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A spatial-temporal model for snow crab (*Chionoecetes opilio*) stock size in the Southern Gulf of St. Lawrence.

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Abstract

We develop a high resolution spatio-temporal model of stock size and harvest rates for snow crab (*Chionoecetes opilio*) in the Southern Gulf of St. Lawrence, which supports an economically important fishery off the east coast of Canada. It is a spatial and weekly model during 1997-2014 that utilizes within-season depletion based on catch per unit of effort (CPUE; kg per pot), and also biomass values from a survey designed specifically for this stock. The model is formulated in a state-space framework. The main contribution of the model is to provide a better understanding of fishery-dependent factors that affect CPUE. There is strong evidence of density-dependence in the relationship with CPUE and stock biomass, in addition to a general increase in CPUE catchability over time that may be related to changes in gear soak time, and spatial variation in catchability. We also find that a natural mortality rate of 0.4 provides a better fit to survey results. Model results suggest that there is no evidence of effort saturation in the fishery.

Keywords: Catch per unit of effort; depletion model; Gaussian markov random field; density-dependence catchability; stock assessment.

Introduction

Snow crab (*Chionoecetes opilio*) have been fished commercially in the southern Gulf of St. Lawrence (sGSL; Figures 1 and 2) since the mid-1960's using baited traps (i.e. pots). Monitoring of this fishery is based on logbook data, dockside monitoring of the catch, and at-sea sampling by observers. Snow crab normally molt every year until maturity (Conan and Comeau 1986) prior to the fishery (e.g. Hébert et al. 2002). After molting, crabs have a soft shell for 8 to 10 months. Males live approximately 5 years (Sainte-Marie et al. 1995) to 7.7 years (Fonseca et al. 2008) after their terminal molt. The fishery targets hard-shelled adult male animals with a minimum landing size of 95 mm carapace width (CW). The management of this fishery is based on total allowable catch (TAC), effort controls (number of licenses, trap limits, and seasons), and a limit on the percentage of the low commercial value soft-shelled crabs in the catch.

This stock is assessed using size and/or stage-based survey indices of biomass and abundance from a post-season trawl survey designed specifically for this stock (Moriyasu et al. 2016; Hébert et al. 2016b). A grid-based sampling design has been used in all survey years, although the survey coverage and grid cell size has changed over time. Total survey biomass for various life stages of crab is estimated using kriging with external drift using depth as a secondary variable (Hébert et al. 2016b). These stages include residual biomass of commercial sized males remaining after the fishery, and recruitment biomass (soft-shelled adult males >= 95 mm CW) that will be available to the fishery in the following fishing season. The exploitable biomass of commercial males is inferred from the residual and recruited biomass from the previous year's survey. A harvest decision rule including precautionary approach reference points based on commercial biomass is used to provide total allowable catch (TAC) advice (Chaput et al. 2014). A simple model has been used to project biomass in the next several years based on survey estimates of pre-recruit stages (Surette and Wade, 2006). The only other model published for this stock was an age-, sex- and stage-structured model by Siddeek et al. (2009), and the purpose of this model was for developing limit and target harvest control rules, but not directly for stock assessment.

Commercial catch rates are considered in sGSL snow crab stock assessments but the relationship between commercial-sized adult male biomass estimated from the snow crab survey and CPUE calculated from logbooks is weak; $r^2 = 0.22$ (Hébert et al. 2016a) and varies across different locations. This results in differences in perception of stock abundance between the fishing industry observations and those from the survey. Fishing industry perceptions not only involve the overall level of CPUE but also the rate of decline in CPUE as the fishing season progresses. They consider that if CPUE does not decline much then this is an indication of a larger stock size than when CPUE declines substantially. This is also related to the sedentary nature of snow crabs (Biron et al. 2008) during the sGSL fishery.

It is possible to estimate absolute biomass based on the within-season rate of decline of a biomass index in response to the fishery removals. The Leslie method (Leslie 1952) has been used for many crustacean species (see review by Smith and Addison 2003) and others (e.g. Bishir and Lancia 1996). Its popularity is partly related to its simplicity. If C_t and E_t are the catch and effort of a fishery at time t, and CPUE is $X_t = C_t/E_t$ and is proportional to stock biomass B_t, then the Leslie method involves fitting the linear model $X_t = qB_o - qK_t$, where q is the catchability coefficient, B_o is the biomass at the start of the fishing season, and K_t is the cumulative catch at time t. These parameters can be estimated using a linear regression of X_t on K_t. Alternatively, the DeLury method (DeLury 1947) involves fitting to cumulative effort rather than cumulative catch. Both methods use the rate of decline of CPUE throughout the fishing season, as a function of either catch or effort, to estimate initial stock size. These are two examples of depletion models.

In practise there are many problems with assumptions for these simple depletion estimators. Miller and Mohn (1993) examined issues with the Leslie method for species like crabs and lobsters. An important assumption is that catchability is the same for all individuals throughout the fishing season. Of particular relevance to sGSL commercial snow crab is the potential for 1) a change (decrease or increase) in capture probability depending on how many crabs are in a trap, which will result in density-dependent CPUE catchability, and 2) increased activity in warmer waters could lead to higher catchability in nearshore areas during the spring and summer. The physical habitat and temperature may affect crab walking rates, and current direction and speed may affect the bait "plume" and trap detection. CPUE catchability may also change for many other reasons (also see Miller 1990, Bacheler et al. 2013). Varying characteristics of fishing effort such as soak time, bait type and amount, and trap design and spacing can affect catchability. Trap saturation may happen with longer soak times for many reasons including space limitation of the gear, inter-species or intra-species interactions, or the loss and degradation of bait (Shertzer et al. 2015). However, Charles et al. (2014) found soak time had little effect in a study of sGSL snow crab. Temporal, spatial, and density-dependent variations in CPUE catchability have been examined extensively in the fisheries literature. Density-dependence relationships between CPUE and stock size (i.e. catchability) are commonly reported (e.g. Harley 2001, Ward et al. 2013) but are not ubiquitous (e.g. Zhou et al. 2007). Many factors may produce a power-law relationship between CPUE and stock size (e.g. Cooke and Beddington 1984). If such factors change in a systematic way, bias can be introduced to depletion estimators.

Another important assumption is that fishing effort is uniformly distributed over the area occupied by the stock. This is not the case for sGSL snow crab. Fishing fleets may adjust their fishing locations when catch rates decline and this can mask the decline in stock size due to fishing (e.g. Hilborn and Walters 1987). Depletion methods also require landings and effort to be accurately reported. Fisheries monitoring for sGSL snow crab is rigorous so reported catch should be reliable. However, effort is not evaluated in dockside monitoring and may be inaccurate. The Leslie method assumes a closed population, with no emigration, natural mortality, or recruitment. The last two issues are relevant for snow crab because of the length of the fishing season. Concerns about within-season recruitment and fleet movements led scientists to conclude that the Leslie method was inappropriate for stock assessment of sGSL snow crab (Loch et al. 1995). Corrections for these problems, when they exist, require additional information (Miller and Mohn 1993).

Various extensions of depletion models have been proposed to address some of the above problems. Gedamke et al. (2004) used information from vessel monitoring systems to disentangle the effects of nonrandom fishing patterns for scallops so that a depletion model could be applied. They used spatial analyses to define regions where assumptions of the depletion method were met. Walter et al. (2007) extended this stratification approach and conducted a geostatistical analysis of their depletion model results. Robert et al. (2010) formulated the DeLury model in a Bayesian framework and included natural mortality and within-season recruitment for an octopus fishery, with simulation testing of various model formulations and data configurations. They also modelled a range of years in a hierarchical framework in which initial abundance and catchability were related across years. Roa-Ureta (2012) proposed generalized depletion models for open populations and a nonlinear relationship between catch and effort. His model allowed for waves of within-season immigration to the fishing grounds. He applied his model to a squid fishery. Roa-Ureta (2015) extended the generalized depletion model to be multi-annual and to include multiple fleets with different catchabilities for a Spanish mackerel fishery. Zhou et al. (2011, 2015) presented a generalized Leslie-type model to estimate natural mortality rates as well as stock size and harvest rates in a Bayesian framework. Their multi-annual biomass model included within-season somatic growth and a parametric year-varying catchability function.

There is often little evidence of depletion in total fishery CPUE for sGSL snow crab. In the 2014 fishery, total CPUE (total catch divided by total effort) increased overall and only decreased for three short periods (Figure 3). Average soak times rapidly increased from about 50 hours at the start of the fishery to about 120 hours by week 25. This may partly explain the stability of CPUE during this period. However, another factor is a change in the distribution of the fishery (Figure 4). There is a pronounced change in the fleet distribution starting in August (week 29). This is a consistent feature throughout the time-series. Also, in some weeks there may be a large concentration of effort in just a few grids cells and pots may compete for crab in these cases. If multiple pots are placed within their effective fishing area then this will eventually produce a saturation effect in which catch is no longer proportional to effort. Not surprisingly, in preliminary analyses we found poor correspondence between stock size and harvest rates from a sGSL spatial depletion model and survey results. Hence, in this paper we also explore changes in model catchability assumptions, both temporal and spatial, to account for changes in the fishery to improve this correspondence.

We propose a novel CPUE and survey integrated spatial biomass depletion model that provides spatio-temporal estimates of snow crab stock size and also density-dependent and within-season spatio-temporal changes in CPUE catchability. We provide more precision on how to interpret CPUE catchability for snow crab, or more generally for stocks in which it is reasonable to assume that the gear catches all fish in the area the gear fishes. We use high resolution spatio-temporal (i.e. weeks and grids) catch and effort data, and also spatial survey data, for model estimation. Extracting more information about stock size using data at the highest resolution possible can produce more reliable stock assessments and more relevant information for fisheries managers, but an important cost of doing this is the need for a highly parameterized model that is potentially computationally complex. Another contribution of this paper is a high resolution spatial biomass depletion model that is restricted in certain ways to make the model computationally efficient. We also include a novel effort saturation effect that is spatial because of differences in the fraction of crab "grounds" within grid cells. Our model is implemented in a state-space modelling framework which has become a favored approach in modeling time varying population dynamics (e.g. Nielsen and Berg, 2014; Cadigan, 2016).

Materials and Methods

Model notation and parameters are described in the text and also Table 1. The data we used are weekly fisherman logbook observations of catch and effort for 314 spatial grid cells in sGSL during 1997-2014. Also, we use the post fishery snow crab survey trawl catches of hard-shelled adult males (i.e. exploitable crab). These data are displayed in Supplementary figures, for catch weight (Figures SC.1-20), effort (Figures SE.1-20), CPUE (Figures SX.1-20), and the snow crab survey results for exploitable biomass (Figures SSEB.1-19) and total biomass (Figures SSTB.1-19) although the latter information is not used in our model but is used in the DFO stock assessment.

The biomass (B) depletion model for grid cell i and week t in year y is

$$B_{y,t,i} = B_{y,t-1,i}exp(-Z_{y,t-1,i}), \tag{1}$$

where the weekly total mortality rate is $Z_{y,t,i} = M/52 + F_{y,t,i}$, $F_{y,t,i}$ is the fishing mortality rate, and M is an assumed constant annual value for the natural mortality rate which we prorate equally to weeks. We examine M = 0.2, 0.3, and 0.4 which are values that are consistent with the survival times in Sainte-Marie et al. (1995) and Fonseca et al. (2008). The depletion model starts at an initial biomass $B_{y,o,i}$ in year y and we project this to the start of the fishery using Equation (1) with no F. Our model does not include movement of crab between grid cells which provides substantial computational efficiencies. Snow crab in the sGSL are relatively sedentary during the fishery (Biron et al. 2008) but they may move somewhat between grid cells during the winter months before the fishery so $B_{y,o,i}$ is only a nominal initial biomass for a grid cell and the actual biomass may be different. However, we assume that $\sum_i B_{y,o,i}$ is the total stock biomass at the beginning of the year because errors due to movements will cancel out in the total biomass. The catch equation is

$$C_{y,t,i} = B_{y,t,i}\{1 - \exp(-Z_{y,t,i})\}\frac{F_{y,t,i}}{Z_{y,t,i}}. \tag{2}$$

A basic assumption underlying our spatial depletion model is that $CPUE = C/E = qB$ where E is the effort which we define as the number of pots fished. This implies that the harvest rate is $H \equiv C/B = qE$ and q represent the harvest rate of a single pot. Some boundary grid cells are small so an area-adjustment is useful. Let a_{fti} be the area fished by a pot which we assume varies spatially (i) and temporally (t) because of a variety of factors related to the fishery (e.g. soak time); however, we assume the area fished by a pot is constant within a grid cell and a week. Let A_i be the area of the grid cell and p_i be the fraction of area that are crab grounds. If crab are homogeneously distributed within the crab grounds and if a pot catches all crab within the area it fishes then the expected catch from a single randomly placed pot in cell i with total biomass $B_{y,t,i}$ is $q_{y,t,i}B_{y,t,i}/A_i$ where $q_{y,t,i} = a_{fy,t,i}/p_i$ is the potential area fished; that is, $a_{fy,t,i} \leq q_{y,t,i}$. The total catch from $E_{y,t,i}$ pots is $C_{y,t,i} = q_{y,t,i}E_{y,t,i}D_{y,t,i}$ where $D_{y,t,i} = B_{y,t,i}/A_i$ is the biomass density in grid cell i. Here we assumed that $E_{y,t,i} << q_{y,t,i}$ so that pots fish independently. Hence the expected CPUE is $X_{y,t,i} = q_{y,t,i}D_{y,t,i}$. The CPUE biomass catchability is proportional to grid cell size and varies across years, weeks and grids.

We have incomplete information on the factors that may cause catchability to change over time but we expect that these factors will be auto-correlated. Hence, we assume that

$$q_{y,t,i} = q_{y,i}\exp(\delta_{y,t,i}), \qquad (3a)$$

where $\delta_{y,t,i}$ are weekly q process errors that we assume for simplicity are AR(1) auto-correlated normal random variables with mean zero, standard deviation σ_δ, and auto-correlation parameter φ_δ. These errors are assumed to be correlated across weeks within grid cells and years but otherwise are independent. Including process error is typical of contemporary stock assessment models (Maunder and Piner, 2014). The $q_{y,i}$ annual spatial effects are further separated into independent year and space effects

$$q_{y,i} = q_y q_i, \qquad (3b)$$

The q_y year-effects account for long-term changes in fishing practices and are modelled as a random walk,

$$\log(q_{y+1}/q_y) \sim N(0, \sigma_{qy}^2). \tag{4}$$

The q_i spatial effects are described below. Hence, we model catchability at high resolution using correlated spatial effects, a random walk year effect, and auto-correlated weekly process errors within grid cells.

The idealized maximum effective effort that can be fished without pot competition is $E_{max,y,t,i} = A_i/q_{y,t,i}$. This is the total number of distinct pot fishing areas in grid i with total area A_i. The model-predicted effort corresponding to $C_{y,t,i}$ is $E_{y,t,i} = C_{y,t,i}/q_{y,t,i}D_{y,t,i}$ and

$$E_{y,t,i} = \frac{C_{y,t,i}A_{y,t,i}}{q_{y,t,i}B_{y,t,i}} = H_{y,t,i}E_{max,y,t,i} \tag{5}$$

We will use Equation (5) to model observed effort. Note that unlike much of the fisheries literature we do not assume effort is a covariate that is known without error and we are therefore better able to account for the reliability of this data. However, if there is pot saturation then pots may compete for crabs and the effective (i.e. independent) effort is less than the model prediction.

If fishermen randomly chose fishing locations regardless of gear that may already be present then this behavior can be approximated as a Poisson process. We assume that each grid cell is comprised of $E_{max,y,t,i}$ distinct fishing locations and that all pots within one location exploit the same as a single pot. Let $E_{o,y,t,i}$ be the nominal total effort and let Y be the number of pots in a fishing location which has an approximate Poisson distribution with mean $\lambda_{y,t,i} = E_{o,y,t,i}/E_{max,y,t,i}$. The probability that a location has at least one pot is $Prob(Y > 0) = 1 - \exp(-\lambda_{y,t,i})$. The number of fishing locations with at least one pot, which is the effective effort $E_{y,t,i}$, is

$$E_{y,t,i} = E_{max,y,t,i}\{1 - \exp(-E_{o,y,t,i}/E_{max,y,t,i})\}. \tag{6a}$$

However, crab fishermen are aware of gear already present at a location and they will usually avoid setting new gear close to existing gear. In this case Equation (6a) will under-estimate effective effort. We propose an alternative smooth "hockey-stick" formulation (e.g. Mesnil and Rochet, 2010) to account for this behavior,

$$E_{y,t,i} = ½E_{o,y,t,i} + ½E_{max,y,t,i}\left\{\sqrt{1+\gamma^2/4} - \sqrt{\left(E_{max,y,t,i}^{-1}E_{o,y,t,i} - 1\right)^2 + \gamma^2/4}\right\}. \tag{6b}$$

Note that we modified the model formulation of Mesnil and Rochet (2010) so that γ is a fraction of $E_{max,y,t,i}$.

Equations (6a) and (6b) are illustrated in Figure 5 for $E_{max,y,t,i} = 2000$. We set $\gamma = 0.3$ in Equation (6b). Effective effort based on Equation (6b) and nominal effort are almost the same until effort is close to E_{max} but effective effort based on Equation (6a) is usually much less than nominal effort unless effort is low. Both Equations (6a) and (6b) imply that $E_{y,t,i} \le E_{o,y,t,i}$. If $E_{o,y,t,i} \ll E_{max,y,t,i}$ then $E_{y,t,i} \approx E_{o,y,t,i}$ but as $E_{o,y,t,i} \to \infty$ then $E_{y,t,i} \to E_{max,y,t,i}$. We can use the inverse of these equations as functions of $E_{o,y,t,i}$ to get the model predicted nominal fishing effort. For Equation (6a) this is

$$E_{o,y,t,i} = -E_{max,y,t,i}log\left(1 - H_{y,t,i}\right). \tag{7a}$$

Let $U_{y,t,i} = 2H_{y,t,i} - 1 - \sqrt{1+\gamma^2/4}$. The inverse of Equation (6b) is

$$E_{o,y,t,i} = E_{max,y,t,i}\left\{1 + \frac{U_{y,t,i}^2 - \gamma^2/4}{2U_{y,t,i}}\right\}. \tag{7b}$$

If there is negligible effort saturation then

$$E_{o,y,t,i} = H_{y,t,i}E_{max,y,t,i}. \quad (7c)$$

We also include a density dependence effect in q. Our basic generating equation is CPUE = qD^{β} and $\beta = 1$ means no density dependence. However, β changes the interpretation of q so we use a slightly modified version, $CPUE = qDD_s^{\beta-1}$ where $D_s = D/\bar{D}$ is the density relative to the average over space and time. We computed an average value of D for all years, weeks, and grid cells in which fishing occurred, using a specific model formulation (M1; see Results) but kept this same value (i.e. 867 kg/km^2 or 49 Kt for the sGSL total area) in other model formulations. The re-scaling of density only affects estimation of q and not β. When $D = \bar{D}$ then $CPUE = qD$, so q represents catchability at average stock density. Our density-dependence model only requires modifying Equation (3),

$$q_{y,t,i} = D_{s,y,t,i}^{\beta-1} q_{y,i} \exp(\delta_{y,t,i}). \quad (8)$$

There is otherwise no change in the way annual and spatial effects ($q_{y,i}$) or weekly effects ($\delta_{y,t,i}$) are modelled. However, this density dependence may be confounded with effort saturation.

There are two groups of spatial effects in our model, the yearly initial biomass densities $D_{y,o,i} = B_{y,o,i}/A_i$ and the catchabilities q_i. We have insufficient data to estimate these effects freely, nor would this be a good idea because we expect spatial correlation in these effects. Hence, we also model these spatial effects as latent random variables on the snow crab survey grid. Let G be the total number of grid cells. The covariance structure we use for these random variables is the same as that described in Kristensen et al. (2013) and is based on a precision matrix (i.e. inverse covariance matrix) that implies that a grid cell is, conditional on the cell's neighbors, independent of all other cells. The precision matrix $\Psi_{G\times G}$ for the logs of $D_{y,o.i}$ or q_i has *i,j*'th element

$$\Psi_{i,j} = \begin{cases} -\tau, & \text{if cell } i \text{ neighbors cell } j, \\ \tau(m_i + \vartheta), & \text{if } i = j, \\ 0, & \text{otherwise,} \end{cases} \quad (9)$$

where m_i is the number of neighbors of grid cell *i* which will typically be four but will be less for boundary cells. The τ and ϑ parameters are estimated separately for each spatial effect. We denote these as τ_D and ϑ_D, etc. The precision matrix approach is typical of those used in Gaussian Markov random fields (GMRF) and implies that the correlation decreases with distance traveled through water and not simply the straight-line distance between two grid cells. This is particularly relevant for the sGSL because of irregular coast lines (i.e. Chaleur Bay) and island obstacles (i.e. the Magdalen Islands; see Figure 1). Let $\underline{D}_{y,o}$ be a vector of spatial density effects for year *y*. We also expect that the spatial distribution of biomass will be similar from year to year. We accommodate this behavior by modelling the density in the first year, $\log(\underline{D}_{1,o})$, as a GMRF with parameters τ_{D1} and ϑ_{D1}, and the relative difference in densities in successive years, $log\left(\underline{D}_{y+1,o}/\underline{D}_{y,o}\right)$, as independent GMRFs with parameters τ_{D2} and ϑ_{D2}. These latter parameters are assumed to be the same for all years. Hence, our model involves a spatially correlated random walk for biomass density from year to year.

The data available to estimate model parameters (θ, see next Section) are spatial catch and effort measurements each week during 1997-2014, and the snow crab survey catches for the same years (see Supplementary figures). Our model is for male commercial biomass so we only use survey catch information for hard-shelled legal size males that were exploited in the same year of the survey (i.e. residual exploitable biomass). We assume a small and fixed value for log-catch measurement error (ME) standard deviation (SD; i.e. $\sigma_C = 0.05$) because this data is obtained from dockside monitoring with reportedly high accuracy. This is approximately the catch measurement error CV. The state-space model log-likelihood (i.e. observation) equation for catch is

$$l(\theta|\{C_{obs}\}) = \sum_y \sum_t \sum_i log\left[\sigma_C^{-1}\varphi_N\left\{\frac{\log(C_{obs,y,t,i}) - \log(C_{y,t,i})}{\sigma_C}\right\}\right], \quad (10)$$

where φ_N is the standard normal probability density function and $\{C_{obs}\}$ indicates the set of all catch observations. The model values for catches, $C_{y,t,i}$, come from Equation (2). Effort is not evaluated in dockside monitoring and is reported less accurately than catches. We assume multiplicative ME, $E_{obs,y,t,i} = E_{o,y,t,i}e^{\varepsilon_{y,t,i}}$ where the model values for reported effort, $E_{o,y,t,i}$, come from Equations (7a), (7b), or (7c) depending on whether a saturation effect is included or not, and the type of effect, and ε is the effort ME. This ME may be auto-correlated across weeks within grid cells and years because it is likely that the same fishing crews are involved and they are likely to report effort with similar error. If there is no effort saturation then using Equations (3) and (5) we can show that

$$\log(E_{obs,y,t,i}) = \log(H_{y,t,i}) + \log(A_{y,t,i}) - \log(q_{y,i}) + \varepsilon_{y,t,i} - \delta_{y,t,i}. \quad (11)$$

The ε effort ME's and the δ catchability process errors are confounded. We can only estimate their total effect. We still refer to these errors as δ process errors although they are a mixture of changes in catchability and ME in effort. Let $t_{f,y,i}$ denote the first week of the fishery in year y and grid cell i. We re-define $\delta_{y,t,i} = \log(E_{obs,y,t,i}) - \log(E_{o,y,t,i})$ and the likelihood equation for effort is

$$l(\theta|\{E_{obs}\}) = \sum_{y}\sum_{i}\sum_{t>t_{f,y,i}} log\left[\sigma_{\delta}^{-1}\varphi_N\left\{\frac{\delta_{y,t,i} - \varphi_{\delta}\delta_{y,t-1,i}}{\sigma_{\delta}}\right\}\right]. \quad (12)$$

For the first week of the fishery, when $t = t_{f,y,i}$ then $\delta_{y,t-1,i} = 0$.

The snow crab survey biomass values, $S_{obs,y,i}$, are assumed to be absolute estimates of the biomass in the trawl swept area. We re-scaled these biomass values to be equivalent to a tow with a standard swept area of 2700 m^2 which is typical in the survey design. The model predicted survey biomass values are $S_{y,i} = 2700B_{y,34,i}/A_i$ where the grid cell area is in m^2. We assumed this survey occurred in week 34 which is about the end of August. This is considered further in the Discussion. In preliminary analysis we found that the ME SD (σ_S) did not depend much on predicted values. Also, there are a large number of zero's in the survey time-series so log-transformation was not an option and did not seem necessary. Hence, the survey likelihood equation is

$$l(\theta|\{S_{obs}\}) = \sum_{y}\sum_{i} log\left[\sigma_{S}^{-1}\varphi_N\left\{\frac{S_{obs,y,i} - S_{y,i}}{\sigma_S}\right\}\right]. \quad (12)$$

The F's in Equation (2) are also treated as unstructured random effects with a common mean and variance. Let $\mu_F = E(F)$ and $\sigma_F^2 = Var\{\log(F)\}$. The likelihood equation for F's is

$$l(\{F\}|\theta) = \sum_{y}\sum_{t}\sum_{i} log\left[\sigma_{F}^{-1}\varphi_N\left\{\frac{\log(F_{y,t,i}) - \log(\mu_F)}{\sigma_F}\right\}\right]. \quad (13)$$

We will show that the estimate of σ_F is fairly large and so the F's are estimated almost freely.

Estimation

The model is high dimensional, based on 314 spatial grid cells and 936 time steps for the 18 years and 52 weeks per year, resulting in slightly over 290 000 space-time cells. However, there are only a small number of parameters to estimate. Most of the model effects are random and are not freely estimated. Fixed effect parameters, denoted collectively as the parameter vector θ, are estimated via maximum likelihood (MLE) based on the total marginal likelihood, $L(\theta)$, in which random effects are "integrated out". Let Γ denote a vector of all random effects. There are 13 or 14 θ's, depending on the model formulation, but there are almost 27 000 Γ's. Note that there are far fewer Γ's than the total number of space-time model cells because δ's and F's are only estimated for cells that had reported catches, and in many weeks there is no fishing in a grid cell (see Supplementary figures).

Let S denote the set of all survey, catch, and effort data used in the model. The marginal likelihood is

$$L(\theta) = \iiint_{\Gamma} f_{\theta}(S \mid \Gamma) g_{\theta}(\Gamma) \partial\Gamma, \qquad (14)$$

where $f_\theta(S|\Gamma)$ is the pdf of the data and $g_\theta(\Gamma)$ is the pdf for the Γ random effects. The template model builder (TMB; Kristensen, 2015) package within R (R Core Team, 2016) was used to implement the model. The MLE's of θ maximize $L(\theta)$. The user has to provide C++ computer code to calculate $f_\theta(S|\Gamma)$ and $g_\theta(\Gamma)$ but the integration in Equation (14) and calculation of θ to maximize this equation is then provided by TMB. The high dimensional integral is numerically evaluated in TMB using the Laplace approximation. The random effects Γ can be predicted by maximizing the joint likelihood, $f_\theta(S|\Gamma)g_\theta(\Gamma)$. Additional information on these procedures is provided by Skaug and Fournier (2006). TMB uses automatic differentiation to evaluate the gradient function of Equation (14) and in the Laplace approximation. The gradient function is produced automatically from $f_\theta(S|\Gamma)$ and $g_\theta(\Gamma)$. This greatly improves parameter estimation using a derivative-based optimizer. We use the *nlminb* function within R (R Core Team, 2016) to find the MLE for θ.

The reliability of model estimates was assessed through detailed examination of model estimates and residuals, and also retrospective analyses in which the model was fit to subsets of data with recent years left out. Some covariance parameters are shared across years in the model so it is possible that there may be retrospective patterns in model estimates. This was done for retrospective years 2007 to 2014. Sensitivity analyses to model assumptions about M (0.2, 0.3, or 0.4), saturation (none or hockey-stick type), and density-dependence (none or estimated) were also performed, leading to a total of 3x2x2 = 12 model formulations that were fitted.

Results

Including a saturation effect did not make much difference to estimates and model fits because the saturation level was usually estimated to be much greater than typical levels of effort. For example, two models described in Table 2 (i.e. M1 and M2), that differed only in whether a "hockey-stick" saturation effect was included or not, produced nearly identical parameter estimates and the model without effort saturation (i.e. M2) produced a better fit. This was a consistent feature in other model formulations we compared for different values of M and the density dependence parameter β. There is also no evidence of saturation in plots of catch versus effort (unreported results) for various regions in sGSL.

The statistical evidence for density dependence was very strong (e.g. compare M2 and M3, and M4 and M5) and the estimate of $\beta \ll 1$ indicating high hyper-stability in CPUE. This effect resulted in a much improved fit to the snow crab survey residual biomass values, as evidenced by the lower value of σ_S for M3 and M4. Density dependence is evident in plots of CPUE versus mean biomass for each grid cell and year (Figure 6) even from a model (i.e. M2 in Table 2) with no density dependence. The slope of log CPUE versus log biomass should be close to one if there is no density dependence but this is clearly not the case. Note that to simplify this figure we only plotted average CPUE and biomass for all weeks within each grid cell and year. Results based on weekly values were very similar. Including density dependence also resulted in substantially different estimates of spatial effects. For example, the total variation, trace(Ψ^{-1}), of the spatial effects for CPUE catchability (i.e. q_i) was 303.0 for M2 but only 51.8 for M3, indicating more between grid variation in q for M2. Conversely, the total variation of the D2 spatial random walk for between year changes in biomass density was 152.1 for M3 but only 69.9 for M2 indicating larger between year changes in the spatial distribution of biomass for M3 compared to M2. The total variation of the D1 spatial distribution of biomass in the first year (i.e. 1997) was 16 221 for M2 and 17 671 for M3. The D1 total variance is much larger than the D2 total variance which indicates relatively small changes in the spatial distribution of biomass from year to year for both models. The ϑ parameters control the decorrelation range in the spatial covariance matrix. When these parameters are small then the decorrelation range is large (see Kristensen et al. 2013); that is, the spatial correlation is high. The relatively large CV's for ϑ's estimates for models M1-M5 indicate that the spatial correlations are estimated with less precision than other parameters.

Another model formulation issue was the choice of M. We investigated three choices (M = 0.2, 0.3, and 0.4). All values resulted in fairly similar fits (see Table 2 for M = 0.3 or 0,4). Models in which $\beta = 1$ indicated $M = 0.4$ was the best choice. When β was estimated and no effort saturation was assumed then the best fit was obtained with $M = 0.2$. The fit was 2.6 AIC units lower than the fit for $M = 0.3$. However, models with M=0.4 produced estimates of beginning of year commercial biomass that agreed more closely with the stock assessment kriging biomass estimates (DFO, 2016) scaled by $\exp(-18M/52)$ to account for natural mortality between the time of the post-season survey and the end of the year (Figure 7). This scaling is described in more detail later. We fit the model only to survey catches of residual biomass so the improved fit to DFO kriging estimates of residual plus recruited biomass provides additional and partially independent support for $M = 0.4$. Hence, our preferred model formulation (i.e. M4 in Table 2) is $M = 0.4$, with density dependence in CPUE, but no effort saturation effect. More specific results from this model are presented in Table 3. Detailed spatial models results are provided in Supplementary Figures S5-S22.

On a tow-by-tow basis the M4 fit to the snow crab survey catches was highly variable (Figure 8; Figures S1, S5-S22). The mean predicted survey catch was 1.0799 and $\hat{\sigma}_S = 1.153$ (Table 2) indicating that the survey CV was 108%. The snow crab survey catches have substantial spatial variability (see Figures SSEB.1 – SSEB.19) and many zero catches that the model did fit well. Of particular concern is the tendency of the model to under-estimate high values (Figure 8) which suggests potential model mis-specification. The model is constructed to fit catches almost exactly. Effort observations were fit less closely but without apparent bias (Figures S2-S4). There was very little retrospective variation in model results (unreported results).

All models indicated significant changes in catchability over year. The standard deviation (σ_{qy}) of the random walk for the q_y year-effects was around 0.1 (Table 2). There was also significant spatial variability in q's (Figure 9). We computed the effort-weighted average of $q_{y,i}$ in Equation (3) for all grid cells each year, which is proportional to q_y, and divided this by the average grid area to estimate the catchability of a pot which is also the exploitation rate of a single pot (Figure 10). We compared this with average soak times and the correlation was high (0.75) suggesting that changes in soak times may be a major factor related to change in trap catchability. The effort-weighted average of $q_{y,i}$ is also an estimate of the average potential pot fishing area and the model results indicate that this has ranged from 46 000 to 79 000 m^2 and has increased over time (unreported results). Recall that these values are upper bounds because they are based on the assumption that an entire grid is snow crab "grounds". We computed the average E_{max} over years for each grid cell, $\bar{E}_{max,i} = A_i/q_i\bar{q}_y$, and $\bar{q}_y$ is the average of $q_{1997}, \ldots, q_{2014}$ Figure 11) . Regions where the area fished by a pot is higher, as indicated in Figure 9, have lower values for E_{max}. Typical levels of effort (i.e. hundreds of pots per grid cell per week) are far less than these saturation levels.

The M4 model harvest rates and those from the stock assessment were usually similar (Figure 12). When computing harvest rates from stock assessment estimates of commercial male biomass, we also projected post-season biomass from year *y-1* to beginning of year biomass in year *y* using $\exp(-18M/52)$ to account for natural mortality between the time of the survey and the beginning of the following year. For $M = 0.4$ this results in a 13% reduction in biomass and a 15% increase in harvest rates compared to stock assessment values (see Figure 9 in DFO, 2016). Although similar in magnitude to values from the stock assessment, the M4 harvest rates were more variable. If the goal of snow crab fisheries management is a constant harvest rate then the

M4 model indicates that past quotas have resulted in landings and harvest rates that were more variable than required, especially the large decreases in 2010 and 2011 (Figure 2). Landings were reduced from around 25 Kt in 2008-2009 to 10 Kt in 2010-2011 which resulted in a sharp drop in M4 exploitation rates, well below potential targets. The M4 model suggests that quotas around 15 Kt in 2010 and 2011 would have resulted in more constant harvest rates.

Discussion

We developed a spatial depletion model for sGSL snow crab based on high resolution (weekly and spatial) catch and effort data, and spatial survey data, to provide more precise estimates of snow crab biomass and population dynamics. Additional information on population size is obtained from the high resolution temporal information by using a within-season biomass depletion model based on the change in fishery CPUE. Such information is often not utilized in stock assessments. However, there are many problems when interpreting CPUE as an index of stock size and we had to incorporate spatio-temporal changes in CPUE catchability. Nonetheless our model did provide somewhat different trends in a few years compared to the snow crab survey that the stock assessment is based on. In particular, our model suggested that some historic reductions in fishery quotas may not have been completely warranted if the objective of snow crab fisheries management was a constant harvest rate near some target level. Also, our model results provide additional information about how CPUE catchability may change and problems with interpreting CPUE as an index of stock size. Some aspects of the model we proposed are specific to sGSL snow crab, or to cases where the fishing gear catches most or all of the fish available to the gear. However, we suggest the basic approach can be used for other stocks where: 1) fish movement within the time-frame of the fishery is expected to be low, 2) high resolution spatio-temporal catch and effort data are available, and 3) high resolution spatial data from a research survey are available.

The original motivation for this research was to validate a spatial CPUE depletion model for application with Newfoundland and Labrador (NL) snow crab. The depletion model was originally formulated with a spatially and temporally constant q and without density-dependence in q or saturation effects. It was felt that sGSL snow crab was a good test case for that model because there were independent estimates of exploitable biomass from the snow crab survey to compare with depletion model estimates. Research surveys in NL have low catchability for snow crab and did not provide a useful comparison. However, this original model based only on seasonal CPUE did not produce plausible values for sGSL snow crab because of the general lack of a CPUE depletion signal for that fishery. This is very different from NL snow crab that often does show a decline in CPUE throughout the fishing season (e.g. see Figures 47, 61, and 78 in Mullowney et al 2016). We then extended the sGSL model to integrate the snow crab survey catches which provided a basis to estimate various changes (i.e. seasonal, spatial, annual, density-dependent) in CPUE catchability.

Our results indicate that there have been substantial changes in sGSL snow crab CPUE catchability and these changes seem to be linked with changes in soak time, among other reasons. There is strong evidence of density-dependence in the relationship with CPUE and stock biomass, in addition to a general increase in CPUE catchability over time, very consistent with changes in fishery soak times across years, and spatial variation in catchability. However, we did not find evidence of CPUE saturation. Hence, our model has contributed additional insights into problems with inferring sGSL snow crab resource status based on CPUE. There are many factors influencing CPUE in addition to stock size. This has been a source of uncertainty in the assessment of this stock (DFO 2016). In addition, the model also indicated potential snow crab survey year effects in 2009 for exploitable biomass and 2011 for total biomass, a problem that has been identified in snow crab assessments (e.g. DFO 2012).

We used our model and additional information from the snow crab survey on soft-shelled male biomass that will recruit to the fishery in the following year to infer that $M = 0.4$ was a more plausible value. This implies 5% survival at the 7.7 year male longevity estimate of Fonseca et al. (2008) which is reasonably consistent. At $M = 0.3$ the survival at 7.7 years is 10%. We showed that with $M = 0.4$ our model provided a good fit to both M-projected beginning of year commercial biomass and post-season residual biomass from the DFO kriging analyses of the snow crab survey. It has often been noted in sGSL snow crab assessments (e.g. DFO, 2016) that the estimated commercial biomass from the survey tends to be higher than the sum of the residual biomass and the landings of the following year, and the difference is attributed to a number of factors. Our results indicate that additional natural mortality at $M = 0.4$ between the end of the post-season survey and the start of the fishery in the following year can explain this difference, but M = 0.3 does not completely explain the discrepancy.

The standard deviation of the process error (σ_δ) was estimated to be large for all model formulations we investigated. This reflects measurement error in effort and also within-season changes in catchability. Reducing this source of error will require additional information from the snow crab fishing fleet, such as accurate measurements of effort and soak time, pot spacing, and other characteristics that may affect catch rates. Such information could be used as covariates to model and explain some of the variation in catchability, and this seems like a useful area for future research. Nonetheless, the model uncertainty in estimates of stock size and harvest rates is low, with CV's in the 2-3% range, which is consistent with the low retrospective variation we found in model M4. Hence, reducing the process error variation may not lead to more precise estimates of stock size or harvest rates.

The low CV's on stock size and harvest rates may seem unrealistic given the highly flexible model with a CPUE *q* that may vary across years, spatial locations, weeks, and stock density. However, the model used a large amount of data, nearly 21 000 catch and effort measurements and 4200 survey catch values, and the model was constrained to fit the catches very closely, which will result in low CV's. There is some evidence of model mis-specification in the lack of fit to the larger catches from the snow crab survey which leads to an overall average positive residual in most years. This suggests that the CV's may be too small because they do not reflect uncertainty due to model mis-specification. There are many zero catches in the snow crab survey that the model also does not fit well. This could be due to site effects in the fixed-station survey sampling design or other operational issues. There have been changes in snow crab survey vessels during 1997 to 2015, including a change in 2013 from the vessel which had been used during 2003 to 2012. Comparative fishing experiments were not conducted to assess if there were changes in catchability between vessels; however, Benoît and Cadigan (2016) found some evidence of a change in vessel catchability by comparing snow crab survey catches from those from the DFO multi-species survey. Hence, changes in survey catch rates over time may not accurately reflect changes in stock size if survey vessels have different catchabilities and this is another source of unaccounted variability.

We assumed that all snow crab survey sets occurred in a single week. In reality the survey takes around 80 days to complete. It would be fairly simple to use the week a grid cell was sampled because the model predicts weekly and spatial biomass.

To simplify the model we treated stock dynamics separately each year and no connection is made between biomass from year to year. Roa-Ureta (2012) took a similar approach. However, population dynamics are of course linked across years, and the biomass remaining at the end of a year is part of the biomass at the start of the next year in addition to recruitment. Linking across years creates additional challenges related to movement between grid cells which may be ignored within a single fishing season because of the low mobility of sGSL snow crab (Biron et al. 2008), but movement will become more of an issue if crab dynamics are modelled over longer time-scales. Linking across years will also create other computational problems related to reduced sparseness of the covariance matrix of the random effects. This may significantly increase model run times, which are about 6-7 minutes for model formulations we investigated.

Best stock assessment practise should involve an assessment model that integrates all of the relevant productivity data for sGSL snow crab, including fishery CPUE, both the snow crab and DFO multi-species trawl survey catch rates, and their stage (maturity/length) composition information. Shell-stage (new/intermediate/old) compositions for mature males can provide important information on mortality rates. An assessment model should include a growth component between immature and newly mature soft-shell crabs and legal-sized hard-shell males. This will provide some capability to provide short-term projections for tactical harvest advice. A spatial assessment model can better integrate data collected at varying spatial scales and provide spatial management advice which is an issue for sGSL snow crab (e.g. DFO, 2016). The results of this paper provide a good basis for further development of such an integrated spatial stock assessment model.

References

Note that most DFO documents cited in this paper are freely available online, at http://www.dfo-mpo.gc.ca/csas-sccs/index.htm.

Bacheler, N.M., Bartolino, V. and Reichert, M.J., 2013. Influence of soak time and fish accumulation on catches of reef fishes in a multispecies trap survey. Fishery Bulletin, 111: 218-232.

Benoît, H.P., and Cadigan, N. 2016. Trends in the biomass, distribution, size composition and model-based estimates of commercial abundance of snow crab (*Chionoecetes opilio*) based on the multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/084. v + 25 p.

Biron, M., Ferron, C. and Moriyasu, M. 2008. Movement of adult male snow crab, *Chionoecetes opilio*, in the southern Gulf of St. Lawrence and eastern Nova Scotia, Canada. Fisheries Research, 91: 260-270.

Bishir, J. and Lancia, R.A., 1996. On catch-effort methods of estimating animal abundance. Biometrics 52: 1457-1466.

Cadigan, N.G. 2016. A state-space stock assessment model for northern cod, including under-reported catches and variable natural mortality rates. Canadian Journal of Fisheries and Aquatic Sciences 73: 296-308.

Chaput, G., and DFO/Industry Joint Working Group. 2014. Evaluation of compliance to the Precautionary Approach of harvest decision rules for the snow crab (*Chionoecetes opilio*) stock of the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/083. v + 57 p.

Charles, Colin, Darren Gillis, and Elmer Wade. Using hidden Markov models to infer vessel activities in the snow crab (*Chionoecetes opilio*) fixed gear fishery and their application to catch standardization. Canadian Journal of Fisheries and Aquatic Sciences 71: 1817-1829.

Conan, G.Y., and Comeau, M. 1986. Functional maturity of male snow crab, (*Chionoecetes opilio*). Canadian Journal of Fisheries and Aquatic Sciences, 43: 1710-1719.

Cooke, J.G. and Beddington, J.R., 1984. The relationship between catch rates and abundance in fisheries. Mathematical Medicine and Biology, 1: 391-405.

DeLury, D.B., 1947. On the estimation of biological populations. Biometrics, 3: 145-167.

DFO. 2012. Assessment of snow crab in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) and advice for the 2012 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/003.

DFO. 2016. Assessment of snow crab (*Chionoecetes opilio*) in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) and advice for the 2016 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/010.

Fonseca, D.B., Sainte-Marie, B., and Hazel, F. 2008. Longevity and change in shell condition of adult male snow crab *Chionoecetes opilio* inferred from dactyl wear and mark-recapture data. Transactions of the American Fisheries Society, 137: 1029-1043.

Gedamke, T., DuPaul, W.D. and Hoenig, J.M., 2004. A spatially explicit open-ocean DeLury analysis to estimate gear efficiency in the dredge fishery for sea scallop Placopecten magellanicus. North American Journal of Fisheries Management, 24: 335-351.

Harley, S.J., Myers, R.A. and Dunn, A., 2001. Is catch-per-unit-effort proportional to abundance? Canadian Journal of Fisheries and Aquatic Sciences, 58: 1760-1772.

Hébert, M., Benhalima, K., Miron, G., and Moriyasu, M. 2002. Molting and growth of male snow crab, *Chionoecetes opilio*, (O. Fabricius, 1788) (Crustacea: Majidae) in the southern Gulf of St. Lawrence. Crustaceana 75: 671-702.

Hébert, M., Wade, E., DeGrâce, P., and Moriyasu, M. 2016a. Review of the 2014 snow crab (*Chionoecetes opilio*) fishery in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/081. v + 43 p.

Hébert, M., Wade, E., DeGrâce, P., and Moriyasu, M. 2016b. The 2014 assessment of the snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/083. v + 43 p.

Hilborn, R. and Walters, C.J., 1987. A general model for simulation of stock and fleet dynamics in spatially heterogeneous fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 44: 1366-1369.

Kristensen, K., Thygesen, U.H., Andersen, K.H. and Beyer, J.E., 2013. Estimating spatio-temporal dynamics of size-structured populations. Canadian Journal of Fisheries and Aquatic Sciences: 326-336.

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H. and Bell, B., 2015. Template model builder TMB .Journal of Statistical Software, 70: 1–21.

Leslie, P.H., 1952. The estimation of population parameters from data obtained by means of the capture-recapture method. II. The estimation of total numbers. Biometrika, 39: 363-388.

Loch, J.S., Moriyasu, M. and Jones, J.B., 1995. An improved link between industry, management and science: review of case history of the Southwestern Gulf of St. Lawrence snow crab fishery. Aquatic Living Resources, 8: 253-265.

Maunder, M. N., and Piner, K. R. 2014. Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science, doi:10.1093/icesjms/fsu015.

Mesnil, B. and Rochet, M.J., 2010. A continuous hockey stick stock–recruit model for estimating MSY reference points. ICES Journal of Marine Science: Journal du Conseil, 67: 1780-1784.

Mullowney, D. Dawe, E., Coffey, W., Quilty, S., Colbourne, E., and Maddock Parsons, D. 2016. An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/026. v+179 p.

Nielsen, A., Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research, 158, 96-101..

Miller, R.J., 1990. Effectiveness of crab and lobster traps. Canadian Journal of Fisheries and Aquatic Sciences, 47: 1228-1251.

Miller, R.J. and Mohn, R.K., 1993. Critique of the Leslie method for estimating sizes of crab and lobster populations. North American Journal of Fisheries Management, 13: 676-685.

Moriyasu, M., Wade, E., Landry, J.F., DeGrâce, P., Surette, T., and Hébert, M. 2016. Summary of 2014 snow crab trawl survey activities in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/082. v + 39 p.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Roa-Ureta, R.H., 2012. Modelling in-season pulses of recruitment and hyperstability-hyperdepletion in the Loligo gahi fishery around the Falkland Islands with generalized depletion models. ICES Journal of Marine Science: Journal du Conseil, 69:1403-1415.

Roa-Ureta, R.H., 2015. Stock assessment of the Spanish mackerel (*Scomberomorus commerson*) in Saudi waters of the Arabian Gulf with generalized depletion models under data-limited conditions. Fisheries Research, 171: 68-77.

Robert, M., Faraj, A., McAllister, M.K. and Rivot, E., 2010. Bayesian state-space modelling of the De Lury depletion model: strengths and limitations of the method, and application to the Moroccan octopus fishery. ICES Journal of Marine Science: Journal du Conseil, 67: 1272-1290.

Sainte-Marie, B., Raymond, S., and Brêthes, J.-C. 1995. Growth and maturation of the benthic stages of male snow crab, *Chionoecetes opilio* (Brachyura: Majidae). Canadian Journal of Fisheries and Aquatic Sciences, 52: 903-924.

Siddeek, M.S.M., Wade, E. and Moriyasu, M., 2009. Proposed harvest control rule for managing the snow crab stock in the southwestern Gulf of St. Lawrence, Canada. Fisheries Research: 268-279.

Skaug H.J., and Fournier D.A. 2006. Automatic approximation of the marginal likelihood in non-Gaussian hierarchical models. Computational Statistics & Data Analysis, 51: 699-709.

Smith, M.T. and Addison, J.T., 2003. Methods for stock assessment of crustacean fisheries. Fisheries Research, 65: 231-256.

Surette, T.J. and Wade, E., 2006. Bayesian serial linear regression models for forecasting the short-term abundance of commercial snow crab (*Chionoecetes opilio*). Canadian Technical Report of Fisheries and Aquatic Sciences, 2672: vi + 33 p.

Ward, H.G., Askey, P.J. and Post, J.R., 2013. A mechanistic understanding of hyperstability in catch per unit effort and density-dependent catchability in a multistock recreational fishery. Canadian Journal of Fisheries and Aquatic Sciences, 70: 1542-1550.

Walter, J.F., Hoenig, J.M. and Gedamke, T., 2007. Correcting for effective area fished in fishery-dependent depletion estimates of abundance and capture efficiency. ICES Journal of Marine Science: Journal du Conseil, 64: 1760-1771.

Zhou, S., Dichmont, C., Burridge, C.Y., Venables, W.N., Toscas, P.J. and Vance, D., 2007. Is catchability density-dependent for schooling prawns?. Fisheries Research, 85: 23-36.

Zhou, S., Punt, A.E., Deng, R. and Bishop, J., 2011. Estimating multifleet catchability coefficients and natural mortality from fishery catch and effort data: comparison of Bayesian state–space and observation error models. Canadian Journal of Fisheries and Aquatic Sciences, 68: 1171-1181.

Zhou, S., Buckworth, R.C., Ellis, N., Deng, R.A. and Pascoe, S., 2015. Getting all information out of logbooks: estimating banana prawn fishable biomass, catchability, and fishing power increase, with a focus on natural mortality. ICES Journal of Marine Science: Journal du Conseil, 72: 54-61.

Figure Captions

Figure 1. Locations of snow crab (*Chionoecetes opilio*) fishing grounds and management areas in the southern Gulf of St. Lawrence. PEI indicates the province of Prince Edward Island. 20 and 200 meter depth contours are shown with heavy grey lines.

Figure 2. Landings (tonnes) by fishery management areas in the southern Gulf of St. Lawrence snow crab fishery, 1969 to 2015.

Figure 3. CPUE and average soak time versus week for the 2014 snow crab fishery.

Figure 4. Weekly catch per unit of effort (CPUE) of snow crab in the southern Gulf of St. Lawrence in 2014. Colors of spatial grids correspond to CPUE levels, as indicated in the legend on the right-hand side. Weeks are indicated in the top-left corner of each panel. Darkest red grids indicate CPUE > 110 Kg/pot which is the 95th percentile.

Figure 5. Illustration of two models for effort saturation. Effective effort is the number of independent fishing locations, with a maximum of Emax = 2000. PP (Poisson Process) indicates randomly chosen fishing locations and HS (hockey-stick) indicates locations chosen to avoid existing gear. Dashed grey lines are references for Emax and Emax/2, and the 1:1 line. Vertical lines indicate the nominal effort corresponding to Emax/2 effective effort.

Figure 6. Log CPUE (total catch divided by total effort) versus log mean biomass for all weeks in each grid cell. Panels correspond to years. Biomass values were obtained from model M1 (see Table 2). The dashed reference lines indicate average log CPUE. The grey lines are linear regressions of log CPUE versus log biomass. Red lines are linear regressions with the slope fixed at one (i.e. no density dependence).

Figure 7. DFO estimates of biomass from the snow crab survey (SCS; green and blue lines) and M4 model estimates (red and black lines). Colors correspond to sources and shaded regions indicate 95% confidence intervals. CPUE is shown using dashed lines. Horizontal lines indicate the series average. SCS biomass values were obtained using kriging estimation (see Hébert et al. 2016b

Figure 8. Snow crab survey (SCS) M4 residuals versus predicted values. The red curve is smoother of residuals versus biomass.

Figure 9. Spatial effects in snow crab catchability. Colors of spatial grids correspond catchability effects, as indicated in the legend on the right hand side and directly on the figure. Darkest red grids indicate effects > 95th percentile.

Figure 10. Pot catchability (solid lines) and soak time (dashed lines) versus year. Catchability is effort-weighted across grid cells and standardized by grid area.

Figure 11. Annual average maximum effective effort (pots x 1000). Colors of spatial grids correspond to effort, as indicated in the legend on the right hand side and directly on the figure. Darkest red grids indicate effort > 5 000 pots.

Figure 12. Harvest rate estimates from the M4 model and values based on projected stock assessment estimates of snow crab survey (SCS) commercial biomass. Colors correspond to sources and shaded regions indicate 95% confidence intervals. Horizontal lines indicate the series average.

Table 1. Acronyms, model notation and parameters.

	Acronyms and notation
sGSL	Southern Gulf of St. Lawrence
CW	Carapace width
TAC	Total allowable catch
ME	Measurement error
SD	Standard deviation
CV	Coefficient of Variation
CPUE, X	Catch per unit of effort
C_{obs}	Reported fishery Catch
E_{obs}	Reported fishery effort
q	CPUE Catchability/potential area fished
E_{max}	Maximum effective effort
E_o	Nominal fishing effort without adjustment for saturation
S_{obs}	Snow crab survey trawl catch (biomass)
A	Grid cell area
p	Fraction of A that is crab grounds
a_f	Area fished by a pot
y	year
i	Grid cell, $i=1,\ldots,G$
G	Total number of grid cells.
t	week
GMRF	Gaussian Markov random field
φ_N	Standard normal probability density function
θ	Fixed effect model parameters
Γ	Model random effects
	model parameters (P) and random effects (RE)
F	Fishing mortality rate (RE)
μ_F	mean F (P)
σ_F	CV F (P)
q_y	Catchability year effects (RE)
σ_{qy}	CV for q_y (P)
δ	Weekly process errors in catchability and ME in effort (RE)
σ_δ	SD for δ (P)
φ_δ	Auto-correlation for δ (P)
q_i	Catchability spatial effects (RE)
τ_q, ϑ_q	Precision matrix parameters for q_i (P)
$D_{y,o,i}$	Initial biomass density (RE)
$\tau_{D1}, \vartheta_{D1}$	Ψ parameters for $D_{1,o,i}$ in first year (P)
$\tau_{D2}, \vartheta_{D2}$	Ψ parameters for log-deviations in $D_{y,o,i}$ in other years (P)
β	Density-dependence catchability parameter (P)
σ_C	Catch measurement error CV (P)
σ_S	Standard deviation of snow crab survey catch (P)

	model derived quantities
Z	Total mortality rate, $Z = F + M$
Ψ	Spatial precision matrix
$q_{y,t,i}$	CPUE catchability in year y, week t and grid cell i
$B_{y,o,i}$	Initial annual biomass, $B_{y,o,i} = D_{y,o,i}A_i$
$C_{y,t,i}$	Catch
$H_{y,t,i}$	Harvest rate, $H_{y,t,i} = C_{y,t,i}/B_{y,t,i}$
$E_{y,t,i}$	Model predicted effort
$D_{y,o,i}$	Initial biomass density,
	fixed model inputs
M	Natural mortality rate
γ	Fixed parameter controlling the transition of effective effort to E_{max}
m_i	The number of neighbors of grid cell i

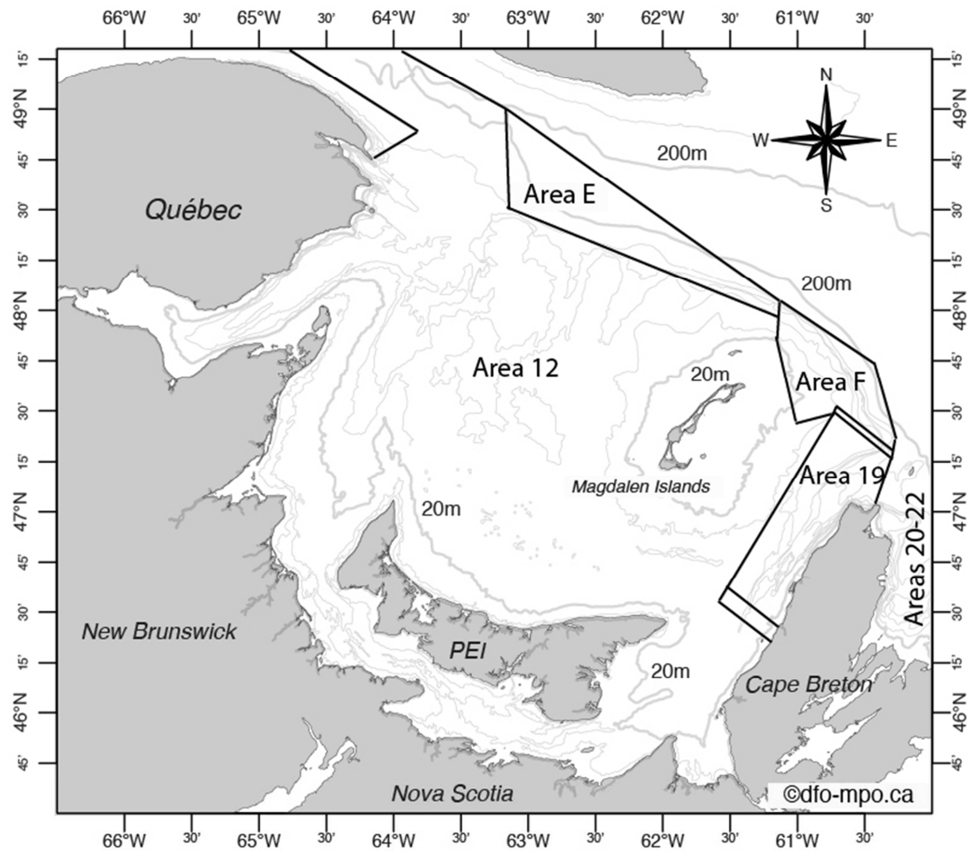
Table 2. Estimates (Est) of model parameters (see Table 1) and some population quantities, with percent coefficients of variation (CVx100), for five model formulations. nll denotes the negative loglikelihood and ΔAIC is the difference in Akaike information criterion from the minimum of the models.

	M1		M2		M3		M4		M5	
ΔAIC:	3442.1		3429.4		0		2.7		3409.7	
nll:	56899		56893		55177		55178		56883	
Quantity	Est	CV%	Est	CV%	Est	CV%	Est	CV%	Est	CV%
q_{1997} ($x10^{-4}$)	6.609	18.7	6.568	18.8	6.474	13.8	6.439	13.8	6.454	18.7
β	-	-	-	-	0.387	2.0	0.388	1.9	-	-
μ_F	0.053	1.3	0.053	1.3	0.078	2.1	0.076	2.0	0.052	1.3
σ_F	1.149	0.5	1.149	0.5	1.130	0.7	1.130	0.7	1.149	0.5
σ_{qy}	0.090	23.0	0.090	23.0	0.106	18.3	0.106	18.3	0.089	23.1
σ_δ	0.474	0.6	0.474	0.6	0.463	0.6	0.464	0.6	0.474	0.6
σ_S	1.409	1.4	1.409	1.4	1.145	4.4	1.153	3.6	1.409	1.5
τ_{D1}	0.614	10.2	0.610	10.2	0.511	11.0	0.514	11.0	0.611	10.2
ϑ_{D1}	0.000	141.8	0.000	141.8	0.000	141.9	0.000	141.9	0.000	141.8
τ_{D2}	3.936	4.8	3.932	4.8	1.440	5.4	1.467	5.1	4.016	5.0
ϑ_{D2}	0.042	24.5	0.042	24.5	0.090	22.1	0.087	21.9	0.041	24.8
τ_q	0.543	11.4	0.535	11.4	3.913	13.3	3.911	13.3	0.538	11.4
ϑ_q	0.227	52.9	0.229	52.8	0.110	66.6	0.109	66.7	0.229	52.8
φ_q	0.359	2.8	0.360	2.8	0.289	3.2	0.288	3.1	0.359	2.8
B_{2014} (Kt)	66.815	1.9	66.802	1.9	56.498	2.3	59.792	2.3	70.799	1.9
$B_{2014}/\bar{B}$	1.118	1.8	1.118	1.8	1.116	2.1	1.119	2.1	1.119	1.8
H_{2014} (%)	34.803	1.9	34.810	1.9	41.155	2.3	38.887	2.3	32.844	1.9
$H_{2014}/\bar{H}$	1.047	1.8	1.047	1.8	1.049	2.1	1.047	2.1	1.046	1.8
$a_{f,2014}$($x10^{-4}$)	7.315	3.4	7.269	3.4	7.566	2.3	7.521	2.3	7.146	3.4
$a_{f,2014}/\bar{a}_f$	1.052	2.8	1.052	2.8	1.128	2.0	1.128	2.0	1.053	2.8

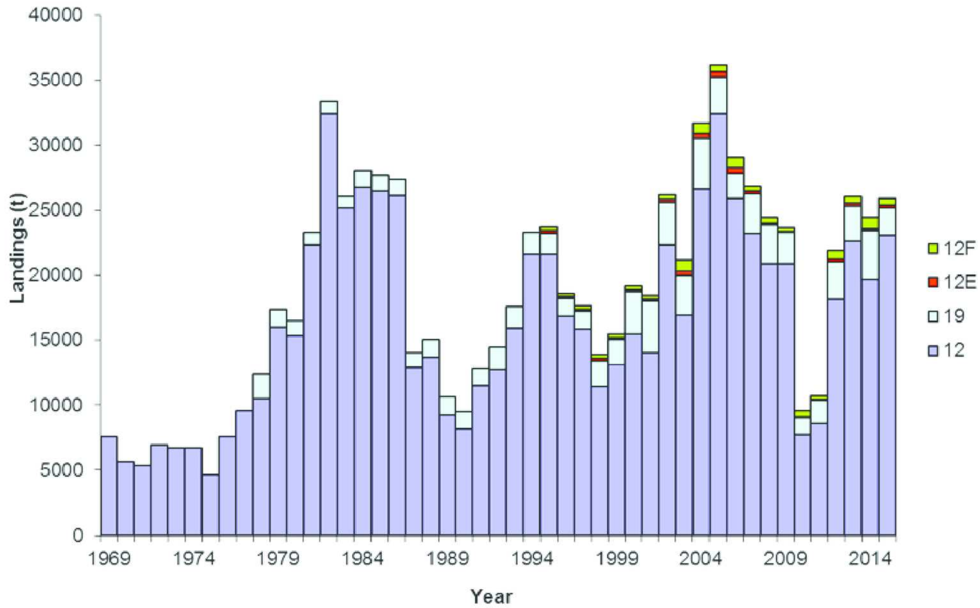
M1: No density dependence ($\boldsymbol{\beta = 1}$), effort saturation, M = 0.3.
M2: No density dependence ($\boldsymbol{\beta = 1}$), no effort saturation, M = 0.3.
M3: Density dependence ($\boldsymbol{\beta}$ estimated), no effort saturation, M = 0.3.
M4: Density dependence, no effort saturation, M = 0.4.
M5: No density dependence, no effort saturation, M = 0.4.

Table 3. Southern Gulf of St. Lawrence snow crab M4 model estimates (Est) and coefficients of variation (CV, %) of 1) beginning of year (i.e. initial) biomass, 2) post-season biomass, 3) harvest rates, and 4) area fished. See Table 2 footnotes for M4 formualtion.

	Initial Biomass (Kt)		Post-Season Biomass (Kt)		Harvest Rate (%)		Area Fished ($x10^4$ m^2)	
Year	Est	CV%	Est	CV%	Est	CV%	Est	CV%
1997	57.3	2.9	28.3	4.5	29.9	2.9	6.3	2.3
1998	53.1	2.5	28.3	3.7	25.7	2.5	5.8	2.4
1999	57.4	2.7	30.2	3.9	26.6	2.7	6.0	2.5
2000	37.7	2.6	12.3	6.1	48.2	2.6	5.2	2.2
2001	40.7	2.5	14.7	5.3	44.8	2.5	5.9	2.3
2002	46.7	1.9	12.4	5.5	55.5	1.9	5.5	2.2
2003	57.7	2.6	25.6	4.4	35.1	2.6	6.1	2.4
2004	66.8	1.9	22.5	4.4	47.0	1.9	6.6	2.1
2005	75.1	1.7	26.0	3.7	46.1	1.7	7.4	2.0
2006	57.8	1.9	20.5	4.0	46.2	1.9	7.5	2.1
2007	61.3	2.1	25.1	4.0	39.6	2.1	7.3	2.3
2008	53.9	2.5	21.5	4.7	40.1	2.5	6.7	2.3
2009	47.4	1.9	16.4	4.1	46.2	1.9	6.5	2.1
2010	30.7	3.0	15.4	4.7	29.9	3.0	7.0	2.7
2011	54.4	3.2	32.4	4.2	19.1	3.2	6.7	2.9
2012	59.6	2.2	26.9	3.8	35.5	2.2	8.3	2.3
2013	65.2	2.0	27.5	3.7	38.1	2.0	9.0	2.3
2014	59.8	2.3	24.5	4.3	39.0	2.3	7.5	2.3

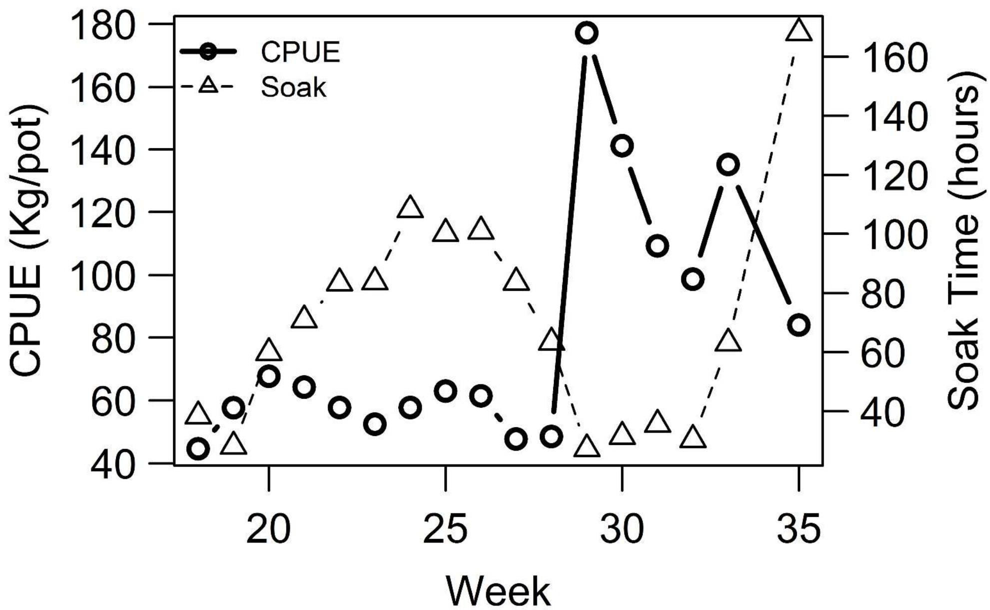


140x125mm (150 x 150 DPI)

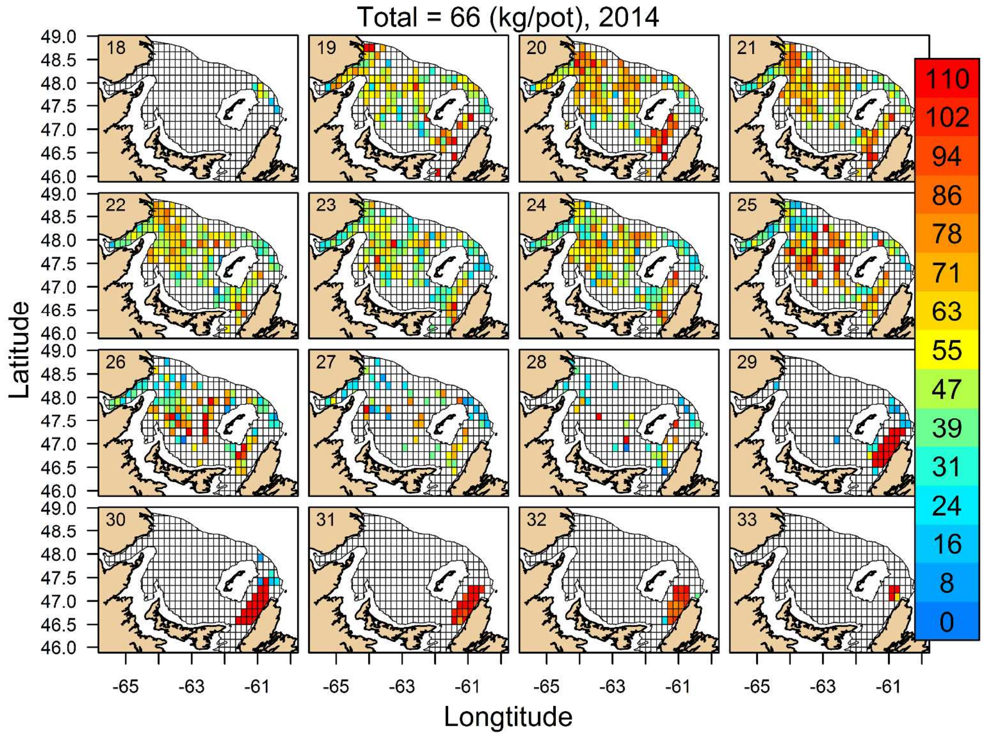


Landings (tonnes) by fishery management areas in the southern Gulf of St. Lawrence snow crab fishery, 1969 to 2015.

275x179mm (150 x 150 DPI)



CPUE and average soak time versus week for the 2014 snow crab fishery.



Weekly catch per unit of effort (CPUE) of snow crab in the southern Gulf of St. Lawrence in 2014. Colors of spatial grids correspond to CPUE levels, as indicated in the legend on the right-hand side. Weeks are indicated in the top-left corner of each panel. Darkest red grids indicate CPUE > 110 Kg/pot which is the 95th percentile.

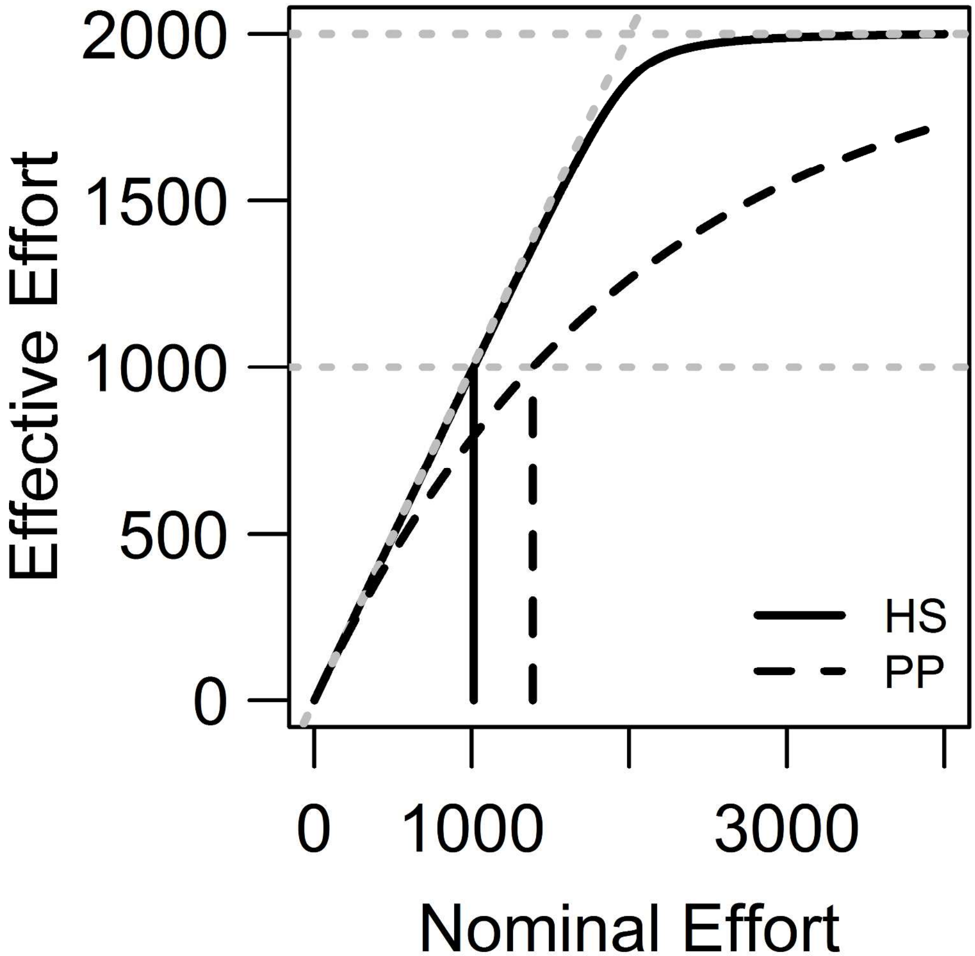
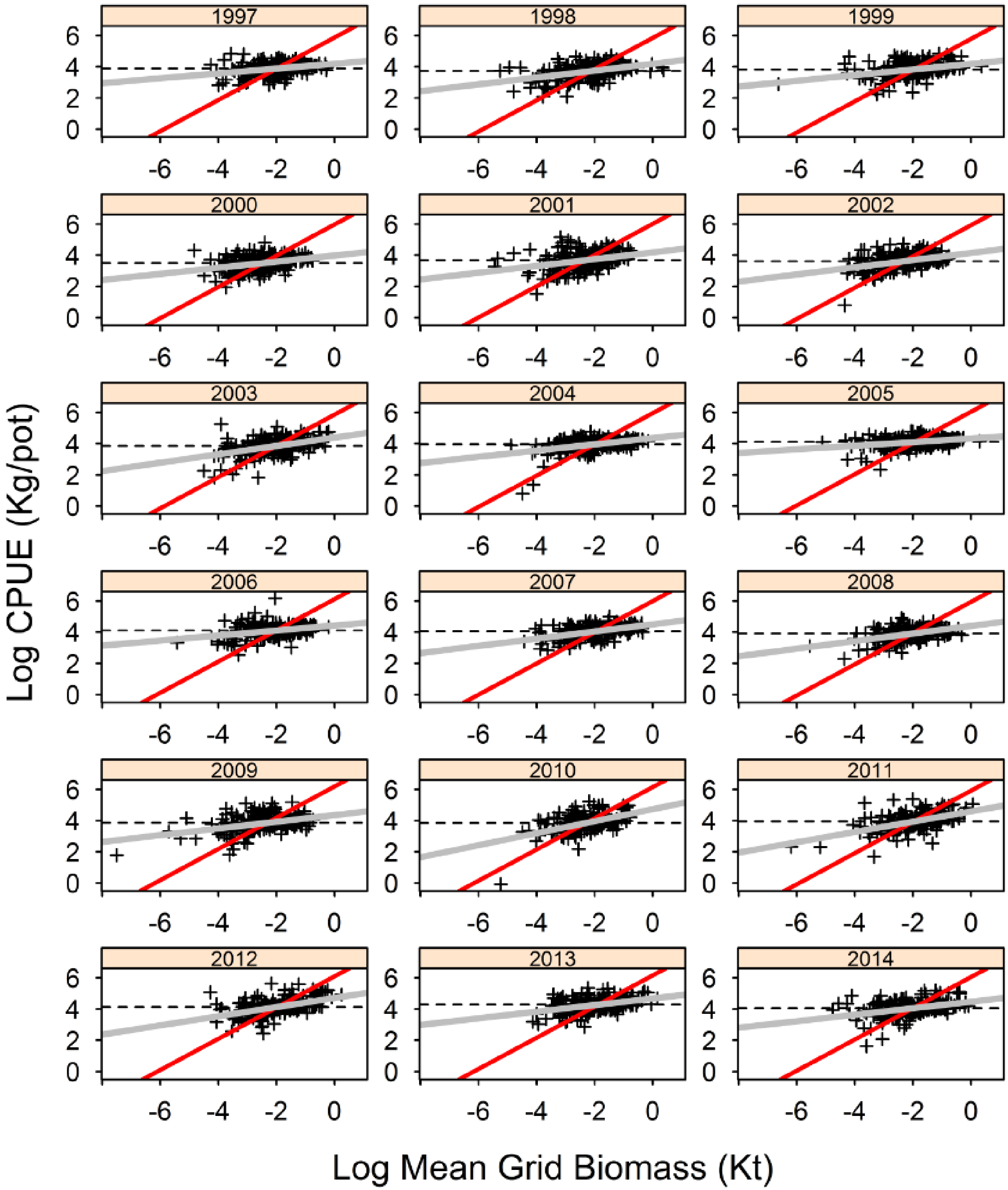
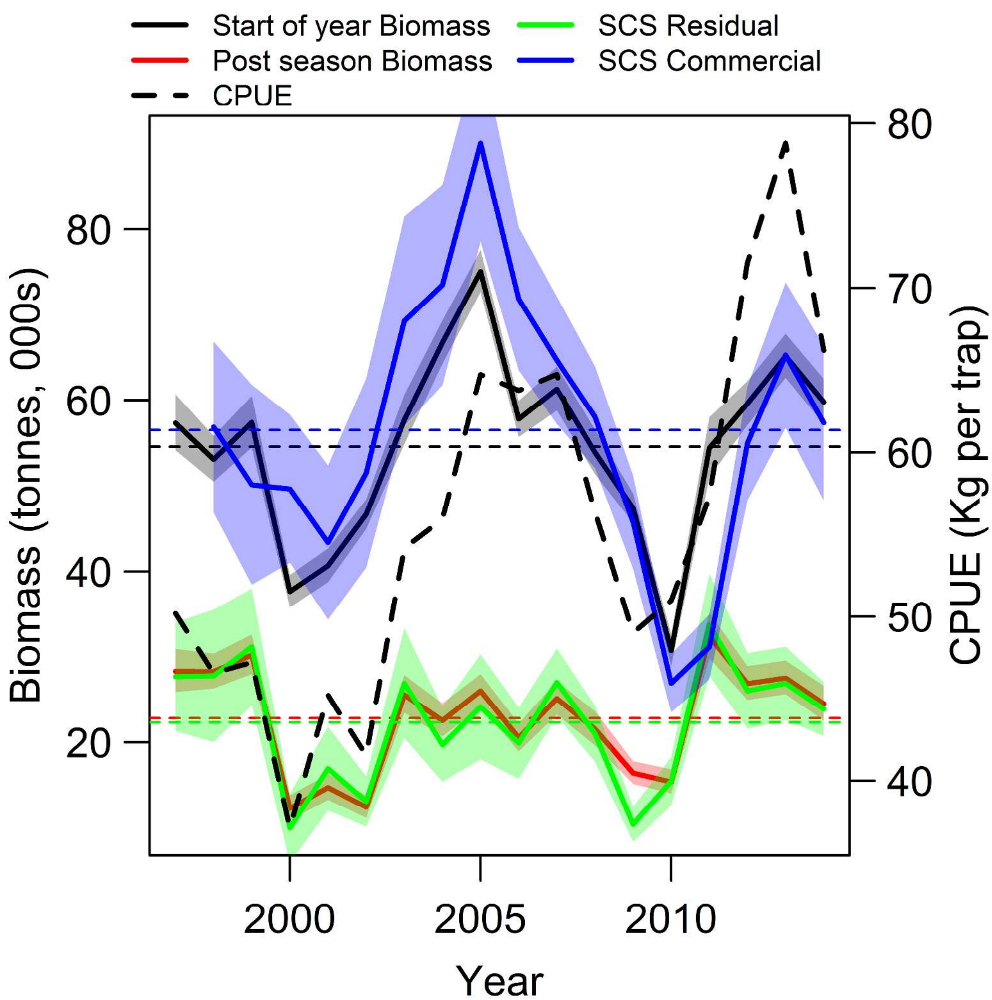
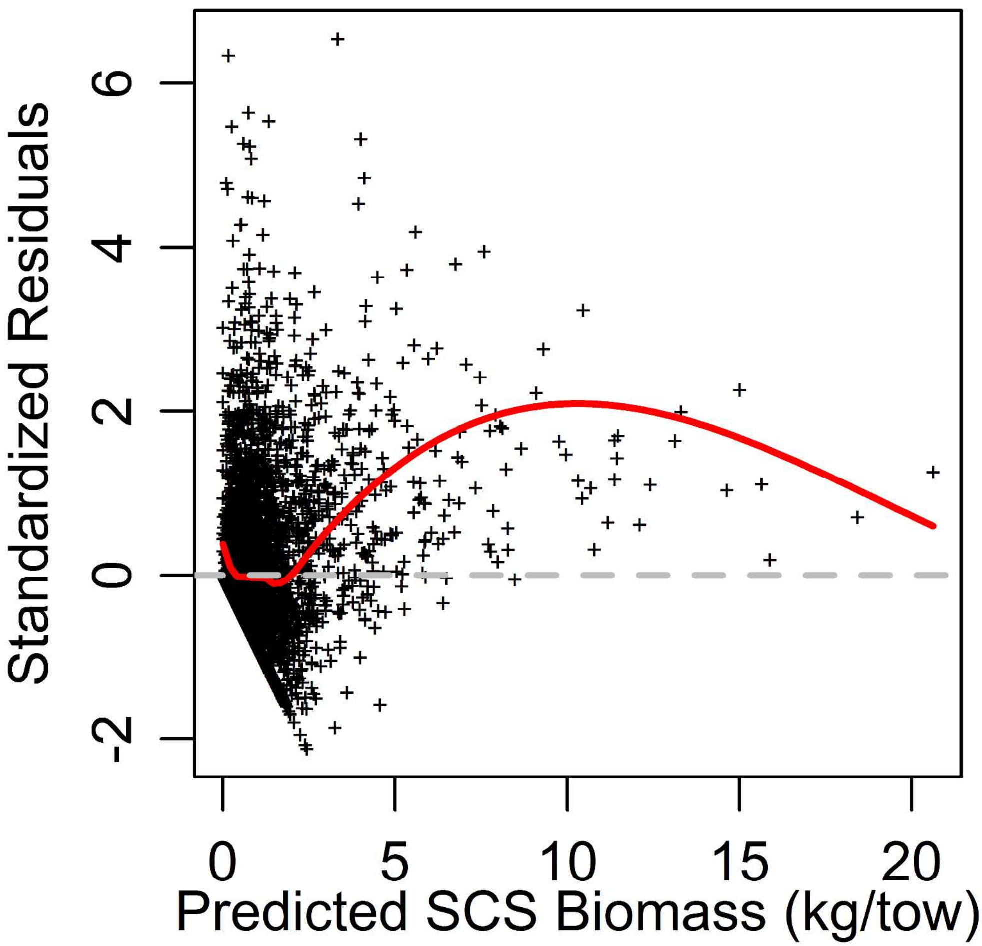


Illustration of two models for effort saturation. Effective effort is the number of independent fishing locations, with a maximum of E_{max} = *2000*. PP (Poisson Process) indicates randomly chosen fishing locations and HS (hockey-stick) indicates locations chosen to avoid existing gear. Dashed grey lines are references for E_{max} and $E_{max}/2$, and the 1:1 line. Vertical lines indicate the nominal effort corresponding to $E_{max}/2$ effective effort.

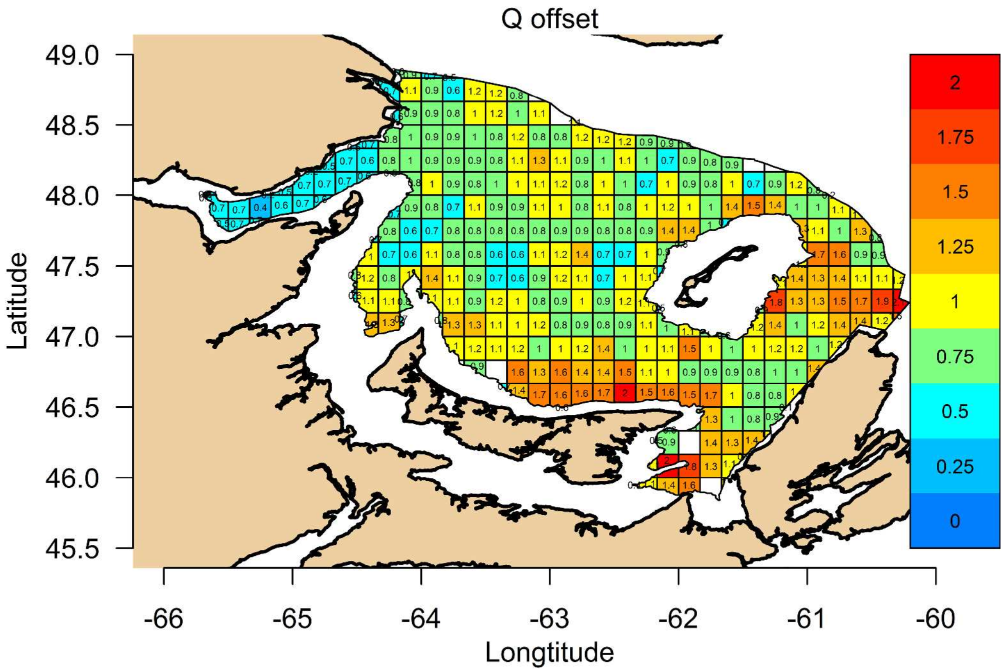

1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Log CPUE (Kg/pot)
Log Mean Grid Biomass (Kt)
0
2
4
6
-6
-4
-2
0



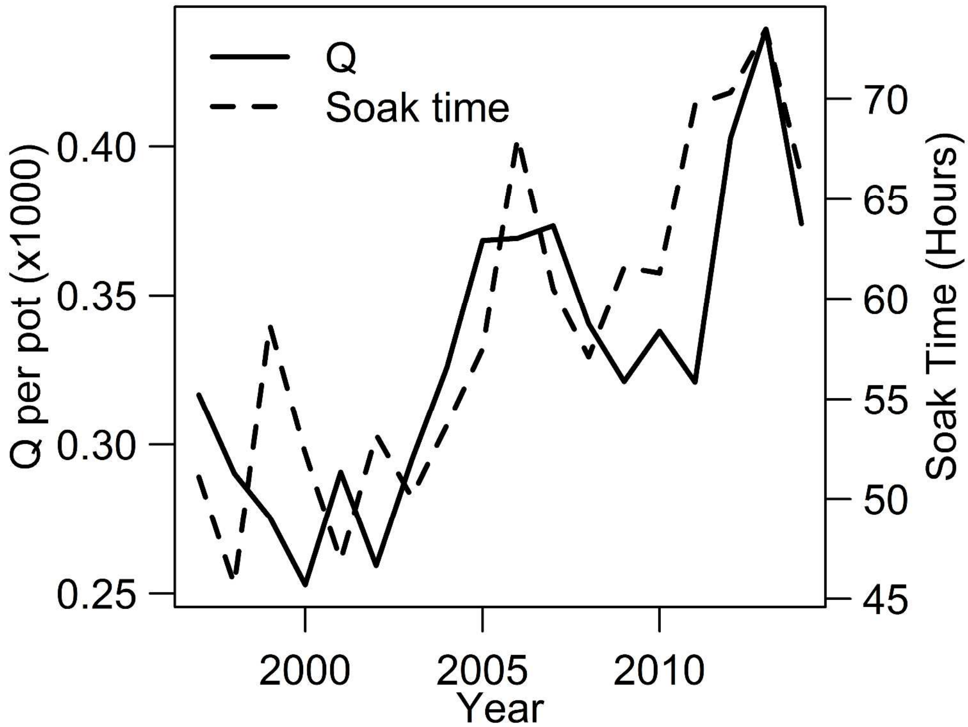
DFO estimates of biomass from the snow crab survey (SCS; green and blue lines) and M4 model estimates (red and black lines). Colors correspond to sources and shaded regions indicate 95% confidence intervals. CPUE is shown using dashed lines. Horizontal lines indicate the series average. SCS biomass values were obtained using kriging estimation (see Hébert et al. 2016b).



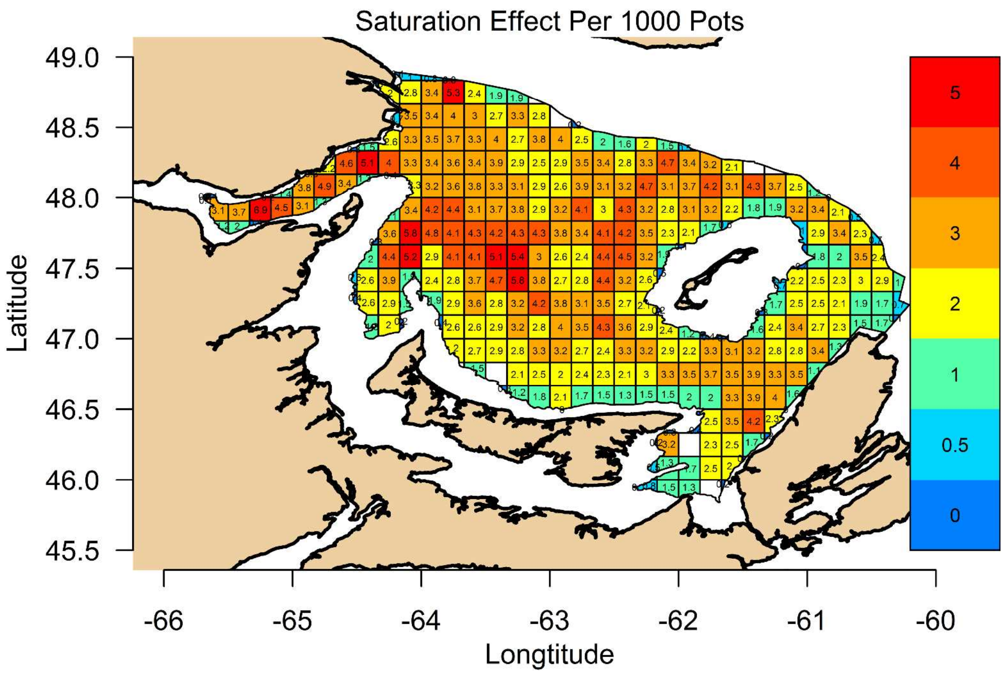
Snow crab survey (SCS) M4 residuals versus predicted values. The red curve is smoother of residuals versus biomass.



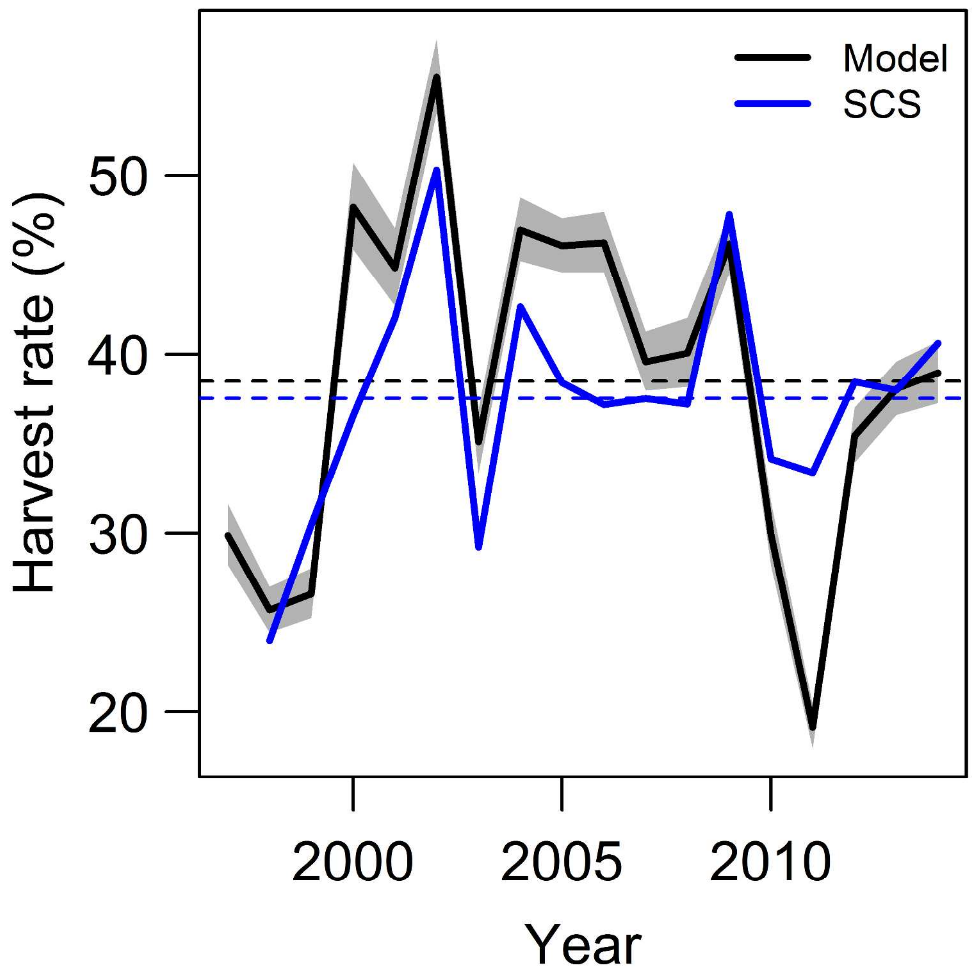
Spatial effects in snow crab catchability. Colors of spatial grids correspond catchability effects, as indicated in the legend on the right hand side and directly on the figure. Darkest red grids indicate effects > 95th percentile.



Pot catchability (solid lines) and soak time (dashed lines) versus year. Catchability is effort-weighted across grid cells and standardized by grid area.



Annual average maximum effective effort (pots x 1000). Colors of spatial grids correspond to effort, as indicated in the legend on the right hand side and directly on the figure. Darkest red grids indicate effort > 5 000 pots.



Harvest rate estimates from the M4 model and values based on projected stock assessment estimates of snow crab survey (SCS) commercial biomass. Colors correspond to sources and shaded regions indicate 95% confidence intervals. Horizontal lines indicate the series average.

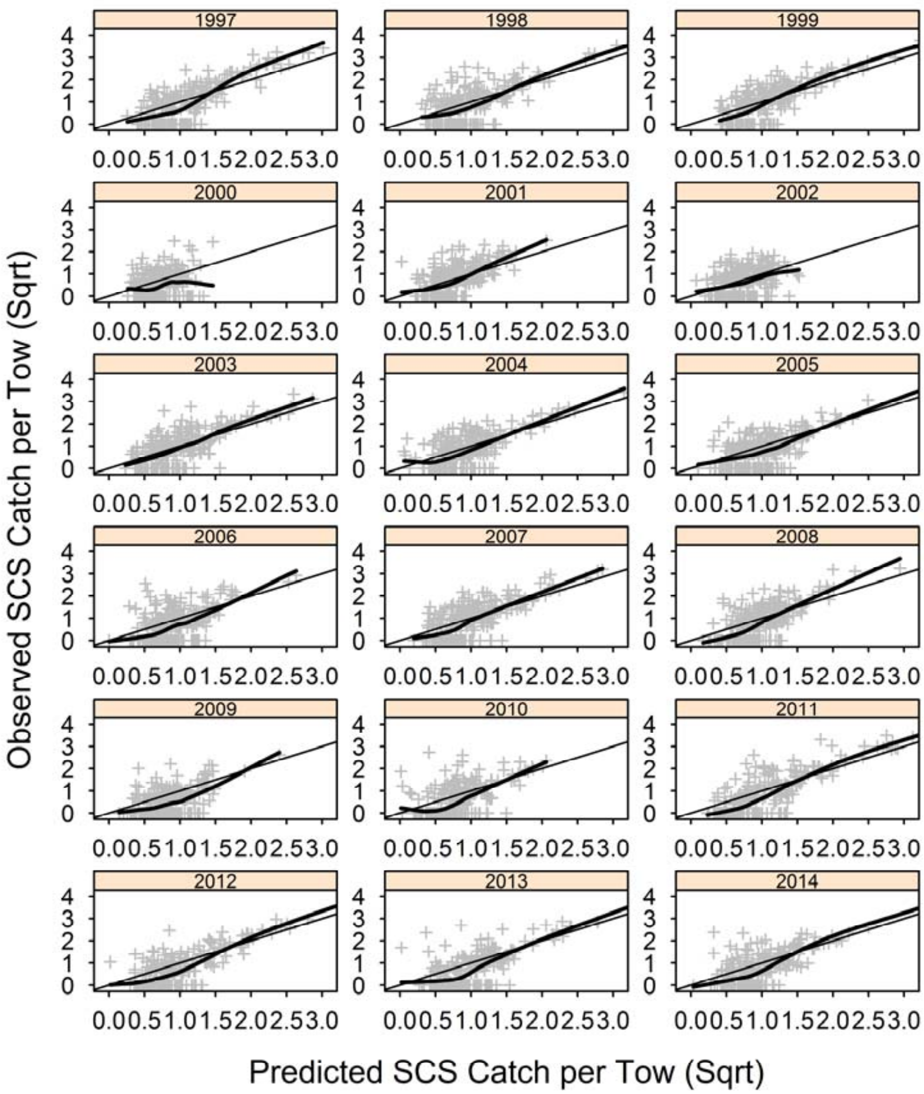


Figure S1. Observed versus predicted snow crab survey exploitable biomass catch per tow (grey +'s). Panels correspond to years. Predicted biomass values were obtained from model M4 (see Table 2). Thin solid lines indicates 1:1 lines, and thick solid lines indicate smoothers.

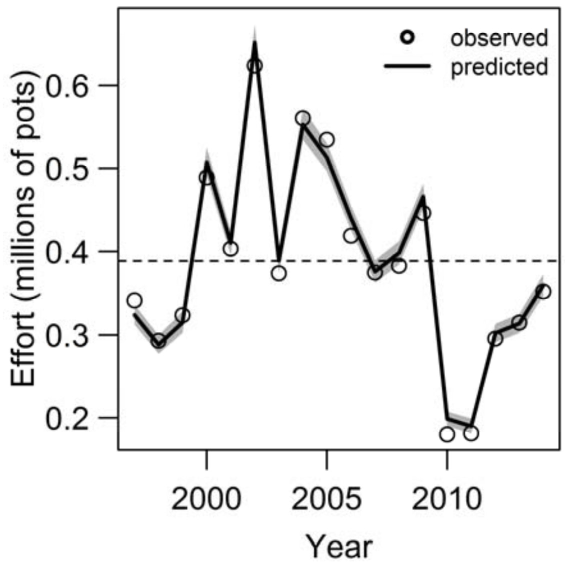


Figure S2. Observed and predicted total annual effort. Shaded regions indicate 95% confidence intervals. Predicted values were obtained from model M4 (see Table 2).

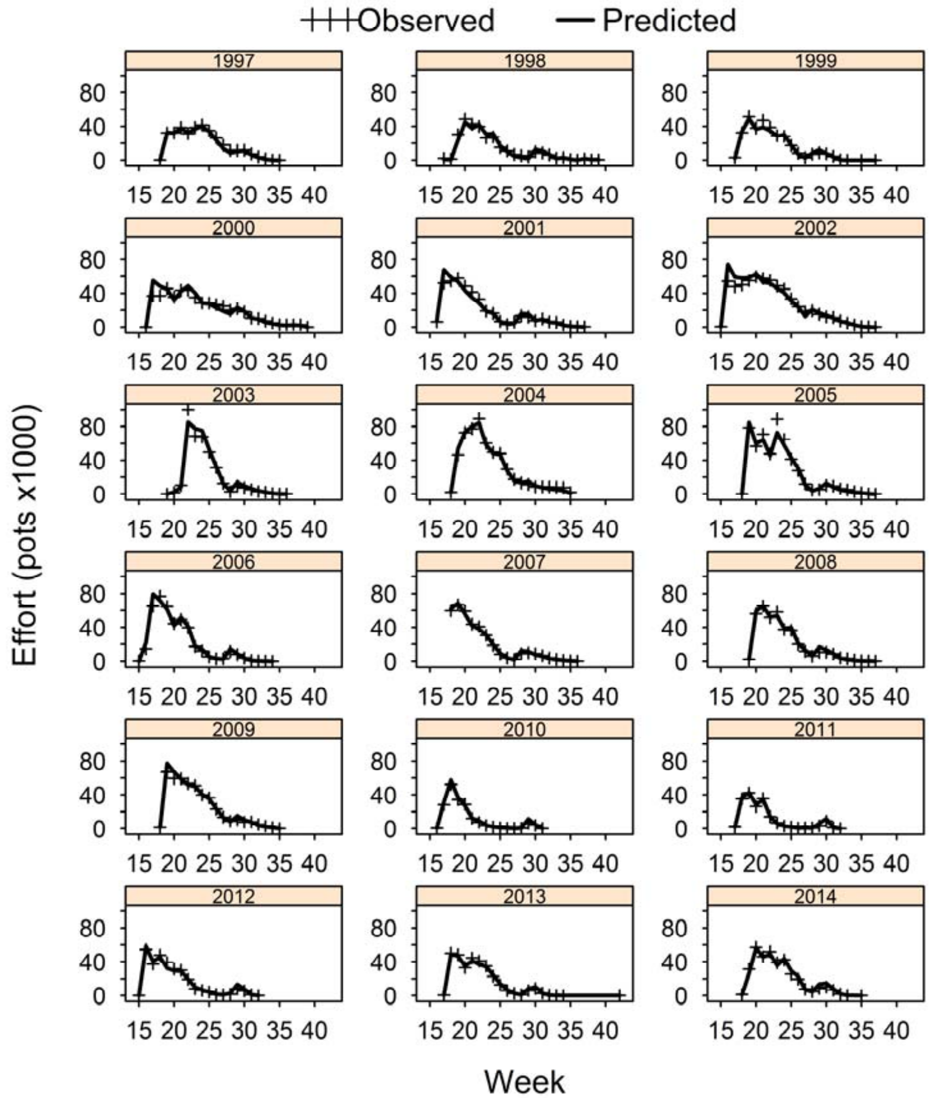


Figure S3. Observed versus predicted total weekly effort. Panels correspond to years. Predicted values were obtained from model M4 (see Table 2).

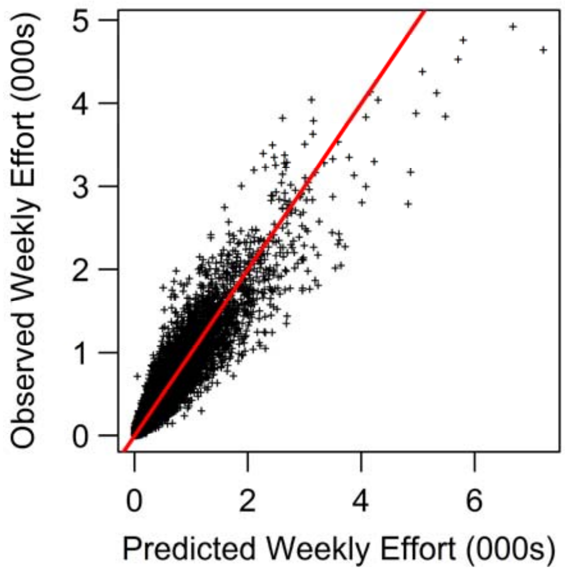


Figure S4. Observed versus predicted effort. Predicted values were obtained from model M4 (see Table 2). The 1:1 line is shown in red.

