DTU Aqua
National Institute of Aquatic Resources

Fisheries resources and socio-economy (JAMBAY WP4)

Grete E. Dinesen, Anna Rindorf, Josefine Egekvist, Ole R. Eigaard, and Josianne G. Støttrup (eds.)

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Preface

The project “Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)” (Grant Agreement No 33113-B-23-189) was funded by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark.

This Work Package 4 Report is the last of four detailed work package reports. This report presents the results of “Fisheries resources and socio-economy (JAMBAY WP4)”. These results are summarised in the Executive Report of the JAMBAY project, where also the detailed results of Work Package 5 are presented (DTU Aqua Report no. 445-2024).

This project had a short timeframe to conduct its work, given the magnitude and complexity of the work involved. It started in March 2023 and ended in December 2023. The initial application was accepted and awarded 12 million Danish kr., and in September was expanded to include additional work and an added 14 million Danish kr., to a total of 26 million Danish kr. More than 100 scientists and consultants from several research institutes and private companies were directly involved. Furthermore, the project indirectly involved several stakeholders.

The data collected, newly developed methods and models generated during this project have been reported upon. Part of the work has been disseminated nationally and internationally, but further work is needed to integrate the data and information across the professional fields. Follow up projects have been initiated towards this end. The outputs will inform and provide the opportunity for cross-sectorial, ecosystem-based management.

Kongens Lyngby, March 2024

Grete Elisabeth Dinesen
Senior Consultant

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English summary

The aims of Task 4.1 were to identify whether recent changes in fisheries landings of cod and plaice in the Jammer Bay and Skagerrak from 2000-2022 could be related to changes in: i), quota level and fishery efficiency, ii), fish population structure and distribution or iii), spatial changes of thermally suitable fish habitats. In order to ensure an ecosystem-based approach, we conducted the first steps of the Systems Approach Framework (SAF).

The SAF was initiated with a clear identification of the issue and listing all relevant stakeholders. Further, system services and human activities and resources were listed for inclusion in the analyses.

The fish survey analyses using data from 2005.2022 showed a regional shift in the relative Atlantic cod (*Gadus morhua*) distribution away from the southern towards the northwestern North Sea. For plaice (*Pleuronectes platessa*), a shift in the highest relative density was observed from the east towards the northwestern North Sea. At the local scale, fish survey data showed significant declines in the large fish populations of both cod and plaice in the Jammer Bay in recent years, while at the same time highlighted the Jammer Bay as an important nursery area for both fish species.

We investigated if the observed changes in relative cod and plaice occurrence was due to changes in thermal habitat distribution. The results of landings data compared with bottom temperature data, showed clear relations between where the cod were caught and the ambient bottom temperature. High bottom temperatures during Q3 in the coastal waters of the Jammer Bay have occurred more frequently in recent years which may explain the increasing avoidance of larger cod in this area. Cod avoided waters higher than 16 °C in accordance with temperature boundaries observed from the cod DST data from previous projects.

Plaice, on the other hand, were caught in temperatures higher than 16 °C and no avoidance seemed to occur for this species, despite the DST information on temperature boundaries for the species. The results imply that the temperature-regulated processes governing cod and plaice landings differ and may be due to differences in behavioural responses to unfavourable environmental conditions. For plaice, however, the recent steep population decline in adults may be due to overfishing, either by local fishers or exacerbated by an influx of a foreign fleet of beam trawlers. Information on the landings from these foreign fleets together with more detailed information on the temperature at the capture positions may provide a definite explanation for the local decline of adult plaice and directly improve the management for this species.

Task 4.2 identifies the distinct types of fisheries in the Jammer Bay area. The relevant features of each fishery, such as vessel lengths, engine sizes, gear types, profitability measures, crew sizes, quota, and ownership, have been organized into four core features, which provide a new, operational framework of conceptual models, called Fishing Cultures. The conceptual models are applied to identify different connections between cultural life-modes and modes of production in the fisheries, their competition for ecosystem resources and their contributions to value chains and socio-cultural sustenance at the local, national, and international level. Further, a model for assessing the local economic effect of each Fishing Culture is developed.

Each Fishing Culture is a unity of four core features: i), life-mode; ii), mode of operation; iii), fishing methods and iv), community (fishing harbour affiliation). Seven Fishing Cultures were identified: FC 1), Beach landing coastal fishery; FC 2), Dutch demersal beam-trawling; FC 3), Expansive harbour-based fishery; FC 4), Harbour based coastal fishery; FC 5), Specialised gillnet fishery; FC 6), Specialised anchor-seine fishery; FC 7), Profit-seeking large-scale fishery.

The problematic coexistence of opposite modes of operation and opposite fishing methods were aggravated by the arrival of a fleet of large beam trawlers in 2017 at the shallow grounds of the Jammer Bay searching for sole (*Solea solea*) and plaice. These beam trawlers subsequently returned to Jammer Bay during the next 6 years because these target species were no longer available in their home waters of the Southern North Sea. The arising conflicts and potential coexistence are discussed in this chapter.

Fishers (among the interviewed stakeholders) realizing the FCs 1, 4, 5, and 6 find themselves caught in an antagonistic relation to large beam-trawlers realizing FC 2 who operate a long-distance fishery in the Jammer Bay, among other places. Their presence in the Jammer Bay conflicts with local fishers realizing the FCs 1, 4, 5 and 6 because of their inability to share common fishing grounds and fish stocks. The impact by FC 2 on the seabed, marine food webs, and juvenile fish puts, according to the local fishers, pressure on their fishing opportunities at the shallow grounds of the Jammer Bay while the beam trawlers are operating in the area and during a considerable time afterwards.

The Dutch beam trawlers of Fishing Culture 2 operate a downright long-distance fishery without any economic contribution of significance to the local fishing communities in the Jammer Bay area. This is reflected in the considerable differences in the Local Economic Effect (LEE) between the Fishing Cultures and highlights another pattern than would otherwise be obtained from calculations of company profitability in business economic practice. FCs 1, 4 and 5 have the highest LEE, calculated to 49%–56% of the catch value. There is a middle LEE for FC 3 and 6, calculated to around 40%. While the lowest LEE is for FC 7 and FC 2. For FC 7, the calculated LEE is 25%. FC 2 generally does not land fish in any of the Jammer Bay harbours. Thus, the LEE of FC 2 (Dutch beam trawlers) is almost zero.

In Task 4.3, we explored the relation between observed bycatch rates of non-target fish and protected, endangered, and threatened (PET) species, fishing effort intensity and distribution, and habitat-related variables. The incidental capture of unwanted species (bycatch) like marine mammals, seabirds, or fish in set net fisheries is a long-known issue in European waters that is susceptible to negatively affect the population dynamics of PET species. Bycatch stems from the concomitant presence of non-target, unwanted species and of fishing gears in an area. Nevertheless, spatiotemporal overlap between PET species and fisheries alone cannot explain observed levels of bycatch, and incidental captures also depend on a number of operational, ecological, and behavioural aspects that are often difficult to separate from one another. In Denmark, considerable effort to monitor incidental captures of PET species in commercial fisheries has been made in the last 15 years, notably using semi-autonomous video-monitoring system, or electronic monitoring (EM) systems to as-sociate high-resolution fishing effort and species-specific bycatch data. These EM data, collected on a sample of the commercial Danish fleet, have been used to highlight areas where bycatch risks are high and estimate PET species bycatch mortalities. In the southern part of Jammer Bay however, EM coverage has been historically relatively low. With the JAMBAY project, two new vessels joined the PET bycatch monitoring programme in 2023, and their EM data were analysed to refine our understanding of the bycatch variability in this important fishing area. Initially, we aimed to link high-resolution fishing effort and bycatch data from EM vessels to the high-resolution habitat maps from Work Package 1, but the data delivery was delayed so we exploited the Copernicus database instead (https://marine.copernicus.eu). The EU Copernicus Marine Service provides daily updates of important oceanographic variables such as sea surface and bottom temperature, indices of primary productivity, or bathymetry, which we could link to each fishing events in the EM fleet (since the latitude, longitude, date, and time were known for all monitored events) to explore the underlying factors influencing PET species bycatch. Bycatch registrations in Jammer Bay involved several species of elasmobranchs (rays and sharks), of seabirds, and of marine mammals. Among the latter, the harbour porpoise (*Phocoena phocoena*) is a common cetacean species highly susceptible to bycatch in gillnets, present in Jammer Bay yearlong, and for which EM data series spans the longest, starting in the early 2010's. Porpoises constituted as such an ideal case study to explore the complex relationships between oceanographic features, habitat, and fishing effort distribution and intensity in the study area. Specifically, we trained a machine learning model (here, a classification tree model) using XGBoost to classify observed fishing operations (hauls) with and without harbour porpoise bycatch depending on fishing and oceanographic characteristics.

The results from our model shows that, although oceanographic features such as depth, salinity, bathymetric slope, or temperature (all of which could be used to define e.g., porpoise bycatch high risk areas) are important contributors to porpoise bycatch in Jammer Bay, the principal contributor to by-catch probability is by large fishing effort measured as the product of net fleet length and soak duration, while at the same time, and quite unexpectedly, gillnet mesh sizes was not found to be an important variable in our data. It is likely that mesh size effects on bycatch probability captures ecological features (e.g., via target species) increasing bycatch probability which are captured by the oceanographic variables considered in this machine learning model.

In Task 4.4, spatial distribution maps and abundance time-series were estimated for four sensitive fish species that occur in the Jammer Bay area: Halibut (*Hippoglossus hippoglossus*), spurdog (*Squalus acanthias*), wolffish (*Anarhichas lupus*), and starry ray (*Amblyraja radiata*). Data from five different trawl surveys (NS-IBTS, BITS, Cod, Sole, and Norwegian shrimp survey) were combined in a model that accounted for different catch efficiency in each survey due to different types of trawls for example. This combination of data from different surveys utilizes the sparse information available for these sensitive species in a better way than any of these surveys alone and allows standardized abundance maps for larger areas and longer time-series to be calculated.

The results showed that for halibut and in particular spurdog the overall trend in abundance from 1983-2023 is positive, whereas the overall trends for wolffish and starry ray are negative.

In addition, landings in Jammer Bay from the period 1895-1910 were digitized and compared to those from the period 2005-2020. Due to potential non-reporting and species-misidentification it was not possible to compare landings of the sensitive species considered, only the most abundant species could be compared. Cod and haddock were by far the two most common landed species from 1895-1910, whereas plaice and herring were more common from 2005-2020.

Under Task 4.5, the predation and resulting mortality of the commercially important fish stocks in the North Sea and Skagerrak have been estimated by the Stochastic Multi-Species model SMS developed and maintained by DTU Aqua. The model includes fisheries and diet data for 12 commercially important species (e.g., cod, saithe (*Pollachius virens*), herring (*Clupea harengus*), sandeel (*Ammodytes marinus*) and sprat (*Sprattus sprattus*), additional 4 fish-eating species, e.g., grey gurnard (*Eutrigla gurnardus*) and starry ray (*Amblyraja radiata*), 8 species of sea birds and marine mammals (harbour porpoise and grey seals). SMS has been updated to include stock assessment data for 2020-2022, revised previous estimates of grey seal abundance and diet, and estimated uncertainties of fish diet estimates and used these in the model likelihood. This work was done in preparation for a week-long meeting in the ICES Working Group on Multispecies Assessment Methods (WGSAM) in October 2023. The output of the updated model quantifies the predator-prey interactions with respect to biomass eaten and predation mortalities and contributes as such to the understanding of the food web for the commercial species in the North Sea.

The changes in data and model made by DTU aqua and additional changes in the abundance of seabirds made by other WGSAM members were quite comprehensive, such that the final run and result first were agreed on by WGSAM at the end of December. The final report from WGSAM (ICES, 2024) provides a detailed description of the work done and the final model results. The results, mainly a new estimate of the natural mortalities, will be used by the ICES stock assessment working groups and in ICES catch advice for 2025.

In Task 4.6 we combined the information on spatial distribution of the fisheries with mobile bottom contacting gears (VMS/AIS) with the information from the landing declarations (logbook information) and data from the observer trips conducted by DTU Aqua to get a spatial distribution of the discard. This was conducted for the period 2018–2022 for nine selected species in Skagerrak. These included some of the main target species such as cod (*Gadus morhua*), whiting (*Merlangius merlangus)*, saithe (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*), deep water shrimp (*Pandalus borealis*), Norway lobster (*Nephrops norvegicus*) and plaice (*Pleuronectes platessa*) and two species designated as sensitive species; starry ray (*Amblyraja radiata*) and piked dogfish (*Squalus acanthias*). Further, in this task we mapped the fishing effort and the observer coverage from the sampled fisheries in Skagerrak in the same period.

An additional aim of this task was to deliver a time series of catch data (discard and landings) from 2015-2022 on an online platform to give easy accessibility for further use of data. Catch data collected is mainly used in stock assessment in ICES (International Council for the Exploration of the Sea) and in fishery advice. The observer program covers a relatively small part of the total fishery (<1%) of all fishing trips and only some of the fleets are covered in the program.

Dansk resume

Formålet med Task 4.1 var at identificere, om ændringer i landinger af torsk og rødspætter i Jammerbugten og Skagerrak i perioden fra 2000-2022 kunne relateres til ændringer i: i), kvoteniveau og fiskerieffektivitet; ii), fiskebestandsstruktur og fordeling; eller iii), rumlige ændringer af termisk egnede fiskehabitater. For at sikre en økosystembaseret tilgang gennemførte vi de første trin af Systems Approach Framework (SAF).

SAF blev indledt med en klar identifikation og formulering af problemstillingen og udarbejdelse af en liste over alle relevante interessenter. Endvidere blev der udarbejdet lister over økosystemtjenester og menneskelige aktiviteter og ressourcer som var relevante at inddrage i analyserne.

Fiskepopulationsanalyserne udført ved hjælp af fiskeriundersøgelsesdata fra perioden 2005-2022 viste en regional forskydning i den relative fordeling af torsk (Gadus morhua) væk fra den sydlige del mod den nordvestlige del af Nordsøen. For rødspætter (Pleuronectes platessa) blev der observeret et skift i de højeste relative tætheder fra øst mod den nordvestlige Nordsø. For Jammerbugten viste fiskeriundersøgelsesdata betydelige fald i fiskebestande af både torsk og rødspætter i de senere år, samtidig med at Jammerbugten blev fremhævet som et vigtigt opvækstområde for unge fisk af begge arter.

Vi undersøgte, om de observerede ændringer i relativ forekomst af torsk og rødspætter skyldtes ændringer i fordelingen af deres foretrukne habitattemperaturer. Resultaterne af landingsdata (VMS & logbogsinformationer) sammenlignet med højopløste modellerede bundtemperaturdata viste klare sammenhænge mellem hvor torskene blev fanget og den stedlige bundtemperatur. Høje bundtemperaturer i 3. kvartal (juli-september) i de kystnære farvande i Jammerbugten er forekommet hyppigere i de senere år, hvilket kan forklare det stigende fravær af større torsk i dette område. Torsk undgik helt vandtemperaturer højere end 16 °C, hvilket var i overensstemmelse med temperaturgrænser observeret for voksne torsk (DST-data) i tidligere projekter (BONUS BALTCOAST).

Rødspætter blev derimod fanget ved vandtemperaturer højere end 16 °C, og det så ikke ud til at de holdt sig væk fra varmere vandmasser på trods af kendte (DST-data) temperaturgrænser for voksne individer af arten. Resultaterne antyder, at de temperaturregulerede processer, der styrer landinger af torsk og rødspætter, er forskellige og kan skyldes forskelle i adfærdsmæssige reaktioner på ugunstige miljøforhold. For rødspætter kan den seneste stejle bestandsnedgang hos voksne dog også skyldes overfiskning, enten af lokale fiskere, eller forværret af en tilstrømning af udenlandske bomtrawlere og fly-shootere, der i de senere år har udøvet et arealmæssigt omfattende fiskeri i Jammerbugten. Information om landingerne fra disse udenlandske flåder mangler (VMS-data og logbogsinformationer er ikke tilgængelige). Adgang til disse data ville sammen med mere detaljerede oplysninger om temperaturen ved fangstpositionerne kunne give en mere præcis forklaring på den lokale tilbagegang af voksne rødspætter, og dermed direkte forbedre forvaltningen for denne art.

Task 4.2 identificerer de forskellige typer fiskeri og tilknyttede kulturer i Jammerbugt-området. De relevante karakteristika i hvert fiskeri, såsom fartøjslængder, motorstørrelser, redskabstyper, opgørelse af rentabilitet, besætningsstørrelser, kvoter og ejerskab, er blevet organiseret i fire strukturtræk, som danner de begrebslige modeller kaldet fiskerikulturer. De er beregnet til at identificere forskellige sammenhænge mellem kulturelle livsformer og produktionsmåder i fiskeriet, deres konkurrence om økosystemressourcer og deres bidrag til værdikæder samt kulturel og samfundsmæssig bæredygtighed på lokalt, nationalt og internationalt plan. Desuden er der udviklet en model til vurdering af de lokale økonomiske effekter for hver fiskerikultur.

Hver fiskerikultur er en enhed af fire kerneegenskaber i), livsform; ii), driftsform; iii), fangstmetode; og iv), tilknytning til fiskerihavn. I Jammerbugten identificerer denne undersøgelse syv forskellige fiskerikulturer (Fishing Cultures, FC): FC 1), Kystfiskeri med strandlanding; FC 2), Hollandsk bomtrawlfiskeri; FC 3), Ekspansivt havnebaseret fiskeri; FC 4), Havnebaseret kystfiskeri; FC 5), Specialiseret garnfiskeri; FC 6), Specialiseret snurrevodsfiskeri; og FC 7), Profitsøgende storindustrielt fiskeri.

Den problematiske sameksistens af fiskerikulturer med modsatte driftsformer og modsatte og/eller konkurrerende fangstmetoder blev forværret ved ankomsten af en flåde af store bomtrawlere i 2017 der fiskede efter tunge og rødspætter, særligt i de centrale områder af Jammerbugten (bl.a. i området kendt af lokale fiskere som ”Store Rev”). De Hollandske bomtrawlere vendte tilbage til Jammerbugten i længere perioder i løbet af de næste 6 år, fordi disse målarter ikke længere var tilgængelige i deres hjemlige farvande i den sydlige Nordsø. De heraf opståede konflikter og potentiel sameksistens diskuteres i dette kapitel.

Fiskere (blandt de interviewede interessenter) der praktiserer FC 1, 4, 5 og 6 oplever at være fanget i en uønsket konflikt med fiskere der praktiserer FC 2 ved et lang-distance fiskeri med store bomtrawlere i blandt andet Jammerbugten. Tilstedeværelsen af FC 2 er i direkte konkurrence med de lokale fiskere der praktiserer FC 1, 4, 5 og 6 på grund af de manglende muligheder for at dele fælles fiskepladser og fiskebestande. Påvirkning af FC2 på havbunden, marine fødenet og juvenile fisk presser, ifølge de lokale fiskere, deres fiskerimuligheder i de lavvandede grunde i Jammerbugten, både mens bomtrawlerne fisker i området og i lang tid herefter.

De hollandske bomtrawlere der praktiserer fiskerikultur FC2 driver alene et lang-distance fiskeri og uden økonomisk bidrag til de lokale fiskerisamfund i Jammerbugt-området. Dette afspejles tydeligt i de store forskelle i Lokal Økonomisk Effekt (Local Economic Effect, LEE) der er imellem de forskellige fiskerikulturer der fisker i Jammerbugten. Anvendelse af LEE belyser væsentlige økonomiske forhold som er forskellige fra de beregninger af virksomhedens rentabilitet der ofte anvendes i erhvervsøkonomisk praksis. FC 1, 4 and 5, har de højeste beregnede LEE værdier mellem 49%-56% af den samlede landingsværdi. De mellemste LEE værdier er beregnet for FC 3 og 6 til ca. 40% af landingsværdien, mens den for FC 7 er 25%. Den laveste LEE værdi er beregnet for FC 2. Da de hollandske bomtrawlere (FC 2) general ikke lander deres fangede fisk nogen af havnene i Jammerbugt-områder, er deres LEE værdi tæt på 0%.

I Task 4.3 undersøgte vi sammenhænge mellem observerede bifangstrater for ikke-målarter af fiske og beskyttede og truede PET-arter, fiskeriindsats og –intensitet, og habitat-relaterede faktorer. Fangst af uønskede arter (uønsket bifangst) som havpattedyr, havfugle eller undermålsfisk og følsomme i garnfiskeri er et velkendt problem i alle europæiske farvande hvor det påvirker PET arternes populationsdynamik negativt. Uønsket bifangst stammer fra den samtidige tilstedeværelse af ikke-målarter, uønskede arter, og ungfisk af målarter og specifikke fiskeredskaber i et område. Ikke desto mindre kan rumligt overlap mellem PET arter og fiskeri ikke alene forklare de observerede niveauer af uønskede bifangst. Uønskede bifangster afhænger også af en række operationelle, økologiske og adfærdsmæssige aspekter, som ofte er svære at adskille fra hinanden. I Danmark er der i de sidste 15 år gjort en betydelig indsats for at overvåge uønskede fangster af PET arter i kommercielt fiskeri, især ved hjælp af semi-automatiske videoovervågningssystemer eller elektroniske overvågningssystemer (EM) der muliggør kobling af højopløselige data for fiskeriindsats med artsspecifikke fangstdata. Disse EM data, der er indsamlet samtidigt med den traditionelle stikprøveovervågning af fangster i den danske kommercielle fiskeriflåde, er blevet brugt til at fremhæve områder og tidspunkter, hvor risikoen for uønskede bifangster er høj, og estimere dødeligheden af PET arters bifangst. I den sydlige del af Jammerbugten har EM dækningen historisk set dog været relativt lav. Med JAMBAY-projektet sluttede to nye fartøjer sig til PET bifangstovervågningsprogrammet i foråret 2023, og deres EM data blev analyseret for at forbedre vores forståelse af bifangstvariabiliteten i dette vigtige fiskeriområde. I første omgang havde vi til formål at forbinde højopløselige fiskeindsats- og bifangstdata fra EM fartøjer til højopløselige habitatkort fra arbejdspakke 1, men dataleveringen blev forsinket, så vi udnyttede Copernicus-databasen i stedet for (https://marine.copernicus.eu). EU Copernicus Marine Service leverer daglige opdateringer af vigtige oceanografiske variabler såsom havoverflade- og bundtemperatur, indekser for primær produktivitet eller bathymetri, som vi kunne knytte til hver fiskebegivenhed i EM flåden (da breddegrad, længdegrad, dato og tid var kendt for alle overvågede hændelser) for at udforske de underliggende faktorer, der påvirker PET arters bifangst. Bifangstregistreringer i Jammerbugten involverede flere arter af elasmobrancher (rokker og hajer), havfugle og havpattedyr. Blandt de sidstnævnte er marsvin (*Phocoena phocoena*) en almindelig hvalart, der er meget udsat som uønsket bifangst i gællegarn der anvendes i Jammerbugten året rundt, og for hvilken EM dataserier strækker sig længst, startende i begyndelsen af 2010'erne. Marsvin udgjorde som sådan et ideelt casestudie til at udforske de komplekse sammenhænge mellem oceanografiske træk, forekomster af habitattyper og fiskeriindsatsfordeling og intensitet i undersøgelsesområdet. Specifikt trænede vi en maskinlæringsmodel (her en klassifikationstræmodel) ved hjælp af XGBoost til at klassificere observerede fiskerioperationer (træk) med og uden marsvins bifangst afhængigt af fiskeri og oceanografiske karakteristika.

Resultaterne fra vores model viser, at oceanografiske træk såsom dybde, saltholdighed, bathymetrisk hældning og vandtemperatur (som alle kunne bruges til at definere f.eks. højrisikoområder for marsvin-bifangst) er vigtige faktorer der kan forklare bifangster af marsvin i Jammerbugten. Herudover har fiskeriindsatsen, målt som produktet af nettoflådens garnlængde og udblødningsvarighed, væsentlig betydning for risiko for uønsket bifangst. Samtidig, og ganske uventet, fandt vi at garnmaskestørrelser var en vigtig variabel i vores data. Det er muligt, at maskestørrelseseffekter på sandsynlighed for bifangst knytter sig til økologiske faktorer (f.eks. via ændring i fangst af målarter), hvilket øger sandsynligheden for bifangst, som fanges af de oceanografiske variabler, der tages i betragtning i denne maskinlæringsmodel.

I Task 4.4 blev rumlige udbredelseskort og tidsserier for tætheder estimeret for fire følsomme fiskearter, der forekommer i Jammer Bugt-området: helleflynder (*Hippoglossus hippoglossus*), pighaj (*Squalus acanthias*), havkat (*Anarhichas lupus*), og tærbe (*Amblyraja radiata*). Data fra fem forskellige fiskeriundersøgelsestogter (NS-IBTS, BITS, torsk, tunge og norsk rejetogt) blev kombineret i en model, der tager højde for forskellige fangsteffektiviteter i hvert togt på grund af blandt andet anvendelse af forskellige typer trawl. Denne kombination af data fra forskellige togter udnytter den sparsomme information, der er tilgængelig for disse følsomme arter på en bedre måde end nogen af disse undersøgelsestogter gør alene, og gør det muligt at beregne standardiserede udbredelseskort for større områder og længere tidsserier. For helleflynder og især pighaj er den overordnede tendens i udbredelse og tætheder positive fra 1983-2023, hvorimod de overordnede tendenser i samme periode for havkat og tærbe er negative.

Desuden blev landinger i Jammerbugten fra perioden 1895-1910 digitaliseret og sammenlignet med dem fra perioden 2005-2020. På grund af potentiel manglende rapportering og arts-fejlidentifikation var det ikke muligt at sammenligne landinger af de følsomme arter; kun de mest talrige arter kunne sammenlignes. Torsk og kuller var de to langt mest almindelige landede arter fra 1895-1910, hvorimod rødspætte og sild var mere almindelige fra 2005-2020.

I Task 4.5 undersøgte vi prædationssammenhænge, og den deraf følgende dødelighed af de kommercielt vigtige fiskebestande i Nordsøen og Skagerrak er blevet estimeret af den Stokastiske Multi-Species model (SMS; flerartsmodellen) udviklet og vedligeholdt af DTU Aqua. Modellen omfatter fiskeri- og diætdata for 12 kommercielt vigtige arter (bl.a. torsk, sej (*Pollachius virens*), sild (*Clupea harengus*), tobis (*Ammodytes marinus*) og brisling (*Sprattus sprattus*), yderligere 4 fiskeædende arter, bl.a. knurhane (*Eutrigla gurnardus*) og tærbe (*Amblyraja radiata*), 8 arter af havfugle og havpattedyr (marsvin og gråsæler). SMS er blevet opdateret til at omfatte data for 2020-2022. Som noget nyt blev der bestemt usikkerhed på fødevalg bestemt ud fra mavedata, og disse usikkerheder blev benyttet i en opdateret SMS til at vægte de enkelte observationer. DTU Aqua har også opdateret estimaterne af bestandsstørrelse og fødevalg for gråsæler, herunder inkluderet rødspætter som føde for gråsæler, for at få et bedre estimat af den naturlige dødelighed for denne bytteart. Data og model-opdateringerne blev præsenteret på et internationalt ICES WGSAM møde i oktober 2023. Outputtet fra den opdaterede model kvantificerer rovdyr-bytte-interaktionerne med hensyn til ædt biomasse og prædationsdødelighed og bidrager som sådan til forståelsen af fødenettet for de kommercielle arter i Nordsøen.

Ændringerne i data og modellen foretaget af DTU Aqua og yderligere ændringer i mængden af havfugle foretaget af andre WGSAM medlemmer var ret omfattende, således at det endelige resultat først blev aftalt af WGSAM i slutningen af december. Den endelige rapport fra WGSAM (ICES, 2024) giver en detaljeret beskrivelse af det udførte arbejde og de endelige modelresultater. Resultaterne, giver et nyt skøn over den naturlige dødelighed, som vil blive anvendt af ICES bestandsvurdering og fangstrådgivning for 2025.

I Task 4.6 har vi kombineret information fra fiskeriets spatio-temporale forekomst vha. VMS/AIS-data og logbogsinformationer, sammen med landingserklæringer og data fra DTU Aquas fiskeriobservatørprogram for at kunne få en spatial fordeling af uønsket bifangst og udsmid, også kaldet discarden. Analyserne er udført for ni udvalgte arter i Skagerrak for tidsperioden 2018-2022. Disse omfattede nogle af fiskeriets vigtigste målarter, bl.a. torsk (*Gadus morhua*), hvilling (*Merlangius merlangus)*, sej (*Pollachius virens*), kuller (*Melanogrammus aeglefinus*), dybvandsrejer (*Pandalus borealis*), jomfruhummer (*Nephrops norvegicus*) og rødspætter (*Pleuronectes platessa*), samt to arter udpeget som følsomme arter, tærbe (*Amblyraja radiata*) og pighaj (*Squalus acanthias*). Desuden vises en detaljeret fordeling af fiskeriet for de udvalgte flåder samt den tilhørende indsats i fiskeriobservatørprogrammet.

Yderligere er der til Task 4.6 leveret en online platform, der viser fangstdata fra 2015-2022 (landing og discard), hvilket giver eksterne brugere mulighed for at se og benytte de indsamlede data på en let og overskuelig måde. De indsamlede fangstdata bruges i bestandsvurderinger igennem ICES og til fiskerirådgivning. Observatørprogrammet dækker en relativ lille del af fiskeriet (<1 % af alle fiskeriture) og ikke alle fiskerityper er omfattet af indsamlingsprogrammet.

1. Introduction to WP4

The aim of this Work Package is to analyse the fisheries resources and socio-economic effects and value chains of all modes of fisheries operating in the Jammer Bay area.

Recent declines in cod (*Gadus morhua*) quotas and landings and in plaice (*Pleuronectes platessa*) landings despite increased quotas have given rise for concern to the Danish coastal fishers and related rural towns. The causes for these declines could be due to changes in the distribution of cod and plaice adults in response to climate change or may be the consequence of over-fishing. According to the UN “overfishing occurs when more fish are caught than the population can replace through natural reproduction”. Both cod and plaice are assessed at a regional and subregional levels in the Greater North Sea. However, overfishing may occur when the spatial quota allocation resulting from the assessments does not match the natural distribution of the targeted fish population. Overfishing can also be due to unaccounted catches of both targeted sizes and juveniles.

In this project, we investigated international fisheries survey data from 2005-2022 to examine whether changes in the distribution of cod and plaice have occurred. Data from the Vessel Monitoring System (VMS) and Automatic Identification System (AIS) together with logbook information were used to identify the spatial distribution of the fisheries. Seawater temperature data (NEMO4 model) was analysed together with landings data to identify whether the catches were linked to the availability of thermal habitats for cod and plaice. We used and further developed methods applied to the Baltic Sea (Dinesen et al. 2019, Neuenfeldt et al. 2019).

From 2005-2022 Danish fisheries with anchor seines and gillnets have taken place in both the coastal areas (i.e., inside the 12 nm zone) and offshore in the central parts of the bay (i.e., outside the 12 nm zone), while Danish bottom trawling occurred offshore on the soft-bottom slopes towards the borders of the Danish EEZ. Beam trawling was limited to one Danish vessel. However, since 2016, Dutch beam trawlers have been operating in the central parts of Jammer Bay and close to the 12 nm boundary. Their presence may result in competition with Danish commercial fishers for fishing grounds and fisheries resources. The diverse fleet segments operating in the area may have different environmental, societal, and economic impacts on the system. In this project, we analysed the linkages between fisheries landing values, modes of operation, cultural life-modes, and economic value chains related to vessel nationality and size, gear type and target species in the Jammer Bay area. We used and further developed methods applied for fisheries in Danish waters (Eliason et al. 2017, 2019; Højrup 2023).

Together with commercial fishers, we investigated relationships between spatial distribution of commercial fisheries, seabed habitat types and protected, endangered and threatened species (PETS).

Predictive spatial models developed provide information on areas of high risk for bycatch relative to gear type used in the fisheries.
Here, we focused on four fish species particularly sensitive to fishing, to evaluate present and future impacts on these species. The fish species include long-lived, late maturing species such

as halibut (*Hippoglossus hippoglossus*), lumpsucker (*Cyclopterus lumpus*), and sharks and rays (Elasmobranchia).

In most fisheries by-catch of unwanted species or sizes of fish are discarded at sea due to landing restrictions or low economic value. This imposes added mortality that can affect population structure and development of sensitive or commercially important fish species. We investigated the discarded amounts (i.e., weight and numbers) by métier to explore the discard impacts relative to the landings values. The discarded amount varies with gear type, fishing area and season and requires quantification for sustainable management.

2. Fisheries seabed habitat resources (Task 4.1)

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2.1 Introduction and aim

In the Skagerrak, at around the turn of the century cod (*Gadus morhua*) quota and landings decreased from ~12,000 tons, to between 2,000-4,000 tons since 2003. Since 2020, the cod quota and landings were less than 2,000 tons. Plaice (*Pleuronectes platessa*) quota and landings have been stable at 6,000-9,000 tons until 2016. In 2017, the quota was raised to 14,000 tons. However, the fishers were unable to meet the quota and landings declined initially to 4,000 tons, and recently to 2,000 tons. This made it difficult for the coastal fishers to earn a livelihood.

The reasons for these historically low landings of cod and plaice could be due to changes in fish distribution and environmental conditions. A similar situation, where Baltic fishers were unable to catch their cod quota, was studied. That study showed a significant link between spatial distribution of cod fishing grounds and suitable cod thermal habitats (Dinesen et al. 2019).

The overall objective of this study was to examine whether the perceived decline in coastal fish occurrences is due to regional or local changes in fish distribution. Such changes could be due to a decline in total stock or suitable habitats.

The aims of this study were to identify whether changes in fisheries landings of cod and plaice in the Jammer Bay and Skagerrak from 2000-2022 may relate to changes in: i), quota level and fishery efficiency, ii), fish population structure and distribution, or iii), spatial changes of thermally suitable fish habitats.

We investigated if cod and plaice distribution have changed in response to: i), regional and local population trends; or ii), local changes of suitable thermal habitat distribution. We included international fisheries survey data from 2005-2022 for the North Sea and Kattegat (i.e., ICES DATRAS) and VMS/AIS and logbook information for the study area to identify landings and fishing grounds relative to thermal habitat conditions.

2.2 Materials and methods

2.2.1 SAF

The Systems Approach Framework (www.safhandbook.net, Støttrup et al. 2019) was applied to facilitate an ecosystem-based analysis that includes all potential stakeholders, ecological interactions, and relevant socio-economic elements. The inclusion of citizen knowledge is ensured using this approach. The first steps of the SAF are especially vital for a holistic approach. Within the first step of the SAF (Issue Identification), the main issue(s) was identified through a process using the Drivers, Pressures, State, Impact, and Response (DPSIR) and Customer, Actor, Transformation, Worldview, Owner, and Environment (CATWOE) frameworks where the pertinent pressures and state of the system are analysed. A further refinement of the DPSIR is the

DPSWR where W (Welfare) replaces Impact (Cooper 2003). Welfare here refers to social system effects such as decrease in either/both use values and non-use values (i.e., ecosystem functionality of viability of particular species). We identified and listed relevant stakeholders, human activities, and ecosystem services. A conceptual model of the system visualises the complexities involved to support an integrated cross-sectorial, ecological, and socio-economic assessment as described in Støttrup et al. (2017). In the following steps, we modelled different aspects of the system towards development of scenario-based trade-offs between fisheries environmental impacts and socio-economic values. Details of this method are given in Støttrup et al. (2019) and specific guidelines outlined in www.safhandbook.net.

2.2.2 Fish distribution

Cod and plaice Catch Per Unit Effort (CPUE) data were retrieved from the ICES DATRAS database (https://www.ices.dk/data/data-portals/Pages/DATRAS.aspx). We then selected the quarter three (Q3) survey data and analysed them at three different spatial scales: i), the entire North Sea; ii), the Kattegat Skagerrak area and iii), the 4 ICES statistical rectangles that encompass the Jammer Bay (43F8, 43F9, 44F8, 44F9). We performed a data-poor assessment for each of the spatial scales separately and compared the trends in catch rates.

The fish survey data used from the DATRAS database included: NS-IBTS Q1, NS-IBTS Q3, BITS Q1, BITS Q4, Cod survey Q4, Sole survey Q4, BTS Q3 (plaice only). Data from 2005 to 2022 were divided into two size classes (i.e., small, large) according to minimum landing sizes, which is 30 cm for cod, and 27 cm for plaice in the Skagerrak.

The fish distribution model is a Delta-Lognormal GAM with the following structure:

$$g(\mu i) = Gear(i) + f1\,(utm.xi, utm.yi) + f2\,(timei) + \quad (1)$$
$$f3\,(utm.xi, utm.yi, timeOfYeari) +$$
$$f4\,(utm.xi, utm.yi, timei) +$$
$$f5\,(\sqrt{depthi}, timeOfYeari) + U(i)ship + \log(HaulDuri + 5)$$

where the response variable *μi* is biomass in the i^{th} haul and *f1* to *f5* are splines. For the geographical coordinates (*utm.x, utm.y*), *time*, *time of yea*r, and *depth*, Duchon splines with first order derivative penalization were used everywhere. $U(i)ship \sim N(0, \sigma u)$ is a random effect for the vessel collecting *haul i*. The function *g* is the link function, which is the logit function for the binomial model. The lognormal part of the delta-lognormal model is fitted by log-transforming the response and using the Gaussian distribution with a unit link. Models were fitted independently for small and large individuals. The abundance maps produced cover the entire North Sea, Skagerrak and Kattegat, and further was analysed independently for the Jammer Bay and the ICES areas IVa, IVbc and 2123 (Fig. 2.1).

Data for cod and plaice population structures included the North Sea, Skagerrak and Kattegat, ICES roundfish areas 7, 8 and 9 from the IBTS fisheries surveys 1999-2022, sampled during the 1^{st} quarter (Q1, January-March) and the 3^{rd} quarter (Q3, July-September). Data for the Jammer Bay area includes all samples collected in the four ICES c-squares 43F8, 43F9, 44F8, 44F9 (i.e., statistical rectangles) all of which are located in the Skagerrak (i.e., ICES NS-IBTS round fish area 8).

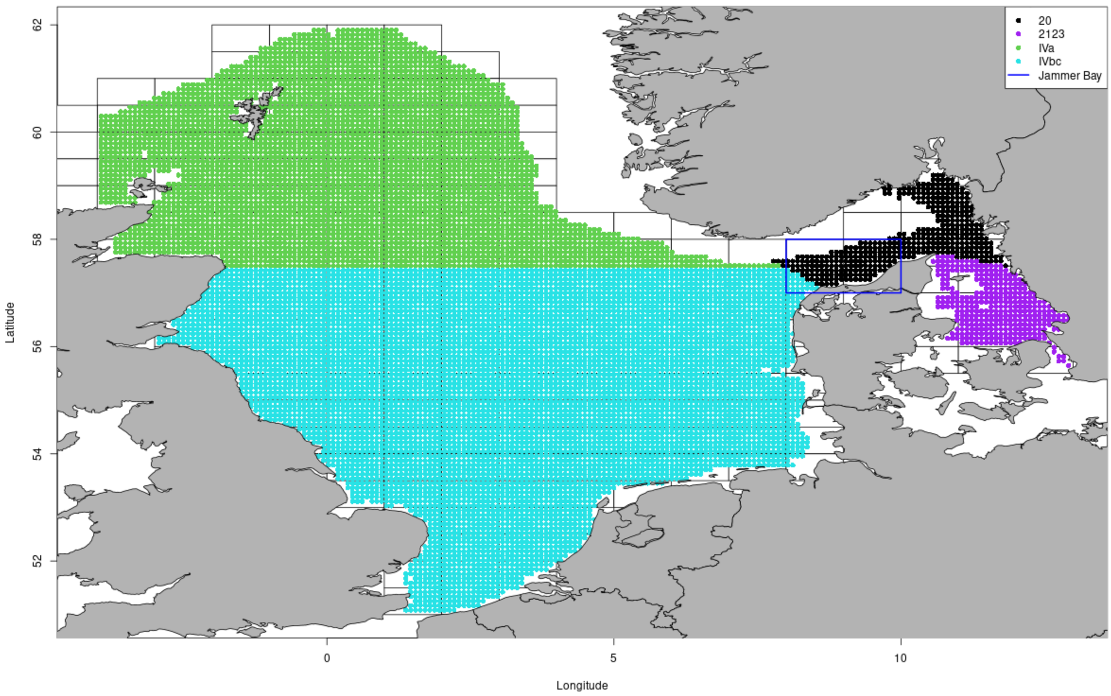


Figure 2.1. Map of areas for data analyses. The purple box shows the area for the data used for the Jammer Bay.

2.2.3 Landings and fishing grounds

Cod and plaice catch per unit effort (CPUE) data were downloaded from the ICES DATRAS database. We selected the quarter three (Q3) survey data and arranged them on three different spatial scales: i), the North Sea; ii), the Kattegat and Skagerrak area and iii), the 4 ICES rectangles that encompass Jammer Bay (Fig. 2.1). We performed a data-poor assessment for each of the spatial scales separately and compared the trends in catch rates (CPUE).

Data storage tag data made available by CEFAS (D. Righton, pers. comm.) for plaice were used to investigate the thermal experience of individuals during an entire year. The storage tags recorded individually experienced temperature every 10 minutes, and we used only tags that had been at large for at least a year. It is worth noting that these tags were not applied for plaice in the Jammer Bay, but the English Channel. Hunter et al (2003) showed that plaice avoided areas with higher temperatures above 16 °C. We hence assumed that the mechanism behind the avoidance of too high temperatures is universal and independent of locality, at least within the North Sea region.

Bottom temperature data for Q3 were available from the COPERNICUS database for the years 2014 to 2022. The data were downloaded and processed to display thermal conditions in the Jammer Bay during July to September.

The VMS positions of fisheries landings from bottom trawling and Danish seining were applied using the VMS position in the centre of a fishing operation as position indicator for this operation.

The specific temperature at each fished position was derived from the Copernicus data (https://www.copernicus.eu/en). The Copernicus data are provided at a grid cell resolution of 2 x 2 km. The sea bottom temperature at each fishing position was computed by linear interpolation of nearby grid cells.

2.3 Results

2.3.1 SAF - Policy Issue (s) and Identification

The EU Common Fisheries Policy (CFP) requires the development of ecosystem based fisheries management that restore and protects healthy marine ecosystems and viable populations, while safeguarding long-term sustainability of resource use and socio-economic development, as well as food provisioning (https://oceans-and-fisheries.ec.europa.eu/policy/common-fisheries-policy-cfp_en).

It is essential that an Ecosystem-based fisheries management transcends, adapts and integrates the long-term goals of the EU environmental and climate policies, especially the Marine Strategy Framework Directive (MSFD), Habitats Directive (HD), Water Framework Directive (WFD), the Biodiversity Strategy for 2030 (BDS2030), and the European Green Deal (EGD) and Climate Law (ECL), as well as related policies, such as the Directive for Maritime Spatial Planning (MSP).

In local terms, this translates to develop and safeguard sustainability of coastal fisheries under climate change and maintain livelihood of rural communities. Fisheries policies that have influenced the Danish fisheries in the Jammer Bay include changed management measures that affected accessibility to the quota. In 2007, a new quota system (ITQs) was introduced to improve economic efficiency of the Danish fishing fleet (Dinesen et al. 2017). This resulted in inequity in fishing opportunity and economic gain. This specifically impacted small-scale coastal fishing companies, which became quota limited. In an attempt to counteract this imbalance, a national coastal fishery policy was introduced in 2017 (in Danish: Kystfiskerordningen). However, coinciding with this new policy, cod and place landings decreased further. This was perceived by the fishers to be due to lack of fish in the Jammer Bay area, possibly due to competition for resources with foreign fleets. Thus, the Policy Issue identified for investigation was “Sustainability of coastal fisheries in the Jammer Bay area under pressure from climate change and fishery”.

2.3.2 DPSIR, CATWOE and Conceptual model

The DPSIR and CATWOE for the Jammer Bay are presented in Table 2.1. We identified three periods from between 1997-2006, 2007-2016, and 2017 to the present, based on changes in fisheries management. Relevant stakeholders, human activities, and ecosystem services are listed in the Appendix (Chapter 2.7).

Table 2.1. DPSIR and CATWOE for the Jammer Bay.

Periods	1997 - 2006	2007 - 2016	2017 - present		
Driving force	Food provision, livelihood	Food provision, livelihood	Food provision, livelihood	**Customers**	Coastal fishers, local fishing industry community
Pressures	Area based and time limited fishing "quota" system (ration fishery, days at sea) - management system inflexible and untransparent	2007: ITQ/VQS (to reduce over-fishing, over-capacity and unprofitability of the fishing fleet, increase economic viability and management transparency and profitability 2008: Global economic crises and recession	FSA/tidsubegrænset/open ended (to mitigate uneven quota distribution), increased competition with foreign fleet with larger vessels and capacity (displacement)	**Actors**	Policy maker and fishery managers
State	Declining fish stocks	Declining fish stocks	Climate change induced redistribution of fish stocks	**Transformational processes**	Changes in quota systems and distribution of fish
Impact	Local competition for fish (but economically viable for the individual fisher), time-limited access to fish, uncertainty regarding fishery management plans	Expropriation of the commons resulting in insufficient access to quotas due to 1000-fold increase in value	Sufficient quota, but decline of target species (plaice, cod) within their fishing range, increase of warm-water species (sole), displacement of fishing	**Worldview**	Over-fishing and over-capacity of fishing fleets and expropriation of the commons (with no compensation)
Response	Developed a lobby to mitigate competition from beam trawlers, and to avoid ITQ implementation	Formed a local common quota fishers guild formalised through a cooperative company, strengthening of lobby for neocultivation of a self-employed life mode to preserve coastal rural communities, upgraded local fish processing facilities and industry	Lobby increased focus on local self-employed life mode, and development of system sustainability incorporating all four pillars (ecological, social, cultural and economic concerns), MSP and MPA possibilities explored, developed collaboration with environmental NGO's, joined new sustainable fishing organisation for low impact coastal fishers (FSK)	**Owners**	Society
				Environmental constraints	Ecological changes in fish distribution due to climate change, public perception of sustain and develop local fishery and communities

Abbreviations. ITQ: Individual Fishing Quota. VQS: Vessel Quota Shares. FSA: Fishery Ship-owners Association. MSP: Marine Spatial Planning. MPA: Marine Protected Area. FSK: Association for gentle fishing production organisation.

2.3.3 Catch Per Unit Effort (CPUE)

Cod

The ICES survey data showed the cod CPUE was similar before 2019 with an increasing trend around 2015 at the three different spatial scales. However, in the Jammer Bay, cod CPUE decreased after 2020 while was increasing at the North Sea scale and stable at the Kattegat and Skagerrak scale (Fig. 2.2).

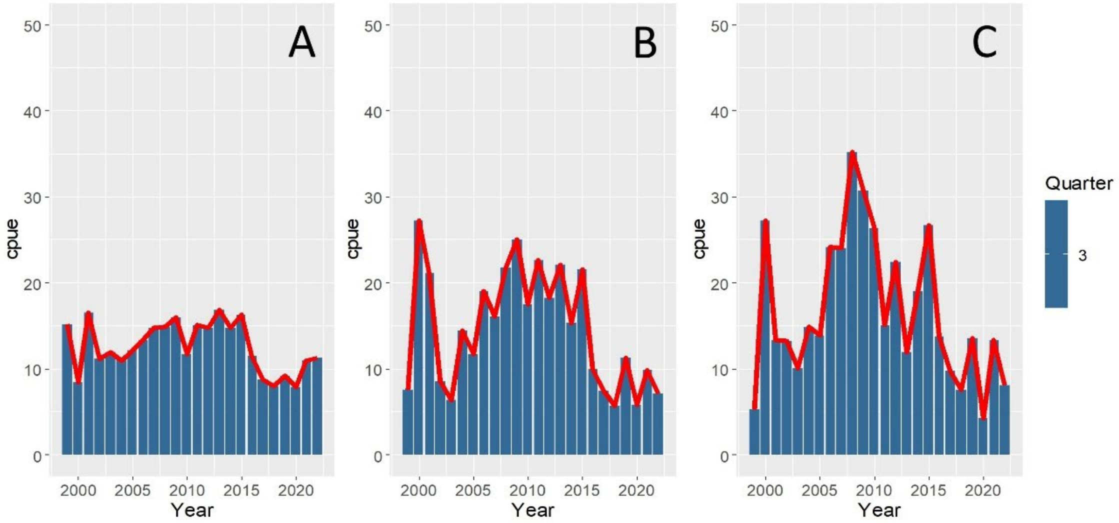


Figure 2.2. Cod Catch Per Unit Effort (CPUE) at three different spatial scales: A), the North Sea, Skagerrak and Kattegat (ICES roundfish areas 7, 8 and 9); B), the Skagerrak ICES roundfish area 8; and C), the four ICES rectangles (44F8, 44F9, 43F8, 43F9) that constitute Jammer Bay. Quarter three (Q3) data retrieved from the ICES DATRAS database.

Plaice

The ICES survey data of plaice CPUE trends differed from those of cod. At the North Sea scale CPUE was stable with a slightly increasing trend, while CPUE declined after 2015 at both the Kattegat/Skagerrak and the Jammer Bay scales (Fig. 2.3).

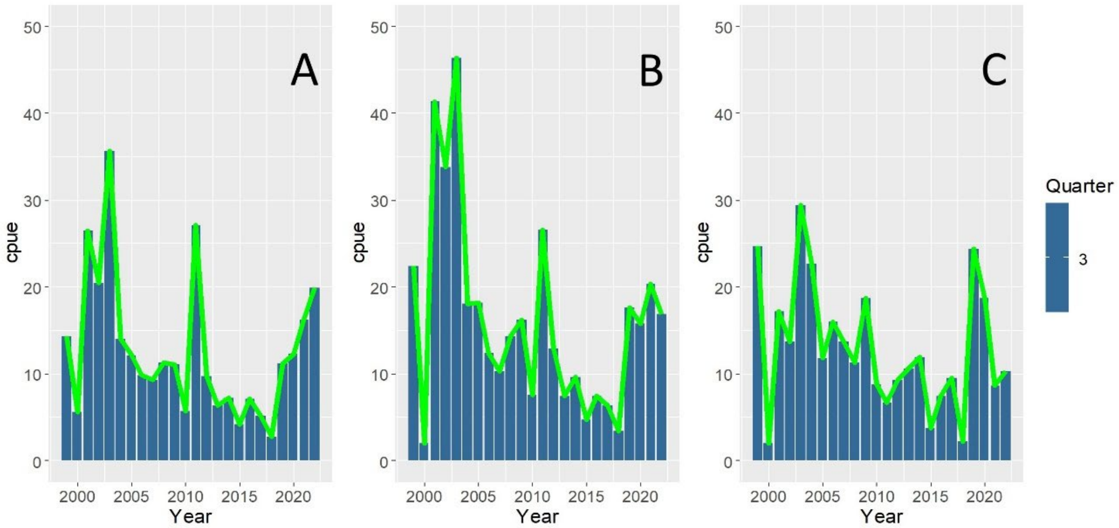
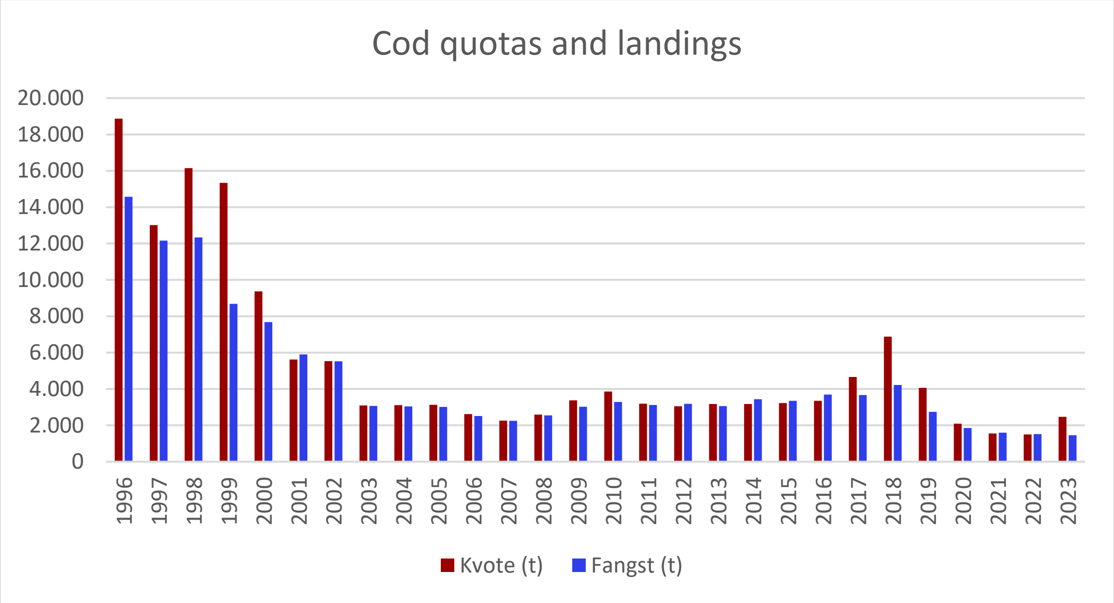


Figure 2.3. Plaice Catch Per Unit Effort (CPUE) at three different spatial scales: A), the North Sea, Skagerrak and Kattegat (ICES roundfish areas 7, 8 and 9); B), the Skagerrak ICES roundfish area 8; and C), the four ICES rectangles (44F8, 44F9, 43F8, 43F9) that constitute Jammer Bay. Quarter three (Q3) data retrieved from the ICES DATRAS database.

2.3.4 Quotas and landings

Cod

The cod quotas decreased dramatically from 18,000 tons in 1996 to 3,000 tons in 2003, reflecting strong decline in the population (Fig. 2.4a). The quota was efficiently fished since 2001 until 2016 (Fig. 2.4b). With the introduction of the Danish Coastal Fisher Regulations in 2017 (in Danish: Kystfiskerordning, https://www.retsinformation.dk/eli/lta/2023/1659, the Skagerrak cod quota for coastal fishers was raised. Despite the higher quota, the landings remained at the same low level as before. Since 2020, both quota and landings further declined to below 2,000 tons. The reason for the fluctuation of the quota utilisation seems to be due to changes in the quota rather than the landings levels.



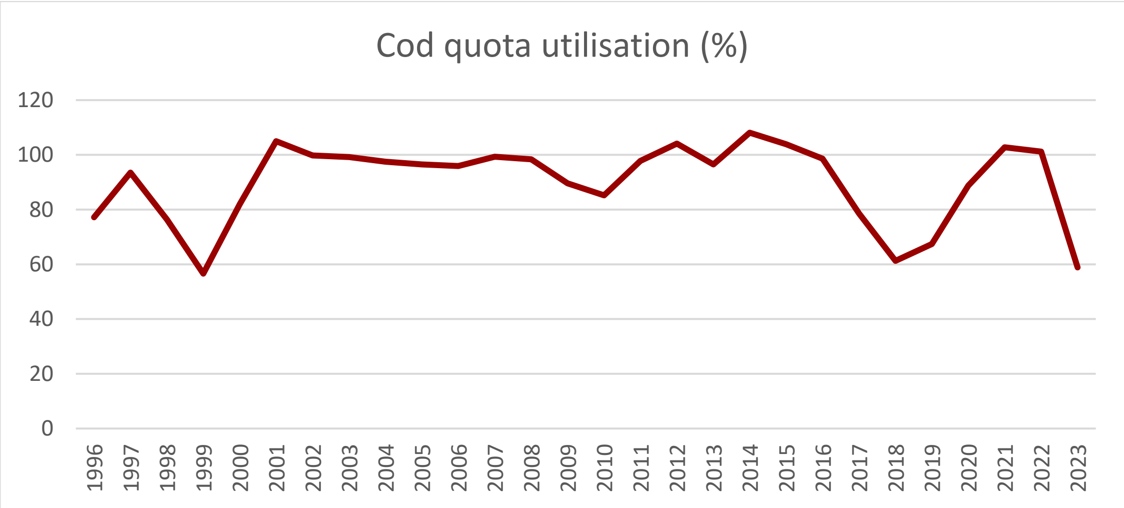


Figure 2.4. Cod fisheries statistics: a) Cod quotas and annual landings (tons) in the Skagerrak from 1996 to 2023, b) percentage utilisation of the quota. Source: The Danish Fisheries Agency, Fiskeristatistisk årbog 1996-2009. From 2010 online "Danmarks kvoter og kvoteudnyttelse".

Plaice

The plaice quotas were relatively stable at 10,000 tons from 1996-2000, after which it was reduced to around 6-8,000 tons until 2016 (Fig. 2.5a). Despite the quota levels between 1996-2016, catch landings were stable at around 5.-8,000 tons. Thus, the quota usage was close to 100% between 2001-2016. With the introduction of the Danish Coastal Fisher Regulation, the quotas were raised to between 12-14,000 tons. Coinciding with the increased quota, total annual catch landings declined dramatically to just over 2,000 tons in 2023. This demonstrated the increasing difficulty to fish up the quota with utilising declining to 20% (Fig. 2.5b).

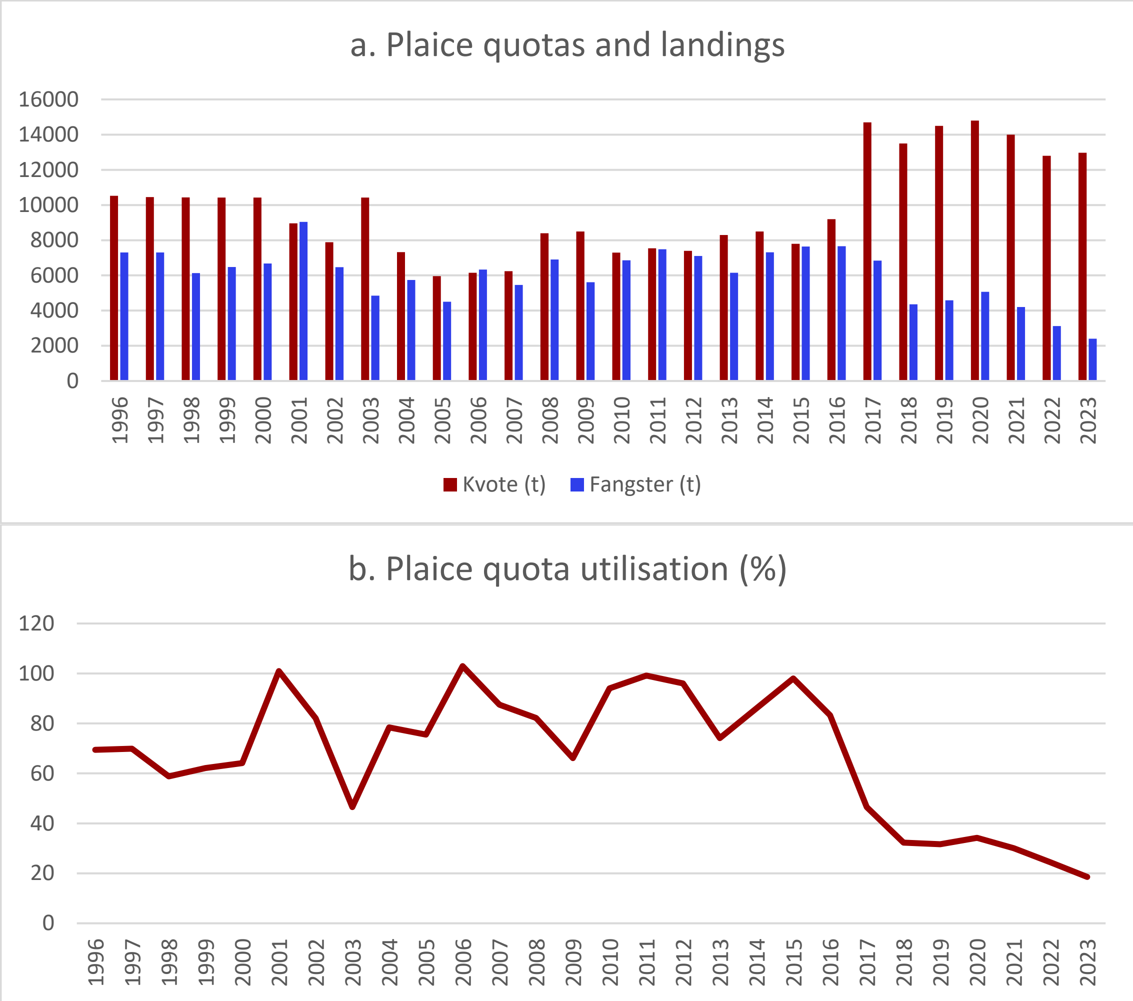


Figure 2.5. Plaice fisheries statistics: a) Plaice quotas and annual landings (tons) in the Skagerrak from 1996 to 2023, b) percentage utilisation of the quota. Source: The Danish Fisheries Agency Fiskeristatistisk årbog 1996-2009. From 2010 online "Danmarks kvoter og kvoteudnyttelse".

2.3.5 Relative fish distribution

Cod

The ICES Q1 survey data coincide with cod spawning and thus was used to identify cod spawning grounds. This data at a regional scale, showed that since 2013 the larger cod no longer occur in the southern part of the North Sea (Fig. 2.6). The higher densities of large cod occur in the deeper parts (>100 m) of the Jammer Bay and along the Norwegian trench with lower densities than average from 2018-2022. These results indicate that the southern North Sea no longer functions as spawning grounds for cod, and that the northern spawning grounds are located more to the west in recent years.

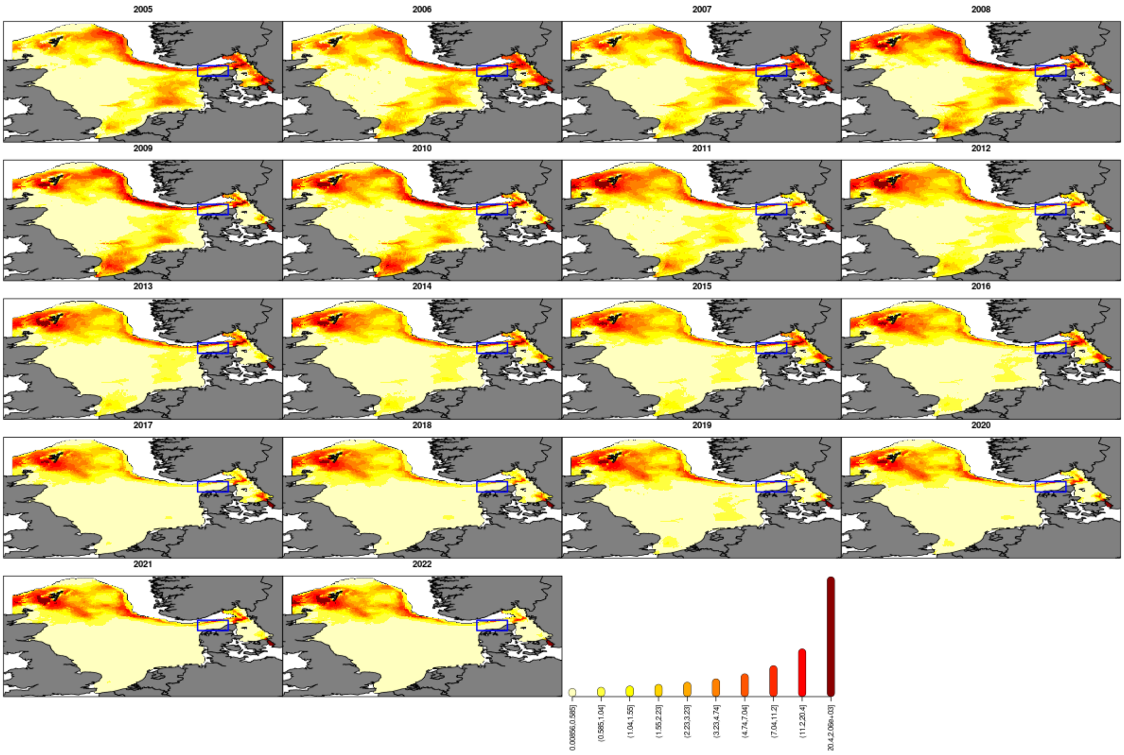


Figure 2.6. Cod (>30 cm) abundance maps for Q1 during the years 2005-2022.

