PFA
PELAGIC FREEZER-TRAWLER ASSOCIATION

REPORT

Report on 2020 scientific research projects

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Pelagic Freezer-trawler Association (PFA) /
Redersvereniging voor de Zeevisserij (RVZ)

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Cover photo: excursion of CERES research project participants on the KW172 Dirk Dirk, January 2020.

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Executive Summary

This report documents the aim, approach and outcomes of research projects carried out in 2020 that were supported by scientific catches allocated to members of the Redersvereniging voor de Zeevisserij (RVZ). Although the scientific catches that have been used for the projects have been allocated by the Netherlands, the report is written in English to allow for international dissemination of results.

In 2020, pelagic scientific catches have been allocated to the following projects:

1. Self-sampling the pelagic fleet
2. 6a herring survey 2020
3. Year of the Mackerel
4. PelAcoustics
5. Gonad en genetic research into horse mackerel
6. Automeasure
7. Broadband demonstrator

In addition, there area two research activities that have been continued from 2019.

8. Fish condition
9. Fat content of herring and mackerel

Main results are summarized below.

Self-sampling the pelagic fleet

The self-sampling on RVZ/PFA vessels has been rapidly expanding over the past years and has covered all vessels in the RVZ/PFA fleet since 2018. This provides detailed insights into the catch compositions and biological parameters on a highly resolved spatio-temporal scale in real time. Dedicated annual reports are produced for each of the relevant expert groups (HAWG, WGWIDE, WGDEEP, SPRFMO, CECAF). The implementation of the dedicated software for self-sampling (MCatch) has now been realized on 11 out of 17 vessels.

6a herring survey

The 2020 industry acoustic surveys on herring in 6a (and 7bc) was successfully executed. In 2020, no spawning herring were encountered in division 6.a although substantial schools of non-spawning herring were encountered. Results will be presented to ICES Planning Group on Surveys (WGIPS) in 2021 and to the Herring assessment working group 2021 (HAWG). The international survey report will be available soon.

Year of the Mackerel

The Year of the Mackerel was a large, dedicated research effort to monitor the gonad development of Northeast Atlantic mackerel throughout the year. The project was carried out from February 2019 until February 2020, with some sampling continuing until the summer of 2020. The main results are that spawning females with eggs present in the gonads were found from February to July in the western area and from June to July in the North Sea. While expected for the western area, for the North Sea this indicates that spawning season is longer than assumed in the North Sea egg survey. A striking result is that developing oocytes in the gonads were found throughout the year. This flexibility in developing oocytes explains the differences in the start of the spawning season that has been found during the most recent mackerel egg surveys.

Spawning males were found during the entire spawning season of the females, with highest number of spawning males at the start of the spawning season. Very few developing males were found, showing that males have a much shorter period for developing the sperm cells compared to the development of oocytes.

PelAcoustics

The PelAcoustics project aims to develop methodologies to utilize acoustic information from pelagic trawlers as supporting information for stock assessment and surveys. The focus in 2020 has been on continued acoustic data collection with the OceanBox (available on 5 trawlers) and on the development of tools to estimate overall biomass from trawler data. Special attention was spent on collecting extensive acoustic and biological data on blue whiting during March and April 2020 which may be used in future to fill in for the Blue whiting acoustic survey that was cancelled due to COVID-19. An inventory of available acoustic and biological data on blue whiting has been presented to WGWIDE 2020. The increased attention to blue whiting resulted in over 150 000 length measurements and 250 additional age measurements.

In addition, the study by Wageningen Marine Research (WMR) into the blue whiting length compositions from RVZ/PFA self-sampling and from previous blue whiting survey samples, indicated that close similarity. The mean length from single survey samples remained within the 95% confidence interval of the measurements from the repeated hauls of RVZ/PFA vessels in relatively close proximity. This indicates that RVZ/PFA length samples can be used as an appropriate data source for the length compositions of blue whiting.

An important aim of the PelAcoustics project is to use the acoustic data from trawlers to estimate biomass of different fish species, currently with a focus on herring and blue whiting. Two approaches are being followed: a machine learning approach developed by Sustainovate and an agent-based modelling

approach developed by WMR. The machine learning approach consists of a fish presence prediction model and a biomass estimation model. The quality assessment of this approach is currently being finalized. The results show that the fish presence prediction model can now generate realistic weekly distribution maps of herring based on several environmental variables. The biomass estimation that is making use of the fish presence prediction model has been shown to be able comparable biomass estimates to the North Sea herring acoustic survey in a particular year and area. The agent-based model suggested by WMR is still at an exploratory stage of application.

Gonad and genetic research on Horse mackerel

The two main activities to improve the knowledge base for horse mackerel in the Northeast Atlantic are: 1) genetic identification of horse mackerel in the mixing areas between the western and North Sea populations, and 2) the estimation of the duration of the spawning period of horse mackerel. Previous research has already shown that horse mackerel can be divided into three distinct populations (North Sea, western stock, southern stock) and that individual assignments of horse mackerel based on genetics are feasible. We have therefore collected genetic samples (725 individuals) of horse mackerel in the mixing zones (divisions 4.a and 7.d) during the autumn of 2020. These samples will be genetically analysed in the spring of 2021 to determine the proportion of western and North Sea fish in those samples.

To address the question of the duration of the spawning period of horse mackerel, relevant for the triennial egg survey, we collected gonad samples (380 individuals) like the approach followed for mackerel. Based on macroscopic maturity stages, length, month and sex, 100 female horse mackerel were selected based and histological sections were prepared of the 100 ovaries. Another 50 samples are expected to be prepared during the beginning of 2021. The analyses of the histological sections will take place in the first half of 2021.

AutoMeasure

Effectively and efficiently measuring both the length and weight of individual fish could supply a vast amount of new information on the condition of fish in different areas and seasons. In 2020 we initiated a new development for a demonstration version of a device for automatic weighing and measuring of fish that can be deployed on a vessel. A next-to-ready demonstration version of the weighing-measuring installation has been assembled. The measurement part is based on stereo camera images with automated corrections for body shape and any potential curvature in the fish. The weighing is based on an integrated, motion-compensated scale. Practical testing of the device on land-

based conditions are expected to start early 2021 and first trials on a fishing vessel in the second quarter of 2021.

Broadband demonstrator

The EMFF funded "RealFishEcho" project has demonstrated that broadband acoustics has promising properties for allowing effective species recognition with acoustics. When that project finished, the benefits of the approach could not yet be implemented on the participating vessels. The broadband demonstrator project aims to implement the finalized broadband species recognition software on the participating trawlers and testing the added value for improved selectivity. Unfortunately, due to the COVID-19 situation during 2020 is has not been possible to carry out the project because of the reduced possibility to work on the vessels for non-vessel crew. A fully worked out proposal by the research partners (WMR and TNO) has been presented to RVZ and commitments have been made for execution of the project in the first half of 2021.

Fish condition

In collaboration with Wageningen Marine Research, an exploratory study has been set up to gain insight into the condition of fish in the catches of pelagic trawlers from the moment the fish comes on board until the end of the catch processing process. A specific monitoring protocol has been developed in 2019.

While it has been challenging, initially, to find the researchers to carry out the sampling work on board of the trawlers, we managed in the end to cover almost all the fisheries. In addition, we managed to carry out camera observations and oxygen measurements inside the fish tanks. Overall, 3000 fish of different species have been scored for condition according to the WMR protocol, covering the following fisheries:

- Winter herring in the Channel
- Summer herring in the northern North Sea
- Horse mackerel in the Channel (December)
- Horse mackerel west of Ireland (January, September)
- Mackerel in the northern North Sea (September)
- Nordic herring in division 2.a (October)

The final report on the fish condition research is being finalized early in 2021 and is expected in January or February.

Fat content of herring and mackerel

A PhD student has been jointly funded by the University of Aberdeen, Scottish Pelagic Fisheries Association and the RVZ/PFA. The PhD student is investigating the use of fat content data collected by the fishing industry to assess the over-

all body condition of fish. Food availability and temperature are two environmental factors which are known to affect the body condition of fish. Initial analyses have been carried out and are now being further explored using advanced statistical models.

Three internships at RVZ/PFA have worked on making the relevant data on fat content and other biological properties available for this research project.

Nederlandse samenvatting

In dit rapport wordt het gebruik en de uitkomsten van onderzoeksprojecten in 2020 beschreven op basis van wetenschappelijke vangsten die zijn toebedeeld aan de leden van de Redersvereniging voor de Zeevisserij (RVZ). Hoewel het wetenschappelijk vangsten voor deze projecten zijn toebedeeld door Nederland, is het rapport in het Engels geschreven om internationale verspreiding van de resultaten mogelijk te maken.

In 2020 zijn pelagisch wetenschappelijk vangsten toegekend voor de volgende projecten:

1. Zelfbemonstering van de pelagische vloot
2. 6a haring survey 2020
3. Jaar van de makreel (voortzetting)
4. PelAcoustics
5. Gonade en Genetisch onderzoek horsmakreel
6. Automeasure
7. Breedband demonstrator

Bovendien is er een aantal onderzoeksactiviteiten die een voortzetting zijn van onderzoek vanuit 2019.

8. Visconditie
9. Vetgehalte haring en makreel

De belangrijkste resultaten zijn hier onder samengevat.

Zelfbemonstering van de pelagische vloot

De zelfbemonstering op RVZ/PFA-vaartuigen is de afgelopen jaren snel uitgebreid en bestrijkt sinds 2018 alle vaartuigen van de RVZ/PFA-vloot. Dit levert in real-time gedetailleerde inzichten op in de vangstsamenstellingen en biologische parameters in hoge ruimte-tijd resolutie. Voor elk van de betrokken deskundigengroepen (HAWG, WGWIDE, WGDEEP, SPRFMO, CECAF) worden specifieke jaarverslagen opgesteld. De implementatie van de speciale software voor zelfbemonstering (MCatch) is nu gerealiseerd op 11 van de 17 vaartuigen.

6a onderzoek naar haring

Het voor 2020 geplande akoestische onderzoek van de sector naar haring in 6a (en 7bc) is met succes uitgevoerd. In 2020 is in sector 6a geen paaiende haring aangetroffen, maar wel aanzienlijke scholen niet-paaiende haring. De resultaten zullen worden voorgelegd aan de ICES Planning Group on Surveys (WGIPS) in 2021 en aan de Herring Assessment Working Group 2021 (HAWG). Het verslag van de survey zal binnenkort beschikbaar zijn.

