The following supplements accompany the article

Environmental associations and assemblage structure of shrimp species in the Gulf of St. Lawrence (Canada) following dramatic increases in abundance

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SUPPLEMENT 1. ABUNDANCE TIME SERIES FOR THE NORTHERN GULF SURVEY

The nGSL survey was conducted by the CCGS Alfred Needler using a URI shrimp trawl from 1991-2005 and by the CCGS Teleost using a Campelen 1800 shrimp trawl since 2004. Comparative fishing experiments involving side-by-side fishing were conducted in 2004 and 2005 to derive conversion factors to adjust for the changes in vessel and gear (Bourdages et al. 2007). However, there were only three shrimp species for which there were sufficient data to estimate the conversion factors: *Pandalus borealis*, *Pandalus montagui* and *Pasipaea multidentata*. The abundance indices for the majority of the remaining species comprise a jump in catch rates in 2004-2005, coincident with the change in vessel and gear (Fig. S1). This is consistent with an uncalibrated greater catchability to the Campelen trawl fished by the Teleost. Furthermore, catch rates for many species prior to 2004 were very low and catches were more sporadic (Fig. S1), suggesting that catchability to the URI trawl fished by the CCGS Alfred Needler was low and variable. Failure to adjust for these differences in catchability means that it is not possible to estimate long-term trends in abundance for these affected species (i.e., the trends prior to 2004 and after 2005 need to be considered separately).

Literature cited

Bourdages H, Savard L, Archambault D, Valois S (2007) Results from the August 2004and 2005 comparative fishing experiments in the northern Gulf of St Lawrence between the CCGS Alfred Needler and the CCGS Teleost. Can Tech Rep Fish Aquat Sci 2750: ix + 57 pp

