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Visualization of Ontogenetic and Interannual Distributional Shifts of Groundfish from the Alaska Fisheries Science Center Eastern Bering Sea Bottom Trawl Survey, 1982-2015

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ABSTRACT

Since 1982, the Alaska Fisheries Science Center has conducted standardized bottom trawl surveys of the eastern Bering Sea (EBS) shelf area between 20 m and 200 m in summer (May - August). During these surveys researchers have collected species composition and bottom temperature for all tows as well as measurements from all fish species encountered. These data have been used to create visualizations of spatial distribution and distribution by bottom depth and temperature by length bins for all available surveys for 22 groundfish and skate species. This provides a unique look at the spatial and environmental preferences of a wide variety of species, as well as ontogenetic shifts in spatial distribution and environmental preferences over 34 years. The visualizations provided in this paper are meant to facilitate a better understanding of the life histories of these species over time and space and provide clues to how climate change may potentially impact species at different life stages.

CONTENTS

INTRODUCTION

The eastern Bering Sea (EBS) shelf supports one of the most productive groundfish and crab fisheries in the world (Bakkala 1993). Fishery-independent data from annual EBS bottom trawl surveys are vital to the management and conservation of commercial and non-target groundfish and crab species under the North Pacific Fishery Management Council (NPFMC) fishery management plans. Objectives for the EBS shelf survey are to provide data on 1) distribution, abundance, and biological condition of groundfish, crabs, and other demersal macrofauna; 2) the age and growth, biology, and dynamics of key ecosystem components for ongoing studies; and 3) catch per unit effort (CPUE) and length composition of commercially important fish and invertebrate species.

Although bottom trawl surveys of the EBS shelf have been conducted since the 1940s, 1982 is considered the starting point of the EBS shelf bottom trawl survey time-series as trawl gear and methods were inconsistent in previous surveys. Since 1982, the EBS shelf bottom trawl survey has been conducted annually from May to August using standardized trawl gear and a systematically designed 20 nautical mile (nmi) sampling grid (Fig. 1) consisting of on average 428 stations within this grid (Table 1) in waters between 50 m and 300 m (Bakkala 1993, Kotwicki and Lauth 2013, Lauth and Connor 2014). In addition to data on fish and invertebrates, the survey also collects ocean temperature (Fig. 2) and depth that can be used to assess effects of environmental covariates on fish and invertebrate density and distribution.

Distributional changes of Bering Sea fish and invertebrates in relation to climate variability have been have been widely reported (Spencer 2008, Kotwicki and Lauth 2013, Baker and Hollowed 2014). No previous study has specifically examined ontogenetic differences in the response of species to climate variability. In many cases the distribution of fish and invertebrates differs considerably between juvenile and adult stages (Ciannelli et al. 2008, Bartolino et al. 2011). This report uses the 34-year time series of summer bottom trawl survey data to explore patterns of groundfish distribution by size in relation to location, temperature, and depth over time, between sexes, and between warmer and colder temperature periods. Such patterns reveal apparent shifts in spatial distribution in response to climate variability. The visualizations provided in this paper are meant to facilitate a better understanding of the life histories of these species over time and space and potentially provide clues to how climate change could impact these species at different life stages. In the appendices we provide R (R Core Team 2015) scripts used to produce these visualizations including the SQL language used to harvest the data from the Alaska Fisheries Science Center (AFSC) RACEBASE database (Groundfish Assessment Program, AFSC, RACEBASE database, https://inport.nmfs.noaa.gov/inport/item/22008).

METHODS

All retrieval and processing of data were done in R (R Core Team 2015). EBS shelf bottom trawl survey data (Bakkala 1993, Lauth and Connors 2014) were recovered from the AFSC Oracle database using the R package **RODBC** (V 1.3-8, Ripley and Lapsley 2013). Data were plotted using the R package **lattice** (V 0.20-29, Sarkar 2008) and **ggplot2** (Wickham 2009). The R function used to retrieve the data from the RACEBASE database can be found in Appendix A.

There were 22 species that had sufficient length data to conduct this analysis. In alphabetical order by common name they were Alaska plaice (*Pleuronectes quadrituberculatus*), Alaska skate (*Bathyraja parmifera*), arrowtooth flounder (*Atheresthes stomias*), Arctic cod (*Boreogadus saida*), Bering flounder (*Hippoglossoides robustus*), Bering skate (*Bathyraja interrupta*), bigmouth sculpin (*Hemitripterus bolini*) , butter sole (*Isopsetta isolepis*), flathead sole (*Hemilepidotus jordani*), great sculpin (*Myoxocephalus polyacanthocephalus*), Greenland turbot (*Reinhardtius hippoglossiodes*), Kamchatka flounder (*Atheresthes evermanni*), northern rock sole (*Lepidopsetta polyxystra*), Pacific cod (*Gadus macrocephalus*), Pacific halibut (*Hippoglossus stenolepis*), Pacific ocean perch (*Sebastes alutus*), rex sole (*Glyptocephalus zachirus*), Sakhalin sole (*Limanda sakhalinensis*), starry flounder (*Platichthys stellatus*), walleye pollock (*Gadus chalcogrammus*), yellowfin sole (*Limanda aspera*), and yellow Irish lord (*Hemilepidotus jordani*). For some of the species identification to species did not occur for the entire timeline; skate identification to species (Alaska skate and Bering skate) began in 2000, northern rock sole in 1995, and sculpin species (great sculpin, bigmouth sculpin, and yellow Irish lord) in 2000.

In one set of visualizations produced for this study the density of fish (number per km^2) for each species by length category were plotted by haul location and year. In another the density of fish (number per km^2) at each bottom temperature increment (0.1 °C) and bottom depth increment (1 m) were plotted by length category and year. Every EBS shelf bottom trawl survey haul has a location in latitude, longitude, bottom depth, and bottom temperature associated with it. For each individual haul, h, and species, s, CPUE was calculated as

$$CPUE_{sh} = \frac{K_{sh}}{W_h D_h}, \quad [1]$$

where K is the total number of fish of species s in haul h , W is the average net width of haul h in kilometers and D is the tow length of haul h in kilometers. The proportion, p, of fish of species s in length bin l in haul h was calculated as

$$p_{slh} = \frac{n_{slh}}{n_{sh}}, \quad [2]$$

where n_{slh} is the number of fish of species s in length bin l for haul h, and n_{sh} is the number of fish of species s in haul h. For each species the length data were binned into five percentile length categories: 0-10%, 10%-30%, 30%-70%, 70%-90%, and 90%-100% of the raw length frequency distribution for the full time series. It was understood that each category may not in itself define an ontogenetic stage, but that having five size categories would result in a clearer picture of where important life-stage divisions might be for each species independent of preconceived notions of importance for a particular species.

The number of fish of species s in length bin l for haul h per km^2, N_{slh}, was calculated as

$$N_{slh} = p_{slh} \times CPUE_{sh}\,. \quad [3]$$

The code implementing this and producing plots can be found in Appendix B.

A further refinement of the analysis was conducted by plotting the CPUE by number weighted mean location or bottom depth and bottom temperature (hereafter centroid) by length category for all years in a single plot. The centroid for each length category by year, M_{xly}, were calculated as the centroid by year, y, as

$$M_{xly} = \frac{\sum N_{slhy} x_{shy}}{\sum N_{slhy}}, \quad [4]$$

where x_{shy} is the location of a haul in latitude, longitude, bottom depth, or bottom temperature. For this analysis we plotted on a single graph the centroids as the combination of mean latitude ($M_{latitude}$) and longitude ($M_{longitude}$), or mean bottom depth (M_{depth}) and mean bottom temperature (M_{temp}) for all years and all length categories for each species.

The standard error of the weighted mean (SEM_{xly}) was calculated following that of Cochran (1977) for the ratio variance approximation where *i* is the number of hauls for species *s*, length *l*, and year *y*, as:

$$\overline{N_{sly}} = \frac{(\sum N_{slhy})}{i_{sly}}, \text{ and} \quad [5]$$

$$(SEM_{xly})^2 = \frac{i_{sly}}{(i_{sly}-1)(\sum N_{slhy})^2}\left[\left(\sum\left(x_{shy}N_{slhy} - \overline{N_{sly}}(M_{xly})\right)^2\right) - 2M_{xly}\sum\left(\left(N_{slhy} - \overline{N_{sly}}\right)\left(x_{shy}N_{slhy} - M_{xly}\overline{N_{sly}}\right)\right) + M_{xly}{}^2\left(\sum\left(N_{slhy} - \overline{N_{sly}}\right)^2\right)\right]. \quad [6]$$

Four sets of visualizations were produced using the centroid method for each species. In the first set the centroids were computed and shaded by length category for location or bottom depth and bottom temperature. In the second and third set of visualizations each figure shows a set of graphs, one for each length category, with the centroids of location or bottom temperature and depth for each year shown. The second analysis shades the data by year of collection, the third by whether the mean shelf-wide bottom temperature for the year as defined by the methods presented in Spencer (2008, Fig. 3) was above, below, or within 0.5 standard deviations of the mean for 1982 through 2015. In the fourth set of analysis the data were shaded by sex, those fish measured but sex left undetermined were not included. The R function used to produce the centroid visualizations is presented in Appendix C.

RESULTS

The 22 fish species examined in this study made up between 62% and 79% of the total biomass and between 26% and 73% of the number of organisms caught in the EBS shelf bottom trawl survey (Table 1). Between 1982 and 2015 the EBS shelf survey scientists measured 8.56 million fish in total. The 22 species examined in this study comprised 94% of all the fish measured (8.04 million fish) over the entire time period. The number of fish measured varied substantially by year and species (Table 2). The most commonly measured for all years were walleye pollock (53% of all fish measured) and yellowfin sole (13% of all fish measured).

The mean shelf-wide bottom temperature for 1982 through 2015 was 2.38 °C with 17 years above and 17 below the mean (Fig. 3 and Table 3). In the colder years the pool of cold water (< 2 °C) running north-south across the middle of the EBS shelf (Fig. 2) expanded farther south and across more the shelf area. The expansion and contraction of this cold pool of water is due to variations in ice cover in the previous winter before the survey and has been documented to impact the distribution and behavior of some Bering Sea species (Wyllie-Echeverria and Wooster 1998, Spencer 2008). There was higher variance and increased autocorrelation on the shelf-wide bottom temperature post-1998 ($\sigma_{1982\text{-}1998} = 0.57$, $\sigma_{1999\text{-}2015} = 0.96$) with a 5-year warm period from 2001 through 2005 (5-year average of 3.28°C) and a 5-year cold period from 2006-2010 (5-year average of 1.51°C). For the years evaluated, 1999 had the coldest shelf-wide bottom temperature at 0.84 °C, while 2003 had the warmest at 3.81 °C.

The CPUE weighted mean bottom temperature for the 22 species examined varied from species to species and between years (Table 3). The mean bottom temperatures were not always directly correlated with the overall mean bottom temperature. Similarly mean bottom depths also varied by species and for individual species by year. Table 3 provides a summary of overall survey measured shelf-wide mean bottom temperature (°C) and mean survey bottom depth (m) by year, whether the shelf-wide mean bottom temperature was warmer or colder than the 1982 through 2015 overall shelf-wide mean, and the annual mean bottom temperature, annual mean bottom depth (Although there was very little variability in mean depth in some years survey stations may have been missed and station locations within a grid cell may have varied), biomass in thousands of tons, and abundance in millions of fish per year by species. Each column in Table 3 is scaled from blue (lowest value) to red (highest value). For the skates and the sculpins these numbers are restricted to after 2000 since these groups were not previously identified and/or measured adequately (Stevenson and Hoff 2009). Abundance and biomass estimates for all species were only available after 1986. For Arctic cod neither biomass or abundance estimates were provided for any year as these estimates were not produced by the Alaska Fisheries Science Center RACE Division in their annual calculations.

For each species there are 13 figures presented in total. The first five figures exhibit the density (number per km^2) of fish at each survey sampling station by length category (Figures ending in 4 or 9; e.g., Fig. 4 for Alaska plaice and Fig. 9 for Alaska skate). The next five figures for each species illustrate the density (number per km^2) of fish at each bottom temperature (0.1 °C) and bottom depth (10 m) by length category (Figures ending in 5 and 0; e.g., Fig. 5 for Alaska plaice and Fig. 10 for Alaska skate). For all species the next three figures presented show location or bottom depth and bottom temperature centroids for all years and length categories. The first figures (Figures ending in 6 and 1; e.g., Figs. 6 for Alaska plaice and Fig. 11 for Alaska skate) show the length category centroids for all years for which there were adequate data for all length bins and years. The length of the fish (length category) is indicated by color from yellow (smallest) to dark red (largest) for each year. The large points with error bars are the overall timeline where data were available mean at each length category and 95% confidence interval. The top figure shows location in km UTM zone 2 while the bottom figure shows bottom depth and bottom temperature. The next figures (Figures ending in 7 and 2; e.g. Figs. 7 for Alaska plaice and 12 for Alaska skate) are a series of graphs, one each for each length category with the color of the points indicating survey year from yellow (1982) to dark red (2015) with 95% confidence intervals for each year. In these figures missing years indicate that there were insufficient length data collected that year for the analysis. Gray lines in this figures connect adjoining years, dark points indicate the weighted centroid for each length category. The next figures (Figures ending in 8 and 3; e.g., Figs. 8 for Alaska plaice and 13 for Alaska skate) is comprise of four separate panels. The top two panels display centroids in terms of overall shelf-wide bottom temperatures being above (red, > + 0.5 standard deviations), below (blue, < -0.5 standard deviations), or at (gray, ± 0.5 standard deviations) the overall 1982-2015 mean, and the bottom two panels in terms of male (blue circle) and female (pink triangle). Each annual centroid is represented by a colored point with 95% confidence intervals. The black points display the overall timeline centroids for each length category.

DISCUSSION

Life History and Environmental Preferences

Plotting the data by length category over time provides a means to evaluate life histories and environmental preferences, as well as effects of changing environmental conditions on fish species. For example the species assessed in this analysis were categorized by their preferred habitat as defined by bottom temperature and bottom depth (Tables 3 and 4). Although alternative sets of criteria could be developed for defining preferences that take into account a wider array of environmental conditions, for this analysis we chose to define them based on the shelf-wide means from the EBS bottom trawl survey area. In this analysis values of ±0.5 °C and ±10 m of the 1982-2015 shelf-wide EBS shelf bottom trawl survey means (2.4 °C and 83 m) were chosen as we wanted to focus on interrelationships among species within the eastern Bering Sea. Here "cold" species were defined as those with overall CPUE weighted bottom temperature centroids in water colder than 0.5 °C below the 1982-2015 shelf-wide mean and "warm" species as those with overall bottom temperature centroids in water warmer than 0.5 °C above the 1982-2015 shelf-wide mean. "Deep" species were defined as those with overall CPUE weighted bottom depth centroids deeper than 10 m below the shelf-wide mean and "shallow" species with centroids shallower than 10 m above the shelf-wide mean.

Of the 22 species assessed 11 were categorized as "warm" species (> 2.9 °C), 4 as "cold" species (< 1.9 °C), and 8 were within ±0.5 °C of the 1982-2015 shelf-wide mean (2.4 °C). The warm species were arrowtooth flounder, Bering skate, butter sole, Kamchatka flounder, northern rock sole, Pacific halibut, Pacific ocean perch, rex sole, starry flounder, yellowfin sole, and yellow Irish lord. The "cold" species were Arctic cod, Bering flounder, Greenland turbot, and Sakhalin sole. The "cold" species tended to be centered on the northern edge of the EBS shelf bottom trawl survey area. The species near the shelf-wide bottom temperature mean were Alaska plaice, Alaska skate, bigmouth sculpin, flathead sole, great sculpin, Pacific cod, and walleye pollock. There were nine species categorized as "deep" species (> 93 m bottom depth centroid), nine as "shallow" species (< 73 m bottom depth centroid), and there were four species whose overall centroids of distribution were within ±10 m from the EBS shelf survey area mean (83 m). The "deep" species were arrowtooth flounder, Bering skate, bigmouth sculpin, flathead sole, Greenland turbot, Kamchatka flounder, Pacific ocean perch, rex sole, and walleye pollock. We should note here that for walleye pollock a substantial portion of the stock may reside in mid-water and be poorly sampled in the bottom trawl survey. The "shallow" species were Alaska plaice, Arctic cod, butter sole, northern rock sole, Pacific cod, Pacific halibut, Sakhalin sole, starry flounder, and yellowfin sole. The species whose distribution was close to the shelf-wide survey mean were Alaska skate, Bering flounder, great sculpin, and yellow Irish lord. The most common combinations of habitat preference were "warm" and "shallow" species (butter sole, northern rock sole, Pacific halibut, starry flounder, and yellowfin sole) and "warm" and "deep" species (arrowtooth flounder, Bering skate, Kamchatka flounder, rex sole, and Pacific ocean perch). There were three species at ±0.5 °C of the mean temperature and "deep" (bigmouth sculpin, flathead sole, and walleye pollock), two "cold" and "shallow" species (Artic cod and Sakhalin sole), two species at ±0.5°C of the mean temperature and "shallow" (Alaska plaice and Pacific cod), and two species within ±0.5°C of the mean temperature and ±10 m of the mean depth (Alaska skate and great sculpin). Greenland turbot was the only "cold" and "deep" species, Bering flounder the only "cold" species within ±10 m of the mean depth, and yellow Irish lord the only "warm" species within ±10 m of the mean depth.

There were distinct ontogenetic patterns that became evident for many of the species included in this analysis. A common ontogenetic pattern was a descending life history where shallow species used Kuskokwim Bay, Bristol Bay, and the near-shore environment as important nursery areas and then migrated to deeper waters of the middle domain as they grew. Species with this type of ontogenetic migration were Alaska plaice (Fig. 6), arrowtooth flounder (Fig. 50), great sculpin (Fig. 51), Greenland turbot (Fig. 56), northern rock sole (Fig. 66), Pacific cod (Fig. 71), Pacific halibut (Fig. 76), Pacific ocean perch (Fig. 81), starry flounder (Fig. 96), and yellowfin sole (Figs. 111). Five species exhibited an ascending life history where small fish settled or originated in deeper waters and then migrated or expanded their distribution into shallower waters as they grew. These species included the Bering skate

(Fig. 31) with distinct nursery grounds (Hoff 2008, Hoff 2010), bigmouth sculpin (Fig. 36), flathead sole (Fig. 46), rex sole (Fig. 86), and yellow Irish lord (Fig. 106). Arctic cod (Figs. 16), Bering flounder (Fig. 26), and Sakhaline sole (Fig. 91) were only observed in the colder northern waters and for these species the EBS bottom trawl survey likely doesn't capture their centers of distribution. There were also some unique life histories that were identified in this analysis. Walleye pollock, exhibited cyclical shifts in distribution by length (Fig. 101). The center of distribution for walleye pollock less than 16 cm in length was in waters less than 100 m. Their center of distribution became deeper with length greater than 16 cm. At greater than 54 cm walleye pollock were found at higher abundance at depths less than 100 m. Whether this shift to shallower waters represented an actual migration, a difference in fishery removals in the shallow areas, or other uninvestigated factors is not known. Annual variability in distribution are also likely density-dependent and influenced by species abundance (Spencer 2008). Kamchatka flounder remained in similar depths throughout their life, but their distribution shifted northwestward along the shelf break to cooler waters at larger lengths (Fig. 61).

Shifts in distribution over time were difficult to determine, only five species showed a distinct pattern. The distribution of Alaska skate (Fig. 12), arrowtooth flounder (Fig. 22), and Kamchatka flounder (Figs. 62) changed to more shallow waters from earlier to later years for some length classes. Flathead sole showed a differential shift in distribution with lengths less than 24 cm in deeper waters, while larger fish (≥ 34 cm) shifted to shallower depths (Figs. 47). Northern rock sole did not change depths but exhibited a southeasterly shift in distribution in the later years (Figs. 67).

For most of the species and length categories evaluated there were no clear shifts in distribution between warm and cold years. For 7 species, Alaska skate between 38 and 84 cm (Fig. 13), arrowtooth flounder between 20 cm and 41 cm (Fig. 23), Bering flounder between 20 cm and 35 cm (Fig. 28), Pacific cod less than 69 cm (Fig. 73), Pacific halibut less than 64 cm (Fig. 78), starry flounder (Fig. 98), and walleye pollock greater than 15 cm (Fig. 293) there were shifts in their distributions to deeper waters in cold years for a subset of the length categories. Kotwicki and Lauth (2013) observed a similar shift in walleye pollock and arrowtooth flounder to deeper waters during colder years. Further Kotwicki et al.

(2015) suggest that pollock may shift to deeper waters later in the season due in part to changes in prey item distribution. Of these species only the Bering flounder (Fig. 28), Pacific halibut (Fig. 78), and starry flounder (Fig. 98) showed distinguishable northward shifts in distribution in the warmer years. For all shallow species in which shifts in distribution were observed between cold and warm years, the effects were not observed at the smallest or largest length categories. This may suggest that depth and location were less elastic for spawning and nursery grounds while mid-sized fish were more mobile and able to move to more favorable feeding grounds and follow temperature preferences. Alternatively this may represent a change in growth between warmer and colder years at these mid-ranged-sized fish which would be on the steepest part of their growth curves.

Two of the species (Pacific ocean perch greater than 26 cm (Fig. 83) and yellow Irish lord greater than 32 cm (Fig. 108) exhibited a shift in distribution to shallower waters in the cold years for at least some of the length categories. For Pacific ocean perch low selectivity for the < 26 cm fish may have affected these results. Yellow Irish lord also exhibited a northeastern shift in distribution for lengths between 25 cm and 42 cm (Fig. 108). The remainder of the species and length categories exhibited no clear shifts in distribution, for some the observation error may have been too large to distinguish patterns, particularly for the smallest and largest length categories where sample sizes were low.

There were six species that presented differences in distribution by sex. In all but one, yellowfin sole, the males were deeper than the females. Alaska skate (Fig. 13) males greater than 85 cm and northern rock sole (Fig. 68) males greater than 31 cm were deeper and further to the west than females. Great sculpin (Fig. 53) males greater than 67 cm, Pacific halibut (Fig. 78) males greater than 81 cm, and starry flounder (Fig. 98) males greater than 49 cm were distributed deeper than females on average. Yellowfin sole (Fig. 113) males greater than 30 cm were on average shallower than females.

Caveats

These analyses and figures are meant as a gross overview of the EBS shelf bottom trawl survey data and understanding potential issues with the data is essential for proper interpretation. Further it should be noted that this analysis is a summer seasonal snap-shot of species distribution using only the EBS shelf bottom trawl survey conducted in May through August. The distributions of most of the species included in this study likely change seasonally. This study could be improved by correcting for the seasonal effects on temperature and growth. It should also be noted that this analysis does not explicitly take into account environmental effects on selectivity. The visualizations are empirical data without correction for any changes in selectivity. However the annual variation in centroid location provides an indication of both observation error and variance due to variable environmental conditions.

There has been substantial efforts in the last few decades to improve species identification (Stevenson and Hoff 2009). This can be seen in the availability of sculpin and skate data since 2000. However there have been efforts over time since 1982 to improve species differentiation in species that are difficult to distinguish. In at least one case this may have created a bias in the data affecting the apparent distribution of the species. In 1992 the AFSC placed more emphasis on properly distinguishing the less abundant Kamchatka flounder from the more common arrowtooth flounder. In Figure 62 a distinct shift in the centroid of distribution of Kamchatka flounder greater than 40 cm to ~20 m shallower between the 1982-1991 and 1992-2015 centroids can be observed. This change in distribution also corresponds with an apparent increase in catch of this species.

Summary

This report has provided a look into the distribution of fish in the eastern Bering Sea that would not have been possible without a consistent, long-term survey. It also demonstrates the importance of understanding the life history of organisms being studied and effects of the environment on different stages of their life history. Having a 34-year time series of the distribution of species at length is invaluable to this understanding and allows us to investigate in detail the sensitivity of species to environmental change and the degree to which species are already adapted to natural variation in the environment. This report is intended to provide a unique look at the patterns in groundfish distribution over this time period in both space and time and by temperature and depth. The visualizations provided in this paper are meant to facilitate a better understanding of the life histories of these species over time and space and potentially provide clues to how climate change could impact species at different life stages. This report and functions included in the Appendices will facilitate the understanding of life histories of eastern Bering Sea species and can be a useful starting place for more in-depth studies.

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CITATIONS

Baker, M. R., and A. B. Hollowed. 2014. Delineating ecological regions in marine systems: Integrating physical structure and community composition to inform spatial management in the eastern Bering Sea. Deep-sea Res. II. 109: 215-240

Bakkala, R. G. 1993. Structure and historical changes in the groundfish complex of the eastern Bering Sea. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 114.

Bartolino, V., L. Cianelli, N. Bacheler, and K. S. Chan. 2011. Ontogenetic and sex-specific difference sin density-dependent habitat selection of a marine fish population. Ecology 92: 189-200.

Ciannelli, L., P. Fauchald, K. S. Chan, V. N. Agostini, and G. E. Dingsor. 2008. Spatial fisheries ecology: Recent progress and future prospects. J. Mar. Syst. 71: 223-236.

Fox, J., and S. Weisberg. 2011. An R Companion to Applied Regression, Second Edition. Thousand Oaks CA.

Hoff, G. R. .2008. A nursery site of the Alaska skate (*Bathyraja parmifera*) in the eastern Bering Sea. Fishery Bulletin 106: 233-244.

Hoff, G. R. 2010. Identification of skate nursery habitat in the eastern Bering Sea. Mar. Ecol. Progr. Ser. 403: 243-254.

Kotwicki, S., J. Horne, A. Punt, and J. Ianelli. 2015. Factors affecting the availablility of walleye pollock to acoustic and bottom trawl survey gear. ICES J. Mar. Sci. 72.5 (2015): 1425-1439.

Kotwicki S., and R.R. Lauth. 2013. Detecting temporal trends and environmentally-driven changes in the spatial distribution of groundfishes and crabs on the eastern Bering Sea shelf. Deep-sea Res. II: Top. Stud. Oceanogr. 94:231-243.

Lauth, R. R., and J. Conner. 2014. Results of the 2011 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-266, 176 p.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ripley, B., and M. Lapsley. 2013. RODBC: ODBC Database Access. R package version 1.3-8. http://CRAN.R-project.org/package=RODBCR.

Sarkar, D. 2008. Lattice: Multivariate Data Visualization with R. Springer, New York. ISBN 978-0-387-75968-5.

Spencer, P.D. 2008. Density-independent and density-dependent factors affecting temporal changes in spatial distributions of eastern Bering Sea flatfish. Fish. Oceanogr. 17:396–410.

Stevenson, D. E., and G. R. Hoff. 2009. Species identification confidence in the eastern Bering Sea shelf survey (1982-2008). AFSC Processed Rep. 2009-04, 46 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Wickham, H. 2009. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, NY.

Wyllie-Echeverria, T., and W. S. Wooster. 1998. Year-to-year variations in the Bering Sea ice cover and some consequences for fish distributions. Fish. Oceanogr. 7:159-170.

Table 1. -- Color of the year indicates warmer (red) or colder (blue) shelf-wide bottom temperature than the 1982-2015 mean. Number of sample stations are the total number of hauls conducted each year. All surveyed species columns include the weight (t) and number (1,000s) of all species caught in the survey, not limited to the 22 species in the study. Study animals as % of all species are the percentages of the overall survey weight and number composed of the 22 species in this study. These columns are shaded red (highest) to blue (lowest) values for the column.

Year	Stations #	All surveyed species Weight (t)	All surveyed species Number (1000s)	Study animals as % of all species Weight	Study animals as % of all species Number
1982	367	414.15	1,782.19	69%	65%
1983	442	603.35	2,023.09	77%	73%
1984	460	636.11	2,133.65	73%	57%
1985	417	471.13	1,329.73	79%	70%
1986	388	435.50	1,540.61	74%	48%
1987	393	550.28	2,159.09	67%	37%
1988	441	683.45	2,477.75	69%	41%
1989	444	630.86	2,250.88	66%	42%
1990	404	535.20	2,092.04	63%	36%
1991	406	541.24	2,426.36	59%	33%
1992	361	428.15	1,641.66	61%	37%
1993	396	613.72	2,299.20	62%	39%
1994	436	648.39	2,361.69	61%	37%
1995	537	686.12	2,310.71	62%	39%
1996	382	506.48	1,808.41	74%	55%
1997	382	569.36	1,961.66	71%	58%
1998	616	502.36	1,820.91	72%	57%
1999	426	489.59	1,770.71	75%	54%
2000	423	512.88	2,004.34	76%	48%
2001	426	541.06	2,275.87	77%	45%
2002	404	545.80	2,174.29	77%	44%
2003	408	632.07	2,446.94	78%	43%
2004	413	627.93	3,032.14	76%	40%
2005	417	626.83	3,160.03	75%	37%
2006	457	638.65	3,814.07	74%	39%
2007	443	674.25	3,158.06	71%	44%
2008	432	567.47	2,914.75	73%	43%
2009	422	512.82	2,451.37	72%	45%
2010	415	633.71	3,017.93	75%	44%
2011	422	627.62	2,794.43	72%	39%
2012	451	696.06	2,749.55	64%	38%
2013	455	599.13	2,846.79	73%	32%
2014	428	719.22	3,093.07	79%	36%
2015	440	630.16	3,655.50	76%	26%

Table 2. -- Number of fish measured for length annually from the eastern Bering Sea shelf bottom trawl survey by species. Color of the year indicates warmer (red) or colder (blue) shelf-wide bottom temperature than the 1982-2015 mean. Color is scaled for each species from highest (red) to lowest (blue) values.

Year	**Alaska plaice** (*Pleuronectes quadrituberculatus*)	**Alaska skate** (*Bathyraja parmifera*)	**Arctic cod** (*Boreogadus saida*)	**arrowtooth flounder** (*Atheresthes stomias*)	**Bering flounder** (*Hippoglossoides robustus*)	**Bering skate** (*Bathyraja interrupta*)	**bigmouth sculpin** (*Hemitripterus bolini*)	**butter sole** (*Isopsetta isolepis*)	**flathead sole** (*Hemilepidotus jordani*)	**great sculpin** (*Myoxocephalus polyacanthocephalus*)	**Greenland turbot** (*Reinhardtius hippoglossoides*)
1982	14,274			3,192					11,894		1,567
1983	11,624			6,169	1,427				15,857		951
1984	14,448		51	6,769	934				16,801		536
1985	10,989			6,796	1,031			151	16,218		685
1986	12,349		369	5,812	1,846			347	13,561		195
1987	8,542		3	8,114	2,570			97	14,029		377
1988	8,036		199	8,337	3,194				16,364		414
1989	8,647			10,831	3,798				17,764		432
1990	7,955		404	6,589	3,560				15,823		544
1991	8,702			5,720	5,095			65	16,359		658
1992	7,590		111	5,711	3,824				15,917		616
1993	8,365		3	7,367	3,786				17,182		632
1994	9,653		672	8,340	4,020			1	18,631		536
1995	25,049			7,791	2,791				27,182		353
1996	10,186			8,749	3,050				19,590		450
1997	10,143		51	7,193	3,136			9	16,567		298
1998	10,104			8,920	2,863			60	22,067	41	445
1999	13,494			7,221	2,208			178	15,482		207
2000	10,147	2,140	190	8,233	2,238	180	52	151	16,202	405	248
2001	12,775	3,236	758	8,664	3,108	193	159	143	16,791	362	274
2002	8,867	2,678		8,669	1,607	171	120	154	17,056	417	455
2003	8,961	2,824	142	14,843	2,050	226	163	87	18,069	725	622
2004	9,182	4,210	11	13,569	2,060	198	238	324	19,098	719	606
2005	11,454	4,589	1,117	14,856	3,990	125	193	146	17,600	870	442
2006	14,527	5,208	1,148	13,381	3,654	214	213	44	18,900	934	427
2007	12,951	5,291	1,644	10,391	2,843	222	130	71	16,190	820	501
2008	13,885	4,242	2,366	12,908	2,782	223	225	53	17,220	781	406
2009	14,073	4,927	475	9,862	2,034	353	175	34	14,343	708	856
2010	11,585	3,940	5,121	10,784	3,735	268	230	10	12,911	469	3,199
2011	11,646	4,606	510	11,760	4,104	238	305	213	14,535	733	4,381
2012	10,763	3,874	3,480	9,358	3,242	189	155	71	11,922	684	2,133
2013	9,710	3,797	776	8,289	2,528	235	220	160	14,375	438	1,160
2014	7,335	3,576	177	8,138	2,403	215	207	9	13,436	453	1,002
2015	5,989	3,906	122	11,441	2,835	205	251	12	14,356	557	771
Total	374,000	63,044	19,900	304,767	94,346	3,455	3,036	2,590	560,292	10,116	27,379

Table 2. -- Continued.

Year	**Kamchatka flounder** *(Atheresthes evermanni)*	**northern rock sole** *(Lepidopsetta polyxystra)*	**Pacific cod** *(Gadus macrocephalus)*	**Pacific halibut** *(Hippoglossus stenolepis)*	**Pacific ocean perch** *(Sebastes alutus)*	**rex sole** *(Glyptocephalus zachirus)*	**Sakhalin sole** *(Limanda sakhalinensis)*	**starry flounder** *(Platichthys stellatus)*	**walleye pollock** *(Gadus chalcogrammus)*	**yellowfin sole** *(Limanda aspera)*	**yellow Irish lord** *(Hemilepidotus jordani)*
1982			11,376	1,201		38		4	44,742	37,023	
1983	720		14,489	1,721		82			166,564	34,447	
1984	741		13,733	1,591		96			54,597	38,385	
1985			17,473	1,013	28	795			216,606	34,170	
1986			15,872	1,058	9	437	68	145	137,690	30,470	
1987	5		10,497	986	15	525	8	43	40,144	31,249	
1988	143		8,004	992	27	394	29		104,025	31,695	
1989	433		4,936	1,827	5	398	33	65	82,674	35,019	
1990	643		5,693	1,819	16	229	100	324	106,802	32,312	
1991	1,056		7,029	2,170	80	392	118	228	140,301	29,451	
1992	1,039		10,129	1,395	109	532	24	212	61,165	23,803	
1993	1,117		10,500	1,799	3	467	55	103	167,268	26,651	
1994	1,245		13,891	1,657	3	304	122	29	129,988	26,916	
1995	838		19,080	1,241	58	352	1	86	152,099	68,283	
1996	826	35,230	9,348	1,190	148	224		151	117,506	27,505	
1997	698	34,927	9,591	1,179	204	341	41	335	125,887	26,034	
1998	1,100	44,206	9,582	1,504	13	609	4	420	108,064	34,589	
1999	920	37,427	11,699	1,659	160	830	244	677	104,633	31,308	
2000	1,054	33,690	12,564	1,350	24	1,503	191	838	132,682	28,199	
2001	1,111	31,784	19,750	1,907	3	1,827	514	832	135,178	30,198	
2002	1,053	29,075	12,238	1,730	217	1,538	51	773	149,465	29,910	
2003	1,530	31,171	12,360	2,039	173	1,738	77	792	54,759	30,060	551
2004	3,112	34,930	10,802	2,810	162	1,396	3	1,193	93,909	29,047	898
2005	3,632	32,122	12,118	2,181	192	1,095	321	677	37,030	26,792	1,078
2006	4,128	39,539	13,417	4,165	285	1,196	468	834	40,932	33,129	823
2007	2,954	33,051	13,847	4,178	44	975	12	1,128	30,415	28,351	400
2008	2,747	34,073	15,368	3,725	41	1,270	19	1,219	114,551	29,644	603
2009	2,084	31,614	25,966	3,892	22	1,019	19	1,192	109,968	25,818	938
2010	3,271	21,851	20,978	4,040	45	1,043	55	783	109,638	22,756	294
2011	2,139	26,652	26,275	4,456	59	748	239	1,407	103,418	24,489	586
2012	2,966	20,780	39,102	3,093	208	711	101	671	206,281	25,778	349
2013	2,954	21,221	21,536	2,232	302	529	121	483	248,225	23,329	340
2014	2,493	22,855	29,322	2,123	84	580	135	619	320,364	20,289	196
2015	2,953	18,294	19,883	2,176	213	537	489	594	296,508	20,834	520
Total	51,705	614,492	508,448	72,099	2,952	24,750	3,662	16,857	4,244,078	1,027,933	7,576

Table 3. -- Summary of temperatures, depths, Biomass and abundance for 22 study species. Whether above (warm) or below (cold) the shelf-wide average temperature (Reg.), CPUE weighted mean bottom temperature (Mean Temp. (°C)) and bottom depth (Mean Depth(m)), EBS bottom trawl survey estimated biomass (Biomass (1,000t)), and abundance in number (Abundance (10^9)) for all species analyzed and for the full survey. Color is scaled for each column from highest (red) to lowest (blue) value. The Average row reports the averages over all years (1982-2015).

		Full Survey		**Alaska plaice** (*Pleuronectes quadrituberculatus*)				**Alaska skate** (*Bathyraja parmifera*)				**Arctic cod** (*Boreogadus saida*)			
Year		Mean Temp (°C)	Mean Depth (M)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)
Average		2.43	81.6	1.94	56.5	516.1	832.5	2.26	78.2	399.3	116.6	-0.60	64.1		
1982		2.26	81.9	1.90	51.3										
1983	WARM	3.02	82.9	2.32	58.7										
1984		2.33	83.4	0.96	58.1							-1.27	60.0		
1985		2.37	81.0	1.35	61.5										
1986	COLD	1.86	83.4	0.96	59.9							-1.00	60.7		
1987	WARM	3.22	80.5	2.67	59.4	547.9	866.8					0.53	65.5		
1988		2.36	82.0	1.83	59.1	676.9	971.4								
1989	WARM	2.97	81.5	2.59	59.7	515.0	753.9								
1990		2.45	81.9	2.00	58.6	495.3	702.9								
1991		2.7	81.7	2.82	55.8	534.3	766.8								
1992	COLD	2.02	81.2	1.58	58.5	516.5	751.3					-1.08	61.0		
1993	WARM	3.06	80.4	2.87	57.3	516.1	787.6					0.40	64.0		
1994	COLD	1.57	79.9	1.09	53.7	623.3	1,011.3					-2.10	80.0		
1995	COLD	1.75	80.2	0.99	56.6	554.8	899.8								
1996	WARM	3.43	81.5	3.12	58.0	532.3	903.4								
1997		2.74	81.4	1.87	59.8	632.1	1,025.5					-1.30	61.0		
1998	WARM	3.28	81.5	3.17	60.3	455.9	737.6								
1999	COLD	0.83	81.0	-0.14	55.0	480.5	836.8								
2000		2.16	81.2	1.66	56.0	446.1	790.8	2.17	81.9	312.0	92.9				
2001		2.58	81.8	1.15	57.7	546.2	957.7	2.32	83.2	414.5	128.0	-1.29	45.9		
2002	WARM	3.25	80.7	2.99	56.1	425.7	661.7	3.09	79.9	364.0	112.2	NA	NA		
2003	WARM	3.81	82.3	3.68	55.9	462.0	663.5	3.60	79.8	372.4	107.6	2.90	60.0		
2004	WARM	3.39	81.5	3.29	55.0	481.0	688.4	3.15	78.9	424.8	119.2	0.52	67.3		
2005	WARM	3.47	82.3	3.15	55.2	507.7	752.7	3.15	78.4	487.0	139.2	-0.24	59.8		
2006	COLD	1.88	81.8	1.10	51.4	641.6	1,036.1	1.65	82.9	437.7	126.3	-1.21	75.3		
2007	COLD	1.79	82.0	1.82	52.3	423.0	809.5	1.65	79.1	479.0	144.0	-0.91	69.4		
2008	COLD	1.29	81.5	0.93	52.4	509.3	939.8	0.91	78.5	361.3	115.6	-0.25	63.1		
2009	COLD	1.39	81.6	1.38	49.6	529.7	1,021.2	1.05	83.1	350.2	118.7	-0.96	55.9		
2010	COLD	1.53	81.5	0.91	51.9	498.1	948.2	1.40	73.9	366.2	102.7	-1.09	64.8		
2011		2.47	81.4	1.95	55.5	519.6	910.2	2.34	76.0	410.3	129.7	-0.78	67.6		
2012	COLD	1.01	81.6	0.74	54.7	581.9	971.1	0.93	78.1	369.9	104.2	-0.93	53.6		
2013	COLD	1.87	81.6	1.39	58.2	505.6	805.6	2.13	73.7	386.8	108.8	-1.28	68.7		
2014	WARM	3.23	81.5	2.79	58.4	451.6	658.0	3.26	71.0	404.4	106.7	-0.65	65.5		
2015	WARM	3.37	81.6	3.02	57.8	355.6	511.9	3.42	73.4	448.2	110.2	-0.70	77.8		

Table 3. -- Continued.

Year	arrowtooth flounder (*Atheresthes stomias*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	Bering flounder (*Hippoglossoides robustus*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	Bering skate (*Bathyraja interrupta*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	bigmouth sculpin (*Hemitripterus bolini*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)
	3.53	111.5	426.1	806.9	0.19	83.1	26.1	162.4	3.34	130.4	11.9	6.7	2.56	110.1	28.5	6.9
1982	3.84	117.3														
1983	3.81	105.4			0.58	83.2										
1984	3.78	119.7			-0.49	81.9										
1985	3.67	116.2			-0.06	83.1										
1986	3.46	121.7			-0.35	85.1										
1987	4.13	105.9	280.1	635.7	0.79	71.1	40.6	270.7								
1988	3.41	110.1	297.3	773.7	-0.08	94.6	36.8	325.2								
1989	3.55	107.0	339.2	916.8	1.66	79.2	35.9	249.0								
1990	3.36	115.6	402.3	825.1	-0.12	88.0	42.9	271.1								
1991	3.49	108.2	298.8	587.5	-0.33	92.0	39.8	242.1								
1992	3.56	119.2	345.6	606.1	-0.31	88.1	35.2	232.2								
1993	3.65	108.3	446.8	694.9	0.58	82.9	42.8	262.3								
1994	3.27	104.3	476.4	758.8	-0.56	97.2	42.2	189.3								
1995	2.95	111.8	448.0	693.4	-0.43	91.1	24.2	112.8								
1996	4.16	115.5	527.3	646.1	1.28	80.9	28.8	161.2								
1997	4.00	118.3	463.1	568.1	0.20	78.0	30.5	147.5								
1998	3.96	109.3	345.2	520.8	1.51	86.5	21.2	112.1								
1999	2.87	115.0	239.7	419.7	-0.35	90.3	28.8	116.1								
2000	3.30	114.7	314.7	576.5	0.47	82.0	15.8	73.7	2.78	120.5	16.8	7.1	2.61	102.2	26.2	5.9
2001	3.82	107.3	378.1	711.9	0.57	73.3	23.2	96.5	3.52	129.9	14.3	7.0	2.70	111.1	25.8	6.8
2002	3.84	105.0	313.1	627.5	1.27	69.5	14.4	59.7	3.63	130.8	12.7	6.2	3.07	104.7	32.2	7.4
2003	4.22	101.7	498.0	933.8	1.47	77.4	16.7	76.3	4.11	128.0	13.6	7.8	4.00	103.4	29.3	6.1
2004	3.83	98.9	519.1	1,176.3	0.48	70.1	22.3	116.4	3.57	127.1	11.2	5.3	3.20	107.3	34.4	7.4
2005	4.01	100.9	662.7	1,502.6	-0.06	73.9	39.0	183.9	3.90	138.4	8.8	4.6	3.64	105.8	31.3	6.8
2006	3.32	106.0	608.1	1,305.6	-0.25	88.3	20.8	89.1	3.20	122.8	11.7	6.3	2.56	104.2	30.1	6.4
2007	2.91	113.5	482.4	1,043.6	-0.05	91.9	26.0	119.3	2.93	127.3	9.5	6.4	2.15	126.1	27.9	7.0
2008	2.62	112.3	530.1	1,230.0	-0.46	89.1	21.5	121.6	2.62	129.4	9.9	6.6	1.66	106.9	30.8	6.8
2009	2.96	118.0	406.9	868.3	-0.23	81.4	9.0	57.4	2.97	136.4	13.3	10.2	2.12	111.9	20.2	5.0
2010	3.07	114.0	528.7	1,060.4	-0.63	75.2	11.9	175.1	3.28	134.4	12.0	7.8	2.03	109.9	32.5	8.2
2011	3.50	113.0	522.1	977.0	0.50	79.6	16.1	199.2	3.49	133.4	9.8	6.8	2.50	112.8	31.6	8.7
2012	2.42	120.3	402.9	805.8	-0.67	81.6	13.0	145.3	2.40	134.1	10.2	5.3	1.32	116.1	24.1	5.4
2013	3.18	118.5	405.5	621.6	-0.44	82.5	11.8	140.5	3.30	135.1	12.1	6.9	2.17	121.1	27.0	7.1
2014	3.75	110.8	465.6	694.5	0.72	85.4	19.7	182.3	3.69	130.5	12.6	6.7	2.77	105.9	23.6	6.8
2015	4.32	105.6	409.2	617.4	0.09	88.1	26.5	182.9	4.07	127.5	12.2	6.3	2.50	111.7	29.5	8.3

Table 3. -- Continued.

Year	**butter sole** (*Isopsetta isolepis*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	**flathead sole** (*Hemilepidotus jordani*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	**great sculpin** (*Myoxocephalus polyacanthocephalus*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)	**Greenland turbot** (*Reinhardtius hippoglossiodes*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^9)
	3.96	70.2	1.4	5.5	2.90	108.1	536.4	1,819.8	2.36	76.1	59.0	32.2	1.47	117.0	25.0	29.6
1982					2.83	101.3							2.14	105.0		
1983					3.10	105.1							1.73	111.0		
1984					3.17	110.1							1.90	130.8		
1985	6.10	80.0			3.20	105.3							1.28	122.8		
1986	2.69	61.2			2.76	111.1							0.52	112.9		
1987	3.82	71.2	2.0	10.8	3.85	107.2	380.0	1,540.7			50.1	35.3	2.30	111.3	11.8	22.0
1988					2.81	113.7	544.1	2,316.9			40.2	37.6	1.18	119.1	13.4	29.2
1989					3.02	107.4	504.1	2,179.1			37.1	29.1	2.30	108.0	13.2	25.5
1990					2.74	116.0	575.6	2,127.6			35.7	25.1	0.89	117.2	16.2	28.9
1991	3.45	72.5	3.1	10.1	3.00	102.2	519.5	2,225.9			67.4	49.0	0.91	120.9	12.5	33.3
1992					2.47	109.3	605.4	2,538.0			93.9	70.9	1.35	120.6	28.6	31.0
1993					3.09	105.7	586.6	2,170.1			67.4	47.8	1.97	115.3	35.7	26.4
1994	3.10	66.0	1.1	1.4	2.73	105.4	666.6	2,373.4			98.3	70.0	1.55	133.1	57.2	23.1
1995					2.22	106.3	579.2	1,974.2			88.6	70.3	1.25	129.7	37.6	14.0
1996					3.68	108.4	608.3	2,099.5			86.8	58.1	2.75	116.5	40.6	13.8
1997	2.80	61.0	2.9	6.6	2.89	110.2	775.2	2,049.3			80.1	42.5	2.24	127.5	35.3	12.8
1998	3.90	70.9	1.9	8.0	3.17	113.6	680.9	2,032.6	4.06	62.5	65.3	24.7	1.97	118.6	34.9	12.5
1999	1.68	59.2	4.2	16.2	1.96	108.7	388.7	1,203.4			48.0	27.4	0.68	131.0	21.5	6.7
2000	2.55	66.5	1.7	6.4	2.51	109.4	386.2	1,185.9	1.71	95.7	62.9	23.4	1.20	125.6	23.2	8.0
2001	3.87	64.2	0.8	3.6	3.02	109.5	506.5	1,641.3	2.59	79.5	40.9	15.9	1.84	122.3	27.3	8.1
2002	4.38	61.8	2.3	9.9	3.26	102.6	551.2	1,493.9	2.97	83.7	65.8	24.3	1.89	113.7	24.0	13.5
2003	5.00	54.0	0.2	0.5	3.96	108.3	512.4	1,581.1	3.59	81.1	66.7	26.3	2.51	118.9	31.0	17.0
2004	5.25	81.3	0.8	7.7	3.48	105.0	610.8	1,884.7	2.97	71.9	60.4	23.6	2.08	117.7	28.3	17.8
2005	5.10	52.4	1.0	4.5	3.77	108.3	620.9	2,029.4	3.44	73.6	59.8	25.7	2.17	123.4	21.3	13.6
2006	4.42	75.2	1.2	3.8	2.73	107.2	622.4	2,043.8	1.71	75.8	57.8	25.8	1.42	124.9	20.9	11.5
2007	2.40	64.8	1.0	2.0	2.33	108.4	553.4	1,835.3	1.43	76.8	65.9	24.5	0.74	111.0	16.7	14.1
2008	2.97	76.2	0.4	1.9	1.89	108.2	535.8	1,731.6	1.06	76.8	70.2	24.7	0.39	115.0	13.5	15.1
2009	4.11	77.4	0.5	3.1	2.02	109.3	412.5	1,337.3	1.11	71.0	44.9	18.6	0.15	98.5	11.0	22.3
2010	4.64	81.4	1.7	6.6	2.36	108.4	488.8	1,558.8	1.53	67.7	49.7	20.2	0.86	100.8	23.4	137.6
2011	5.19	77.9	0.4	2.8	3.12	104.5	578.0	1,745.6	2.47	79.4	54.2	23.0	1.55	104.1	26.2	143.6
2012	3.04	81.5	0.5	4.0	1.67	109.5	376.9	1,222.4	0.88	70.4	40.7	20.5	0.59	116.7	21.8	61.3
2013	4.13	77.7	1.3	8.2	2.47	110.3	486.7	1,476.7	1.93	76.9	32.2	13.0	0.70	113.4	24.9	43.9
2014	4.91	74.6	0.5	2.1	3.41	109.8	514.3	1,831.5	3.34	75.2	44.2	19.2	1.75	109.8	28.0	30.2
2015	5.62	77.0	0.3	1.2	3.75	110.9	385.5	1,344.4	3.28	76.4	36.0	18.1	1.38	112.8	25.2	21.3

Table 3. -- Continued.

Year	**Kamchatka flounder** (*Atheresthes evermanni*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)	**northern rock sole** (*Lepidopsetta polyxystra*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)	**Pacific cod** (*Gadus macrocephalus*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)	**Pacific halibut** (*Hippoglossus stenolepis*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)
	3.15	119.6	38.7	81.5	3.07	52.1	2,004.1	8,739.1	2.50	67.5	752.4	669.4	3.53	60.6	140.0	62.4
1982									2.16	75.2			2.86	65.0		
1983	3.59	135.9							3.60	58.3			4.50	58.9		
1984	3.98	118.4							2.18	75.7			4.09	63.8		
1985									2.73	71.1			3.86	70.4		
1986									1.88	73.6			2.91	72.9		
1987	4.30	99.0							3.31	70.5	1,064.6	697.1	4.08	67.2	84.3	26.9
1988	2.44	140.3	13.7	15.9					2.30	82.1	976.2	512.1	3.52	68.7	104.0	27.4
1989	3.12	123.3	17.1	31.4					2.99	85.9	868.8	301.7	3.70	54.5	77.4	33.4
1990	3.07	124.6	32.9	65.3					2.33	83.1	729.0	438.1	3.96	48.8	84.8	57.1
1991	3.23	119.3	37.8	72.9					2.98	67.3	530.5	496.8	5.02	44.1	93.2	63.7
1992	2.92	125.8	45.1	71.4					2.09	68.8	538.9	585.4	3.44	62.6	97.8	46.9
1993	3.22	116.1	40.4	59.9					3.45	57.5	669.3	814.2	3.83	59.9	152.8	49.8
1994	2.54	120.7	52.7	66.8					1.78	65.7	1,377.1	1,255.5	2.58	63.2	160.7	47.5
1995	2.31	121.0	28.5	35.1					1.70	71.8	1,008.3	761.7	2.95	67.9	146.5	35.7
1996	3.63	113.8	25.0	29.4	4.16	53.3	2,070.3	9,803.0	3.24	69.4	909.1	614.5	4.54	72.7	162.9	34.5
1997	3.57	120.3	19.6	27.6	3.30	53.0	2,623.2	12,176.8	2.79	65.4	627.2	493.7	4.45	64.4	141.5	35.2
1998	3.39	119.4	24.0	37.4	3.89	54.9	2,196.2	9,861.7	3.22	63.1	550.5	522.6	4.35	64.6	161.3	44.7
1999	2.61	126.9	19.1	36.1	0.30	63.1	1,648.1	7,133.6	0.75	79.9	618.7	542.2	0.85	74.4	129.1	46.4
2000	2.99	123.8	21.5	38.7	2.32	48.2	2,080.7	8,110.6	1.90	66.3	537.6	488.6	2.71	66.2	118.7	36.6
2001	3.35	121.0	31.2	50.0	3.10	50.6	2,344.2	8,383.5	2.65	64.6	827.2	974.0	3.53	60.4	141.2	53.2
2002	3.35	117.3	23.6	40.5	4.06	50.2	1,883.6	6,500.6	3.07	67.5	597.9	544.6	4.33	57.6	101.7	39.6
2003	4.02	119.1	27.7	52.8	4.60	51.6	2,111.3	8,265.5	3.60	66.2	625.7	516.5	5.12	54.0	132.2	60.5
2004	3.77	114.7	30.2	138.3	4.19	50.7	2,196.2	9,930.6	2.93	68.8	578.1	404.7	4.76	51.3	130.1	66.8
2005	3.88	116.1	46.4	179.4	4.14	49.7	2,121.1	11,431.5	3.05	66.4	638.8	464.6	4.56	52.9	132.5	66.2
2006	3.15	120.0	61.6	187.9	2.31	48.7	2,216.4	15,083.3	1.06	73.3	544.0	407.6	2.57	52.3	156.0	133.4
2007	2.72	124.6	65.3	145.8	2.62	49.2	2,034.3	10,954.2	2.68	54.4	450.3	753.8	3.56	48.0	143.9	119.5
2008	1.93	119.8	58.2	119.5	1.72	49.6	2,031.9	10,534.0	1.12	63.4	427.5	492.6	1.75	54.6	140.2	108.2
2009	2.33	119.7	49.5	83.6	1.72	55.2	1,539.0	8,175.3	1.40	66.9	430.1	721.8	1.20	70.1	168.1	101.9
2010	2.65	112.6	58.3	132.2	2.11	52.1	2,065.7	9,298.6	1.25	68.0	870.6	896.3	2.31	56.6	195.5	105.9
2011	3.03	114.2	46.1	87.5	3.12	50.4	1,977.3	7,675.6	2.51	63.8	911.1	844.5	3.16	56.7	186.7	96.2
2012	2.06	119.1	42.8	112.3	1.12	56.6	1,920.4	6,474.0	1.38	55.6	896.4	991.3	1.50	61.5	189.0	79.6
2013	2.92	118.8	46.4	110.8	2.93	52.2	1,753.0	5,476.2	2.87	58.1	811.7	760.2	3.20	61.4	184.0	65.1
2014	3.64	114.7	58.0	130.2	4.80	50.6	1,857.4	5,317.5	4.28	51.8	1,095.3	1,129.3	5.04	56.1	171.4	62.8
2015	3.88	108.7	60.3	123.4	4.87	51.2	1,411.8	4,196.5	3.78	54.5	1,109.1	985.7	5.20	55.3	172.2	64.2

Table 3. -- Continued.

	Pacific ocean perch (*Sebastes alutus*)				**rex sole** (*Glyptocephalus zachirus*)				**Sakhalin sole** (*Limanda sakhalinensis*)				**starry flounder** (*Platichthys stellatus*)			
Year	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^8)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^8)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^8)	Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^8)
	3.48	151.6	36.0	45.4	3.76	126.7	15.7	39.5	-0.18	66.7	0.4	7.7	3.95	38.9	52.3	37.9
1982					3.50	198.0							0.60	46.0		
1983					3.91	122.9										
1984					3.90	112.0										
1985	3.70	132.0			3.62	138.0										
1986	3.40	130.0			3.84	127.2			-1.15	74.0			3.03	45.1		
1987			0.2	0.5	4.28	122.9	12.9	36.4	0.53	63.5	0.1	0.8	5.03	62.7	22.7	14.7
1988	3.70	126.0	0.6	1.7	3.70	138.1	15.7	49.7			1.0	13.5			9.2	6.6
1989	3.50	143.0	0.1	0.2	3.60	133.6	12.9	40.9	2.44	53.0	0.1	1.4	5.19	21.8	22.1	19.4
1990	3.40	139.0	0.2	0.7	3.51	131.9	11.9	37.0	-1.20	84.0	0.5	5.8	4.43	35.5	15.0	12.3
1991			4.6	6.7	3.86	124.6	16.1	44.9	-1.35	83.3	0.3	3.1	4.92	33.5	34.3	27.3
1992	3.10	218.0	15.4	20.2	3.89	125.3	14.0	35.0	-1.20	73.0	0.2	1.6	4.68	39.1	27.5	21.2
1993			0.2	0.3	4.17	121.0	14.4	32.4	-0.16	67.9	0.2	2.2	5.50	30.0	16.5	12.7
1994			0.1	0.4	3.33	117.8	15.9	34.6	-1.39	65.2	0.5	7.5	3.68	29.6	18.2	15.5
1995	2.81	115.1	0.5	3.0	3.31	128.1	10.3	21.2	-1.00	62.0	0.2	3.7	3.48	37.3	17.7	13.3
1996	3.50	179.0	41.9	60.8	4.23	125.4	10.3	17.6			0.2	2.8	5.48	36.3	40.4	26.4
1997	3.80	179.9	21.7	28.9	3.95	122.9	8.3	15.6			1.2	24.1	4.84	38.2	41.0	29.1
1998	3.90	140.0	0.3	0.8	3.95	125.3	7.6	21.0			0.7	9.9	4.76	38.3	49.6	29.3
1999	2.30	116.0	3.5	8.1	2.97	121.4	8.0	31.8	-1.61	68.5	0.8	13.1	0.22	47.1	45.4	47.3
2000	3.42	142.7	0.3	0.8	3.58	128.2	9.2	48.6	0.35	73.4	0.4	5.8	2.65	39.8	45.9	36.5
2001			0.1	0.2	3.94	127.2	21.7	77.9	0.59	69.2	0.1	1.4	3.94	40.8	43.4	29.8
2002	3.53	170.5	6.2	8.4	3.88	127.2	26.0	74.8			0.2	1.9	4.56	41.4	60.0	39.6
2003	4.01	172.7	56.9	71.6	4.50	119.8	27.5	64.9	1.86	71.6	0.3	2.4	5.05	41.7	52.5	36.6
2004	3.70	167.0	97.1	116.0	4.18	117.7	28.8	56.2	0.59	63.4	1.0	9.5	4.72	40.7	87.1	58.3
2005	4.20	171.0	308.4	362.7	4.25	123.3	23.2	47.3	0.96	69.9	0.8	7.9	5.57	36.9	71.7	45.8
2006	3.66	166.2	34.3	49.4	3.78	119.9	21.6	54.7	-1.11	62.2	0.1	1.4	3.29	35.7	112.3	78.4
2007	3.50	139.0	2.1	2.0	3.41	122.8	17.0	42.7	-0.65	61.1	0.0	0.3	3.95	40.1	98.6	69.7
2008	3.30	140.2	0.3	1.3	3.23	124.1	18.8	49.2	-0.65	75.1	0.1	0.7	2.22	40.6	74.1	57.5
2009	3.35	128.9	0.2	0.6	3.28	119.2	18.1	44.8	-0.27	60.7	0.1	0.6	2.89	39.7	79.4	57.1
2010	3.68	136.7	0.3	1.5	3.56	123.3	20.3	44.6	-0.24	63.4	0.1	1.9	3.18	40.4	80.4	61.3
2011	3.46	144.9	0.5	1.8	3.85	121.5	18.5	34.8	0.70	62.1	0.5	17.1	3.98	35.1	64.0	49.3
2012	2.60	174.5	81.2	102.6	2.78	125.0	12.8	24.1	-1.30	66.2	0.4	11.5	1.51	45.0	62.6	51.6
2013	3.28	142.2	256.5	327.1	3.58	125.8	9.8	20.2	-0.07	56.0	0.6	15.7	4.17	34.9	58.9	39.1
2014	3.90	168.2	25.4	34.9	4.08	124.1	13.3	25.0	0.31	57.3	0.6	12.4	5.69	32.1	110.9	75.8
2015	3.76	159.5	83.5	102.6	4.56	123.5	9.5	18.7	0.39	60.9	1.8	41.9	5.26	40.8	56.2	38.0

Table 3. -- Continued.

Year	walleye pollock (*Gadus chalcogrammus*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)	yellowfin sole (*Limanda aspera*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)	yellow Irish lord (*Hemilepidotus jordani*) Mean Temp (°C)	Mean Depth (M)	Biomass (1,000 t)	Abundance (10^6)
	2.40	97.4	4,757.3	7,792.0	3.10	47.7	2,171.5	8,688.9	3.12	73.0	22.8	34.4
1982	2.94	96.8			2.00	46.9						
1983	2.52	95.0			3.82	51.6						
1984	2.33	108.1			2.86	52.1						
1985	2.81	91.8			2.85	54.2						
1986	2.06	101.6			2.29	48.8						
1987	3.39	102.2	5,498.4	9,119.3	3.47	48.1	2,511.8	9,984.2				
1988	2.24	107.8	7,184.0	12,818.0	2.97	46.7	2,180.8	9,170.0				
1989	2.95	103.1	6,550.4	11,080.9	3.43	45.0	2,313.6	9,631.7				
1990	2.37	109.5	7,296.7	11,406.3	3.39	46.0	2,179.6	9,061.0				
1991	2.46	107.9	5,129.5	8,569.8	3.88	47.7	2,391.9	9,530.9				
1992	2.04	102.1	4,526.2	7,254.9	2.79	46.6	2,201.5	9,379.6				
1993	2.80	86.0	5,294.8	9,269.4	3.84	50.3	2,468.4	10,039.2				
1994	2.23	93.7	5,027.3	8,361.6	2.34	45.8	2,597.2	10,646.0				
1995	1.69	91.7	5,477.8	9,690.7	2.36	46.2	2,012.4	8,247.7				
1996	3.42	88.0	3,125.3	5,593.5	4.16	49.4	2,216.5	9,301.0				
1997	2.63	91.6	3,562.2	7,523.0	3.68	47.5	2,161.4	9,009.4				
1998	2.82	83.4	2,687.8	5,219.4	3.83	54.0	2,210.2	9,351.8				
1999	1.49	106.7	3,798.5	7,111.6	0.35	49.1	1,257.2	5,583.3				
2000	2.27	93.0	5,103.6	8,338.2	2.27	47.9	1,589.8	6,759.8				
2001	2.75	94.6	4,196.9	7,756.3	2.79	47.1	1,679.5	7,303.8				
2002	2.78	89.7	4,953.4	7,425.0	4.16	45.1	1,910.1	8,020.2				
2003	3.33	95.8	8,392.3	10,425.3	4.39	49.1	2,158.1	8,147.0	4.56	74.3	14.4	23.8
2004	3.29	90.6	3,863.0	5,414.4	4.35	47.0	2,542.1	9,412.8	4.04	76.5	33.6	55.6
2005	3.35	102.7	4,868.6	7,011.7	4.55	47.1	2,820.8	9,636.6	4.42	75.8	27.4	41.3
2006	2.09	95.1	3,045.4	4,700.8	2.28	47.5	2,132.5	8,446.9	3.04	75.4	31.7	50.1
2007	1.80	101.9	4,338.2	7,226.5	2.76	47.5	2,153.1	8,516.7	1.95	71.3	23.6	36.2
2008	1.28	105.0	3,023.3	3,955.3	1.69	47.0	2,099.7	8,884.8	1.79	70.9	32.4	49.2
2009	1.72	105.5	2,282.4	3,458.4	2.26	45.3	1,739.4	8,408.6	2.42	72.3	23.1	35.6
2010	2.00	108.5	3,737.9	5,397.1	2.22	42.5	2,368.3	10,056.1	1.46	70.3	21.5	29.3
2011	2.57	99.0	3,112.3	4,844.7	3.07	45.0	2,403.2	9,317.2	3.80	74.8	20.2	28.2
2012	0.40	89.0	3,487.2	6,475.1	1.88	45.1	1,951.4	7,589.6	1.59	71.6	22.2	31.9
2013	1.26	99.0	4,575.4	7,707.1	2.99	46.1	2,279.0	7,948.2	2.17	68.9	8.0	12.7
2014	2.59	88.0	7,430.0	11,831.0	4.63	48.2	2,512.3	8,172.2	4.45	70.9	9.2	14.8
2015	2.77	85.9	6,394.4	10,982.9	4.76	47.2	1,932.3	6,421.9	4.87	75.5	28.8	38.4

Table 4. -- Summary table for the 22 study species. Max length is the maximum length measured in the 1982-2015 eastern Bering Sea bottom trawl survey. Temperature and bottom preferences were determined for each species by the overall 1982-2015 species means. Ontogenetic migration is determined by whether a species moves deeper (Descend↓) or shallower (Ascend↑) as they grow. Trends over time evaluated on whether there was an apparent and consistent trend from 1982 through 2015. Temperature effect on depth looks at the apparent correlation between shelf-side temperatures and depth of a species at size. Temperature effect on location looks at the apparent change in location of centroids with changes in shelf-wide bottom temperatures. Effect of sex on distribution evaluates whether centroids are different between males and females.

	Max length (cm)	**Temp. pref.** (±0.5 °C survey mean 2.4 ° C)	**Depth pref.** (±10 m survey mean 83 m)	**Onto. migration** (Descend ↓ or Ascend ↑)	**Trends over time** (Lengths affected)	**Temp. effect on depth** ± correlation (Lengths affected)	**Temp. effect on location**	**Effect of sex on distribution** (Lengths affected)
Alaska plaice (*Pleuronectes quadrituberculatus*)	72	Mean ±0.5 °C	Shallow	Descend ↓				
Alaska skate (*Bathyraja parmifera*)	162	Mean ±0.5 °C	Mean ±10 m		Shallower (≥85 cm)	- (38-84 cm)		Males deeper (≥85 cm)
Arctic cod (*Boreogadus saida*)	30	Cold	Shallow	Descend ↓				
arrowtooth flounder (*Atheresthes stomias*)	98	Warm	Deep	Descend ↓	Shallower (≥42 cm)	- (20 - 41 cm)		Females on southwest shelf edge and less variable (≥53 cm)
Bering flounder (*Hippoglossoides robustus*)	51	Cold	Mean ± 10 m			- (≥15 cm)	North in warm years	Females less variable (≥36 cm)

Table 4. -- Continued.

	Max length (mm)	**Temp. pref.** (±0.5 °C survey mean 2.4 ° C)	**Depth pref.** (±10 m survey mean 83 m)	**Onto. migration** (Descend ↓ or Ascend ↑)	**Trends over time** (Lengths affected)	**Temp. effect on depth** ± correlation (Lengths affected)	**Temp. effect on location**	**Effect of sex on distribution** (Lengths affected)
Bering skate (*Bathyraja interrupta*)	131	Warm	Deep	Ascend ↑				
bigmouth sculpin (*Hemitripterus bolini*)	79	Mean ±0.5 °C	Deep	Ascend ↑				
butter sole (*Isopsetta isolepis*)	46	Warm	Shallow					
flathead sole (*Hemilepidotus jordani*)	66	Mean ±0.5 °C	Deep	Ascend ↑	Deeper (≤33) Shallower (≥34 mm)			
great sculpin (*Myoxocephalus polyacanthocephalus*)	94	Mean ±0.5 °C	Mean ±10m	Descend ↓				
Greenland turbot (*Reinhardtius hippoglossiodes*)	109	Cold	Deep	Descend ↓				
Kamchatka flounder (*Atheresthes evermanni*)	96	Warm	Deep		Shallower (≥40 cm)			
northern rock sole (*Lepidopsetta polyxystra*)	65	Warm	Shallow	Descend ↓	More SE (all lengths)			Males further west and deeper than females (≥31 cm)
Pacific cod (*Gadus macrocephalus*)	117	Mean ±0.5 °C	Shallow	Descend ↓	Shallower (≥35 cm)	- (≤69 cm)		

Table 4. -- Continued.

	Max length (mm)	**Temp. pref.** (±0.5 °C survey mean 2.4 ° C)	**Depth pref.** (±10 m survey mean 83 m)	**Onto. migration** (Descend ↓ or Ascend ↑)	**Trends over time** (Lengths affected)	**Temp. effect on depth** ± correlation (Lengths affected)	**Temp. effect on location**	**Effect of sex on distribution** (Lengths affected)
Pacific halibut (*Hippoglossus stenolepis*)	198	Warm	Shallow	Descend ↓		- (≤63 cm)	North in warm years	Males further west and deeper than females (≥82 cm)
Pacific ocean perch (*Sebastes alutus*)	66	Warm	Deep	Descend ↓		+ (≥20 cm)		
rex sole (*Glyptocephalus zachirus*)	75	Warm	Deep	Ascend ↑				
Sakhalin sole (*Limanda sakhalinensis*)	380	Cold	Shallow					
starry flounder (*Platichthys stellatus*)	78	Warm	Shallow	Descend ↓		- (All lengths)	North in warm years	
walleye pollock (*Gadus chalcogrammus*)	95	Mean ±0.5 °C	Deep			- (≥16 cm)		
yellowfin sole (*Limanda aspera*)	73	Warm	Shallow	Descend ↓				
yellow Irish lord (*Hemilepidotus jordani*)	51	Warm	Mean ±10 m	Ascend ↑		+ (≥32 cm)		

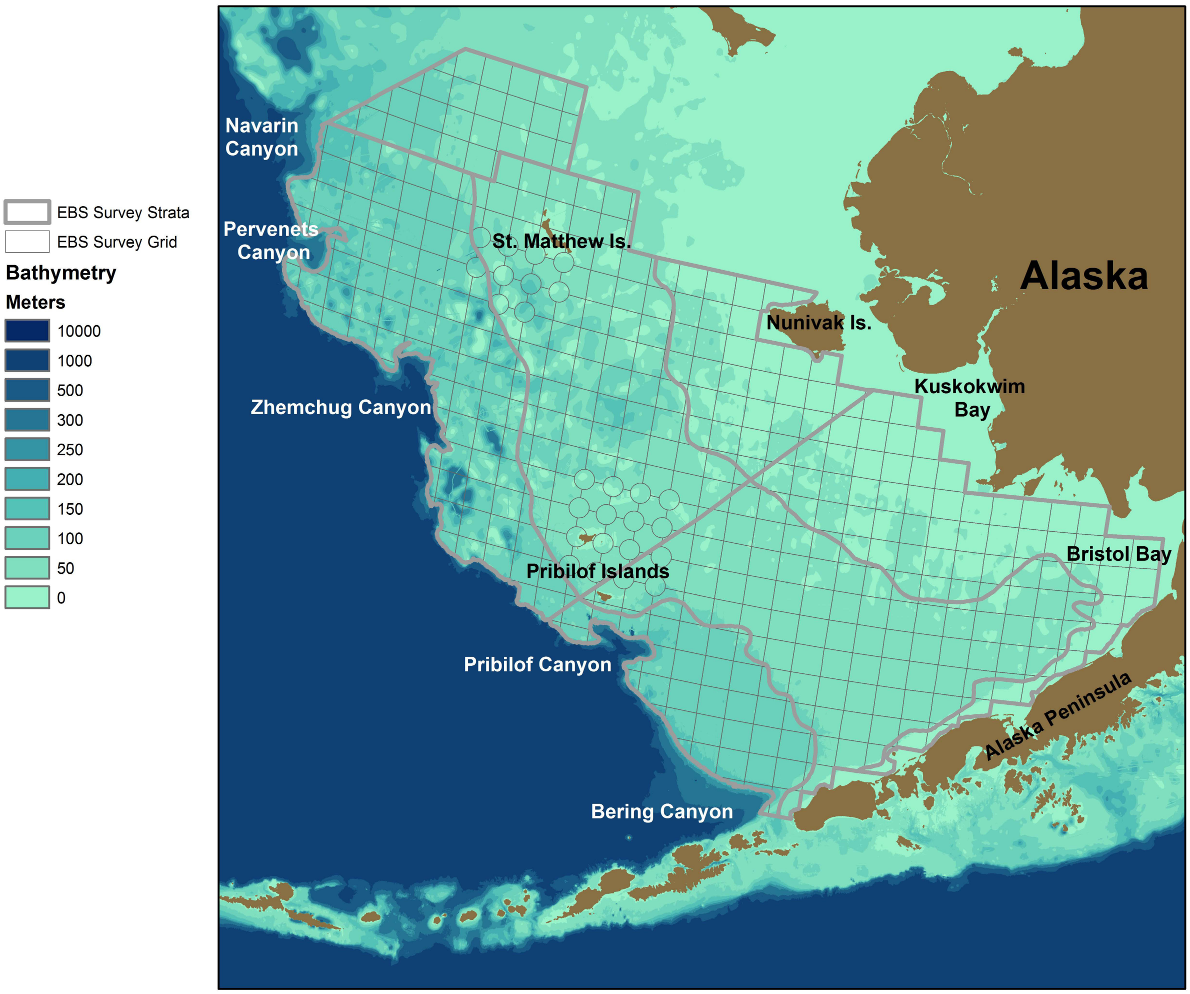


Figure 1. -- Map of the eastern Bering Sea (EBS) shelf with bathymetry from 0 m and 10,000 m, EBS shelf bottom trawl survey strata, EBS shelf bottom trawl survey station grid cells, and relevant features.

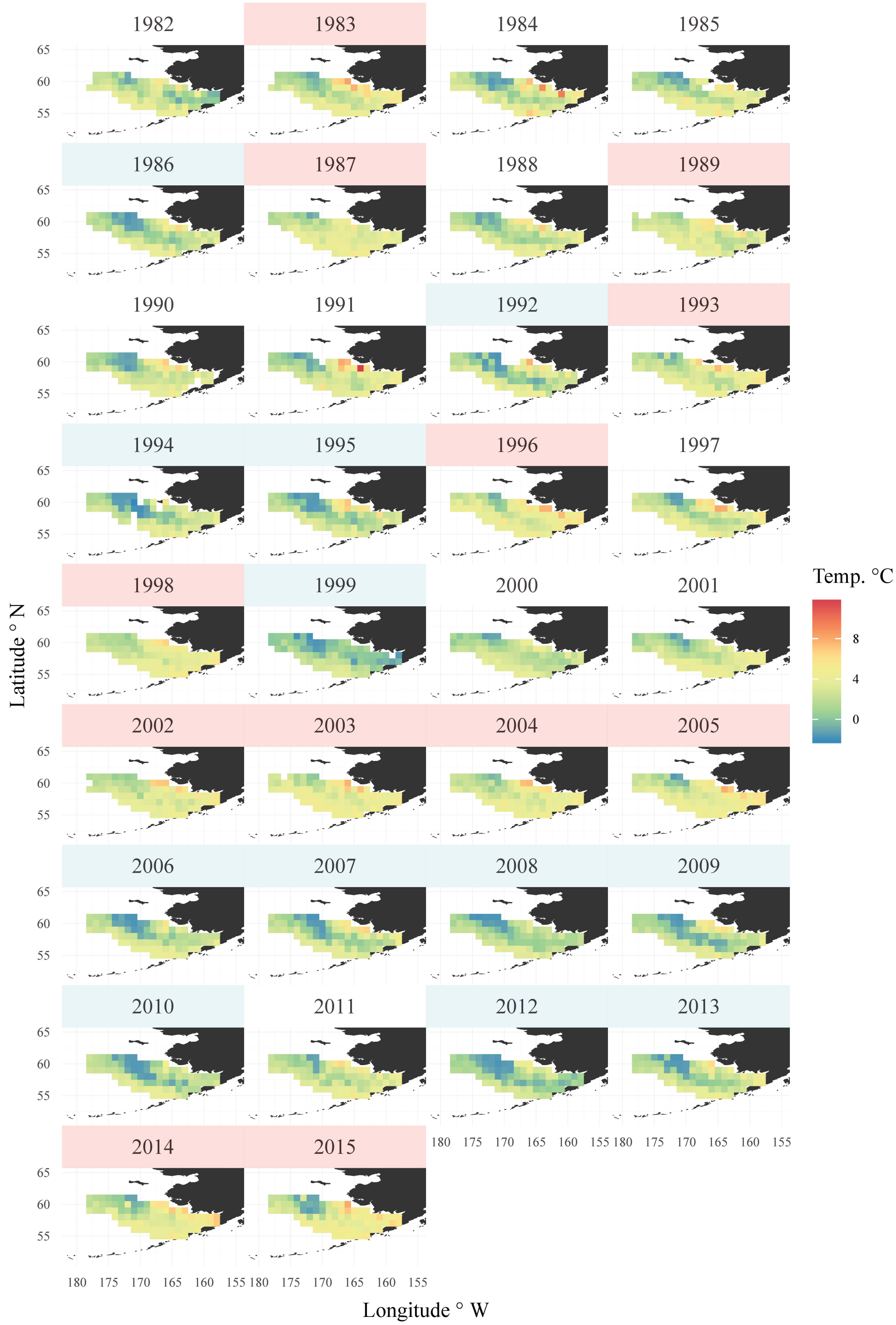


Figure 2. -- Maps of bottom temperatures (°C) measured at eastern Bering Sea (EBS) shelf bottom trawl survey stations by year. Colored red for warmer and blue for colder than average shelf-wide bottom temperatures.

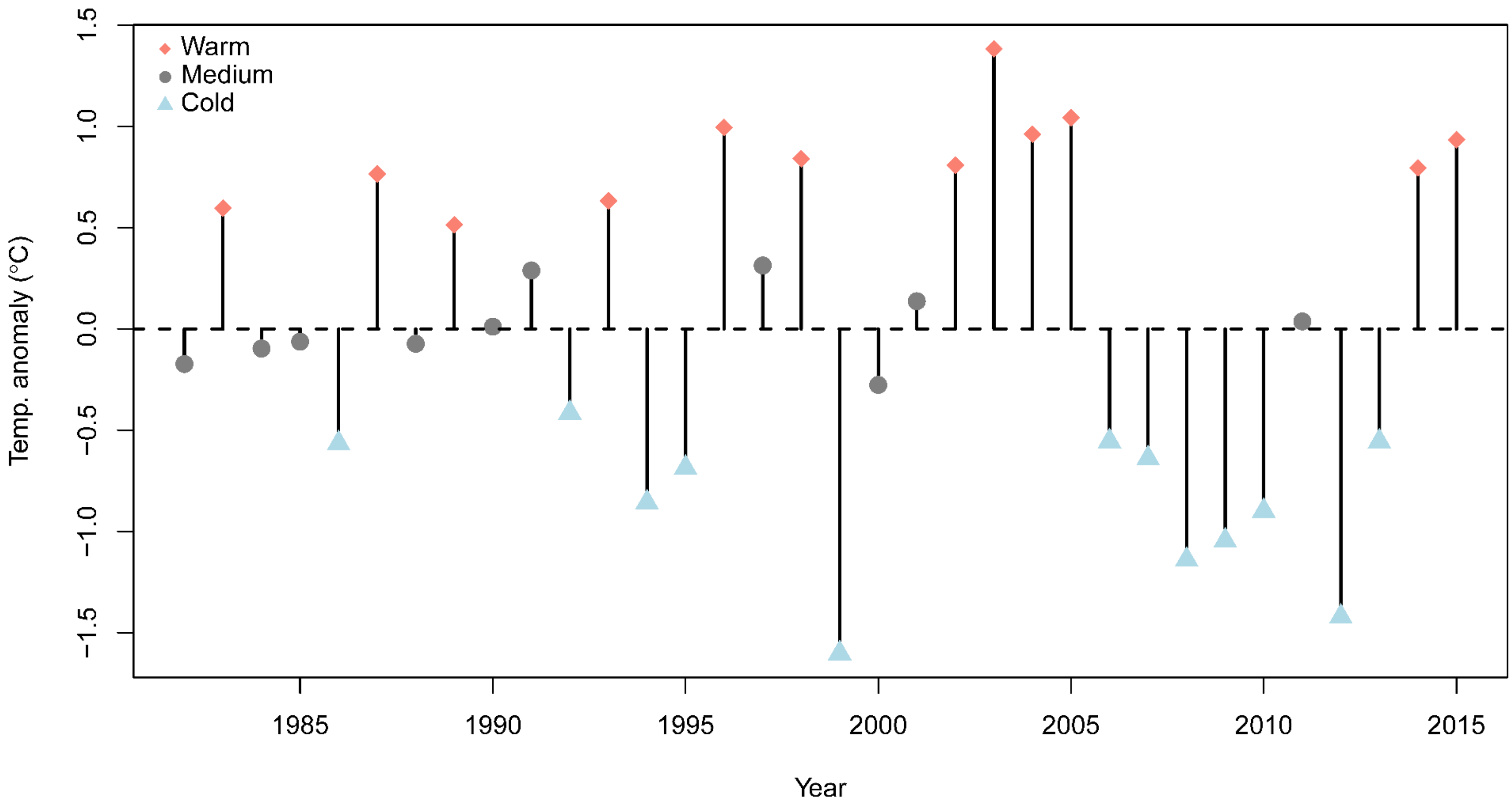


Figure 3. -- Eastern Bering Sea shelf survey bottom temperature anomalies from the 1982-2015 mean as calculated by Spencer (2008)

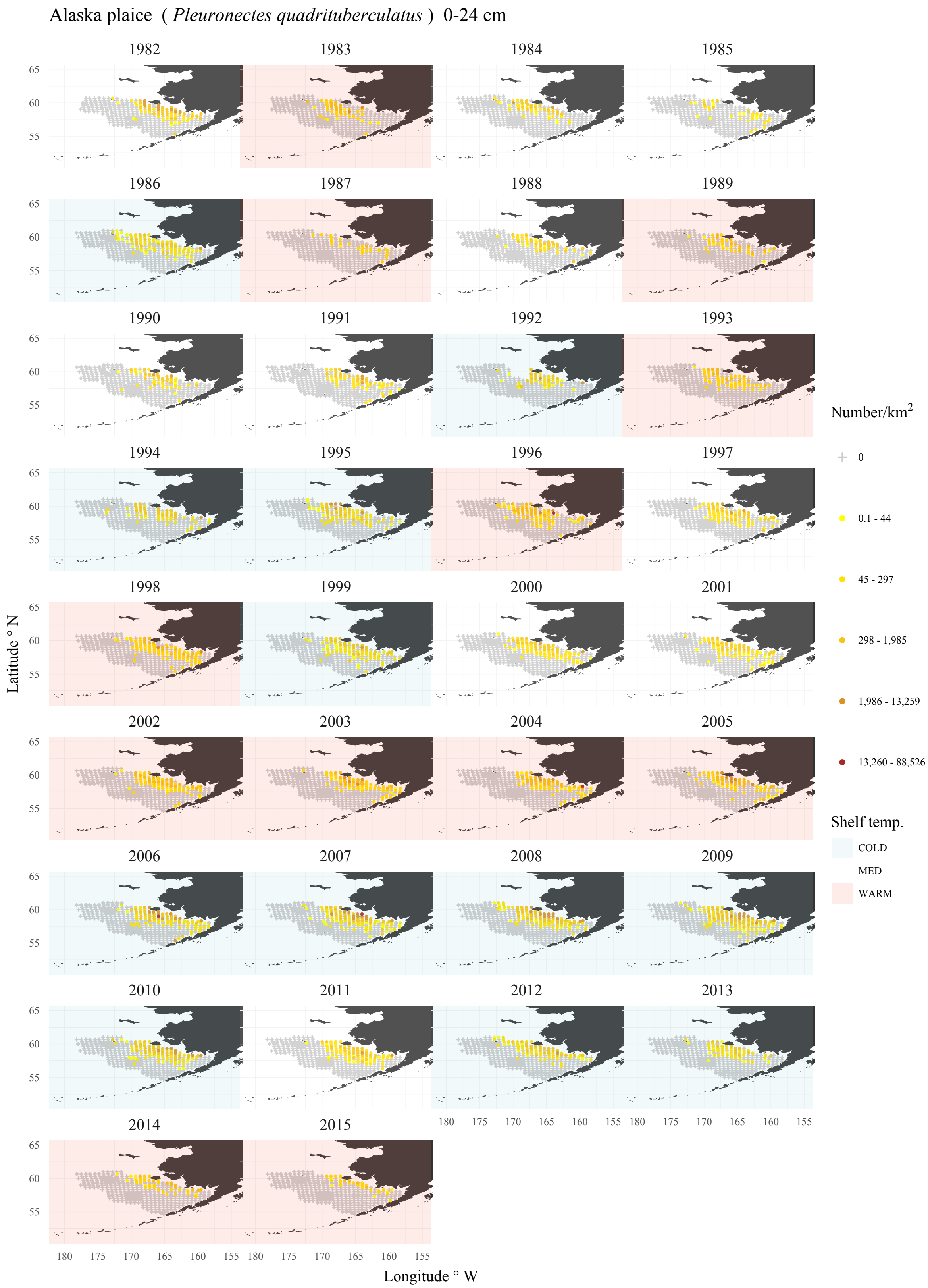


Figure 4 . -- The Alaska plaice (*Pleuronectes quadrituberculatus*) CPUE by number weighted mean location for each length category for all years.

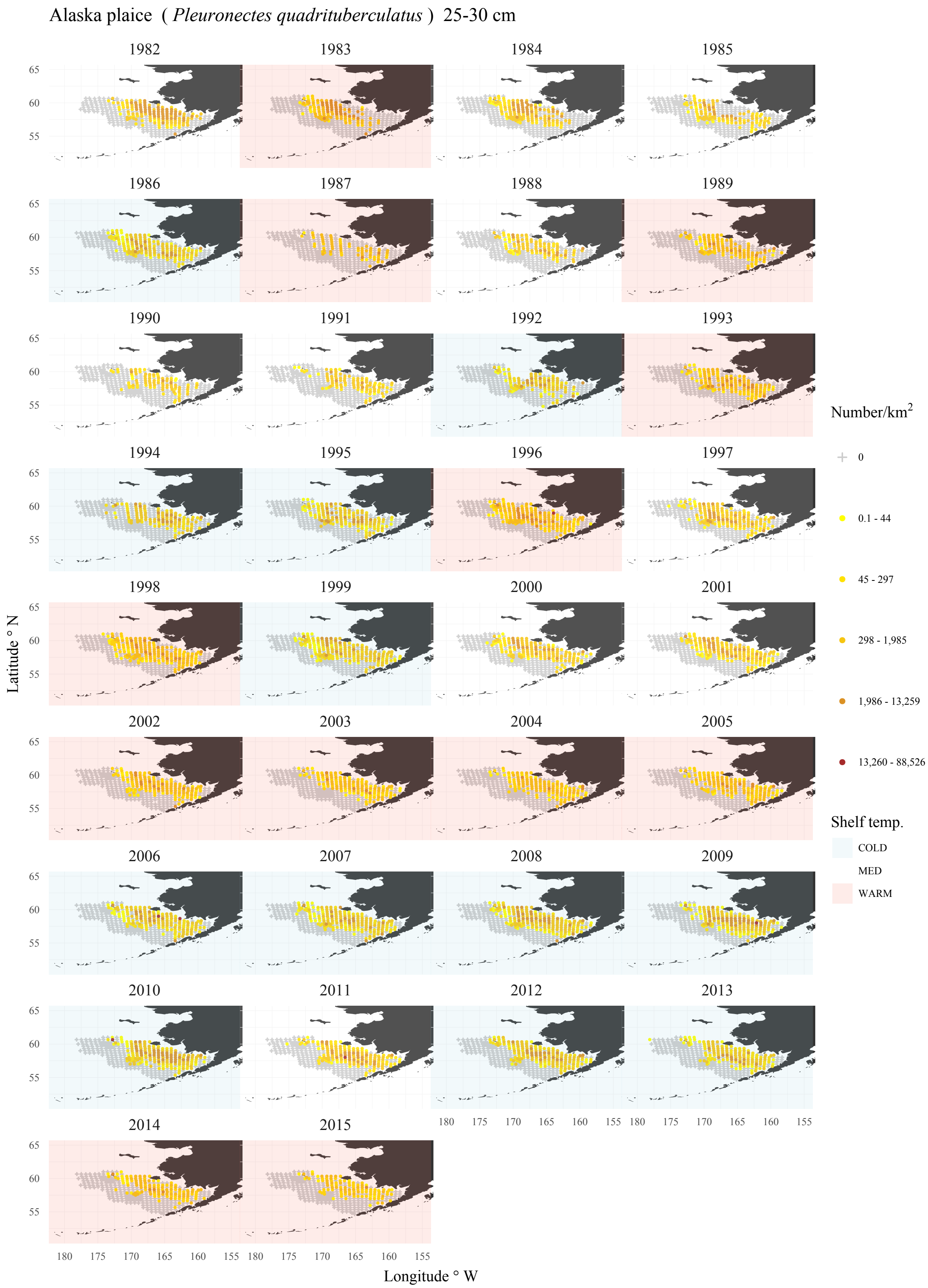


Figure 4 . -- Continued.

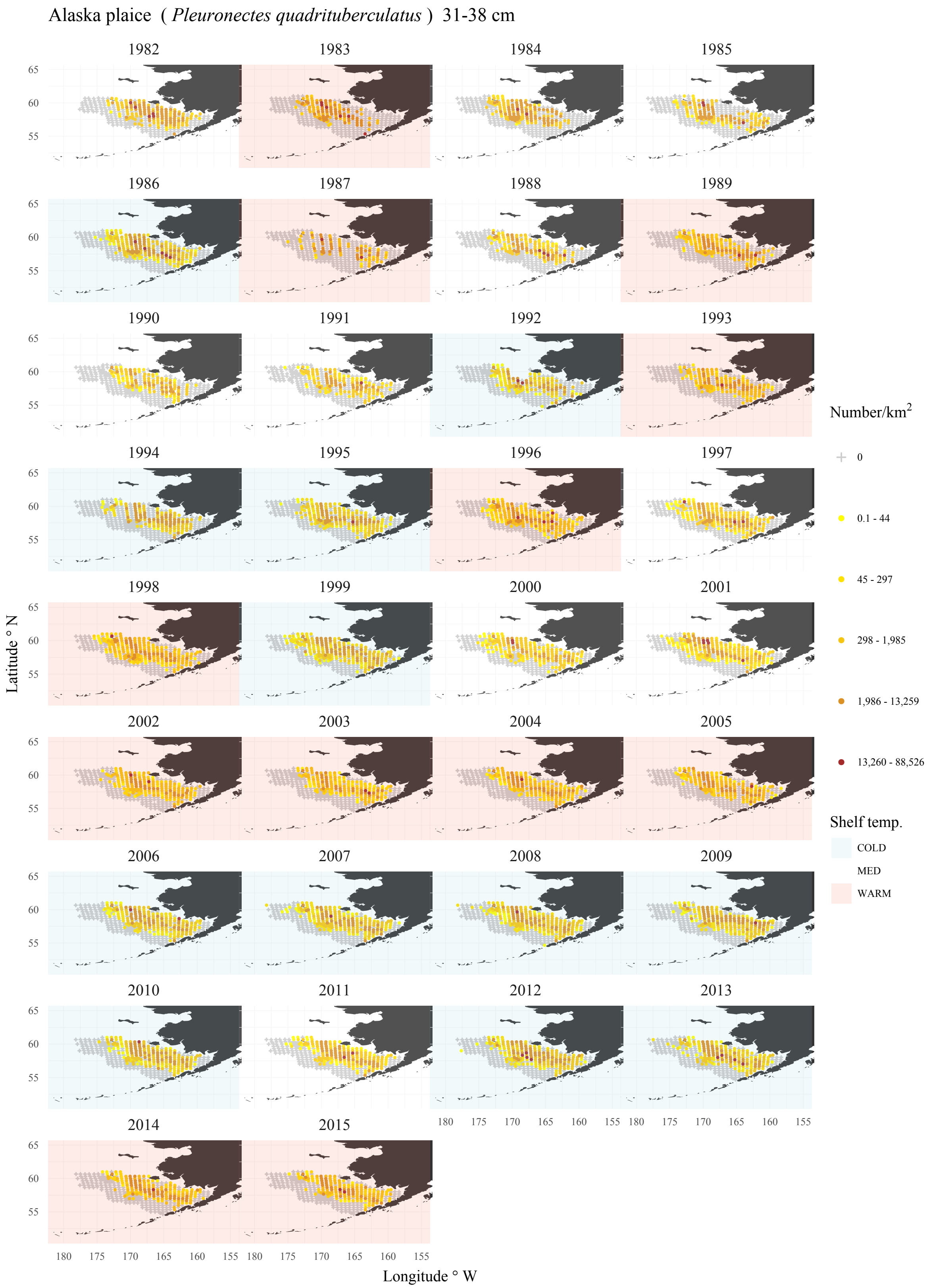


Figure 4 . -- Continued.

Alaska plaice (*Pleuronectes quadrituberculatus*) 39-45 cm

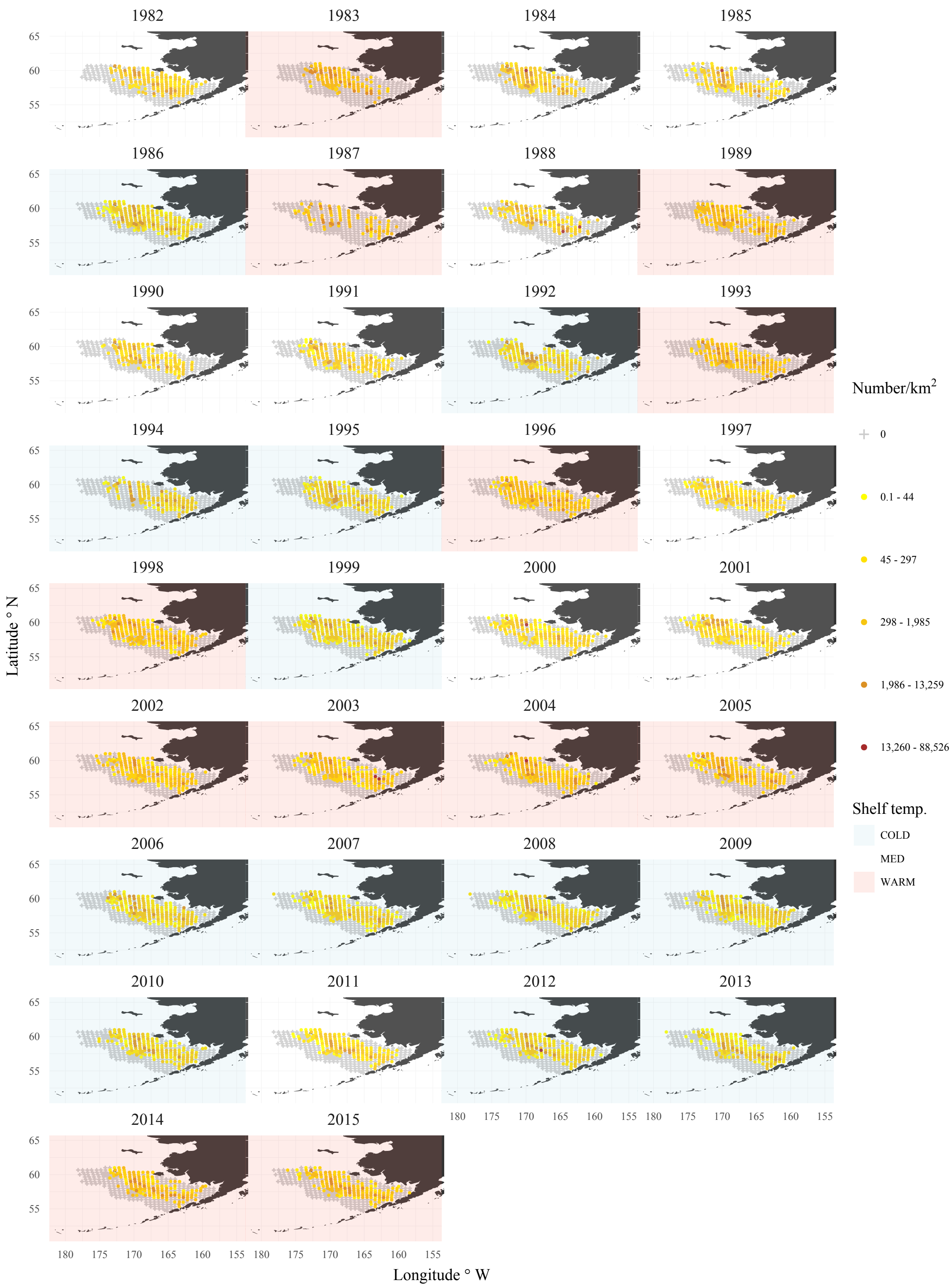


Figure 4 . -- Continued.

Alaska plaice (*Pleuronectes quadrituberculatus*) 46-72 cm

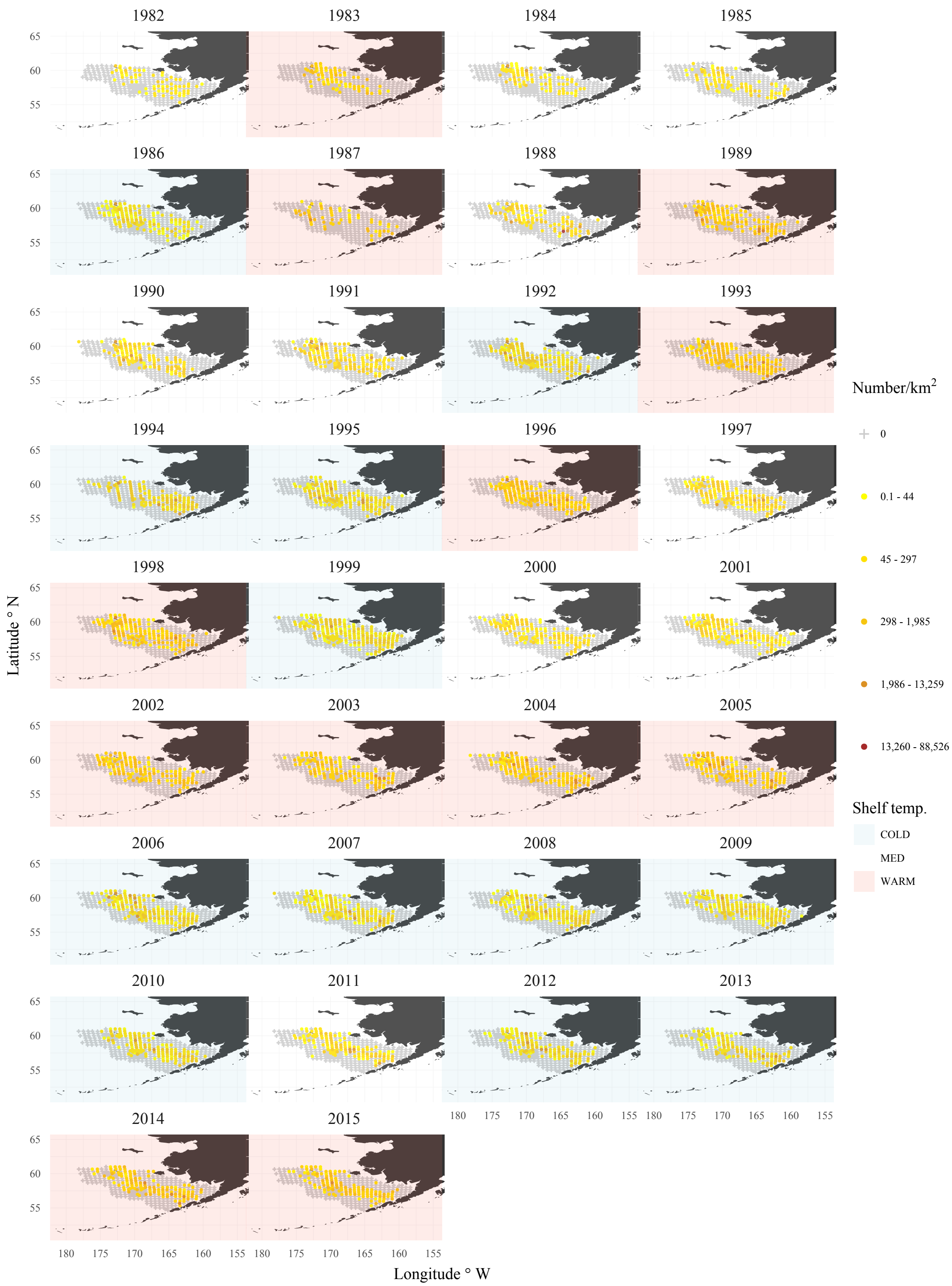


Figure 4 . -- Continued.

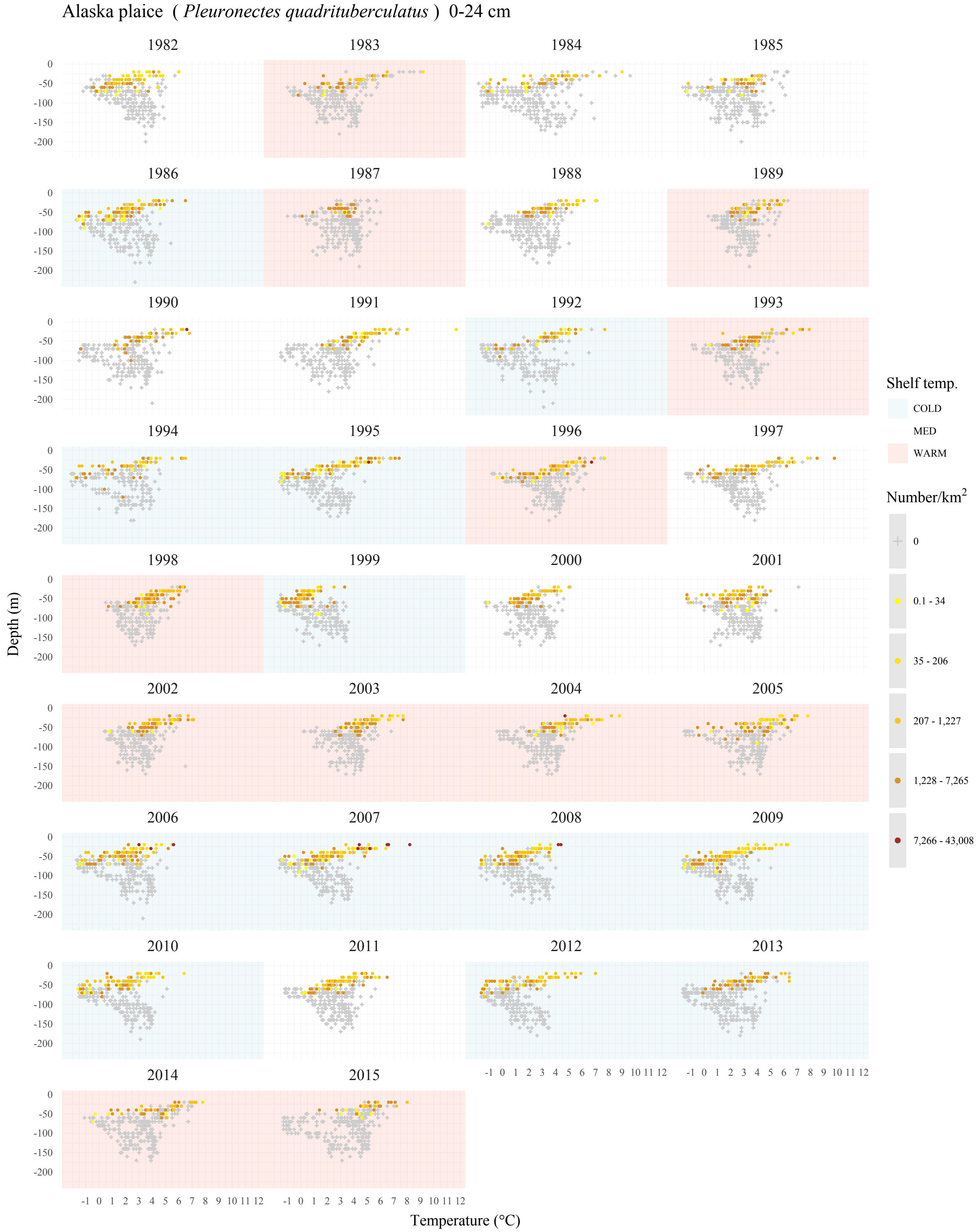
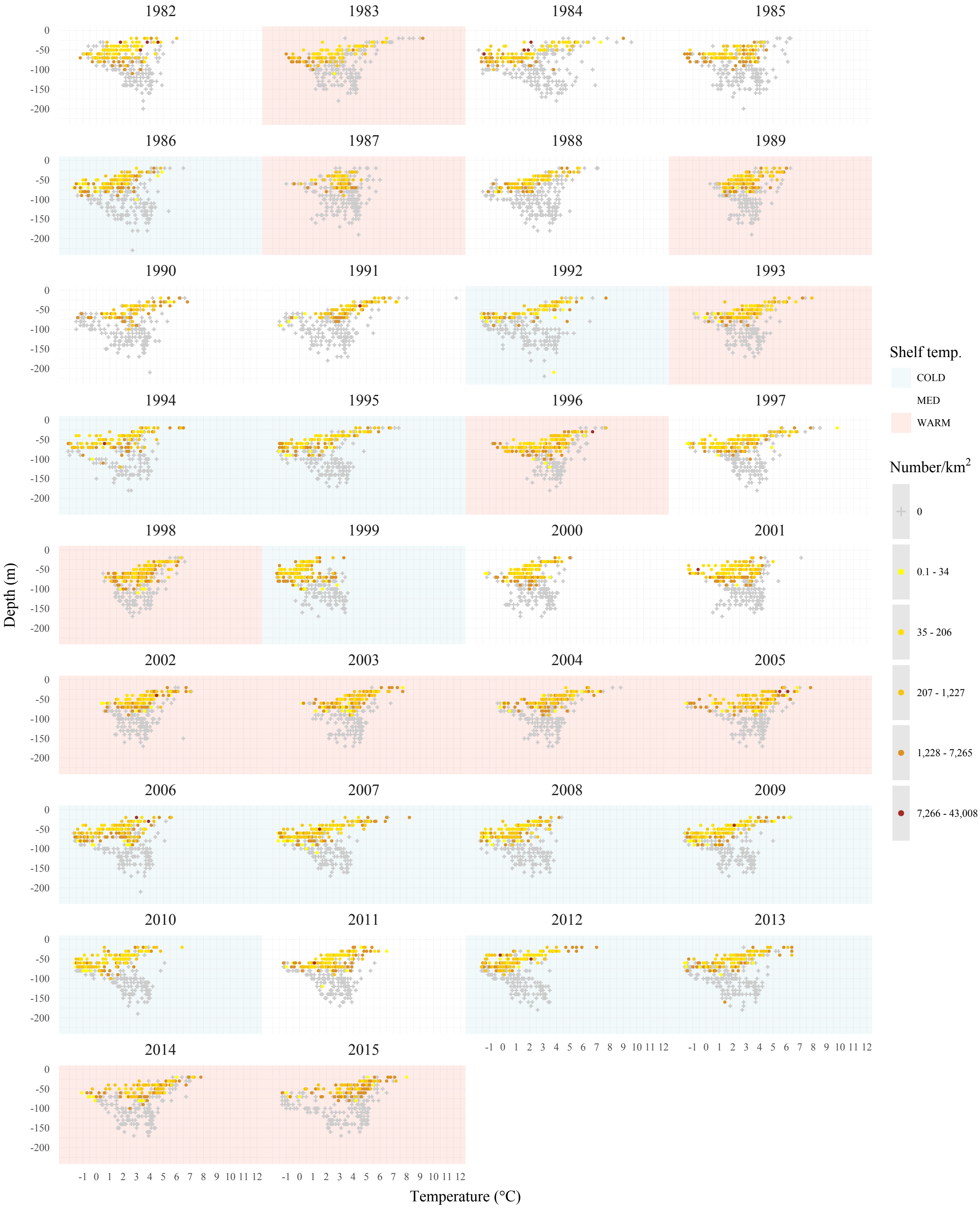


Figure 5 . -- The Alaska plaice (*Pleuronectes quadrituberculatus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

Alaska plaice (*Pleuronectes quadrituberculatus*) 25-30 cm



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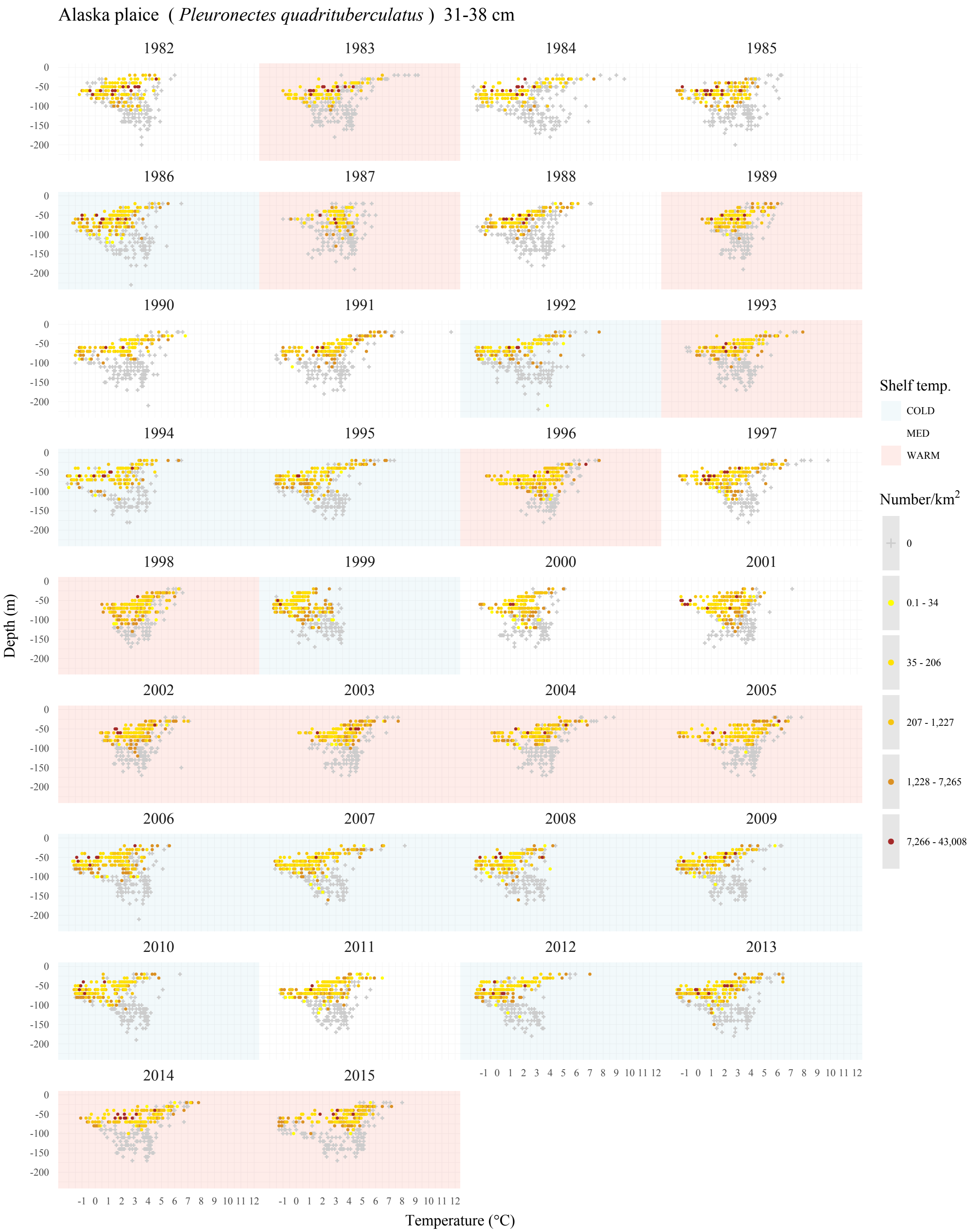

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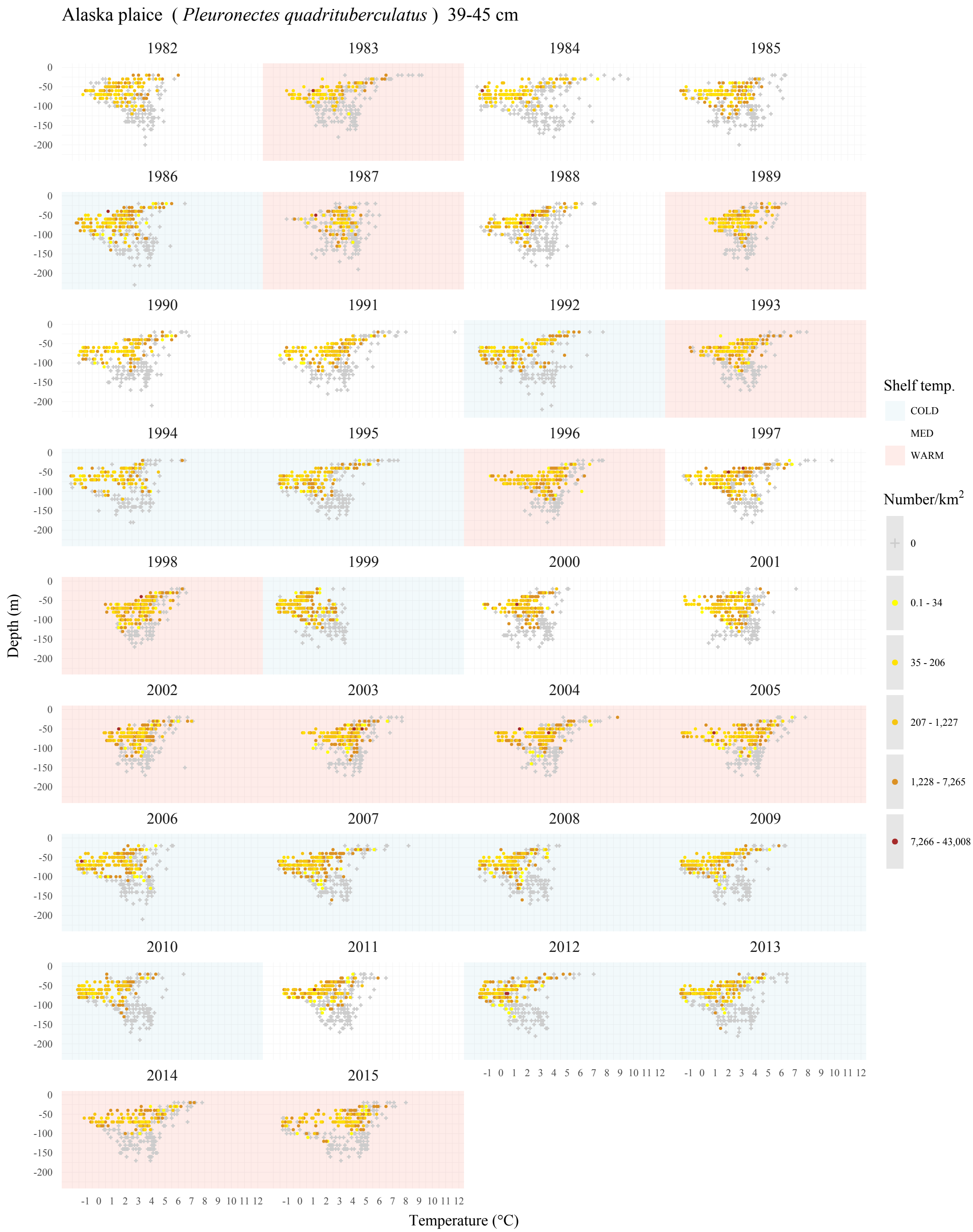

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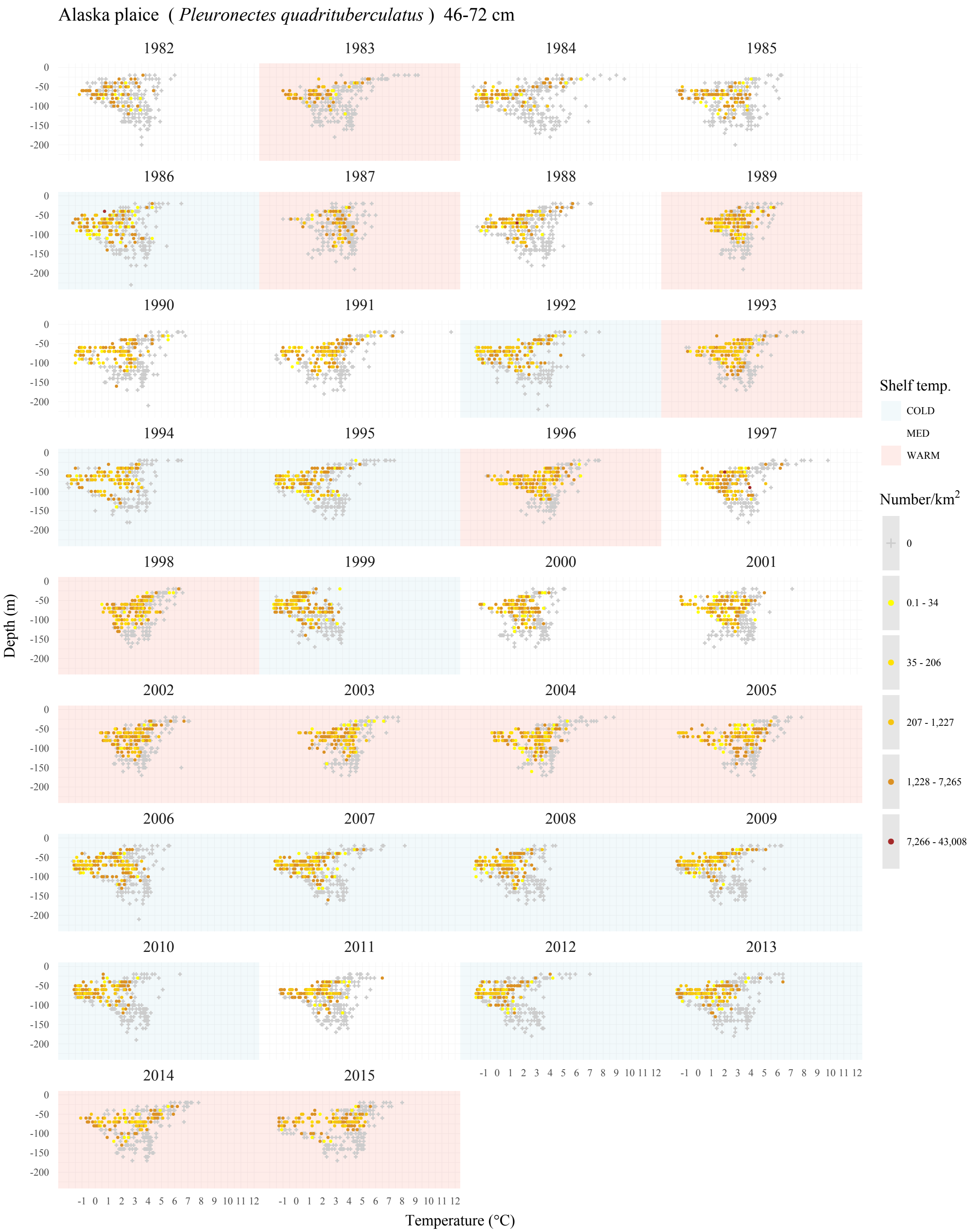


Figure 5 . -- Continued.

Figure 6 . -- The Alaska plaice (*Pleuronectes quadrituberculatus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

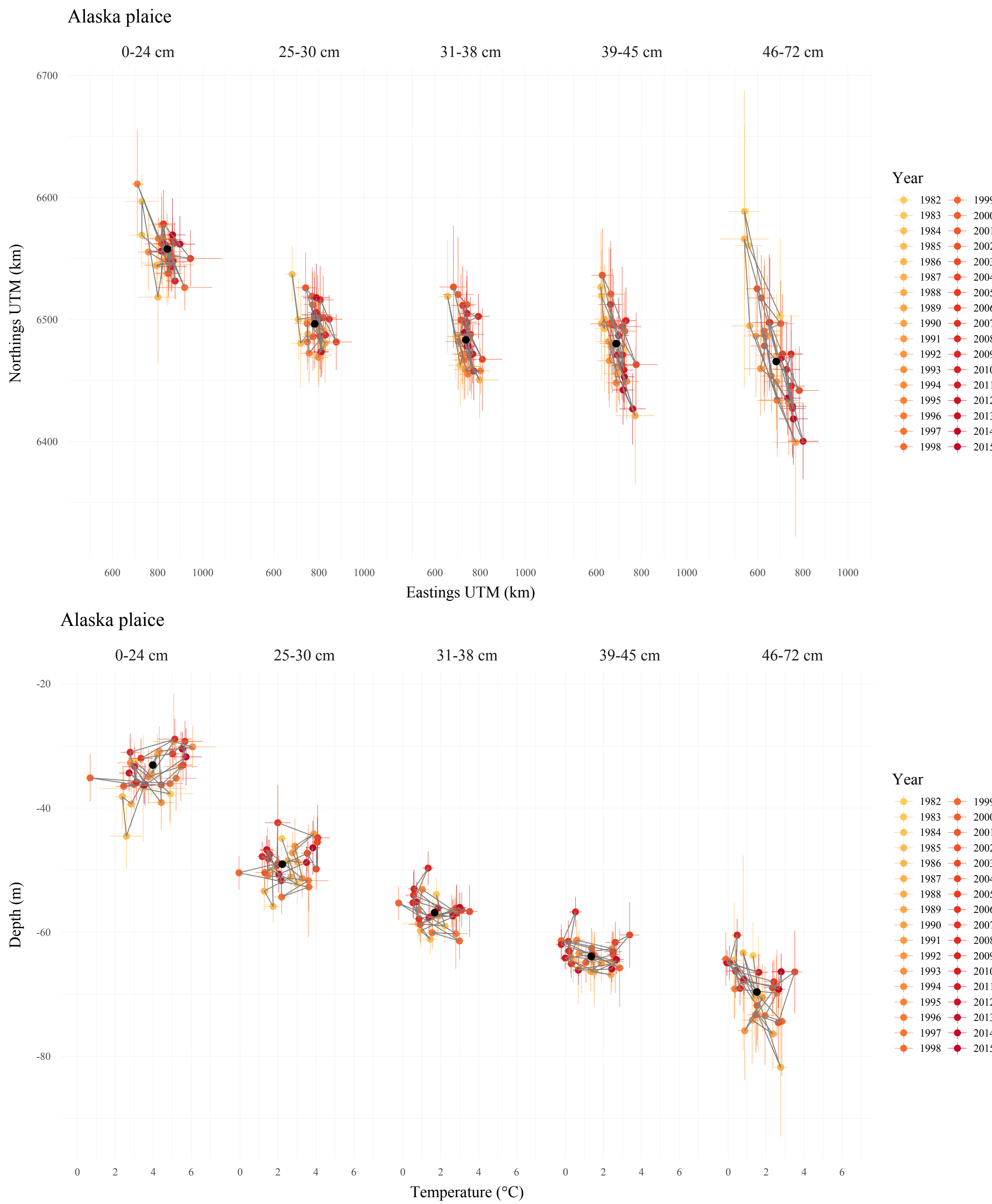


Figure 7 . -- The Alaska plaice (*Pleuronectes quadrituberculatus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

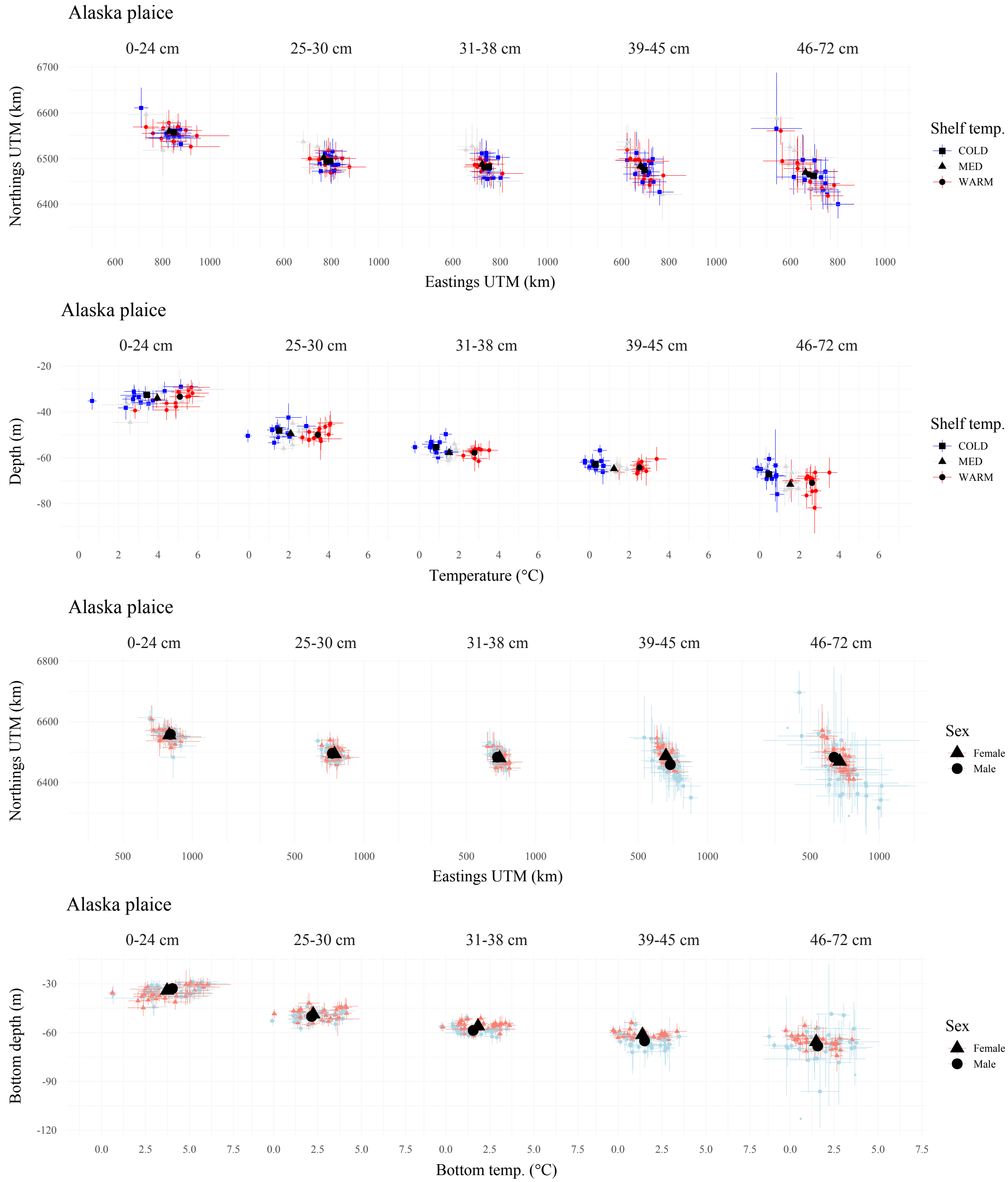


Figure 8 . -- The Alaska plaice (*Pleuronectes quadrituberculatus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

Alaska skate (*Bathyraja parmifera*) 0-37 cm

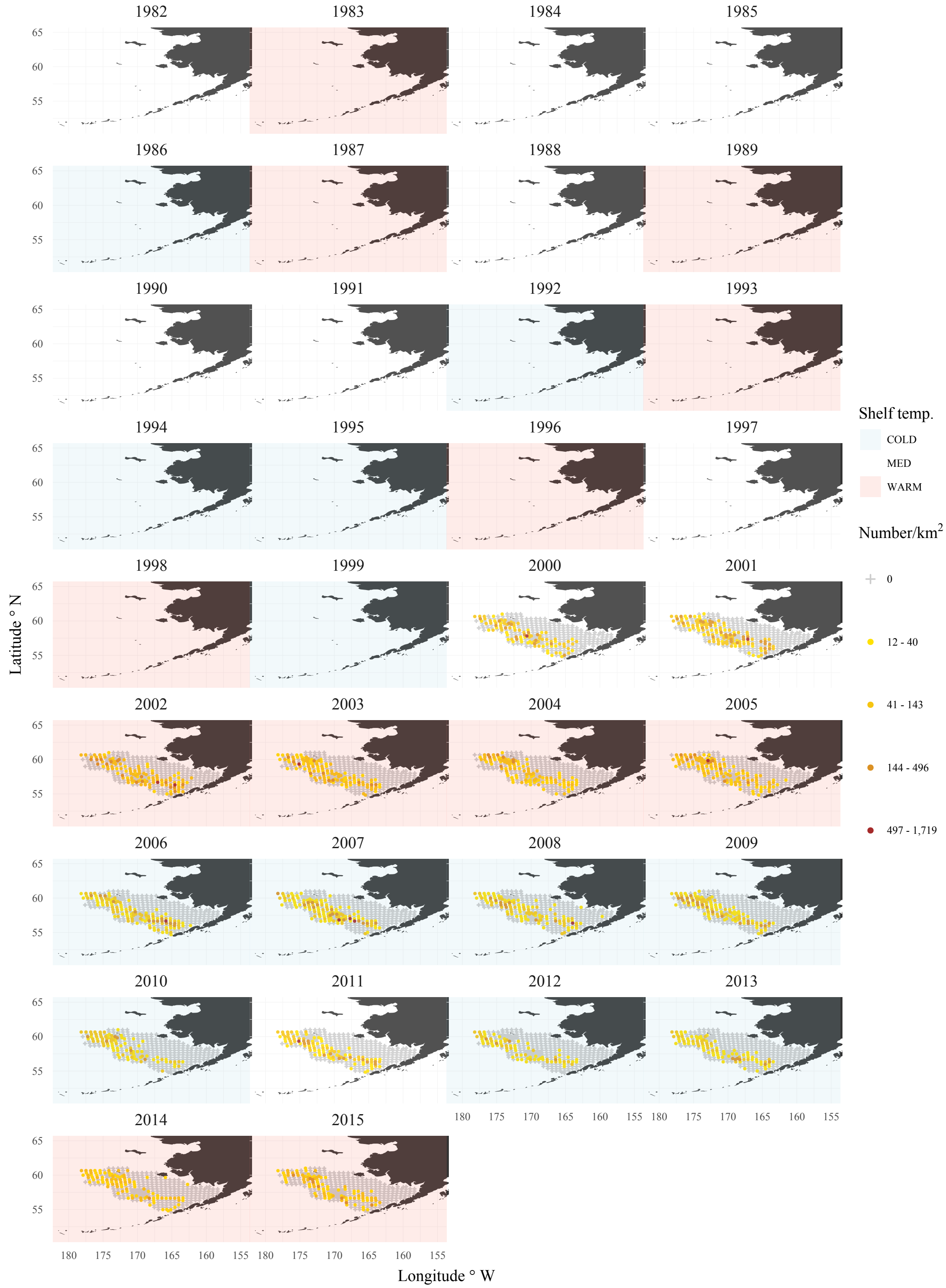
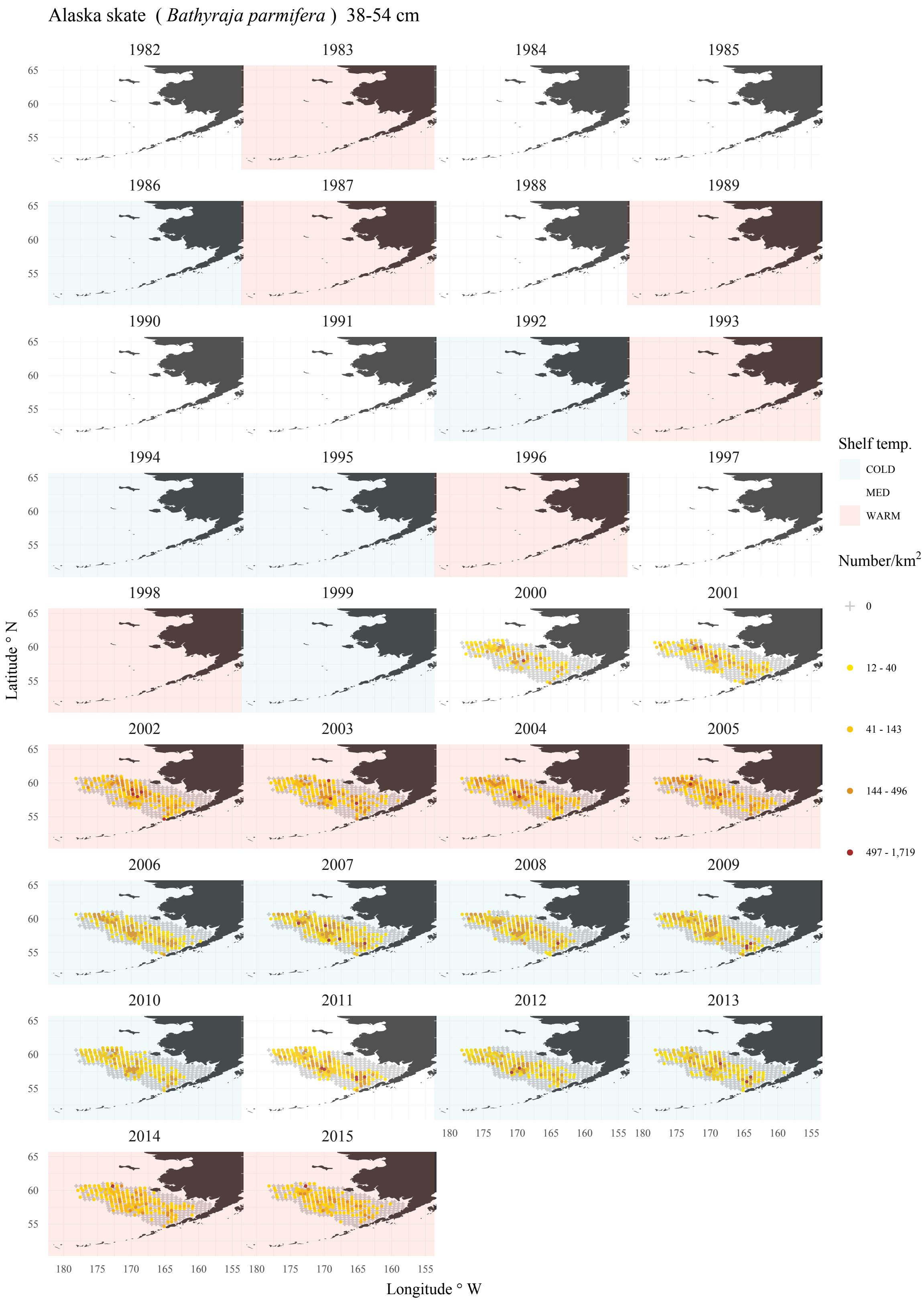


Figure 9 . -- The Alaska skate (*Bathyraja parmifera*) CPUE by number weighted mean location for each length category for all years.



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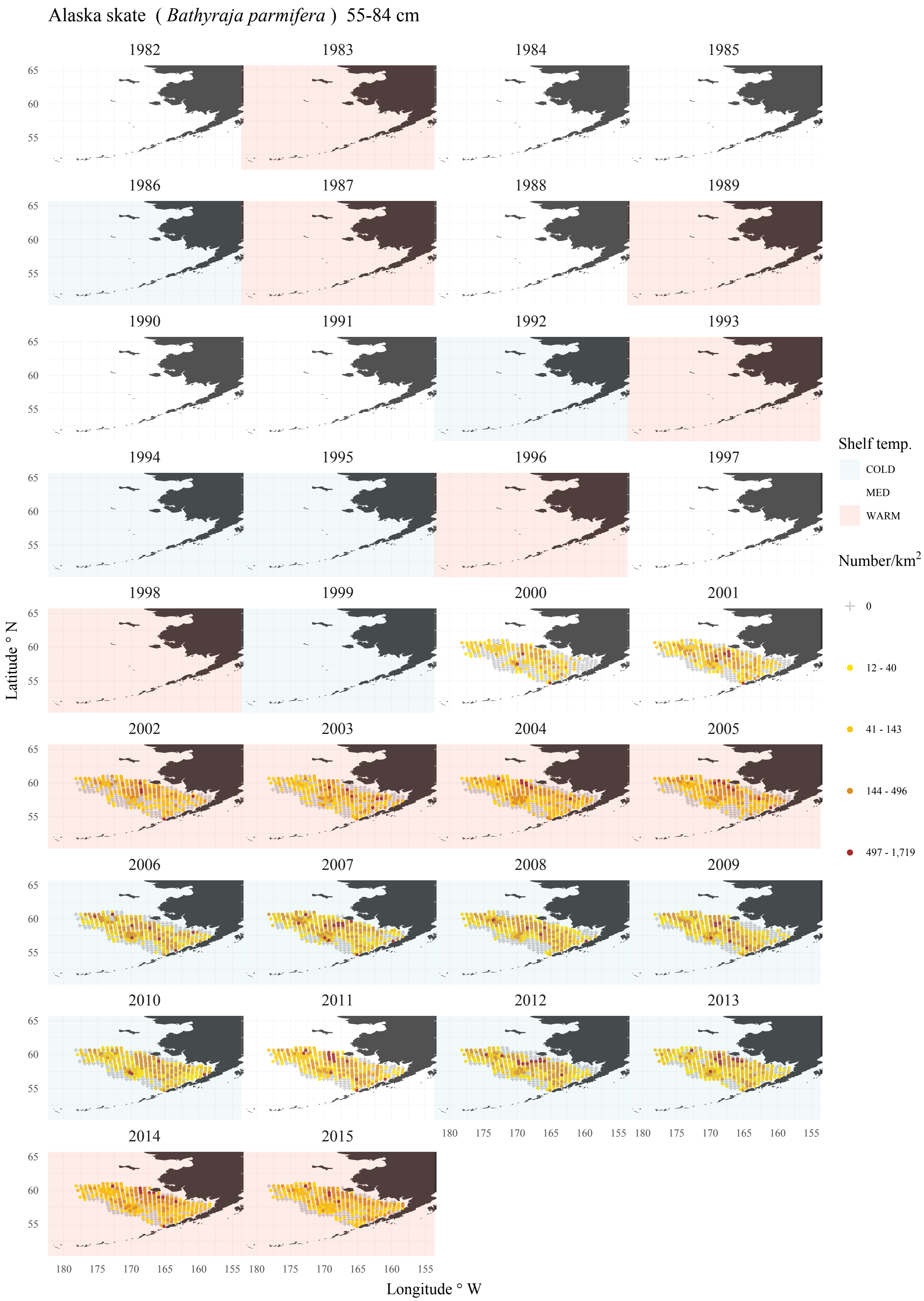

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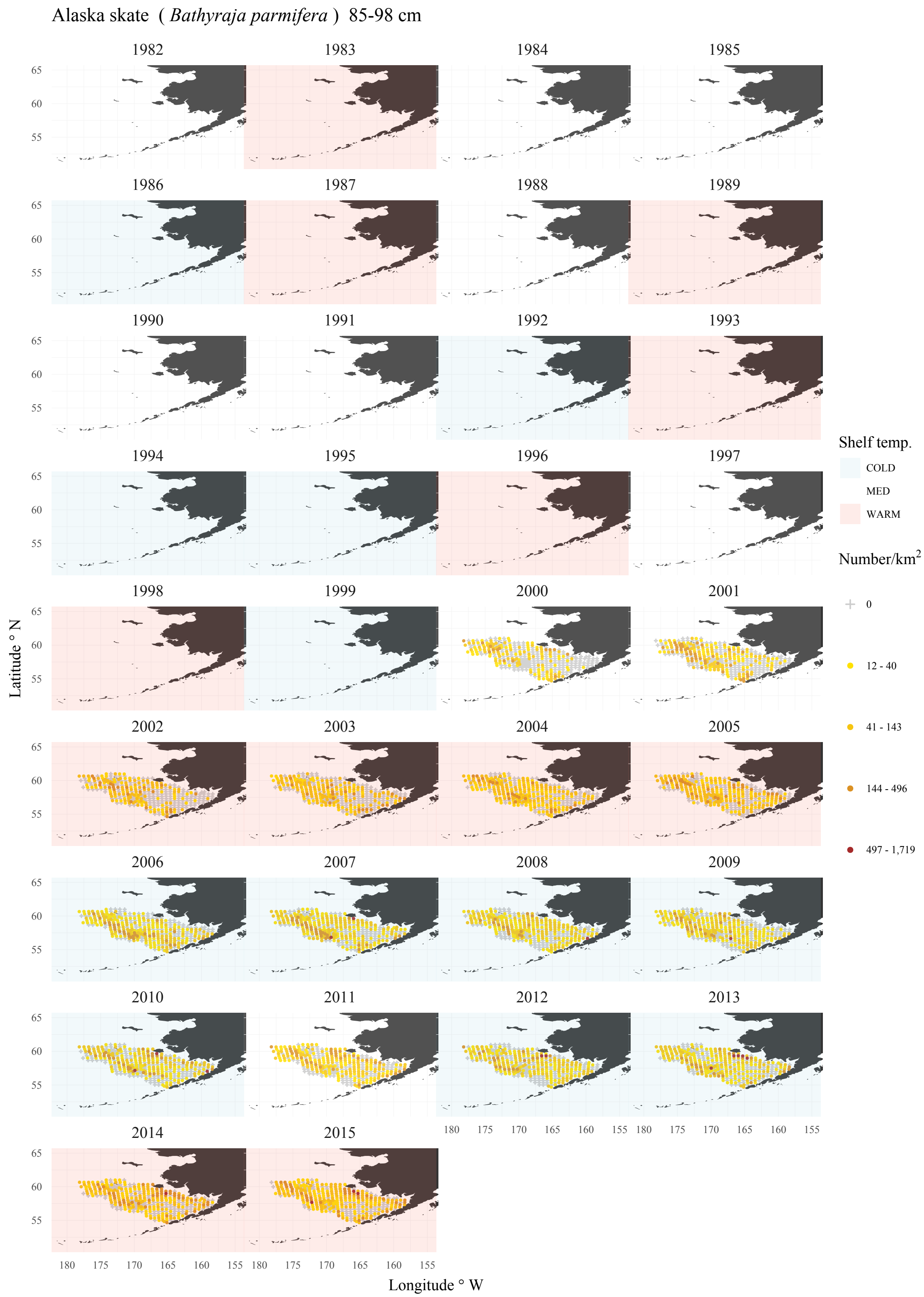

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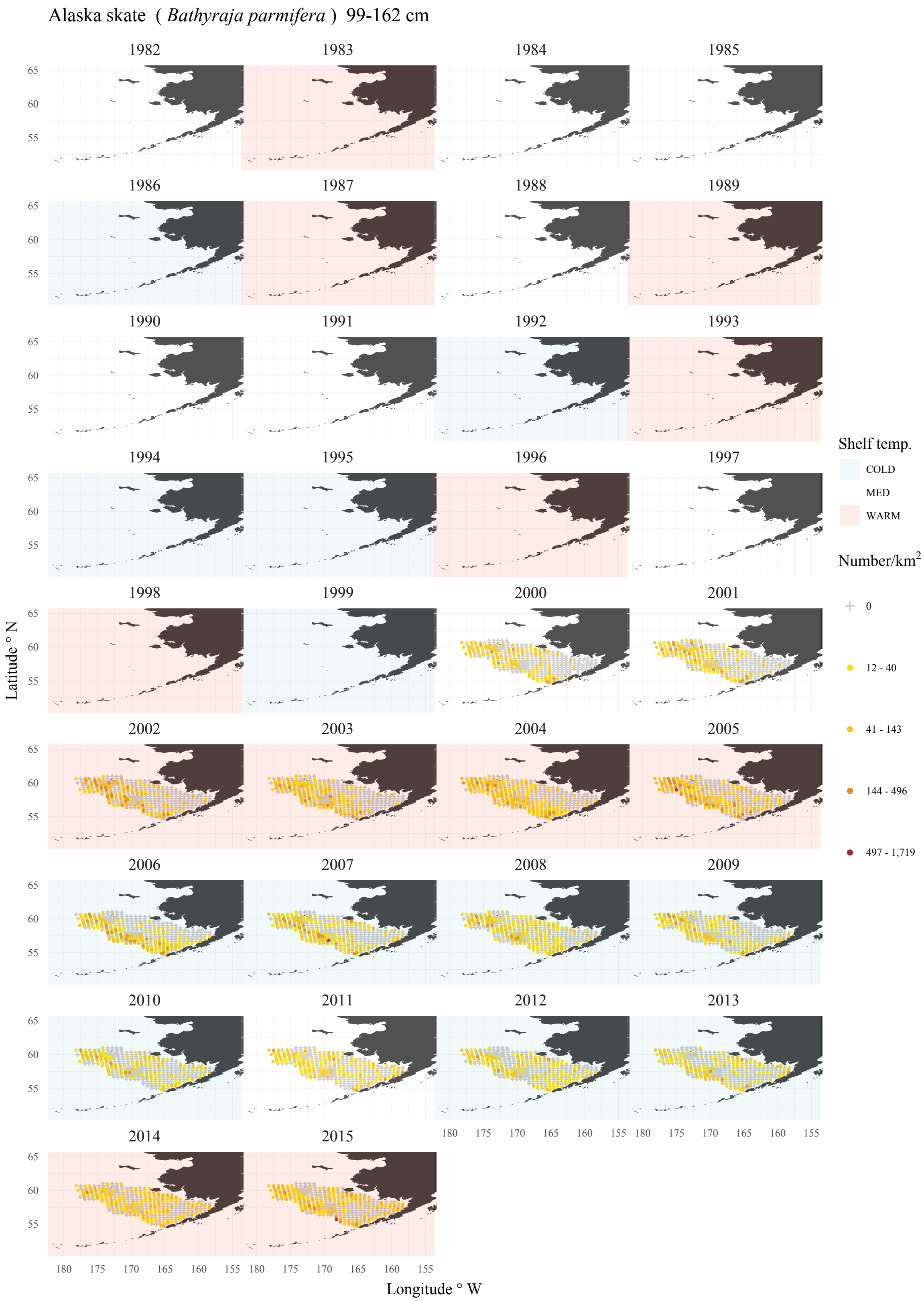

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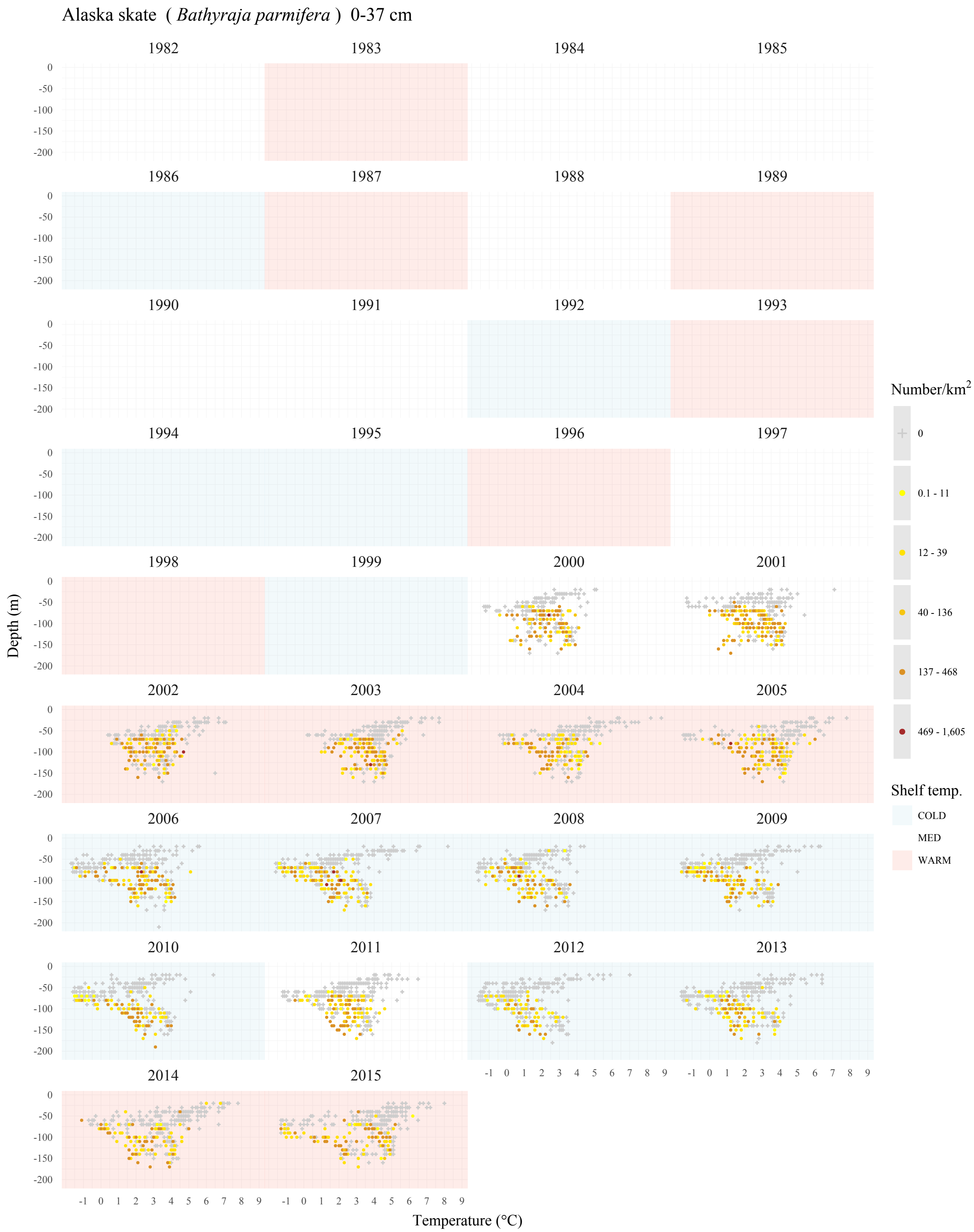
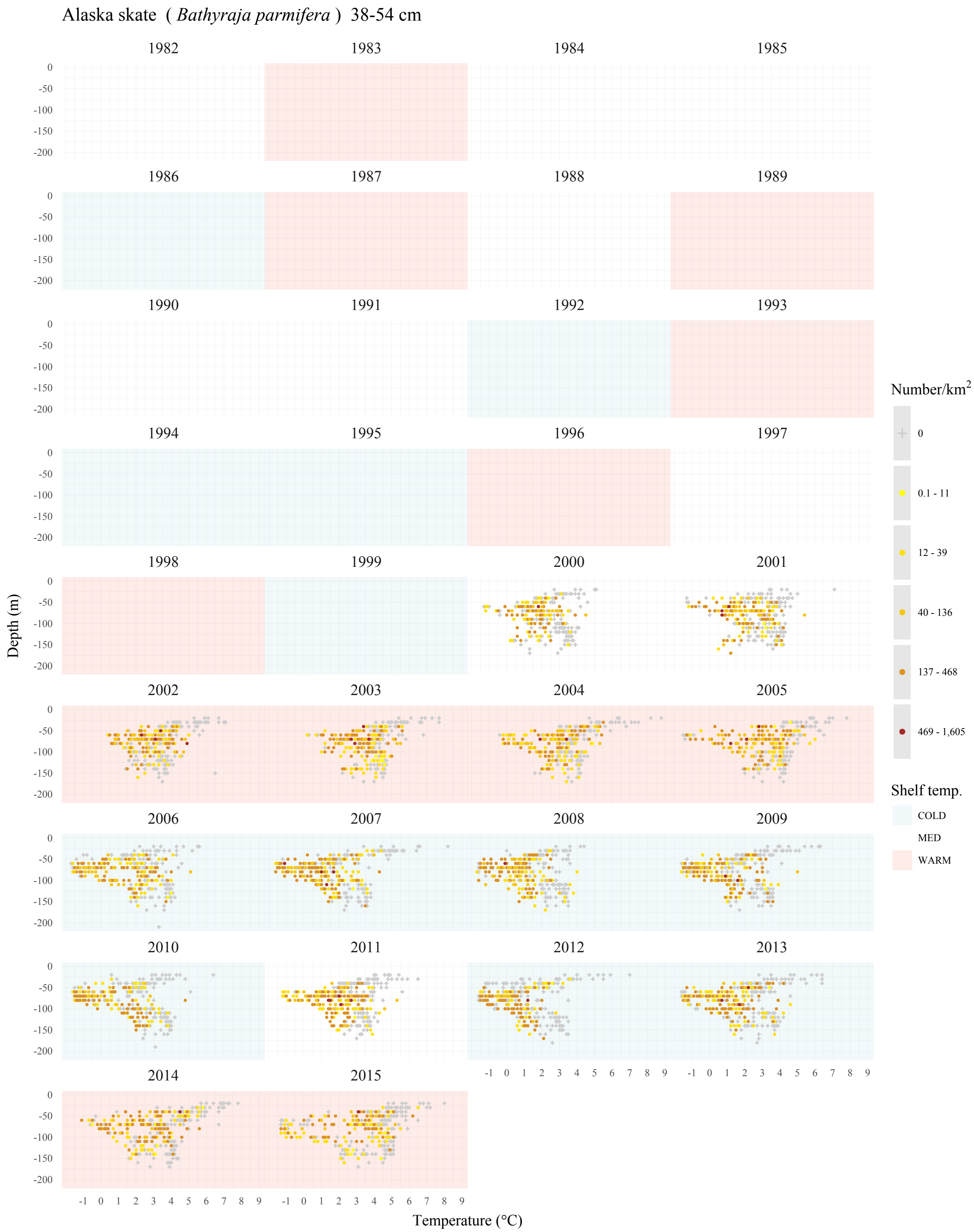


Figure 10 . -- The Alaska skate (*Bathyraja parmifera*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.