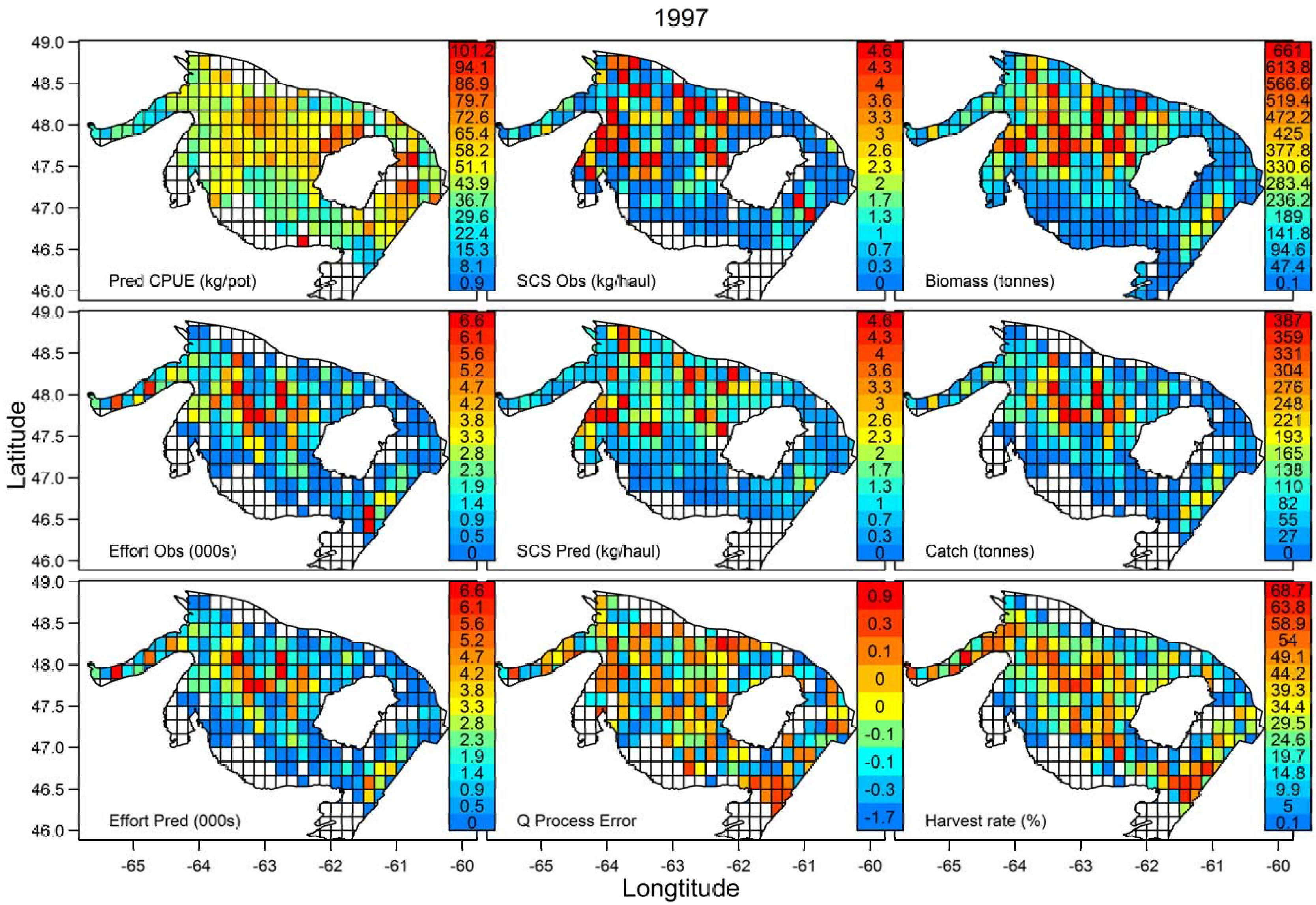


Figure S5. Model M4 (see Table 2) spatial results for 1997. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

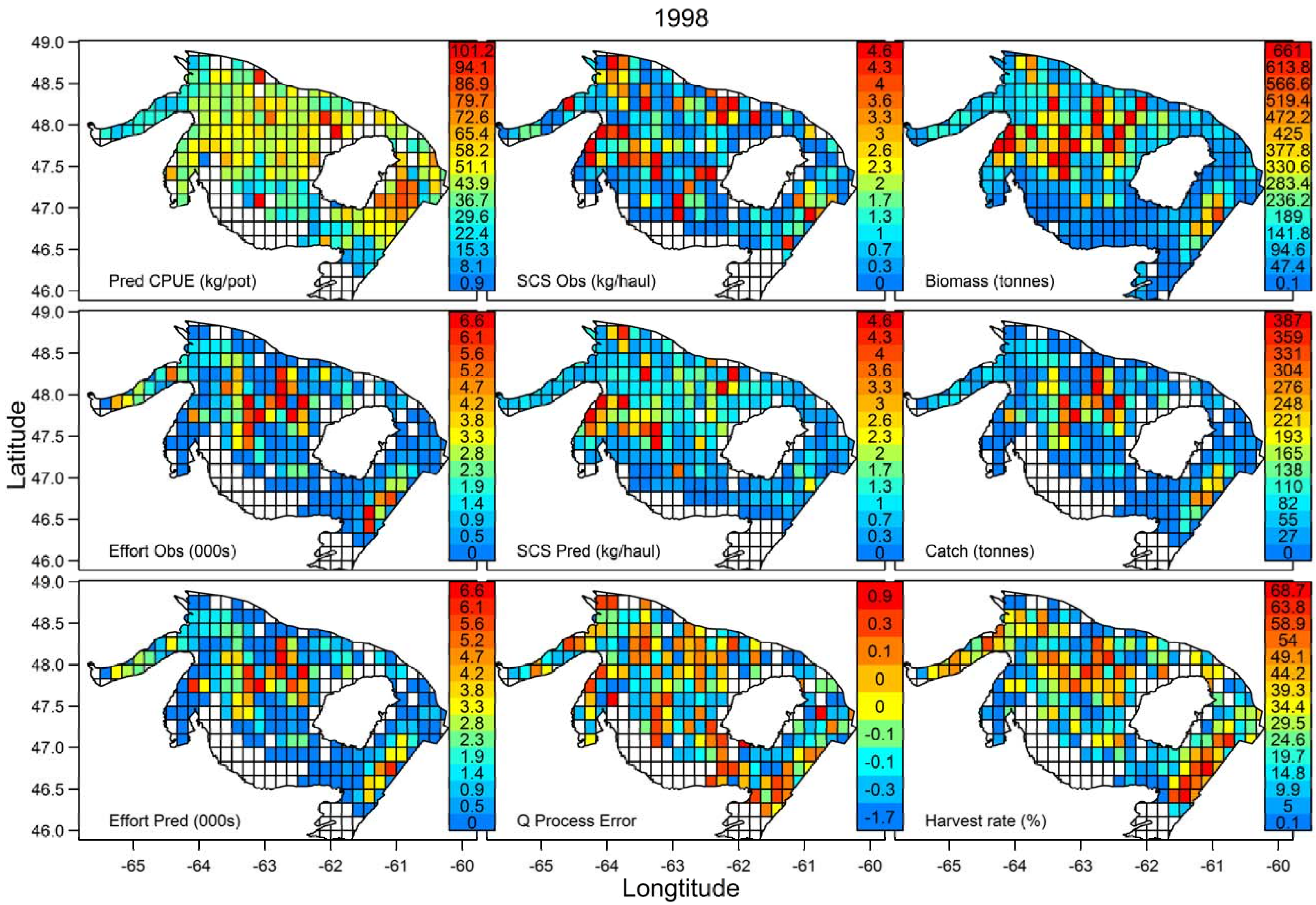


Figure S6. Model M4 (see Table 2) spatial results for 1998. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

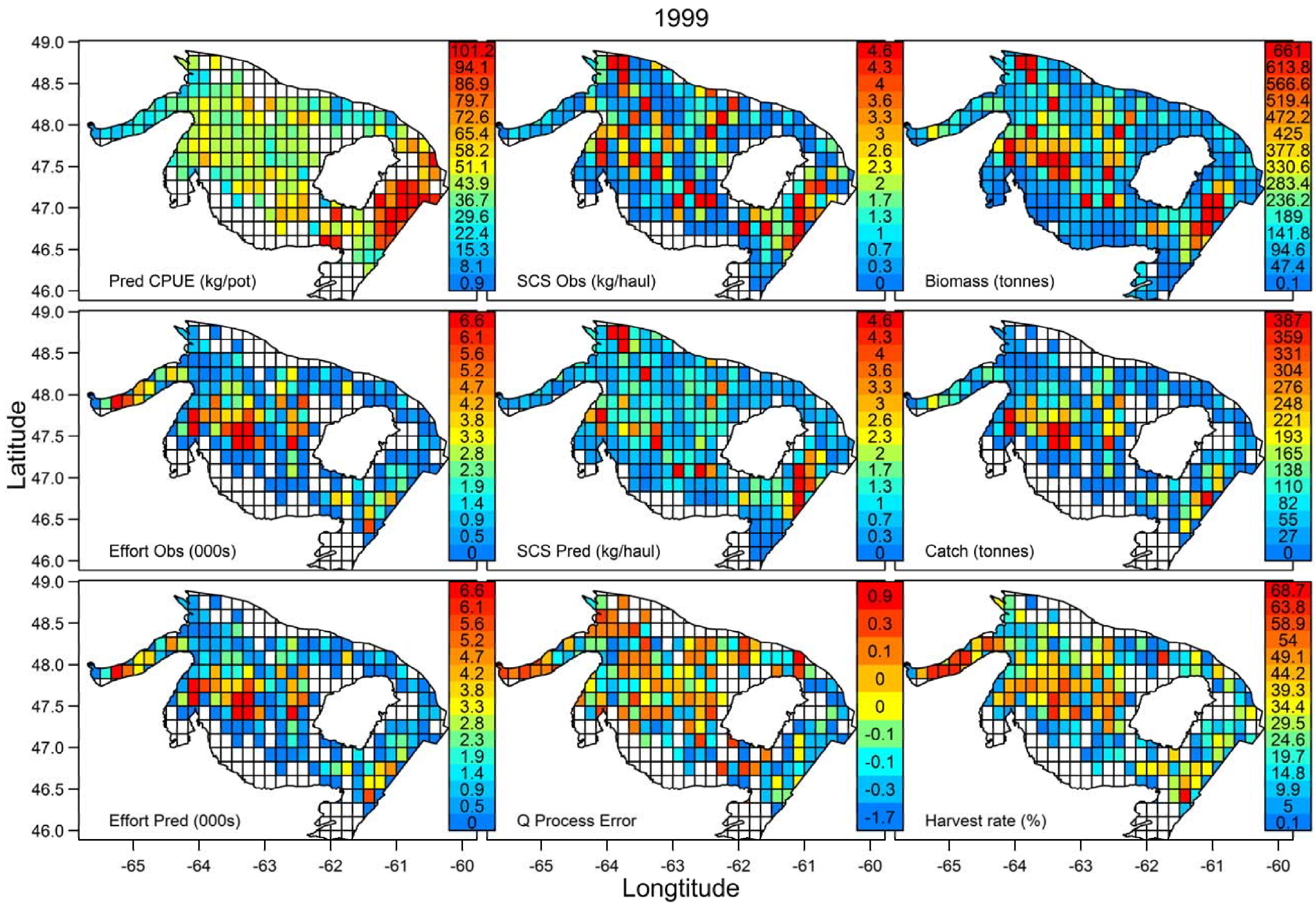


Figure S7. Model M4 (see Table 2) spatial results for 1999. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

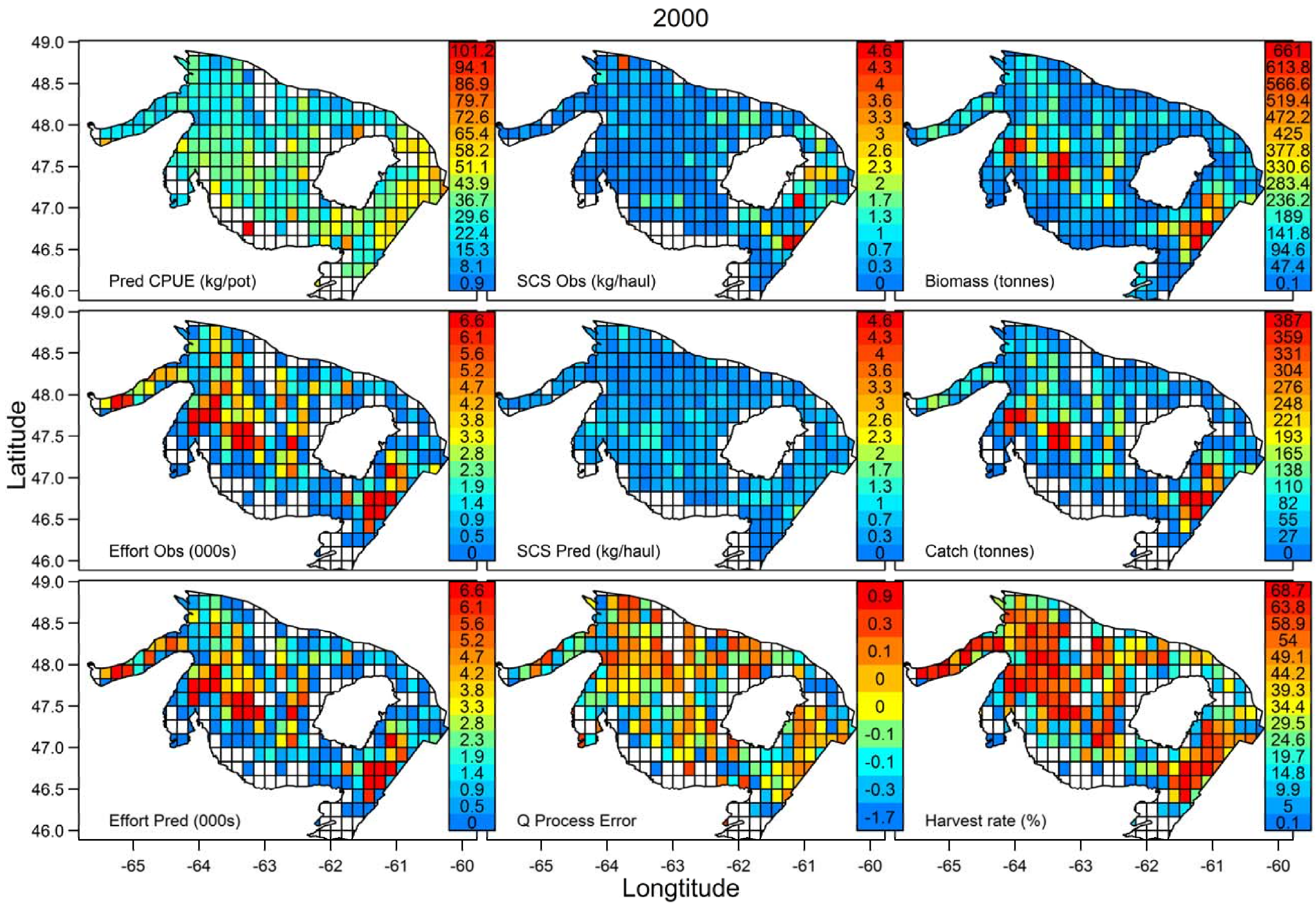


Figure S8. Model M4 (see Table 2) spatial results for 2000. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

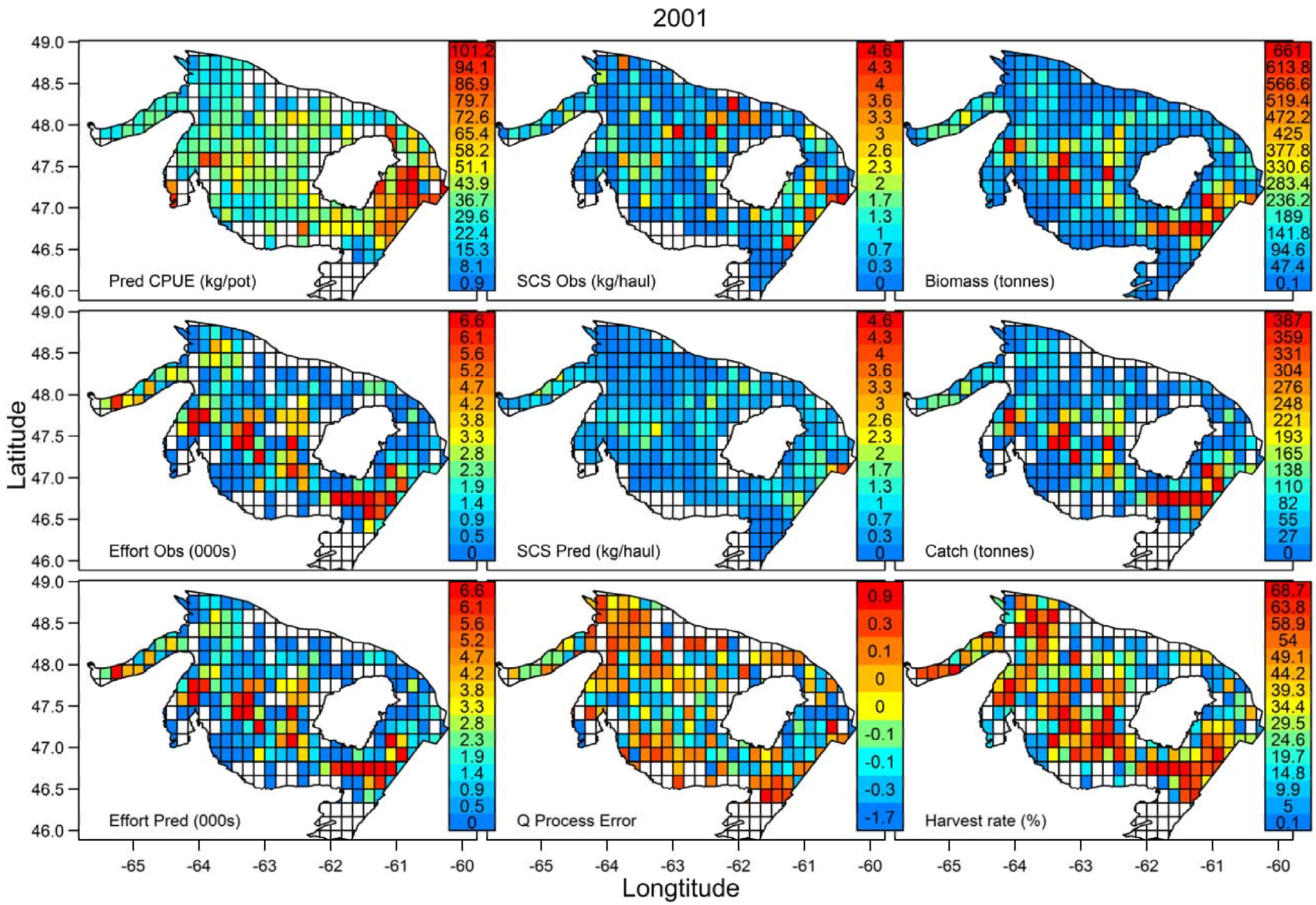


Figure S9. Model M4 (see Table 2) spatial results for 2001. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

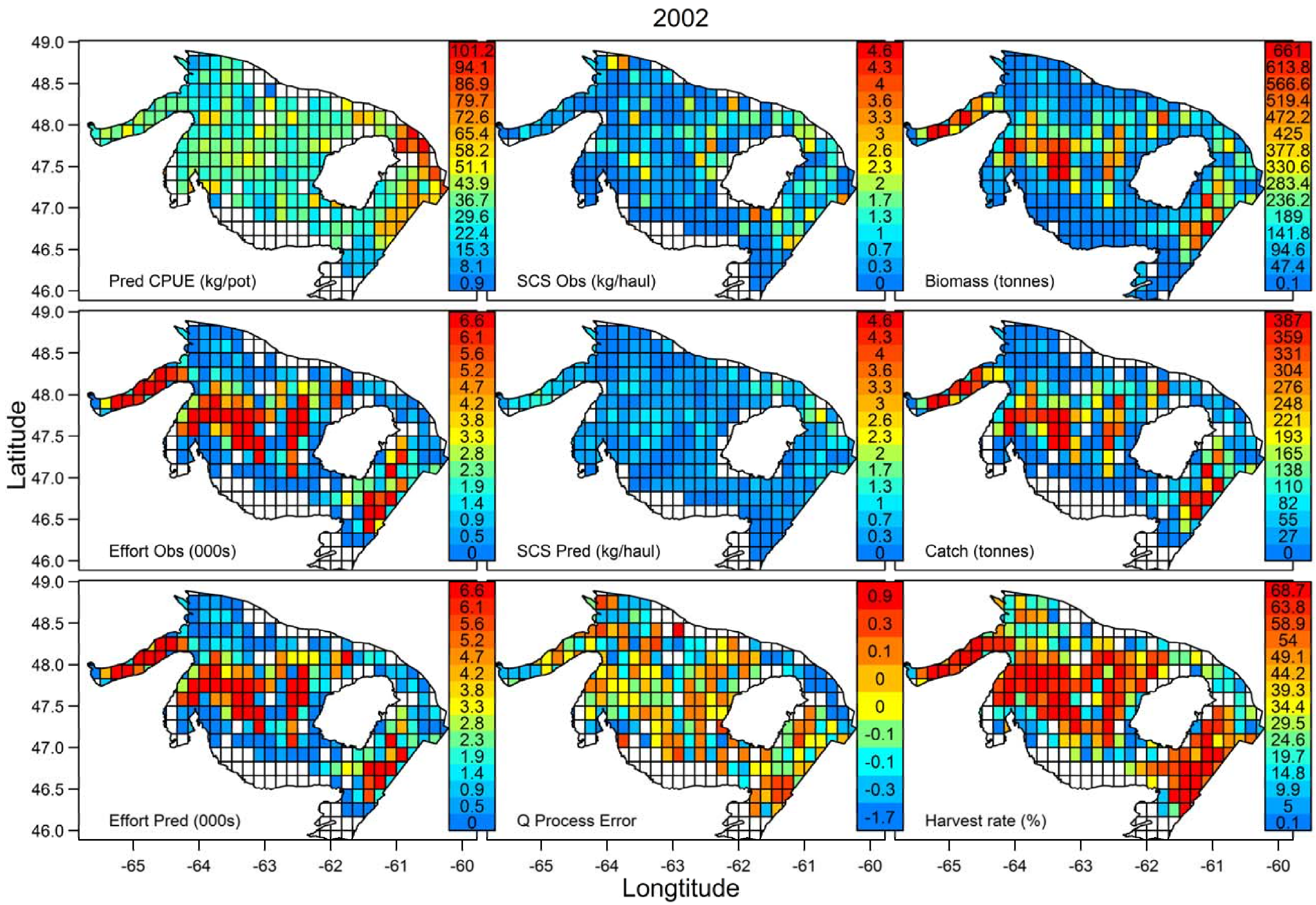


Figure S10. Model M4 (see Table 2) spatial results for 2002. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

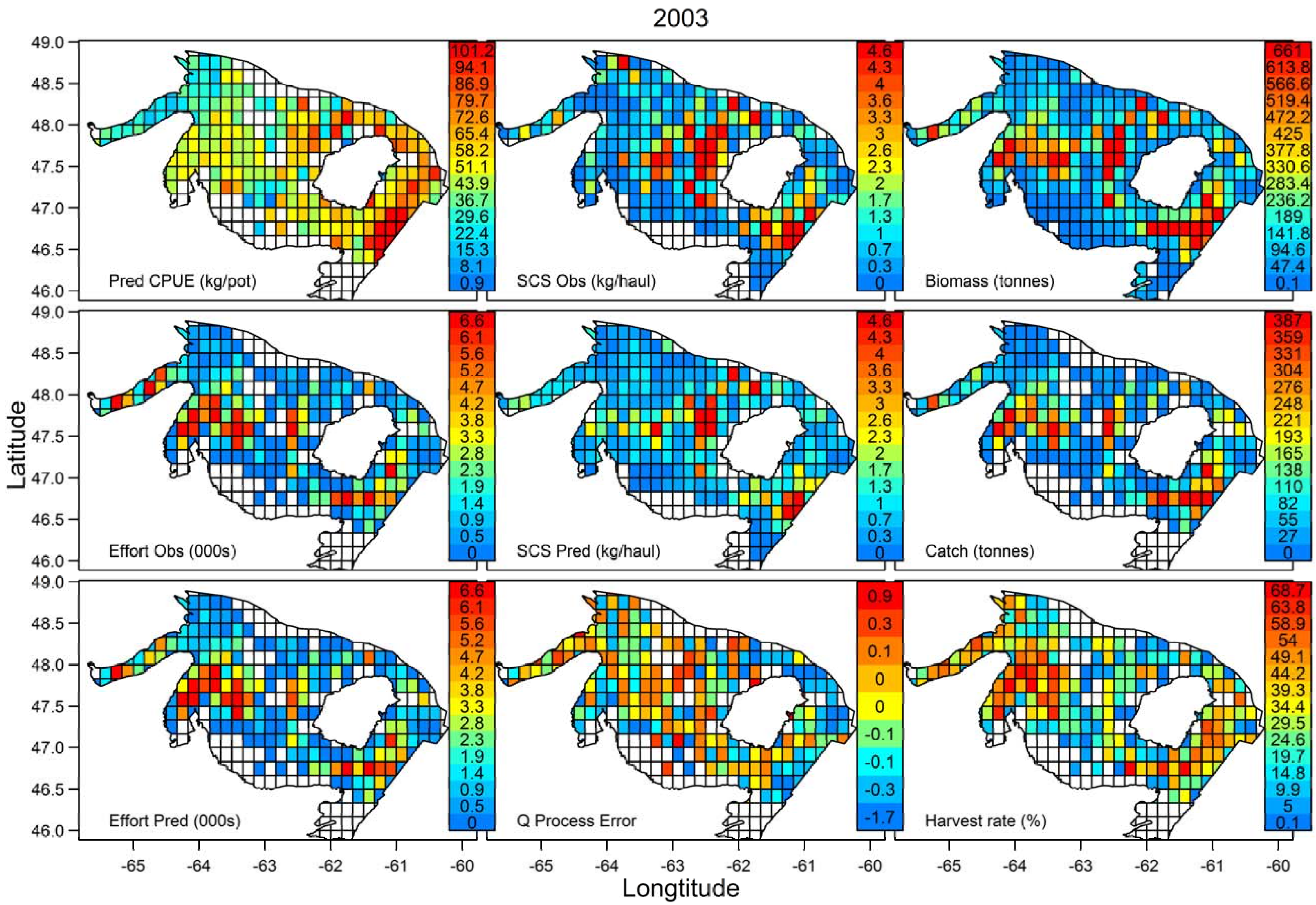


Figure S11. Model M4 (see Table 2) spatial results for 2003. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

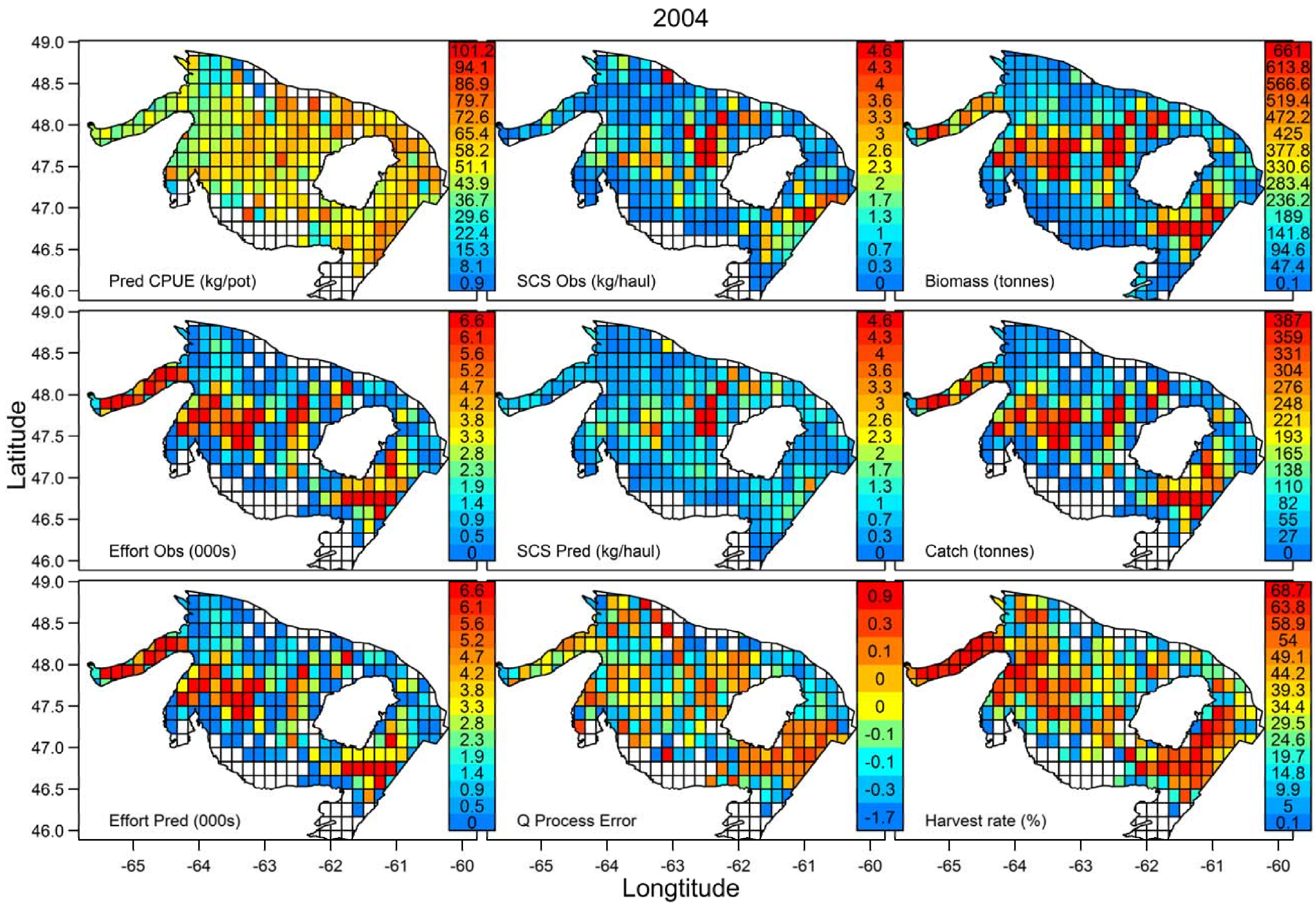


Figure S12. Model M4 (see Table 2) spatial results for 2004. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

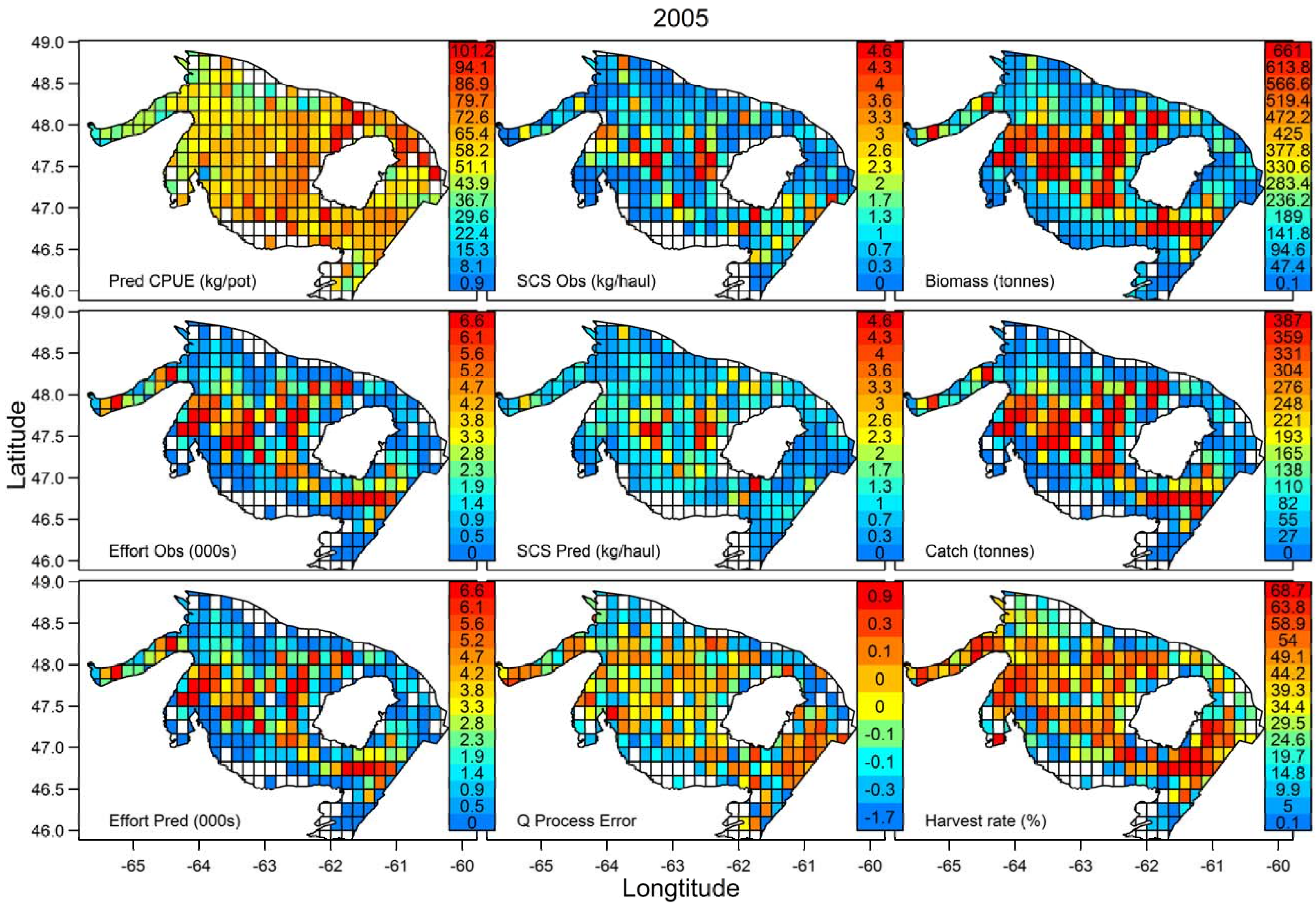


Figure S13. Model M4 (see Table 2) spatial results for 2005. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

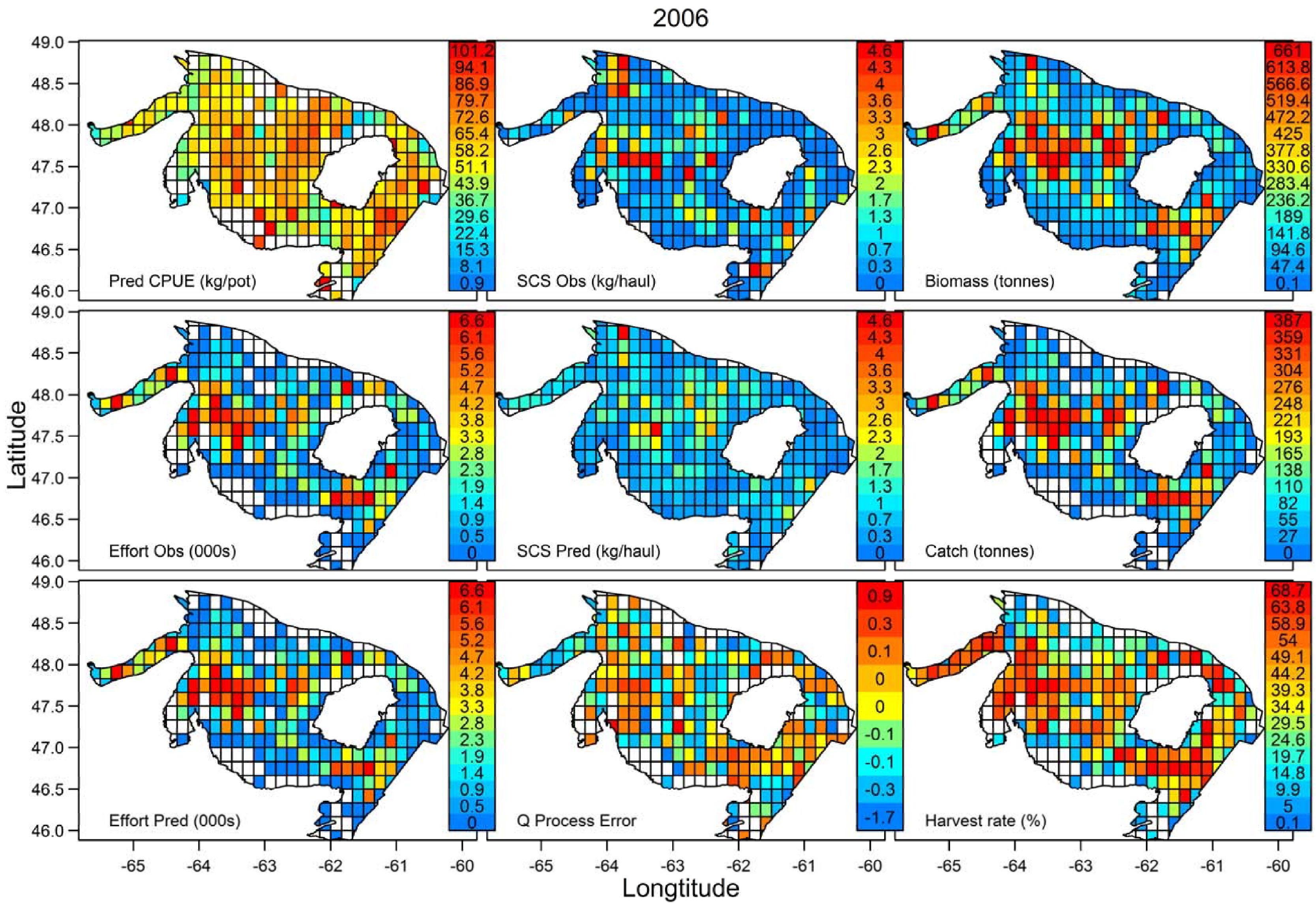


Figure S14. Model M4 (see Table 2) spatial results for 2006. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

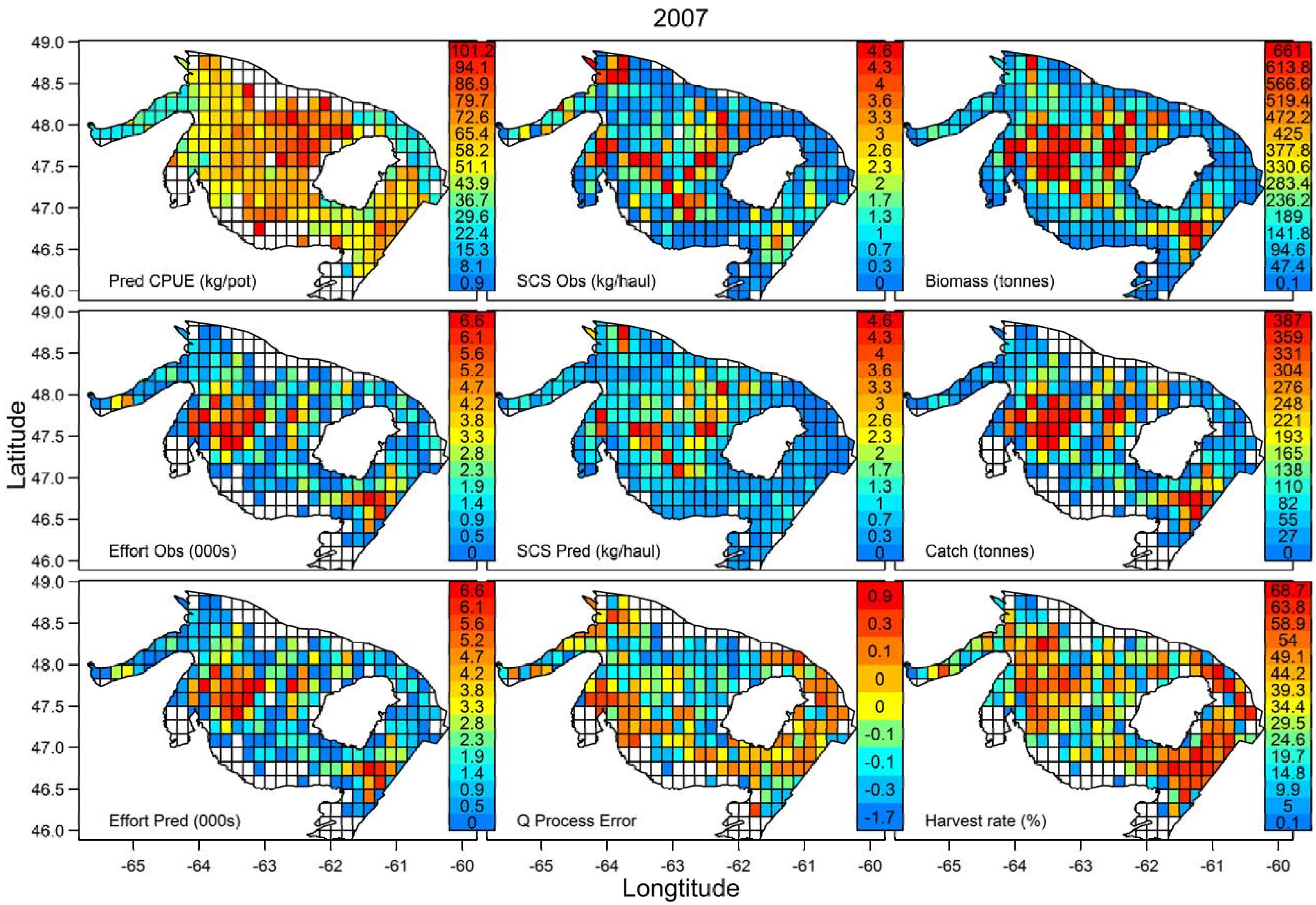


Figure S15. Model M4 (see Table 2) spatial results for 2007. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

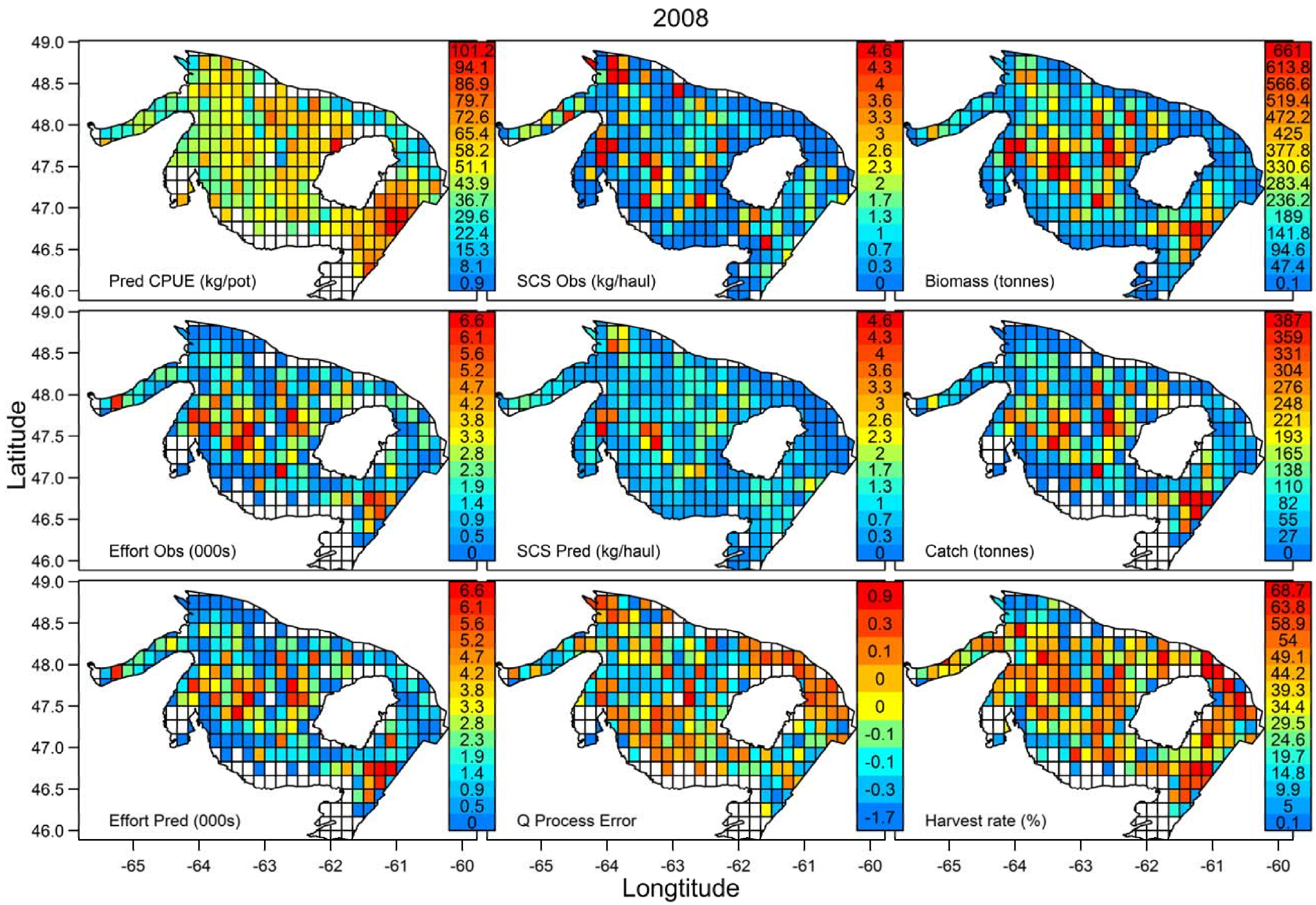


Figure S16. Model M4 (see Table 2) spatial results for 2008. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

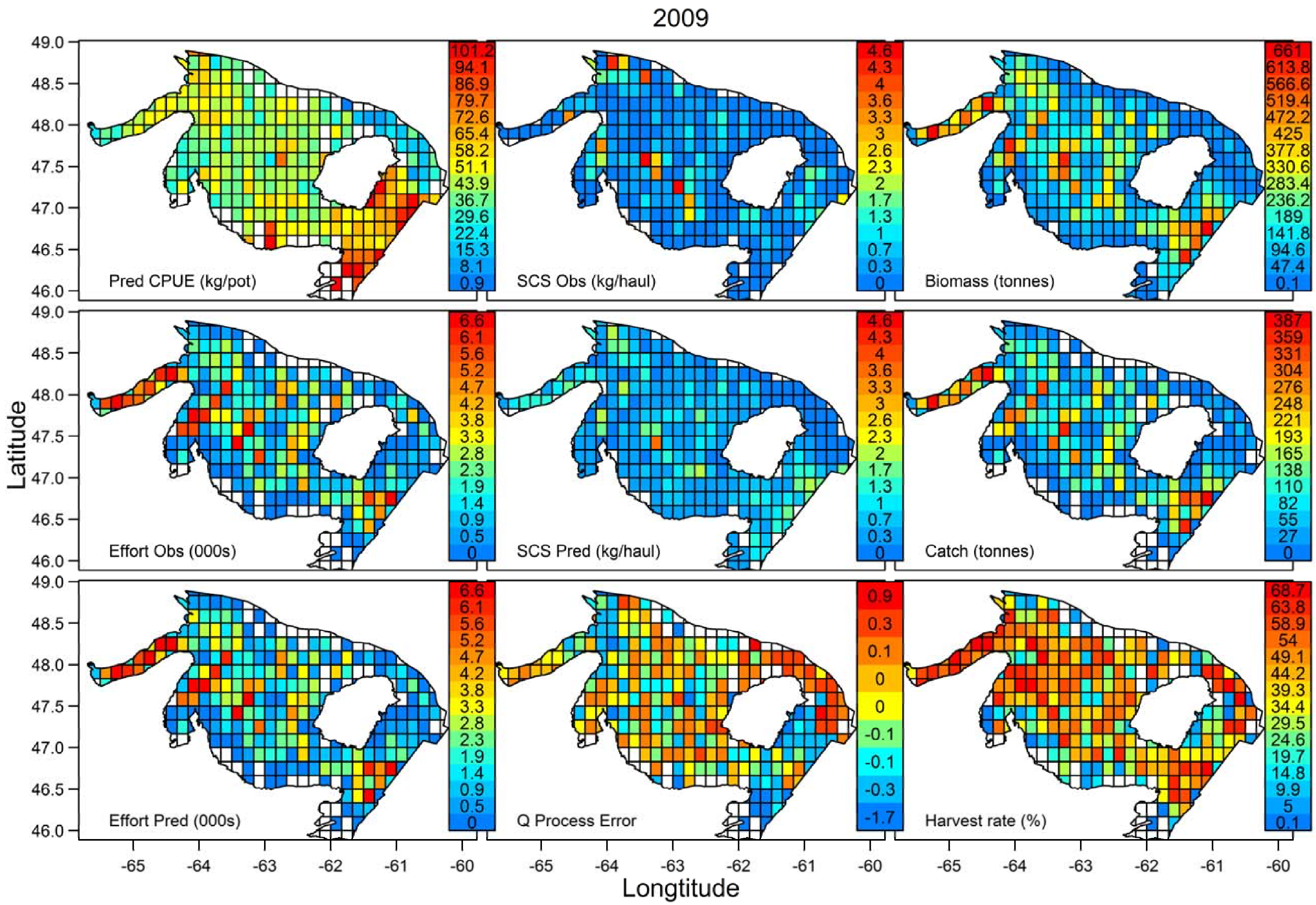


Figure S17. Model M4 (see Table 2) spatial results for 2009. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

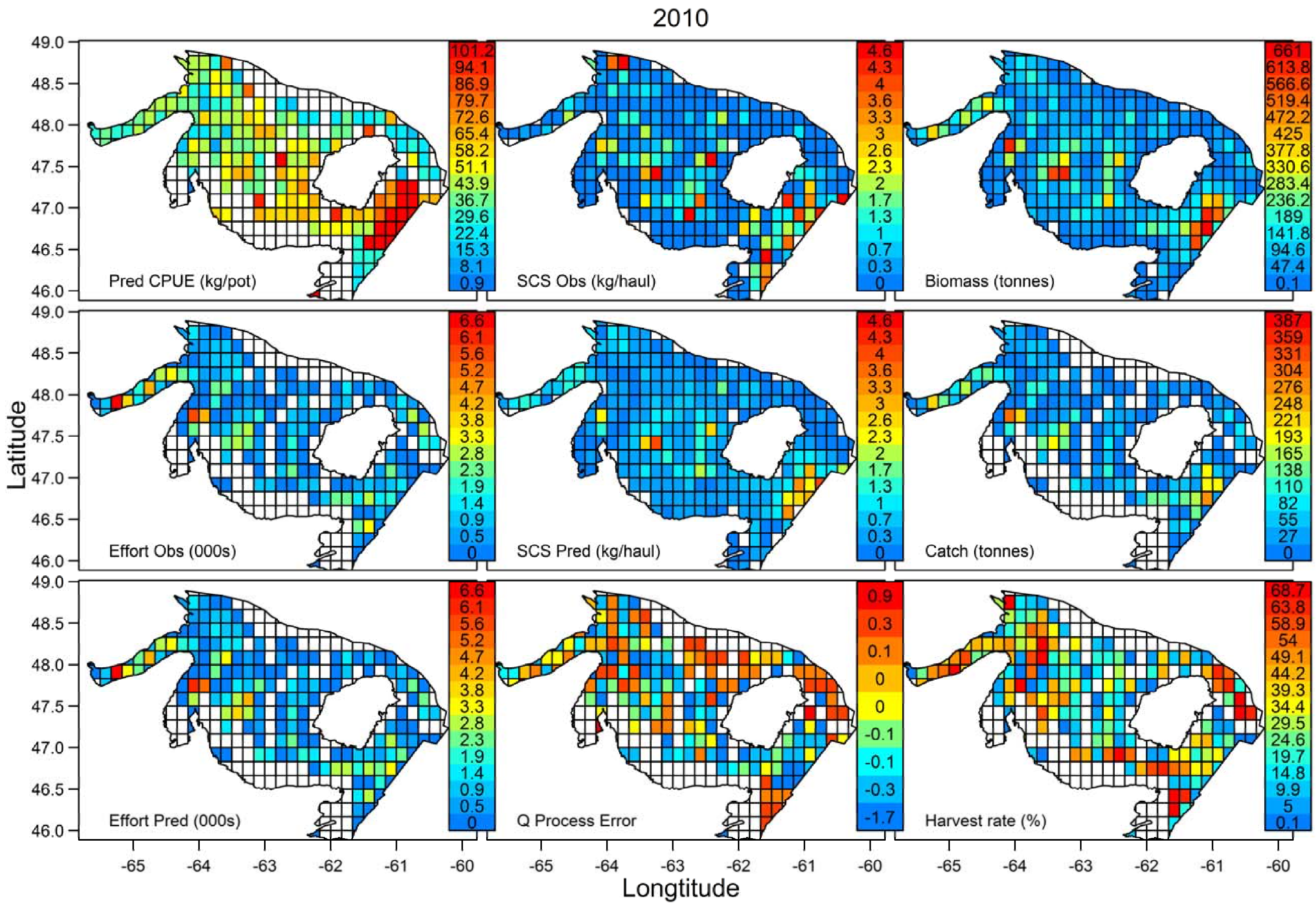


Figure S18. Model M4 (see Table 2) spatial results for 2010. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

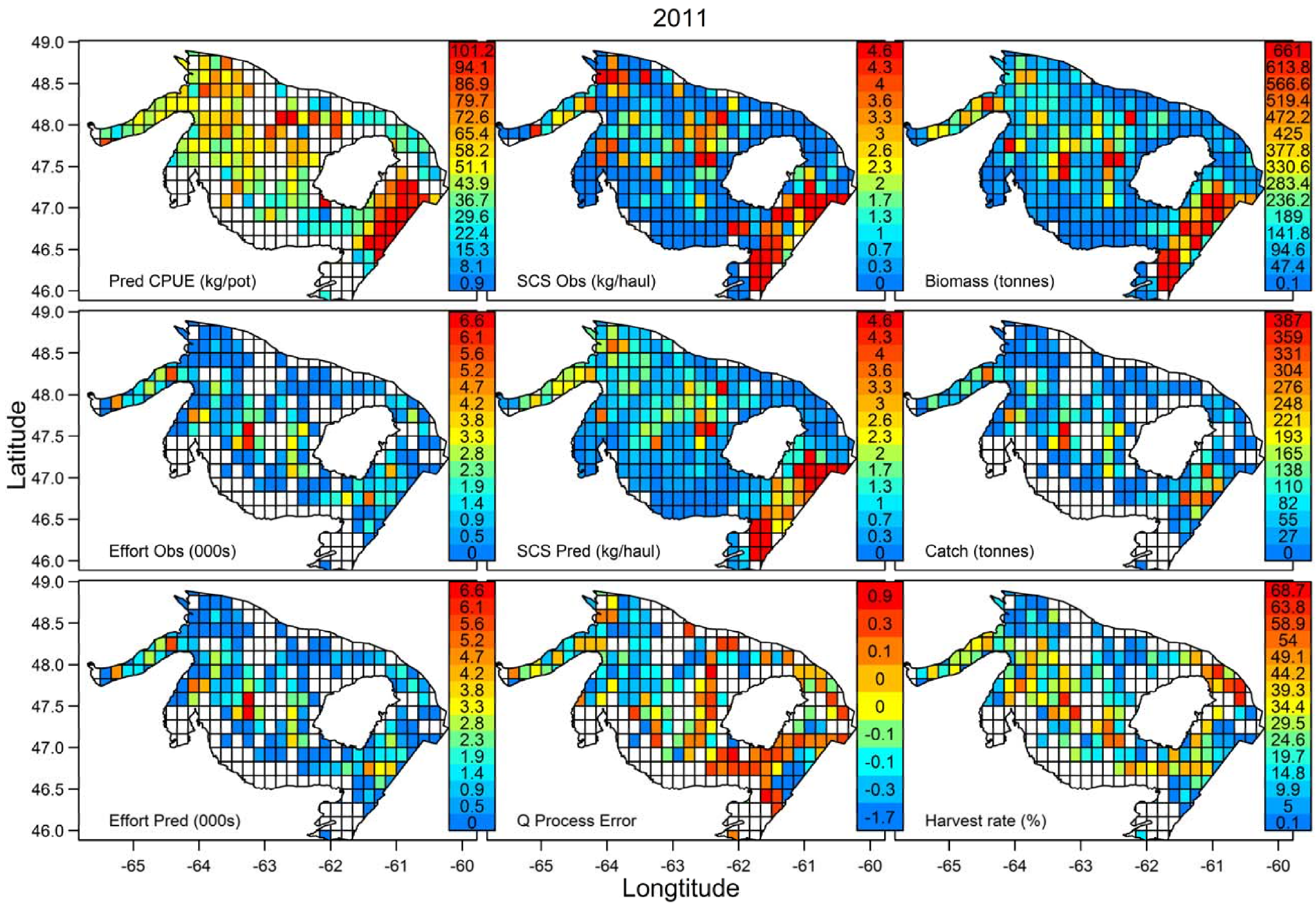


Figure S19. Model M4 (see Table 2) spatial results for 2011. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

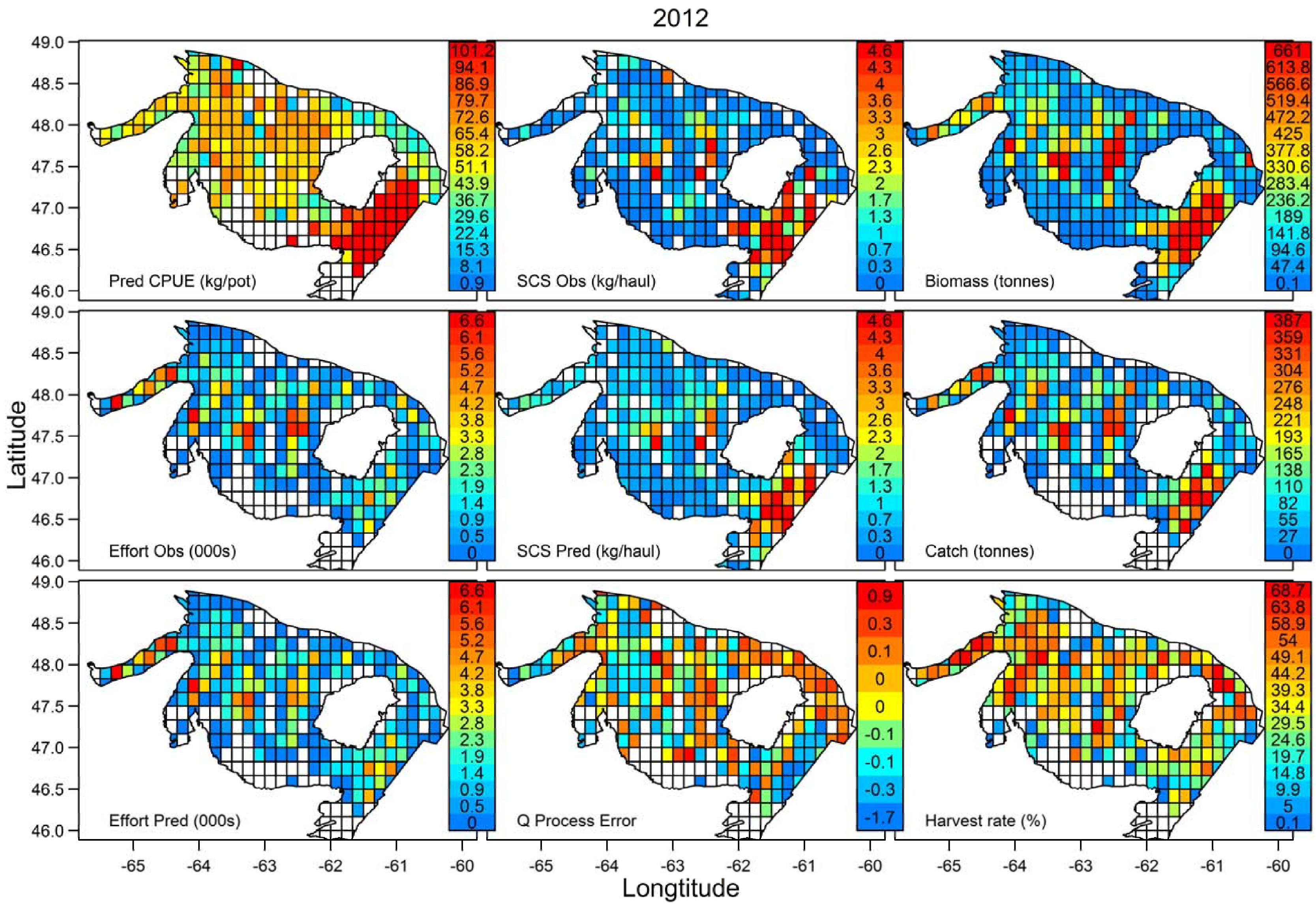


Figure S20. Model M4 (see Table 2) spatial results for 2012. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

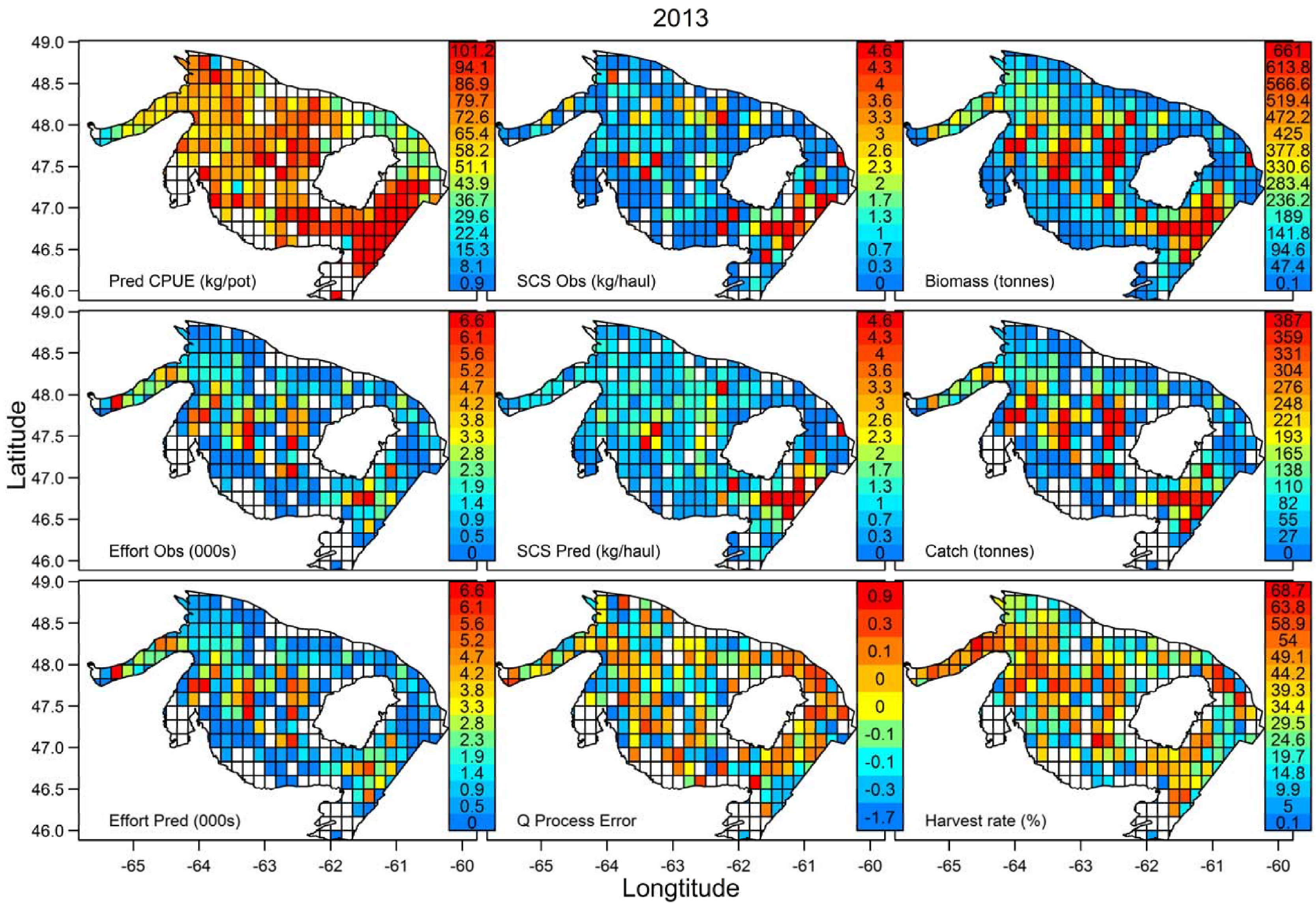


Figure S21. Model M4 (see Table 2) spatial results for 2013. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

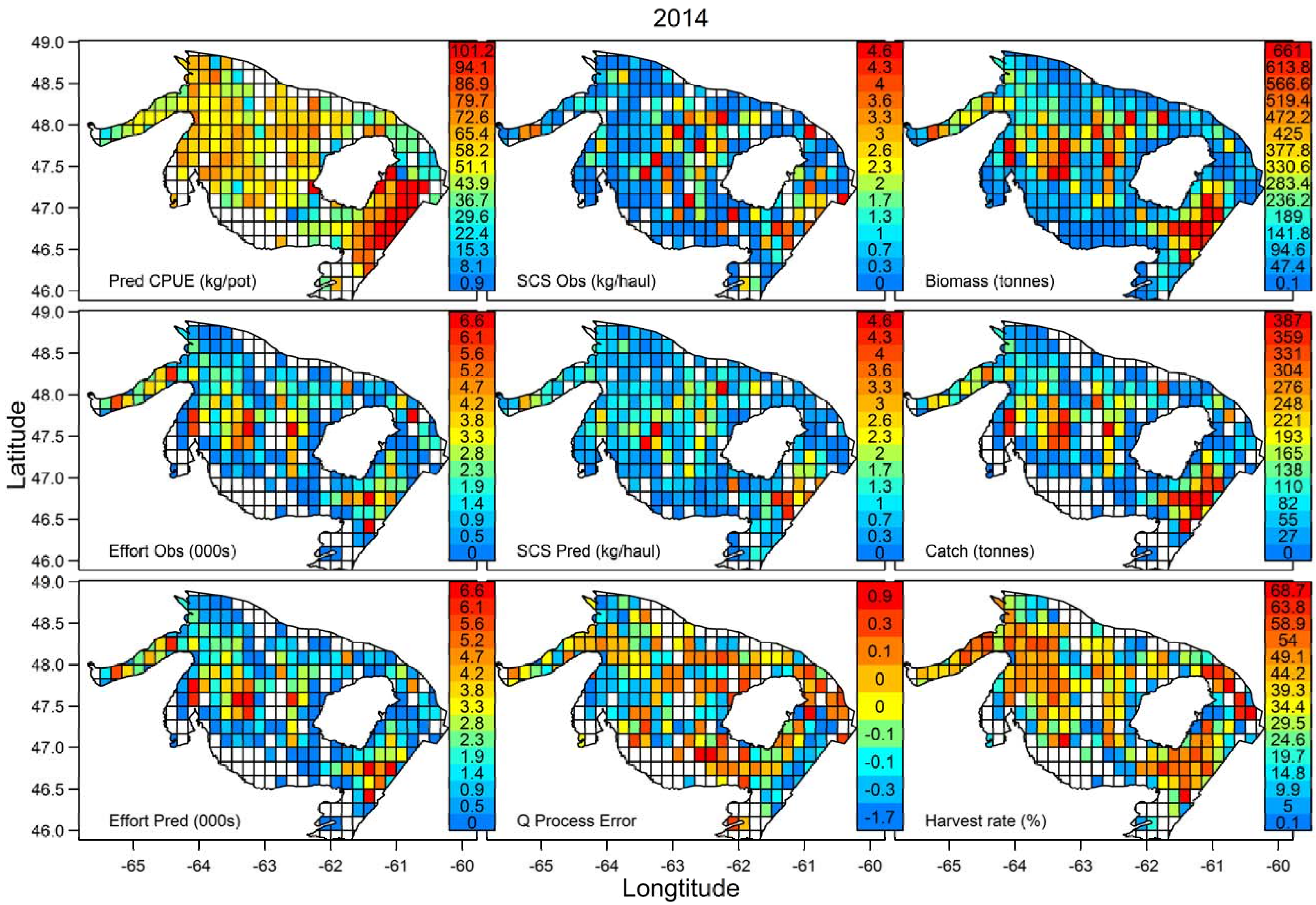


Figure S22. Model M4 (see Table 2) spatial results for 2014. Catch and effort are aggregated across weeks, and CPUE is the ratio of aggregated catch divided by aggregated effort. Q process errors are averaged over weeks. White cells indicate no observations.

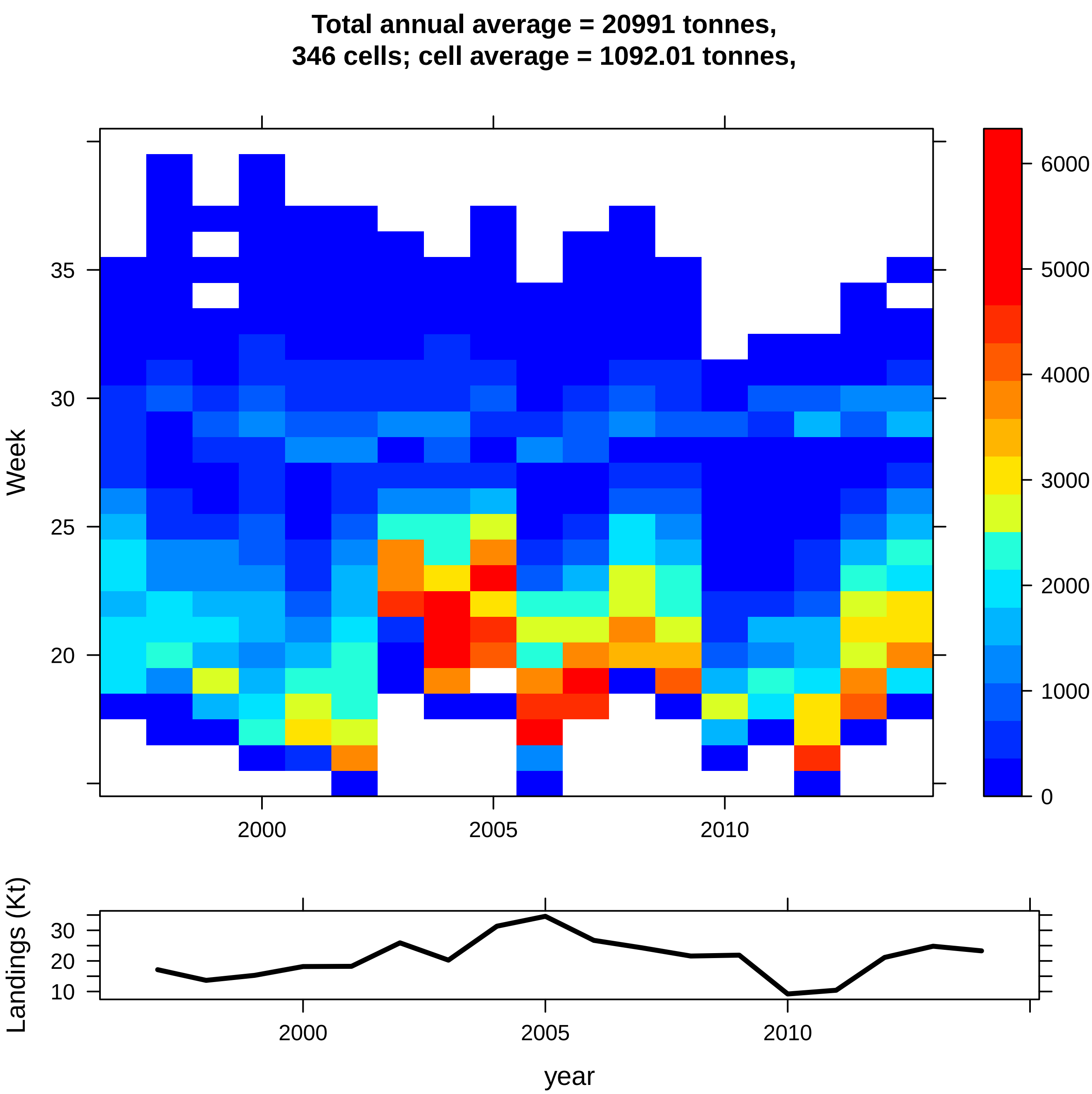


Figure SC.1. Top panel: Total catch (tonnes) of snow crab each week (rows) and year (columns). Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile. Bottom panel: Total catch (000 tonnes) each year for all weeks.

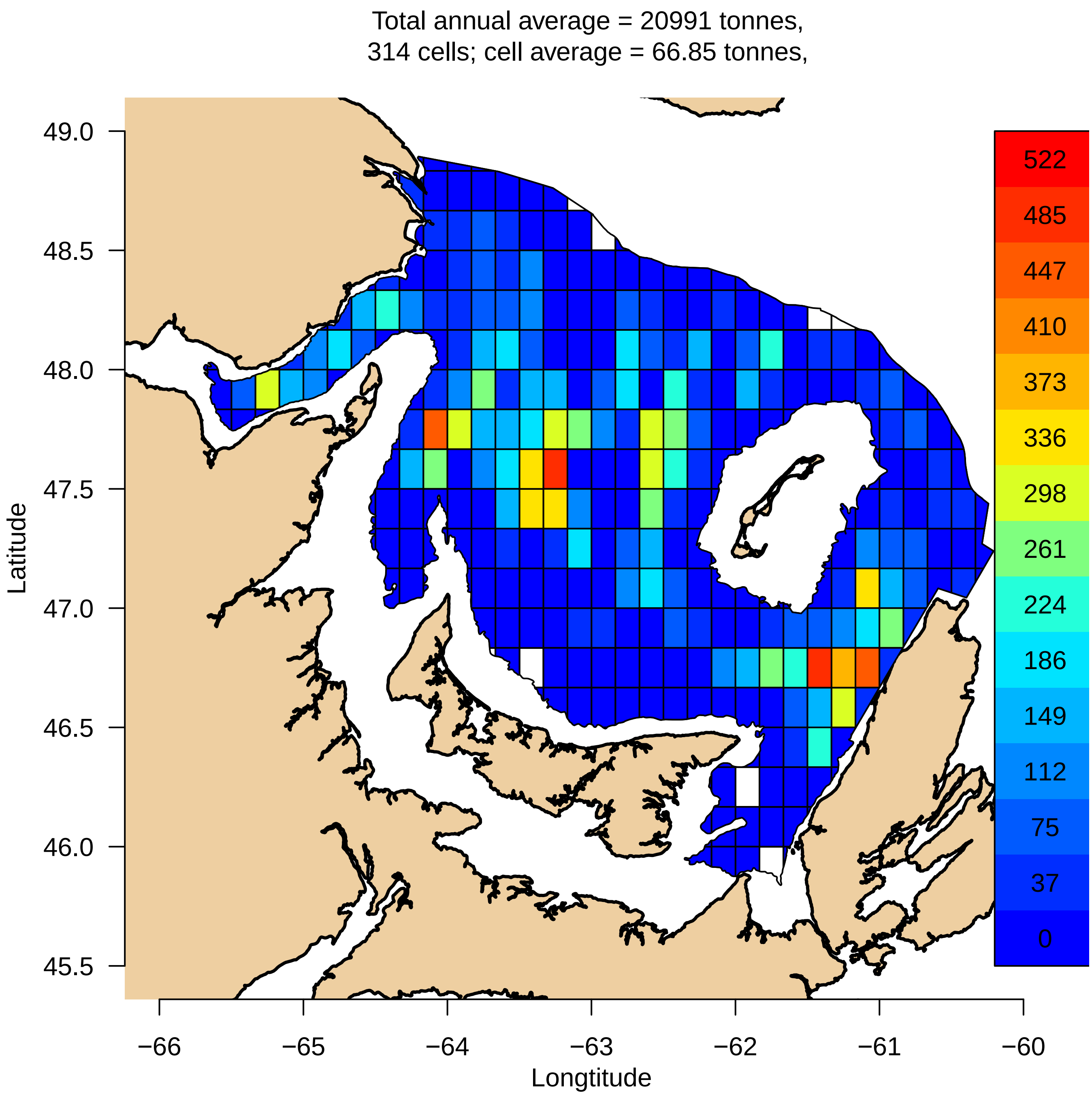


Figure SC.2. Total annual catch (tonnes) of snow crab in each grid cell, averaged for 1997-2014. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

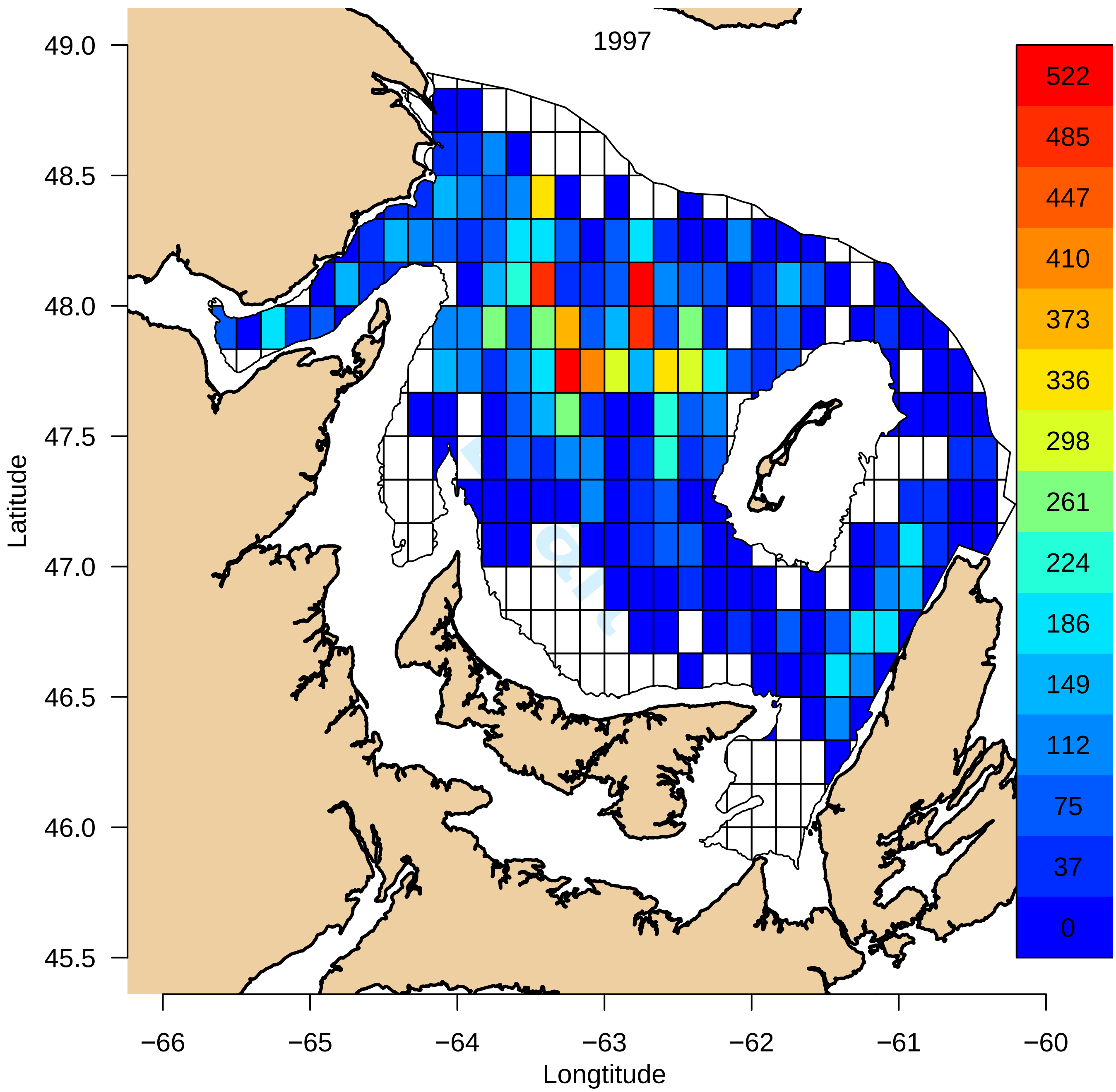


Figure SC.3a. Total annual catch (tonnes) of snow crab in each grid cell in 1997. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

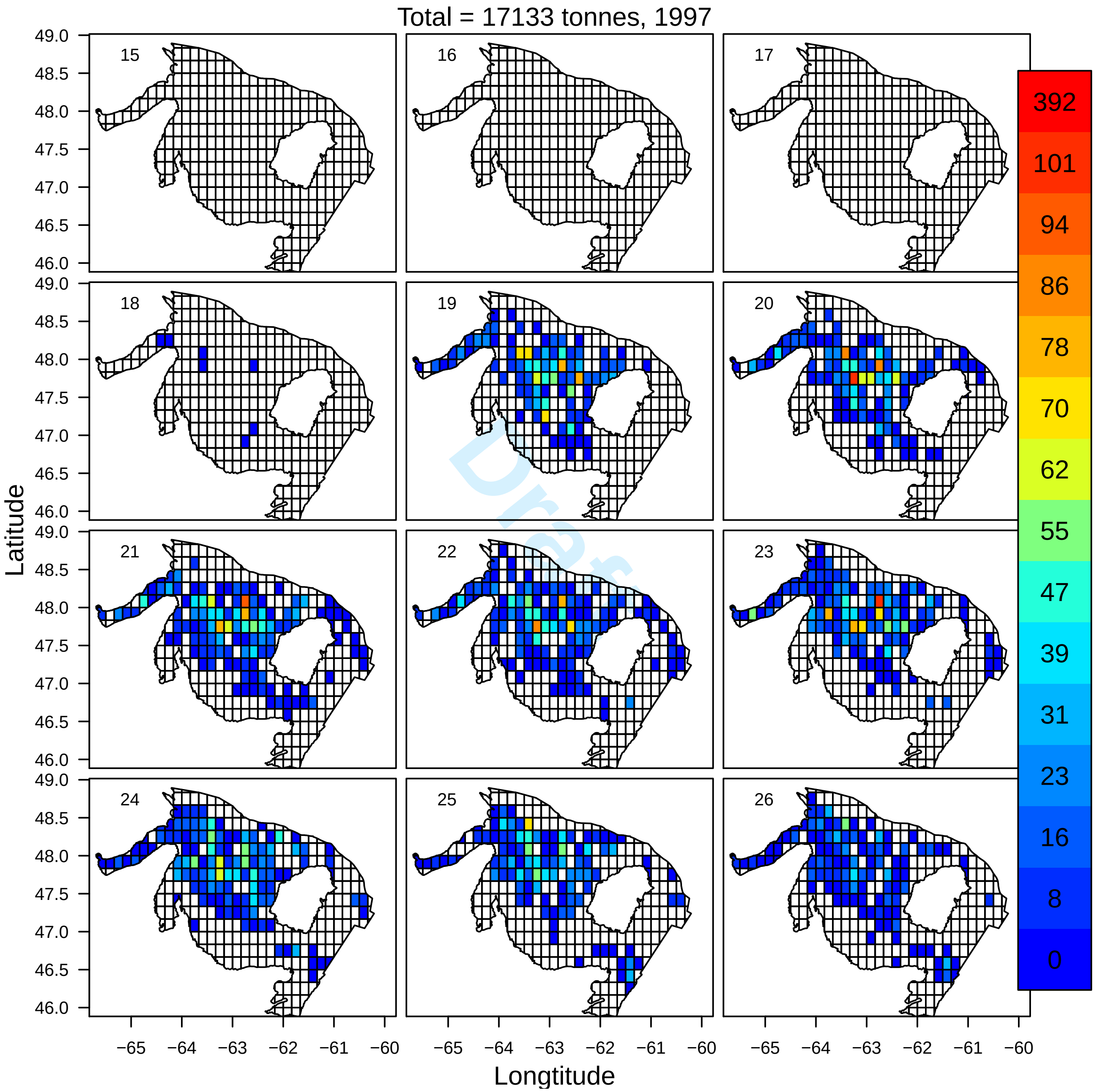


Figure SC.3b. Catch (tonnes) of snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

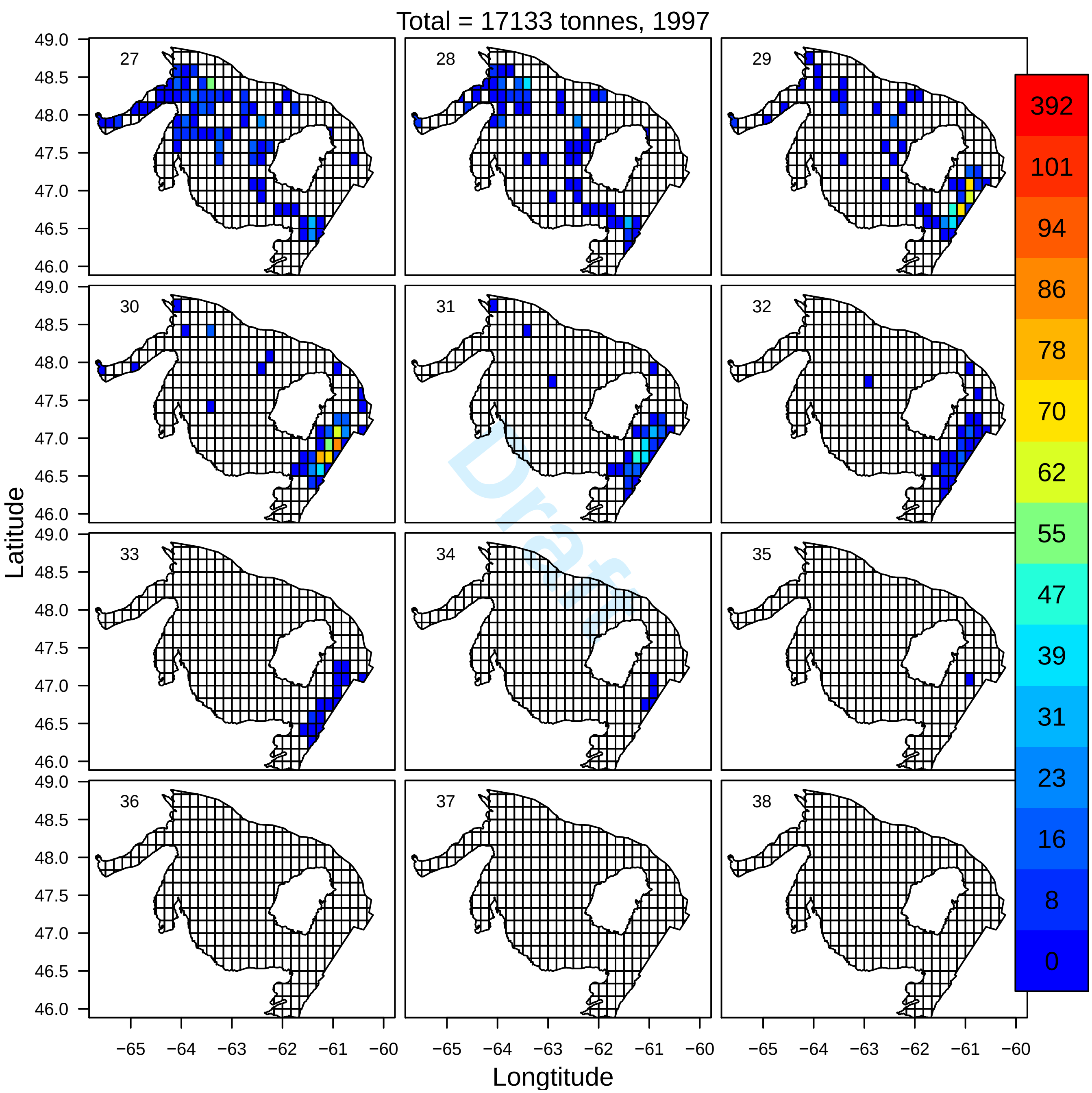


Figure SC.3c. Catch (tonnes) of snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

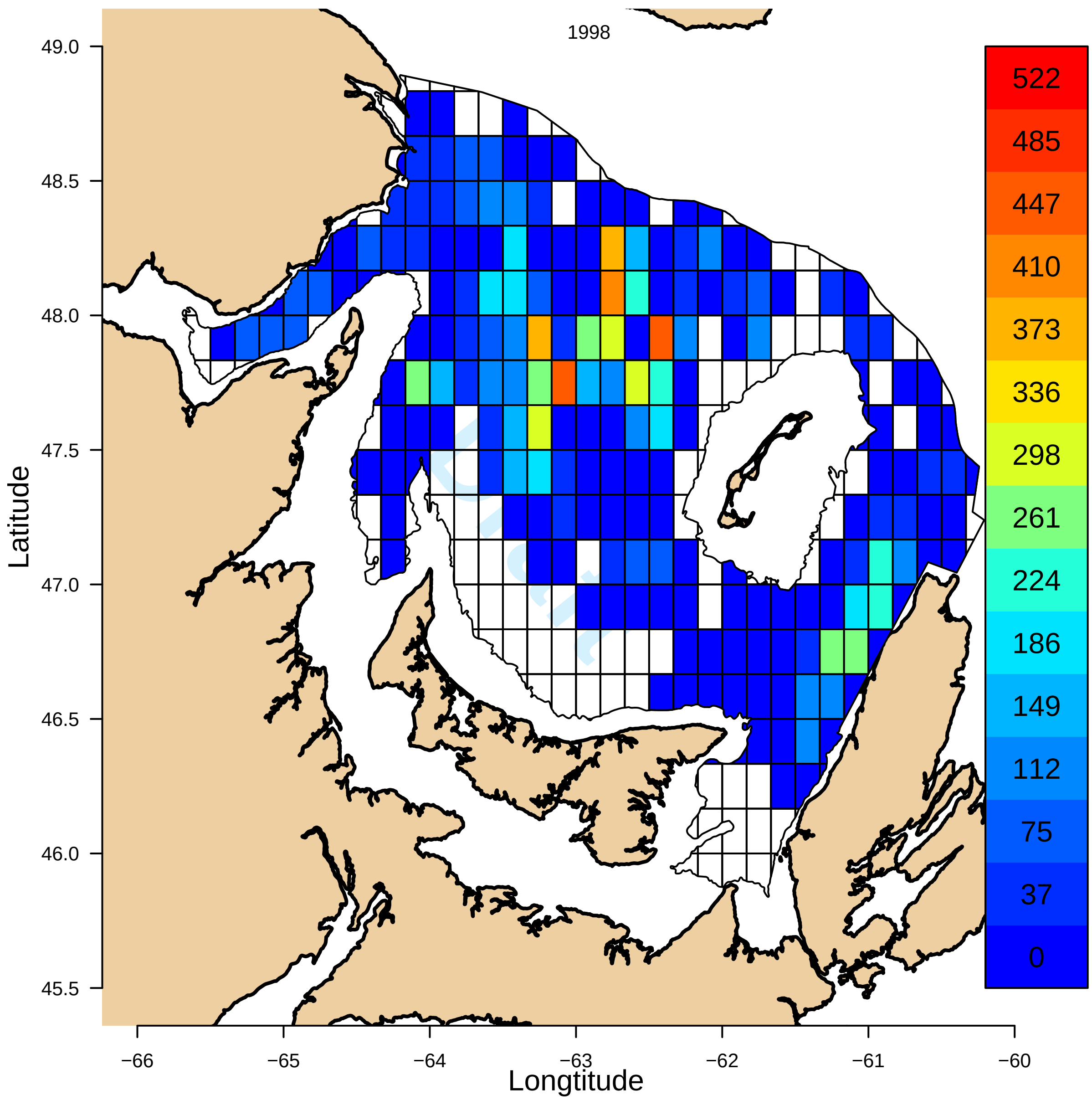


Figure SC.4a. Total annual catch (tonnes) of snow crab in each grid cell in 1998. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

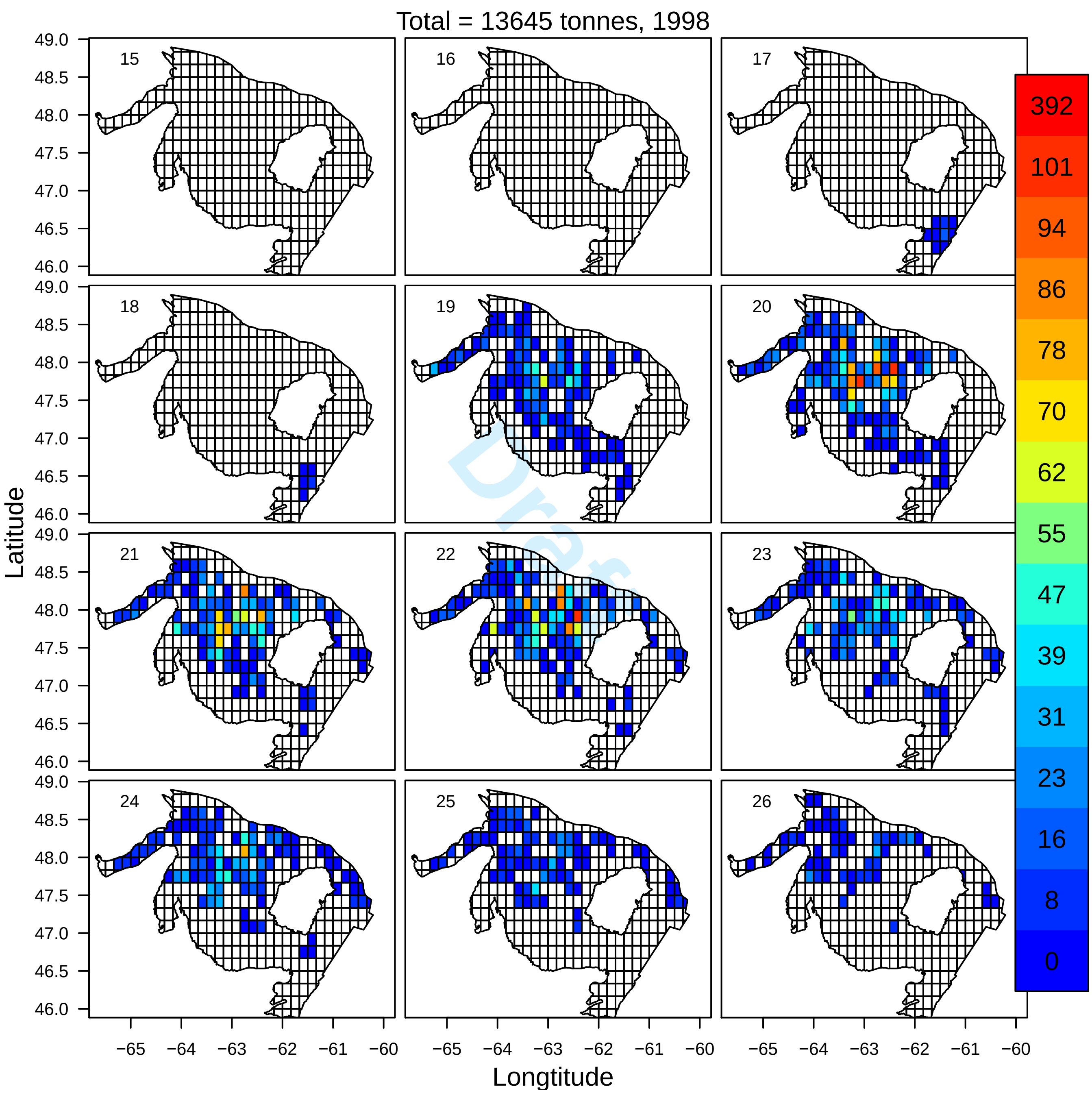


Figure SC.4b. Catch (tonnes) of snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

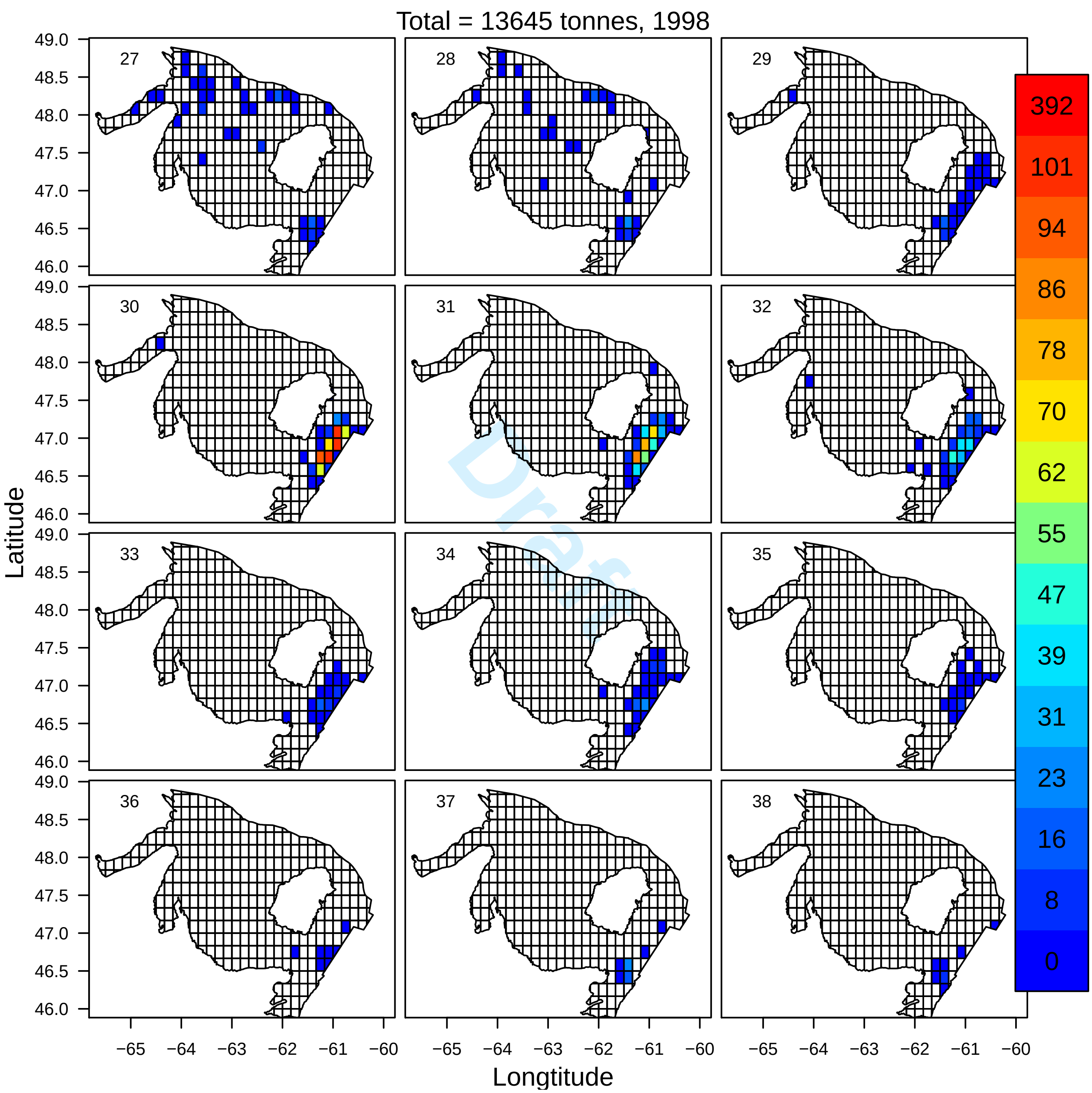


Figure SC.4c. Catch (tonnes) of snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

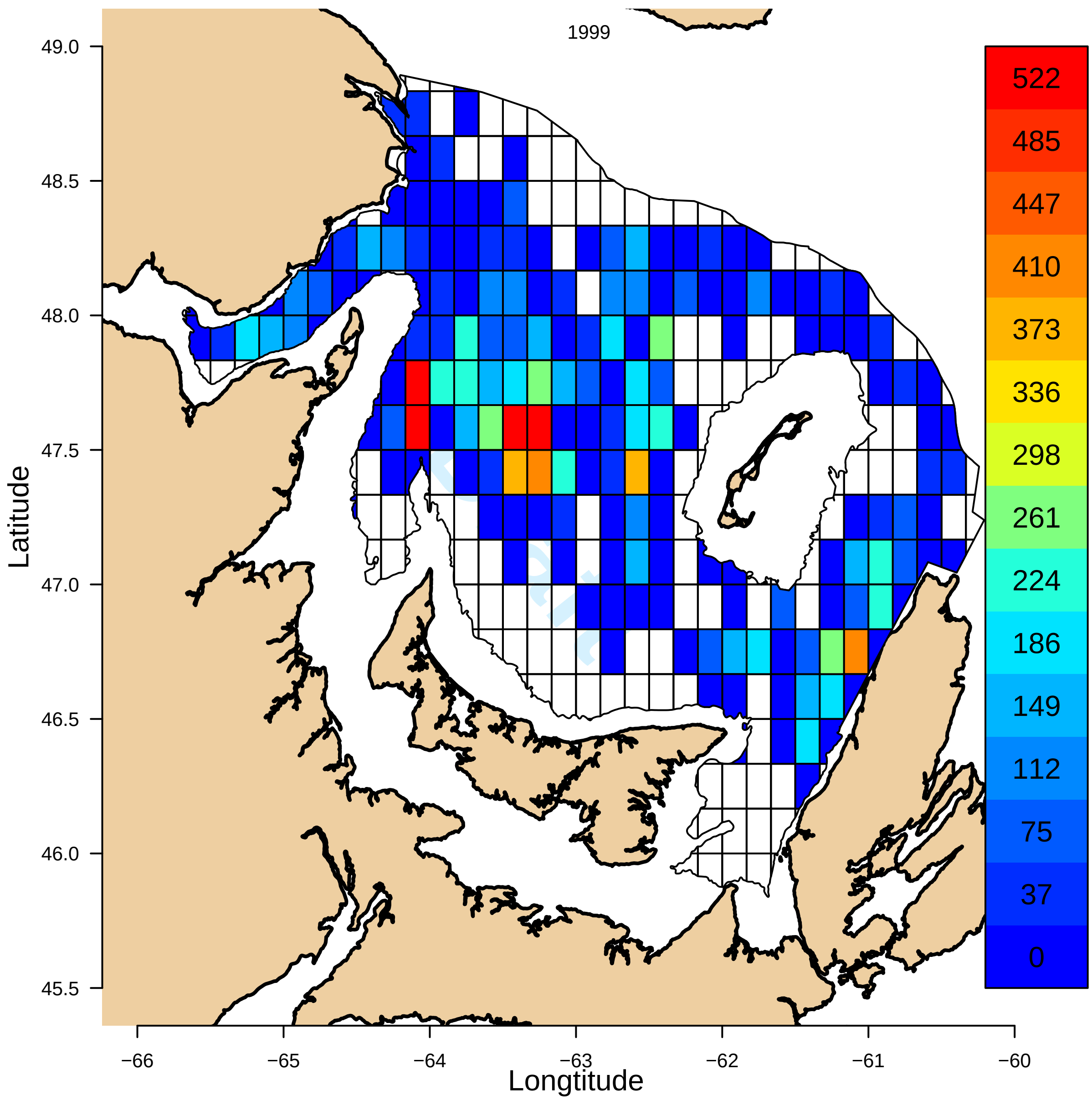


Figure SC.5a. Total annual catch (tonnes) of snow crab in each grid cell in 1999. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

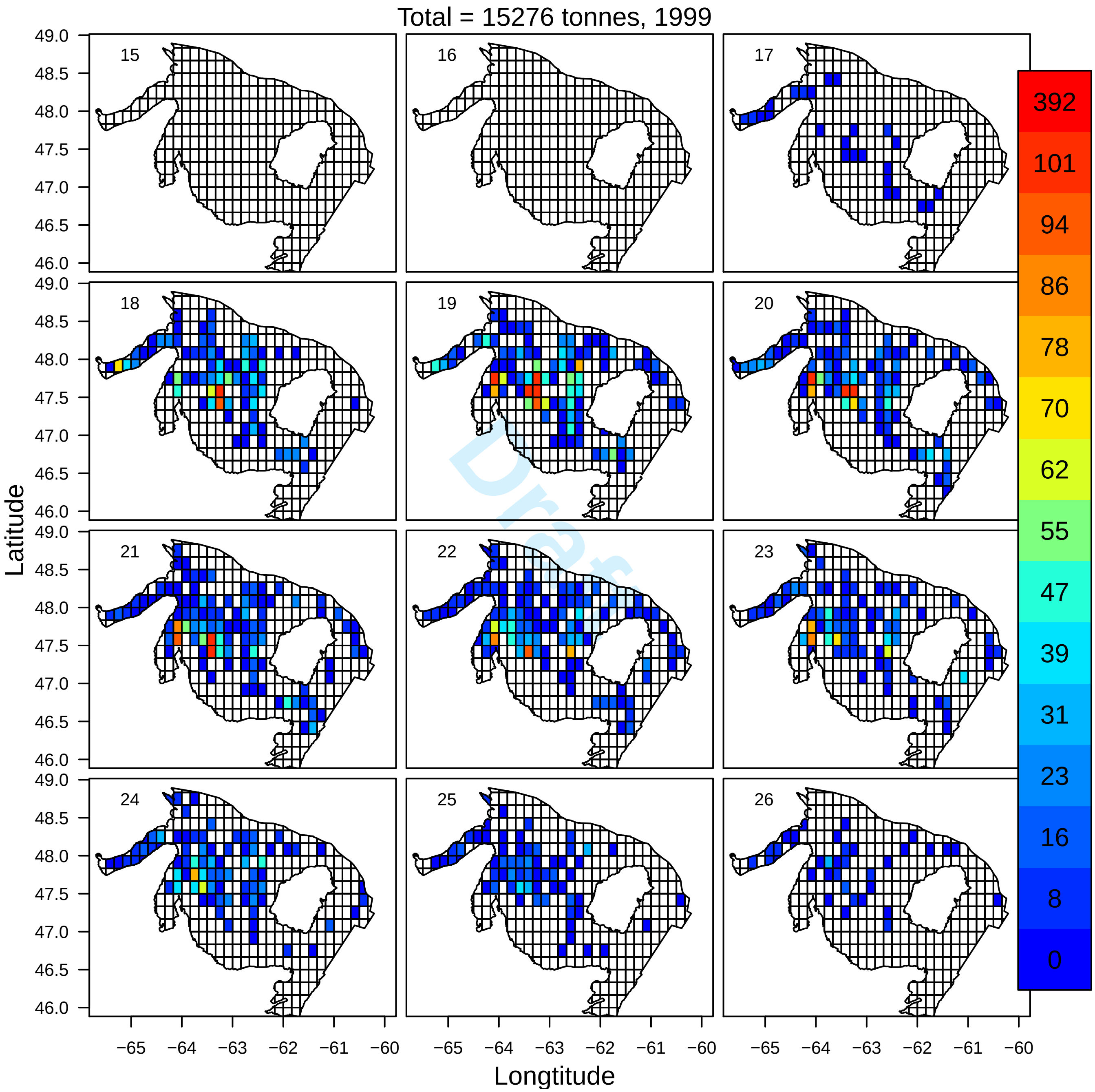


Figure SC.5b. Catch (tonnes) of snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

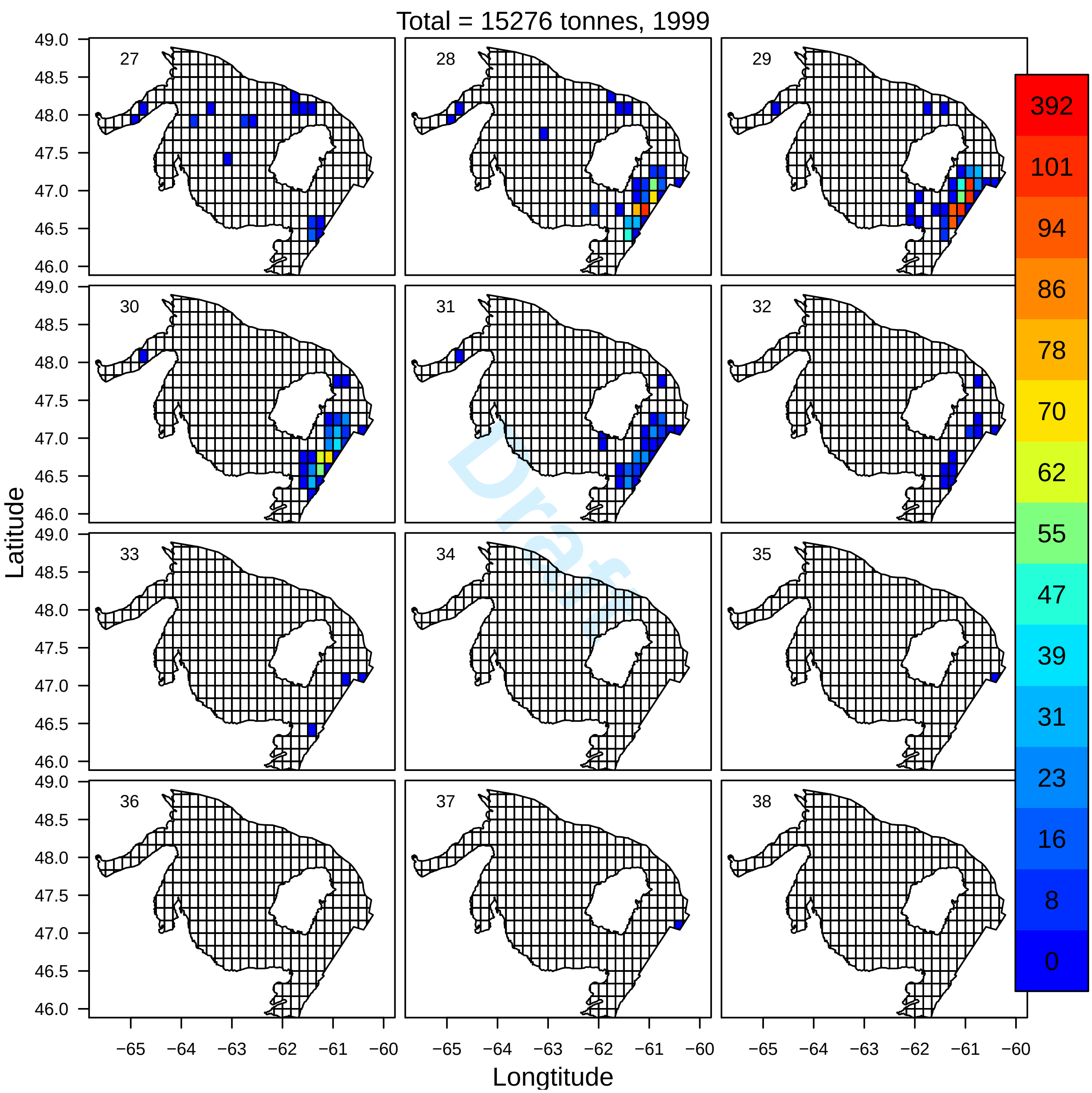


Figure SC.5c. Catch (tonnes) of snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

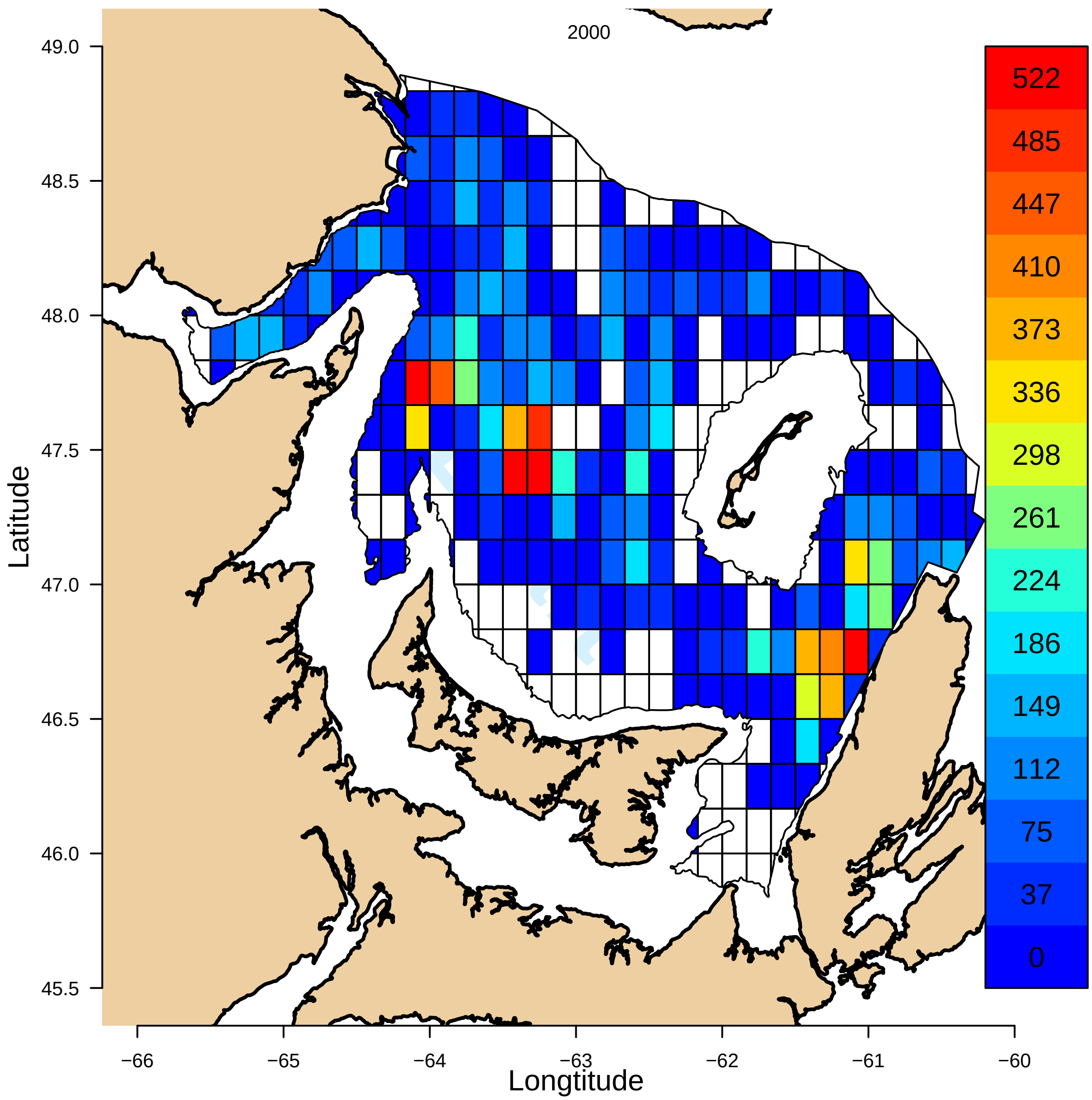


Figure SC.6a. Total annual catch (tonnes) of snow crab in each grid cell in 2000. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

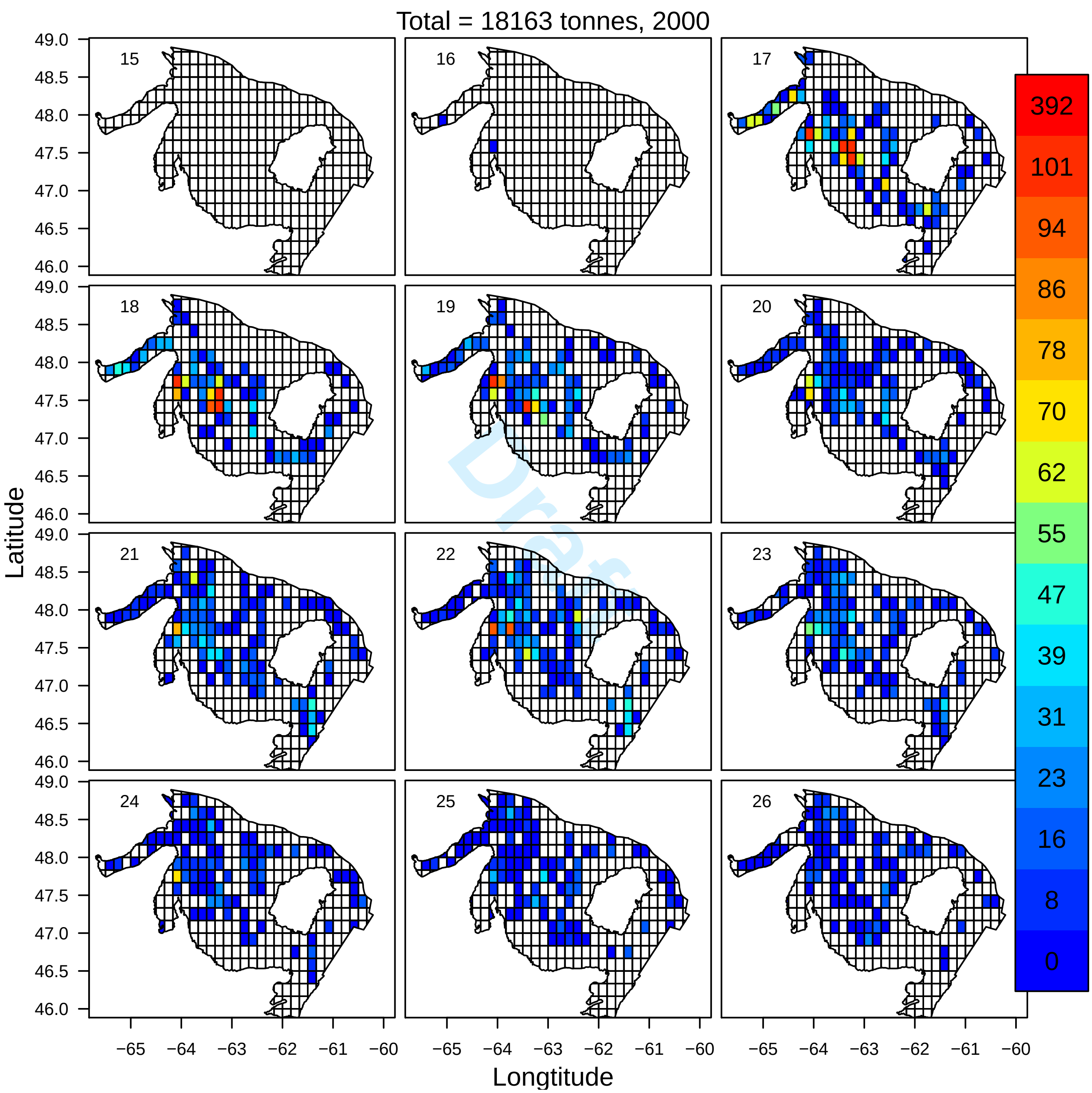


Figure SC.6b. Catch (tonnes) of snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

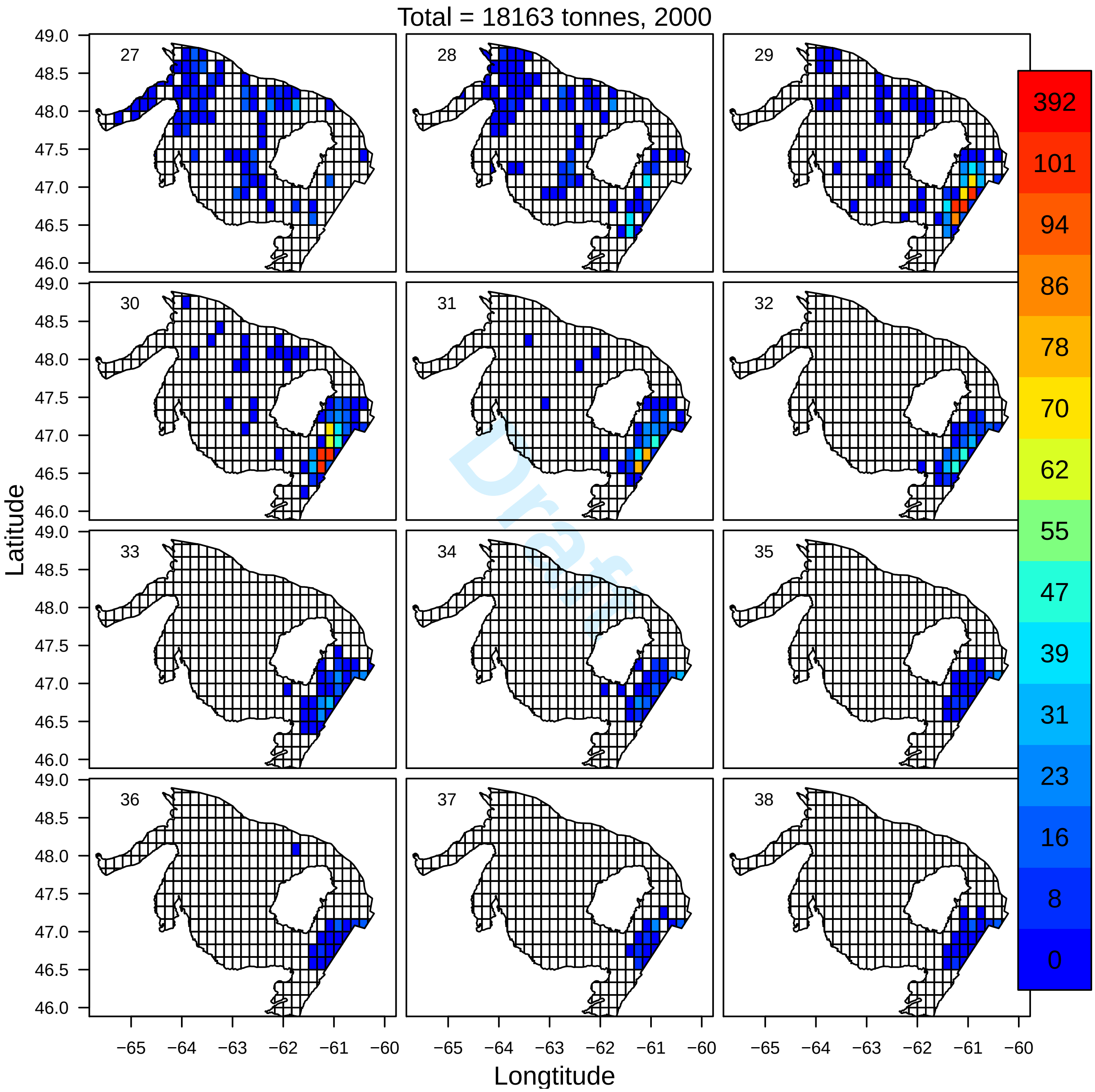


Figure SC.6c. Catch (tonnes) of snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

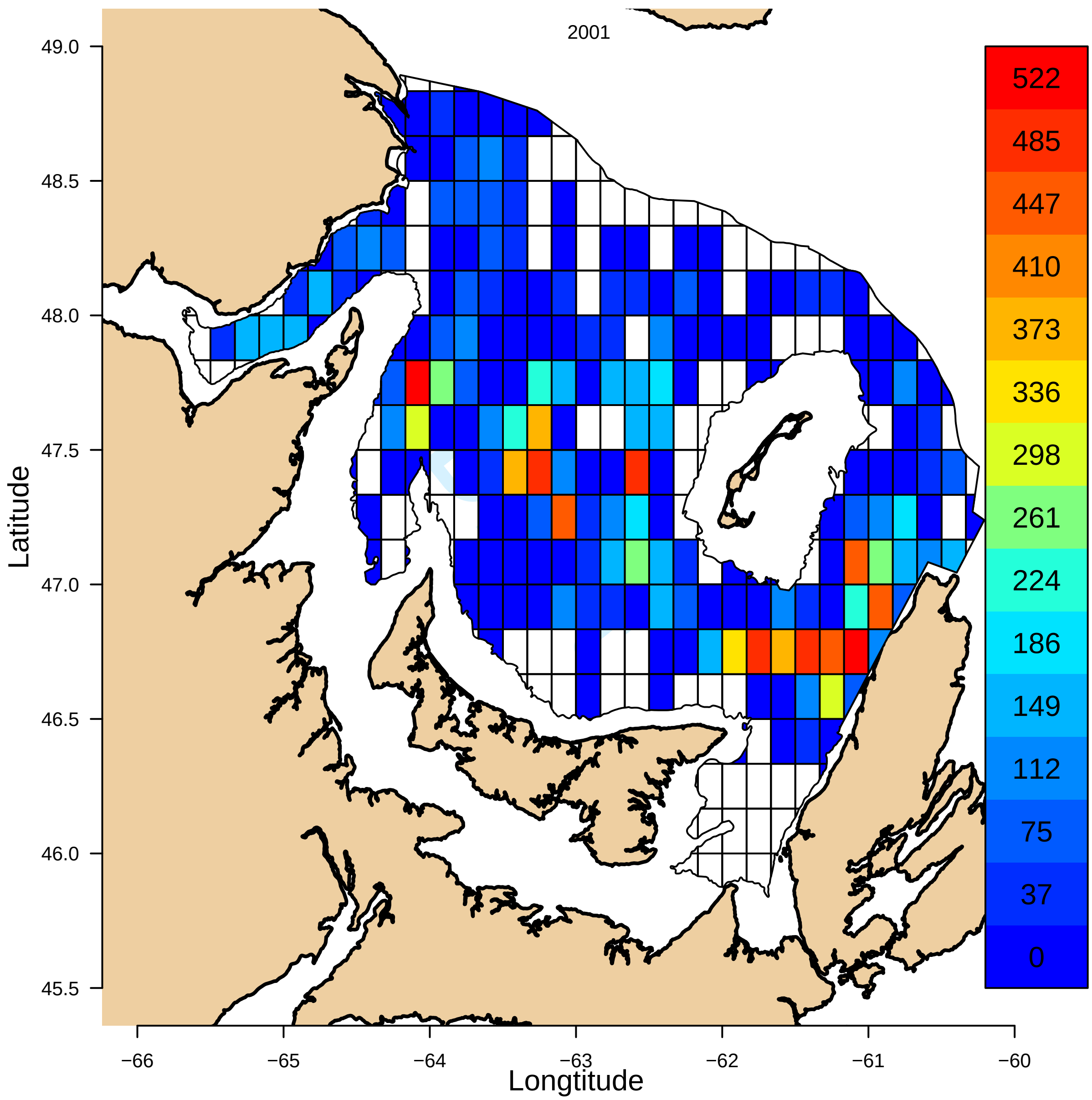


Figure SC.7a. Total annual catch (tonnes) of snow crab in each grid cell in 2001. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

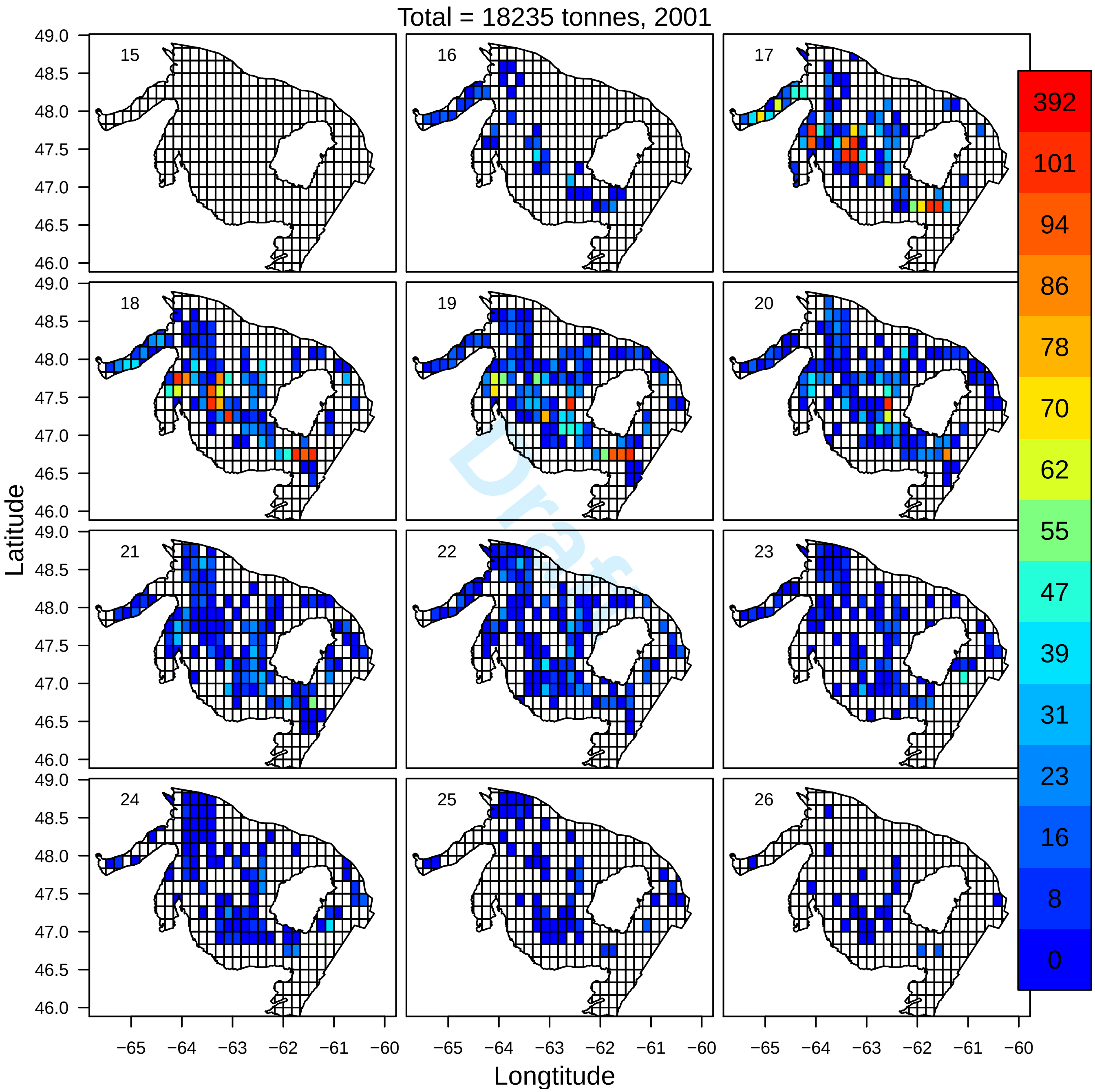


Figure SC.7b. Catch (tonnes) of snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

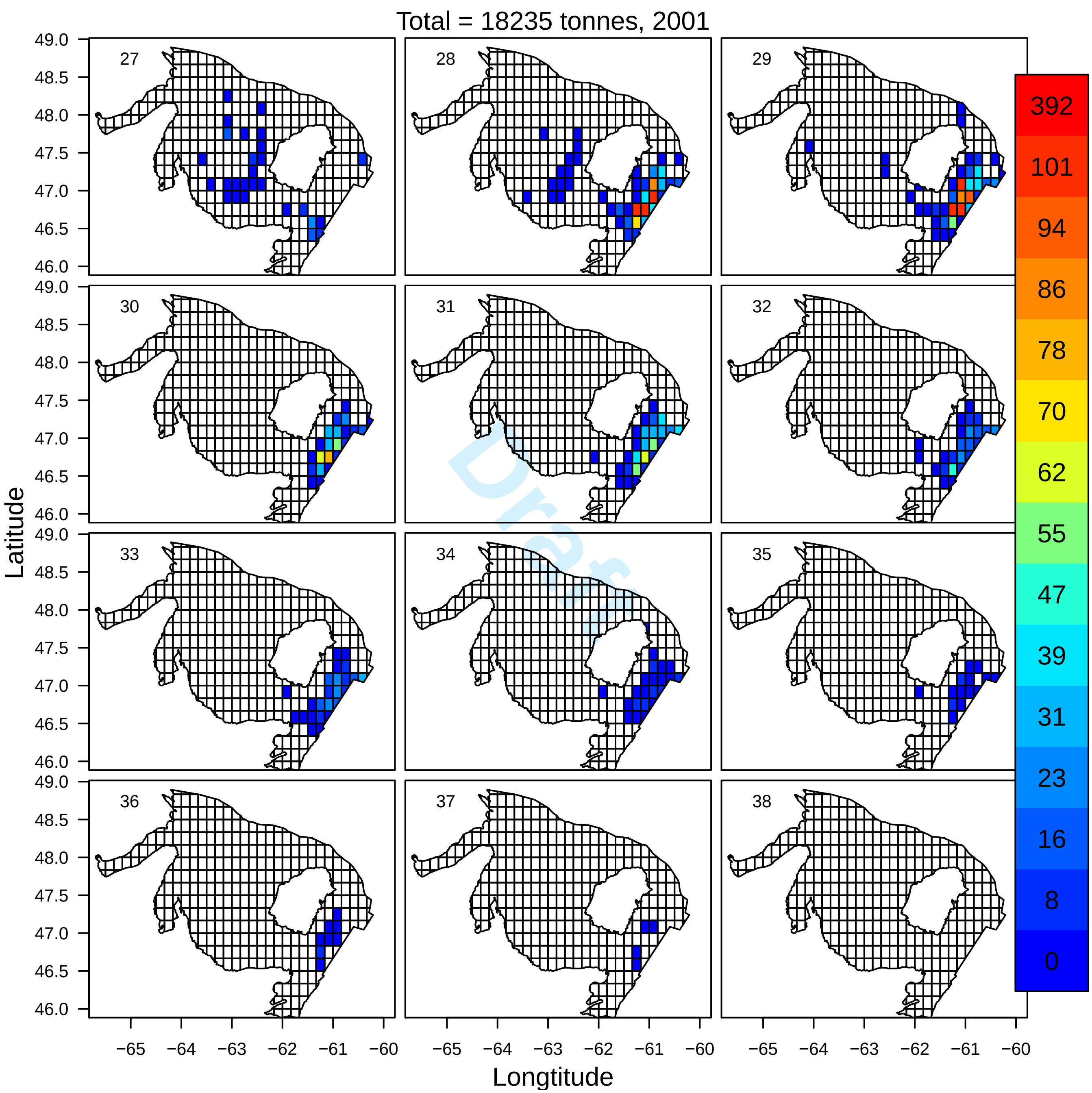


Figure SC.7c. Catch (tonnes) of snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

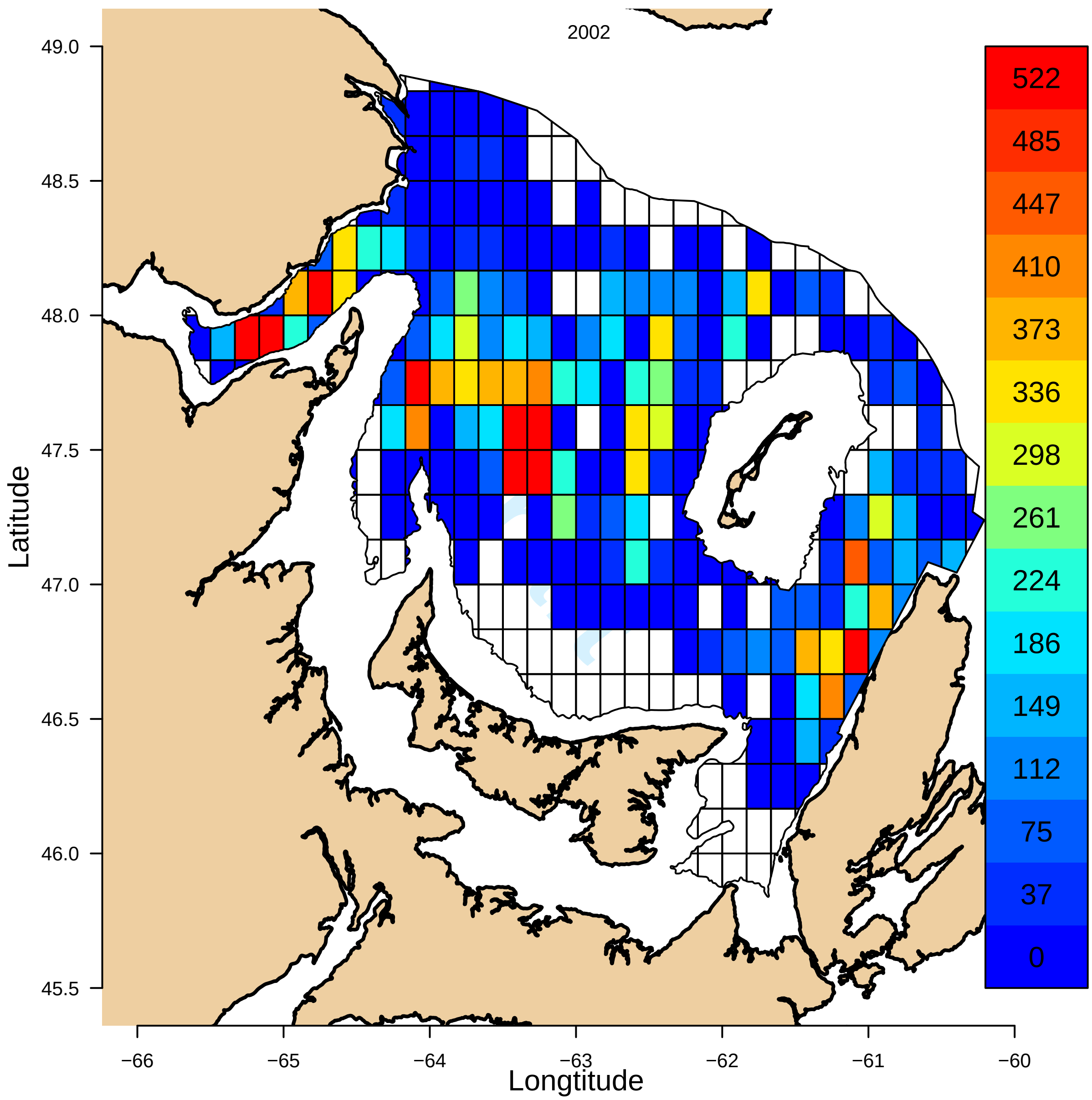


Figure SC.8a. Total annual catch (tonnes) of snow crab in each grid cell in 2002. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

