 2016, there appears to be little geographical variation in the distribution of hauls containing or devoid of mackerel. Hauls containing over 20kg of Mackerel are also widely distributed over the survey area.

A1.6 Portuguese groundfish surveys (ICES Division 9a) (IBTS Western Quarter 4 Survey)

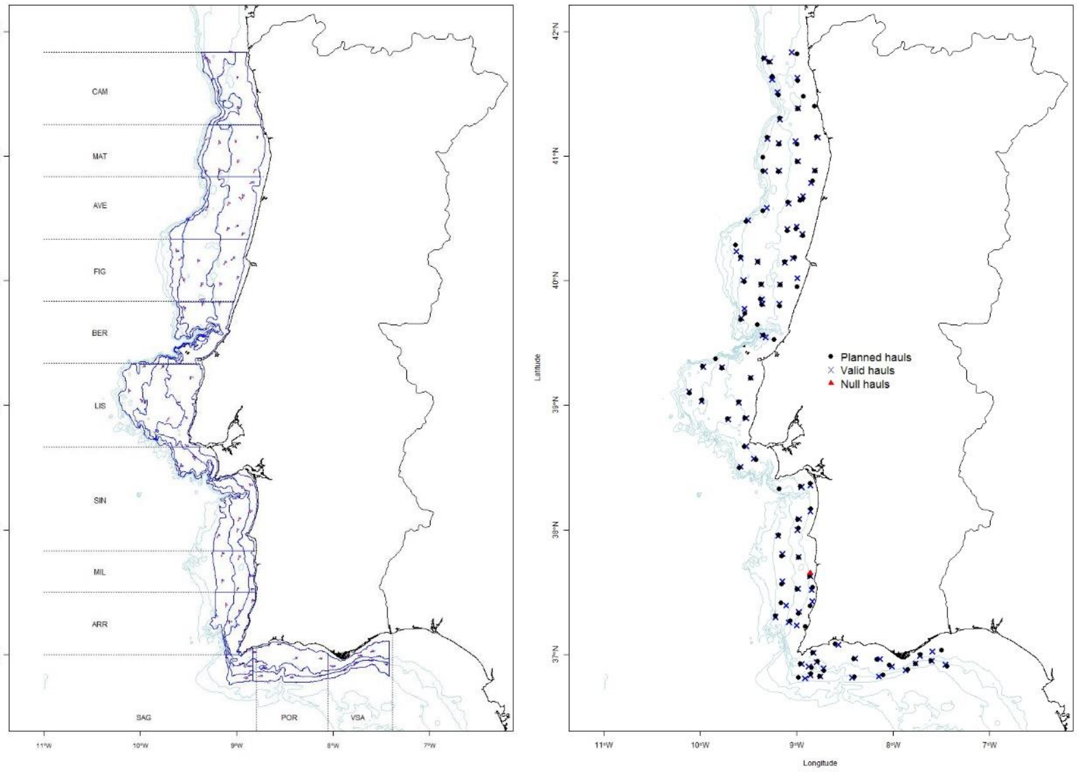
Portuguese groundfish surveys are conducted along the whole Portuguese continental waters (ICES Division 9a) since June 1979, onboard R/V Noruega, annually in Autumn and partially in Summer (until 2001) and Winter (until 2008). The main objectives of these surveys are to monitor the abundance and distribution of hake and horse mackerel recruitment (Autumn), monitor the abundance and distribution of hake in spawning season (Winter) and, for all surveys: (i) estimate abundance indices and biomass of the most important commercial species; (ii) biological parameters (e.g. maturity, ages, sex-ratio, weight, food habits); and (iii) biodiversity on the sampling area. The primary species were hake, horse mackerel, blue whiting, mackerel, chub mackerel, anglerfish, megrim and Norway lobster (ICES, 2017).

Methodology (relevant for mackerel)

The Portuguese Autumn groundfish/or demersal survey (PT-PGFS-Q4) plan, comprises 96 fishing stations, 66 at fixed (grid) positions and 30 at random, spread over 12 sectors, subdivided into 3 depth ranges 20–100m, 101–200m and 201–500m (Figure A1.6.1). Details of the survey design can be found in ICES (2017) and references therein.

Due to misreporting or irregular sampling (before 1990) and due to disruption of the series (Summer and Winter series), the available data are from 1990 onwards and limited to Autumn surveys (1990-2021, except 2012, 2019 and 2020). Since the survey design does not cover depths below 500 m since 2005 and as mackerel was poorly caught in this depth range before, those depths were excluded from the analyses.

Abundance (number per hour) and biomass (kg per hour) estimation and their standard deviations were computed for the whole surveyed area and based on the methodology presented by Cochran (1977) for calculation of estimators for the stratified random sampling. As the species can form big shoals, catches in the survey were higher than 900 kg in 10 hauls in the whole series and were reduced to the 99% quantile of the remaining observations in the same survey. Data was corrected for maximum catches in 10 hauls in 1997, 2006, 2007, 2009, 2010, 2014 and 2017.



a b

Figure A1.6.1. Stratification (a) and hauls performed (b) during Portuguese groundfish Survey 2017.

Potential data contribution

The abundance in weight per hour tow of mackerel in the PT-PGFS-Q4 time series are shown in Figure 4.3.5.2. Some high values of mackerel have been recorded in the time series (e.g., 1997, 2006, 2009 and 2018).

A maximum length of 23 cm is used for this survey as a proxy of recruitment. The recruitment index is usually highly related with the abundance index.

The spatial distribution of mackerel in the demersal surveys is shown in Figures A1.6.2 and A1.6.3 as weight per hour tow and recruits (<23cm) per hour tow. The presence of mackerel in the Northern region of Portugal is constant, but is starting to expand to the Southern regions.

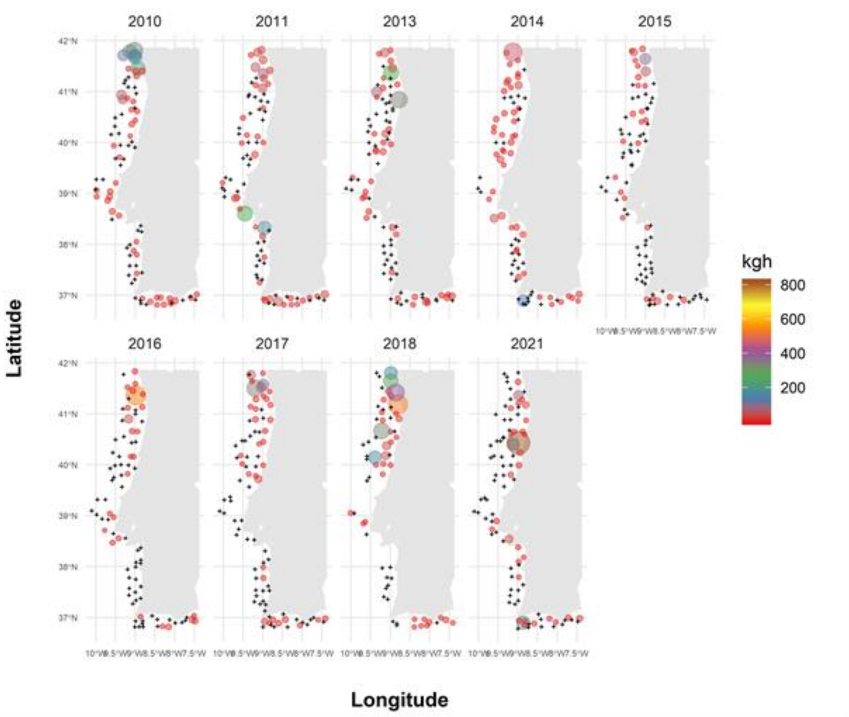


Figure A1.6.2. Mackerel abundance and spatial distribution as weight (Kg) per hour tow in the period from 2010 to 2021 Portuguese Autumn groundfish surveys.

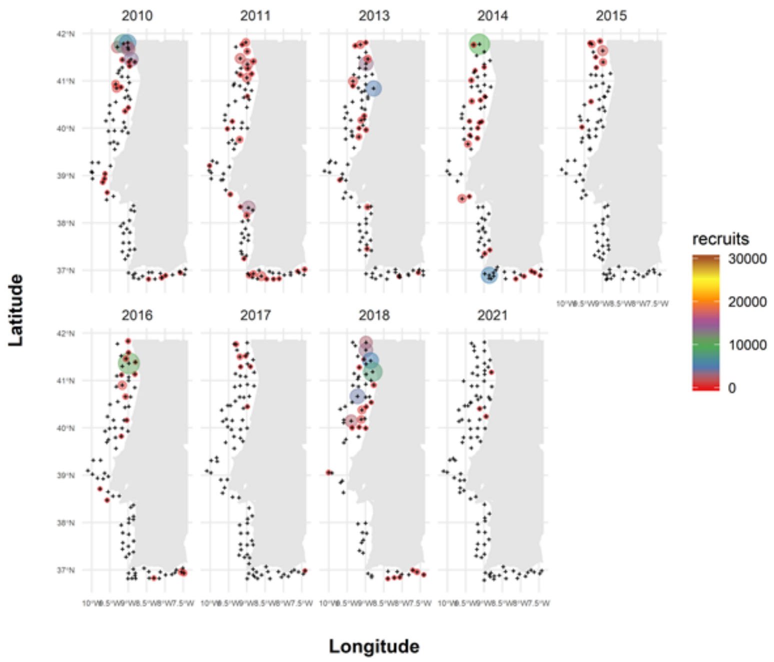


Figure A1.6.3. Mackerel recruits (<23cm) abundance and spatial distribution as number per hour tow in the period from 2010 to 2021 Portuguese Autumn groundfish surveys.

References

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A1.7 Spanish acoustic survey PELACUS in southern Biscay (northern Spain)

The Spanish acoustic survey PELACUS is carried out by Instituto Español de Oceanografía to monitor pelagic fishery resources in the north and north western shelf of Iberian Peninsula (ICES division 8c and 9a North). PELACUS survey takes place annually in spring (March to April). PELACUS survey started in 1984 and initial objective was to estimate the spring biomass of sardine. The list of fish species targeted for stock assessment purposes has expanded over time.

The most important species in terms of both frequency of occurrence and standardized mass in hauls were mackerel *Scomber scombrus*, hake *Merluccius merluccius*, horse mackerel *Trachurus trachurus*, *Sardina pilchardus* and bogue *Boops boops*. During the surveys, the acoustic energy reflected by marine organisms is measured continuously and pelagic trawls are carried out to help identify the species that are reflecting the acoustic energy. Both length and biological samples (weight, age, sex, and maturity stage) for each target species are collected at fishing stations.

The survey design consisted of a grid with systematic parallel transects with random start, separated by 8 nautical miles, perpendicular to the coastline, and is surveyed during daylight hours over a period of 30 days. This survey covers the continental shelf from 40 to 1000 m depth and from Portuguese-Spanish border to the Spanish-French border (see Figure A1.7.1).

The PELACUS survey provides a good indicator of the mackerel populations with an overlap in time and space for the start of spawning season of mackerel in the western part of Cantabrian Sea. The majority of the distribution, is located just in the middle of the Cantabrian Sea (Cape Peñas), extending throughout the surveyed area in last years. Biomass estimation of mackerel is done for on each survey stratum using the arithmetic mean of the backscattering energy attributed to each fish species and the surface expressed in square nautical miles and summed over the whole area (Figure A1.7.2)

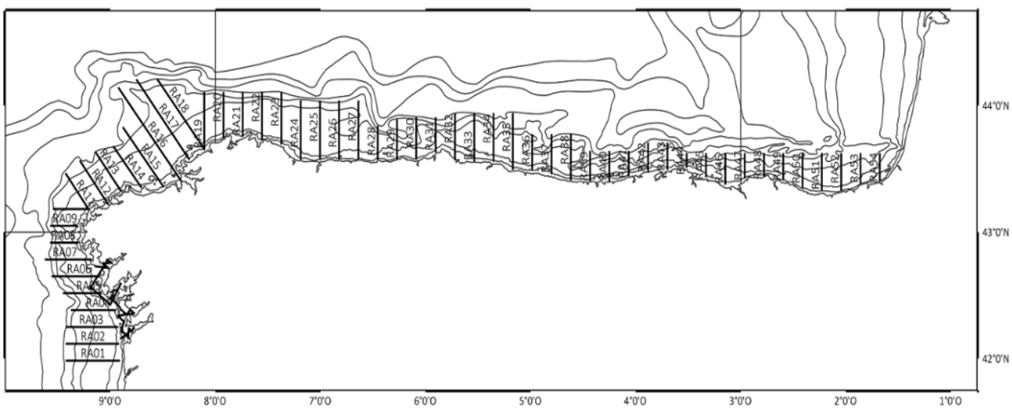

Figure A1.7.1. survey design of PELACUS acoustic survey.

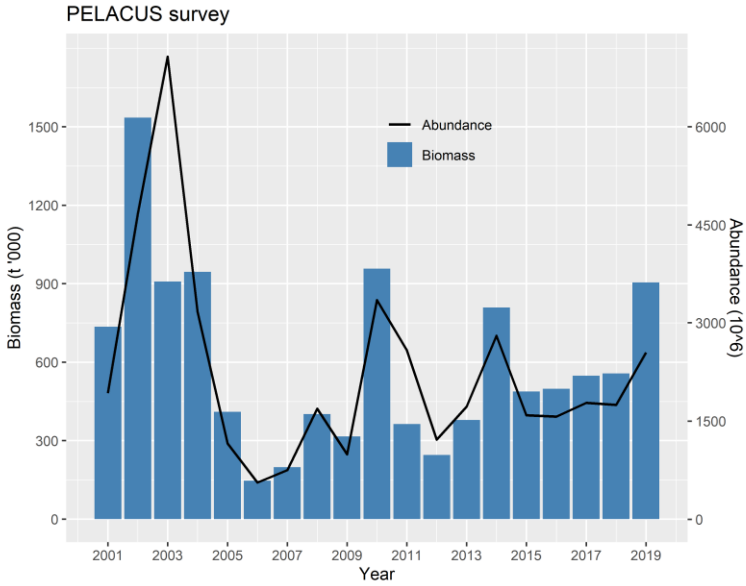

Figure A1.7.2. Mackerel biomass and abundance estimates from PELACUS acoustic survey.

A1.8 Acoustic surveys in the western English Channel and the Celtic Sea during Quarter 4

There are two acoustic surveys in the area encompassing the western English Channel and the Celtic Sea (south of Ireland) in the fourth quarter that record data from the 200 kHz echosounders. The western English Channel survey (Pelagic Ecosystem Survey of the Celtic Sea and Western Channel PELTIC) is undertaken in October/November each year and covers the years 2012 to the present. This survey is primarily targeting the sprat and sardine stocks in the area. The survey coverage has varied over the years, generally extending to the present coverage in recent years (see Figure A1.8.1). Whilst the acoustic and trawl catch data exist neither have been analysed to provide relative biomass distributional data.

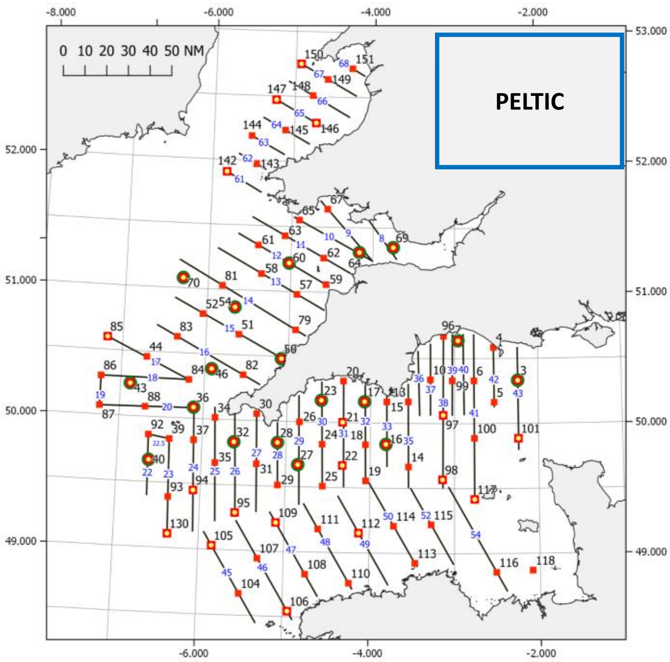

Figure A1.8.1. Survey coverage for the PELTIC survey in the western English Channel and the eastern Celtic Sea.

The second acoustic survey (Celtic Sea Herring Acoustic Survey CSHAS) in this area is targeted at the autumn/winter spawning herring stock (Celtic Sea, 7g-k) along the southern coast of Ireland and undertaken in October each year. The time series currently used in the Celtic Sea herring assessment encompasses the years 2002 to the present (2004 and 2007 are excluded primarily due to the timing and coverage in relation to the targeted herring stock). The coverage and survey design has changed over the years with the current coverage shown in Figure A1.8.2. As with the PELTIC survey, the acoustic and trawl catch data are stored but the acoustic data have not been processed.

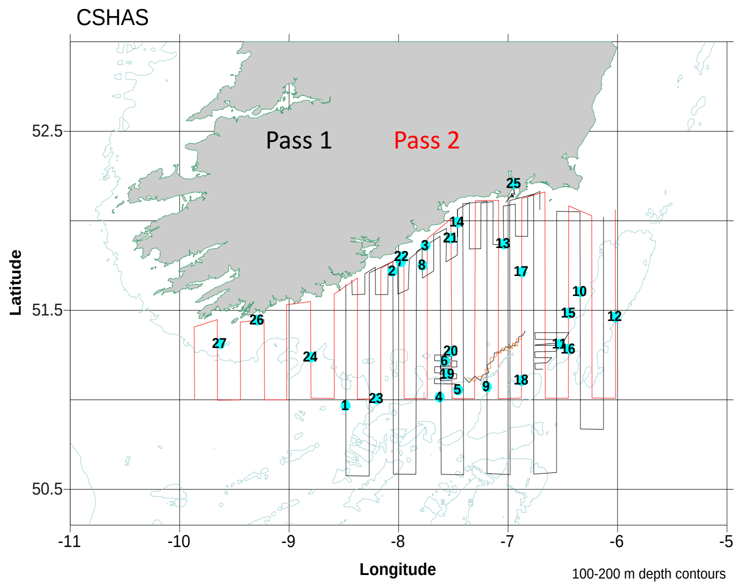

Figure A1.8.2. The acoustic coverage of the CSHAS off the southern coast of Ireland.

A1.9 Acoustic surveys and acoustic data from other surveys in the North Sea during Quarter 3

The Herring Acoustic survey, primarily covering herring and sprat (HERAS) covers the majority of the North Sea (Subarea 4) and the Skagerrak (Sub Division 3a). Two of the survey vessels have the capability to and routinely collect 200 kHz acoustic data which could provide distributional data for the northern North Sea in the early part of Quarter 3 each year. The full acoustic coverage for the HERAS as shown in Figure A1.9.1 and the area where acoustic data at 200 kHz is likely to be available is indicated on the map.

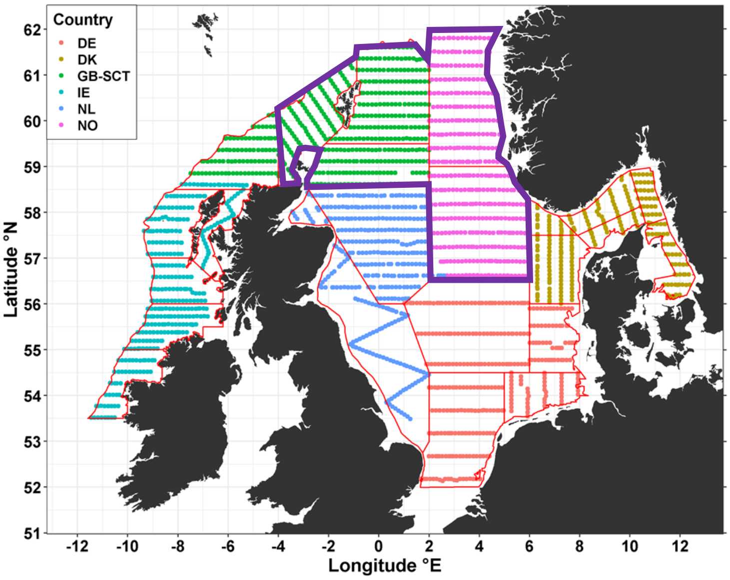

Figure A1.9.1. The spatial coverage of the HERAS. The area where 200kHz data are likely to be available around the northern North Sea are shown by the purple outline.

Additional acoustic data are also potentially available for the North Sea from the Quarter 3 International Bottom Trawl Survey (IBTS). 200 kHz acoustic data have been collected during the UK England portion of this survey since 2007. The acoustic data from 2007 to 2013 have been analysed and are reported in van der Kooij et al. (2016). The acoustic distribution of mackerel over this time period are shown in Figure A1.9.2.

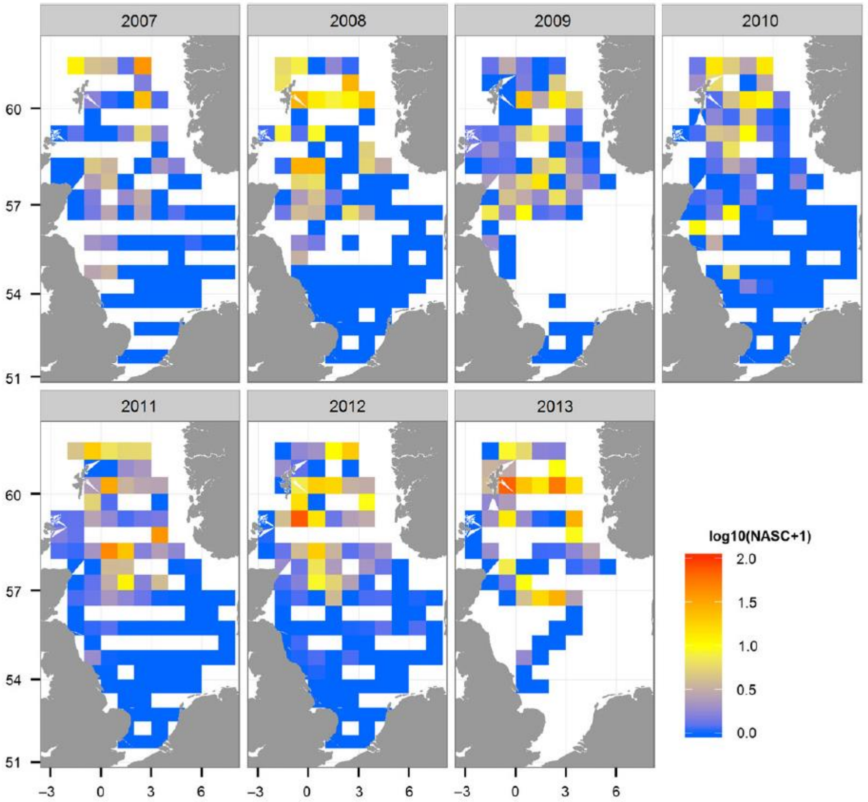

Figure A1.9.2. The daytime acoustic densities of schooling mackerel at 200 kHz per ICES statistical rectangle (legend: log mean s_A in m^2 nautical mile^{-2}) during the Q3 International Bottom Trawl Surveys (2007–2013). Data are log transformed so as to highlight the spatial patterns

References

van der Kooij, J., Fässler, S. M.M., Stephens, D., Readdy, L., Scott, B. E., and Roel, B. A. 2016. Opportunistically recorded acoustic data support Northeast Atlantic mackerel expansion theory. ICES Journal of Marine Science, 73: 1115–1126.