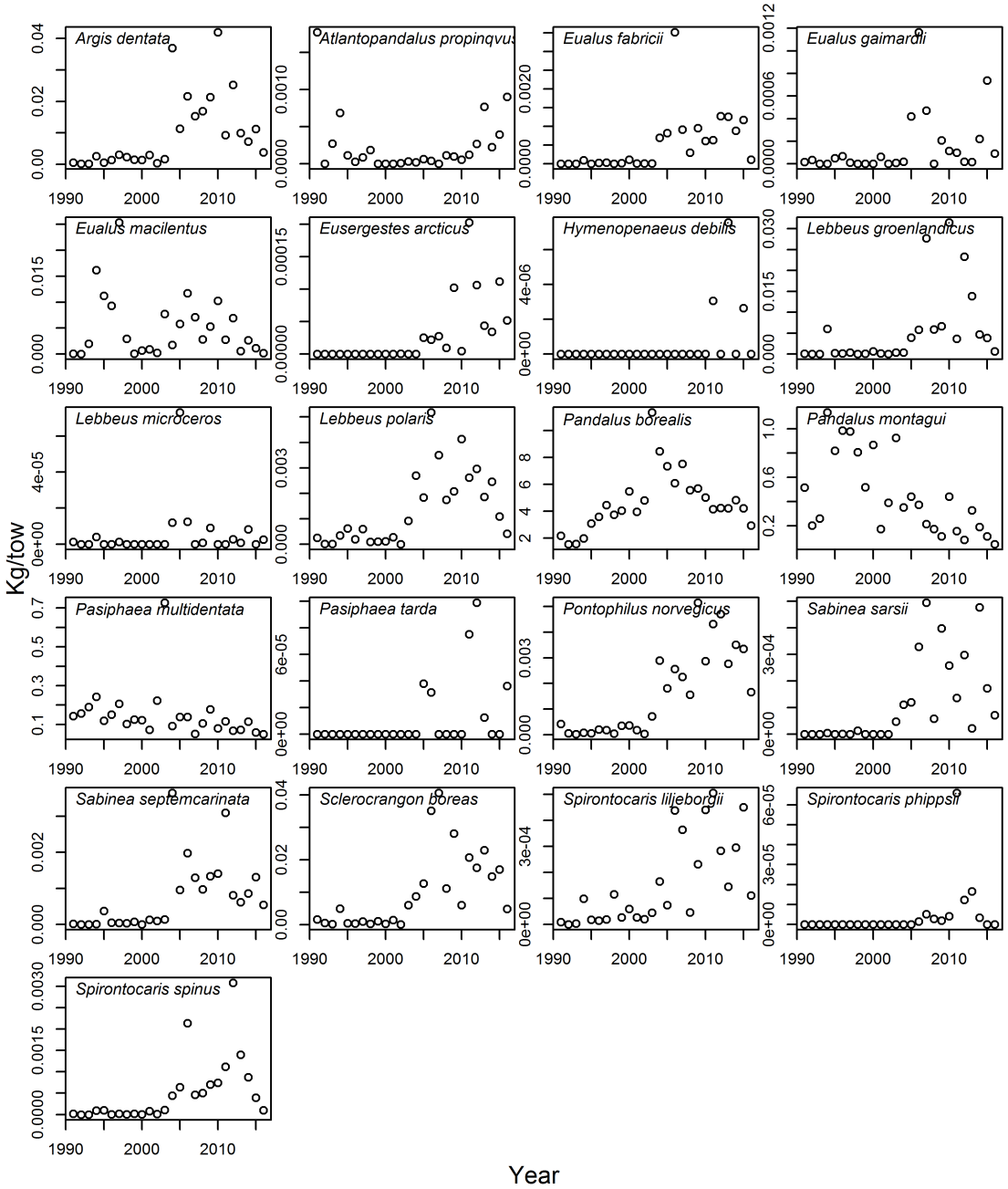

Figure S1. Abundance indices (Kg/tow) for the shrimp species in the survey of the northern Gulf of St. Lawrence. The time series for *Pandalus borealis*, *Pandalus montagui* and *Pasipaea multidentata* were adjusted for the changes in gear and vessel based on results from comparative fishing experiments. Conversion factors were not available for the other species to adjust for the changes in the survey.

SUPPLEMENT 2. AVAILABILITY OF TEMPERATURE RECORDS FOR THE NORTHERN GULF SURVEY

Temperature and depth records are available for all sets in the southern Gulf of St. Lawrence (sGSL) survey. In contrast, temperature values were not available for 562 of the 1703 survey sets in the northern Gulf of St. Lawrence (nGSL) survey, though depth records were available in all cases. To properly assess the associations of species and assemblages to these two habitat variables required estimating the missing temperature values.

First we assessed the spatial distribution of sets with missing values relative to sets with temperature records to determine whether large interpolations of values would be required. This was done in two ways. The spatial distributions of sets with and without temperature were compared visually to determine whether there were spatial gaps in the temperature sampling. There was no strong evidence for gaps or clusters in temperature sampling (Fig. S2). In addition, the frequency distributions of depth records in the nGSL survey for sets without temperature records and for all sets were compared to determine whether there might be a depth-dependent bias in temperature records. The frequency distributions were quite similar suggesting that there was no such bias (Fig. S3).

Second, we used general additive modelling (GAM; Wood 2006) to model bottom temperature in the nGSL survey as a function of depth and other factors. The resulting model was used to estimate the missing temperature values. We evaluated the six following candidate models, each of which assumed $Y_{ijk} \sim N(\mu_{ijk}, \sigma^2)$ where i indexes set i in stratum j and year k:

Model 1: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i)_k + stratum_j$

Model 2: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i)_k$

Model 3: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i) \quad + stratum_j$

Model 4: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i)$

Model 5: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i)_k + stratum_{jk}$

Model 6: $\mathrm{E}[Y_{ijk}] = \mu_{ijk} = \beta_0 + s(depth_i) \quad + stratum_{jk}$

where $s(depth_i)_k$ are cubic spline functions of depth that can vary annually (models 1, 2 and 5), whereas $s(depth_i)$ represents a single overall spline function (models 3, 4 and 6). The effect of stratum was added to account for potential small scale deviations in the relationship between depth and bottom temperature, either as time invariant effects (models 1 and 3) or ones that varied by year (models 5 and 6). The models were compared using Aikaike's Information Criterion (AIC).

