Stichting Wageningen Research
Centre for Fisheries Research (CVO)

Tare conversion factors for whole-frozen mackerel, horse mackerel, herring, blue whiting, and greater argentine

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CVO report: 23.013

Commissioned by:
Ministry of Agriculture, Nature and Food Safety (LNV)
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Project number: 4311210029
BAS code: WOT-05-001-002

Publication date: 15 June 2023

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This research is conducted as part of the statutory task programme "fisheries research" and subsidised by the Dutch Ministry of Agriculture, Nature and Food Quality.

DOI: https://doi.org/10.18174/638645

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VAT nr. NL 8089.32.184.B01

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Summary

Fish from pelagic freezer trawlers is landed as whole, sea-frozen fish packed in cardboard boxes. A standard tare weight conversion[1] factor of 1.5kg/box is applied to calculate the net weight per box per species, which implies that of each box 1.5kg is assumed to be 'non-fish'.

This project aims to determine tare conversion factors for boxes of frozen fish based on actual measurements, enabling an empirical conversion from complete frozen boxes to live weight. A complete box contains cardboard, plastic, frozen fish, water and possibly straps. A protocol was developed to weigh the different components in the sample after thawing. Based on these weights, the appropriate conversion factor is estimated. The analysis to determine the conversion factor by species and for all species combined was carried out irrespective of time and spatial characteristics. By design, seasonal or area-specific conversion factors cannot be determined based on the collected data. All samples were processed in-house at the research institute Wageningen Marine Research (WMR) in IJmuiden. Apart from the site visits, no external visitors have been present during the processing and analysis of the samples.

Two analyses have been conducted:

1. Computation of the mean difference between the complete frozen box and the thawed fish (δ, delta) with an approximation of the 95% confidence interval.
2. A statistical test to determine if the empirically estimated δ differs significantly from 1.5kg.

Conversion factors are determined species-specific as well as for all species combined. In addition, a statistical test is conducted to identify if the new estimated combined tare conversion factor differs significantly from the standard tare factor currently in use. The species included in this study are greater argentine (*Argentina silus*, ARG), mackerel (*Scomber scombrus*, MAC), horse mackerel (*Trachurus trachurus*, HOM), herring (*Clupea harengus, HER*) and blue whiting (*Micromesistius poutassou*, WHB).

In total, 1240 boxes of fish were collected, of which 1218 were used for the analysis. The boxes originated from 18 different vessels flying the flag of 7 countries. All vessels belong to the pelagic freezer trawler fleet and either fish individually or conduct pair-trawling. Ten boxes were declared invalid for the analysis as they contained more than 10% in weight of other fish than the main species in the box. In addition, twelve boxes were considered invalid due to signs of leakage, damage, missing data or other abnormalities.

The confidence intervals of the one-sample t-test and Wilcoxon signed-rank test indicate that the calculated combined factors based on the mean δ deviate significantly from the standard tare weight conversion factor of 1.5kg. Across all species, a conversion factor of 1.05kg is realistic.

The variation between species is considerable. Boxes of greater argentine have the highest tare conversion weight of 1232 g per box (upper bound 1266 g), followed by blue whiting with 1116 g (upper bound 1135 g) and horse mackerel with 1001 g per box (upper bound 1032 g). The upper bounds of the conversion weight of herring and mackerel are less than 1 kg; the average tare conversion weight for herring is 896 g (upper bound 971 g), and for mackerel, 876 g (upper bound 898 g).

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[1] COMMISSION REGULATION (EC) No 1542/2007 of 20 December 2007 on landing and weighing procedures for herring, mackerel and horse mackerel

1 Introduction

Fish from pelagic freezer trawlers is landed as whole, sea-frozen fish packed in cardboard boxes. A standard tare weight conversion[2] factor of 1.5kg/box is applied to calculate the net weight per box per species. This implies that of each box, 1.5kg is assumed to be 'non-fish'.
This project aims to determine tare conversion factors for boxes of frozen fish based on actual measurements, enabling an empirical conversion from complete frozen boxes to live weight. A complete box contains cardboard, plastic, frozen fish, water and possibly straps. A protocol was developed to weigh the different components in the sample after thawing. Based on these weights, the appropriate conversion factor is estimated. All samples were processed in-house at research institute Wageningen Marine Research (WMR) in IJmuiden. Apart from the site visits, no external visitors have been present during the processing and analysis of the samples.

The project was conducted in 2021 and 2022 in two phases[3]. This report contains the outcomes of both phases and should be considered final and complete, thus superseding previous reports. The history of the current tare factor and (potential) future implementation of the combined tare factor and consequences thereof are beyond the scope and outside the scientific remit of this study.

In November 2022 and February 2023, site visits to observe the project's activities were carried out by representatives of the European Commission, European Fisheries Control Agency (EFCA), The Dutch Ministry of Agriculture, Nature and Food Safety (LNV), The Netherlands Food and Consumer Product Safety Authority (NVWA), national members from the Coastal States Monitoring, Control and Surveillance Working Group (CS MCS WG), fishing companies and the overarching Pelagic Freezer Association. During the visits, the setup of a methodology of the project was discussed and demonstrated to the visitors. For example, to observe the selection of boxes in the cold store, in February, visitors were welcomed to a cold store where the selection of boxes was demonstrated by selecting 30 additional boxes (similar relative distributions over the species) on top of the already collected and planned samples.

The species included in this study are greater argentine (*Argentina silus*, ARG), mackerel (*Scomber scombrus*, MAC), horse mackerel (*Trachurus trachurus*, HOM), herring (*Clupea harengus, HER*) and blue whiting (*Micromesistius poutassou*, WHB). Conversion factors were determined by species and for the five species combined. A statistical test has been conducted to identify if the new estimated combined tare conversion factor differs significantly from the current standard tare factor. The geographical area of interest is the FAO area 27 (Northeast Atlantic) insofar as relevant for the pelagic freezer trawlers. The analysis to determine the conversion factor by species and for all species combined was conducted irrespective of time and spatial characteristics.

This document presents a statistical analysis to determine if the standard conversion factor of 1.5 kg is appropriate. For this, two analyses have been conducted:

- Computation of the mean of δ with (an approximation of) the 95% confidence interval for all species combined and species-specific.

A statistical test to determine if the empirically estimated δ differs significantly from 1.5 kg.

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[2] COMMISSION REGULATION (EC) No 1542/2007 of 20 December 2007 on landing and weighing procedures for herring, mackerel and horse mackerel

[3] By request of the European Commission, the Dutch Ministry of Agriculture, Nature and Food Safety (LNV) tasked the Centre for Fisheries Research (CVO) in 2021 to determine a combined tare factor for certain species important to the pelagic fisheries, primarily to test whether or not this combined factor deviates from the standard tare weight conversion factor. As a follow-up, CVO was tasked to determine species-specific conversion factors in 2022 and to repeat the estimation of the combined factor based on the additional data collected during the second phase.

2 Materials and methods

2.1 Sample size determination

The number of boxes required for a robust estimate of the conversion factor (95% confidence interval) is based on an exploratory exercise (Table 2.1) (Wilkes, 2021) using readily available data from the market sampling project (MARSAM) as carried out in response to the Dutch data collection obligations towards the EU. The data points provided served as a proxy for sample size determination. The boxes used in the market sampling project are collected under a different method than routine fish processing procedures and could, consequently, not be used for this study.

The sample size analysis indicated that 200-250 boxes should be analysed to enable the estimation of a species-combined conversion factor. The estimation of species-specific conversion factors would require a total of 924-1175 boxes. The first phase focussed on the estimation of a species-combined factor. To allow any loss of samples, it was decided to analyse 300 samples, keeping the same distribution over the species as in the exploratory analysis. Note that the distribution over the species reflects the sample distribution and not, e.g. TAC shares or catch volumes. In the second phase, the 300 samples were supplemented by sufficient samples to estimate species-specific factors to reach the maximum value of the exploratory exercise. The methodology applied during both phases was similar, so all samples were pooled and treated equally for the final analysis, described in this report. Additional samples collected during the site visit (see introduction) were processed as all other boxes, apart from the additional measuring of fish length to provide insight into the length distribution (see discussion).

2.2 Sampling protocol

The complete sampling protocol is given in Annex 1. This paragraph contains an outline of the sampling protocol.

Boxes of fish (greater argentine, mackerel, horse mackerel, herring and blue whiting) were obtained directly from the cold storages of various fishing companies. The companies were requested to randomly select boxes from different vessels, areas, and seasons. The boxes were readily available in stores and had undergone routine processing procedures. These boxes can therefore be considered standard boxes as they were not explicitly composed for this study. Once selected, the fish was transported to WMR and kept frozen below -20°C until further processing. During sample processing, the core temperature of the thawed fish did not exceed 7°C, and the ambient room temperature did not exceed 25°C.

Each complete box was weighed and unwrapped, and the individual elements such as cardboard, straps, plastic and the fish were weighed. Then, the fish was put in plastic bags and left to thaw. After thawing, the remaining components (fish and remaining liquid) were weighed again. The remaining liquid was transferred from the plastic bag to a jar and filtered to separate solid organic materials like scales, slime and intestines from the liquid. After filtering, the different fractions were weighed. The remaining liquid fraction is the difference between the total weight and the sum of all solid fractions.

2.3 Dataset

2.3.1 Information collected

In total, 1240 boxes of fish were collected, of which 1218 have been used for the analysis (Table 2.1). Ten boxes were declared invalid for the analysis as they contained more than 10% in weight other fish than the main species in the box. The other species observed included boarfish, squid, haddock, and whiting, but also e.g. blue whiting in boxes with greater argentine, or mackerel in boxes of horse mackerel occurred. Twelve boxes were considered invalid due to signs of leakage, damage, missing data or other abnormalities. Boxes with variations that occurred while processing the fish, like different types of plastic or variation in the number of straps, were accepted in the analysis.

The distribution over the species differed less than 1% from the species level compared to the planned maximum number.

Table 2.1. The number of packages in the data set compared to the required boxes.

Major Species	Total number of valid boxes	Indicated minimum and maximum number of required boxes[4]
Greater Argentine	203 (16.6%)	166-205 (17.4%)
Herring	246 (20.2%)	183-229 (19.4%)
Horse Mackerel	233 (19.1%)	179-224 (19.0%)
Mackerel	155 (12.7%)	124-146 (12.4%)
Blue Whiting	381 (31.3%)	272-371 (31.5%)
Total number	1218	1175

The following information has been registered for each box (all weights recorded in gram):

- Species: Species code.
- Valid: An indicator if the observation was valid (i.e. no missing weights and weight of other fish is less than 10% in the package).
- Box weight: the weight of the total package with frozen fish.
- Total fish weight: the weight of the total fish of the thawed fish in a package.
- Other fish: the weight of the thawed fish from different species.
- Straps: the weight of the straps of the package.
- Carton: the weight of the carton of the package.
- Plastic: the weight of the plastic of the package.
- Residue: the weight of residue such as slime, scales, eyes of fish, etc.
- Water: the weight of water in the package after thawing.

2.3.2 Sample distribution

The boxes originated from 18 different vessels flying the flag of 7 countries. All vessels belong to the pelagic freezer trawler fleet and either fish individually or conduct pair-trawling.

On board the commercial vessels, fish is processed in batches. These yield numerous boxes, and some of the boxes provided may come from the same batch. Although spatial and temporal distribution are not included as such in the analysis, this section provides insight into the spatial and temporal spread of the samples. By design, seasonal or area-specific conversion factors cannot be determined based on the collected data.

[4] Wilkes, T 2021: ‘Vriesgewichten’ exploratory analysis to determine sample size. Internal memo to CVO 2100517-TW-lcs

All valid samples originate from Northeast Atlantic waters (FAO area 27) (Figure 2.1). 189 unique catchday*subdivision combinations were observed, while 233 species*quarter combinations were observed. For most batches, the catch location could be retrieved, e.g. by combining data provided by the fishing companies and the Vessel Monitoring System (VMS) data. However, four batches could not be allocated to an exact location but only to a subarea or subdivision. These batches are included based on a central position in the respective subdivision.

