A comparison of two sampling designs to estimate krill biomass in the St. Lawrence Estuary and the northwest Gulf of St. Lawrence

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ABSTRACT

Lehoux, C., McQuinn, I.H., Paquet, L.F. and Plourde, S. 2023. A comparison of two sampling designs to estimate krill biomass in the St. Lawrence Estuary and the northwest Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 3572: viii + 71 p.

Spatially-stratified acoustic surveys based on krill habitat characteristics were conducted by the F.G. Creed in the estuary and Northern Gulf of St. Lawrence from 2008 to 2017 to describe krill distribution and estimate biomass. To provide estimates of biomass after 2017, we aimed to rely on acoustic data recorded by the Teleost since 2012 during the multidisciplinary stratified-random surveys of the northern Gulf of St. Lawrence. This document aimed to evaluate methods to intercalibrate the two surveys to provide a continuous time series of krill biomass in the long term. We extended the F.G. Creed survey-based estimates of biomass up to 2017 and developed model-based methods for the two surveys. For the Teleost, the proportion of each krill species was biased and the predicted biomass was overall lower compared to the F.G. Creed survey. Nevertheless, the two data series provided similar interannual variations of krill biomass from 2012 to 2016 and linear models provided effective tools for the intercalibration of the two surveys.

RÉSUMÉ

Lehoux, C., McQuinn, I.H., Paquet, L.F. and Plourde, S. 2023. A comparison of two sampling designs to estimate krill biomass in the St. Lawrence Estuary and the northwest Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 3572 : viii + 71 p.

Des relevés acoustiques stratifiés spatialement basés sur les caractéristique de l'habitat du krill ont été effectués par le F.G. Creed dans l'estuaire et le nord du golfe du Saint-Laurent de 2008 à 2017 pour décrire la distribution du krill et en estimer la biomasse. Pour fournir des estimations de la biomasse après 2017, nous visions à nous appuyer sur les données acoustiques enregistrées par le Teleost depuis 2012 lors des relevés multidisciplinaires du nord du golfe du Saint-Laurent. Ce document a pour but d'évaluer les méthodes d'intercalibration des deux relevés afin de fournir une série temporelle continue de la biomasse de krill à long terme. Nous avons étendu les estimations de biomasse basées sur les relevés du F.G. Creed jusqu'en 2017 et développé des méthodes basées sur des modèles pour les deux relevés. Pour le Teleost, la proportion de chaque espèce de krill était biaisée et la biomasse prédite était plus faible que pour le relevé du F.G. Creed. Néanmoins, les deux séries de données ont fourni des variations interannuelles similaires de la biomasse de krill de 2012 à 2016 et les modèles linéaires ont fourni des outils efficaces pour l'intercalibration des deux relevés.

1. INTRODUCTION

Krill is a key trophic component of the Estuary and Gulf of St. Lawrence ecosystem (EGSL). It is consumed by a variety of predators ranging from macrozooplankton, pelagic and demersal fishes and large baleen whales (Savenkoff et al. 2013). More specifically, blue whales forage almost exclusively on the two dominant species *Meganictyphanes norvegica* and *Thysanoessa raschii* and are considered endangered under the Species at Risk Act(Gavrilchuk et al. 2014). McQuinn et al. (2016) have shown that blue whales are more associated with *Thysanoessa* spp*.,* which forms denser and shallower aggregations over the slope of deep channels typical of the northern GSL where they are more available than the larger and deeper *M. norvegica*. Considering the specialized diet of blue whales, decrease in krill biomass could have impacts on the blue whale population foraging in the EGSL. In the Southern Ocean, reproductive success of the blue whale is predicted to decrease non-linearly with a decrease in krill availability due to fishing and/or climate change (Wiedenmann et al. 2011). Long-term time series of krill biomass in the EGSL are not available despite their key role in the ecosystem.

In the EGSL, long-term net-based monitoring programs use sampling gears mainly targeting meso-zooplankton that do not quantify krill accurately due to their swarming behaviour and avoidance of sampling gears. On the other hand, multifrequency hydroacoustic data have been available since 2008 in the EGSL. Using these data, McQuinn et al (2013, 2015) developed indices of krill biomass for the summer of 2008 and 2009 in the estuary and north-west Gulf of St. Lawrence (enwGSL). Standard stratified-random acoustic surveys were conducted annually, but were discontinued after 2017 due to priorities associated with fish stock assessment and due to limited access to adequate sampling platforms. To extend the acoustic time series of krill biomass past 2009, there was another source of acoustic data in the EGSL which could be exploited. The DFO annual summer multidisciplinary survey has also collected calibrated multifrequency acoustic data since 2012 and may provide us with the opportunity to continue the krill biomass time series. However, since the two series do not have the same coverage of the area of interest and sampling design, there is a need to develop statistical tools for their intercalibration.

This document compares the biomass estimates of the two dominant krill species in the enwGSL from two series of sampling surveys in August during 5 years that the surveys overlapped. To achieve this objective, we 1) extended the series developed by McQuinn et al (2015) up to 2017 using their survey-based approach, 2) developed model-based methods for both surveys, 3) compared the biomass estimates from the model-based methods developed in this document to the survey-based biomass estimate method from McQuinn et al (2015), 4) compared the efficiency of each model-based methods developed in this document and 5) developed statistical tools for the intercalibration of the two series. The intercalibration of the two series is necessary to extend the krill time series beyond 2017 using the Teleost survey.

2. METHODS

2.1 ACOUSTIC DATA

Acoustic data were acquired from two survey series on two different platforms. The first series was conducted in August between 2008 and 2017 (2017 partially analyzed) (Figure 1) aboard the CCGS research vessel F.G. Creed (Creed survey, hereafter), a 20-m SWATH (Small Water Area Twin Hull) cruising at ~ 10–15 knots providing stability and high-quality acoustic signals. The stratified-random survey design was employed to quantify the krill biomass in the enwGSL based on equidistant transects oriented perpendicularly to the coast (McQuinn et al. 2015). The number of transects varied between years and strata and, in some cases, the strata were modified to account for species distribution and to reduce the estimated variance (Figure 2). Acoustic data in 2017 were partially analyzed and only data on transects were available (see impact below).

The second series was conducted with the CCGS research vessel Teleost (Teleost survey, hereafter), a 63-m trawler, with its primary function to quantify groundfish biomass throughout the northern GSL in August from bottom trawl sets. Acoustic data have also been collected continuously along the cruise track since 2012 (Figure 3). For the bottom trawl sets, stations were randomly selected among strata mainly determined from the bathymetry. These Teleost surveys have a reduced spatial resolution compared to the Creed surveys and do not sample as close to the coast (Figure 4). However, they cover areas such as the Anticosti gyre that are not part of the Creed survey.

Acoustic data were integrated along 25 m, 1 km, and 2 km bins for the 0–250 m depth layer, which is the practical limit of the krill vertical distribution in these waters and also to avoid contamination of the signal by mysids and other deep-water crustaceous organisms (McQuinn et al. 2015). For the Teleost survey of 2014, the acoustic data were not recorded below 200 m for part of the survey. Krill vertical distributions predict a very low proportion of the biomass below 200 m (Plourde et al. 2014, Lehoux et al. 2020). We evaluated that the proportion of krill in the 200–250 m layer for the Creed survey in 2014 was very low (not shown). It is thus unlikely that the absence of data below 200 m for the 2014 Teleost survey would have any noticeable effect on the results.

Krill biomass was calculated according to the multifrequency acoustic methodology described in McQuinn et al. (2013, 2015) using data from three frequencies (38, 120, 200 kHz). Krill was classified into two species or species groups, *Thysanoessa* spp. (mainly *T. raschii*) and *M. norvegica* and a mixed signal group that includes a mixture of these two species (McQuinn et al. 2013). The mixed category is redistributed according to the information available (see below). A small portion of the backscatter was classified as *T. inermis* in 2012 and 2013 (Table A.3. 3 and Table A.3. 4). *T. inermis* biomass was included in the *Thysanoessa* spp*.* category.

For the Creed survey of 2011, a different classification algorithm was used that led to possibly more contamination by *M. norvegica* in the *Thysanoessa* category. The proportion of zeros in 2 km bins for *Thysanoessa* spp. was 0.24 % for 2011, whereas it was between 4 and 36% (mean=17% of zeros) for other years. Biomass values less than 0.5 g/m^2 were adjusted to 0 and resulted in a proportion of zeros equal to 15% for 2011.

2.2 ENVIRONMENTAL DATA

Environmental data were considered as covariates in model-based methods. Relationships between the environment and krill distribution are discussed in Plourde et al. (2016). We excluded chlorophyll from the potential covariates given the higher uncertainty in satellite colour data close to the coast due to contamination by riverine coloured material. Bathymetry was extracted from an interpolated layer of bathymetric data on a 20-m mesh from the Canadian Hydrographic Service (2018, 2019). The resulting grid (format ArcGIS Raster Grid float) was produced in the Esri environment (ArcGIS 10.6) using the natural neighbour interpolation. This layer was then downscaled to a resolution of 2 km from which slope and the Topographic Position Index (TPI) were calculated using the terrain function of the raster package in R (Hijmans 2019). Slope was expressed in degrees (Horn, 1981) and TPI was the difference between the depth value of a cell and the mean value of its 8 surrounding cells (Wilson et al. 2007), meaning that near zero values are more representative of shelves and negative (positive) values of channels (slopes) . Sea surface temperature was extracted from MODIS Aqua Level 3 monthly average (NASA 2018).See Figure 5 for maps of environmental data (sea surface temperature not shown).

2.3 BIOMASS ESTIMATES

Three methods were used to predict krill biomass at all locations covered by the Creed survey strata in the enwGSL. The first method was the classic stratified-random estimate which was the *a priori* design of the survey (survey-based method). This method is only available for the Creed survey data. Biomass estimated by this survey-based method was available from McQuinn et al (2015) for 2008 and 2009, to which we have included additional estimates for 2010–2017. Stratum 8B (Banc des Orphelins) and 9B (between Anticosti and Gaspé) were removed from further analyses because they were rarely sampled during the Creed survey and were not sampled in the years for which the Teleost survey was available. This method used concurrent biological samples collected at least once for each stratum/year using a 1-m diameter plankton net equipped with a 333 µm mesh net and a strobe light to minimize net avoidance (JackNet). The composition and length distribution are used to estimate biomass with equations presented in McQuinn et al. (2015). We summarized the mean length by stratum in Figure 6.

The second and third methods are model-based methods. The second method used a Generalized Additive Mixed Model (GAMM) with a stochastic partial differential equation (SPDE) approach (Lindgren & Rue, 2011) and a Gaussian random field to account for spatial autocorrelation with the Integrated Nested Laplace Approximation (Rue et al., 2009) implemented in R INLA library (v.22.05.07) (Lindgren & Rue, 2015) (spatial GAMM, hereafter). The third method used kriging with or without environmental covariates (ordinary kriging and universal kriging, hereafter).

In both model-based methods, biomass was transformed as $x^{1/5}$ to avoid outliers in predictions unless otherwise specified. Biomass estimates were restricted to strata covered by the Creed survey to allow comparison with the survey-based estimates. For the Creed survey. to provide the best coverage of the region, we considered acoustic data collected during transects, as well as inter-transects (transits between transects). Inter-transect data were not available for 2017. Data from 2017 were thus only included in the survey-based method. For the Teleost survey, we considered data from the inter-stations (transits between stations) and also all other transits through the region (e.g., to and from ports-of-call). Data from west of the -63° meridian excluding Chaleur Bay were considered for the Teleost survey analyses.

Concurrent biological samples were not available from the Teleost survey. For the model-based methods (Creed and Teleost), , an overall mean size per species from the 2009 Creed survey from McQuinn et al. (2013) was used to transform the backscatter into biomass, specifically for *T. raschii* (mean length = 22.0 mm; mean weight = 56.2 mg) and for *M. norvegica* (mean length = 35.7 mm; mean weight = 298 mg). This approximation was representative of the length distribution for most years (Figure 6).The length distributions of 2015-2017 suggest that the mean length of 2009 overestimate the size of krill which could result in an overestimation of the biomass (see equations in McQuinn et al. (2015)). The mixed category was redistributed according to the relative mean biomass of *T. raschii* and *M. norvegica* in each stratum for each year.

2.3.1 <u>Survey-based estimates</u>

The method, described in McQuinn et al. (2015), is the classical design-based stratified-random approach where transects are chosen perpendicular to the shoreline within each stratum, the strata are divided into a number of bins equal to the number of transects, the first transect is chosen randomly from within the first bin of the stratum and the remaining transects are chosen equidistant from the first. This method has the benefits of (a) systematic coverage of all strata, (b) having a random element to reduce the chance of bias in the estimator, (c) using concurrent biological samples to assign a mean individual biomass per stratum to inform the overall biomass estimates and (d) using the species composition of these biological samples to assign the mix category to the appropriate taxa. This method used acoustic data integrated on 25 m bins.

2.3.2 Model-based estimates

2.3.2.1. Spatial GAMMs using INLA

Acoustic data integrated in 2 km bins were projected on a non-convex hull mesh with a maximum edge length of 20 km and a cutoff of 10 km. Models using 1 km bins exceeded computer memory. One mesh was created for each survey (Figure A.1. 1). Environmental data were first included with a linear relationship to the response. Depth showed non-linear patterns across residuals and was included with a thin plate regression spline with k=3 using the mgcv package (Wood 2003) for the smoother construction. Slope was log-transformed and all covariates considered in linear relationships were standardized $\left(\frac{x-\mu}{\sigma}\right)$. Models with spatial correlations that differed among years were considered for all years and surveys. A Gaussian distribution with 5th root transformation of the biomass was used for *M. norvegica*. For *Thysanoessa* spp., having a high proportion of zeros, we used a zero altered gamma distribution (ZAG) in which presence/absence was modelled using a Bernouilli distribution and abundance given presence was modelled using a gamma distribution. Final biomasses were obtained by multiplying the probability of presence by the predicted biomass given presence:

$$Biomass_{it} = ZAG(\mu_{it}.\pi_{it})$$

$$E(Biomass_{it}) = \pi_{it} \times \mu_{it}$$

$$var(Biomass_{it}) = \frac{\pi_{it} \times r + \pi_{it} - \pi_{it}^2 \times r}{r} \times \mu_{it}^2$$

$$\log(\mu_{it}) = Year + f(Depth) + SST + Slope + TPI + w_{it} + \varepsilon_{it}$$

$$log\,it(\pi_{it}) = Year + f(Depth) + SST + Slope + TPI + w_{it} + \varepsilon_{it}$$

Where μ_{it} is the biomass given presence for observation i for year t given by the Gamma distribution, π_{it} is the probability of positive biomass given by the Bernouilli distribution, r is a scaling factor, *f* is a smoother and *w* is the random Gaussian Field with a Matérn covariance structure (Gaussian Markov Random Field; Lindgren et al. 2011),.

We set penalized complexity (PC) prior probability distributions (Fuglstad et al. 2016, Simpson et al. 2015) for the spatial correlation range *r* and the standard deviation *σ* so that P ($r < 100$) = 0.05 and P ($\sigma > 1$) = 0.05. We set a low resolution of the mesh and prior for a large range to account for the low coverage of the Teleost surveys. The models were validated by randomly splitting the data into 70% for model fitting and 30% for model validation and the Spearman's correlation between the observed and predicted biomass was evaluated. Conditions of applications (diagnostics) were verified graphically. Predictions were done on 10 km² cells.

2.3.2.2 Kriging

Inverse distance weighted interpolation, ordinary kriging and universal kriging using the slope, TPI or SST as covariates were done for each year, taxa and survey separately. We used an exponential model for all years and taxa. Depth was not included in kriging because of its non-linear relationship with biomass. Geostatistical exponential models were fitted on acoustic data integrated in 1 or 2 km² bins using the gstat package (Gräler et al. 2016). Anisotropy was verified by fitting a Cressie's robust variogram (Cressie, 1993) for each 45° as per Pebesma (2019). Interpolation between 5 or 10 km² cells was done using the raster package. Validation with the Spearman's correlation coefficient was applied as for the spatial GAMMs predictions. To verify the effect of averaging acoustic data to 1 or 2 km, we compared the estimated range, Spearman correlation coefficient and estimated biomass between the two resolutions. We also assess the effect of the resolution of the prediction grid on the estimated biomass.

Predictions from models gave the biomass in $g \cdot m^{-2}$ which is equivalent to $t \cdot km^{-2}$. The mean biomass ($t \cdot km^{-2}$) per stratum was multiplied by the stratum area in km² to obtain the total biomass by stratum. The biomass for all strata were then summed to obtain the total biomass for each year by taxa.

2.4 COMPARISON OF BIOMASS ESTIMATES

The key objective of this document was to intercalibrate the two surveys with the aim of using the Teleost data after 2017 to build a time series of krill biomass in the enwGSL. To achieve this objective, we first compared model-based methods to inform on the best parsimonious method. Second, we compared the survey-based to the model-based biomass estimates for the Creed survey to evaluate if the model-based estimates are accurate. Third, we compared model-based estimates between the Creed and Teleost surveys to evaluate if the two surveys can be intercalibrated. Finally, to assess the limitations due to the difference in sampling design between the two surveys, we evaluated the taxonomic composition and the spatial correlation between model-based estimates of the two surveys.

First, to verify if kriging benefitted from the addition of covariates, differences in biomass estimates for each stratum/year across methods, taxa and surveys were verified using a linear model (LM) fitted with glmmTMB (Brooks et al. 2017).

Second, we used a similar approach to construct a LM between the survey-based estimates of biomass (response variable) and the model-based estimates of biomass from the Creed survey between 2008 and 2016. Method and survey were included as interactions to allow for different slopes and intercepts. One model was constructed for each taxon to simplify the interpretation of results. Biomass (t) was transformed with $x^{1/5}$ and followed a Gaussian distribution. Application conditions were verified graphically.

Third, we used the same approach to compare the Creed and Teleost survey estimates of biomass in each stratum, year and taxa. Taxa and method are included as interaction factors. We used the biomass estimate from the Creed survey as the response variable because we wanted to reproduce the Creed time series using the biomass estimated during the Teleost survey (predictor variable).

The spatial correlation between the Creed and Teleost survey for each stratum, year and species was calculated by superimposing the two surveys and calculating the Spearman's correlation coefficient between all 10 x10 km cells by region (groups of strata, Figure 2). It provides information about the similarity in the position of the krill aggregations between the surveys.

3. RESULTS

3.1 BIOMASS ESTIMATES

3.1.1 Survey-based estimates

Estimates of biomass and associated standard deviations per year for each stratum using the survey-based method are available for 2010–2017 in Appendix 3 (Table A.3. 1– A.3.8); the 2008 and 2009 estimates are presented in McQuinn et al. (2015). Annual trends for the entire 2008–2017 period are presented in Figure 7. Biomasses were lowest for both species in 2014 and increased afterwards.

3.1.2 Model-based estimates

3.1.2.1. Spatial GAMMs using INLA

The range of spatial correlation estimated with the spatial GAMM was between 15 and 50 km (Table 1). The Spearman's correlation coefficient between observations and predictions was higher for the *M. norvegica* models (0.86 and 0.9) than for the *Thysanoessa* spp. (0.73 and 0.67) models for the Creed and Teleost survey respectively (Table 1). The maximum of the predicted values was however closer to the observed values for the ZAGs used for *T. raschii* whereas the Gaussian models for *M. norvegica* tended to underestimate the higher biomasses (Figure A.1.2).

Spatial GAMM results are presented in Table A.1. 1-A.1.6. The fixed linear effect for Slope was never significant. TPI had a significant negative effect on the occurrence of *Thysanoessa* spp. during the Creed survey, meaning that *Thysanoessa* spp. prefers areas that are deeper than surrounding cells. SST had a significant positive effect in most models, except on the abundance of T*hysanoessa* spp. in the Teleost survey. The depth smoother was significant for each combination of survey and taxa (Figure A.1. 3).

3.1.2.2. Kriging

The estimated range of spatial autocorrelation was slightly larger when a bin resolution of 2 km was used (Figure A.2. 1) and the Spearman's correlation coefficient was generally higher using the 1 km resolution (Figure A.2. 2). The estimated annual biomass did not differ between the two resolutions when using a prediction grid of 5 or 10 km, suggesting that the 2 km bin resolution and the 10-km² grid can be used without severe impact on the accuracy of the estimates (Figure A.2. 3). The 2 km-bin resolution and 10km² grid were therefore used as this reduced computation costs, which were especially high and limiting for the spatial GAMMs.

The LM for the comparison of interpolation methods showed some differences between taxa estimates and surveys. *M. norvegica* estimates differed between the Creed and Teleost series and kriging estimates differed from Spatial GAMM estimates for *Thysanoessa* spp (Table 2). However, no differences were detected among kriging methods (including inverse distance). To simplify the results going forward, we excluded results for universal kriging using TPI as covariate because it predicted a higher value than other series for the *M. norvegica* biomass sampled by the Teleost in 2014. This higher value was not corroborated by the survey-based method and seemed to derive from one extreme prediction in only one cell (not shown).

Estimated ranges of spatial autocorrelation and validation of kriging and inverse distance interpolation are presented in Table 3 for the Creed survey and in Table 4 for the Teleost survey. The range was between 5 and 12 km depending on the species and interpolation method for the Creed survey (Table 3). There was more year-to-year variation in the ranges for the Teleost survey (Table 4). The average range was similar between surveys, but the range was larger for *M. norvegica* for the Teleost survey (12 km) compared to the estimated range for the Creed survey (8.6 km). The ranges estimated with kriging were smaller than the ranges estimated by spatial GAMM for which a mesh with a given resolution and priors were used that could have forced a higher range. Spearman's correlation coefficients were similar among species, survey and methods but were higher for the Teleost survey and highest for *M. norvegica* for the Teleost survey (0.74). The Spearman's correlation coefficients were slightly higher or equal to other methods for the ordinary kriging.

3.2 COMPARISON OF BIOMASS ESTIMATES

Comparison of annual biomass estimates are presented in Figure 7 and Figure 8. Total biomass estimates for 2008 should be interpreted with caution since the survey only covered half of the area. The biomass estimates for the Teleost survey were 2–3 times lower than the estimates for the Creed survey from the kriging methods.

The annual Teleost estimates were similar to the Creed estimates for the Spatial GAMMs for *M. norvegica.* For *Thysanoessa* spp, although the scale of the estimates was similar for both surveys, there was a year-to-year variation. The biomass was slightly declining for *Thysanoessa* spp*.* from 2008–2013. The lowest biomass occurred in 2014 for both taxa and it increased in 2015 and 2016. The biomass estimated by the survey-based and the spatial GAMMs were in the same order of magnitude but they did not follow the same year-to-year variation. The survey-based estimates followed the same year-to-year variation than estimates by the kriging methods but was around 2–3 times higher than the kriging method estimates for the Creed survey and 5 times higher than the kriging estimates for the Teleost survey.

3.2.1 Comparison between survey-based and model-based methods

Relationships between survey-based and model based estimates of biomass in each stratum are presented in Table 5 and Figure 9 for *Thysanoessa* spp*.* and Table 6 and Figure 10 for *M. norvegica*. The closer the slope is to 1, and the intercept is to 0, the more similar the estimates of biomass are between the two series. All kriging methods gave similar performance. The Creed and Teleost model-based estimate were significantly correlated with the Creed survey-based estimates. The spatial GAMMs was the method with the poorest relationship (lowest slope) with survey-based estimates especially concerning the Teleost survey estimates for *Thysanoessa* spp*.* (Figure 9). *M. norvegica* gave a better correspondence between model-based and survey-based than *Thysanoessa* spp*.* with slopes closer to 1 and intercepts closer to 0 compared to *Thysanoessa* spp. For Thysanoessa, the model-based estimates were systematically biased low compared to the survey-based estimates.

3.2.2 Comparison between surveys

Details of LM between the Creed and Teleost survey for each taxa, stratum and year, using the model-based methods are presented in Table 7 and the relationships are presented in Figure 11. The various methods show a slope between 0.43 and 0.64 for *Thysanoessa* spp*.* and between 0.77 and 1.11 for *M. norvegica*.

Using this linear model, we reconstructed the Creed time series using the Teleost survey estimates to determine how the model would perform for years without Creed estimates (2018 forward). The spatial-GAMM was inadequate to replicate *Thysanoessa* spp. estimates (Figure 12). The predicted biomass for *Thysanoessa* spp. using kriging and inverse distance interpolation were very close to observations for 2013, 2014 and 2016, while they were underestimated for 2012 and 2015 with all methods. Predicted biomass for *M. norvegica* was underestimated in 2013 with all methods, but was otherwise close to observations. Interannual variation was well represented with the reconstructed biomass, although *Thysanoessa* spp resulted in a weaker signal.’’

3.2.3 Comparison of taxa composition

Species-specific proportions of the annual biomass estimates determined by each method are presented in Figure 13. The survey based biomass estimates show a proportion of *M. norvegica* that is close to or higher than 50% starting in 2010. *M. norvegica* was relatively more abundant than *Thysanoessa* spp*.* particularly in 2011 (73%) and to a lesser degree in 2013 (62%). The model-based methods show similar proportions of the two taxa except for the spatial GAMM estimates, which estimated a larger proportion of *Thysanoessa* spp. The model-based estimates from the Creed survey show similar proportions of *Thysanoessa* spp. and *M. norvegica* compared to the survey-based estimates with the proportion of *M. norvegica* close to 50 % and higher than 50% for 2011 and 2013. The proportion of *M. norvegica* was, however, between 60 and 70% for the Teleost survey except in 2016 where the proportions of taxa are closer to the Creed data survey.