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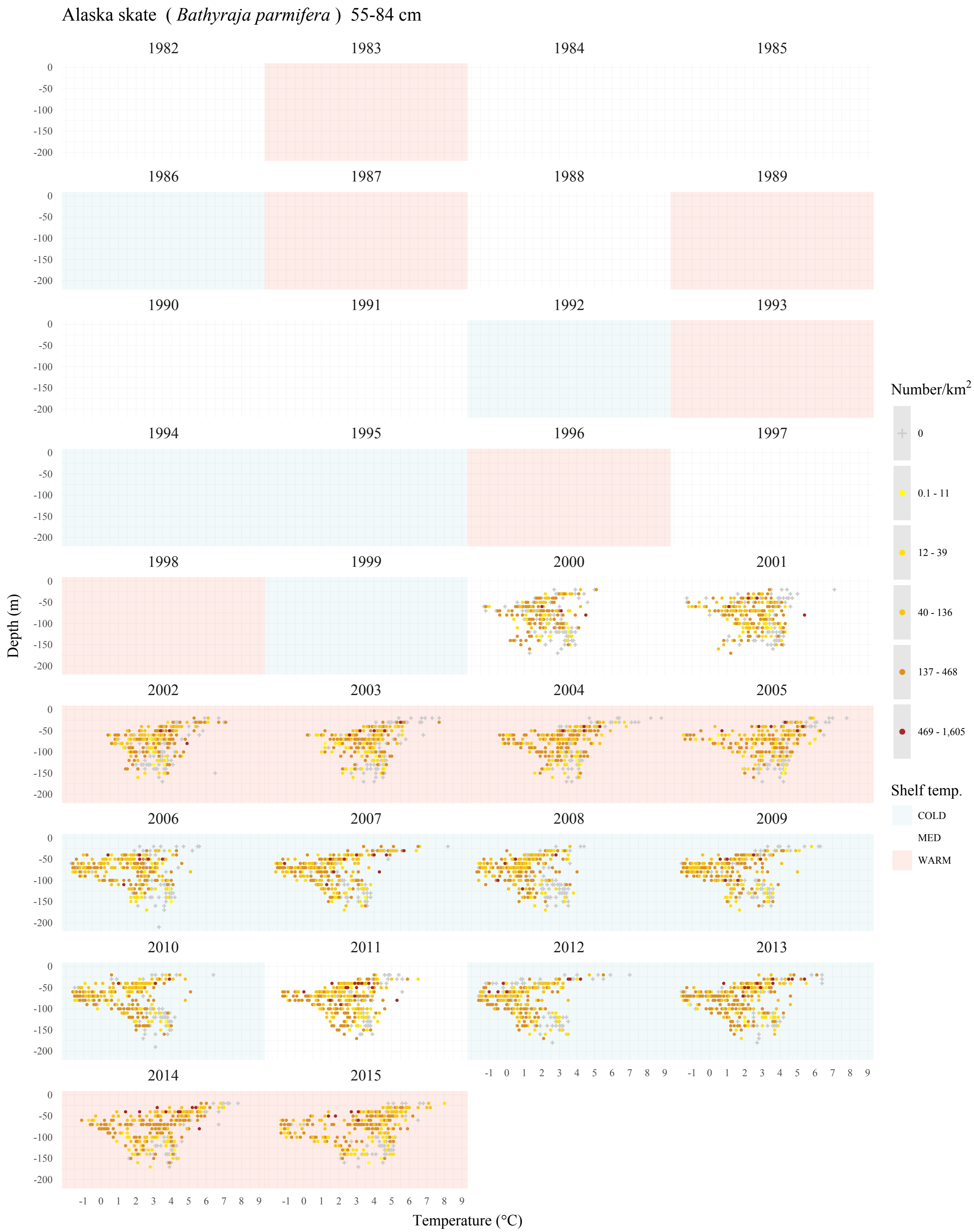

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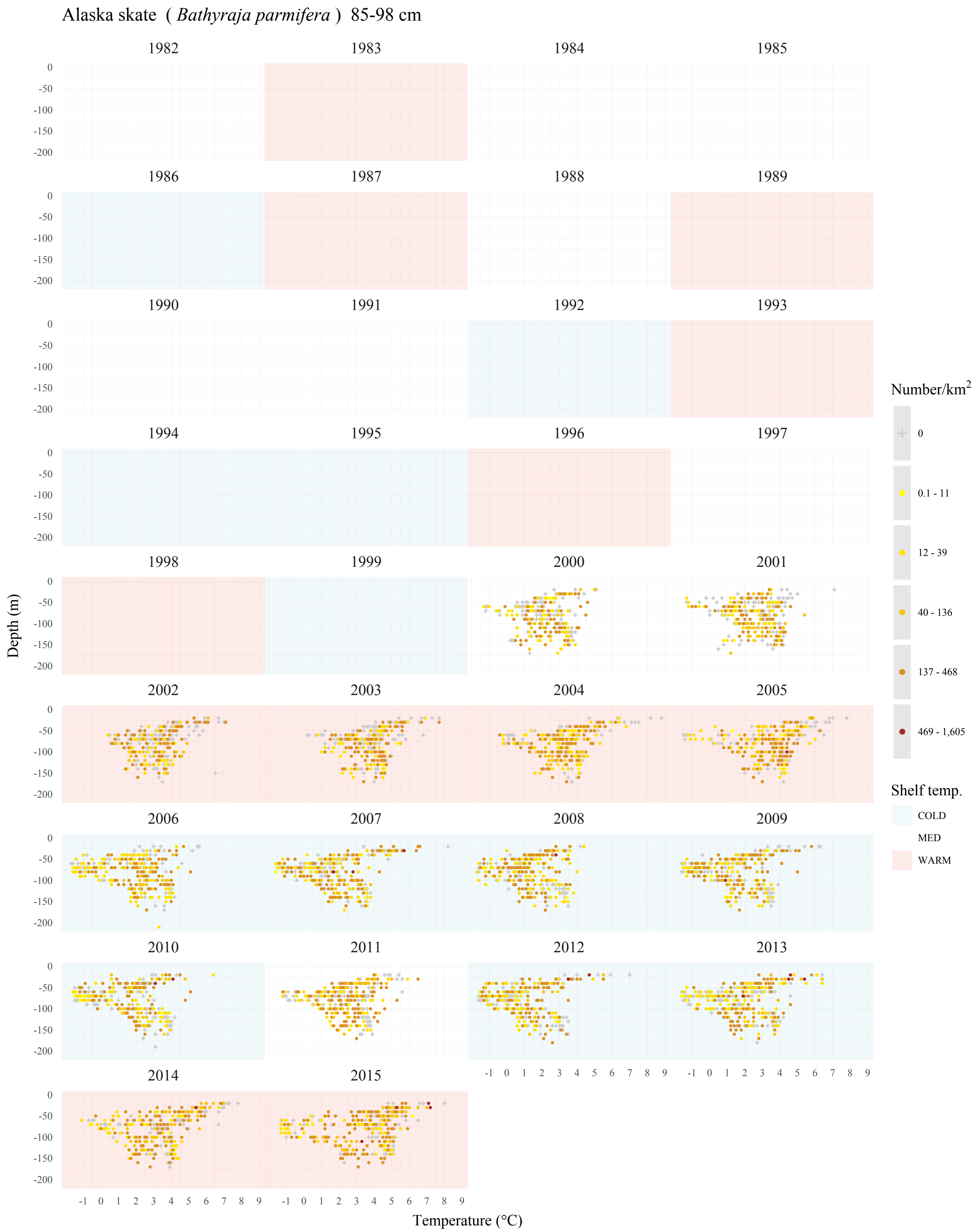

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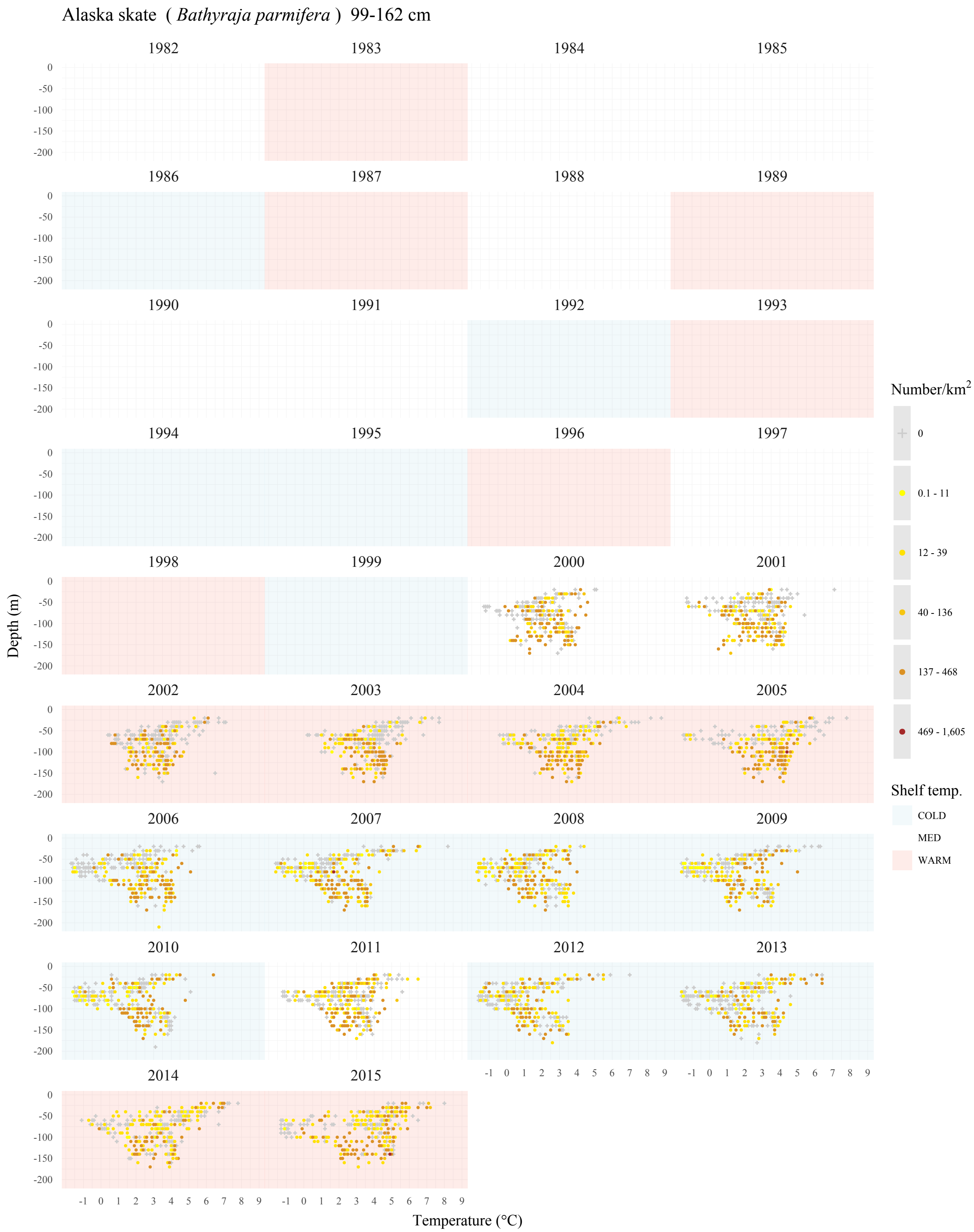


Figure 10 . -- Continued.

Figure 11 . -- The Alaska skate (*Bathyraja parmifera*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

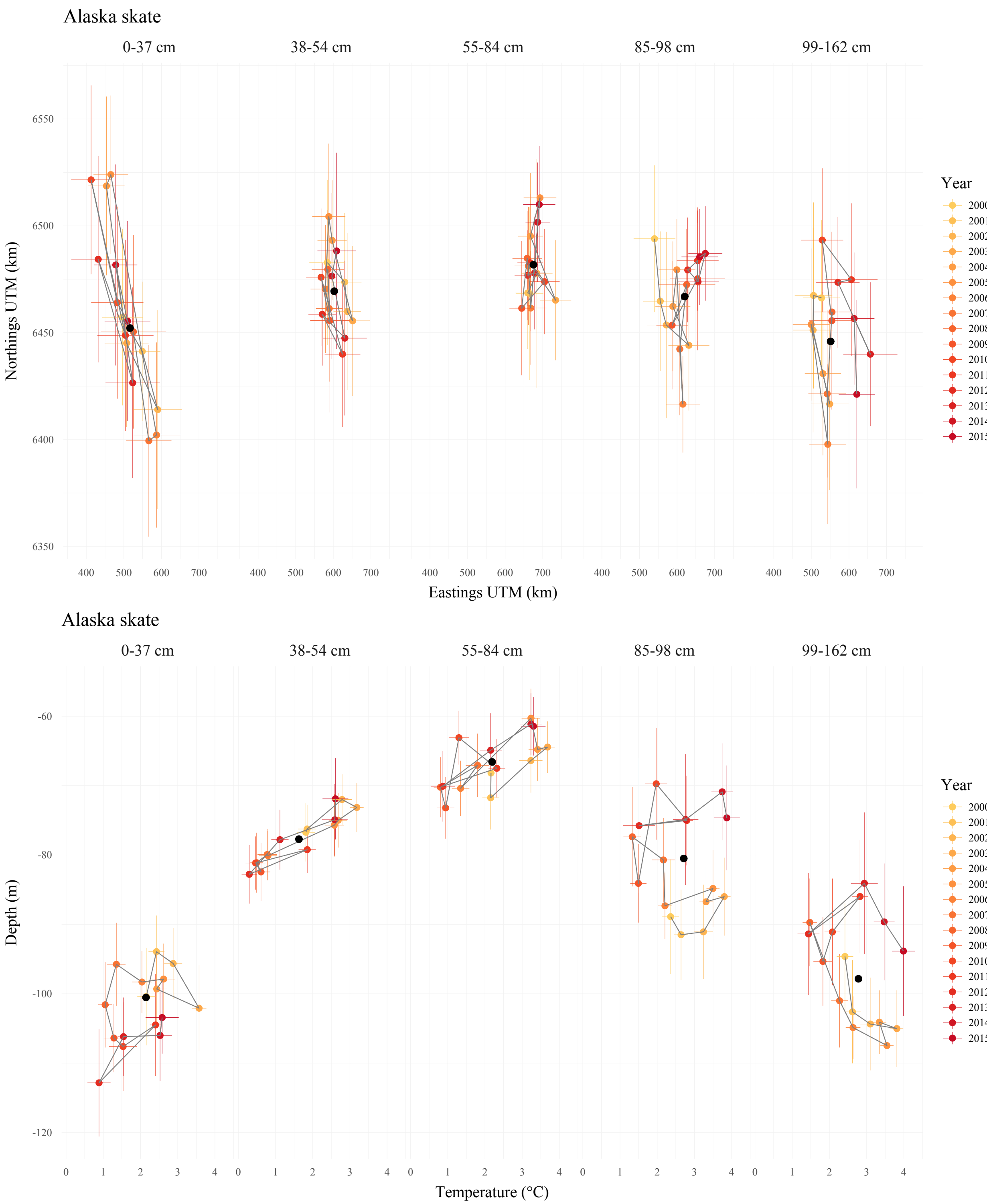


Figure 12 . -- The Alaska skate (*Bathyraja parmifera*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

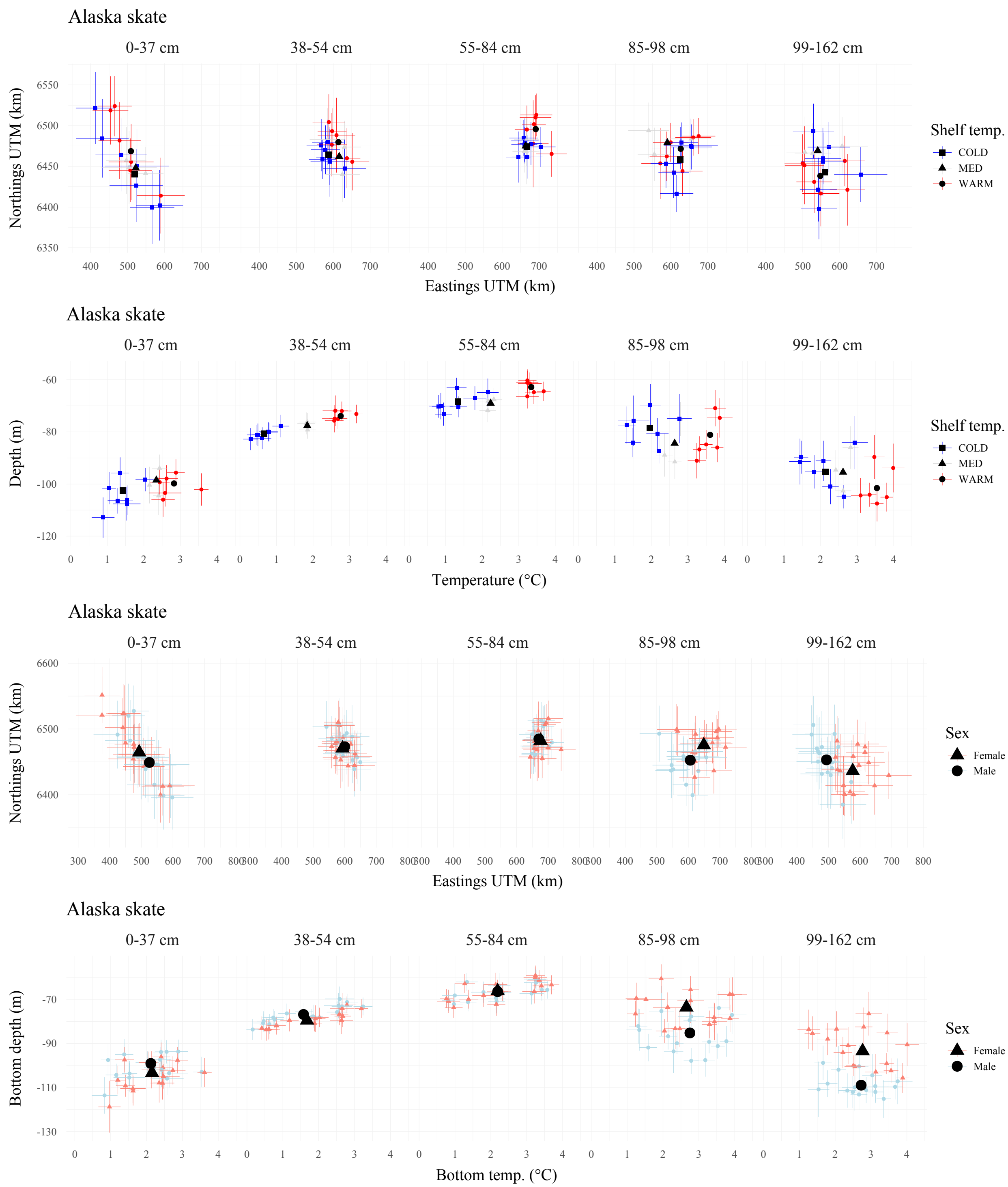


Figure 13 . -- The Alaska skate (*Bathyraja parmifera*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

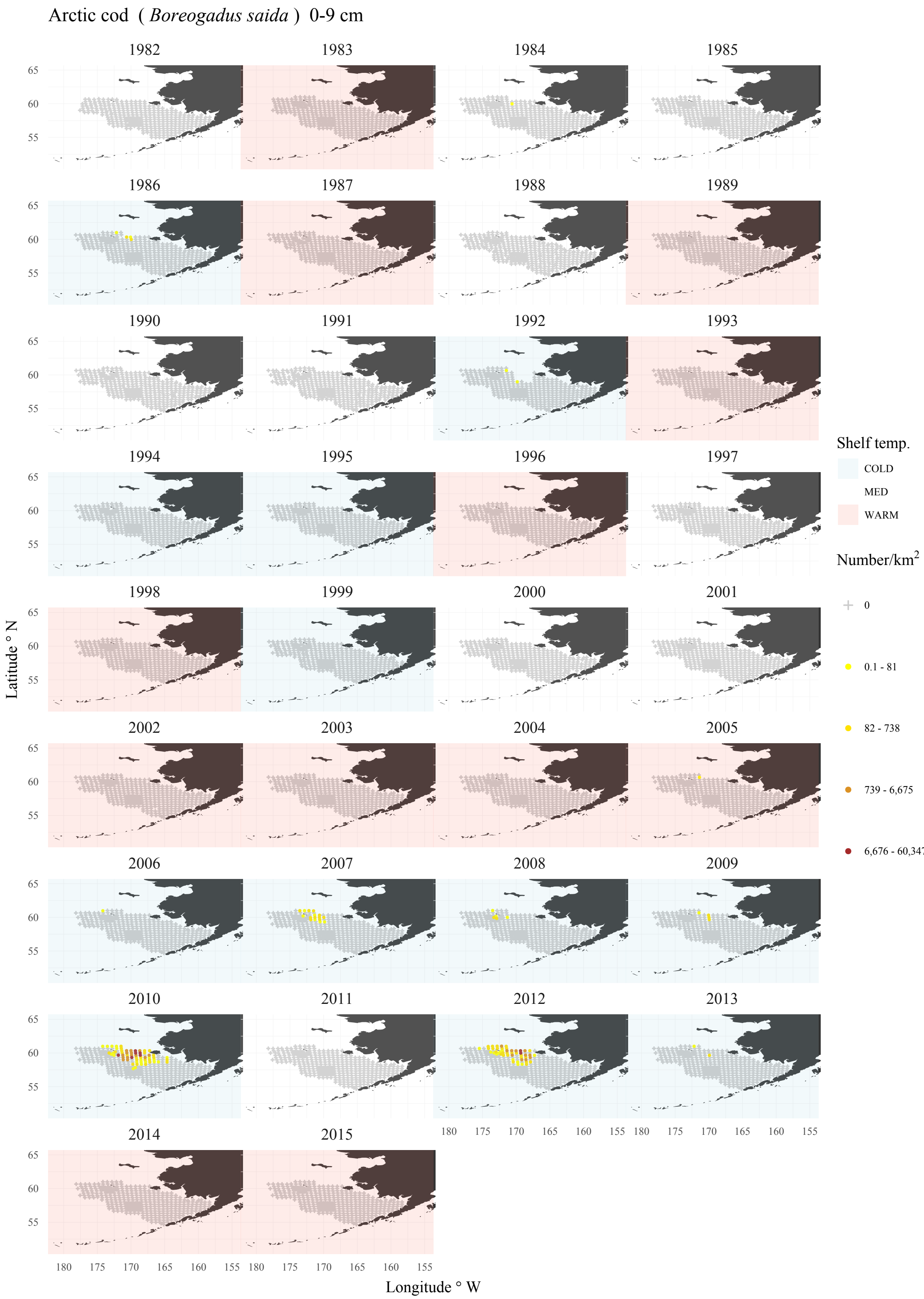


Figure 14 . -- The Arctic cod (*Boreogadus saida*) CPUE by number weighted mean location for each length category for all years.

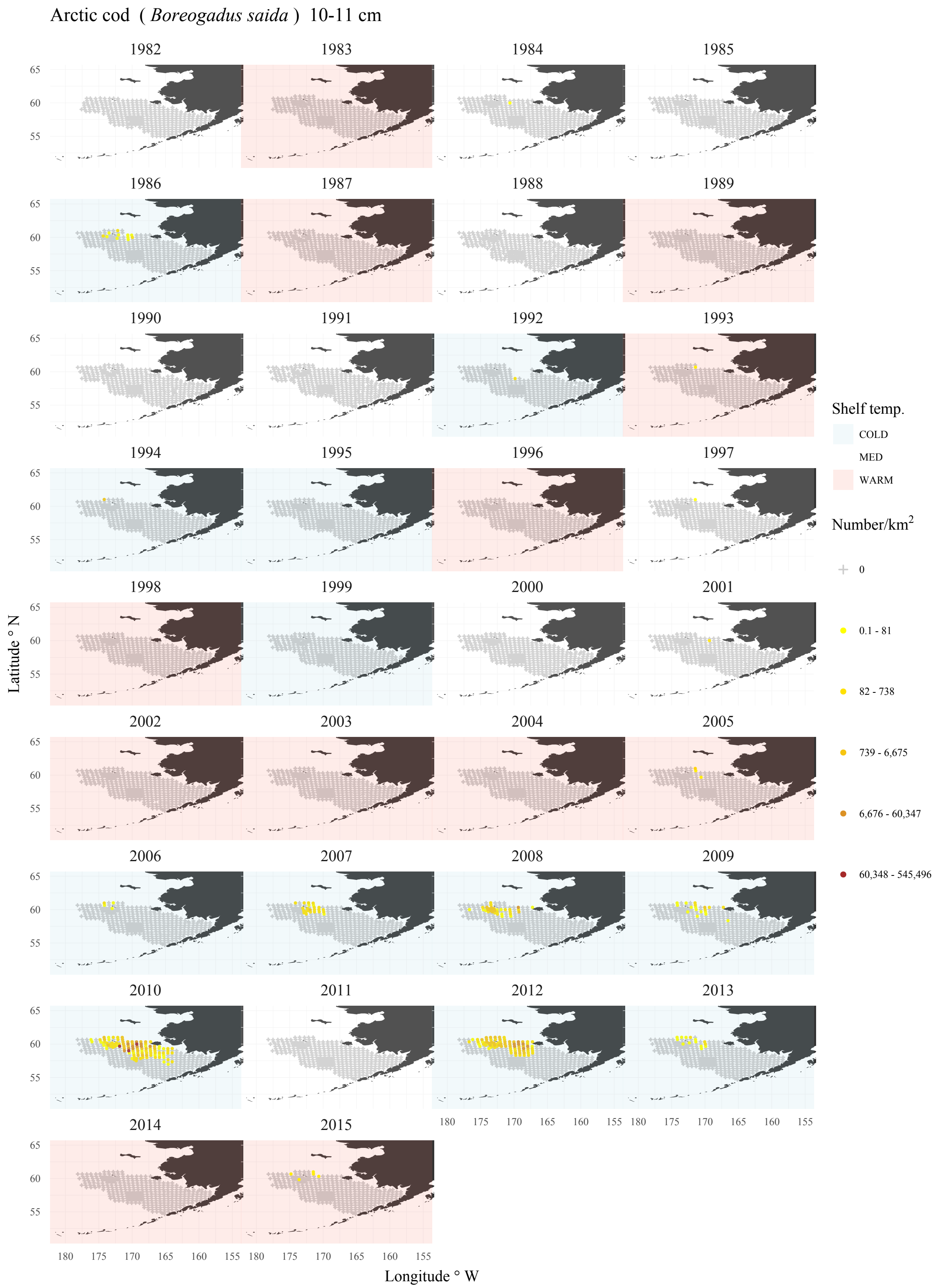
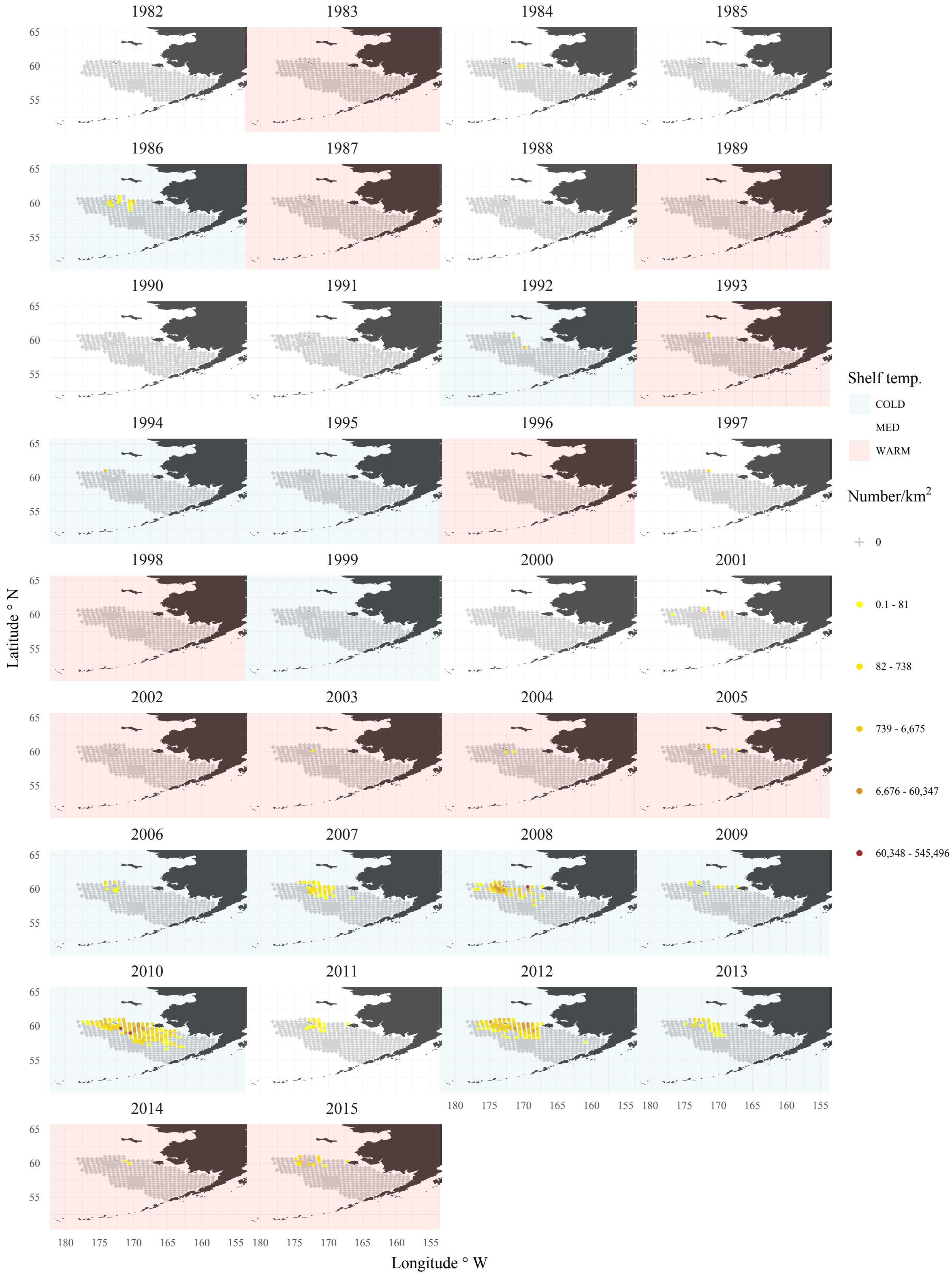


Figure 14 . -- Continued.

Arctic cod (*Boreogadus saida*) 12-15 cm



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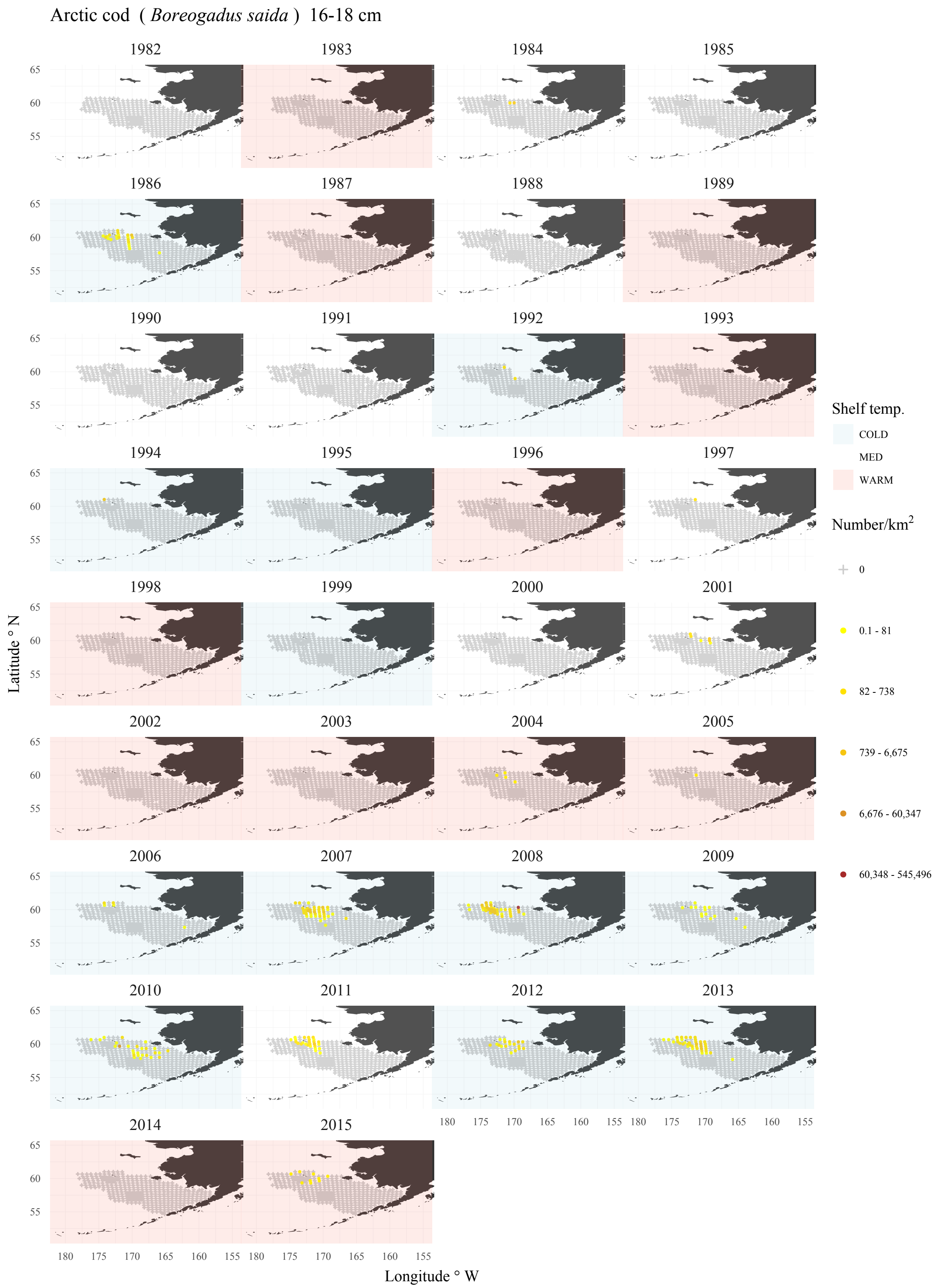

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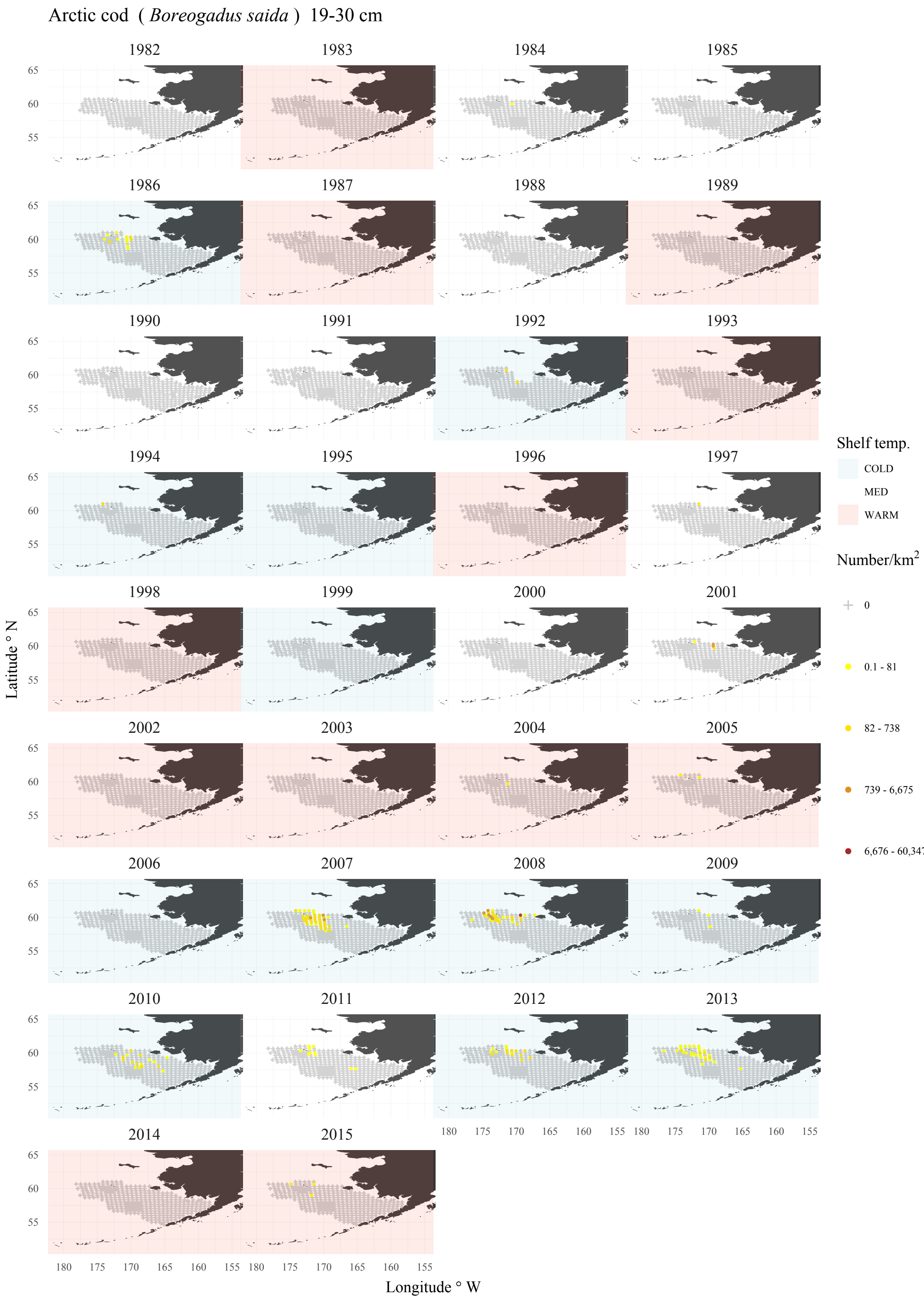

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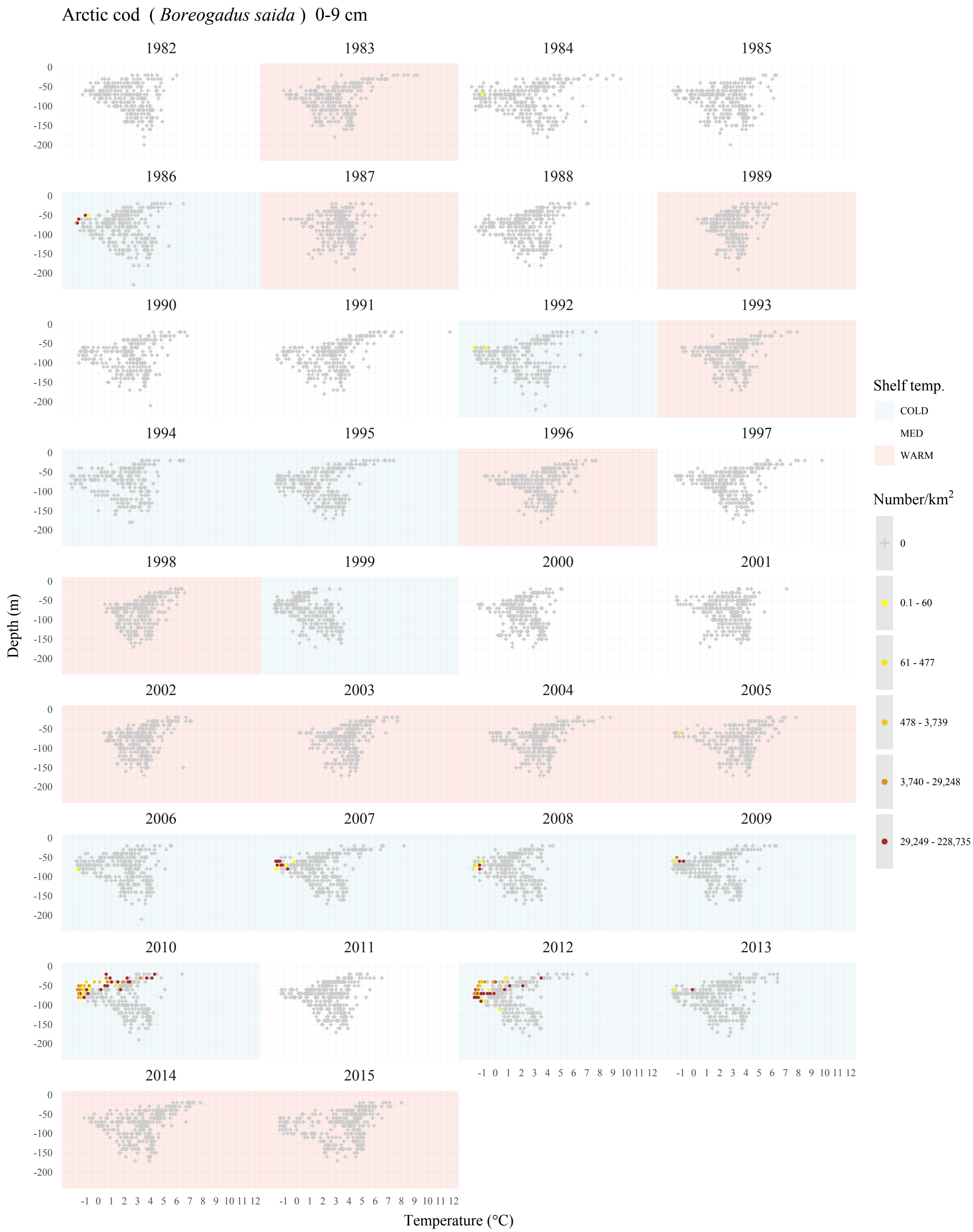
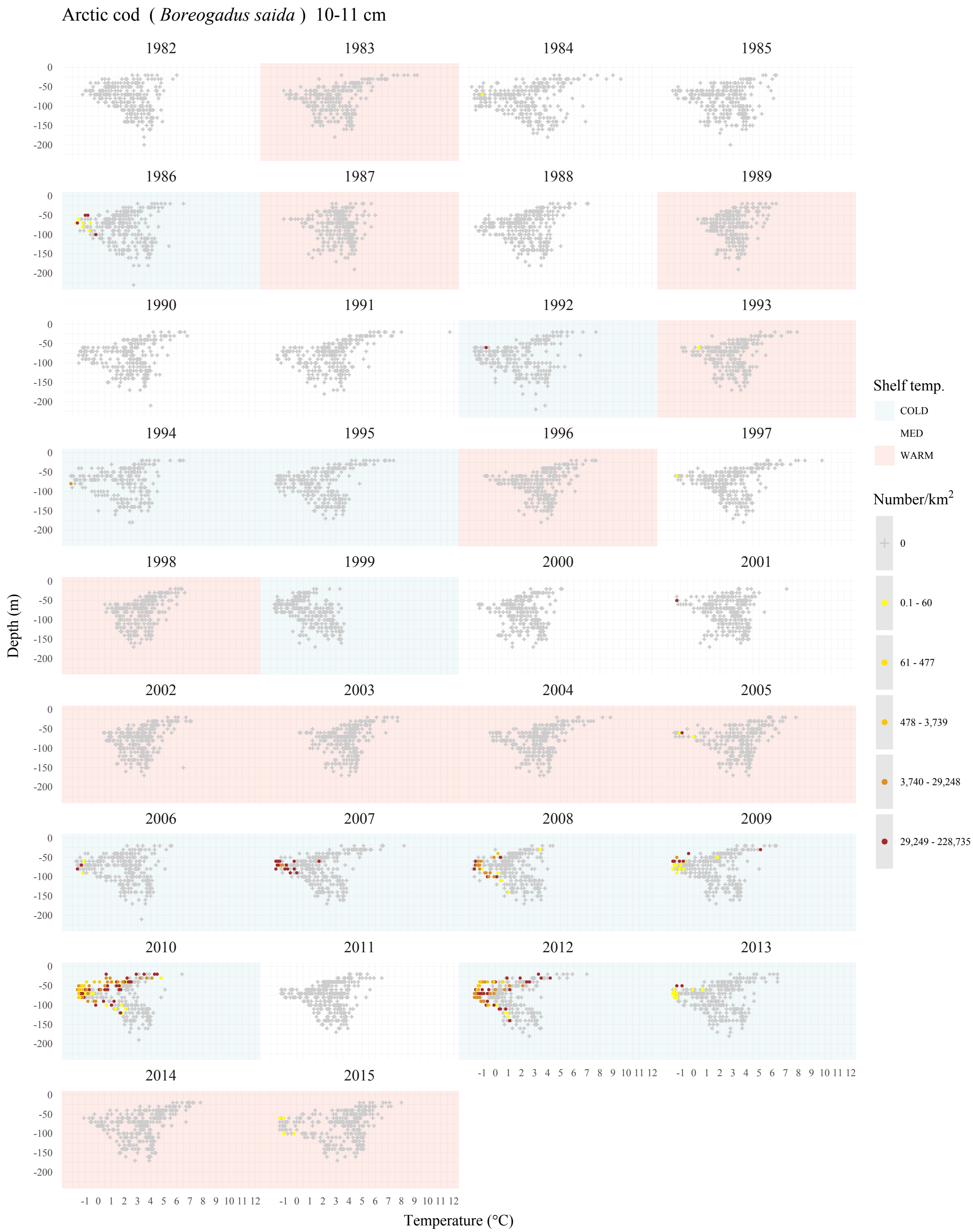


Figure 15 . -- The Arctic cod (*Boreogadus saida*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.



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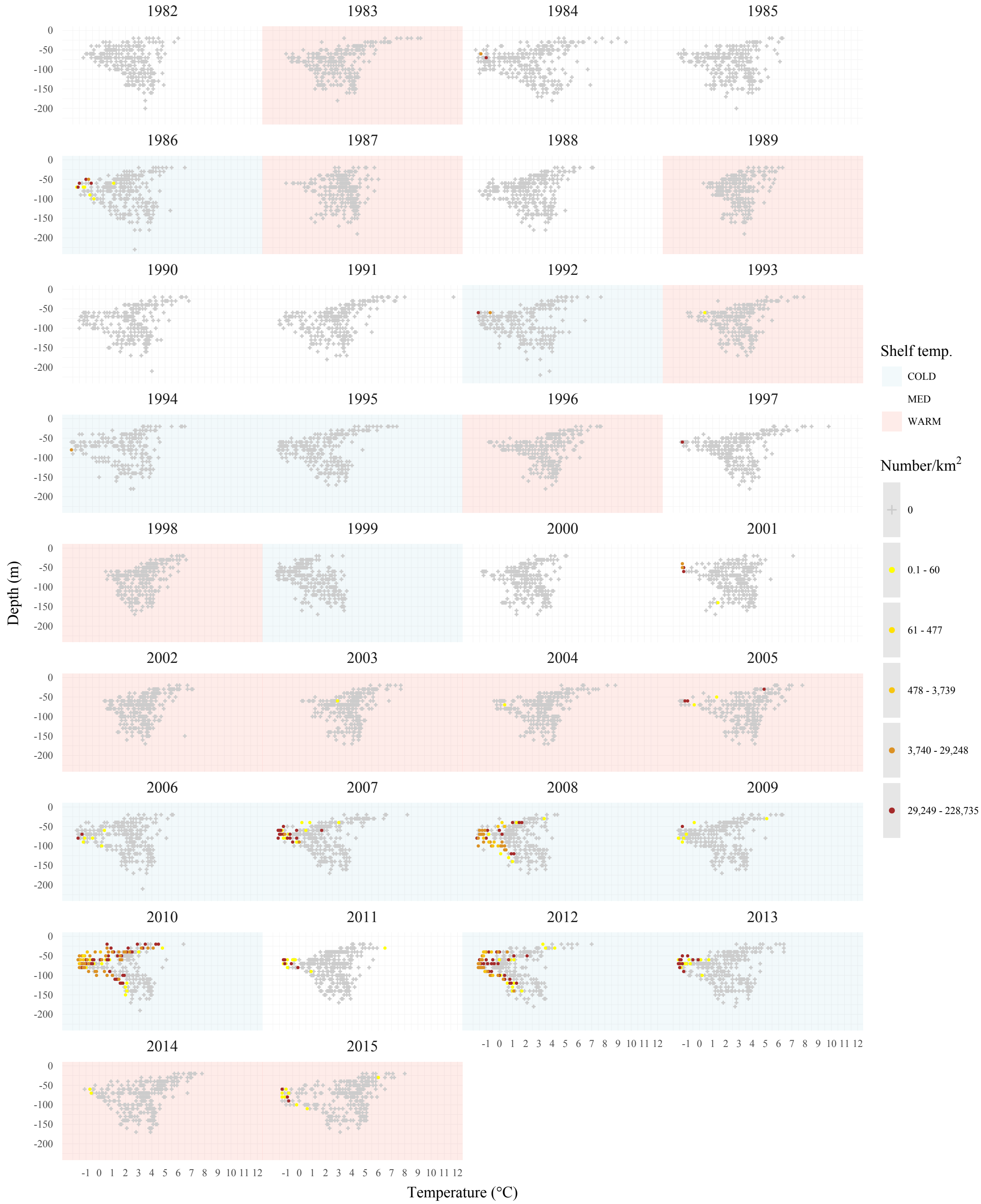
Arctic cod (*Boreogadus saida*) 12-15 cm



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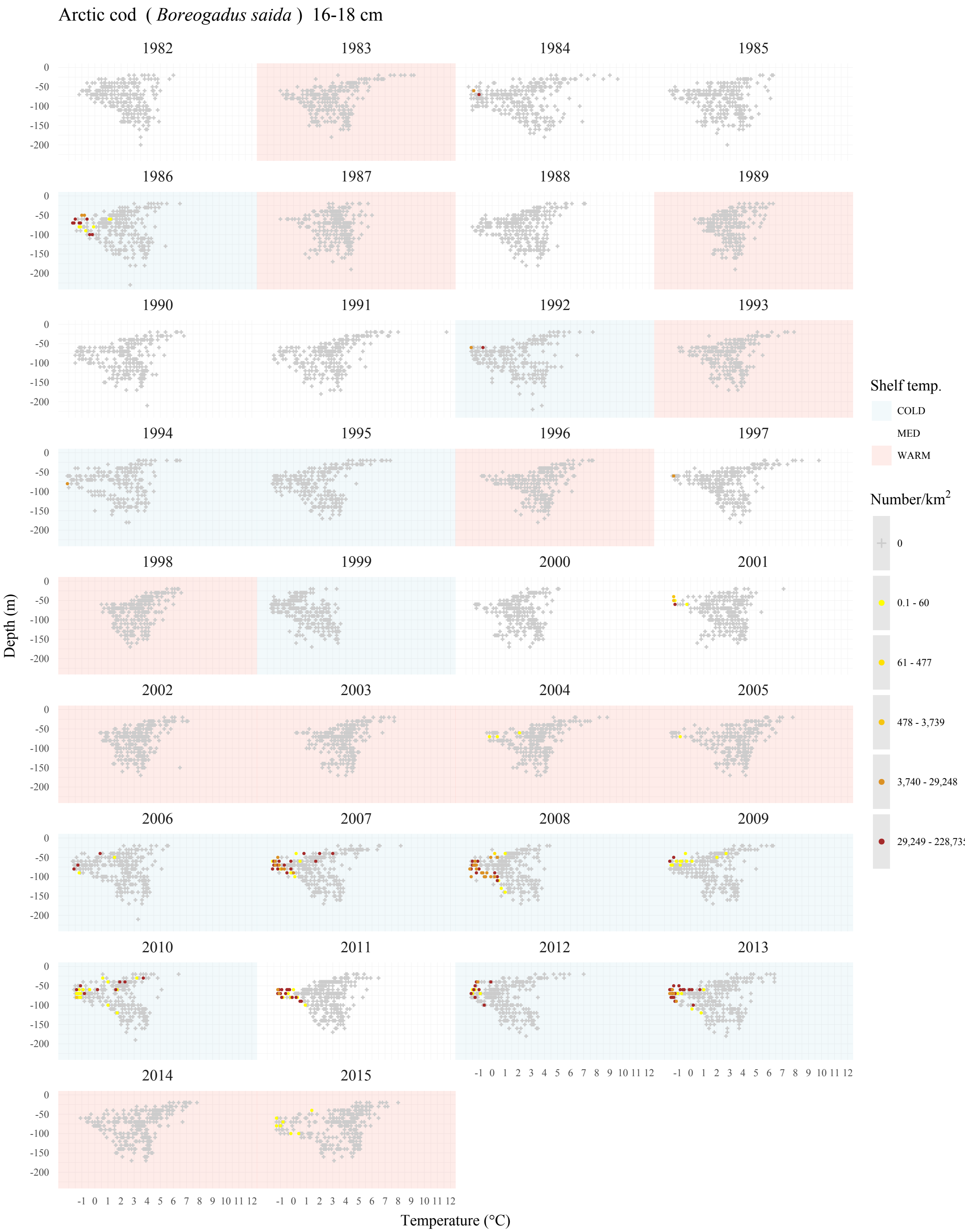


Figure 15 . -- Continued.

Figure 15 . -- Continued.

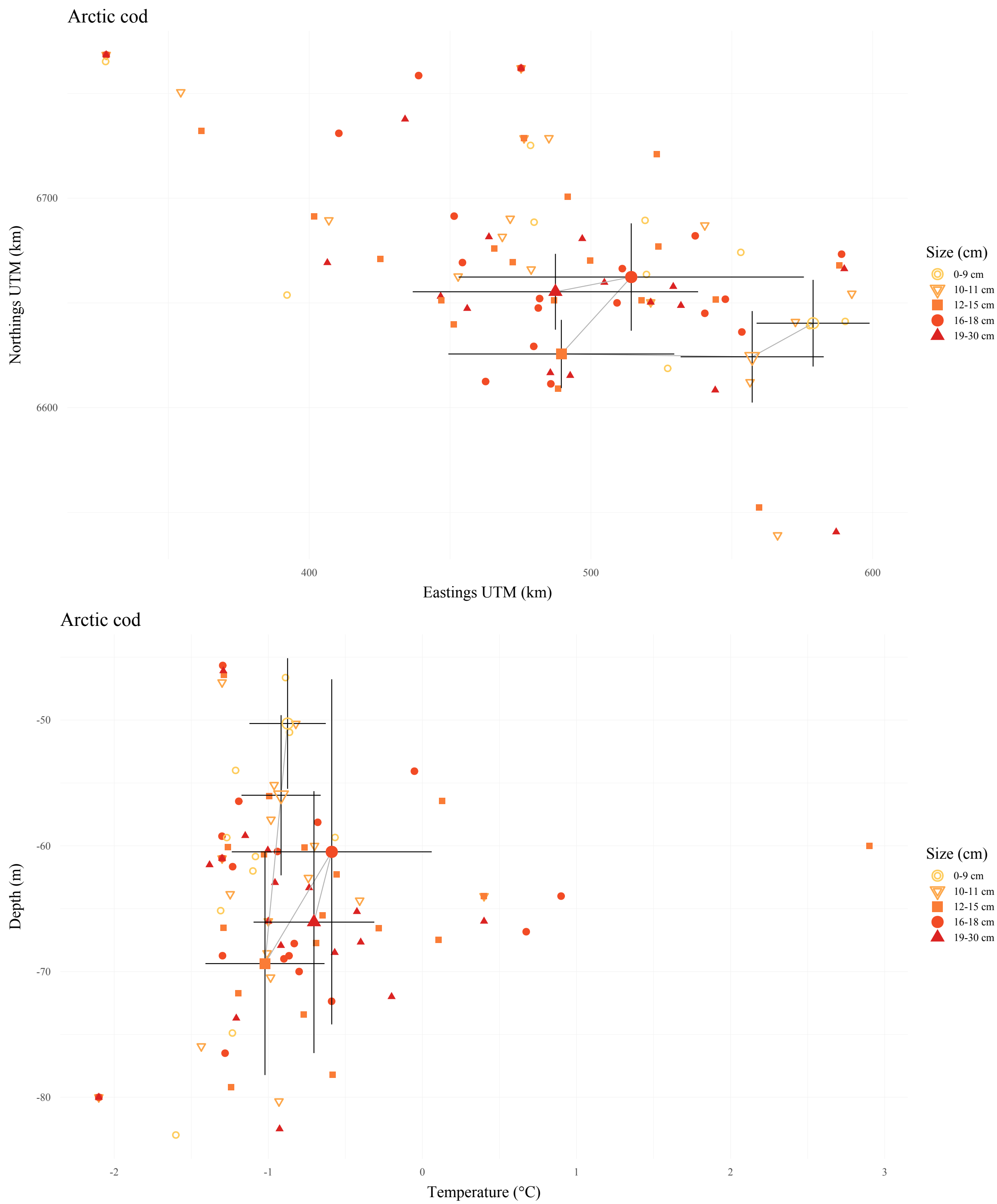


Figure 16 . -- The Arctic cod (*Boreogadus saida*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

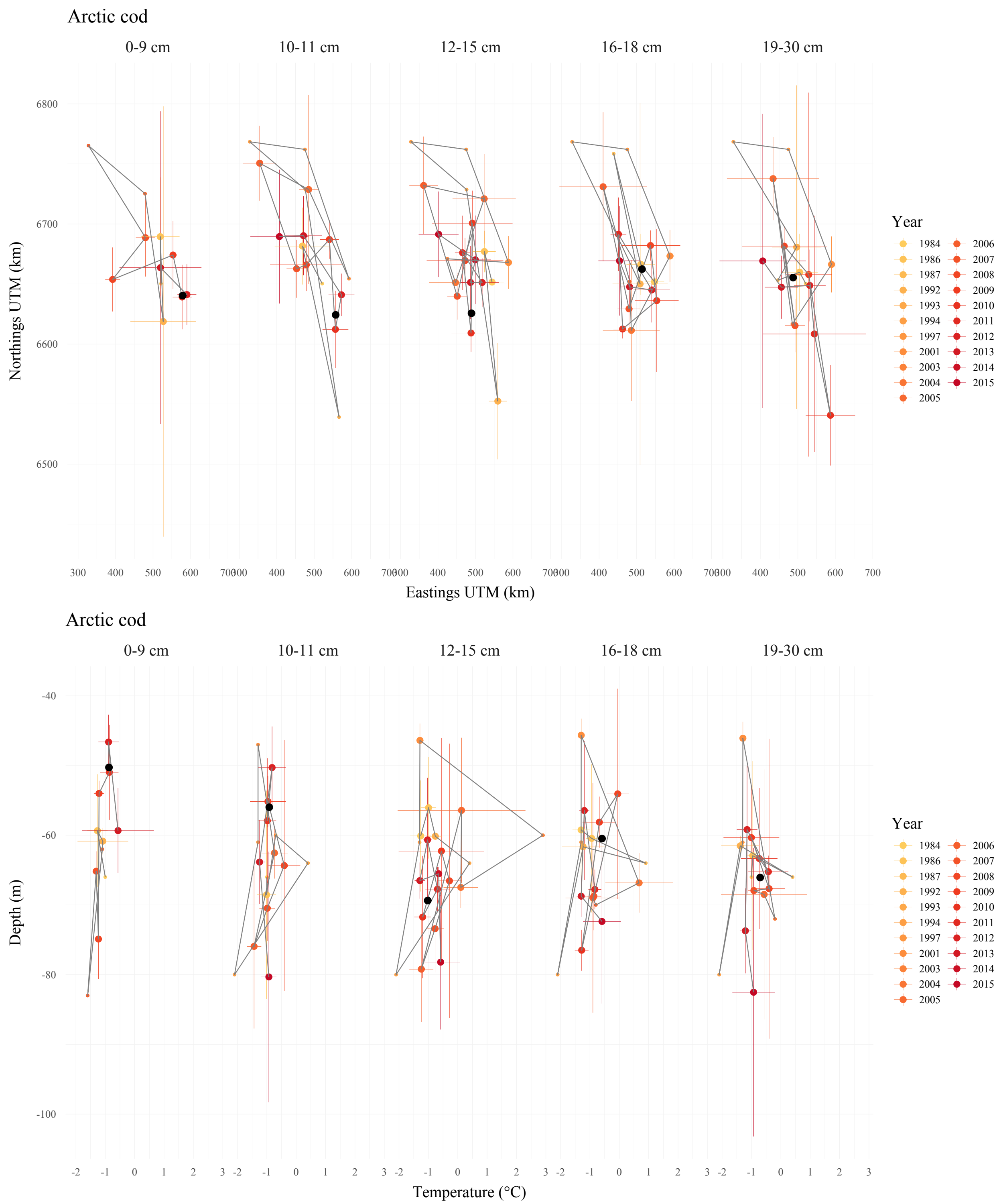


Figure 17 . -- The Arctic cod (*Boreogadus saida*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

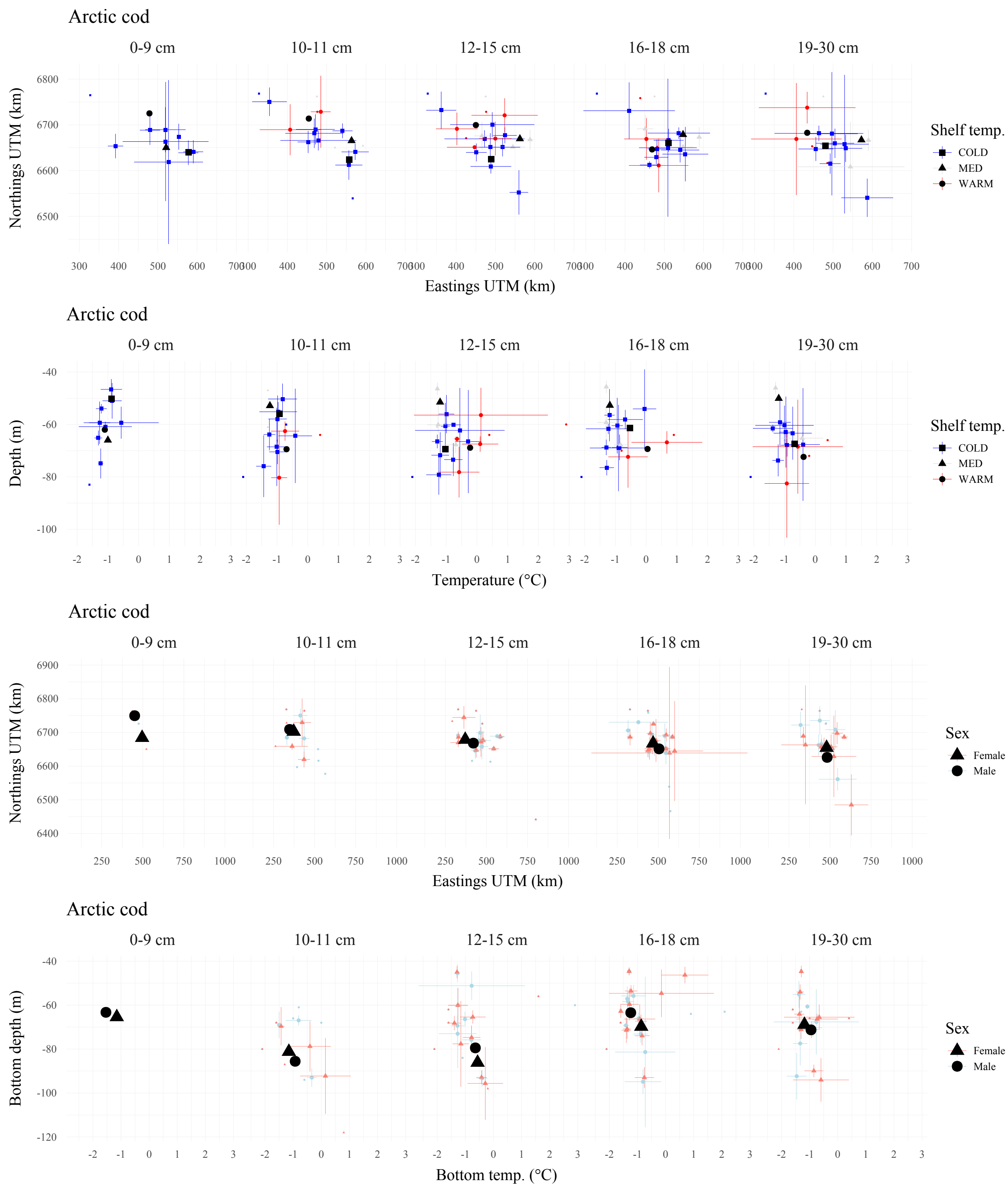


Figure 18 . -- The Arctic cod (*Boreogadus saida*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

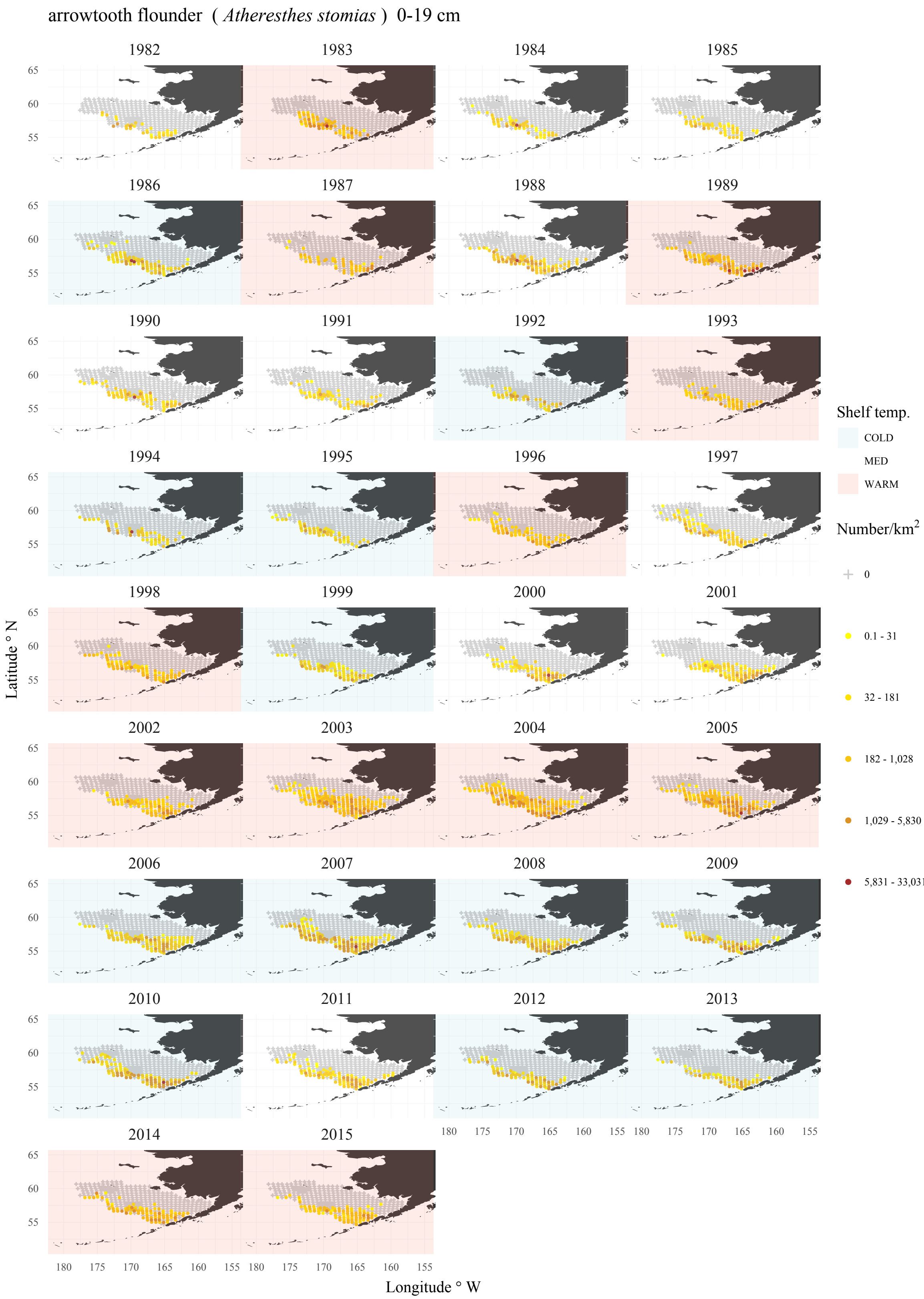


Figure 19 . -- The arrowtooth flounder (*Atheresthes stomias*) CPUE by number weighted mean location for each length category for all years.

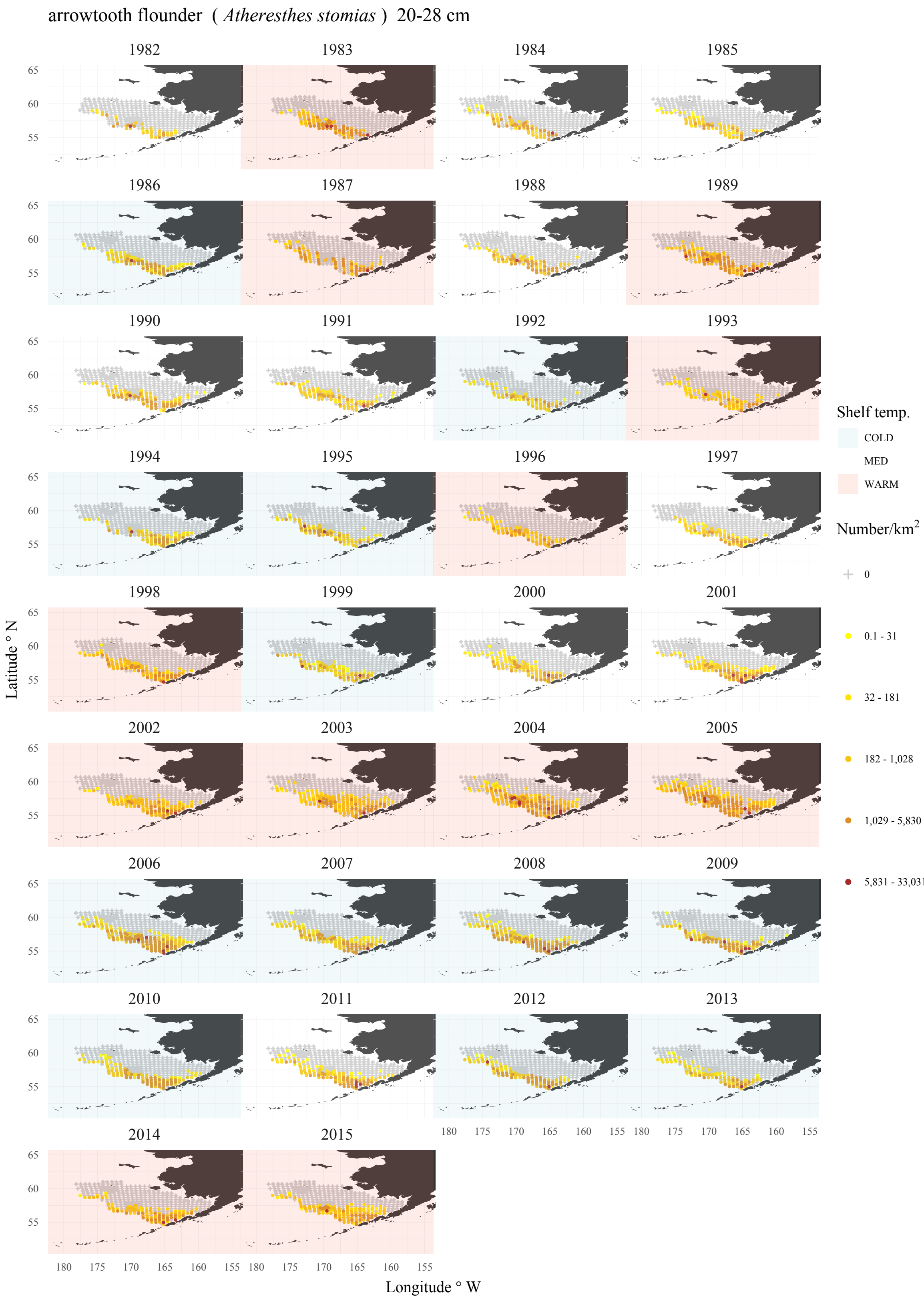


Figure 19 . -- Continued.

arrowtooth flounder (*Atheresthes stomias*) 29-41 cm

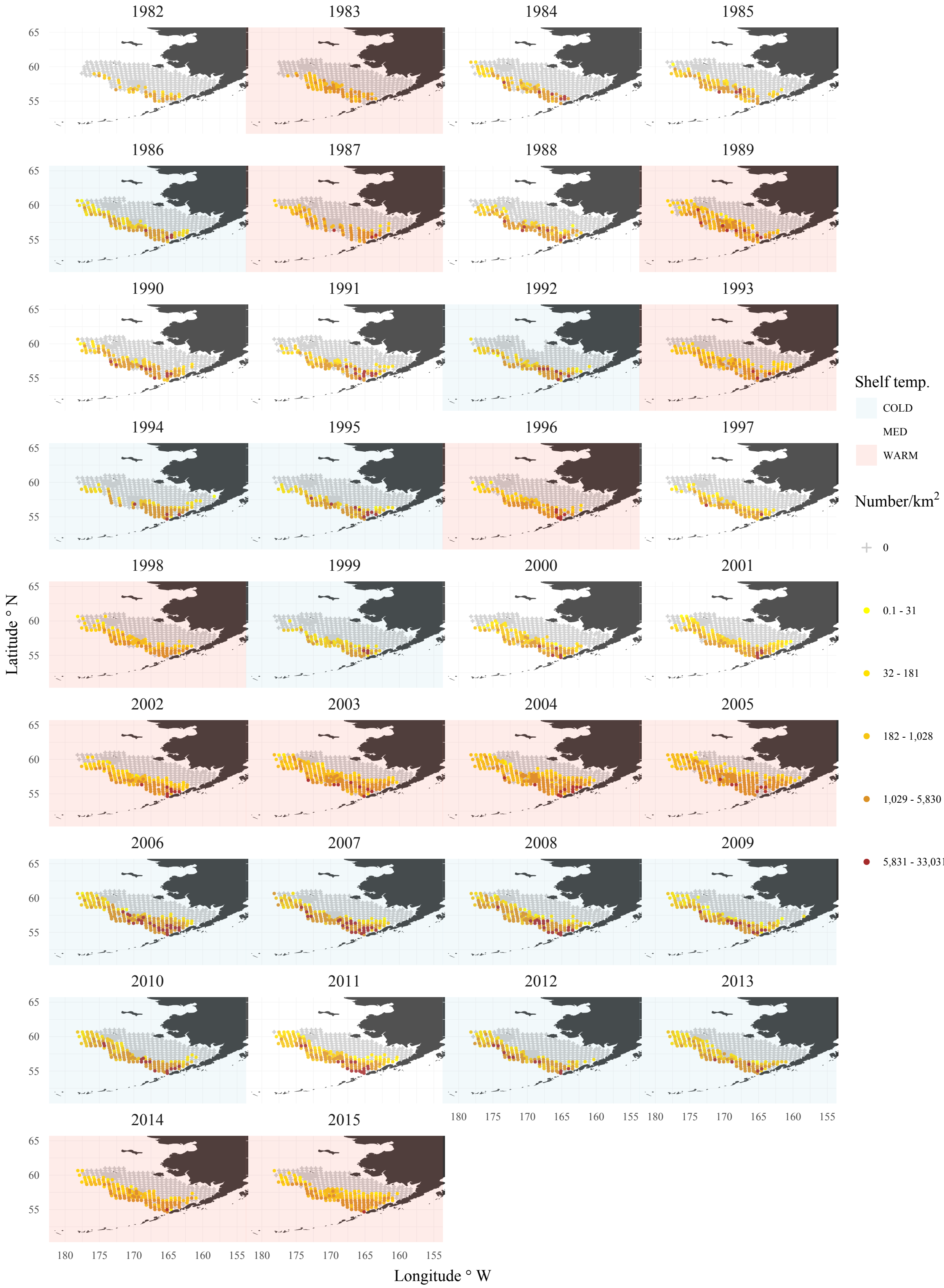


Figure 19 . -- Continued.

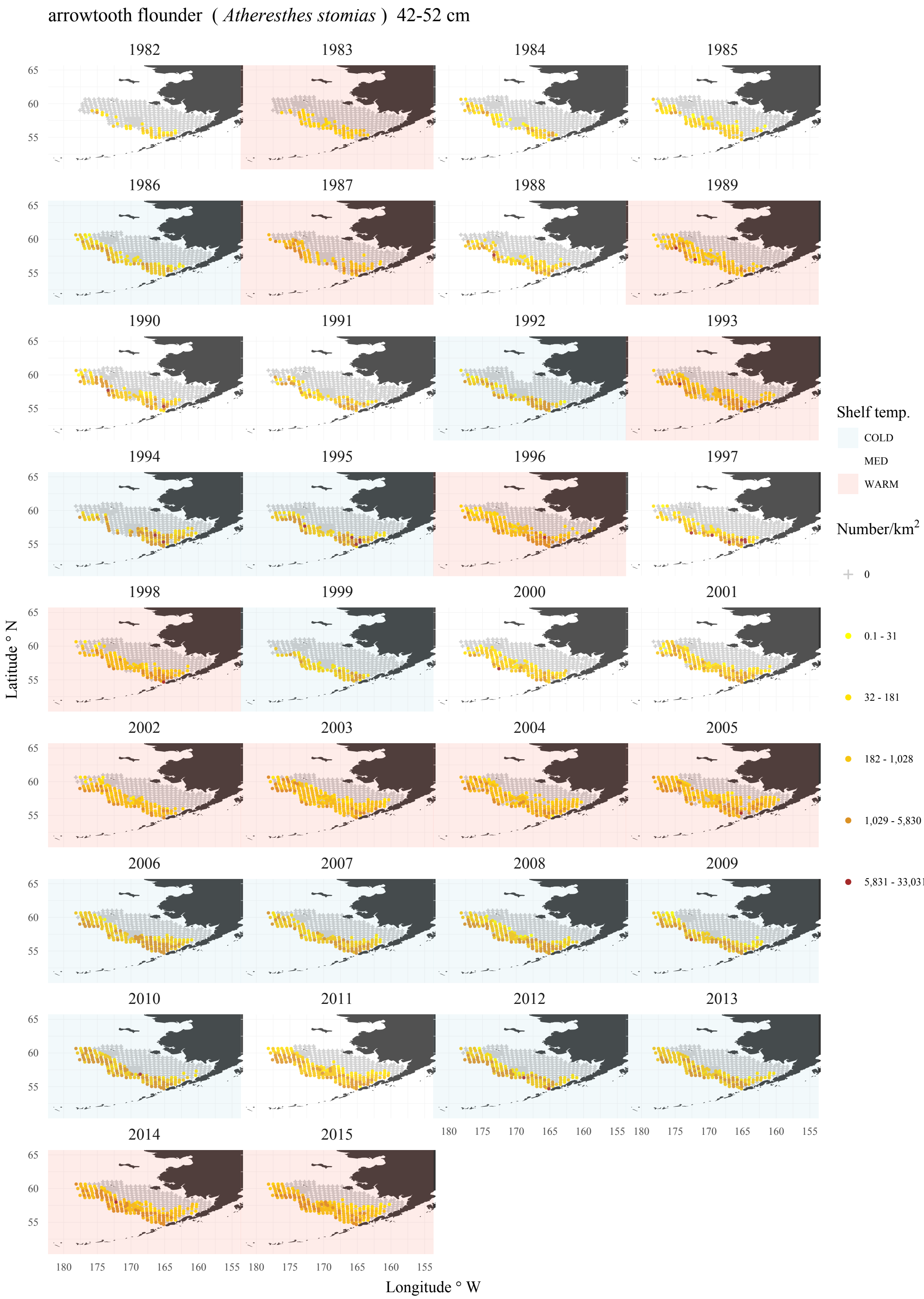


Figure 19 . -- Continued.

arrowtooth flounder (*Atheresthes stomias*) 53-98 cm

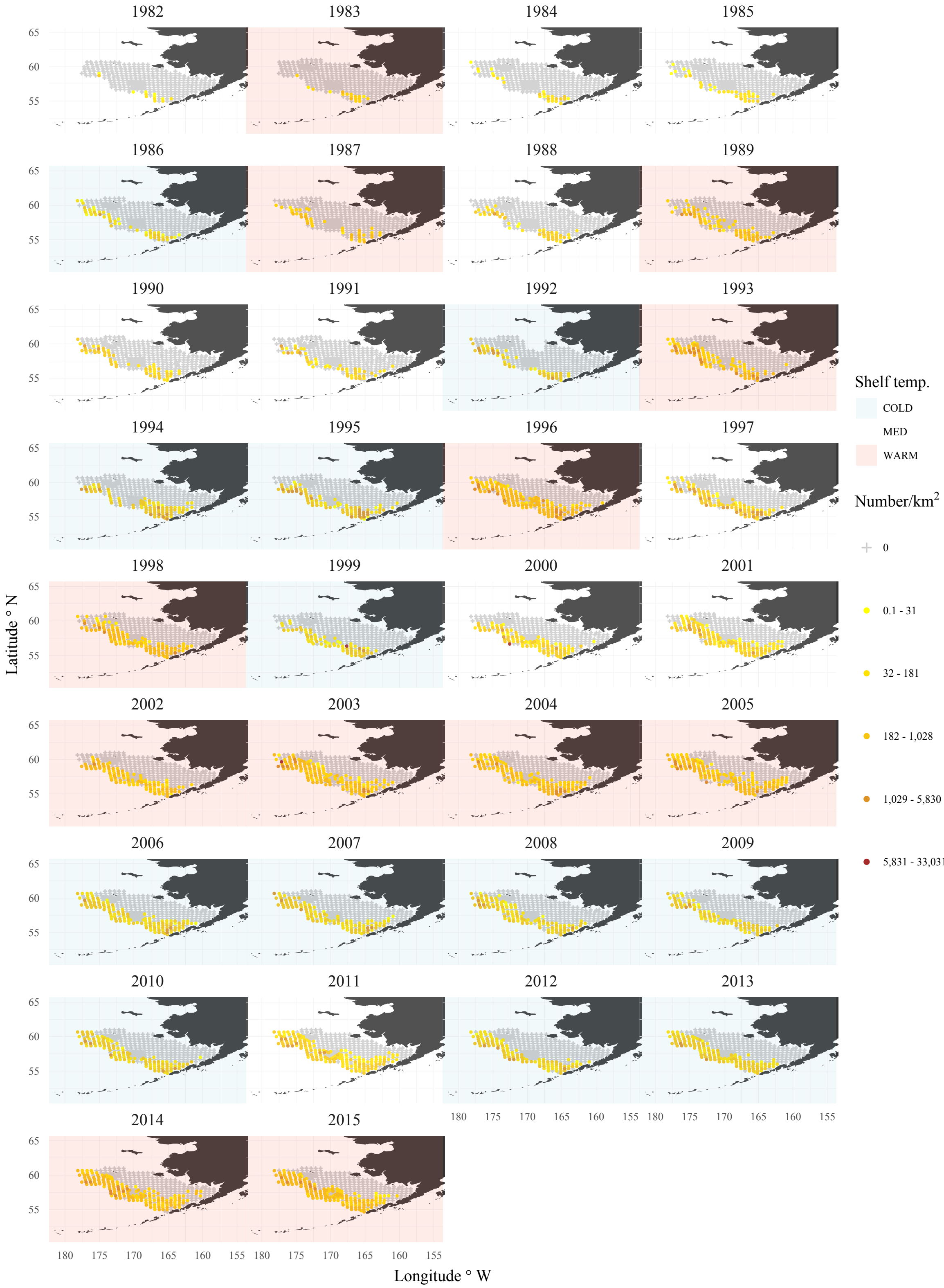


Figure 19 . -- Continued.

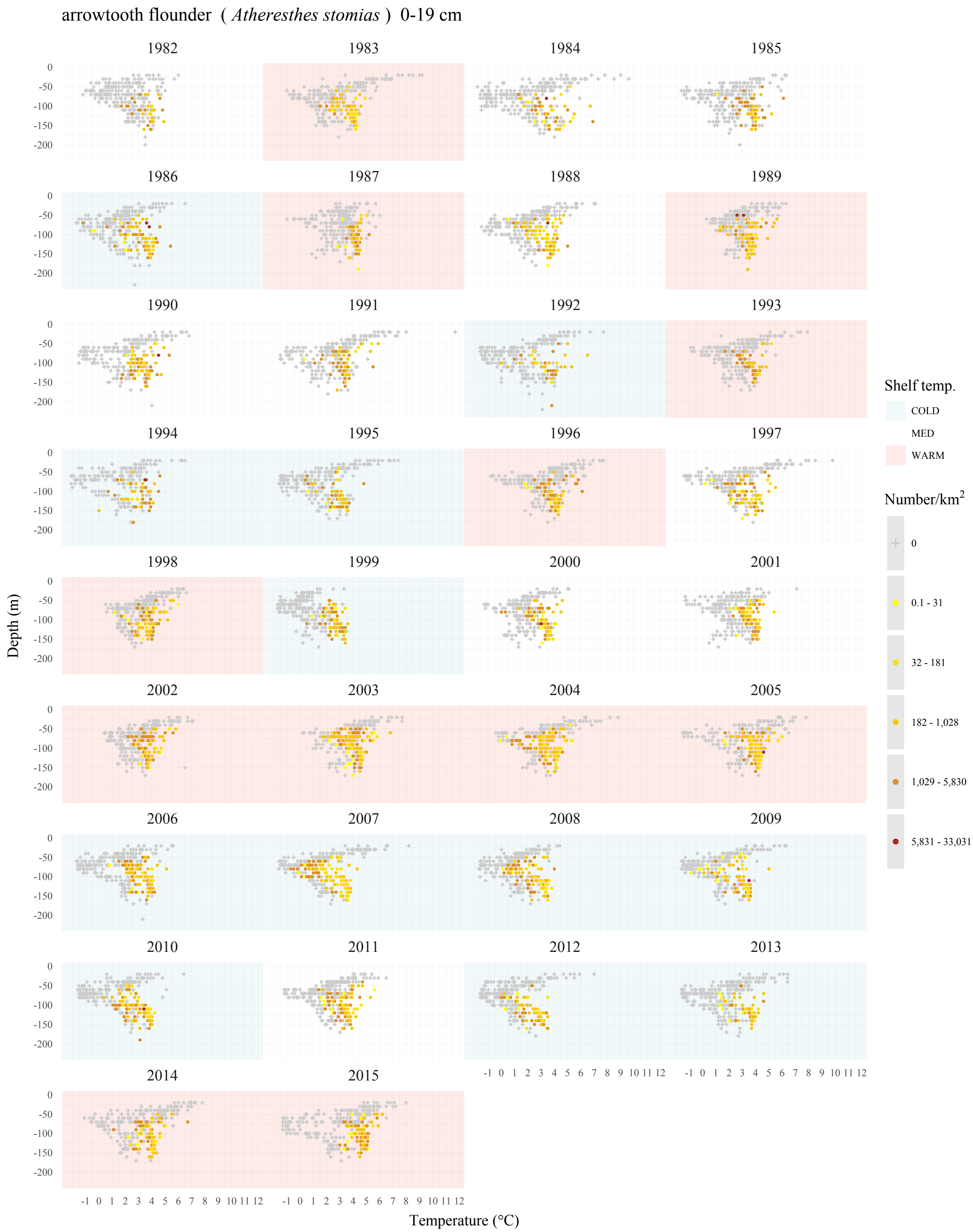


Figure 20 . -- The arrowtooth flounder (*Atheresthes stomias*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

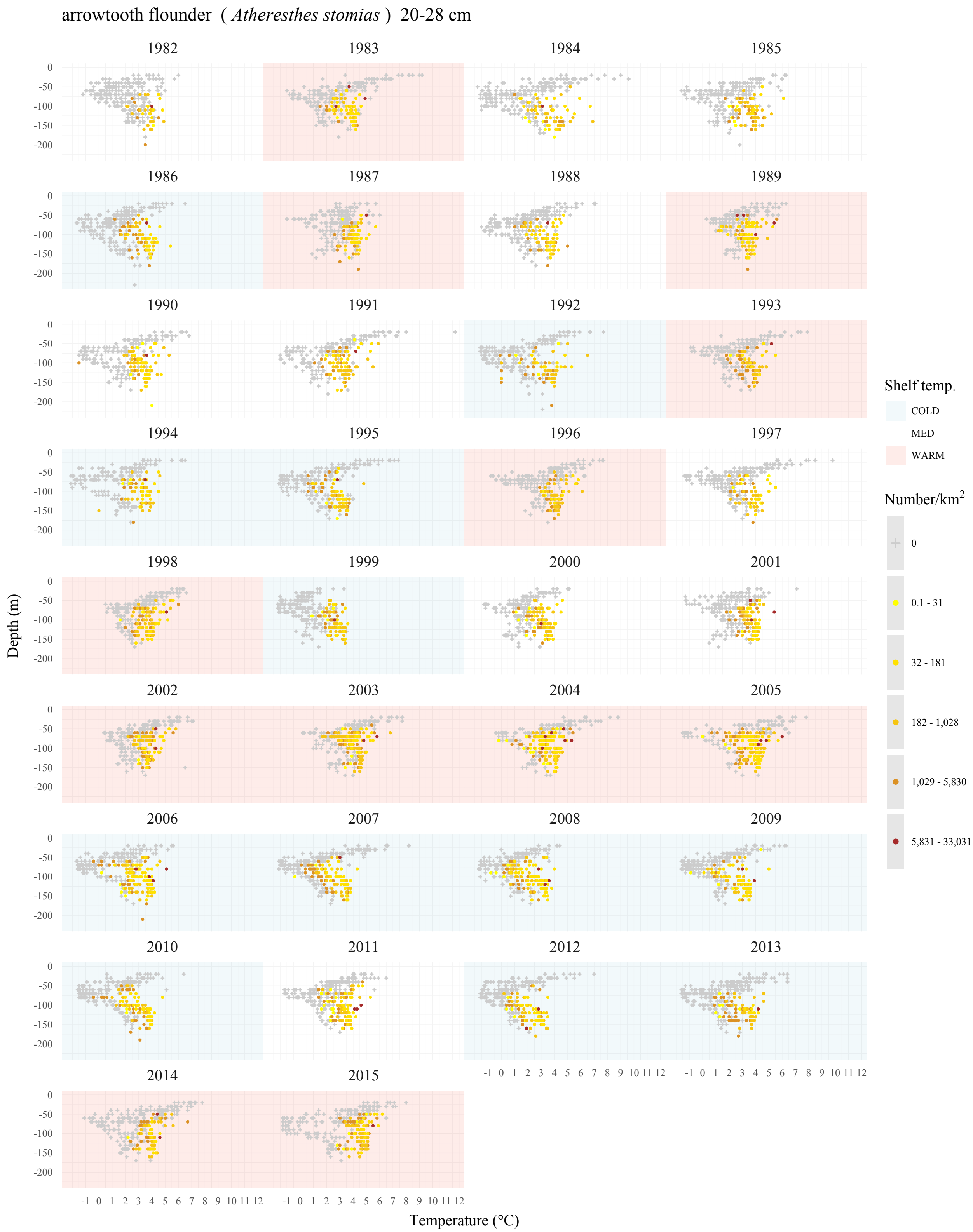
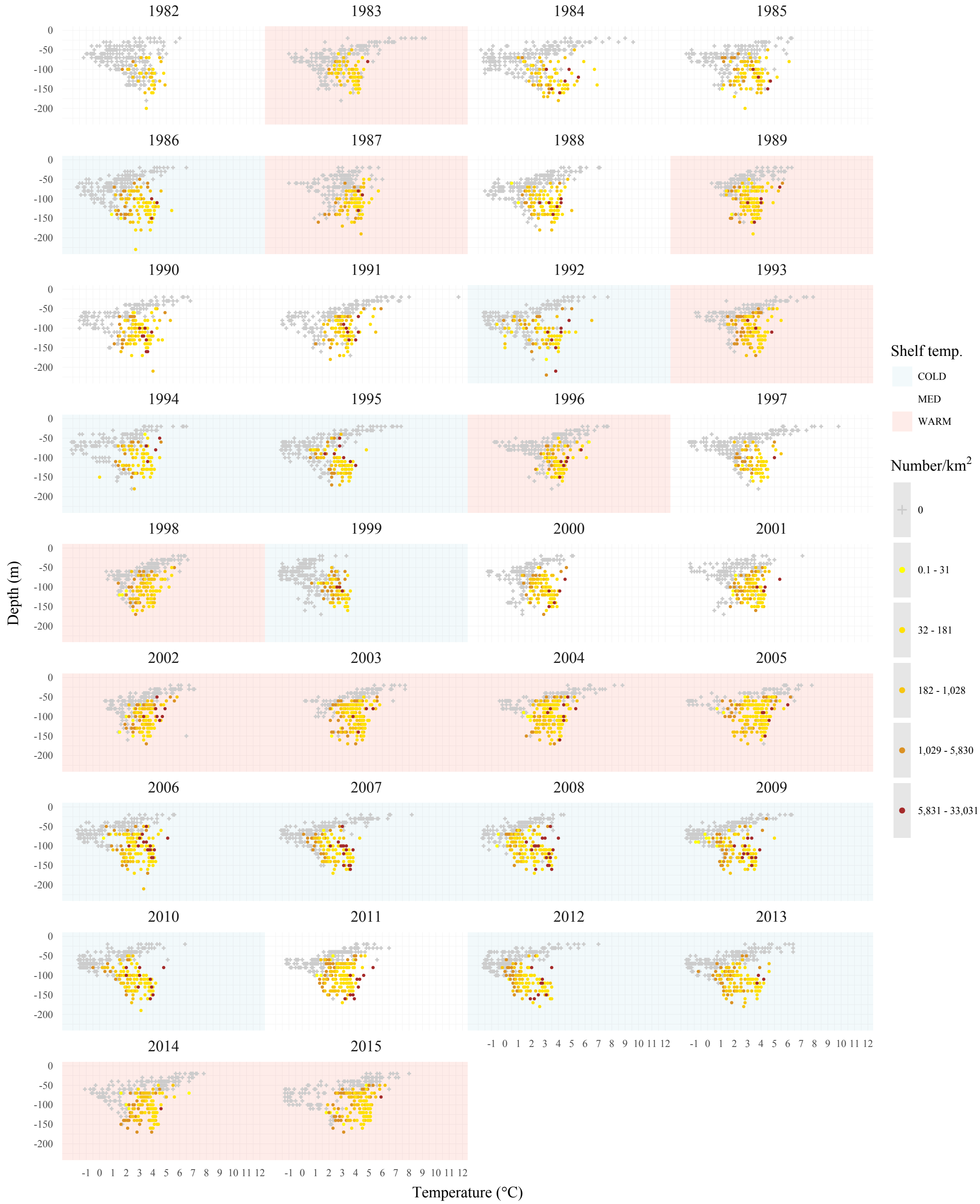


Figure 20 . -- Continued.

arrowtooth flounder (*Atheresthes stomias*) 29-41 cm



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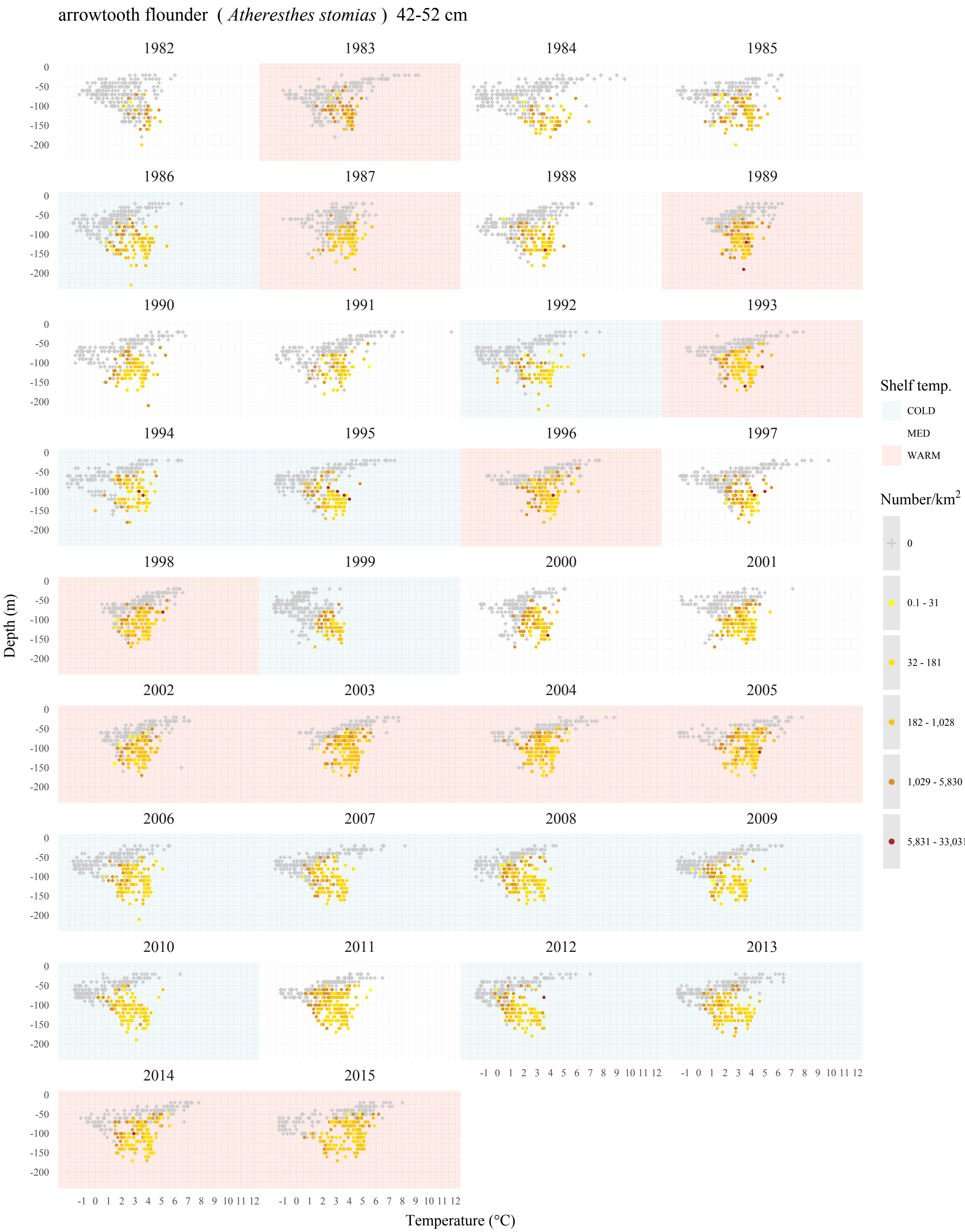


Figure 20 . -- Continued.

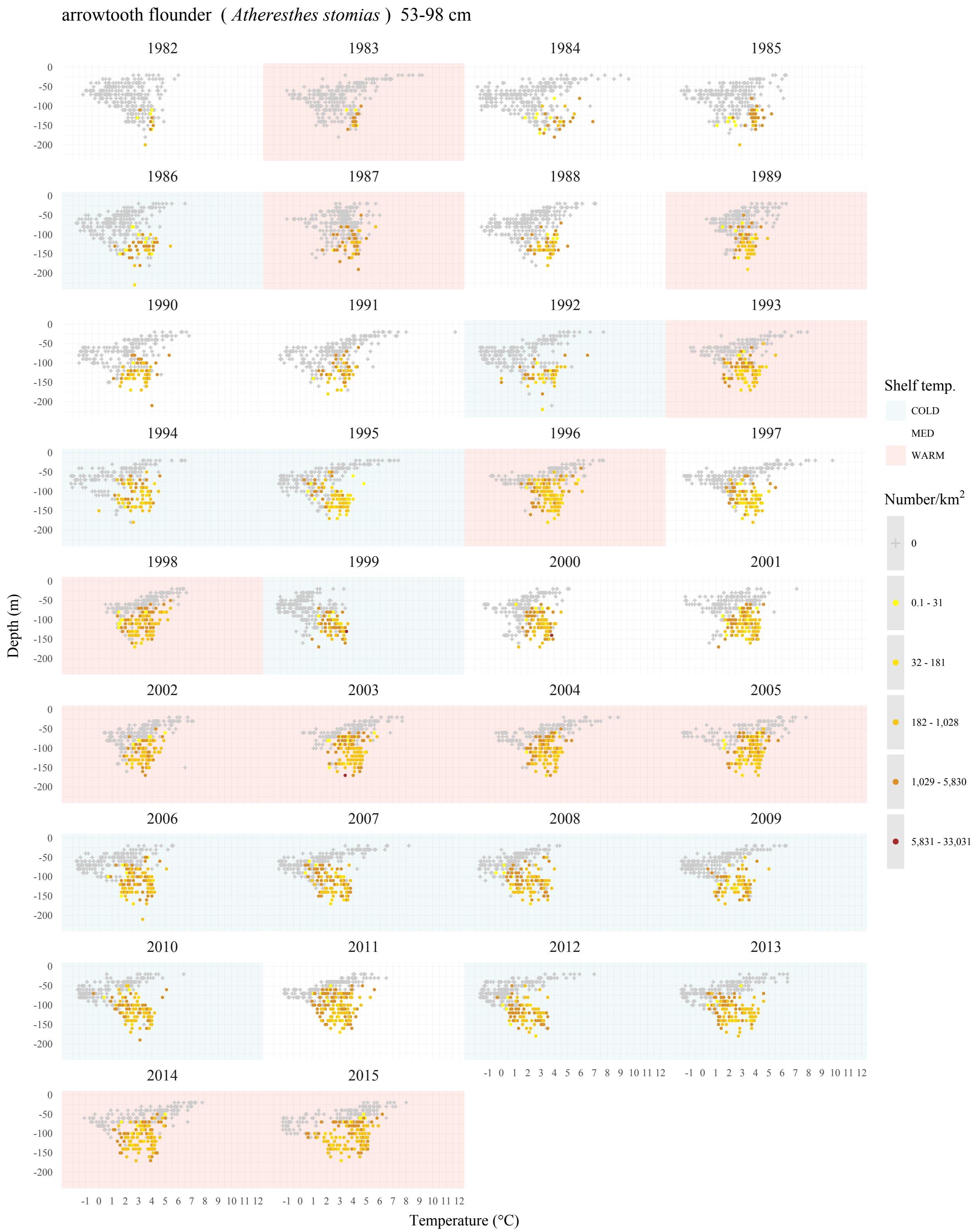
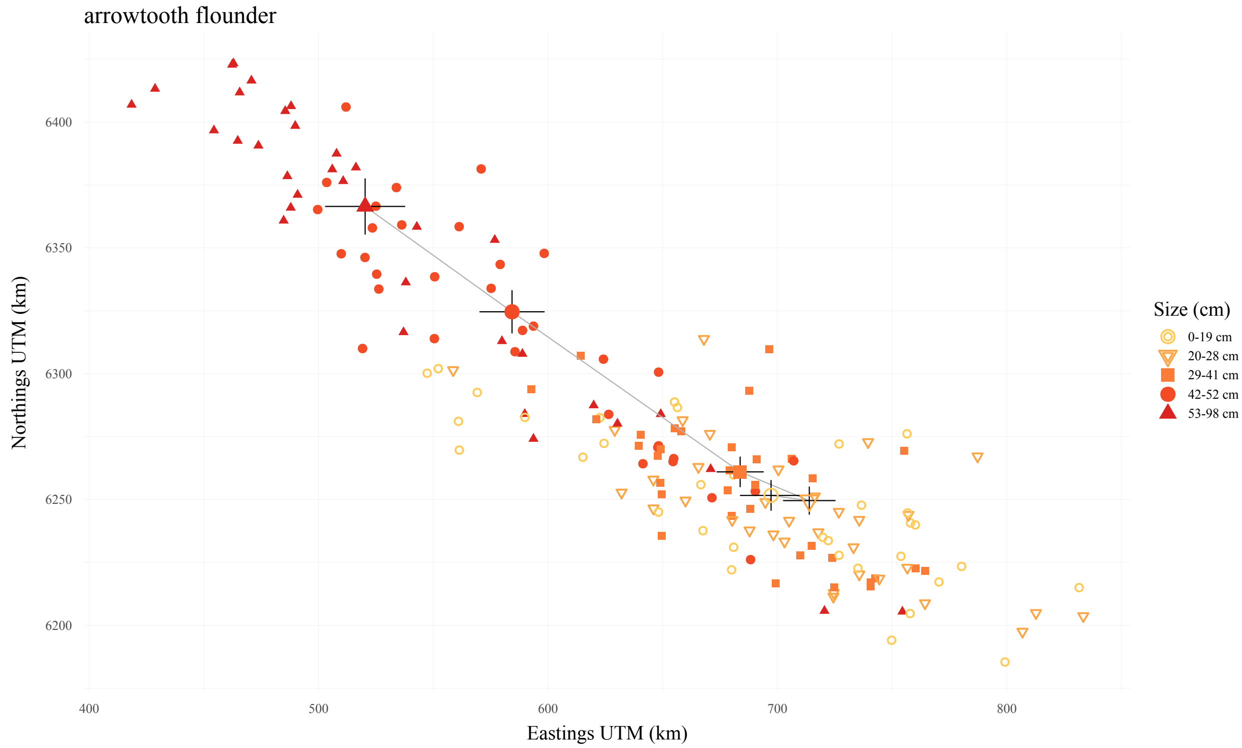


Figure 20 . -- Continued.



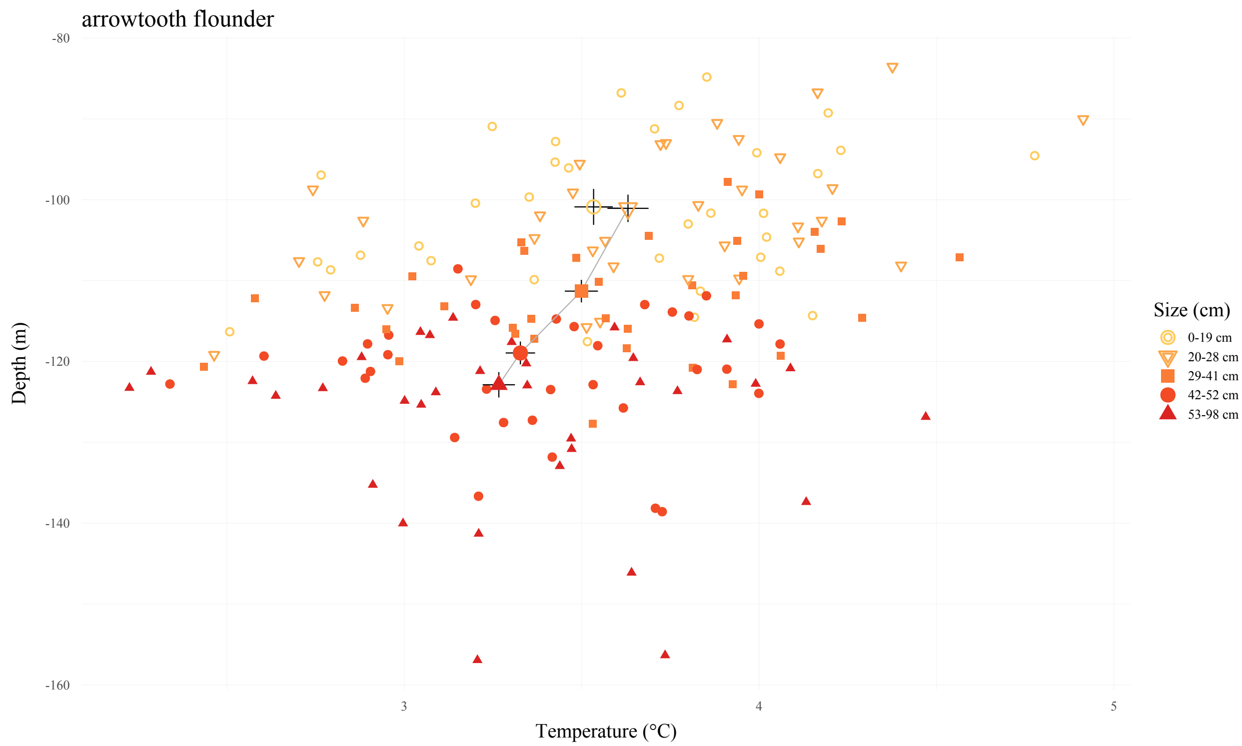
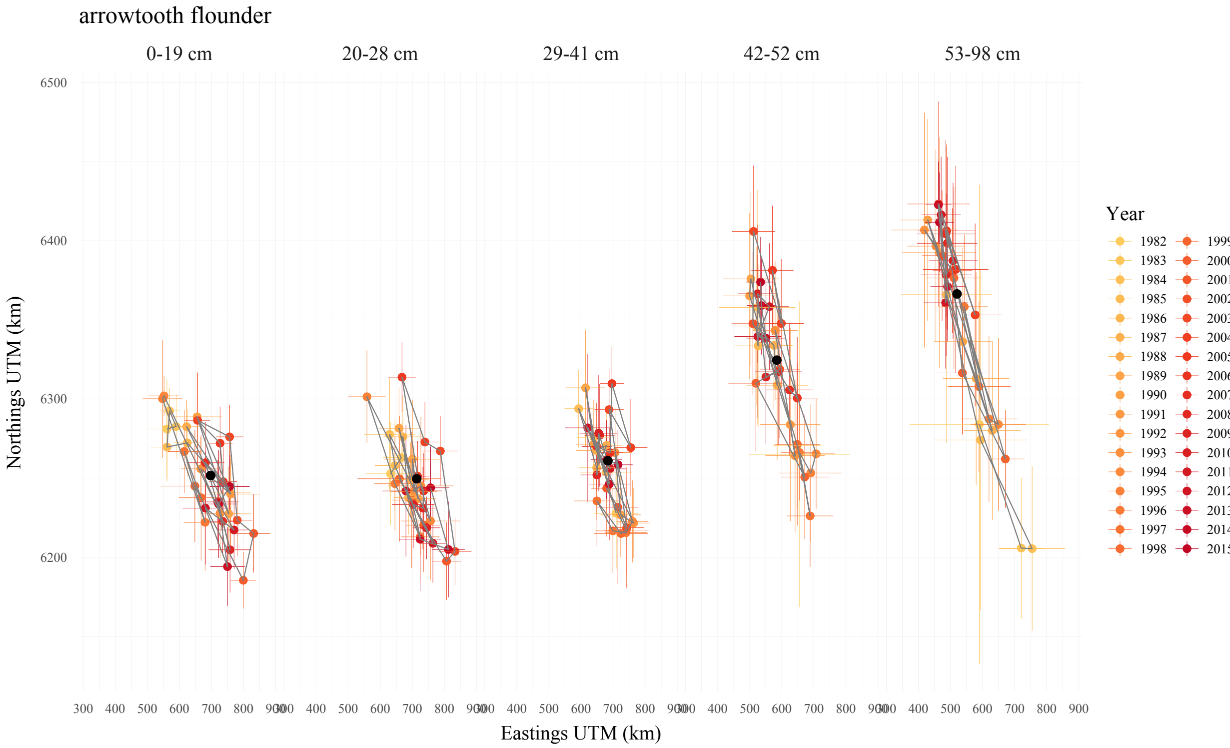


Figure 21 . -- The arrowtooth flounder (*Atheresthes stomias*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.



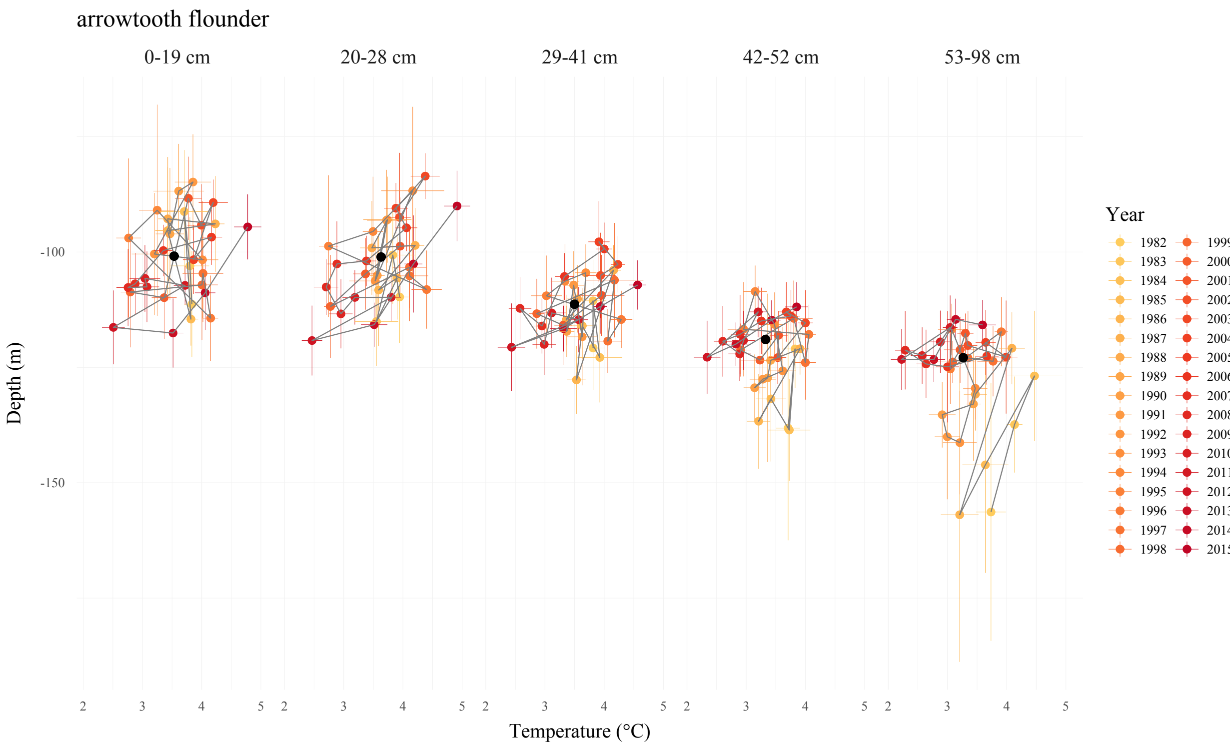


Figure 22 . -- The arrowtooth flounder (*Atheresthes stomias*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

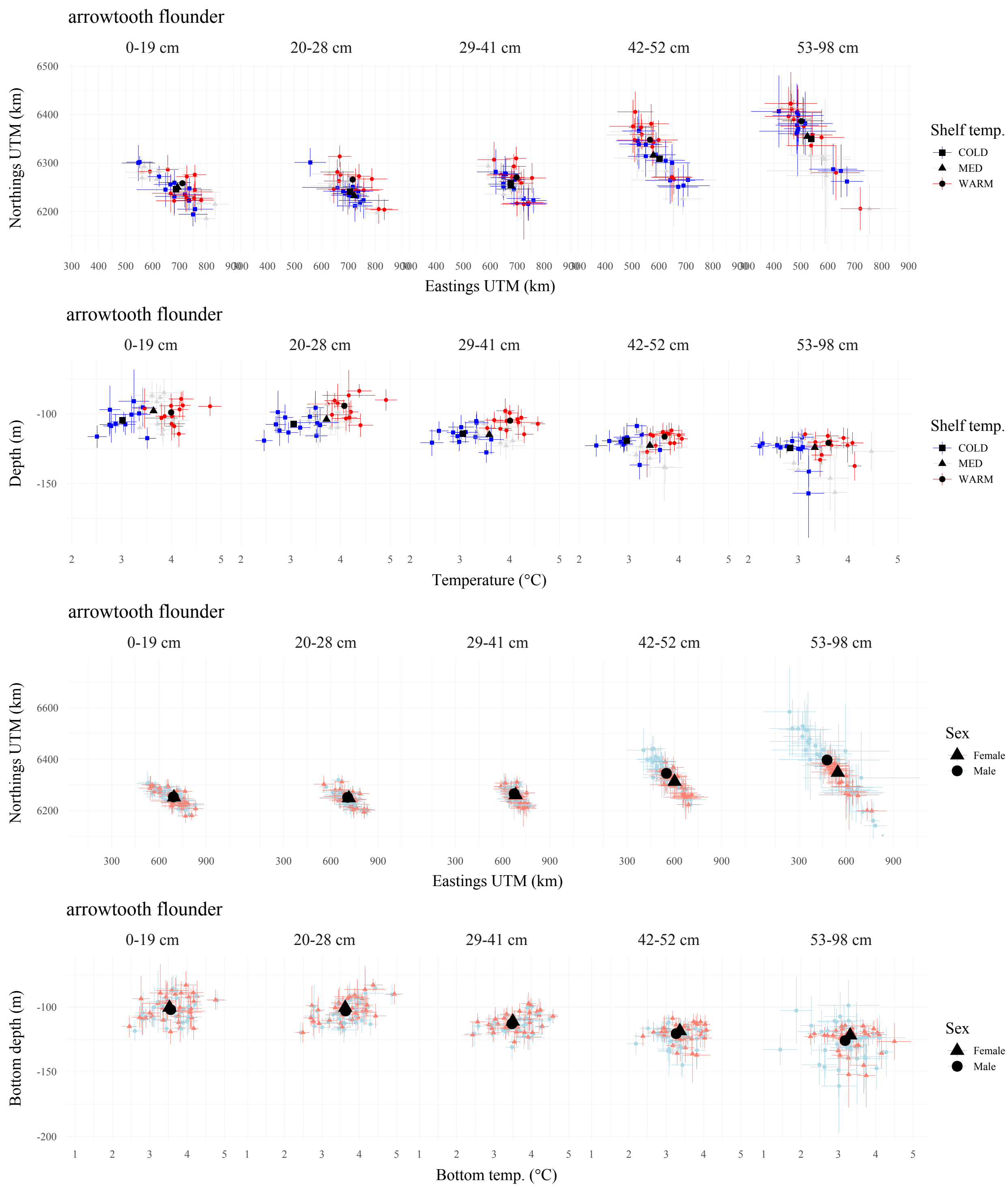


Figure 23 . -- The arrowtooth flounder (*Atheresthes stomias*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

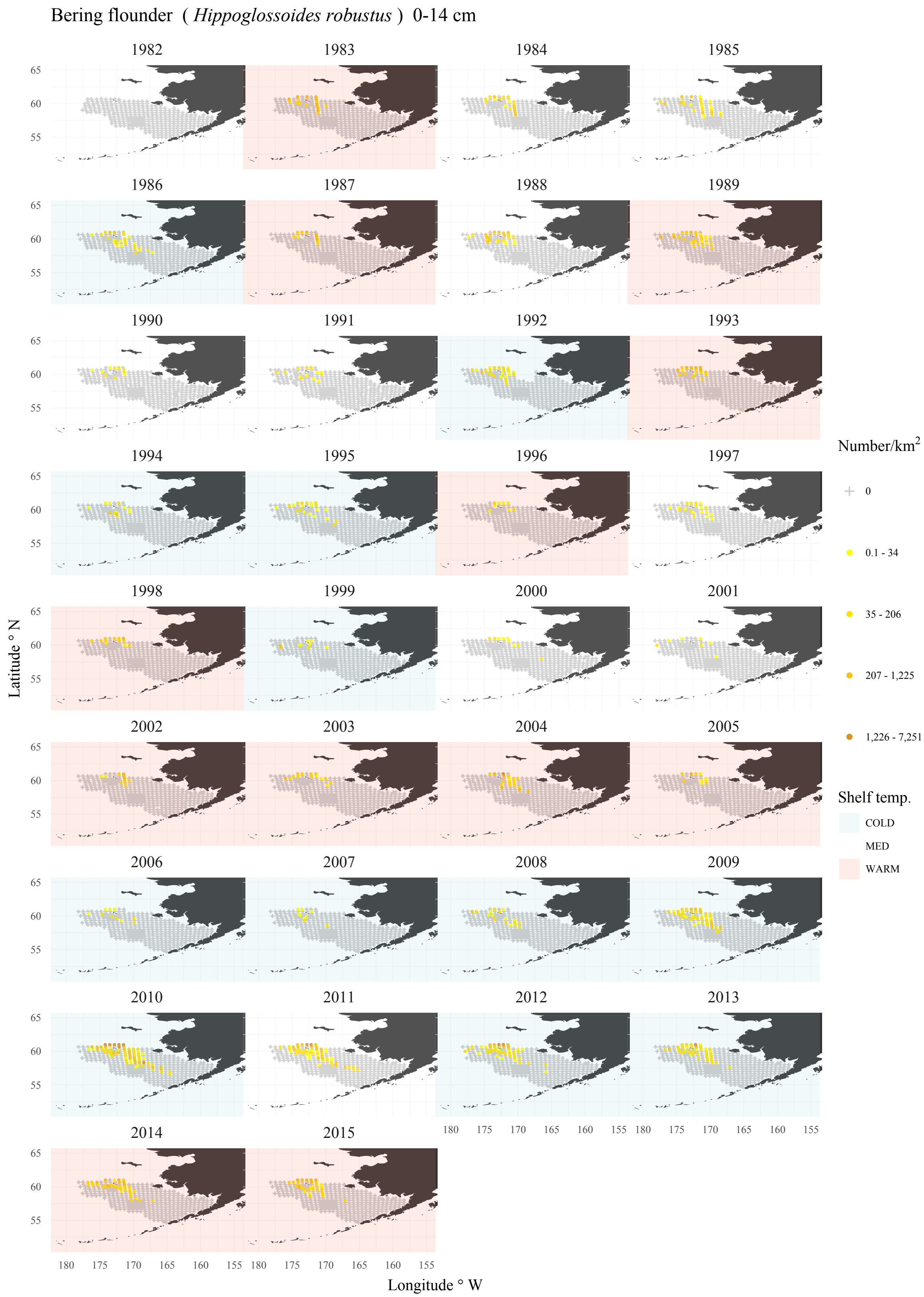


Figure 24 . -- The Bering flounder (*Hippoglossoides robustus*) CPUE by number weighted mean location for each length category for all years.

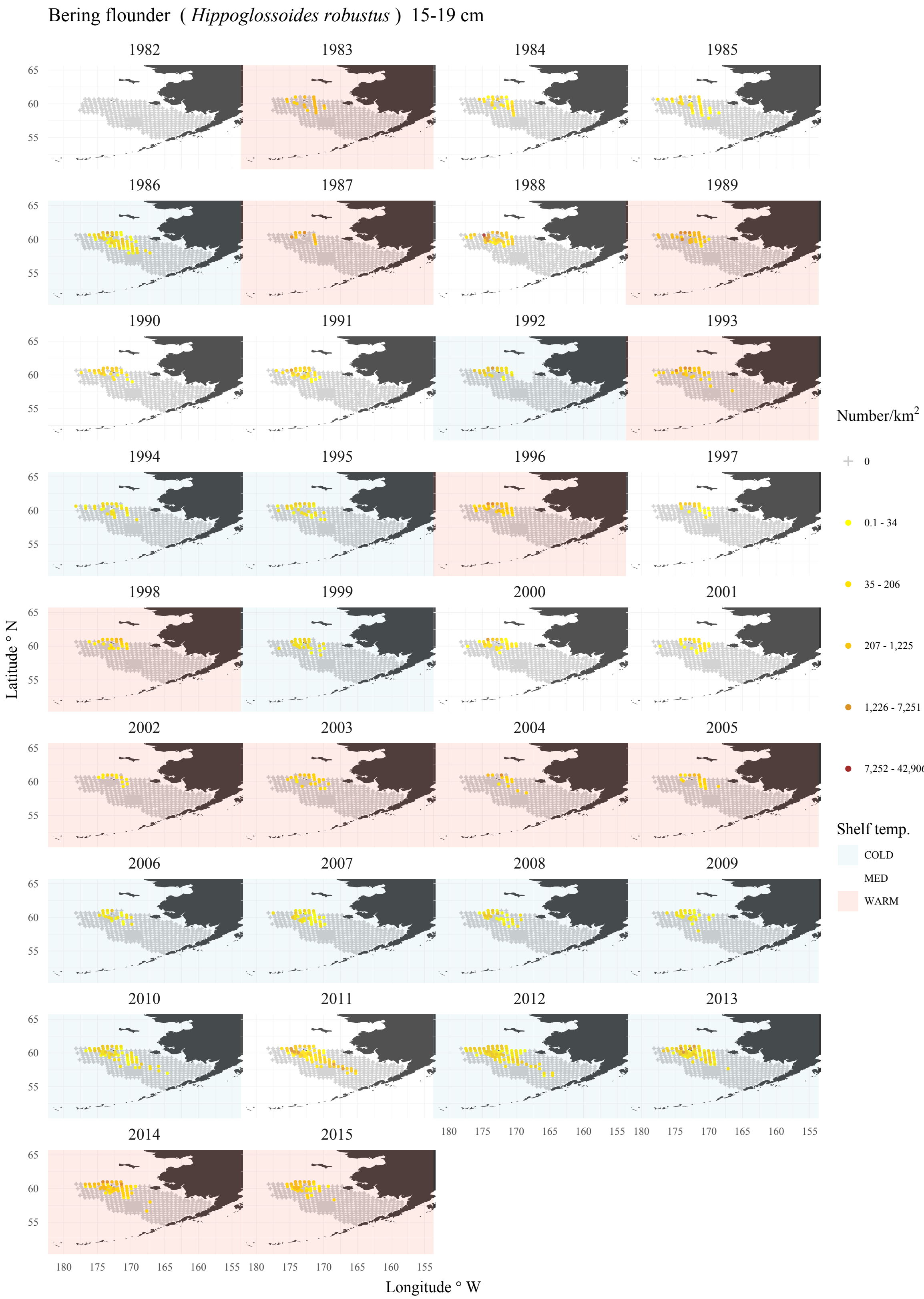


Figure 24 . -- Continued.

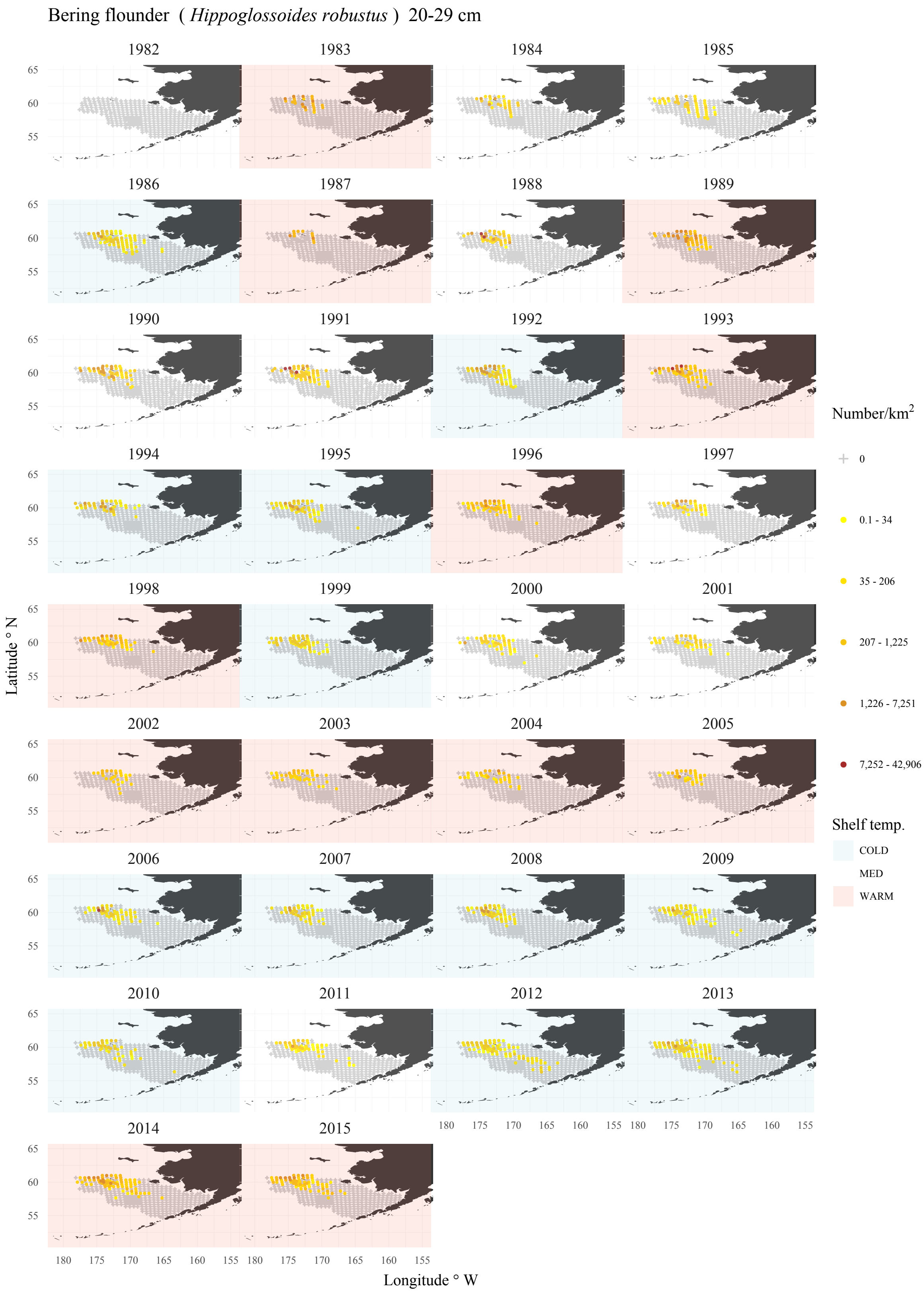
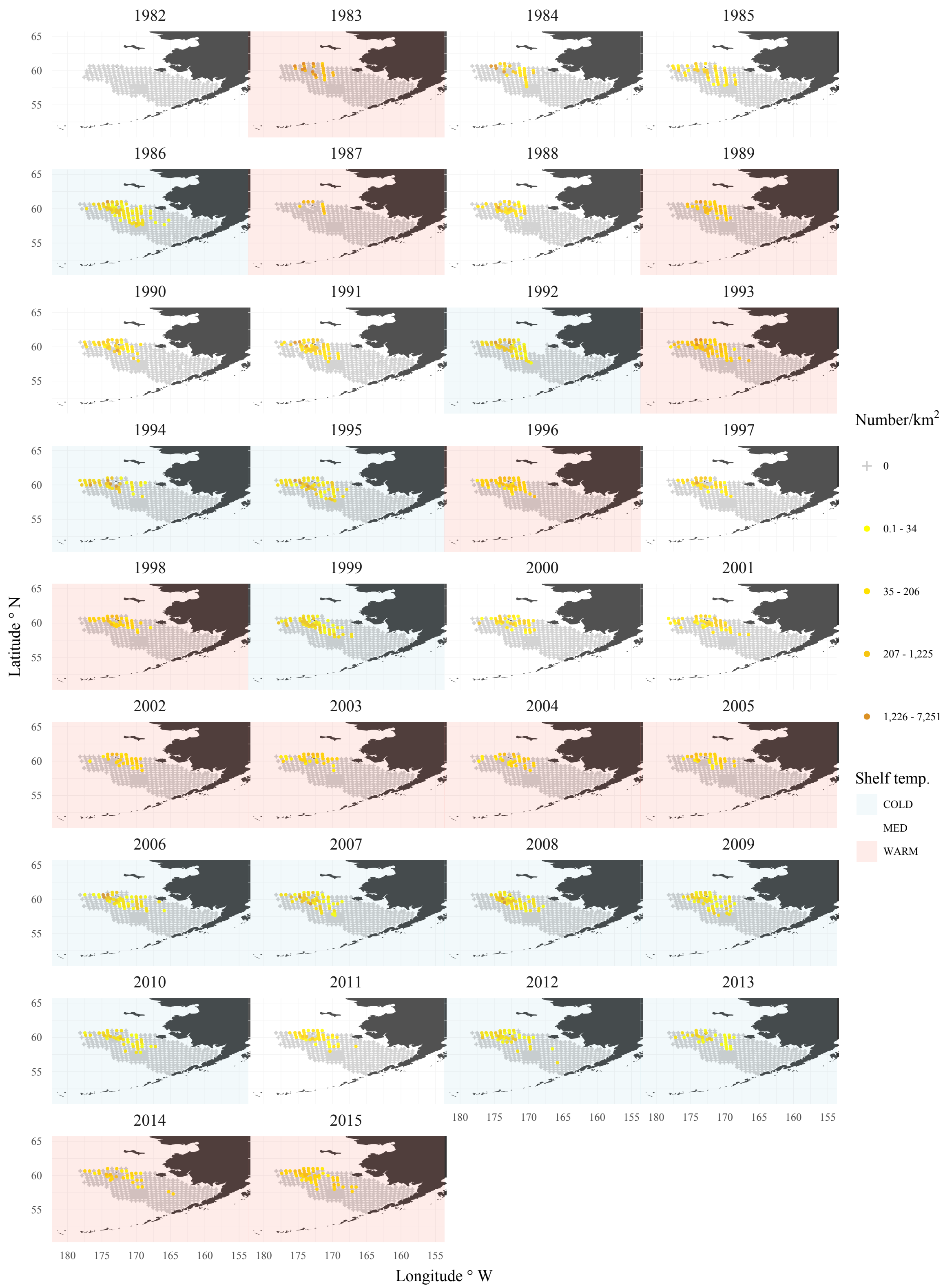


Figure 24 . -- Continued.

Bering flounder (*Hippoglossoides robustus*) 30-35 cm



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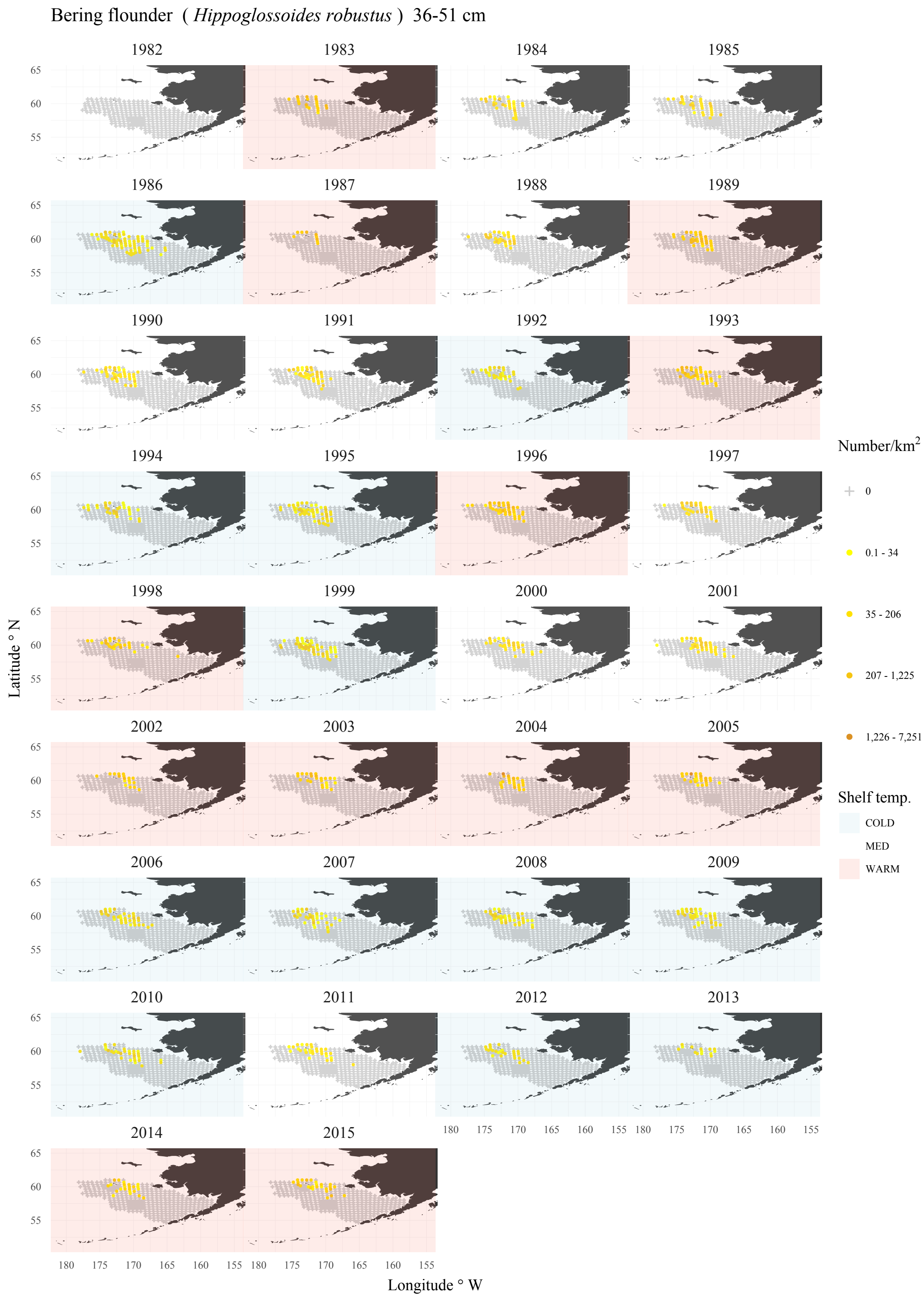


Figure 24 . -- Continued.

Figure 25 . -- The Bering flounder (*Hippoglossoides robustus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

Bering flounder (*Hippoglossoides robustus*) 15-19 cm

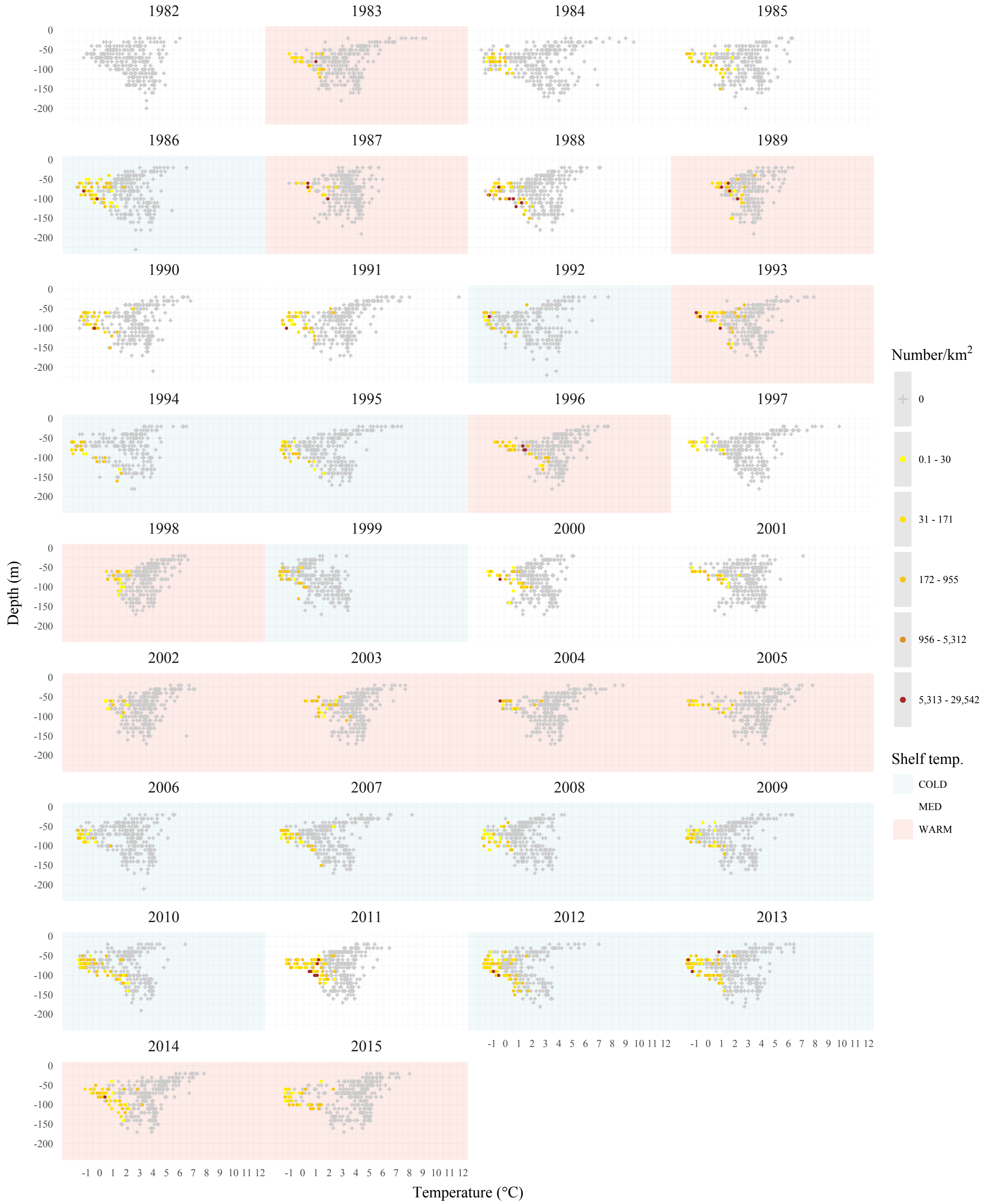


Figure 25 . -- Continued.

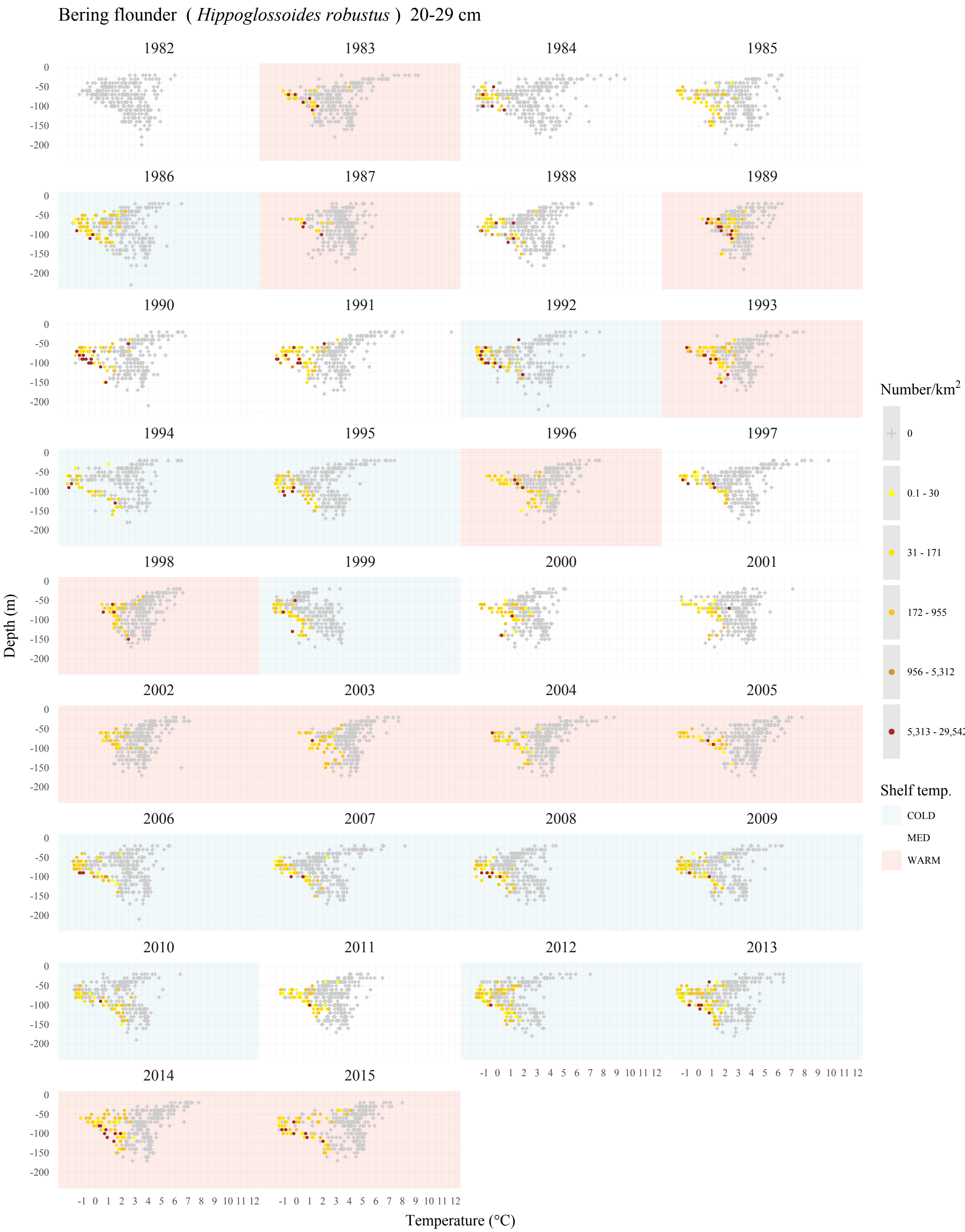


Figure 25 . -- Continued.