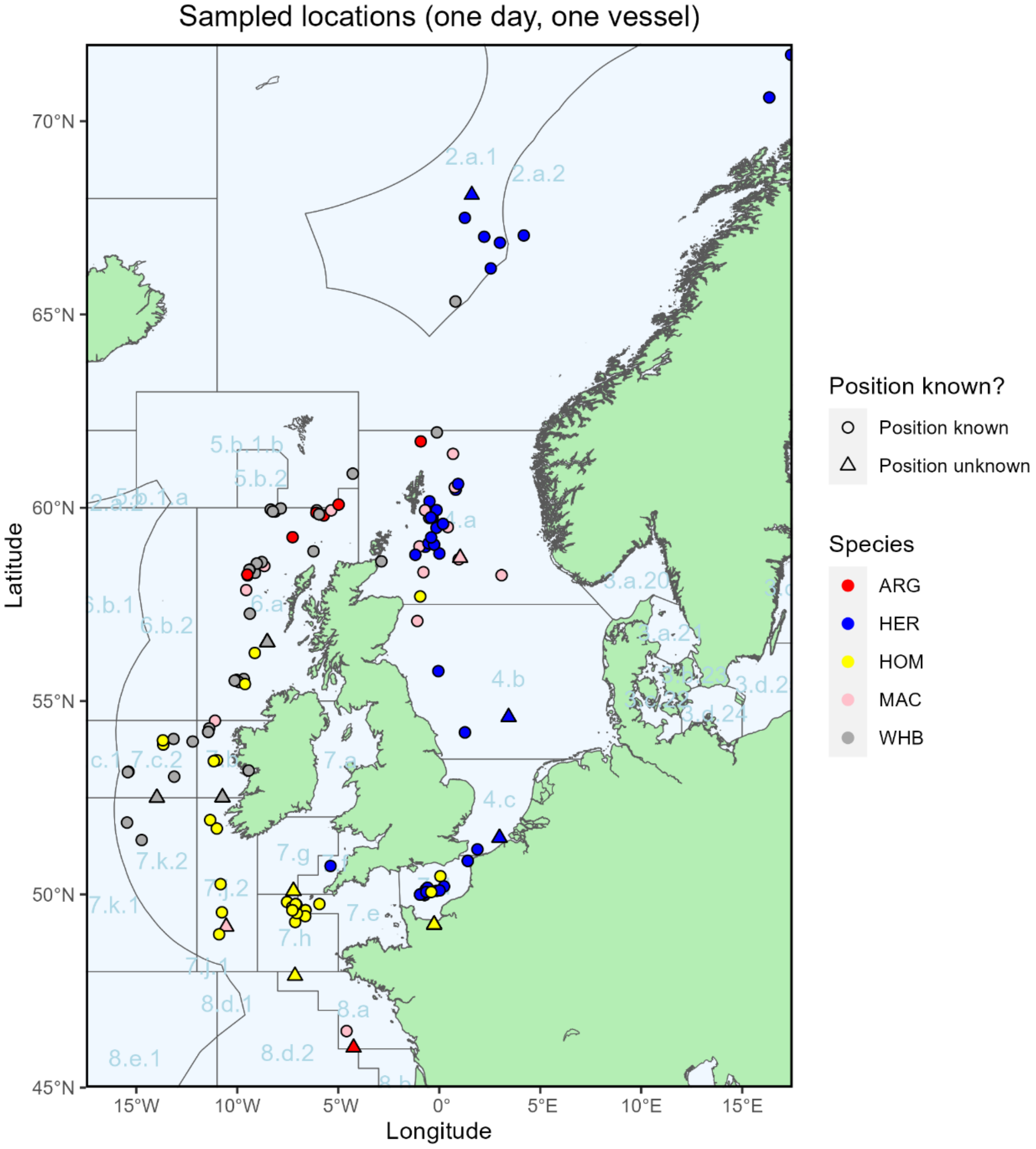

Figure 2.1. Overview of the geographical distribution of the samples by species.

The analysed batches were processed on board between 2019-2023 and originated from different quarters (Table 2.2, maps by quarter over all years in Annex 3).

Table 2.2 Batch distribution by quarter (% of the batches per species). NB: multiple samples can be related to one batch

	Fraction of batches by quarter				
Species	*unknown*	*Quarter 1*	*Quarter 2*	*Quarter 3*	*Quarter 4*
Greater argentine	0%	10%	60%	0%	30%
Herring	0%	13%	3%	30%	54%
Horse mackerel	0%	76%	5%	11%	8%
Mackerel	10%	36%	21%	8%	26%
Blue whiting	0%	52%	36%	2%	11%

2.4 Statistical analysis

2.4.1 Basis for estimation

Two analyses have been conducted:

- Computation of the mean difference between the complete, frozen box and the thawed fish (δ) with an approximation of the 95% confidence interval.
- A statistical test to determine if the empirically estimated δ differs significantly from 1.5kg.

The mean difference between the total box with frozen and the thawed fish, the variable δ ("delta"), is defined as follows:

$$\delta = W_{\text{total}} - W_{\text{thawed fish}}$$

where W_{total} is the weight of the total box with frozen fish, in kilograms, and $W_{\text{thawed fish}}$is the weight of the thawed fish, also in kg.

2.4.2 Bootstrap

Bootstrap is a computational resampling technique to repeatedly draw samples with replacement from the sample that is actually observed. In our analysis, we implemented a function with 20,000 replicates with replacement to estimate the empirical bootstrap mean and standard error for the delta and the species-specific delta. The sample is big enough and representative of the population. The benefit of using bootstrap resampling is that bootstrapping is a non-parametric statistical analysis. There is no need to assume a particular distribution of our observations, or the underlying populations. Samples were taken directly from our observations. Because of the Central Limit Theorem, the resampling distribution of the effect size will approach a normal distribution.

The bootstrap distribution is based on the information in the original (observed) sample. Therefore, the expected mean and variance of the bootstrap distribution ($mean_{boot}$ and var_{boot}) align with the mean and variance of the observed sample and can therefore differ from what we should expect based on the population. The bootstrap distribution will give an idea about any bias in the estimator and its standard error: the difference between $mean_{boot}$ and the sample statistic estimates the bias, i.e. the difference between sample statistic and true population parameter. sd_{boot} estimates the standard error of the sample statistic.

2.4.3 Confidence interval

The primary goal of this statistical analysis is to determine the mean of δ, with the corresponding 95% confidence interval. The 95% confidence interval is constructed from the resampling distribution. We use 2.5% and the 97.5% value of the ranked differences as boundaries of the lower and upper bounds of a

95% confidence interval. With the R package boot function, there are four kinds of confidence intervals in the boot.ci function.

2.4.4 *Statistical test*

As stated above, the δ does not follow an approximate normal distribution, and its actual distribution is unknown. Therefore, the one-sample Wilcoxon signed rank test (Wilcoxon, 1992) was used to test if the mean of δ differed significantly from 1500 g (a two-sided test). A significance level of 0.05 was used.

2.4.5 *Software*

R version 4.2.1 and R studio version 2022.07.0.548 extension of R-Markdown were used as the main software for the statistical analyses. Package ggplot2 and dplyr were used for data editing and descriptive statistics.

3 Results

3.1 Delta (δ) variable

This study aims to determine the mean difference between the total box weight and the weight of the fresh fish. To this end, variable δ ("delta") is defined as follows:

$$\delta = W_{total} - W_{thawed\ fish}$$

where W_{total} is the weight of the total box with frozen fish, in grams, and $W_{thawed\ fish}$ is the weight of all the thawed fish of all species, also in grams.

The distribution of δ was determined across all species (Figure 3.1) and by species (Figure 3.2).

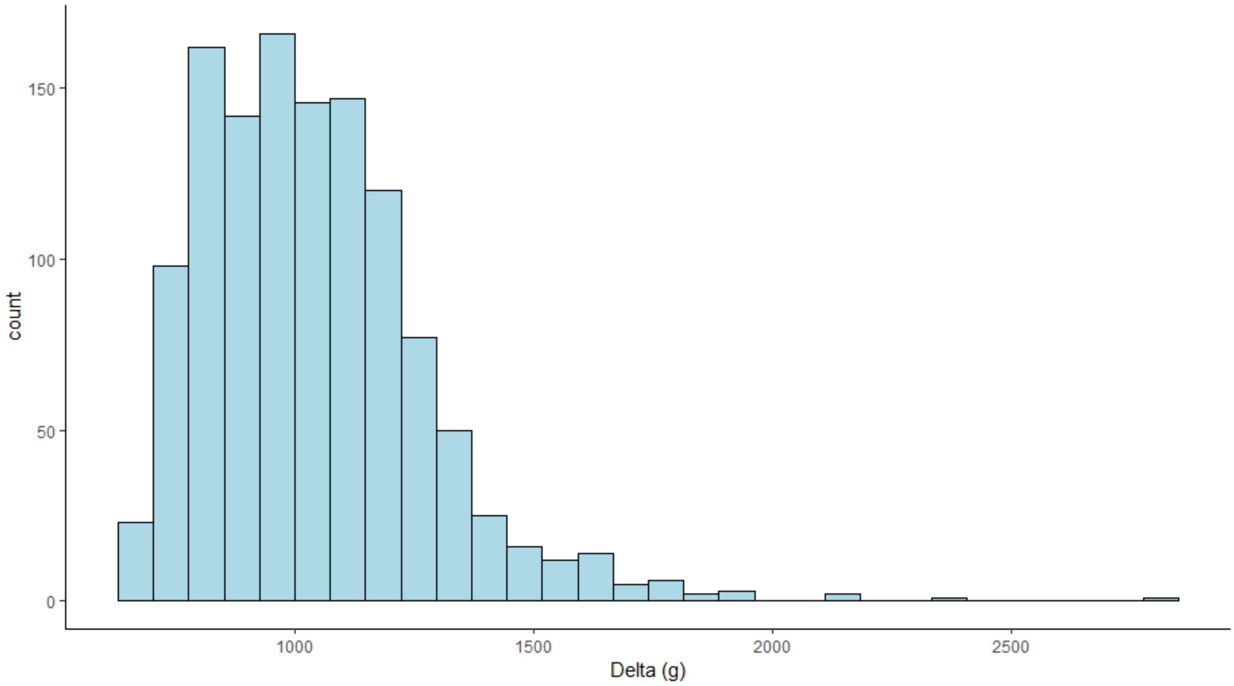

Figure 3.1. Histogram of δ (delta). The mean of delta is 1038 g. The standard deviation is 33 g. Minimum delta is 648 g. The maximum of delta is 2796 g.

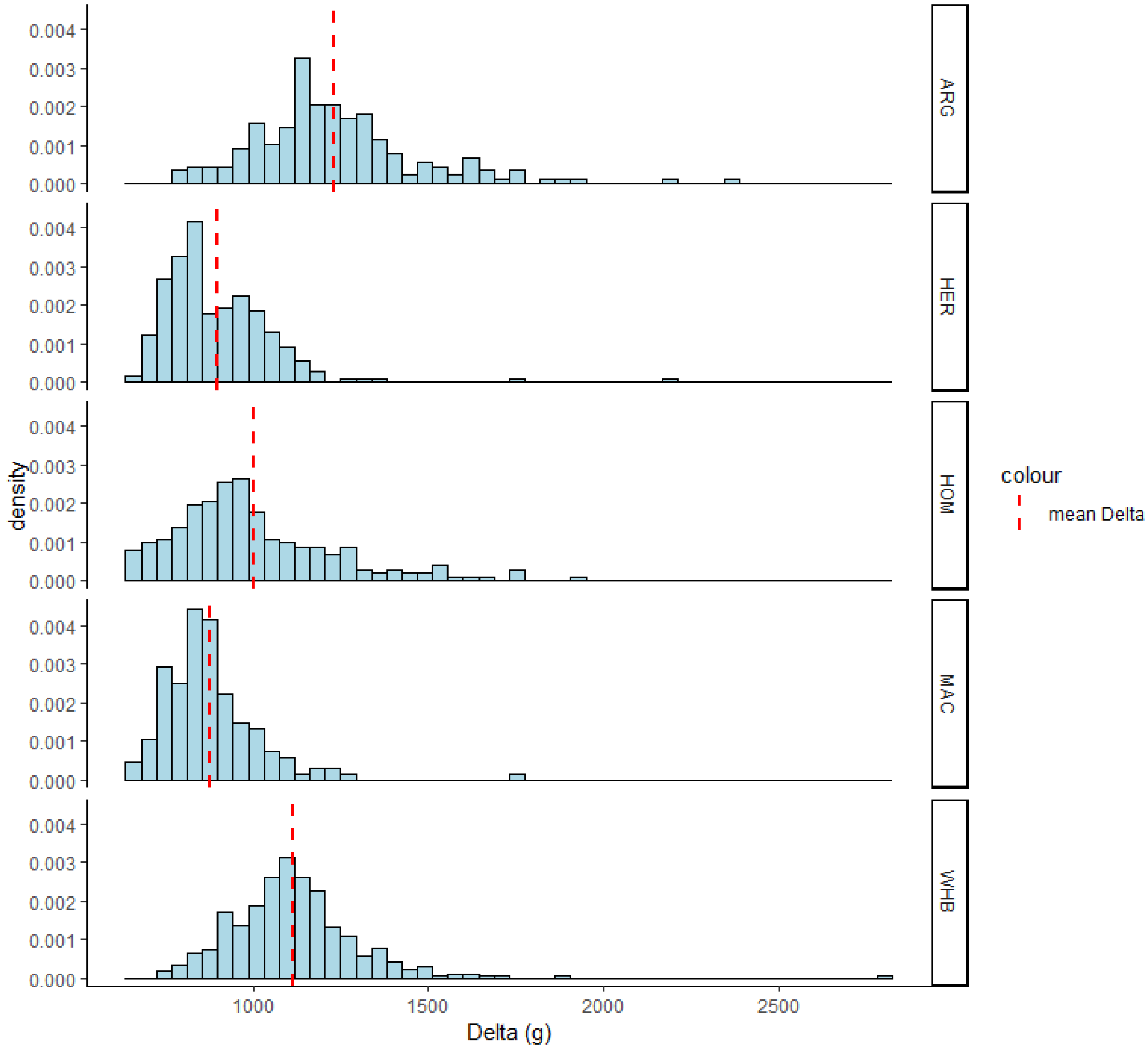

Figure 3.2. Histogram of δ (delta) of different species. ARG: greater Argentine; HER: herring; HOM: horse mackerel; MAC: mackerel; WHB: blue whiting. The mean delta for each species were 1232, 896, 1001, 876, 1116 g, respectively.