At a local scale, the abundance of larger cod in the Jammer Bay were lower in recent years. The abundance in Q3 was lower than in Q1, possibly due to a more dispersed distribution of the feeding cod (Fig. 2.7).

The relative abundance of small cod is significantly higher in Q3 compared to Q1 (Fig. 2.7) reflecting the recruitment of year-0 cod. It should be noted, that no IBTS data is available from the shallow, inshore areas because the survey sampling takes place in the offshore areas of the ICES rectangles. These results indicated the value of the deeper, offshore areas of Jammer Bay as important cod nursery grounds. Due to the lack of data, there is no information whether the shallower areas function as cod nursery grounds.

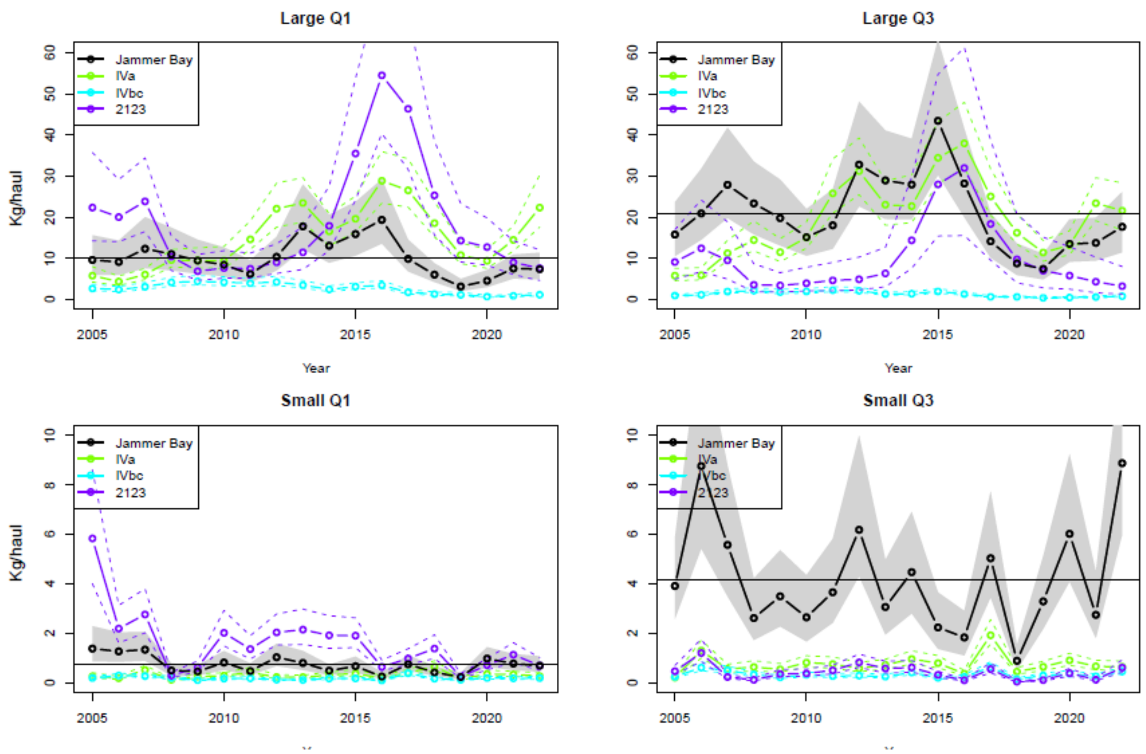


Figure 2.7. Abundance index (density) of cod at different spatial scales covering the Jammer Bay area (ICES squares 43F8, 43F9, 44F8, 44F9), northern North Sea (ICES areas IVa) and mid and southern North Sea (ICES area IVbc), Kattegat and the Sound (ICES area 2123). The top figures are densities of allowable landing size of fish (Large ≥30 cm) and the bottom figures show abundances of the undersized cod (Small <30).

Plaice

At a regional scale, the ICES survey data showed evidence of a shift in relative occurrence of large plaice from the east to the northwest in both Q1 and Q3 (Figs. 2.8 and 2.9). The timing of the surveys does not coincide with plaice spawning (in Q2).

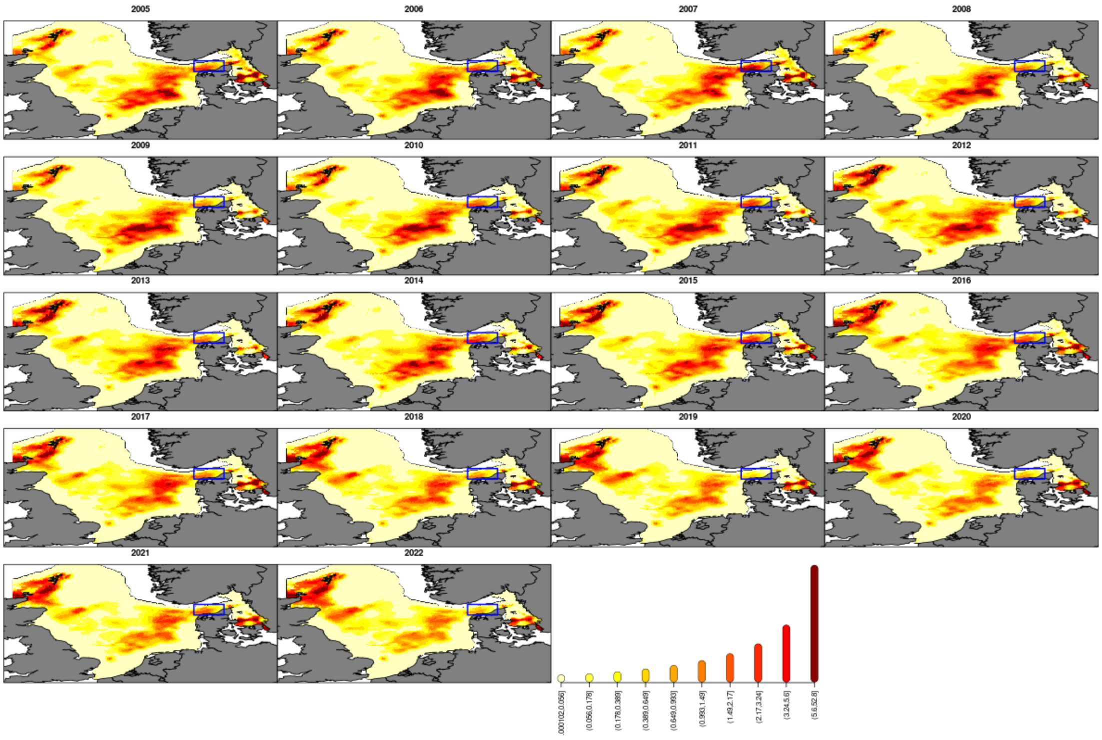


Figure 2.8. Plaice (≥27 cm) abundance maps in Q1 for the years 2005-2022.

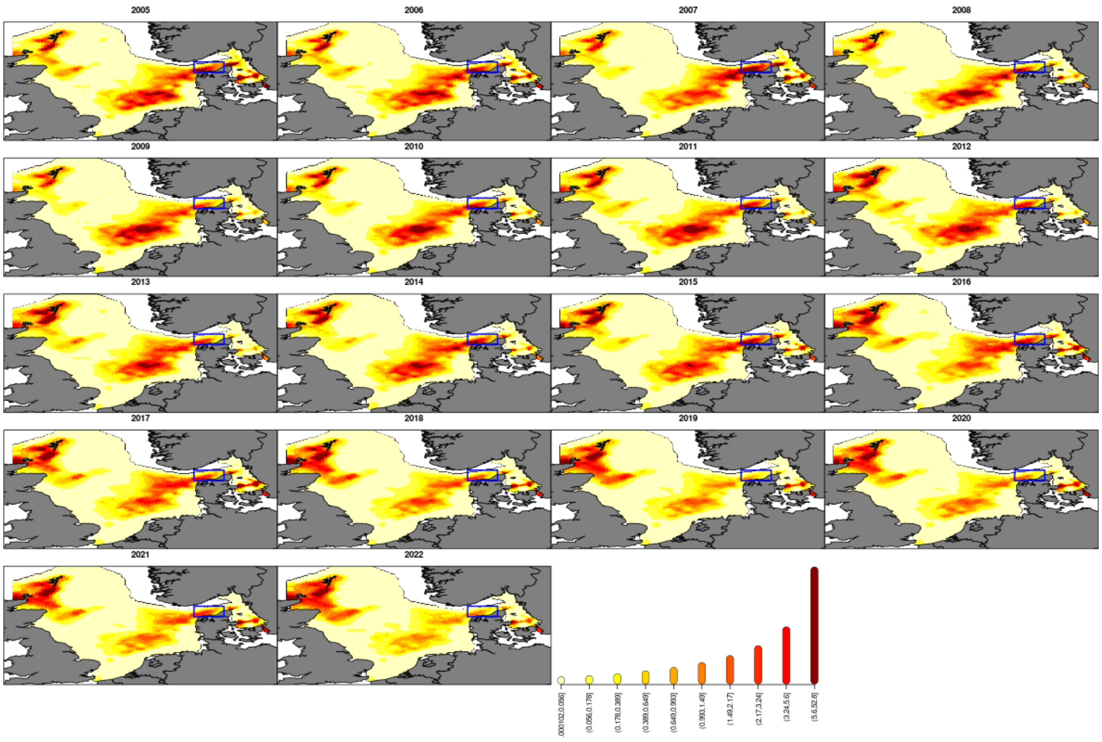


Figure 2.9. Plaice (≥27 cm) abundance maps in Q3 for the years 2005-2022.

At the local scale, large plaice were also abundant in the Jammer Bay but mostly in areas shallower than 100 m depth. Plaice was significantly more abundant in Q3 compared to Q1 and clearly declined in recent years from 2018-2022 (Fig. 2.10).

Juvenile plaice were more abundant in the Jammer Bay in Q3 than Q1 (Fig. 2.10). It should be noted that the survey sampling takes place in the offshore areas of the ICES rectangles and no IBTS data is available from the shallow, inshore areas within the ICES rectangles. These results indicated the value of the deeper, offshore areas of the Jammer Bay as important plaice nursery grounds.

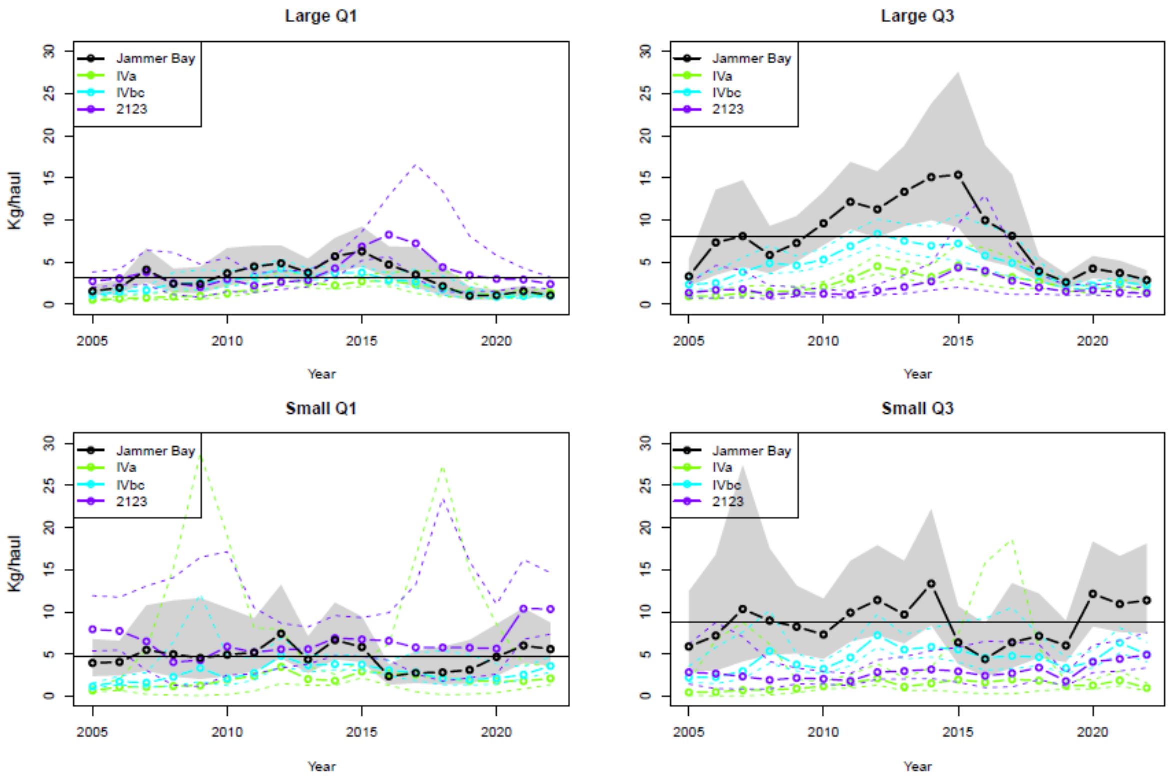


Figure 2.10. Landings index (density) of plaice at different spatial scales covering the Jammer Bay area (ICES squares 43F8, 43F9, 44F8, 44F9), northern North Sea (ICES areas Iva) and mid and southern North Sea (ICES area IVbc), Kattegat and the Sound (ICES area 2123). The top figures are abundances of allowable landing size of fish (≥27 cm) and the bottom figures show abundances of the undersized plaice.

2.3.6 Thermal habitats and fishing grounds

Data Storage Tag (DST) recovered from 21 plaice individuals that had been recording for at least one year represented >1 million individual temperature measurements (Hunter et al. 2003). The temperature records retrieved from the 21 plaice individuals are shown in Fig. 2.11.

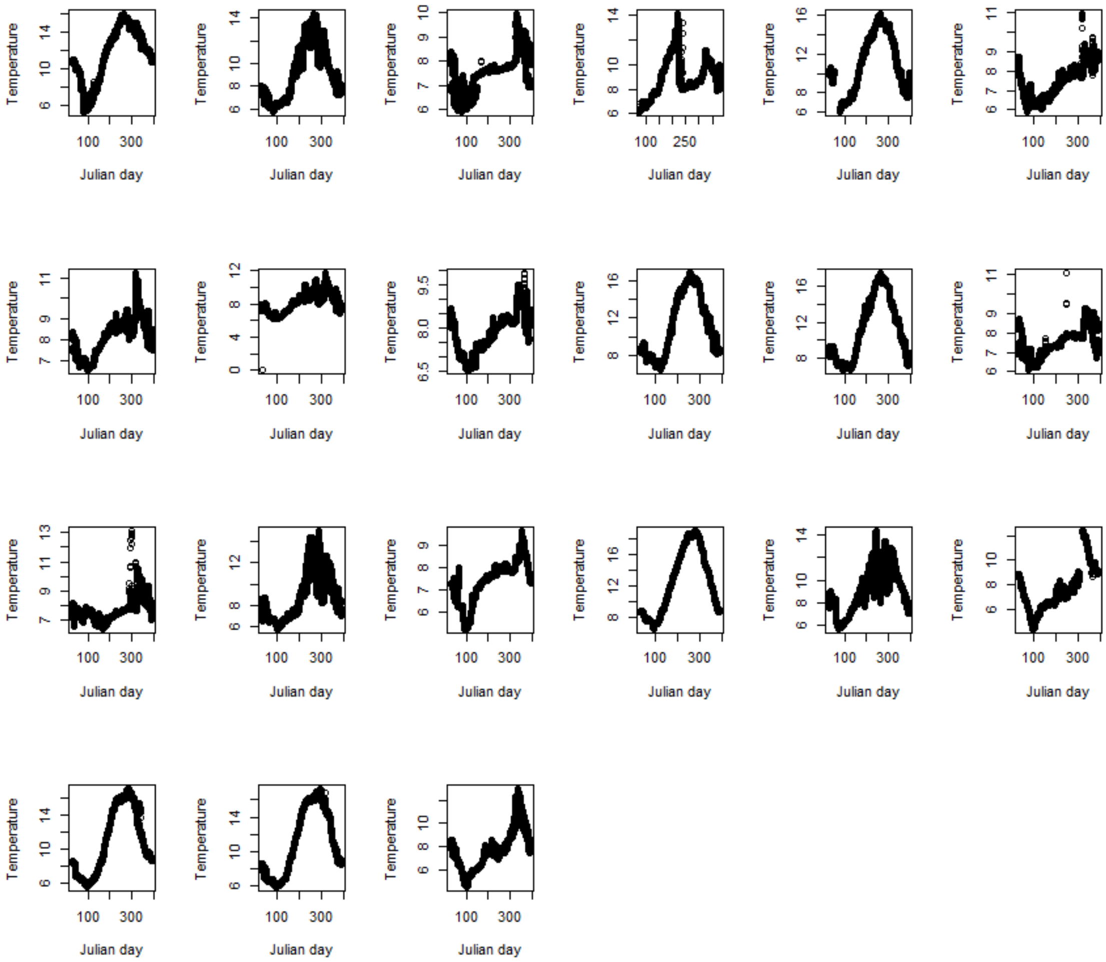


Figure 2.11. Data Storage Tag (DST) records of temperature retrieved from 21 plaice individuals.

The maximum temperature experienced by plaice was around 16 °C (Fig. 2.12). Approximately 5% of the temperature observations were above 16 °C. Hence, we assumed a similar upper temperature limit of 16 °C for plaice as for cod (Righton et al., 2010, Dinesen et al. 2019). More detailed modelling is required to delineate the upper temperature tolerance limit for plaice.

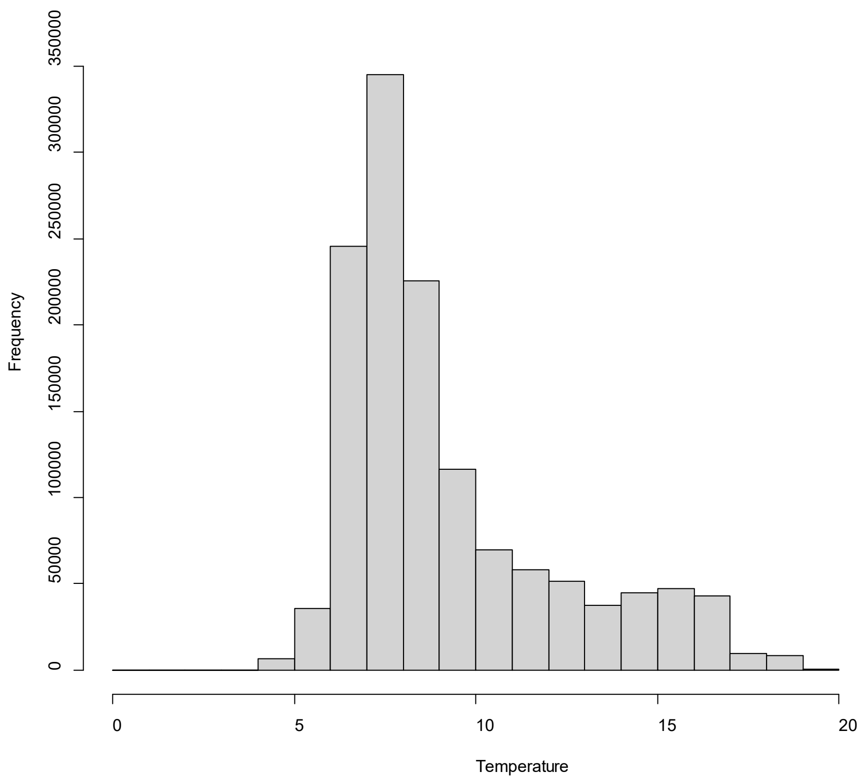


Figure 2.12. Histogram of DST temperature measurements for 21 plaice.

In the Jammer Bay, spatial distribution of bottom temperature conditions during the summer period (July-September) varied between 2014 and 2022 (Fig. 2.13). In 2018 and 2021 the spatial distribution of warm bottom water temperatures (i.e., exceeding 16 °C) was limited. On the other hand, warm bottom waters dominated the Jammer Bay especially in 2016, but also in 2017 and 2020 (Fig. 2.14).

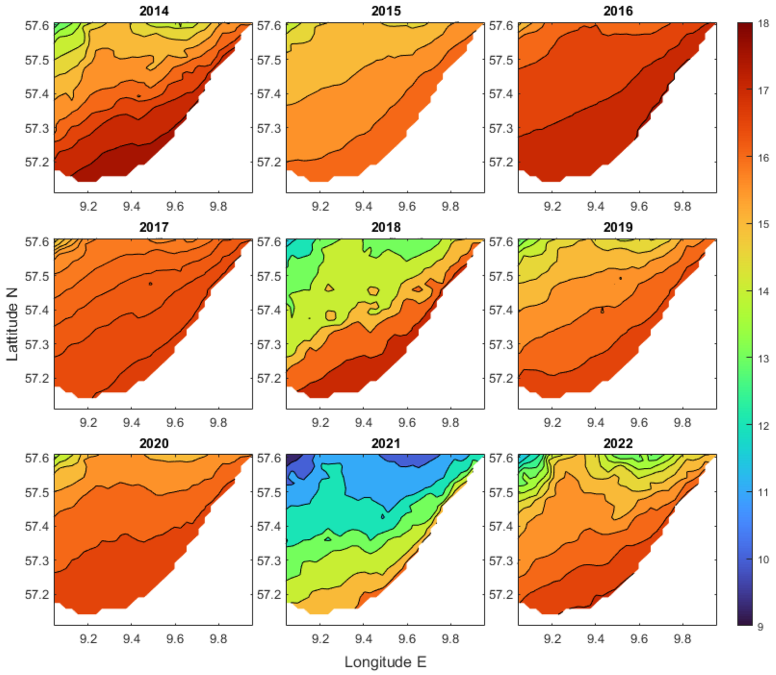


Figure 2.13. Bottom water temperature (°C) during the summer months in the Jammer Bay from 2014-2022.

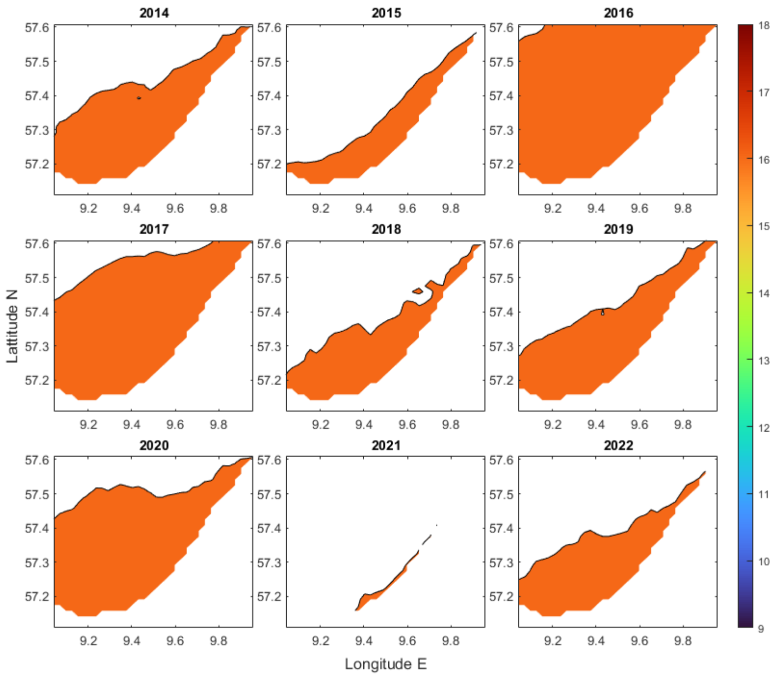


Figure 2.14. Seabed area in the Jammer Bay covered by bottom water with a temperature of at least 16 °C.

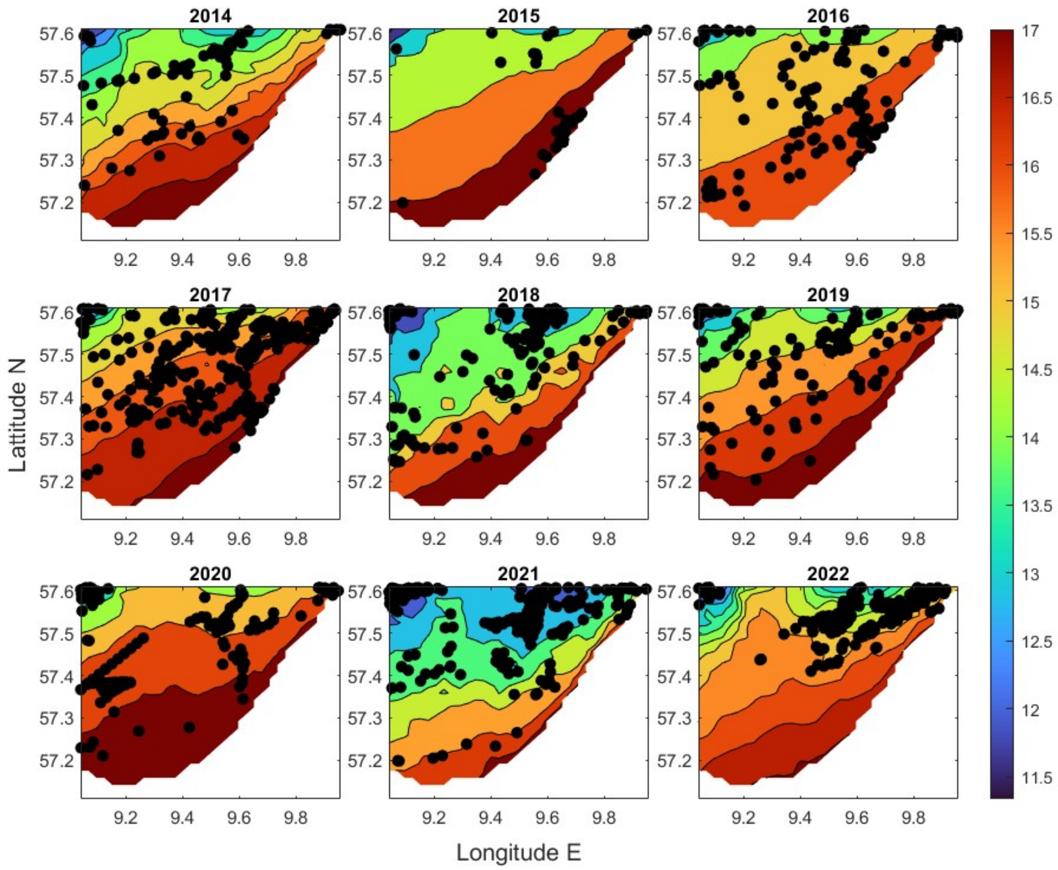


Figure 2.15. VMS positions from bottom trawling in July-September over bottom water temperature (°C) in the Jammer Bay from 2014-2022.

The coarsely approximated fishing positions and corresponding landings of cod and plaice from commercial bottom trawling (Fig. 2.15, 2.17) and Danish seining (Fig. 2.16, 2.18) are shown relative to temperatures and years. In the following, the information only applies to cod and plaice that were landed.

Almost no cod were caught at temperatures exceeding 16 °C either by Danish seiners or by bottom trawlers (Figs. 2.17 and 2.18). Average cod catches by trawlers were highest in 2015, 2018 and 2019. These coincided with three of the four years in which distribution of water temperature exceeding 16 °C were smallest (Fig. 2.14). Although fishing did take place in areas with warmer waters than 16 °C, hardly any cod were caught in these positions. This supports the DST information of cod thermal preferences. However, local peaks in abundance in 2019 and 2021 (Fig. 2.2) were not reflected in the commercial catches.

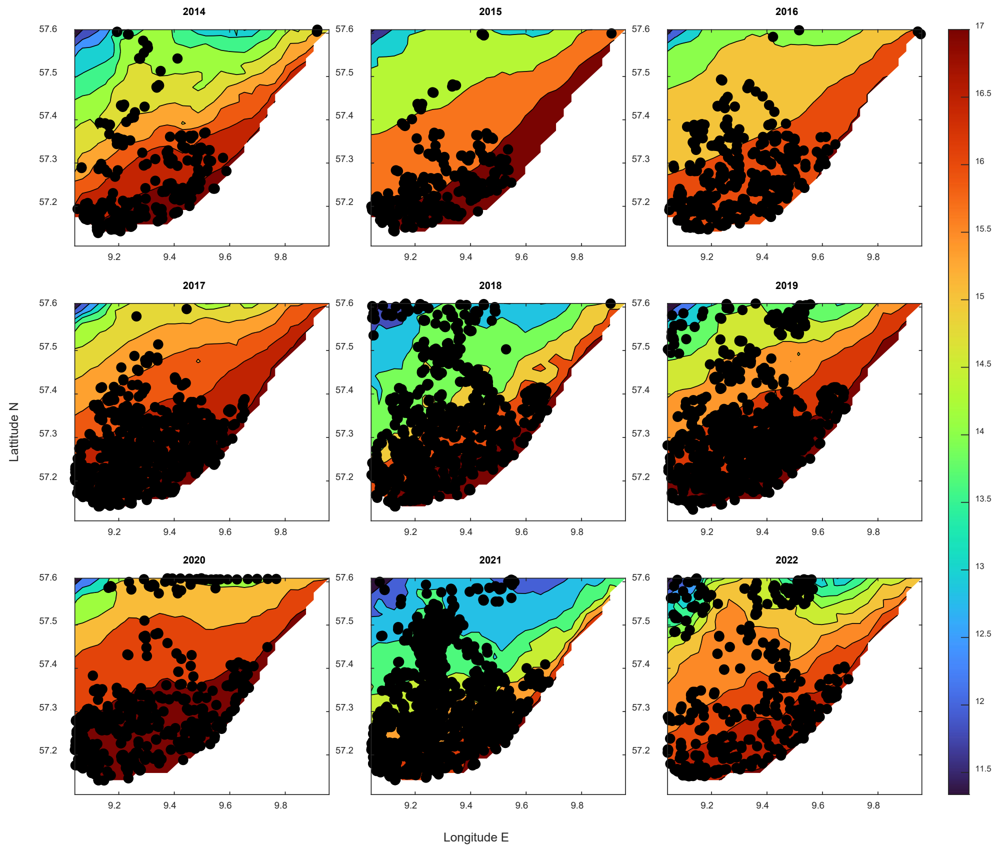


Figure 2.16. VMS Positions from fisheries with Danish seines in July-September over bottom water temperature (°C) in the Jammer Bay from 2014-2022.

In contrast to cod, most plaice were caught at temperatures above 16 °C with the highest catch rates observed in 2014-2016 (Figs. 2.17, 2.18). This was especially evident in the catches from Danish seining which targets plaice. Local peaks in abundance in the ICES survey data in 2019 and 2020 were not reflected in the commercial catches.

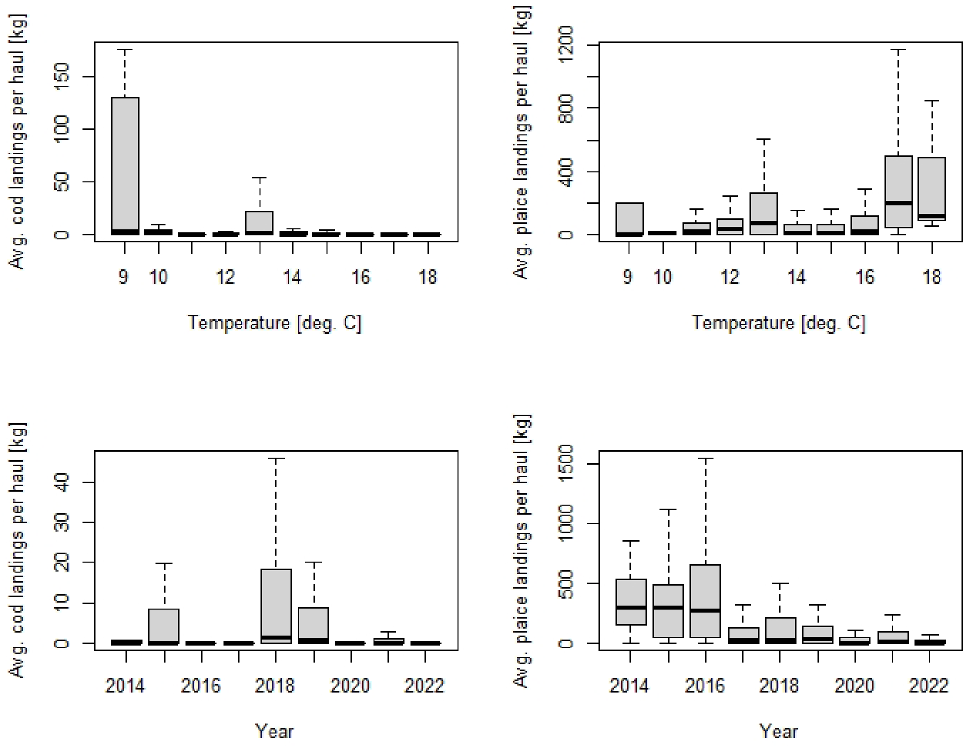


Figure 2.17. Average landings per haul for bottom trawlers during summer months (July-September) in the Jammer Bay from 2014-2022 for cod and plaice.

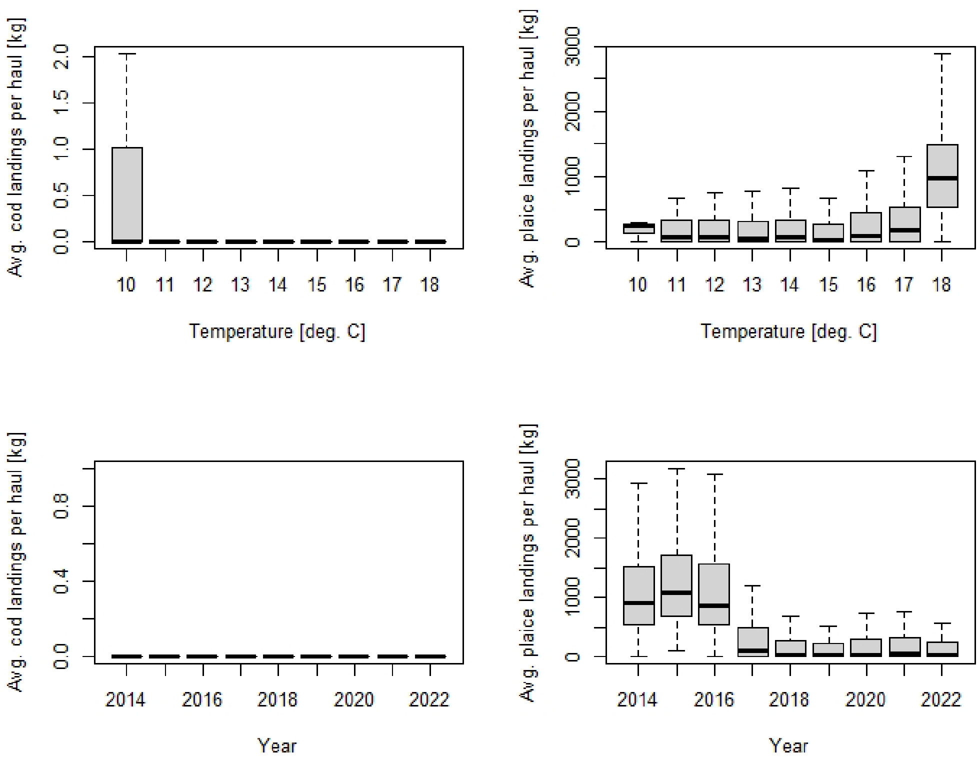


Figure 2.18. Average landings per haul for Danish seine during the summer months (July-September) in the Jammer Bay from 2014-2022 for cod (left figures) and plaice (right figures).

2.4 Discussion and perspectives

To achieve sustainable management, outcomes of polices should ensure environmental stability, economic efficiency, and social equity. With the larger scale, global and regional changes taking place due to climate change, environmental processes are hard to predict especially when values, such as temperature and rainfall continue to provide new records and climatic systems become more dramatically expressed. Despite these changes, or more likely because of these changes, it is imperative that policymaking is transparent and in communication with citizens and especially stakeholders. The application of the SAF in this study made it possible to consider the fisher's perceptions of the system and to explore possible causes for discrepancies between quotas and landings. The quotas had intended towards social equity and economic efficiency, and since the expected results were not realised, it is important to reiterate the SAF steps to explore which conditions changed, or caused the changes, and adjust management towards the desirable outcomes (Støttrup et al., 2019: Step 6, Evaluation).

The results showed clear relations between cod distribution and temperature. While the North Sea distribution of cod was uniform until 2017, in later years they no longer occurred in the southern and south-eastern parts. The fisheries landings data revealed that cod avoided temperature above 16 °C, which concurred with the temperature boundaries from cod DST data (Dinesen et al. 2019). These results reflected well the fishers' perception of lack of cod in near-coastal waters in recent decades. During this period, the quotas were set at low levels and fishers were able to fish up the full quota in most years. The offshore movement of cod in a north-western direction apparent in this study can be due to a general increase in bottom temperature. In the Jammer Bay, the spatial distribution of high bottom temperatures correlates with decline of cod landings. This suggests that suitable adult cod habitats have diminished in the coastal waters of Jammer Bay.

DST data for plaice suggested a temperature boundary of around 16 °C. However, this was not evident in the landings data from Skagerrak, as most of the plaice were caught in years 2014-2016 and at temperatures of 17-18 °C. These patterns imply that the temperature-regulated processes governing cod and plaice catches differ. This difference could be due to dissimilarities in cod and plaice behaviour towards environmental conditions. While cod clearly avoided temperatures over 16 °C, plaice seemed to endure higher temperatures. Since 2018, plaice landings were extremely low and fishers were only able to fish a small proportion of the allocated quotas, which had been raised based on regional scale population levels. The sharp decline in plaice landings corresponds well with the lack of large plaice in the Jammer Bay observed from the ICES survey distribution results. We therefore hypothesise that plaice in high temperature waters are rendered more vulnerable to fishery, which can result in local overfishing. This situation may have been exacerbated by an influx of foreign fleet of beam trawlers targeting plaice.

It is interesting to note, that the deeper offshore areas of the Jammer Bay essentially serve as important nursery grounds for both cod and plaice, apparent from the juvenile distributions in the survey results. This is an important finding, which should be incorporated in the management of the fisheries that operate in these offshore areas. Management should address gear selectivity to reduce unwanted bycatch of juveniles as well as spatial closures to protect nursery areas. While gear selectivity improvements and implementation of marine protected areas (MPAs) can be decided upon at the national level for the Danish fleet, the activities of foreign fleets in Danish waters can only be regulated via bilateral or international collaboration.

2.5 Acknowledgements

The work was funded in the project ‘Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)’ (Grant Agreement No 33113-B-23-189) by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark.

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Støttrup JG, Dinesen GE, Schumacher J, Gillgren C, Inácio M, Schernewski G. 2019. The Systems Approach Framework for collaborative, science-based management of complex systems. Journal of Coastal Conservation. https://doi.org/10.1007/s11852-018-00677-5

2.7 Appendix

List of stakeholders identified for the Jammer Bay

List of stakeholders			**List of institutions**
	Local		
Fisher vessel owners			Thorupstrand Fishing Guild
Share organised fishers			Han Herred Havbåde (Coastal Cultural Association) incl. Center of Sustainable Life Forms, Shipyard, turist cruises with 5 renovated traditional coastal vessels
Fishing guild employee			
Fishing industry share organised employees			
Han Herred Havbåde employees			
Hanstholm & Strandby Fish Auction			
Camping site owners			Bank and other investers (fill in ?)
Summerhouse owners			Danish Society for Nature Conservation - local and national
Local communities (Mathilde fill in types?)			Thorupstrand Fishers Association
Recreational divers			Winch and packing house Association
Winch facilities employees			
Tourists (fill in types?)	**Visitors**		
Fishery managers	**Authorithies**		Ministry of Agriculture Food and Fishery
Environmental managers			Ministry of Environment
			Jammerbay Municipal
			Ministry of Defence

List of human activities in the Jammer Bay

Human activites
Beam trawling and bottom trawling
Danish seining
Gillnetting
Tourist cruises
Turism
Recreational fishery
Recreeational diving
Recreational sailing
Recreational fishery
Military marine shooting range
Agriculture
Forestry and nature protection on land

Ecosystem Services identified for the Jammer Bay

Section	Division	Group	Class	Class type	Examples
Provisioning services	Nutrition	Biomass	Wild animals and their outputs	Fish by amount	list commercial target species
			Wild animals and their outputs	Shellfish by amount	Cancer pagurus
Regulating and maintenance services	Maintenance of chemical, physical and biological conditions	Life cycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats	By amount and source	Benthic habitats
					Vegetation
					Commersial fish, shelfish
					Non-commersial benthos
					Birds and mammals
	Mediations of flow	Mass flows	Mass stabilisation and control of erotion rate	By reduction of risk or area protected	Coastal defence structures, leveling of beach
Cultural services	Physical and intellectual interactions with biota, ecosystems and habitats	Physical and experiental interaction	Experiental use of biota and habitat	By visits	In-situ nature watching by boating/diving/surfing/beaches/ natural reserves
			Physical use of biota and habitats	By visits/catch	Recreational fishing, hunting
			Physical use of biota and habitats	By visits	Military shooting
		Intellectual and representative interactions	Scientific	By use/citation	Subject matter for research on location and other media
			Educational	By use/citation	Subject matter for research on location and other media
			Heritage, cultural	By use/citation	Historic records, cultural heritage
			Entertainment	By use/citation	Ex-situ viewing/experience
			Aesthetic	By use/citation	Sense of place, artistic representation
	Spiritual and symbolic interactions		Symbolic	By use	Emblematic
		Other cultural outputs	Existence	By environment al feature	Enjoyment provided by environment
			Bequest	By environment al feature	Willingness to preserv…

3. Analyses of fishing cultures identified by core features pertaining to life modes, modes of operation, fishing gears, communities and economic value chains in the Jammer Bay area (Task 4.2)

Søren Qvist Eliasen, Kirsten Monrad Hansen, Thomas Højrup

3.1 Introduction and aim

As discussed by C. F. Drechsel in his work from 1890, *Oversigt over Vore Saltvandsfiskerier,*[1] on the geology, biology, technology, and ethnology of Danish saltwater fishery, 'grand fishery' and 'coastal fishery' have always been coexisting in Danish waters. Hence, the interesting question for the fisheries management is still "how do the distinct kinds of fishery impact each other, the fish stocks, and their habitats?"

The aim of this study was to identify and describe in a systematic way the present diversity and characteristics of the Fishing Cultures operating in the Jammer Bay area. The distinct life-modes of the different economic cultures in the present fishing industry are linked to distinct modes of operation, fishing gear, and catching methods applied by fishing crews coming from four different hometowns in the Jammer Bay area as well from fishing ports far away from this area. Hence, each Fishing Culture is elaborated as a specific composition of life-mode, mode of operation, gear types, and home port communities.

The Fishing Cultures are expected to benefit from ecosystem goods and services and impact the system in distinct ways. Moreover, they contribute to societal sustenance of communities at the local, regional, and international levels in contrasting ways. Thus, the further aim of this study was to investigate interactive patterns of co-existence and competition for resource use as well as the environmental impacts and contributions to the value chains of communities in the Jammer Bay area.

The study addresses the relation between the Fishing Cultures and fishing communities in the Jammer Bay area and ports in other sea areas, whose long-distant vessels are operating in Jammer Bay. This analysis includes the development of a model for Local Economic Effect (LEE) applied on the fishing communities of the Fishing Cultures (FCs).

By developing the concept of Fishing Cultures, the study offers new structured ways to understand the complexity, dilemmas, and modes of coexistence of the different kinds of fishery in Jammer Bay and their linkages to the Jammer Bay area fishing communities. The linkages are further qualified by the assessment of the Fishing Cultures' contribution to the local economy,

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[1] Drechsel 1890. C. F. Drechsel did continue and improve the government-initiated studies of Danish fishery elaborated by G. C. Oeder in 1771 and A. F. Smidth in 1859, 1861, 1864. Schmidt 1864 describes among others the fishery in Jammer Bay 1863. See Moustgaard 1987.

via the model of Local Economic Effects. The study contributes with conceptual tools for managing the fisheries in Jammer Bay area taking into consideration environmental aspects as well as cultural, social and local economic aspects.

3.2 Materials and methods

3.2.1 Method

The first approximation of an applicable conceptual model was developed on the basis of two scientific concepts, the life-mode theory and mode of operation theory, and preliminary interview data collection. The following procedures were applied: i), The relevant data about all aspects of the conceptual model's distinct fishing methods, modes of operation and life-modes were collected; ii), A second data collection allowed for realized features of distinct Fishing Cultures to be empirically identified; iii), The relevant features of the distinct Fishing Cultures were correlated and quantified by means of statistical data and controlled by means of qualitative data and iv), The explicated and documented Fishing Cultures in Jammer Bay area were applied in analyses of relevant fishing communities and their value chains and co-existence of distinct fishing activities at specified locations in the Jammer Bay area.

3.2.2 Data collecting techniques and sources

The qualitative data was collected by applying 10 in-depth stakeholder interviews with fishers individually representing the different, investigated fisheries' life-modes, supplemented with in-depth key-informant interviews and participant observation[2] (see Appendix 3.A1).

All 241 Danish vessels (of which a few are owned by Swedish companies) and the Dutch vessels operating in Jammer Bay area during 2022 were analysed and classified individually at the basis of a systematic collection of all publicly available data in the Danish Vessel Register (https://shipregister.dma.dk/), the Danish Register of Companies (https://datacvr.virk.dk/), the Fish auctions' statistics (https://fiskeristatistik.fiskeristyrelsen.dk – dynamiske tabeller – danske fiskeriauktioner), the AIS vessel tracks (https://www.vesselfinder.com/), the Danish Register on Quota Ownership (https://fiskeristatistik.fiskeristyrelsen.dk – fartøjers andele og landinger – andele og landinger), Fisher Forums vessel register (https://fiskerforum.dk/skibsdatabase/), and qualitative data from fieldwork in the relevant Danish as well as Dutch fishing communities.

The quantitative data was collected from official databases of Statistics Denmark (https://www.statistikbanken.dk/ FIREGN2 and REGN1) and the Danish Fisheries Agency (https://fiskeristatistik.fiskeristyrelsen.dk - dynamiske tabeller – table for landinger and danske fiskeriauktioner). The main part of the more detailed quantitative data for Jammer Bay area, such as fishing time and intensity, was provided by DTU-Aqua after anonymization of logbook data, AIS data, etc.[3]

3.2.3 Materials

The *in-depth interviews with fishers* deliver data on: i), the year-cycles of distinct vessels and modes of operation; ii), the use of fishing gear and applied catching methods; iii), the fishing grounds inside and outside their present reach; iv), the organization and work of the crews; v),

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[2] Participant observation is a qualitative ethnographic data collecting technique comprising observing and participating in the social life of a group. In this study we apply the variant called 'moderate participant observation' conducting a balance between an 'insider' and an 'outsider' role in relation to the informants (Spradley, 1980).
[3] More specific use of statistics is mentioned in relation to the specific use throughout the report. Link and data can be found in the reference list.

investment strategies, running costs and operating economies; vi), family and generation-cycles; vii), conceptions of 'the good life' as fisher and fisher family; viii), recruitment of new generations and income-sharing or wage tariffs and working conditions; ix), the fishers' personal experiences and attitudes, their view on different kinds of fishing and other occupations, their economic thinking, and their perspective on their own life-course; x), the state management of the fisheries; xi), how to stay and survive in the markets and xii), their plans and goals and reasons to stay or leave the fishing industry.

The *in-depth interviews with key-stakeholders other than fishers* deliver data on; i), the distribution of different kinds of fishing and fishers in the three main and analysed harbours and landing sites; ii), the situation and conditions of the fishing industry and fishing families in each place; and iii), the service companies, auctions, and export.

The *applied register data* (as listed above in "Data collecting techniques and sources") deliver data on all vessels relating to their individual size, tonnage, kilowatt, home port, gear complex, years of construction and reconstruction, ownership, annual accounts, transferable quota, loans, and field of activity at sea. For the assessment of value chains, selected vessels provided original account data supplemented with account data from Statistics Denmark.

Structured and unstructured observations were conducted in the locations of the personal interviews. A structured observation was conducted in the visited port for seeing the vessels and catch technologies as well as the general situation in the ports. Furthermore, unstructured observations (urban drifting) were conducted in the local communities including shorter conversations with inhabitants. The observations contributed to a deeper understanding of the different types of fishing technology as well as of the local communities and the role of fisheries in social and cultural terms.

3.3 Results

3.3.1 Core features of distinct Fishing Cultures

In this study, we identified four core features of which combinations of elements and their modalities can be used to distinguish between different operational types of commercial fisheries. We defined these as distinct Fishing Cultures. We developed this new concept based on life-mode theory and the empirical analyses of modes of production in the fisheries. The concept of the Fishing Cultures provides a new framework for analysing and understanding how commercial fisheries cooperate, contribute and/or compete for spatial and biological resources, as well as economically sustain human societies at the local, national, and international level.

The four core features were identified based on applied conceptual theories and explorative data collection. Subsequently, further data were collected and analysed, which resulted in the identification and conceptualisation of seven distinctive Fishing Cultures. The conceptual models of Fishing Cultures provide a new framework for analysing and improve the understanding of how fisheries operate in the Jammer Bay area.

The four core features of commercial fishery are: i), life-modes; ii), modes of operation; iii), fishing gear and methods and iv), communities (fishing harbour affiliations). Below is an overview (Table 3.1) and detailed description of each core features and associated elements and modalities.

Table 3.1. The four core features to be combined into Fishing Cultures. The core features are detailed described on the following pages.

The four core features to be combined into Fishing Cultures				
Life-modes		***Mode of operation***	***The catching methods of distinct fishing gear***	***Community***
The self-employed, share-organised	*Thrifty*	The broadly complex, versatile mode of operation	Anchor seining	Shared landing facilities (SLF)
			Gillnetting	Private landing facilities (PLF)
	Expansive		Longlining	Shared quota ownership (SQO)
	Niche		Purse seining	Family quota ownership (FQO)
The profit-seeking entrepreneurial life-mode			Pelagic trawling	Cooperative shared quota ownership (CSQO)
		The unilaterally specialized mode of operation.	Fly-shooting	Company quota ownership (CQO)
Wage worker			Bottom trawling	Harbour (H)
Investor			Beam trawling	Beach landing site (BLS)
Profit seeking career skipper				

3.3.2 Eight basic life-modes operating in Jammer Bay area[4]

The self-employed, share-organised fisher life-mode

The self-employed fishers must ensure that the quantity they deliver to market multiplied by the price should at least cover the fishing units' overheads plus the quantity multiplied by the unit cost. For the share organised fishing unit, it is just as important to keep a skilled crew together as it is to keep the vessel and equipment in tip-top condition.

The enterprise's overheads, both fishing and family-related, are a necessary whole. Hence, based on experience and depending on the size and cost of maintaining the vessel, the income is normally distributed with 40-60% to the ship + gear and 60-40% to the fishing families.

The praxis of self-employed fishers connects four manipulable components: quantity, price, overheads, and unit costs. These components can be elaborated into three basic variants of the self-employed by focusing on different features:

[4] For further elaboration see Appendix 3.A2.

The thrifty fisher life-mode
The overheads are kept down to make ends meet. In this praxis, the fishing families remain free and independent of bank loans and the race for higher quantity by keeping the overheads down. The thrifty fisher life-mode operates within a 'just enough' ideology.

The expansive fisher life-mode
The quantity is increased, and unit costs are kept down to make ends meet. The expansive producer is characterised by large investments in basic means of operation and operates within a 'we have to improve our capability' ideology.

The niche fisher life-mode
The niche fisher keeps the price high to make ends meets. When the quality, specialisation, fishing with care, or individualisation (increasing the use value for the consumer) of the product is optimised, it may be necessary and possible to keep a higher price for the product on the exclusive niche of a market. This life-mode operates within a 'we are cultivating our niche' ideology.

The profit-seeking entrepreneurial life-mode
The profit seeking entrepreneurial life-mode's basic end is to optimise the return on the entrepreneur's total investment in wages, materials, and basic operational equipment. These three factors are means to reach the goal, which is to maximise the individual profit. The fishing entrepreneurial life-mode operates within 'my individual profit counts' ideology.

The entrepreneurial life-mode can be divided into the profit seeking investor praxis (ship owner) and the profit maximising manager praxis (skipper) who complement each other and appropriate the individual profit.

A wage-worker life-mode
Delivering paid labour is involved in this mode of production. Fish workers are attracted by means of fixed wages, favourable tariffs, and a bonus system. The fish worker life-mode operates within a 'work is a means to leisure' ideology.

The investor life-mode
The investor life-mode operates within 'we have to invest where profitability is promising' ideology.

The profit seeking career skipper
This mode operates within an 'our ship must be ahead of the other vessels' ideology.

3.3.3 Modes of operation
A fishing method and its gear complex are applied to selected fish species in distinct marine ecosystems and are, therefore, dependant on the habitat preferences and behaviour of the species. Furthermore, fisheries are influenced by the natural and cultural geography of the seas in question, inshore as well as offshore. The hydrographic conditions and the distances between

fishing grounds and landing sites are important for the design and application of catching methods, gears and vessel types. This combination of ecological and technical aspects of fishing practices constitutes the 'mode of operation' of a fishing industry.[5]

Two modes of operation coexist in the Jammer Bay fisheries: i), The broadly complex, versatile mode of operation; and ii), the unilaterally specialized mode of operation.

i), *The broadly complex, versatile mode of operation* is based on the principle that the fishing unit combines the different kinds of gear of several distinct catching methods aimed to catch a range of fish species, which during the year stay or migrate through a local body of water, appearing in sufficient concentrations that it pays to fish for them. By being able to switch rigs from one type of gear and method to another, it is possible to switch between fisheries of different species, so that over the course of a year, fishing can be operated as a versatile, local fishery, whereby the proximity to the home port can be maintained.

ii), *The unilaterally specialized mode of operation* is based on the principle that the fishing unit is specialized in using a particular fishing method aimed to catch a number of distinct species or a group of species (e.g., pelagic, benthic or demersal lifeforms), which are hunted and pursued throughout the year, if necessary, in different seas. This hunt follows the ecologically and hydrographically determined migrations and gatherings of the fish populations. In the case of migratory shoals, year-round fishing with the unilaterally specialized mode of operation can be conducted by the fishing unit only if it operates far from the home port during certain periods of the year. Hence, this mode of operation brings large foreign long-distance fishing vessels into the Jammer Bay area, just as larger Danish long-distant fishing vessels operate in waters far away from the Jammer Bay area.

3.3.4 The catch methods of distinct fishing gear[6]

Eight distinct catch methods are described by the fishers as being the fishing gear and method used in Jammer Bay[7]

1. the audio-visual herding method (anchor seining),
2. the fish entangling method (gillnetting),
3. the baited hook, fish attracting method (longlining),
4. the fish shoal surrounding method (purse seining).
5. the pelagic fish shoal capture method (pelagic trawling),
6. the fast wire towing, fish herding and encircling method (fly-shooting),
7. the seabed towed, demersal fish and shellfish filtering and catching method (bottom trawling),
8. the seabed dredging, benthic fauna churning and crushing, and fish attracting method (beam trawling).

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[5] Højrup & Nielsen 2024, p. 859ff.
[6] The Figures 3.1-3.3. and 3.5-3.8 are based on screen dumps from active fishing vessels registered on on www.vesselfinder.com.
[7] See also Gislason et al. 2021.

Anchor seining
Anchor seining applies an audio-visual herding method. At each haul, a plain area of the sea-floor is surrounded by two half-circles of nylon lines connected to a seine in their one end and the anchored vessel in their other. When the warping end of the vessel's winch hauls in the lines, each rope cracks and shakes.[8] The noise and vibrations from the ropes frighten the fish and herd them into the centre between the lines, where the seine in the last part of the hauling process collects the fish. After emptying the seine net, the lines and seine are redeployed for the next haul using the same anchor point. Redeployment in distinct directions from the same anchor point can be repeated several times. The method entails low fuel consumption (Fig. 3.1).

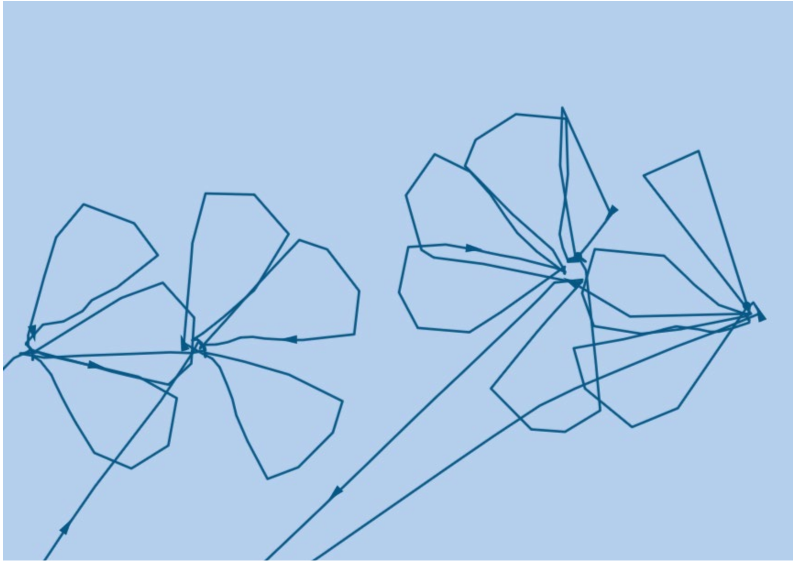

Figure 3.1. Gear track pattern from deployed anchor seining.

Gillnetting
When gill nets are deployed fish are entangled by their gills, fins or tails as they try to swim through the net. The gillnet can be used as an anchored bottom net, or as a drift net without contact to the seafloor. The soaking time is typically short and varying between 0.5 and up to 2, or sometimes 4 days. Drift nets are used to catch schools of pelagic fish, such as herring and mackerel[9]. The method entails low fuel consumption (Fig. 3.2).

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[8] Gislason et al. 2021 also describe the method as 'herding' the fish, but do not specify the way the lines are herding, which is the lines' cracking and shaking caused by the warping end of the boat's winch. This core feature is the reason why we characterise this herding method as audio-visual. Brandt 1972, p.164f. Højrup and Schriewer 2012, p. 56. Højrup & Nielsen 2024, p. 895f and note 592.

[9] Brandt 1972, p. 204ff. Højrup and Schriewer 2012, p. 54. Højrup & Nielsen 2024, note 589.

Figure 3.2. Gear track pattern from deployed gill nets.

Longlining

Applying the baited hook, fish-attracting method, a longline to which short lines (snoods) with baited hooks are connected is deployed. On its way down to, or when at, the seafloor the fish are caught by the baited hook. The soaking time is short and varying between 1-2 hrs and 1 day. The longline fishery in Jammer Bay area is mainly deployed at boulder reefs to procure day-caught cod and other high value species[10]. The method entails low fuel consumption (Fig. 3.3).

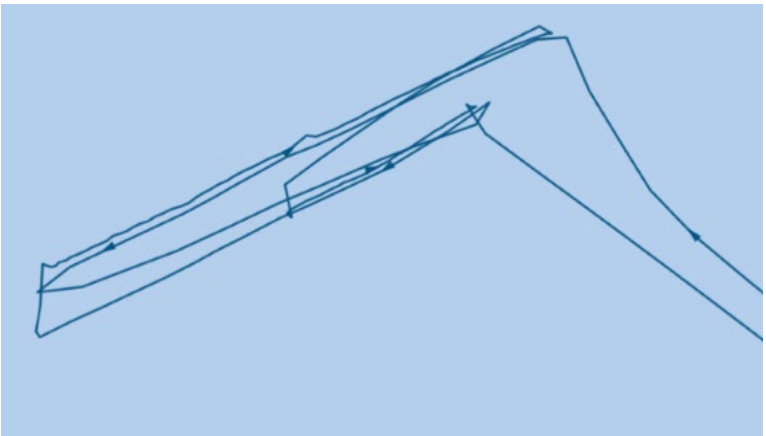

Figure 3.3. Gear track pattern from deployed longlining.

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[10] Brandt 1972, p. 48. Højrup and Schriewer 2012, p. 54.

Purse seining

Purse seines are vertical nets deployed to surround shoals of pelagic fish (e.g., herring, mackerel). After encircling a shoal, the bottom of the net is drawn together and 'pursed' upwards through the water column preventing the shoal from escape. The fish are sucked with a pump into refrigerated seawater tanks on board the fishing vessel[11]. The method entails a moderate fuel consumption as vessels have to encircle the shoal at high speed, but without mobile towing the gear (Fig. 3.4).

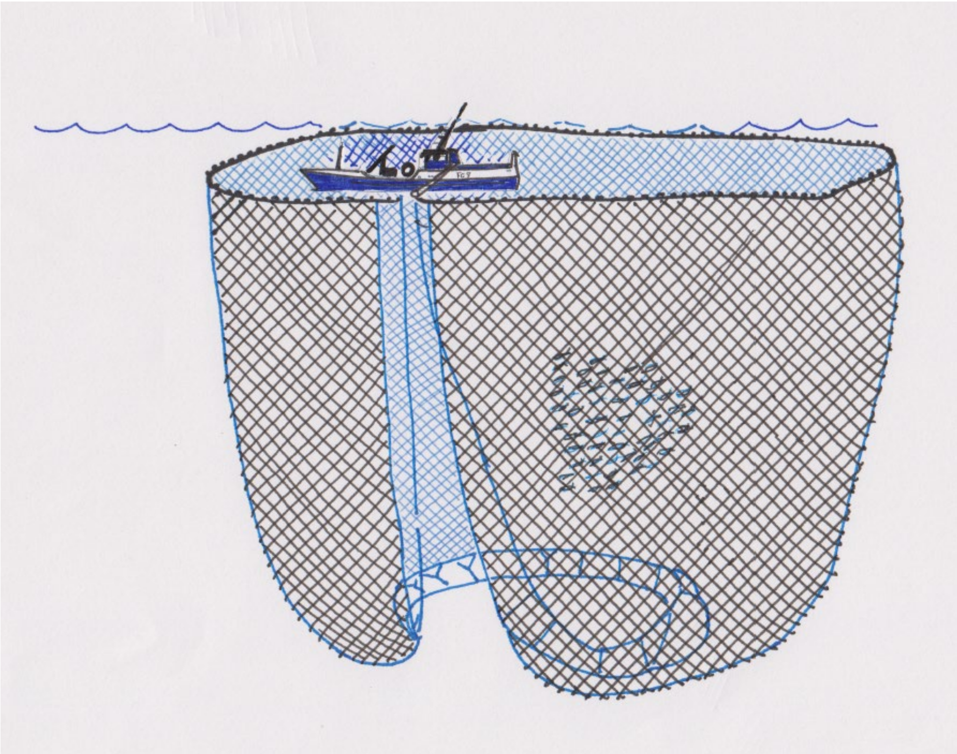

Figure 3.4. Illustration of purse seine.