Jaar van de makreel

Het Jaar van de Makreel was een grote, toegewijde onderzoeksinspanning om de ontwikkeling van de gonaden van Noordoost-Atlantische makreel het hele jaar door te volgen. Het project werd uitgevoerd van februari 2019 tot februari 2020, waarbij sommige bemonsteringen doorgingen tot de zomer van 2020. De belangrijkste resultaten zijn dat paaiende wijfjes met in de gonaden aanwezige eitjes werden aangetroffen van februari tot juli in het westelijke gebied en van juni tot juli in de Noordzee. Voor het westelijke gebied was dit te verwachten, maar voor de Noordzee wijst dit erop dat het paaiseizoen langer duurt dan in het ei-onderzoek voor de Noordzee werd aangenomen. Een opvallend resultaat is dat zich ontwikkelende oöcyten in de gonaden het hele jaar door werden aangetroffen. Deze flexibiliteit in de ontwikkeling van oöcyten verklaart de verschillen in het begin van het paaiseizoen die zijn geconstateerd tijdens de meest recente makreelei surveys.

Paaiende mannetjes werden gedurende het hele paaiseizoen van de vrouwtjes aangetroffen, met het hoogste aantal paaiende mannetjes aan het begin van het paaiseizoen. Er werden zeer weinig zich ontwikkelende mannetjes gevonden, waaruit blijkt dat de mannetjes een veel kortere periode hebben voor de ontwikkeling van de spermacellen in vergelijking met de ontwikkeling van de oöcyten.

PelAcoustics

Het PelAcoustics-project is gericht op de ontwikkeling van methodologieën om akoestische informatie van pelagische trawlers te gebruiken als ondersteunende informatie voor bestandsbeoordelingen en onderzoeken. In 2020 lag de nadruk op de voortzetting van de akoestische gegevensverzameling met de OceanBox (beschikbaar op 5 trawlers) en op de ontwikkeling van instrumenten om de totale biomassa te schatten aan de hand van trawlergegevens. Bijzondere aandacht is besteed aan het verzamelen van uitgebreide akoestische en biologische gegevens over blauwe wijting in maart en april 2020, die in de toekomst kunnen worden gebruikt ter vervanging van het akoestisch onderzoek naar blauwe wijting dat in verband met COVID-19 is geannuleerd. Een inventaris van de beschikbare akoestische en biologische gegevens over blauwe wijting is voorgelegd aan de WGWIDE 2020. De toegenomen aandacht voor blauwe wijting heeft geresulteerd in meer dan 150 000 lengtemetingen en 250 extra leeftijdsmetingen.

Bovendien bleek uit de studie van Wageningen Marine Research (WMR) naar de lengtesamenstelling van blauwe wijting uit RVZ/PFA-zelfbemonstering en uit eerdere surveymonsters voor blauwe wijting dat er een grote gelijkenis is. De gemiddelde lengte uit afzonderlijke survey-monsters bleef binnen het 95%-betrouwbaarheidsinterval van de metingen van de herhaalde trekken van

RVZ/PFA-vaartuigen die relatief dicht bij elkaar lagen. Dit wijst erop dat de RVZ/PFA-lengtemonsters kunnen worden gebruikt als een geschikte gegevensbron voor de lengtesamenstelling van blauwe wijting.

Een belangrijk doel van het PelAcoustics-project is de akoestische gegevens van trawlers te gebruiken om de biomassa van verschillende vissoorten te schatten, momenteel met de nadruk op haring en blauwe wijting. Er worden twee benaderingen gevolgd: een machine learning-benadering die is ontwikkeld door Sustainovate en een agent-based modelling-benadering die wordt ontwikkeld door WMR. De machine learning-benadering bestaat uit een model voor de voorspelling van de aanwezigheid van vis en een model voor de schatting van de biomassa. Momenteel wordt de laatste hand gelegd aan de kwaliteitsbeoordeling van deze aanpak. Uit de resultaten blijkt dat het voorspellingsmodel voor de aanwezigheid van vis nu realistische wekelijkse verspreidingskaarten van haring kan genereren op basis van verschillende omgevingsvariabelen. De schatting van de biomassa, waarbij gebruik wordt gemaakt van het voorspellingsmodel voor de aanwezigheid van vis, blijkt in staat te zijn biomassaschattingen te maken die vergelijkbaar zijn met die van het akoestisch onderzoek van de Noordzeeharing in een bepaald jaar en gebied. Het door WMR voorgestelde agent-based model bevindt zich nog in een verkennend stadium van toepassing.

Gonade en genetisch onderzoek bij horsmakreel

De twee belangrijkste activiteiten ter verbetering van de kennisbasis voor horsmakreel in het noordoostelijk deel van de Atlantische Oceaan zijn: 1) genetische identificatie van horsmakreel in de menggebieden tussen de westelijke en de Noordzeepopulaties, en 2) de schatting van de duur van de paaiperiode van horsmakreel. Eerder onderzoek heeft reeds aangetoond dat horsmakreel kan worden onderverdeeld in drie verschillende populaties (Noordzee, westelijk bestand, zuidelijk bestand) en dat individuele toewijzingen van horsmakreel op basis van genetische technieken haalbaar zijn. Daarom hebben we in het najaar van 2020 genetische monsters (725 individuen) van horsmakreel in de mengzones (sectoren 4.a en 7.d) verzameld. Deze monsters zullen in het voorjaar van 2021 genetisch worden geanalyseerd om het aandeel van westelijke en Noordzeevis in deze monsters te bepalen.

Om de vraag naar de duur van de paaiperiode van horsmakreel te beantwoorden, die relevant is voor de driejaarlijkse eisurvey, hebben we monsters van de gonaden (380 individuen) genomen op dezelfde manier als voor makreel. Op basis van macroscopische rijpheidsstadia, lengte, maand en geslacht, werden 100 vrouwelijke horsmakrelen geselecteerd en van de 100 eicellen werden histologische coupes geprepareerd. Verwacht wordt dat begin 2021 nog eens 50 monsters zullen worden bereid. De analyses van de histologische secties zullen in de eerste helft van 2021 plaatsvinden.

AutoMeasure

Het effectief en efficiënt meten van zowel de lengte als het gewicht van individuele vissen zou een enorme hoeveelheid nieuwe informatie kunnen opleveren over de conditie van vissen in verschillende gebieden en seizoenen. In 2020 zijn we begonnen met een nieuwe ontwikkeling voor een demonstratieversie van een apparaat voor het automatisch wegen en meten van vis dat op een vaartuig kan worden ingezet. Er is een demonstratieversie van de weeg-meet-installatie in elkaar gezet. Het meetgedeelte is gebaseerd op stereocamera-beelden met automatische correcties voor de lichaamsvorm en eventuele krommingen van de vis. De weging is gebaseerd op een geïntegreerde, bewegingsgecompenseerde weegschaal. Naar verwachting zal begin 2021 worden begonnen met praktische tests van het apparaat op het land en zullen in het tweede kwartaal van 2021 de eerste proeven op een vissersvaartuig worden gedaan.

Breedbanddemonstrator

Het door het EMFF gefinancierde "RealFishEcho"-project heeft aangetoond dat breedband-akoestiek veelbelovende eigenschappen heeft om met akoestiek een doeltreffende soortherkenning mogelijk te maken. Toen dat project werd afgerond, konden de voordelen van de aanpak nog niet op de deelnemende schepen worden toegepast. Het breedbanddemonstratieproject heeft tot doel de afgeronde breedbandsoftware voor de herkenning van soorten te implementeren op de deelnemende trawlers en de toegevoegde waarde voor een verbeterde selectiviteit te testen. Door de situatie in COVID-19 in 2020 is het helaas niet mogelijk gebleken het project uit te voeren vanwege de verminderde mogelijkheid om op de vaartuigen te werken voor de bemanning die niet aan boord van de vaartuigen werkt. Een volledig uitgewerkt voorstel van de onderzoekspartners (WMR en TNO) is voorgelegd aan RVZ en er zijn toezeggingen gedaan voor uitvoering van het project in de eerste helft van 2021.

Conditie vissen

In samenwerking met Wageningen Marine Research is een verkennend onderzoek opgezet om inzicht te krijgen in de conditie van vis in de vangsten van pelagische trawlers vanaf het moment dat de vis aan boord komt tot aan het einde van het vangstverwerkingsproces. In 2019 is een specifiek monitoring-protocol ontwikkeld.

Hoewel het aanvankelijk een uitdaging was onderzoekers te vinden om de bemonsteringswerkzaamheden aan boord van de trawlers uit te voeren, zijn we er uiteindelijk in geslaagd bijna alle visserijtakken te bestrijken. Bovendien zijn we erin geslaagd cameraobservaties en zuurstofmetingen in de vistanks uit te voeren. In totaal zijn 3000 vissen van verschillende soorten gescoord op conditie volgens het WMR-protocol, voor de volgende visserijtakken:

- Winterharing in het Kanaal
- Zomerharing in de noordelijke Noordzee
- Horsmakreel in het Kanaal (december)
- Horsmakreel ten westen van Ierland (januari, september)
- Makreel in de noordelijke Noordzee (september)
- Noordse haring in sector 2.a (oktober)

Het eindrapport over het onderzoek naar de toestand van de vis wordt begin 2021 afgerond en wordt in januari of februari verwacht.

Vetgehalte van haring en makreel

Een promovendus is gezamenlijk gefinancierd door de Universiteit van Aberdeen, de Schotse Pelagische Visserij Associatie en de RVZ/PFA. De promovendus onderzoekt het gebruik van door de visserijsector verzamelde gegevens over het vetgehalte om de algemene lichaamsconditie van vissen te beoordelen. De beschikbaarheid van voedsel en de temperatuur zijn twee milieufactoren waarvan bekend is dat zij de lichaamsconditie van vissen beïnvloeden. Er zijn voorlopige analyses uitgevoerd die nu verder worden onderzocht met behulp van geavanceerde statistische modellen.

Drie stagiaires van RVZ/PFA hebben meegewerkt aan het beschikbaar maken van de relevante gegevens over het vetgehalte en andere biologische eigenschappen voor dit onderzoeksproject.

1 Introduction

For many years already, the Dutch *Redersvereniging voor de Zeevisserij* (RVZ) and the international *Pelagic Freezer-trawler Association* (PFA) have been active players on the interface between industry, science and management. RVZ and PFA members have all contributed to data collection initiated by scientific institutes (observer trips, catch sampling, logbook information). In addition, RVZ and PFA have initiated and commissioned several scientific research projects, for example on stock structure of horse mackerel, on the improvement of the knowledge base for horse mackerel, catch sampling in Mauritanian waters etc.