Bering flounder (*Hippoglossoides robustus*) 30-35 cm

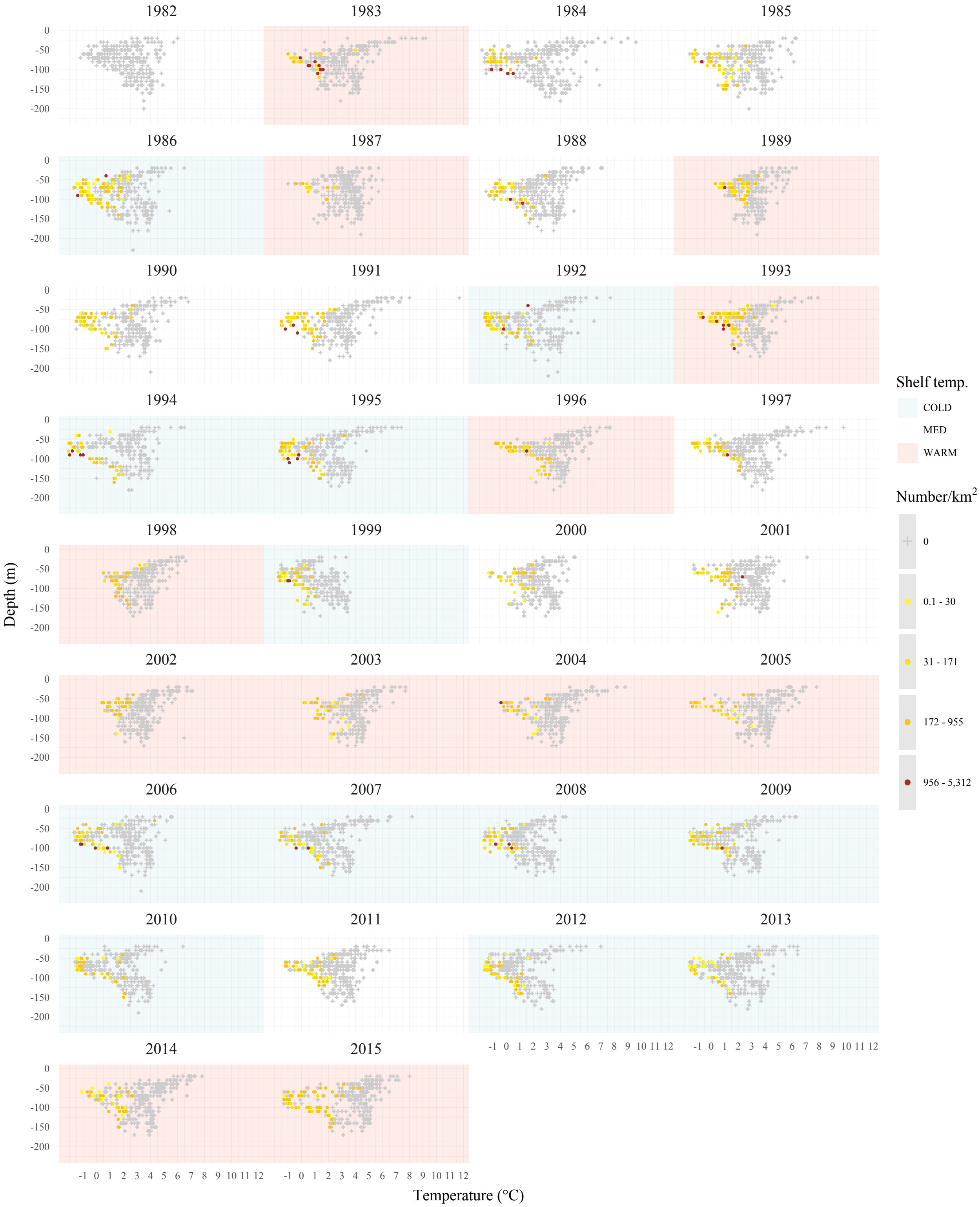
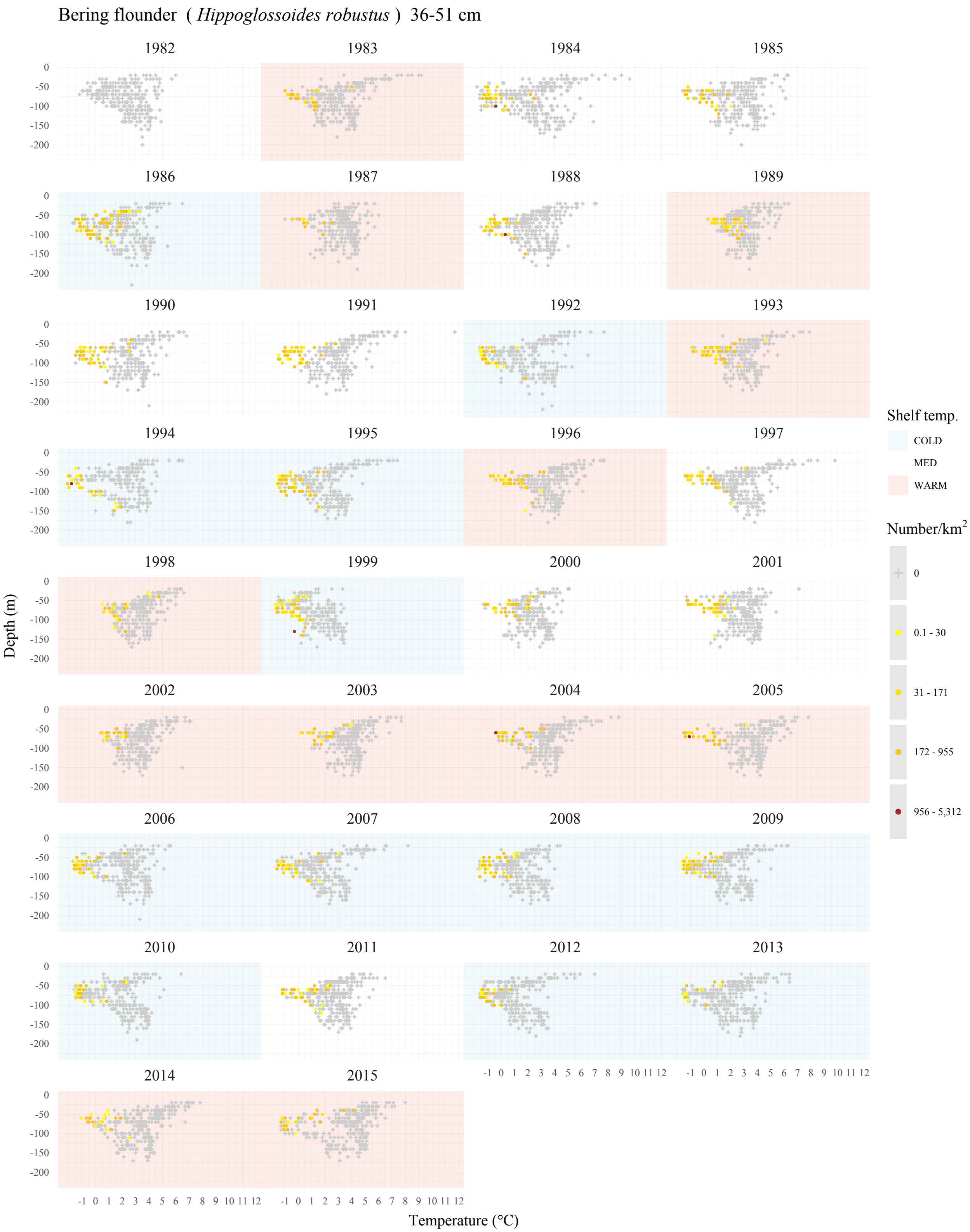


Figure 25 . -- Continued.



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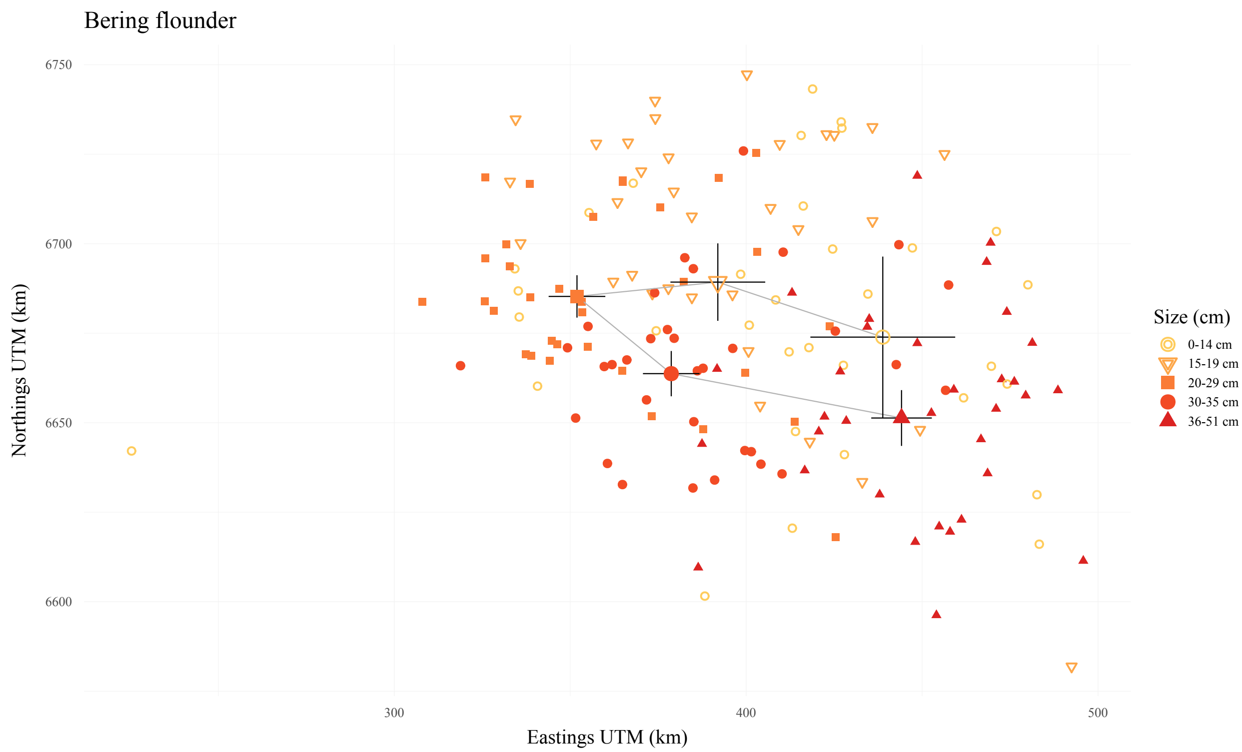


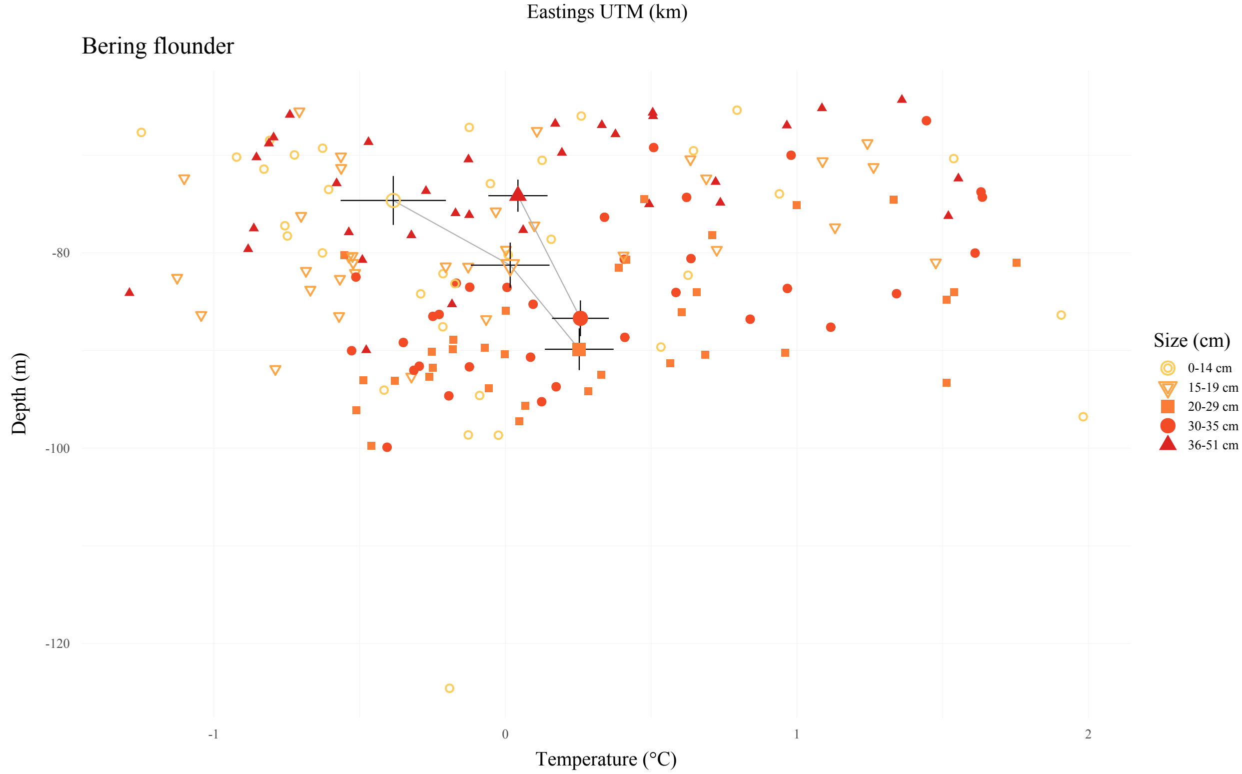


Figure 26 . -- The Bering flounder (*Hippoglossoides robustus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

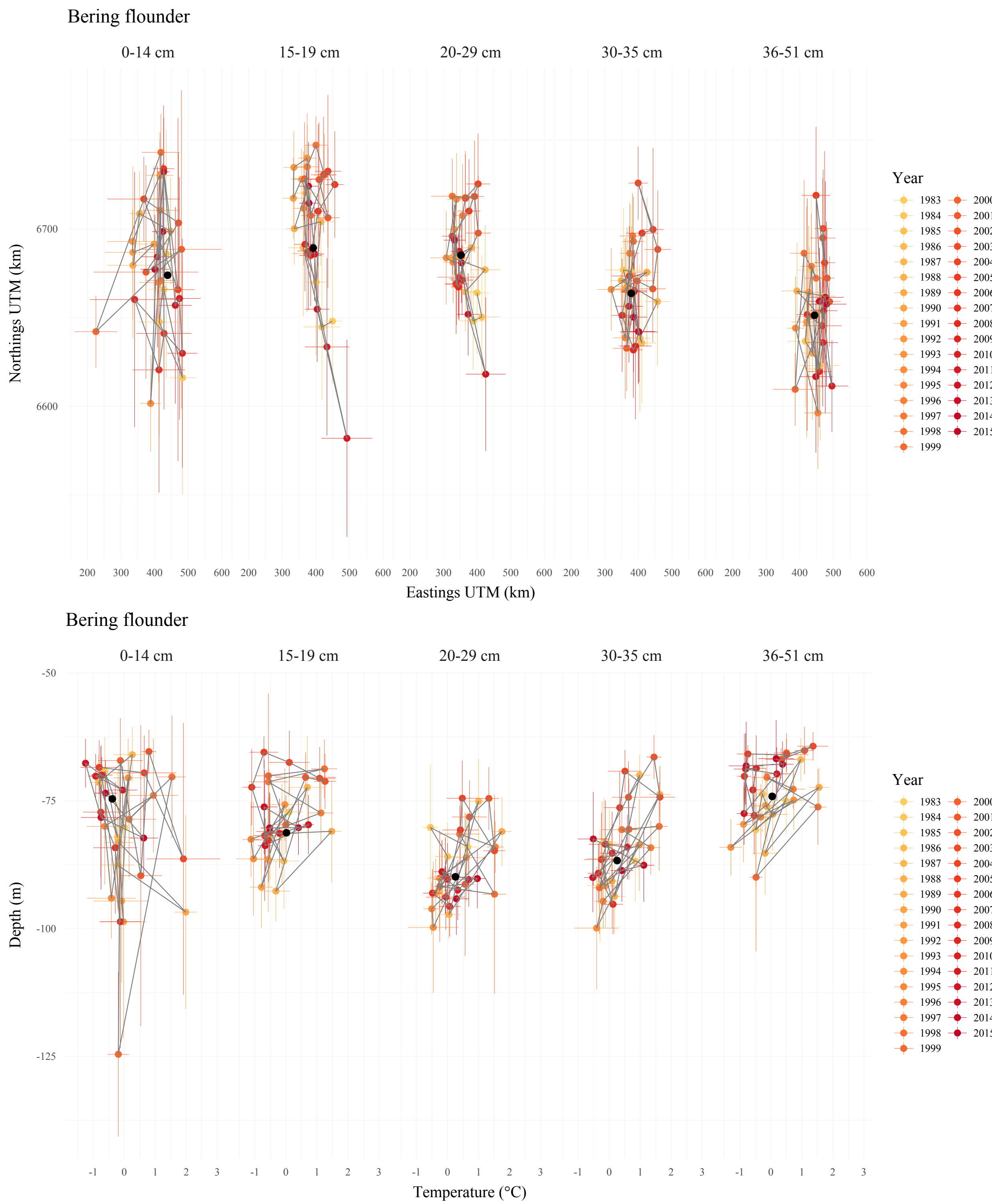


Figure 27 . -- The Bering flounder (*Hippoglossoides robustus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

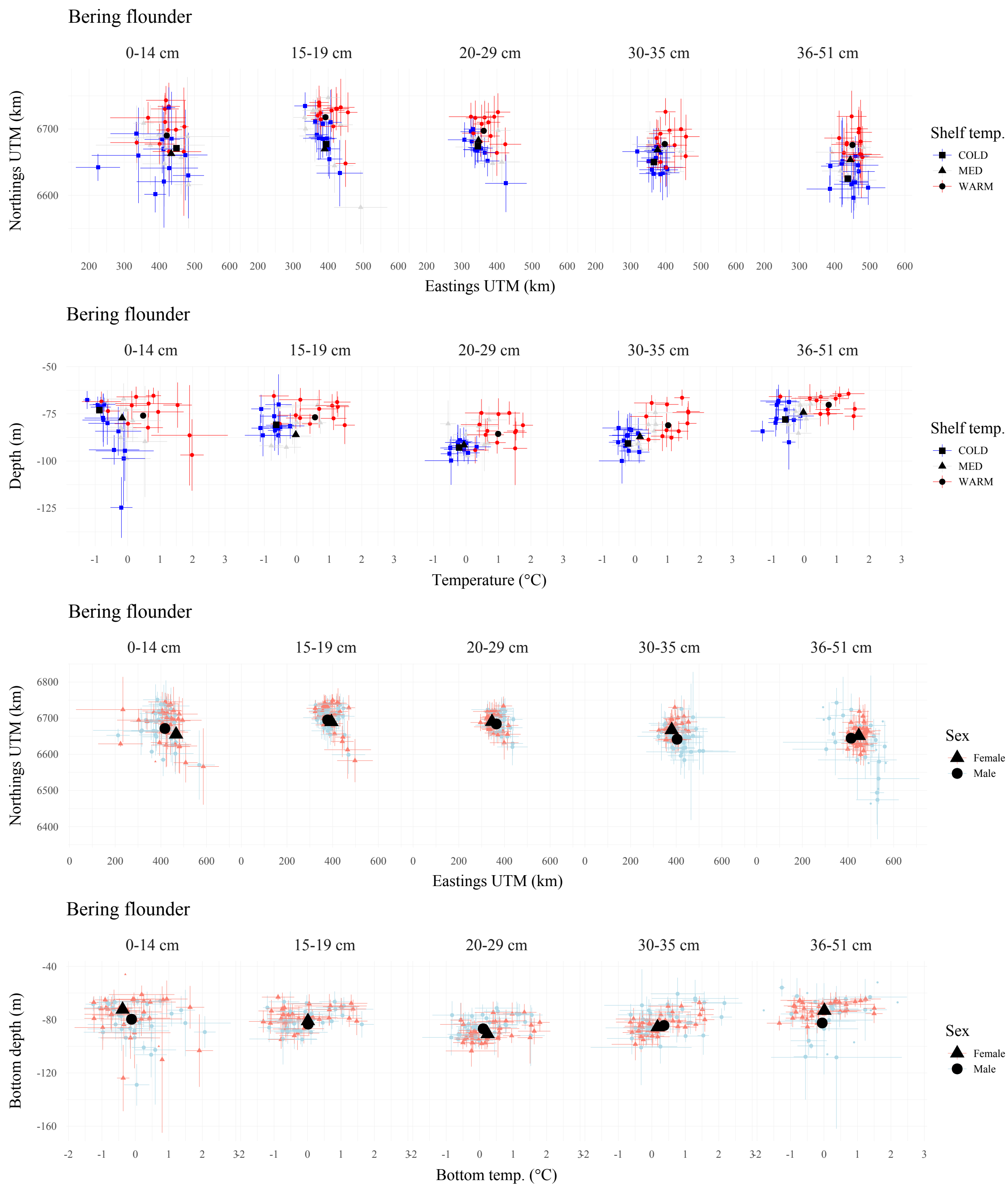


Figure 28 . -- The Bering flounder (*Hippoglossoides robustus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

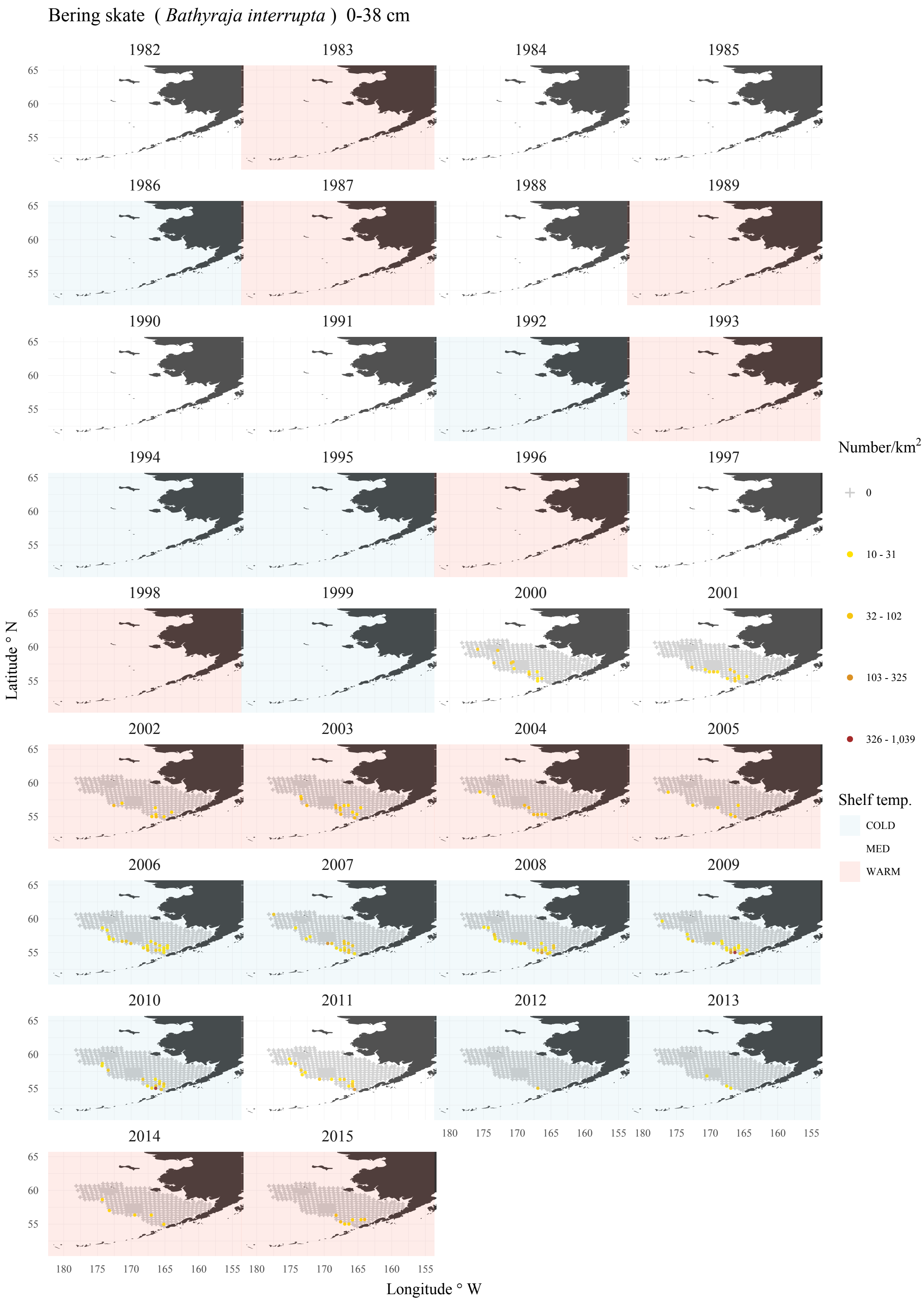


Figure 29 . -- The Bering skate (*Bathyraja interrupta*) CPUE by number weighted mean location for each length category for all years.

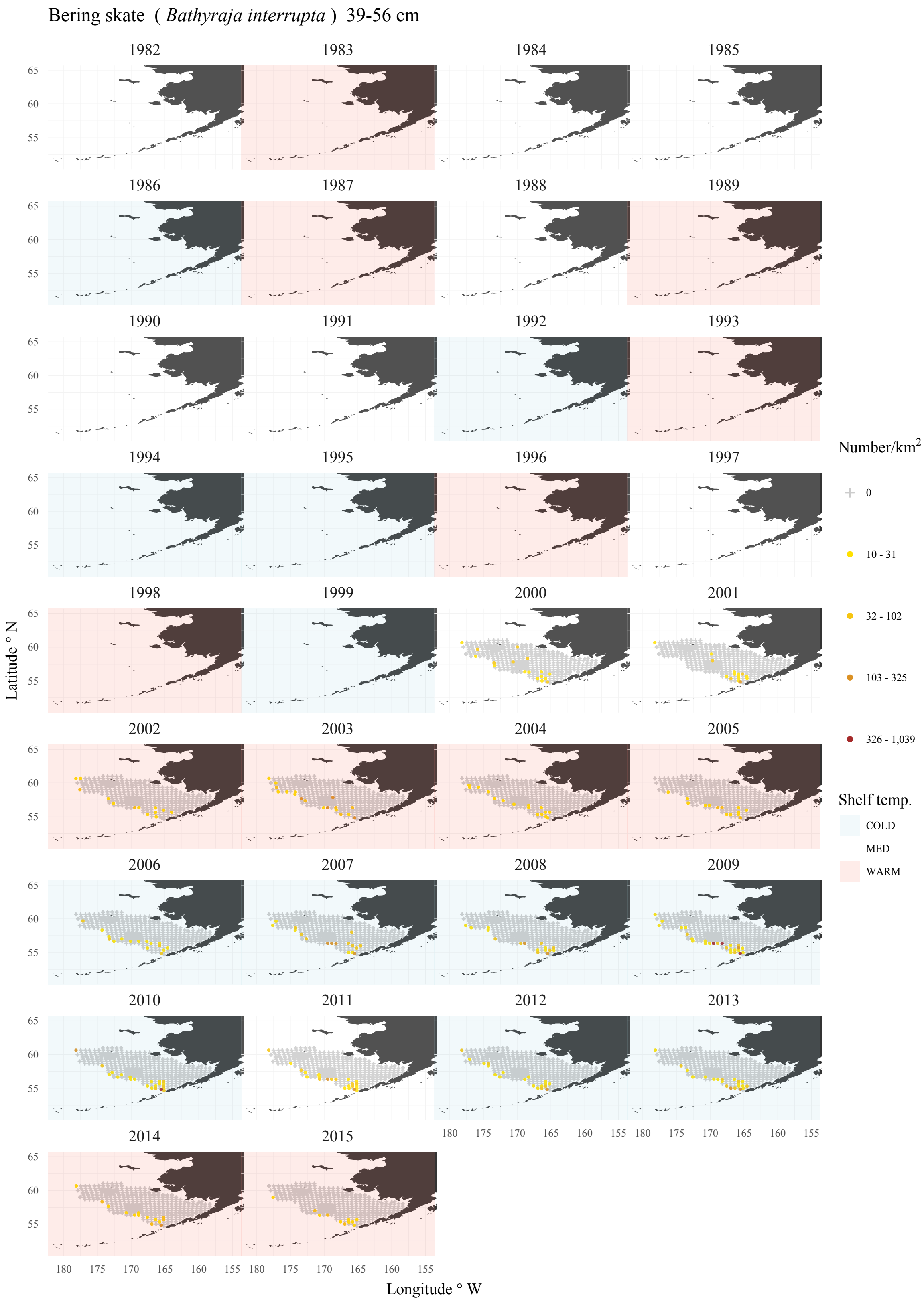


Figure 29 . -- Continued.

Bering skate (*Bathyraja interrupta*) 57-72 cm

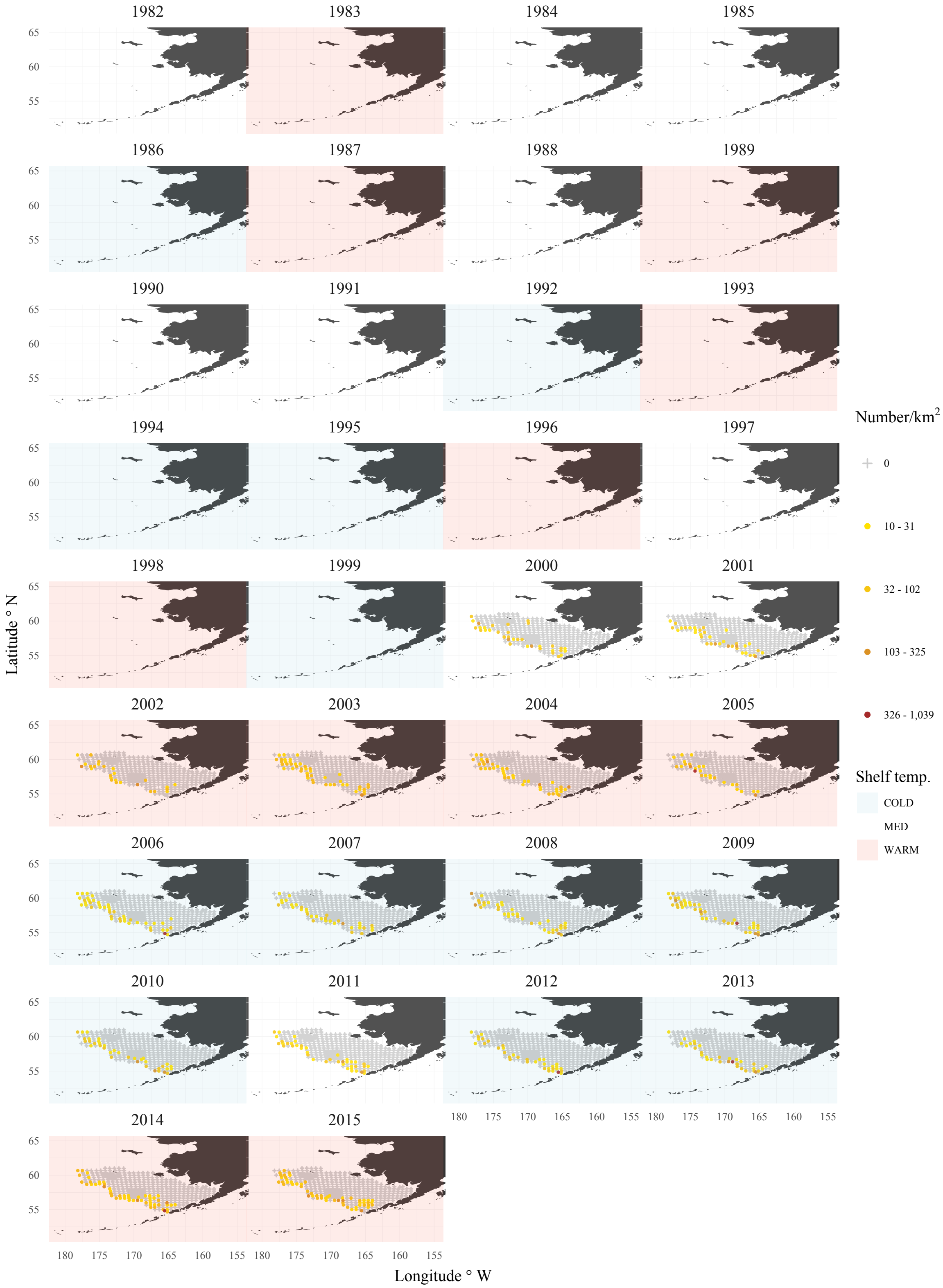


Figure 29 . -- Continued.

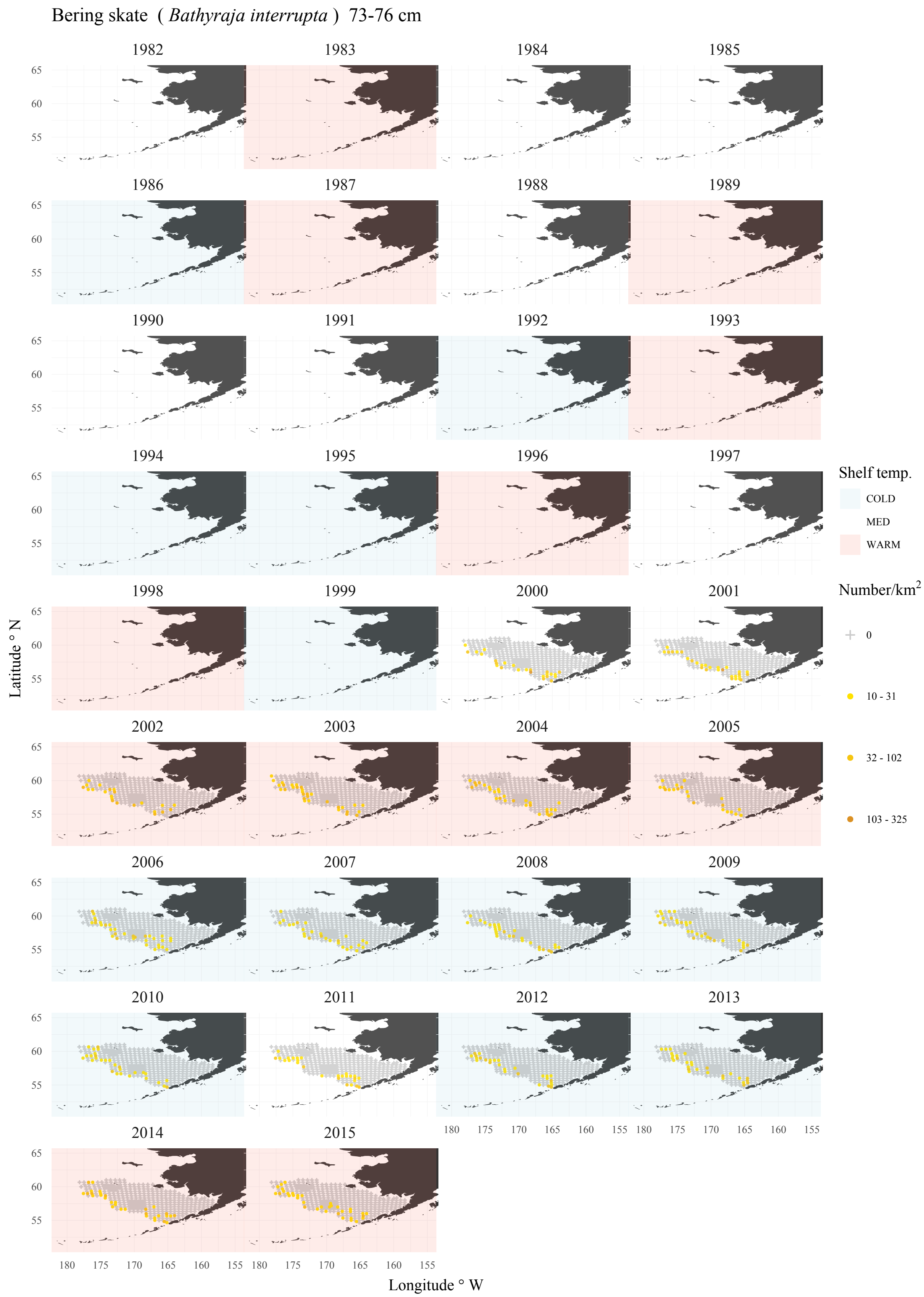


Figure 29 . -- Continued.

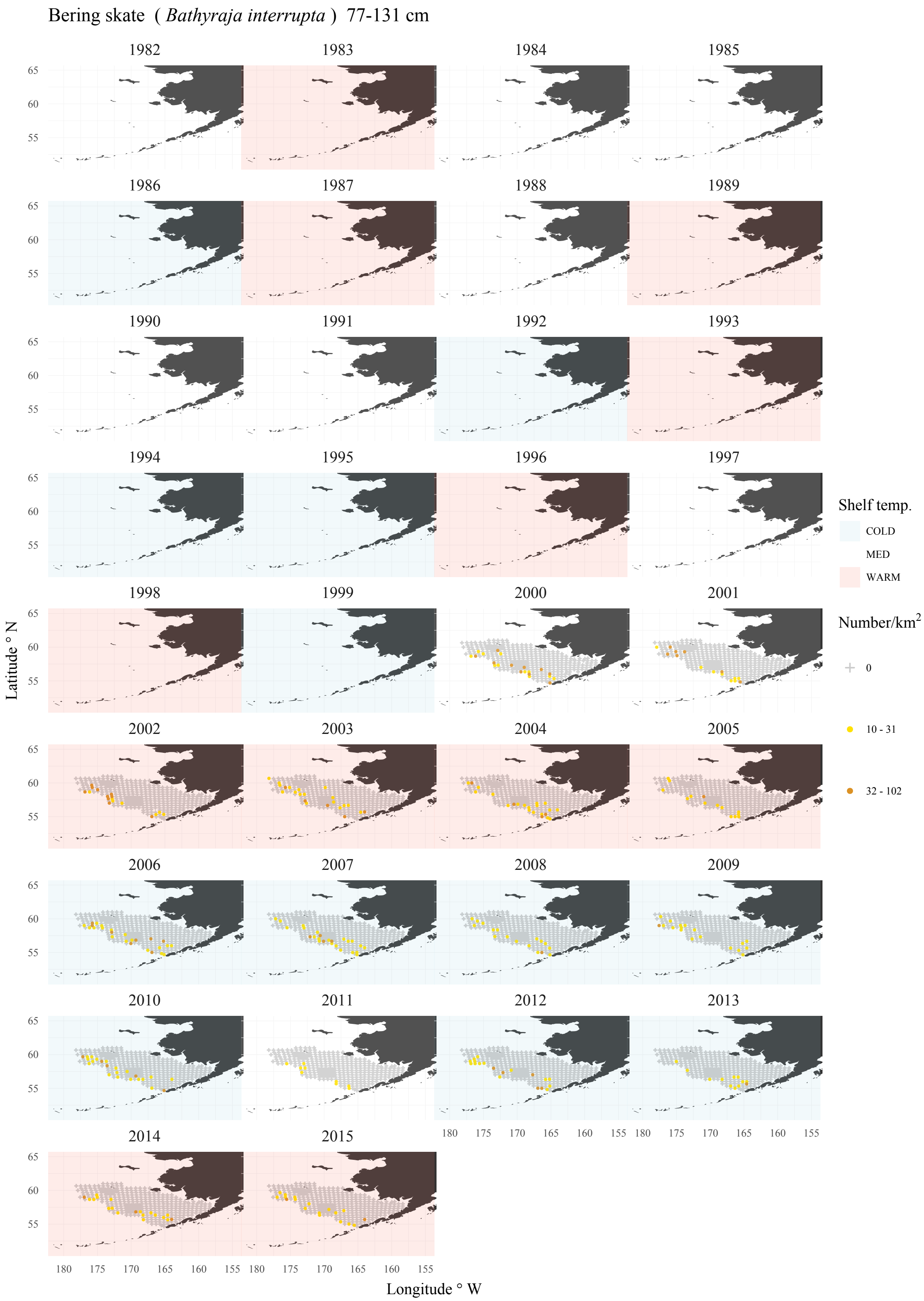


Figure 29 . -- Continued.

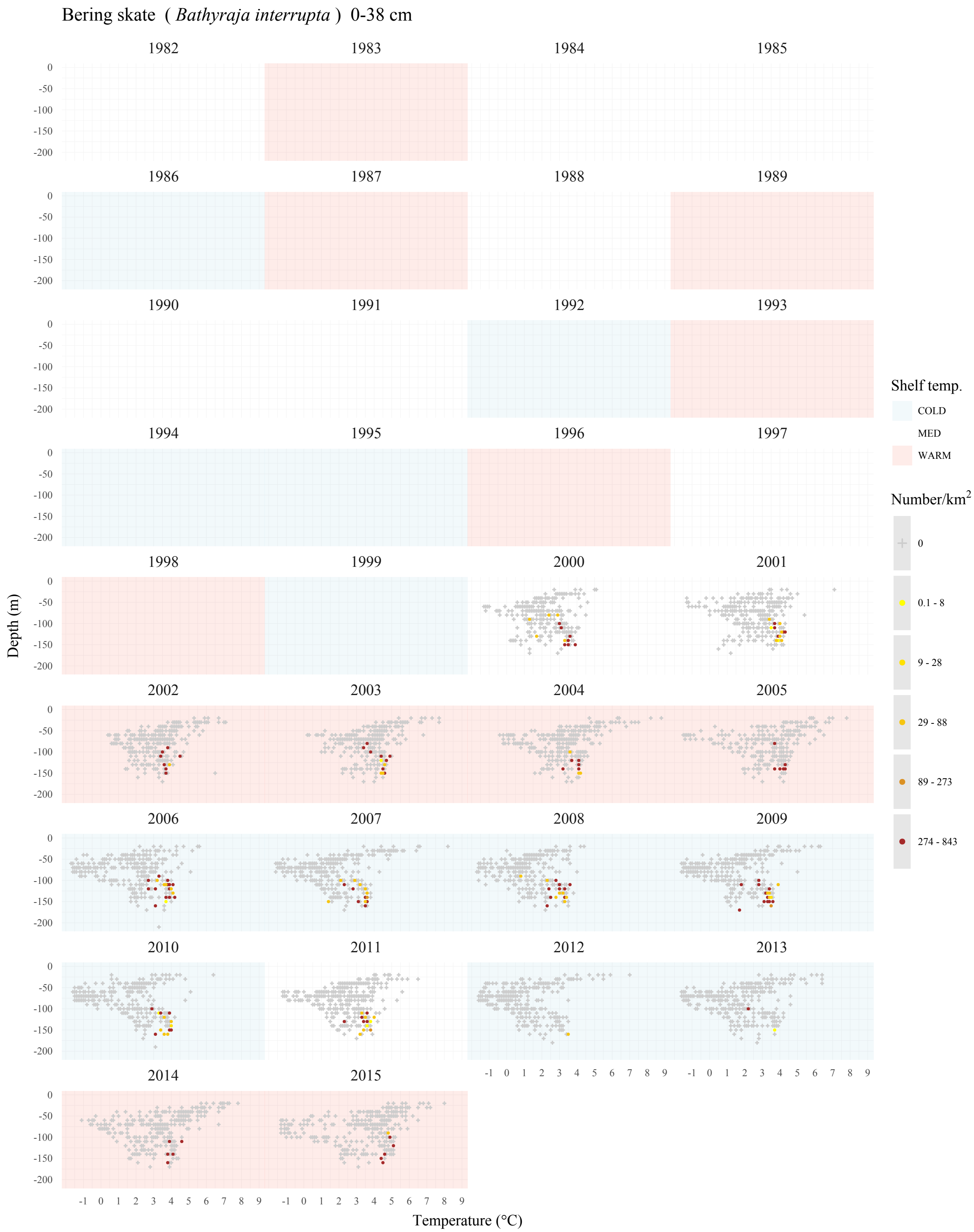


Figure 30 . -- The Bering skate (*Bathyraja interrupta*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

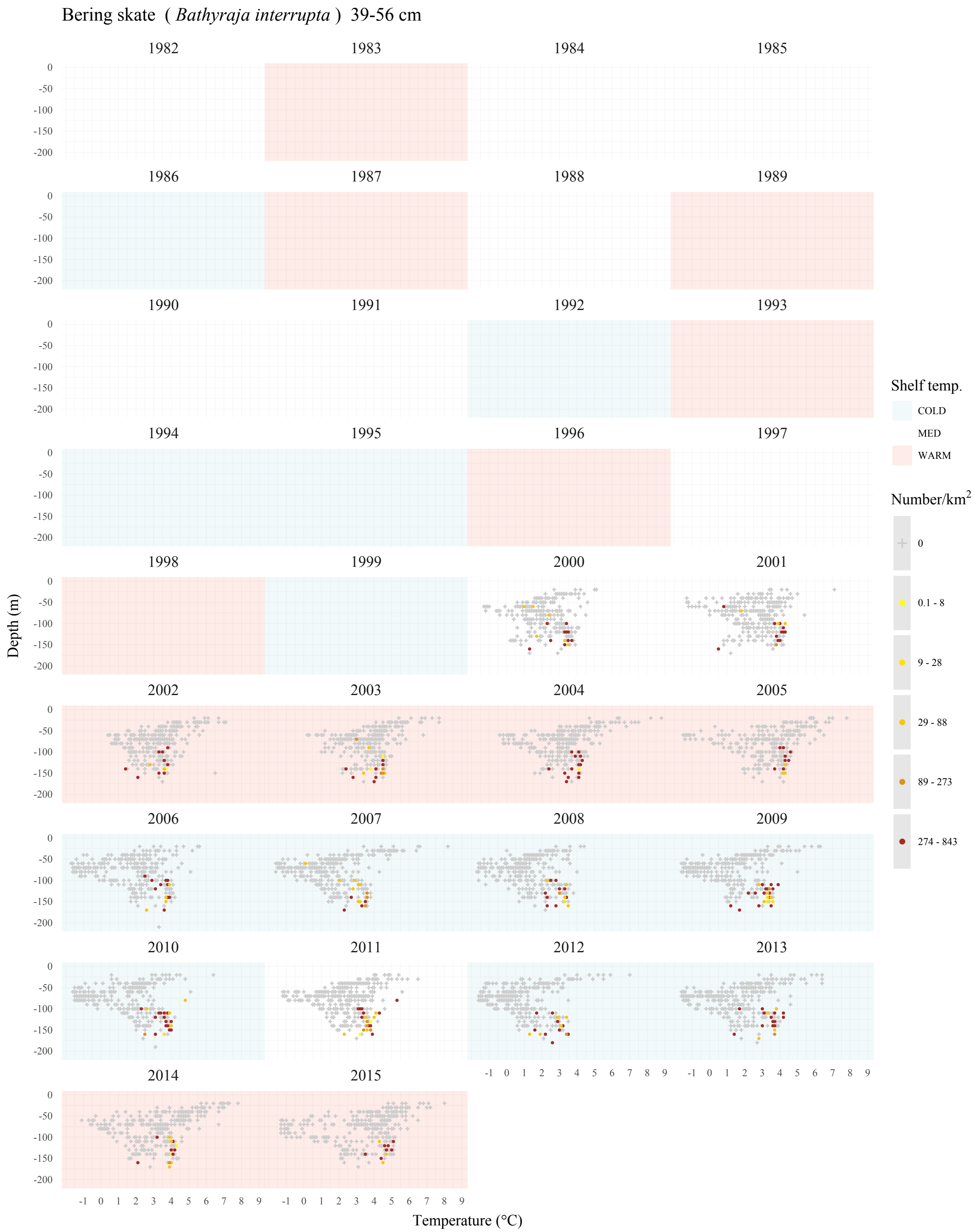


Figure 30 . -- Continued.

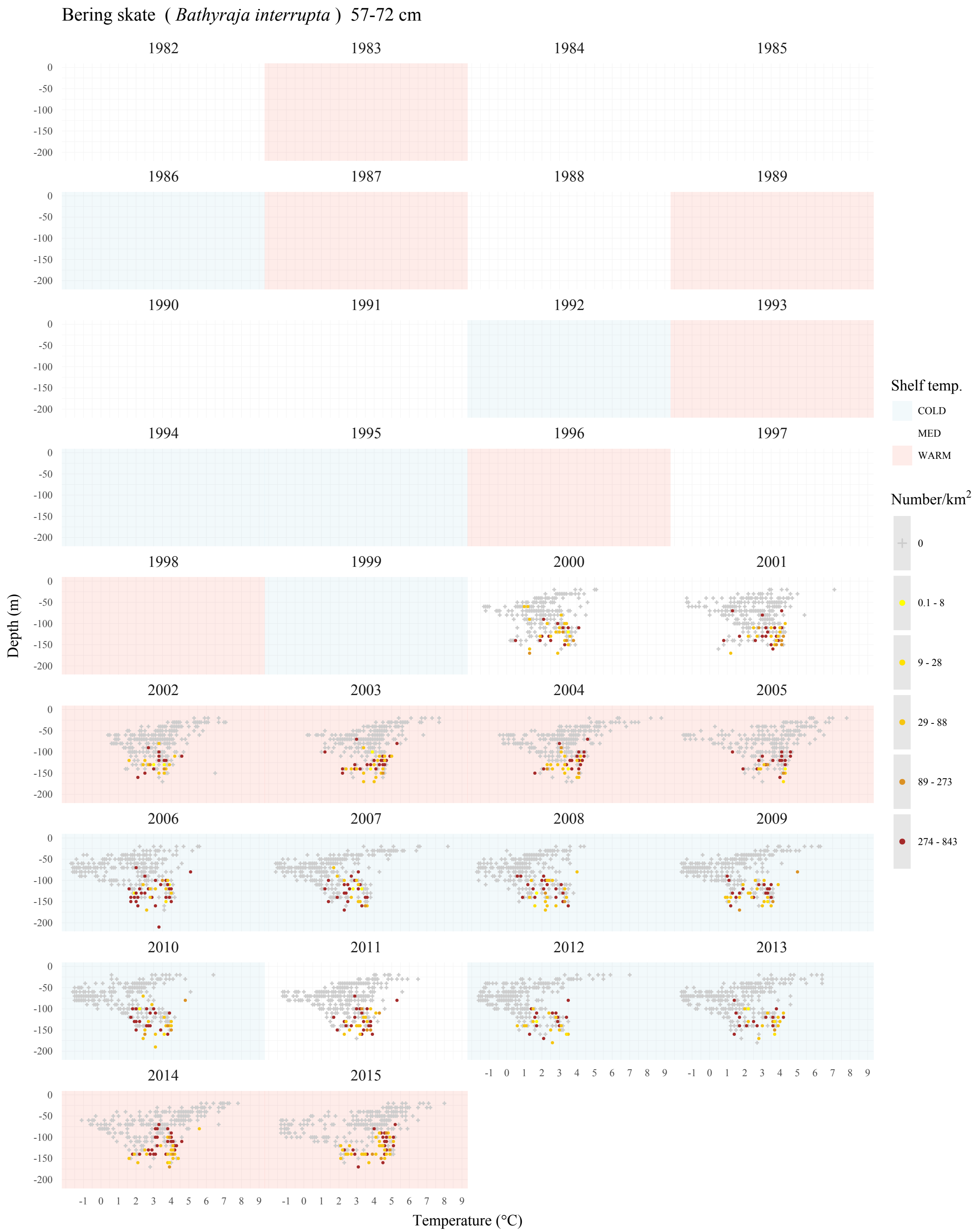


Figure 30 . -- Continued.

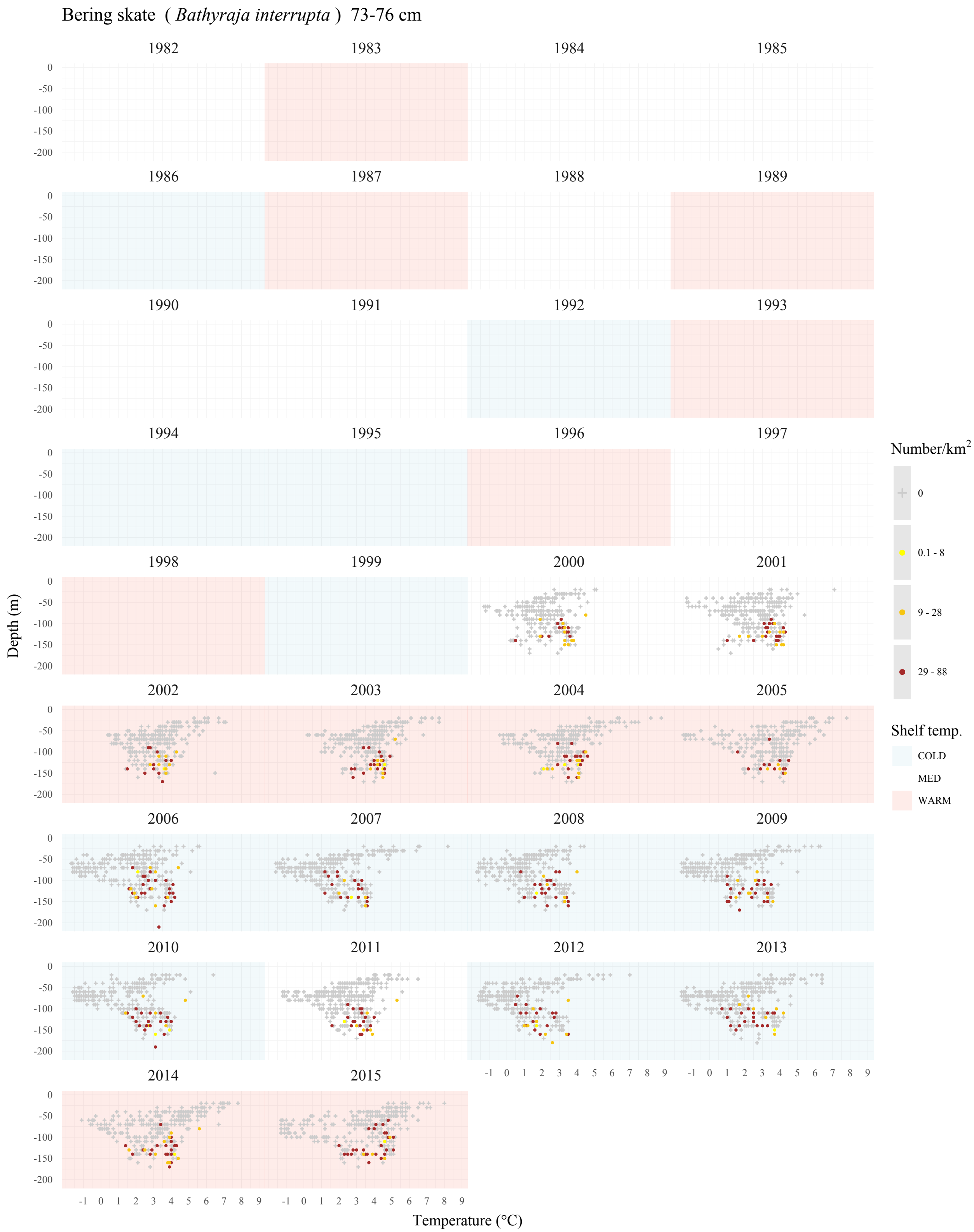


Figure 30 . -- Continued.

Bering skate (*Bathyraja interrupta*) 77-131 cm

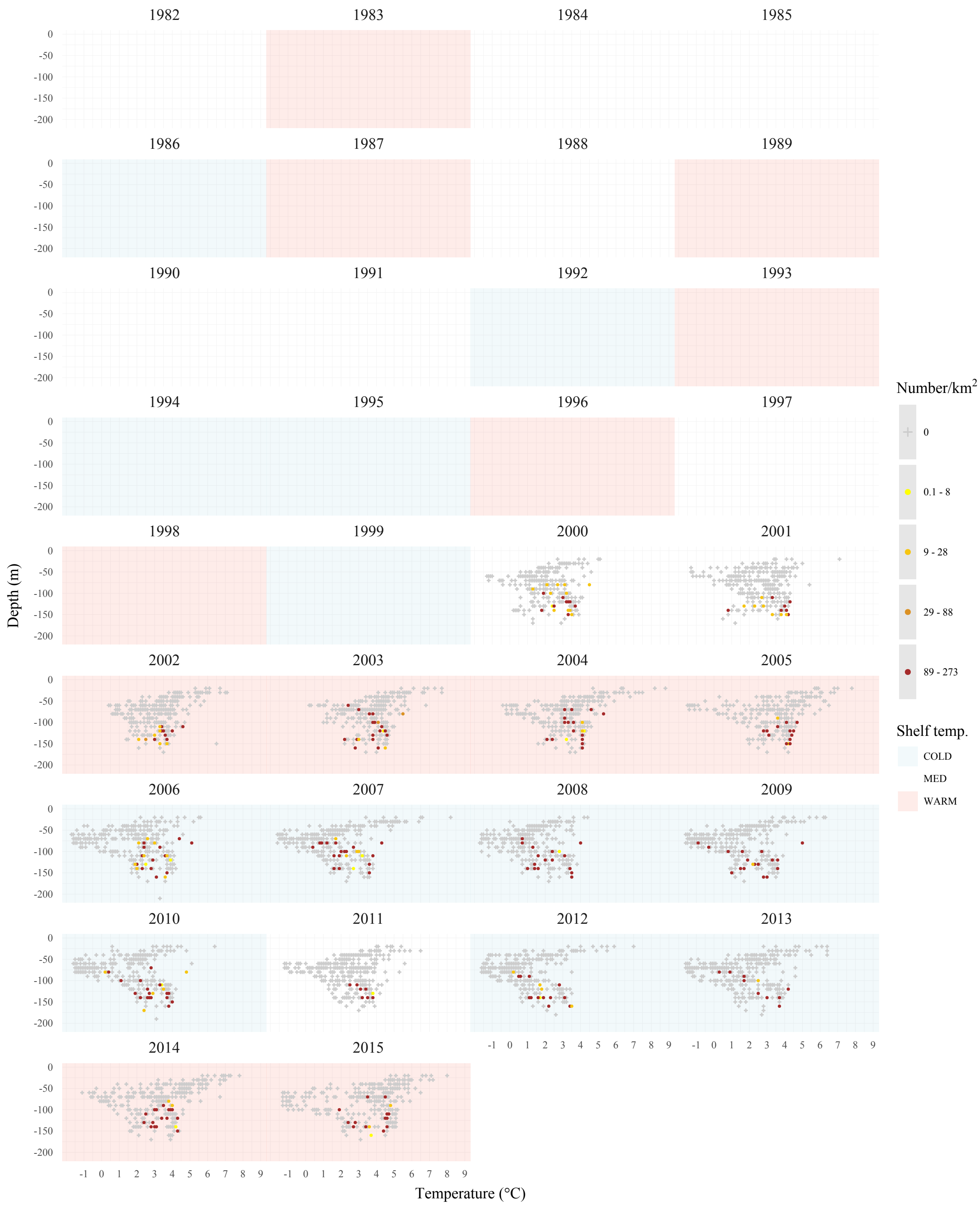
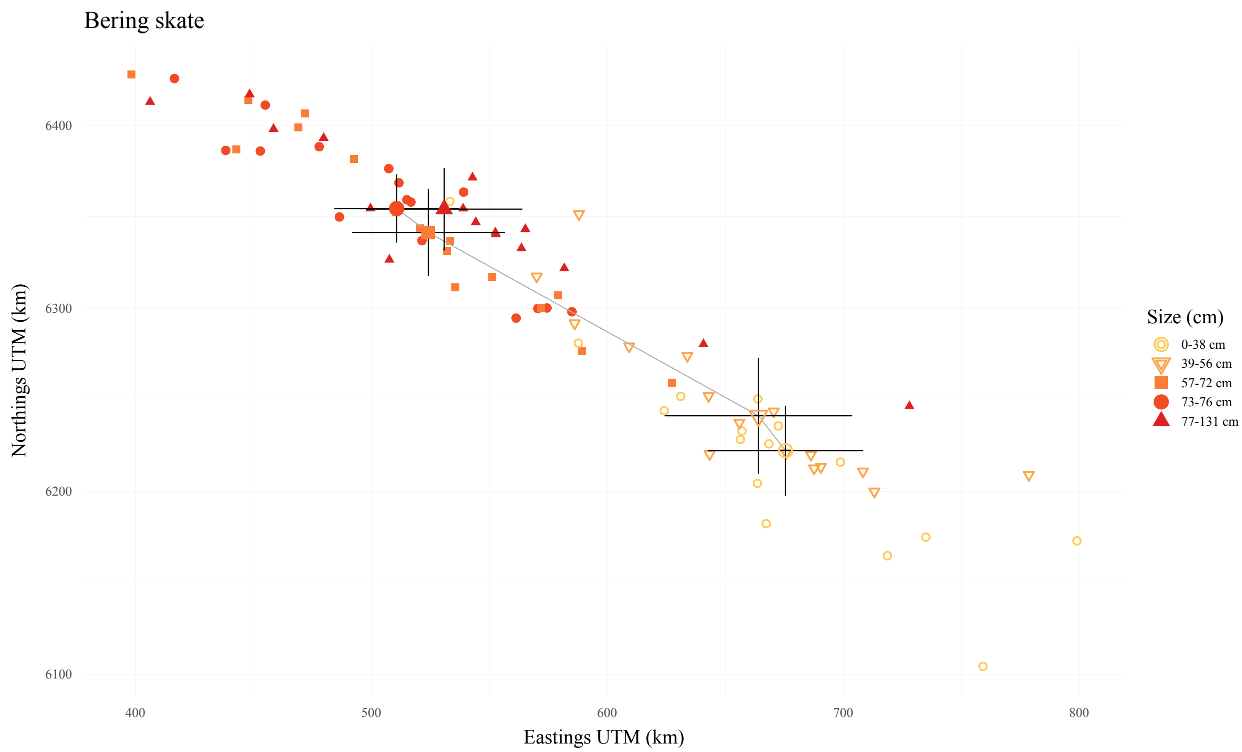


Figure 30 . -- Continued.



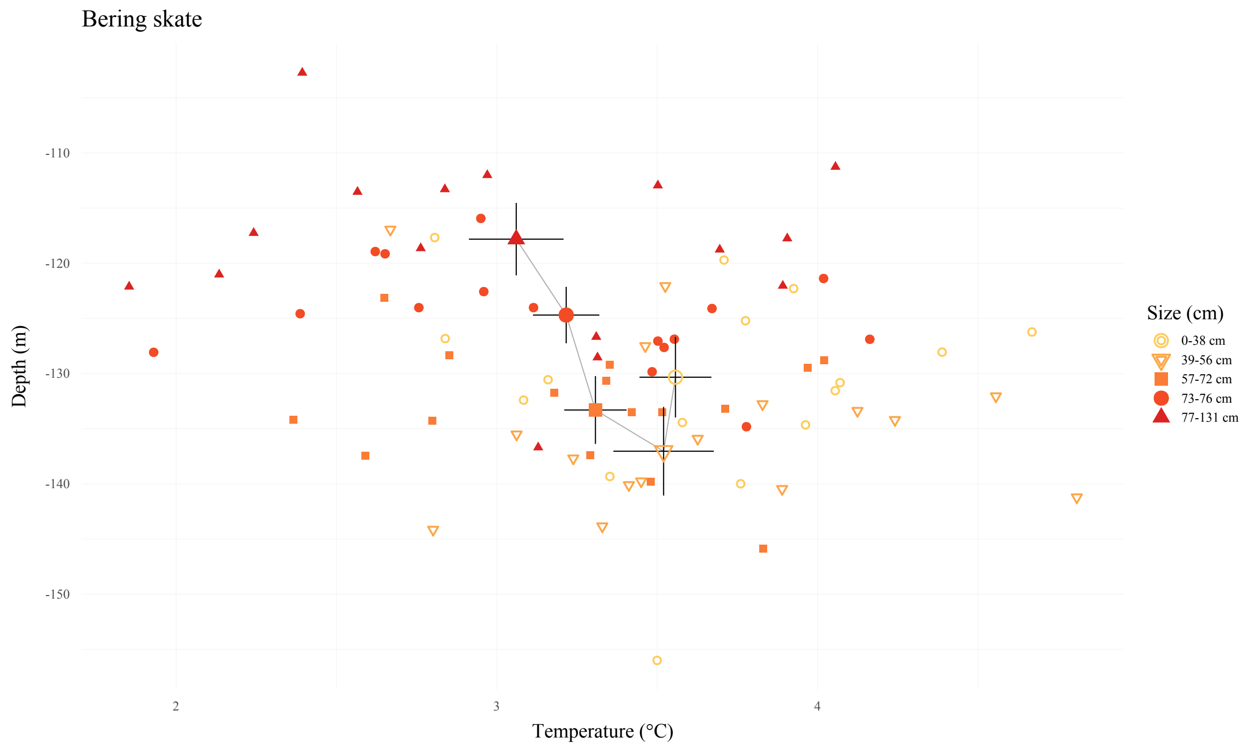


Figure 31 . -- The Bering skate (*Bathyraja interrupta*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

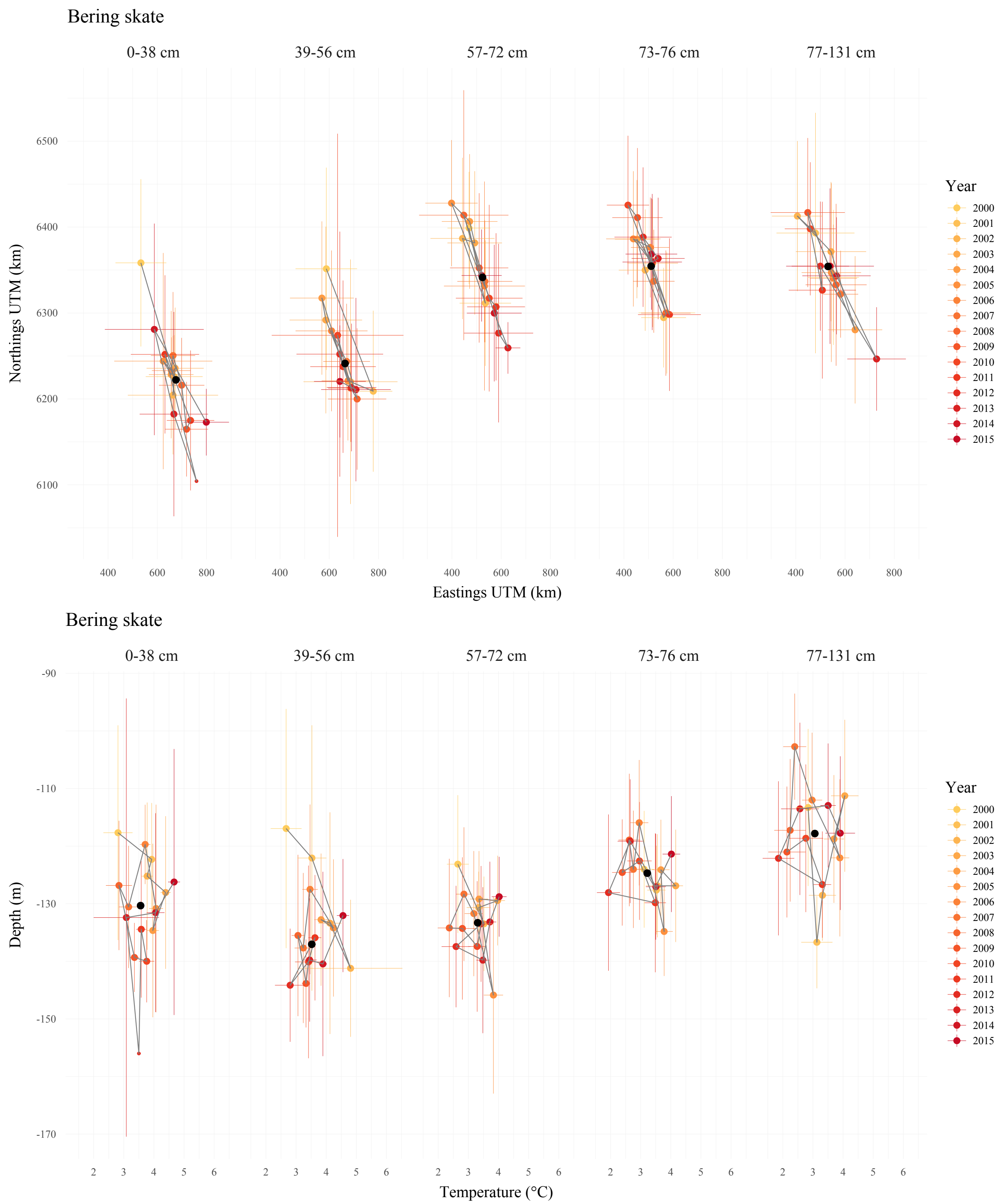


Figure 32 . -- The Bering skate (*Bathyraja interrupta*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

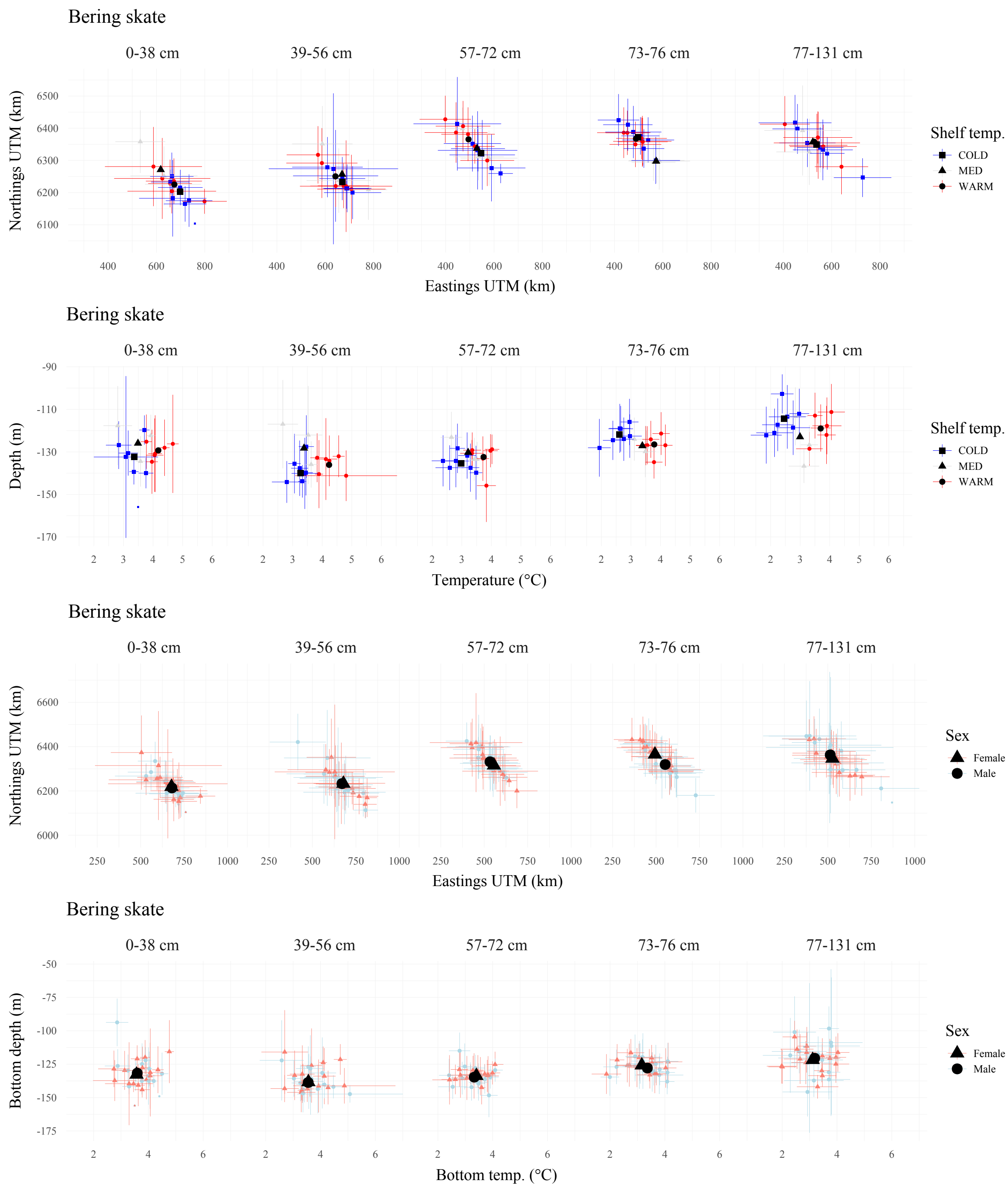


Figure 33 . -- The Bering skate (*Bathyraja interrupta*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

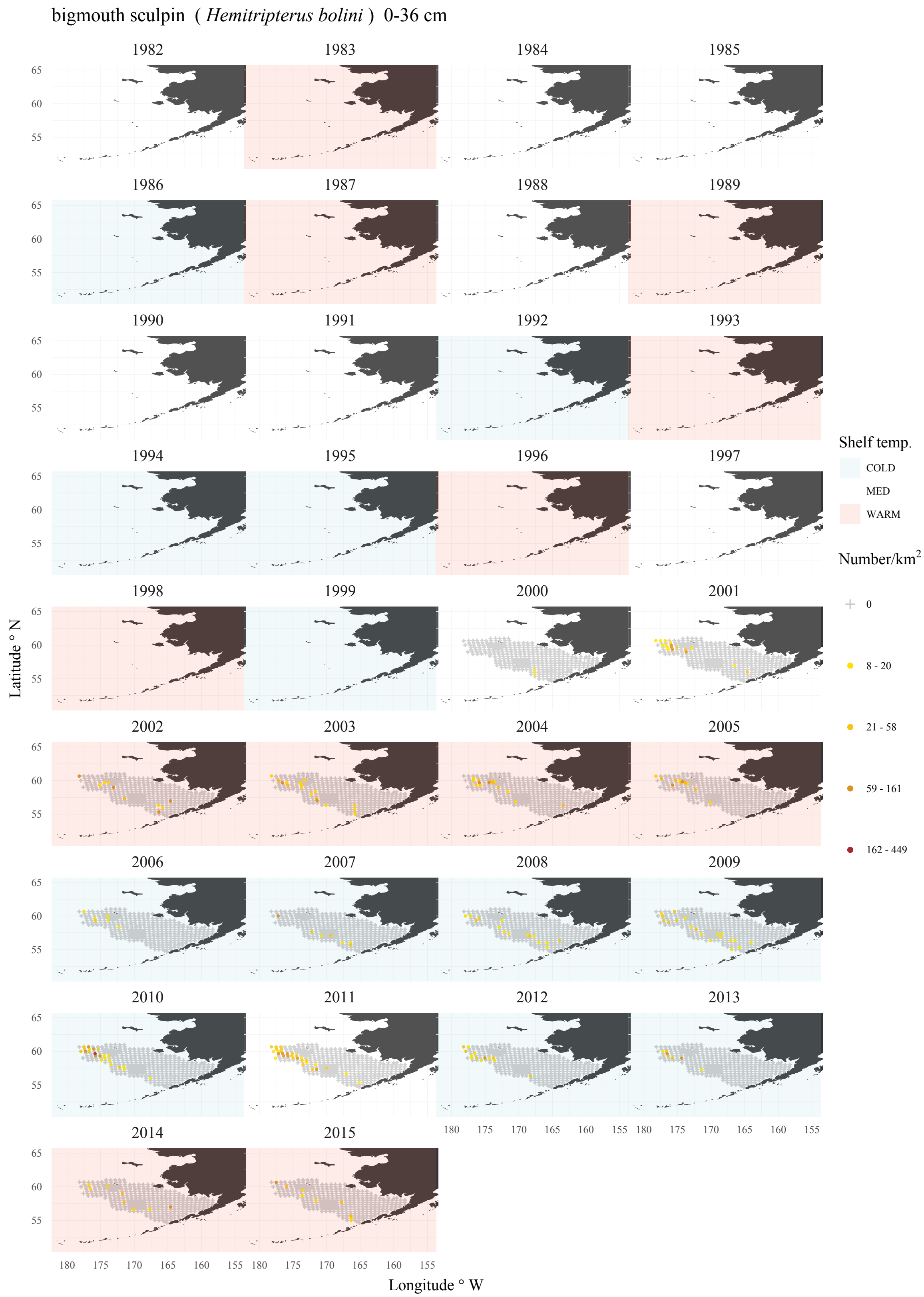


Figure 34 . -- The bigmouth sculpin (*Hemitripterus bolini*) CPUE by number weighted mean location for each length category for all years.

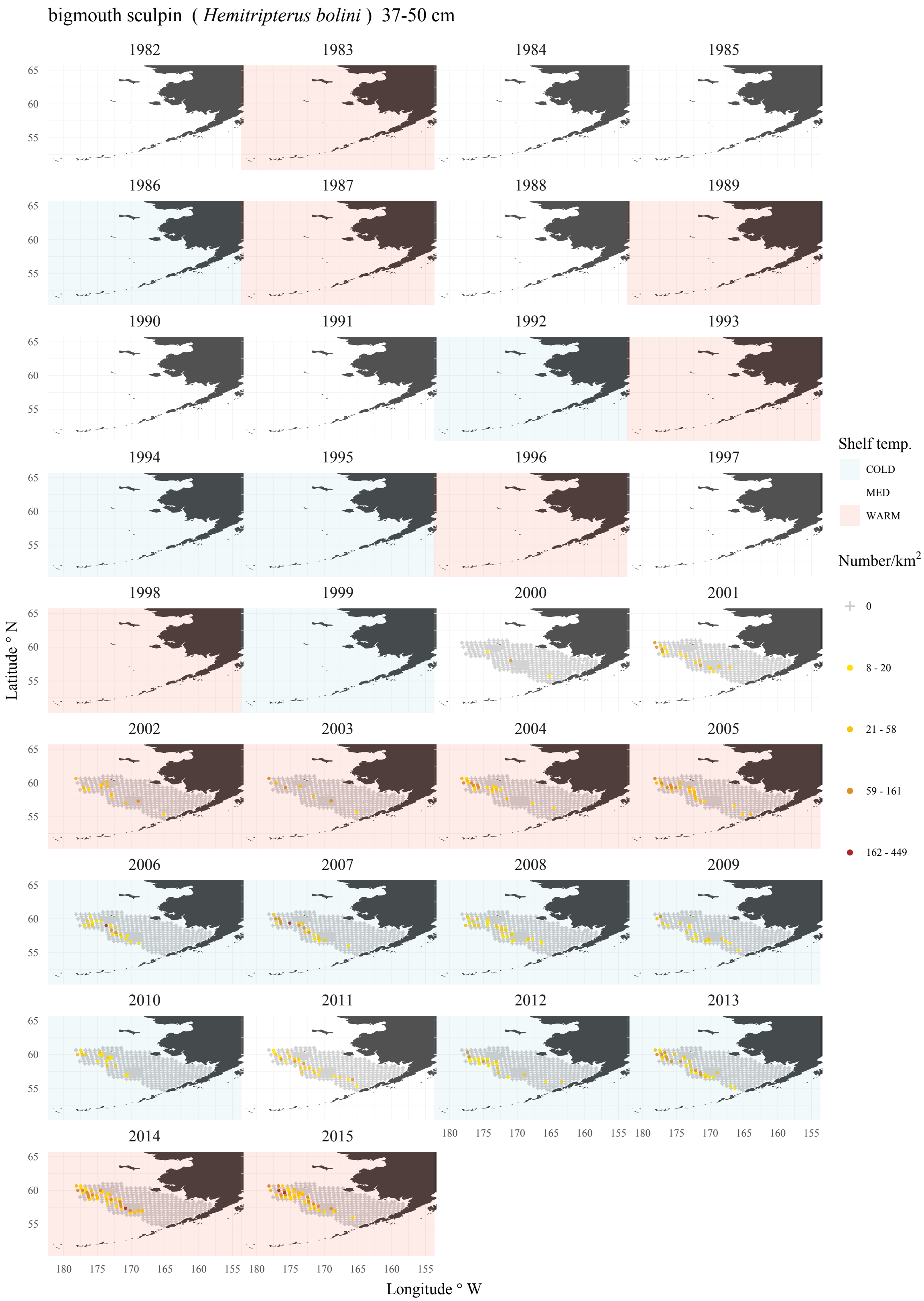


Figure 34 . -- Continued.

bigmouth sculpin (*Hemitripterus bolini*) 51-63 cm

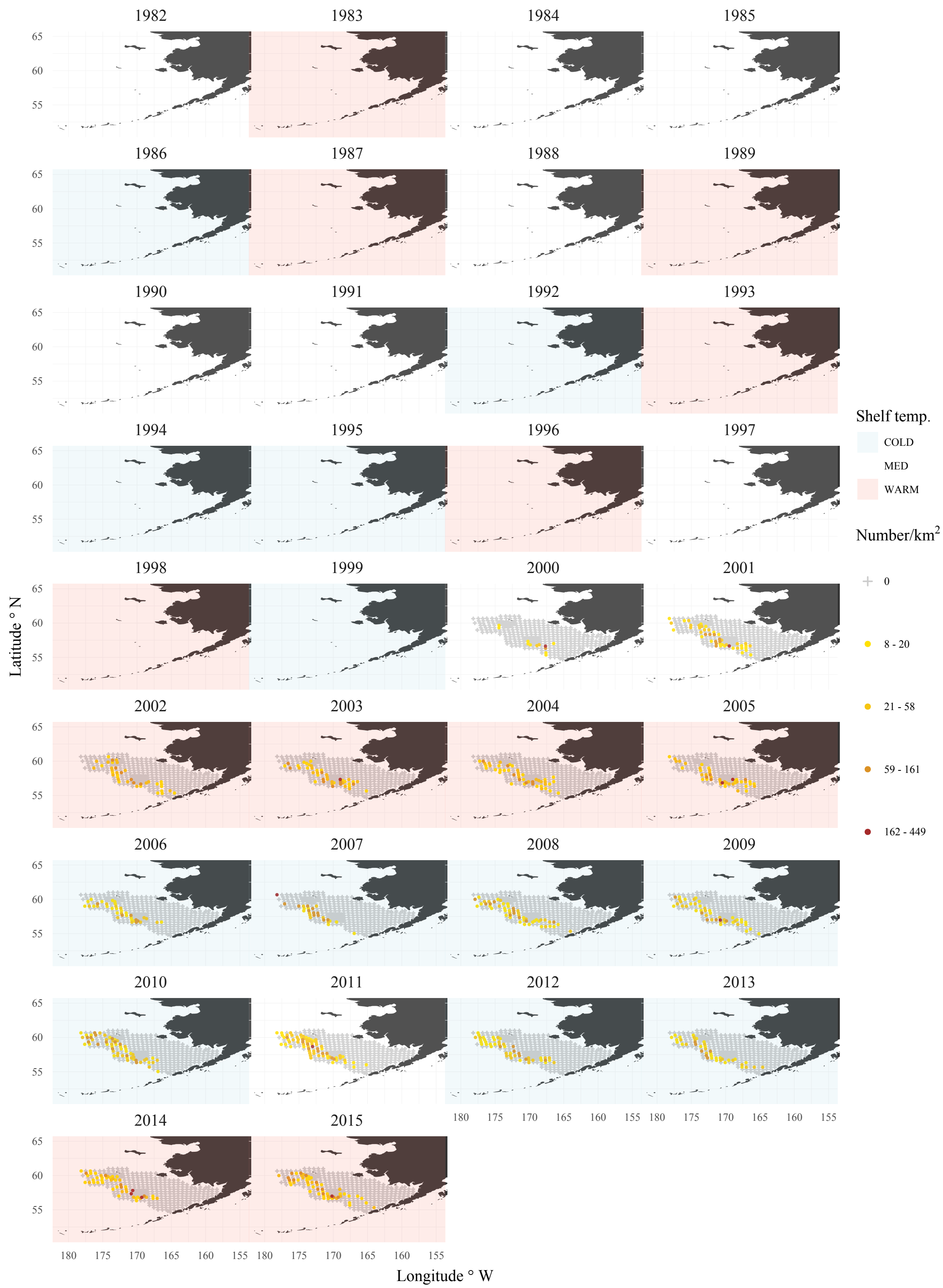


Figure 34 . -- Continued.

bigmouth sculpin (*Hemitripterus bolini*) 64-68 cm

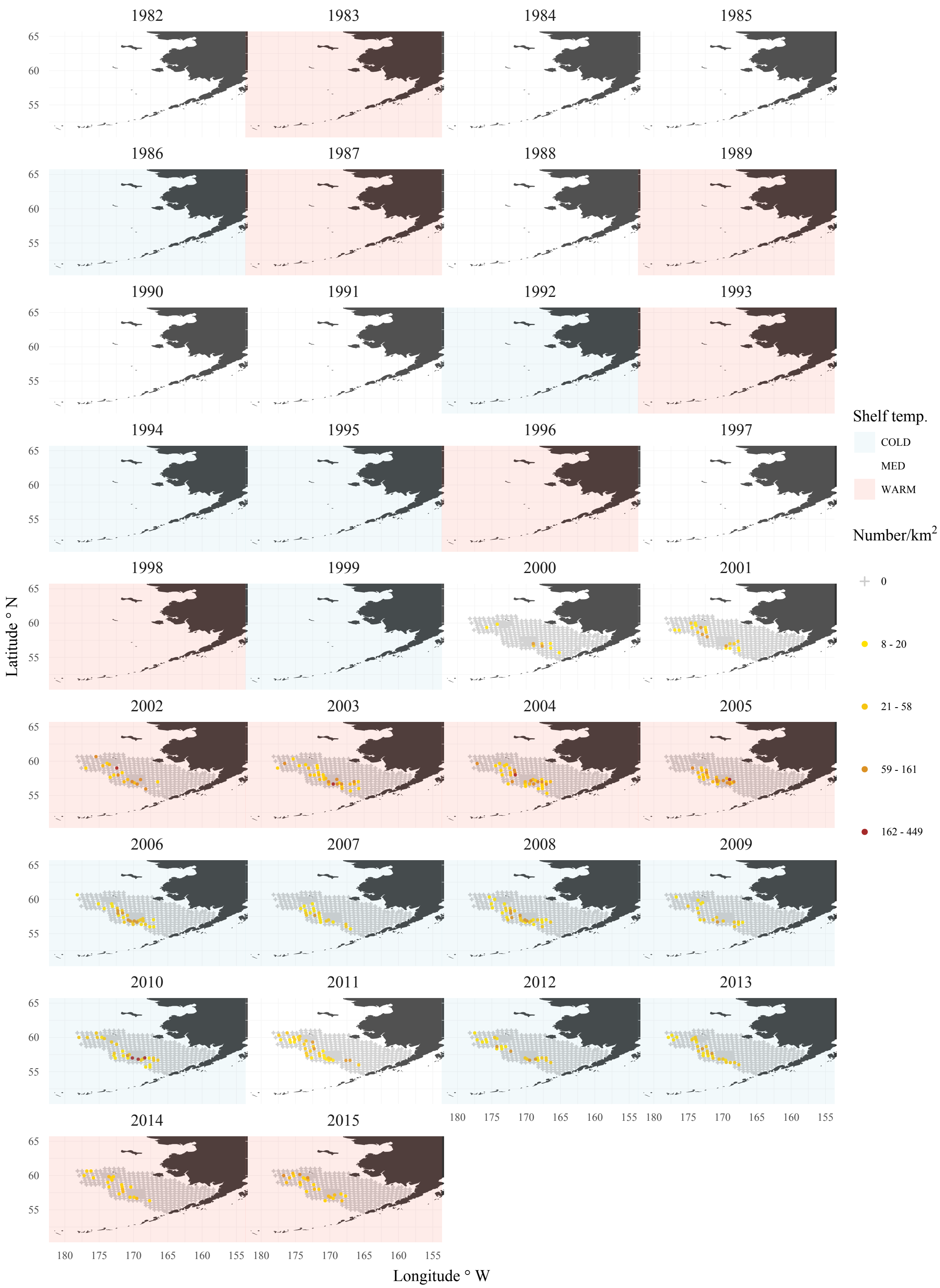


Figure 34 . -- Continued.

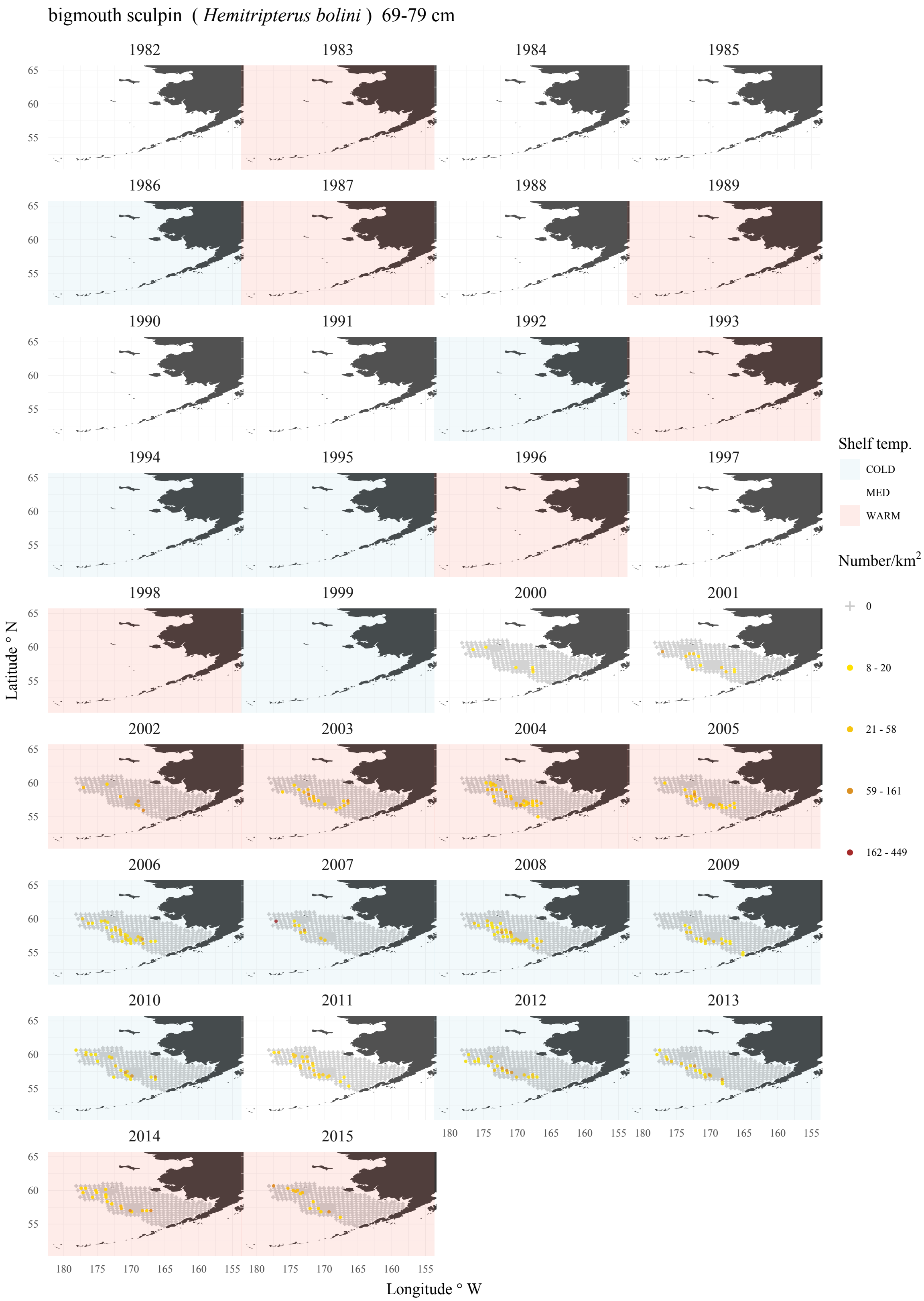


Figure 34 . -- Continued.

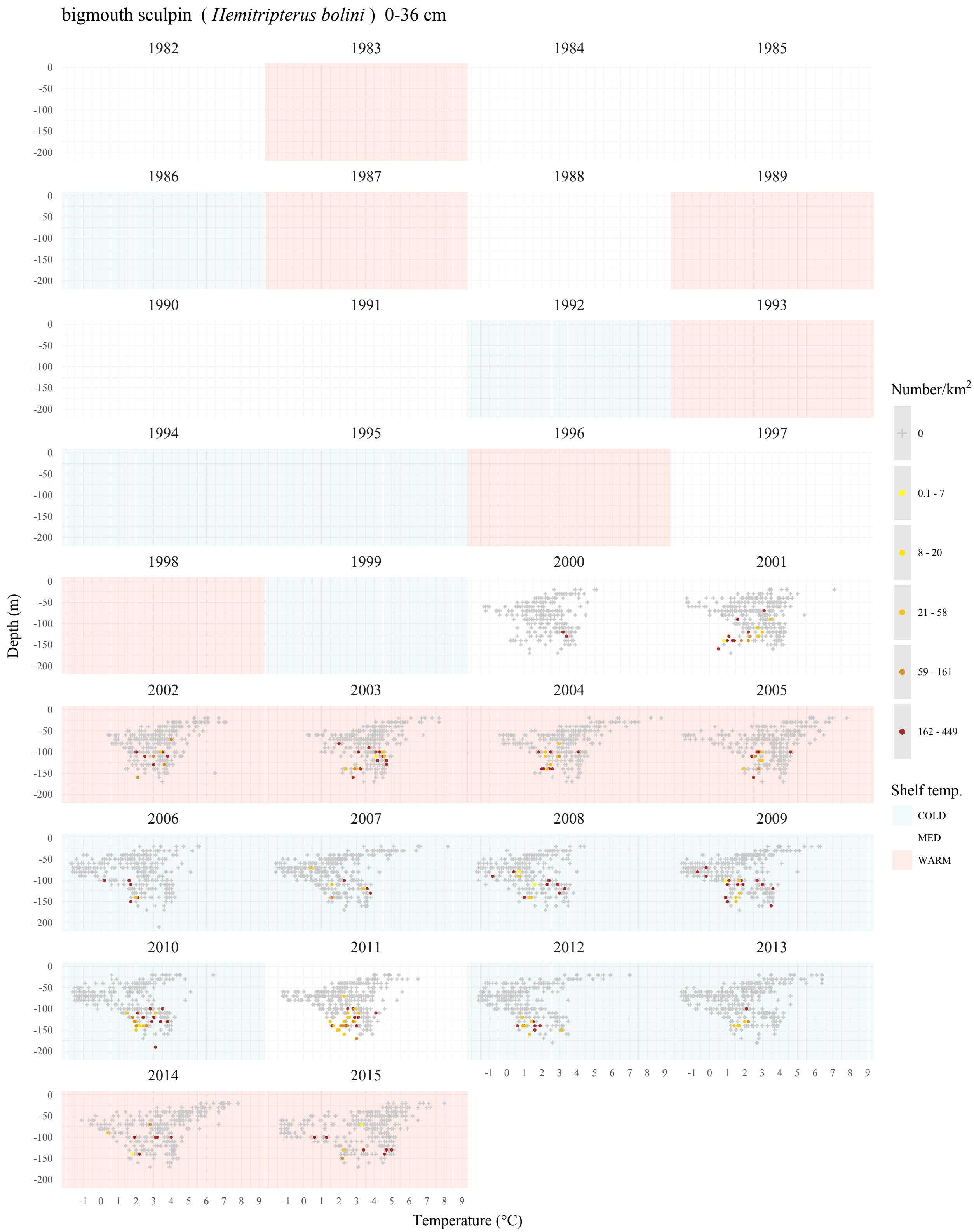


Figure 35 . -- The bigmouth sculpin (*Hemitripterus bolini*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

bigmouth sculpin (*Hemitripterus bolini*) 37-50 cm

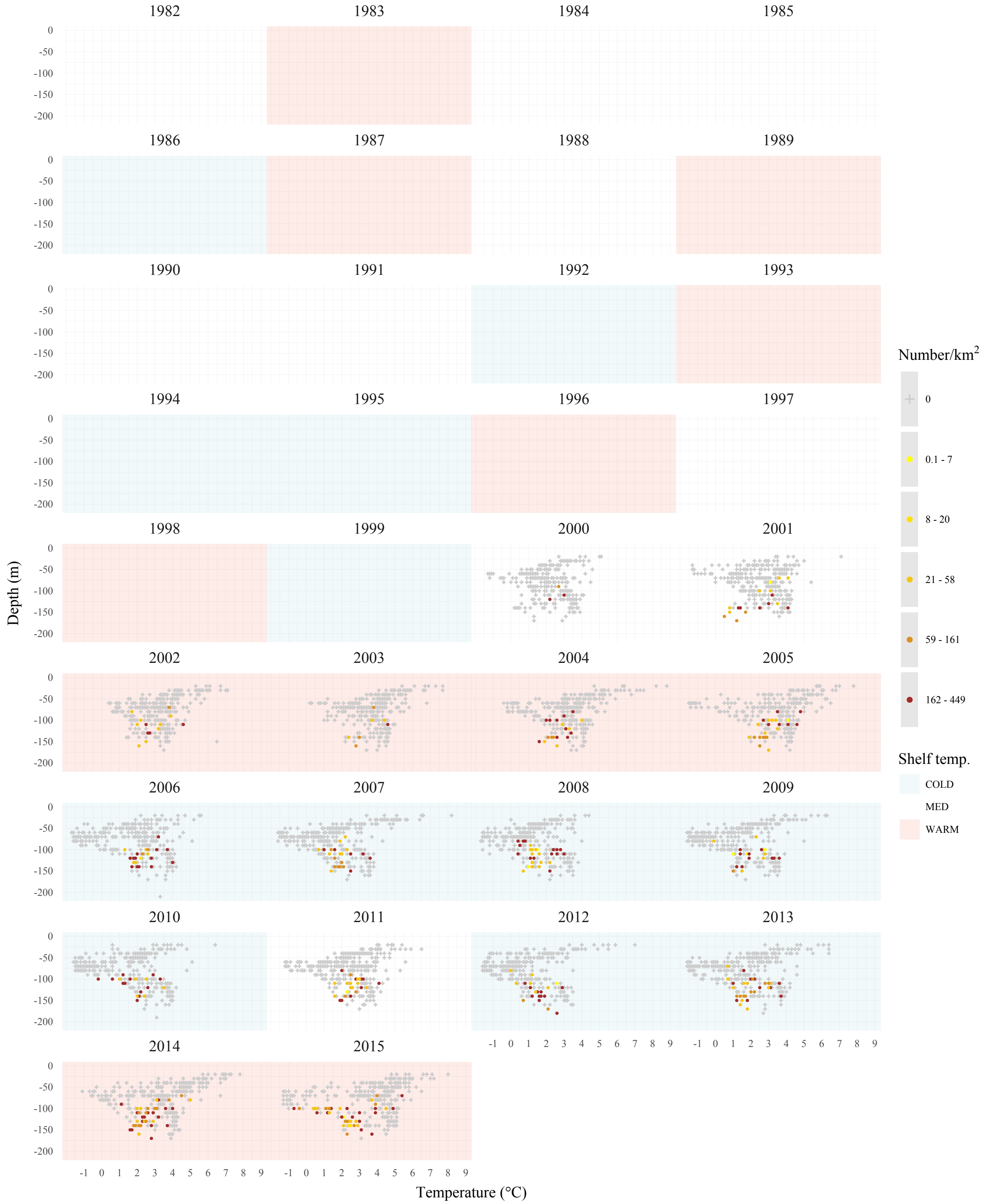


Figure 35 . -- Continued.

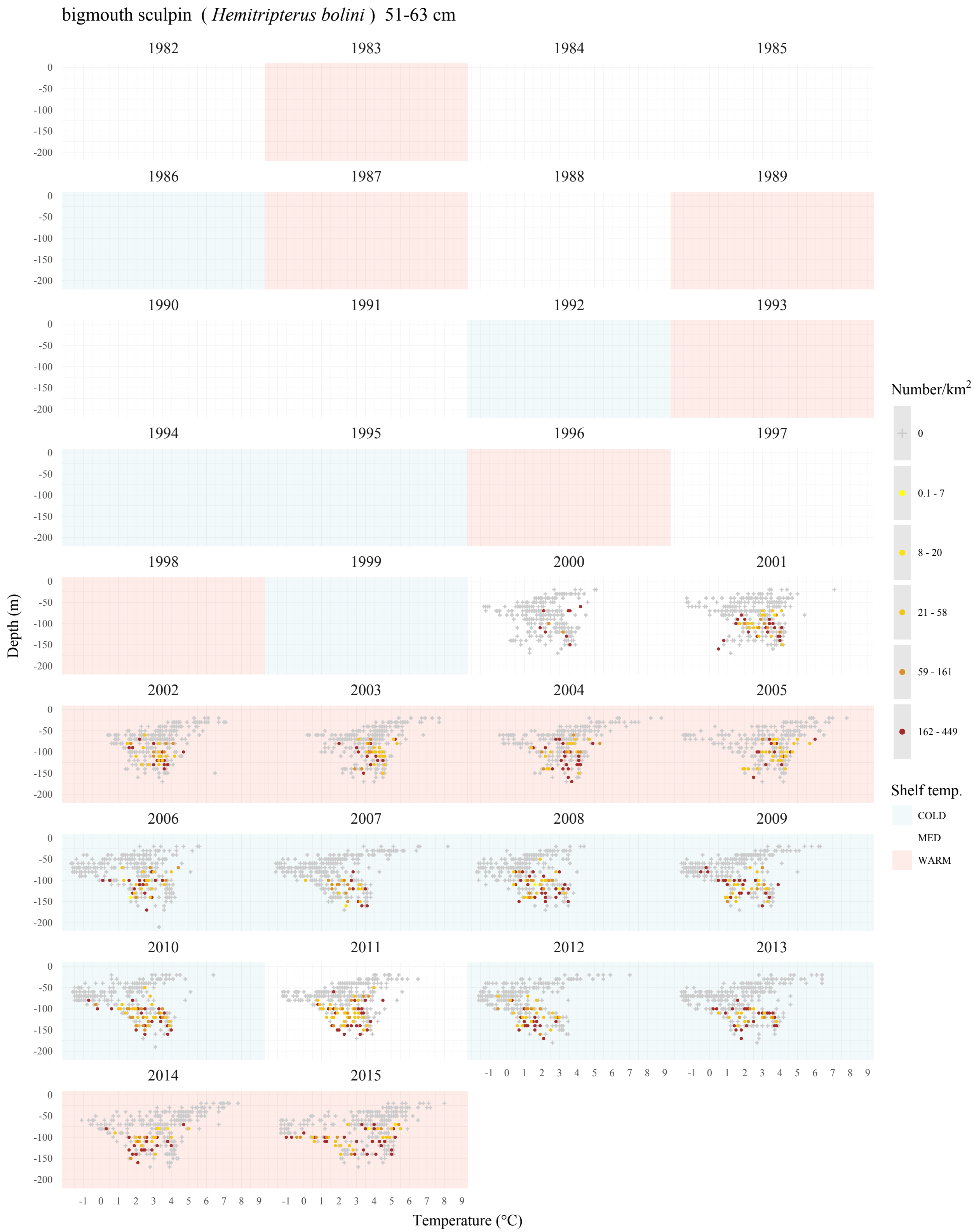


Figure 35 . -- Continued.

bigmouth sculpin (*Hemitripterus bolini*) 64-68 cm

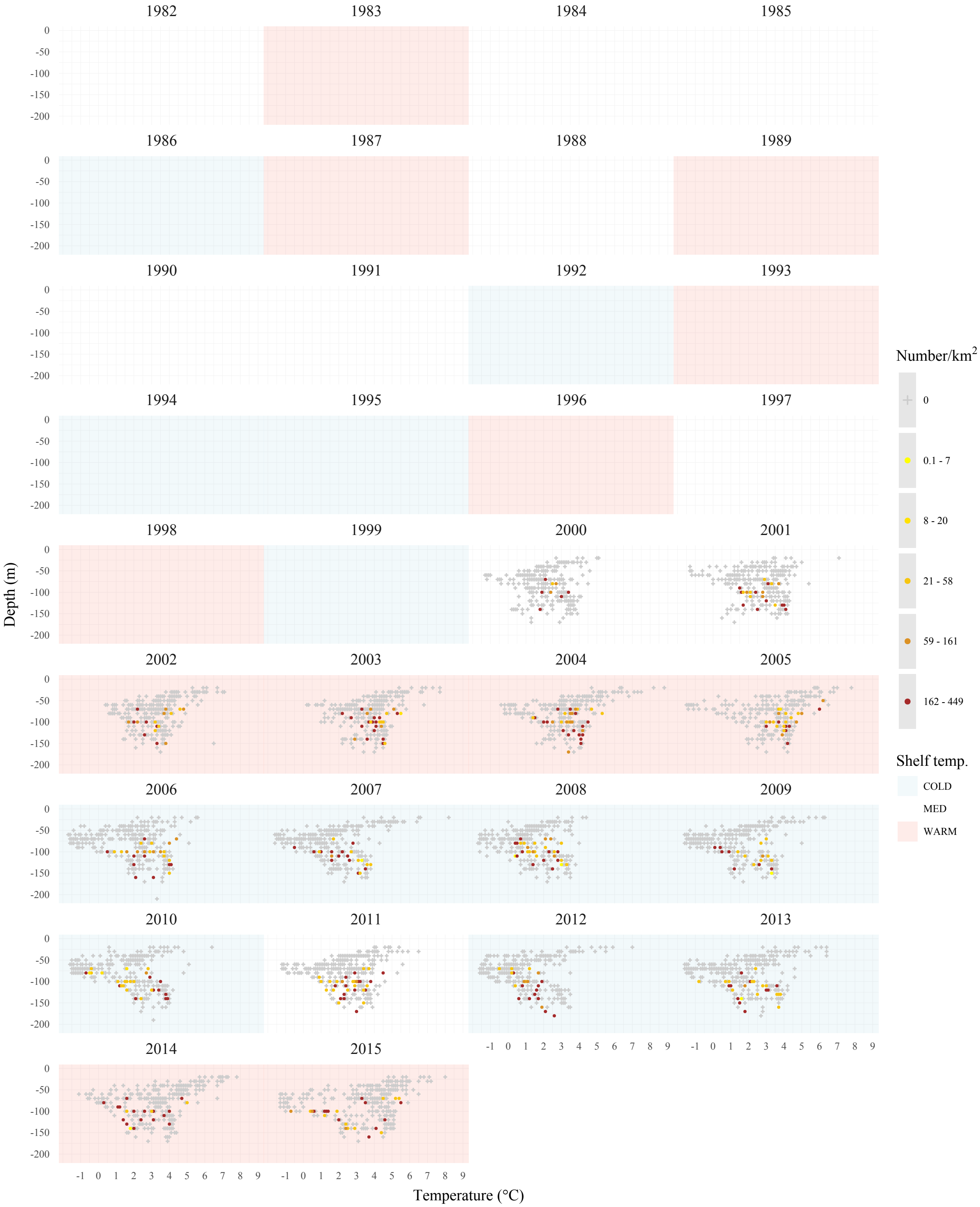


Figure 35 . -- Continued.

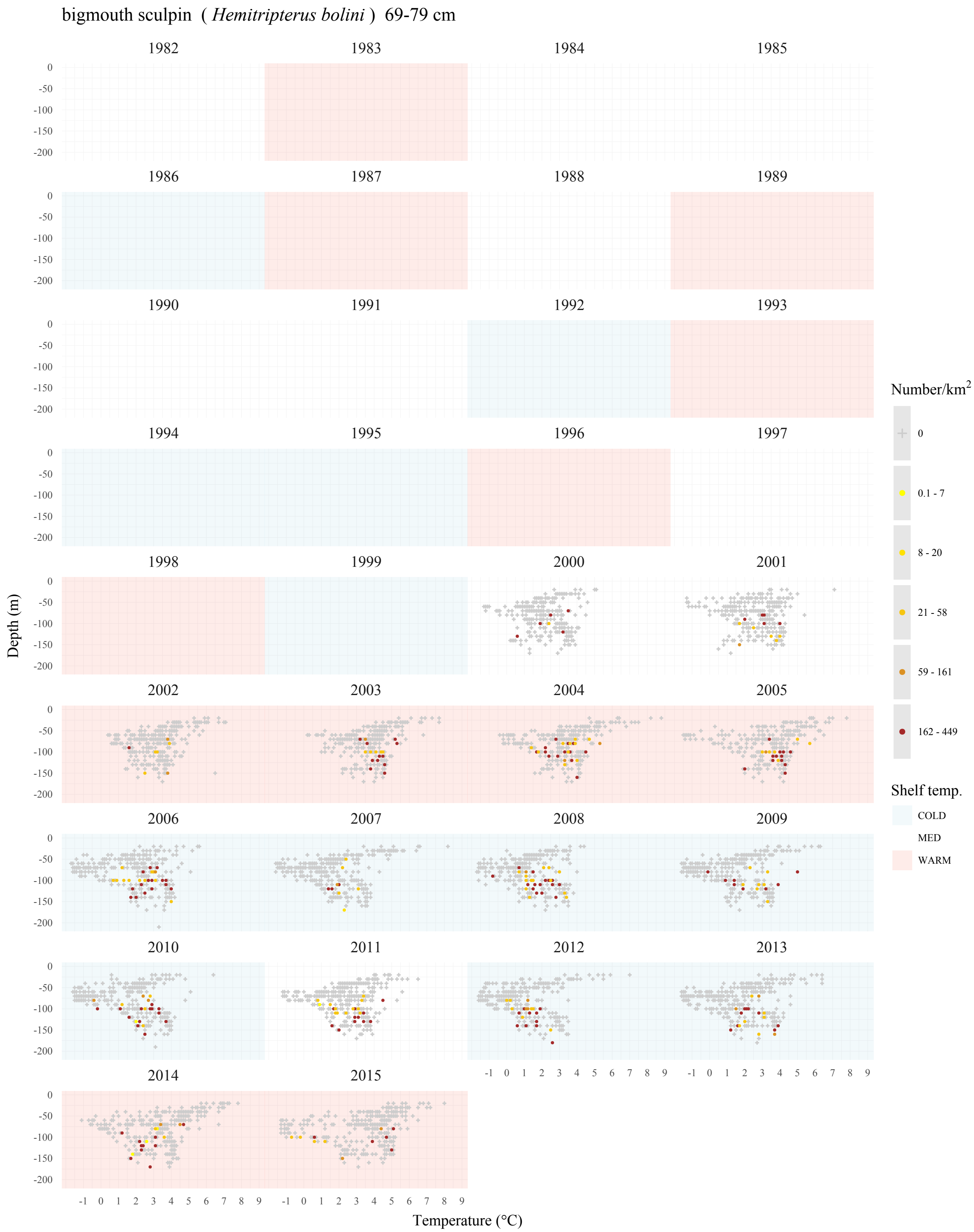


Figure 35 . -- Continued.

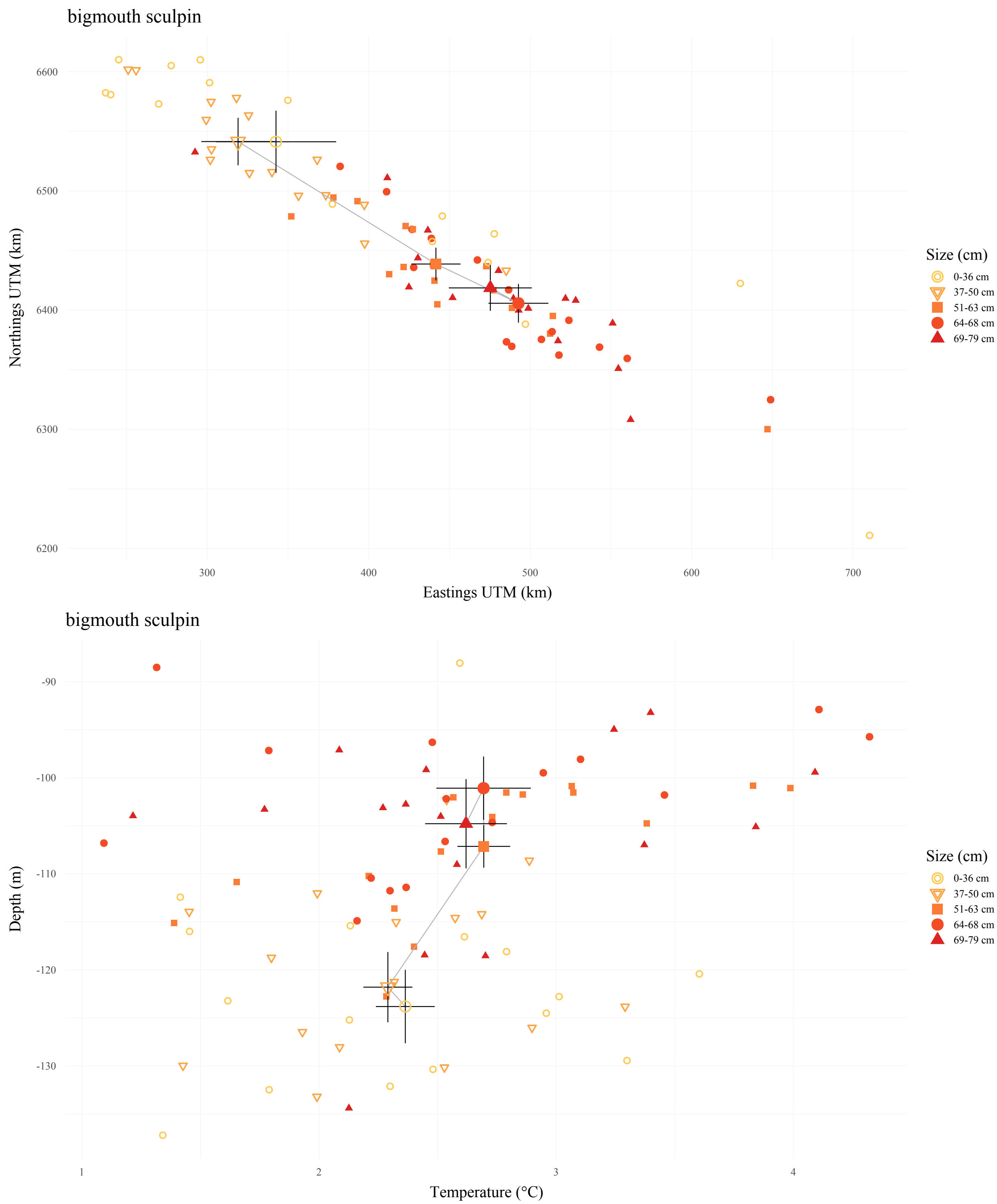


Figure 36 . -- The bigmouth sculpin (*Hemitripterus bolini*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

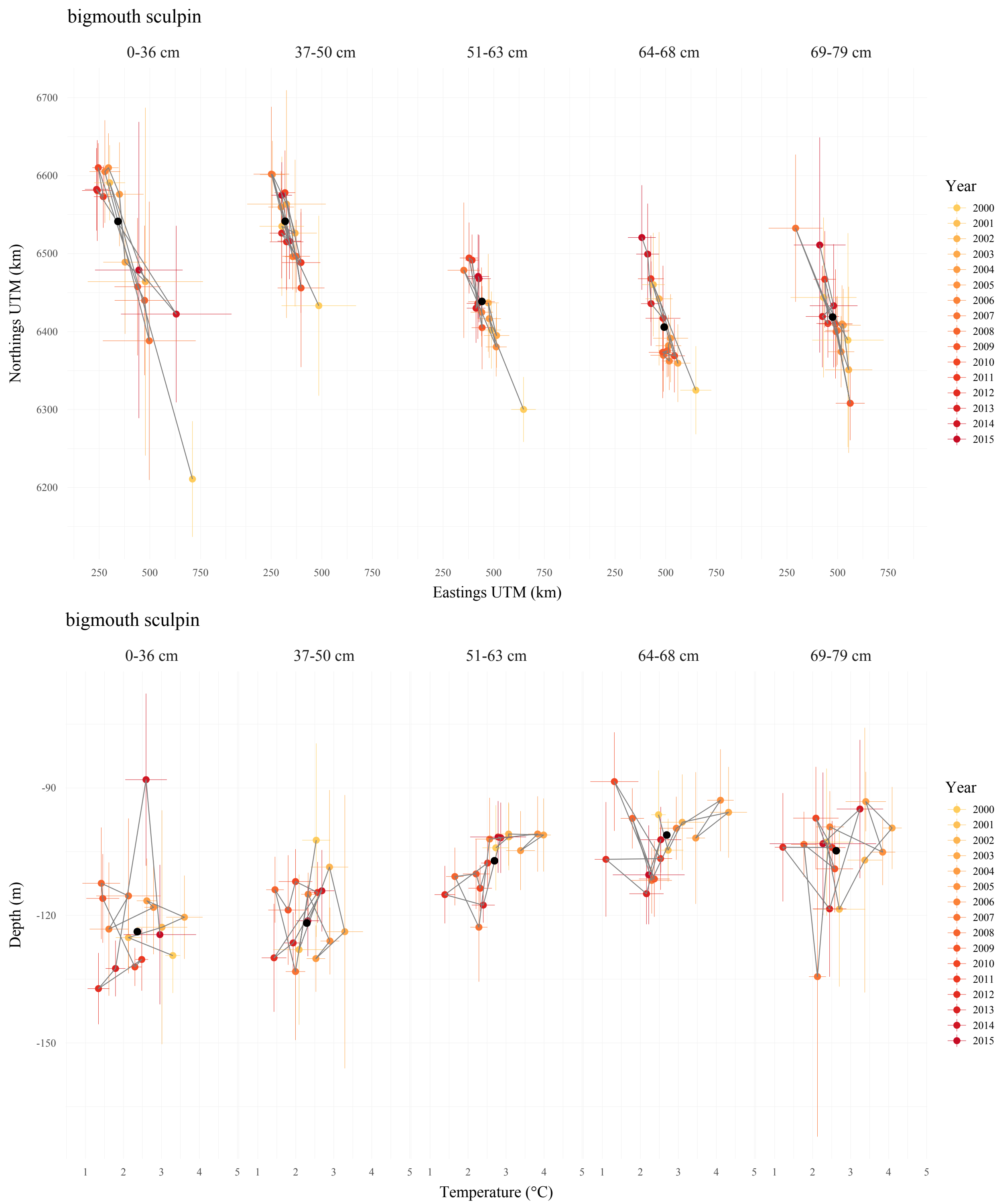


Figure 37 . -- The bigmouth sculpin (*Hemitripterus bolini*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

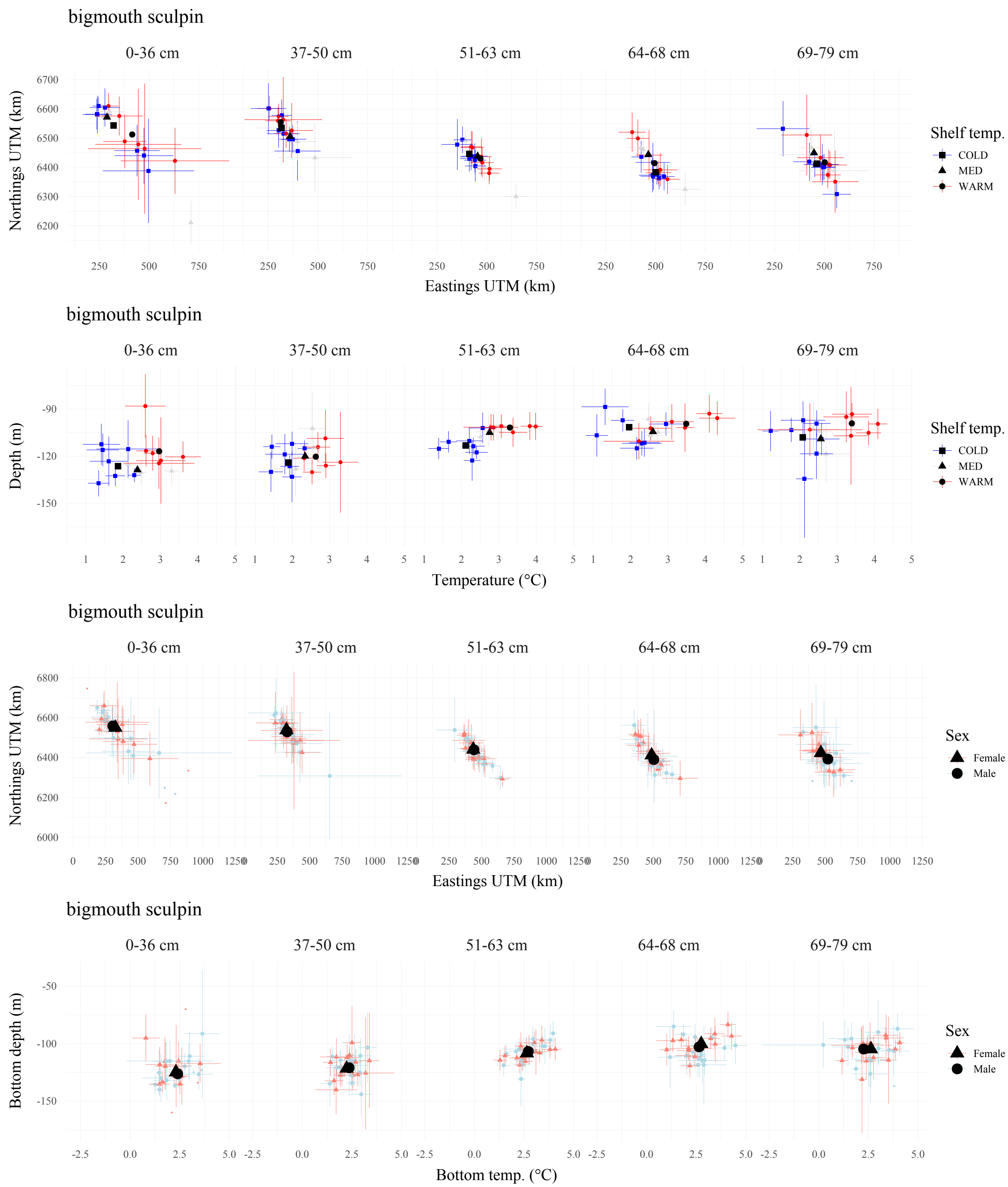


Figure 38 . -- The bigmouth sculpin (*Hemitripterus bolini*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

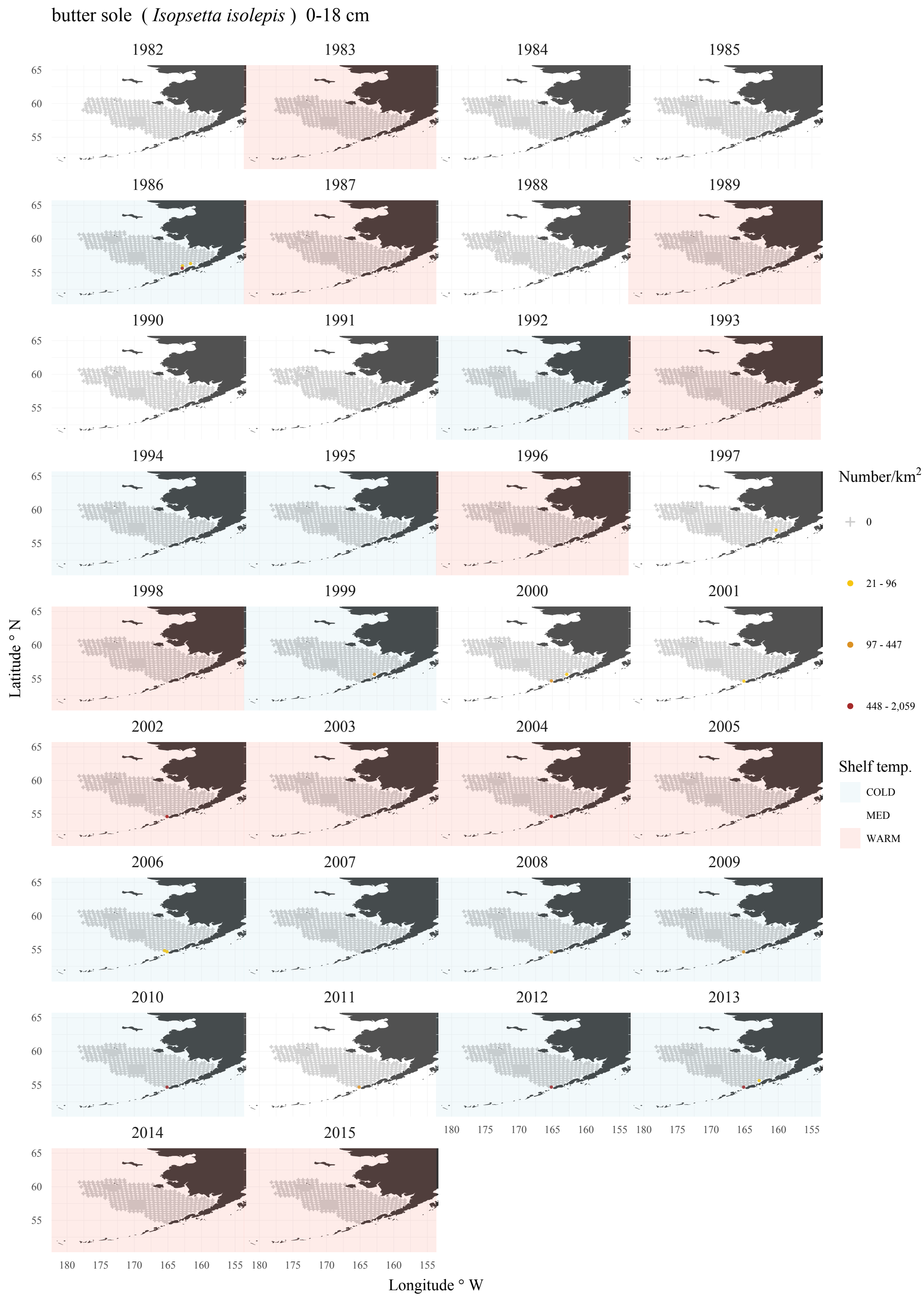


Figure 39 . -- The butter sole (*Isopsetta isolepis*) CPUE by number weighted mean location for each length category for all years.

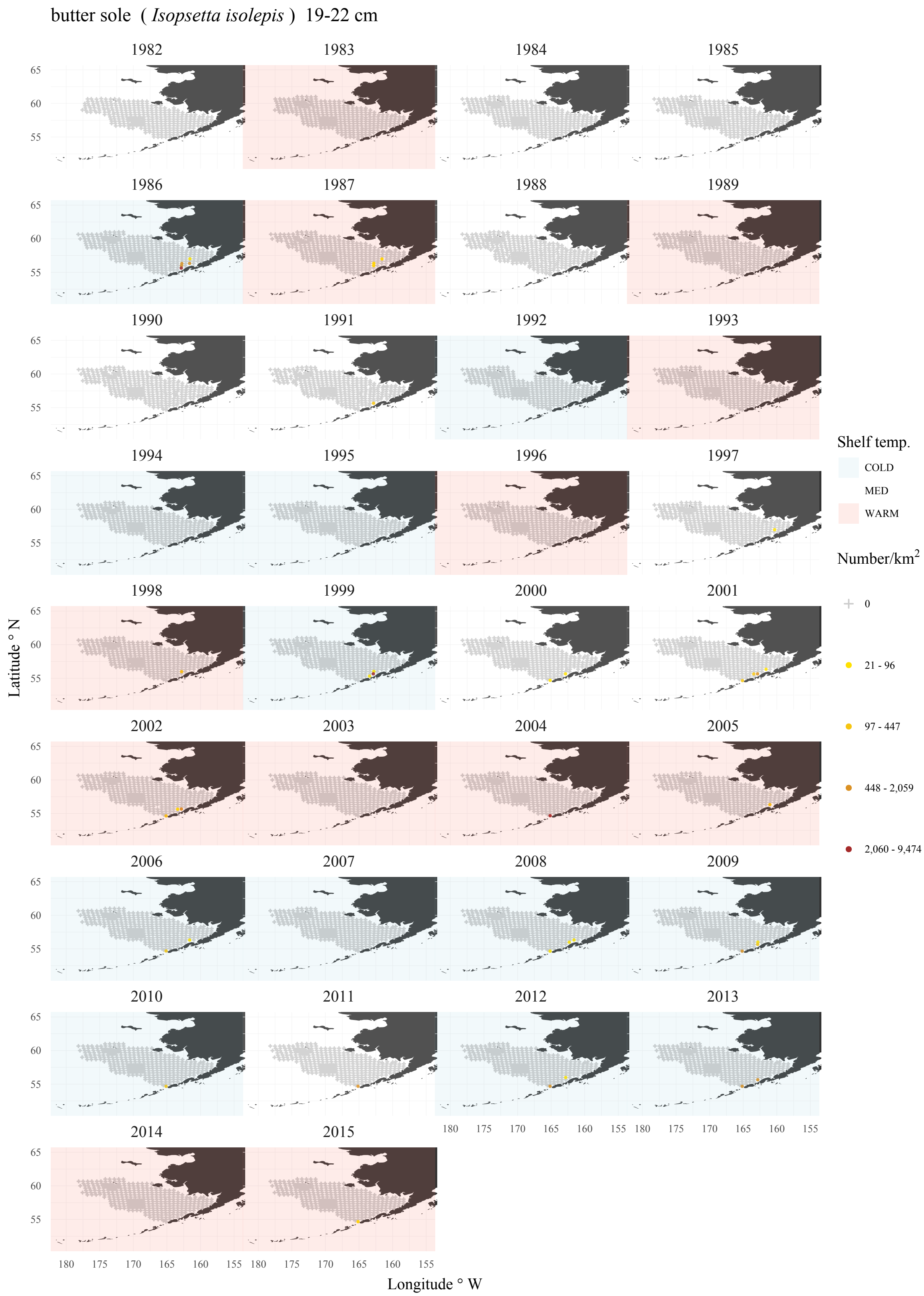


Figure 39 . -- Continued.

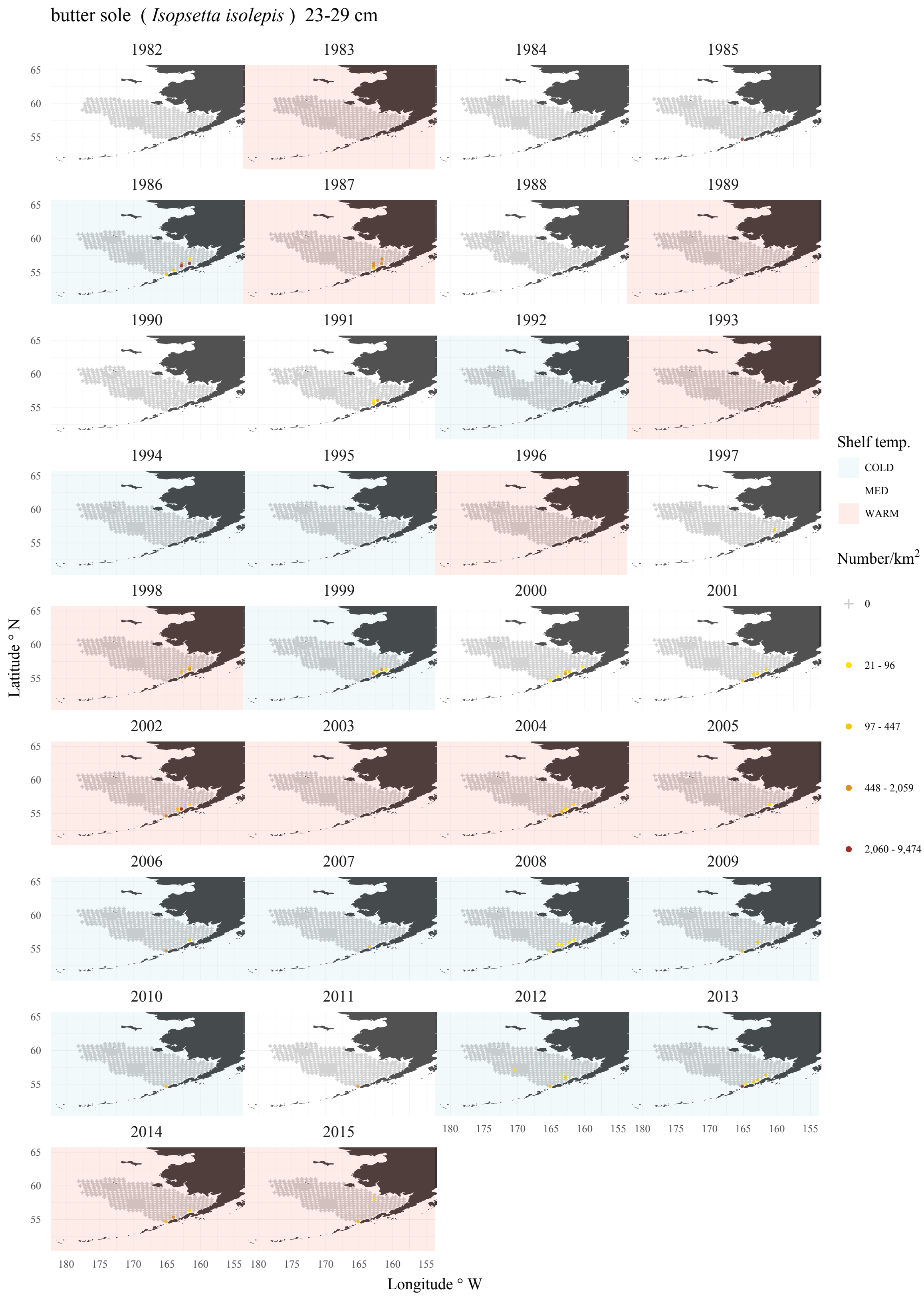


Figure 39 . -- Continued.

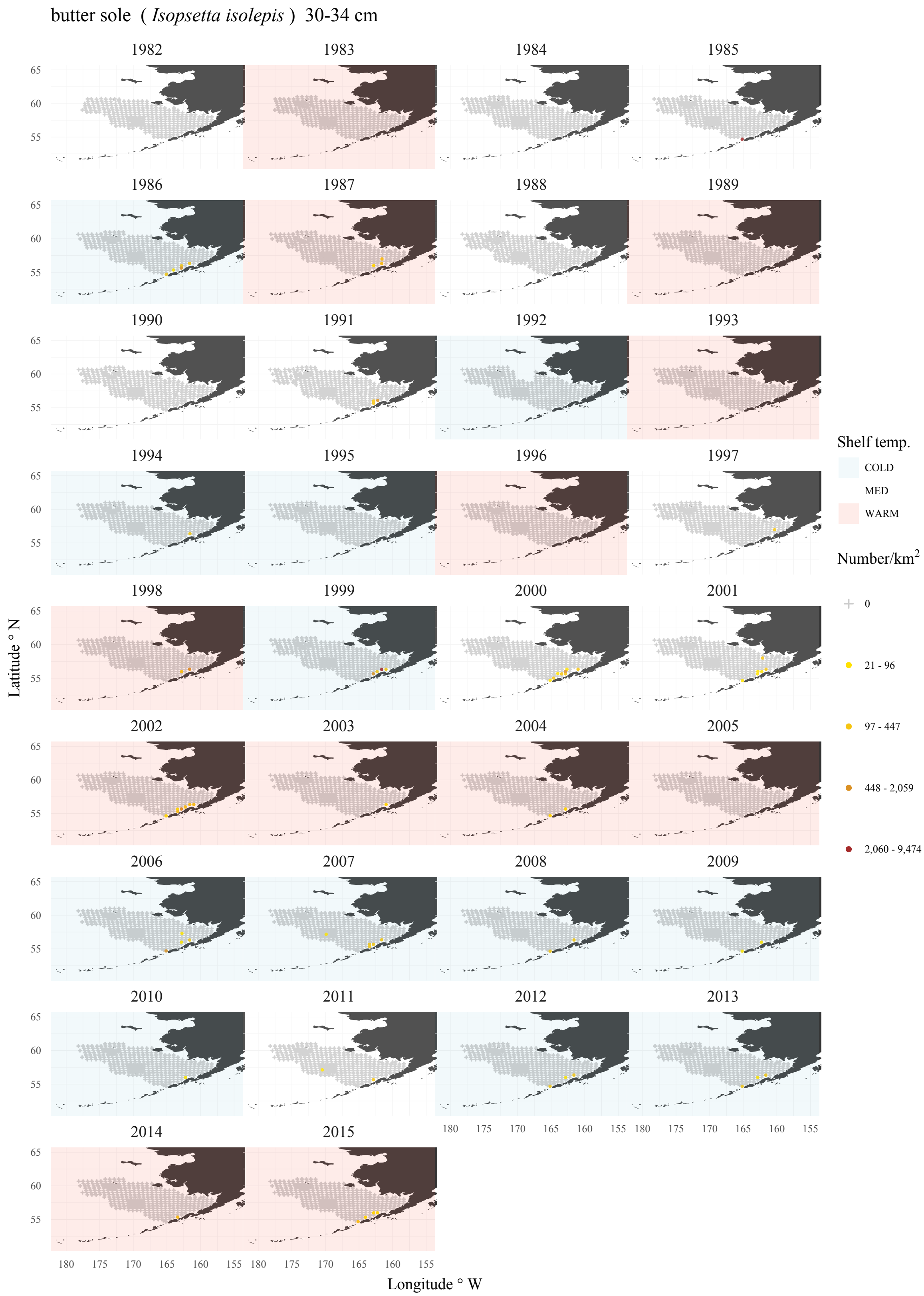


Figure 39 . -- Continued.

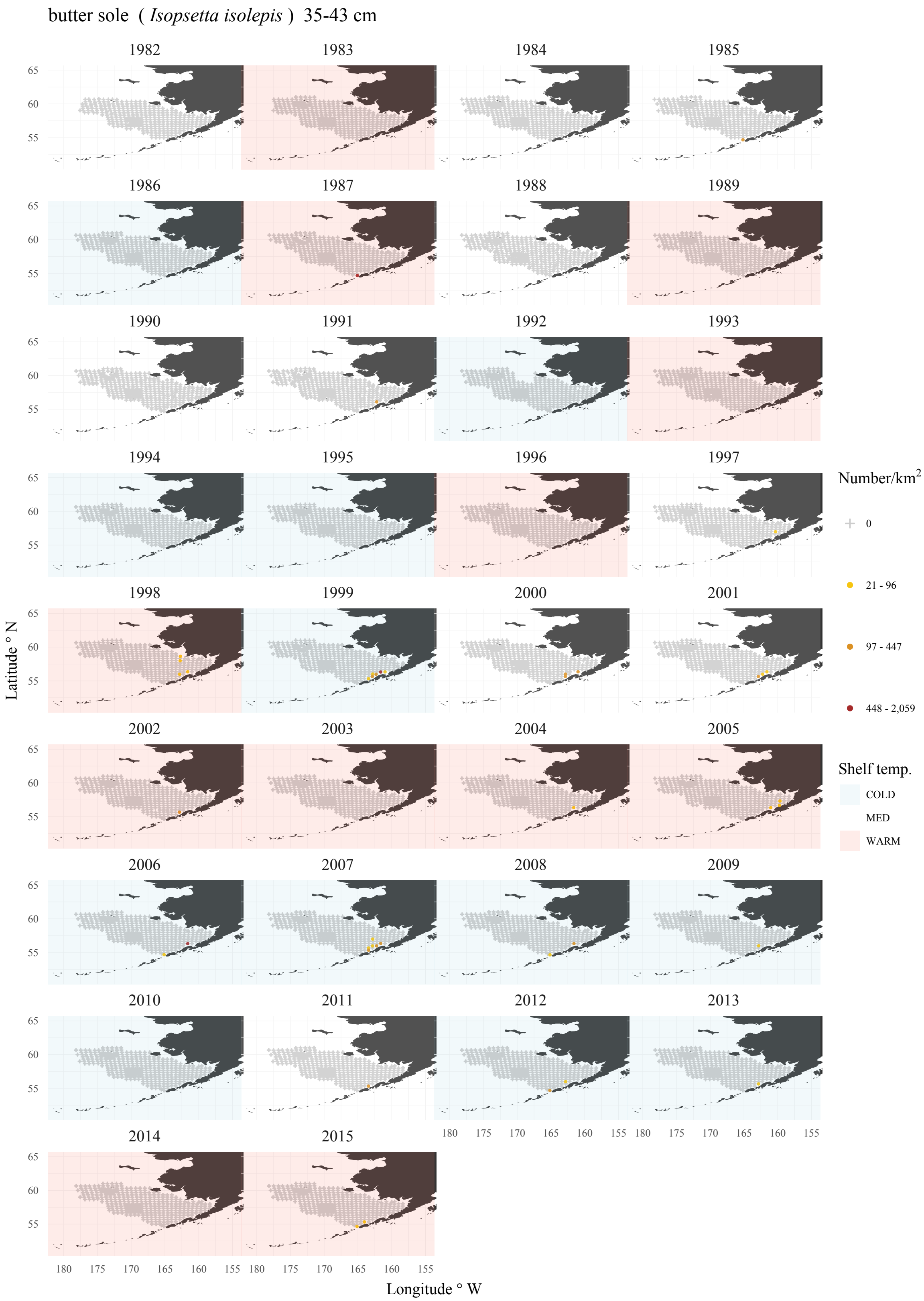


Figure 39 . -- Continued.

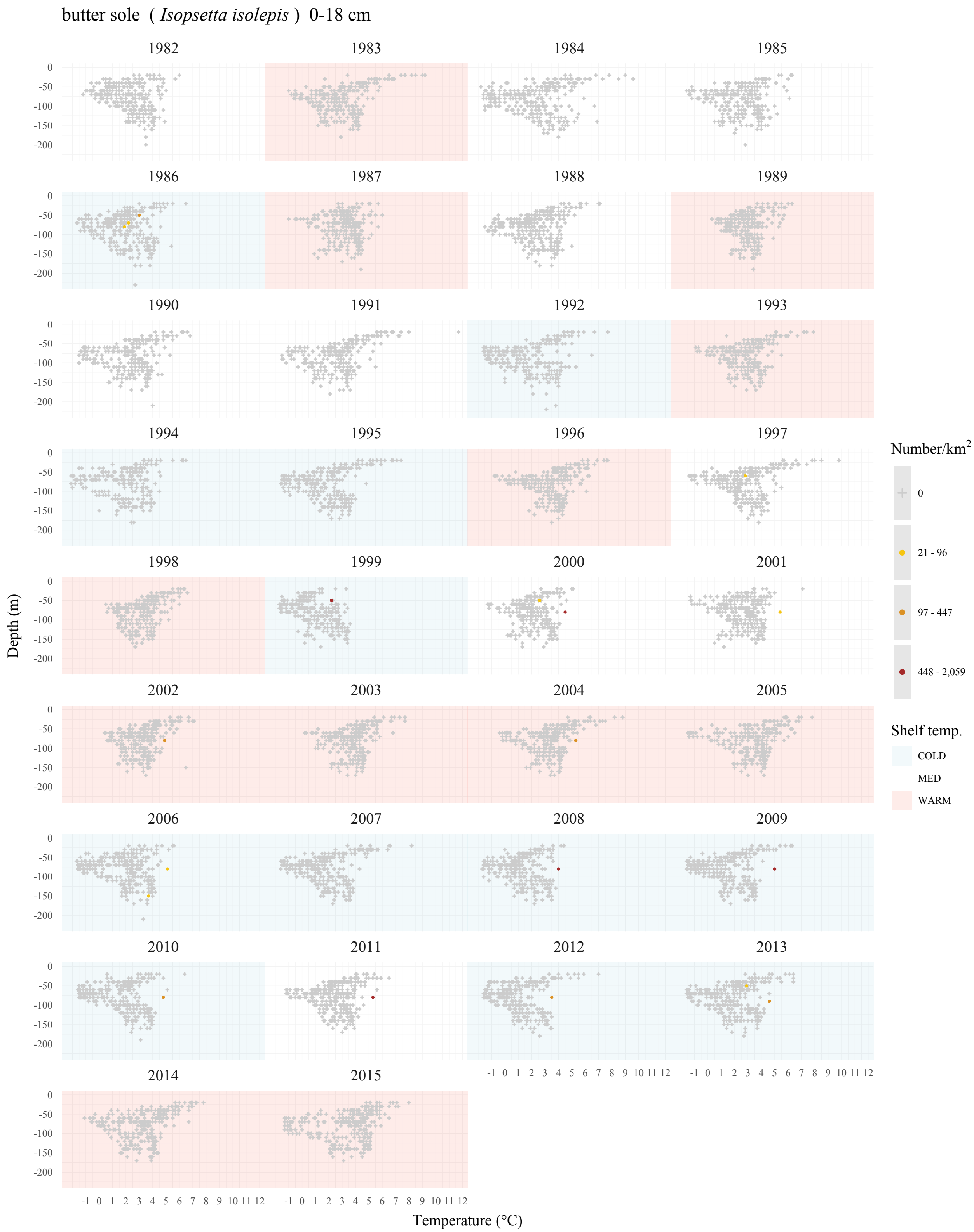


Figure 40 . -- The butter sole (*Isopsetta isolepis*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

Figure 40 . -- Continued.

Figure 40 . -- Continued.

Figure 40 . -- Continued.

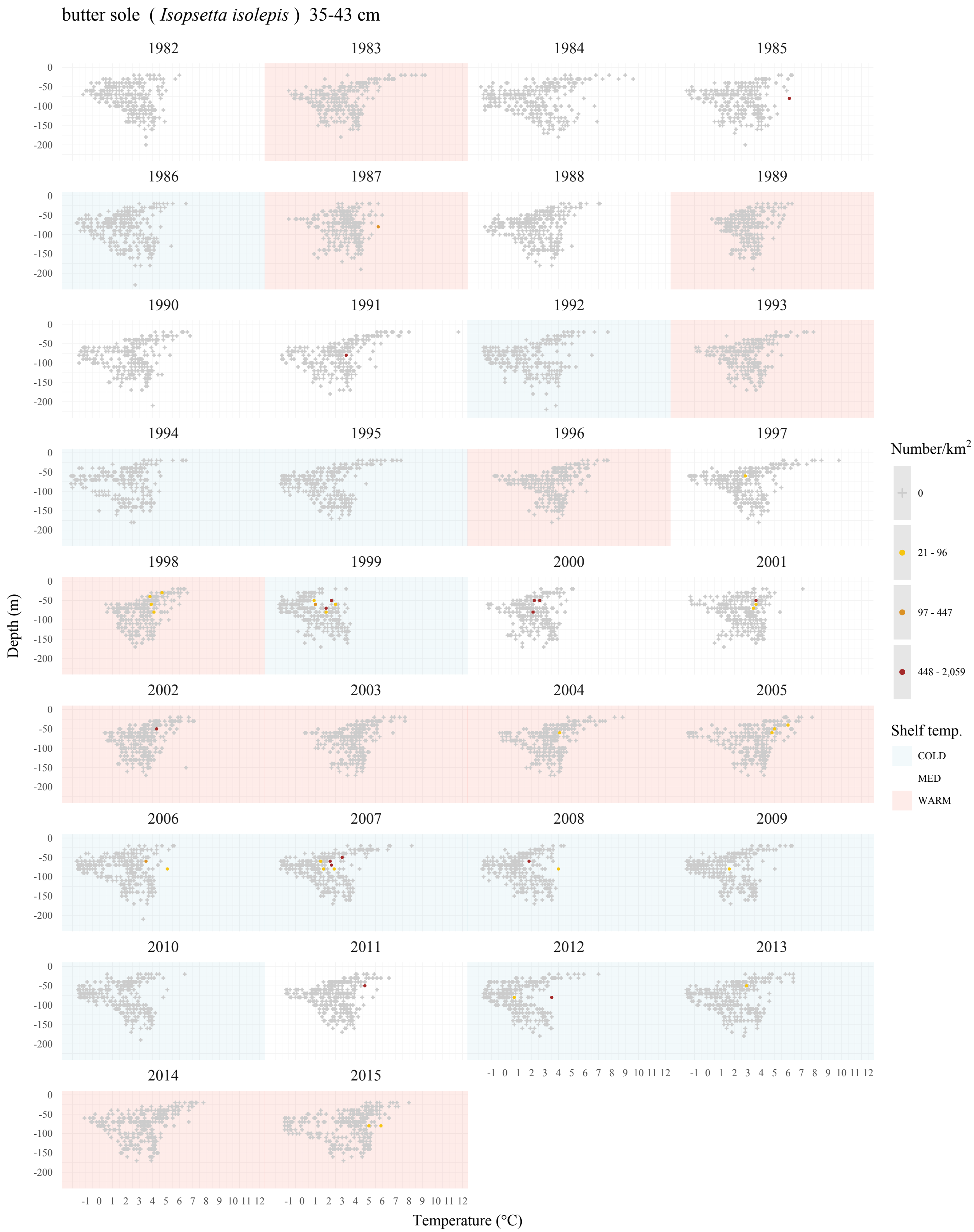
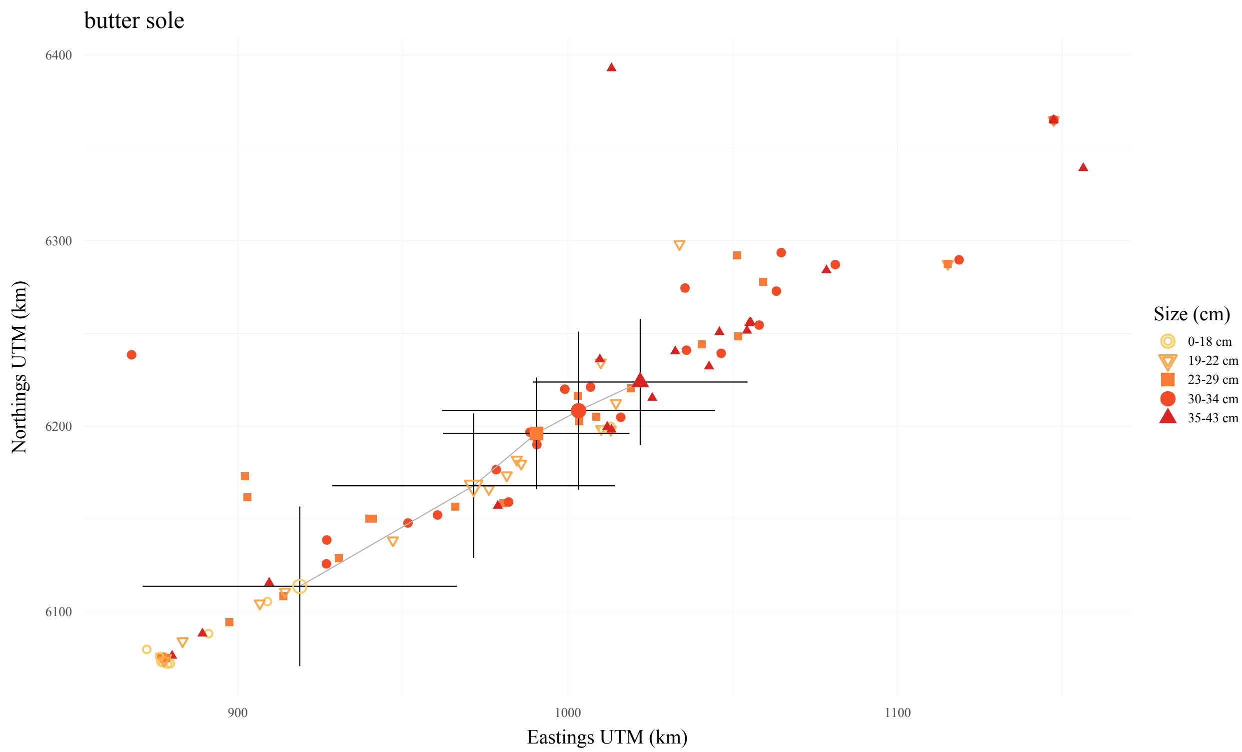


Figure 40 . -- Continued.