Pelagic trawling

Pelagic trawls are designed to catch fish shoals located through the water column. This type of fishery necessitates manoeuvrable and fast moving vessels to be able to pursue the shoals in midwater. Pelagic trawls are generally constructed with larger openings (>8 m width). Ropes in the anterior part of the trawl herd fish towards the trawl opening. The narrowing of the trawl acts as a funnel, which increases the water flow whereby the fish are sucked towards the smaller-meshed cod-end. The method often entails fisheries by larger vessels with high engine power. On the other hand, because pelagic species living in shoals are highly concentrated, the pelagic trawlers obtain an efficient fuel consumption resulting in economic large-scale advantages. These vessels bring their catch to the fish-processing plant in Refrigerated Salt Water (RSW)

[11] Højrup and Schriewer 2012, p. 56. Brandt 1972, p. 168ff. Højrup & Nielsen 2024, p. 900f and note 593.

tanks and operate in a wide North Atlantic area inside and outside Exclusive Economic Zones[12] (Fig. 3.5).

Figure 3.5. Gear track pattern from deployed pelagic trawling.

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[12] The pelagic trawl funnel may be able to suck and catch even greater parts of a fish shoal by means of larger trawl mouths and trawl bags, towed by still larger vessels with more kilowatt engines than even the (much smaller) expansive demersal trawlers are using. Højrup and Schriewer 2012, p. 56. Brandt 1972, p. 168ff. Højrup & Nielsen 2024, p. 899ff and note 593.

Fly-shooting (Scottish seining)

Fast-sailing vessels shoot two half-circles of typhoon wire rope connected to a seine in one end and a buoy at the other end. This method herds and encircles the fish. Having fastened both ropes to the vessel after shooting, the half circle of typhoon wire ropes and the seine is towed along the seafloor until the fish are caught in the seine. Modern fly-shooting is an elaboration of anchor seine fishing, but resembles bottom trawling. When the fly-shooting vessel returns to the buoy after having encircled a large bottom area with the draglines and seine, the crew fasten the two drag-lines on board. At this point, the vessel steams forward while dragging and at the same time hauling in the draglines and seine across the seafloor like a wide stretched trawl. This ‘shooting on the fly’ requires larger engine power, higher fuel consumption, draglines of unbreakable typhoon wire (twined by nylon and steel) and strong nets. With this technology, the vessel can operate on most seabed substrates, such as mud, sand and mixed substrates with gravel and boulders. Especially when fly-shooting is conducted on mixed substrates, fishers perceive the method “to level out and cultivate the seafloor”. Modern fly-shooters are large vessels with powerful engines, heavy typhoon wires, and entails a high fuel consumption similar to mobile bottom contacting trawling [13] (Figure 3.6).

Figure 3.6. Gear track pattern from deployed fly-shooting.

[13] Højrup & Nielsen 2024, note 769.

Bottom trawling of demersal fish and shellfish

In bottom trawling the trawl-net is kept open by means of two otter boards connected with long ropes (sweeps) to each side of the trawl opening. The design of the otter boards causes them to spread apart due to the hydrodynamic forces as the vessel speeds forward. This is similar to pelagic trawling, but the gear is dragged along the seafloor. The fish are herded into the trawl by the sweeps, which are shortened when targeting only Norway lobster. The fishers described a suction action of the trawl funnel at the seabed causing demersal fish, shellfish and other mate-rials to be caught. This method entails high fuel consumption[14] (Figure 3.7).

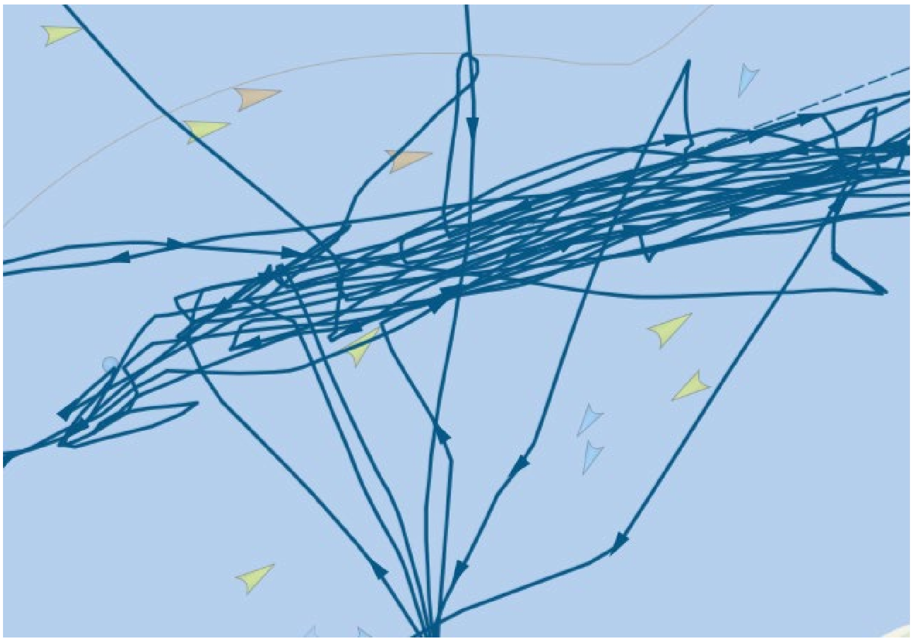

Figure 3.7. Gear track pattern from deployed bottom trawling.

[14] The otter trawl was developed through an epistemological rupture with the beam trawl in the 1890s. To optimise the sucking effect by so-called 'multi-trawling', the trawler may drag from 2 to 12 trawls beside each other. Twin-rigs are used by the fish- and lobster trawlers in Skagerrak. Brandt 1972, p. 136ff. Højrup and Schriewer 2012, p. 56. Højrup & Nielsen 2024, p. 884ff.

Beam trawling of demersal fish

The beam-trawl method applies fast-dragged heavy chains to churn the sediment and crush benthic fauna, which act as bait to attract fish to the area. This is a core feature of the method, described by beam-trawl fishers as “opening the bottom”. By repeating the hauls, the method attracts still more fish to be caught in that area, and the churning and crushing affects the fauna in deeper layers of the sediment with each consecutive haul. The horizontal opening of the net bag is provided by a beam. Rows of 9-10 tickler-chains are used on sand and gravel sediments, and chain-mats are used on mixed bottoms with boulder reefs. The largest gears weigh up to 10 tons and are towed at speeds up to 7 knots. This method implies extraordinarily high fuel consumption (a 500 GT beam-trawler consumes 32,000 litre diesel every 5 days).[15] Small shrimp beam trawls without tickler-chains are much lighter and are towed at speeds from 2.5 to 3 knots[16] (Figure 3.8).

Figure 3.8. Gear track pattern from deployed beam trawling.

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[15] This gear type is briefly described by Gislason et al. 2021 (p. 24). Our detailed description herein of this gear type and method is informed by the teachers at the education and research centre at the Maritime Campus Urk, Netherlands. See also Højrup & Nielsen, 2024, chapter 6.

[16] By pulling the beam trawl back and forth over the same piece of seabed, the beam-trawler catches the fish attracted by crushed molluscs from the previous tow and at the same time scoop up a new and deeper layer of the seabed’s flora and fauna, which, as food and bait, will attract more swimming fish. Hence, beam-trawling can be optimised by ’syncro-trawling’, which is often used by 2 – 8 beam-trawlers, who are scratching the same area at the same time and by so doing maintain a huge cloud in the water of (fish attracting) crushed flora and fauna from the seabed’s biotopes. Højrup & Nielsen 2024, p. 880ff.

3.3.5 Community (Fishing harbour affiliation)

The fourth feature of each Fishing Culture comprises the community features (e.g., quota ownership, landing facilities) of each fishing homeport where the individual vessel is registered, also referred to as fishing harbour affiliation. In the identification of the Fishing Cultures, we focus on the registry homeport. In the Jammer Bay area, there are three such homeports. These are the landing site, Thorupstrand, located on the beach in the middle of Jammer Bay, and the two harbours, Hanstholm and Hirtshals, located south and north of the Jammer Bay. Thorupstrand depends mainly on the fishery in the Jammer Bay area, whereas the local vessels of Hirtshals harbour fish in the Tannis Bay and other parts of the Skagerrak. The Thorupstrand catch landing facility sends most of its packed landings to the auction in Hanstholm. The local vessels of Hanstholm harbour fish in the Skagerrak and greater North Sea. The auctions of the two harbours also receive landings from vessels and trucks coming from other Danish homeports, and from other countries around Kattegat, Skagerrak, and the North Sea.

Other important harbours for the Fishing Cultures that operate in the Jammer Bay area comprise the Danish Thyborøn, Skagen, Strandby and Nexø, as well as the Swedish Fotö, Rörö, and Donsö (in the Bohuslen archipelago). These harbours host headquarters of some of large-scale fishing companies.

Of the foreign fleets operating in the Jammer Bay area, beam trawlers from the Dutch fishing community of Urk, play an important role. Since 1980, these vessels have intensively fished the shallow grounds of the Jammer Bay area at regular intervals (three waves of several years). Beam trawls are among the heavier mobile bottom contacting gears known to negatively impact seabed habitats.

3.3.6 Fishing Cultures identified in Skagerrak

Of key importance in this section is the 7 Fishing Cultures, which are identified based on their individually unique combinations of the 4 core features and the modalities of their elements.

The core features: life-modes, modes of operation, fishing gears and methods and fishing harbour of registry, is used to combine modalities of their elements in individually unique ways, thereby forming seven distinct Fishing Cultures, which are operating in the Jammer Bay area (see Appendix 3.A2 regarding life-mode definitions, and Appendix 3.A3 regarding the relation between life-mode and Fishing Culture). Hence, the Fishing Cultures cannot be identified by one of the features but only by their combination. The order of description (and numbering) of the fishing cultures was structured by the life-modes (Table 3.2).

Table 3.2. The 7 Fishing Cultures structured according to life-mode and ownership form with corresponding name and number (detailed description on the following pages).

Life-mode	Mode of operation	Catching methods	Community	Fishing Culture no
Self-employed, share-organised, niche	Broadly complex, versatile	Anchor seine + Gillnetting	SLF + CSQO + BLS	FC 1
Self-employed, share-organised, expansive	Unilaterally specialized	Beam trawling	SHL (NL) +FQO + H	FC 2
Self-employed, share-organised, expansive	Unilaterally specialized	Trawling (bottom/pelagic), Fly-shooting	PLF/SLF + SQO/FQO + H	FC 3
Self-employed, share-organised, thrifty/niche	Specialized/versatile	Bottom trawling (small), Gillnetting, Longlining	SLF/PLF + FQO/SQO + H	FC 4
Self-employed, share-organised, thrifty/expansive	Unilaterally specialized	Gillnetting	SLF/PLF + FQO/SQO + H	FC 5
Self-employed, share-organised, thrifty	Unilaterally specialized	Anchor seining	SLF/PLF + FQO/SQO + H	FC 6
Expansive, profit-seeking/investor+career & wage worker	Unilaterally specialized	Pelagic/bottom trawl/purse seine/fly-shooting	SLF/PLF + CQO/FQO + H	FC 7

SLF = Shared landing facilities, PLF = Private landing facilities, SQO = Shared quota ownership, FQO = Family quota ownership, CQO = Company quota ownership, CSQO = Cooperative shared quota ownership, H = Harbour, BLS = Beach landing site.

Table 3.3. The detailed features of the seven Fishing Cultures (described in detail on the following pages).

FC no	1	2	3	4	5	6	7
	Self-employed, share organised, family		Self-employed, share organised				Profit seeking + wage-earning
Fishing harbour affiliations	Thorup-strand, Løkken	Urk (NL)	Hanst-holm, Hirtshals, Skagen, Strandby	Hirtshals, Hans-tholm	Hvide Sande, Thors-minde, Thyborøn, Hanstholm	Thy-borøn, Hans-tholm Hirtshals	Thyborøn Hirtshals, Skagen, Nexø (all DK) Rörö, Öckerö, Fotö (S)
GT KW	<30 221	500 1115-1471	17-388 177-1320	1-130 16-441	20-160 81-520	25-114 121-405	111-4319 200-6.000
Landing port(s)	Thorup-strand Løkken	Urk via Thyborøn Hanst-holm Hirtshals	Hanst-holm, Hirtshals	Hanst-holm, Hirtshals	Thyborøn, Thors-minde, Hanstholm	Hirtshals, Hanst-holm	Skagen, Hirtshals, Hanst-holm
Mainte-nance place	Slet-testrand Thorup-strand Hanstholm	NL Minor tasks: Thyborøn Hans-tholm	Hanst-holm, Hirtshals, Skagen, Strandby	Hirtshals, Hans-tholm	Hvide Sande, Thyborøn, Hanstholm	Hirtshals, Hans-tholm	Skagen, Hirtshals, Hanst-holm, Neksø
Fishing distance from home port	1-30 Nautical miles	300 Nau-tical miles	10-110 Nautical miles	1-25 Nautical miles	10-110 Nautical miles	10-–60 Nautical miles	30-350 Nautical miles
Fishing area at Skagerrak	Outer Central Coastal	Central	Outer Central	Outer Central Coastal	Outer Coastal	Outer Central Coastal	Outer Central
2016 2022 No. vessels	17 8	2 20	49 57	116 118	8 14	16 14	23 27

Fishing Culture 1: Beach landing coastal fishery[17]
The niche variant of the self-employed share fisher life-mode from Thorupstrand uses sand-banks and stone reefs of the inshore, central, and offshore parts of Jammer Bay area in a broadly, versatile mode of operation employing small anchor seines during summer and gillnets during the winter months (vessels below 30 GT) (Fig. 3.9).

They land their catches in Thorupstrand and Løkken, and most are sold at the auction in Hans-tholm. This fishery gets their vessels constructed at the local, cooperative boatyard and main-tains 1), service on boats and gear, 2), collectively owned quotas and 3), the infrastructure be-hind family life in the local area.

Specification: No further specification.

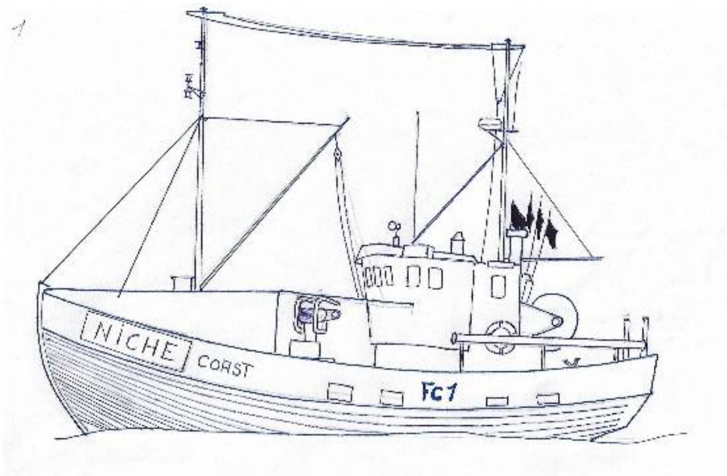

Figure 3.9. Typical vessel of the beach landing coastal fishery.

Fishing Culture 2. Dutch demersal beam trawling
The expansive variant of the self-employed share fisher life-mode from Urk (and other fishing communities in Holland) uses sandbanks and stone reefs in the central Jammer Bay area - as one of several long-distant fishing grounds - with a unilaterally specialised mode of operation employing beam trawl (and vessels around 500 GT) in a long distant fishery. The few Danish beam trawlers fishing in the Skagerrak are included in this Fishing Culture (Fig 3.10).

They land their catch mainly in Thyborøn from where it is sold and transported to processing plants in Urk. Their cooperative service company delivers most of the necessary service and gear to the Dutch beam trawlers from Urk.

Specification:
2a: Vessels < 200 GT
2b: Vessels > 200 GT

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[17] The drawings of the fishing vessels in each Fishing Culture were made by Thomas Højrup.

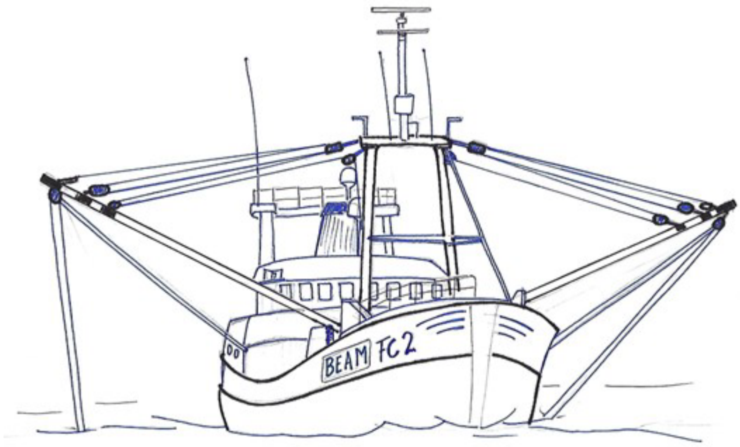

Figure 3.10. Beam trawler using two beam trawls towed from long derricks projecting over each side of the vessel.

Fishing Culture 3. Expansive harbour-based fishery

The expansive variant of the self-employed fisher life-mode from Hanstholm, Hirtshals, Skagen and Strandby, as part of a yearly circle, uses sandbanks and stone reefs in the north-western offshore parts of Jammer Bay area with a unilaterally specialised mode of operation employing bottom trawl all year round or combined with fly-shooting or pelagic trawl (Fig 3.11 and Fig. 3.12).

They land their catches at the auctions in Hanstholm and Hirtshals. This fishery gets most of their boats constructed outside the region but maintain service on boats and gear and the infrastructure behind family life in the hometowns.

Specification:
3t: Vessels using bottom trawl
3ta: Vessels 60 – 200 GT
3tb: Vessels 200 – 500 GT
3f: Vessels using fly-shooting
3p: Vessels using pelagic trawl

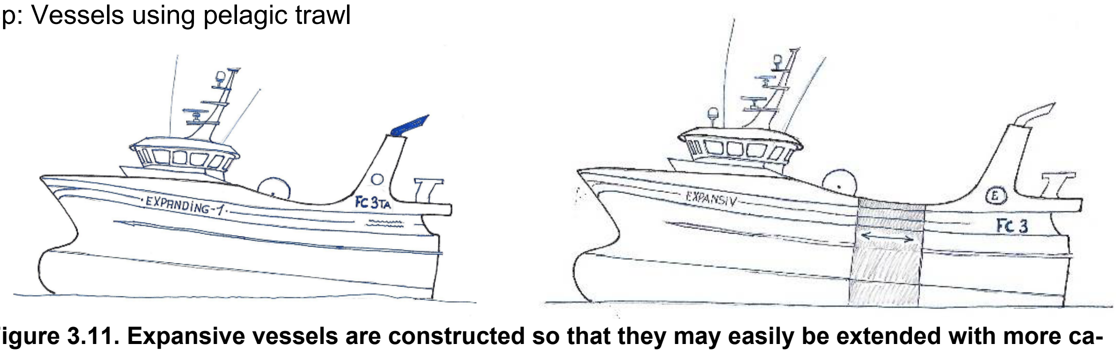

Figure 3.11. Expansive vessels are constructed so that they may easily be extended with more capacity, gear and horsepower.

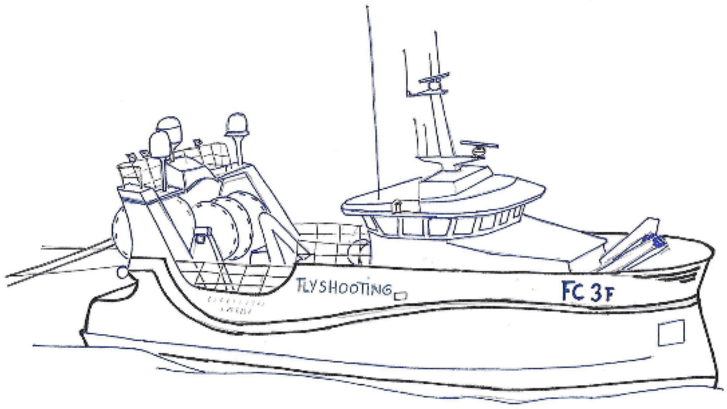

Figure 3.12. Fly-shooter vessels are constructed with still more horsepower, fish handling facilities and capacity.

Fishing Culture 4. Harbour-based coastal fishery

The thrifty and the niche variants of the self-employed share fisher life-mode from Hirtshals and Hanstholm use sandbanks and stone reefs in the inshore (close to the harbours) and offshore parts of Jammer Bay area in a broadly or specialised mode of operation employing small bottom trawls, gillnets and/or longlines all year round (vessels between 10 and 120 GT) (Fig. 3.13).

They land their catches at the auctions in Hanstholm and Hirtshals. This fishery gets most of their vessels constructed outside the region but maintain service on vessels and gear and the infrastructure behind family life in the two towns.

Specification:
4t: Vessels using bottom trawl
4ta: Vessels 5 – 15 GT
4ta n: Vessels 5 – 15 GT
4tb: Vessels 15 – 60 GT
4tb th: Vessels 15 – 60 GT
4tc th: Vessels > 60 GT
4g n: Vessels using gillnet
4l n: Vessels using longline
4p: Vessels (4tb & 4tc) using pelagic trawl part of the year

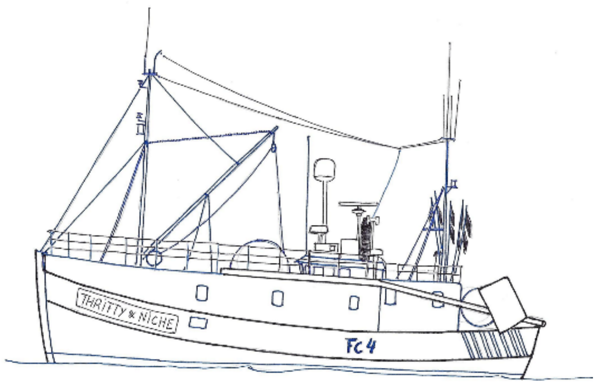

Figure 3.13. Multifunctional coastal vessel that can easily switch between e.g., gillnetting, trawling, longlining, trap fishing or seining during a year-cycle.

Fishing Culture 5. Specialised gillnet fishery

The thrifty and the expansive variants of the self-employed fisher life-mode from Hvide Sande, Thorsminde, Thyborøn, and Hanstholm, as part of a yearly circle, use sandbanks and stone reefs in the inshore, central, and offshore parts of Jammer Bay area in a unilaterally specialised mode of operation employing gillnets (Fig. 3.14).

They land their catches at the auctions in Hanstholm, Thyborøn and Thorsminde. This fishery supports suppliers of construction and service on vessels and gear and the infrastructure behind family life in the hometowns.

Specification:
5: Vessels using gillnet
5a: Vessels 20 – 50 GT
5b: Vessels > 100 GT

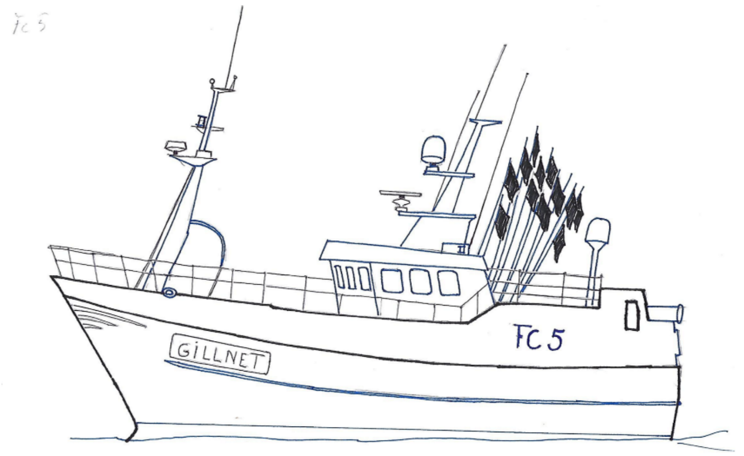

Figure 3.14. Specialised gillnet vessel with full shelter-deck to protect the crew when handling nets and fishes.

Fishing Culture 6. Specialised anchor-seine fishery

The thrifty variant of the self-employed fisher life-mode from Thyborøn, Hanstholm and Hirtshals uses sandbanks in the inshore, central and offshore parts of Jammer Bay area in a unilaterally specialised mode of operation using large anchor seines. (Fig. 3.15)

They land their catches at the auction in Hirtshals. This fishery maintains local service on boats and gear and the infrastructure behind family life in the homeports.

Specification:
6: Vessels using large anchor seines
6a: Vessels 20 – 40 GT
6b: Vessels 50 – 60 GT
6c: Vessels 80 – 120 GT

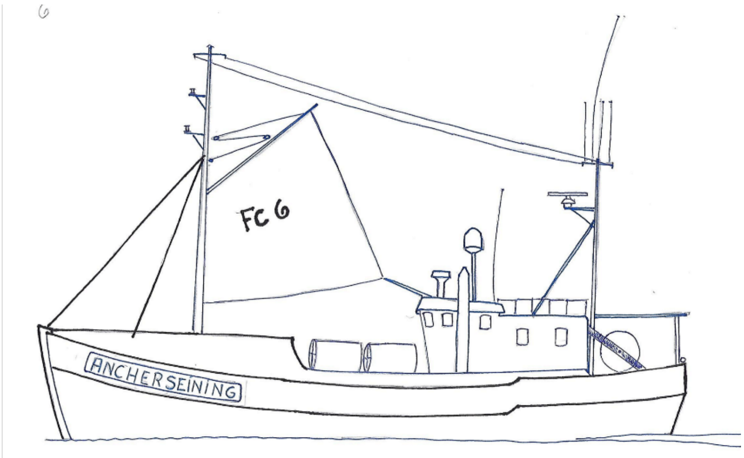

Figure 3.15. Specialised Danish anchor seining vessel equipped with half shelter-deck and large line drum magazines.

Fishing Culture 7. Profit-seeking large-scale fishery

The expansive variant of the entrepreneurial life-mode from Hanstholm, Hirtshals, Skagen, and Nexø, (Denmark) and Rörö, Öckerö, and Fotö (Sweden) uses sandbanks and stone reefs of the north-western offshore parts of the Jammer Bay area with a unilaterally specialised mode of operation employing bottom and pelagic trawl (or purse seine) as part of a yearly circle. These vessels are less bound to the home port, also for maintenance and service. The crew is recruited from a larger area, including the northern and western Jutland. (Fig. 3.16).

Specification:
7sv: Vessels owned by Swedish companies (Bohuslän), registered in Denmark.
7dk: Vessels owned by Danish companies.

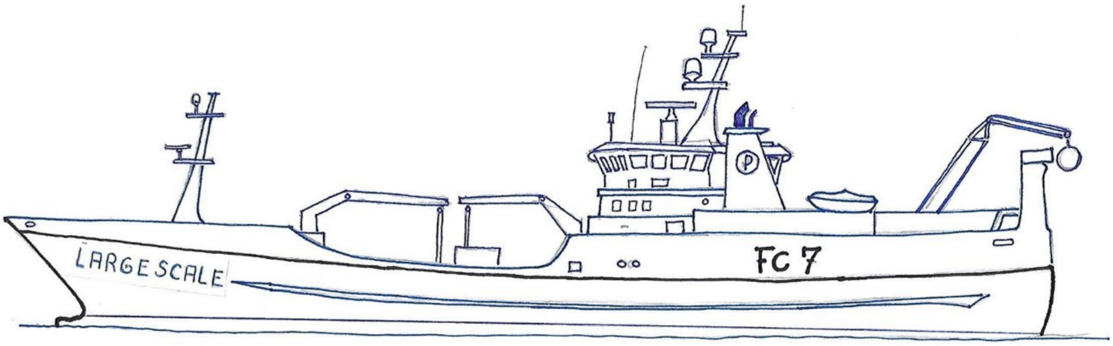

Figure 3.16. Large-scale pelagic trawler and purse-seiner equipped with refrigerated salt water (RSW) tanks to keep a sufficiently raw fish quality until the catch is landed to the harbour-based processing industry.

3.3.7 Value chain

The value chain description comprises the first and second value chain links related to the Fishing Cultures in Skagerrak.

A value chain is a series of value adding steps from the landing of caught fish to the finished product's arrival at a customer's door (here called value chain 1), or the series of consecutive value adding steps (implements and services from sub-suppliers to fishing vessels) that go into the creation of the catch that fish fishing vessels are landing (here called value chain 2).

Value chain 1 investigates whether there are direct relations between certain Fishing Cultures (FCs) and particular value adding steps at distinct fish markets. This is addressed below as the fish value chains, following the product from landing facility to customer.

Value chain 2 investigates the (indicative) geographical and social distribution of income from the fisheries in each FC to sub-suppliers and service providers. Based on this indication the purpose is to outline the importance of the distinct FCs' fishing for the communities of the Jammer Bay area.

Value chain 1 - from landings to distinct sea-food markets
The value chain links 1 and 2 descriptions have two purposes:

The brief presentation of the FCs above demonstrated that catches from the Jammer Bay area are landed at facilities in the harbours of Hirtshals, Hanstholm, Thyborøn, and the landing site of Thorupstrand. This is where the fish value chains begin, though it is not possible to document statistically unambiguous connections between distinct value chains and FCs. In the following the first-hand sales are described, while a deeper analysis of the further value chain would require an analysis of import/export structures, which is out of the scope of this work. It is though known that the main part of the Danish catches is exported to the European market, directly from auctions or after processing or re-packaging in Denmark. The exact share is not known as some parts of the catches are exported directly and others are bought for processing in Denmark for subsequent export.

Direct sales to processing plants
Direct sales of 'protein-fish' to processing meal- and oil industries
Industrial species are landed by demersal and pelagic trawlers directly (or sent by truck) to the meal and oil industries FF Skagen A/S (Skagen) and possibly TripleNine (Thyborøn), where they are processed into meal and oil aimed at protein-rich food in aquaculture and livestock farming or ingredients to other industries. The sale is based on contracts or in some cases day-to-day agreements (Taskov et al. 2018). FCs 3, 4, 7 provide the landings.

Direct sales of RSW herring and mackerel to processing industry
Herring and mackerel are landed by pelagic RSW (Refrigerated Sea Water) trawlers directly to Scandic Pelagic Skagen or Saeby Fish Canners Ltd. (Sæby Fiskeindustri), where they are processed to human consumption products. FC 7 provides the landings.

Direct sales of 'Norway lobster' to processing industry
80-90% of the Norway lobster landed in Hanstholm and Hirtshals are trucked directly to industries, especially the *Nephrops* processing industry at Læsø (Læsø Fiskeindustri), or for sale at the home ports of the vessels, e.g., the fish auction in Strandby (Strandby fiskeauktion). The products are generally exported to European markets (especially Italy). FCs 3, 4, 7 provide the landings.

Direct sales of plaice for Urk, Netherlands
Until 2021, beam trawlers from the Netherlands landed their catches directly into Dutch trucks in the Thyborøn or Hanstholm harbours, from where they were transported to landing facilities and

processing industries in Urk and registered to Dutch authorities. By common agreement the Dutch fishers committed themselves to send their landings directly to their hometown. After the implementation of the EU regulation on landing registration before the catches leave the arrival harbour, the beam trawlers during a short period landed their catches (especially plaice) from the North Sea and Skagerrak (including the Jammer Bay area) in Hanstholm for direct export (Tornsberg 2021). In 2022 the direct sales stopped and is now sold via the auction in Thyborøn.

Sales via auctions
The remaining catches, which comprise the main part of benthic and demersal fish for human consumption, are sold via fish auctions. We have limited information about the next links in the value chain. We therefore structured the next part according to type of market, which can partly be linked to Fishing Cultures.

High value products to European niche markets

- Seine, gillnet, longline (and some specialized trawl) fishers provide the catch landing facilities in Thorupstrand, Hirtshals, Hanstholm, and Thyborøn with day-caught E-quality codfish and flatfish, which are sold at the auctions aimed at European retail and restaurant customers or Danish fishmongers. FCs 1, 4, 5, 6 are main providers.
- The larger vessels in the FCs 3 and 7 can sea-pack the fish, which is landed directly to the auctions in Thyborøn, Hanstholm and Hirtshals. The fish is only handled once, fast packaged and from known vessels. Therefore, parts of the sea packed fish are also sold for the European niche markets.
- While most landings are marked with the brand Marine Stewardship Council (MSC) this does not automatically provide access to niche markets. The NaturSkånsom brand, which is mainly linked to FC 1 vessels, is relatively new (2020 – see https://naturskånsom.dk/) and developed for niche markets. However, this brand is not well established on the market and therefore not assignable to specific value chains for the Jammer Bay auction, neither for export, nor for the national market.

Products for the general European fresh fish markets and further industrial processing
The fish for the general European market, fresh fish market, and industrial processing for filets, consist of sea-packaged fish (from some FC 3 and FC 7 vessels). These are mainly iced fish from vessels operated by all Fishing Cultures, mainly FCs 2, 3, 5 and 6, but also FCs 1, 4 and 7. Also for these market segments, most fish are of E-quality with few of low A-quality. The fish is brought to catch landing facilities in Thyborøn, Hanstholm, Thorupstrand, and Hirtshals, where they are sorted, weighed, and packed in ice aimed at being sold at the auctions in batches which can contain fish from several different vessels.

From a point of departure in the fish landing facility or auction, the next step in the fish value chain may be mediated by distinct actors at the market and in two different ways:

- Traders or processing plants located in Denmark, of which some are owned by foreign companies can buy the catch directly from the vessel. Parts of the products are sold in Denmark, but the main part is probably exported (requires further analysis of the value chains).
- Direct export mediated via buyers at the physical auctions acting on behalf of foreign companies, or direct sales at the online auction in Thyborøn. This export increased after the direct sales to Urk fish processing companies of especially plaice

(and other species) was redirected to the online auction of Thyborøn due to EU legislation.

Although several FCs contribute to the same direct value chains the quality and prices might differ in a complex pattern. The prices obtained at the auctions depend on the quality of the fish, on the quantity of landed catches (buyers prefer larger 'pots'), and on the seasons. Fish caught by gillnet and anchor seine shortly after they are brought on board, have a high quality, and get the highest prices during the season May – November, when the weather conditions are appropriate for these fisheries and considerable quantities of well-nourished fish from near-shore grounds are landed. This is the main source of income for the FCs 1, 4, 5, and 6. In the autumn and winter months, weather conditions are dominated by high winds and water currents. These conditions favour the larger trawlers that obtain high prices for the large-sized plaice caught on the slope of the Norwegian trench.

Local stakeholders interviewed in this study, perceived plaice to be well-nourished at this time of year due to warmer offshore waters than close to shore. Just before Christmas, prices are always high for plaice, the quantities are limited and typically sold to fish shops, restaurants and fish counters in the supermarkets. This is an important income for the larger demersal and benthic trawlers of the FCs 3, 4 and 7. When the gill-netters catch cod in the autumn, winter, and spring months, they land high quality fish sold at high prices. This was a highly important source of income for the FC 1, until the cod population in the Jammer Bay area diminished around 2000 (see 2.3.4 Quotas and landings Fig. 2.4).

An example of the result of this complex price setting structure is illustrated in the table below comparing average kilo prices for FC 1 (gillnet and anchor seine) and FC 3 (small and larger trawlers) landing top E-quality plaice and sole. The FC 1 gillnetters obtain the highest kilo price for plaice in March and June-August, whereas the trawlers obtain the highest prices during the other months. Landed sole usually obtains high prices and are caught year-round by FC1 gillnetters and Danish seiners, and by larger trawlers operating further offshore during the winter months (Nov-Feb).

Table 3.4. Comparison of kilo prices (DKK/kilo) for plaice and sole. FC 1 (gillnet and Danish seine), and FC 3 (bottom trawl, small = 60-200 BT, and larger = 200-500 BT). Average monthly kilo price for landings over 100 kg/group/month during 2022. Red text marks the highest kilo price. Source: DTU Aqua, clt_land_kval.

Aver-age	Kilo price Plaice_E				Kilo price sole_E			
Month, no.	FC 1 gill-net	FC 1 an-chor seine	FC 3 trawl, small	FC 3 trawl, larger	FC 1 gill-net	FC 1 Danish seine	FC 3 trawl, small	FC 3 trawl, larger
1			23.12	21.22			124.18	129.82
2			32.57	33.18			139.20	163.10
3	22.20		22.12	22.05	147.68			
4	21.81	20.82	25.72	21.43	149.73			
5	23.90	19.90	24.24	20.67	152.99			
6	26.11	20.87	22.62	21.97		140.60		
7	32.36	24.74	24.07	24.49		129.34		
8	44.09	23.67	25.07	23.26		125.83		
9		23.52	25.06	26.73				
10	27.60	24.94	28.92	27.17	149.94		112.40	126.00
11		20.82	30.48	29.75			110.63	113.04
12			30.00	32.34			126.48	142.99
year	23.57	22.84	*25.34*	*24.80*	150.03	134.53	*116.77*	*130.06*

Value chain 2 - Fishing Cultures' contribution to local economy, community and welfare
The activities in- and around the Fishing Cultures (FCs) contribute to the local economy as well as the broader community and societal welfare. The extent of this contribution differs between the FCs depending on the geographical dimension of the value chains supplying input for the fishing process. In this section, the general (spatial) organization of the industry and supplying value chains (backward linkages) are linked to the different FCs. A local economic effect (LEE) analysis is conducted including direct and indirect economic effects. Moreover, the induced effects of the FCs on other local value chains and activities are considered.

The local effects of the value chains are linked to the distribution of the income from the fishing activity. It is used for owner-profits and investments, skipper remunerations, and fish-workers' wages (in FC 7), for boat shares, gear shares and crew shares (in FCs 1 – 6) and it is linked to the payment of operating expenses (provisions, fuel, oil, ice, landing- and auction fees, maintenance, etc.). Watson et al. (2021) referred to these as direct and indirect economic effects of the fisheries.

Depending on the spatial distribution of suppliers for these costs, they contribute to the total income of fishing communities in the Jammer Bay area, or they are channelled to communities outside the area. With the aim to evaluate how much the FCs contribute to the local economy, we assessed the value that is channelled to a Jammer Bay fishing community. This was based on the assumption that income related to owner remuneration, wages in the vessel unit, as well as wages in companies providing fuel, maintenance, and landing related activities are local. To the extent they are local, these cost areas will contribute to the local economy. The calculation of the value of local economic effect for each FC, as well as the relative local economic effect of catch values are based on the identification of the specific vessel composition in each distinct

FC and the average account statistics for vessel categories (FIREGN2, DST). See Table 3.5. For the method see Appendix 3.A4.

Table 3.5. Local Economic Effects (LEE) per Fishing Culture 1-7. Total landing values, LEE (i.e., income for crew and owner and income in local supplying sectors) and LEE in % of landing value. Qualitative assessment of the actual LEE level. Own calculations based on FIREGN2 and REGN1, DST. (See Appendix 3.A4).

FC number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Number of vessels	10	**-**	54	118	14	13	25
Landing value, mill. DKK*1	14.7	**Na**	484.2	256.2	78.5	51.3	698.1
LEE, mill DKK*2	7.7	**Na**	186.9	124.9	44.1	20.8	178.9
LEE, % of landing value, %	52.2	**Na**	38.6	48.8	56.3	40.5	25.6
Calculated level for FC LEE, compared to qualitative assessed level							
Qualitative assessment of the calculated LEE for Jammer Bay	Mini-mum	Very low for Jam-mer Bay	Maxi-mum	Mini-mum	Maxi-mum	Maxi-mum	Over maxi-mum

The calculated LEE, including the direct and indirect economic effects, is a result of the structure for integrating the Fishing Culture´s vessels and crew, as well as their supply into the local economy. This is illustrated in diagrams of the value chains for the FCs below.

The induced effects describe in qualitative terms how the presence and performance of FCs contribute to e.g., tourist business (experience economy), permanent settlement, and policies (blue growth, green transition, and sustainable management of marine nature) of state, and EU.

The value chains from Fishing Culture 1 [18]**,** *beach-landing coastal fisheries*
The niche variant of the self-employed share fisher life-mode from Thorupstrand.

The value chain is characterized by most of the effort depending on operating expenses being paid to landing site, catch landing facility, artisanal and service shops, providers of provisions, consultants, bookkeepers, cooperative quota guild and wholesale society, savings bank and similar second links in the local community.

[18] The illustrations of the value chains are made by Thomas Højrup.

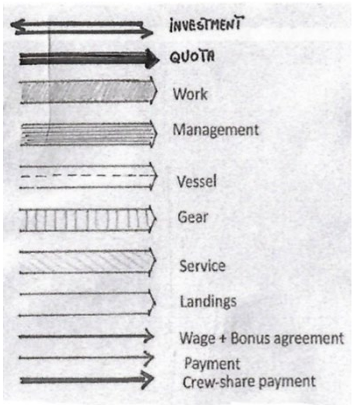

Figure 3.17. Symbols and their meaning in the value chain figures 3.18-3.22 and 3.25-3.28.

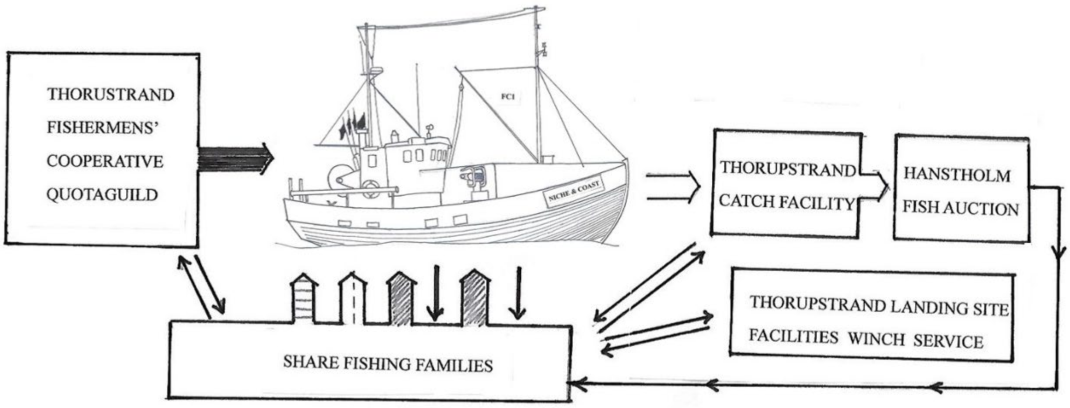

Figure 3.18. Value chain 2, step 1 for Fishing Culture 1, the share fisher life-mode from Thorupstrand.

The high value niche fishery is labour intensive, and the crew-share of the fishing unit's net-income is primarily used by the local share fishers to pay their families' living expenses, investments in their homes, the children's activities plus tax to the state and municipality, which in turn provide public schooling, elderly care and other parts of the welfare service.

The boat-share is used to pay the local yard, smithy, and other shops, who maintain the necessary back-up of local service and knowledge behind the fishing units. The fleet is an important customer of the local savings bank. Insurance fees go to national insurance companies, member fees to national fishing associations and subscription fees to international telecom companies.

The gear-share of each fishing unit go partly to family members, who maintain and renew gill-nets and other gear, partly to local and regional gear providers. Seines are bought in regional dragnet factories and maintained locally. In contrast to many other FCs and communities, the fishers in Thorupstrand conduct gill-net fishing for plaice, sole, anglerfish, hake, cod, and lumpsucker during the high seasons locally in the Jammer Bay area.

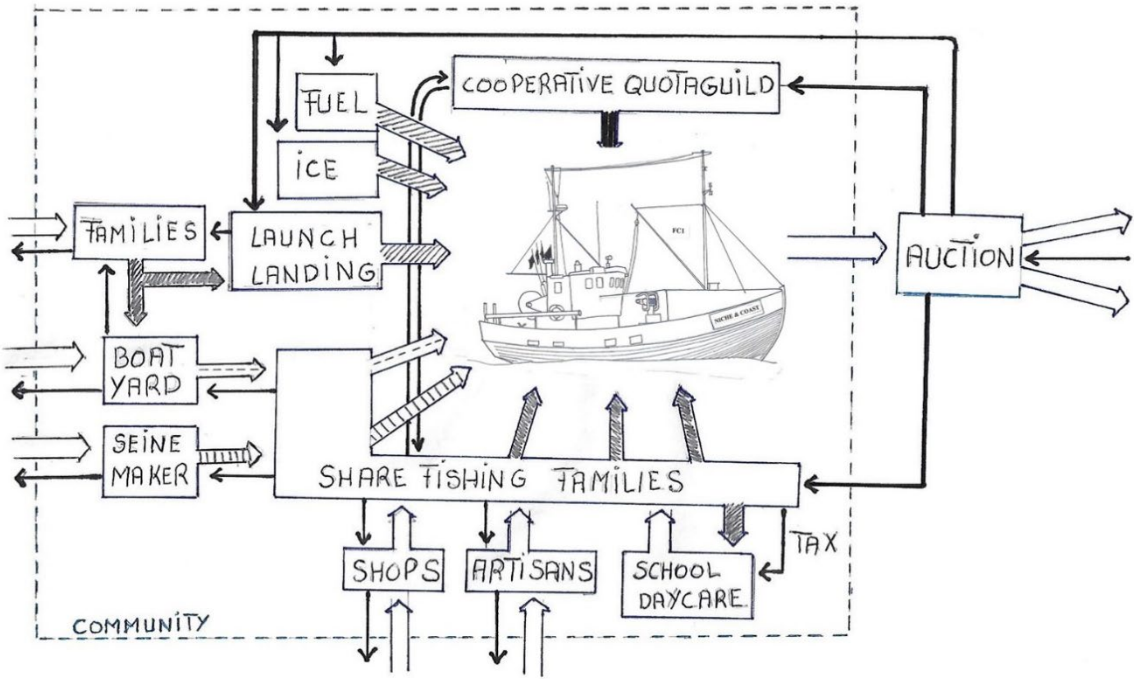

Figure 3.19. Value chain 2, step 2 from Fishing Culture 1.

Based on 2022 account data (average for vessel categories), the FC1 vessels landed fish for a value of 14.7 mill DKK. The relatively labour-intensive fishing process means that up to 44% of the value of the landings goes to wages for employees and owners, and 9% of the value of the fish landings are the wage share in the used services, fuel, landing, and maintenance costs. The calculated local economic effect, LEE is therefore 7.7 mill DKK, 52% of the value of fish landings. The vessels operate locally, with regards to fishing and associated services, such as provisions and banking. The auction is not local but situated within the Jammer Bay area. The calculated average for the FC 1 is therefore probably a minimum of the local economic effect of fishing in Thorupstrand, and certainly for Jammer Bay area as “the local”.

The induced effects from the presence and performance of FC 1 to tourist business are decisive for the local experience economy, because more than 100.000 guests visit the Thorupstrand landing site each year. The core attraction is to watch the fishers launch their clinker crafts and land again on the beach to unload fresh fish. Also popular is the building and repair of these beach landing ‘sea boats’ at the clinker craft yard nearby and on the beach. The fishers cooperatively owned fish shop and restaurant feeds 30.000-40.000 dining guests each year, and at least three times as many visit the landing site. These guests make up an important market for the shops in the neighbourhood and the nearby small town of Fjerritslev. The municipality counts the fishing community as its most important asset of the experience economy. FC 1 is one of the last shore-based landings sites in Denmark.[19]

The value chains from Fishing Culture 2, Dutch demersal beam trawling
The expansive variant of the beam-trawling, self-employed share fisher life-mode from Urk.

[19] Hofmann, 2016, Hofmann 2020, Eigaard og Olsen 2020.

The value chains from the long-distant fishing vessels of Urk's beam trawler fleet are conditioned by the fact that they are operating far away from Urk because of their perception of increasing depletion of the habitats and stocks of sole, plaice, and cod in the southern parts of the North Sea. Besides general depletion of the stocks, the Dutch beam-trawlers also consider themselves under pressure from competition for space with wind turbines, which are erected in the southern North Sea. This reinforces an increased competition for sea areas. Expansion of offshore wind farms in the southern North Sea increases the displacement of beam-trawlers[20]. The direct value chain of the distant-water fleet is characterized on the one hand by effort depending operating expenses being paid to North Sea ports and catch landing facilities (located outside Urk) and on the other hand by expenses regarding lubricant oil, fuel, provisions, technical service, advisory, construction and renewal of gear and spare parts of the vessels being paid to the TCD VCU cooperative production and wholesale society of Urk. The huge business of the Fisheries Cooperative of Urk employs technical and economic experts, artisans, wage-workers and sub-contractors, and deal with local banks and similar second links in the Urk community.

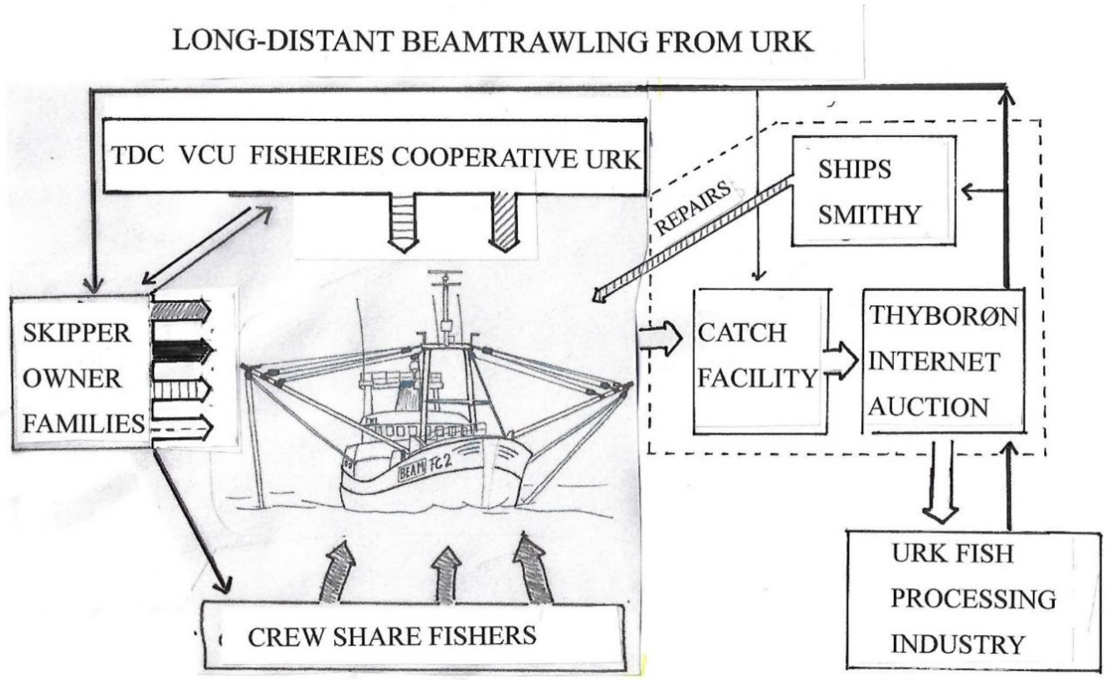

Figure 3.20. The value chain 2, step 1 from Fishing Culture 2.

The beam trawl fishery employs 7 fishers in each vessel and the crew-share of the fishing unit's net-income is used by: i), commuting fishers from East European and Baltic countries; and ii), the local share fishers from Urk to pay their families' living expenses, investments in their homes, the children's activities as well as taxes to the Dutch state, and municipality's provision of public school, elderly care and other parts of their local welfare service.

[20] A Dutch beam-trawl skipper stated: "We're using the same fishing grounds. The Danish fishers have to move, the Dutch fishers have to move, because of the wind farms. So you have to go closer and closer to each other."

The boat-share is appropriated by skipper-owner families, who have their vessels constructed at their local yard or one of the larger Dutch yards. The vessel owner families are important customers of the local bank. Insurance fees go to national insurance companies, member fees to the local fishing association, and subscription fees to international telecom companies.

The local economic effects from the Dutch fleet are not calculated in this study due to lack of data. It is however quite clear, that the economic effects of fishing in the Jammer Bay area are limited to the costs related to fuel, catch landings facility costs, and to some degree the repairs of folded beams that are required while docking in the landing port (Thyborøn) between each week's 5 fishing days. The organization of the Urk fleet and service industry ensures relatively high local economic effects in the Urk region, despite the long-distance operation in the Danish parts of the northern North Sea and Skagerrak/Jammer Bay area. The local economic effect for Jammer Bay region is correspondingly low.

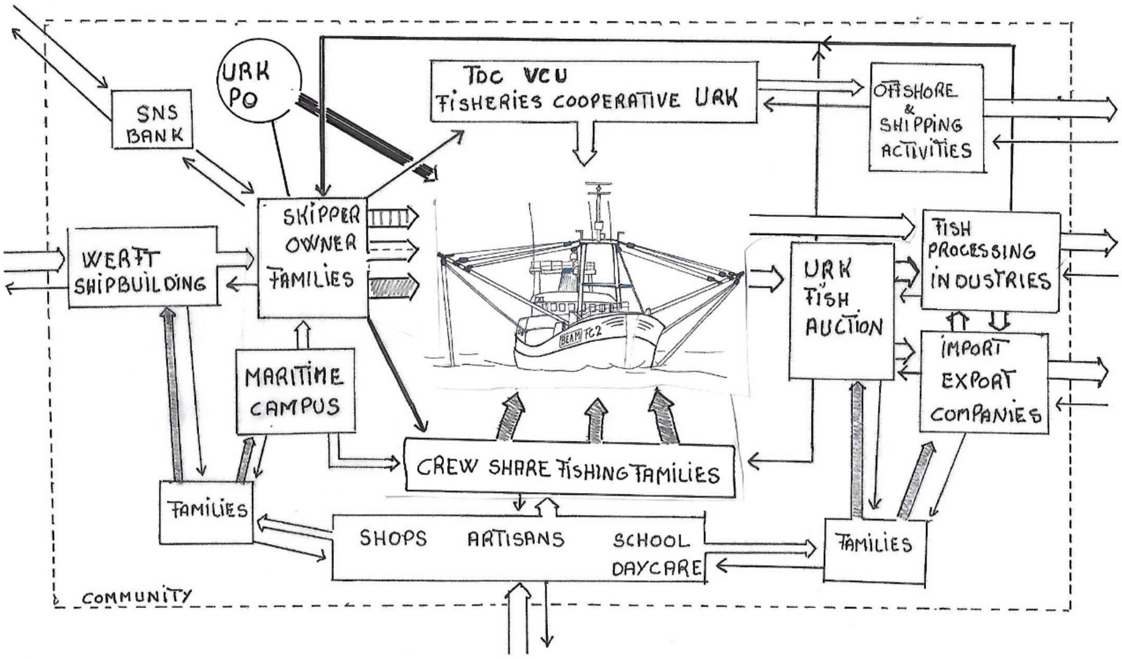

Figure 3.21. Value chain 2, step 2 from the Urk fleet.

The two main Urk plaice processing plants purchase nearly all catches in Thyborøn and are presently readjusting their production and export to process and market Norwegian farmed salmon in order to offset decreased landings of flatfish and round fish from the North Sea. These plants employ engineers as well as technical experts and wageworkers, whose families are living in Urk, and just like the fishing families, they contribute to maintain the local Urk shops, artisans, schools and other welfare institutions.

Until summer 2021, the long distant fishing crews who landed their catches every Friday afternoon in Thyborøn, unloaded directly into refrigerated vans from the Urk Fish Auction. The catches were weighed and registered when they arrived in Urk. After the implementation of new EU landing regulations, these vessels now unload to the Thyborøn landing facility, and the two main Urk fish processing industries then buy it on the internet-auction in Thyborøn.

The induced effects from the presence and performance of Urk's fishing fleet, the VCU *De Maritieme Specialist*, and the fish processing plants, consist of the development of maritime service functions to other offshore activities than the fishing industry. The widening of VCU's product portfolio of maritime services makes Urk a maritime hub that also includes Maritime Urk and the Maritime Campus Urk, where the specialists in beam trawling teach and educate professional fishers as well as other categories of seamen, engine operators and navigators. Specialists and their families including young people under education contribute to the community's magnitude of shops, artisans and services. Concurrent with the decrease of crews in the fishing fleet, the young people pursue alternative jobs and positions in the expanding maritime industry of the community.

The value chains from Fishing Culture 3, the expansive harbour-based fishery
The expansive variant of the self-employed fisher life-mode from Hanstholm, Hirtshals, Skagen and Strandby.

The value chains from the vessels of FC 3 are characterized by a considerable effort, impact, and appropriation of the fish resources in the Jammer Bay area, however a minority of the vessels come from the two local ports. The catches of sand eel in the area are only occasional and trucks drive these landings to the fishmeal and oil plant FF-Skagen. This chain developed after the local plants lost an economic power struggle and consolidation process, in which FF-Skagen concentrated Northern Jutland's processing of 'industrial fish' into protein ingredients in Skagen.

The catches of Norwegian lobster are for a large part sold on contract to Læsø fish industry. The vessel owning skipper families of FC 3 are constantly trying to improve their capability by means of new and larger boats and engines supplied with still more quotas bought up and owned by the skipper families and paid off by the gross income of the vessel. Out of 33 FC3 bottom trawlers between 60-200 GT, fishing in Jammer Bay (2022) only 8 come from the local ports, the rest depart to their long-distant fishery from Baltic, Kattegat and North Sea ports implying unstable landings in the Jammer Bay ports. In the class of 200-500 Brt. FC3 bottom trawlers, 3 come from the local ports, and 17 from the North Sea, Kattegat, and Baltic ports (2022). Hence, the heavy bottom trawling after Norwegian lobster and fish at the wide edge of the Norwegian Slope, the 'Great Reef' inside this 'edge', and the 'Hirtshals Trench' is – together with the absent demand of full documented fishery – attracting expansive bottom trawlers from these vessels' distant home waters, which are plagued by environmental degradation and declining stocks of especially plaice and cod – and in Kattegat forced camera control aboard.

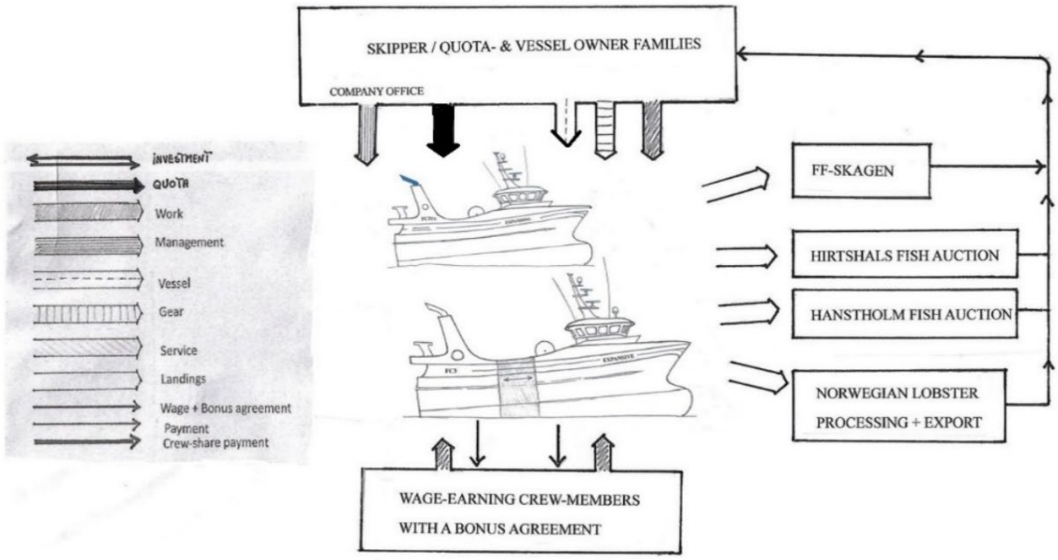

Figure 3.22. Value chain 2, step 1 from Fishing Culture 3.

Based on 2022 account data (average for vessel categories in the Skagerrak), the FC 3 vessels landed fish for a value of 484 mill DKK. The fishing process is less labour intensive than e.g., FC 1, which means that 31% of the value of the landings goes to wages for employees and owners, and 7% of the value of the fish landings are the wage share in the used services, such as fuel, landing, and maintenance costs. The calculated local economic effect is therefore 187 mill DKK, 39% of the value of fish landings. The vessels tend to roam, being less locally connected to the Jammer Bay area. The calculated average wage share of the FC 3 vessels' value chain is therefore probably a maximum for the local economic effects in the Jammer Bay area.

The induced effects from the activities of FC 3 consist of distant fishing's contribution to the survival of expansive bottom trawler skipper companies, coming from crisis-ridden waters (the Baltic, Kattegat and Southern and Eastern part of the North Sea) and fishing harbour affiliations outside Jammer Bay area.

The FC 3 provides food and income in a broader inter-regional sense and contributes to the maintenance of the profile of their fishing communities in Skagerrak, and especially outside the Jammer Bay area (North Sea, Kattegat, Baltic).

The value chains from Fishing Culture 4, the harbour-based coastal fishery
The thrifty and the niche variants of the self-employed share fisher life-mode from Hirtshals and Hanstholm.

The value chains from FC 4 vessels are important and stable supplies of fish to the two local auctions and purchases of Norway lobster. Instead of competing for increased capacity by means of new vessels, these share fishing skippers and vessel owners maintain and gradually modernize existing vessels to avoid being too dependent upon expensive bank loans and having to maintain high landing volumes. Hence, they contribute to the local artisans, service shops and providers of instruments and equipment.

In FC 4, fishers prefer to be as independent as possible upon not only banks and dominant merchants, but also on ‘unreliable’ authorities. This loss of trust in authorities was generated by the refusal in 2023 to reduce the TAC of the North Sea and Skagerrak plaice quota, even though the fishers’ organizations informed authorities about their inability since 2017 to land more than 20 - 30% of the TAC (Figs. 3.23 and 3.24).

Independency, self-employment, and proximity to one’s fishing grounds are much more important cultural values for these fishers than comfort like the ‘luxury cabins’ on the expansive and large-scale company vessels.

Of a total of 118 vessels (2022) in FC 4, half are registered in the two local harbours. They use a wide variety of fishing methods and fishing gears and contribute in this way to maintain a similar wide market for providers of gears and services to the local fishing fleet. This means that the value chain has an important local economic effect on local families’ incomes in the second link of the local value chain.