The 95% confidence interval of the mean of delta was determined using bootstrapping, coming with multiple types of confidence intervals. Notice that the normal, basic, percentile and adjusted bootstrap percentile confidence intervals are all very similar (Table 3.1). All the types of the bootstrap confidence interval indicate that 1.5kg does not lie within the 95% confidence interval of the mean of δ. Bootstrapping was conducted for all species combined (Figure 3.3, Table 3.1) and by species (Figures 3.4-3.8, Table 3.2). On average, MAC has the lowest δ, whereas ARG has the highest δ (Table 3.2).

Table 3.1. Four different types of bootstrap-based 95% confidence intervals of delta.

Type	Mean of δ (g)	Lower bound (2.5%)	Upper bound (97.5%)
Normal approximation	1038	1025	1051
Basic	1038	1025	1051
Bootstrap percentile	1038	1025	1052
Adjusted bootstrap percentile (BCa)	1038	1026	1052

Table 3.2. The bootstrap δ (delta) and 95% confidence intervals of all species and the major species in the package.

	Mean of δ (g)	Lower bound (2.5%)	Upper bound (97.5%)
All packages	1038	1025	1052
Species			
Greater Argentine (ARG)	1232	1199	1266
Herring (HER)	896	875	971
Horse Mackerel (HOM)	1001	971	1032
Mackerel (MAC)	876	854	898
Blue Whiting (WHB)	1116	1096	1135

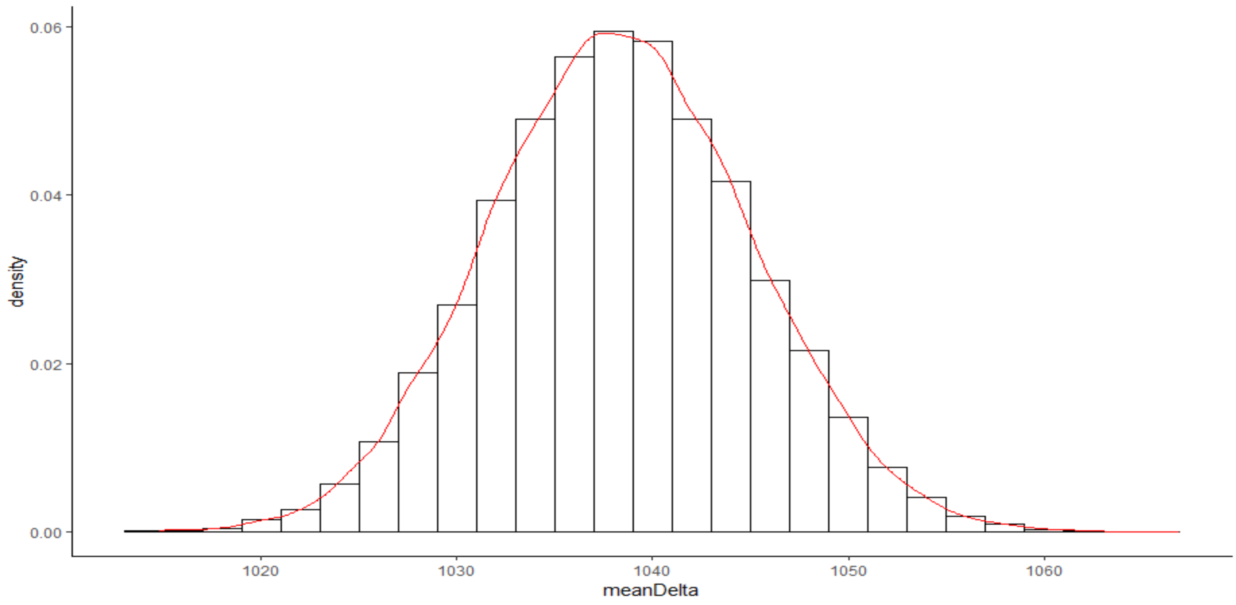

Figure 3.3. Bootstrap distribution of δ (delta) based on 20,000 resampling across all species (in g). The mean δ is 1038 g. Standard error of δ is 6.7 g. 95% confidence interval of δ is [1025, 1052].

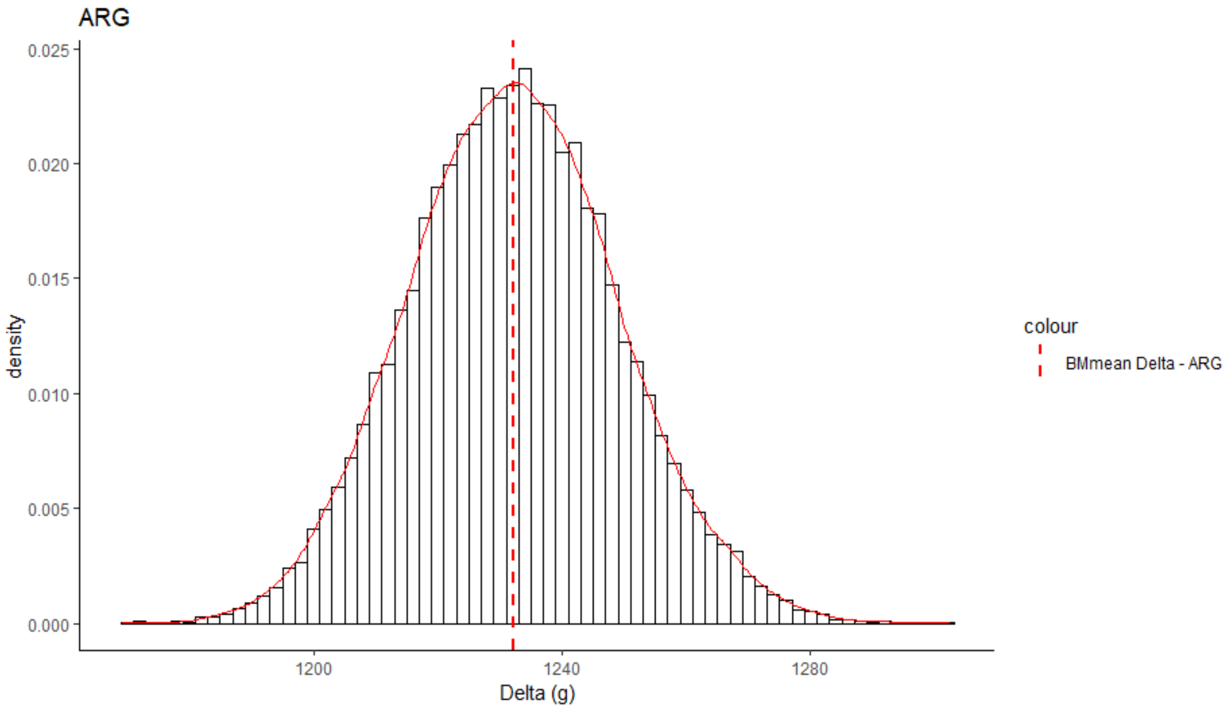

Figure 3.4. Bootstrap distribution of δ (delta) in Greater Argentine (ARG) based on 20,000 resampling (in g). The mean δ is 1232 g. Standard error of δ is 16.8 g. 95% confidence interval of δ is [1199, 1266].

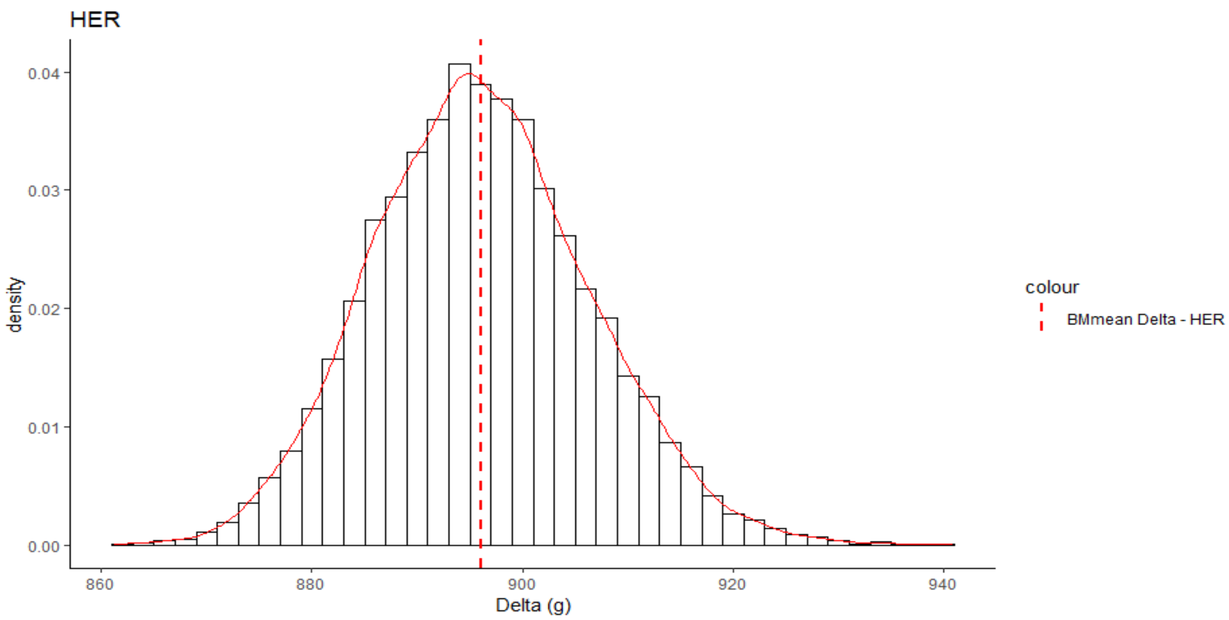

Figure 3.5. Bootstrap distribution of δ (delta) in Herring (HER) based on 20,000 resampling (in g). The mean δ is 896 g. Standard error of δ is 10.3 g. 95% confidence interval of δ is [875, 917].

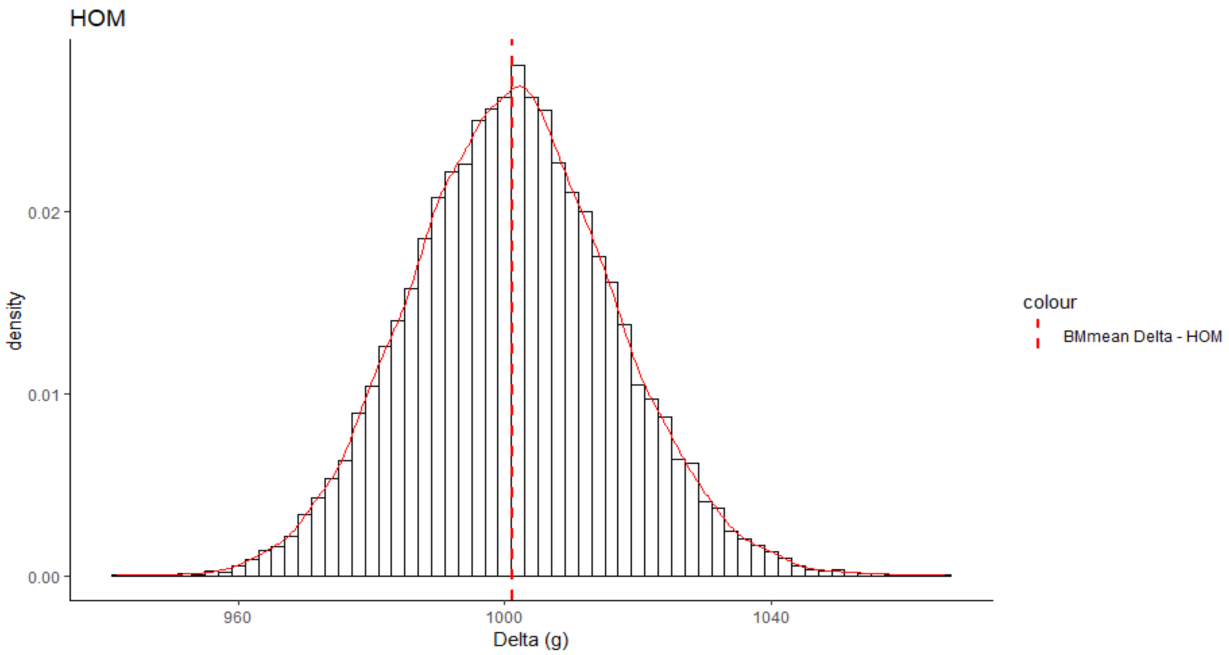

Figure 3.6. Bootstrap distribution of δ (delta) in Horse Mackerel (HOM) based on 20,000 resampling (in g). The mean δ is 1001 g. Standard error of δ is 15.2 g. 95% confidence interval of δ is [971, 1032].