In 2014, the RVZ/PFA has developed their Science and Knowledge strategy (PFA 2014) that provides for strategic foresight on the directions of research. This science and knowledge strategy is still being followed. Important themes in the strategy are:

1. documenting of catch and effort
2. using vessel acoustics for stock trends
3. improving selectivity
4. assessing impacts

The utilization of scientific catches provides an important avenue to facilitate the research ambitions of the RVZ and PFA. Even though the scientific catches are allocated to Dutch vessels only, many of the research activities are carried out in an international context. As RVZ, we are annually submitting an integrated request for the utilization of (Dutch) scientific catches. And as RVZ/PFA, we are reporting on the outcomes in the integrated results in the document that you have in front of you.

In 2020, pelagic scientific catches have been allocated to the following projects:

1. Self-sampling the pelagic fleet
2. 6a haring survey 2020
3. Year of the Mackerel (continued)
4. PelAcoustics
5. Gonad en Genetic research into horse mackerel
6. Automeasure
7. Broadband demonstrator

In addition, there are two research activities that have been continued from 2019.

8. Fish condition
9. Fat content of herring and mackerel

2 Research projects

2.1 Self-sampling the pelagic fleet

The self-sampling program in pelagic fishing was launched in 2014 and now forms a solid basis for the role of pelagic fishing in scientific research. The self-sampling data is now widely used for various applications (stock assessment, MSC, spatial-temporal occurrence of different types).

2.1.1 Catch compositions of RVZ/PFA trawlers

An overview in number of vessels , trips, number of days, total catch of self-sampled vessels and number of length measurements is presented in the text table below.

year	nvessels	ntrips	ndays	nhauls	catch	nlength
2015	8	43	761	1,738	128,054	111,931
2016	11	98	1,538	4,066	274,622	158,324
2017	15	122	2,030	4,940	333,291	299,361
2018	17	157	2,489	5,919	456,753	336,991
2019	17	158	2,664	6,571	420,689	296,813
2020	18	171	2,582	6,259	489,952	385,017
(all)		749	12,064	29,493	2,103,361	1,588,437

Details by large FAO area (27, 34 and 87) are below.

area	year	nvessels	ntrips	ndays	nhauls	catch	nlength
27	2015	7	34	584	1,360	107,380	119,726
27	2016	10	74	1,123	2,851	252,238	141,285
27	2017	14	98	1,507	3,470	328,819	203,060
27	2018	16	141	2,161	5,048	439,062	274,055
27	2019	16	138	2,076	4,780	375,795	213,844
27	2020	18	151	2,254	5,213	455,416	320,813
27	(all)		636	9,705	22,722	1,958,710	1,272,783
34	2016	3	20	320	1,046	40,337	29,989
34	2017	4	14	250	861	31,712	80,409
34	2018	4	11	198	635	24,105	57,556
34	2019	4	17	503	1,629	48,376	76,789
34	2020	4	20	328	1,046	52,913	54,361
34	(all)		82	1,599	5,217	197,443	299,104
87	2015	2	9	177	378	28,972	7,381
87	2016	1	4	95	169	10,284	6,905
87	2017	2	10	273	609	29,652	20,722
87	2018	1	5	130	236	10,234	4,692
87	2019	1	3	85	162	12,114	7,680
87	(all)		31	760	1,554	91,256	47,380
(all)	(all)		749	12,064	29,493	2,247,409	1,619,267

Most of self-sampling activities are taking place in the Northeast Atlantic (FAO area 27). However, (near to) all trips in FAO areas 34 and 87 are also covered by the self-sampling program. Results of self-sampling are summarized in an annual report (Pastoors and Quirijns 2021) and in specific reports targeted at different scientific groups (Pastoors 2020a; Pastoors 2020b; Pastoors 2020c; Pastoors and Quirijns 2020). Self-sampling data was also used to generate an abundance index for Greater silversmelt that is now included in the assessment of that stock (Quirijns and Pastoors 2020). A comparison between the observer data and self-sampling data in the South Pacific Fishery has been presented to the SPRFMO Scientific Committee in 2020 (Pastoors and Wojcek 2020)

2.1.2 Development of a standardized catch-handling system

Next to the Excel-based self-sampling data capture system, we started in 2016 with the development of an integrated knowledge-information system (M-Catch) from fishing vessels. M-Catch currently allows for the recording of fishing activity data, production data and basic biological sampling. In 2020, the M-Catch application is used on roughly half of the vessels within the RVZ/PFA. Because the M-Catch database had to be converted into separate database instances for the different participating companies (Cornelis Vrolijk BV, Parlevliet en van der Plas BV en Willem van der Zwan BV), the development of the app has slowed down somewhat. While the uptake of M-Catch has increased on the vessels, the extension of the app to allow the entering of raw sampling data has yet to be realized.

2.2 Industry survey for herring in 6a-north (2020)

This project combines the research efforts towards assessing the state of the 6a herring stock(s) and developing the tools to separate between 6a north and 6a south-7bc herring. The research has been carried out together with Wageningen Marine Research, member companies of RVZ/PFA and international partners. The 2020 survey was the fifth iteration of the survey.

2.2.1 Results of 2020 industry acoustic survey on 6a-7bc herring

2020 was the fifth industry-led survey of herring in 6a/7bc. Industry and scientific institutions from Scotland, Northern Ireland, Netherlands, Ireland, and England successfully carried out scientific surveys with the aim to improve the knowledge base for the herring spawning components in 6a north and 6a south, 7bc, and submitted the relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan (Mackinson et al. 2019).

Two industry vessels were used for the industry acoustic surveys in 6aN and one vessel as add-on to the scientific survey in July. In addition, one industry vessel has carried out an industry acoustic survey in 6aS/7b. The vessels used in 6aN were each equipped with a calibrated Simrad EK80 transceiver using the ship's hull-mounted transducer.

In 6aN, the two vessels undertook the industry acoustic survey in sequence (Ocean Star FR77 and Alida SCH6), covering a somewhat reduced survey grid compared to the previous years. The reduction in the survey grid was implemented because of the smaller number of days at sea that were available for the vessels. The two remaining strata covered the main spawning distribution of all the previous survey years. Although there were many herring marks, there were almost no spawning herring encountered. Most of the herring were age 2 immature fish.

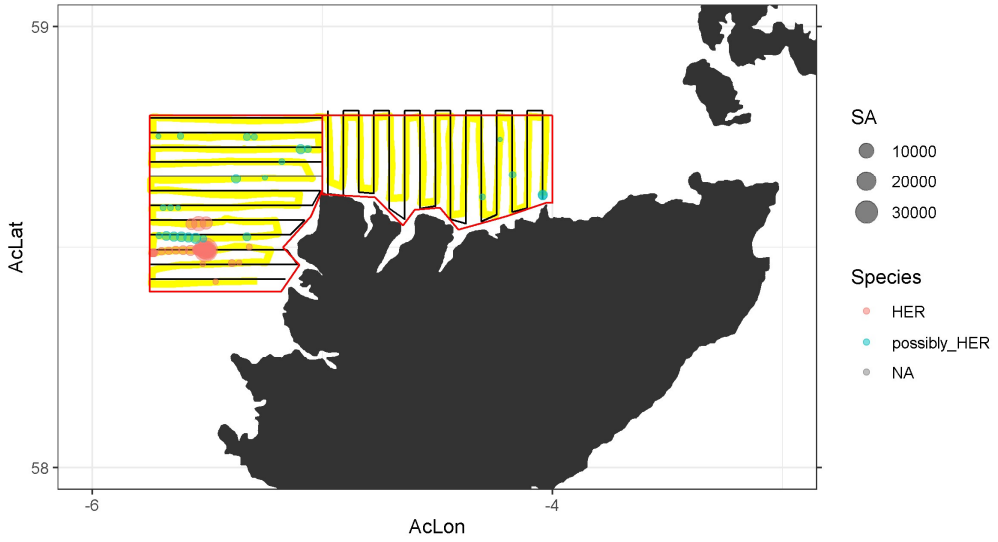


Figure 1 Survey areas used in the 6aNorth surveys. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides, Area 5 – east Minch.

2.2.2 Results of herring genetic research

The genetic research into the stock identity of herring stocks in ICES Divisions 6.a, 7.b and 7.c has been initiated at the start of the 6a herring survey in 2016 and has been co-initiated and fully supported by RVZ/PFA. During the years 2018-2020 a substantial part of the research activities were carried out by University College Dublin, the Marine Institute Ireland, Marine Scotland Science and EDF Ireland in the context of an EASME funded research project. A final report has been submitted to EASME in December 2020 and is now waiting for final approval. The following text is an abbreviated version of the project summary.

The main aim of the research has been to develop genetic profiles of the northern (ICES Division 6.a North) and southern (ICES Divisions 6.a South, 7.b and 7.c) stocks, which could be used to discriminate the two stocks during times of mixing, such as, in the summer acoustic surveys. In addition, body and otolith morphometric methods were developed to test if morphometric methods were also able to discriminate the stocks in these areas.

Baseline spawning samples were collected over five spawning seasons (2014-2019) and archive samples from the WESTHER project (2003-2004) were also reanalysed (Hatfield 2006; Hatfield et al. 2007). In total c.4,900 individuals from Divisions 6.a, 7.b and 7.c, 1,860 individuals from outgroup populations, 650 individuals from the WESTHER samples and 3,665 individuals from the Malin Shelf Herring Acoustic Survey (MSHAS) samples were analysed as part of the genetic analysis tasks. A total of 1,815 baseline spawning individuals from Division 6.a were also analysed for the morphometric component of the project.

*The genetic analyses indicated that herring in ICES Division 6.a comprise at least three distinct populations; 6.a south herring, 6.a north **autumn spawning** herring and 6.a north **spring spawning** herring. The 6.a south herring are a primarily a winter spawning population though there is a later spawning component present in the area also. These components are currently inseparable and for the purposes of stock assessment should be combined as 6.a south herring. No baseline spawning samples could be collected in Divisions 7.b or 7.c therefore the relationship between the herring that spawn in this area and those that spawn in 6.a south is unknown. Non-spawning herring caught in Division 7.b were assigned genetically to the 6.a south population.*

There is no historical or contemporary evidence to support the differentiation of 6.a north autumn spawning herring and North Sea autumn spawning herring. The term 'west of Scotland herring' originally referred to populations of spring spawning herring that spawned in the Minch area. It now refers to autumn spawning herring that occur west of the 4°W boundary.

The morphometric methods used in the current study indicated significant differences between the 6.a south herring and the 6.a north autumn spawning herring, however they did not show sufficient power to discriminate mixed survey catches in ICES Division 6.a.

The genetic markers and assignment methods presented in the current study constitute a tool that can be used for the assignment of herring caught in mixed survey and commercial catches in Division 6.a into their population of origin with a high level of accuracy (>90%). This approach should be used for regular monitoring of MSHAS and commercial catches of herring in this area and further efforts should be made to expand the genetic screening to the North Sea also.