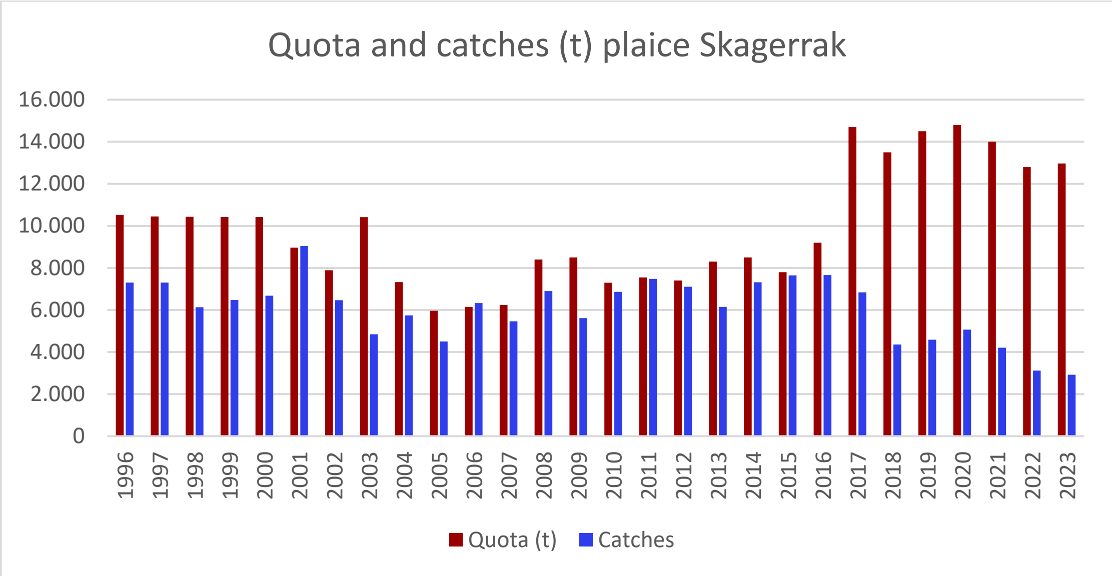

Figure 3.23. Quota and catches, Danish vessels in Skagerrak (3AN). 1996 to 2023 Source: The Danish Fisheries Agency, Fiskeristatistisk årbog 1996-2009, from 2010 online "Danmarks kvoter og kvoteudnyttelse".

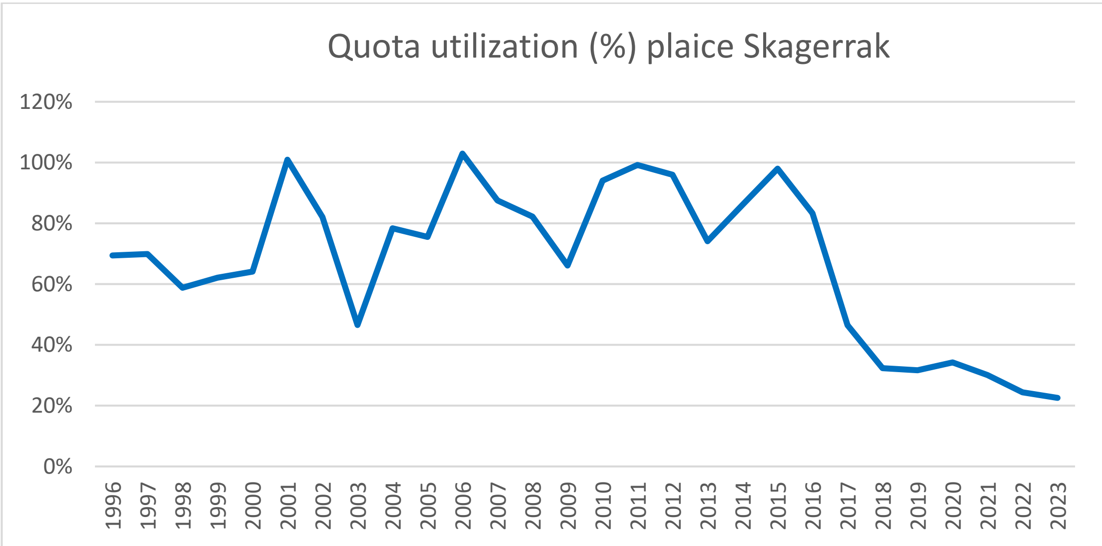

Figure 3.24. Quota utilization (%), Danish vessels in Skagerrak (3AN). 1996 to 2023. Source: The Danish Fisheries Agency, Fiskeristatistisk årbog 1996-2009, from 2010 online "Danmarks kvoter og kvoteudnyttelse").[21]

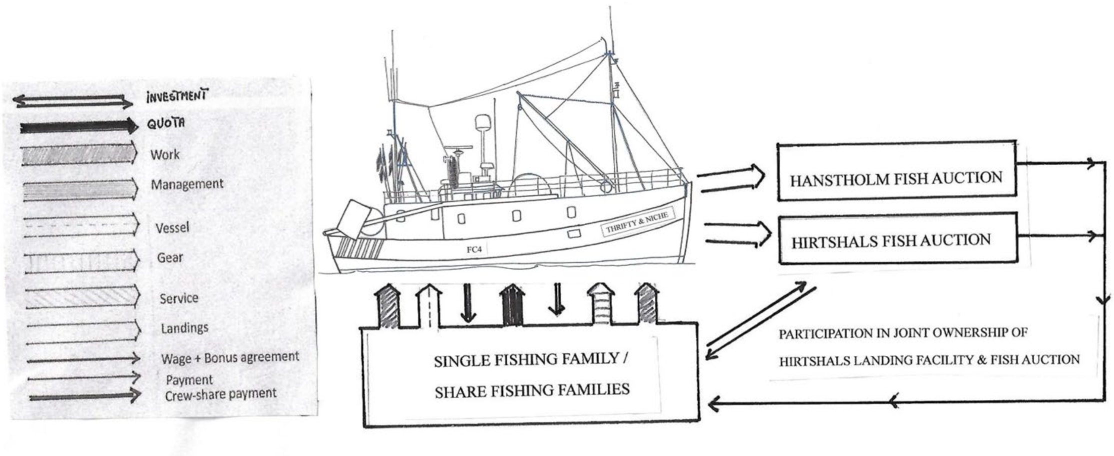

Figure 3.25. Value chain 2, step 1 from Fishing Culture 4.

Based on the 2022 account data (average for vessel categories), the FC 4 vessels landed fish at a value of 256 mill DKK. The fishing process is relatively labour intensive, which means that 41% of the landings value goes to wages for employees and owners, and 8% to the wage share in the used services, such as fuel, landing, and maintenance costs. The calculated local economic effect is therefore 125 mill DKK, equivalent to 49% of the value of fish landings. Because vessels are very local in their field of activity, the calculated average for FC 4 vessels is probably a minimum of the local economic effect within the Jammer Bay area.

[21] Figs. 3.23 and 3.24 are based on data from Fiskeristyrelsen, data for landing statistics and quota utilization (landingsstatistik og kvoteudnyttelse) (https://fiskeristyrelsen.dk/fiskeristatistik/landingsstatistik-og-kvoteudnyttelse#c82836). The appendixes “Alle kvoter [år] som pdf-fil” for 2010 til 2023.Plaice (rødspætte), 3AN, i alt og kvote. For 1996-2009: Fiskeristatistisk årbog tabel 2.2. Danmarks kvoter og kvoteudnyttelse. Plaice 3a. on paper, from 1999 online: https://fiskeristyrelsen.dk/fiskeristatistik/publikationer/fiskeristatistisk-aarbog

The induced effects from the activities of FC 4 have three important features: i), significance for the local auction; ii), significance as presupposition of a mixed household economy; and iii), significance for the local events and festivals around seafood, sustainability, and experience economy.

The first feature is illustrated by the fact, that Hirtshals and Hanstholm prefer to focus on a manned and 'handmade' auction where the byers can inspect the quality of the fish in the boxes on the auction floor. Thyborøn, a harbour where FCs 2, 3 and 7 presently dominate, has changed to an internet-auction (Pefa-auction), where the byers cannot physically inspect the fish quality, but must rely on a detailed quality classification scheme filled in by the auction's employees. This feature is underlined by the fact, that the fisher-owned catch facility in Hirtshals has bought the auction and restructured it to a 'service facility' to improve the facilitating and appropriation of the high-value landings from the FC 4 vessels and FC 6 vessels. The present result of this venture is that the small vessels of FC 4 deliver 33% of the landed value and Danish seiners of FC 6 another 33% of the total landed value at this auction.

The second feature is demonstrated by the fact, that 100-200 small vessels operated by part-time fishers maintain the basis for the continuation of an extensive mixed household business in the area around the port town, combining wage-work, farming, craft, liberal profession, and other occupations with coastal fishing.

The third feature is manifested by the fruitful cultural and industrial environment for events and yearly festivals such as 'Hook and Cook' arranged by Destination North-West Coast and 'The Fish Day', where guests can taste seafood, hear about fishing, sustainability, and fish quality, as well as experience a live fish auction and guided tours by friendly fishers on board fishing vessels. Similar events are also hosted in Hanstholm and Thorupstrand.

The value chains from Fishing Culture 5, the specialized gillnet fishery
The thrifty and the expansive gill-netting variant of the self-employed fisher life-mode from Hvide Sande, Thorsminde, Thyborøn, and Hanstholm.

The value chains from the landings of FC 5 are characterized by the low impact and work intensive mode of operation and fishing method, and by the disappearance of most of the former fleets of gill-netting vessels above 12 m length from the two local ports. It has been still more difficult to recruit young Danish fishers in port towns, who want to be crew-share fishers on vessels operated by another vessel and quota owning family than their own. Hence, in the little class (20-50 Brt.) only three vessels come from the two Jammer Bay ports and three from North Sea ports. In the large class (<100 Brt.), all six vessels come from North Sea ports and operate between 13 and 83 fishing days in the Jammer Bay area (2022).

These unilaterally specialized gill-net vessels are the remaining rest of the formerly large modern fleet of high value gill-netters catching sole, plaice and cod all over the North Sea and Skagerrak from the ports of Hvide Sande, Thorsminde, and Thyborøn. Depending on the number of their days at sea the FC 5 crews land relatively high-valued fish in Thyborøn, Hanstholm and Hirtshals, but do not contribute much further to the value chain in the Jammer Bay area ports.

Based on 2022 account data (average for vessel categories), the FC 5 vessels landed fish for a value of 78 mill DKK. The fishing process is quite labour intensive, which means that 49% of the value of the landings goes to wages for employees and owners, and 7% of the value of the fish landings are the wage share in the used services; fuel, landing, and maintenance costs. The calculated local economic effect is therefore 44 mill DKK, as much as 56% of the value of fish landings. The vessels are specialized, mainly departing from fishing harbour affiliations south of Jammer Bay and operating in the North Sea as well as Jammer Bay. The calculated local economic effect is therefore probably a maximum or higher than the actual effect in the Jammer Bay area.

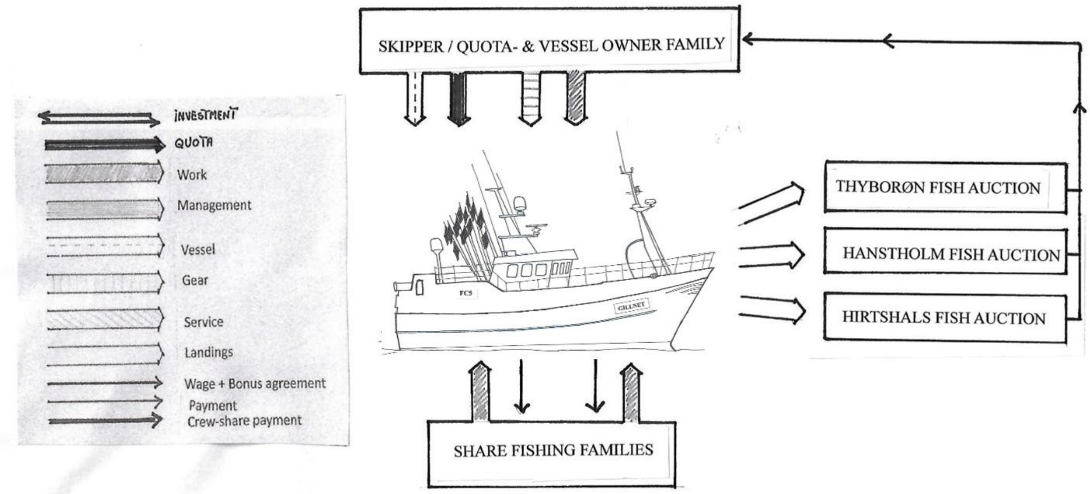

Figure 3.26. Value chain 2, step 1 from Fishing Culture 5.

The induced effects from the presence and performance of the FC 5 gill-net vessels have declined concurrently with displacement of the Danish gill-net fleet by the Dutch and Belgian beam trawlers, which is a conflict caused by the antagonism between the entangling and the bait-digging fishing methods. Furthermore, the gillnets are highly vulnerable where beam trawlers operate. The problems of the gill-net fleet fostered public awareness and concern about the devastating impact by FC 2 on the perceived environmentally low-impact fishing methods as well as on the marine habitats in the North Sea. Even before the third wave of heavy beam trawling since the 1980s hit the Jammer Bay area in Skagerrak, cod overfishing on the wrecks by FC 2 was already gaining public awareness and concern. (Højrup & Nielsen 2024, p. 946, 1022f)

The value chains from Fishing Culture 6, the specialized anchor-seine fishery
The thrifty variant of the anchor-seining self-employed fisher life-mode from Thyborøn, Hanstholm and Hirtshals.

The value chains from the harbour-based anchor seine boats of FC 6 represent the last reminiscent of the huge Danish sea-going seine fleet, that dominated North Sea fishing from Danish ports until a couple of decades after World War 2. Today, fresh caught and properly gutted, iced and stored 'seine plaice' reach the highest prices at the auctions, but concurrently with the collapse of the plaice stock in the North Sea and Skagerrak during the last six years the active fleet of active anchor seiners from Thyborøn has disappeared. Most of the remaining fleet in Hanstholm has been forced to seek the plaice stock out in the Northern part of Skagerrak's coastal sand grounds, and are presently landing their catch in Hirtshals, which the fleet of 3 large wooden anchor seiners presently use as their home-port, even if they are registered in Hanstholm and their crew of share fishers drive by car to Hirtshals from their homes in Thorupstrand and around Hanstholm.

Based on 2022 account data (average for vessel categories), the FC 6 vessels landed fish for a value of 51 mill DKK. The fishing process is less labour intensive than e.g. FC 5, and thus only 32% of the value of the landings goes to wages for employees and owners, and 8% of the value of the fish landings are the wage share in the used services, fuel, landing, and maintenance costs. The calculated local economic effect is therefore 21 mill DKK, 42% of the value of fish landings. The vessels operate mainly in the Jammer Bay and the Tannis Bay areas, though in 2022 very few were registered south of Jammer Bay. While the direct income share follows the crew and the boat-share owners to their home communities, the operational costs tend to stay in the landing port, at present within the Jammer Bay area. The calculated local economic effect is therefore a maximum for the Jammer Bay Area, distributed to the fishing harbour affiliations of the vessels.

This unilateral specialized FC 6 fleet contributes 1/3 of the landed value of Hirtshals auction and, together with the broadly combined and versatile fishing units of FC 4, delivers a high value portion of the auction’s turnover. The appropriation of these near shore hunted fish stocks have to be caught with care, to avoid bycatch of juvenile and under-sized fish. The Hirtshals fishers proposed that the Danish Fisher Organization PO should demand of the authorities to introduce stepwise increasing mesh-sizes that make it possible to avoid bycatch of small and juvenile fish, but the proposal was promptly turned down by the organization.

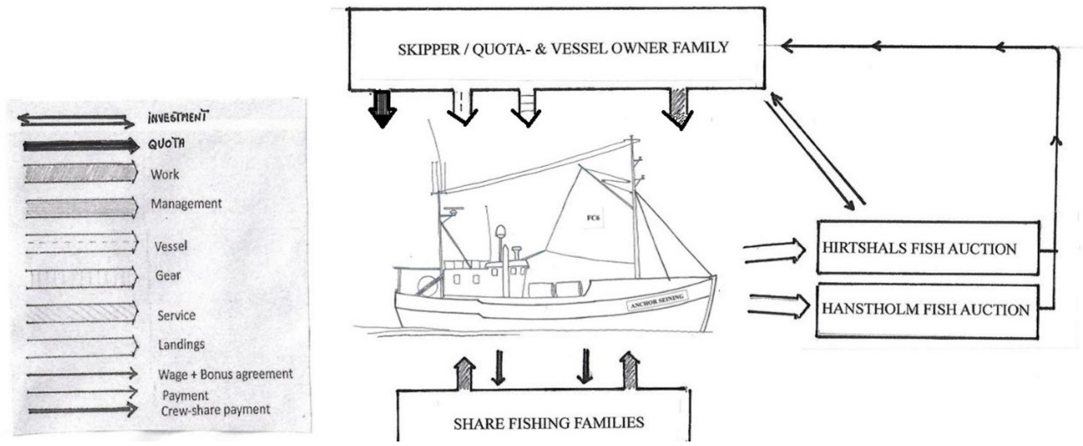

Figure 3.27. Value chain 2, step 1 from Fishing Culture 6.

The induced effects of the presence and performance of the wooden anchor seiners consist not least in the attractive sight of the light blue vessels in the harbour of Hirtshals, where they are enjoyed by locals as well as tourists. The old-timer anchor seiner (HG 159 Johs. Hejlesen) is owned and operated by local organizations in Hirtshals and informs about anchor seining at an exhibition on the quayside where the active anchor seiner fleet is moored when the crews visit their families between each trip on the sea. This fleet contributes to the environment of the festivals and events in Hirtshals, attracting guests and locals around debates on fishery politics, sustainability, and food qualities.

The value chains from Fishing Culture 7, the profit-seeking large-scale fishery
The expansive variant of the entrepreneurial life-mode from Hanstholm, Hirtshals, Skagen, Nexø, Rörö, Öckerö, Fotö.

The value chains from the vessels in FC 7 are differentiated between the (mainly) demersal, industrial and the pelagic vessels respectively. As the unilaterally specialized pelagic vessels employ only a minor part of their yearly circle in local waters, it is the demersal and industrial trawlers' activity in Skagerrak that delivers the largest contribution from the fishing grounds in Jammer Bay area to the direct value chains of FC 7. Only a few of these vessels are registered in a Jammer Bay fishing harbour affiliation, whereas twice as many come from the North Sea, Kattegat, and Baltic ports (2022). These distant-water fishing vessels land their catch wherever they anticipate the highest prices or lowest costs of operation (use of fuel to reach a landing facility). Hence, many of them are regarded as 'unstable' by the catch facilities and auctions of the two Jammer Bay ports.

The crews of FC 7 are recruited from all parts of Denmark. The vessels are being constructed at yards in the North Sea and Kattegat harbours and most of these vessels are kept in repair by service providers in their hometowns. With its access to risk capital, this FC is the one that accumulates most transferable quotas as company property, despite the difficulties they encounter when it comes to develop capital, demanding large-scale advantages in the demersal fisheries (with absent fish shoal formation) because of their huge fuel consumption (due to the suction caused by the increased catch current speed near the funnel part of the trawl)

Based on 2022 account data (average for vessel categories in the Skagerrak), the FC 7 vessels landed fish for a value of 698 mill DKK. The fishing process is the least labour intensive of the FCs, with only 21% of the value of the landings for wages for employees and owners, and 5% of the value of the fish landings are the wage share in the used services, fuel, landing, and maintenance costs. The calculated local economic effect is therefore 179 mill DKK, as low as 26% of the value of fish landings. Of the 27 vessels, 9 are owned by companies in Jammer Bay ports (even if most pelagic vessels land their catch in Skagen). Hence, the local economic effect for the Jammer Bay area of FC 7 vessels is probably significantly lower than the calculated value, where fishing communities in e.g., Bohuslen and Bornholm might benefit more of the local economic effects.

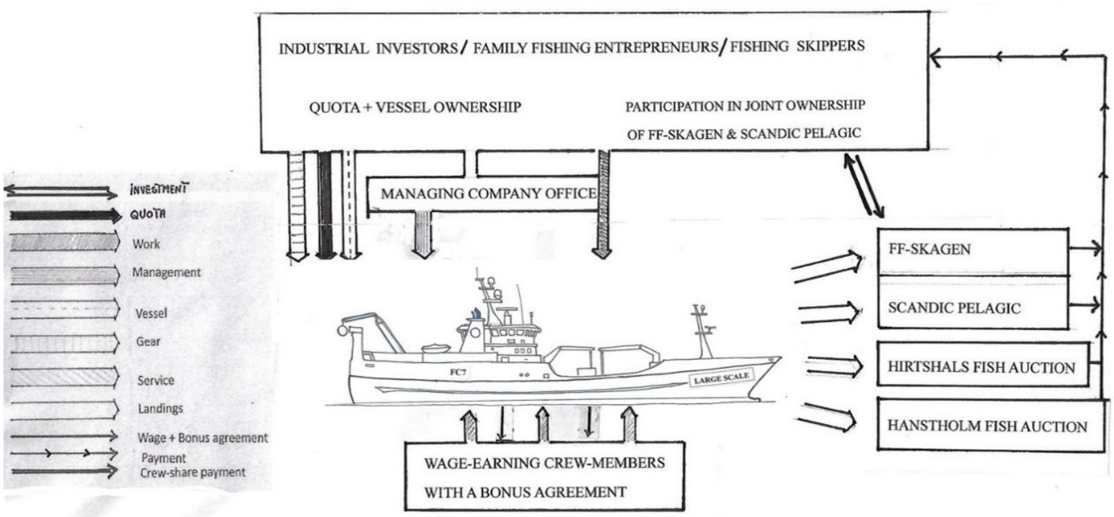

Figure 3.28. Value chain 2, step 1 from Fishing Culture 7.

The induced effects from the presence and performance of FC 7 are primarily located in Skagen outside the Jammer Bay area, where Karstensen's Shipyard and its many subcontractors create the employment and family incomes that make it possible to keep permanent residents in Skagen despite the disappearance of most of the local vessels of FCs 3, 4, 5, and 6 from this community. Furthermore, the presence of many large-scale pelagic vessels at the equipment quayside maintains the visual impression of being in a ‘fishing harbour’, which is an important part of the identity that tourists enjoy. Tourists visiting Skagen experience the connection between the motifs of the fisherfolks and vessels by the famous ‘Skagen painters’ from around 1900 (visible at the local museums) to the modern fishing fleet and industry. It is noted that only an insignificant part of these vessels’ landings is caught in Jammer Bay.

3.3.8 Fishing Communities

Thorupstrand – a Jammer Bay beach landing site

Thorupstrand is a community located around a landing site on the open beach at the north facing coast of central Jammer Bay area. The fleet of beach-landing trading and fishing vessels has employed most of the families of the little community behind the dunes since ancient times. After 1900 the fish export was eased by the railway and the share fishing families modernized their crafts, installed engines and winches aimed at the operation of anchor seines. Usually, the size of the fleet varies between 10 and 20 vessels. Each vessel can switch between and combine longlining, trap fishing, gillnetting and anchor seining in a broad, versatile mode of operation. Around 150 days a year these fishing units catch a wide spectre of fish species that stay in or visit the mosaic of stone reefs and sand banks in the Jammer Bay area during a yearly cycle. The self-employed fishing families cooperate in share-organised crews and represent the thrifty and niche-oriented Fishing Culture (FC)1.

When the demersal and benthic fishing quotas were privatised in 2006-2007, Thorupstrand's survival strategy initiated the formation of a cooperative community quota company incorporating all share fishing families, independently of their (life- and family-cycles-depending) status as boat-share owners, gear-share owners, and crew-share fishers. This company, or 'guild' in fishers’ language, Thorupstrand Kystfiskerlaug, owns 5,3% of the cod quota and 10,37% of the plaice quota in Skagerrak plus 5,28% of the sole quota and 3% of the cod quota in the North Sea. The members have equal access to the guild's 'yearly amount' of each species of fish to be caught, and each fisher has one vote at the assembly.

As a major quota owner, the guild's fishing families are self-consciously concerned about how to avoid depletion of the fish stocks and damage to the habitats in Jammer Bay area and the surrounding waters. The guild has invested 50 Mio. DKK in necessary quotas and must pay interests and instalments to the local savings-banks. These fishing families see themselves as guardians and custodians of the sea based on their experience and ecological knowledge and cooperation with marine biologists and geologists. Since 2016 they have witnessed a systematic destruction of their fishing grounds and displacement of their vessels from the central Jammer Bay by a huge wave of large FC 2) beam-trawlers (see Appendix 3.A5). I 2023 the fleet of Thorupstrand could catch as little as 65 tons plaice out of their plaice quota’s 1000 metric tons, and 56 tons cod out of their 135 metric tons cod in Skagerrak. Hence, the Thorupstrand fishing families do not think it is possible for the fishing community to survive a continuing beam-trawling in Jammer Bay.

Hirtshals harbour
Hirtshals is a Jammer Bay harbour with a variable fishing fleet.

A large fleet of smaller vessels, which accounts for 1/3 of the turnover measured by value at the auction are affiliated to Hirtshals harbour. Many of these vessels are so small that they do not have Automatic Identification System (AIS) on board. This means that when planning the marine spatial area, the large fishing area south of Hirtshals along the coast does not appear in the available data. Many of those who fish with smaller boats either with gillnet or small trawlers are partly commercial fishers, which means that they have another job on shore. The group deliver daily mixed fish of high quality. They land plaice, sole, monkfish, haddock and hake when they are in season. In addition, roundfish species that thrive in the areas such as pollack, coalfish and ling, if it is deep enough, are landed, in addition to cod. The small boats constitute the basis of the auction.

Another 1/3 of the turnover comes from the Danish seine vessels. Both groups are weather-dependent, which is why the harbour is extra important. Several Danish seine vessels now have Hirtshals as their landing port, as the last of the plaice stock (in 2022) inhabit the sea area between the northern end of Jammerbugt and Skagen Reef.

The larger vessels incl. the foreigners, apart from FC 2, most often land in the port closest to their fishing grounds. For the smaller vessels, the transport time is decisive. This means that many land in Hirtshals, as most of the fishing takes place in that area. The very largest vessels – the pelagic ones – sail to Skagen regardless of where they catch the fish to land at FF Skagen A/S.

Although many vessels land Norwegian lobster in Hirtshals, only a small part comes to the auction. Most often, they are driven directly to Strandby.

Cooperative fish auction
Historically, auctions were privately owned. In preparation of a generation change, the Hirtshals auction entered cooperation with the auction in Strandby to form Fish Auction Nord. Fish Auction Nord split up after five years and the Fishers' Catch Landing Facility in Hirtshals, which is a cooperative with limited liability owned by the fishers, bought the auction and a director was hired for both the Hirtshals auction and fish landing facility.

It is crucial that the auction is fishing-owned, because it gives the small fishers good conditions to land their fish and at the same time take advantage of the high quality and value that can be achieved thereby. The auction picks up the landed fish for their members free of charge in Løkken, Hals and Skagen - if there is one box - and at the same time delivers the empty boxes to the fishers. They also pick up fish boxes during the weekends, as this is often when the part-time fishers land, in order to get the best quality for the auction. The auction is always "open", so fish can be landed, and boxes delivered 24/7, which requires employees willing to work flexible hours.

The auction considers itself as a service business. It is important that the auction supports both the fishers and the buyers (some have businesses in Hirtshals). Everything with fish is about trust, so it is important for the auction to create trust both to the fishers and to the buyers. It is important for buyers to know what they are getting. The buyers also know the boats and know who the skipper and crew are on the individual trips when it comes to vessels that have multiple crews.

By attracting as much fish as possible, the auction supports the fishing industry with processing and sales, the service industry, and logistics in the city. From the auction's point of view, it is crucial that it is a "floor auction" and not a pefa auction that only takes place online and where the buyers are not physically present.

Port-related companies
A variety of port-related craft businesses means that the harbour attracts many ships. When they land in Hirtshals, they can have a wide range of repairs done. Absolutely crucial is the 24/7 service provided and that quality is assured. Fishing must take place when the fish are there, so the boats cannot afford to lie still.

The large fleet of the thrifty and niche FC has since 2016 been seriously affected by the Dutch beam-trawling long-distance fishery (FC 2) in the shallow waters along the coast in Jammer Bay area. The beam-trawlers with their heavy gear move larger stones around on the seabed, negatively affecting the habitat and the fishing grounds and negatively influencing the activity of the small thrifty and niche trawlers. This activity from FC 2 is threatening 1/3 of the landings to the auction. Hence, the community is exposed to this antagonist co-existence between the two FCs.

Hanstholm – North Sea and Jammer Bay harbour
In contrast to Hirtshals, Hanstholm Fish Auction is a private profit-seeking business, and the auction in Hanstholm is important for local boats belonging to all Fishing Cultures as well as expansive and large-scale bottom trawlers and fly-shooters from other North Sea countries (German, Belgian, French, English, Scottish). Like Hirtshals, Hanstholm is a centre for landing and distribution of fresh fish for human consumption at the national and international level (especially southern European markets). More detailed information about the specific profile of this auction is required.

Thyborøn - North Sea harbour
Thyborøn is a North Sea port, the closest larger port South of Jammer Bay. Since 2015 official registrations record that 2 to 5% of the total landings of fish for consumption in Thyborøn originate from Skagerrak. Thyborøn is therefore mainly of interest as a landing place for most of the Dutch beam trawlers.

Thyborøn was in 2022 the second largest Danish port in volume of landings. As industrial species dominate, Thyborøn is the fourth largest port for fish for consumption. Most important consumption species were plaice followed by herring, and cod (in value plaice, cod, and monkfish respectively).

The fleet has, as in most other ports, been reduced over a period of years. According to the official statistics (Fiskeristyrelsen.dk)[22], there are 83 registered vessels in 2022 of which 65% are

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[22] Fiskeristyrelsen Registrerede fartøjer pr. 31/12, Periode: 2022, Erhvervsstatus: Erhverv, Fartøjstype: no marking, Havnekending: no marking, Basishavn: Thyborøn, Længde: no marking, Tonnage: no marking.

gillnetters and vessels below 12 meters. Most of these are no longer active and have disappeared concurrently with the diminishing fish stocks in the coastal waters. The tonnage is primarily on the trawlers, fly-shooters and the little fleet of anchor seine vessels, which also account for the majority of the landings. Most of the Fishing Cultures can be found in this relatively large harbour.

The fish auction of Thyborøn, “Danske Fiskeauktioner”, is privately owned. The auction takes place online only. A few buyers are present at the auction, buying on behalf of a range of industries and fish mongers. The online buyers depend on precise classification of the quality made by the auction. The auction offers logistics and fast transportation of the fresh fish to the whole of Europe. Thyborøn has traditionally been the main port for landings by Dutch vessels. After a regulatory tightening transit fish must be weighed and registered in the landing port. Since then, the main part of Dutch landings is sorted and sold via the Thyborøn auction. The main part of plaice and cod at the auction are bought by Dutch buyers and trucked directly to Holland/Urk. Up to 20% of the landings are sold for local fish processing (Hanstholm) another 5% for processing abroad.

There are a few small processors of fish for human consumption in Thyborøn. One of the two large processors of industrial species for fish meal and oil, TripleNine, is located at the port of Thyborøn and attracts direct landings from Danish and foreign vessels.

Thyborøn is dominated by the fish and other marine industries. The port has expanded in the last years both with better facilities for the huge pelagic vessels for TripleNine, and facilities for cargo and service for the offshore wind industry. The port offers 24/7 services for fishing and other vessels, as well as a floating dock, shipyards, and craft businesses, which are oriented towards the fisheries while also servicing other sectors.

Urk - Dutch harbour, southern North Sea

The city of Urk was originally located on an island in the Zuiderzee. Characteristic of the city are the families with many sons, who have formed the basis for large family businesses. Fishing traditionally took place with static gear as pound-net, gillnet and longline in the large sea area that made up the Zuiderzee and at the islands of Zeeland in the north of the Netherlands. Some also sailed their large boats to the North Sea and fished.

When the large dike, “Afsluitdijk”, which is 32 km long, was completed in 1933, 3/4 of the area was cut off from the North Sea. The Urk fishers thereby lost their main fishery as the fish stocks diminished and changed.

In the city they talk about the "wonders of Urk". The first was when fishing changed to North Sea fishing for sole and plaice. The second, when they entered the fish trade and processing industry. It reflects the entrepreneurial spirit in the city.

In the 1950s, the Dutch and especially the fishers from Urk developed beam trawl fishing, inspired by the German beam trawlers. The crew on the ships from Urk were traditionally family members or people from the town. About 10-15 years ago, they started recruiting labour from, e.g., Poland, due to cheap wages. Otherwise, the fishing is conducted as share fishing.

Several family businesses have many beam trawlers – for example 7 – and Urk is the place in the Netherlands that in legal terms has changed the largest part of their beam trawlers into foreign registered vessels (‘flag vessels’). These are vessels that never visit their registered fishing harbour affiliations, but fish on the foreign country’s quotas. Several family businesses are joint stock companies, but it is exclusively members of the family that own the shares.

To overcome rising fuel prices, an experimental fishery with pulse fishing was developed from 2009. Pulse fishery sends electricity down to the seabed, "this makes the muscles of the fish contract, whereupon the fish detach from the seabed and land in the net." (LEI Wagening UR 2014). However, pulse fishing was banned in the EU, but since 2007, 5% of the beam trawl fleet of all Member States has had a temporary dispensation in the southern North Sea. The Netherlands got a dispensation for experimental fishing with pulse for 42 vessels and a further 42 vessels in 2014. Pulse fishing also as experimental fishing was banned by the EU in 2021, and the beam trawlers had to go back to the traditional fishing method.

Catches of plaice have fallen sharply in recent years. At the same time, the beam trawlers use 30-35,000 litres of diesel in 5 days of fishing. In 2023, the Netherlands would therefore carry out a large scrapping round.

Since landings of all types of fish have reduced significantly in Holland, logistics have collapsed, and auctions are closing. Several beam trawlers are currently being re-rigged to twin riggers or fly shooters.

There have been around 75 large beam trawlers in Holland, a large part was scrapped in 2023. This means that the fishing industry loses both expertise and the youth. Some have suggested downscaling the vessels and restructuring the fishery, where it is important that it is on a 10-year term, otherwise the entire infrastructure collapses.

Parlevliet & Van der Plas B.V. buys up quotas and ships including beam trawlers. On their big vessels only a minor part of the crew has experience with fishing, the rest are technical engineers and factory workers. The crew gets a basic salary and a bonus at the end of the year - "But because the company owns the whole line from catch, processing, freezing, transport until the super-market who decides where the profit is?" (personal communication, Dutch fisher, June 2023).

The auction in Urk was founded in 1905, and as the Urk North Sea fleet experienced great growth, the Urk North Sea fishers decided in 1962 to drive their catches to hometown and auction their fish at the Urk fish auction. It created a basis for fish traders and the following year Urk-Export was founded, with the aim to market the fish in Europe. They were also involved in the development of a market for plaice fillets.

In 1922 Urk Fisheries Cooperative VCU was founded and according to its own statement, it has since then been a leading name in the fishing industry. It was founded by the fishers who, by joining forces to purchase gas oil and lubricants, allowed them as an organization to purchase these wares collectively and cost-effectively. Today they also target coastal and inland shipping, the dredging industry, and industrial companies besides the fishing industry. VCU does not only deliver service in Urk but drives out to the North Sea ports where the fishers from several countries land. They cover virtually all service areas, also making and repairing fishing gear. They also drive abroad and have 24/6 service (VCU n.d.).

The companies at Urk that used to live by processing fish from the North Sea and Skagerrak, especially plaice, now process 90% of other fish, largely imported cod and farmed salmon from Norway. The city has a very large industrial area in relation to its size where fish processing and trade is the main industry. But there is also a large shipping industry and several shipyards. The city's fishing fleet has Urk as their fishing harbour affiliation, but the vessels rarely come to the city anymore.

3.3.9 Fishing Cultures as a framework for development of diversity and co-existence of commercial fisheries

Herein, we have identified and described, in a systematic way, the diversity of distinct kinds of fisheries operating in the Jammer Bay area. We have organised the many fisheries elements and modalities, such as vessel lengths, engine sizes, gear types, profitability measures, crew sizes, quota and ownership, into four core features, and provide an operational framework that can be applied to identify cooperation, contribution and competition of ecosystem resources and economic and societal sustenance at the local, national and international level. This enables a paradigm shift from a focus solely on economic maximisation thereby neglecting the societal and ecosystem components of the system in development of long-term sustainable management solutions. The Fishing Culture framework is based on a theoretical concept of what we specify as the four dimensions of a "Fishing Culture" supported by detailed descriptions with conceptual models of 7 uniquely distinct Fishing Cultures of the Jammer Bay area. Each Fishing Culture is identified and specified as a particular unity of life-mode, mode of operation, fishing method and community (fishing harbour affiliation). This framework can be further developed for other geographic areas by encompassing additional Fishing Cultures operating in those areas.

The empirically realized Fishing Cultures operating in the 4 ICES squares of the Jammer Bay area exploit and impact the marine environment in different ways and contribute to the sustainability of fishing communities and the general society at quite different levels and magnitudes.

Specifying the four dimensions of each Fishing Culture makes it possible to shed light on the ways the 7 Fishing Cultures co-exist and impact each other in Jammer Bay. The actual forms of co-existence appear to be either unproblematic or antagonistic, depending on where they are operating in the area and how each of them impacts the seafloor, the marine species composition, the mode of operation, and the fishing methods of each other.

Co-existence and competition between Fishing Cultures

The co-existence between the modes of operation of some vessels with a unilaterally specialised mode of operation and other vessels' broadly complex, versatile mode of operation turns out to be problematic in the Jammer Bay area. The versatile mode of operation is especially seen in FCs 1 and 4. The unilateral specialised mode is the form in FCs 3, 5, 6 and 7, and especially in FC 2.

There is a general conflict between the two opposite modes of operation, where unilateral, and very mobile vessels can harvest the areas when the target species is in high season (in volume or value). As a strong competitor they can partly displace the more local, versatile vessels from the areas they fish year-round for a broad range of species also outside the high seasons.

This problematic co-existence is especially clear in the shallow and narrow grounds along the shores of Jammer Bay between FCs 1 and 2. The large mobile vessels of FC 2 can roam around a wide range of fishing grounds in the EU-waters. Since 1980, a fleet of 500 GT long-distance vessels from the Netherlands, operating unilaterally specialised beam-trawls in the North Sea and adjacent waters, have entered the shallow grounds of the central Jammer Bay area several times and stayed there in the high season for plaice during several years in a row each time, until the fishing grounds were exhausted. Each time this migrating unilaterally specialised beam-trawling has – according to local single-trawler, longliner, gillnetting and anchor seining fishers in this study - undermined major parts of the year cycle of the local vessels' broadly complex, versatile mode of operation and the unilaterally specialised mode of operation with gillnets and anchor seine.[23]

The co-existence between the fishing methods of FC 2 and the FCs 1, 4, 5, 6 turns out to be antagonistic in the Jammer Bay area.

The antagonism between catching methods arises when opposite methods cannot be used in the same fishing area at the same time. In the Jammer Bay area, most of the local stakeholders find that this is the case because: 1), beam trawling contributes to undermining the durableness and continuity of the habitat and 2), gillnetting and anchor seining (with each boat's several km long net-chains and seine-lines) restrict the beam trawlers' freedom to move in the same area. Hence, one FC may limit or prohibit other FCs directly by its fishing gear's impact on the competition for access to core fishing grounds and the fishing resources, and indirectly due to the potential time-lag in recovery ecosystem provisioning (e.g., of fish stocks and seabed habitats) – if recovery is at all possible.[24]

Because the audio-visual herding (anchor seining), the gill-seizing/entangling (gillnetting) and the hook baited fish attracting (longlining) methods catch their target species implying an extremely low impact on the habitat and food-chain feeding the fish species, these fishing gear types and methods are – according to local fishers in this study - able to exploit a wide spectre of fish species in Jammer Bay area's local biotopes all year round and year after year, i.e., without exhausting the marine food-chains feeding the fish stocks. Hence, from the perspective of stakeholders from the FCs 1, 3, 4, 5, and 6, they cannot coexist with beam trawling due to severe impacts on the seabed (Bylow 2023). According to stakeholders from FC 2, deploying beam trawls 'open the ground' with their gear and attract fish, a method they conceive as an advantage for gillnetters, anchor seiners and long liners too, if these are willing to fish sufficiently close to the tracks of the beam-trawlers.

The antagonism between the fishing methods and viewpoints becomes exaggerated by the fact, that beam trawling is forced to operate on relatively shallow grounds (where anchor seining and gillnetting is going on) because towing the heavy tickle chains and chain matts becomes too fuel consuming if it must operate at the deeper grounds in the Jammer Bay area.

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[23] See also: Højrup & Nielsen 2024, p. 880ff.

[24] Examples are described in Højrup & Nielsen 2024, p. 879, 885ff, 913ff, 1037ff.

To get rid of this conflict it is necessary to choose which of the two groups of methods will be allowed to operate in Jammer Bay area.[25]

Interview information sheds light on oppositions between Fishing Cultures in the Jammer Bay. The contribution from the fisheries of the FCs to the local communities differs, as described in the value chain section 3.3.7, and will be discussed below. In this regard especially FC 2 has a very low (or zero) contribution in the Jammer Bay area, as the vessels are channelizing the caught fish from the Jammer Bay area to North Sea auctions and further to processing industries in the Dutch fishing harbour affiliations and fish processing hub (in Urk) of FC 2.

The registration and official statistical catch and landings data are not reliable enough to shed light over the real amount of fish caught by vessels from FC 2. Concurrently with the reduced presence of the plaice stock (in 2022 only 25% of the total Skagerrak plaice quota was caught, see Figs. 3.23 and 3.24) and the EU authorities' continually raising of the Total Allowable Catch of plaice, the fisheries management did and does not protect the plaice stock and its feeding grounds in Jammer Bay against a too high fishing pressure. Despite the low quota percent (in Skagerrak belonging to Dutch fleet) FC 2 has met no restrictions to intensify the time used for fishing after plaice in Jammer Bay. This development and its impact are reflected visually in the diagrams (Figs. 3.29 and 3.30 below) showing the development of TAC on plaice, the amount of plaice landed by FC 1 (from the central part of Jammer Bay, entered by FC 2), and the maps showing the officially registered presence of FC 2 in central Jammer Bay (even if this registration is incomplete).

The above-mentioned interviewed fishers' descriptions of antagonist practices and viewpoints related to modes of operation and catching methods turn out to be very clear when put into perspective by the combined dimensions of each Fishing Culture. The niche variant of the self-employed share fishing family life-mode (FCs 1 and 4) operates with vessels < 25 GT and has a limited field of activity and range of action (< 30 miles from the coast). Hence, these FCs are particularly vulnerable to the long-distance beam trawler fleet (vessels around 500 GT) of the expansive variant of the family business life-mode (FC 2), from the Dutch fishing communities (primarily Urk). As the fishers from FCs 1 and 4 explain, the FC 2 vessels move constantly from one area to another in the North Sea, alternately entering, exhausting and leaving these areas depleted and degraded.

The latest wave of beam-trawlers entering the central part of Jammer Bay reached the area in 2016-17 and has continued until 2024, when the presence of plaice and cod almost disappear from the coastal and central part of Jammer Bay. Fishers (among the stakeholders) realizing FCs 1, 4, 5, and 6 find themselves caught in an antagonistic relation to large beam-trawlers realizing FC 2 due to different use of area and worldviews. Moreover, local stakeholders realizing FCs 1, 4, 5, 6 consider the beam trawlers perception of their impact as far too short-sighted and not considering the long-term degradation of the seabed. Stakeholders realizing FC 2 find that their colleagues from the FCs 1, 4, 5 and 6 have to adapt to a longer ranging fishery, that allow the exploitation of alternate fishing areas, while local grounds recover. These contrasting points of view are at the core of the antagonist character of this coexistence.

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[25] See also: Højrup & Nielsen 2024, p. 1036ff.

To survive the privatization of demersal and benthic quotas (2006/7) the fishing families of Thorupstrand created the Guild of Coastal fishers and invested in 10% of the plaice quota and 5% of the cod quota in the Skagerrak. From 2013 to 2017 the Thorupstrand crews caught their common plaice quota from May to December and delivered between >1/2 and 1/3 the total amount of plaice landed to Hanstholm auction (Fig. 3.20). From 2017 the Thorupstrand fishers lost still more of their plaice and cod fishery, which in 2018 fell to 30% of the Guild's yearly amount of plaice-quota and in 2023 the catches were diminished to below 20 % of the quota. This development seriously threatens the survival of the Thorupstrand fishing community because it undermines its economic foundation and sustainability.

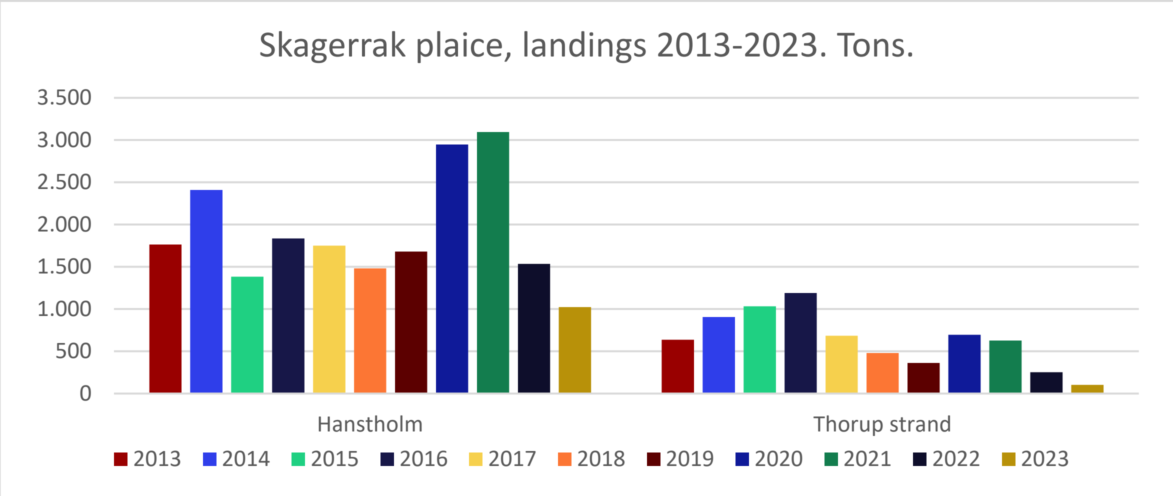

Figure 3.29. Landings of plaice from Skagerrak 2014-2023, Hanstholm and Thorupstrand. For all landings of plaice from Skagerrak, see Appendix 3.A6. Source: Fiskeristyrelsen, dynamic table for landings[26].

According to stakeholders from Hirtshals' large fleet of the thrifty/niche boats, the FC 4 has since 2016 been seriously affected by the Dutch beam-trawling (FC 2) in the shallow waters along the coast in Jammer Bay area. Stakeholders from gillnetting, seining, and single trawling boats state, that the large beam-trawlers move big stones around on the seabed causing the small thrifty/niche fishing trawlers and seiners to be unable to use the impacted fishing grounds and preventing anchor seining on the shallow grounds by FC 6. Since the activity of FC 2 is perceived to directly or indirectly negatively affect the landings to Hirtshals auction, threatening its viability, the community is exposed to what the local fishers to this study describe as an antagonist coexistence.

The local stakeholders from all Fishing Cultures fear the consequences of the high, constant, and still increasing fishing pressure in the outer part of Jammer Bay. They point at the combination of an extraordinary high fishing pressure in Skagerrak and Jammer Bay based on attraction of vessels from other devastated sea areas in the North Sea, the Baltic Sea, and Kattegat and

[26] Landed weight, plaice, all conditions, from Skagerrak, all nations, landings in Danish ports only.

unregistered catches and discard due to 'too small' trawl and seine mesh-sizes, and lack of implementation of full documented fishery.[27]

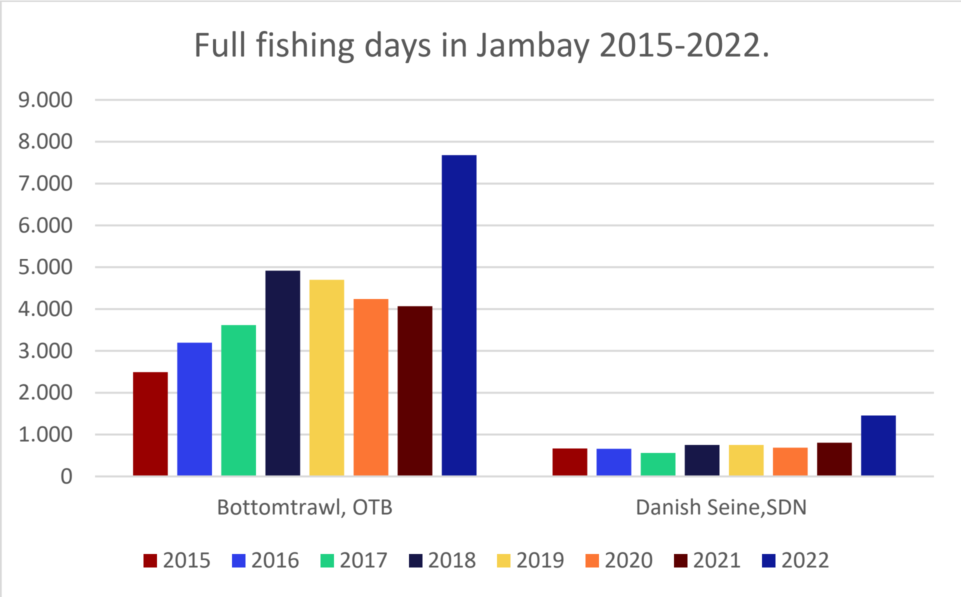

Figure 3.30. Number of fishing days (24 hours) in Jammer Bay 2015-2022, Danish seine and bottom trawl. Source: DTU-A, Shiplist. The increase in Danish Seine reflects that the FC6 seiners have moved to the northern part of Jammer Bay.

The experiences of the local stakeholders of this study and the frequent closures by the fisheries authorities of particular areas because of intensive presence of juvenile fish[28] indicate how difficult it is to avoid bycatch of juvenile fish in the trawl and in the seine fishery if the mesh size is too small and the trawl-net becomes too loaded with fish. The fishing pressure (fishing time) in the outer parts of Jammer Bay area is by stakeholders across the Fishing Cultures perceived as one of the possible conditions behind the decreasing number of cod entering the sand eel and sprat rich feeding grounds in the central and coastal parts of Jammer Bay as part of their yearly cycle. Hence, this is perceived by local stakeholders to reduce the foundation of high value, niche, and thrifty coastal fishing (FC 1) from the landing sites on the open beach and from local harbours (FC 4).

3.3.10 Fishing Cultures' contribution to the local economy of fishing communities

Apart from the large pelagic vessels of FC 7, there is no permanent relation between Fishing Cultures and the size of crew members' income. The income-level varies with the conjunctures and changing conditions for the distinct fisheries and species in Jammer Bay. The levelling of income is partly due to the constant flux of individual fishers between the different Fishing Cultures. It is often presupposed, that a large expansive trawler yields a larger or more convenient income to the fishing families than a small line or gill-net boat. An illustrating example of the opposite is demonstrated by two (FC 3) boat-share owners of a modern and extended 297 GT

[27] The stakeholders do not mention gillnet mesh sizes because gillnetters usually use large sizes with the intent to avoid wasting time on entangling by hand too many under-sizes fish.

[28] https://fiskeristyrelsen.dk/nyheder/straksregulering-tidl-bilag-6-meddelelser/maalgruppe/generelt

twin-trawler in Hanstholm who sold their ship and replaced it with a 10 GT longline boat. From the perspective of the families this shift (in our terminology: from FC 3 to FC 4) was a preferable solution instead of ‘struggling to make ends meet’ by expansive trawl fishery. Another example is the young man, who after having bought a house, married, and settled down in his native town returns from his well waged position on a large-scale pelagic trawler registered in a North Sea port town to the self-employed role as share-fishing skipper of a beach landing gillnet and anchor seine boat in Thorupstrand.

The actors of the Fishing Cultures contribute in various ways to the fishing communities. The presence of the vessels, the landings, the handling of landings and varying degrees of settlement in the community all contribute to a vivid community, with social and cultural activities linked to the fisheries. This has been qualitatively described in relation to the fishing cultures and the description of their communities as home ports or landing sites for fishing harbour affiliation of the vessels.

The fisheries also contribute in economic terms to the community. Generally, economic analyses focus on profitability from an investor and wage-earner perspective, or from a national economic perspective. This thinking is aimed to improve the allocation of labour and capital to the most profitable activities. In this study, the focus has been on the Local Economic Effects. The analysis therefore focuses on the spatial distribution of the income generated by fisheries rather than the private business or national economic profitability. This is central for the local communities and regions that hold the natural resources, which are extracted, and therefore bear the burdens of the ‘externalities’ (e.g., the decreasing durableness of productive marine habitats and fish stocks caused by highly ‘profitable’ fishing business models). From the local community’s economic, cultural, and organic sustainability perspective, the business economy of the most profitable vessels may be of less interest than the community’s totality of integrated value chains, especially if the (negative) externalities are local and the profit is appropriated elsewhere (i.e., outside the community, the region, or the country). Following this perspective, it is interesting, that FCs with a high level of income contribution to the local economy are found in the segments normally (in business and national economics without an integrated socio-cultural and organic sustainability perspective) regarded as less valuable because they are primarily seen as low productive and low profitable fisheries.

For the Local Economic Effect (LEE) analysis, focus has been on the income generated by the vessel, income for the owners and employees/share part fishers (the direct effect) as well as in the sectors supplying the fishing activity, which is assumed mainly local (fuel, maintenance and landing related costs) (the indirect effect) (See Appendix 3.A4 for method). The share of costs for wages and local supply-costs differs considerably between the FCs. The LEE therefore also differs considerably between the FCs. The calculated LEE-level is further qualified based on qualitative knowledge for an assessment of the calculation to be a maximum or minimum of the actual Local Economic Effect of the FCs.

FCs 1, 4 and 5 have the highest Local Economic Effect, calculated to 49- 56% of the catch value. These Fishing Cultures land most of their catch in a permanent home port/landing-site and get local service. Hence, the LEE counts in the fishing communities where they have their fishing harbour affiliation. Based on the qualitative knowledge of the behaviour and geographical location of the vessels of the FC, the calculated LEE is assessed to be the maximum for FC 5, but a minimum for FCs 1 and 4. The latter because these FCs also source other services and supplies locally, although in the calculation these were regarded as non-local.

FCs 3 and 6 have a middle Local Economic Effect, calculated to be around 40% of the catch value. The unilaterally specialized mode of operation characterizes these FCs. They are forced to be less fishing harbour affiliation oriented because they must move to the northern grounds (of Jammer Bay and Tannis Bay), where most of the remaining plaice are still to be found. Hence, most of the FC 6 vessels land in Hirtshals, a couple in Hanstholm, and a couple did in 2022 still land in Thyborøn. The FC 3 vessels also land their catch outside the local area. Based on the qualitative knowledge of the large operation range, the calculated LEE is assessed to be the maximum level for both FCs.

FCs 2 and FC 7 have the lowest Local Economic Effect. No data are available for the Dutch beam trawlers, but – employing Dutch crew and receiving most services via home companies – they contribute very little to the Jammer Bay area. The calculated LEE for FC 7 is 25%. These vessels operate over larger areas, employ many crew members from all over Denmark and from Sweden. The qualitative assessment therefore points at the calculated LEE to be significantly higher than the actual LEE for the Jammer Bay area.

The differences between the Fishing Cultures in relative LEE (the contribution to the local economy/fish value) is an important aspect in the discussion of the importance of fisheries for the coastal fishing communities. The business economic focus on profitability tends to favour Fishing Cultures with highly efficient larger trawlers and high profitability. The Fishing Cultures consisting mainly of minor labour-intensive vessels tend to be regarded as economic unimportant, but with importance in social and cultural terms, as cultural heritage, and as an attractive cultural background for the tourism industry. If instead (or if supplemented with) the local and regional economic effects of this fishery are addressed, these Fishing Cultures demonstrate an economic importance at the local scale. Therefore, the economic effects on the specific fishing community, depends on how the fishing rights are distributed between Fishing Cultures – which Fishing Culture has the rights and opportunities to catch, land and sell the fish.

3.4 Discussion and perspectives

This chapter identifies and describes, in a systematic way, the diversity of distinct kinds of fisheries operating in the Jammer Bay area. The many relevant features of the fishery, such as vessel lengths, engine sizes, gear types, profitability measures, crew sizes, quota, and ownership, were organized into four core features, which provided an operational framework of conceptual models, called Fishing Cultures (FCs). These models were applied to identify distinct types of connections between cultural life-modes and modes of production in the fishery, their competition on ecosystem resources and their contribution to value chains, economic and socio-cultural sustenance at the local, national, and international level. This enabled a paradigm shift from a primary economic focus on the profitability of companies and investments (that tends to neglect the societal and ecosystem components of the fishery and development of long-term sustainable management solutions) to a primary focus on different coexisting Fishing Cultures and their contribution to value chains, community, and sustainability.

This study elaborated each Fishing Culture concept as a particular unity of; i), life-mode; ii), mode of operation; iii), fishing method and iv), community (fishing harbour affiliation). For the Jammer Bay area, seven uniquely distinct Fishing Cultures were identified. The Fishing Culture framework is based on the four core features, supported by detailed descriptions of the fishing units in Jammer Bay area. This framework can be further developed for other geographic areas by elaborating additional Fishing Culture concepts and study the empirical realization of their conditions of existence, operation, and co-existence in those areas.

The Fishing Cultures of Jammer Bay area are: FC 1, Beach landing coastal fishery; FC 2, Dutch demersal beam-trawling; FC 3, Expansive harbour-based fishery; FC 4, Harbour based coastal fishery; FC 5, Specialised gillnet fishery; FC 6, Specialised anchor-seine fishery, and FC 7, Profit-seeking large-scale fishery.

The empirically realized Fishing Cultures operating in the 4 ICES squares of the Jammer Bay area exploit and impact the marine environment in different ways and contribute to the sustainability of fishing communities and the general society at quite different levels and magnitudes, socially, cultural, and economic. This study identified the direct value chains via sales to processing plants and via auctions. There is no one-to-one relation between Fishing Cultures and direct value chains, though the main fishing-culture-specific contributors to each of the direct value chains are identified.

Generally, economic analysis focuses on profitability from an investor and wage-earner perspective, or from a national economic perspective. This thinking is aimed to improve the allocation of labour and capital to the most profitable activities. In this study, the focus was on the Local Economic Effects (LEE). A model for assessing the LEE of each Fishing Culture was developed based on the direct effects (wages and income for crew and owners) and indirect effects (wage part for services purchased locally). The latter adds another specific feature to each Fishing Culture; the LEE, measured in absolute terms and relative LEE/landing value. LEE was assessed for the fishing communities in Jammer Bay, where Hanstholm, Thorupstrand, Løkken and Hirtshals were characterised as the “local” communities, even if Hanstholm and Hirtshals receive considerable parts of the landings from other sea areas than Jammer Bay. The analysis therefore focuses on the spatial distribution of the income generated by fisheries rather than the private business or national economic profitability. This is central for the local communities and regions that hold the natural resources, which are extracted, and therefore bear the burdens of the ‘externalities’ (e.g., the decreasing durableness of productive marine habitats and fish stocks caused by highly ‘profitable’ fishing business models). From the local community’s economic, cultural, and organic sustainability perspective, the business economy of the most profitable vessels may be of less interest than the community’s totality of integrated value chains, especially if the (negative) externalities are local and the profit is appropriated elsewhere (i.e., outside the community, the region, or the country). Following this perspective, it is interesting, that FCs with a high level of income contribution to the local economy are found in the segments normally (in business and national economics without an integrated socio-cultural and organic sustainability perspective) regarded as less valuable because they are primarily seen as low productive and low profitable fisheries.

The Dutch beam trawlers of Fishing Culture 2 operate a downright long-distance fishery without any economic contribution of significance to the local fishing communities in the Jammer Bay area. This is reflected in the considerable differences in the Local Economic Effect (LEE) between the Fishing Cultures and highlights another pattern than would otherwise be obtained from calculations of company profitability in business economic practice. FCs 1, 4 and 5 have the highest LEE, calculated to 49%–56% of the catch value. There is a middle LEE for FC 3 and 6, calculated to around 40%. While the lowest LEE is for FC 7 and FC 2. For FC 7, the calculated LEE is 25%. FC 2 generally does not land fish in any of the Jammer Bay harbours. Thus, the LEE of FC 2 (Dutch beam trawlers) is almost zero.

Specifying the dimensions of each Fishing Culture makes it possible to shed light on the ways the 7 Fishing Cultures co-exist and impact each other in the Jammer Bay area. Most of the actual forms of co-existence appear to be unproblematic between Fishing Cultures with activities in different areas of the Jammer Bay area and when the impact of their catch technology allows competitive sharing of common fishing grounds, habitats, and fish stocks. Though, we also find different kinds of asymmetrical competition between vessels realizing a broadly composed, versatile mode of operation (mostly found in FCs 1 and 4) and larger vessels realizing a unilateral specialized mode of operating (mostly found in FCs 3, 5, 6 and 7). The larger and more mobile vessels of the last categories may be able to displace the more local versatile vessels from their year-round grounds or resources during a high season.

Fishers (among the interviewed stakeholders) realizing the FCs 1, 4, 5, and 6 find themselves caught in an antagonistic relation to large beam-trawlers realizing FC 2 who operate a long-distance fishery in the Jammer Bay, among other places. Their presence in the Jammer Bay conflicts with local fishers realizing the FCs 1, 4, 5 and 6 because of their inability to share common fishing grounds and fish stocks. The impact by FC 2 on the seabed, marine food webs, and juvenile fish puts, according to the local fishers, pressure on their fishing opportunities at the shallow grounds of the Jammer Bay while the beam trawlers are operating in the area and during a considerable time afterwards. Stakeholders realizing FC 2 argue, that their own endeavour to ‘open the ground’ by means of beam trawls is, from their point of view, advantageous for other fishers too, if they dare to fish nearby the ground that has been opened by the beam trawler vessels. The local stakeholders realizing FCs 1, 4, 5, 6 conceive this point of view as far too short-sighted and missing the temporariness of any imagined positive impact of heavy beam trawling on habitats and fishing stocks in the Jammer Bay. Stakeholders realizing FC 2 observe that their colleagues from FCs 1, 4, 5 and 6 need to adopt a longer ranging fishery, exploiting alternative areas and thereby allowing local fishing areas to recover after having been ‘opened up’, and that only the too high fuel prices are preventing such a development. The response of the coastal fishers to this argument is that it is neither appropriate nor necessary to ‘destroy’ the seabed applying heavy gear and much fuel. These contrasting points of view bear the fishers’ witness about the antagonistic character of this coexistence.

The problematic coexistence of; i), opposite modes of operation and ii), opposite fishing methods aggravated each other when a fleet of large beam trawlers in 2017 arrived at the shallow grounds of the Jammer Bay searching for sole and plaice and subsequently returned to Jammer Bay during the next 7 years because these target species were no longer available in their home waters of the southern North Sea.