3.2.4 Comparison of spatial distributions

Excluding the spatial GAMMs, all interpolation methods gave similar estimates and a similar performance in the LM comparing the Creed and Teleost biomass. Ordinary kriging showed a non-significant improvement over inverse distance weighted interpolation but showed a similar performance to universal kriging. Given the added difficulty of undertaking universal kriging, we selected ordinary kriging as the best parsimonious method to evaluate krill biomass in the enwGSL. We present the resulting interpolated maps of krill biomass from the two surveys from 2012 to 2016 in Figure 14 and Figure 15 and the spatial correlation between the two in Figure 16.

The aggregations of the two taxa are denser (higher biomass on a small surface) with the Creed survey than the Teleost survey. The Teleost survey predicted relatively higher biomass on the South shore (2A-2B-3A) and in Jacques Cartier (11A-11B) especially in 2016 (Figure 14Figure 14–15). The Teleost surveys detected aggregations similar to the Creed survey at the tip of Gaspe (8A) and in the St Lawrence Estuary (4A-4B). The spatial correlation between the two surveys was high in the Gaspe current (5-6-7-8A) especially in 2013 (*M. norvegica* only) and 2015 but the predictions were not correlated in 2016 (2014 was positive but not significant) in this area (Figure 16). In the estuary, including the north shore and south shore areas, the spatial correlations are higher in 2012 for all taxa.

The aggregations west of Anticosti Island (10B) are usually comparable between the two surveys. In 2016, the Teleost predicted an aggregation at a larger scale than the Creed for *Thysanoessa* spp. (Figure 14–15) which resulted in a lower spatial correlation for that year (Figure 16). An aggregation of *Thysanoessa* spp. near Pointe des Monts (1B) was generally detected by the Teleost survey, but limited Creed coverage in this area makes the comparison less reliable. The spatial correlation was higher but not significant for *M. norvegica* in the Pentecôte (1A-1B) area but generally low for *Thysanoessa* spp*.* The Creed survey detected *Thysanoessa* spp*.* aggregations near Sept-Iles (1A) almost all years, while the Teleost survey did not detect these aggregations. This could be reflected in the spatial correlation in the Pentecôte region (1A-1B) which was poor for both taxa in all years. The same observations apply for *M. norvegica,* which was more abundant on the Gaspe coast (southern coast of the nwGSL). The Teleost survey detected them accurately although at a lower density. Overall the correlations between the predictions of the two surveys were significant, although no higher than 0.48 (bottom row of Figure 16) and were considerably lower for *Thysanoessa* spp.

4. DISCUSSION AND CONCLUSION

The objectives of our study were to: 1) extend the series of estimated krill biomass developed by McQuinn et al (2015) up to 2017 using their survey-based approach, 2) develop model-based methods for biomass estimation for both surveys, 3) compare the biomass estimates from the model-based methods developed in this document to the survey-based biomass estimate method from McQuinn et al (2015), 4) compare the efficiency of each model-based methods developed in this document and 5) develop statistical tools for the intercalibration of the two surveys. The first two objectives have been completed and in the following sections, we will discuss the results for objectives 3–5.

4.1 COMPARISON BETWEEN SURVEY-BASED AND MODEL-BASED METHODS

Model-based estimates of biomass were correlated to survey-based estimates with no model-based method standing out as a predictor of biomass better than the others. However, the model-based estimates were generally three to five times lower than survey-based estimates. This could be attributed to 1) the krill size used to calculate biomass that differed between the two surveys, 2) the inadequacy of the 5th root transformation to reproduce the peak biomasses or 3) the spacing between transects making interpolation difficult.

First, the model-based methods would underestimate the biomass when large krill are present in the strata compared to the average used in the biomass-TS relationship and overestimate biomass when juveniles are present. However, this caveat would have little effect when comparing the Creed and Teleost surveys using model-based methods unless the krill size changed between the Creed and Teleost surveys, which is not likely to happen considering that both surveys were conducted in August.

Second, spatial GAMM estimates for *Thysanoessa* spp. were in the same range of values to the survey-based methods. This was attributed to the use of the ZAG distribution that removed the need for transformation. The use of the ZAG distribution was not possible for *M. norvegica* because the proportion of zeros was too low to justify the use of ZAG. Kriging does not allow the use of different distributions.

Third, the distance between adjacent transects varies between 10–20 km in the Creed surveys (McQuinn et al. 2015). This is close to or larger than the range of spatial correlation. We detected no significant directional anisotropy in our kriging analyses. However, if local anisotropy were to occur, kriging between adjacent transects could underestimate the biomass. Complementary information on spatial structure provided by covariates in universal kriging did not help to fill in the gaps between transects. Considering these changes of scale among methods, our estimates from ordinary kriging are best considered as relative values instead of absolute estimates of biomass.

4.2 COMPARISON OF MODEL-BASED METHODS

Spatial GAMMs have statistical benefits upfront over kriging. It permits 1) the inclusion of more than one covariate, 2) the modelling of non-linear relationships with covariates and 3) the consideration of the statistical distribution of the response variables. However, it requires more computation cost which limited the resolution of the data that were included (2 km instead of 1 km or 500 m), the resolution of the prediction grid (10 km) and the resolution of the spatial field (~ 20 km). Furthermore, there was no significant improvement of biomass estimation with spatial GAMMs compared to kriging throughout our analyses. Cross-validation and statistical tools for intercalibration showed no superior performance by spatial GAMMs. The spatial GAMMs for *Thysanoessa* spp*.,* while predicting values in the same range as the survey-based estimates, failed to reproduce the interannual variability of the survey-based estimates. Among kriging methods, the estimates did not vary significantly. Ordinary kriging provided a small non-significant improvement over inverse distance, but the addition of covariates in universal kriging did not improve predictions. Given the added computation cost of running universal kriging as well as the added difficulty of sourcing satellite data for SST, we suggest that ordinary kriging should be used in the future to continue the krill biomass time series.

4.3 INTERCALIBRATION OF THE SURVEYS

We developed a linear model between kriging estimates for the Creed survey and the Teleost survey. The objective moving forward is to use the Teleost estimates for years after 2017 and predict the biomass as if it were sampled from the Creed to provide a continuous and comparable times series. The linear model provided a significant relationship between the two surveys for both species. The slope was lower for *Thysanoessa* spp and the intercept was higher than 0 (2) suggesting that the Teleost survey tended to underestimate the biomass at low values and could overestimate at higher values. The same was true for *M.norvegica* but to a lesser extent. . The reconstruction of the times series showed that 2 years and 1 year out of 5 for *Thysanoessa* spp. and *M. norvegica* respectively had non-overlapping confidence intervals for the Creed estimates and the Creed predicted estimate using the Teleost survey. However, the interannual variation was nonetheless correctly followed for *M. norvegica*.

This document presents partial annual estimates of krill biomass for the enwGSL. The Teleost survey tended to underestimate the proportion of *Thysanoessa* spp*. Thysanoessa spp*. prefers shallower areas than *M. norvegica* (McQuinn et al. 2015) which are less likely to be sampled by the Teleost survey since it is designed around groundfish distributions. It also has a lower sampling resolution than the Creed survey which most likely contributed to the predictions of larger and less dense aggregations as it could not resolve small, dense aggregations closer to the coast. Using only the Teleost survey in future years would not allow for any fine spatial studies using the distribution of krill biomass. Therefore, depending on only the groundfish survey will reduce yearly operational costs but will only provide partial information on krill distribution and interannual variation.

This report suggests that the Teleost survey can be used in future to approximate the krill biomass time series. While it can provide some information for *Thysanoessa* spp., small variations might not be significantly detected. However, if a large drop or increase in *Thysanoessa* spp. biomass occur, it would most likely be detected with the Teleost survey estimates. The diet of blue whales is composed of both *Thysanoessa* spp. and *M. norvegica*. The proportion of arctic krill (*T. raschii*) in the diet has increased between 2000 and 2010 but on average during this period, the contribution of each species was around 40%-50% (Gavrilchuk et al. 2014).

Using the Teleost data, it would also be possible to produce regional-scale krill abundance estimates for other areas in the GSL which were not previously surveyed by the Creed. Total biomass could be obtained when estimates are available for all strata. Methods for the imputation of values in missing strata would be the subject of a future document. The partial analysis of 2017 provides an opportunity to test the quality of our statistical tools when the Teleost acoustic data for 2017 are made available.

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REFERENCES

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., ... & Bolker, B. M. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modelling. The R journal **9**(2) : 378–400.

Canadian Hydrographic Service. 2018. 1:25000 (11(K, L, M,N), 12(C,D,E,F,G,I,J,K,L,O,P), 21(L,M,N,P),22(A,B,C,D,F,G,H,I,J),31(G,H,I) et 32A. Institut Maurice-Lamontagne Pêches et Océans Canada, 850 route de la mer case postale 1000, Mont-Joli(QC) G5H 3Z4. Courriel: chsinfo@dfo-mpo.gc.ca) Data extracted on 2018-02-01

Canadian Hydrographic Service. 2019. (1(E,L,M), 2(E,L,M), 11(E,F,G,H,I,J,K,L,M,N,O,P), 12(A,B,C,D,F,G,H,I,J,P), 21 (H,I,O,P),22 (A,B) Institut océanographie de Bedford Pêches et Océans Canada, 1 promenade Challenger, Darmouth (NS) B2Y 4A2. Courriel: chsinfo@dfo-mpo.gc.ca)).Data extracted on 2019-01-09

Cressie, N.A.C.1993. Statistics for Spatial Data, John Wiley & Sons, New York.

Fuglstad, G.-A., Simpson, D., Lindgren, F., and Rue, H. 2016. Constructing Priors that Penalize the Complexity of Gaussian Random Fields. arXiv:1503.00256

Gavrilchuk, K., Lesage, V., Ramp, C., Sears, R., Bérubé, M., Bearhop, S., & Beauplet, G. 2014. Trophic niche partitioning among sympatric baleen whale species following the collapse of groundfish stocks in the Northwest Atlantic. Marine Ecology Progress Series 497: 285–301

Gräler B., Pebesma E. and Heuvelink G. 2016. Spatio-Temporal Interpolation using gstat. The R Journal **8**(1): 204–218

Hijmans R.J. 2019. Raster: Geographic Data Analysis and Modeling. R package version 2.9-23.https://CRAN. R-project. Org/package=raster

Horn, B.K.P. 1981. Hill shading and the reflectance map. Proceedings of the IEEE 69:14-47

Lehoux, C., Plourde S., and Lesage, V. 2020. Significance of dominant zooplankton species to the North Atlantic Right Whale potential foraging habitats in the Gulf of St. Lawrence: a bio-energetic approach. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/033. Iv + 44 p.

Lindgren, F., Rue, H., and Lindström, J. 2011. An explicit link between gaussian fields and gaussian markov random fields: The stochastic partial differential equation approach. J. R. Stat. Soc. Ser. B Stat. Methodol. **73**(4): 423–498

Lindgren, F., & Rue, H. 2015. Bayesian Spatial Modelling with R-INLA. Journal of Statistical Software **63**(19): 1–25.

McQuinn, I.H., Dion, M., and St-Pierre, J.-F. 2013. The acoustic multifrequency classification of two sympatric euphausiid species (*Meganyctiphanes norvegica* and *Thysanoessa raschii*), with empirical and SDWBA model validation. ICES J. Mar. Sci. **70**(3) : 636–649.

McQuinn, I.H., Plourde, S., St. Pierre, J.F., and Dion, M. 2015. Spatial and temporal variations in the abundance, distribution, and aggregation of krill (*Thysanoessa raschii* and *Meganyctiphanes norvegica*) in the lower estuary and Gulf of St. Lawrence. Prog. Oceanogr. 131 : 159–176.

McQuinn, I.H., Gosselin, J.-F., Bourassa, M.-N., Mosnier, A., St-Pierre, J.-F., Plourde, S., Lesage, V., Raymond, A. 2016. The spatial association of blue whales (*Balaenoptera musculus*) with krill patches (*Thysanoessa* spp. and *Meganyctiphanes norvegica*) in the estuary and northwestern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/104. Iv + 19 p.

NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group. Moderate-resolution Imaging Spectroradiometer (MODIS) Aqua Remote-Sensing Reflectance Data; 2018 Reprocessing. NASA OB.DAAC, Greenbelt, MD, USA.

Pebesma E.2019.The meuse data set: a brief tutorial for the gstat R package

Plourde, S., McQuinn, I.H., Maps, F., St-Pierre, J.-F., Lavoie, D., and Joly, P. 2014. Daytime depth and thermal habitat of two sympatric krill species in response to surface salinity variability in the Gulf of St Lawrence, eastern Canada. ICES J. Mar. Sci. **71**(2): 272–281.

Plourde, S., Lehoux, C., McQuinn, I.H., and Lesage, V. 2016. Describing krill distribution in the western North Atlantic using statistical habitat models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/111. v + 34 p.

Rue, H., Martino, S., and Chopin, N. (2009). Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. Journal of the Royal Statistical Society: Series B (Statistical Methodology) **71**(2): 319–392.

Savenkoff, C., Comtois, S., and Chabot, D. (2013). Trophic interactions in the St. Lawrence Estuary (Canada): Must the blue whale compete for krill? Estuarine, Coastal and Shelf Science 129: 136–151.

Simpson, D., Rue, H., Martins, T., Riebler, A., and Sørbye, S. 2015. Penalising model component complexity: A principled, practical approach to constructing priors. arXiv:1403.4630

Wiedenmann, J., Cresswell, K. A., Goldbogen, J., Potvin, J., & Mangel, M. 2011. Exploring the effects of reductions in krill biomass in the Southern Ocean on blue whales using a state-dependent foraging model. Ecological Modelling **222**(18): 3366–3379.

Wilson, M.F.J., O'Connell, B., Brown, C., Guinan, J.C., Grehan, A.J., 2007. Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Marine Geodesy 30: 3–35.

Wood, S.N. 2003. Thin plate regression splines. J. R. Stat. Soc. Ser. B Stat. Methodol. **65**(1): 95–114.

TABLES

Table 1. Range of spatial dependency and validation of spatial GAMMs. The models are validated using 70% of data for model fitting and 30% for model validation and the Spearman’s correlation coefficients between predicted and observed data are presented.

Survey	Species	Years	Distribution	Range (km)	Validation 70/30% Spearman' s correlation coefficient
Creed	*Thysanoessa* spp.	2008–2016	Bernouilli	30.5-53.8	0.73
			Gamma	22.3-30.3	
	M. norvegica	2008-2016	Gaussian	15.4-21.5	0.86
Teleost	*Thysanoessa* spp.	2012–2015	Bernouilli	20.5-36.3	0.67
			Gamma	18.6-27.2	
	M. norvegica	2012–2015	Gaussian	17.0-26.1	0.90

Table 2. Results of the LM for model-based estimates of biomass for each stratum for all years across survey, taxa and method. The 5th root transformation was applied to biomass. The estimate (Est.) is the value as given in the LM output (differences compared to the first factor combination). Standard error of the estimates (SE), z-value, p-value (p) and confidence intervals apply on the estimates and give the significance of the difference between each combination and the first combination (first line of the table).

Survey	Taxa	Method	Est.	SE	z-value	*p*	Conf. intervals	
Creed	*M. norvegica*	Spatial - GAMM - INLA	11.70	0.48	24.58	<0.0001	10.77	12.63
	Thysanoessa spp.		1.24	0.67	1.85	0.05	-0.07	2.56
Teleost	*M. norvegica*	Spatial - GAMM - INLA	-1.96	0.80	-2.46	0.01	-3.52	-0.40
Creed	*M. norvegica*	Inverse distance	-0.54	0.67	-0.81	0.42	-1.86	0.78
		Ordinary kriging	-0.11	0.67	-0.16	0.87	-1.43	1.21
		Universal kriging - Slope	-0.19	0.67	-0.28	0.78	-1.51	1.13
		Universal kriging - SST	-0.08	0.67	-0.11	0.91	-1.40	1.24
		Universal kriging - TPI	0.09	0.67	0.13	0.89	-1.23	1.41
Teleost	*Thysanoessa* spp.	Spatial - GAMM - INLA	0.64	1.13	0.57	0.57	-1.57	2.85
Creed	*Thysanoessa* spp.	Inverse distance	-2.80	0.95	-2.94	0.002	-4.67	-0.93
		Ordinary kriging	-2.62	0.95	-2.75	0.004	-4.49	-0.75
		Universal kriging - Slope	-2.57	0.95	-2.70	0.005	-4.44	-0.71
		Universal kriging - SST	-2.61	0.95	-2.74	0.004	-4.47	-0.74
		Universal kriging - TPI	-2.47	0.95	-2.59	0.007	-4.33	-0.60
Teleost	*M.norvegica*	Inverse distance	0.05	1.13	0.04	0.97	-2.16	2.26
		Ordinary kriging	-0.23	1.13	-0.21	0.84	-2.44	1.98
		Universal kriging - Slope	-0.19	1.13	-0.17	0.87	-2.40	2.02
		Universal kriging - SST	-0.19	1.13	-0.17	0.87	-2.40	2.02
		Universal kriging - TPI	0.07	1.13	0.06	0.95	-2.14	2.28
	Thysanoessa spp.	Inverse distance	-1.47	1.59	-0.92	0.36	-4.59	1.65
		Ordinary kriging	-1.39	1.59	-0.87	0.38	-4.51	1.74
		Universal kriging - Slope	-1.49	1.59	-0.93	0.35	-4.61	1.63
		Universal kriging - SST	-1.34	1.59	-0.84	0.40	-4.46	1.78
		Universal kriging - TPI	-1.98	1.59	-1.25	0.21	-5.11	1.14

Table 3. Range of spatial dependency and validation of ordinary kriging (OK), universal kriging (UK) and inverse distance weighted interpolation for the Creed survey**.** The models are validated using 70% of data for model fitting and 30% for model validation and the Spearman's correlation coefficients between predicted and observed data are presented.

		Range (km)				Validation 70/30% Spearman' s correlation coefficient			
	Year	Inverse distance	Ordinary kriging	Universal kriging Slope	Universal kriging SST	Inverse distance	Ordinary kriging	Universal kriging Slope	Universal kriging SST
Thysanoessa spp.	2008		7.026	6.636	6.298	0.43	0.52	0.49	0.49
	2009		9.181	9.329	9.712	0.71	0.73	0.66	0.67
	2010		11.943	11.043	11.816	0.63	0.71	0.63	0.62
	2011		6.256	6.174	6.270	0.62	0.64	0.66	0.67
	2012		11.547	10.874	11.344	0.62	0.66	0.65	0.65
	2013		7.647	7.541	7.646	0.52	0.55	0.62	0.66
	2014		10.467	10.164	9.952	0.57	0.57	0.56	0.57
	2015		11.138	9.160	12.447	0.65	0.67	0.65	0.67
	2016		13.028	12.713	12.39	0.64	0.71	0.67	0.66
	Mean		**9.804**	**9.292**	**9.764**	**0.6**	**0.64**	**0.62**	**0.63**
M. norvegica	2008		6.978	6.799	6.979	0.48	0.53	0.61	0.61
	2009		7.873	7.812	7.860	0.64	0.65	0.67	0.67
	2010		11.823	11.474	11.919	0.73	0.76	0.73	0.77
	2011		9.297	9.026	9.348	0.61	0.67	0.65	0.66
	2012		9.182	9.371	9.074	0.61	0.65	0.69	0.69
	2013		6.941	6.964	6.922	0.54	0.57	0.65	0.64
	2014		7.280	7.329	7.233	0.52	0.56	0.53	0.53
	2015		9.742	9.502	9.746	0.61	0.63	0.61	0.64
	2016		10.402	10.421	10.378	0.65	0.74	0.68	0.68
	Mean		**8.835**	**8.744**	**8.829**	**0.60**	**0.64**	**0.65**	**0.65**

Table 4. Range of spatial dependency and validation of ordinary kriging (OK), universal kriging (UK) and inverse distance weighted interpolation for the Teleost survey. The models are validated using 70% of data for model fitting and 30% for model validation and the Spearman's correlation coefficients between predicted and observed data are presented

		Range (km)				Validation 70/30% Spearman' s correlation coefficient			
		Inverse	Ordinary	Universal kriging		Inverse	Ordinary	Universal kriging	
	Year	distance	kriging	Slope	SST	distance	kriging	Slope	SST
Thysanoessa spp.	2012		6.447	6.041	6.144	0.7	0.71	0.71	0.65
	2013		4.402	4.180	4.354	0.73	0.65	0.60	0.58
	2014		4.993	4.874	4.976	0.66	0.63	0.62	0.56
	2015		10.247	9.702	10.405	0.59	0.6	0.61	0.57
	2016		13.250	11.944	12.992	0.79	0.8	0.79	0.81
	Mean		**7.868**	**7.348**	**7.774**	**0.69**	**0.68**	**0.67**	**0.63**
M. norvegica	2012		8.942	8.643	8.506	0.75	0.74	0.73	0.82
	2013		12.389	13.145	12.482	0.73	0.75	0.73	0.73
	2014		6.103	4.757	6.135	0.79	0.74	0.72	0.76
	2015		21.444	18.779	21.265	0.73	0.68	0.68	0.75
	2016		11.812	11.853	11.532	0.78	0.8	0.79	0.75
	Mean		**12.138**	**11.435**	**11.984**	**0.75**	**0.74**	**0.73**	**0.76**

Table 5. Results of the linear model between Survey-based estimates of *Thysanoessa* spp. biomass and model-based estimates of biomass for each stratum for each year (Survey and method are tested as interactions, N=1216, 2 surveys x 5 methods x 8 years x N strata).). The 5th root transformation was applied to biomass. β_0 is the intercept and β_1 the slope of the LM.The estimated coefficient (Est.) is the value as given in the LM output. The calculated coefficient is used in the equation for each combination of taxa*method and is obtained by adding the estimates for the lesser level interactions. Standard error of the estimates (SE), z-value, p-value (p) and confidence intervals apply on the estimates and give the significance of the difference between each combination and the first combination (first two lines of the table).

Coeff	Survey	Method	Est.	Calculated coefficient	SE	z-value	*p*	Conf. intervals	
β_0	Creed	Spatial GAMM - INLA	2.00	2.00	0.37	5.45	<0.0001	1.28	2.71
β_1		Spatial GAMM - INLA	0.65	0.65	0.06	11.60	<0.0001	0.54	0.76
β_0	Teleost	Spatial GAMM - INLA	1.49	3.49	0.52	2.85	0.004	0.47	2.51
	Creed	Inverse distance	0.08	2.08	0.52	0.16	0.87	-0.93	1.10
		Ordinary kriging	-0.09	1.91	0.52	-0.17	0.86	-1.11	0.93
		Universal kriging - Slope	-0.08	1.92	0.52	-0.15	0.88	-1.09	0.94
		Universal kriging - SST	0.13	2.13	0.52	0.26	0.80	-0.88	1.15
β_1	Teleost	Spatial GAMM - INLA	-0.14	0.51	0.09	-1.59	0.11	-0.32	0.03
	Creed	Inverse distance	0.20	0.85	0.09	2.12	0.03	0.02	0.38
		Ordinary kriging	0.18	0.83	0.09	2.02	0.04	0.01	0.36
		Universal kriging - Slope	0.18	0.83	0.09	2.01	0.04	0.00	0.36
		Universal kriging - SST	0.13	0.78	0.09	1.48	0.14	-0.04	0.31
β_0	Teleost	Inverse distance	0.37	3.85	0.73	0.50	0.62	-1.07	1.81
		Ordinary kriging	0.37	3.85	0.73	0.50	0.61	-1.07	1.80
		Universal kriging - Slope	0.34	3.83	0.74	0.47	0.64	-1.10	1.79
		Universal kriging - SST	0.17	3.66	0.74	0.24	0.81	-1.27	1.62
β_1	Teleost	Inverse distance	-0.05	0.45	0.16	-0.34	0.73	-0.36	0.26
		Ordinary kriging	-0.01	0.50	0.15	-0.04	0.96	-0.31	0.29
		Universal kriging - Slope	-0.01	0.50	0.15	-0.04	0.97	-0.31	0.30
		Universal kriging - SST	0.02	0.53	0.15	0.14	0.89	-0.28	0.32

Table 6. LM results between Survey-based estimates of *M. norvegica* biomass and model-based estimates of biomass for each stratum and year (Survey and method are tested as interactions, N=1459, 2 surveys x 6 methods x 8 years x N strata). The 5th root transformation was applied to biomass. β_0 is the intercept and β_1 the slope of the LM. The estimate (Est.) is the value as given in the GLMM output. The calculated coefficient is used in the equation for each combination of taxa*method and is obtained by adding the estimates for the lesser level interactions. Standard error of the estimates (SE), z-value, p-value (p) and confidence intervals apply on the estimates and give the significance of the difference between each combination and the first combination (first two lines of the table).

