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Standardized Catch Per Unit Effort Indices for Bottomfish Management Unit Species of Guam, 1982–2023

DRAFT for WPSAR CIE Review July 8–12, 2024
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Erin C. Bohaboy and Toby Matthews

NOAA Technical Memorandum NMFS-PIFSC-???
Pacific Islands Fisheries Science Center
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Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, HI 96818

NOAA Technical Memorandum NMFS-PIFSC-###

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Executive Summary

This working paper documents the standardized catch per unit effort (CPUE) of the bottomfish management unit species (BMUS) of Guam based on the Guam Department of Agriculture, Division of Aquatic and Wildlife Resources boat-based creel survey. CPUE indices for 1982–2023 are presented for 11 of the 13 Guam BMUS: *Aphareus rutilans*, *Caranx ignobilis*, *C. lugubris*, *Etelis coruscans*, *Lethrinus rubrioperculatus*, *Lutjanus kasmira*, *Pristipomoides auricilla*, *P. filamentosus*, *P. flavipinnis*, *P. zonatus*, and *Variola louti*. There were insufficient data to produce standardized CPUE indices for the remaining two BMUS, *E. carbunculus* and *P. sieboldii*. We followed the delta-type modeling approach that assumed the overall expected catch per boat-based survey interview of a given BMUS is the product of two independent processes: the probability of occurrence (the presence/absence process) and the CPUE given that the species occurred in the interview (the positive process). Each process was modeled with a mixed-effect general additive model and included covariates for area, time of year, and vessel. Additional covariates that could affect catch independently of changes in stock abundance were also explored using forward stepwise model selection, including time of day, type of day, charter status, bottomfishing type, total fishing effort, wind speed and direction, and moon phase. The selected models explained between 21 and 68 percent of deviance in the data and most often included bottomfishing type and total fishing effort. The CPUE indices presented in this working paper all show high interannual variability and wide confidence intervals, which may be due partially to overall small sample sizes and high observation error of the Guam boat-based creel survey. However, these CPUE indices are a result of continued improvement in CPUE standardization approaches for the assessment of BMUS of Guam, and will be used in the upcoming single-species benchmark stock assessments.

Introduction

The Bottomfish Management Unit Species (BMUS) of Guam include 13 species of snappers, jacks, and a grouper that are managed in Federal waters by the Western Pacific Regional Fishery Management Council (WPRFMC) under the Fishery Ecosystem Plan (FEP) for the Mariana Archipelago (FEP; (WPRFMC, 2009). This working paper is one of four documents prepared ahead of an external review, to be conducted in July 2024 as part of the Western Pacific Stock Assessment Review (WPSAR), to present data that will be used in benchmark stock assessments of Guam BMUS. Previous stock assessments of Guam BMUS have been conducted on the multi-species complex (Langseth et al., 2019; Bohaboy and Matthews, in review). For the upcoming BMUS benchmark assessment, single-species assessments will be considered, which greatly increases the amount and complexity of data and modeling analyses that will need to be presented and reviewed. This working paper documents the standardized catch per unit effort (CPUE) indices for each of the BMUS of Guam. Additional working papers will also be presented detailing species-specific catch, length, and life history data.

Methods

Catch Data

The Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (DAWR) has conducted its boat-based creel survey (BBS) since 1982. The survey uses a stratified design to estimate total catch from boat fishing across Guam, and is fully documented in (Jasper et al., 2016) and summarized in Matthews and Bohaboy (*in review*, "Catch of Bottomfish Management Unit Species of Guam, 1982–2023"). The BBS includes fishermen interviews, for which DAWR staff visit the main landing points of Guam and speak with fishermen to collect trip-level information, including fishing effort (hours fished, number and types of fishing gear, number of fishermen/people on board, and whether the trip was chartered), locations fished (Figure 1), and catch. Catch information includes total catch per species in numbers and weight (which may sometimes be estimated), and may also include individual fish length or weight observations.

We downloaded 1982–2023 BBS interview records from the Guam SQL-server Datawarehouse curated by the Western Pacific Fisheries Information Network (WPacFIN) on 01May, 2024. We used only interviews with reported fishing method of “bottomfishing” and minimally filtered the interview set to remove incomplete records and records containing values suggestive of a possible data entry or sampling error, leaving 6,062 total interviews. CPUE was calculated as catch per trip; trip duration and fishing intensity, recorded as hours fished and number of fishers or gears, were investigated within the standardization models as possible covariates (see below).

In the BBS, catch is occasionally recorded using common name groups or families. There are nine such groupings that may contain BMUS: ‘shallow bottomfish’, ‘assorted bottomfish’, ‘deep bottomfish’, ‘Lethrinidae’, ‘deep snappers’, ‘Carangidae’, ‘Lutjanidae’, ‘Serranidae’, and ‘shallow snappers’. When estimating total catch from the BBS, the unidentified catch within these groups was allocated into presumptive component species following the approach detailed in Matthews and Bohaboy (in review). However, for producing the standardized CPUE index, unidentified catch from groups was not allocated to presumptive species at the interview level, because doing so would inflate the occurrence of each species by adding a small amount of catch to each interview that recorded groups that could include the species. For example, in 1985, there were 36 interviews that recorded *L. kasmira* and 37 interviews that recorded ‘shallow bottomfish’, but did not identify *L. kasmira*. The species composition of the ‘shallow bottomfish’ encountered in these 37 interviews is unknown, but, based on DAWR catch identification practices, could include *L. kasmira*, as well as 39 other species of jacks, emperors, snappers, butterfishes, scorpaenids, and small groupers. Allocating 2% of recorded catch of ‘shallow bottomfish’ in every interview to *L. kasmira* (the proportion of ‘shallow bottomfish’ recorded in 1985 presumed to be *L. kasmira*, by weight), would double the number of interviews positive for *L. kasmira* in 1985, and likely introduce false occurrences to the set of interviews used for the CPUE standardization. Similarly, assuming no species-level decomposition of ‘shallow bottomfish’ would be classifying these 37 interviews as negative for *L. kasmira*, which would also introduce bias into the dataset. We chose instead to exclude these 37 interviews from the interview set used for the *L. kasmira* CPUE index. When preparing the interview sets used for the CPUE standardization of each individual BMUS, we excluded interviews containing unidentified groups that could include the particular BMUS (Table 1).

The 2019 benchmark and 2024 update stock assessments used a standardized CPUE index for aggregate BMUS. As a result, allocating unidentified group catch into presumed BMUS introduced less positive bias to the occurrence data because in aggregate, the 13 BMUS were well represented in unidentified groups.

Table 1. For each bottomfish management unit species (BMUS) in Guam, interviews containing groups that could include the BMUS were excluded from the dataset used in the catch per unit effort (CPUE) standardization analysis.

BMUS	Unidentified groups								
	Assorted bottomfish	Shallow bottomfish	Deep bottomfish	Shallow snappers	Deep snappers	Carangidae	Lethrinidae	Lutjanidae	Serranidae
A. rutilans	x		x		x			x	
C. ignobilis	x	x				x			
C. lugubris	x	x				x			
E. carbunculus	x		x		x			x	
E. coruscans	x		x		x			x	
P. auricilla	x		x		x			x	
P. filamentosus	x		x		x			x	
P. flavipinnis	x		x		x			x	
P. sieboldii	x		x		x			x	
P. zonatus	x		x		x			x	
L. rubrioperculatus	x	x					x		
L. kasmira	x	x						x	
V. louti	x	x							x

Modeling Approach

CPUE standardization was performed on each BMUS individually. The proportion of interviews where a given BMUS was not caught (absence) ranged from 0.73 for the most commonly encountered BMUS, *L. rubrioperculatus*, to 0.99 for the most rarely recorded BMUS, *P. sieboldii*. The high number of zero-catch (absence) observations in the data required we follow the delta-type modeling approach that assumed the overall expected CPUE of a given BMUS is the product of two independent processes: the probability of occurrence (the presence/absence process) and the CPUE given the species occurred in the interview (the positive process). The presence/absence process carried the assumption of a binomial error distribution and used a logit link function. The positive process modeled the natural logarithm of the CPUE, in kg per trip, following a gaussian error distribution and used an identity link.

Each process was modeled with a general additive model (GAM) using the gam() function in R package 'mgcv' (Wood, 2019). For BMUS and processes with sufficient interviews, vessel identification was added as a random intercept term after covariate selection was complete (see below). Covariates were included in the models as categorical, linear, or smooth terms using cyclic cubic regression splines. Cyclic cubic regression splines were penalized to ensure model effects for minimum and maximum values matched, e.g. 0 and 1 for moon phase, 0 and 366 for time of year, and 0 and 360 for wind direction. The dimension of the basis (e.g., maximum number of knots) for all smooth terms was from 6–8.

Covariates and Model Selection

We compiled timeseries of data for variables that we believed would affect catch independently of changes in stock abundance. All covariate data were either taken from BBS interview records or publicly available data sources. Year, time of year, and area were included *a priori* in all standardization models and were not subject to selection. Time of year was modeled in the GAMs as a cyclic cubic regression spline, with a value ranging from 1 (i.e., January 1) to 365 or 366 (i.e., December 31 in normal or leap years, respectively). Bottomfishing interviews included 36 unique offshore area codes (Figure 1), ranging in detail from specific location (e.g., 11 Mile Bank, Area 14 offshore of Agana, etc.) to relatively undefined fishing locations such as quadrants (e.g., "Southwest") and cardinal directions from Guam (e.g., "North"). We included area as a categorical variable by grouping offshore area codes into 5 larger areas: the northern banks (45 Degree and Rota), the southern banks (11 Mile, Galvez, Baby, Santa Rosa, and White Tuna), the eastern side of Guam (offshore area codes 31, 32, 50–52), the northwestern side of Guam (offshore area codes 10–16), and the southwestern side of Guam (offshore area codes 69, 71–73). Conversations with fishermen and preliminary data analyses suggested catch rates and fishing behaviors vary considerably between the banks and nearshore areas of Guam, hence we had to exclude 456 interviews that were recorded only to the northeast or southwest quadrants (offshore area codes 30 and 70) because it is unknown whether these trips were conducted on the banks or nearshore areas. The cardinal directions of north, west, and south were also ambiguous because they could include banks or nearshore areas, so interviews recorded for offshore area codes 20, 40, 60, and 80 (N = 218 interviews) were also excluded. We included a random interaction between year and area when there were sufficient interviews to allow model fitting, in order to accommodate possible differences in CPUE trends over time among areas.

We explored time of day as a categorical variable in the models with levels corresponding to quarters of the day (midnight until 6 am, 6 am until noon, noon until 6 pm, 6 pm until midnight). Type of day was explored in the CPUE standardization as a categorical variable with 2 values: weekday (Monday through Friday, excluding holidays) and weekend (Saturdays, Sundays, and holidays as determined within the BBS sampling protocol). Charter status (e.g., whether a fishing trip was for-hire, meaning the fishers on board would have been paying the boat owner/operator to be taken fishing) was evaluated as a 2-level variable (yes / no). Charter fishing trips were previously excluded from the CPUE standardization of Guam BMUS during the 2019 benchmark stock assessment (Langseth et al., 2019). However, we chose to retain all charter trips in the dataset and instead evaluate charter status within the standardization models because the number of interviews positive for individual BMUS, particularly the less common species, is far less than for all BMUS considered in aggregate, hence, by excluding charter trips, there would have been too few interviews to estimate CPUE for some BMUS in some years. We also considered the amount of effort per fishing trip, which can be recorded in the BBS interview data as the length of time (hours) spent fishing, the number of fishermen that were fishing, and the number of gears fished (although not clearly defined, a fishing line, regardless of the number of hooks per line, is considered a single gear).

Fishermen may target different species of bottomfish by varying fishing practices such as where, when, and how they fish. For the 2019 benchmark stock assessment, bottomfishing interviews were filtered to exclude trips by fishermen (identified by vessel) that did not have any history of catching BMUS or groups potentially containing BMUS. We instead chose to retain all bottomfishing interviews and account for the targeting behavior of fishermen by the type of bottomfishing that was reported (‘shallow’, ‘deep’, or ‘mixed’). There are no quantitative depth ranges established for these identifications, instead they roughly correspond to the types of bottomfishes a fisherman may be targeting. For example, many fishermen indicate when they are ‘shallow’ bottomfishing, they catch *C. ignobilis, C. lugubris*, *L. rubrioperculatus*, *L. kasmira*, and *V. louti*, whereas they often catch *A. rutilans*, and *Etelis* and *Pristipomoides* spp. while ‘deep’ bottomfishing (Iwane et al., 2023). Interviews recorded as ‘mixed’ within the BBS data describe fishing trips where the fishermen engaged in both types of fishing, and was considered as a third level of the type of bottomfishing variable.

The environmental variables we selected that may affect catchability of BMUS were moon phase, wind speed, and wind direction, which were all indicated by Guam fishermen as important factors affecting bottomfishing (Iwane et al., 2023). Moon phase was assigned for each interview using the R package ‘lunar’ (Lazaridis, 2015) providing values between 0 and 1, with 0 and 1 as the beginning and end of the moon cycle (new moon), 0.25 as the first quarter, 0.5 as the full moon, and 0.75 as the last quarter. Moon phase was considered as a cyclic cubic regression spline, penalized to ensure model effects for 0 and 1 were equivalent. Daily average wind speed (miles per hour; mph) and wind direction (origination of wind, degrees from north) for 1982–2023 were downloaded from the publicly available dataset at visualcrossing.com, which was produced by combining multiple nearby meteorological monitoring stations to create the entire timeseries (Visual Crossing Corporation, 2024). Wind speed was considered as a linear term and wind direction was considered as a cyclic cubic regression spline, penalized to ensure model effects for 0 and 360 degrees were equivalent.

For BMUS and processes with sufficient interviews to allow for model minimization, vessel identification was added after covariate selection as a random effect to account for differences in skill of the fishermen, which would be expected to vary over time in the CPUE standardization dataset as more or less skilled fishermen are represented in BBS interviews. BBS interviews include vessel identification information in terms of the boat registration number, name, or description. Of the covariates investigated in these analyses, vessel identification was the most computationally demanding for model fitting and most frequently missing information in BBS interviews, so it was considered last after all other covariates were added to the models. There were 1,515 unique vessel names recorded in bottomfishing interviews, however, after interviews attributed to ambiguous identifiers such as “white boat” and “unknown#” were eliminated, and assumed duplicate values were standardized (e.g., “25”, “025”, “0025” were assumed to represent the same vessel/fisherman), there were 1,450 unique vessels remaining in the dataset.

Models were selected using a forward-stepwise approach. All perspective covariates were evaluated at each step. Models containing each candidate covariate were compared to the previous step using a chi-squared likelihood ratio test (Ott & Longnecker, 2001). The model with the lowest Akaike information criterion (AIC) value and a significant likelihood ratio chi-squared test statistic at alpha = 0.05 was retained at each step. Addition of covariates to each model continued only if the percent deviance explained relative to the intercept only (null) model was at least 1% greater than the percent deviance explained by the previous simplest model.

Table 2. Summary of covariates considered in the CPUE standardization of Guam BMUS.

Covariate name	**Type of variable**	**Description in model: number of levels or range.**	**Included in model?**	**Notes / source**
Year	categorical	42 (each year 1982–2023)	*a priori*	Recorded in interview.
Area	categorical	5 (E_banks, E_nearshore, NW, SW_banks, SW_nearshore)	*a priori*	Based on DAWR BBS offshore survey codes (**Figure 1**).
Year*area interaction	random interaction	42*5 year*area interactions, modeled as *iid* normal.	data permitting	
Time of year	cyclic cubic regression spline	2–365 (day of year)	a priori	Penalized to ensure modeled values of 0 and 366 were equal.
Vessel	random intercept	1,450 unique vessels, modeled as *iid* normal.	data permitting	
Time of day	categorical	4 (by quarter 0000–0600, 0600–1200, 1200–1800, 1800–0000)	if selected	Based on recorded time of interview.
Type of day	categorical	2 (weekday, weekend/holiday)	if selected	Recorded in interview.
Charter status	categorical	2 (charter, non-charter)	if selected	Recorded in interview.
Type of fishing	categorical	3 (deep, shallow, mixed)	if selected	Recorded in interview as “depth”.
Hours fished per trip	linear	1–24	if selected	Recorded in interview.
Number of fishermen per trip	categorical	6 (1, 2, 3, 4, 5, or 6+)	if selected	Recorded in interview.
Number of gears per trip	categorical	4 (1, 2, 3, or 4+)	if selected	Recorded in interview.
Moon phase	cyclic cubic regression spline	0–1 (new moon: 0 and 1, first quarter: 0.25, full moon: 0.5, last quarter: 0.75)	if selected	Determined by date using R package ‘lunar’ (Lazaridis, 2015). Penalized to ensure modeled values of 0 and 1 were equal.
Wind speed	linear	5.1–49.4 miles per hour (mph)	if selected	Daily average wind speed compiled from meteorological stations in Guam (Visual Crossing Corporation, 2024).
Wind direction	cyclic cubic regression spline	0.6–357.5 degrees from north	if selected	Daily average wind direction compiled from meteorological stations in Guam (Visual Crossing Corporation, 2024). Penalized to ensure modeled values of 0 and 360 were equal.

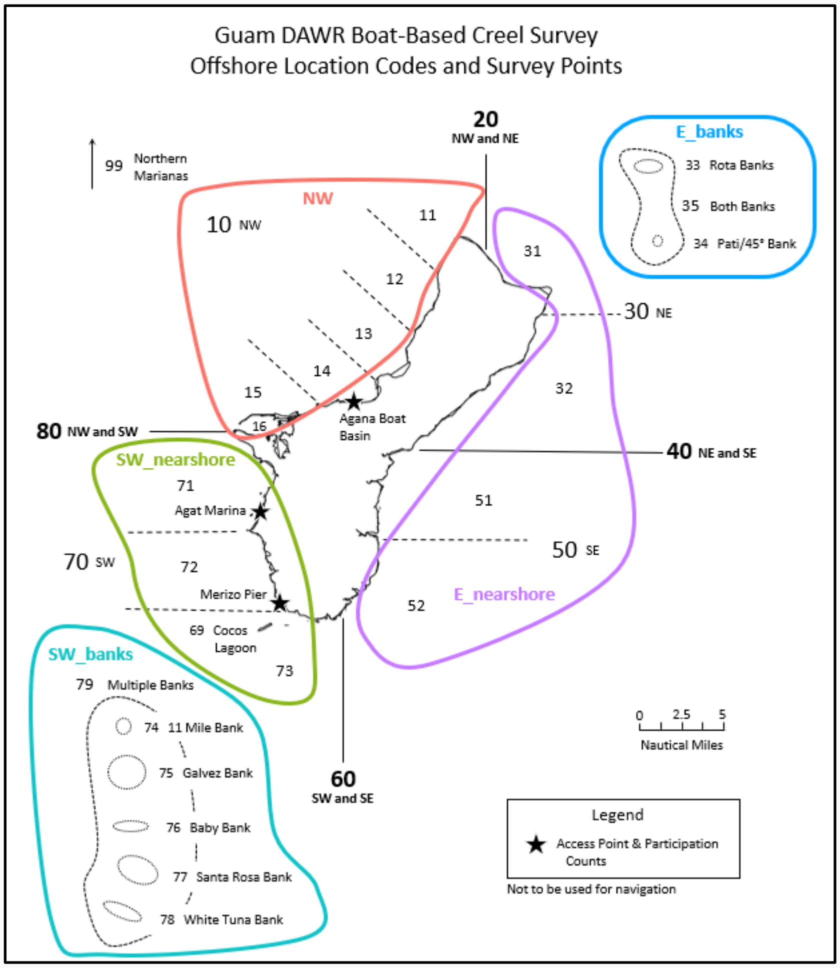

Figure 1. Guam Department of Agriculture and Wildlife Resources (DAWR) Boat-based Creel Survey offshore location codes, grouped into 5 larger areas: the east/northeast banks (E_banks), the northwestern quadrant of Guam (NW), the southwestern nearshore areas (SW_nearshore), the south / southwestern banks (SW_banks), and the eastern nearshore areas (E_nearshore).

Index Generation

The annual probability of occurrence (presence/absence process) and expected CPUE given positive catch (positive process), together with variance estimates, were estimated from the selected models for all combinations of year × area × month for each BMUS (Walters, 2003). This approach, sometimes referred to as “estimated marginal means” or “Walter’s large table” (Campbell, 2015) was used because the number of interviews for each area and time of year were not expected to be constant over the 42 years of the timeseries. Time of year was predicted as the mid-point of each month for the purposes of index generation to reduce the size of the prediction grid (i.e., there were 12 levels for time of year within the prediction grid, instead of 365 or 366). For models that included random vessel effects, predictions were calculated assuming the central random effect of vessel, e.g., a vessel coefficient of zero, or the most typical fishing vessel. For all other covariates, median values across the dataset were used for linear and smooth covariates, and mode values were used for categorical covariates.

Yearly mean values and variances were calculated over time of year and area for each process and then were combined following the approach of (Goodman, 1960) as described in (Campbell, 2015) to produce the final standardized CPUE indices. Areas were weighted within the mean by the relative amount of seafloor within either the 0–100 m or 100–400 m depth range (Figure 2Figure 3), as indicated by the General Bathymetric Chart of the Oceans (GEBCO) 2023 global bathymetry 15 arc-second spatial resolution model (GEBCO Compilation Group, 2023). Either the 0–100 or 100–400 m depth ranges were used for each BMUS based on information provided by Guam fishermen regarding where they catch each species (Iwane et al., 2023): 0–100 m was used for *Caranx* spp., *L. rubrioperculatus*, *L. kasmira*, and *V. louti*; 100–400 m was used for *A. rutilans*, *Etelis* spp., and *Pristipomoides* spp.