The Fishing Cultures’ contribution to the local community has different characters. The fishing activity is basis for cooperation, income, and jobs in the communities, which ensure a permanent residence based on fishing families’ conceptions on what is a ‘good life’ in the community. In the fishing communities the families’ history of seafaring and fishery, and their recent (with) sea faring (connected) life also contribute to the identity and local culture. This is documented in this study's interviews and the description of Fishing Cultures and coastal communities in the Jammer Bay and the Netherlands.

3.5 Acknowledgements

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3.7 Appendices

Appendix 3.A1. Use of qualitative methods - observations and interviews

The qualitative data are collected by use of personal interviews and in this relation observations.

The interviewed persons were selected as stakeholders representing central employees at the relevant auctions, chairmen of the local fisheries associations, fishers, and skippers of different types of vessels. In the Danish context, most of the stakeholders were chosen based on the authors' experience and knowledge of the sector. In a few cases, stakeholders proposed other interview persons in a snowballing process. For the interviews in the Netherlands, a local contact person was the entrance for a snowballing choice of interview persons. The input from interviews was supplemented by observations in the relevant ports. A structured observation of the ports, vessels, and catch technologies was documented in notes and pictures and provided a hands-on understanding of the technologies as well as the general situation in the ports. This was supplemented by a more unstructured observation (urban drifting) in the local communities including shorter conversations with inhabitants. The structured and unstructured observations all contributed to a deeper understanding of the local communities and the role of fisheries in social and cultural terms.

The interviews were conducted by 1-3 persons. The themes were loosely agreed on in advance and the interviews took place on location (auction, vessel, company office) and in a few situations in the fisher's home. The interviews were semi-structured with themes to cover defined in advance but often developed in other directions depending on what seemed relevant in the situation. See examples of general interview guides for auctions and fishers below.

General interview guide for auctions:

- Tell us about the auction - physical frameworks, how does the trade work?
    - Relation to and competition with online/onsite auctions?
    - What is the difference and advantages here?
- Which vessels land here?
    - Do you know where they have caught the fish?
    - Can you identify the catches from Jammer Bay area?
- For the Jammer Bay project, we should seek to identify vessels of different types that fish in Jammer Bay and land here (nn port)
    - Can you come up with suggestions? – e.g.,
        - Nets - small/large
        - Trawlers small/large
        - Danish seine
- Please describe how the fish reaches the final market from the auction. Who are buying, for which markets in first and second link?
    - Local buyers for companies with fresh export or processing
    - Directly to the end-user - or another short value chain locally?
    - Direct export of the fresh fish?
- Can you give examples of- or maybe even a list of the different types of vessels landing for the auction?
- What about vessels under 10 m – and thus without AIS – are there any in the “white” areas of misleading activity when only AIS data is used?

General interview guide for fishers:

- Please tell us about your fisheries.
    - Vessel and gear
    - What are you catching and how/where is the catch sold?
    - How is the organization aboard – share-part fishers/employees? How many
- Tell us a little about yourself.
    - History and family background
    - The fishing history/career – experiences from different vessel/gear types and locations?
- Describe the annual cycle in the present fishery,
    - Where are you fishing and which species?
    - Where are the catches landed?
        - Illustrate on a map
    - Have this changed over the years?
        - How has it changed?
        - Why has it changed? (his understanding of reasons)
- We are trying to map the value chains of the fisheries. If you are willing to- and can, please give of an insight in the accounts of the vessel, in form of percentage of expenses for:
    - oil,
    - catch expenses (oil, ice, fish boxes, packing, auction),
    - tools, other maintenance,
    - wages
        - fixed or shares (of what?)
        - are costs first deducted for operation or for boat and leasing of quotas etc.?
    - possibly: insurance, memberships - possibly leasing of quotas?
    - [Could we - in all confidentiality - have a copy of your accounts?]
- For the Jammer Bay project, we should seek to identify vessels fishing in Jammer Bay and to see if we can group them in a reasonable way.
    - Can you point at other vessels like you? Who would you compare your vessel with – and why? – which parameters?

Appendix 3.A2. Life-modes

The analysis of life-mode-features of the fisheries in Jammer Bay area

The five basic life-mode concepts applied in the analysis:

- The self-employed, share-organised fisher life-mode, which includes:
  - The thrifty fisher life-mode
  - The expansive fisher life-mode
  - The niche fisher life-mode
- The profit-seeking entrepreneurial life-mode
- The wage-earner life-mode
- The investor life-mode
- The skipper life-mode

The self-employed, share-organised fisher life-mode

$$p \cdot q \geq r + q \cdot f$$

The self-employed fishers' conditions of possibility are that the quantity they deliver to market multiplied by the price must at least cover the fishing units' overheads plus the quantity multiplied by the unit cost.

The term, which on the expense side constitutes their overheads (*r*) is on the production side the basic means of operation, which makes it possible to increase the quantity produced (*q*) or reduce the cost per unit (*f*). The cost per unit comprises provisions, fuel, oil, ice, landing- and auction fees. The fishing crew's praxis consists of operating the means, such that the expenses of the production cycle and its earnings cancel each other out and make it possible to maintain the end of the fishers' praxis as an independent and share-organised crew of self-employed commodity producers.

For the share organised fishing unit, it is just as important to keep a skilled crew together as it is to keep the vessel and equipment in tip-top condition; basically, the personal economy and the enterprise's economy, while not identical, are nevertheless two sides of the same economic coin, i.e., the unit's the basic means of operation.[29] It would be just as precarious for the catching unit to lose the crew because they could not pay for their house as it would be to lose the vessel because they could not pay interest and instalments on the ship's purchase loan. The enterprise's overheads, both fishing and family-related, are a necessary whole. Hence, based on experience and depending on the size and cost of maintaining the vessel the income (minus $f \cdot q$) is normally distributed with 40 - 60% to the ship + gear and 60 - 40% to the fishing families.

[29] In reality, this is an artificial distinction when the tax authorities try to distinguish between the ship engine's consumption of diesel fuel and the fishers households' consumption of heating oil/electricity, between the ship's accounting of its provisions and the households' food budget, between TV in the crew's cabin and the TV in their families' living rooms, between slipway expenses for hauling in the boat and engine service on the crew's personal cars, between interest payments on the vessel and mortgage on the house. This distinction between the fishers' 'business' and their 'personal' expenses is irrelevant for the self-employed producers. It is irrelevant because these kinds of expenses are equally necessary parts of the basic operational costs. The distinction appears as an alien element in the self-employed life-mode while it is the attempt of the state apparatus to impose a tax-based overlap between the wages of a worker and income of the self-employed person.

The boat, gear and crew have overheads, regardless of whether the vessel is moored in the harbour or out at sea. Rent of mortgage, family food budget, insurance expenses, subscriptions to digital navigation services, interest, and instalments on bank loans (for a new or renewed vessel), harbour fees, servicing electronic equipment and membership fees to organisations must be paid, whether the crew are out fishing or at home due to bad weather. In turn, these basic means of production make it possible to go out to sea and operate a fishing enterprise, the potential capacity and productivity of which is determined by the crew's skill and motivation as well as by the efficiency of the ship and equipment.

While these basic means of operation enable fishing within a quantity range, operating expenses are incurred as soon as the vessel leaves port. Depending on the length and duration of the trip, which depends on the quantity of fish that the crew aims to bring home, the ship will incur expenses for fuel, ice, spare parts and lubricating oil, provisions, landing- and auction fees as well as for ropes and nets to repair wear and tear. The more fishing carried out, the greater these operating expenses, and the greater the amount of caught fish needed to offset these expenses.

The fishing unit's basic means of production determine the extent of the quantity range within which it has its normal production; outside this range, marginal costs are incurred. In addition, the basic means of production determine the size of unit costs within the quantity range of normal production, i.e., the normal operating expenses. When the fishers use their basic means of production (to which the skills, experience, pursuit, and teamwork of the fishers themselves belong) as a means of lowering their unit costs, raising the quantity or quality, these are the fishing unit's basic means of operation, and the fishers count these as their 'capability'.

The praxis of self-employed fishers connects four manipulable components: quantity, price, overheads, and unit costs. These components can be elaborated into three basic variants by focusing on different components:
If the overheads are kept down to make ends meet, we get the thrifty fisher life-mode:

$$r \leq q \cdot (p - f)$$

If the quantity is increased and/or unit costs are kept down to make ends meet, we get the expansive fisher life-mode:

$$f \leq \frac{q \cdot p - r}{q}$$

If the price is kept high to make ends meet, we get the niche fisher life-mode:

$$p \geq \frac{f + r}{q}$$

The thrifty fisher life-mode

$$r \leq q \cdot (p - f)$$

When the overheads are kept down in order to lower production costs and remain independent on bank loans, we get the 'thrifty producer', characterised by saving on all investments in the basic means of operation, so that the basic operational costs ('fixed costs') remain low enough that it will always be possible to cover them by spending a little more time catching the kilos of fish needed in order that when multiplied by the market price, they can create enough earnings to cover these fixed costs for the basic means of production. In this praxis, the fishing families remain free and independent of bank loans and employees by keeping the overheads down. The thrifty fisher life-mode operates within a 'just enough' ideology.

The expansive fisher life-mode

$$f \leq \frac{q \cdot p - r}{q}$$

The expansive producer is characterised by large investments in basic means of operation. What are ambiguously called 'capital-intensive' sectors of the fishing industry are those fishers for which the primarily manipulable means is a growth in landed quantity and reduction in unit costs. This requires investments in the basic means of operation of the catching unit. To maintain the return on investment by increasing *r*, *f* is decreased, and *q* is increased. The expansive fisher life-mode operates within a 'we have to improve our capability' ideology.

The niche fisher life-mode

$$p \leq \frac{f + r}{q}$$

When the quality, specialisation, or individualisation (i.e., increasing the use value for the consumer) of the product is optimised, it may be necessary and possible to keep a higher price for the product on the exclusive niche of a market and cover larger basic operational costs and/or operating expenses, even if the quantity is lower than the conventional variants of the product. This variant explicates the niche product as a particular means to make ends meet. It may demand e.g., particular expertise in landing high quality fish, using modes of operation based on exquisite craftsmanship, cultivating storytelling about process and product, sustainable catching methods, 'fishing with care', delivering high-end, climate-friendly seafood. This intentional feature is realised by the niche fisher life-mode who counterbalances lower quantities with higher price. This life-mode operates within a 'we are cultivating our niche' ideology.

The profit-seeking entrepreneurial life-mode and the wage-earner life-mode

$$p \cdot q \geq ((w + m) \cdot q + bc) \cdot (1 + IP)$$

This formula describes how the profit seeking entrepreneurial life-mode's basic end is to optimise the return on the entrepreneur's total investment in wages, materials, and basic operational equipment. These three factors are means to reach the goal, which is to maximise the individual profit, *IP*. The fishing entrepreneurial life-mode operates within 'my individual profit counts' ideology.

The formula describes the different possible means, beyond the ongoing wage negotiations (that affect *w*), of creating maximum individual profit for the individual company: It brings the necessary operational equipment and their basic costs (*bc*) into focus, because it is by means of these that the profit seeking investor can increase the income ($p \cdot q$) as well as decrease the total costs ($(w + m) \cdot q + bc$). The basic costs (*bc*) represent the material equipment and mental skills which are the primary manipulative means of improving 1) the productivity, the necessary unit cost ($w + m$) and the production capability (potential *q*) of the production process and 2) the (demand and) price of the produced product (*p*). On the one hand, one can lower consumption of paid work (*w*) and reduce raw material costs (*m*) by reducing the waste of time, energy, and materials, increasing productivity, and increasing the potential, produced quantity. This is synonymous with, in different parts of the value chain, reducing, on the one hand, the expenditures of paid labour and thus the finished product's exchange value. Hence, a wage-worker life-mode delivering paid labour is involved in this mode of production. Fish workers are attracted by means of fixed wages and favourable tariffs. The fish worker life-mode operates within a 'work is a means to leisure' ideology.

The entrepreneur's developing and managing of the individual company is primarily about cutting the determinate unit cost, increasing the capacity, quantity, and product quality, or creating a new product, all of which depends on the entrepreneur's ability to develop the basic operational equipment. This includes all the forms of machinery, plant, organisation, automation, digitisation, quality, knowledge, innovation, and motivation that are important for the levels of unit costs, the production capacity and the quality of the products produced. The saleable quantity is not only determined by the production capacity but also by the demand. Demand, in turn depends on the degree to which the entrepreneur succeeds in developing the use-value of the product for the consumer - before the competitors have achieved the same potential.

The entrepreneurial life-mode can be divided into the profit seeking investor praxis (ship owner) and the profit maximising manager praxis (skipper) who complement each other and appropriate the individual profit. The fishing investor operates within 'we have to invest where profitability is promising' ideology. The profit seeking career skipper operates within a 'our ship has to be ahead of the other vessels' ideology.

Appendix 3.A3. Possible shift of Fishing Culture to maintain life-mode

Whereas a 'life-mode' implies a conceptual world structuring what is conceived as 'the good life' and therefore a mode of living whose conditions of existence people defend and try to improve, a 'fishing culture' (FC) also comprises a mode of operation, distinct technical methods (fishing gear) and a geographical setting - community (fishing harbour affiliation). It is possible to change, shift, or replace an FC in order to improve the conditions and survival of the life-mode. These kind of choices and changes, in which people are shifting gear, replacing one mode of operation with another or are moving from one homeport to another as a means to replace or improve the conditions of existence of their life-mode, exemplify the so-called 'neoculturation' processes (Højrup & Nielsen 2024), which are constantly changing the society.

Hence, in Jammer Bay we often find fishers who are shifting gear types and methods, modes of operation and sometimes even their fishing harbour affiliation – and in this sense are changing their Fishing Culture or are moving from one Fishing Culture to another. Presently we see crews who (e.g., to survive the worsened conditions in the North Sea fishing after Brexit) are selling their large bottom trawler and buying a little longliner (e.g., in Hanstholm) and shift from trawl gear to longlines. We also see anchor-seining crews moving from Hanstholm to Hirtshals to compensate for the disappearing of plaice in the western and central part of Jammer Bay and the remaining presence of plaice in the north-eastern part of Jammer Bay and Tannis Bay, and fishers employed by large pelagic trawlers and purse-seiners who return to the landing sites, where they grew up, to be hired on a local seiner or gillnetting boat. For some fishers the growing consciousness about the connection between economic and organic sustainability and the need to fish with care, protect and maintain the habitats and fish stocks, motivates them to shift gear and mode of operation.

The last two examples may also illustrate a life-cycle change (instead of a neoculturation), where you e.g., can start in a local small scale fishing team and learn your métier from fellow villagers, then shift to employment on a large vessel with the aim to earn more money and save up for your own house and boat-share, and subsequently leaving the company because you are ready to move home and start for your-self. A third variant of life-cycle change we find in Jammer Bay presently, are the entrepreneurial owners of huge pelagic vessels who sell or hand over their stocks and practice in the large-scale company, retire and buy a little boat to fish with gillnets, seines or hooks as aged senior fishers.

The conclusion is that whereas people used to maintain their life-mode, they may be ready to shift or move from one fishing culture to another, which is the reason why we find a flow of individuals between the distinct fishing cultures, even if these cultures are maintained as different modes of fishing in the area.

Appendix 3.A4. Value chains, method for calculation of Local Economic Effects (LEE)

1. Identified fish value chains for fish from Jammer Bay
The direct value chain of fish from Jammer Bay is based on interviews with representatives from the auctions in Thyborøn, Hanstholm, and Hirtshals.

2. The local economic effects (LEE) of the fisheries and the fish value chains
Several interviewees point to the importance for the local communities of the economic input from the fisheries in the form of local wages and as income in companies supplying goods and services to the fisheries.

The most obvious effects of the fisheries are the direct effects, such as jobs at a factory. The indirect effects are the secondary impacts on suppliers and related industries, e.g., increased demand for raw materials. The direct and indirect economic effects in form of jobs generates income, which is spent on food, clothes, housing, etc. by employees in the relevant industries. This is called an induced effect of the first activity. Finally, complex and long-term changes in the economy and society can arise from the direct, indirect, and induced effects – called the Derivative effects. In a local economy all four types of effects are of importance over time.

In this relation a simple model for local economic effect (LEE) analyses is made, inspired e.g., by Cowi (2013), Jordal-Jørgensen et al. (2014), and Watson et al. (2021). The model focuses on *revenues* generated by the fisheries (the immediate effects) and the suppliers and related industries, which are assumed to be mainly local based. The focus is thus the local direct and indirect effects of the fisheries, and, measured in revenue, the potential for induced effects (Table 3.A4.1). To which degree the revenues generate the potential local induced effect of the fishing activity is not included in the local economic effect analysis.

The induced and derived effects on the community where the vessels are affiliated are to some degree discussed in the qualitative description of the seven fishing cultures and the selected local fishing communities.

Table 3.A4.1. Economic effects discussed in the analysis. Direct and indirect (for potential induced effects) are handled in the LEE. Induced and derived are briefly mentioned in description of Fishing Cultures and Fishing communities.

Economic effects	LEE	Fishing Culture- and Community description	Data
Direct	Yes	No	Stat-DK. Account statistics, vessel categories
Indirect	Selected	No	Stat-DK. Account statistics, industries
Induced	No, potential	Anecdotal	Interviews and vessel accounts
Derived	No	Anecdotal	Interviews and observations

To assess the revenue generated for the LEE, a range of assumptions were made:

The direct effect on local community of the fisheries is the salaries and revenues in the fisheries, based on accounts statistics for vessel categories, defined by main type of gear and vessel length (Statistics Denmark, FIREGN2).

- Crew and owners are assumed to be local to the registered affiliated port of the vessel. For some Fishing Cultures the qualitative analysis points to the contrary though.
- Each vessel is linked to a vessel category (according to the account statistics) and assumed to be operating at average economic terms according to the statistics.

The indirect effect on local community of the fisheries is the salaries and revenues for local supplier and service industries, based on the relevant operating costs in the fisheries (the account statistics for vessel types).

- A link between the operational cost types in the fisheries and the supplier and service industries is established by a detailed cost analysis below (including Fig. 3.A4.1).
- Three types of operation costs for the vessels are assumed to be linked to local companies:
  - Energy (the cost E.1) assuming that bunkering takes place locally.
  - Landing, sale, and distribution (E.3), assuming that the first-hand operation is local.
  - Maintenance (E.5), assuming the main part of maintenance is local, though central parts of maintenance (yard etc.) tend to be specialised and centralised.
- For each cost type, account statistics for one or more typical supplying sectors are used for assessing the relation between turnover = Gross output (D.) and wage share (E.8). This indicates the rate of operational cost (E.1, E.3 or E.5) to salaries in supplying companies and thereby the indirect effect.

The main part of the calculations is based on accounts received from a few fishing companies in Jammer Bay, and account statistics from Statistics Denmark (FIREGN2). The account statistics are based on accounts from representative vessels and presented as average data for 17 vessel categories defined by main type of gear and vessel length. For the calculation of the indirect effects, a rate between fisheries cost of operation and local salaries in the assumed local supplier and service industries are calculated based on aggregated account statistics at 5-digit industry level, Statistics Denmark (REGN1).

Calculation of the direct local economic effect of fisheries

The direct effect of the fisheries is expressed in the income generated by the fisheries. In the standardised accounts statistics, the “wage expenses” is the payment of the crew. This covers wages for the crew in FC 7, and income for the share fishers in the share-part organized vessels in FCs 1-6. This does not include payment to the official owner. In the account statistics, remuneration for the owner is not seen as a cost but as a part of the profit. For the small vessels the registered owner might be a part of the share crew or might even be the only crew member (1-person vessels). Therefore, in this relation remuneration for the owner (H.3 in the account statistics) is included as a cost with the same LEE as income for the crew.

The direct LEE of the fisheries is thus the sum of a) Crew share of income (E.8) and b) Remuneration of the owner (H.3) for the vessels in the Fishing Culture.

Calculation of the indirect local economic effect of fisheries

The calculation of the indirect local economic effect of fisheries goes over three steps.

1) An analysis of the operating costs for the vessels, linked to points in the account statistics for Statistics Denmark and the typical supplier/service provider, and a discussion of which operational costs are supplied locally.
2) An analysis of which industry groups (5-digit level) typically contain the supplying/servicing companies – to thereby calculate a rate of wage-to-turnover (=cost of operation in the fisheries) for the type of cost.
3) A calculation of the indirect local economic impact of the Fishing Culture based on the sum of the wage-to-cost rate for the selected local operational costs of the vessel category.

The first step in the indirect LEE analysis is to analyse the operational costs of the vessel[30]. In the account statistics (FIREGN2), the different cost types in the operation are grouped in E.1 to E.9 (some broken further down), as illustrated in the list below.

- Fuel and lubricant oil – (E.1)
- Quota rent – (E.2)
- Landing costs: (E.3): Ice, Fish boxes, Packing of catch, Auction fee
- Maintenance: (E.5): Of the vessel, of the gear and of equipment
- Administration (E.6): Membership fees, Subscription fees
- Insurance fees: (E.7)
- Crew share of income (or salaries) (E.8)
- Other, e.g., Rent and use of cares (E.4) and Depreciations (E.9)

The different types of operational costs for the vessel are illustrated in Fig. 3.A4.1 below. The costs are specified in the first blue and orange boxes. The green stars indicate how this cost is linked to the account statistics for the vessel categories. For each of the cost type a typical supplier/service provider is mentioned.

[30] In this version of the assessment, financial expenditures (interest expenditure for ship financing and mortgage and bank loans) or quota rent are not included in the statistical measures. These might be reflected on in the qualitative assessment.

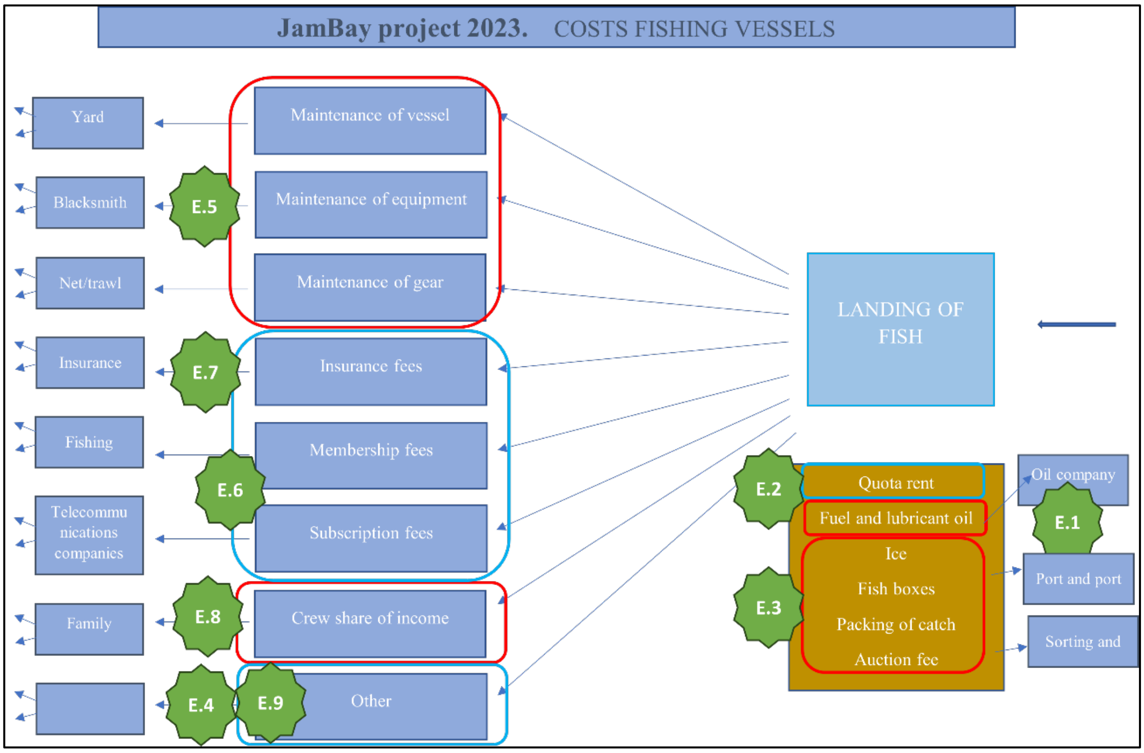


Figure 3.A4.1. Operating cost for the fishing operation. Green stars indicate the cost types in account statistics. Boxes with a red ring (E.1, E.3, E. 5 and E.8) are regarded as costs taking place in the local area. Boxes with blue rings (E.2, E. 4, E.6, E.7 and E.9) are regarded as costs taking place elsewhere and not included in the local economic effect assessment. Own model and FIREGN2.

The service providers and suppliers can be located locally or within a larger distance to the affiliated port of the vessel. For the model, we assume that some types of activities (linked to costs) are typically local, while others are typically handled by companies located outside the local area. In Fig. 3.A4.1, the local costs are marked by a red frame, non-local costs are marked by a blue frame. Typically, the direct handling of the fish is mainly local based (registered in the accounts as E.3). Fuel is in this regard seen as provided locally, though bunkering can also take place where the vessel lands. Finally, we assume that maintenance is mainly local, though yard maintenance takes place in the few ports with relevant yards.

The second step of assessing the indirect LEE of the fisheries is to assess the wage-to-turnover (cost in fisheries accounts) in the local based service and supplying companies. The wage-to-cost rate (secondary effects) for the three types of costs (Energy (E.1), Landing, sale, and distribution (E.3), and Maintenance (E:5)) are argued below[31]

E.1 Energy: Although not local produced, fuel must be provided locally – either in harbour or landing site. The industry code representing the providers of energy is “19000 Oil refinery etc.”. There is no data available on the relation between turnover = Gross output (D.) and wage share

[31] Data for the calculation of the wage-to-turnover ratio for the companies providing services and supply for the fishing vessels is based on Statistics Denmark, REGN1 Accounts statistics by industry and items. This is Accounts Statistics for Non-Agricultural Private Sector at 5-digit level of DB07. The latest data, 2021, is used for the mentioned industries. For each industry, the calculation is based on Wages, salaries, pensions etc.. / turnover.

(E.8) for this branch. Knowing that the price of energy is based on the price for the oil/fuel, energy-taxes for the state, and general handling costs including wages, the wage share of the energy costs is assessed to be small. The wage-to-turnover rate is therefore assumed to be 0,1 – meaning that the indirect LEE (wages) of the energy costs is assumed to be 10% (of what the vessel has paid for energy).

E.3 Landing, sale, and distribution: These activities will necessarily take place in the landing port, or in the port of the fish auction if the landing is trucked elsewhere for auction. Several types of companies are involved in this activity. To assess the wage share in these the accounts for three branches are analysed, and the average share cost of wages (E.8) to gross output (D.) (E.8/D) is regarded as the indirect LEE of the cost for landings, etc. for the fishing vessel. The account data is at a very general level, as account data for e.g. auctions is not available. Three industries selected include central service providers but not necessarily representative for all supply and service providers. The three branches are 49003: Freight transport by road and via pipeline, 52000: Support activities for transportation (e.g., cooling stores), and 82000: Other business service activities (e.g., packaging) (Table 3.A4.2).

Table 3.A4.2. Wage-to-turnover rate in three industries (49003, 52000, 82000, 5-digit level), with companies with landing, sale and distribution of fish. Source: Statistics Denmark, REGN1.

	49003 Freight transport by road and via pipeline	52000 Support activities for transportation	82000 Other business service activities	The three industries
Enterprises (No)	4702	1487	3352	9541
Turnover (DKK million)	54062	117959	30068	202089
Wages, salaries, pensions, etc. (DKK million)	14390	15801	7679	37870
Rate: wages-to-turnover	27%	13%	26%	19%

The average wage share of gross output for the three branches is 0,2. This means that the indirect LEE (wages) of the landing costs is assumed to be 20% (of the landing costs).

E.5 Maintenance: Maintenance will in general (apart from the large pelagic vessels) often take place in the home port (fishing harbour affiliation). Emergency maintenance will take place where the damage occurs and periodic maintenance and checks can take place at nearby shipyards, not necessarily in the home port. Nevertheless, the input from interviewees indicates that as much maintenance as possible is placed locally. Several types of companies are involved in this activity. To assess the wage share in these, the accounts for three branches are analysed, and the average share cost of wages (E.8) to gross output (D) (E.8/D) is regarded as the indirect LEE of the cost for maintenance for the fish vessel. The branches are 30000: Manufacture of ships and other transport equipment, 33000: Repair and installation of machinery and equipment and 43002: Building completion and finishing (painters etc.) (Table 3.A4.3).

Table 3.A4.3. Wage-to-turnover rate in three industries (30000, 33000, 43002, 5-digit level), with companies withing maintenance of fishing vessels. Source: Statistics Denmark, REGN1.

	30000 Manufacture of ships and other transport equipment	33000 Repair and installation of machinery and equipment	43002 Building completion and finishing	The three industries
Enterprises (No)	153	2501	16227	18881
Turnover (DKK million)	6323	22004	70910	99237
Wages, salaries, pensions, etc. (DKK million)	1442	5878	19974	27294
Rate: wages-to-turnover	23%	27%	28%	28%

The average wage-to-turnover rate for the three industries branches is assessed to be 0,3. This means that the indirect LEE (wages) of the maintenance is assumed to be 30% (of the maintenance costs).

To assess the LEE of the FCs, four calculations are made. This is based on the assumptions mentioned above, including that the vessels in each FC are operating at average economic terms according to the account statistics for vessel categories. The basis is account statistics for 2022, in the table FIREGN2 at Statistics Denmark (Table 3.A4.4).

1) The direct LEE is calculated for each FC, based on the number of vessels in each of the vessel categories of Statistics Denmark. For each of the vessels in the FC, the (assumed average) wages (E.8) and the remuneration for the owner (H.3) is calculated and summed.
2) The indirect LEE is calculated for each FC, based on the number of vessels in each of the vessel categories of Statistics Denmark. For each of the vessels in the FC, the (assumed average) wage share of the costs for Energy (10% of E.1), Landing, sale, and distribution (20% of E.3), and Maintenance (30% of E.5) are calculated and summed.

The size and number vessels differ considerably between the FCs. In order to assess the relative LEE per fish (value) for the FC, the LEE (direct and indirect) is related to the fish gross output for each vessel in the FC, and an average level is calculated.

3) The direct LEE of the fish catch value per FC is calculated as the value of direct LEE for the FC (1 above) as share of the gross output value of landings of D.1: Fish for consumption + D.2: crustaceans and molluscs and D.3: Industrial fish. This is expressed as percentage of fish value contributing to the local economy.
4) The indirect LEE of the fish catch value per FC is calculated as the value of indirect LEE for the FC (2 above) as share of the gross output value of landings of D.1: Fish for consumption + D.2: crustaceans and molluscs and D.3: Industrial fish. This is expressed as percentage of fish value contributing to the local economy.
5) Finally, the LEE (direct and indirect effect on the local economy) is calculated as the sum of 3) and 4).

Table 3.A4.4. Local economic effects (LEEs) of the FCs, 2022. Landing values, direct and indirect LEE, and direct and indirect LEE per fish value. Own calculations based on Statistics Denmark, FIREGN2, REGN1 and own identification of FC vessels in Jammer Bay. *Due to discretion, there is no economic data available for industrial trawlers 24-39 m.

Fishing Culture no.	**1**	**3**	**4**	**5**	**6**	**7**
Net/hook under 12 m	4		40			
Trap setters under 12 m						
Trawlers under 12 m			21			
Net/hook from 12 to 14,9 m	1		3	4		
Danish seiners from 12 to 14,9 m	5				3	
Trawlers from 12 to 14,9 m		1	15			
Danish seiners from 15 to 17,9 m					5	
Net/hook from 15 to 17,9 m			1	6		
Trawlers from 15 to 17,9 m		12	31			3
Net/hook from 18 to 23,9 m				4		
Danish seiners from 18 to 23,9 m					5	
Trawlers from 18 to 23,9 m		19	7			3
Industrial trawlers from 24 to 39,9 m		*				*
Other trawlers from 24 to 39,9 m		22				7
Industrial trawlers 40,0 m and over						8
Purse seiners & trawlers 40,0 m and over						4
No of vessels in each FC	**10**	**54**	**118**	**14**	**13**	**25**
Landing value, mill DKK	14,7	484,2	256,2	78,5	51,3	698,1
Direct and indirect local economic effect, mill DKK	7,7	186,9	124,9	44,1	20,8	178,9
Direct local economic effect, % of landing value	43,5	31,3	40,9	49,1	32,2	21,0
Indirect local economic effect, % of landing value	8,8	7,3	7,9	7,2	8,3	4,6
Local Economic Effect (LEE), % of landing value	52,4	38,6	48,8	56,2	40,5	25,6

Appendix 3.A5. Development of activity of Dutch beam-trawl activity 2016-2019

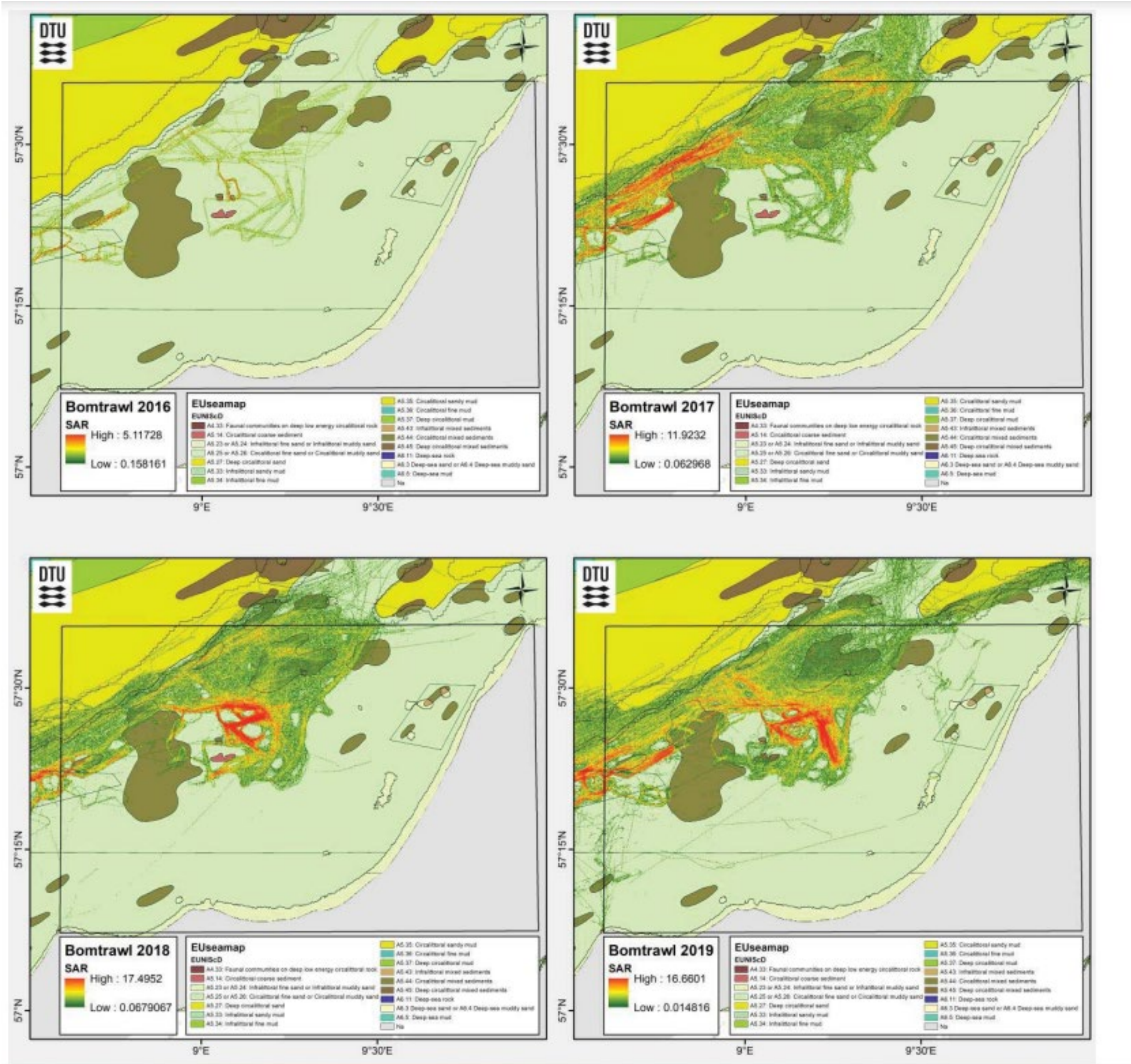


Figure 3.A5.1. Maps of the distribution and intensity of Dutch beam-trawlings for each of the years 2016, 2017, 2018, 2019. The intensity of fishing is calculated as a swept area ratio (SAR based on AIS data). From: Eigaard & Olsen, 2020, Bilag 1e, p. 13).

It is clear from Fig. 3.A.1. that the Dutch beam trawlers fish exactly in the area just outside the 12 nautical mile limit, where the Thorupstrand fishers had their main fishing ground before they were displaced. The map in Fig. 3.A5.2 shows some of Thorupstrand fleet's preferred fishing ground in 2016, before the fleet of Dutch beam trawlers began their third period of plaice fishing in the Jammer Bay area.

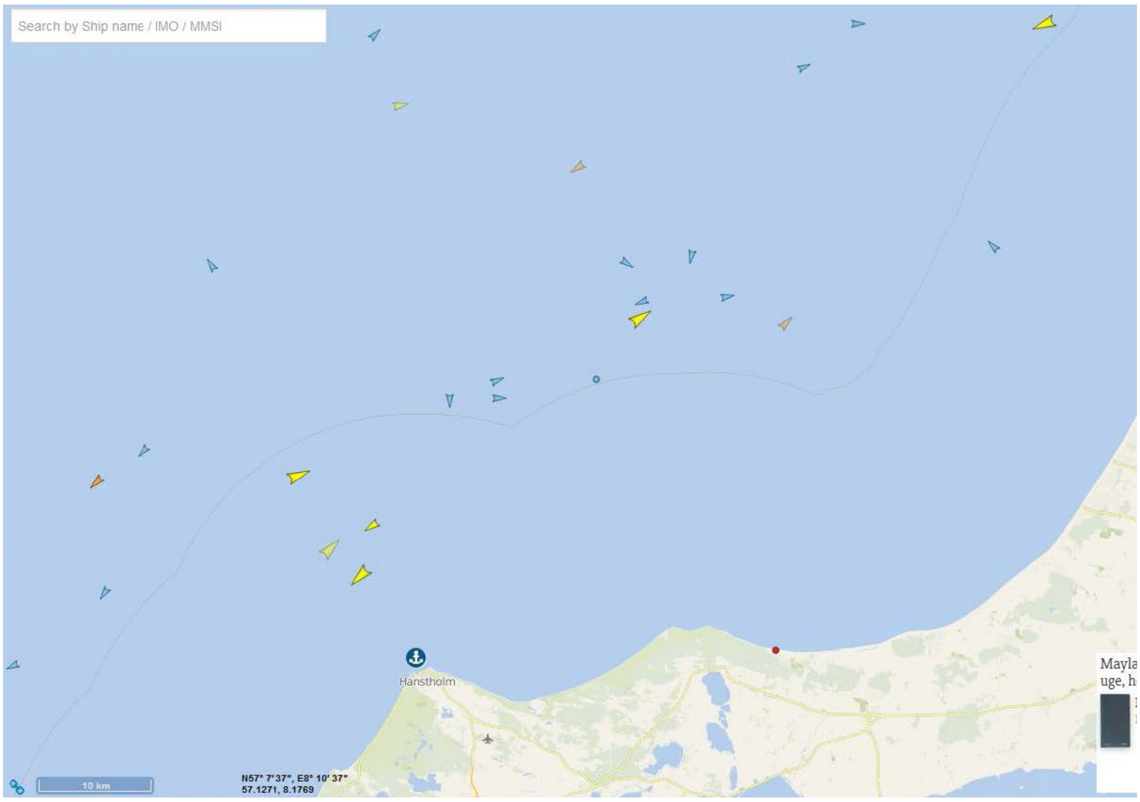
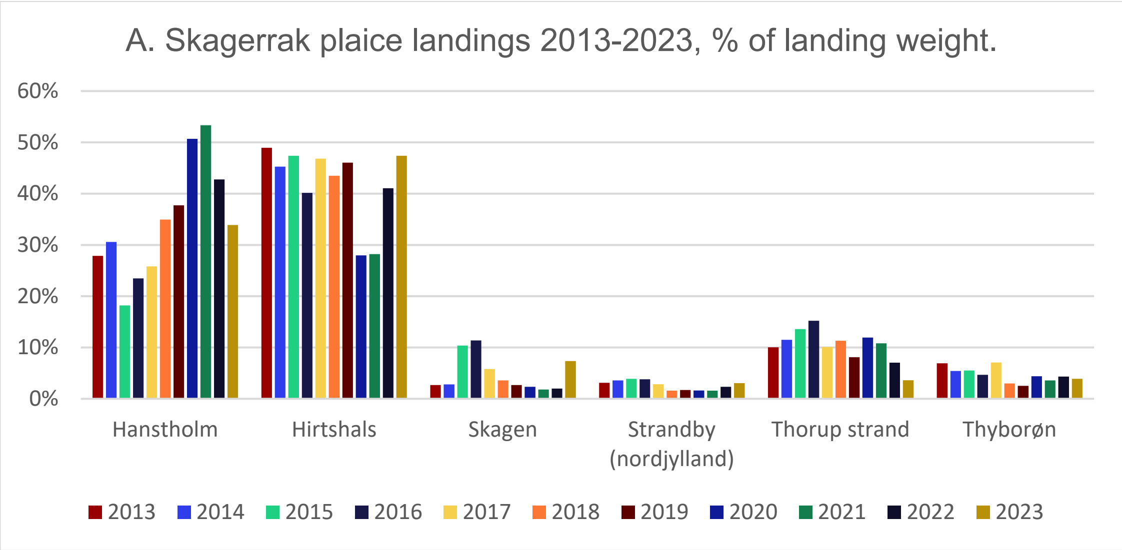


Figure 3.A5.2. Map of some of Thorupstrand fleet's preferred fishing ground in 2016 before the fleet of Dutch beam trawlers began their third period of plaice fishing in Jammer Bay. Based on screen dumps from active vessels registered on www.vesselfinder.com.

Appendix 3.A6. Landings of plaice in Skagerrak 2013-2023



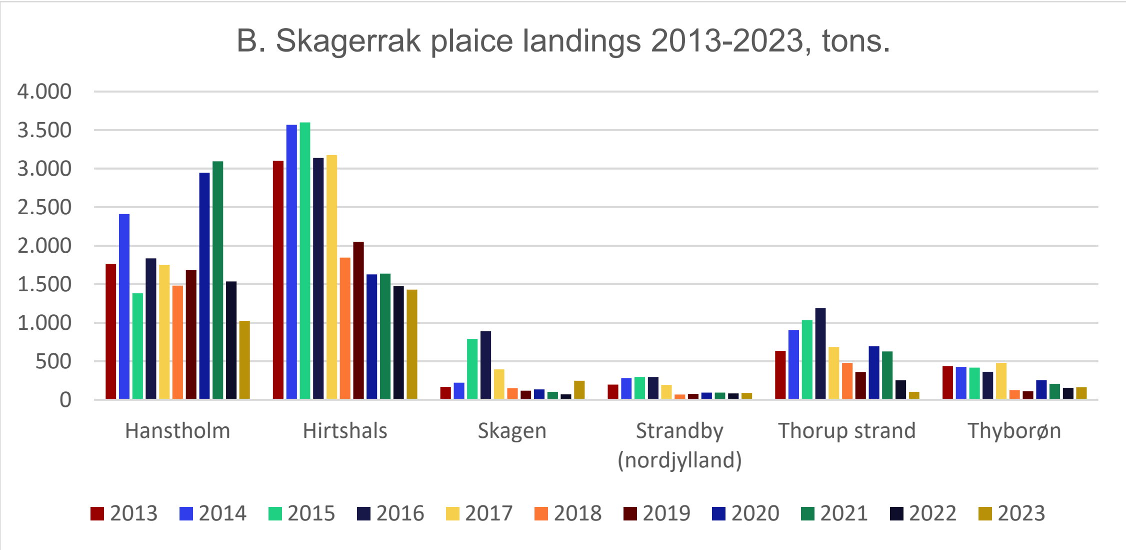


Figure 3.A6.1. Landings of plaice from Skagerrak 2013-2023 (Dec 17, 2023), Danish ports with +2 % of landings. A) % of landed weight, B) tons landed weight. Source: Fiskeristyrelsen, dynamic table for landings (Landed weight, plaice, all conditions, from Skagerrak, all nations, landings in Danish ports only).

4. Habitat-related by-catch of non-target fish and protected, endangered, and threatened (PET) species (Task 4.3)

David Lusseau; Gildas Glemarec, Lotte Kindt-Larsen

4.1 Introduction and aim

The incidental capture of unwanted species (bycatch) like marine mammals, seabirds, or fish in set net fisheries is a long-known issue in Danish waters (Vinther 1999; Gislason et al. 2014, 2021). The additive mortality induced by bycatch is susceptible to affect negatively the population dynamics of protected, endangered, and threatened (PET) species and is a matter of concern at the level of the European Union (EC 2023).

Bycatch emerges from the interactions of multiple factors associated with fishing characteristics and with the distribution and behavioural ecology of the impacted sensitive species (Northridge et al. 2017). While we can monitor fishing operations to understand the former, it is more challenging to understand aspects of behaviour and ecology of the sensitive species that *cause* individuals to become entangled. While animal density alone is often a useful proxy variable to explain some of those biological aspects, it does not fully capture the activity of individuals, which can be an important factor influencing bycatch probability. Previous studies have been able to estimate bycatch risk at moderate resolution using both porpoise density inferred from satellite tagged animals and fishing effort information (Kindt-Larsen et al. 2016). However, it is difficult to estimate this risk at higher spatial, and especially temporal, resolution from density estimation methods alone. More informative risk maps than simple overlaps between fisheries and PET species distributions can be obtained from including additional information to ad-hoc models, as shown in e.g., Kindt-Larsen & Glemarec et al. (2023), which in turn can help understand the scale and magnitude of the bycatch problem in order to act upon it effectively. At its simplest, bycatch results from the simultaneous presence of fishing gears and PET species in a given area. As a result, mapping the spatial and temporal overlap between PET species populations and the fisheries identified as problematic in terms of bycatch of these PET species populations is an important step to identify potential bycatch-problematic areas and thus help informing fisheries management. Nevertheless, PET species bycatch also typically depend on a range of operational and ecological factors, including but not limited to fishing gear characteristics, fishing effort intensity, season, depth, distance to shore, or PET species population density, which are likely both species and fisheries-dependant (Northridge et al. 2017). More informative risk maps than simply overlapping fisheries and PET species distributions can be obtained from including this additional information to ad-hoc models, as shown in e.g., Kindt-Larsen & Glemarec et al. (2023), which in turn can help understand the scale and magnitude of the bycatch problem in order to act upon it effectively.

4.1.1 Collecting fishing effort and PET species bycatch data in Jammer Bay (T4.3.1)

Starting in 2010, Denmark put in place a long-term bycatch monitoring programme using electronic monitoring (EM) that provides high-resolution fisheries-dependant data that can be used *inter alia* to evaluate the variability of bycatch rates in Danish waters spatially and temporally or estimate mortality from bycatch for different species of seabirds and marine mammals (Kindt-Larsen et al. 2016, 2023; Larsen et al. 2021; Glemarec et al. 2022). The general description of the method used to collect and analyse these EM data from gillnet vessels is described in detail in Glemarec et al. (2020). Up until the beginning of the JAMBAY project, EM data on bycatch of PET species in the Jammer Bay area was mostly stemming from vessels harbouring in Hirtshals, which typically fish north and outside the Bay, while EM data from the southern part of the Bay was scarcer. In July 2023, two commercial vessels fishing in the Jammer Bay are joined the EM programme and were equipped with identical Black Box Video systems from the Danish EM provider Anchorlab. The EM systems comprised two embedded rugged cameras placed so that we could monitor the entirety of the vessels' fishing activity, including any potential bycatch event. The vessels were either 14 m or smaller. One was a gillnet vessel, while the other was a commercial Danish seiner that switches seasonally to gillnets (usually during the winter period).

The first vessel totalled 8 gillnet fishing trips from July to December 2023, which were all analysed for bycatch, while in the same period the second vessel went out to fish 30 times, among which 27 fishing trips were using a Danish seine and only 3 were using bottom-set gillnets (all of them during November-December). Within the period July-December 2023, we registered the bycatch of 20 sharks of the two species tope (*Galeorhinus galeus*) and dogfish (*Squalus acanthias*), 1 ray (species unidentified), 3 harbour porpoises (*Phocoena phocoena*), 1 harbour seal (*Phoca vitulina*), and 2 Arctic loons (*Gavia arctica*).

4.1.2 Mapping harbour porpoise bycatch risk in Jammer Bay (T4.3.2 & T.4.3.3)

We aimed to appraise the spatial and temporal variability in bycatch risk for harbour porpoises (*Phocoena phocoena*) in Jammer Bay. Harbour porpoise was selected as case study in this report on the basis that this common cetacean species is highly susceptible to bycatch in gillnets and is present in Jammer Bay yearlong. As such, porpoises are one of the best-known bycatch species in the region and could thus be used to develop a model to explore the complex relationships between oceanographic features, habitat, and fishing effort distribution and intensity in Jammer Bay and the bycatch in gillnets. We know that both the density and the behavioural ecology of harbour porpoises are tightly linked to well-known and measured oceanographic features (Lockyer and Kinze 2003; Johnston et al. 2005; Bjørge and Tolley 2009; Marubini et al. 2009; Edrén et al. 2010; Booth et al. 2013; Jones et al. 2014; Gilles et al. 2016; van Beest et al. 2018; Stalder et al. 2020). A reduced set of oceanographic variables known to affect both aspects of porpoise lives can be retrieved globally from satellite observations, generating daily measurements at high spatial resolution. In European waters, the Copernicus satellite constellation, and the EU Copernicus Marine Service information (https://marine.copernicus.eu) provide such data. In this study, we aimed to use harbour porpoise bycatch observation in monitored commercial fisheries to learn bycatch probability from recorded bycatch occurrence. For each fishing operation, we know the fishing characteristics for the variables known to affect bycatch probability (Kindt-Larsen et al. 2023) in these monitored fisheries. We can therefore use measures of oceanographic variables at high resolution to learn the additional, ecological context in which bycatch occurs for these different fishing characteristics. This oceanographic knowledge provides a mean to inform both the unobserved density and the unobserved activity of porpoises during fishing operations. As we are able to observe both fishing operations with and without bycatch events, we can learn the fishing and ecological context affecting bycatch risk and make predictions at high spatial and temporal resolution establishing the regional variability in porpoise bycatch.

4.2 Materials and methods

We used a supervised machine learning approach to learn the fishing and ecological contexts in which bycatch becomes more prevalent. We know from previous targeted studies that this context is complex and influenced by non-linear interactions between factors contributing to bycatch (Kindt-Larsen et al. 2016, 2023). We therefore decided to use a classification tree model to classify observed fishing operations (hauls) with and without harbour porpoise bycatch depending on fishing characteristics and oceanographic features.

4.2.1 Monitored fishing data

Fishing operations have been observed in the North Sea and Skagerrak sections of Danish waters using electronic monitoring (EM) since 2010, following a method described in Larsen et al. (2021). Essentially, we observed and recorded information on fishing effort at haul level and porpoise bycatch for a sample of commercial gillnet vessels operating in the region and used these data to estimate the local variability in porpoise bycatch rates, associated with effort variables.

4.2.2 Fishing Effort data

Fishing operations in Jammer Bay were inferred for commercial vessels using static nets and equipped with either VMS, EM, or AIS data from 1st January 2019 to 5th of December 2023. No further fishing was observed in the Bay after the 5th of December, so we can assume that our samples are representative of the whole of 2023. For the most part, this concerns gillnet vessels longer than 12m for which VMS usage is mandatory, but the dataset also contained data for some smaller vessels using AIS for safety purposes. In short, the positions and time of net retrievals (hauls) were estimated from a simple model using the geospatial as input, where we assumed that hauls correspond to the phases during which vessels travel at low to moderate speeds, here, <4 knots (ICES 2022). This gave us access to secondary information on e.g., the total length of each individual haul, the average fishing depth, and the distance of the fishing gear to shore. The dataset was coupled with landings and sales notes data from which we could estimate other important effort variables (e.g., mesh size, or soak duration). This inference was made for a grid at 0.01° x 0.01° resolution of Jammer Bay projected using EPSG:4326 (Fig. 4.1).

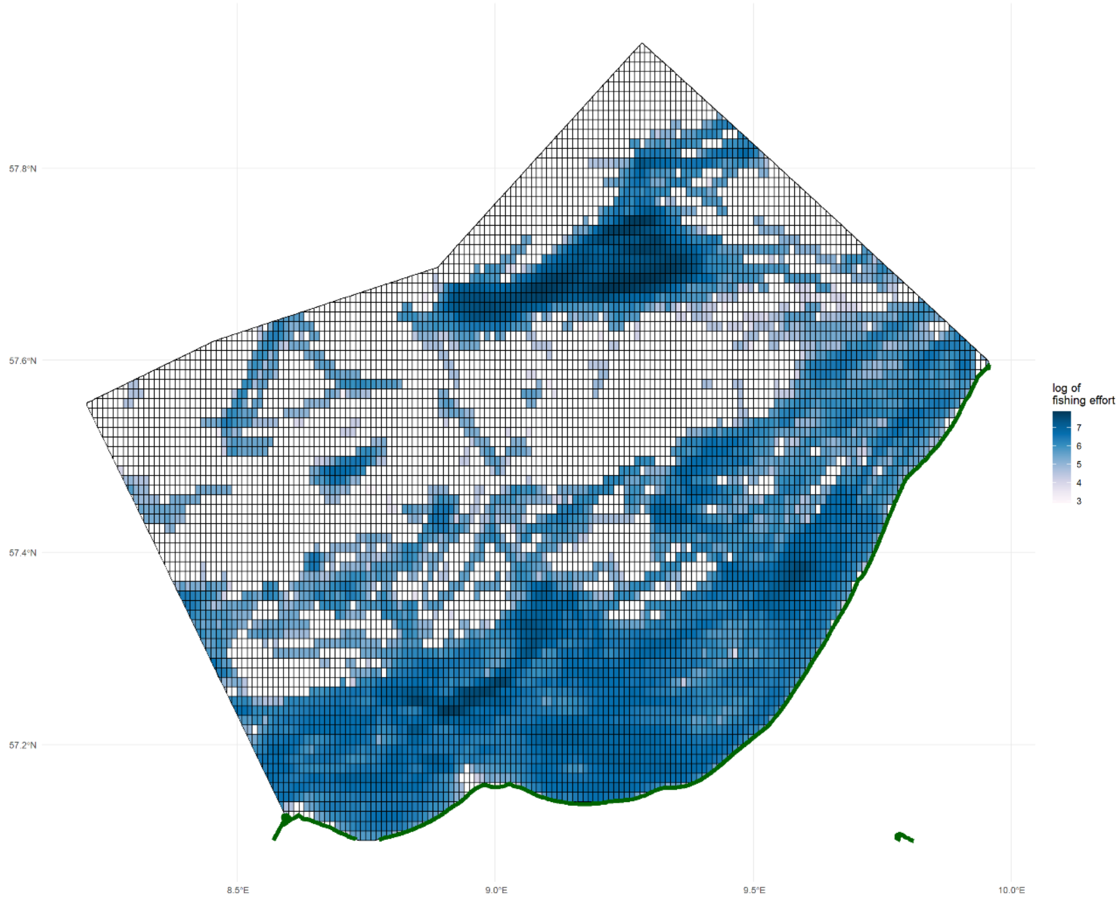


Figure 4.1. Grid for which bycatch risk predictions are inferred. The grids present the log of the total fishing effort (std_effort, see methods) for the period 1st January 2019 to 5th of December 2023.

4.2.3 Fishing and oceanographic explanatory variables

We used gillnet mesh size (in mm) and a standardised measure of effort (std_effort) which captures both the length of nets used (in meters) and the soaking duration (or soak time, in hours) such as std_effort = net length x soak time (Kindt-Larsen et al. 2023). Because the values of std_effort spanned over several orders of magnitude, we used std_effort on a log scale. Both measures could be estimated for each haul in the monitored fishery. We could also estimate a daily aggregated measure of std_effort for each grid cell of the Jammer Bay grid. Importantly, nets can be longer than the grid cells. Since we were interested in estimating a measure of bycatch risk within each grid cell, it was important to keep for each cell the fishing feature influencing this risk. That is, if a net deployment spanned over multiple cells (because the haul length was longer than a single cell), each of the intersected cells were attributed the std_effort value calculated from the whole net length. Therefore, in this case, the fishing characteristics contribution to bycatch risk was duplicated for each cell over which the net was deployed.

We then retrieved oceanographic variables from the EU Copernicus Marine Service for each fishing events in the monitored fishery (as the latitude, longitude, date, and time were known for all monitored events), for each grid cell, and for each day for which the fishing effort was estimated (2019-2023). Namely, we retrieved data from:

- the 1970-2023 time series of Atlantic - European North West Shelf - Ocean Physics Analysis and Forecast (doi:10.48670/moi-00054) available at a 0.03° x 0.014° resolution (Tonani *et al.*, 2019):
    - Sea potential temperature ($theta_o$), bottom potential water (bottomT), salinity (s_o), northward velocity (v_o), and mixed layer thickness (mlostst);
- the 1 May 2019-1 Dec 2023 time series of Atlantic - European Northwest Shelf - Ocean Biogeochemistry Analysis and Forecast (doi:10.48670/moi-00056) available at a 0.11° x 0.067° resolution:
    - net primary productivity for three depth bands (0-3m: NPP0, 3-10m: NPP3, and 10-15m: NPP10)
- EMODNET (doi:10.12770/ff3aff8a-cff1-44a3-a2c8-1910bf109f85) high-resolution bathymetry (0.001° x 0.001° resolution)
    - mean depth and slope

These variables captured recurrent oceanographic features known to affect porpoise distribution, density, and activity (particularly foraging).

4.2.1 Modelling approach

We used a statistical technique called eXtreme Gradient Boosting (XGBoost) to teach a decision tree to classify fishing events as having bycatch or not. The outcome was chosen to be a probability of bycatch ($p_{bycatch}$) rather than a binary classification (bycatch present or not) as this provides a mean to discriminate events where the bycatch probability is different but still not exactly zero or one.

Decision trees have traditionally been estimated using multivariate statistics such as clustering methods, more recently expanded to random forest (Self et al. 2021), where many trees are drawn as independent estimates of the way to classify observations based on various approaches to resample the covariates describing the state of the observations (De'ath 2007). Boosted trees are machine learning extension of this modelling approach and introduced the possibility for machines to learn from each tree produced during this resampling process, so that the combination of variables tried at each iteration in a random forest is no longer independent, but instead makes use of what was learnt in the previous iterations sequentially to fine-tune the final decision tree. However, boosted tree learning can lead to overfitting, among several limitations (Elith et al. 2008). Extreme gradient boosted models (https://xgboost.readthedocs.io/en/stable/tutorials/model.html) are learning from tree model ensembles using a similar approach to boosted tree models, but introducing a regularisation step for parameters that ensures against overfitting (Ghafarian et al. 2022; Poisot 2023). Hence, XGBoost was a good candidate method for our task to develop a predictive model of bycatch risk.

We implemented XGBoost models in R (XGBoost version 1.7.6.1; Chen et al. (2023), implementing supervised learning in a distributed approach over a GPU (Nvidia RTX 2080 Ti) in Windows OS following the approach from Chen and Guestrin (2016). Specifically, we selected 70% of the monitoring data (EM data) to train the model and 30% to test it. This 70/30 division of the available monitoring data was set so that the proportion of bycatch events was the same in both sets and the proportion of hauls coming from each ICES area was the same. This helped to ensure representativity of fishing and oceanographic conditions present over the area of interest.

We first tuned the hyperparameters of the model (learning rate, depth of trees, observation subsample proportion used at each iteration, proportion of explanatory variables used for each tree, scaling of positive sample weight, and minimum number of observations left in a final node of the tree) using a grid search and using multiple evaluation metrics to also assess the influence of the evaluation metric (root-mean-square error [RSME], area under curve [AUC], and area under precision-recall curve [AUCPRC]). All three metrics converged on similar hyperparameter values and AUC was used for the final fit. As the distribution of bycatch is unbalanced, we assessed whether scaling for the proportion for bycatch events observed was required as part of the hyperparameters tuning. Once the hyperparameters were tuned, we then search the regularisation parameter space, using a grid search approach, and multiple evaluation metrics again, to determine the L1 (α) and L2 (λ) regularisation tree leaf weights and the minimum loss reduction to create new tree splits (γ). Once both hyperparameters and regularisation parameters were tuned, we fitted the model to the training data using these tuned parameter values and estimated the extreme gradient boosted tree using the final total number of trees determined in the final best model of the parameter tuning step. We then used the test data to predict bycatch probability for both hauls with and without bycatch to determine the validity of the model. We also used Shapley values to interpret the tree (Ghafarian et al. 2022), which are useful to describe how the considered explanatory variables interact to yield the bycatch probability predictions. We used functions native to XGBoost for this as well as functions of the library *treeshap* (Lundberg et al. 2020).

4.2.2 Bycatch risk prediction approach

Once we fitted and understood the predictive model, we predicted bycatch probability for each grid cell (Fig. 4.1) of Jammer Bay and each day from 1st January 2019 to 5th of December 2023 (16,790,377 predictions). One challenge in predicting bycatch probabilities in this setting is that not all the fleet fishing effort is reported. So, while we have a good understanding of the spatio-temporal variability of fishing effort for the vessels >12m (i.e., vessels with mandatory VMS) operating in Jammer Bay, we do not have a comprehensive view of the effort of the smaller vessels of the fleet. It means that in setting the fishing characteristic values for each day and each grid cell, we may attribute zero effort to some cells, whereas in reality, fishing occurred in these cells. To deal with this shortcoming, we produced three sets of predictions to capture the range of bycatch probability which could be predicted depending on whether we treat the missing fishing effort information conservatively or liberally.

In the first set **(SET I)**, the probability of bycatch for each cell.day for which no fishing was observed is set to zero. The bycatch probability is not predicted, and it is assumed that the risk is not existent because fishing did not take place there and then. We then take the average $p_{bycatch}$ for each cell over the reporting time period (see next paragraph).

In the second set **(SET II)**, we assume that some bycatch is possible in all grid cells and all days. If no fishing effort is reported, we set the fishing characteristics to the values which would return the lowest possible partial effect on bycatch probability for the model, i.e., a very small mesh size and a very small net length (<1m). We then predict bycatch probability $p_{bycatch}$ for all cells and all days. This set captures a conservative measure of bycatch risk: on days and places without known fishing, we consider what the bycatch probability for relatively safe fishing practices would be given the oceanographic conditions.