Coeff	Survey	Method	Est.	Calculated coefficient	SE	z-value	*p*	Conf. intervals	
B_0	Creed	Spatial GAMM - INLA	0.35	0.35	0.38	0.91	0.36	-0.40	1.10
β_1		Spatial GAMM - INLA	0.99	0.99	0.06	16.66	<0.0001	0.87	1.11
B_0	Teleost	Spatial GAMM - INLA	1.00	1.35	0.59	1.70	0.09	-0.15	2.16
	Creed	Inverse distance	-0.52	-0.17	0.56	-0.93	0.35	-1.61	0.57
		Ordinary kriging	-0.29	0.06	0.54	-0.54	0.59	-1.35	0.77
		Universal kriging -Slope	-0.27	0.08	0.54	-0.50	0.62	-1.33	0.79
		Universal kriging - SST	-0.23	0.12	0.55	-0.41	0.68	-1.30	0.85
β_1	Teleost	Spatial GAMM - INLA	0.00	0.99	0.11	-0.04	0.97	-0.21	0.20
	Creed	Inverse distance	0.13	1.12	0.09	1.46	0.15	-0.04	0.30
		Ordinary kriging	0.06	1.05	0.08	0.69	0.49	-0.11	0.22
		Universal kriging - Slope	0.06	1.05	0.09	0.72	0.47	-0.11	0.23
		Universal kriging - SST	0.04	1.03	0.09	0.46	0.64	-0.13	0.21
B_0	Teleost	Inverse distance	0.65	2.00	0.84	0.77	0.44	-1.00	2.30
		Ordinary kriging	0.66	2.01	0.82	0.80	0.42	-0.95	2.27
		Universal kriging - Slope	0.59	1.94	0.82	0.71	0.48	-1.03	2.20
		Universal kriging - SST	0.68	2.03	0.83	0.82	0.41	-0.94	2.30
β_1	Teleost	Inverse distance	-0.11	0.88	0.15	-0.69	0.49	-0.40	0.19
		Ordinary kriging	-0.09	0.90	0.15	-0.61	0.54	-0.38	0.20
		Universal kriging -Slope	-0.08	0.91	0.15	-0.53	0.60	-0.37	0.21
		Universal kriging - SST	-0.10	0.89	0.15	-0.66	0.51	-0.39	0.19

Table 7. Results of the LM between Creed and Teleost estimated biomass for each stratum for each year (Taxa and method are tested as interactions, N=1650; 22 strata x 5 Year x 3 Taxa x 5 methods). The 5th root transformation was applied to biomass. β_0 is the intercept and β_1 the slope of the LM. The estimated coefficient (Est.) is the value as given in the LM output. The calculated coefficient is used in the equation for each combination of taxa*method and is obtained by adding the estimates for the lesser level interactions. Standard error of the estimates (SE), z-value, p-value (p) and confidence intervals apply on the estimates and give the significance of the difference between each combination and the first combination (first two lines of the table).

Coeff	Taxa	Method	Est.	Calculated coefficient	SE	z-value	*p*	Conf. intervals	
β_0	*Thysanoessa* spp.	Spatial GAMM - INLA	2.94	2.94	0.30	9.95	<0.0001	2.36	3.51
β_1		Spatial GAMM - INLA	0.58	0.58	0.06	10.52	<0.0001	0.47	0.69
β_0	*M.norvegica*	Spatial GAMM - INLA	-1.51	1.43	0.58	-2.59	0.01	-2.65	-0.37
	Thysanoessa spp.	Inverse distance	-0.44	2.49	0.41	-1.07	0.28	-1.25	0.37
		Ordinary kriging	-0.37	2.57	0.41	-0.89	0.37	-1.17	0.44
		Universal kriging - Slope	-0.30	2.63	0.41	-0.73	0.46	-1.11	0.51
		Universal kriging -SST	-0.42	2.51	0.41	-1.02	0.31	-1.23	0.39
β_1	*M.norvegica*	Spatial GAMM - INLA	0.33	0.92	0.11	2.99	0.003	0.12	0.55
	Thysanoessa spp.	Inverse distance	-0.01	0.57	0.10	-0.12	0.91	-0.21	0.19
		Ordinary kriging	0.04	0.62	0.10	0.38	0.70	-0.15	0.23
		Universal kriging - Slope	0.01	0.59	0.10	0.08	0.94	-0.19	0.20
		Universal kriging - SST	0.05	0.64	0.10	0.53	0.60	-0.14	0.24
β_0	*M.norvegica*	Inverse distance	0.96	2.38	0.81	1.17	0.24	-0.64	2.55
		Ordinary kriging	0.93	2.36	0.80	1.16	0.24	-0.64	2.50
		Universal kriging - Slope	0.91	2.34	0.81	1.13	0.26	-0.67	2.49
		Universal kriging - SST	1.01	2.43	0.80	1.25	0.21	-0.57	2.58
β_1	*M.norvegica*	Inverse distance	-0.09	0.82	0.17	-0.55	0.58	-0.43	0.24
		Ordinary kriging	-0.13	0.79	0.17	-0.78	0.44	-0.46	0.20
		Universal kriging - Slope	-0.12	0.8	0.17	-0.70	0.49	-0.45	0.21
		Universal kriging - SST	-0.14	0.77	0.17	-0.87	0.39	-0.47	0.18

FIGURES

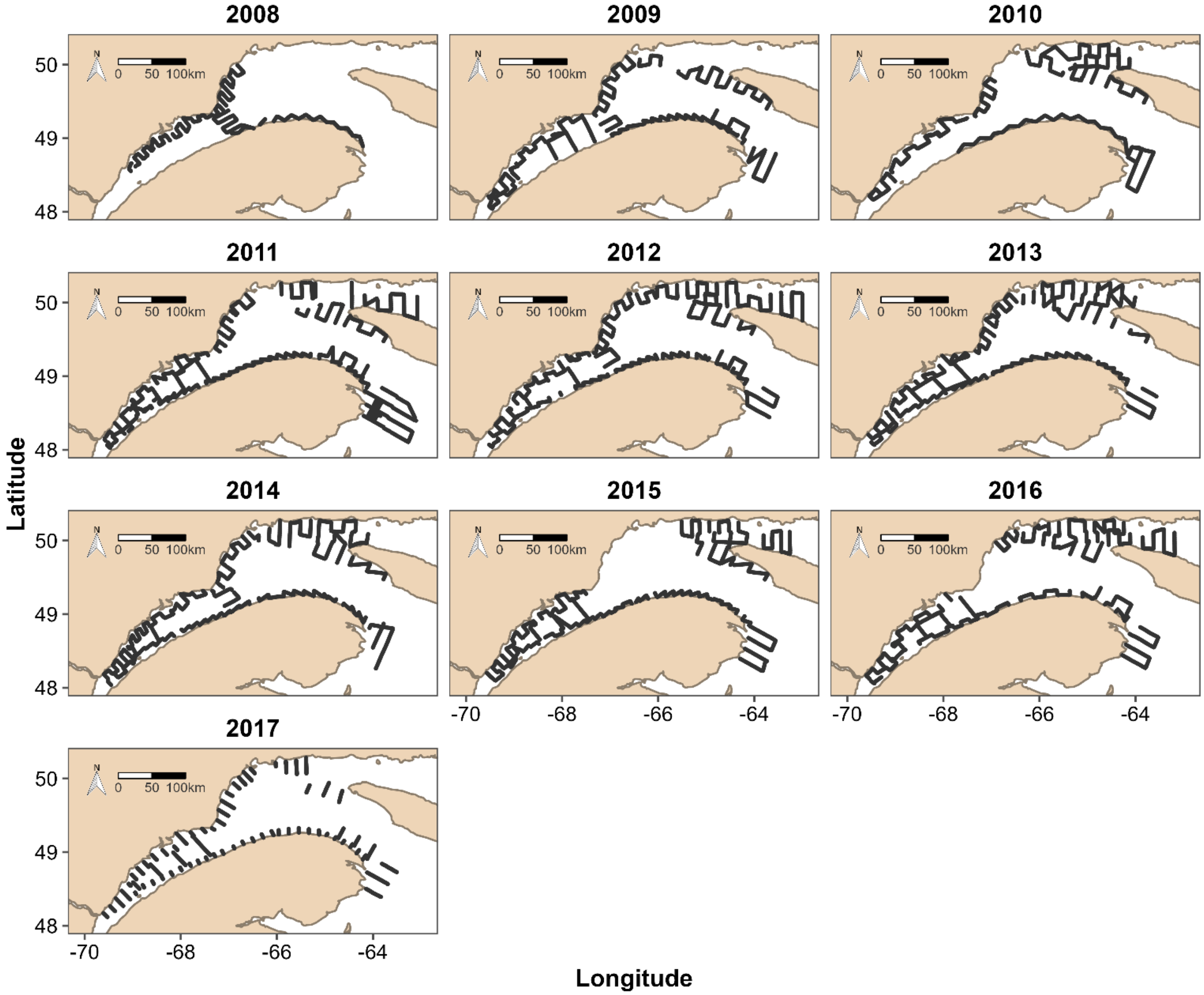

Figure 1. Cruise tracks (thick black lines) from the Creed survey for each year used for the analysis (2 km -bins). Transits were removed from the analyses.

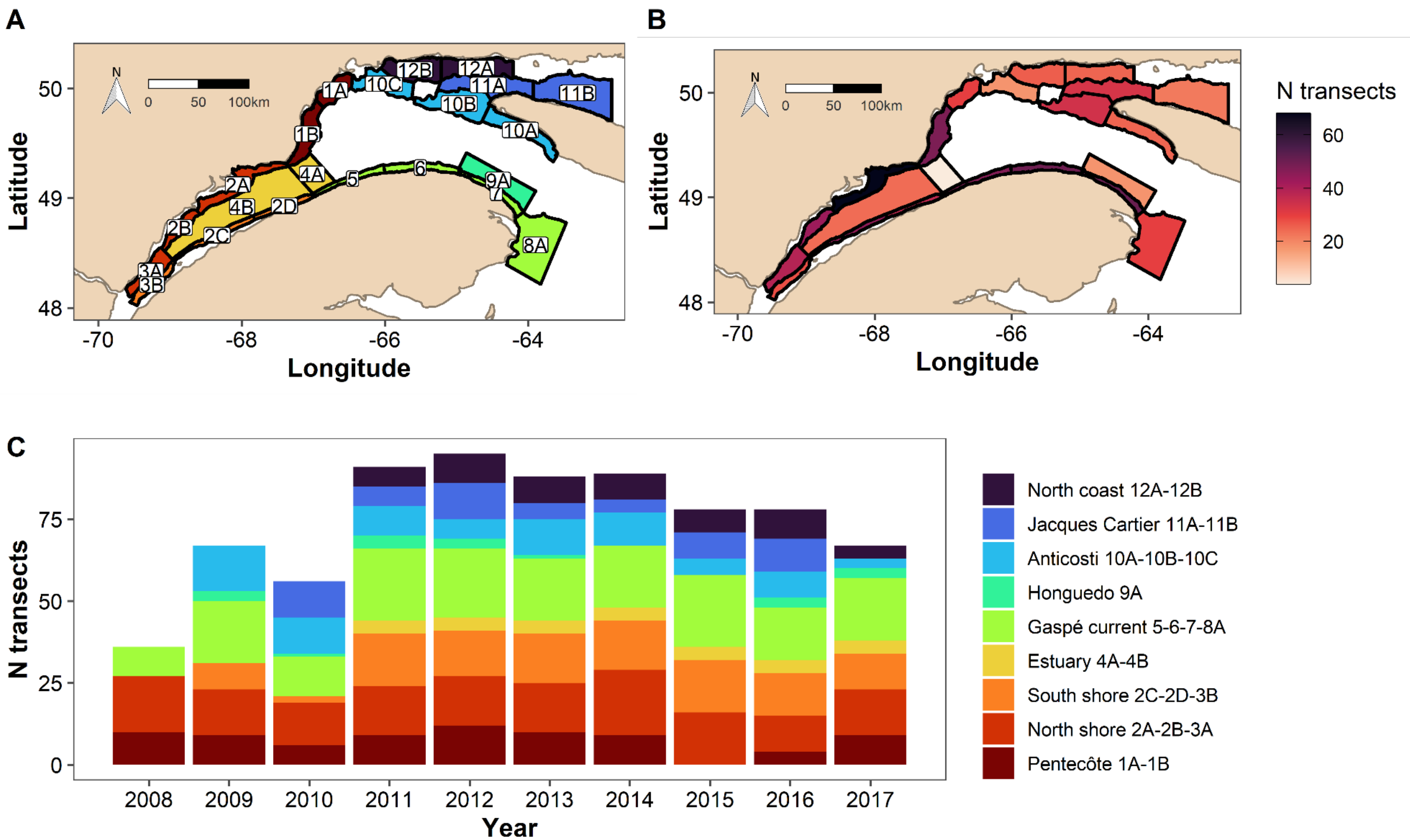

Figure 2. Annual sampling effort for the Creed survey. A. Stratum locations, strata are coloured by regions that share circulation or bathymetric similarities. B. Colour gradient is equal to N transects summed over all years. C: Geographic repartition of effort for each year. Colourscale in C corresponds to colours in A.

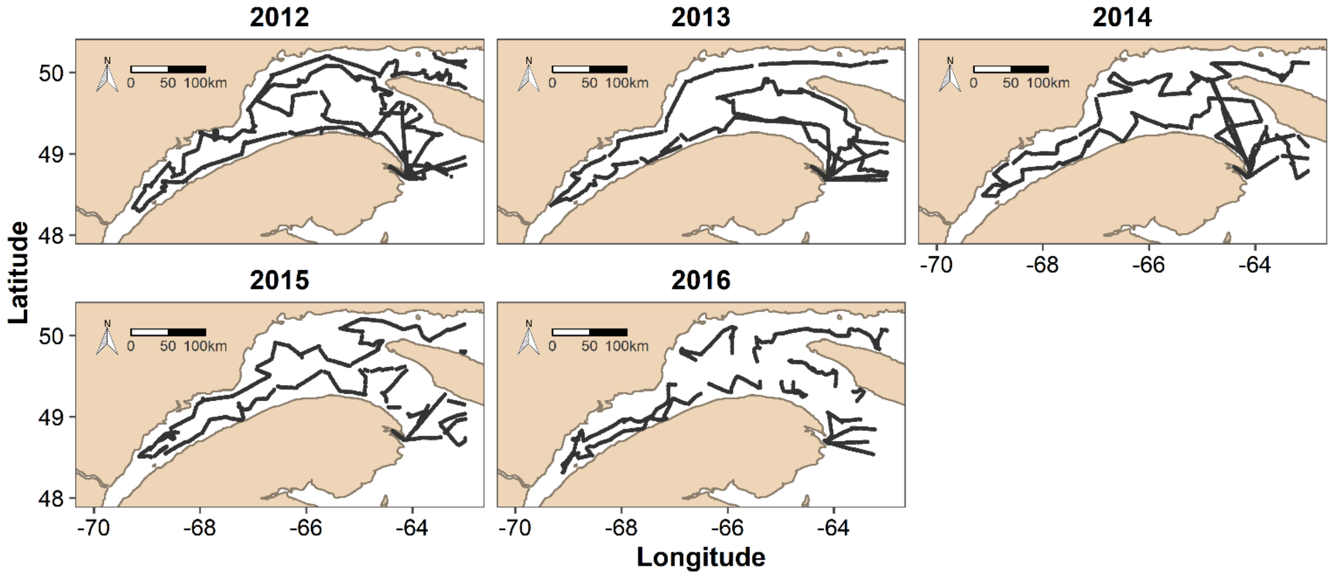

Figure 3. Cruise tracks (thick black lines) from the Teleost survey for each year used for the analysis (2 km bins)

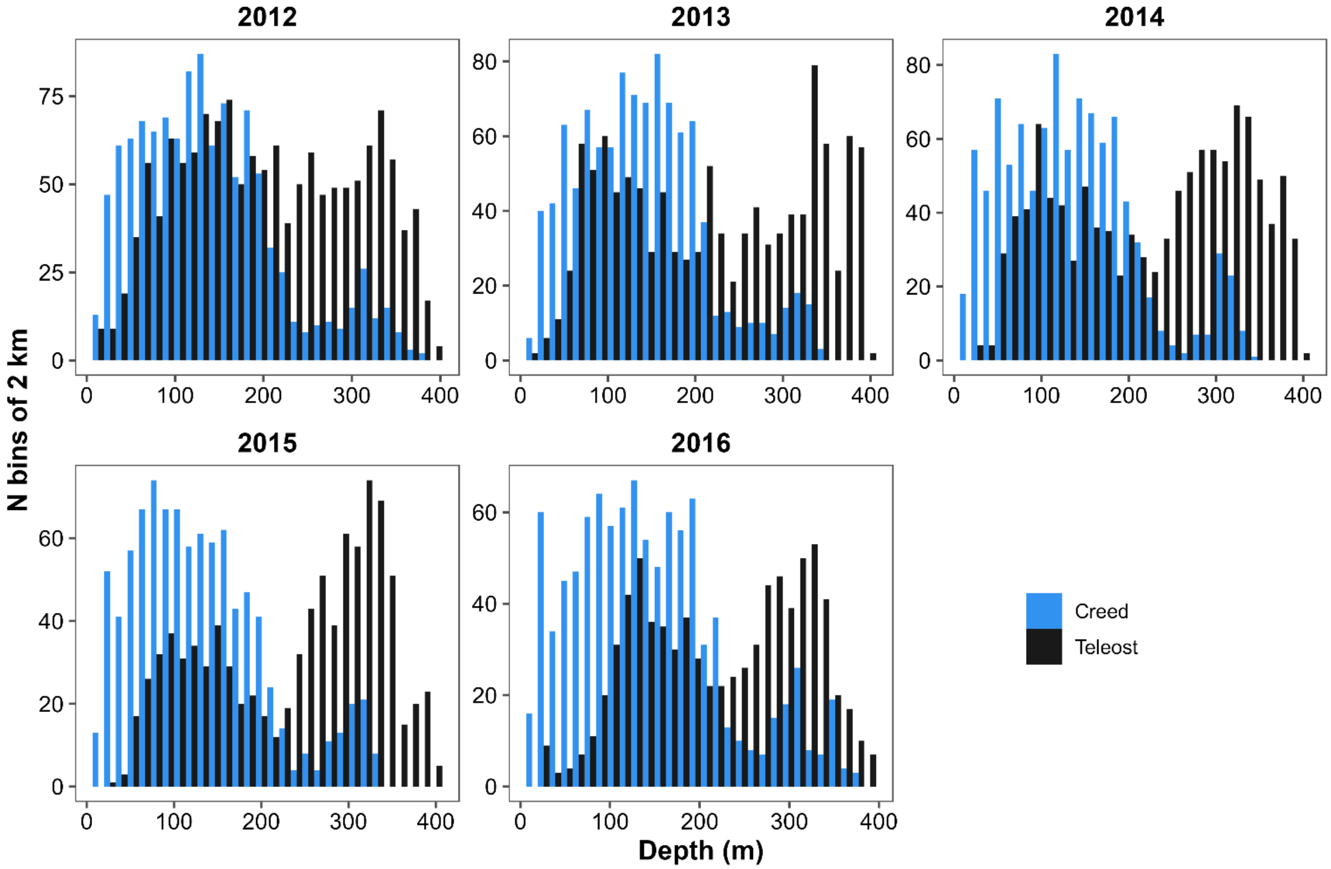

Figure 4. Sampling distribution of the two surveys according to depth. Sampling units are bins of 2 km.

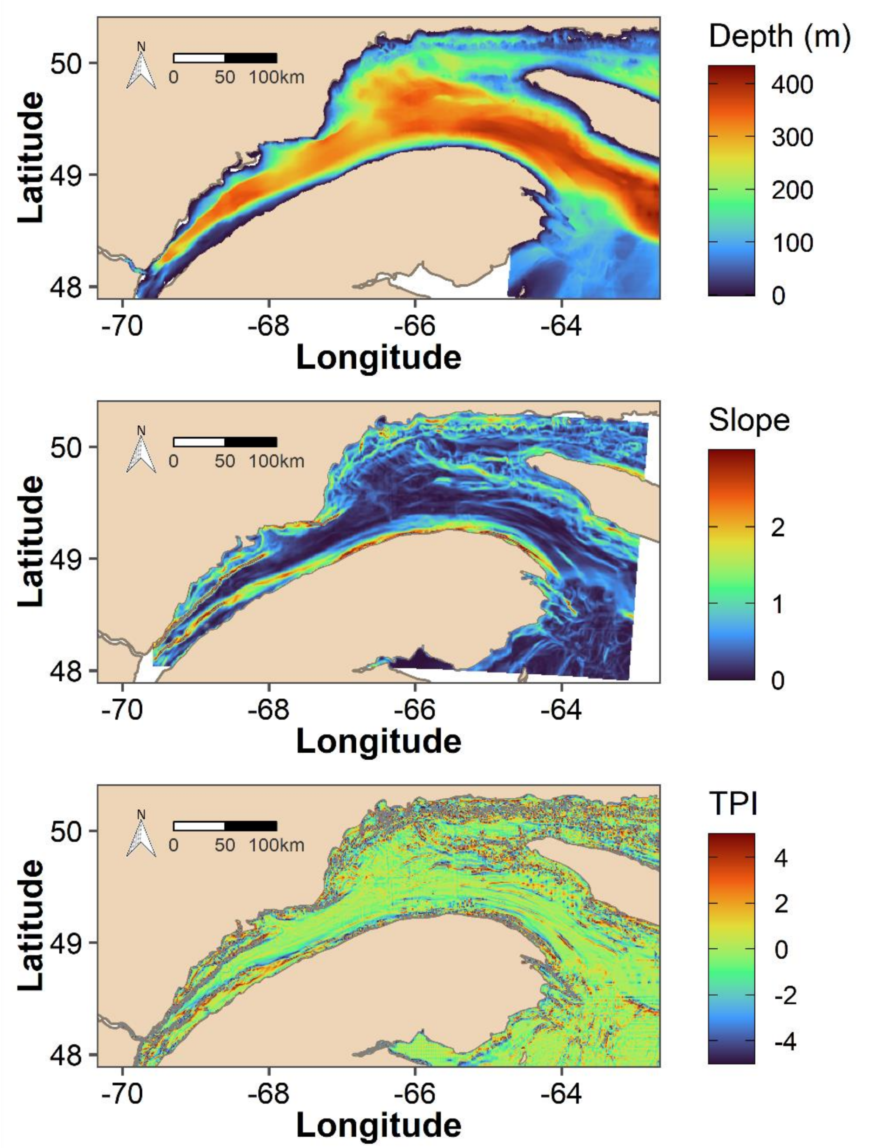

Figure 5. Covariates depth, slope (degrees) and TPI derived from the bathymetry layer included in model-based methods.

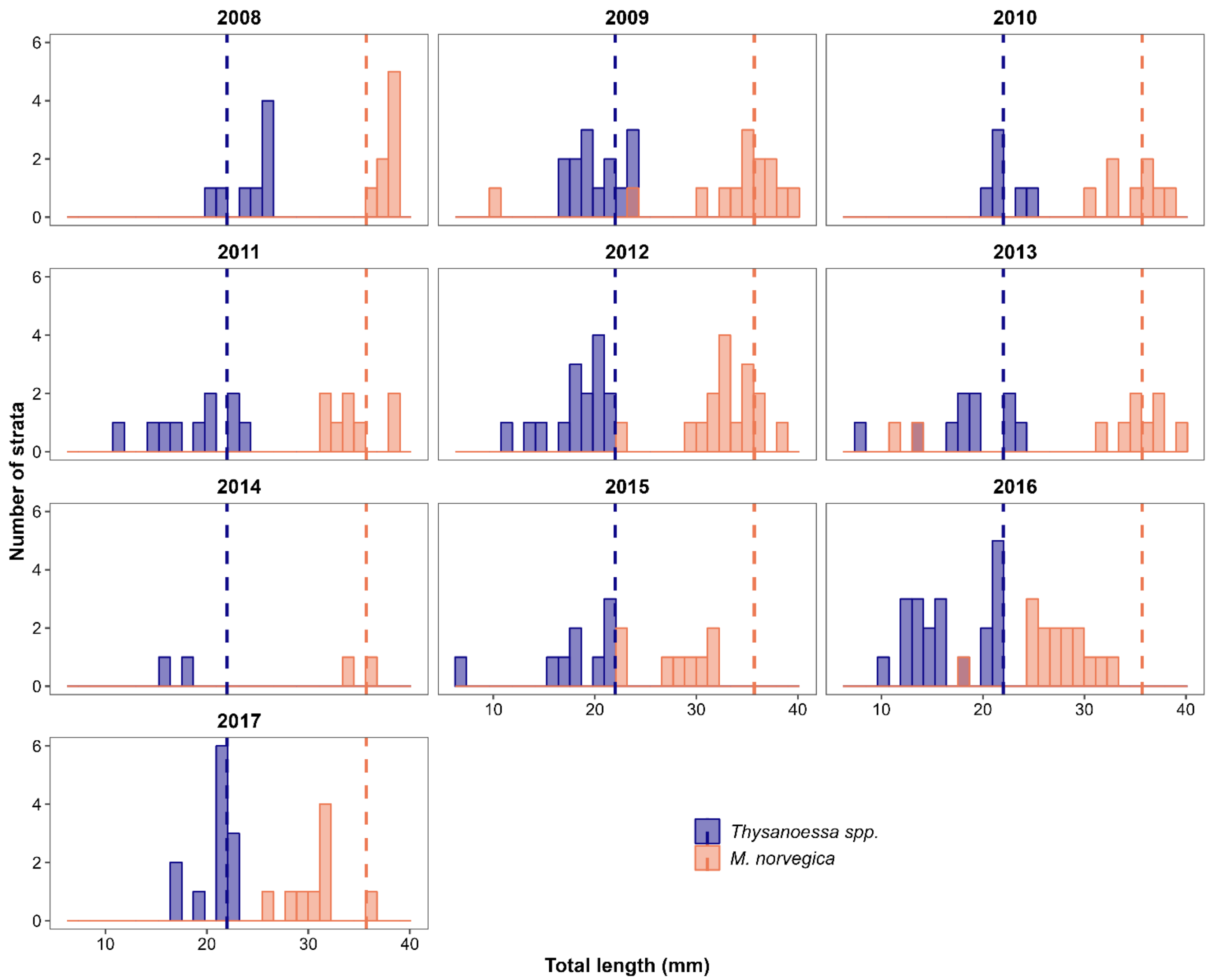

Figure 6. Annual distribution of mean lengths by stratum by bins of 1mm for each taxa shown with bars. The data used to plot these distributions are used for the survey-based estimation of biomass. The model-based estimation is based on the mean length calculated in 2009 indicated by the dashed-vertical lines.