2.3 Year of the mackerel continued (YotMc)

The stock of Northeast Atlantic mackerel has raised a lot of attention over the last number of years. The expansion of the area of distribution of mackerel has been very conspicuous, with mackerel now being caught much more westerly and northerly compared to the past. In recent years also changes in spawning are apparent, with changes in timing and centre of gravity of spawning. Dealing with a stock with such a wide area of distribution from the west of Portugal all the way to the Norwegian Sea is providing a continuous challenge to attempt to monitor the development of this stock. One approach, that is followed here, is to improve our understanding of how mackerel gonads develop and when and where mackerel spawn. This information could affect the design of the mackerel egg survey and possibly also how spawning stock biomass is calculated from the stock in numbers within the stock assessment model. This work was mostly carried out in 2019 with a short extension into the first half of 2020.

The fishing industry has been getting involved in providing data on mackerel through different means, such as the mackerel tagging program and providing vessels to conduct the swept-area survey and the mackerel egg survey. In all cases, understanding the spatial-temporal patterns of mackerel is key to making these sources reliable indicators for stock assessment. The overall aim of the Year of the Mackerel project is to gain insight in the gonad development of female and male mackerel throughout the year to better understand the spawning strategy.

On a monthly basis male and female mackerel have been collected by the pelagic industry throughout the distribution area of mackerel. Wageningen Marine Research and partner institutes have prepared histological sections of the gonads. Each gonad will be analysed to identify which development stages of oocytes and spermatozoa are present in the gonad. This will allow to follow the gonadal development over time and determine the timing when mackerel is ready for spawning.

An overview of the samples taken by quarter is shown in the Figure 2 below.

For the analyses, on mackerel sampled up to February 2020 were used. In total 890 mackerel were collected from February 2019 to February 2020. Histological sections were prepared of 431 female and 271 male gonads of which 381 female and 104 male samples were analysed for gonad development. An example of the gonad cells of mackerel at different magnification is shown in Figure 3.

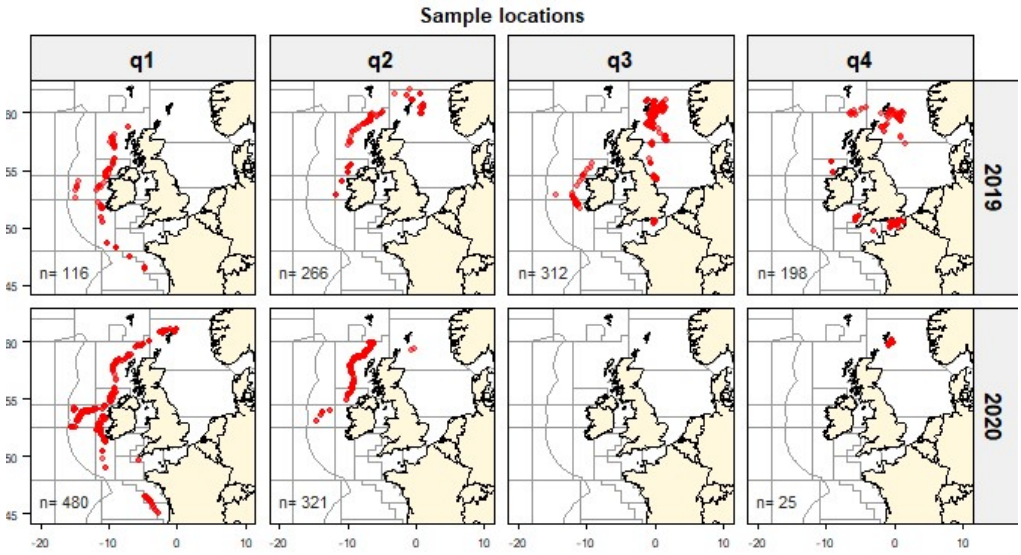


Figure 2 Mackerel samples taken by quarter during 2019 and 2020.

The female histological slides were screened for presence/absence of different oocyte stages and eggs. Oocytes and eggs were counted and measured. The male histological slides were screened for presence/absence of different sperm cell stages.

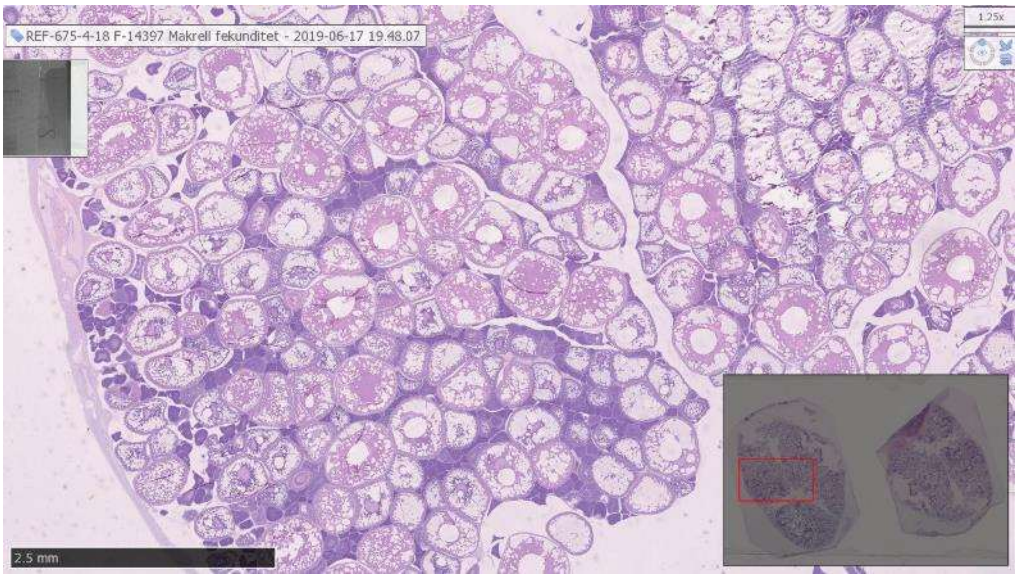
Spawning females with eggs present in the gonads were found from February to July in the western area and from June to July in the North Sea. For the western area this is the period that is assumed in the egg surveys, but for the North Sea the spawning season is longer than assumed in the egg surveys. During the spawning season, oocytes of various developing stages were present indicating mackerel keeps developing oocytes during the spawning season. Atretic oocytes were only found in the period when eggs were present. This regulating mechanism only occurs during the spawning season of the mackerel. The proportion of non-developing oocytes in the ovaries also showed that the same spawning seasons with low proportions during the spawning season.

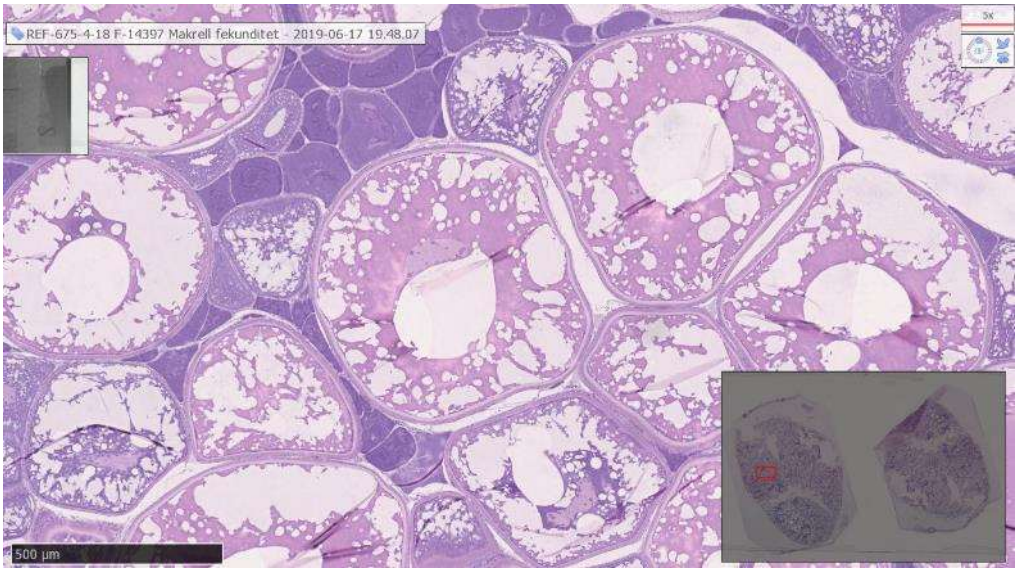
A striking result is that developing oocytes in the gonads were found throughout the year, apart from a few individuals (3 in the western and 30 in the North Sea) that did not have developing oocytes. This shows that mackerel is continuously developing oocytes, even outside the spawning season, although on the individual level some females have a resting period. This flexibility in developing oocytes explains the differences in the start of the spawning season that has been found during the most recent egg surveys. When the environmental circumstances are favourable, the mackerel females are ready to spawn their eggs.

Few developing males were found, indicating that males have a much shorter period for developing the sperm cells compared to the oocytes. Most males were either in spawning or spent condition. Spawning males were found dur-

ing the entire spawning season of the females, with highest number of spawning males at the start of the spawning season. Of the males analysed, 13% in the western area and 8% in the North Sea, had encapsulated eggs in the testes. This has never been shown for mackerel. In other species this occurs due to pollution of the sea water. It is unknown if this is also the case in mackerel.

The final report on the research activities is expected in February 2021 (Damme et al. 2021).





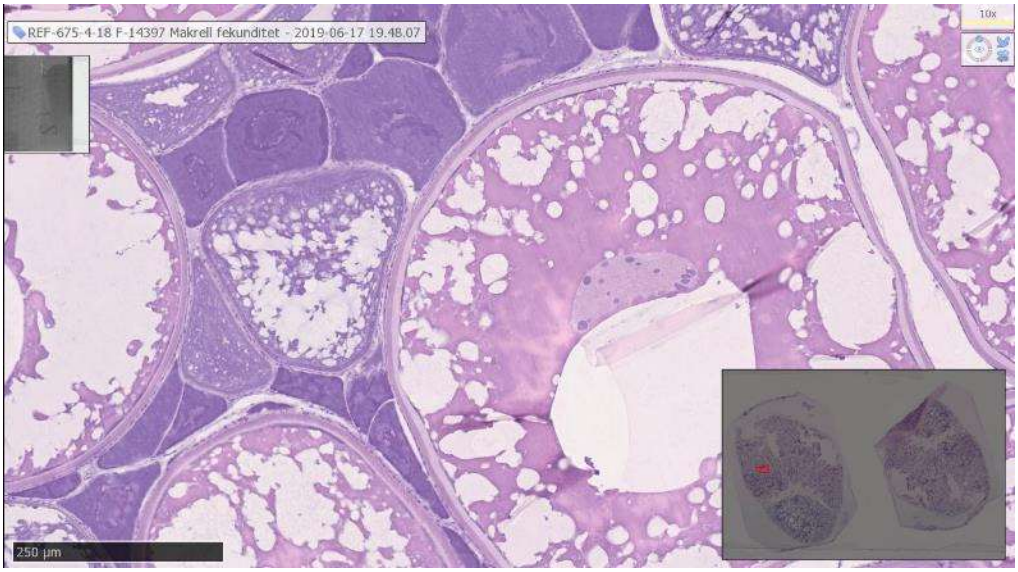


Figure 3 Examples of mackerel gonad cells at different magnification.