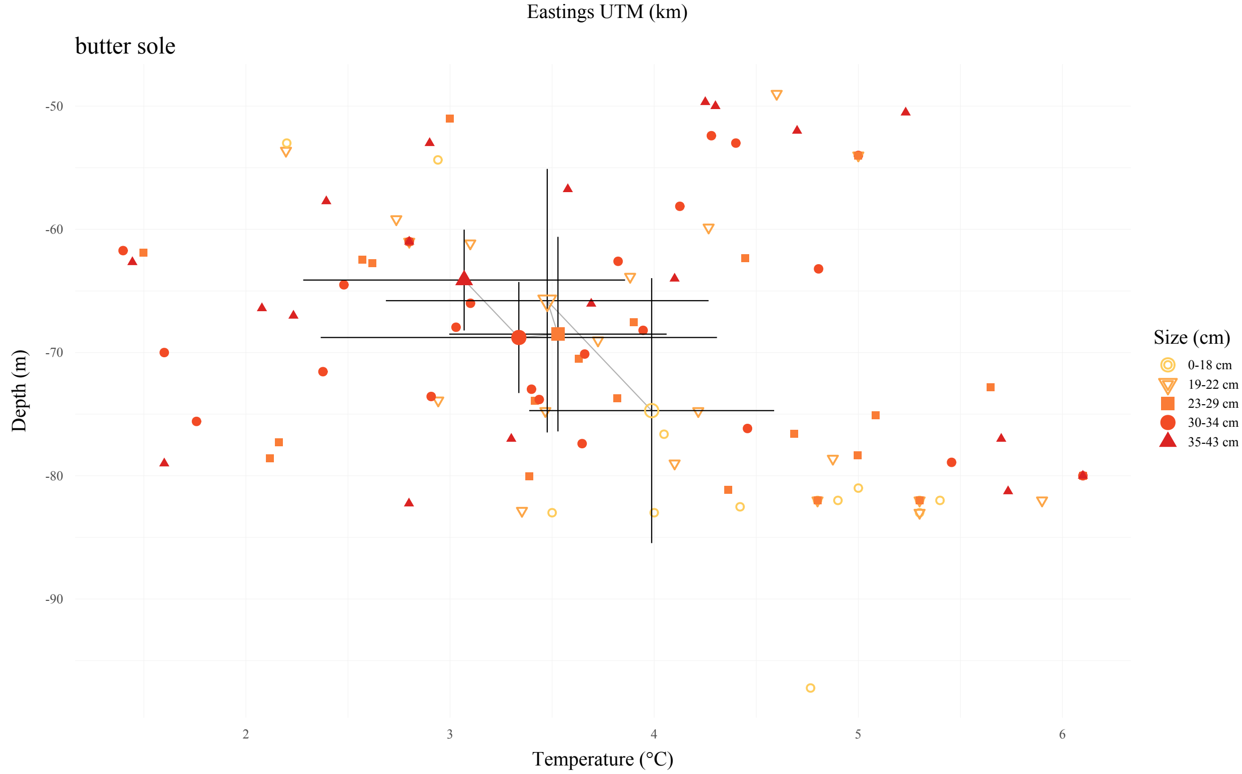
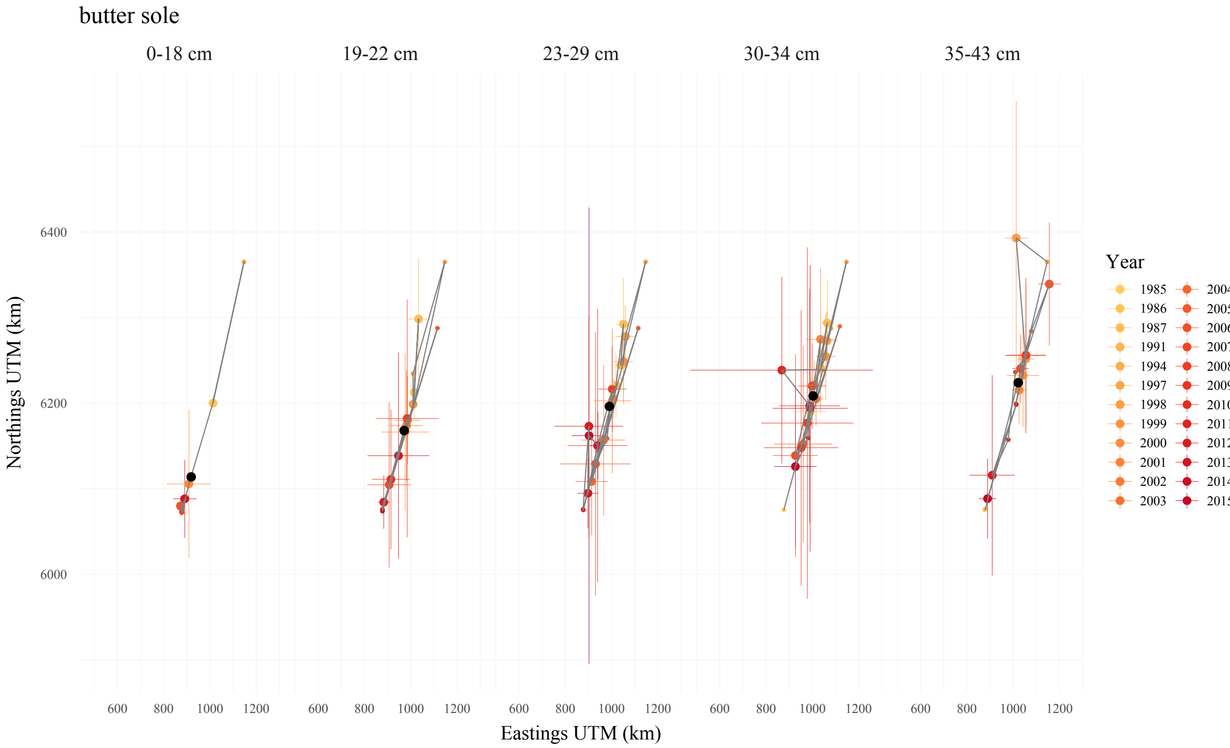


Figure 41 . -- The butter sole (*Isopsetta isolepis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.



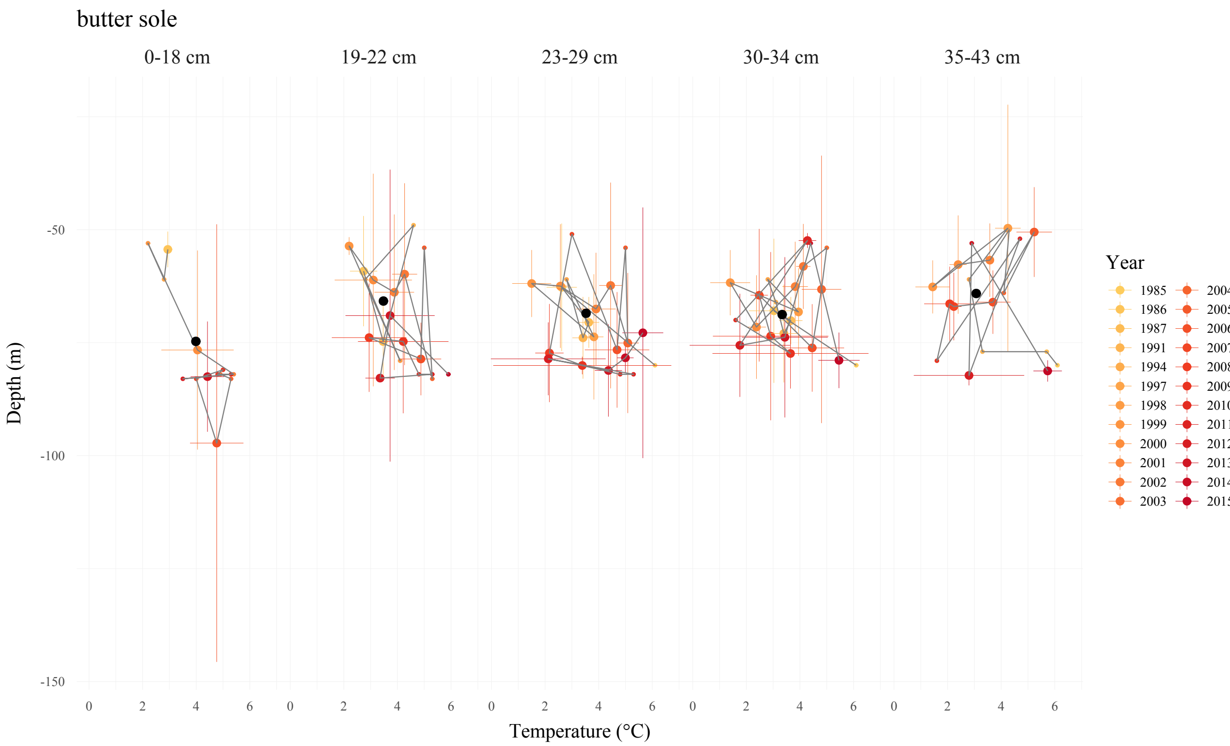


Figure 42 . -- The butter sole (*Isopsetta isolepis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

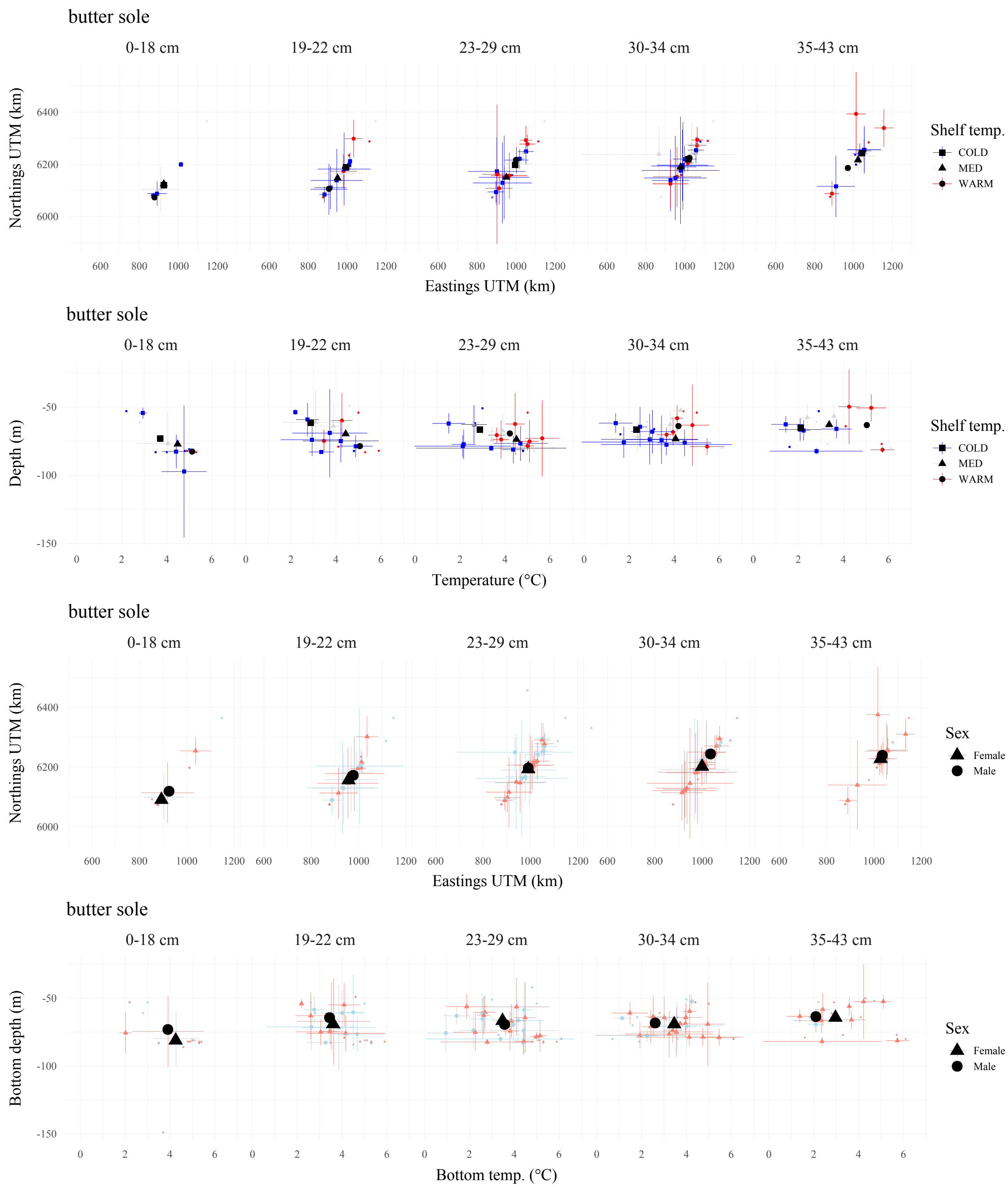


Figure 43 . -- The butter sole (*Isopsetta isolepis*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

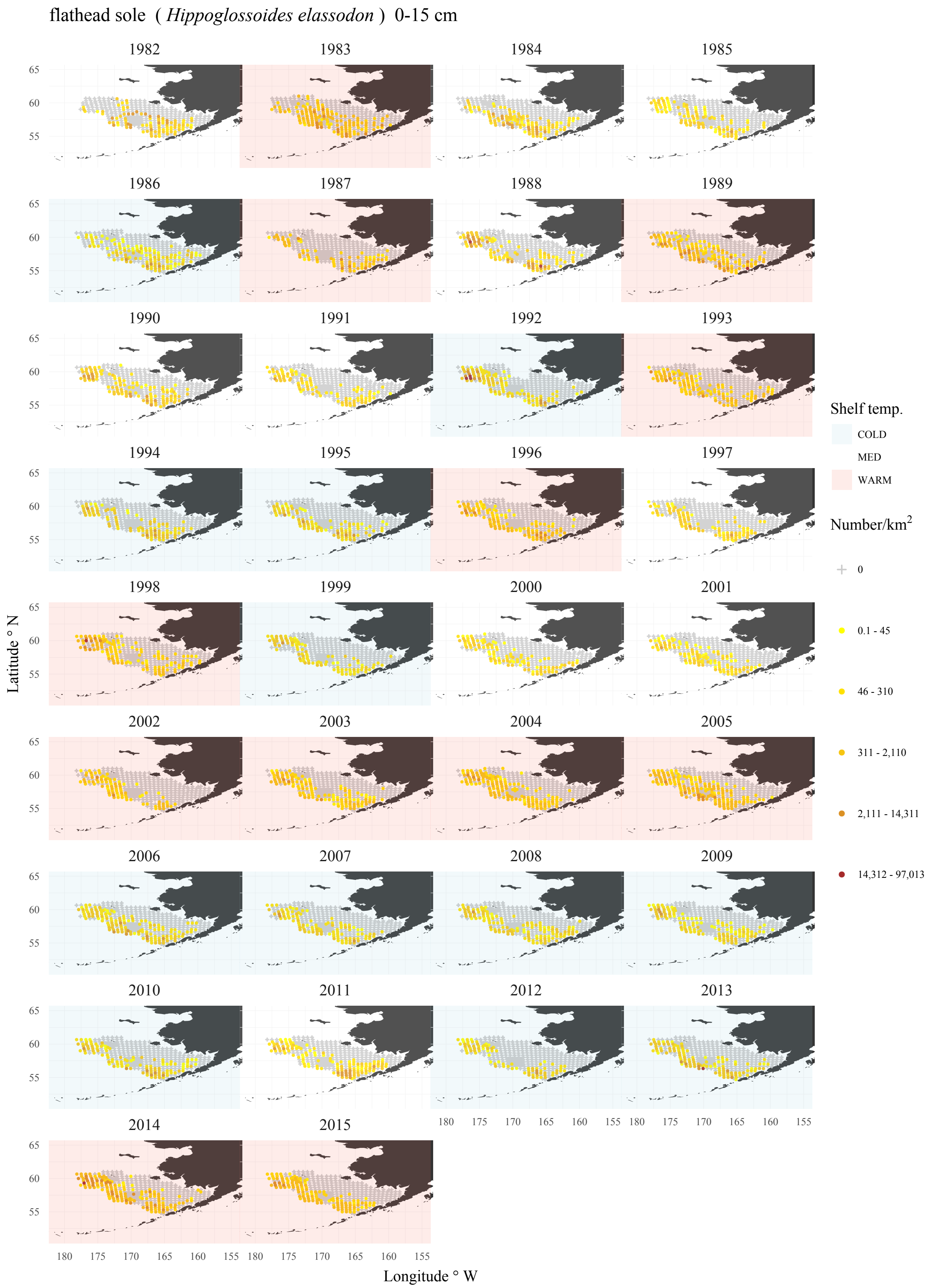


Figure 44 . -- The flathead sole (*Hippoglossoides elassodon*) CPUE by number weighted mean location for each length category for all years.

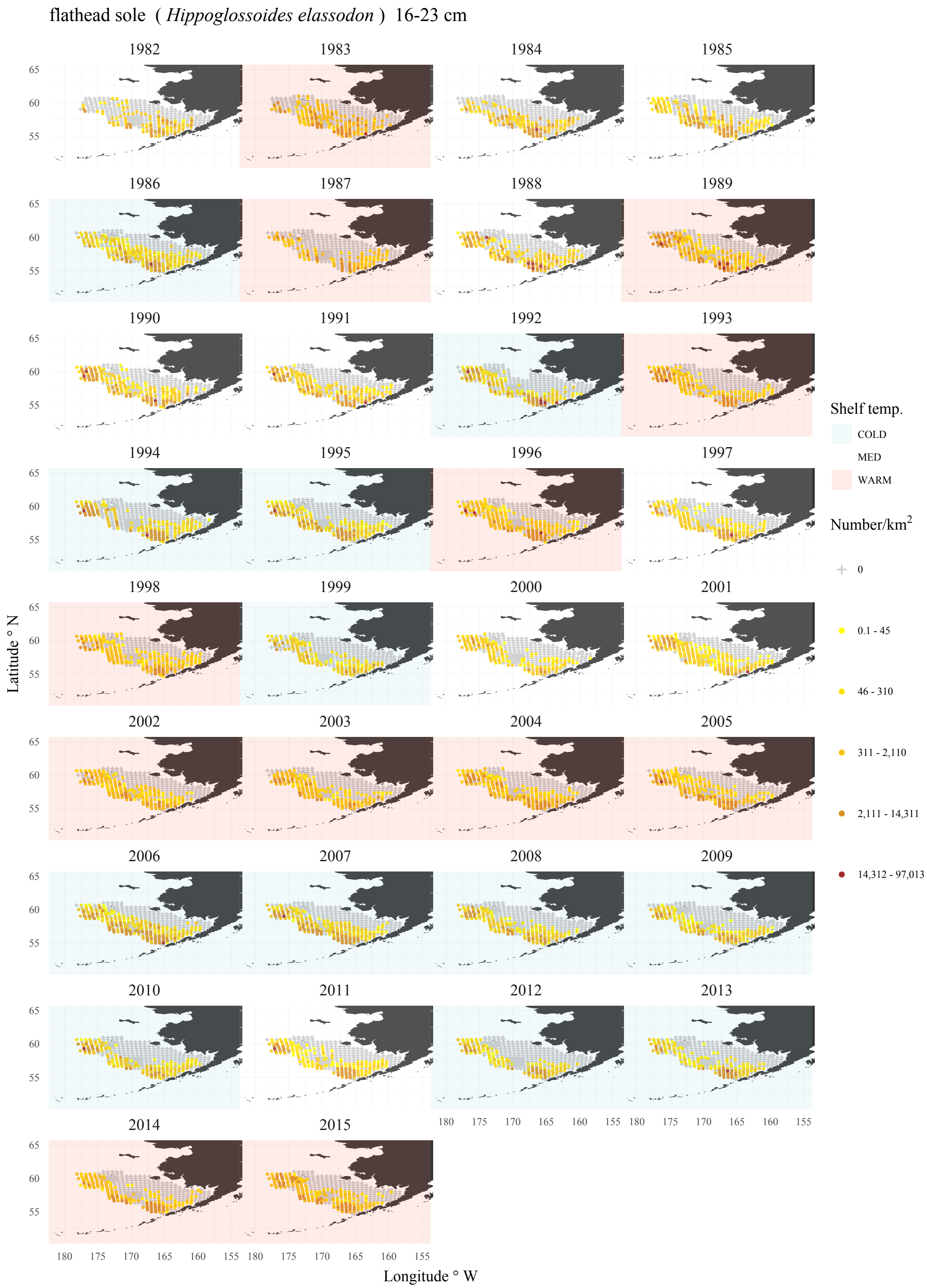


Figure 44 . -- Continued.

flathead sole (*Hippoglossoides elassodon*) 24-33 cm

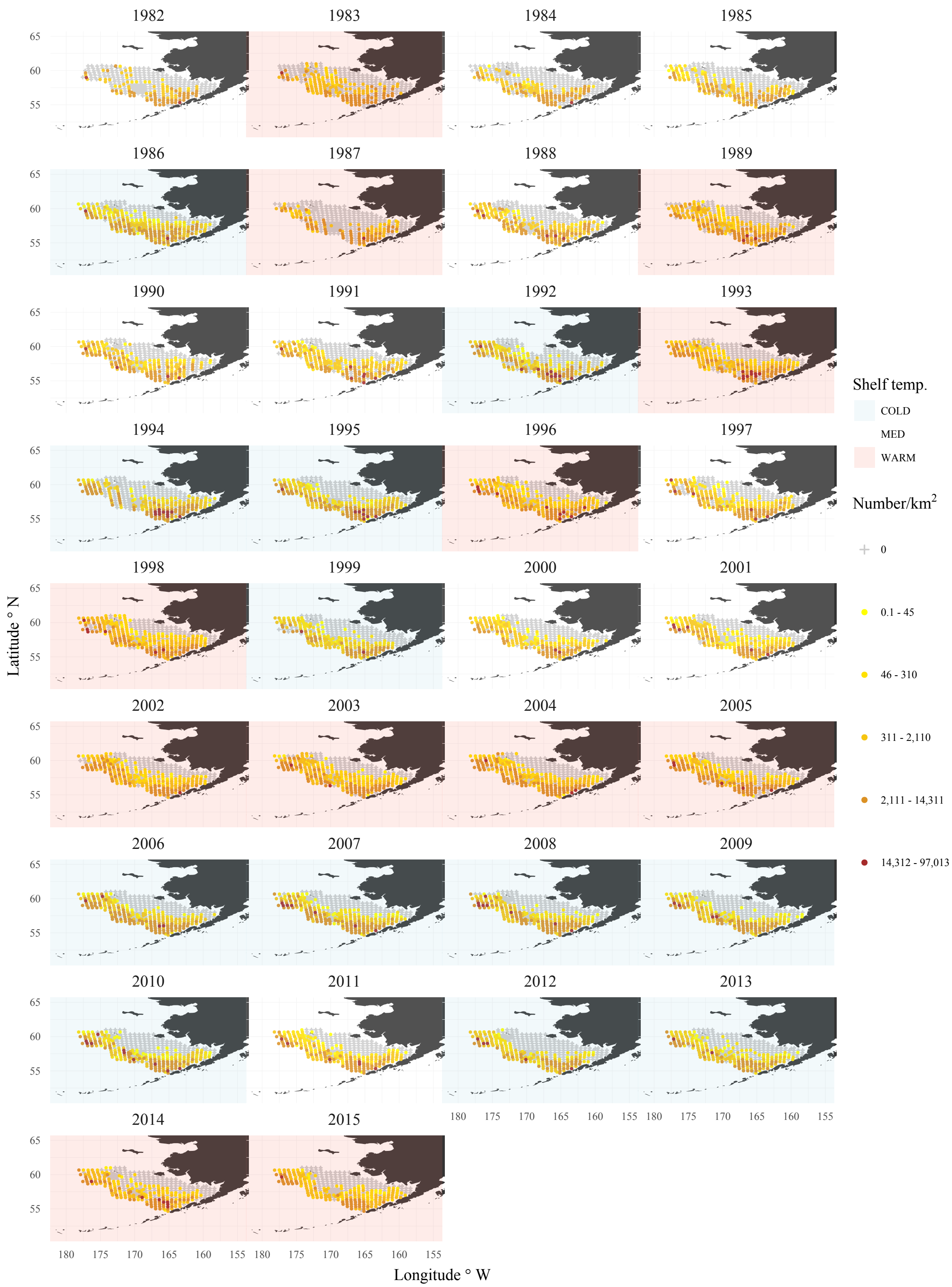


Figure 44 . -- Continued.

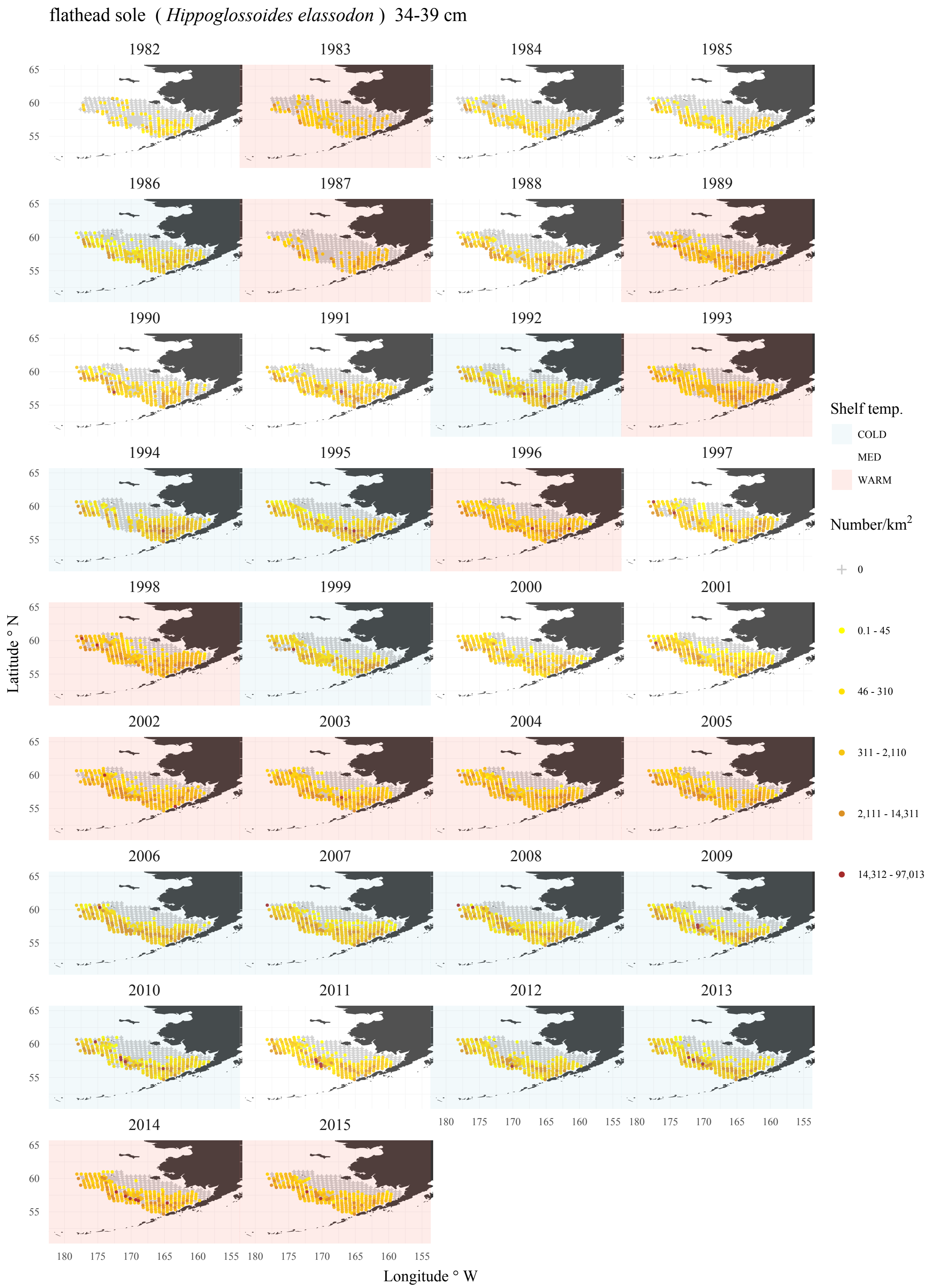


Figure 44 . -- Continued.

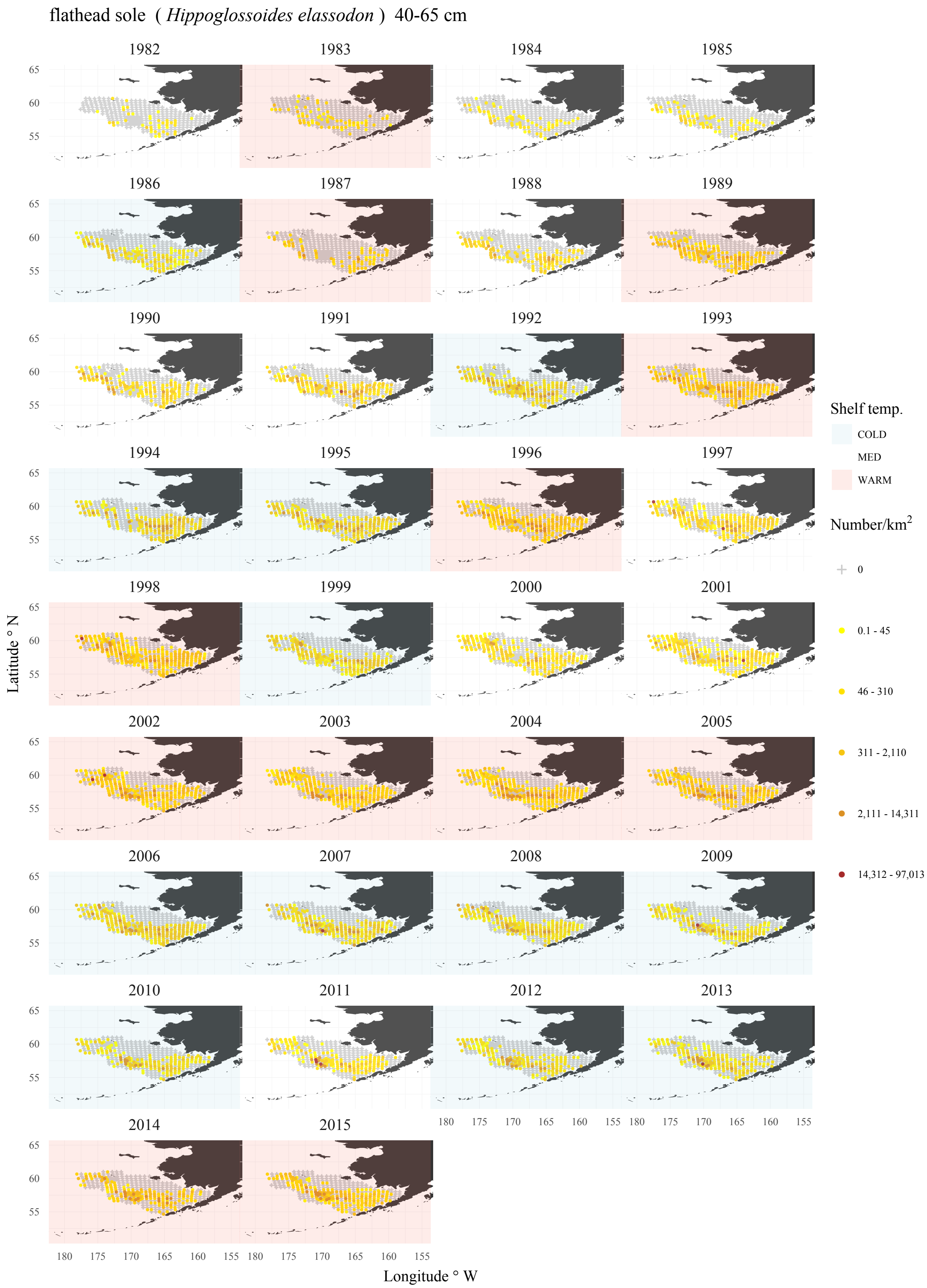


Figure 44 . -- Continued.

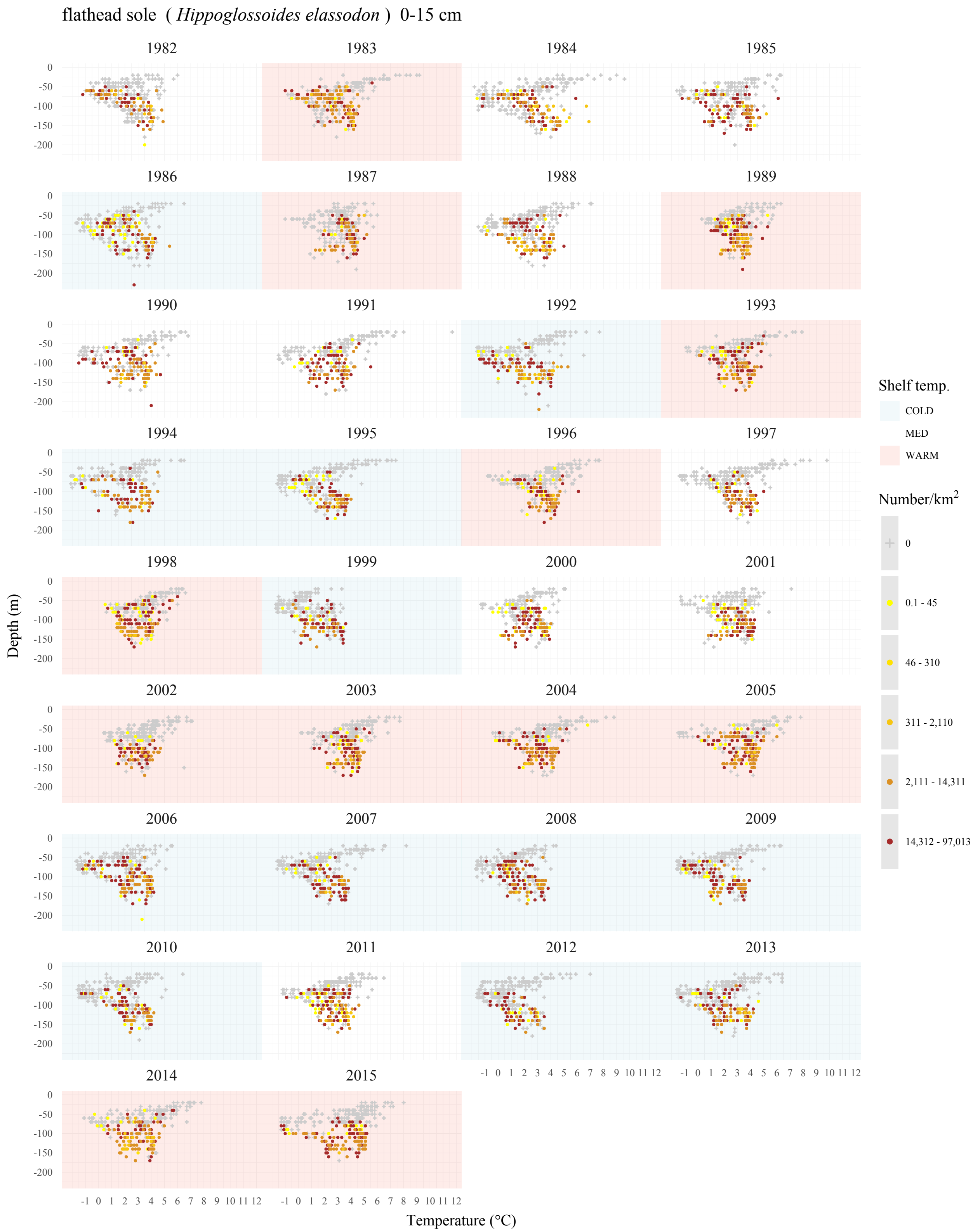


Figure 45 . -- The flathead sole (*Hippoglossoides elassodon*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

flathead sole (*Hippoglossoides elassodon*) 16-23 cm

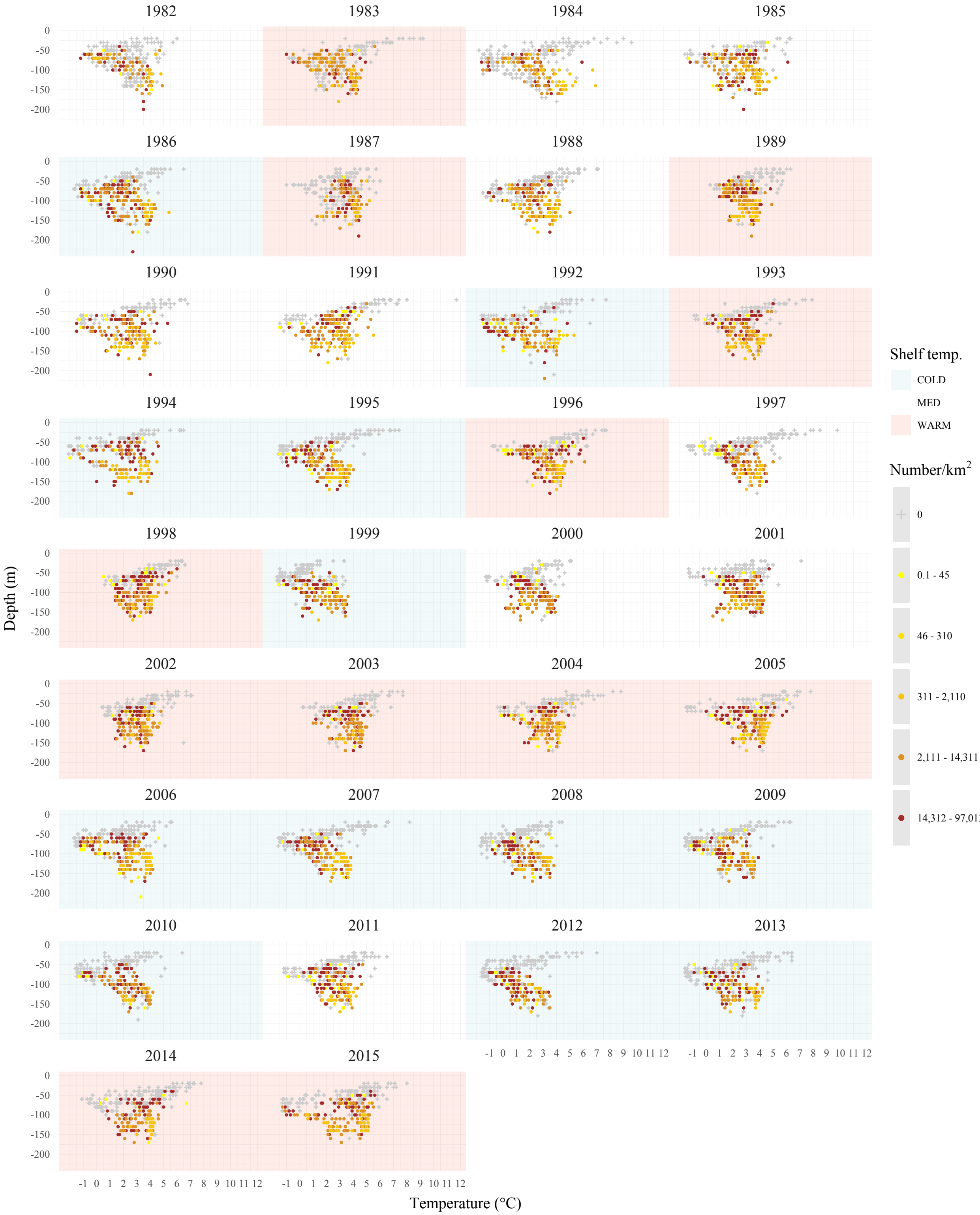


Figure 45 . -- Continued.

flathead sole (*Hippoglossoides elassodon*) 24-33 cm

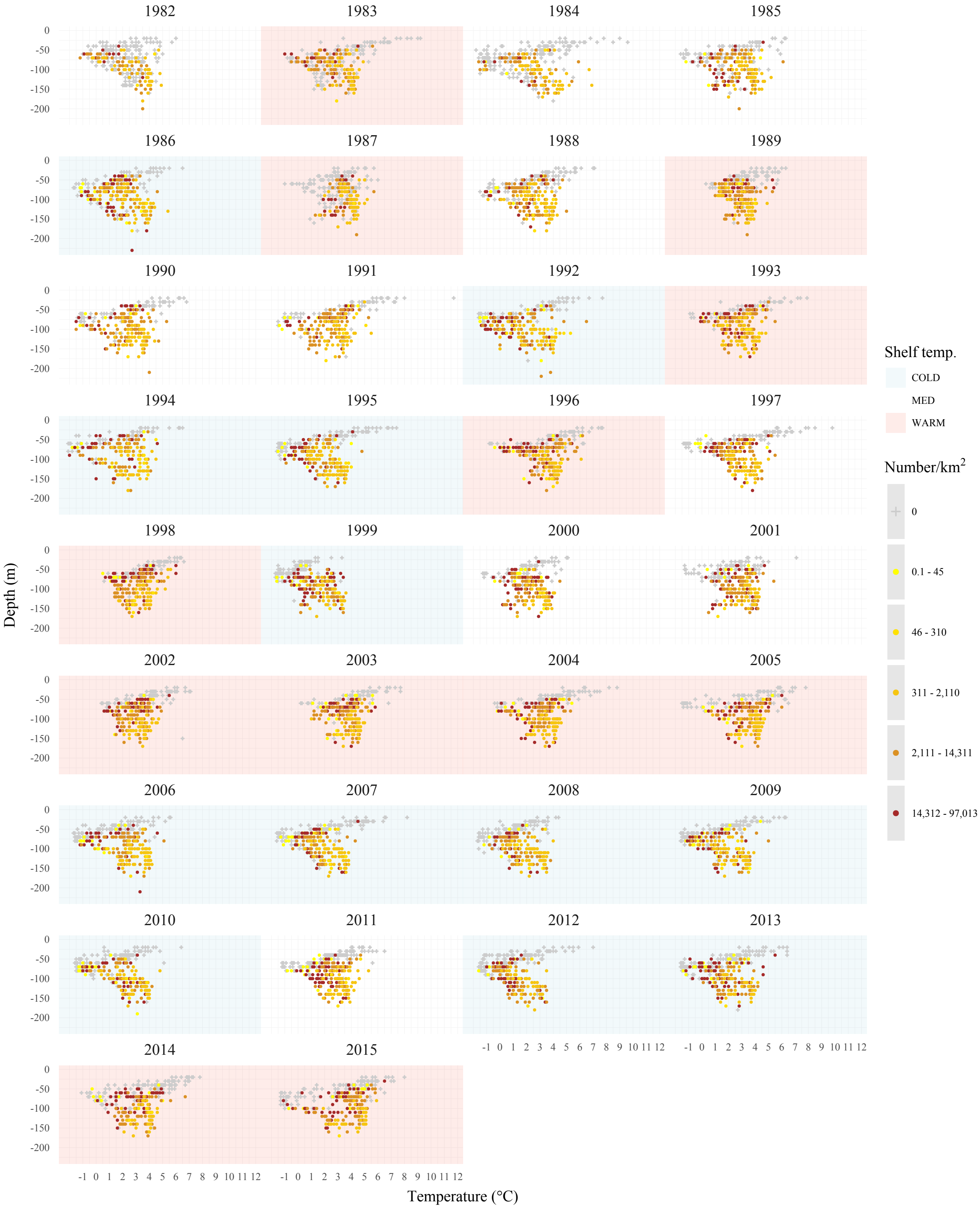


Figure 45 . -- Continued.

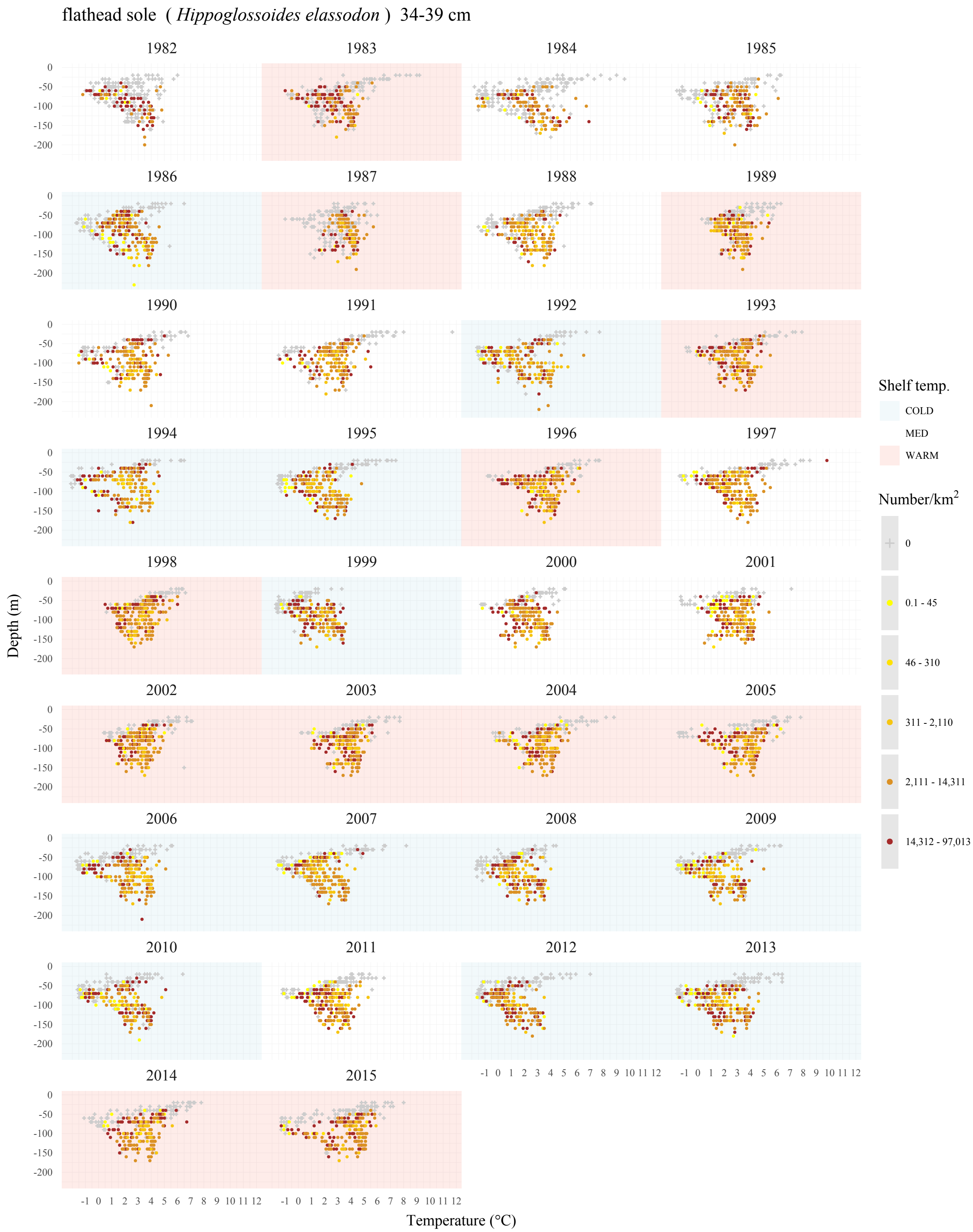


Figure 45 . -- Continued.

flathead sole (*Hippoglossoides elassodon*) 40-65 cm

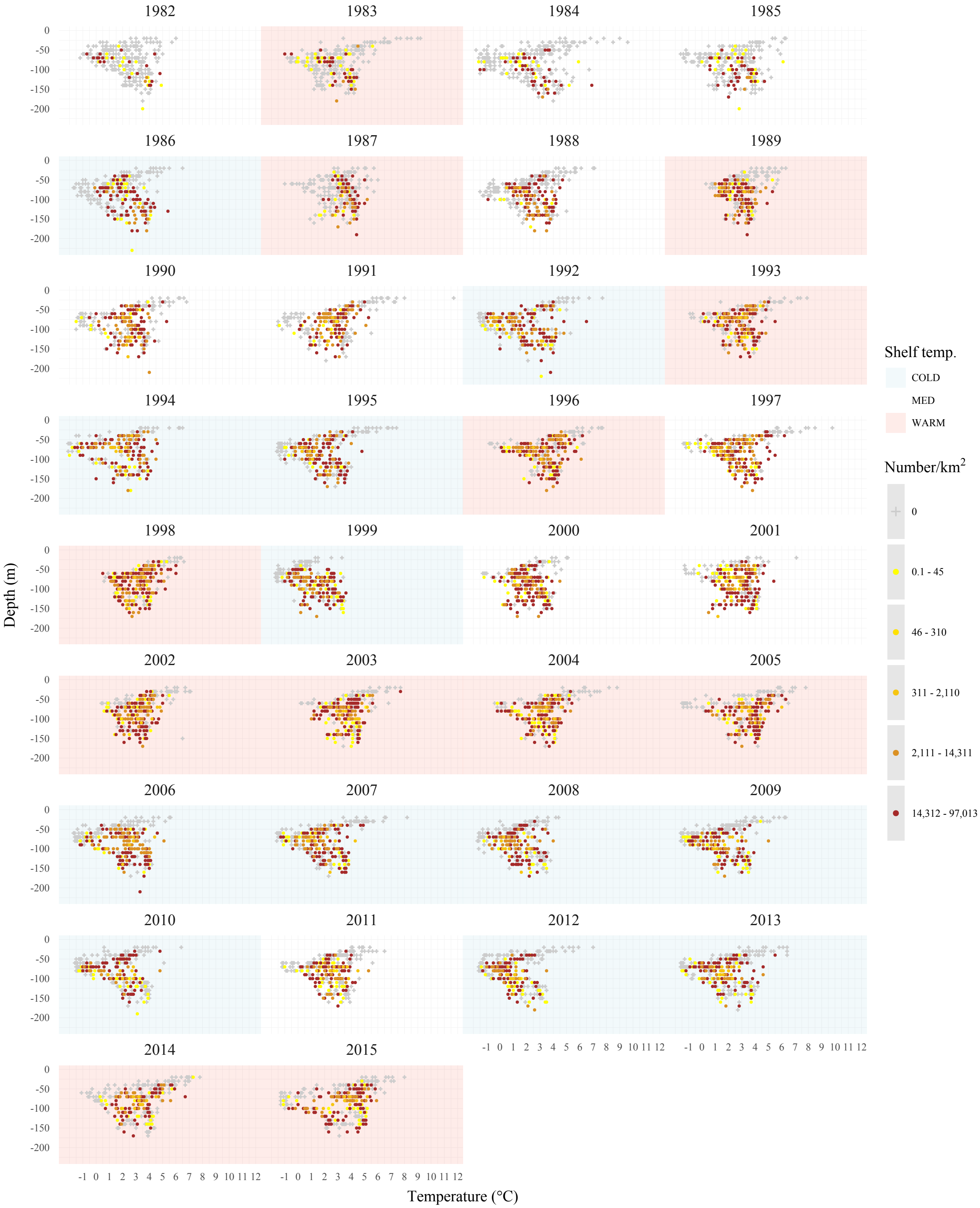


Figure 45 . -- Continued.

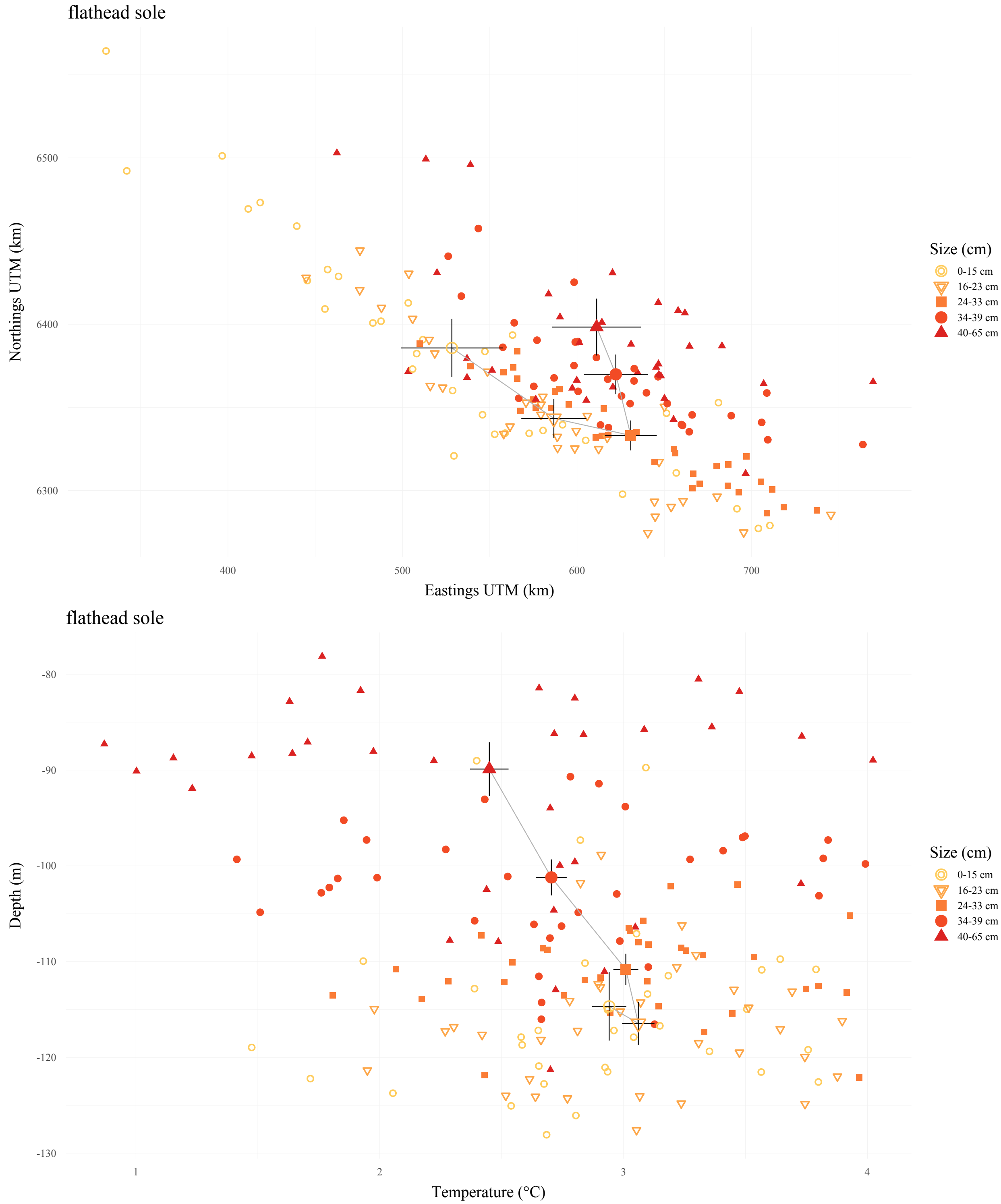


Figure 46 . -- The flathead sole (*Hippoglossoides elassodon*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

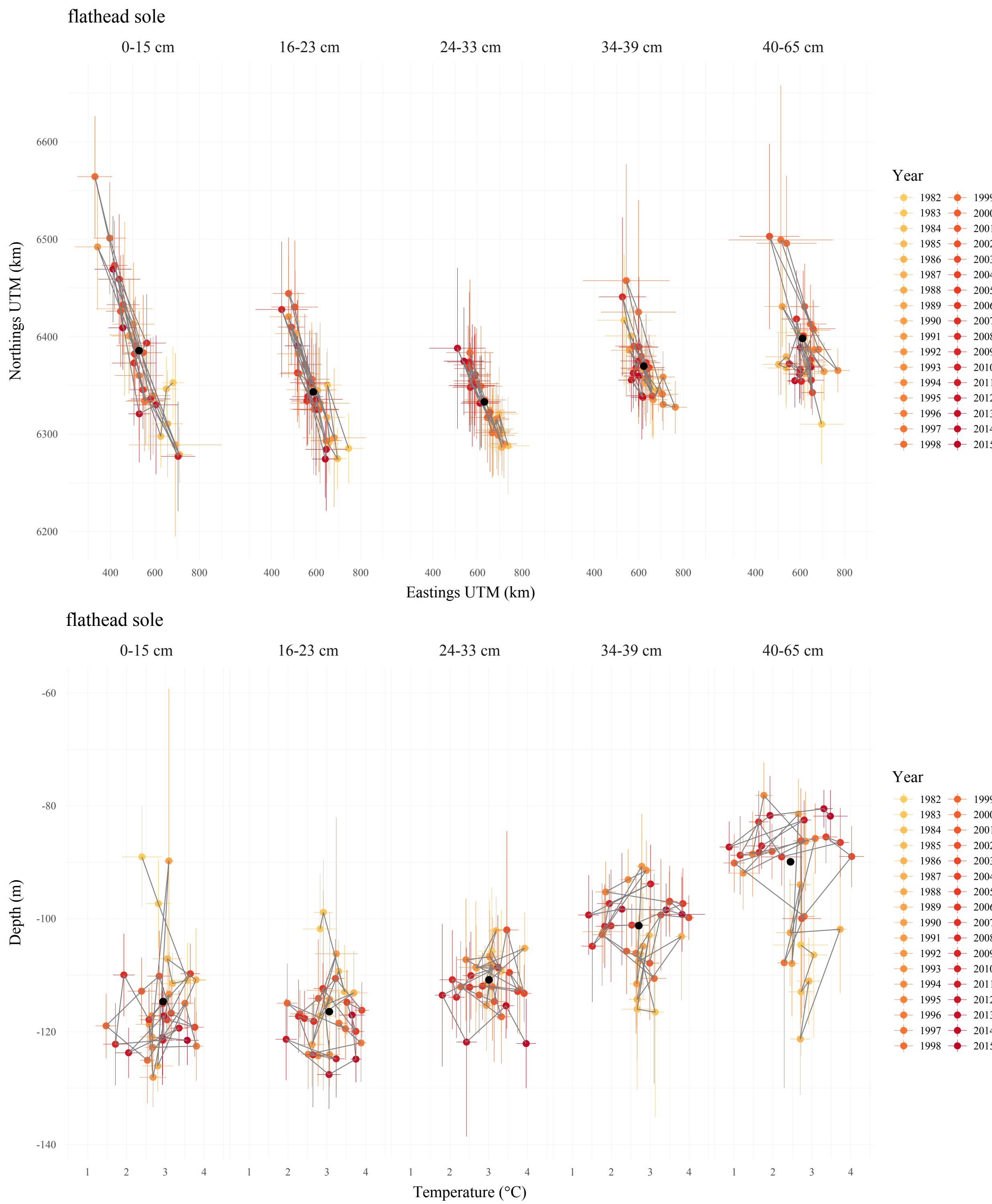


Figure 47 . -- The flathead sole (*Hippoglossoides elassodon*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

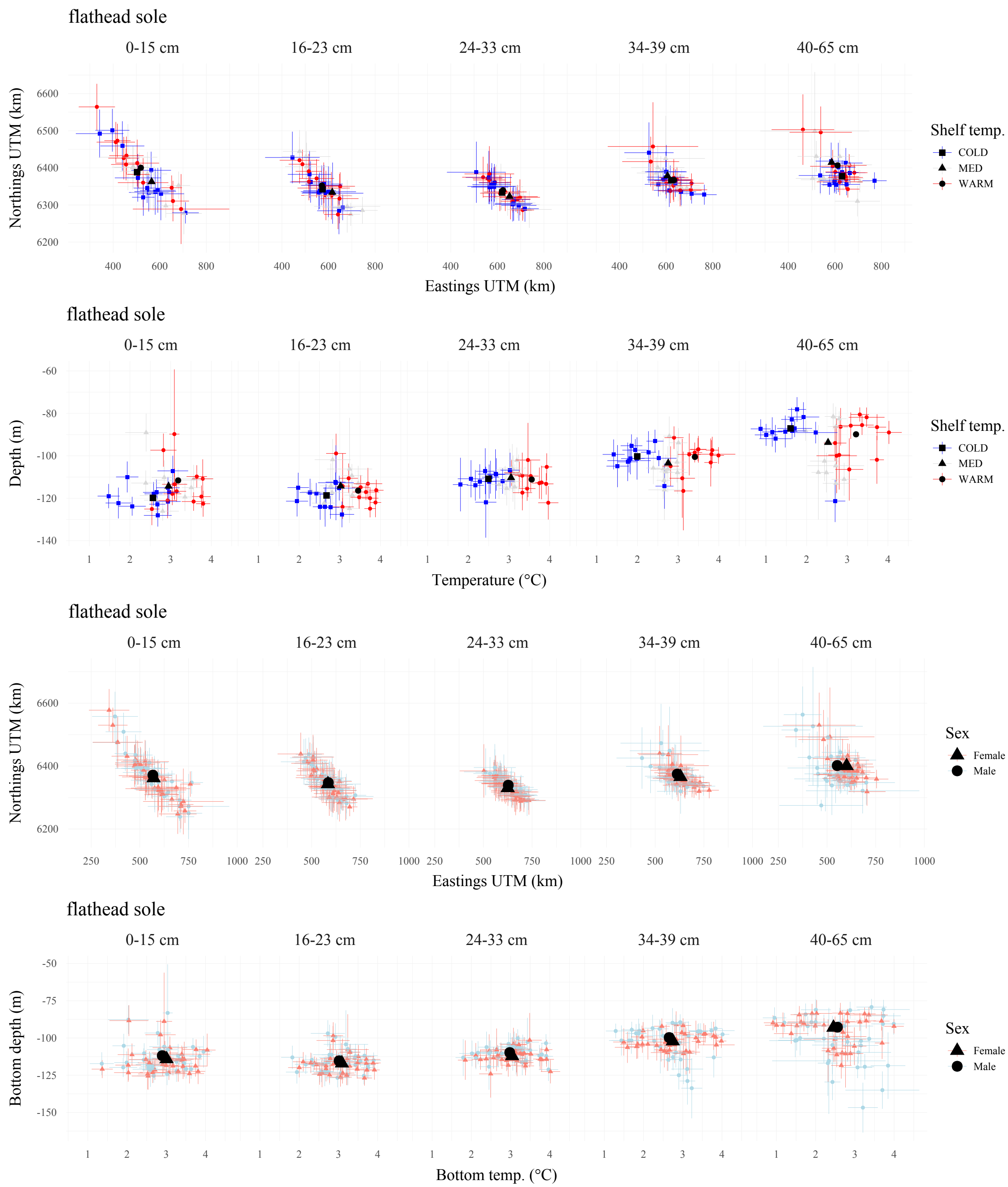


Figure 48 . -- The flathead sole (*Hippoglossoides elassodon*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

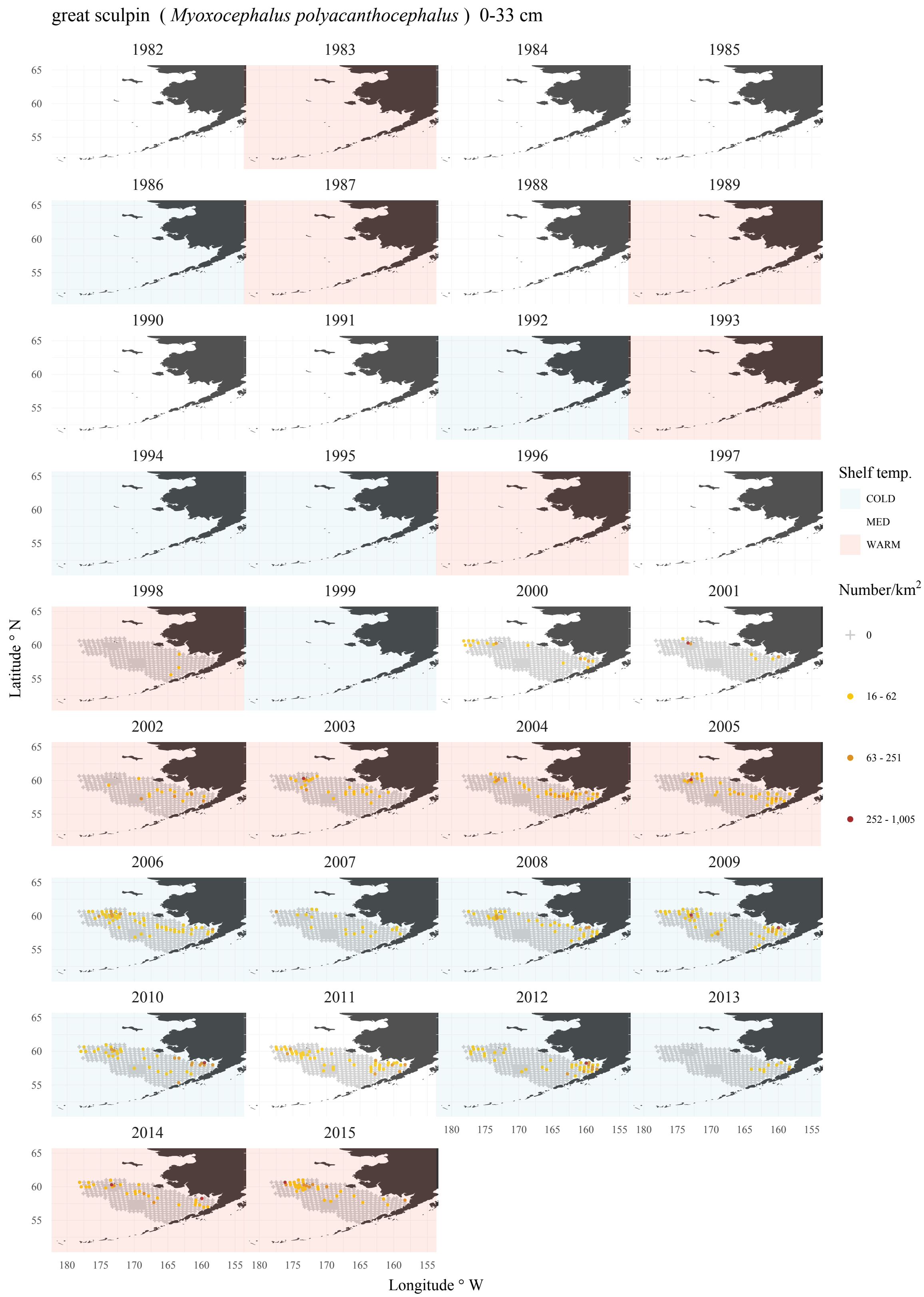


Figure 49 . -- The great sculpin (*Myoxocephalus polyacanthocephalus*) CPUE by number weighted mean location for each length category for all years.

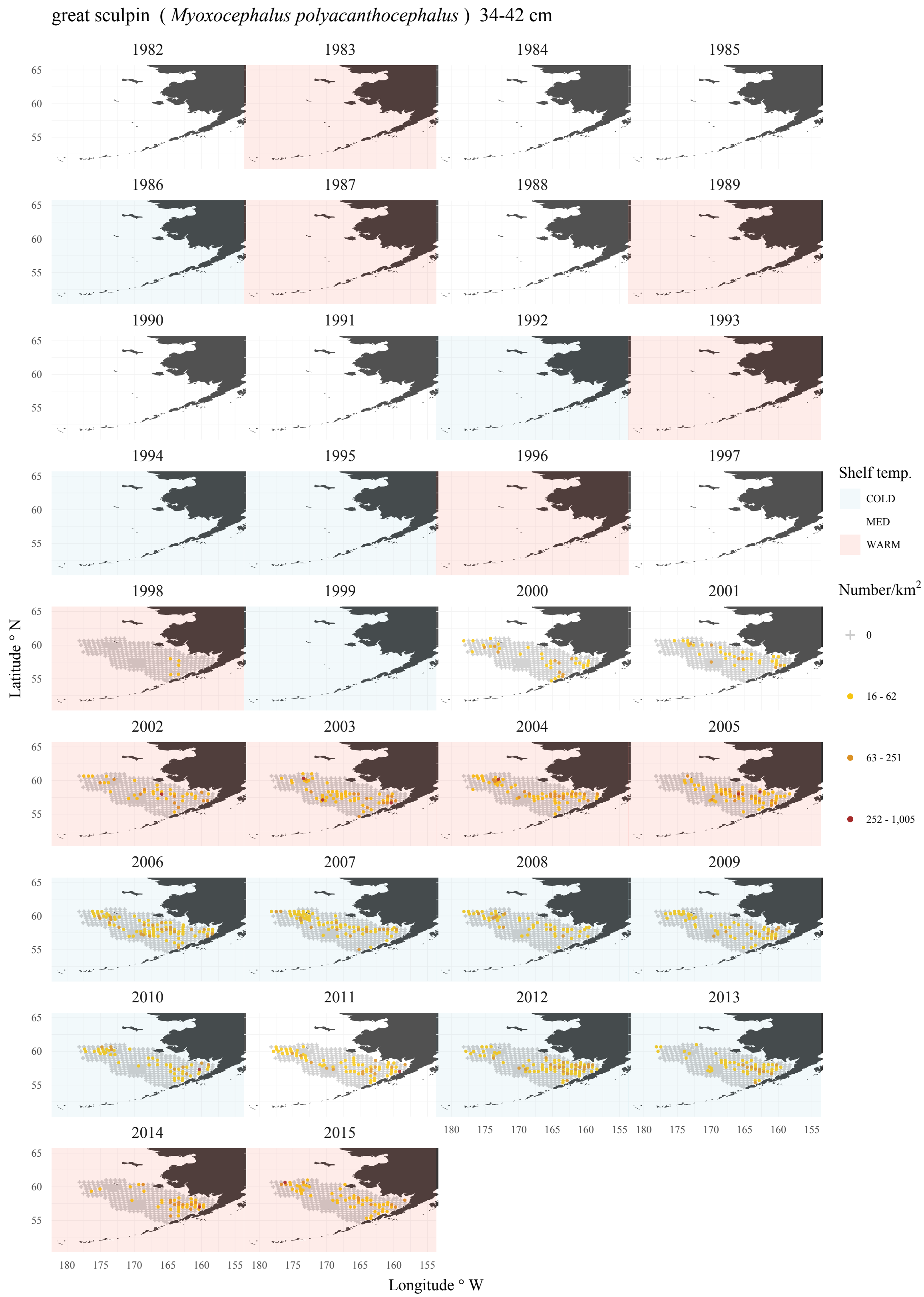


Figure 49 . -- Continued.

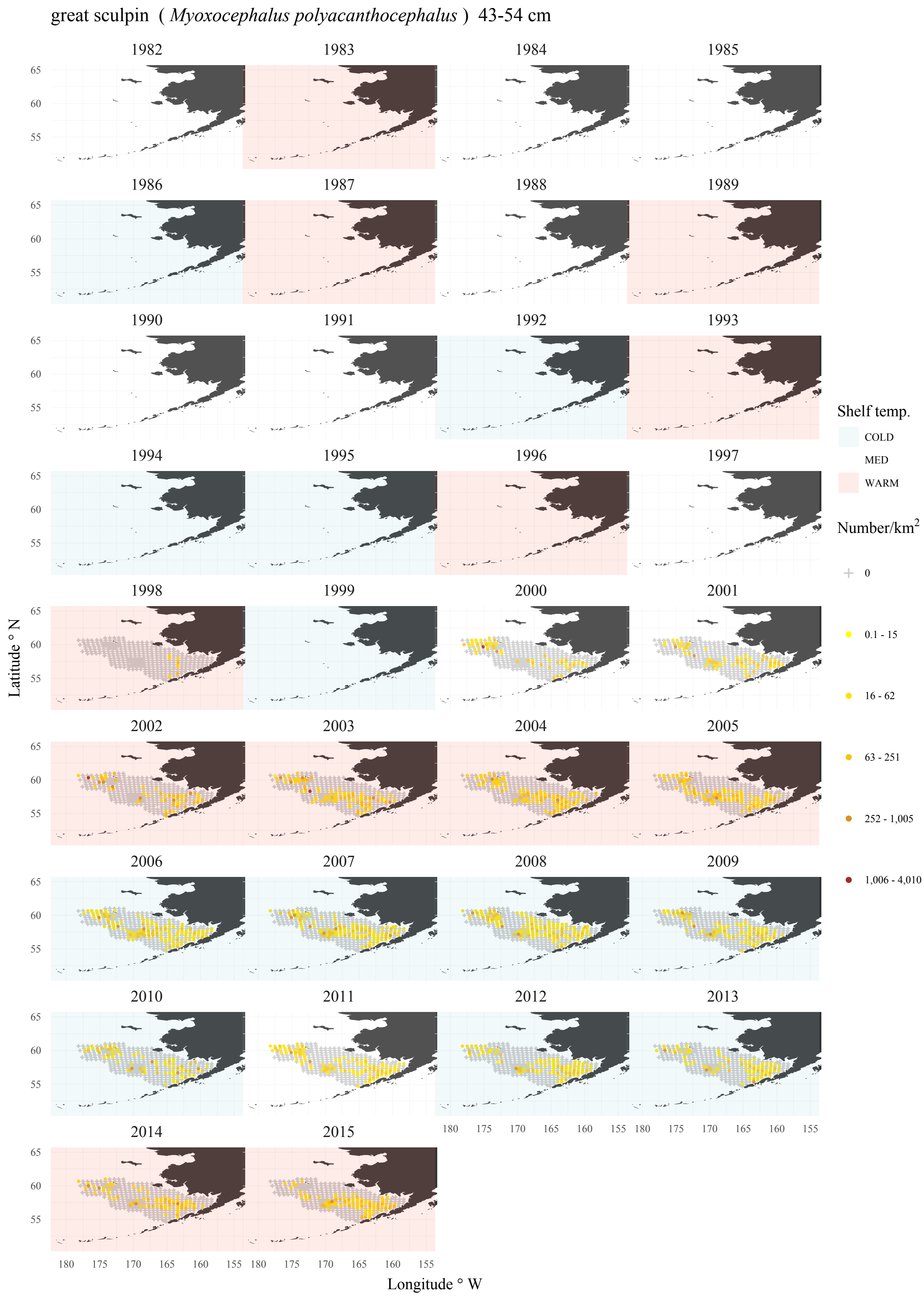


Figure 49 . -- Continued.

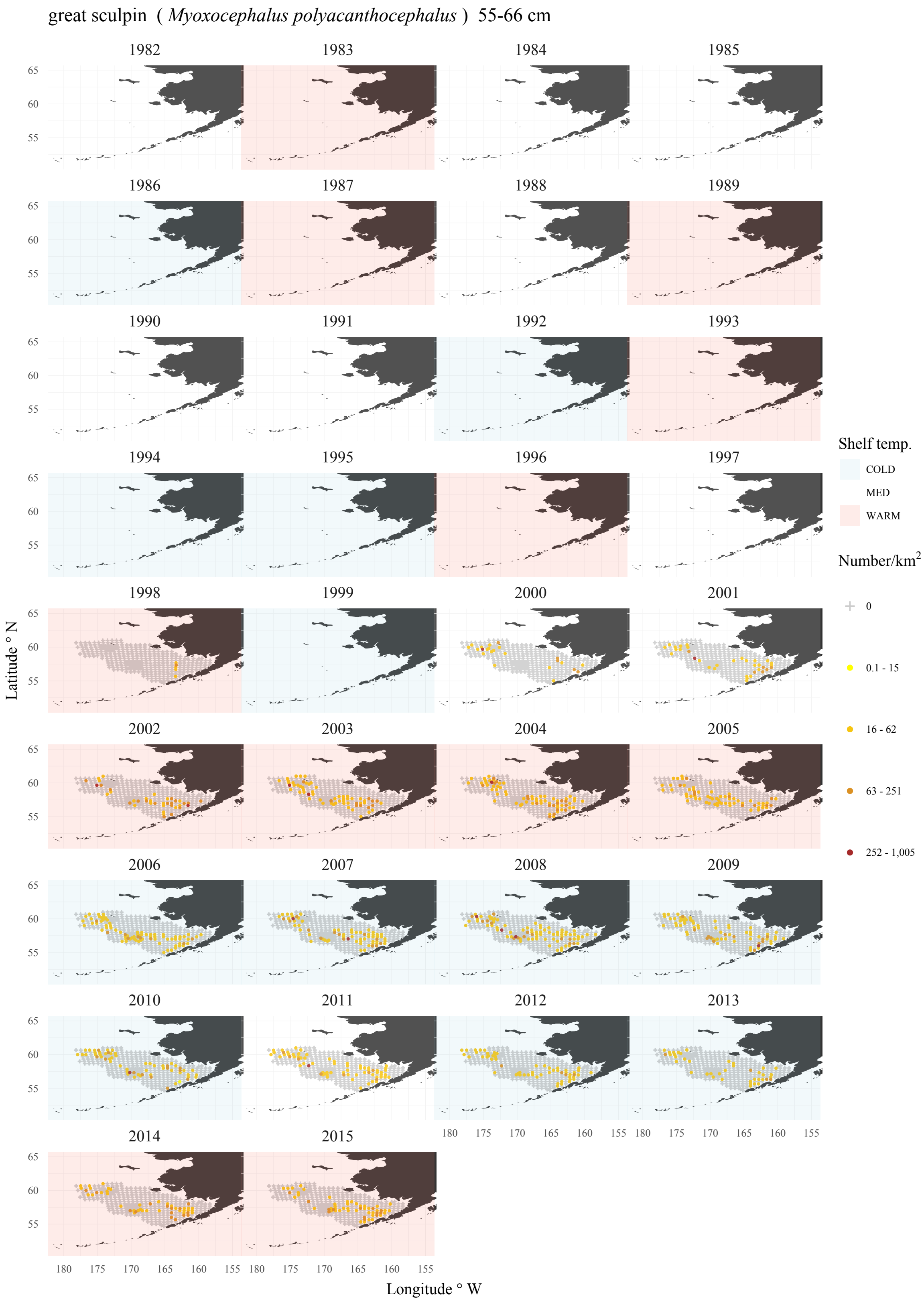


Figure 49 . -- Continued.

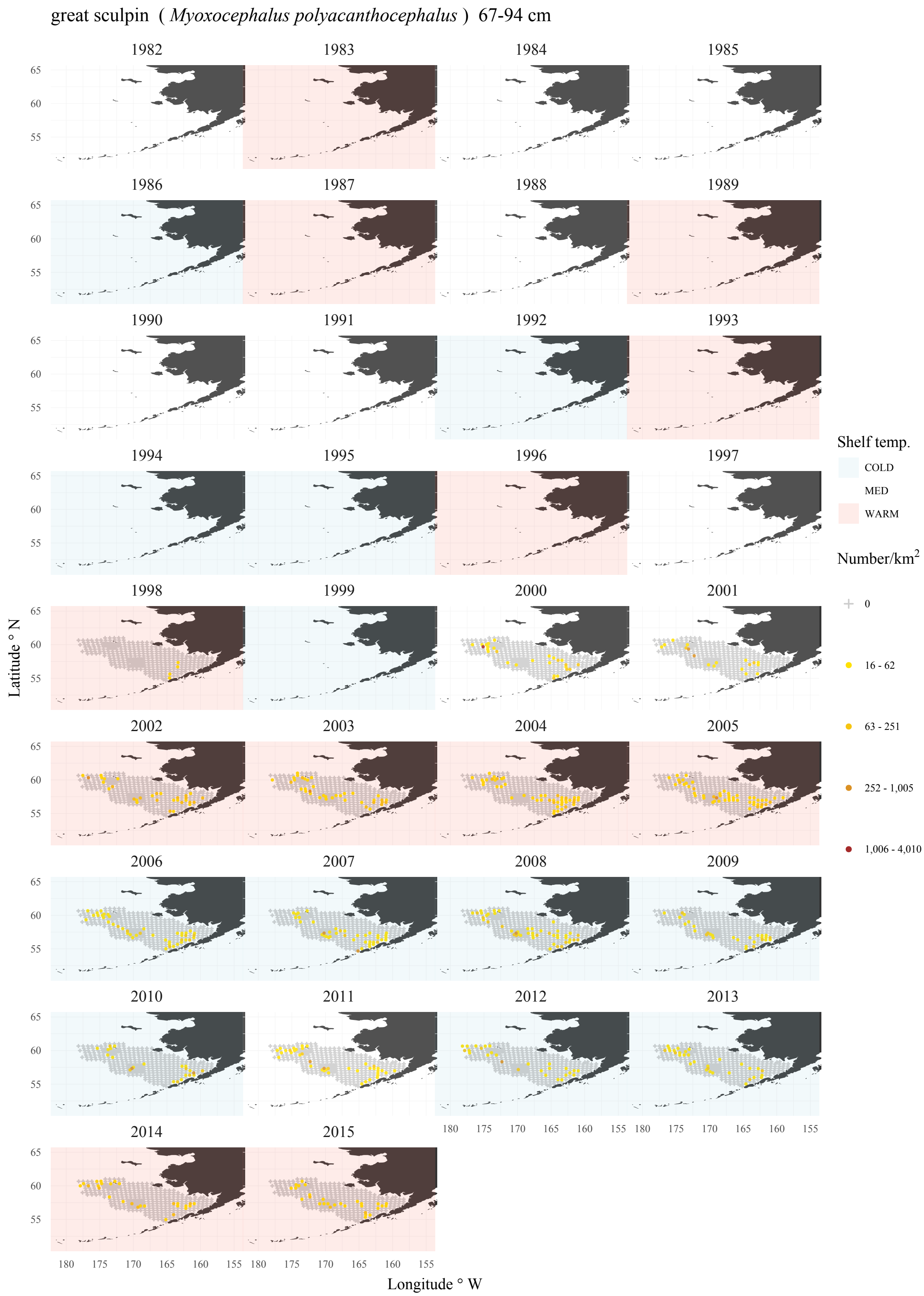


Figure 49 . -- Continued.

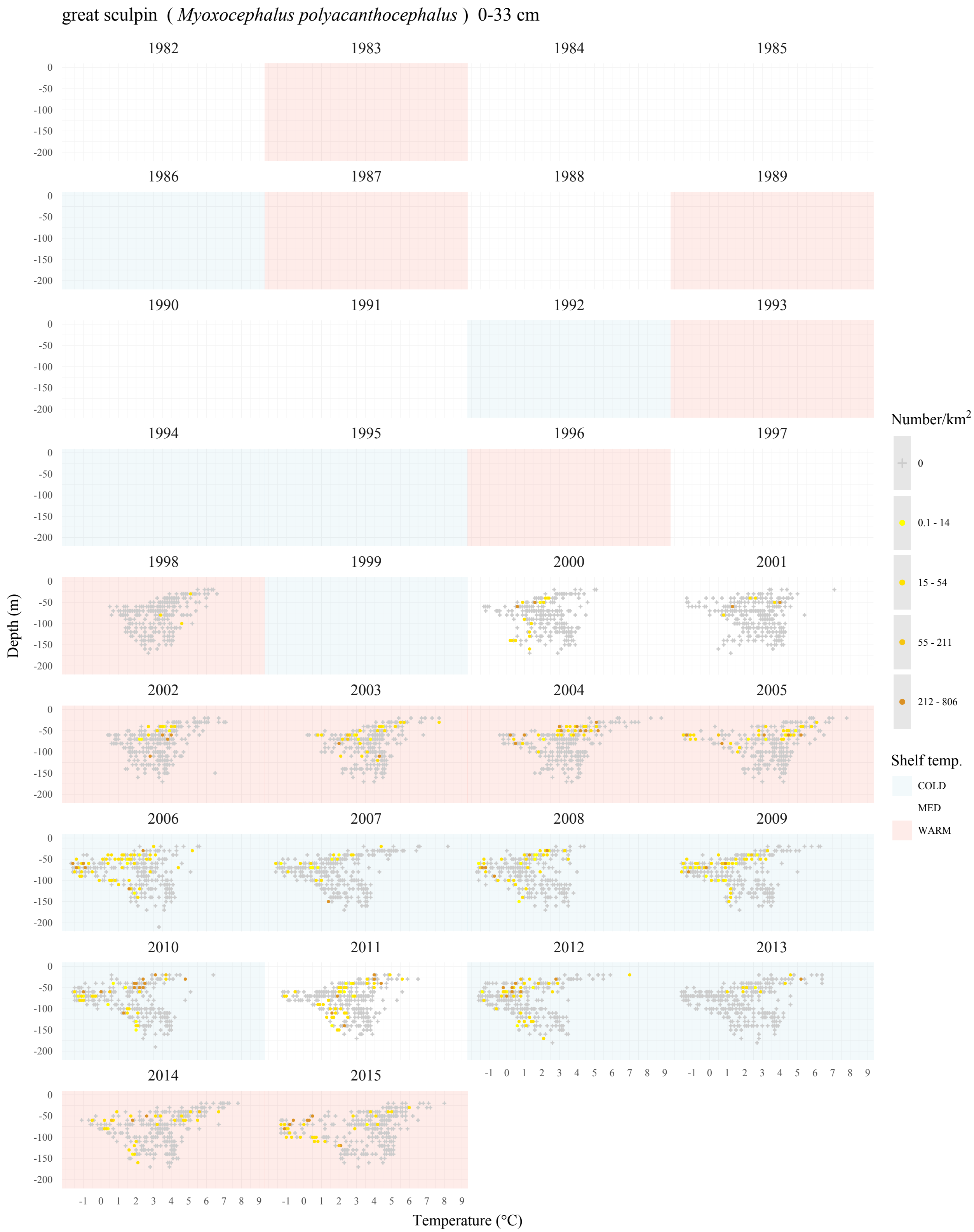


Figure 50 . -- The great sculpin (*Myoxocephalus polyacanthocephalus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

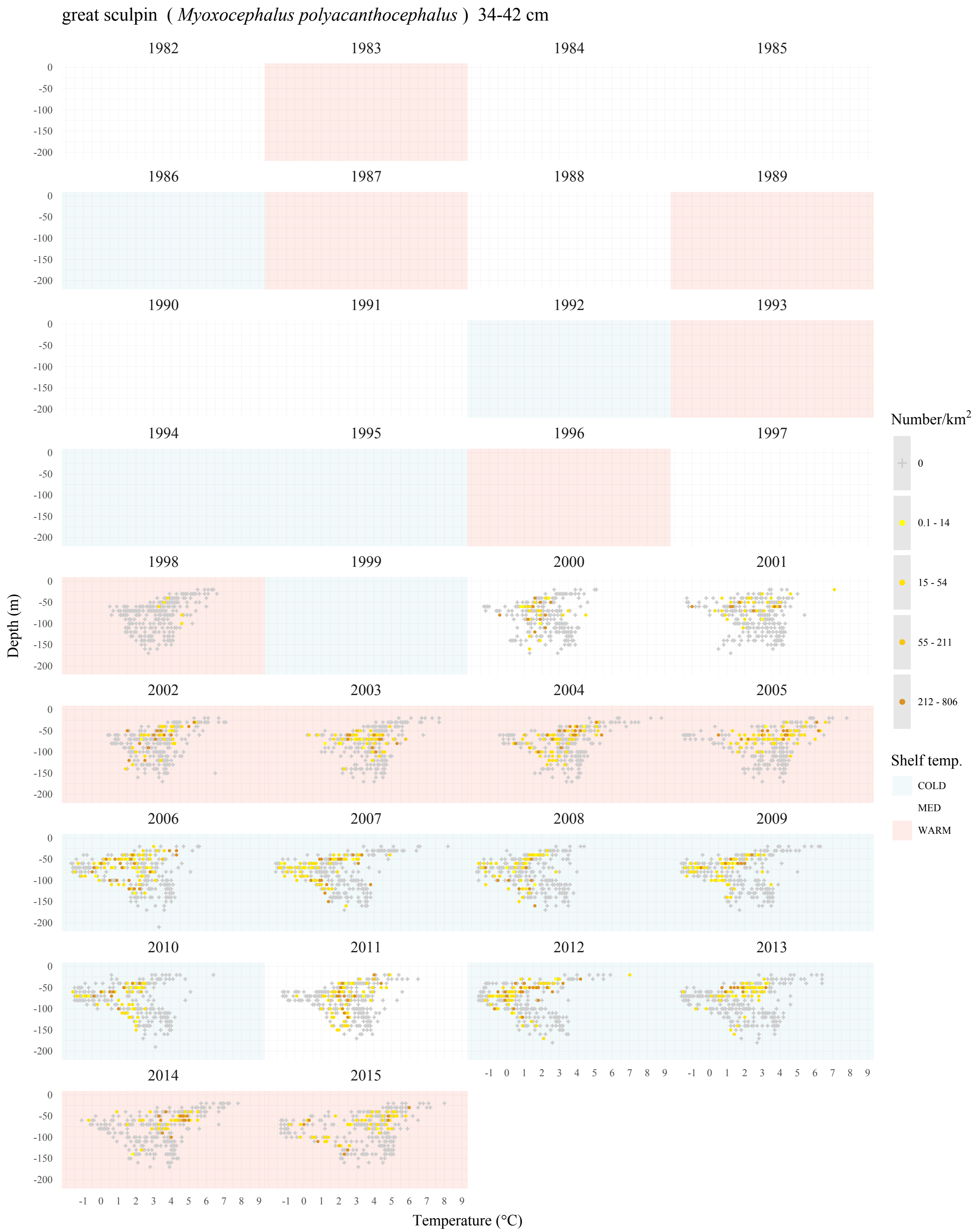


Figure 50 . -- Continued.

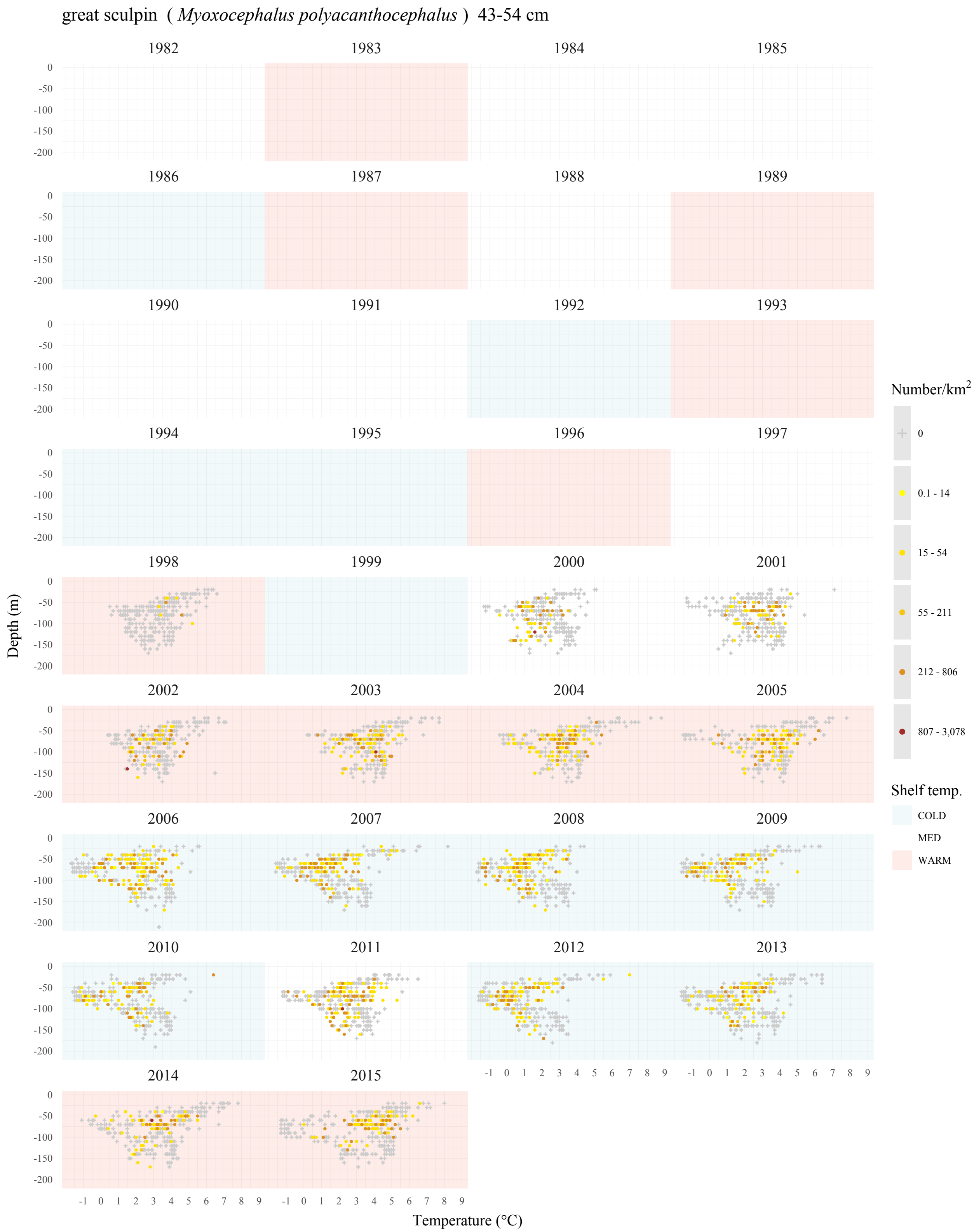


Figure 50 . -- Continued.

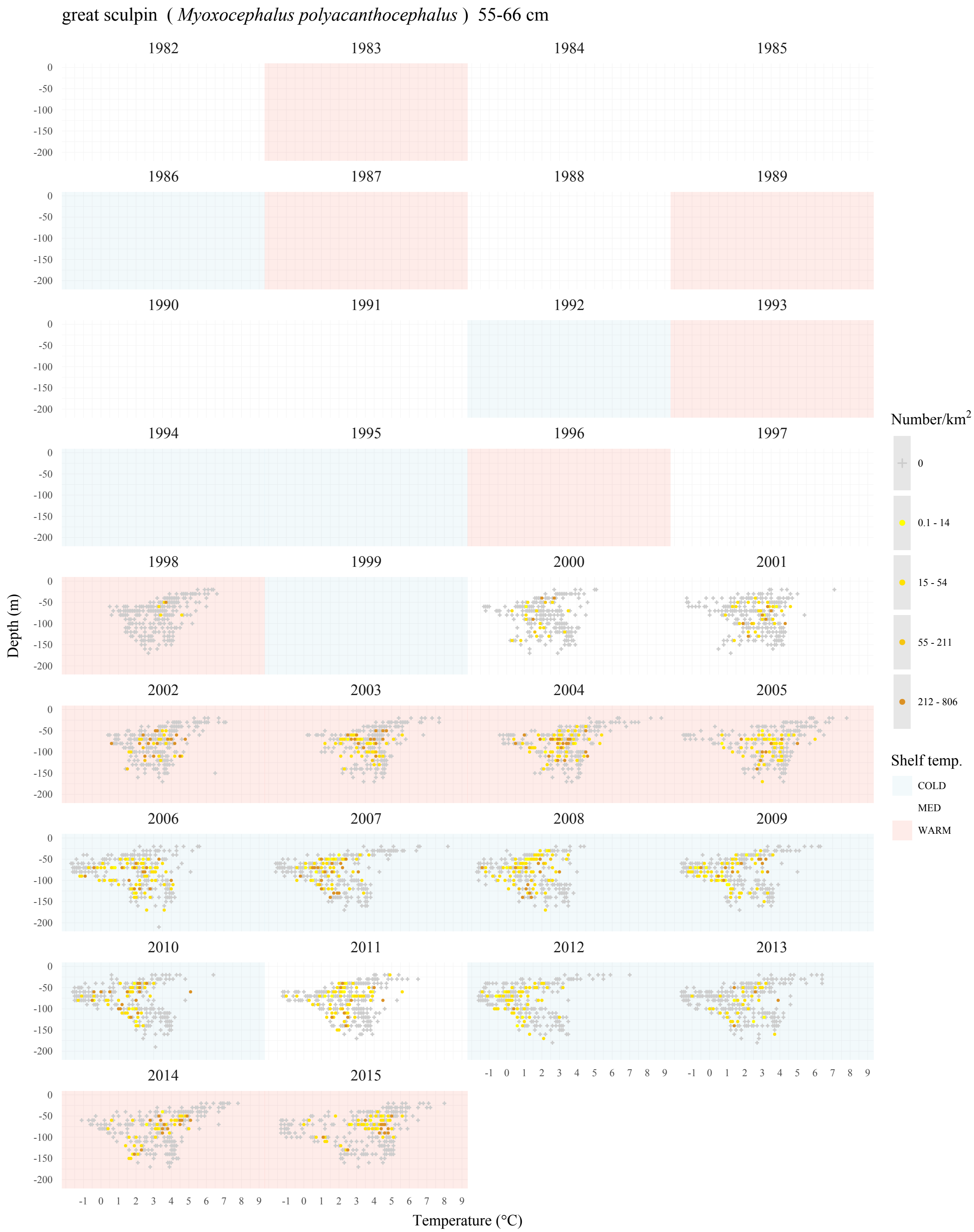


Figure 50 . -- Continued.

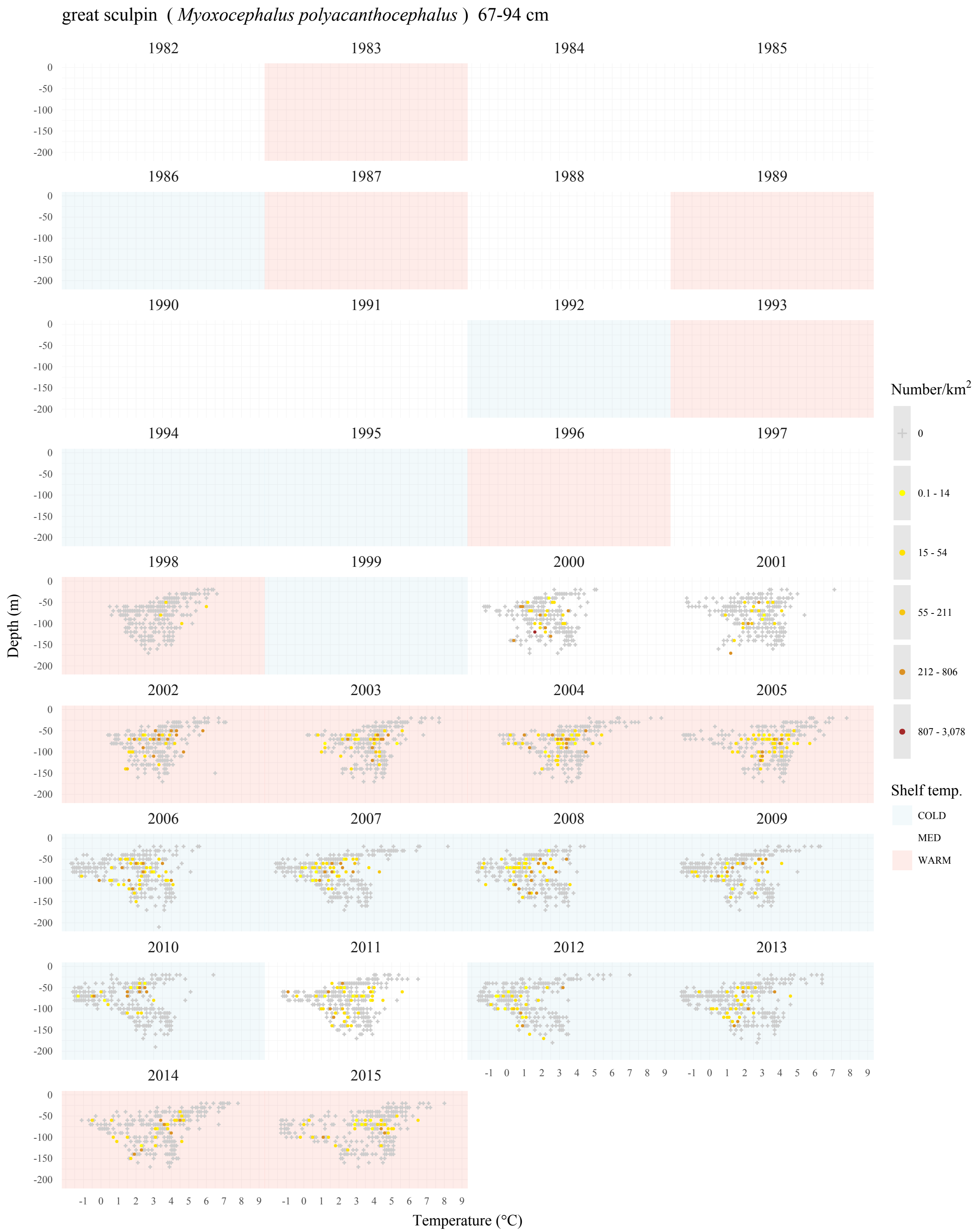


Figure 50 . -- Continued.

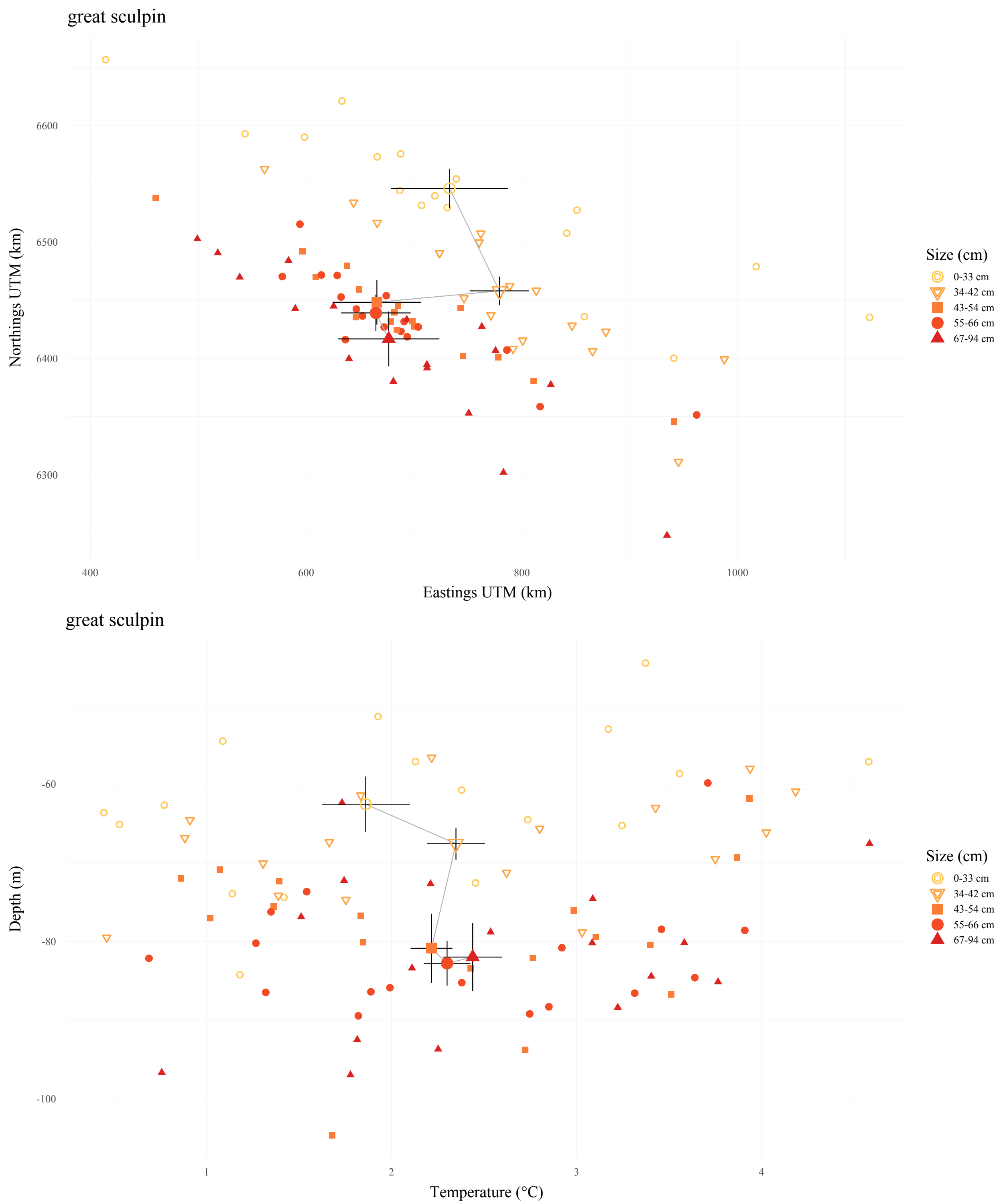


Figure 51 . -- The great sculpin (*Myoxocephalus polyacanthocephalus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

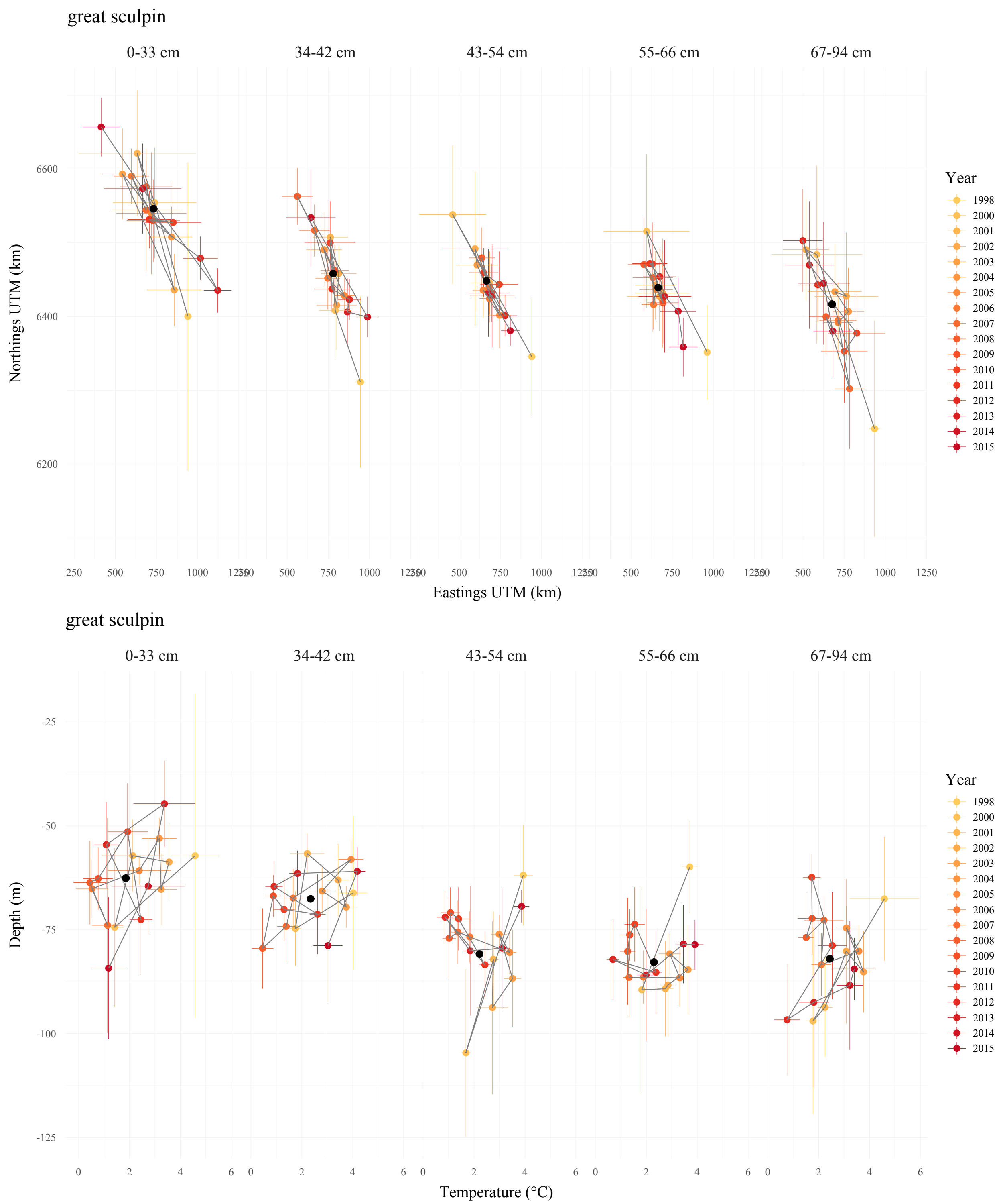


Figure 52 . -- The great sculpin (*Myoxocephalus polyacanthocephalus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

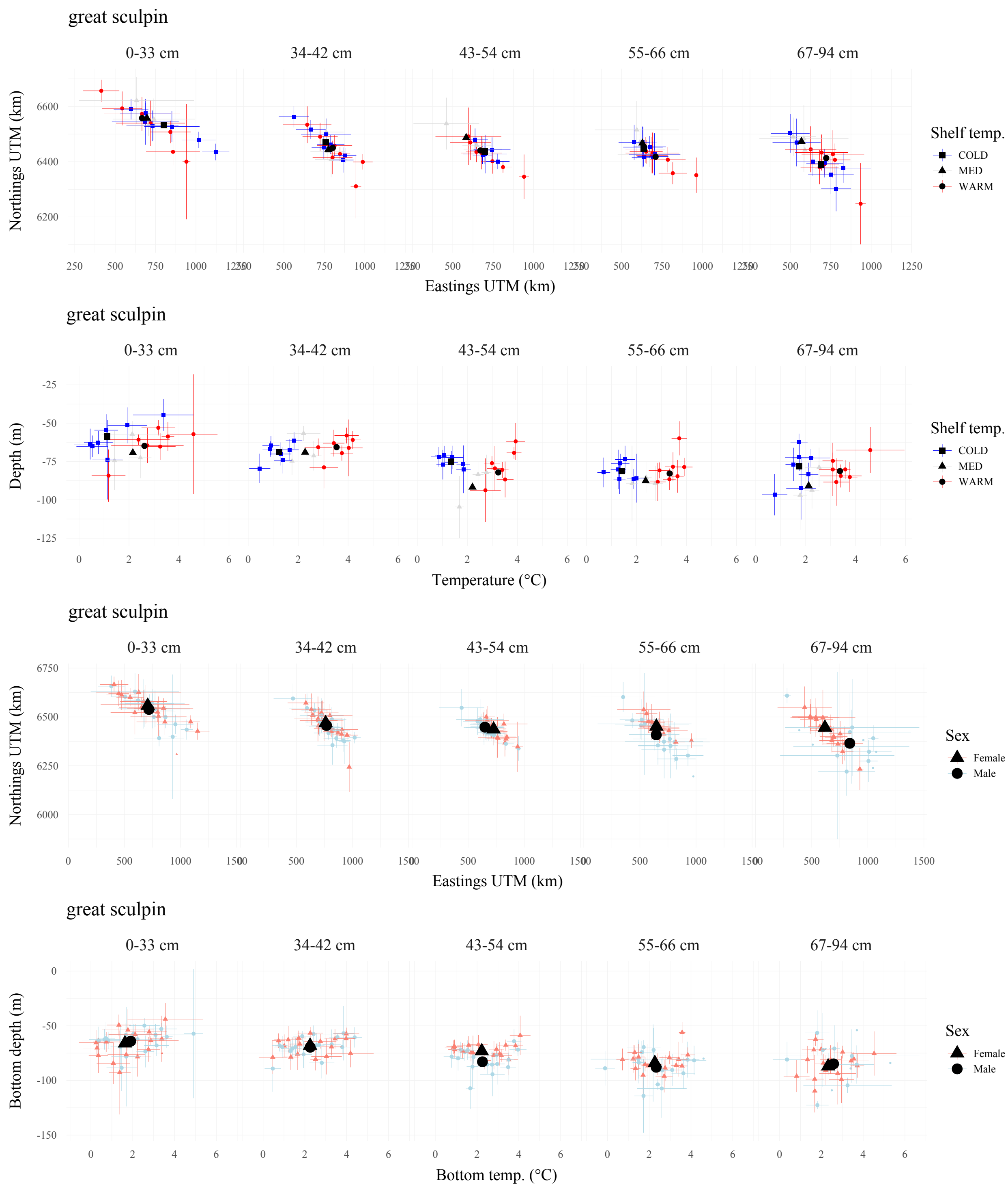


Figure 53 . -- The great sculpin (*Myoxocephalus polyacanthocephalus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

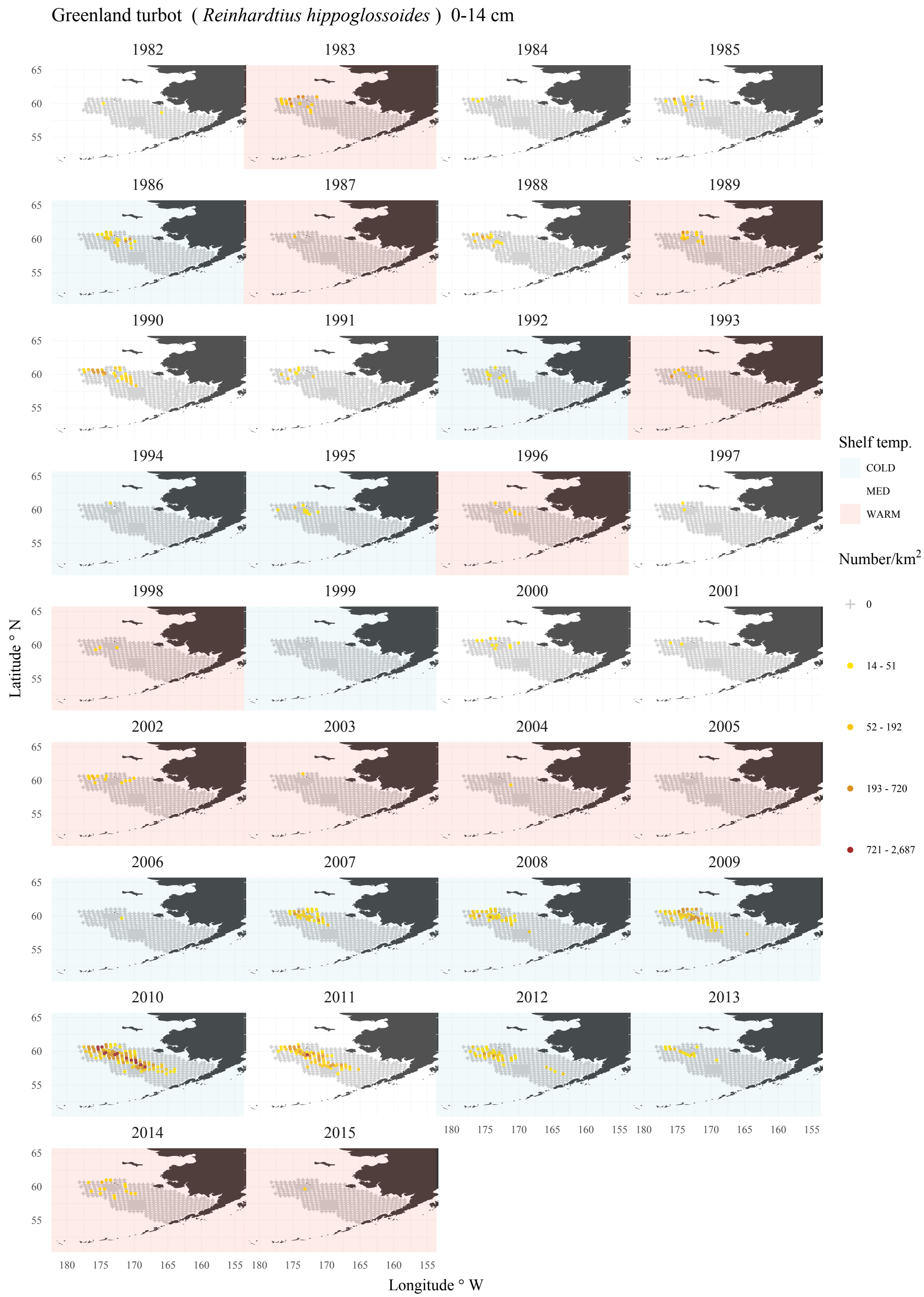


Figure 54 . -- The Greenland turbot (*Reinhardtius hippoglossoides*) CPUE by number weighted mean location for each length category for all years.

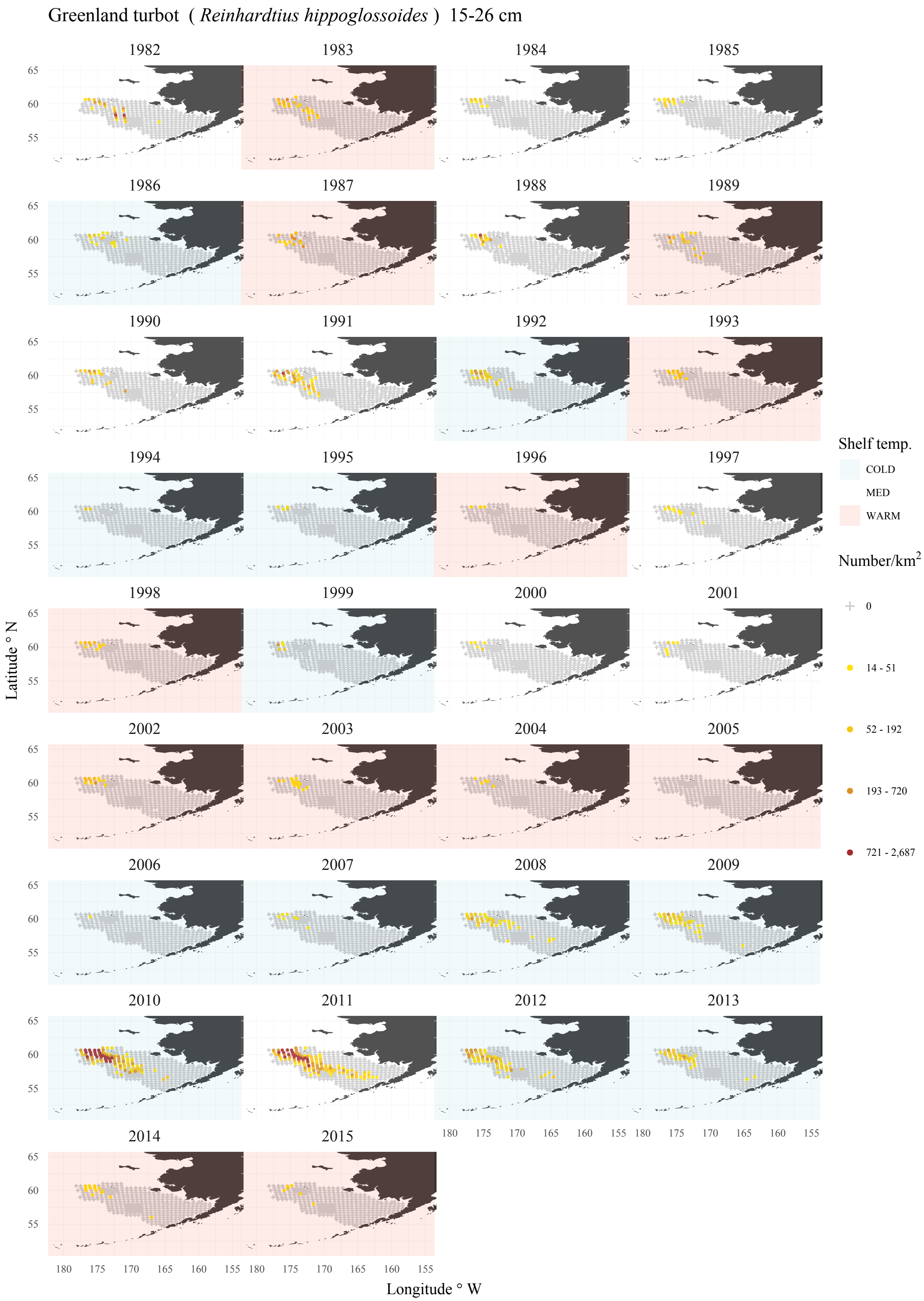


Figure 54 . -- Continued.

Greenland turbot (*Reinhardtius hippoglossoides*) 27-46 cm

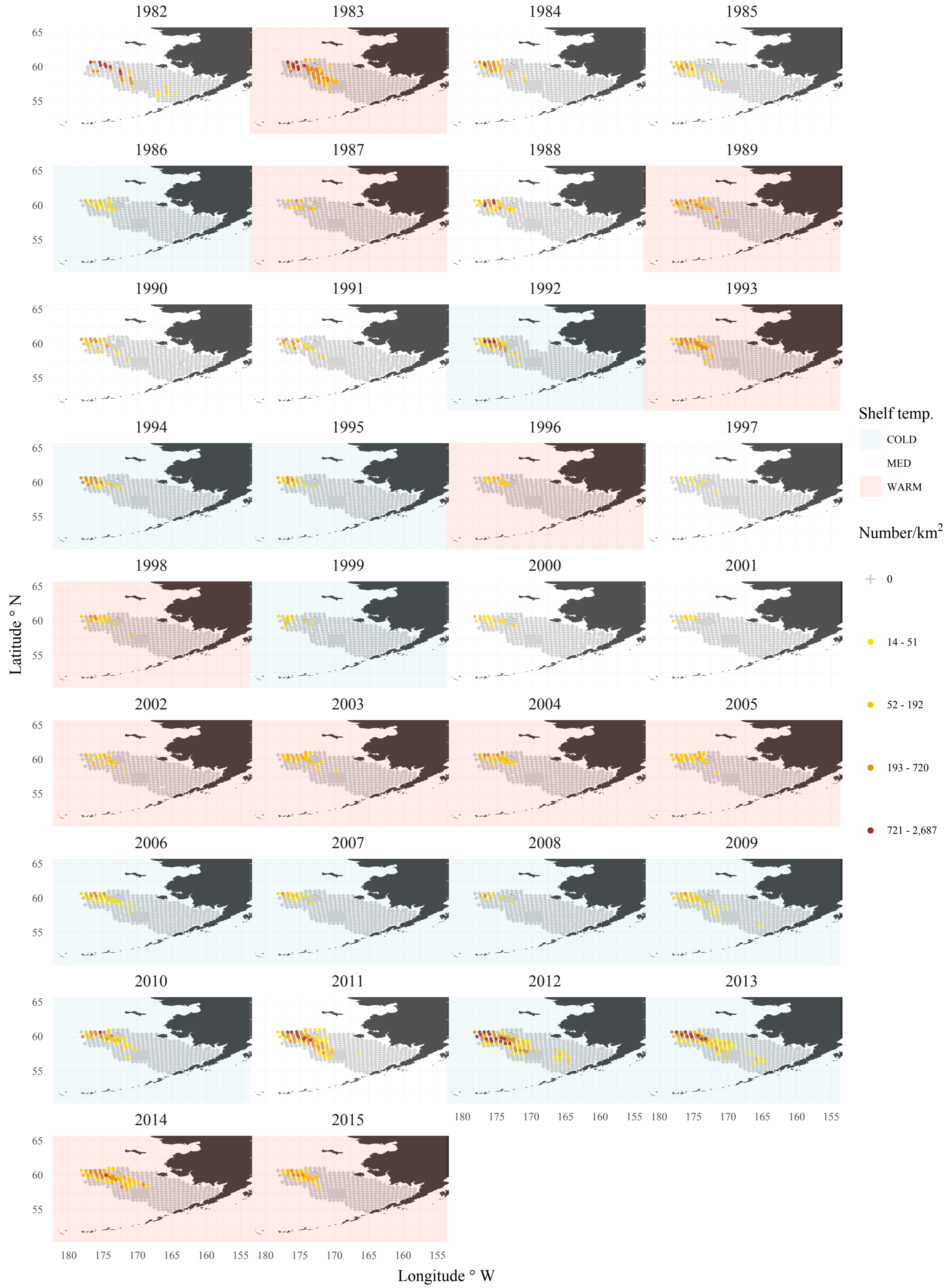


Figure 54 . -- Continued.

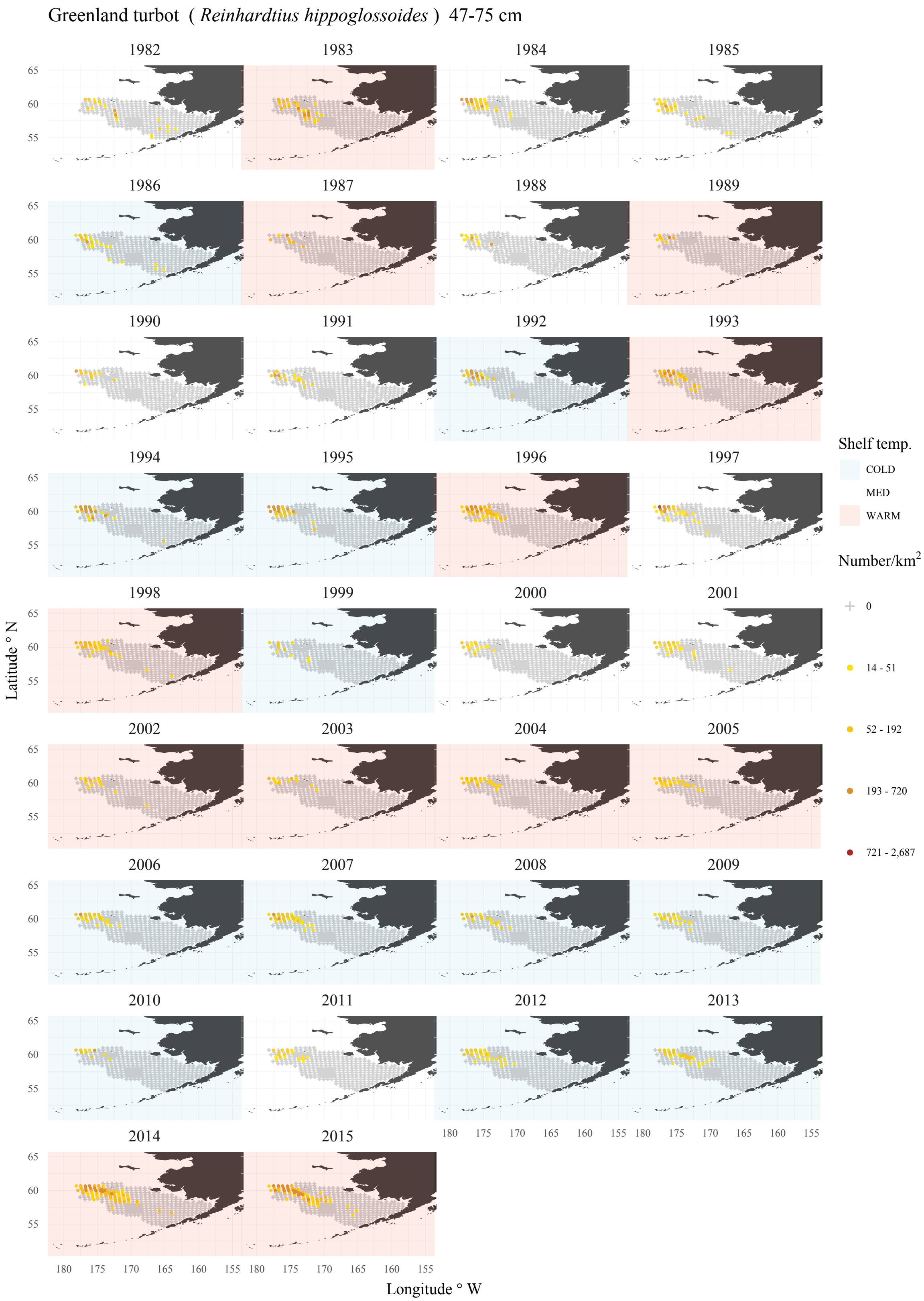


Figure 54 . -- Continued.

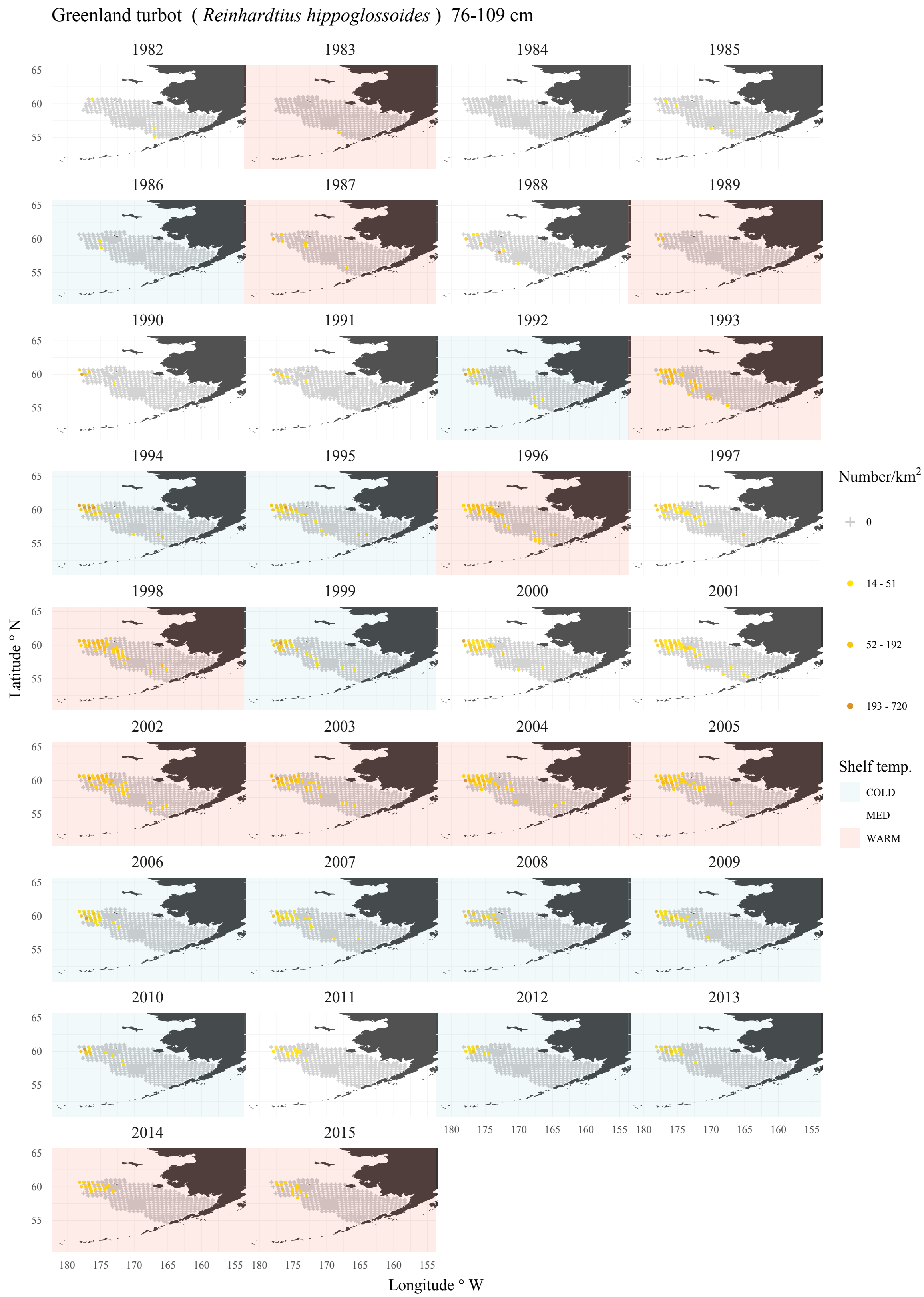


Figure 54 . -- Continued.

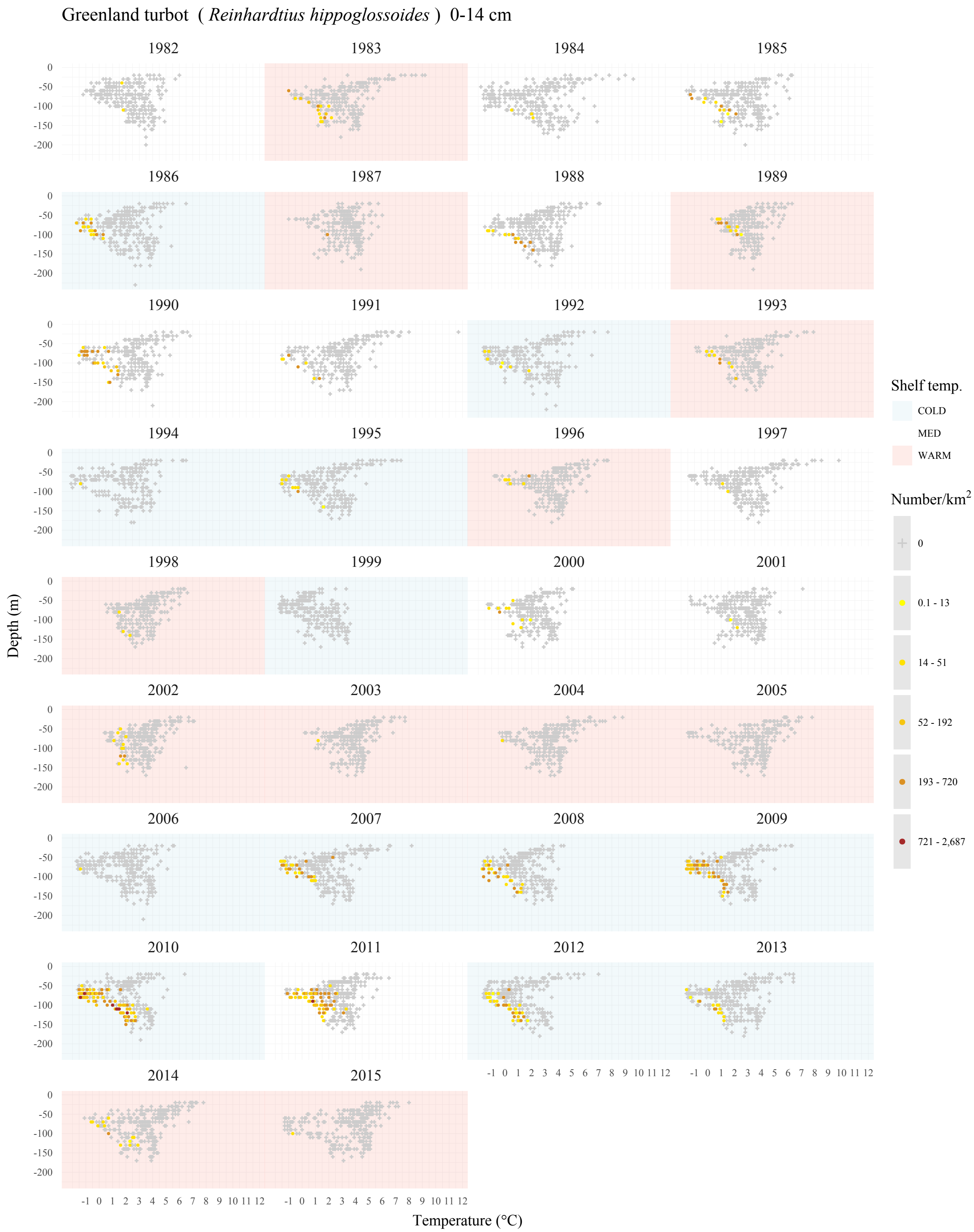


Figure 55 . -- The Greenland turbot (*Reinhardtius hippoglossoides*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

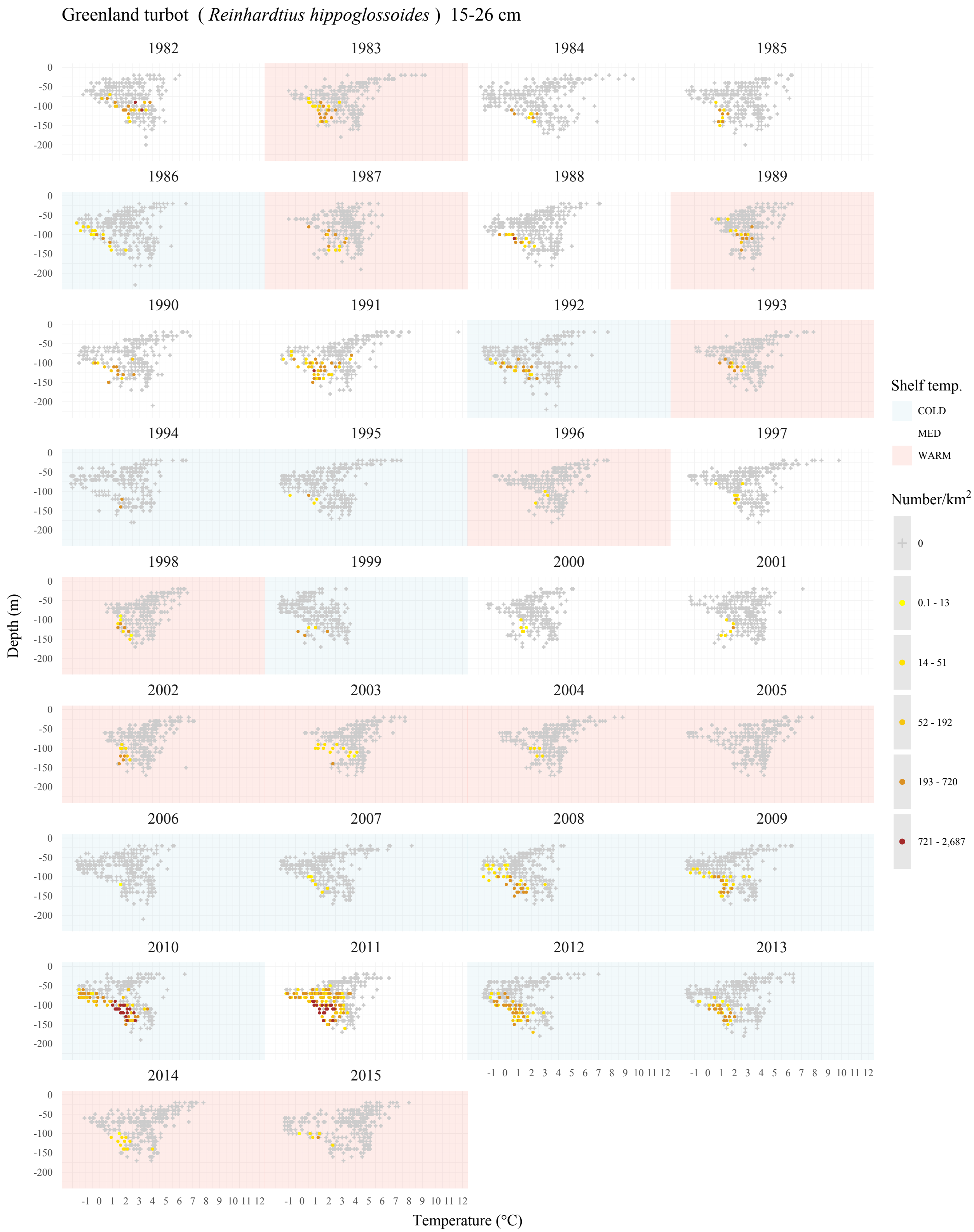


Figure 55 . -- Continued.

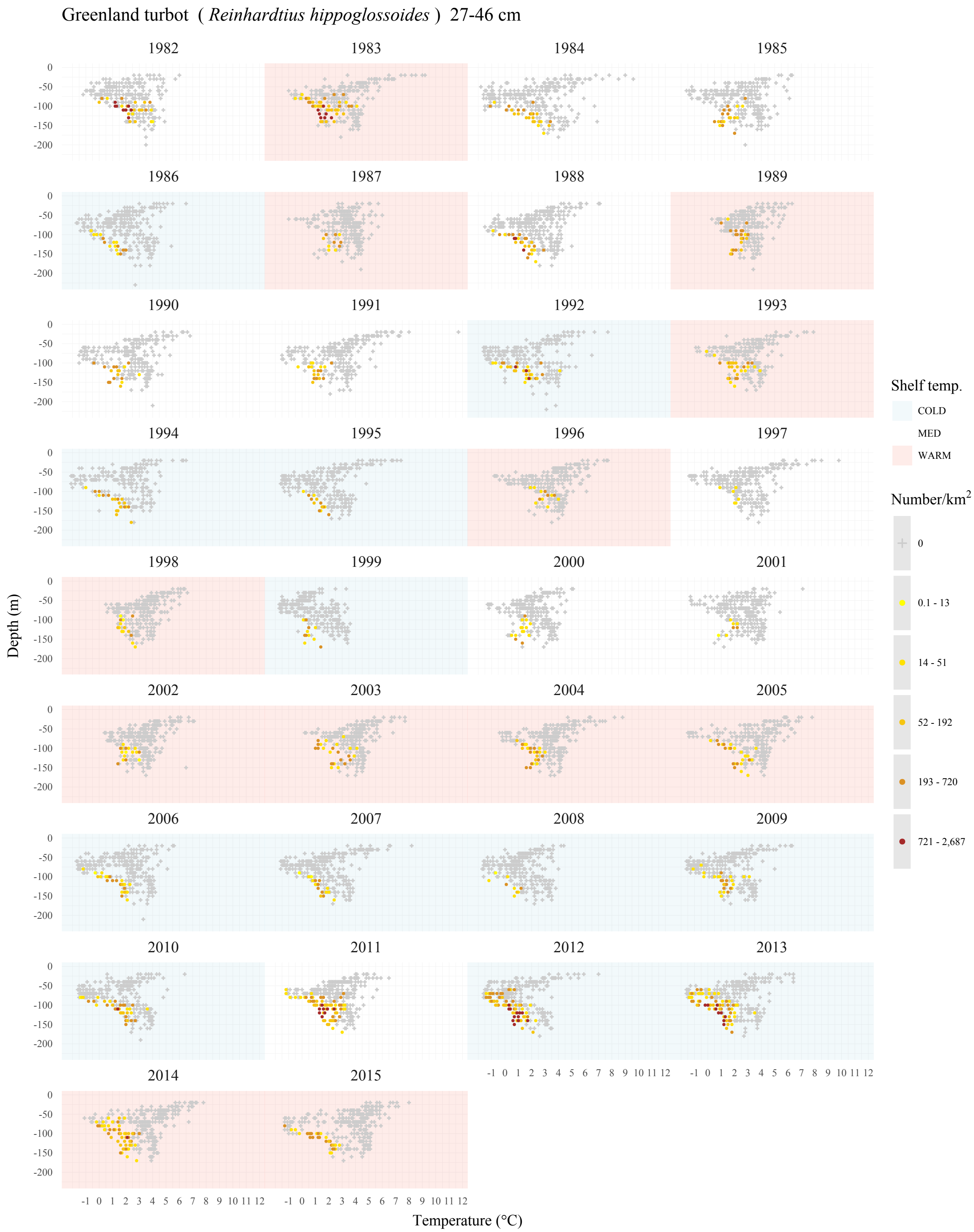


Figure 55 . -- Continued.

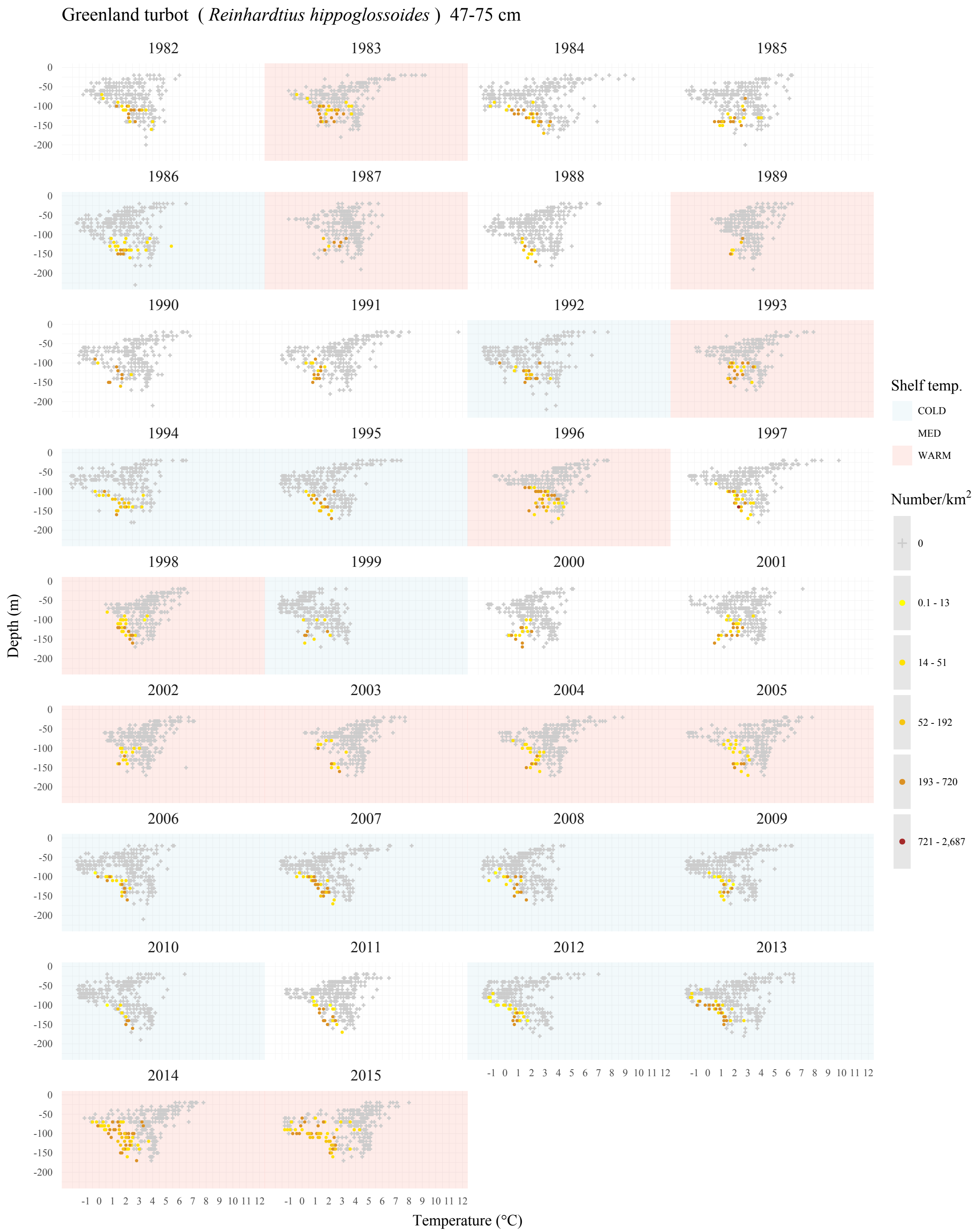


Figure 55 . -- Continued.

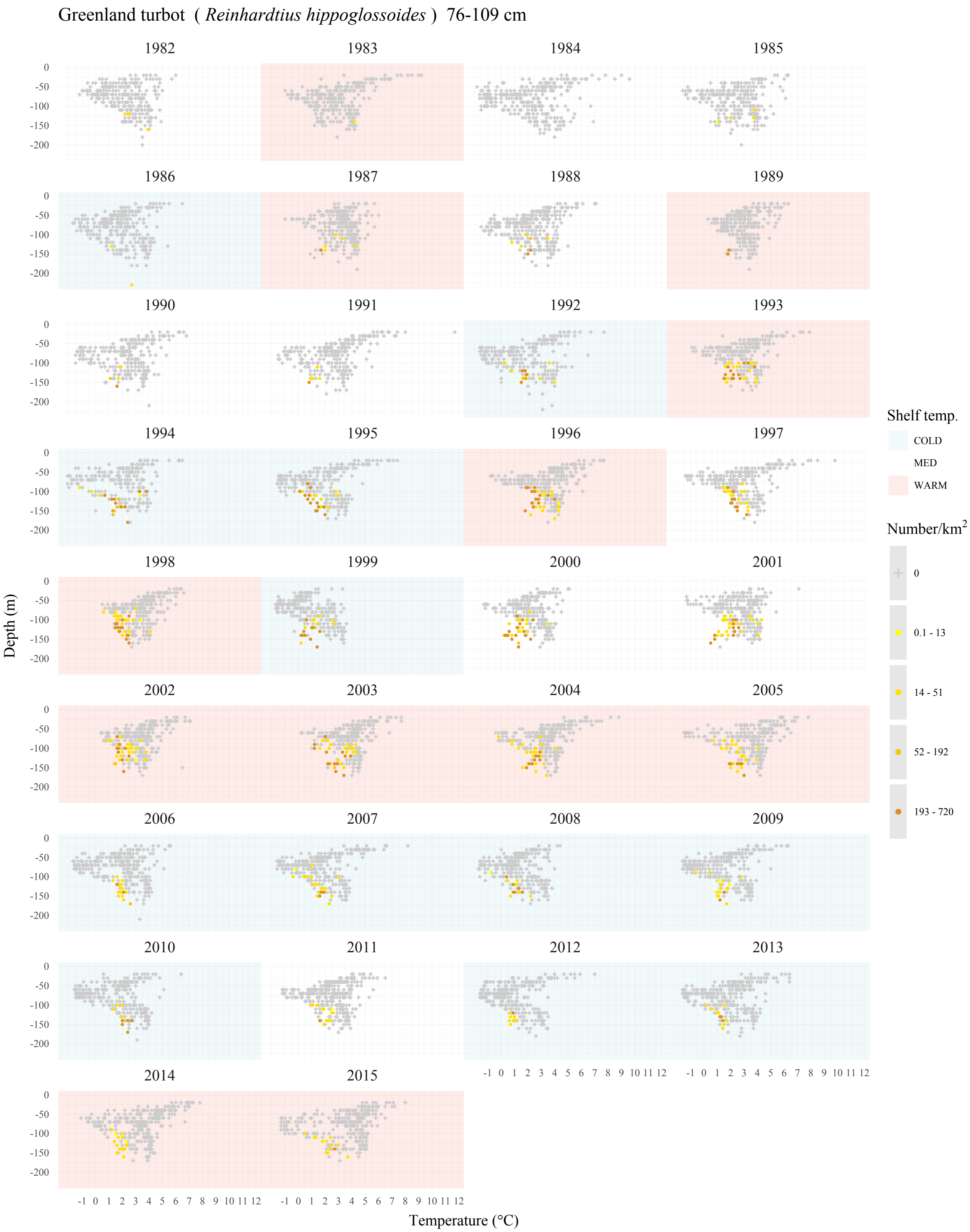
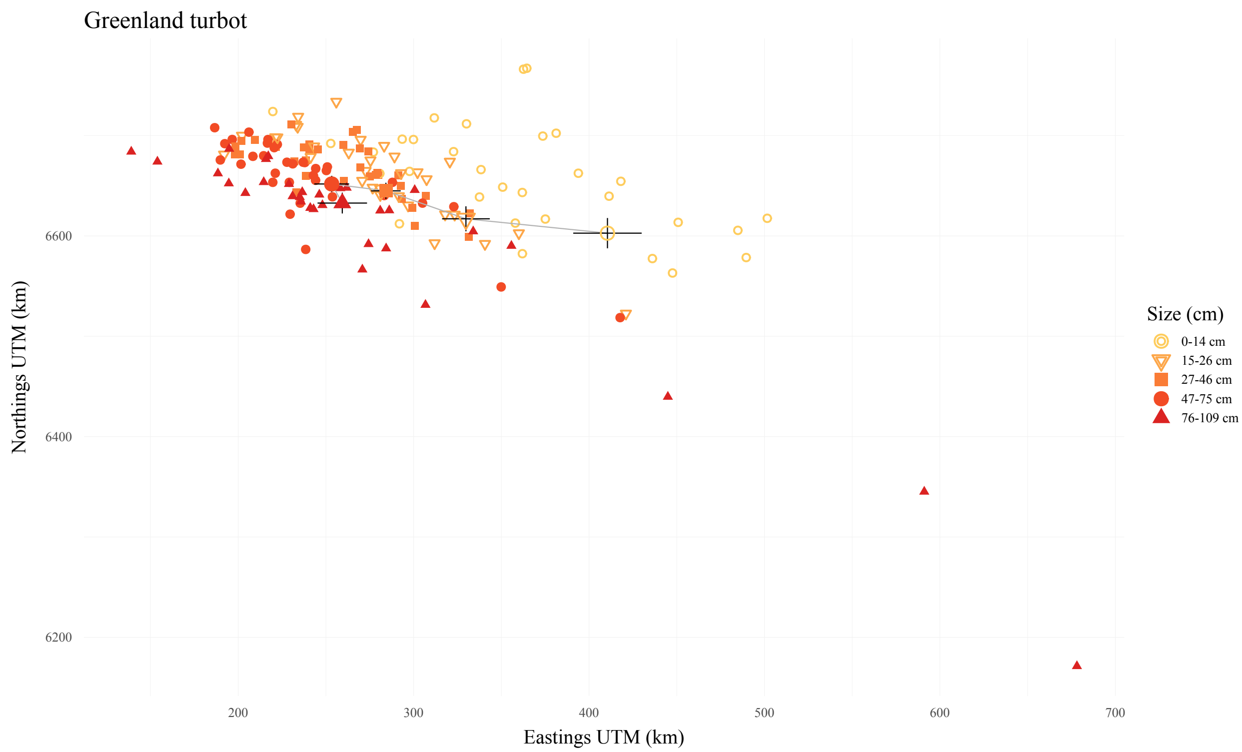


Figure 55 . -- Continued.