Based on AIC there was strong relative evidence for model 6 (Table S1; Fig. S4). This model was superior to the next best one, model 5, with a difference in AIC of 8 units, though the two explained equivalent amounts of deviance. Values predicted by the model matched observations very closely, with only a small number of larger residual values. Model 6, which modelled bottom temperature as a time-invariant spline function of depth with stratum-level annual deviations, was therefore used to predict the bottom water temperatures for the sets for which the values were missing.

Literature cited:

Wood, S.N. (2006) Generalized Additive Models: An Introduction with R. Chapman and Hall/CRC, Boca Raton, FL, USA

Table S1. Summary results of the GAM model fits for the six candidate models of bottom-temperatures.

Model number	AIC	% deviance explained
1	3465	90.8
2	3907	87.3
3	3566	89.2
4	3974	85.4
5	3198	95.9
6	3187	95.5

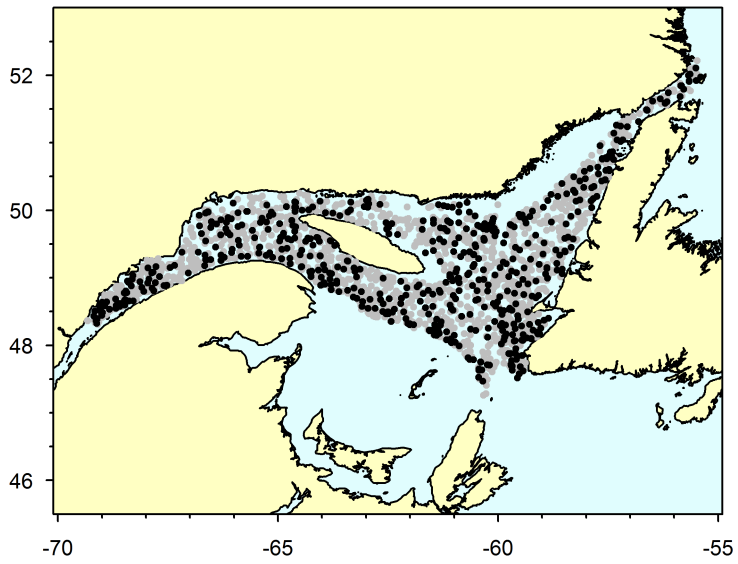

Figure S2. The spatial distribution of survey sets in the northern Gulf of St. Lawrence survey for which there were both temperature and depth records (grey circles) and depth recorded only (black circles).

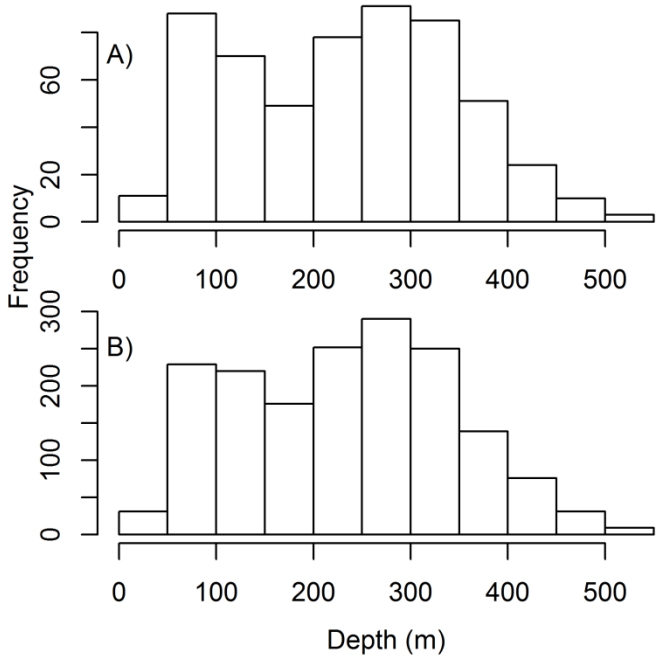

Figure S3. Frequency distribution, as a function of depth, of sets reporting (A) both temperature and depth and (B) depth only in the northern Gulf of St. Lawrence survey.