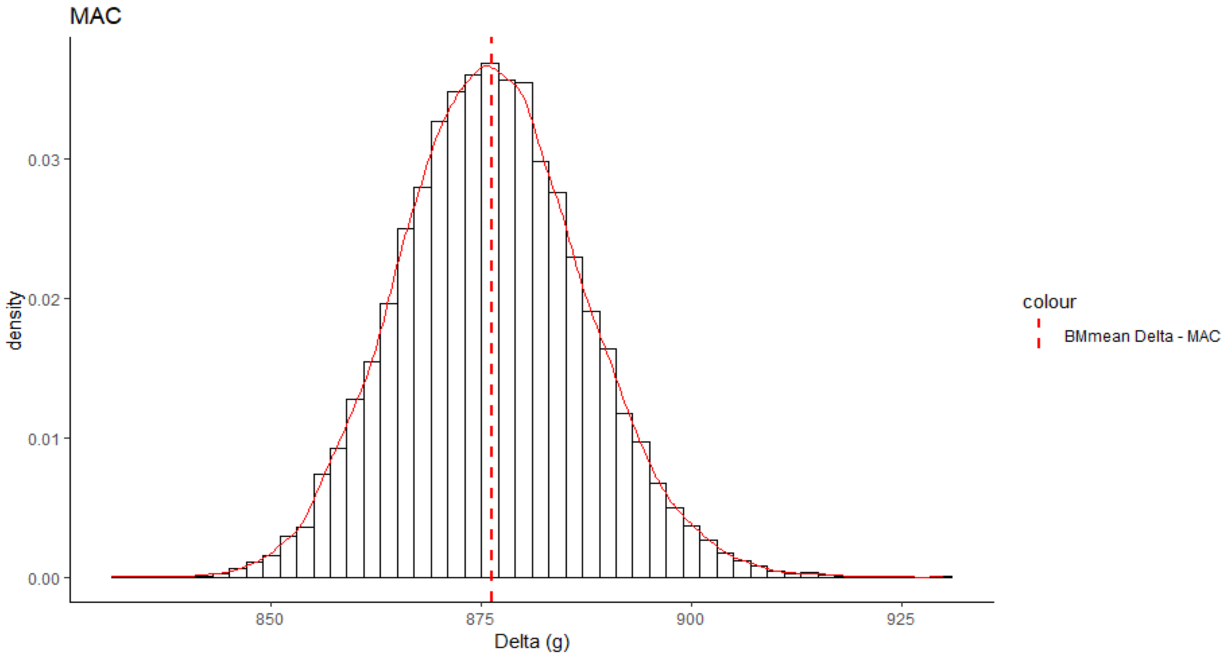

Figure 3.7. Bootstrap distribution of δ (delta) in Mackerel (MAC) based on 20,000 resampling (in g). The mean δ is 876 g. Standard error of δ is 10.9 g. 95% confidence interval of δ is [854, 898].

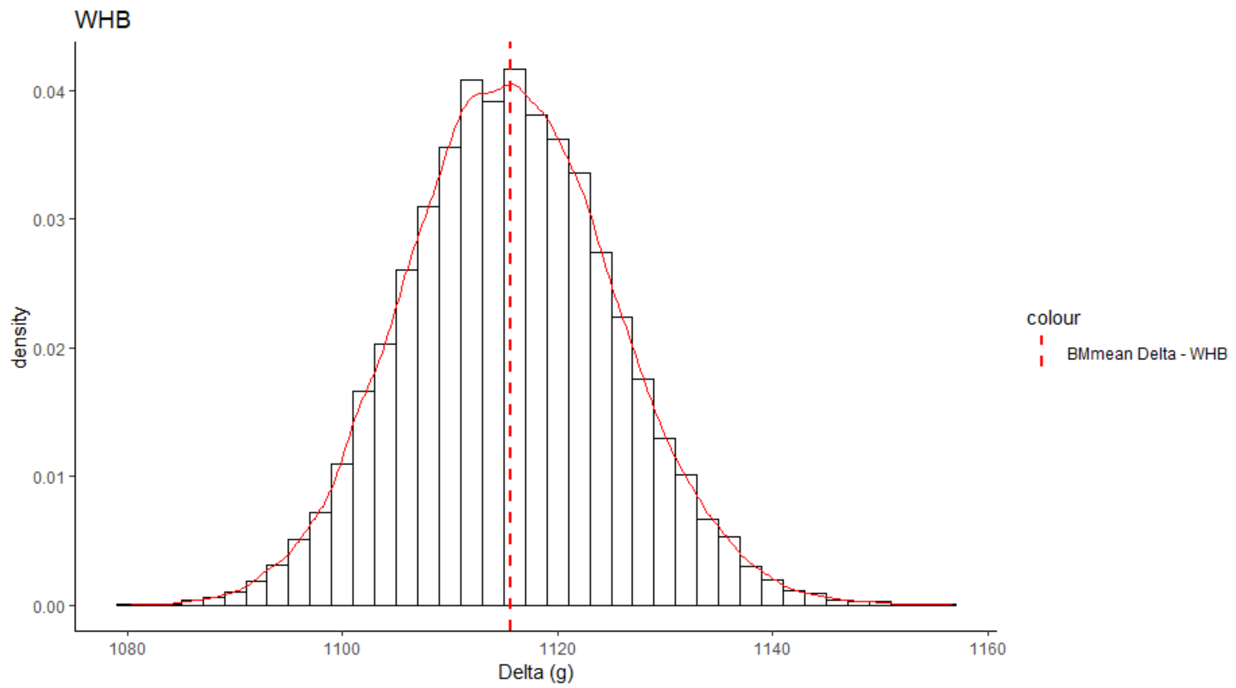

Figure 3.8. Bootstrap distribution of δ (delta) in Blue Whiting (WHB) based on 20,000 resampling (in g). The mean δ is 1116 g. Standard error of δ is 9.7 g. 95% confidence interval of δ is [1096, 1135].

3.2 Test for the difference of mean δ from 1.5kg

The one-sample t-test and Wilcoxon signed-rank test both show that the mean of δ is significantly different from 1.5kg (applied as 1500g in the test) (Figure 3.9). The null hypothesis of the mean of δ is 1.5kg. When p-value < 0.05, the null hypothesis is rejected.

```
        One Sample t-test

data:  delta.all$boot.statistics
t = -9796.7, df = 19999, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 1500
95 percent confidence interval:
 1038.249 1038.434
sample estimates:
mean of x
 1038.342
```

```
        Wilcoxon signed rank test with continuity correction

data:  delta.all$boot.statistics
V = 0, p-value < 2.2e-16
alternative hypothesis: true location is not equal to 1500
```

Figure 3.9. Results of the one-sample t-test (upper) and Wilcoxon signed-rank test (lower).

3.3 Weight fractions

Based on the data collected within this project, the mean weight of various fractions contributing to the total box weight can be estimated. A straightforward assumption based on these means implies that, on average, a box of fish contains 22.8kg fish, 0.581kg of package material and 0.456kg of liquids (Table 3.3, Annex 2).

Table 3.3 Mean weights for all (combined) fractions. Total fish weight, box weight, and delta are presented in kilogram, whereas straps, carton, plastic, residue, and water weight are presented in gram.

	Mean total fish weight (kg)	**Mean box weight (kg)**	**Mean straps weight (g)**	**Mean cardboard weight (g)**	**Mean plastic weight (g)**	**Mean weight of packing materials* (g)**	**Mean residue weight (g)**	**Mean water weight (g)**	**Mean weight of the liquid § (g)**
Combined species	22.8	23.8	7.5	532.1	42.3	581.9	14.8	441.2	456.0
ARG	22.3	23.5	7.7	534.8	38.4	580.9	11.6	639.3	650.9
HER	23.4	24.3	7.6	531.6	45.3	584.5	18.6	292.5	311.1
HOM	21.3	22.4	7.5	528.3	42.5	578.3	10.9	411.5	422.4
MAC	22.5	23.4	7.7	530.6	51.1	589.4	16.2	270.2	286.4
WHB	23.7	24.8	7.3	533.7	38.7	579.8	15.9	519.4	535.4

*: weight of packing materials contains the sum of straps weight, carton weight, and plastic weight.

§: weight of the liquid in the package composed of residue and water weight.

4 Conclusion

The confidence intervals of the one-sample t-test and Wilcoxon signed-rank test indicate that the calculated combined factors based on the mean δ deviate significantly from the standard tare weight conversion factor of 1.5kg. Across all species, a conversion factor of 1.05kg is realistic.

The variation between species is considerable. Boxes of greater argentine have the highest tare conversion weight of 1232 g per box (upper bound 1266 g), followed by blue whiting with 1116 g (upper bound 1135 g) and horse mackerel with 1001 g per box (upper bound 1032 g). The upper bounds of the conversion weight of herring and mackerel are less than 1 kg, the average tare conversion weight for herring is 896 g (upper bound 971 g), and for mackerel, 876 g (upper bound 898 g).

5 Discussion

Sampling intensity
Given oversampling compared to the planned number of samples set in the exploratory analysis, any influence of the difference between planned and analysed boxes is considered negligible.

Sample distribution in space and time
Samples are obtained from a wide-spread area and all seasons. Seasonal coverage fluctuation occurs due to the seasonality of specific fisheries. Based on the data collected, it is not possible to estimate area or season-specific conversion factors as this would require numerous additional samples. It would require a further specification of the selection of boxes by species.

Impact of freezing process and duration
During the freezing process, fish may lose weight by dehydration or due to physical damage during freezing, which may cause water loss during thawing. A fraction of the liquid remaining after thawing may originate from the fish due to the thawing process. Given the freezing methods (plate freezing) applied to the fish, it is anticipated that weight loss due to freezing is negligible[5]. In general, fish encounters some drip loss during thawing, up to 5% of the original weight[6].

Also, the shelf life (time between catching and processing the sample at the lab) of the samples is not expected to influence the box weight, e.g. by impacting the cardboard. The shelf life of the samples differed from a few weeks to just over two years. Visual inspections did not indicate differences between relatively old boxes compared to recently produced ones.

Filtration
Different filtration methods were tested. The glass filter filtration method was applied when processing a limited number of samples. Filtration by paper filter was tried and initially abandoned as filters clogged up almost immediately, and the funnels couldn't contain the required volume. However, larger filters, funnels and flasks and more time for filtration allowed for using paper filtration to process large numbers of samples. As filter characteristics used in the different methods are similar, the method is not believed to impact the variability of the outcomes.

Length
The boxes for this study were provided upon request without setting prerequisites concerning, e.g. characteristics such as the minimum weight or fish length. Length measurements were performed in this study, except when processing the 30 additional samples during the site visit in February 2023. As the boxes have standard dimensions, the main impact of a different length distribution would be on the number of fish rather than the total weight of the fish or the box. Consequently, the actual length distribution is considered to have limited influence on the results.

To underpin this assumption, a quick scan was carried out on boxes of fish collected in the Dutch market sampling project MARSAM 2016-2021 for the five species in this study. Despite being collected under a different regime, the MARSAM boxes themselves are identical to the boxes used in this study and filled with the same species subject in this study. In the MARSAM project, all fish from the boxes are measured, and a length-representative sample of 25 fish is weighed individually. Therefore, as part of the quick scan, data from the 30 additional boxes were used as a proxy for the variety of samples taken for this study.

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[5] http://www.fao.org/3/v3630e/v3630e10.htm WEIGHT LOSS FROM FISH DURING FREEZING AND COLD STORAGE
[6] http://www.fao.org/3/x5904e/x5904e01.htm Some facts about thawing

The total fish weight by box of the MARSAM samples was back-calculated based on the individual length/weight measurements of 25 length-representative fish from a box and the total number of fish in the box. For the additional 30 boxes in this study, a similar approach was chosen: all fish were measured, back-calculation to the total fish weight in a box was done by applying a box-specific length-weight relationship to the measured fish. Back-calculation eliminates the risk of including methodological differences in estimating the weight. For all species combined, the calculated weight vs. the modal fish length plot (Figure 5.1) shows that the total weight of the fish in a box varies across all observed modal lengths, thus indicating that (modal) length is not directly influencing the total weight of the fish in a box.