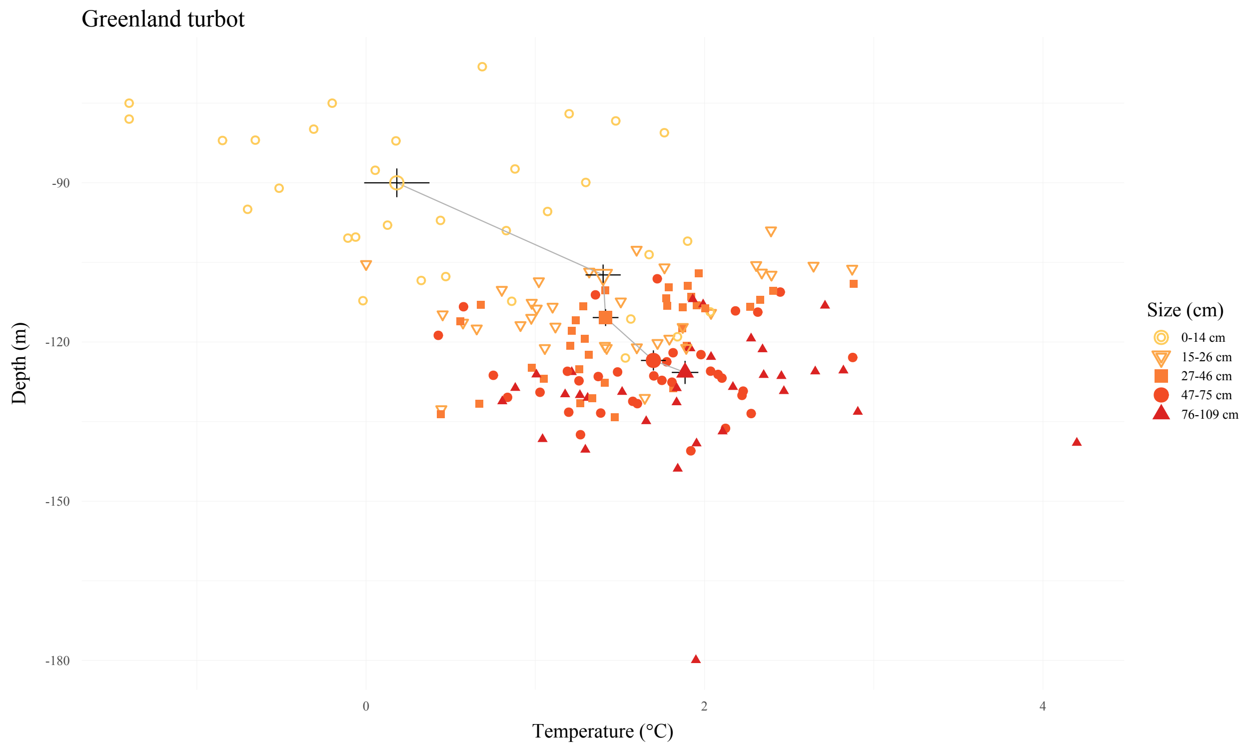


Figure 56 . -- The Greenland turbot (*Reinhardtius hippoglossoides*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

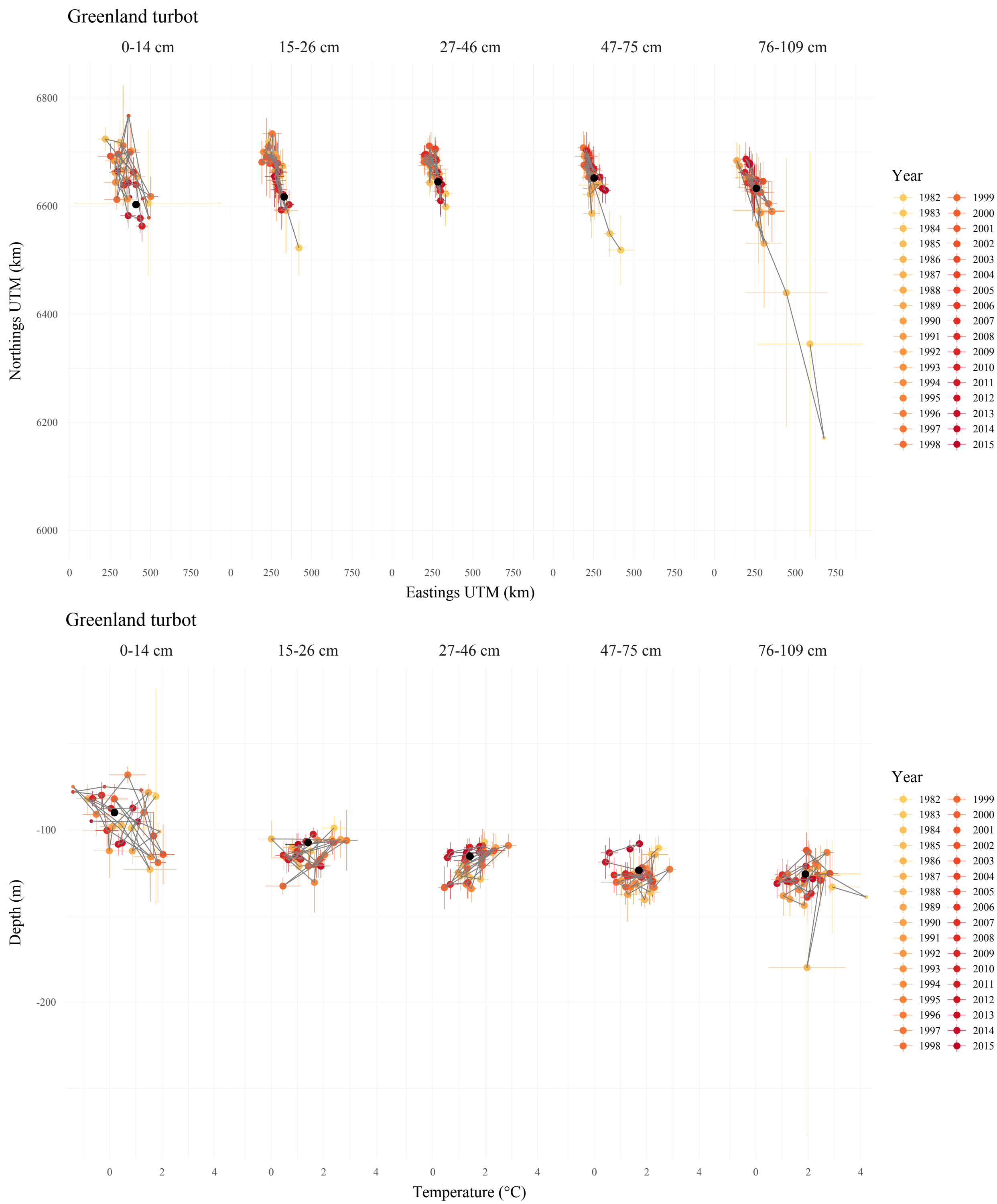


Figure 57 . -- The Greenland turbot (*Reinhardtius hippoglossoides*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

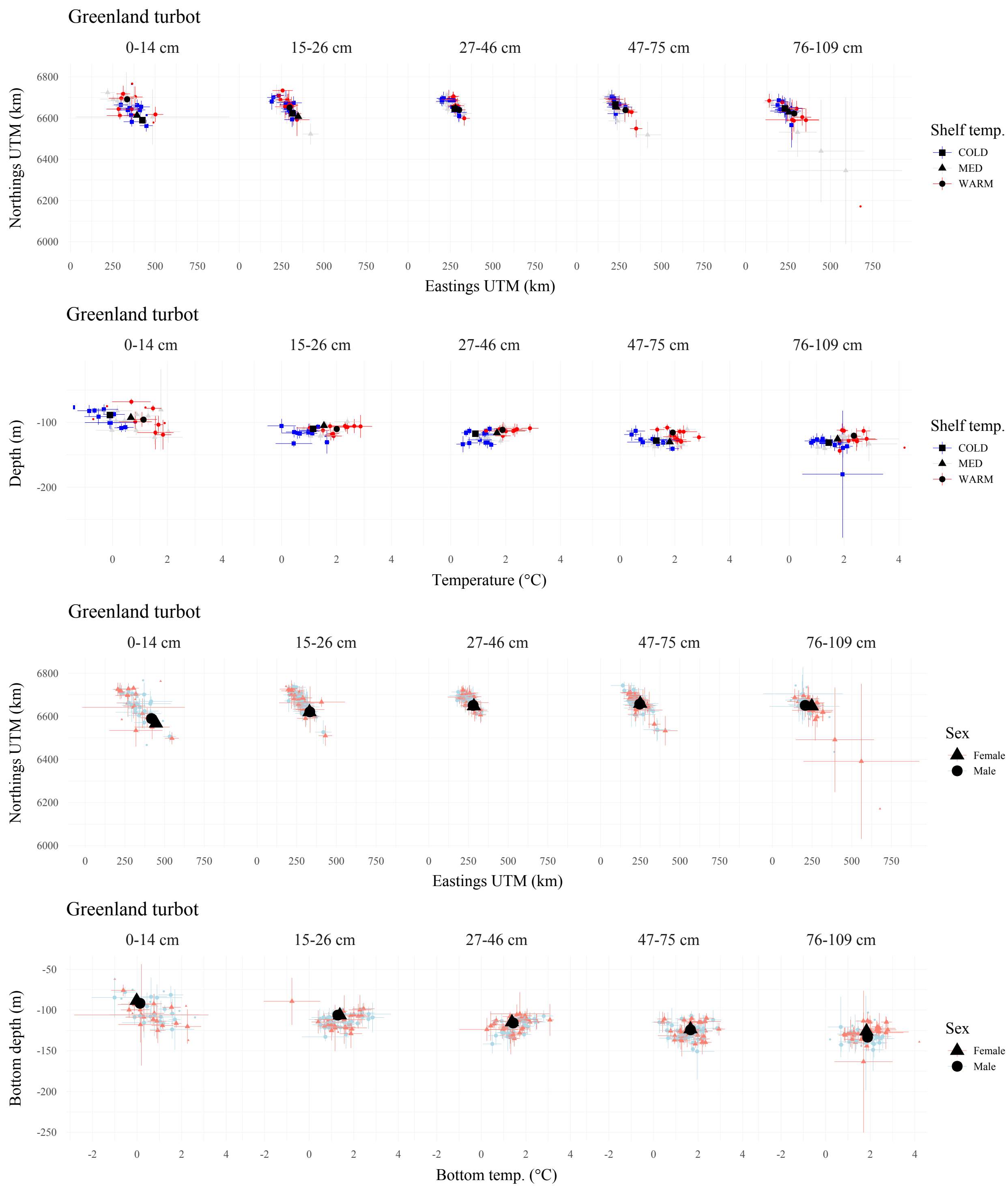


Figure 58 . -- The Greenland turbot (*Reinhardtius hippoglossoides*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

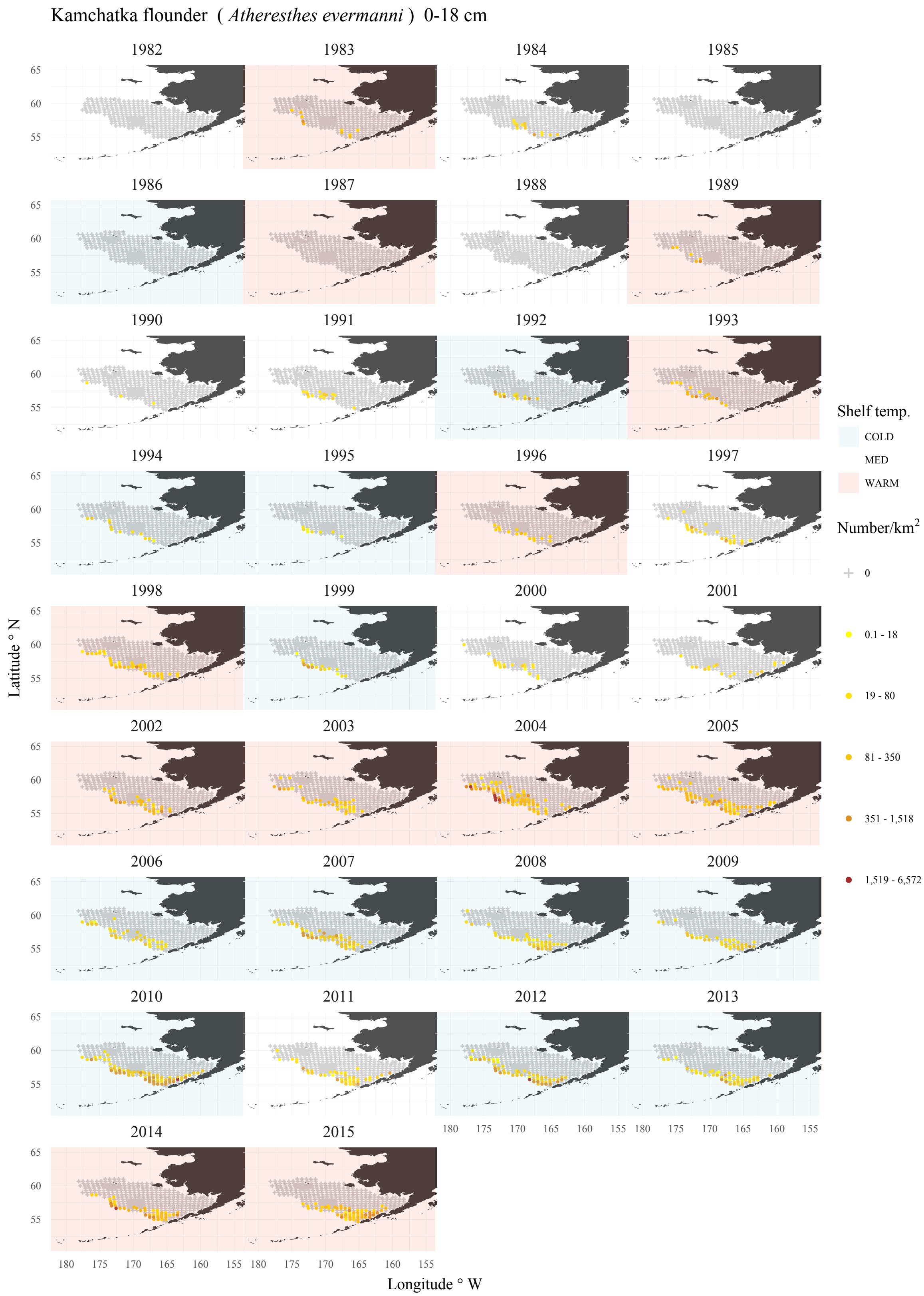


Figure 59 . -- The Kamchatka flounder (*Atheresthes evermanni*) CPUE by number weighted mean location for each length category for all years.

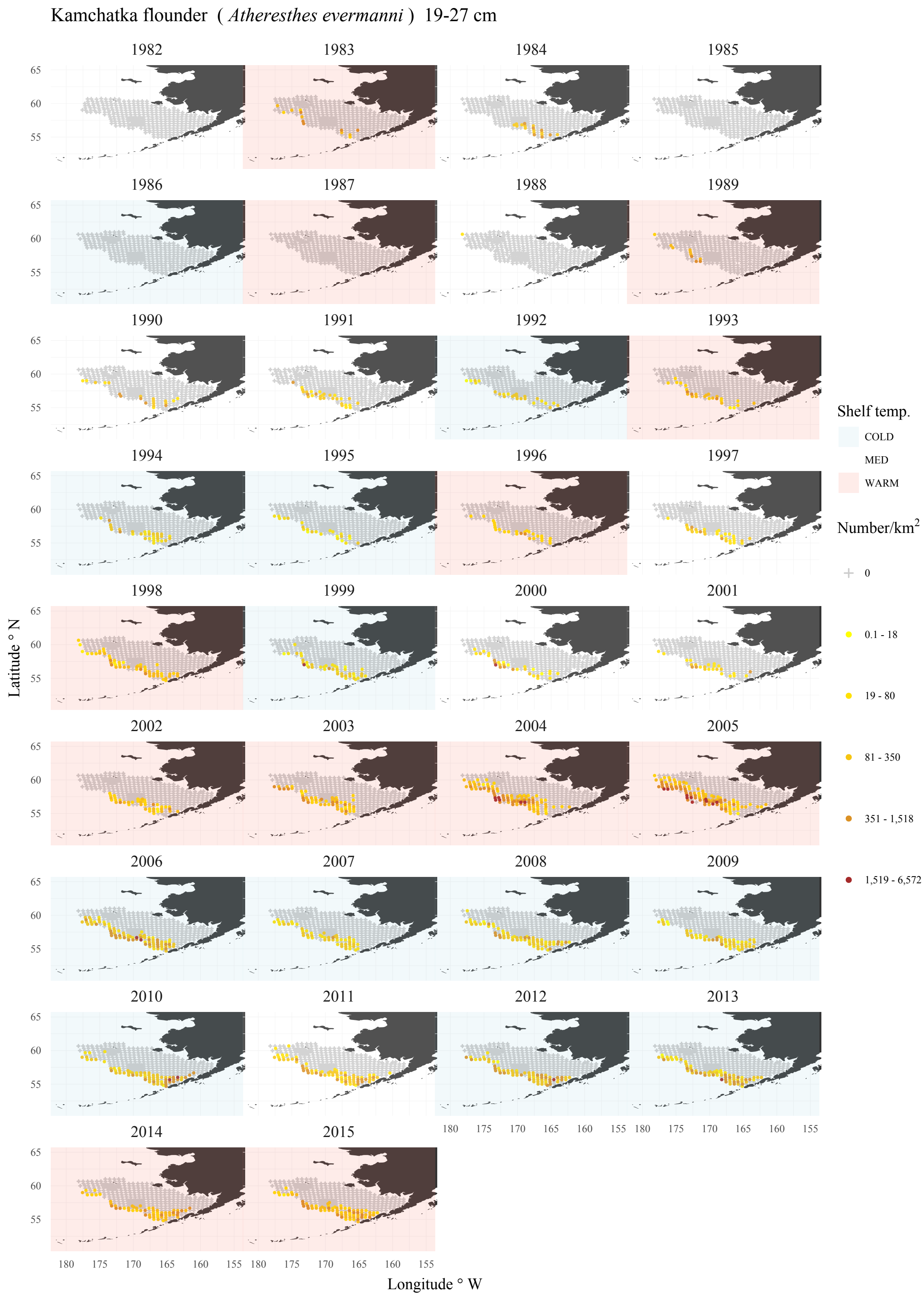


Figure 59 . -- Continued.

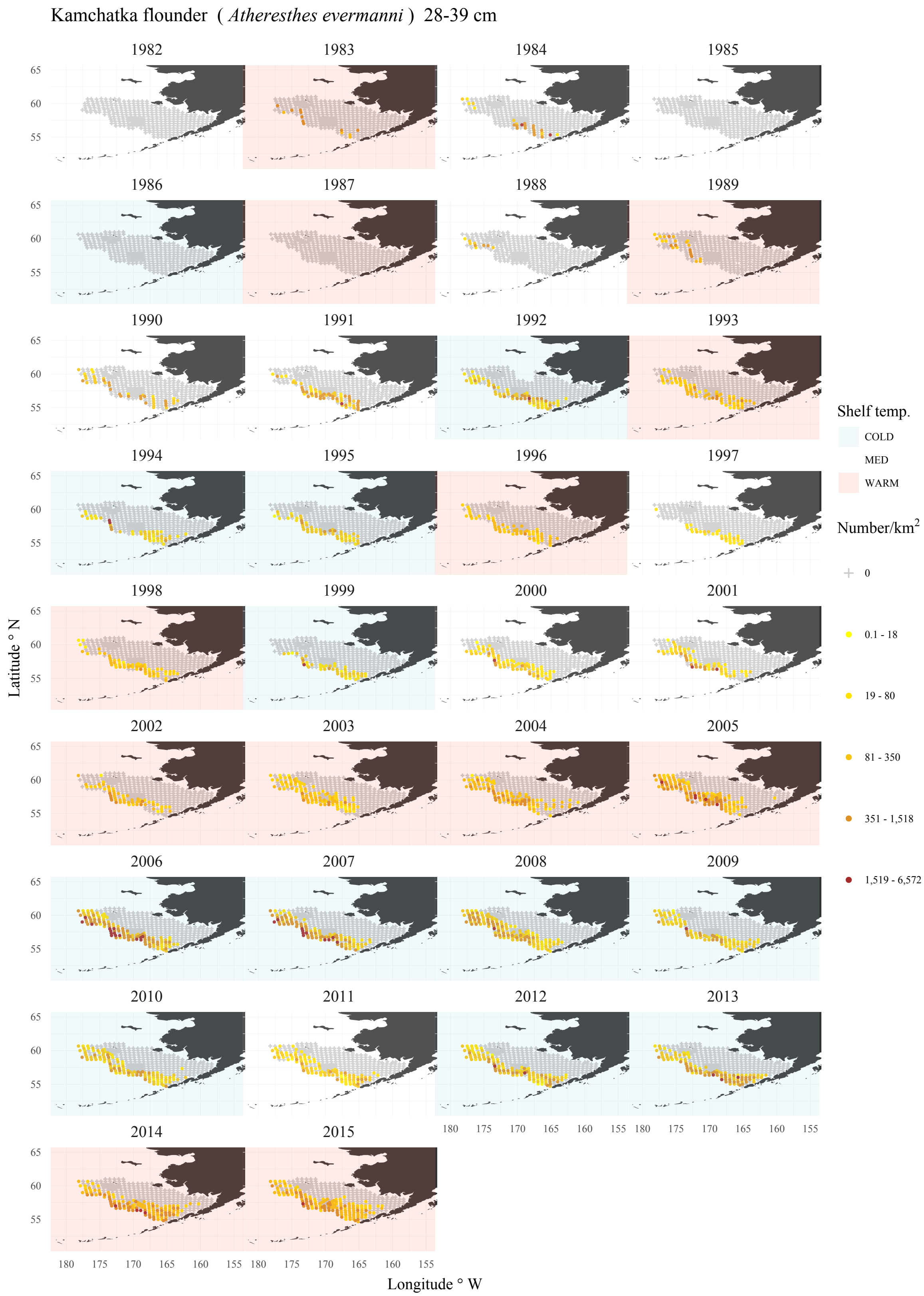


Figure 59 . -- Continued.

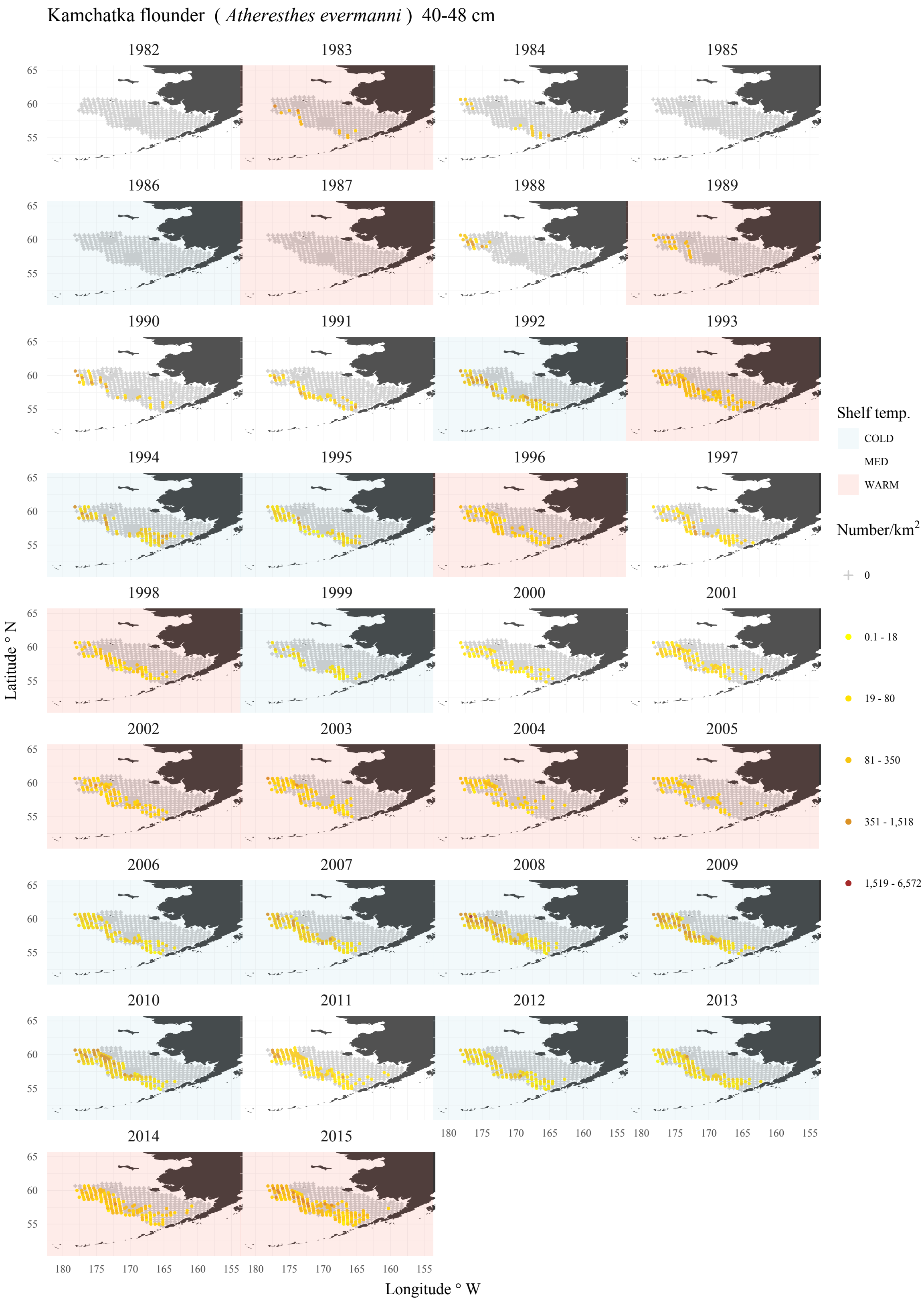


Figure 59 . -- Continued.

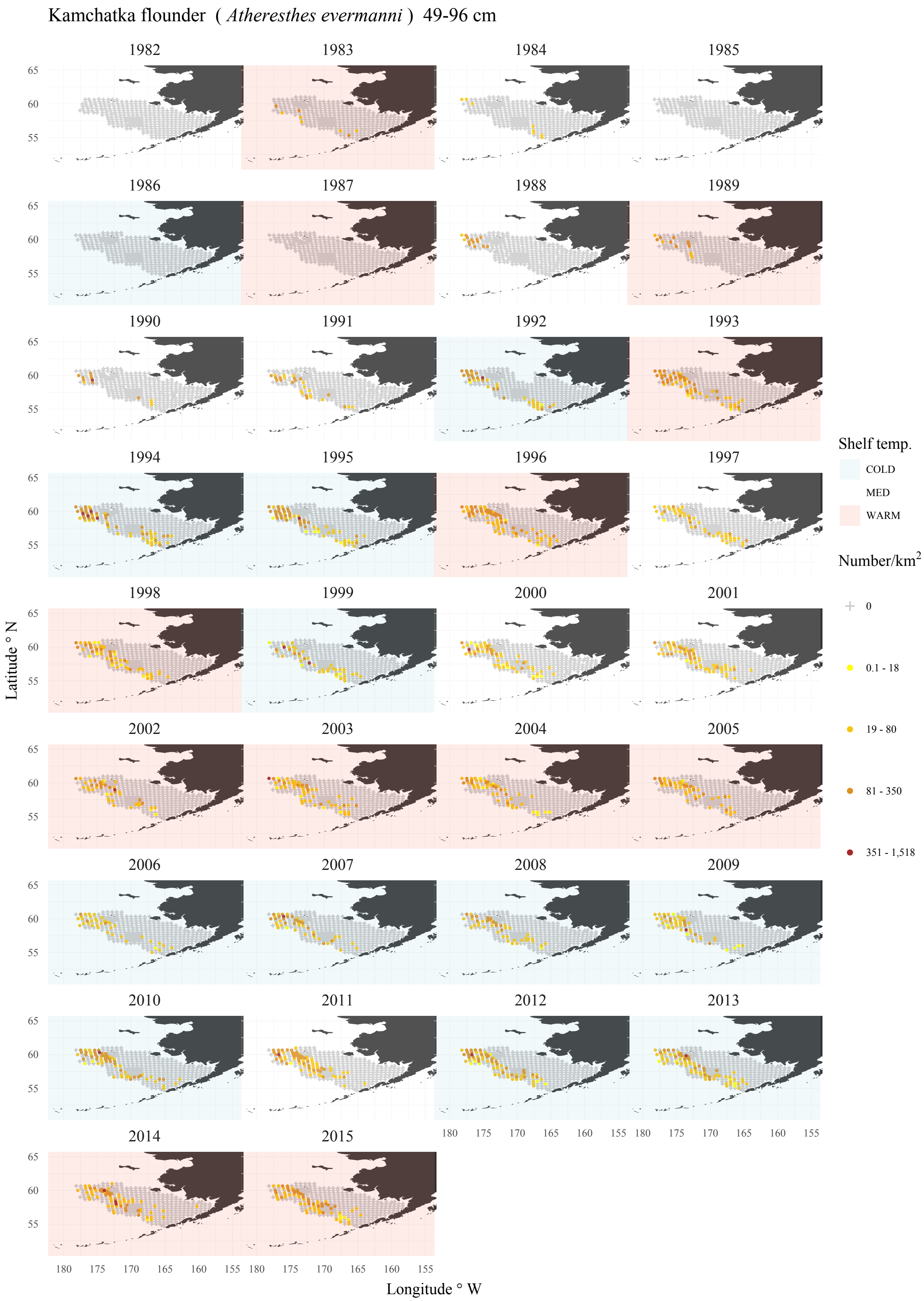


Figure 59 . -- Continued.

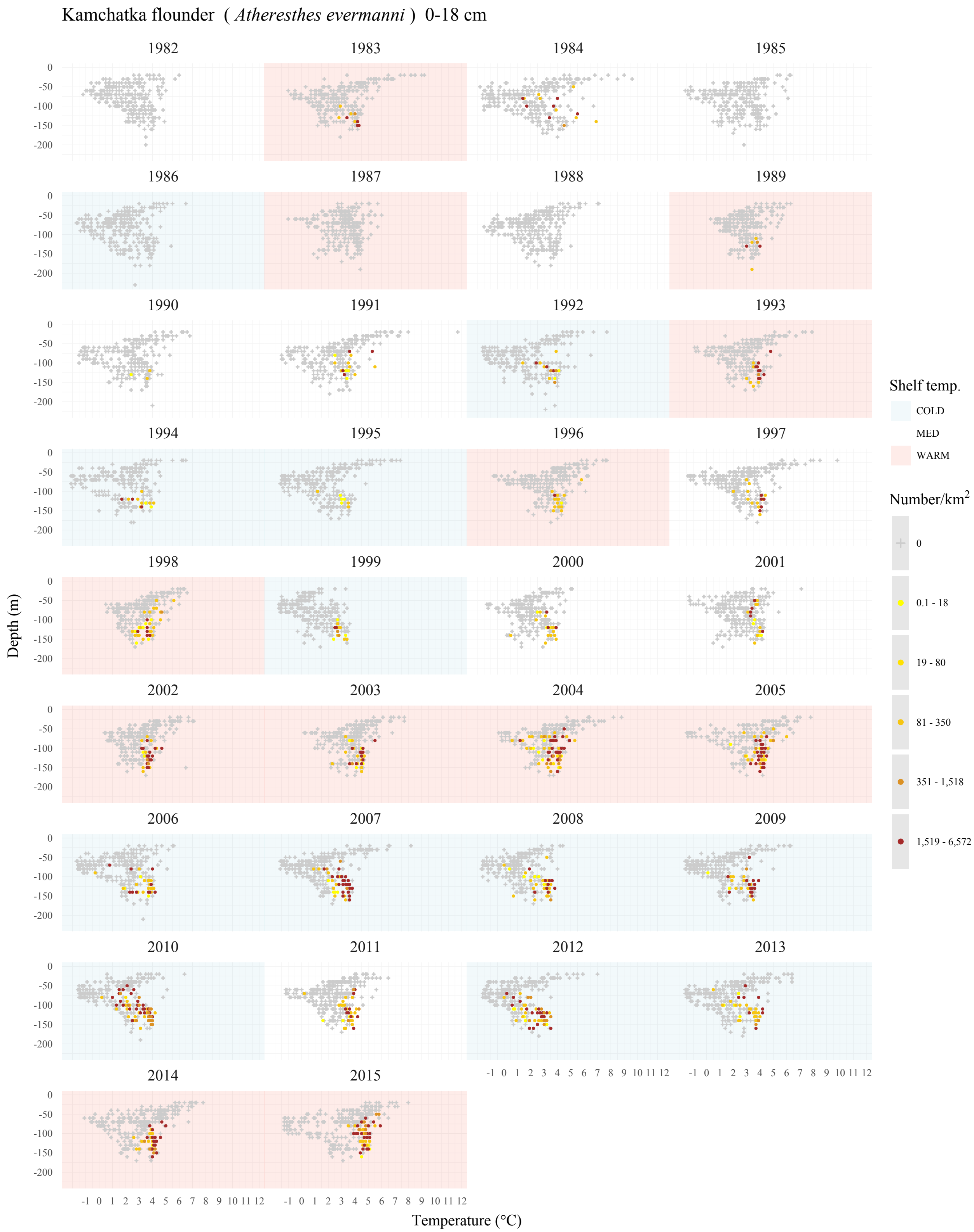


Figure 60 . -- The Kamchatka flounder (*Atheresthes evermanni*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

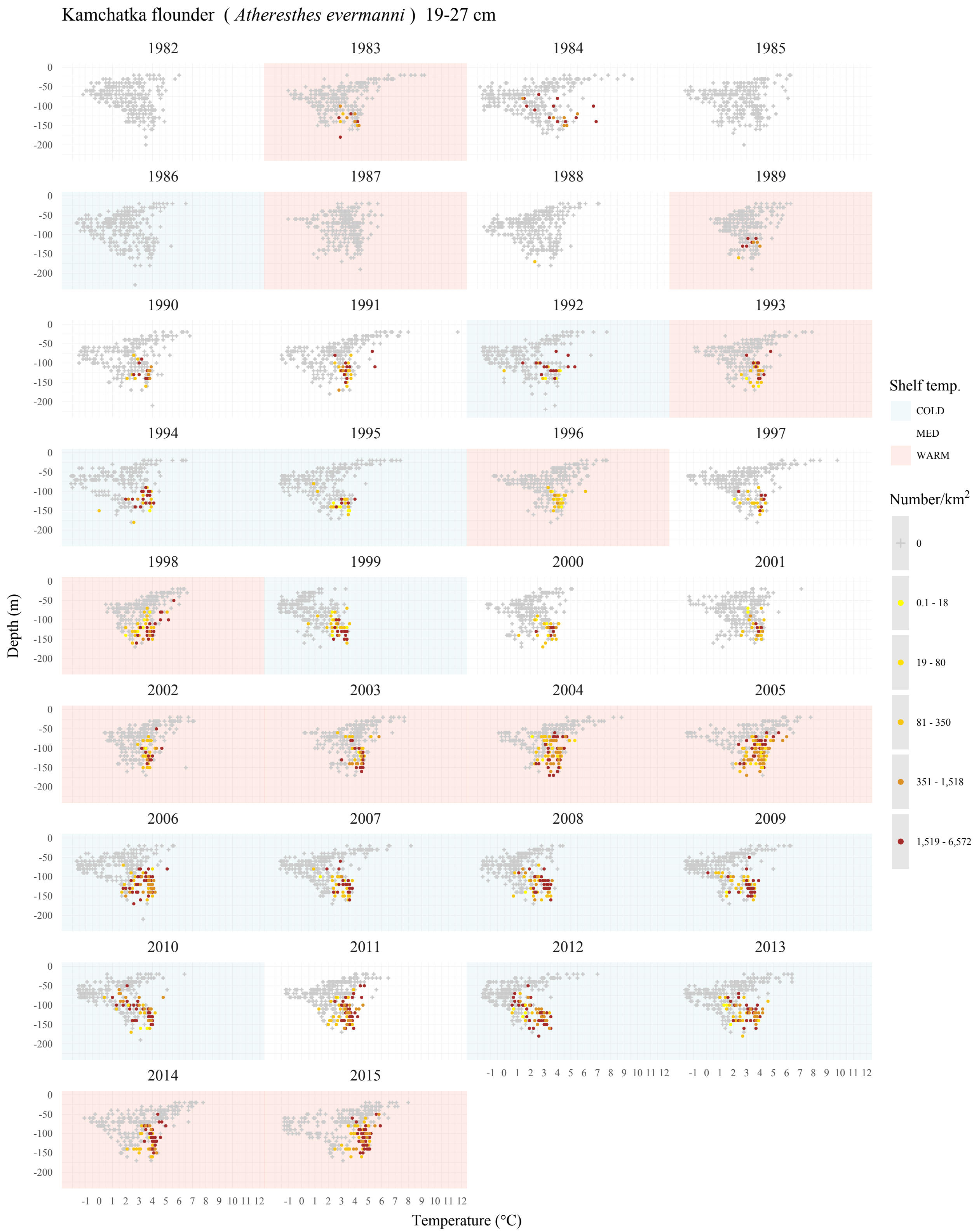


Figure 60 . -- Continued.

Kamchatka flounder (*Atheresthes evermanni*) 28-39 cm

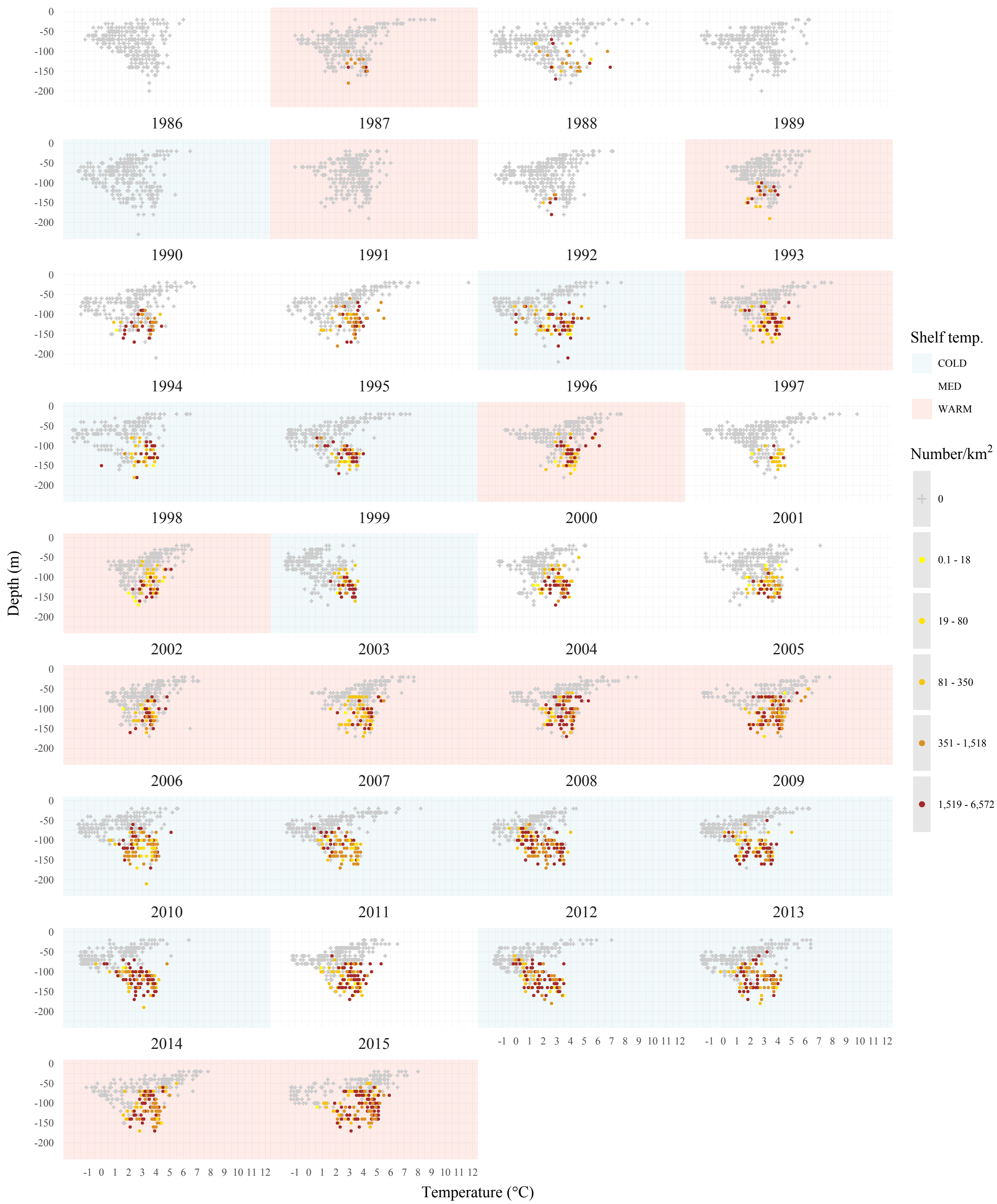


Figure 60 . -- Continued.

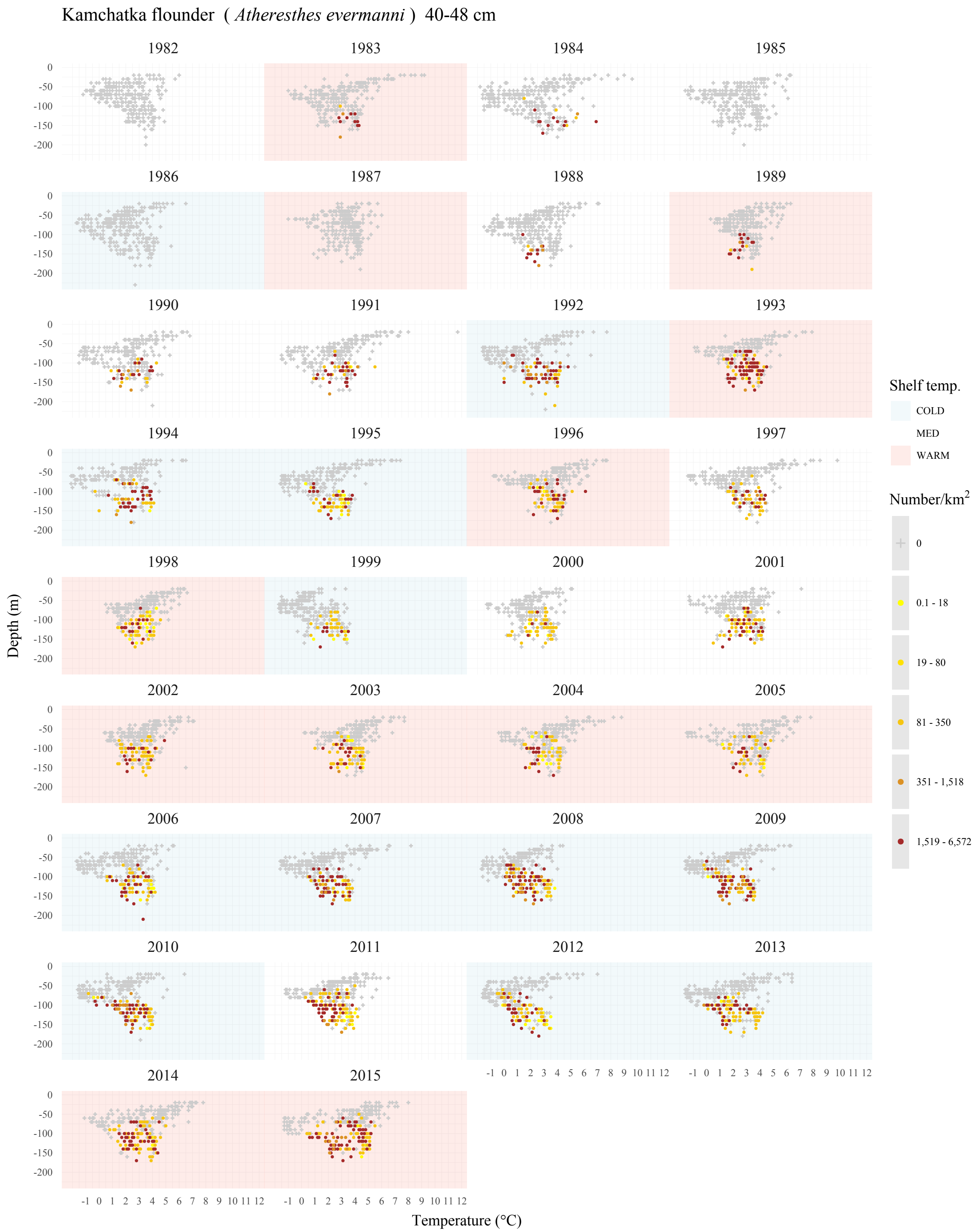


Figure 60 . -- Continued.

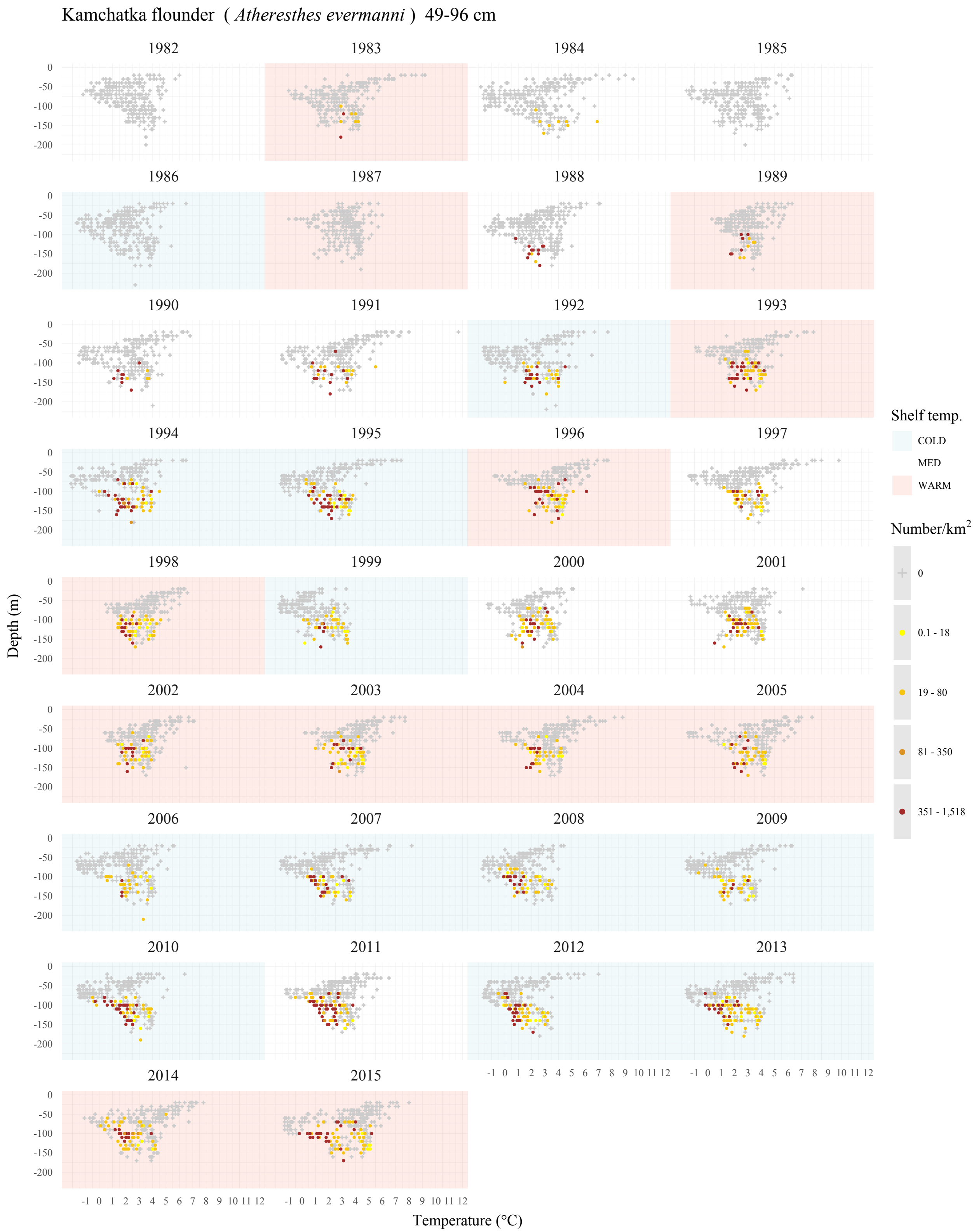


Figure 60 . -- Continued.

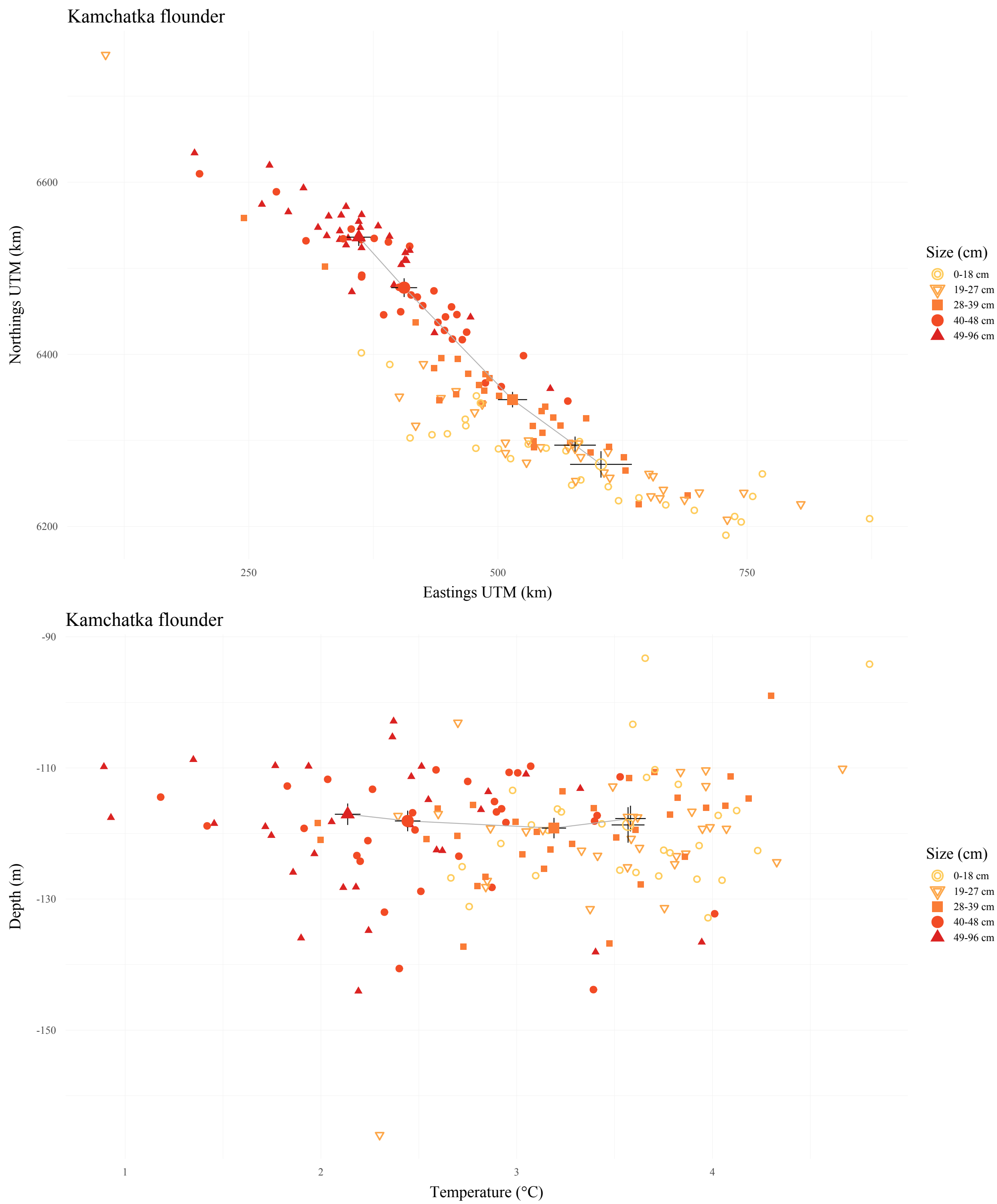


Figure 61 . -- The Kamchatka flounder (*Atheresthes evermanni*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

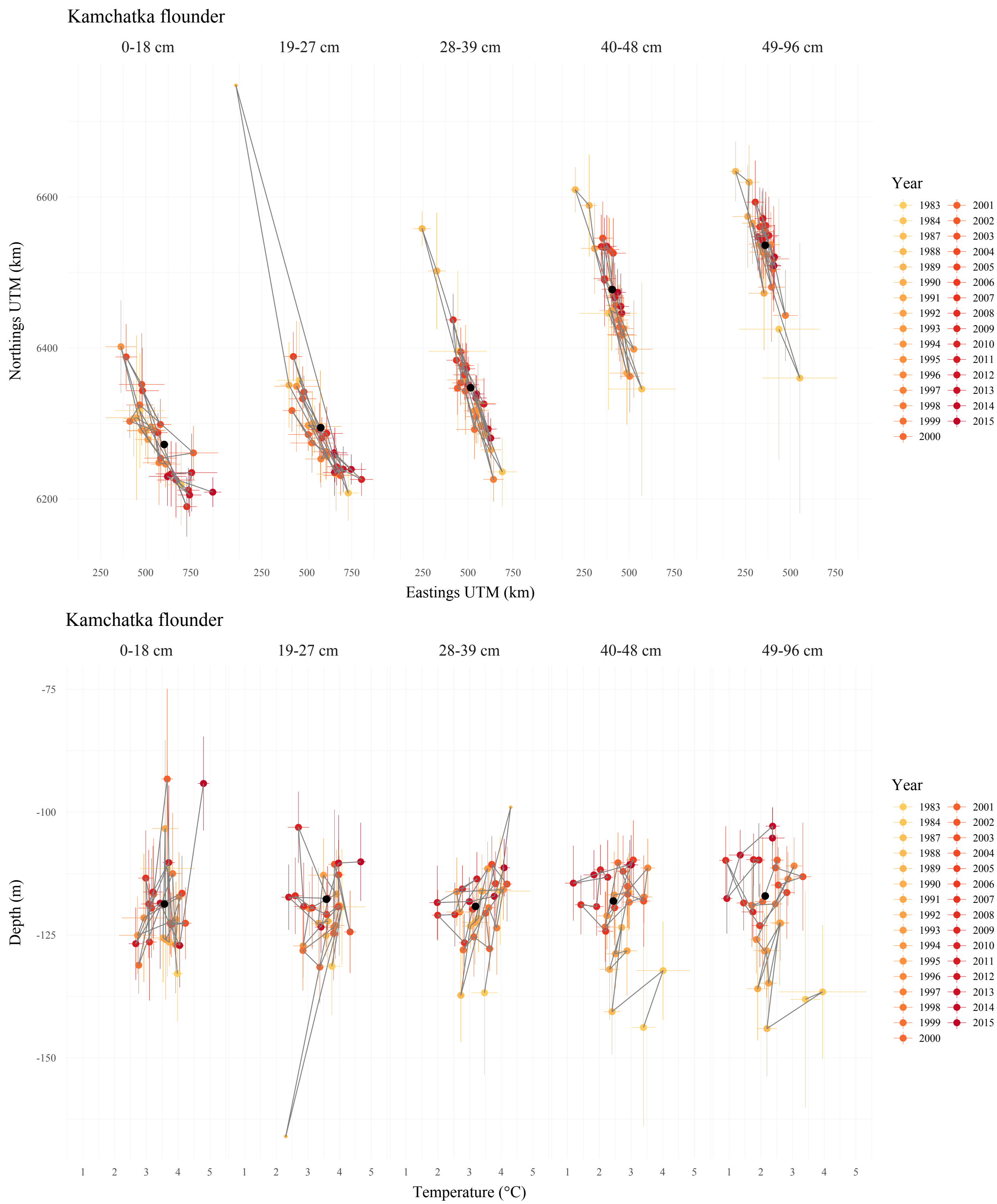


Figure 62 . -- The Kamchatka flounder (*Atheresthes evermanni*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

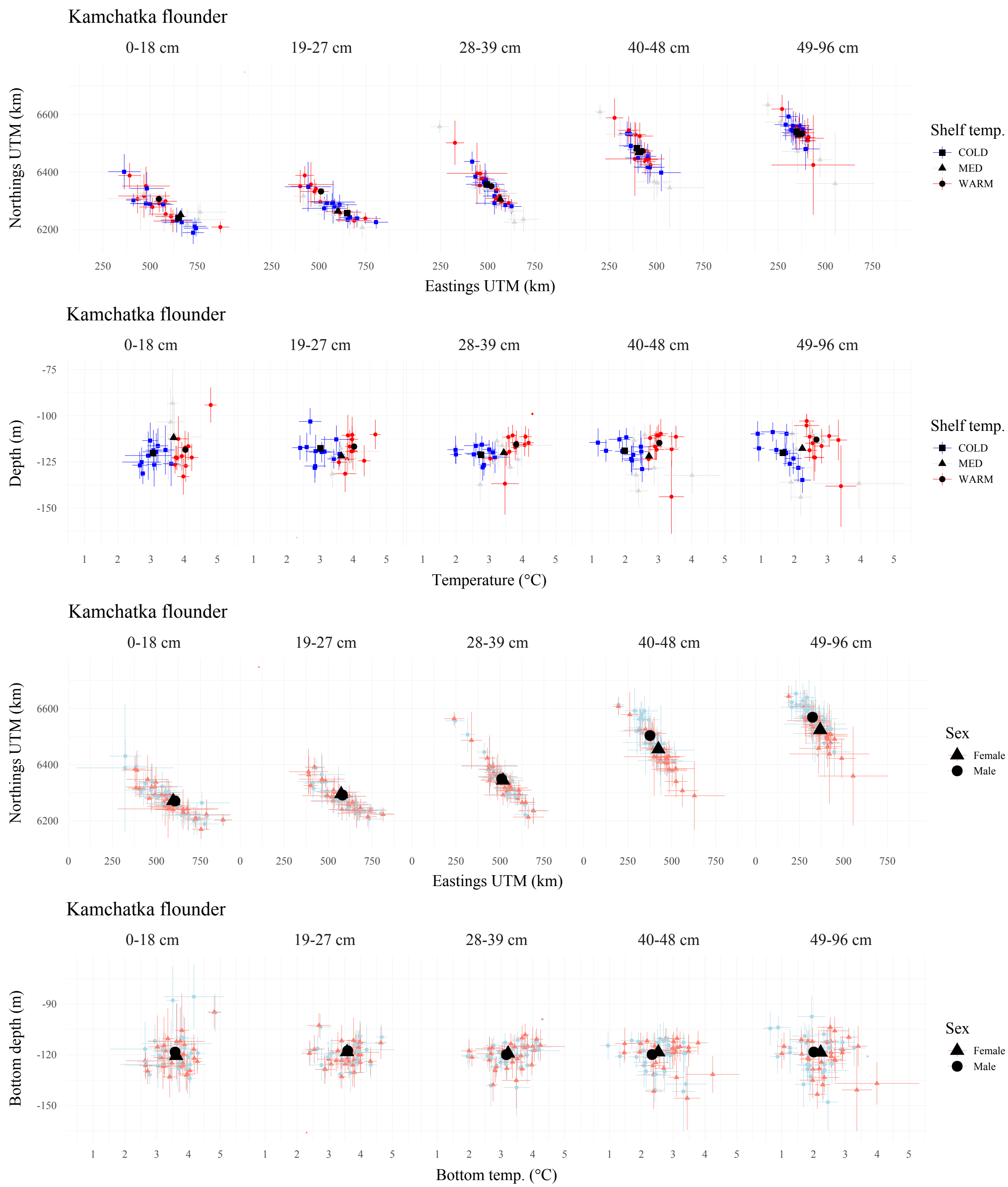


Figure 63 . -- The Kamchatka flounder (*Atheresthes evermanni*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

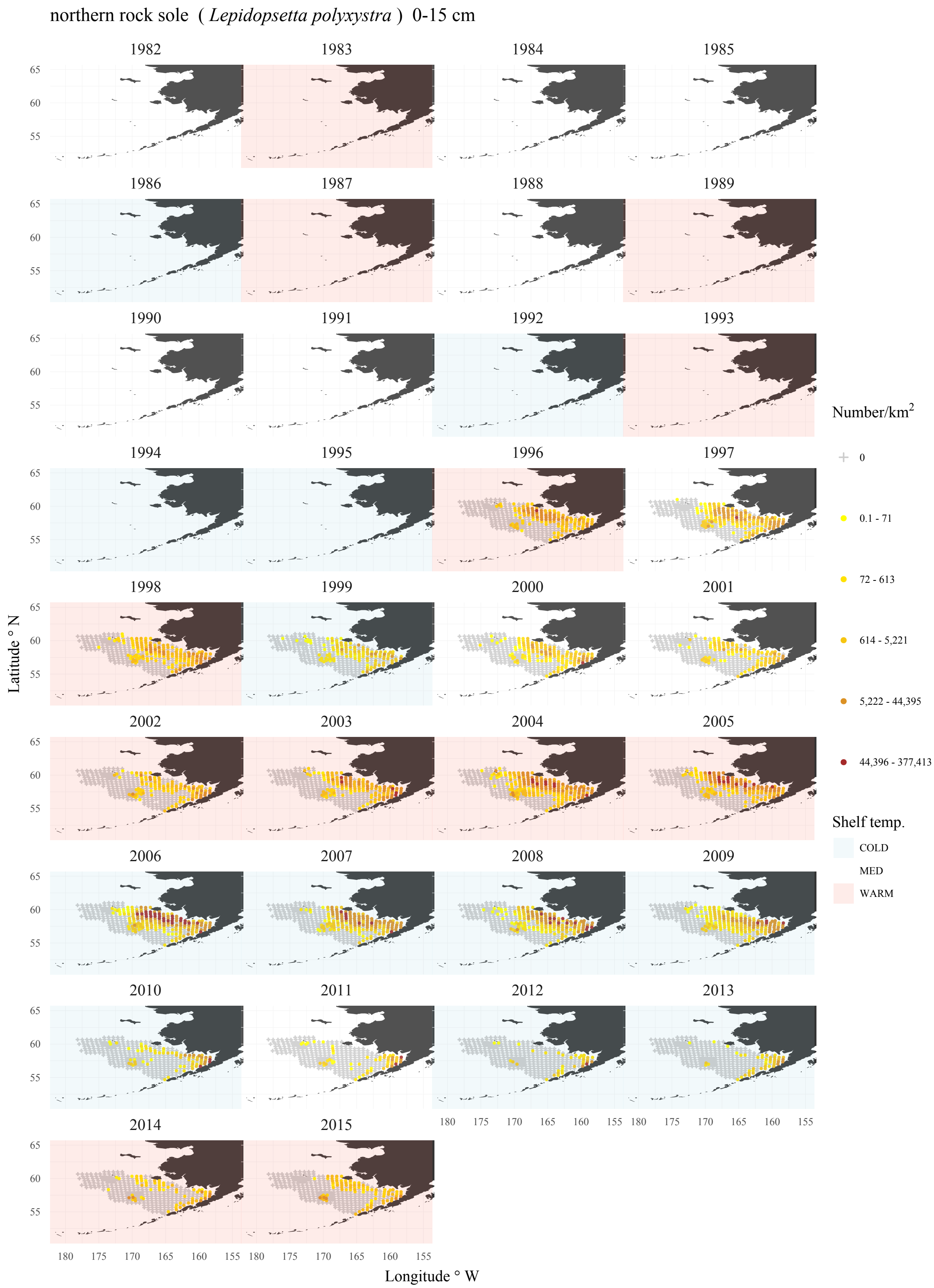


Figure 64 . -- The northern rock sole (*Lepidopsetta polyxystra*) CPUE by number weighted mean location for each length category for all years.

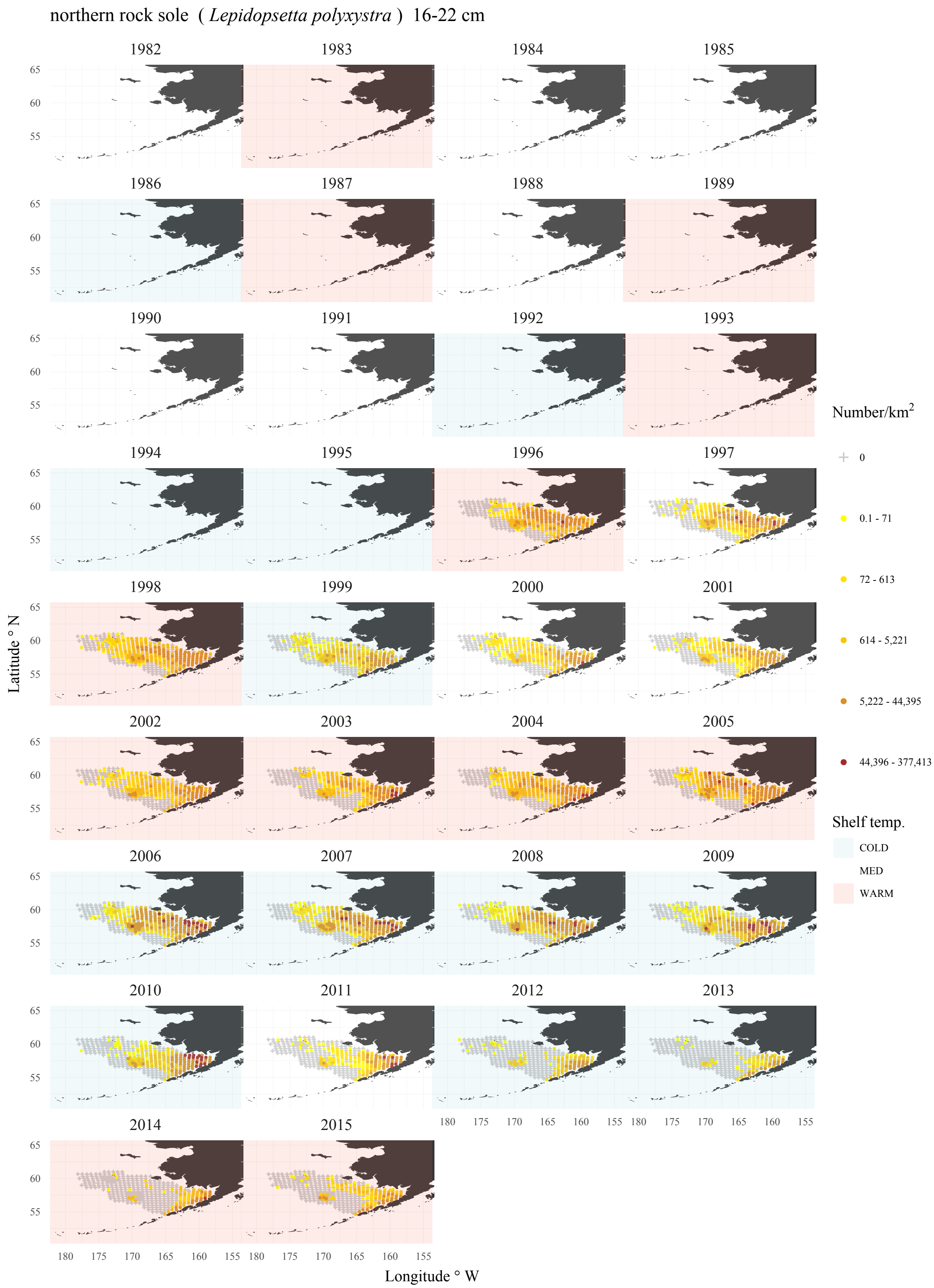


Figure 64 . -- Continued.

northern rock sole (*Lepidopsetta polyxystra*) 23-30 cm

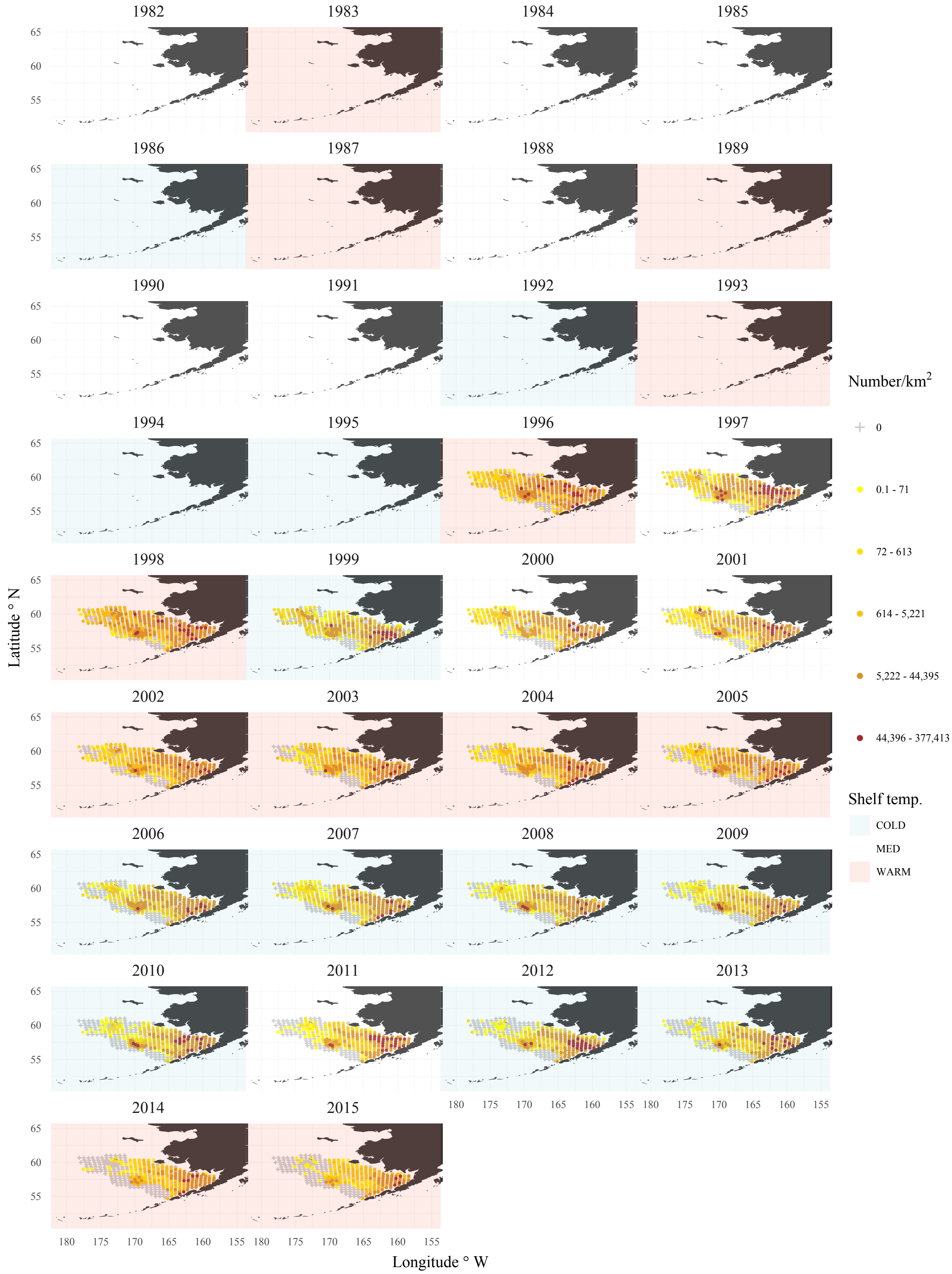


Figure 64 . -- Continued.

northern rock sole (*Lepidopsetta polyxystra*) 31-35 cm

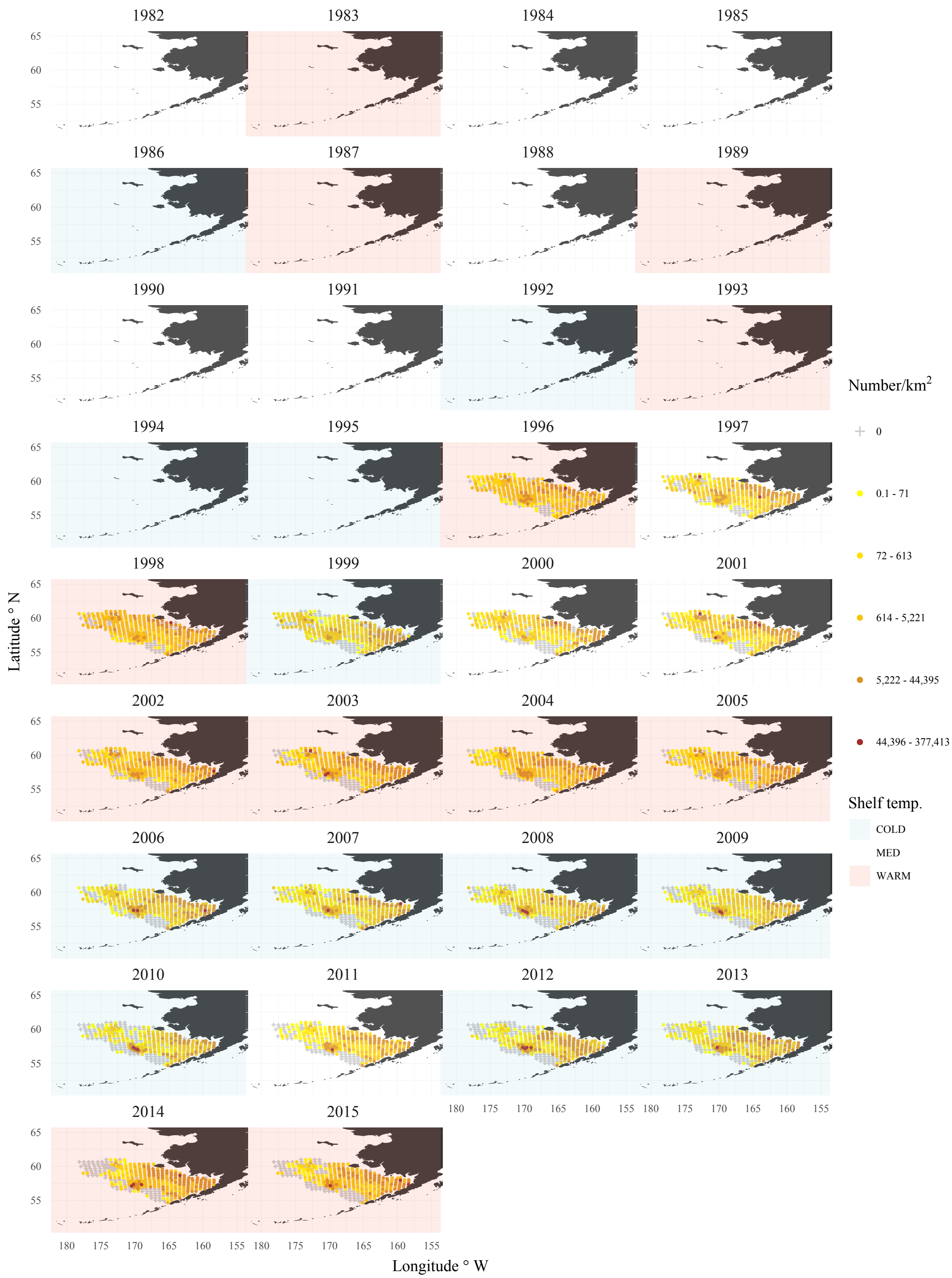


Figure 64 . -- Continued.

northern rock sole (*Lepidopsetta polyxystra*) 36-60 cm

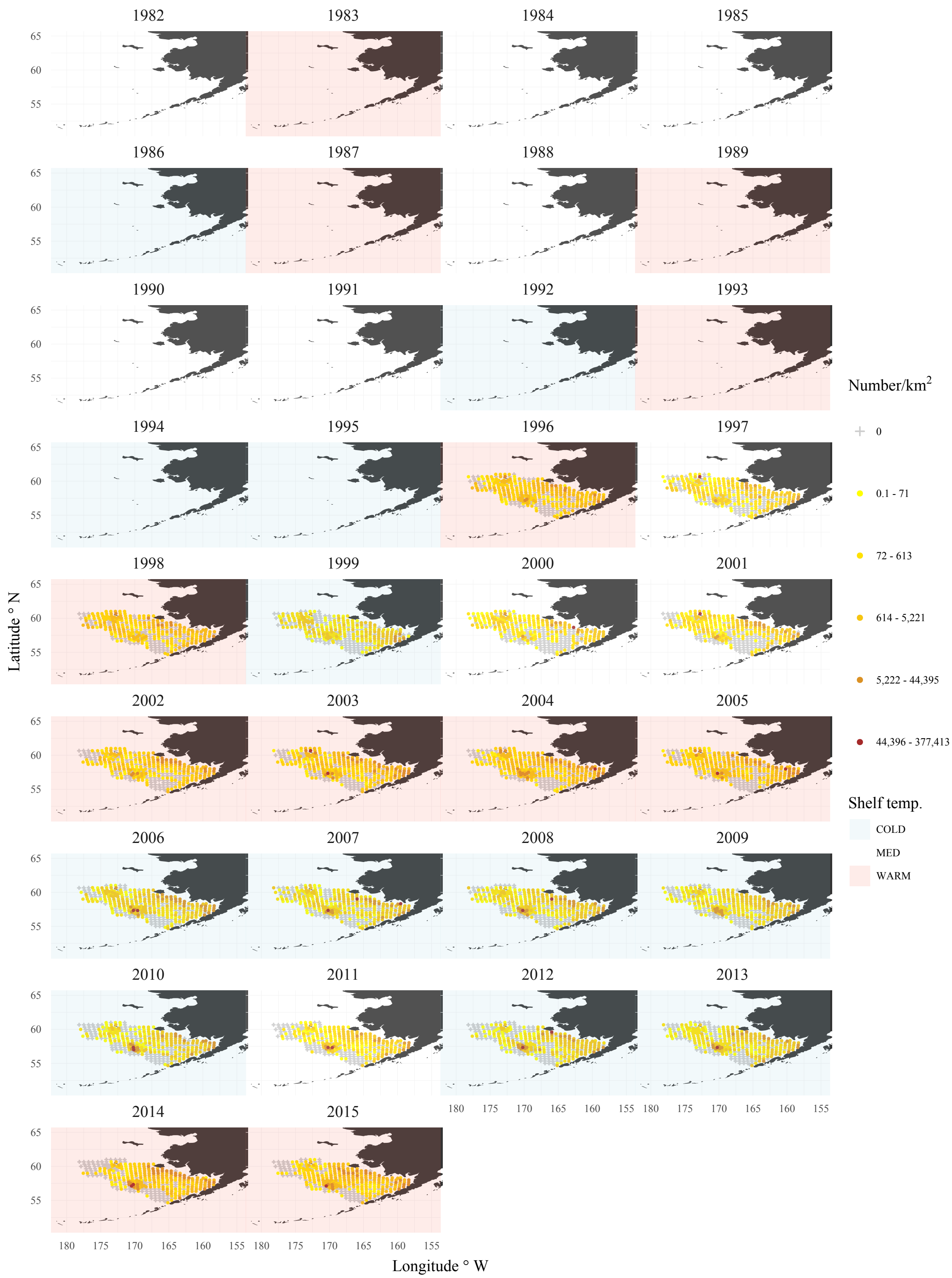


Figure 64 . -- Continued.

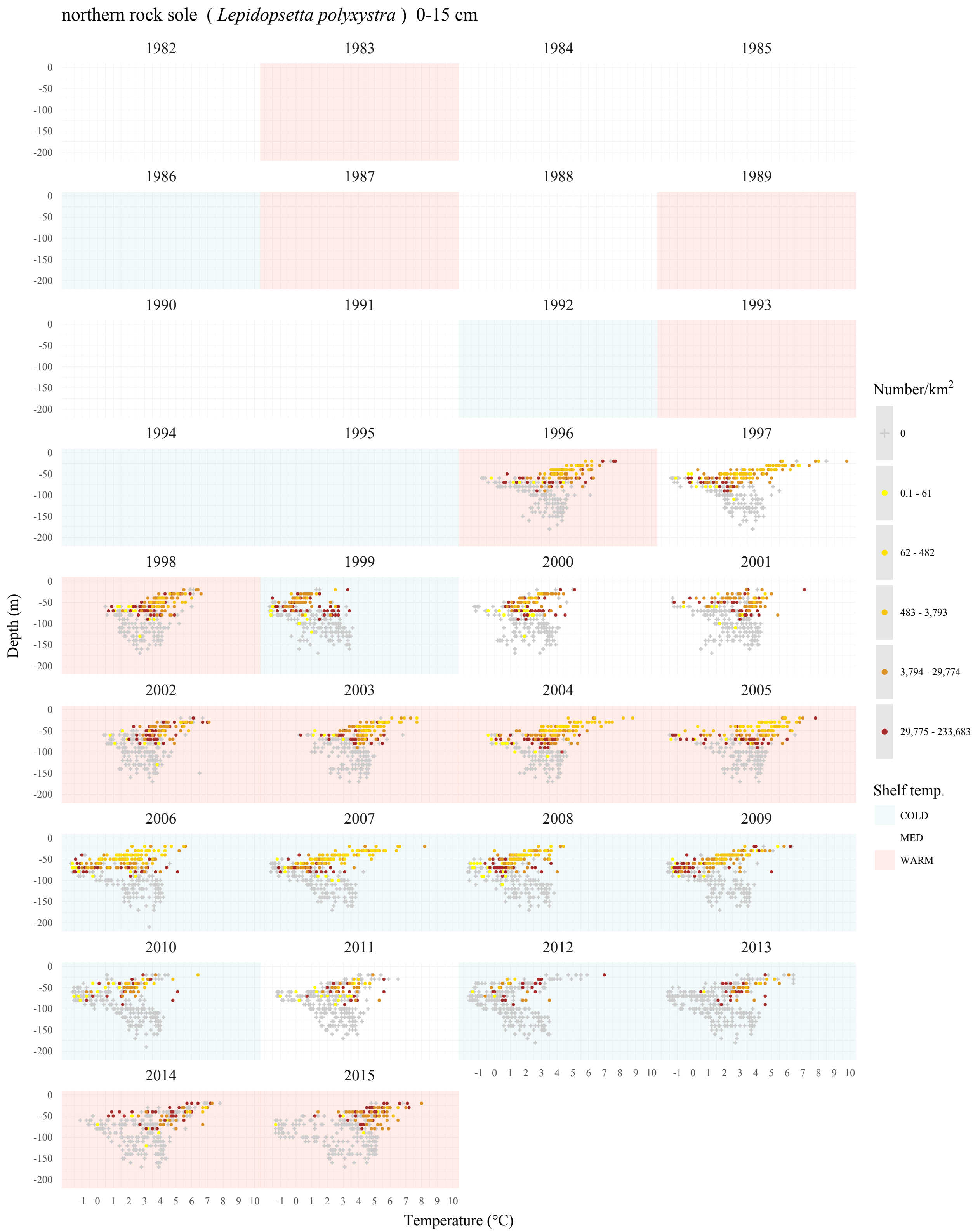


Figure 65 . -- The northern rock sole (*Lepidopsetta polyxystra*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

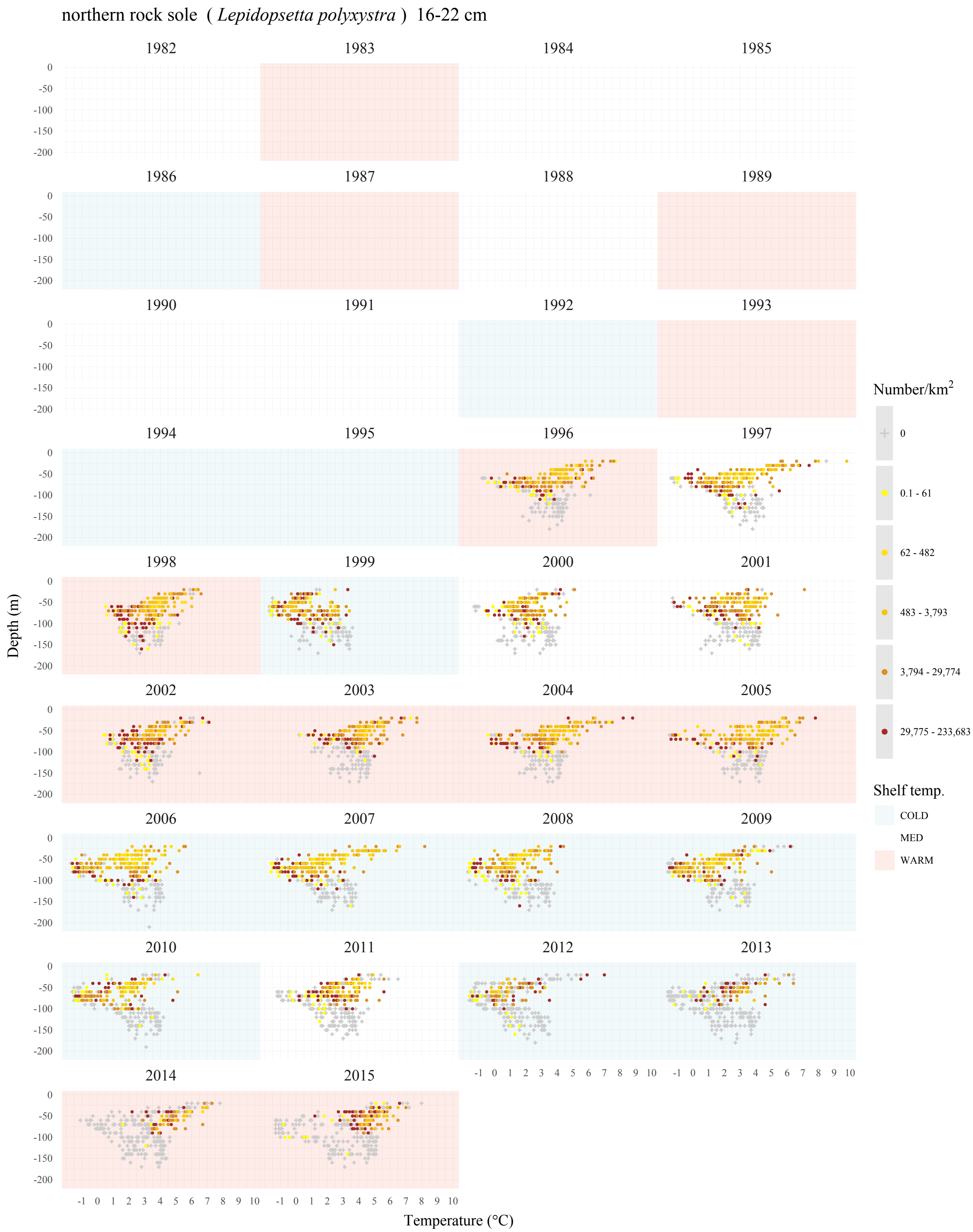


Figure 65 . -- Continued.

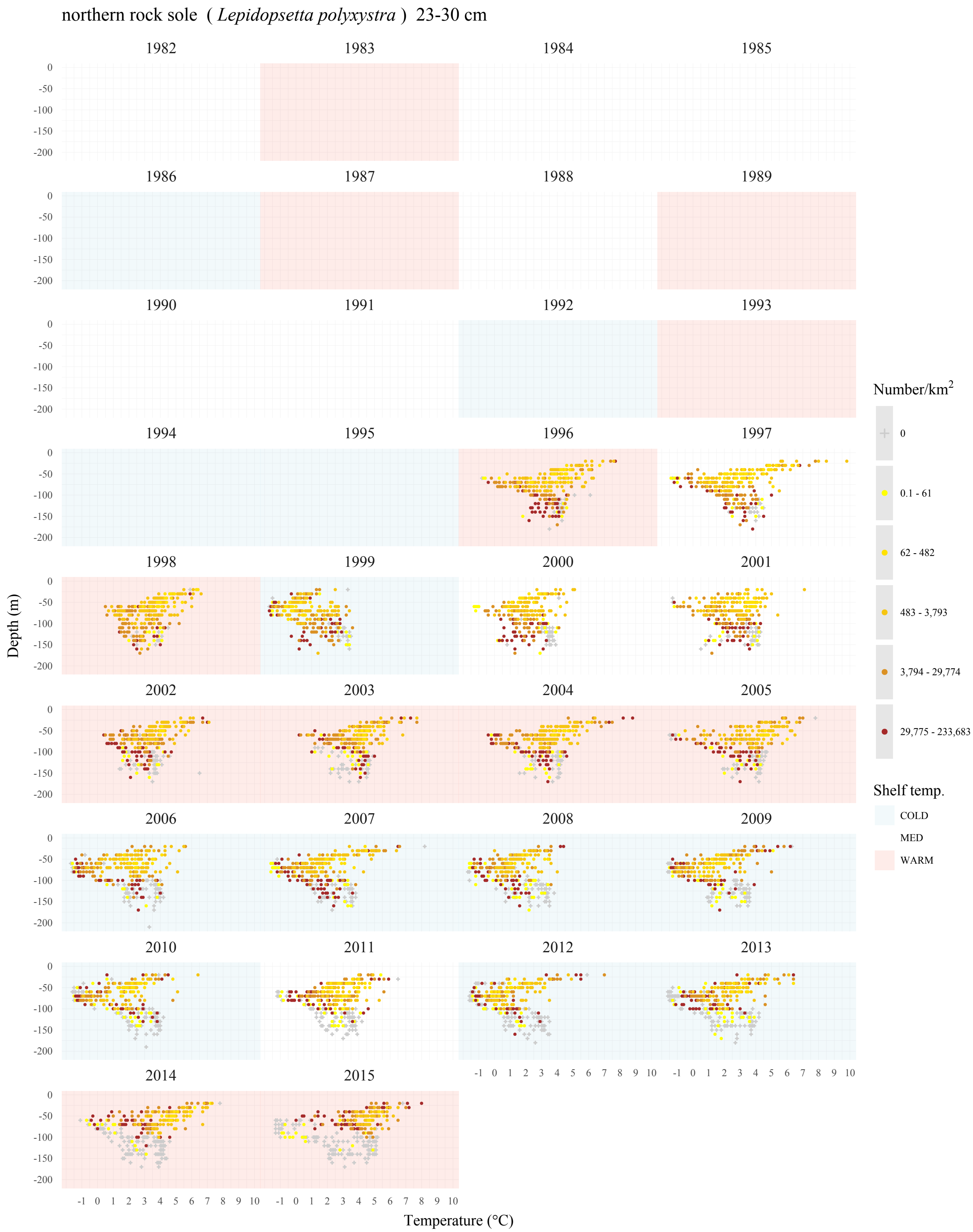


Figure 65 . -- Continued.

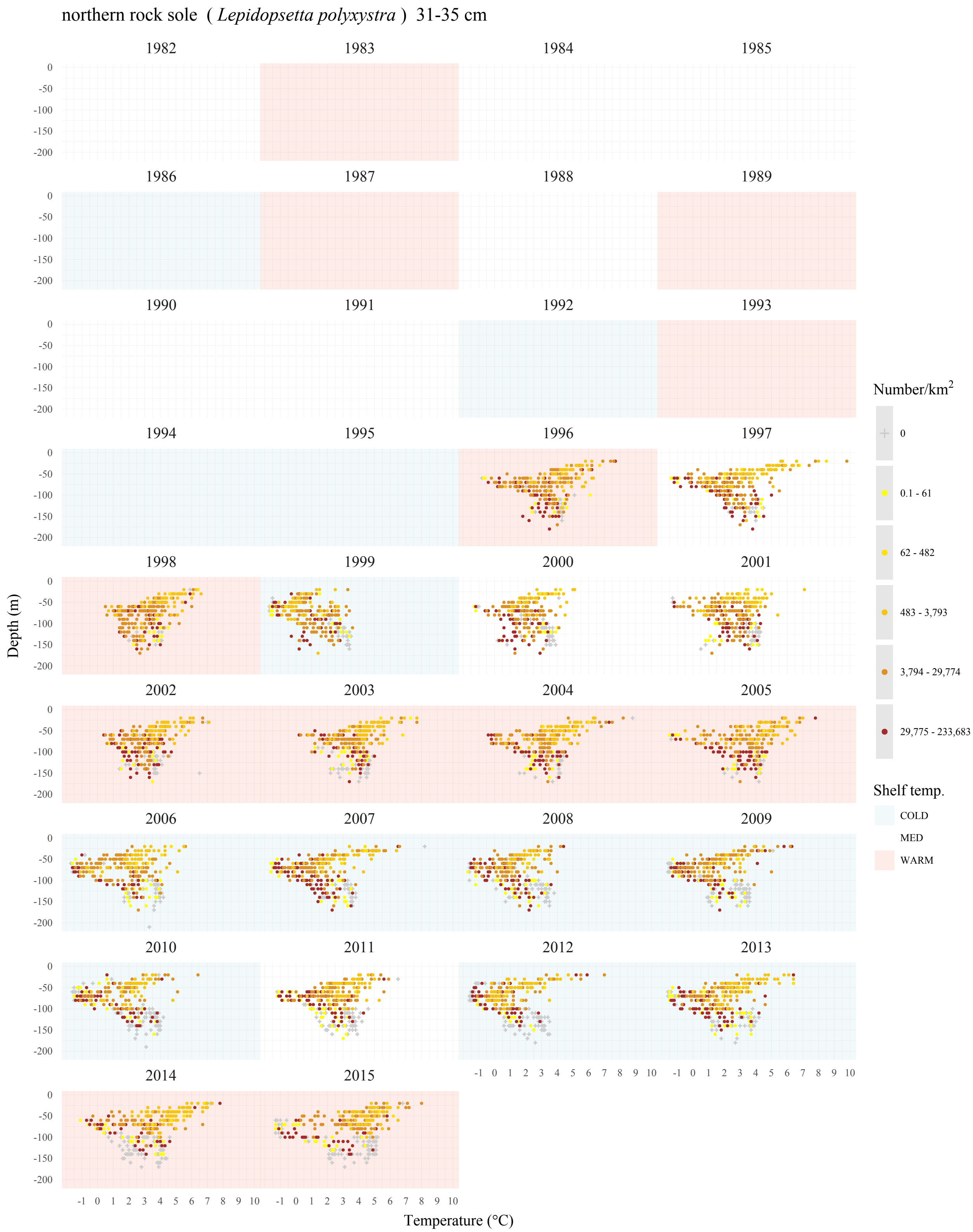


Figure 65 . -- Continued.

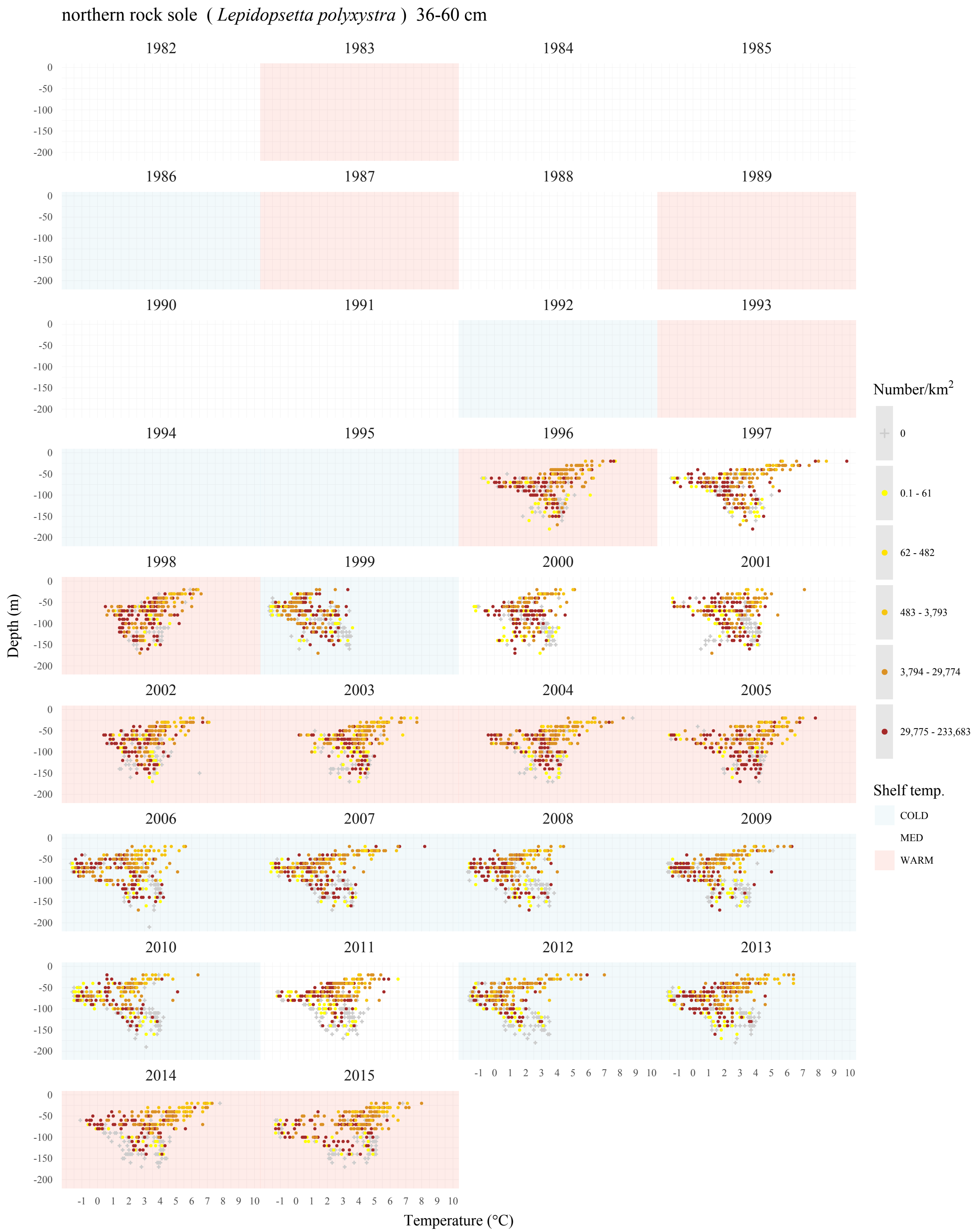


Figure 65 . -- Continued.

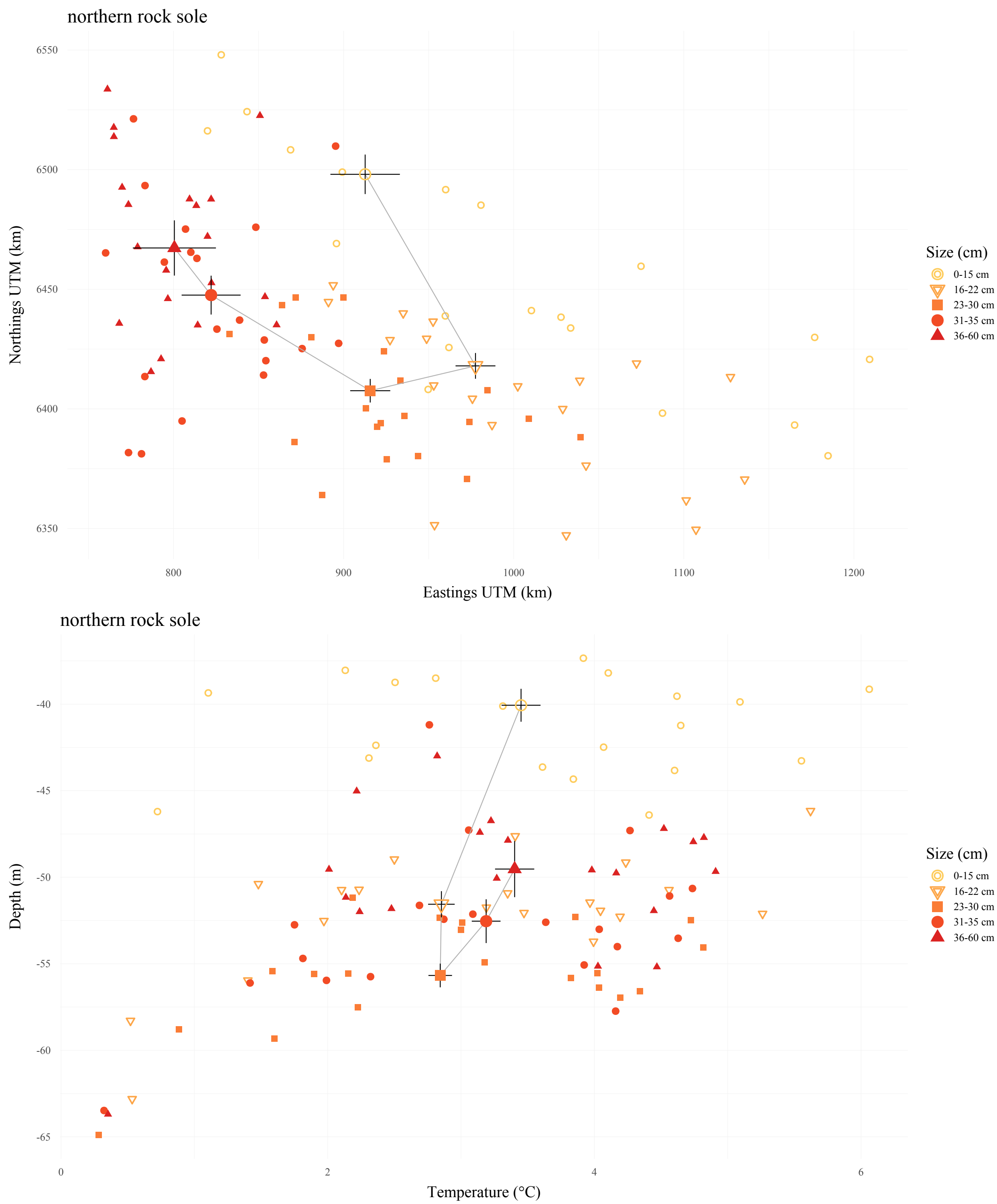


Figure 66 . -- The northern rock sole (*Lepidopsetta polyxystra*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

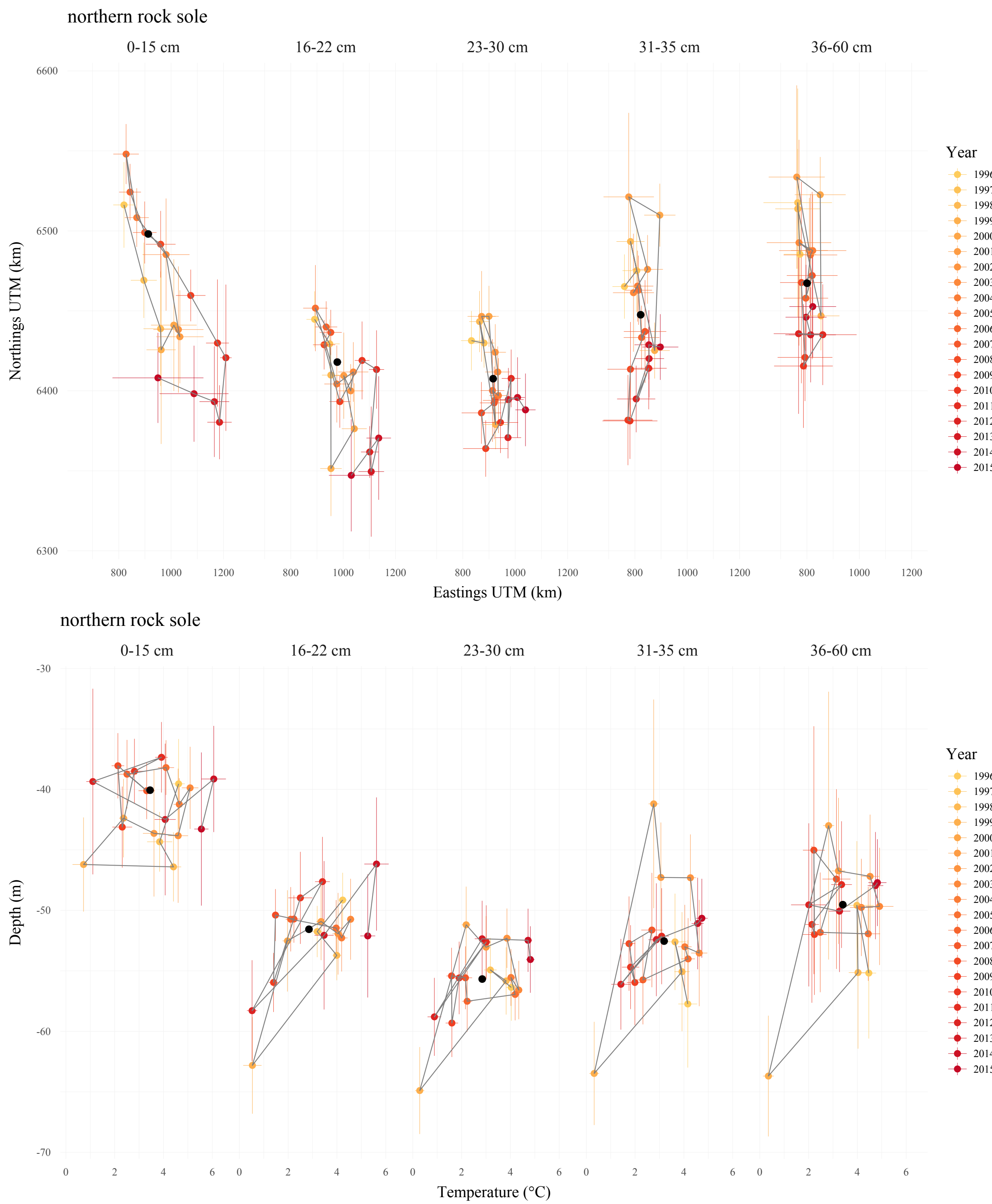


Figure 67 . -- The northern rock sole (*Lepidopsetta polyxystra*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

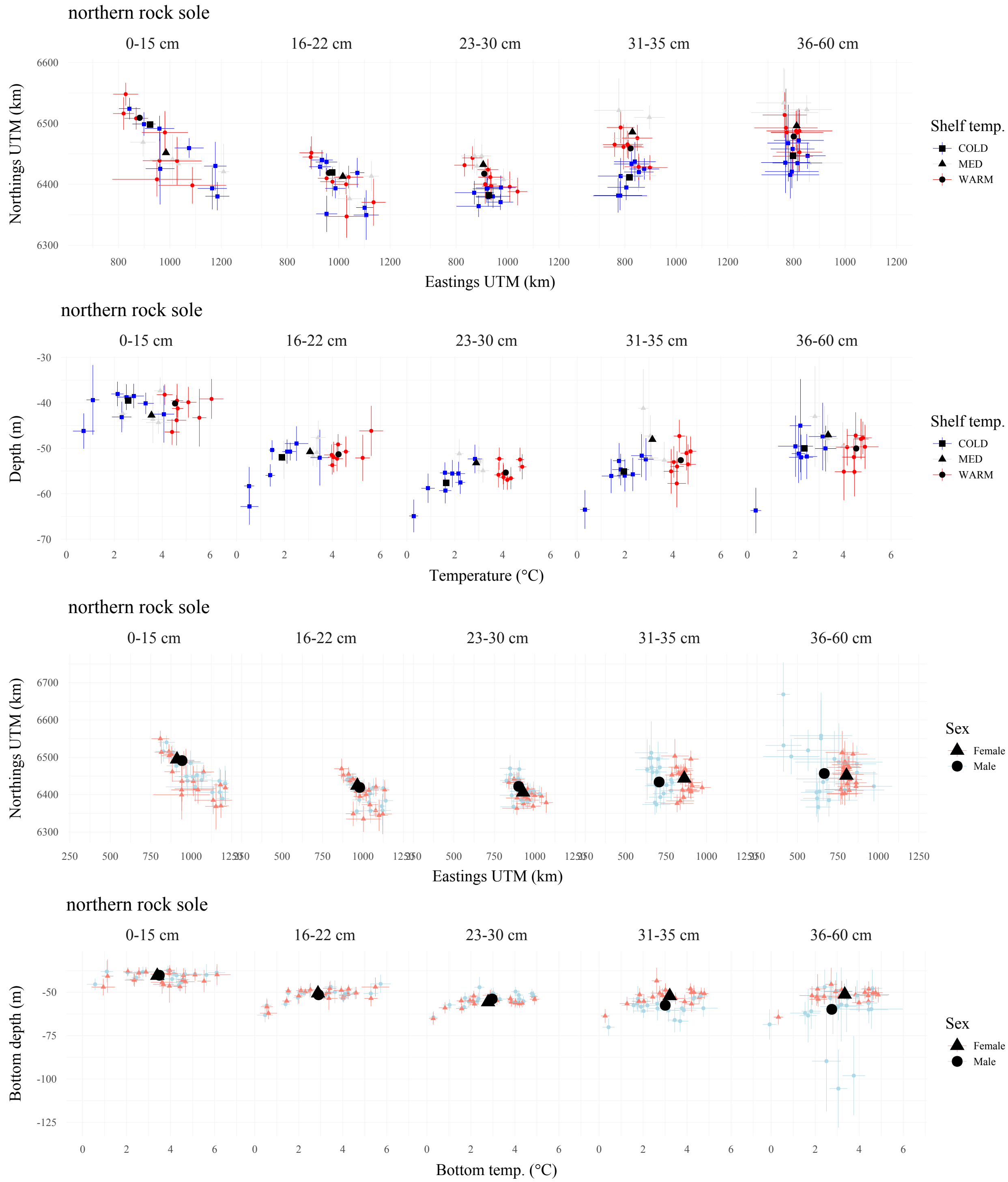


Figure 68 . -- The northern rock sole (*Lepidopsetta polyxystra*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

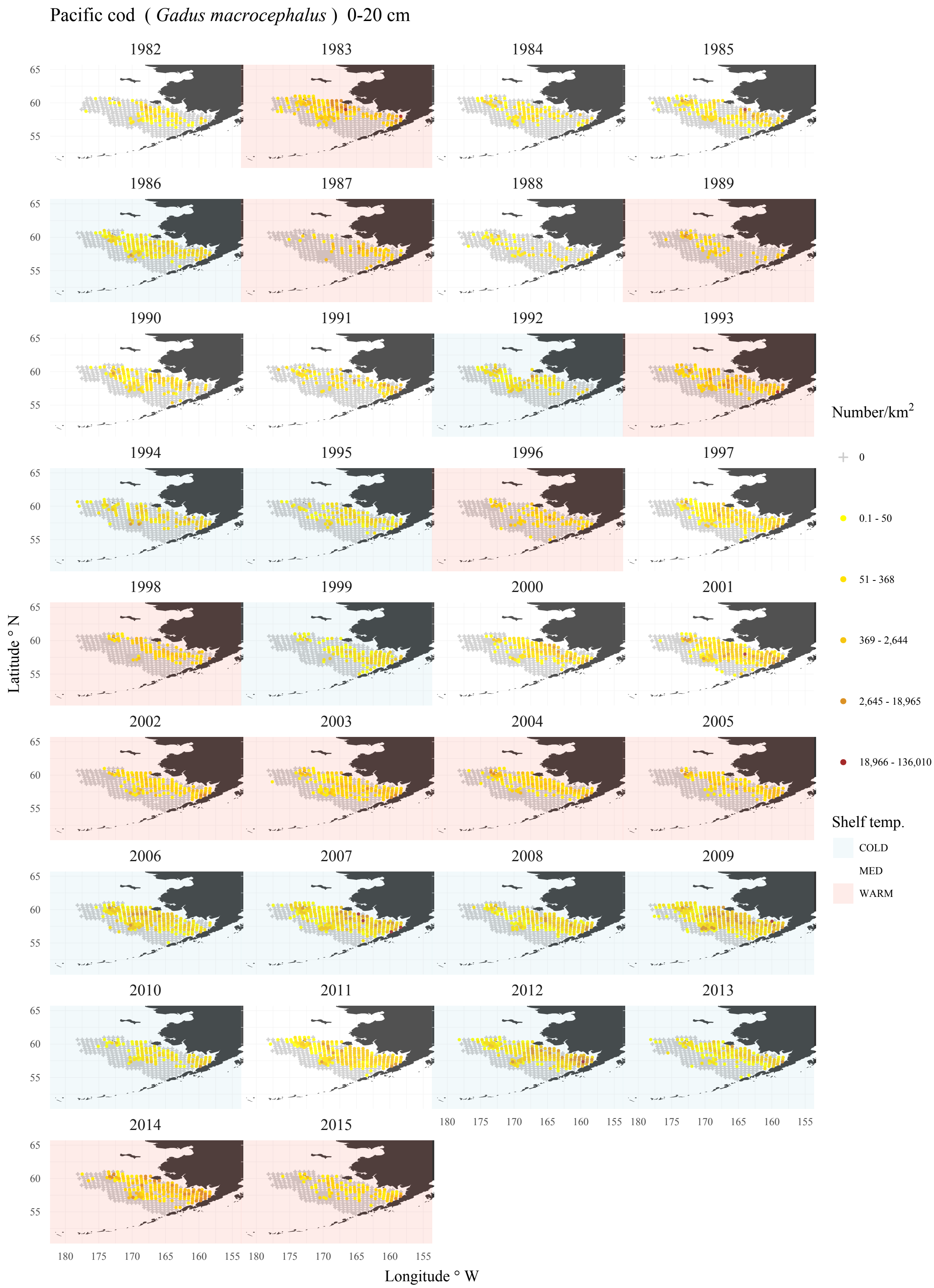


Figure 69 . -- The Pacific cod (*Gadus macrocephalus*) CPUE by number weighted mean location for each length category for all years.

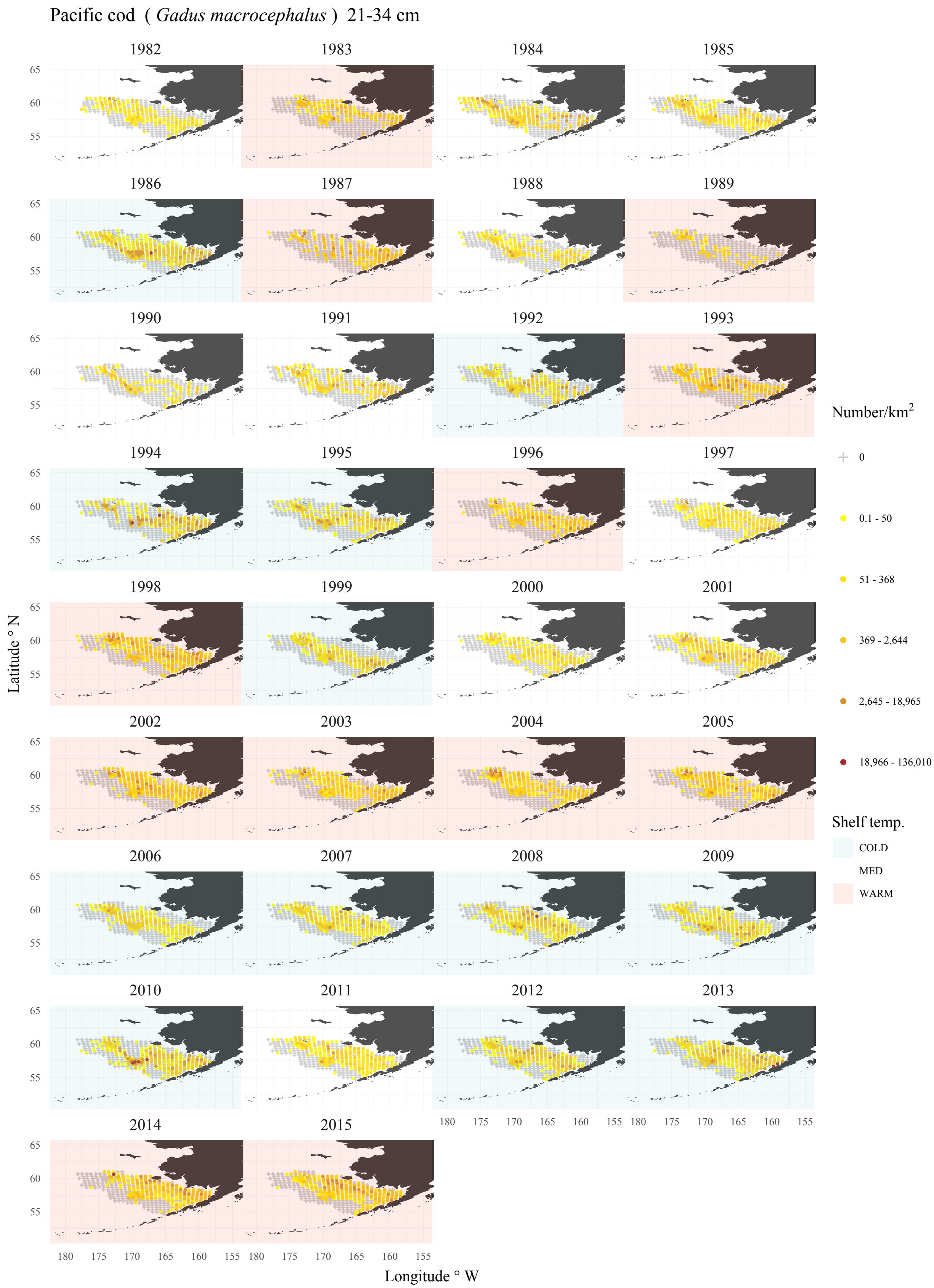


Figure 69 . -- Continued.

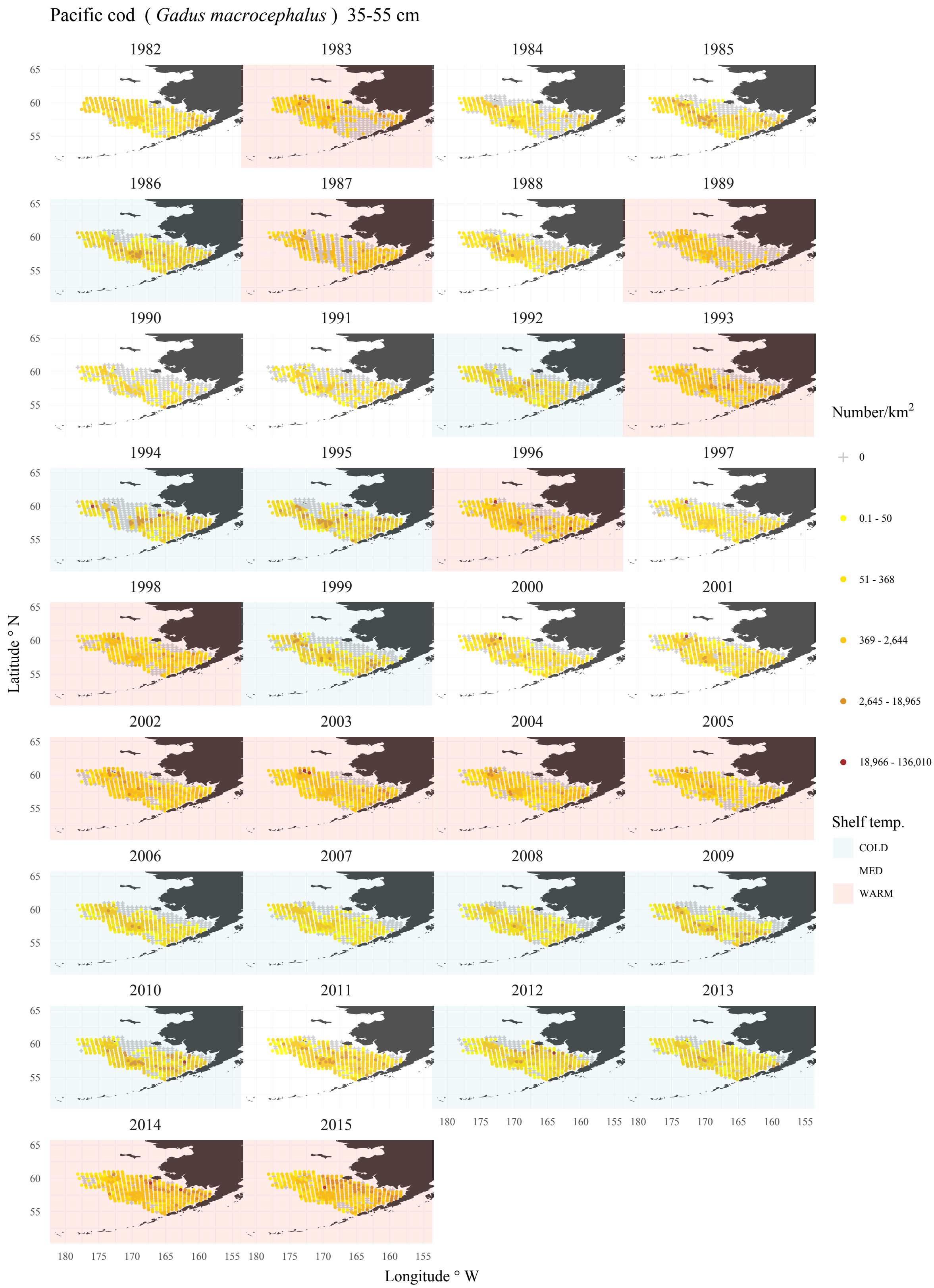


Figure 69 . -- Continued.

Pacific cod (*Gadus macrocephalus*) 56-69 cm

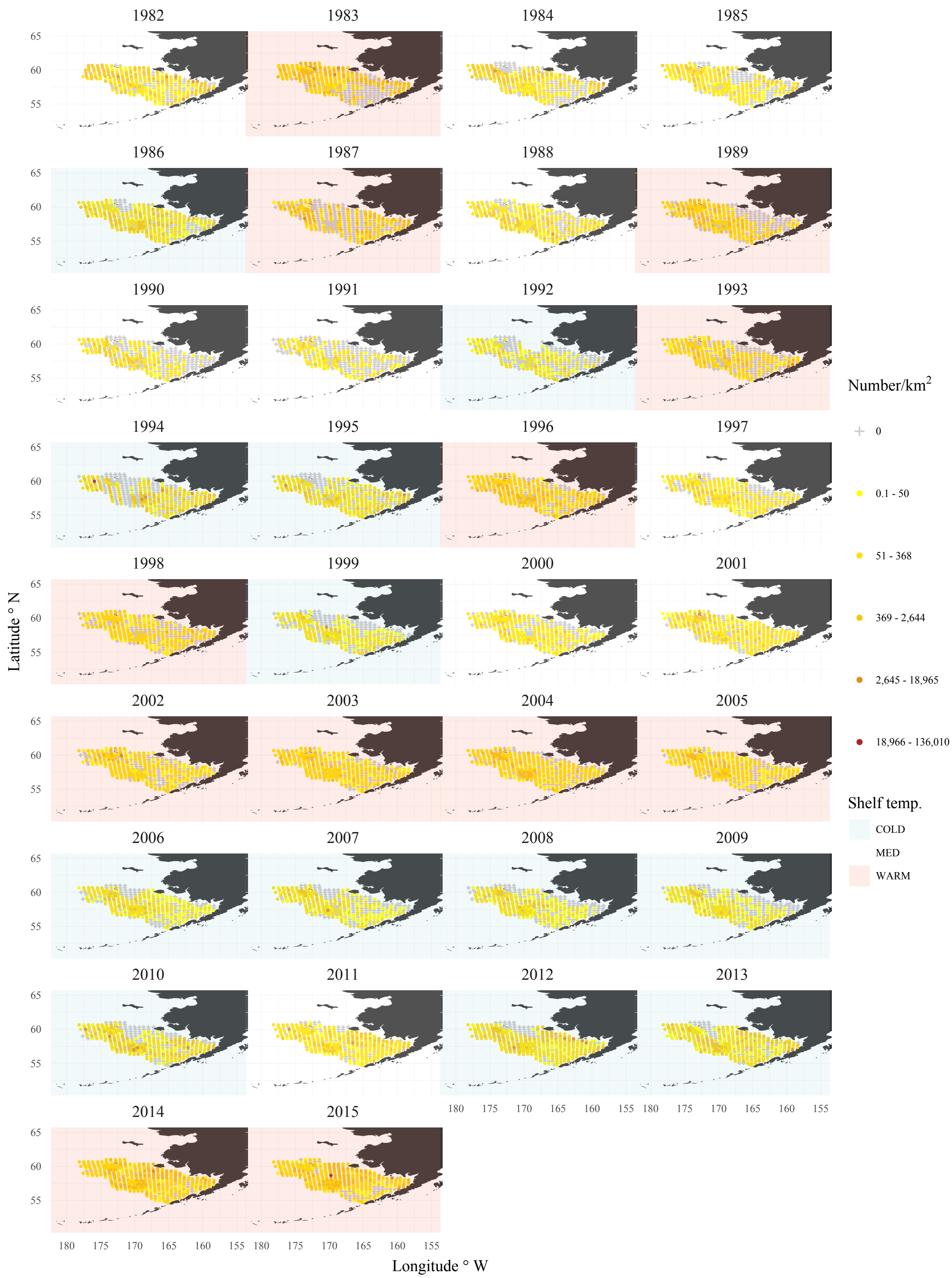


Figure 69 . -- Continued.

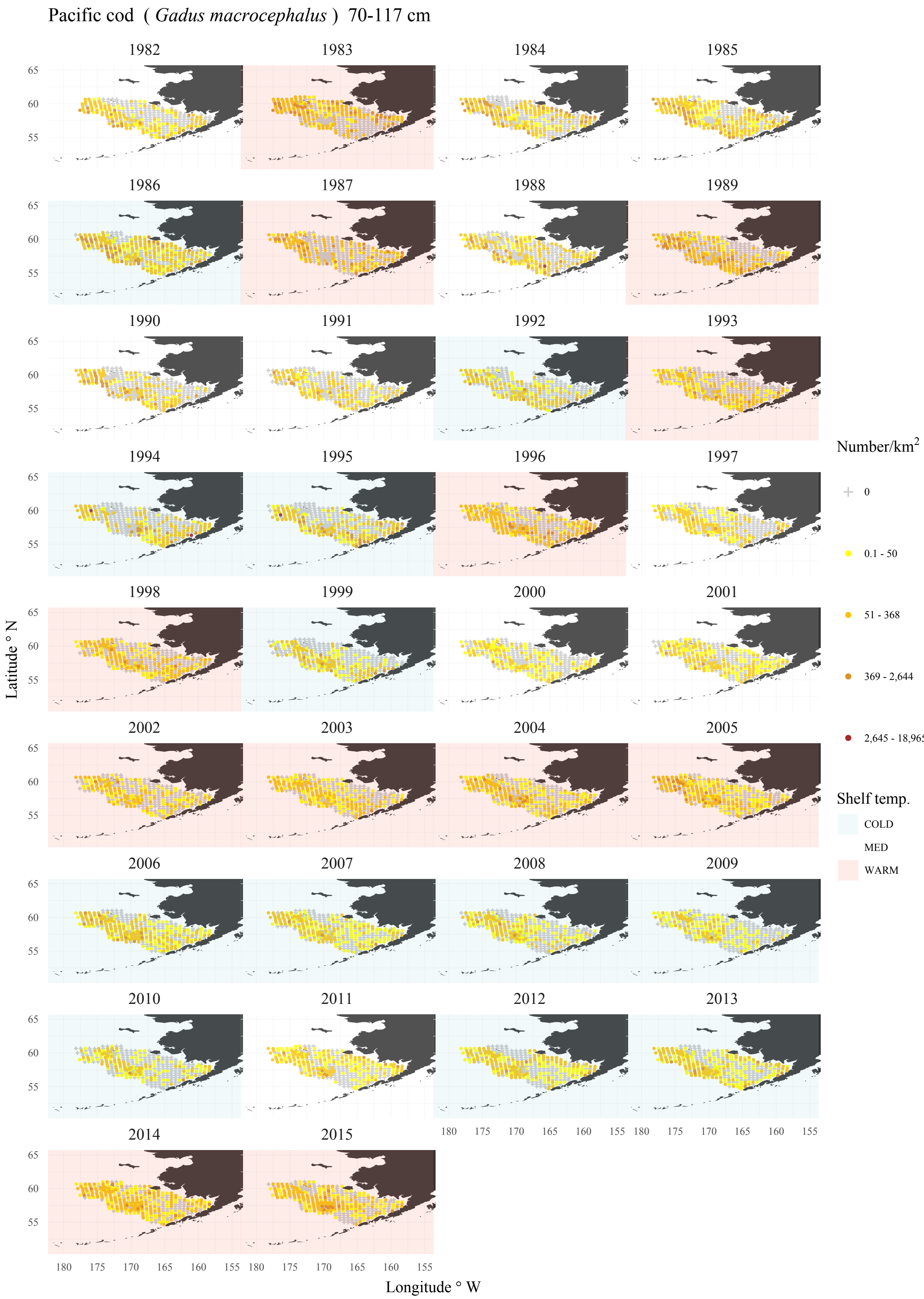


Figure 69 . -- Continued.

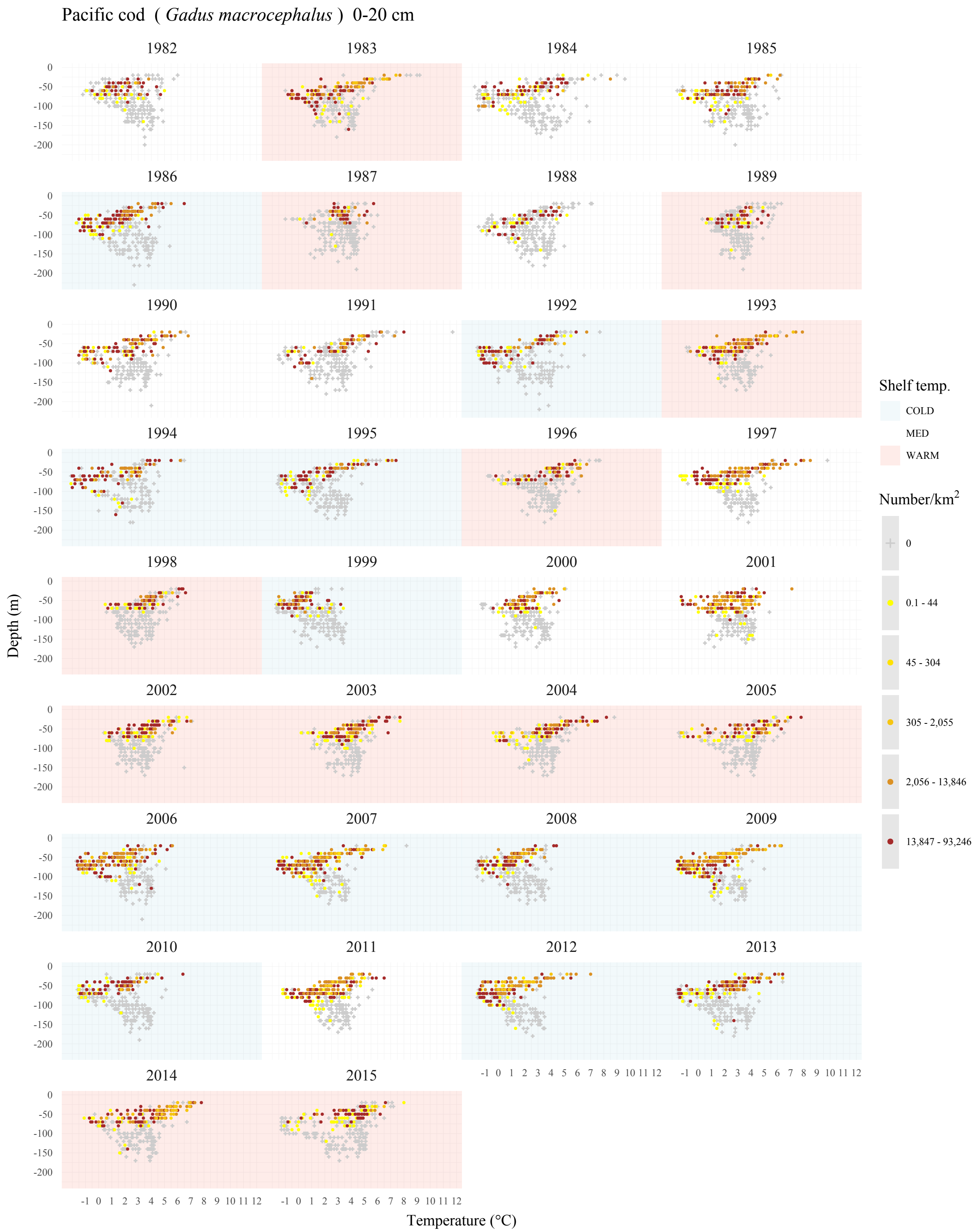


Figure 70 . -- The Pacific cod (*Gadus macrocephalus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

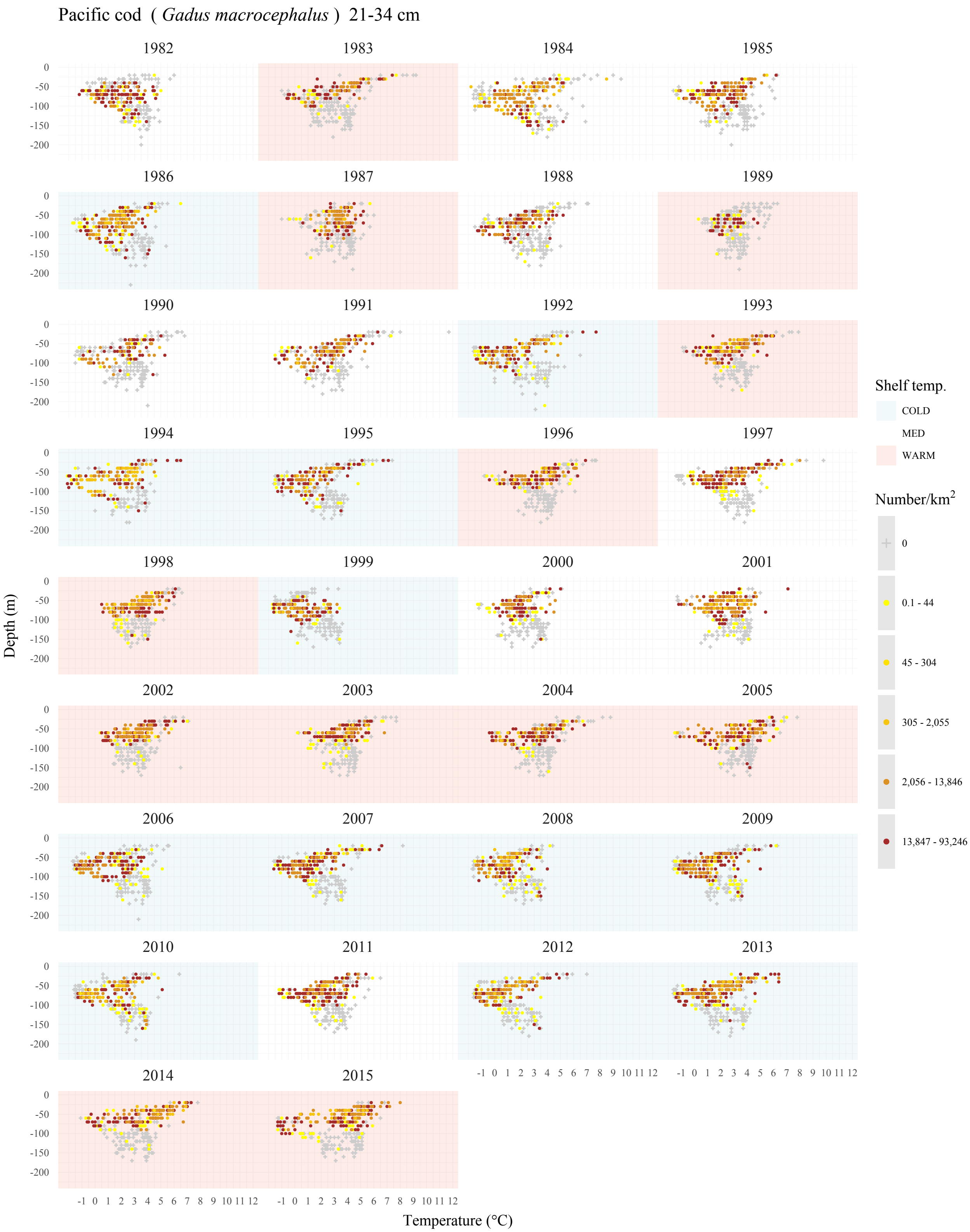


Figure 70 . -- Continued.

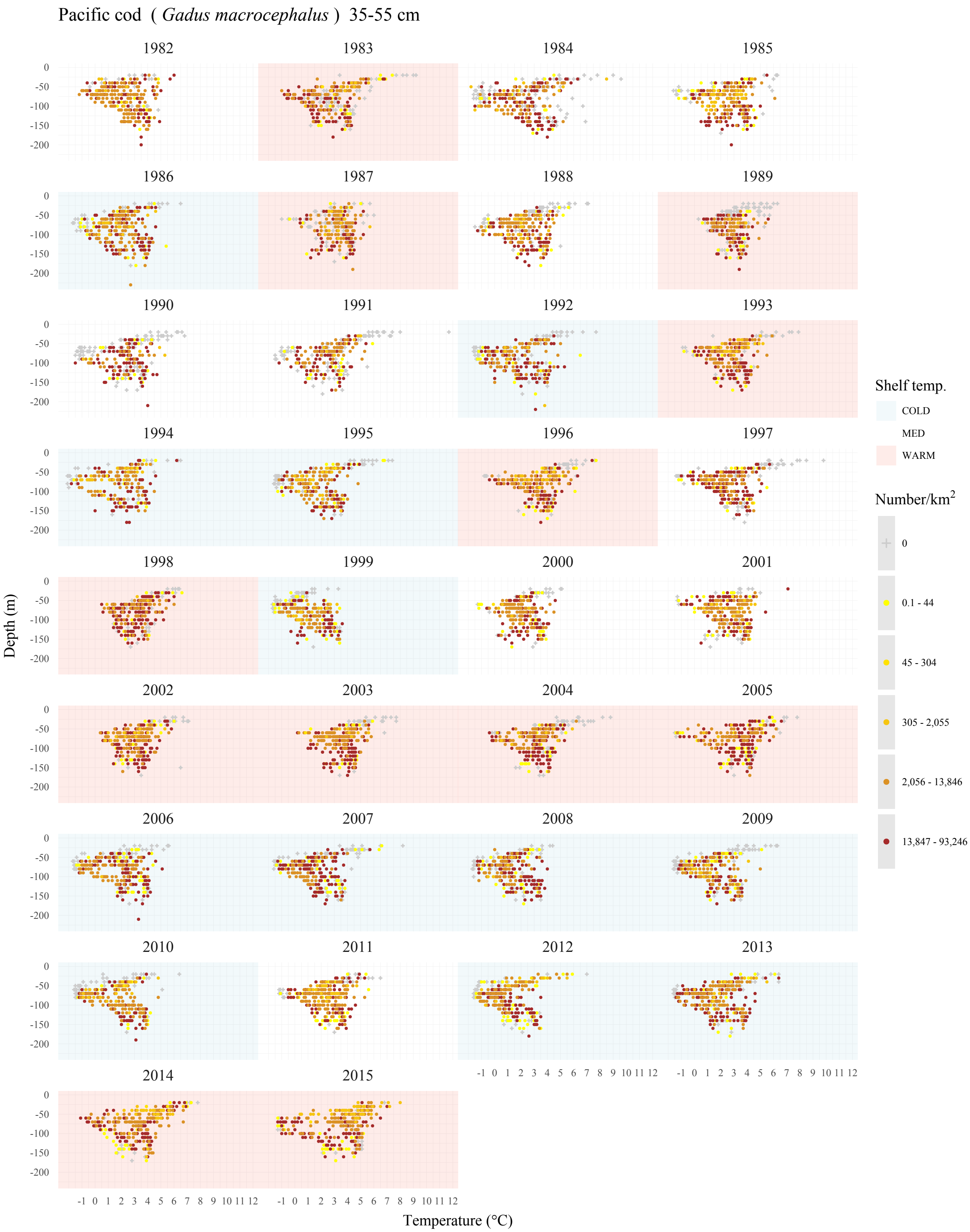


Figure 70 . -- Continued.

Pacific cod (*Gadus macrocephalus*) 56-69 cm

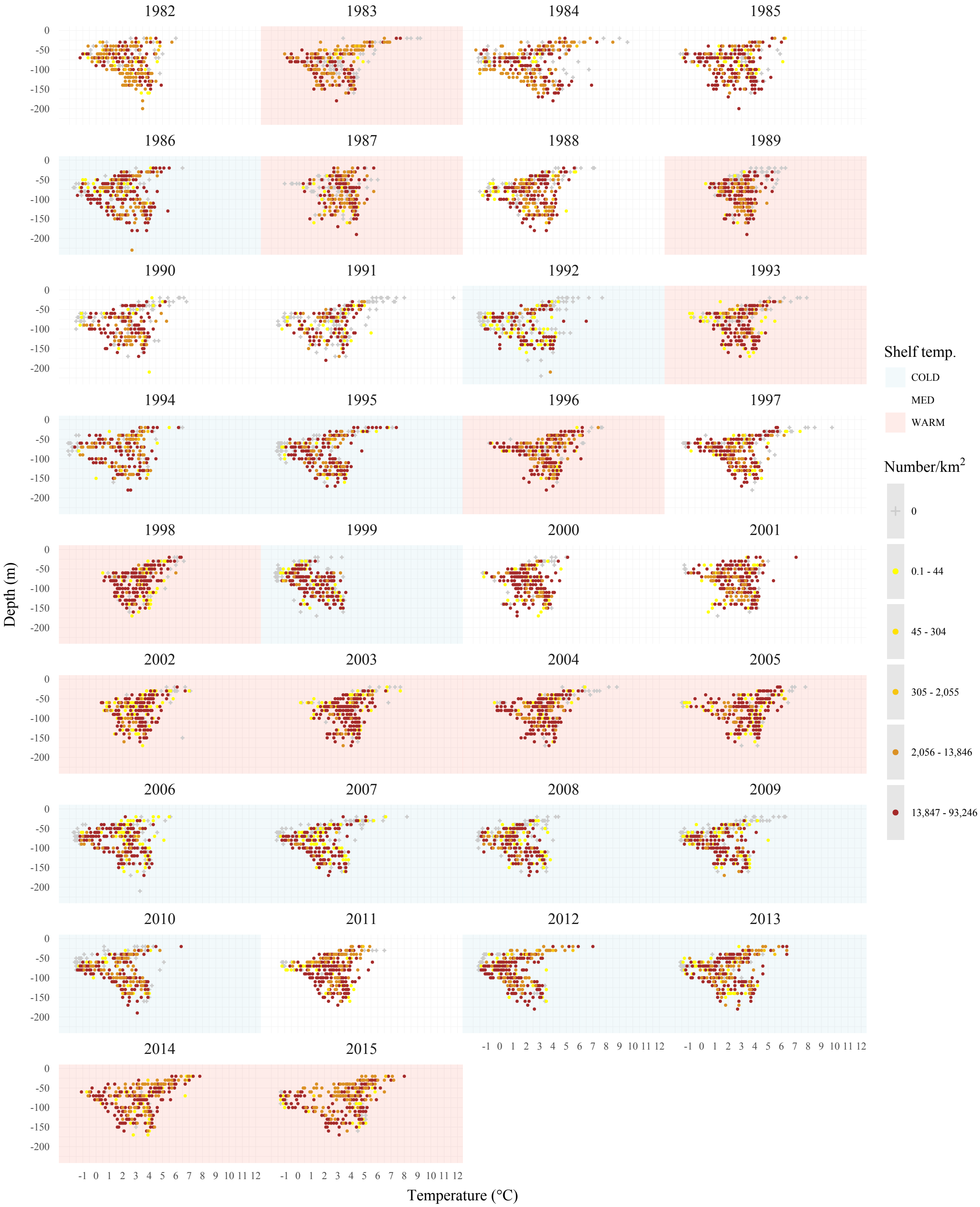


Figure 70 . -- Continued.

Pacific cod (*Gadus macrocephalus*) 70-117 cm

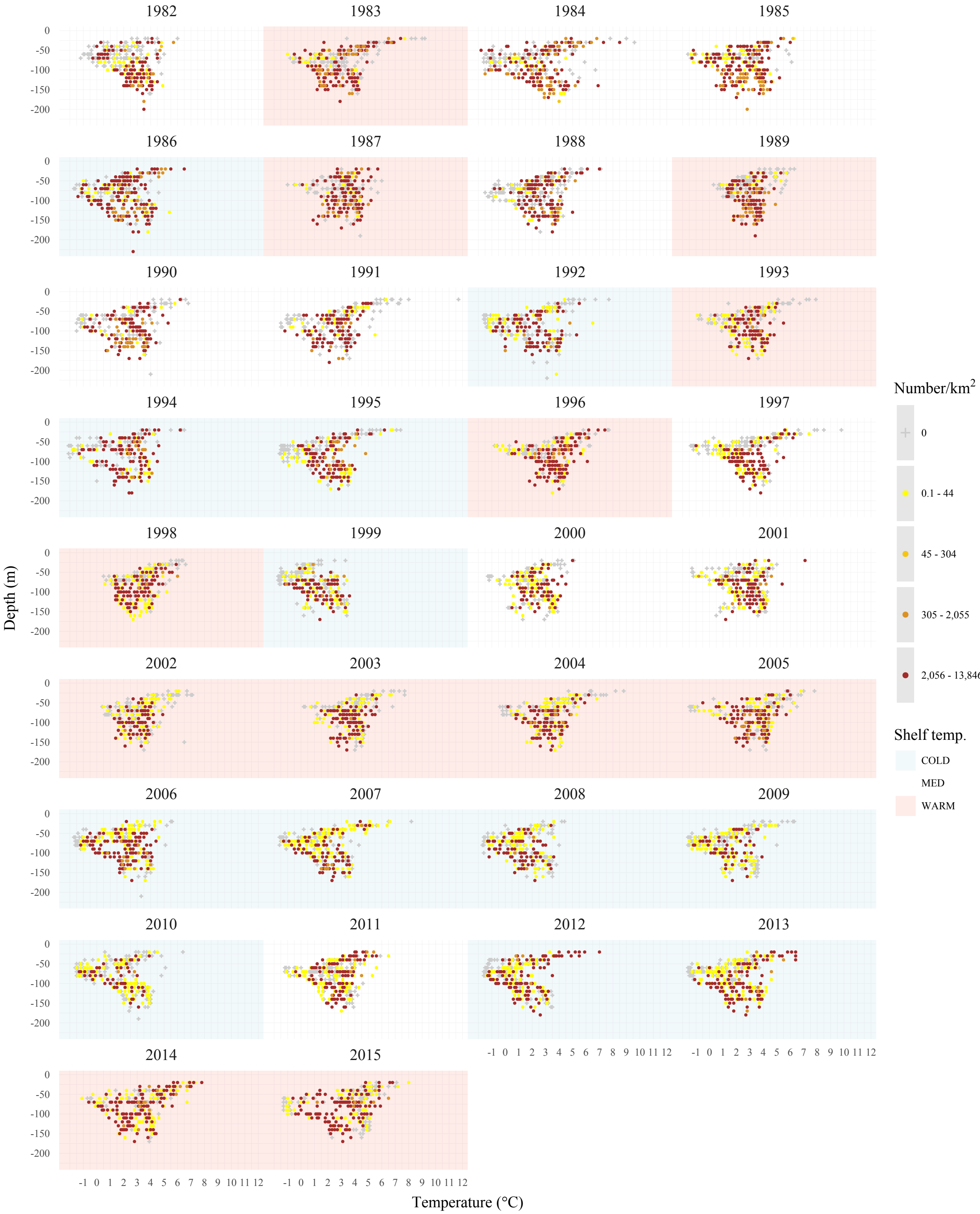


Figure 70 . -- Continued.