The collection of mackerel samples has continued in 2020 (Year of the Mackerel continued) beyond the samples that were already collected in 2019. While these additional samples have not been processed as part of the overall gonad analyses, the 377 samples have been sliced and embedded in resin so that they could be further processed in future analyses, if required.

	Processed?		
Row Labels	yes	no	Grand Total
2019	738		738
2020	152	377	529
Grand Total	**890**	**377**	**1267**

2.4 PelAcoustics

How could acoustic information collected by commercial fishing vessels be used as an addition or alternative to traditional acoustic surveys for estimating biomass of different fish species? This is the core question for the PelAcoustics project. The project looks at the mechanisms of collecting the acoustic data from trawlers and at the methods of generating biomass estimates.

2.4.1 Oceanbox as data-collector and integrator

The ambition to collect and use acoustic data from fishing trawlers has been an important ambition for RVZ/PFA (Fässler et al. 2016). Initially such approaches depended on calibrating a limited number of vessels, recording raw data on external harddisks and analysing the acoustic signals manually. From 2018 onwards we have been working on a new way of acoustic data recording on pelagic trawlers. The new program is focussing the attention on automatic data capture and data processing on board of many trawlers at the same time. To achieve this ambition a collaboration has been developed between RVZ and Sustainovate (www.sustainovate.com) and several other partners.

The OceanBox is the key mechanism for collection and integration of sensor data onboard of commercial fishing vessels. The OceanBox is a system that collects and automatically analyses the sensor data. The OceanBox has a live link with shore where summarized data is being exchanged. Raw (acoustic) data is being stored on the OceanBox and can be (manually) collected for detailed scientific analyses.

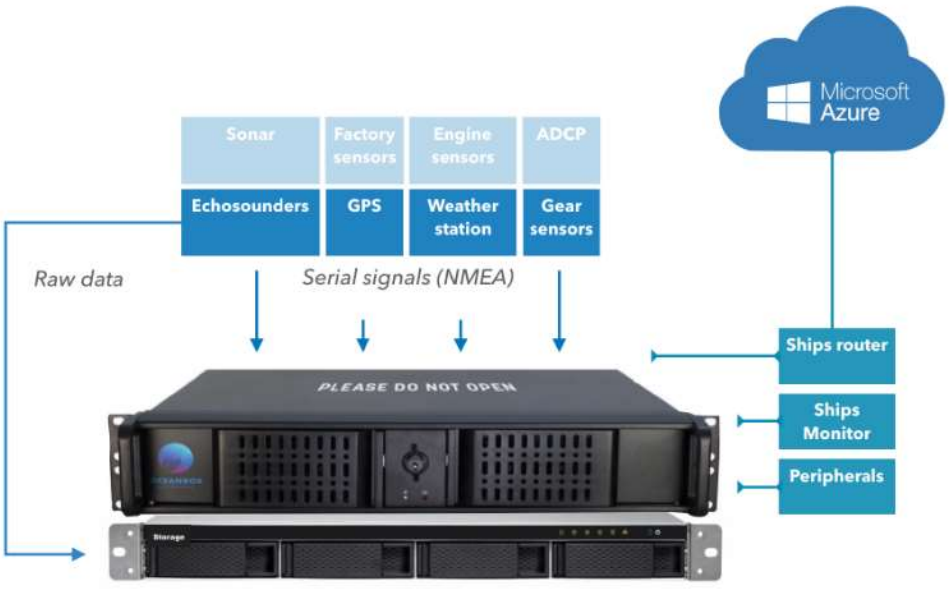


Figure 4 OceanBox systems design

The OceanBox was first installed onboard H72 Frank Bonefaas (December 2018), followed by the SCH6 Alida, SCH302 Willem van der Zwan, GDY151 Annelies Ilena and ROS171 Maartje Theodora (March/April 2019).

In 2020, the COVID-19 crisis has led to the cancellation of the blue-whiting survey which would normally be carried out during March and April. That has been the reason to propose a PelAcoustics follow-up to start immediate expansion of data collection and speeding up the process of developing an innovative biomass estimation based on commercial data. The main aim was to develop a blue whiting spawning stock biomass index (SSB) and geographic distribution using a new and innovative methodology that takes acoustic data from commercial trawlers as an input. The following activities were foreseen and will be reported below:

- Calibrate participating vessel and collect additional samples of blue whiting during 2020 fishery; optimize the data collection procedures on board of commercial trawlers
- Develop the methodology for generating abundance indices from commercial acoustic data
- Make available all historical and recent acoustic data to generate biomass indices for blue whiting and North Sea herring and analysis of acoustic data to generate abundance indices
- Collate descriptions of methods, data and resulting indices in a working document for WGWIDE 2020.

2.4.2 Calibrate participating vessel and collect additional samples of blue whiting during 2020 fishery; optimize the data collection procedures on board of commercial trawlers

Acoustic data collection during the blue whiting fishery 2020 has been carried out on the following vessels: Frank Bonefaas H72, Afrika (SCH24), Annelies Ilena GDY151, Maartje Theadora (ROS171), Alida (SCH6) en Willem van der Zwan (SCH302). Most of the data were collected using the OceanBox data capture system. Raw acoustic data files were manually collected and stored on a dedicated server environment. During March and April 2020, around 1.1 TB of acoustic were recorded by the participating vessels.

Calibration of the acoustic devices on the vessels could unfortunately only be realized on the Alida and Willem van der Zwan (where the crew can do the calibration themselves. For other vessels it was not possible to carry out a calibration due to the COVID-19 restrictions).

Additional sampling for length and age was carried out during the blue whiting fishery in 2020. Below is an overview of the number of age determinations (nage) and the number of length measurements (nlength) by year, clearly indicating the increased sampling during 2020. Sampling for ages

year	nage	nlength	(all)
2015	0	28,461	28,461
2016	0	39,343	39,343
2017	0	95,548	95,548
2018	0	136,185	136,185
2019	0	69,837	69,837
2020	250	154,725	154,975
(all)	250	524,099	524,349

Age samples were taken by the Annelies Ilena (GDY151) and Maartje Theadora (ROS171) and analysed by Wageningen Marine Research.

year	GDY151	ROS171	(all)
2020	52	198	250
(all)	52	198	250

Results of studies commissioned in 2019 on the comparison of survey and commercial sampling has been finalized in 2020 (Sakinan 2021). A summary of the results is reproduced below.

In this study, the length frequency data collected by the self-sampling program on RVZ/PFA vessels during the blue whiting fishing trips was compared with the survey measurements with a focus on 2017 and 2018. In 2018, from different vessel contributed to the data set, only 4 vessels had adequate overlap in space and time in 2018 and 2 vessels in 2017. The results indicated that the mean length and the distributions are promisingly similar from the two of the vessels contributed to this data set in 2018. In addition, the third vessel showed very high similarity when the sampling dates are very close to the survey station while geographical distance is below 20 nmi. In 2017, the measurements from the two of the vessels had very close similarity to the survey measurements. As further supporting these close similarities, the mean length from a single survey samples (that were focus of the comparisons) remained within the 95% confidence interval of the measurements from the repeated hauls of RVZ/PFA vessels in relatively close location. In 2018, one of the vessels contributed to the data did not have adequate similarity based on the statistical comparisons, however its samples also did not have very close overlap with survey samples in space and time compared to the other vessels. (Sakinan 2021)

2.4.3 Develop the methodology for generating abundance indices from commercial acoustic data

The development of a methodology for generating abundance indices from commercial acoustic data is a critical element of the ambition to contribute to the scientific process with acoustic data from trawlers. Because trawlers are known to target the fish species in the areas where they are most abundant, a straight conversion of acoustic observations to an abundance index would risk

the overestimation of stock size due to the observations mostly being taken in areas of high density. Therefore, some type of spatial and/or temporal corrections need to be made to compensate for the targeting behaviour. Such techniques of converting acoustic biomass from trawlers to abundance indices is not very common, although some approaches have been proposed already in the scientific literature (Alegria and Sepulveda 2019; Melvin et al. 2016; Niklitschek and Skaret 2016)

We followed two main approaches to develop potentially useable techniques for generating biomass indices from trawler data:

- Machine learning approach with fish mapping and spatio-temporal smoothing (Sustainovate)
- Geostatistical approaches (WMR)

Machine learning approach (Sustainovate)

The machine learning approach consists of two interlinked sub-projects:

- Fish presence prediction project, and
- Biomass estimation project

Previously, the scientific team has carried out a promising initial exploration of a machine learning approach to estimating biomass indices from trawler acoustic data in combination with catch data and environmental variables (Ybema and Johannsen 2020). Here we are reporting the new results from the biomass estimation project and the fish presence prediction project.

Biomass estimation project

To gain a better understanding of the extent to which the acoustic data from the trawlers can be used as a proxy for, or as a supplement to, the data collected during scientific surveys, a comparison was made between two datasets from the same area and virtually in the same period (July 2017). The herring targeted by the trawlers is likely the same herring as seen by ICES acoustic survey, even though they can be several days and sometimes tens of miles apart.

To be able to compare the biomass estimates from the ICES acoustic survey with estimates based on trawler acoustic data, the research area needs to be aligned (Ybema et al. 2021). This implies that the trawler data needs to represent a larger area than where the vessels fished, because otherwise the trawler data would be too concentrated in a small area. The expansion of the area is achieved by an extrapolation method that is based on the fish presence predictor which is a machine learning model that combines historical commercial catch information and environmental variables to predict when and where certain fish species may be present (or not). Using the fish presence predictor, we can assess the probability of encountering fish in areas even if there are no acoustic observations from the trawlers.

The comparison of the raw acoustic densities from the small study area of trawler activities indicates, as expected, that the trawlers observe large densities of fish in concentrated locations while the scientific vessels detect less fish over a larger area. Without smoothing, the data from the different datasets cannot be compared, because they do not overlap. After smoothing, the comparison becomes informative but scaling of the trawler acoustic density was necessary to make the acoustic estimates from the trawlers comparable to the estimates from the survey in the same times-space domain. This scaling could have a major influence on the final biomass estimates because it could introduce an arbitrary factor in the data processing.