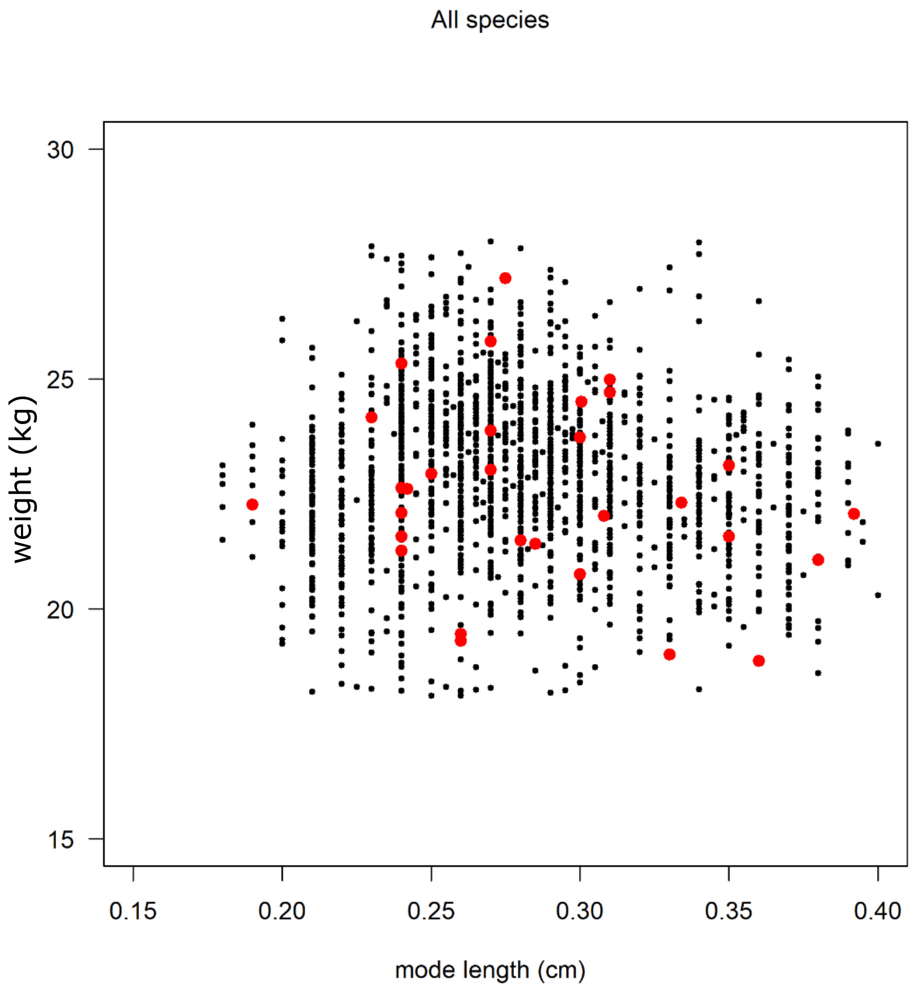

Figure 5.1. modal fish length against back-calculated total fish weight in a box. Data based on market samples (•) and additional samples from this study (•)

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Acknowledgments

The fishing companies Cornelis Vrolijk, Parlevliet & Van der Plas and W. van der Zwan are thanked for providing infomation and the samples for this study. Cornelis Vrolijk is thanked for demonstrating the selection procedure of the boxes in their cold store. Henk Besse and Thomas Ruiter carried out all the practical work in this project, sometimes supported by Hans Tap and Beanne Snaar. Harriet van Overzee (length distributions) and Lennert van der Pol (maps) provided valuable input to this report.

Dr. C. Stransky (Dpt. Director Thünen Institute, Bremerhaven, Germany) is thanked for his review of the report.

Quality assurance

The sampling protocol developed in the first phase of the study has also been applied to the samples in the second phase. In total, two persons were responsible for the sample processing and data entry: one in the first phase, and one in the second. Apart from the site visits, external visitors have not been present during the processing and analysis of the samples.

All samples were processed in-house at Wageningen Marine Research.

As part of the ISO-certified quality control measures, all scales and measuring boards are maintained centrally, checked annually, and calibrated when applicable.

CVO is certified to ISO 9001:2015 (certificate number: 268632-2018-AQ-NLD-RvA). This certificate is valid until December 15th, 2024 Wageningen Marine Research is also ISO 9001:2015 certified. The organisation has been certified since 27 February 2001. DNV issued both certifications.

Justification

CVO Report: 23.013
CVO Project number: 4311210029

The quality of this report has been peer reviewed by a colleague scientist, director WMR and the deputy head of CVO.

External review by: Dr. C. Stransky
Dpt. Director Thünen Institute, Bremerhaven, Germany

Date: 16 May 2023

Approved by: dr.ir. T.P. Bult
Director Wageningen Marine Research (WMR)

Signature:

Date: 15 June 2023

Approved by: Ing. I.J. de Boois
Dpt. Head Centre for Fisheries Research

Signature:

Date: 15 June 2023

Annex 1 Protocol

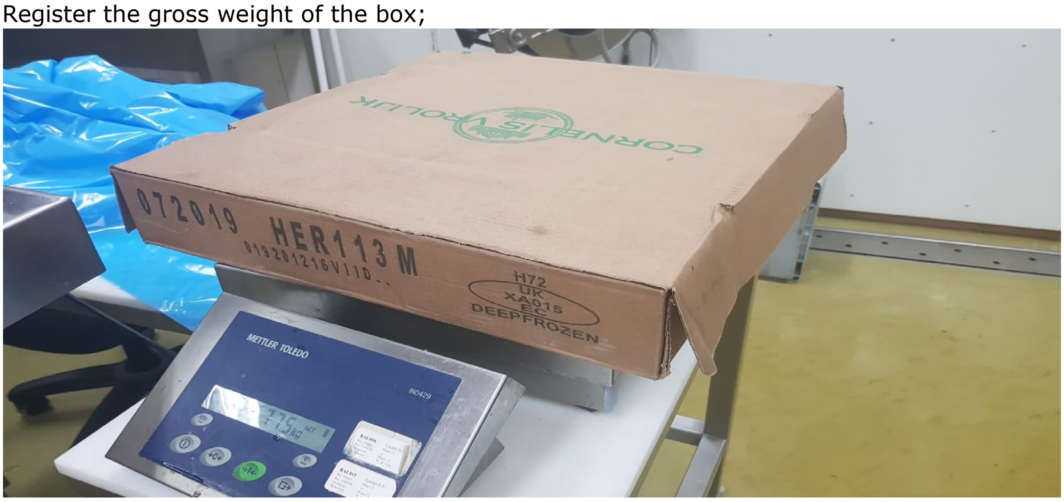
1. Select a representative fish box

- Check the box for leaking or other abnormal signs. Odd boxes are discarded. Register the sample code for the box; all data is stored in an Excel sheet.

2. Transfer fish from box to collection bag to thaw

- Weigh a sizeable plastic container bag;
- Place the container bag open on the table;

- Register the gross weight of the box;



- Weigh the straps, if included;
- Open the box;

- Transfer the block of fish while in plastic in the large plastic container bag; NB do this carefully and don't move the bag afterwards to prevent leakage;

- Weigh the cardboard box;

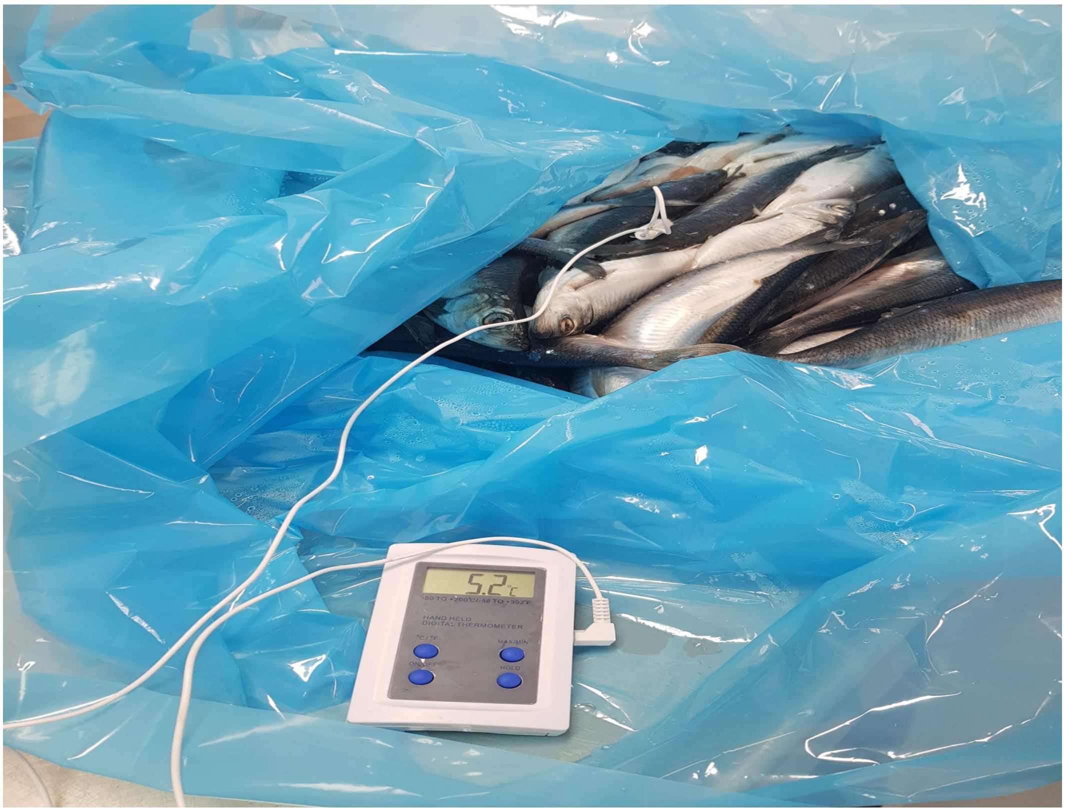
- Remove the original plastic wrapping from the fish;

- Weigh the plastic;
- Leave the fish to thaw[7].

[7] Thawing is completed when "the product can be readily separated without tearing." (FAO CODEX ALIMENTARIUS C165e/1989)

3. Process thawed fish

- Measure the core temperature of the fish block; the core temperature of the fish block after thawing should not exceed 7°C.



- Take an empty plastic tray;
- Take the fish one by one and shake off residual liquids. Check the mouth for remaining ice and remove when present. Ice and water are collected in the bag. ;

- Clean gloves to ensure that no residual liquids or other substances remain

- Weigh the total amount of fish;
- Weigh a plastic container (0.5/1.0 L);
- Transfer the excess amount of liquid;
- Weigh the amount of liquid;

- Proceed with step 4 or temporary store liquid in the freezer with a sample code.

4. Process the liquid from the sample

- When the liquid has been stored in the freezer: defrost the sample;
- Weigh the bottle;
- Weigh the clean glass funnel with a glass filter;
- Weigh the empty Erlenmeyer flask;
- Prepare the setup: (1L Erlenmeyer flask and a sintered glass funnel por.2,150 ml);

- Start the vacuum;
- Add the water on the funnel and keep adding till no more water is extracted from the container;
- Remove the vacuum hose;

- Identify the components in the residue on the funnel (e.g. blood, slime, scales, other); NB if the filter is saturated and liquid is present, it could be carefully transferred in the Erlenmeyer flask;

- Weigh the filled Erlenmeyer flask;
- Weigh the used funnel.

The method described above was used when only a limited number of samples had to be processed. For mass-processing, the paper filter method was applied.

Annex 2 Weight distribution of various fractions

The histograms of all weight variables converted to kg are for all species combined and not limited to one specific species. Note that the mean, standard deviation, and quartiles shown on the histogram are also in kg.