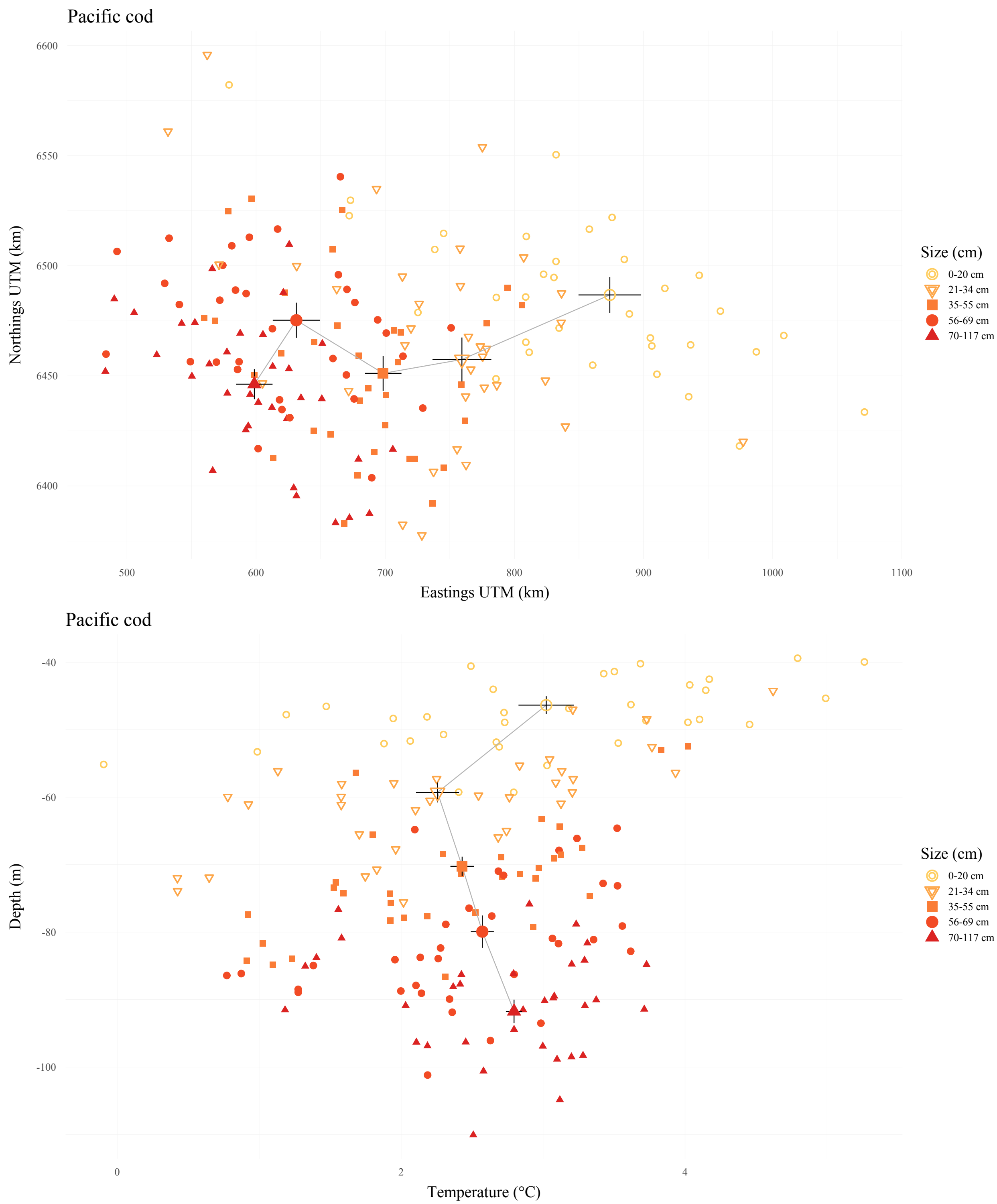
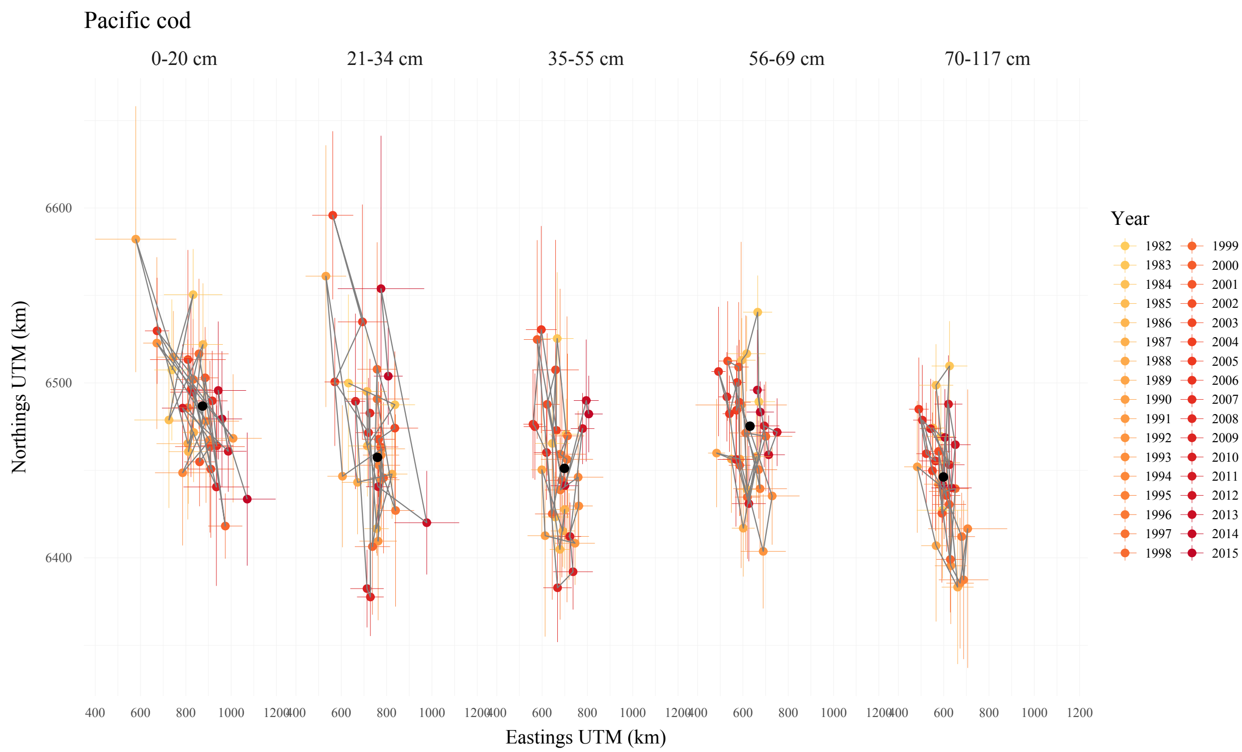


Figure 71 . -- The Pacific cod (*Gadus macrocephalus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.



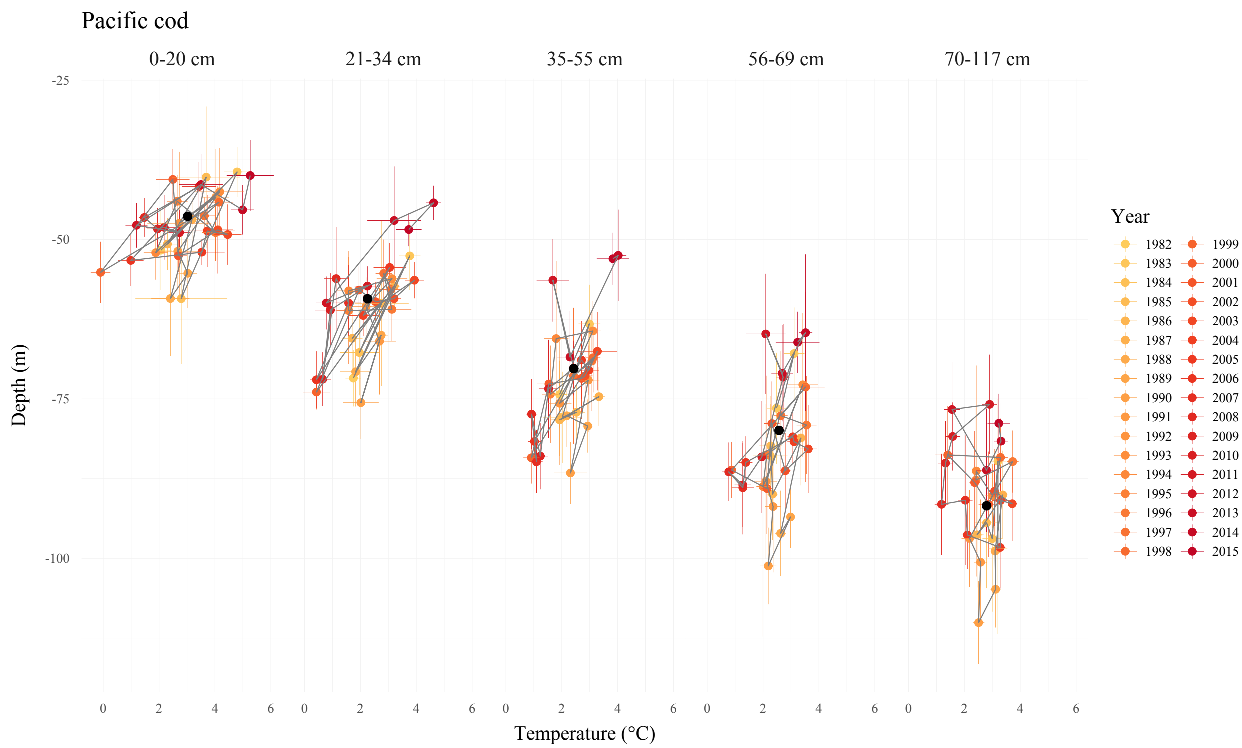


Figure 72 . -- The Pacific cod (*Gadus macrocephalus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

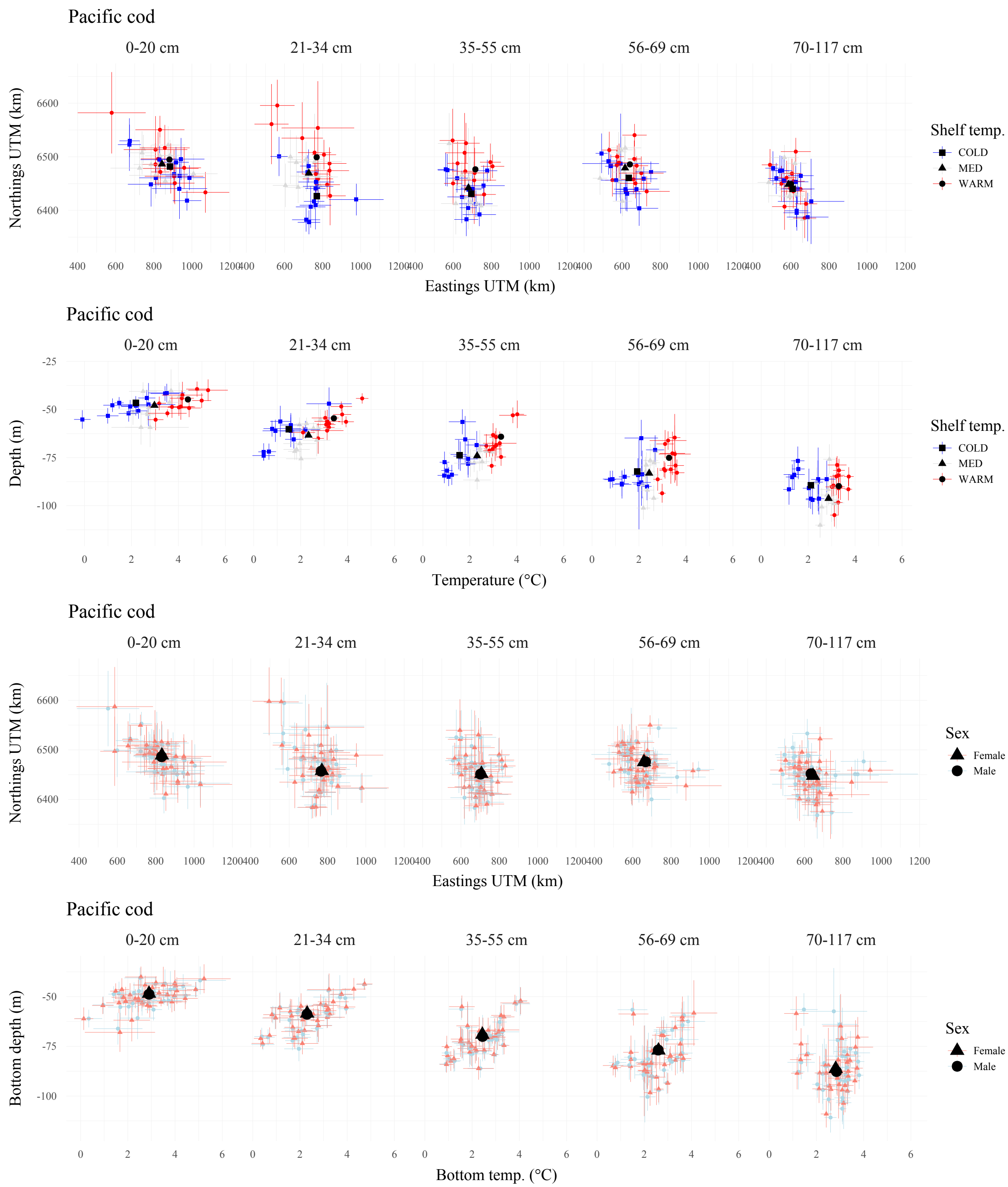


Figure 73 . -- The Pacific cod (*Gadus macrocephalus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

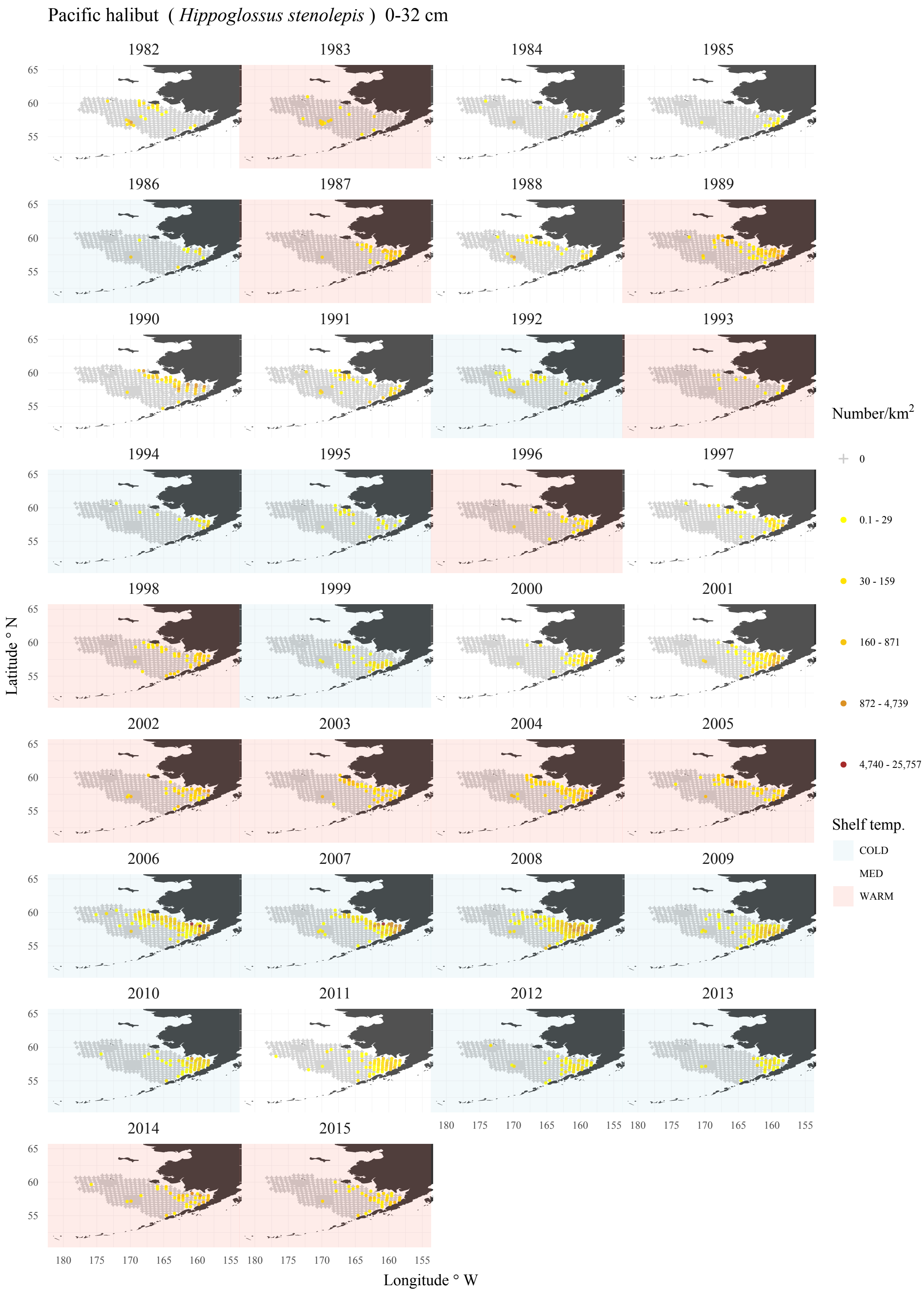


Figure 74 . -- The Pacific halibut (*Hippoglossus stenolepis*) CPUE by number weighted mean location for each length category for all years.

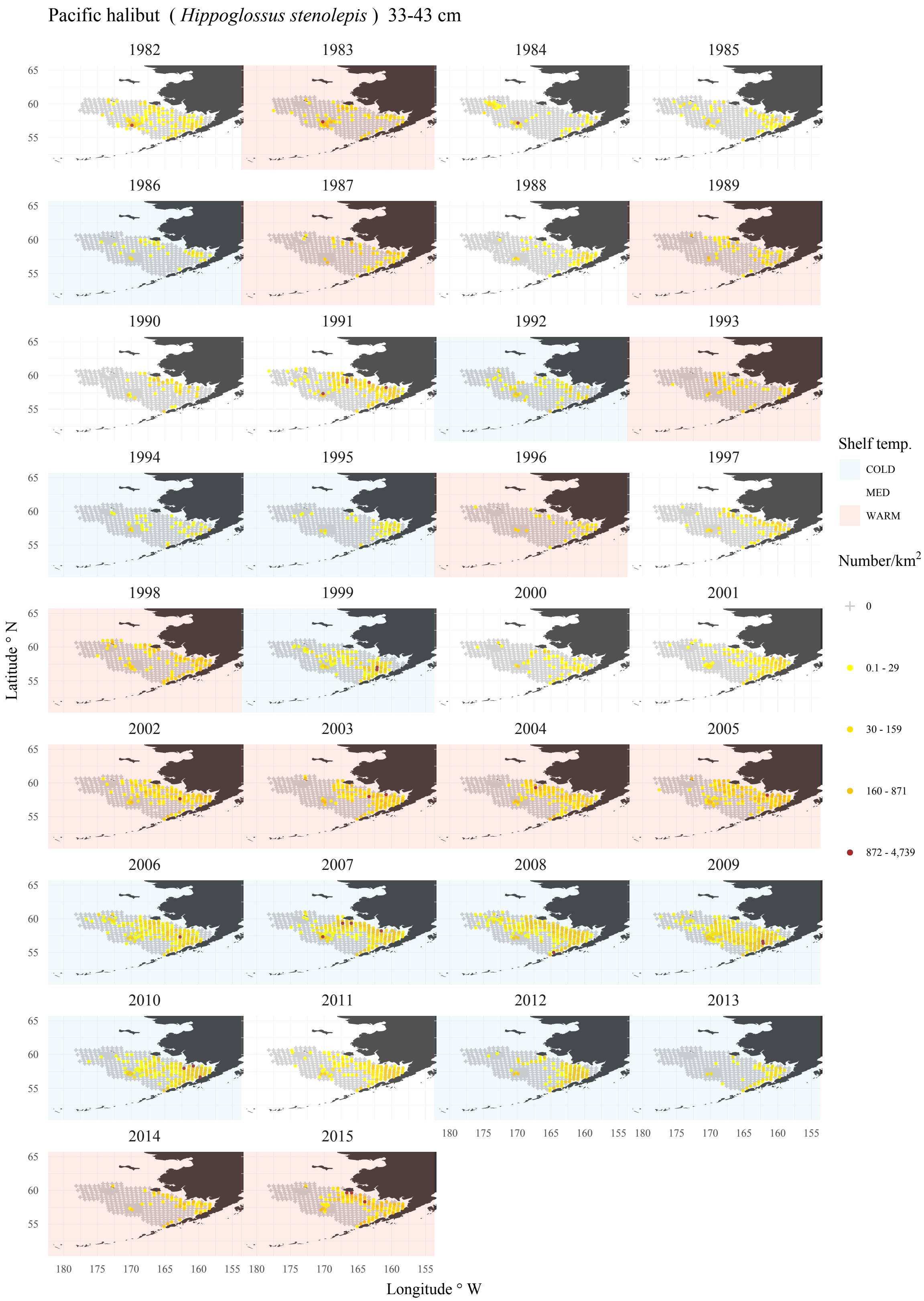


Figure 74 . -- Continued.

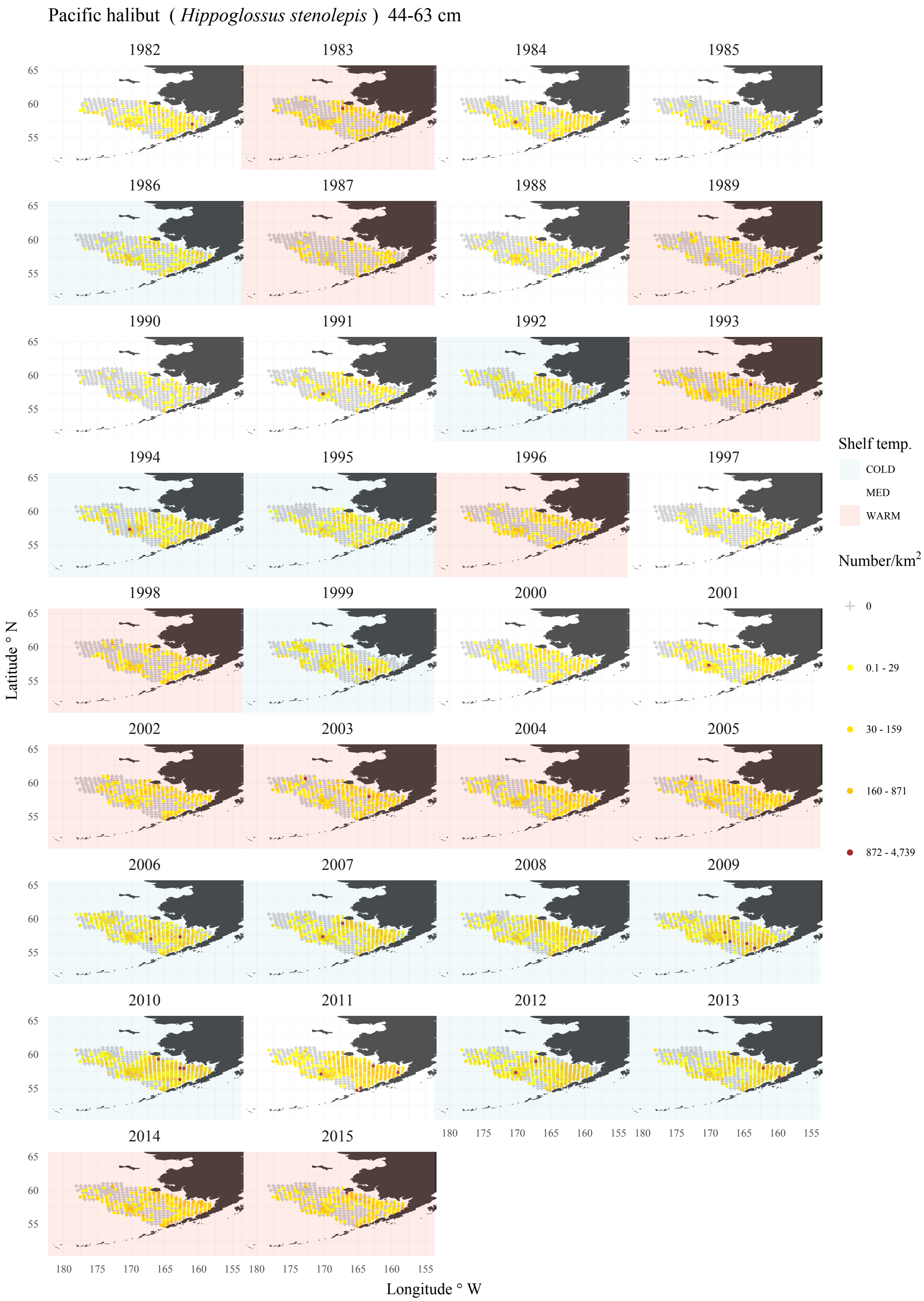


Figure 74 . -- Continued.

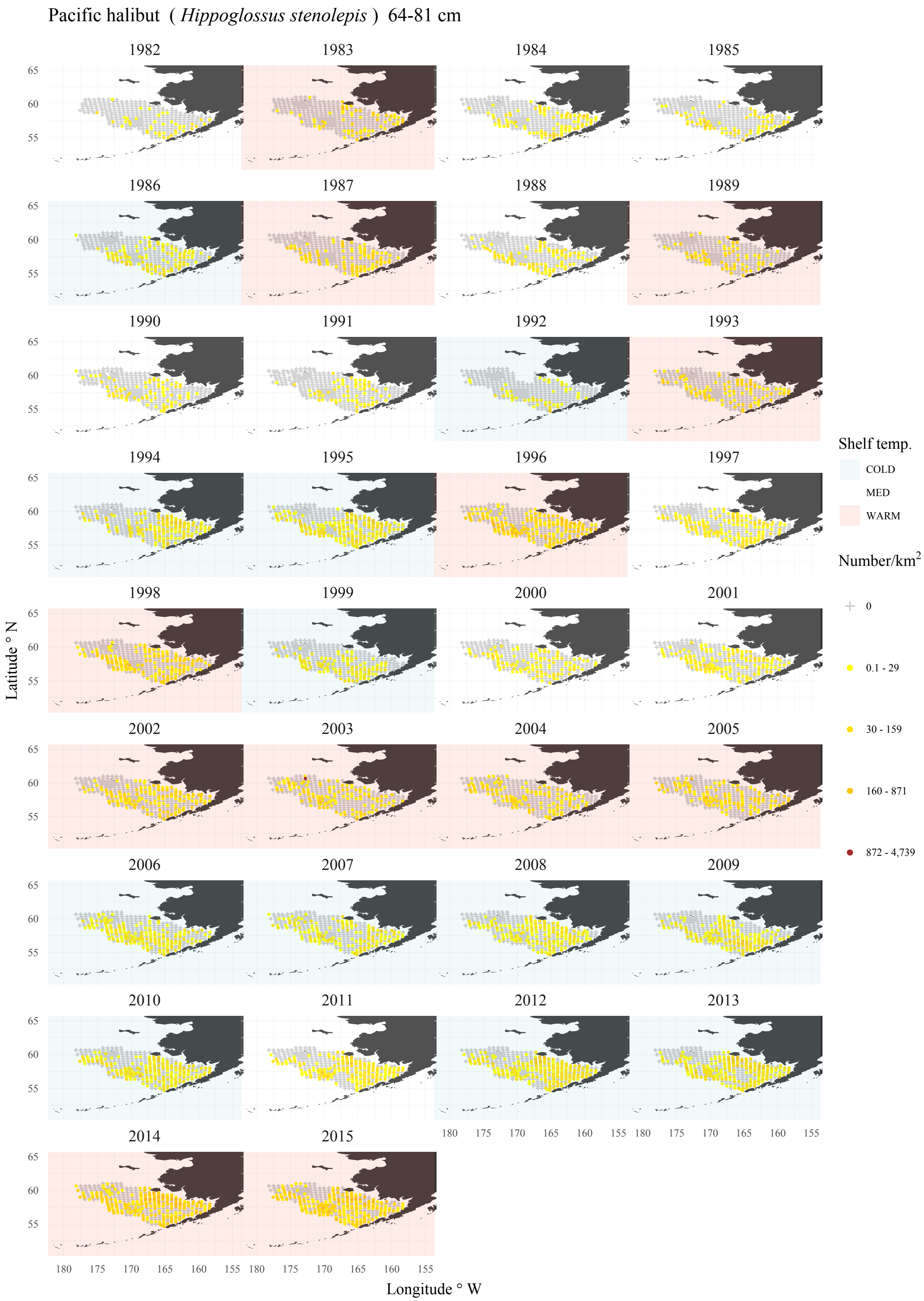


Figure 74 . -- Continued.

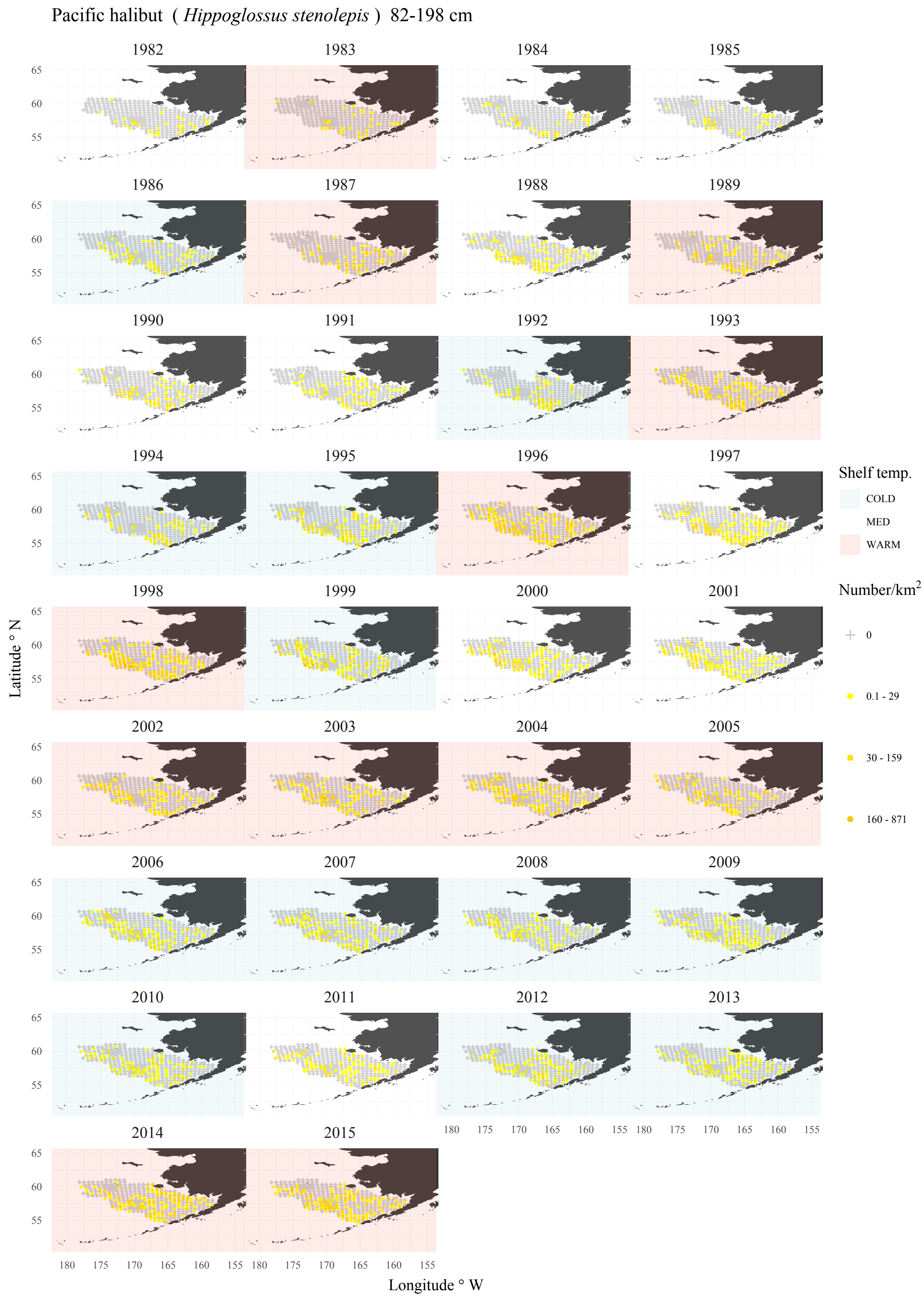


Figure 74 . -- Continued.

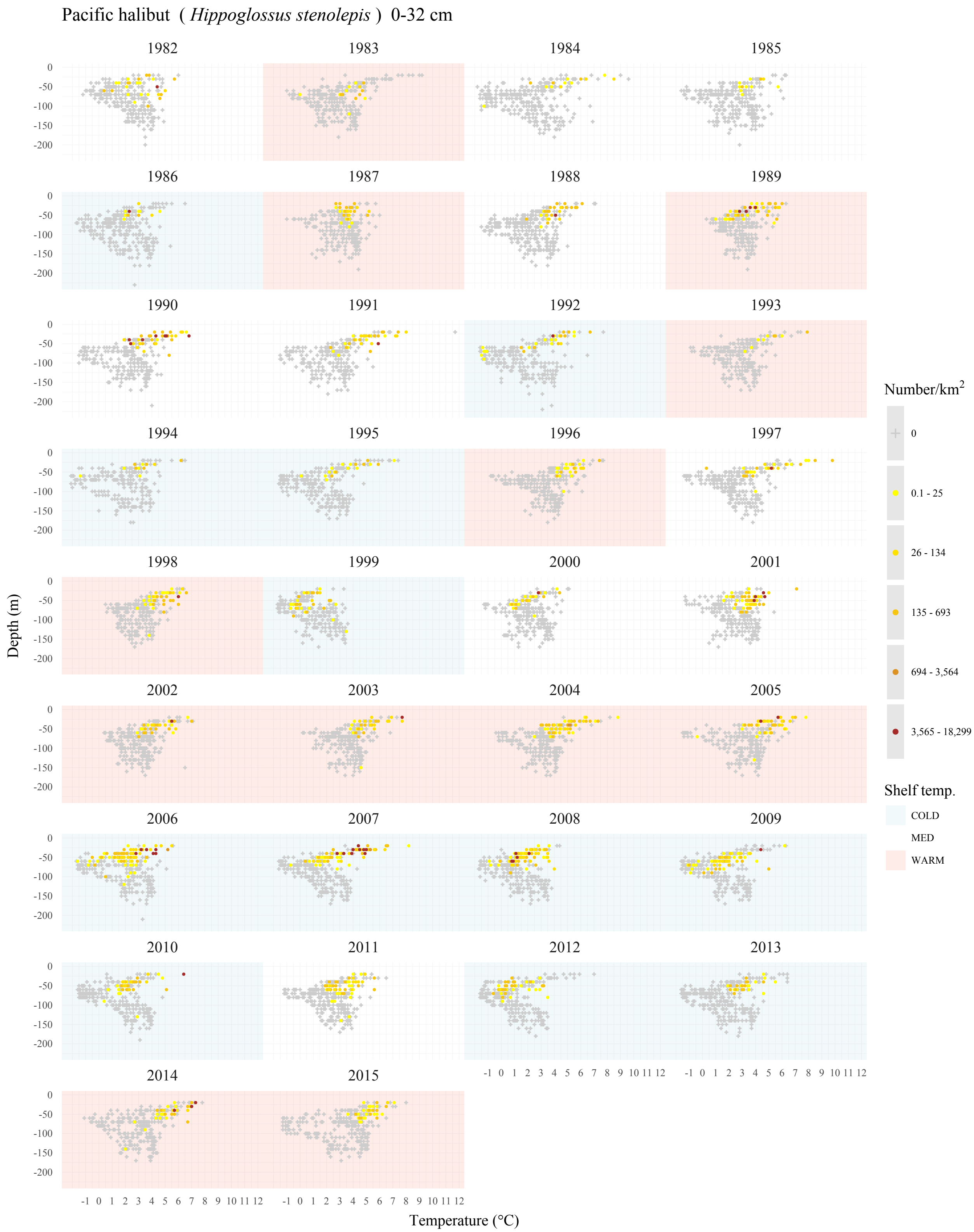


Figure 75 . -- The Pacific halibut (*Hippoglossus stenolepis*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

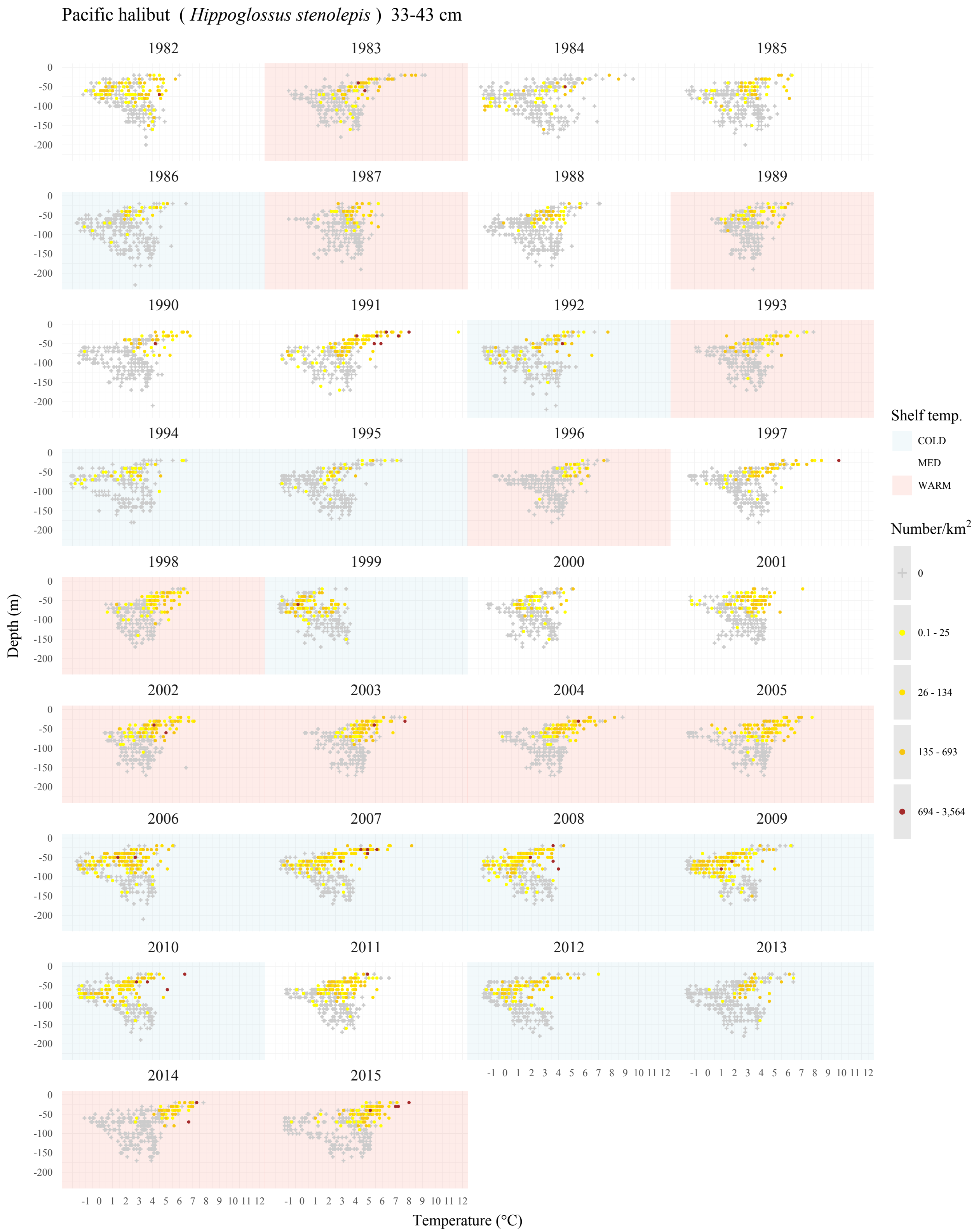


Figure 75 . -- Continued.

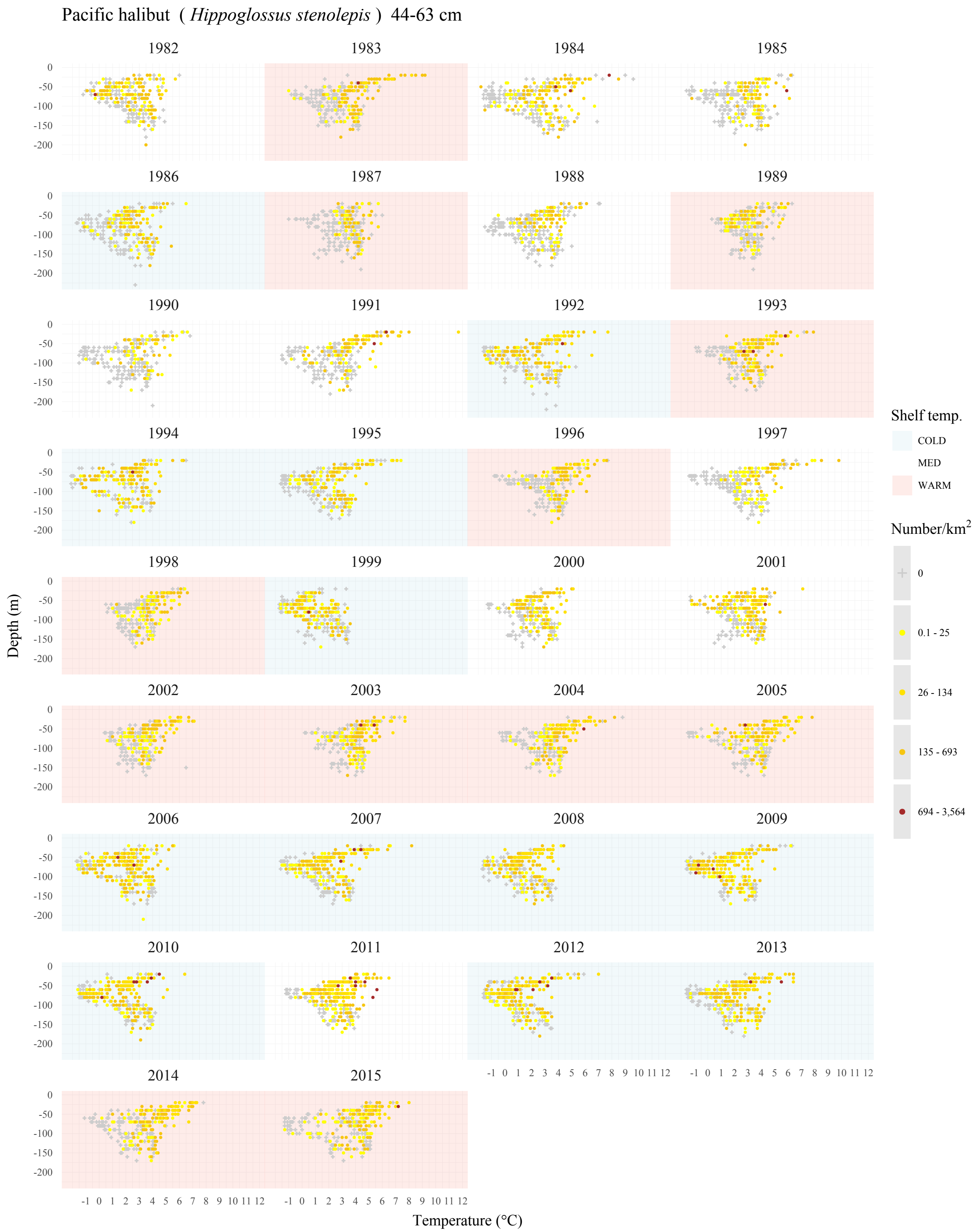


Figure 75 . -- Continued.

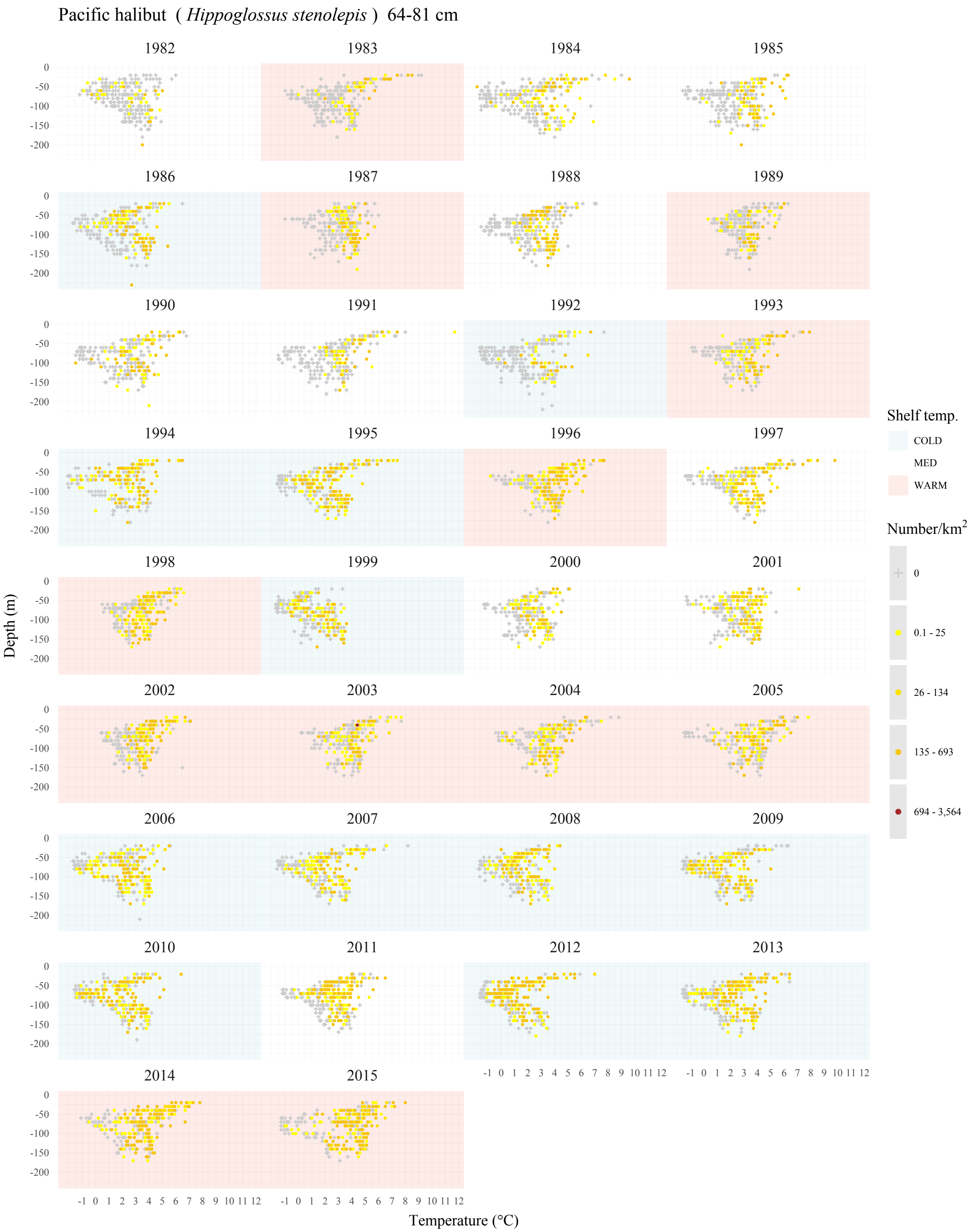


Figure 75 . -- Continued.

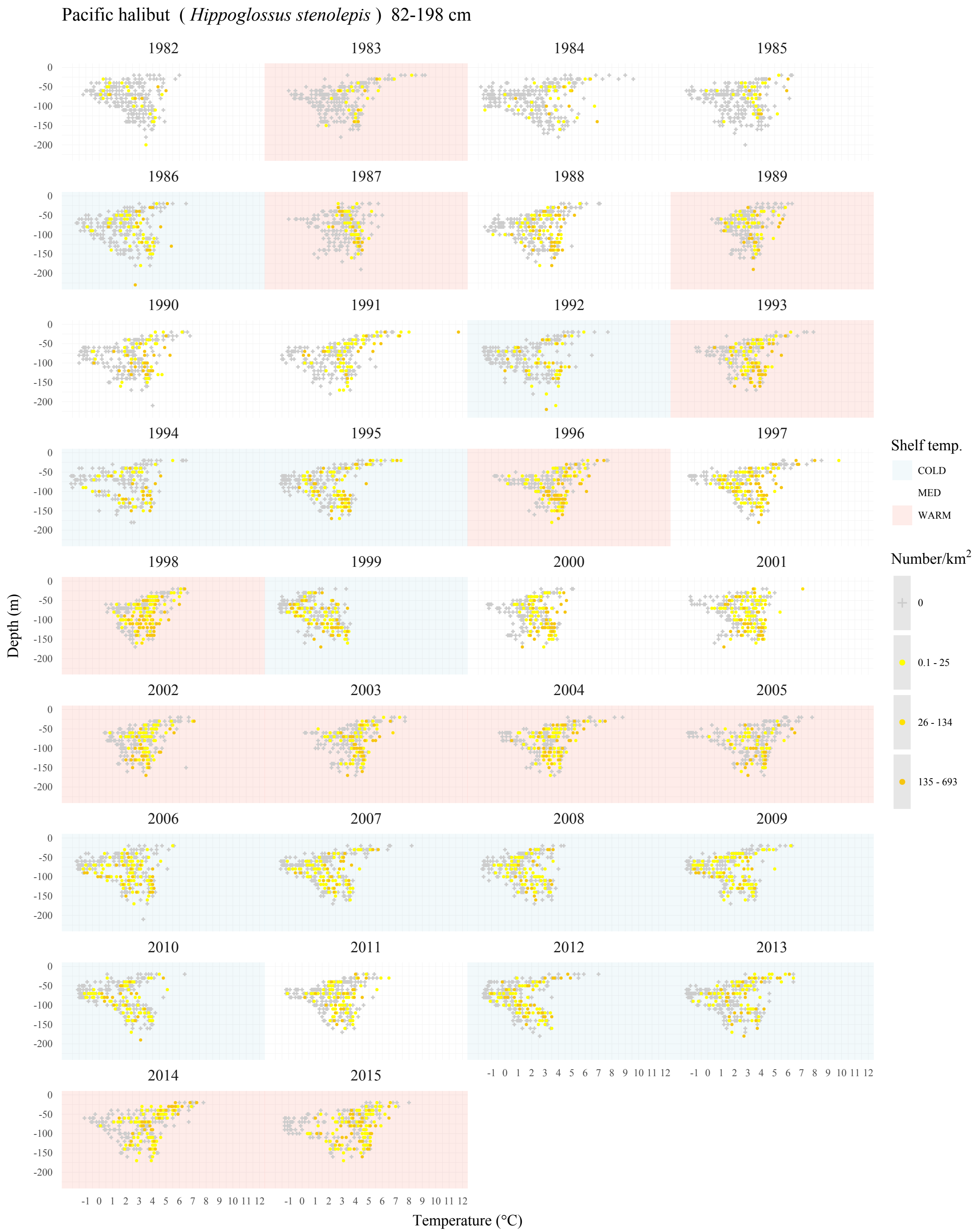


Figure 75 . -- Continued.

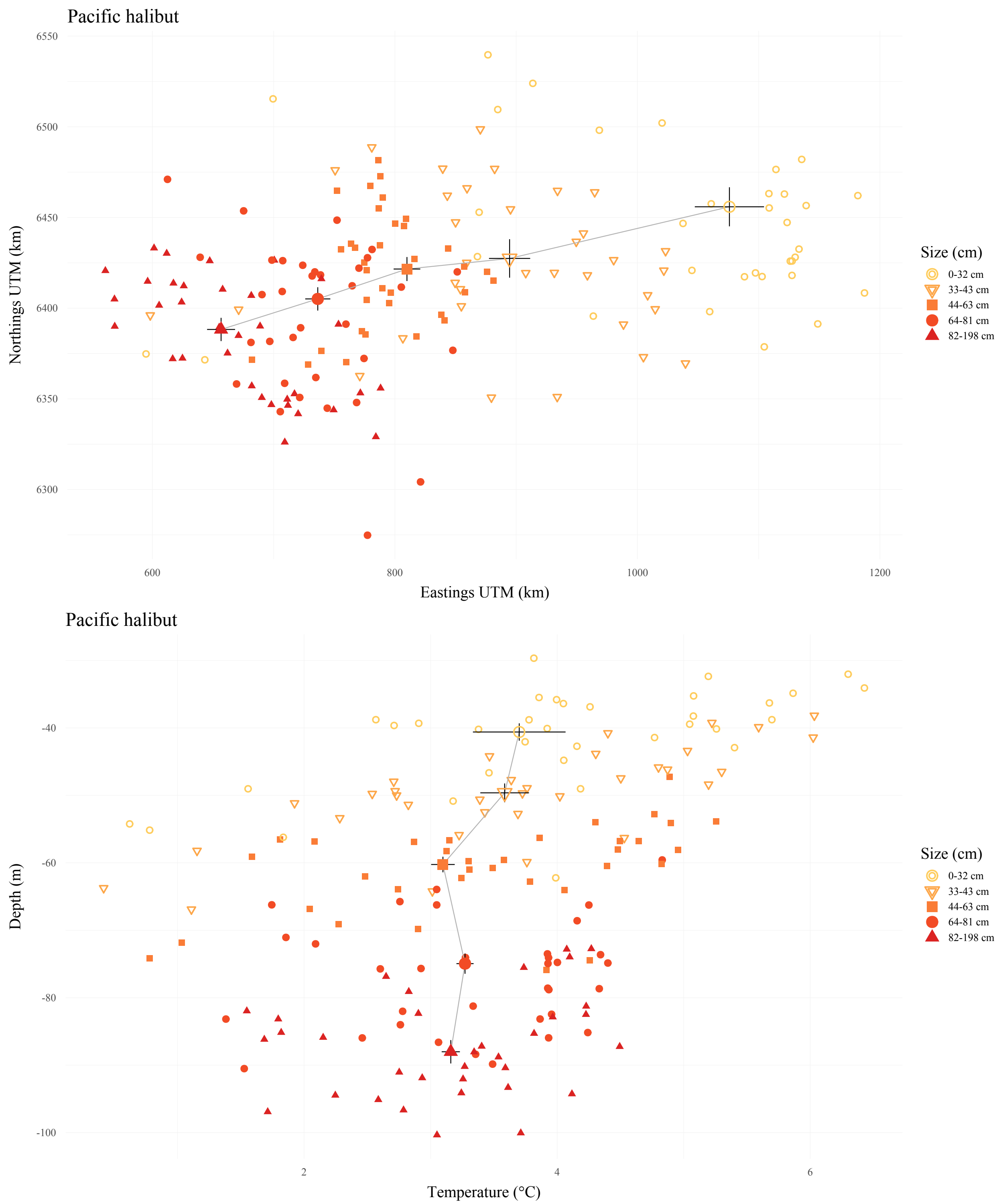


Figure 76 . -- The Pacific halibut (*Hippoglossus stenolepis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

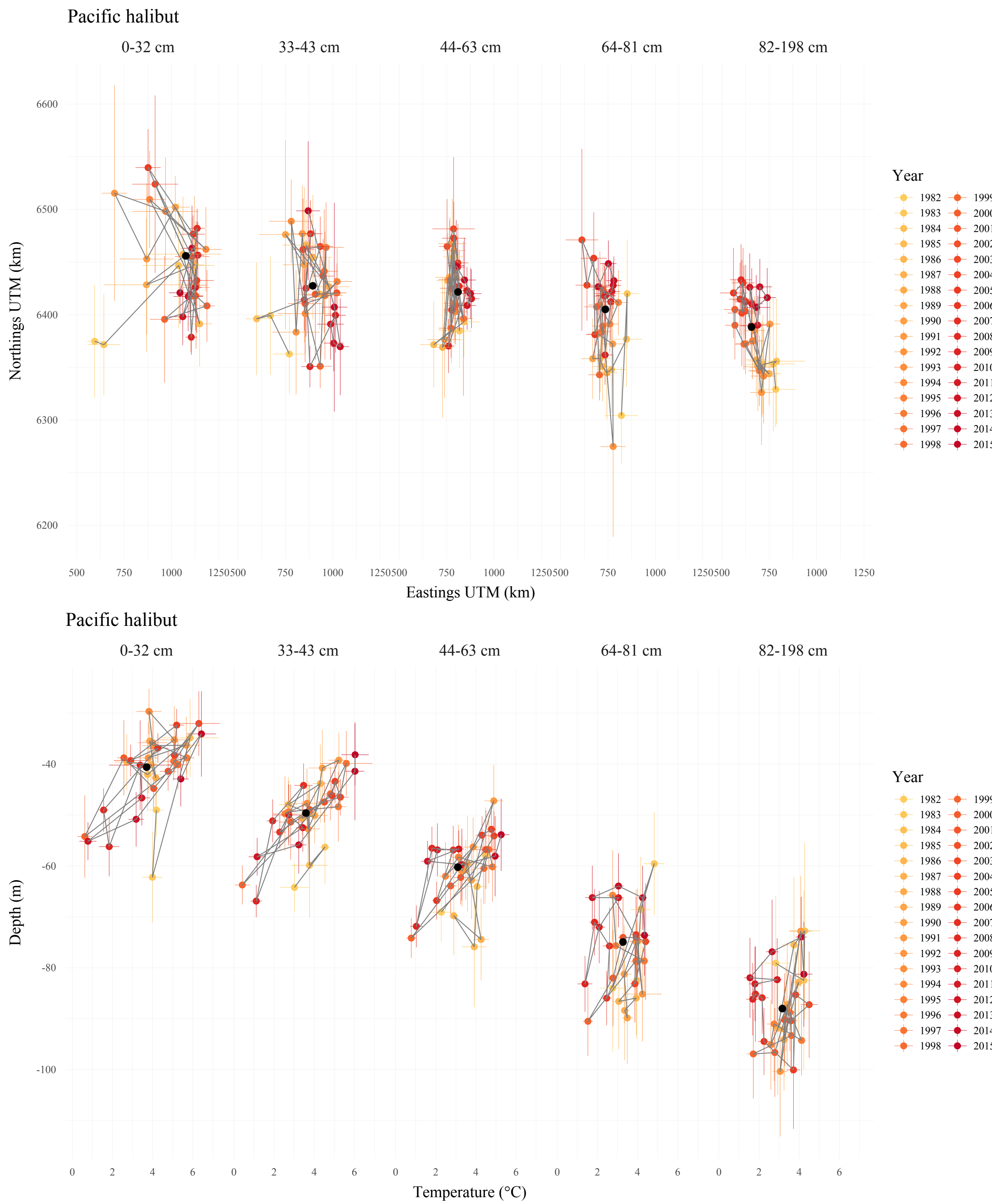


Figure 77 . -- The Pacific halibut (*Hippoglossus stenolepis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

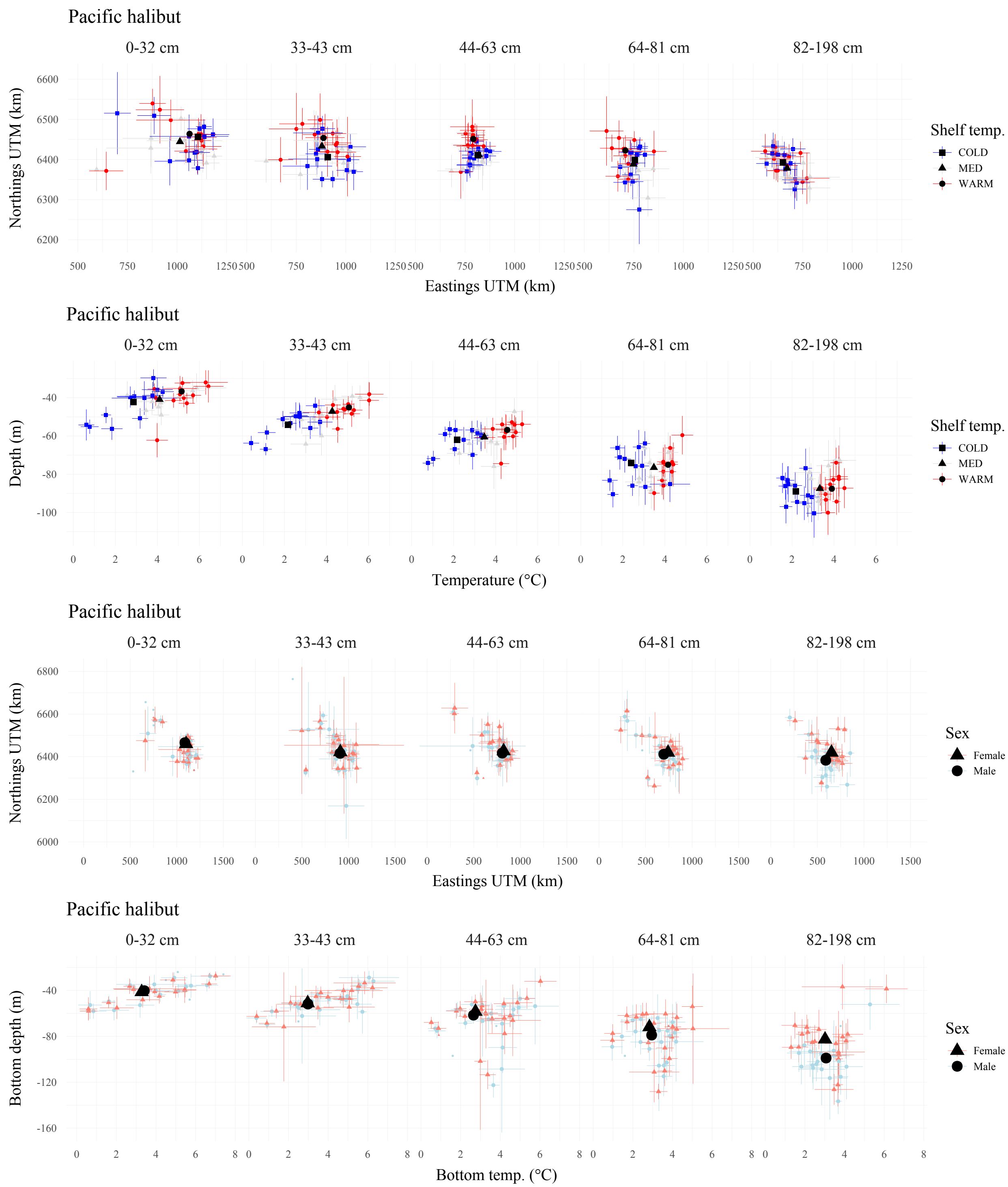


Figure 78 . -- The Pacific halibut (*Hippoglossus stenolepis*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

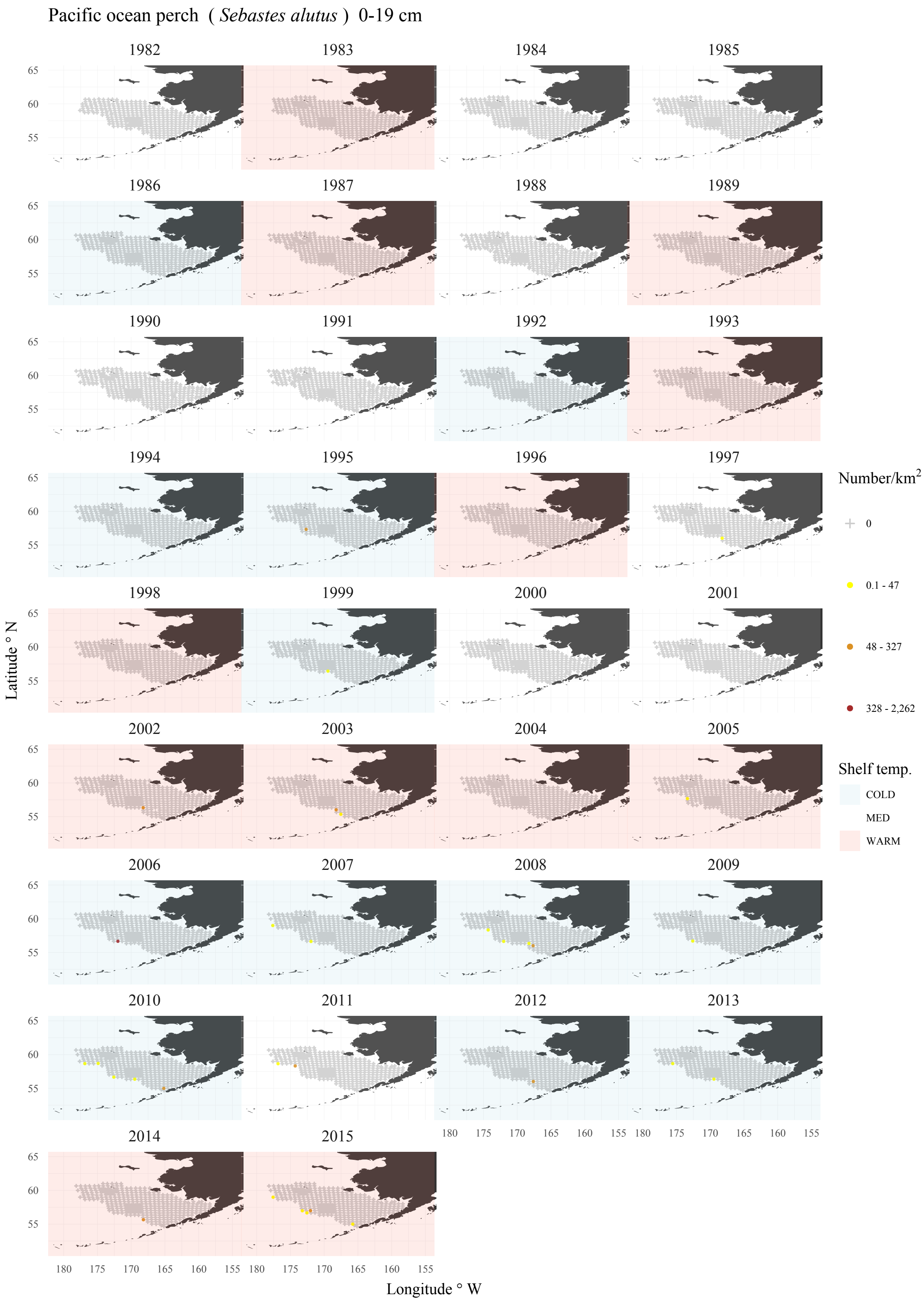


Figure 79 . -- The Pacific ocean perch (*Sebastes alutus*) CPUE by number weighted mean location for each length category for all years.

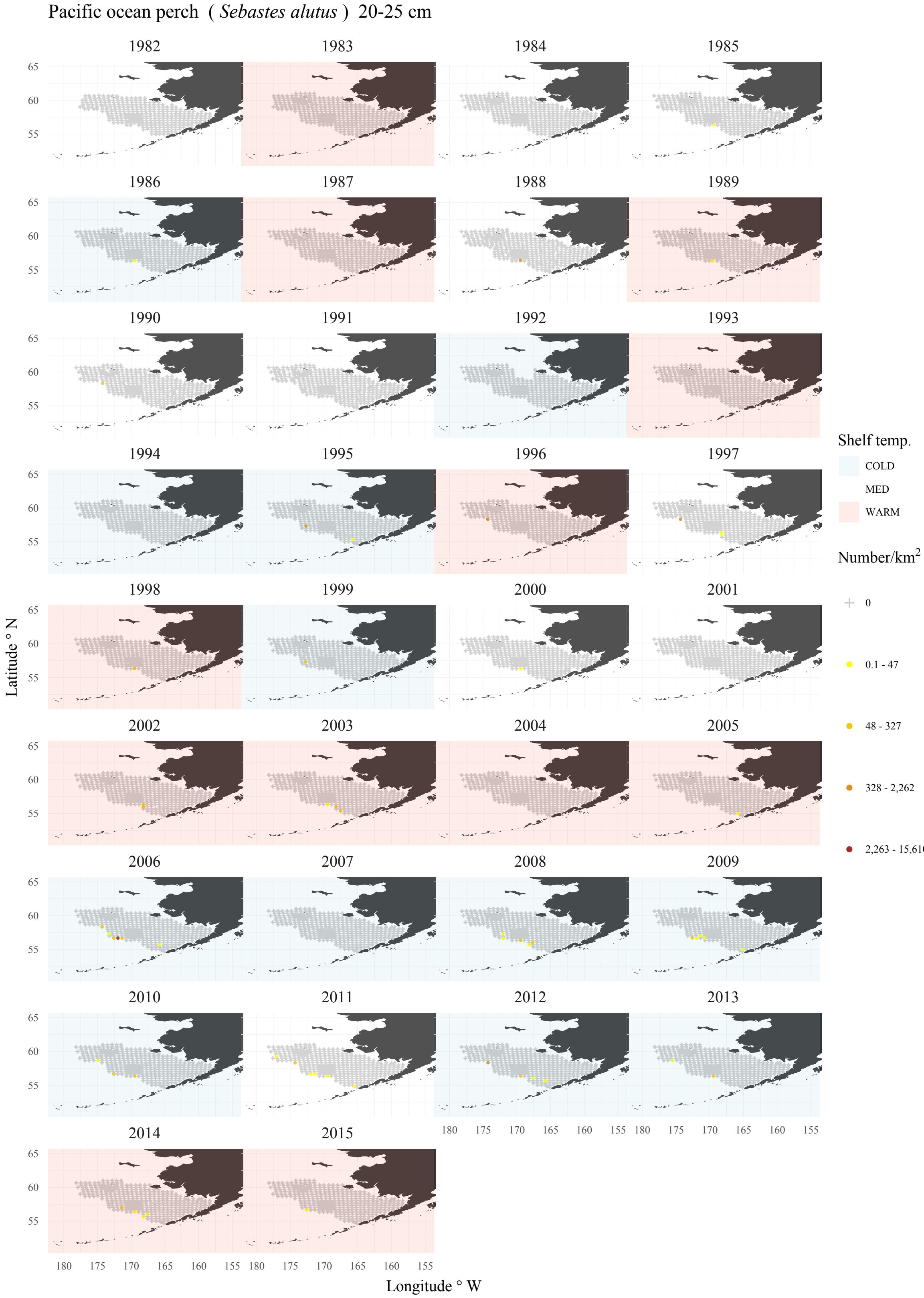


Figure 79 . -- Continued.

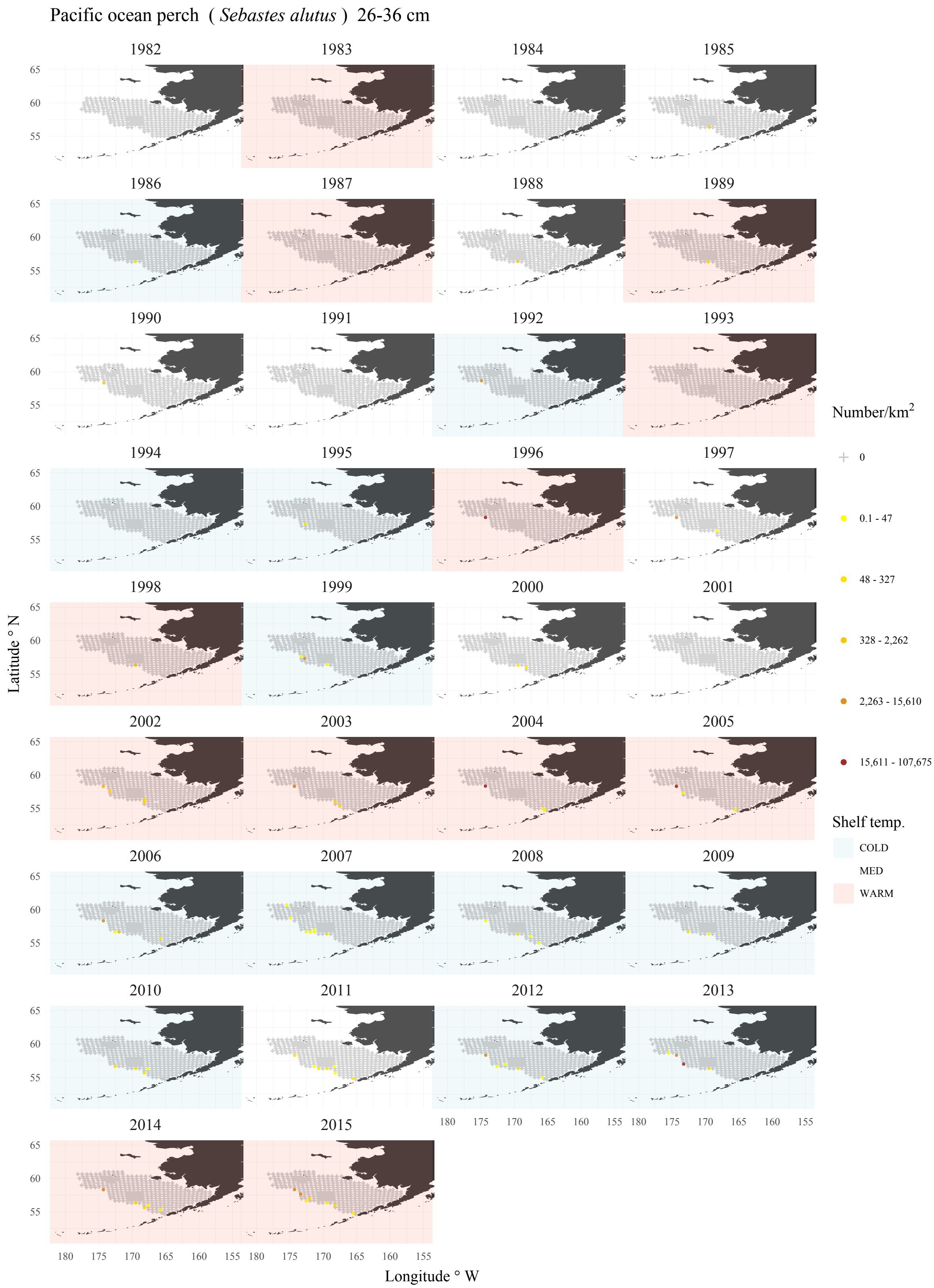


Figure 79 . -- Continued.

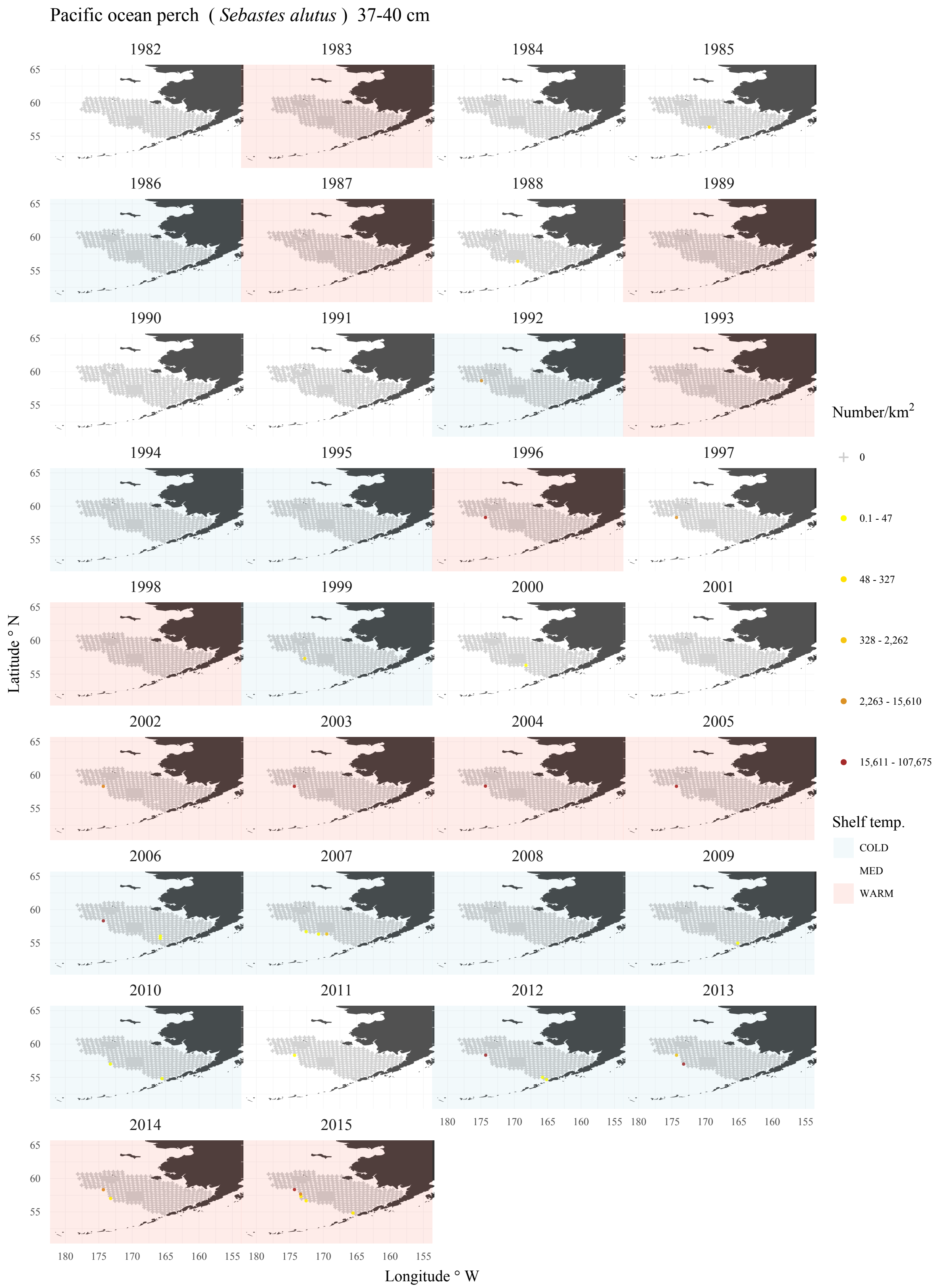


Figure 79 . -- Continued.

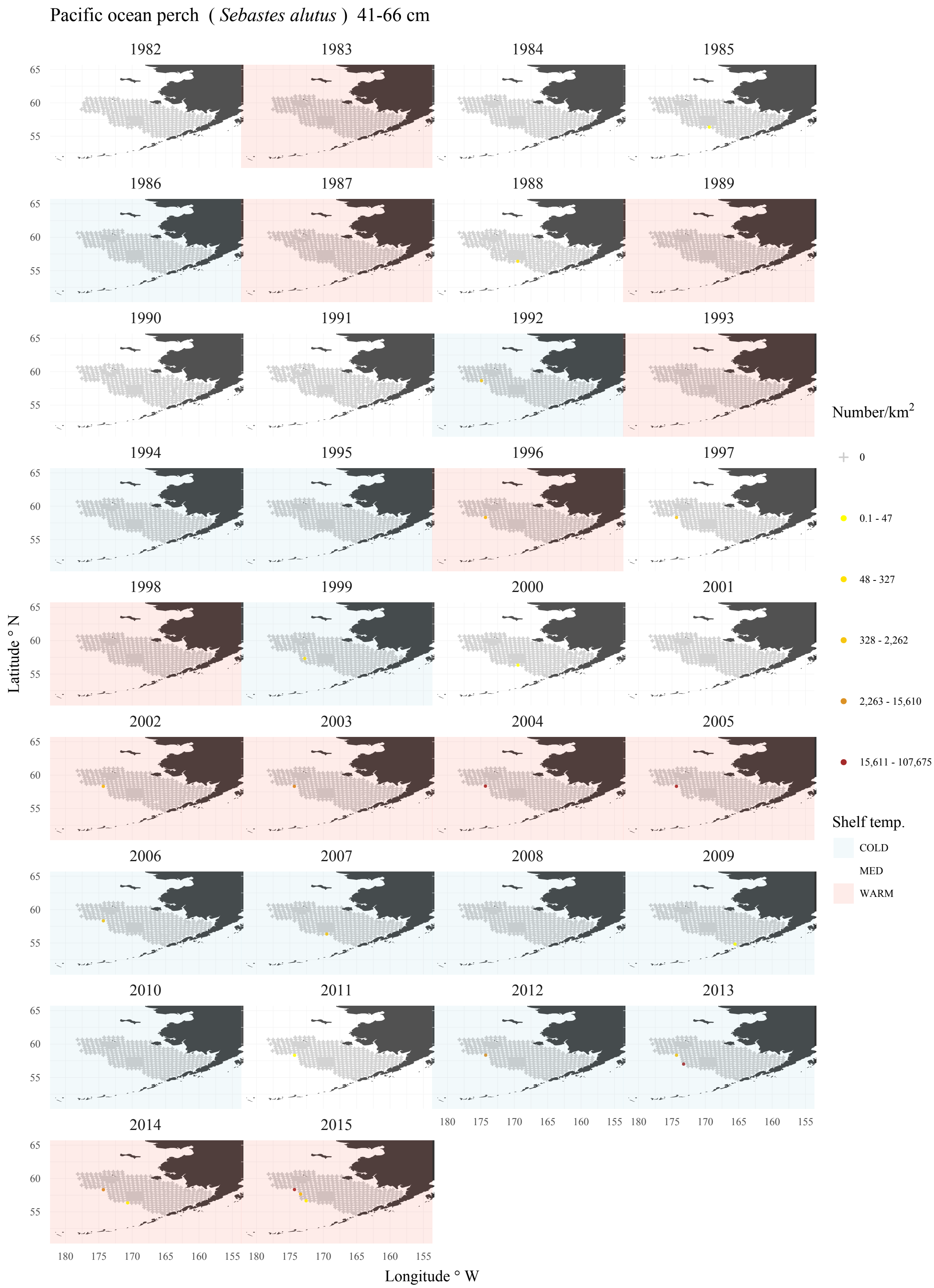


Figure 79 . -- Continued.

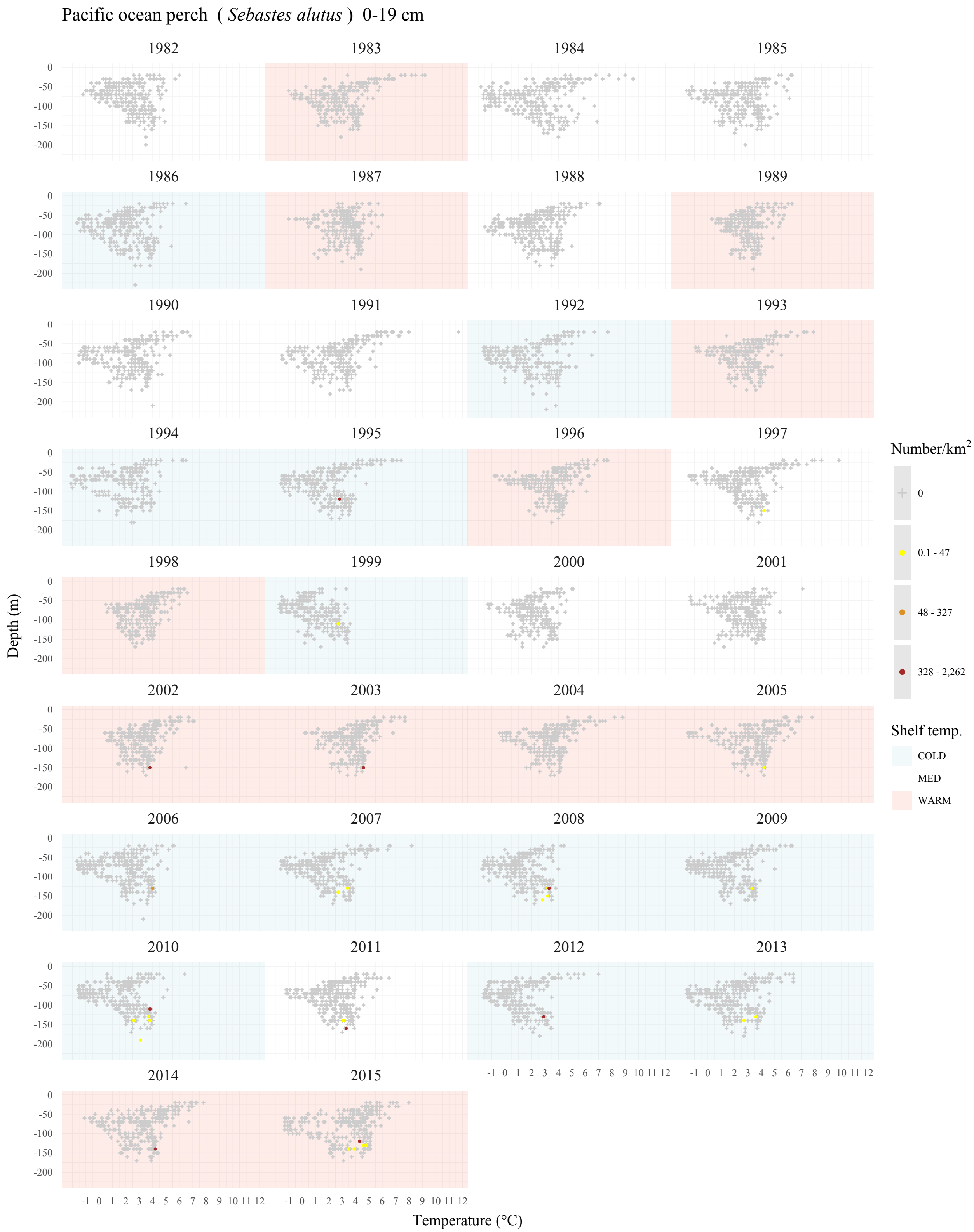


Figure 80 . -- The Pacific ocean perch (*Sebastes alutus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

Figure 80 . -- Continued.

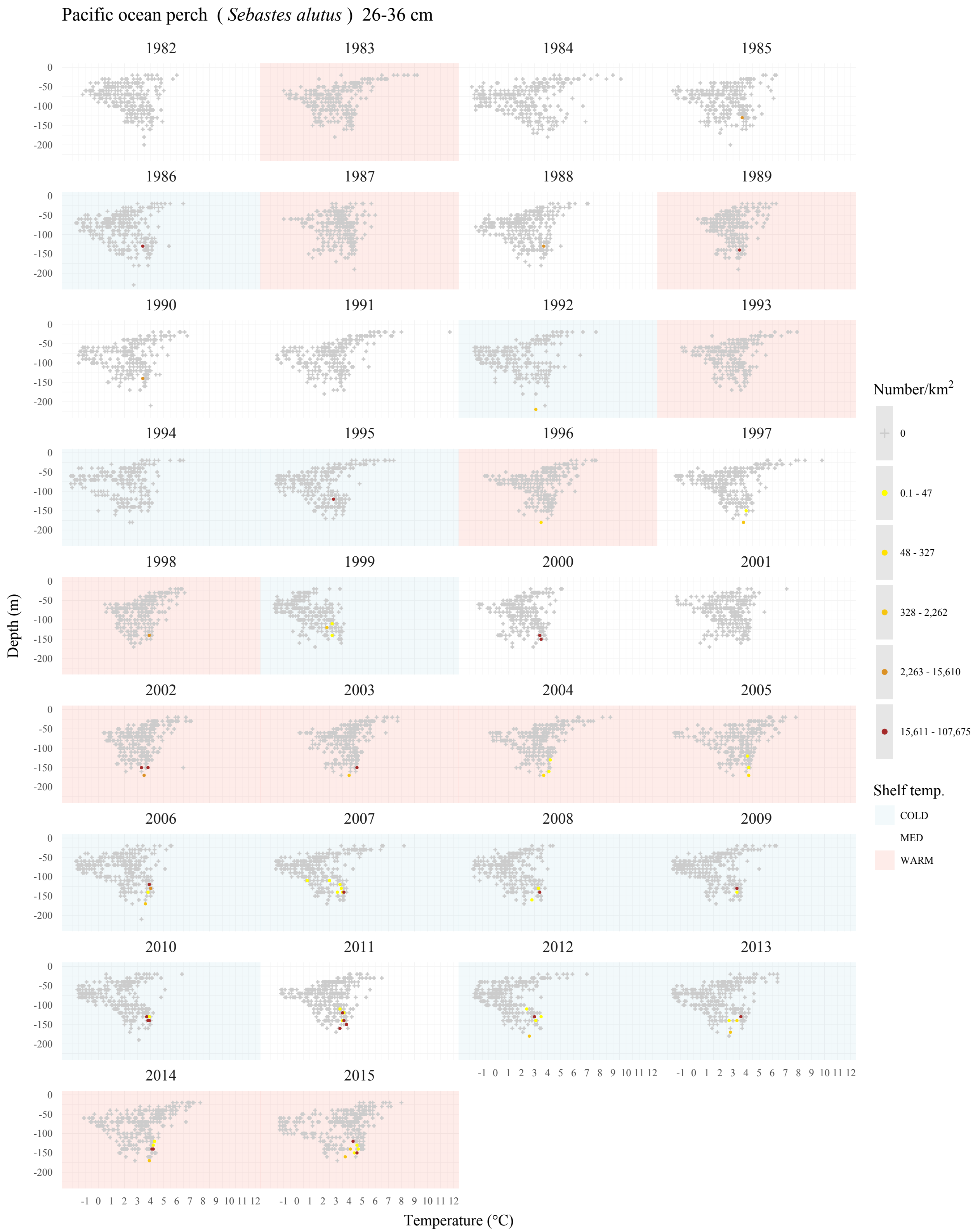


Figure 80 . -- Continued.

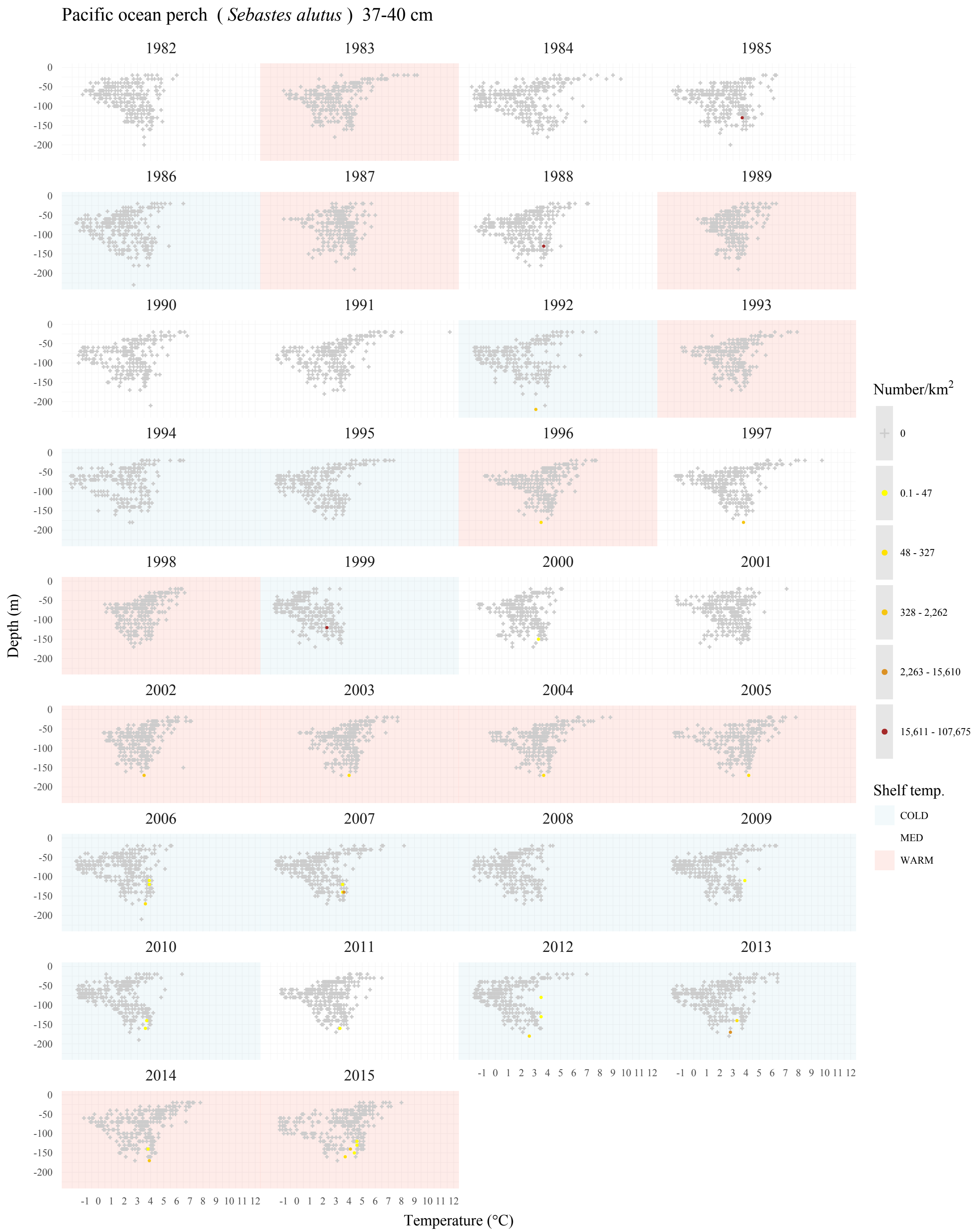


Figure 80 . -- Continued.

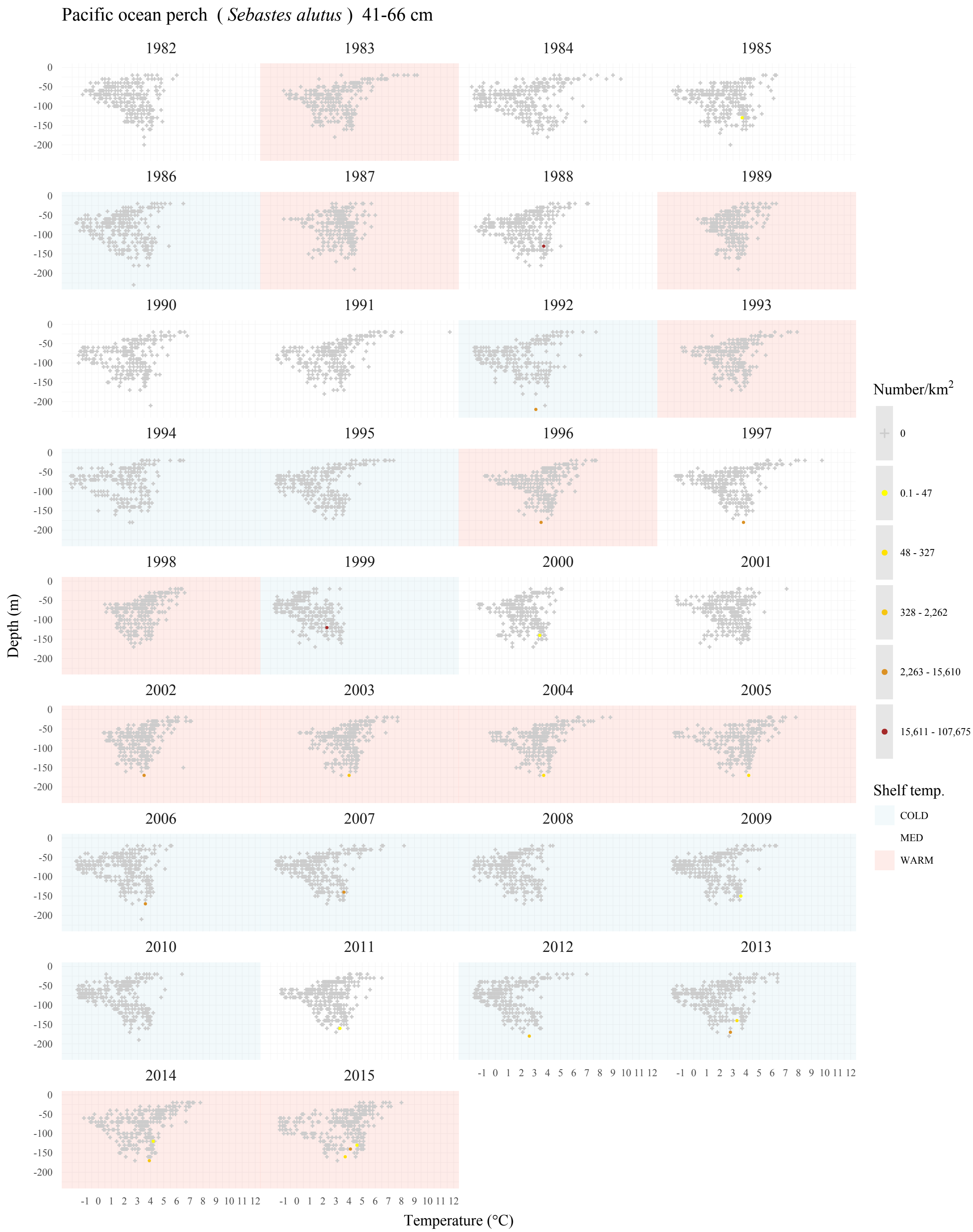
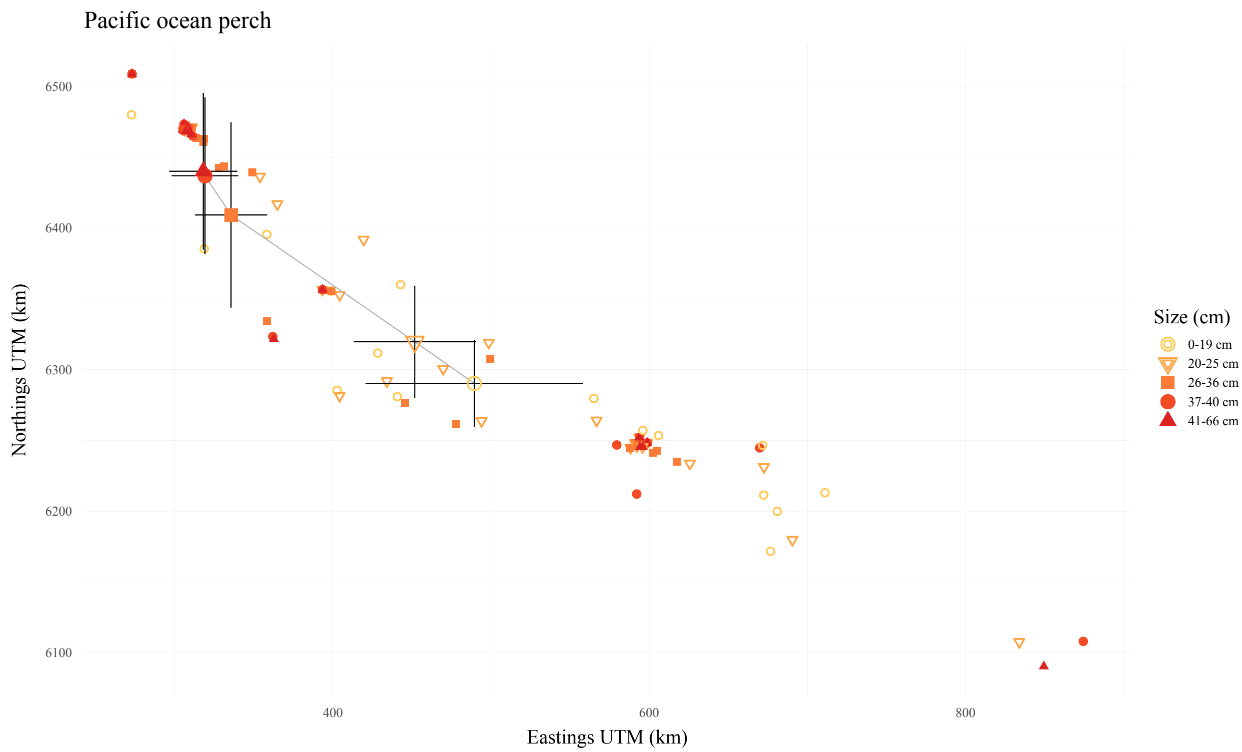


Figure 80 . -- Continued.



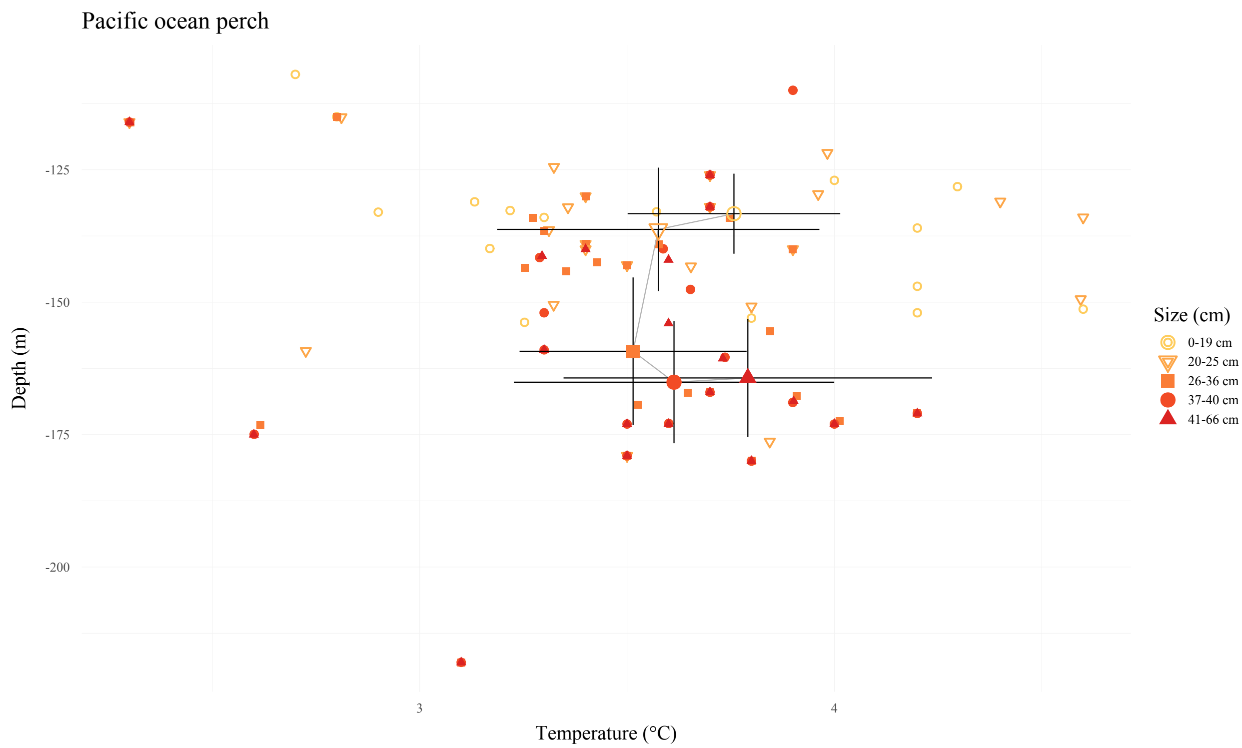


Figure 81 . -- The Pacific ocean perch (*Sebastes alutus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

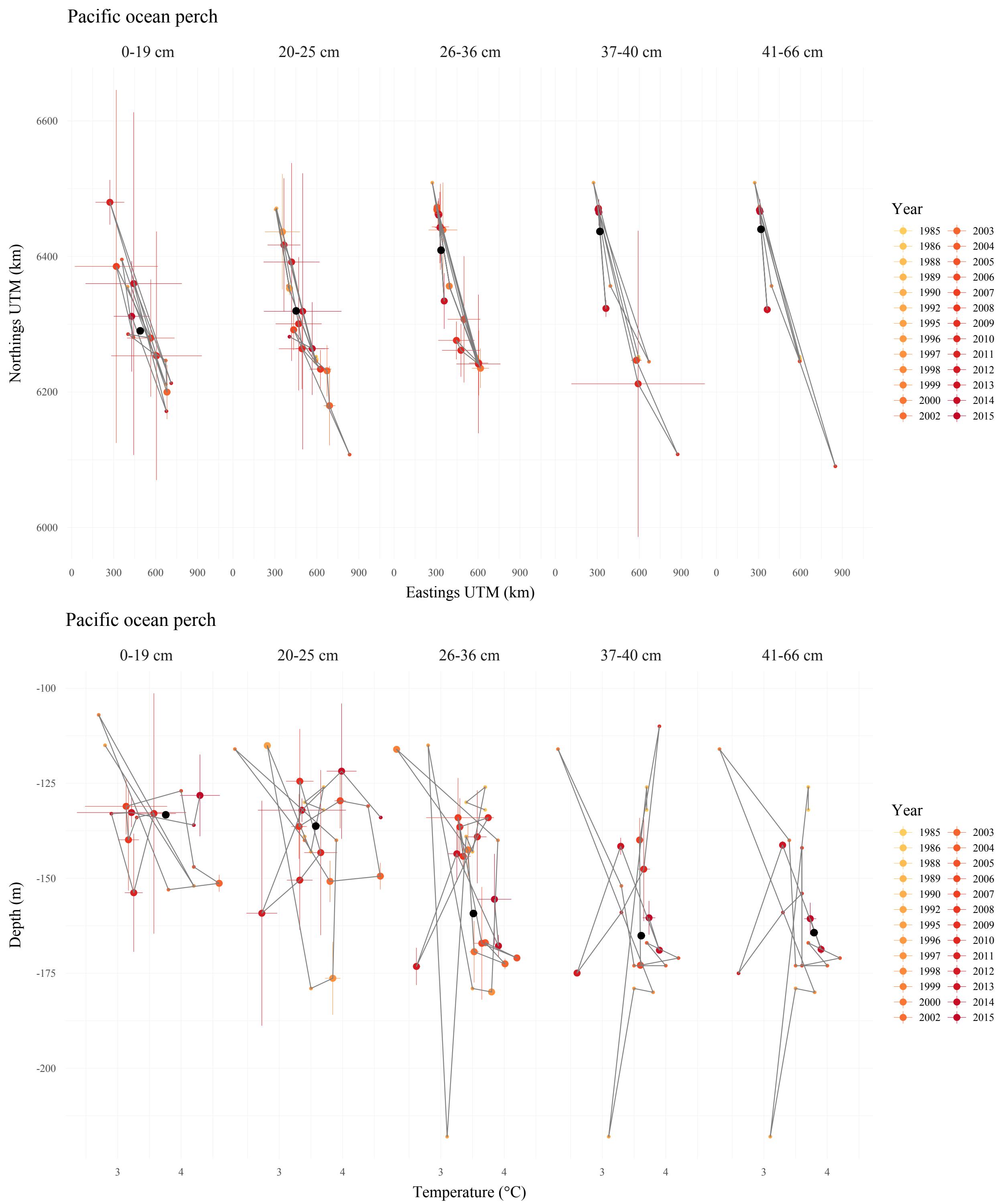


Figure 82 . -- The Pacific ocean perch (*Sebastes alutus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

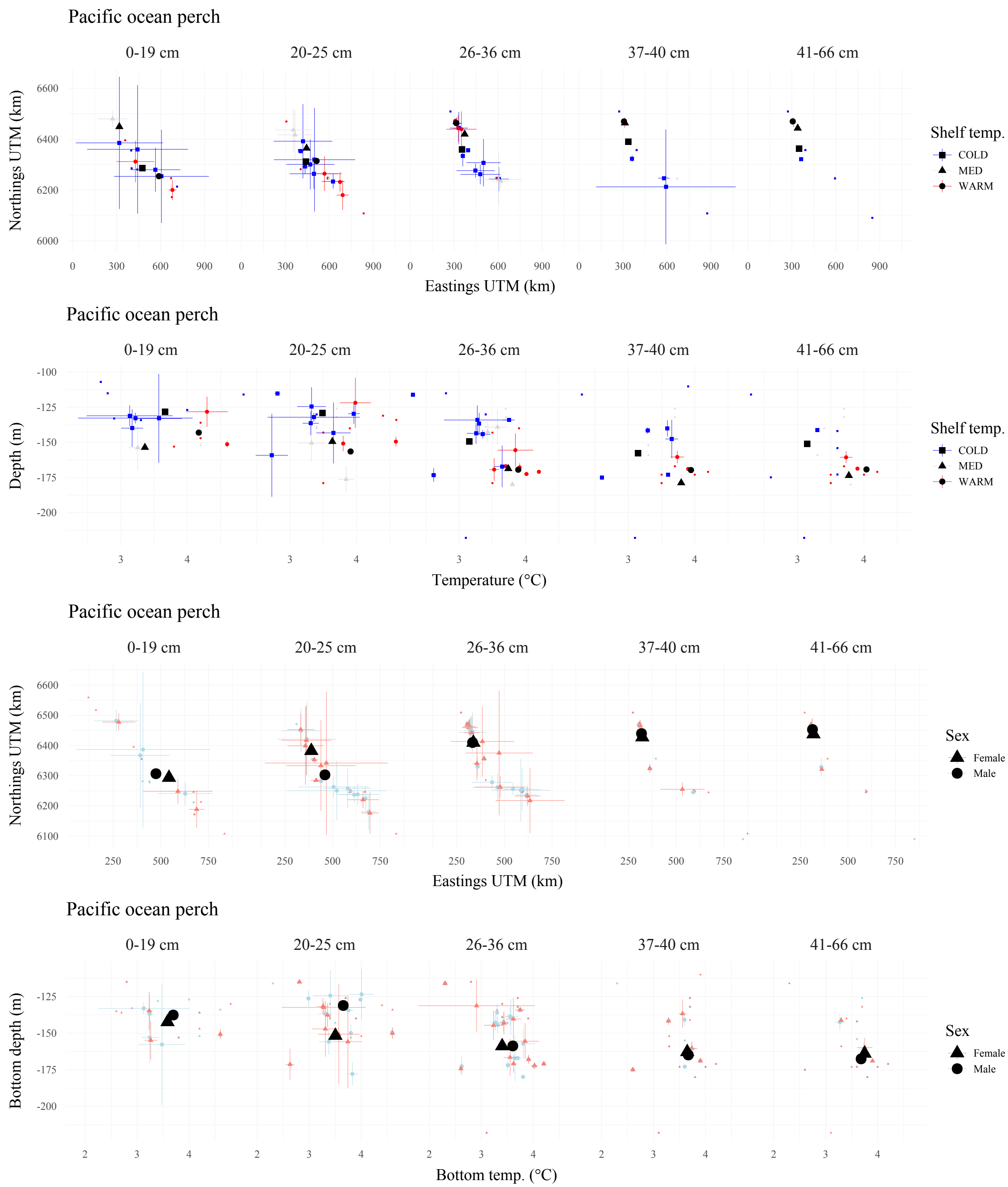


Figure 83 . -- The Pacific ocean perch (*Sebastes alutus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

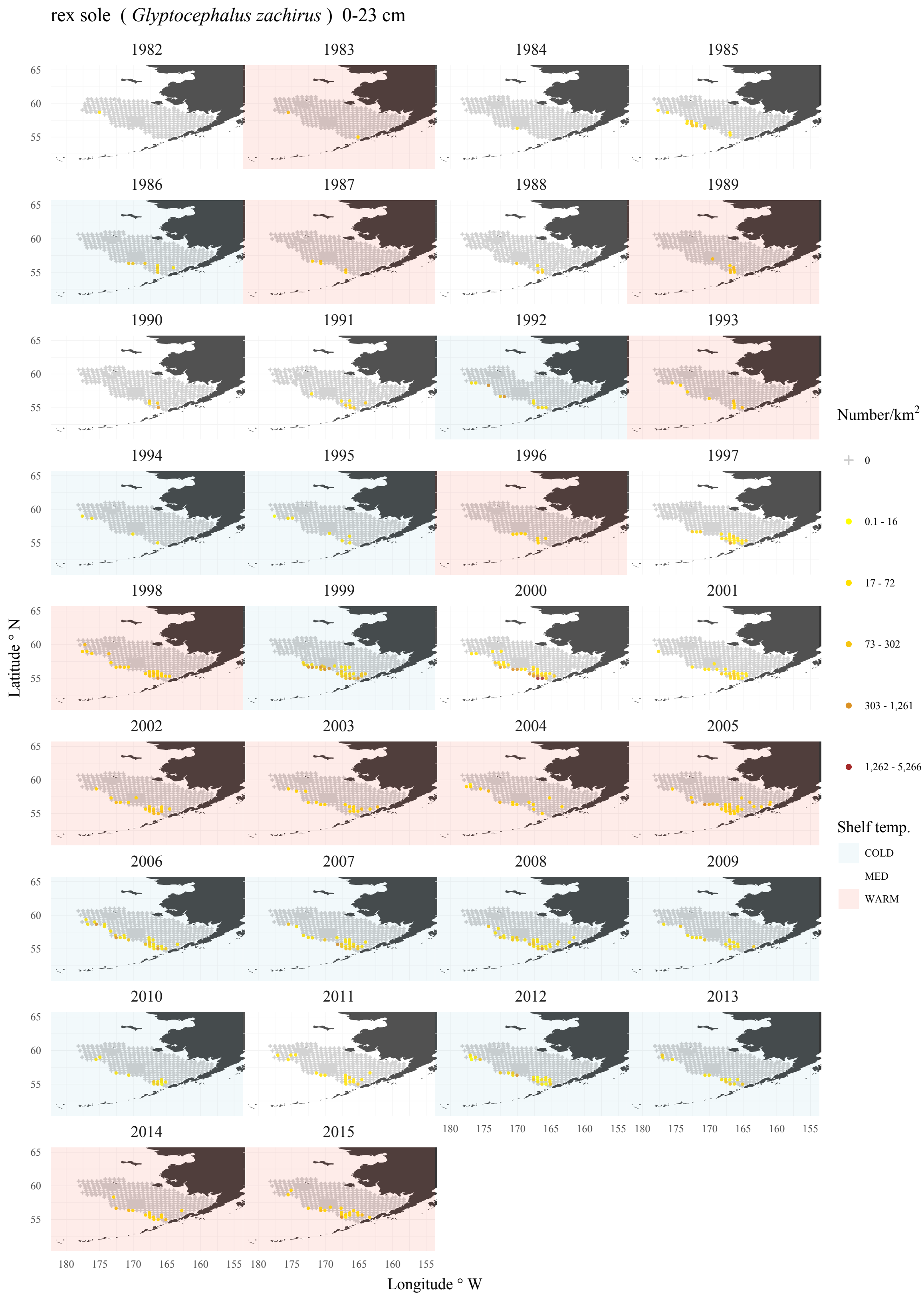


Figure 84 . -- The rex sole (*Glyptocephalus zachirus*) CPUE by number weighted mean location for each length category for all years.

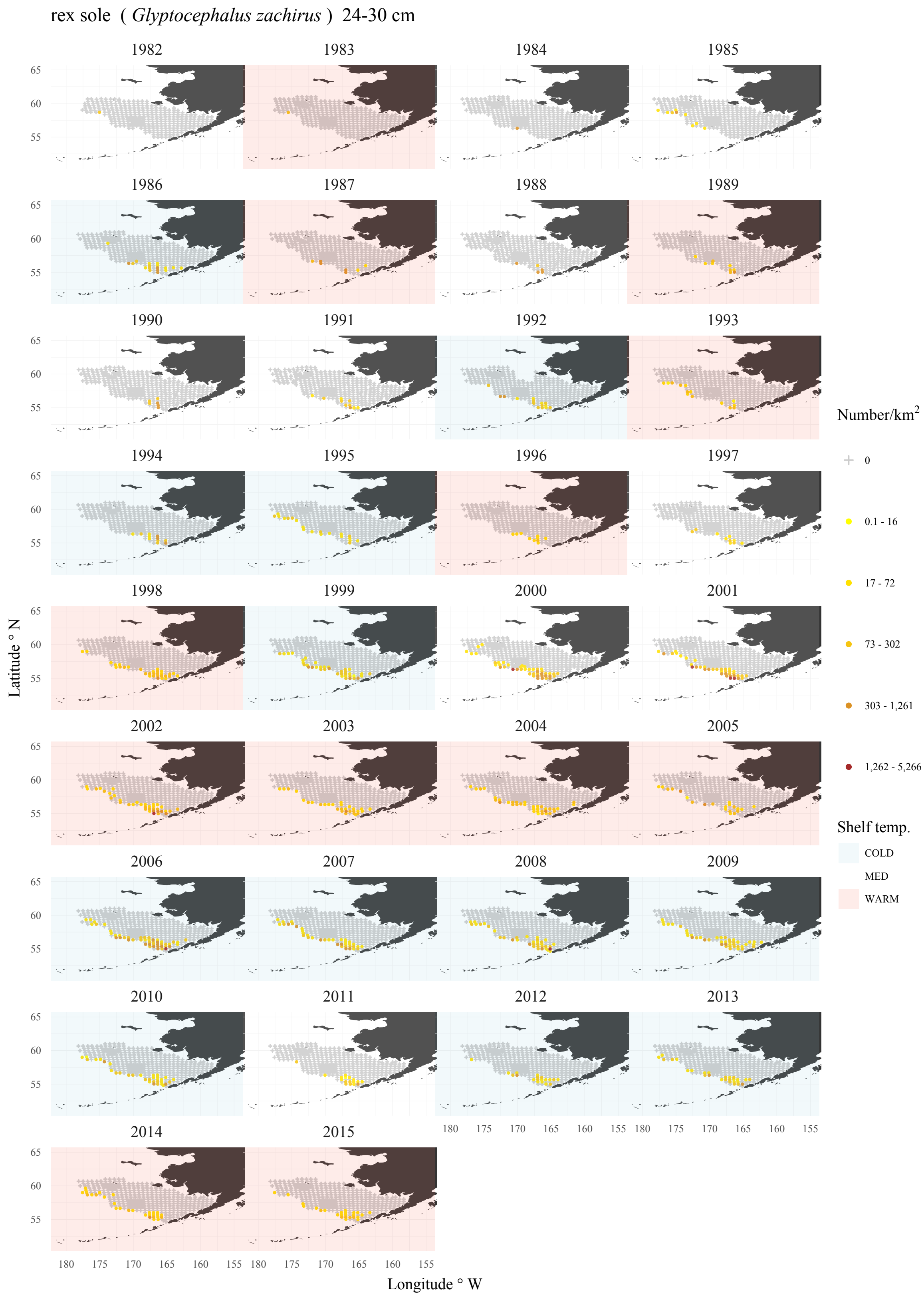


Figure 84 . -- Continued.

rex sole (*Glyptocephalus zachirus*) 31-39 cm

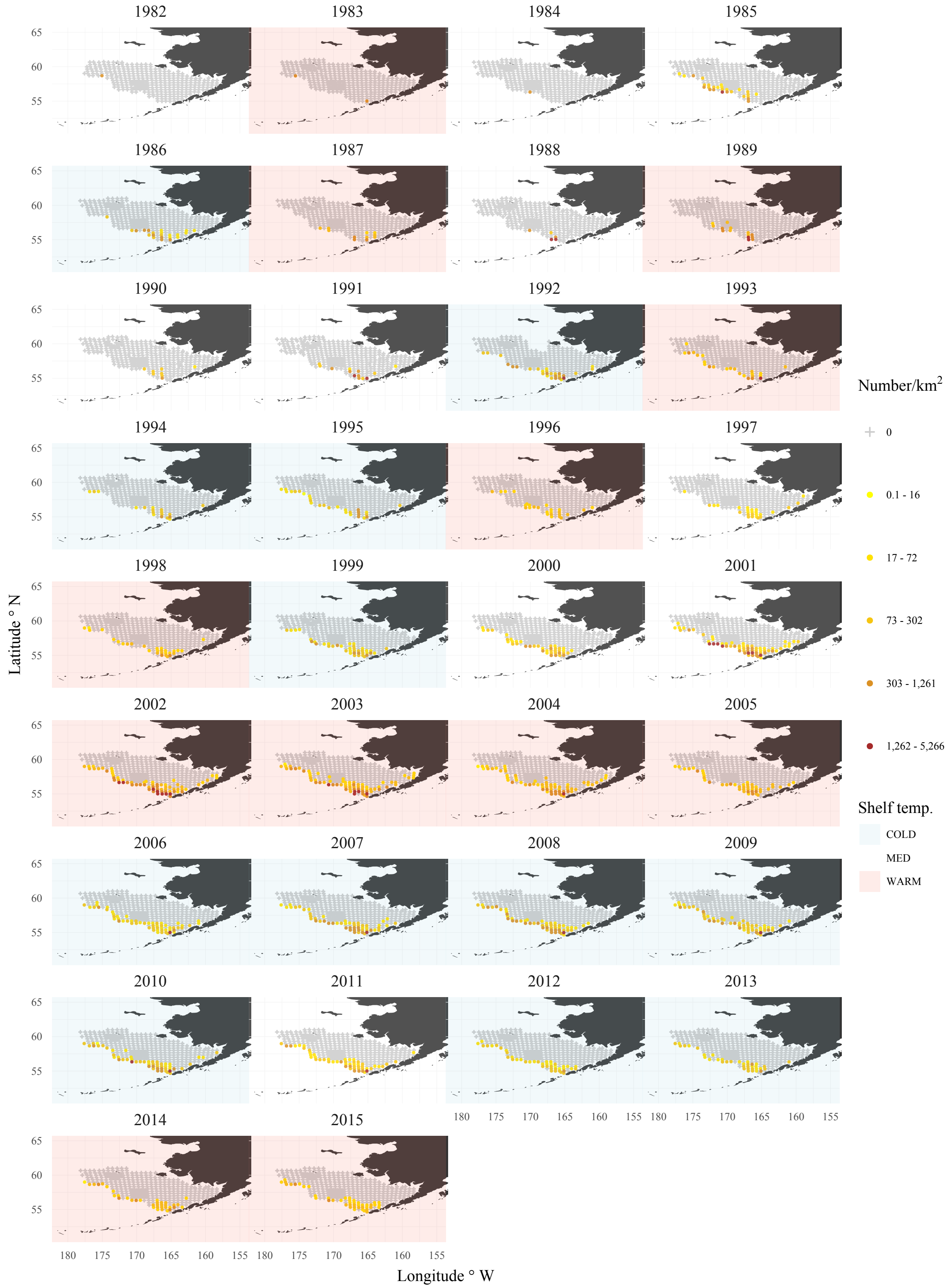


Figure 84 . -- Continued.

rex sole (*Glyptocephalus zachirus*) 40-45 cm

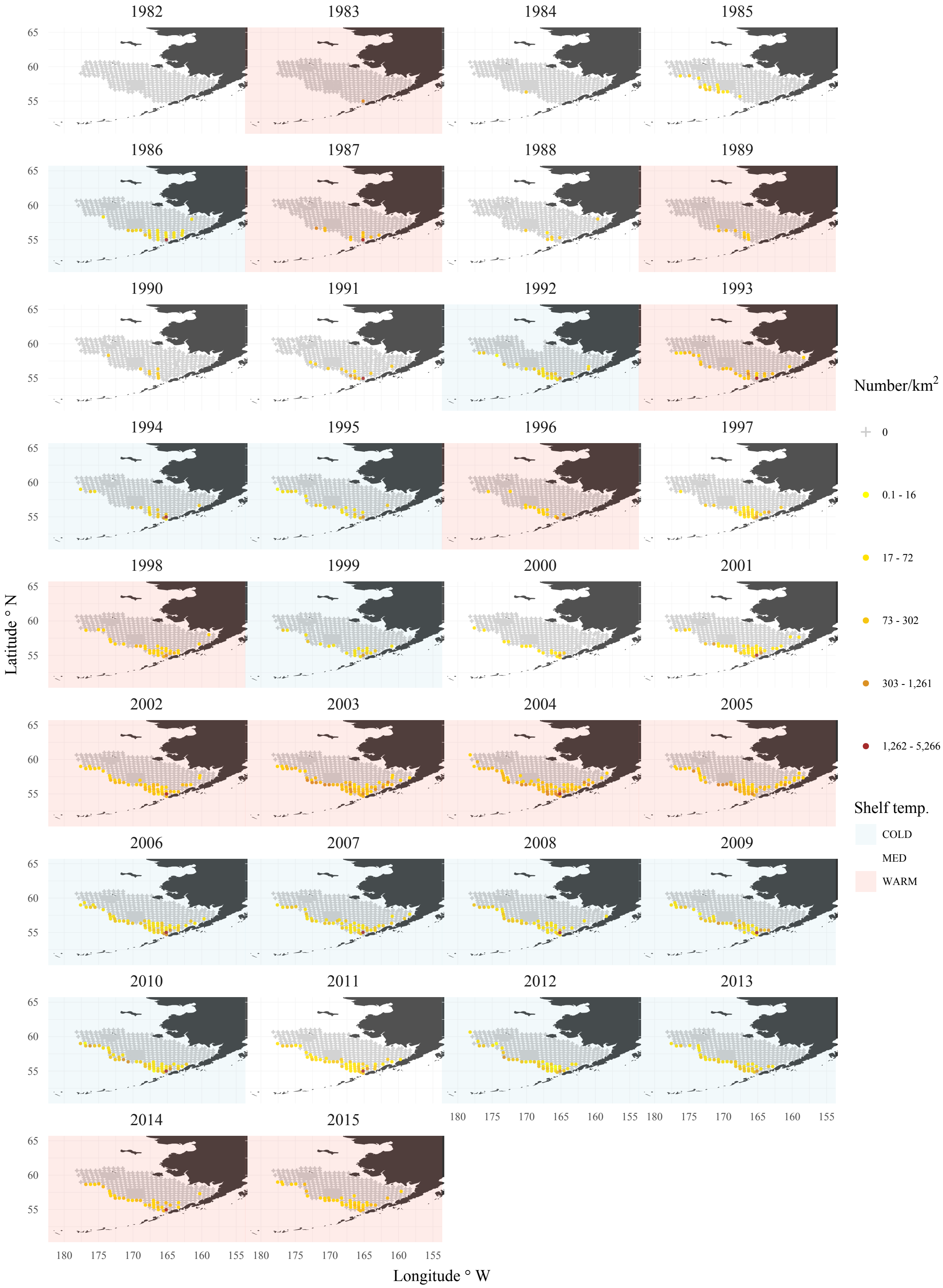


Figure 84 . -- Continued.

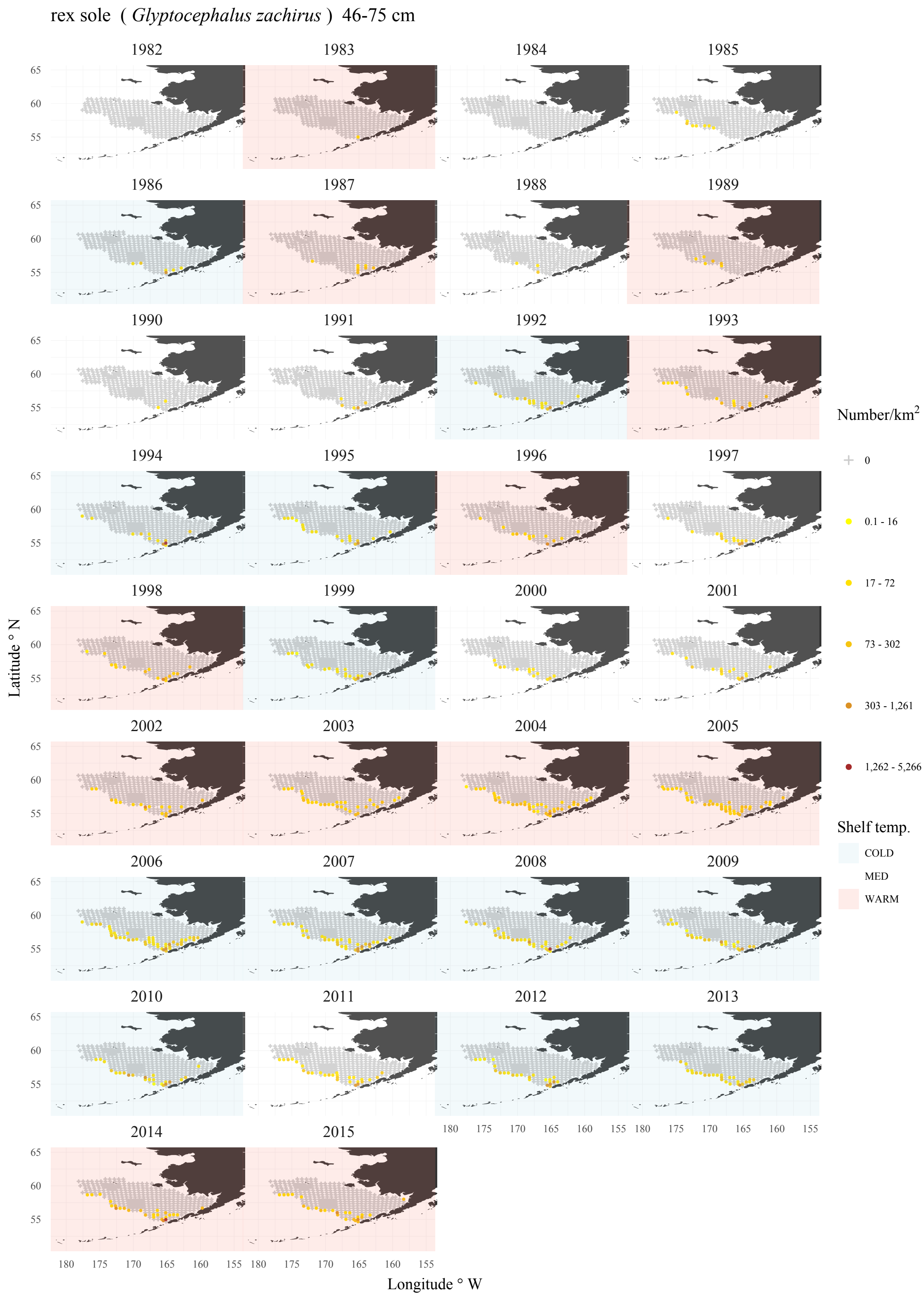


Figure 84 . -- Continued.

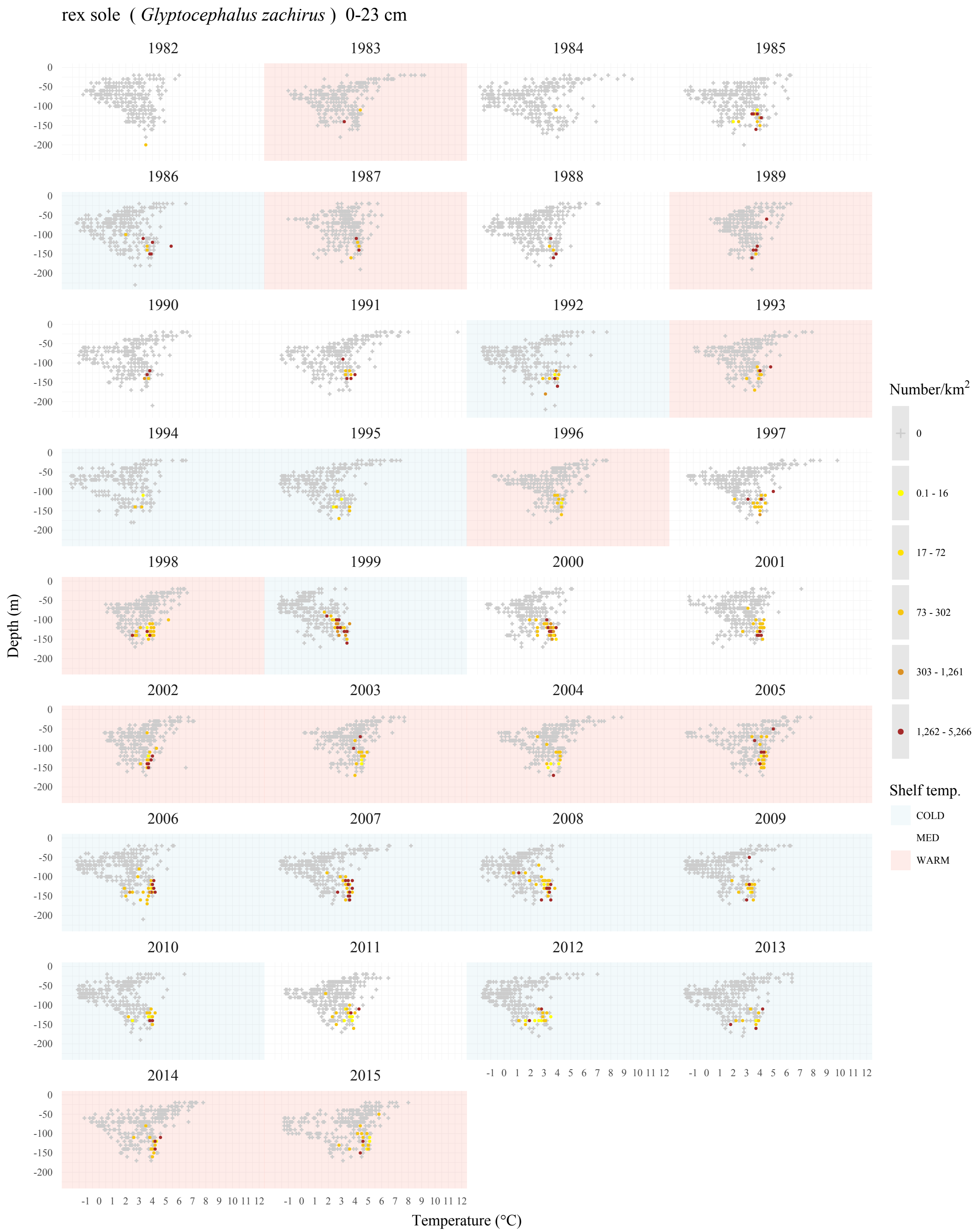


Figure 85 . -- The rex sole (*Glyptocephalus zachirus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

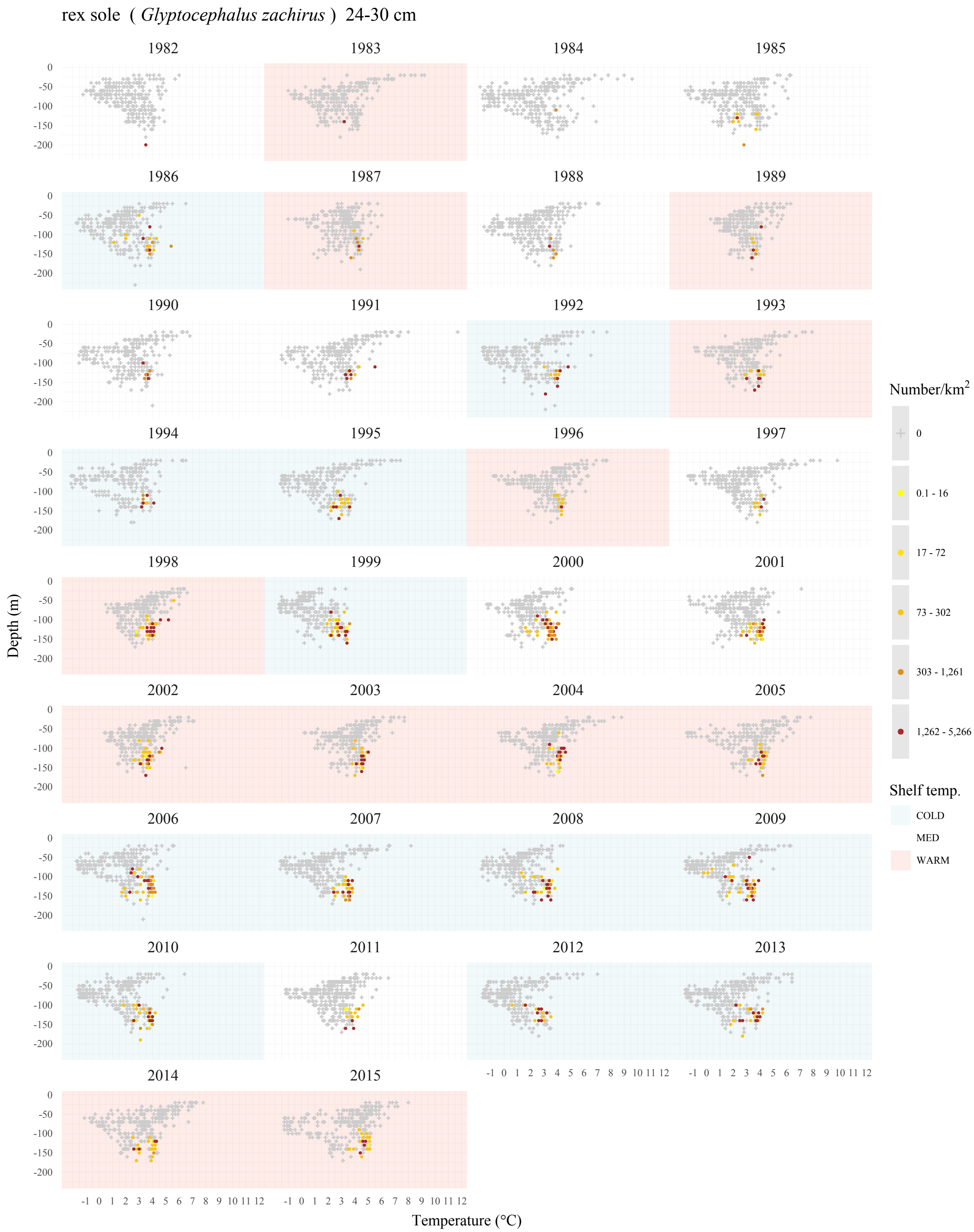


Figure 85 . -- Continued.

rex sole (*Glyptocephalus zachirus*) 31-39 cm

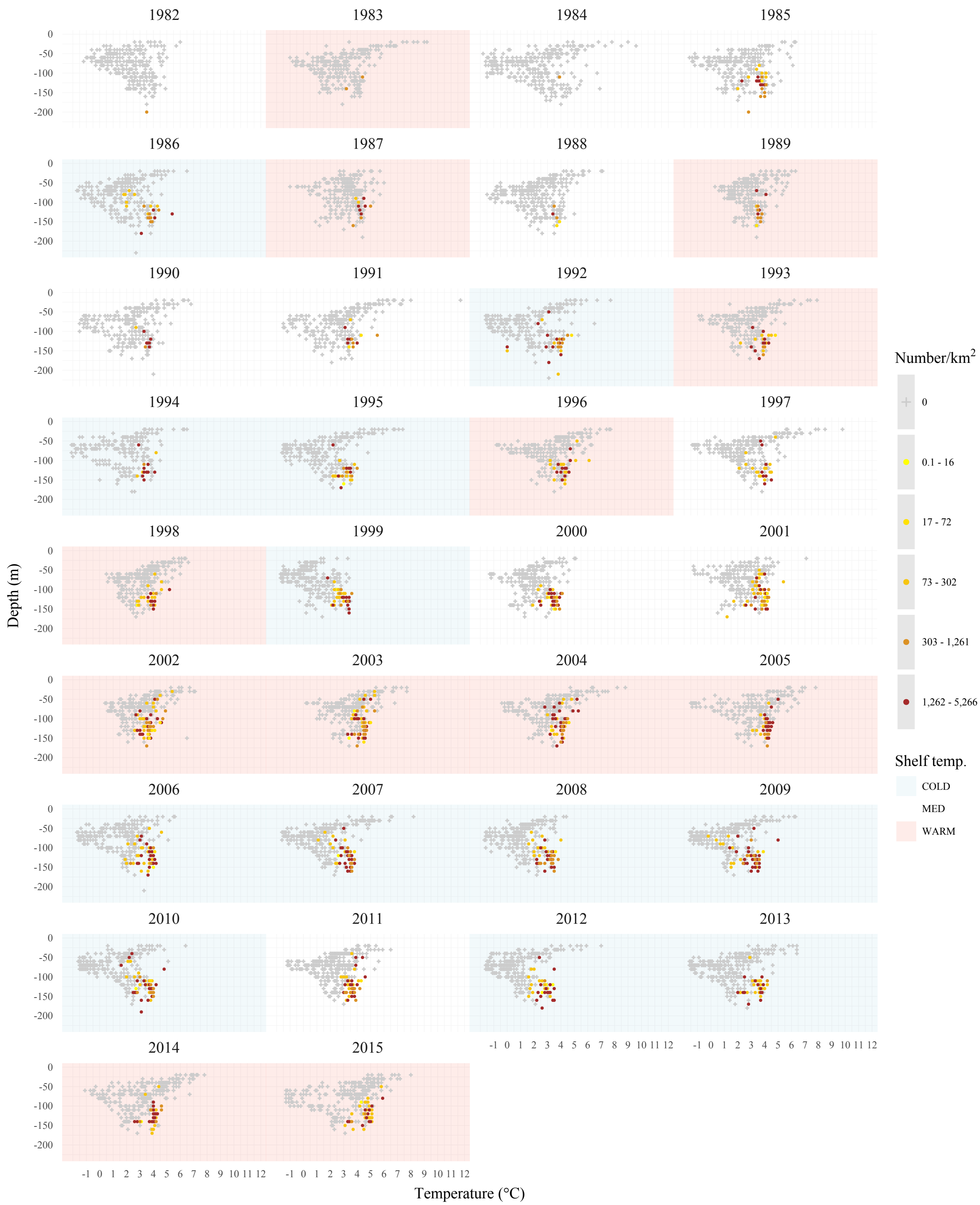


Figure 85 . -- Continued.

rex sole (*Glyptocephalus zachirus*) 40-45 cm

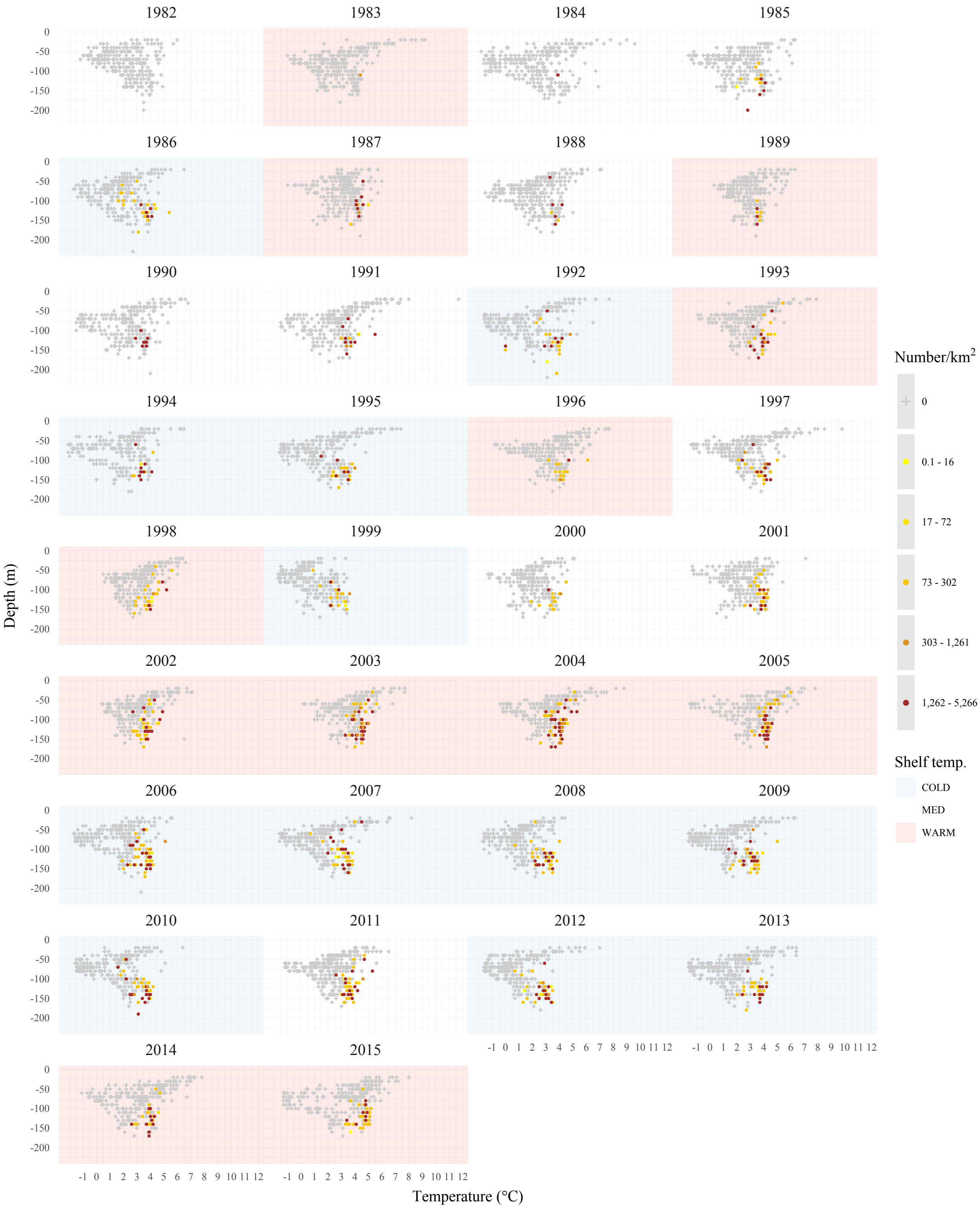


Figure 85 . -- Continued.

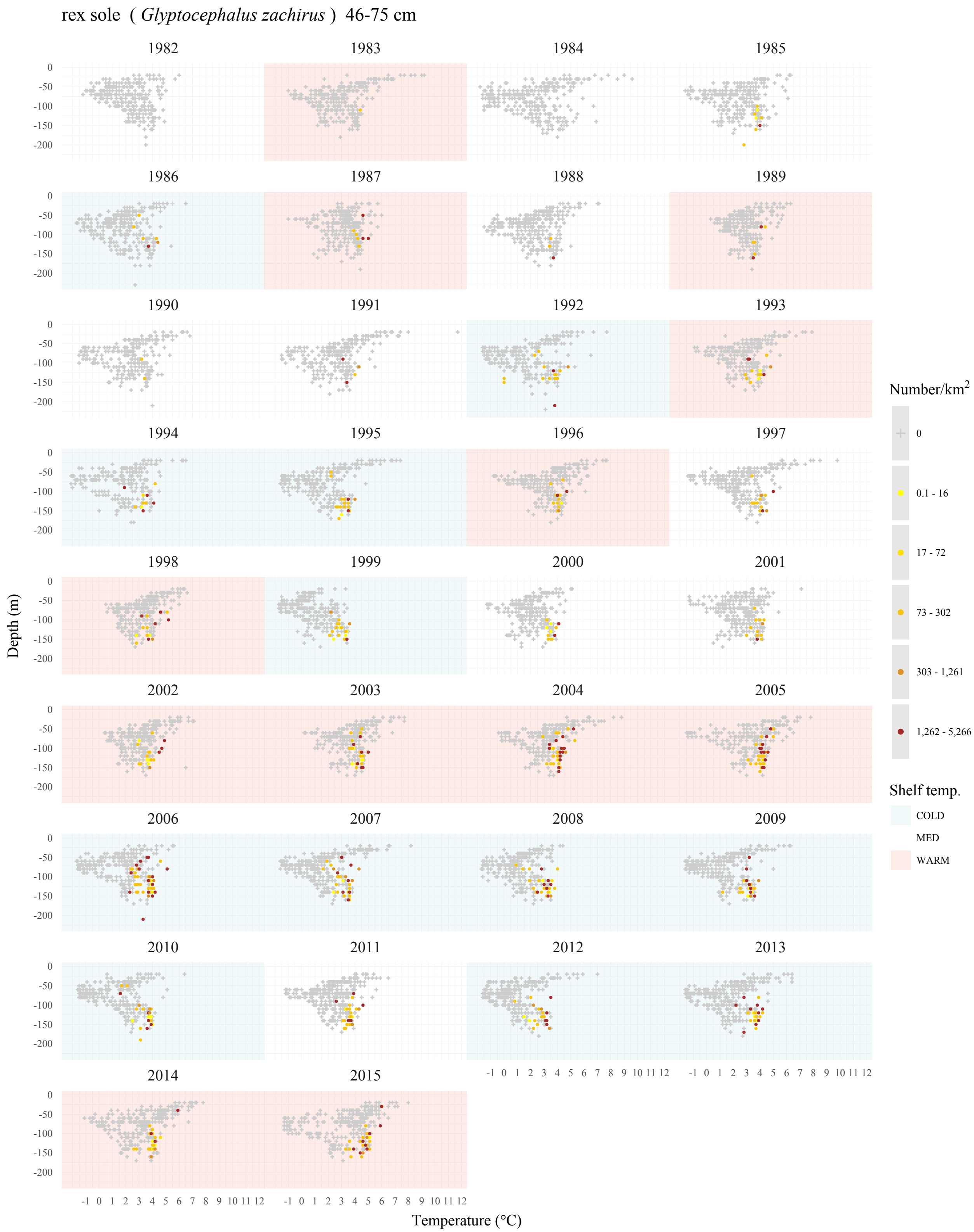


Figure 85 . -- Continued.