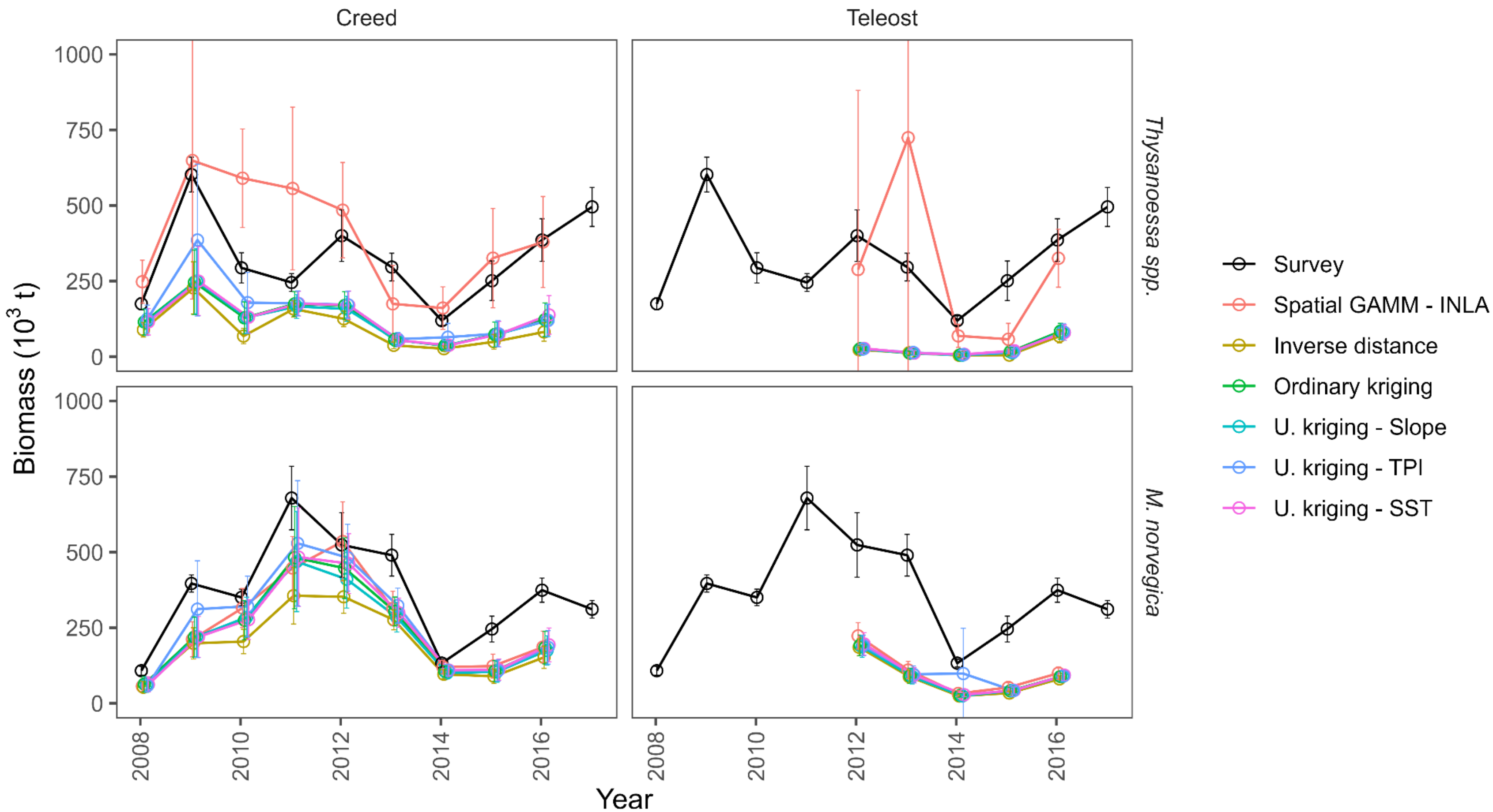

Figure 7. Annual total biomass estimated for the Creed and Teleost survey by each method considered. The survey only estimated biomass for the Creed survey but the estimates are superimposed on the Teleost panel. Error bars are standard deviation on estimates.

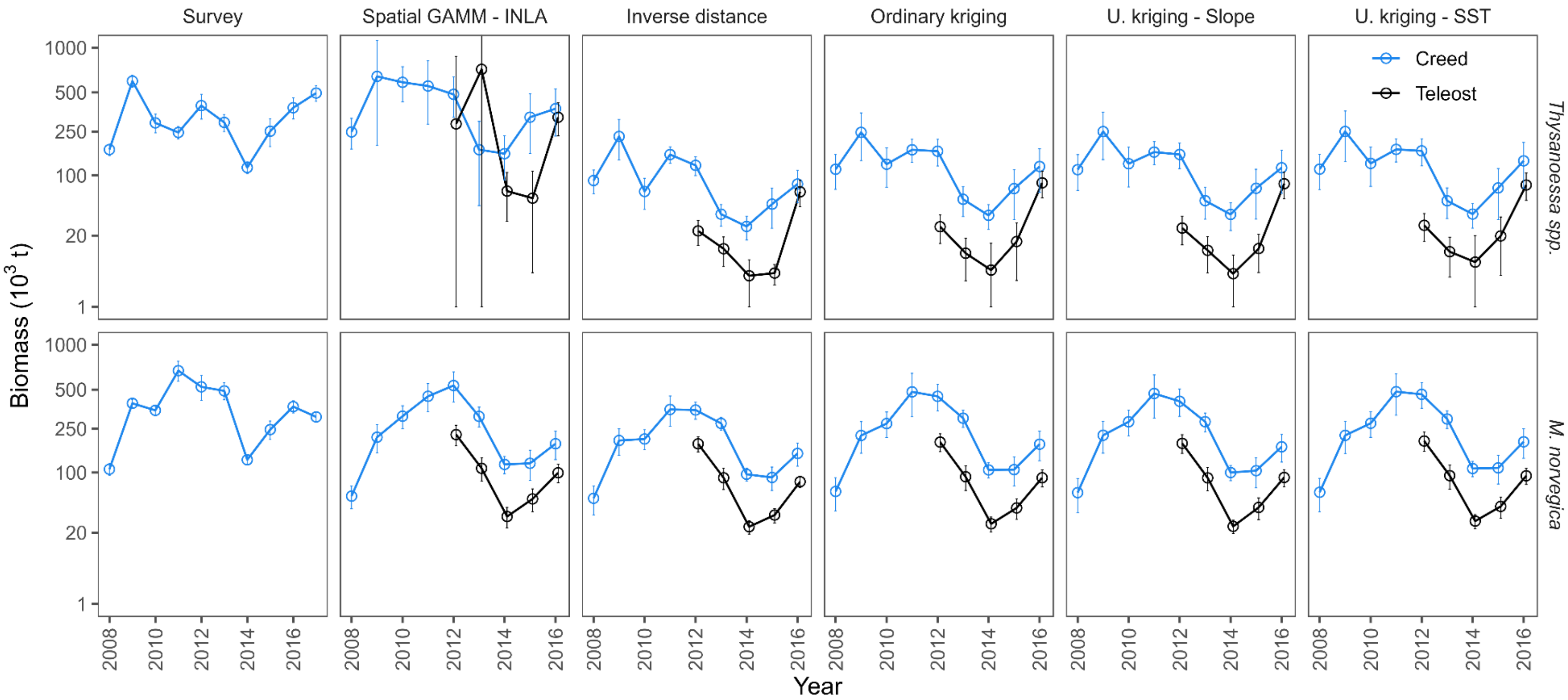

Figure 8. Annual total biomass estimated for the Creed (blue) and Teleost (black) surveys by each method. Vertical bars represent the standard deviation. The y-axis is scaled to follow a 5th root transformation, but actual values are represented.

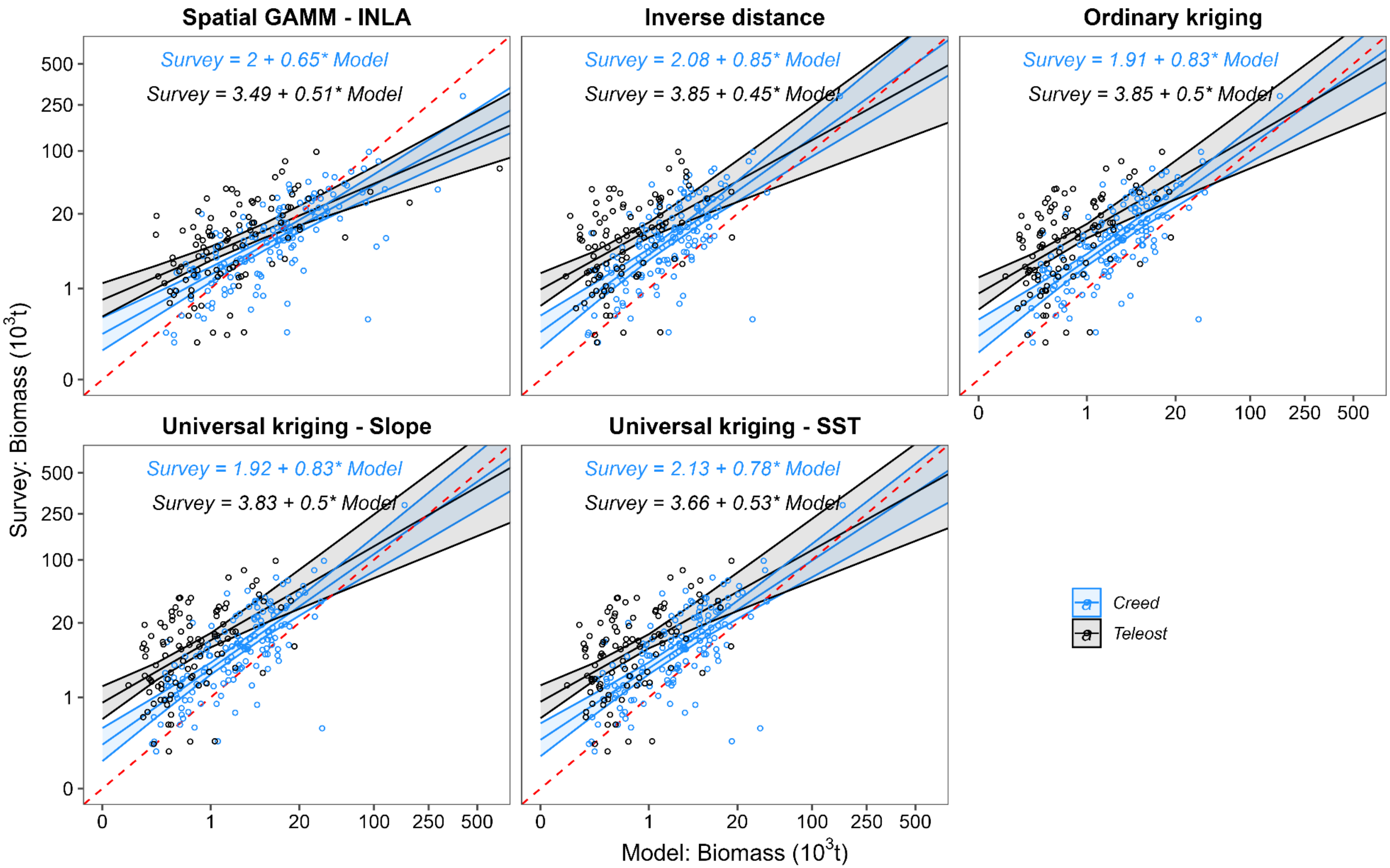

Figure 9. Linear regressions of *Thysanoessa* spp. biomass estimated by the survey-based method against the model-based methods for each year in each stratum. The y-axis is scaled to follow a 5th root transformation, but actual values are represented. Equations of the model are based on transformed biomass ($x^{\frac{1}{5}}\,t$). The shaded areas represent 95% confidence intervals. The dashed red line represent the identity line (slope of 1, intercept of 0).

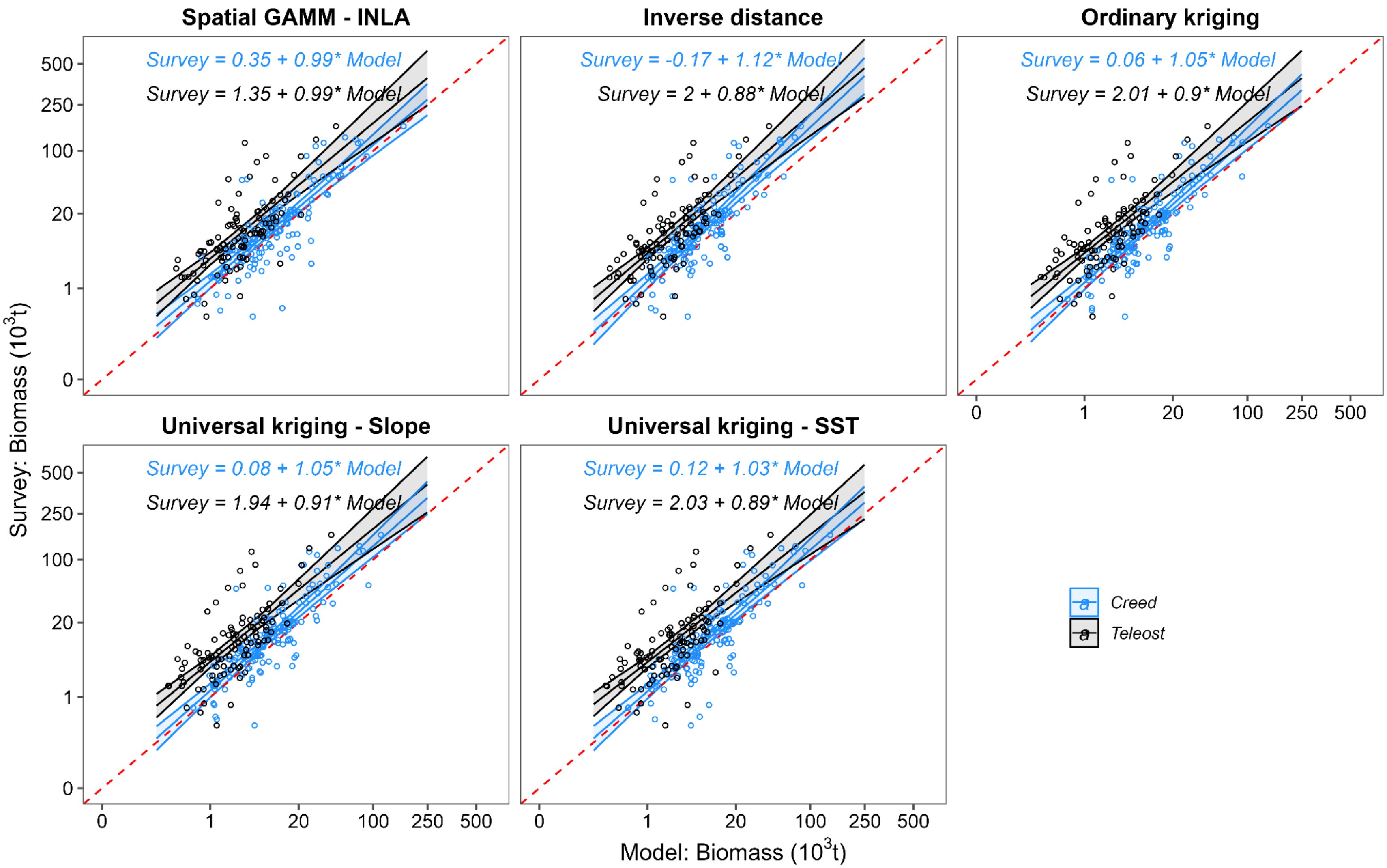

Figure 10. Linear regressions of the *M. norvegica* biomass estimated by the survey-based method against the model-based methods for each year at each stratum. The y-axis is scaled to follow a 5th root transformation, but actual values are represented. Equations of the model are based on transformed biomass ($x^{\frac{1}{5}}$ t). The shaded areas represent 95% confidence intervals. The dashed red line represent the identity line (slope of 1, intercept of 0).

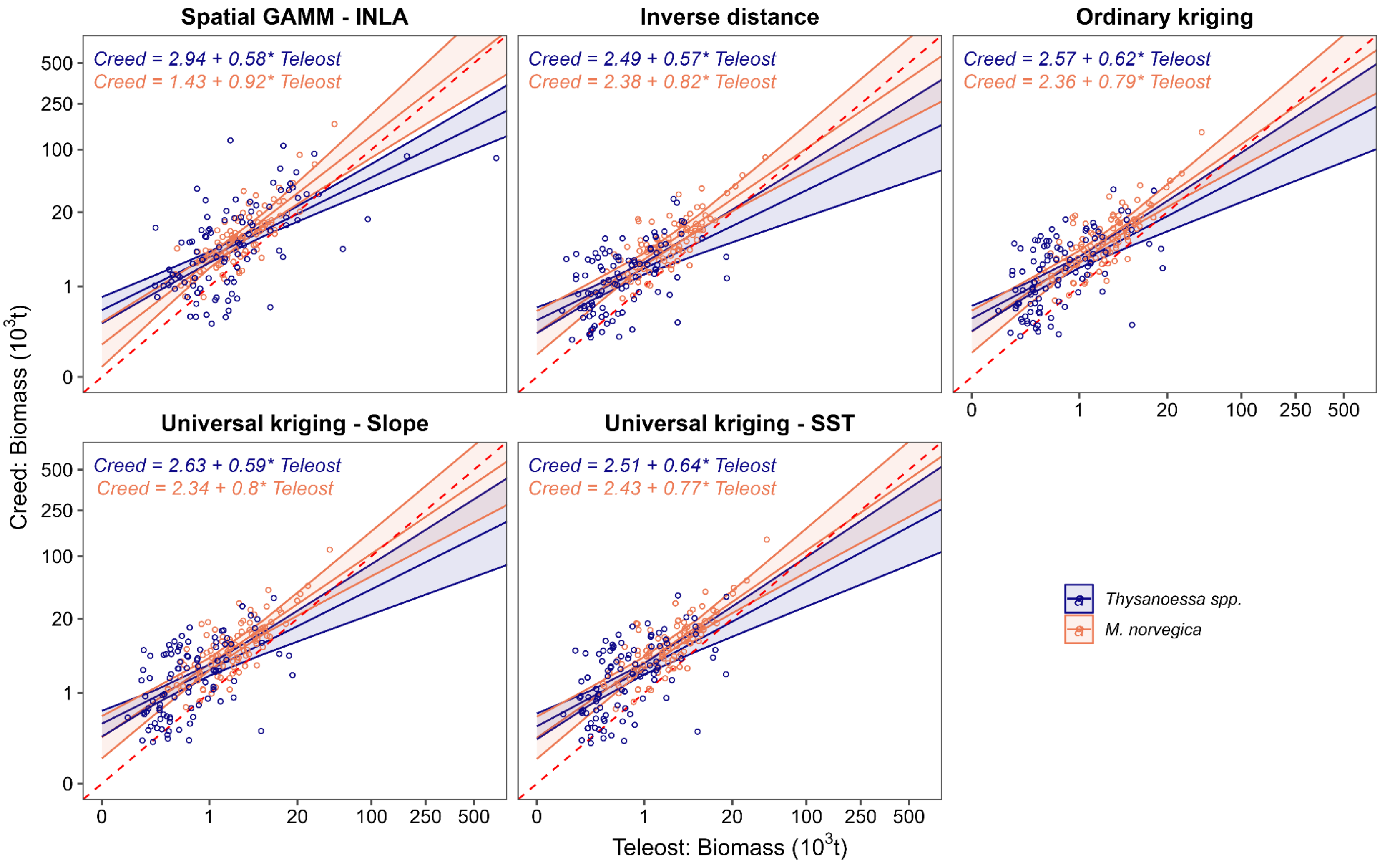

Figure 11. Linear regressions between the biomass estimated by the Creed and Teleost surveys for each year and stratum. The y-axis is scaled to follow a 5th root transformation, but actual values are represented. Equations of the model are based on transformed biomass ($x^{\frac{1}{5}}$ t). The shaded areas represent 95% confidence intervals. The dashed red line represent the identity line (slope of 1, intercept of 0).

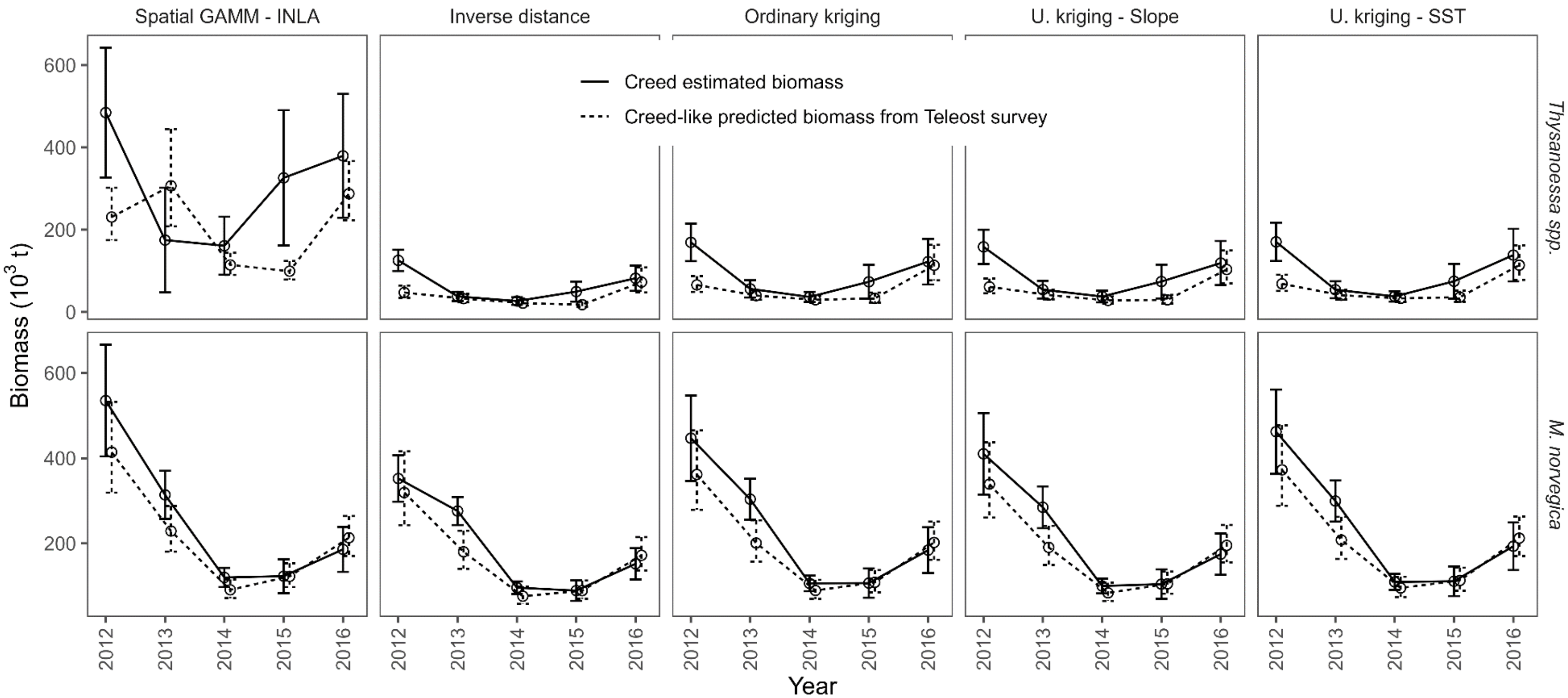

Figure 12. Time series of the estimated biomass for the Creed survey (black line) by model-based methods and predicted Creed-equivalent biomass estimated using the Teleost survey data and the linear regressions between Creed and Teleost estimates. The error bars correspond to the S.D. on estimates for the solid (Creed) series and to 95% confidence intervals on LM predictions for the dotted (Creed predicted) series.