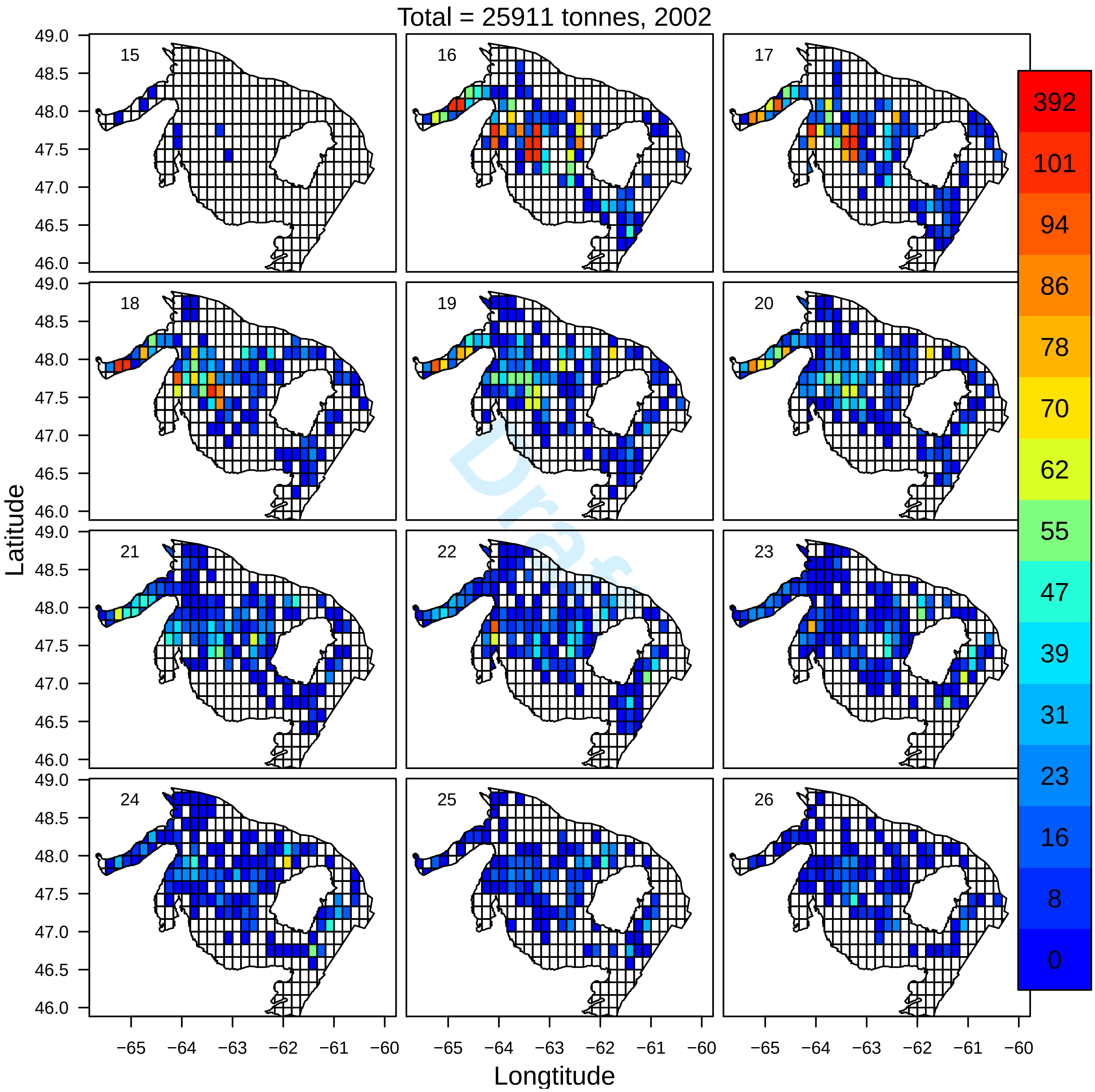


Figure SC.8b. Catch (tonnes) of snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

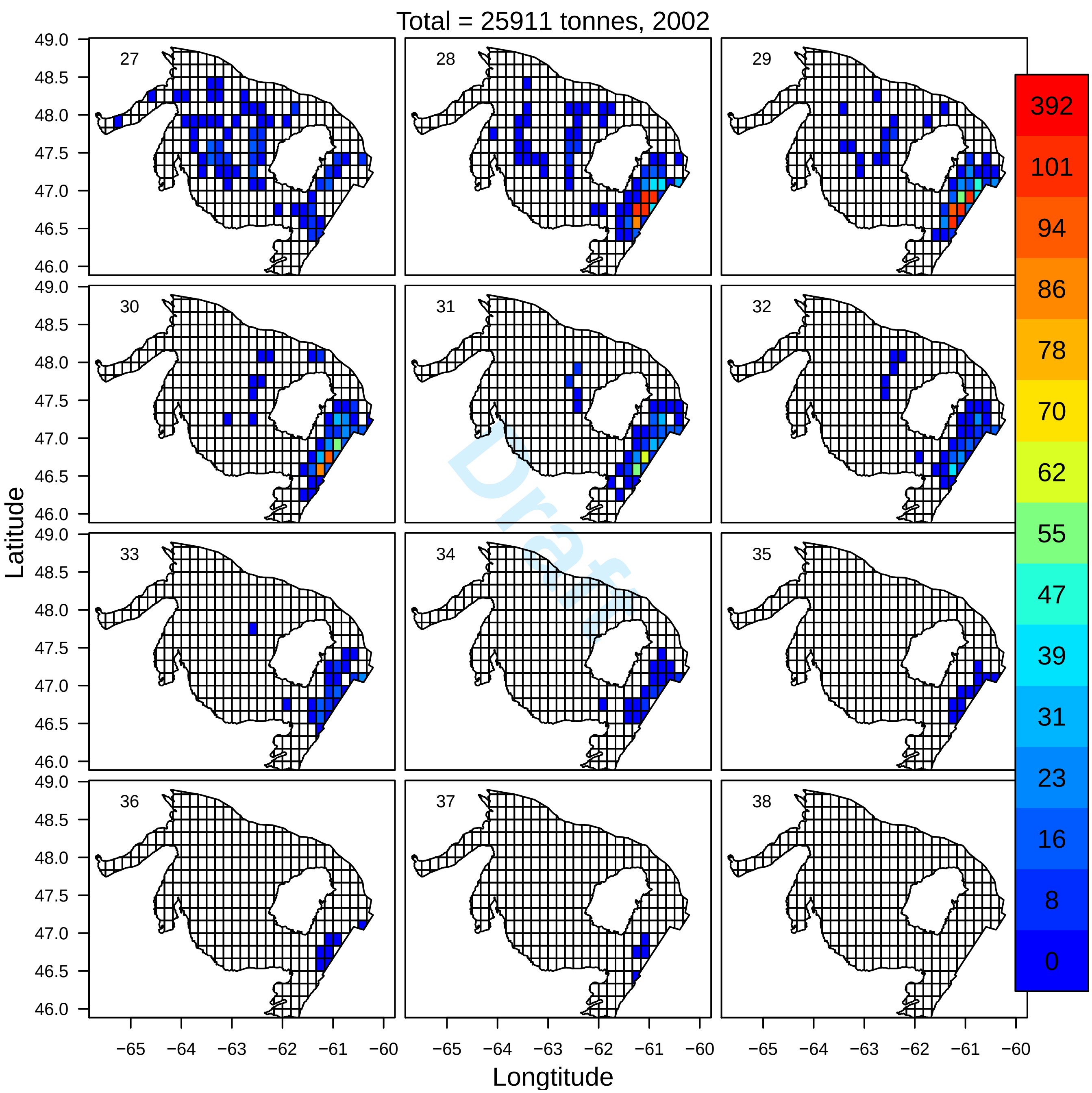


Figure SC.8c. Catch (tonnes) of snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

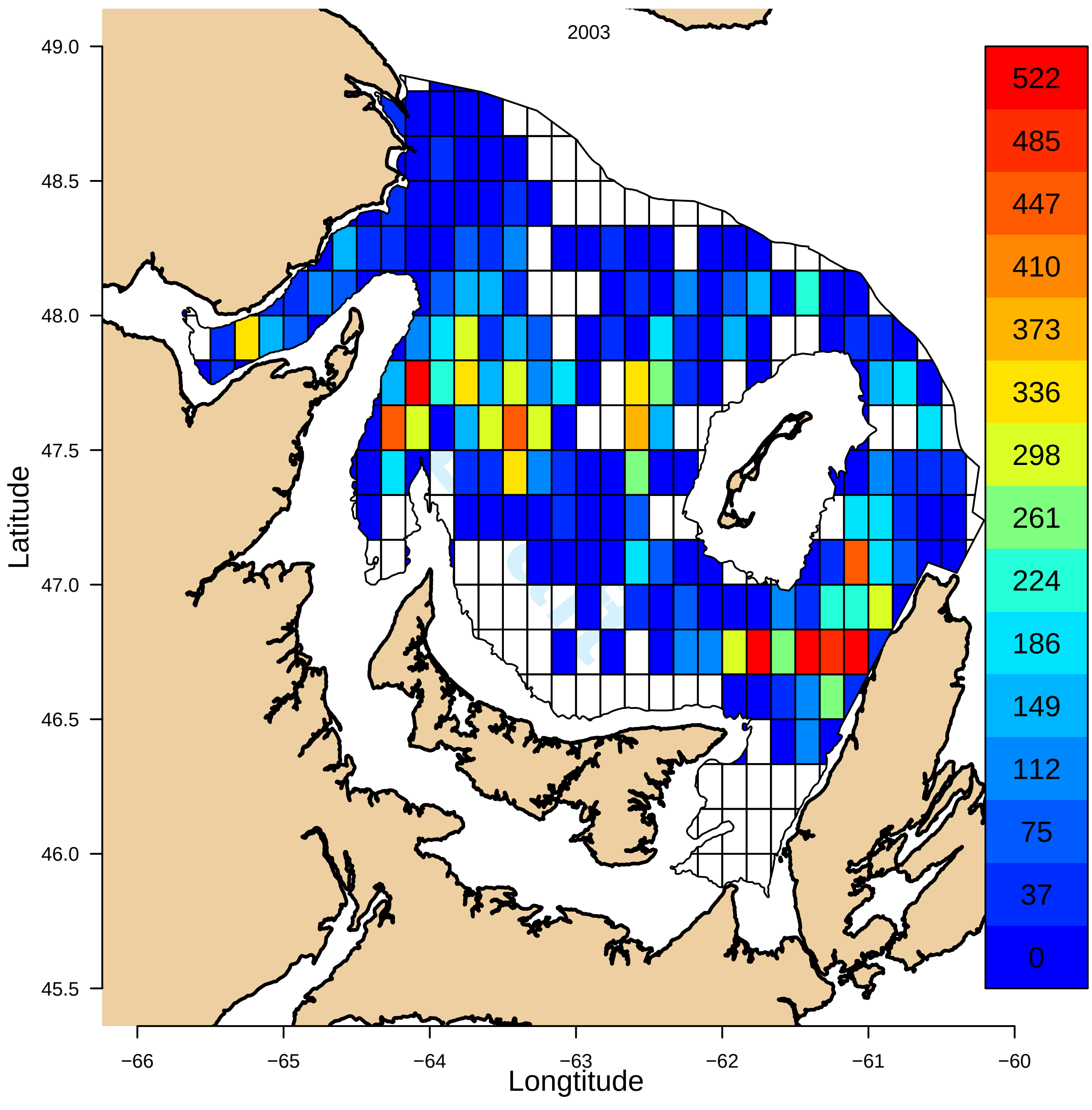


Figure SC.9a. Total annual catch (tonnes) of snow crab in each grid cell in 2003. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

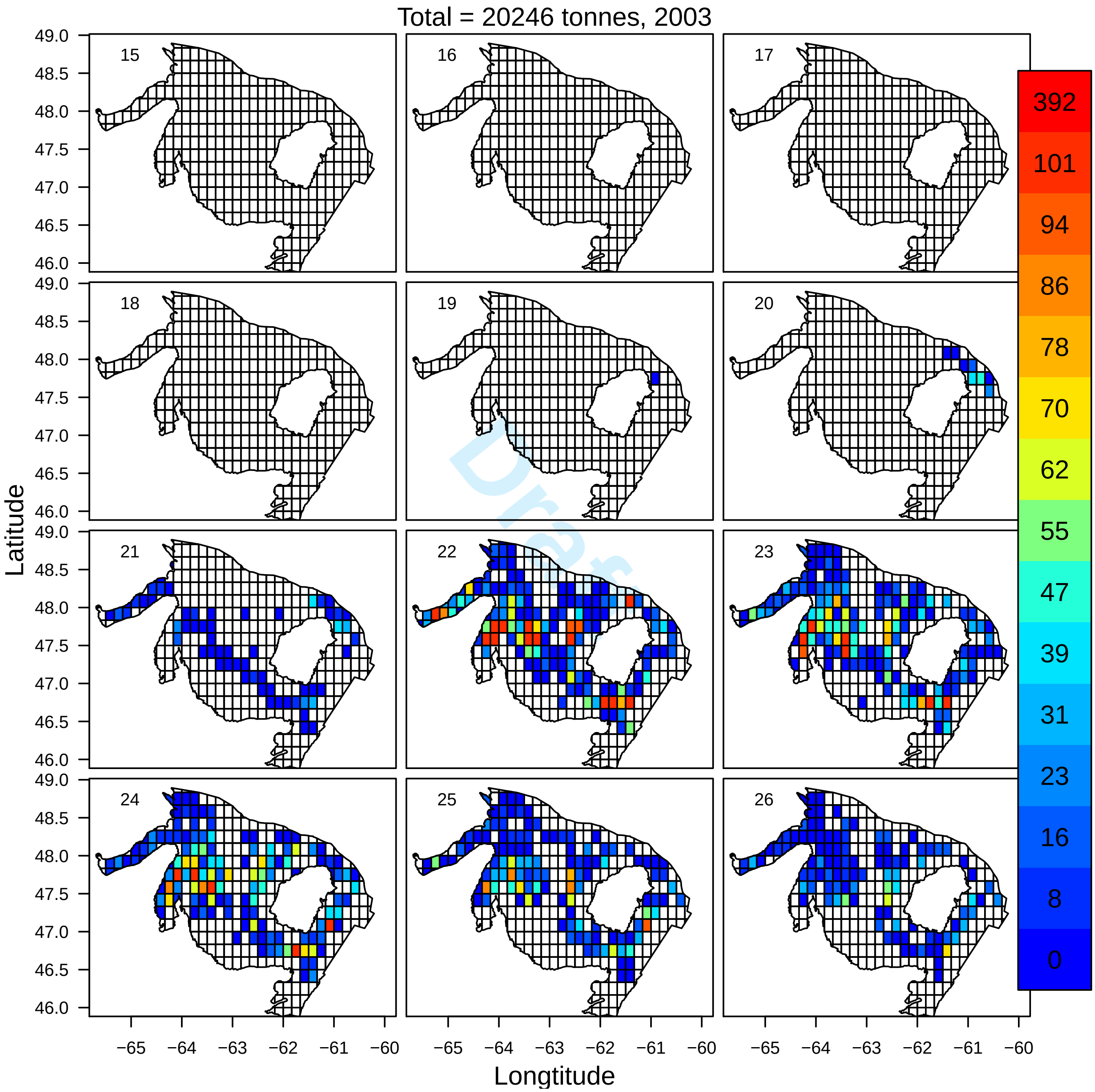


Figure SC.9b. Catch (tonnes) of snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

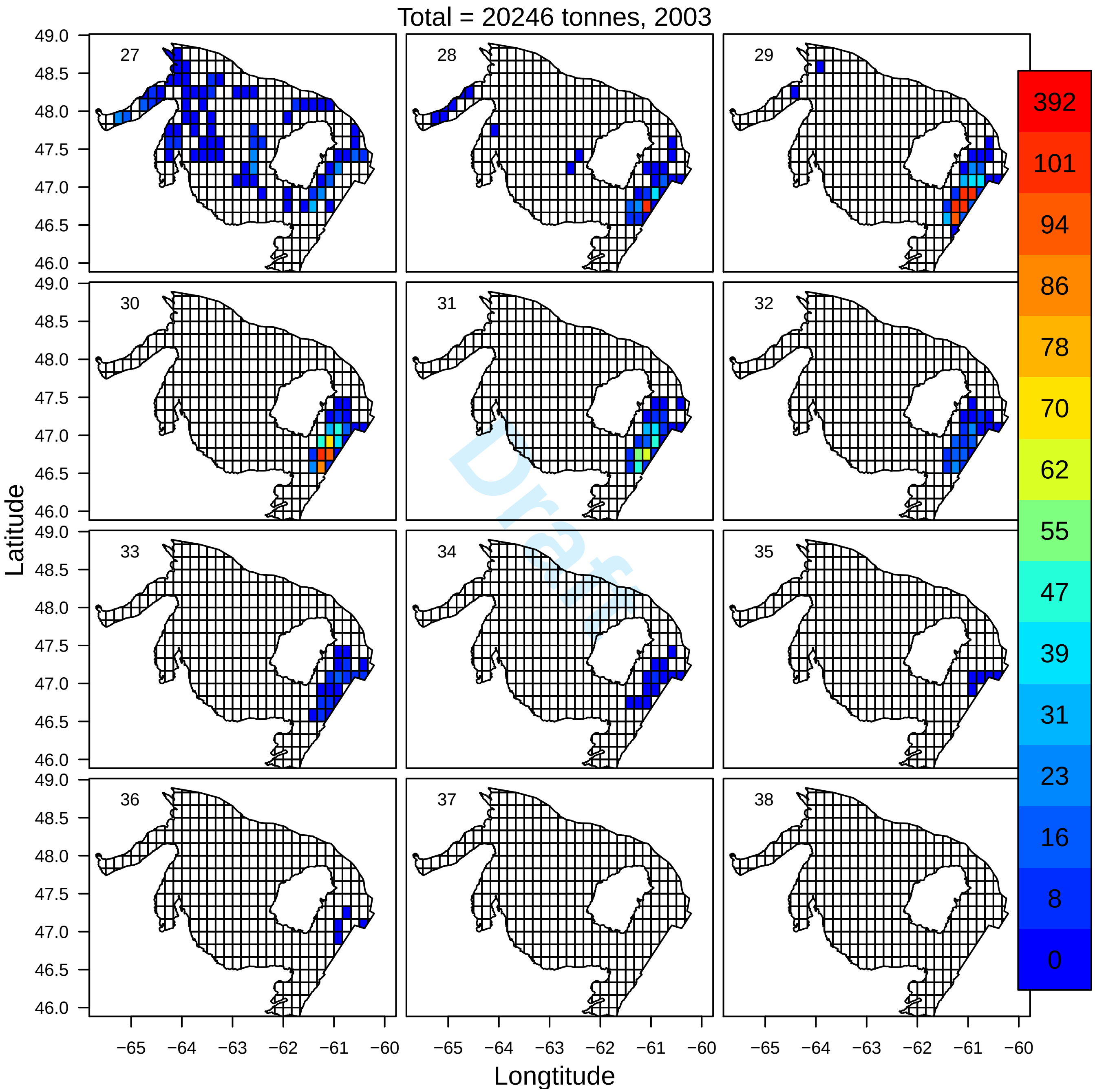


Figure SC.9c. Catch (tonnes) of snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

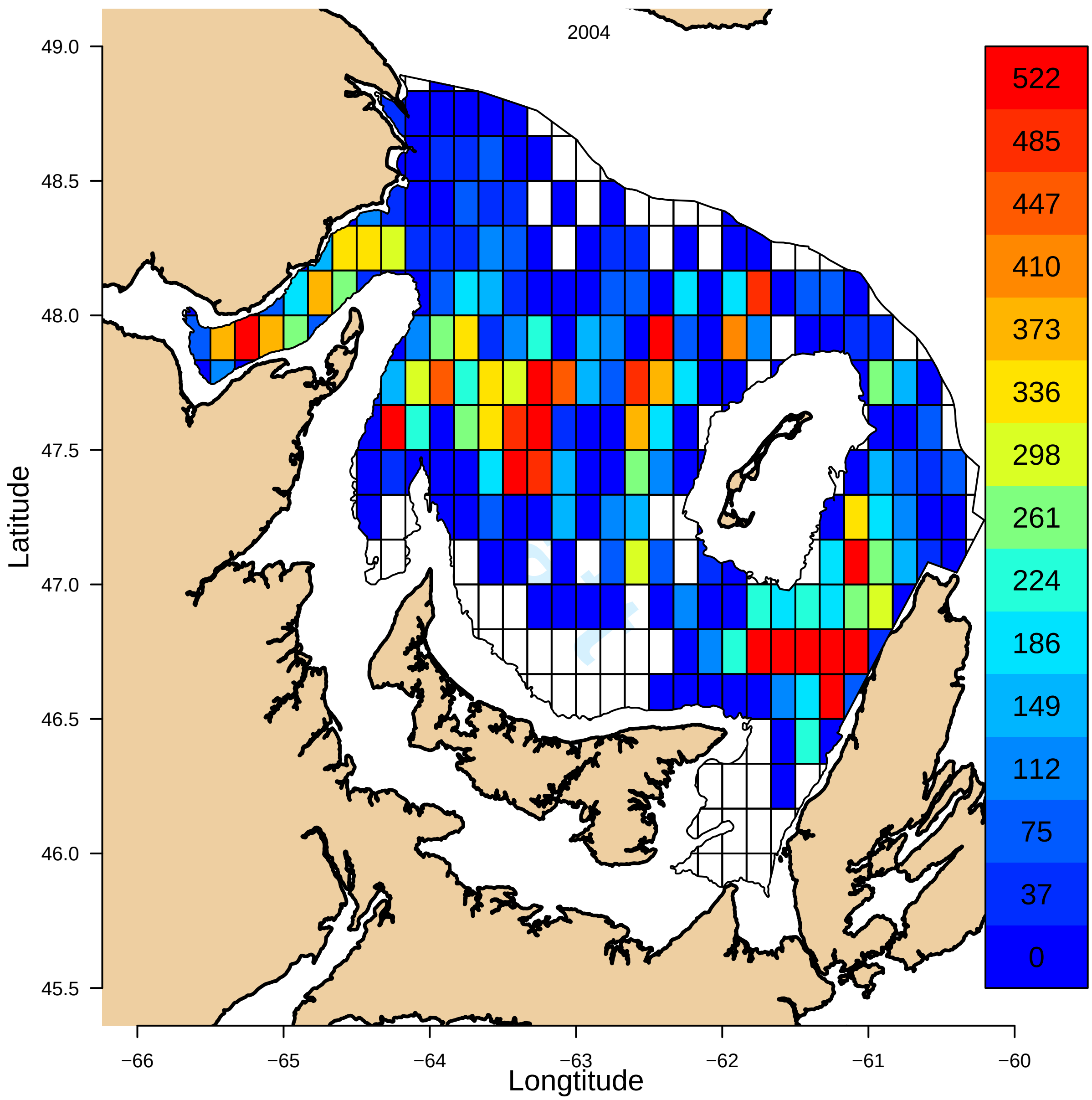


Figure SC.10a. Total annual catch (tonnes) of snow crab in each grid cell in 2004. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

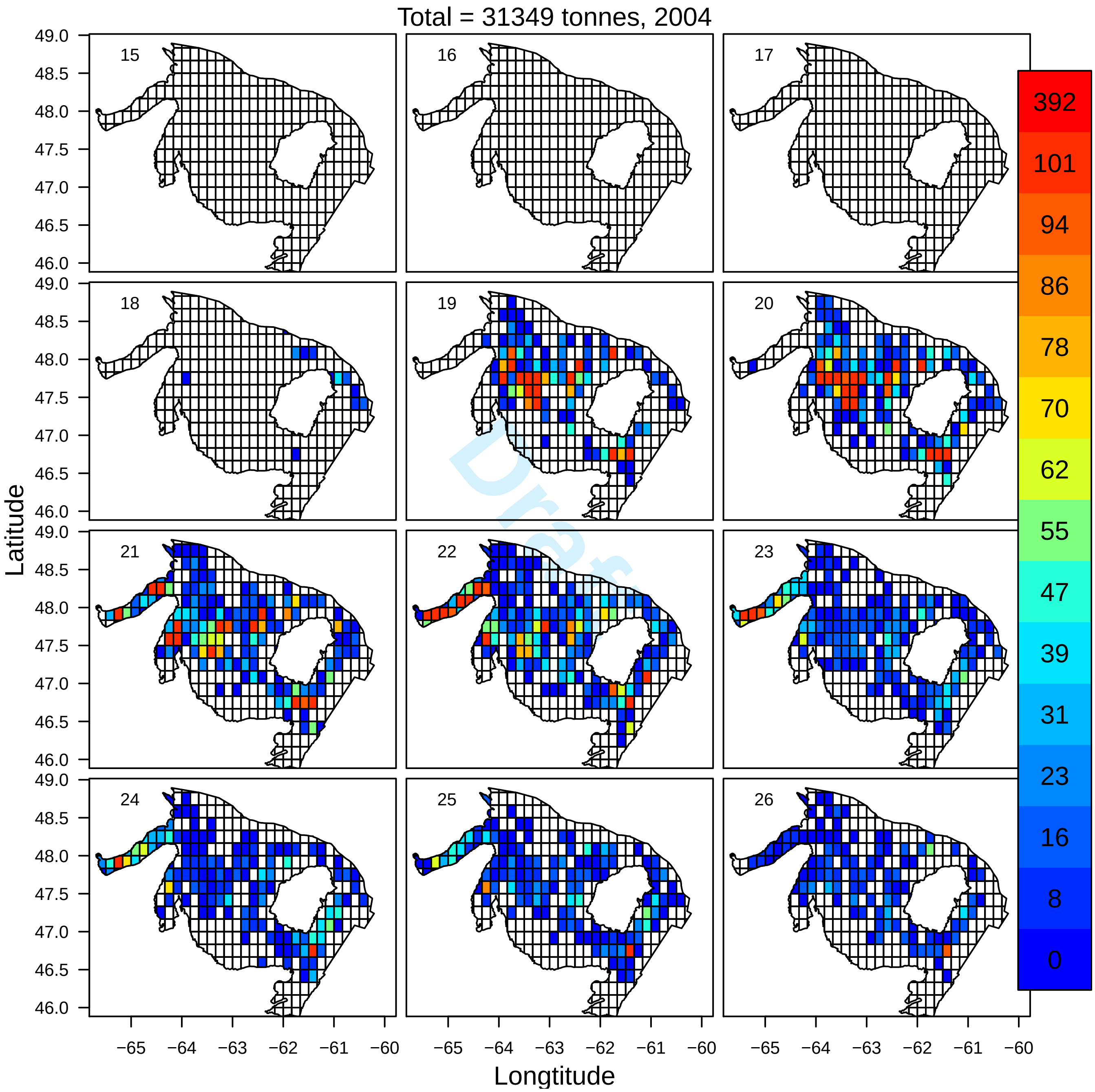


Figure SC.10b. Catch (tonnes) of snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

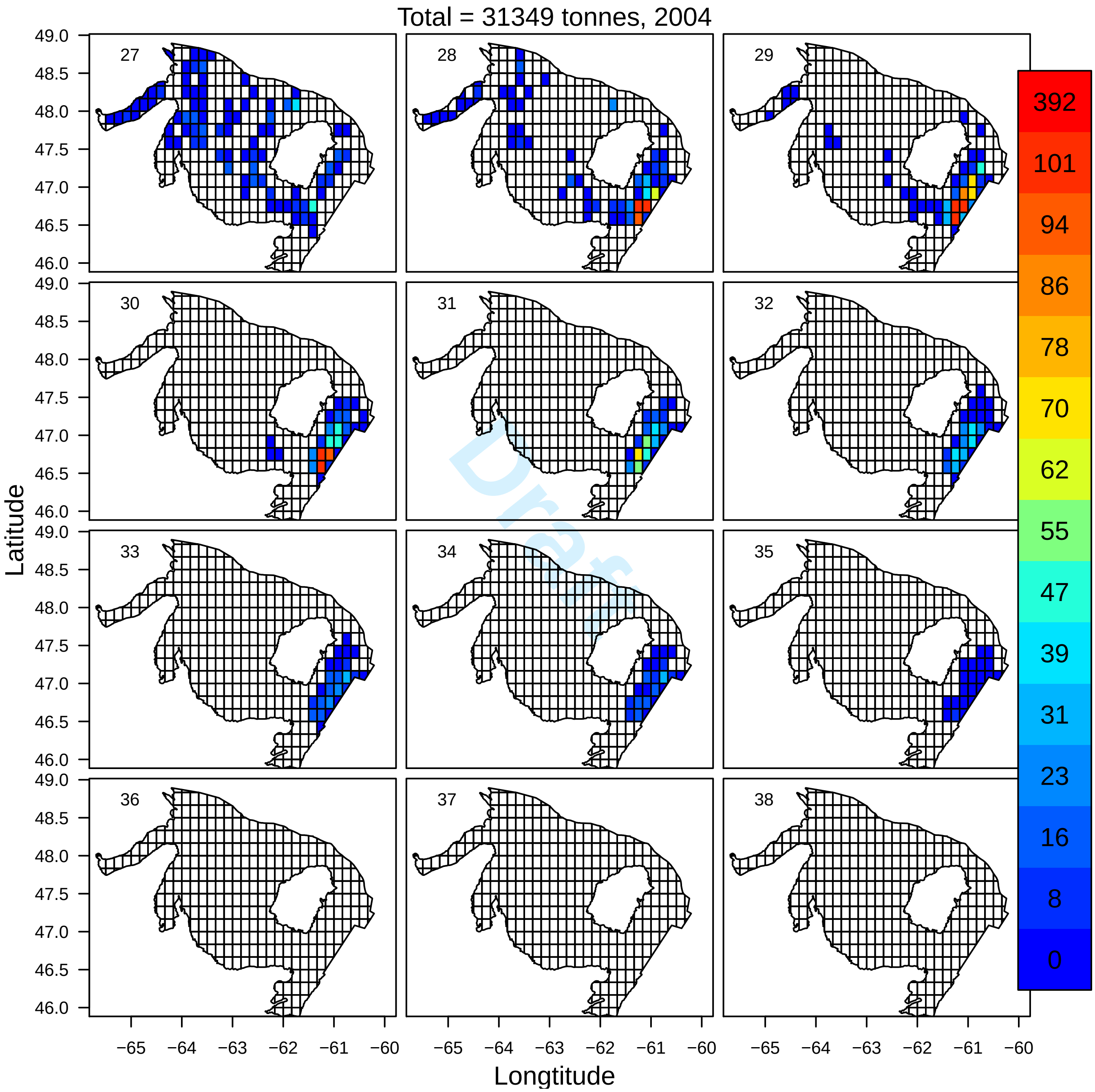


Figure SC.10c. Catch (tonnes) of snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

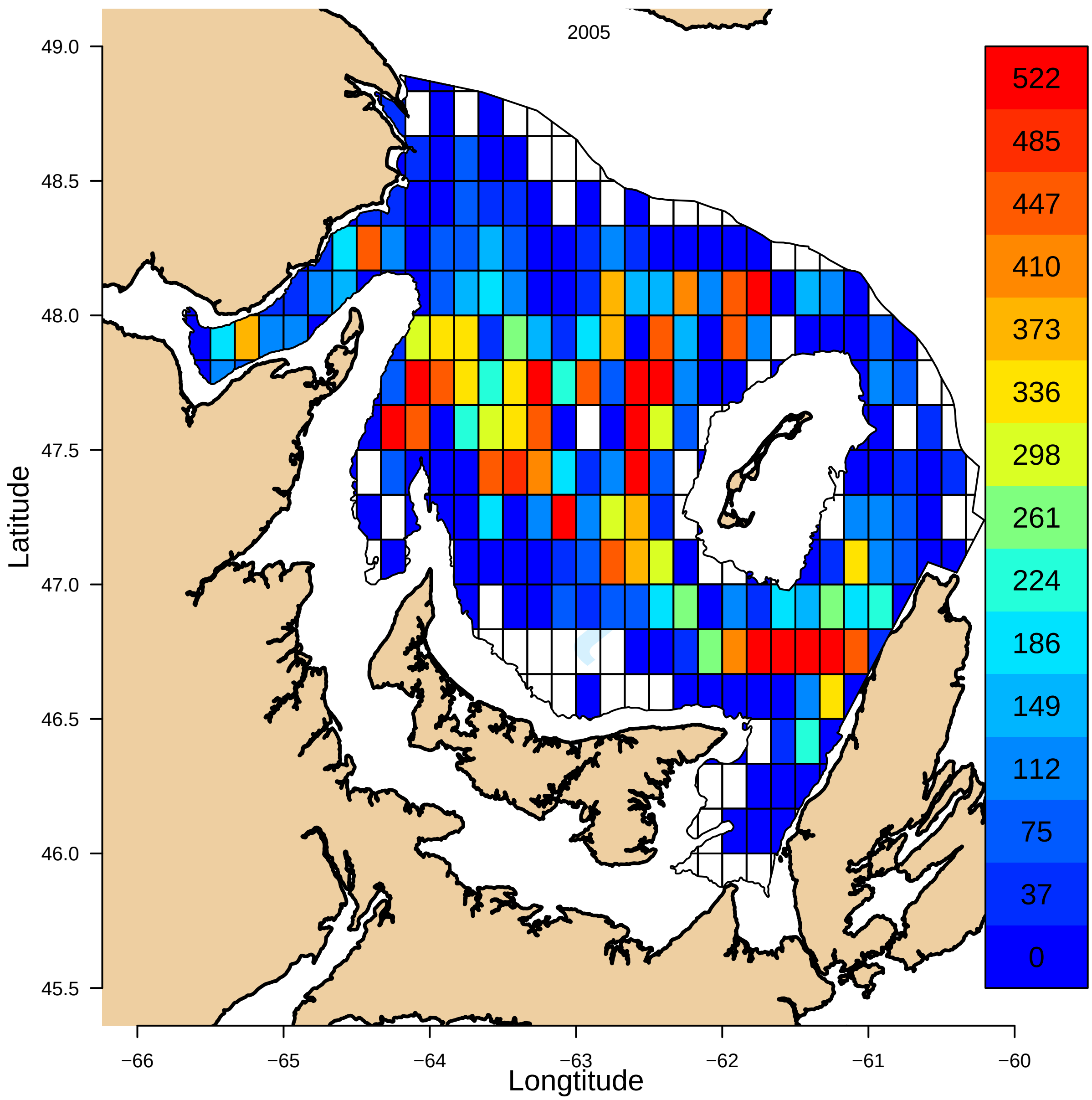


Figure SC.11a. Total annual catch (tonnes) of snow crab in each grid cell in 2005. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

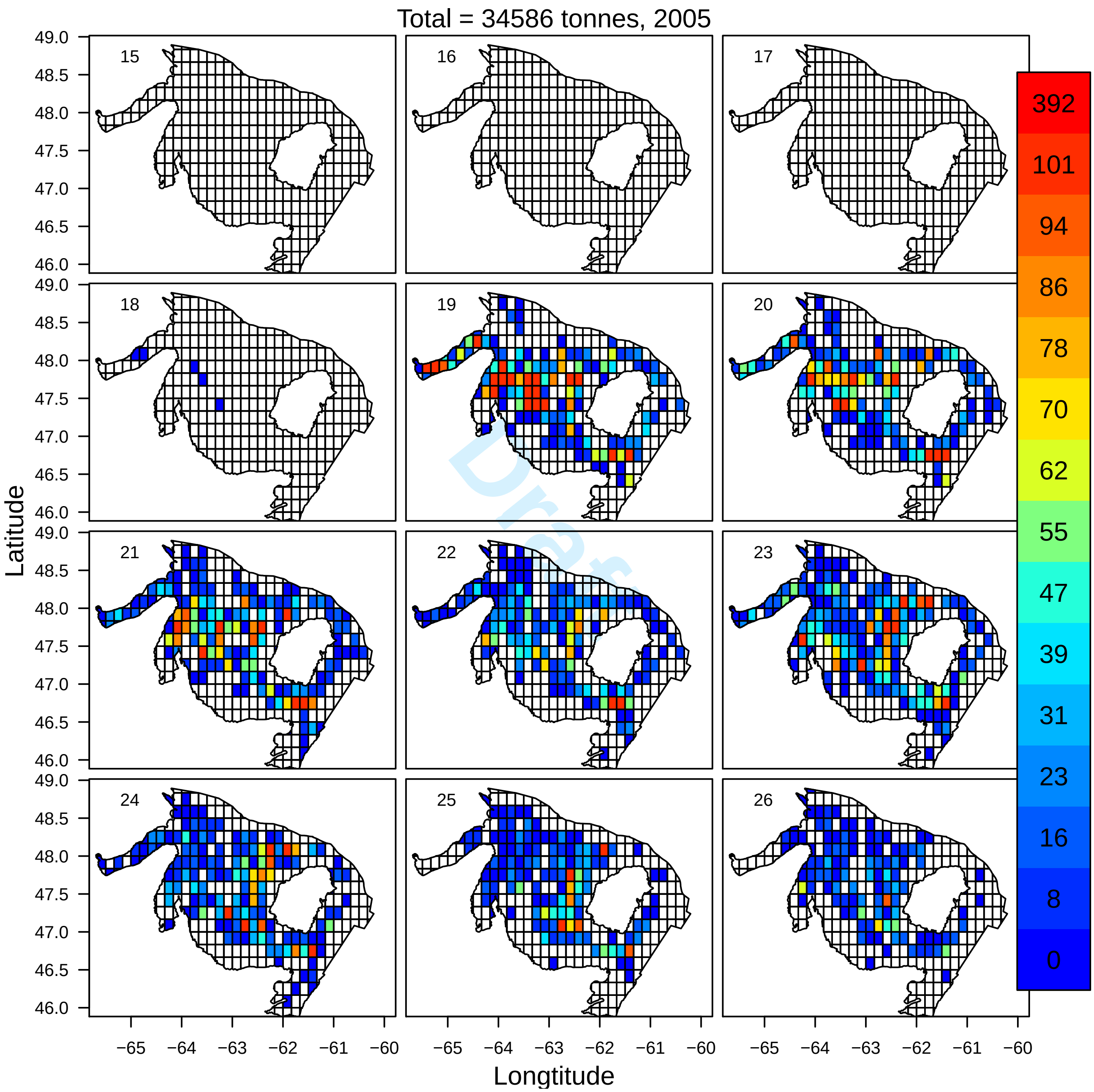


Figure SC.11b. Catch (tonnes) of snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

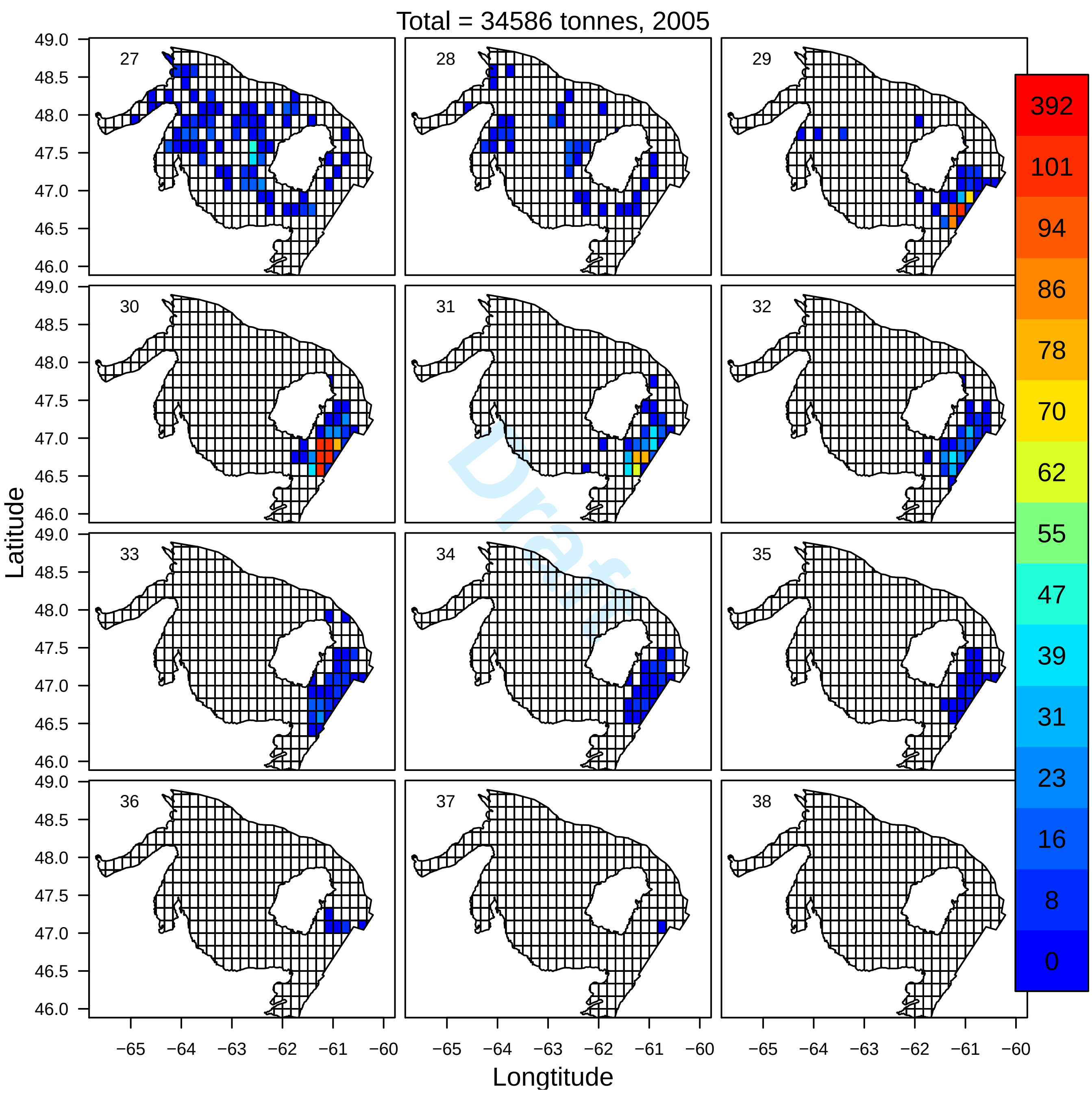


Figure SC.11c. Catch (tonnes) of snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

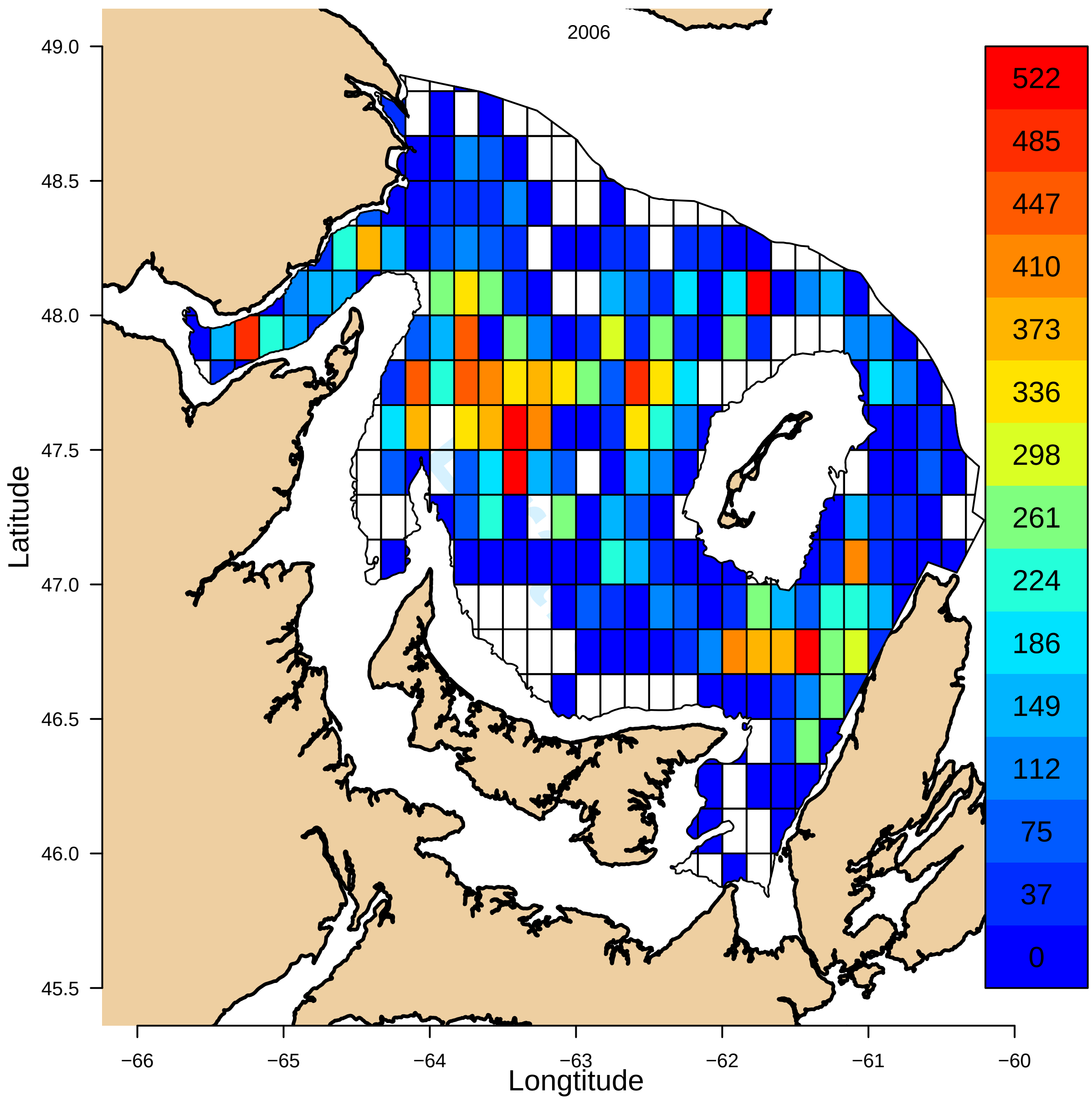


Figure SC.12a. Total annual catch (tonnes) of snow crab in each grid cell in 2006. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

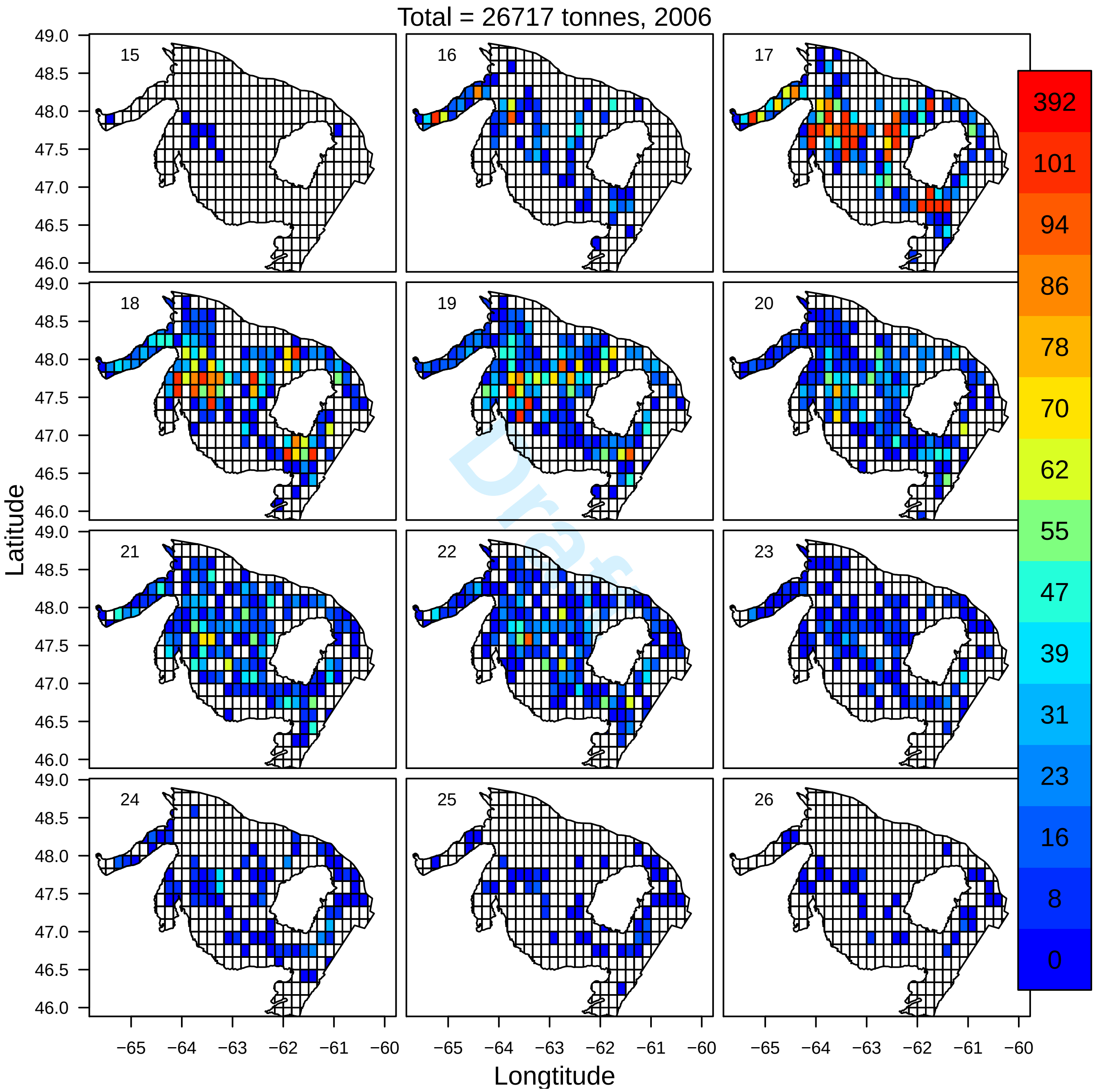


Figure SC.12b. Catch (tonnes) of snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

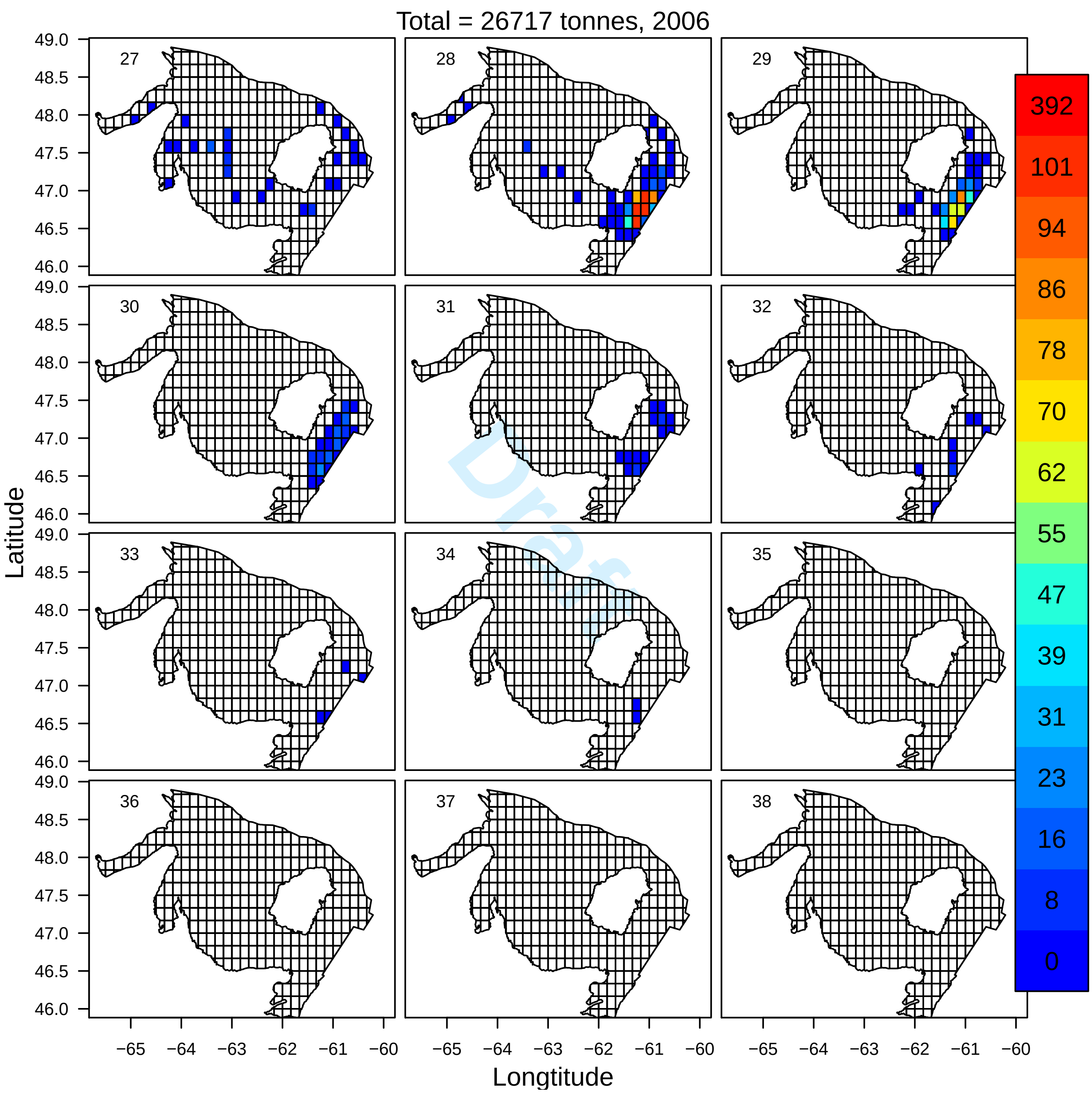


Figure SC.12c. Catch (tonnes) of snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

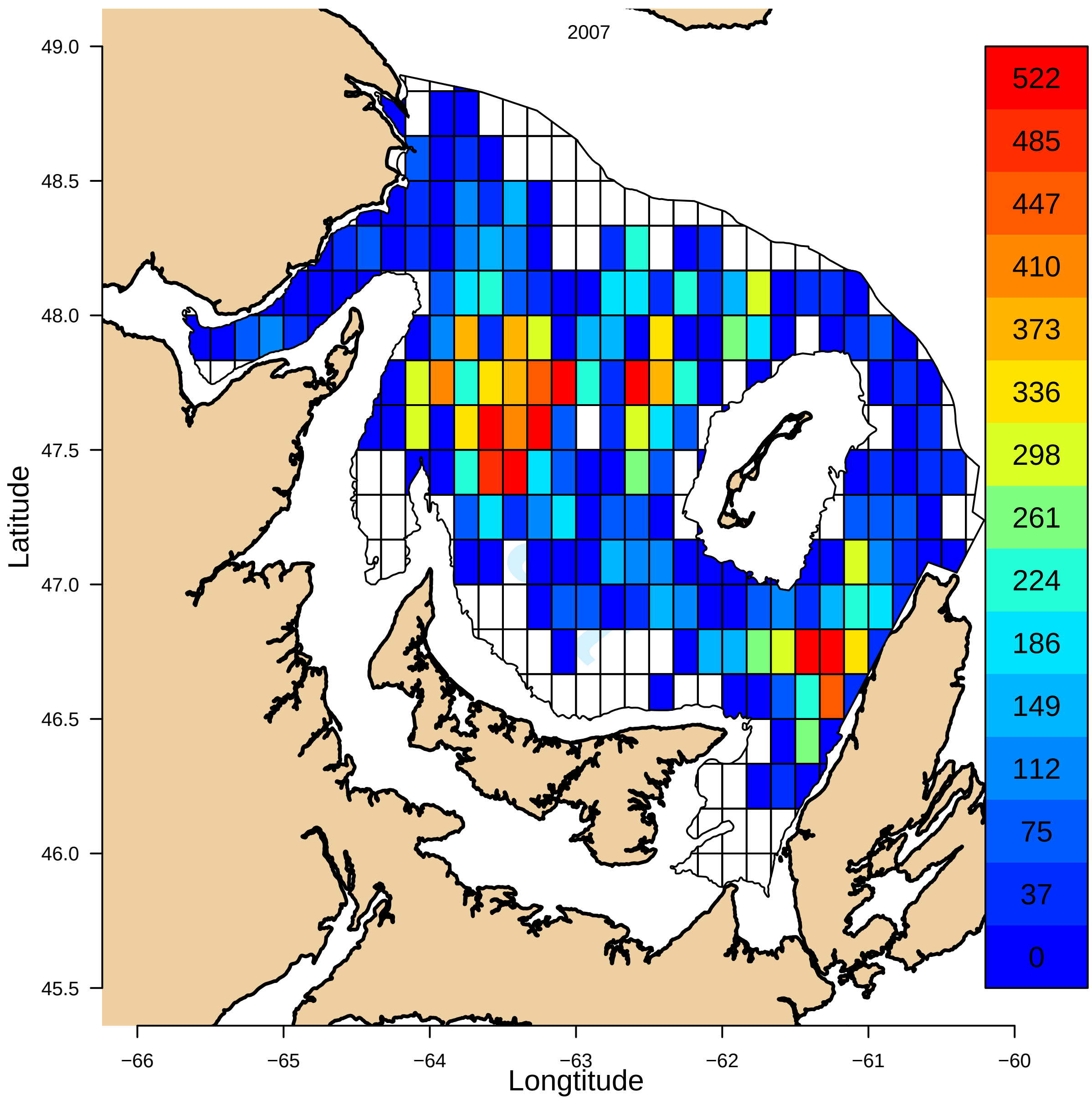


Figure SC.13a. Total annual catch (tonnes) of snow crab in each grid cell in 2007. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

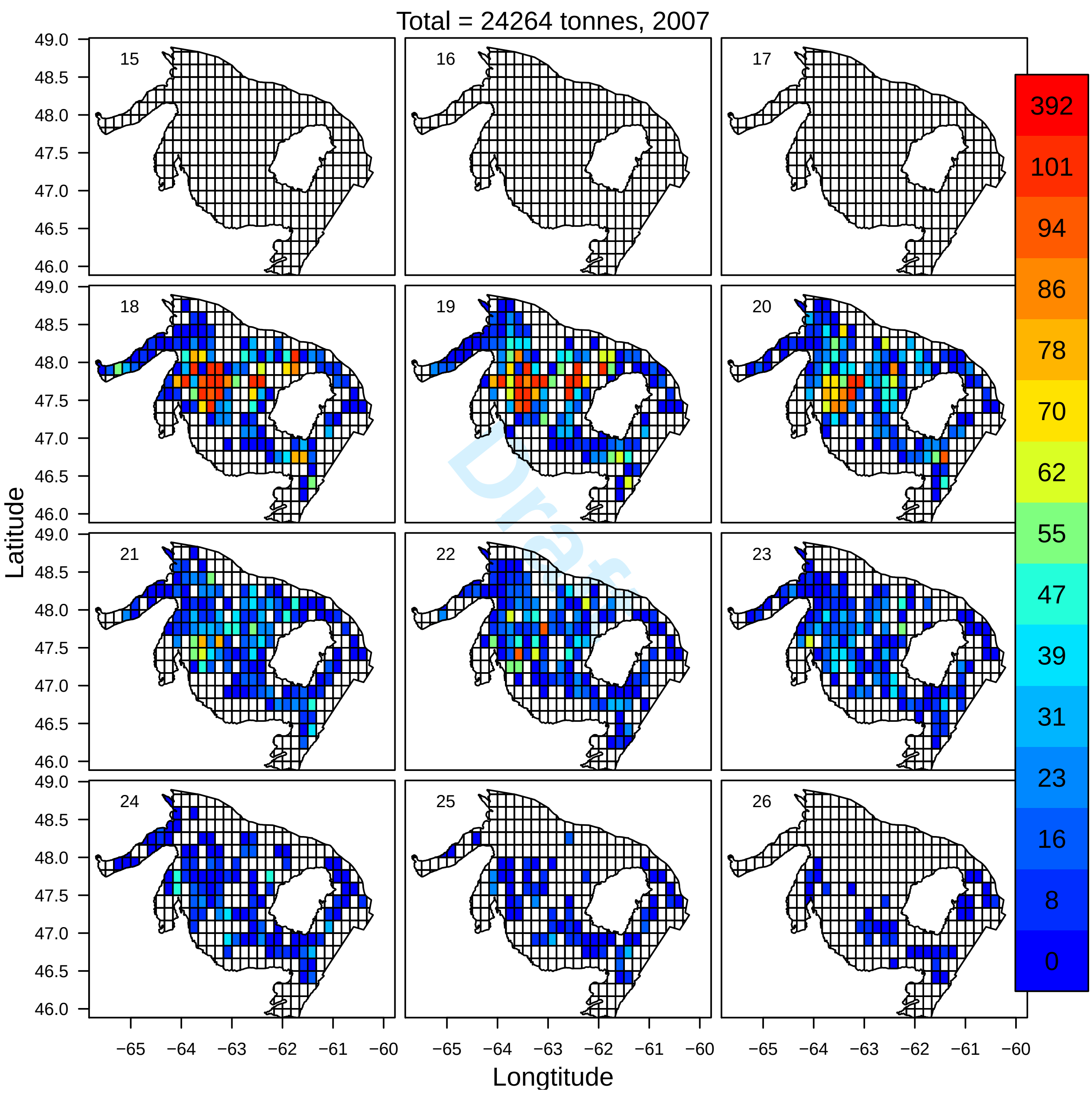


Figure SC.13b. Catch (tonnes) of snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

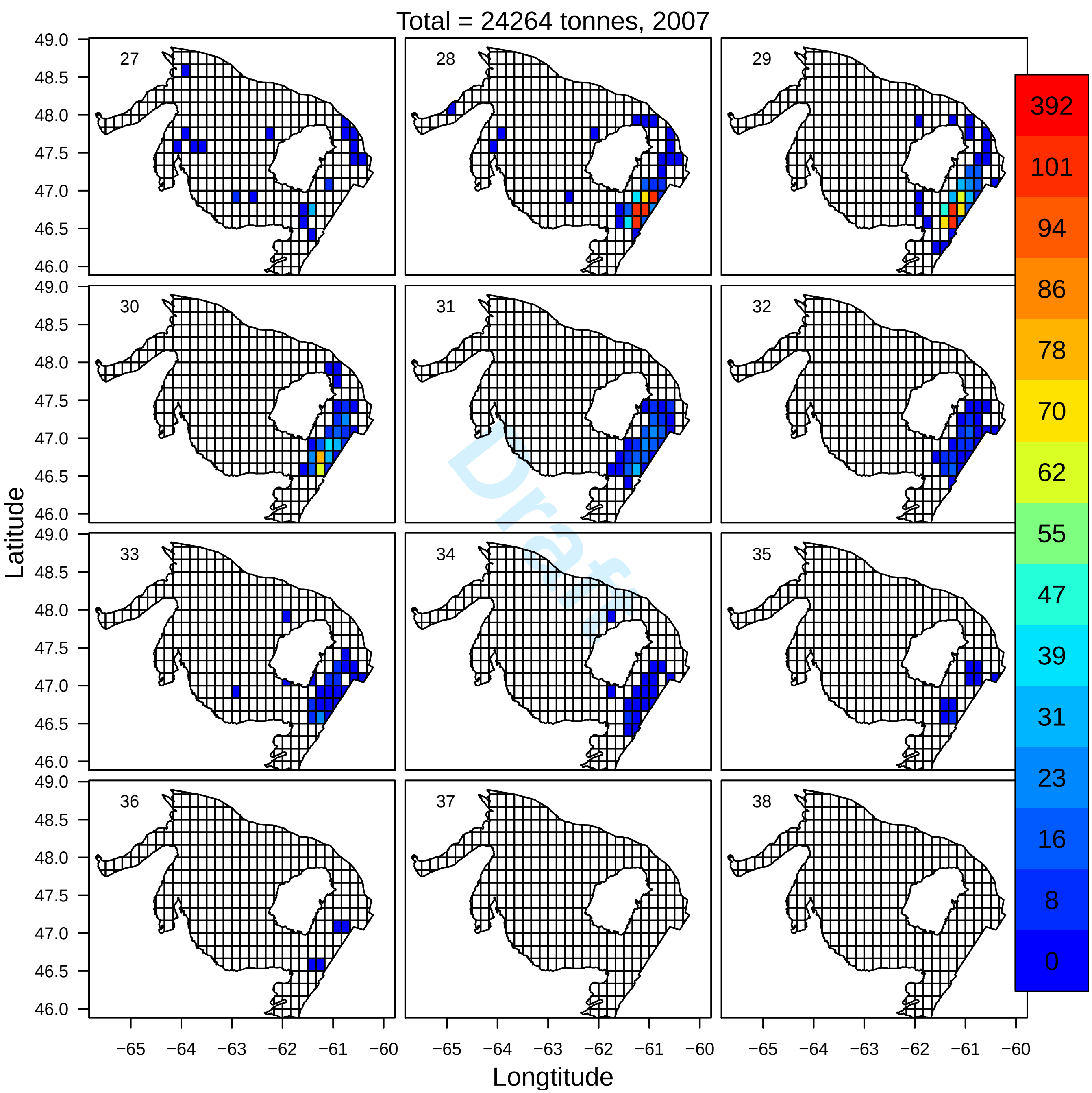


Figure SC.13c. Catch (tonnes) of snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

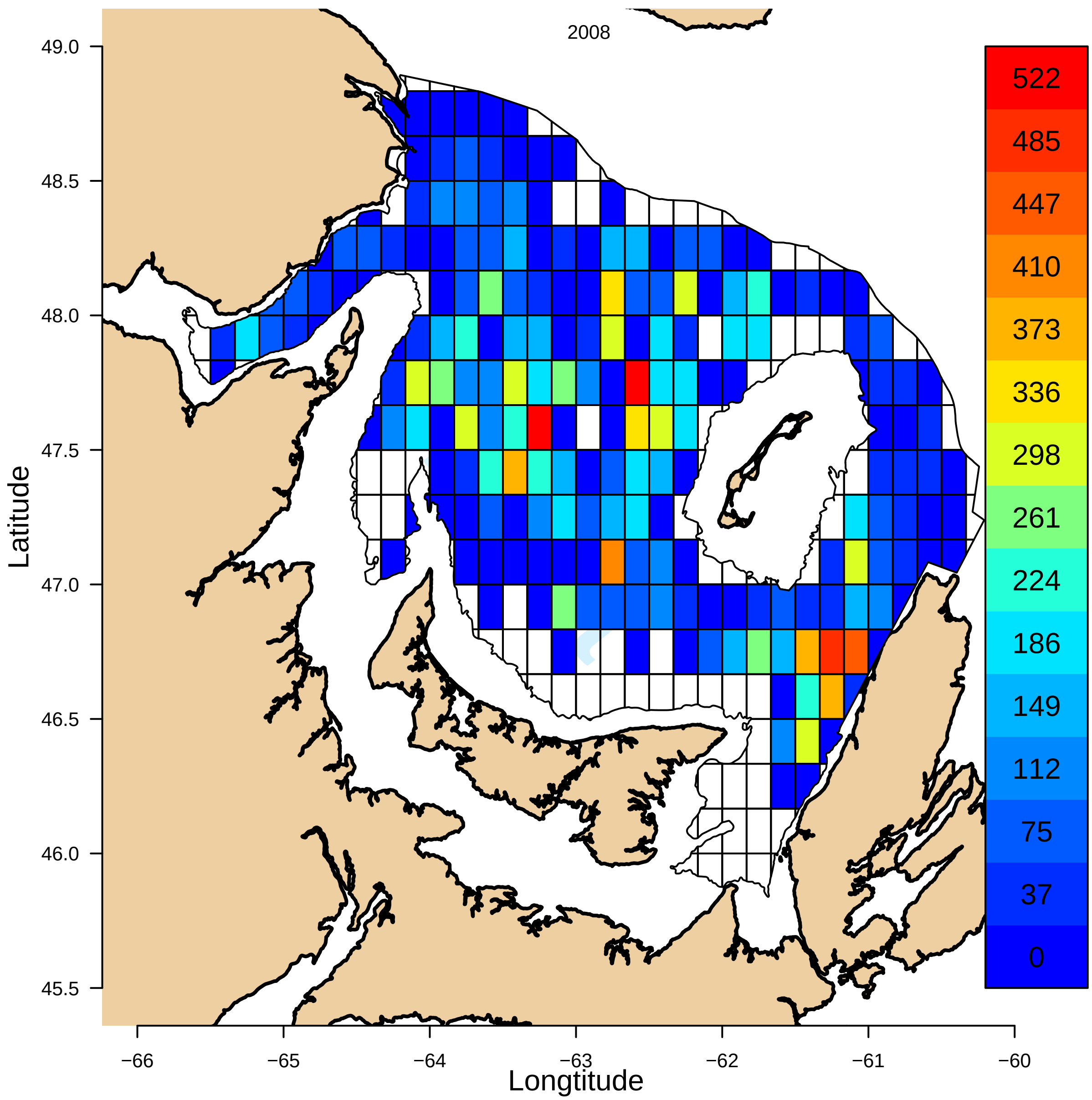


Figure SC.14a. Total annual catch (tonnes) of snow crab in each grid cell in 2008. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

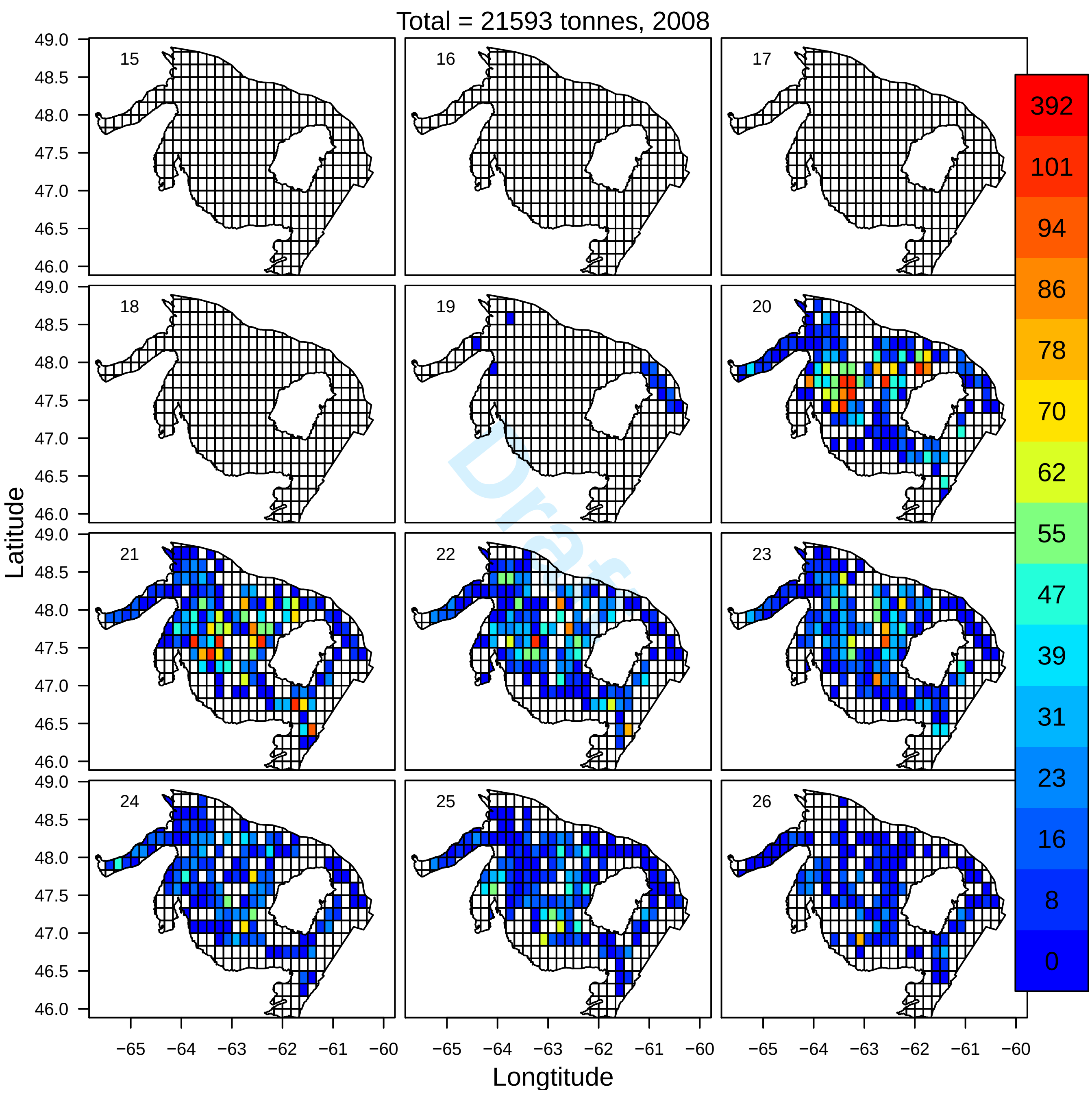


Figure SC.14b. Catch (tonnes) of snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

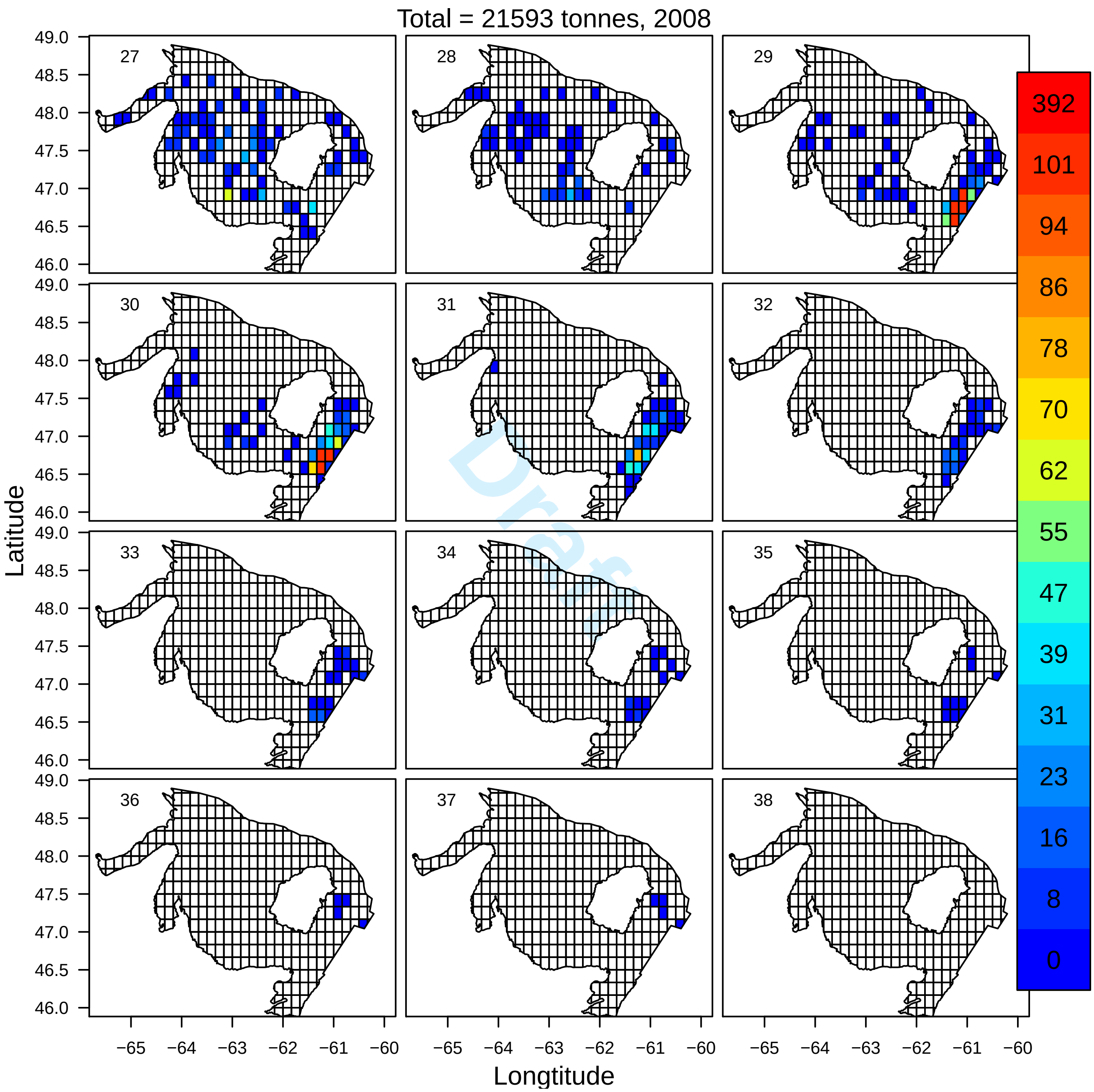


Figure SC.14c. Catch (tonnes) of snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

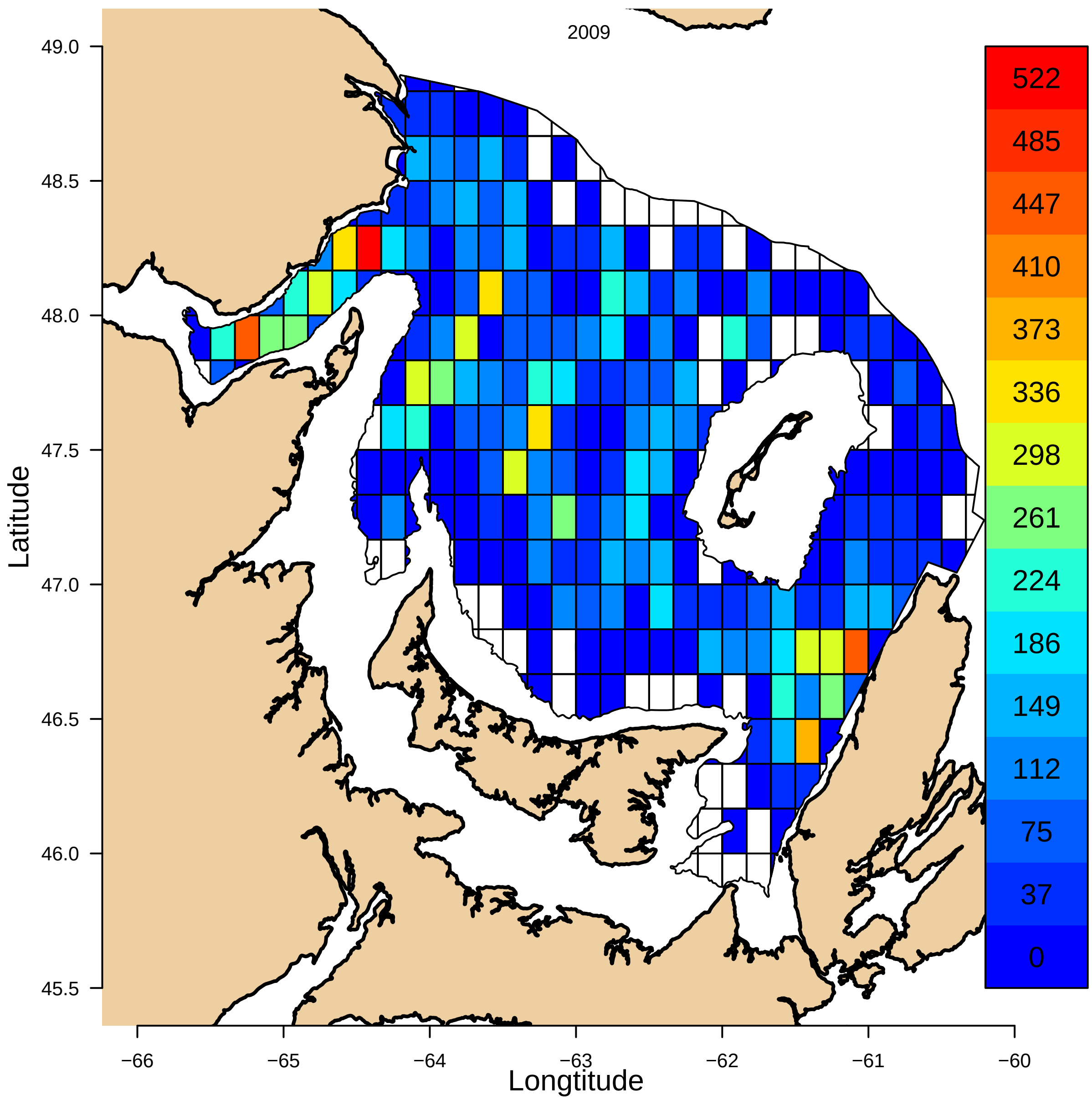


Figure SC.15a. Total annual catch (tonnes) of snow crab in each grid cell in 2009. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

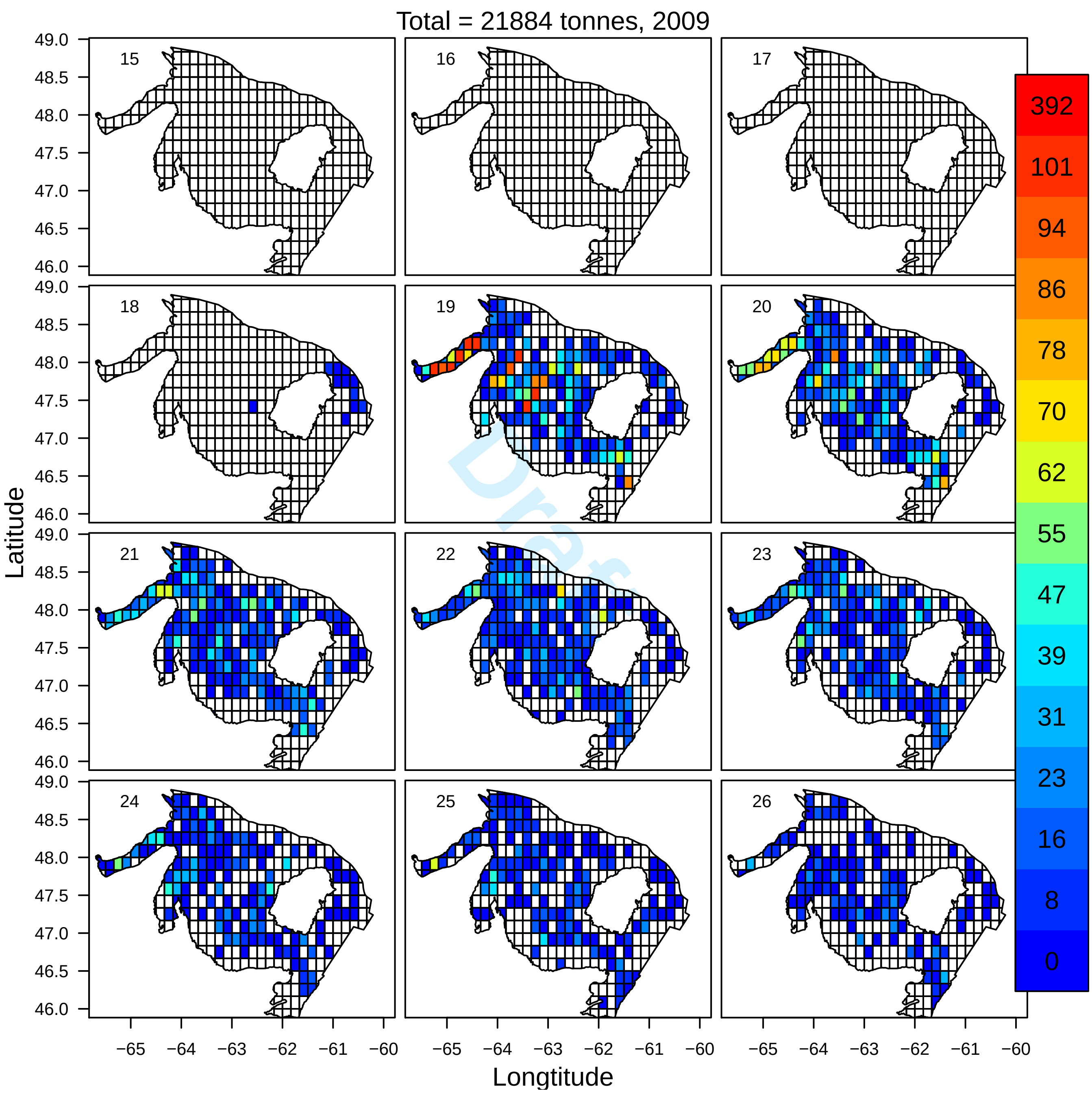


Figure SC.15b. Catch (tonnes) of snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

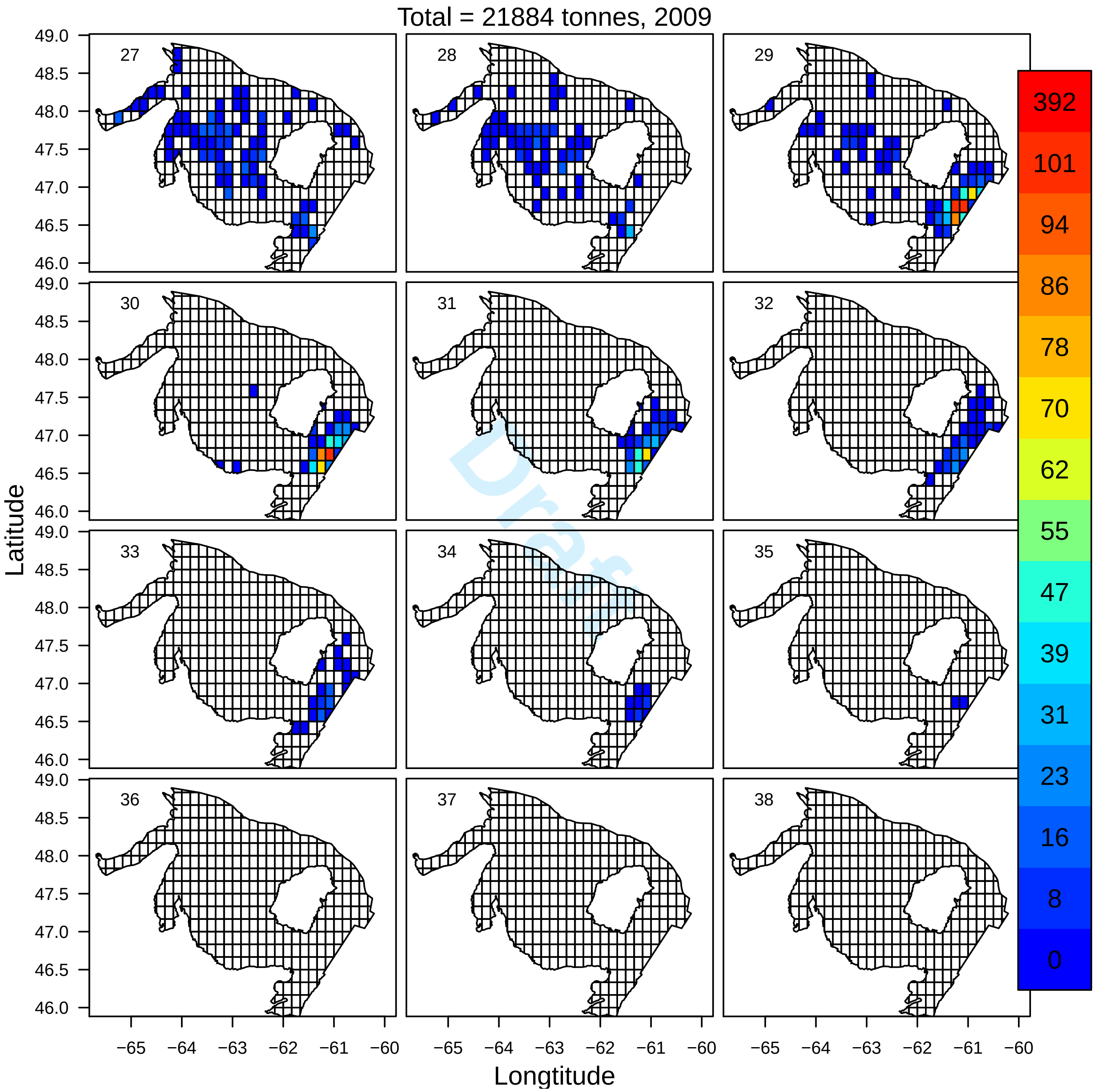


Figure SC.15c. Catch (tonnes) of snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

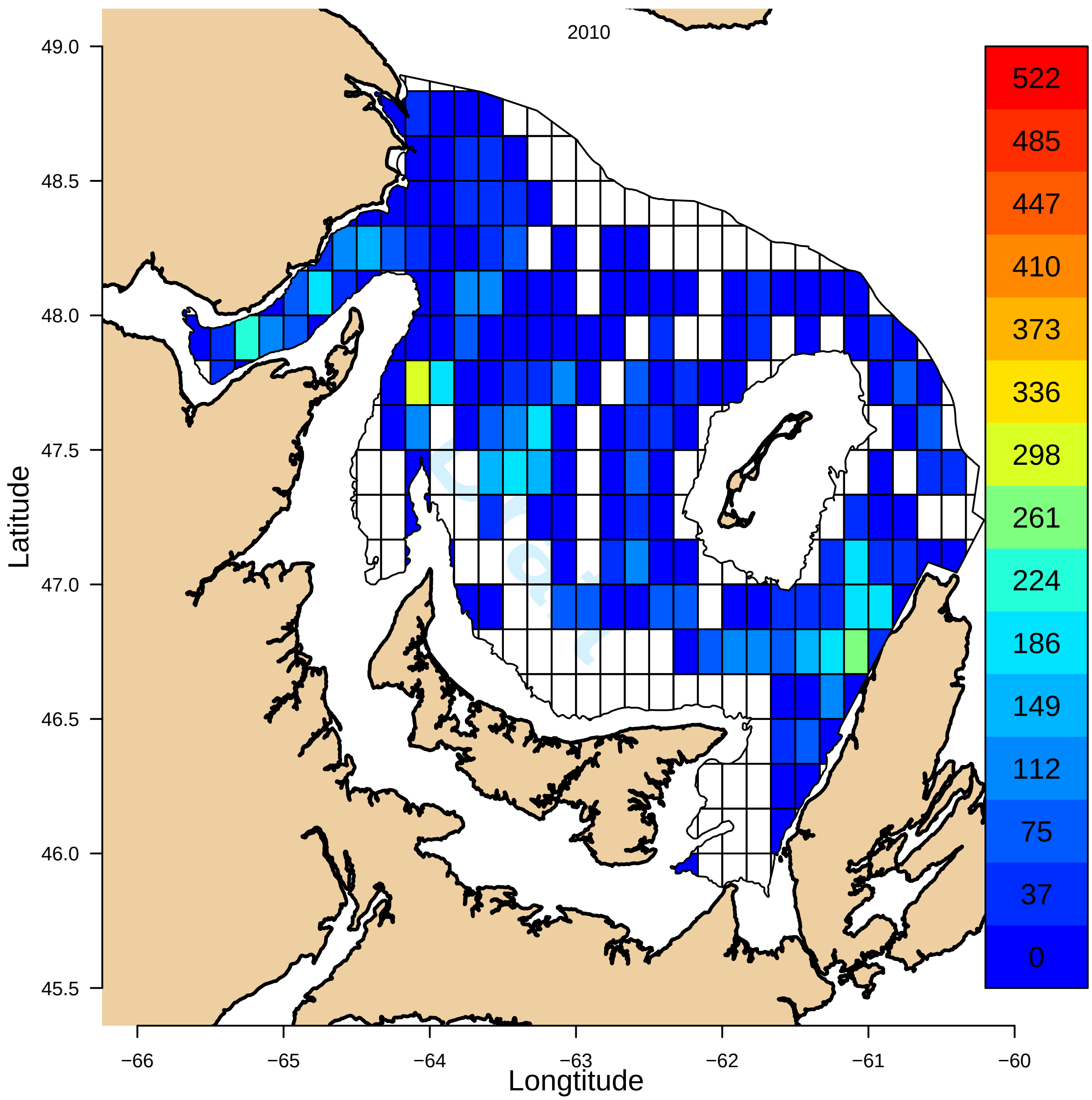


Figure SC.16a. Total annual catch (tonnes) of snow crab in each grid cell in 2010. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

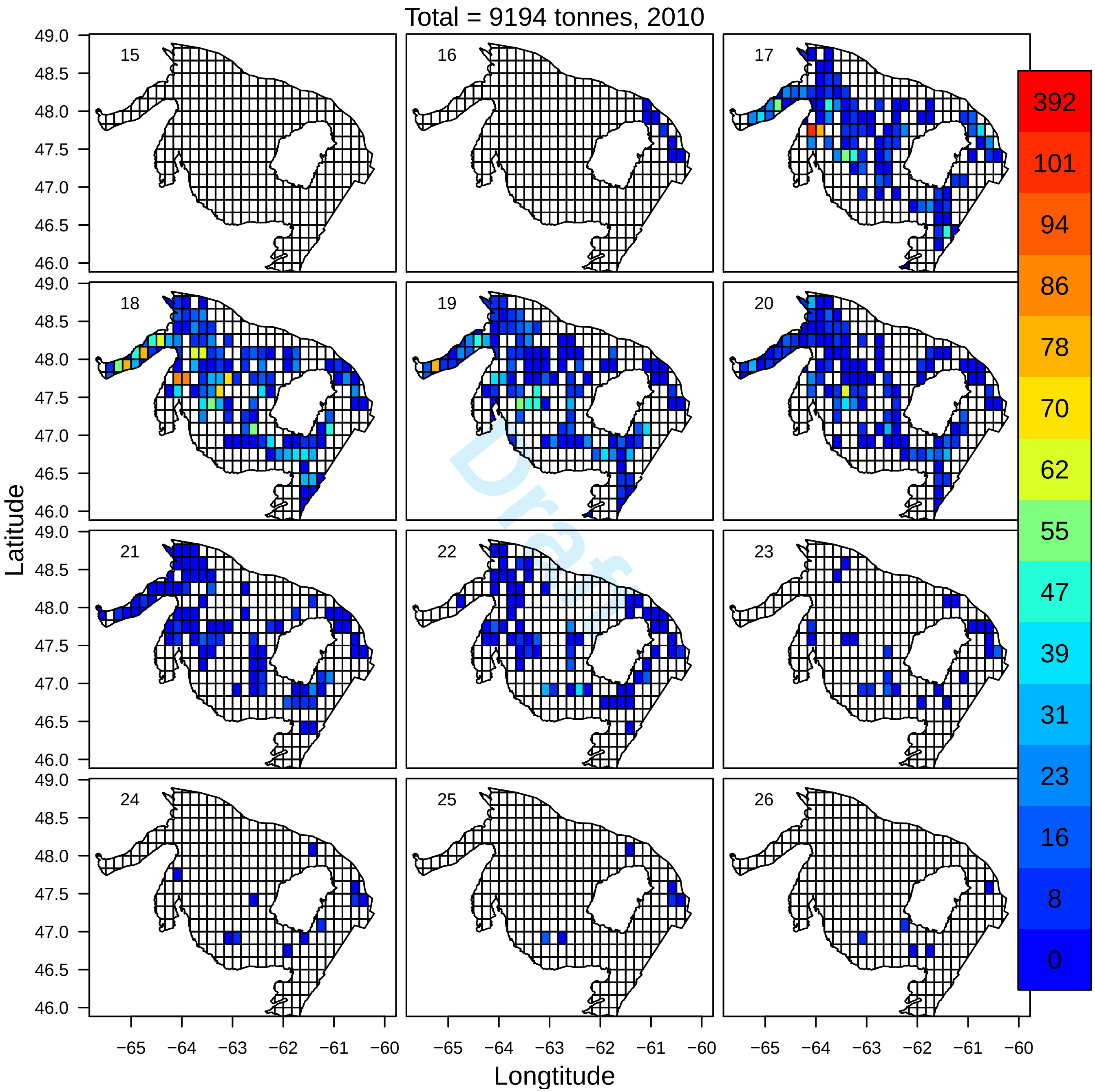


Figure SC.16b. Catch (tonnes) of snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

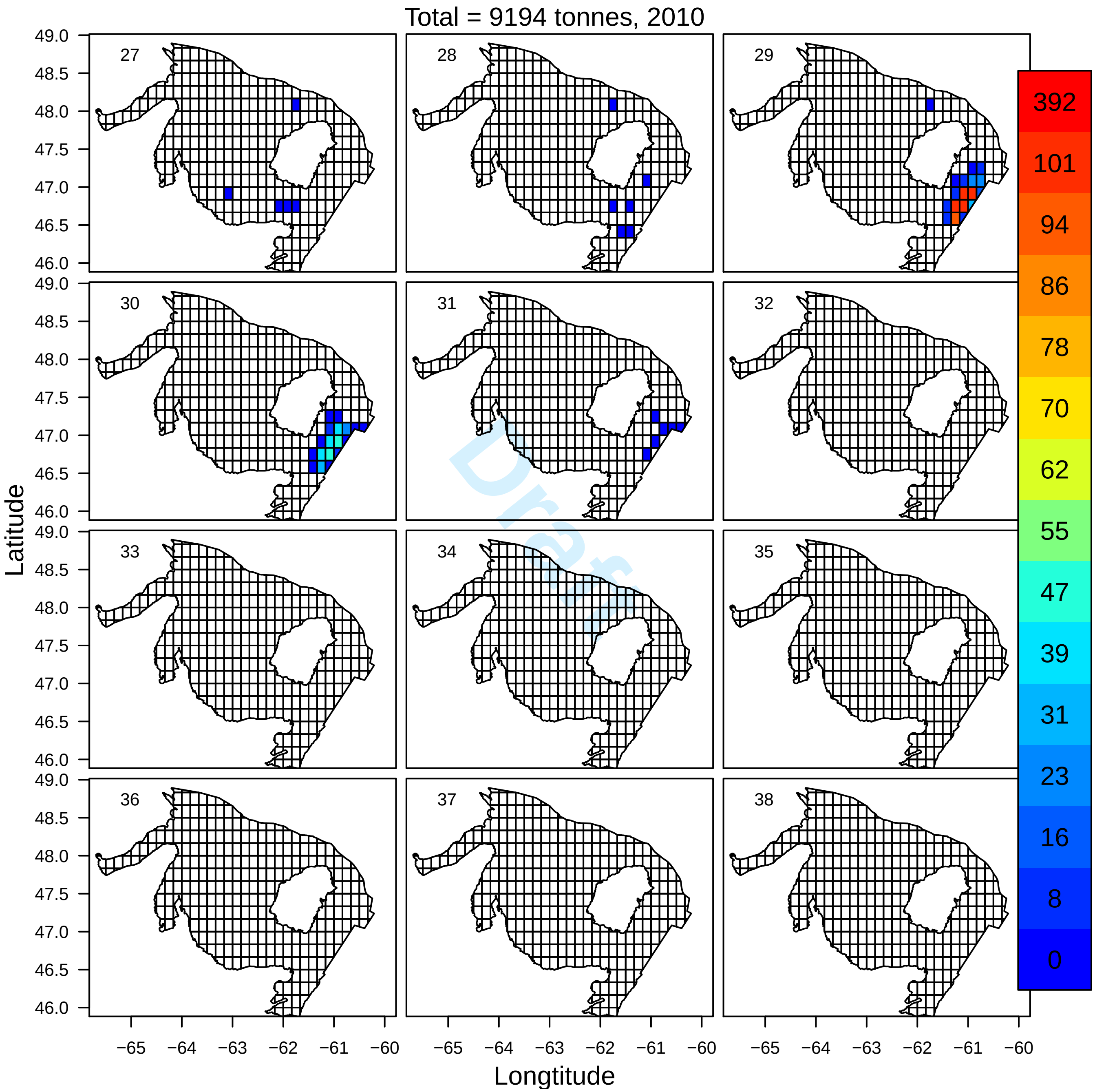


Figure SC.16c. Catch (tonnes) of snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

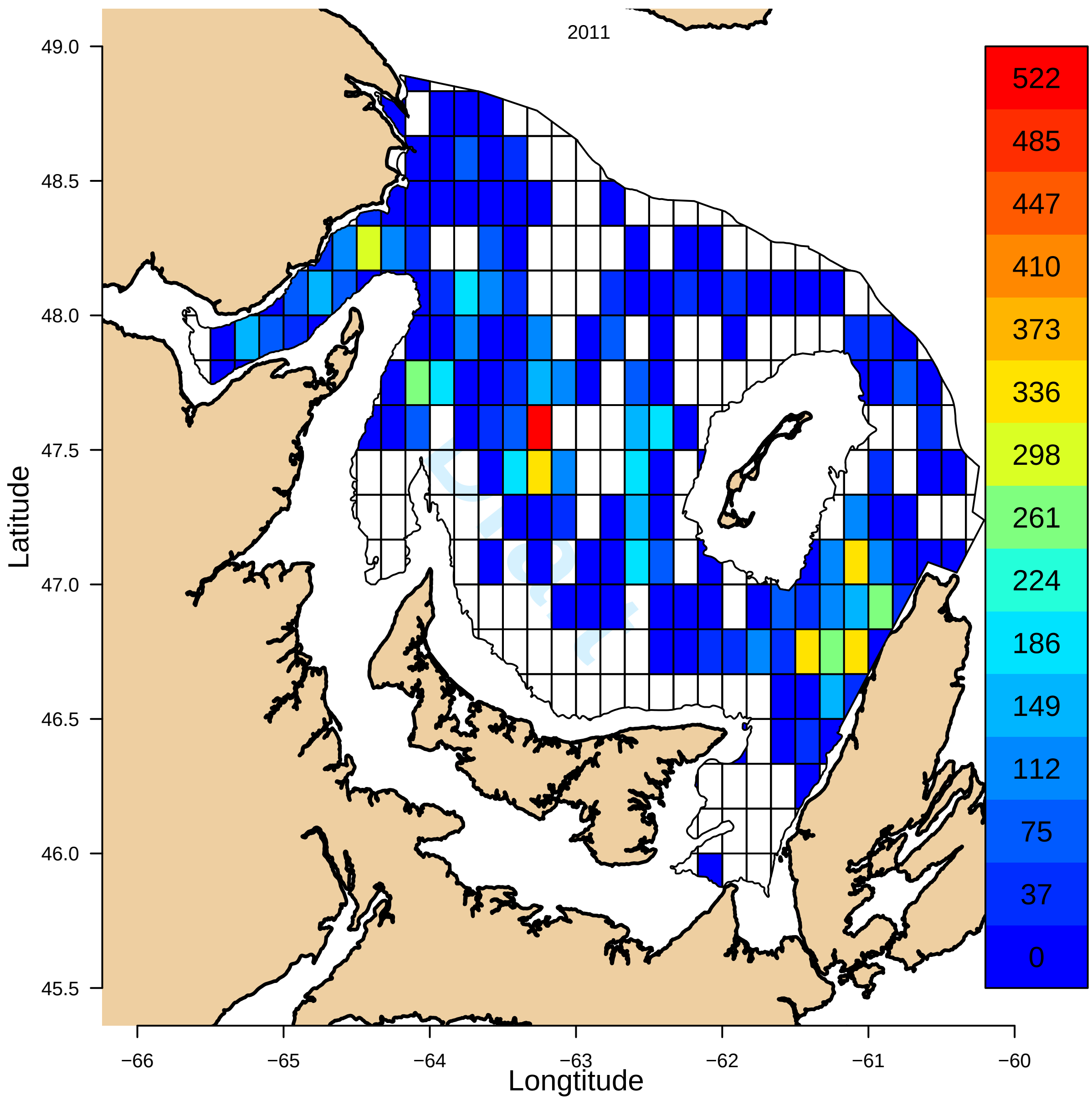


Figure SC.17a. Total annual catch (tonnes) of snow crab in each grid cell in 2011. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

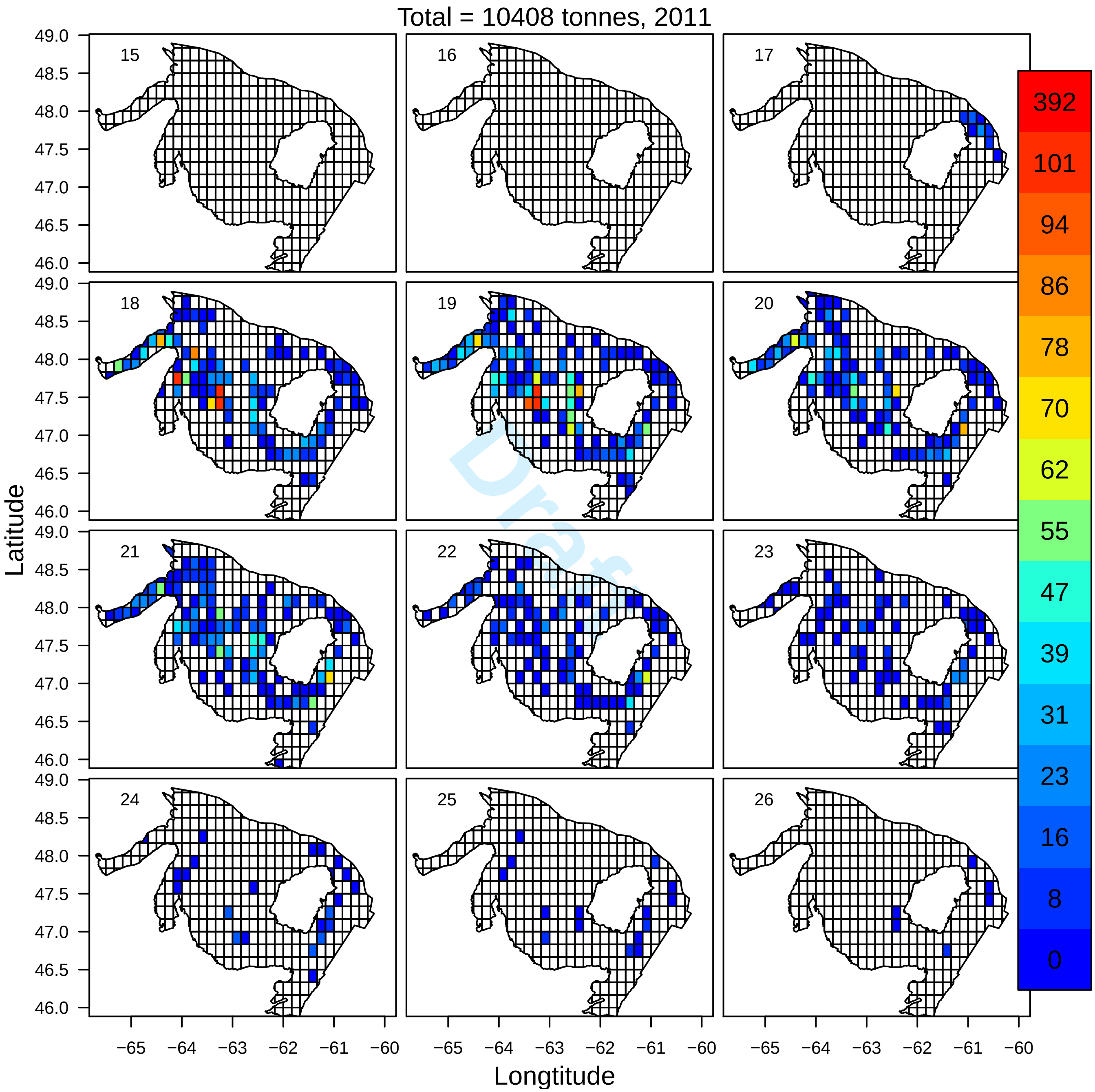


Figure SC.17b. Catch (tonnes) of snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

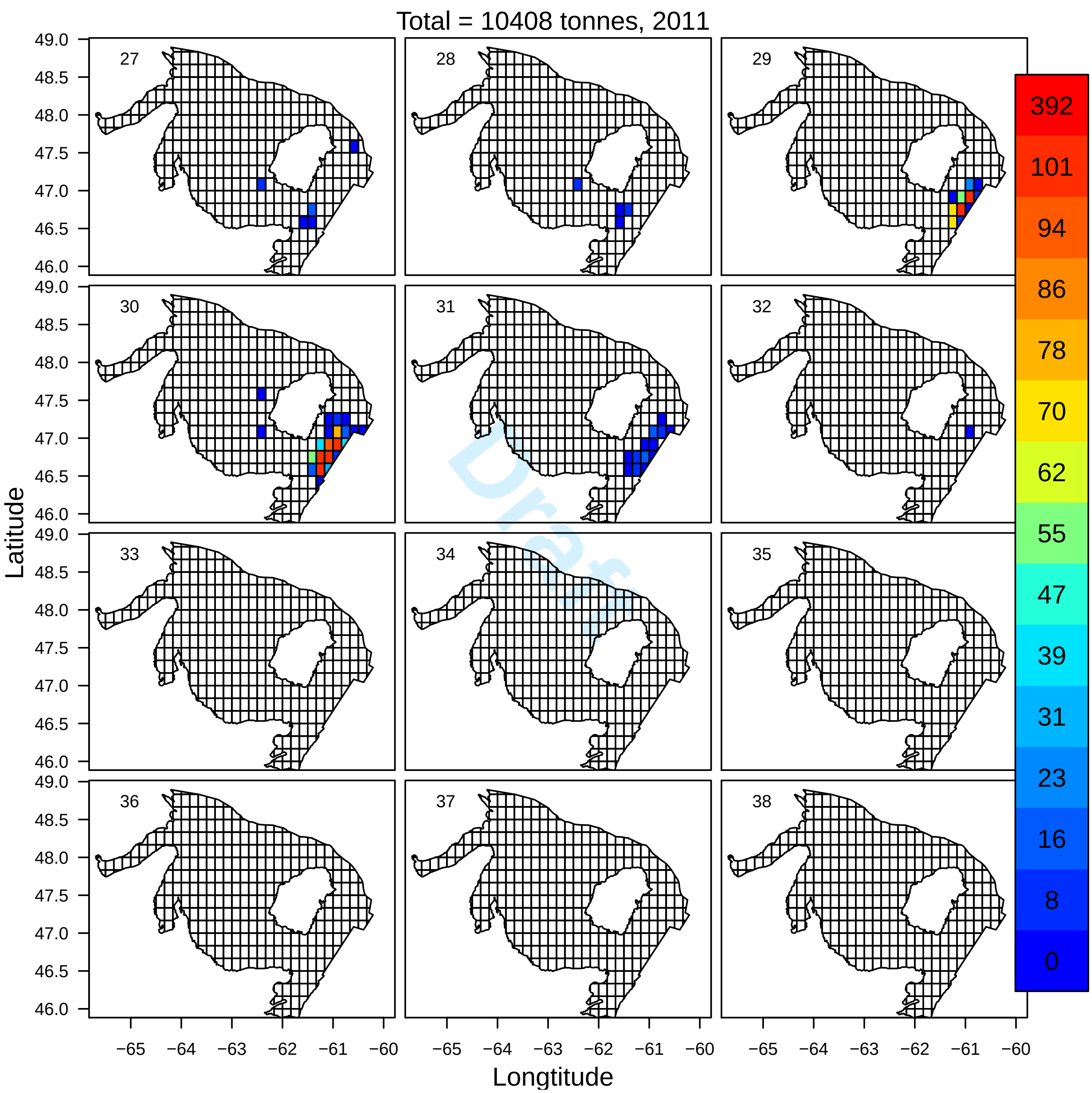


Figure SC.17c. Catch (tonnes) of snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

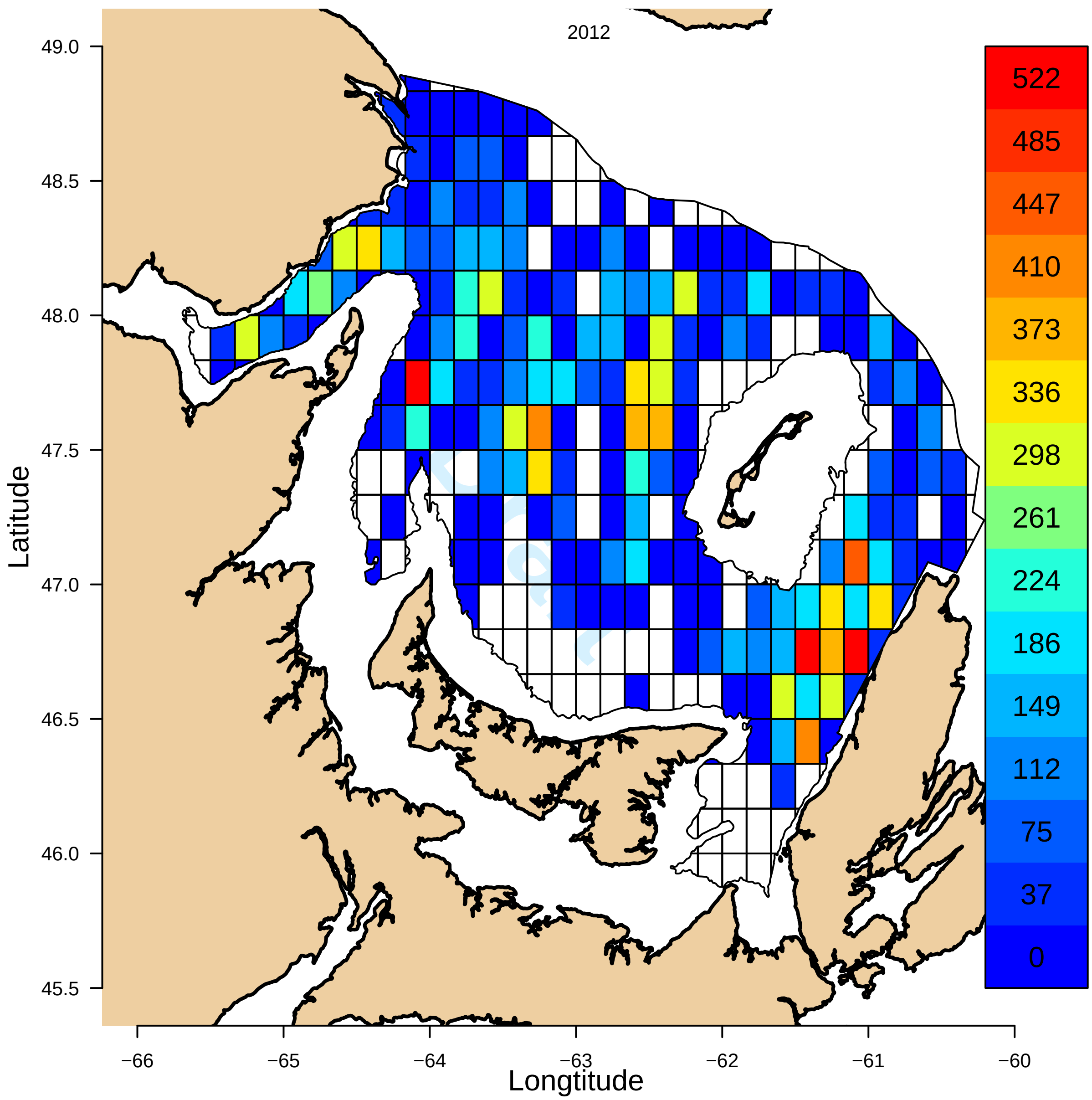


Figure SC.18a. Total annual catch (tonnes) of snow crab in each grid cell in 2012. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

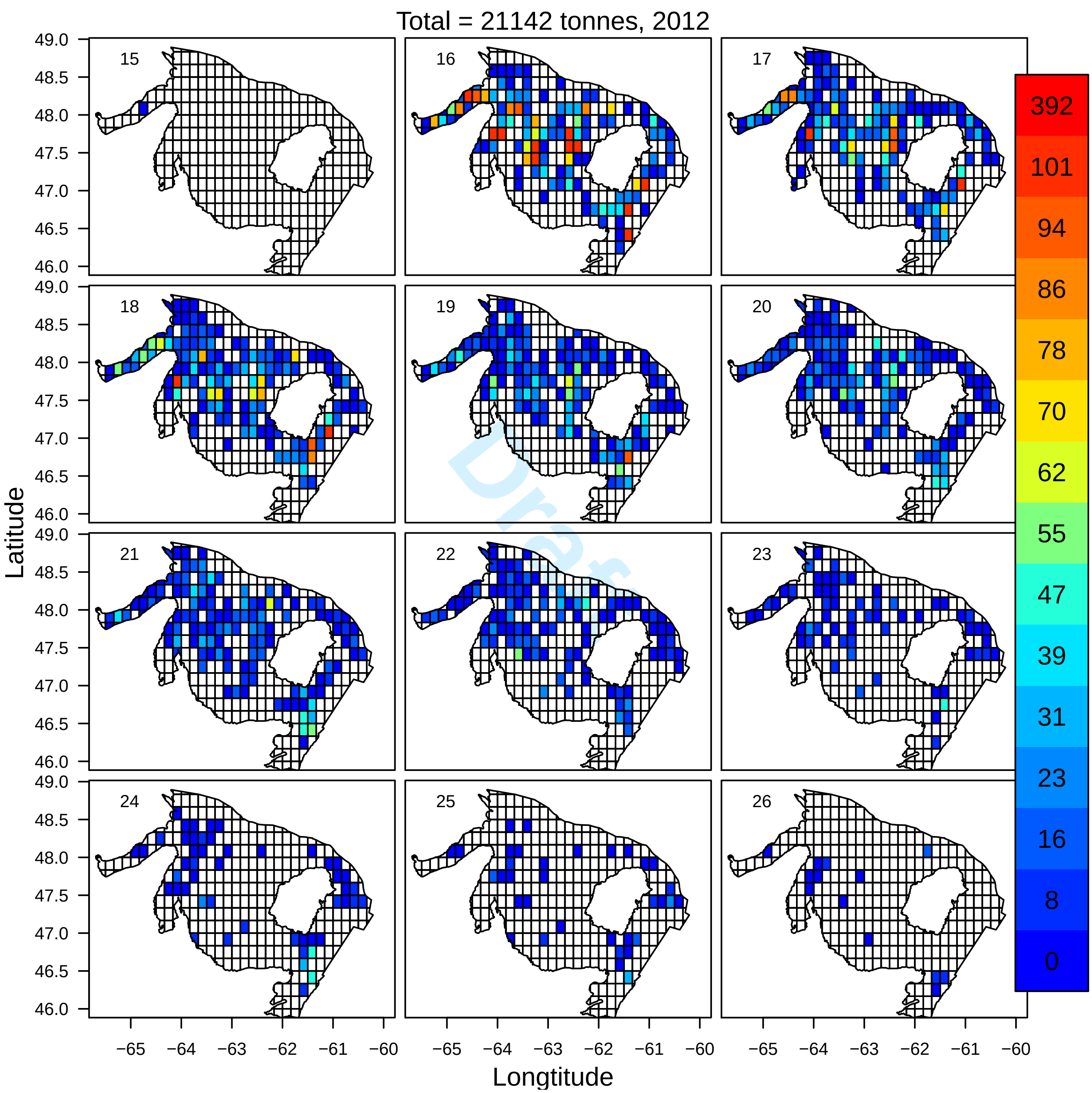


Figure SC.18b. Catch (tonnes) of snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