Fortunately, the importance of scaling decreased when the fish presence prediction model became more accurate. We included both additional PFA self-sampling data and verified ICES echosounder observations of North Sea herring to improve the fish presence prediction model. When this additional training data was used to improve the predictive capability of the fish presence prediction model, then the importance of the scaling factor in the biomass estimation model decreased. We conclude that the combined application of the fish presence prediction model and the biomass estimation model results in an acceptable agreement between the trawler data and the survey data. Because these results are based on relatively small number of trawler data observations, no extrapolation could be made to the whole survey area in this phase of the project. Likewise, no comparison has been made between the biomass estimates for different years to explore whether trends over time would be comparable. But the results obtained for these small number of observations do indicate that such comparisons could be feasible if sufficient acoustic trawler data is available.

The final report on the biomass estimation model will be available in February 2021.

Fish presence prediction model

The fish presence prediction model is designed to predict the presence of fish species at a particular location and time based on environmental parameters such as current weather, sea water temperature, ocean floor sediment type, depth and chlorophyll index. The first implementation of the fish presence prediction model was included in the 2020 report (Ybema and Johannsen 2020) and despite the progress at that stage, compared to pure statistical approaches, there were two main challenges: 1) the model provided many false positive predictions (prediction of fish when it not there) and 2) the model had a relatively poor generalization over longer time periods, leading to "jumping behaviour of hotspots".

This fish presence prediction model has been upgraded with the latest machine learning approaches and with newly available data (Ybema and Sapronova 2021). These adjustments resulted in a new model formulation with higher accuracy than any of the standard machine learning approaches. The accuracy of the new fish presence prediction model continues to increase as more training data becomes available, while standard machine learning models reached a limit in the achieved accuracy despite adding more data.

After the latest improvements, the model is now able to generate more realistic weekly maps showing areas in which North Sea herring is likely to be found.

At present, the fish presence prediction model does require some manual adjustments such as how it handles the assumption that trawler movements are only driven by the presence of the fish and not, for example, by a specific itinerary that includes multiple target species. The model also does not make use of any information about the co-occurrence of species, for example in the case that mackerel forages on young herring. Such underlying data would probably be available in the commercial data and in some ICES survey data.

We envision that the model may have to react differently in different geographic regions. This means that the model for herring in the North Sea may be different from the model for Atlanto-scandian herring for example. The report that will be finalized in February 2021, will contain recommendations on how that can be achieved.

Geostatistical approaches (WMR)

The approach suggested by WMR consists of three steps:

1. Comparing commercial acoustic recordings with data from acoustic surveys
2. Developing a library of fish abundance maps for fishers. The maps could show both raw biomass estimates along the track of the vessels, or maps with interpolation between vessel tracks, based on spatio-temporal modelling approaches such as GAMs or INLA models).
3. Derive abundance estimates from commercial data using agent-based models, like the Poseidon model (Madsen et al. 2020). This type of model would correct for the behavioural aspects of fishing that are dependent on management rules, group behaviour, economic drivers etc. This modelling approach would generate the most likely abundance and distribution of the resource (blue whiting) given the catch information, the acoustic observations and the behavioural aspects of the fleet. The abundance and distribution of blue whiting as derived from the model, would then be used to test the performance of the survey for blue whiting.

While the approach suggested by WMR has been agreed between RVZ and WMR, the work has not been completed in 2020 and will be continued in the first half of 2021.

2.4.4 Make available all historical and recent acoustic data to generate biomass indices for blue whiting and North Sea herring and analysis of acoustic data to generate abundance indices

Since 2012, RVZ/PFA has been engaged in the collection of acoustic data at a large scale. An overview of historical and recent acoustic data has been made available to the ICES expert group on blue whiting (Berges et al. 2020). This document contains a rough analysis of the available data. During 2020, special efforts have been put into collecting additional acoustic and biological data on blue whiting.

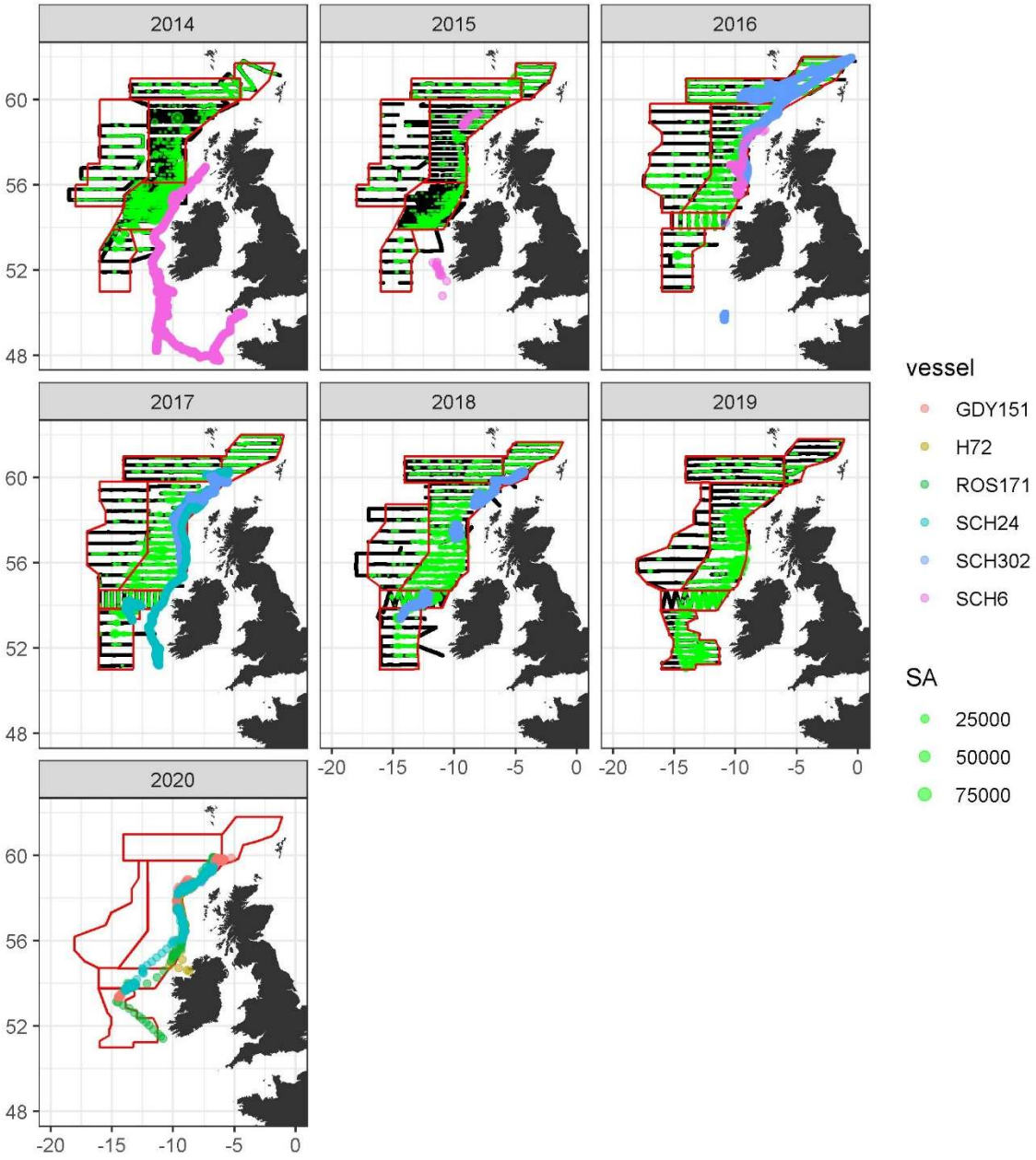


Figure 5 Annual maps of acoustic data collected by RVZ/PFA trawlers around the IBWSS surveys in the different years (March/April). Red boxes are the different strata used for the analysis of the IBWSS survey. The green circle markers are the WHB acoustic densities in 1 nmi intervals.

It is intended that the available data will be used for a time series of biomass estimates that can be submitted to WGWIDE 2021.

2.4.5 Collate descriptions of methods, data and resulting indices in a working document for WGWIDE 2020.

Since 2012, RVZ/PFA has been engaged in the collection of acoustic data at a large scale. This working document presents an overview of the acoustic data with a focus on blue whiting. Further work will be carried out to (automatically)

analyse the acoustic data and couple those results with the RVZ/PFA self-sampling data. The ambition is to explore the development of an index of abundance from commercial acoustic data that could aid the blue whiting acoustic survey in case of missing surveys or bad weather conditions.

2.5 Horse mackerel

Can we improve the knowledge base for horse mackerel in the Northeast Atlantic, especially with regards to stock components and spawning behaviour? Those are the main questions that have been addressed in the 2020 research activities on horse mackerel.

In 2015, work began to strengthen the knowledge base of North Sea and Western horse mackerel. In the past, much work has been carried out around developing alternative indicators for stock development and in the genetic characterization of horse mackerel. In 2019 and 2020, the complete genome of horse mackerel was mapped by EDF Scientific Limited and University of Uppsala (Farrell et al. 2020). Using this complete genome knowledge, it is now possible to make an assessment for individual fish of the population to which they belong. This means that a horse mackerel caught in 7d or 7e, for example, can be determined whether it is a western or a North Sea type of horse mackerel.

In 2019, the triennial international egg survey for mackerel and horse mackerel was conducted. Especially about horse mackerel, there are still questions about whether the entire spawning season is covered by the survey. By determining the spawning maturity stages of horse mackerel throughout the year, we want to contribute to the knowledge of the spawning cycle of horse mackerel.

2.5.1 Assigning individual horse mackerel to different populations

The aim was to test the ability to assign individual horse mackerel to different populations and collect additional samples from mixed populations. The testing with individual samples has been carried out by the same research team that had carried out the full-genome sequencing based on pooled samples. The individual genotype data for the subset of samples corroborated the main results of the pooled-sample analyses (Farrell et al. 2020). The same pattern of sample clustering was observed with temporally stable samples in the North Sea that were distinct from all others. The two samples collected west of Ireland did not display any significant genetic differentiation between themselves or with the northern Spanish Shelf sample. The northern Portuguese sample was also closely affiliated with these western samples and could not be ro-

bustly separated based on the reduced marker panels. The southern Portuguese samples formed a separate cluster, however there was evidence of mixing between this and the northern Portuguese group. As expected, the outlier group consisting of the African samples was significantly differentiated to all other samples but most closely related to the most geographically close sample in southern Portugal. Whilst these results should be treated with caution, as the sample sizes were small and temporal stability was not tested in all populations, they do prove the potential for using the reduced marker panels to investigate the population structure of horse mackerel on a larger scale.