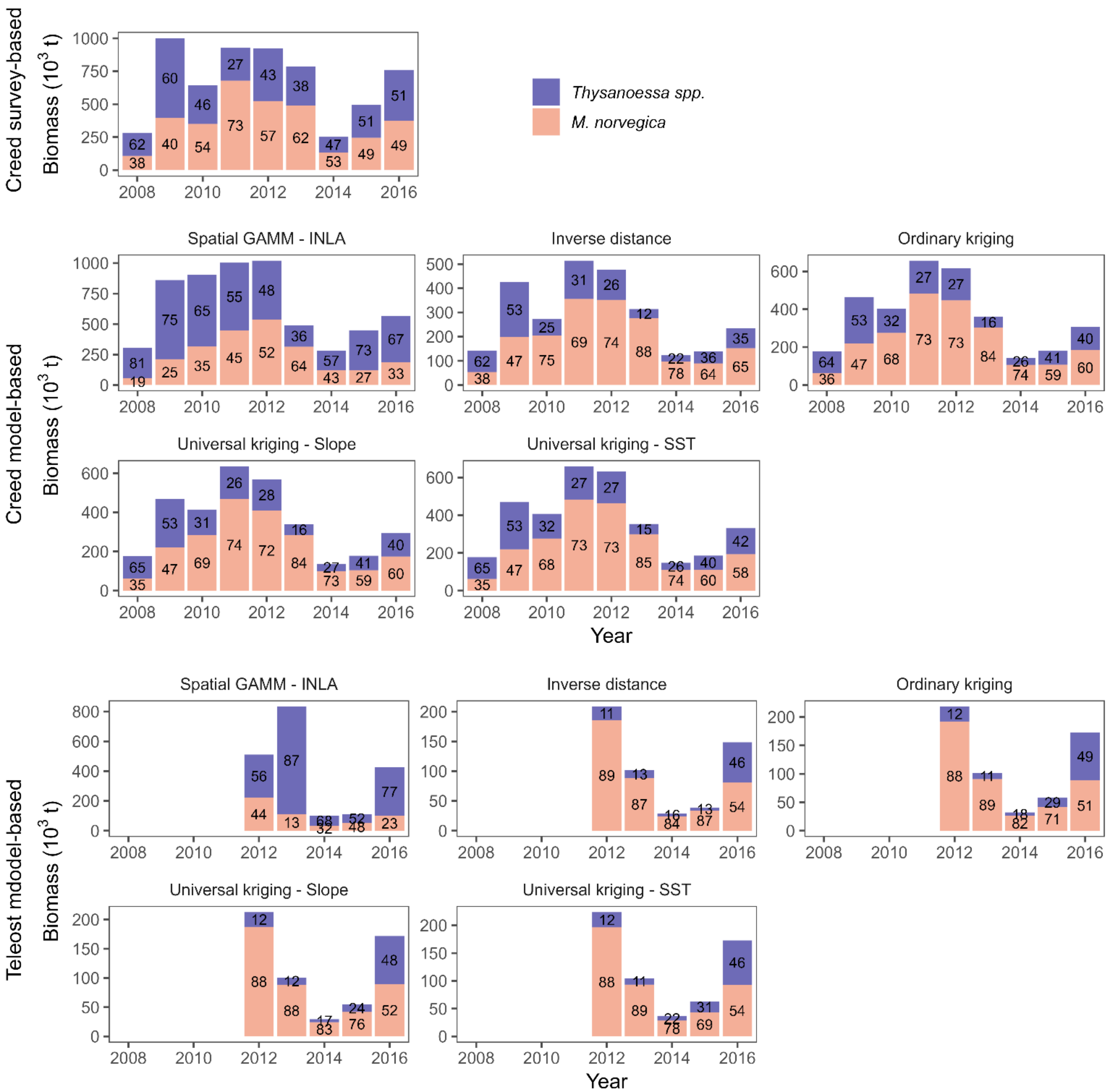

Figure 13. Annual total biomass contributed by taxa from the Creed survey- and model-based methods, and Teleost model-based estimates of biomass. Numbers represent species percentages for contribution.

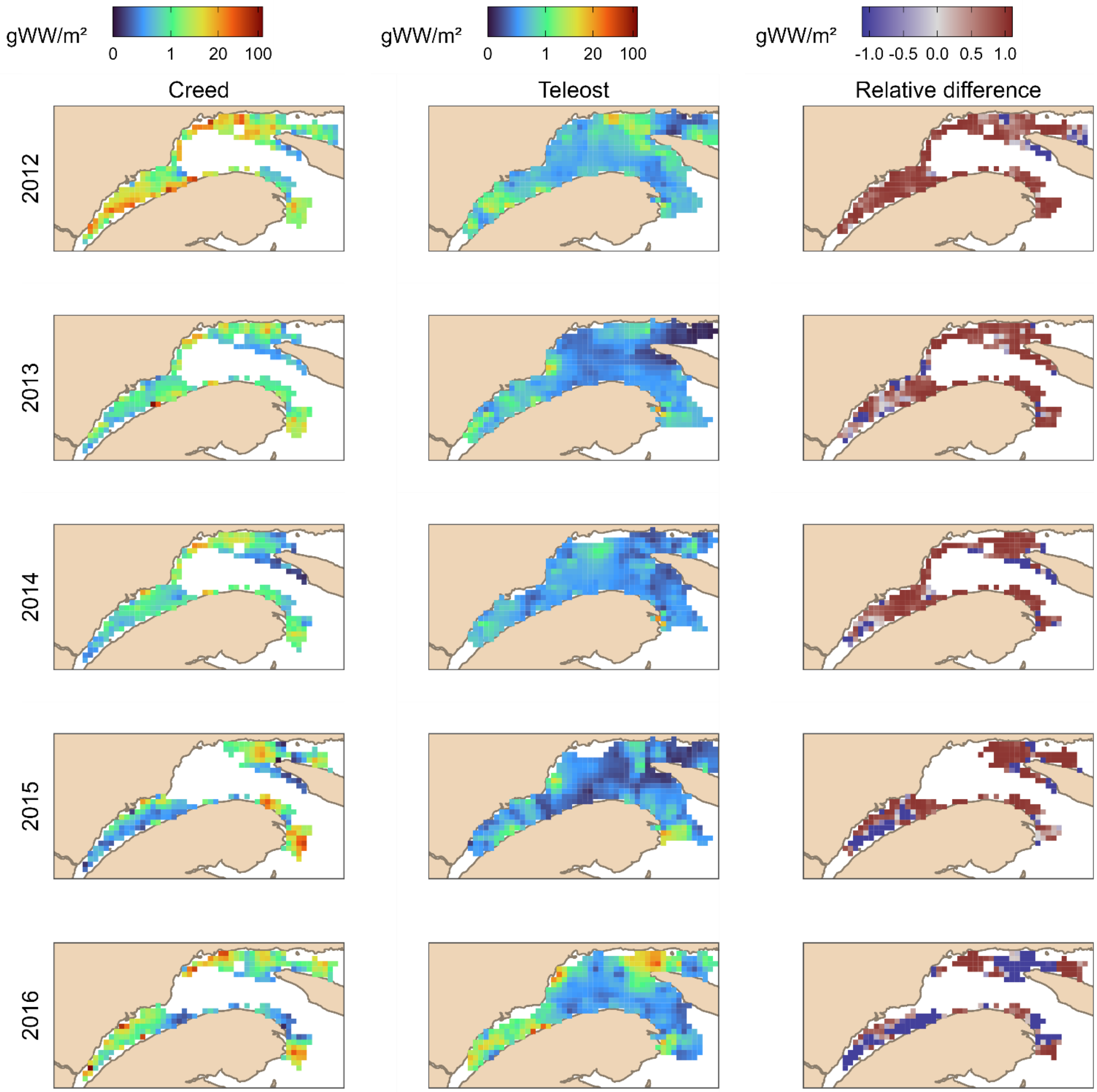

Figure 14. Spatial distribution of biomass prediction by ordinary kriging for *Thysanoessa* spp. Each cell is 10 x 10 km. The values reported in the first and second panel are expressed as the average biomass in grams of wet weight per m² in the cell. The colourscale follows a 5th root transformation and actual values are represented. The last panel represents the relative difference: (Creed-Teleost)/Creed and the scalebar is cropped between -1 and 1 for increased interpretability.

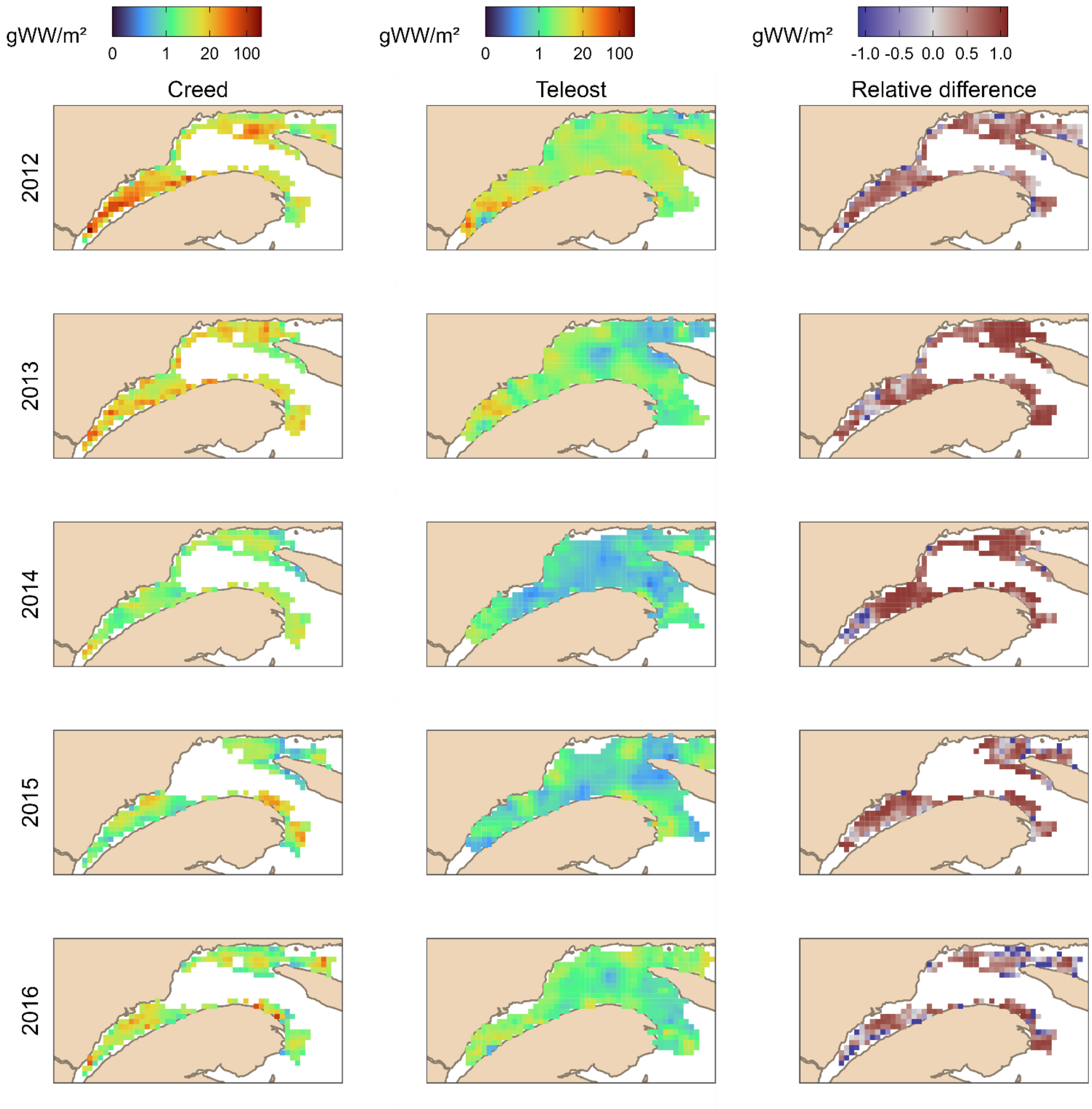

Figure 15. Spatial distribution of biomass prediction by ordinary kriging for *M. norvegica*. Each cell is 10 x 10 km. The values reported in the first and second panel are expressed as the average biomass in grams of wet weight per m² in the cell. The colorscale follows a 5th root transformation and actual values are represented. The last panel represents the relative difference: (Creed-Teleost)/Creed and the scalebar is cropped between -1 and 1 for increased interpretability.

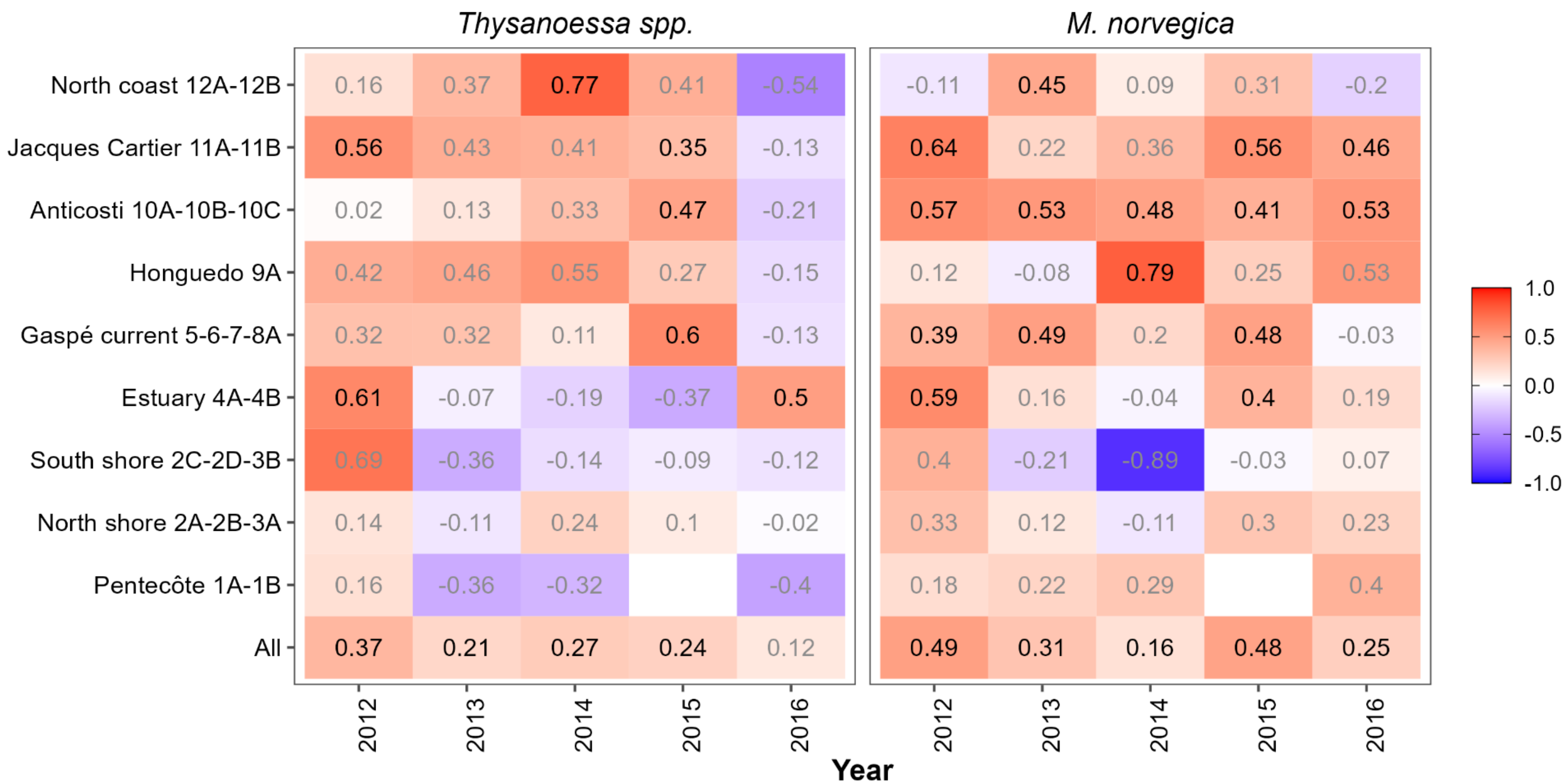

Figure 16. Spearman's correlation coefficients between spatial cells of the Creed and Teleost survey biomass estimates. Significant correlations are highlighted in black, not significant or lower than 0 in grey.

APPENDIX 1– SPATIAL GAMMS

Table A.1. 1. Results for the fixed effects of the Bernoulli spatial GAMM using INLA for *Thysanoessa* spp. sampled during the Creed survey. Slope, TPI and SST were standardized (mean ± SD: lSlope=-0.24± 0.98, TPI= -0.31±8.28, SST=13.97±2.19)

	Mean estimates	S.D.	95 % Credible intervals	
Intercept : Year 2008	6.353	0.745	4.899	7.826
Year2009	-0.270	0.952	-2.138	1.608
Year2010	-4.077	0.861	-5.777	-2.388
Year2011	-2.644	0.839	-4.298	-0.997
Year2012	-2.654	0.846	-4.329	-0.999
Year2013	-2.111	0.897	-3.871	-0.343
Year2014	-3.016	0.854	-4.711	-1.348
Year2015	-4.285	0.852	-5.968	-2.613
Year2016	-3.557	0.858	-5.253	-1.878
lSlope.std	0.065	0.079	-0.090	0.220
Depth1	5.529	0.328	4.888	6.174
Depth2	-0.978	0.098	-1.172	-0.787
Depth3	0.056	0.058	-0.059	0.170
TPI.std	**-0.306**	**0.138**	**-0.575**	**-0.032**
SST.std	**6.353**	**0.745**	**4.899**	**7.826**

Table A.1. 2. Results for the fixed effects of the Gamma spatial GAMM using INLA for *Thysanoessa* spp. sampled during the Creed survey. See table A.1.1. for mean and SD values used for standardization.

	Mean estimates	S.D.	95 % Credible intervals	
Intercept: Year 2008	2.117	0.614	0.904	3.319
Year2009	-1.473	0.758	-2.957	0.021
Year2010	-1.045	0.760	-2.535	0.451
Year2011	-0.276	0.726	-1.698	1.156
Year2012	-0.916	0.734	-2.356	0.530
Year2013	-2.523	0.757	-4.006	-1.032
Year2014	-2.431	0.748	-3.897	-0.958
Year2015	-1.823	0.756	-3.302	-0.331
Year2016	-1.721	0.749	-3.190	-0.246
lSlope.std	-0.030	0.030	-0.089	0.029
Depth1	2.777	0.139	2.505	3.049
Depth2	-0.051	0.048	-0.146	0.043
Depth3	-0.055	0.020	-0.095	-0.015
TPI.std	0.086	0.094	-0.099	0.270
SST.std	**2.117**	**0.614**	**0.904**	**3.319**

Table A.1. 3. Results for fixed effects of the spatial GAMM using INLA for *M. norvegica* sampled during the Creed survey. See table A.1.1. for mean and S.D. values used for standardization.

	Mean estimates	**S.D.**	**95 % Credible intervals**	
Intercept: Year 2008	1.420	0.082	1.259	1.581
Year2009	0.113	0.101	-0.085	0.311
Year2010	0.119	0.101	-0.079	0.317
Year2011	0.137	0.096	-0.052	0.327
Year2012	0.119	0.097	-0.072	0.310
Year2013	0.140	0.101	-0.058	0.339
Year2014	-0.162	0.099	-0.356	0.032
Year2015	-0.177	0.100	-0.372	0.019
Year2016	-0.154	0.099	-0.349	0.041
lSlope.std	0.008	0.006	-0.003	0.019
Depth1	0.821	0.024	0.775	0.868
Depth2	-0.201	0.008	-0.217	-0.185
Depth3	0.007	0.004	-0.001	0.014
TPI.std	0.011	0.015	-0.017	0.040
SST.std	**1.420**	**0.082**	**1.259**	**1.581**

Table A.1. 4. Results for fixed effects of the Bernoulli spatial GAMM using INLA for *Thysanoessa* spp. sampled during the Teleost survey. Slope, TPI and SST were standardized (mean ± SD: Slope=-0.85 ± 0.99, TPI= -0.64±5.56, SST=14.89 ± 2.28)

	Mean estimates	**S.D.**	**95 % Credible intervals**	
Intercept: Year 2012	4.757	0.584	3.630	5.928
Year2013	-1.826	0.854	-3.509	-0.143
Year2014	-1.788	0.770	-3.318	-0.283
Year2015	-2.714	0.750	-4.200	-1.243
Year2016	-1.133	0.831	-2.767	0.508
lSlope.std	0.052	0.101	-0.147	0.251
Depth1	3.425	0.519	2.413	4.451
Depth2	-1.423	0.183	-1.787	-1.069
Depth3	0.011	0.064	-0.115	0.138
TPI.std	-0.432	0.264	-0.947	0.092
SST.std	**4.757**	**0.584**	**3.630**	**5.928**

Table A.1. 5. Results for the fixed effects of the Gamma spatial GAMM using INLA for *Thysanoessa* spp. sampled during the Teleost survey. See table A.1.4. for mean and S.D. values used for standardization.

	Mean estimates	**S.D.**	**95 % Credible intervals**	
Intercept: Year 2012	-1.139	0.405	-1.934	-0.341
Year2013	-1.313	0.631	-2.552	-0.071
Year2014	-0.834	0.588	-1.995	0.320
Year2015	-1.369	0.584	-2.520	-0.220
Year2016	-0.241	0.606	-1.430	0.954
lSlope.std	-0.061	0.042	-0.143	0.021
Depth1	1.820	0.289	1.254	2.386
Depth2	0.213	0.104	0.007	0.417
Depth3	-0.092	0.026	-0.144	-0.040
TPI.std	-0.233	0.157	-0.540	0.075
SST.std	**-1.139**	**0.405**	**-1.934**	**-0.341**

Table A.1. 6. Results for fixed effects of the spatial GAMM using INLA for *M. norvegica* sampled during the Teleost survey. See table A.1.4. for mean and S.D. values used for standardization.

	Mean estimates	**S.D.**	**95 % Credible intervals**	
Intercept: Year 2012	1.393	0.047	1.302	1.485
Year2013	-0.221	0.073	-0.363	-0.078
Year2014	-0.494	0.067	-0.626	-0.362
Year2015	-0.394	0.067	-0.526	-0.263
Year2016	-0.257	0.070	-0.394	-0.118
lSlope.std	-0.001	0.005	-0.011	0.009
Depth1	0.678	0.032	0.615	0.741
Depth2	-0.073	0.012	-0.096	-0.049
Depth3	-0.001	0.003	-0.007	0.005
TPI.std	-0.019	0.018	-0.055	0.017
SST.std	**1.393**	**0.047**	**1.302**	**1.485**

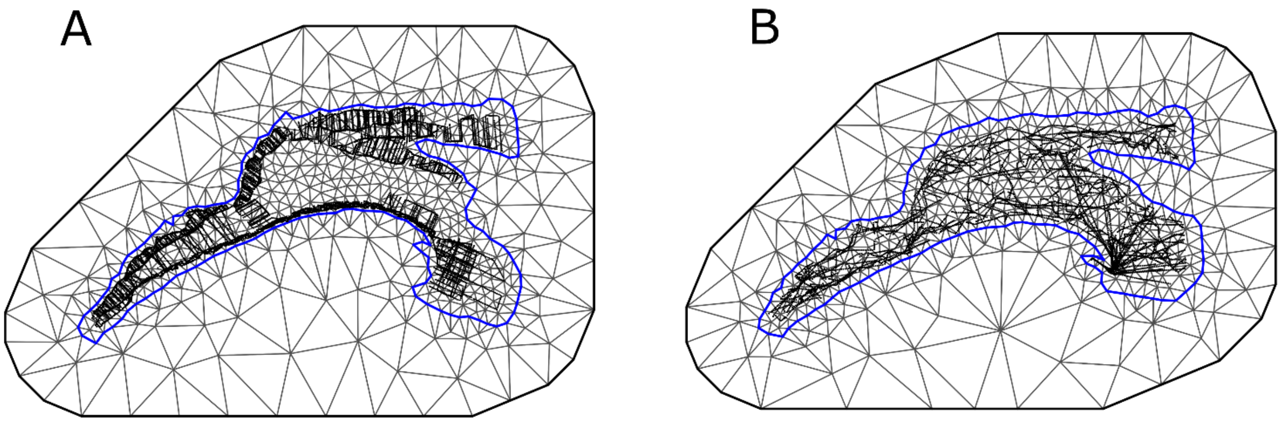

Figure A.1. 1. Mesh used in the spatial GAMMs-INLA analysis for the Creed survey (A) and the Teleost survey (B). The maximum edge between nodes inside the boundary is set to 20 km and the cutoff is 10 km.