A1.10 Faroe Plateau demersal surveys during Quarter 1 and 3

On the Faroe plateau two annual demersal bottom trawl surveys are carried out by the Faroe Marine Research Institute (FAMRI), one during spring (FO-GFS-Q1) from March 1996 to present and one during late summer/early autumn (FO-GFS-Q3) from August 1994 to present. The surveys are aimed at cod, haddock and saithe, but varying amounts of mackerel are caught as by-catch on the shelf. The size of the mackerel ranges from 15-50 cm. The mackerel is caught on most of the Faroe Plateau from 50 to 400 m depth (Figure A1.10.1).

The time-series of mackerel by-catches (number per trawl hour) on the Faroe Plateau summer (August) survey since 1996 is shown in Fig. 2. This shows that by-catches were very low from 1996 to 2006, but from 2007 and onwards an increasing number of mackerel were caught during the survey, with maximum by-catches in 2011 and 2013. In the most recent years from 2018 the by-catches dropped again to low pre-2007 levels (Figure A1.10.2).

In some years 0 and 1-group juvenile mackerel are found on the shelf regions and are caught in the demersal surveys, especially since 2007 however in very small quantities (Figure A1.10.3).

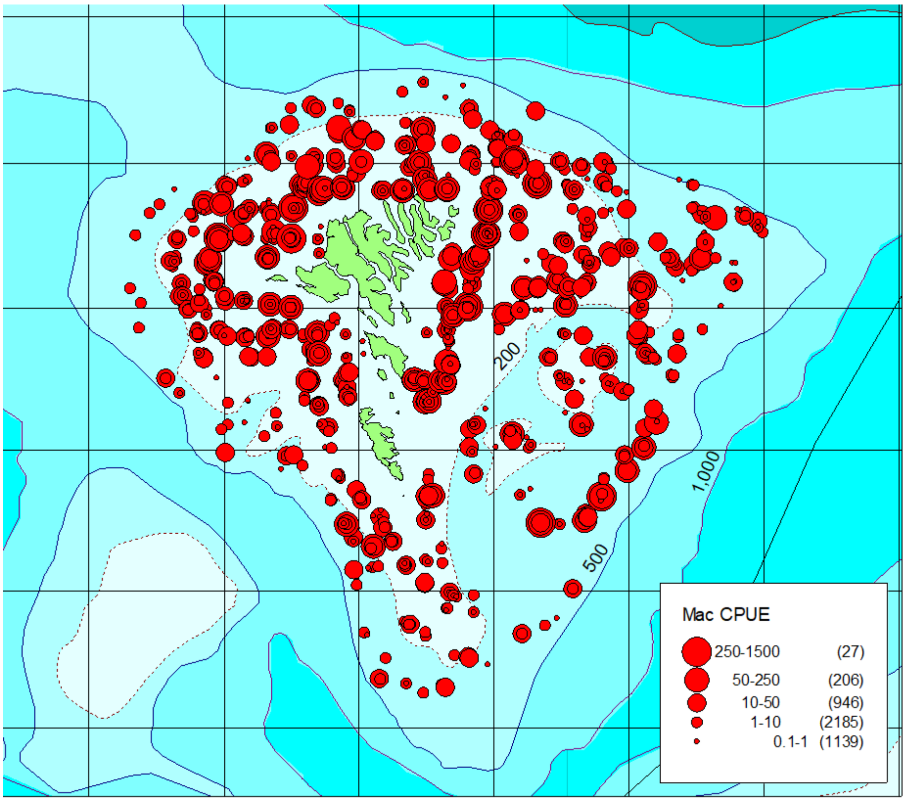

Figure A1.10.1. Map showing standardised mackerel CPUE (number per trawl hour) caught during the two Faroese demersal trawls surveys (spring and summer) on the Faroes Plateau since 1994. The 200, 500 and 1000 m depth contours are shown. Note that many circles sit on top of each other due to presence of mackerel at the same station during multiple annual surveys.

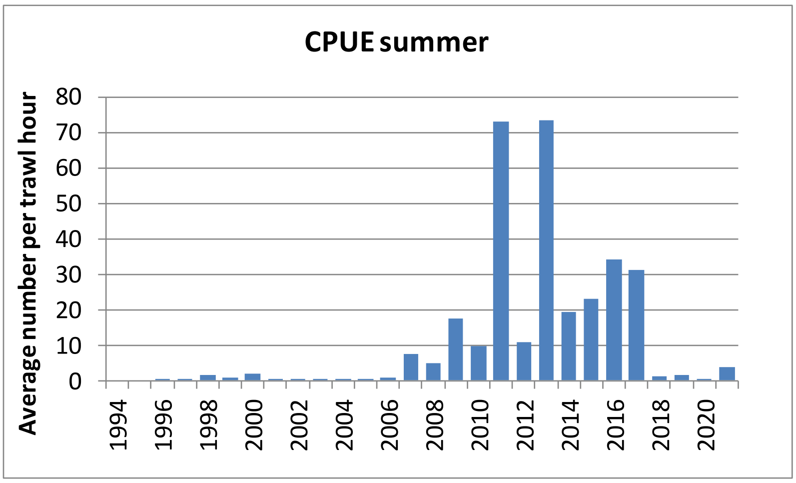

Figure A1.10.2. Average number of mackerel caught per trawl hour as by-catch in the demersal trawl surveys in August on the Faroe Plateau since 1996.

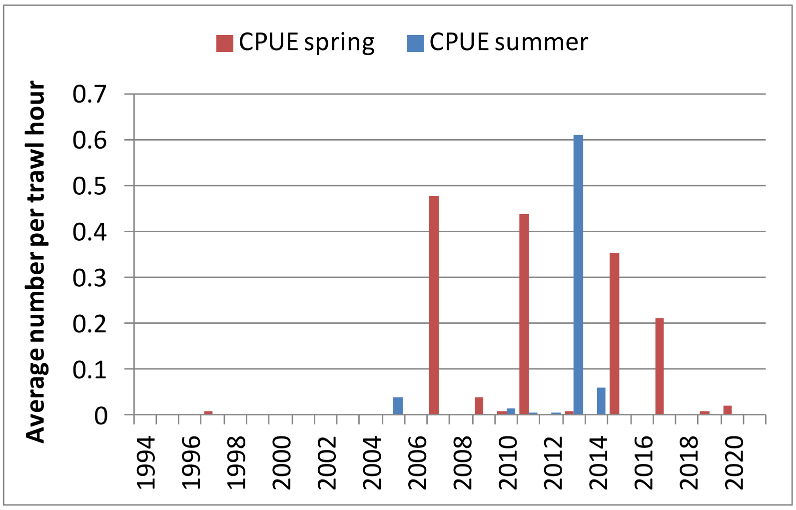

Figure A1.10.3. Average number of juvenile (< 25 cm) mackerel caught per trawl hour as by-catch in the demersal trawl surveys on the Faroe Plateau since 1994 (spring surveys, red bars and summer surveys, blue bars).

A1.11 Icelandic bottom trawl surveys in spring and autumn

Marine and Freshwater Research Institute (MFRI) has conducted annual bottom trawl survey in March (SMB) (Sólmundsssson *et al.*, 2021) and October (SMH) (Jakobsdóttir *et al.*, 2021) respectively since 1985 and 1995. The surveys target demersal fish species on and in the vicinity of the continental shelf around Iceland within the national exclusive economic zone. Location of trawl stations is fixed. Approximately 600 stations are samples during SMB and approximately 360 during SMH.

Mackerel is caught as by-catch during both surveys (Figure A1.11.1). Distribution and frequency vary between surveys and is higher during SMH. In SMB, mackerel by-catch is limited to the south coast with the highest frequency southeast of Iceland. In SMH, mackerel is caught around the island with highest frequency southwest and west of Iceland.

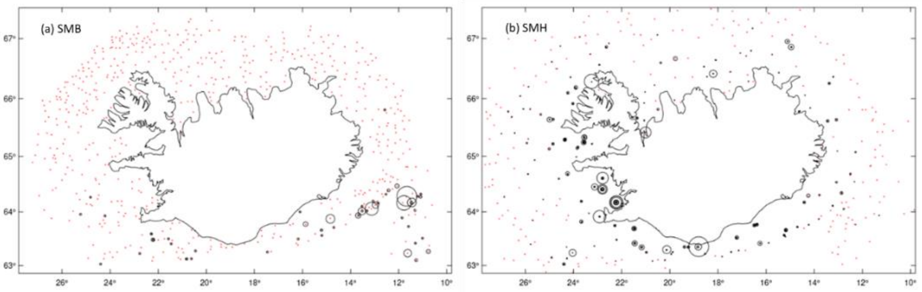

Figure A1.11.1. Mackerel by-catch (open black circles) during SMB (a) and SMH (b) from 2001 to 2021. Bottom trawl stations with no mackerel caught are also displayed (red dot). Number of mackerel caught is presented by size of black open circle. Maximum catch per tow was 96 specimens for SMB and 985 specimens for SMH.

For the period 2001 to 2021, mackerel was not caught every year during either survey (Figure A1.11.2). For SMB, mackerel was caught in 11 of 21 years and often one specimen at one station. The years 2011 and 2015 were exception with total of 285 and 31 specimens caught at 26 and 12 stations, respectively. For SMH, mackerel was caught every year from 2005 to 2021 excluding 2008. Peak mackerel frequency was during period 2010 - 2014 when total of 482 – 2065 specimens were caught at 40 – 57 stations per year.

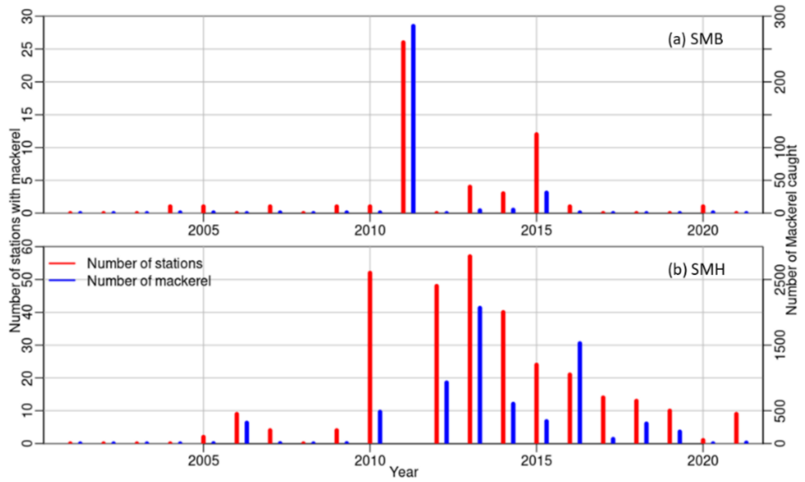

Figure A1.11.2. Number of stations with mackerel caught and total number of specimens caught during SMB and SHM from 2001 to 2021. There was no SMH in 2011.

The two surveys appear to catch different life history stages with SMB mostly catching juveniles (Figure A1.11.3) and SMH mostly mature specimen from 2012 onward but juveniles prior to 2012 (Figure A1.11.4).

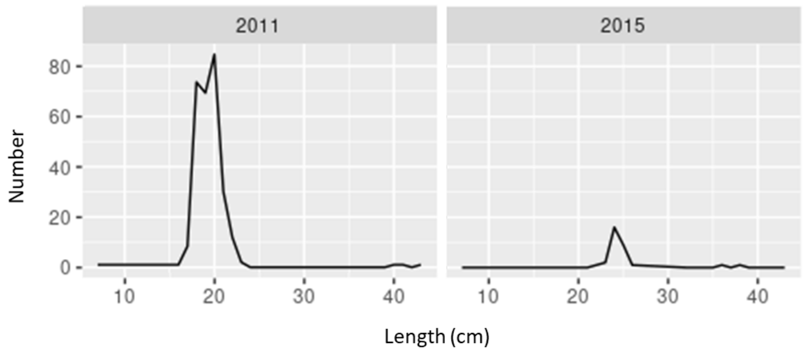

Figure A1.11.3. For SMB, mackerel length frequency distribution for years with > 5 specimens caught in total.

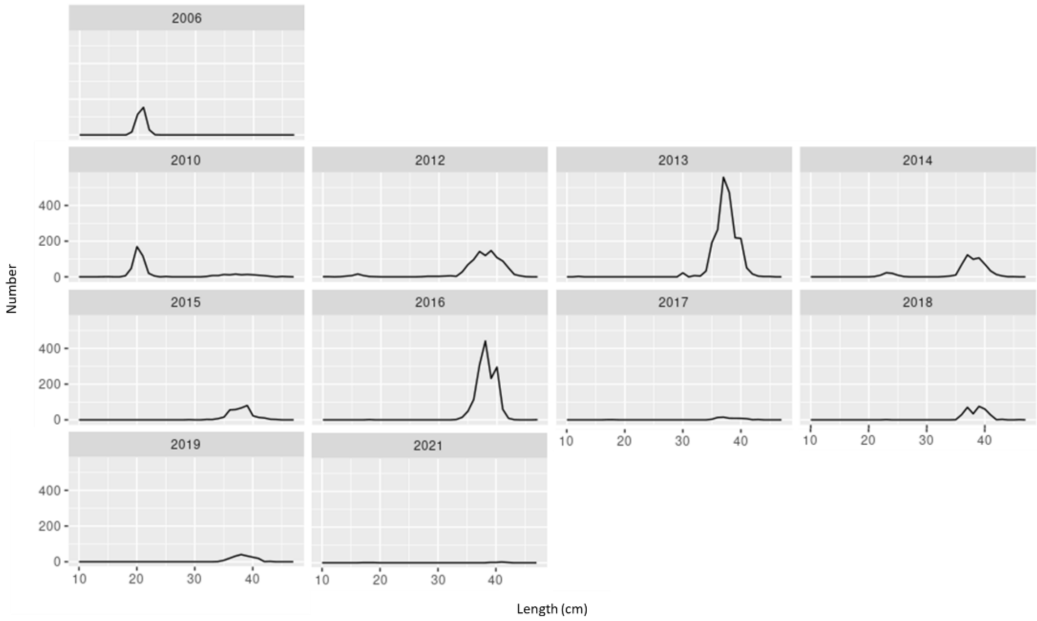

Figure A1.11.4. For SMH, mackerel length frequency distribution for years with > 10 specimens caught in total.

Relevance of SMB and SMH time series for mackerel

By-catch trends in SMH temporally coincide with expansion of mackerel feeding range into Icelandic EEZ in the early 2000´s and decline in late 2010´s as displayed in IESSNS data and the catch data time series. Hence, SMH can be considered to provide a qualitative index for high – medium – low index of mackerel in Icelandic EEZ. Mackerel by-catch in SMB does not show similar temporal trend as IESSNS but provides qualitative information about mackerel presence in Icelandic EEZ during winter.

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A2. Norwegian Tagging-Recapture Programs for NEA mackerel 1966-2020

Methods and analyses of tagging and recapture data for NEA mackerel can provide quantitative and valuable data on distribution and migration patterns (Uriarte and Lucio, 2001; Tenningen et al. 2011), estimate natural mortality (Simmonds et al. 2010) and for abundance estimation (Simmonds et al. 2010; Tenningen et al. 2011).

Norway has conducted annual dedicated tagging surveys on mackerel for several decades, as far back as 1966, for estimation of biomass, natural mortality, and distribution (Tenningen et al. 2011). The Institute of Marine Research (IMR) in Bergen, Norway has used internal steel tags for tagging mackerel since 1966 and used to quantify mackerel in the North Sea (Revheim 1966; Hamre, 1970; ICES 2013).

Tenningen et al. (2011) recommended switching from the conventional tagging system to automatic systems using Radio Frequency Identification (RFID)-technology, thereby increasing the screening, and removing uncertainties inherent in manual handling. ICES WGWIDE also recommended that IMR continued the tagging-programme with RFID, with the aim of including the data in future assessments.

The RFID data were a new time series with a different scaling factor (survival) than the steel tags and have been used in assessments following the ICES WKWIDE2017 benchmark (ICES, 2017). Steel tag data covering ages 2-11 and all recapture years are used in the assessment. Regarding the assessment of mackerel, only the RFID data from release years 2013 onwards, ages 5-11 and recapture year 1 and 2 after release are utilised.

The Norwegian tagging and recapture program on NEA mackerel was accepted to be used as an index of abundance after a mackerel benchmark in 2019 (ICES, 2019). Ages 5 and older (age of release) are presently used in the mackerel assessment (ICES, 2021).

Methodology

The tagging has been carried out in the spawning area west of Ireland, where an average of 20 000 fish have been tagged each year up until 2012 (ICES, 2013). Since 1986 commercial catches of mackerel have been screened through metal detectors connected to conveyor belt systems located in from four factories in Norway up until 2012, and then increasing to eight factories in Norway and several factories in other countries in Europe. Each year up until 2012 a total of 10 000 - 45 000 tons of mackerel were screened, and the recaptured fish identified and sent to IMR for data collection. (ICES, 2013).

Information from steel tagging experiments conducted by IMR on mackerel at spawning grounds west of Ireland and British Isles in May-June and the respective recaptures at Norwegian factories with metal detectors (Tenningen *et al*., 2011), was introduced to the mackerel assessment during ICES WKPELA 2014 (ICES, 2014). Data from release years 1980-2004, and recapture years 1986-2006 have been used in the update assessments following this benchmark. From 2011 onwards IMR changed tagging methodology to radio-frequency identification (RFID), more specifically passive integrated transponder tags (PIT-tags). This allowed for more automatic data processes with recaptures from scanned landings at factories in Norway, Scotland and Iceland now being updated real time in an IMR data base over internet.

Data availability

Recaptured mackerel from commercial catches had an extensive distribution over large areas (Figure A2.1).

A full overview and update of the RFID tagging experiments of NEA mackerel 2011-2021, as well as the recaptures and scanned fish 2012-2020 are given in Slotte and Hølleland (2021). Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel during 2012-2020 are shown in Figure A2.2.

Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel related to release years 2011-2015 and years after release (0=same year as tagging, 1= year after tagging etc.) are shown in Figure A2.3.

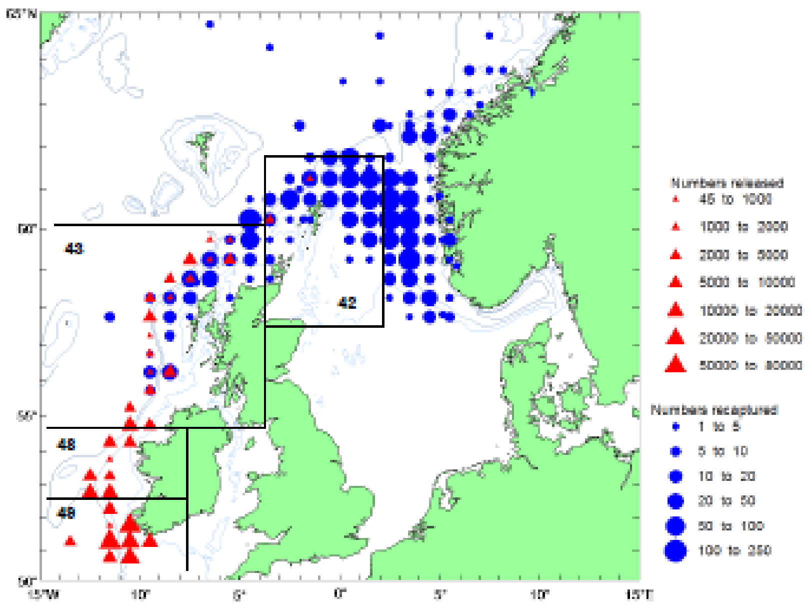

Figure A2.1. Numbers and geographical position of released NEA mackerel (red) and recaptured NEA mackerel (blue). Reproduction from Tenningen et al. 2011.

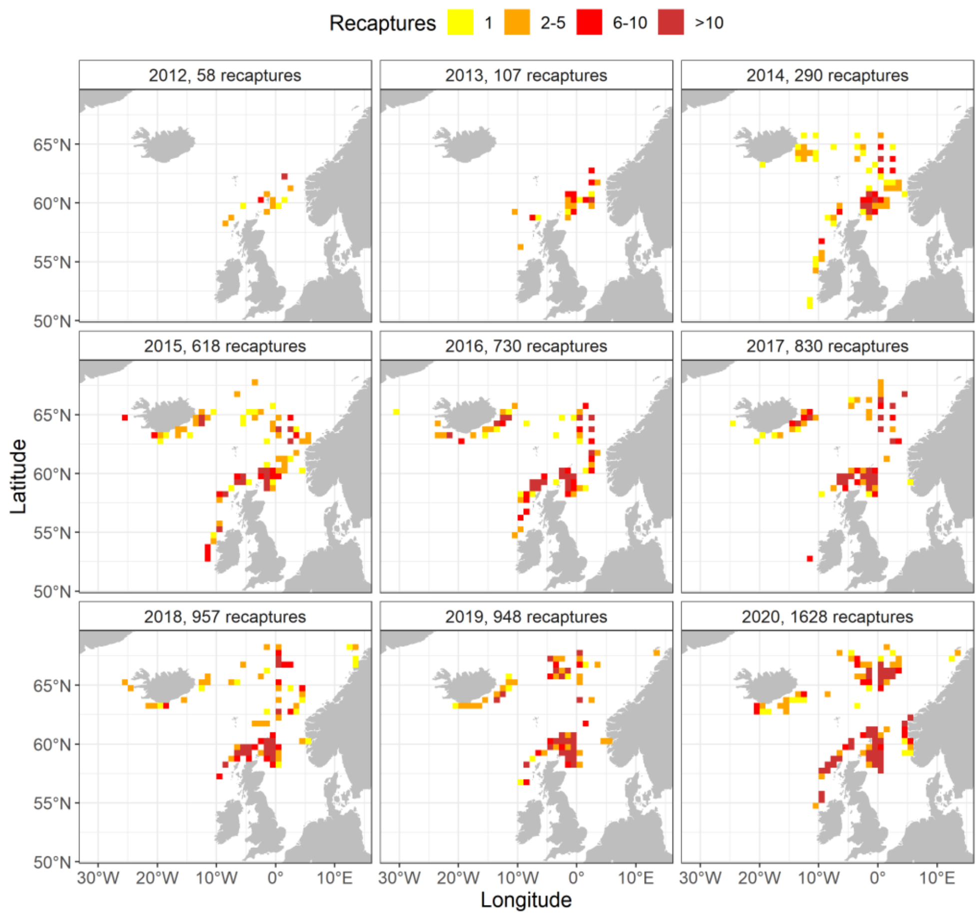

Figure A2.2. Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel during 2012-2020. Note that data on recaptures in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).