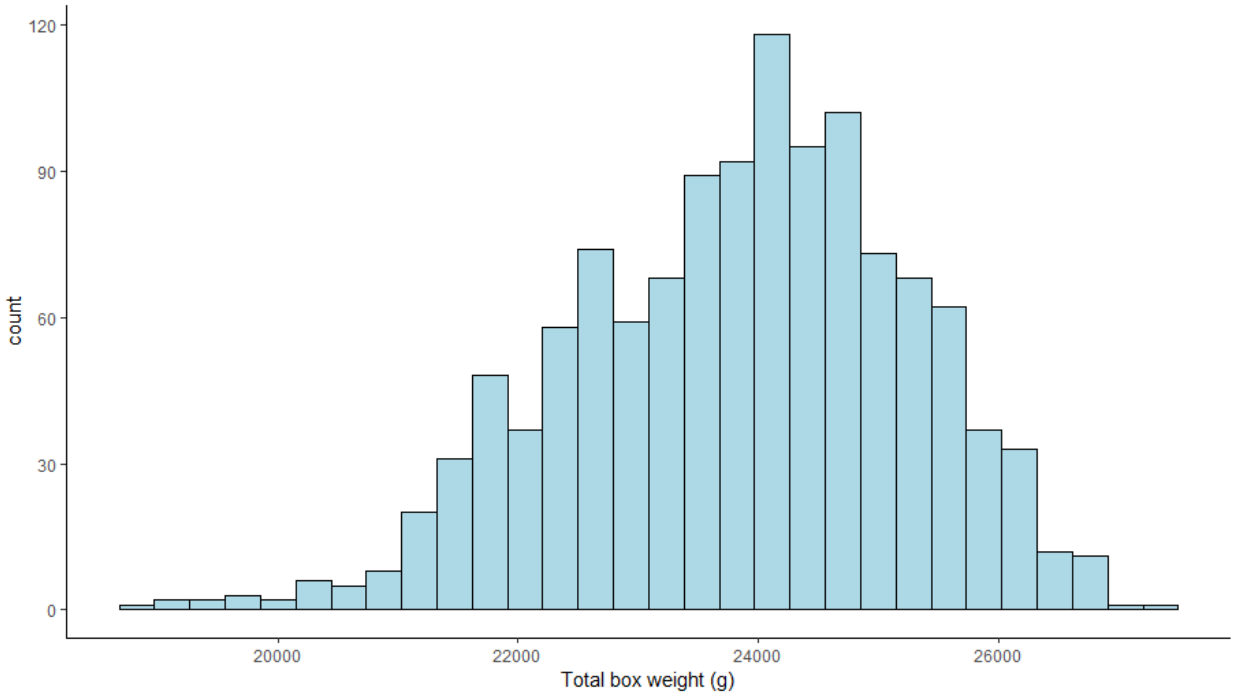


Figure A2.1. Histogram of total weight of all frozen-boxes (in g). Mean total weight is 23842 g, standard deviation is 1408 g, minimum total weight is 18800 g, and maximum total weight is 27330 g.

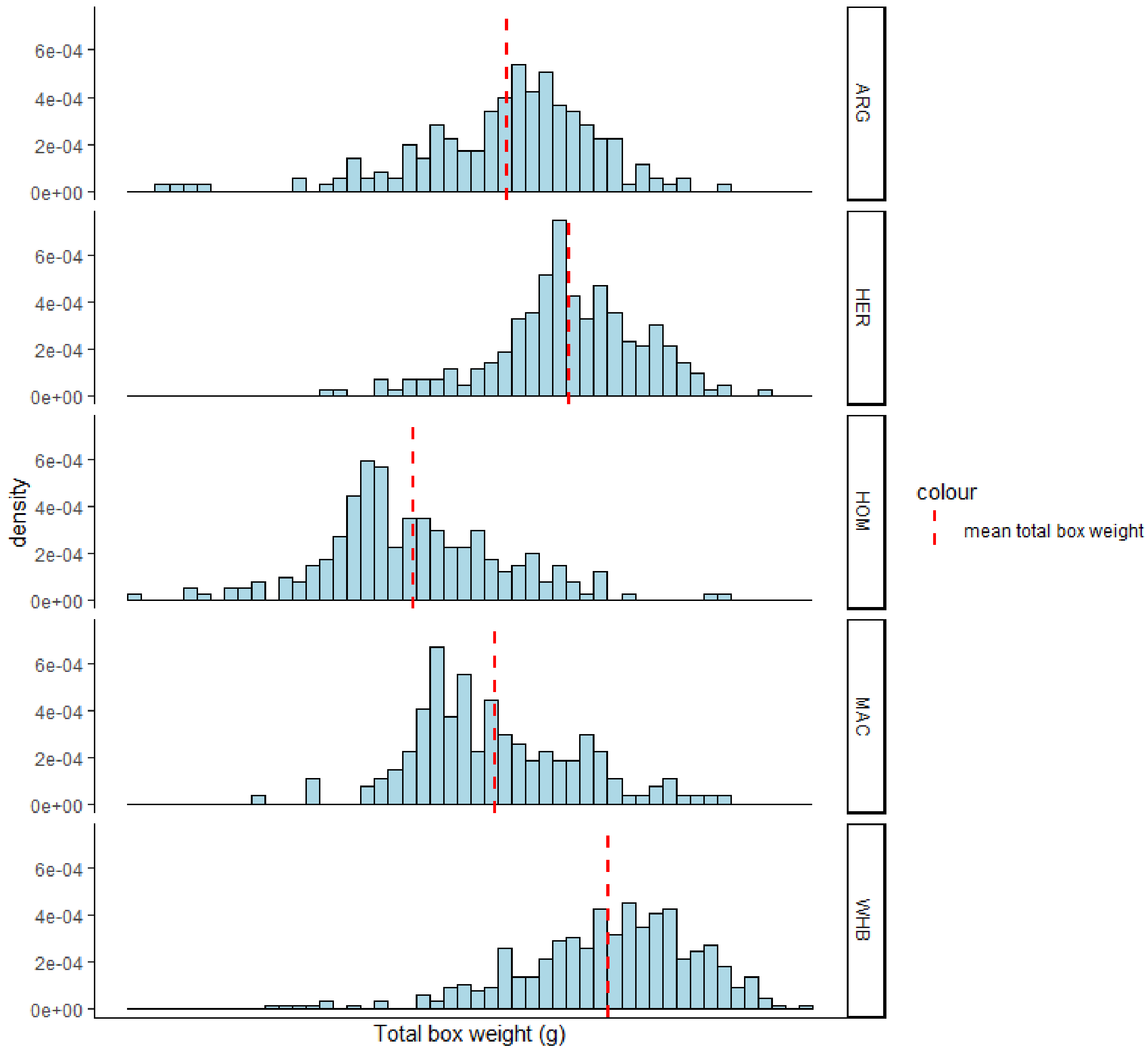


Figure A2.2. Histogram of total frozen weight of boxes in different species (in g). ARG: greater Argentine; HER: herring; HOM: horse mackerel; MAC: mackerel; WHB: blue whiting. Mean total box weights for each species were 23538, 24312, 22346, 23367, 24809 g, respectively.

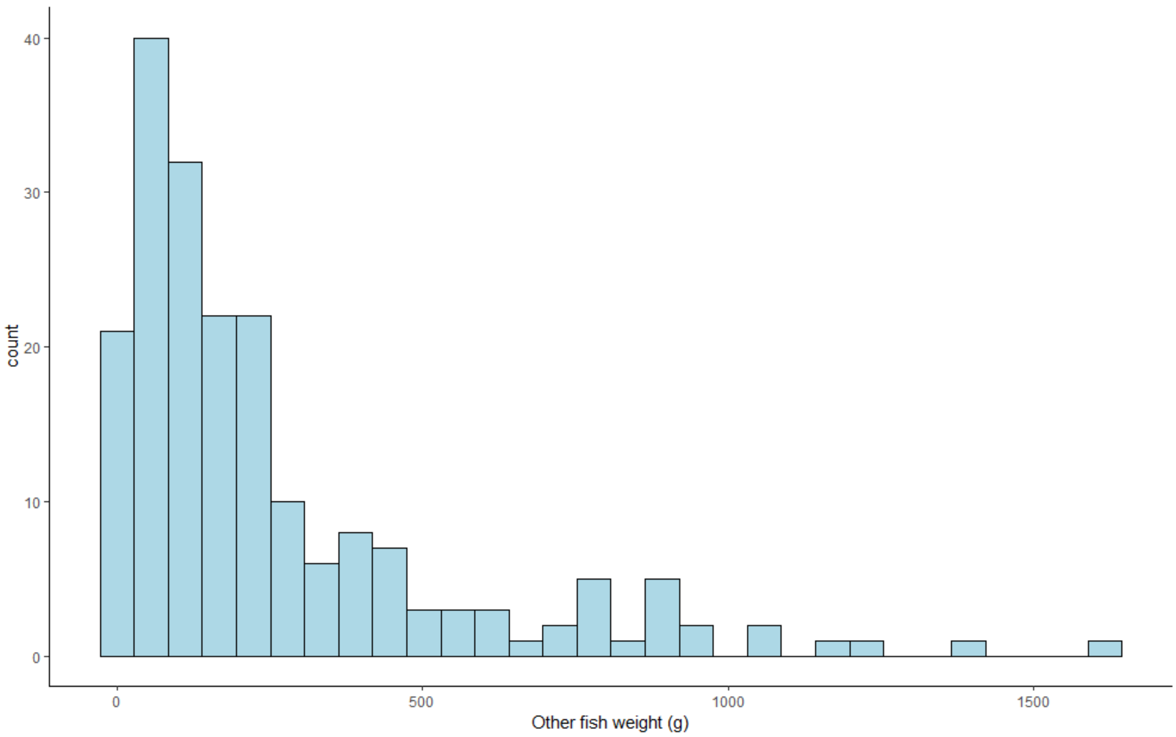


Figure A2.3. Histogram of other fish weight (in g). There are 199 boxes of fish with less than 10% of other fish species. Mean weight of other fish in these boxes is 259 g, standard deviation of other fish weight is 291 g, minimum other fish weight is 5 g, maximum other fish weight is 1622 g.

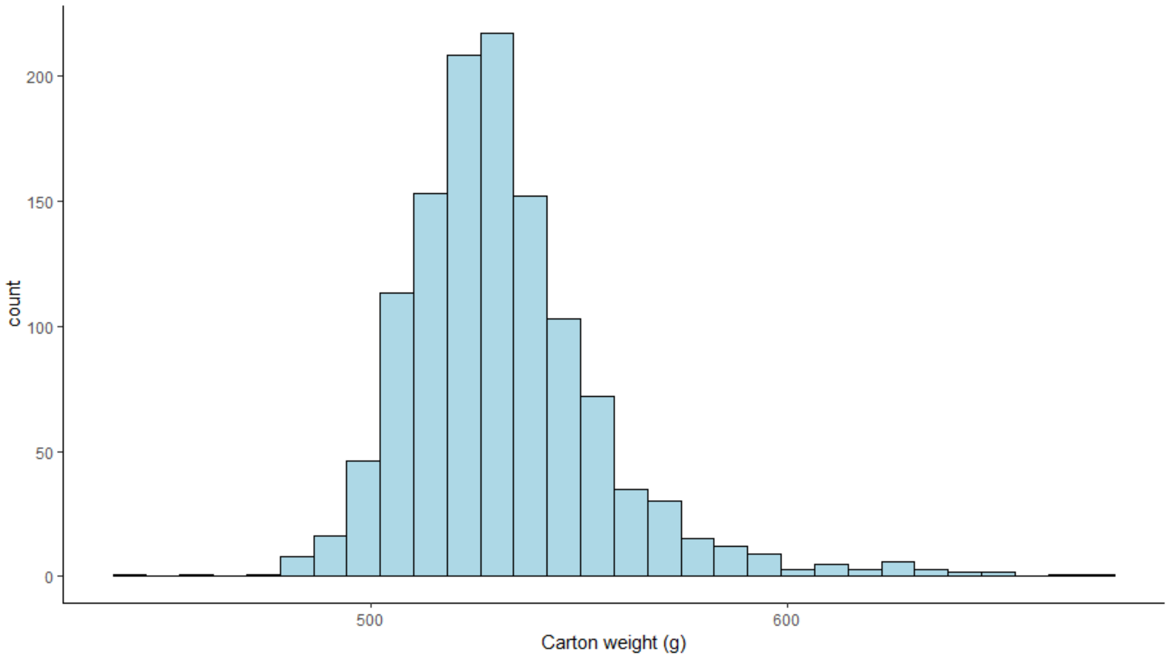


Figure A2.4. Histogram of carton/card board (in g). Mean carton weight is 532 g, standard deviation of carton weight is 25 g, minimum carton weight is 442 g, maximum carton weight is 675 g.