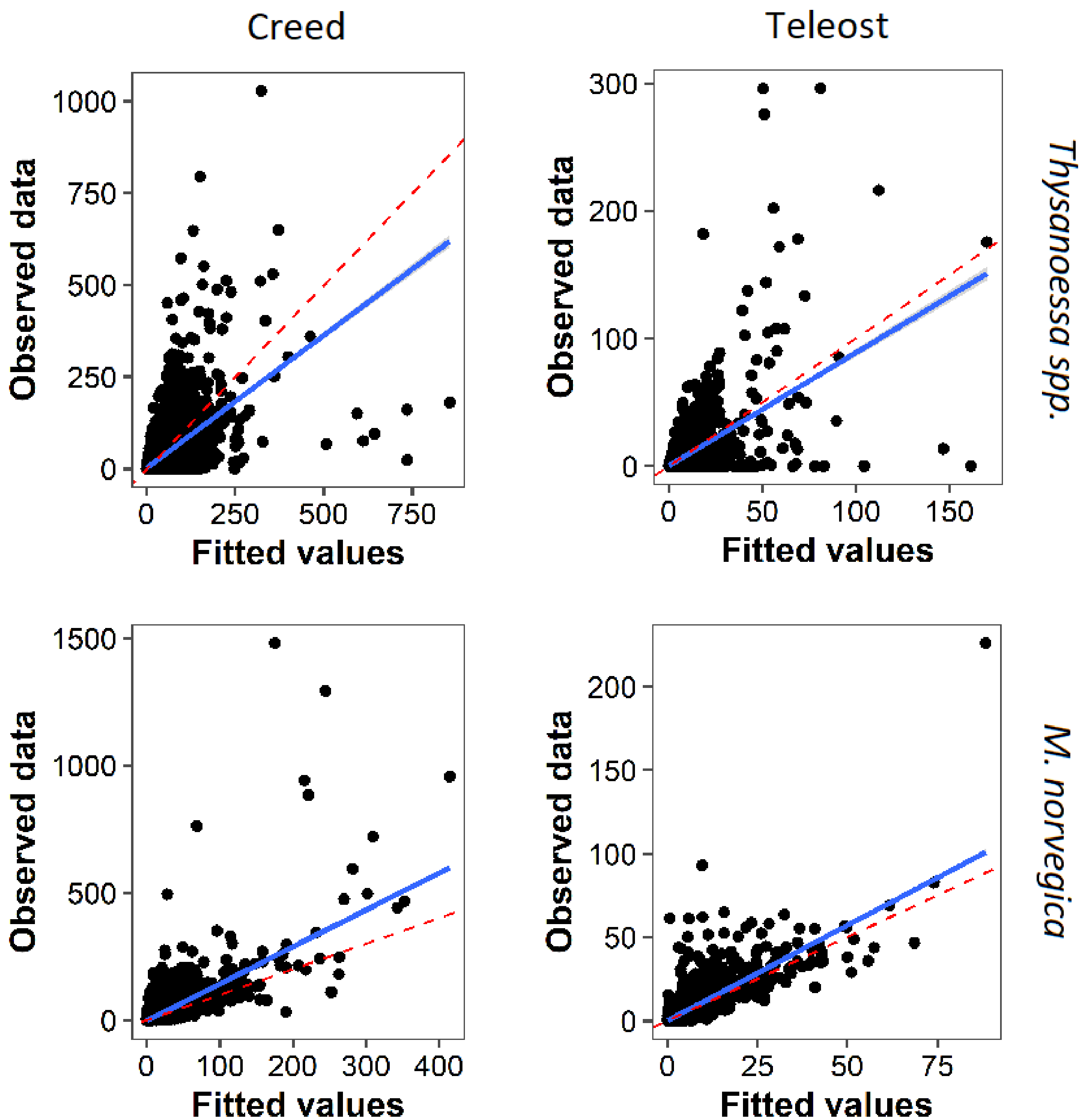

Figure A.1.2. Model validation for spatial GAMMs showing the observed values against fitted values. The red dotted line has a slope of 1 and an intercept of 0 and the blue line is the linear relationship between observed and fitted values.

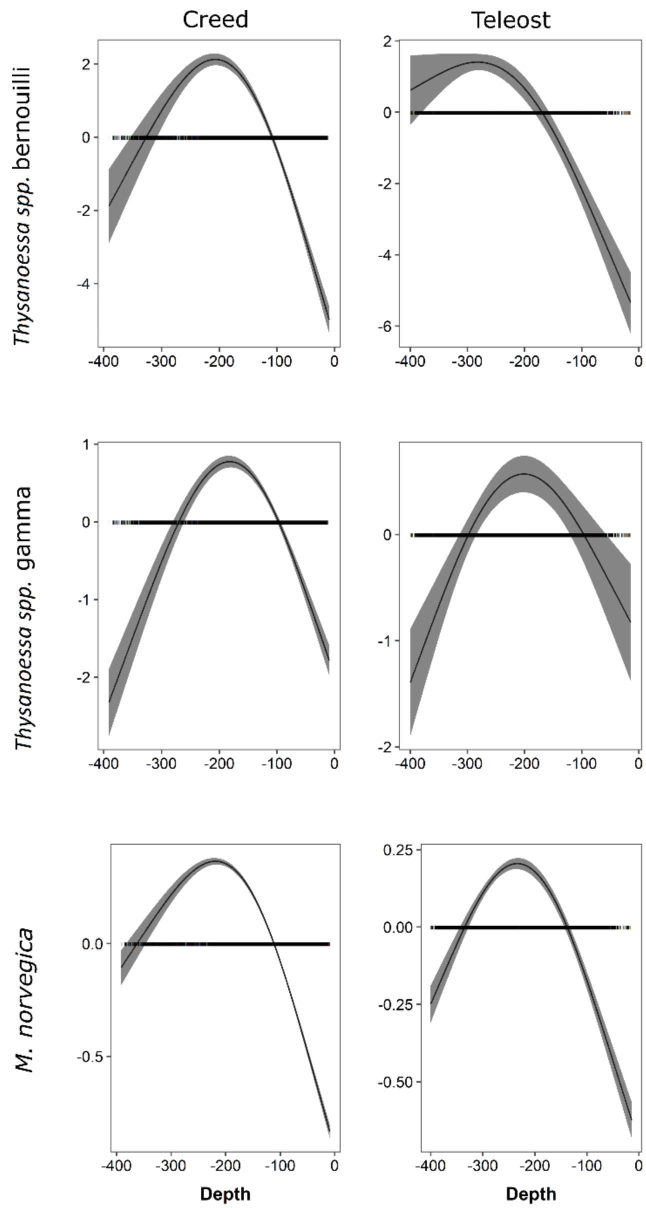

Figure A.1. 3. Partial effect of depth for each taxon and survey for the spatial GAMs using INLA. Vertical bars at a value of 0 indicate data position. The smoother and its 95% confidence intervals are indicated by the black line and the grey shaded area respectively. When the smoother is above (below) the 0 line, it indicates a positive (negative) effect on biomass. Depth is more negative for deeper waters.

APPENDIX 2 – KRIGING

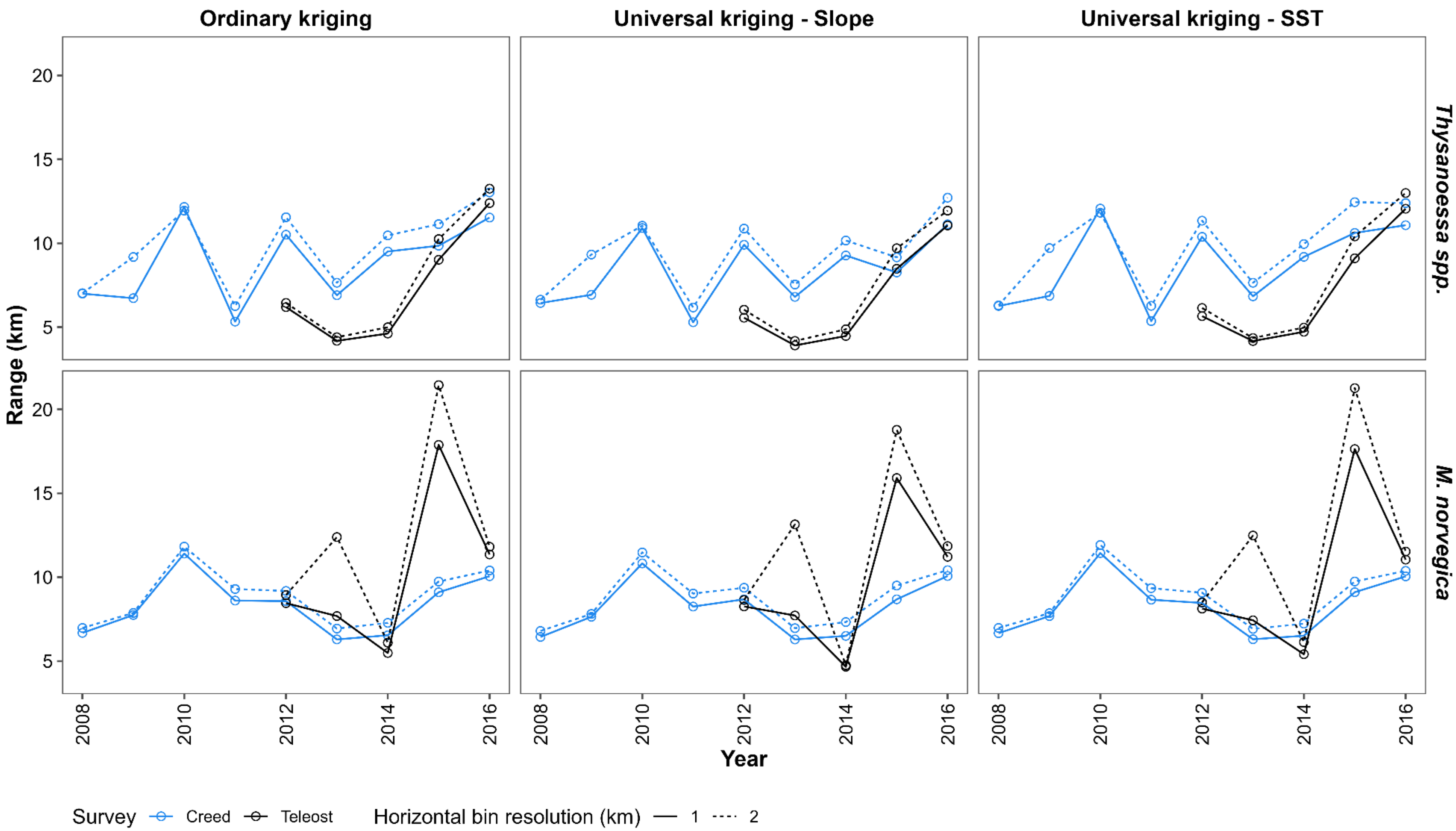

Figure A.2. 1. Effect of binning acoustic data to 1 or 2 km on the estimated variogram range for each kriging method/species/survey.

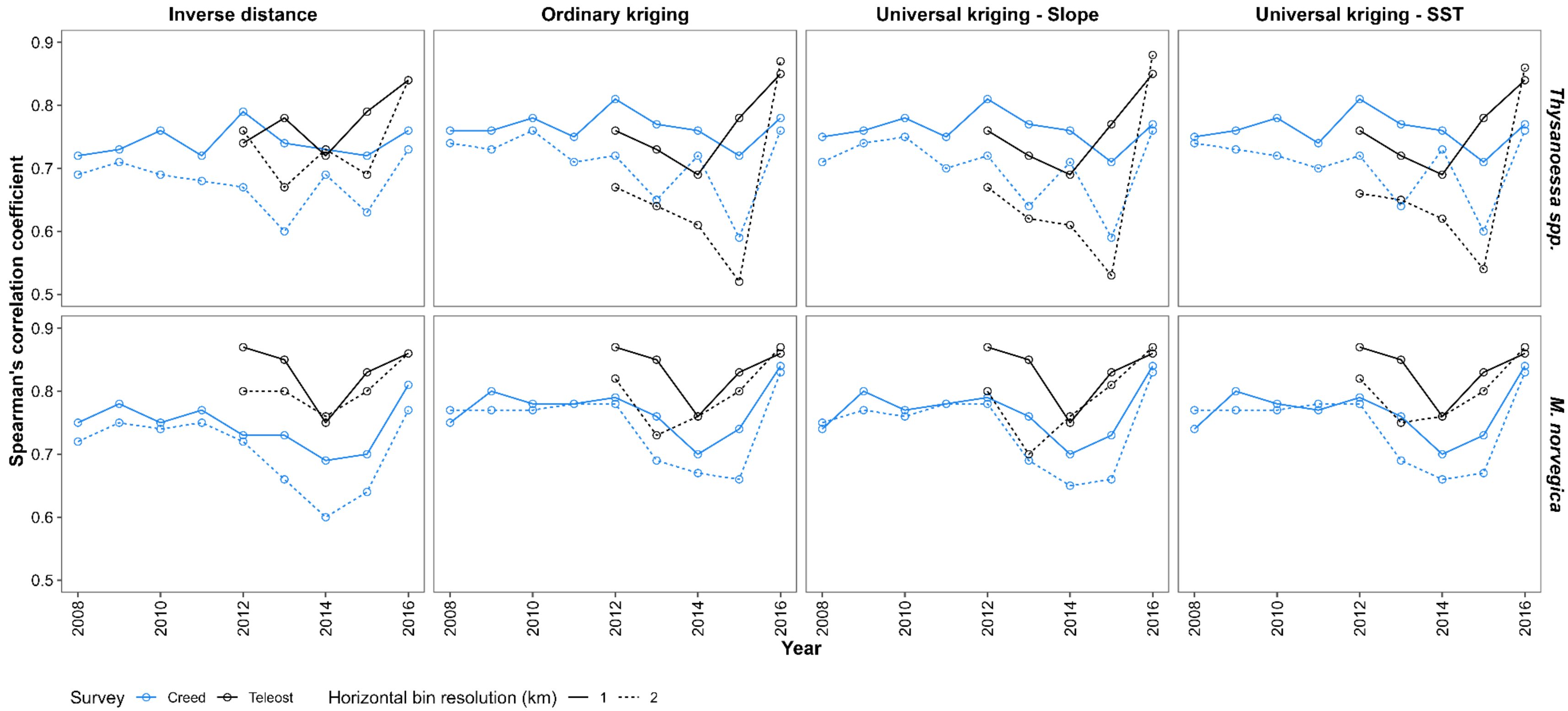

Figure A.2. 2. Effect of binning acoustic data to 1 or 2 km on the spearman's correlation coefficient during cross-validation for each kriging method/species/survey.

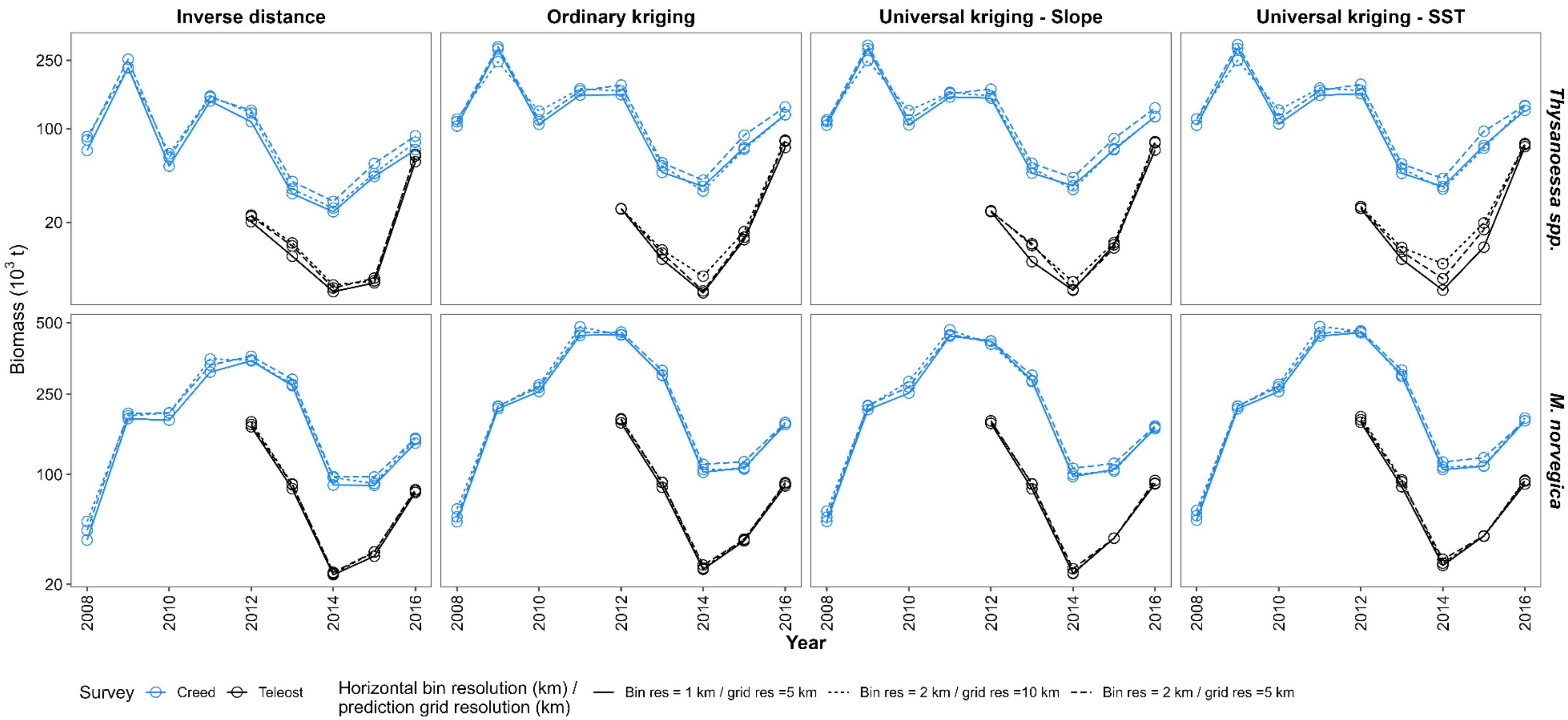

Figure A.2. 3. Effect of binning acoustic data to 1 or 2 km and prediction grid resolution on the estimated biomass for each kriging method/species/survey.

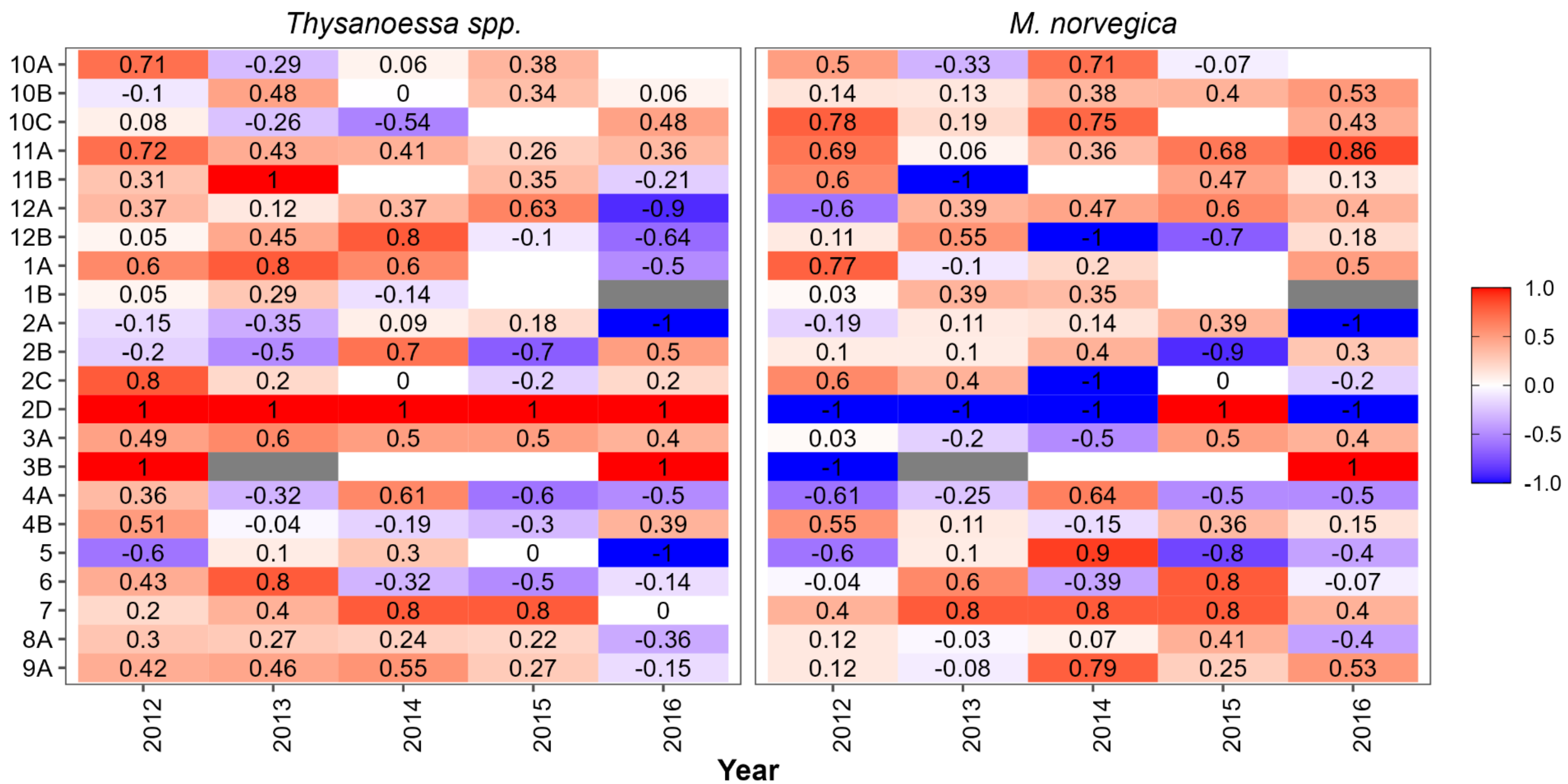

Figure A.2. 4. Spearman's correlation coefficients between spatial cells of the Creed and Teleost survey biomass estimated with ordinary kriging for each stratum.

APPENDIX 3 – BIOMASS ESTIMATES

Table A.3. 1. Survey-based biomass estimates for the Creed survey in 2010. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates.

2010				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1B-Pentecôte	973.2	6	0.078	47.31	46040.1	11229.4	24.4	42.77	41623.7	8417.7	20.2
2A-Baie Comeau	1065.2	6	0.064	11.58	12335.9	7049.6	57.1	17.70	18850.5	6602.0	35.0
2 B-Forestville	512.5	3	0.057	46.70	23934.7	20843.5	87.1	31.39	16085.9	5183.1	32.2
2D-Matane	306.8	2	0.104	37.35	11460.2	7217.8	63.0	21.17	6494.1	2389.9	36.8
3A-Les Escoumins	807.1	4	0.071	70.85	57179.4	36206.0	63.3	85.56	69053.3	18880.8	27.3
5-Cap Chat	403.6	3	0.113	8.99	3628.4	3164.5	87.2	12.90	5206.1	2113.7	40.6
6-Mont-Louis	548.0	3	0.082	3.26	1783.8	323.3	18.1	38.60	21152.6	5783.6	27.3
7-R. au Renard	452.4	3	0.094	2.12	958.2	367.0	38.3	14.04	6350.0	3538.6	55.7
8A-Gaspé	2575.3	3	0.055	9.65	24838.7	6618.8	26.6	20.33	52349.2	5882.7	11.2
9A-Hongudo Sud	1386.3	1	0.012	0.19	268.2	0.0	0.0	12.55	17403.8	0.0	0.0
9B-Honguedo	3239.0	1	0.013	0.98	3183.0	0.0	0.0	17.28	55976.4	0.0	0.0
10A-Sud Anticosti	1069.9	4	0.05	2.28	2443.8	2076.3	85.0	4.65	4978.4	777.6	15.6
10B-Banc Parent	1525.4	4	0.051	2.56	3911.1	1116.8	28.6	15.84	24162.9	2896.5	12.0
10C-Sept-Iles	1028.7	3	0.051	8.06	8292.3	3506.4	42.3	14.14	14541.1	2205.6	15.2
11A-N.O. Anticosti	1497.5	6	0.06	11.91	17832.5	5590.3	31.3	30.14	45133.9	11543.5	25.6
11 B-Cod Bank	1208.1	5	0.063	32.74	39551.4	10007.7	25.3	6.73	8127.4	1552.0	19.1
11C-Baie de Moisie	1158.5	2	0.045	34.19	39610.2	18354.4	46.3	13.97	16179.0	476.1	2.9
Total/Average	**19757.5**	**59**	**0.051**	**14.87**	**293800.0**	**50134.0**	**17.1**	**17.73**	**350288.0**	**27171.7**	**7.8**

Table A.3. 2. Survey-based biomass estimates for the Creed survey in 2011. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates. Stratum 8B and 9B were removed from comparison analyses.