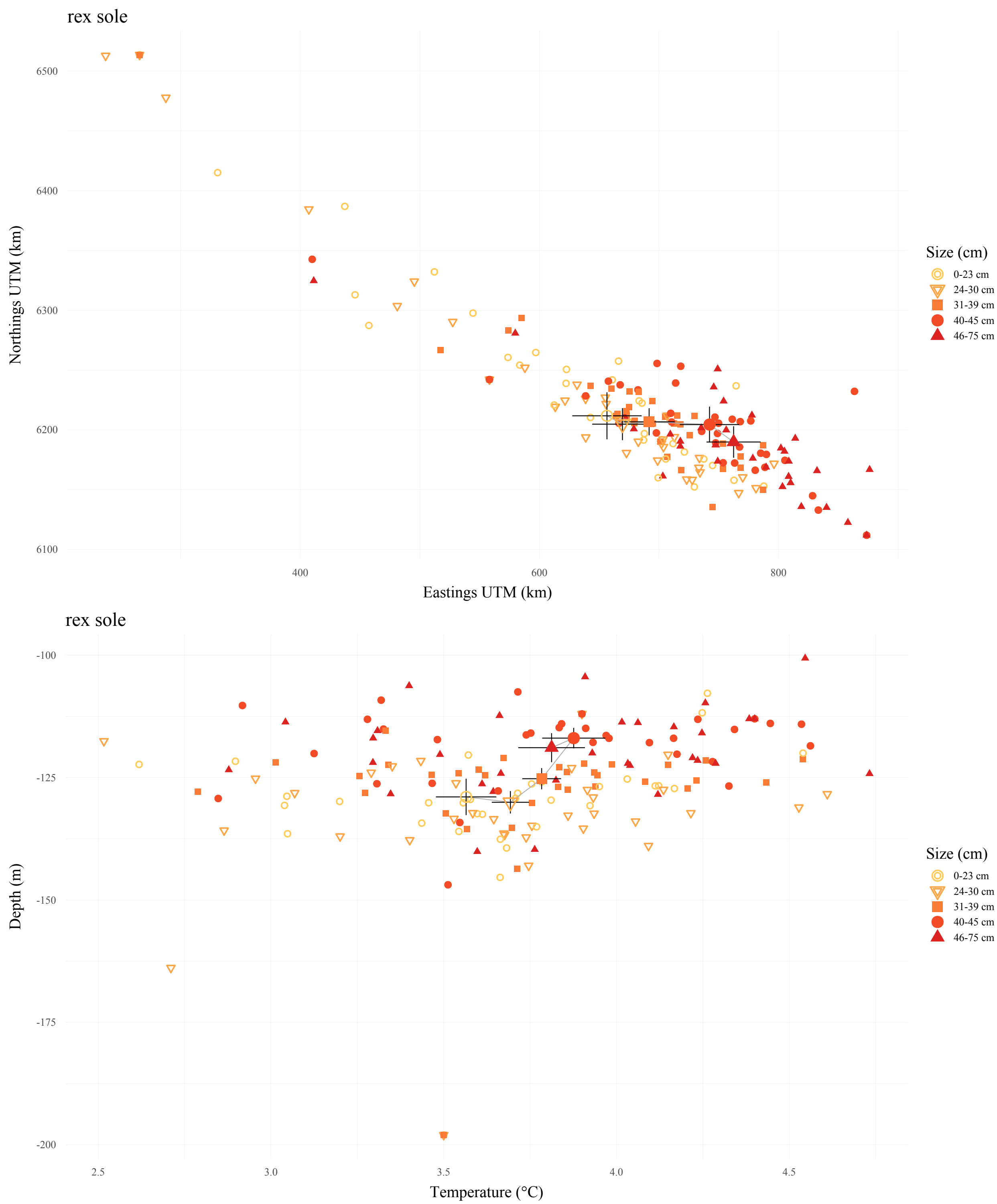


Figure 86 . -- The rex sole (*Glyptocephalus zachirus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

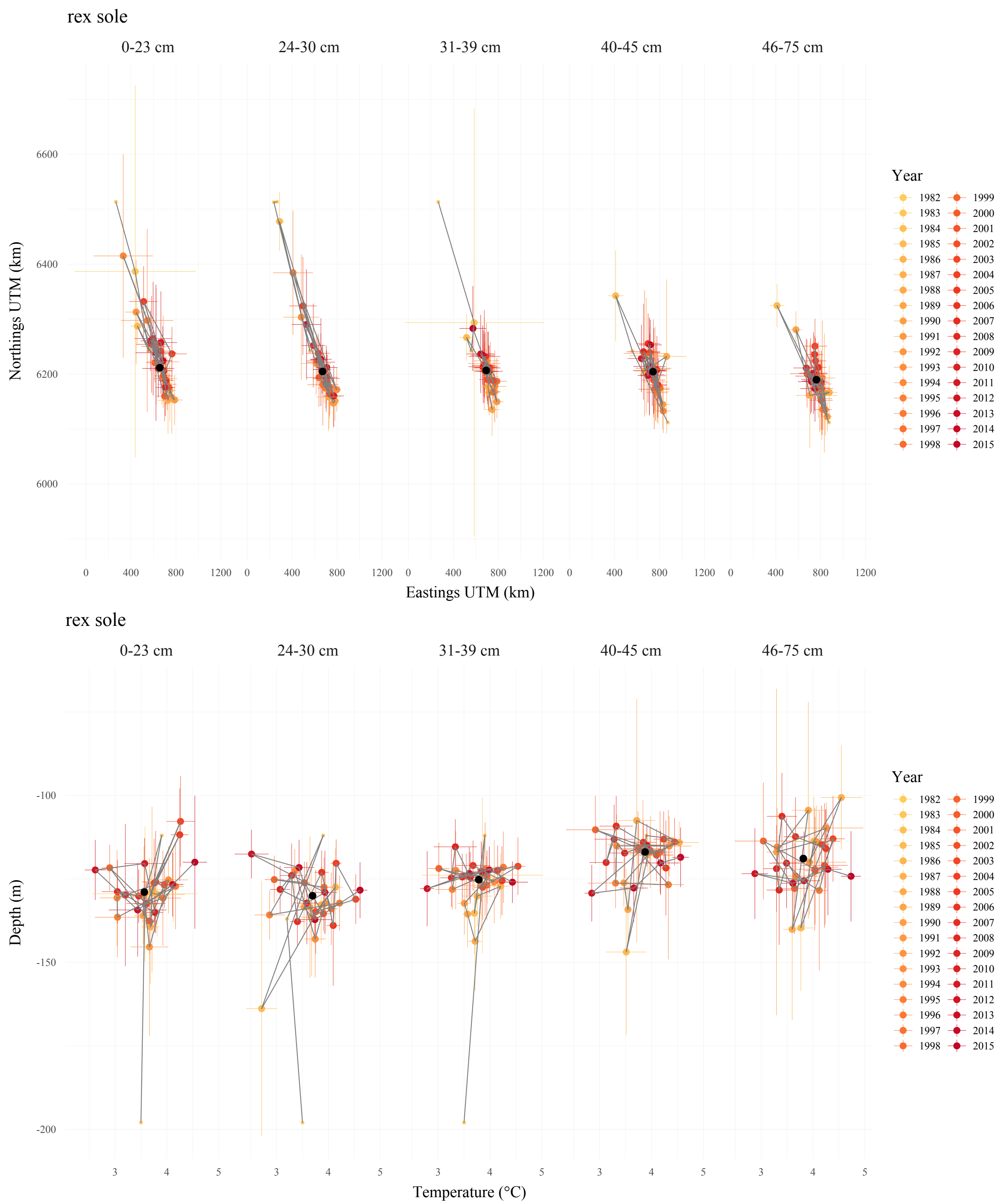


Figure 87 . -- The rex sole (*Glyptocephalus zachirus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

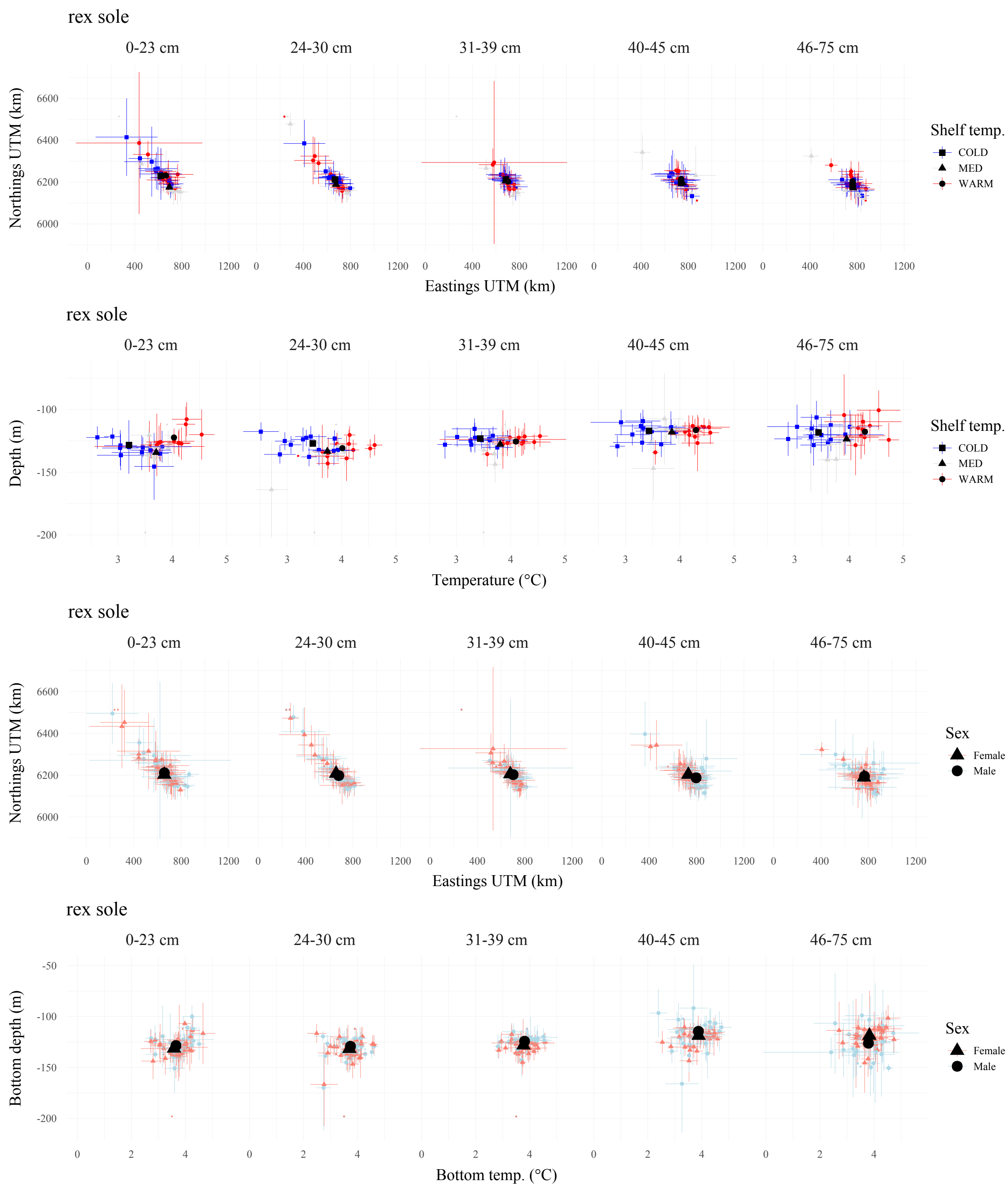


Figure 88 . -- The rex sole (*Glyptocephalus zachirus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

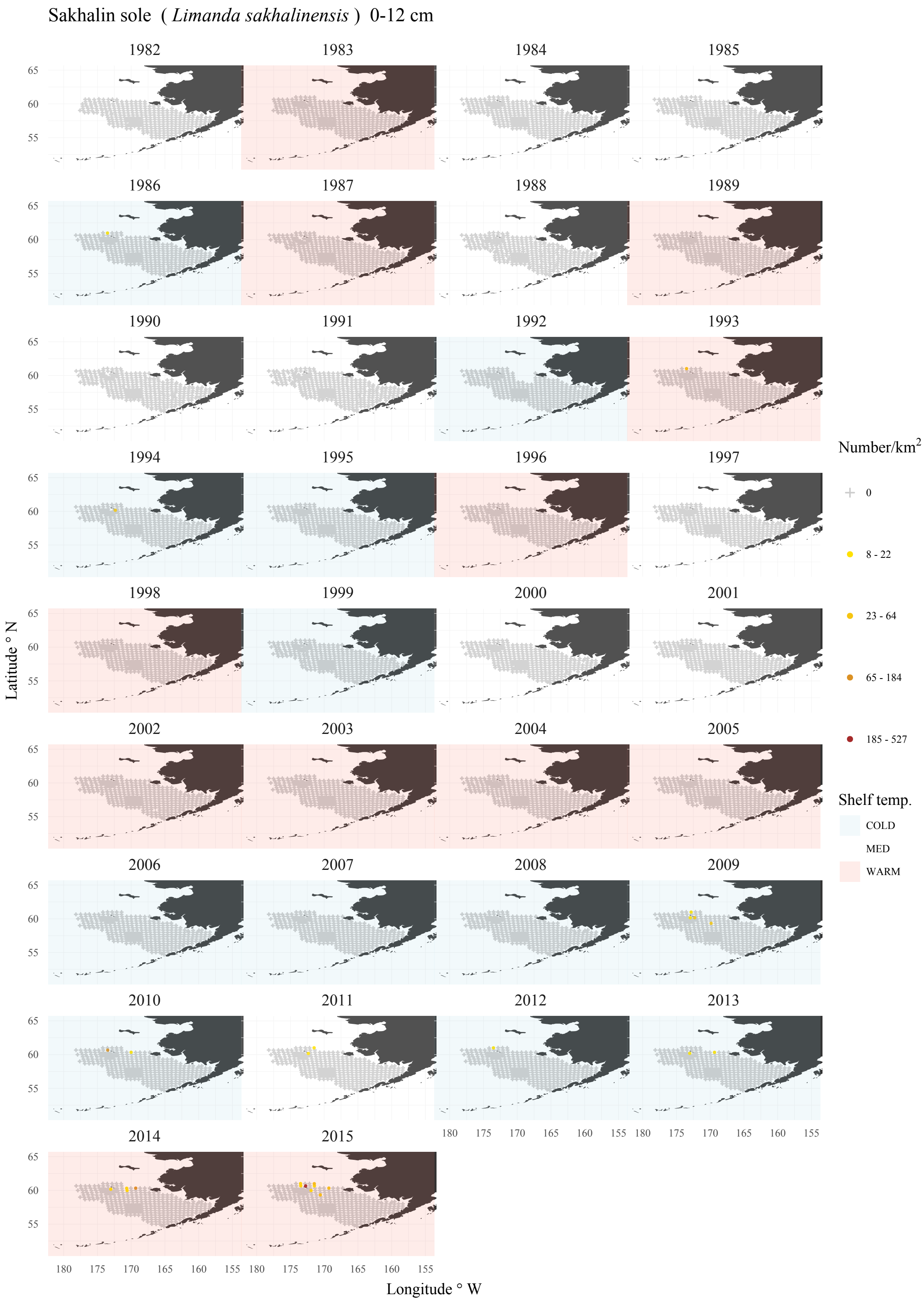


Figure 89 . -- The Sakhalin sole (*Limanda sakhalinensis*) CPUE by number weighted mean location for each length category for all years.

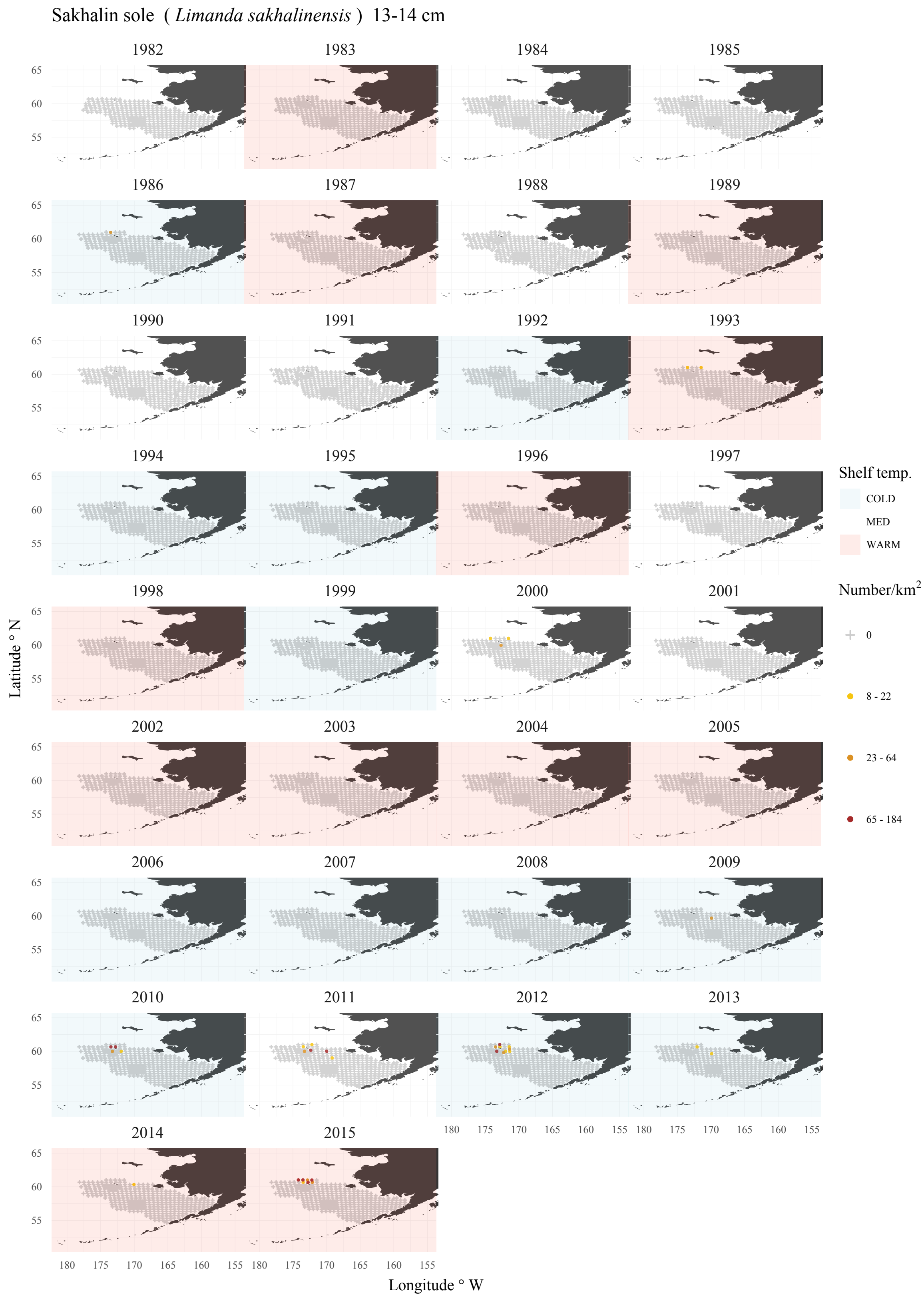


Figure 89 . -- Continued.

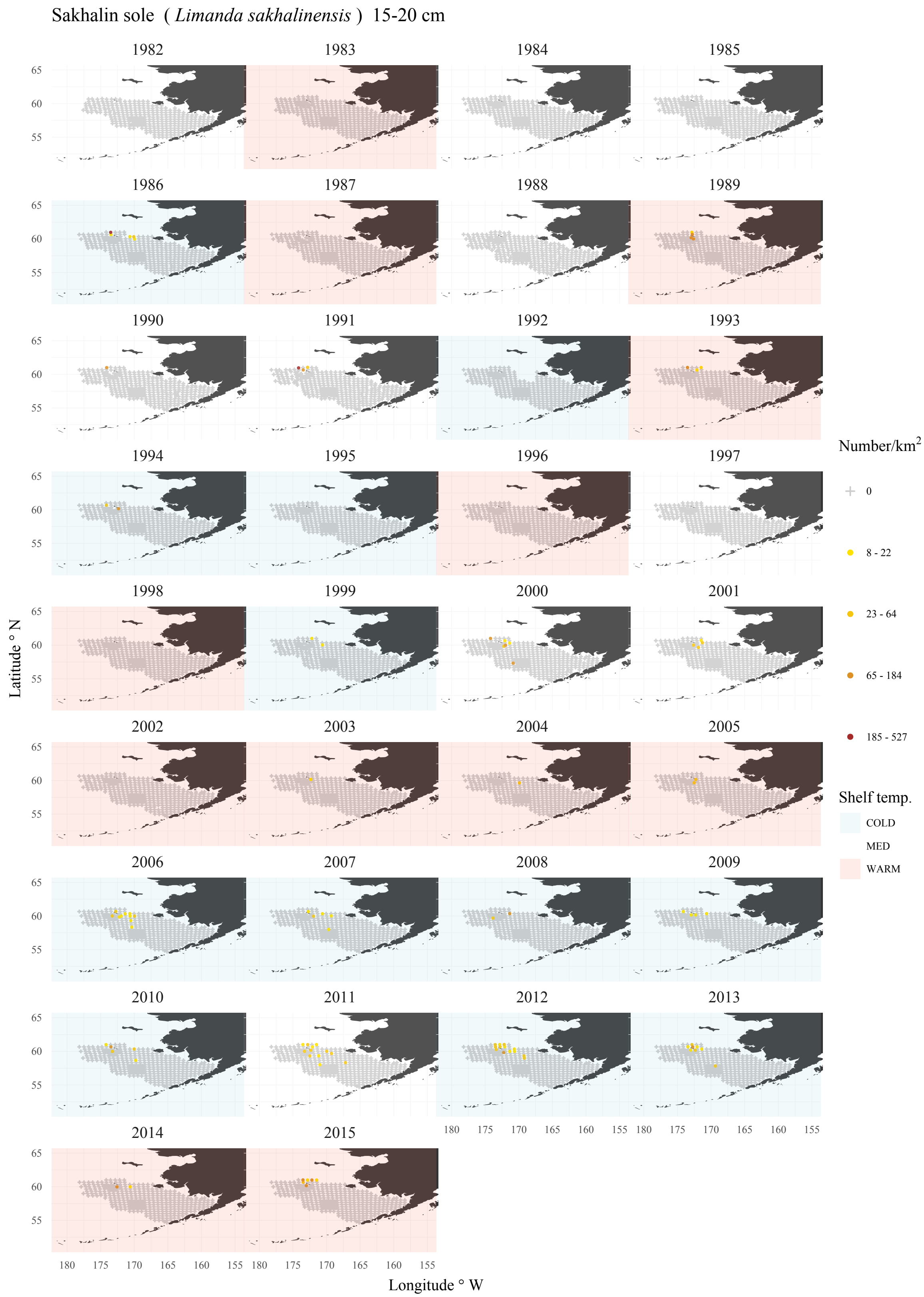


Figure 89 . -- Continued.

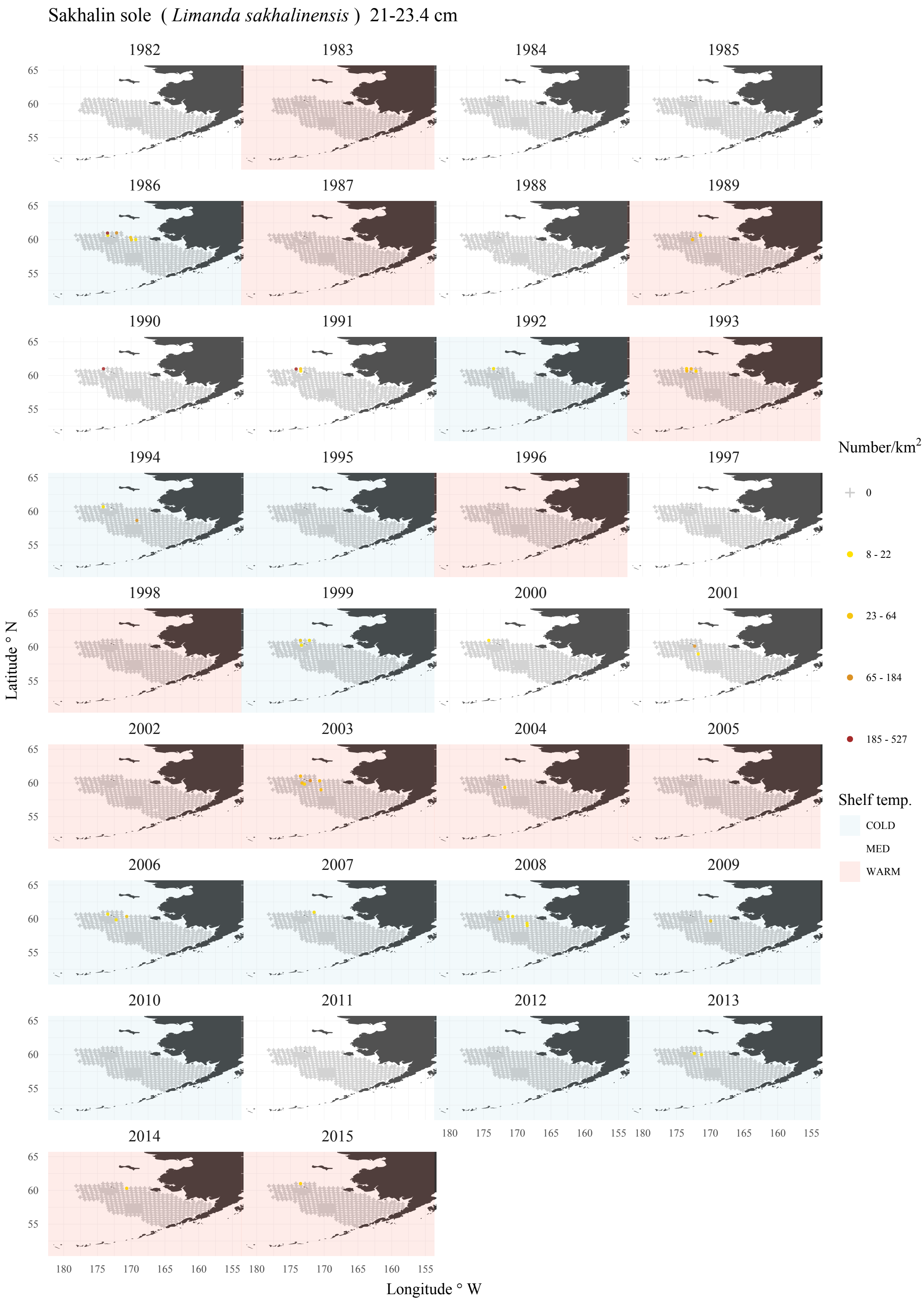


Figure 89 . -- Continued.

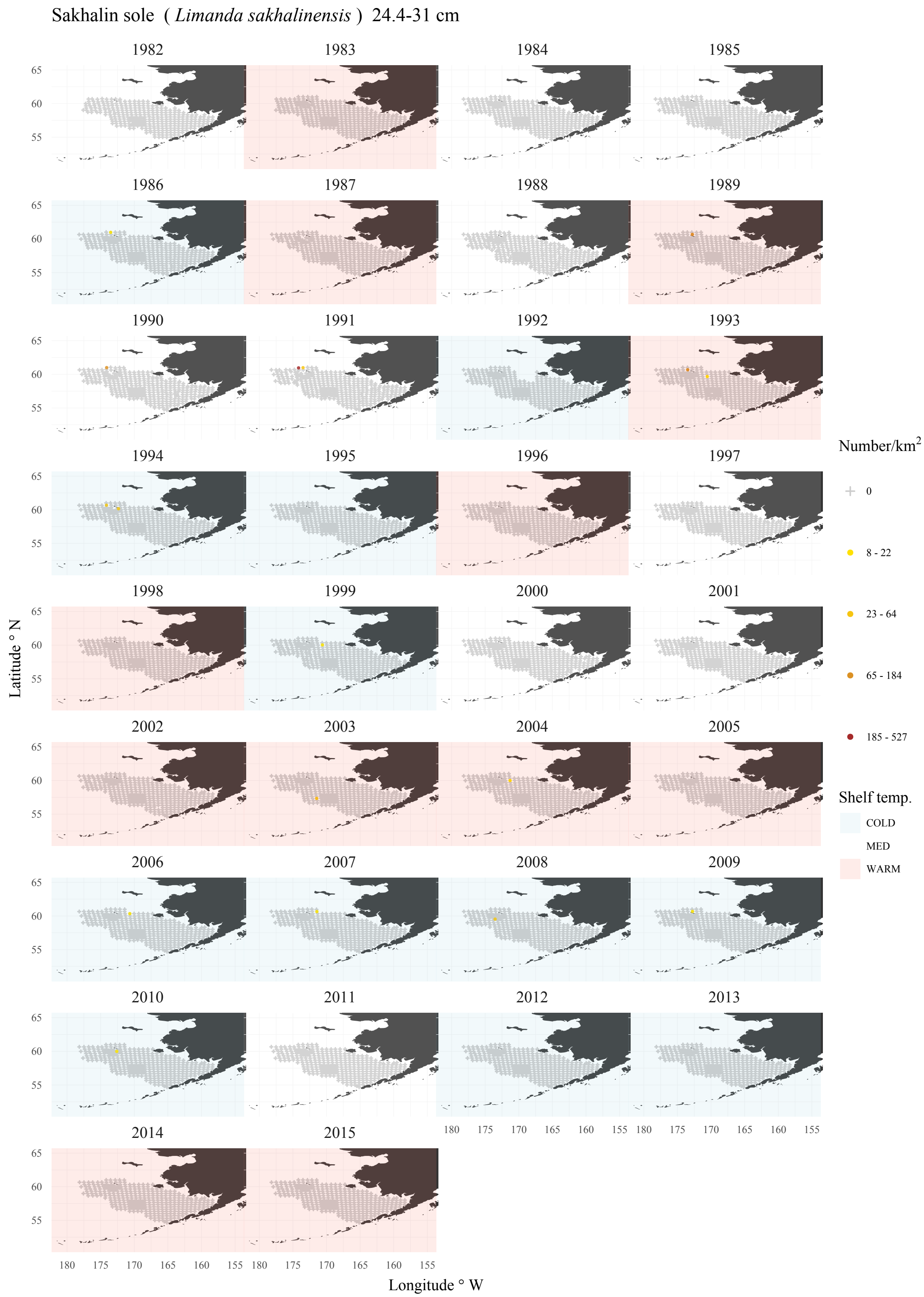


Figure 89 . -- Continued.

Figure 90 . -- The Sakhalin sole (*Limanda sakhalinensis*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

Sakhalin sole (*Limanda sakhalinensis*) 13-14 cm

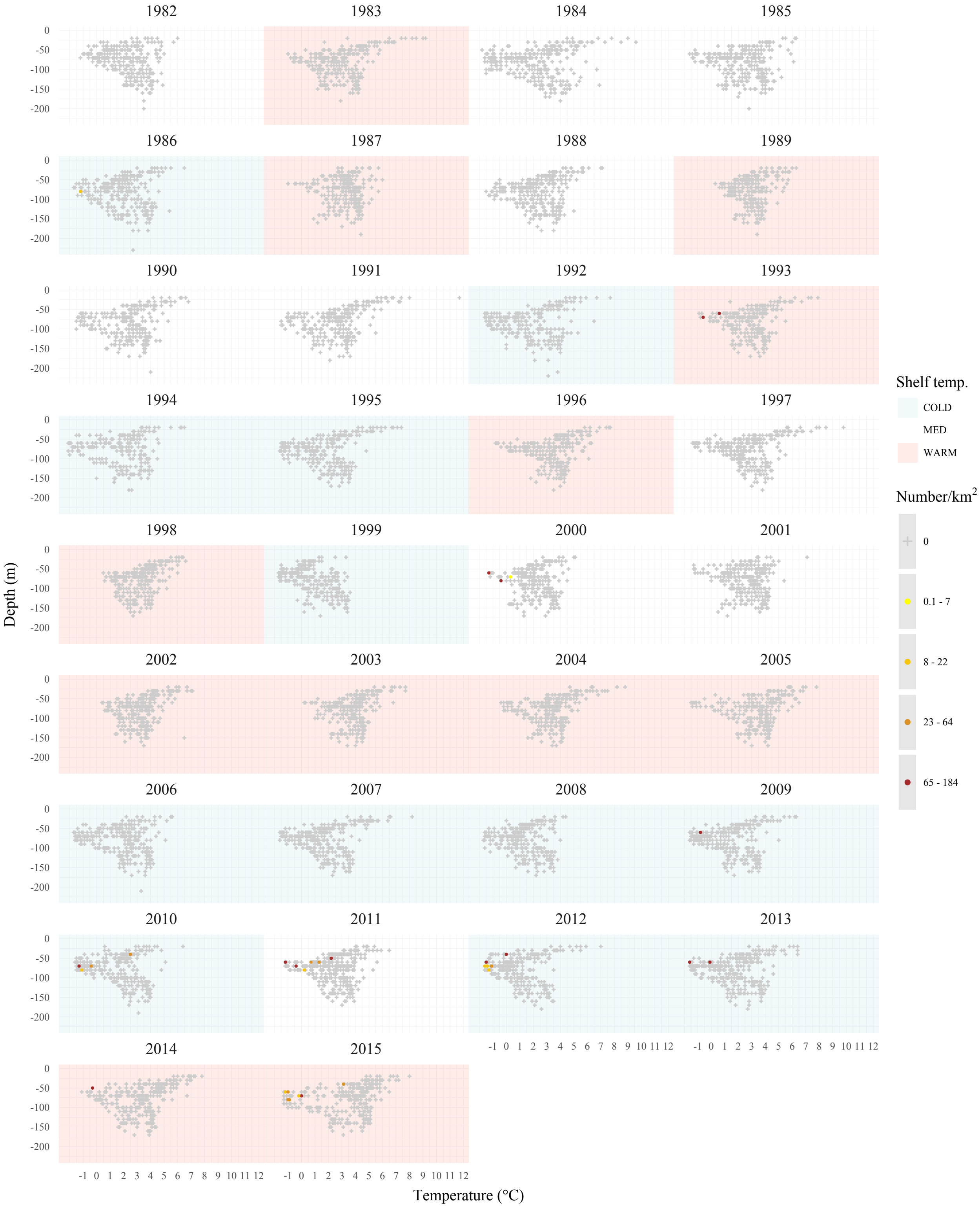


Figure 90 . -- Continued.

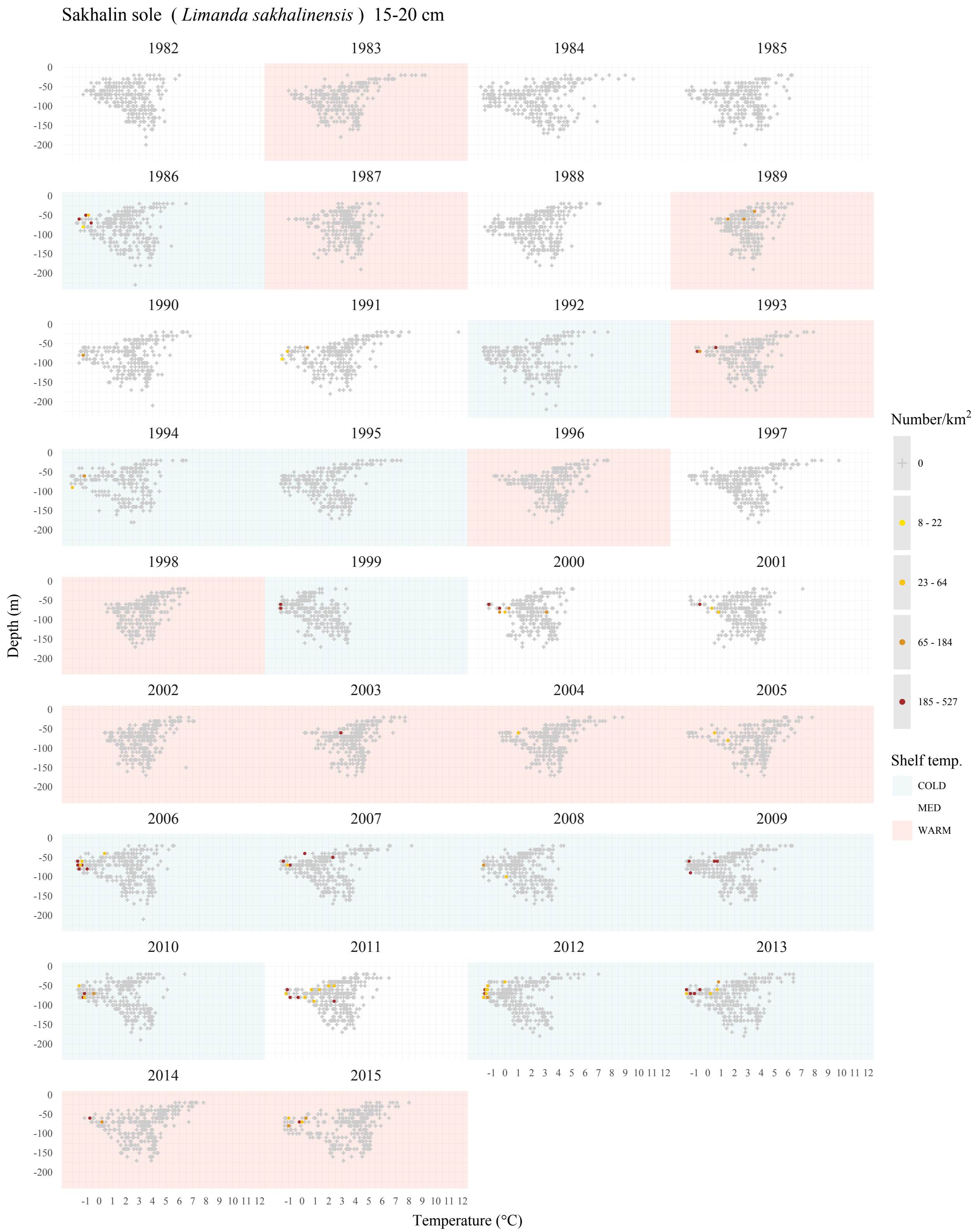


Figure 90 . -- Continued.

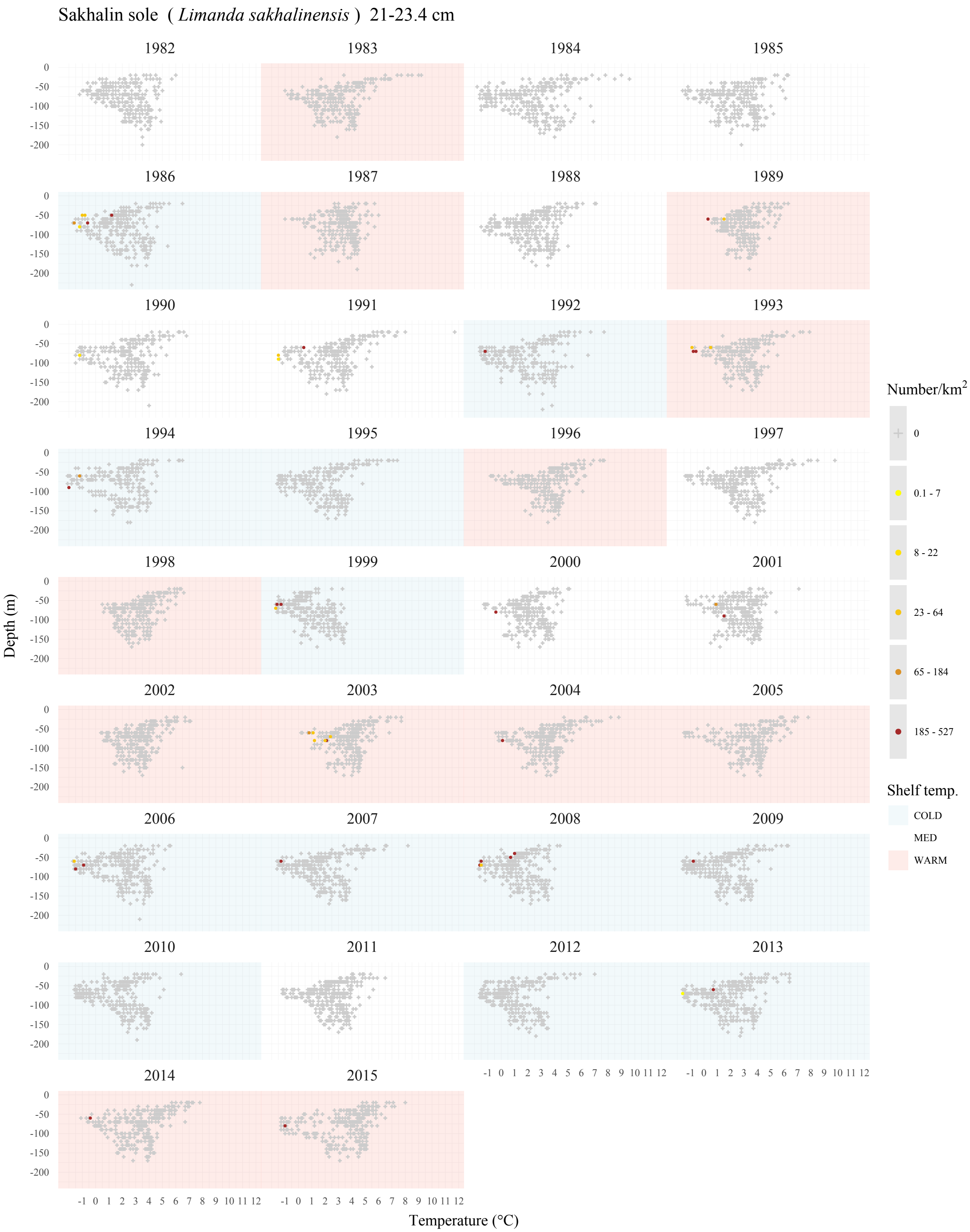
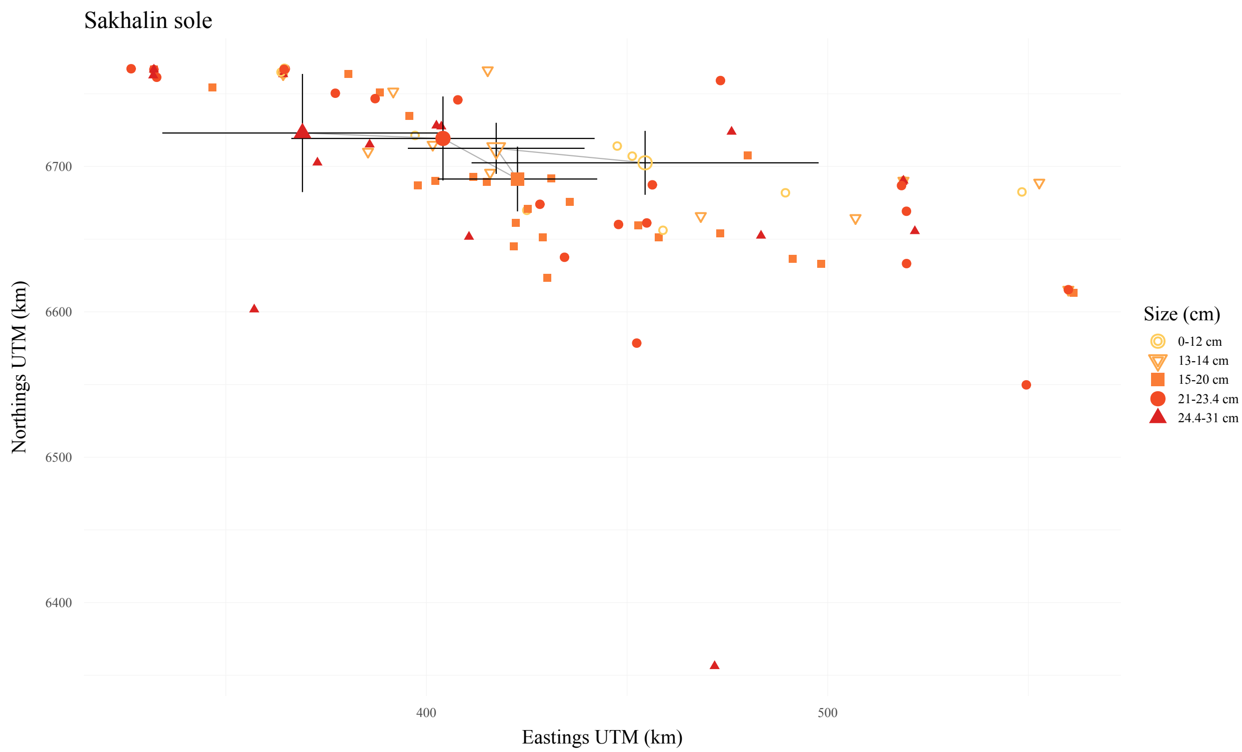


Figure 90 . -- Continued.

Figure 90 . -- Continued.



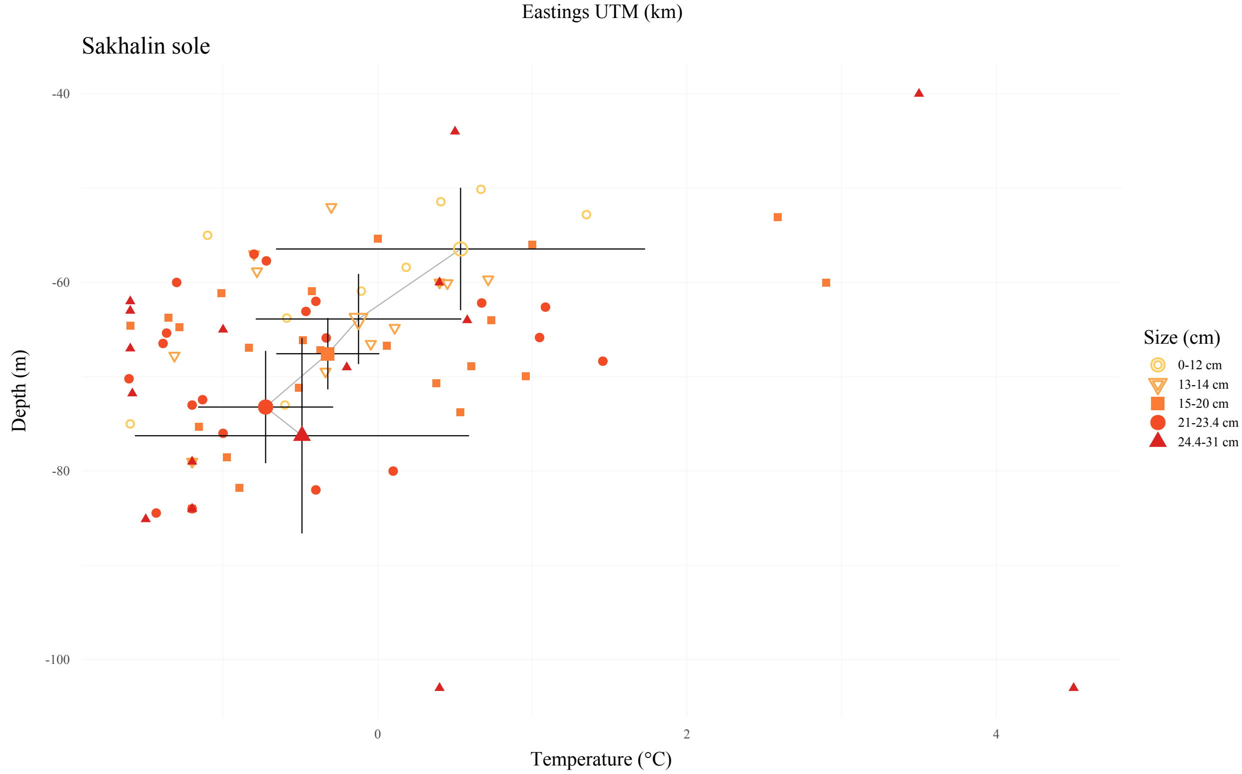


Figure 91 . -- The Sakhalin sole (*Limanda sakhalinensis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

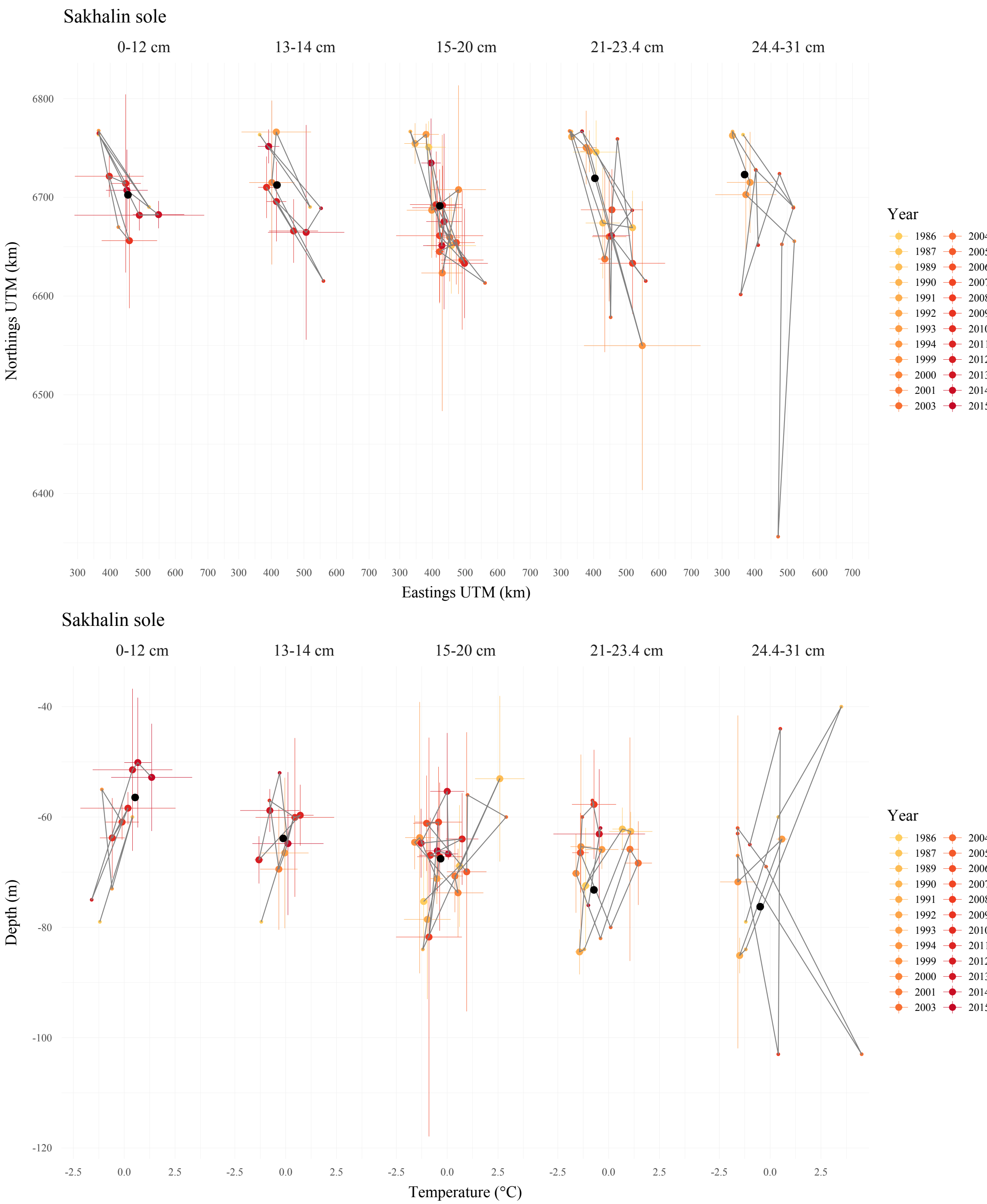


Figure 92 . -- The Sakhalin sole (*Limanda sakhalinensis*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

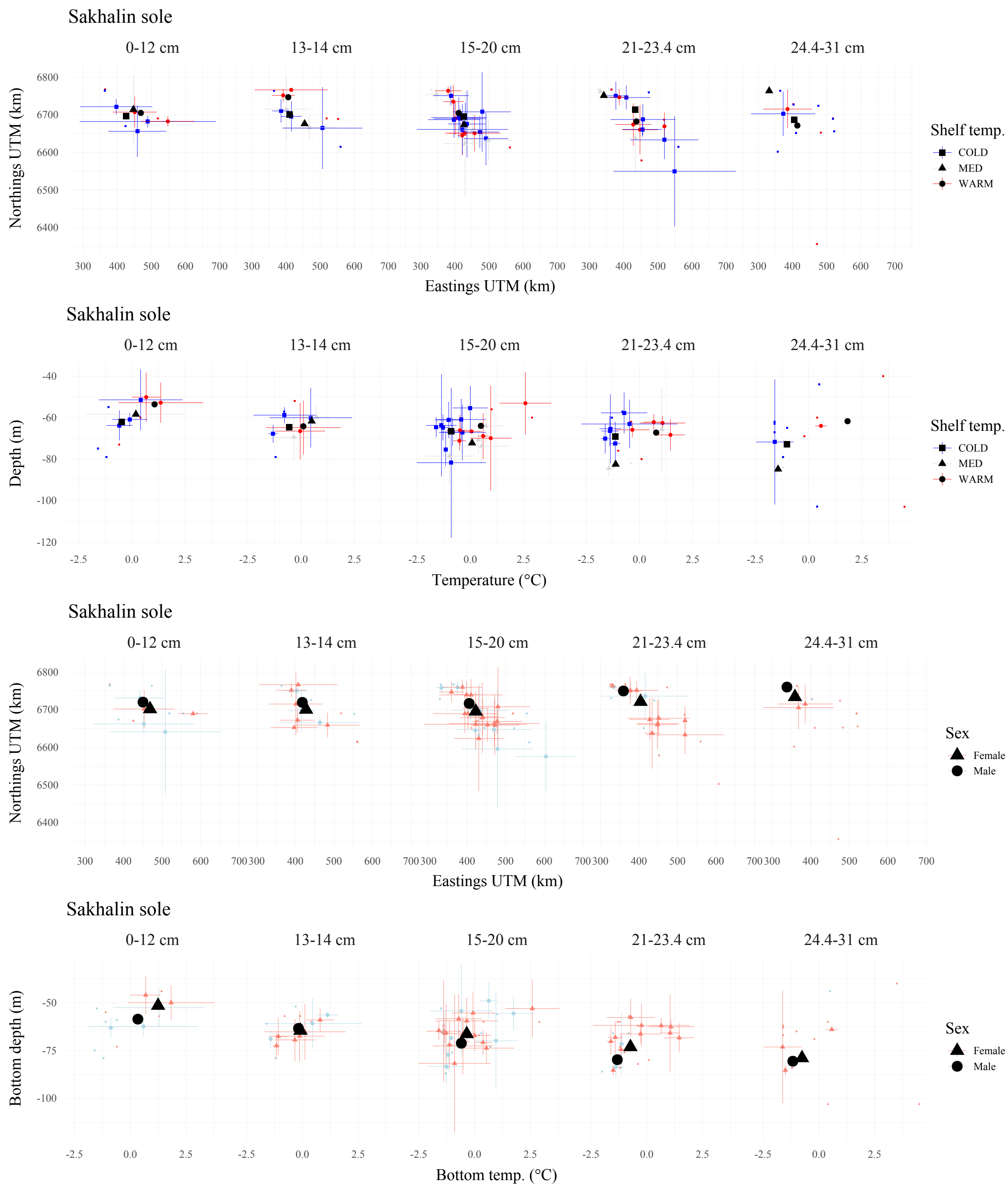


Figure 93 . -- The Sakhalin sole (*Limanda sakhalinensis*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

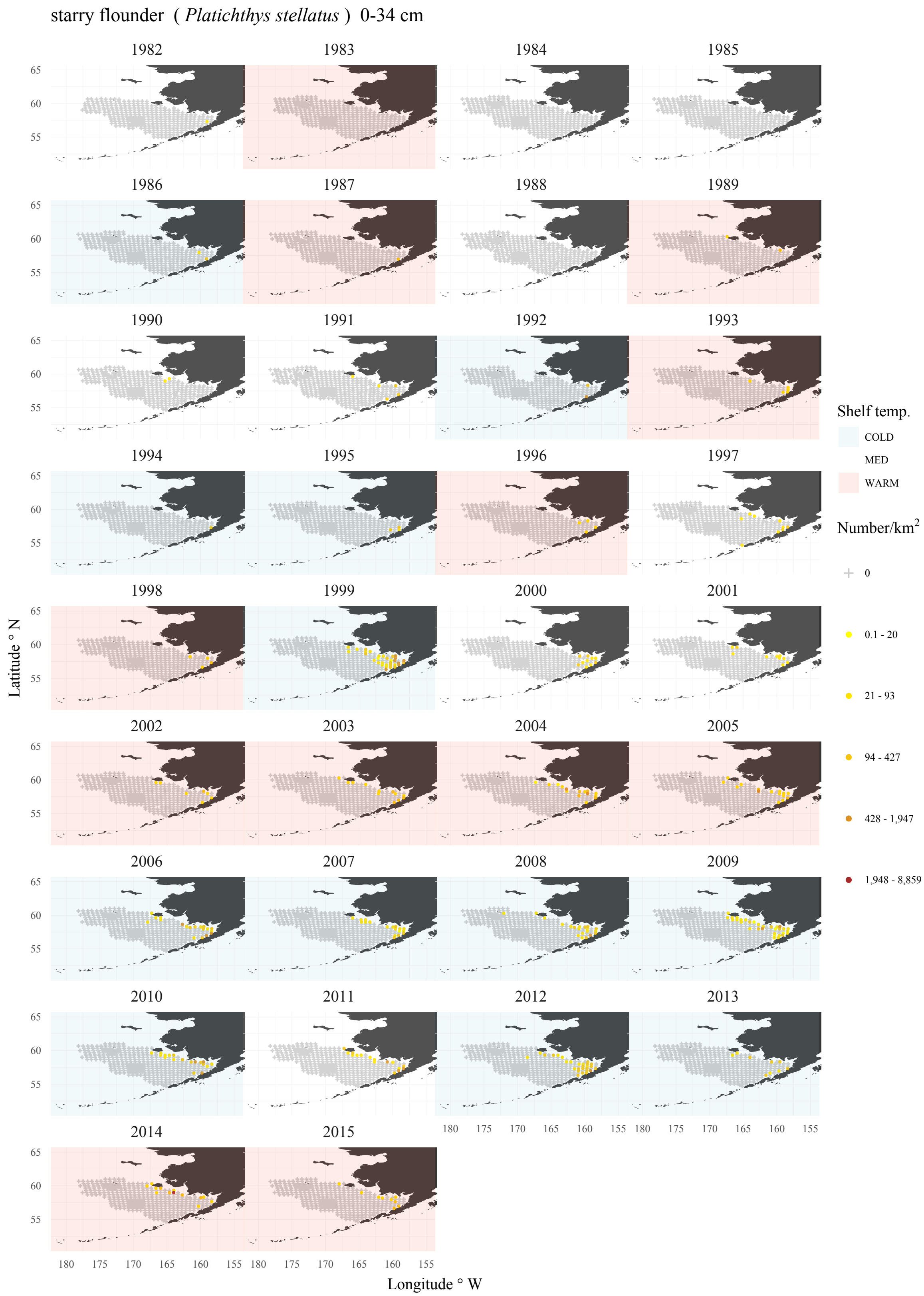


Figure 94 . -- The starry flounder (*Platichthys stellatus*) CPUE by number weighted mean location for each length category for all years.

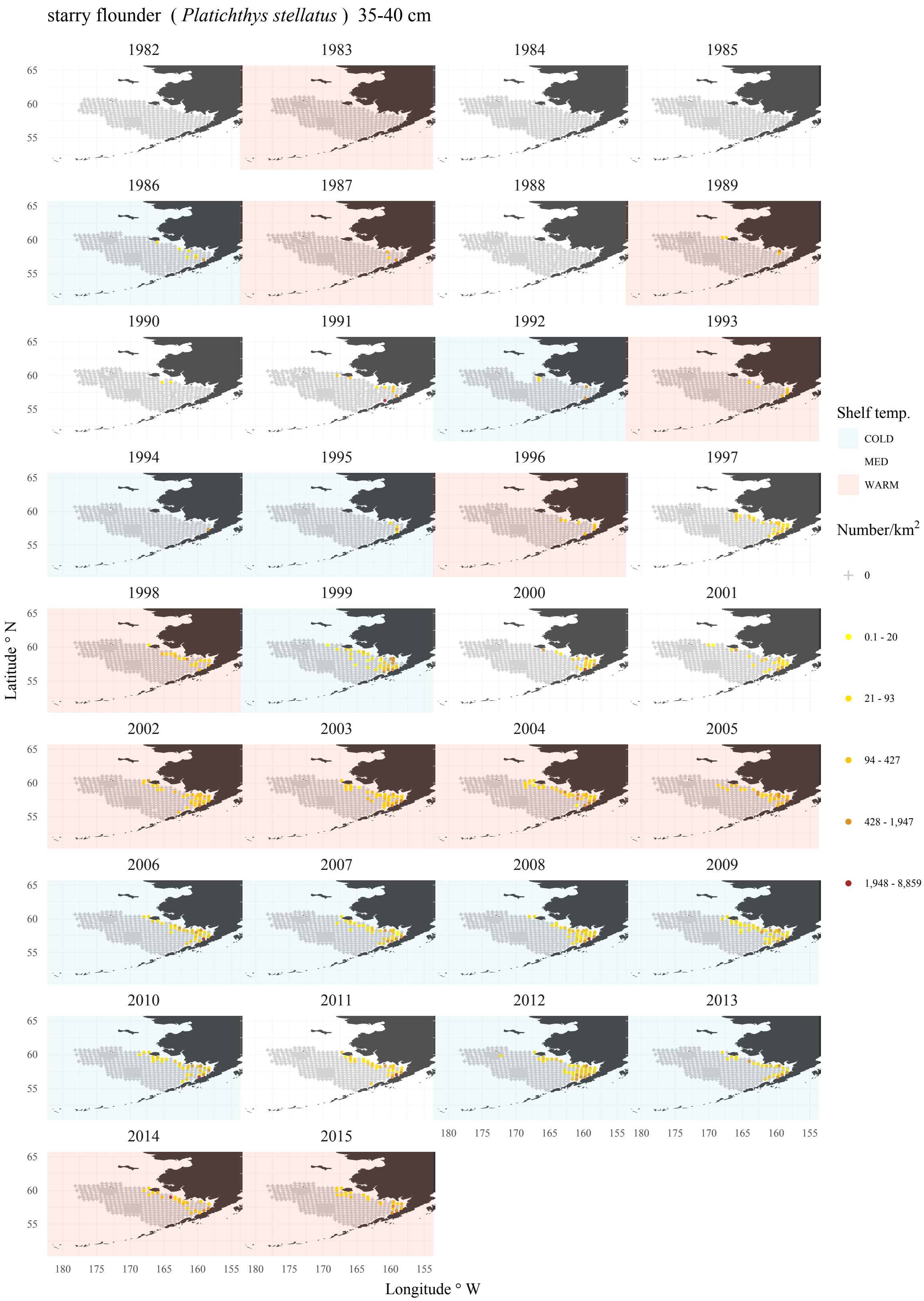


Figure 94 . -- Continued.

starry flounder (*Platichthys stellatus*) 41-49 cm

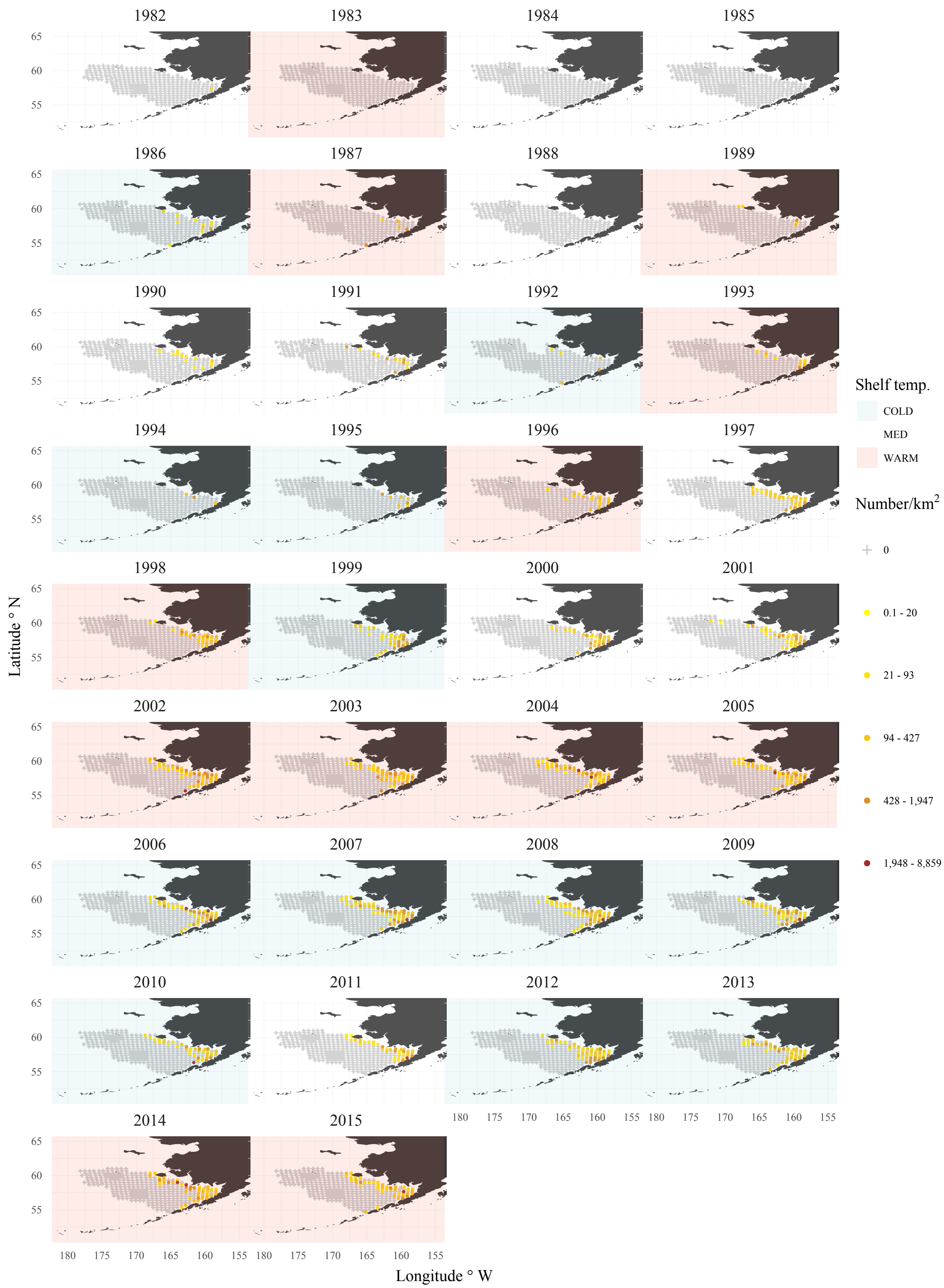


Figure 94 . -- Continued.

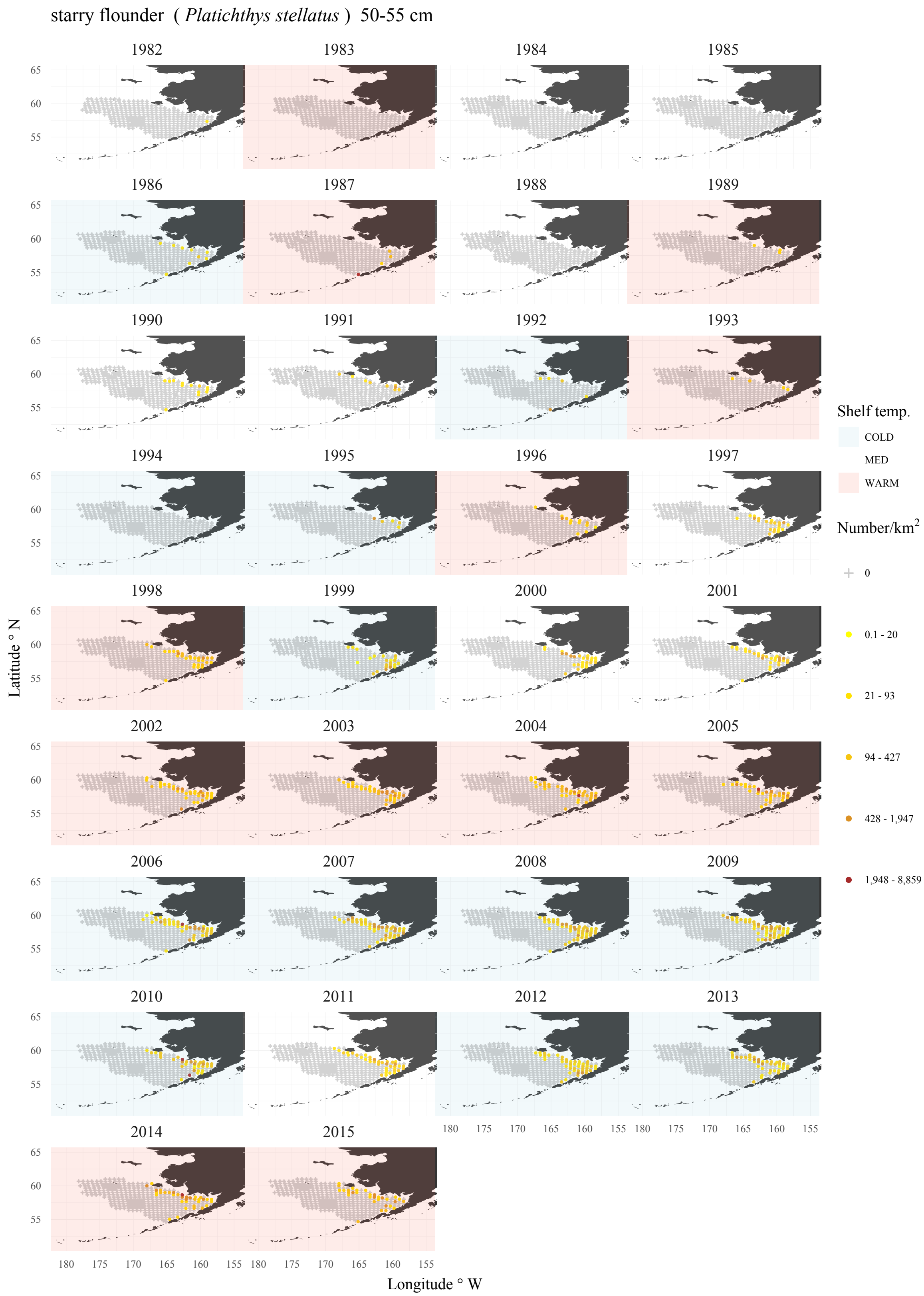


Figure 94 . -- Continued.

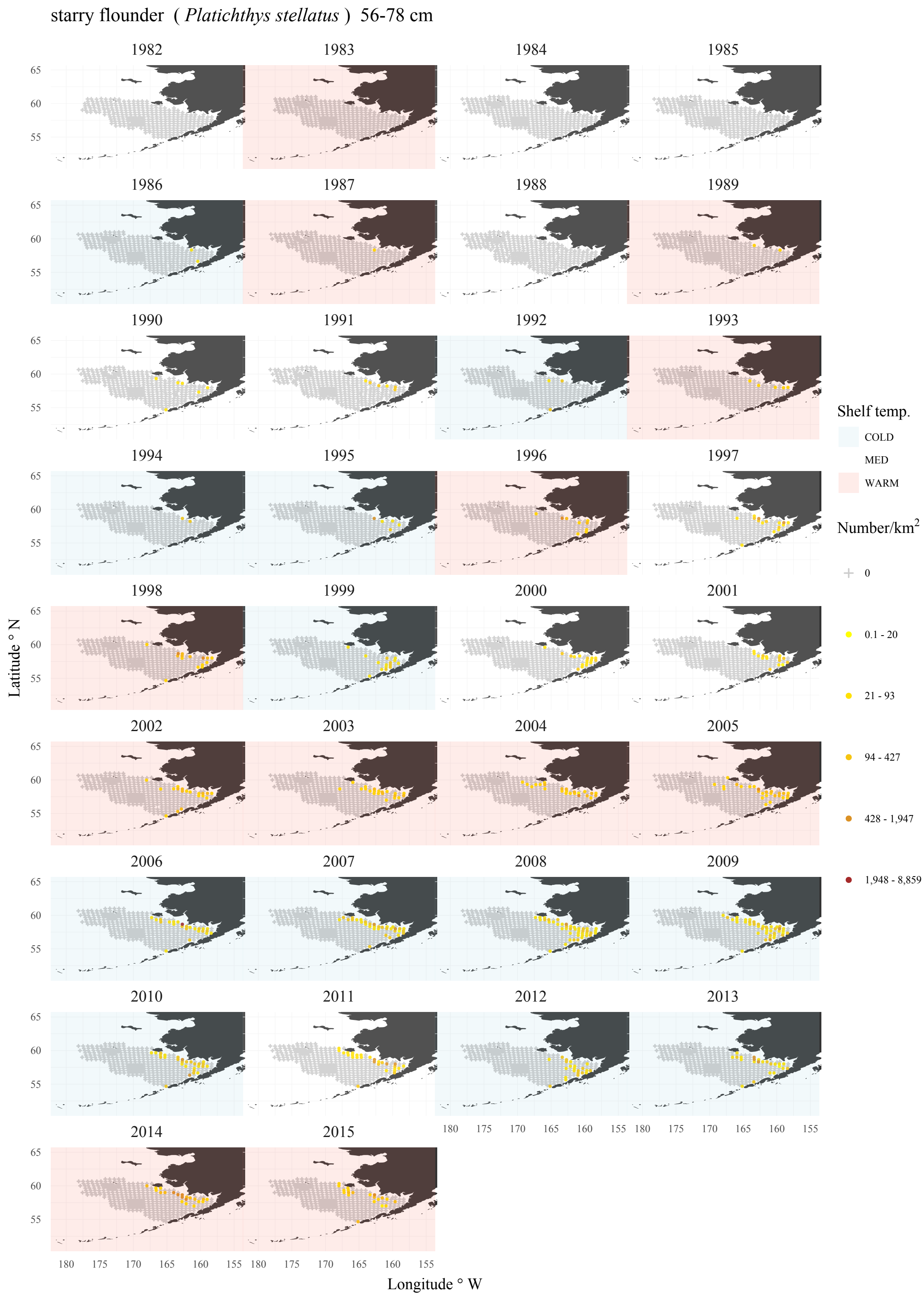


Figure 94 . -- Continued.

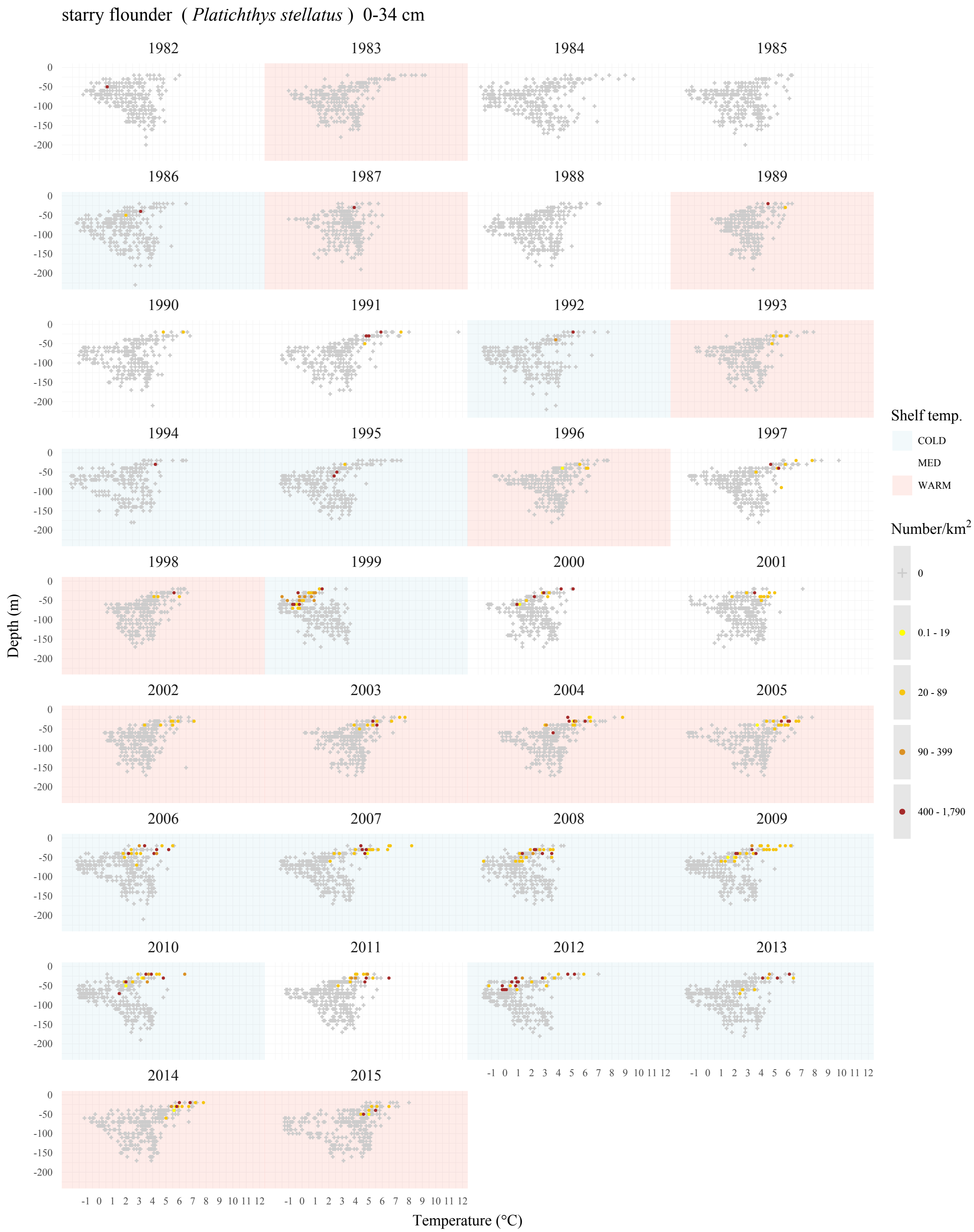


Figure 95 . -- The starry flounder (*Platichthys stellatus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

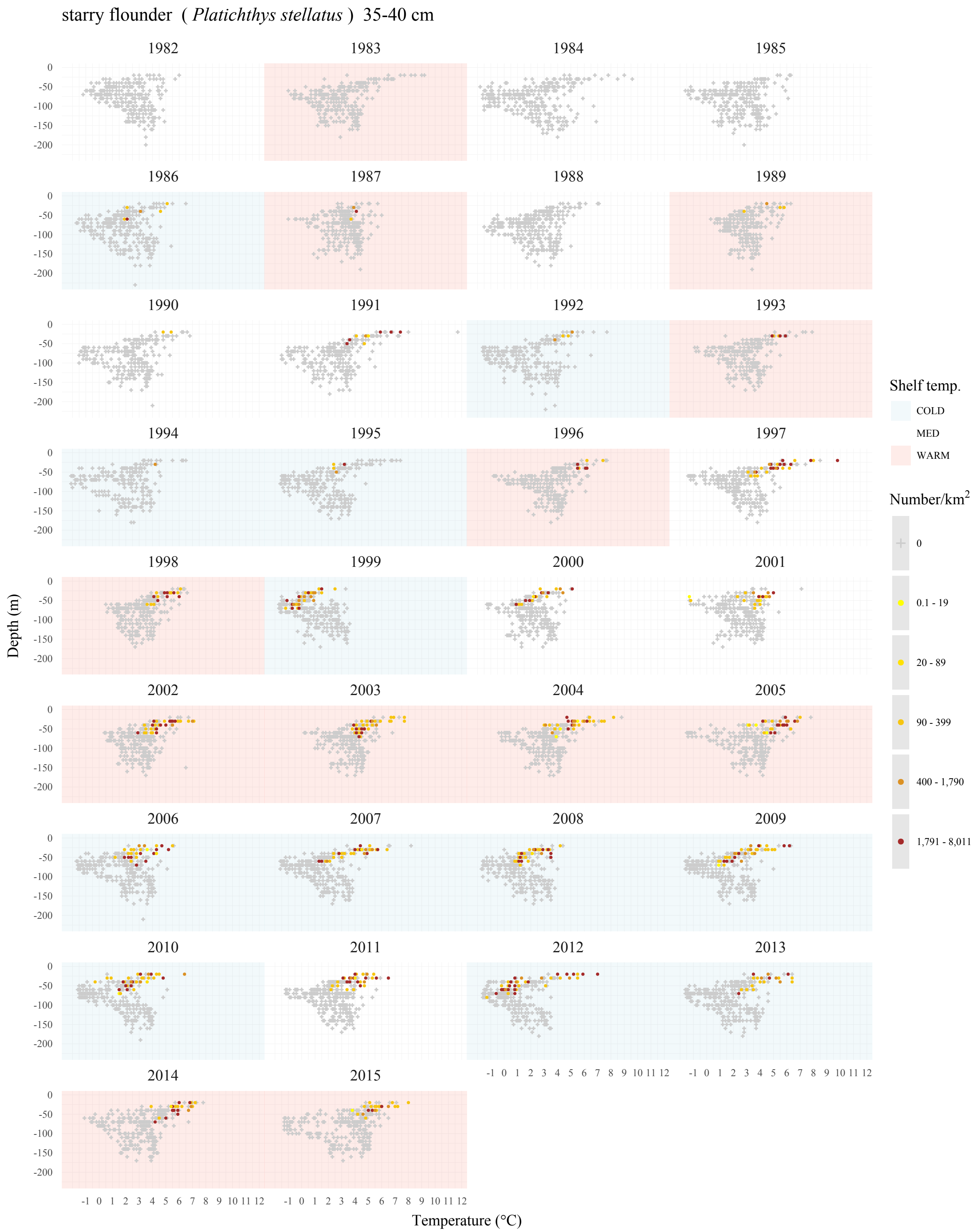


Figure 95 . -- Continued.

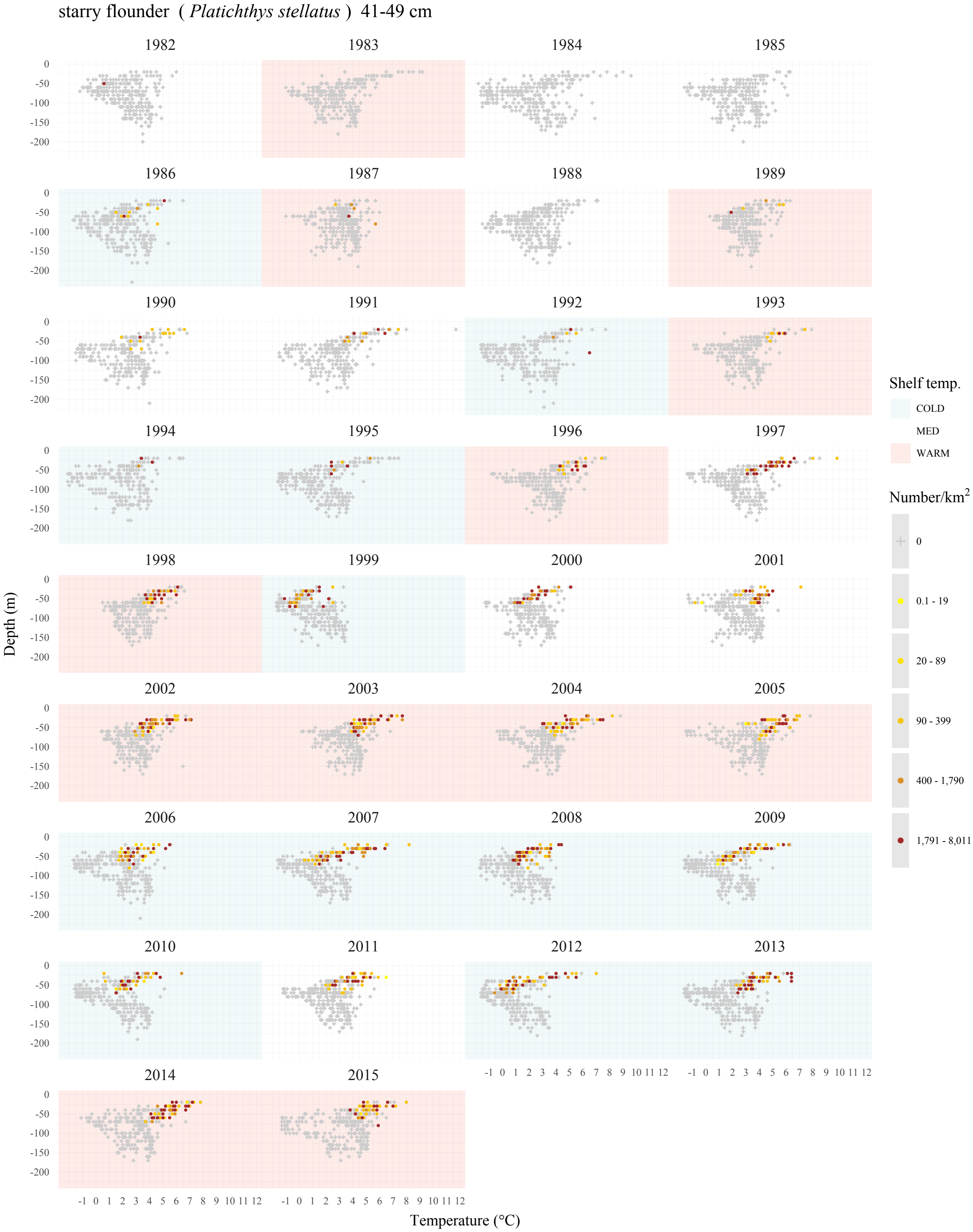


Figure 95 . -- Continued.

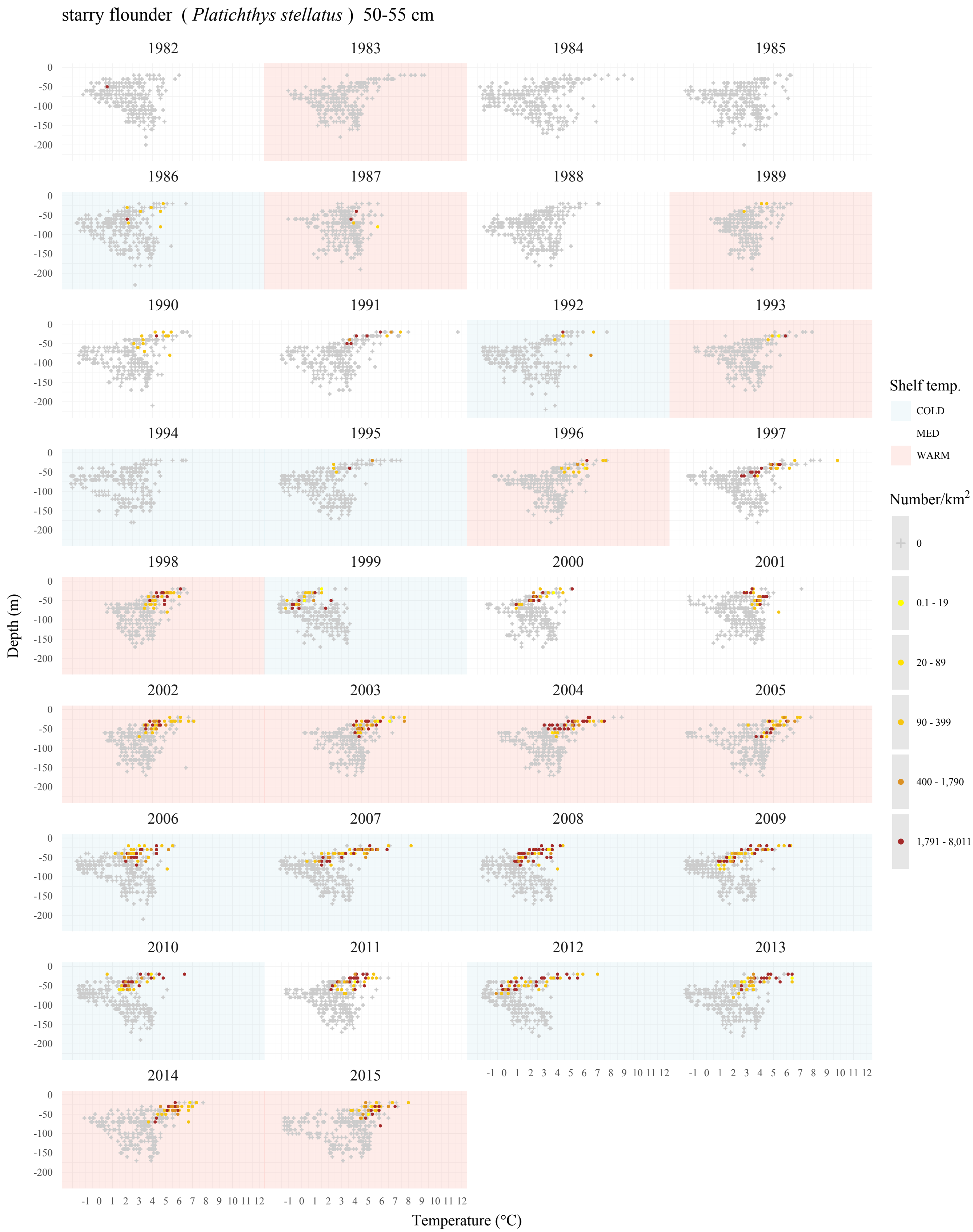


Figure 95 . -- Continued.

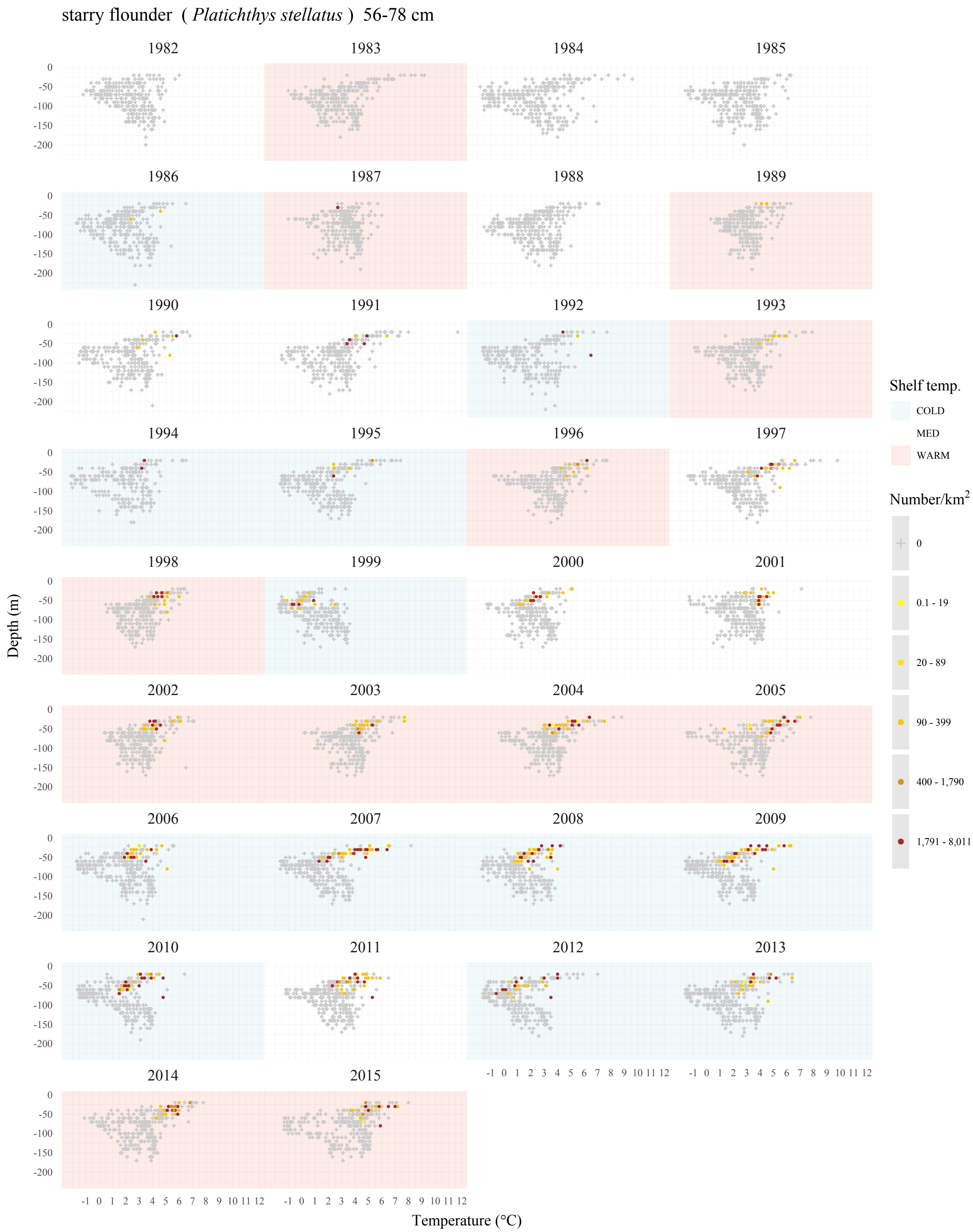
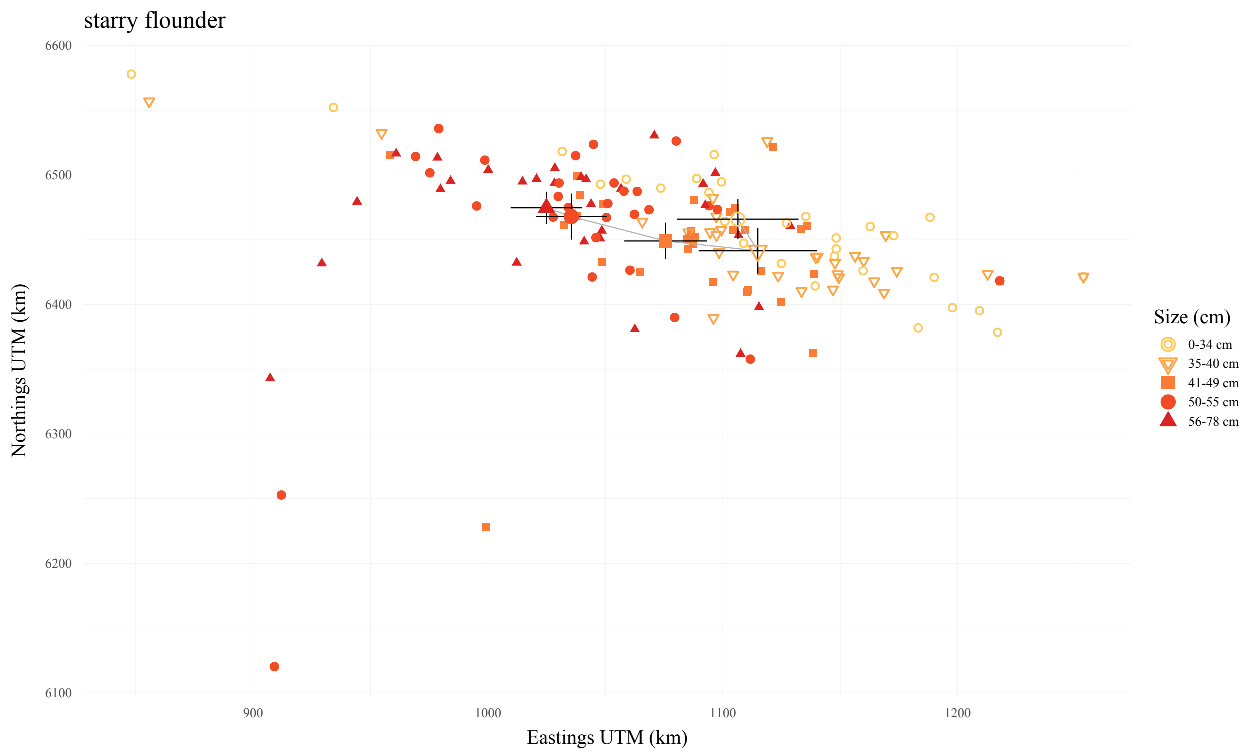


Figure 95 . -- Continued.



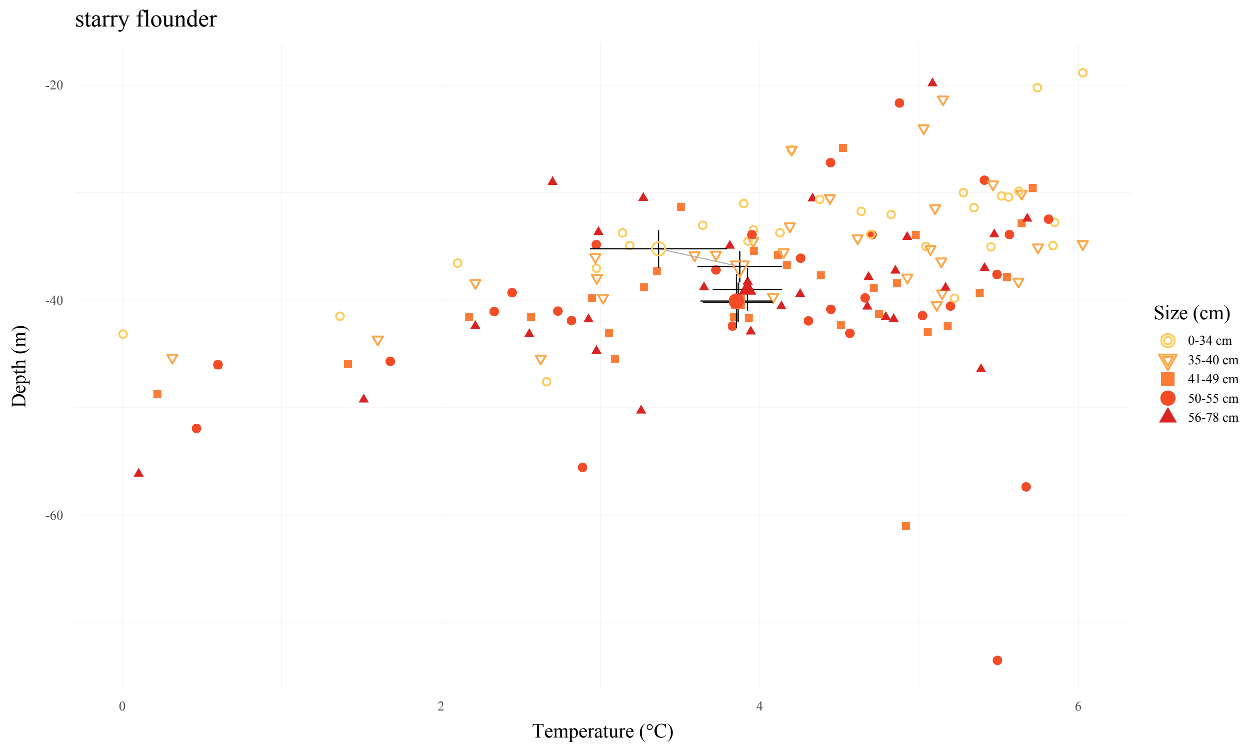


Figure 96 . -- The starry flounder (*Platichthys stellatus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

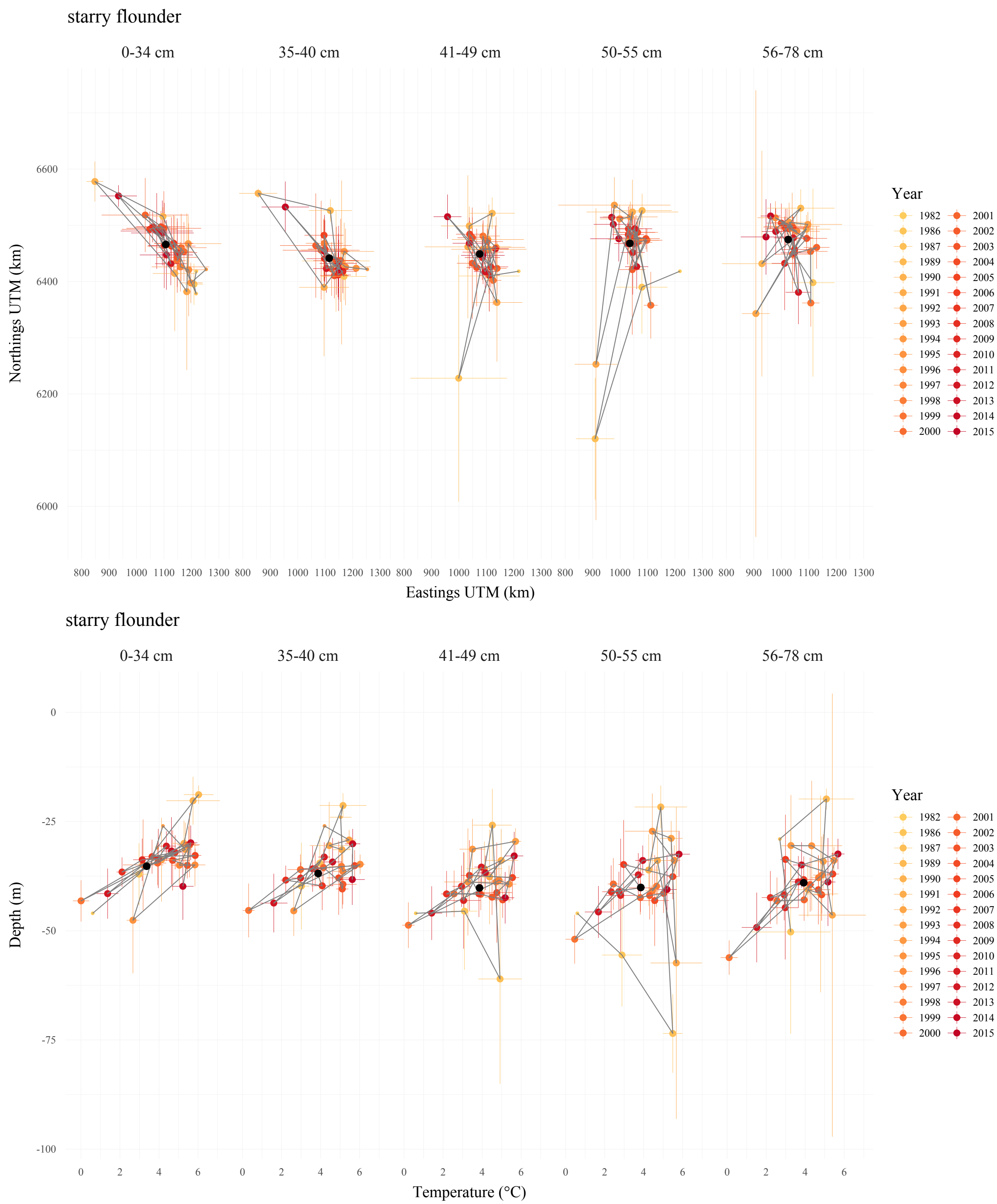


Figure 97 . -- The starry flounder (*Platichthys stellatus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

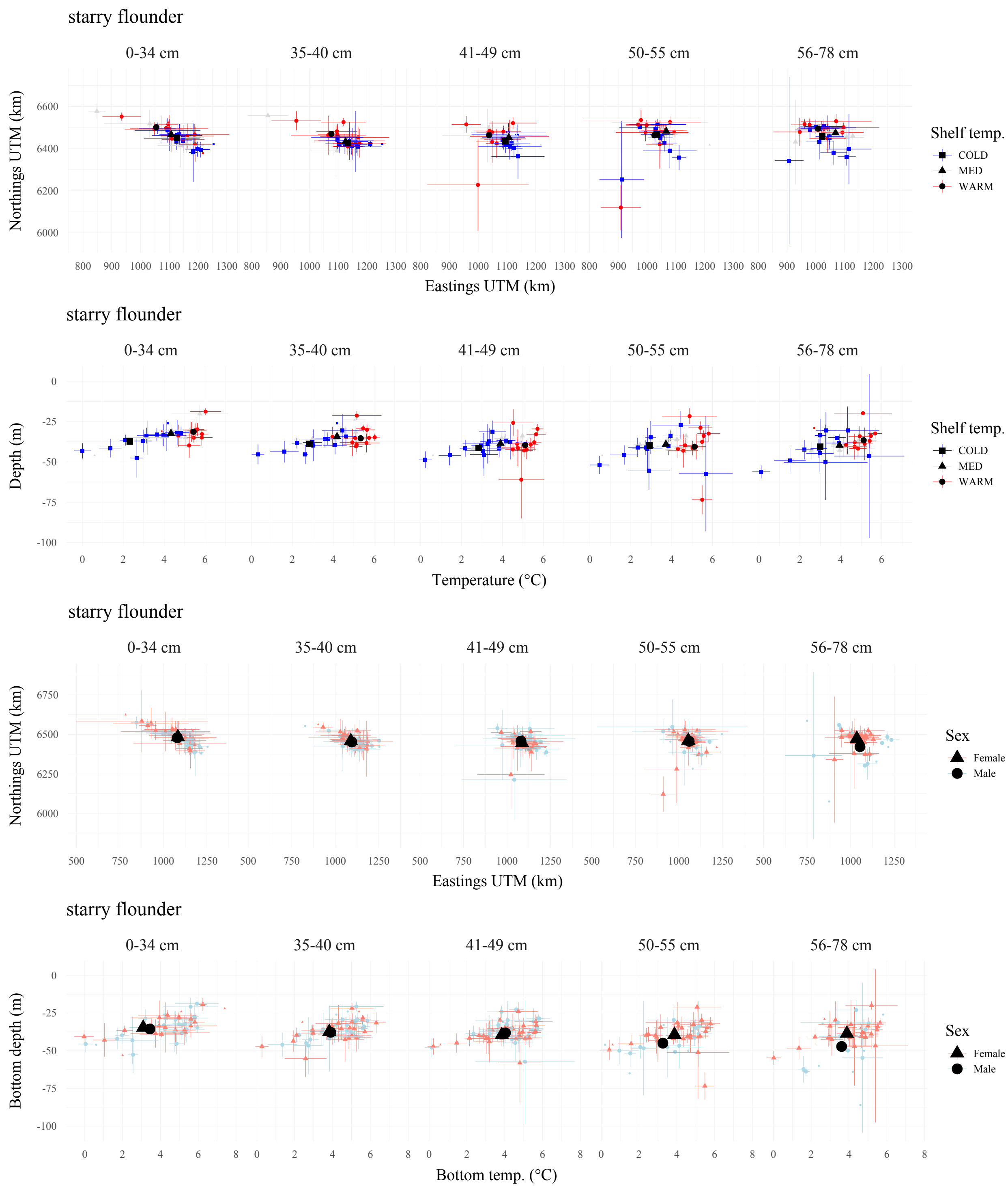


Figure 98 . -- The starry flounder (*Platichthys stellatus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

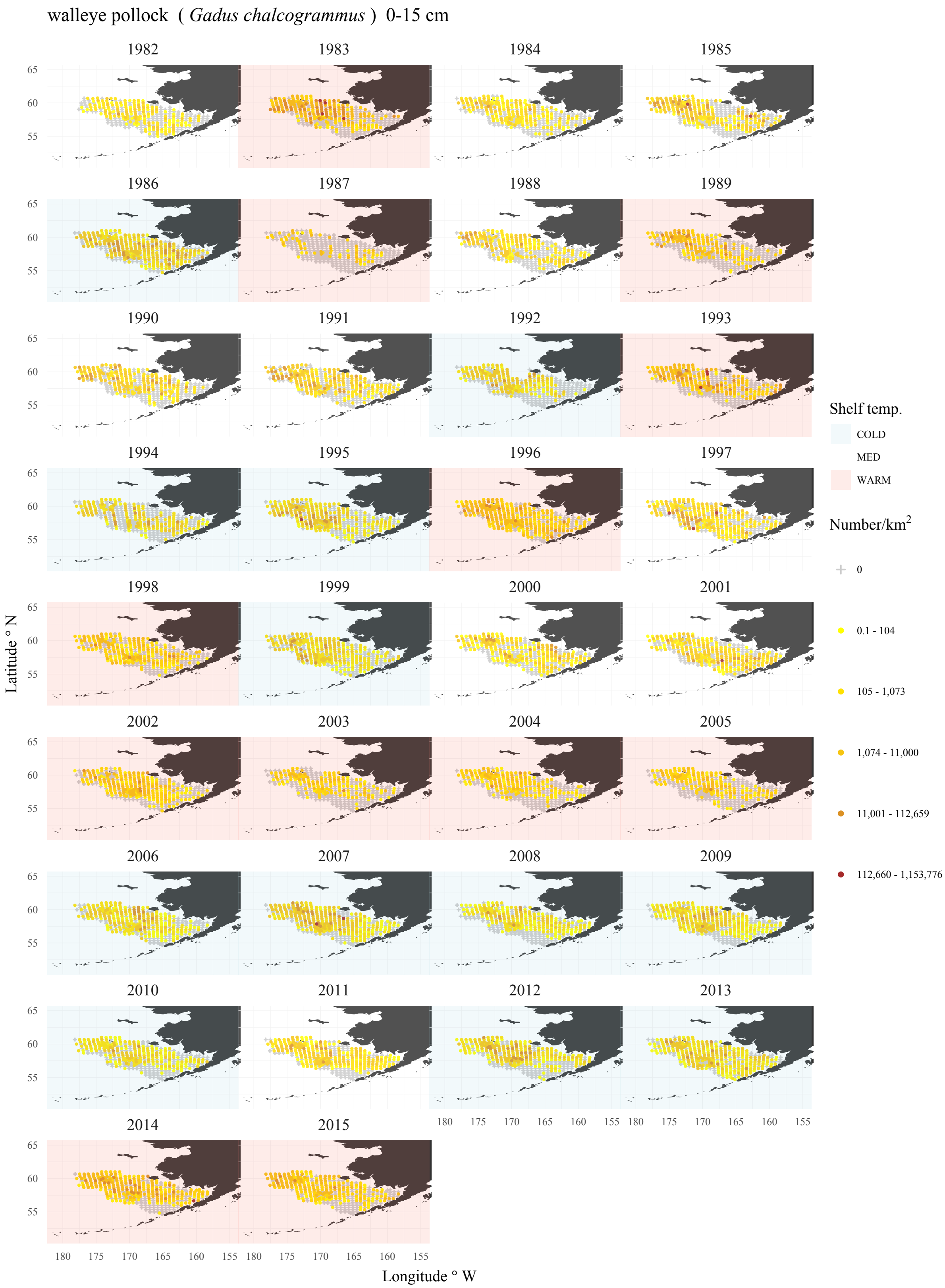


Figure 99 . -- The walleye pollock (*Gadus chalcogrammus*) CPUE by number weighted mean location for each length category for all years.

walleye pollock (*Gadus chalcogrammus*) 16-39 cm

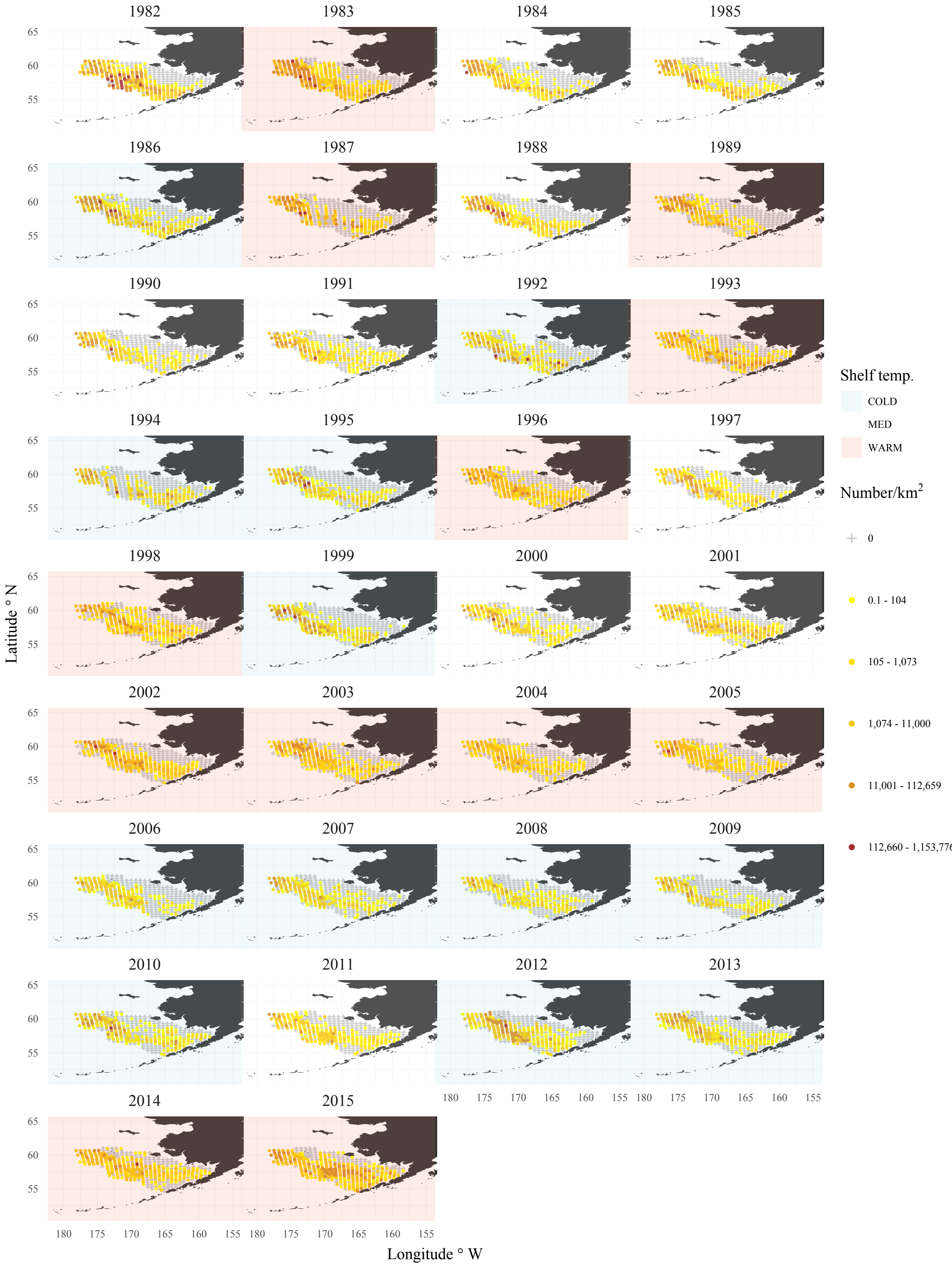


Figure 99 . -- Continued.

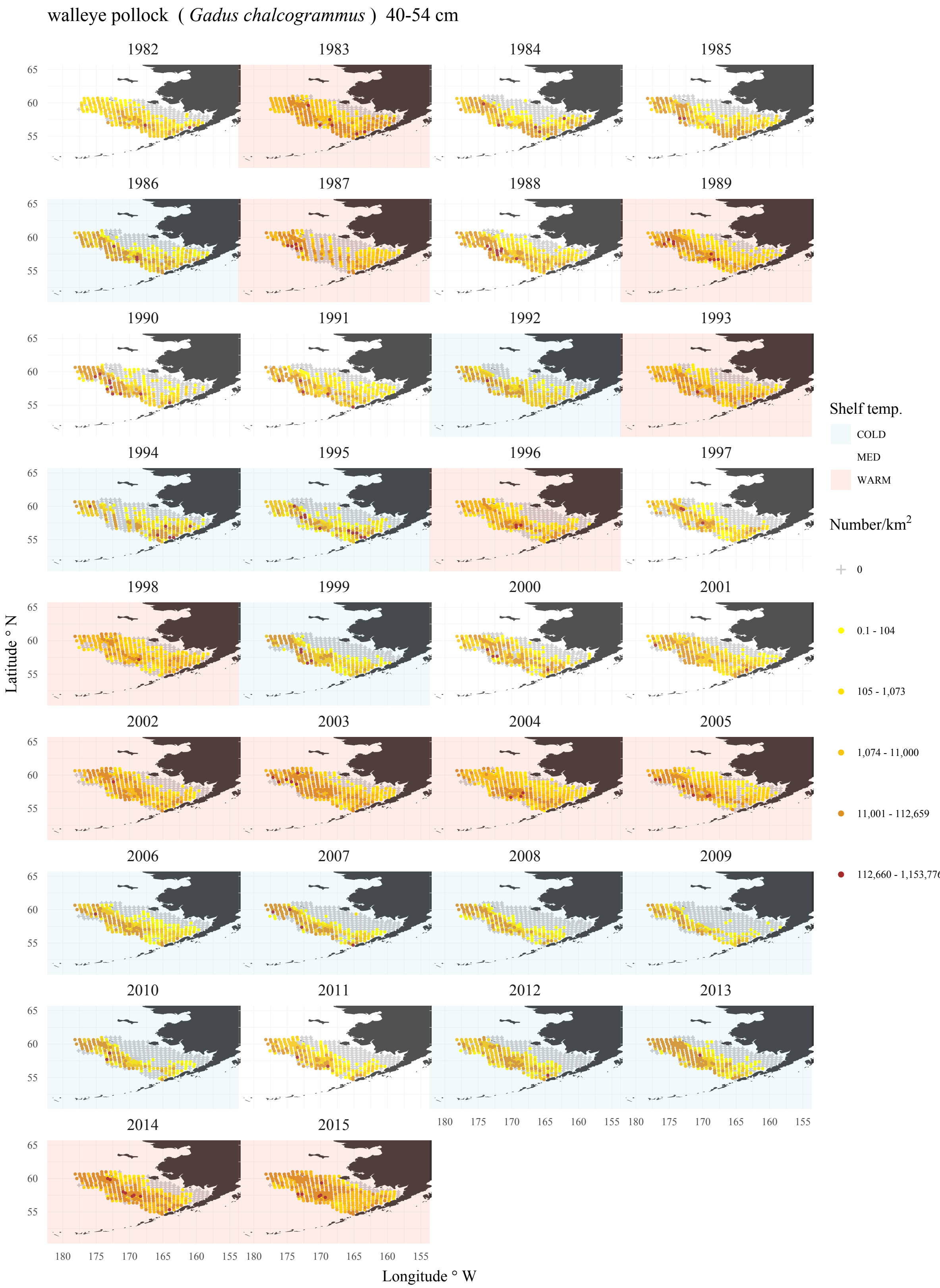


Figure 99 . -- Continued.

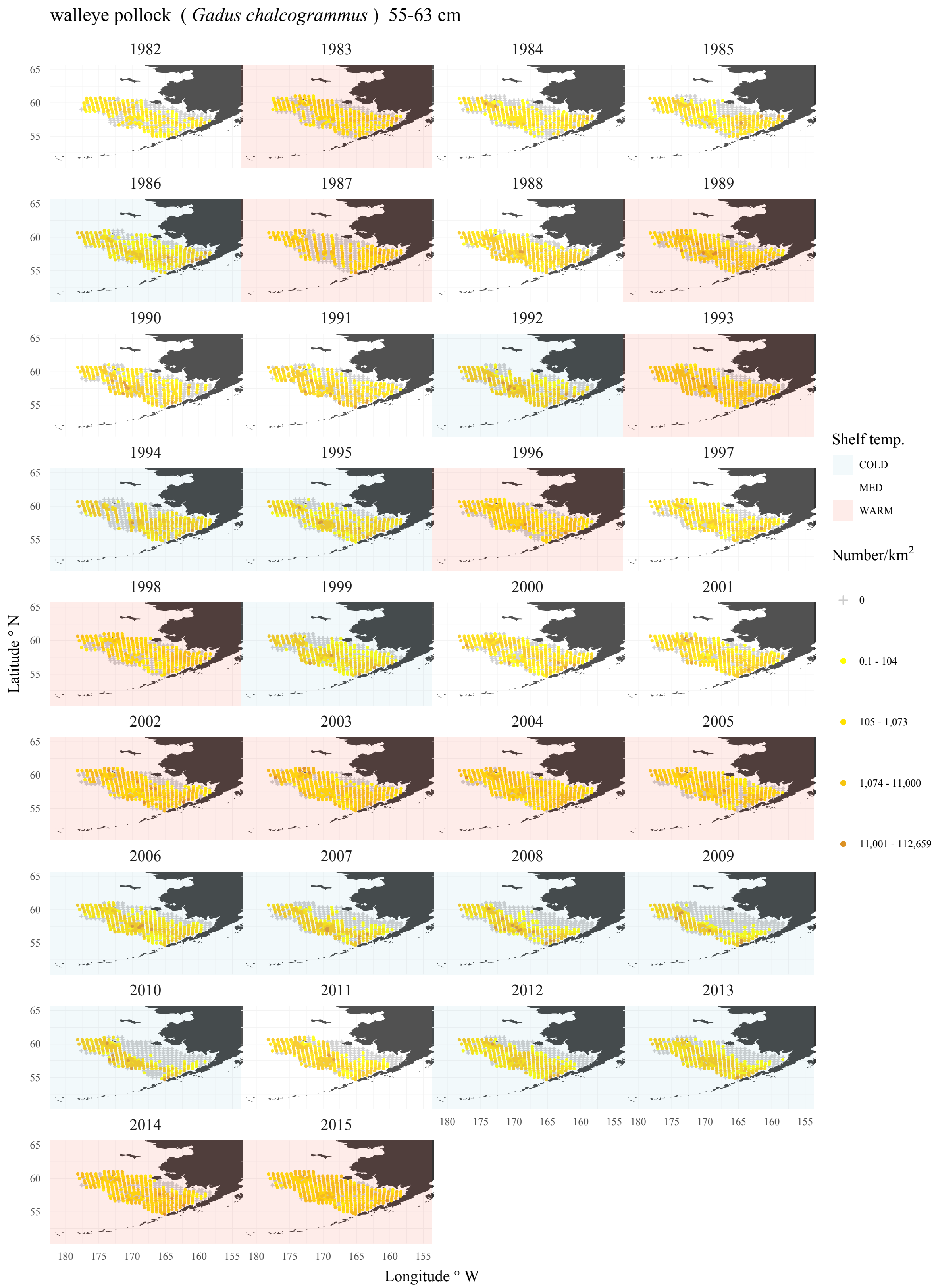


Figure 99 . -- Continued.

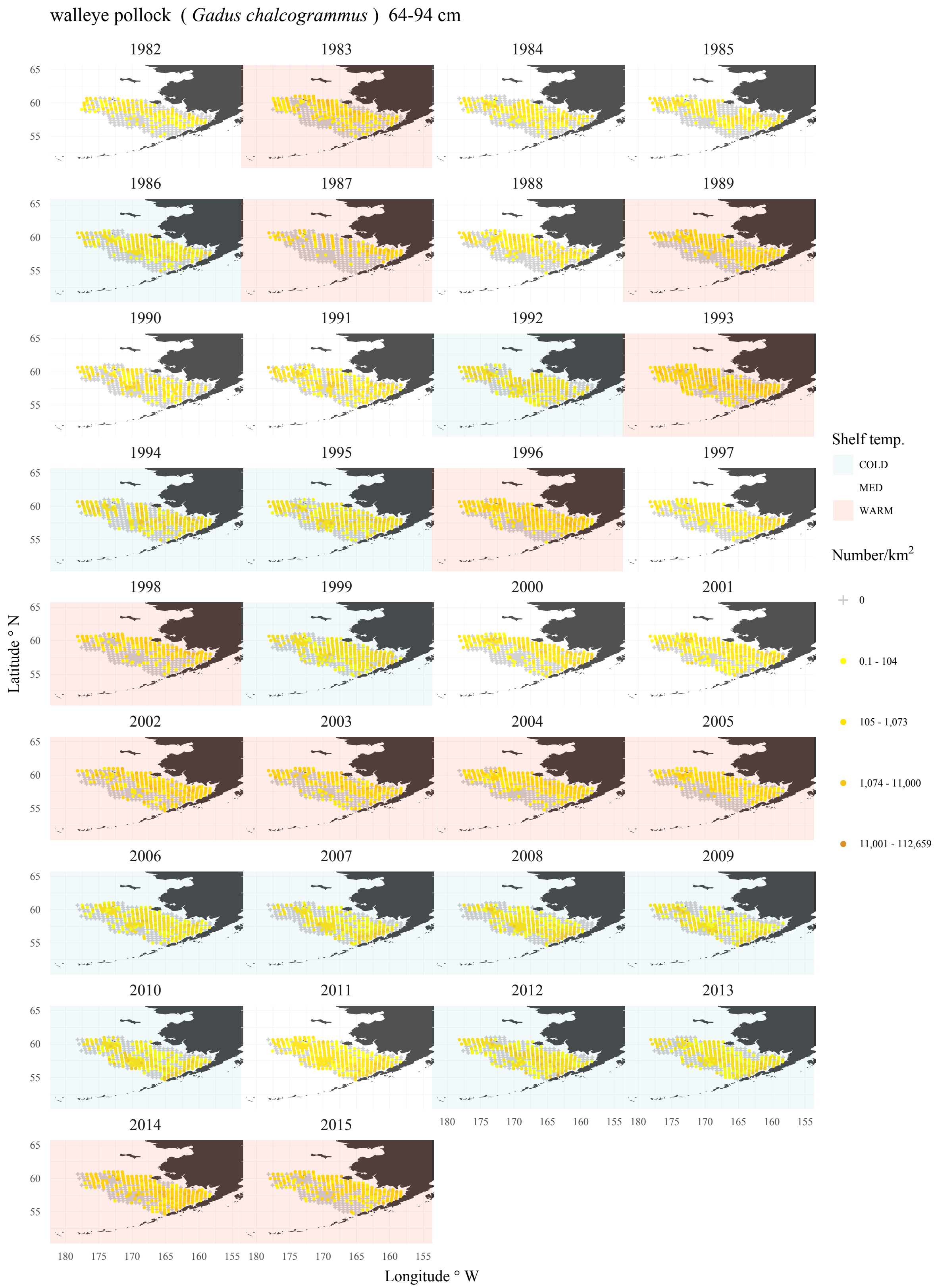


Figure 99 . -- Continued.

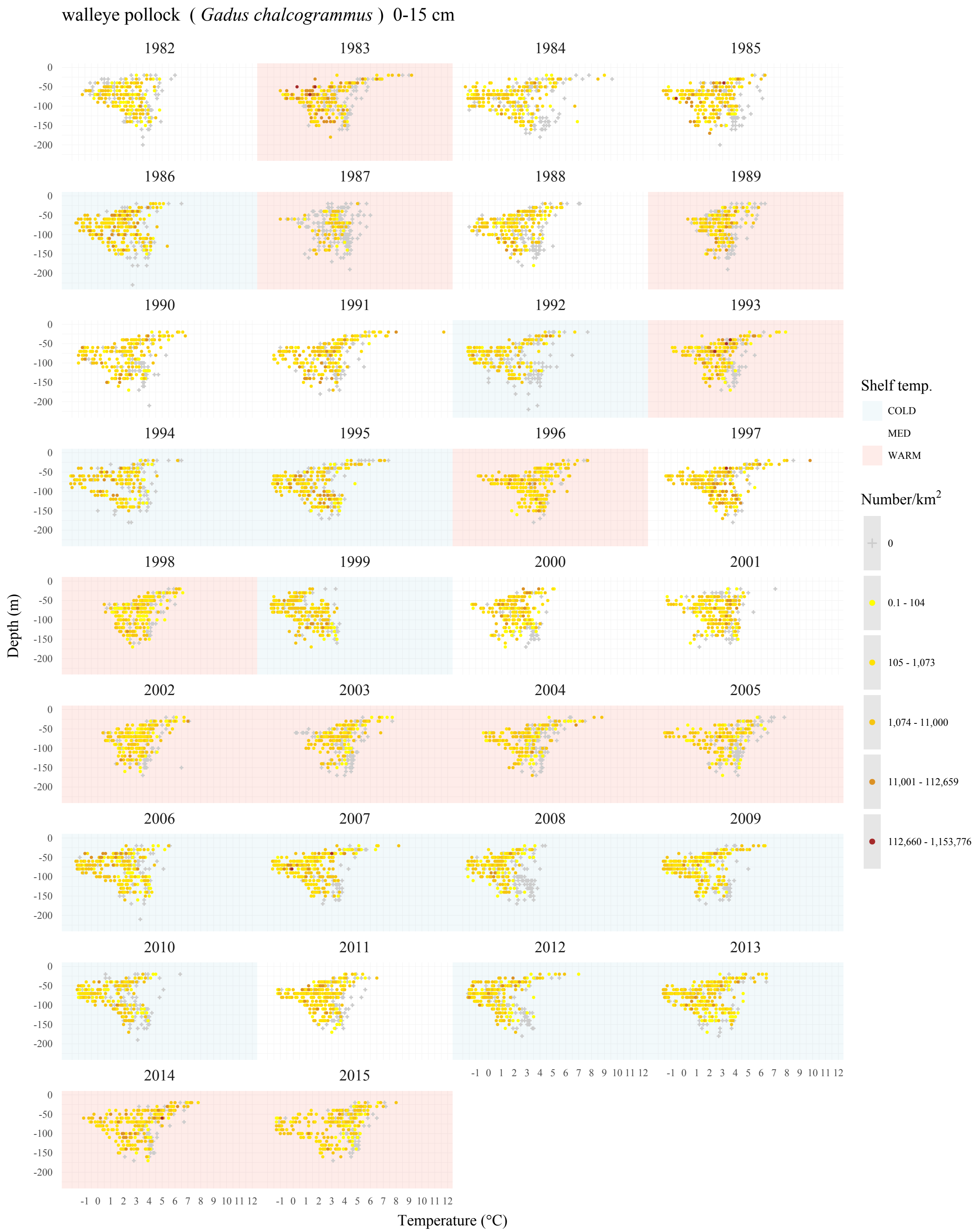


Figure 100 . -- The walleye pollock (*Gadus chalcogrammus*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

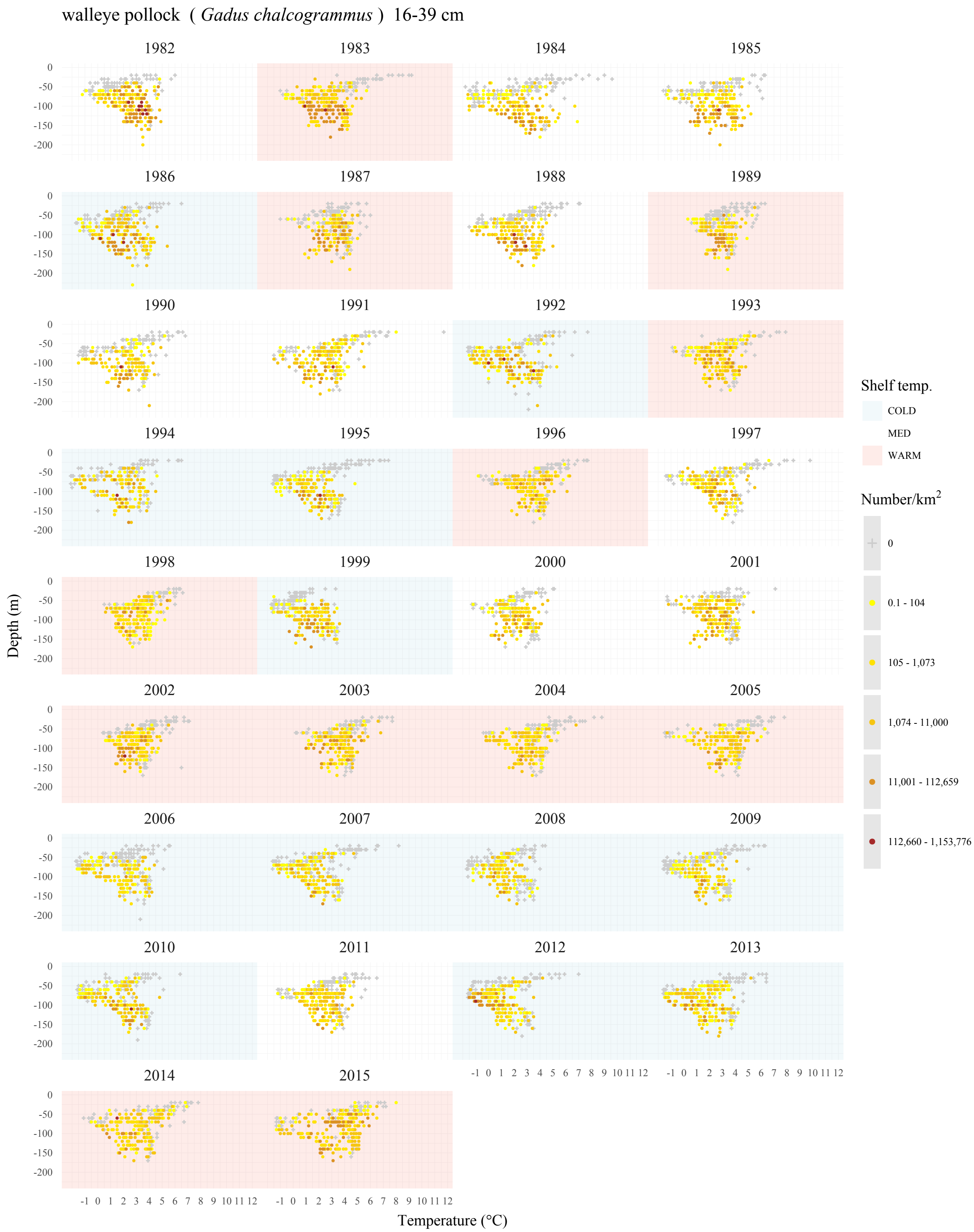


Figure 100 . -- Continued.

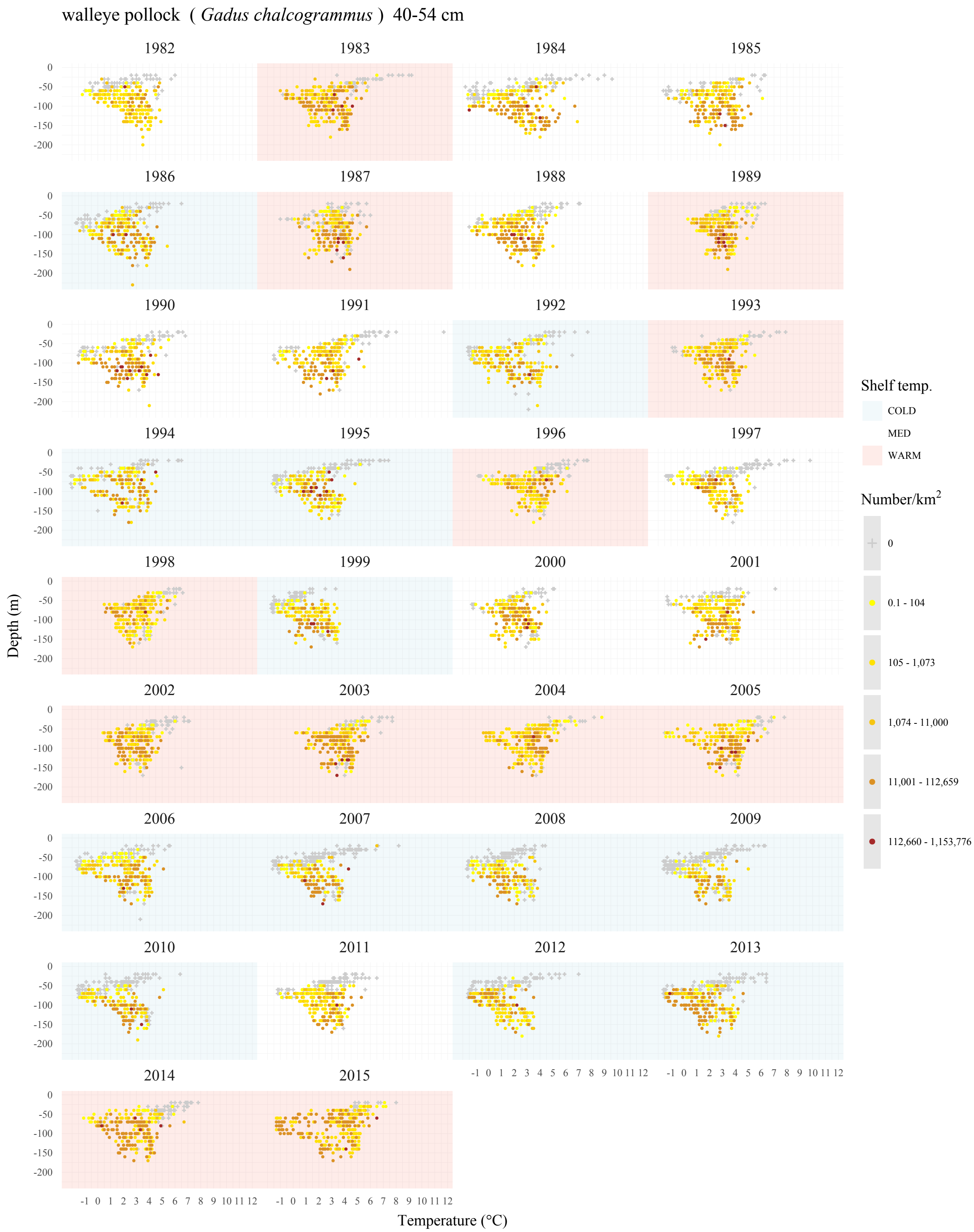


Figure 100 . -- Continued.

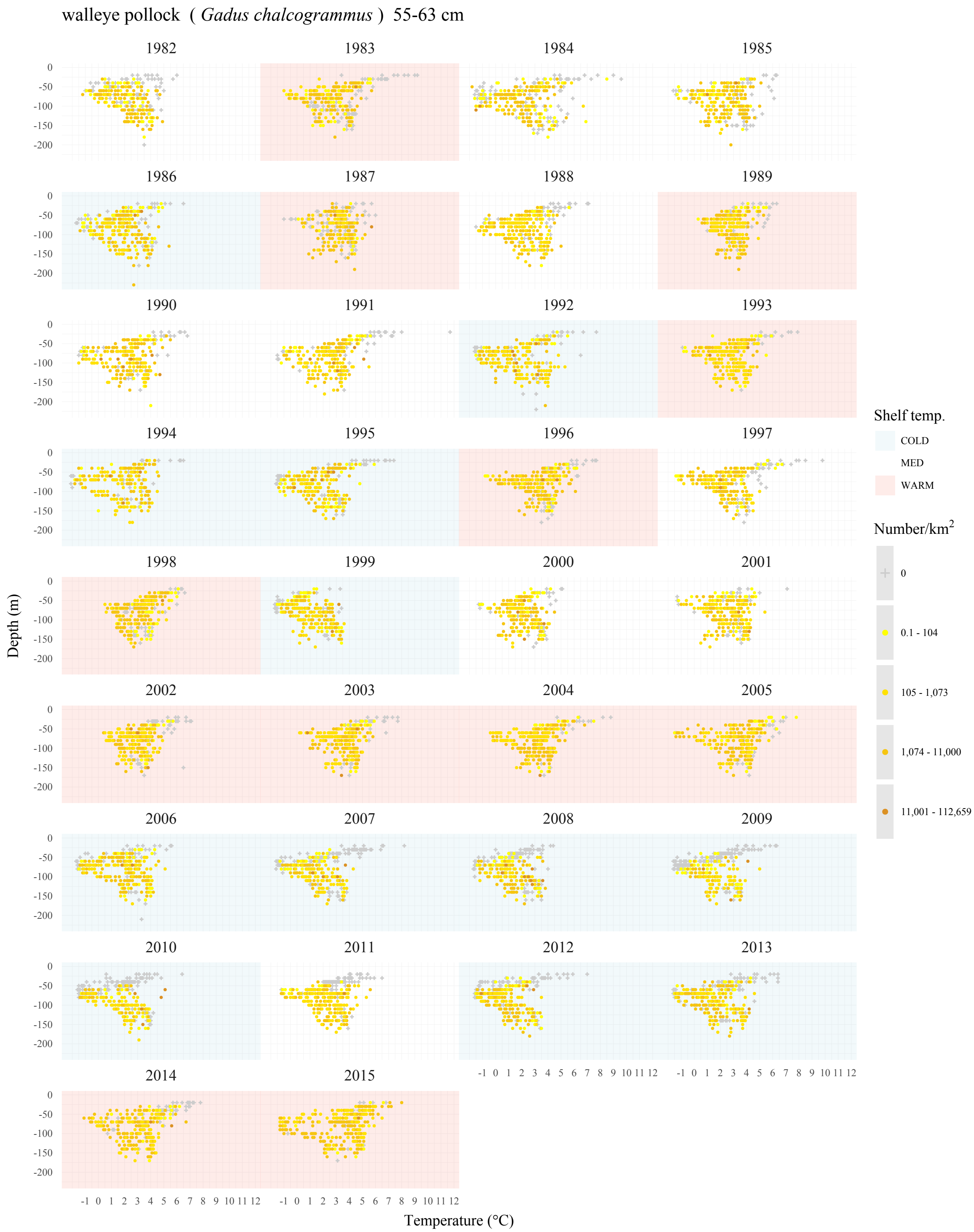


Figure 100 . -- Continued.

Figure 100 . -- Continued.