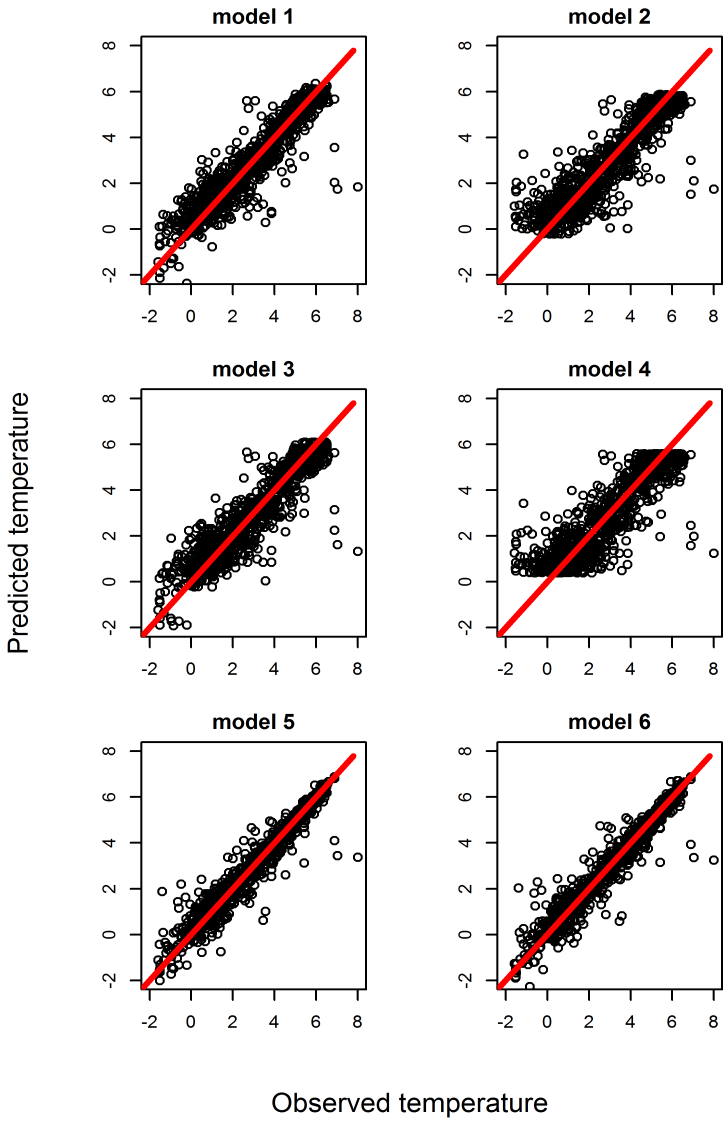

Figure S4. Bottom water temperatures predicted by individual GAM models (panels) as a function of observed temperatures, with the 1:1 line indicated in red.

SUPPLEMENT 3. TEMPORAL STABILITY IN COMMUNITY COMPOSITION, 2004-2105

This paper examines the spatial distribution and habitat associations of shrimp species and assemblages in the Gulf of St. Lawrence over the period 2004-2015. The data were pooled across years and temporal changes in community composition were not considered for the paper. This choice was made because there was no evidence for changes in the relative abundance of species over time in either survey (Fig. S5). Furthermore, species distribution maps for four three-year periods did not suggest changes in distribution for any species (H. Tamdrari, unpublished results).