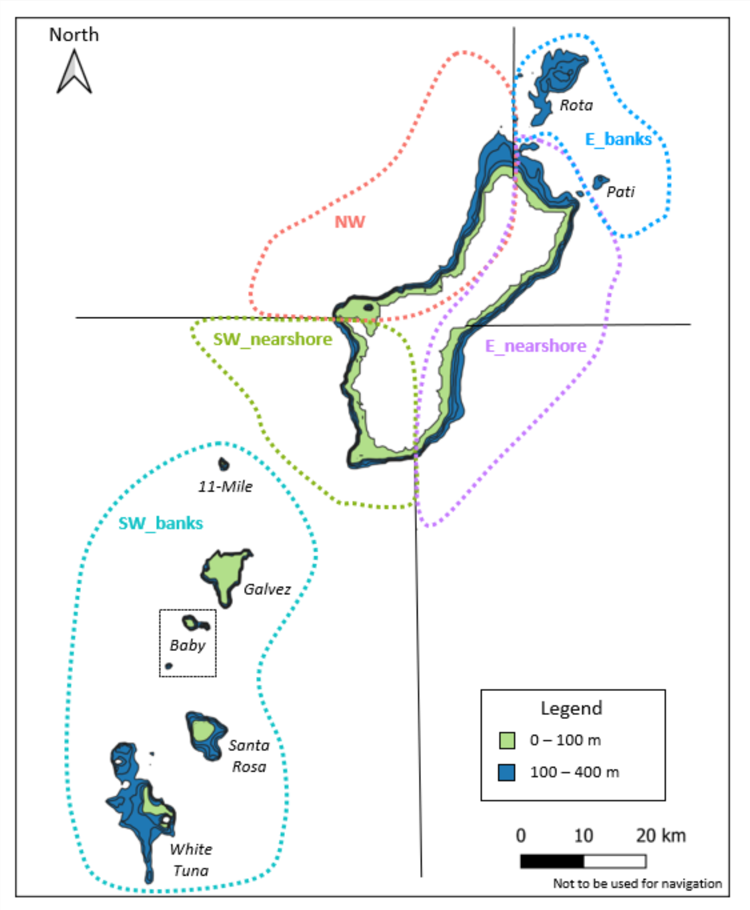

Figure 2. A map showing the relative amount of seafloor bottom, by 0–100 m and 100–400 m depth ranges for the 5 areas around Guam.

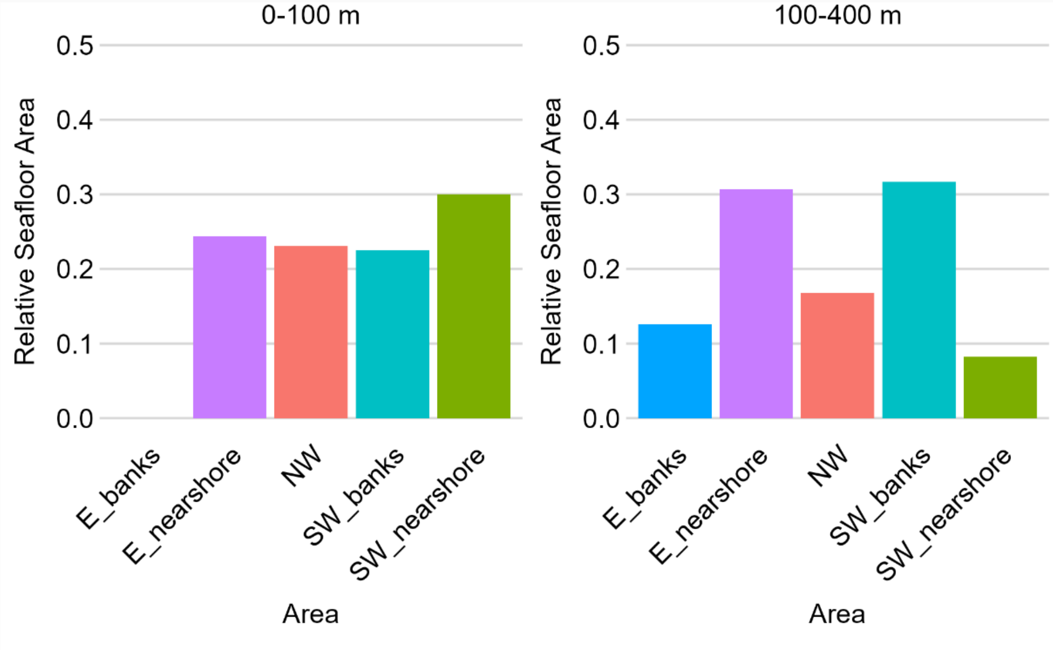

Figure 3. A barplot showing the proportion of seafloor area for the 5 regions around Guam, by 0–100 m depth (left) and 100–400 m depth (right).

Model Diagnostics and Visualization

Residual distributions for each selected presence/absence and positive process model were examined to ensure model appropriateness. A predictive check was performed by simulating 50 datasets from each model (computed using R package ‘performance’; (Ludecke, 2024)) and visually comparing the density distributions of the simulations and the model input data.

We plotted the partial effects of each covariate within each model using the ggpredict() function from the R package ‘ggeffects’ (Ludecke et al., 2022). The partial effect is the effect of each level or value of the covariate on the response when all other variables in the model are held constant. For fixed-effect categorical covariates, the partial effects are proportional to the coefficient values for each level of the variable. We also plotted the number of BBS interviews for each level or value of the covariate by year in order to visualize variability or shifts in the number of observations (interviews) for a covariate over time. As described in the previous section, we accounted for any temporal variation in the number of interviews by area and time of year by including those variables in the calculated marginal means of the estimated CPUE indices. For all other covariates, we used influence plots following (Bentley et al., 2012) to visualize the combined influence of the covariate effect and any trends or variability in the number of observations (interviews) for each level or values of the covariate over time. For a given covariate, this annual metric of relative influence can be summarized as the partial effects averaged over all observations within a year minus the partial effect averaged over all observations and years.

General Results and Discussion

We present standardized CPUE indices for 11 of the 13 Guam BMUS. We do not attempt to provide a CPUE index for *E. carbunculus* because this species is not reliably identified in the Guam BBS. We also do not provide a CPUE index for *P. sieboldii* because it is rarely encountered by Guam bottomfishermen and there are insufficient observations in the BBS to produce a standardized CPUE index.

The number of BBS interviews available for the CPUE standardization models varied among BMUS, especially for the positive process, ranging from 86 for the rarest BMUS in the BBS data for which we attempt to perform a standardization, *C. ignobilis*, to 1321 for the most common BMUS, *L. rubrioperculatus*. The number of interviews in the presence/absence process models ranged from 4,533 to 5,083 and was variable among BMUS. Of the total 6,062 bottomfishing interviews in the dataset, the interviews excluded for containing unidentified species groups varied by BMUS and interviews excluded for missing covariate information varied by the covariates within the model. The amount of deviance explained by each model ranged from 10 to 68 percent, being expectedly higher for models with less data.

Targeting (bottomfishing type, or 'depth') was the first selected covariate in the presence/absence models for all BMUS except *C. ignobilis* (Table 3Table 4). The models suggest *A. rutilans*, *C. lugubris*, *E. coruscans*, *P. auricilla*, *P. filamentosus*, *P. flavipinnis*, and *P. zonatus* were unlikely to be encountered in shallow bottomfishing trips and more likely to be encountered in deep or mixed bottomfishing trips. In contrast, *L. rubrioperculatus*, *L. kasmira*, and *V. louti* were more likely to be encountered in shallow bottomfishing trips. Targeting was included, but minimally influential, in the positive process models for *A. rutilans*, *P. auricilla*, *P. flavipinnis*, and *P. zonatus*. In these models, if encountered, the CPUE of each BMUS was marginally higher for deep relative to shallow or mixed bottomfishing trips. These general trends agree with the information from fishermen that they effectively target different groups of BMUS by undertaking either shallow or deep bottomfishing.

Considered in isolation, the effect of targeting within the models suggests that the increase in deep relative to shallow bottomfishing interviews over the timeseries (Figure 27) has a stabilizing effect on the year-only model estimated CPUE of species that are more likely to be encountered in deep bottomfishing (e.g., *P. auricilla*). In contrast, for BMUS that are much more likely to be encountered on shallow bottomfishing trips (e.g., *L. rubrioperculatus*) the heavy proportion of shallow trips in the dataset during the early part of the timeseries (e.g., 1992, 1995, 1997, 1999) would have increased the year-only model estimated CPUE, yet decreased CPUE in years when deep bottomfishing was more prevalent (e.g., 2009, 2012, 2020). It is important to remember within the final CPUE standardization models, no covariates operate in isolation, and partial effects of covariates that appear strong or unidirectional may be obscured by opposing effects of other covariates in the final CPUE index estimation.

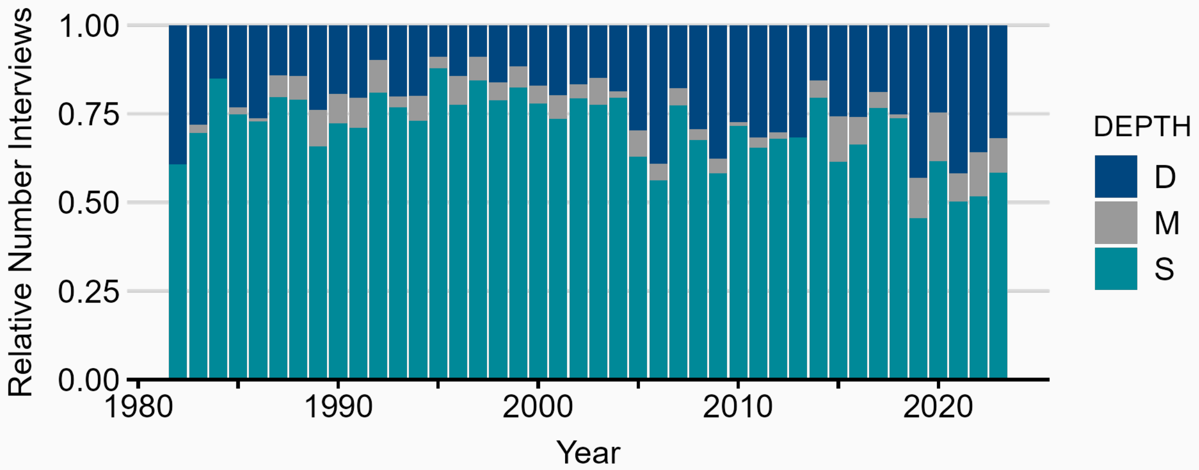

Figure 4. The relative number of interviews by bottomfishing type, 1982–2023. “D” is deep, “M” is mixed, and “S” is shallow.

Fishing effort per trip in the form of hours fished was selected in one or both processes for all BMUS. In the presence/absence models, the probability of encountering each BMUS increased with a greater number of hours fished. For example, the presence/absence process model for *A. rutilans* included a relatively strong partial effect of effort on catch: a trip with 10 hours fished was twice as likely to encounter *A. rutilans* than a trip with 2 hours fished. It is important to note that hours fished was not included in the positive process models for either *C. ignobilis* or *E. coruscans*. This suggests if hours fished had been included within the effort definition of the CPUE standardization (i.e., if CPUE were modeled in terms of catch per hour fished instead of catch per trip), then for these 2 BMUS, variation in trip length between years would have unduly influenced modeled CPUE trends. The other effort covariates, number of fishers and number of gears, were selected in only the positive process models for *C. ignobilis*, *P. auricilla*, *P. flavipinnis*, and *V. louti*, and were selected last in each case. Similar to the hours fished effort metric, including either of number of fishers or number of gears within the effort definition of the CPUE standardization (e.g., if CPUE were modeled in terms of catch per gear, or catch per gear × hour fished instead of catch per trip) would have had a potentially spurious or obscuring effect on modeled CPUE for most of the BMUS.

A time of day covariate was not selected in the majority of models, but was included in the presence/absence process models for *C. ignobilis* and *E. coruscans*, and the positive process models for *L. kasmira*, *P. filamentosus*, and *V. louti*. The effect of time of day on *C. ignobilis* and *P. filamentosus* was very slight and could have been largely spurious, being driven by small sample size. However, the influence of time of day on the standardization of the other BMUS revealed some interesting trends. For example, in the presence/absence process model for *E. coruscans*, the probability of occurrence in interviews reported between 1800 and 0600 was roughly twice that than during 0600 and 1800. There is high interannual variability in the relative contribution of nighttime to daytime trips within the dataset, and a general shift towards daytime trips in recent years. As a result, time of day has had a negative influence within the presence/absence process model for *E. coruscans*. For the positive processes for *L. kasmira* and *V. louti*, the influence of time of day, although included in the models, was relatively minor.

The type of day was not selected in any model. This was somewhat unexpected because there is a persistent perception that fishermen who fish only on weekends and holidays would have different abilities to catch bottomfishes relative to fishermen who fish during the week and are likely more dedicated or experienced bottomfishers. This may certainly be the case, but within the CPUE model selection, there may be insufficient data or too much variability for this relationship to be quantifiable. Similarly, whether or not a fishing trip was a charter trip had an effect in only two models: the positive processes for *E. coruscans* and *L. kasmira*. In both instances, catch was slightly lower for charter trips than non-charter trips. As for type of day, there is an indication from the fishing community that charter fishing trips are conducted differently than non-charter trips, but within the CPUE standardization models presented here, it is possible that those differences are being captured in other model covariates such as area fished, depth, or hours fished.

Environmental factors were also surprisingly not selected for in most models. Wind direction was not retained in any models, while wind speed was retained in only the positive process model for *P. zonatus*. Fishermen indicate that sea conditions, both on the fishing grounds and near the boat harbors, largely influence their decisions whether to go fishing, but within the interview data available in this analysis, whether a given BMUS is encountered and how much is caught is not influential when considered together with all the other covariates explored. Moon phase, in addition to affecting tidal currents, was suggested by fishermen to affect the feeding behaviors and catchability of certain fish. In particular, there was a suggestion that the jacks, *C. ignobilis* and *C. lugubris*, would hunt more actively at night, and hence be easier to catch, when more moonlight was available (Iwane et al., 2023). The relatively small sample size, especially for the positive process for these BMUS (86 and 196 interviews for *C. ignobilis* and *C. lugubris*, respectively) may have prevented such a relationship from being apparent in the data. Further, it is expected that the amount of moonlight would only affect fish behavior at night, hence to properly account for it would require a moon phase × time of day interaction, for which there are not sufficient interview data. Moon phase was retained in one model: the positive process for *E. coruscans*, with fishermen catching slightly more *E. coruscans* closer to the full moon. Interestingly, this is contrary to information from fishermen, who suggested too much moon light causes *E. coruscans* to “go away” (Iwane et al., 2023), which would be associated with the opposite relationship in the model.

Unlike the covariates discussed thus far, area was included in all models without being subject to selection. Both processes for all BMUS except *C. ignobilis* had sufficient data to use a 5-level area variable in the models, which maintained a delineation between the offshore banks and nearer shore areas around Guam (Figure 1). The number of interviews where *C. ignobilis* was observed was very small, and there were not enough data to fit models with 5-levels of area. Instead, both processes for the *C. ignobilis* models used a modified 3-level area, where the banks and nearshore areas were combined (e.g., SW banks and SW nearshore were pooled to SW; E banks and E nearshore were pooled to E). The effect of area within the models was generally minor, but most notable for *A. rutilans*, *E. coruscans*, *L. rubrioperculatus*, *P. filamentosus*, and *P. flavipinnis*, where the southwest nearshore area had the lowest probabilities of occurrence and lowest catches.

Including area as a fixed categorical effect allowed for scaling of the response among areas, however, we assumed the trends in response over time may differ among areas, hence, we added a year × area interaction term into all models, with the exception of instances where data were insufficient to fit the interaction term (the positive process models for *C. ignobilis*, *C. lugubris*, *E. coruscans*, and *P. filamentosus*). The year × area interaction terms were generally unnoticeable and not significant in most models, with the exception of the presence/absence models for *E. coruscans*, *L. rubrioperculatus*, and *V. louti*, and the positive processes for *L. kasmira* and *P. auricilla*. It is important to note that because area was included in the final CPUE estimation of the marginal means by year, shifts in the number of interviews per area over the timeseries of the BBS (Bohaboy & Matthews, 2023) are not expected to influence trends in the estimated CPUE indices.

Time of year was also included in all models *a priori*, but had relatively minor effects on either probability of occurrence or catch. The most noticeable trends were for *L. rubrioperculatus*, *P. auricilla*, and *P. zonatus*, that exhibited peaks in both probability of occurrence and catch during the summer months (July–September). In contrast, *A. rutilans*, *L. kasmira*, and *P. flavipinnis* showed slightly higher probability of occurrence in the winter/spring (November–February).

We added a random intercept term for vessel to the selected models, in instances when there were enough data to do so. For the presence/absence process, only *C. ignobilis* had too few interviews to include a vessel term. For the positive process models, there were too many vessels relative to interviews to include a vessel term for *A. rutilans*, *C. ignobilis*, *P. filamentosus*, *P. flavipinnis*, or *V. louti*. In most instances, the amount of model deviance explained by the addition of the random vessel effect was relatively large, explaining an additional 10–30% of model deviance. For the majority of models that could include a random vessel effect, it is apparent that some vessels may "specialize" on certain BMUS (or multiple BMUS) and are more likely to encounter them, or have higher catches when they are encountered. In general, these specialized fishermen may enter and leave the fishery at different times, often concurrently with less skilled or specialized fishermen, hence the influence within the model is not strong or clearly directional. For instance, in the presence/absence models for *E. coruscans*, *P. filamentosus*, and *P. flavipinnis*, there are a small number of fishermen who are more likely to catch these species, but these fishermen have been participating in the fishery over the timeseries, concurrently with many less experienced fishermen, so the overall influence within the model is small. The vessel effect is perhaps most influential for the relatively shallow BMUS (*L. rubrioperculatus* and *L. kasmira*, and to a lesser extent, *V. louti*), where between 1985 and 1995, there was a peak in interviews from vessels that were particularly likely to catch these species.

It is important to note that shifting compositions of fishing fleets over time can be challenging to account for in CPUE standardization models. Often, particularly for largescale industrialized fisheries, less effective fishermen or fishing vessels might leave the fishery, especially if costs increase. For the Guam bottomfish fishery, it has been suggested by fishermen that during the pandemic when restaurant demand for bottomfishes decreased, many commercial fishermen fished less for deep BMUS, while fishermen who were new to bottomfishing, and perhaps had more free time due to pandemic lock-downs, fished more for deep BMUS. The vessel effect influence values for 2020, 2021, and 2022 are negative relative to the timeseries average for most BMUS, however, this observation applies to both the "shallow" and "deep" BMUS, suggesting that during the pandemic, representation of newer or less skilled fishermen increased in the interview data generally, not necessarily for only the deeper species.

Residual distributions for all presence/absence process models do not indicate any notable degree of overdispersion or heteroskedasticity. Predictive checks also indicated that the binomial error distribution is appropriate. The diagnostics of the positive process models suggest the assumptions of lognormal error structure are not unreasonable, although for some models, including *C. ignobilis*, *C. lugubris*, *E. coruscans*, *P. auricilla*, and *P. filamentosus*, model residuals are slightly negatively skewed. Although not ideal, we believe the estimated variance of the final CPUE indices is sufficiently large to reasonably reflect any uncertainty this may confer within the modeled indices.

The 11 BMUS CPUE indices presented in this working paper all show high interannual variability, which may be due partially to overall small sample sizes or high observation error that is expected from a creel survey attempting to capture information on a fishery as large and diverse as all boat-based fishing in Guam. However, Guam bottomfishermen report that BMUS catches spike in 2–7 year cycles (Iwane et al., 2023), and these observations are apparently captured within the CPUE indices. However, it is uncertain whether these short-term highs and lows in CPUE are reflective of underlying trends in abundance, but may be an artifact of some other variable affecting catchability of BMUS that has not been adequately addressed in these models.

We are confident the CPUE standardization approaches and indices presented in this working paper are appropriate for use in the next benchmark stock assessment of Guam BMUS. Although the generally small number of available interviews and uneven sample coverage over space and time introduce difficulty in the CPUE standardization process, we feel we have sufficiently captured the primary influences of catch rates that are independent of underlying abundance trends, particularly shifts in fishermen behavior over the timeseries regarding areas fished, trip length, and fishermen skill.

The analyses presented here represent an improvement over the CPUE standardization used in the most recent benchmark stock assessment (Langseth et al., 2019). We addressed several suggestions made by members of the WPSAR panels and SSC, including: 1) Account for shifts in overall BMUS species composition over time through the use of single species CPUE standardization models; 2) Account for potential differences in CPUE trends between areas, particularly in the nearshore versus banks. Additionally, we grouped location definitions into larger regions and eliminated interviews with ambiguous location information from the data. We also considered a year × area interaction to account for potential differences in CPUE trajectories over time; 3) Account for changes in the fishermen participating in the fishery over time, i.e., fishermen skill, by including a random intercept term for vessel ID *a priori*; 4) Account for targeting of species within the BMUS complex by using the reported bottomfishing method within the interview data, recognizing that Guam bottomfishermen often target either shallow or deep bottomfishes; 5) More accurately retain the zero catch interviews within the data because species groups are not being broken down to presumptive BMUS at the interview level; 6) Retain charter fishing trips in the data and evaluated the effect for relevance, whereas previously, charter trips were excluded; 7) Treat effort variables (hours fished, gears, fishers) as potential covariates in the model, as opposed to in the definition of effort in the response, to allow for more flexibility.

Table 3. Summary of the selected CPUE standardization models for *A. rutilans*, *C. ignobilis*, *C. lugubris*, *E. coruscans*, and *L. rubrioperculatus*. For each BMUS, the presence/absence (p/a) and positive process (pos) models are shown. An ‘x’ indicates the covariate was included in the model.

Covariate name	*A. rutilans*		*C. ignobilis*		*C. lugubris*		*E. coruscans*		*L. rubrio-perculatus*	
	p/a	pos	p/a	pos	p/a	pos	p/a	pos	p/a	pos
Year	x	x	x	x	x	x	x	x	x	x
Area	x	x	x	x	x	x	x	x	x	x
Year*area interaction	x	x					x		x	x
Time of year	x	x	x	x	x	x	x	x	x	x
Vessel	x				x	x	x	x	x	x
Time of day			x				x			
Type of day										
Charter status								x		
Type of fishing (depth)	x	x			x		x		x	
Hours fished per trip	x	x	x		x	x	x			x
Number of fishermen per trip				x						
Number of gears per trip										
Moon phase								x		
Wind speed										
Wind direction										

Table 4. Summary of the selected CPUE standardization models for *L. kasmira*, *P. auricilla*, *P. filamentosus*, *P. flavipinnis*, P. zonatus, and *V. louti*. For each BMUS, the presence/absence (p/a) and positive process (pos) models are shown. An ‘x’ indicates the covariate was included in the model.