We have collected additional horse mackerel samples for mixed genetic analysis during the second half of 2020 in the Northern North Sea and the Channel area, according to the following table:

year	month	nvessels	ntrips	nhauls	hom
2020	7	1	1	1	50
2020	8	2	3	3	75
2020	9	1	1	1	100
2020	10	1	1	1	100
2020	11	2	3	3	300
2020	12	1	1	1	100
2020	(all)		10	10	725

The spatial distribution of the horse mackerel genetic samples is shown in figure . Almost all fish have been processed for genetics during 2020 and will be submitted for genetic analyses during the first quarter of 2021. We are expecting the results of this work to become available in the first half of 2021.

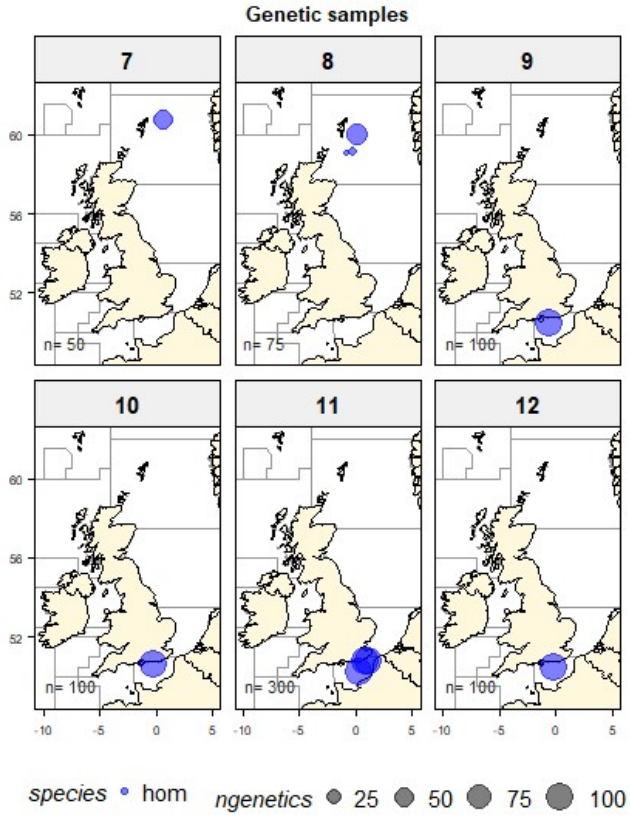


Figure 6 Horse mackerel samples collected for genetic analysis during 2020, by month.

2.5.2 Determining horse mackerel maturity stages

The aim was to determine the spawning stages of horse mackerel throughout the year to inform timing and interpretation of the triennial egg survey for horse mackerel. Horse mackerel samples were collected mostly during the second half of 2020. Based on macroscopic maturity stages, length, month and sex, 100 female horse mackerel were selected based and histological sections were prepared of the 100 ovaries. Another 50 samples are expected to be prepared during the beginning of 2021. The analyses of the histological sections will take place in the first half of 2021.

year	month	nvessels	ntrips	nhauls	hom
2020	5	3	3	23	30
2020	6	4	6	46	83
2020	7	2	2	21	66
2020	8	3	4	35	77
2020	9	3	3	13	20
2020	10	2	2	25	38
2020	11	3	4	24	64
2020	12	1	1	1	2
2020	(all)		25	188	380

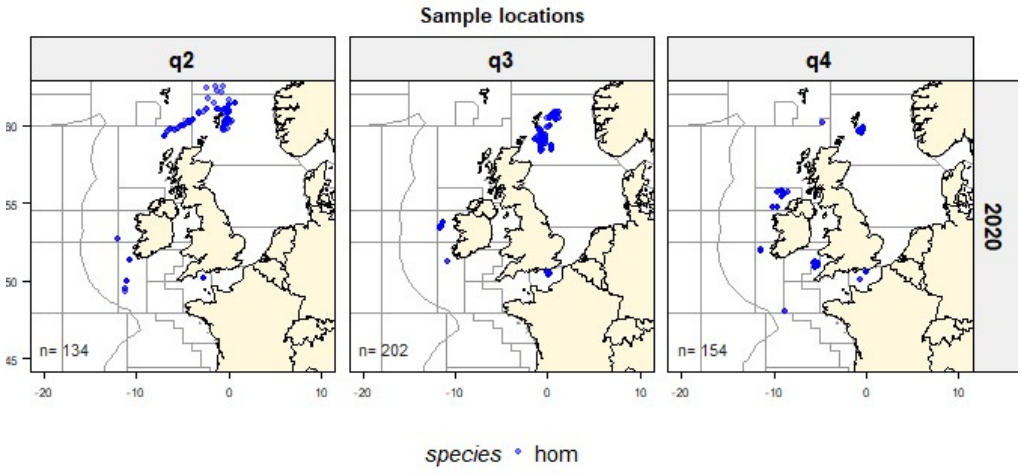


Figure 7 Horse mackerel samples collected for gonad analysis during 2020, by quarter.

2.6 AutoMeasure

Effectively and efficiently measuring both the length and weight of individual fish could supply a vast amount of new information on the condition of fish in different areas and seasons. So far, the additional measurement of lengths has been implemented within the RVZ/PFA, but the combined manual measurement of length and weight has proven to be a too onerous task. That is why we are searching for an automated solution to this challenge.

In 2017, RVZ commissioned the first development of a device for integrated recording of length and weight of individual fish. This device was indeed developed but in practice proved not to meet the criteria set. The development was subsequently aborted.

In 2020 we initiated a new development with a company that has a lot of experience in image processing and automatic processing of data (e.g., from fish processing techniques). The aim of the project is the development of a demonstration version of a device for automatic weighing and measuring of fish that can be deployed on a vessel.

This company has now developed next-to-ready demonstration version of a weighing-measuring installation that could be used on board of ships. The measurement part is based on stereo camera images with automated corrections for body shape and any potential curvature in the fish. The weighing is based on an integrated, motion-compensated scale.

The weighing-measuring device has been demonstrated to potential users on 23 December 2020. Results of the length measurements looked very promising although there were still some issues with small spots or stains giving rise to false measurements. The weighing part worked flawlessly as far as could be detected. Some impressions on the demonstration devices are shown in the images below.

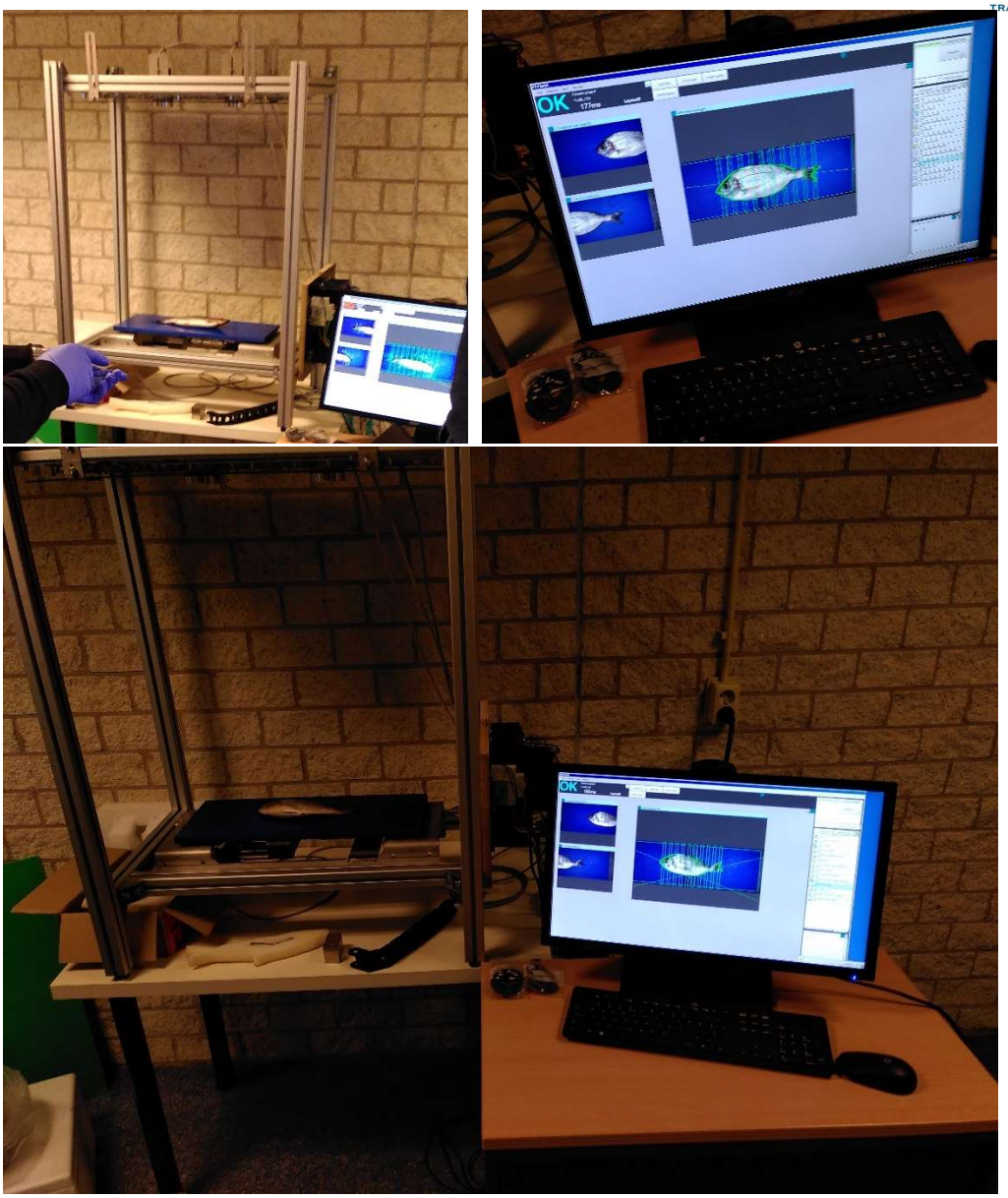


Figure 8 Setup and impressions of the weighing-measuring device. The two stereo camera and light panel are integrated in the top panel of the (temporary) housing. The scale is included in the bottom panel. The screen to the side shows the approximation of the length measurement algorithms.

After the demonstration in December 2020, the development has worked on the testing of the motion compensation in the scale and the removal of spots for the measuring algorithms. Figure x demonstrates that the spot removal has now been achieved. It is foreseen that the full version of the measuring-weighing device will be available for testing at the RVZ/PFA member companies and/or vessels in the spring of 2021.

Figure 9 Spot removal on the camera recognition software.