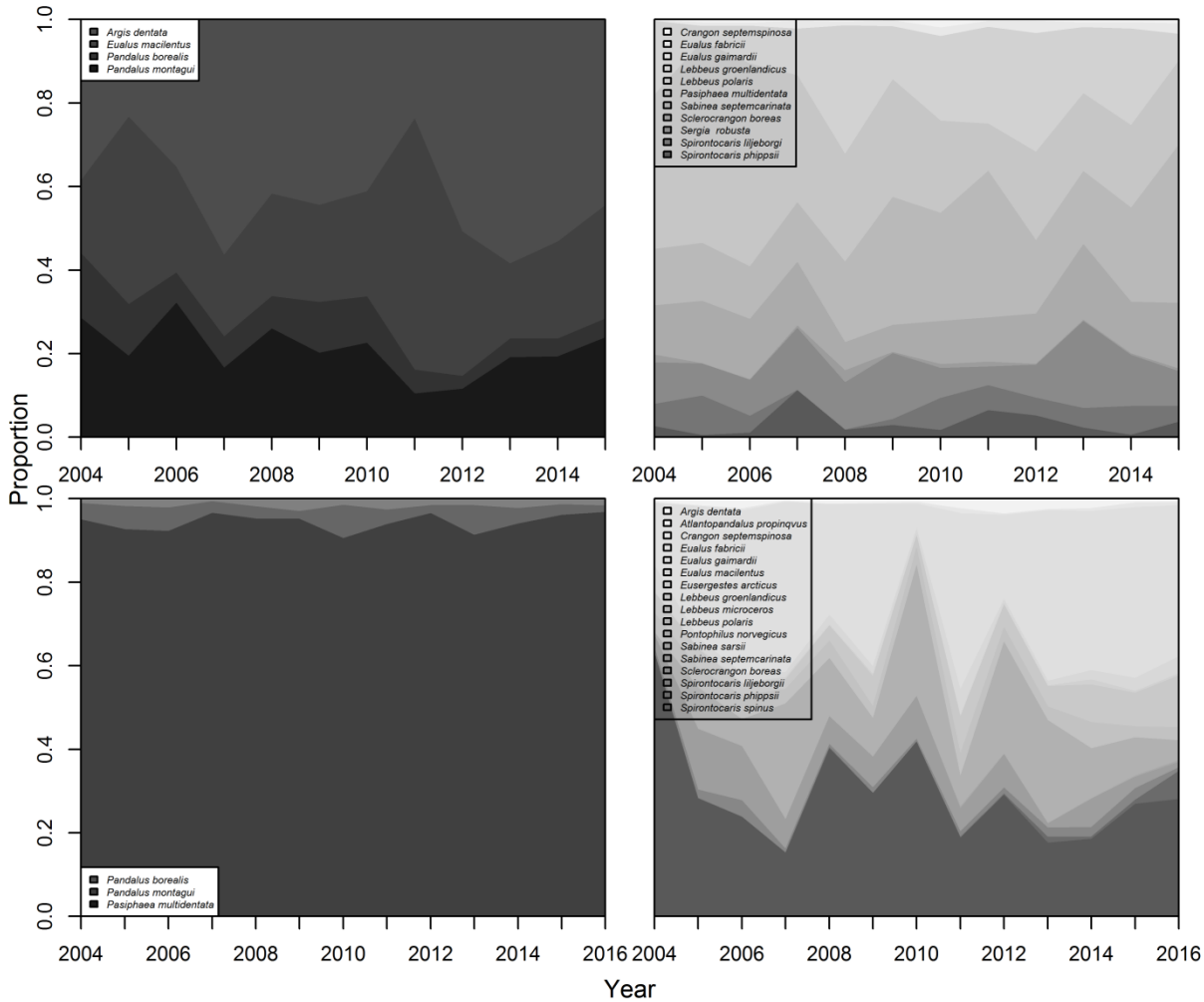

Figure S5. Relative contribution of individual shrimp species to total shrimp biomass in the southern (top panels) and northern (bottom panels) Gulf of St. Lawrence bottom-trawl surveys for 2004-2015). The most abundant species (left panels) were plotted separately from the others (right panels) for clarity for each survey. Note that because catchability to the surveys likely differs among species, relative composition in the surveys likely does not reflect relative composition in the ecosystems.