Covariate name	*L. kasmira*		*P. auricilla*		*P. fila-mentosus*		*P. flavipinnis*		*P. zonatus*		*V. louti*	
	p/a	pos	p/a	pos	p/a	pos	p/a	pos	p/a	pos	p/a	pos
Year	x	x	x	x	x	x	x	x	x	x	x	x
Area	x	x	x	x	x	x	x	x	x	x	x	x
Year*area interaction	x	x	x	x	x		x	x	x	x	x	x
Time of year	x	x	x	x	x	x	x	x	x	x	x	x
Vessel	x	x	x	x	x		x		x	x	x	
Time of day		x										x
Type of day												
Charter status		x										
Type of fishing (depth)	x		x	x	x		x	x	x	x	x	
Hours fished per trip	x	x	x	x		x		x		x		x
Number of fishermen per trip				x				x				
Number of gears per trip				x								x
Moon phase												
Wind speed										x		
Wind direction												

Results by BMUS

Aphareus rutilans

A. rutilans was moderately represented in the BBS, occurring in 6.1% of interviews over all years, ranging from 1–20 positive interviews per year (Figure 4). There were sufficient data to included 5 levels of area, and a year × area interaction, for both the presence/absence and positive processes (Table 3). A random vessel effect was included for the presence/absence process only. The selected CPUE standardization models explained 31% and 41% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 5Figure 6), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *A. rutilans*). CPUE was relatively higher on the east/northeast banks. Type of bottomfishing and trip duration had effects within the standardization models, suggesting species were more likely to be caught, and at higher catch rates during deep bottomfishing and longer duration fishing trips (Appendix, Supplemental Results for *A. rutilans*). Overall, there was no clear trend in the standardized CPUE of *A. rutilans* over time (Figure 7).

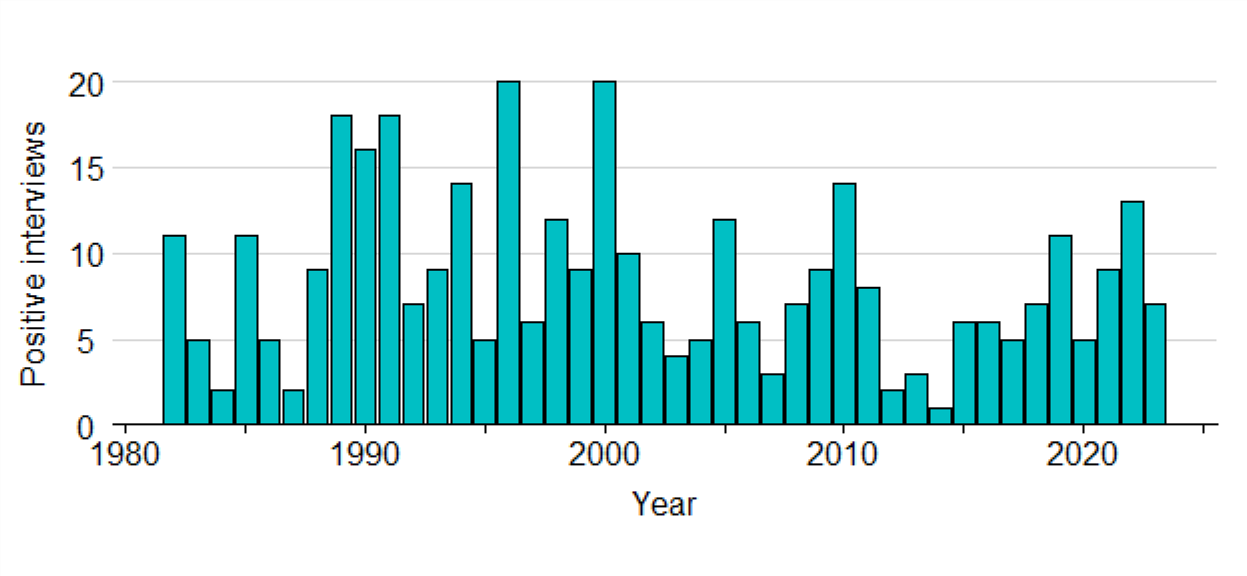

Figure 5. Number of bottomfishing interviews positive for *A. rutilans* by year. The nominal probability of occurrence for 1982–2023 was 0.0608.

Table 5. Selected models for the presence/absence and positive processes for *A. rutilans* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	5039	1574	0.3068
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + HOURS_FISHED	316	261	0.4121

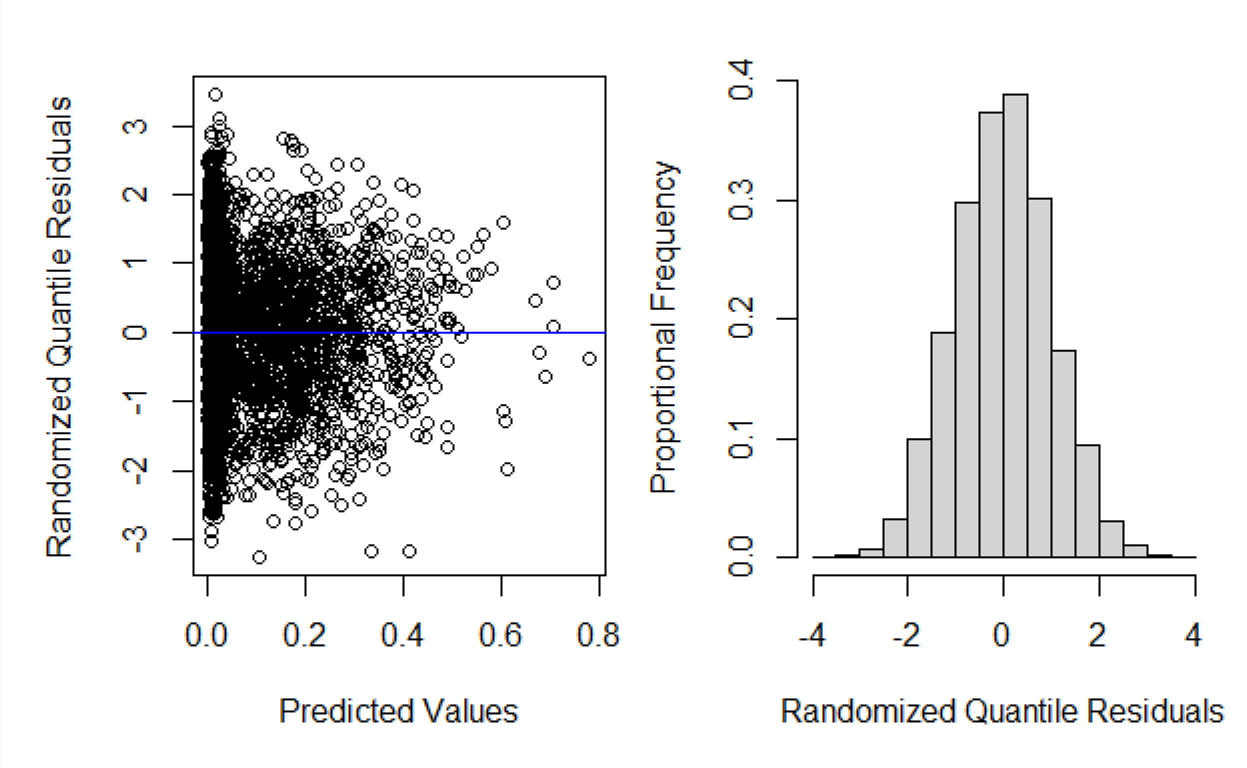

Figure 6. Residual distributions of the presence/absence process model selected for the *A. rutilans* CPUE standardization.

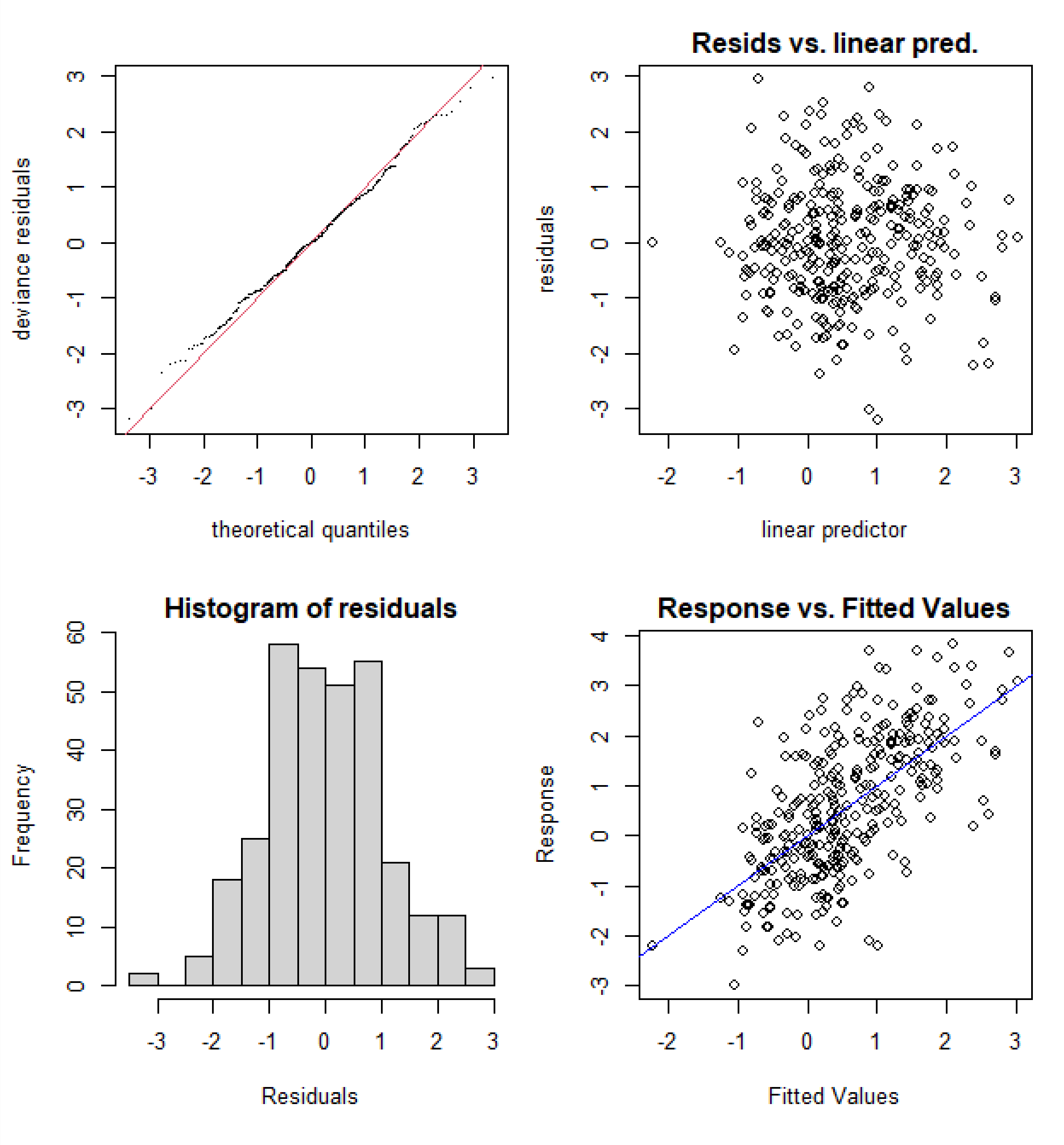

Figure 7. Residual distributions of the positive process model selected for the *A. rutilans* CPUE standardization.

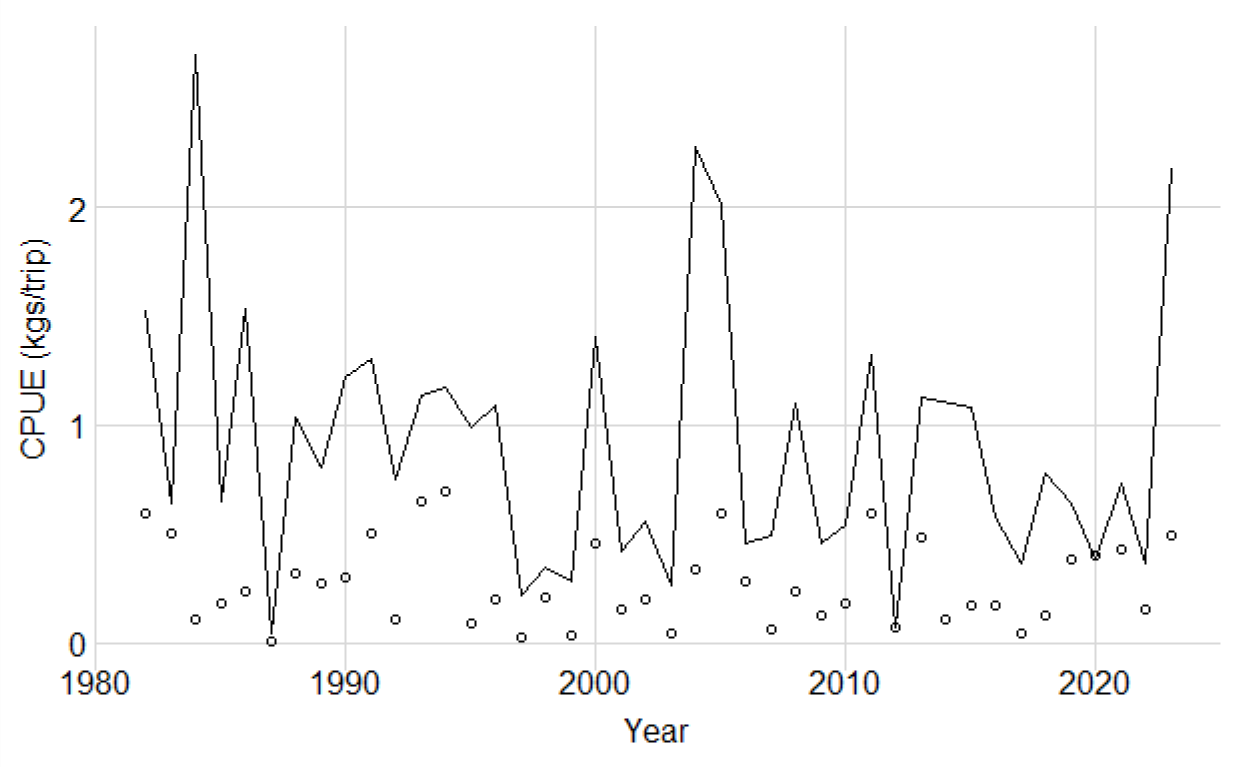

Figure 8. Standardized CPUE index (line) and nominal CPUE (points) of *A. rutilans*.

Caranx ignobilis

C. ignobilis was rarely encountered in the BBS, occurring in 1.6% of interviews over all years, and were not encountered in any interviews during 4 years of the timeseries (Figure 8). There were insufficient data to include a random vessel effect or a year × area interaction in either model (Table 4). The rarity of *C. ignobilis* in the BBS data necessitated reducing area to 3 levels, which combined the banks and nearshore. Nearly all optional covariates were initially selected in the forward stepwise model selection for the *C. ignobilis* positive process model. To avoid excessive overparameterization, the positive process model was limited to just 1 optional covariate. Still, the positive process model was likely highly overparameterized, given the model contained 53 parameters and only 86 data (positive interviews). The selected CPUE standardization models explained 9.7% and 59.7% of deviance in the data for the presence/absence and positive processes, respectively. The high amount of deviance explained by the positive process model was likely driven by overparameterization. Model residual diagnostics (Figure 9Figure 10) suggest model residuals are negatively skewed for the positive process. Overall, there was no clear trend in the standardized CPUE of *C. ignobilis* over time (Figure 11) and relative error (approximated as the standard deviation divided by the CPUE index) of the standardized CPUE index exceeded 100% in all years (Appendix, Supplemental Results for *C. ignobilis*).

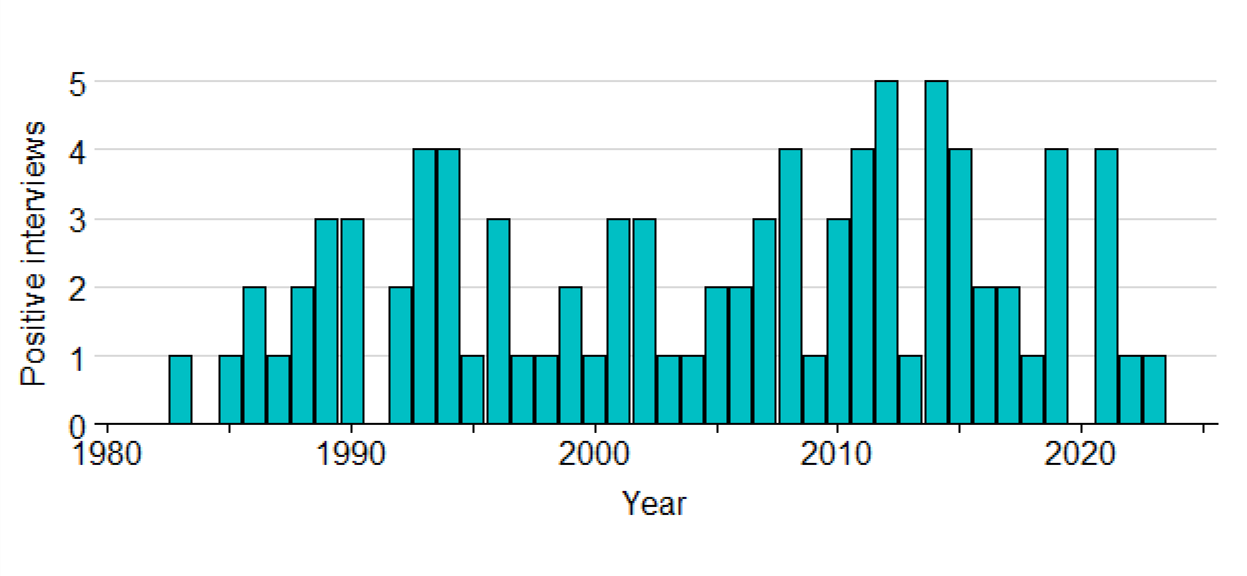

Figure 9. Number of bottomfishing interviews positive for *C. ignobilis* by year. The nominal probability of occurrence for 1982-2023 was 0.016.

Table 6. Selected models for the presence/absence and positive processes for *C. ignobilis* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_D + s(yday, bs = "cc") + HOURS_FISHED + tod_quarter	4991	52	0.0974
Positive	log(catch_kgs) ~ year_fac + AREA_D + s(yday, bs = "cc") + num_fisher_fac	86	53	0.5973

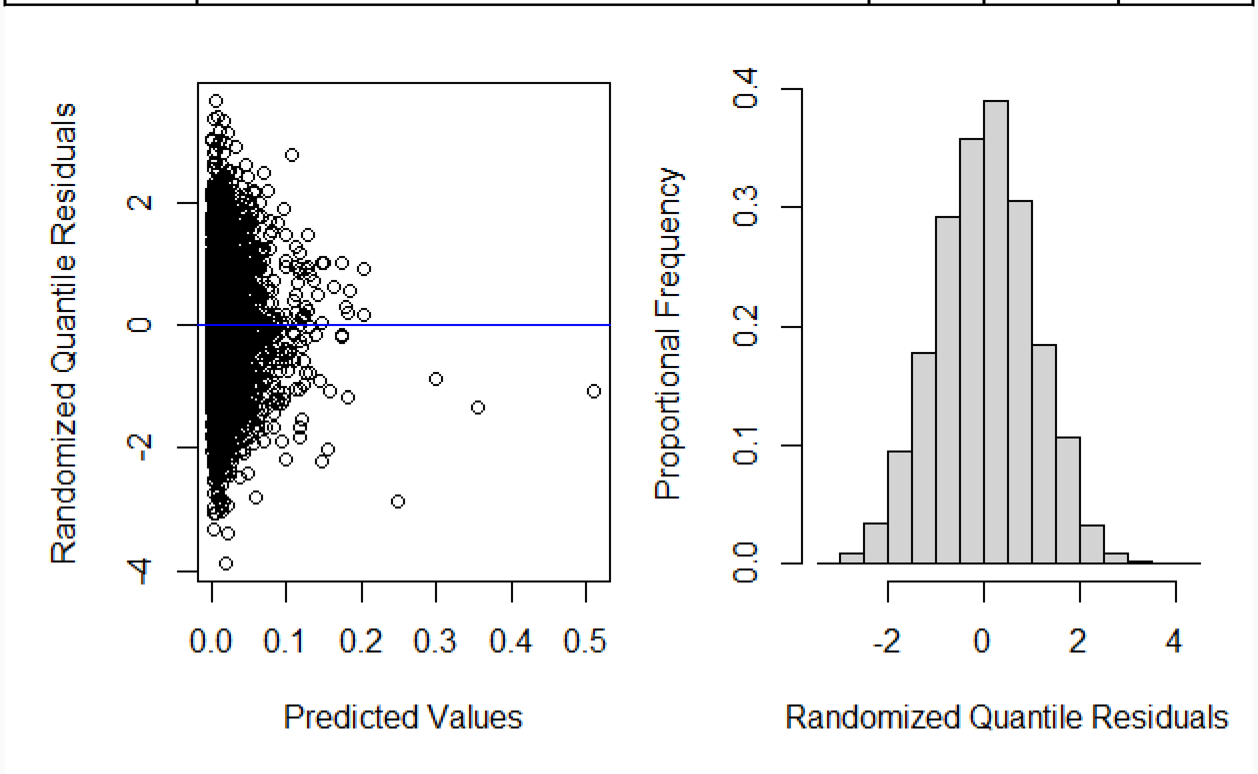

Figure 10. Residual distributions of the presence/absence process model selected for the *C. ignobilis* CPUE standardization.