In the third set **(SET OBSERVED)**, we only make predictions for cells and days for which fishing effort was observed (i.e., for the vessels for which we have information on fishing effort from geospatial data; mostly vessels >12m). Here, we do not consider places and days when fishing did not take place at all. The bycatch probability is therefore only representing what the risk is when known fishing took place, capturing the spatial and temporal changes in fishing practices over the studied period.

In the following section, we present for each set of predictions the mean bycatch probability in each grid cell, both yearly and quarterly.

4.3 Results

4.3.1 Model training

The fitted model is available as a XGB object and had the following tuned hyperparameters: learning rate: 0.1, evaluation metric: AUC, observation subsampling: 80%, maximum tree depth: 10, variable subsampling: 80%, minimum child weight: 3, and tuned regularisation parameters: $\gamma=0$, $\alpha=0$, and $\lambda=1$. It was trained on 30 trees. The trained model had a 2.6% error rate on the test data (AUC = 90.4% on the test data) and bycatch probability was discriminated between hauls with and without bycatch, even though the bycatch probability for hauls with bycatch was far from 100% (Fig. 4.2a). Given that we are to use this measure as a relative measure of variation in bycatch probability in an area and time period covered by the training data, this lack of ability to determine bycatch occurrence in absolute terms is not diminishing the value of the trained model to provide the insight we aimed to reveal.

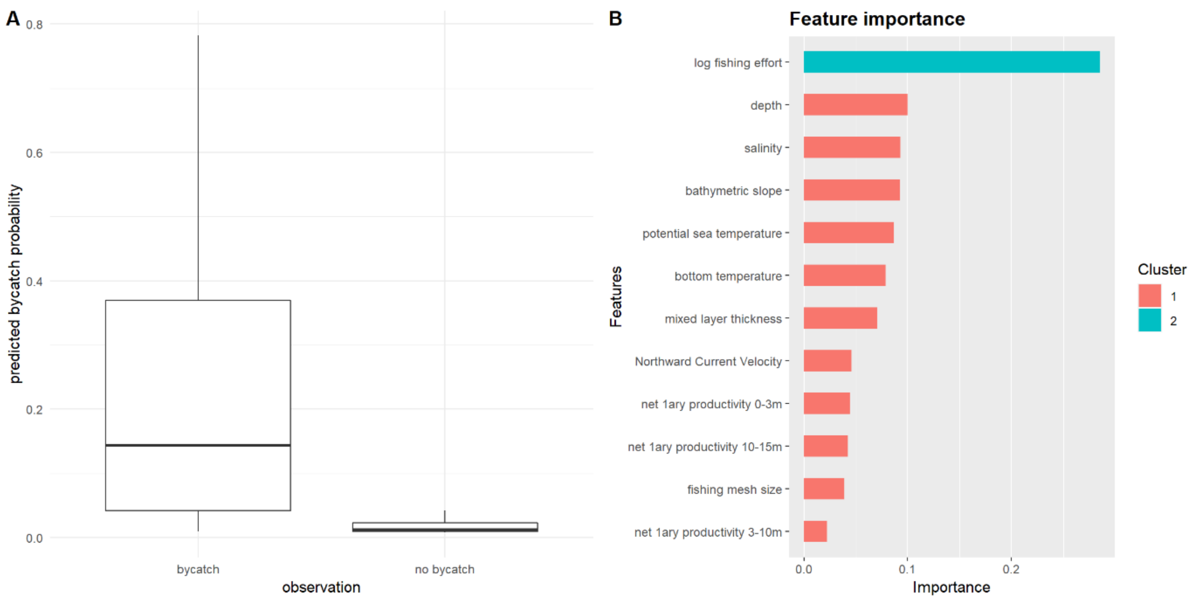


Figure 4.2. Predicted harbour porpoise bycatch probability in gillnets for observations with and without bycatch in the test dataset (A) and variable importance in the discrimination of hauls with and without bycatch in the training set (B). The clusters correspond to variables that have somewhat similar importance for the classification.

SHAP (SHapley Additive exPlanations) values provide a way to explain how features (*i.e.,* explanatory variables) contribute to the classifier (Lundberg and Lee 2017). Here, positive SHAP values contribute towards an increase in bycatch probability and negative values towards a decrease in bycatch probability. We can estimate the feature dependence of bycatch probability accounting for the interactions (caused by the branches of the tree) between features for each feature (Figs. 4.3 and 4.4). We can note that oceanographic conditions increasing bycatch probability are associated with situations when we would expect more porpoises to be present and them being likely to forage (see references in introduction). It is particularly interesting to note that the two oceanographic variables likely associated with prey availability (slope and bottom temperature) are interacting with the effect of fishing effort and the partial dependence (effect in other modelling frameworks) of bycatch probability on short fishing effort increases as bottom temperature increases and slope increases (Fig. 4.5).

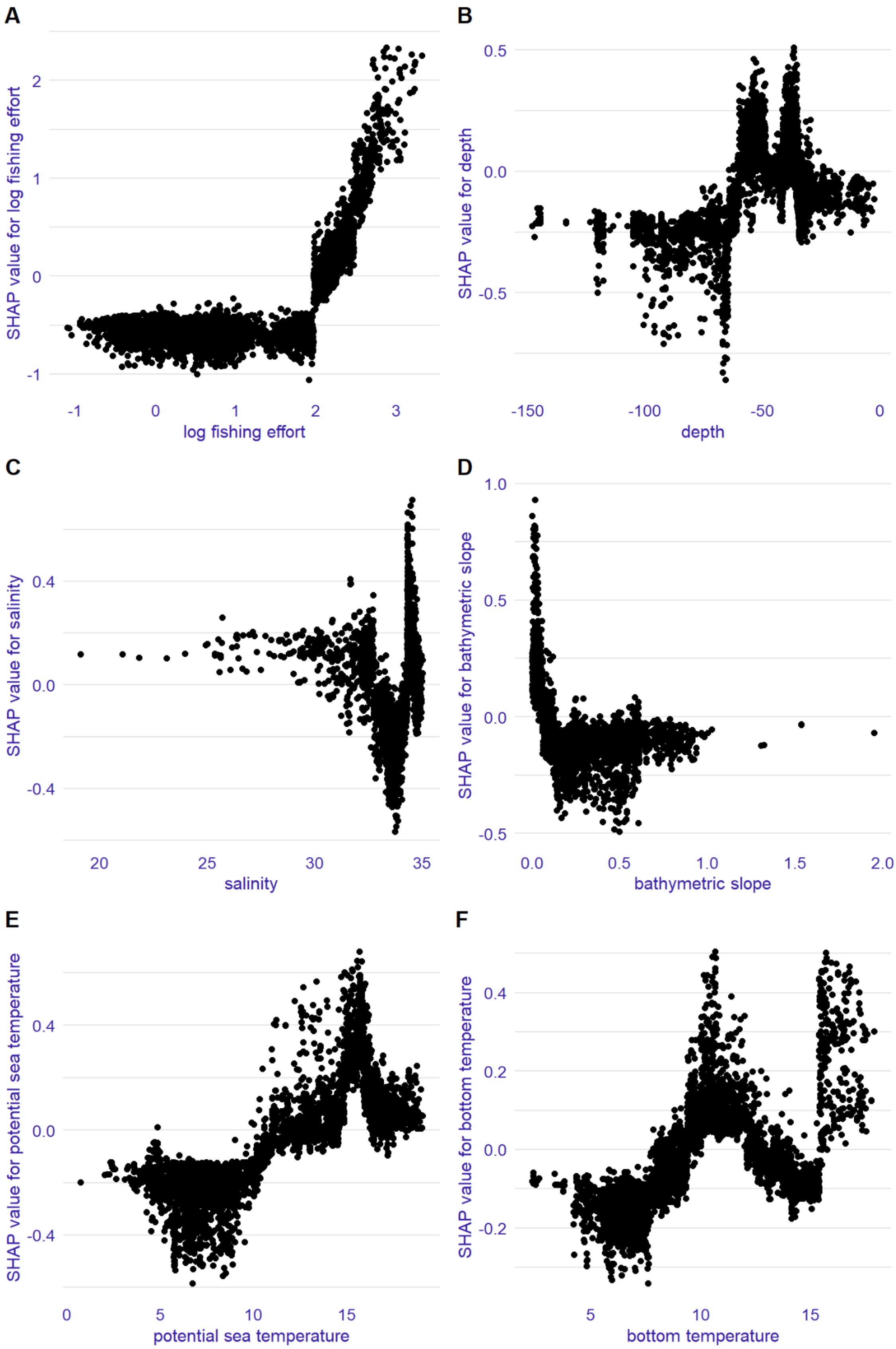


Figure 4.3. SHAP value for the 6 first important features of the classifier; each point is a fishing event.

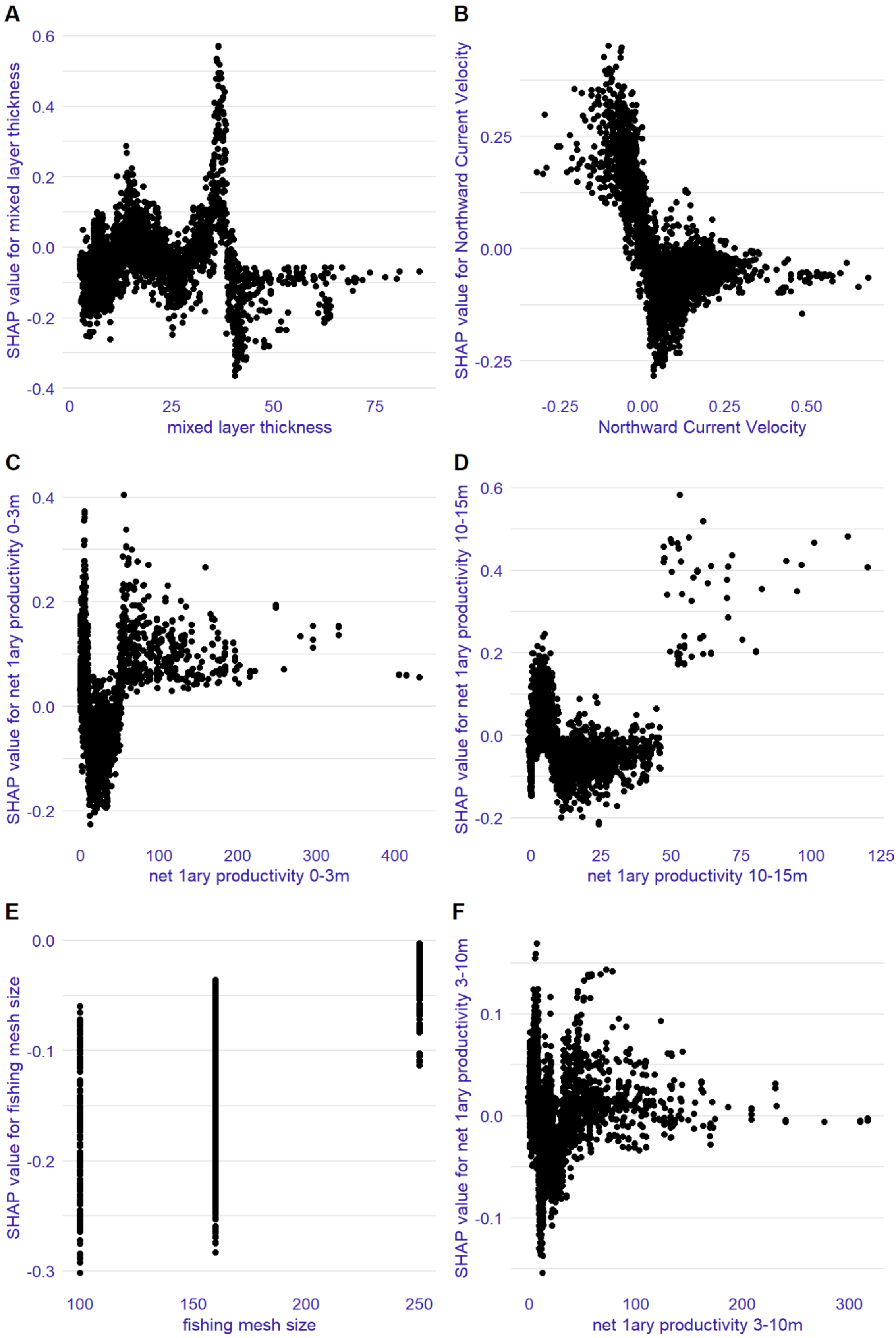


Figure 4.4. SHAP values for the 6 last important features of the classifier (fig. 4.2); each point is a fishing event.

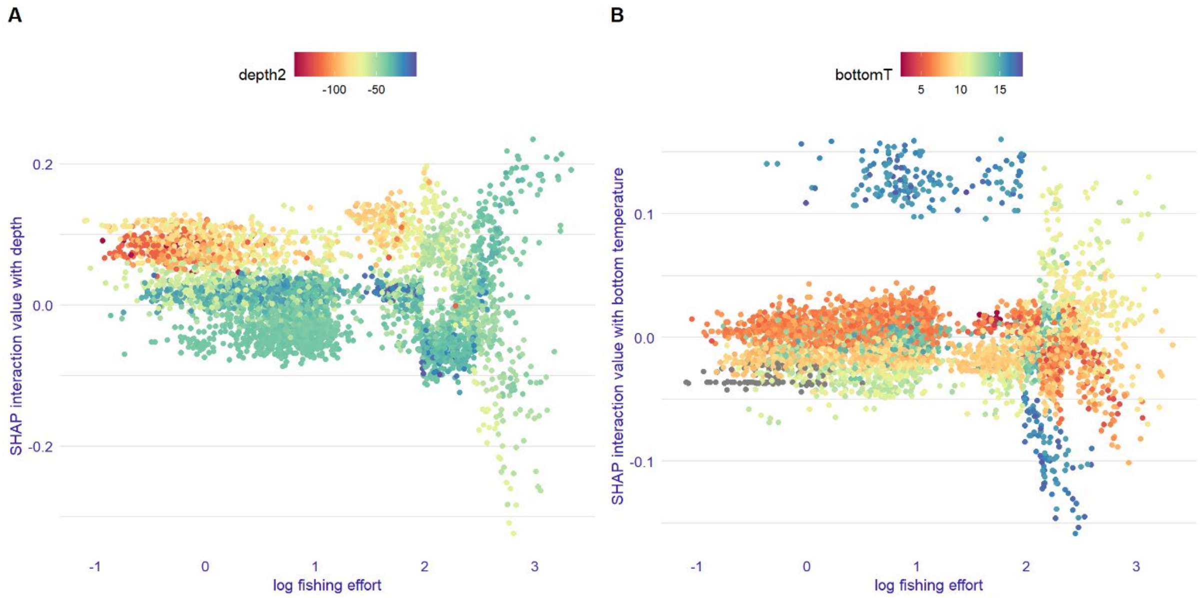


Figure 4.5. SHAP values for feature interactions between fishing effort and depth (A) and fishing effort and bottom temperature (B).

4.3.2 Predictions for Jammer Bay

When summarising predictions for the full study period (5 years) we can see that bycatch probability varies spatially in Jammer Bay (Fig. 4.6) and is broadly consistent with the fishing effort distribution (Fig. 4.1); as expected given the importance of this feature in the model (Fig. 4.2). There is substantial departure between SET I and the other sets (Fig. 4.6) off the coastline near Tranum Strand. This indicates that in this area we have fewer reported fishing days and whether we assume that those days are risk free (SET I) or not is important.

We observed a decrease in overall fishing effort during the COVID-19 pandemic, however this reflected in the spatial distribution of bycatch probability in increased heterogeneity when fishing effort was lower (Fig. 4.7 A-C). Quarters 2 and 3 have overall more bycatch risk and in consistent areas (Figs. 4.8 – 4.10), however, it is worth noting that Quarter 1 has a different spatial pattern of risk than Quarters 2 and 3 and does have more risk near shore (Tranum Strand area).

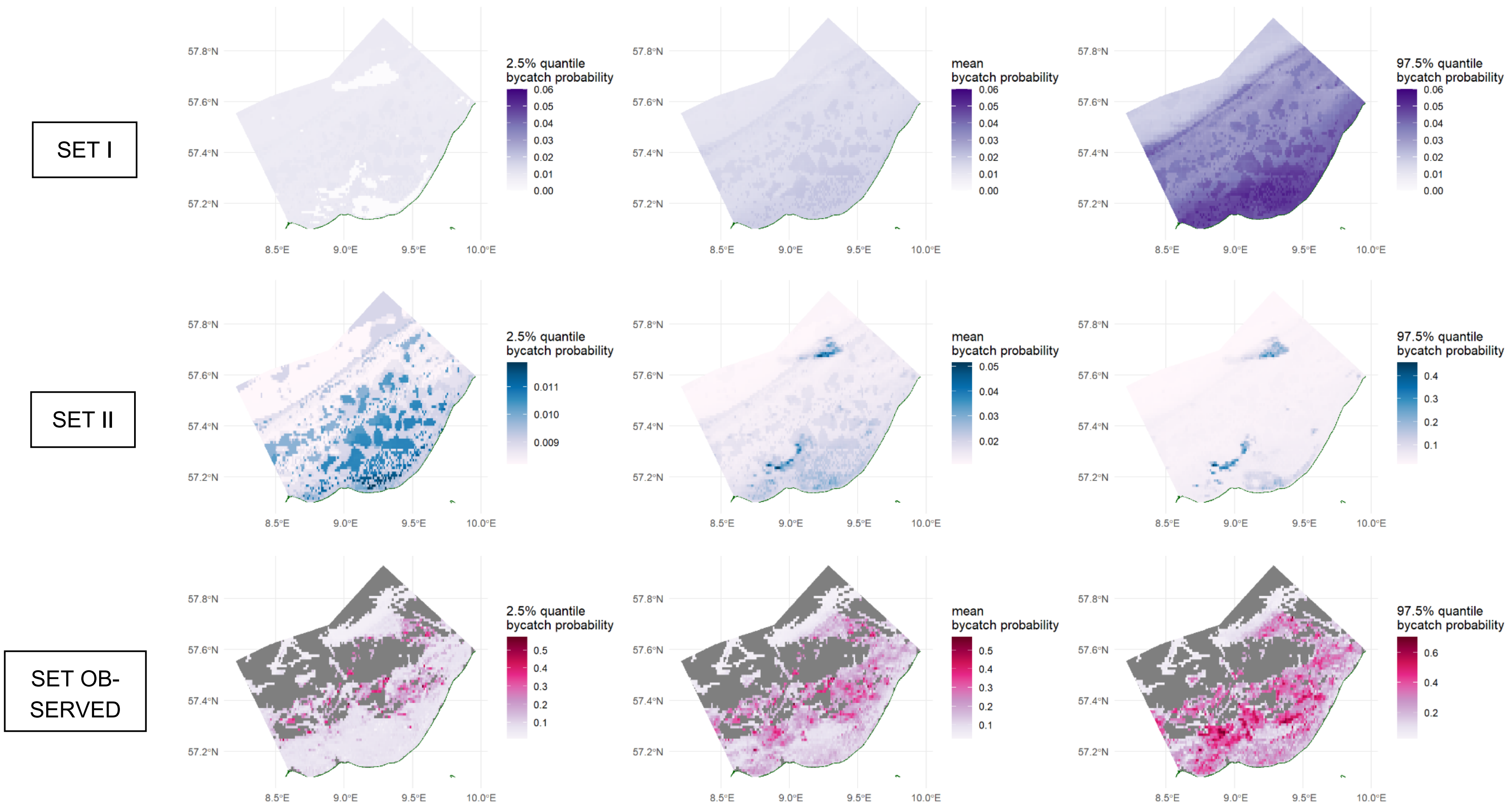


Figure 4.6. Distribution (mean, 2.5% and 97.5% quantiles) of harbour porpoise bycatch probability in gillnets for each set for the whole studied period.

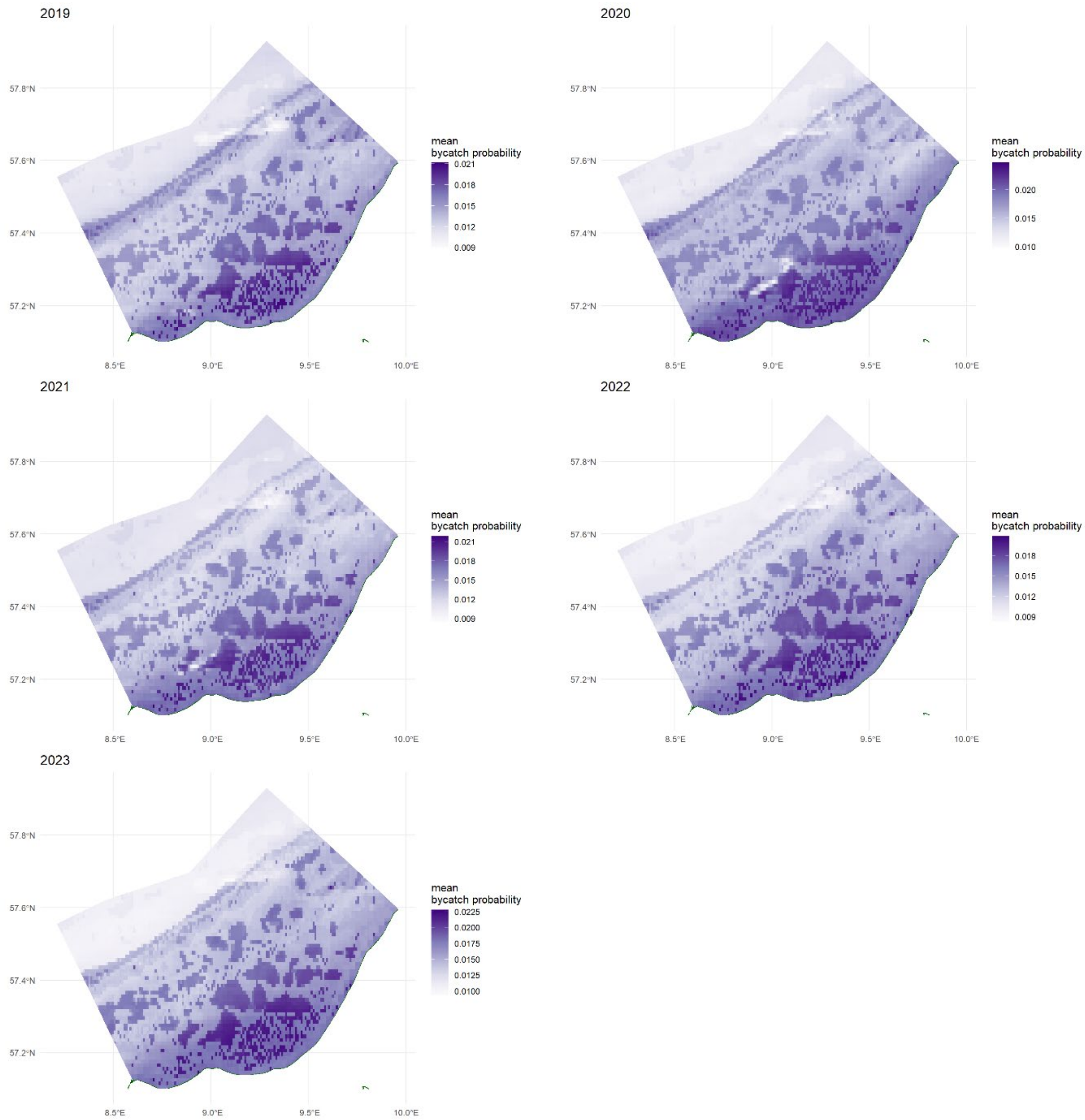


Figure 4.7A. Yearly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET I for years for which fishing effort was available for the whole year (cells are dark grey when no predictions are available).

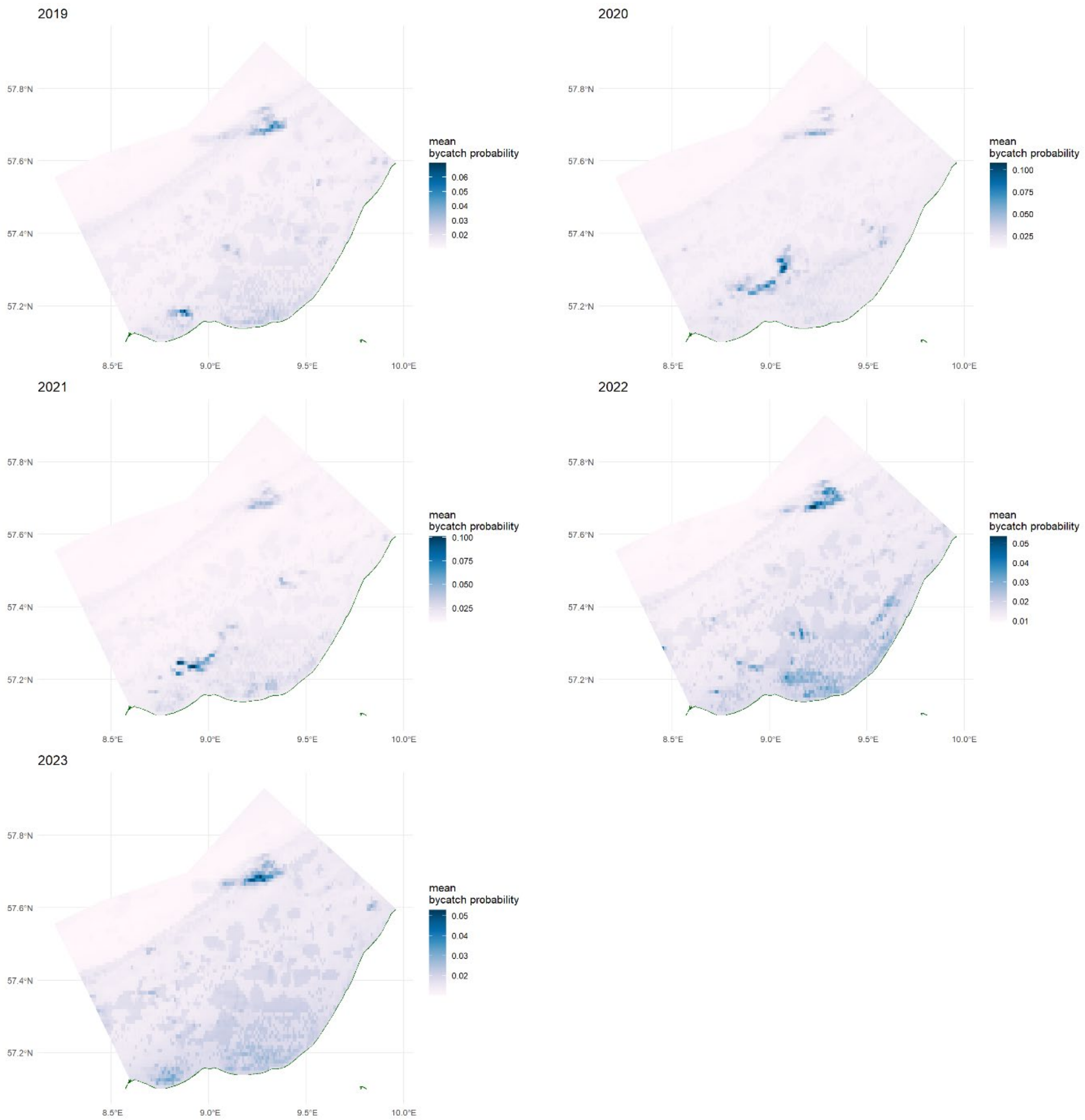


Figure 4.7B. Yearly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET II for years for which fishing effort was available for the whole year (cells are dark grey when no predictions are available).

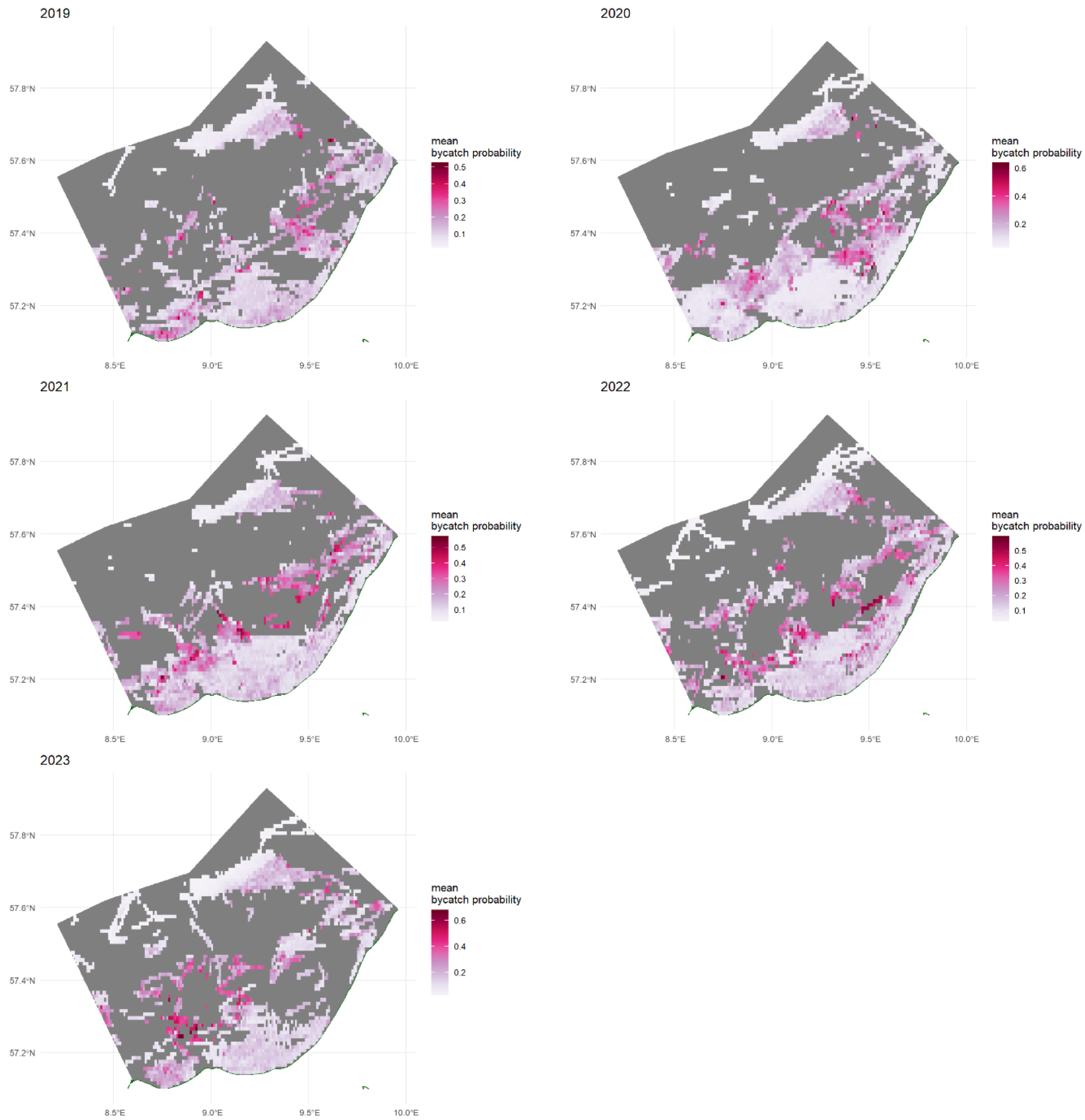


Figure 4.7C. Yearly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET OBSERVED for years for which fishing effort was available for the whole year (cells are dark grey when no predictions are available).

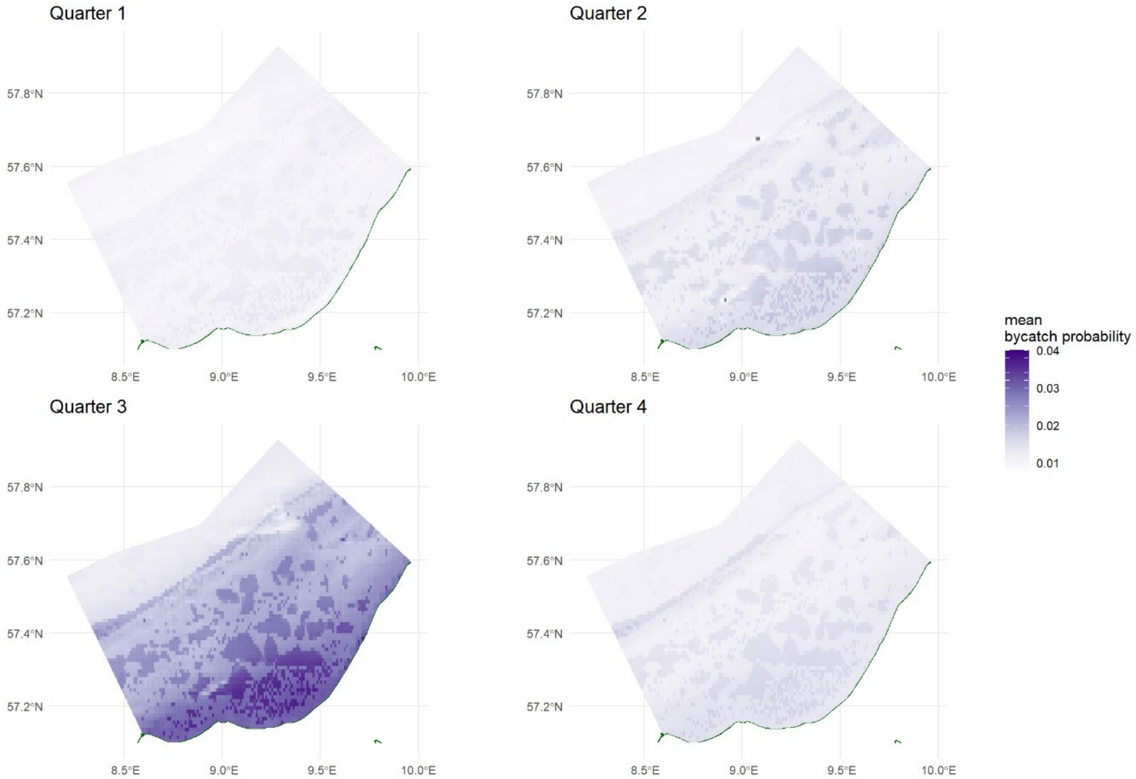


Figure 4.8. Quarterly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET I (cells are dark grey when no predictions are available).

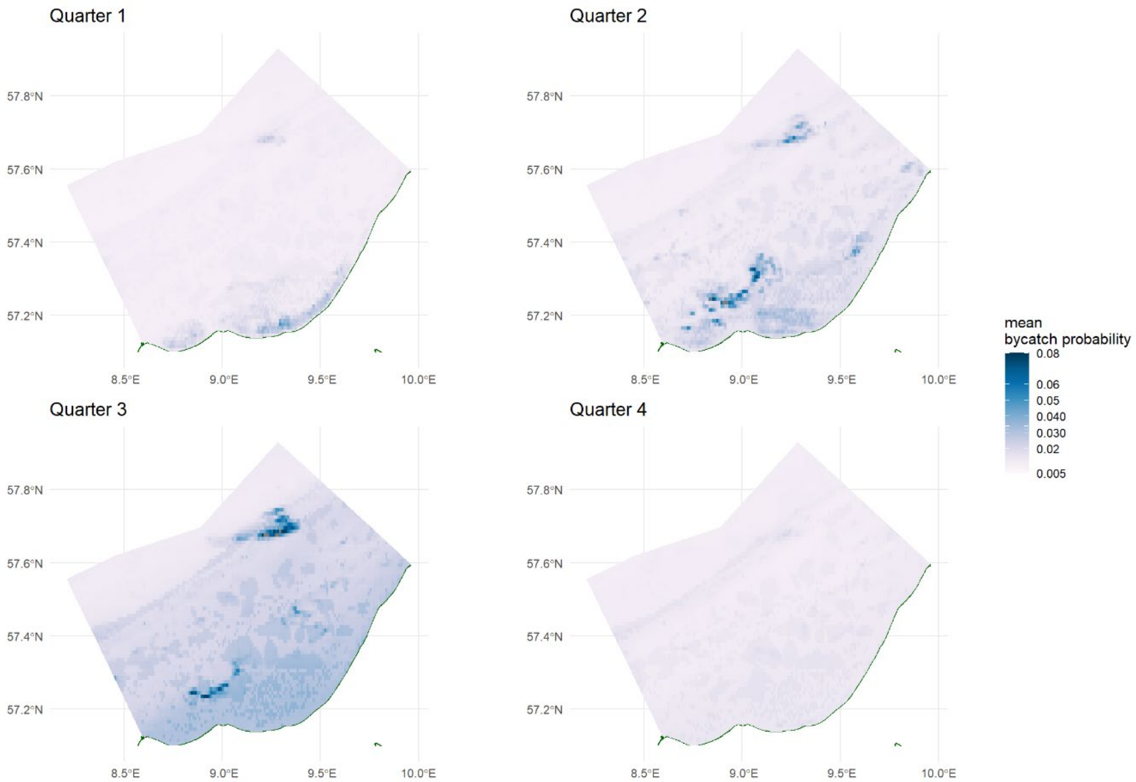


Figure 4.9. Quarterly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET II (cells are dark grey when no predictions are available).

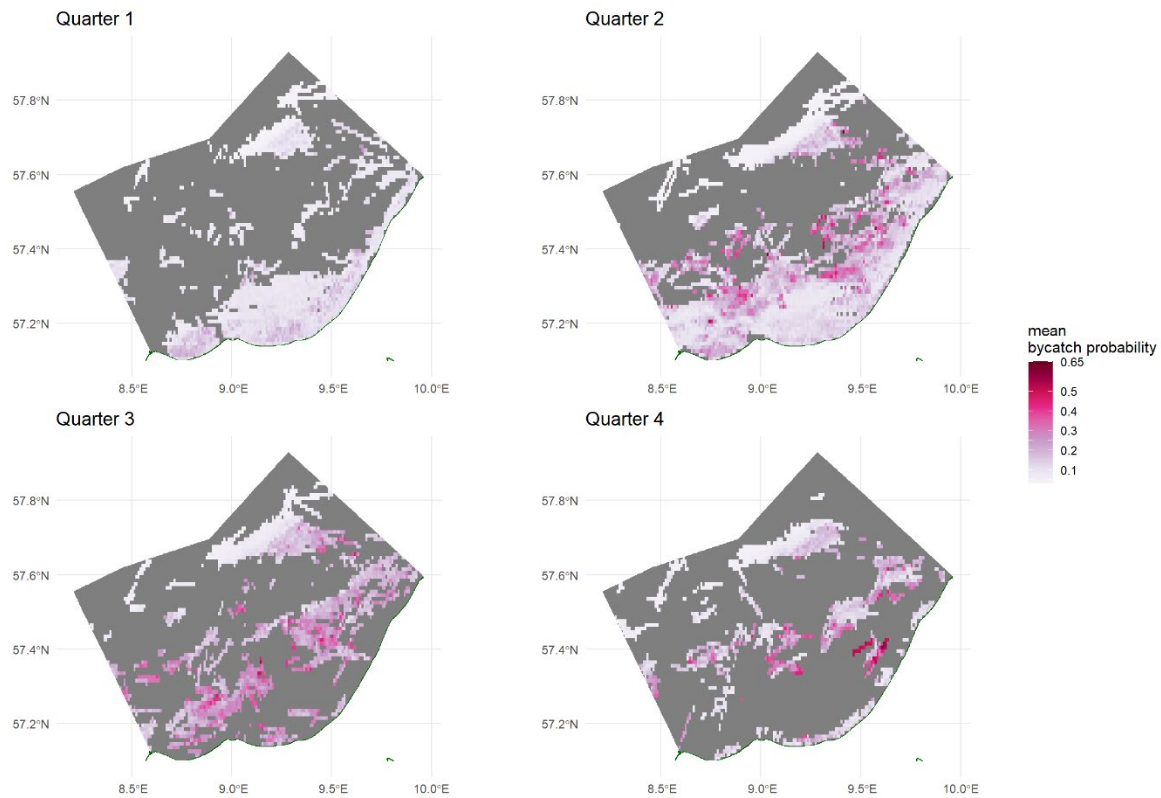


Figure 4.10. Quarterly distribution of mean daily harbour porpoise bycatch probability in gillnets for SET OBSERVED (cells are dark grey when no predictions are available).

4.4 Discussion and perspectives

The EU Copernicus Marine Service database provided information on important oceanographic features that we could link to the data collected with electronic monitoring (EM) to explore the complex relationships between habitat and fishing effort distribution and intensity on bycatch of PET species in Jammer Bay. In order to validate the method that we present in this section of the report, we focussed on the bycatch of only one species, the harbour porpoise, for which we had abundant data to train our models. The results of this modelling exercise shows that, although oceanographic features such as depth, salinity, bathymetric slope, or temperature (all of which could be used to define *e.g.*, areas of high-risk of porpoise bycatch) are important contributors to porpoise bycatch in Jammer Bay, the principal contributor to bycatch probability is – by large – fishing effort (measured as the product of net fleet length and soak duration), while at the same time, and quite unexpectedly, gillnet mesh sizes was not found to be an important variable in our data (Fig. 4.2B). It is likely that mesh size effects on bycatch probability captures ecological features (*e.g.*, via target species) increasing bycatch probability which are captured by the oceanographic variables considered in this machine learning model.

In a fisheries management context, this information points toward reducing the effort in key areas/seasons if ones goal is to minimise harbour porpoise bycatch in the study area, particularly in quarters 2 and 3 in the south-west of the Jammer Bay near shore and in the northern part of the Jammer Bay offshore (Figs. 4.8 to 4.10), and in quarter 1 near shore.

Here, we presented the results for only one species, but the method developed in this study ought to be applied to more species to understand what contributes the most to PET species bycatch in gillnets in Jammer Bay and inform management accordingly to reduce bycatches of PET species to a minimum.

4.5 Acknowledgements

We address our sincere gratitude to all the vessels' owners who accepted to participate in this study by allowing us to monitor their fishing activity using EM, and without whom none of this work would have been possible.

The work was funded in the project 'Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)' (Grant Agreement No 33113-B-23-189) by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark and by the SEAwise project from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000318.

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5. Spatial and density model for sensitive species (Task 4.4)

Casper W. Berg, Anna Rindorf, Tobias Mildenberger, Mikael van Deurs, Jasmin Thomassen

5.1 Introduction and aim

Fish of different species occur in different areas of the sea resulting in diverse temporal and spatial impacts of fisheries on fish and benthos. Knowledge on species, which are particularly sensitive to fishing can therefore potentially be used to evaluate current and future impacts of fishing on these species. These species include long-lived, late maturing species such as halibut (*Hippoglossus hippoglossus*), lump sucker (*Cyclopterus lumpus*) and sharks and rays (Elasmobranchia). Unfortunately, the distribution of these species in the Jammer Bay area is currently poorly known.

The work under this task analysed catches in scientific trawl surveys and catches in historical fisheries, to investigate how the abundance of these sensitive species has changed over time and how they are distributed in the Jammer Bay area and the surrounding areas. This study took into account factors such as depth, trawl duration, trawl speed and gear-width in the analyses of abundance. These factors were suspected to impact catch of sensitive species but had not previously been investigated. The historical data was investigated to derive information on historical variability in the catches and the distribution of these where possible, and this information was compared to results from analyses of scientific surveys. Together, these two information types provided the foundation for potential subsequent stock assessments of these species.

5.2 Materials and methods

The first part focused on data from the scientific trawl surveys from the period 1983-2023.
The following bottom trawl surveys cover the Jammer Bay area or parts of it, and were thus considered:

- The North Sea International Bottom Trawl Survey (NS-IBTS)
- Baltic International Trawl Survey (BITS)
- Cod survey (Cod)
- Sole survey (Sole)
- Norwegian Shrimp survey (NO-shrimp).

These surveys are conducted using different types of trawling gear, which means their relative catch efficiency must be estimated in order to use them for abundance estimation.

A Delta-lognormal generalized additive model with the following structure was used:

$$\begin{aligned} g(\mu_i) = {} & \mathrm{Gear(i)} + \mathrm{Quarter(i)} + f_1\left(\mathrm{utm.x}_i, \mathrm{utm.y}_i, \mathrm{Quarter}_i\right) + f_2\left(\mathrm{time}_i, \mathrm{Quarter}_i\right) + \\ & f_3\left(\mathrm{utm.x}_i, \mathrm{utm.y}_i, \mathrm{time}_i, \mathrm{Quarter}_i\right) + \\ & f_4\left(\sqrt{\mathrm{depth}_i}, \mathrm{Quarter}_i\right) + \mathrm{U(i)}_{\mathrm{ship}} + \log\left(\mathrm{HaulDur}_i + 5\right) \end{aligned} \tag{1}$$

where the response variable μi is the biomass in the ith haul and f1 to f4 are splines. For geographical coordinates (utm.x,utm.y), time, and depth, Duchon splines with first order derivative penalization are used everywhere. All space, time, and depth related splines are all fit independently by quarter (Q1 or Q3).

U(i)ship is a normal distributed random effect for the vessel collecting the ith haul.
The function g is the link function, which is the logit function for the binomial model. The lognormal part of the delta-lognormal model is fitted by log-transforming the response and using the Gaussian distribution with a unit link.

The following list of species were considered:

- Halibut (*Hippoglossus hippoglossus*),
- Spurdog (*Squalus acanthias*),
- Wolffish (*Anarhichas lupus*),
- Starry ray (*Amblyraja radiata*).

5.3 Results

5.3.1 Halibut

Atlantic halibut is among the largest bony fish in the world and is globally classified as “Near Threatened” on the IUCN Red list (2021) and as “Vulnerable” in Europe (2013). Very limited amounts of halibut were found in the BITS, cod, and sole surveys, so only NS-IBTS and NO-shrimp were included in the model (see Figs. 5.1 to 5.4). No significant change in the spatial distribution of halibut in the period considered was found. Therefore, the abundance trend in Jammer Bay was estimated to be the same for the whole area. The overall trend was positive for halibut, but there was some decline since the peak in 2019. The model indicated that the highest abundances of halibut are found at depths greater than 500 m, where there is limited coverage by the surveys.

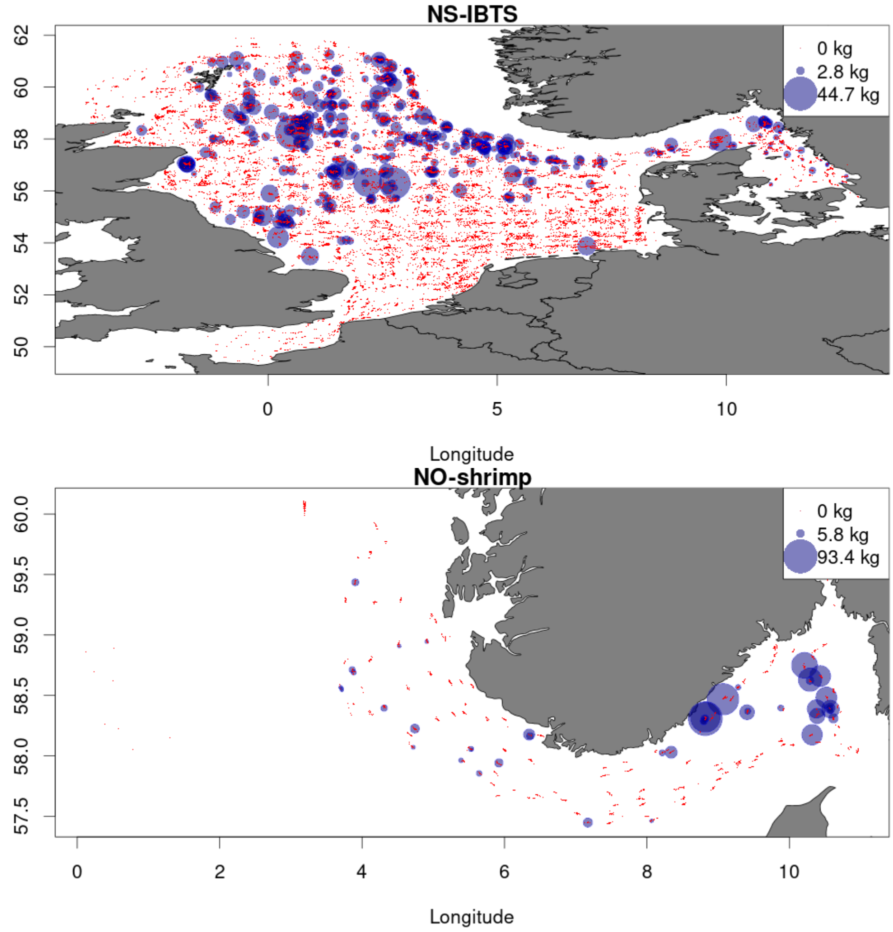

Figure 5.1. All catches of halibut in the trawl surveys.

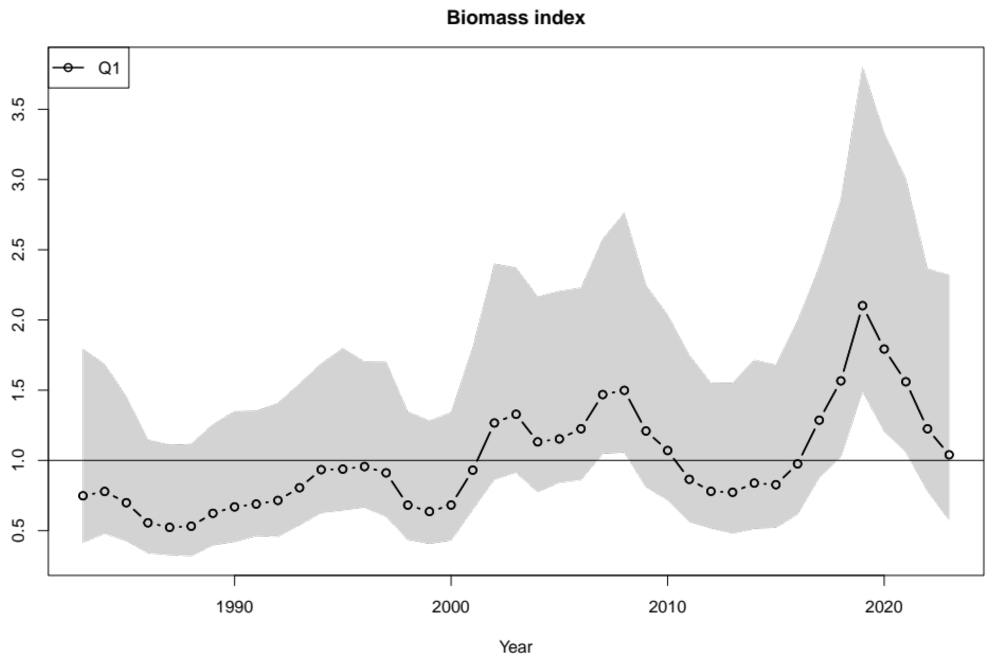

Figure 5.2. Halibut: Abundance index for whole area (scaled to mean 1).

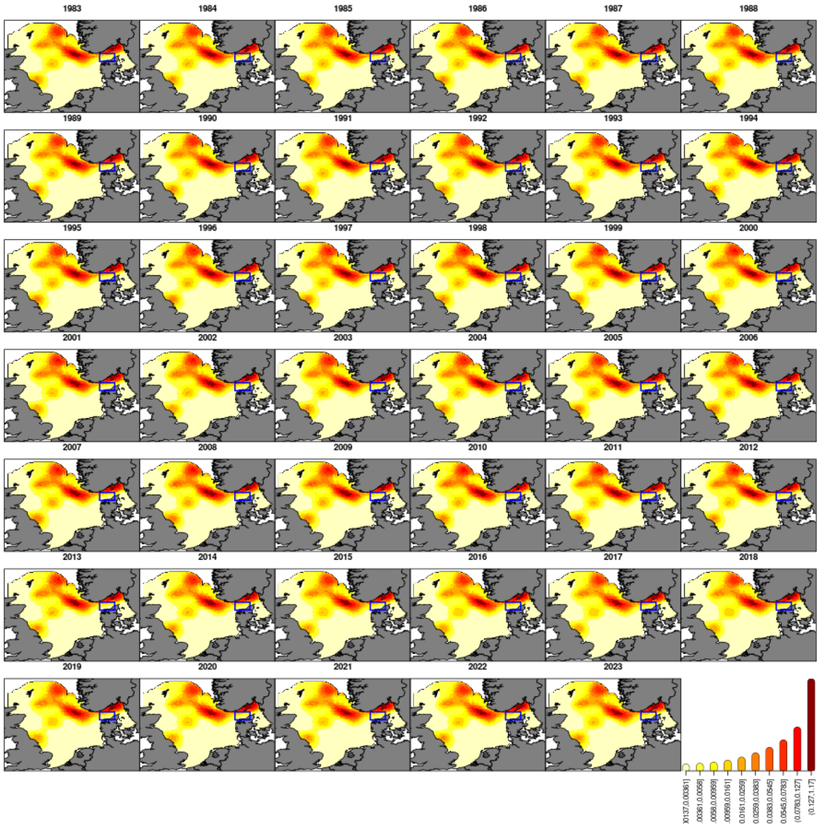

Figure 5.3. Halibut: Abundance maps Q1. Blue rectangle indicates the Jammer Bay area.

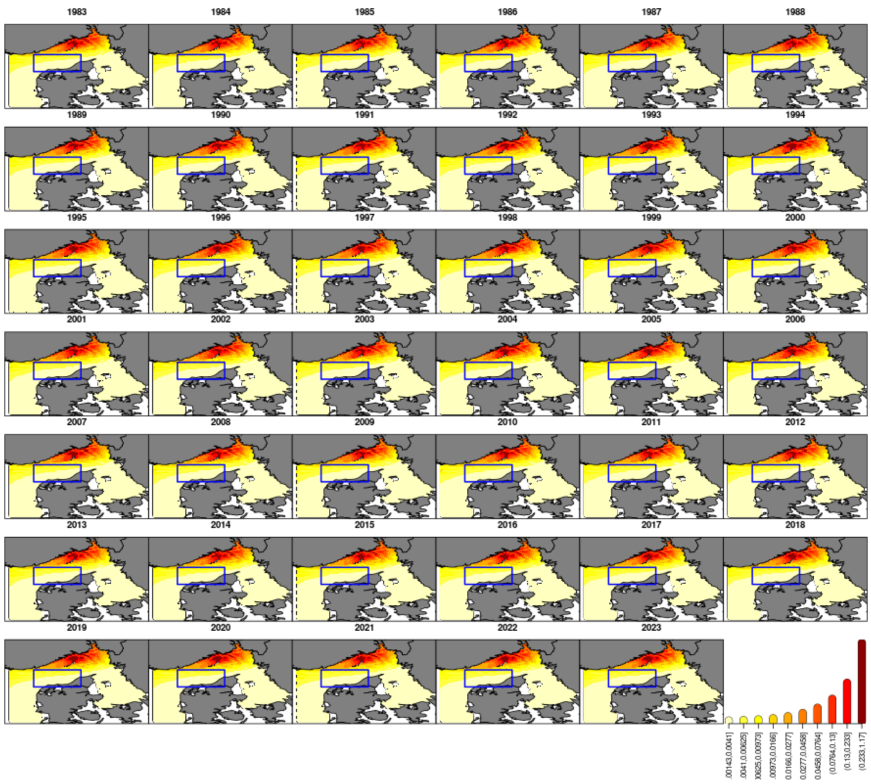

Figure 5.4. Halibut: Abundance maps Q1 zoomed. Blue rectangle indicates the Jammer Bay area.

5.3.2 Spurdog

The spurdog (also known as spiny dogfish) was one of the most abundant shark species in the world, but has declined significantly, and is classified as “vulnerable” on the IUCN red list globally (2019), and as “endangered” in Europe (2014).

The present analysis showed that abundance of spurdog was low in Jammer Bay, but a hotspot exists north-east of Jammer Bay (see Figs. 5.5 to 5.11). This hotspot has become more important in recent years, as some previous hotspots in the southern North Sea have disappeared. The abundance of spurdog was historically low around 2009 but appears to have recovered in recent years to levels well above the mean in the observed period.

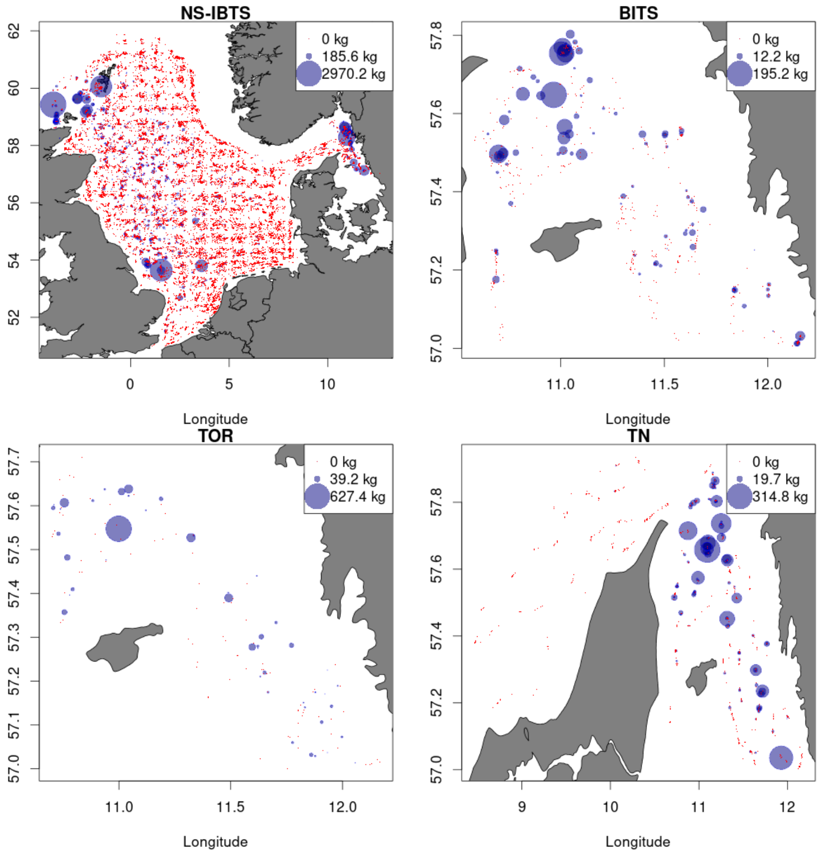

Figure 5.5. All catches of spurdog in the trawl surveys.

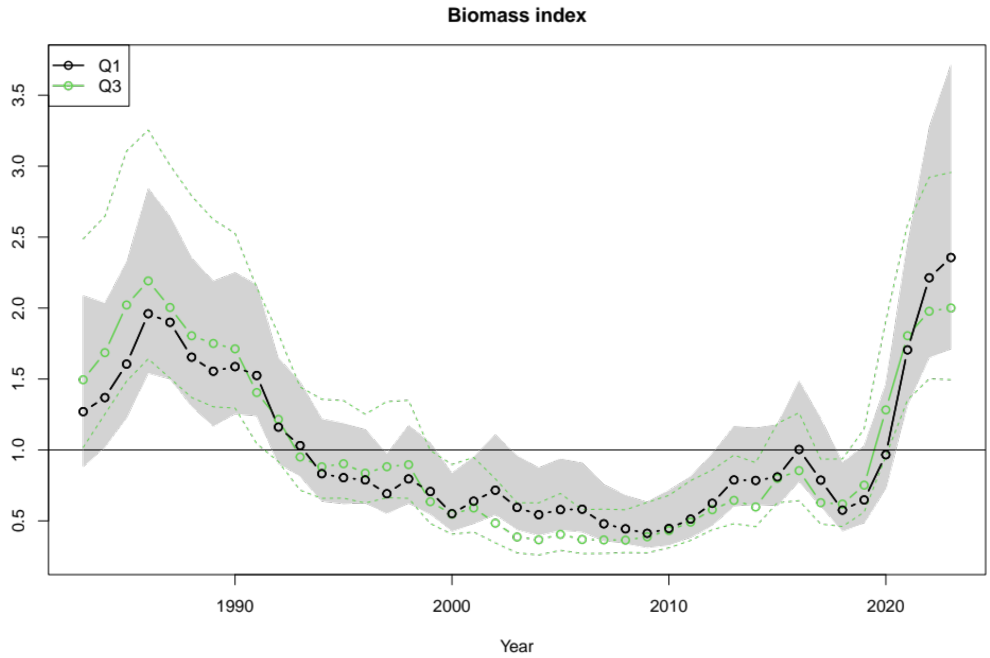

Figure 5.6. Spurdog: Abundance index for whole area (scaled to mean 1).

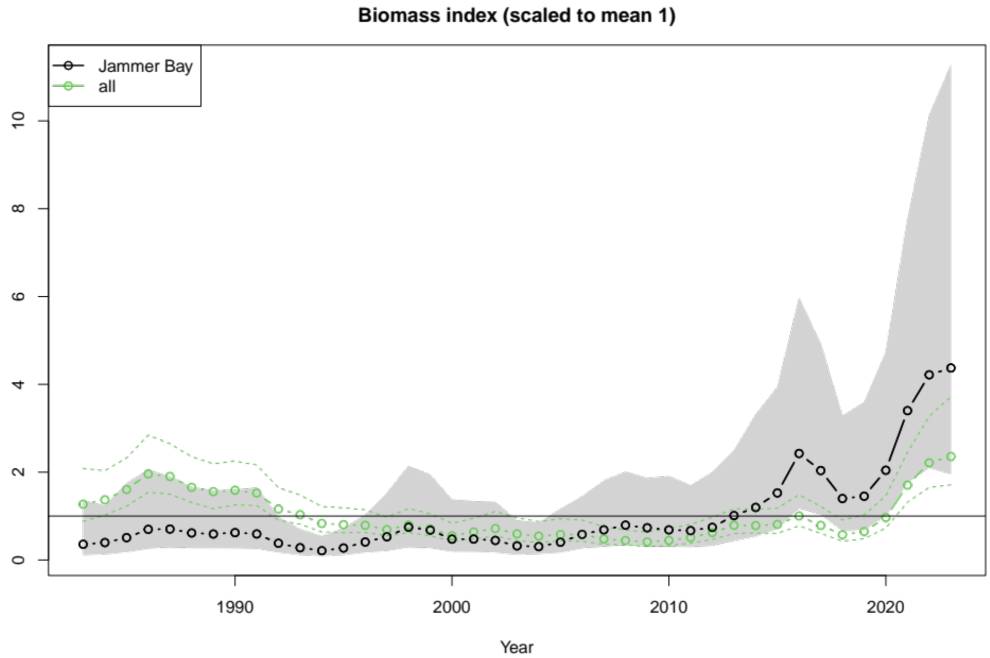

Figure 5.7. Spurdog: Q1 Abundance index for Jammer Bay and whole area (scaled to mean 1).