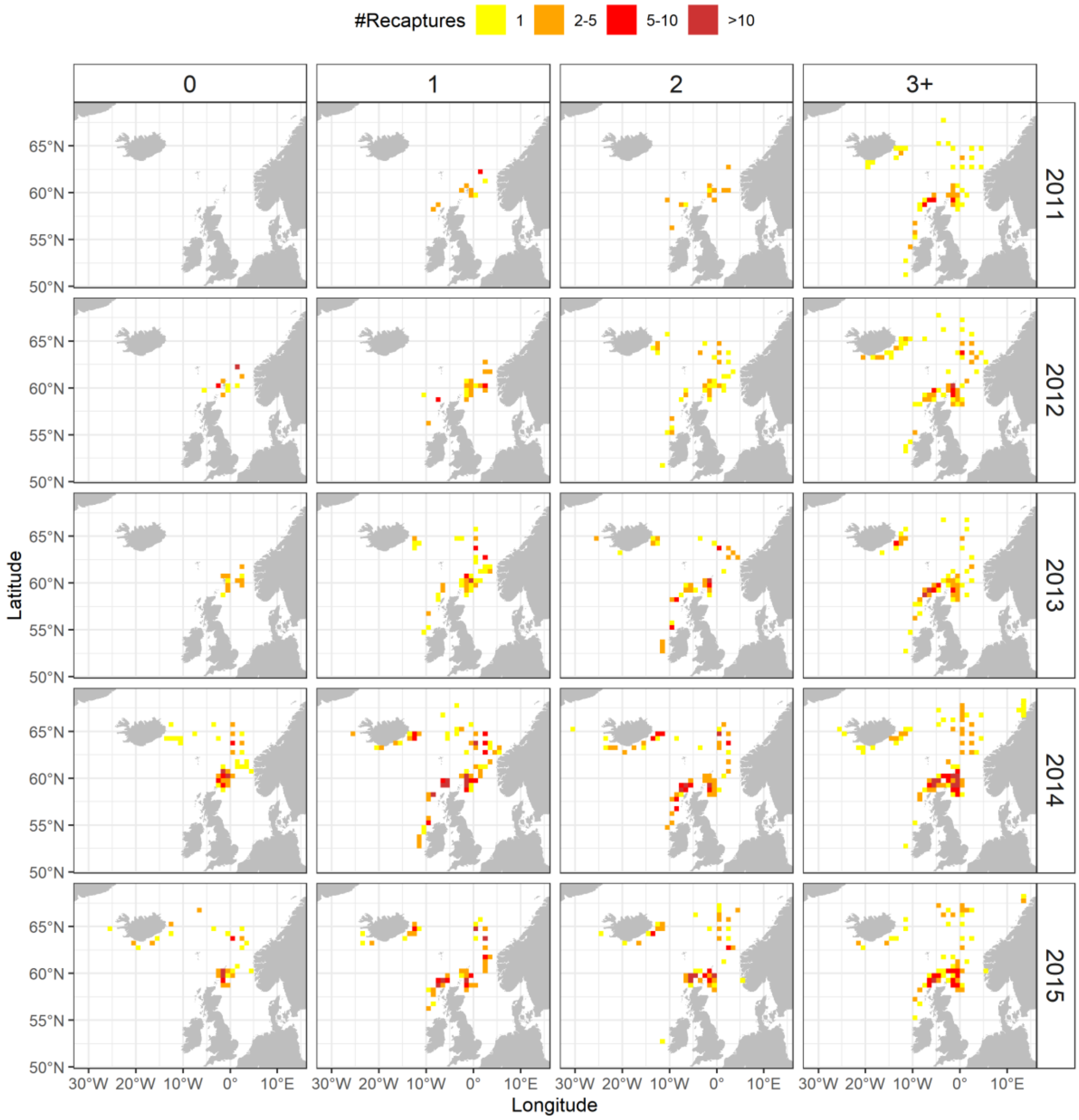

Figure A2.3. Distribution (summed per ICES rectangle) of recaptures of RFID tagged mackerel related to release years 2011-2015 and years after release (0=same year as tagging, 1= year after tagging etc.). Note that data on recaptures from 2011-2012 release years and from year 0 and 3+ after tagging are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).

Tagging data potential, evaluation, and caveats

Mackerel catches scanned for RFID tagged during 2012-2020 were not taken randomly in space and time (see Figures A2.2-A2.3). The location of the mackerel catches is not necessarily representative of any true zonal distribution of mackerel, when comparing with fishery-independent mackerel data on biomass and distribution in space and time. This is to a large extent due to national and international regulations and agreements on mackerel between Coastal States from 2014 to 2020. This can be clearly seen on the maps from 2014 to 2020, for example, where there is every year a large area in Norwegian EEZ were there are no tag returns, because the Norwegian fishermen to a large extent did not fish mackerel in Norwegian waters even when it was present and abundant. This area with very few mackerel catches taken annually in large areas of Norwegian waters from 2014 to 2020 (*see* Figures A2.2, A2.3), is in sharp contrast to recaptured mackerel from commercial catches from large areas, including a large amount taken in the Norwegian EEZ between 1986 and 2006 (see Figure A2.1).

This illustrates some of the important limitations when using these tagging data which are partially dependent on the fishery-dependent catch data on mackerel when using these data to partition the stock to the different EEZs over all years. To fully understand these data there is a necessity to investigate the fishing regulations, access limitations and market forces that were in place each year.

However, what the recent tag-recapture data (Figures A2.2 - A2.3) clearly do demonstrate, is that mackerel tagged off Ireland and British Isles during the May spawning season, show a very consistent migration pattern repeated over time. Recaptures from a release year is spread over large areas off Iceland and Norwegian Sea during summer July-September, aggregating in wintering areas off Shetland in October-December, followed by spawning migration during January-February along west of British Isles and Ireland, and this pattern is repeated over subsequent years. The data support the notion that this is one population with specific migration patterns spreading over several EEZs during annual migration cycles. Some of the mackerel tagged along Ireland-British Isles are likely to be fish returning from spawning further south e.g., the Bay of Biscay, supporting the earlier studies by Uriarte and Lucio (2001) and Tenningen et al. (2011).

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A3. Additional figures and tables

A3.1 Figures

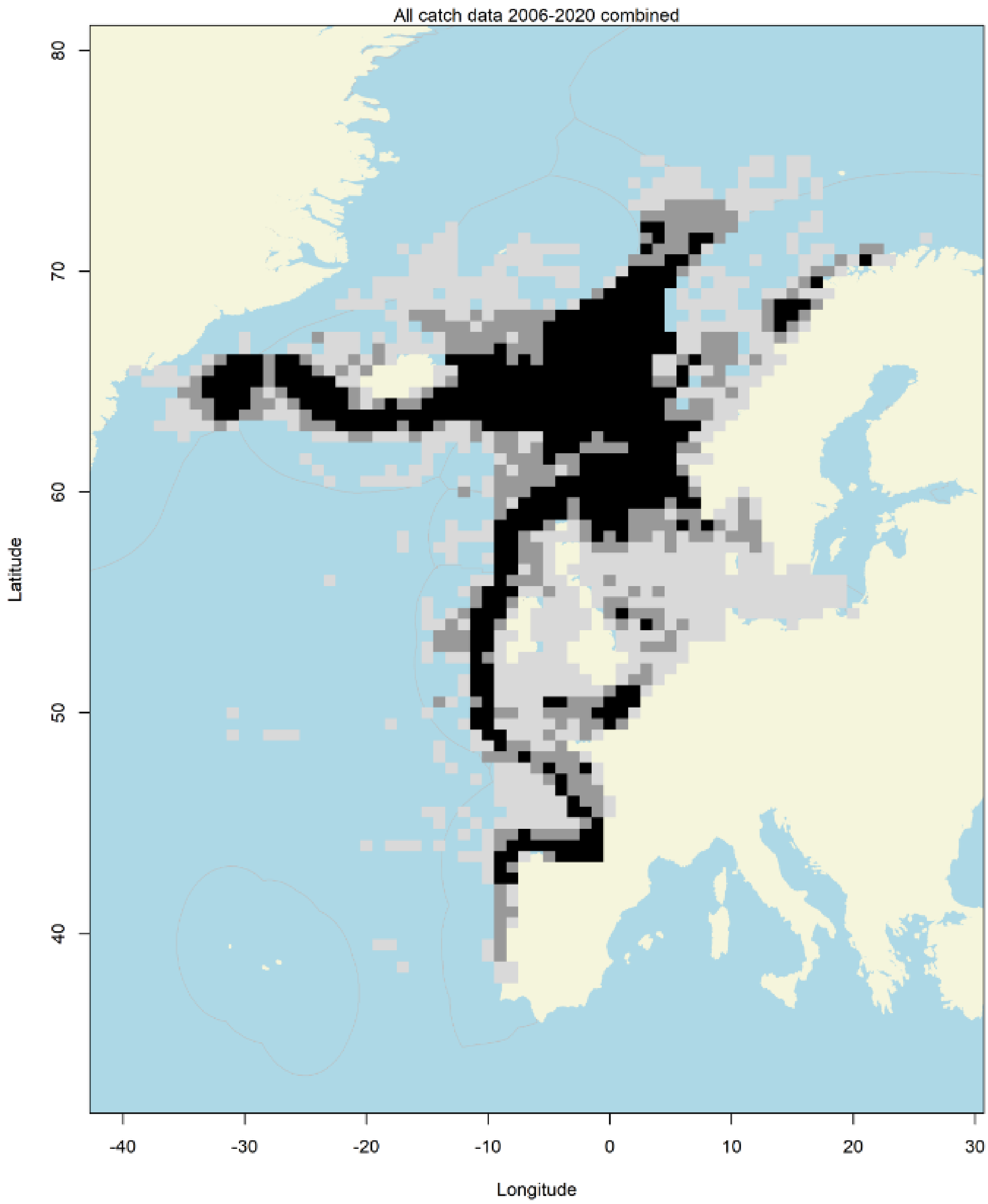

Figure A3.1.1. Aggregated catches of Northeast Atlantic (NEA) mackerel for all years between 2006–2020.

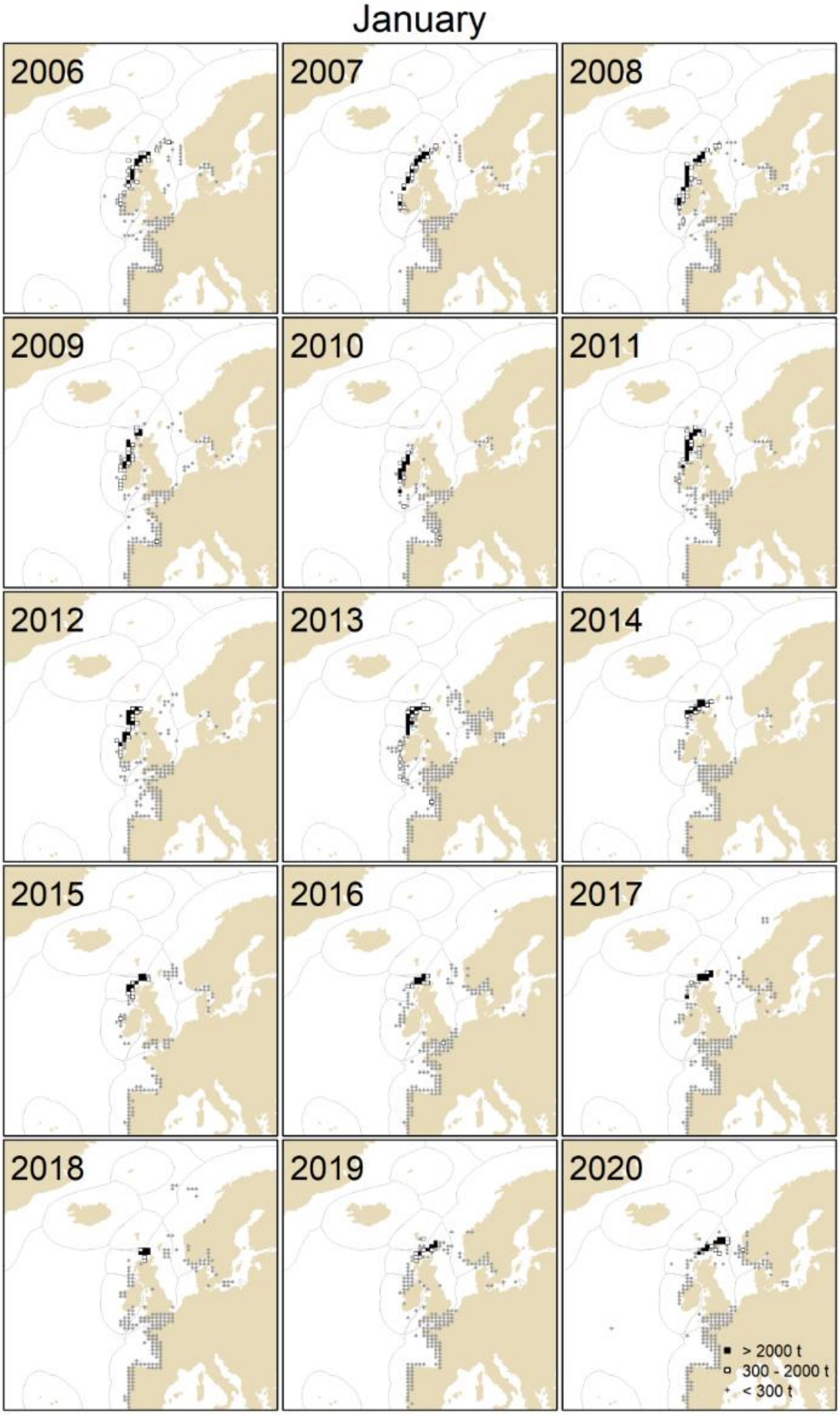

Figure A3.1.2. Annual catches of Northeast Atlantic (NEA) mackerel for January between 2006–2020.

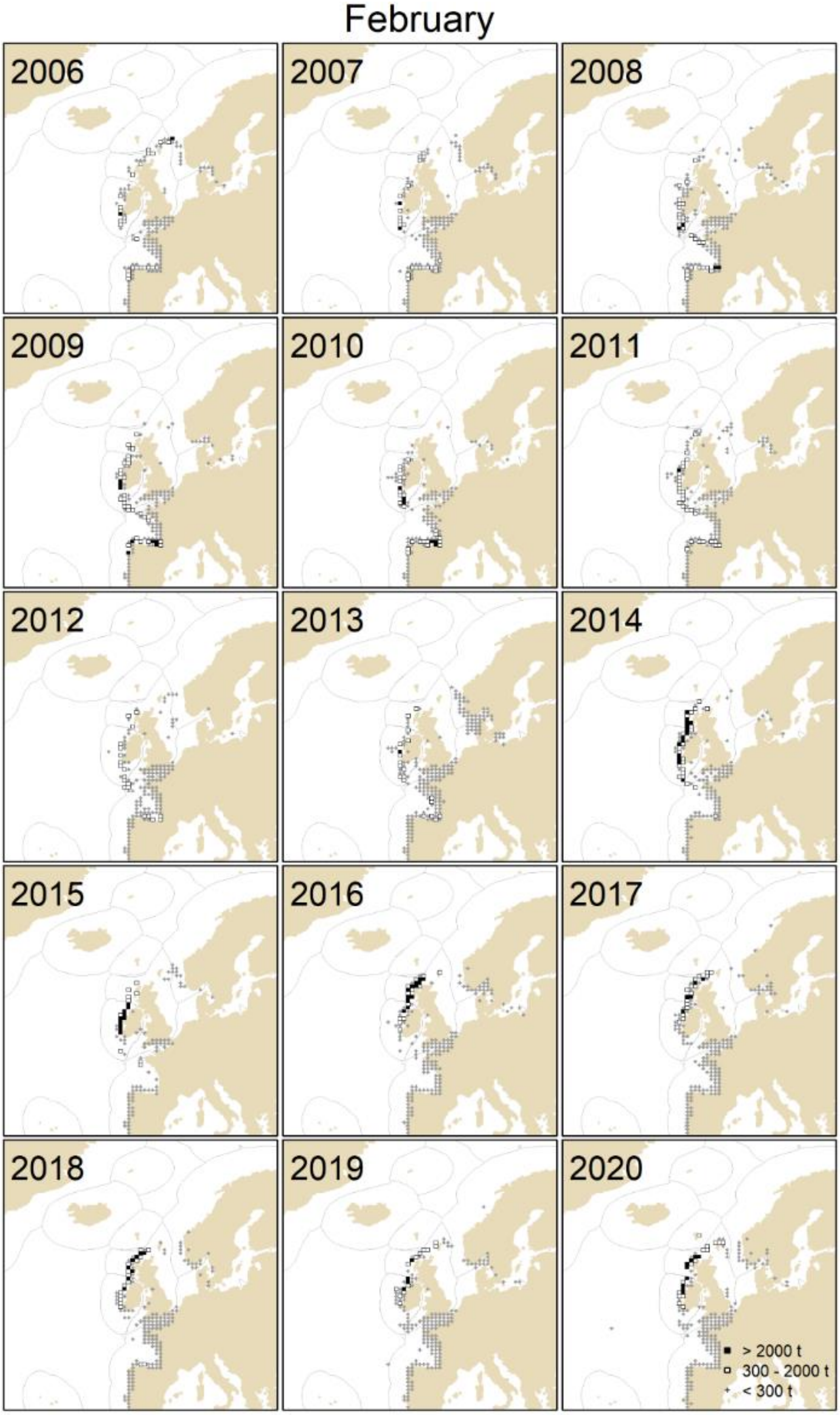

Figure A3.1.3. Annual catches of Northeast Atlantic (NEA) mackerel for February between 2006–2020.

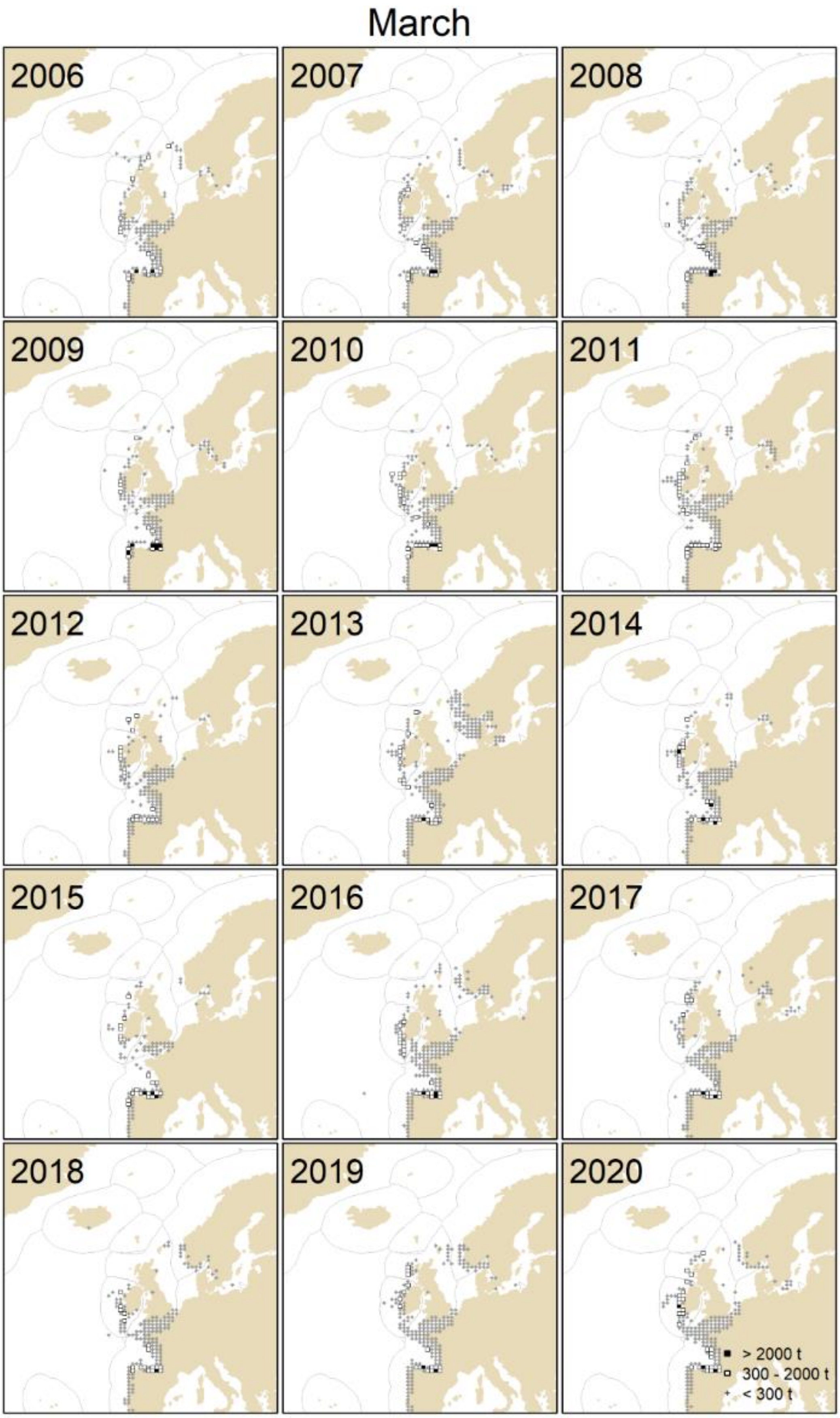

Figure A3.1.4. Annual catches of Northeast Atlantic (NEA) mackerel for March between 2006–2020.