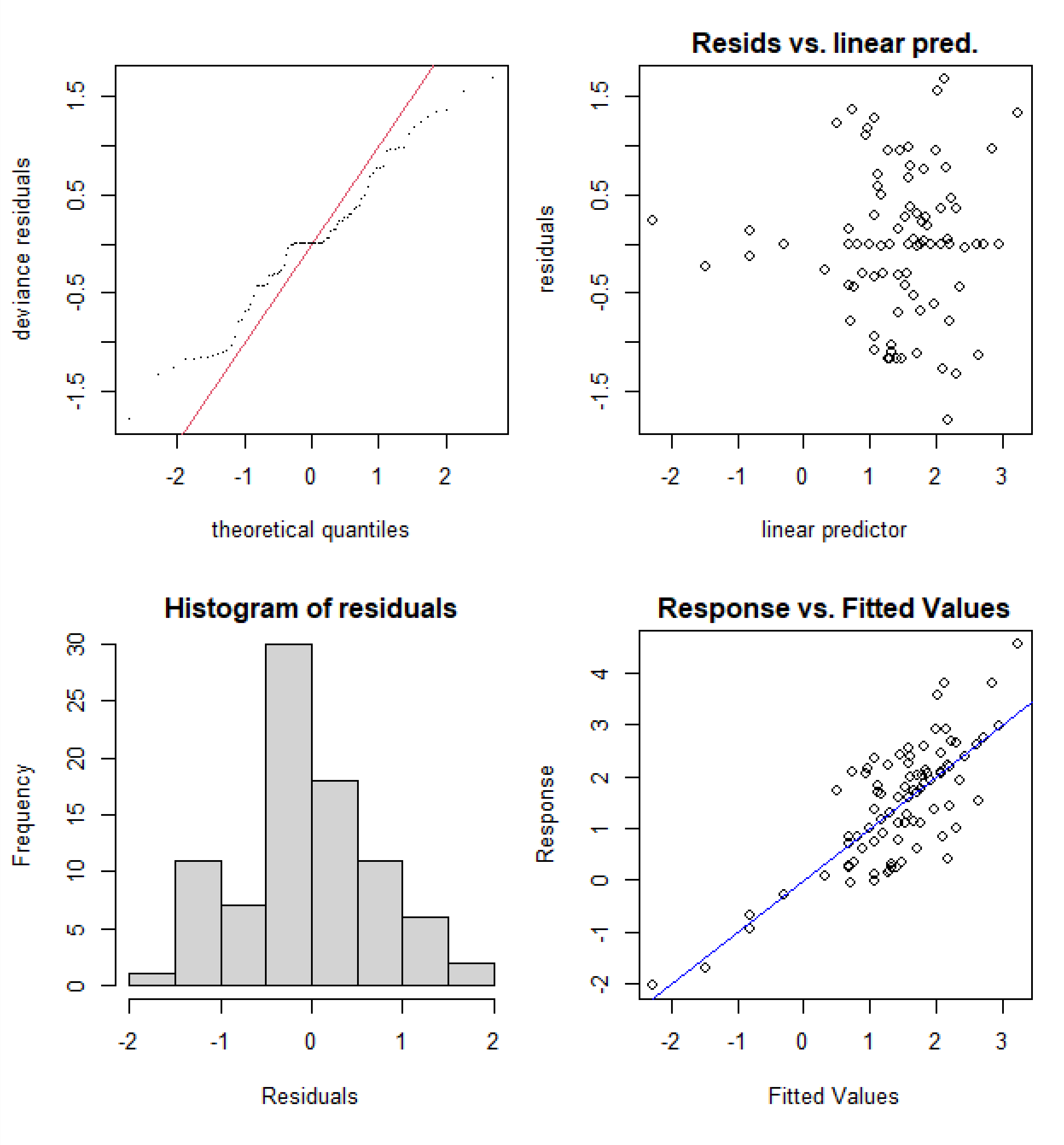

Figure 11. Residual distributions of the positive process model selected for the *C. ignobilis* CPUE standardization.

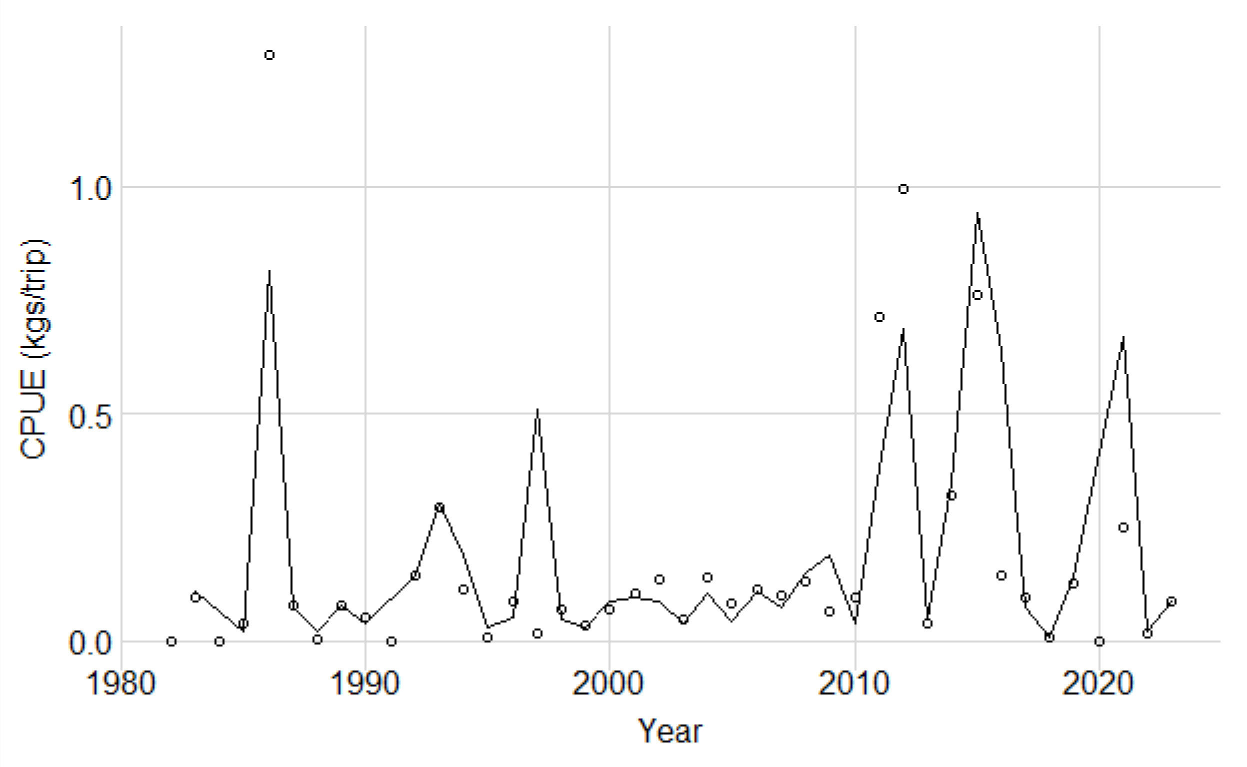

Figure 12. Standardized CPUE index (line) and nominal CPUE (points) of *C. ignobilis*.

Caranx lugubris

C. lugubris was rare in the BBS, occurring in 4.0% of interviews over all years, ranging from 0 interviews in 2023 to 15 interviews in 1998 (Figure 12). Area (as a 5-level variable) and a random effect of vessel were included in both the presence/absence and positive processes (Table 5). However, there were insufficient data to include a year × area interaction in either model. The selected CPUE standardization models explained 28.9% and 68.0% of deviance in the data for the presence/absence and positive processes, respectively. The high amount of deviance explained by the positive process model was likely driven by overparameterization. Model residual diagnostics (Figure 13Figure 14) suggest model residuals are negatively skewed for the positive process. Overall, there was no clear trend in the standardized CPUE of *C. lugubris* over time (Figure 15) and relative error (approximated as the standard deviation divided by the CPUE index) of the standardized CPUE index exceeded 100% in all years (Appendix, Supplemental Results for *C. lugubris*).

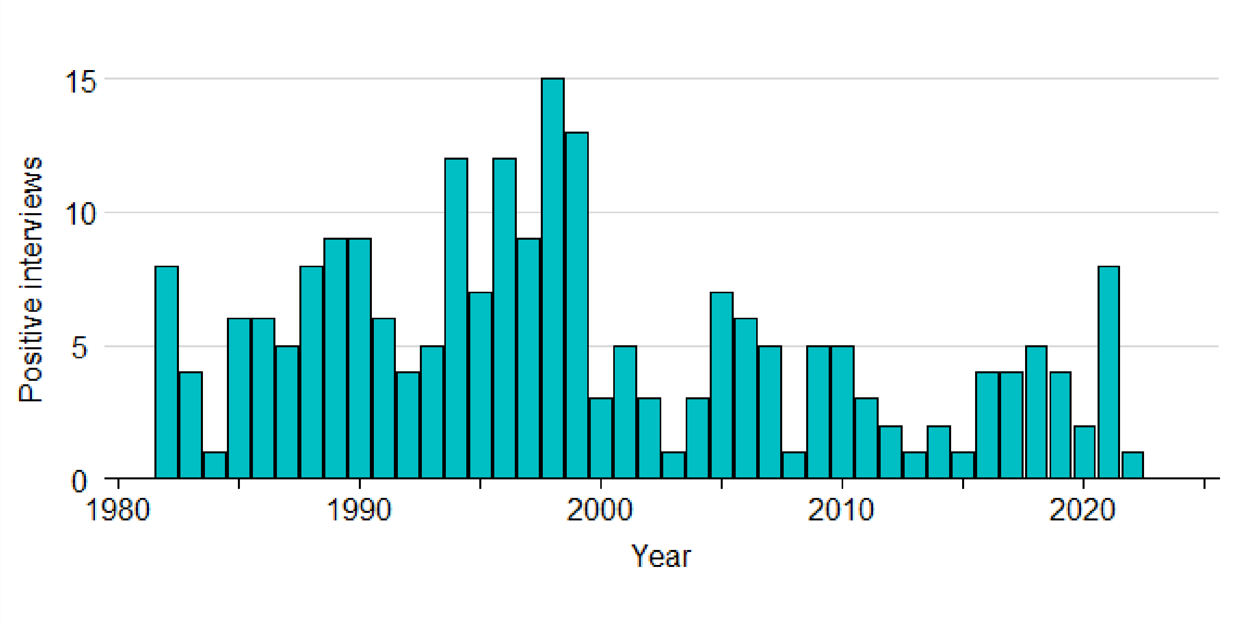

Figure 13. Number of bottomfishing interviews positive for *C. lugubris* by year. The nominal probability of occurrence for 1982–2023 was 0.0396.

Table 7. Selected models for the presence/absence and positive processes for *C. lugubris* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(yday, bs = "cc") + DEPTH + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	4533	1301	0.2889
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(yday, bs = "cc") + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	196	180	0.6803

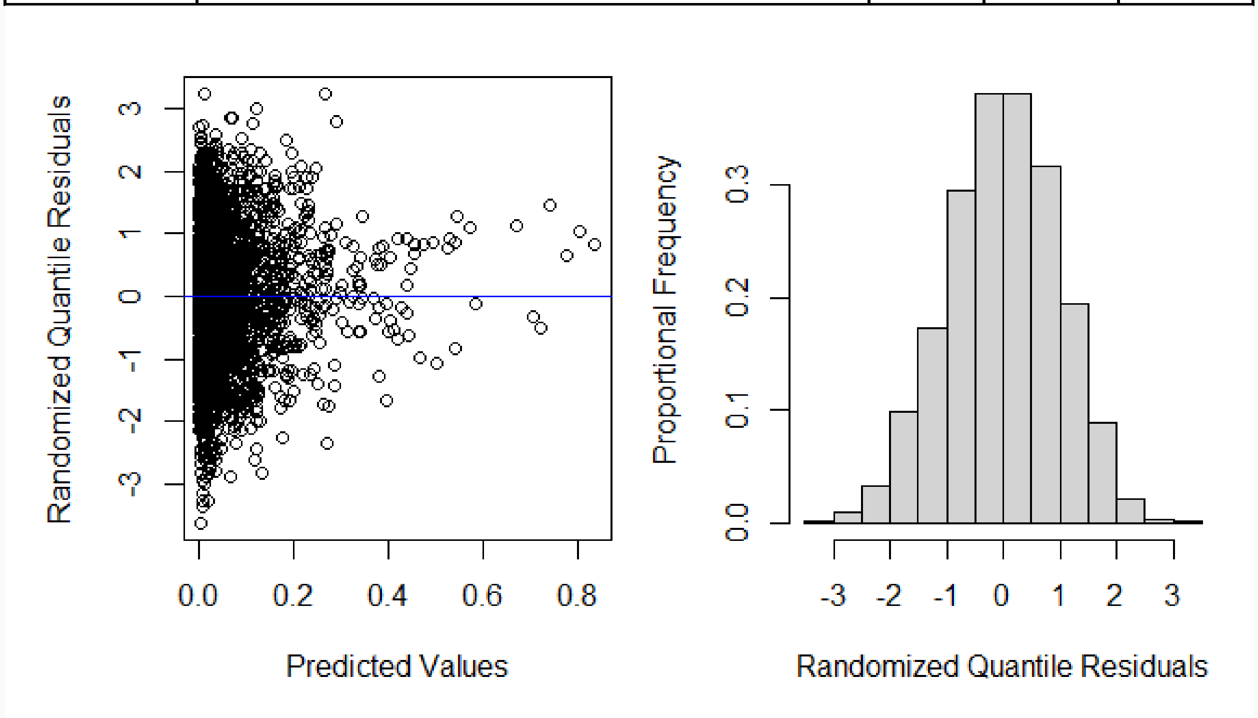

Figure 14. Residual distributions of the presence/absence process model selected for the *C. lugubris* CPUE standardization.

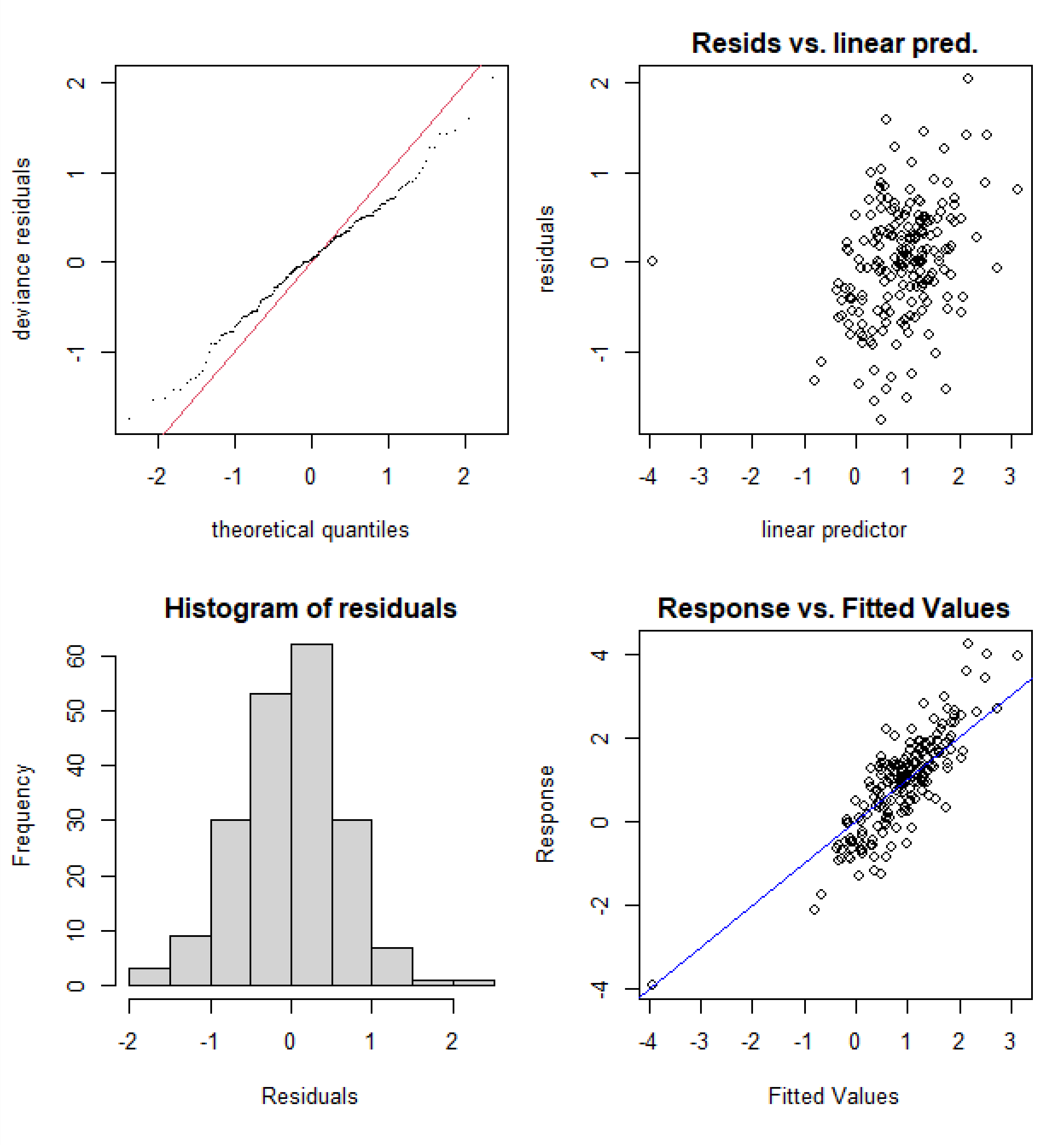

Figure 15. Residual distributions of the positive process model selected for the *C. lugubris* CPUE standardization.

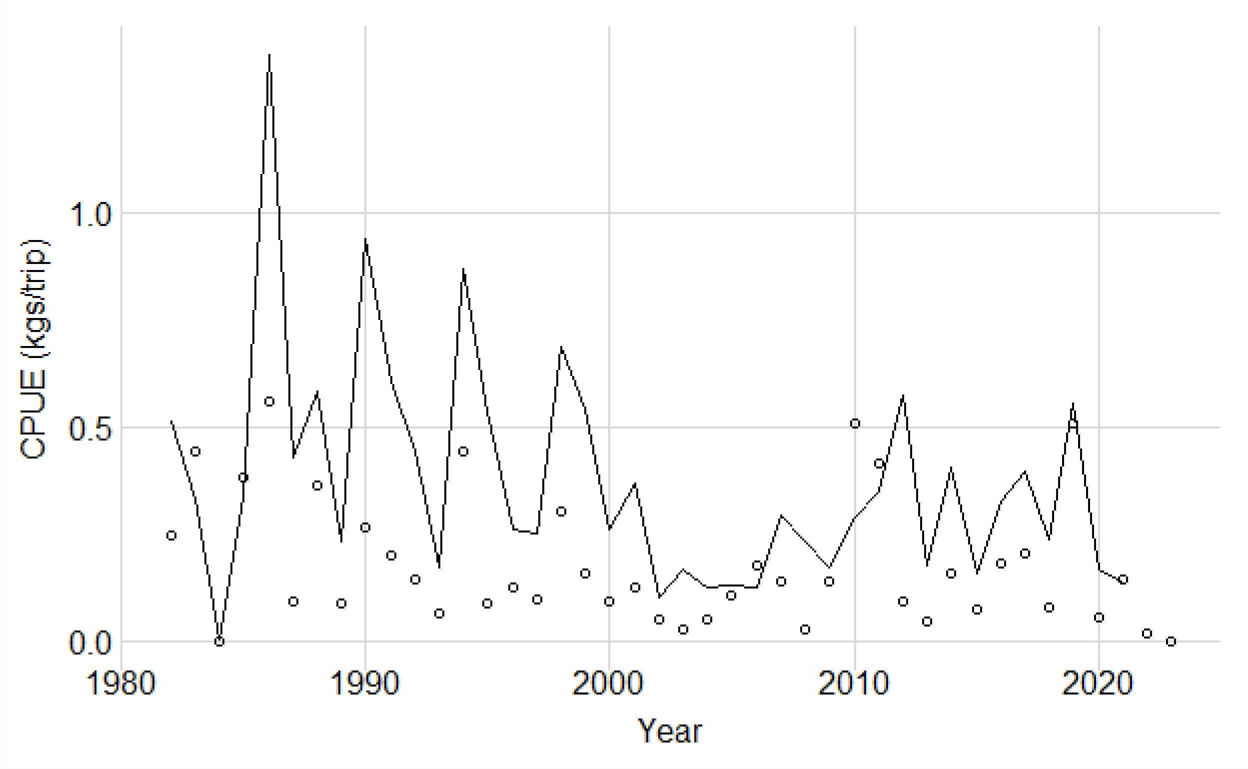

Figure 16. Standardized CPUE index (line) and nominal CPUE (points) of *C. lugubris*.

Etelis carbunculus

E. carbunculus is very similar in appearance to *E. boweni*, which was only recently identified and described (Andrews et al., 2021) and is not listed as a BMUS in the Fishery Ecosystem Plan (FEP) for the Mariana Archipelago. Accounts provided by fishermen, Guam Department of Agriculture and Wildlife Resources (DAWR) staff, and NOAA Fisheries scientists confirm *E. boweni* are present in Guam (Dahl et al., 2024; Iwane et al., 2023) and have likely been previously misidentified as *E. carbunculus* within the BBS data. Because of the high difficulty of differentiating these two species, the relative occurrences of *E. boweni* and *E. carbunculus* in Guam are unknown and it is possible that the apparent catch rates of *E. carbunculus* over the BBS timeseries are heavily influenced by *E. boweni*. In summary, we do not have sufficient data to provide CPUE timeseries for *E. carbunculus*. In addition, it would be unreasonable to aggregate *E. boweni* and *E. carbunculus* within a CPUE index or assessment, because *E. boweni* grow much larger than *E. carbunculus* (Andrews et al., 2021), and hence the growth and population dynamics of these two *Etelis* species are likely very dissimilar.

Etelis coruscans

E. coruscans was moderately represented in the BBS, occurring in 5.1% of interviews over all years. However, *E. coruscans* have become more common over time in the BBS data, having been absent in 1991 and 1997 to being observed in 34 interviews in 2021 (Figure 16). There were sufficient data to included 5 levels of area and a random vessel effect for both the presence/absence and positive processes and a year × area interaction for the presence/absence process only (Table 8). The selected CPUE standardization models explained 55.8% and 51.1% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 17Figure 18), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *E. coruscans*). Type of bottomfishing had a noticeable effect within the presence/absence model: *E. coruscans* was unlikely to be encountered while shallow bottomfishing. The selected CPUE standardization models for *E. coruscans* included time of day (probability of occurrence was higher at nighttime) and moon phase (CPUE was higher near the full moon), which were rarely included variables among all BMUS models (Appendix, Supplemental Results for *E. coruscans*).The standardized CPUE of *E. coruscans* has increased over time, being notably higher since approximately 2000 (Figure 19).