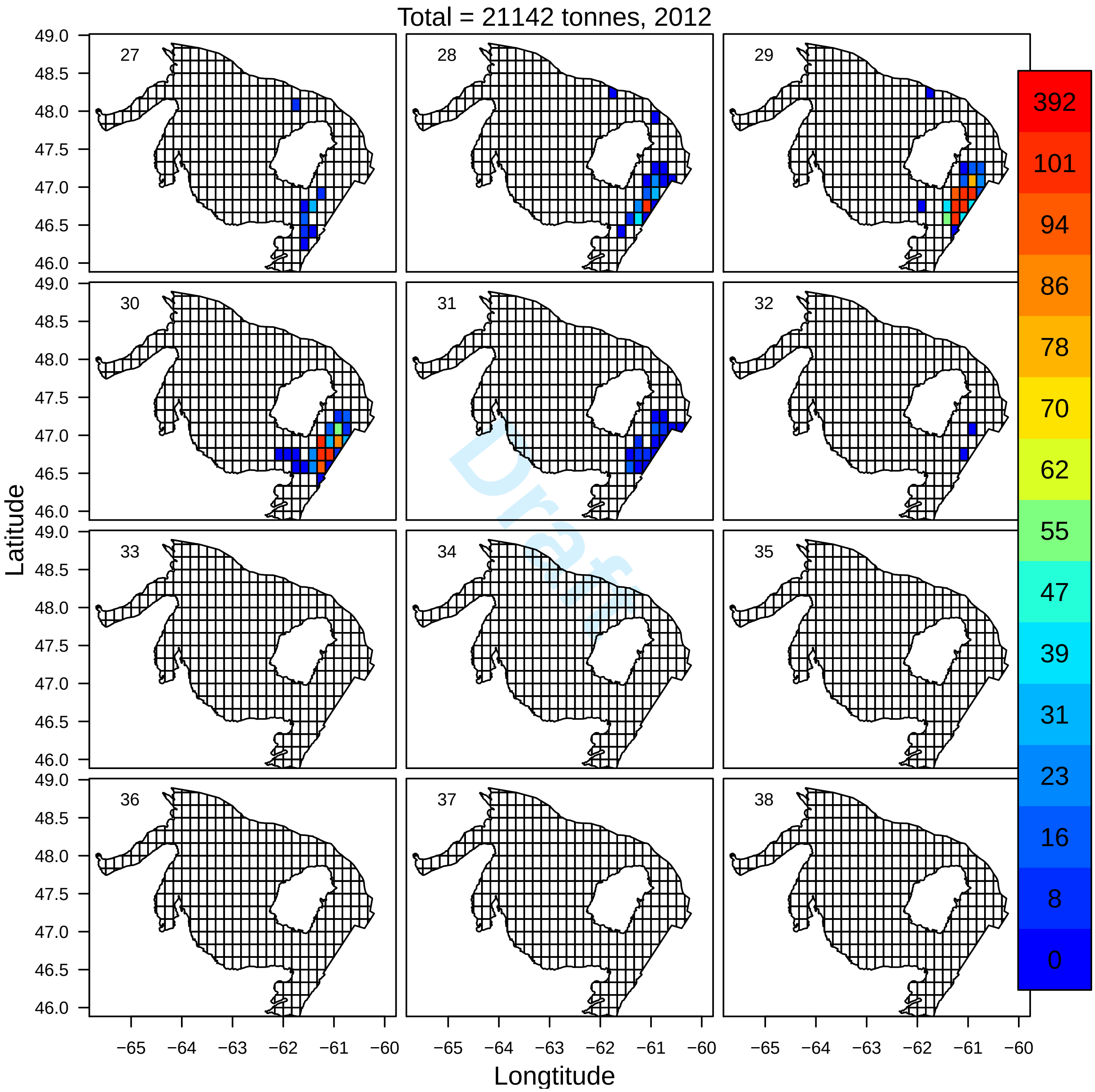


Figure SC.18c. Catch (tonnes) of snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

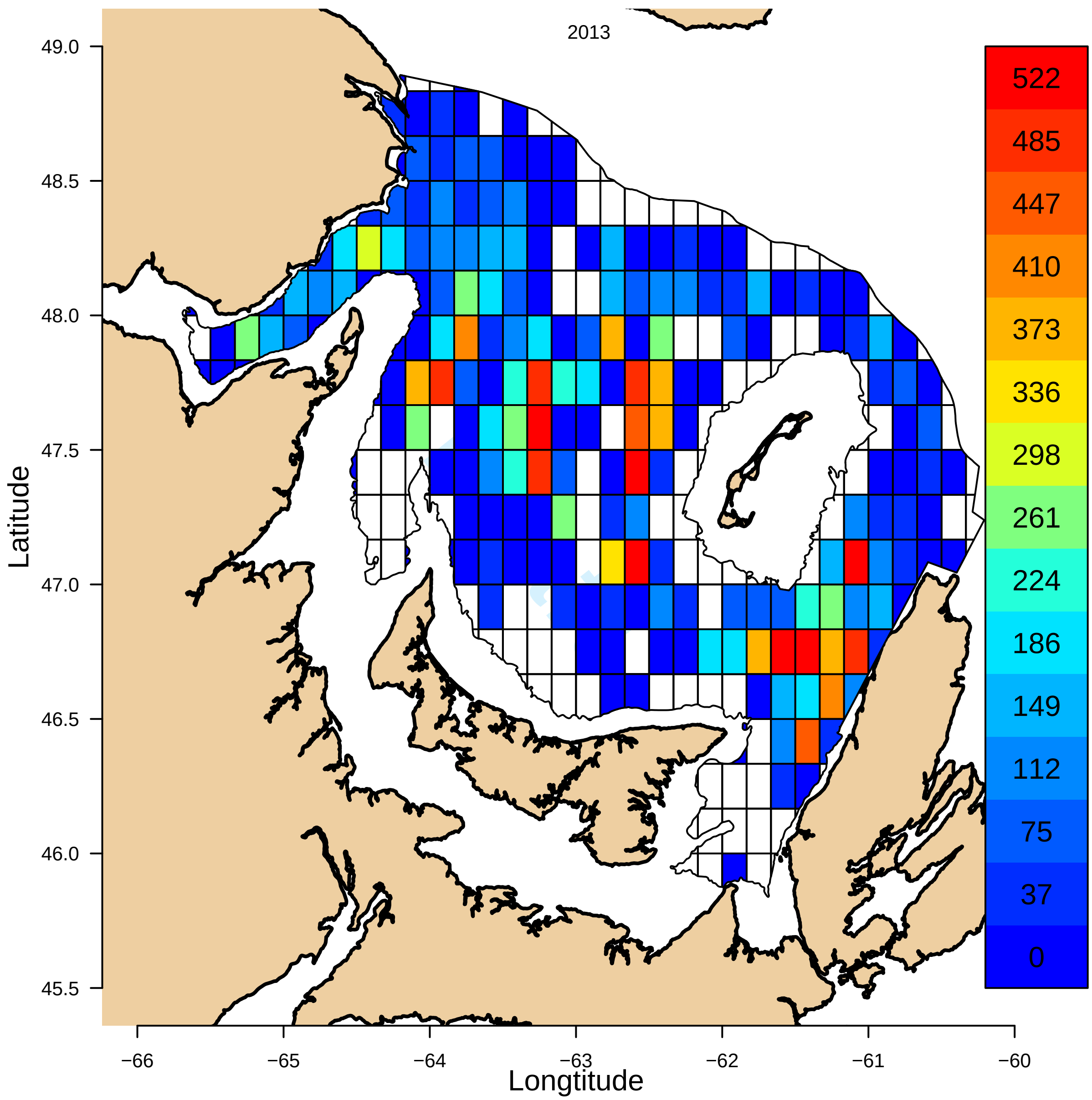


Figure SC.19a. Total annual catch (tonnes) of snow crab in each grid cell in 2013. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

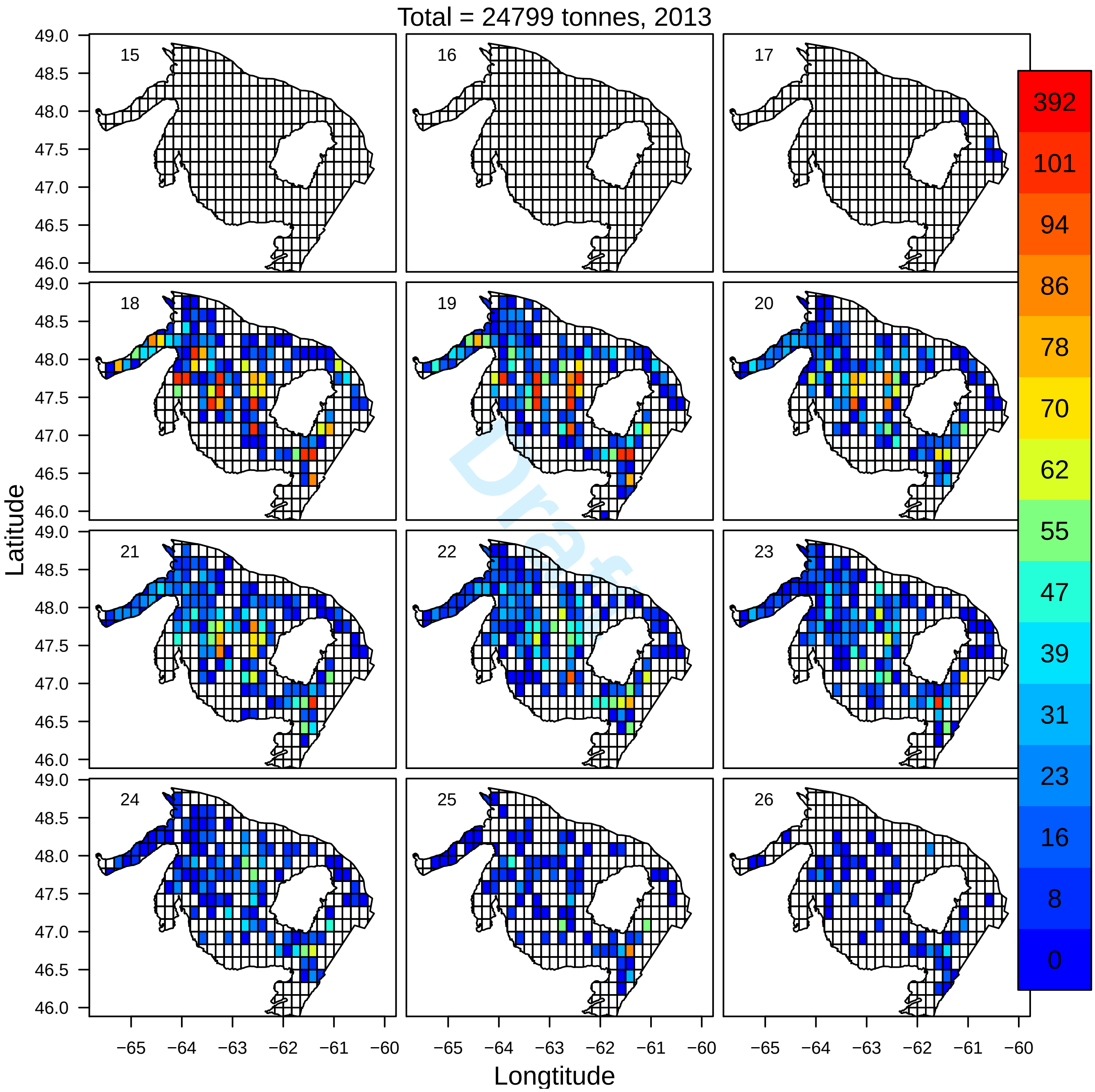


Figure SC.19b. Catch (tonnes) of snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

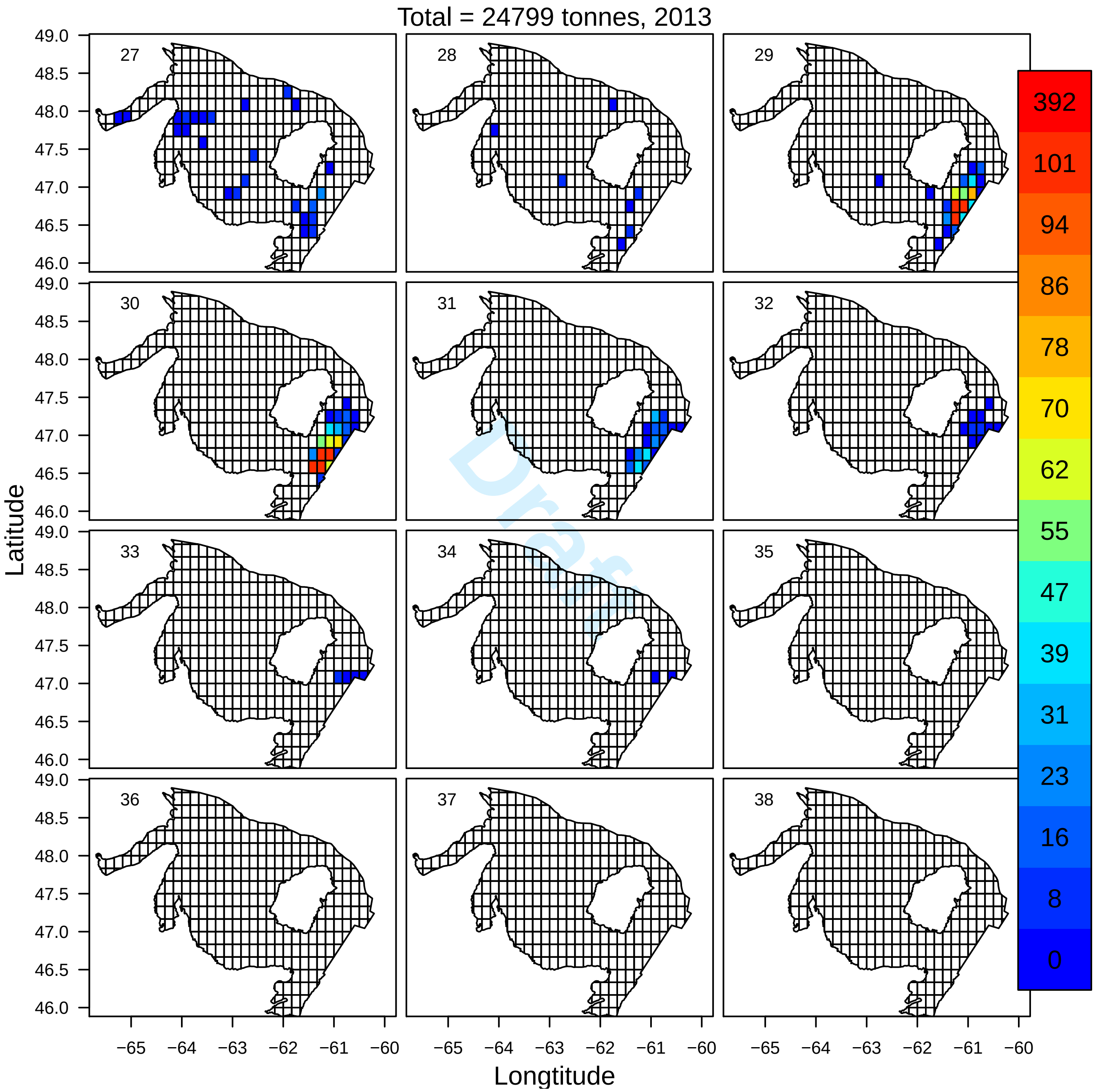


Figure SC.19c. Catch (tonnes) of snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

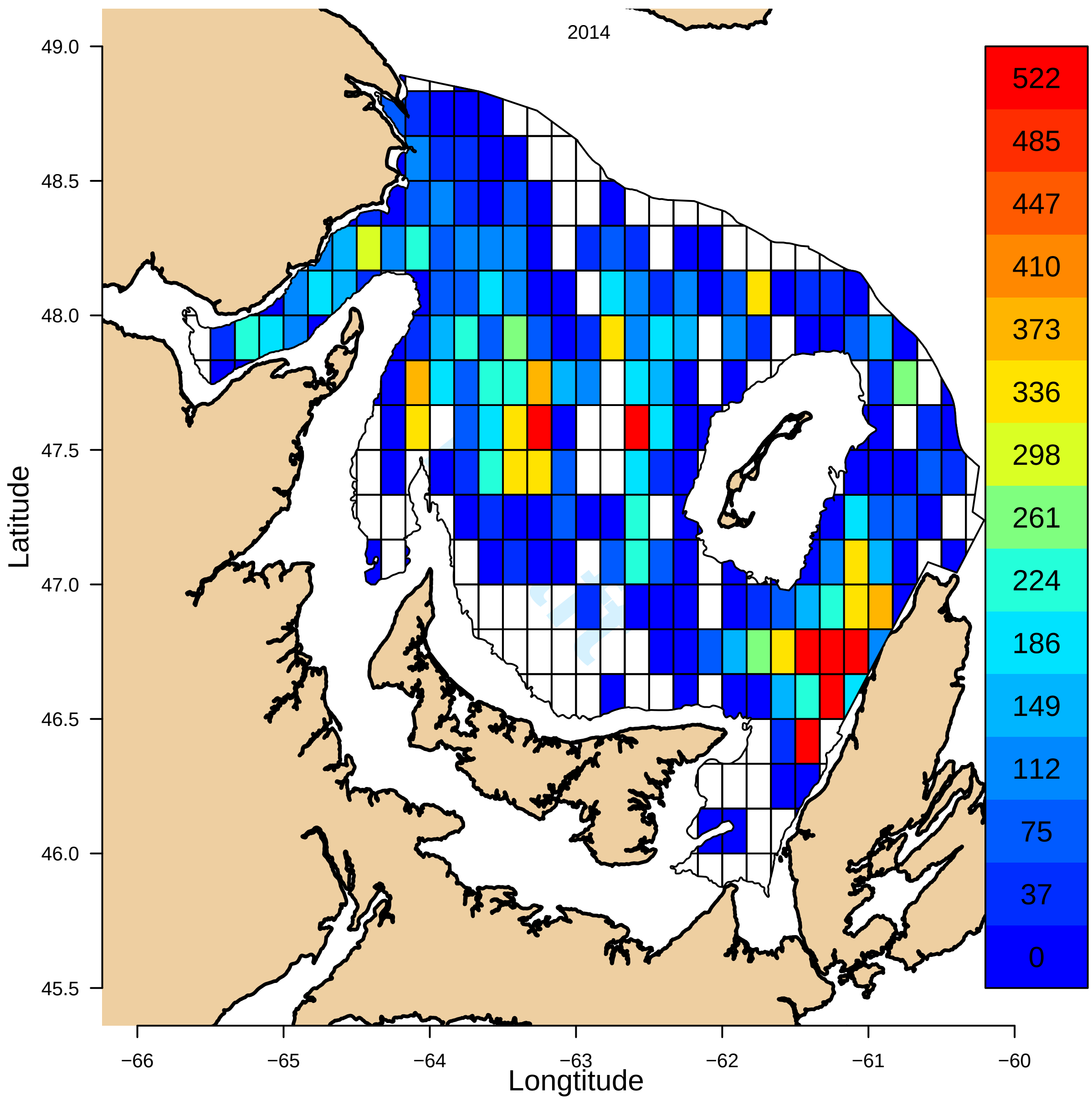


Figure SC.20a. Total annual catch (tonnes) of snow crab in each grid cell in 2014. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

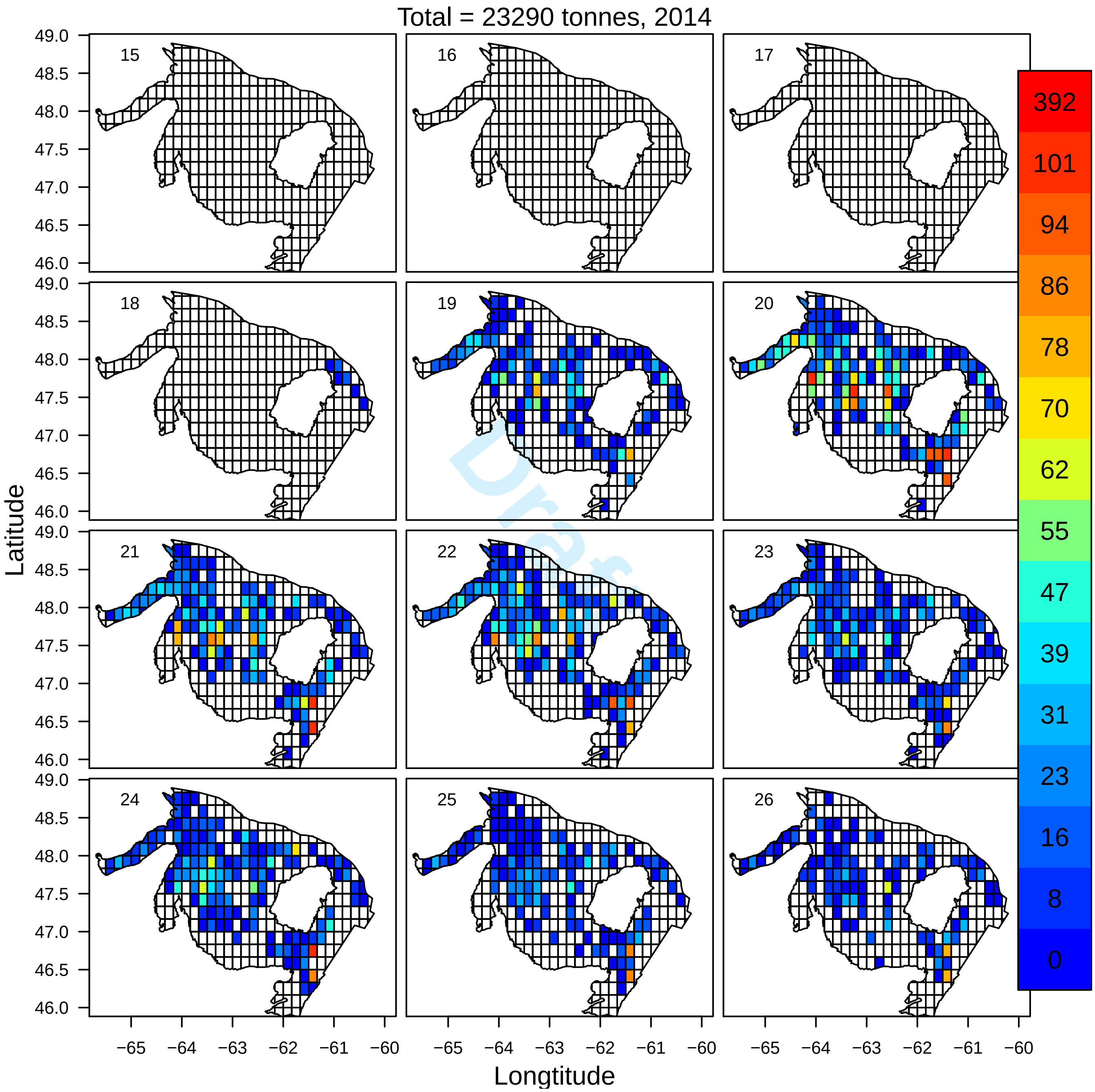


Figure SC.20b. Catch (tonnes) of snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

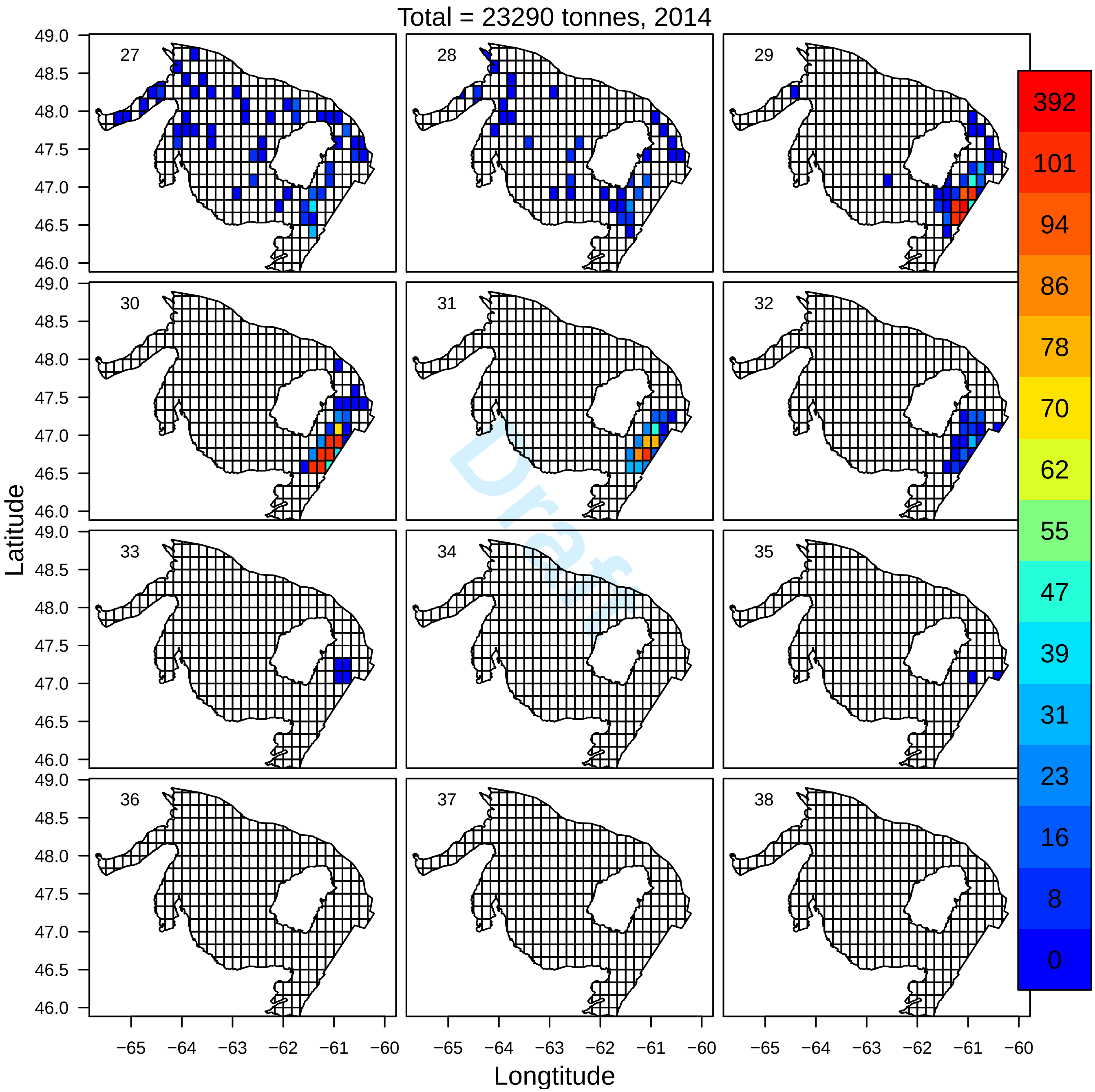


Figure SC.20c. Catch (tonnes) of snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to catch levels, as indicated in the legend on the right-hand side. Darkest red grids indicate catch > 98th percentile.

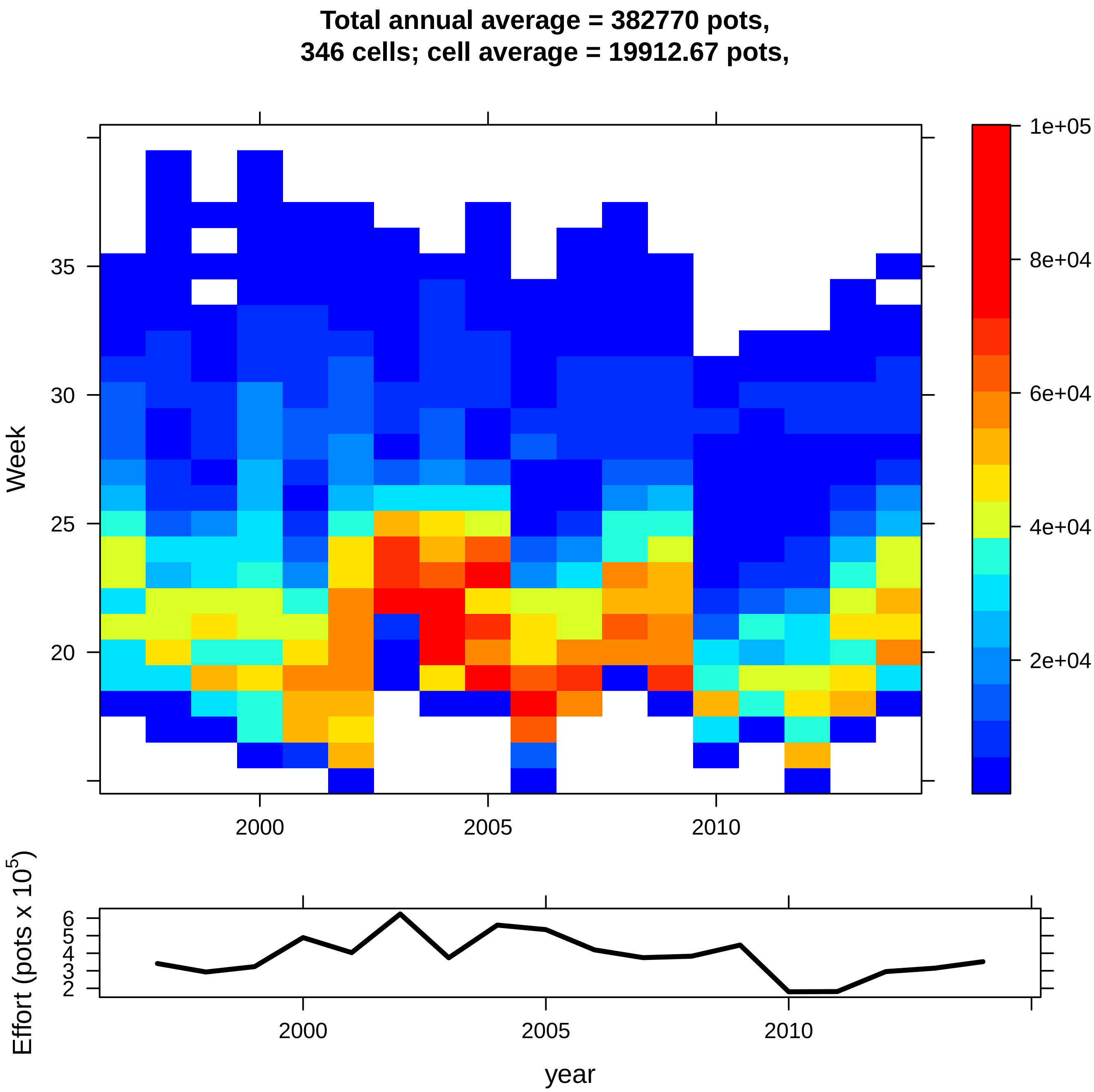


Figure SE.1. Top panel: Total effort (number of pots) of snow crab each week (rows) and year (columns). Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile. Bottom panel: Total efforteach year for all weeks.

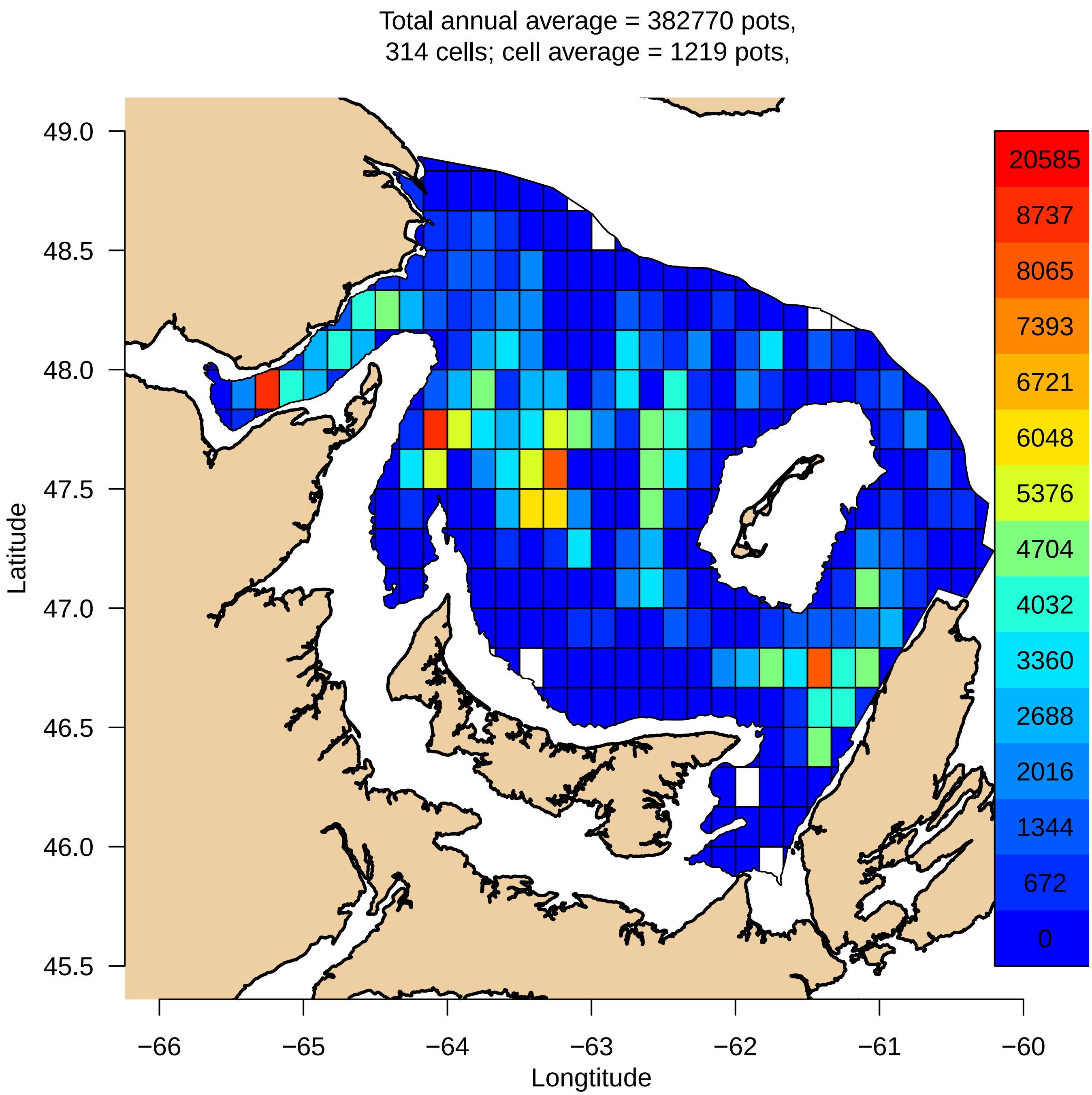


Figure SE.2. Total annual effort (number of pots) for snow crab in each grid cell, averaged for 1997-2014. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

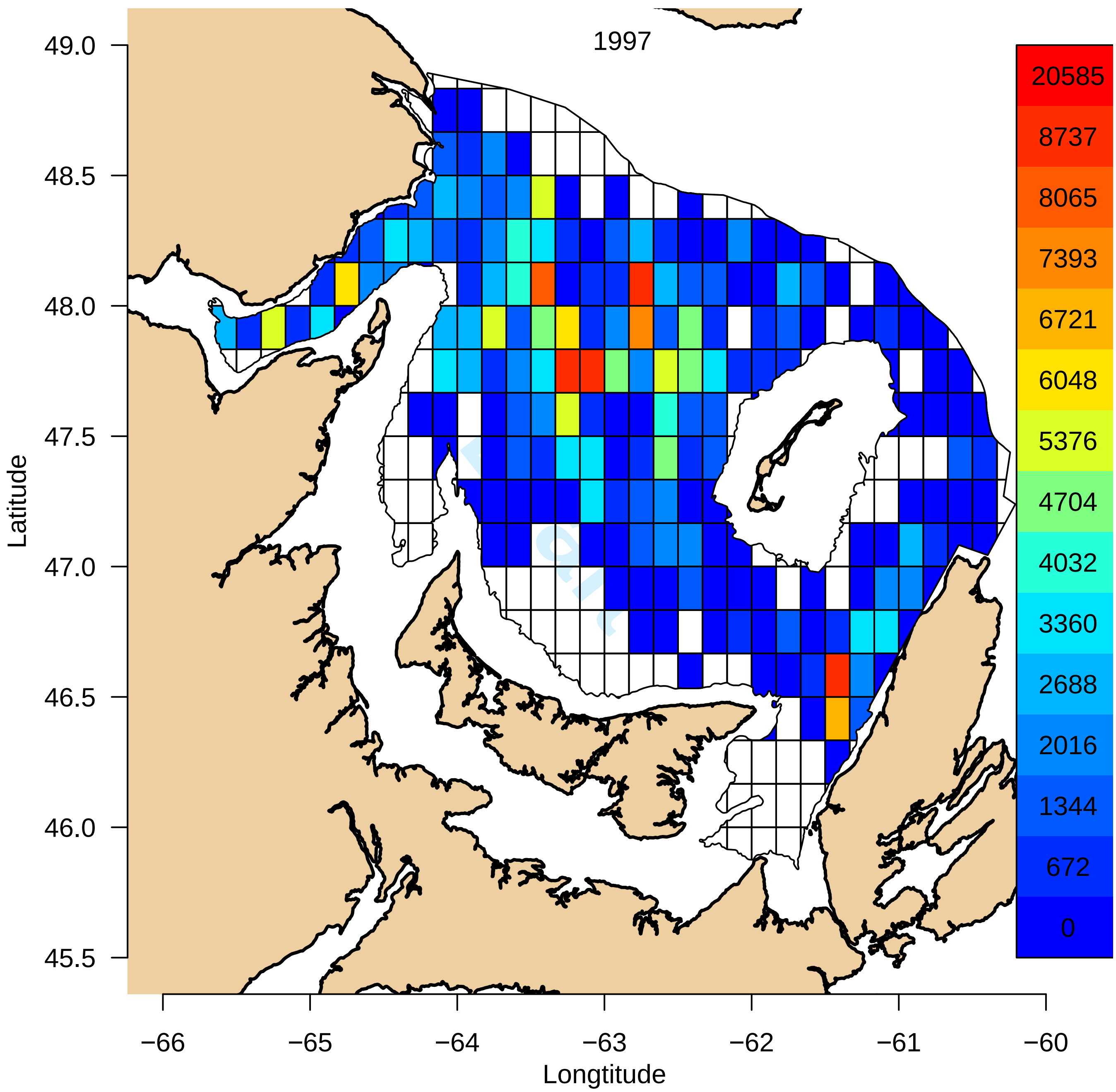


Figure SE.3a. Total annual effort (number of pots) for snow crab in each grid cell in 1997. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

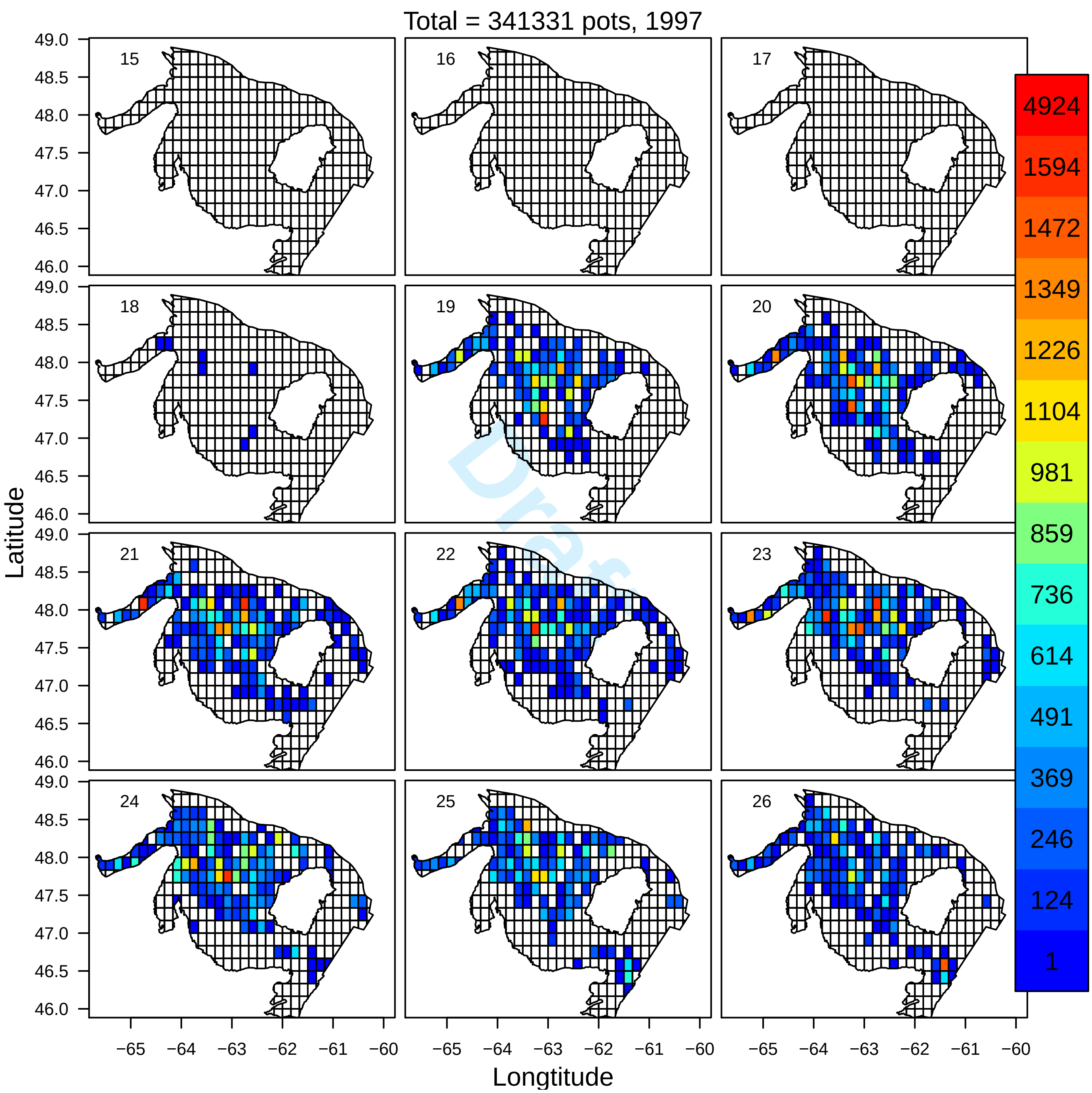


Figure SE.3b. Effort (number of pots) for snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

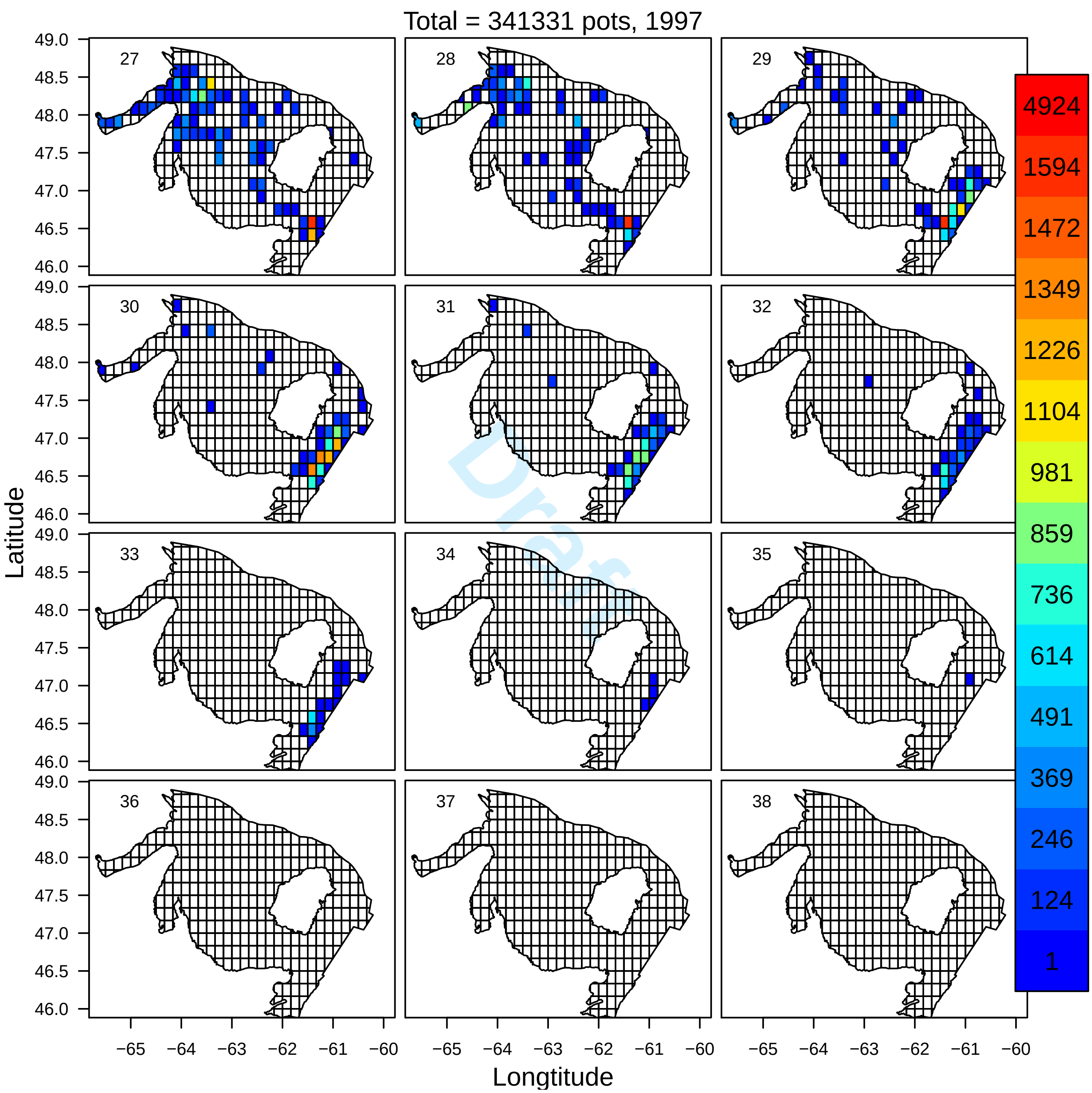


Figure SE.3c. Effort (number of pots) for snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

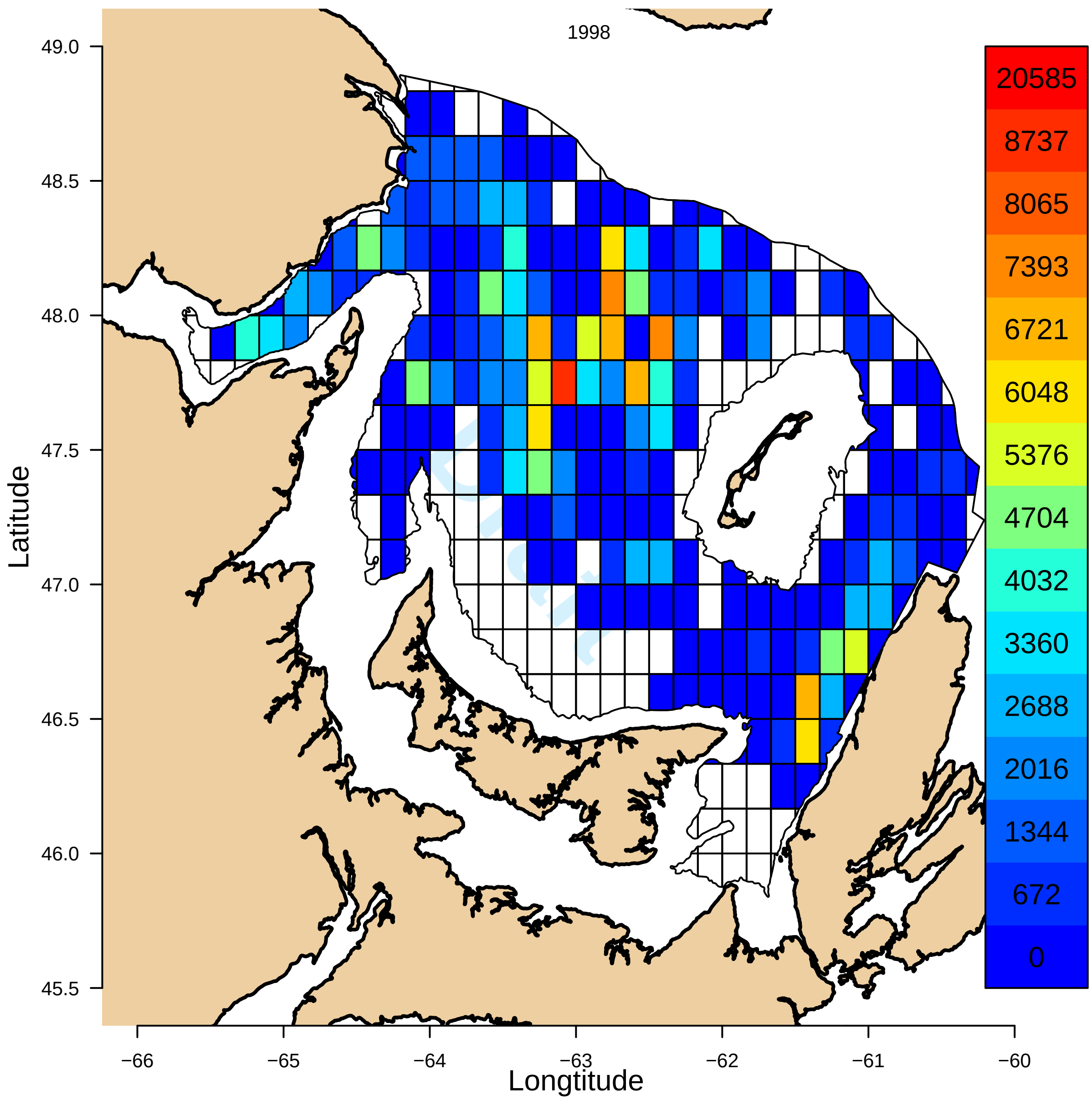


Figure SE.4a. Total annual effort (number of pots) for snow crab in each grid cell in 1998. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

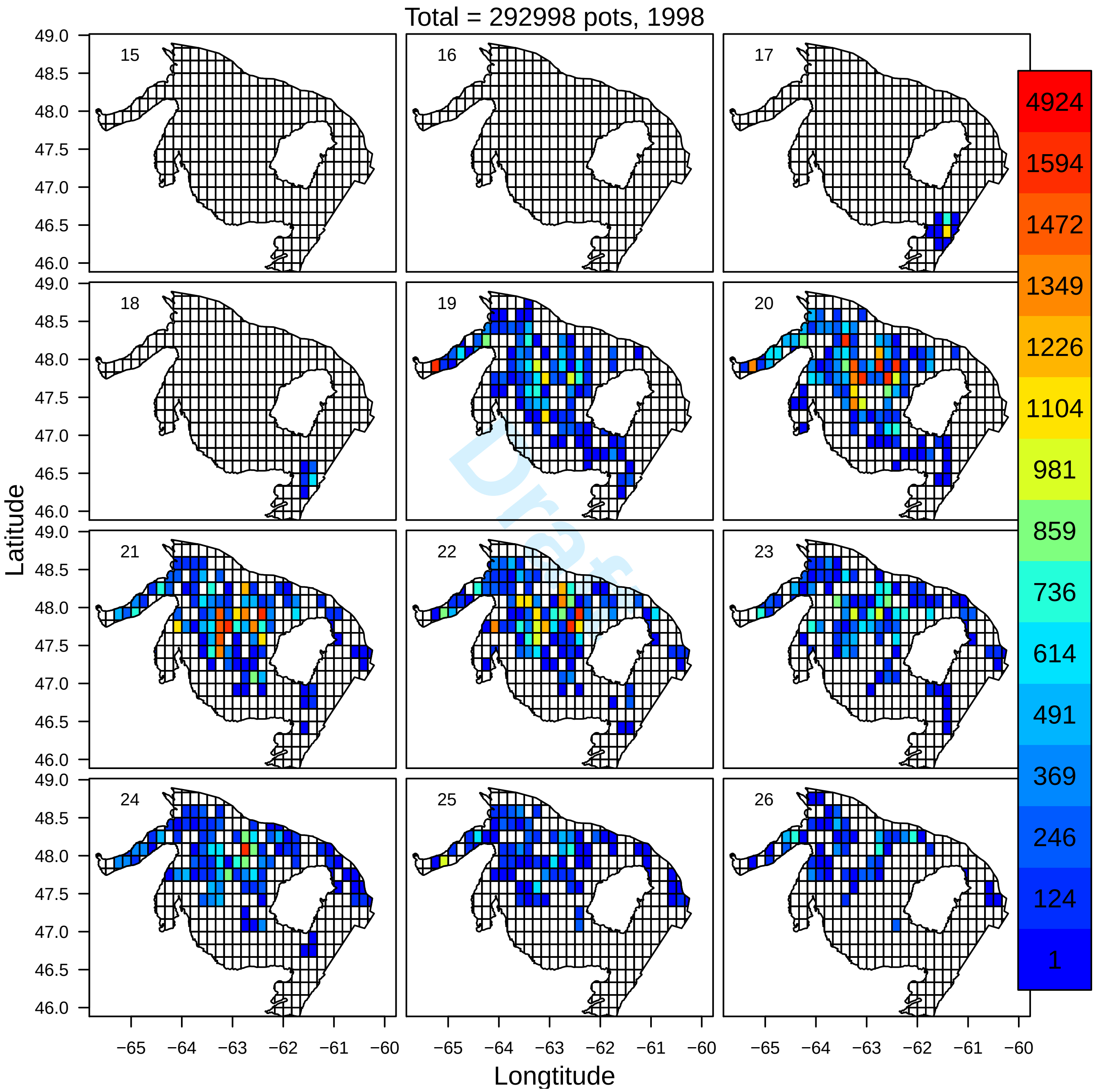


Figure SE.4b. Effort (number of pots) for snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

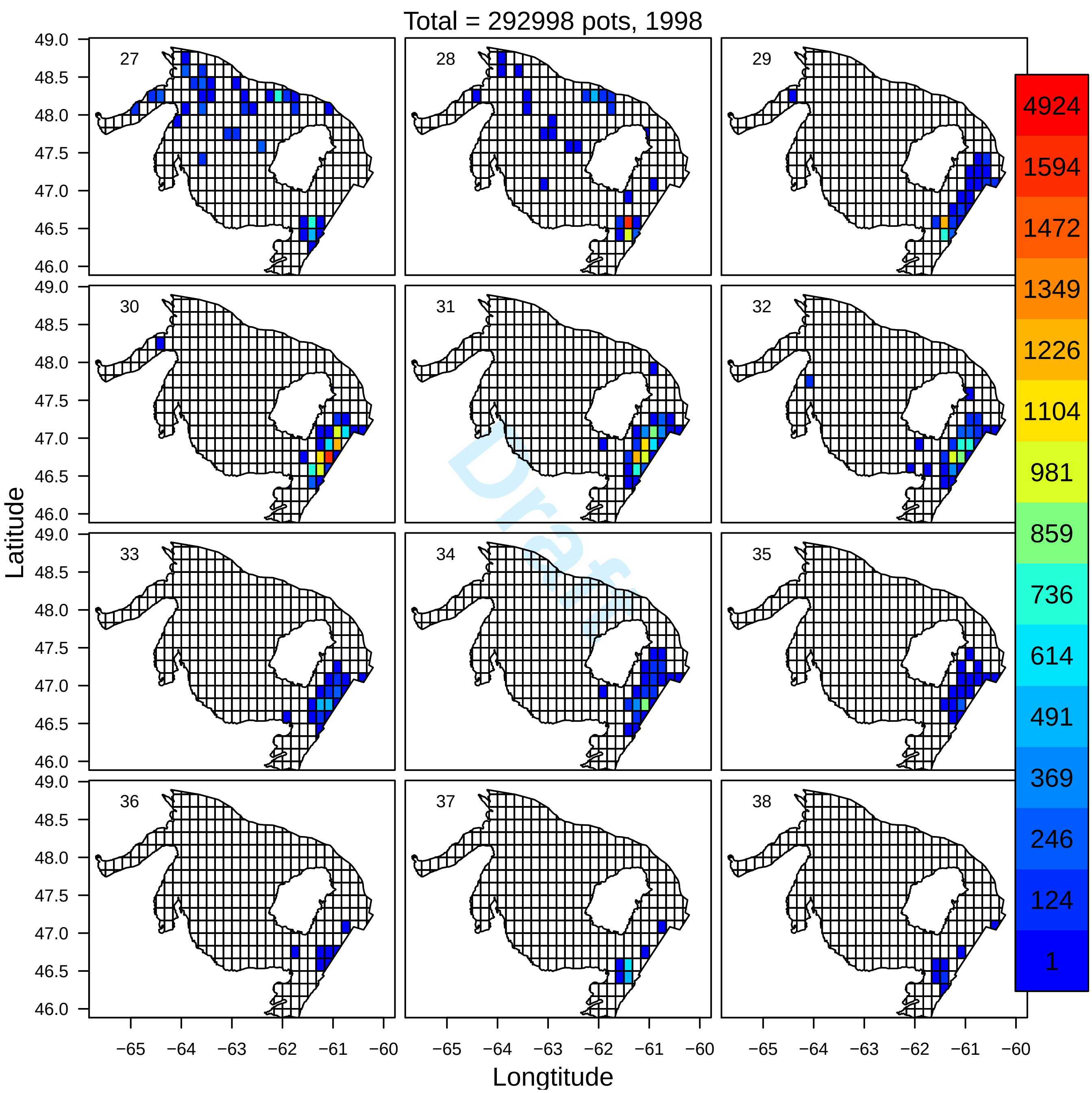


Figure SE.4c. Effort (number of pots) for snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

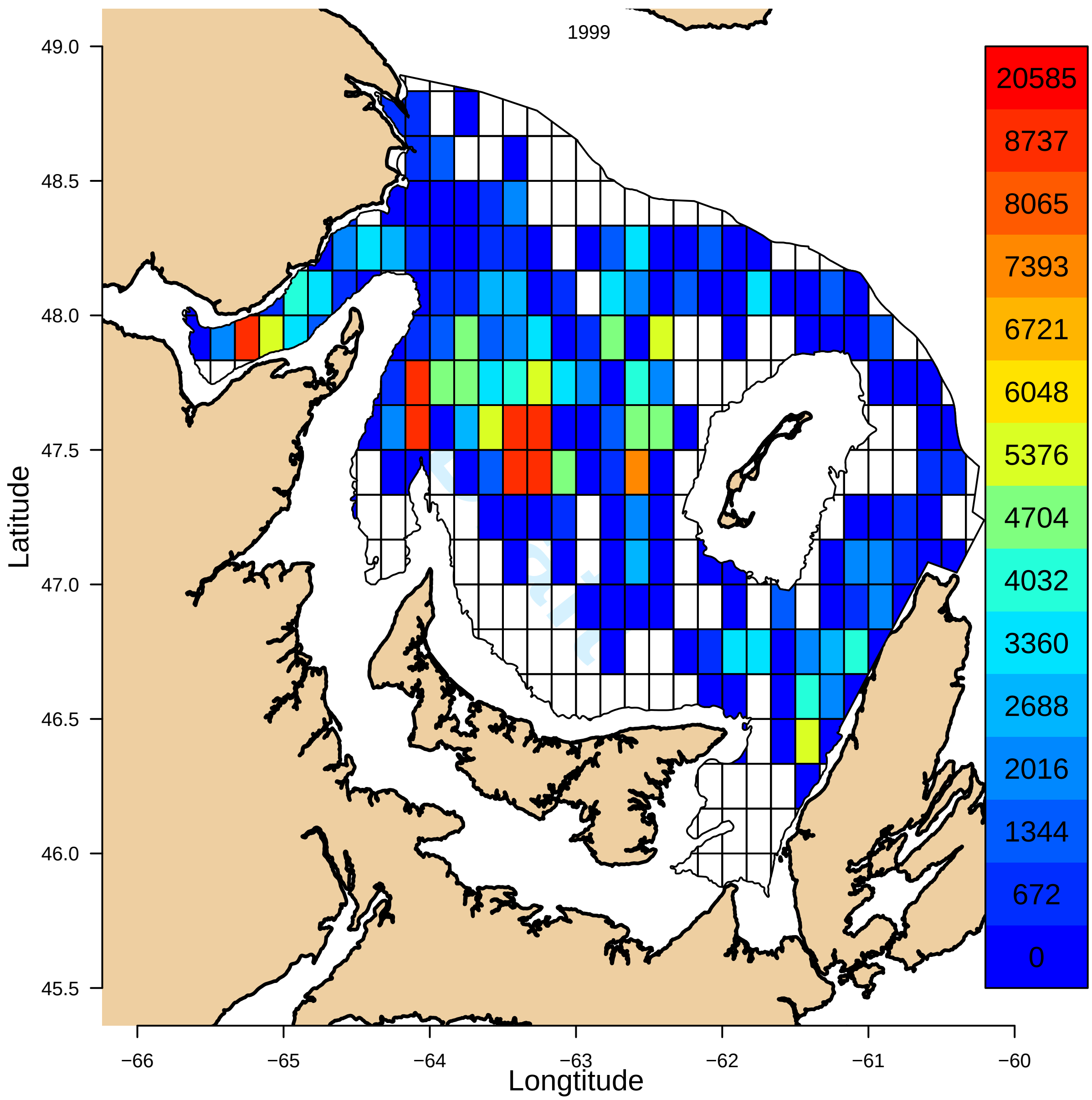


Figure SE.5a. Total annual effort (number of pots) for snow crab in each grid cell in 1999. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

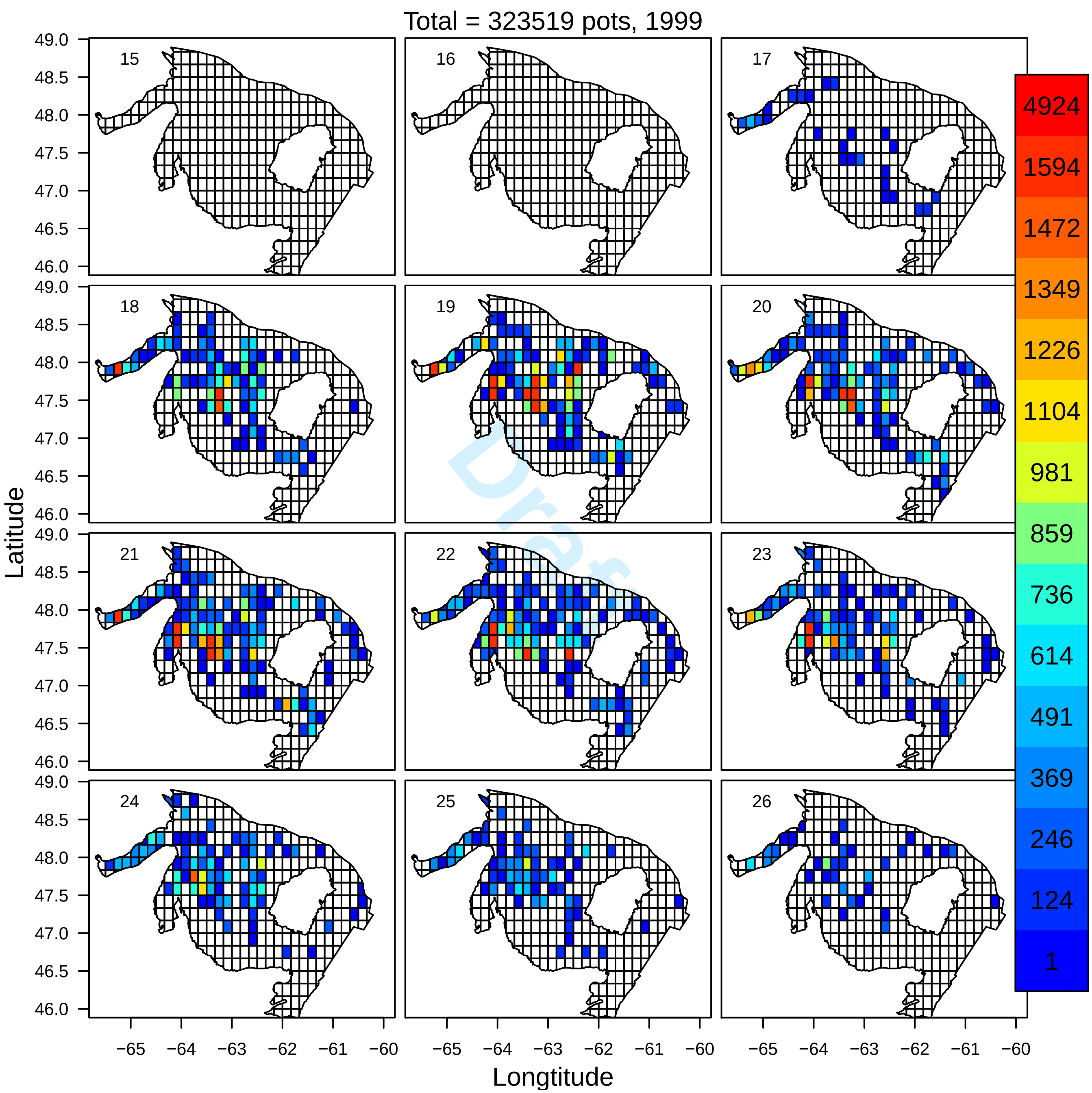


Figure SE.5b. Effort (number of pots) for snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

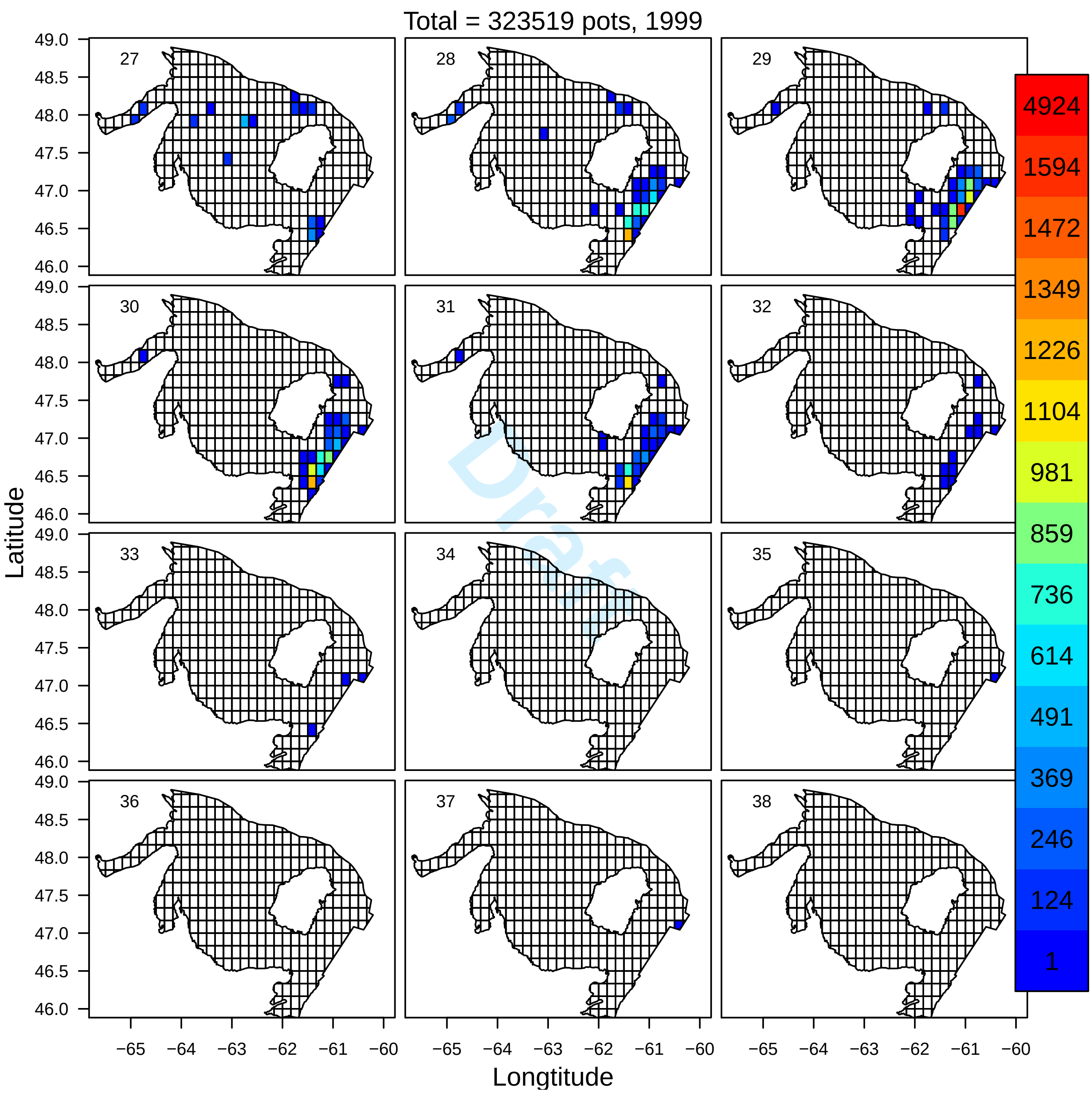


Figure SE.5c. Effort (number of pots) for snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

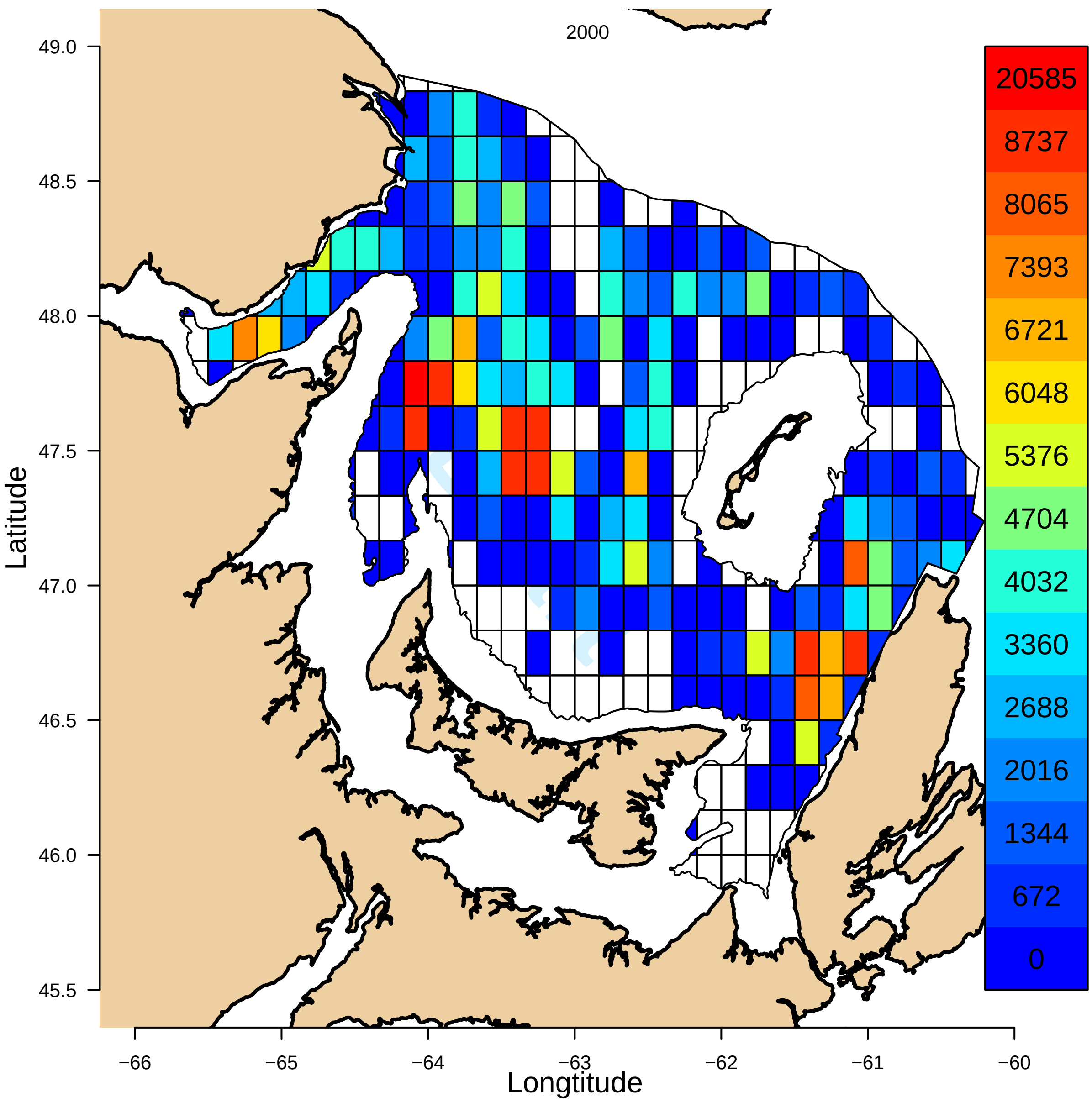


Figure SE.6a. Total annual effort (number of pots) for snow crab in each grid cell in 2000. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

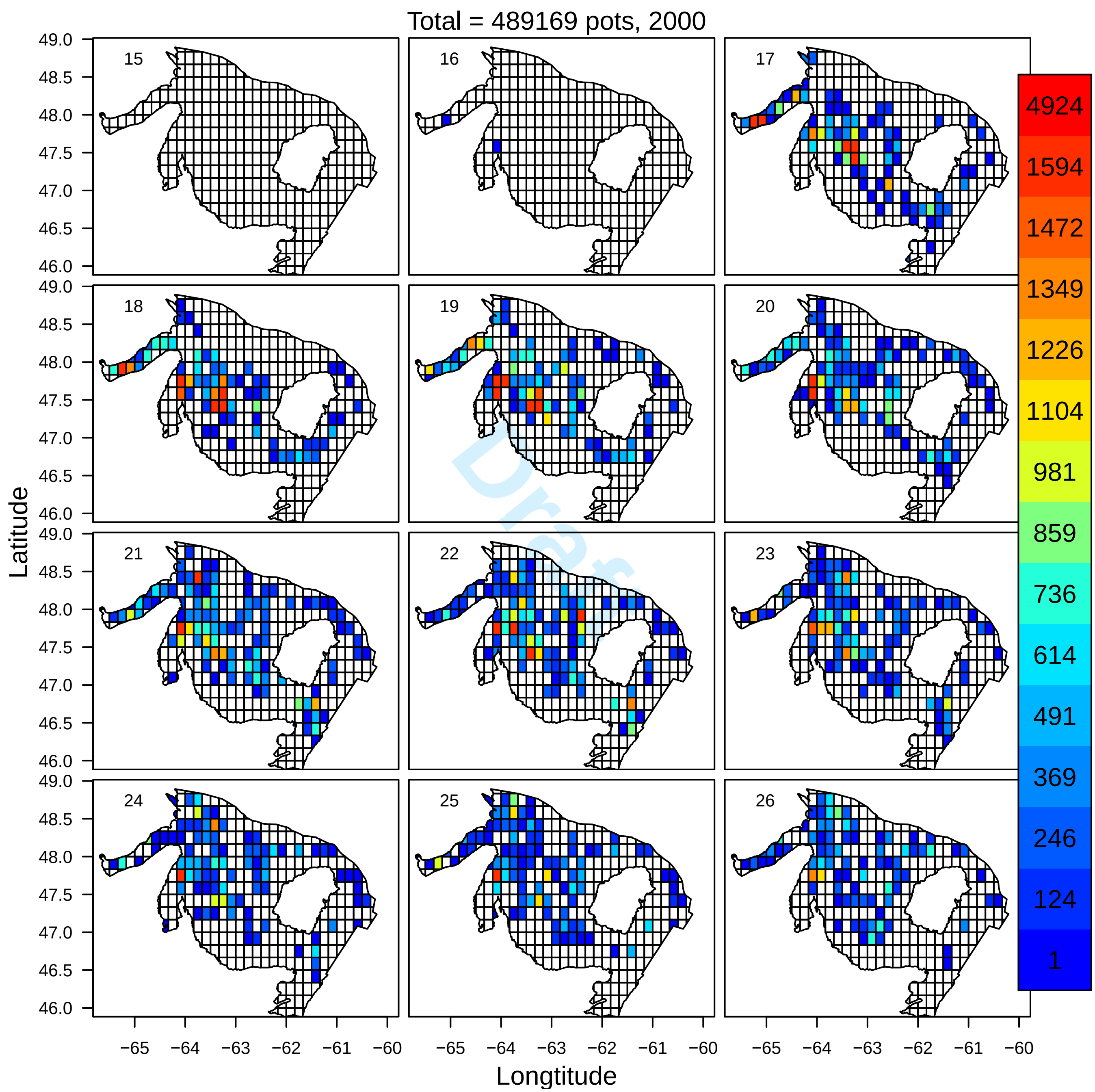


Figure SE.6b. Effort (number of pots) for snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

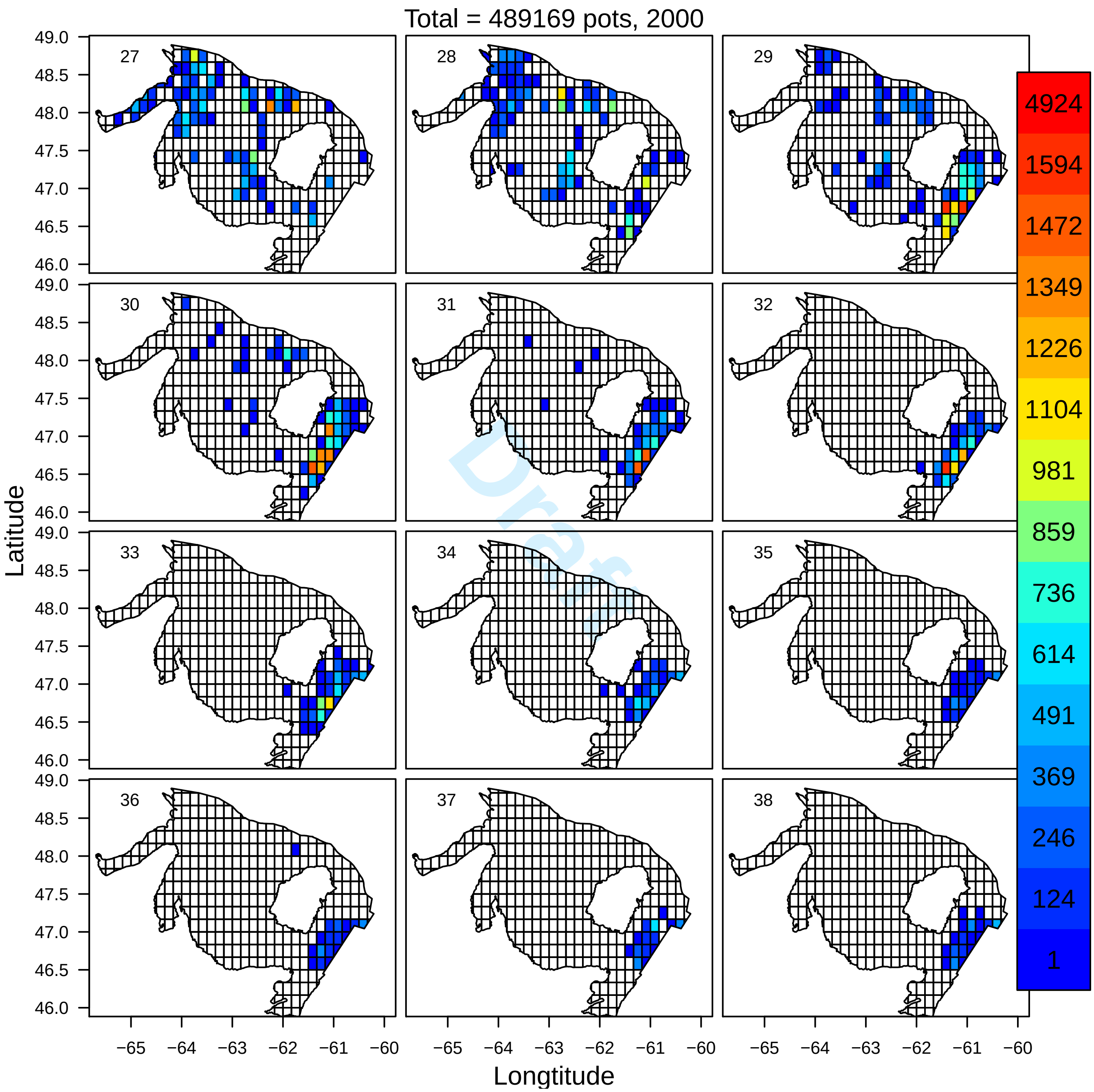


Figure SE.6c. Effort (number of pots) for snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

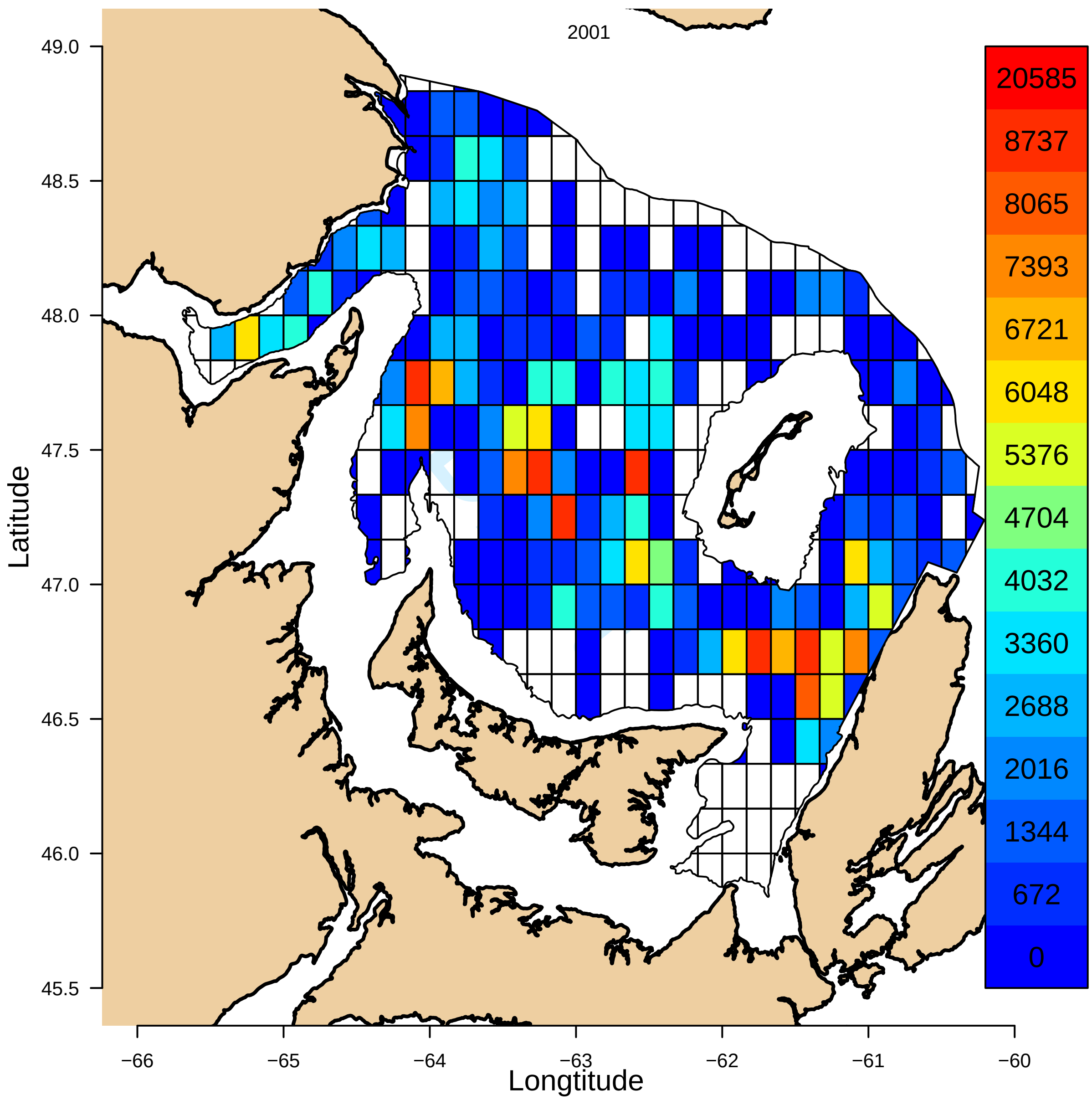


Figure SE.7a. Total annual effort (number of pots) for snow crab in each grid cell in 2001. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

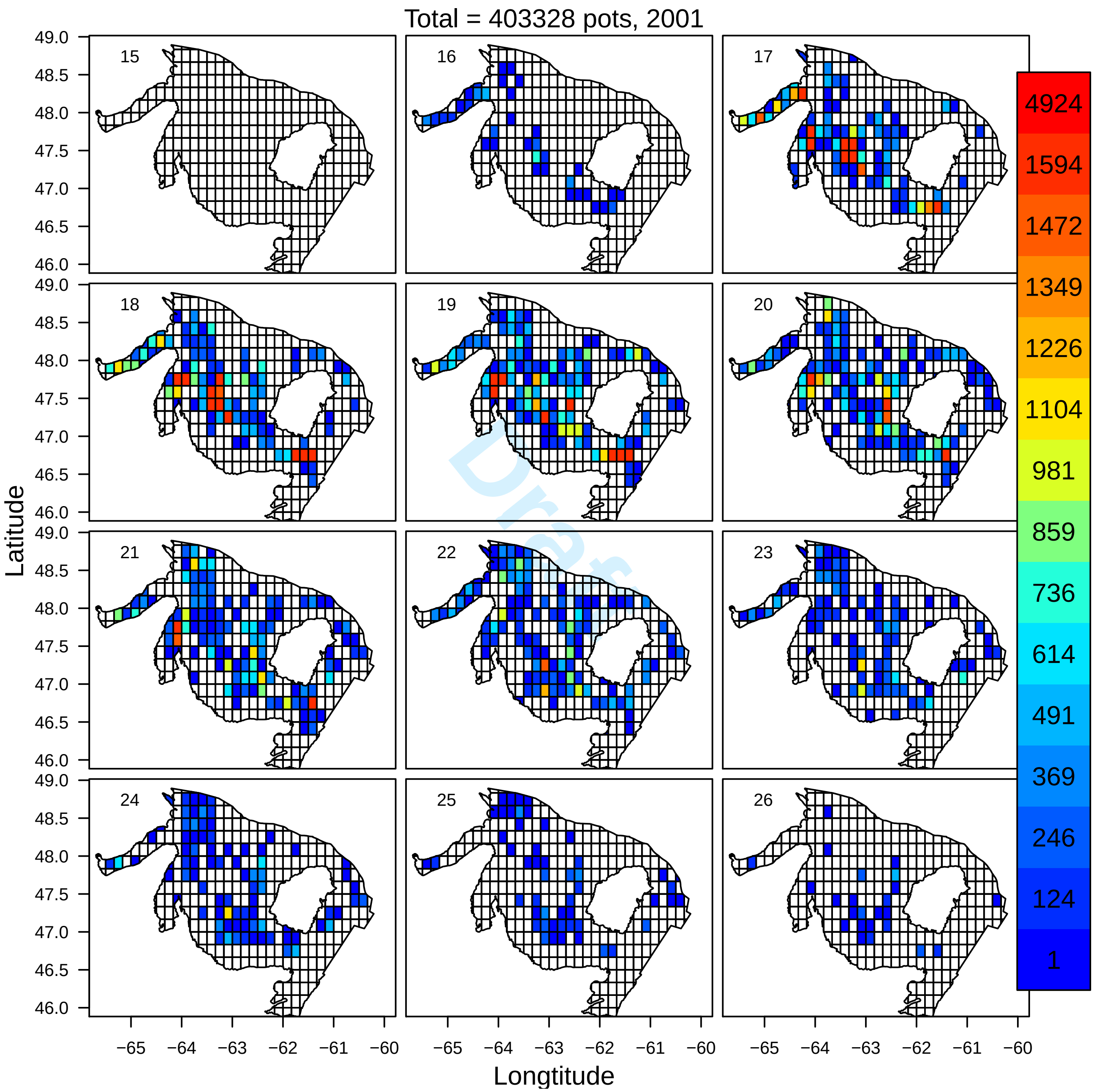


Figure SE.7b. Effort (number of pots) for snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

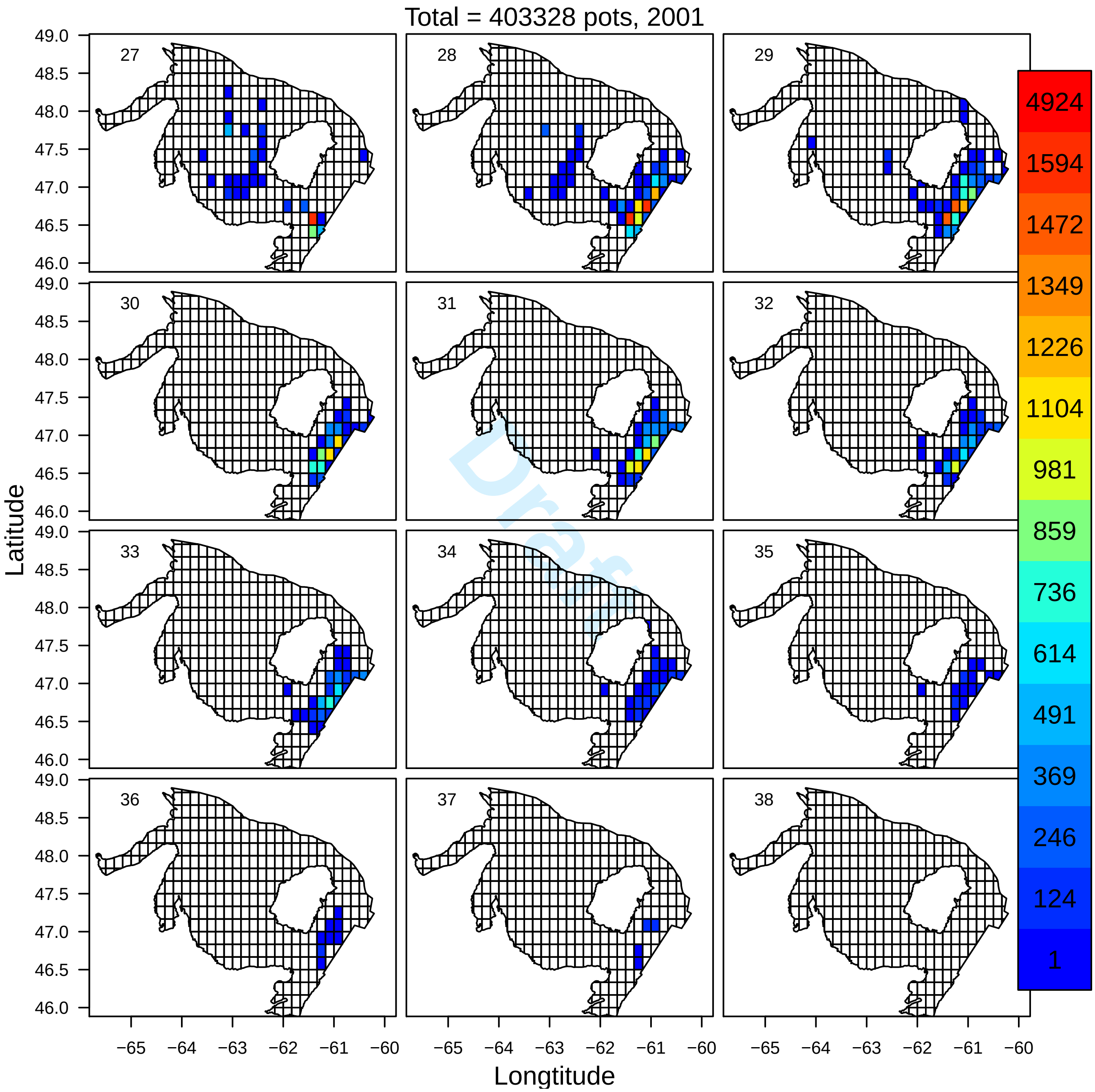


Figure SE.7c. Effort (number of pots) for snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

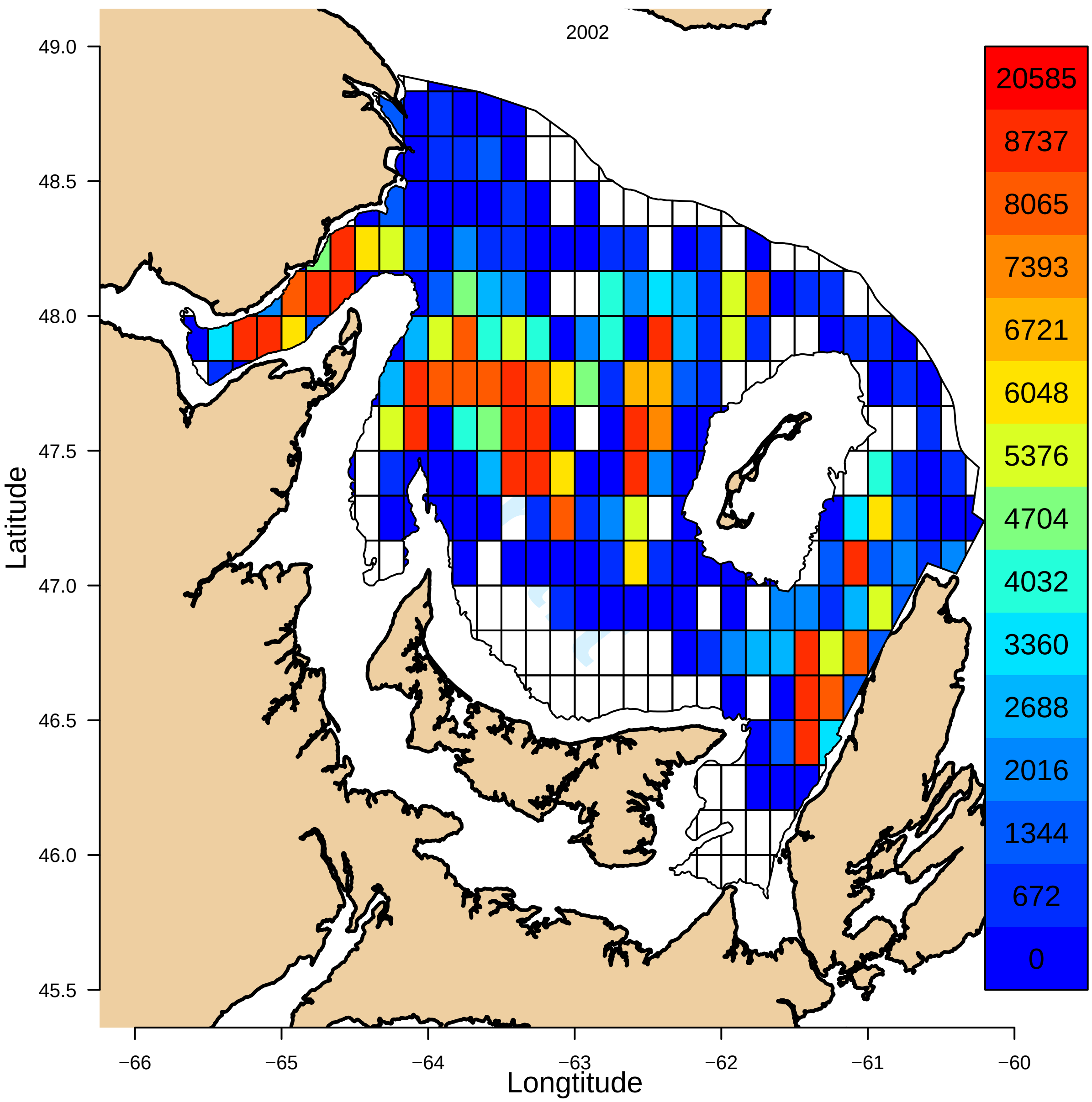


Figure SE.8a. Total annual effort (number of pots) for snow crab in each grid cell in 2002. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

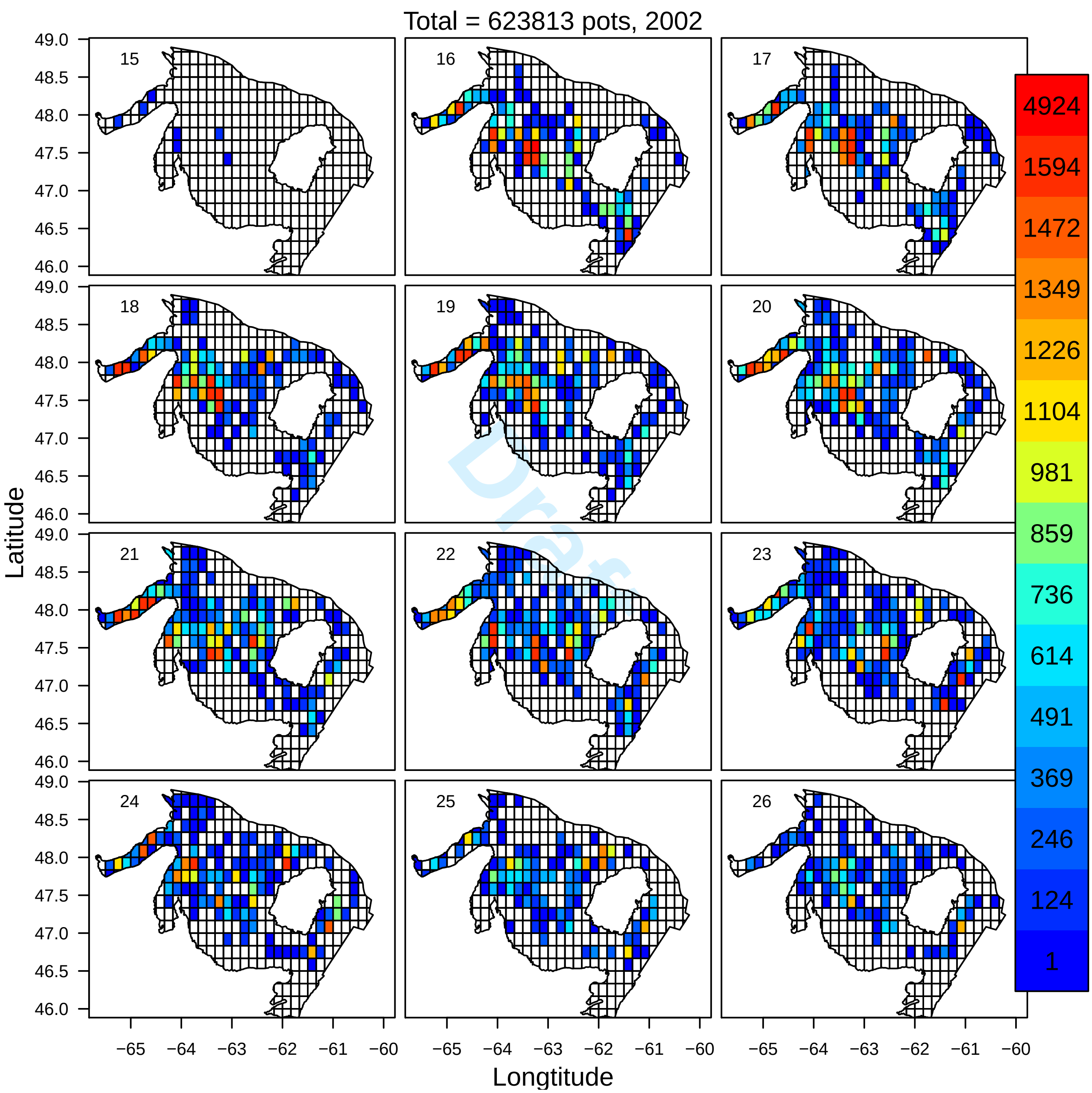


Figure SE.8b. Effort (number of pots) for snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

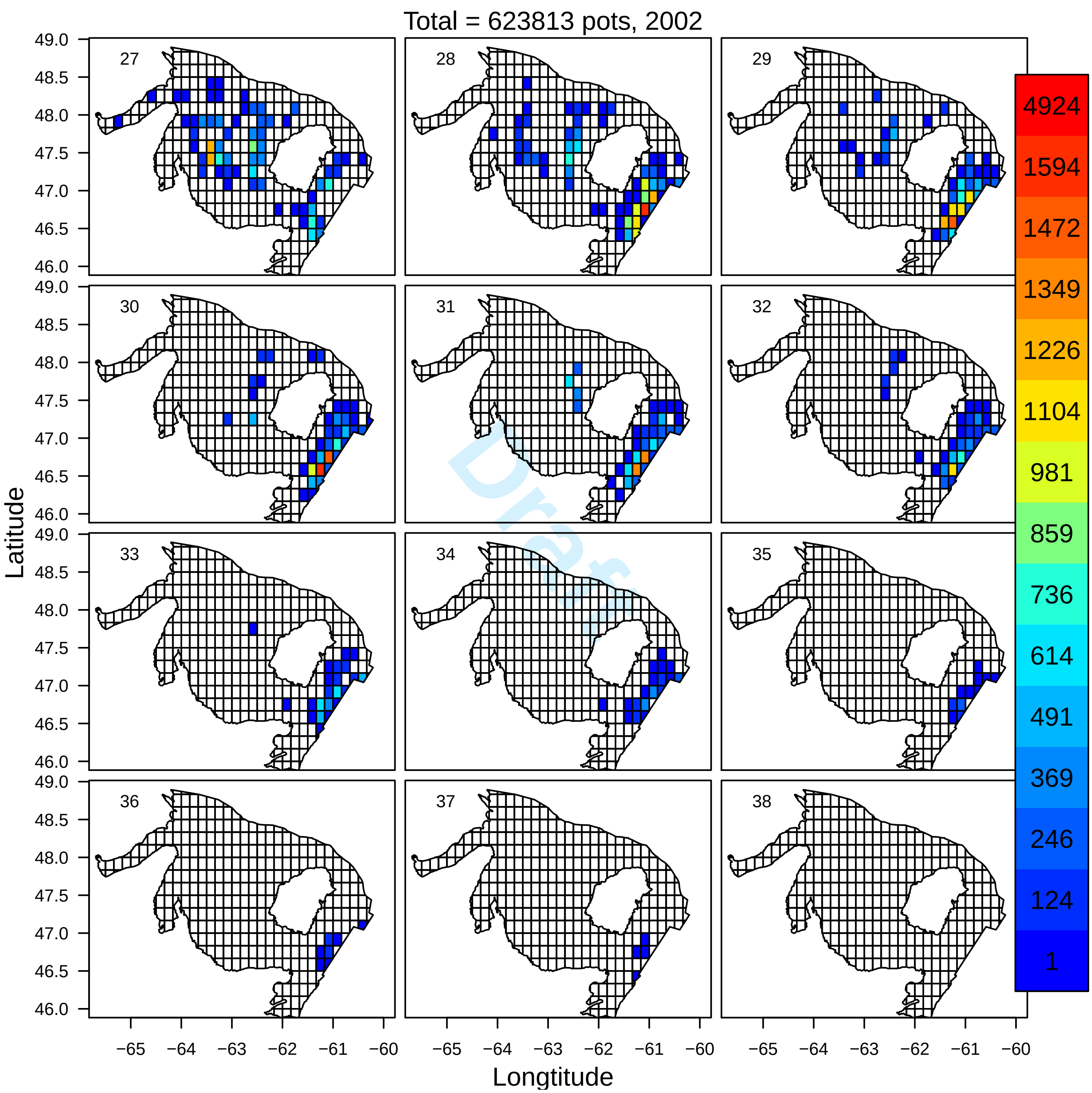


Figure SE.8c. Effort (number of pots) for snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

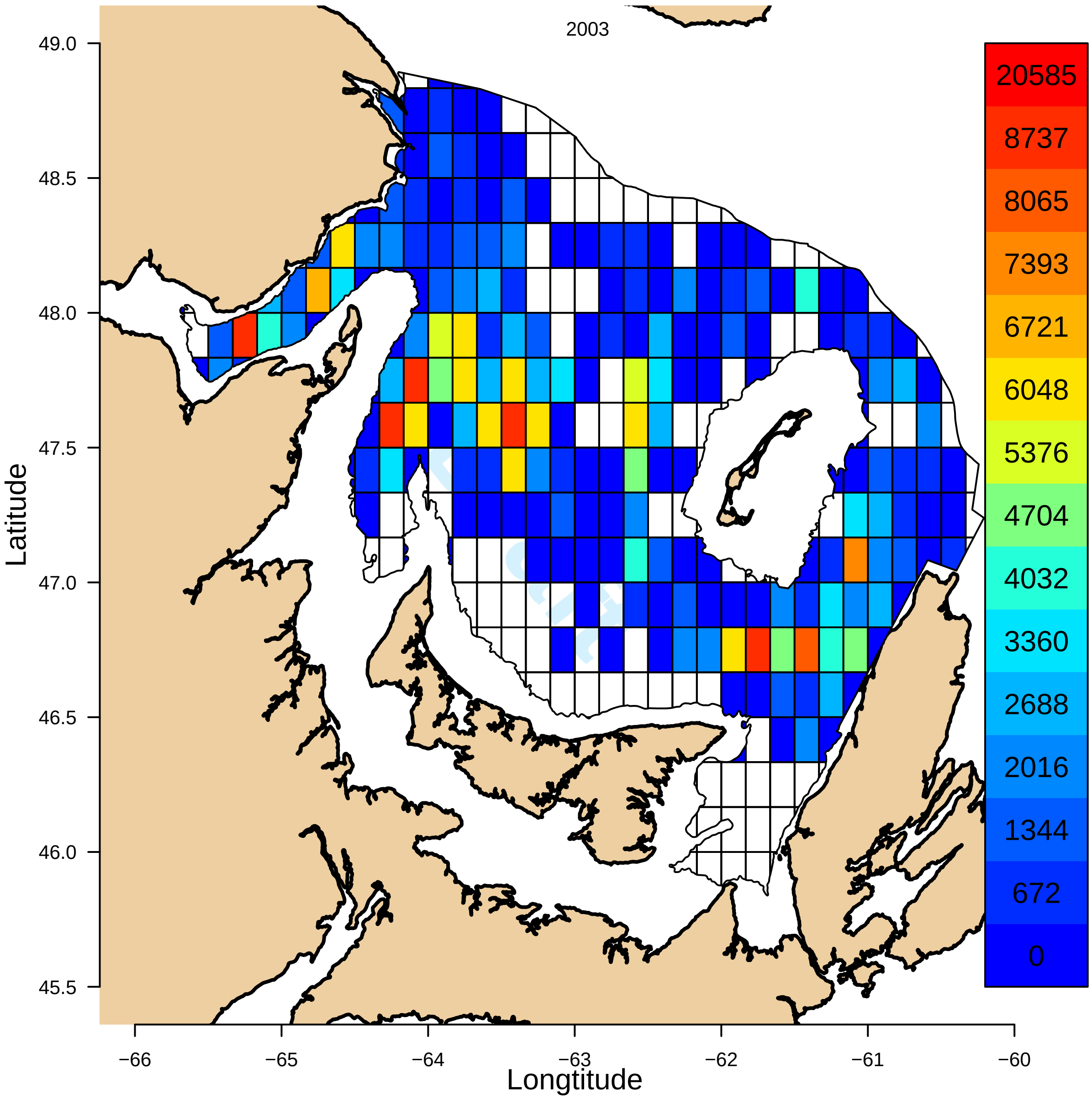


Figure SE.9a. Total annual effort (number of pots) for snow crab in each grid cell in 2003. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

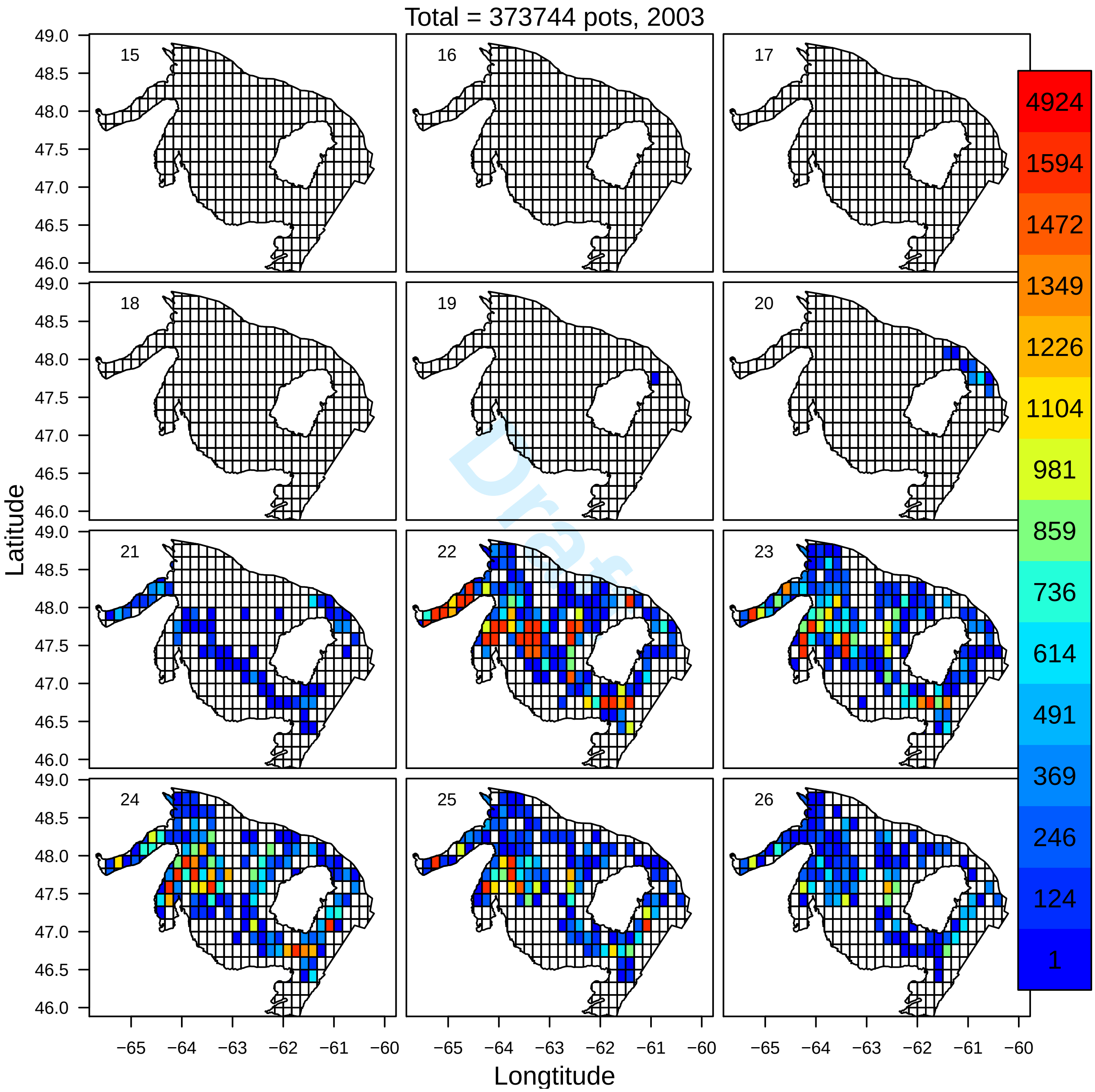


Figure SE.9b. Effort (number of pots) for snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

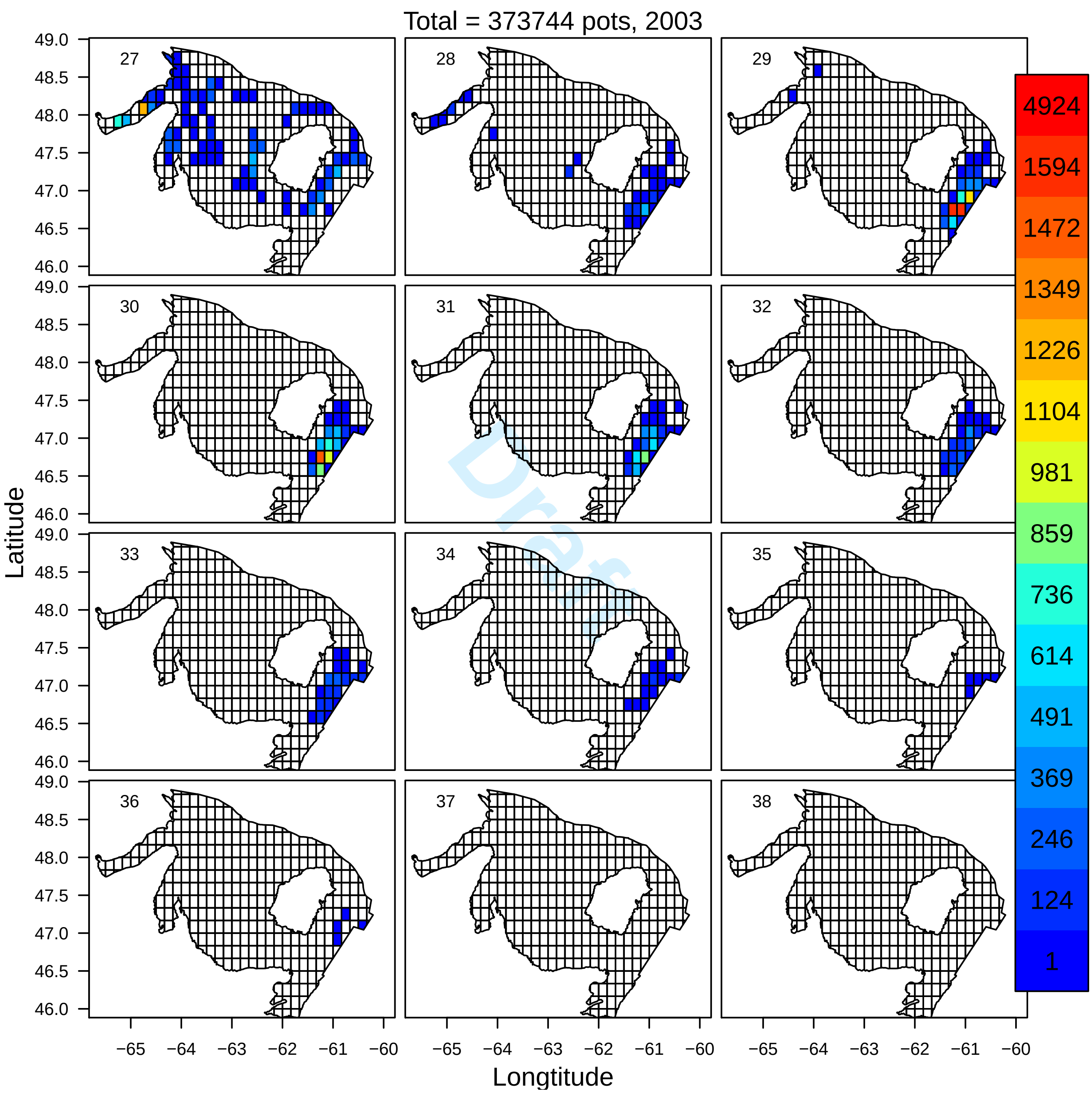


Figure SE.9c. Effort (number of pots) for snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

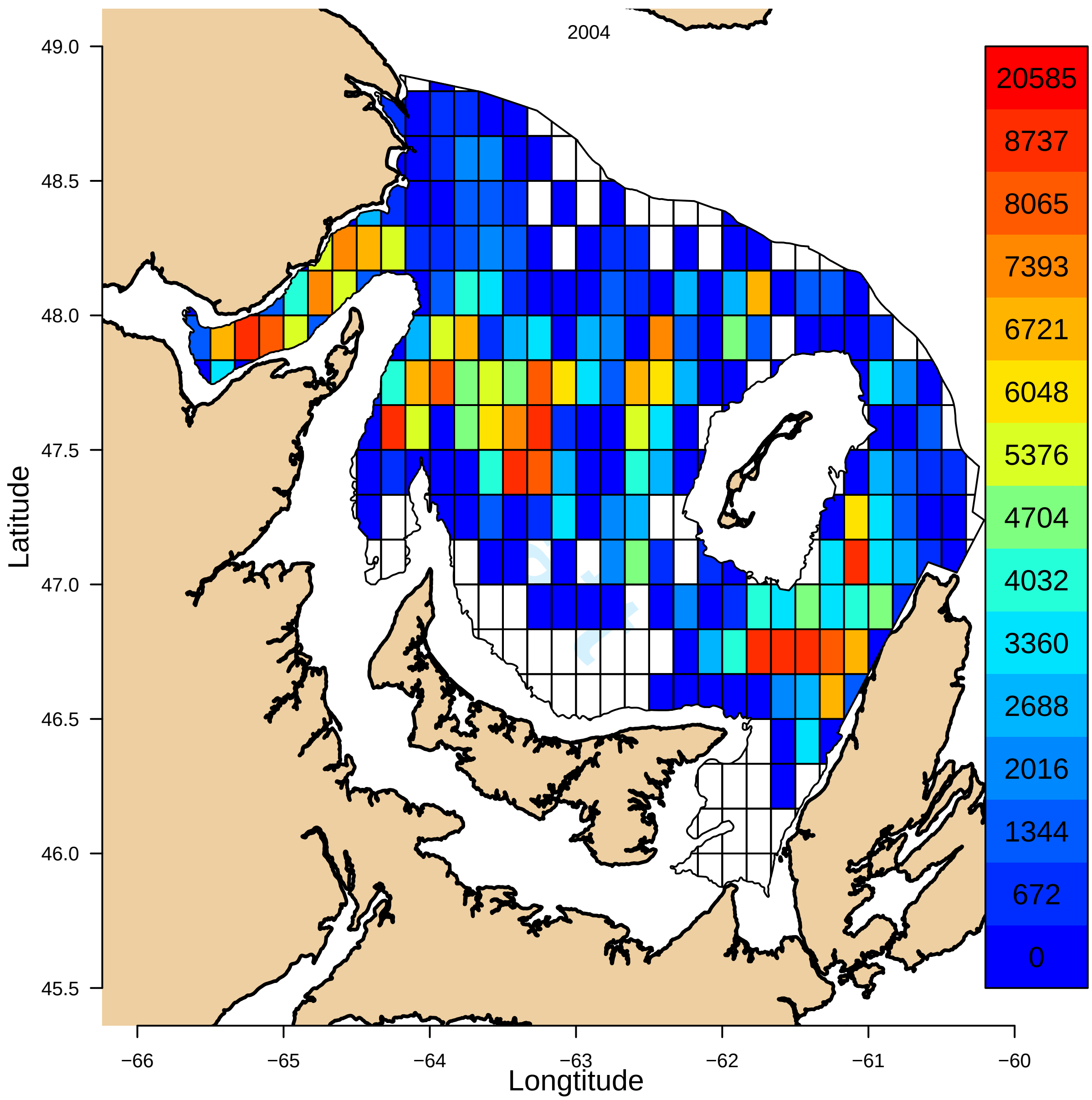


Figure SE.10a. Total annual effort (number of pots) for snow crab in each grid cell in 2004. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

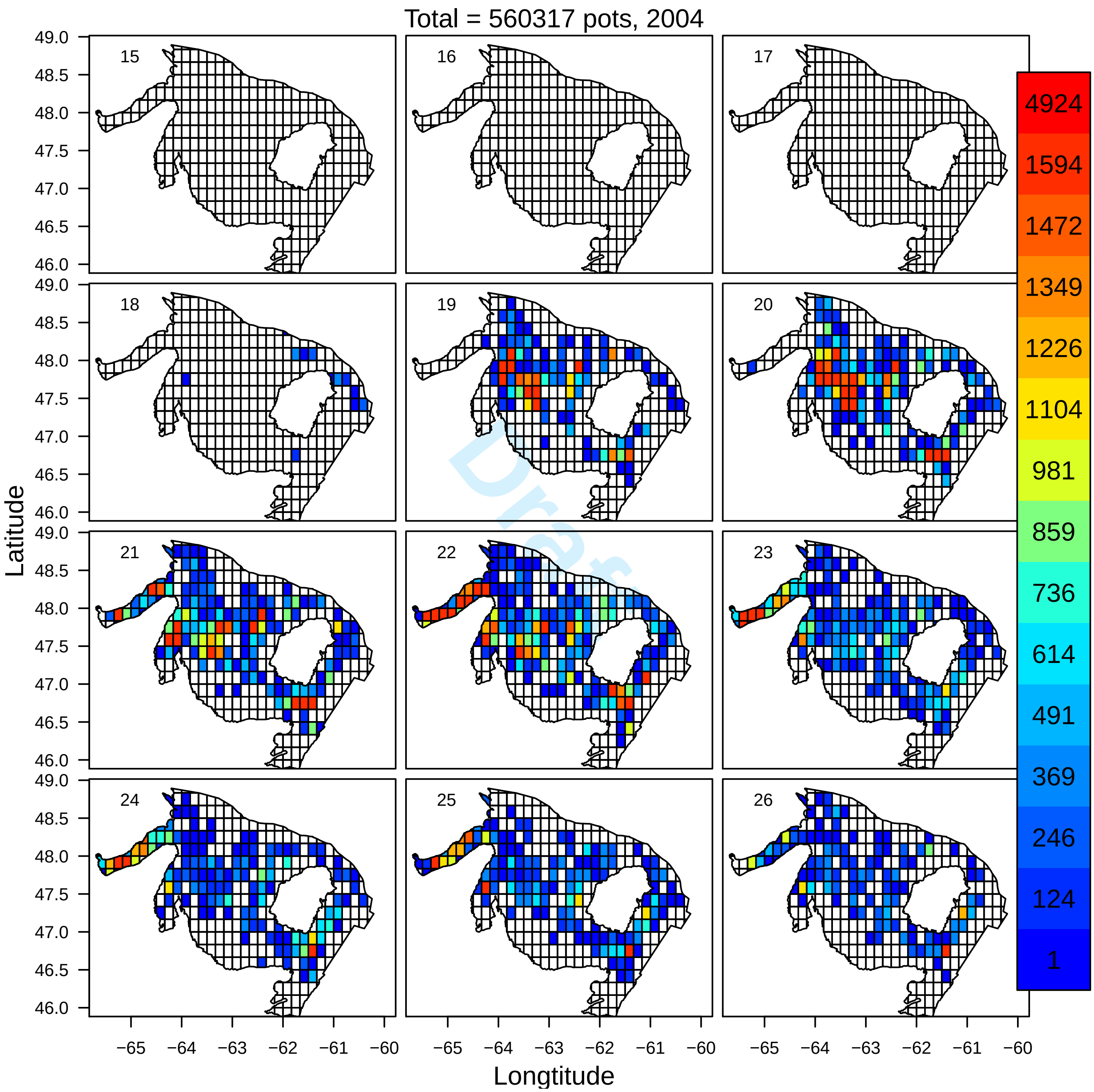


Figure SE.10b. Effort (number of pots) for snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