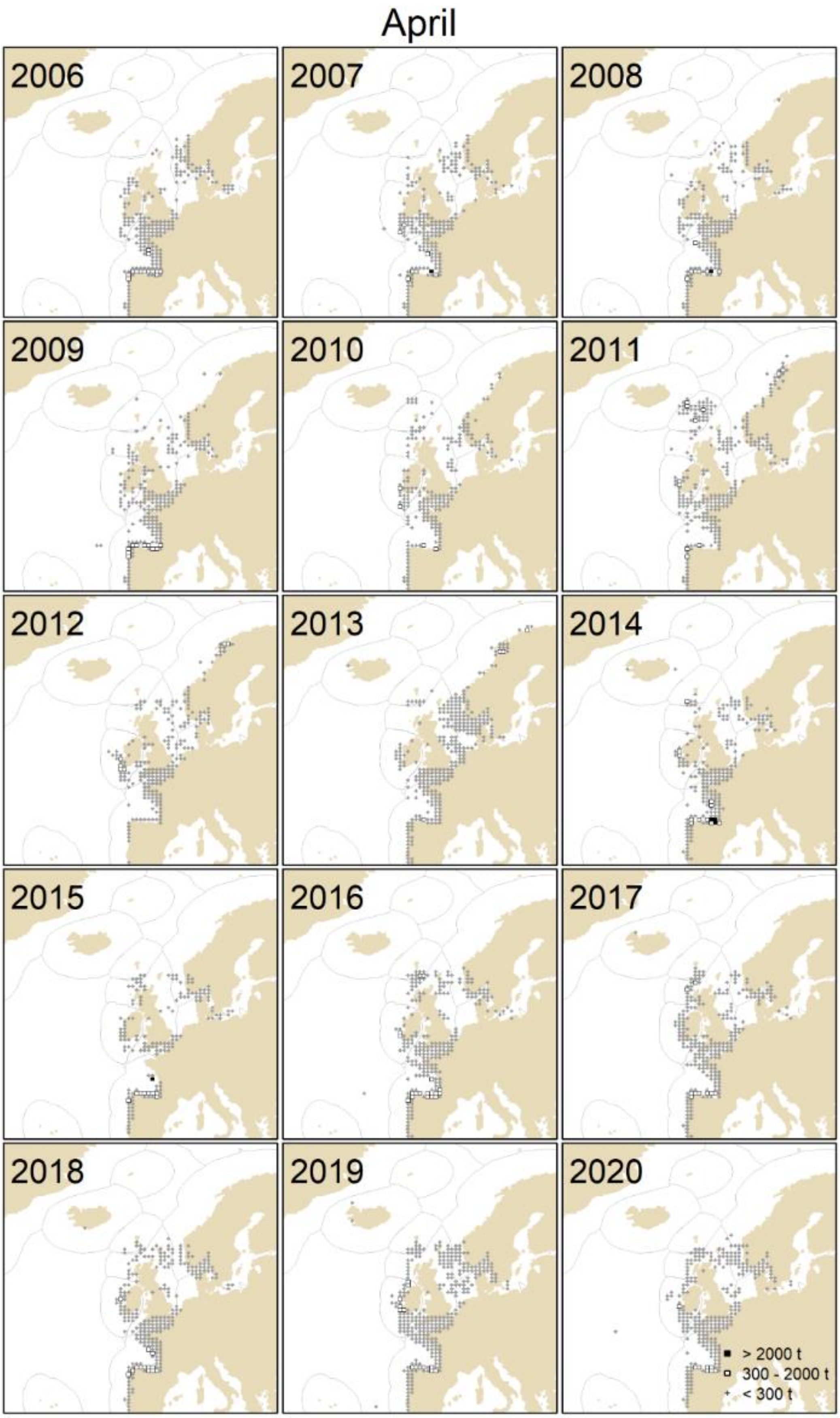

Figure A3.1.5. Annual catches of Northeast Atlantic (NEA) mackerel for April between 2006–2020.

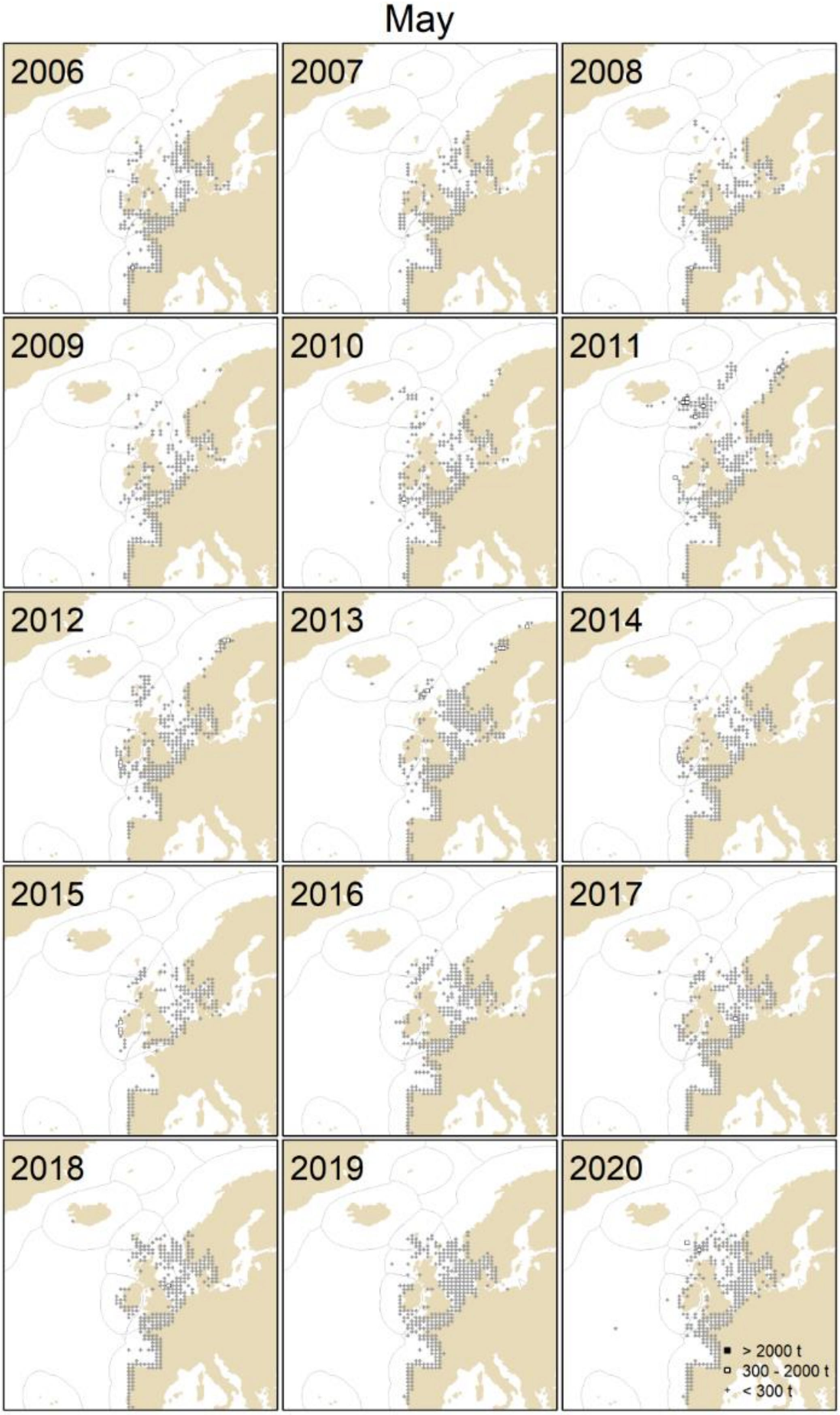

Figure A3.1.6. Annual catches of Northeast Atlantic (NEA) mackerel for May between 2006–2020.

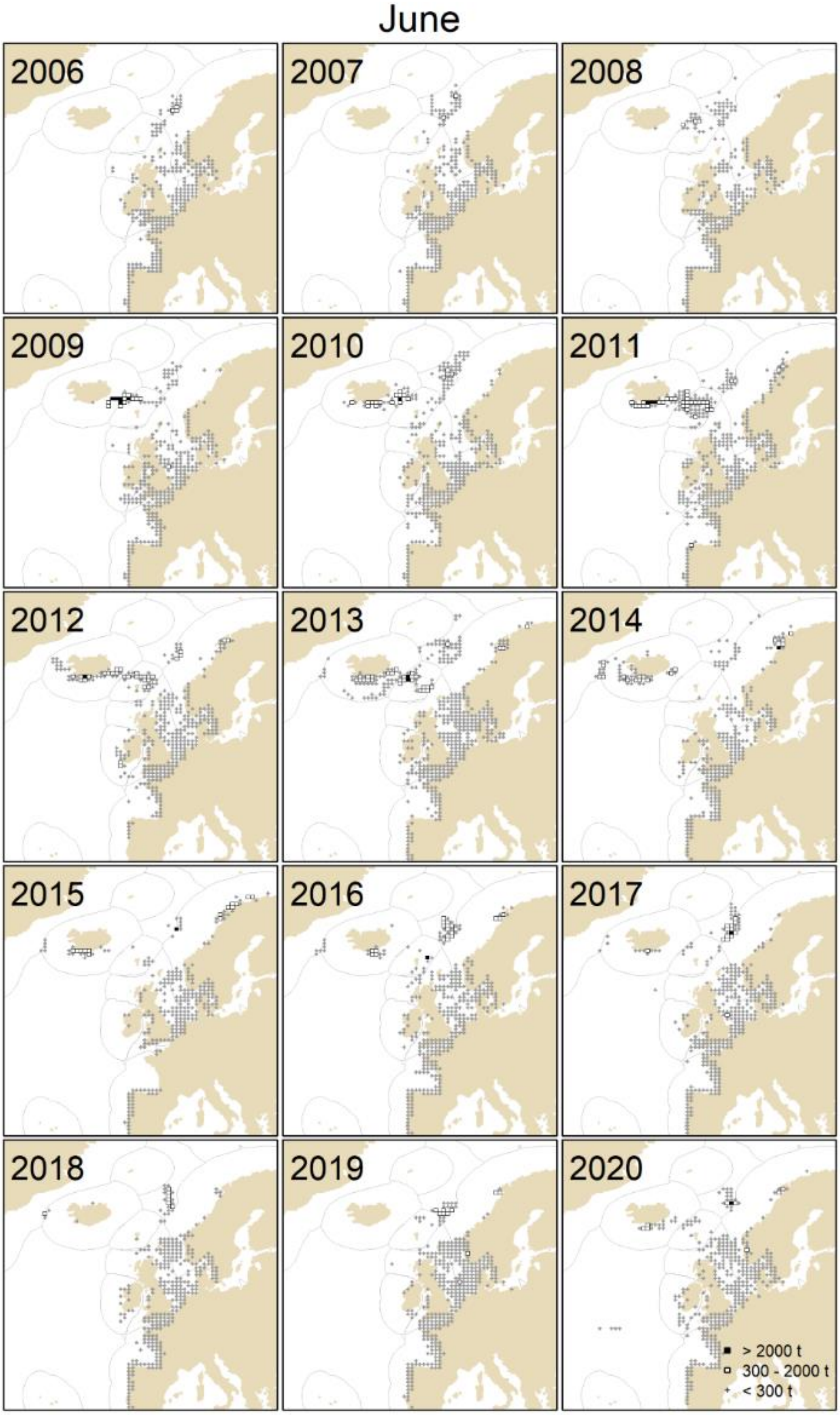

Figure A3.1.7. Annual catches of Northeast Atlantic (NEA) mackerel for June between 2006–2020.

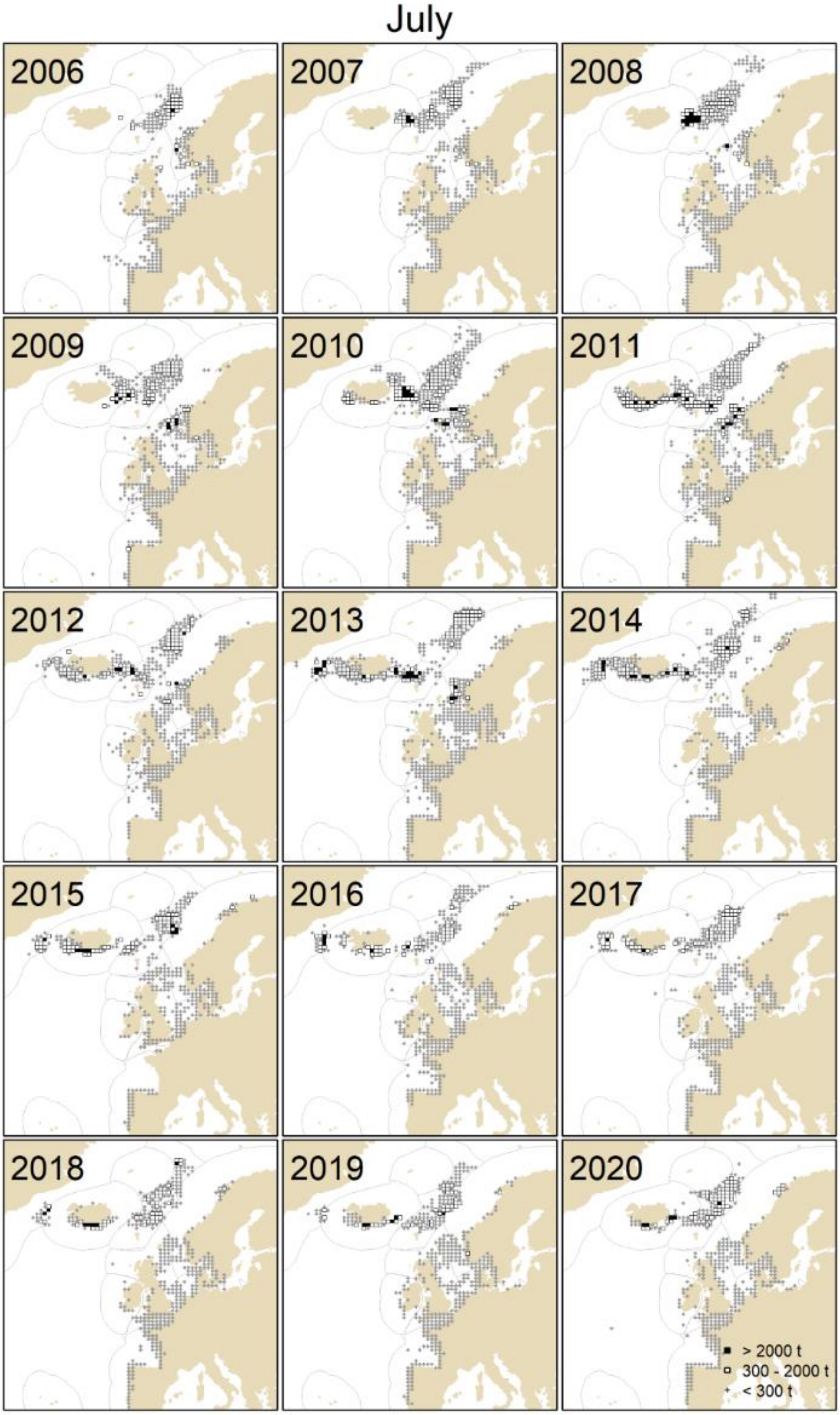

Figure A3.1.8. Annual catches of Northeast Atlantic (NEA) mackerel for July between 2006–2020.

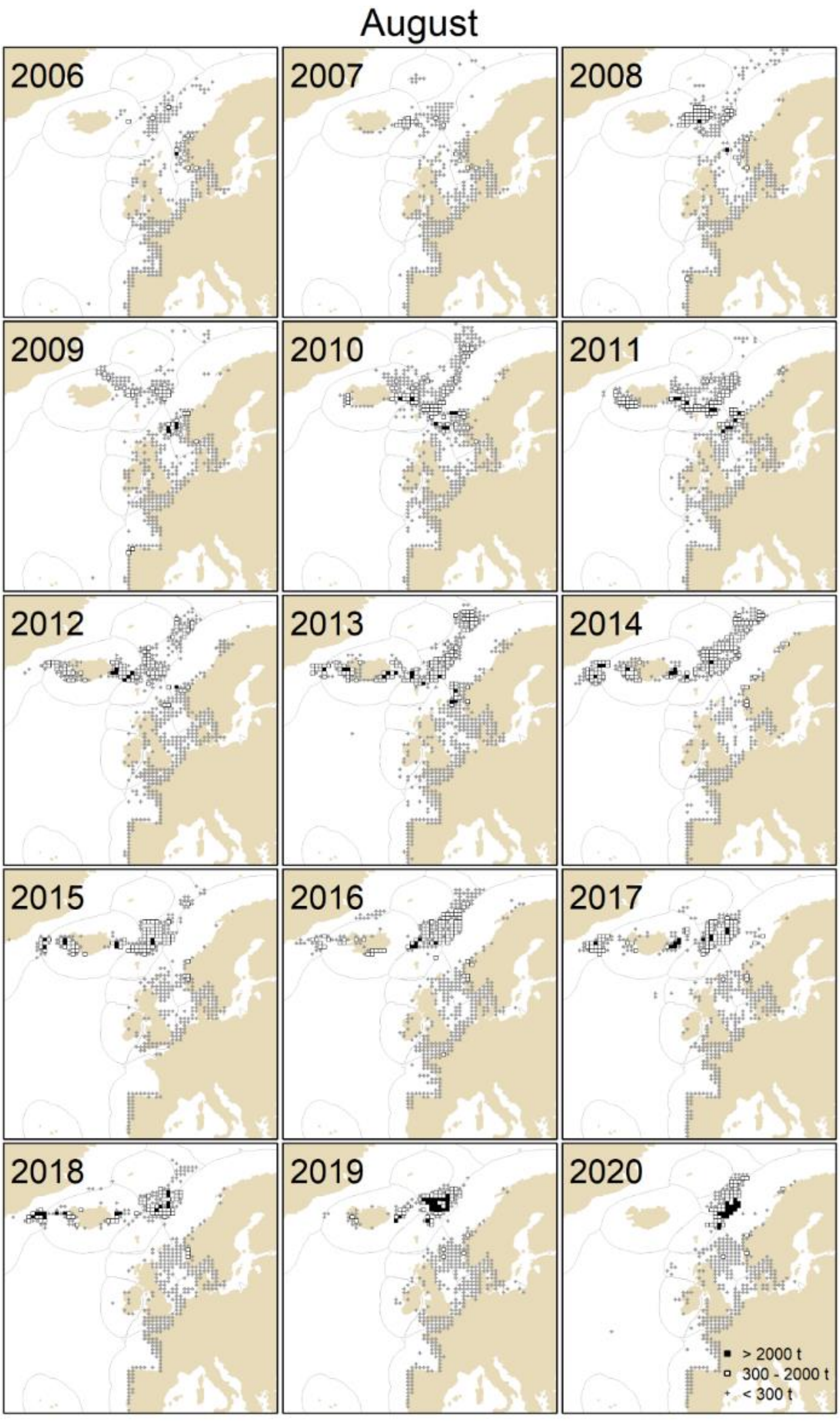

Figure A3.1.9. Annual catches of Northeast Atlantic (NEA) mackerel for August between 2006–2020.

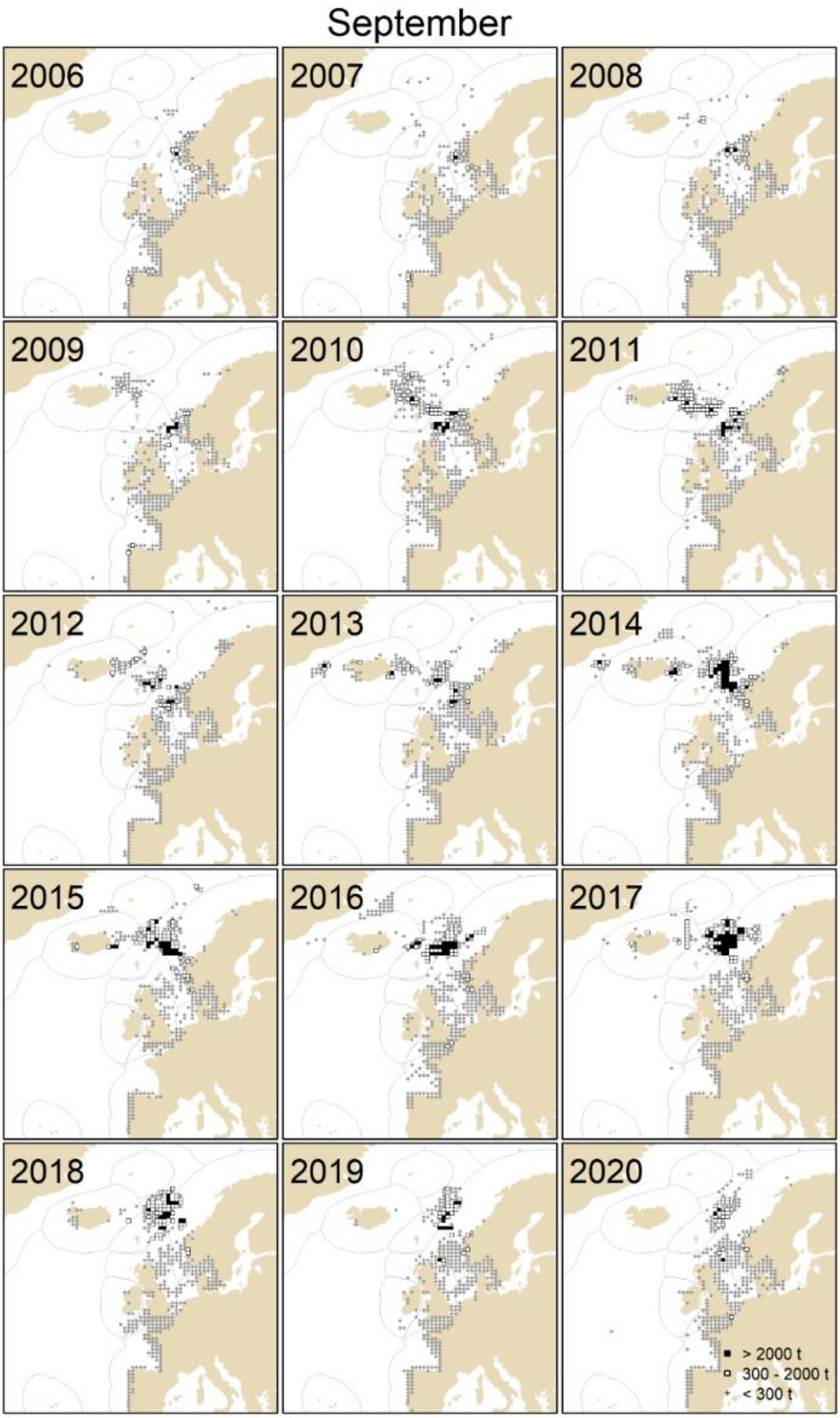

Figure A3.1.10. Annual catches of Northeast Atlantic (NEA) mackerel for September between 2006–2020.