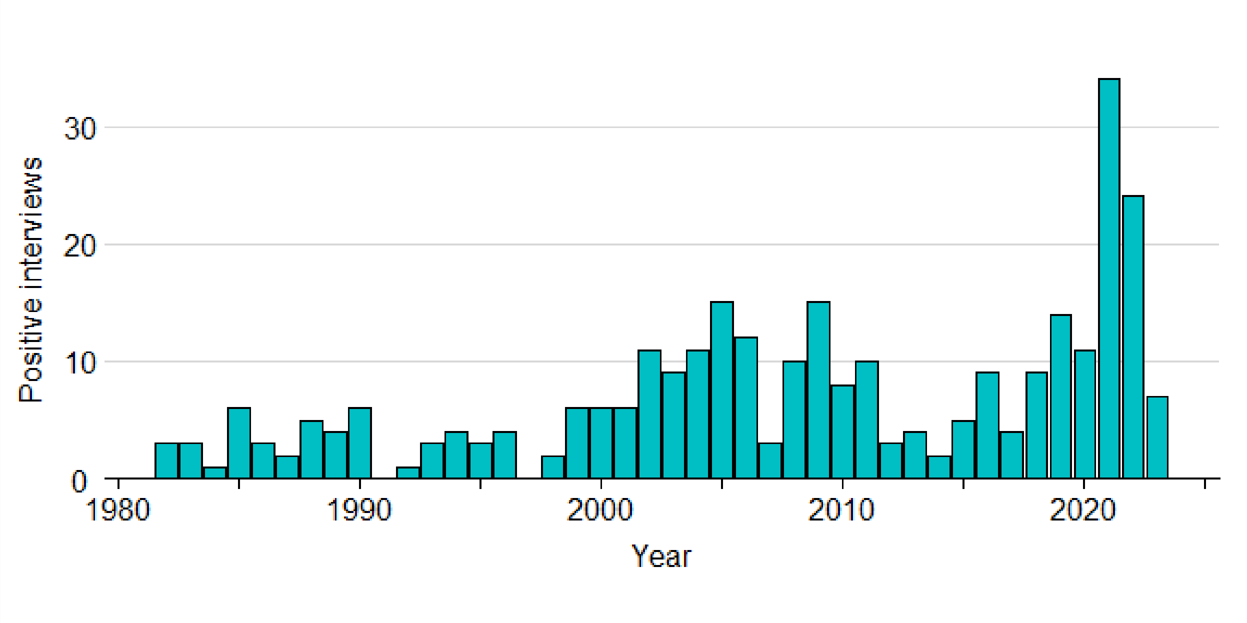

Figure 17. Number of bottomfishing interviews positive for *E. coruscans* by year. The nominal probability of occurrence for 1982–2023 was 0.0506.

Table 8. Selected models for the presence/absence and positive processes for *E. coruscans* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + HOURS_FISHED + tod_quarter + s(VESSEL_ID_2, bs = "re")	4718	1536	0.5575
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(yday, bs = "cc") + s(moon, bs = "cc") + CHARTER_F + s(VESSEL_ID_2, bs = "re")	250	187	0.5107

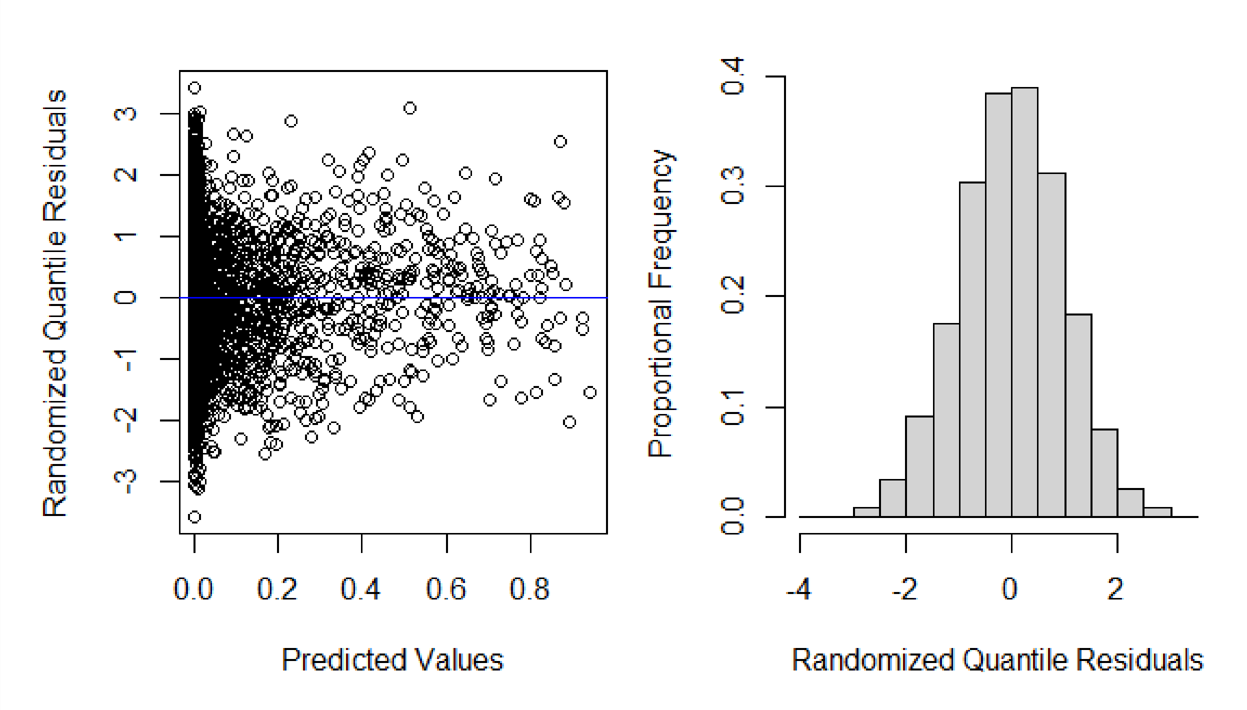

Figure 18. Residual distributions of the presence/absence process model selected for the *E. coruscans* CPUE standardization.

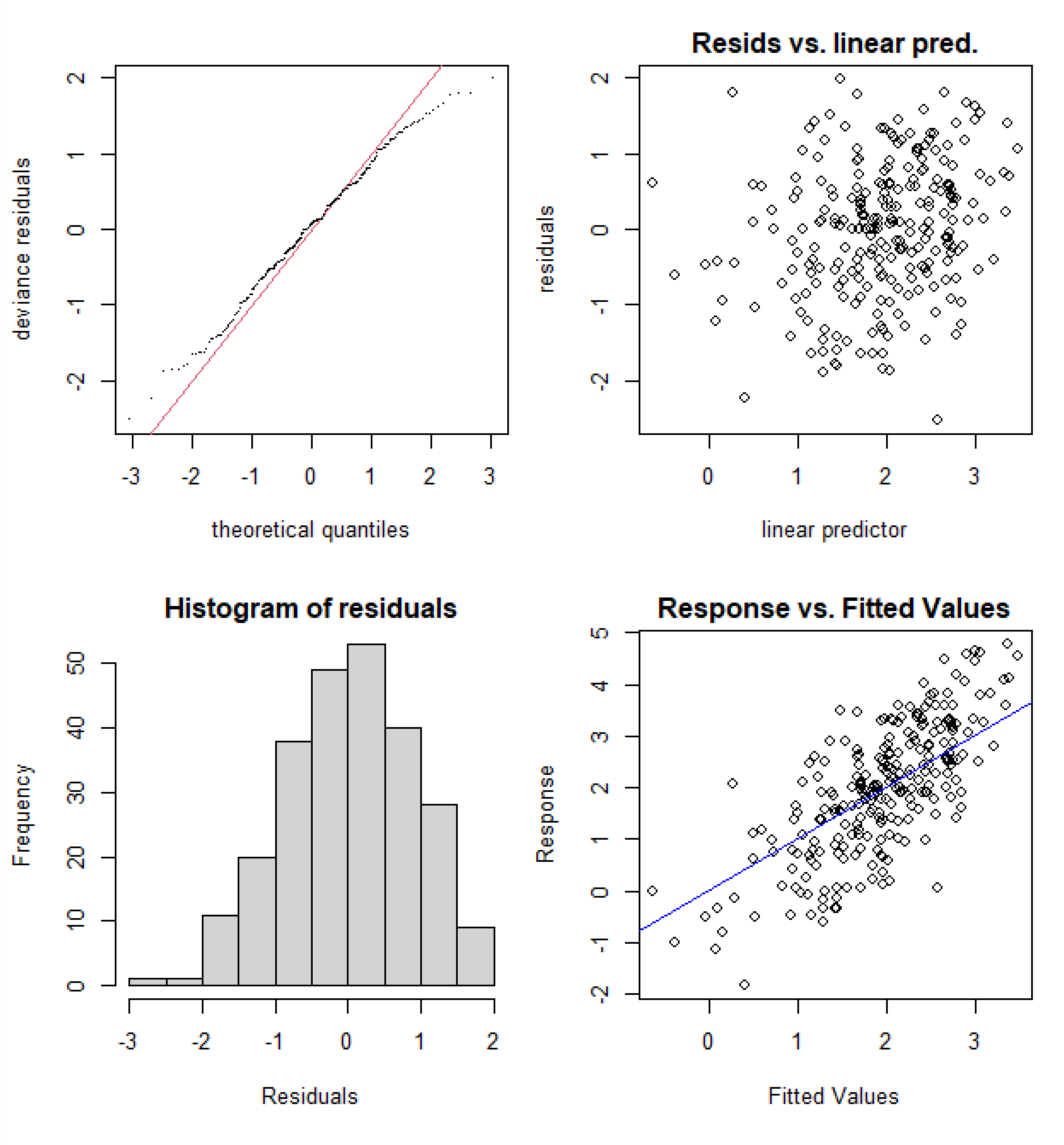

Figure 19. Residual distributions of the positive process model selected for the *E. coruscans* CPUE standardization.

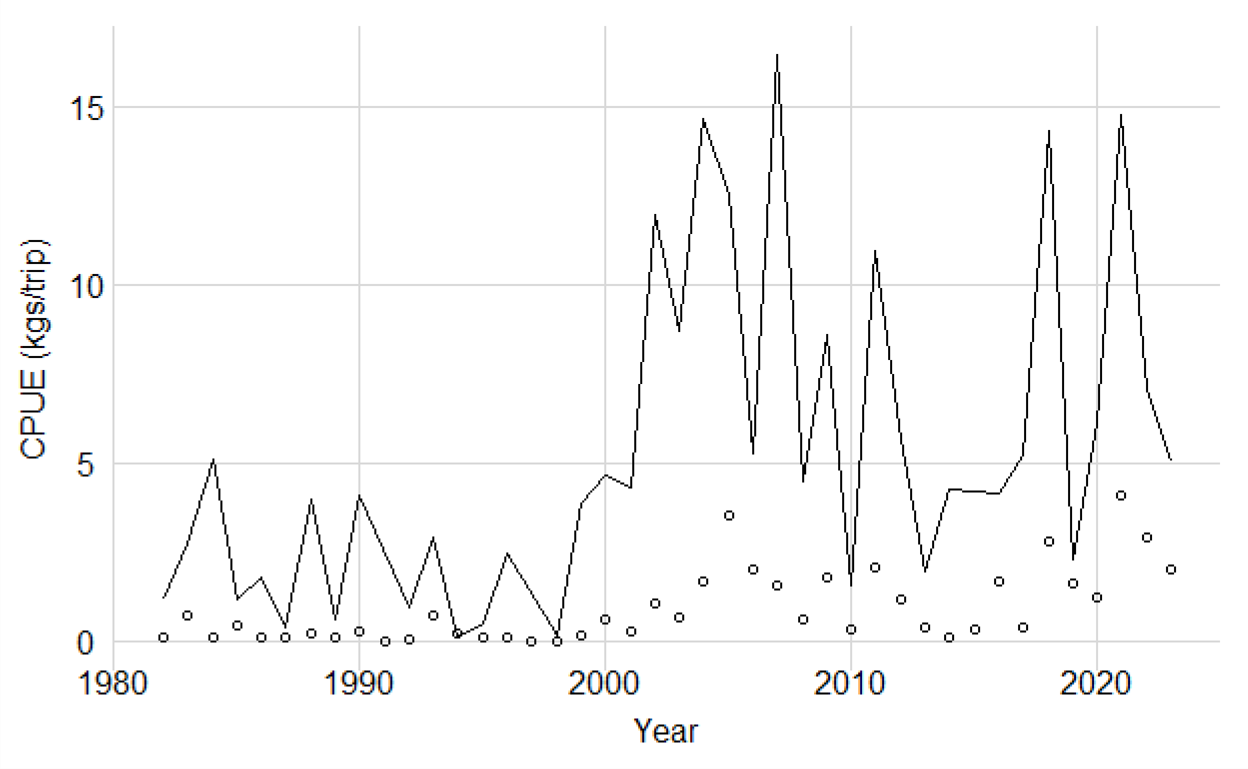

Figure 20. Standardized CPUE index (line) and nominal CPUE (points) of *E. coruscans*.

Lethrinus rubrioperculatus

L. rubrioperculatus was the most frequently encountered BMUS in the BBS data, occurring in 27.1% of interviews over all years, ranging from 4–97 positive interviews per year (Figure 20). There were sufficient data to included 5 levels of area, a year × area interaction, and a random vessel effect for both the presence/absence and positive processes (Table 7).The selected CPUE standardization models explained 34.7% and 37.5% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 21Figure 22), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *L. rubrioperculatus*). The probability of occurrence and CPUE when present were highest in the Southwest Banks and East Nearshore regions, and lowest in the Southwest Nearshore Region. The random vessel effect within the presence/absence process model was also interesting because relatively more effective *L. rubrioperculatus* encountering vessels were well-represented in the BBS dataset between 1985 and 1995, but less so in the later years. Type of bottomfishing had a prominent effect on the probability of presence, suggesting *L. rubrioperculatus* were relatively unlikely to be caught on shallow bottomfishing trips (Appendix, Supplemental Results for *L. rubrioperculatus*). Overall, there was an apparent decreasing trend in the standardized CPUE of *L. rubrioperculatus* over time (Figure 23).

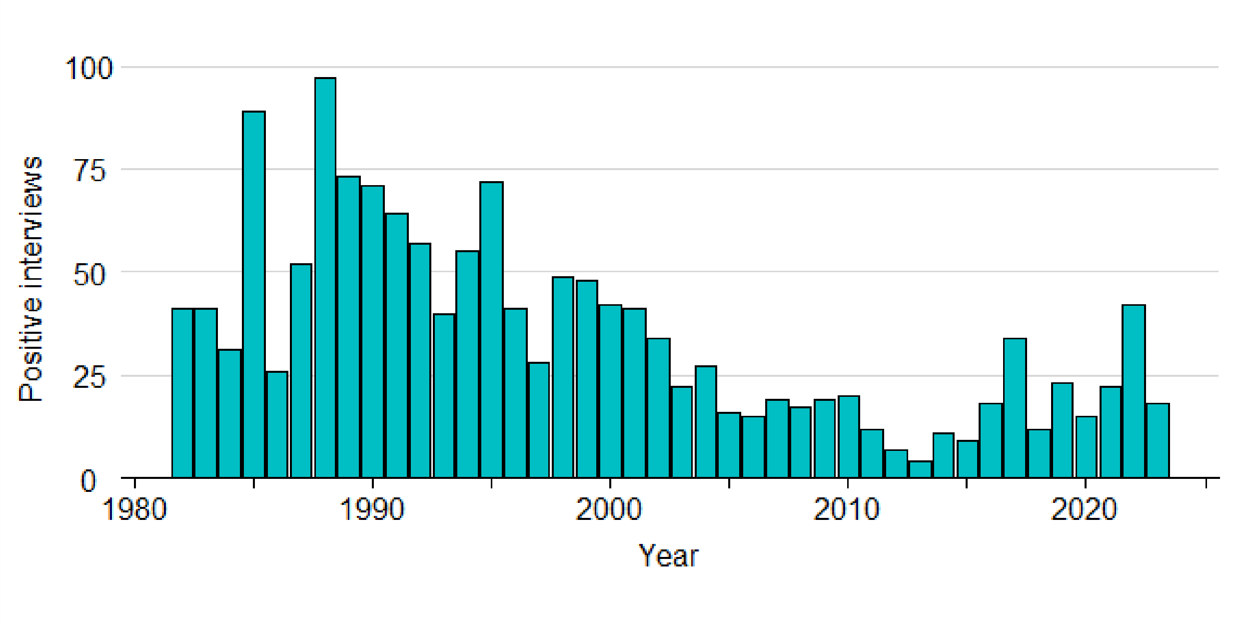

Figure 21. Number of bottomfishing interviews positive for *L. rubrioperculatus* by year. The nominal probability of occurrence for 1982–2023 was 0.2713.

Table 9. Selected models for the presence/absence and positive processes for *L. rubrioperculatus* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	**Formula**	**n**	**nparm**	**Dev. Expl.**
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + s(VESSEL_ID_2, bs = "re")	4661	1553	0.3471
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	1321	823	0.3754

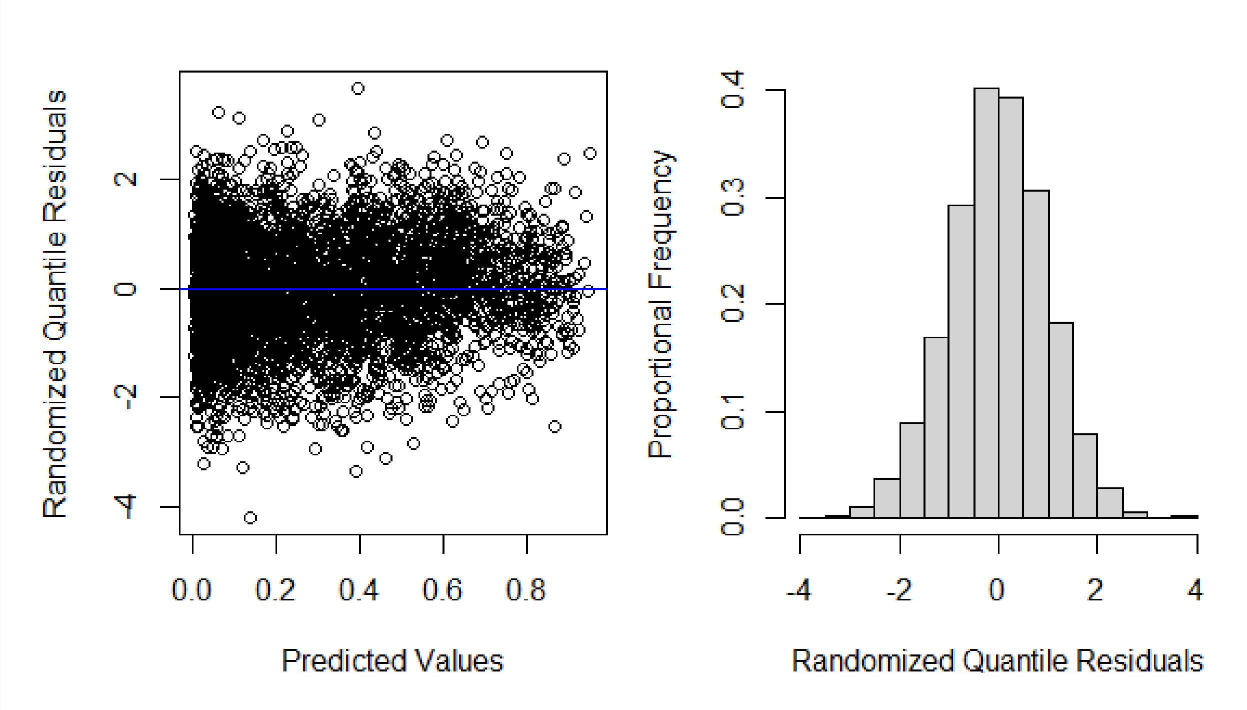

Figure 22. Residual distributions of the presence/absence process model selected for the *L. rubrioperculatus* CPUE standardization.