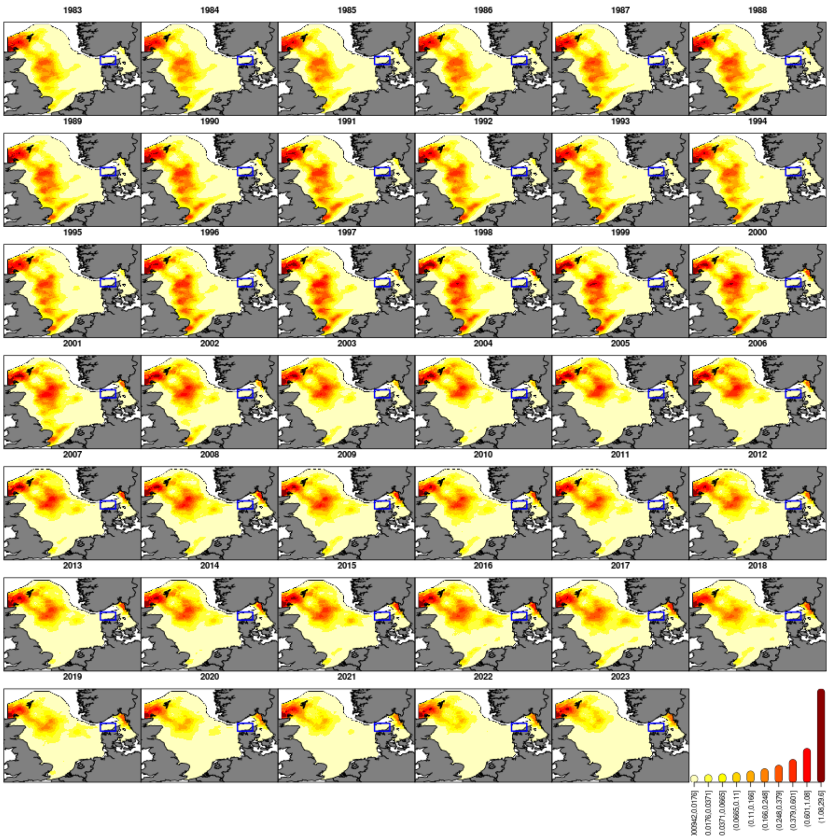

Figure 5.8. Spurdog: Abundance maps Q1. Blue rectangle indicates the Jammer Bay area.

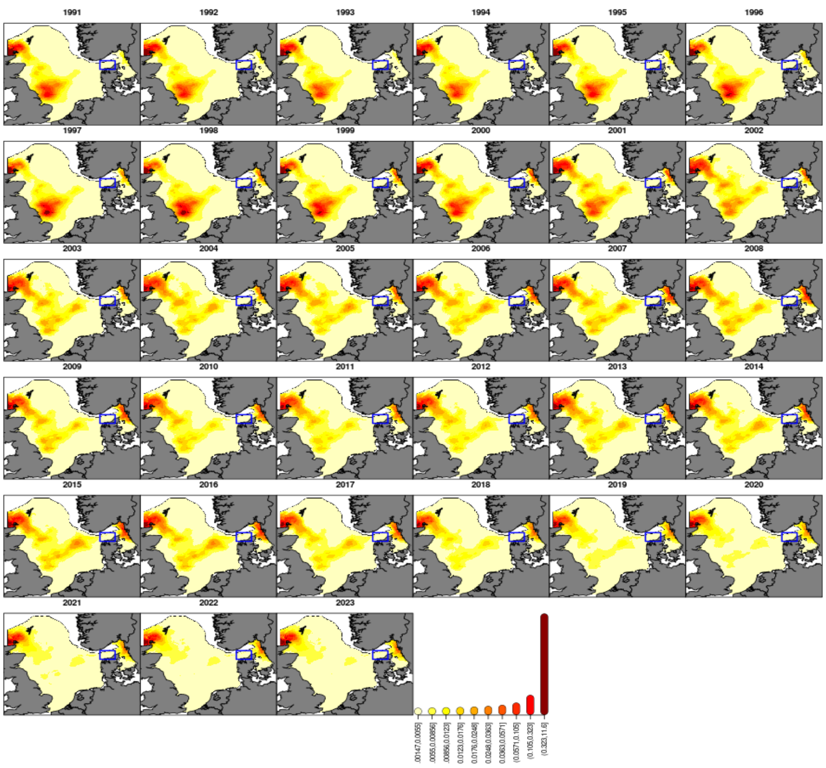

Figure 5.9. Spurdog: Abundance maps Q3. Blue rectangle indicates the Jammer Bay area.

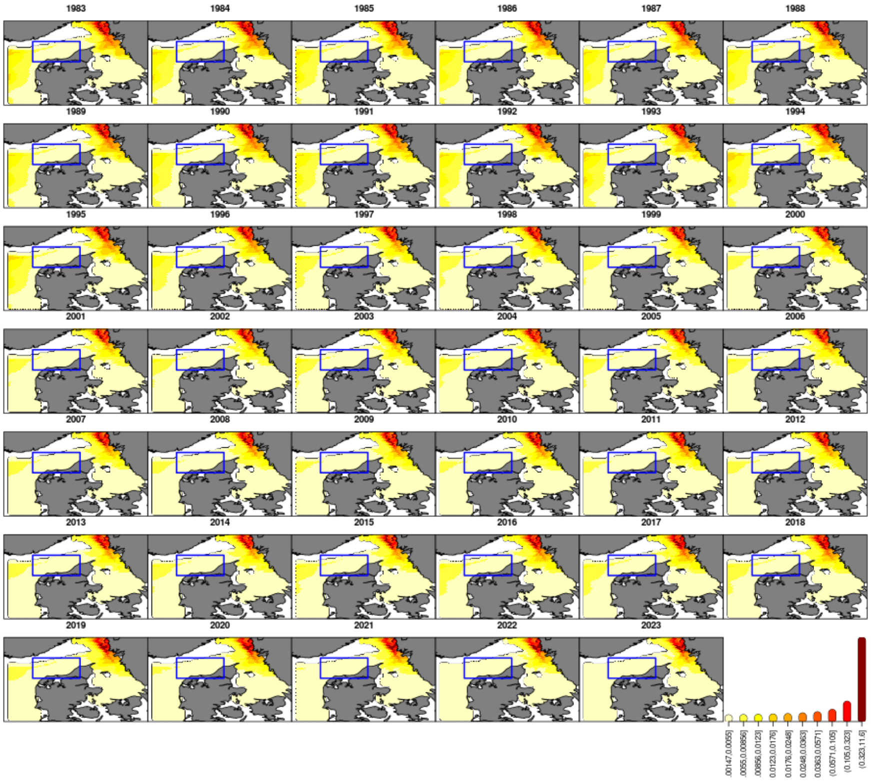

Figure 5.10. Spurdog: Abundance maps Q1 zoomed. Blue rectangle indicates the Jammer Bay area.

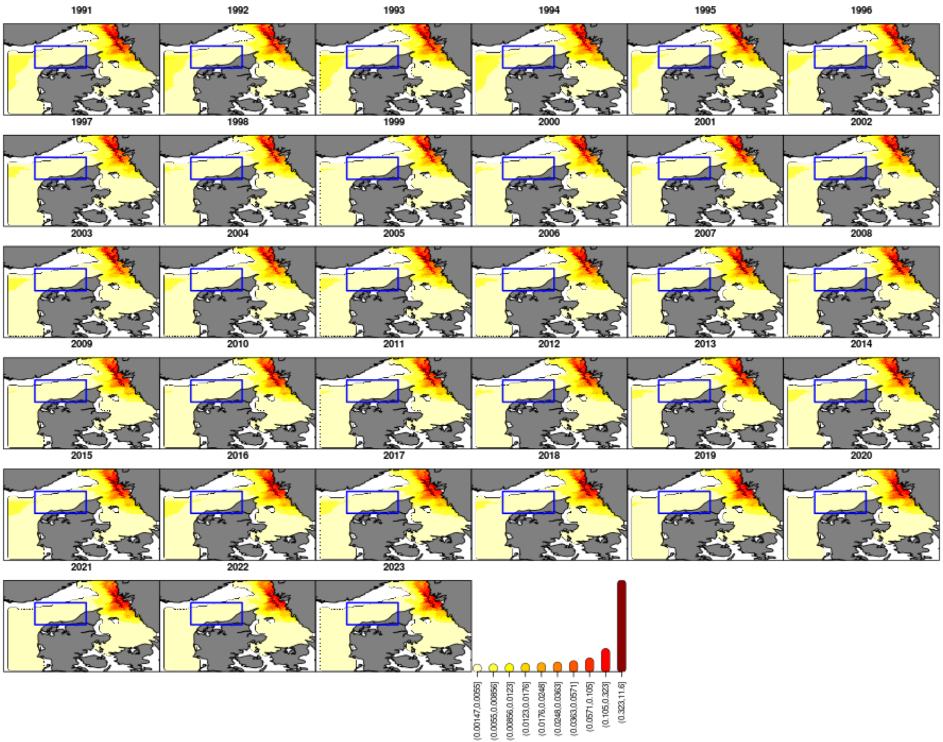

Figure 5.11. Spurdog: Abundance maps Q3. Blue rectangle indicates the Jammer Bay area.

5.3.3 Wolffish

Atlantic wolffish (also known as ocean catfish, devil fish or wolf eel) is listed as “Data deficient” on the IUCN red list (2014), because data for three generation lengths (45 years) are needed to evaluate its status. It is a relatively sedentary and long-lived species (maximum age more than 22 years) and a highly valued commercial species.

Among the surveys considered, it is only in NS-IBTS that significant amounts of wolffish are observed, thus only NS-IBTS data were used to estimate abundance trends and distribution maps (see Figs. 5.12 to 5.16).

The analysis showed that the abundance of wolffish declined significantly since 1983, but since 2010 a slight increase in abundance was estimated, although mainly outside the Jammer Bay area, where the abundance is still very low compared to the levels in the 1980’s.

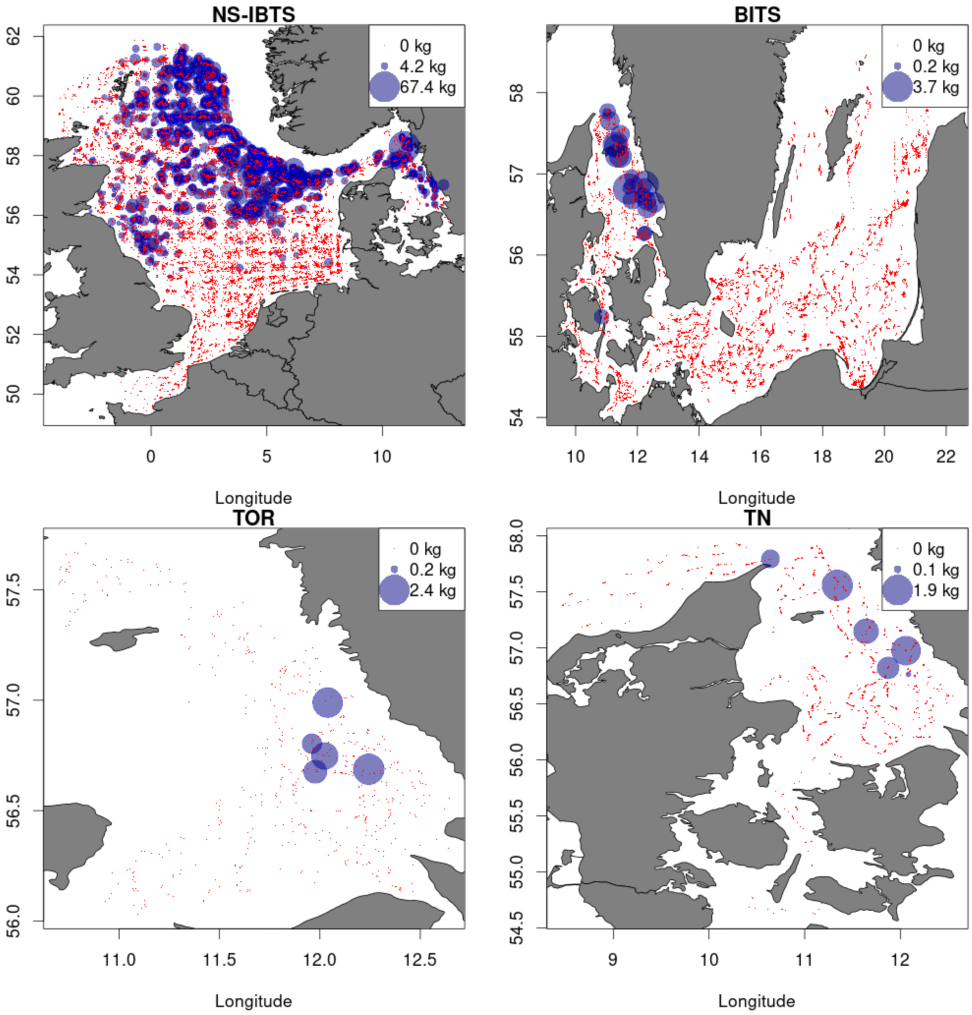

Figure 5.12. All catches of wolffish in the trawl surveys.

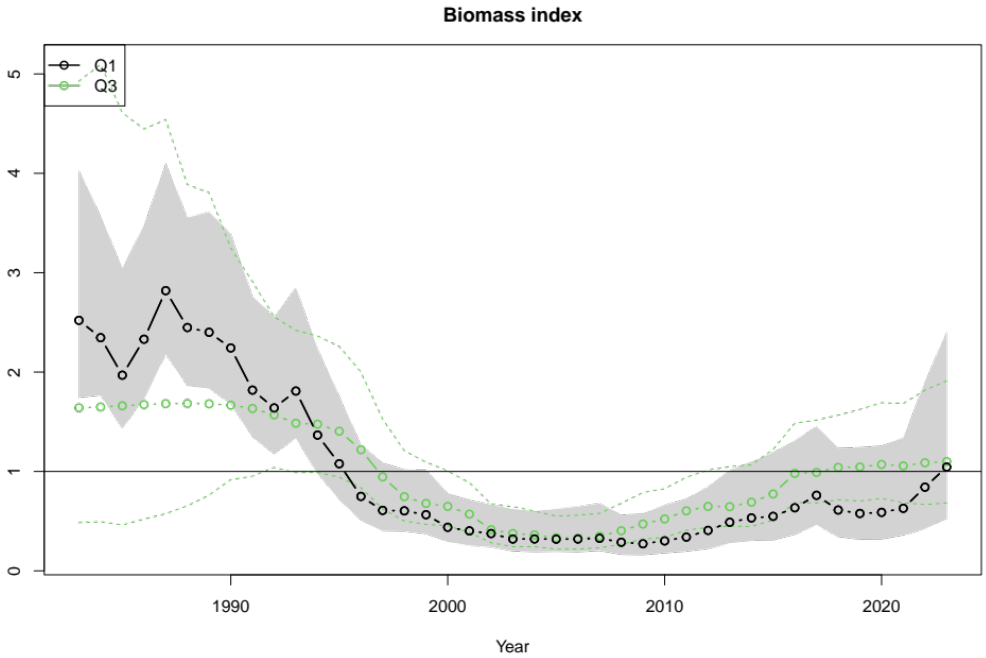

Figure 5.13. Wolffish: Abundance index for whole area (scaled to mean 1).

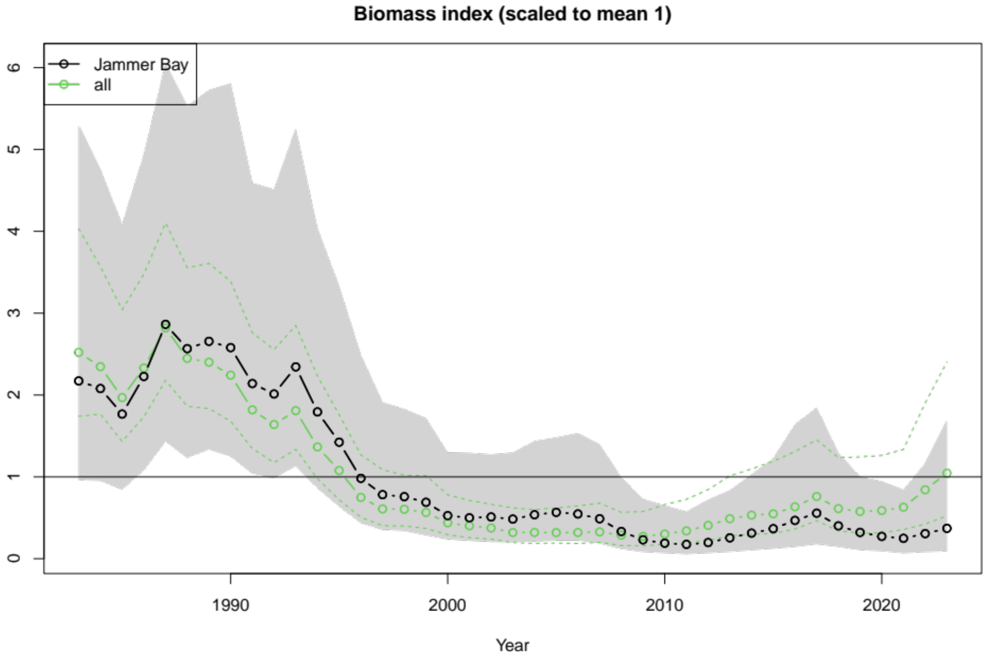

Figure 5.14. Wolffish: Q1 Abundance index for Jammer Bay and whole area (scaled to mean 1).

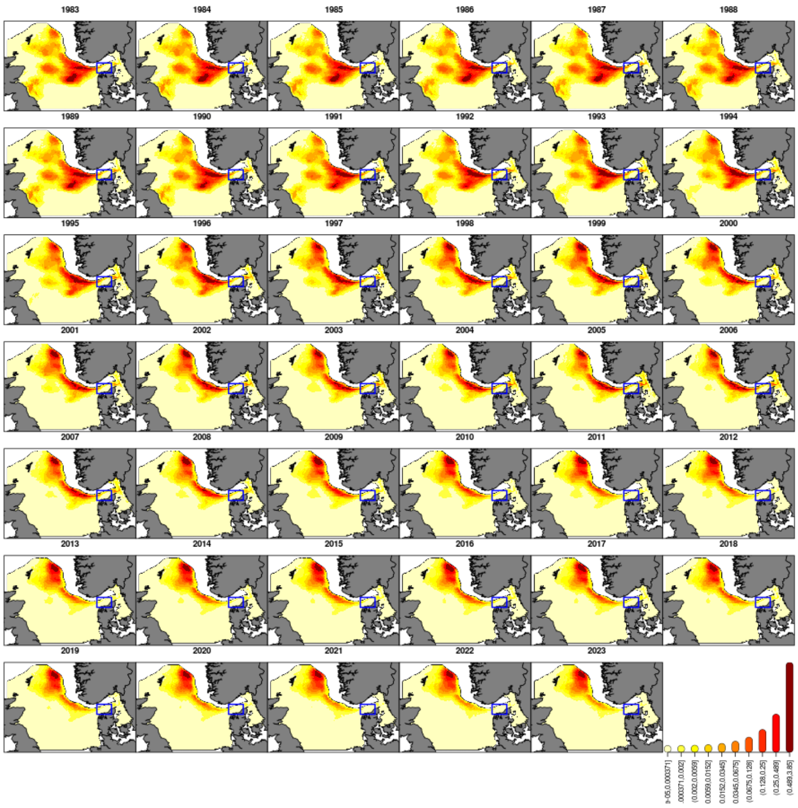

Figure 5.15. Wolffish: Abundance maps Q1. Blue rectangle indicates the Jammer Bay area.

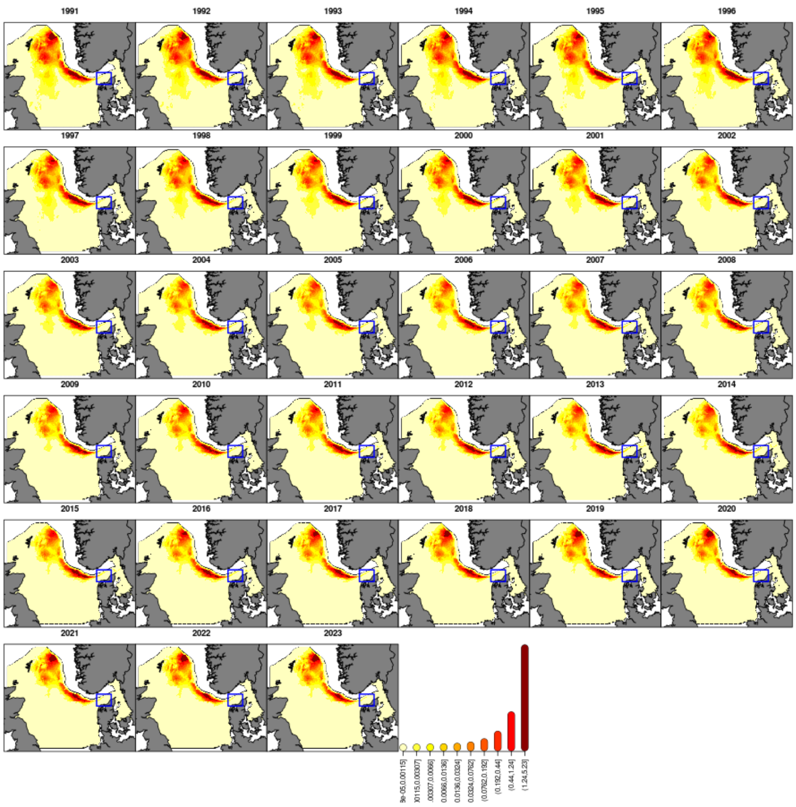

Figure 5.16. Wolffish: Abundance maps Q3. Blue rectangle indicates the Jammer Bay area.

5.3.4 Starry ray

Starry ray (also known as thorny skate) has the status “vulnerable” globally (2019) and “least concern” in Europe (2014) on the IUCN red list. It is the most abundant skate species in the central and northern North Sea, and is also quite abundant in the Jammer Bay area, in particular in Q1 (see Figs. 5.17 to 5.24). However, our analysis indicated that the abundance of starry ray is at historically low levels in the most recent years.

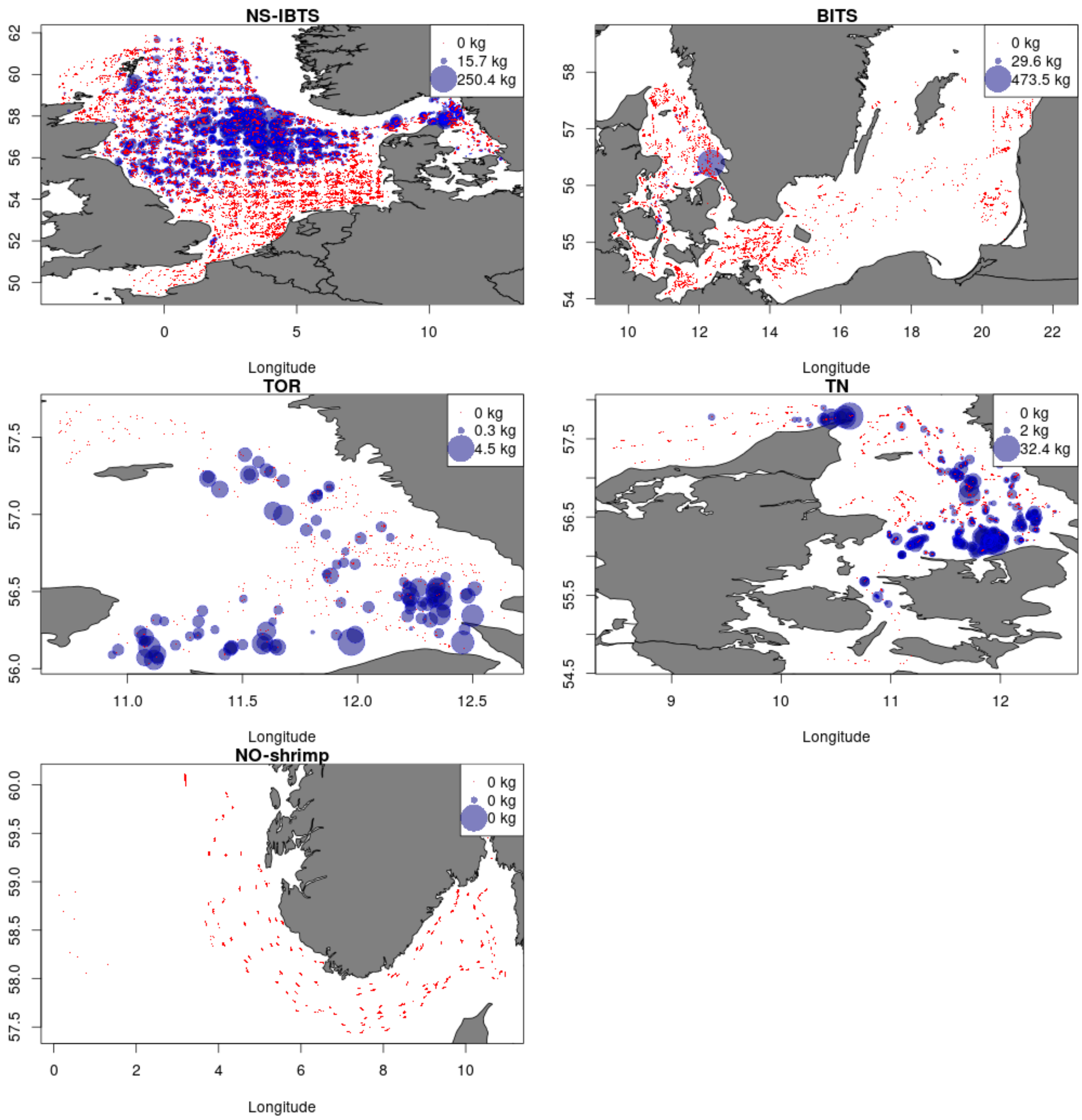

Figure 5.17. All catches of starry ray in the trawl surveys.

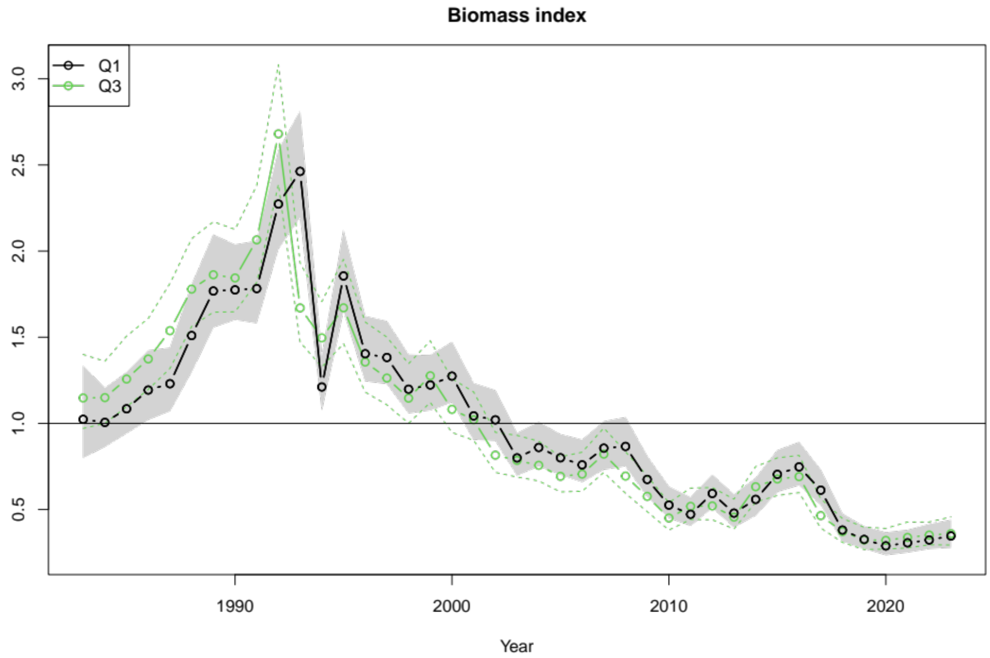

Figure 5.18. Starry ray: Abundance index for whole area (scaled to mean 1).

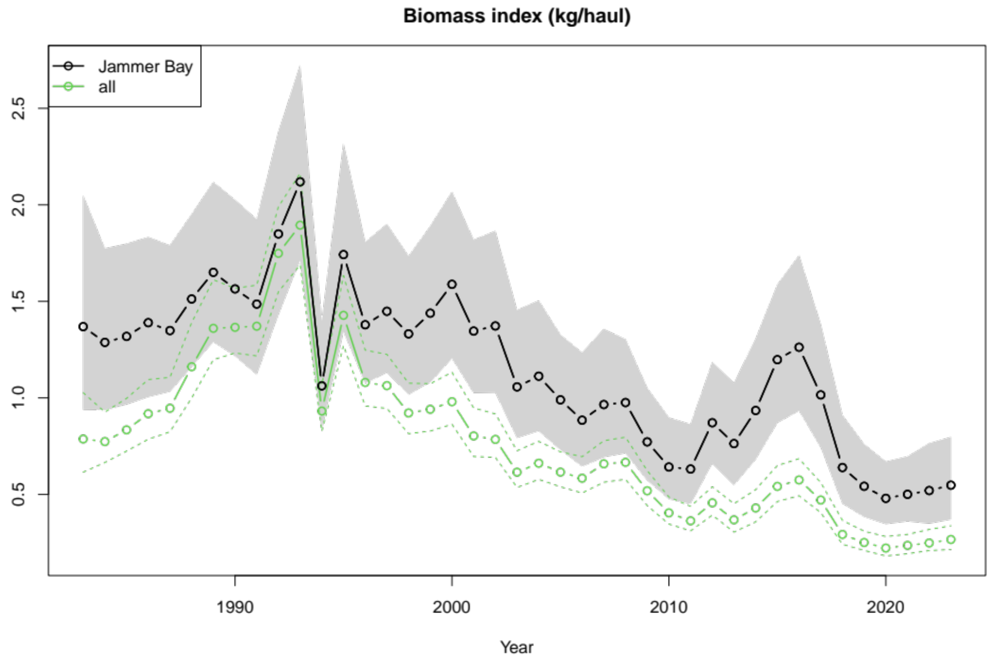

Figure 5.19. Starry ray: Q1 Abundance index (density) for Jammer Bay and whole area.

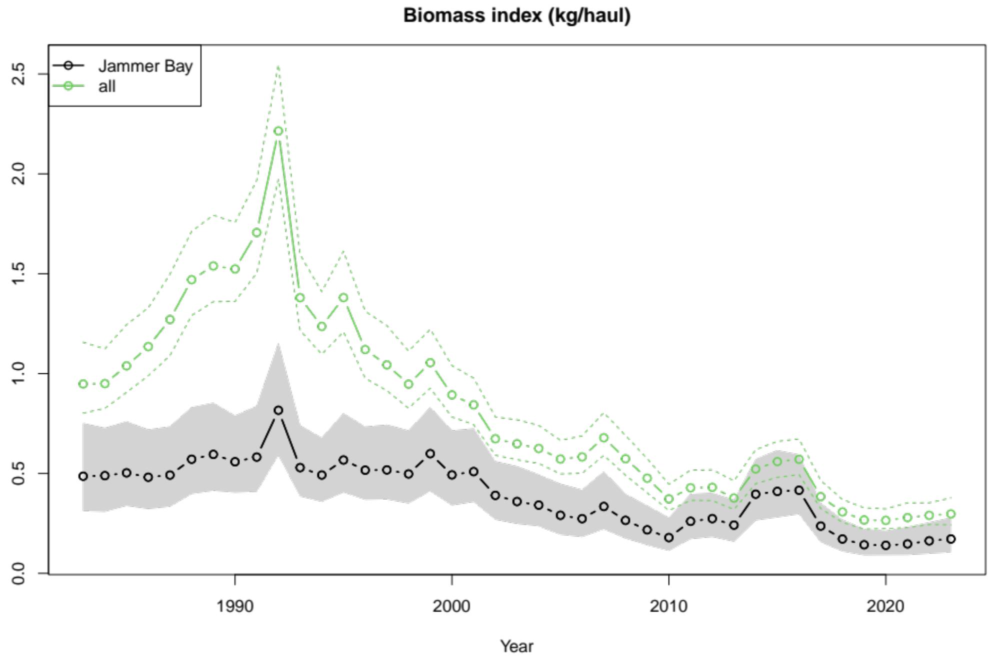

Figure 5.20. Starry ray: Q3 Abundance index (density) for Jammer Bay and whole area.

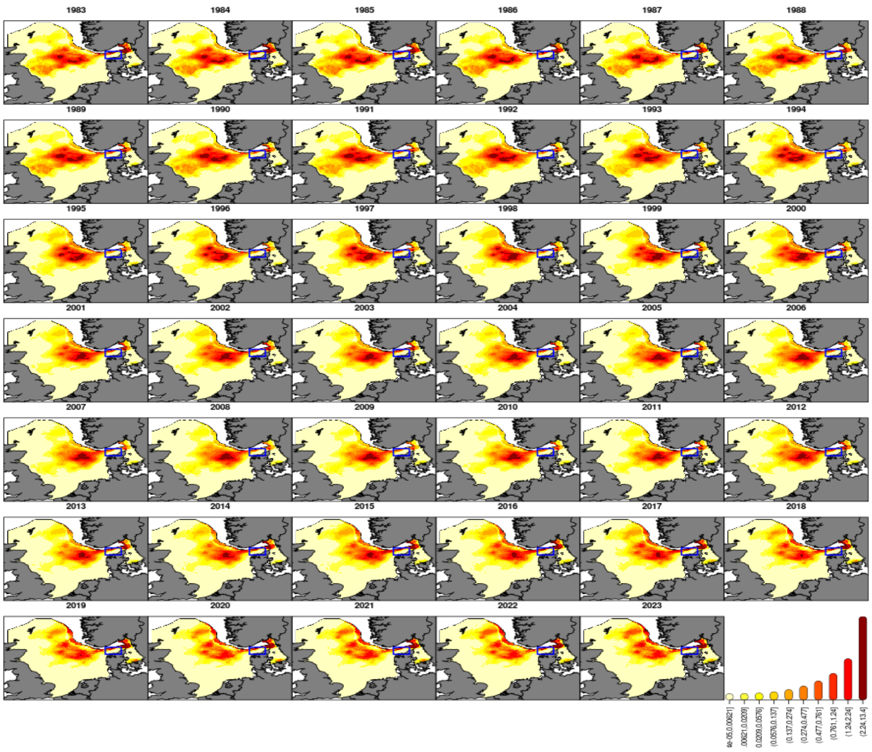

Figure 5.21. Starry ray: Abundance maps Q1. Blue rectangle indicates the Jammer Bay area.

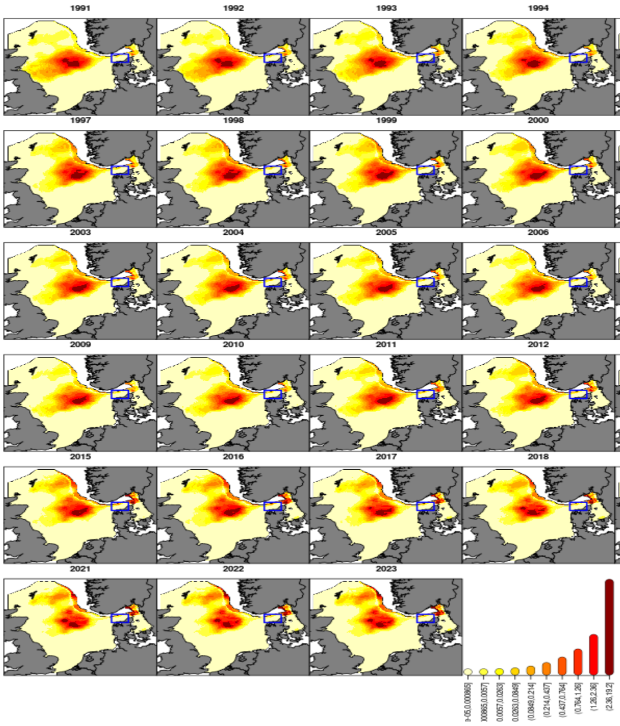

Figure 5.22. Starry ray: Abundance maps Q3. Blue rectangle indicates the Jammer Bay area.

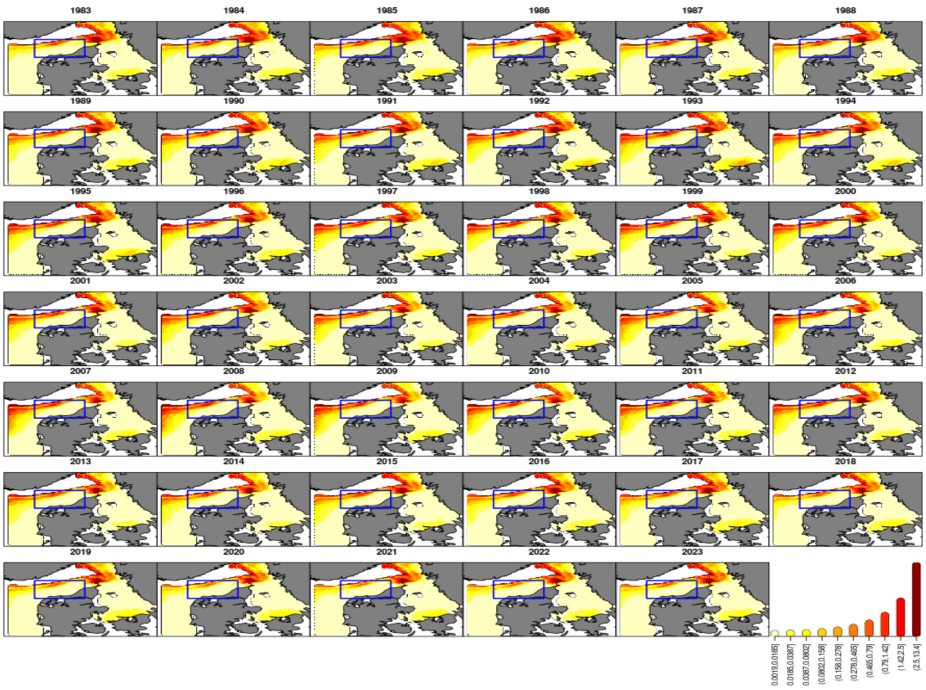

Figure 5.23. Starry ray: Abundance maps Q1 zoomed. Blue rectangle indicates the Jammer Bay area.

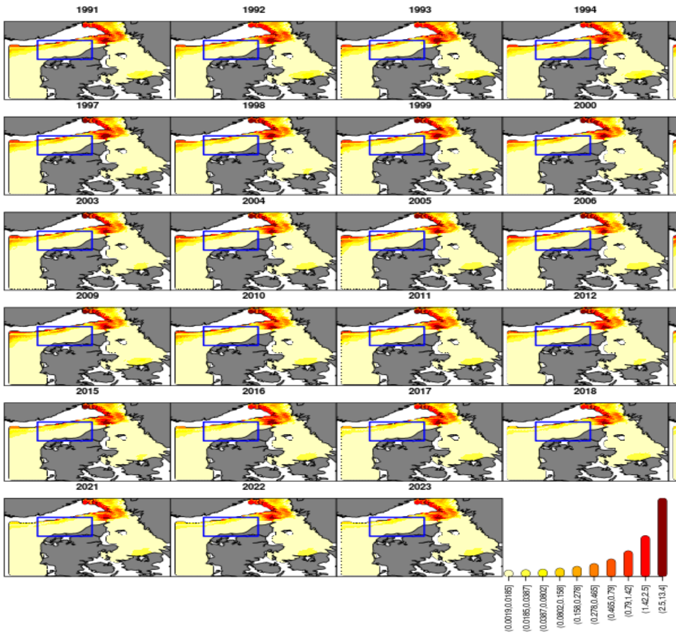

Figure 5.24. Starry ray: Abundance maps Q3 zoomed. Blue rectangle indicates the Jammer Bay area.

5.3.5 Landings in Jammer Bay between 1895 and 1910.

The historic landings from the period 1895-1910 in Jammer Bay are reported based on data extracted from "Fisker-beretningerne" (see under reference), where landings by district and species are recorded. To estimate landings in tons by species for the Jammer Bay, the districts located in the Jammer Bay were selected and landing units were normalized to kg, to the best of our knowledge. For example, landings were recorded in different units, depending on species and year. To reestimate from units in numbers, species-specific mean weights were assumed. Furthermore, we grouped elasmobranchs together to overcome species identification errors. Both raw data and the processed data are provided, together with R-script used to process the data and create graphs.

The total recorded landings by species are shown in Fig. 5.25. To put these landings into a current day perspective, we show the recorded landings for ICES-rectangle 43F8, 43F9 and 44F9 for the period 2005-2020 in Fig. 5.26. (note that we only plotted the 14 most abundant species to match the 14 species (or species groups) recorded in "Fisker-beretningerne").

Not all species were recorded in all years. It is not clear if this means zero landings or merely that not all species were reported in all years (i.e. should be treated as NAs).

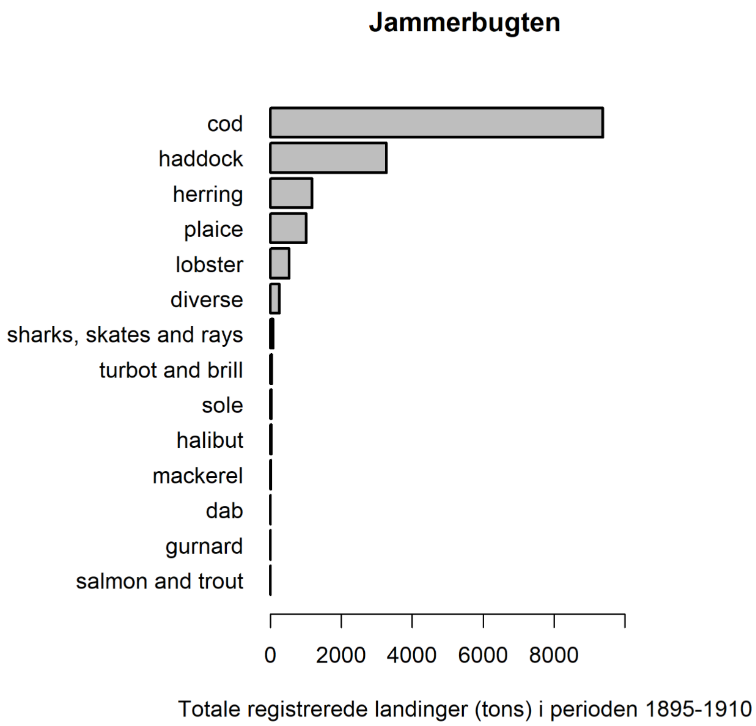

Figure 5.25. Total registered landings (tons) by species during the period 1895-1910.

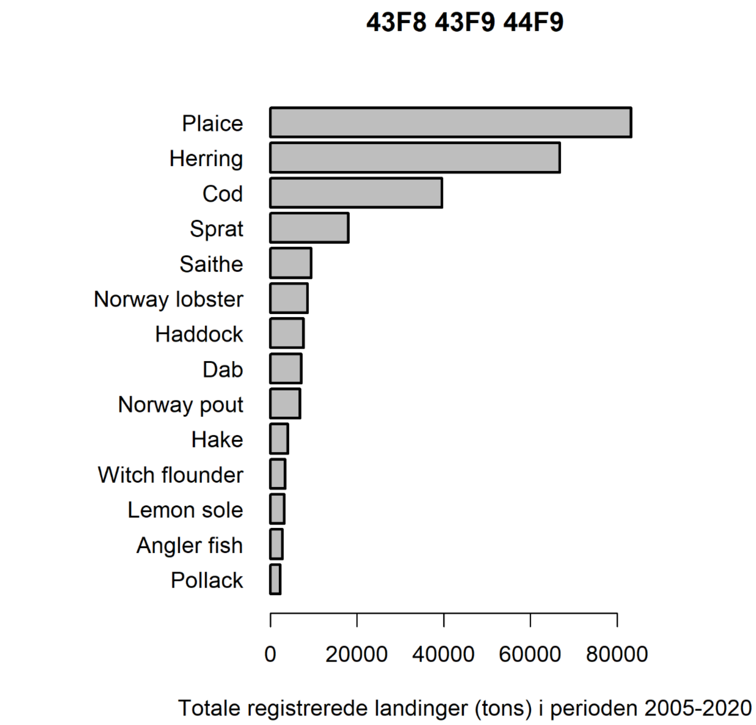

Figure 5.26. Total registered landings (tons) by species during the period 2005-2020.

5.4 Discussion and perspectives

Spatial distribution maps and abundance time-series were estimated for four sensitive fish species that occur in the Jammer Bay area: halibut, spurdog, wolffish, and starry ray.

Data from five different trawl surveys (NS-IBTS, BITS, cod, sole, and Norwegian shrimp survey) were combined in a model that accounted for different catch efficiency in each survey due to different types of trawls for example.

This combination of data from different surveys utilizes the sparse information available for these sensitive species in a better way than any of these surveys alone and allows standardized abundance maps for larger areas and longer time-series to be calculated.

For halibut and in particular spurdog the overall trend in abundance from 1983-2023 is positive, whereas the overall trends for wolffish and starry ray are negative.

In addition, landings in Jammer Bay from the period 1895-1910 were digitized and compared to those from the period 2005-2020. Due to potential non-reporting and species-misidentification it was not possible to compare landings of the sensitive species considered, only the most abundant species could be compared. Cod and haddock was by far the two most common landed species from 1895-1910, whereas plaice and herring were more common from 2005-2020.

5.5 Acknowledgements

Thanks to Guldborg Søvik from IMR Norway for sharing the Norwegian shrimp survey data. The work was funded in the project 'Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)' (Grant Agreement No 33113-B-23-189) by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark

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6. Improving estimates of the relative importance of fishing and predation induced by cod and marine mammals on cod (*Gadus morhua*), plaice (*Pleuronectes platessa*) and other North Sea fish stocks (Task 4.5)

Morten Vinther, Vanessa Trijoulet, Nis Sand Jacobsen

6.1 Introduction and aim

Fish are removed both by fisheries and natural predators. Higher removal by predators means that fewer fish survive and can be fished. Cod (*Gadus morhua*) and marine mammals are significant predators on commercial fish stocks and affect the potential fisheries yield of e.g., sprat (*Sprattus sprattus*), sandeel (*Ammodytes marinus*), herring (*Clupea harengus*), cod, plaice (*Pleuronectes platessa*) and haddock (*Melanogrammus aeglefinus*). Historical changes in the abundance of these predators may have changed the potential yield of these species.

Under this task, the predation and resulting mortality (denoted M) of the commercially important fish stocks in the North Sea and Skagerrak are estimated by the Stochastic Multi-Species model (SMS model). The model includes fisheries and diet data for 12 commercially important species (e.g., cod, saithe (*Pollachius virens*), herring, sandeel and sprat), additional 4 fish-eating species (e.g., grey gurnard (*Eutrigla gurnardus*) and starry ray (*Amblyraja radiata*)), 8 species of sea birds and marine mammals (harbour porpoise (*Phocoena Phocoena*) and grey seals (*Halichoerus grypus*)). Under this task, the project will update the SMS model for the North Sea to include data for 2020- 2022 and to appropriately include the newly developed sub-stock-specific assessments of cod in the greater North Sea.

In addition to the updated estimates, the project will consider the possibilities to include the estimation of natural mortality of plaice as well as the additional predator harbour seal (*Phoca vitulina*). Harbour seal consumes substantial amounts of flatfish, including plaice.

Lastly, the model will be presented for review by the ICES Working Group on Multispecies Assessment Methods in Edinburgh in October 2023, ensuring that the results are acceptable for use in internationally used fisheries and ecosystem advice.

6.2 Materials and methods

Natural mortalities (M) used for ICES stock assessment and catch advice for the main fish stocks in the North Sea are estimated from the SMS model (Vinther and Lewy 2004). SMS is a stock assessment model with predation estimated from a parameterised size-dependent food selection function. The model is formulated and fitted to observations of total catches at age, survey CPUE and stomach contents for the main species in the North Sea.

The time series of data for the model include data for the period 1974-2019. The model is updated every 3 years to include new (2020-2022) data and the potential to revise methods and historical data. These data and a final model run make the so-called North Sea key-run.

The data update for the 27 stocks included in SMS is comprehensive. It includes ideally an electronic update from available ICES fish stock assessment data, but in other cases, data are not available in electronic form and data were entered manually from various ICES reports.

The update of data is fully documented in the so-called StockAnnex for the North Sea key-run (see https://github.com/ices-eg/wg_WGSAM/blob/master/StockAnnex/NorthSea/2023 NorthSea.pdf).

The grey seal data (numbers and diet) had not been updated in SMS for a long time. In this report, the update of the diet and population numbers of grey seals are documented in section 6.2.1. The existing stomach contents data includes more than 200,000 fish stomachs sampled primarily in the years 1981-1991. For a fully documented compilation of stomach contents data into a fish diet, these data were recompiled before using them in SMS (see section 6.2.2 on stomach contents). Some new data stomach contents data were available, but the sampling in the individual years and quarters was too scarce to be included in the SMS model.

The ICES cod assessment for the North Sea area has changed from a one-stock assessment to a combined assessment of three sub-stocks. This change in stock definitions should ideally also be implemented in SMS. However, catch data for each sub-stock do not exist outside quarter 1 (Q1), and WGSAM concluded to maintain the one-stock assessment for cod in SMS.

6.2.1 Grey seals

The methods and review of the methods used to update grey seal data are fully documented in the WGSAM report (ICES, 2024) as well as in the StockAnnex. Scripts and Rmd reports are also available at https://github.com/ices-eg/wg_WGSAM/tree/master/NorthSeaKeyRun_2023. Just a summary of the methods is presented here.

Grey seal numbers had not been updated in SMS since the 2011 key-run. Most recent data on grey seal numbers were therefore collected for the new 2023 North Sea key-run.

Most recent British grey seal numbers come from Thomas (2021) and include estimates for the period 1984-2020. Seal numbers from 2021-2022 were obtained via personal communication (Phil Hammond, Sea Mammal Research Unit, SMRU). Seal estimates are given for the beginning of the breeding season, which corresponds to Q4 and relate to seals associated with the regularly monitored colonies. A multiplier is required to account for the seals that breed outside these colonies. Multipliers on the grey seal estimates to account for non-monitored colonies were made available for the years 1985, 2002, 2010, 2019, and 2022 (pers. comm. Phil Hammond (SMRU)). Estimates for 1984-2022, were therefore extrapolated to the full British colonies following a linear regression between the scaled estimates. Numbers before 1984 are predicted following a linear regression on the log scale so that the population is assumed to have exponential growth in 1984-1990 (using 1984–1990 to estimate parameters, similar method as for the 2020 key-run).

ICES (2022) provides pup counts for different areas of the North Sea from recent surveys (2017, 2019, 2020, or 2021). The colonies in the North Sea were extracted, and the proportion of the pup counts outside the UK was estimated and resulted in a proportion of around 0.044. A multiplier of around 1.044 was applied to the British grey seal population estimates to extrapolate the numbers to the entire North Sea grey seal population in Q4. The resulting grey seal numbers are given in Table 6.1. For Q1-3, we assume the same population estimates as in the Q4 the year before.

Table 6.1. Grey seal numbers (thousands) used for the 2023 North Sea key-run.

Year	Final seal numbers	Year	Final seal numbers
1973	12.93	1998	60.05
1974	13.853	1999	62.395
1975	14.841	2000	64.741
1976	15.901	2001	67.087
1977	17.035	2002	69.9
1978	18.251	2003	71.779
1979	19.554	2004	74.125
1980	20.949	2005	76.471
1981	22.444	2006	78.817
1982	24.046	2007	81.163
1983	25.762	2008	83.509
1984	27.206	2009	85.855
1985	29.693	2010	86.963
1986	31.898	2011	90.547
1987	34.244	2012	92.893
1988	36.59	2013	95.239
1989	38.936	2014	97.585
1990	41.282	2015	99.931
1991	43.628	2016	102.277
1992	45.974	2017	104.623
1993	48.32	2018	106.968
1994	50.666	2019	109.42
1995	53.012	2020	111.66
1996	55.358	2021	114.006
1997	57.704	2022	116.877

Seal diet data derived from scats were sampled in 1985, 2002, and 2010-2011 at haul-out sites around the UK coast. At the 2023 North Sea key-run, seal diet was re-extracted by the SMRU to include the most recent data (2010-2011) and plaice as prey (Phil Hammond pers. comm.). The data included seal consumption per fish stock that are considered in SMS (cod, whiting, haddock, herring, sandeel, Norway pout (*Trisopterus esmarkii*), sprat and plaice) in tonnes per year, quarter (Q1-4), and regions of the North Sea (regions 1-4, Shetland, Orkney and northern North Sea, central North Sea, and southern North Sea respectively). The data also included outputs from otolith experiments as estimated fish length in the diet given otolith size (per year, region, and quarter).

Each fish length sample is converted to weight using length-weight relationship parameters from Coull (1989). The fish weights (weighed by the total consumption per region and quarter) are summed across regions such that the weight consumed is given per species, length bin, quarter, and year. Weights are then converted to proportion consumed per length bin, and these proportions are multiplied by the total grey seal consumption (in weight) per species and quarter to obtain the weight of prey consumed per length bin. The biomass of other food eaten by grey seals is derived from the total grey seal consumption per quarter and year. The number of scat samples per quarter and year is used to give information on uncertainty in the diet data.

A few assumptions were made while handling grey seal diet, as follows:

- Sprat was added to other food because of the small total consumption in each year and the lack of length samples.
- If there were less than 5 length bins for a prey in one quarter and year, the length distribution from the adjacent quarter was added to these samples. This “borrowing” was made between Q1-2 and Q3-4. The 5 samples threshold was chosen after realizing that in a few instances, only 1-3 samples were available despite fish being consumed. We assumed these were not representative of the real length distribution in the diet. The borrowing between quarters was chosen to try to maintain a distinction between spawning seasons, e.g., spring, autumn.
- The diet in 1985 and 2010-2011 is given for a set of years e.g., 1983, 1985, 1988, and 2010-2011. In SMS, we assumed the diet was in the year where there was the largest number of samples, i.e., 1985, and 2010.

Sandeel in the North Sea area is managed as six individually assessed stocks. Given the lack of input data at the correct spatial scale, two sandeel stocks were considered in SMS and split into northern and southern North Sea stocks. In the previous SMS key-runs, the total grey seal predation was attributed entirely to the northern sandeel stock. In the 2023 key-run, the proportion of sandeel consumed by grey seals was extracted from the diet data with the assumption that the northern areas correspond to Shetland, Orkney and the northern North Sea, and the southern area to the central North Sea, and the southern North Sea. This resulted in the proportions shown in Table 6.2. These proportions are used to split the diet data between northern and southern sandeel.

Table 6.2. Proportion of sandeel consumed per area.

	1985 North	1985 South	2002 North	2002 South	2010 North	2010 South
Quarter 1	0.879	0.121	0.795	0.205	0.598	0.402
Quarter 2	0.892	0.108	0.781	0.219	0.657	0.343
Quarter 3	0.844	0.156	0.776	0.224	0.669	0.331
Quarter 4	0.820	0.180	0.805	0.195	0.637	0.363

The resulting size distribution for sandeels in the grey seal diet suggests that a considerable proportion of the diet in 1985 consisted of sandeels greater than 20cm in length. Because sandeels caught by the fishery are generally smaller, there is some uncertainty about whether these sandeels are *Ammodytes marinus*, and it has been suggested that they may instead be a different sandeel species, such as *Hyperoplus lanceolatus*. To avoid this problem, sandeels larger than 20 cm were assumed to be ‘other food’. Net consumption was assumed to be 5.5 kg per seal per day.

An example of the estimated diet of grey seals is shown in Fig. 6.1.

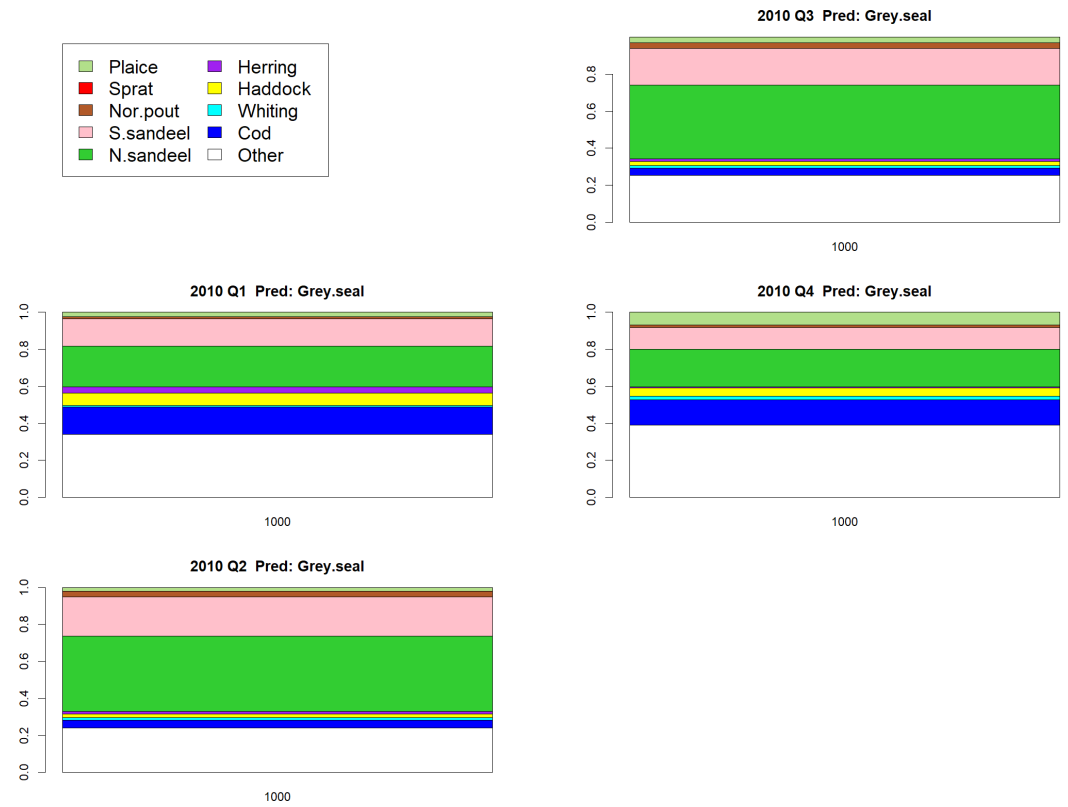

Figure 6.1. Estimated diet proportion (in weight) for grey seal in quarters 1-4 of 2010 as used for SMS. Grey seals in the SMS model include only one size class denoted "1000" on the x-axis.

6.2.2 Fish stomach contents

An international stomach sampling programme was initiated in 1981 to collect stomach contents data from economically important piscivorous fish species in the North Sea. The sampling program was under the auspices of ICES to collect data on "who eats whom" of the exploited fish in the North Sea for use in fish stock assessment. Stomachs were sampled from saithe, cod, haddock, whiting and mackerel. Stomach sampling continued in the period after 1981 with the inclusion of more fish species, however, the highest sampling intensity was in 1981 and 1991.

The compilation of the individual stomach samples from trawl hauls into the average diet of the North Sea predators is basically calculated from a stratified mean of the individual stomach content samples, weighted by the strata density of the predator and the area of the strata. This seems simple, but incomplete and patchy sampling makes it often necessary to use a series of *ad hoc* solutions.

The compilation of stomach contents for the 2023 key-run was done as part of the JAMBAY project using the FishStomachs R-package (available from https://github.com/Morten-Vinther/FishStomachs).

The FishStomachs package defines data structures suitable for stomach data and provides the necessary methods to compile observed stomach data into population diet and biomass eaten, used for multispecies models. The methods applied for a set of observations are stored within the data output to document the compilation steps taken.

The stomach contents compilation followed the steps outlined below:

1. Read and check data from the agreed exchange format;
2. Bias correct to take into account variable evacuation rate;
3. Assign size classes for predators and preys;
4. Bias correct to take into account regurgitated stomachs within sample units;
5. Aggregate stomach contents within sample-id and size classes;
6. Allocate unidentified or partly identified prey items;
7. Calculate the population diet and food ration from a weighted average.

The FishStomachs package was further developed as part of the JAMBAY project, to estimate uncertainties of estimated diet, expressed as the so-called "concentration parameter" in the Dirichlet distribution applied for diet proportions. This approach and the use of the estimated uncertainties in SMS are described further in the Working Document 05 to ICES WGSAM "Estimating uncertainties of diet data for use in Stochastic Multispecies Models (SMS)" (Vinther, 2023). This document is available from the ICES WGSAM 2023 SharePoint.

6.3 Results

The results of the North Sea key-run are presented in the report (ICES 2024) from the ICES WGSAM meeting in October 2023. Additional input and output data are presented in an HTML document to be downloaded from https://github.com/ices-eg/wg_WGSAM/blob/master/NorthSeaKeyRun_2023/HTML/NS_2023_key_run.html

The results presented in this report are a brief overview of cod as predator and prey, and on grey seal predation on plaice.

6.3.1 Cod as predator and prey

Cod acts both as a predator of other commercial fish species and as a prey species for both fish, marine mammals and sea birds. On top of that, fisheries remove a considerable biomass of cod. The summary plot from SMS (Fig. 6.2) shows that catches of cod have declined from more the 500,000 tonnes in the early eighties to around 25,000 tonnes in most recent years. Fishing mortality (F) was high (around 1) until the year 2000, followed by a decline to below F_{MSY} since 2020. Spawning biomass has in general declined in the time series shown. Recruitment is variable from one year to the next and has declined slightly over the full period. While fishery at the beginning of the period was the main cause for the removal of cod biomass, natural causes (M1 and M2) removed more biomass than fishery since around the year 2000. The predation mortality (M2) of cod is high and slightly increasing for ages 0-4 throughout the full time series.