2011				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	632.6	3	0.074	20.941	13247.0	2254.6	17.0	86.825	54925.5	30931.2	56.3
1B-Pentecôte	973.2	6	0.093	8.454	8227.1	2173.9	26.4	113.207	110172.0	65294.1	59.3
2A-Baie Comeau	1065.2	7	0.075	7.852	8363.7	2143.0	25.6	11.122	11847.4	3330.5	28.1
2 B-Forestville	512.5	4	0.073	43.115	22096.7	7176.7	32.5	27.043	13859.5	4287.3	30.9
2 CCC-Rimouski	213.6	7	0.146	20.729	4428.5	1302.3	29.4	15.379	3285.6	1178.3	35.9
2D-Matane	306.8	5	0.082	13.467	4131.8	1494.4	36.2	25.389	7789.8	3871.7	49.7
3A-Les Escoumins	807.1	4	0.061	39.932	32229.1	4092.5	12.7	69.322	55949.9	22874.1	40.9
3B-Rive sud	438.5	4	0.071	1.58	692.8	303.0	43.7	0.672	294.5	225.7	76.6
4B-Estuaire	3992.8	4	0.025	9.155	36554.2	10805.2	29.6	30.118	120253.0	54185.9	45.1
5-Cap Chat	403.6	6	0.073	11.358	4584.3	1091.0	23.8	21.793	8795.7	2658.7	30.2
6-Mont-Louis	548	6	0.073	6.982	3826.2	1607.6	42.0	7.997	4382.4	1982.3	45.2
7-R. au Renard	452.4	6	0.073	8.67	3922.4	988.0	25.2	5.061	2289.7	465.5	20.3
8A-Gaspé	2575.3	4	0.06	7.121	18340.0	2773.6	15.1	45.616	117475.0	35079.2	29.9
8B-Banc de l'Orphelin	2553.9	4	0.056	11.779	30082.8	24429.4	81.2	17.562	44852.2	25120.9	56.0
9A-Hongudo Sud	1386.3	4	0.046	3.841	5324.3	1818.3	34.2	3.79	5254.7	1225.5	23.3
9B-Honguedo	3239	1	0.012	1.919	6214.6	0.0	0.0	6.645	21523.0	0.0	0.0
10A-Sud Anticosti	1069.9	4	0.051	1.017	1088.3	153.5	14.1	3.254	3481.6	327.4	9.4
10B-Banc Parent	1525.4	5	0.064	6.378	9729.1	2214.2	22.8	7.606	11602.2	3093.0	26.7
11A-N.O. Anticosti	1497.5	2	0.024	4.436	6643.1	4107.0	61.8	6.554	9815.2	7209.0	73.4
11B-N.E anticosti	2376.9	4	0.046	7.249	17229.2	4642.3	26.9	23.789	56544.3	17090.8	30.2
12 A-Cod Bank	1208.1	2	0.034	7.485	9043.1	2344.7	25.9	13.014	15722.8	10462.6	66.5
12B-Baie de Moisie	1158.5	4	0.073	7.467	8650.4	1993.1	23.0	17.543	20323.7	3455.0	17.0
Total/Average	**28937.3**	**96**	**0.049**	**8.585**	**248434.0**	**29475.3**	**11.9**	**23.462**	**678919.0**	**105236.7**	**15.5**

Table A.3. 3. Survey-based biomass estimates for the Creed survey in 2012. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates.

2012				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	1092.9	6	0.079	24.718	27014.6	7663.2	28.4	9.726	10630.1	1229.2	11.6
1B-Pentecôte	973.2	6	0.08	15.986	15557.7	3410.8	21.9	9.198	8951.3	1445.2	16.1
2A-Baie Comeau	1065.2	7	0.076	11.139	11864.9	1572.4	13.3	16.35	17416.2	4659.3	26.8
2 B-Forestville	512.5	4	0.076	25.457	13046.8	4055.9	31.1	41.141	21084.9	6068.2	28.8
2 C-Rimouski	213.6	5	0.107	32.44	6930.4	1659.8	23.9	53.401	11408.5	1366.0	12.0
2D-Matane	306.8	5	0.074	31.924	9795.0	3415.6	34.9	26.513	8134.6	2673.5	32.9
3A-Les Escoumins	807.1	4	0.071	35.808	28900.3	10975.8	38.0	109.256	88180.4	25502.8	28.9
3B-Rive sud	438.5	4	0.076	4.826	2116.3	1790.3	84.6	7.576	3321.9	2736.7	82.4
4A-Chenal	903.5	2	0.057	0.726	656.0	532.4	81.2	7.326	6619.1	1936.9	29.3
4B-Estuaire	3992.8	2	0.012	19.818	79129.2	68619.1	86.7	41.715	166558.0	102560.5	61.6
5-Cap Chat	403.6	6	0.088	28.966	11690.9	3757.5	32.1	35.3	14247.1	3958.4	27.8
6-Mont-Louis	548	6	0.082	6.13	3359.3	1159.1	34.5	12.124	6643.8	519.7	7.8
7-R. au Renard	452.4	6	0.078	4.376	1979.7	1089.0	55.0	8.802	3982.0	324.1	8.1
8A-Gaspé	2575.3	3	0.045	10.75	27685.0	7453.2	26.9	7.901	20346.5	5953.9	29.3
9A-Hongudo Sud	1386.3	3	0.038	0.615	853.2	199.3	23.4	10.658	14775.2	2649.4	17.9
9B-Honguedo	3239	1	0.016	0.347	1125.3	0.0	0.0	11.192	36249.7	0.0	0.0
10A-Sud Anticosti	1069.9	3	0.041	0	0.0	0.0		9.998	10696.6	2154.5	20.1
10B-Banc Parent	1525.4	3	0.048	0	0.0	0.0		22.503	34326.3	5079.9	14.8
11A-N.O. Anticosti	1497.5	6	0.061	10.064	15071.2	4740.0	31.5	19.763	29595.5	5223.7	17.7
11B-N.E anticosti	2376.9	5	0.063	5.611	13336.9	5136.1	38.5	8.163	19403.3	3821.4	19.7
12 A-Cod Bank	1208.1	5	0.072	20.16	24356.1	10060.5	41.3	10.625	12836.7	2883.7	22.5
12B-Baie de Moisie	1251.6	4	0.06	35.097	43927.4	17587.4	40.0	11.782	14745.9	1576.1	10.7
Total/Average	**27840.2**	**96**	**0.049**	**12.115**	**337271.0**	**73944.9**	**21.9**	**18.818**	**523904.0**	**106738.4**	**20.4**

Table A.3.3 (continued). Survey-based biomass estimates for the Creed survey in 2012. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates.

2012				Euphausiids (*T. inermis*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %
1 A-Port Cartier	1092.9	6	0.079	12.208	13342.1	7173.3	53.8
1B-Pentecôte	973.2	6	0.08	15.986	15557.7	3410.8	21.9
2A-Baie Comeau	1065.2	7	0.076	0	0.0	0.0	
2 B-Forestville	512.5	4	0.076	0	0.0	0.0	
2 C-Rimouski	213.6	5	0.107	0	0.0	0.0	
2D-Matane	306.8	5	0.074	0	0.0	0.0	
3A-Les Escoumins	807.1	4	0.071	0	0.0	0.0	
3B-Rive sud	438.5	4	0.076	0	0.0	0.0	
4A-Chenal	903.5	2	0.057	0	0.0	0.0	
4B-Estuaire	3992.8	2	0.012	0	0.0	0.0	
5-Cap Chat	403.6	6	0.088	0	0.0	0.0	
6-Mont-Louis	548	6	0.082	0	0.0	0.0	
7-R. au Renard	452.4	6	0.078	0	0.0	0.0	
8A-Gaspé	2575.3	3	0.045	0	0.0	0.0	
9A-Hongudo Sud	1386.3	3	0.038	0	0.0	0.0	
9B-Honguedo	3239	1	0.016	0.347	1125.3	0.0	0.0
10A-Sud Anticosti	1069.9	3	0.041	3.233	3458.8	1895.5	54.8
10B-Banc Parent	1525.4	3	0.048	20.019	30537.0	7757.1	25.4
11A-N.O. Anticosti	1497.5	6	0.061	0	0.0	0.0	
11B-N.E anticosti	2376.9	5	0.063	0	0.0	0.0	
12 A-Cod Bank	1208.1	5	0.072	0	0.0	0.0	
12B-Baie de Moisie	1251.6	4	0.06	0	0.0	0.0	
Total/Average	**27840.2**	**96**	**0.049**	**2.259**	**62895.7**	**11263.0**	**17.9**

Table A.3. 4. Survey-based biomass estimates for the Creed survey in 2013. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates.

2013				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	632.6	4	0.095	14.821	9376.0	1615.4	17.2	21.517	13611.9	5819.0	42.7
1B-Pentecôte	973.2	6	0.087	7.798	7588.7	2383.4	31.4	29.811	29012.3	20621.0	71.1
2A-Baie Comeau	1065.2	7	0.07	11.168	11896.3	2821.1	23.7	10.534	11221.0	2066.7	18.4
2 B-Forestville	512.5	4	0.074	8.403	4306.7	1213.2	28.2	30.669	15717.9	6364.0	40.5
2 C-Rimouski	213.6	6	0.129	4.263	910.7	220.6	24.2	12.209	2607.8	585.6	22.5
2D-Matane	306.8	5	0.087	17.599	5399.5	1795.8	33.3	17.915	5496.3	1350.1	24.6
3A-Les Escoumins	807.1	4	0.07	17.345	13999.1	3824.3	27.3	146.579	118303.0	45651.8	38.6
3B-Rive Sud	438.5	4	0.066	4.189	1836.9	1019.9	55.5	0.356	155.9	121.1	77.7
4B-Estuaire	3992.8	4	0.026	7.927	31649.3	8725.6	27.6	31.789	126927.0	33636.6	26.5
5-Cap Chat	403.6	5	0.062	25.176	10161.1	2677.1	26.3	10.651	4298.6	1914.9	44.5
6-Mont-Louis	548	5	0.064	11.667	6393.7	1377.1	21.5	3.558	1949.9	456.7	23.4
7-R. au Renard	452.4	6	0.076	7.886	3567.4	1184.4	33.2	5.274	2386.0	661.2	27.7
8A-Gaspé	2575.3	3	0.044	25.951	66830.5	36037.2	53.9	30.144	77628.8	13965.8	18.0
9A-Hongudo Sud	1386.3	1	0.012	2.329	3229.0	0.0	0.0	15.54	21543.3	0.0	0.0
9B-Honguedo	3239	1	0.013	3.074	9957.3	0.0	0.0	13.667	44267.6	0.0	0.0
10A-Sud Anticosti	1069.9	3	0.029	2.129	2277.9	706.0	31.0	6.69	7157.6	3798.2	53.1
10B-Banc Parent	1525.4	4	0.058	13.044	19897.9	10240.4	51.5	23.106	35246.3	27132.9	77.0
10C-Sept-Iles	1028.7	4	0.067	4.816	4954.6	2345.3	47.3	17.007	17495.3	7424.9	42.4
11A-N.O. Anticosti	1497.5	5	0.055	12.086	18098.9	4057.7	22.4	2.898	4339.2	1439.8	33.2
12 A-Cod Bank	1208.1	4	0.052	19.184	23175.7	12727.0	54.9	5.024	6069.2	2855.8	47.1
12B-Baie de Moisie	1158.5	4	0.072	22.646	26235.0	6968.3	26.6	8.918	10332.1	2927.3	28.3
Total/Average	**25035**	**89**	**0.047**	**10.727**	**268556.0**	**41950.1**	**15.6**	**19.571**	**489958.0**	**68887.2**	**14.1**

Table A.3.4 (continued) Survey-based biomass estimates for the Creed survey in 2013. Estimates shaded in grey are not included in the total since only 1 transect by stratum was measured and there is no measure of uncertainty for these estimates.

2013				Euphausiids (*T. inermis*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %
1 A-Port Cartier	632.6	4	0.095	14.821	9376.0	1615.4	17.2
1B-Pentecôte	973.2	6	0.087	7.798	7588.7	2383.4	31.4
2A-Baie Comeau	1065.2	7	0.07	0	0.0	0.0	
2 B-Forestville	512.5	4	0.074	0	0.0	0.0	
2 C-Rimouski	213.6	6	0.129	0	0.0	0.0	
2D-Matane	306.8	5	0.087	0	0.0	0.0	
3A-Les Escoumins	807.1	4	0.07	0	0.0	0.0	
3B-Rive Sud	438.5	4	0.066	0	0.0	0.0	
4B-Estuaire	3992.8	4	0.026	0	0.0	0.0	
5-Cap Chat	403.6	5	0.062	0	0.0	0.0	
6-Mont-Louis	548	5	0.064	0	0.0	0.0	
7-R. au Renard	452.4	6	0.076	7.886	3567.4	1184.4	33.2
8A-Gaspé	2575.3	3	0.044	0	0.0	0.0	
9A-Hongudo Sud	1386.3	1	0.012	2.329	3229.0	0.0	0.0
9B-Honguedo	3239	1	0.013	3.074	9957.3	0.0	0.0
10A-Sud Anticosti	1069.9	3	0.029	2.129	2277.9	706.0	31.0
10B-Banc Parent	1525.4	4	0.058	0	0.0	0.0	
10C-Sept-Iles	1028.7	4	0.067	4.816	4954.6	2345.3	47.3
11A-N.O. Anticosti	1497.5	5	0.055	0	0.0	0.0	
12 A-Cod Bank	1208.1	4	0.052	0	0.0	0.0	
12B-Baie de Moisie	1158.5	4	0.072	0	0.0	0.0	
Total/Average	**25035**	**89**	**0.047**	**1.109**	**27764.8**	**3961.3**	**14.3**

Table A.3. 5. Survey-based biomass estimates for the Creed survey in 2014.

2014				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	632.6	4	0.083	20.793	13153.4	4250.1	32.3	8.673	5486.5	1453.6	26.5
1B-Pentecôte	973.2	5	0.067	22.192	21597.3	10752.5	49.8	6.245	6077.9	1364.7	22.5
2A-Baie Comeau	1065.2	7	0.07	8.838	9414.2	4319.0	45.9	7.246	7717.9	1579.1	20.5
2 B-Forestville	512.5	7	0.134	5.589	2864.3	1279.4	44.7	5.623	2881.9	612.7	21.3
2 C-Rimouski	213.6	6	0.129	0.791	169.0	51.9	30.7	3.249	694.0	146.6	21.1
2D-Matane	306.8	5	0.086	4.322	1326.1	557.4	42.0	5.804	1780.6	662.2	37.2
3A-Les Escoumins	807.1	6	0.105	3.306	2668.5	1897.3	71.1	28.5	23002.6	9845.0	42.8
3B-Rive Sud	438.5	4	0.066	0.388	170.3	86.0	50.5	7.021	3078.8	1302.5	42.3
4A-Chenal	903.5	2	0.057	0.386	348.9	244.5	70.1	1.654	1494.8	757.0	50.6
4B-Estuaire	3992.8	2	0.009	0.464	1854.3	1361.2	73.4	2.575	10282.7	5189.4	50.5
5-Cap Chat	403.6	5	0.063	5.904	2383.0	875.0	36.7	6.638	2679.1	441.6	16.5
6-Mont-Louis	548	5	0.067	1.275	698.7	213.8	30.6	7.078	3879.0	662.0	17.1
7-R. au Renard	452.4	6	0.082	1.93	873.2	549.0	62.9	6.336	2866.4	660.1	23.0
8A-Gaspé	2575.3	3	0.044	4.679	12049.0	1343.0	11.1	7.592	19551.1	2521.3	12.9
10A-Sud Anticosti	1069.9	3	0.035	0.011	11.2	8.2	73.1	1.415	1514.3	371.1	24.5
10B-Banc Parent	1525.4	3	0.052	1.033	1575.1	408.0	25.9	4.279	6526.9	396.4	6.1
10C-Sept-Iles	1028.7	4	0.06	8.888	9143.0	6216.2	68.0	4.815	4953.1	1975.3	39.9
11 A-NO Anticosti	1497.5	4	0.042	4.432	6637.2	1774.8	26.7	7.726	11569.1	2879.8	24.9
12 A-Cod Bank	1208.1	4	0.053	6.832	8253.3	2433.6	29.5	6.306	7617.9	1223.8	16.1
12B-Baie de Moisie	1158.5	4	0.073	20.867	24174.5	5790.3	24.0	7.983	9248.2	2138.5	23.1
Total/Average	**21313.2**	**89**	**0.053**	**5.6**	**119364.0**	**15624.6**	**13.1**	**6.236**	**132902.0**	**12625.9**	**9.5**

Table A.3. 6. Survey-based biomass estimates for the Creed survey in 2015.

2015				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
2 A-Baie Comeau	1065.2	7	0.076	7.8700	8383.3	3039.1	36.3	13.3880	14261.4	3062.8	21.5
2 B-Forestville	512.5	4	0.074	5.6820	2912.1	1072.9	36.8	7.3970	3791.5	707.2	18.7
2 C-Rimouski	213.6	7	0.133	0.1700	36.2	19.7	54.4	1.8580	396.8	64.1	16.2
2D-Matane	306.8	5	0.079	1.3670	419.4	353.4	84.3	1.7470	536.1	191.4	35.7
3A-Les Escoumins	807.1	5	0.100	2.1960	1772.1	1082.4	61.1	7.0870	5720.5	2473.0	43.2
3B-Rive Sud	438.5	4	0.055	0.0640	28.2	19.0	67.6	4.1480	1819.1	754.7	41.5
4B-Estuaire	3992.8	4	0.026	0.5120	2045.6	1016.3	49.7	22.2520	88848.0	29490.6	33.2
5-Cap Chat	403.6	6	0.083	4.6320	1869.4	569.7	30.5	4.3730	1765.0	414.4	23.5
6-Mont Louis	548	6	0.075	4.0570	2223.4	830.1	37.3	10.3050	5646.9	872.0	15.4
7-R. au Renard	452.4	6	0.071	38.8390	17572.3	9188.2	52.3	29.6670	13422.8	4631.2	34.5
8A-Gaspé	2575.3	4	0.065	37.9070	97624.4	56819.5	58.2	19.6120	50508.0	28816.0	57.1
10A-sud Anticosti	1069.9	2	0.023	0.2770	296.0	22.6	7.6	1.9970	2136.3	845.4	39.6
10B-Banc Parent	1525.4	3	0.05	2.5640	3910.7	1805.1	46.2	4.1720	6363.8	2036.2	32.0
11A-NO Anticosti	1497.5	4	0.043	18.4270	27594.6	11915.7	43.2	7.9640	11926.8	3359.5	28.2
11B-NE Anticosti	2376.9	4	0.049	16.7980	39926.9	14023.1	35.1	9.7010	23058.5	8839.4	38.3
12 A-Cod Bank	1205.5	5	0.068	29.6850	35785.3	24245.0	67.8	6.8470	8254.7	1833.7	22.2
12B-Baie de Moisie	1158.5	2	0.039	7.5650	8763.8	1651.7	18.8	6.2200	7205.6	766.1	10.6
Total/Average	**20149.7**	**78**	**0.053**	**12.4650**	**251163.0**	**65261.4**	**26.0**	**12.1920**	**245661.0**	**42863.5**	**17.4**

Table A.3. 7. Survey-based biomass estimates for the Creed survey in 2016.

2016				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	632.7	4	0.09	58.0040	36696.3	15853.8	43.2	6.926	4381.9	995.1	22.7
2A-Baie Comeau	1065.2	4	0.042	17.9540	19124.4	13831.5	72.3	16.316	17380.0	2861.6	16.5
2 B-Forestville	512.5	3	0.057	20.1680	10337.2	2576.8	24.9	8.214	4210.1	478.2	11.4
2 C-Rimouski	213.6	4	0.087	52.7010	11256.9	7828.0	69.5	17.426	3722.2	1557.5	41.8
2D-Matane	306.8	5	0.081	10.7230	3290.2	3243.7	98.6	13.831	4243.6	1951.4	46.0
3A-Les Escoumins	807.1	4	0.066	77.0820	62216.3	56792.7	91.3	67.697	54641.3	30498.7	55.8
3B-Rive Sud	438.5	4	0.071	0.0860	37.7	30.3	80.2	1.445	633.8	508.3	80.2
4B-Estuaire	3992.8	4	0.026	7.7800	31062.4	8930.8	28.8	14.316	57161.8	6459.4	11.3
5-Cap Chat	403.6	4	0.05	6.2100	2506.3	1054.5	42.1	14.14	5706.2	1341.7	23.5
6-Mont-Louis	548	4	0.053	19.6750	10781.1	4655.6	43.2	94.064	51544.1	3673.5	7.1
7-R. au Renard	452.4	4	0.051	5.5950	2531.4	1068.0	42.2	60.789	27503.3	14442.1	52.5
8A-Gaspé	2575.3	4	0.056	21.0750	54274.4	27430.0	50.5	9.43	24285.7	7765.2	32.0
9A-Honguedo	1386.3	3	0.038	0.8260	1144.6	1006.7	88.0	11.516	15965.4	8483.7	53.1
10B-Banc Parent	1525.4	4	0.053	2.6680	4070.2	1521.4	37.4	8.385	12790.6	3533.2	27.6
10C-Sept-Iles	1028.7	4	0.065	14.7520	15174.8	6718.4	44.3	16.734	17213.7	2666.0	15.5
11A-NO Anticosti	1497.5	6	0.063	6.1860	9263.7	4589.7	49.5	12.017	17995.5	7401.5	41.1
11B-NE Anticosti	2376.9	4	0.054	14.5950	34691.2	11091.8	32.0	14.572	34636.1	12578.3	36.3
12 A-Cod Bank	1205.5	5	0.069	30.8870	37234.8	6068.5	16.3	7.914	9540.2	1878.0	19.7
12B-Baie de Moisie	1158.5	4	0.058	34.7060	40207.3	10828.4	26.9	9.299	10773.2	4005.4	37.2
Total/Average	**22127.4**	**78**	**0.052**	**17.4400**	**385901.0**	**70350.8**	**18.2**	**16.917**	**374328.0**	**39951.1**	**10.7**

Table A.3. 8. Survey-based biomass estimates for the Creed survey in 2017.

2017				Arctic krill (*T. raschii*)				Northern krill (*M. norvegica*)			
Stratum name	Stratum Area (km2)	Number of Transects	Sampling Density (km/km2)	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
					Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A-Port Cartier	632.7	4	0.087	77.4330	48988.1	18443.8	37.6	20.2160	12789.5	3780.8	29.6
1B-Pentecote	632.7	5	0.106	49.0540	31034.1	15967.9	51.5	16.2570	10284.8	1549.3	15.1
2A-Baie Comeau	1065.2	6	0.049	40.2360	42858.8	18530.2	43.2	11.7410	12506.2	2960.4	23.7
2 B-Forestville	512.5	4	0.076	48.9830	25105.6	6941.1	27.6	23.2810	11932.3	3333.2	27.9
2 C-Rimouski	213.6	6	0.136	14.5120	3099.7	1559.4	50.3	15.8870	3393.4	640.6	18.9
2D-Matane	306.8	5	0.079	35.7390	10965.5	10504.8	95.8	12.6840	3891.7	1308.1	33.6
3A-Les Escoumins	807.1	4	0.069	50.3480	40638.1	16804.6	41.4	38.7600	31284.9	7323.5	23.4
4B-Estuaire	3992.8	4	0.027	6.0380	24106.7	11130.8	46.2	19.2030	76675.7	9382.1	12.2
5-Cap Chat	403.6	5	0.07	7.7770	3138.4	1017.4	32.4	12.3120	4968.7	1088.0	21.9
6-Mont Louis	548	5	0.064	20.8010	11398.4	4957.0	43.5	45.0450	24683.5	6271.6	25.4
7-R. au Renard	452.4	6	0.073	19.1050	8644.1	8014.7	92.7	19.1190	8650.4	4261.5	49.3
8A-Gaspé	2575.3	3	0.035	24.2080	62345.1	21078.5	33.8	16.6670	42922.6	21035.4	49.0
9A-Honguedo Sud	1386.3	3	0.04	0.8930	1237.7	999.7	80.8	6.1930	8586.1	277.5	3.2
10B-Banc Parent	1525.4	3	0.034	40.4190	61655.1	21153.6	34.3	23.9420	36521.4	11904.2	32.6
12B-Baie de Moisie	1158.5	4	0.058	103.7640	120212.0	40836.6	34.0	19.0120	22025.8	3970.3	18.0
Total/Average	**16212.9**	**67**	**0.049**	**30.5580**	**495427.0**	**64467.2**	**13.0**	**19.1890**	**311117.0**	**28966.6**	**9.3**

Table A.3. 9. Model-based biomass estimates using ordinary kriging for the Creed survey in 2008.

2008	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	18.77	11877.8	4614.2	38.8	6.91	4374.1	2804.8	64.1
1B	38.86	37821.6	31211.3	82.5	19.61	19080.6	22303.0	116.9
2A	12.28	13075.1	13198.4	100.9	13.63	14517.9	9059.3	62.4
2B	28.60	14656.1	21666.3	147.8	11.79	6043.6	4062.1	67.2
2C								
2D								
3A								
3B								
4A								
4B								
5	11.10	4480.3	2528.9	56.4	6.21	2506.9	515.5	20.6
6	51.92	28448.6	13593.2	47.8	22.34	12239.2	3677.3	30.0
7	10.06	4550.7	4439.0	97.5	10.67	4827.5	5404.0	111.9
8A								
9A								
10A								
10B								
10C								
11A								
11B								
12A								
12B								
Total/ Average	**24.51**	**114910.3**	**43011.9**	**37.4**	**13.02**	**63589.8**	**25433.3**	**40.0**

Table A.3. 10. Model-based biomass estimates using ordinary kriging for the Creed survey in 2009.