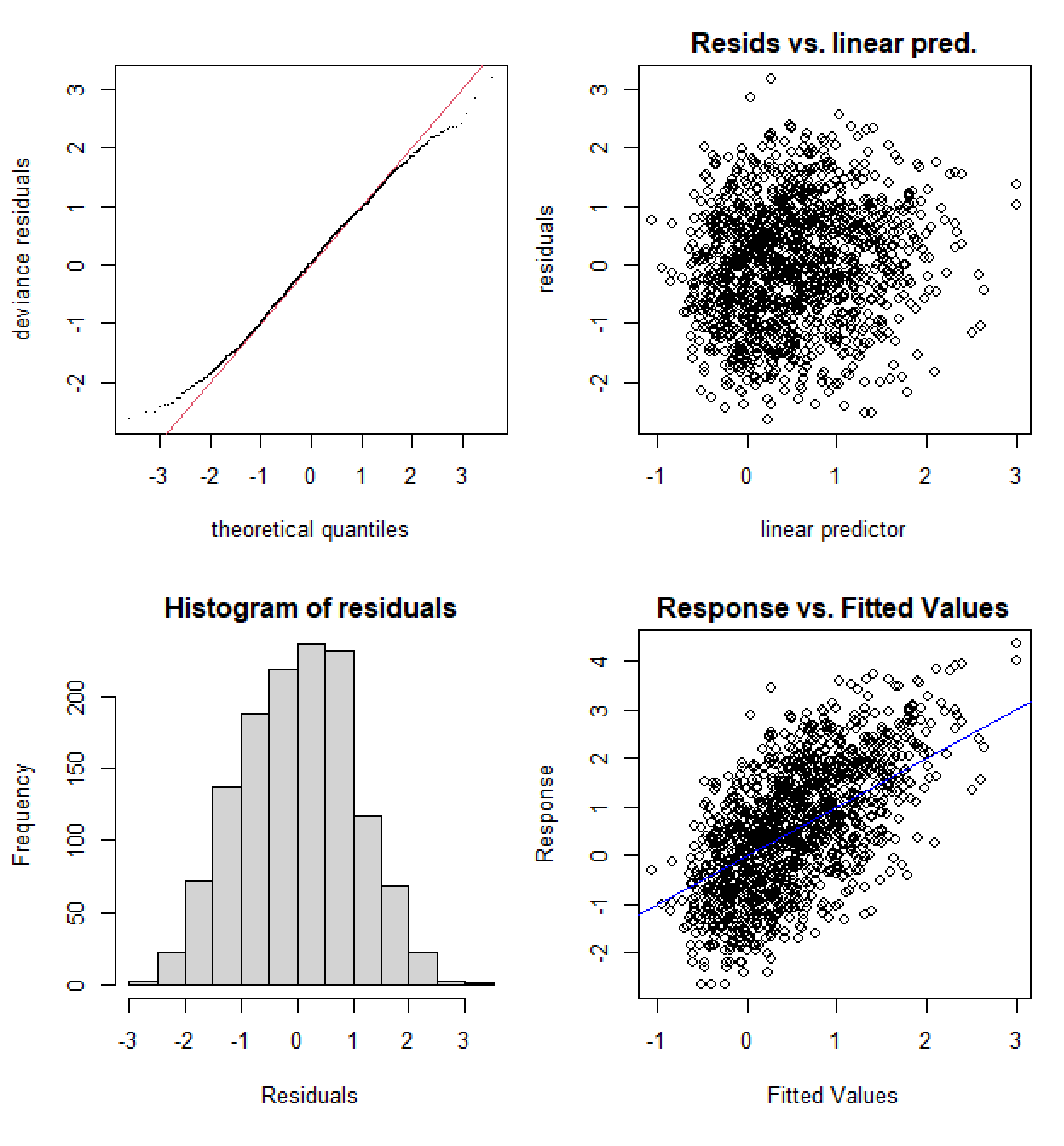

Figure 23. Residual distributions of the positive process model selected for the *L. rubrioperculatus* CPUE standardization.

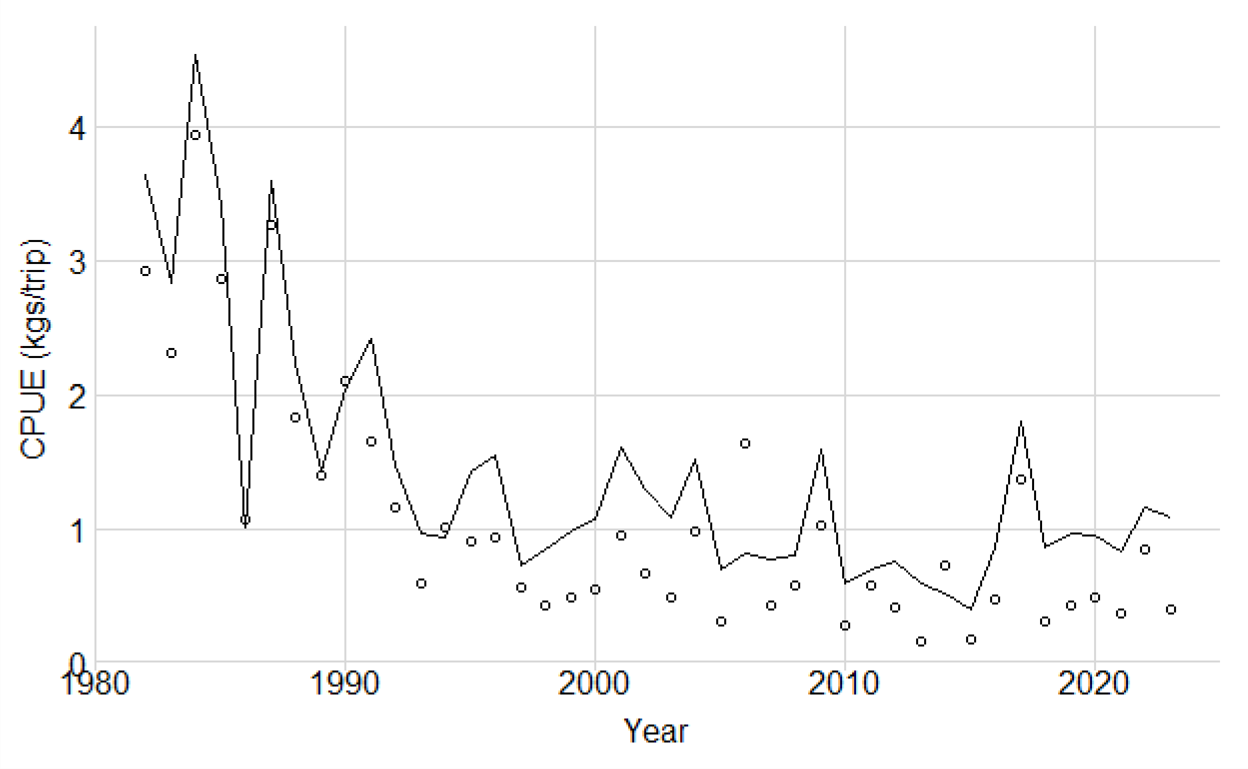

Figure 24. Standardized CPUE index (line) and nominal CPUE (points) of *L. rubrioperculatus*.

Lutjanus kasmira

L. kasmira was the second most frequently encountered BMUS in the BBS data, occurring in 14.3% of interviews over all years, ranging from 4–44 positive interviews per year (Figure 24). There were sufficient data to included 5 levels of area, a year × area interaction, and a random vessel effect for both the presence/absence and positive processes (Table 8).The selected CPUE standardization models explained 20.6% and 45.9% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 25Figure 26), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *L. kasmira*). *L. kasmira* were unlikely to be encountered while deep bottomfishing, and similar to *L. rubrioperculatus*, the random vessel effect in the model suggests more specialized vessels were represented in the data during the earlier part of the timeseries. (Appendix, Supplemental Results for *L. kasmira*). The standardized CPUE of *L. kasmira* shows somewhat decadal periods of increase and decrease, and there are no overall trends in the timeseries (Figure 27).

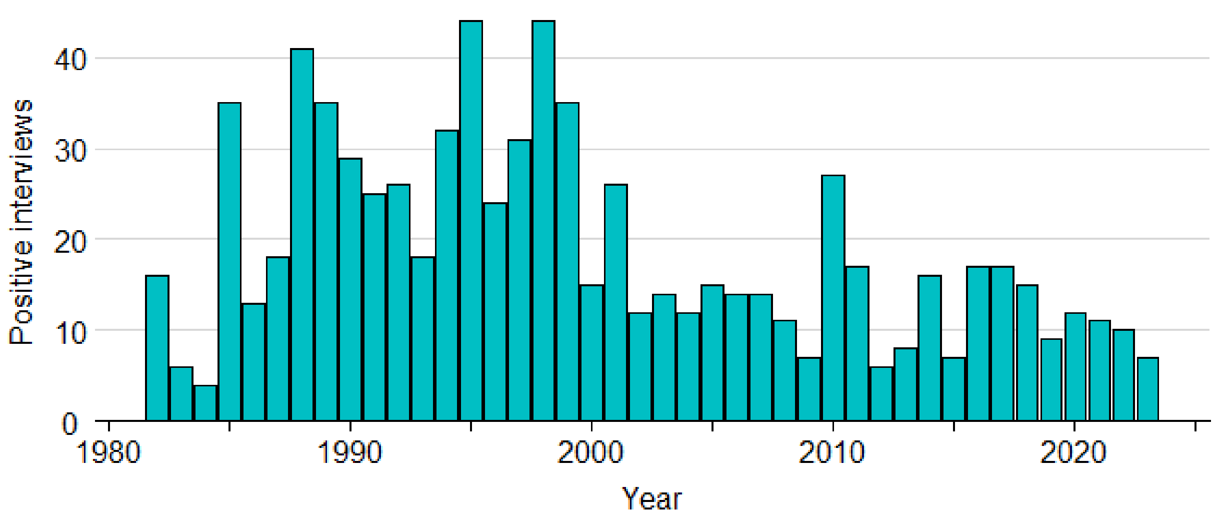

Figure 25. Number of bottomfishing interviews positive for *L. kasmira* by year. The nominal probability of occurrence for 1982–2023 was 0.1429.

Table 10. Selected models for the presence/absence and positive processes of *L. kasmira* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	**Formula**	**n**	**nparm**	**Dev. Expl.**
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	4785	1568	0.2056
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + tod_quarter + CHARTER_F + s(VESSEL_ID_2, bs = "re")	703	642	0.4591

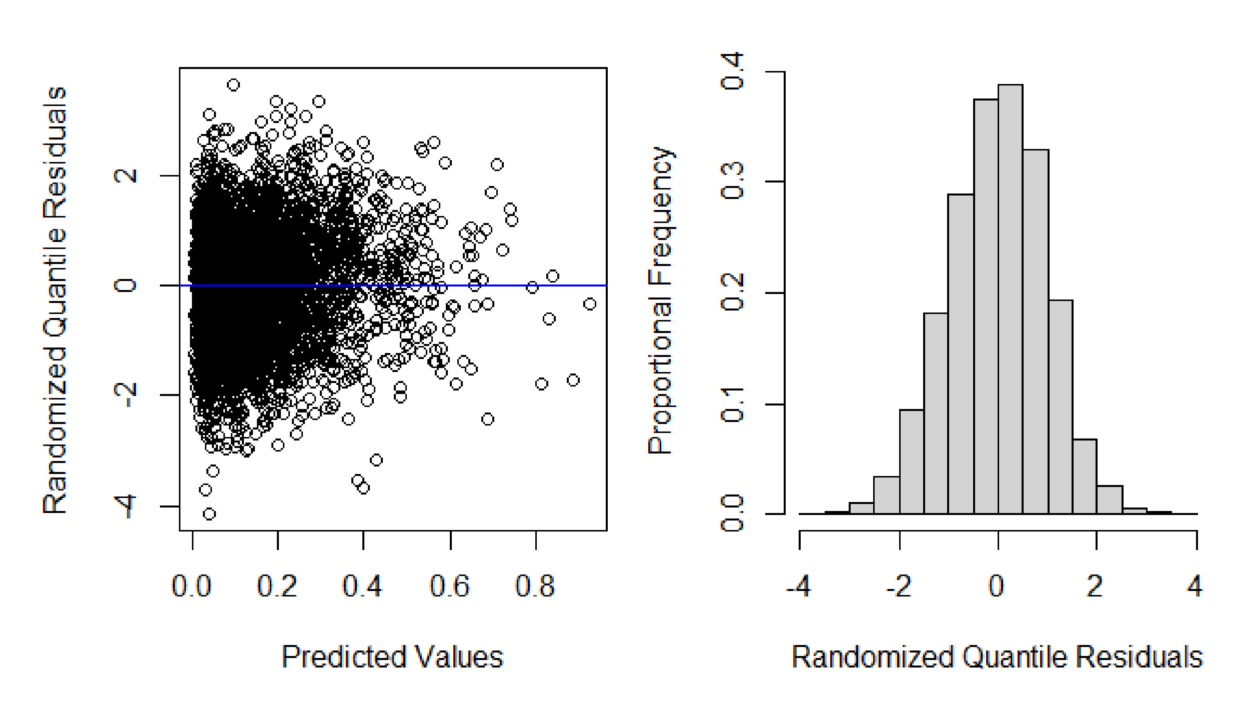

Figure 26. Residual distributions of the presence/absence process model selected for the *L. kasmira* CPUE standardization.

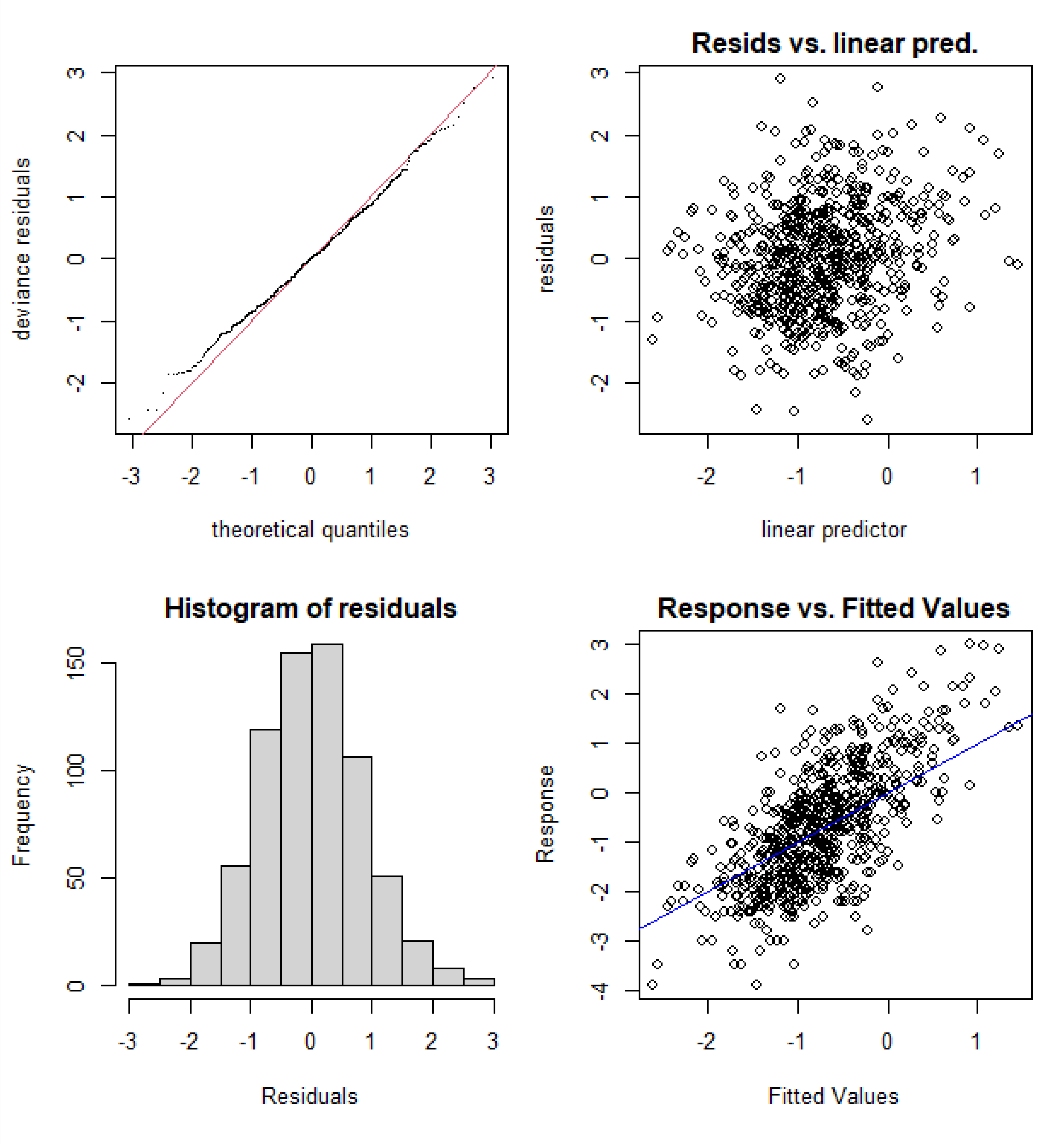

Figure 27. Residual distributions of the positive process model selected for the *L. kasmira* CPUE standardization.

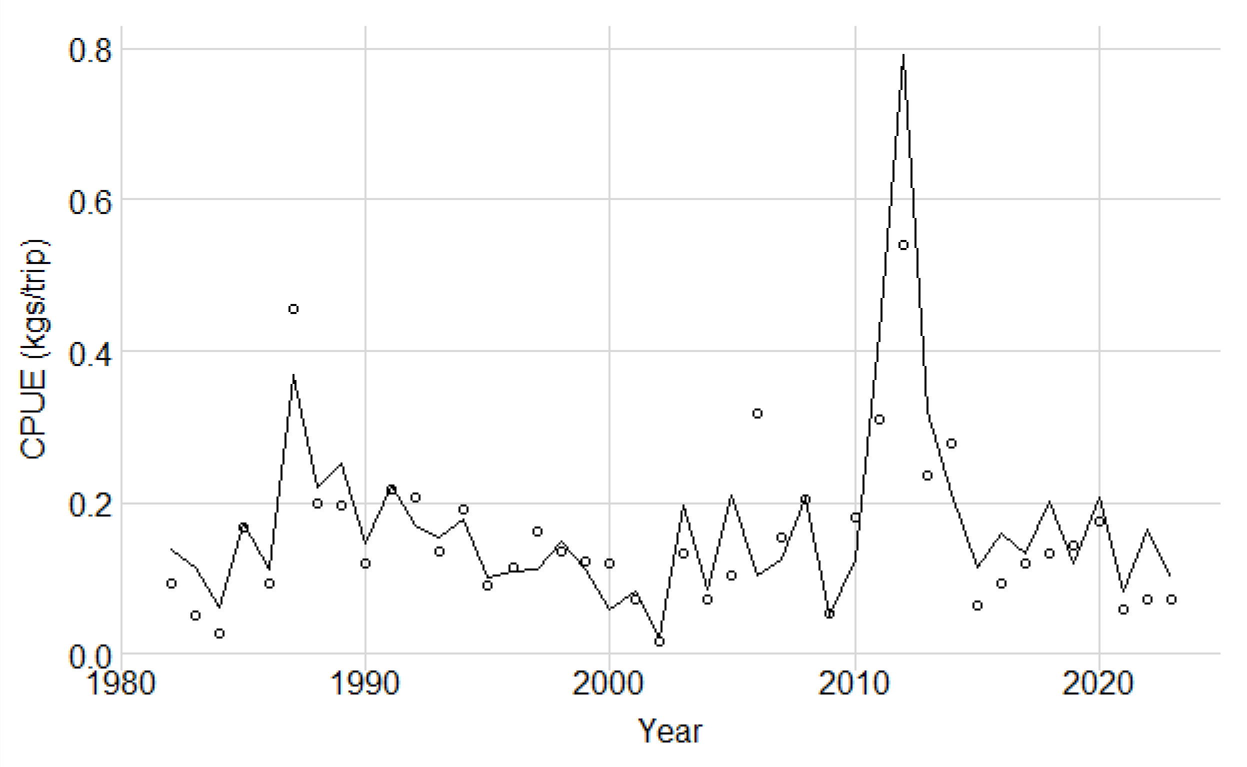

Figure 28. Standardized CPUE index (line) and nominal CPUE (points) of *L. kasmira*.

Pristipomoides auricilla

P. auricilla was relatively well represented in the BBS, occurring in 12.8% of interviews over all years, ranging from 4–48 positive interviews per year (Figure 28). There were sufficient data to included 5 levels of area, a year × area interaction, and a random vessel effect for both the presence/absence and positive processes (Table 9). The selected CPUE standardization models explained 58.9% and 52.5% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics (Figure 29Figure 30) suggest model residuals are slightly negatively skewed for the positive process, but otherwise there was no notable degree of overdispersion or heteroskedasticity, and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *P. auricilla*). Bottomfishing type and trip duration were both retained in the selected models. P. auricilla was more likely to be encountered and was characterized by higher catch per trip for deep bottomfishing and longer duration trips (Appendix, Supplemental Results for *P. auricilla*). The standardized CPUE index shows a general decrease, albeit with high inter-annual variability, between 1990 and 2020, and a pronounced spike in 2021-2023 (Figure 31).

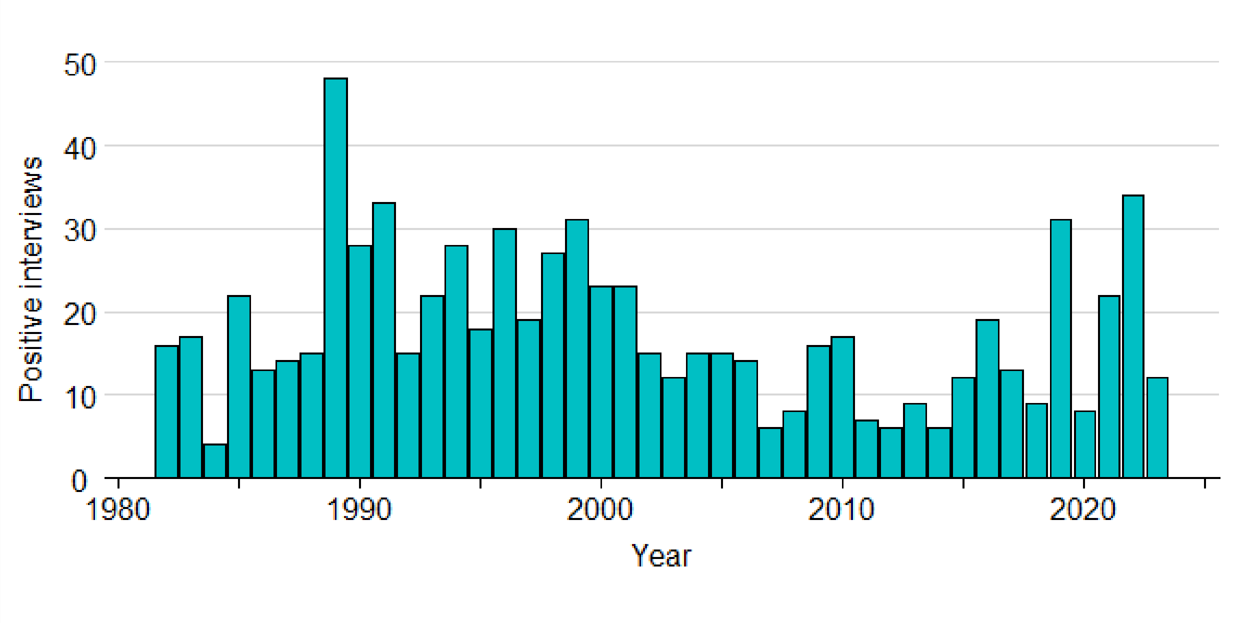

Figure 29. Number of bottomfishing interviews positive for *P. auricilla* by year. The nominal probability of occurrence for 1982–2023 was 0.1277.