Figure 101 . -- The walleye pollock (*Gadus chalcogrammus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

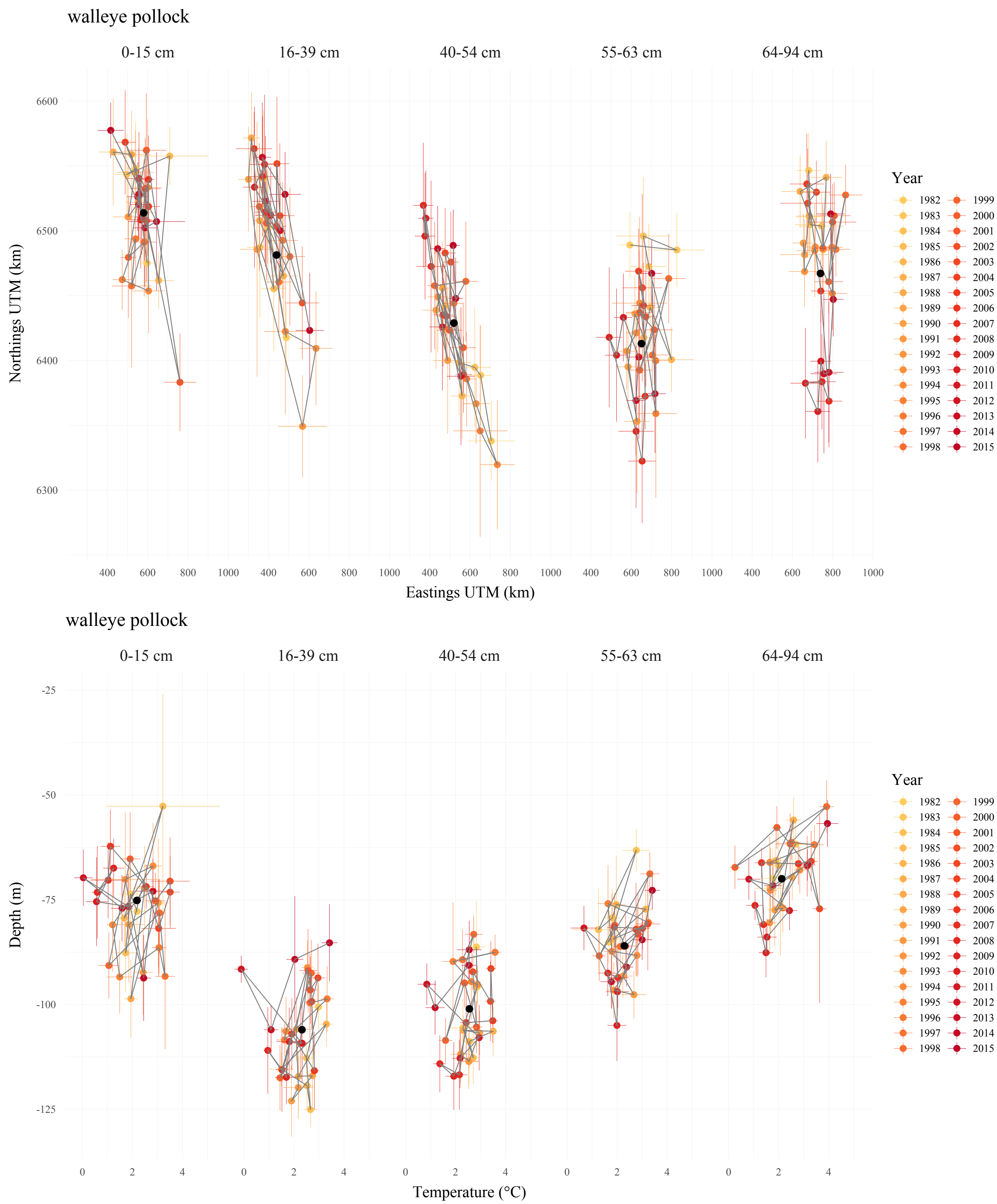


Figure 102 . -- The walleye pollock (*Gadus chalcogrammus*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

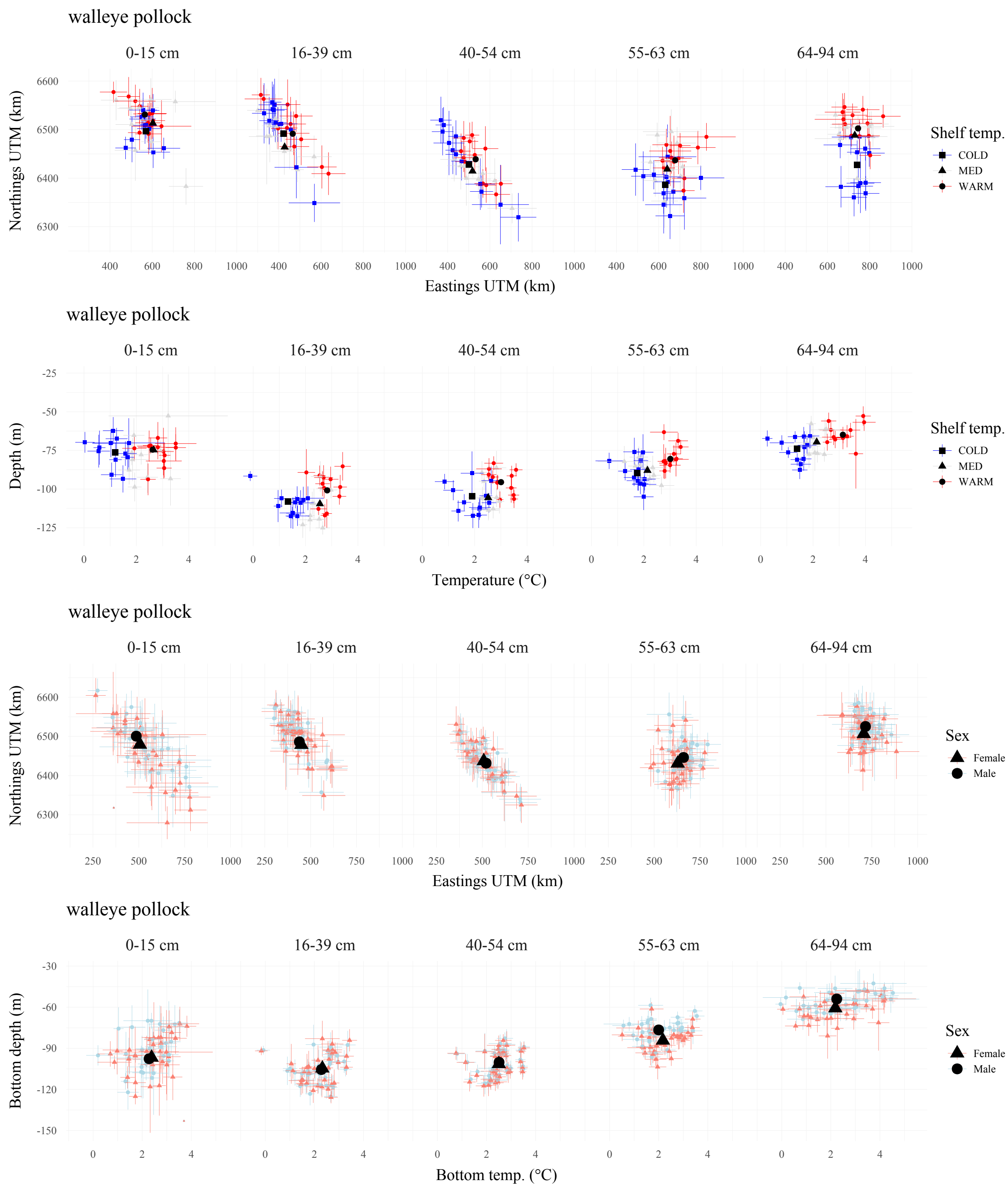


Figure 103 . -- The walleye pollock (*Gadus chalcogrammus*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

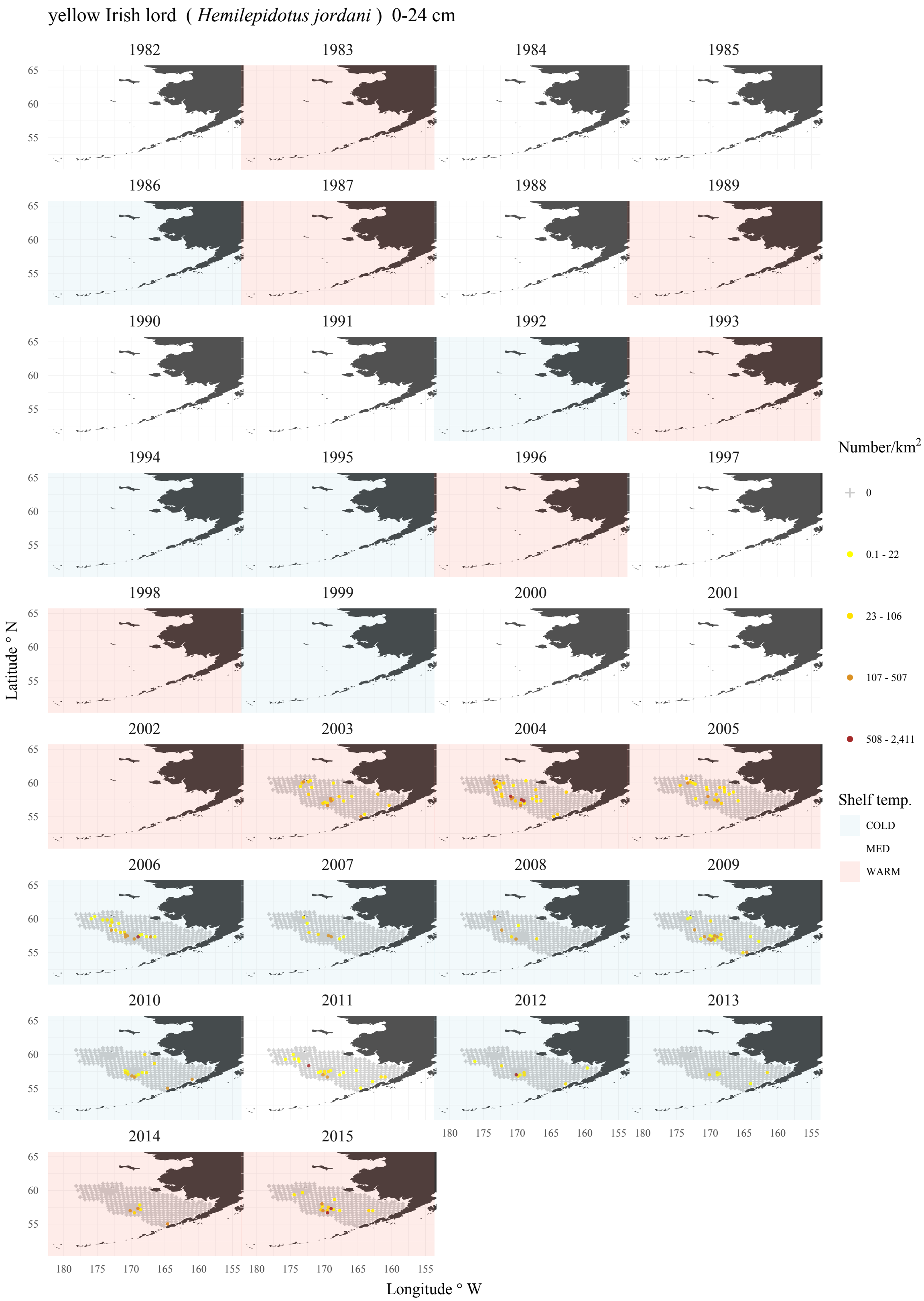


Figure 104 . -- The yellow Irish lord (*Hemilepidotus jordani*) CPUE by number weighted mean location for each length category for all years.

yellow Irish lord (*Hemilepidotus jordani*) 25-31 cm

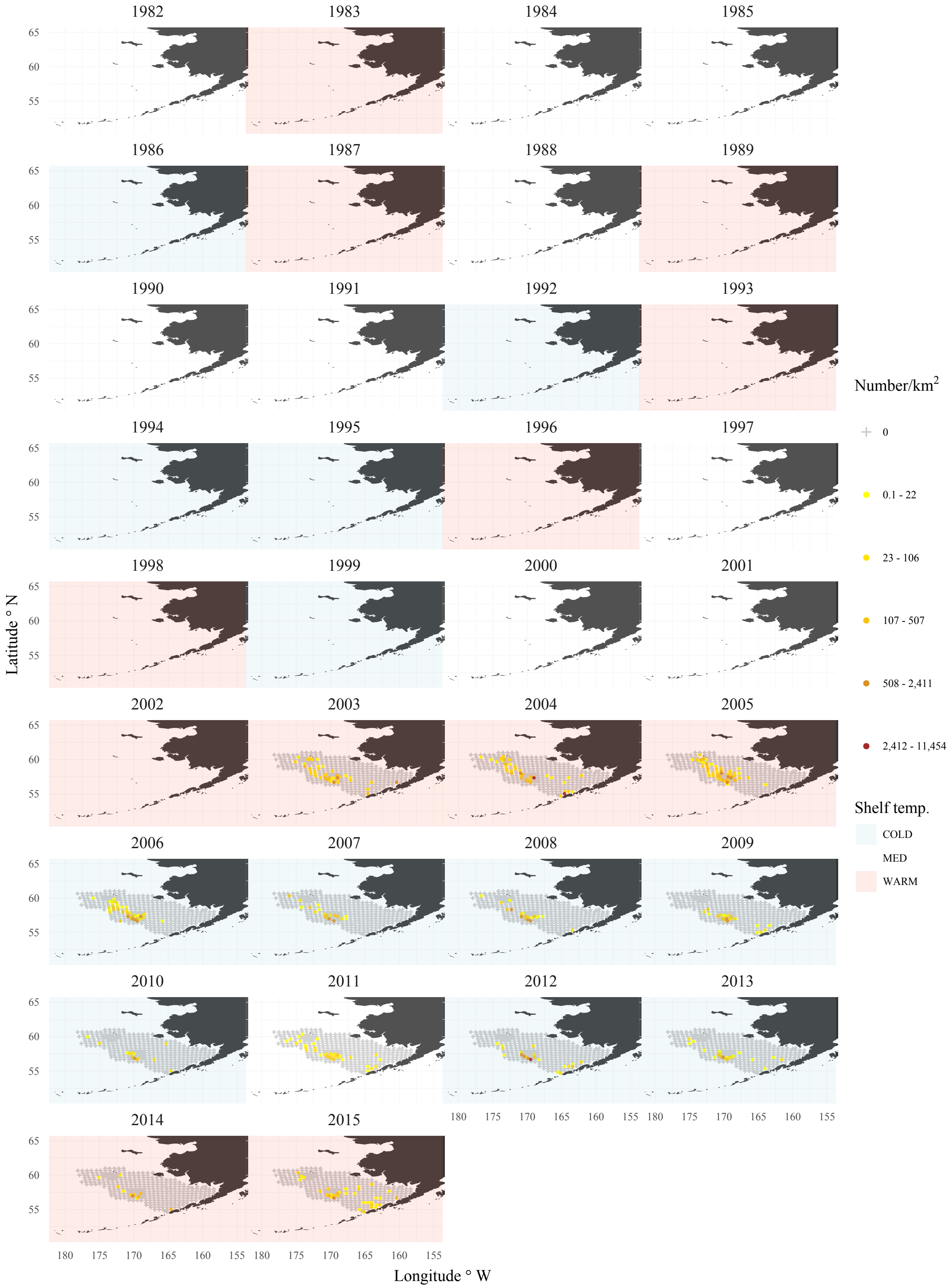


Figure 104 . -- Continued.

yellow Irish lord (*Hemilepidotus jordani*) 32-38 cm

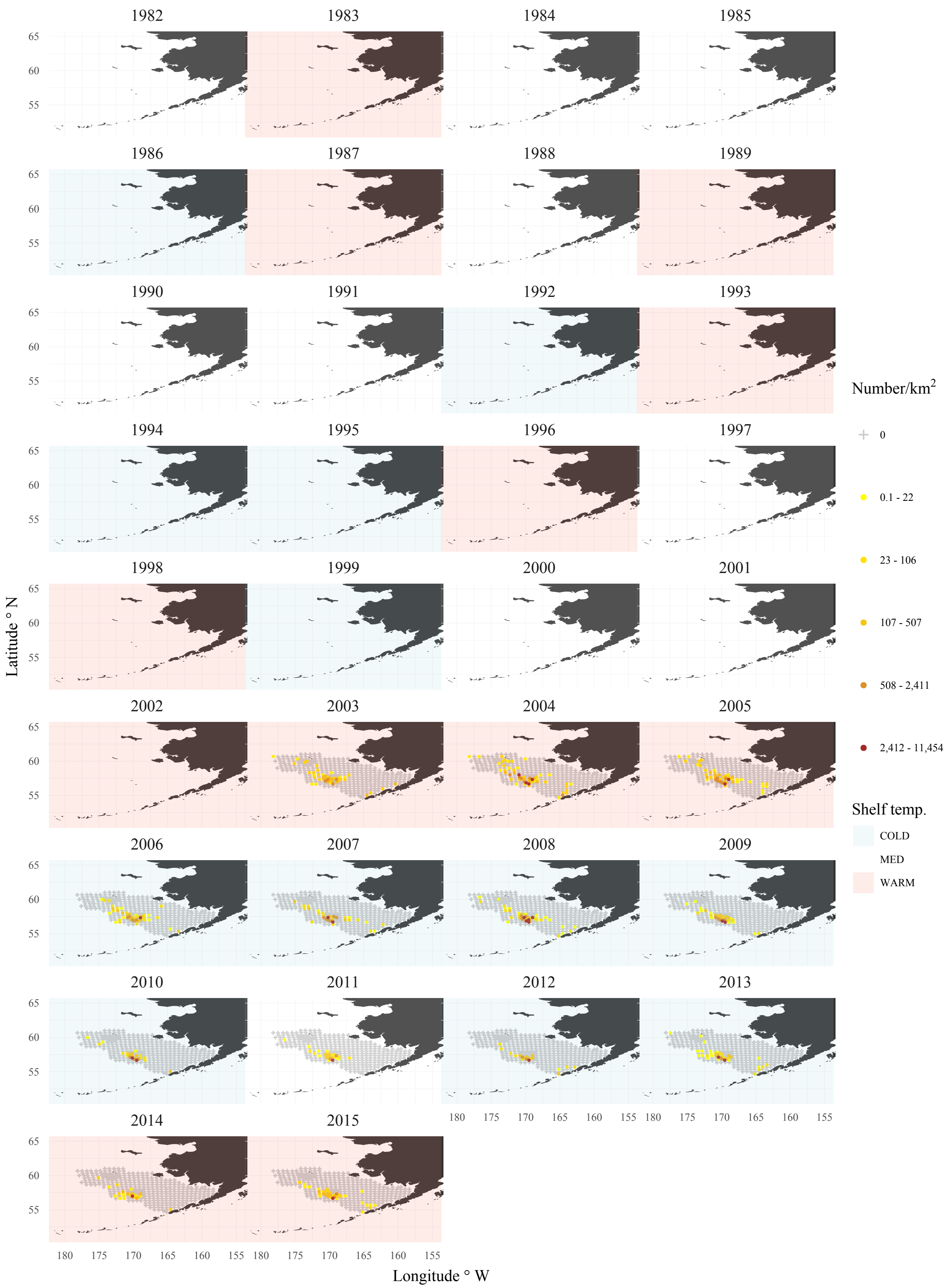


Figure 104 . -- Continued.

yellow Irish lord (*Hemilepidotus jordani*) 39-42 cm

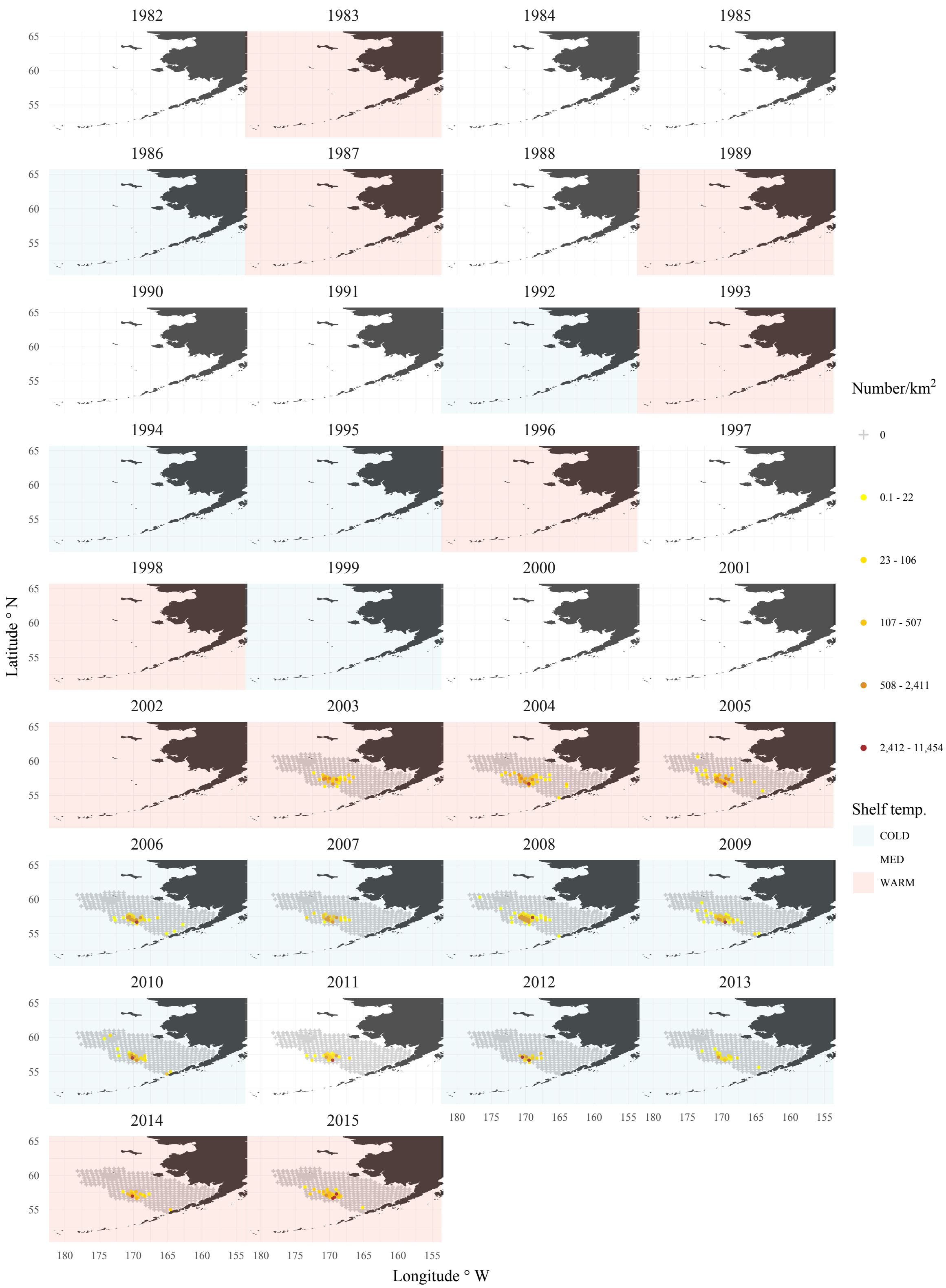


Figure 104 . -- Continued.

yellow Irish lord (*Hemilepidotus jordani*) 43-51 cm

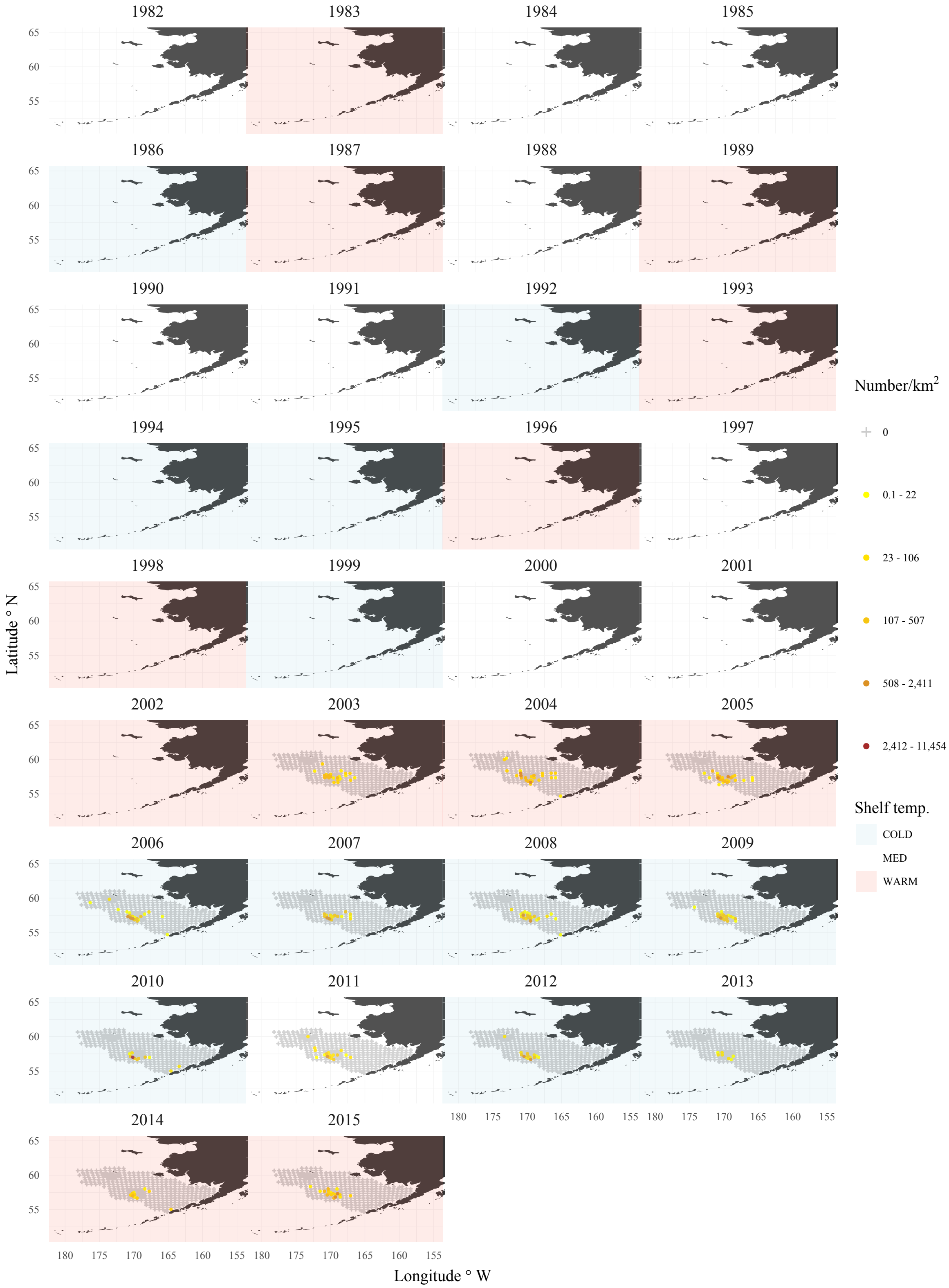


Figure 104 . -- Continued.

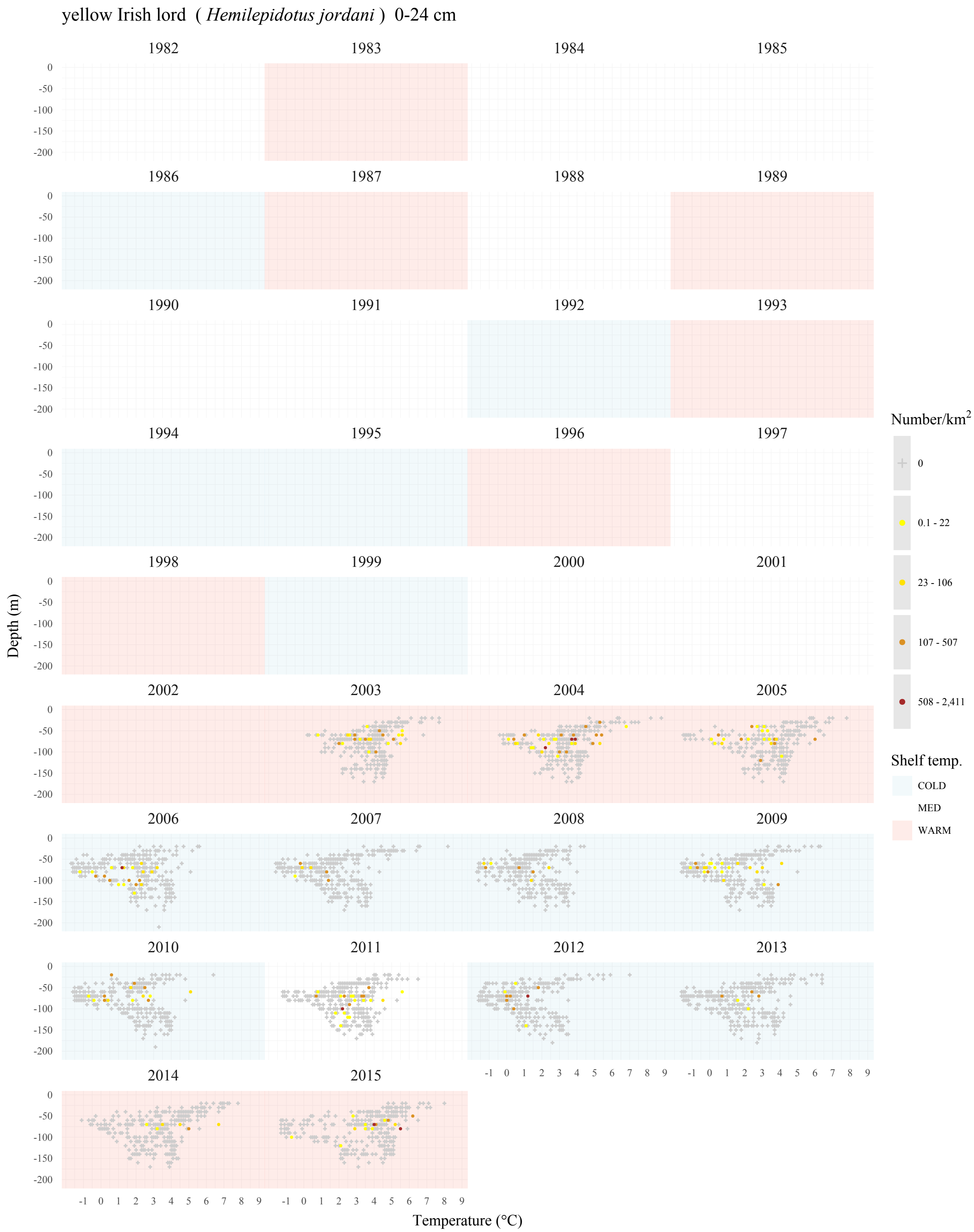


Figure 105 . -- The yellow Irish lord (*Hemilepidotus jordani*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

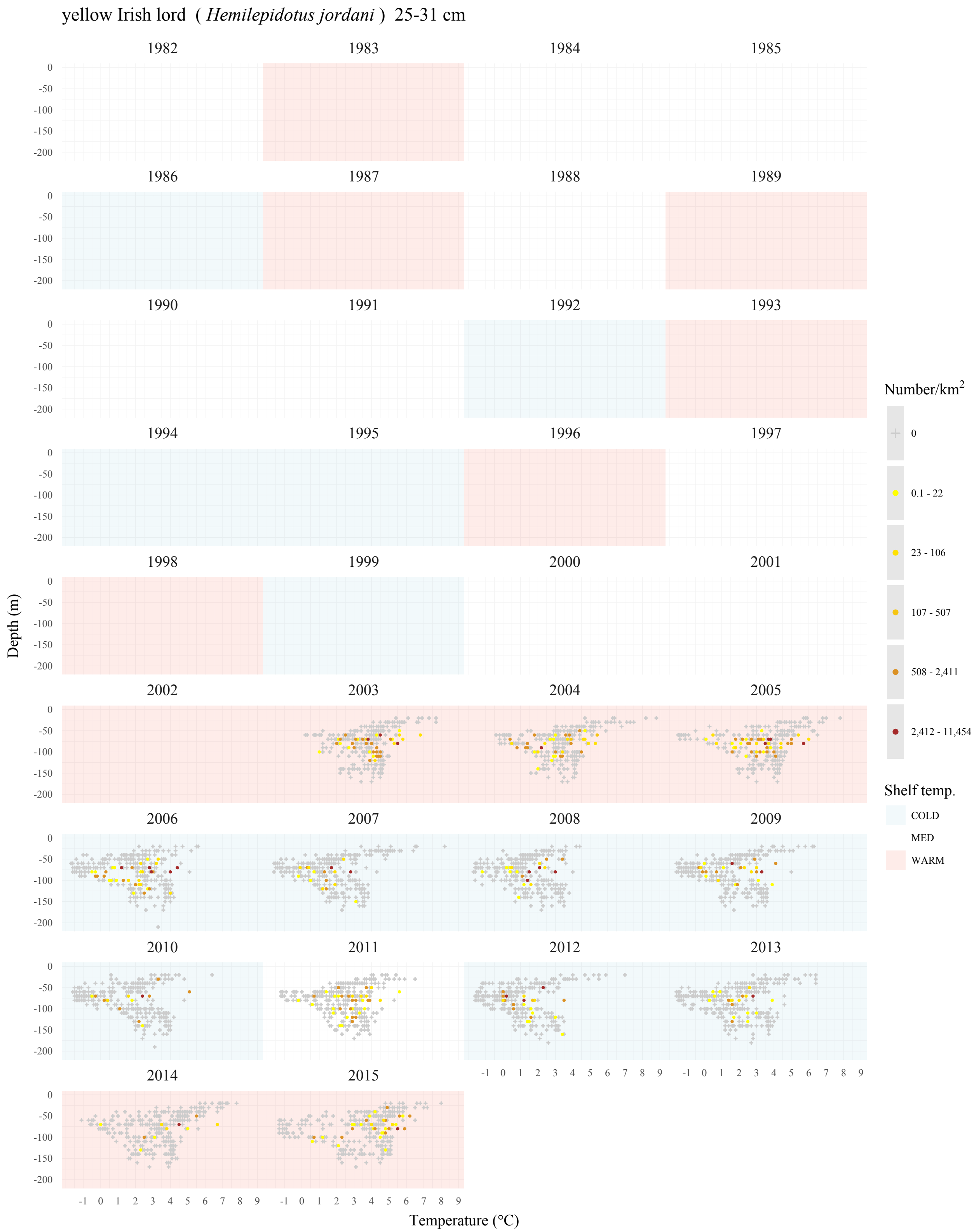


Figure 105 . -- Continued.

yellow Irish lord (*Hemilepidotus jordani*) 32-38 cm

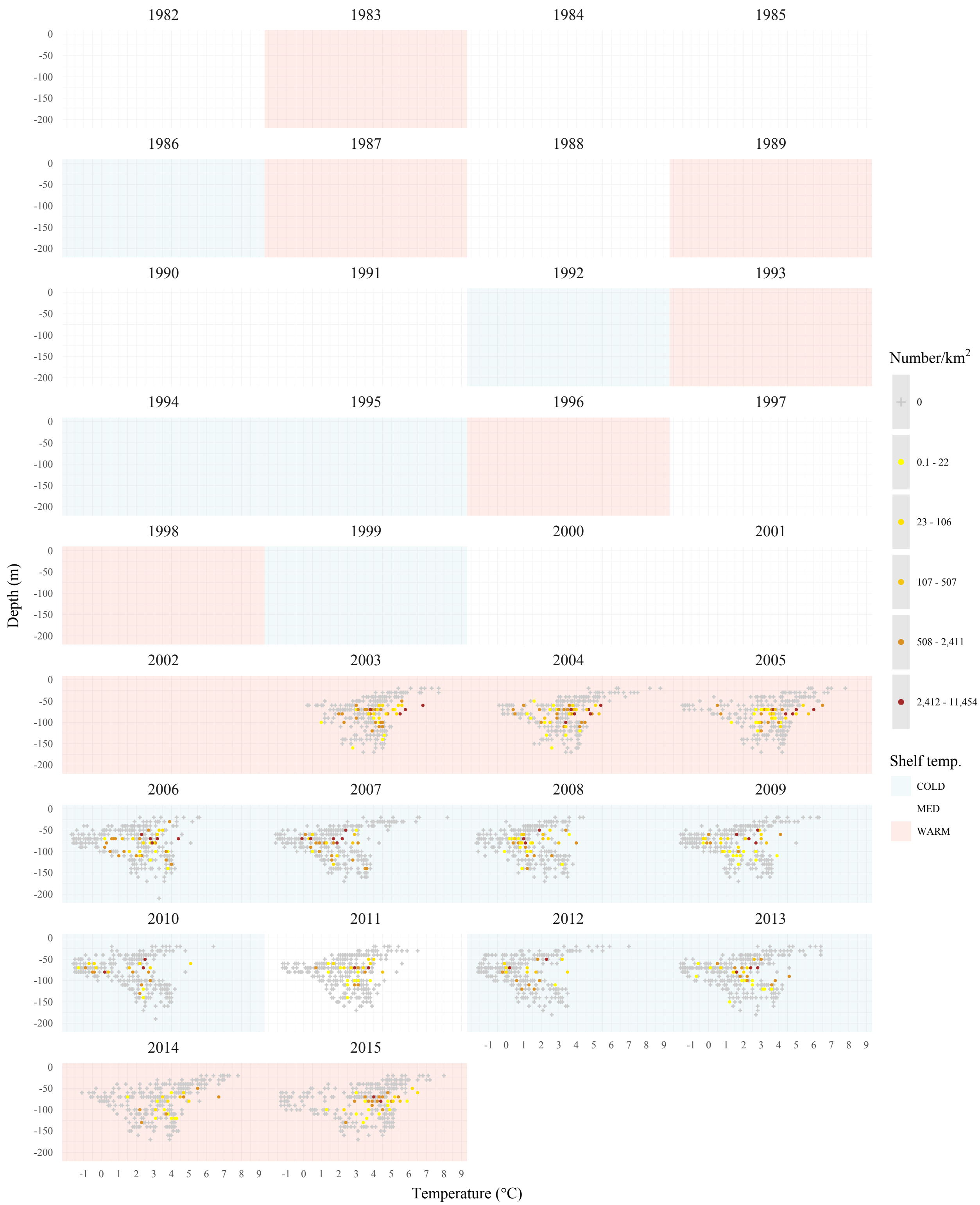


Figure 105 . -- Continued.

yellow Irish lord (*Hemilepidotus jordani*) 39-42 cm

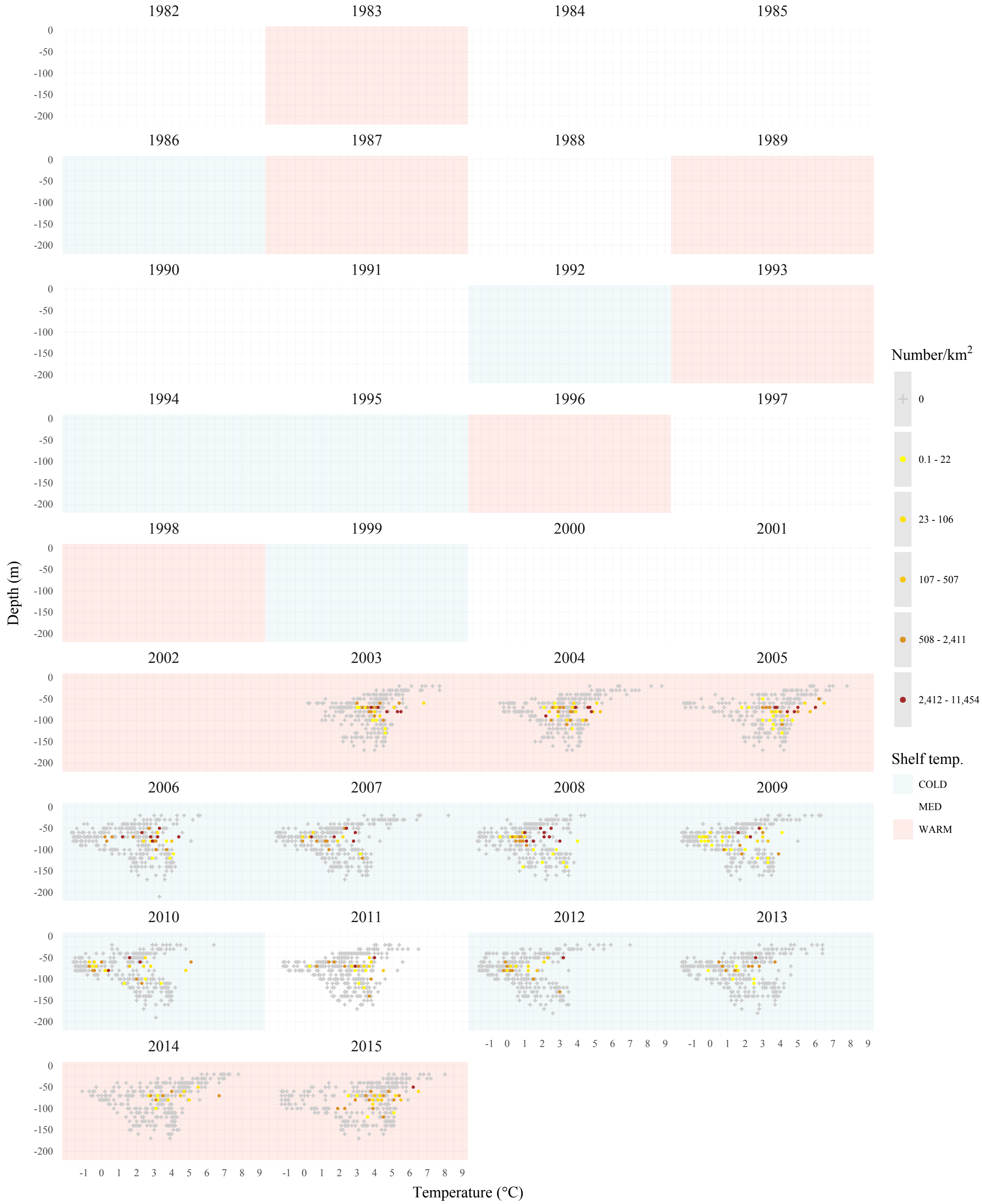


Figure 105 . -- Continued.

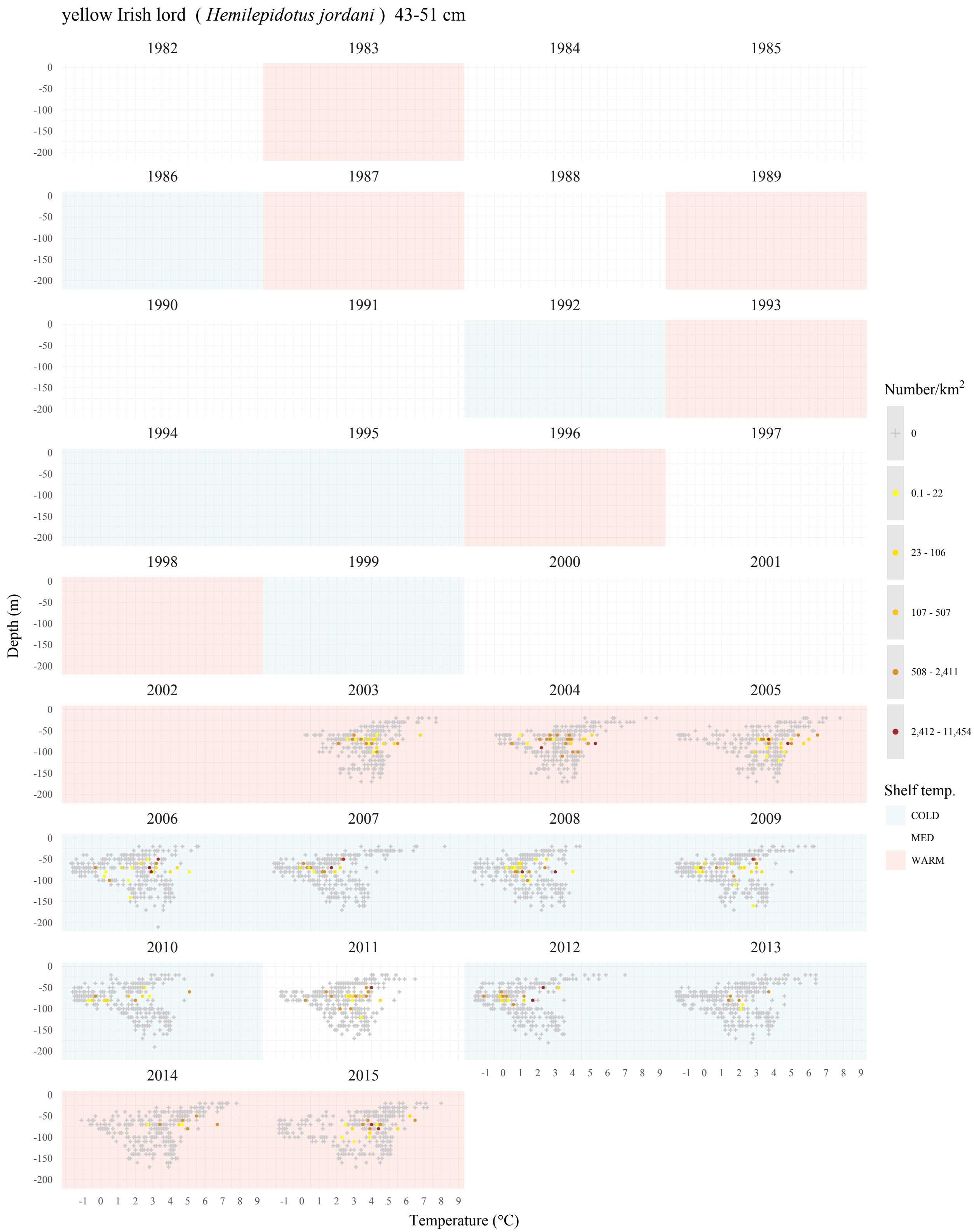
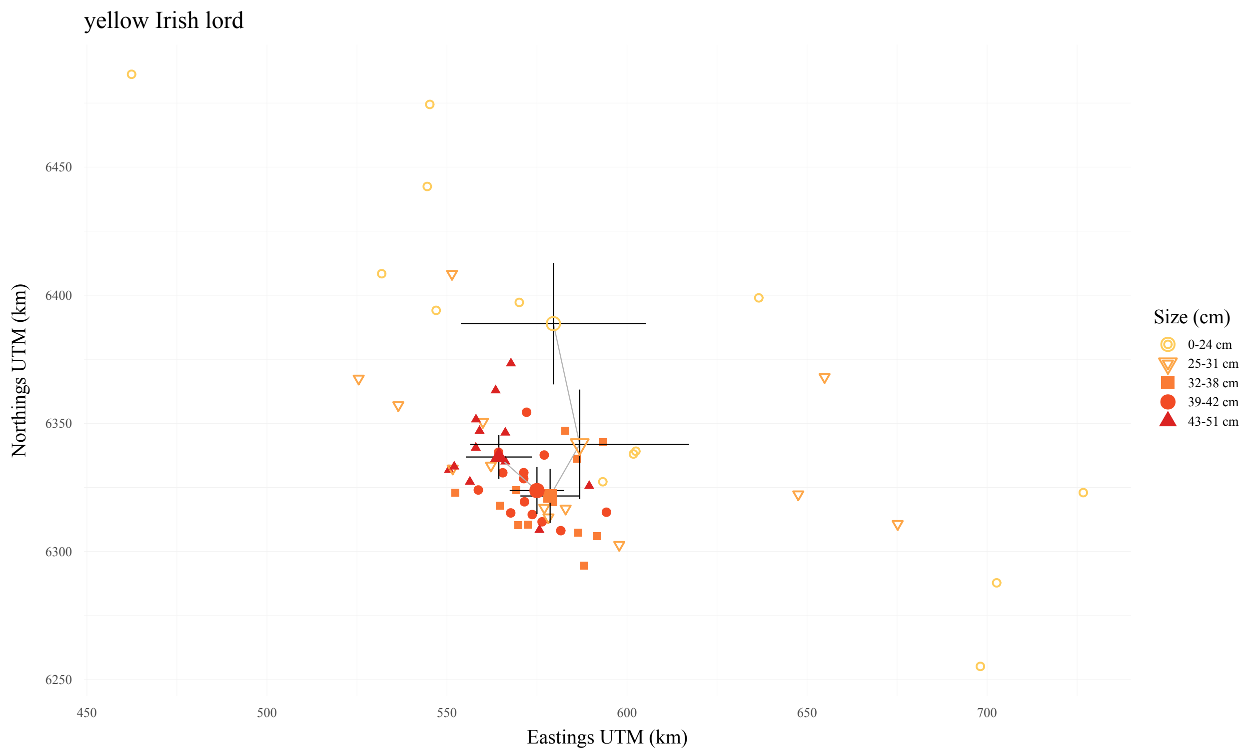


Figure 105 . -- Continued.



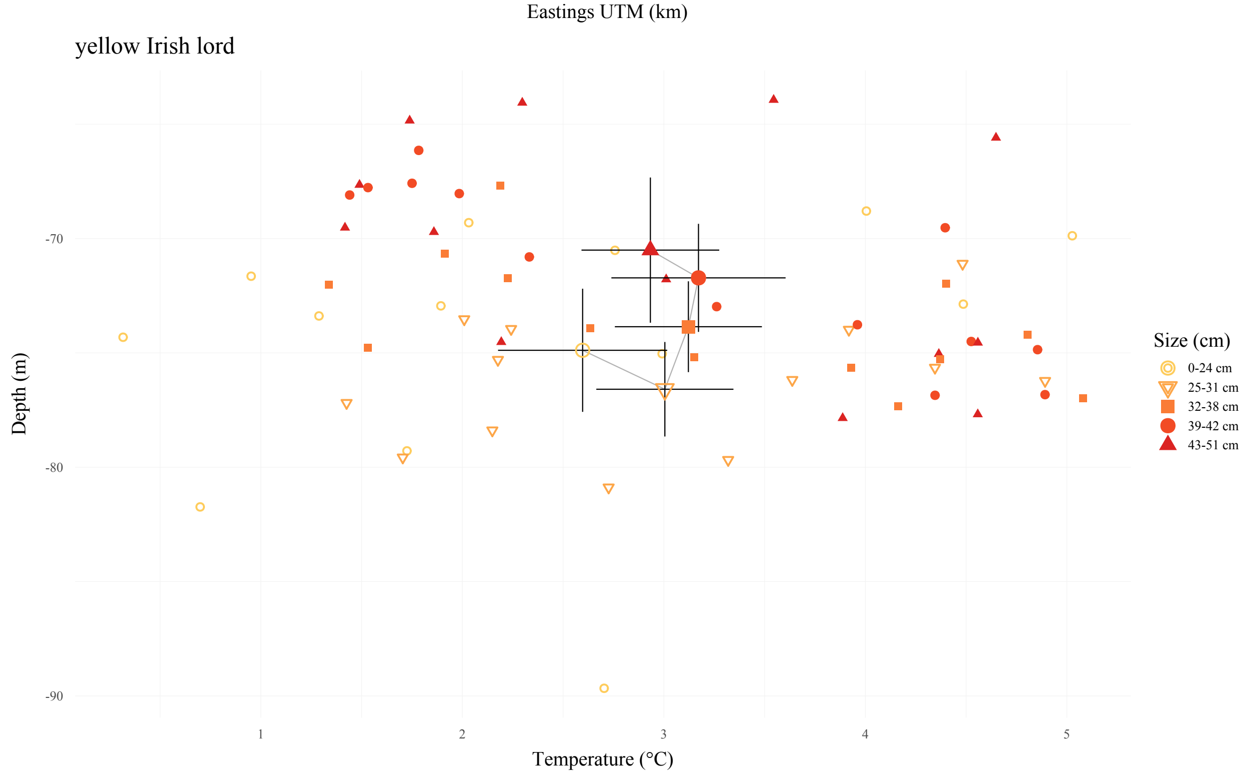


Figure 106 . -- The yellow Irish lord (*Hemilepidotus jordani*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.

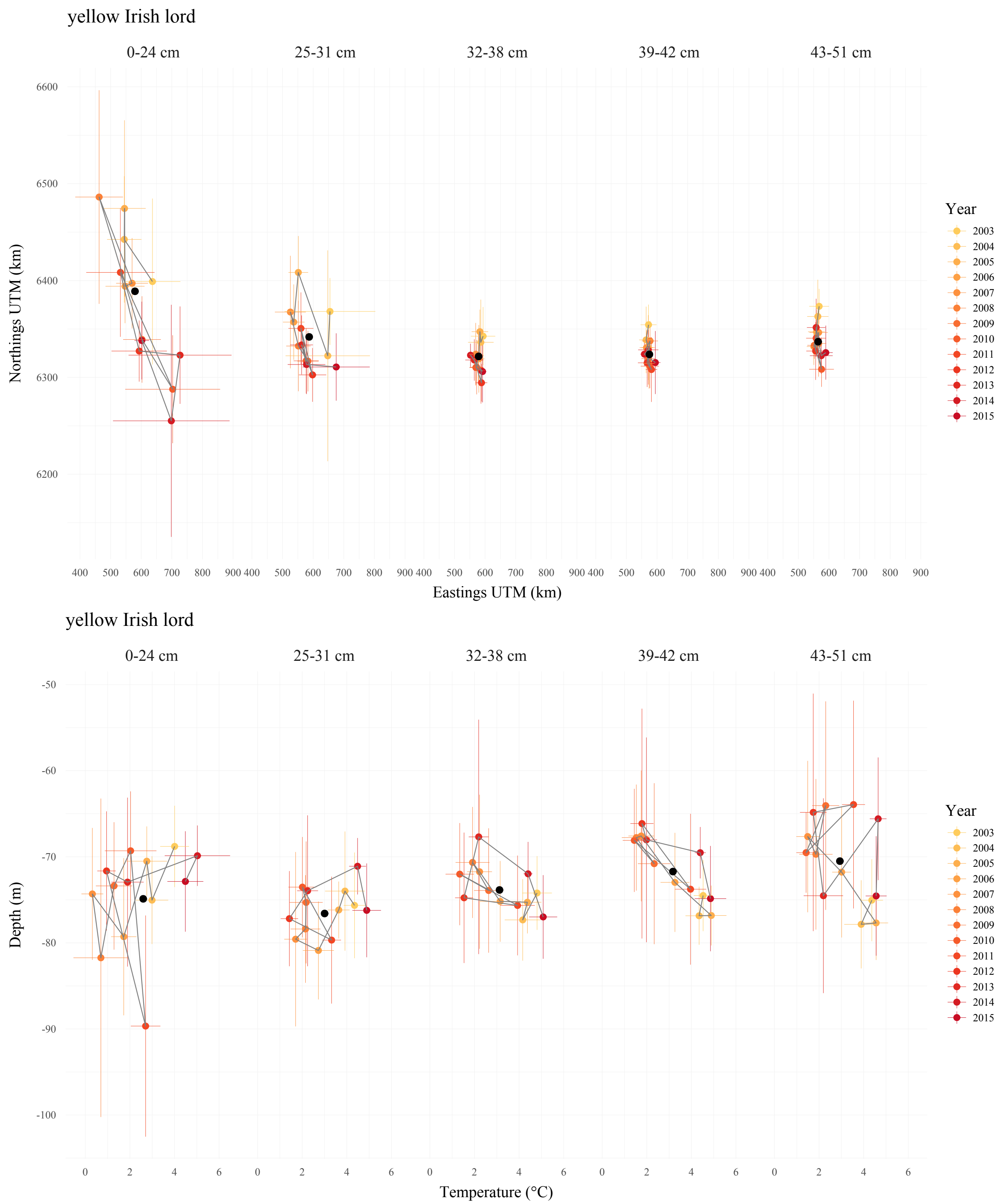


Figure 107 . -- The yellow Irish lord (*Hemilepidotus jordani*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

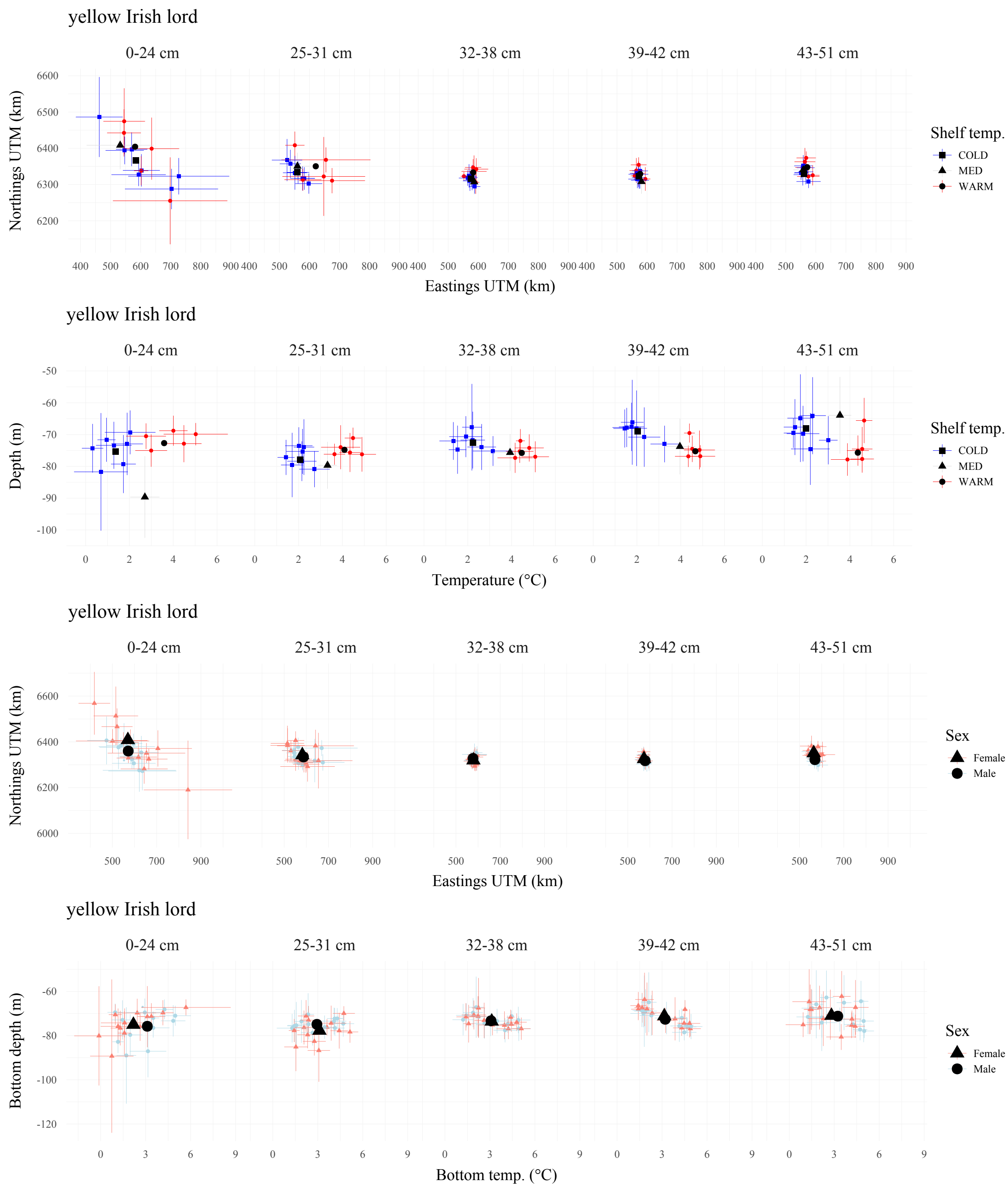


Figure 108 . -- The yellow Irish lord (*Hemilepidotus jordani*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

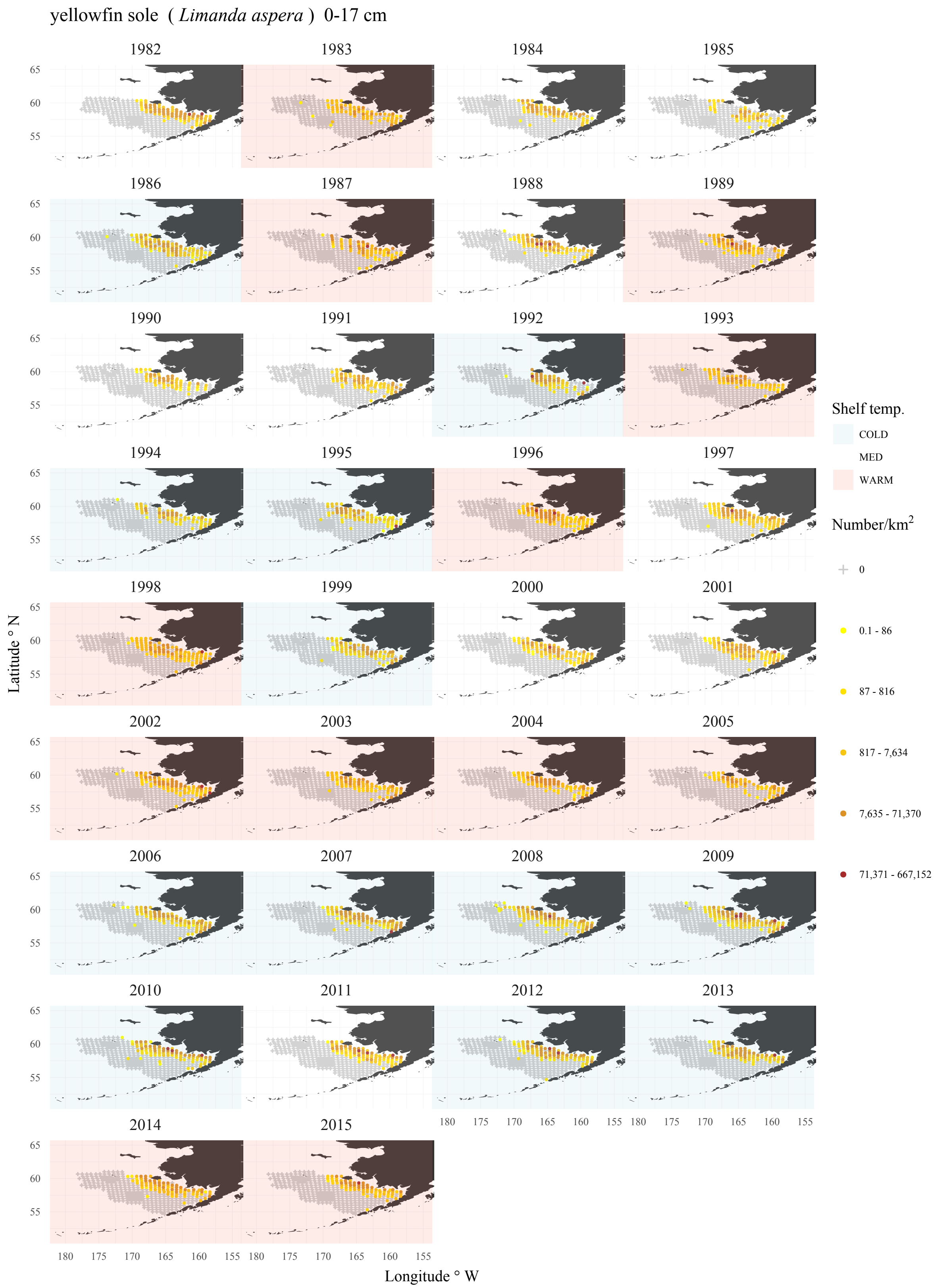


Figure 109 . -- The yellowfin sole (*Limanda aspera*) CPUE by number weighted mean location for each length category for all years.

yellowfin sole (*Limanda aspera*) 18-23 cm

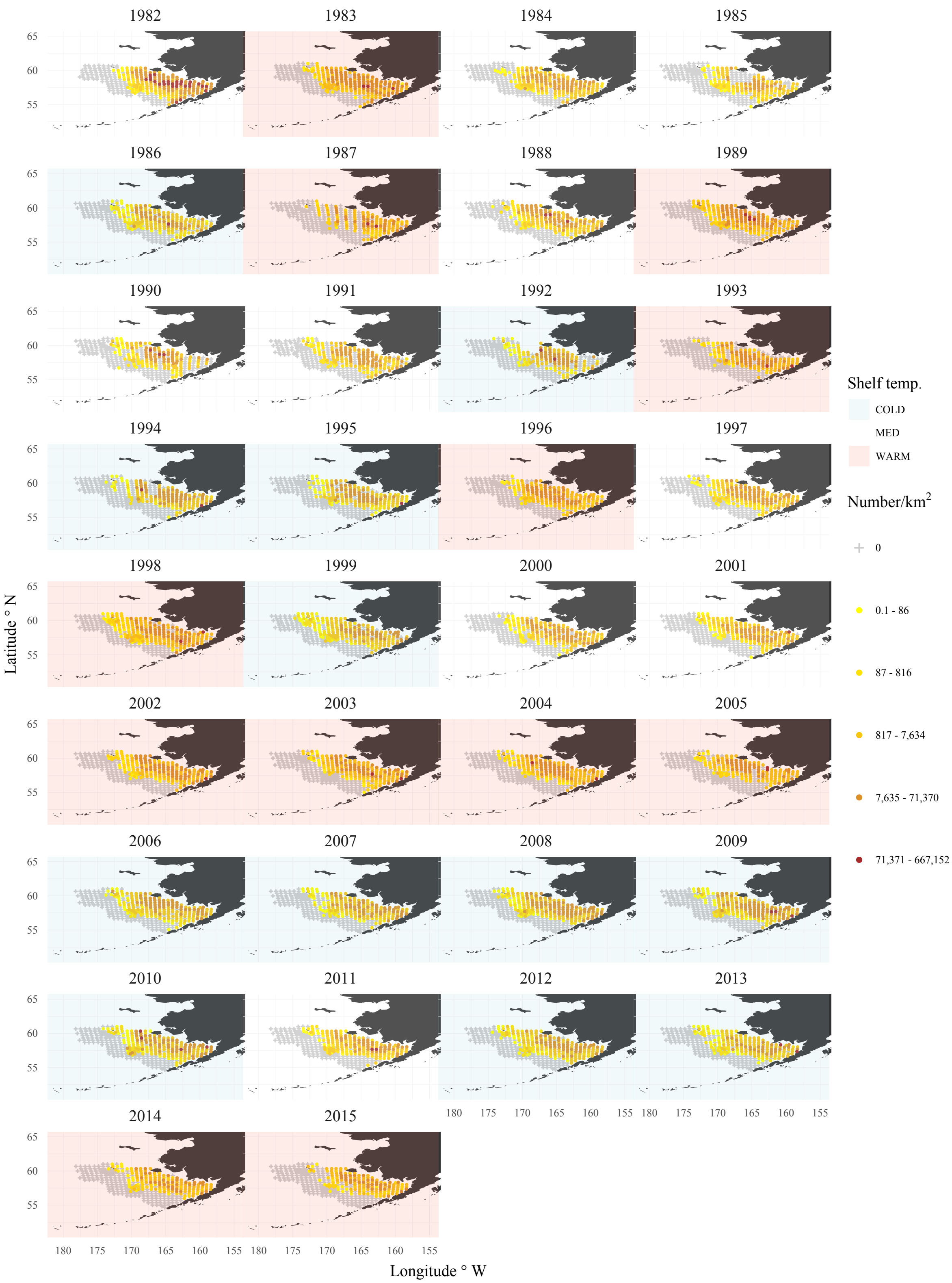


Figure 109 . -- Continued.

yellowfin sole (*Limanda aspera*) 24-30 cm

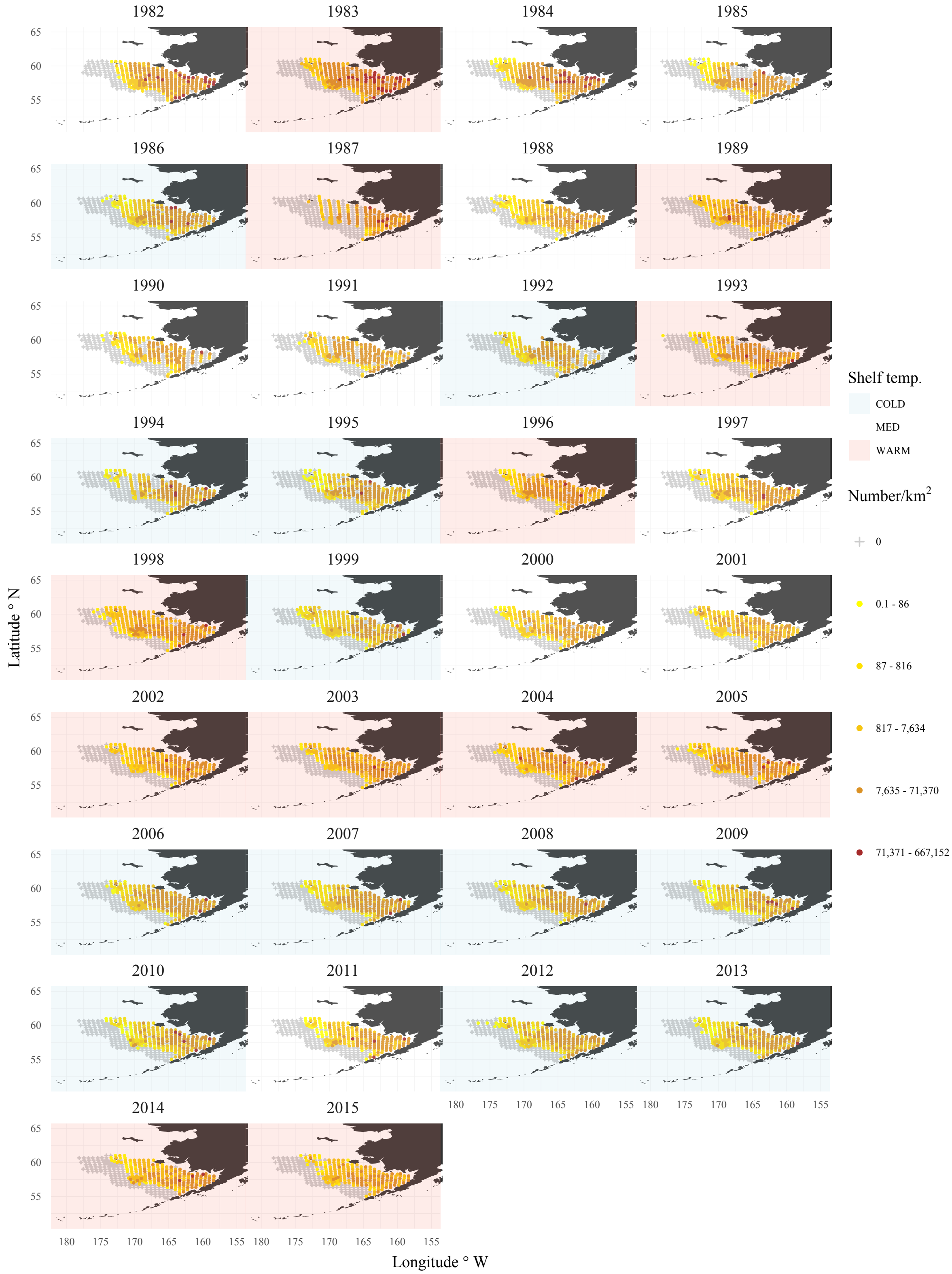


Figure 109 . -- Continued.

yellowfin sole (*Limanda aspera*) 31-34 cm

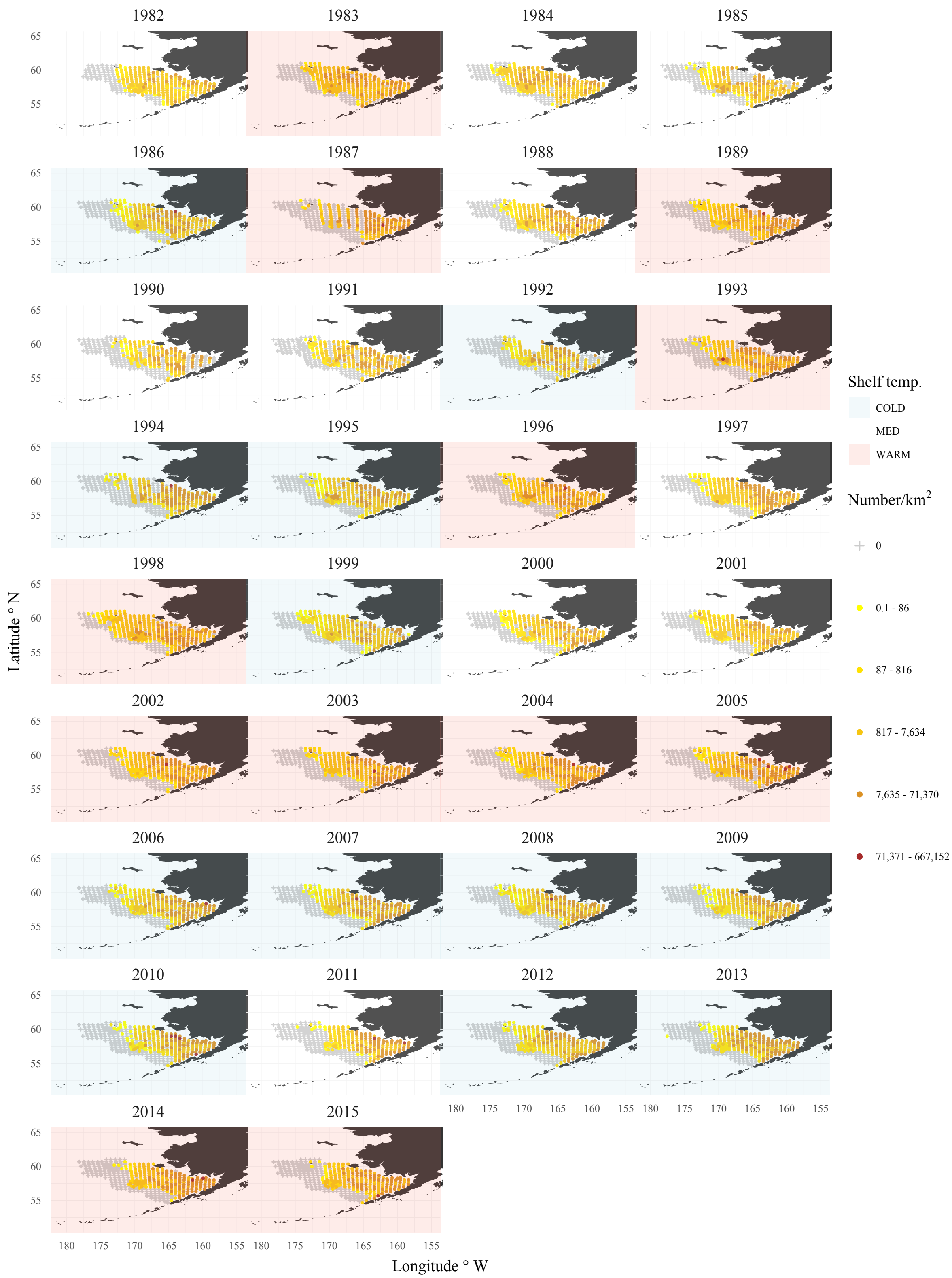


Figure 109 . -- Continued.

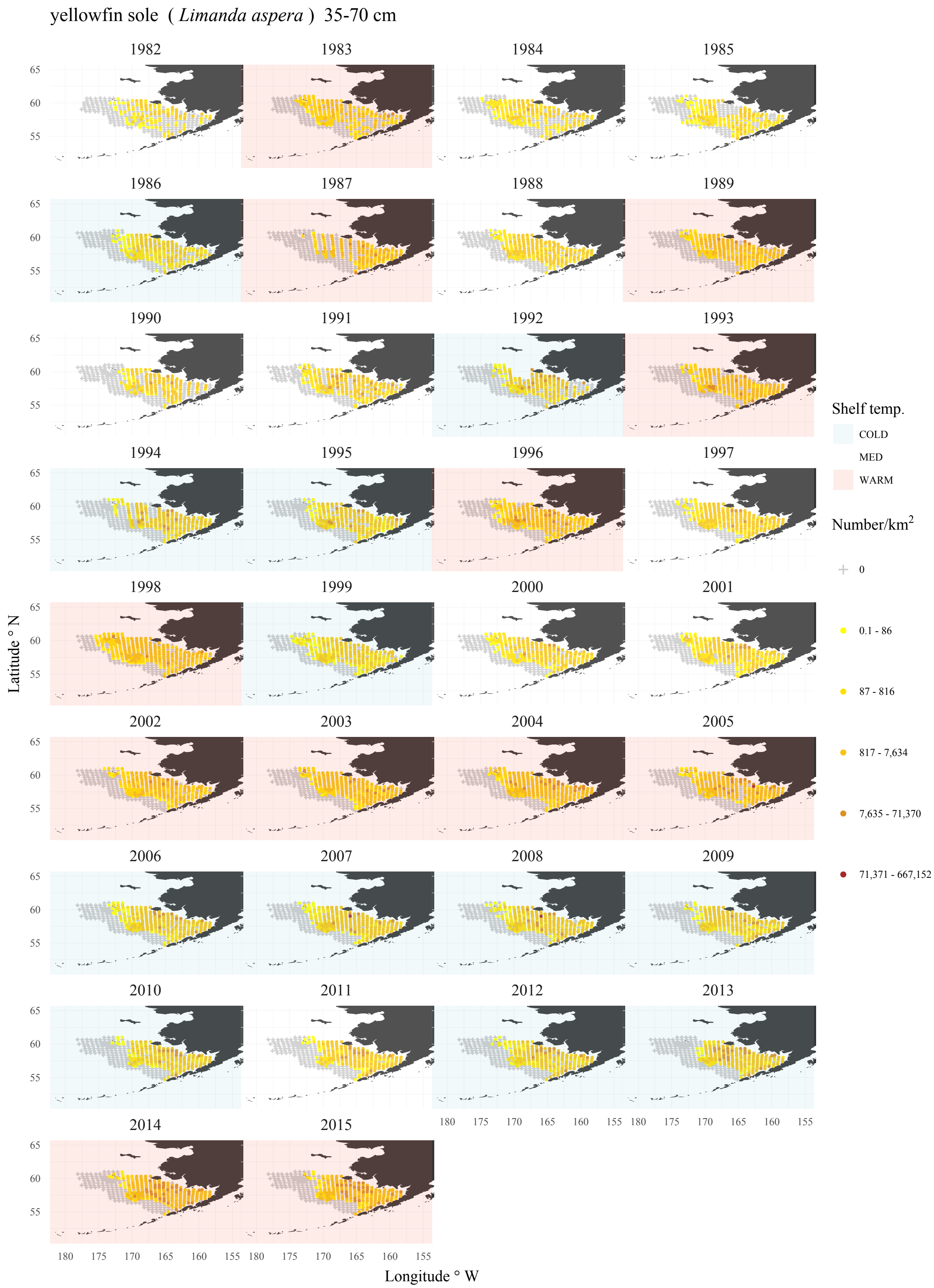


Figure 109 . -- Continued.

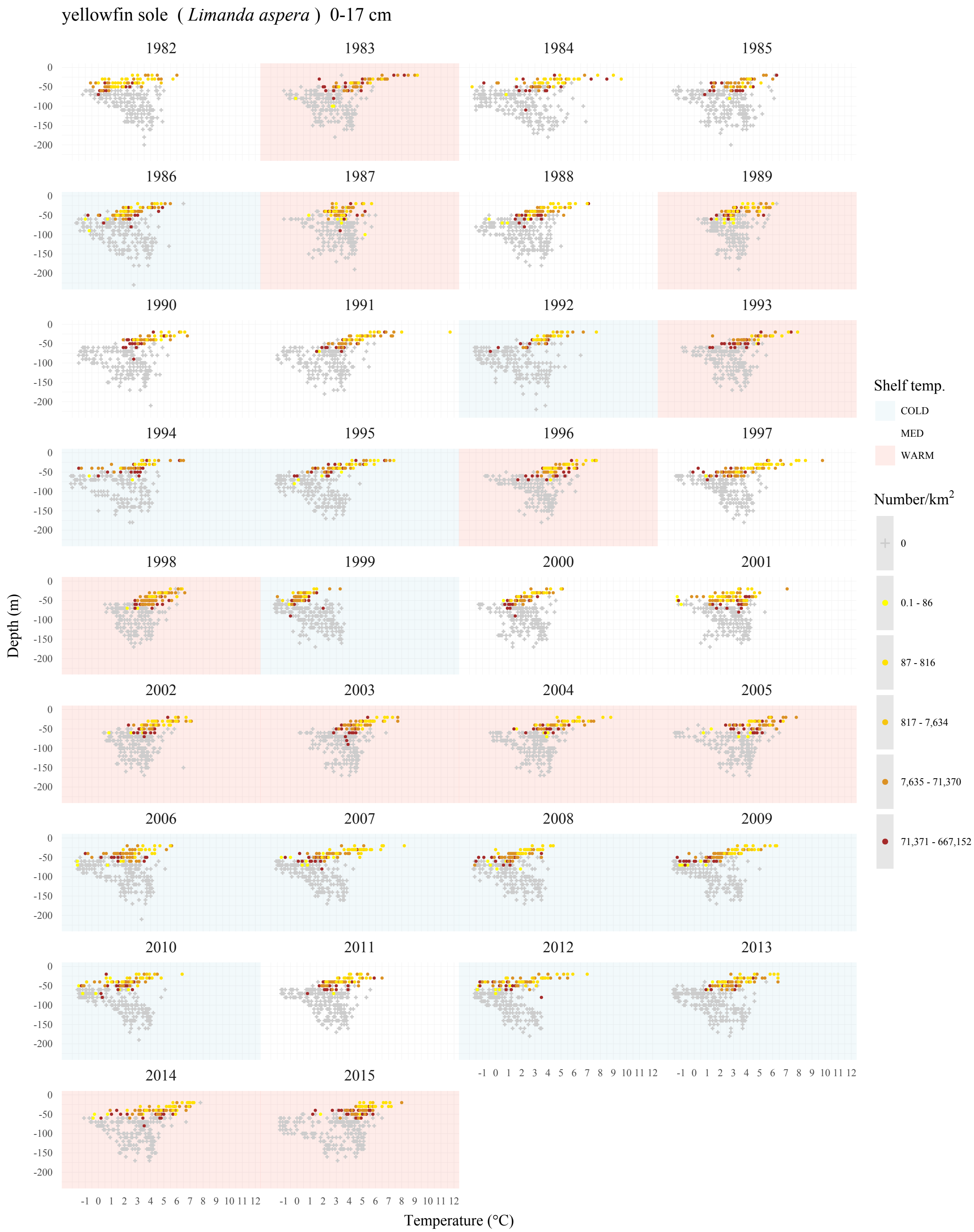


Figure 110 . -- The yellowfin sole (*Limanda aspera*) CPUE by number weighted mean mean bottom depth (m) and bottom temperature (° C) for each length category for all years.

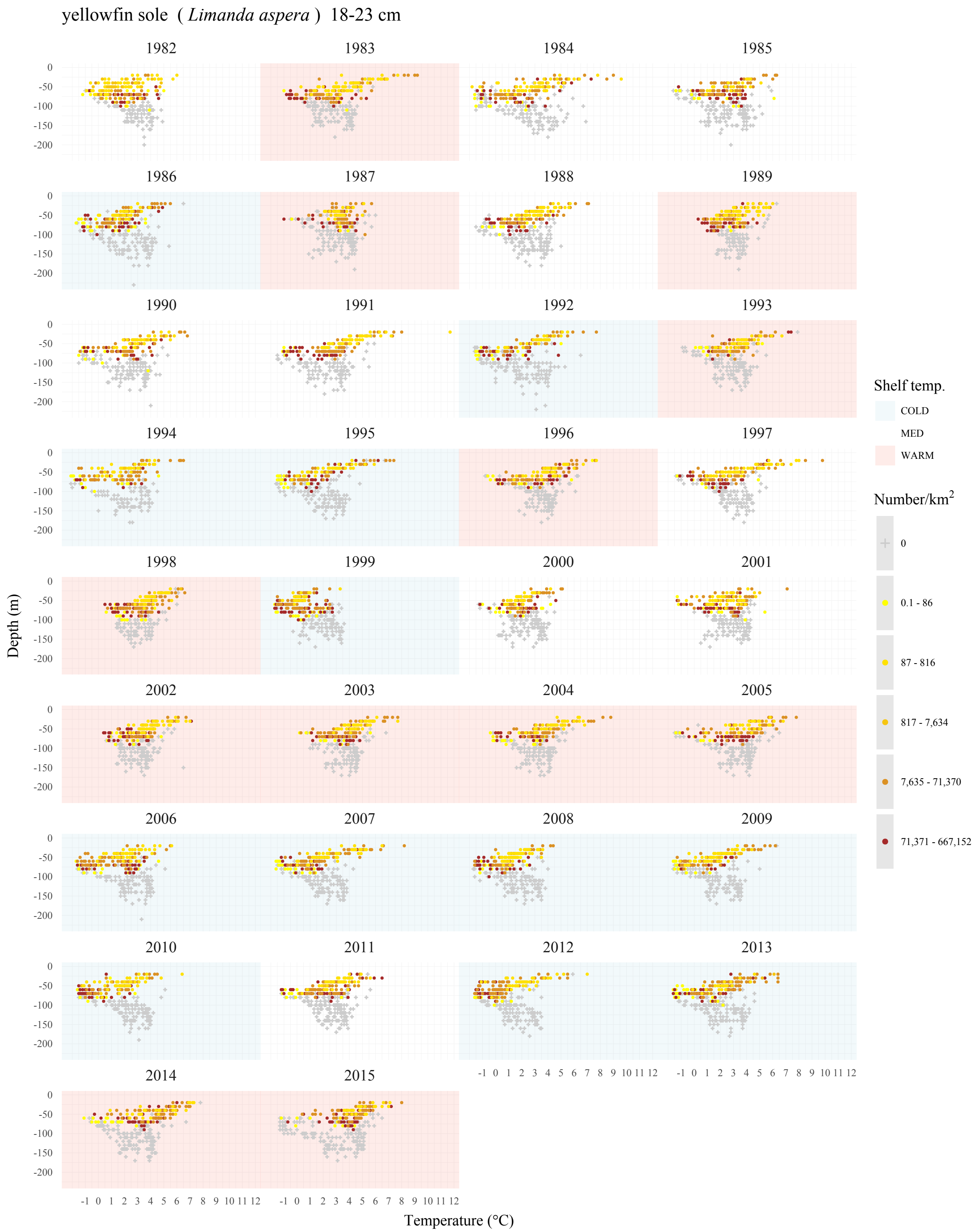


Figure 110 . -- Continued.

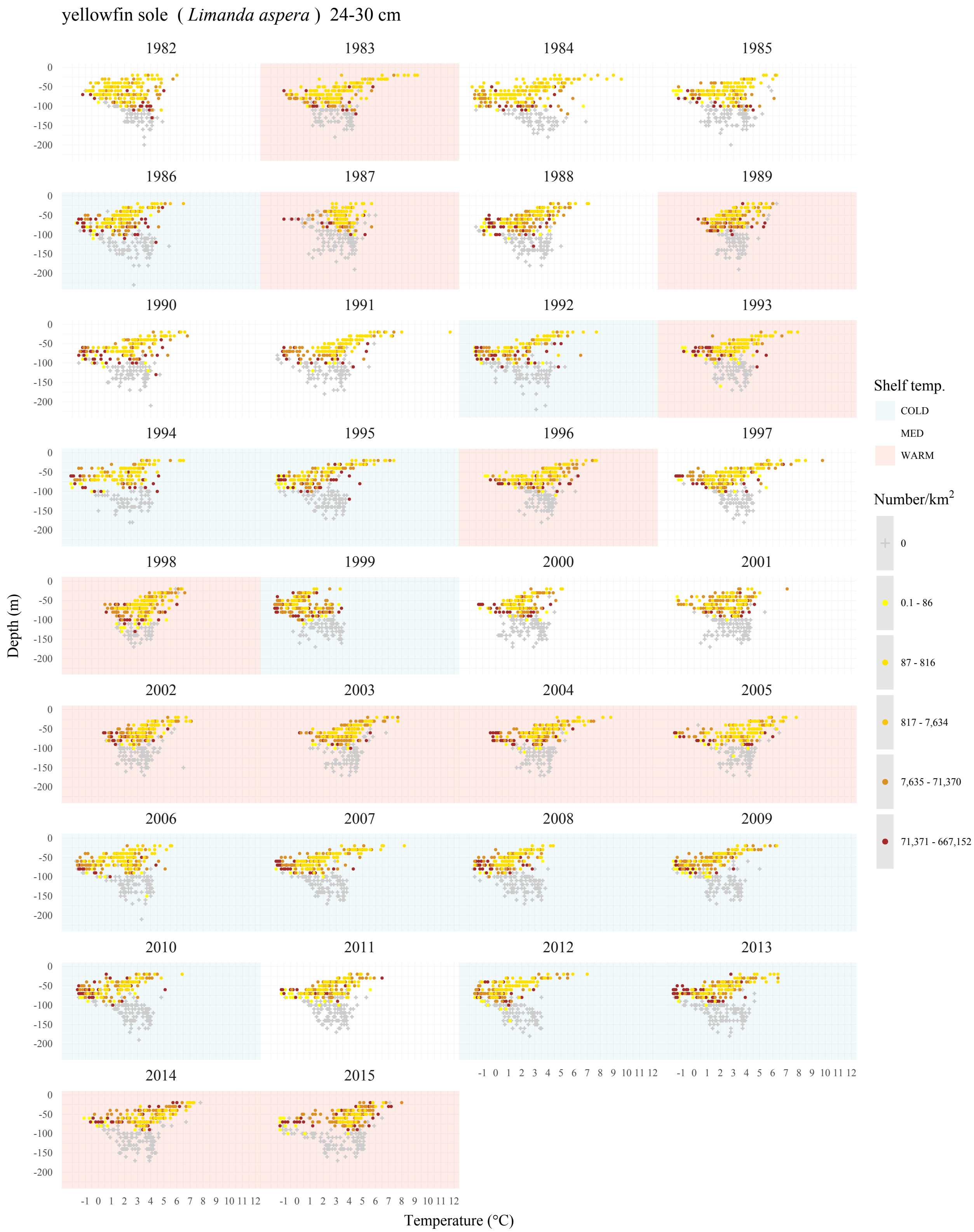


Figure 110 . -- Continued.

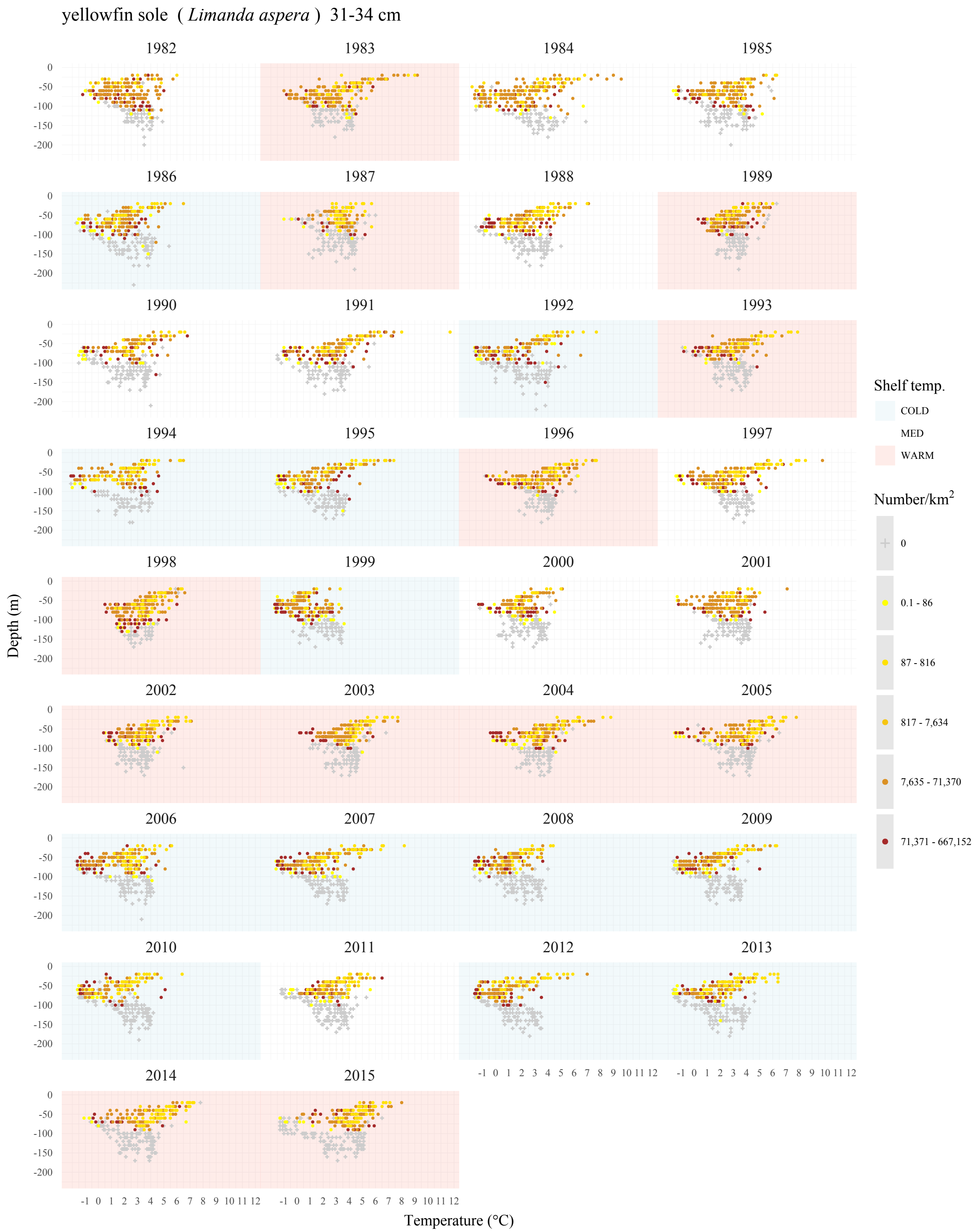


Figure 110 . -- Continued.

yellowfin sole (*Limanda aspera*) 35-70 cm

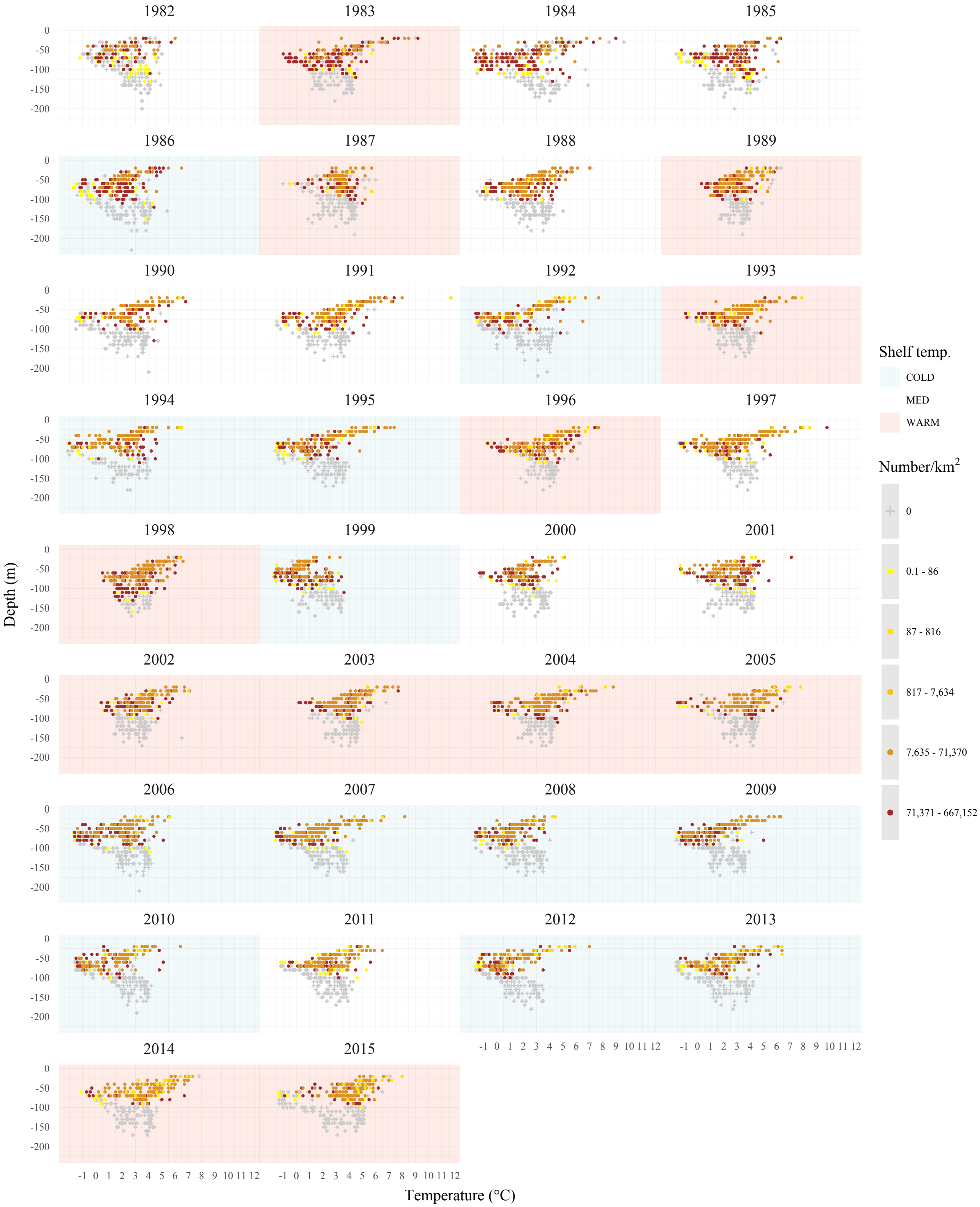
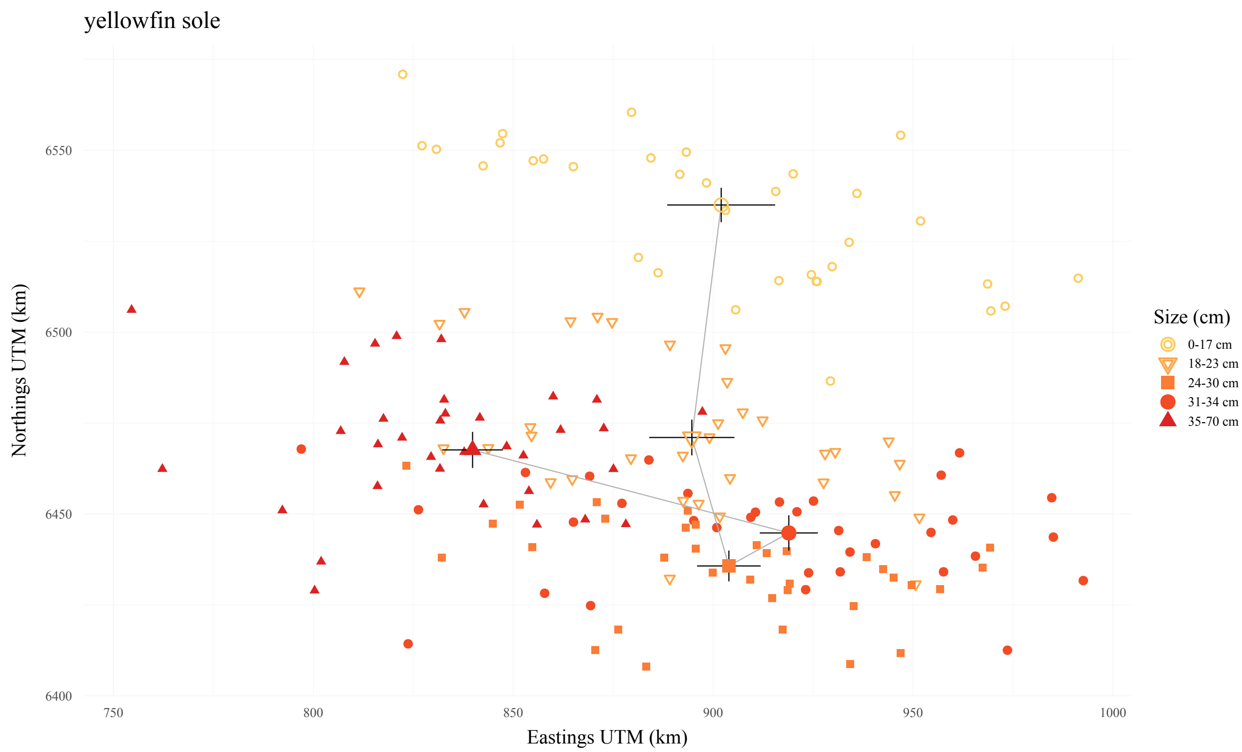


Figure 110 . -- Continued.



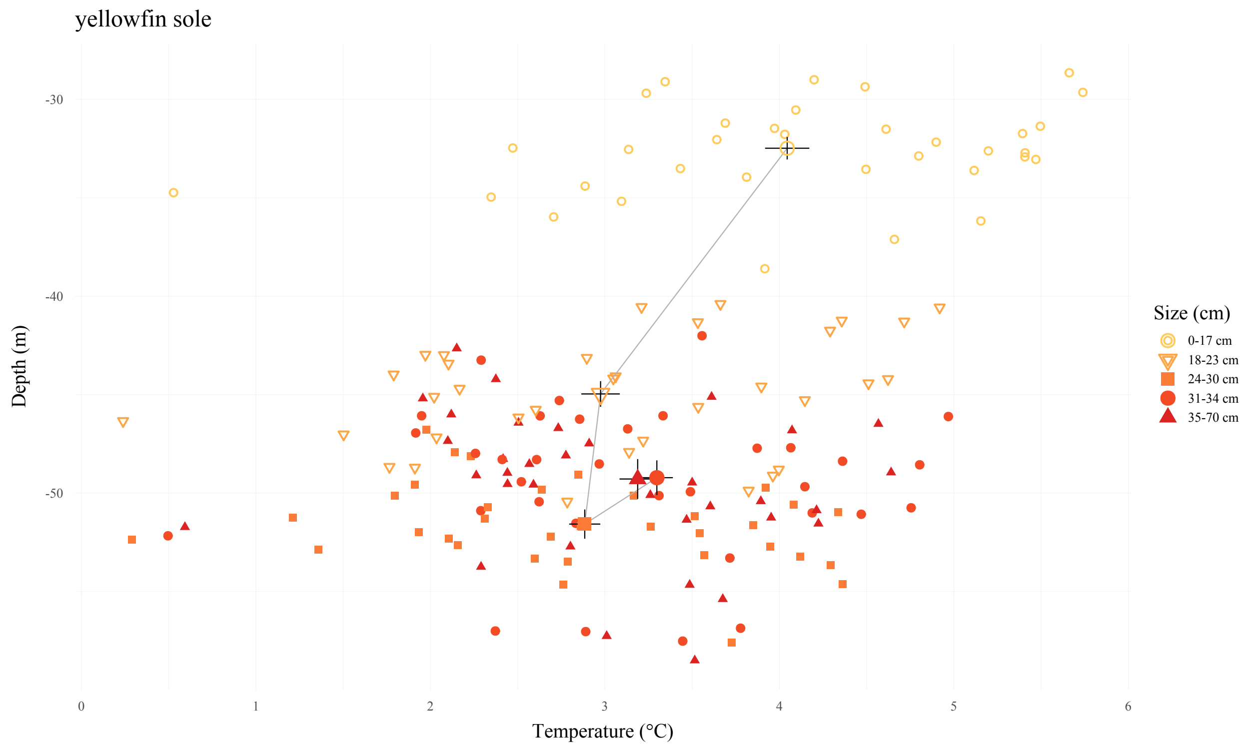
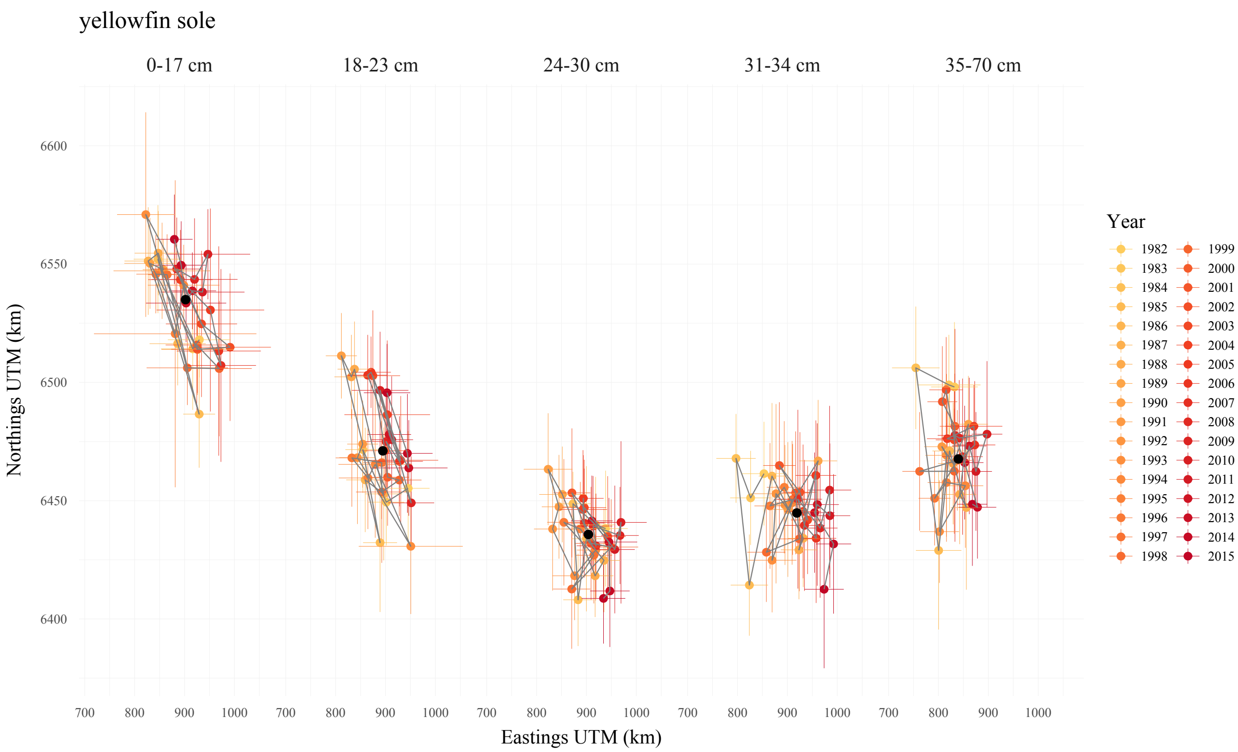


Figure 111 . -- The yellowfin sole (*Limanda aspera*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years. Points with error bars are the full timeline mean and 95% confidence intervals.



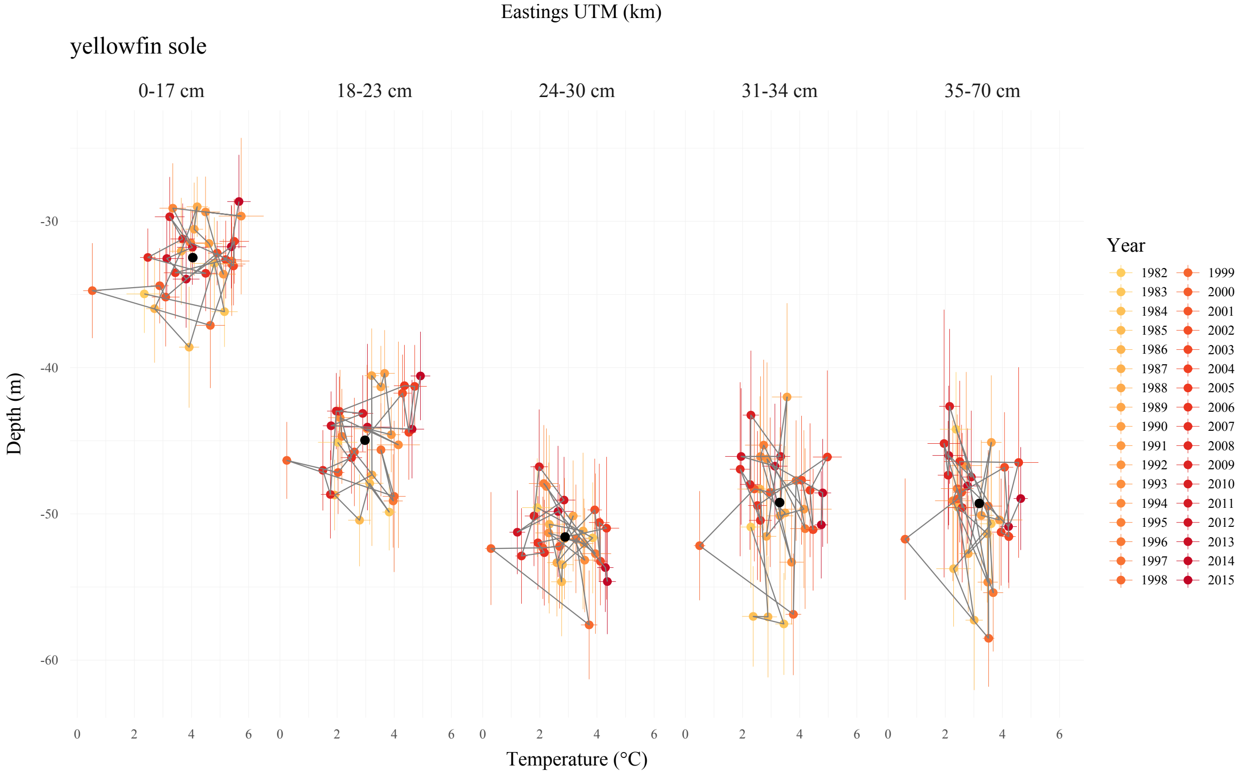


Figure 112 . -- The yellowfin sole (*Limanda aspera*) CPUE by (top) number weighted mean location and (bottom) mean bottom depth (M) and bottom temperature (° C) for each length category for all years separated by length category with 95% confidence intervals for each year. Points are the full timeline means for each length category

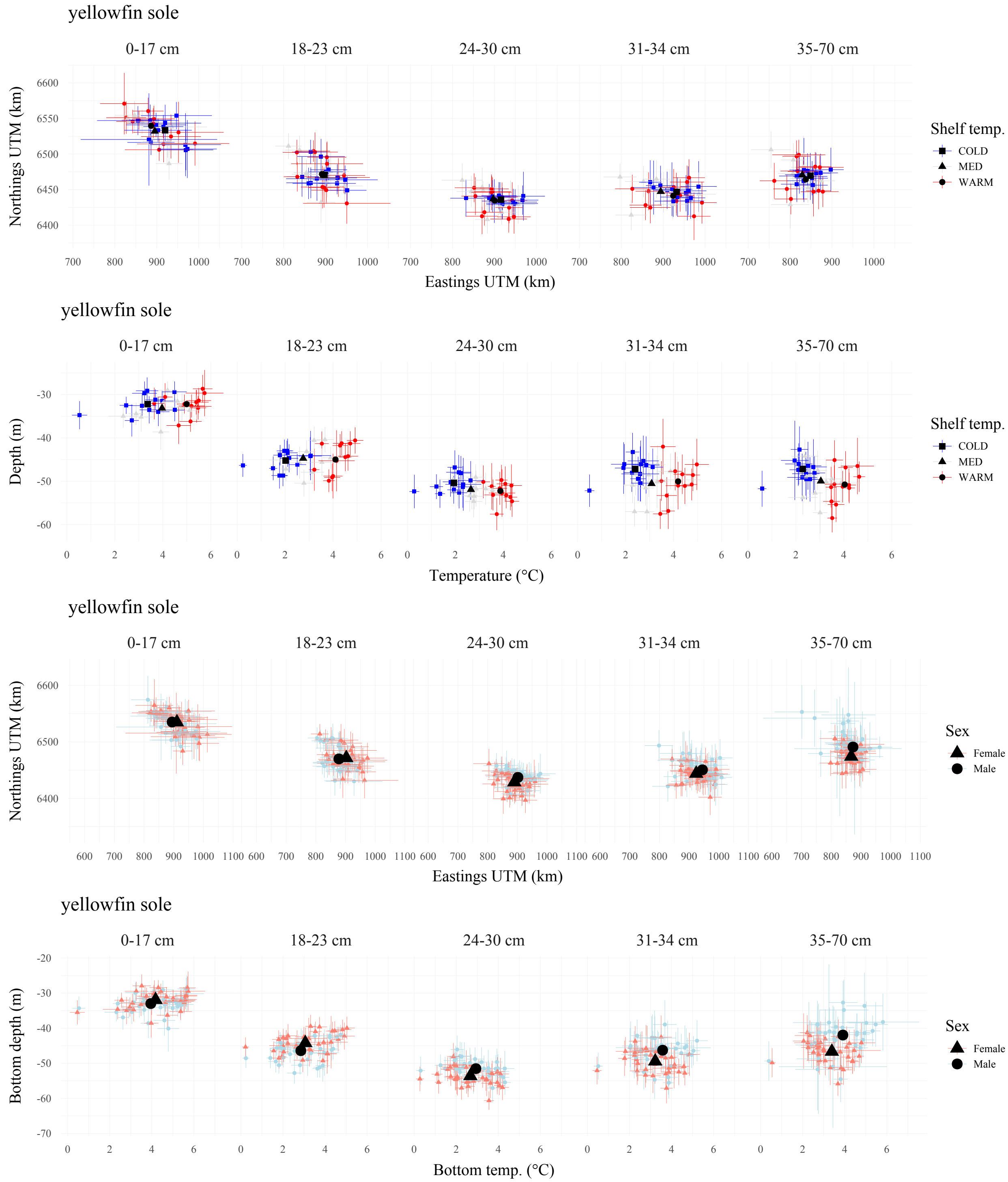


Figure 113 . -- The yellowfin sole (*Limanda aspera*) CPUE by number weighted mean location and by mean bottom depth (M) and bottom temperature (° C) for each length category by (top two figures) annual bottom temperature anomaly and by (bottom two figures) sex for all years. Error bars are annual 95% confidence intervals, black points are the overall means for each stratum and length category.

APPENDIX A – GET_DATA.R

```
## R Function for retrieving data from the RACEBASE database, username, password, species code,
## survey number and bins to be used must be specified. Access to these data are restricted to
## within the Alaska Fisheries Science Center firewall.
## Survey Codes
## 98 Bering Sea Bottom trawl survey
## 78 eastern Bering Sea Slope Survey
## 52 Aleutian Islands Bottom Trawl Survey
## 47 Gulf of Alaska Bottom Trawl Survey
## Species code book can be found here
## http://www.afsc.noaa.gov/RACE/groundfish/species_codebook.pdf
## In this paper fish were binned at percentiles 0%-10% 10%-30% 30%-70% 70%-90% 90%-100%.
## This is a special configuration with bins=5 and FIG=TRUE. Bins could be specified with
## specific values with for example bins=c(100,200,300) to have bins at those mm sizes or the
## number of percentiles specified with a single number such as bins = 5 and FIG = FALSE would
## give 5 percentiles bins.


Get_DATA<- function(username="",password="",species=21720,survey = 98,bins = 5, FIG=TRUE,
yr=c(1982:2016)) {
  require(RODBC)
  require(data.table)
  years<-paste(yr,collapse=",")
  if(R.Version()$arch=="i386"){
    AFSC=odbcConnect("AFSC",username,password)
    }
  else {
    AFSC=odbcConnect("AFSC",username,password,believeNRows=FALSE)
    }

  spec<-paste("SELECT RACEBASE.SPECIES.COMMON_NAME, \n",
    "RACEBASE.SPECIES.SPECIES_NAME \n",
    "FROM RACEBASE.SPECIES \n",
    "WHERE RACEBASE.SPECIES.SPECIES_CODE = ", species, sep="")

   SN=sqlQuery(AFSC,spec)

   test<-paste("SELECT TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') AS YEAR, \n",
   "RACEBASE.HAUL.STRATUM,\n",
   "RACEBASE.HAUL.GEAR_TEMPERATURE AS TEMP, \n",
   "RACEBASE.HAUL.SURFACE_TEMPERATURE AS STEMP, \n",
   "RACEBASE.HAUL.BOTTOM_DEPTH AS DEPTH, \n",
   "RACEBASE.HAUL.END_LATITUDE AS LAT, \n",
   "RACEBASE.HAUL.END_LONGITUDE AS LON \n",
   "FROM RACE_DATA.V_CRUISES \n",
   "INNER JOIN RACEBASE.HAUL \n",
   "ON RACE_DATA.V_CRUISES.CRUISEJOIN = RACEBASE.HAUL.CRUISEJOIN \n",
   "WHERE RACE_DATA.V_CRUISES.SURVEY_DEFINITION_ID = ", survey," \n",
   "AND RACEBASE.HAUL.HAUL_TYPE = 3 \n",
   "AND RACEBASE.HAUL.PERFORMANCE >= 0 \n",
   "AND TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') IN (",noquote(years),") \n",
   "AND RACEBASE.HAUL.STATIONID IS NOT NULL",sep="")

  test2<-paste("SELECT TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') AS YEAR, \n",
    "RACEBASE.HAUL.STRATUM,\n",
    "RACEBASE.HAUL.END_LATITUDE AS LAT, \n",
    "RACEBASE.HAUL.END_LONGITUDE AS LON, \n",
    "RACEBASE.CATCH.NUMBER_FISH/(RACEBASE.HAUL.DISTANCE_FISHED*(RACEBASE.HAUL.NET_WIDTH/1000))
     AS CPUE, \n",
    "RACE_DATA.V_CRUISES.SURVEY_DEFINITION_ID, \n",
    "RACEBASE.CATCH.SPECIES_CODE \n",
    "FROM RACE_DATA.V_CRUISES \n",
    "INNER JOIN RACEBASE.HAUL \n",
    "ON RACE_DATA.V_CRUISES.CRUISEJOIN = RACEBASE.HAUL.CRUISEJOIN \n",
    "INNER JOIN RACEBASE.CATCH \n",
    "ON RACEBASE.HAUL.CRUISEJOIN = RACEBASE.CATCH.CRUISEJOIN \n",
    "AND RACEBASE.HAUL.HAULJOIN = RACEBASE.CATCH.HAULJOIN \n",
```

```
    "WHERE RACE_DATA.V_CRUISES.SURVEY_DEFINITION_ID = ", survey," \n",
    "AND RACEBASE.HAUL.HAUL_TYPE = 3 \n",
    "AND RACEBASE.HAUL.PERFORMANCE >= 0 \n",
    "AND RACEBASE.HAUL.STATIONID IS NOT NULL \n",
    "AND TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') IN (",noquote(years),") \n",
    "AND RACEBASE.CATCH.SPECIES_CODE = ",species, sep="")

  test3<-paste ("SELECT TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') AS YEAR, \n",
    "RACEBASE.HAUL.STRATUM,\n",
    "RACEBASE.LENGTH.LENGTH, \n",
    "RACEBASE.LENGTH.FREQUENCY, \n",
    "RACEBASE.LENGTH.SEX, \n",
    "RACEBASE.HAUL.GEAR_TEMPERATURE AS TEMP, \n",
    "RACEBASE.HAUL.SURFACE_TEMPERATURE AS STEMP, \n",
    "RACEBASE.HAUL.BOTTOM_DEPTH AS DEPTH, \n",
    "RACEBASE.HAUL.END_LATITUDE AS LAT, \n",
    "RACEBASE.HAUL.END_LONGITUDE AS LON, \n",
    "RACEBASE.LENGTH.SPECIES_CODE, \n",
    "RACE_DATA.V_CRUISES.SURVEY_DEFINITION_ID \n",
    "FROM RACE_DATA.V_CRUISES \n",
    "INNER JOIN RACEBASE.HAUL \n",
    "ON RACE_DATA.V_CRUISES.CRUISEJOIN = RACEBASE.HAUL.CRUISEJOIN \n",
    "INNER JOIN RACEBASE.LENGTH \n",
    "ON RACEBASE.HAUL.CRUISEJOIN                    = RACEBASE.LENGTH.CRUISEJOIN \n",
    "AND RACEBASE.HAUL.HAULJOIN                     = RACEBASE.LENGTH.HAULJOIN \n",
    "WHERE RACE_DATA.V_CRUISES.SURVEY_DEFINITION_ID = ", survey," \n",
    "AND RACEBASE.HAUL.HAUL_TYPE                    = 3 \n",
    "AND RACEBASE.HAUL.PERFORMANCE                 >= 0 \n",
    "AND RACEBASE.HAUL.STATIONID                   IS NOT NULL \n",
    "AND TO_CHAR(RACEBASE.HAUL.START_TIME, 'yyyy') IN (",noquote(years),") \n",
    "AND RACEBASE.LENGTH.SPECIES_CODE = ", species, sep="")

  location      <- data.table(sqlQuery(AFSC,test))
  location_poll <- data.table(sqlQuery(AFSC,test2))
  length        <- data.table(sqlQuery(AFSC,test3))
  #length        <- length[SEX<3]
  odbcClose(AFSC)

## if survey is EBS, exlcude far north regions.
  if(survey==98){
    length        <- length[!is.na(STRATUM)&STRATUM<63]
    location      <- location[!is.na(STRATUM)&STRATUM<63]
    location_poll <- location_poll[!is.na(STRATUM)&STRATUM<63]
  }

  if(survey==52){
    length        <- length[!is.na(STRATUM)&STRATUM<800]
    location      <- location[!is.na(STRATUM)&STRATUM<800]
    location_poll <- location_poll[!is.na(STRATUM)&STRATUM<800]
  }

## for SLope survey exclue 2000 from all plots
  if(survey==78){
      length        <- subset(length,length$YEAR!=2000)
      location      <- subset(location,location$YEAR!=2000)
      location_poll <- subset(location_poll,location_poll$YEAR!=2000)
      }

##Exclude null locations and transform to all positive longitudes
  location      <-location[!is.na(location$LON)]
  location_poll <-location_poll[!is.na(location_poll$LON)]
  length        <-length[!is.na(length$LON)]

  location$LON[location$LON<0]           <-  360 + location$LON[location$LON<0]
  location_poll$LON[location_poll$LON<0] <-  360 + location_poll$LON[location_poll$LON<0]
  length$LON[length$LON<0]               <-  360 + length$LON[length$LON<0]

## rounding bottom depth to nearest 0.5 meters and temperature to nearest 0.1 degree to simplify
calculations
  location$DEPTHR <- round(location$DEPTH)
  location$TEMPR  <- round(location$TEMP,1)
```

```
  length$TEMPR    <- round(length$TEMP,1)
  length$DEPTHR   <- round(length$DEPTH)

  length          <- merge(length,location_poll,by = c("YEAR","LON","LAT",
       "SURVEY_DEFINITION_ID", "SPECIES_CODE"))
  length          <-subset(length,!is.na(length$CPUE))


  if(length(bins)>1){
    bins2<-bins
    bins<-length(bins2)
    }

  if(length(bins)==1 & FIG==F){
    x<-quantile(length$LENGTH,probs=seq(0,1,length=(bins+1)))
    bins2<-c(0,as.numeric(x$BIN[2:bins]))
  }


  if(bins==5 & FIG==T){
     x<-quantile(length$LENGTH,probs=c(0.1,0.3,0.7,0.9,1.0))
    bins2<-c(0,as.numeric(x))
  }


## create length bins
  for ( i in 2:length(bins2)){
    length$BIN[length$LENGTH<bins2[i] & length$LENGTH >= bins2[(i-1)]] <- bins2[(i-1)]
    }

  label<-array(dim=bins)
  label2<-array(dim=bins)


  lab1<-c(bins2[1:bins]/10,max(length$LENGTH/10))
  lab2<-lab1-1
  lab2[1]<-0

   for(i in 1:(bins-1)){
        label[i]<-paste(as.character(lab1)[i],"-",as.character(lab2)[i+1]," cm",sep="")
        label2[i]<-i

      }

  label[bins]<-paste(as.character(lab1)[bins],"-",as.character(lab1)[bins+1]," cm",sep="")
  label2[bins]<-bins

   label<-data.frame(BIN=bins2[1:bins],LABEL=as.factor(label))
   length<-length[!is.na(length$TEMPR)]
   length<-merge(length,label,by="BIN")

## output data
  data1 <- vector(mode="list")
  data1$length        <- length
  data1$location      <- location
  data1$location_poll <- location_poll
  data1$SN            <- SN
  return(data1)

}
## example data draw
POLLOCK<-GET_BS_BIOM(username=””,password=””,species=21740,survey=98,bins=5,FIG=TRUE)
```

APPENDIX B – PLOT_DIST.R

```
## function for plotting data by temperature (plotT=1) or location (plotT=2)and specified length
## bin range (Lbin)

plot_dist_num<- function(data=POLLOCK,bin=1,plotT=1){
  require(mgcv)
  require(data.table)
  require(ggplot2)
  require(grid)

  td1 <- Get_TEMP(data=data, plotT=F)
  td1$LON=1;td1$LAT=1; td1$DEPTHR=1;td1$TEMPR=1;td1$bin2=1;td1$CPUELAB="0"

  location   <- data.table(data$location)
  length    <- data.table(data$length)
  location_poll <- data.table(data$location_poll)

  survey  <- unique(length$SURVEY_DEFINITION_ID)
  species <- unique(length$SPECIES_CODE)
  bins    <- sort(unique(length$BIN))
  cn      <- data$SN$COMMON_NAME
  sn      <- data$SN$SPECIES_NAME
  nc      <- min(5,trunc(length(unique(length$YEAR))/4)+1)  ## number of columns for plotting
  yers    <- unique(length$YEAR)
  yers2<- sort(unique(location$YEAR))

  if(!1994 %in% length$YEAR){ location<-location[YEAR %in% yers]}

  length <- length[complete.cases(length[,c('CPUE','TEMPR','STEMP')])]

  Max_L <- max(length$LENGTH)
  Lbin  <- bin

  if(length(Lbin) < 2){
    Lbin <- c(bins[bin],bins[bin+1])
    if(is.na(Lbin[2])){ Lbin[2] <- Max_L}
    }

  rgb.palette <- colorRampPalette(c("yellow","gold","goldenrod2","brown"),space = "rgb")
  color1      <- c("gray80",rgb.palette(5))

## Temperature plot
  if(plotT==1)
    {
## rounding depth to 20 m increments for visualization purposes.
    location$DEPTHR <- round(location$DEPTH,-1)
    length$DEPTHR   <- round(length$DEPTH,-1)
    location$TEMPR <- round(location$TEMP,1)
    length$TEMPR   <- round(length$TEMP,1)

    location1 <- location[complete.cases(location[,c('DEPTHR','TEMPR','STEMP')])]
    location$T<-1
    location1  <- location[,list(NUMBER=sum(T)),by= 'YEAR,DEPTHR,TEMPR']
    data1      <- length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),by=
'YEAR,BIN,LABEL,DEPTHR,TEMPR']
    data2      <- length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,DEPTHR,TEMPR']
    data3      <- merge(data1,data2,all=T,by=c("YEAR","DEPTHR","TEMPR"))
    data3      <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),by = 'YEAR,BIN,LABEL,TEMPR,DEPTHR']
    }

## Location plot
 if(plotT==2)
    {
    location1  <- location[,list(NUMBER=length(YEAR)),by= 'YEAR,LON,LAT']
    data1      <- length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),by= 'YEAR,BIN,LABEL,LON,LAT']
    data2      <- length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,LON,LAT']
    data3      <- merge(data1,data2,all=T,by=c("YEAR","LON","LAT"))
    data3      <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),by = 'YEAR,BIN,LABEL,LON,LAT']
    }
```

```
bins2x     <- seq(0,max(log(data3$PLOT)),length=7)
bins2      <- c(0,exp(bins2x[2:7]))

for( j in 3:7){
  data3$bin2[data3$PLOT>bins2[j-1] & data3$PLOT<=bins2[j]]<-max(1,round(bins2[(j-1)]))
  }

data3$bin2[is.na(data3$bin2)]<-0

dataT <- data3[order(data3$bin2),]
label2<-array(dim=6)

binsx<-sort(bins2)
binsx[binsx>0&binsx<0.5]<-1
binsx<-round(binsx)
lab1<-binsx
lab2<-lab1-1
lab2[1]<-1

lab1<-formatC(lab1,format="d",big.mark=",")
lab2<-formatC(lab2,format="d",big.mark=",")

label2[1]<-"0"
label2[2]<-paste("0.1-",lab2[3],sep="")

for(i in 4:(length(lab1)-1)){
  label2[i-1]<-paste(lab1[i-1],"-",lab2[i],sep="")
  }

label2[6]<-paste(lab1[6],"-",lab1[7],sep="")

label3<-data.frame(bin2=binsx[1:6],CPUELAB=label2)
label3$ID<-as.numeric(as.factor(label3$CPUELAB))
label3$ID2<-c(1:6)
label3$color<-color1
dataT<-merge(dataT,label3,by="bin2")

#x2<-label3[order(label3$ID),]
#x2$color<-color1[x2$ID2]
dataT$CPUELAB <- factor(dataT$CPUELAB,levels=label3$CPUELAB)

dataT <- dataT[dataT$BIN>=Lbin[1]&dataT$BIN<Lbin[2]]
title1 <- paste(cn," (",sn,") ",unique(dataT$LABEL))

if (plotT==1){ dataT <- merge(location1,dataT,all.x=T,by=c("YEAR","TEMPR","DEPTHR"),
      allow.cartesian=TRUE)}
if (plotT==2){ dataT <- merge(location1,dataT,all.x=T,by=c("YEAR","LON","LAT"),
      allow.cartesian=TRUE)}

dataT$PLOT[is.na(dataT$PLOT==T)] <- 0
dataT$bin2[is.na(dataT$bin2==T)] <- 0
dataT$CPUELAB[is.na(dataT$CPUELAB==T)] <- "0"
dataT$ID2[is.na(dataT$ID2==T)] <- 1
dataT$ID[is.na(dataT$ID==T)] <- 1
dataT$color[is.na(dataT$color==T)] <- "gray80"
dataT<-dataT[order(dataT$ID2)]

dataT$YEAR<-factor(dataT$YEAR,levels=yers2)
td1$YEAR<-factor(td1$YEAR,levels=yers2)

if(plotT==1)
  {
  d <- ggplot(data=dataT,aes(x=TEMPR,y=-DEPTHR,color=CPUELAB,shape=CPUELAB,size=CPUELAB))
  d <- d + geom_rect(data=td1,aes(fill=REGI),xmin=-Inf,xmax=Inf,
      ymin=-Inf,ymax=Inf,alpha=0.2,linetype=0)
  d <- d + geom_point(data=dataT)
  d <- d + scale_x_continuous(breaks=seq(-1,20,by=1))
  d <- d + xlab(expression("Temperature ("* degree * C *")"))
  d <- d + ylab("Depth (m)")
  }
```

```
  if(plotT==2)
    {
    B_sea <- map_data("world2","USA:alaska")
    p <- ggplot()

    if(survey[1]==98){  p <- p + coord_fixed(ylim=c(51,65),xlim=c(179,205))}
    if(survey[1]==47){  p <- p + coord_fixed(ylim=c(50,61.5),xlim=c(185,230))}
    if(survey[1]==52){  p <- p + coord_fixed(ylim=c(51,55),xlim=c(170,205))}
    if(survey[1]==78){  p <- p + coord_fixed(ylim=c(51,63),xlim=c(175,195))}

    d <- p + geom_polygon(data=B_sea,aes(x=long,y=lat,group=group))
    d <- d + geom_point(data=dataT,aes(x=LON,y=LAT,color=CPUELAB,shape=CPUELAB,size=CPUELAB))
    d <- d + geom_rect(data=td1,aes(fill=REGI),xmin=-Inf,xmax=Inf,
        ymin=-Inf,ymax=Inf,alpha=0.15,linetype=0)
    if(survey[1]==98){  d <- d + scale_x_continuous(breaks=seq(180,205,by=5),
        labels=seq(180,155,by=-5)) + ylab(expression(paste("Latitude ",degree,
        " N",sep="")))+xlab(expression(paste("Longitude ",degree," W",sep=""))) }
    if(survey[1]==47){  d <- d + scale_x_continuous(breaks=seq(190,230,by=10),
        labels=seq(170,130,by=-10)) + ylab(expression(paste("Latitude ",degree,
        " N",sep="")))+xlab(expression(paste("Longitude ",degree," W",sep=""))) }
    if(survey[1]==52){  d <- d + scale_x_continuous(breaks=seq(170,200,by=10),
        labels=c(170,180,170,160)) +ylab(expression(paste("Latitude ",degree,
        " N",sep="")))+xlab(expression(paste("Longitude ",degree," W",sep=""))) }
    if(survey[1]==78){  d <- d + scale_x_continuous(breaks=seq(175,195,by=5),
        labels=c(175,180,175,170,165)) +ylab(expression(paste(
        "Latitude ",degree,sep="")))+xlab(expression(paste("Longitude ",degree," W",sep=""))) }
    }
    d <- d + scale_fill_manual(name="Shelf temp.",values=c("light blue","white","salmon"))
    d <- d + scale_color_manual(name=expression(paste("Number/k",m^2,sep="")),
        values=color1[sort(unique(dataT$ID))],labels=unique(dataT$CPUELAB))
    d <- d + scale_shape_manual(name=expression(paste("Number/k",m^2,sep="")),
        values=c(3,rep(16,(length(unique(dataT$bin2))-1))),labels=unique(dataT$CPUELAB))
    d <- d + scale_size_manual(name=expression(paste("Number/k",m^2,sep="")),
        values=c(0.4,rep(0.75,(length(unique(dataT$bin2))-1))),labels=unique(dataT$CPUELAB))
    d <- d + ggtitle(title1)

    d <- d + theme(panel.spacing=unit(0,"lines"),
                   panel.background = element_rect(fill = 'white', color = 'white'),
                   plot.title=element_text(vjust=1,hjust=0),
                   legend.key=element_rect(fill = 'white', color = 'white',linetype=0),
                   legend.key.width=unit(1,"cm"),
                   axis.text=element_text(size=6))
    d <- d + guides(colour = guide_legend(keyheight=2,override.aes = list(size=1)))
    d <- d + facet_wrap(~YEAR,ncol=nc,shrink=FALSE)
    d<-d+theme1(base_size=10)
    print(d)
    return(d)
}
#Example plot
plot_dist_num(data=data1,Lbin=c(100,400),plotT=1)
## Function for creating multiple PDFs of length bins as defined in the Get_DATA Function.
Plotting_bins<-function(datas=POLLOCK) {
    length    <- datas$length
    survey    <- unique(length$SURVEY_DEFINITION_ID)
    species    <- unique(length$SPECIES_CODE)
    bins     <- sort(unique(length$BIN))
    cn      <- datas$SN$COMMON_NAME
    name     <- paste(cn,survey,"NUM",sep="_")

    pdf(paste(name,".pdf",sep=""),width=10,height=7.5)

    for(i in 1:length(bins)) {
        plot_dist_num(data=datas,bin=i, plotT=2 )
        }

    for(i in 1:length(bins)) {
        plot_dist_num(data=datas,bin=i,plotT=1 )
        }

    dev.off()
```

```
    print(paste("Plots are in ",getwd(),sep=""))

}

## example plot
Plotting_bins(data=POLLOCK)
```

APPENDIX C – PLOT_CENTROIDS_NUM.R

```
## Function for plotting RACE survey data for any species temperature and depth (TD) and location
## (LL) by specified length bins
## This function takes data pulled using the get_DATA() function.
## Confidence intervals are based on 1.96*SE
## plotT (1= TD by overall shelf temperature, 2= LL by overall shelf temperature, 3= TD by year, 4
## = LL by year, 5 = td annual all one plot, 6 = LL annual all one plot, 7 = TD plot by sex, and
## 8 = LL plot by sex)

plot_centroids_num <- function(data=data1,plotT=1,colx=1){
  require(data.table)
  require(ggplot2)
  require(grid)
  require(ggmap)
  require(sp)

# Computes the variance of a weighted mean following Cochran 1977 definition
  weighted.var.se <- function(x, w, na.rm=FALSE)
  {
    if (na.rm) { w <- w[i <- !is.na(x)]; x <- x[i] }
    n = length(w)
    xWbar = weighted.mean(x,w,na.rm=na.rm)
    wbar = mean(w)
    out = n/((n-1)*sum(w)^2)*(sum((w*x-wbar*xWbar)^2)-2*xWbar*sum((w-wbar)*
       (w*x-wbar*xWbar))+xWbar^2*sum((w-wbar)^2))
    return(out)
  }

  if(colx==2){rgb.palette <- colorRampPalette(c("red","orange","green","turquoise","blue"),
      space = "rgb")}
  if(colx==1){rgb.palette <- colorRampPalette(c("#fecc5c","#fd8d3c","#f03b20","#bd0026"),
      space = "rgb")}

  length    <- data$length
  survey    <- unique(length$SURVEY_DEFINITION_ID)
  species   <- unique(length$SPECIES_CODE)
  bins      <- sort(unique(length$BIN))
  cn        <- data$SN$COMMON_NAME
  sn        <- data$SN$SPECIES_NAME
  SN        <- data$SN

  MTEMP  <- Get_TEMP(data=data,plotT=F)
  length <- length[complete.cases(length[,c('CPUE','TEMPR','DEPTHR')])]
  Length <- merge(length,MTEMP,by=c("YEAR"),all=T)

  if(plotT %in% c(1,2))
    {
    if(plotT==1)
      {
      Length <- Length[complete.cases(Length[,c('TEMP','DEPTH')])]
      data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
        by= 'YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2,TEMP,DEPTH']
      data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,REGI,TEMP,DEPTH']
      data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","REGI","TEMP","DEPTH"))
      data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
        by = 'YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2,TEMP,DEPTH']
      data8<-data3[,list(my=-weighted.mean(DEPTH,PLOT),mx=weighted.mean(TEMP,PLOT),
        myVAR=weighted.var.se(DEPTH,PLOT),mxVAR=weighted.var.se(TEMP,PLOT)),
        by='SPECIES_CODE,REGI,BIN,LABEL,LABEL2']
      data6<-data3[,list(yC=-weighted.mean(DEPTH,PLOT),xC=weighted.mean(TEMP,PLOT),
        yVAR=weighted.var.se(DEPTH,PLOT),xVAR=weighted.var.se(TEMP,PLOT)),
        by='YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2']
      }

    if(plotT==2)
      {
      Length <- Length[complete.cases(Length[,c('LAT','LON')])]
      length1<-Length
      length1$x<-length1$LON
```

```
      length1$y<-length1$LAT
      coordinates(length1)<-c("x","y")
      proj4string(length1)<-CRS("+proj=longlat +datum=WGS84")
      LENGTH<-spTransform(length1,CRS("+proj=utm +zone=2 ellps=WGS84"))
      Length$x<-LENGTH$x/1000
      Length$y<-LENGTH$y/1000
      Length<-Length[!is.na(x)]
      data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
        by= 'YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2,x,y']
      data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,REGI,x,y']
      data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","REGI","x","y"))
      data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
        by = 'YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2,x,y']
      data8<-data3[,list(my=weighted.mean(y,PLOT),mx=weighted.mean(x,PLOT),
        myVAR=weighted.var.se(y,PLOT),mxVAR=weighted.var.se(x,PLOT)),
        by='SPECIES_CODE,REGI,BIN,LABEL,LABEL2']
      data6<-data3[,list(yC=weighted.mean(y,PLOT),xC=weighted.mean(x,PLOT),
        yVAR=weighted.var.se(y,PLOT),xVAR=weighted.var.se(x,PLOT)),
        by='YEAR,SPECIES_CODE,REGI,BIN,LABEL,LABEL2']
      }

    data6$xSEM <-sqrt(data6$xVAR)*1.96
    data6$ySEM <- sqrt(data6$yVAR)*1.96
    data7<-merge(data6,SN,by="SPECIES_CODE")

    x1<-data.table(data7)
    x1<-x1[,list(LABEL2=min(as.numeric(LABEL2))),by="LABEL"]
    x1<-x1[order(x1$LABEL2),]
    data7$LABEL <- factor(data7$LABEL,levels=x1$LABEL)

    d <- ggplot(data=data7)
    d <- d+geom_point(data=data7,aes(y=yC,x=xC,color=REGI,shape=REGI,size=REGI))
    d <- d + geom_pointrange(data=data7,aes(y=yC,x=xC,ymax = yC + ySEM,
        ymin=yC - ySEM,color=REGI,shape=REGI,size=REGI))
    d <- d + geom_errorbarh(data=data7,aes(x=xC,y=yC,xmax = xC + xSEM,
        xmin=xC - xSEM,color=REGI,size=REGI))
    d <- d + geom_point(data=data8,aes(y=my,x=mx,shape=REGI),size=1)
    d <- d + scale_colour_manual(name="Shelf temp.",values=c("blue","gray85","red"))+
        scale_shape_manual(name="Shelf temp.",values=c(15,17,16))+
        scale_size_manual(name="Shelf temp.",values=rep(0.05,3))

    if(plotT==1){
      d <- d + xlab(expression("Temperature ("* degree * C *")"))
      d <- d + ylab("Depth (m)")
      }

    if(plotT==2){
      d <- d + xlab("Eastings UTM (km)")
      d <- d + ylab("Northings UTM (km)")
      }

    d  <- d + guides(colour = guide_legend(keyheight=0.5))
    d <- d + theme1(base_size=7)
    plot.title=paste(cn)
    d <- d + ggtitle(plot.title)
    d <- d + facet_wrap(~LABEL,shrink=FALSE,ncol=length(unique(data7$LABEL2)))
    print(d)

    }

if(plotT %in% c(3,4))
  {
  if(plotT==3)
      {
      Length <- Length[complete.cases(Length[,c('TEMP','DEPTH')])]
      data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
        by= 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,TEMP,DEPTH']
      data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,TEMP,DEPTH']
      data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","TEMP","DEPTH"))
      data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
        by = 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,TEMP,DEPTH']
```

```
  data8<-data3[,list(my=-weighted.mean(DEPTH,PLOT),mx=weighted.mean(TEMP,PLOT),
    myVAR=weighted.var.se(DEPTH,PLOT),mxVAR=weighted.var.se(TEMP,PLOT)),
    by='SPECIES_CODE,BIN,LABEL,LABEL2']
  data6<-data3[,list(yC=-weighted.mean(DEPTH,PLOT),xC=weighted.mean(TEMP,PLOT),
    yVAR=weighted.var.se(DEPTH,PLOT),xVAR=weighted.var.se(TEMP,PLOT)),
    by='YEAR,SPECIES_CODE,BIN,LABEL,LABEL2']
  }

if(plotT==4)
  {
  Length <- Length[complete.cases(Length[,c('LAT','LON')])]
  length1<-Length
  length1$x<-length1$LON
  length1$y<-length1$LAT
  coordinates(length1)<-c("x","y")
  proj4string(length1)<-CRS("+proj=longlat +datum=WGS84")
  LENGTH<-spTransform(length1,CRS("+proj=utm +zone=2 ellps=WGS84"))
  Length$x<-LENGTH$x/1000
  Length$y<-LENGTH$y/1000
  Length<-Length[!is.na(x)]
  data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
    by= 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,x,y']
  data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,x,y']
  data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","x","y"))
  data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
    by = 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,x,y']
  data8<-data3[,list(my=weighted.mean(y,PLOT),mx=weighted.mean(x,PLOT),
    myVAR=weighted.var.se(y,PLOT),mxVAR=weighted.var.se(x,PLOT)),by='SPECIES_CODE,
    BIN,LABEL,LABEL2']
  data6<-data3[,list(yC=weighted.mean(y,PLOT),xC=weighted.mean(x,PLOT),
    yVAR=weighted.var.se(y,PLOT),xVAR=weighted.var.se(x,PLOT)),by='YEAR,
    SPECIES_CODE,BIN,LABEL,LABEL2']
  }

data6$xSEM <-sqrt(data6$xVAR)*1.96
data6$ySEM <- sqrt(data6$yVAR)*1.96
data7<-merge(data6,SN,by="SPECIES_CODE")

x1<-data.table(data7)
x1<-x1[,list(LABEL2=min(as.numeric(LABEL2))),by="LABEL"]
x1<-x1[order(x1$LABEL2),]
data7$LABEL <- factor(data7$LABEL,levels=x1$LABEL)

d <- ggplot(data=data7)
d <- d+geom_point(data=data7,aes(y=yC,x=xC,color=factor(YEAR),size=factor(YEAR)))
d <- d + geom_pointrange(data=data7,aes(y=yC,x=xC,ymax = yC + ySEM, ymin=yC –
     ySEM,color=factor(YEAR),size=factor(YEAR)))
d <- d + geom_errorbarh(data=data7,aes(x=xC,y=yC,xmax = xC + xSEM, xmin=xC –
     xSEM,color=factor(YEAR),size=factor(YEAR)))
d <- d + geom_path(data=data7,aes(x=xC,y=yC,group=1),size=0.2,color="gray50")
d <- d + geom_point(data=data8,aes(y=my,x=mx),size=1)
d <- d + scale_colour_manual(name="Year",values=c(rgb.palette(length(unique(data7$YEAR))+1)))
    +scale_size_manual(name="Year",values=rep(0.05,length(unique(data7$YEAR))))

if(plotT==4){
  d <- d + xlab("Eastings UTM (km)")
  d <- d + ylab("Northings UTM (km)")
  }

if(plotT==3){
  d <- d + xlab(expression("Temperature ("* degree * C *")"))
  d <- d + ylab("Depth (m)")
  }

d  <- d + guides(colour = guide_legend(keyheight=0.5))
d <- d + theme1(base_size=7)
plot.title=paste(cn)
d <- d + ggtitle(plot.title)
d <- d + facet_wrap(~LABEL,shrink=FALSE,ncol=length(unique(data7$LABEL2)))
print(d)
}
```

```
if(plotT %in% c(5,6))
  {
  if(plotT==5)
    {
    Length <- Length[complete.cases(Length[,c('TEMP','DEPTH')])]
    data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
      by= 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,TEMP,DEPTH']
    data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,TEMP,DEPTH']
    data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","TEMP","DEPTH"))
    data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
      by = 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,TEMP,DEPTH']
    data8<-data3[,list(my=-weighted.mean(DEPTH,PLOT),mx=weighted.mean(TEMP,PLOT),
      myVAR=weighted.var.se(DEPTH,PLOT),mxVAR=weighted.var.se(TEMP,PLOT)),
      by='SPECIES_CODE,BIN,LABEL,LABEL2']
    data6<-data3[,list(yC=-weighted.mean(DEPTH,PLOT),xC=weighted.mean(TEMP,PLOT),
      yVAR=weighted.var.se(DEPTH,PLOT),xVAR=weighted.var.se(TEMP,PLOT)),
      by='YEAR,SPECIES_CODE,BIN,LABEL,LABEL2']
    }

  if(plotT==6)
    {
    Length    <- Length[complete.cases(Length[,c('LAT','LON')])]
    length1   <- Length
    length1$x <- length1$LON
    length1$y <- length1$LAT
    coordinates(length1)<-c("x","y")
    proj4string(length1)<-CRS("+proj=longlat +datum=WGS84")
    LENGTH    <- spTransform(length1,CRS("+proj=utm +zone=2 ellps=WGS84"))
    Length$x  <- LENGTH$x/1000
    Length$y  <- LENGTH$y/1000

    Length <- Length[!is.na(x)]
    data1  <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
      by= 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,x,y']
    data2  <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,x,y']
    data3  <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","x","y"))
    data3  <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
      by = 'YEAR,SPECIES_CODE,BIN,LABEL,LABEL2,x,y']
    data8  <- data3[,list(my=weighted.mean(y,PLOT),mx=weighted.mean(x,PLOT),
      myVAR=weighted.var.se(y,PLOT),mxVAR=weighted.var.se(x,PLOT)),
      by='SPECIES_CODE,BIN,LABEL,LABEL2']
    data6  <- data3[,list(yC=weighted.mean(y,PLOT),xC=weighted.mean(x,PLOT),
      yVAR=weighted.var.se(y,PLOT),xVAR=weighted.var.se(x,PLOT)),
      by='YEAR,SPECIES_CODE,BIN,LABEL,LABEL2']
    }

  data8$mxSEM <-sqrt(data8$mxVAR)*1.96
  data8$mySEM <- sqrt(data8$myVAR)*1.96
  data7<-merge(data6,SN,by="SPECIES_CODE")

  x1<-data.table(data7)
  x1<-x1[,list(LABEL2=min(as.numeric(LABEL2))),by="LABEL"]
  x1<-x1[order(x1$LABEL2),]
  data7$LABEL <- factor(data7$LABEL,levels=x1$LABEL)
  data8$LABEL <- factor(data8$LABEL,levels=x1$LABEL)
  data8       <- data8[order(LABEL),]

  d <- ggplot(data=data7)
  d <- d + geom_point(data=data7,aes(y=yC,x=xC,color=LABEL,size=LABEL,shape=LABEL))
  d <- d + geom_path(data=data8,aes(y=my,x=mx,group=1),size=0.2,color="gray70")
  d <- d + geom_errorbar(data=data8,aes(x=mx,ymax = my + mySEM,
     ymin=my - mySEM),size=0.2,width=0.0)
  d <- d + geom_errorbarh(data=data8,aes(x=mx,y=my,xmax = mx + mxSEM,
     xmin=mx - mxSEM),size=0.2,height=0.0)

  d <- d + geom_point(data=data8,aes(y=my,x=mx,shape=LABEL,color=LABEL),size=2)
  d <- d + scale_colour_manual(name="Size (cm)",
     values=c(rgb.palette(length(unique(data7$LABEL))+1)))
  d <- d + scale_size_manual(name="Size (cm)",values=rep(1,length(unique(data7$LABEL))))
  d <- d + scale_shape_manual(name="Size (cm)",values= c(21,25,15,19,17))
```

```
  if(plotT==6){
    d <- d + xlab("Eastings UTM (km)")
    d <- d + ylab("Northings UTM (km)")
    }

  if(plotT==5){
    d <- d + xlab(expression("Temperature ("* degree * C *")"))
    d <- d + ylab("Depth (m)")
    }

  d  <- d + guides(colour = guide_legend(keyheight=0.5))
  d <- d + theme1(base_size=7)
  plot.title=paste(cn)
  d <- d + ggtitle(plot.title)
  print(d)
}

if(plotT %in% c(7,8))
  {
  Length <- Length[SEX %in% c(1,2)]

  if(plotT==7)
    {
    Length <- Length[complete.cases(Length[,c('TEMP','DEPTH')])]
    data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
      by= 'YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2,TEMP,DEPTH']
    data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,SEX,TEMP,DEPTH']
    data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","SEX","TEMP","DEPTH"))
    data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
      by = 'YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2,TEMP,DEPTH']
    data8<-data3[,list(my=-weighted.mean(DEPTH,PLOT),mx=weighted.mean(TEMP,PLOT),
      myVAR=weighted.var.se(DEPTH,PLOT),mxVAR=weighted.var.se(TEMP,PLOT)),
      by='SPECIES_CODE,SEX,BIN,LABEL,LABEL2']
    data6<-data3[,list(yC=-weighted.mean(DEPTH,PLOT),xC=weighted.mean(TEMP,PLOT),
      yVAR=weighted.var.se(DEPTH,PLOT),xVAR=weighted.var.se(TEMP,PLOT)),
      by='YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2']
    }

  if(plotT==8)
    {
    Length <- Length[complete.cases(Length[,c('LAT','LON')])]
    length1<-Length
    length1$x<-length1$LON
    length1$y<-length1$LAT
    coordinates(length1)<-c("x","y")
    proj4string(length1)<-CRS("+proj=longlat +datum=WGS84")
    LENGTH<-spTransform(length1,CRS("+proj=utm +zone=2 ellps=WGS84"))
    Length$x<-LENGTH$x/1000
    Length$y<-LENGTH$y/1000
    Length<-Length[!is.na(x)]
    data1 <- Length[,list(FREQ=sum(FREQUENCY),CPUE=mean(CPUE)),
      by= 'YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2,x,y']
    data2 <- Length[,list(SUM=sum(FREQUENCY)),by = 'YEAR,SPECIES_CODE,SEX,x,y']
    data3 <- merge(data1,data2,all=T,by=c("YEAR","SPECIES_CODE","SEX","x","y"))
    data3 <- data3[,list(PLOT=sum((FREQ/SUM)*CPUE)),
      by = 'YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2,x,y']
    data8 <- data3[,list(my=weighted.mean(y,PLOT),mx=weighted.mean(x,PLOT),
      myVAR=weighted.var.se(y,PLOT),mxVAR=weighted.var.se(x,PLOT)),
      by='SPECIES_CODE,SEX,BIN,LABEL,LABEL2']
    data6<-data3[,list(yC=weighted.mean(y,PLOT),xC=weighted.mean(x,PLOT),
      yVAR=weighted.var.se(y,PLOT),xVAR=weighted.var.se(x,PLOT)),
      by='YEAR,SPECIES_CODE,SEX,BIN,LABEL,LABEL2']
    }

  data8$SEX2 <-as.factor(ifelse(data8$SEX==1,"Male","Female"))
  data6$xSEM <-sqrt(data6$xVAR)*1.96
  data6$ySEM <- sqrt(data6$yVAR)*1.96
  data7<-merge(data6,SN,by="SPECIES_CODE")

  x1<-data.table(data7)
```

```
    x1<-x1[,list(LABEL2=min(as.numeric(LABEL2))),by="LABEL"]
    x1<-x1[order(x1$LABEL2),]
    data7$LABEL <- factor(data7$LABEL,levels=x1$LABEL)
    data7$SEX2 <-as.factor(ifelse(data7$SEX==1,"Male","Female"))

    plot.title=paste(cn)
    d <- ggplot(data=data7)
    d <- d + geom_point(data=data7,aes(y=yC,x=xC,color=SEX2,shape=SEX2,size=SEX2))
    d <- d + geom_pointrange(data=data7,aes(y=yC,x=xC,ymax = yC + ySEM,
       ymin=yC - ySEM,color=SEX2,shape=SEX2,size=SEX2))
    d <- d + geom_errorbarh(data=data7,aes(x=xC,y=yC,xmax = xC + xSEM,
       xmin=xC - xSEM,color=SEX2,size=SEX2))
    d <- d + scale_colour_manual(name="Sex",values=c("salmon","light blue"))+
       scale_shape_manual(name="Sex",values=c(17,16))+scale_size_manual(name="Sex",
       values=rep(0.05,2))
    d <- d + geom_point(data=data8,aes(y=my,x=mx,color=SEX2,shape=SEX2),size=5)

    if(plotT==7)
      {
      d <- d + xlab(expression("Bottom temp. ("* degree * C *")"))
      d <- d + ylab("Bottom depth (m)")
      }

    if(plotT==8)
      {
      d <- d + xlab("Eastings UTM (km)")
      d <- d + ylab("Northings UTM (km)")
      }

    d <- d + guides(colour = guide_legend(keyheight=0.5))
    d <- d + theme1(base_size=7)
    d <- d + ggtitle(plot.title)
    d <- d + facet_wrap(~LABEL,shrink=FALSE,ncol=length(unique(data7$LABEL2)))
    print(d)
    }
  return(d)
}

## GGPLOT Theme for all plots


theme1 <- function (base_size = 10, base_family = "serif")
  {
    half_line <- base_size/2
    theme(line = element_line(colour = "black", size = 0.5, linetype = 1, lineend = "butt"),
      rect = element_rect(fill = "white", colour = "black", size = 0.5, linetype = 1),
      text = element_text(family = base_family , face = "plain", colour = "black",
       size = base_size, lineheight = 0.9, hjust = 0.5, vjust = 0.5, angle = 0,
       margin = margin(), debug = FALSE),
      axis.line = element_blank(),
      axis.line.x = NULL,
      axis.line.y = NULL,
      axis.text = element_text(size = rel(0.5), colour = "grey30"),
      axis.text.x = element_text(margin = margin(t = 0.8 * half_line/2), vjust = 1),
      axis.text.x.top = element_text(margin = margin(b = 0.8 * half_line/2), vjust = 0),
      axis.text.y = element_text(margin = margin(r = 0.8 * half_line/2), hjust = 1),
      axis.text.y.right = element_text(margin = margin(l = 0.8 * half_line/2), hjust = 0),
      axis.ticks.length = unit(half_line/2, "pt"),
      axis.title = element_text(size=rel(0.75)),
      axis.title.x = element_text(margin = margin(t = half_line), vjust = 1),
      axis.title.x.top = element_text(margin = margin(b = half_line),vjust = 0),
      axis.title.y = element_text(angle = 90, margin = margin(r = half_line), vjust = 1),
      axis.title.y.right = element_text(angle = -90, margin = margin(l = half_line), vjust = 0),
      axis.ticks = element_blank(),

      legend.background = element_blank(),
      legend.key = element_blank(),
      legend.spacing = unit(0.2, "cm"),
      legend.spacing.x = NULL,
      legend.spacing.y = NULL,
      legend.margin = margin(0.1, 0.1, 0.1, 0.1, "cm"),
```

```
      legend.key.size = unit(0.75, "lines"),
      legend.key.height = NULL,
      legend.key.width = NULL,
      legend.text = element_text(size = rel(0.5)),
      legend.text.align = NULL,
      legend.title = element_text(hjust = 0,size=rel(0.75)),
      legend.title.align = NULL,
      legend.position = "right",
      legend.direction = NULL,
      legend.justification = "center",
      legend.box = NULL,
      legend.box.margin = margin(0, 0, 0, 0, "cm"),
      legend.box.background = element_blank(),
      legend.box.spacing = unit(0.2, "cm"),

      panel.background = element_blank(),
      panel.border = element_blank(),
      panel.grid.major = element_line(colour = "grey95",size=0.1),
      panel.grid.minor = element_line(colour = "grey95", size = 0.01),
      panel.spacing = unit(0,"null"),
      panel.spacing.x = NULL,
      panel.spacing.y = NULL,
      panel.ontop = FALSE,

      strip.background = element_blank(),
      strip.text = element_text(colour = "grey10", size = rel(0.75)),
      strip.text.x = element_text(margin = margin(t = half_line, b = half_line)),
      strip.text.y = element_text(angle = -90, margin = margin(l = half_line, r = half_line)),
      strip.placement = "inside",
      strip.placement.x = NULL,
      strip.placement.y = NULL,
      strip.switch.pad.grid = unit(0.03, "cm"),
      strip.switch.pad.wrap = unit(0.08, "cm"),

      plot.title = element_text(size = rel(0.9), hjust = 0, vjust = 1,
       margin = margin(b = half_line * 0.75)),
      plot.subtitle = element_text(size = rel(0.5), hjust = 0, vjust = 1,
       margin = margin(b = half_line * 0.5)),
      plot.caption = element_text(size = rel(0.9), hjust = 1, vjust = 1,
       margin = margin(t = half_line * 0.5)),
      plot.margin = margin(half_line/2, half_line/2, half_line/2, half_line/2),
      plot.background = element_blank(),
      complete = TRUE)
}
```

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