2.7 Broadband demonstrator

The EMFF funded "RealFishEcho" project has demonstrated that broadband acoustics has promising properties for allowing effective species recognition with acoustics (Berges et al. 2019). When the project finished, the benefits of the approach could not yet be implemented on the participating vessels. The broadband demonstrator project aims to implement the finalized broadband species recognition software on the participating trawlers and testing the added value for improved selectivity.

The aim of the project is to carry out operational testing of the capabilities of the broadband fish species classifier developed during the realFishEcho project and implementing additional features like automatic recording to the fish species classifier.

Due to the COVID-19 situation during 2020 is has not been possible to carry out the project because of the reduced possibility to work on the vessels for non-vessel crew. A fully worked out proposal by the research partners (WMR

and TNO) has been presented to RVZ and commitments have been made for execution of the project in the first half of 2021.

2.8 Fish condition research

In 2018 the Dutch Council for Animal Affairs (*Raad voor Dier-aangelegenheden*) issued a vision document on the welfare of fish, in which it stated that "the welfare and integrity of fish are still insufficiently taken into account when dealing with fish." Specifically, for commercial fishing, the Council recommended more attention to the catching and handling of fish. The RVZ/PFA has therefore initiated an exploratory study to the condition of pelagic fish as they are caught in pelagic fisheries. This study was proposed, commissioned and initiated in 2019, but the main bulk of the work was carried out during 2020.

In collaboration with Wageningen Marine Research, the exploratory study has been set up to gain insight into the condition of fish in the catches of pelagic trawlers from the moment the fish comes on board until the end of the catch processing process. Factors that can be considered are the catch volume, fish species and conditions at sea such as water temperature, depth, wind force and wave height. Specific equipment has been developed to allow for assessment of Fish condition on board. WMR has compiled a fish condition monitoring protocol (Molenaar and Schram 2019) which has been applied subsequently.

While it has been challenging, initially, to find the appropriate researchers to carry out the sampling work on board of the trawlers, we managed in the end to cover almost all the fisheries. We were helped by one of the WMR observers who could carry out some of the sampling work next to his observer work, and an intern at WMR who was available for two dedicated full-time trips on trawlers. In addition, the possibilities of camera observations and oxygen measurements inside the fish tanks were realized during a short fishing trip in December 2020. Overall, 3000 fish of different species have been scored for condition according to the WMR protocol, covering the following fisheries:

- Winter herring in the Channel
- Summer herring in the northern North Sea
- Horse mackerel in the Channel (December)
- Horse mackerel west of Ireland (January, September)
- Mackerel in the northern North Sea (September)
- Nordic herring in division 2.a (October)

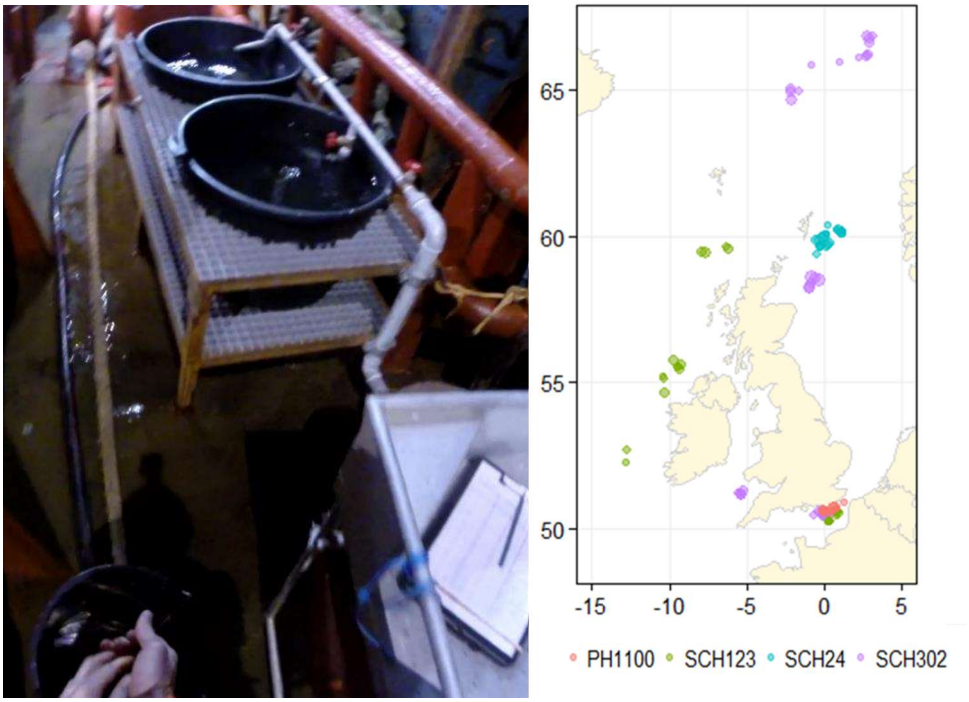


Figure 10 Left: Fish condition monitoring tubs developed specifically for the research project. Each of the tubs contain flowing seawater where fish can be held until vitality assessments can be carried out. Right: fish condition sampling sites from different vessels and trips.

The final report on the fish condition research is being finalized early in 2021 and is expected in January or February.

2.9 Fat content of herring and mackerel

The fat content of fish is a good indicator of overall body condition, which influences important traits such as survival, growth and reproduction. Therefore, condition has an impact on stock productivity and availability to fisheries. Thus, understanding drivers of variation in fat content is important for fisheries management. A joint research project with the University of Aberdeen, Scottish Pelagic Fishermen Association (SPFA) and the RVZ/PFA is looking into the utilization of industry data to elucidate these questions.

The PhD student Susan Kenyon has been jointly funded by the University of Aberdeen, Scottish Pelagic Fisheries Association and the RVZ/PFA. She started her PhD research by the beginning of 2019. Food availability and temperature are two environmental factors which are known to affect the body condition of fish. However, these interactions have not been formally investigated within Atlantic herring and mackerel, two commercially important species within the North-East Atlantic.

The PhD student is working with data from Scottish fish processing factories and from RVZ/PFA vessels and companies. Initial results on mackerel (Figure 11) and herring (not shown) fat content have been generated and are being

embedded into advanced statistical analysis. Two draft chapters for the PhD document have been generated.

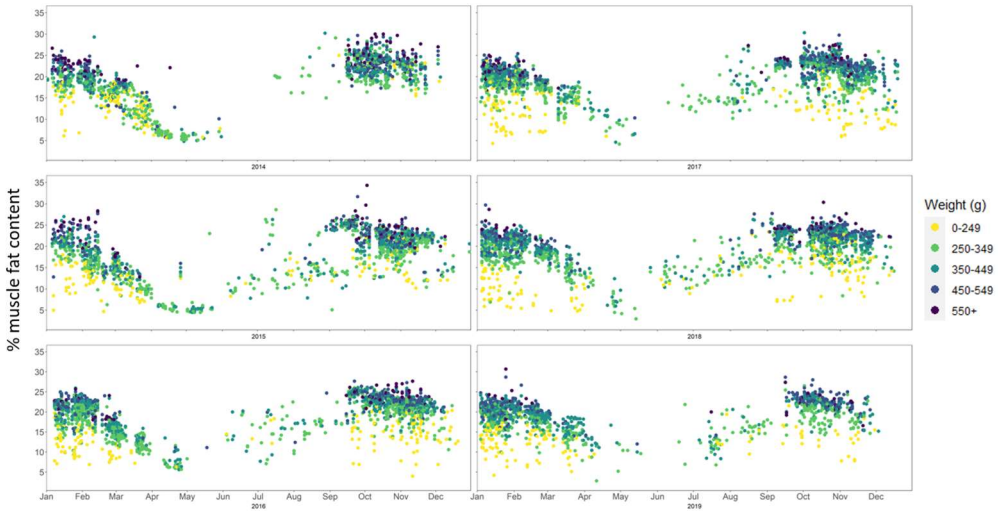


Figure 11 Fat content of mackerel by weight class and year as derived from Scottish and RVZ/PFA industry sampling.

Three internship/thesis subjects were opened at RVZ/PFA during 2019 and 2020 in relation to the PhD research:

- The first internship was fulfilled by Jorn School for the period November 2019-March 2020, during which he worked on the historical fat content and other biological data that has been collected by the RVZ/PFA member companies.
- The second internship was fulfilled by Felix IJpelaar for the period September 2020 until January 2021 during which he worked on the historical gonad data that has been collected by the RVZ/PFA member companies and on digitizing paper version of fat content data.
- The third thesis topic was fulfilled by Herman de Munnik during October 2020 until March 2021 and which is focussed on statistical analysis of the RVZ/PFA fat content data.

3 Publications

Publications that were realized as part of the research projects described in this document:

Berges, B., S. Sakinan, M. S. Ybema, G. J. Kooij and M. A. Pastoors (2020). Inventory of industry-acoustic data for potential application on blue whiting biomass estimates, ICES WGWIDE. Working document 07, WGWIDE 2020.

Damme, C. J. G. v., E. Blom, E. Koelemij, I. Pennock, H. Wiegerinck, T. Wilkes, A. Thorsen, G. J. B. Thorsheim, P. Alvarez, M. A. Korta, C. Perez, J. Tomkiewicz and J. J. Nielsen. (2021). Year of the Mackerel. A study on gonadal development of mackerel., Wageningen Marine Research. *(forthcoming)*

Mackinson, S., M. A. Pastoors, S. Lusseau, S. O'Connell, J. Forbes-Birnie, S. Sakinan, B. Berges, K. Brigden, M. O'Malley and E. D. Farrell (2020). Report on the 2019 industry-science survey of herring in the Western British Isles (ICES Divisions 6a, 7bc): 96 pp.

Pastoors, M. A. and F. J. Quirijns (2021). PFA self-sampling report 2015-2020, PFA. 2021/02.

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Ybema, M. S., K. Johannsen and A. Sapronova (2021). Quality assessment of the OceanBox biomass index estimation approach. Oslo, Sustainovate. *(forthcoming)*

Ybema, M. S. and A. Sapronova (2021). Fish mapping - part II. Oslo, Sustainovate. *(forthcoming)*

4 Acknowledgments

A research program like described in this report can only be carried out with a sustained commitment of many persons within the fishing industry and the research community. The skippers, officers and the quality managers of the participating vessels are investing a lot of time and effort in making the self-sampling work and other research projects become a reality. A special word of thanks to the strong support by the fleet-managers, project-officers and quality managers on shore. Many thanks also to the skippers and crew of the participating vessels for their warm welcomes whenever I came on board and for the thought-provoking discussions and the sharing of deep knowledge and insight in fishing strategies and fish behaviour.

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