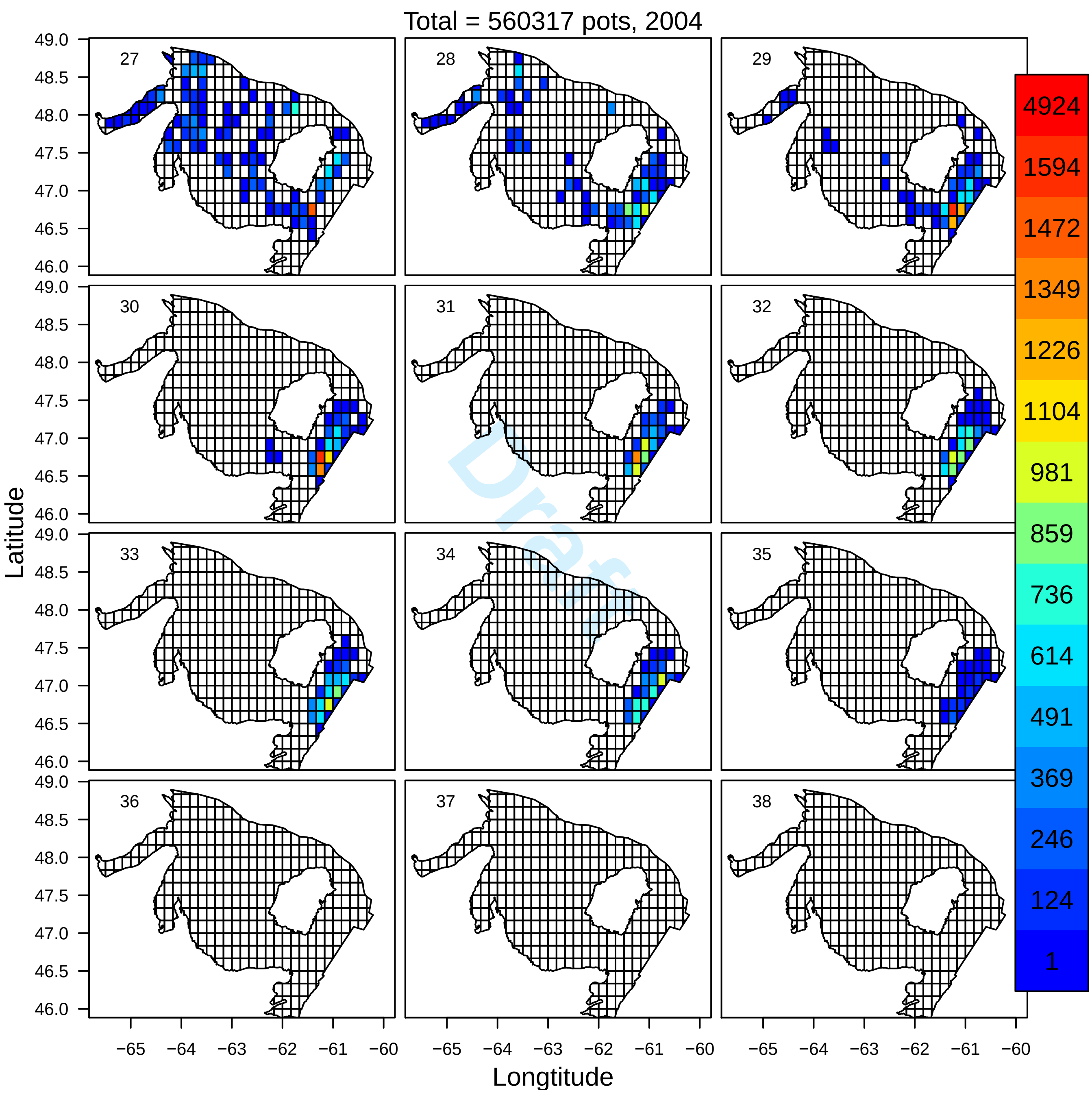


Figure SE.10c. Effort (number of pots) for snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

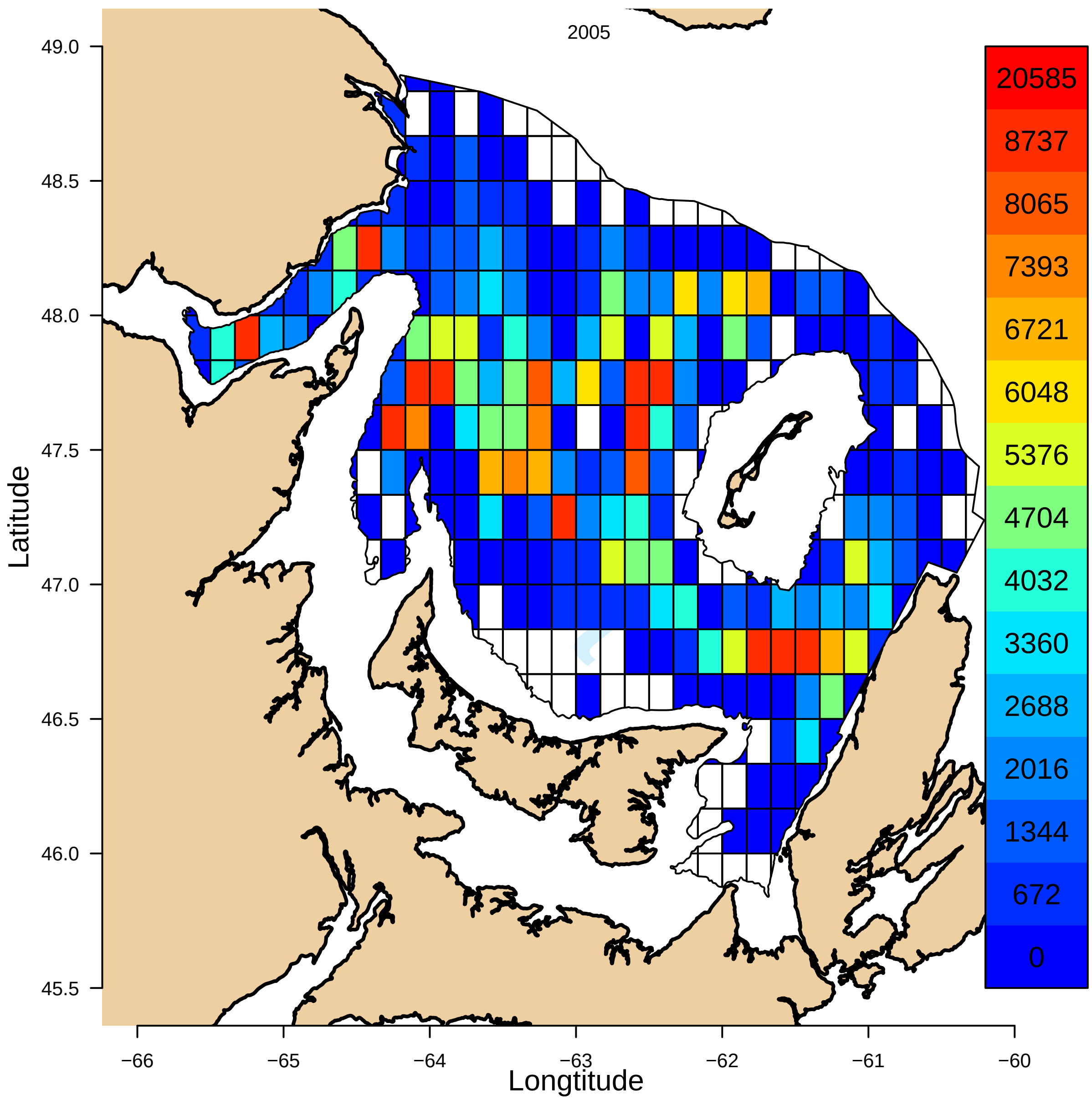


Figure SE.11a. Total annual effort (number of pots) for snow crab in each grid cell in 2005. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

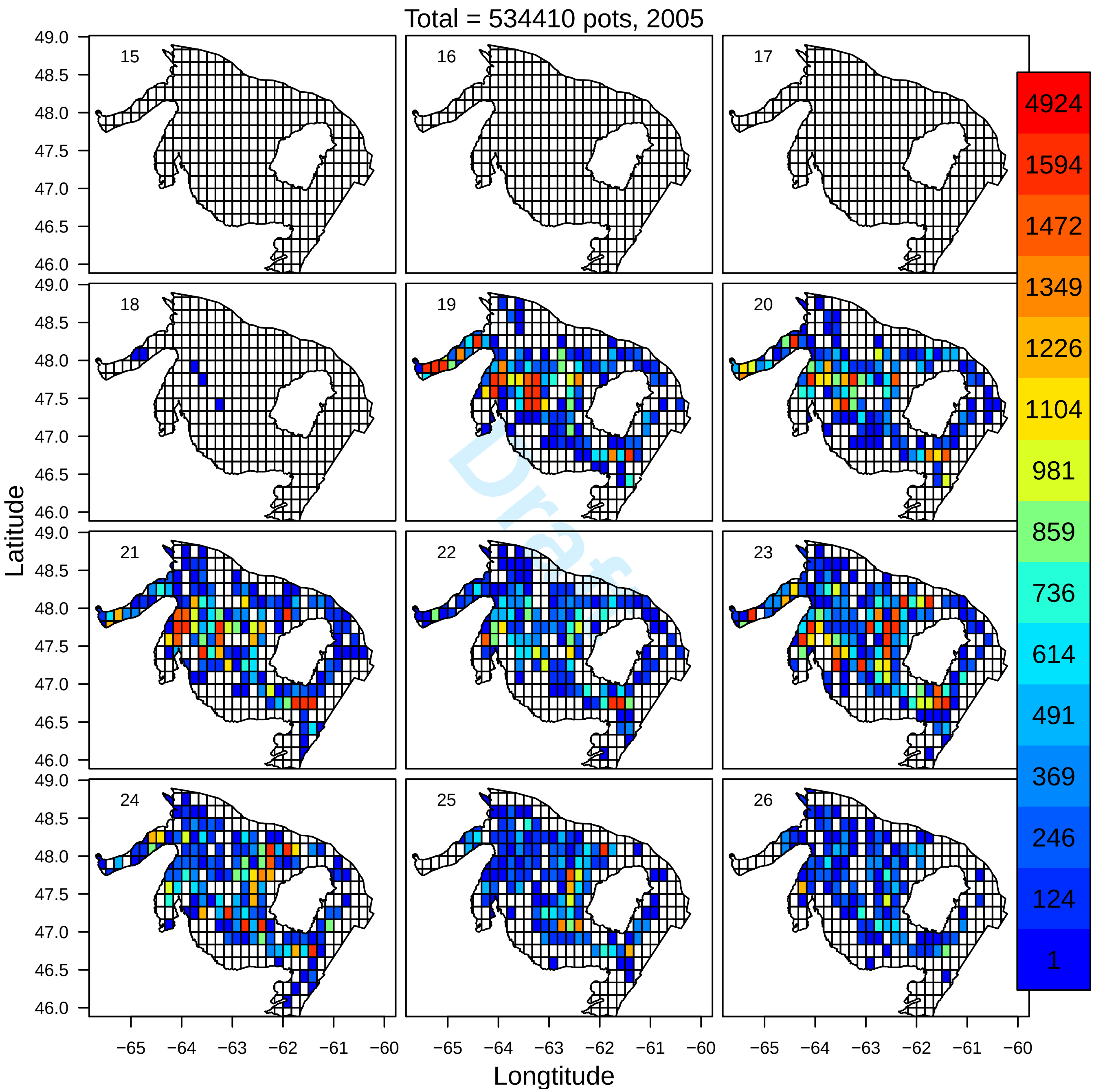


Figure SE.11b. Effort (number of pots) for snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

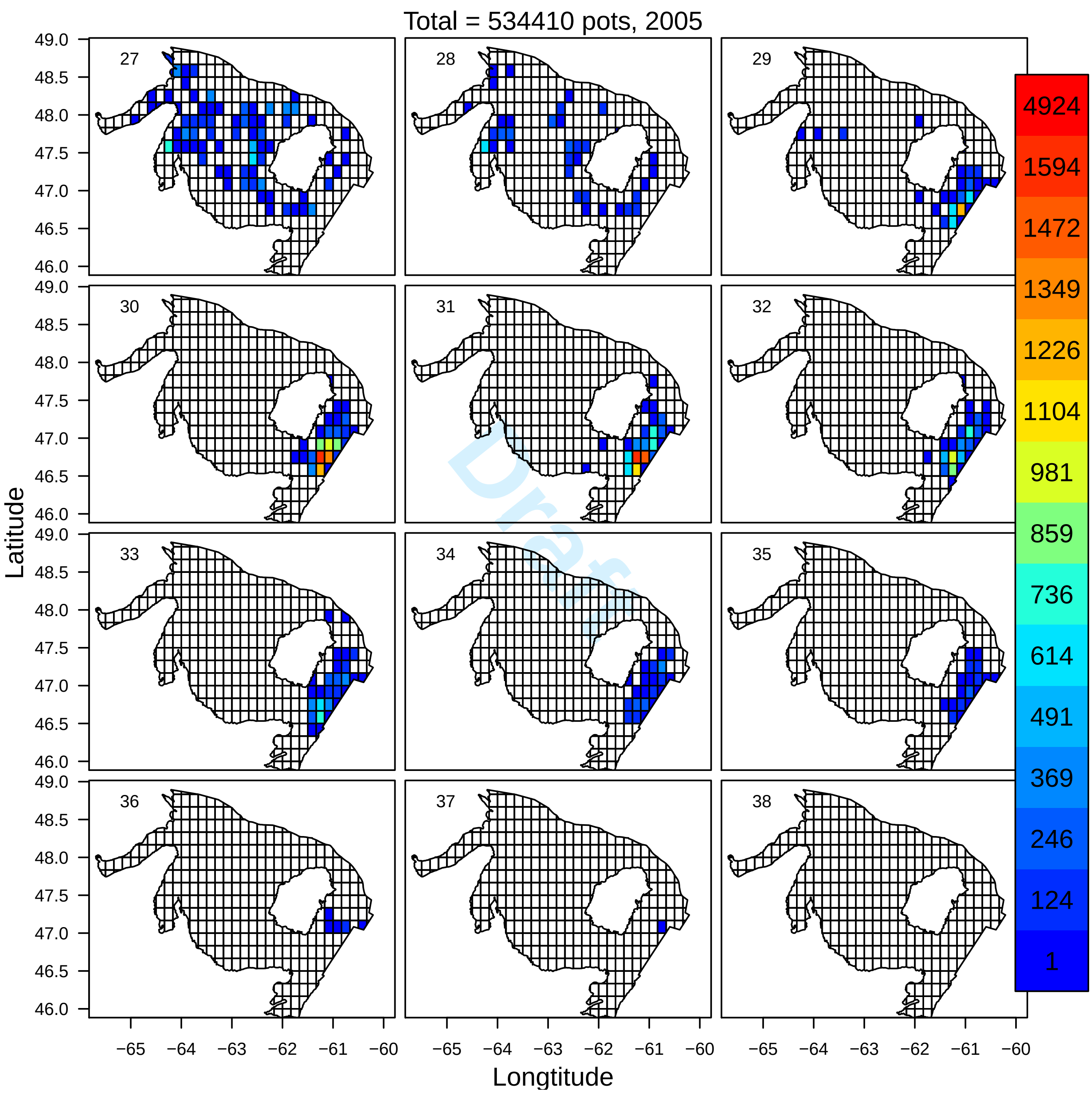


Figure SE.11c. Effort (number of pots) for snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

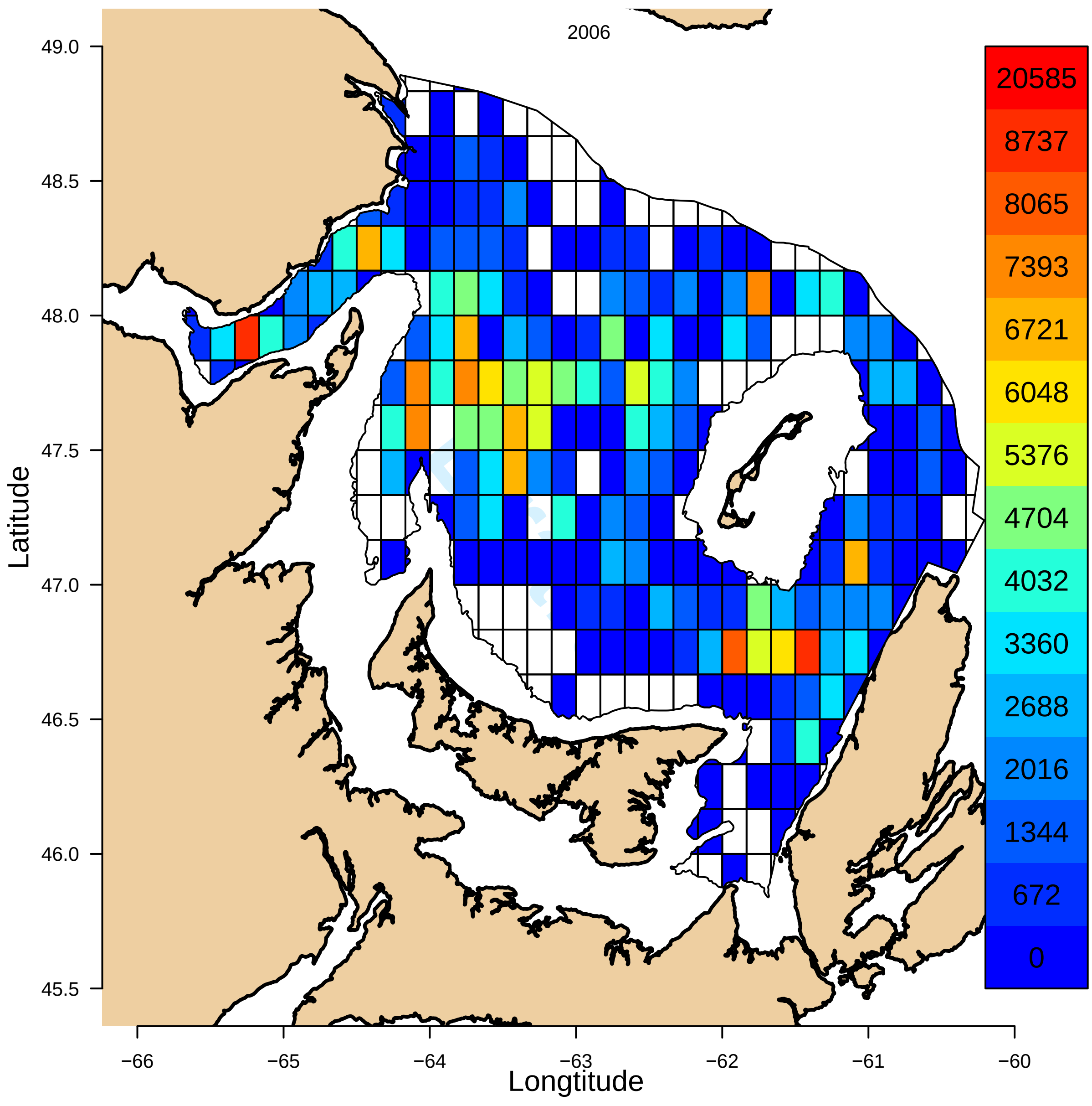


Figure SE.12a. Total annual effort (number of pots) for snow crab in each grid cell in 2006. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

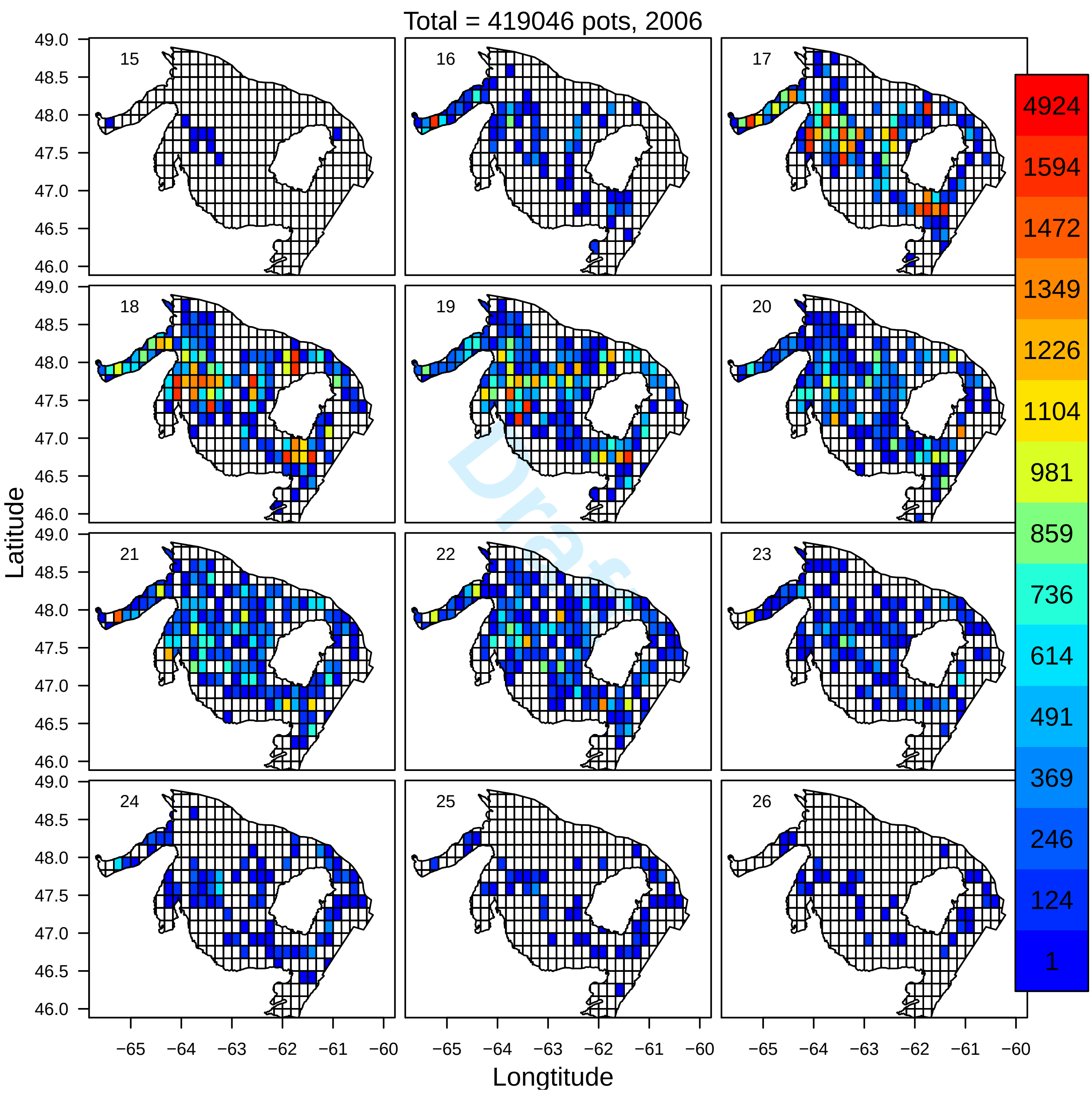


Figure SE.12b. Effort (number of pots) for snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

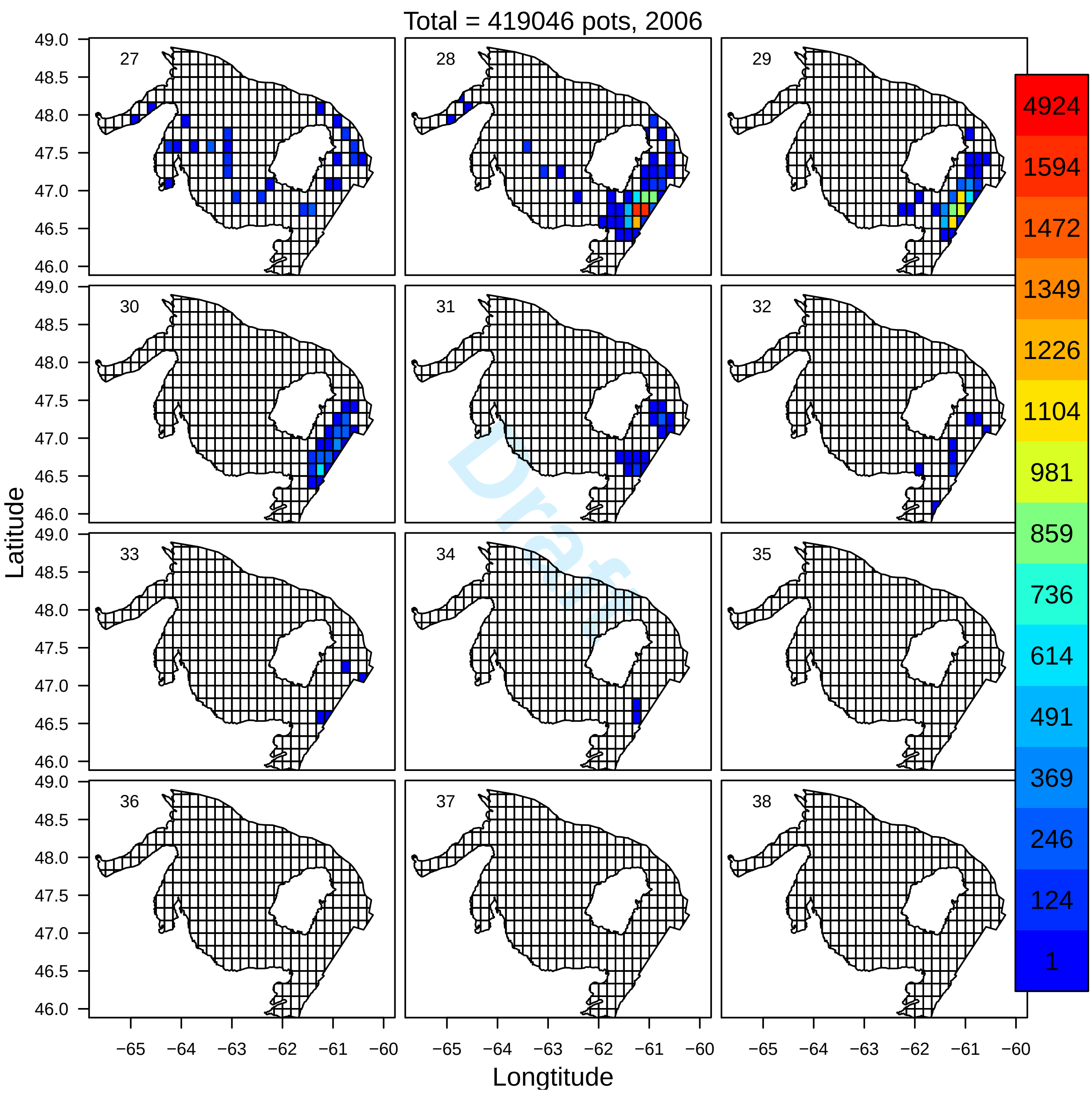


Figure SE.12c. Effort (number of pots) for snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

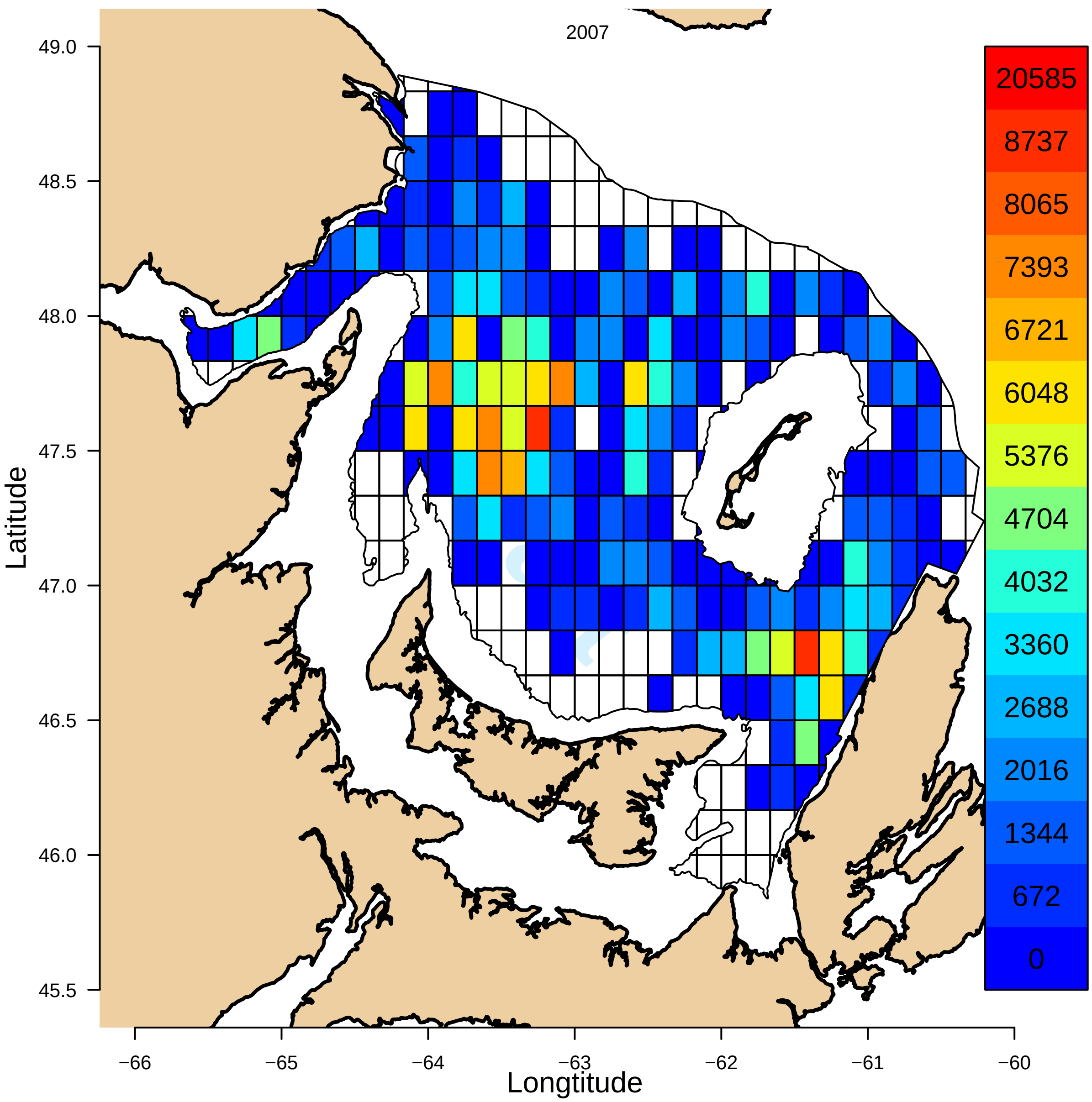


Figure SE.13a. Total annual effort (number of pots) for snow crab in each grid cell in 2007. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

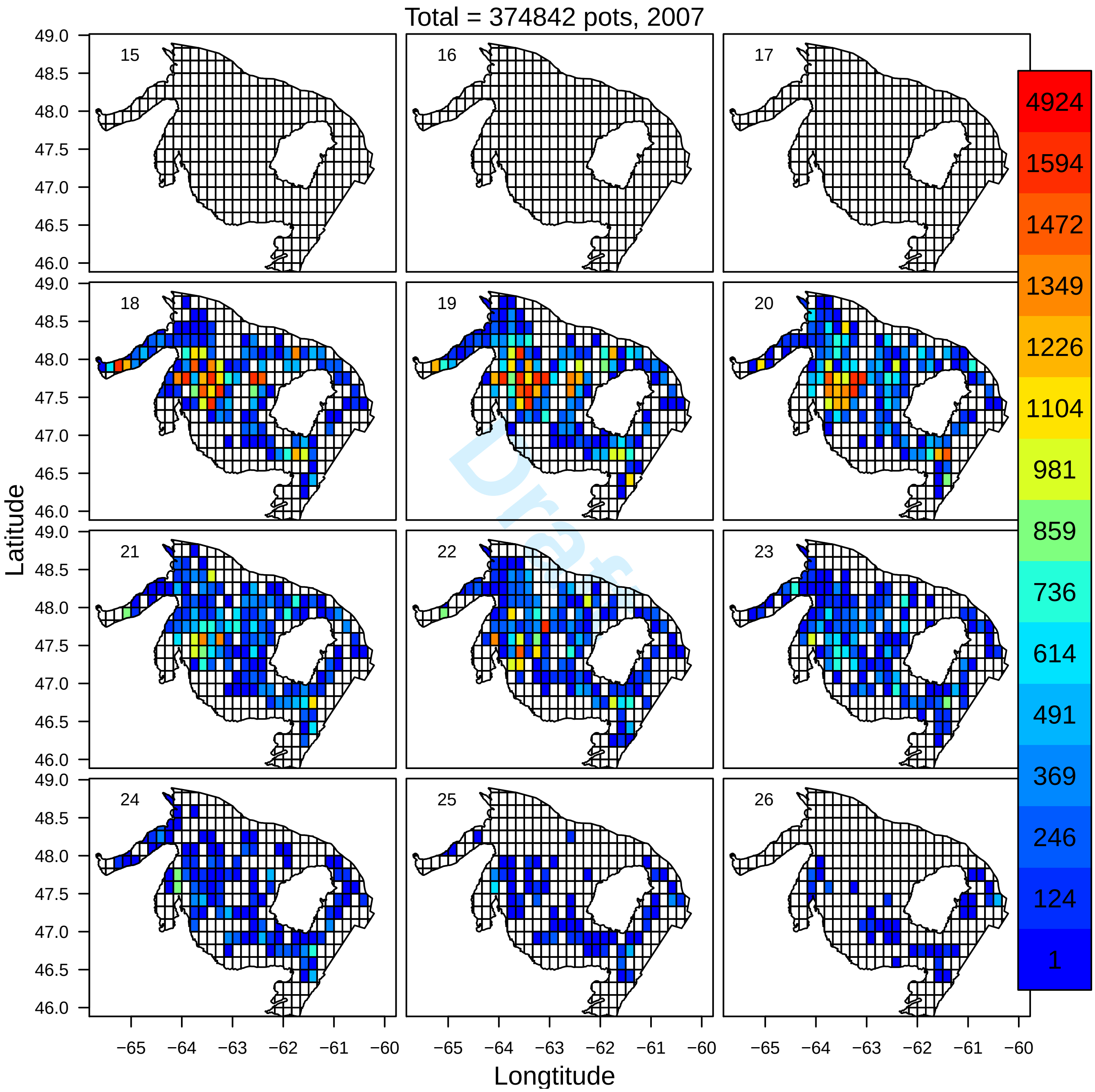


Figure SE.13b. Effort (number of pots) for snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

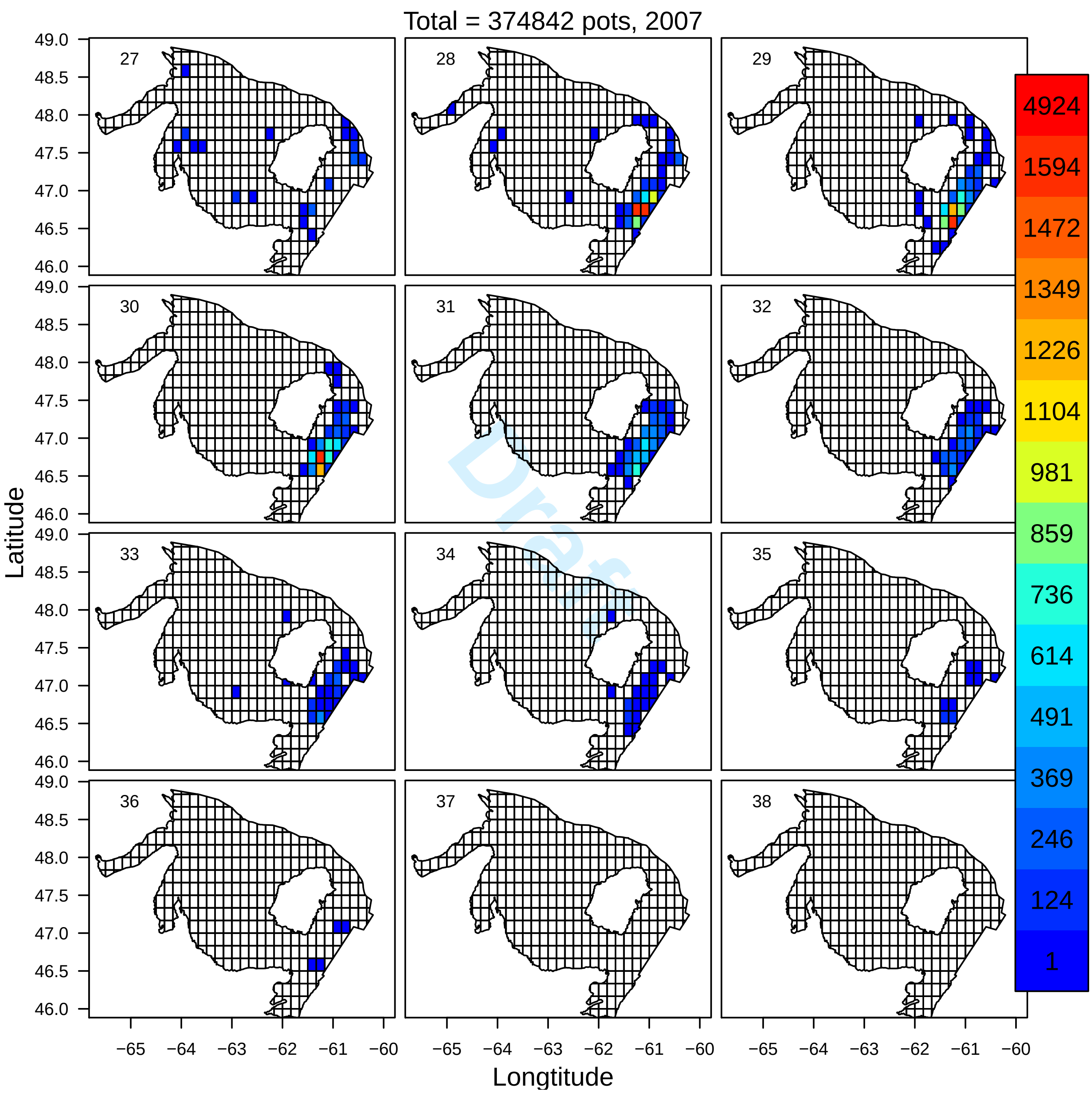


Figure SE.13c. Effort (number of pots) for snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

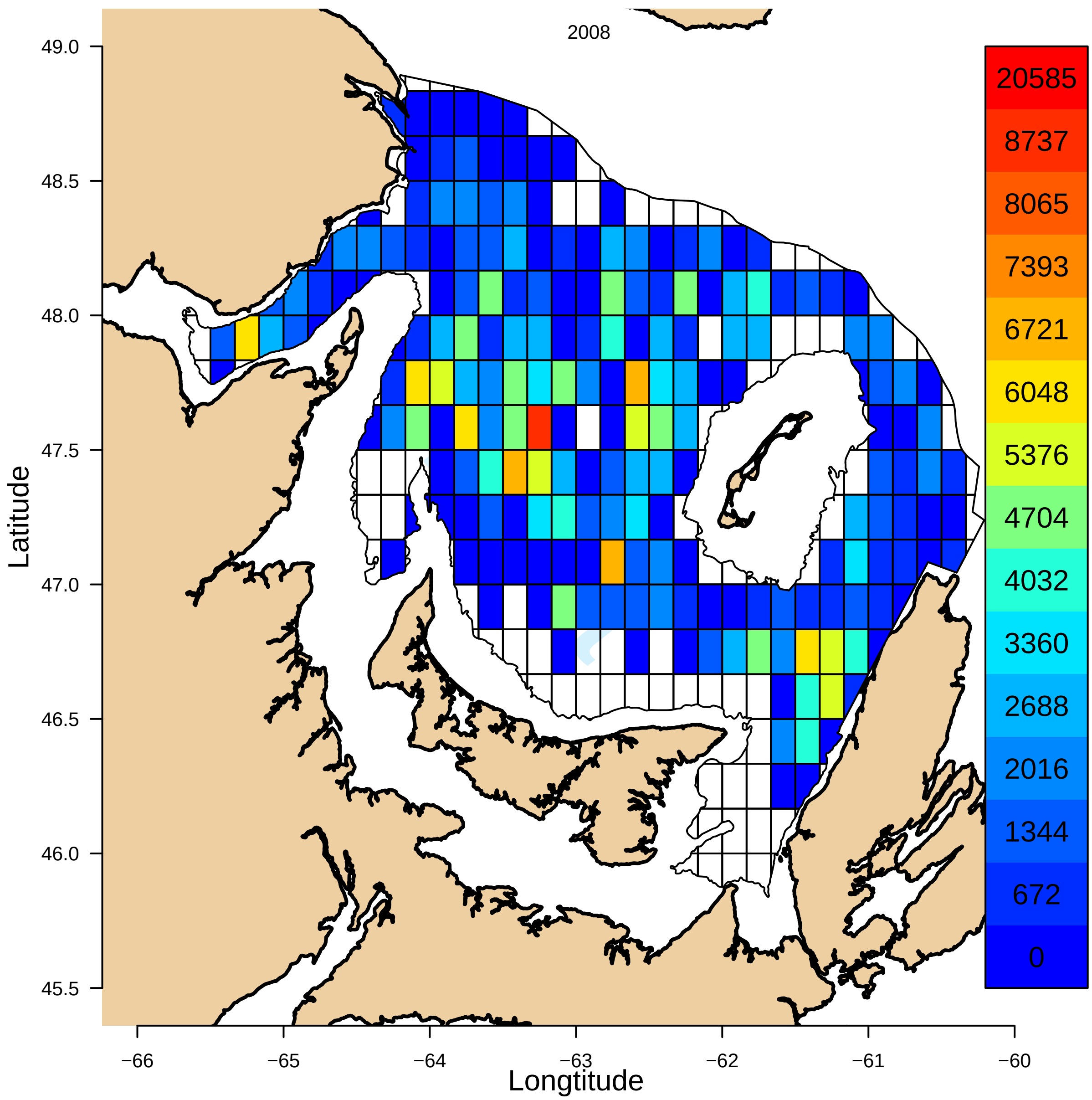


Figure SE.14a. Total annual effort (number of pots) for snow crab in each grid cell in 2008. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

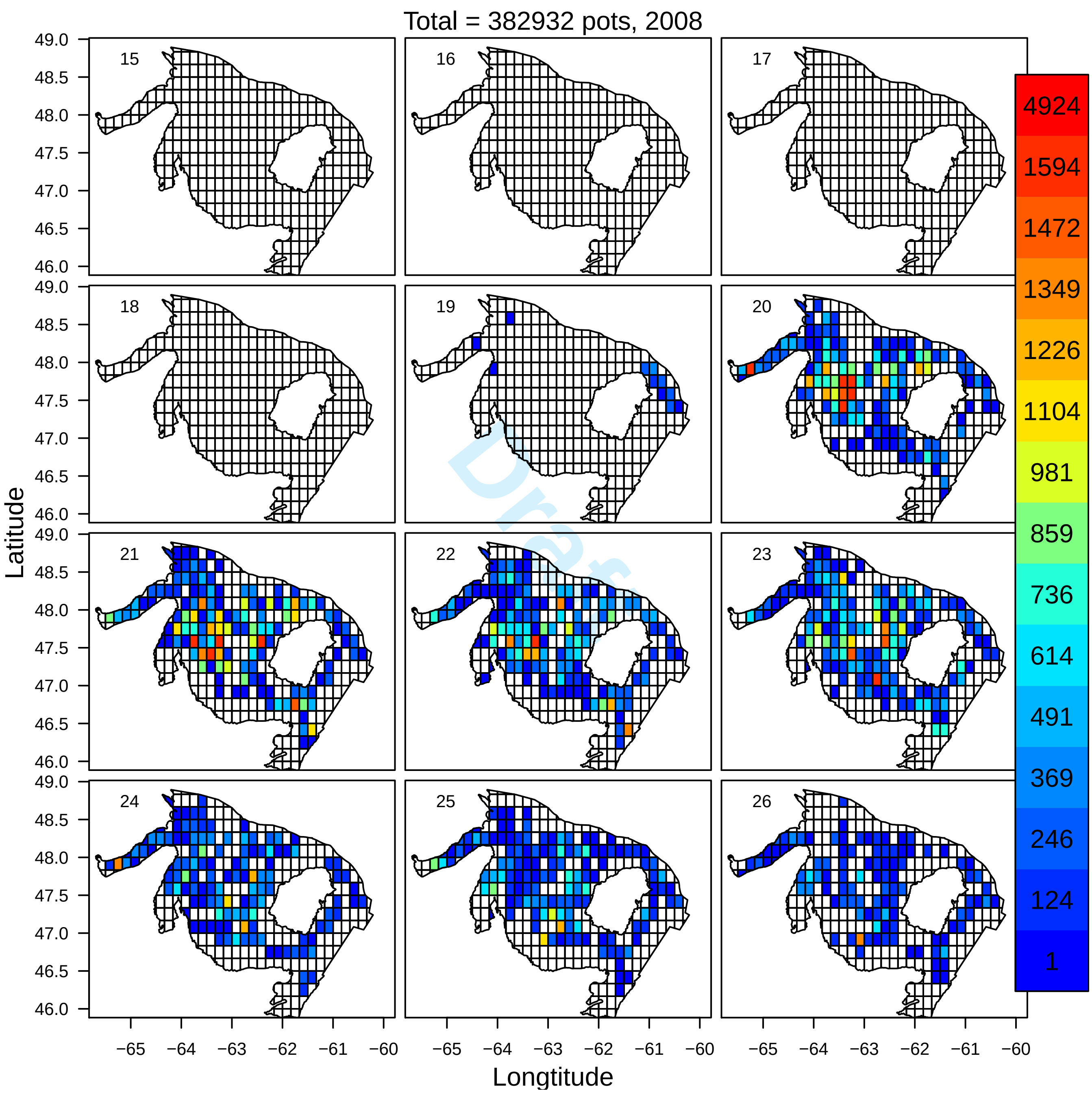


Figure SE.14b. Effort (number of pots) for snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

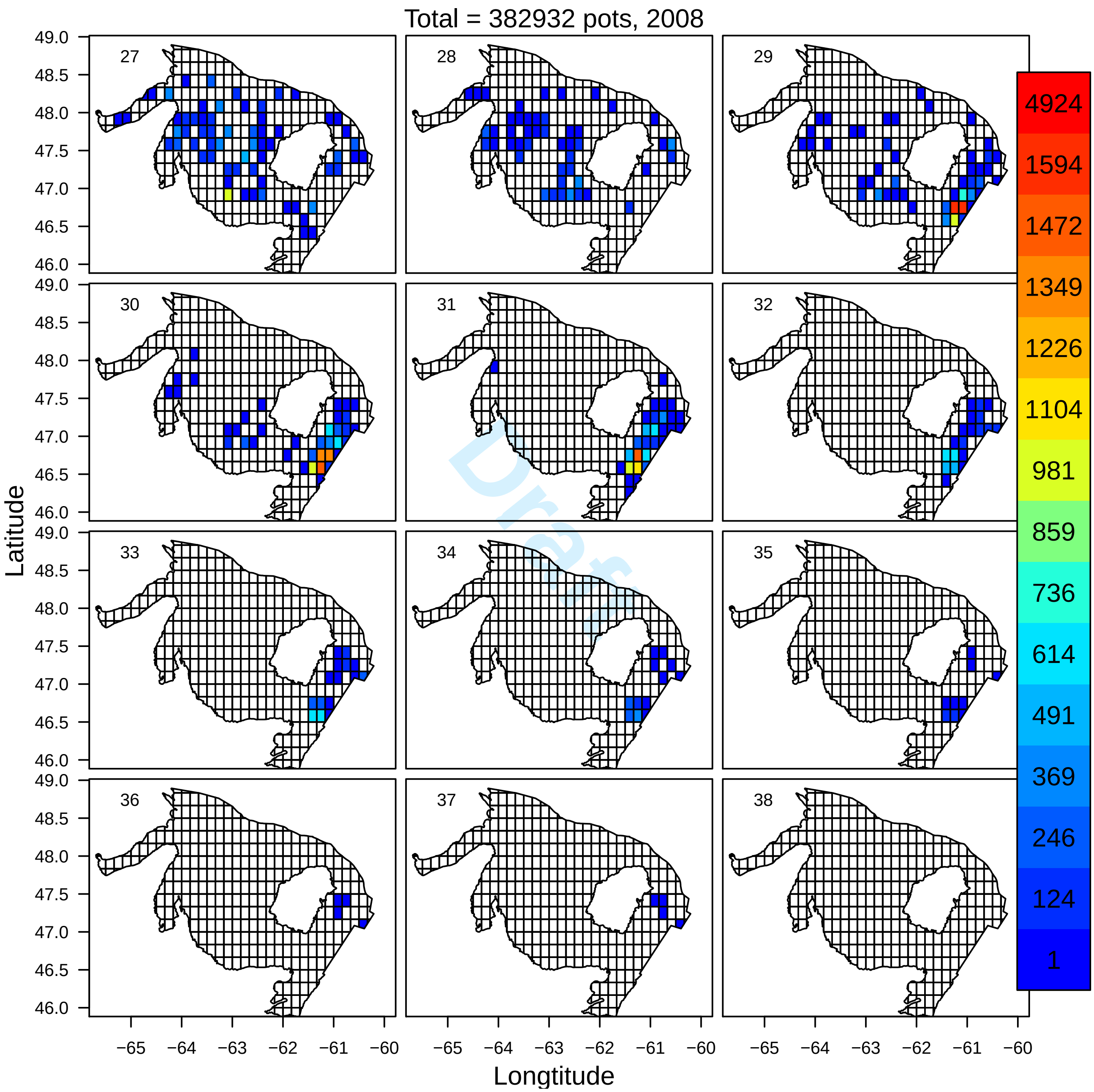


Figure SE.14c. Effort (number of pots) for snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

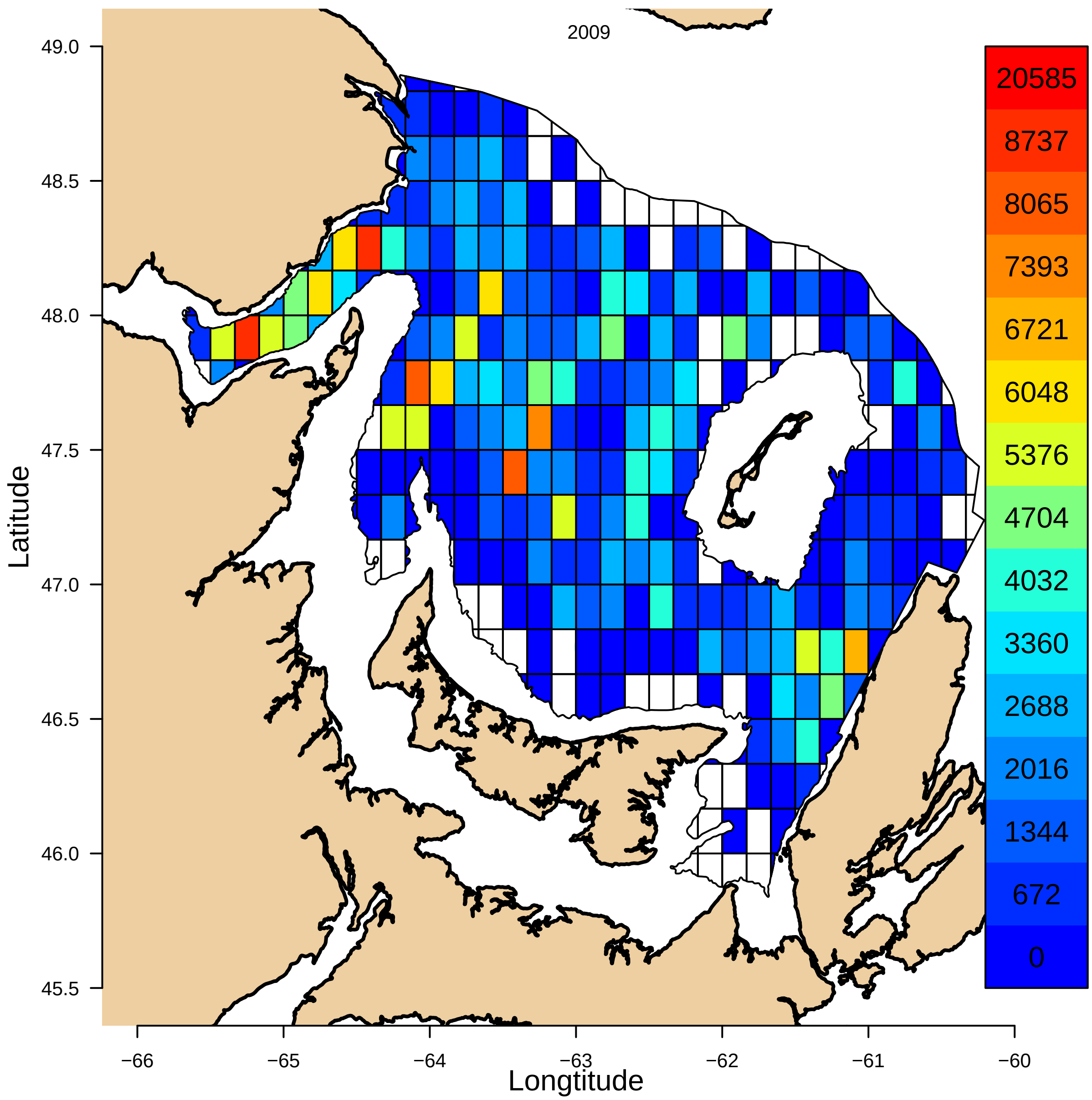


Figure SE.15a. Total annual effort (number of pots) for snow crab in each grid cell in 2009. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

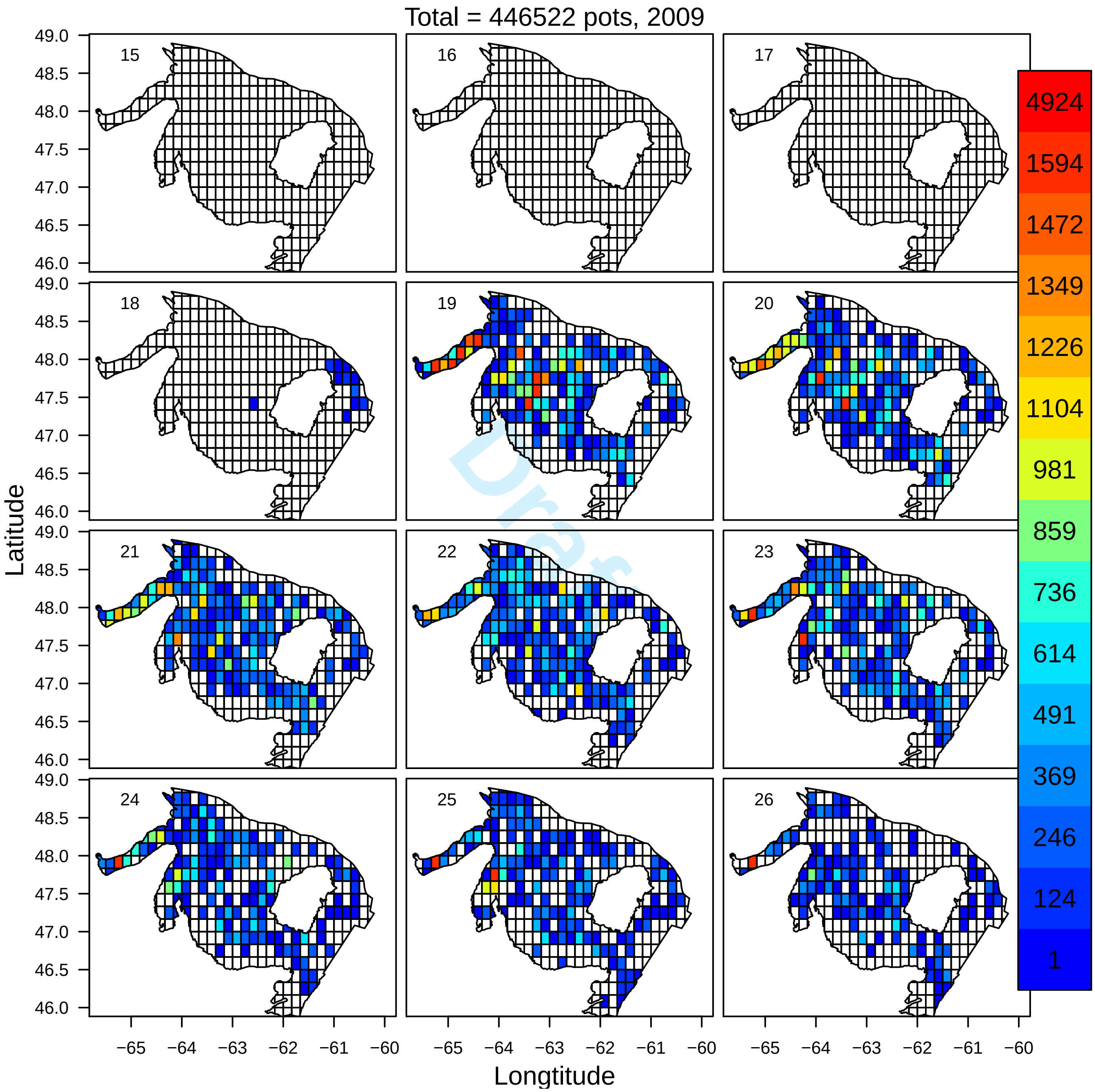


Figure SE.15b. Effort (number of pots) for snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

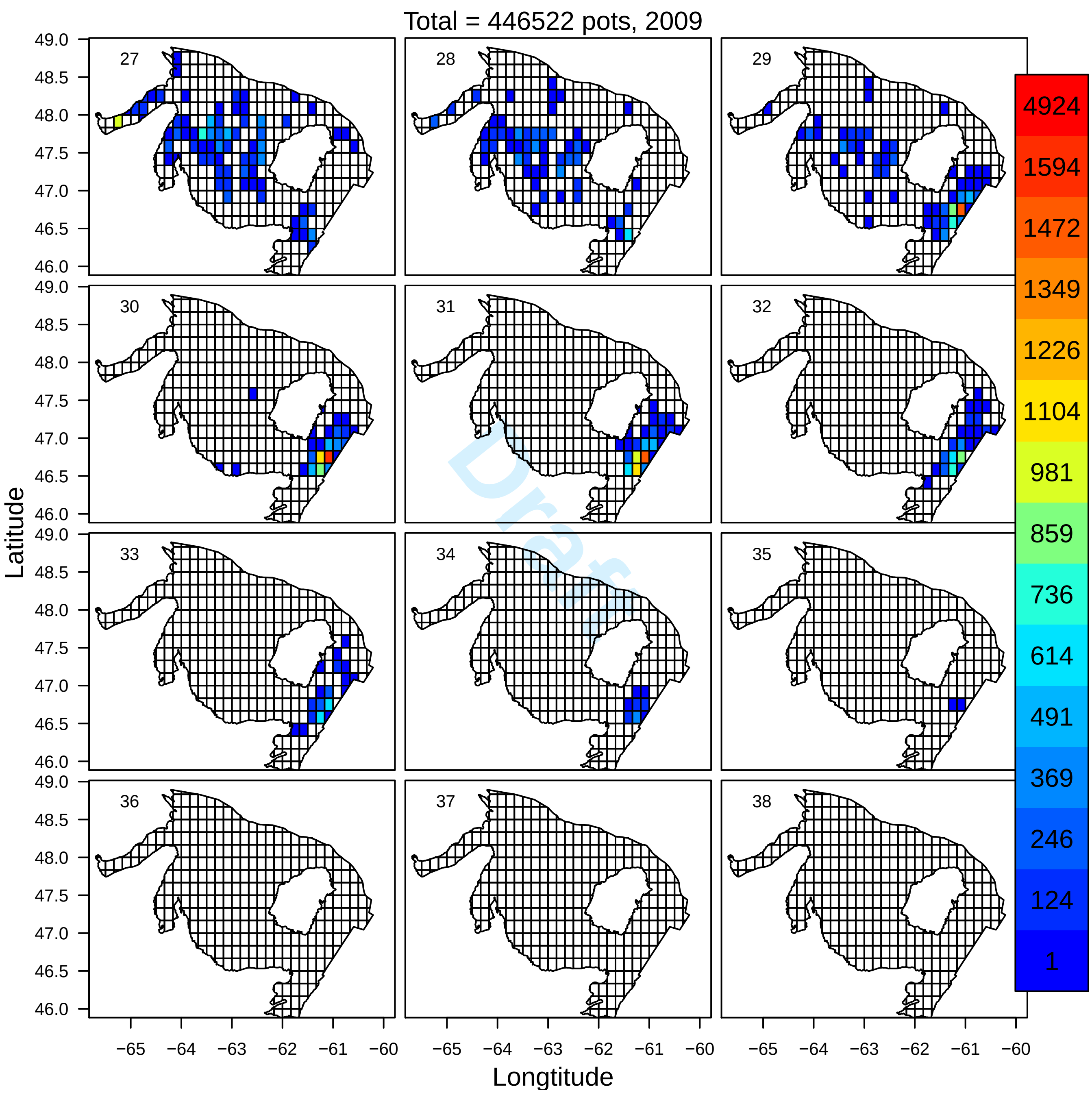


Figure SE.15c. Effort (number of pots) for snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

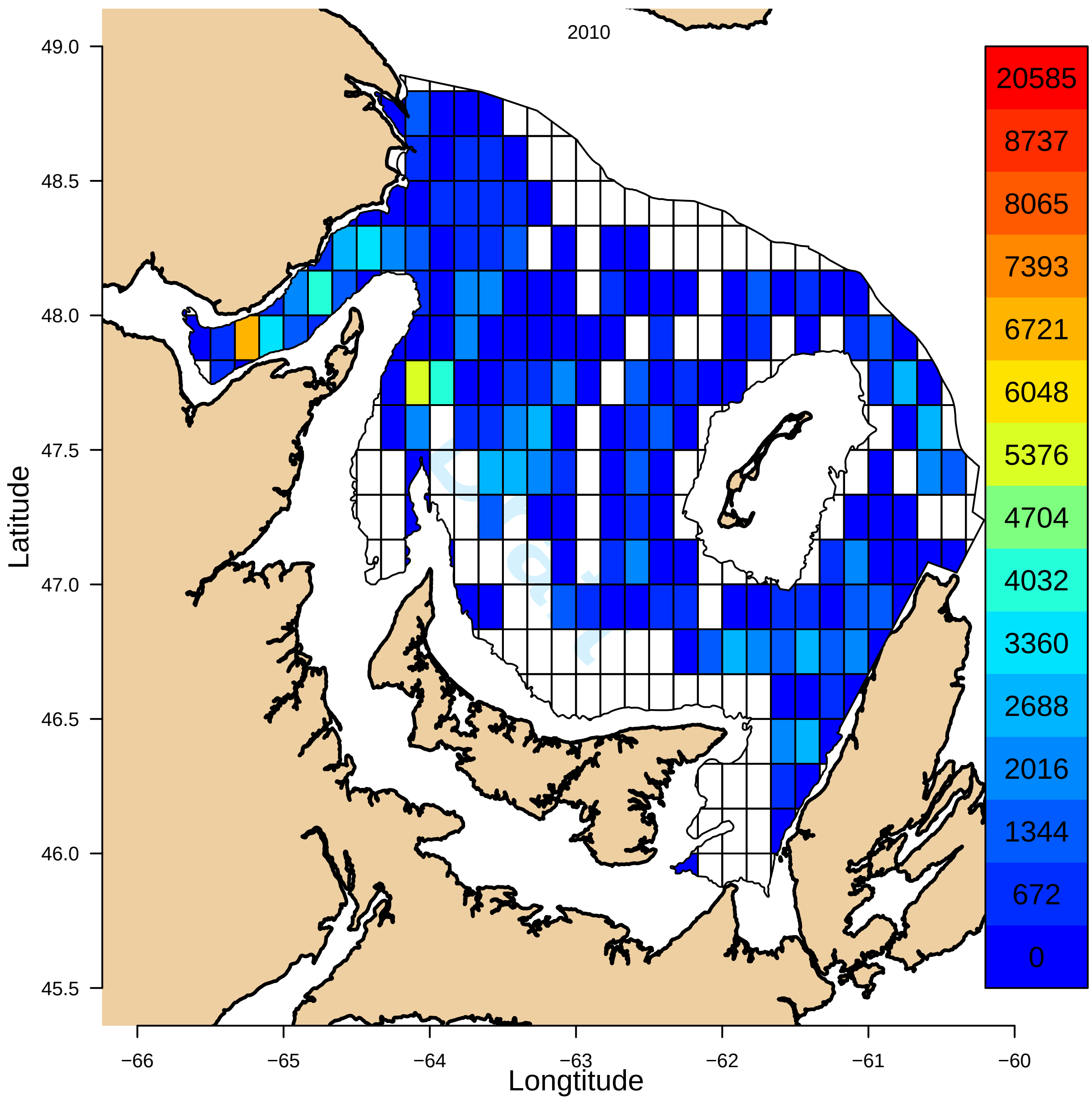


Figure SE.16a. Total annual effort (number of pots) for snow crab in each grid cell in 2010. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

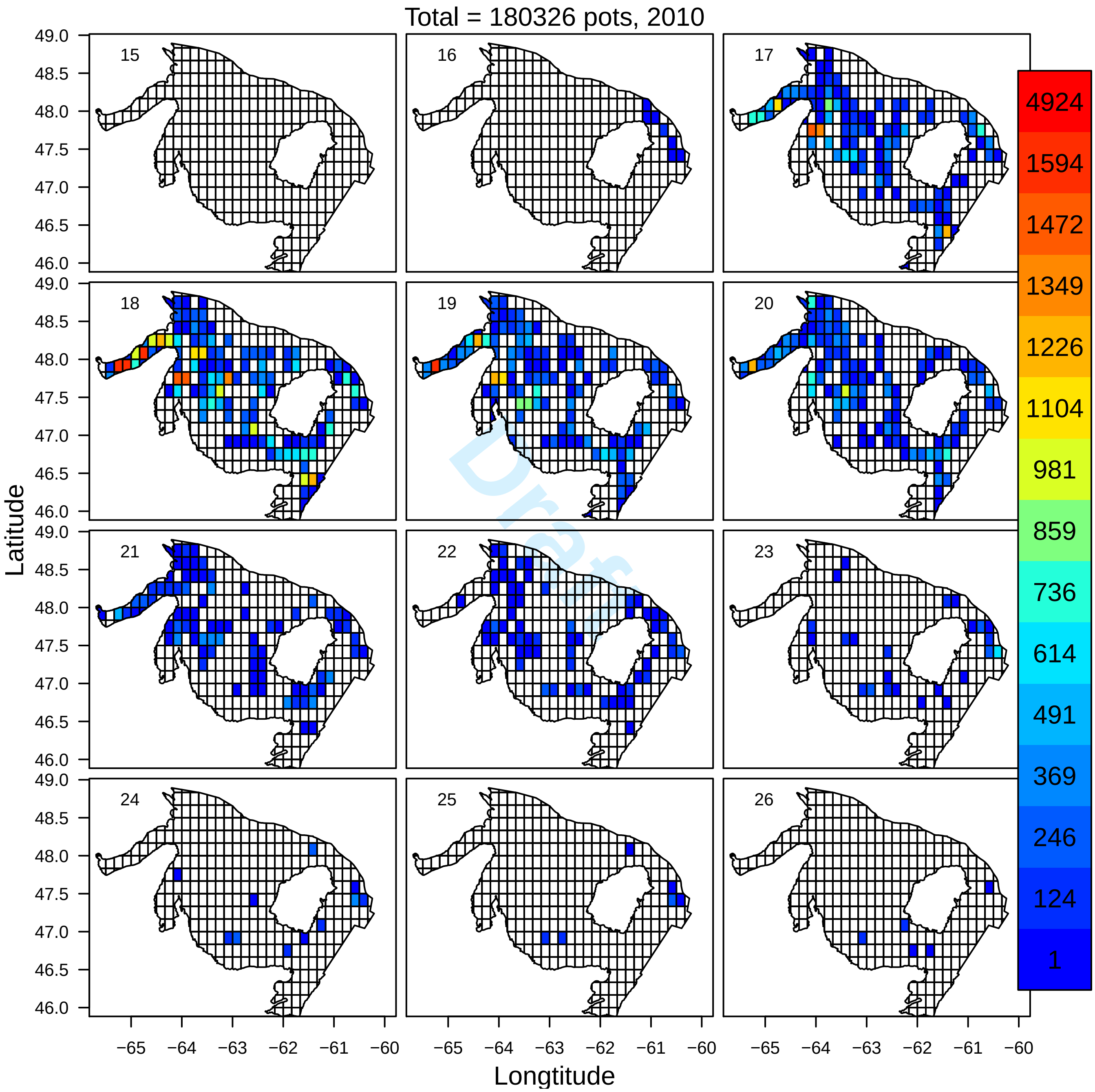


Figure SE.16b. Effort (number of pots) for snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

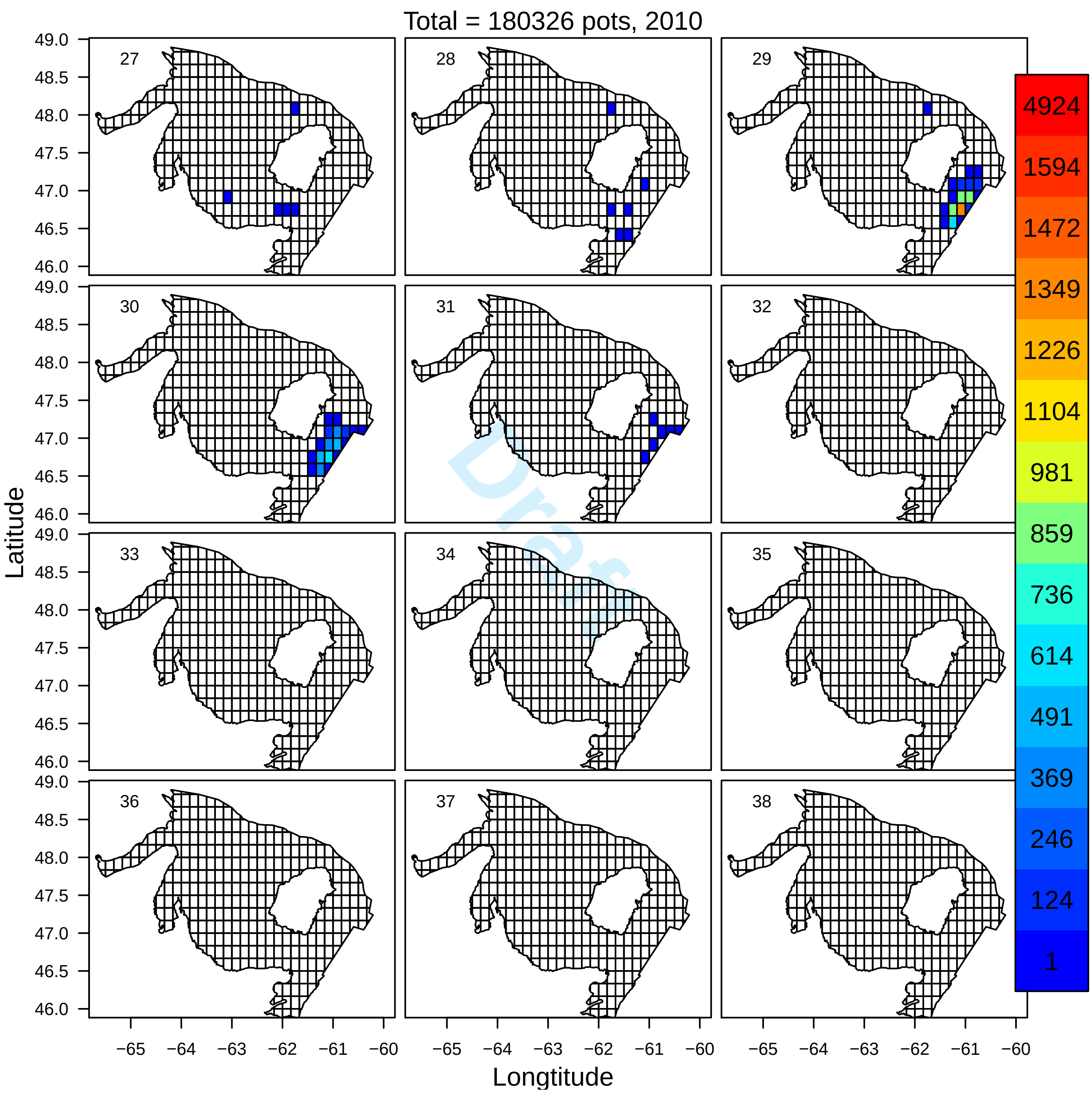


Figure SE.16c. Effort (number of pots) for snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

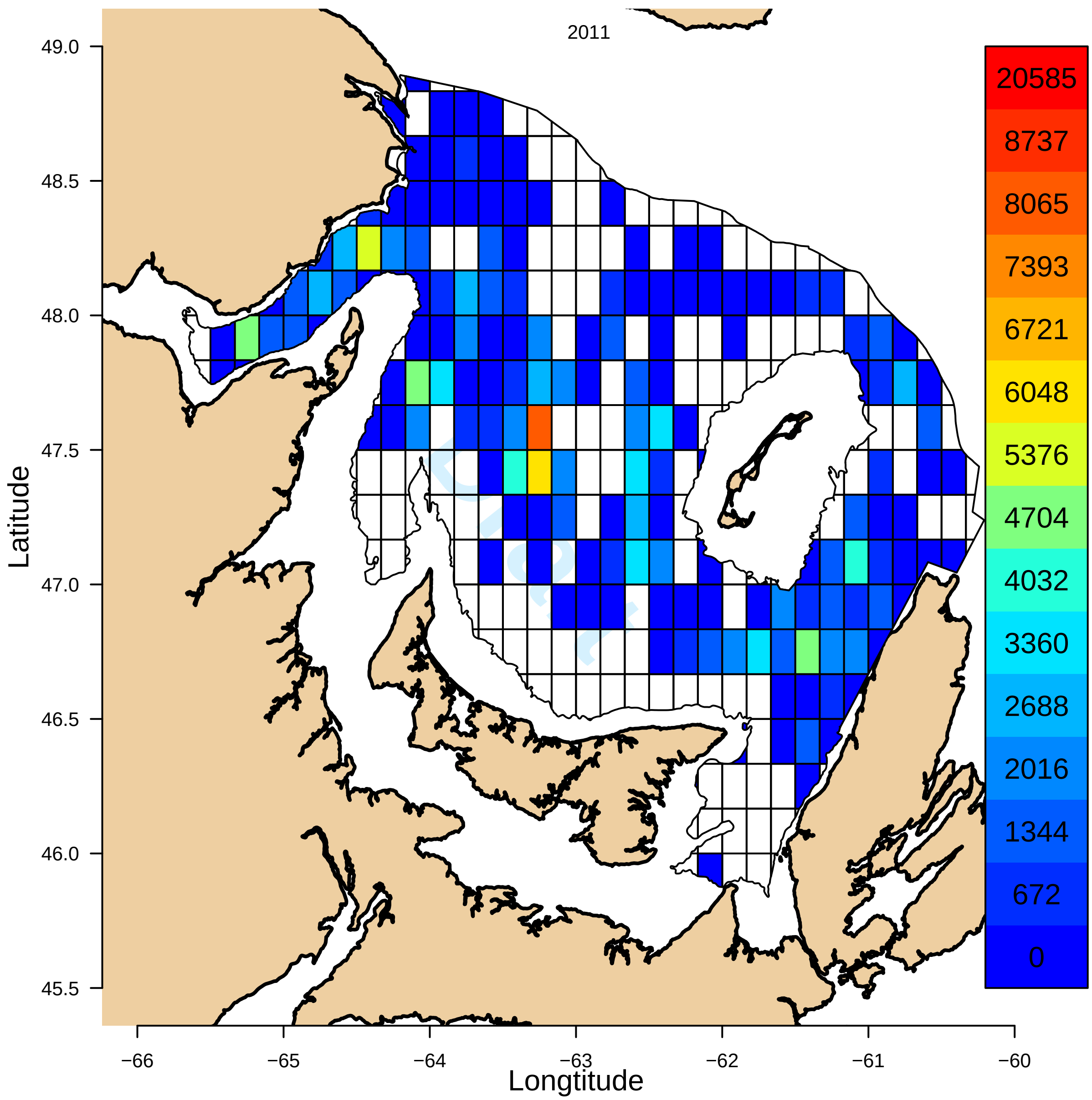


Figure SE.17a. Total annual effort (number of pots) for snow crab in each grid cell in 2011. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

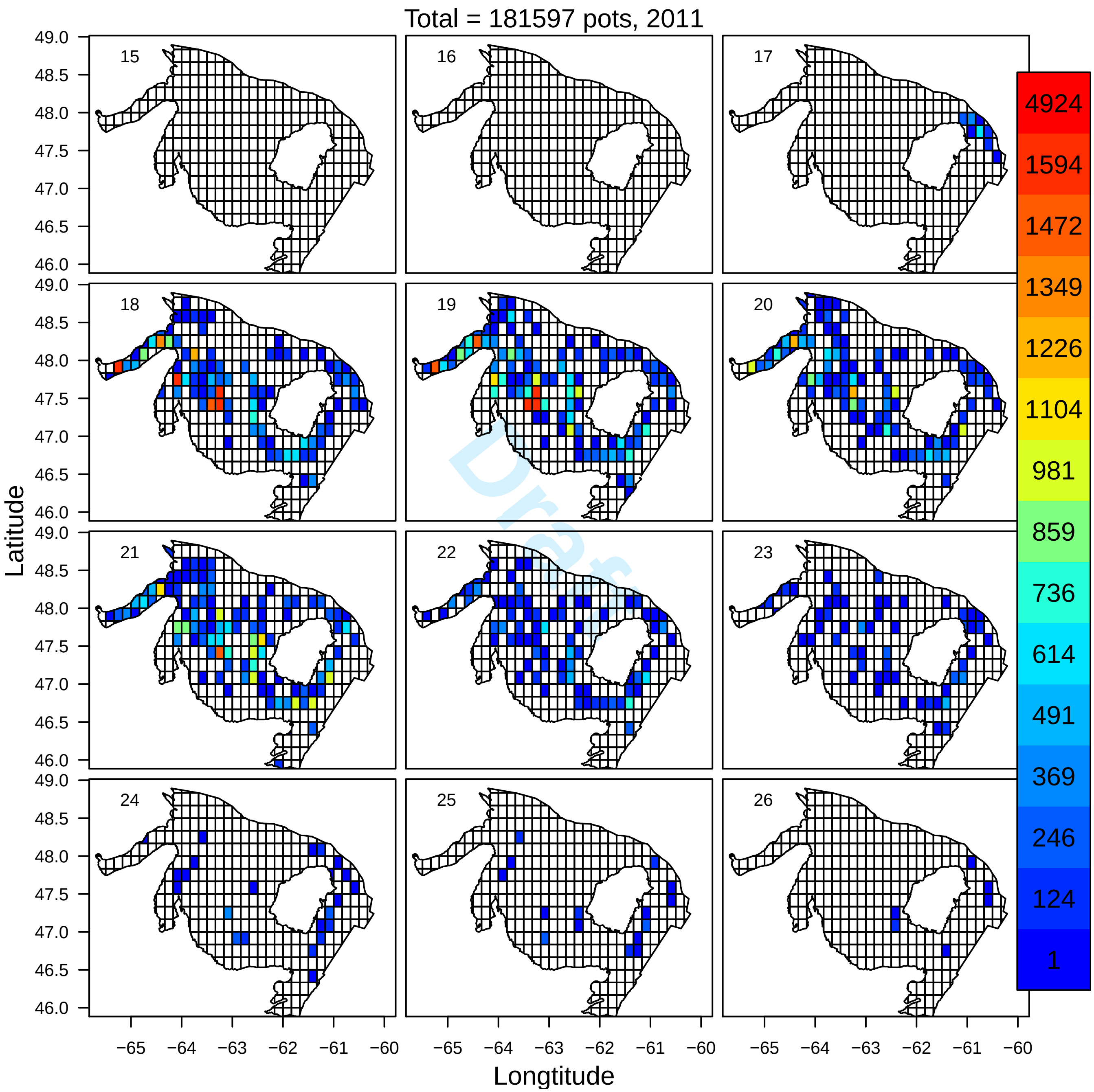


Figure SE.17b. Effort (number of pots) for snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

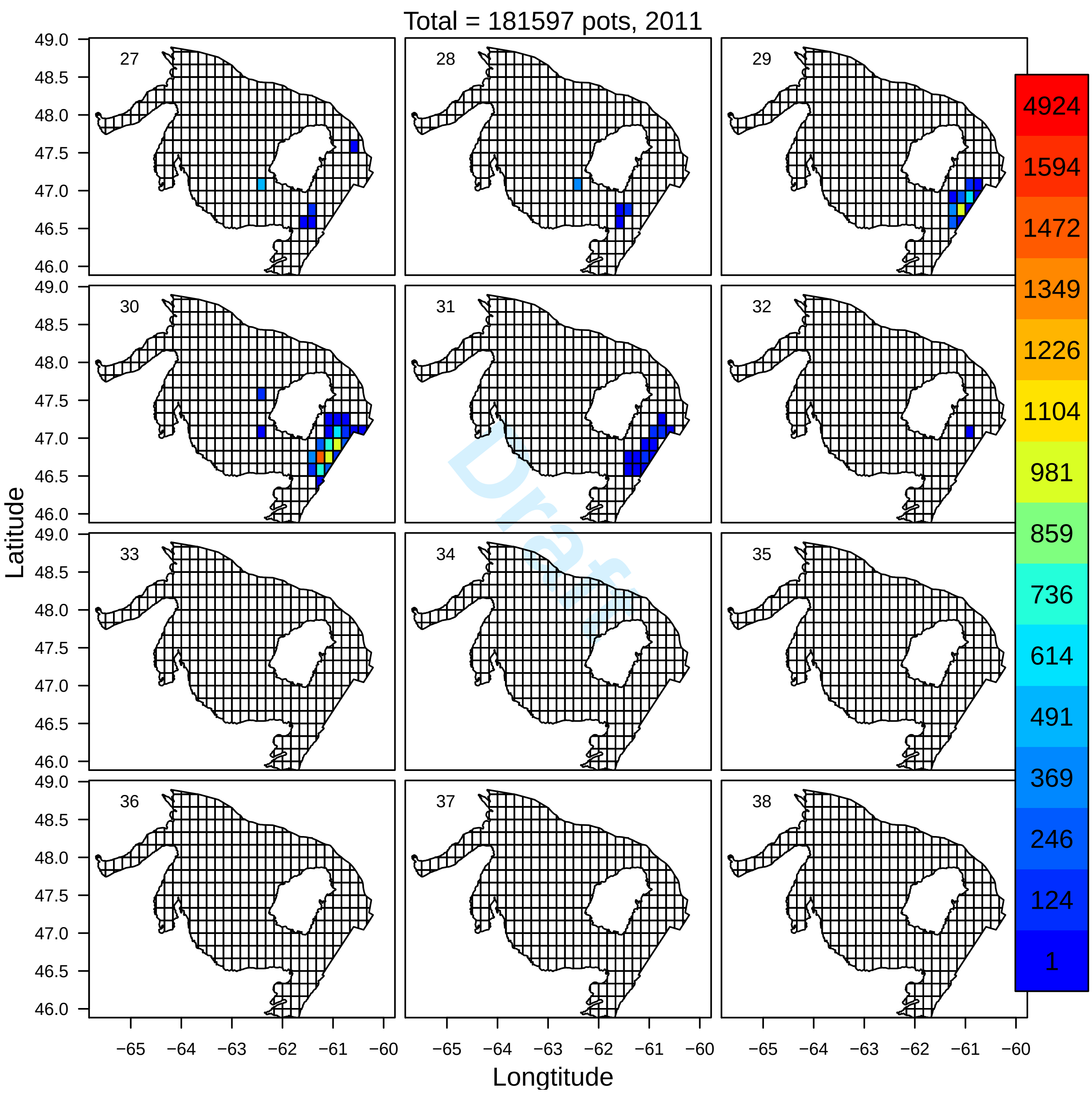


Figure SE.17c. Effort (number of pots) for snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

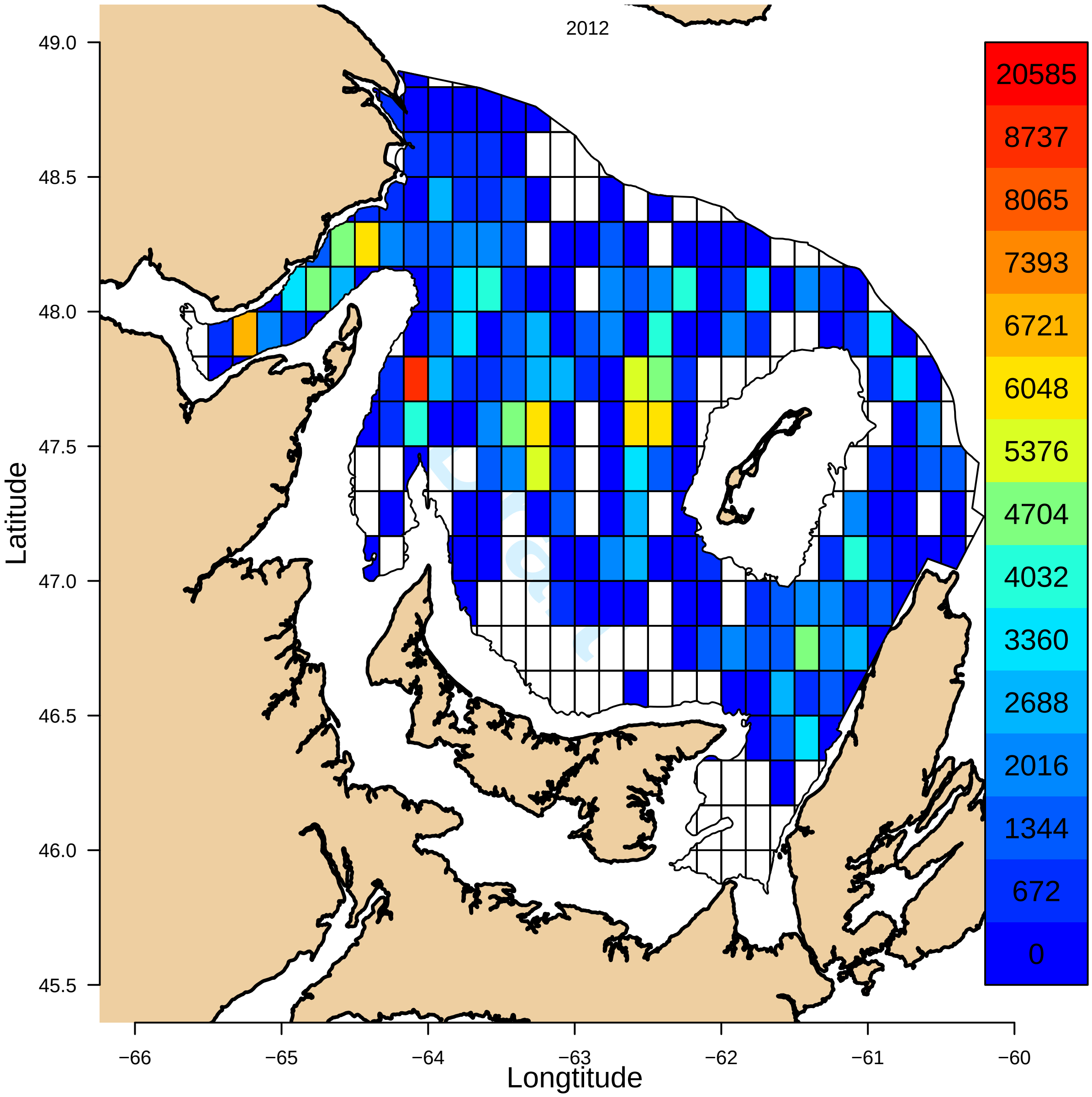


Figure SE.18a. Total annual effort (number of pots) for snow crab in each grid cell in 2012. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

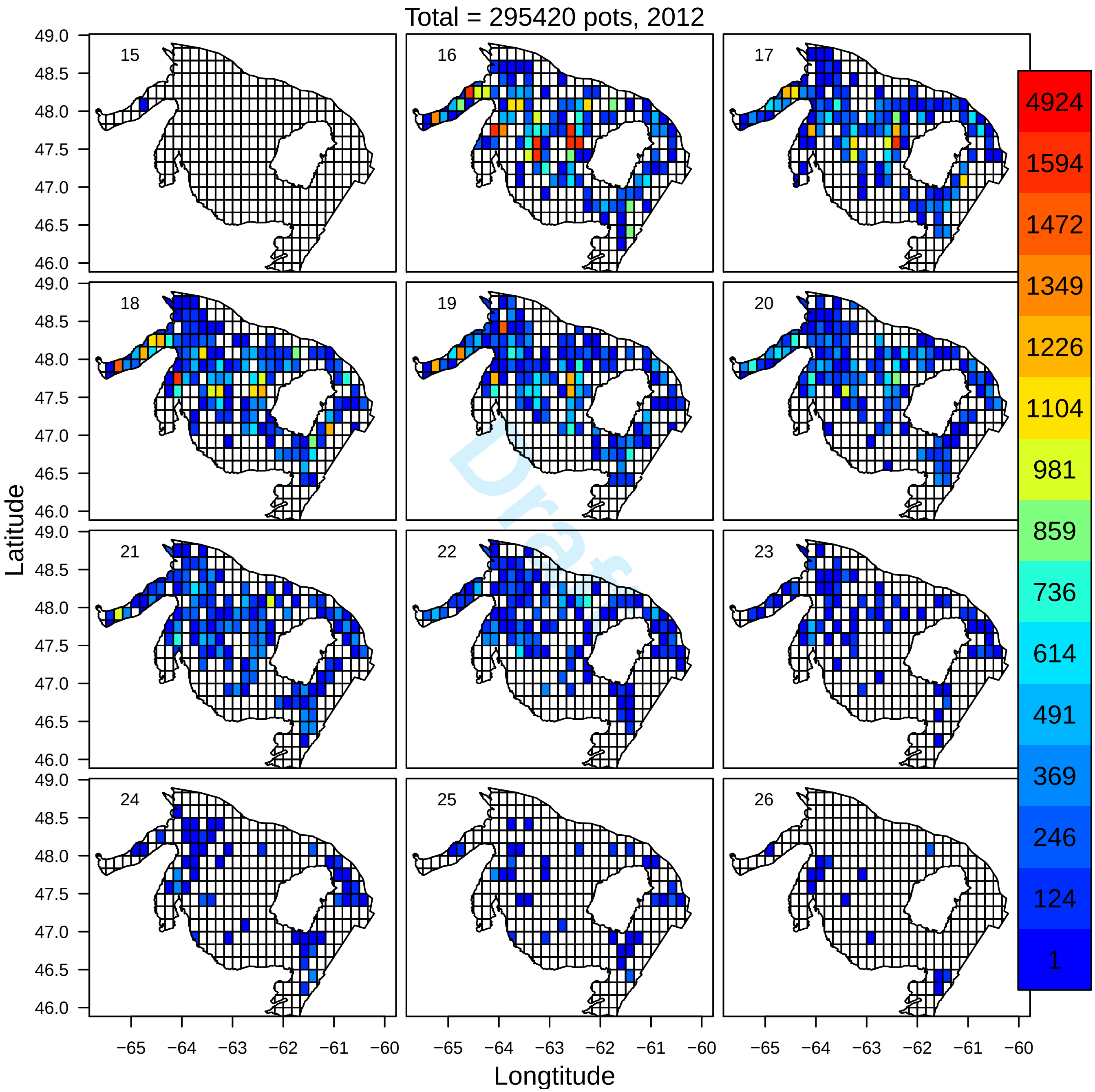


Figure SE.18b. Effort (number of pots) for snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

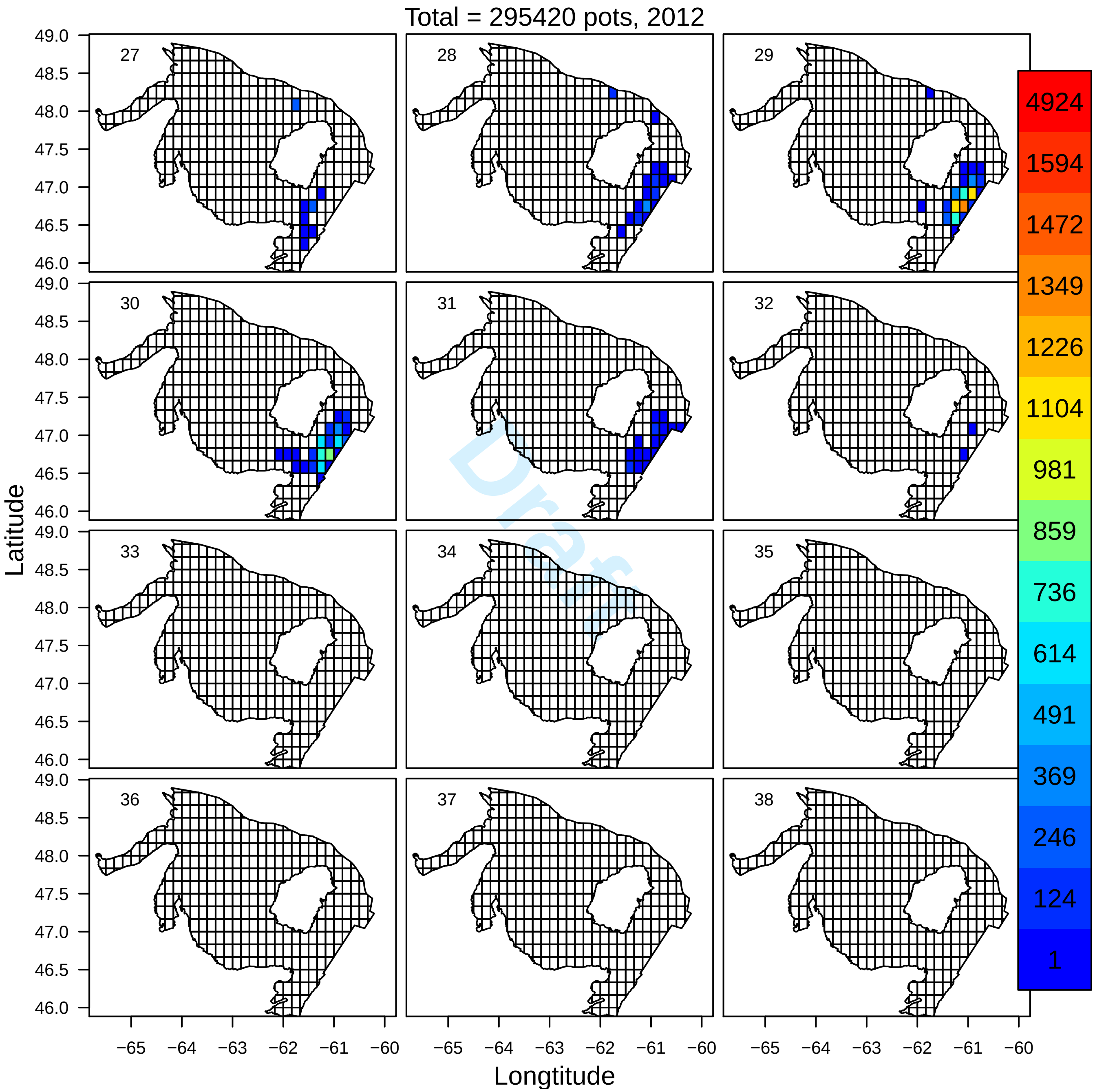


Figure SE.18c. Effort (number of pots) for snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

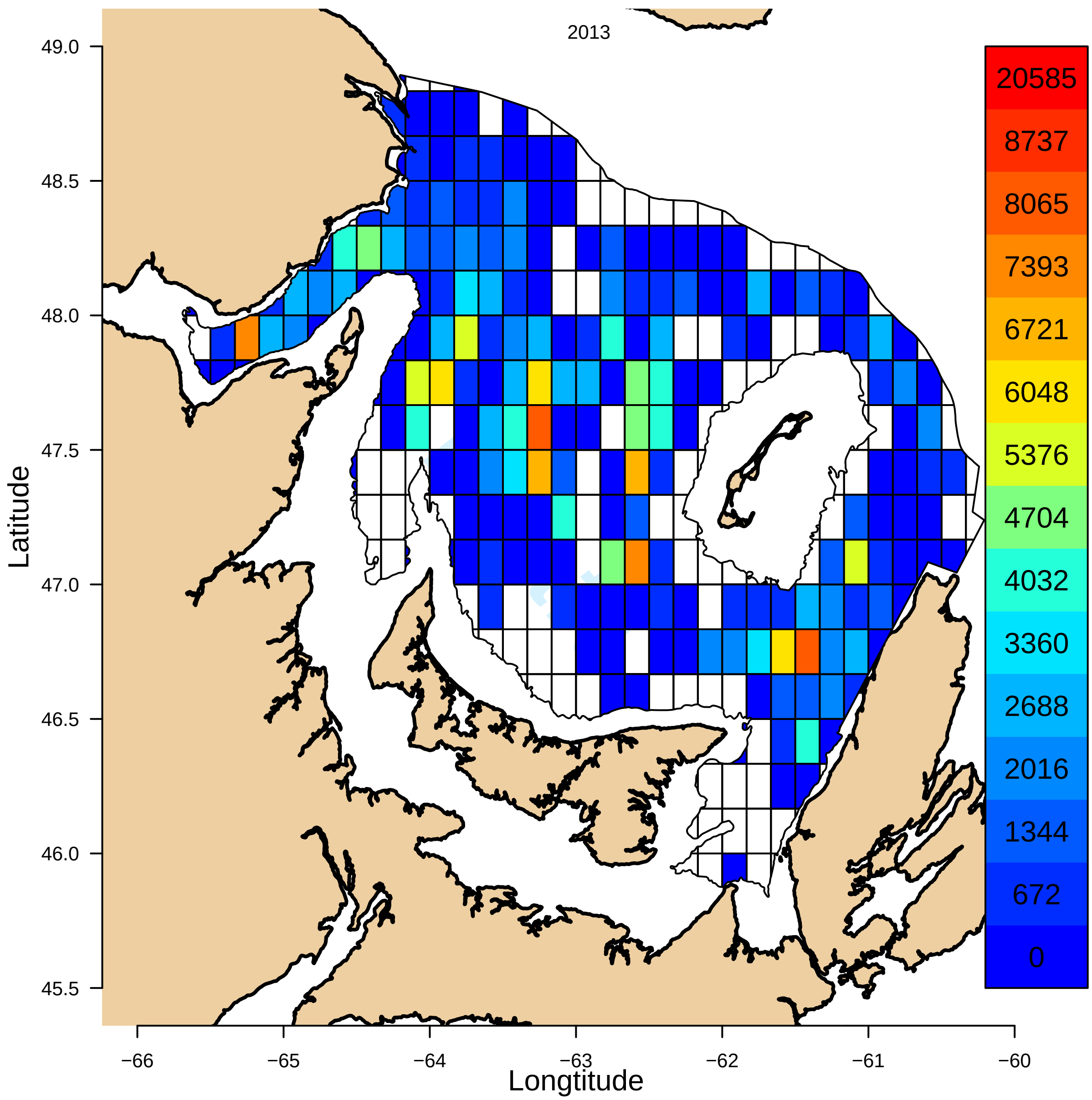


Figure SE.19a. Total annual effort (number of pots) for snow crab in each grid cell in 2013. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

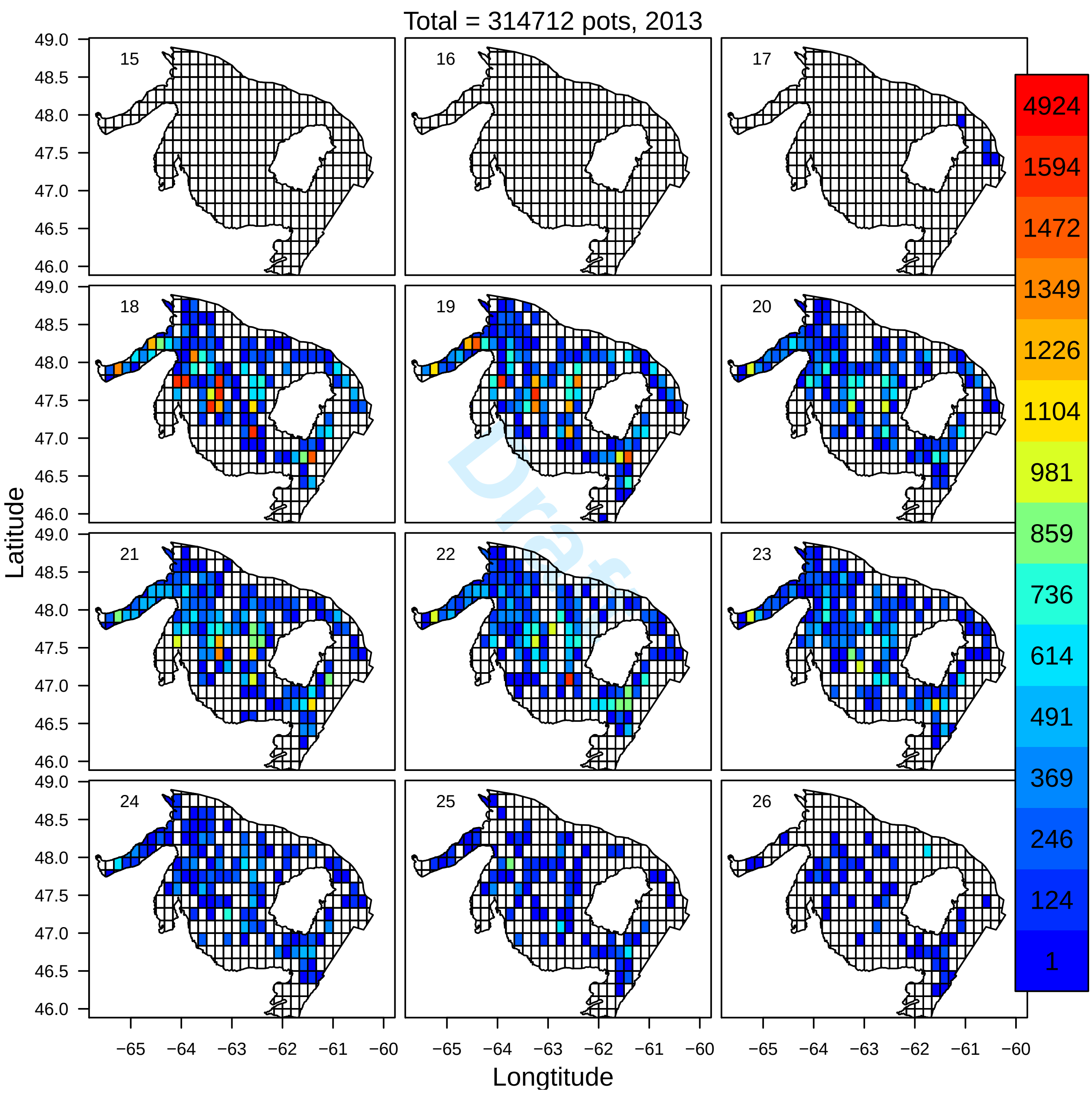


Figure SE.19b. Effort (number of pots) for snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

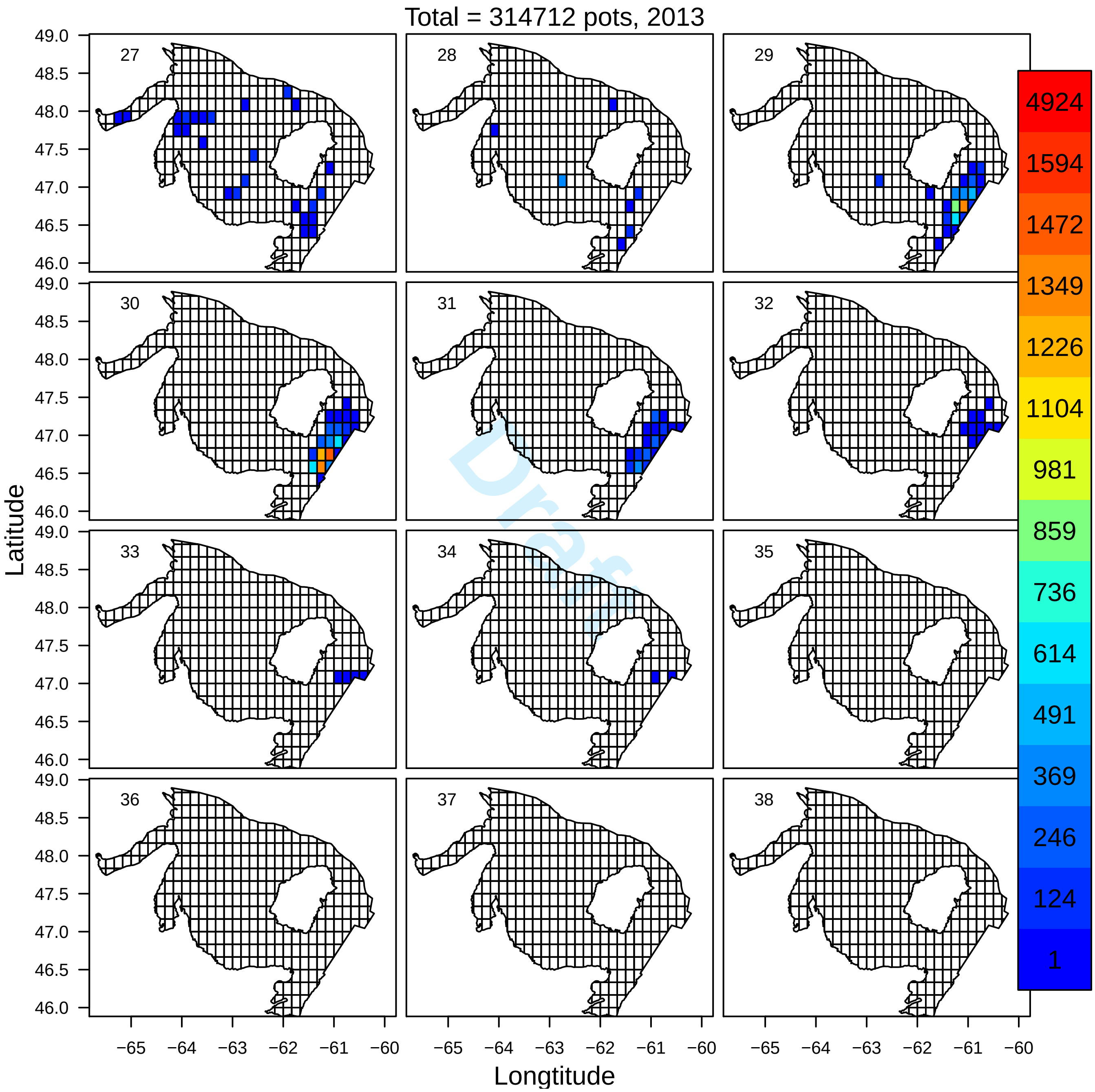


Figure SE.19c. Effort (number of pots) for snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

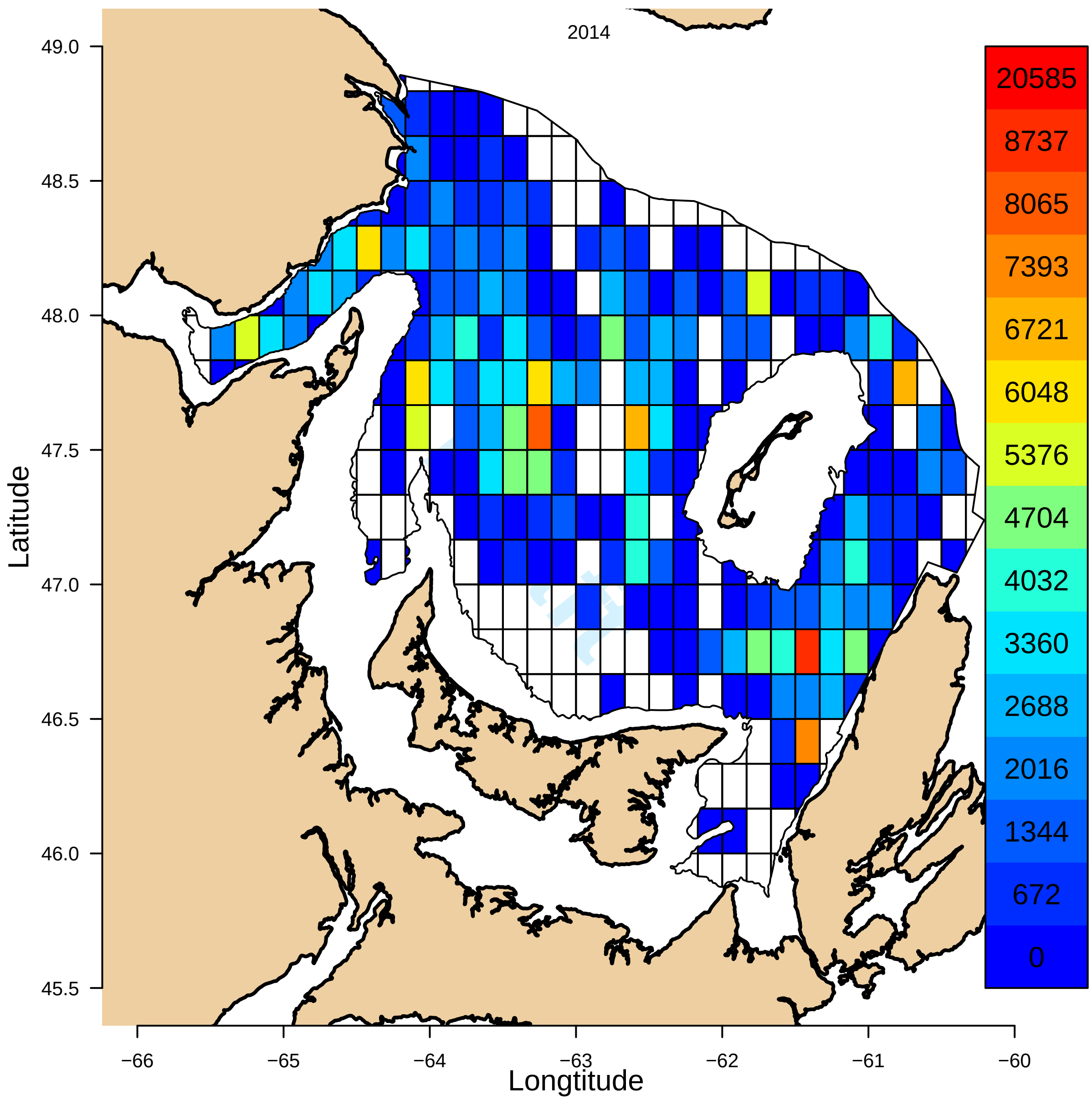


Figure SE.20a. Total annual effort (number of pots) for snow crab in each grid cell in 2014. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

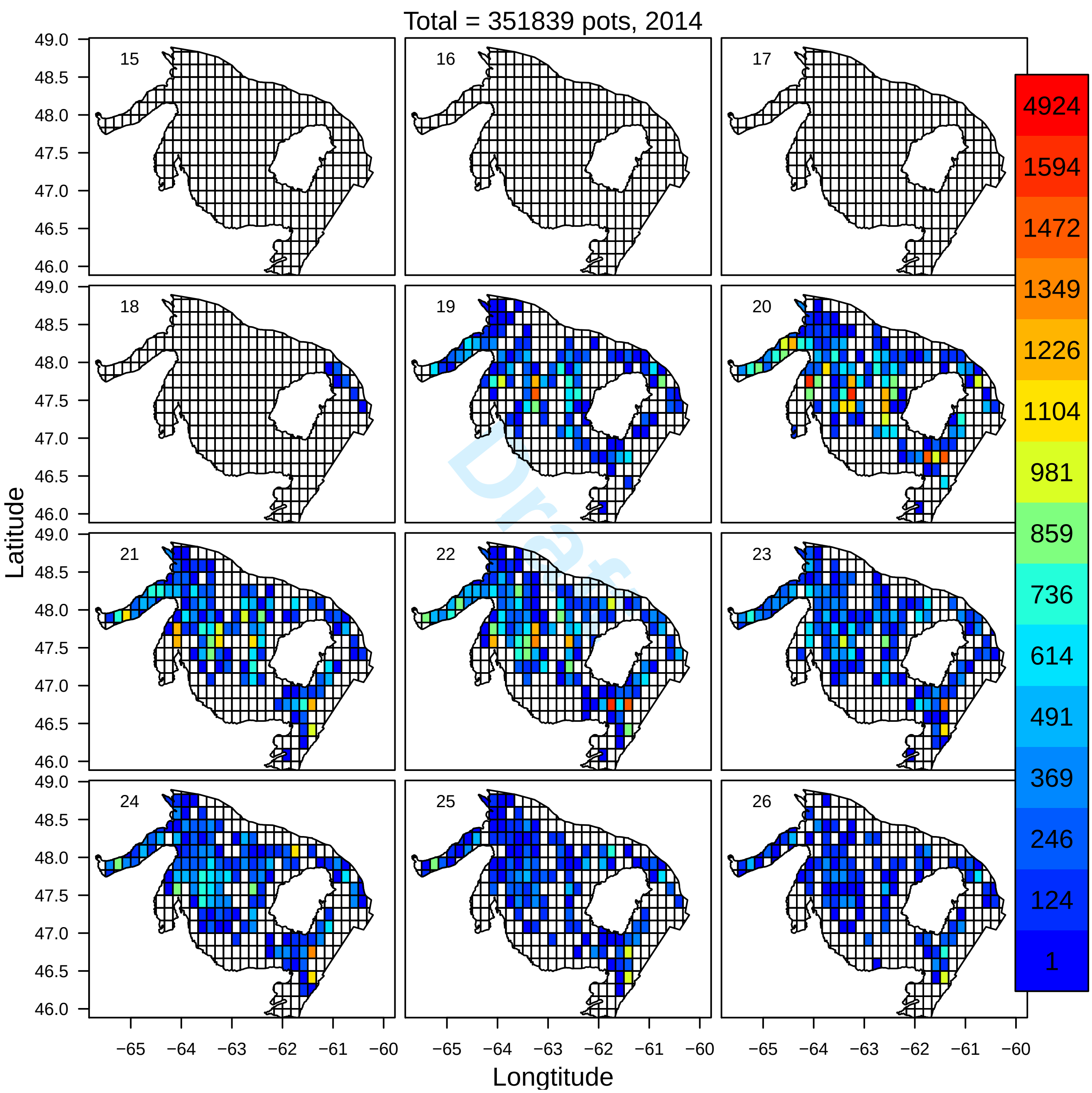


Figure SE.20b. Effort (number of pots) for snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

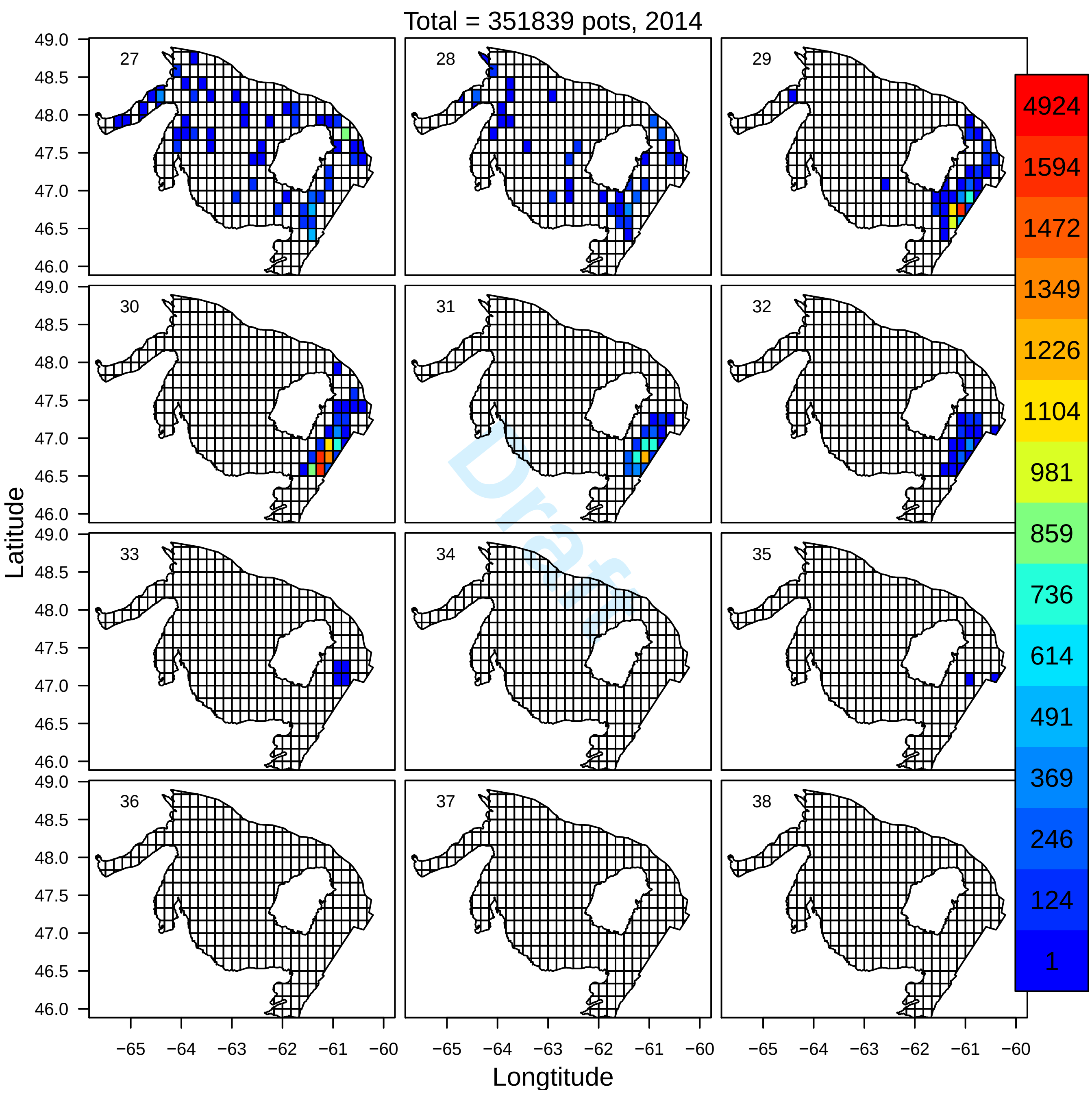


Figure SE.20c. Effort (number of pots) for snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to effort levels, as indicated in the legend on the right-hand side. Darkest red grids indicate effort > 98th percentile.