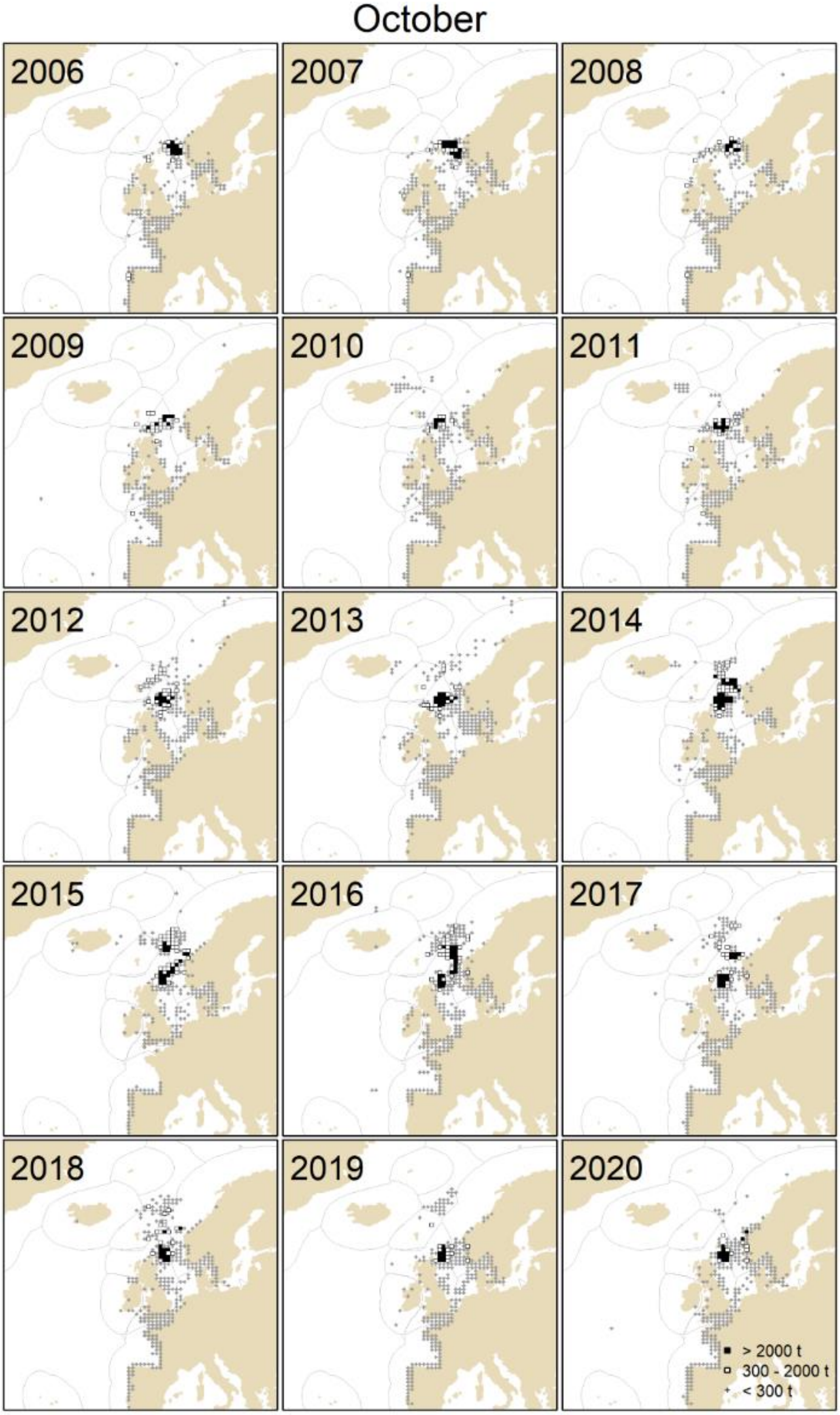

Figure A3.1.11. Annual catches of Northeast Atlantic (NEA) mackerel for October between 2006–2020.

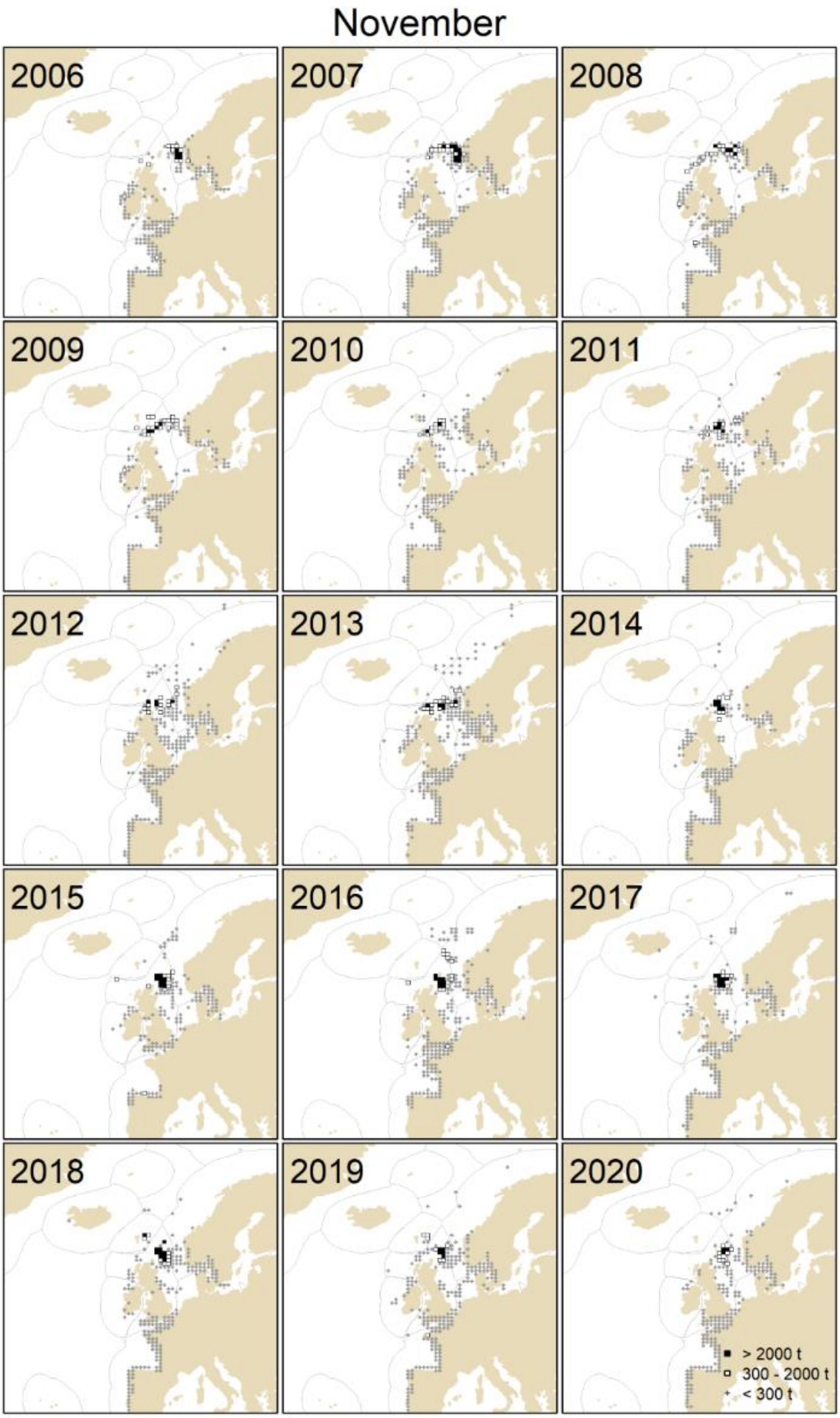

Figure A3.1.12. Annual catches of Northeast Atlantic (NEA) mackerel for November between 2006–2020.

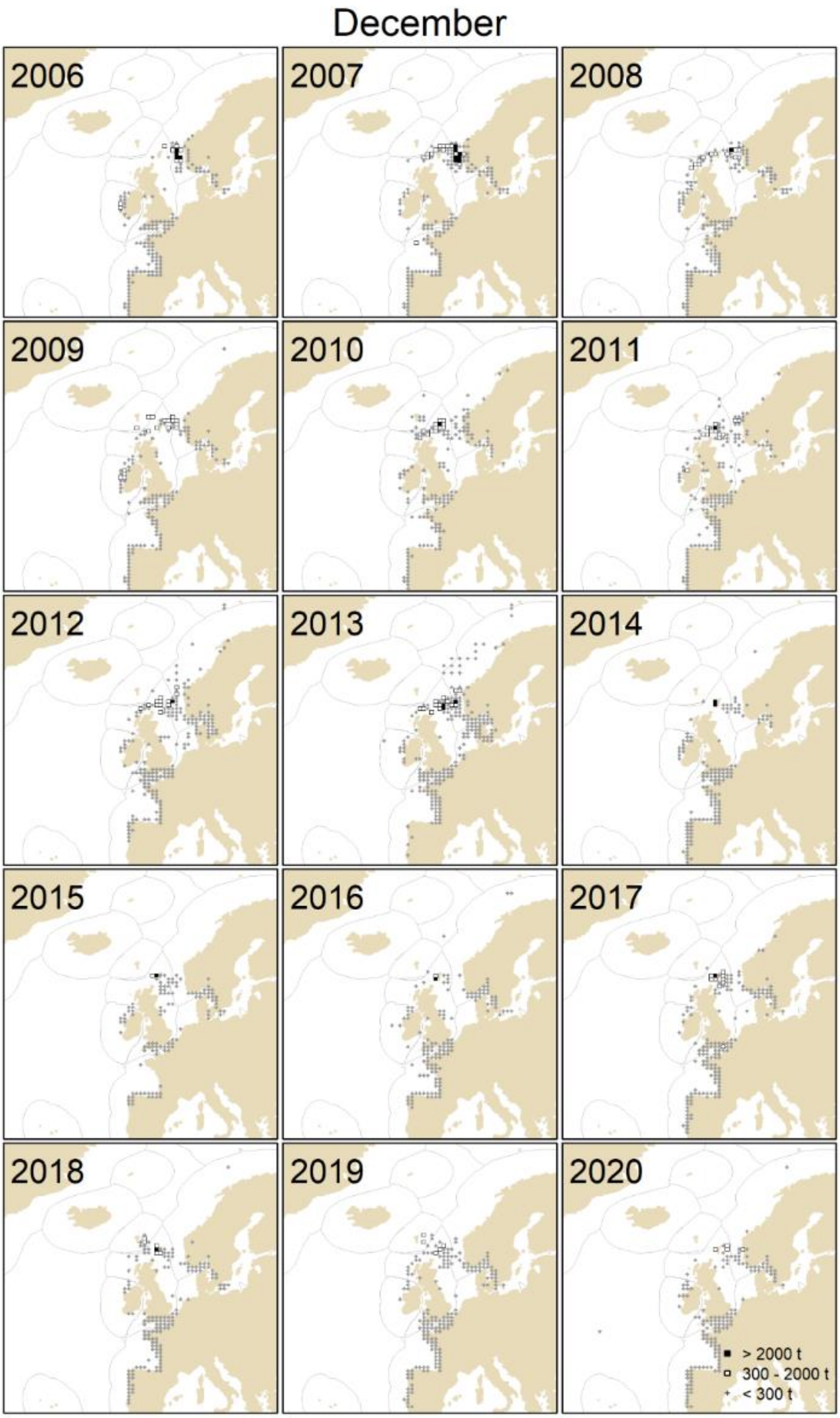

Figure A3.1.13. Annual catches of Northeast Atlantic (NEA) mackerel for December between 2006–2020.

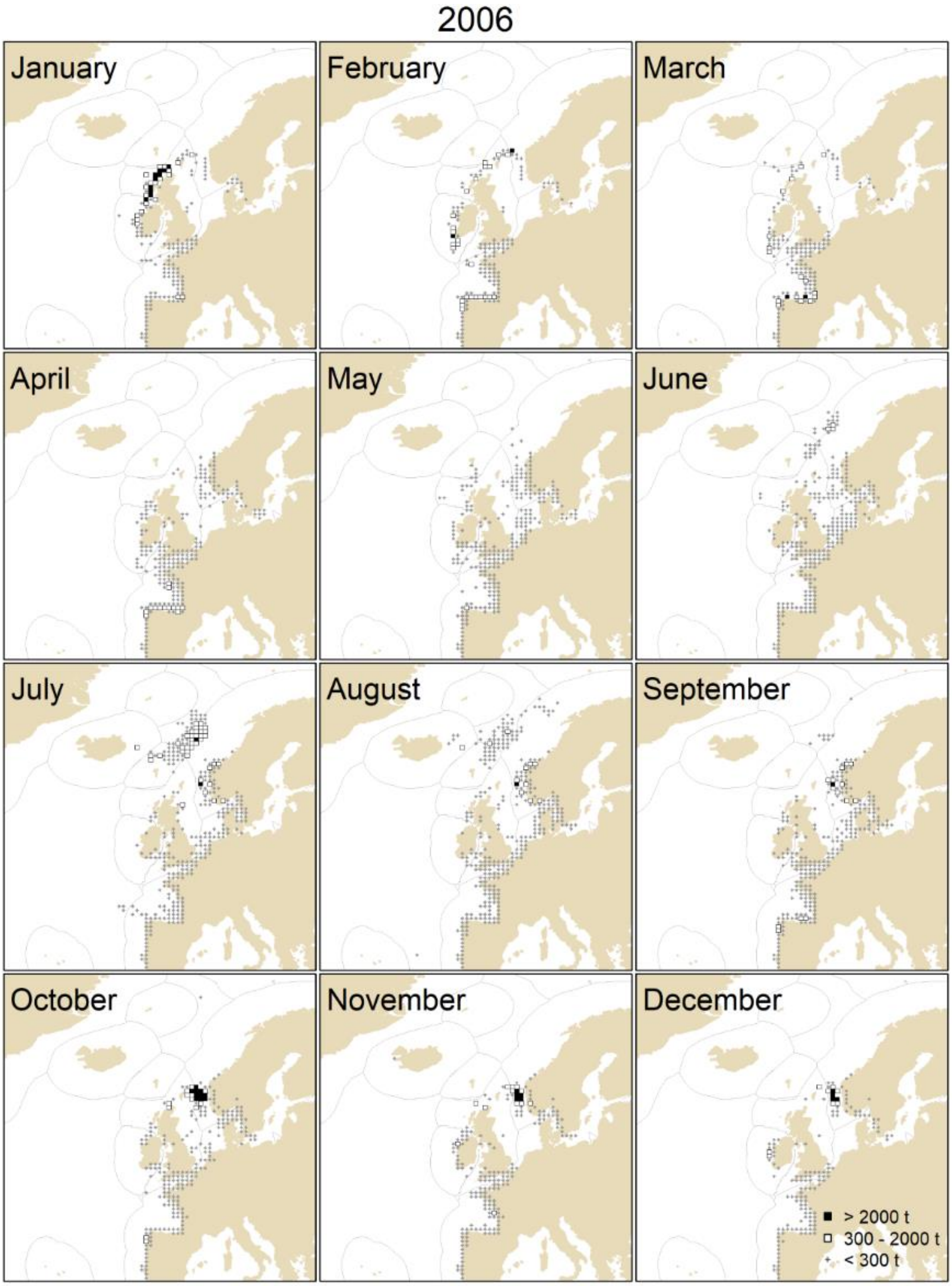

Figure A3.1.14. Monthly catches of Northeast Atlantic (NEA) mackerel in 2006.

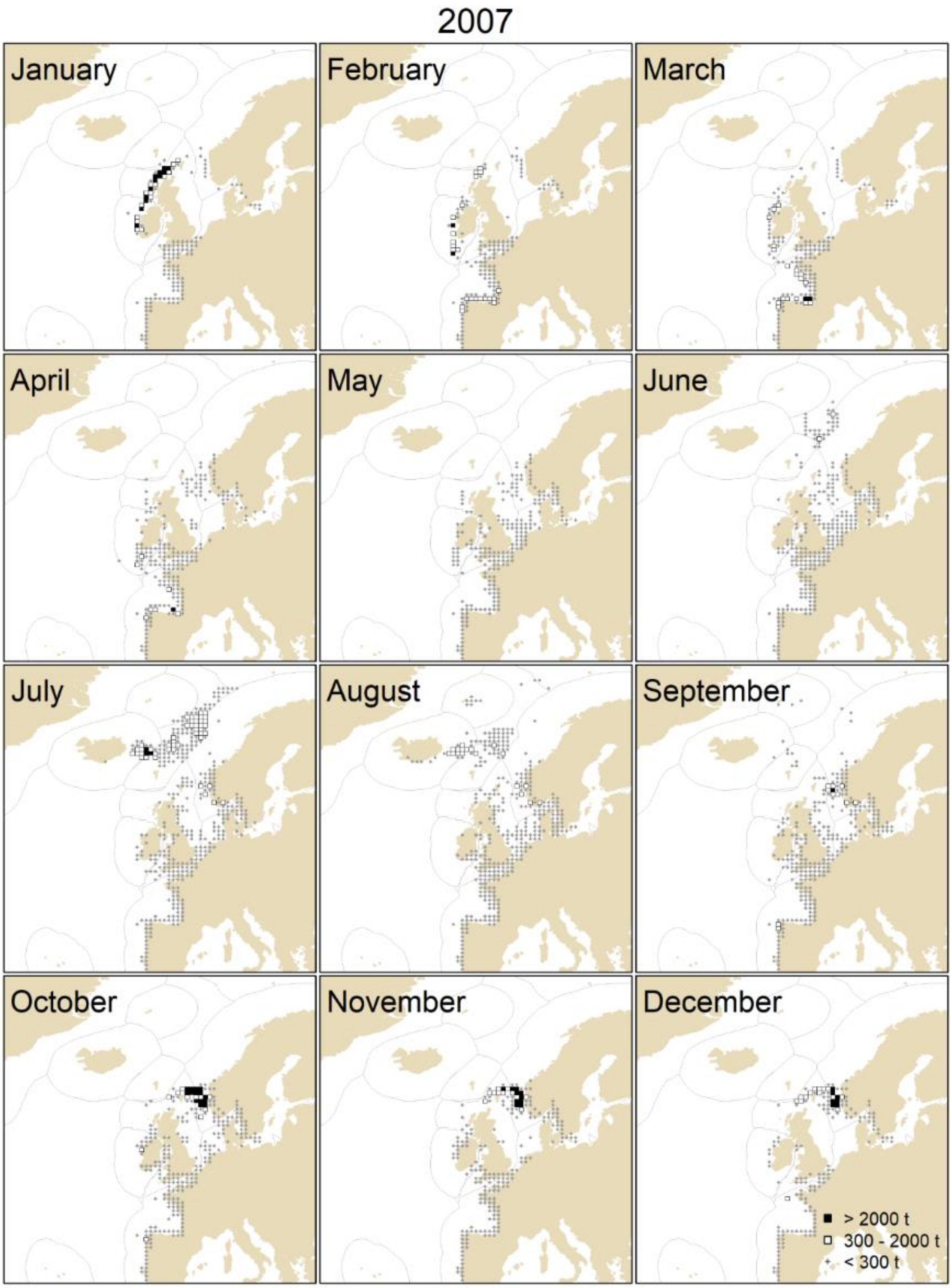

Figure A3.1.15. Monthly catches of Northeast Atlantic (NEA) mackerel in 2007.

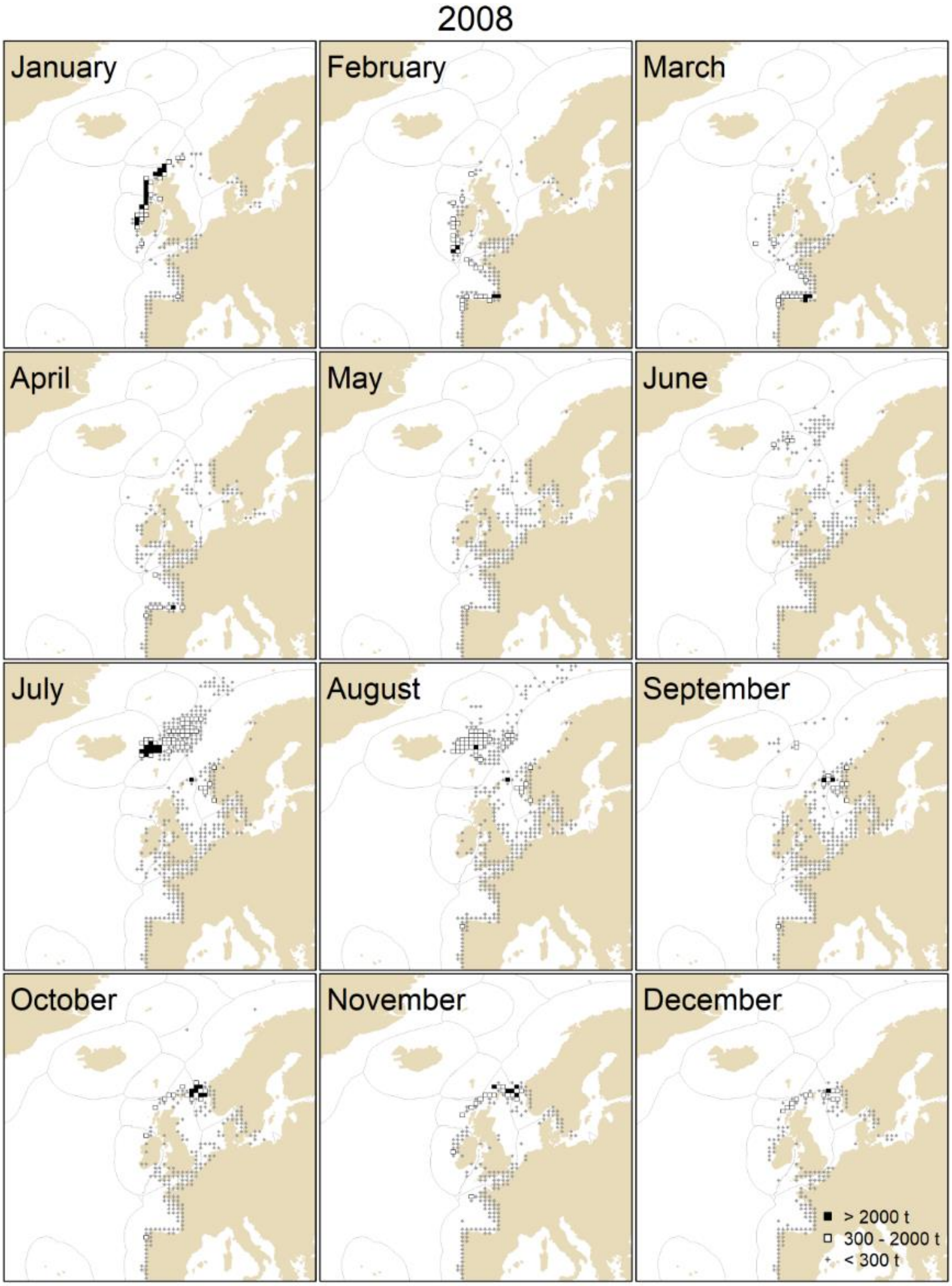

Figure A3.1.16. Monthly catches of Northeast Atlantic (NEA) mackerel in 2008.