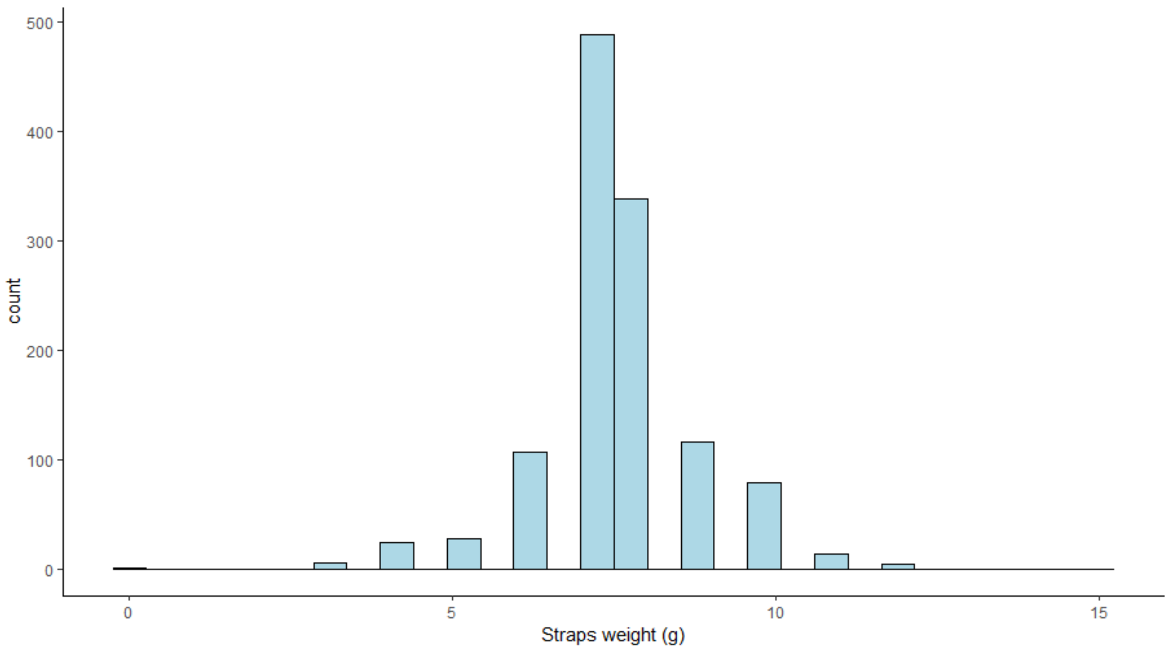


Figure A2.5. Histogram of straps (in g). Mean straps weight is 7.5 g, standard deviation of straps weight is 1.4 g, minimum straps weight is 0 g, maximum straps weight is 15 g.

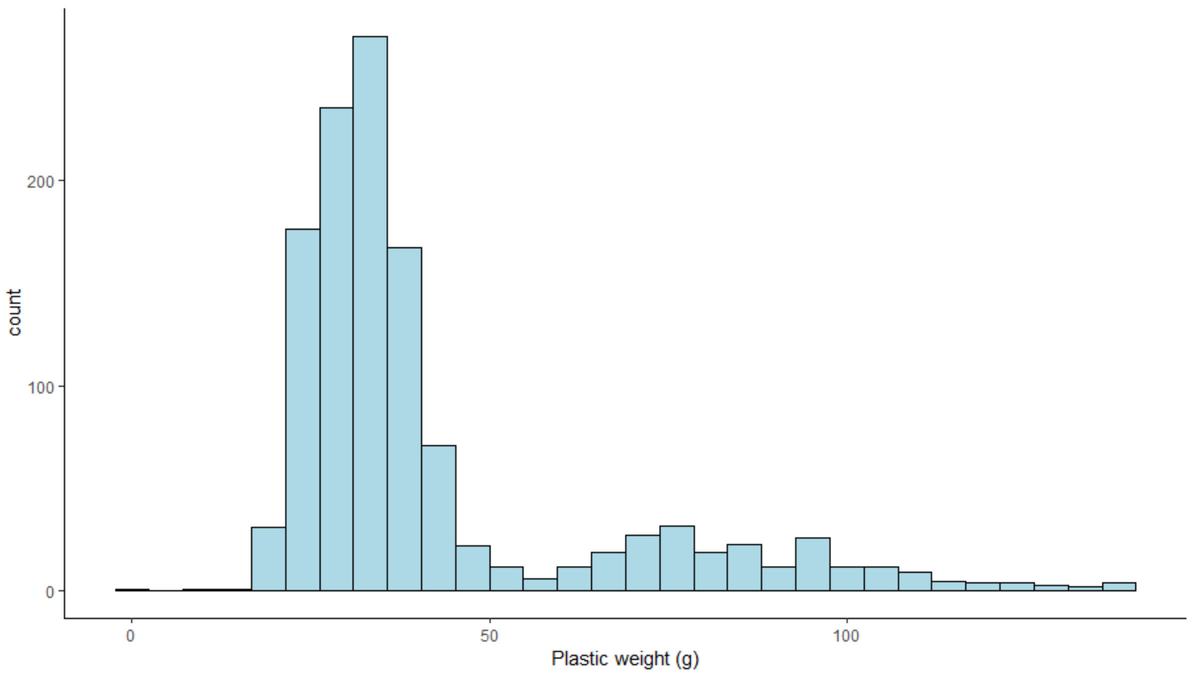


Figure A2.6. Histogram of plastic (in g). Mean plastic weight is 42 g, standard deviation of plastic weight is 24 g, minimum plastic weight is 0 g, maximum plastic weight is 138 g.

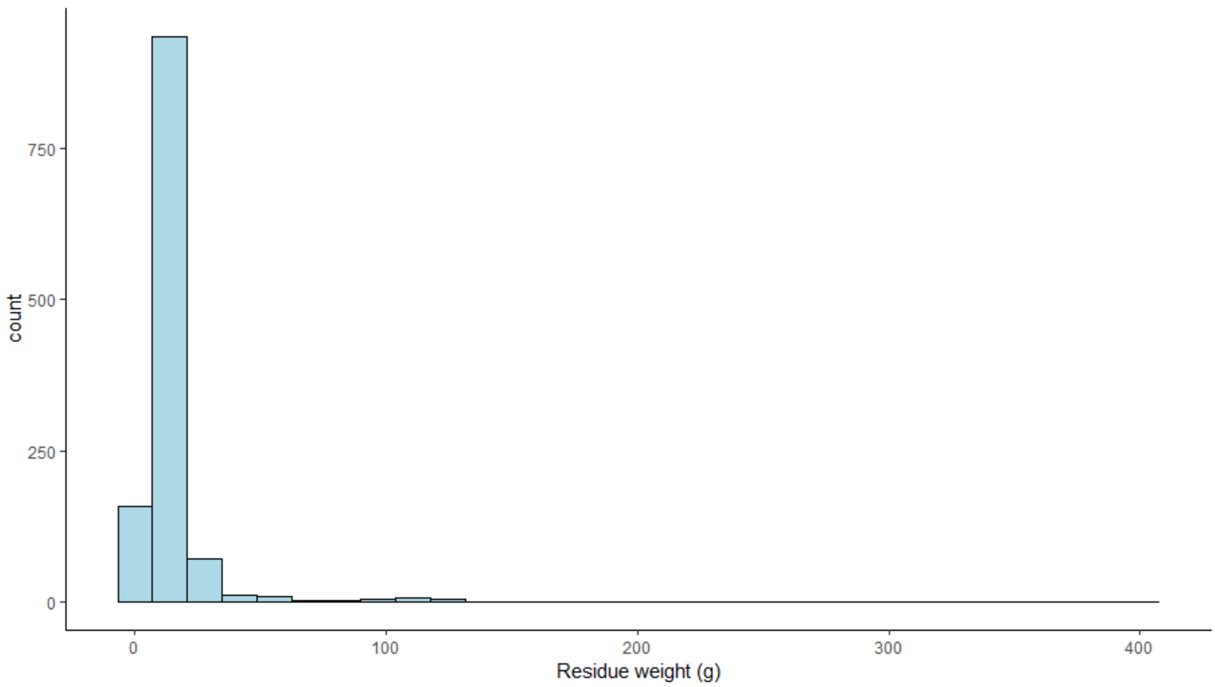


Figure A2.7. Histogram of residue (in g). Mean residue weight is 15 g, standard deviation of residue weight is 21 g, minimum residue weight is 0 g, maximum residue weight is 401 g.

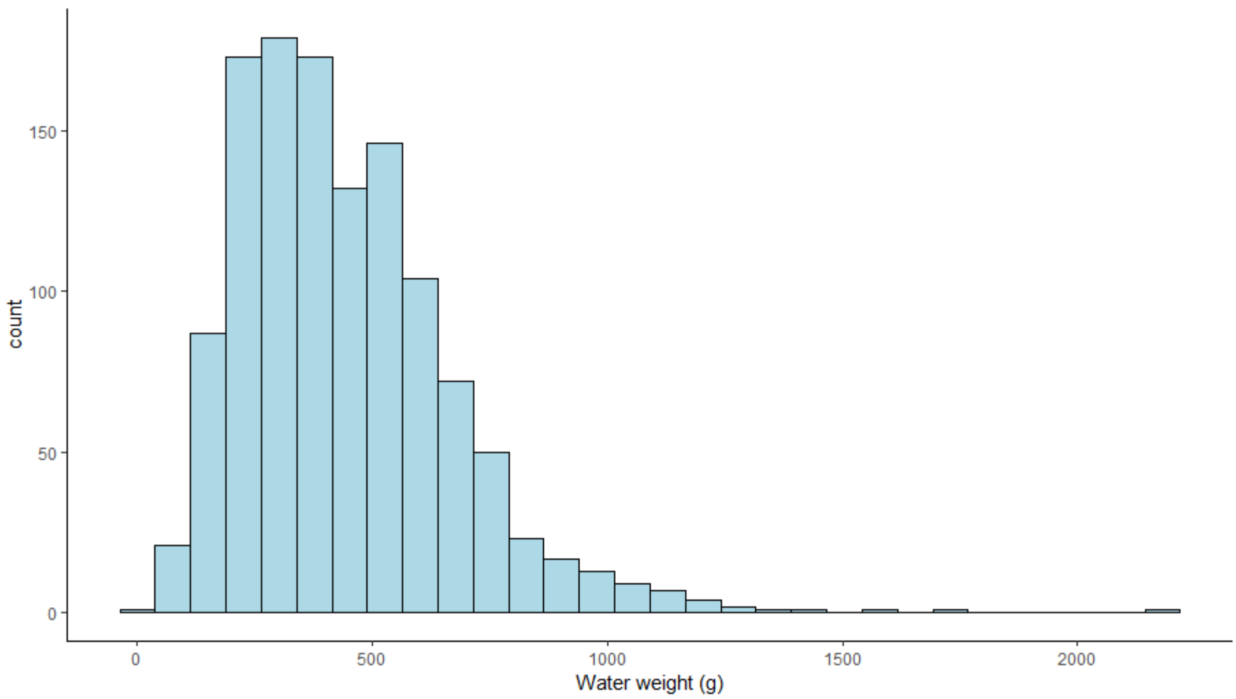


Figure A2.8 Histogram of water (in g). Mean water weight is 441 g, standard deviation of water weight is 229 g, minimum water weight is 14 g, maximum water weight is 2195 g.

Annex 3 Spatial and temporal distribution of the samples

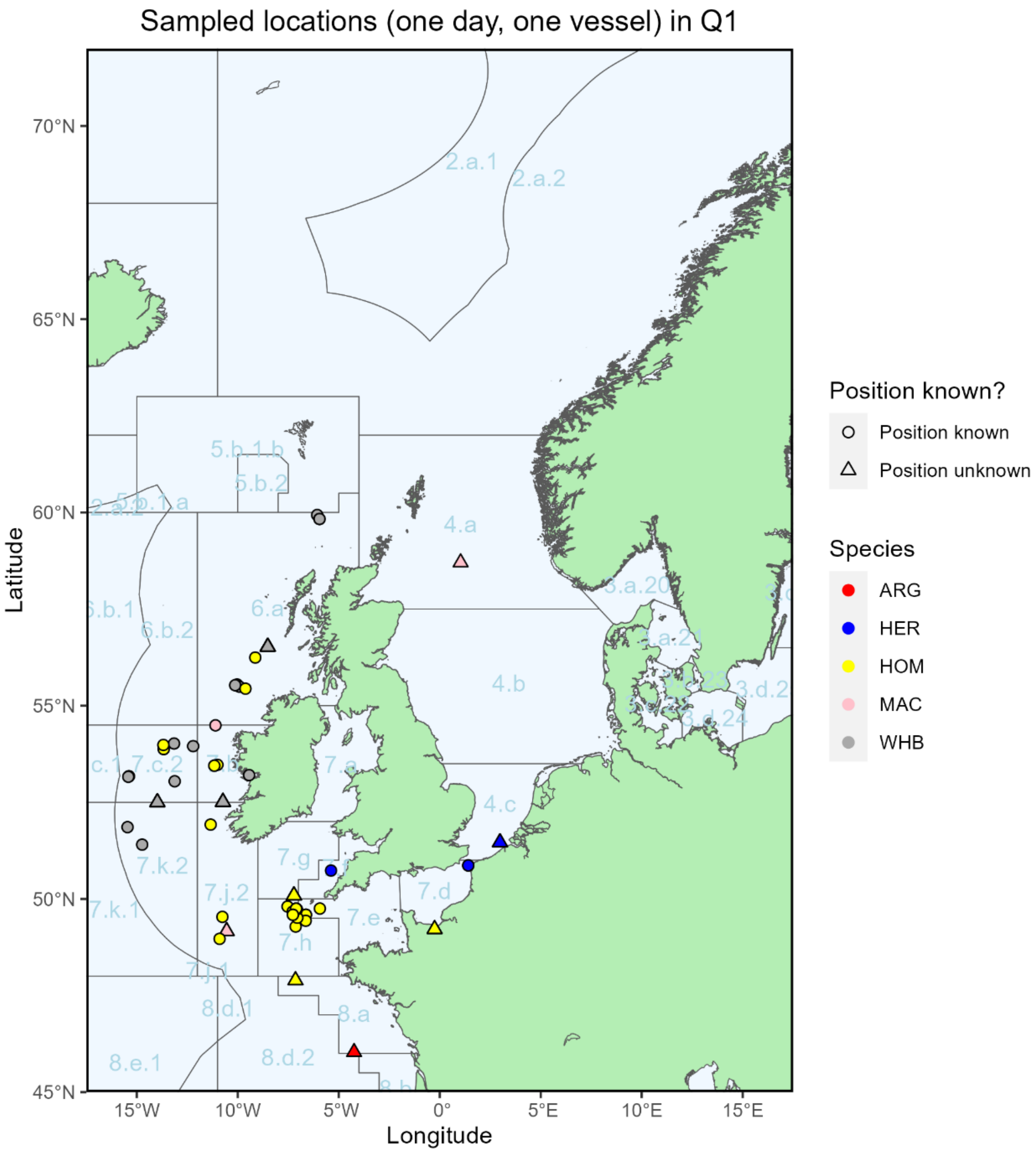


Figure A3.1. Overview of the geographical distribution of the samples caught in quarter 1, by species.