SUPPLEMENT 4. SPATIAL DISTRIBUTION OF OCCURRENCE BY SPECIES AND SURVEY

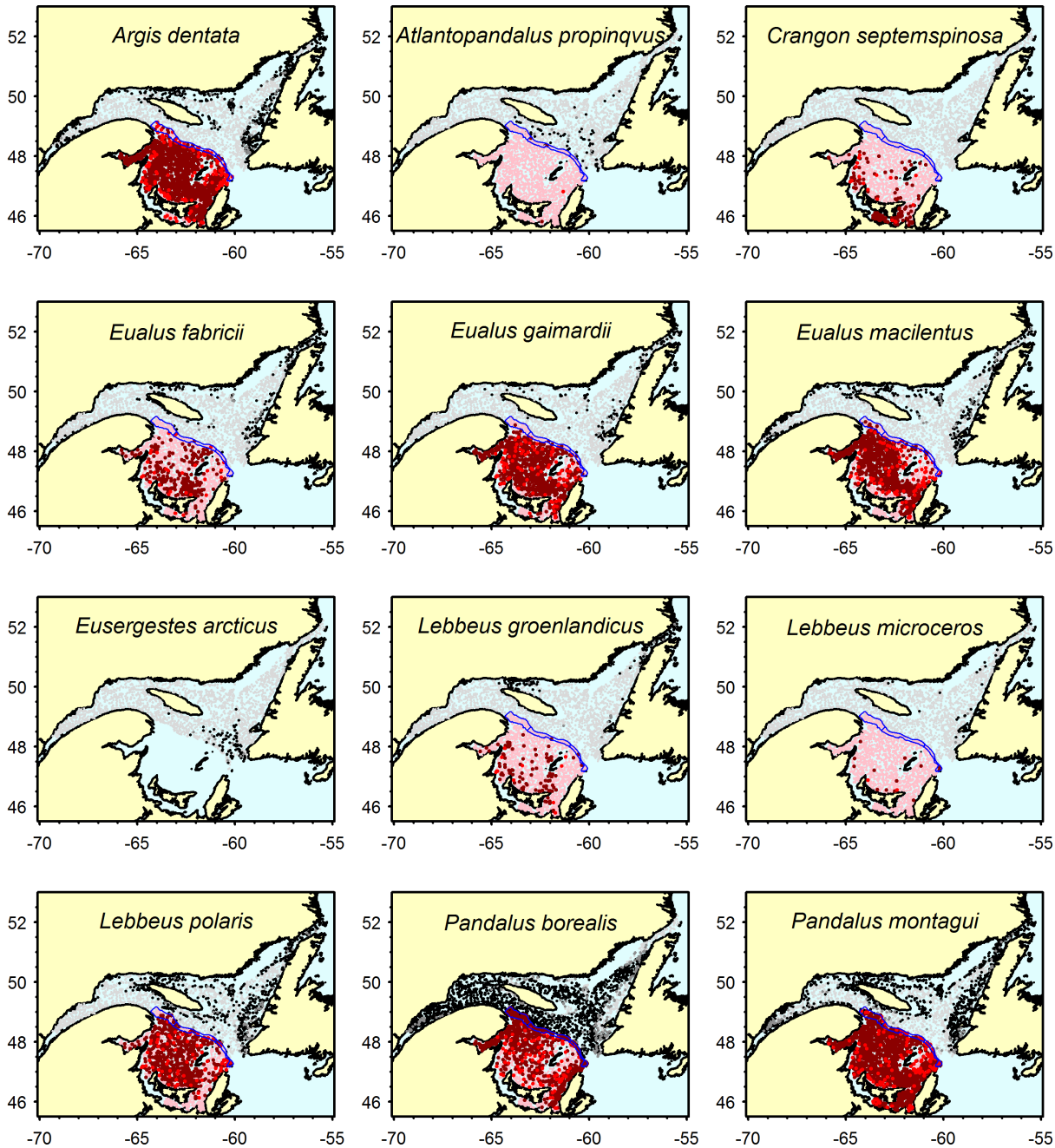

Figure S6. Spatial distribution of catches of each shrimp species (panels) in the northern and southern Gulf of St. Lawrence surveys. Crosses (north – light grey; south – light pink) indicate sets from which the species was absent and dark circles indicate sets where the species was captured. Positive sets were further divided into those with relatively small catches (≤ the 10th percentile of positive catch values in the respective surveys; north – dark grey; south – red) and larger catches (north – black; south – dark red) to highlight the areas in which the species are most typically found. The blue polygon in the Laurentian channel indicates the area covered by both surveys. The last panel shows the catch locations for the six rare species not considered in the analyses for the paper.