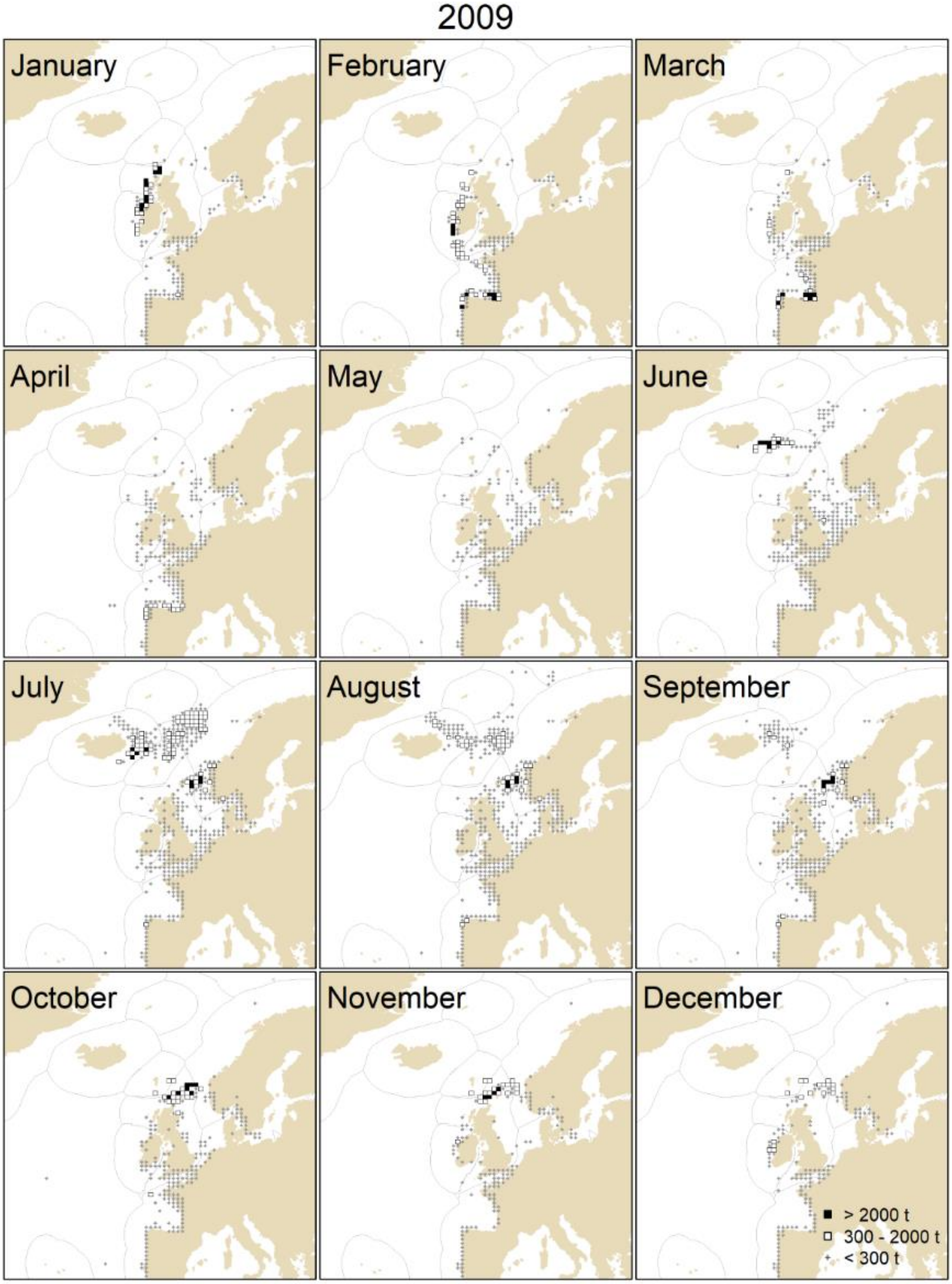

Figure A3.1.17. Monthly catches of Northeast Atlantic (NEA) mackerel in 2009.

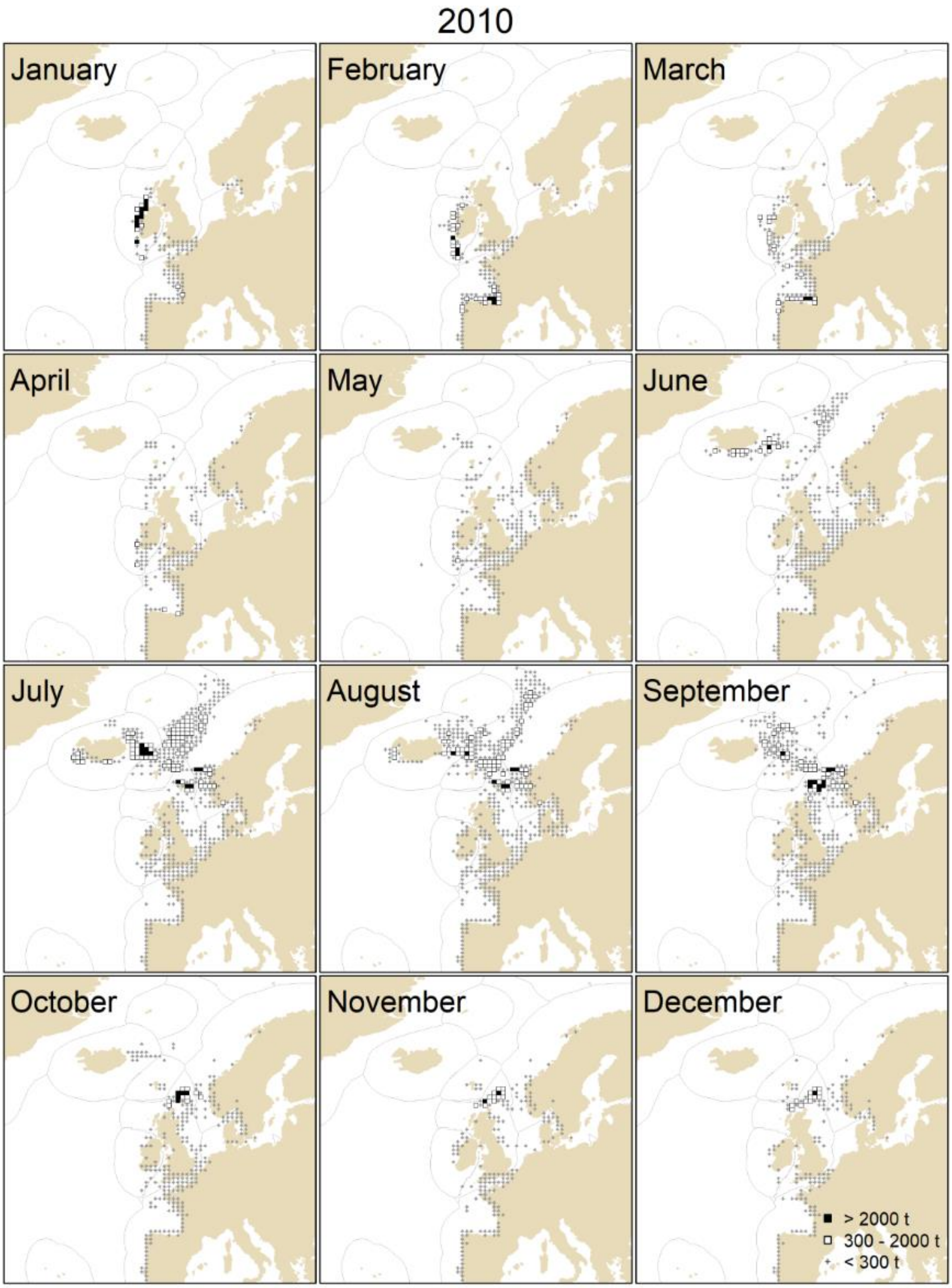

Figure A3.1.18. Monthly catches of Northeast Atlantic (NEA) mackerel in 2010.

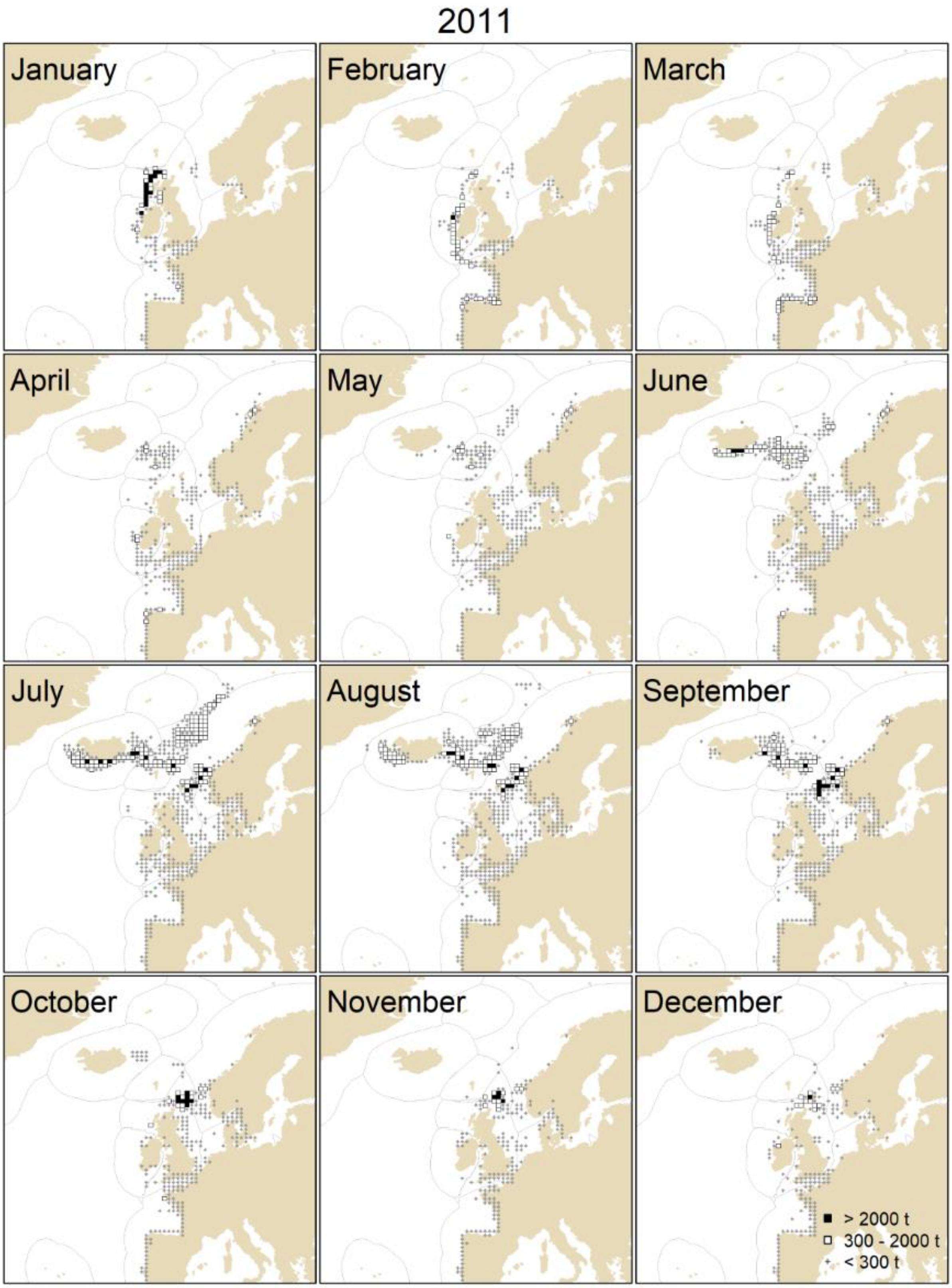

Figure A3.1.19. Monthly catches of Northeast Atlantic (NEA) mackerel in 2011.

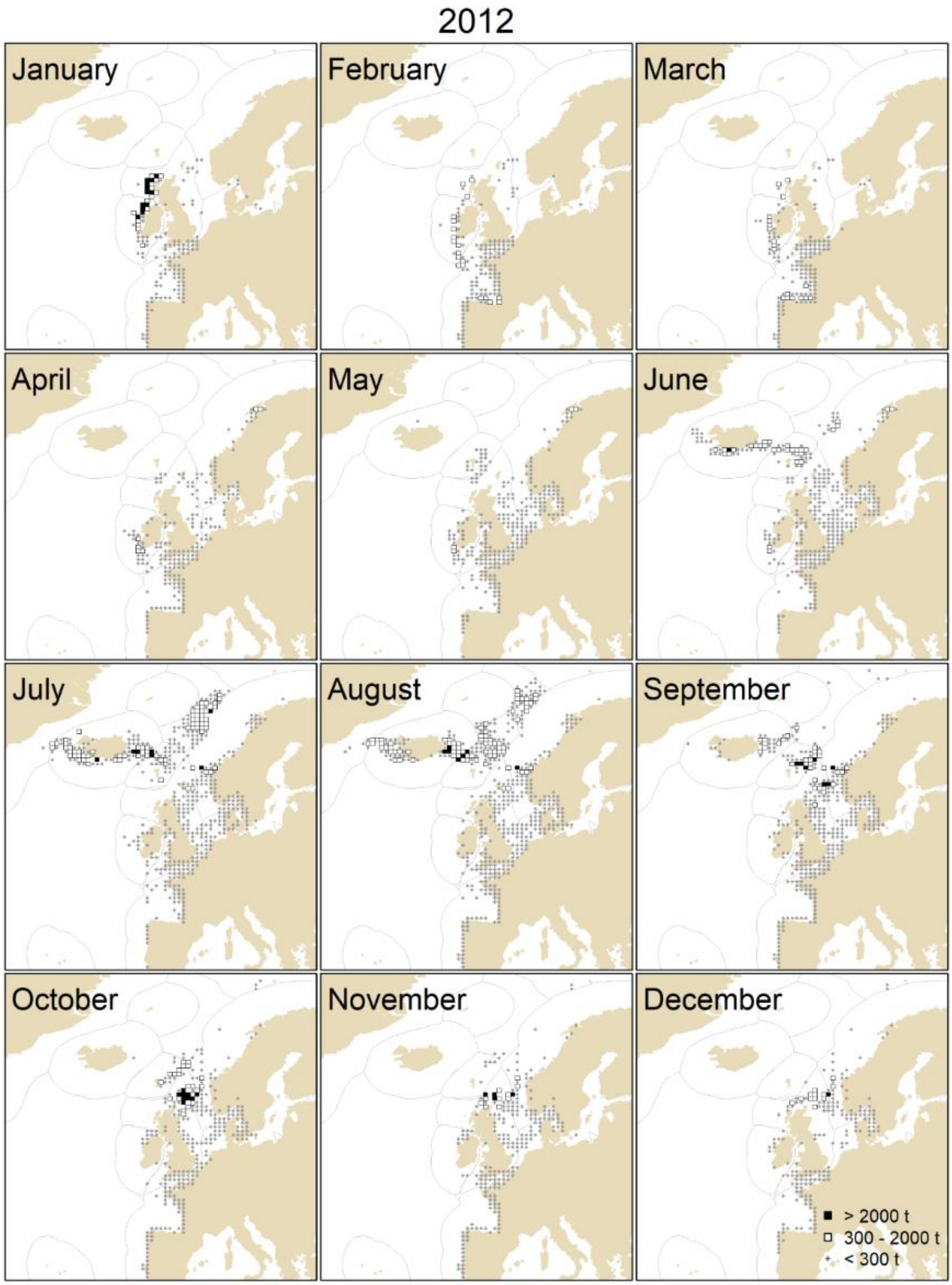

Figure A3.1.20. Monthly catches of Northeast Atlantic (NEA) mackerel in 2012.

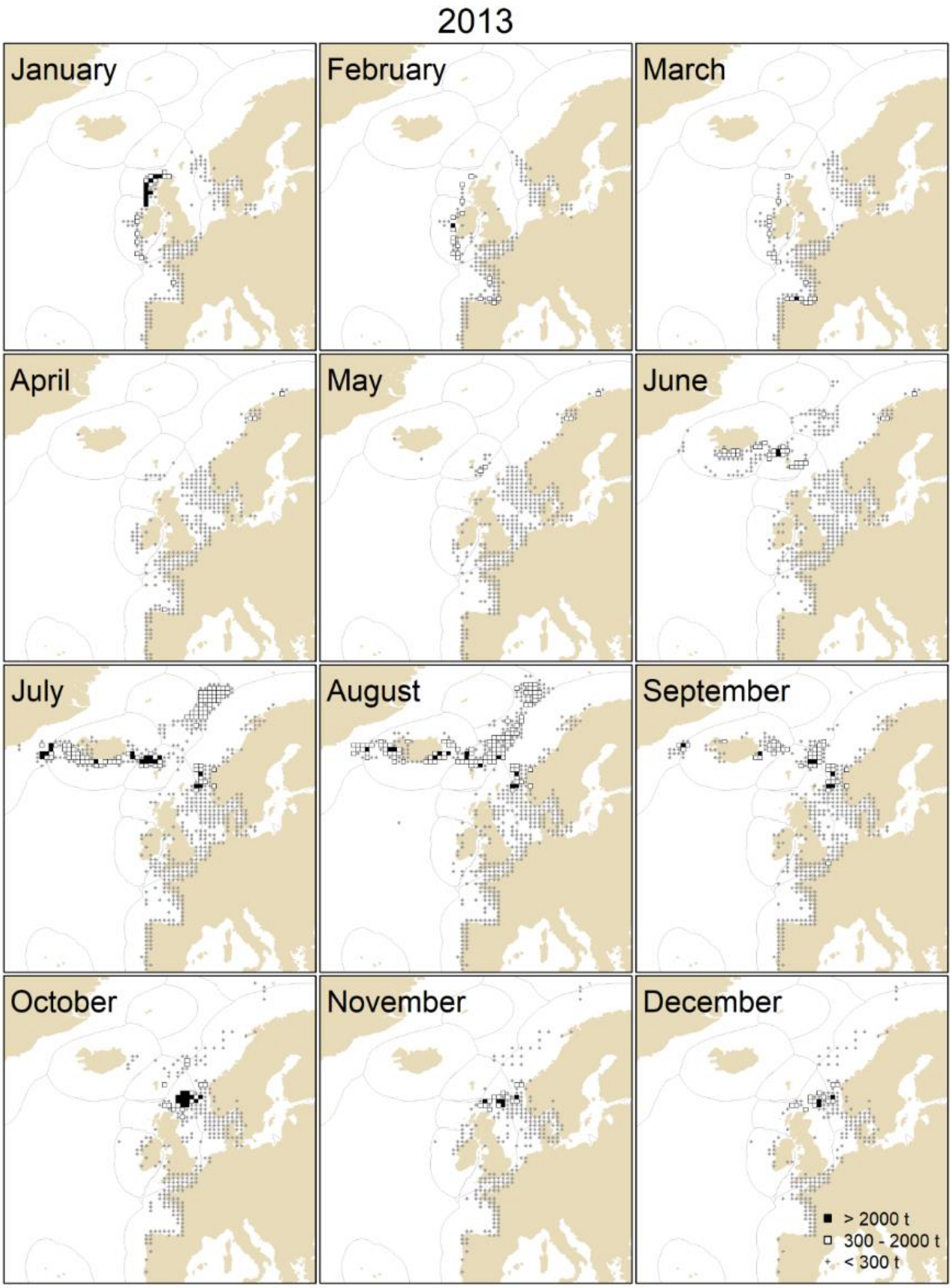

Figure A3.1.21. Monthly catches of Northeast Atlantic (NEA) mackerel in 2013.

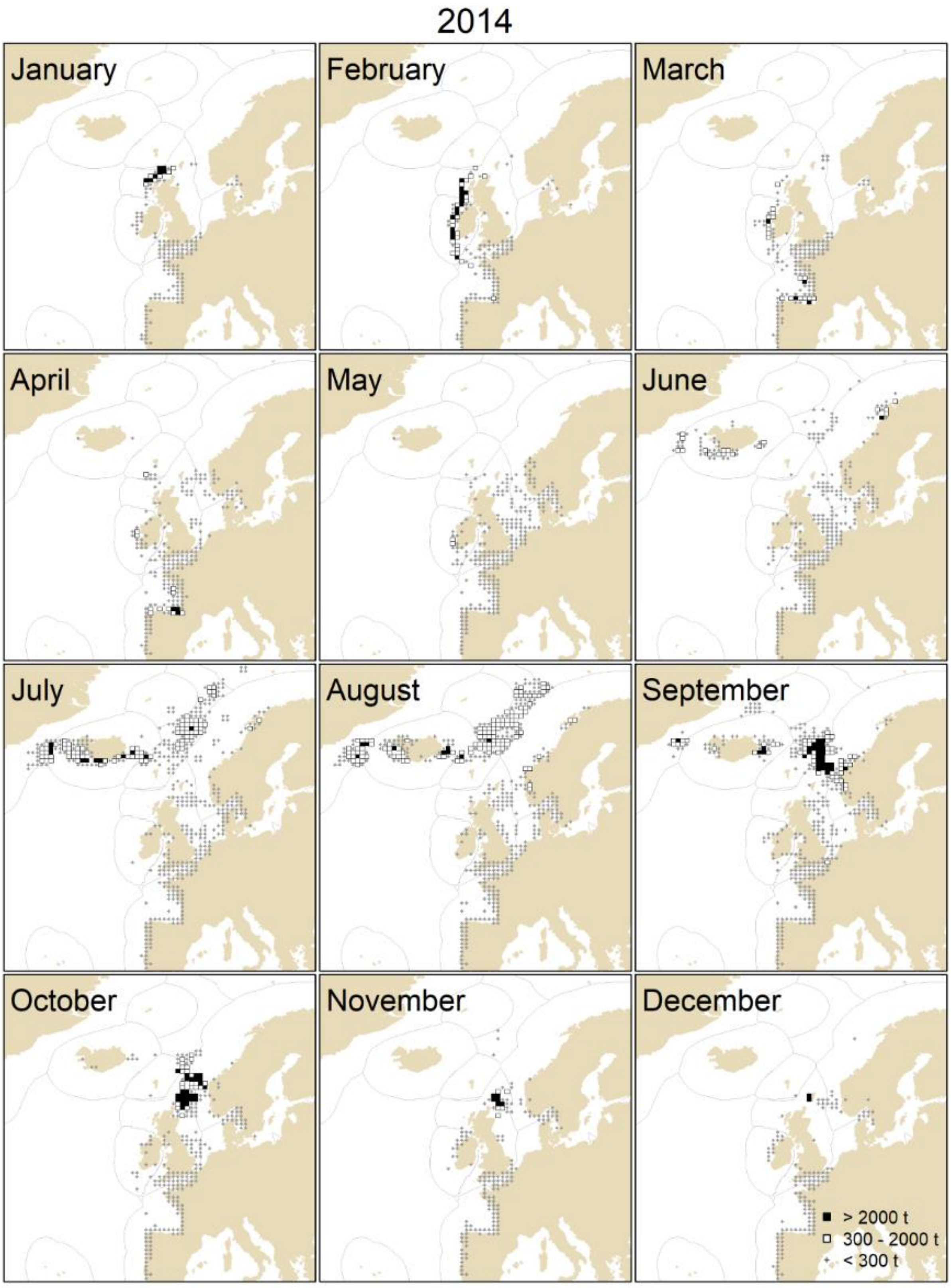

Figure A3.1.22. Monthly catches of Northeast Atlantic (NEA) mackerel in 2014.