Table 11. Selected models for the presence/absence and positive processes for *P. auricilla* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + HOURS_FISHED + s(VESSEL_ID_2, bs = "re")	5083	1589	0.5887
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + DEPTH + num_gear_fac + num_fisher_fac + s(VESSEL_ID_2, bs = "re")	644	548	0.5254

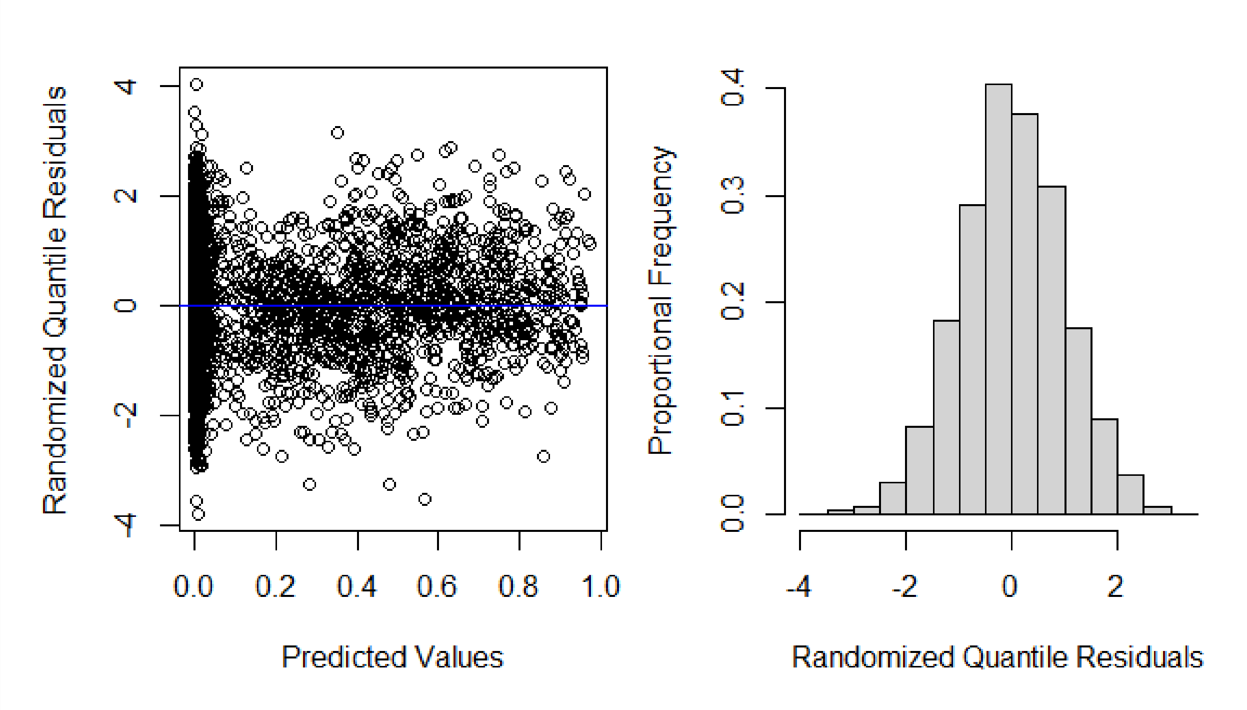

Figure 30. Residual distributions of the presence/absence process model selected for the *P. auricilla* CPUE standardization.

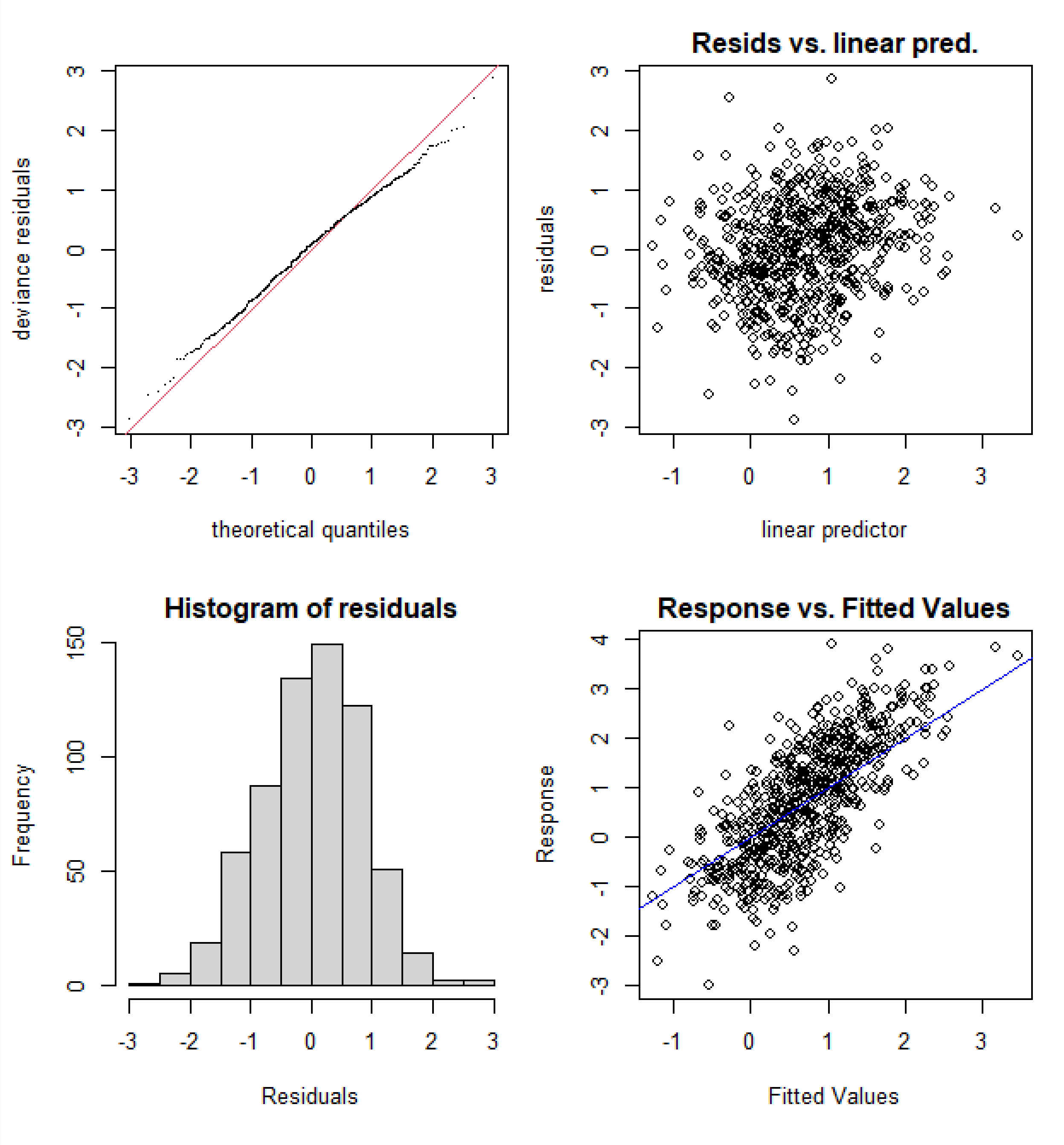

Figure 31. Residual distributions of the positive process model selected for the *P. auricilla* CPUE standardization.

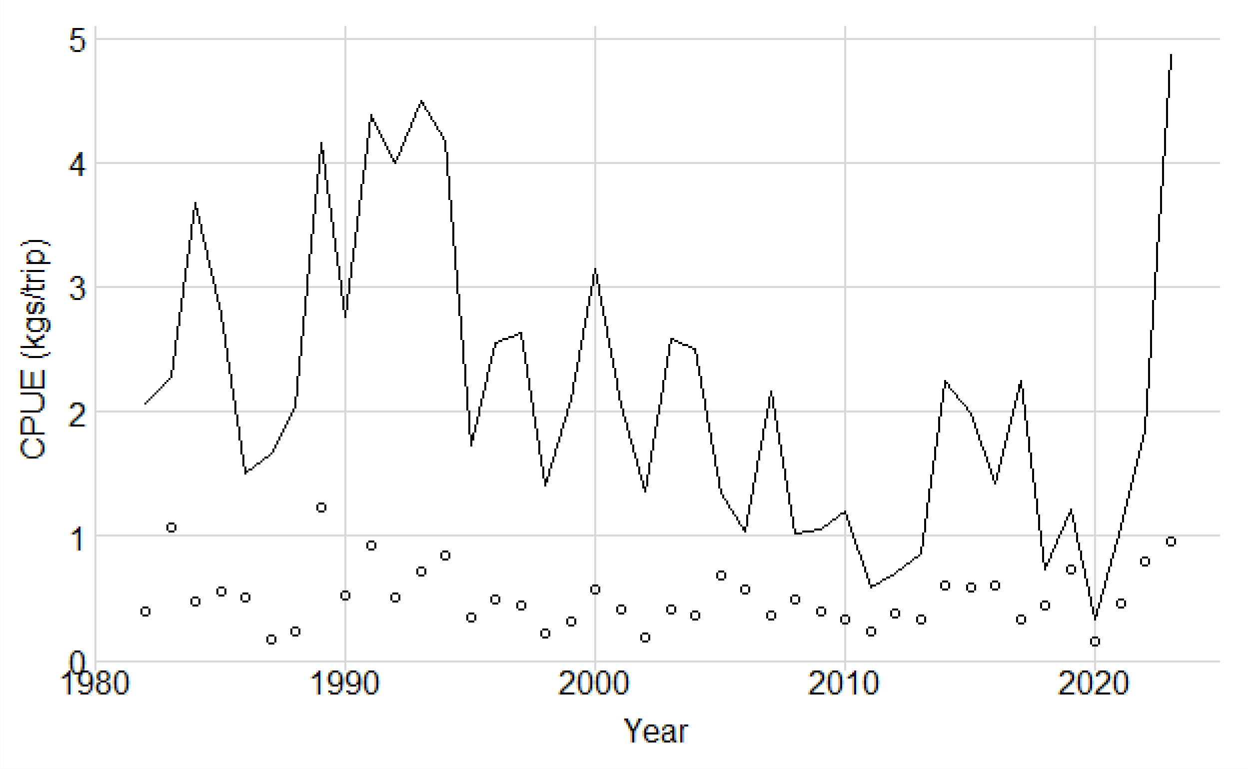

Figure 32. Standardized CPUE index (line) and nominal CPUE (points) of *P. auricilla*.

Pristipomoides filamentosus

P. filamentosus was rarely encountered in the BBS, occurring in 3.1% of interviews over all years, ranging from 0–13 interviews per year (Figure 32). There were sufficient data to include area (as a 5-level variable), a year × area interaction, and a random effect of vessel in the presence/absence process (Table 10). However, given the low overall occurrence of *P. filamentosus* in the data, the positive process model did not include a year × area interaction or a random effect of vessel. The selected CPUE standardization models explained 39.5% and 33.3% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics (Figure 33Figure 34) suggest model residuals were slightly negatively skewed for the positive process, but otherwise there was no notable degree of overdispersion or heteroskedasticity, and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *P. filamentosus*). CPUE was notably lowest in the Southwest Nearshore region. The models indicate *P. filamentosus* was more likely to be encountered and was characterized by higher catch for deep bottomfishing trips (Appendix, Supplemental Results for *P. filamentosus*). Overall, there was no clear trend in the standardized CPUE of *P. filamentosus* over time (Figure 35).

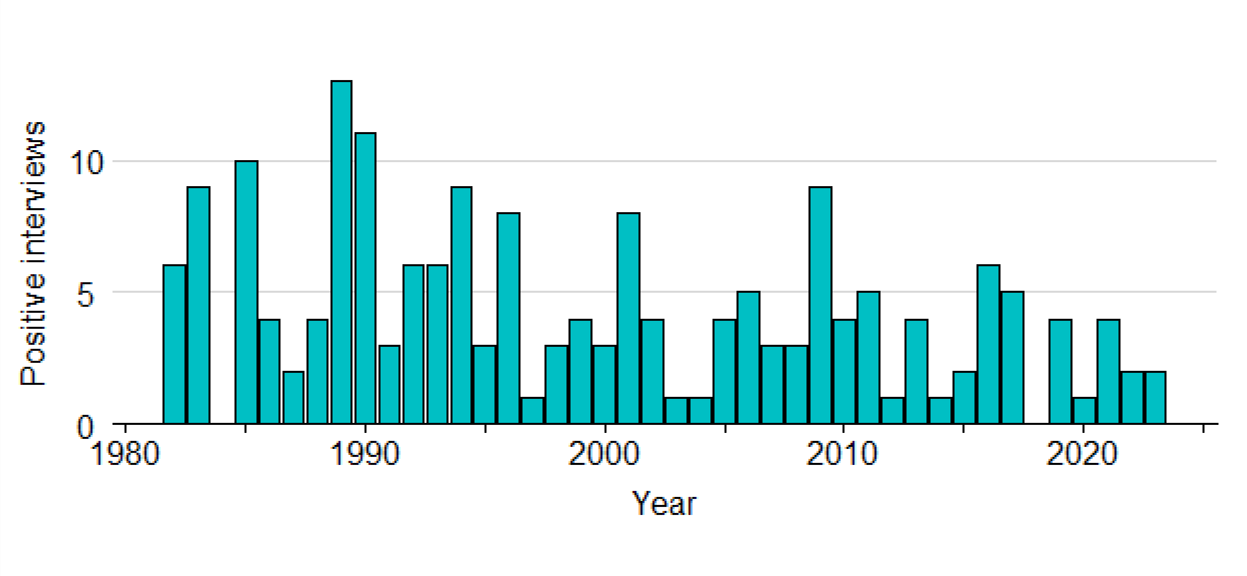

Figure 33. Number of bottomfishing interviews positive for *P. filamentosus* by year. The nominal probability of occurrence for 1982-2023 was 0.0312.

Table 12. Selected models for the presence/absence and positive processes for *P. filamentosus* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + s(VESSEL_ID_2, bs = "re")	4959	1555	0.3954
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(yday, bs = "cc") + HOURS_FISHED	169	53	0.3332

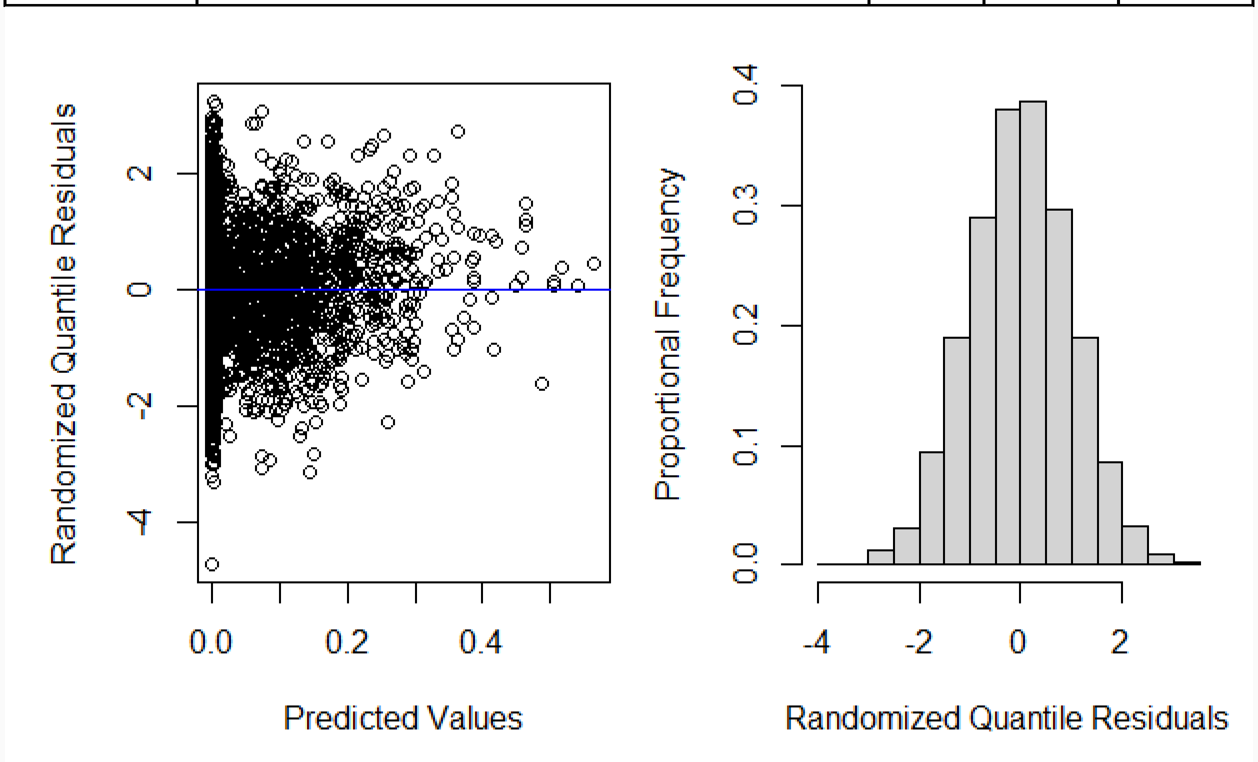

Figure 34. Residual distributions of the presence/absence process model selected for the *P. filamentosus* CPUE standardization.

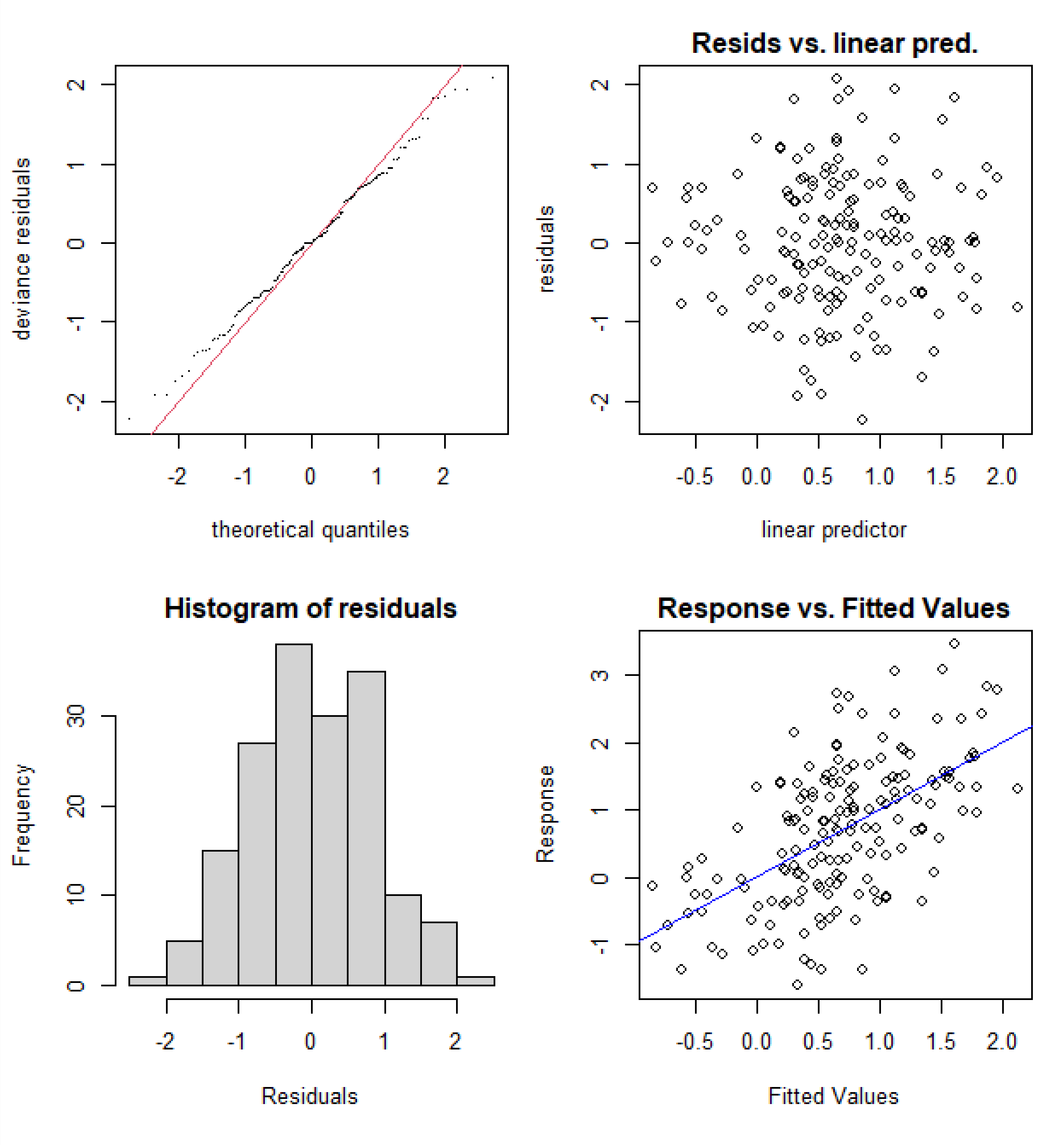

Figure 35. Residual distributions of the positive process model selected for the *P. filamentosus* CPUE standardization.