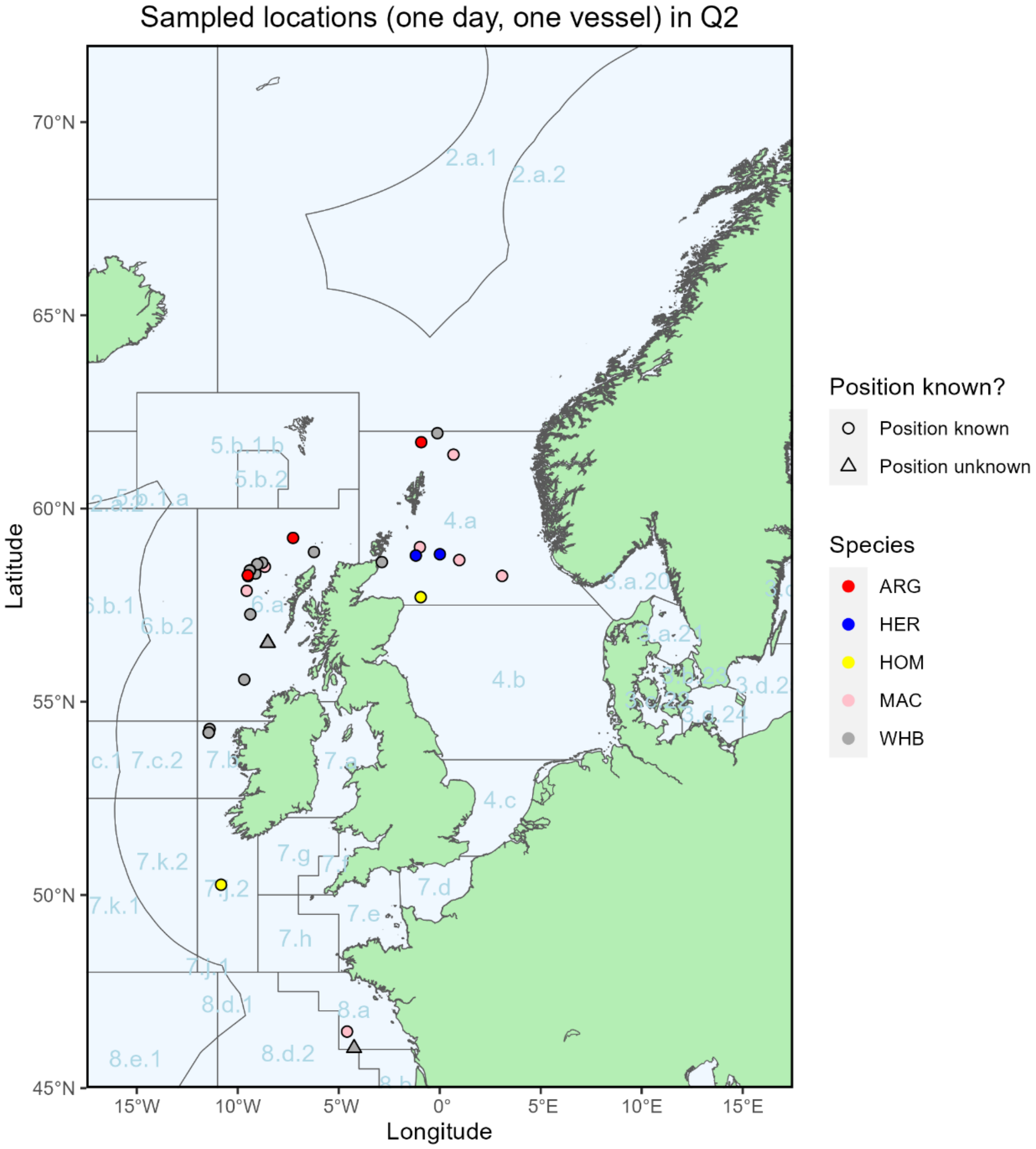


Figure A3.2. Overview of the geographical distribution of the samples caught in quarter 2, by species.

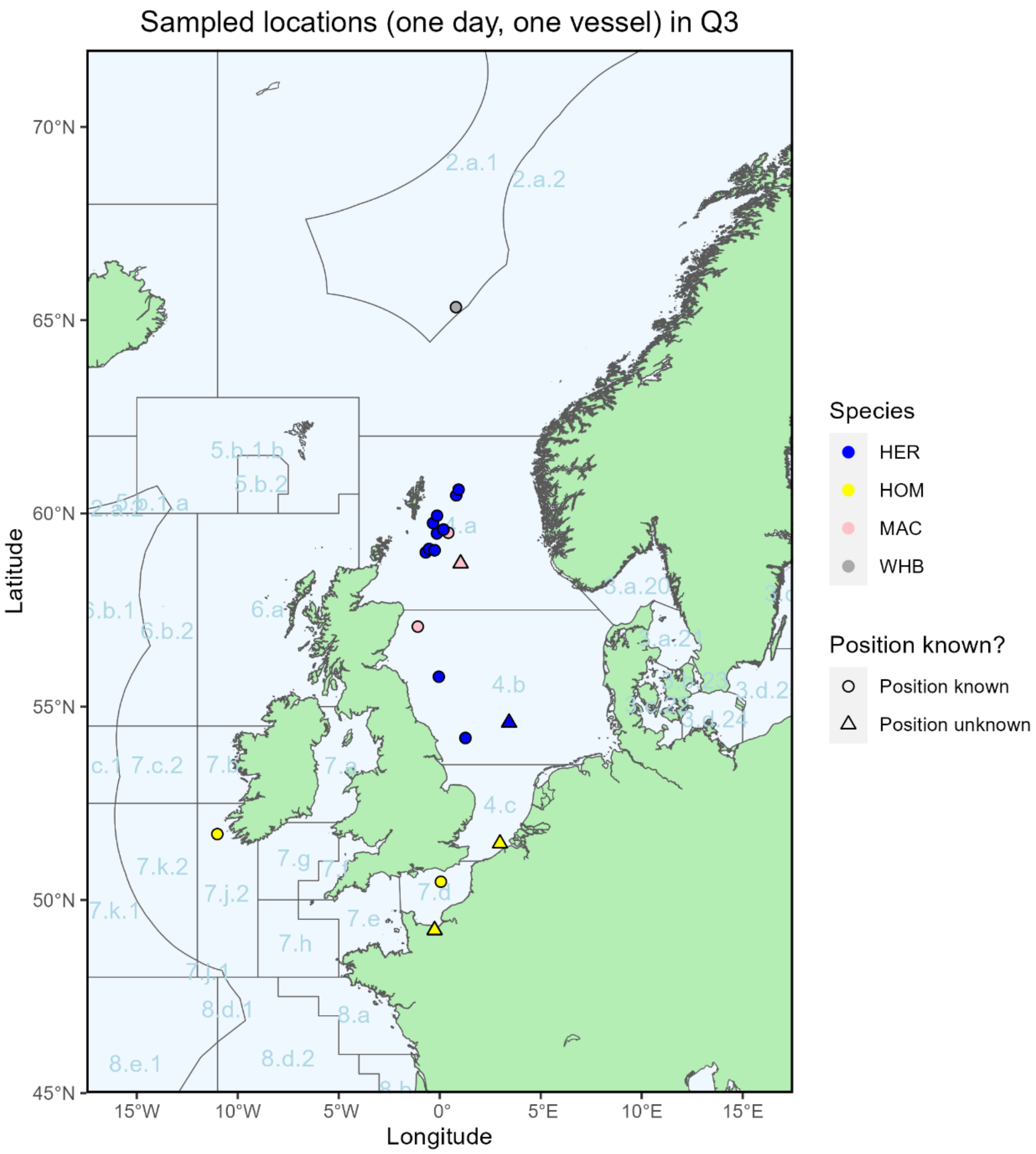


Figure A3.3. Overview of the geographical distribution of the samples caught in quarter 3, by species.

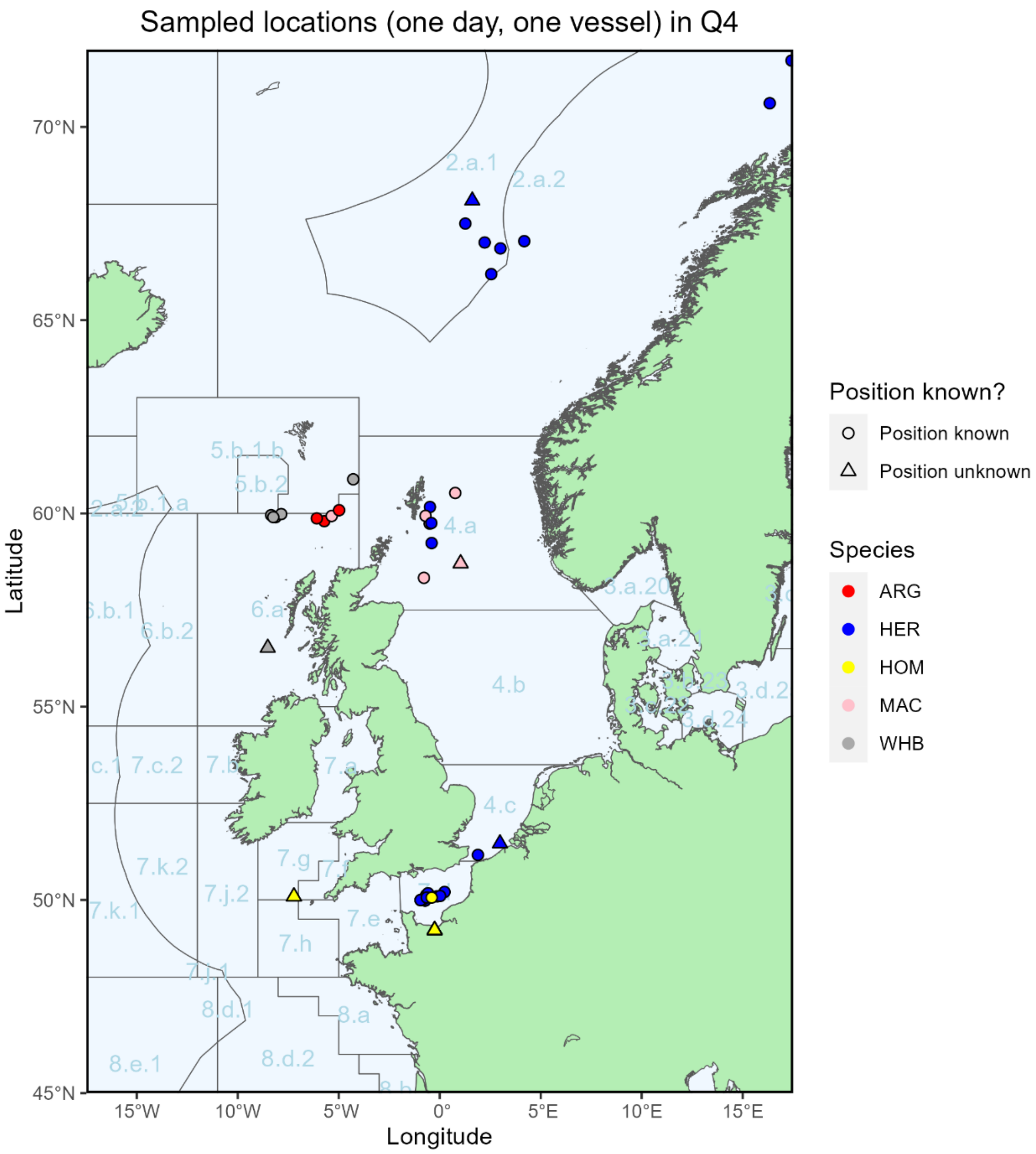


Figure A3.4. Overview of the geographical distribution of the samples caught in quarter 4, by species.