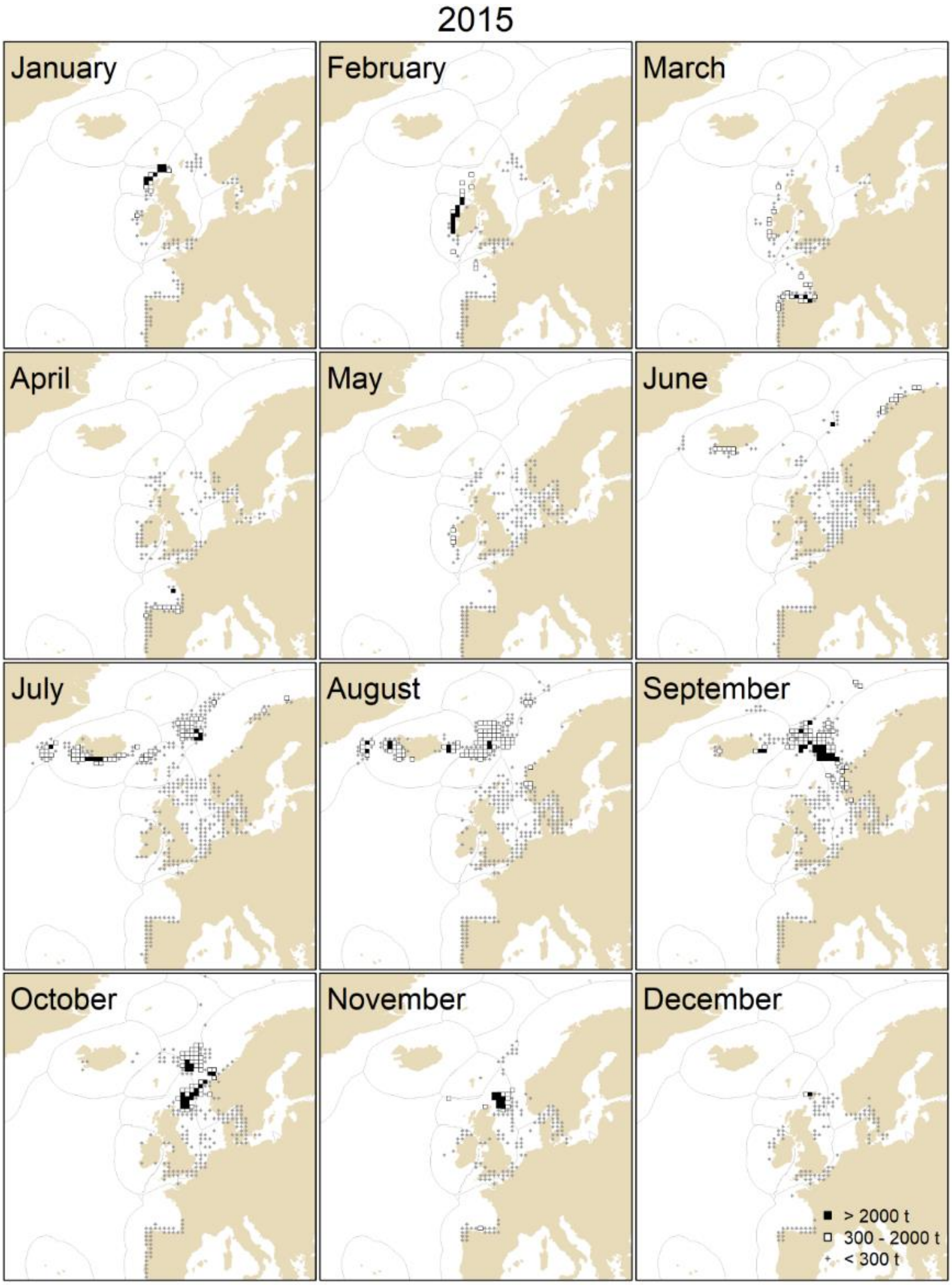

Figure A3.1.23. Monthly catches of Northeast Atlantic (NEA) mackerel in 2015.

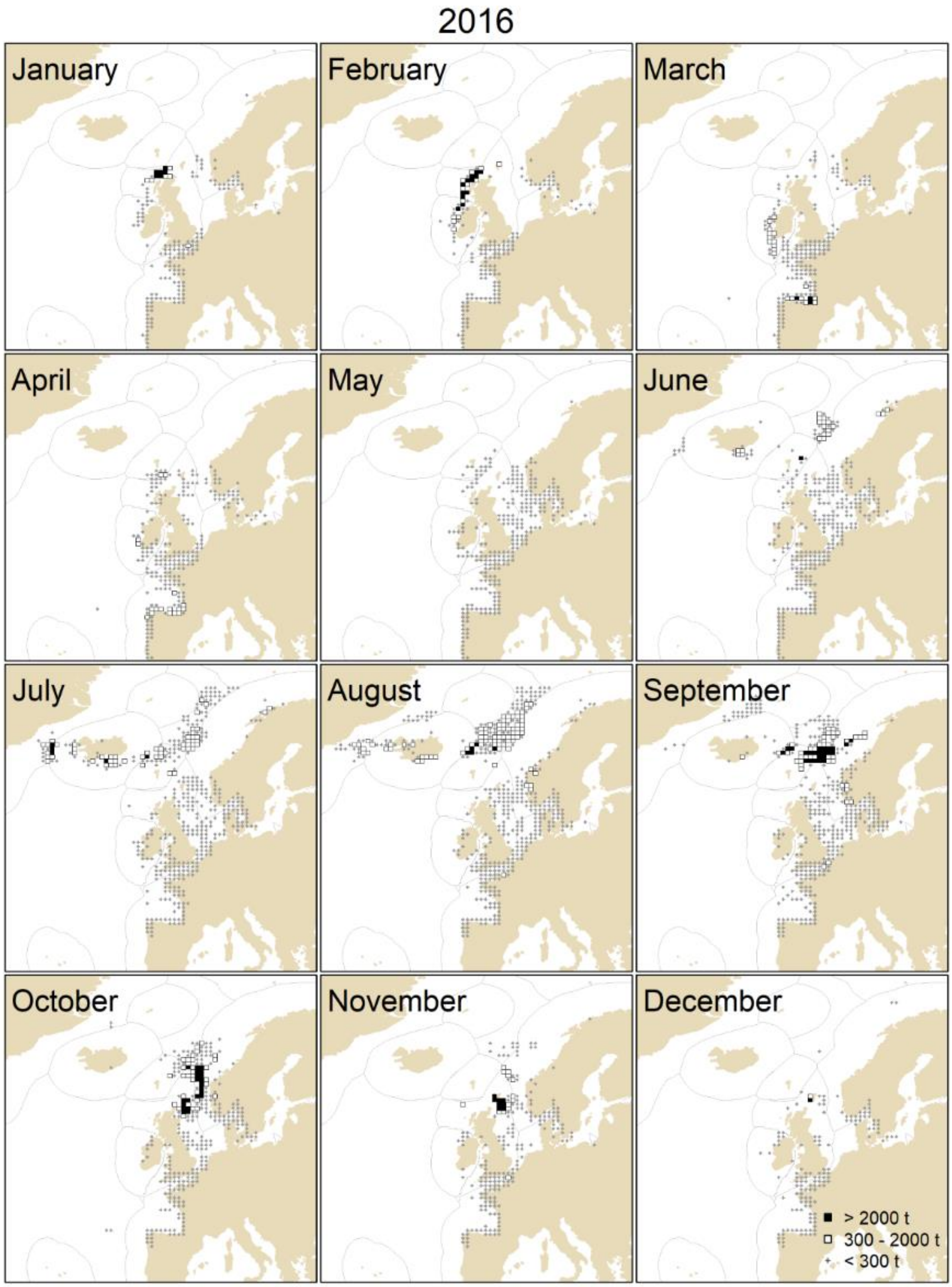

Figure A3.1.24. Monthly catches of Northeast Atlantic (NEA) mackerel in 2016.

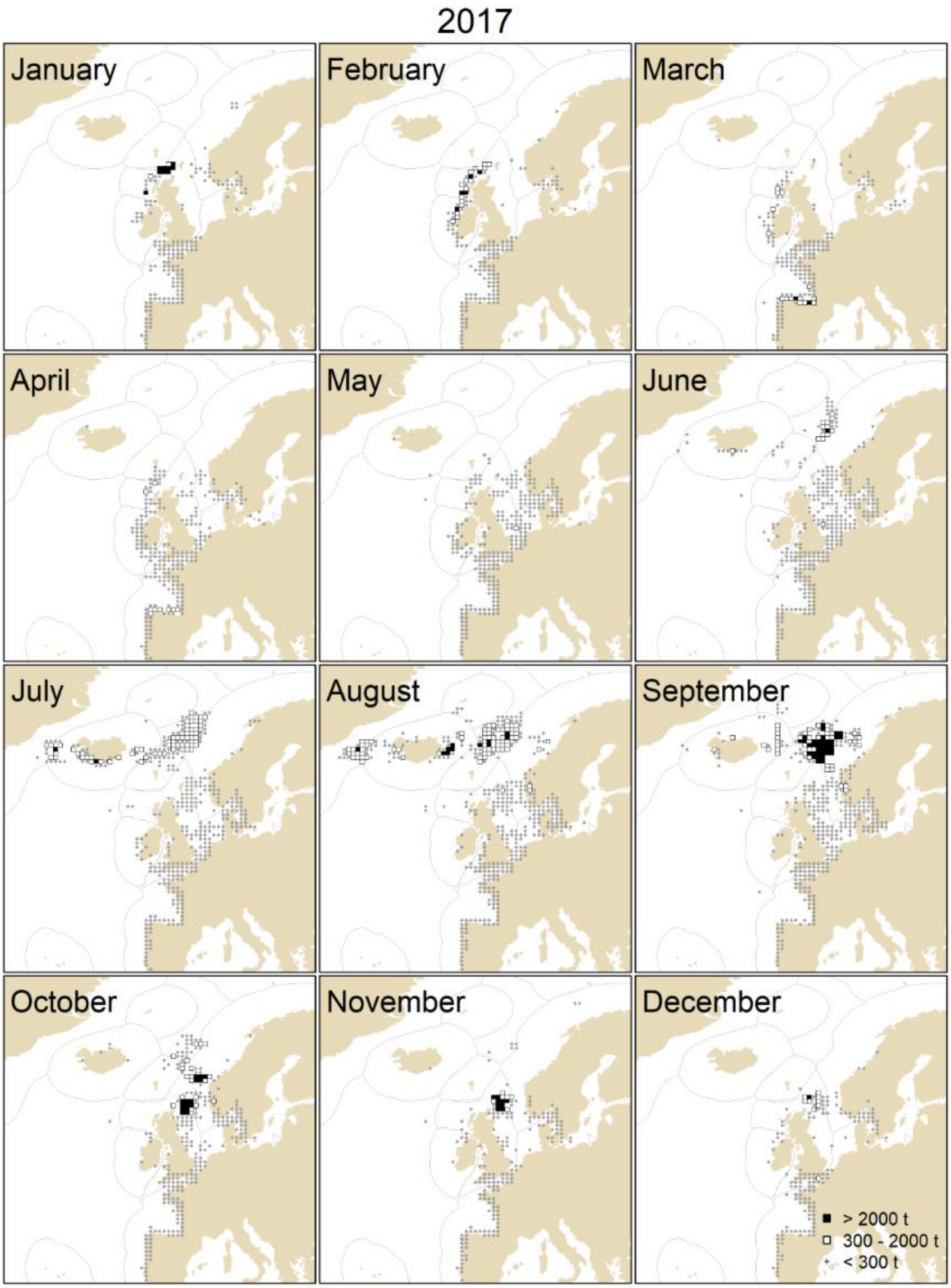

Figure A3.1.25. Monthly catches of Northeast Atlantic (NEA) mackerel in 2017.

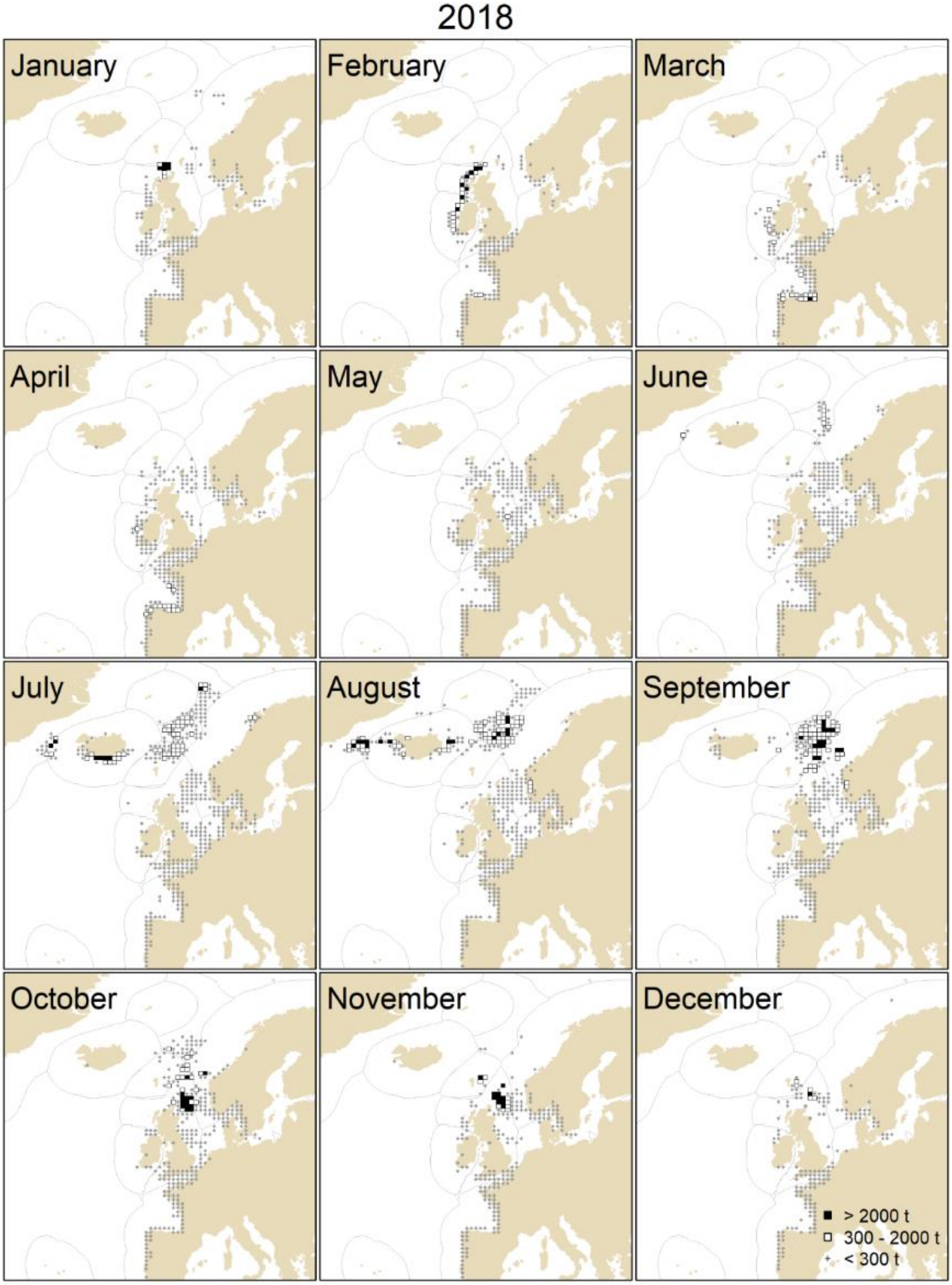

Figure A3.1.26. Monthly catches of Northeast Atlantic (NEA) mackerel in 2018.

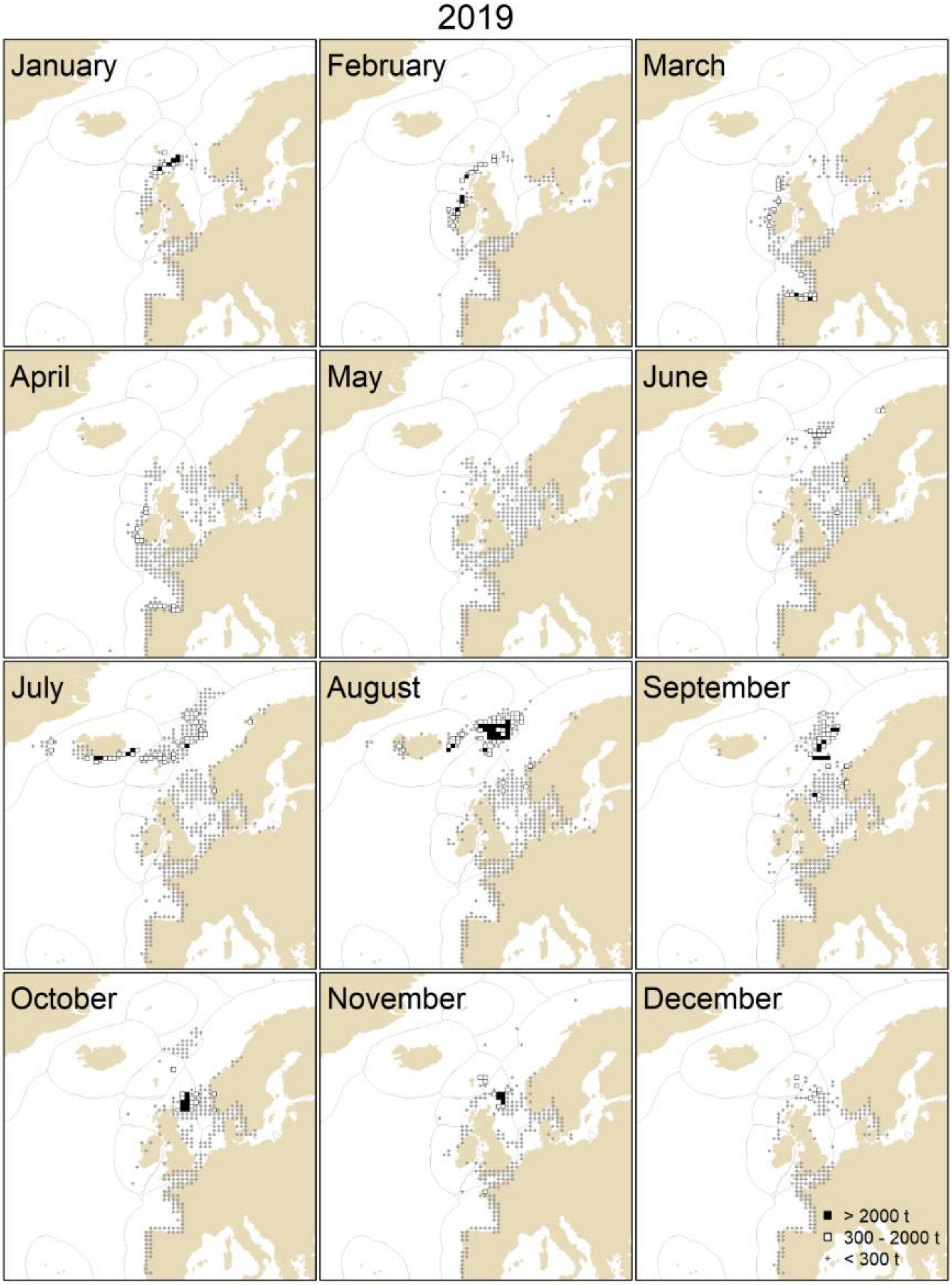

Figure A3.1.27. Monthly catches of Northeast Atlantic (NEA) mackerel in 2019.