2009	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	6.88	4353.5	1851.4	42.5	9.27	5863.4	5266.1	89.8
1B	35.80	34841.5	20100.0	57.7	21.15	20579.8	17498.2	85.0
2A	7.61	8108.3	11091.1	136.8	7.55	8042.6	8751.9	108.8
2B	6.69	3430.0	3114.0	90.8	6.19	3174.0	2228.9	70.2
2C	4.74	1984.7	1694.4	85.4	7.31	3063.4	577.6	18.9
2D								
3A	3.26	2627.8	2506.9	95.4	12.98	10474.1	7553.2	72.1
3B	0.96	420.6	495.4	117.8	3.16	1387.5	781.6	56.3
4A								
4B								
5	4.66	1882.3	2745.8	145.9	11.05	4459.5	482.6	10.8
6	1.95	1067.8	340.1	31.8	8.12	4451.2	1144.8	25.7
7	14.28	6458.6	6662.6	103.2	15.11	6836.6	5774.4	84.5
8A	65.14	167746.3	103431.3	61.7	29.99	77240.6	60241.4	78.0
9A	2.90	4015.3	6719.6	167.4	11.50	15946.6	6742.6	42.3
10A	0.20	209.1	238.6	114.1	13.48	14420.6	3137.2	21.8
10B	1.58	2413.8	2346.5	97.2	21.84	33318.3	13410.8	40.3
10C	6.12	6299.3	4372.9	69.4	9.51	9785.5	4144.2	42.4
11A								
11B								
12A								
12B								
Total/ Average	**10.85**	**245858.8**	**106627.7**	**43.4**	**12.55**	**219043.6**	**66254.9**	**30.2**

Table A.3. 11. Model-based biomass estimates using ordinary kriging for the Creed survey in 2010.

2010	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A								
1B	23.54	22914.3	21348.4	93.2	24.66	23997.8	17777.6	74.1
2A	9.66	10287.9	19805.9	192.5	15.99	17033.4	7408.8	43.5
2B	54.39	27875.7	32305.8	115.9	32.35	16578.6	13901.8	83.9
2C								
2D	29.00	8898.5	12330.1	138.6	17.82	5468.1	4286.6	78.4
3A	17.23	13910.7	11455.7	82.4	50.80	41005.3	28076.1	68.5
3B								
4A								
4B								
5	5.67	2289.2	2315.1	101.1	16.89	6815.1	5229.1	76.7
6	1.82	996.2	890.5	89.4	40.49	22187.2	13170.7	59.4
7	0.34	152.1	240.0	157.8	10.42	4713.5	6275.7	133.1
8A	3.52	9074.4	10140.5	111.7	14.73	37943.0	28071.5	74.0
9A	0.22	309.9	206.0	66.5	10.97	15214.0	8889.3	58.4
10A	2.51	2689.1	6157.5	229.0	7.07	7565.1	9263.0	122.4
10B	5.69	8672.9	14716.2	169.7	19.92	30385.4	30751.2	101.2
10C	3.97	4085.5	2058.3	50.4	13.27	13653.4	3274.6	24.0
11A	10.86	16265.7	15849.5	97.4	21.74	32549.6	26192.4	80.5
11B								
12A								
12B								
Total/ Average	**12.03**	**128422.4**	**52858.0**	**41.2**	**Ü**	**275109.3**	**64855.7**	**23.6**

Table A.3. 12. Model-based biomass estimates using ordinary kriging for the Creed survey in 2011.

2011	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	13.91	8797.0	3127.2	35.5	142.98	90458.7	120692.0	133.4
1B	7.26	7067.0	4514.9	63.9	32.77	31892.6	41045.5	128.7
2A	10.54	11228.0	6668.5	59.4	15.20	16191.5	14198.4	87.7
2B	13.89	7118.0	3560.4	50.0	17.65	9047.3	9984.6	110.4
2C	14.07	5895.1	3177.8	53.9	16.78	7033.1	4364.3	62.1
2D	10.95	3360.8	2233.7	66.5	10.90	3345.3	3047.9	91.1
3A	19.22	15516.5	10770.5	69.4	39.44	31831.9	24122.2	75.8
3B	3.14	1376.3	530.7	38.6	3.20	1404.3	996.6	71.0
4A								
4B	10.04	40102.7	24690.7	61.6	22.84	91185.7	75255.5	82.5
5	7.68	3097.7	1040.7	33.6	9.26	3735.6	2530.5	67.7
6	3.40	1863.5	565.0	30.3	2.23	1222.4	560.2	45.8
7	5.99	2708.5	1722.5	63.6	2.81	1271.5	1061.4	83.5
8A	4.87	12534.3	8922.4	71.2	29.08	74878.2	66998.4	89.5
9A	3.13	4337.3	2202.5	50.8	3.95	5480.6	4123.2	75.2
10A	1.48	1581.9	1658.3	104.8	6.13	6561.0	7351.9	112.1
10B	9.88	15074.3	23662.1	157.0	9.96	15192.0	10900.8	71.8
10C								
11A	7.40	11077.7	11522.5	104.0	8.79	13168.2	7198.8	54.7
11B	3.89	9252.4	3954.1	42.7	20.23	48076.6	30067.6	62.5
12A	3.63	4383.5	1586.6	36.2	7.12	8605.8	4808.1	55.9
12B	6.84	7919.9	4145.9	52.3	18.45	21375.5	9225.3	43.2
Total/ Average	**8.06**	**174292.4**	**40594.3**	**23.3**	**20.99**	**481957.9**	**169049.7**	**35.1**

Table A.3. 13. Model-based biomass estimates using ordinary kriging for the Creed survey in 2012.

2012	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	12.00	7591.0	7441.2	98.0	9.24	5844.4	3271.0	56.0
1B	9.33	9078.6	7308.6	80.5	7.57	7367.0	4624.8	62.8
2A	4.54	4838.7	3479.6	71.9	14.95	15922.6	12285.3	77.2
2B	7.41	3797.2	866.7	22.8	29.67	15206.2	15362.4	101.0
2C	18.81	7881.4	6381.8	81.0	27.83	11662.8	5498.9	47.1
2D	29.55	9068.1	7457.4	82.2	11.22	3442.2	1571.4	45.7
3A	14.58	11766.2	9335.6	79.3	59.21	47791.1	39764.4	83.2
3B	2.02	887.3	940.5	106.0	16.78	7356.7	7699.3	104.7
4A	6.04	5456.3	12600.2	230.9	20.48	18505.6	25301.4	136.7
4B	9.54	38084.0	33119.2	87.0	36.12	144213.8	78687.9	54.6
5	19.49	7863.9	8952.0	113.8	19.72	7960.1	1837.5	23.1
6	4.29	2348.9	1443.2	61.4	11.89	6514.5	512.0	7.9
7	1.37	621.7	791.3	127.3	10.88	4922.2	2391.9	48.6
8A	4.28	11010.7	10825.9	98.3	6.94	17880.9	11395.6	63.7
9A	0.26	358.5	165.7	46.2	9.21	12763.5	2565.6	20.1
10A	0.67	717.0	1563.5	218.0	9.84	10529.5	7344.8	69.8
10B	8.33	12705.5	8602.0	67.7	27.78	42371.6	21586.3	50.9
10C								
11A	5.91	8850.1	7259.0	82.0	19.03	28498.9	18925.3	66.4
11B	1.29	3068.2	3194.3	104.1	7.14	16959.9	9719.1	57.3
12A	2.23	2697.6	2637.6	97.8	7.86	9490.2	4617.0	48.6
12B	17.69	20492.4	13395.8	65.4	10.20	11813.6	4073.8	34.5
Total/ Average	**8.55**	**169183.3**	**45689.0**	**27.0**	**17.79**	**447017.4**	**100401.3**	**22.5**

Table A.3. 14. Model-based biomass estimates using ordinary kriging for the Creed survey in 2013.

2013	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	10.94	6923.9	4128.0	59.6	13.50	8541.4	3719.7	43.5
1B	1.97	1914.0	1977.4	103.3	13.41	13055.6	10740.1	82.3
2A	1.33	1416.0	1838.2	129.8	13.96	14870.0	10519.4	70.7
2B	0.54	278.8	204.7	73.4	29.81	15278.8	12119.0	79.3
2C	0.14	59.6	36.7	61.5	13.15	5510.4	3701.6	67.2
2D	37.70	11568.0	15203.5	131.4	18.73	5746.5	4586.0	79.8
3A	2.27	1830.4	1856.5	101.4	32.95	26592.0	14715.6	55.3
3B	0.12	52.6	31.6	60.0	11.22	4919.4	2887.2	58.7
4A								
4B	1.16	4647.6	5944.6	127.9	14.35	57301.3	31482.7	54.9
5	5.47	2206.5	2460.0	111.5	25.49	10287.7	5035.5	48.9
6	0.45	247.1	143.8	58.2	9.88	5412.1	2235.8	41.3
7	1.59	717.6	549.3	76.6	13.42	6072.2	2786.5	45.9
8A	4.14	10662.0	9030.5	84.7	12.20	31430.1	12387.3	39.4
9A	0.90	1247.1	556.1	44.6	10.51	14573.8	3021.8	20.7
10A	0.13	134.2	129.9	96.8	3.06	3273.8	1338.9	40.9
10B	0.22	341.8	442.9	129.6	9.12	13904.7	10106.3	72.7
10C	0.83	849.8	1347.2	158.5	13.71	14107.2	4730.8	33.5
11A	0.72	1070.9	1097.6	102.5	11.34	16987.0	9689.2	57.0
11B								
12A	4.64	5601.4	6542.5	116.8	14.89	17989.1	13944.4	77.5
12B	3.71	4302.9	3469.3	80.6	15.56	18028.5	6953.4	38.6
Total/ Average	**3.95**	**56072.2**	**20990.7**	**37.4**	**15.01**	**303881.7**	**479070.6**	**15.8**

Table A.3. 15. Model-based biomass estimates using ordinary kriging for the Creed survey in 2014.

2014	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	9.11	5761.2	6235.7	108.2	4.63	2928.0	2186.9	74.7
1B	3.05	2968.1	2502.5	84.3	4.01	3906.1	1479.0	37.9
2A	3.31	3520.9	6400.5	181.8	5.12	5456.9	4055.8	74.3
2B	0.78	400.6	359.4	89.7	2.26	1160.2	314.0	27.1
2C	0.45	186.8	155.1	83.0	2.80	1174.9	639.3	54.4
2D	1.16	355.7	195.9	55.1	3.51	1075.5	315.6	29.3
3A	0.15	117.5	121.9	103.8	11.21	9046.1	7476.0	82.6
3B	0.10	44.3	56.2	126.8	8.98	3937.2	1840.2	46.7
4A	0.29	262.3	216.6	82.6	2.35	2120.9	1316.9	62.1
4B	0.63	2511.2	1853.8	73.8	3.99	15948.6	10139.9	63.6
5	5.29	2134.1	2612.8	122.4	5.62	2269.8	1700.0	74.9
6	1.47	807.5	119.8	14.8	8.67	4751.2	1846.5	38.9
7	1.07	485.7	426.8	87.9	7.98	3609.2	1159.4	32.1
8A	1.92	4937.7	5126.8	103.8	6.82	17571.5	7883.6	44.9
9A								
10A	0.03	31.3	71.5	228.5	1.13	1212.0	819.4	67.6
10B	0.12	189.3	227.8	120.3	4.43	6756.4	3398.2	50.3
10C	3.52	3616.2	4646.4	128.5	3.74	3845.5	2170.2	56.4
11A	0.63	937.3	1203.2	128.4	5.49	8226.9	6076.4	73.9
11B								
12A	0.68	819.0	1176.2	143.6	3.24	3912.7	3788.0	96.8
12B	5.44	6297.0	2122.0	33.7	6.35	7359.7	2854.8	38.8
Total/ Average	**1.96**	**36383.8**	**12332.6**	**33.9**	**5.12**	**106269.3**	**18275.7**	**17.2**

Table A.3. 16. Model-based biomass estimates using ordinary kriging for the Creed survey in 2015.

2015	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A								
1B								
2A	4.01	4273.4	6376.9	149.2	9.14	9735.5	8055.1	82.7
2B	0.69	355.0	311.3	87.7	5.74	2944.1	1673.3	56.8
2C	0.06	23.5	26.7	113.4	1.42	596.5	353.6	59.3
2D	0.98	301.3	358.4	118.9	1.40	429.3	194.6	45.3
3A	0.11	90.2	83.4	92.4	2.18	1755.7	1107.8	63.1
3B	0.04	18.6	25.6	137.5	3.39	1487.5	619.8	41.7
4A								
4B	0.52	2065.0	5711.4	276.6	5.86	23413.0	17669.8	75.5
5	0.52	208.5	330.9	158.7	2.95	1191.2	935.2	78.5
6	0.19	104.8	83.5	79.7	7.03	3852.5	1824.2	47.4
7	7.47	3381.0	4993.5	147.7	13.90	6288.5	5698.0	90.6
8A	14.29	36803.0	36722.9	99.8	9.99	25739.8	25578.5	99.4
9A								
10A	0.03	27.7	54.0	194.7	1.35	1440.2	1972.9	137.0
10B	2.38	3634.6	5720.5	157.4	4.05	6180.1	3172.8	51.3
10C								
11A	5.20	7793.4	9629.2	123.6	3.03	4541.5	4146.9	91.3
11B	2.70	6425.4	8821.0	137.3	3.27	7776.8	7729.6	99.4
12A	4.94	5971.9	6683.7	111.9	2.93	3535.4	2801.0	79.2
12B	1.57	1816.9	879.2	48.4	5.19	6014.6	1957.7	32.5
Total/ Average	**2.69**	**73294.4**	**41180.7**	**56.2**	**4.87**	**106922.3**	**34281.1**	**32.1**

Table A.3. 17. Model-based biomass estimates using ordinary kriging for the Creed survey in 2016.

2016	*Thysanoessa* spp.				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	17.95	11353.6	12577.8	110.8	4.76	3012.5	2358.1	78.3
1B								
2A	13.42	14292.0	23057.2	161.3	11.17	11893.3	4699.0	39.5
2B	6.29	3226.0	2535.3	78.6	6.04	3096.1	2027.4	65.5
2C	16.14	6764.0	10743.4	158.8	5.04	2114.1	1228.9	58.1
2D	0.20	62.8	91.3	145.2	4.16	1276.1	1495.0	117.1
3A	19.57	15794.5	31743.1	201.0	18.38	14836.1	16014.5	107.9
3B	3.40	1492.2	2125.5	142.4	3.06	1340.6	1082.8	80.8
4A								
4B	1.72	6855.3	6112.5	89.2	10.08	40251.7	30631.4	76.1
5	0.18	71.7	73.5	102.5	4.50	1817.8	944.7	52.0
6	0.14	74.8	98.7	132.0	11.50	6303.3	3817.9	60.6
7	0.18	83.4	110.3	132.3	31.13	14083.1	17111.7	121.5
8A	8.20	21105.3	25496.7	120.8	4.75	12227.1	8071.5	66.0
9A	0.12	169.2	215.7	127.5	8.39	11636.6	12624.5	108.5
10A								
10B	0.49	744.2	791.5	106.3	5.28	8051.8	8110.4	100.7
10C	7.42	7631.1	7264.9	95.2	9.71	9990.4	5586.8	55.9
11A	1.67	2505.1	2389.3	95.4	5.85	8763.4	7723.6	88.1
11B	3.53	8385.2	8879.7	105.9	10.31	24507.0	30939.9	126.2
12A	4.70	5684.0	5228.0	92.0	3.10	3748.3	2689.0	71.7
12B	13.74	15921.4	20386.9	128.0	4.54	5257.7	3213.4	61.1
Total/ Average	**6.27**	**122215.9**	**55608.2**	**45.5**	**8.51**	**184207.0**	**53811.7**	**29.2**

Table A.3. 18. Model-based biomass estimates using ordinary kriging for the Teleost survey in 2012.

2012	*Thysanoessa spp.*				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	0.30	192.1	154.6	80.5	6.90	4363.5	934.3	21.4
1B	0.11	107.8	39.8	37.0	2.81	2729.9	1402.7	51.4
2A	0.46	492.4	880.5	178.8	7.39	7870.3	1847.9	23.5
2B	2.58	1320.1	1024.7	77.6	17.23	8832.0	3332.5	37.7
2C	3.23	1355.5	1698.3	125.3	20.37	8536.7	7310.6	85.6
2D	1.00	306.1	312.8	102.2	13.60	4173.4	779.7	18.7
3A	1.72	1384.8	1342.3	96.9	26.68	21532.9	12292.6	57.1
3B	0.35	153.5	202.3	131.8	10.91	4784.0	6198.9	129.6
4A	0.07	60.6	32.7	54.0	4.35	3927.8	792.1	20.2
4B	1.00	3997.5	6116.1	153.0	11.28	45042.2	25285.2	56.1
5	0.18	70.9	40.3	56.9	6.88	2778.3	1218.0	43.8
6	0.18	98.5	35.9	36.5	8.07	4423.7	185.4	4.2
7	0.11	49.5	80.0	161.4	7.89	3569.7	3449.2	96.6
8A	0.52	1334.4	2735.5	205.0	3.76	9690.5	6449.0	66.5
9A	0.05	70.6	79.5	112.6	6.74	9341.9	3588.4	38.4
10A	0.90	960.0	951.4	99.1	6.06	6485.7	4543.5	70.1
10B	1.26	1922.5	1583.5	82.4	6.21	9476.1	3737.7	39.4
10C								
11A	1.77	2655.7	2872.5	108.2	5.82	8722.1	6559.9	75.2
11B	0.70	1660.2	2379.3	143.3	5.83	13850.0	9606.8	69.4
12A	1.22	1470.9	1287.4	87.5	5.22	6306.5	4045.1	64.1
12B	5.66	6555.7	6728.6	102.6	4.95	5733.6	2191.1	38.2
Total/ Average	**1.11**	**26219.2**	**10762.7**	**41.0**	**9.00**	**192170.8**	**34057.3**	**17.7**

Table A.3. 19. Model-based biomass estimates using ordinary kriging for the Teleost survey in 2013

2013	*Thysanoessa spp.*				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	0.02	9.7	9.4	96.2	4.56	2885.1	378.6	13.1
1B	3.02	2941.4	3888.8	132.2	7.24	7042.1	3217.8	45.7
2A	0.32	343.0	257.8	75.2	7.10	7563.3	5377.9	71.1
2B	0.96	489.7	922.7	188.4	16.24	8321.3	2930.7	35.2
2C	0.21	87.1	81.7	93.9	7.84	3286.1	2584.4	78.6
2D	0.75	230.0	356.6	155.0	2.31	708.1	234.3	33.1
3A	1.78	1433.0	907.7	63.3	6.68	5393.9	2332.3	43.2
3B	0.49	216.1	245.2	113.4	3.27	1435.3	1364.6	95.1
4A								
4B	0.46	1842.6	2197.8	119.3	7.17	28609.1	23761.3	83.1
5	0.02	7.7	2.5	32.0	4.21	1697.8	595.1	35.1
6	0.02	11.4	0.7	6.5	2.22	1218.4	863.3	70.9
7	0.16	71.8	109.4	152.5	2.46	1113.9	725.6	65.1
8A	0.88	2274.6	5588.3	245.7	1.34	3440.2	1431.2	41.6
9A	0.05	67.2	26.1	38.8	3.44	4762.1	2016.1	42.3
10A	0.03	30.7	92.8	302.4	0.57	605.8	884.9	146.1
10B	0.03	49.2	34.1	69.3	0.88	1338.5	773.8	57.8
10C	0.06	57.7	62.9	109.0	4.84	4974.7	1849.4	37.2
11A	0.22	328.9	640.1	194.6	0.49	732.1	578.1	79.0
11B								
12A	0.32	380.9	263.3	69.1	0.68	822.9	593.3	72.1
12B	0.15	172.2	75.4	43.8	4.13	4788.0	3484.0	72.8
Total/ Average	**0.50**	**11044.8**	**7323.2**	**66.3**	**4.38**	**90738.7**	**25534.4**	**28.1**

Table A.3. 20. Model-based biomass estimates using ordinary kriging for the Teleost survey in 2014.

2014	*Thysanoessa spp.*				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	0.03	19.2	16.4	85.4	1.10	693.7	234.1	33.8
1B	0.13	124.6	154.3	123.8	0.98	951.3	392.9	41.3
2A	0.16	172.8	129.5	74.9	1.15	1230.0	1002.9	81.5
2B	0.68	349.2	363.3	104.0	2.50	1282.8	605.2	47.2
2C	0.22	94.0	65.7	69.9	1.85	775.9	576.1	74.2
2D	0.05	16.3	11.8	72.2	0.68	209.4	191.2	91.3
3A	0.27	219.0	36.1	16.5	5.85	4717.9	1183.1	25.1
3B	0.17	76.5			4.68	2050.8		
4A	0.12	104.9	90.5	86.3	0.54	485.2	466.4	96.1
4B	0.13	513.1	569.6	111.0	0.92	3691.9	4793.8	129.8
5	0.06	23.1	16.8	72.5	0.34	136.8	105.2	76.9
6	0.04	24.2	15.3	63.2	0.39	213.0	30.5	14.3
7	0.21	93.9	146.7	156.2	3.74	1694.2	1414.4	83.5
8A	1.17	3018.5	9676.2	320.6	1.55	3982.2	1993.6	50.1
9A								
10A	0.08	90.4	162.6	179.8	0.70	745.3	646.8	86.8
10B	0.03	48.8	53.3	109.3	0.73	1106.1	572.1	51.7
10C	0.62	641.3	389.5	60.7	0.29	302.5	108.5	35.9
11A	0.04	57.9	48.3	83.4	0.78	1164.2	650.7	55.9
11B								
12A	0.01	11.1	14.0	126.3	0.39	473.4	193.1	40.8
12B	0.12	138.7	91.9	66.3	0.31	358.0	142.2	39.7
Total/ Average	**0.22**	**5837.6**	**9713.6**	**166.4**	**1.47**	**26264.3**	**5811.4**	**22.1**

Table A.3. 21. Model-based biomass estimates using ordinary kriging for the Teleost survey in 2015.

2015	*Thysanoessa spp.*				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A								
1B								
2A	0.20	207.9	321.7	154.8	1.70	1811.9	2058.1	113.6
2B	0.03	14.6	16.1	110.1	1.76	901.2	448.6	49.8
2C	0.83	347.8	249.5	71.7	1.45	606.7	492.1	81.1
2D	0.04	12.5	13.4	107.5	0.90	277.0	113.6	41.0
3A	0.04	36.1	13.5	37.3	0.28	223.7	172.0	76.9
3B	0.04	18.9			0.17	76.1		
4A								
4B	0.21	847.1	1738.3	205.2	1.50	5983.0	3885.0	64.9
5	0.00	0.9	1.1	116.0	0.24	96.6	88.1	91.2
6	0.04	20.3	29.0	142.9	2.57	1406.1	1307.0	92.9
7	0.14	63.0	52.9	84.0	4.88	2207.0	1491.1	67.6
8A	5.45	14043.4	12600.0	89.7	4.76	12257.6	7060.0	57.6
9A								
10A	0.01	6.1	10.9	178.8	0.22	235.9	223.4	94.7
10B	0.20	302.1	455.2	150.7	1.50	2292.2	2246.4	98.0
10C								
11A	0.06	87.6	121.0	138.1	1.83	2741.8	3967.0	144.7
11B	0.07	168.4	483.8	287.3	2.75	6530.5	5562.0	85.2
12A	0.26	319.4	289.5	90.6	2.37	2867.6	2382.1	83.1
12B	0.01	7.6	6.6	86.3	0.75	865.7	425.5	49.2
Total/ Average	**0.45**	**16503.8**	**12747.2**	**77.2**	**1.74**	**41380.3**	**11455.2**	**27.7**

Table A.3. 22. Model-based biomass estimates using ordinary kriging for the Teleost survey in 2016.

2016	*Thysanoessa spp.*				Northern krill (*M. norvegica*)			
Stratum	Mean Biomass Density (g/m2)	Biomass Density (t/stratum)			Mean Biomass Density (g/m2)	Biomass Density (t/stratum)		
		Biomass (t)	S.D.	C.V. %		Biomass (t)	S.D.	C.V. %
1A	11.49	7272.2	7133.3	98.1	4.13	2612.9	608.5	23.3
1B								
2A	1.73	1846.9	418.6	22.7	3.71	3951.2	556.0	14.1
2B	3.21	1644.2	1752.0	106.6	6.41	3285.2	1547.6	47.1
2C	1.54	647.2	434.2	67.1	5.60	2345.2	1081.0	46.1
2D	24.15	7410.7	6486.8	87.5	4.35	1333.3	1189.5	89.2
3A	7.71	6221.2	3126.2	50.3	5.80	4680.8	1840.9	39.3
3B	2.63	1152.1	239.1	20.8	7.12	3124.1	2302.7	73.7
4A								
4B	3.09	12331.1	12709.0	103.1	4.91	19616.5	10876.5	55.4
5	0.09	37.2	46.8	125.7	3.93	1586.8	1935.2	122.0
6	0.11	60.4	41.4	68.5	3.02	1652.6	413.2	25.0
7	0.05	22.9	21.2	92.6	1.65	746.0	433.7	58.1
8A	2.04	5264.2	8274.7	157.2	2.35	6061.2	7985.2	131.7
9A	0.07	100.9	79.0	78.3	1.75	2423.6	1584.1	65.4
10A								
10B	1.75	2671.3	2952.2	110.5	2.55	3890.5	2550.2	65.5
10C	0.16	163.0	147.5	90.5	2.34	2406.5	904.9	37.6
11A	11.87	17775.2	15885.9	89.4	4.16	6224.8	4302.6	69.1
11B	0.83	1984.3	5255.0	264.8	5.48	13018.6	7997.2	61.4
12A	14.08	17009.2	6376.3	37.5	5.33	6437.4	3857.6	59.9
12B	0.44	508.5	928.8	182.7	2.85	3303.6	1021.2	30.9
Total/ Average	**4.58**	**84122.8**	**25815.9**	**30.7**	**4.08**	**88700.8**	**17570.9**	**19.8**