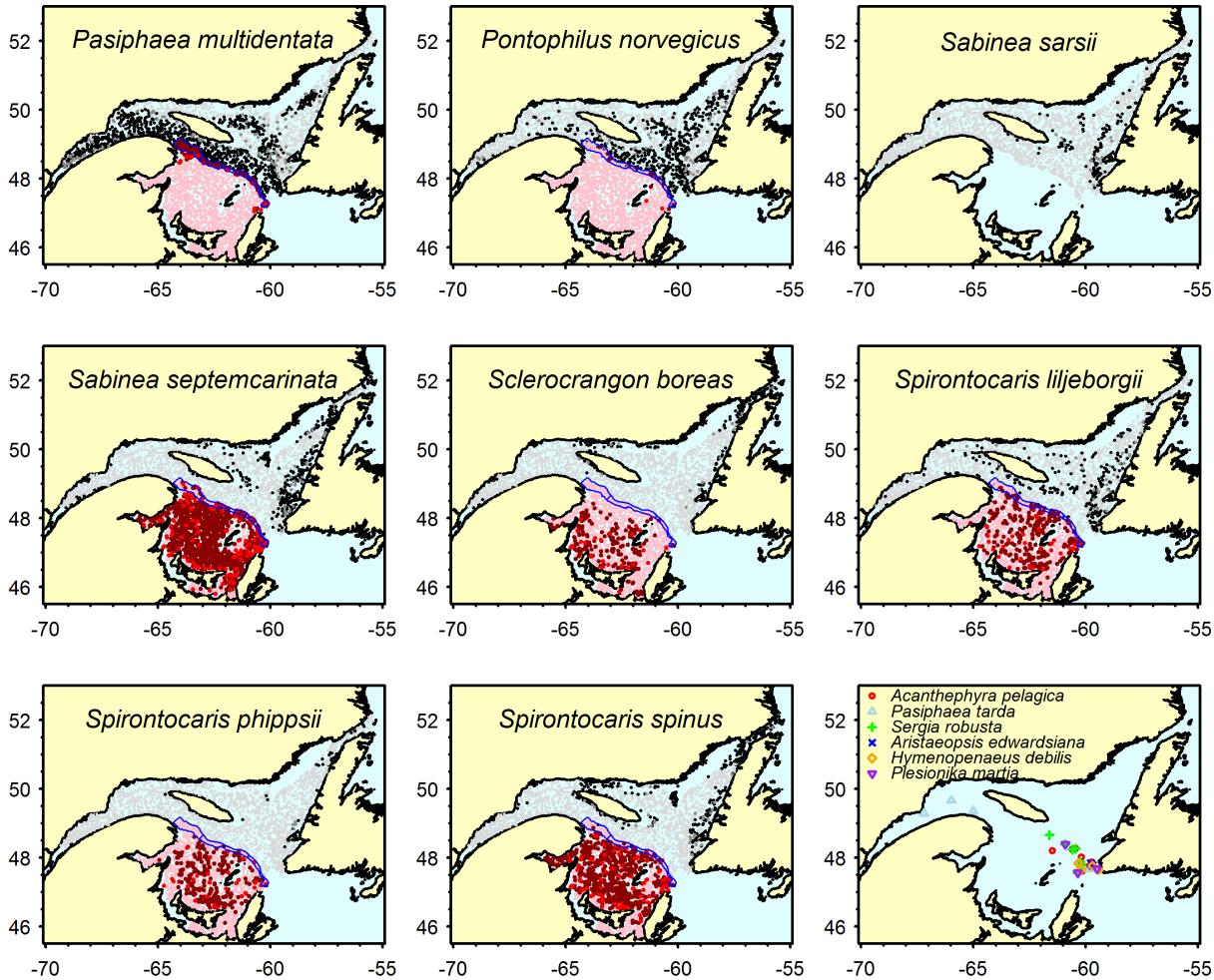

Figure S6. continued