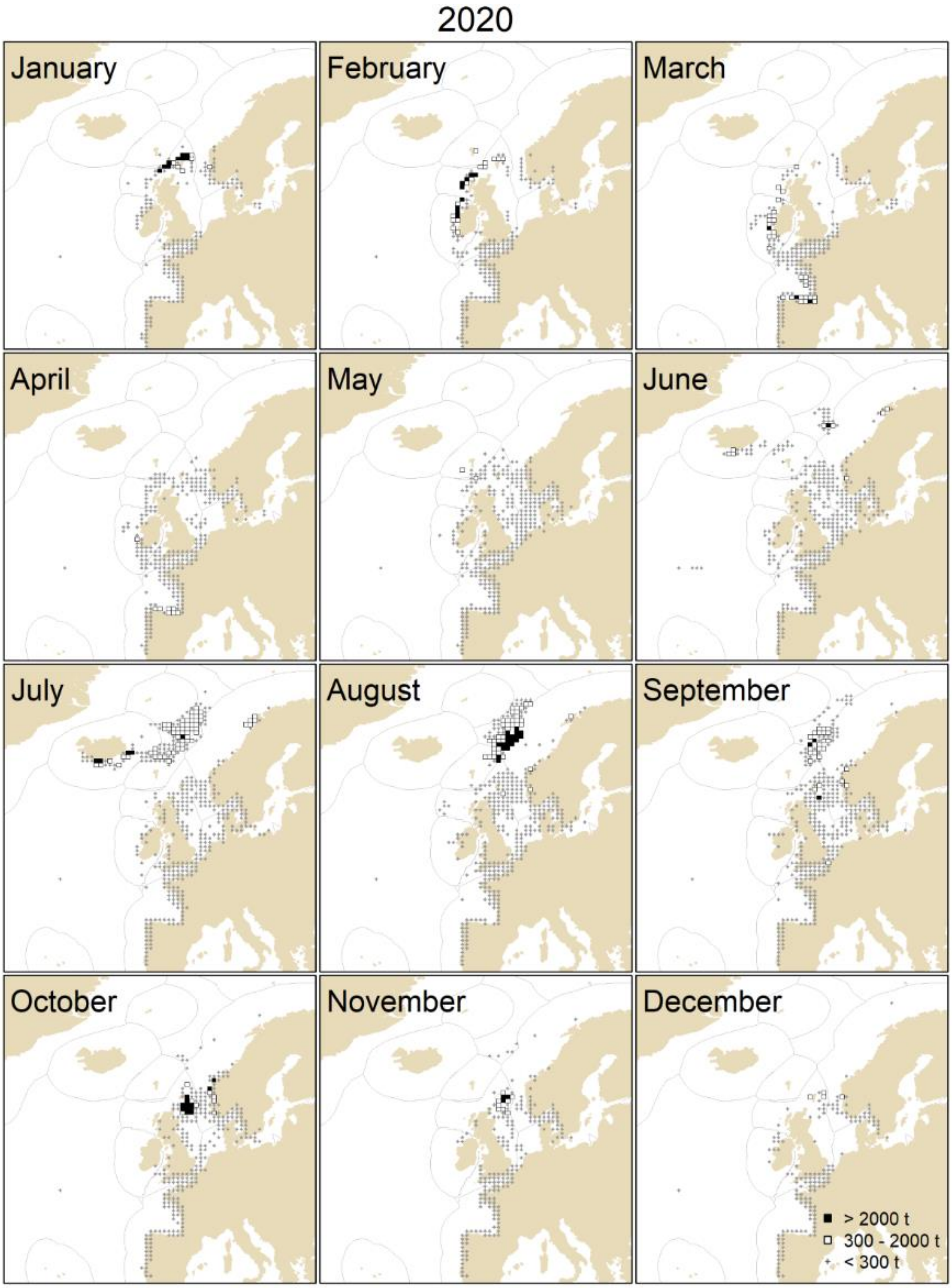

Figure A3.1.28. Monthly catches of Northeast Atlantic (NEA) mackerel in 2020.

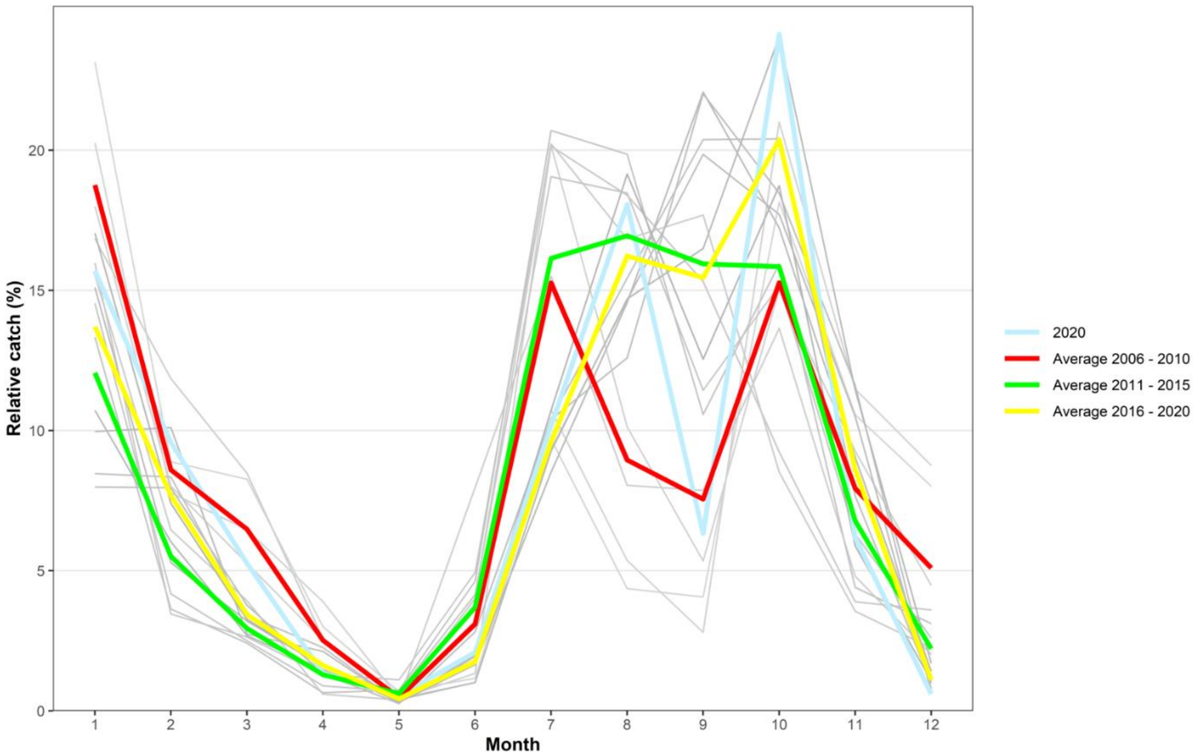

Figure A3.1.29. Relative catch of Northeast Atlantic (NEA) mackerel in 5-year averages between 2006–2020. Individual years are represented by the grey lines with the final year (2020) in blue.

A3.2 Tables

Table A3.2.1. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2006.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	15685	223	0	0	3	0	53	0	0	0	0	89103	121	105188
2	27973	65	0	0	0	0	2167	0	0	0	0	10152	20	40377
3	34832	21	0	0	0	0	53	0	0	0	0	2655	6	37567
4	12729	0	0	0	0	0	229	0	0	0	0	703	0	13661
5	2305	0	0	0	8	0	252	0	0	0	0	540	0	3105
6	1501	551	0	0	1295	0	1081	0	0	0	0	852	0	5280
7	1627	6375	0	0	16462	703	17988	0	0	24	0	899	0	44078
8	2008	1201	0	0	2848	933	12387	0	0	0	0	454	0	19831
9	3305	2	0	0	29	0	14050	0	0	0	0	1077	0	18463
10	2379	0	0	0	1	0	48746	0	0	0	0	31387	0	82513
11	5169	12	0	0	0	85	36072	0	0	0	0	6679	3	48020
12	2856	0	0	0	0	0	31907	0	0	0	0	1646	0	36409
Total	112369	8450	0	0	20646	1721	164985	0	0	24	0	146147	150	454492

Table A3.2.2. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2007.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	28454	0	0	0	0	0	53	0	0	0	0	82522	389	111418
2	38109	17	0	0	0	0	53	0	0	0	0	4608	13	42800
3	34940	0	0	0	0	0	53	0	0	0	0	566	0	35559
4	20850	0	0	0	0	0	214	0	0	0	0	366	7	21437
5	1537	0	0	0	0	0	215	0	0	0	0	709	0	2461
6	1256	177	0	0	2397	0	1254	0	0	0	0	445	0	5529
7	1916	10333	0	0	18860	17262	9791	0	0	259	3	573	0	58997
8	2147	4678	0	0	2773	11295	7950	0	0	28	1	634	0	29506
9	2634	66	0	0	0	25	10315	0	0	14	0	2354	0	15408
10	3335	142	0	0	0	0	55711	0	0	0	0	56202	121	115511
11	2489	48	0	0	0	0	43865	0	0	0	0	16724	6	63132
12	1263	80	0	0	0	0	38421	0	0	0	0	8349	25	48138
Total	138930	15541	0	0	24030	28582	167895	0	0	301	4	174052	561	549896

Table A3.2.3. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2008.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	45567	79	0	0	0	0	9	0	0	0	0	61418	114	107187
2	46602	0	0	0	37	0	13	0	0	0	0	1069	0	47721
3	30986	0	0	0	0	0	8	0	0	0	0	365	0	31359
4	14167	0	0	0	0	0	367	0	0	0	0	434	0	14968
5	1695	50	0	0	0	0	371	0	0	0	0	450	0	2566
6	1175	2935	34	0	1216	1481	476	0	0	0	0	652	0	7969
7	2298	35739	36	0	18286	43967	15296	0	0	265	1	4203	0	120091
8	2177	10833	0	0	8538	18989	15420	0	0	90	20	4237	0	60304
9	2514	894	0	0	25	507	19852	0	0	0	0	8030	0	31822
10	2406	111	0	0	0	0	26495	0	0	0	0	60469	52	89533
11	2502	117	0	0	0	0	16885	0	0	0	0	35596	64	55164
12	1973	6	0	0	0	0	13074	0	0	0	0	11539	24	26616
Total	154062	50764	70	0	28102	64944	108266	0	0	355	21	188462	254	595300

Table A3.2.4. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2009.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	35198	0	0	0	0	0	0	0	0	0	0	87183	281	122662
2	82984	0	0	0	2	0	0	0	0	0	0	3323	0	86309
3	60884	0	0	0	0	0	0	0	0	0	0	842	0	61726
4	17780	3	0	0	5	0	357	0	0	0	0	620	2	18767
5	1759	144	0	0	0	221	355	0	0	0	0	414	3	2896
6	1867	6240	1094	0	1254	45938	396	0	0	0	0	1235	2	58026
7	1915	7670	189	0	21203	46315	17148	0	0	554	0	17905	0	112899
8	2316	2855	0	6	7576	10778	17198	0	0	41	11	17815	0	58596
9	1772	721	0	0	22	3074	18291	0	0	0	0	33403	0	57283
10	2493	1075	0	0	0	0	8373	0	0	0	0	87201	210	99352
11	1201	1012	0	0	0	0	4357	0	0	0	0	28232	177	34979
12	3226	882	0	0	0	0	4356	0	0	0	0	6028	131	14623
Total	213395	20602	1283	6	30062	106326	70831	0	0	595	11	284201	806	728118

Table A3.2.5. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2010.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	133388	0	0	0	0	0	0	0	0	0	0	810	0	134198
2	55426	0	0	0	0	0	0	0	0	0	0	333	0	55759
3	33521	0	0	0	0	0	0	0	0	0	0	372	0	33893
4	4164	258	0	0	0	43	266	0	0	0	0	356	36	5123
5	2038	260	0	0	109	98	271	0	0	0	0	580	31	3387
6	1310	699	27	0	3594	27740	415	0	0	10	0	859	31	34685
7	1590	22128	0	0	27455	53439	37250	0	0	507	1	32189	0	174559
8	2059	27113	0	0	13339	29831	38818	0	0	153	6	33978	0	145297
9	2146	16726	0	0	299	15585	38459	0	0	97	3	79347	0	152662
10	882	102	0	0	63	440	1362	0	0	0	0	70658	3	73510
11	1065	89	0	0	0	0	307	0	0	0	0	29219	3	30683
12	767	89	0	0	0	0	560	0	0	0	0	17932	8	19356
Total	238356	67464	27	0	44859	127176	117708	0	0	767	10	266633	112	863112

Table A3.2.6. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2011.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	27919	0	0	0	0	0	1	0	0	0	0	121758	255	149933
2	29062	0	0	0	0	0	0	0	0	0	0	3328	43	32433
3	21908	0	0	0	0	0	0	0	0	0	0	2789	43	24740
4	4454	4420	73	0	3	248	2341	0	0	0	0	647	2	12188
5	1806	4544	113	0	279	724	2344	0	0	0	0	573	2	10385
6	1426	13584	193	0	1501	26131	2504	0	0	0	0	990	2	46331
7	3114	34735	468	0	32132	59829	32275	0	0	132	0	26334	0	189019
8	2561	41074	455	59	14418	58381	28916	0	0	0	0	26732	0	172596
9	1216	32029	455	0	8	18343	29750	0	0	0	0	61928	0	143729
10	2061	64	0	0	0	248	2299	0	0	0	0	82007	1	86680
11	1183	161	0	0	6	0	1123	0	0	0	0	34041	26	36540
12	1594	75	0	0	0	0	1111	0	0	0	0	30924	59	33763
Total	98304	130686	1757	59	48347	163904	102664	0	0	132	0	392051	433	938337

Table A3.2.7. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2012.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	54684	0	0	0	0	0	8	0	0	0	0	73640	0	128332
2	33530	0	0	0	479	0	8	0	0	0	0	2841	0	36858
3	20127	0	0	0	0	0	8	0	0	0	0	1915	0	22050
4	5503	24	0	0	0	0	2178	0	0	0	0	166	22	7893
5	2320	891	0	0	0	2	2184	0	0	0	0	665	12	6074
6	1894	11238	154	0	2137	15993	4564	0	0	0	0	632	0	36612
7	1051	15359	3	3561	28981	71916	43928	0	0	532	0	2800	0	168131
8	1653	35210	962	1815	16616	65141	38008	0	0	767	0	2807	0	162979
9	1302	30395	0	31	1357	9724	37137	0	0	20	10	20916	0	100892
10	813	9224	0	0	210	35	3583	0	0	0	1	120028	8	133902
11	811	366	0	0	97	0	2350	0	0	0	0	51909	97	55630
12	407	0	0	0	0	0	2350	0	0	0	0	20182	1	22940
Total	124095	102707	1119	5407	49877	162811	136306	0	0	1319	11	298501	140	882293

Table A3.2.8. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2013.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	21230	0	0	0	0	0	1	0	0	0	0	102128	0	123359
2	31967	0	0	0	0	0	2	0	0	0	0	1652	0	33621
3	21060	0	0	0	0	0	2	0	0	0	0	1304	0	22366
4	2312	37	0	0	0	2	3289	0	0	0	0	349	18	6007
5	1128	1846	0	0	0	41	3297	0	0	0	0	576	8	6896
6	929	24280	404	97	1747	10846	3588	0	0	5	0	873	0	42769
7	989	37890	802	32635	31145	59025	19139	1	0	1657	58	8194	0	191535
8	1174	52276	208	15889	24582	60589	19179	0	0	136	219	9469	0	183721
9	1242	24622	0	10140	3098	18671	20908	0	0	0	0	19156	0	97837
10	760	3501	0	0	958	715	9748	0	0	0	0	131781	68	147531
11	576	74	0	0	50	0	7912	0	0	0	0	32139	0	40751
12	435	4	0	0	29	0	7907	0	0	0	0	20439	0	28814
Total	83802	144530	1414	58761	61609	149889	94972	1	0	1798	277	328060	94	925207

Table A3.2.9. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2014.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	1326	0	0	0	0	0	0	0	0	0	0	111481	4157	116964
2	87949	0	0	0	0	0	0	0	0	0	0	27222	103	115274
3	45905	0	0	0	0	0	0	0	0	0	0	1117	0	47022
4	30453	490	0	0	0	8	26	0	0	0	0	246	49	31272
5	2655	1	0	0	0	30	480	0	0	0	0	831	0	3997
6	918	282	0	2028	664	9200	12804	0	0	0	0	894	36	26826
7	963	10274	388	26097	37054	65258	2894	1	0	565	15	475	0	143984
8	1215	30975	412	43658	57213	69225	8515	0	0	1011	384	643	0	213251
9	1448	54237	0	9889	34917	22972	108538	0	0	42	0	49558	0	281601
10	1187	6217	0	0	1123	246	35322	0	0	0	0	237864	1	281960
11	895	0	0	0	26	0	75	0	0	0	0	105005	0	106001
12	1260	28	0	0	0	0	18	0	0	0	0	12269	31	13606
Total	176174	102504	800	81672	130997	166939	168672	1	0	1618	399	547605	4377	1381758

Table A3.2.10. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2015.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	1210	0	0	0	0	0	219	0	0	0	0	91431	847	93707
2	86934	0	0	0	0	0	244	0	0	0	0	6204	0	93382
3	42139	0	0	0	0	0	68	0	0	0	0	2023	0	44230
4	15428	7	0	0	0	0	66	0	0	0	0	111	20	15632
5	2217	41	0	0	0	31	535	0	0	0	0	223	37	3084
6	996	450	0	29	5979	5144	19970	0	0	0	0	469	0	33037
7	475	4207	288	10444	34859	56658	13784	1	0	64	0	1182	0	121962
8	560	27452	0	12485	47164	53185	5036	1	0	915	38	891	0	147727
9	498	44104	0	12	49531	25277	113228	0	0	14	0	25589	0	258253
10	1112	12625	0	0	4896	115	63537	0	0	3	0	134297	0	216585
11	1489	7	0	0	4	0	159	0	0	0	0	134583	0	136242
12	670	0	0	0	0	0	38	0	0	0	0	8503	0	9211
Total	153728	88893	288	22970	142433	140410	216884	2	0	996	38	405506	904	1173052

Table A3.2.11. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2016.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	1540	0	0	0	0	0	53	0	0	0	0	105768	59	107420
2	23135	0	0	0	0	0	11	0	0	0	0	85737	52	108935
3	28877	0	0	0	16	0	88	0	0	0	0	579	0	29560
4	20065	1308	0	0	77	0	40	0	0	0	0	625	748	22863
5	1928	259	0	0	0	0	472	0	0	0	0	624	13	3296
6	1100	3936	0	121	7606	3270	4928	0	0	0	0	694	2	21657
7	1536	19893	39	17948	15368	39826	4367	0	0	338	14	1060	0	100389
8	1821	49587	0	12541	50121	32022	10382	0	0	557	16	881	0	157928
9	1529	66990	0	357	33496	6316	96691	0	0	105	0	8497	0	213981
10	813	5514	0	0	4168	4	90667	0	0	0	0	89782	0	190948
11	1431	172	0	0	146	0	1401	0	0	0	0	110144	0	113294
12	1004	0	0	0	0	0	2	0	0	0	0	6651	0	7657
Total	84779	147659	39	30967	110998	81438	209102	0	0	1000	30	411042	874	1077928

Table A3.2.12. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2017.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	979	144	0	0	0	0	11	0	0	0	0	172291	953	174378
2	10321	95	0	0	0	0	6	0	0	0	0	50445	155	61022
3	31324	0	0	0	0	1	3	0	0	0	0	5718	0	37046
4	15573	362	0	0	0	0	36	0	0	0	0	2113	167	18251
5	1460	152	0	0	2	2	656	0	0	0	0	1301	60	3633
6	607	551	11	5	10439	1147	5357	0	0	1	0	930	0	19048
7	750	8920	81	6155	35045	43097	3209	1	0	182	0	819	0	98259
8	919	22483	0	18738	56572	62527	4866	0	0	81	0	1903	0	168089
9	1037	38136	0	38	109209	7494	89852	0	0	131	0	8848	0	254745
10	1045	3353	0	0	3129	378	56509	0	0	0	0	134393	0	198807
11	869	10	0	0	0	1	94	0	0	0	0	103472	0	104446
12	650	126	0	0	0	0	15	0	0	0	0	15561	0	16352
Total	65534	74332	92	24936	214396	114647	160614	1	0	395	0	497794	1335	1154076

Table A3.2.13. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2018.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	892	0	0	0	0	0	6	0	0	0	0	107594	585	109077
2	21273	0	0	0	0	0	5	0	0	0	0	39922	169	61369
3	27022	0	0	0	0	0	0	0	0	0	0	286	0	27308
4	14174	252	0	0	0	1	27	0	0	0	0	425	68	14947
5	1380	145	0	0	0	0	884	0	0	0	0	1604	59	4072
6	843	41	0	874	5566	151	1812	0	0	11	0	1030	0	10328
7	926	10442	0	12314	23434	41024	2556	0	0	2584	0	899	0	94179
8	1039	2231	0	35675	64905	39089	3618	0	0	1621	0	1263	0	149441
9	902	28610	0	0	98660	1869	24701	0	0	9	0	12968	0	167719
10	901	2495	0	0	6549	4	7433	0	0	0	0	227298	0	244680
11	492	8185	0	0	2	122	177	0	0	0	0	107480	0	116458
12	398	1186	0	0	0	0	2	0	0	0	0	15682	1	17269
Total	70242	53587	0	48863	199116	82260	41221	0	0	4225	0	516451	882	1016847

Table A3.2.14. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2019.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	765	1482	0	0	0	0	0	0	0	0	0	139343	80	141670
2	33564	0	0	0	0	0	0	0	0	0	0	27942	13	61519
3	23718	0	0	0	0	0	1	0	0	0	0	3432	0	27151
4	11537	250	0	0	0	0	85	0	0	0	0	1275	140	13287
5	2038	556	0	0	0	0	371	0	0	0	0	1903	51	4919
6	1220	1569	0	0	8777	0	3581	0	0	0	0	1432	0	16579
7	1640	10104	91	5567	19410	43874	7615	0	0	227	0	576	0	89104
8	963	6784	0	2	125491	19749	2964	0	0	1145	0	2116	0	159214
9	739	10625	0	0	33639	46	21795	0	0	27	0	37408	0	104279
10	666	420	0	0	88	4	2374	0	0	0	0	152183	0	155735
11	1007	4078	0	0	5	0	185	0	0	0	0	43661	0	48936
12	462	3874	0	0	0	0	4	0	0	0	0	4584	0	8924
Total	78319	39742	91	5569	187410	63673	38975	0	0	1399	0	415855	284	831317

Table A3.2.15. Monthly catches (tonnes) of Northeast Atlantic (NEA) mackerel by Exclusive Economic Zone (EEZ) for 2020.

Month	EU27	FO	FO_IS	GR	INT	IS	NO	NO_EU27	RU	SJM	SVA	UK	UK_FO	Total
1	918	516	0	0	0	0	849	0	0	0	0	158525	237	161045
2	33305	393	0	0	0	0	0	0	0	0	0	64481	41	98220
3	51526	0	0	0	0	0	1	0	0	0	0	2478	21	54026
4	12904	247	0	0	0	0	56	0	0	0	0	454	188	13849
5	2064	725	0	0	0	0	444	0	0	0	0	1970	262	5465
6	1075	884	7	0	6583	7130	4293	0	0	0	0	1483	0	21455
7	1399	8851	12	0	49342	38362	3522	0	0	1777	0	1054	0	104319
8	926	19646	0	0	128201	0	32624	0	0	262	0	3585	0	185244
9	1134	12281	0	0	30514	0	4742	0	0	41	0	16142	0	64854
10	884	1	0	0	4	0	19945	0	0	0	0	226818	0	247652
11	865	0	0	0	1	0	274	0	0	0	0	62357	0	63497
12	531	0	0	0	4	0	353	0	0	0	0	5258	0	6146
Total	107531	43544	19	0	214649	45492	67103	0	0	2080	0	544605	749	1025772