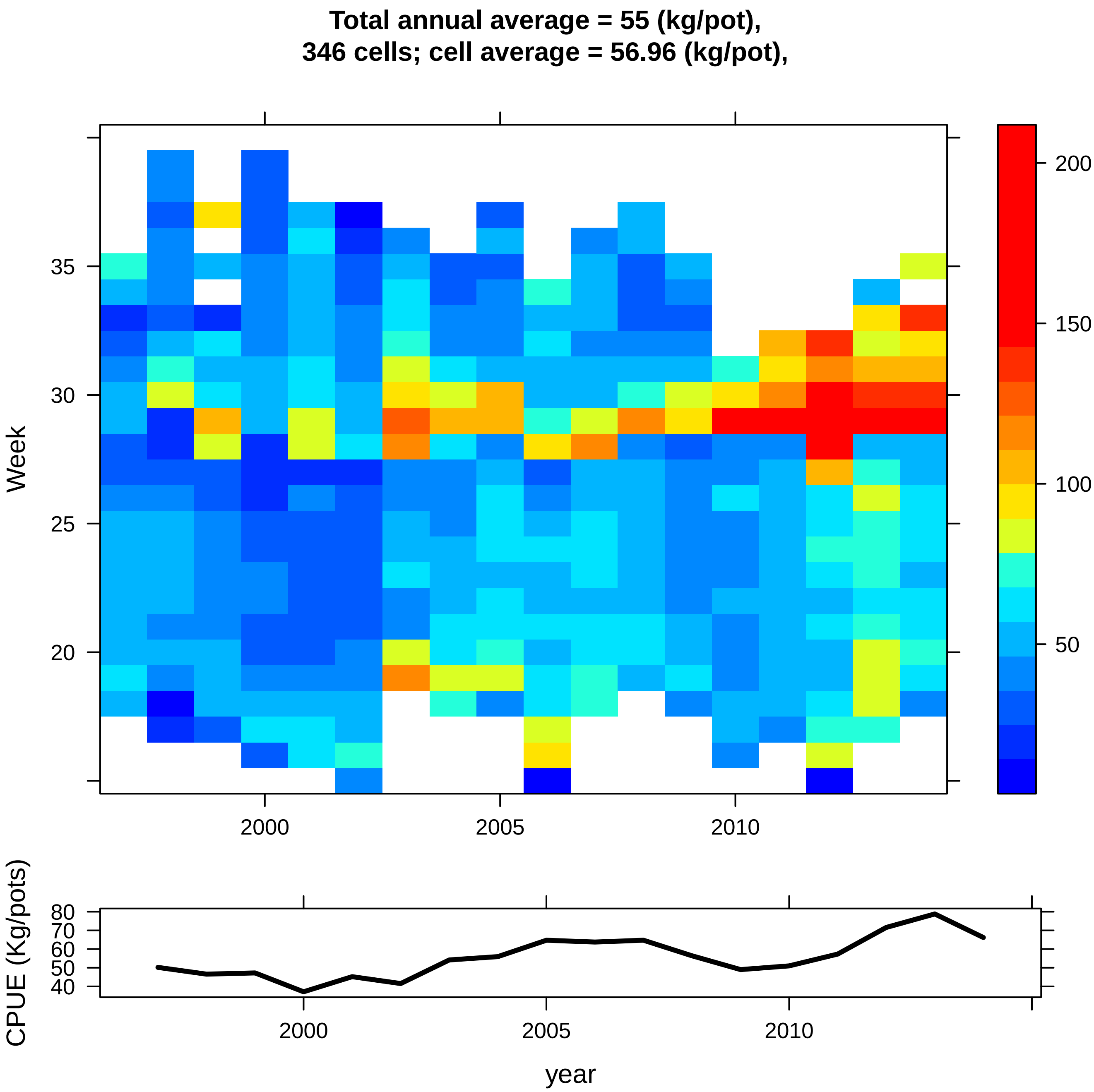


Figure SX.1. Top panel: Total CPUE of snow crab each week (rows) and year (columns). Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile. Bottom panel: Total CPUE each year for all weeks.

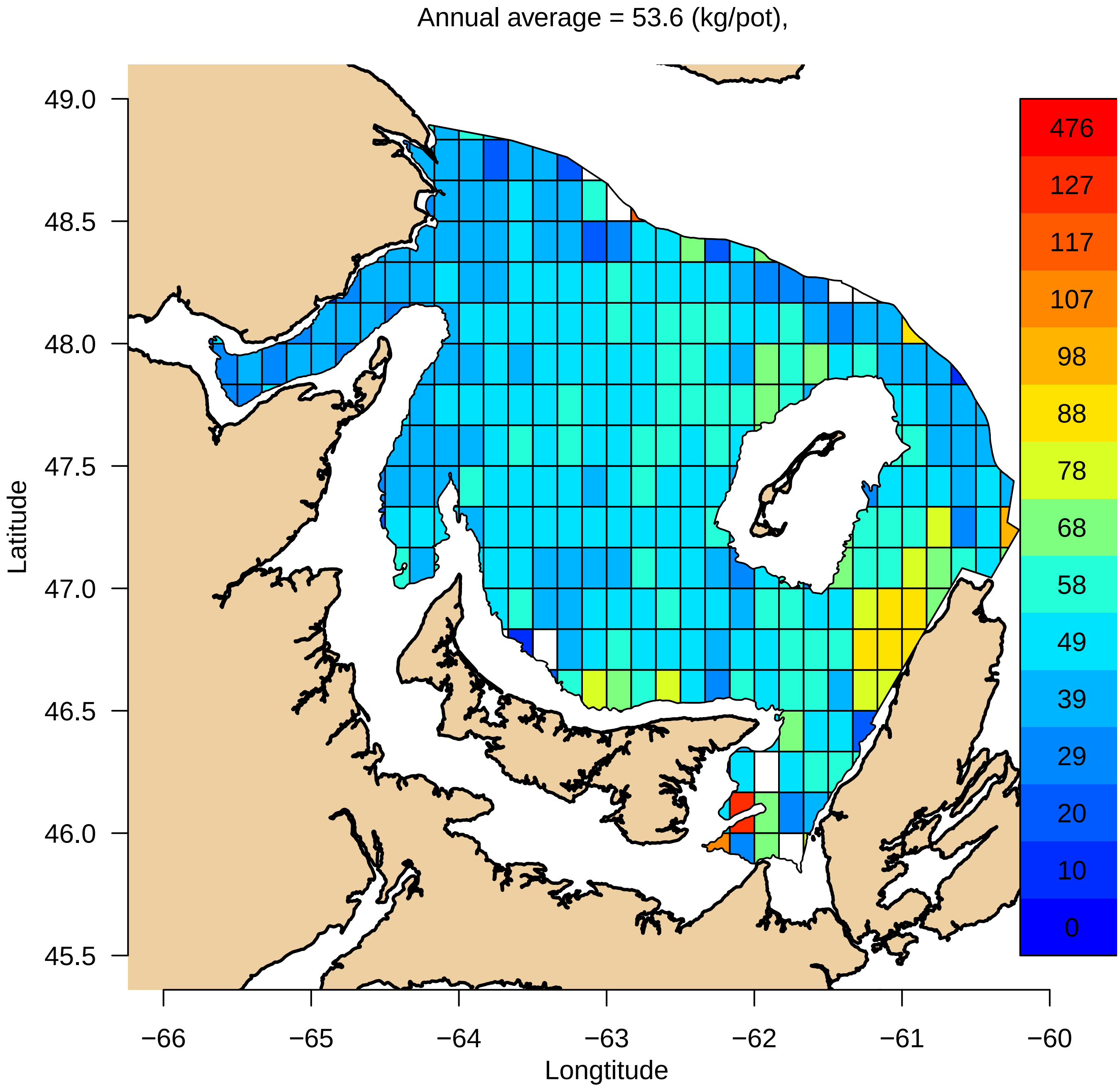


Figure SX.2. Total annual CPUE of snow crab in each grid cell, averaged for 1997-2014. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

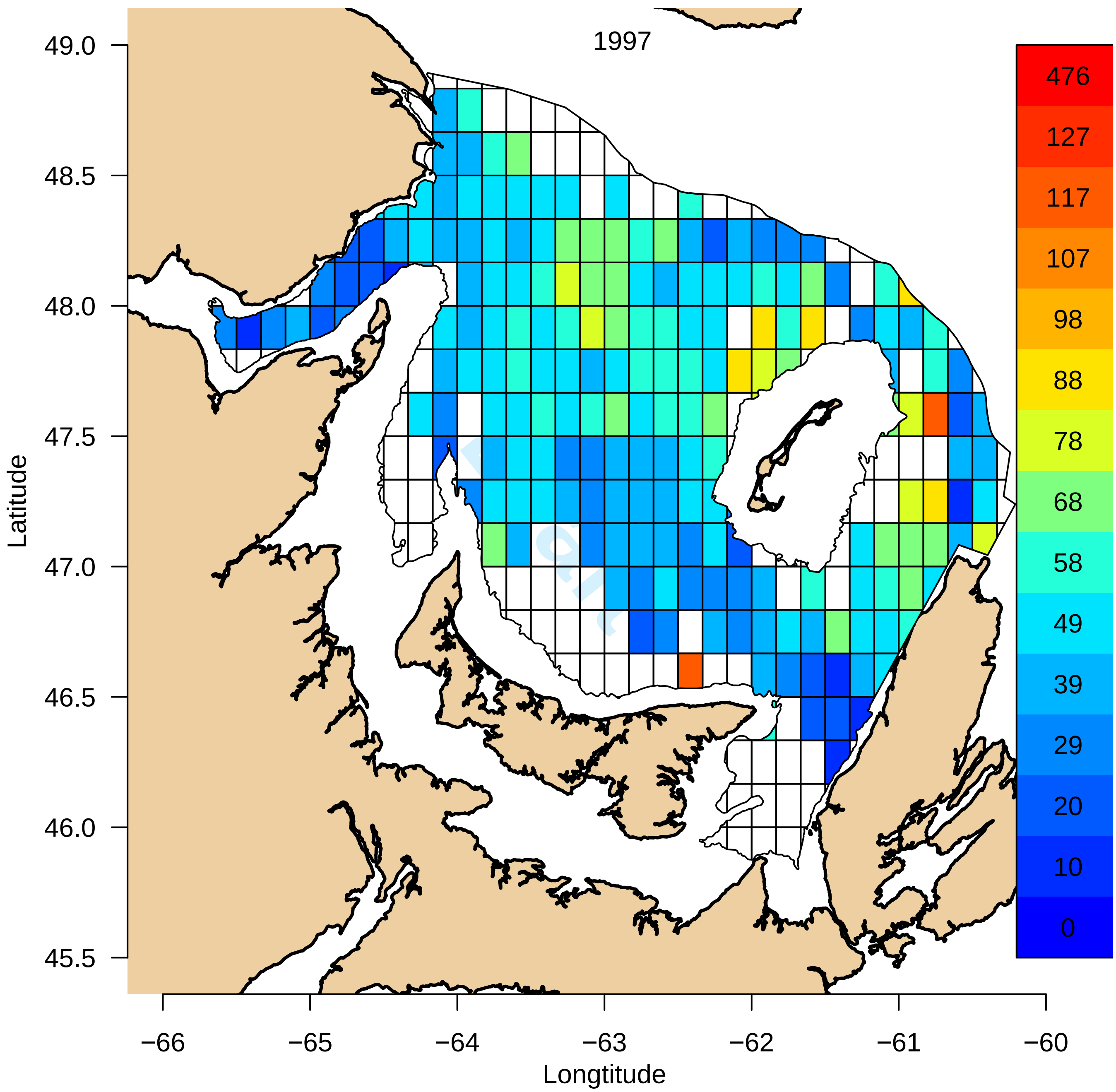


Figure SX.3a. Total annual CPUE of snow crab in each grid cell in 1997. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

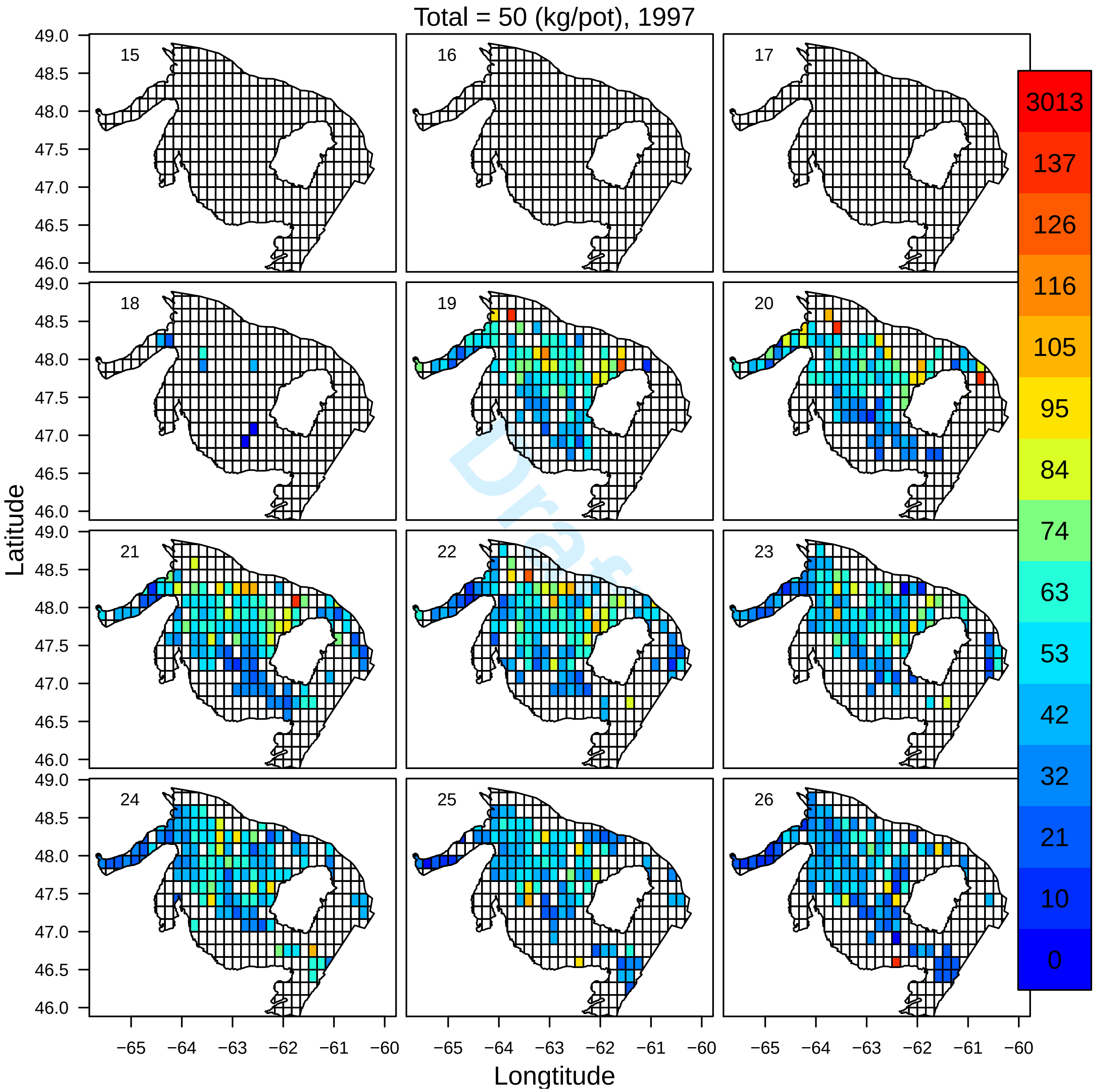


Figure SX.3b. CPUE of snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

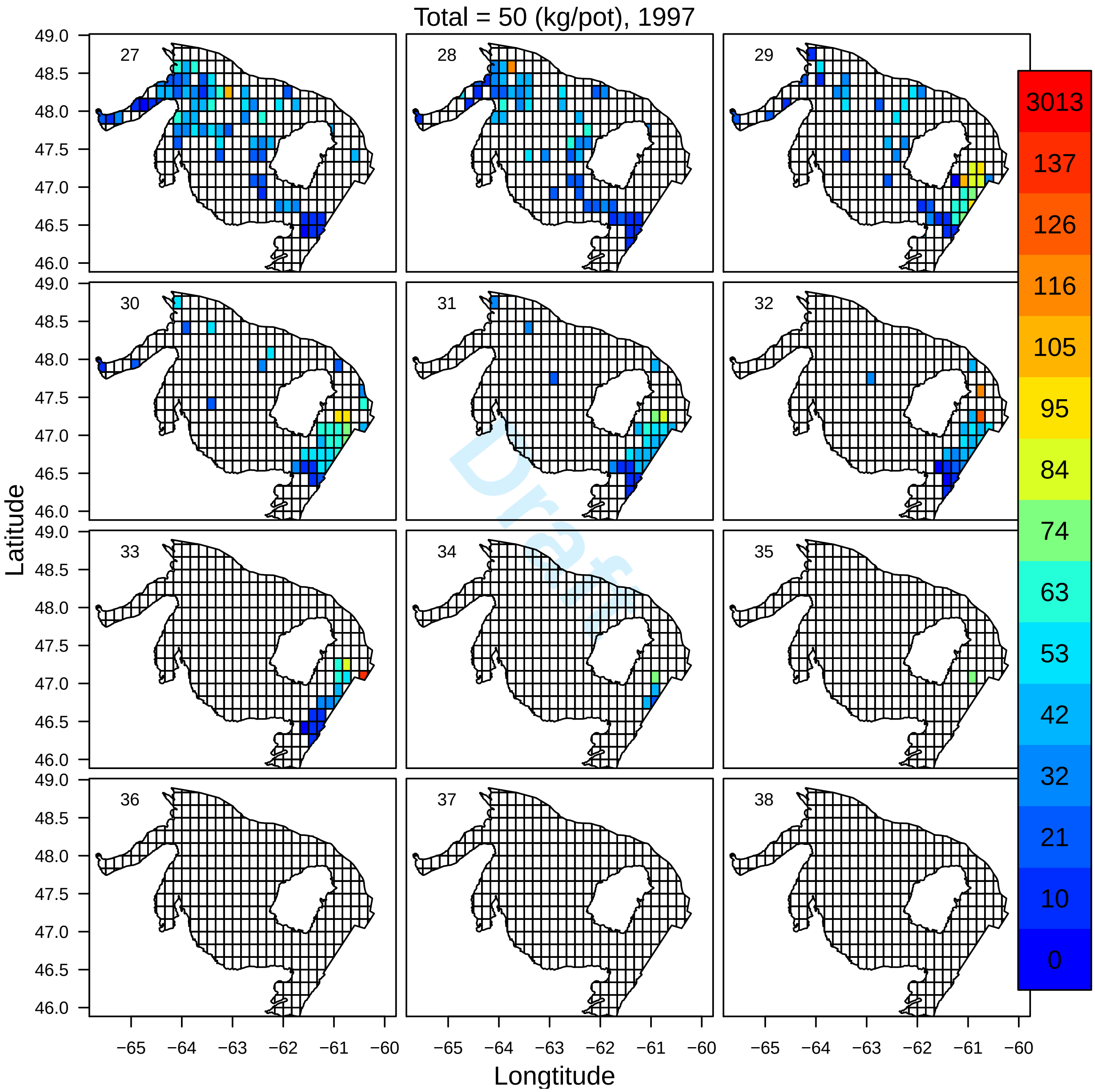


Figure SX.3c. CPUE of snow crab in each week and grid cell in 1997. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

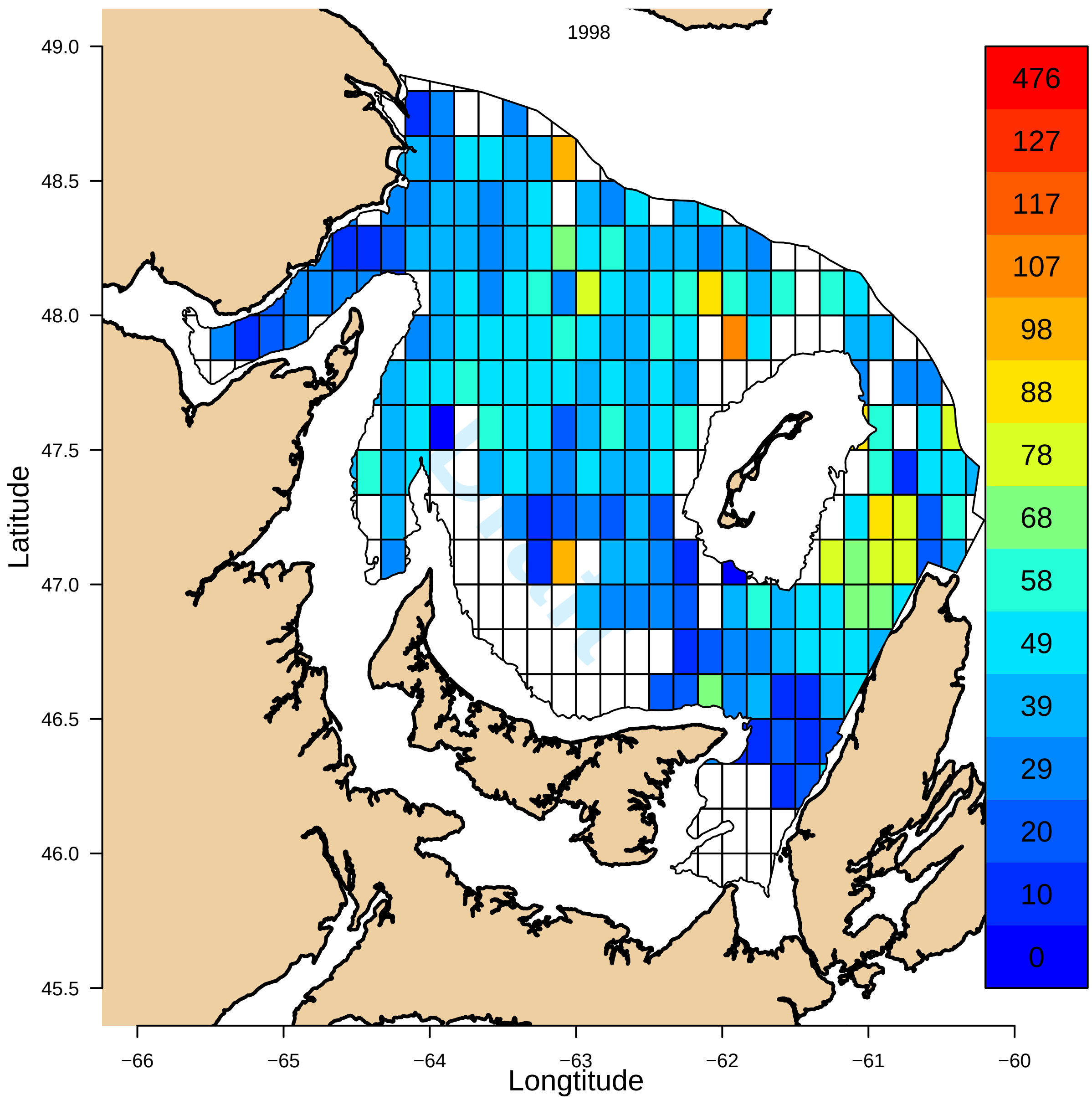


Figure SX.4a. Total annual CPUE of snow crab in each grid cell in 1998. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

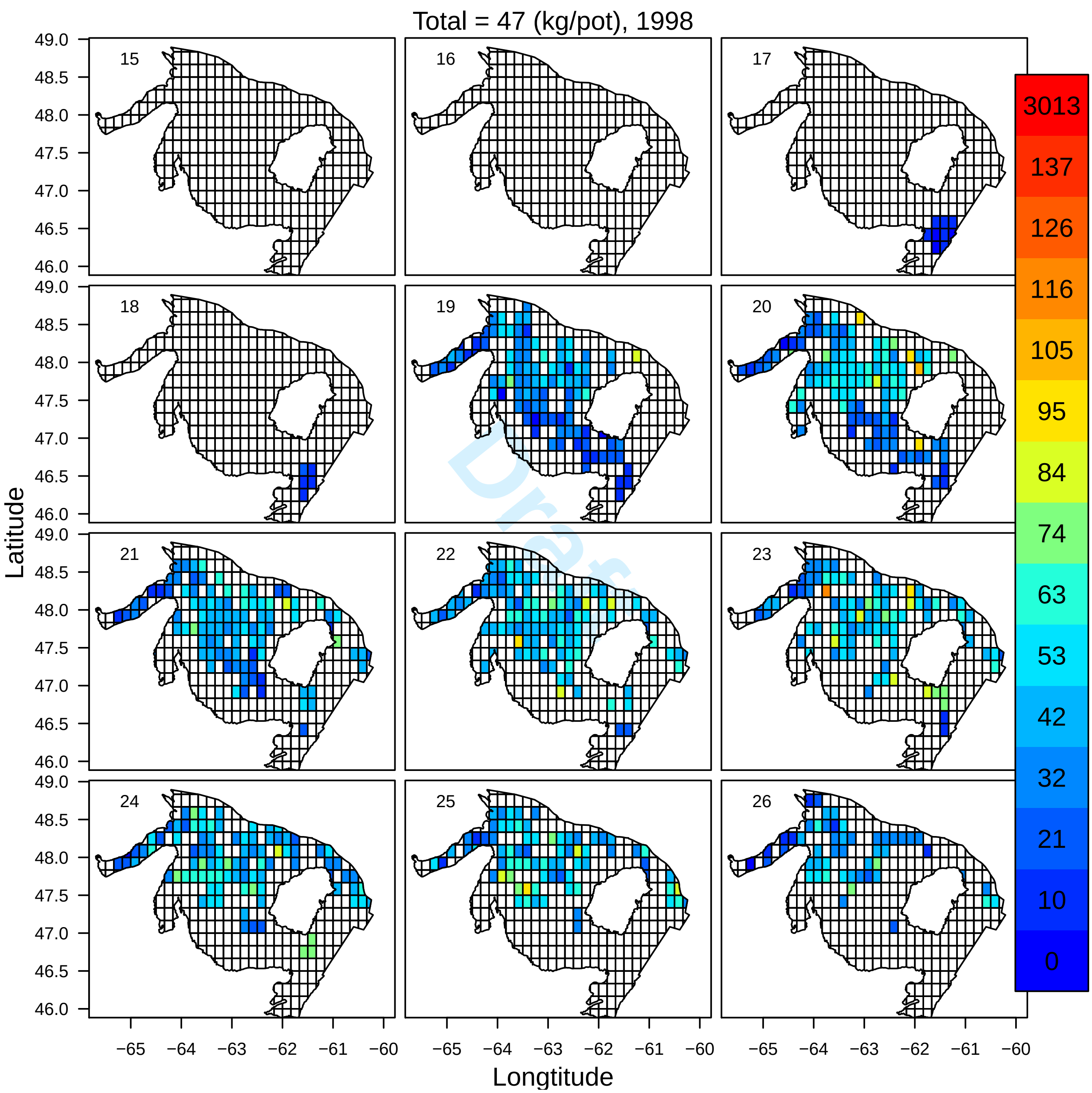


Figure SX.4b. CPUE of snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

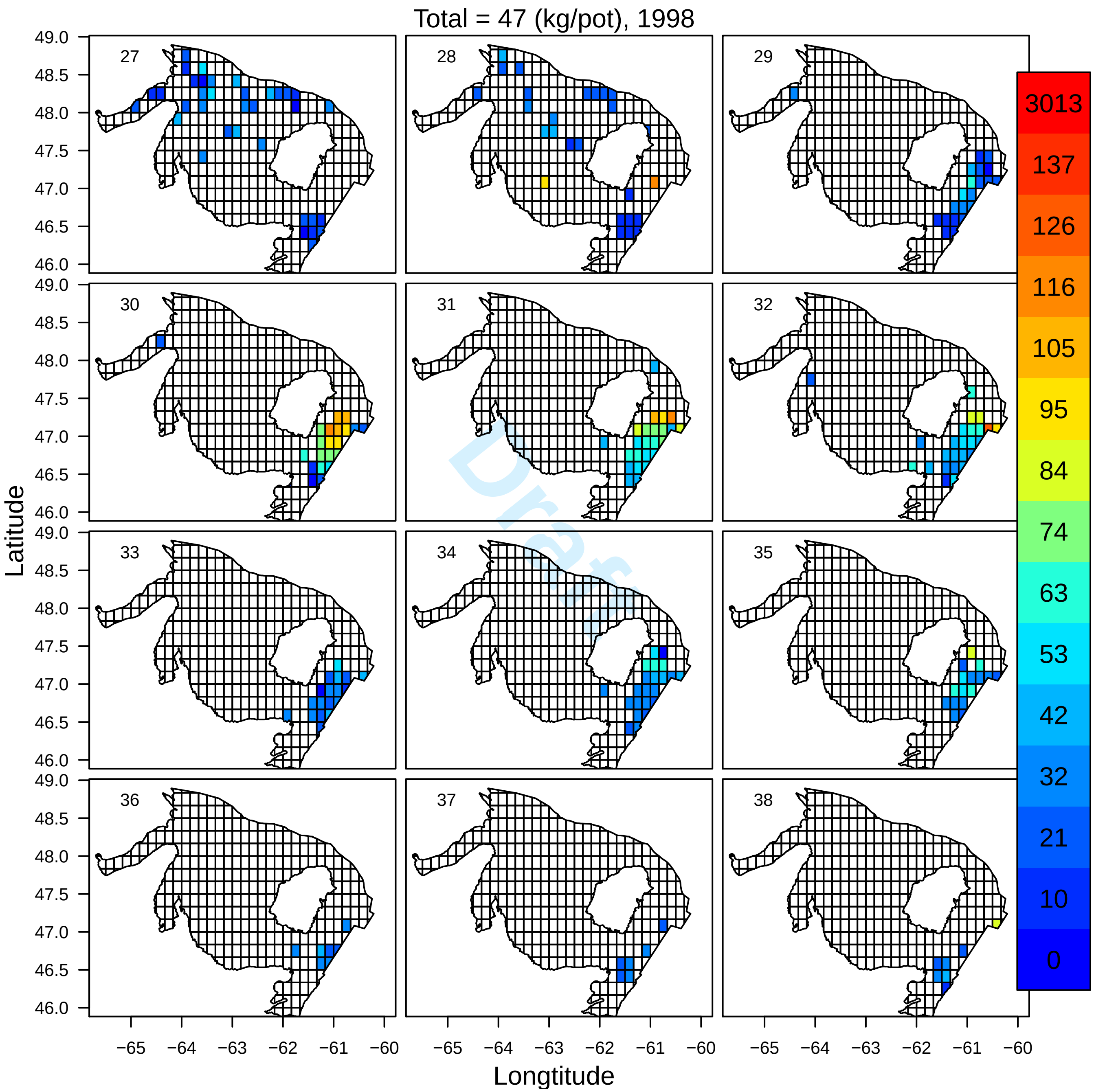


Figure SX.4c. CPUE of snow crab in each week and grid cell in 1998. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

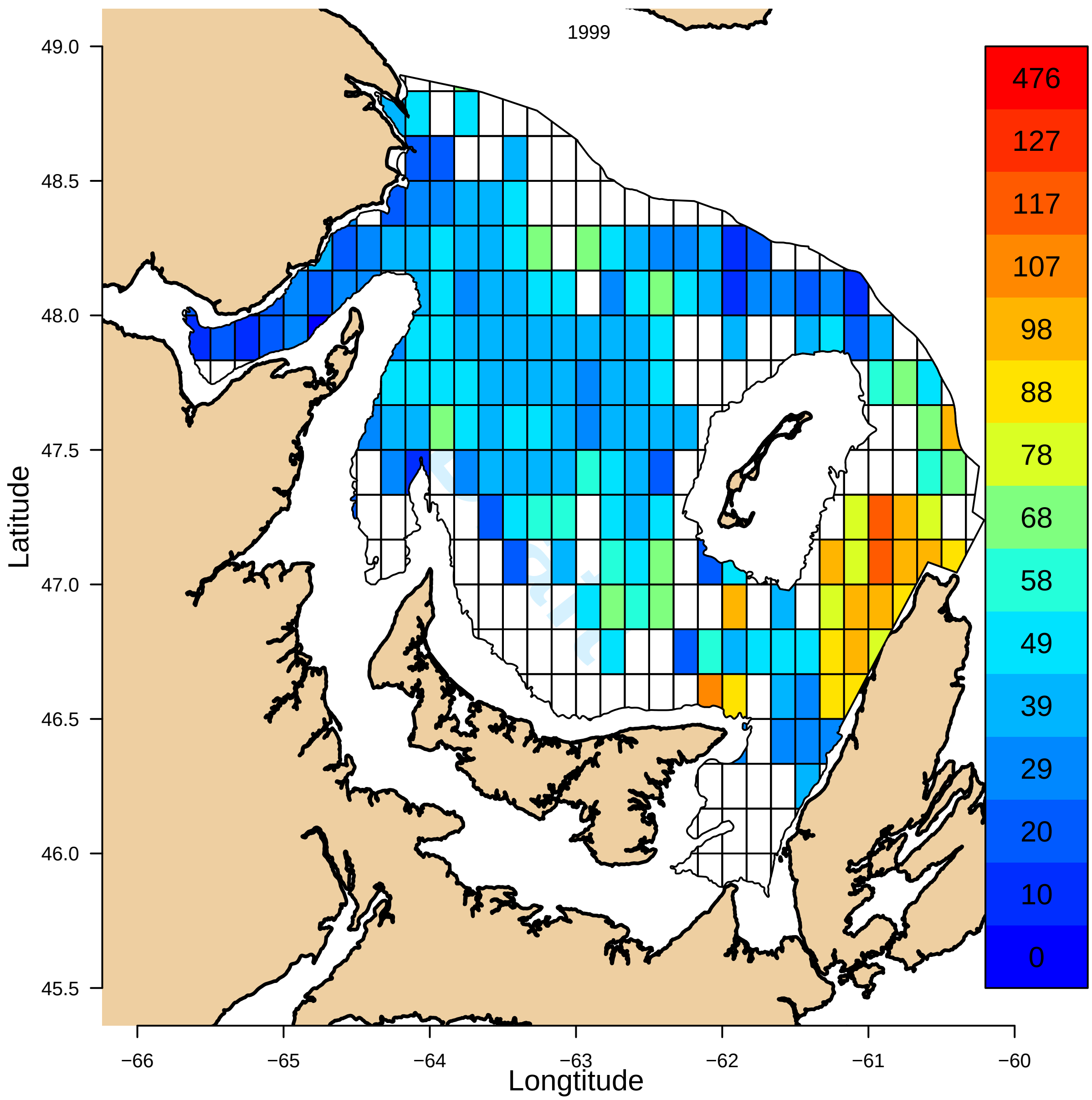


Figure SX.5a. Total annual CPUE of snow crab in each grid cell in 1999. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

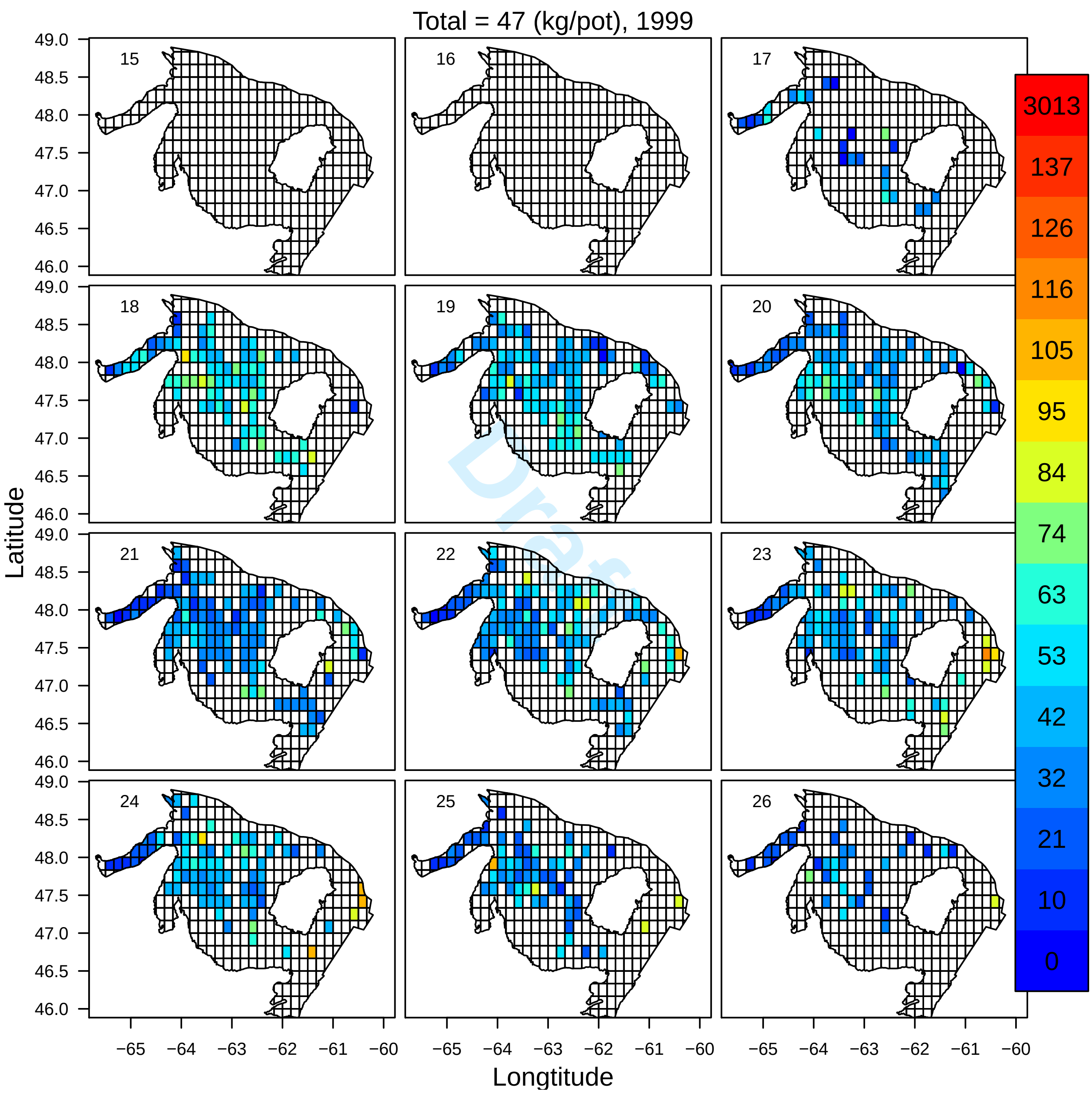


Figure SX.5b. CPUE of snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

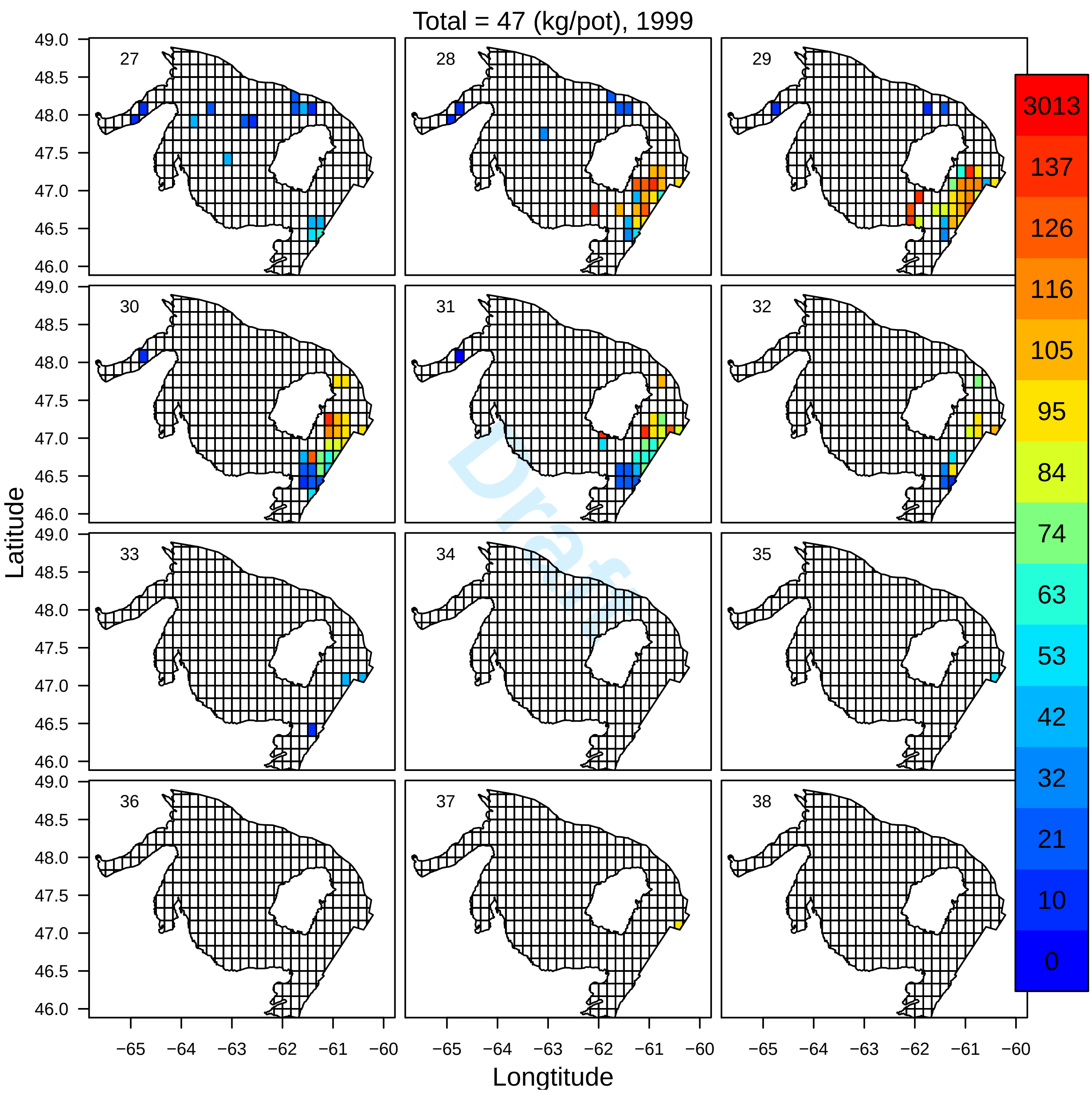


Figure SX.5c. CPUE of snow crab in each week and grid cell in 1999. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

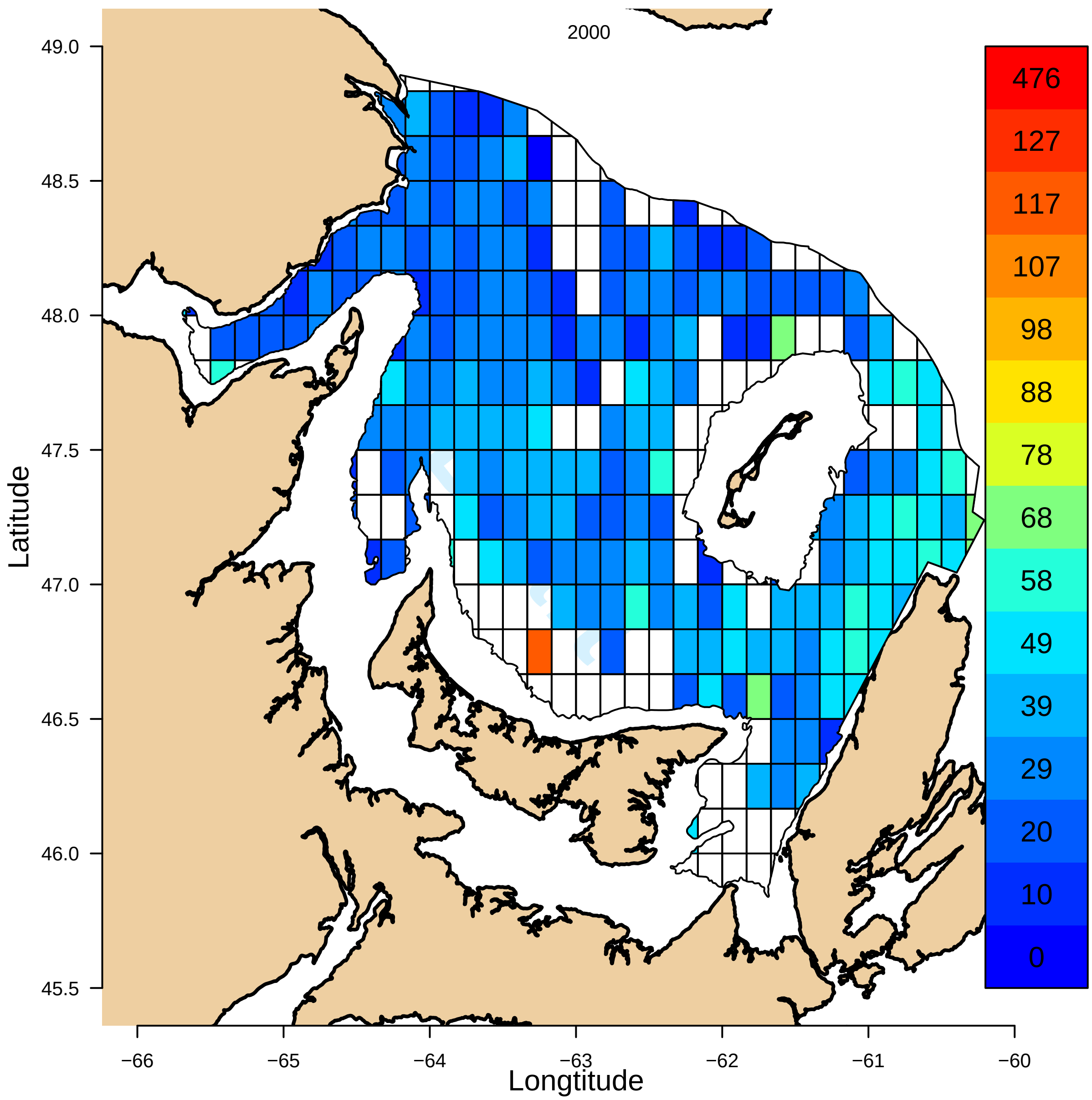


Figure SX.6a. Total annual CPUE of snow crab in each grid cell in 2000. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

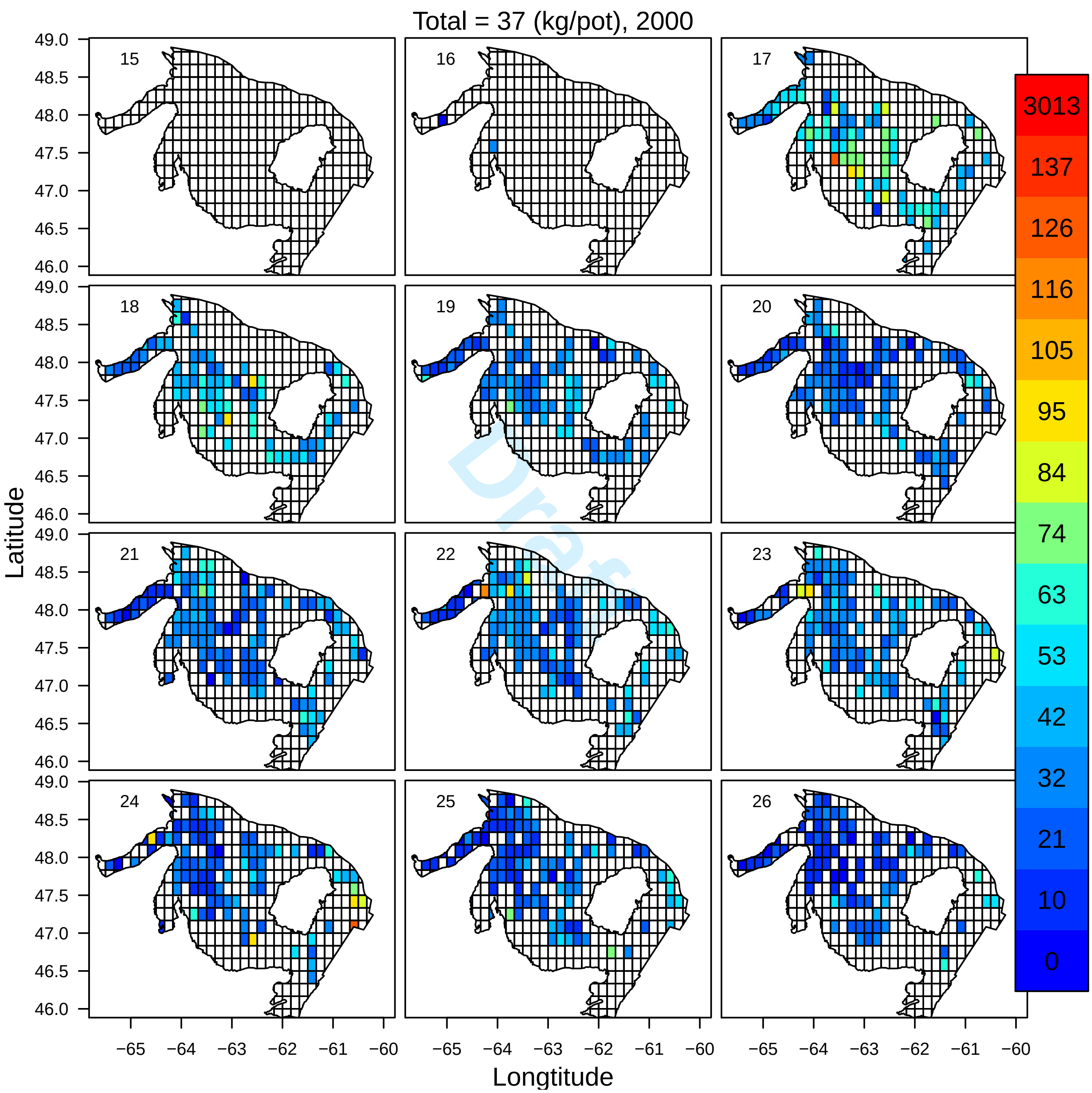


Figure SX.6b. CPUE of snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

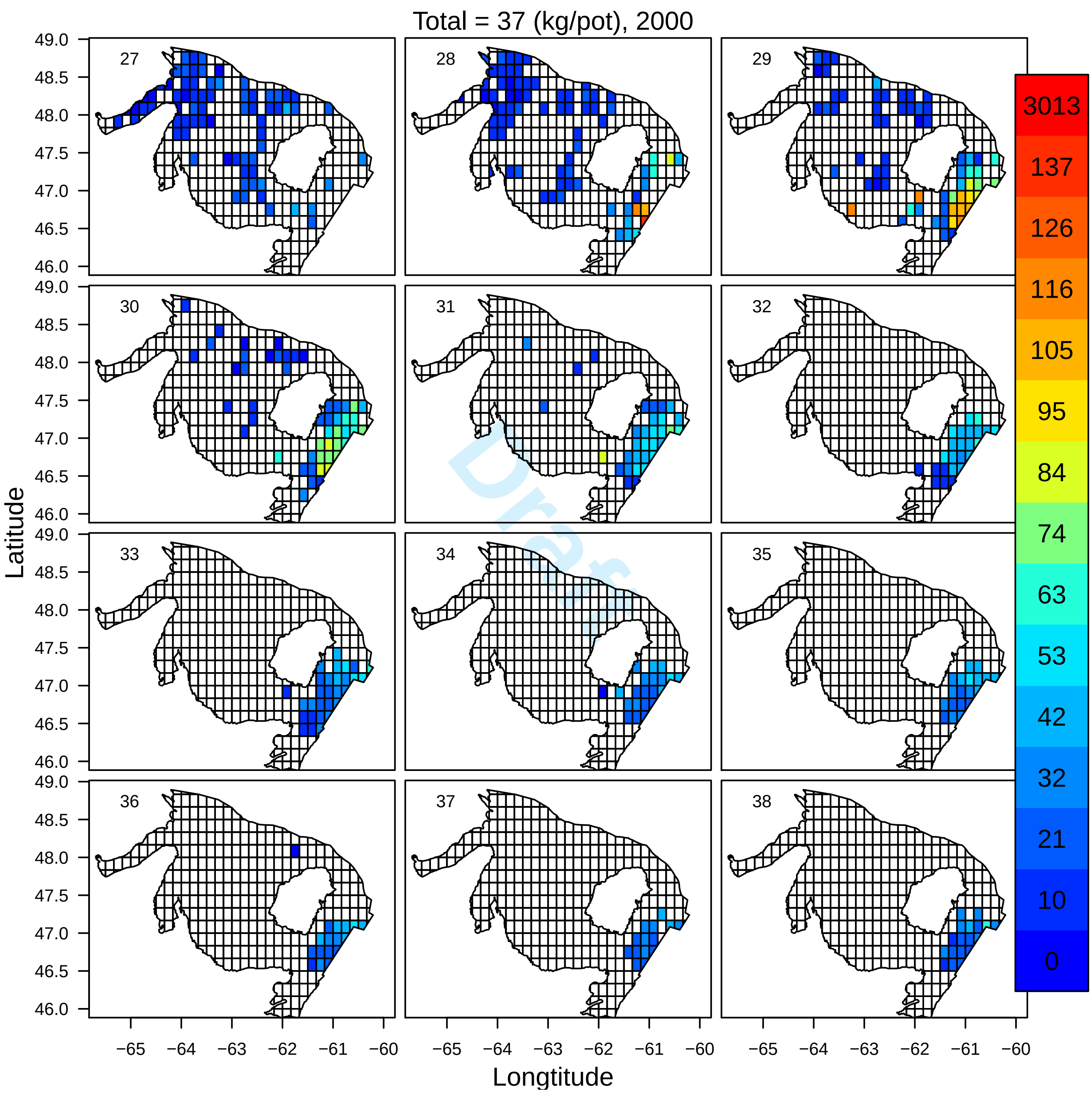


Figure SX.6c. CPUE of snow crab in each week and grid cell in 2000. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

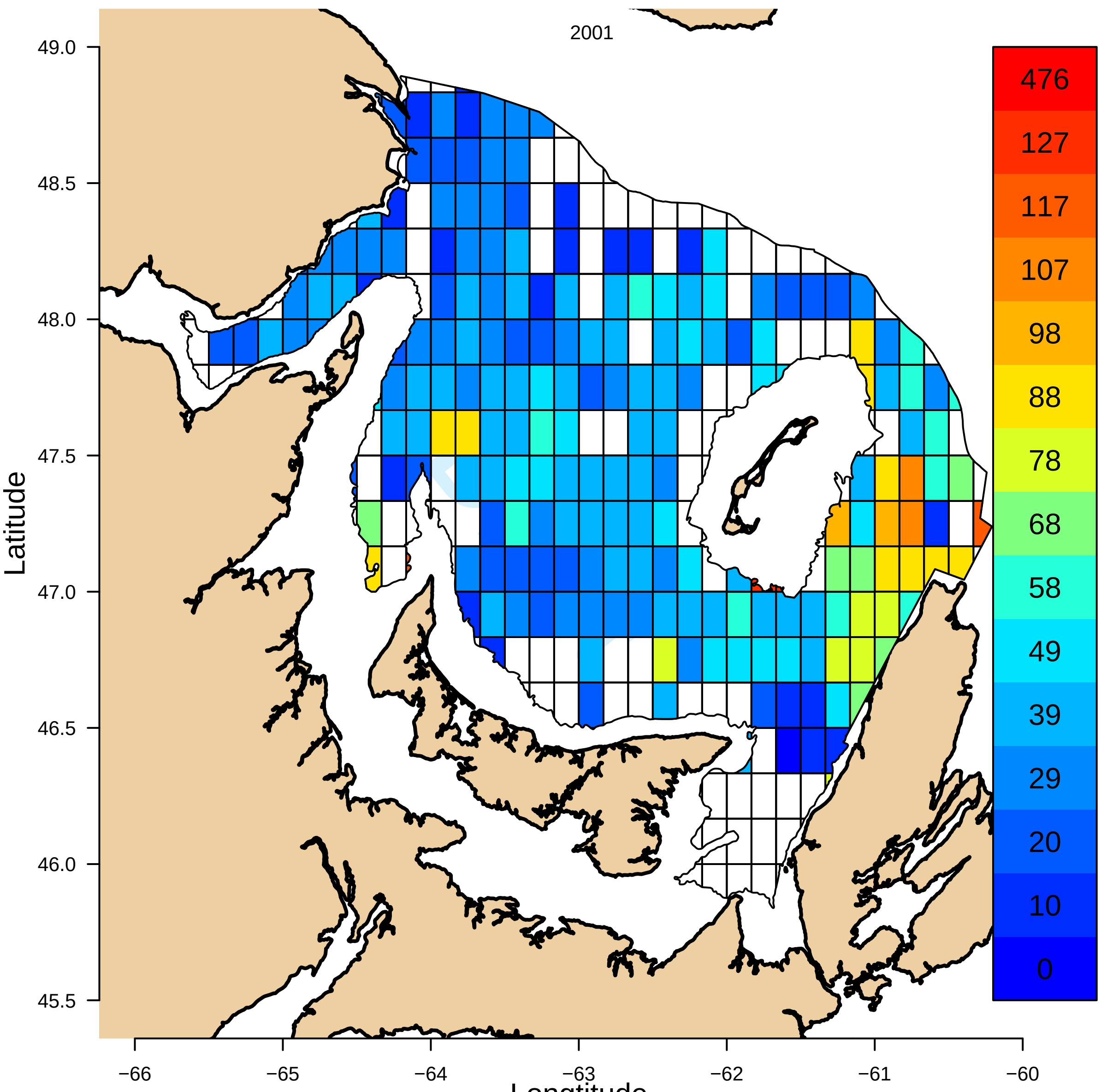


Figure SX.7a. Total annual CPUE of snow crab in each grid cell in 2001. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

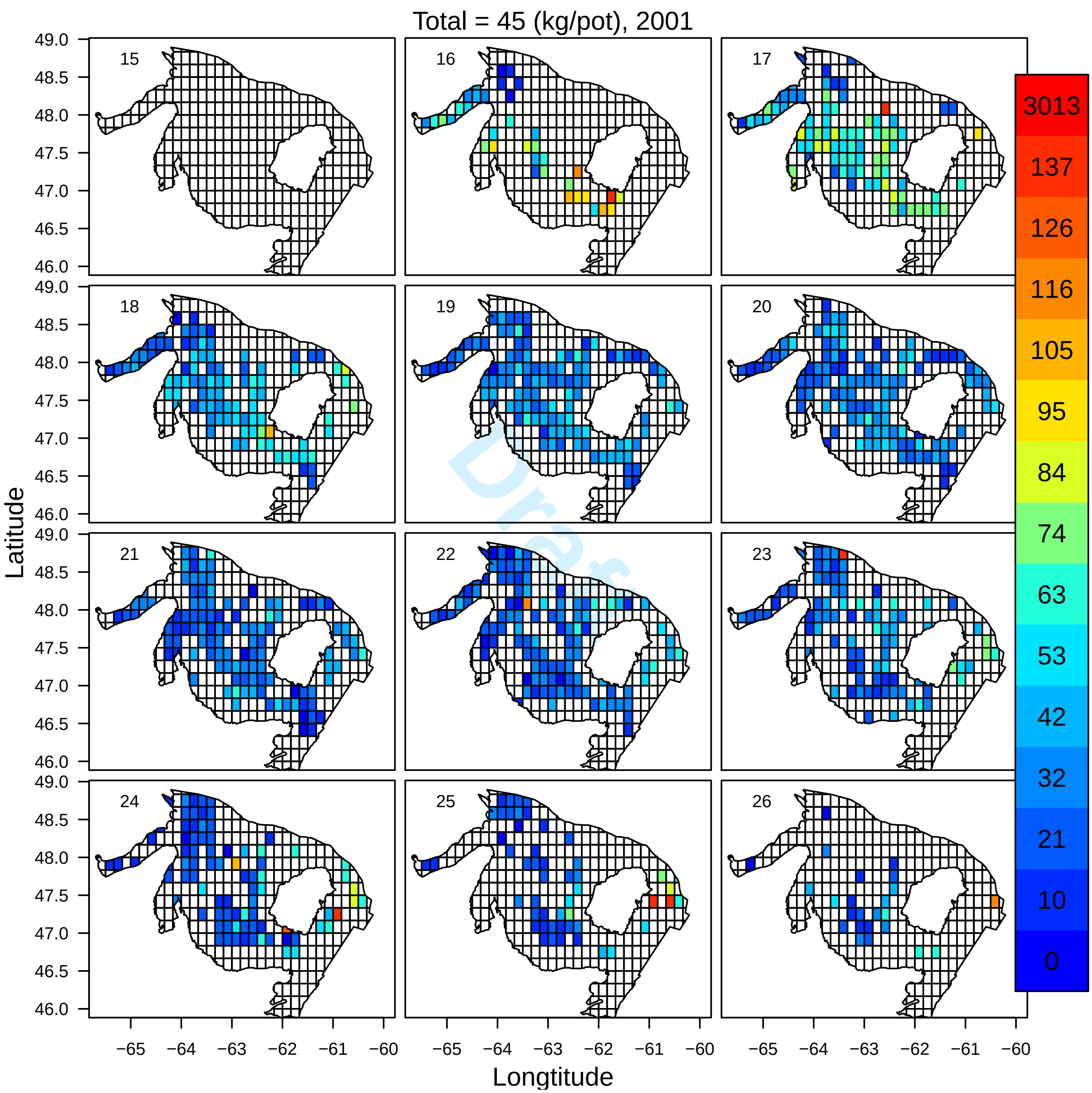


Figure SX.7b. CPUE of snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

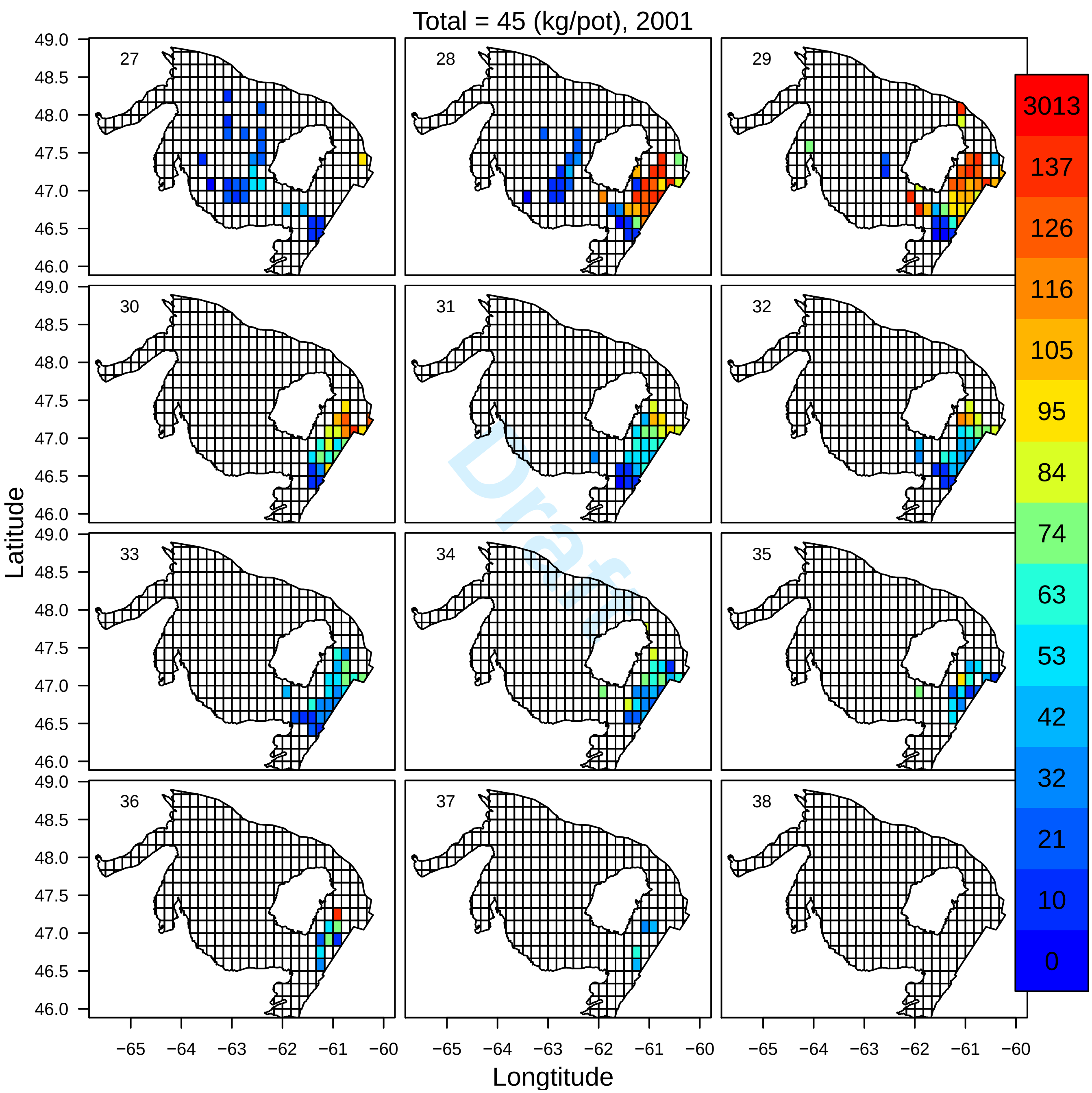


Figure SX.7c. CPUE of snow crab in each week and grid cell in 2001. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

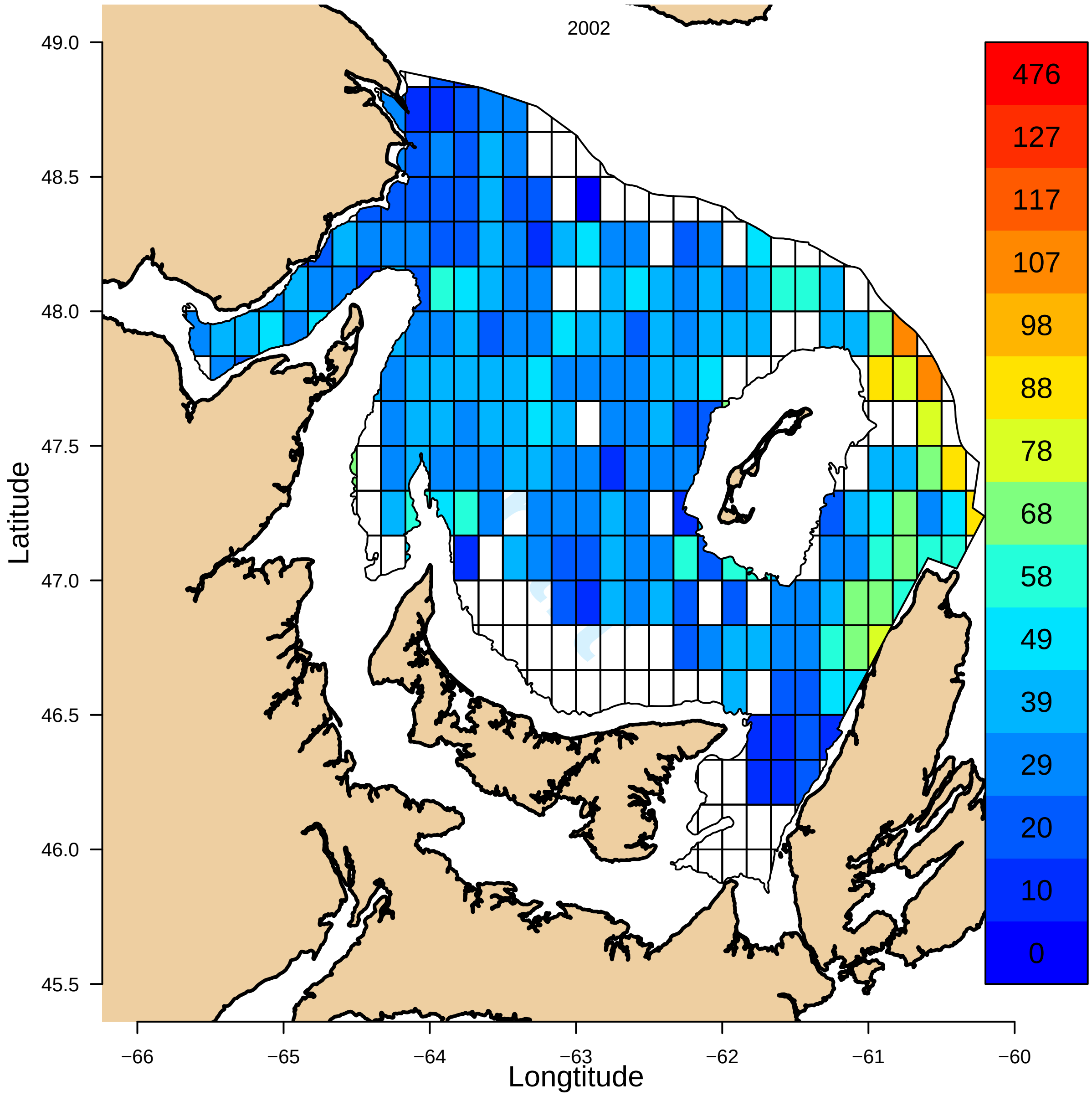


Figure SX.8a. Total annual CPUE of snow crab in each grid cell in 2002. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

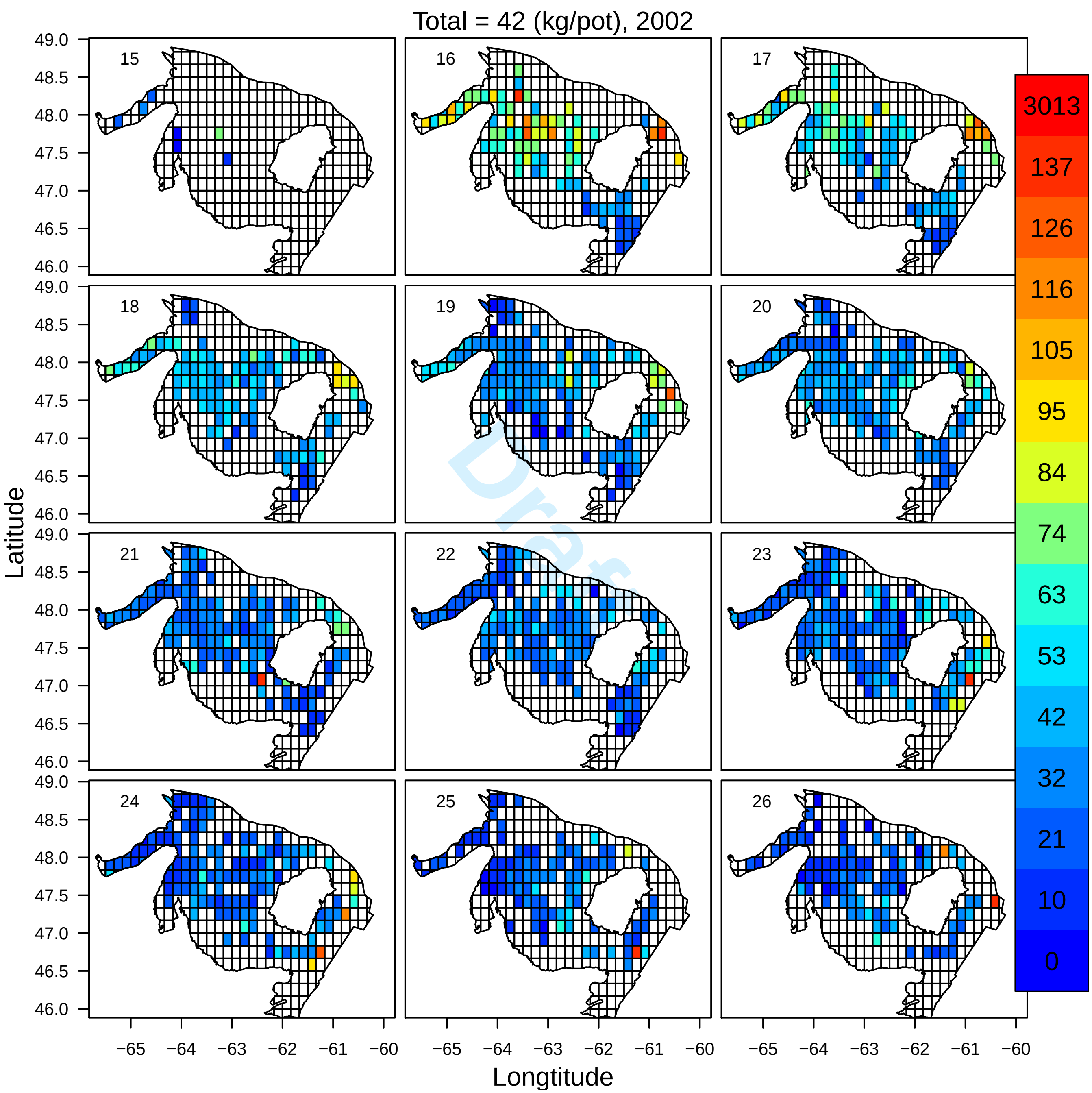


Figure SX.8b. CPUE of snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile

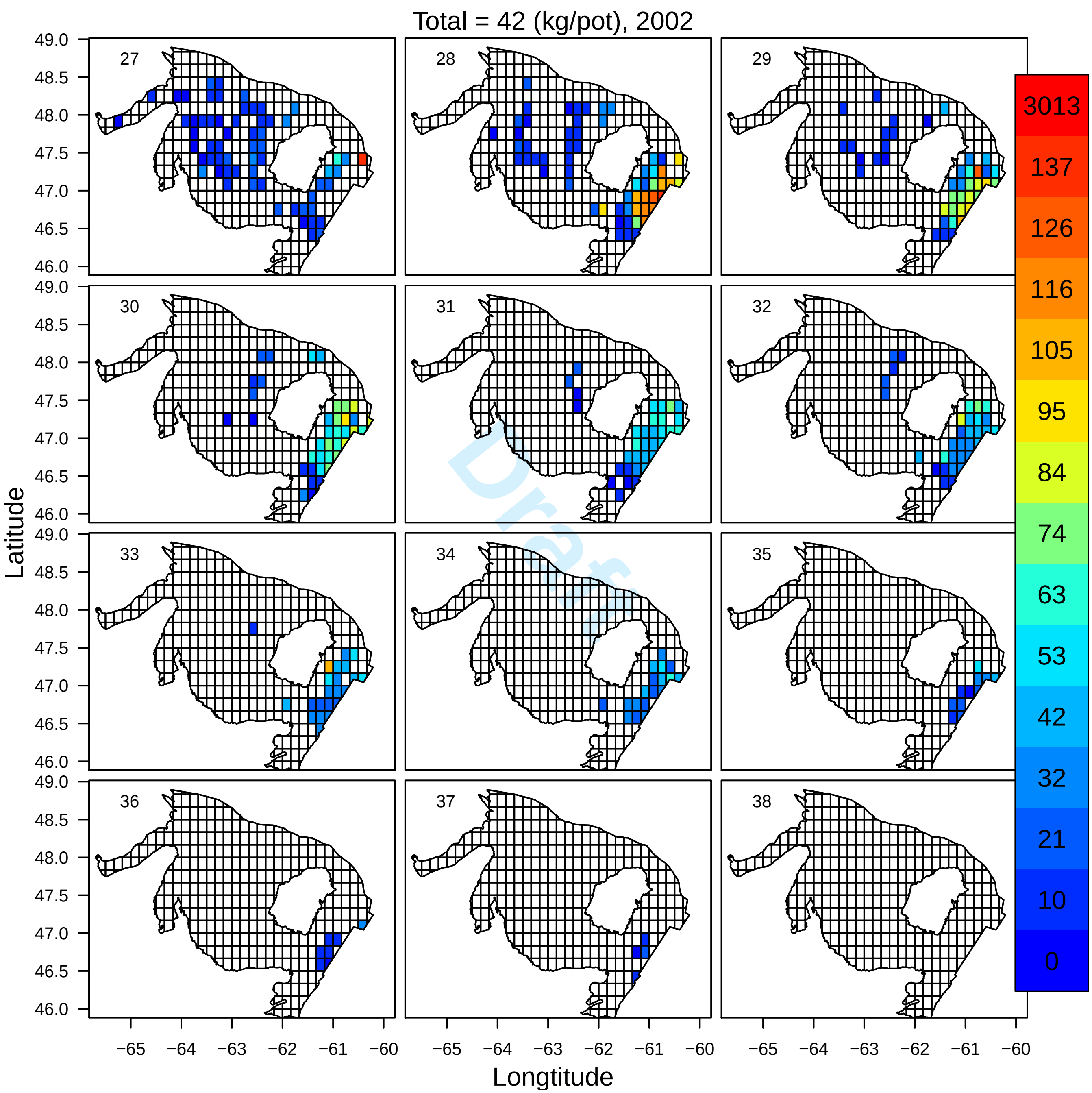


Figure SX.8c. CPUE of snow crab in each week and grid cell in 2002. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

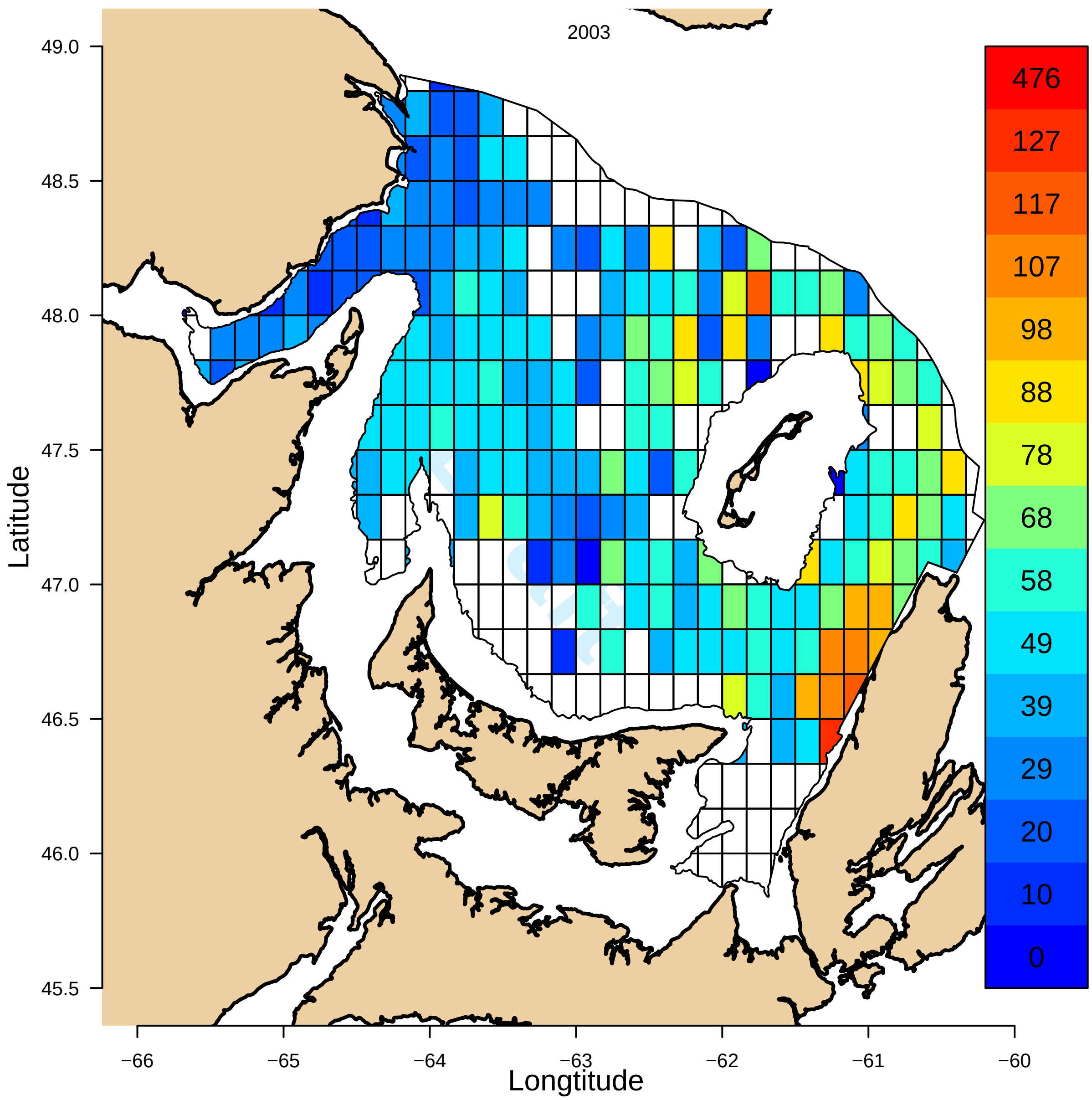


Figure SX.9a. Total annual CPUE of snow crab in each grid cell in 2003. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

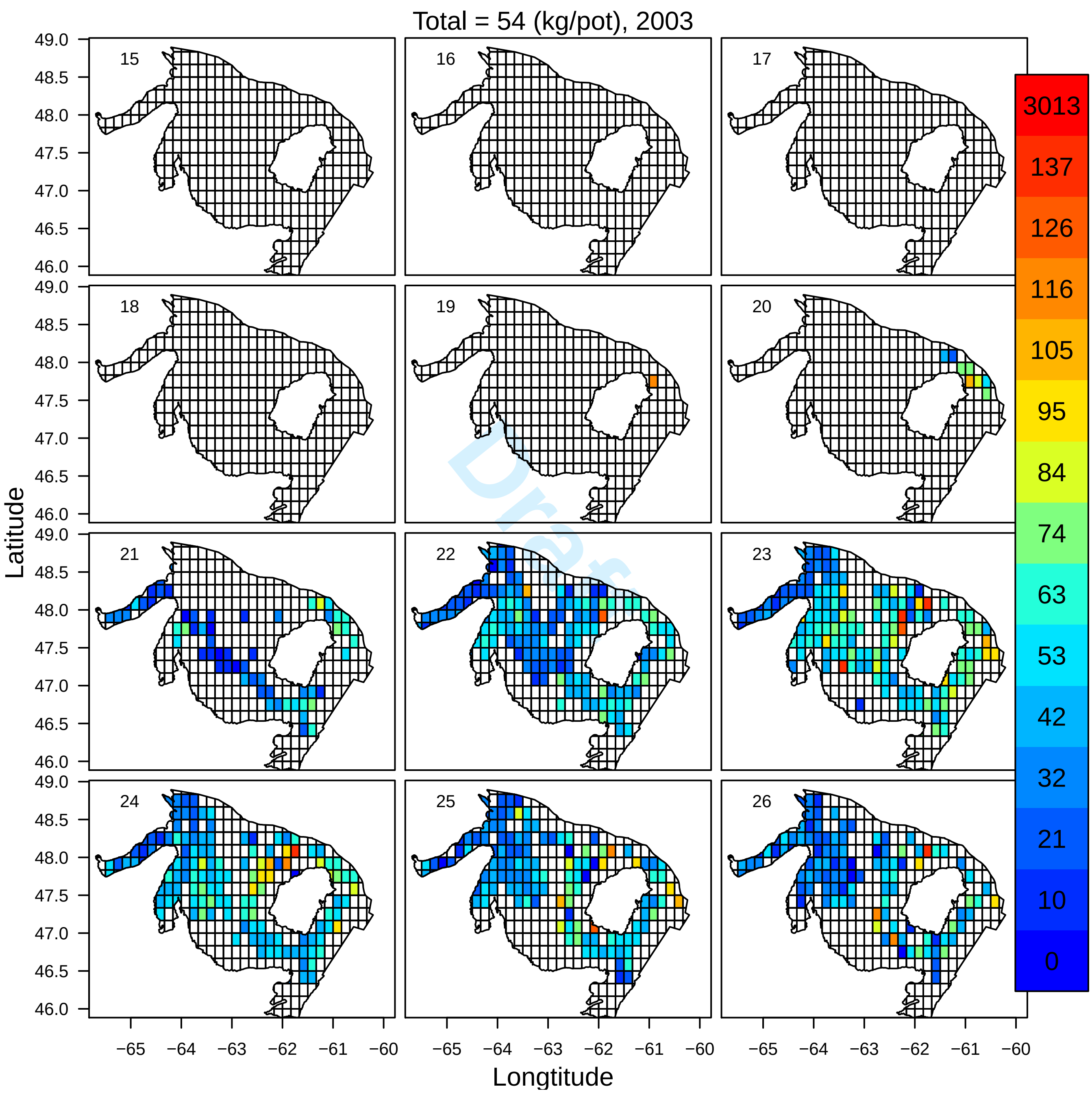


Figure SX.9b. CPUE of snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

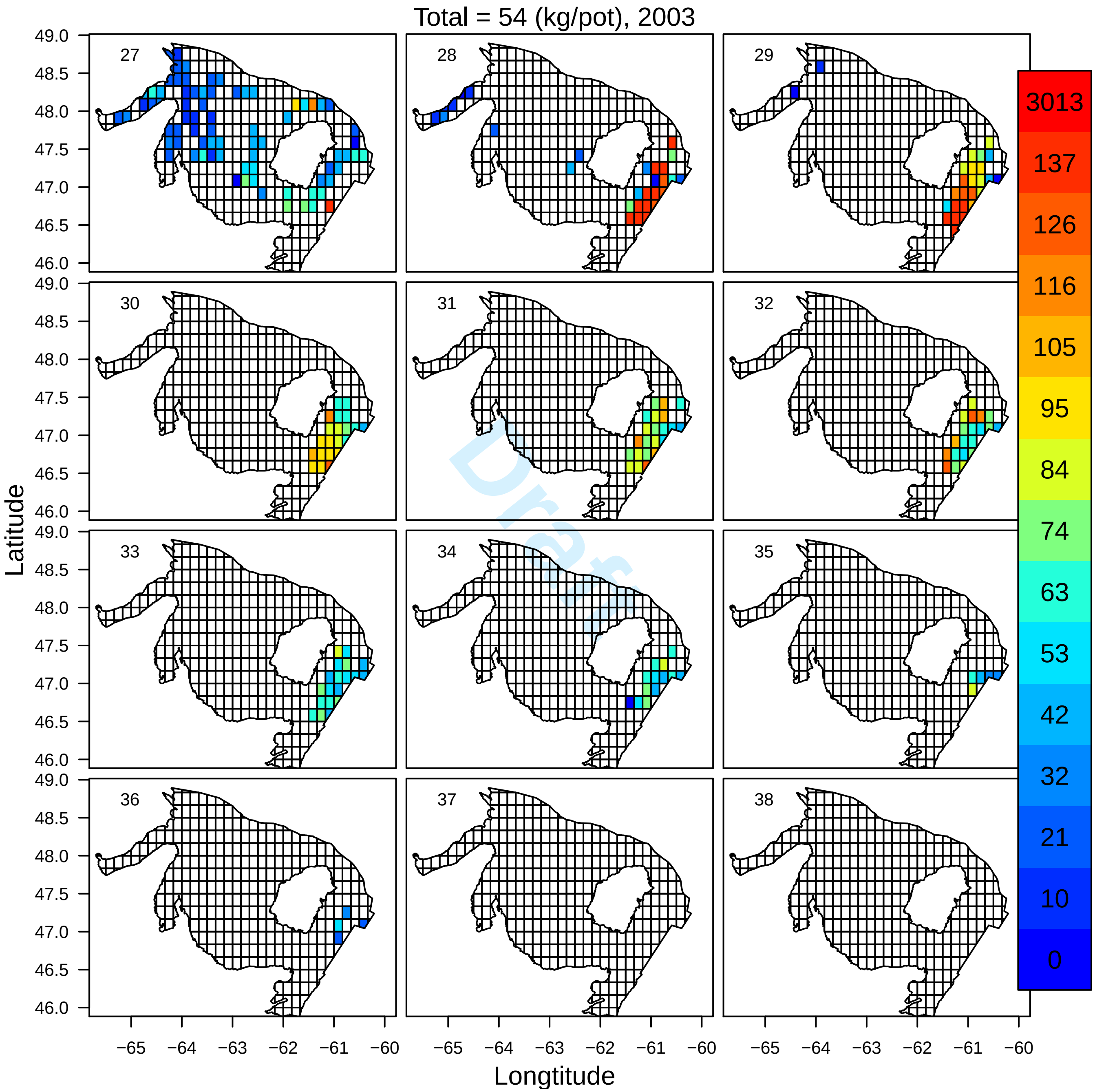


Figure SX.9c. CPUE of snow crab in each week and grid cell in 2003. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

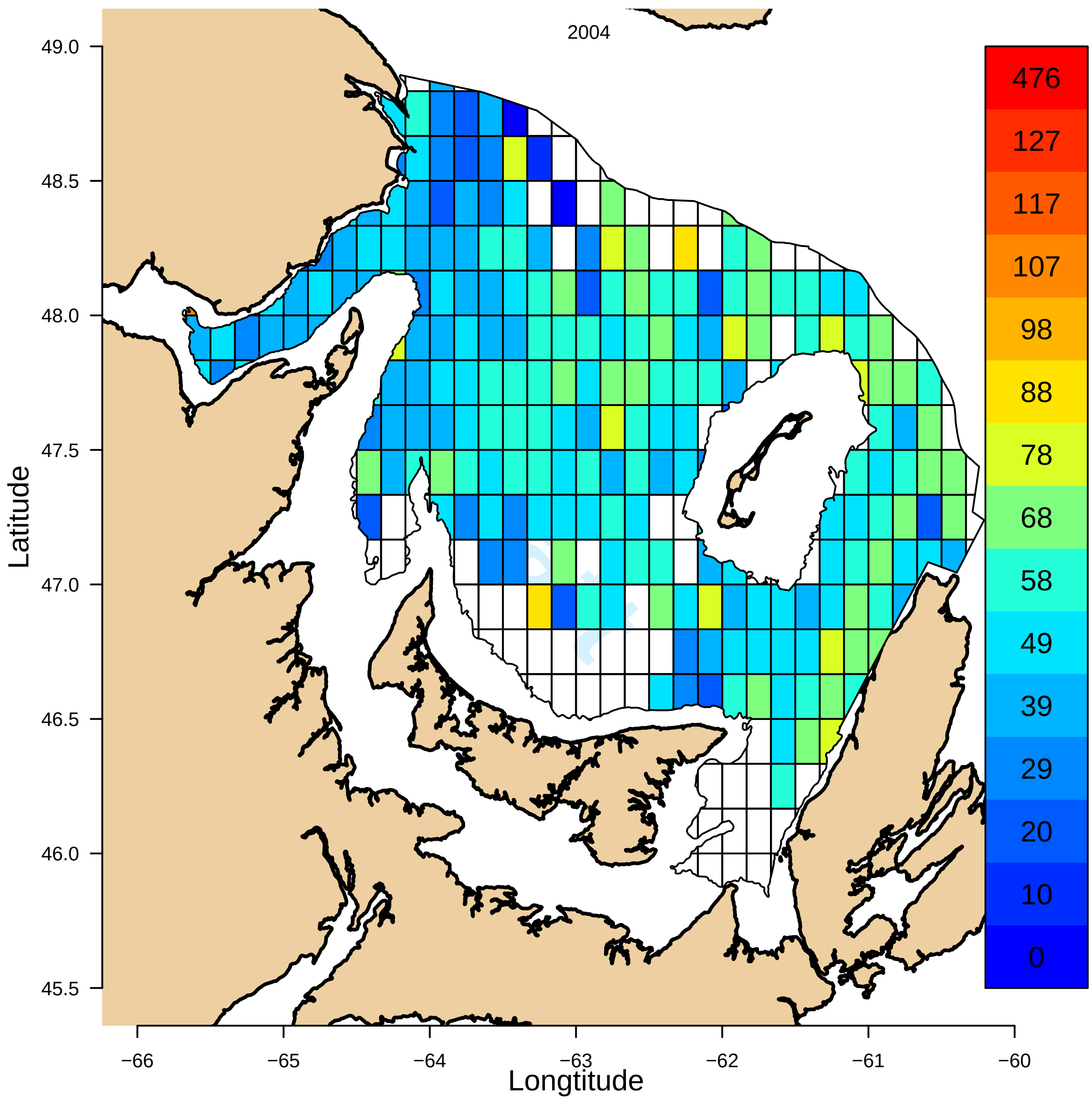


Figure SX.10a. Total annual CPUE of snow crab in each grid cell in 2004. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

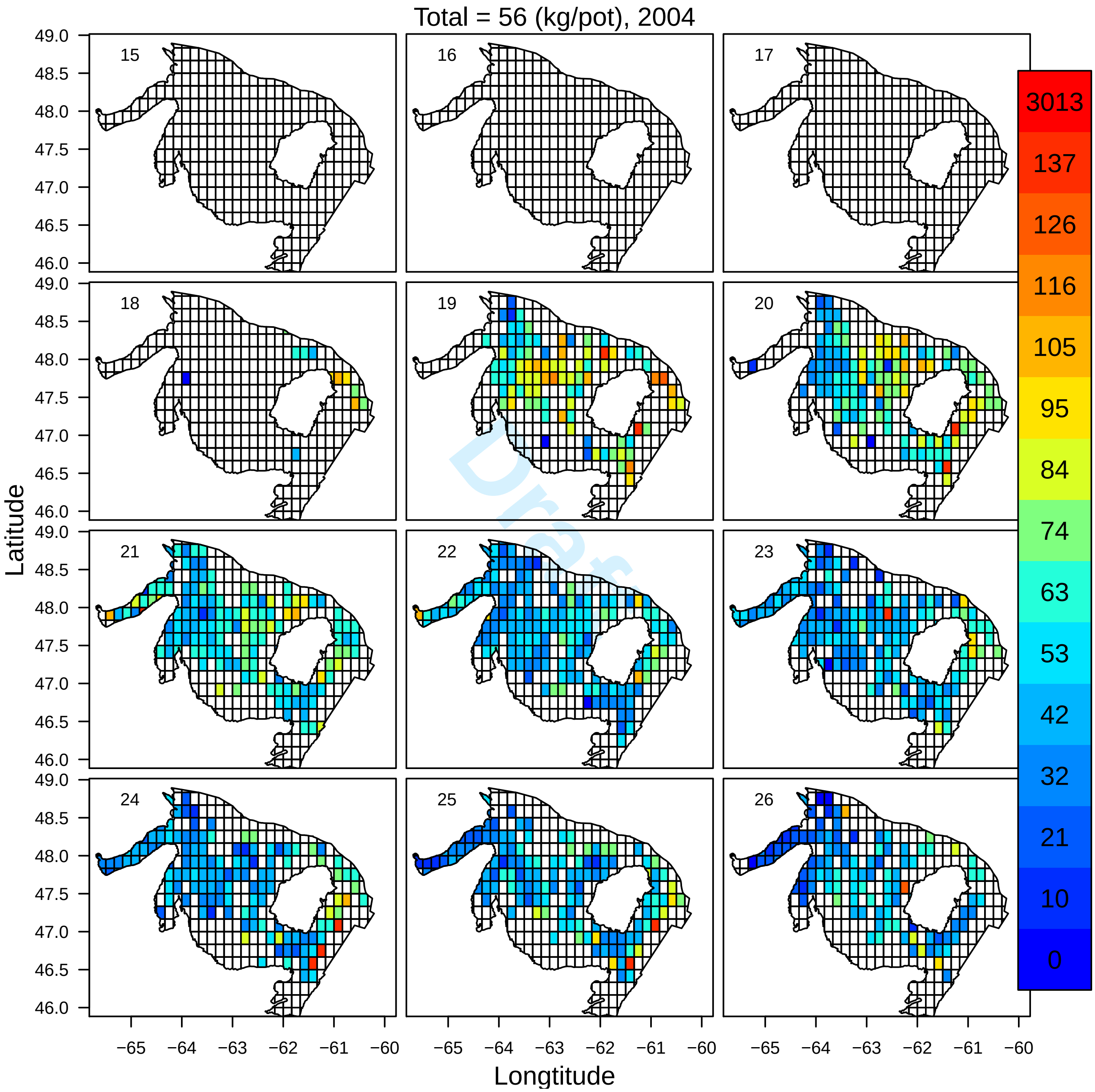


Figure SX.10b. CPUE of snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

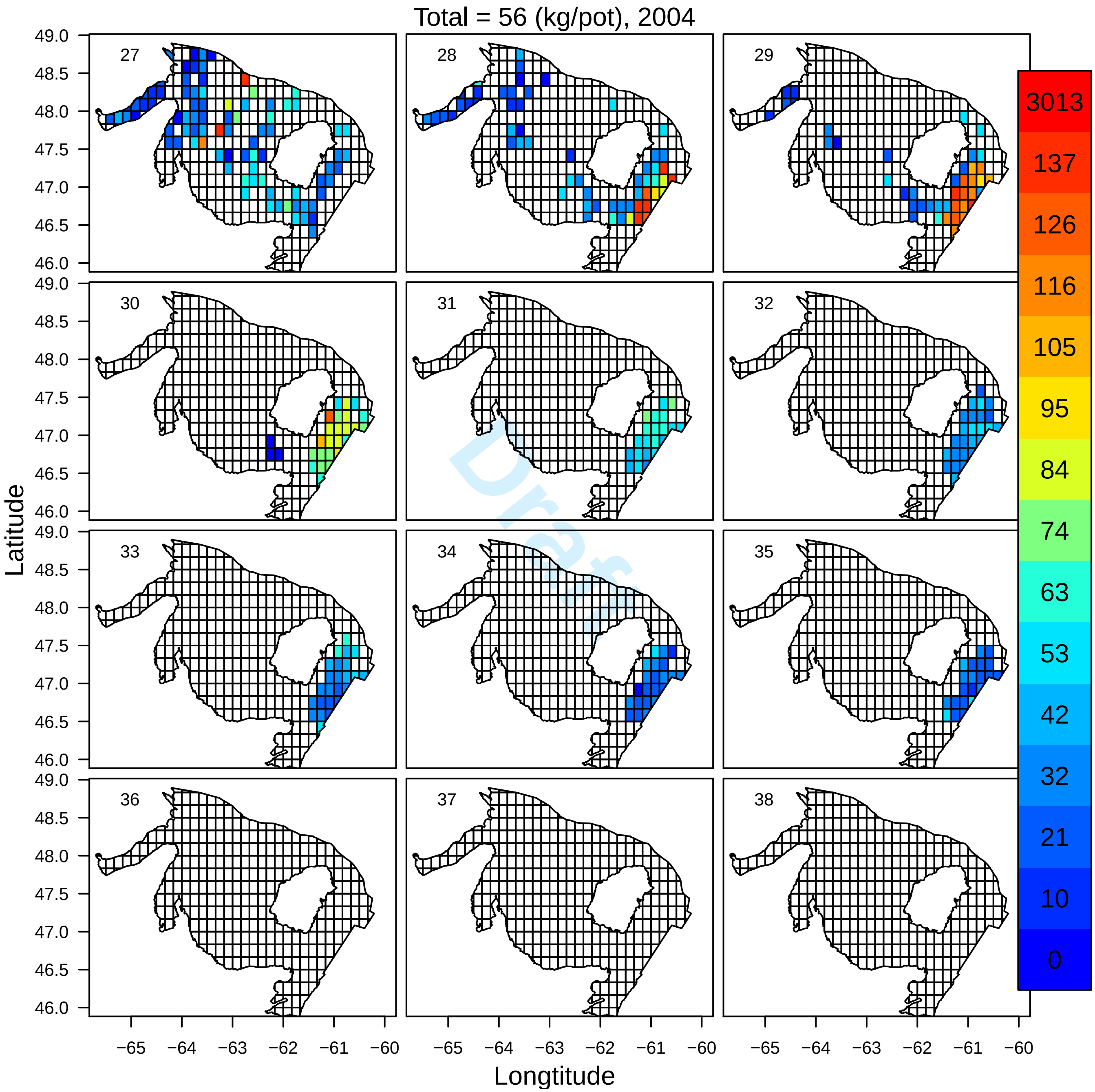


Figure SX.10c. CPUE of snow crab in each week and grid cell in 2004. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

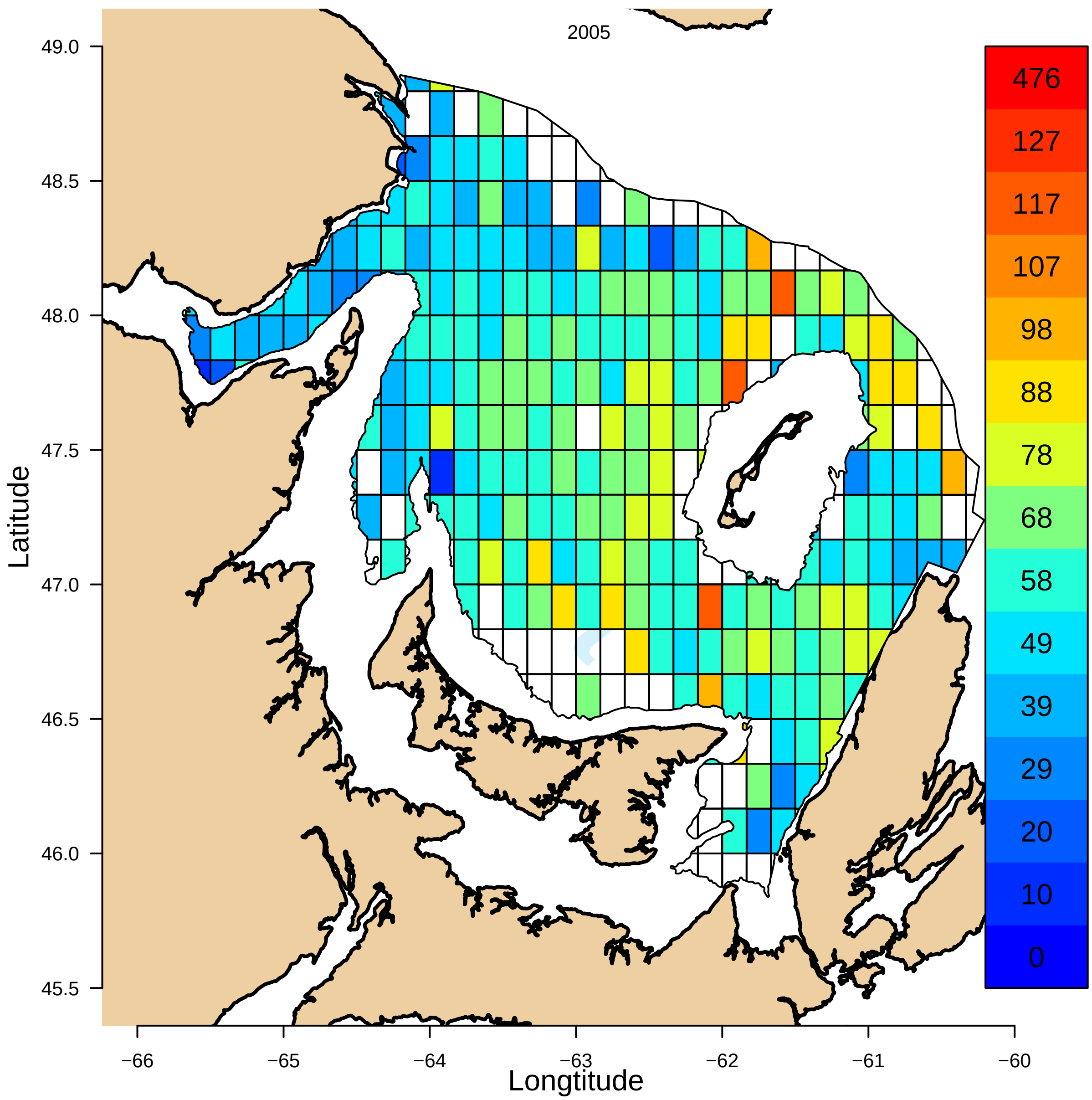


Figure SX.11a. Total annual CPUE of snow crab in each grid cell in 2005. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

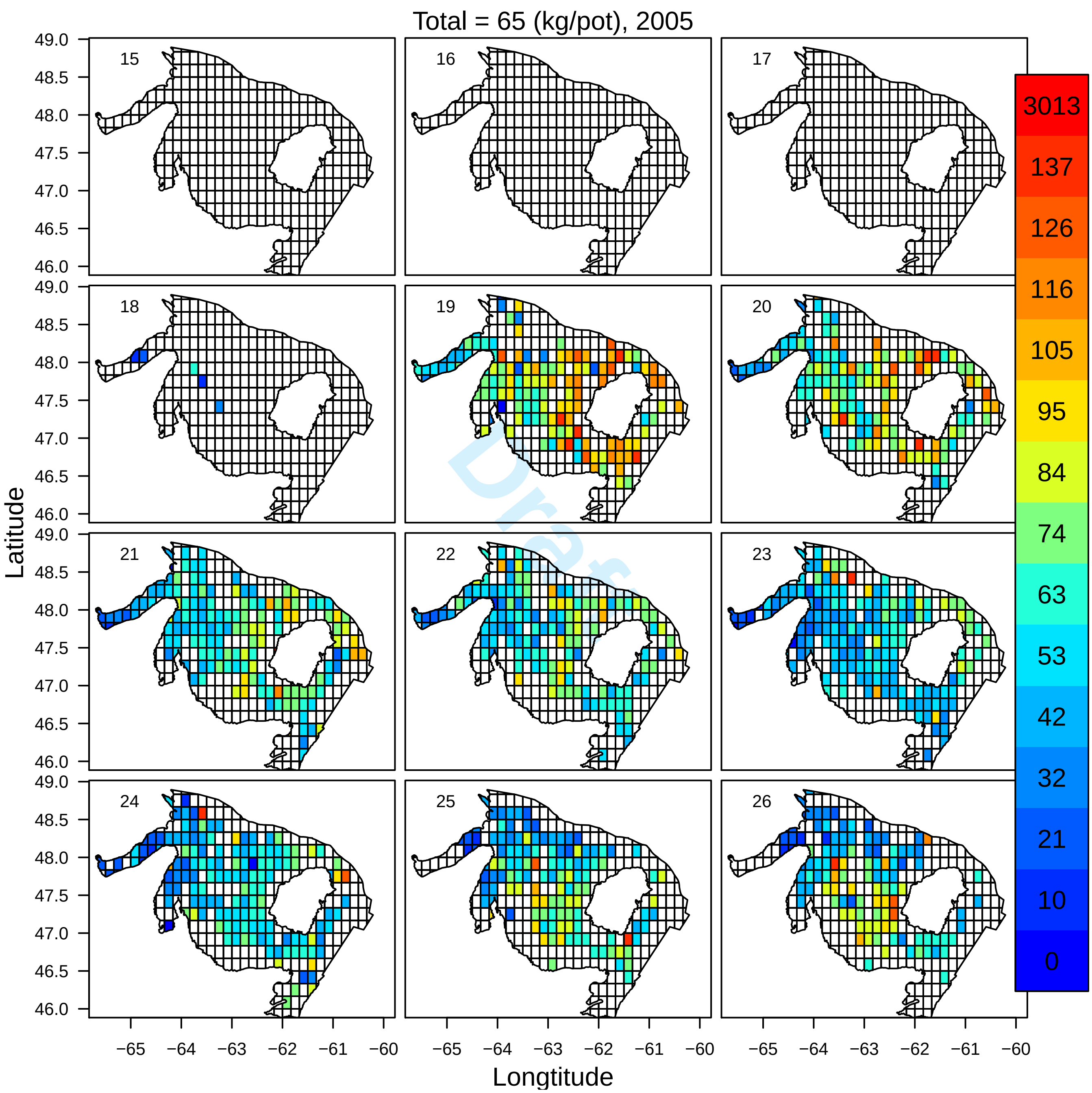


Figure SX.11b. CPUE of snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

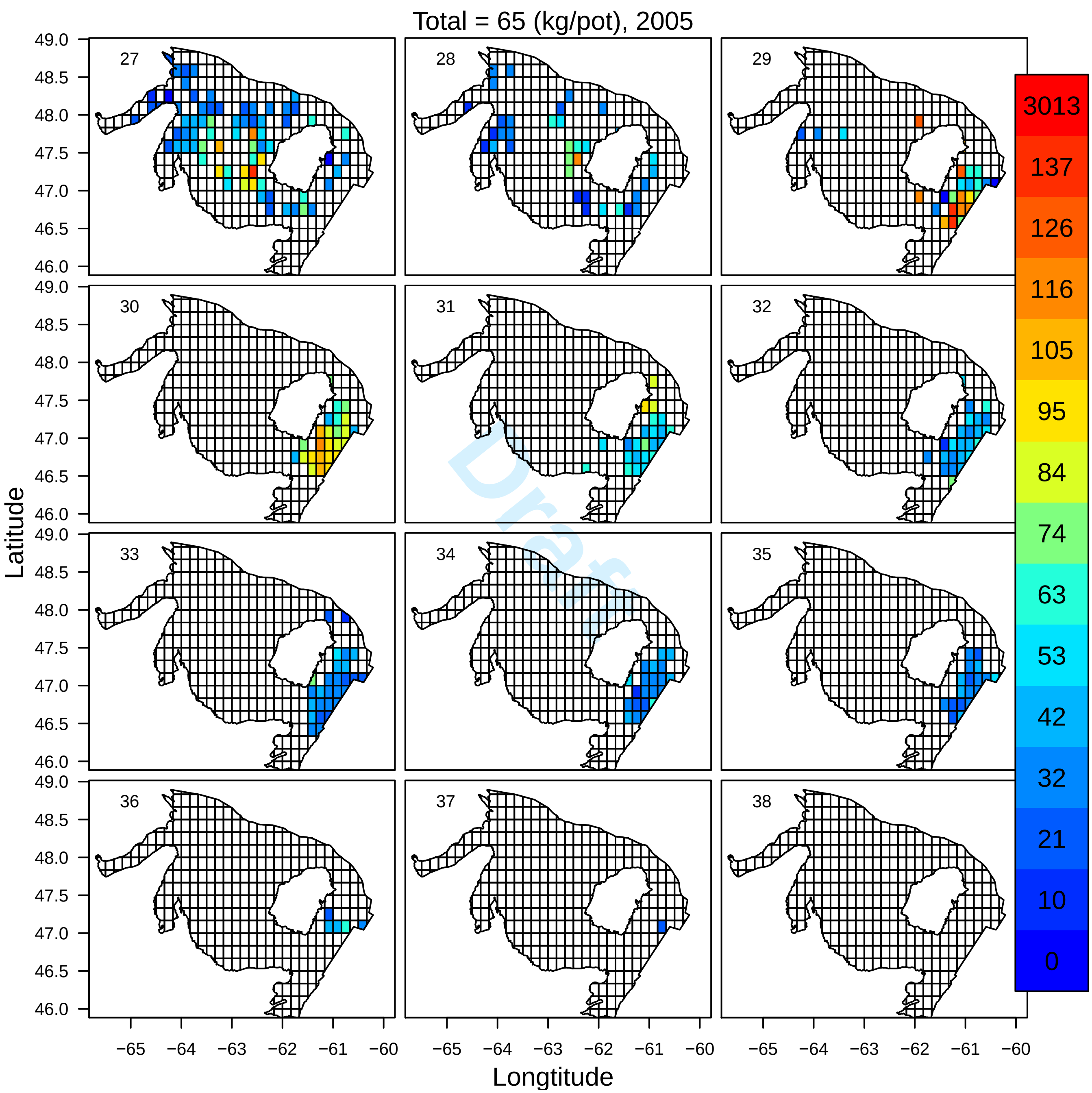


Figure SX.11c. CPUE of snow crab in each week and grid cell in 2005. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

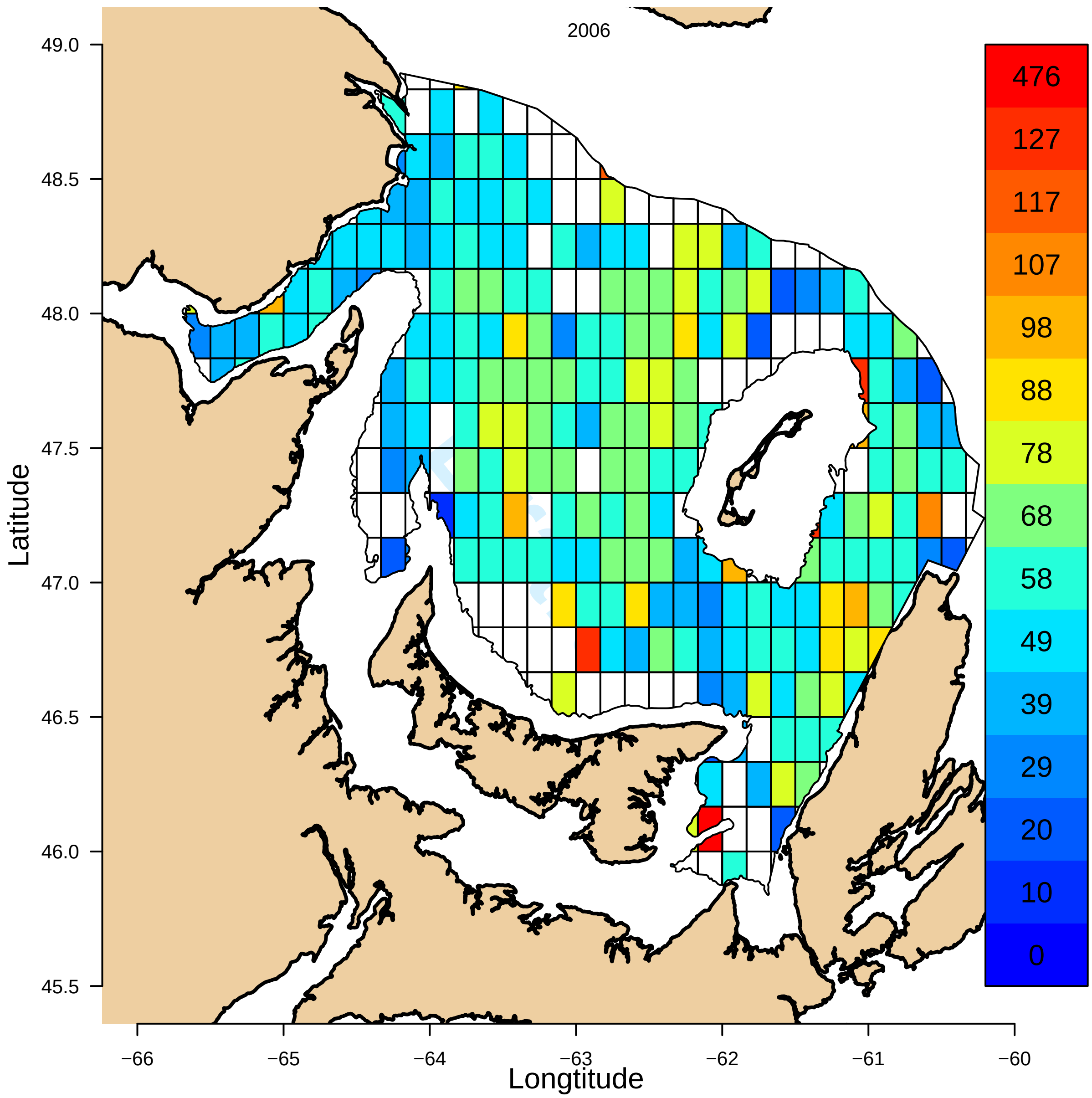


Figure SX.12a. Total annual CPUE of snow crab in each grid cell in 2006. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

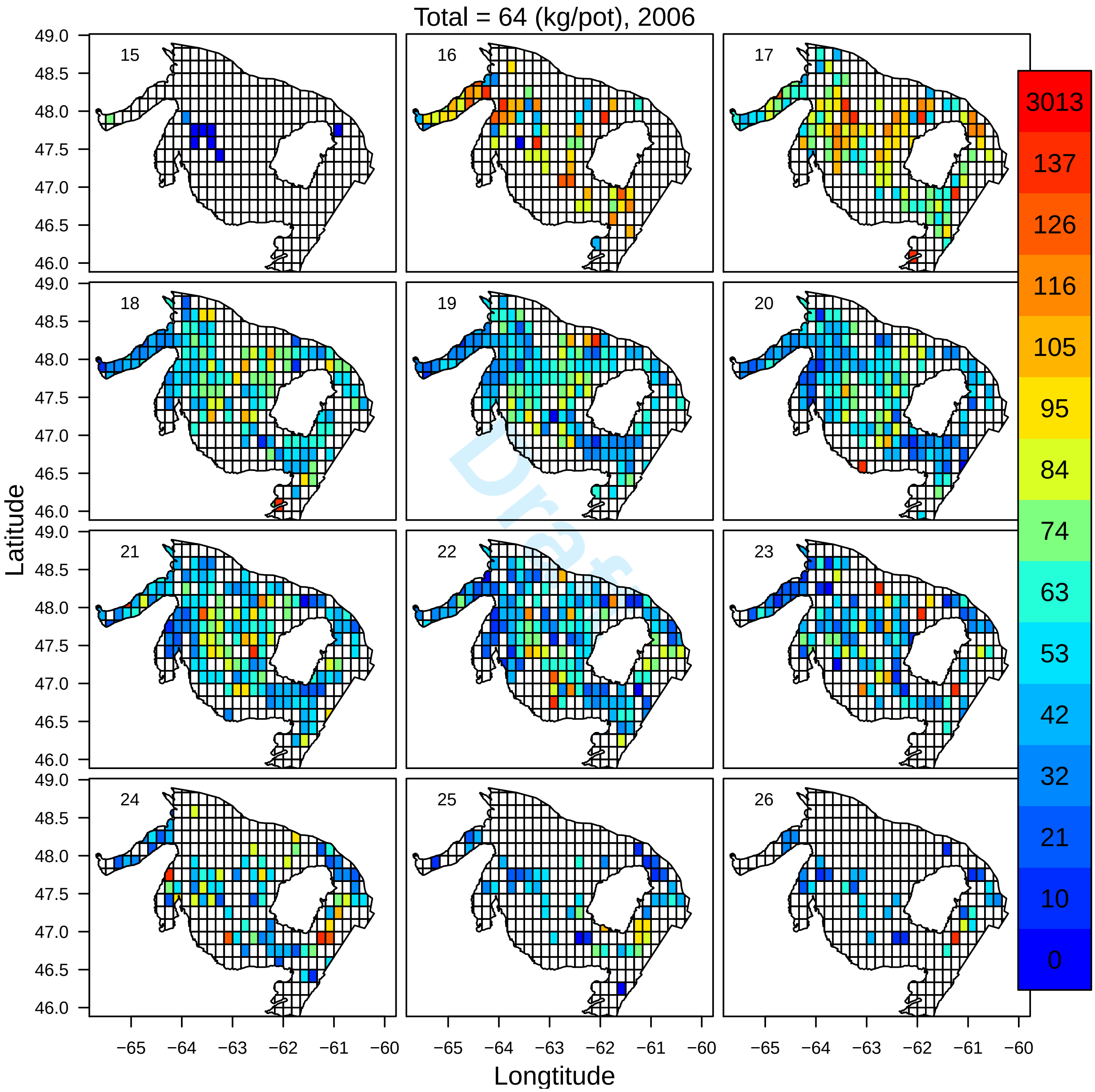


Figure SX.12b. CPUE of snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

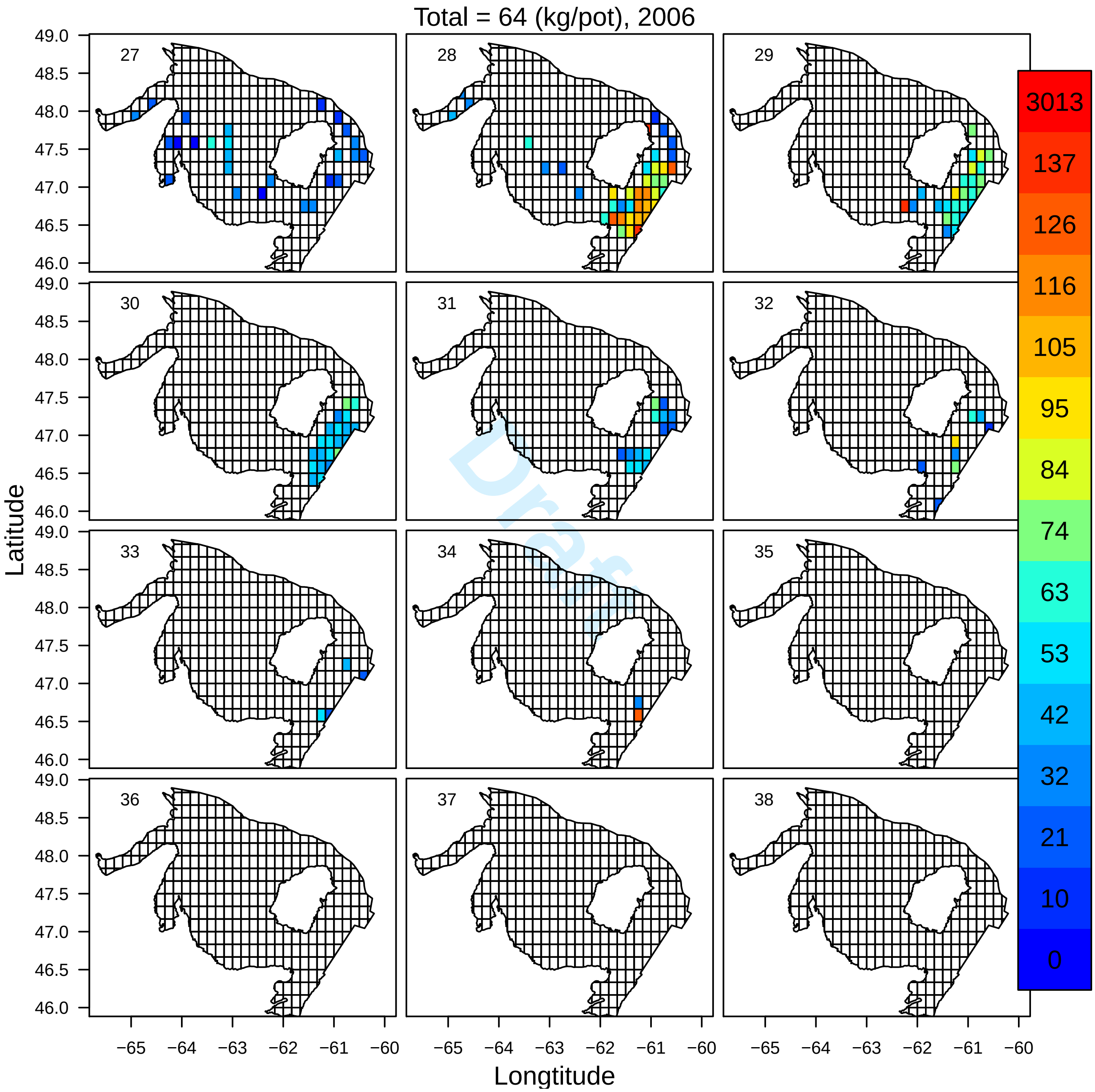


Figure SX.12c. CPUE of snow crab in each week and grid cell in 2006. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