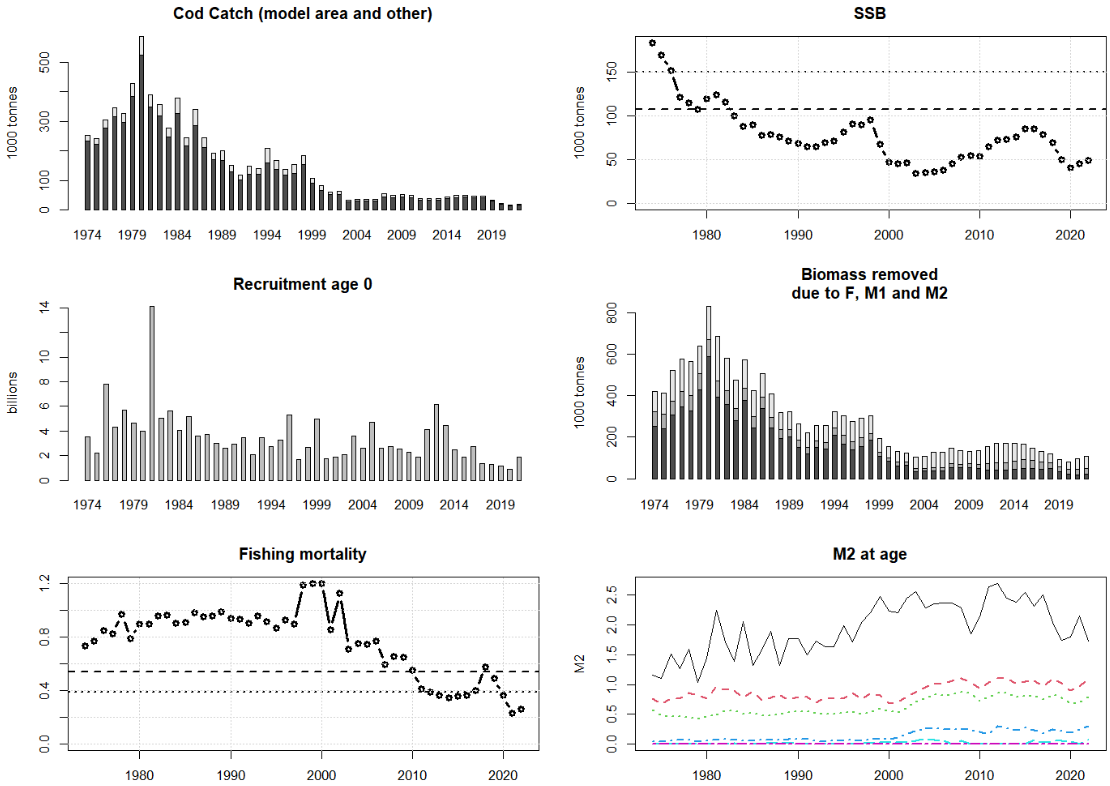

Figure 6.2. Summary plot for cod in the North Sea as estimated by SMS (WGSAM, 2023). Upper left: Catch of cod within the model area (black, the North Sea) and other areas (grey, Skagerrak and eastern English Chanel; Upper right: Spawning biomass, total weight of sexually mature cod; Mid left: Recruitment, number of juvenile cod at age 0 in Q3; Mid right: Biomass removed by fisheries (black, F), eaten by predators in the model (white, M2) and died from other causes (grey, M1); Lower left: Fishing mortality (F), a measure of fishing intensity on cod; Lower right: Predation mortality (M2) at age, a measure of predation pressure from species within the model. M2 is highest for age 0 of cod, followed by age 1, 2 and 3 in descending order.

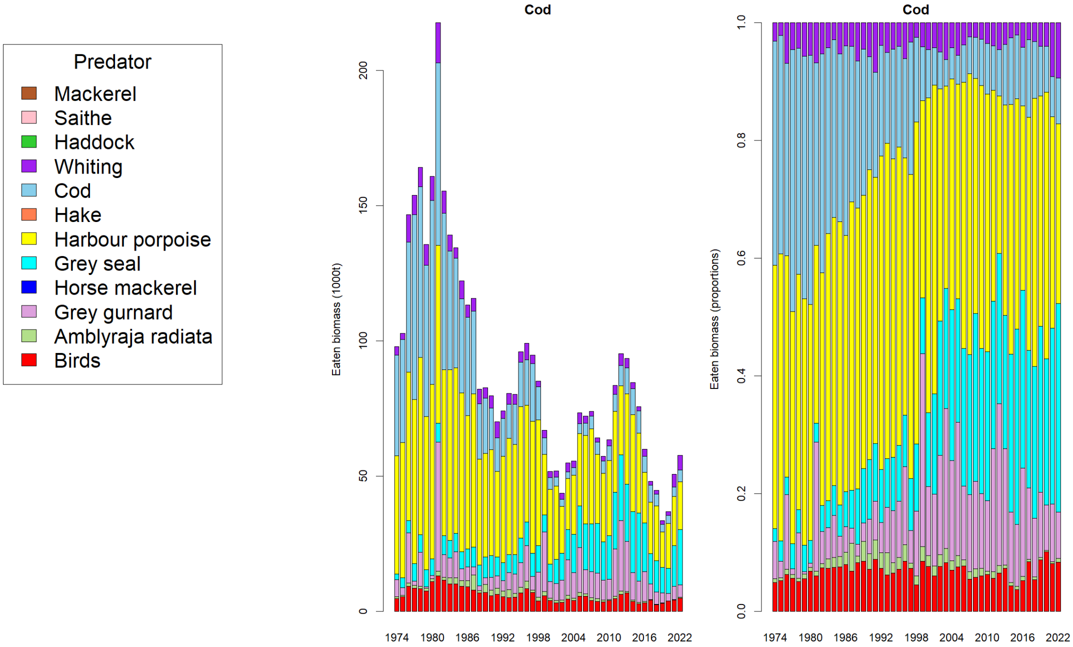

Figure 6.3. Biomass of cod eaten by predators in the SMS model, both in absolute terms (left) and as weight proportions (right).

Cod is prey for a range of predators (Fig. 6.3). With the high cod biomass at the beginning of the time series, a considerable proportion of the cod eaten was due to cod cannibalism. The low cod stock in recent years has reduced this mortality significantly. The biomass of grey seals has increased which gives a substantial increase in the proportion eaten by seals. The abundance of harbour porpoise has been high and stable throughout the period, which gives a high, and rather stable proportion eaten by this predator. The abundance of grey gurnards increased during the 1990'ies followed by a decline in more recent years, which is reflected in the proportion eaten by gurnards.

The predation mortality in SMS is calculated from a general predator-prey species food preference, a predator-prey encounter rate and a predator size preference ratio, estimated within the model. Cod is a fast-growing species which means that the older (and larger) cod can only be eaten by a few larger body-sized species. This is seen in the predation mortality by age (or size) of cod (Fig. 6.4). Age 0 cod is mainly eaten by smaller body-sized grey gurnards, whiting and starry ray, but also eaten by the much larger harbour porpoise. Age 1 cod seems to be too large for e.g. gurnards and is mainly eaten by harbour porpoise, grey seals and larger cod. Only the largest cod, grey seals and harbour porpoise can eat age-2 cod, while older (larger) cod are only eaten by grey seals and the few very large cod.

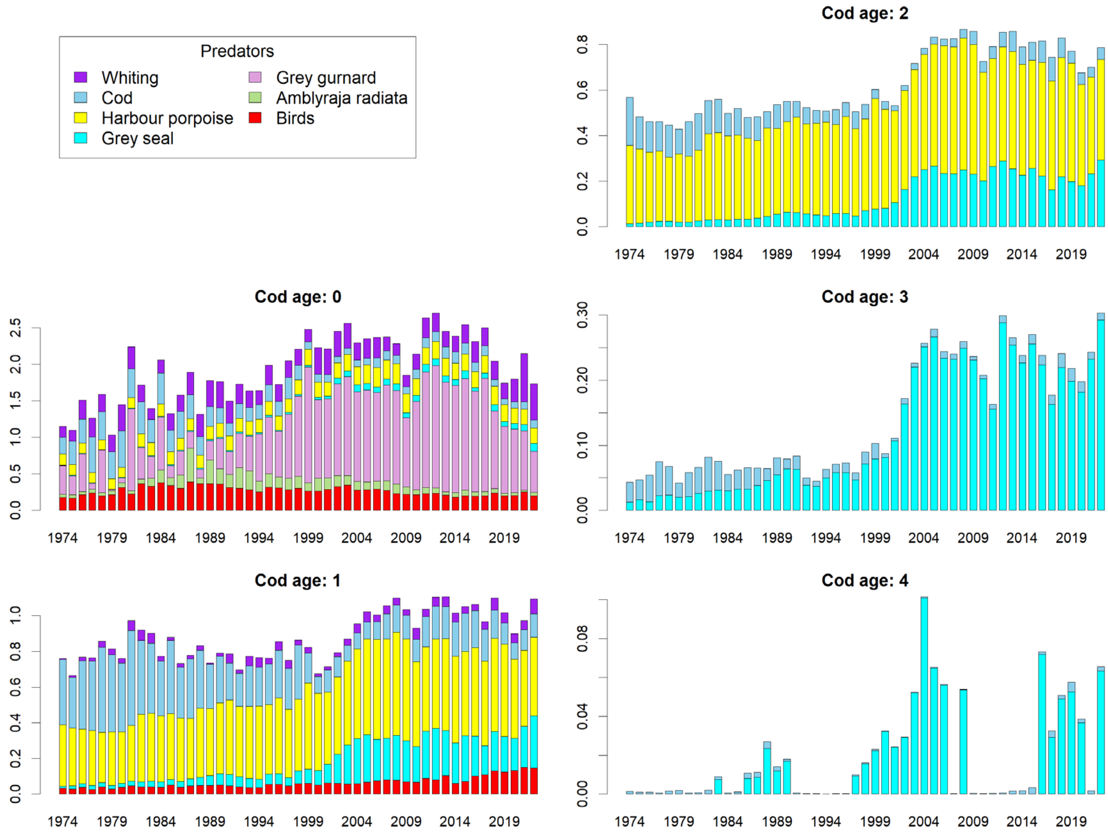

Figure 6.4. Predation mortality (M2) at age of cod induced by individual predators.

Cod feeds on a wide variety of prey species (Fig. 6.5). Most of the diet is from species not included in the model (e.g., not commercial species) labelled as “other” in Fig. 6.5. That includes a long list of invertebrates, mainly crustaceans and polychaetes. With increasing cod size, various non-commercial fish species and flatfish like dab and long rough dab make an increasing part of the diet. The number of samples can be low (less than 50 stomachs) for the largest and smallest cod size classes, which may result in sudden changes in diet between cod size classes, due to the few samples and higher uncertainties.

The SMS key-run made use of estimated uncertainties of the diet data for the first time this year. As an example, Fig. 6.6 shows the estimated uncertainties of diet data for 40-50 cm cod in Q3 of 1991, estimated from a total of 263 stomachs. This sampling level is considered an “average” level compared to other samples, and the confidence interval for each prey species seems wide. The fit to the assumed Dirichlet distribution (a statistical distribution often used for proportions) is in this case rather good and the estimated “concentration” parameter is at the high end compared to other samples.

Stomach contents data for cod are available for 1981, 1985-87 and 1991. Based on these data, SMS estimates the biomass eaten by model species as presented in Fig. 6.7. The absolute biomass eaten follows the abundance of cod which declines to less than 25% of what it was at the beginning of the time series. The relative diet changes over time, mainly due to changes in the available biomass of each individual prey species, but also due to changes in the size composition of cod. The herring stock was depleted in the late 1970'ies which is seen in the very low biomass eaten of herring in that period. A rather low biomass of Norway pout and sandeel in the period 2002-2005, in combination with a higher biomass of herring makes herring the most important prey species in that period.

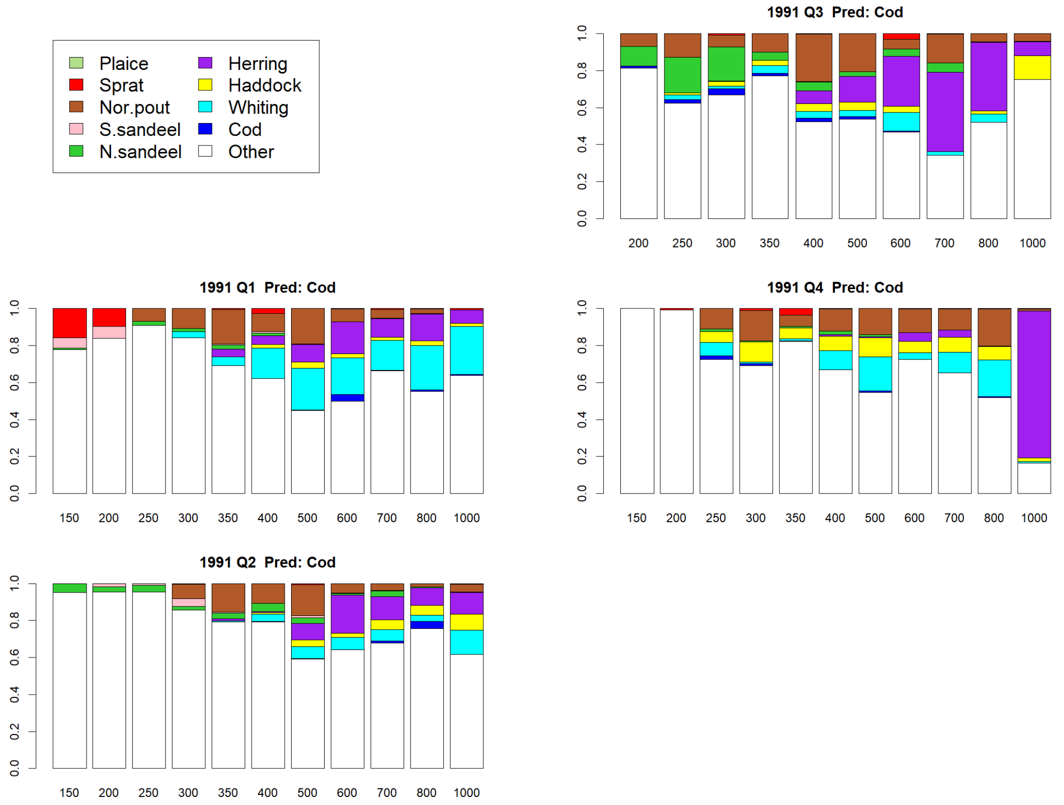

Figure 6.5. Estimated diet composition in weight of cod by quarter of 1991, by cod size class in mm (x-axis).

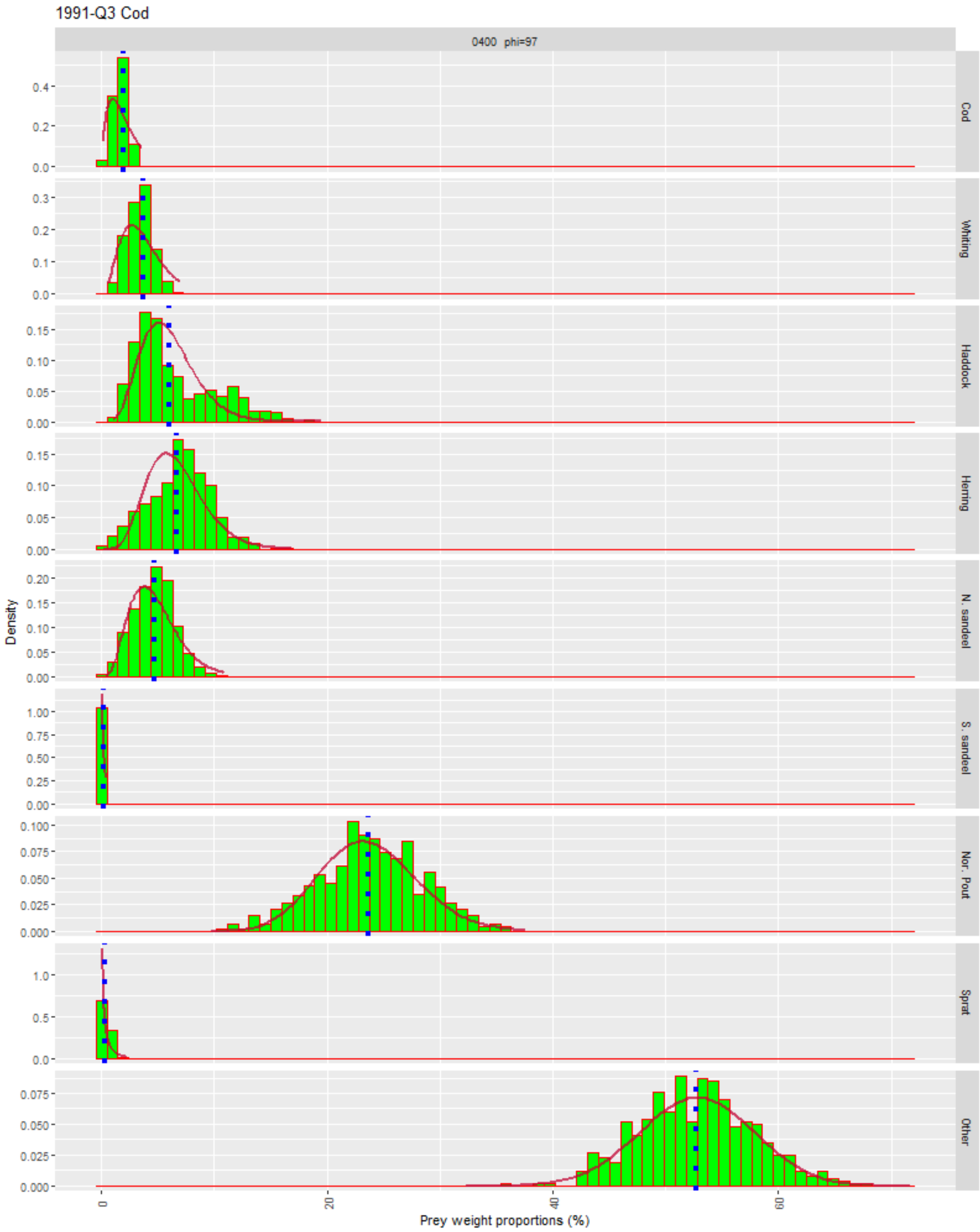

Figure 6.6. Bootstrap replicates of diet weight proportions for predator cod 40-50 cm in quarter 3 of 1991. The red curve shows the fitted Dirichlet distribution, the blue line shows the average weight proportion of the full (non-bootstrapped) dataset. The fitted concentration parameter (phi) is shown in the top panel.

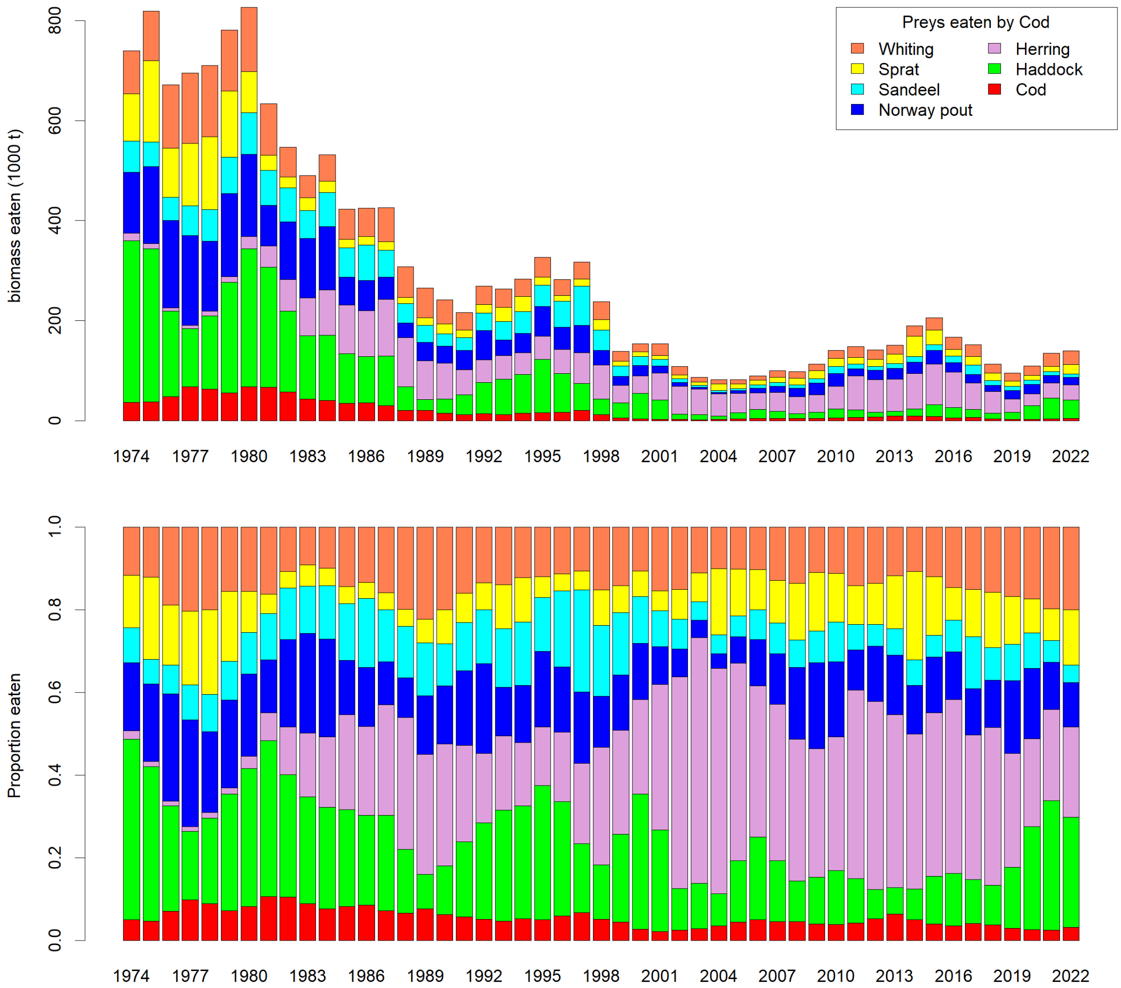

Figure 6.7. Biomass of species eaten by cod as estimated by SMS, both in absolute terms (top) and as weight proportions (bottom).

6.3.2 Grey seal predation on plaice

SMS estimated predation mortality (M2) for plaice that is low and significantly lower than the residual natural mortality (M1) excluding grey seal predation (Fig. 6.8). Reducing M1 does increase M2, but M2 is still very low. This is because grey seals are only one of the predators of plaice. Plaice is also eaten by other fish and other mammals such as harbour seals. However, here we only consider predation on plaice by grey seals.

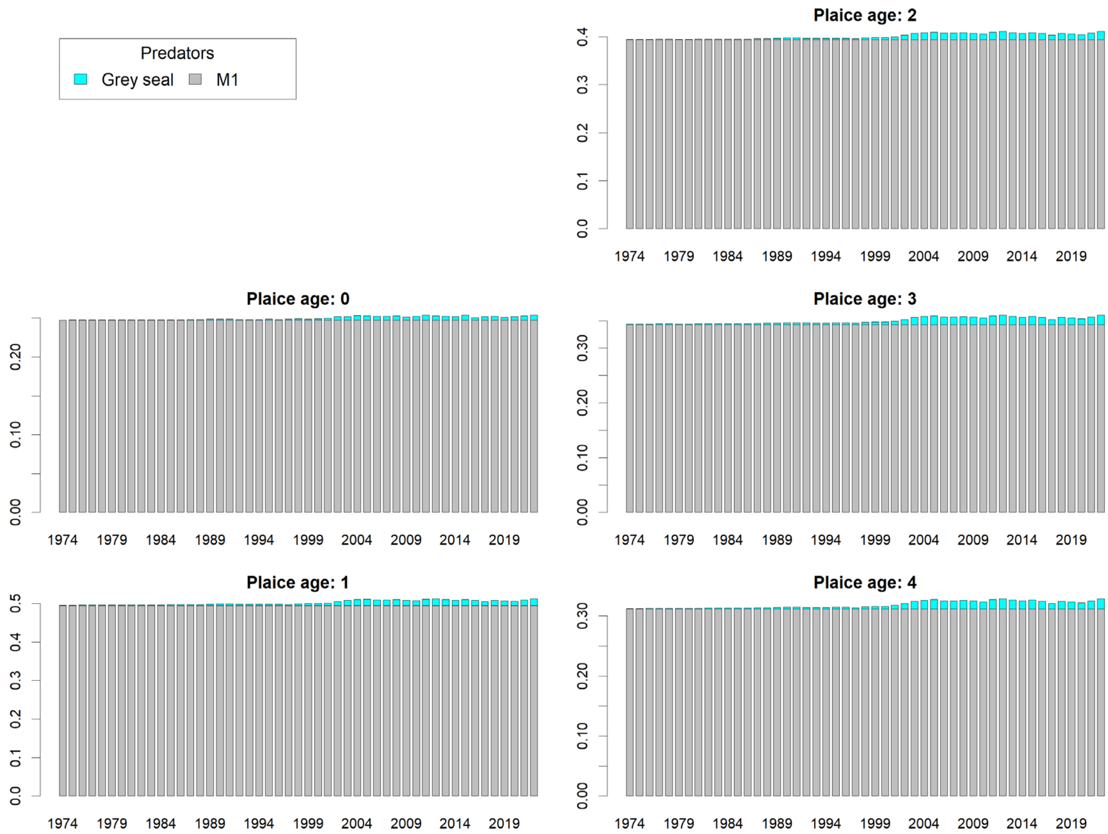

Figure 6.8. Estimated natural mortality (M) for plaice. M due to grey seal predation (M2, blue), and residual natural mortality (grey, M1).

Given that the M2 for plaice were estimated to be low and sensitive to the M1 assumption, the review panel at WGSAM chose to accept the model for plaice while considering the M2s unfit for use in the plaice single species assessment model.

6.4 Discussion and perspectives

ICES establishes the ecosystem approach as the central tenet that governs how ICES provides independent advice on the management of human activities in our seas and oceans (ICES 2023). Predator-prey interaction and quantification of the food web as done by SMS, is crucial for implementing the ecosystem approach in advice. Presently ICES is using the natural mortalities estimated by WGSAM for most of the traditional catch advice for North Sea fish stocks. The North Sea is one of the very few regions worldwide where quantitatively based, and often time-varying predation mortality is routinely included in species assessments. For most other sea regions, natural mortalities are assumed constant in providing catch advice.

In the report from the Danish “Fiskerikommissionen”, December 2023, one of their recommendations was the implementation of an ecosystem-based management. The Commission also recognises that the use of multispecies models for stock assessment and advice is essential for such an approach to management.

The presently used practice, to update the natural mortalities (M) every three years and subsequent adjustment of M in the traditional single-species stock assessment and advice, is seen as a first step in implementing an ecosystem-based management. Logistics and other practical considerations do not presently allow a concurrent update of both the natural mortalities and annual catch advice.

SMS and the ICES stock assessments operate at "stock level", meaning that e.g. local conditions cannot be taken into account. As an example, the Technical Services by ICES on "EU-UK request on ecosystem considerations in the provision of single-stock advice for forage fish species" (ICES 2023b), concludes the importance of time-varying predation mortality (from SMS) as the primary way that predator-prey interactions are handled in assessments supporting advice. However, it also concludes that fishing opportunities are given at the stock level and cannot function at the level of individual feeding grounds, which goes beyond the detail level of the stock assessment models. This conclusion is important for the specific case, breeding success of seabirds in relation to Danish fisheries of sandeel but also for other applications like a local model for e.g. the Jammer Bay area. Such a model would require additional data and model development.

Another limitation with the presently used predator-prey interaction approach in ICES (i.e., SMS), pointed out by the ICES request, is that the present framework is not sufficient to analyse whether the forage fish biomass is kept high enough for specific predator requirements. For the North Sea area, food limitation is not generally seen as an issue, however it may be the case for some specific predators with low mobility. Starving (poor body condition) cod is widespread in the Baltic Sea, however, whether this is due to a decrease in the available food, or an indirect effect of poor environmental conditions and parasites, is not clear.

6.5 Acknowledgements

The work was funded in the project 'Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)' (Grant Agreement No 33113-B-23-189) by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark.

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7. Discard assessment of commercial fish species (Task 4.6)

Kirsten Håkansson, Marie Storr-Paulsen

7.1 Introduction and aim

The Danish observer program is collected according to EU's Data Collection Framework, DCF - EU 2017/1004 and a multiannual programme (EU MAP) and is part of Danish obligation for data collection. Discarding of fish and shellfish has been a common practice in the fishery for many years regarding that part of the catch, which is unwanted for some reason. Before the implementation of the landing obligation, the main reason for discard was that it was mandatory to discard the part of the catch that was below the minimum landing size. Today there can be several reasons for a fisher to discard part of the catch and the reasons can vary with time and area and are listed below (modified from Feekings 2012):

- The size of the fish is considered to be too small, below the minimum reference size (indicating there is a quota on the stock, there are no exemptions and it is mandatory to land the fish, which likely fetch lower prices.
- The quota on the given fish is depleted, but the fisher still has quotas on other fish stocks caught within the same area and gear, indicating that the fishery continues, but with discard for all sizes for the species whose quota is depleted. This term choke species is applied to a single species with no, or a much reduced, quota, and which can potentially prevent a fishery within a given area.
- To optimize the sale value the smallest (still above minimum landing size) and lowest value fish are discarded. This is because larger fish generally have a higher landing price per kg than smaller fish. However, for the fisher the pull on the quota is the same. This practice is called high-grading.
- Lack of marketing opportunities or too low prices for the fisher to cover the expense for handling and landing the fish. An example could be dab (*Limanda limanda*) in Skagerrak.
- Fish not suitable for human consumption (this could include many gobies (Gobiidae) and thorny skate (*Amblyraja radiata*)
- Species with documented high survival and thereby exempted for the landing obligation. For some species it has been documented that with correct handling the species have a high survival. This is the case for several flatfish species and Norwegian lobsters. The survival is however often related to the gear, season, towing time, and correct handling onboard.
- Some sensitive species. For several shark and ray species it is mandatory to discard them, and most of these species also have a documented high survival.
- Space capacity on board the vessel. If a very large catch is caught and there is limited space onboard the fisher would typically discard the lower value fish.
- Most fishers catching fish for human consumption gut the fish at sea, to ensure a higher quality, and discard the waste.

Although the fisher can have many different reasons for discarding part of the catch, the discard amount can also be influenced by many other reasons (Rochet and Trenkel 2005, Frandsen et al. 2010):

- Environmental factors such as the season, water depth and area can influence the amount of discard. The season will reflect the growth of a new incoming year class, and this will influence when the fish reach a size where it is retained by the gear. Species that migrate may only be caught in special periods or areas. Often juvenile fish are located in more shallow waters than older fish.
- The size of a year class can have a large influence on the discarded amount. If a large year class enters a fishing area before it reaches the size where it is suitable for human consumption but is still retained by the gear, this can lead to high discards. In 2023, many small haddock were discarded due to a large year class entering the fishery.
- The gear used in the fishery is very influential on the amount of discard. Some passive gears such as longlines or gillnets have a relatively low amount of discard of the target species as the gear is very size selective. However, they can experience unwanted by-catch of mammals and birds in specific areas and seasons. Pound net can also have high amount of unwanted bycatch. However, with this gear and correct handling, high survival of the unwanted bycatch can be achieved. Beam trawlers are equipped with heavy ground gear and animals in contact with the gear will experience relatively low survival, however this gear is seldom catching birds or mammals. More information on gear and their influence on the environment and discard can be found in the DTU Aqua report "Miljøskånsomhed og økologisk bæredygtighed i dansk fiskeri" (Gislason 2021).
- The mesh size on the gear is very influential on the amount of discard. The same type of fishery, in the same area and season will have a different discard pattern relative to the mesh size used. Gear with smaller mesh sizes often give the largest discard.
- The species composition in the catch may also influence the discard amount. If a fishery is targeted towards e.g., cod and a large haul of flounder is caught, the flatfish will tend to block the escape windows for the smaller cod.
- Further, the fishing time can also influence the amount of discard.

7.2 Materials and methods

DTU Aqua has since 2002 conducted between 150-250 annual trips with Danish commercial fishing vessels to register the discard portion of the catch. The sampling program does not cover all Danish fleet segments and the main emphasis is on fleet segments where earlier investigations have shown relative high amounts of discard on fish and shellfish species. The investigated fisheries were classified in 7 different fleet lists based on the fishery and gear that was conducted with the vessel the year before (Table 7.1). A group of designated observers from DTU Aqua randomly selected a vessel from the vessel list and contacted hereafter the vessel owner, to ask for permission to participate in the next fishing trip by the vessel. The effort in the program is spread over the seasons and areas. On a commercial fishing trip, the participating observer quantified the discarded amount by species and haul and noted the landed amount by haul. From the discarded part, a length distribution by species was conducted and 1 fish / cm / haul for selected species was brought on shore for further measurements (age, individual weight, genetics, etc.). The observer does not record if a given act from the fisher is legal or non-legal as his responsibility is to get as correct biological data as possible to be used in fish stock advice and not to ensure law enforcement.

Table 7.1. The seven-vessel list for the observer sampling program in 2022.

Vessel list
1. Trawler in the Eastern Baltic Sea 2. Trawler and Danish Seine in the Western Baltic Sea and Kattegat Trawler 3. Trawler and Danish Seine in the North Sea 4. Trawler and Danish Seine in Skagerrak 5. Beam trawl in the North Sea 6. Shrimp trawler in Skagerrak and the North Sea 7. Gillnetters in inner Danish waters

The observer program covers all Danish areas but includes only vessels larger than 9.5 meters and for this reason the coverage is not as good in the coastal areas.

In Jammer Bay two of the vessel lists are active. The 4), trawler and Danish Seine in Skagerrak and the 6), Shrimp trawler in Skagerrak. However, as indicated above, the discard pattern can be very different according to the mesh size and gear, and for this reason the analysis was conducted on a dataset further divided in four groups:

- Shrimp fishery with a mesh size between 32-69 mm,
- Trawl fishery conducted with mesh sizes >120 mm,
- Trawl fishery targeting mainly Norway lobster conducted with smaller mesh sizes (90-119 mm),
- Danish Seine fishery with a mesh size >90 mm.

Nine species were selected for a spatial mapping of the distribution in Skagerrak. These included some of the main target species such as cod (*Gadus morhua*), whiting (*Merlangius merlangus)*, saithe (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*), deep water shrimp (*Pandalus borealis*), Norway lobster (*Nephrops norvegicus*) and plaice (*Pleuronectes platessa*) and two species designated as sensitive species; starry ray (*Amblyraja radiata*) and piked dogfish (*Squalus acanthias)*.

Table 7.2. Observed and total number of fishing trip in Skagerrak per year and fishery.

	2018		2019		2020		2021		2022	
	Observed	Total	Observed	Total	Observed	Total	Observed	Total	Observed	Total
GNS_DEF_>=220_0_0	2	148	1	119		309		593		232
GNS_DEF_120-219_0_0	9	5712	3	5065		4302		3730		3224
OTB_CRU_32-69_0_0	6	810	9	720	9	812	9	820	8	779
OTB_MCD_>=120_0_0	16	1438	6	756	3	641	1	509	1	334
OTB_MCD_90-119_0_0	55	7226	54	7259	34	5781	33	7118	27	6013
SDN_DEF_>=90_0_0	13	1333	5	1408	10	1215	8	1291	6	1212

Estimating discards and mapping discards

The discard rate is estimated by a ratio estimator, which is a commonly used method (ICES 2020, McAfee et al. 2023). The amount of discard can be related to different measurements that are available for the total target population, e.g., fishing time, number of hauls, total landings of the same species or total landings of all species. Generally, at DTU Aqua, we relate the discard per species to the total landings of all species.

$$Discard\ rate_{year,quarter,area,fishery,art} = \frac{\sum Discard\ (kg)_{year,quarter,area,fishery,art}}{\sum Landings\ (kg)_{year,quarter,area,fishery}}$$

The discard rate is calculated by year, quarter, area, and fishery. Due to the low sampling levels in the Jammer Bay, it was not considered reasonable to split Skagerrak into two spatial domains, Jammer Bay and the rest, so a rate is calculated for the entire Skagerrak.

The discards per year, species and grid were calculated by multiplying the discard rate and total landings of all species per year, quarter, fisheries, and grid within Skagerrak, and then summarising the results per year, species, and grid. Both VMS and AIS were used to estimate the total landings per position.

7.3 Results

For each of the years 2018-2022 the sampled fisheries were mapped with (a), the fishery intensity for the given fishery and with black dots indicating where DTU Aqua had conducted sampling for the same fishery, (b), the landings by area for the nine selected species; cod, plaice, haddock, Northern prawn, Norway lobsters, saithe, whiting and the two “sensitive species”; starry ray and piked dogfish, and (c), the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2022.

The following maps provide the results for 2022, maps for 2018-2022 can be found in the appendix (see Chapter 7.7).

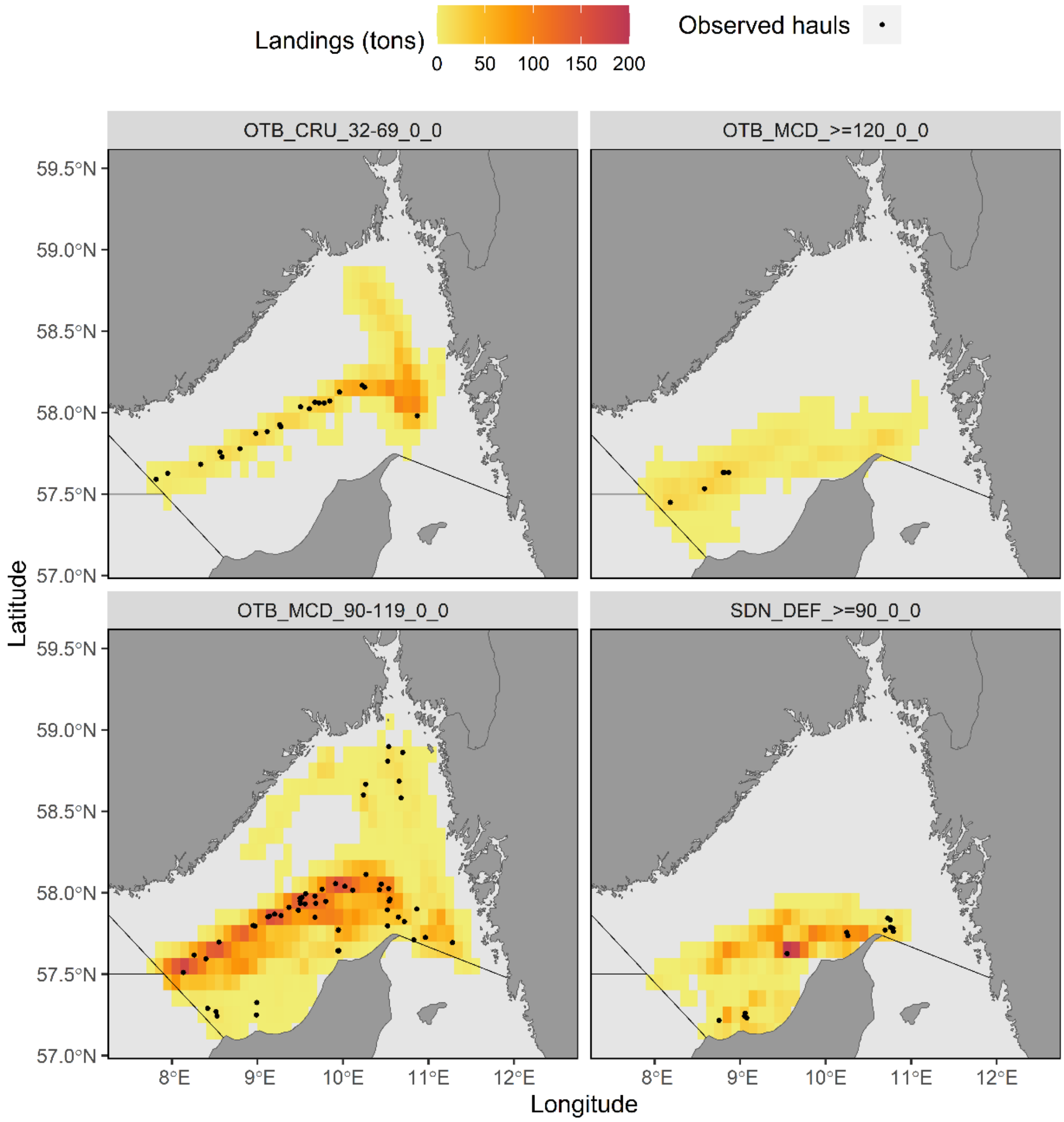

Figure 7.1. The distribution of the total amount of landings by gears for the sampled fisheries combined in 2022 and the observed hauls (black dots). OTB_CRU_32-69 is the deep shrimp fishery, OTB_MCD=>120 is the mixed demersal fishery with mesh size larger than 120, OTB_MCD_90-119 is the mixed demersal fishery with mesh size smaller than 120 mm and the SDN_DEF>90 is the Danish Seine fishery with all mesh sizes. Darker reddish colours indicate higher effort in the fishery.

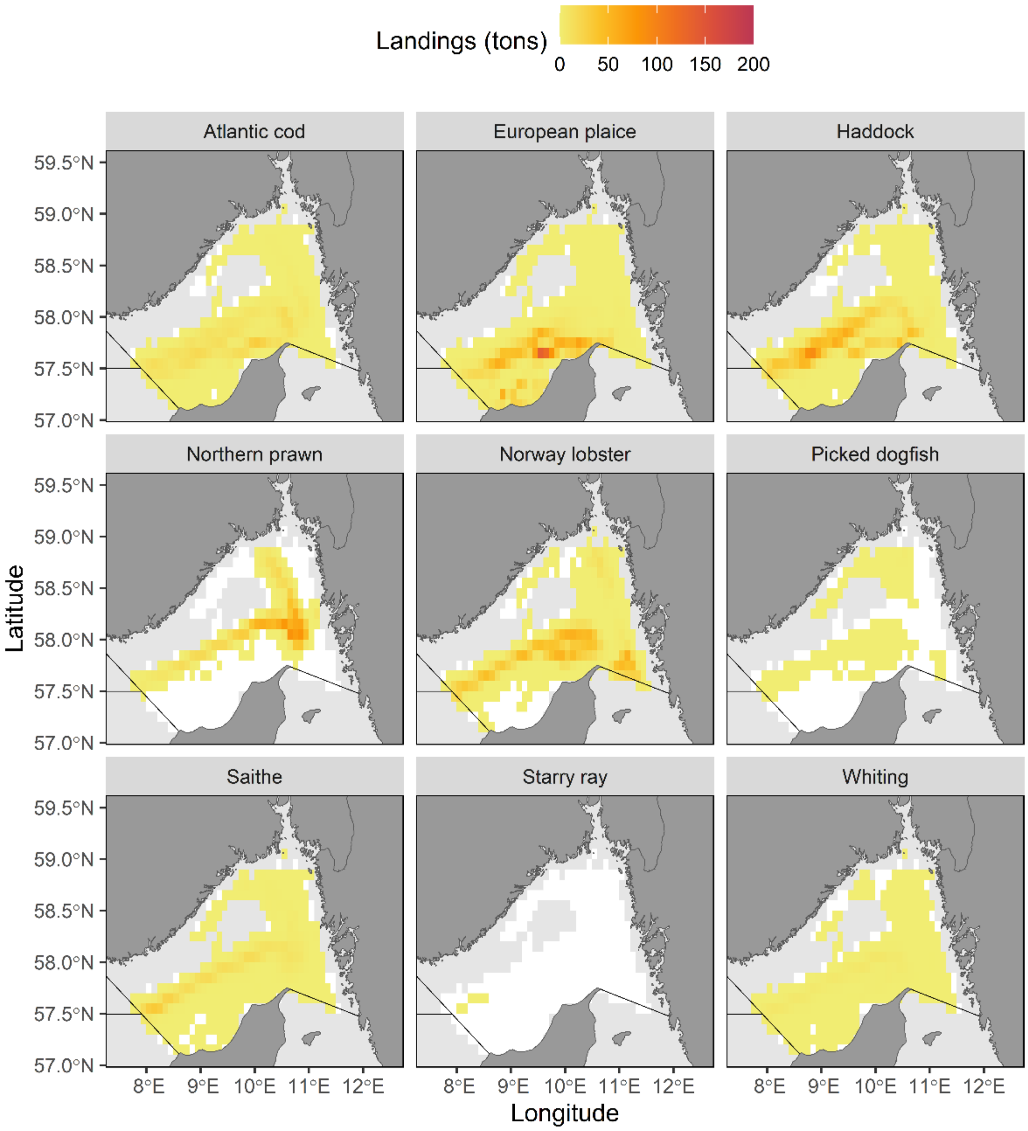

Figure 7.2. The distribution of the total amount of landings per species for the combined sampled fisheries in 2022. The species are cod, plaice, haddock, Northern prawn, Norway lobsters, piked dogfish, saithe, starry ray and whiting.

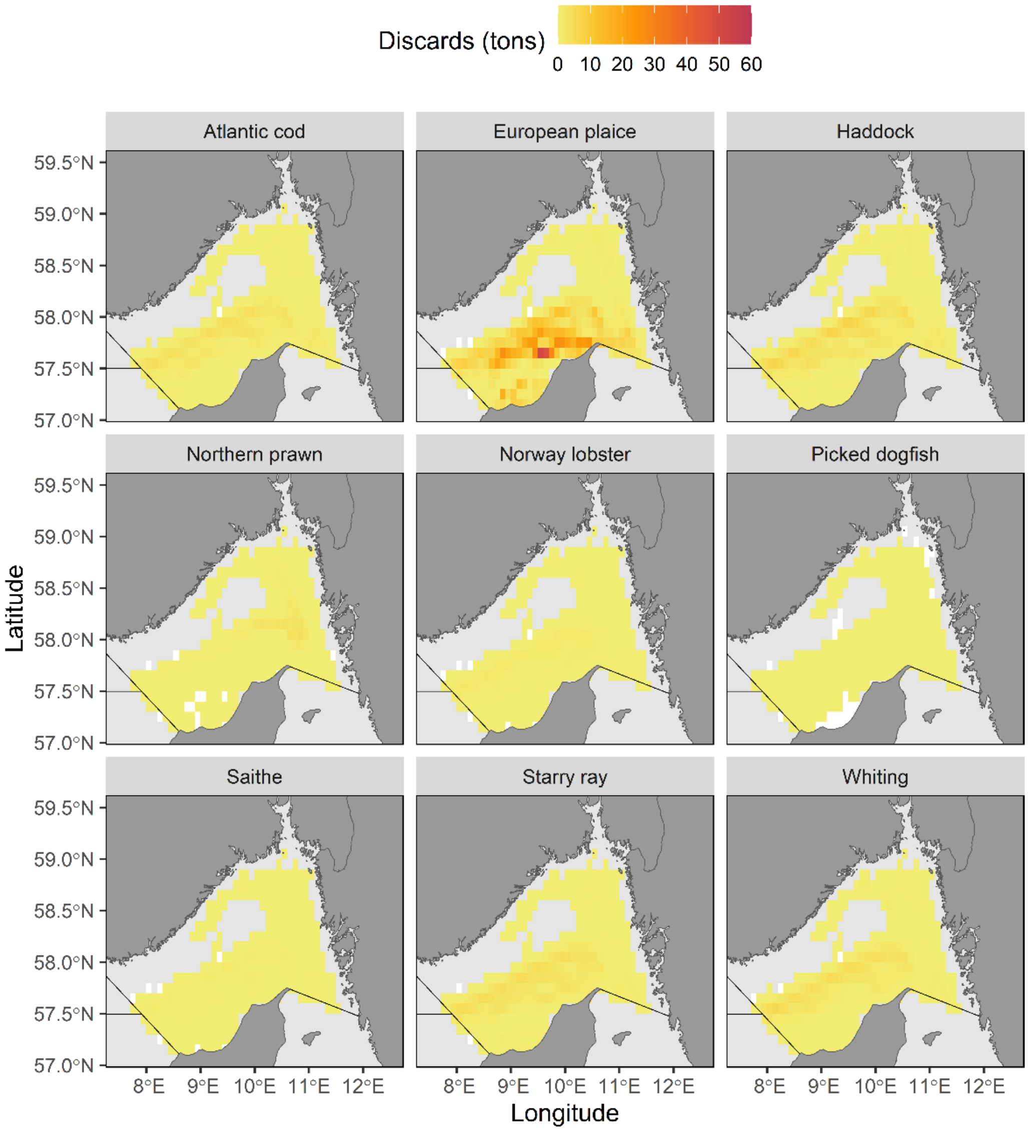

Figure 7.3. The distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2022. The species are cod, plaice, haddock, Northern prawn, Norway lobsters, piked dogfish, saithe, starry ray and whiting.

7.4 Discussion and perspectives

The method can in principle be used for all sampled fisheries and used to display all species observed in the Danish fisheries. However, due to the coarse domains, fishery, quarter and Skagerrak as a whole, when estimating the discard, fishery and quarter, care should be taken when interpreting the maps. As the same discard ratio by species is used for a sampled fishery, the amount of discard in a grid is only driven by the summed total amount of landings of all species per fishery and quarter within that grid. However, the maps give an impression of which fisheries are causing the discard. For example, haddock and whiting discard seem to derive mainly from the bottom trawler fishing with a mesh size between 90-119, while plaice discard mainly comes from both from the bottom trawler fishing with mesh size between 90-119 and Danish seiners. The main part of the discard of Northern prawn derives from the targeted shrimp fishery.

If the aim is to identify hotspots for discarding of specific species, or group thereof, by different fisheries, then a more refined model for estimating discard is needed, where information such as depth is included.

7.5 Acknowledgements

The work was funded in the project ‘Mapping of seabed habitats and impacts of beam trawling and other demersal fisheries for spatial ecosystem-based management of the Jammer Bay (JAMBAY)’ (Grant Agreement No 33113-B-23-189) by the European Maritime and Fisheries Fund (EMFF) and the Ministry of Food, Agriculture and Fisheries of Denmark.

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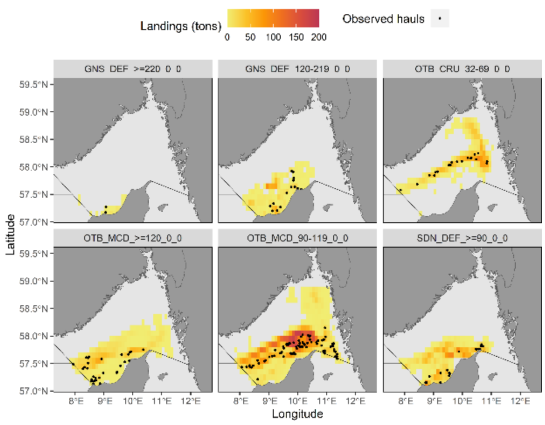
7.7 Appendix

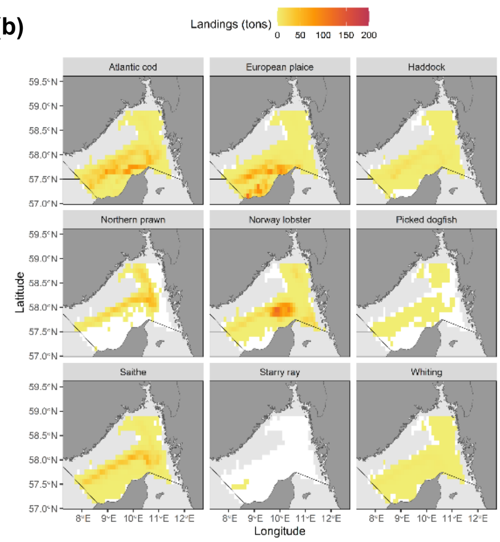
Maps of historic catches 2018-2022

Figure 7.A1. Maps showing the distribution of the total amount landed in the sampled fisheries and observed hauls in 2018 (a), the distribution of the total amount of landings per species for the sampled fisheries combined in 2018 (b) and the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2018 (c).

(a)



(b)



(c)

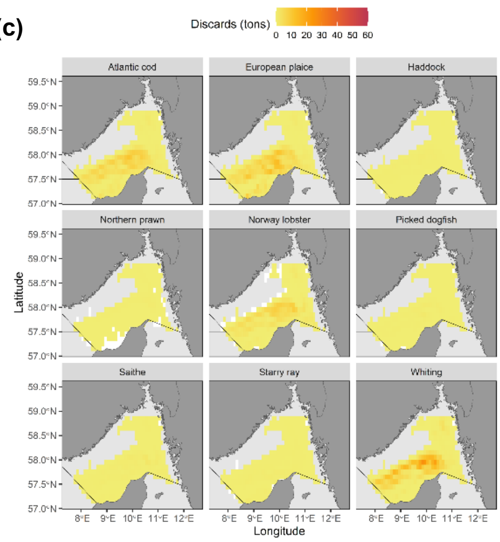
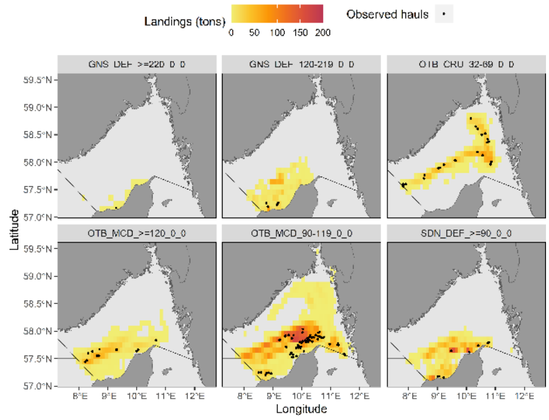
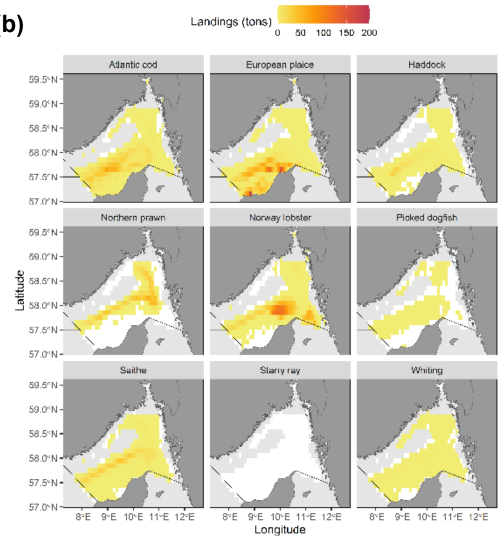


Figure 7.A2. Maps showing the distribution of the total amount landed in the sampled fisheries and observed hauls in 2019 (a), the distribution of the total amount of landings per species for the sampled fisheries combined in 2019 (b) and the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2019 (c).

(a)



(b)



(c)

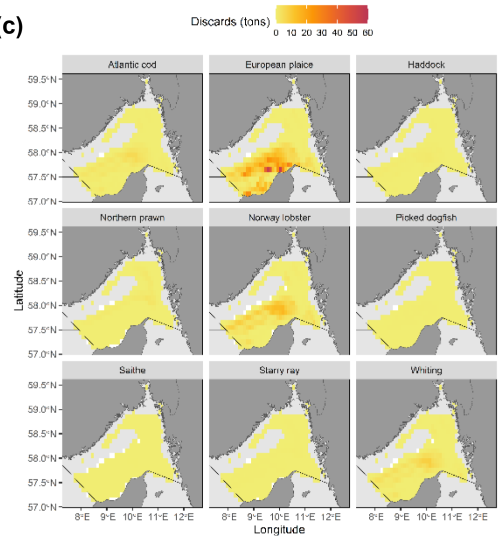
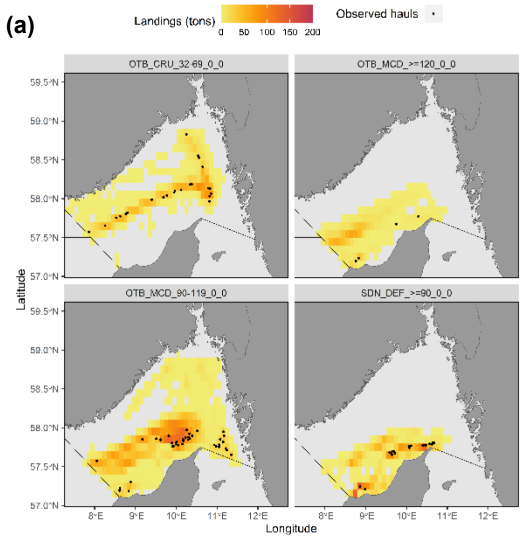


Figure 7.A3. Maps showing the distribution of the total amount landed in the sampled fisheries and observed hauls in 2020 (a), the distribution of the total amount of landings per species for the sampled fisheries combined in 2020 (b) and the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2020 (c).



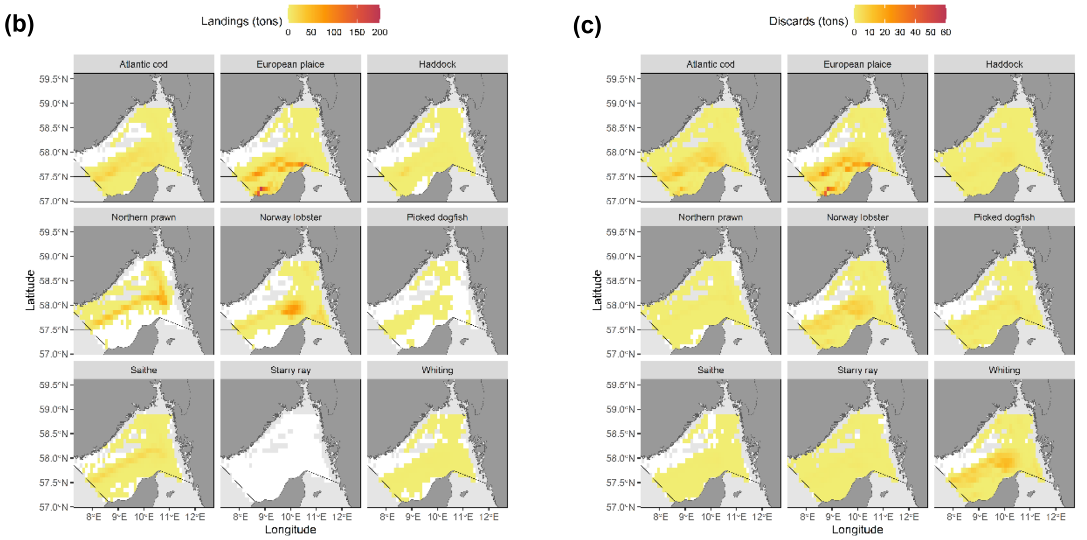
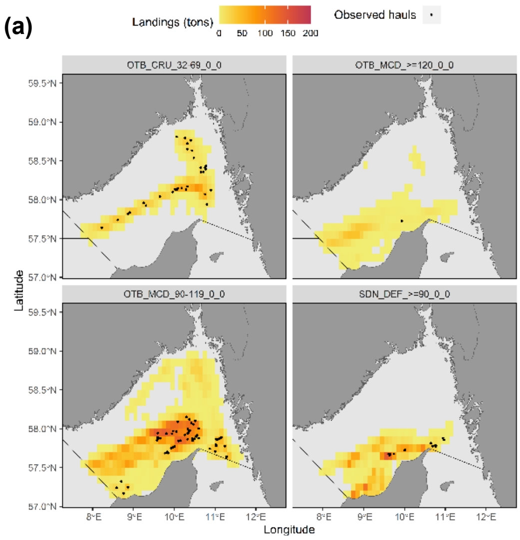
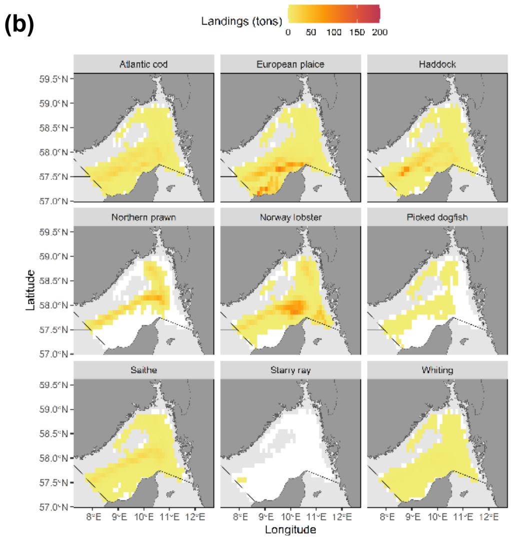


Figure 7.A4. Maps showing the distribution of the total amount landed in the sampled fisheries and observed hauls in 2021 (a), the distribution of the total amount of landings per species for the sampled fisheries combined in 2021 (b) and the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2021 (c).





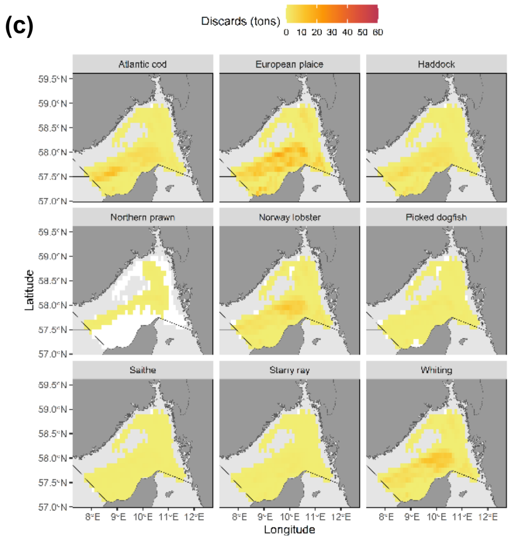
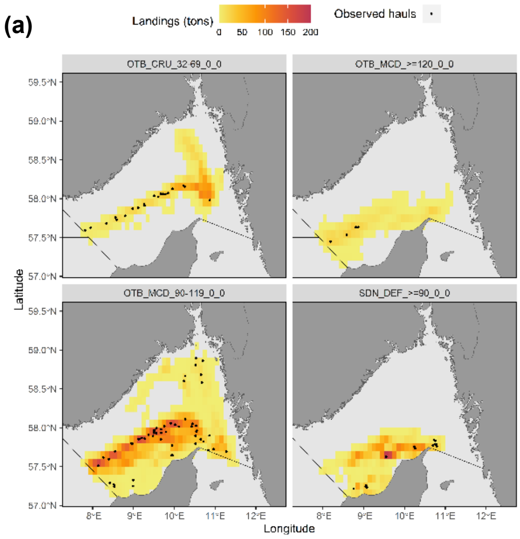
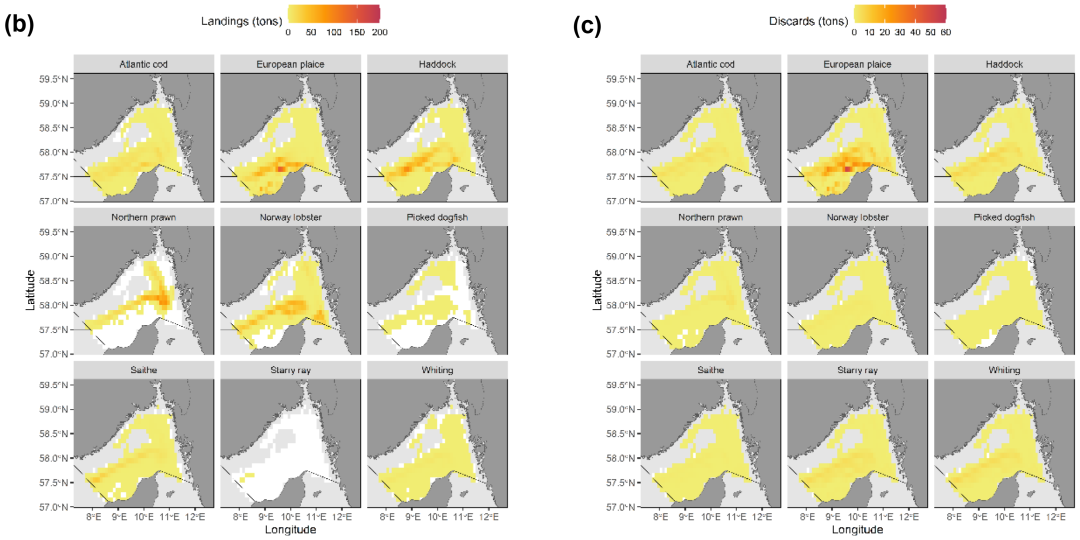


Figure 7.A5. Maps showing the distribution of the total amount landed in the sampled fisheries and observed hauls in 2022 (a), the distribution of the total amount of landings per species for the sampled fisheries combined in 2022 (b) and the distribution of the total estimated amount of discards per species for the sampled fisheries combined in 2022 (c).





8. Acknowledgements

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