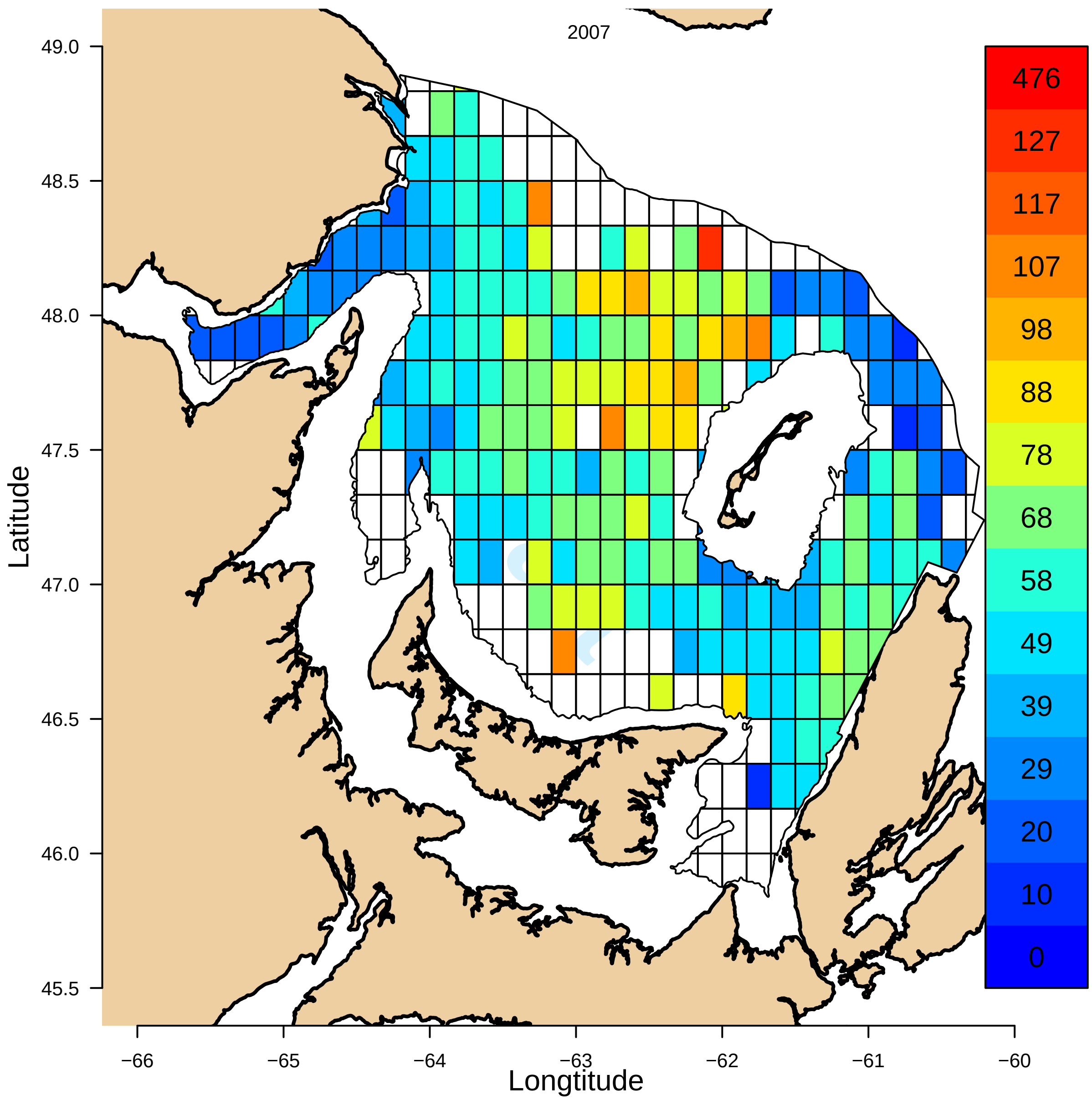


Figure SX.13a. Total annual CPUE of snow crab in each grid cell in 2007. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

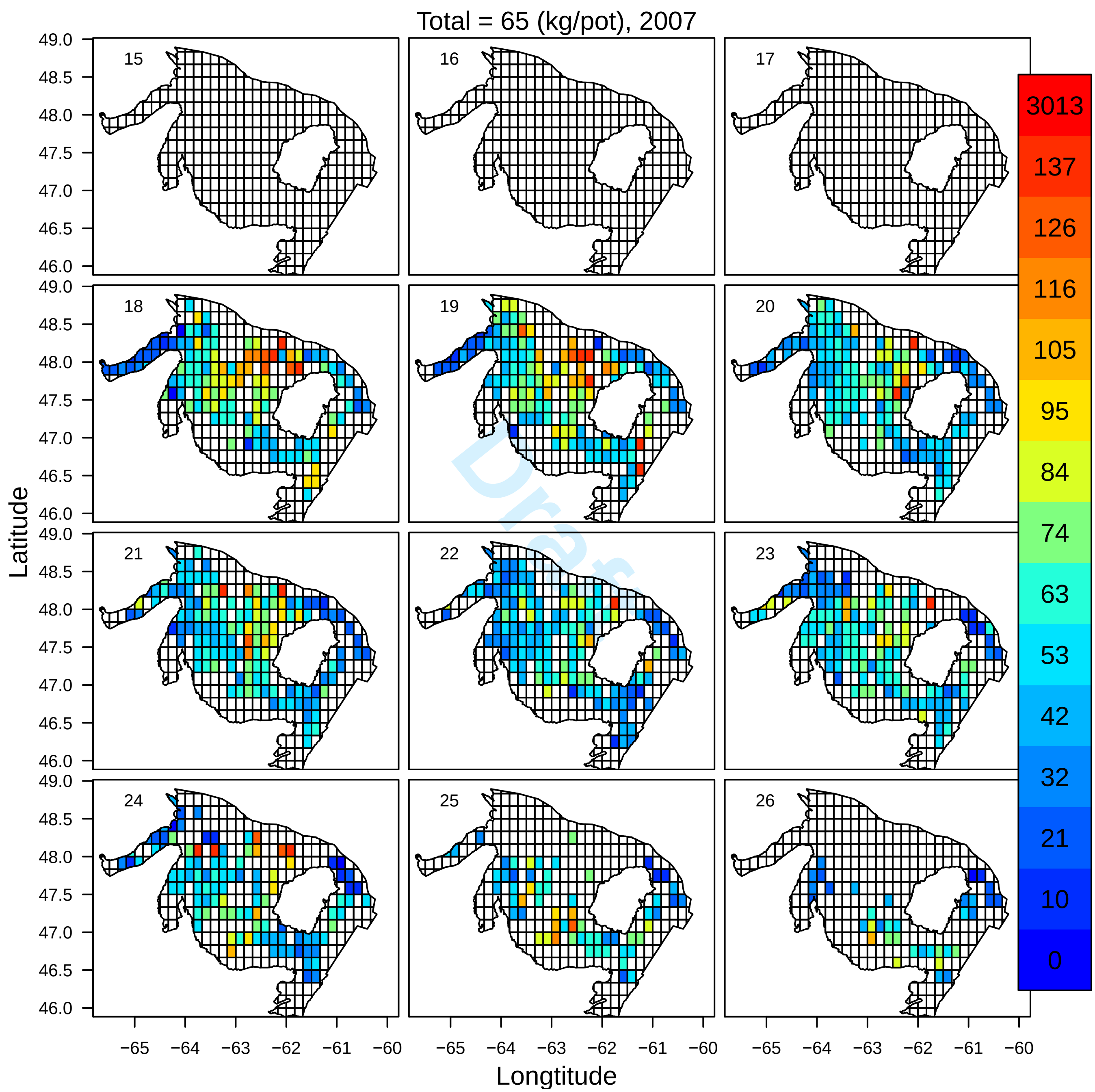


Figure SX.13b. CPUE of snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

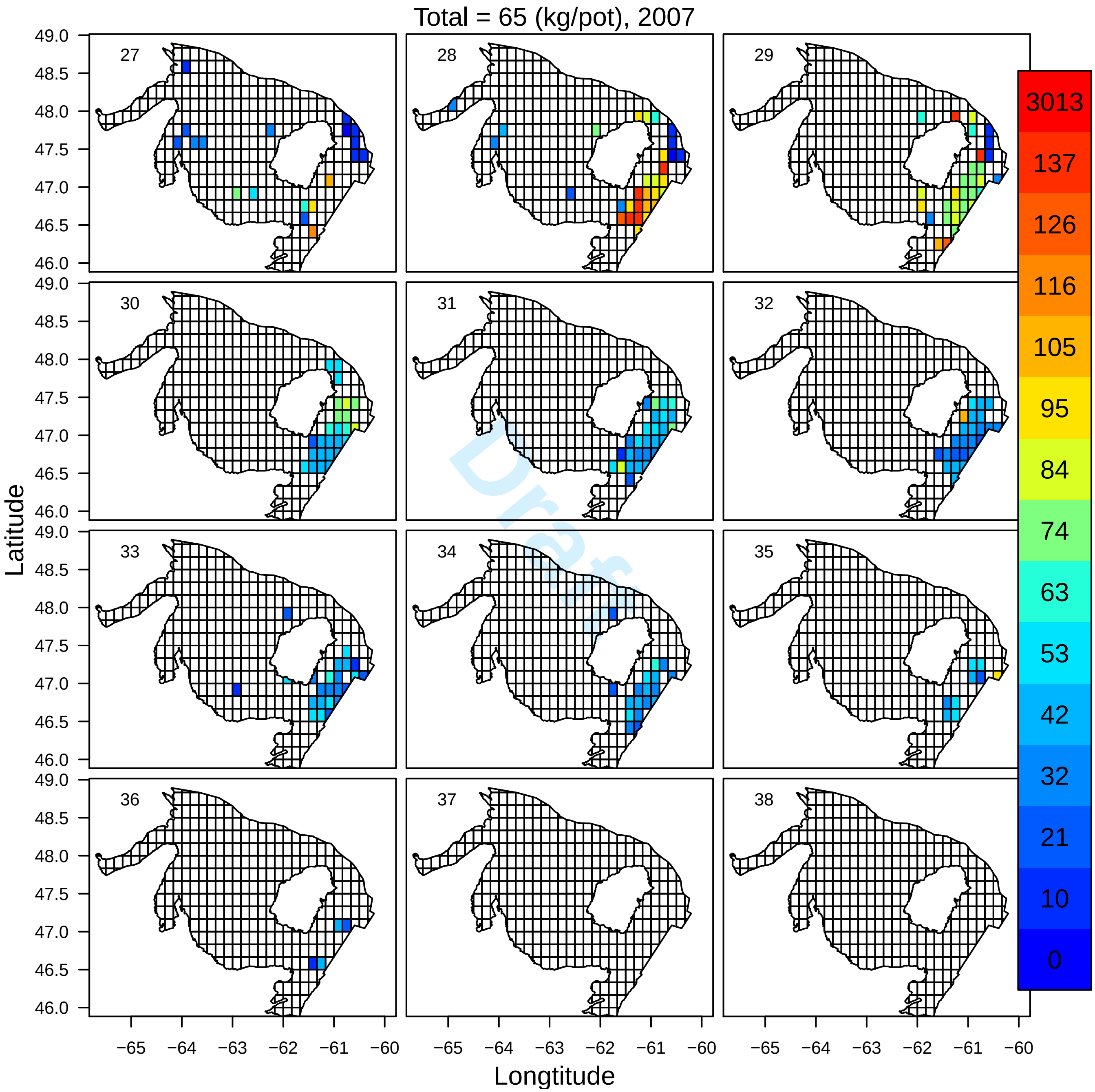


Figure SX.13c. CPUE of snow crab in each week and grid cell in 2007. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

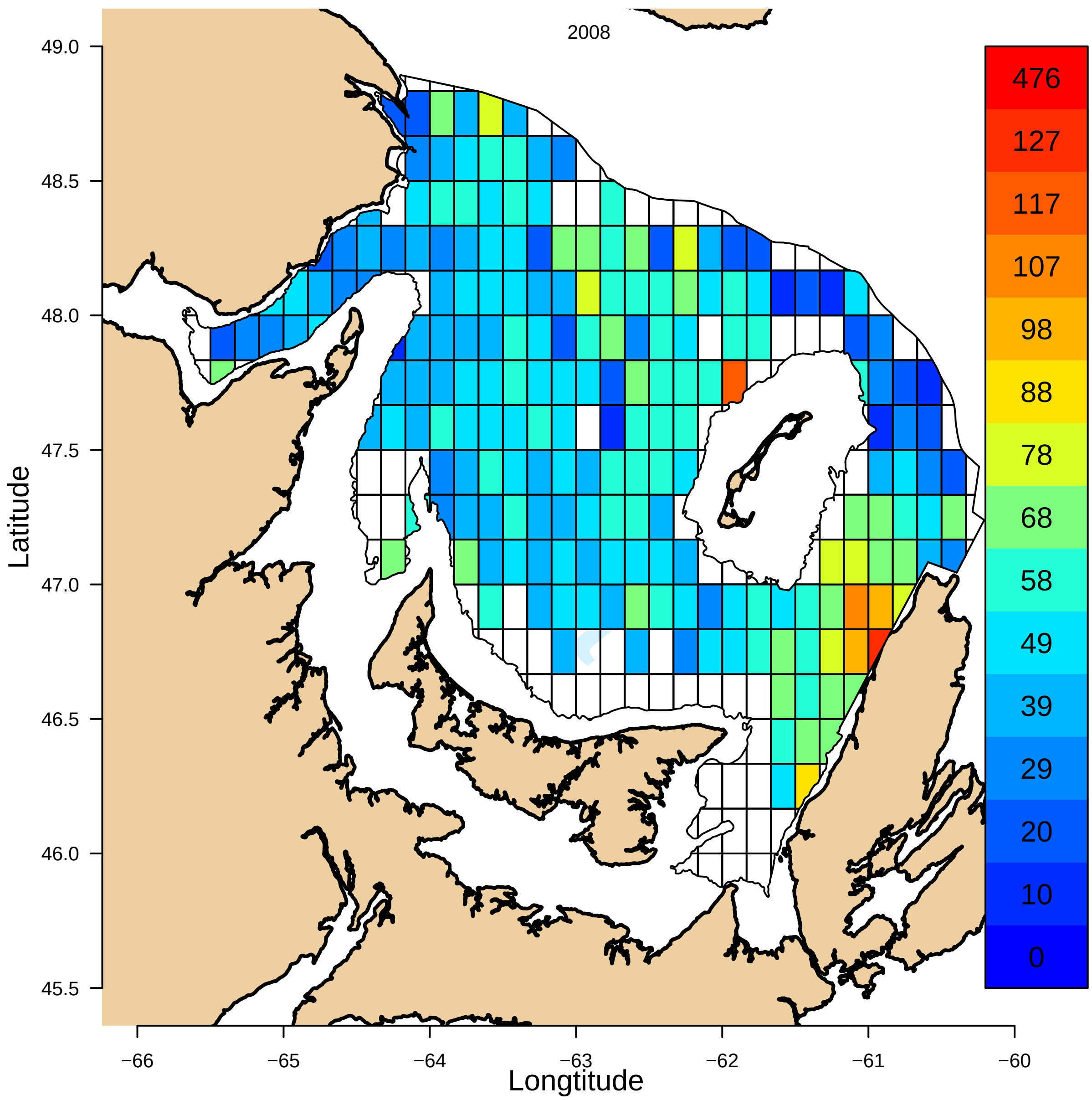


Figure SX.14a. Total annual CPUE of snow crab in each grid cell in 2008. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

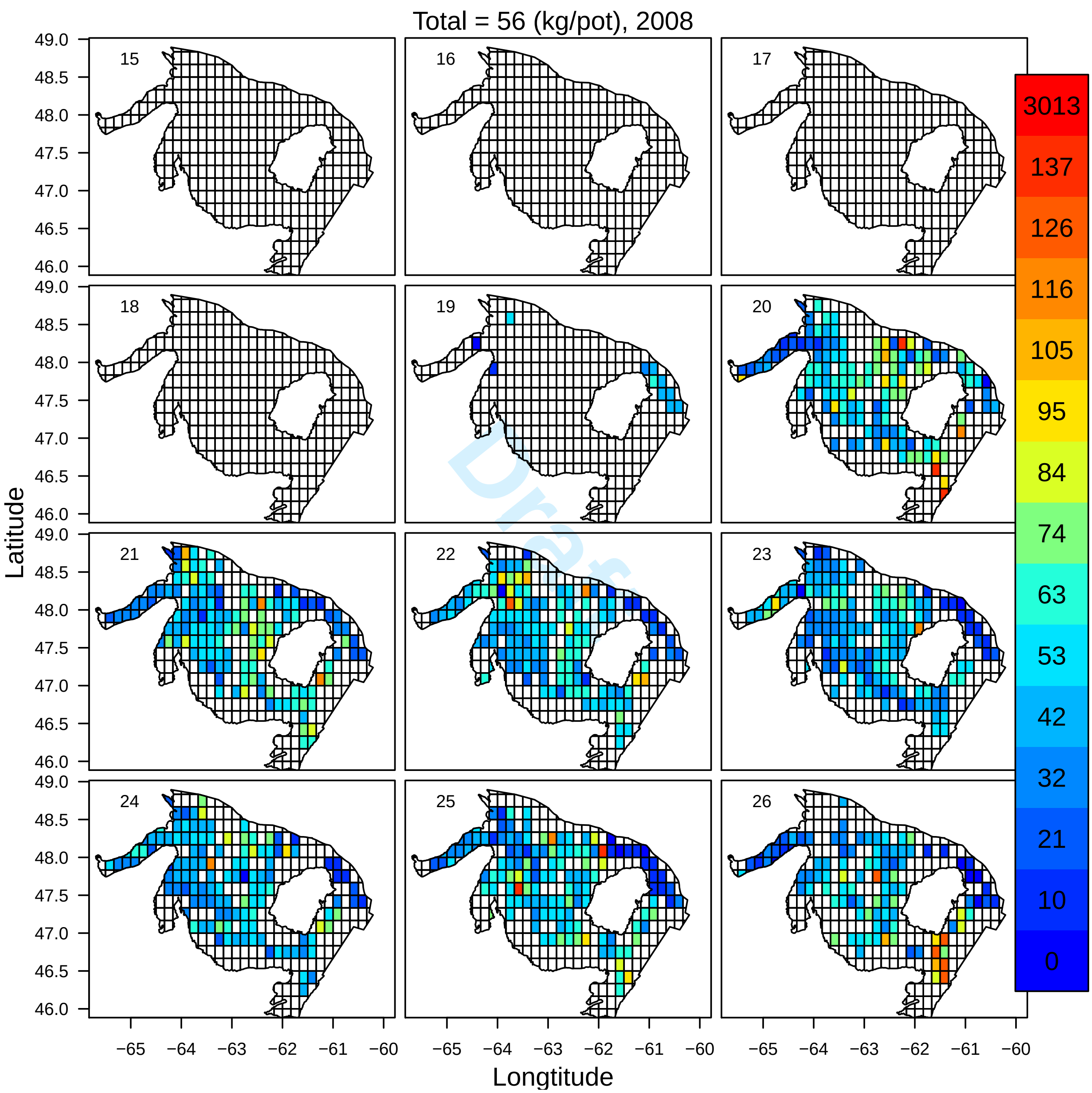


Figure SX.14b. CPUE of snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

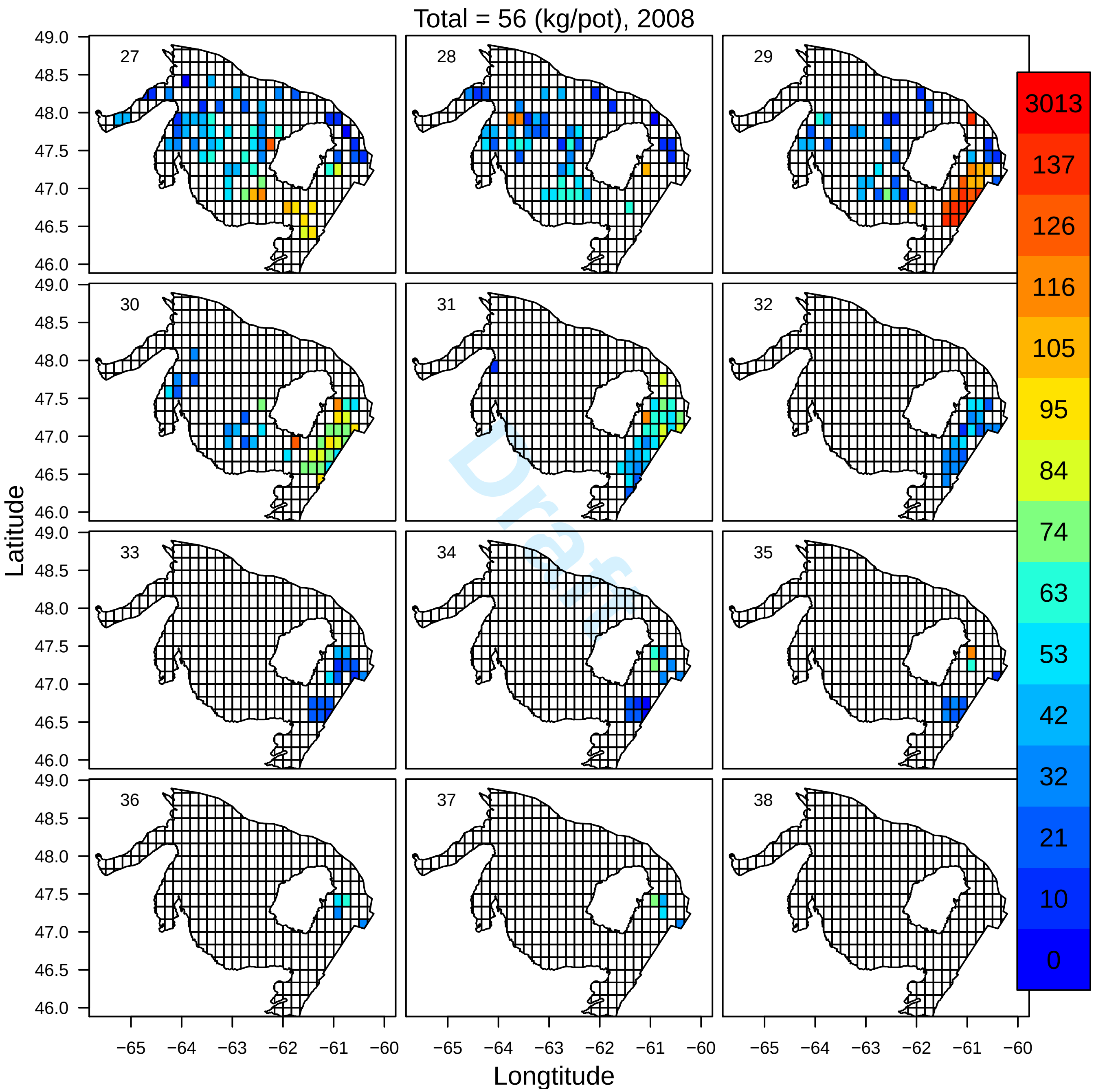


Figure SX.14c. CPUE of snow crab in each week and grid cell in 2008. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

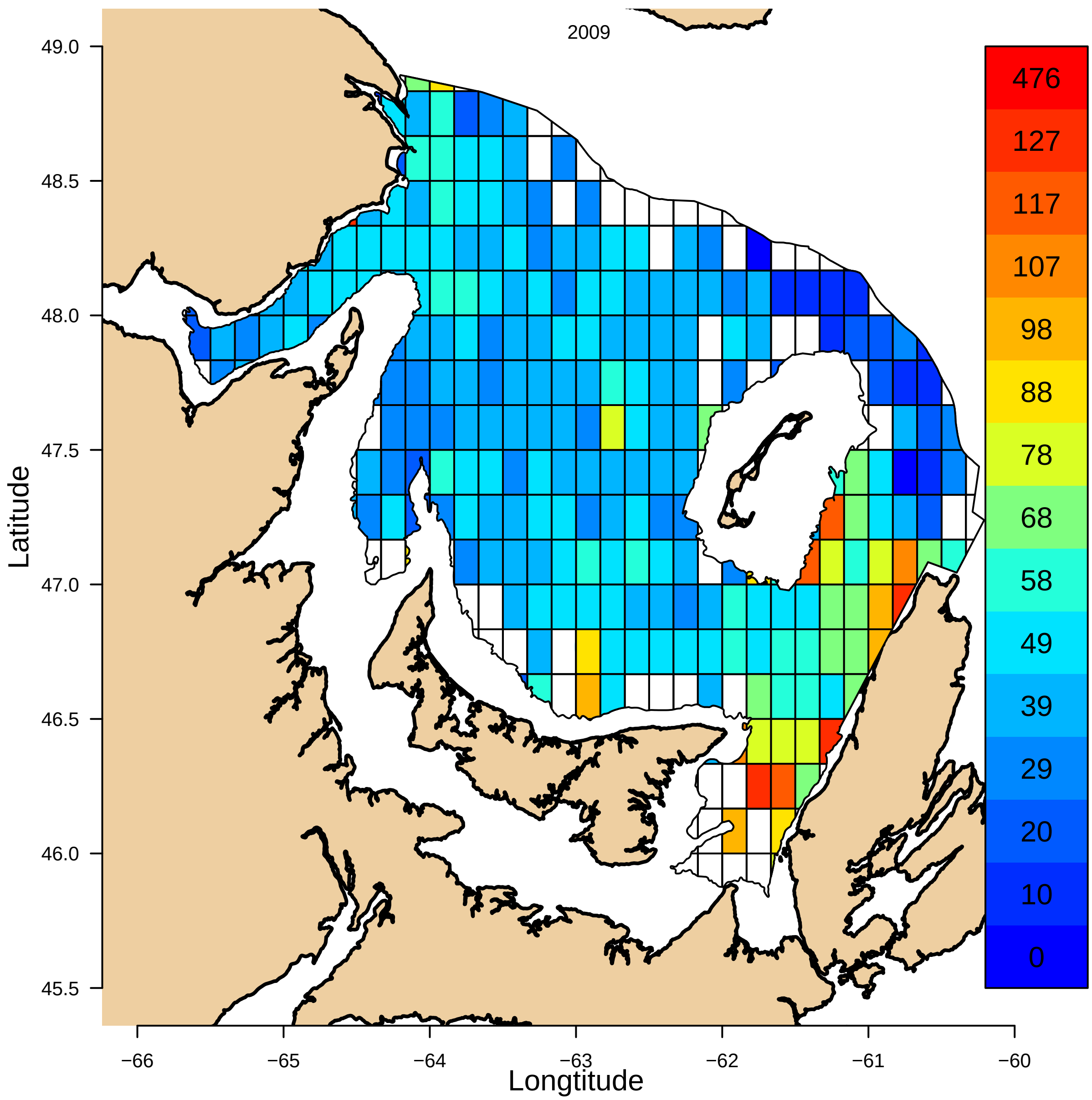


Figure SX.15a. Total annual CPUE of snow crab in each grid cell in 2009. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

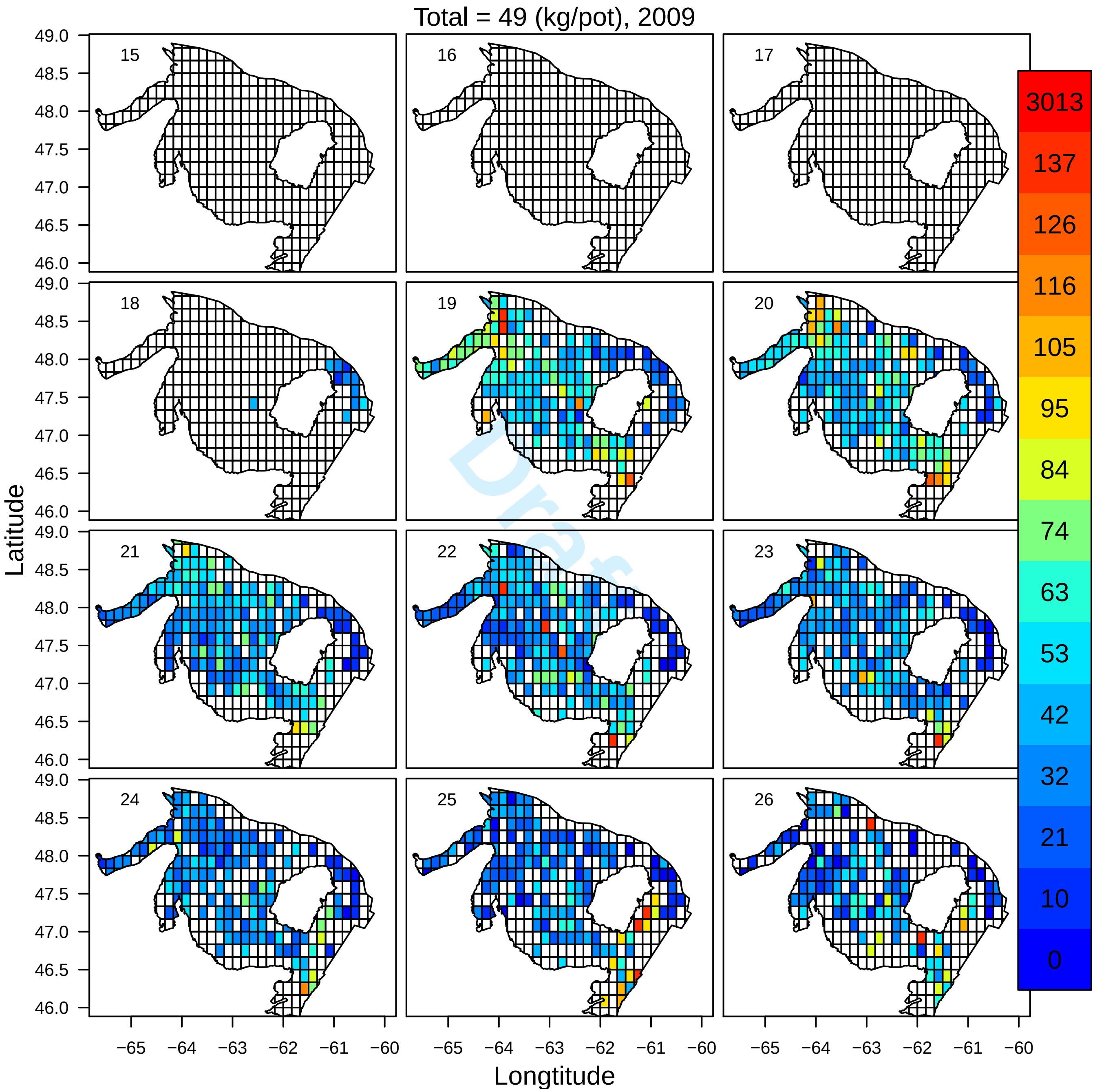


Figure SX.15b. CPUE of snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

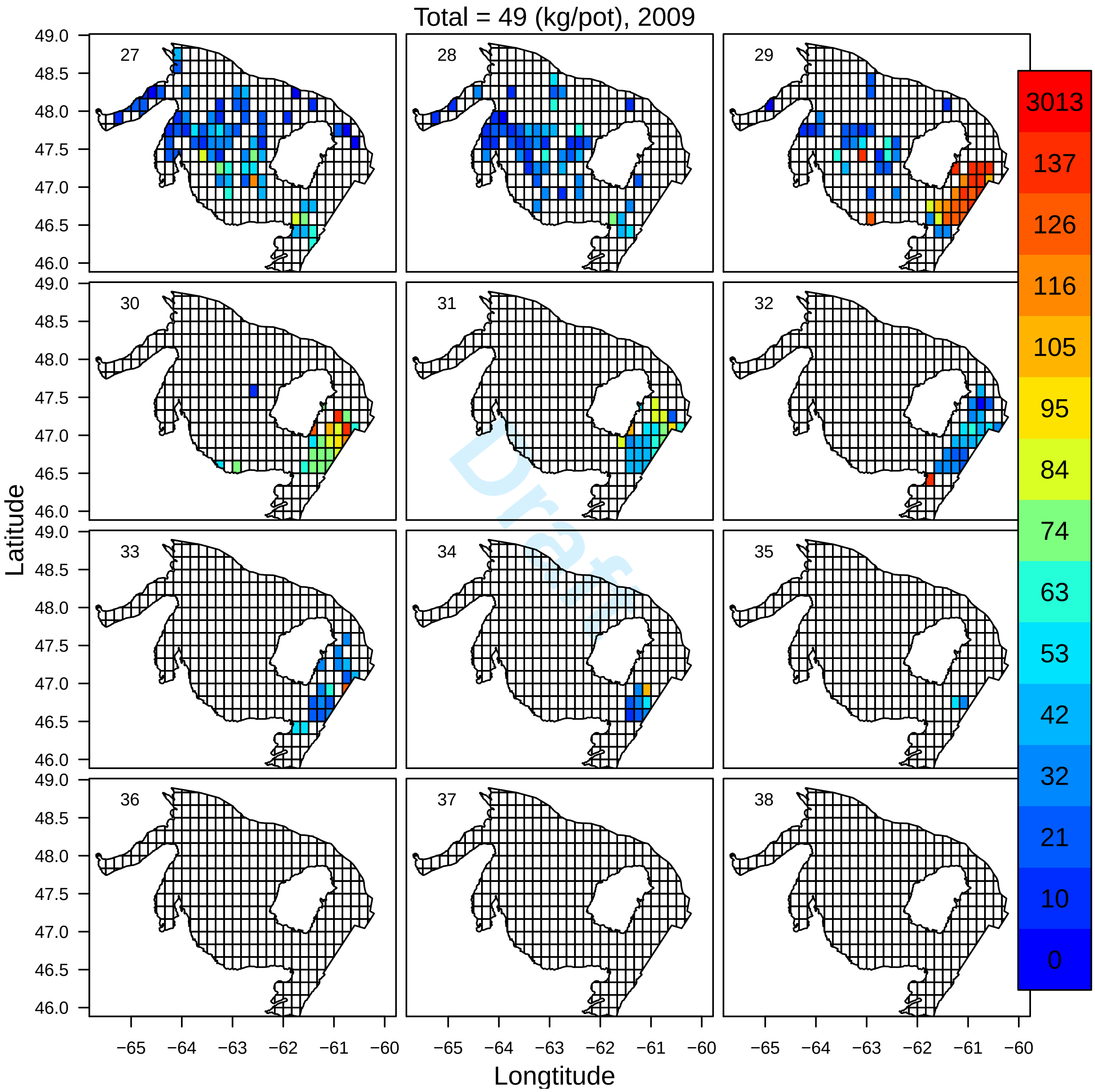


Figure SX.15c. CPUE of snow crab in each week and grid cell in 2009. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

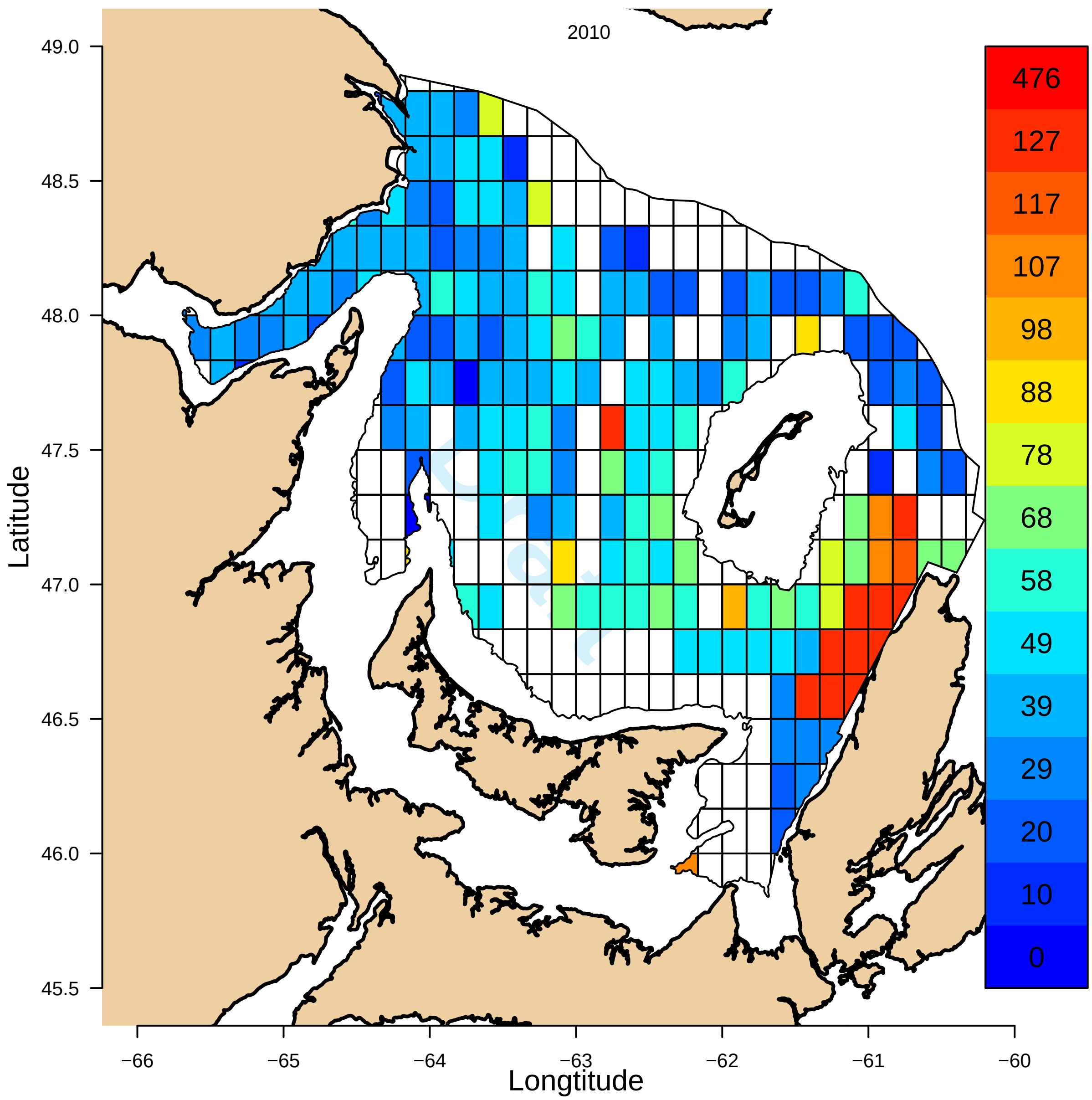


Figure SX.16a. Total annual CPUE of snow crab in each grid cell in 2010. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

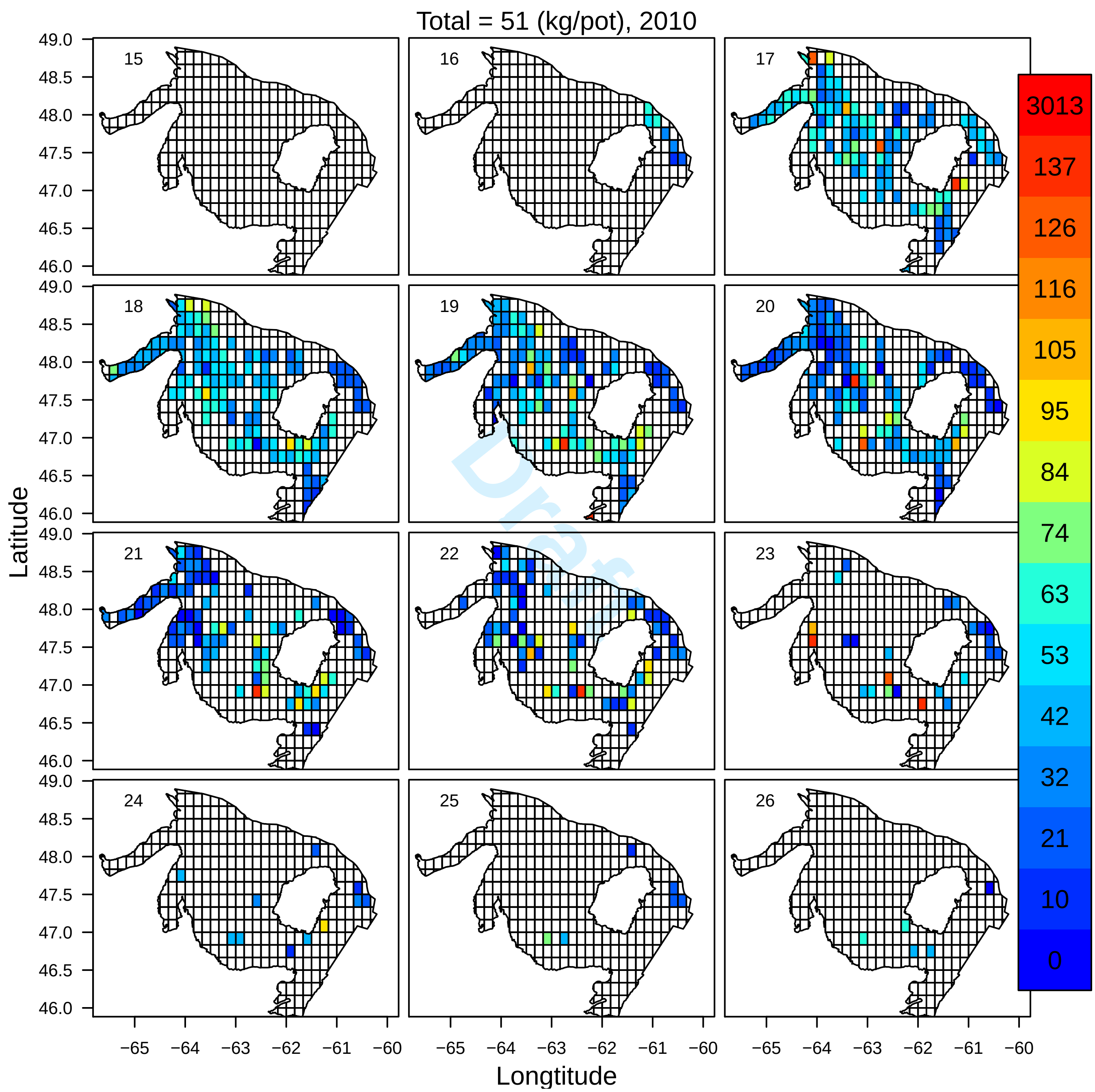


Figure SX.16b. CPUE of snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

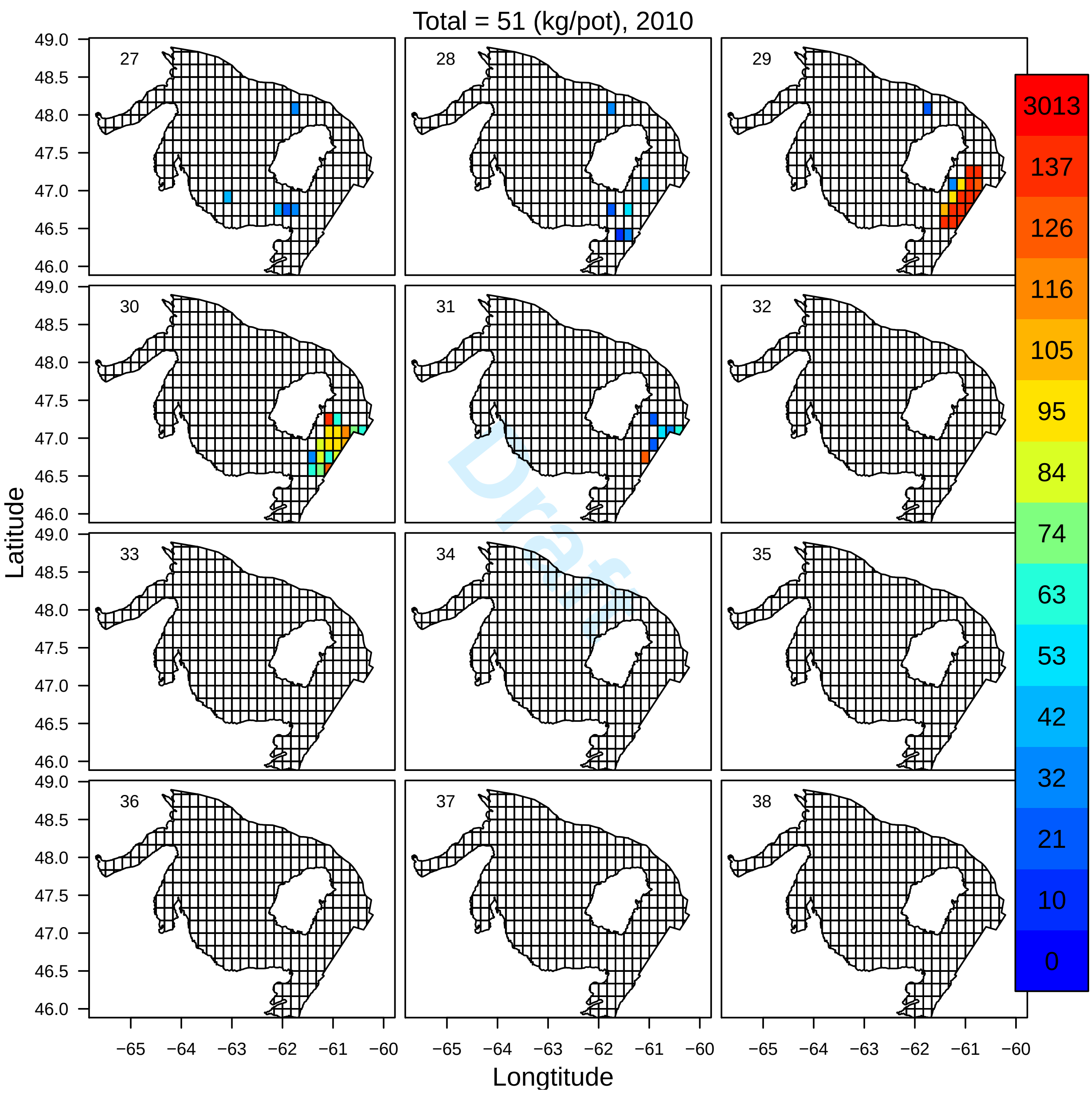


Figure SX.16c. CPUE of snow crab in each week and grid cell in 2010. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

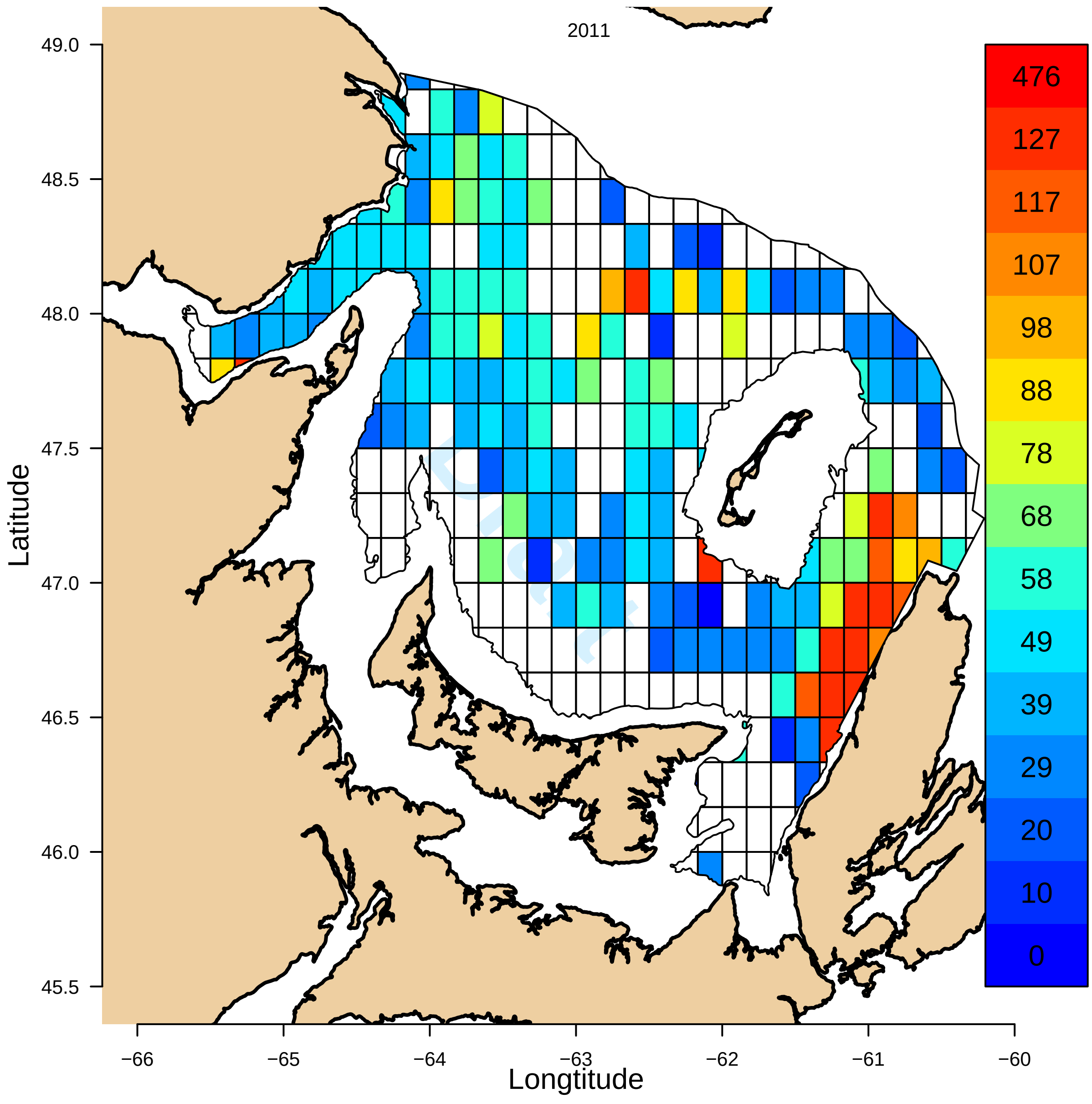


Figure SX.17a. Total annual CPUE of snow crab in each grid cell in 2011. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

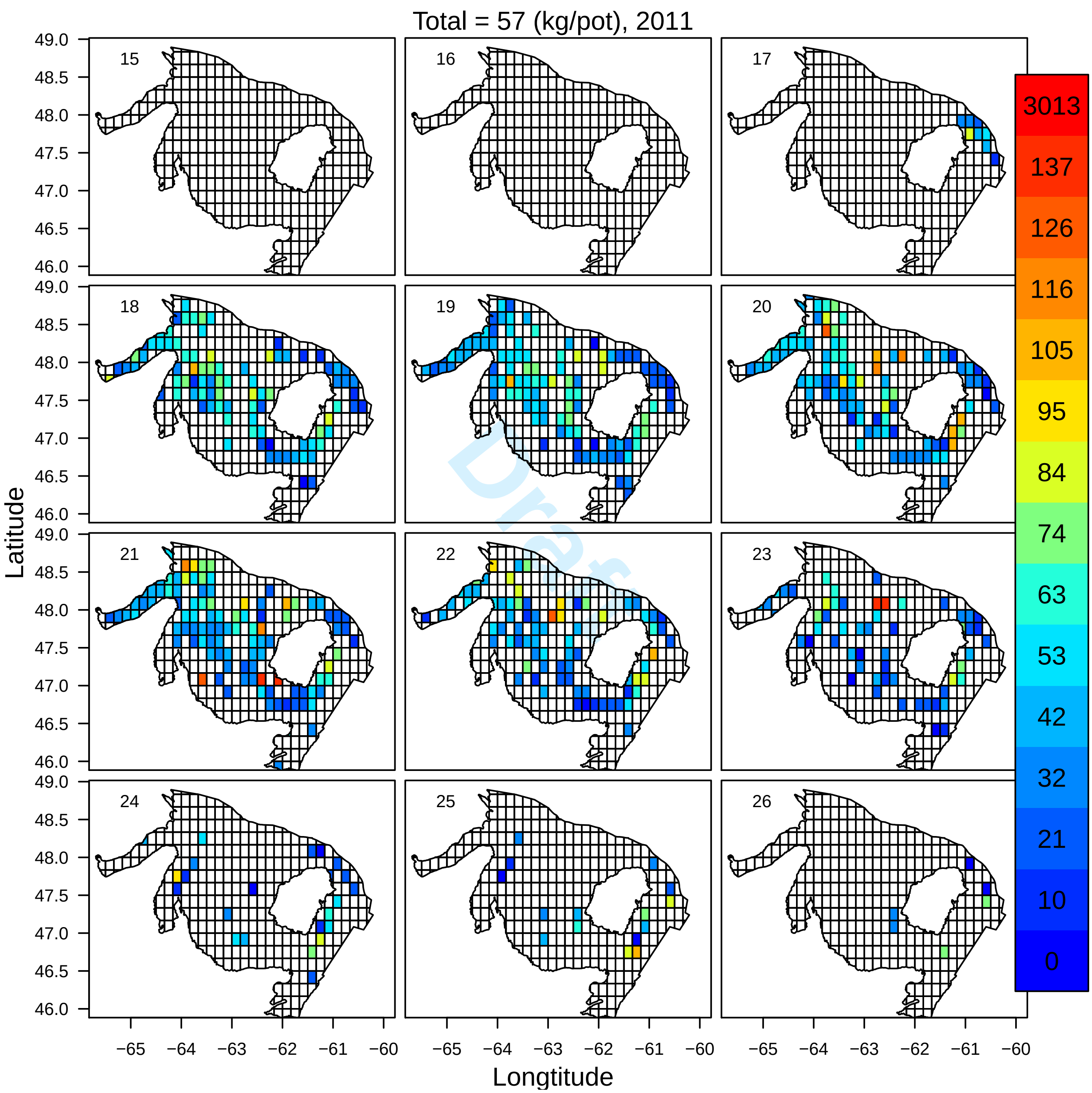


Figure SX.17b. CPUE of snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

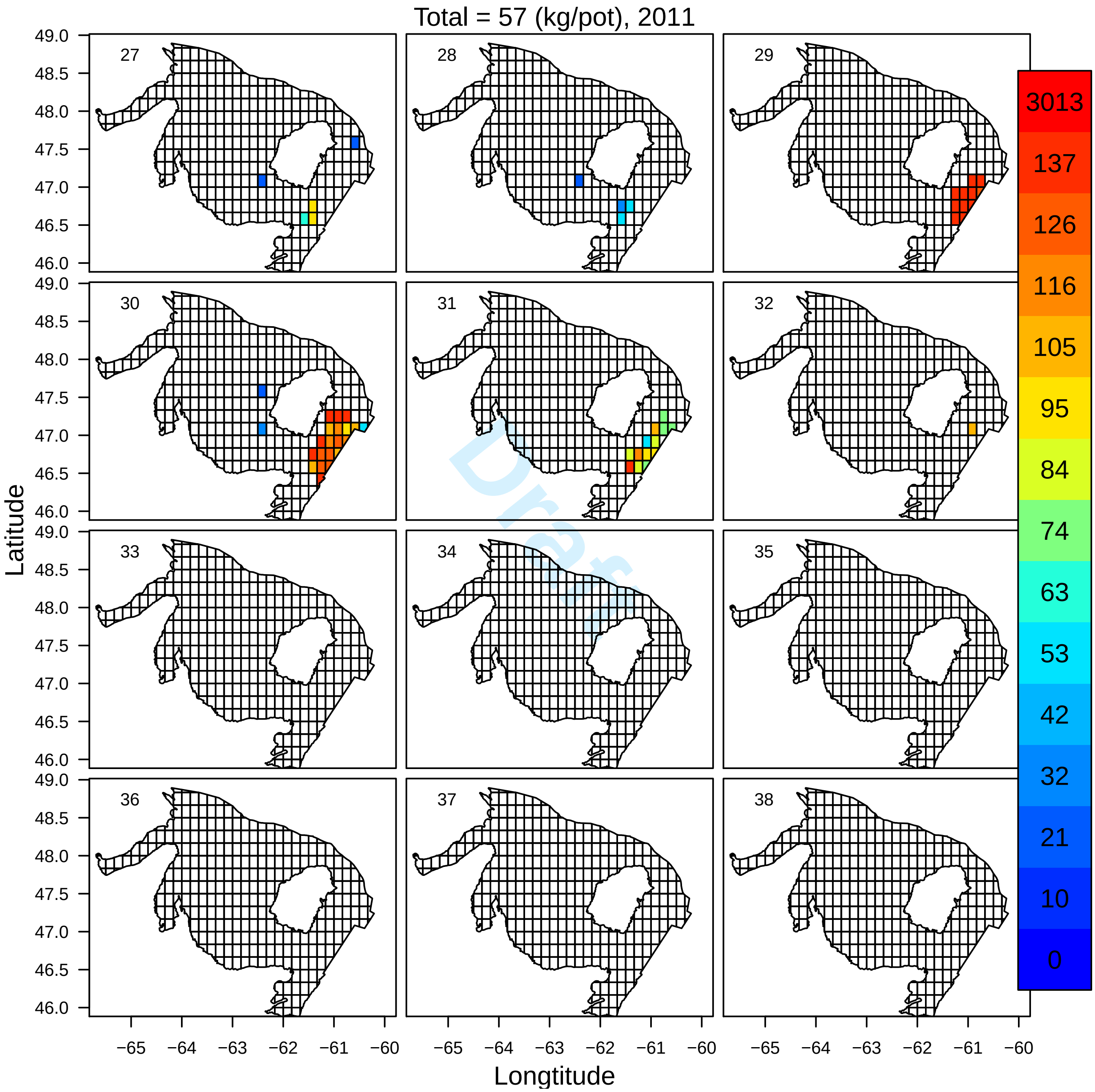


Figure SX.17c. CPUE of snow crab in each week and grid cell in 2011. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

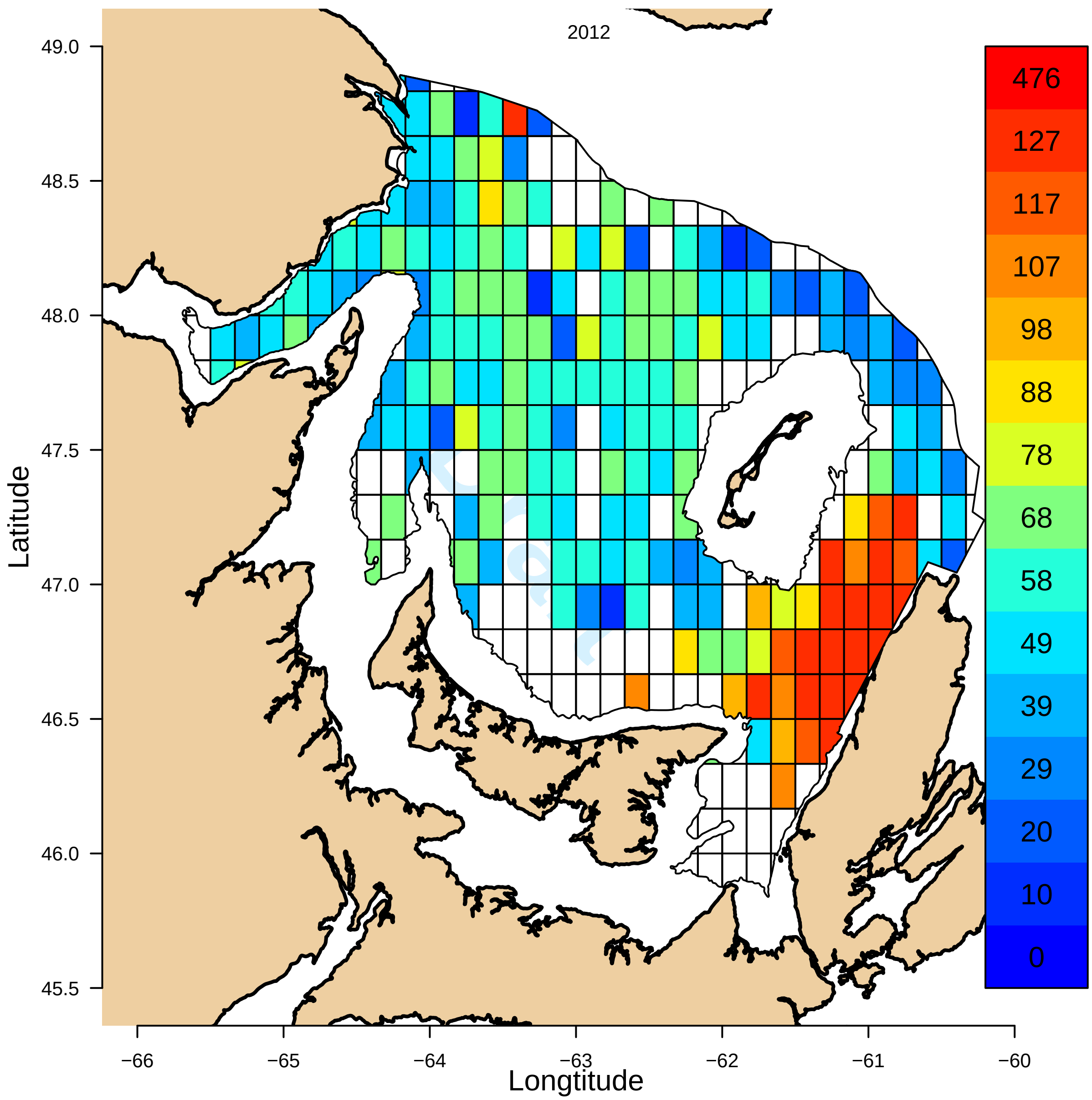


Figure SX.18a. Total annual CPUE of snow crab in each grid cell in 2012. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

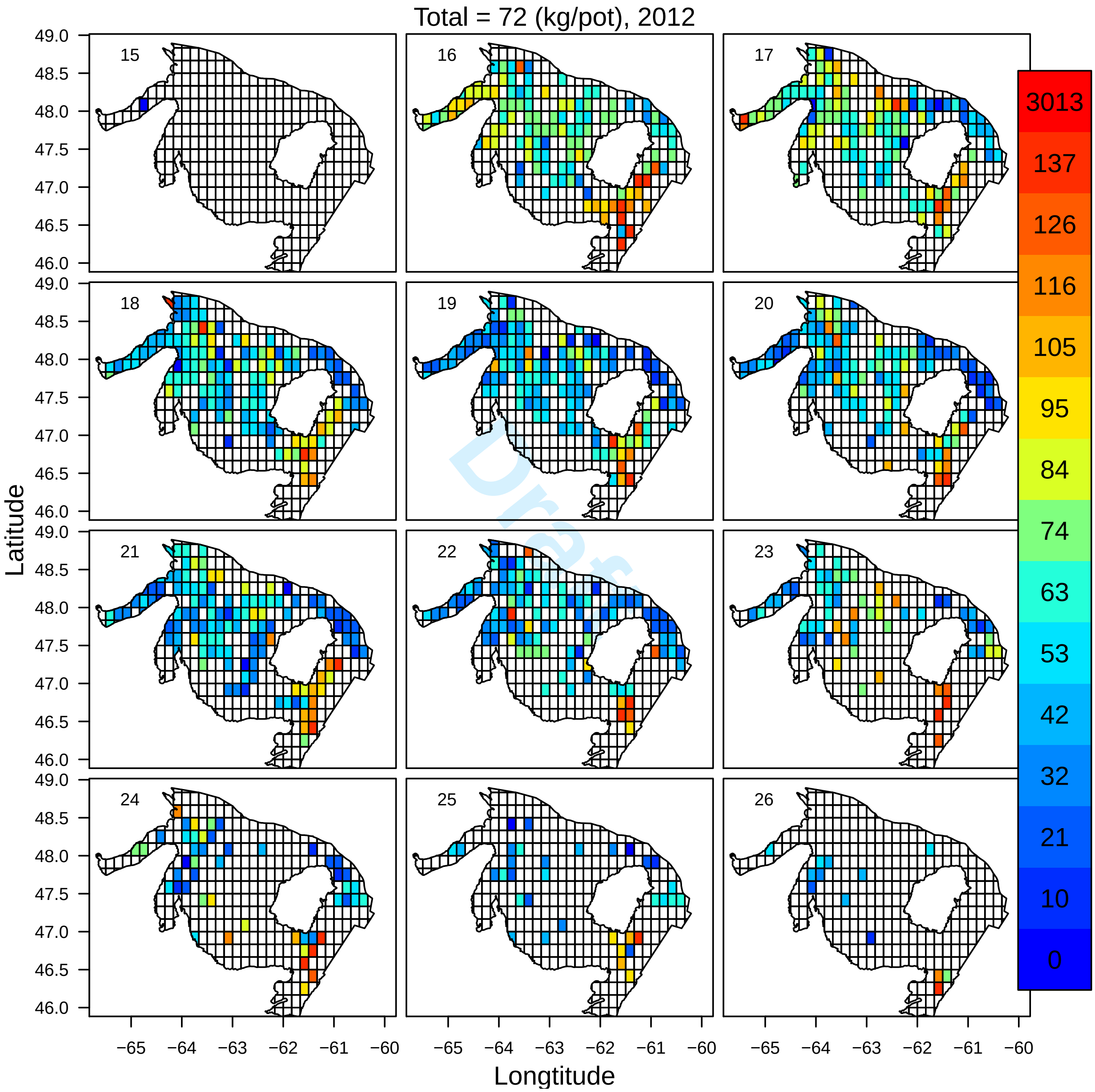


Figure SX.18b. CPUE of snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

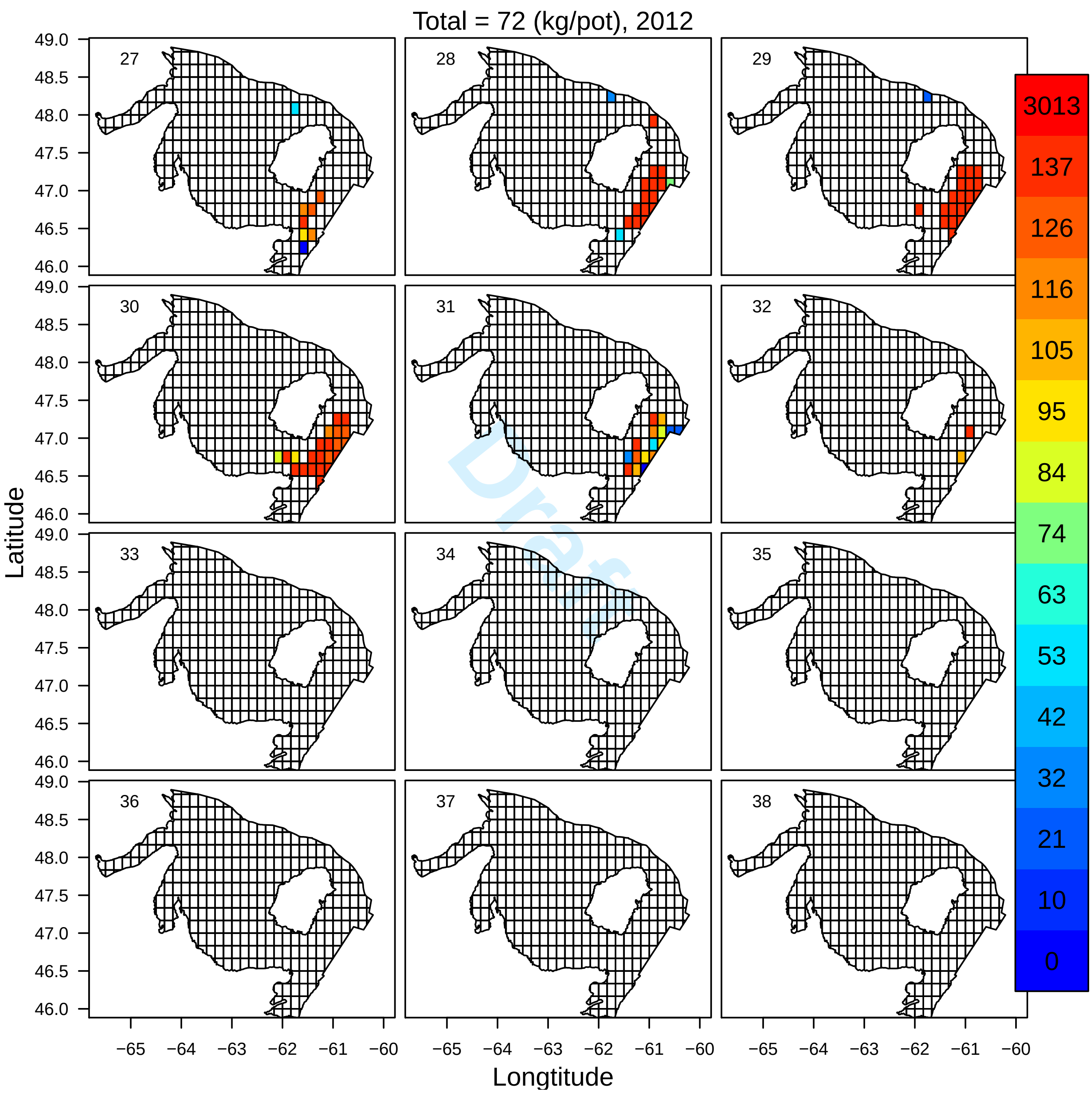


Figure SX.18c. CPUE of snow crab in each week and grid cell in 2012. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

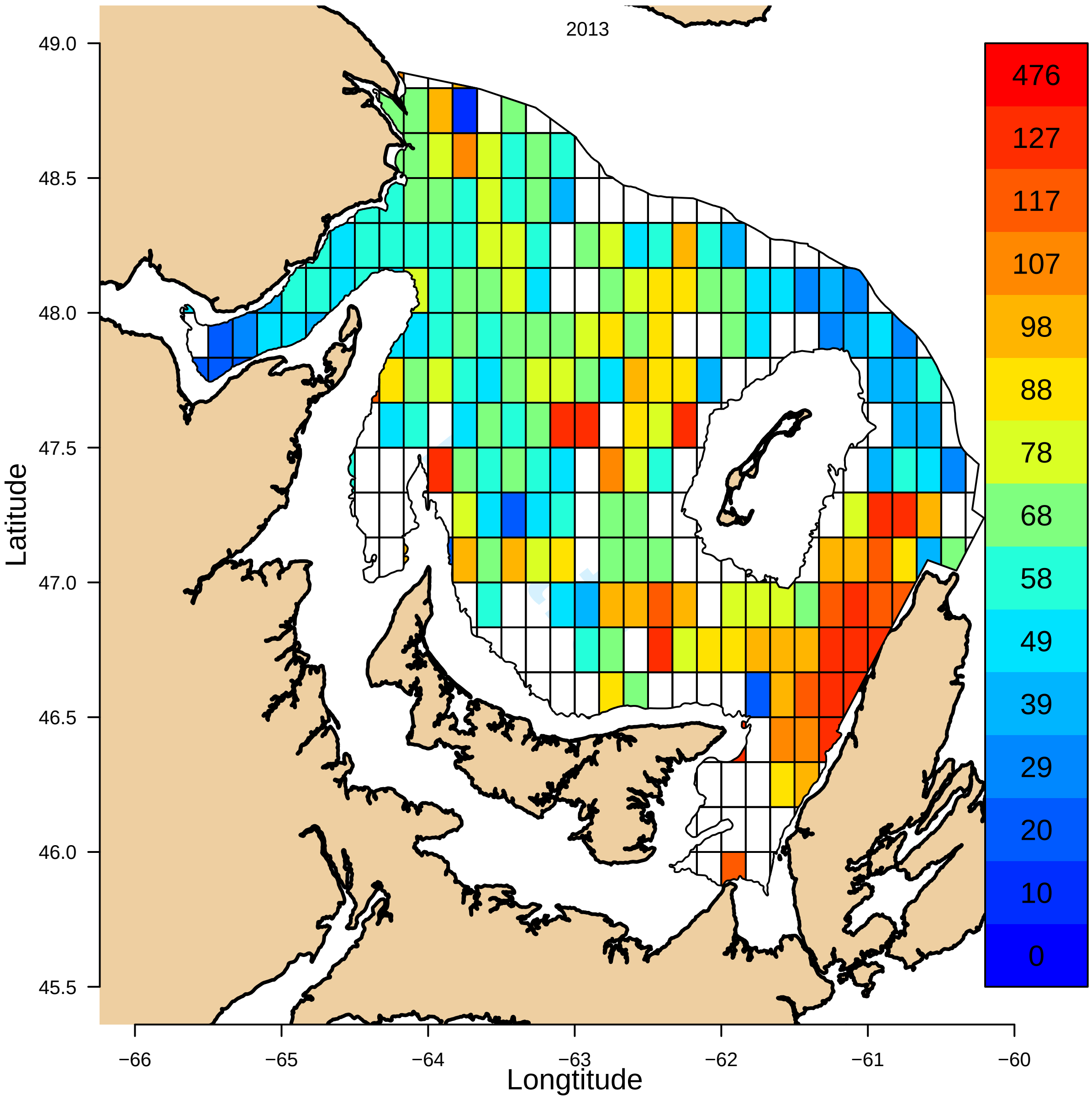


Figure SX.19a. Total annual CPUE of snow crab in each grid cell in 2013. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

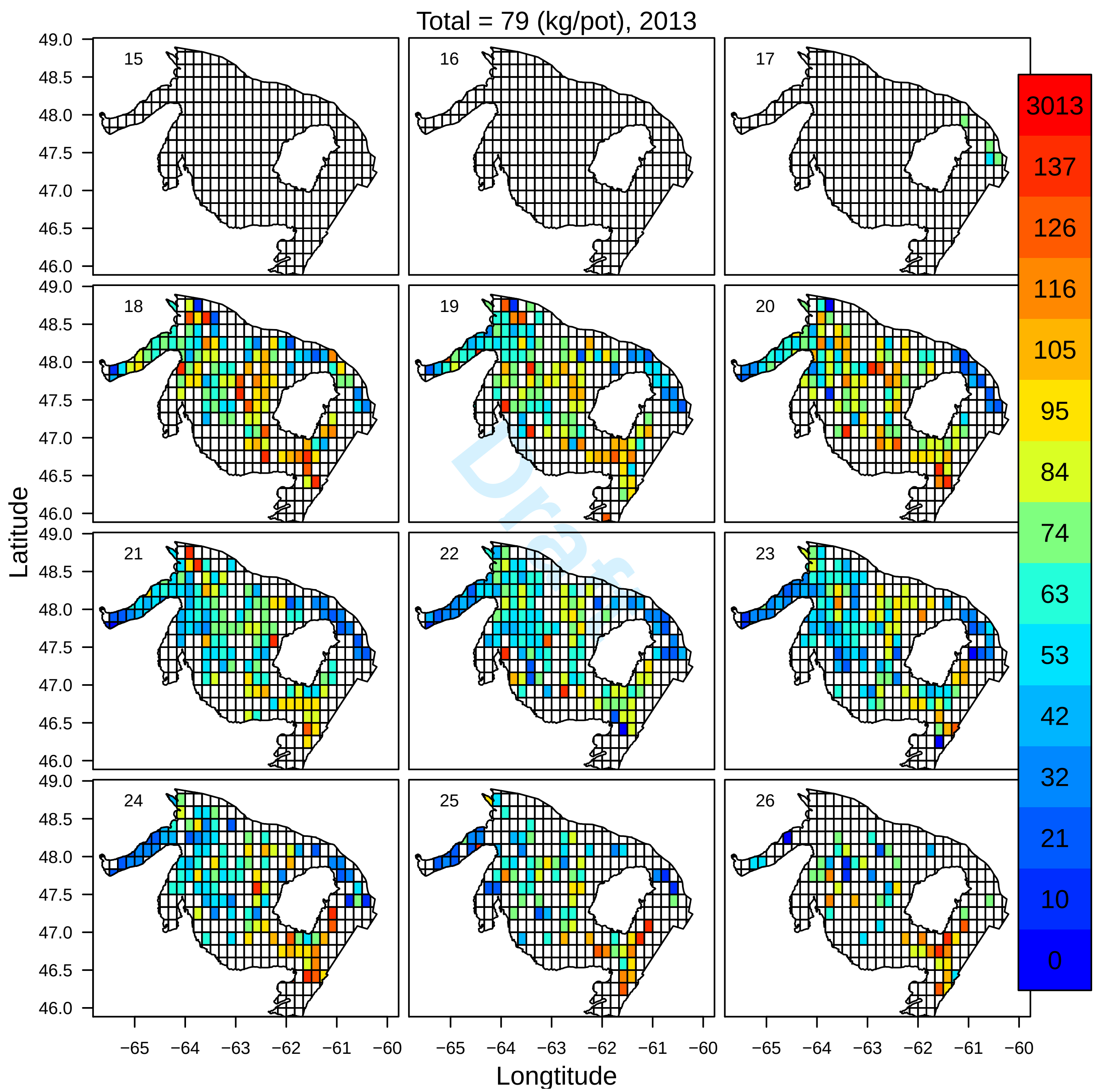


Figure SX.19b. CPUE of snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

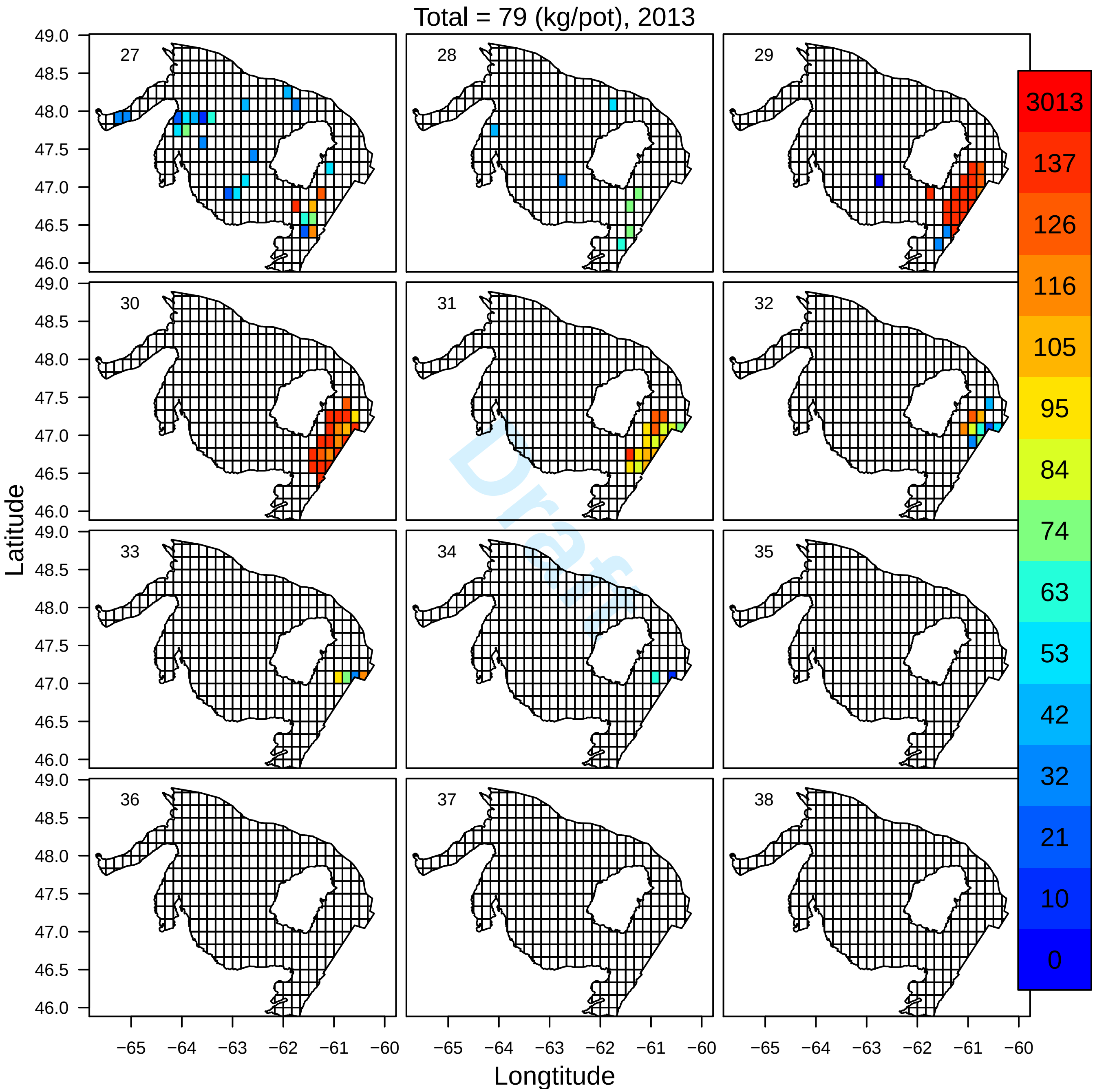


Figure SX.19c. CPUE of snow crab in each week and grid cell in 2013. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

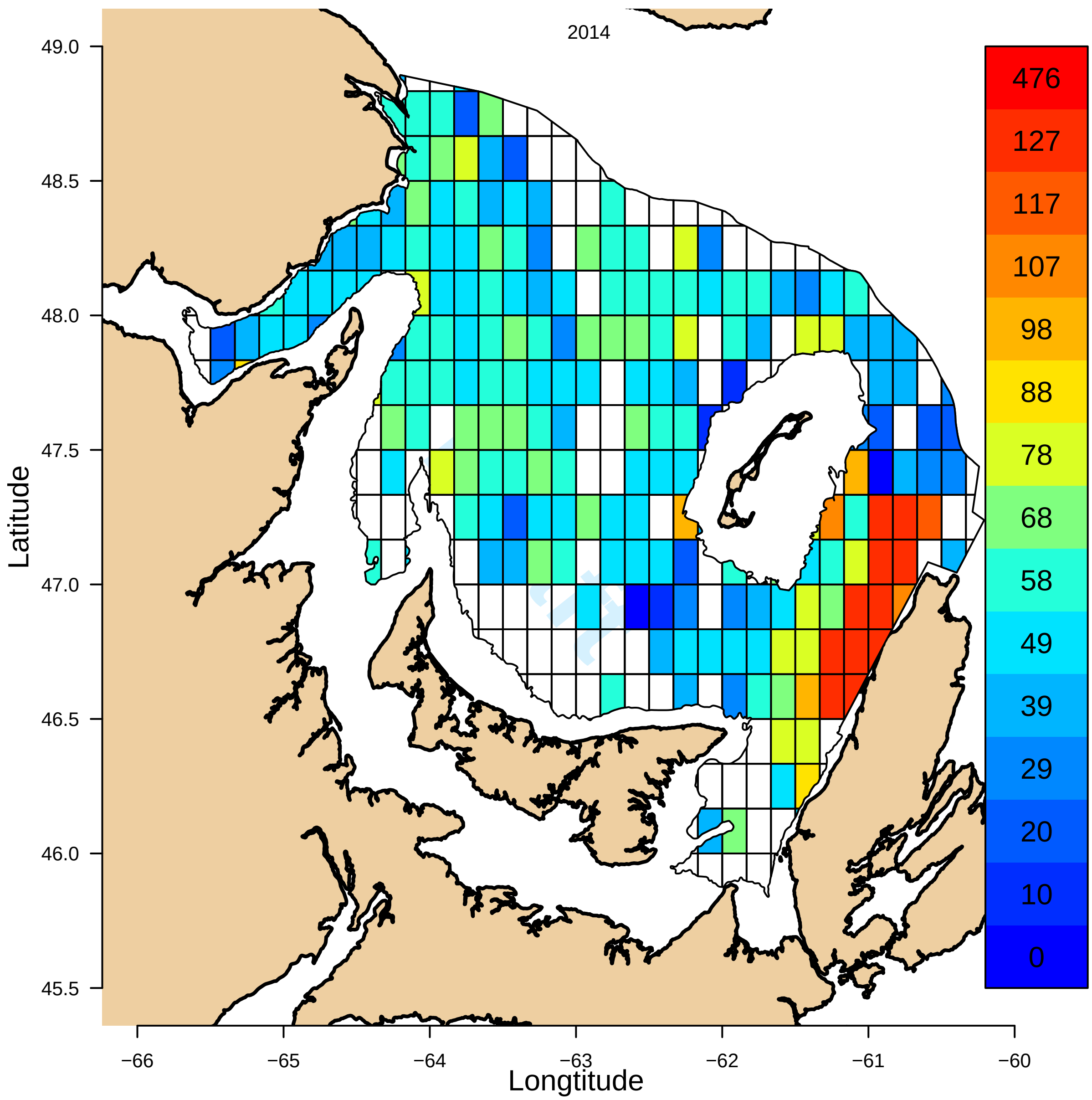


Figure SX.20a. Total annual CPUE of snow crab in each grid cell in 2014. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

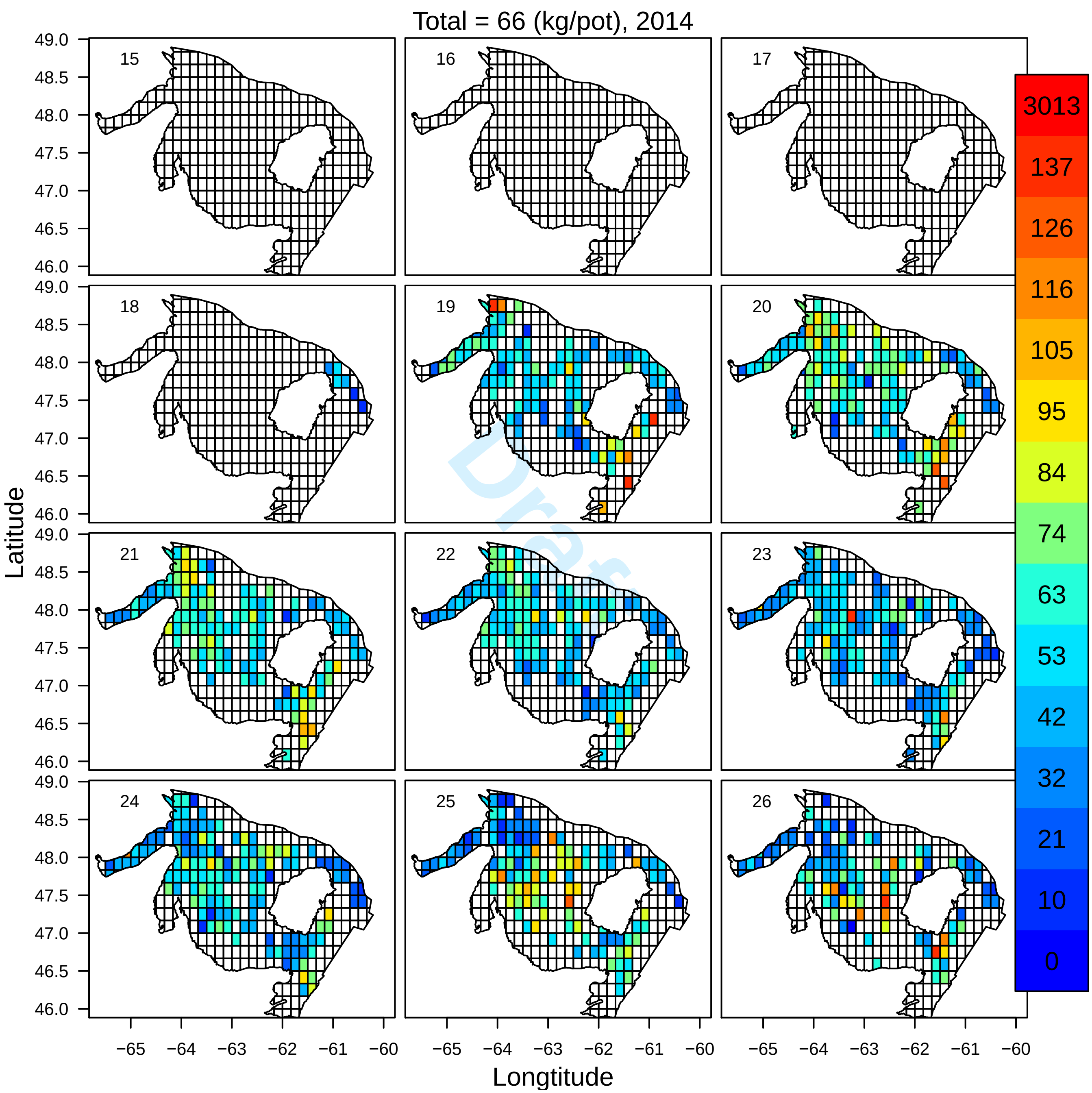


Figure SX.20b. CPUE of snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

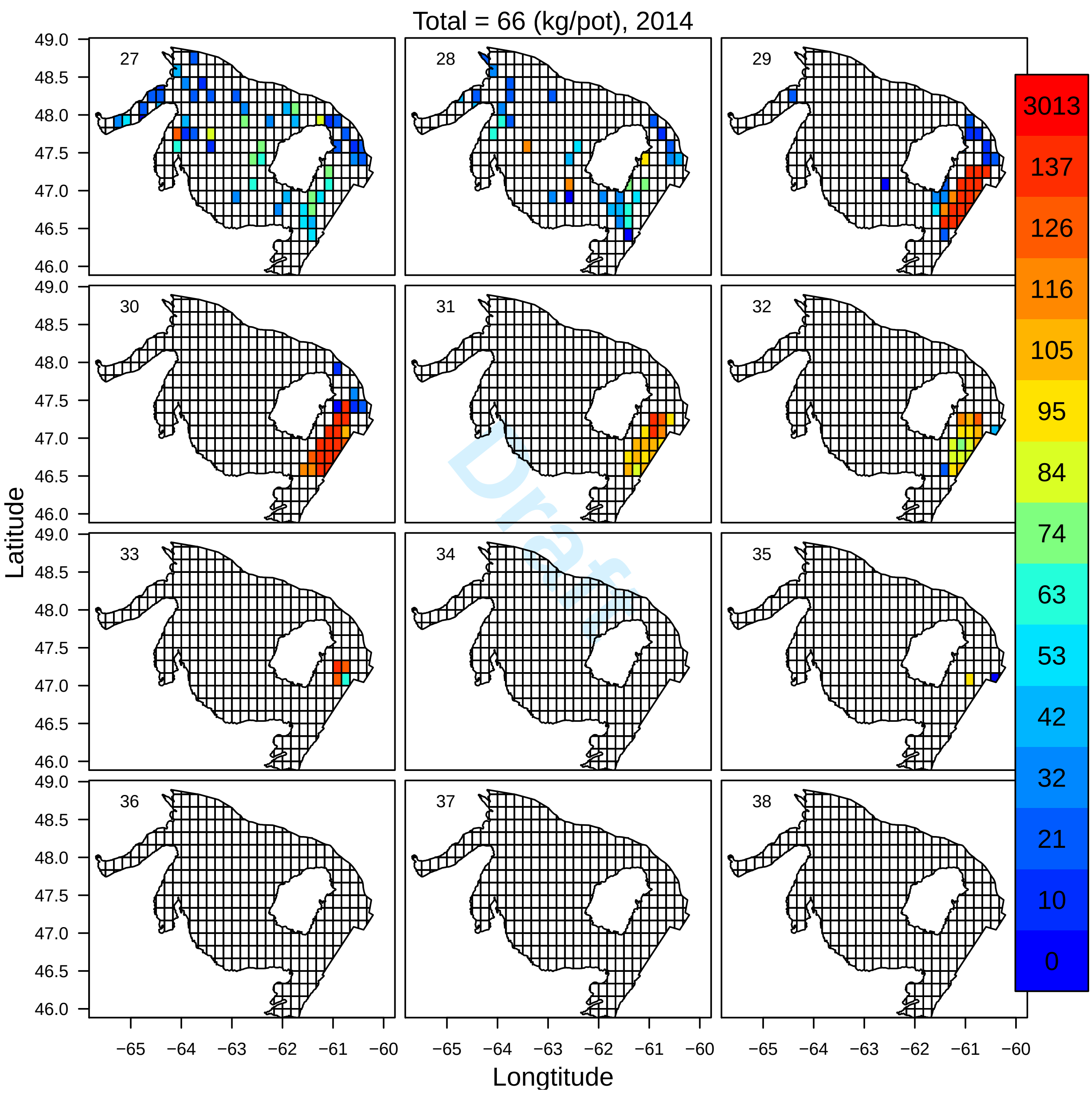


Figure SX.20c. CPUE of snow crab in each week and grid cell in 2014. The week number is indicated in the top left-hand corner. Colors correspond to CPUE levels, as indicated in the legend on the right-hand side. Darkest red grids indicate CPUE > 98th percentile.

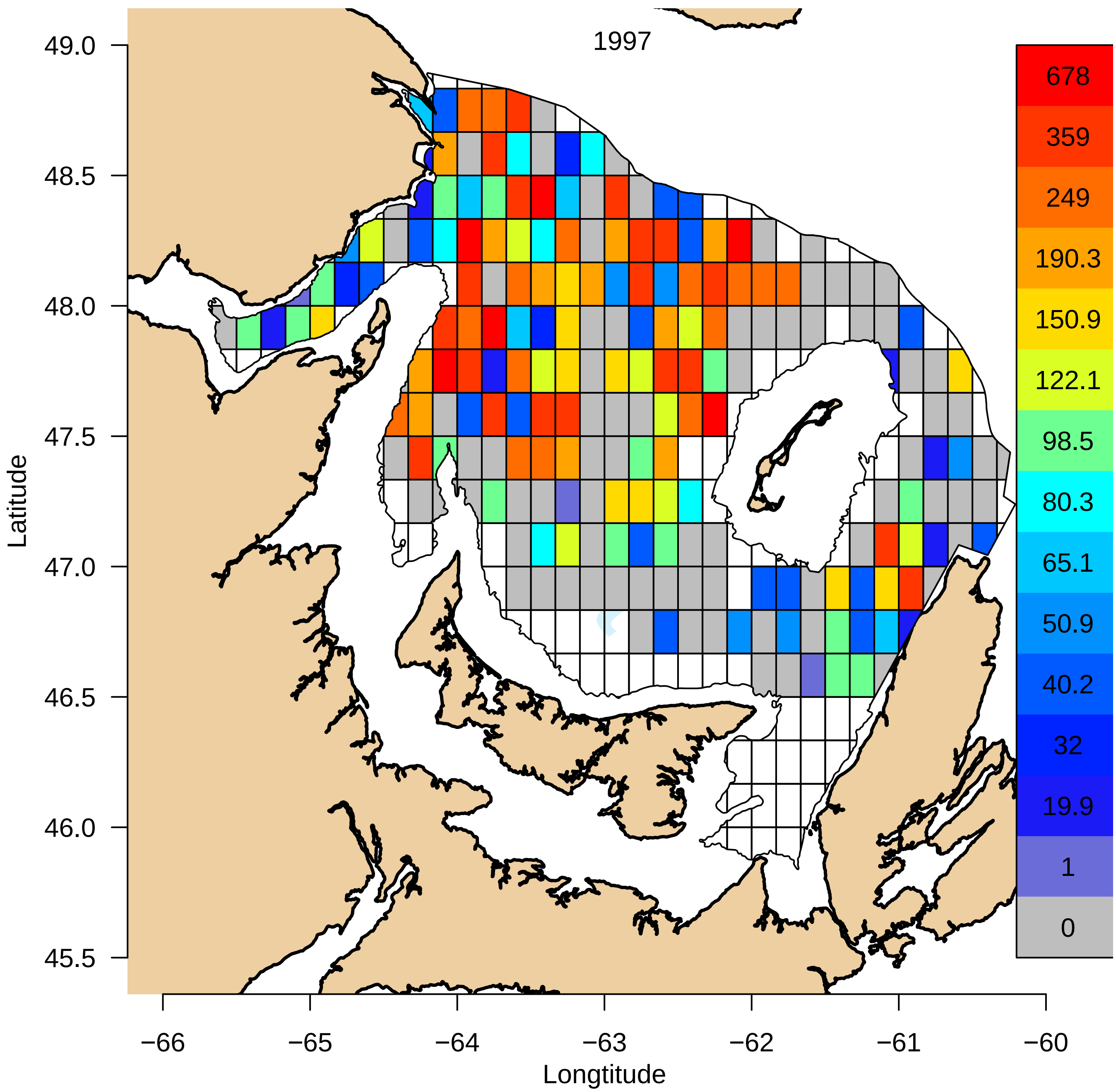


Figure SSEB.1. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 1997. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

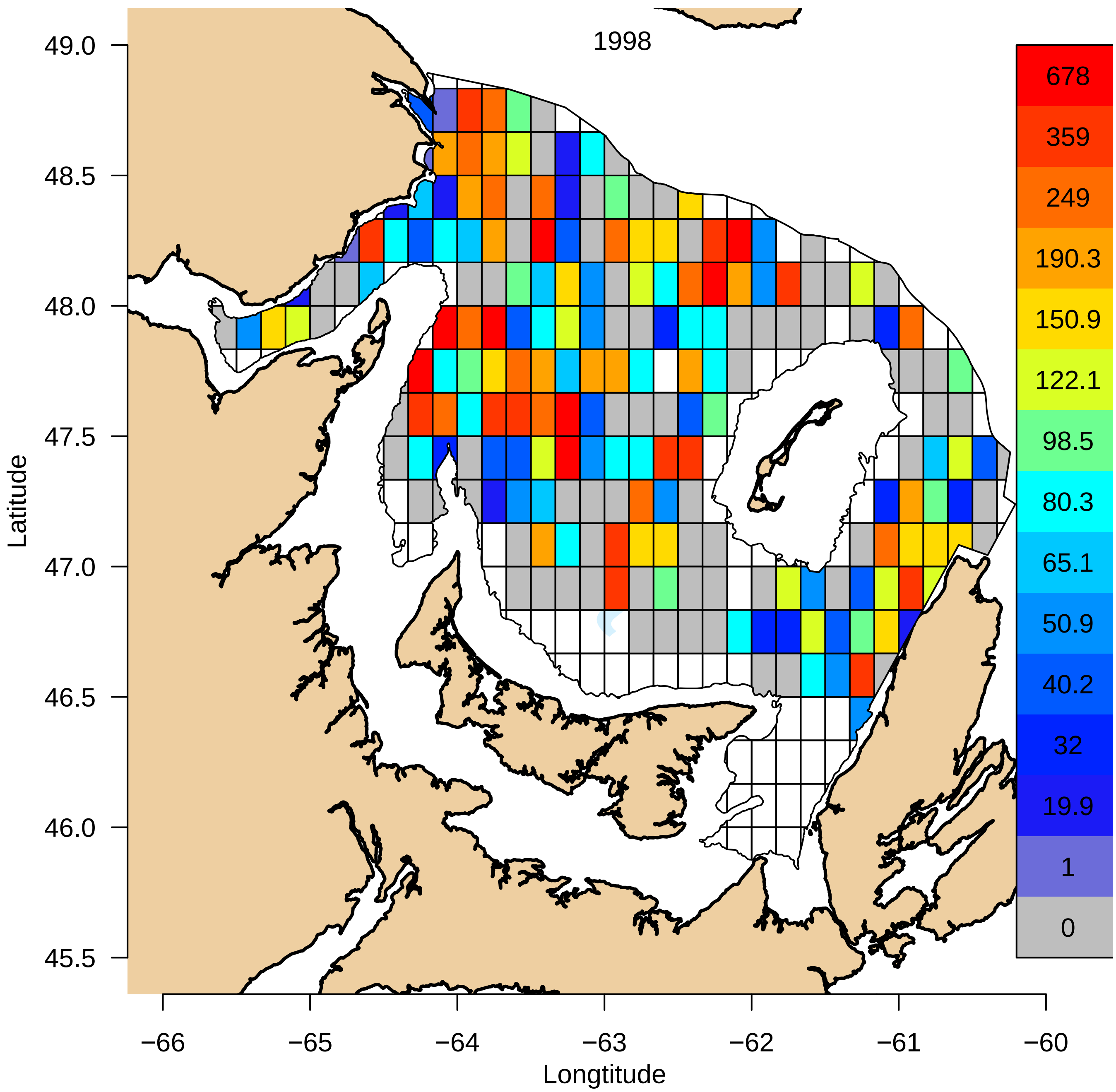


Figure SSEB.2. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 1998. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

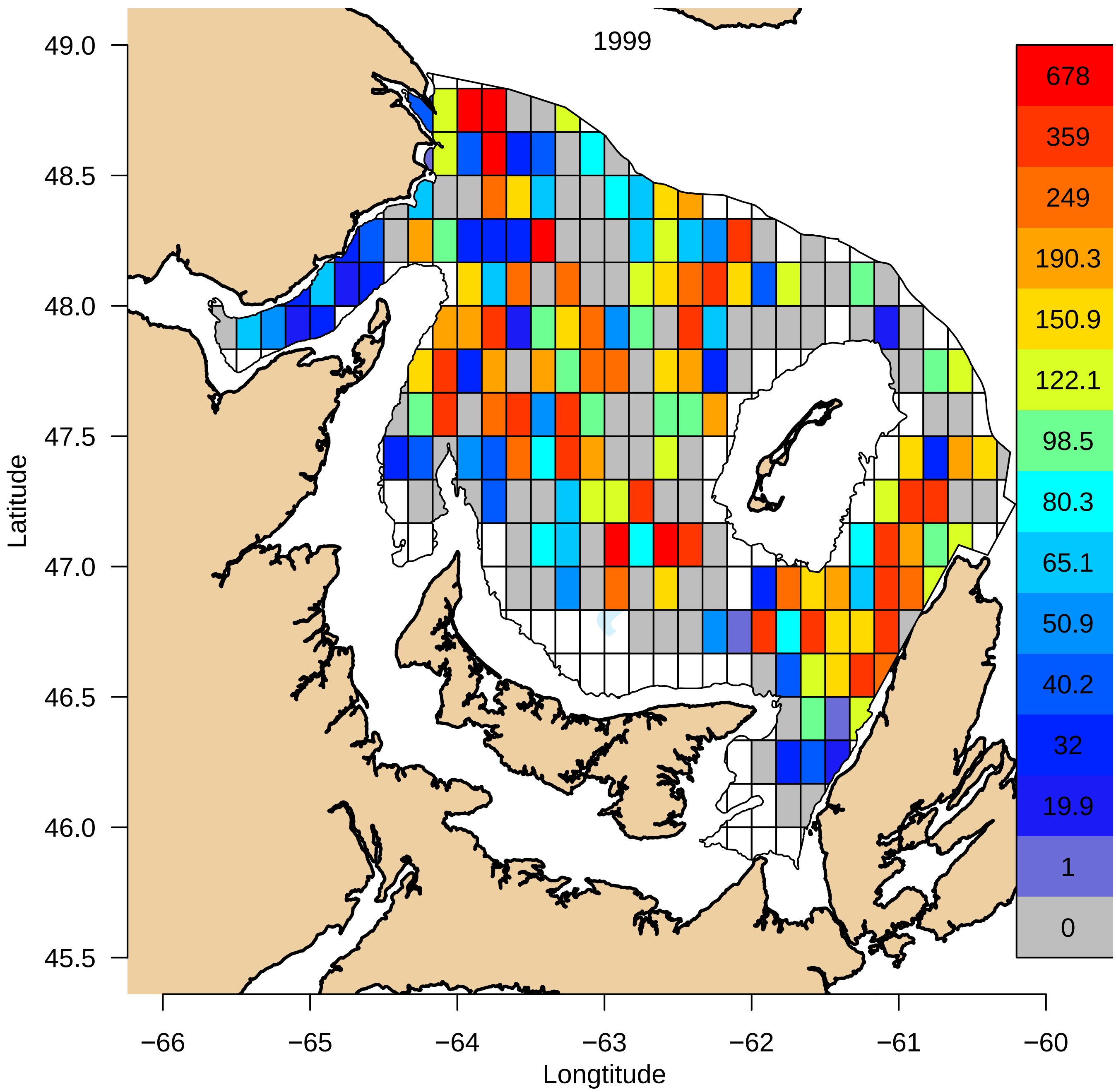


Figure SSEB.3. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 1999. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

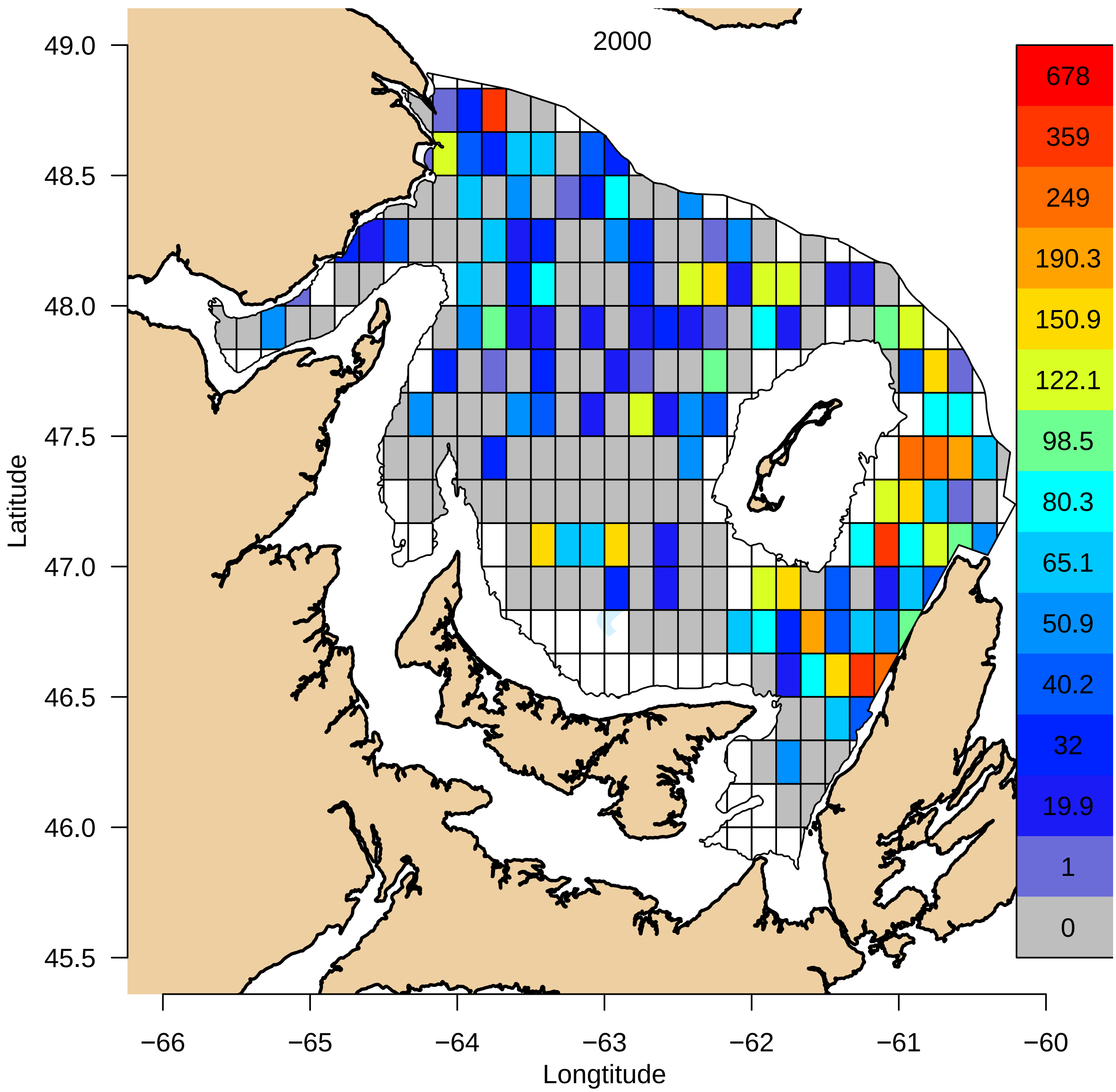


Figure SSEB.4. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2000. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

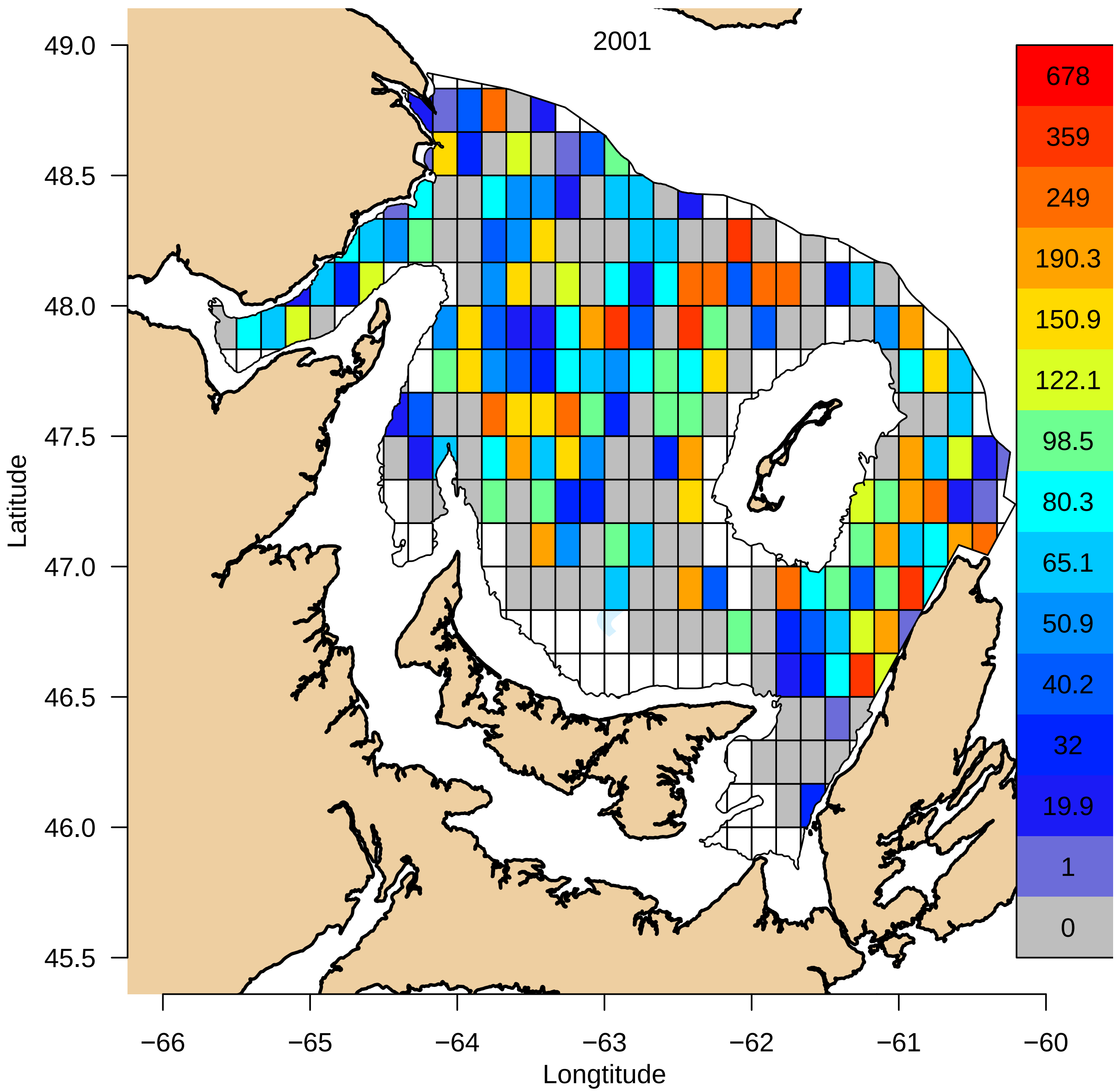


Figure SSEB.5. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2001. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

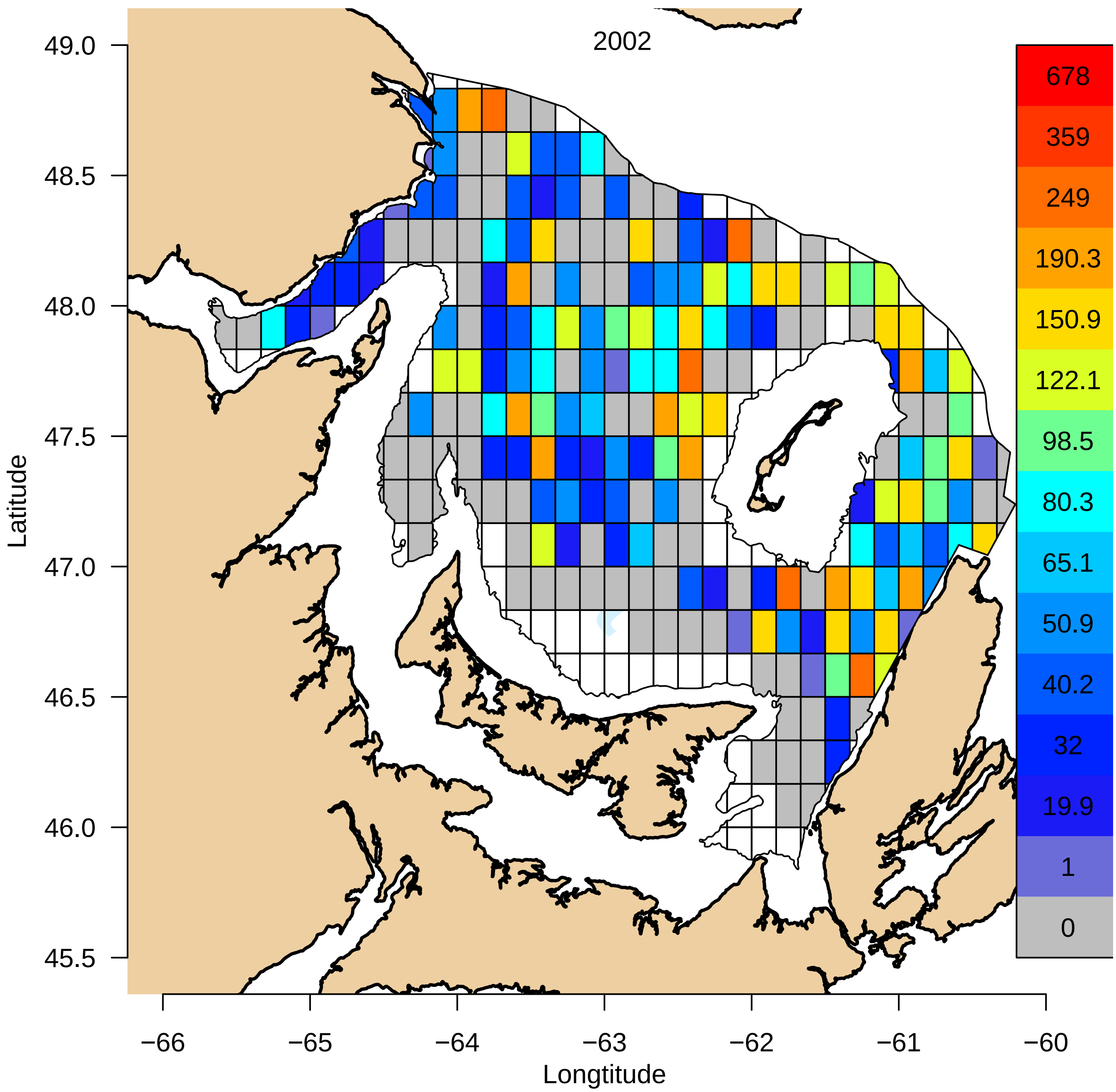


Figure SSEB.6. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2002. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

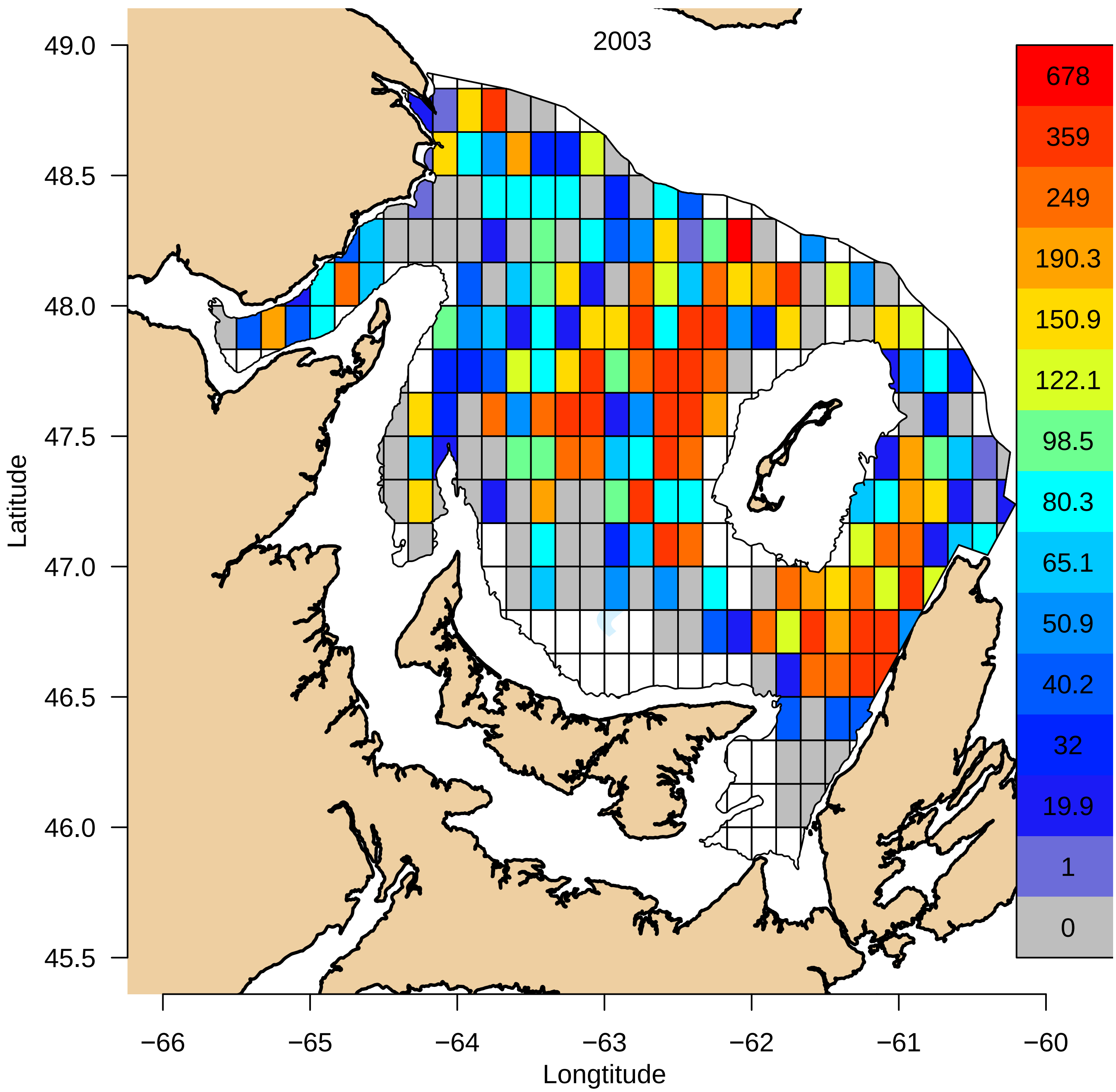


Figure SSEB.7. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2003. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

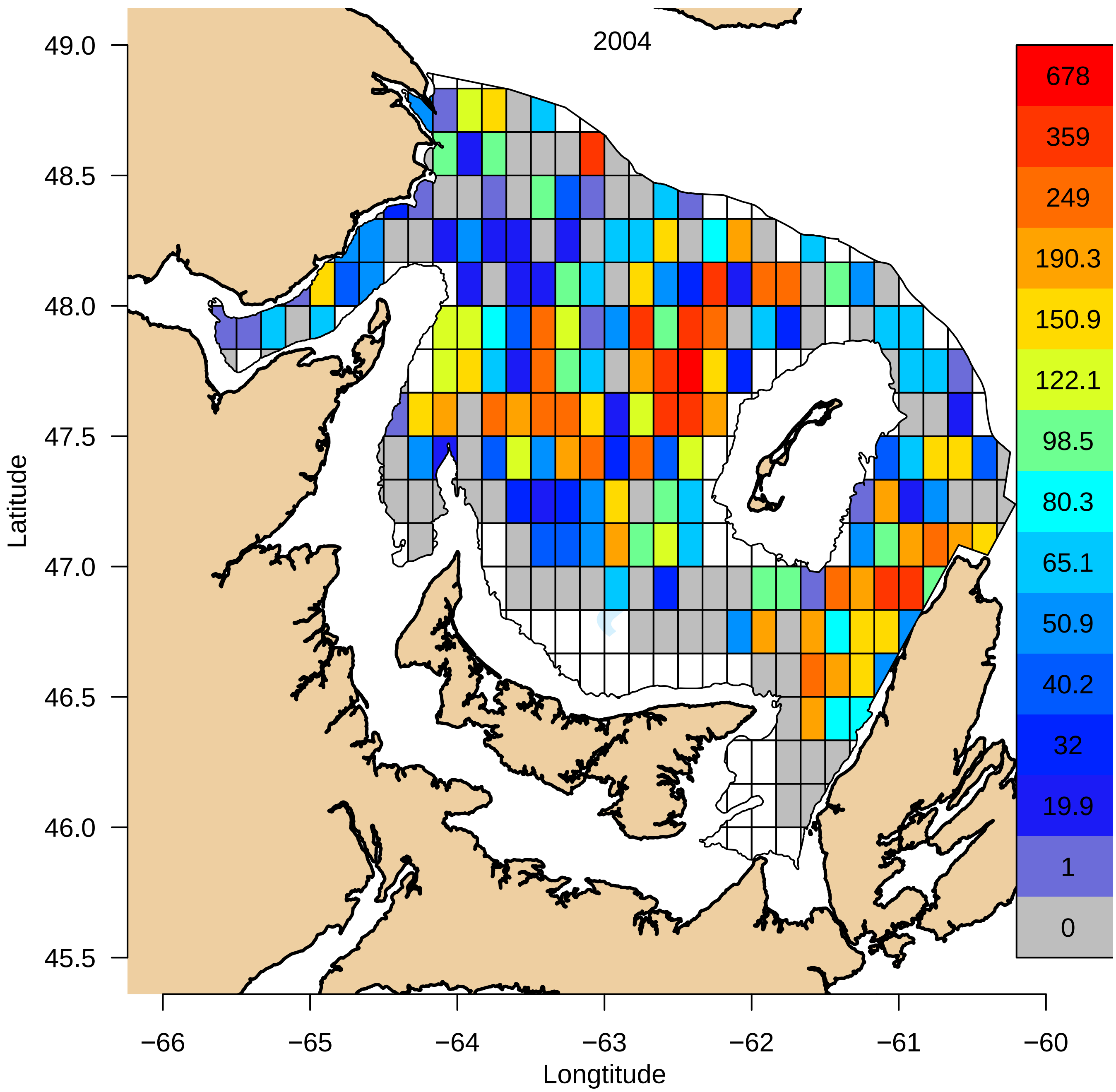


Figure SSEB.8. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2004. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

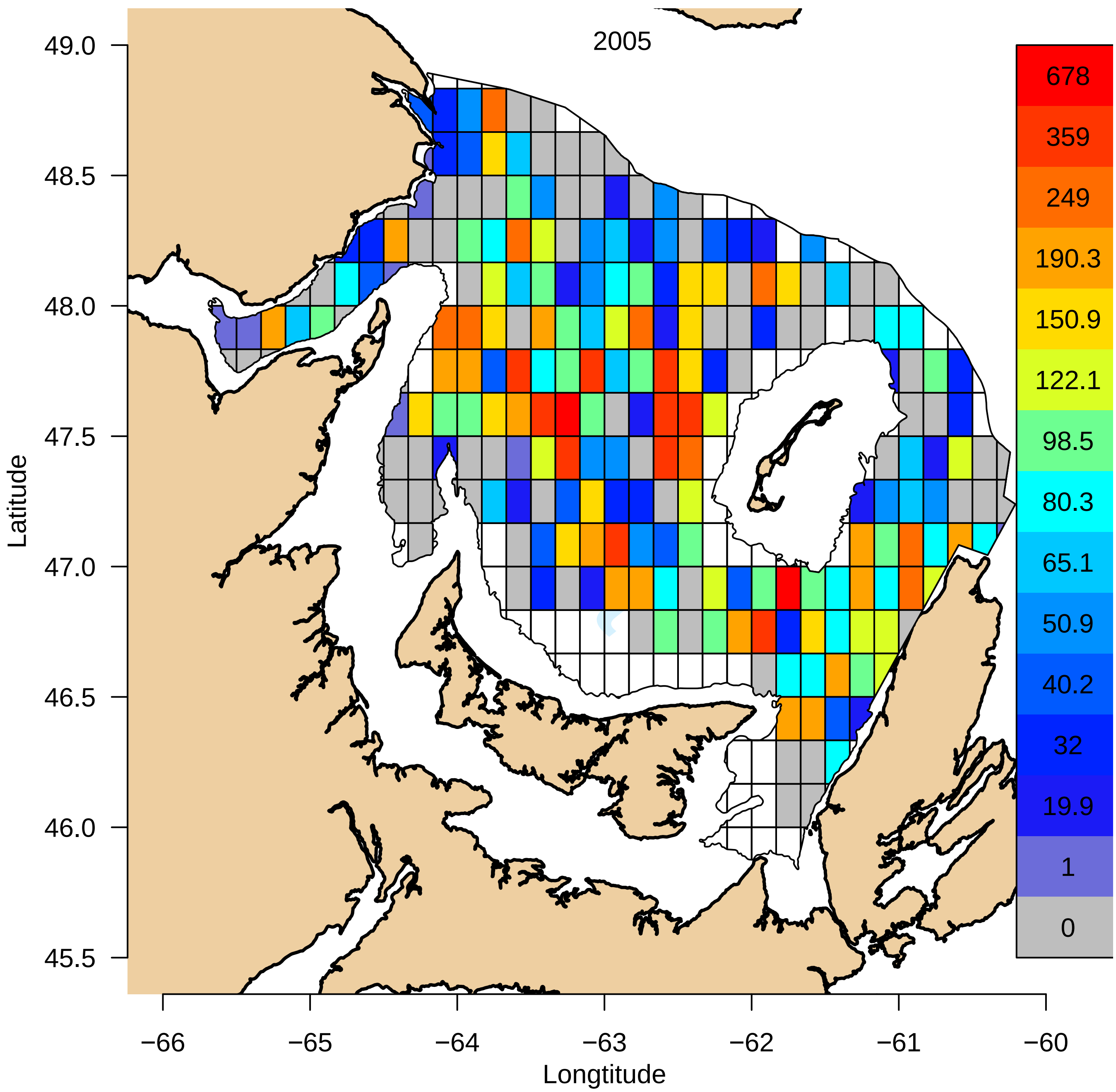


Figure SSEB.9. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2005. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

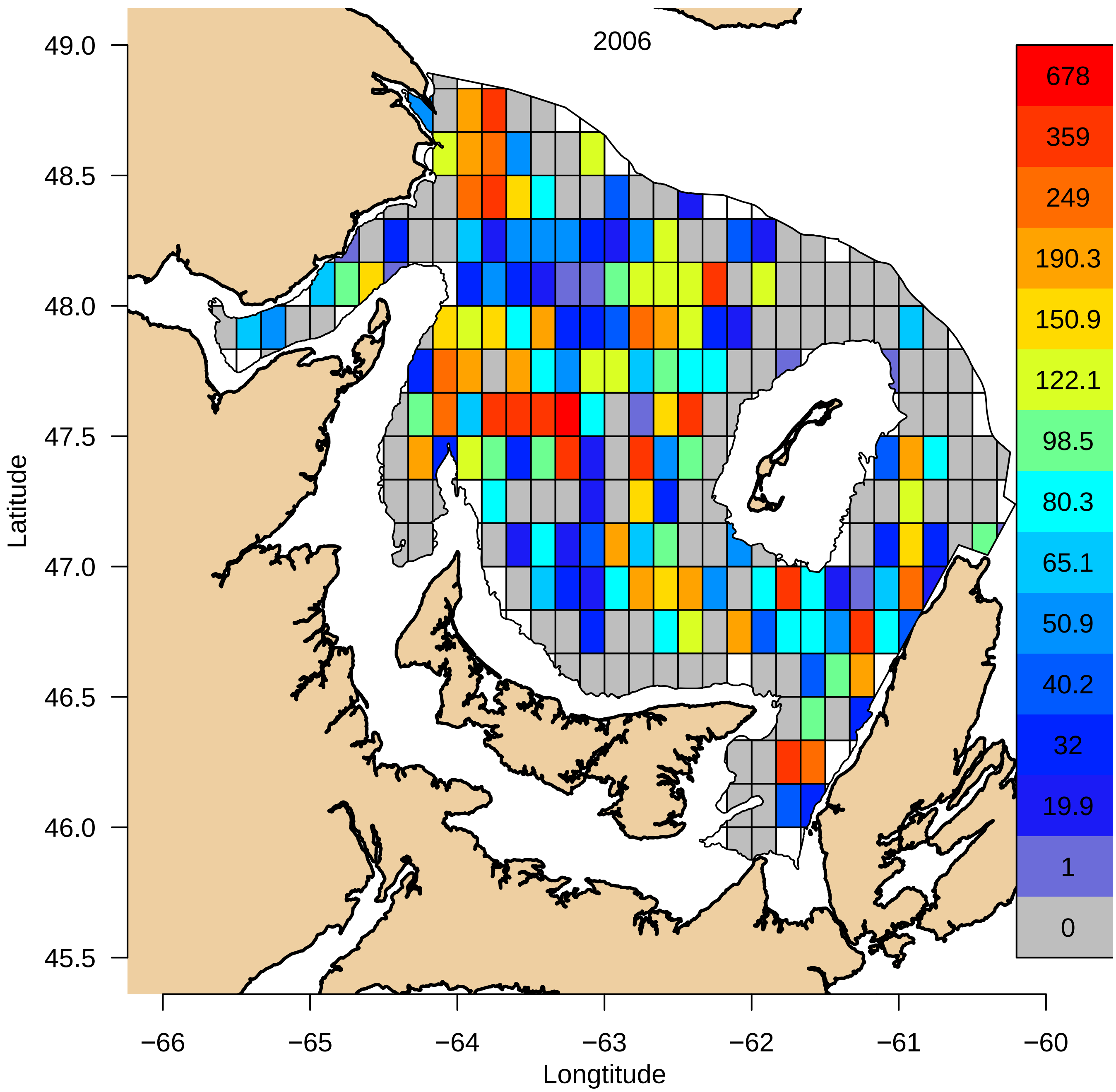


Figure SSEB.10. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2006. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

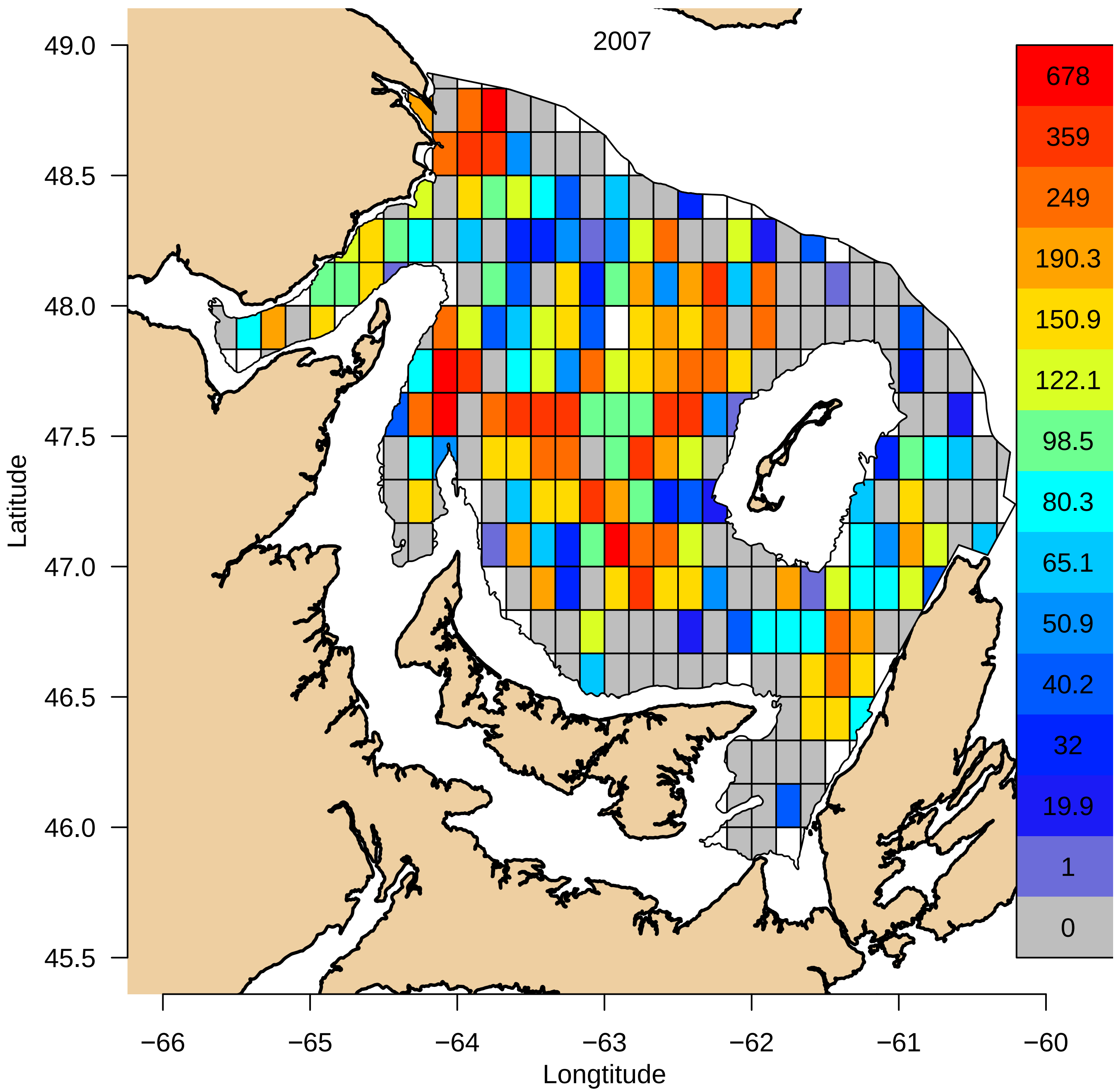


Figure SSEB.11. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2007. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

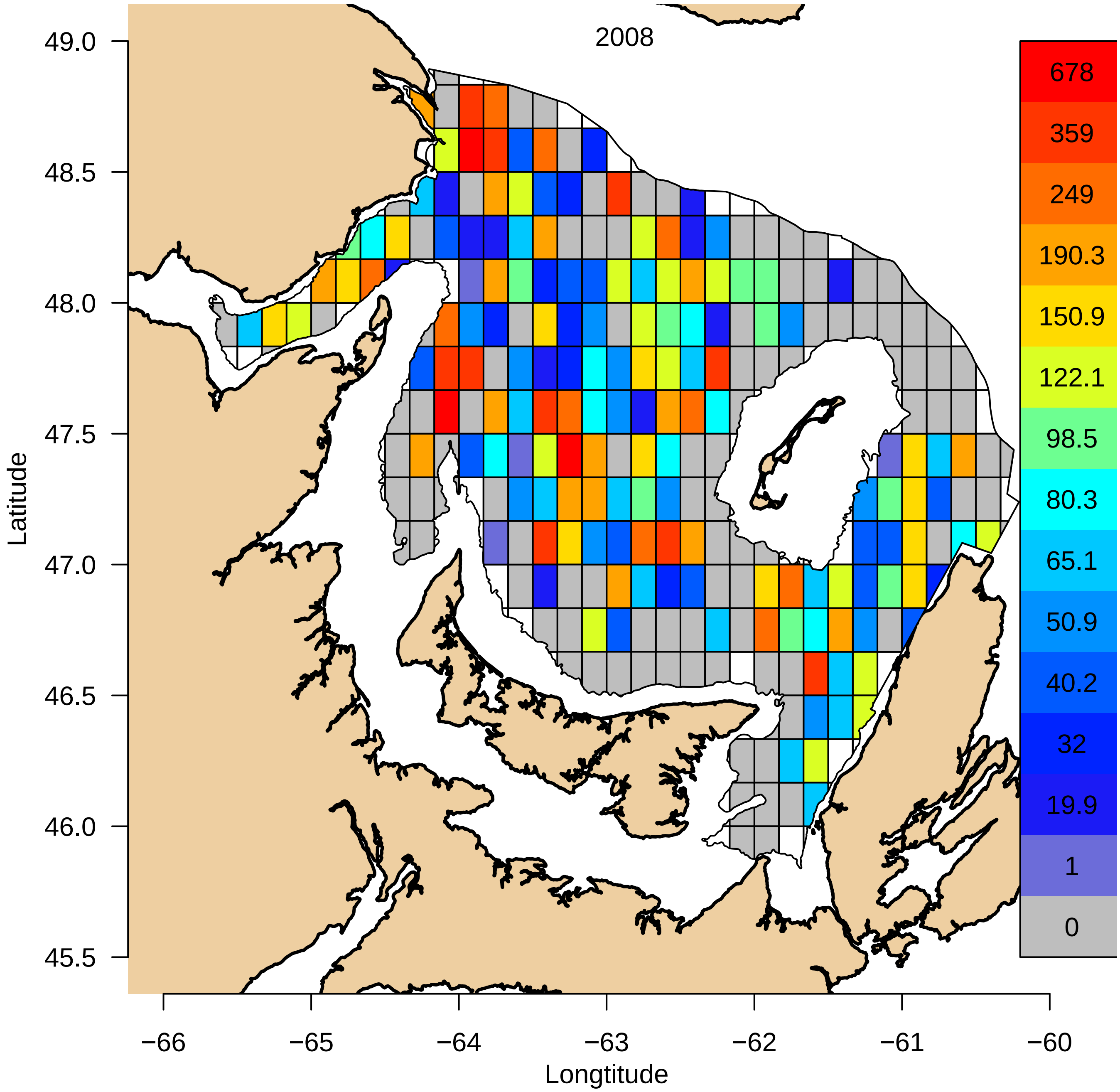


Figure SSEB.12. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2008. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

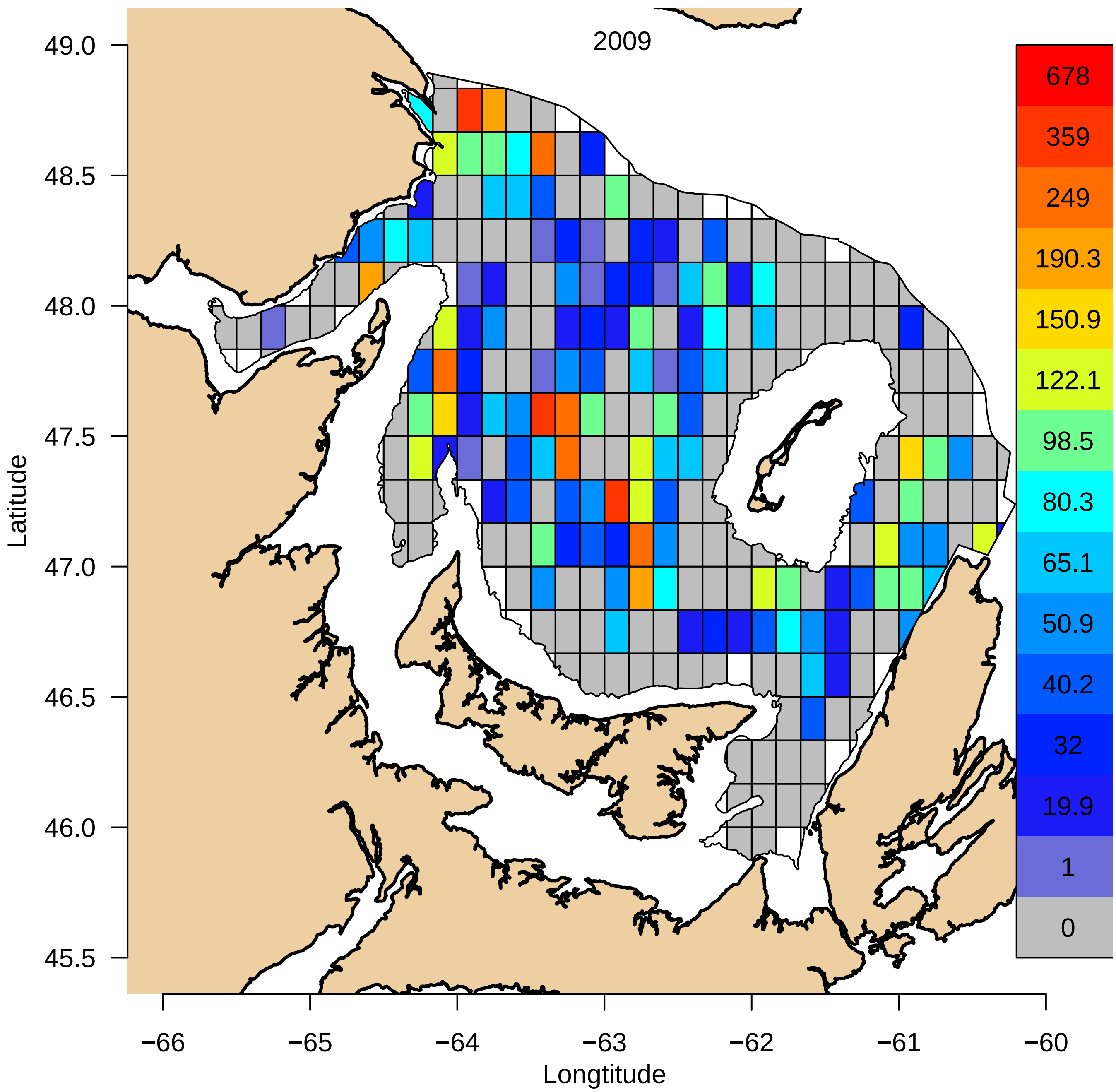


Figure SSEB.13. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2009. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

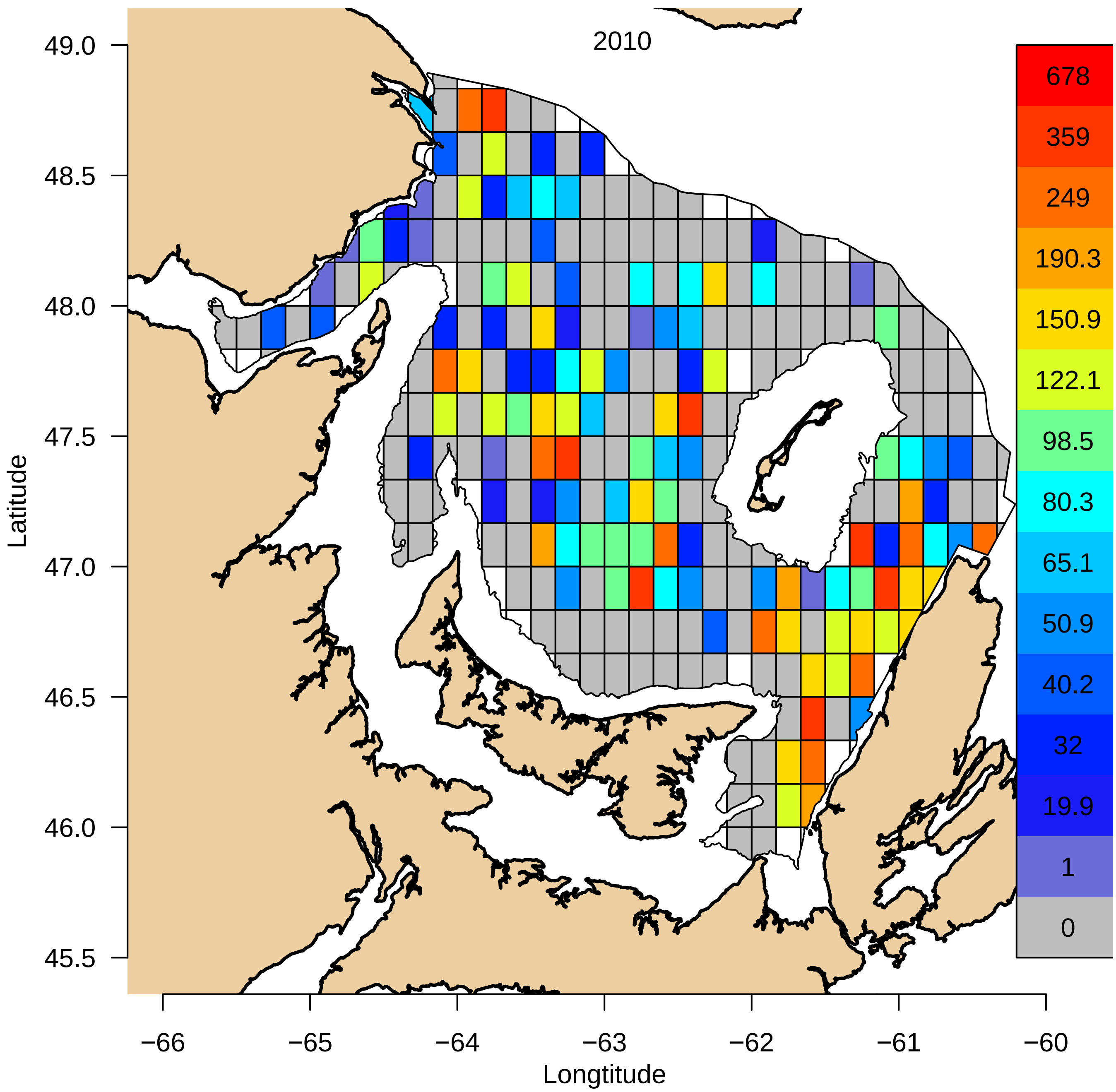


Figure SSEB.14. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2010. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

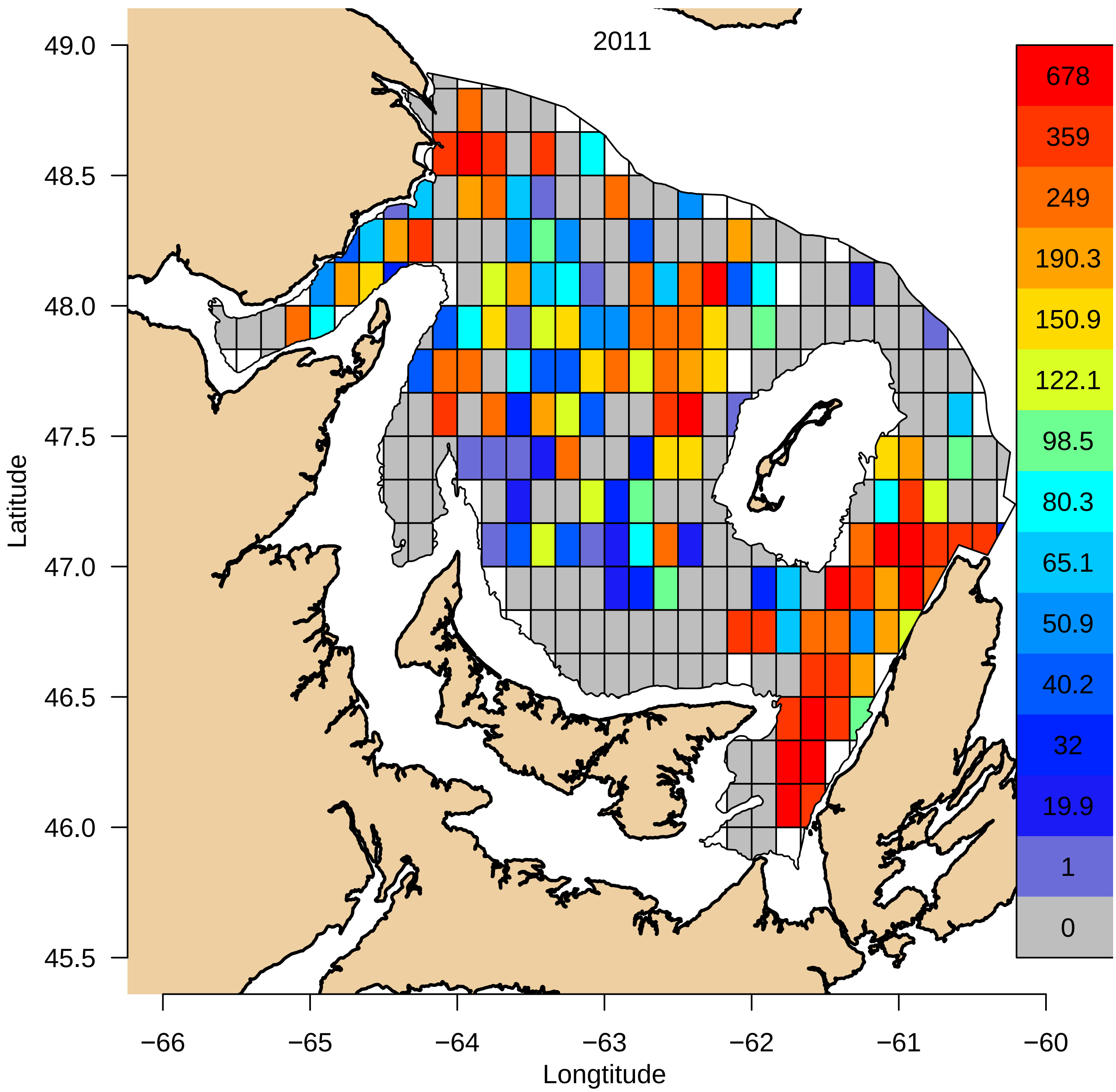


Figure SSEB.15. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2011. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

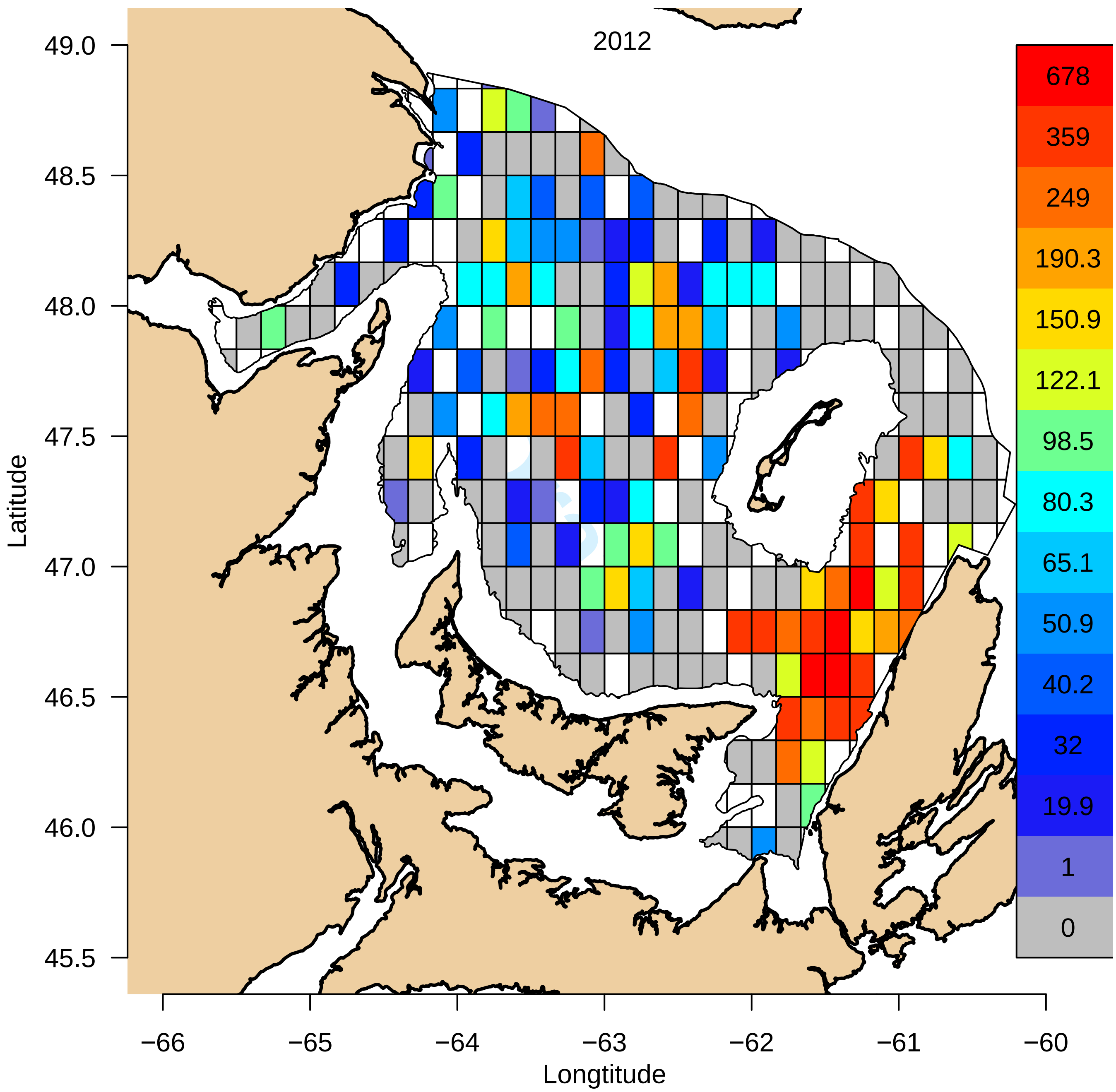


Figure SSEB.16. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2012. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

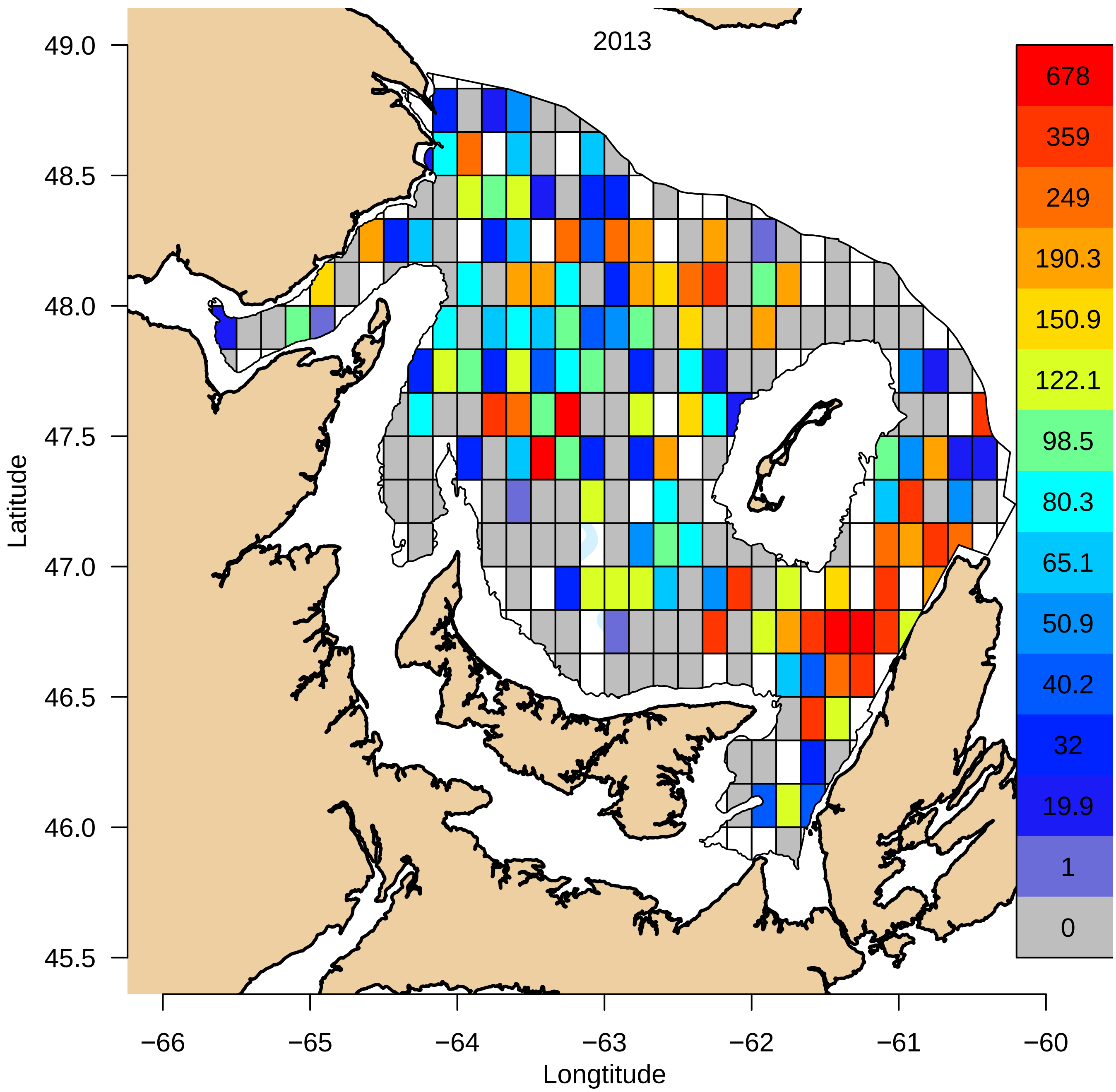


Figure SSEB.17. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2013. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

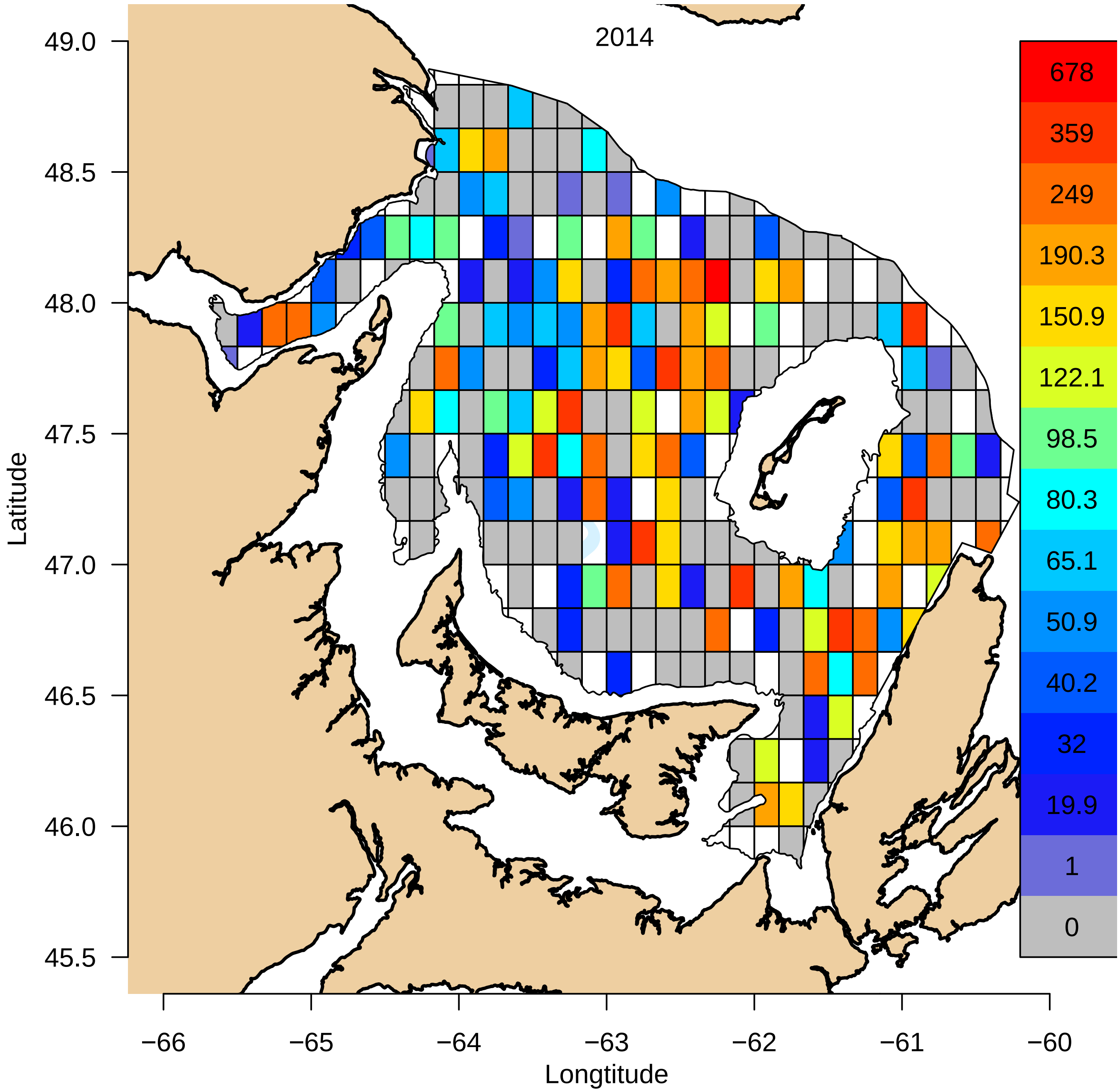


Figure SSEB.18. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2014. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

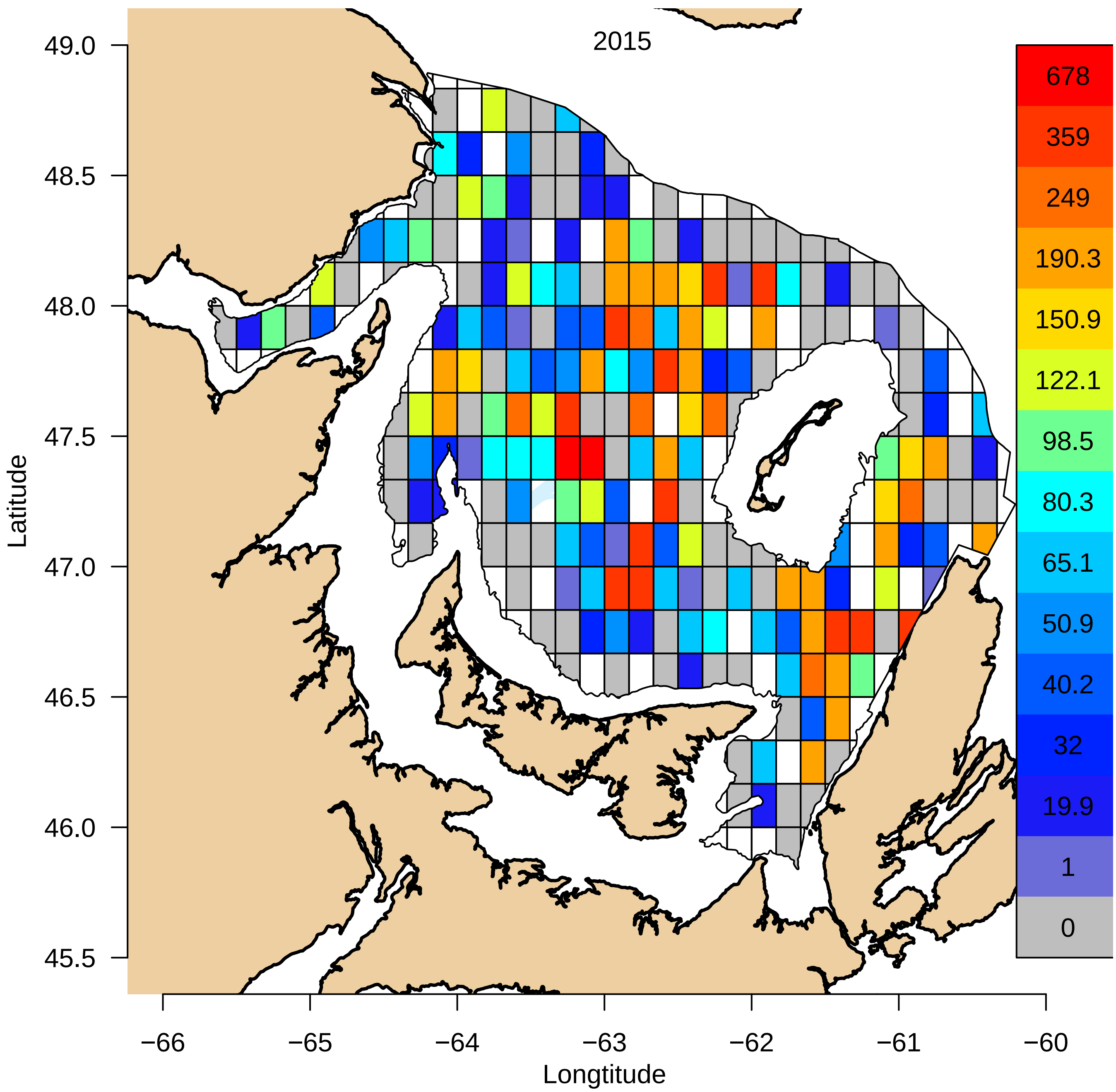


Figure SSEB.19. Snow crab survey exploitable biomass (shell conditions 3-5; tonnes per grid) results for 2015. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

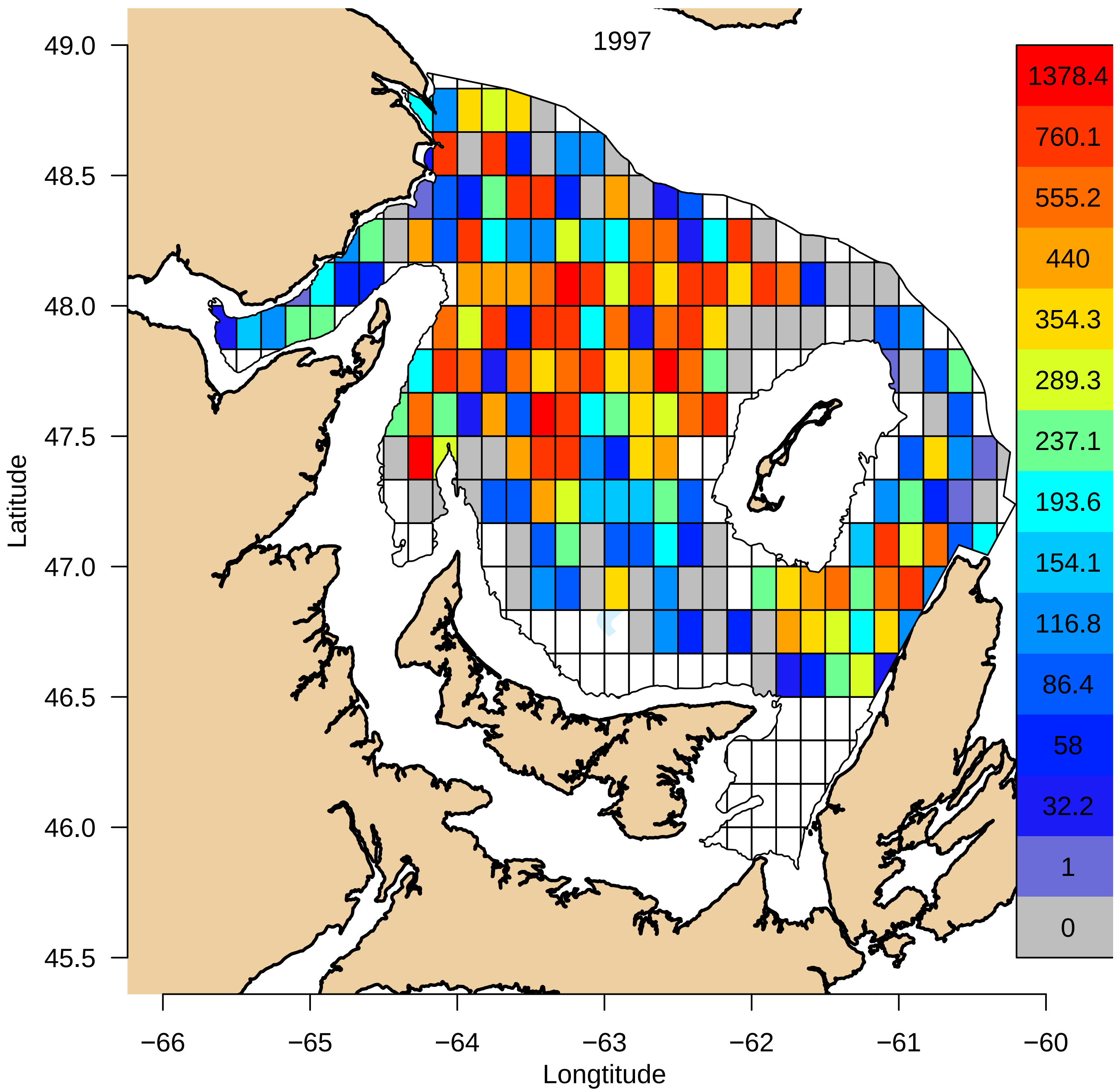


Figure SSTB.1. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 1997. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

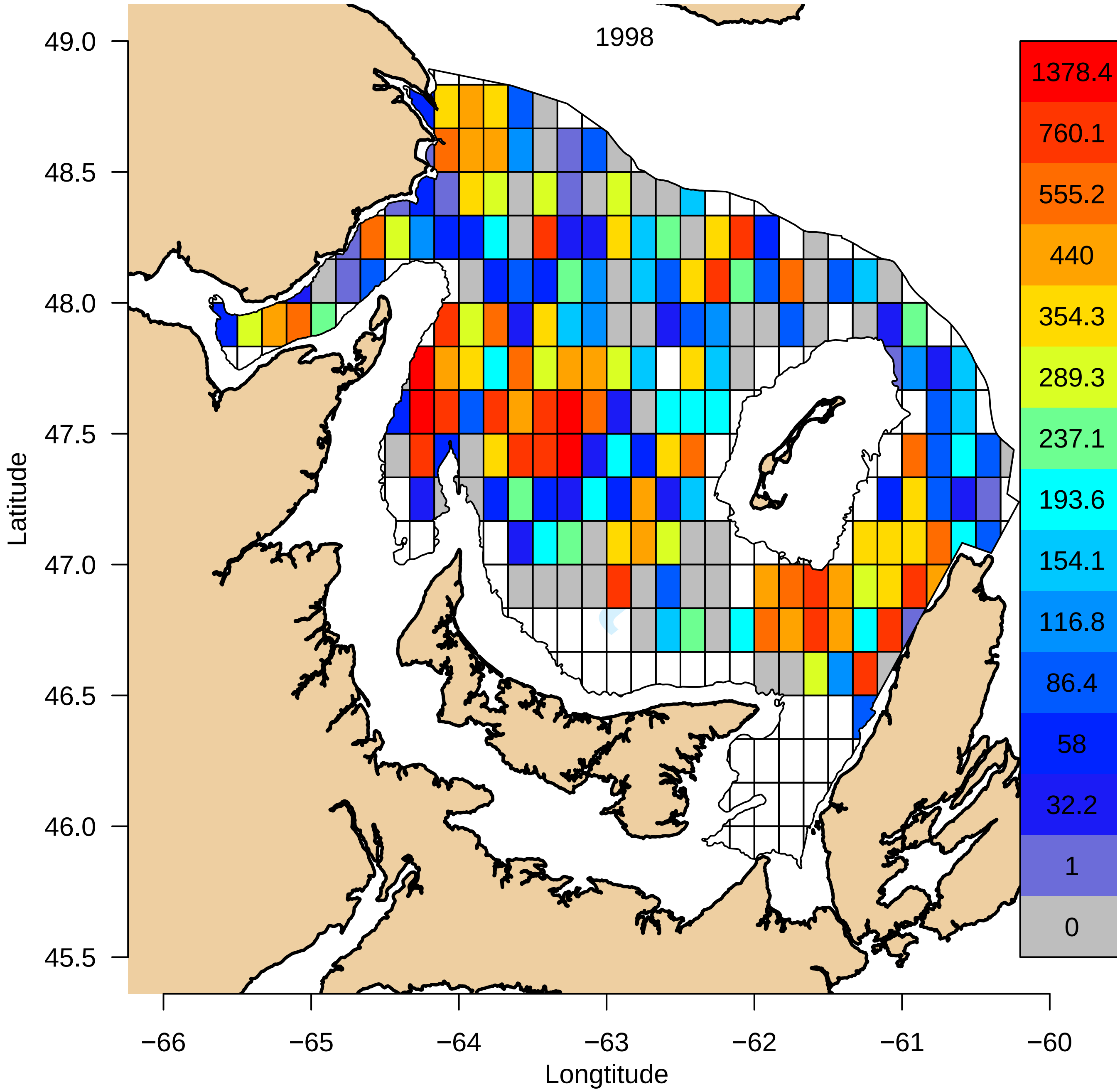


Figure SSTB.2. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 1998. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

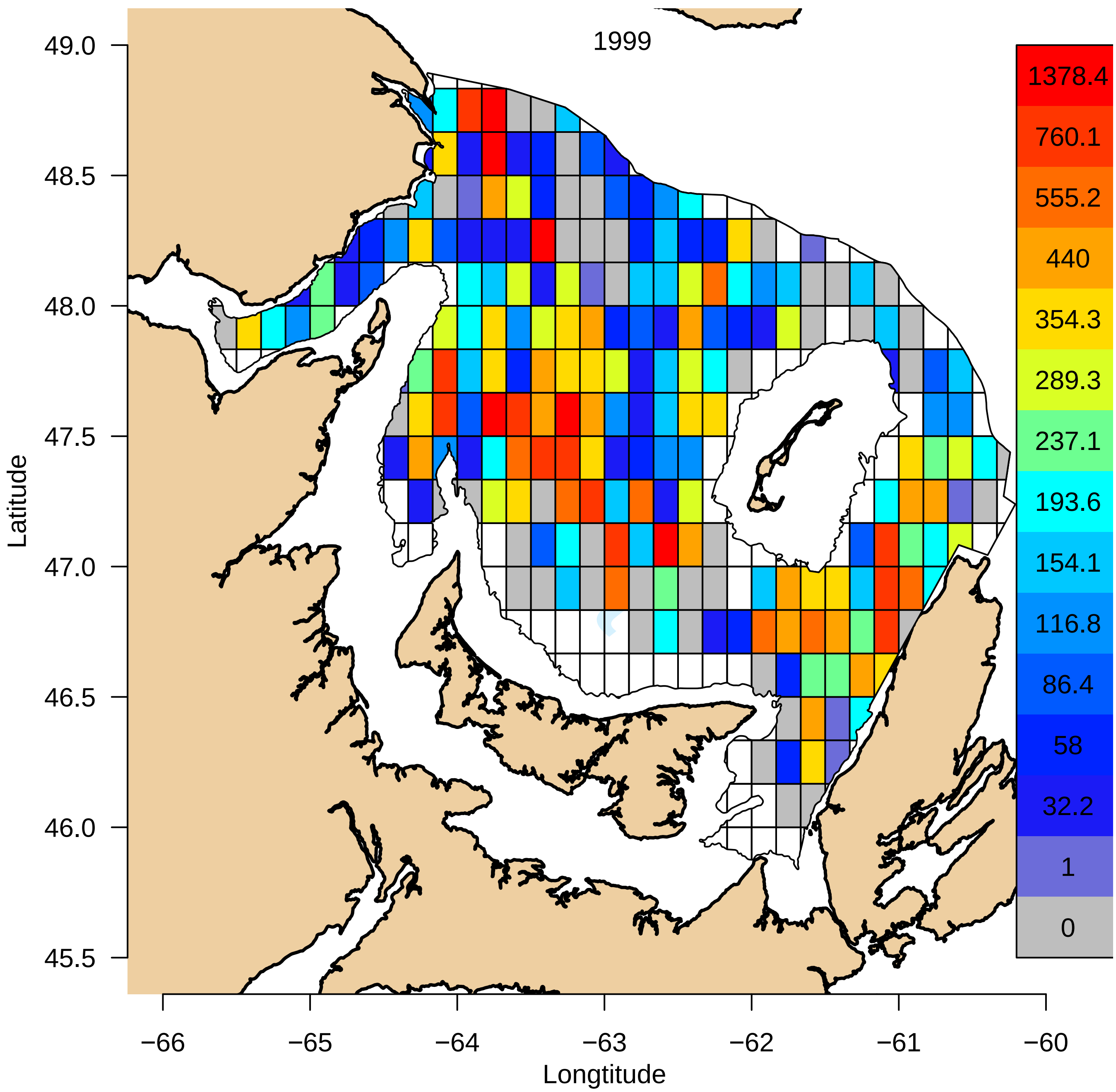


Figure SSTB.3. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 1999. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

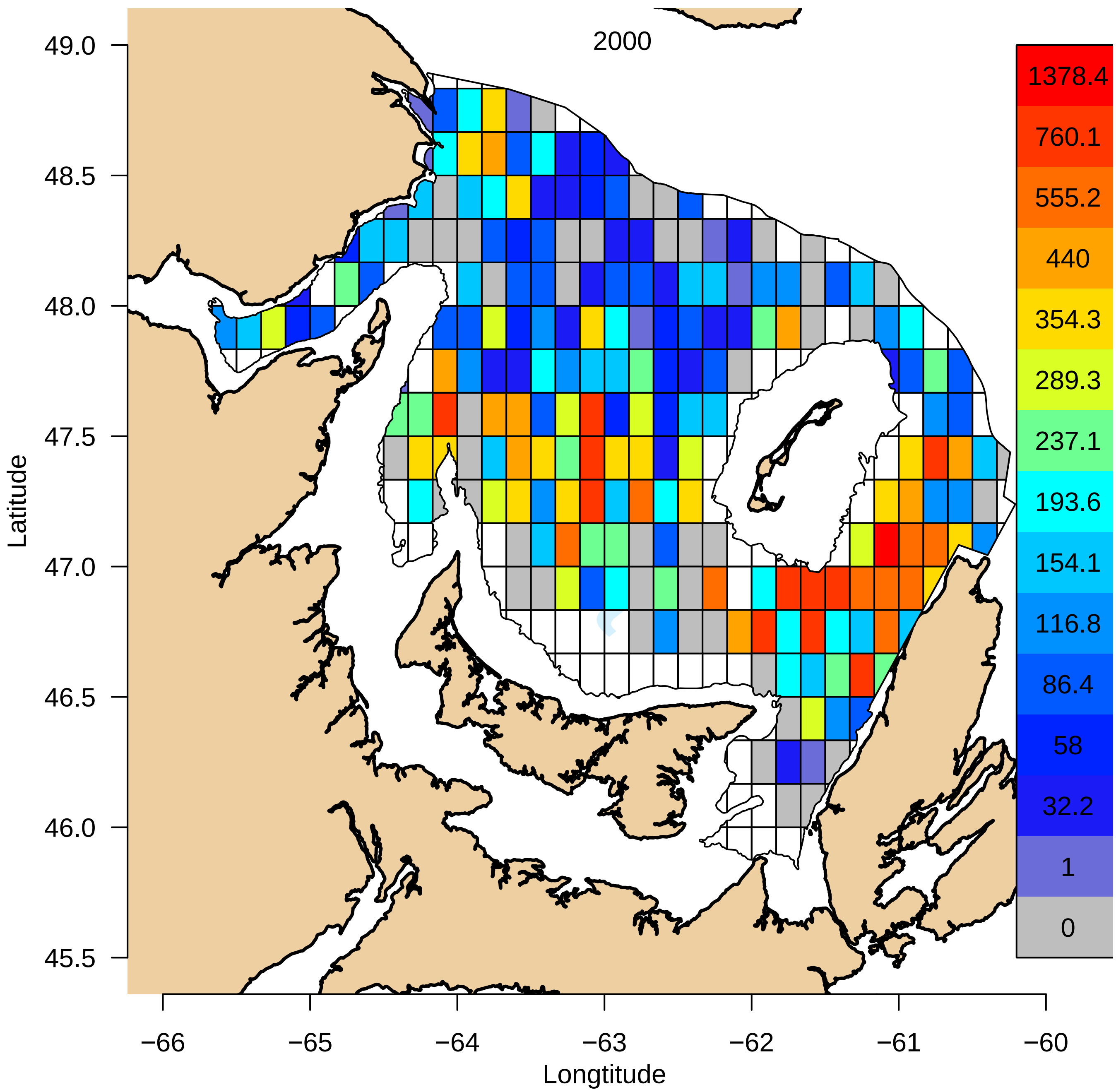


Figure SSTB.4. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2000. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

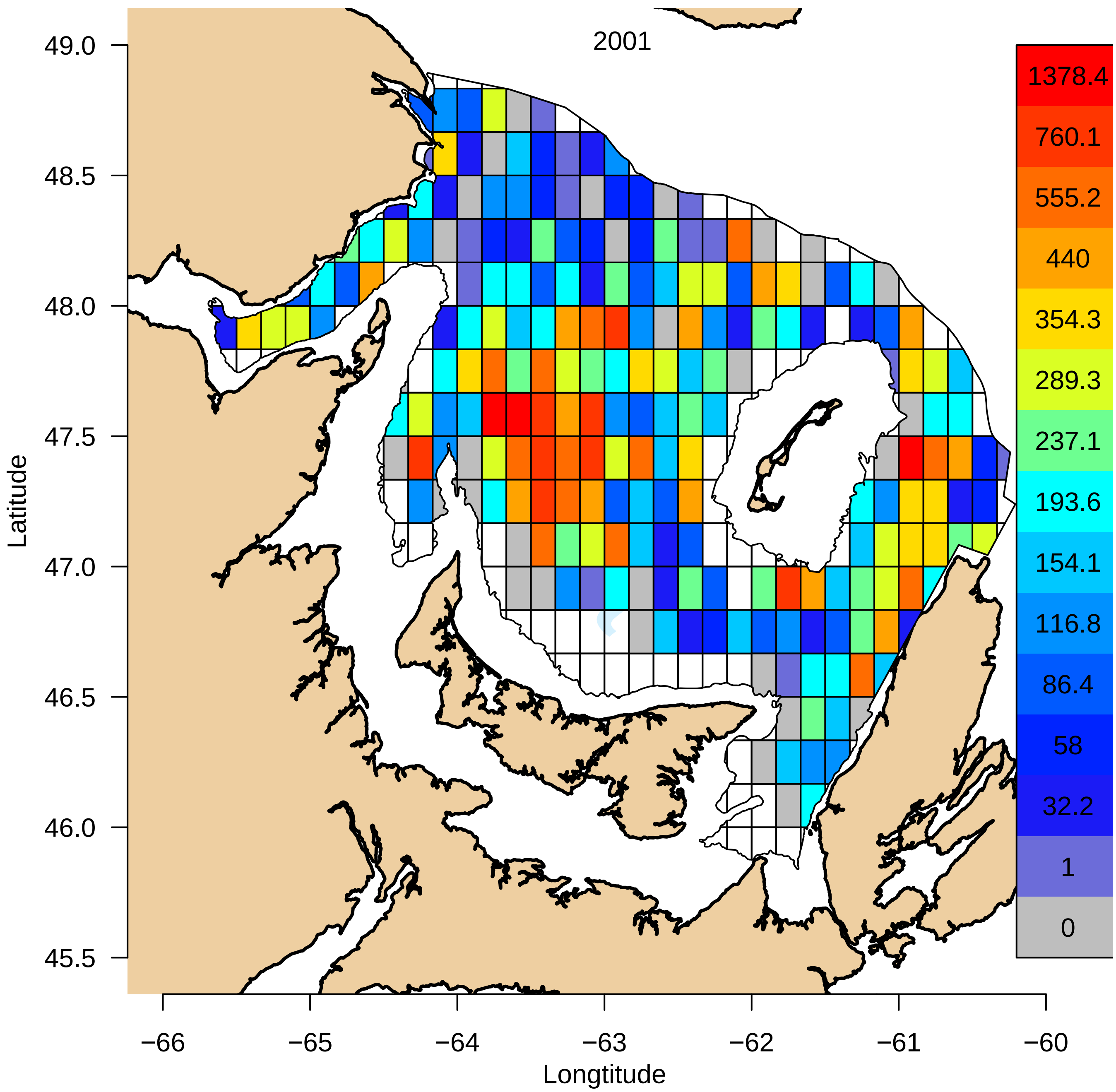


Figure SSTB.5. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2001. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

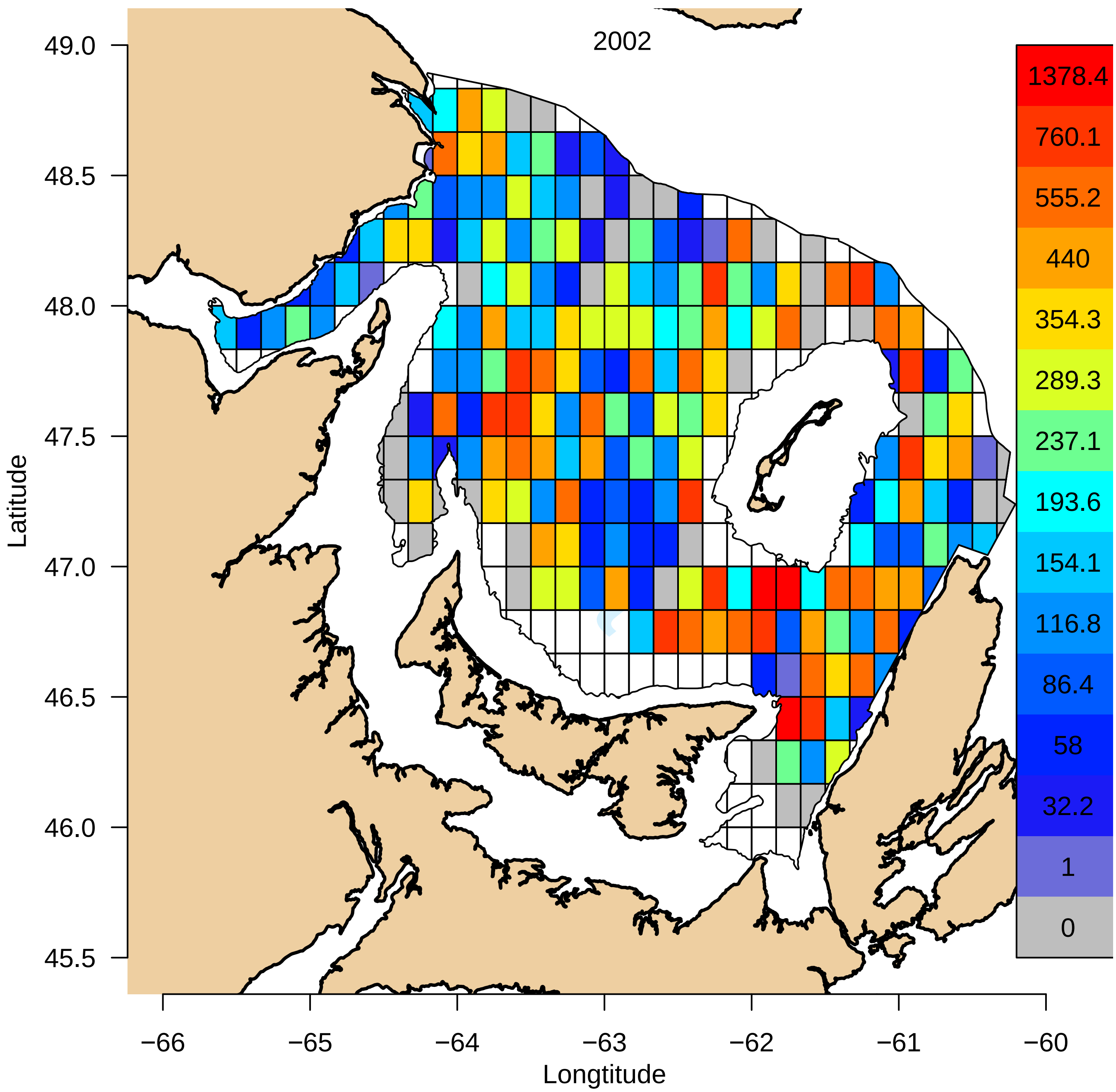


Figure SSTB.6. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2002. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

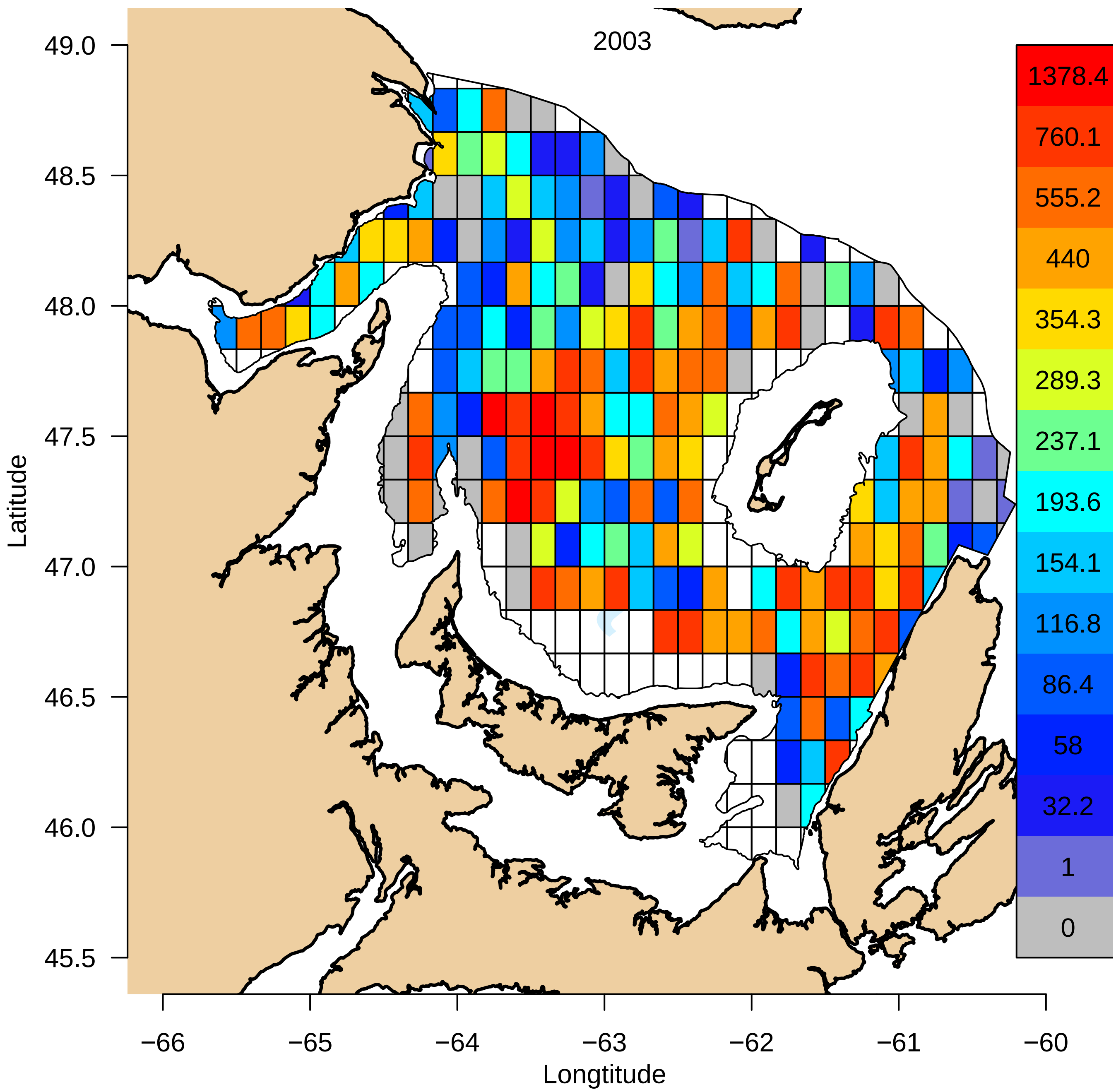


Figure SSTB.7. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2003. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

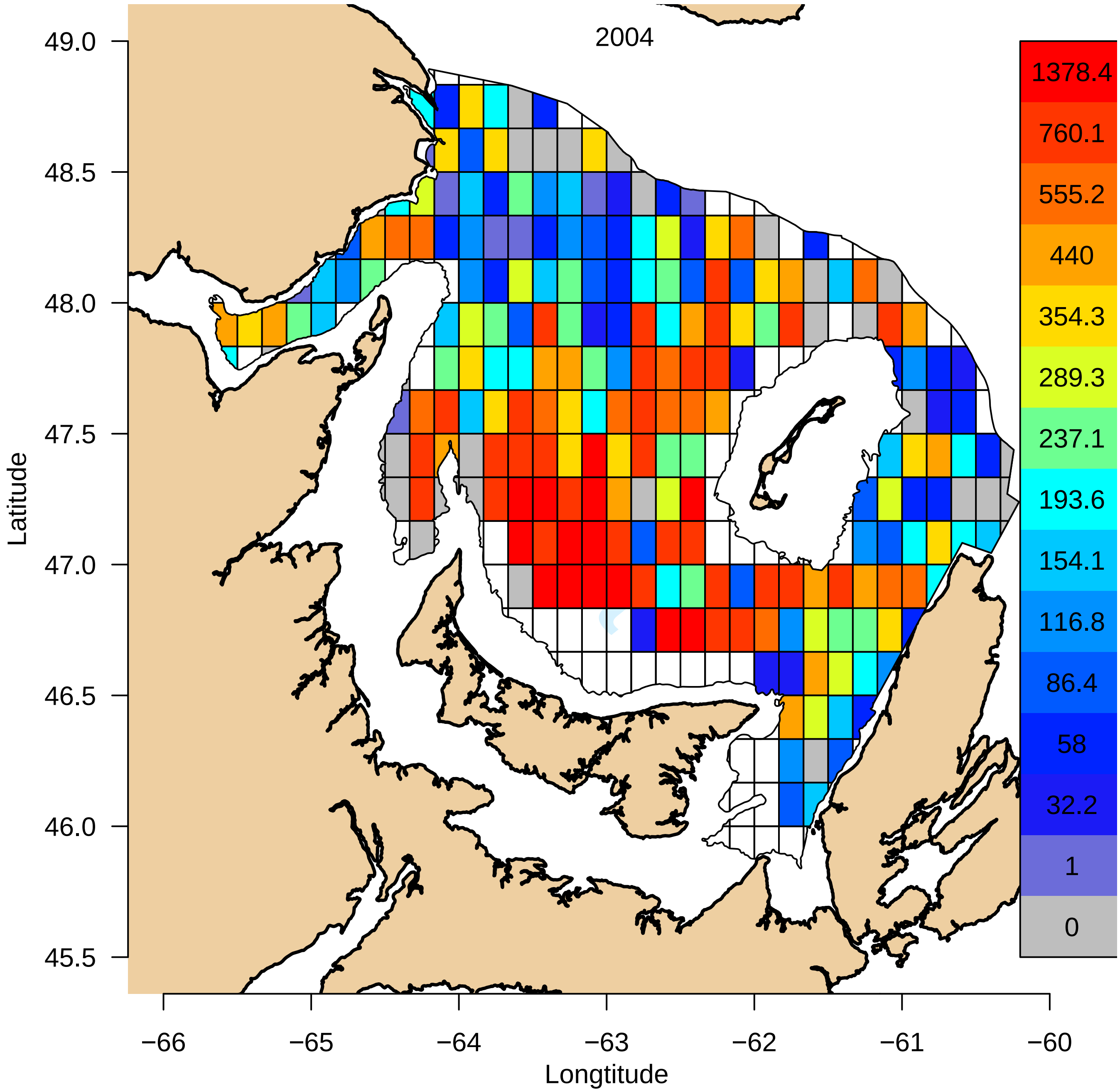


Figure SSTB.8. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2004. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

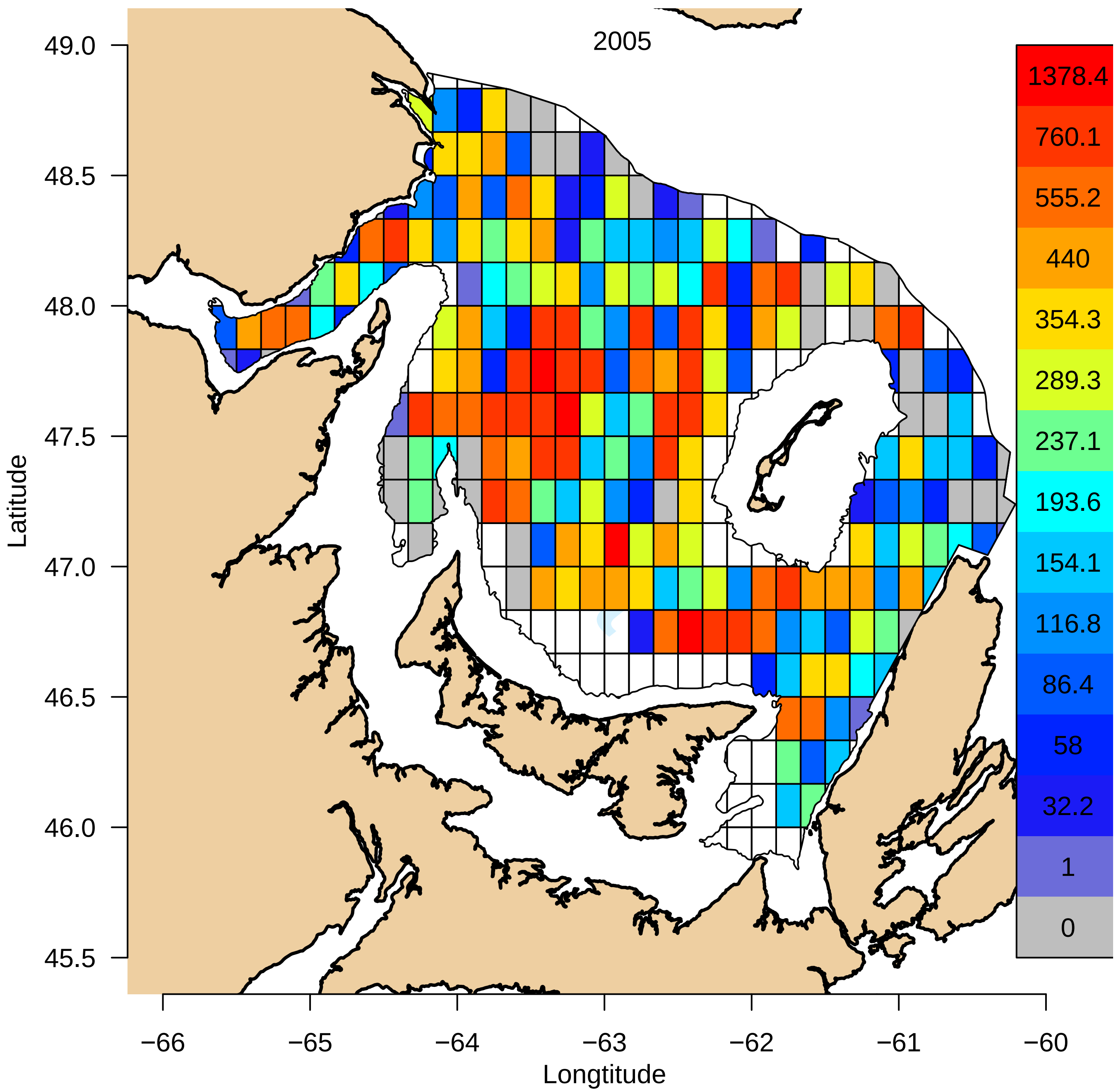


Figure SSTB.9. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2005. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

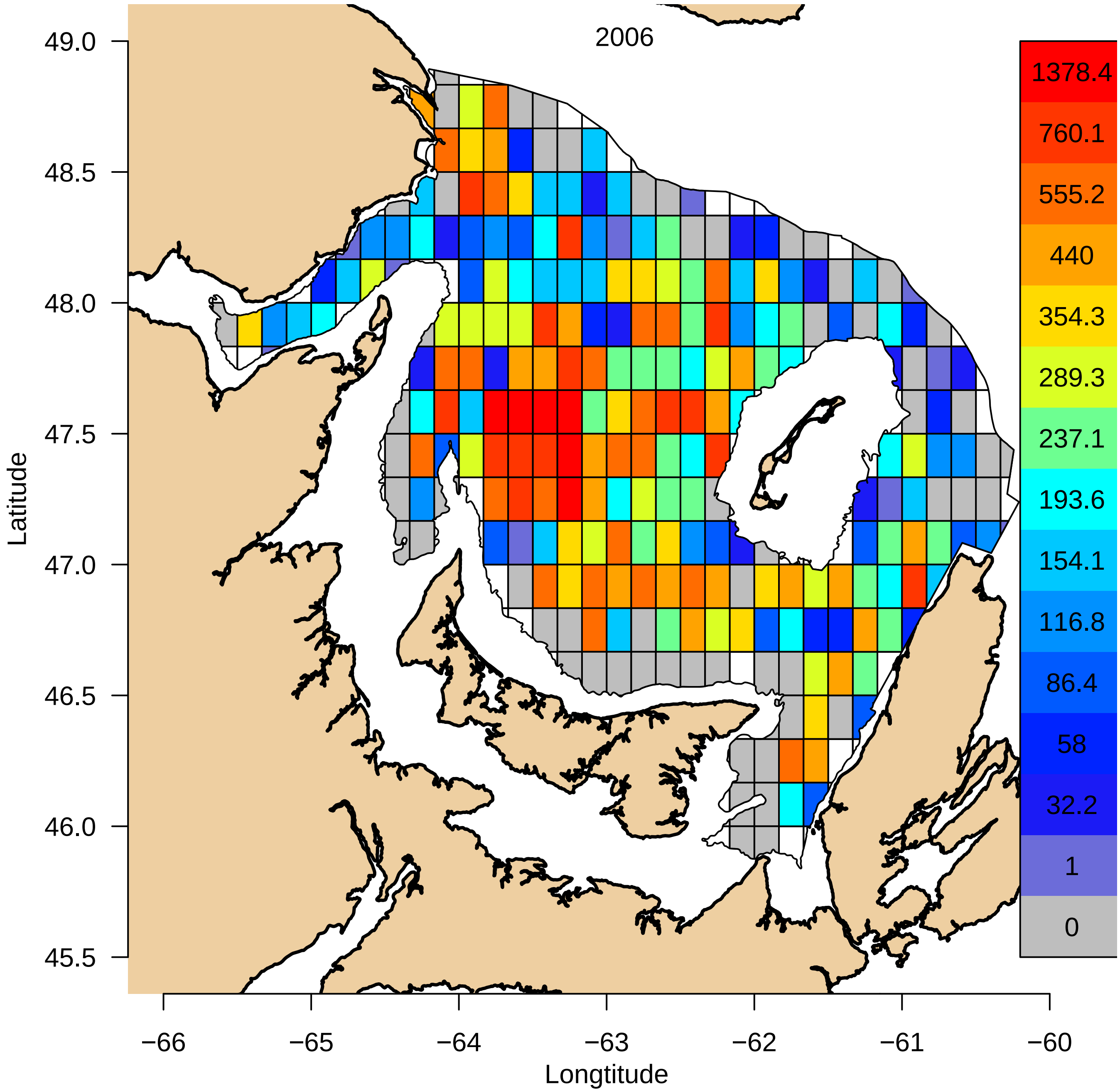


Figure SSTB.10. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2006. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

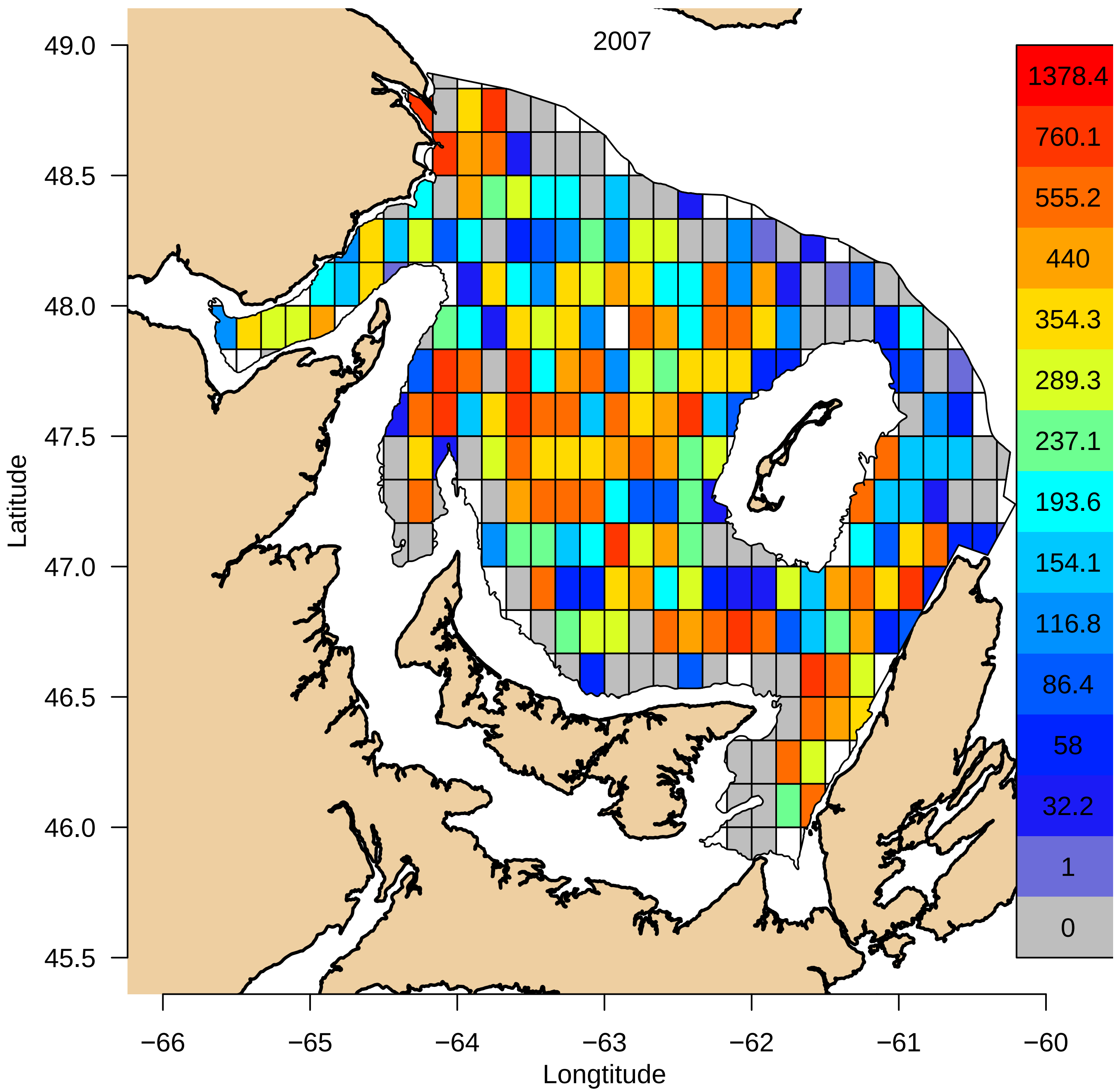


Figure SSTB.11. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2007. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

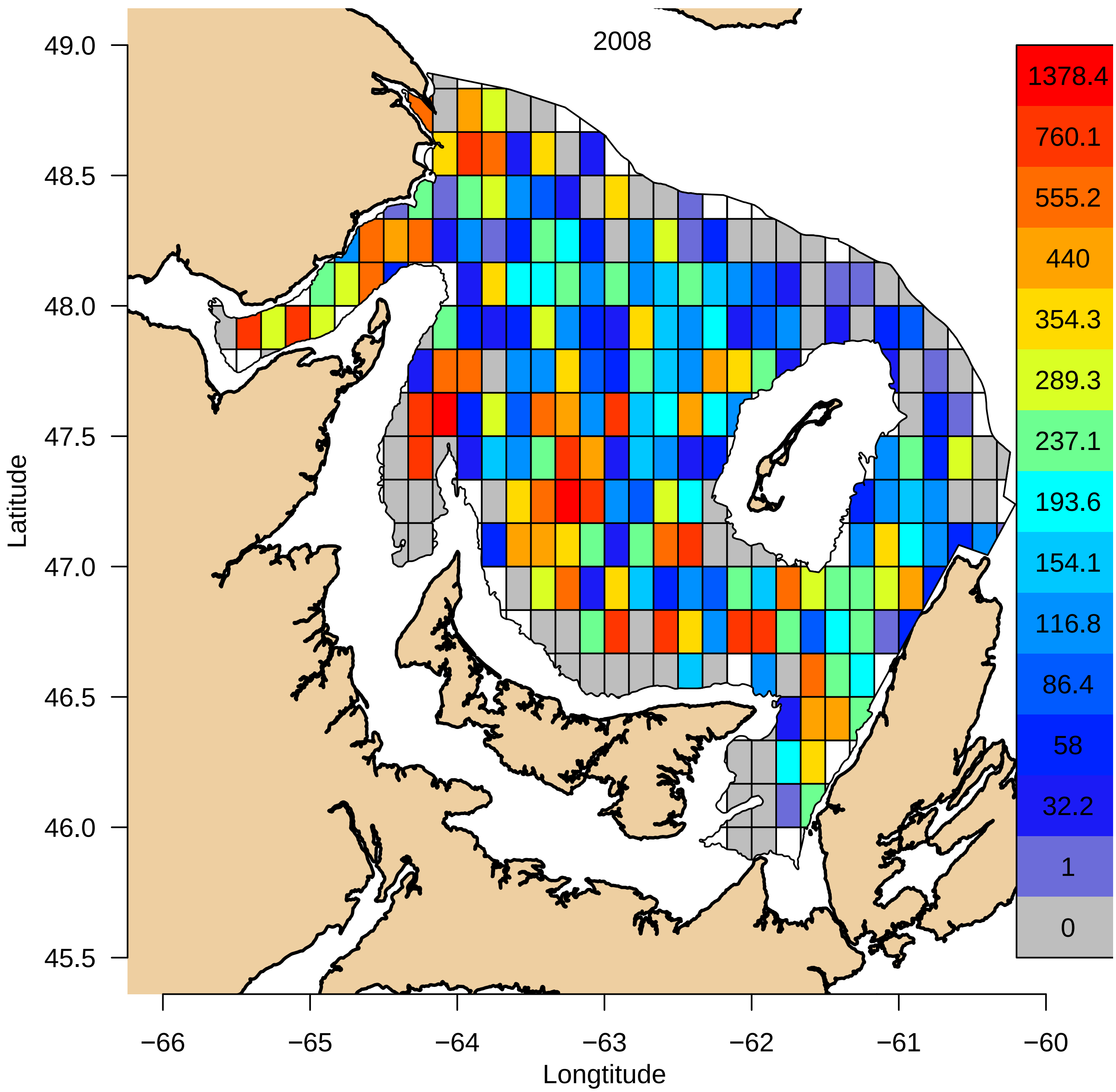


Figure SSTB.12. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2008. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

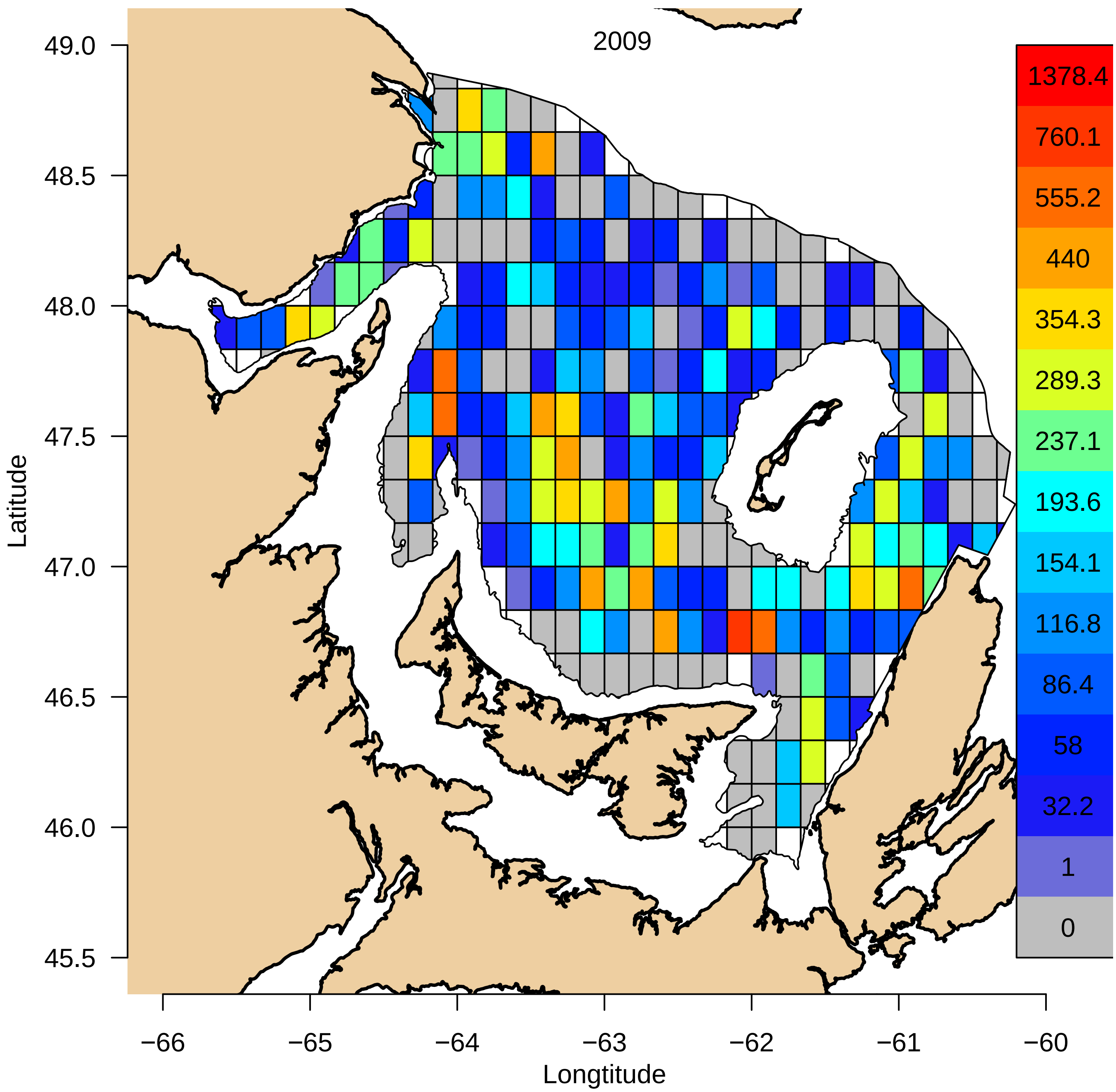


Figure SSTB.13. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2009. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

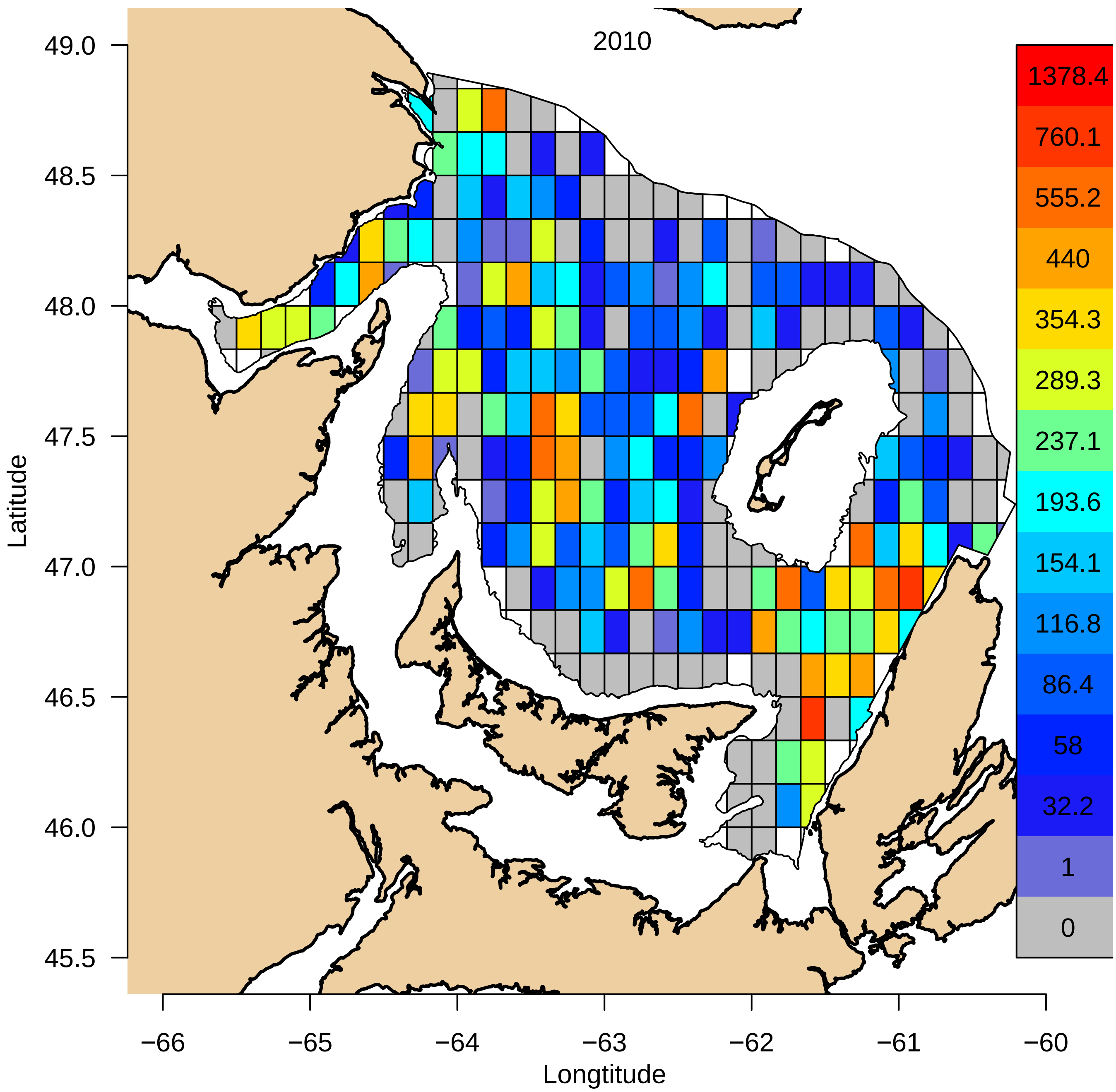


Figure SSTB.14. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2010. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

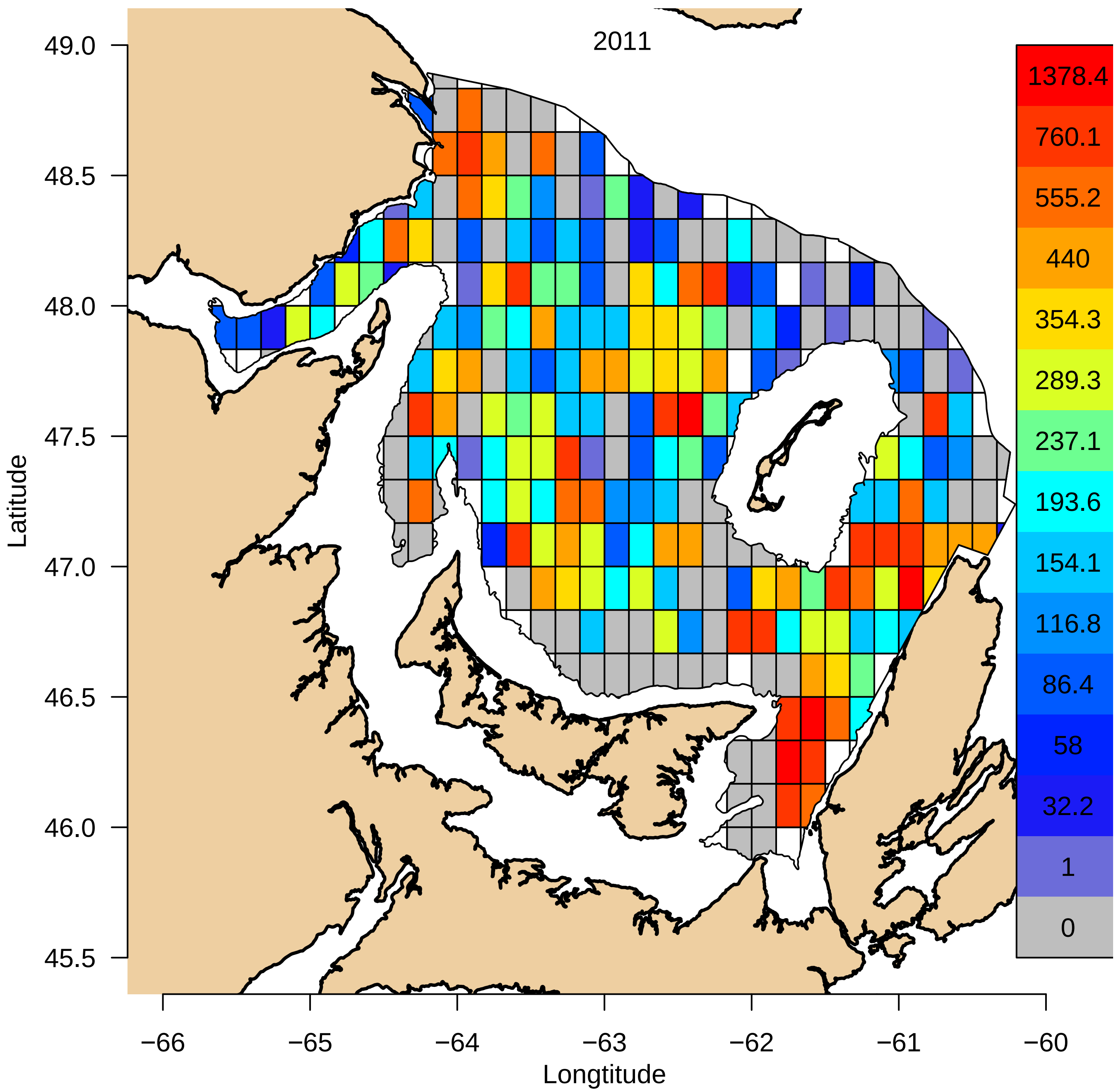


Figure SSTB.15. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2011. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

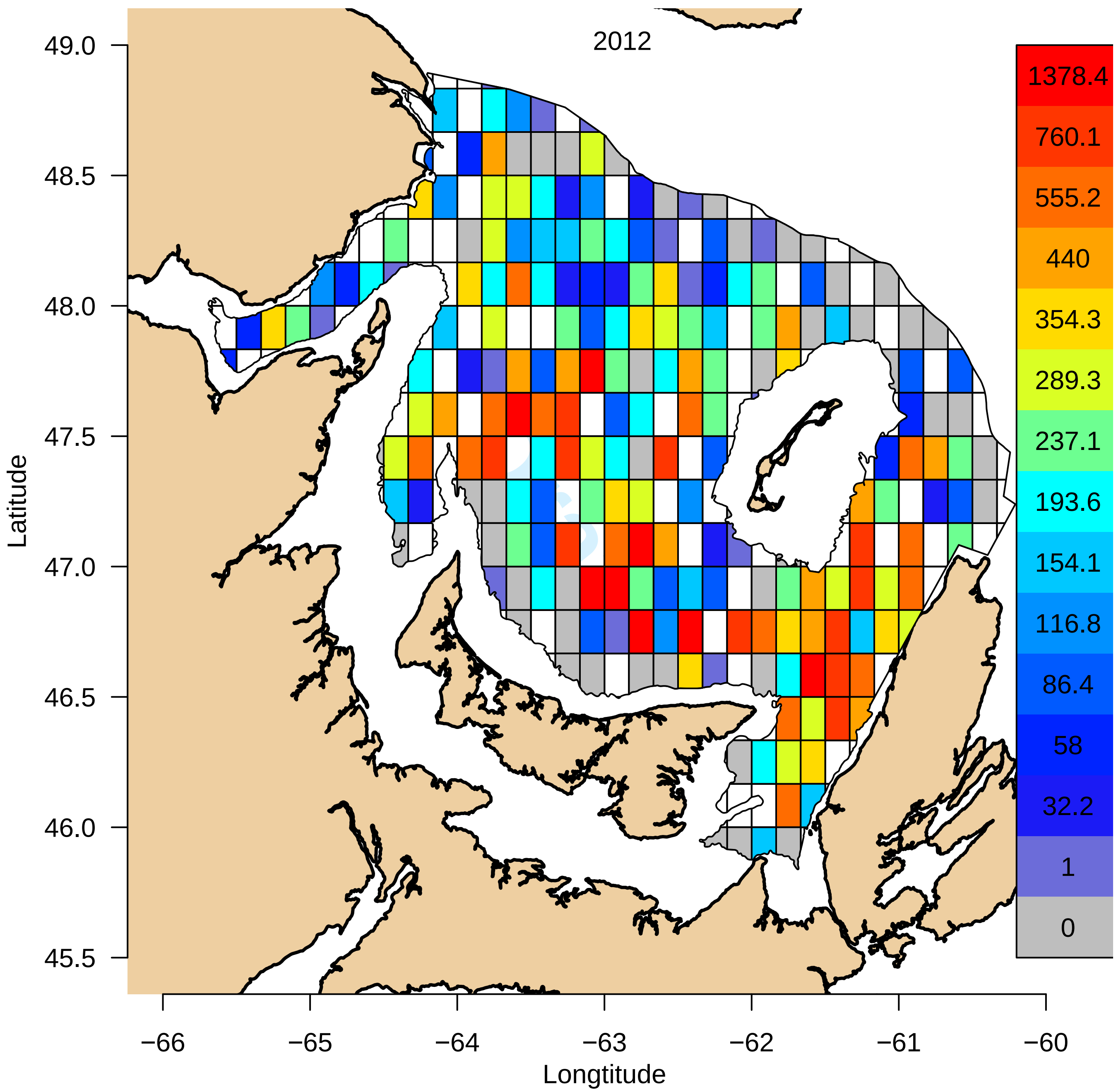


Figure SSTB.16. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2012. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

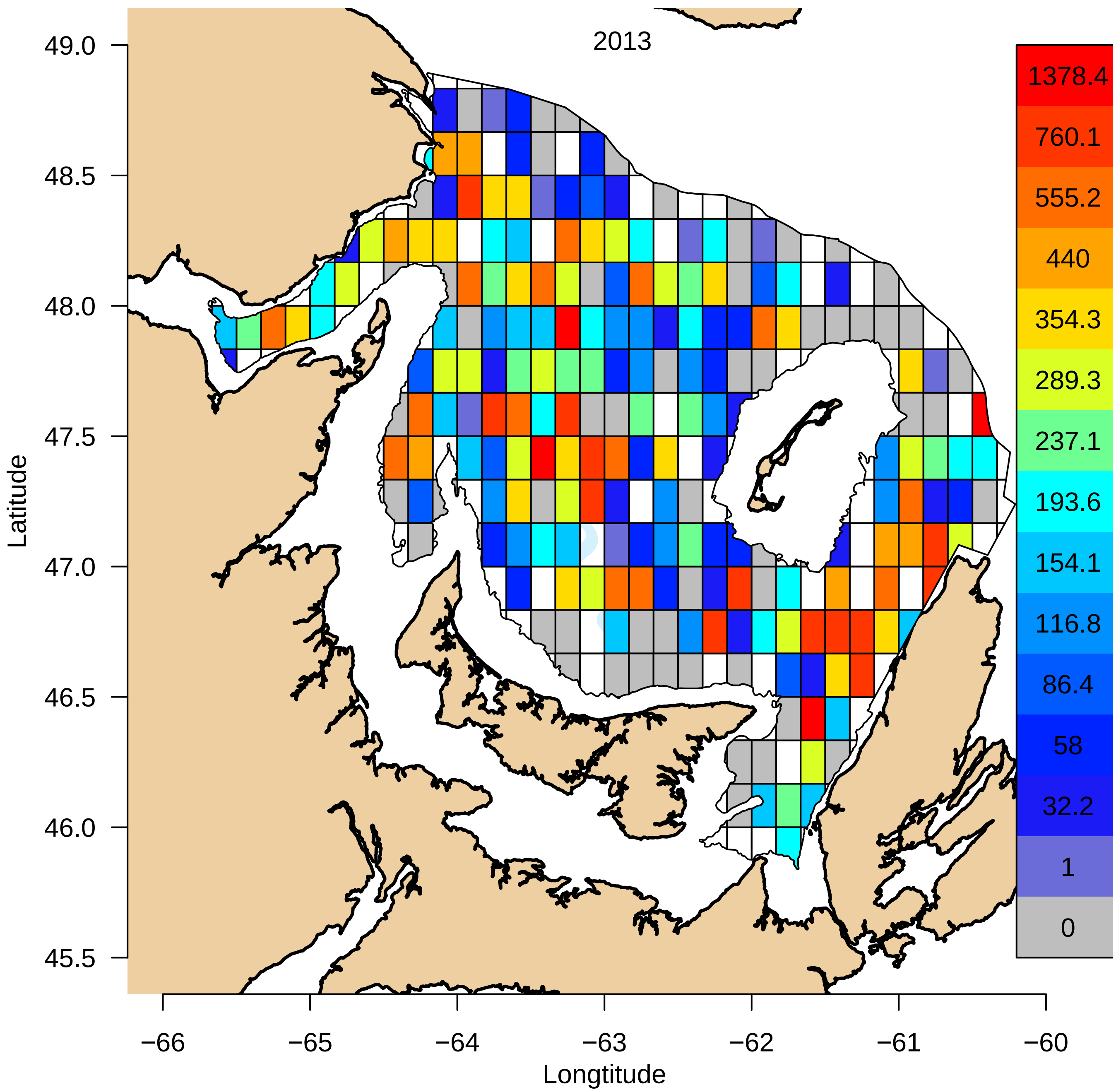


Figure SSTB.17. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2013. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

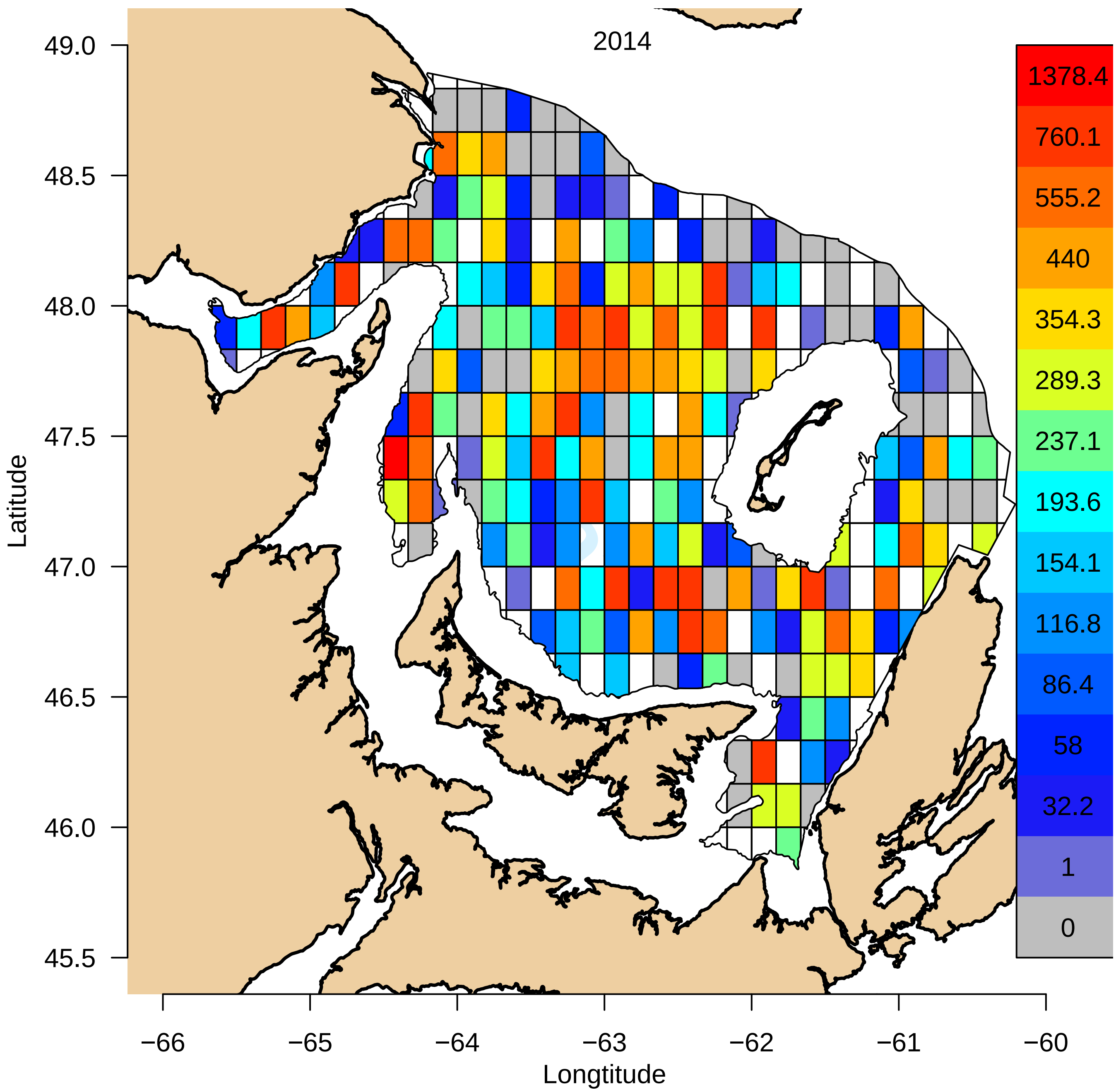


Figure SSTB.18. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2014. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.

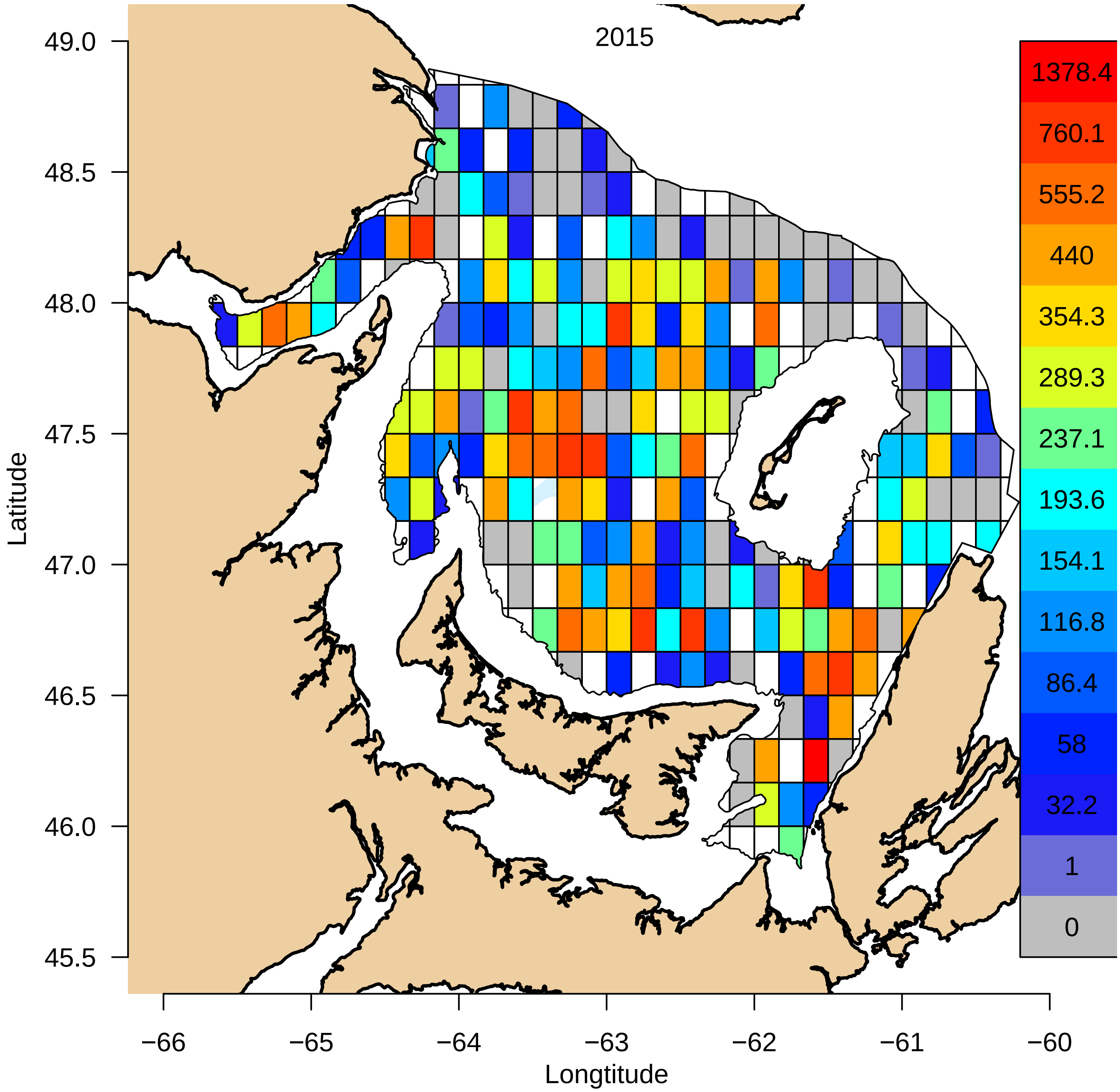


Figure SSTB.19. Snow crab survey total biomass (shell conditions 1-5; tonnes per grid) results for 2015. Colors correspond to biomass levels, as indicated in the legend on the right-hand side. Darkest red grids indicate biomass > 98th percentile.