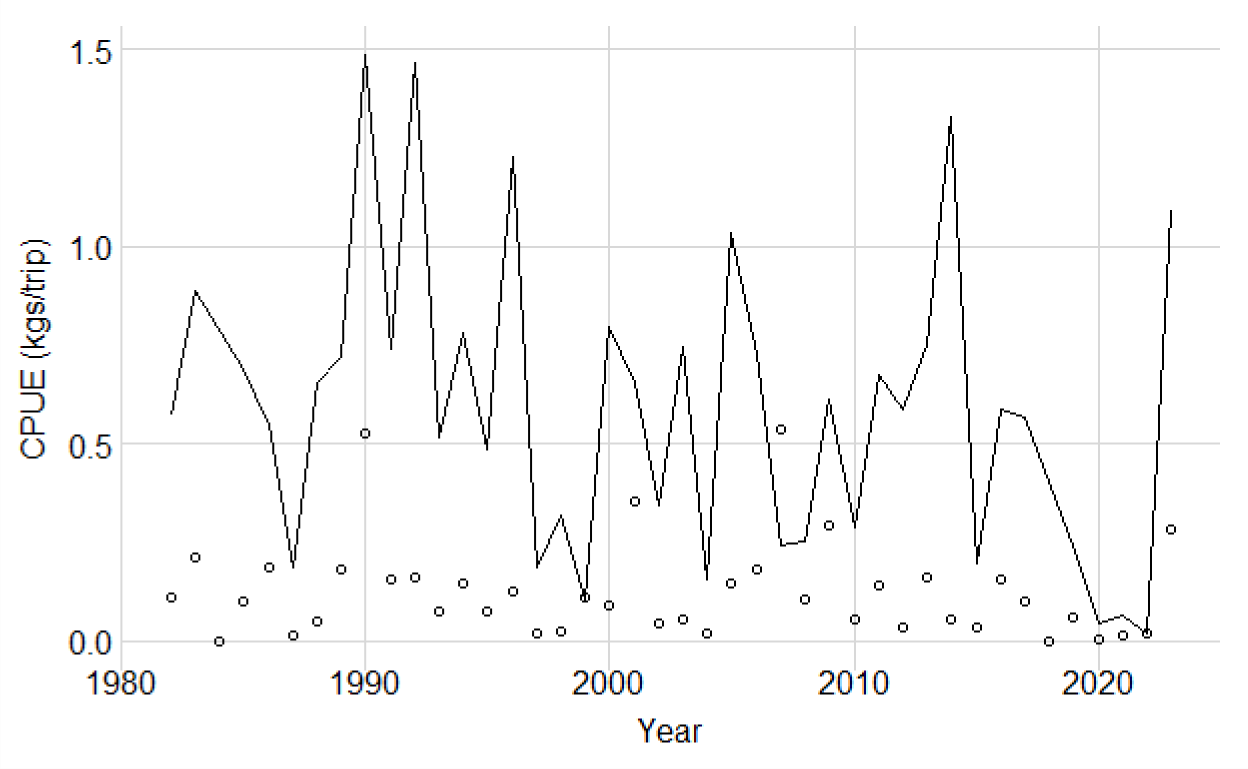

Figure 36. Standardized CPUE index (line) and nominal CPUE (points) of *P. filamentosus*.

Pristipomoides flavipinnis

P. flavipinnis was moderately represented in the BBS, occurring in 5.7% of interviews over all years, ranging from 2–19 positive interviews per year (Figure 36). There were sufficient data to included 5 levels of area, and a year × area interaction, for both the presence/absence and positive processes (Table 11). A random vessel effect was included for the presence/absence process only. The selected CPUE standardization models explained 38.2% and 33.5% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 37Figure 38), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *P. flavipinnis*). CPUE was lowest in the Southwest Nearshore region. Type of bottomfishing had a noticeable effect within the presence/absence model: *P. flavipinnis* were unlikely to be encountered while shallow bottomfishing (Appendix, Supplemental Results for *P. flavipinnis*). Overall, there was an apparent decreasing trend in the standardized CPUE of *P. flavipinnis* over time, although with high interannual variability (Figure 39).

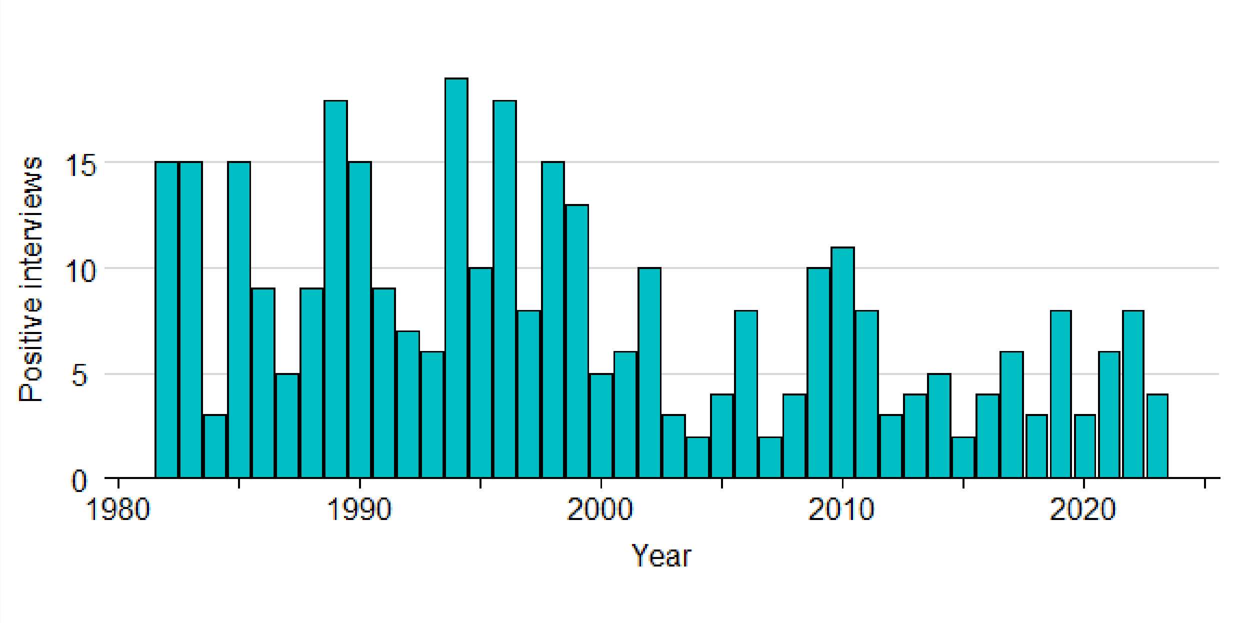

Figure 37. Number of bottomfishing interviews positive for *P. flavipinnis* by year. The nominal probability of occurrence for 1982–2023 was 0.0574.

Table 13. Selected models for the presence/absence and positive processes for *P. flavipinnis* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	**Formula**	**n**	**nparm**	**Dev. Expl.**
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + s(VESSEL_ID_2, bs = "re")	4999	1573	0.3816
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + DEPTH + num_fisher_fac	287	264	0.3346

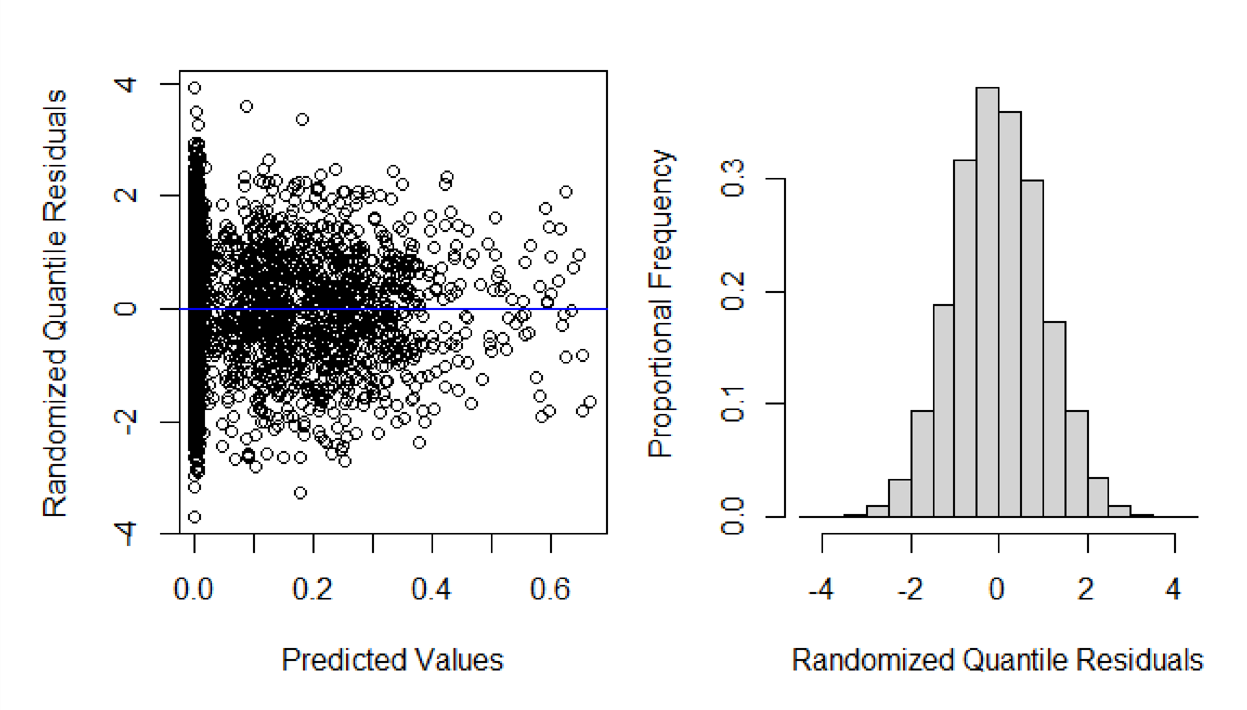

Figure 38. Residual distributions of the presence/absence process model selected for the *P. flavipinnis* CPUE standardization.

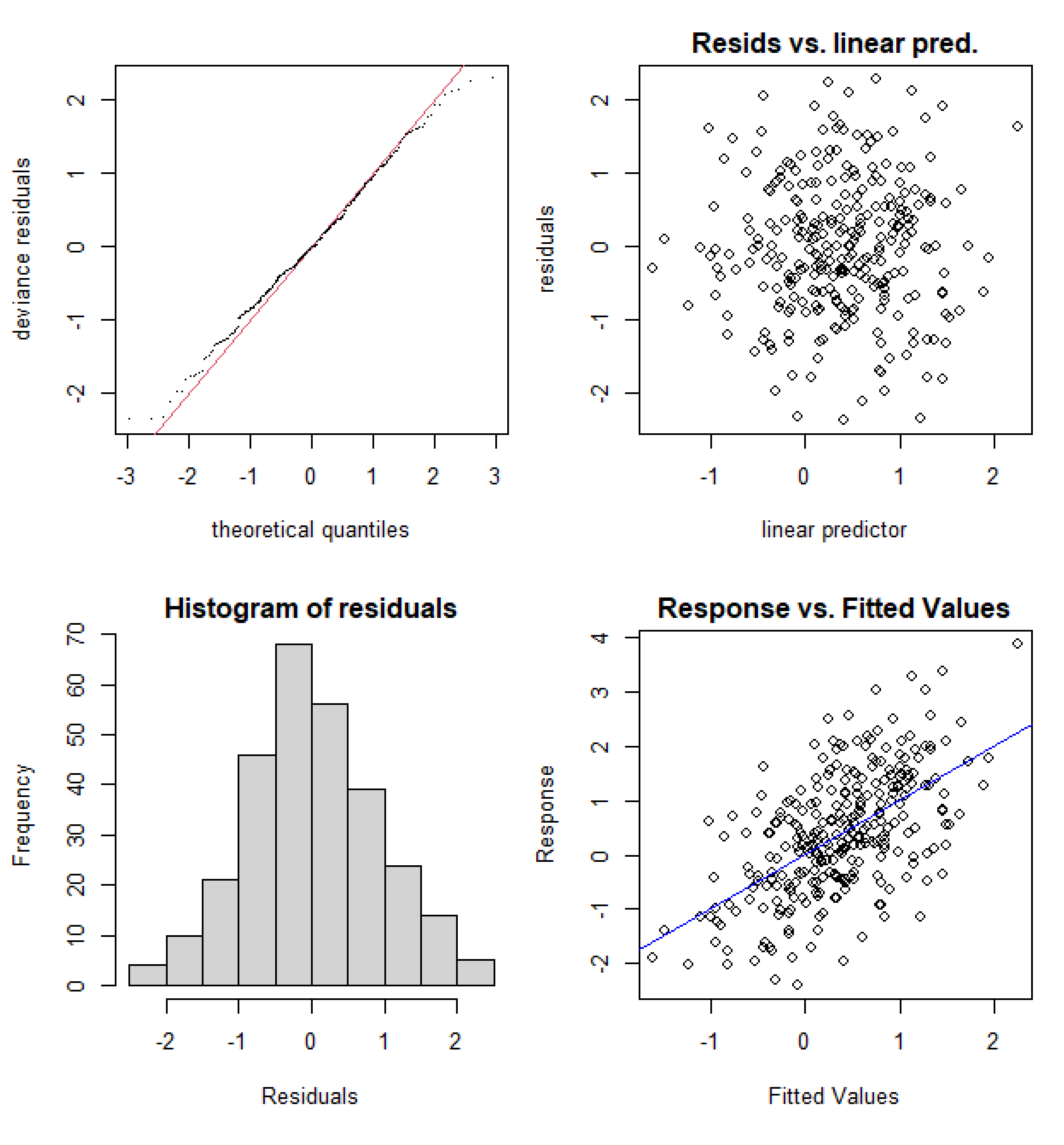

Figure 39. Residual distributions of the positive process model selected for the *P. flavipinnis* CPUE standardization.

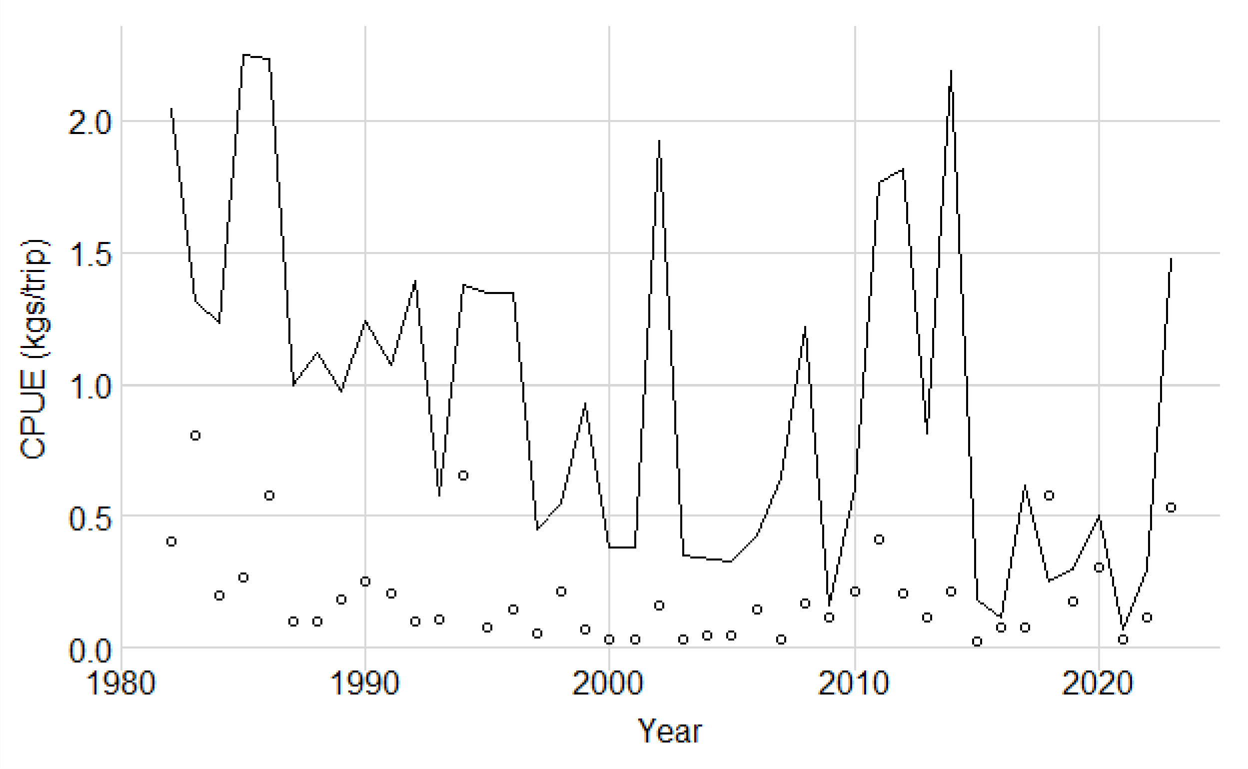

Figure 40. Standardized CPUE index (line) and nominal CPUE (points) of *P. flavipinnis*.

Pristipomoides sieboldii

P. sieboldii are rarely encountered in the BBS, with overall percent of positive interviews equal to 0.83. *P. sieboldii* were not observed at all in 19 years, and were recorded in only 1 interview in 11 additional years. Although it is possible that some *P. sieboldii* have been incorrectly identified as *P. filamentosus* (Iwane et al., 2023), this species is likely not commonly encountered by fishermen in Guam. Regardless, there are insufficient observations in the BBS to produce a standardized CPUE index for *P. sieboldii*.

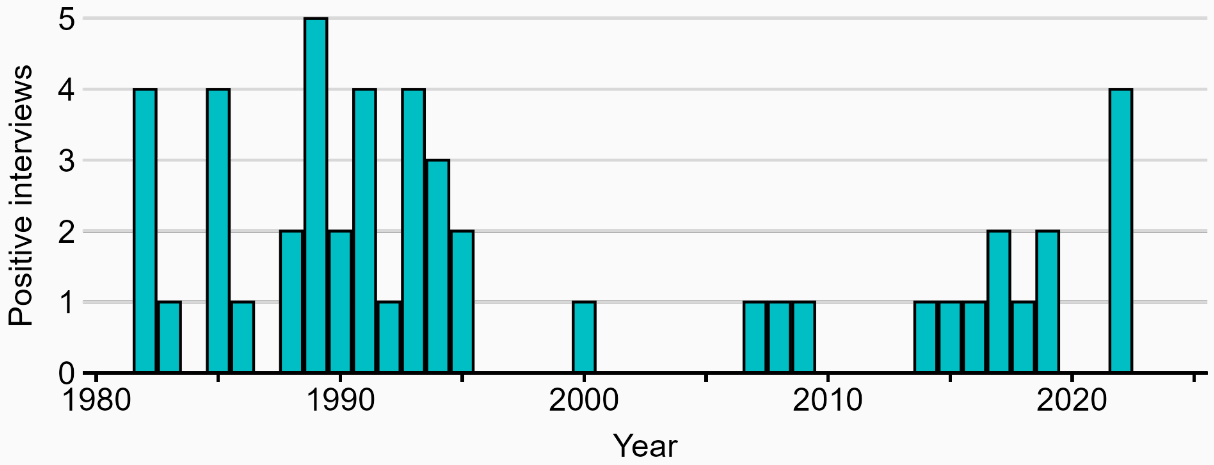

Figure 41. Number of bottomfishing interviews positive for *P. sieboldii* by year. The nominal probability of occurrence for 1982–2023 was 0.0083.

Pristipomoides zonatus

P. zonatus was relatively well represented in the BBS, occurring in 11.4% of interviews over all years, ranging from 4–32 positive interviews per year (Figure 41). There were sufficient data to included 5 levels of area, a year × area interaction, and a random vessel effect for both the presence/absence and positive processes (Table 12). The selected CPUE standardization models explained 56.9% and 31.3% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 42Figure 43), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *P. zonatus*). Type of bottomfishing had a noticeable effect within the presence/absence model: *P. zonatus* were unlikely to be encountered while shallow bottomfishing. *P. zonatus* was the only BMUS for which wind speed was selected in either model: there was a negative effect of wind speed on catches. Also, in contrast to the *P. filamentosus* and *P. flavipinnis*, and to a lesser degree, *P. auricilla*, the CPUE of *P. zonatus* was not noticeably lower in the Southwest Nearshore Region (Appendix, Supplemental Results for *P. zonatus*). Overall, there was an apparent decreasing trend in the standardized CPUE of *P. zonatus* over time, although with high interannual variability (Figure 44).

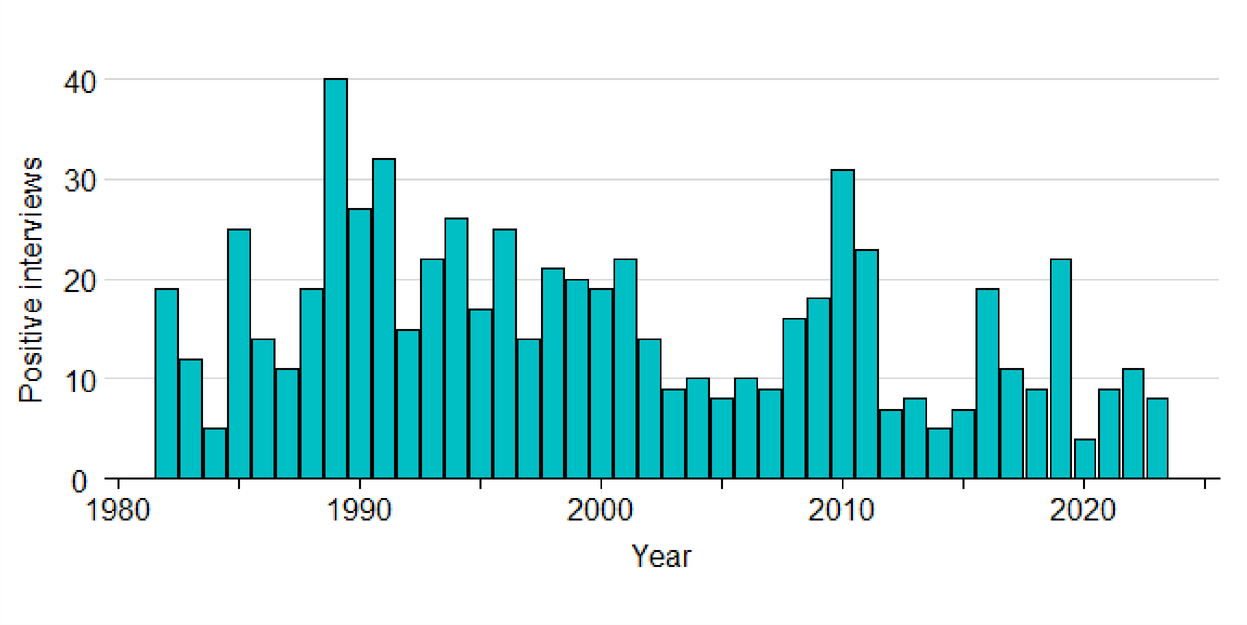

Figure 42. Number of bottomfishing interviews positive for *P. zonatus* by year. The nominal probability of occurrence for 1982–2023 was 0.1143.

Table 14. Selected models for the presence/absence and positive processes for *P. zonatus* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	**Formula**	**n**	**nparm**	**Dev. Expl.**
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + s(VESSEL_ID_2, bs = "re")	5083	1588	0.5692
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + DEPTH + vc_windspeed + s(VESSEL_ID_2, bs = "re")	582	513	0.3133

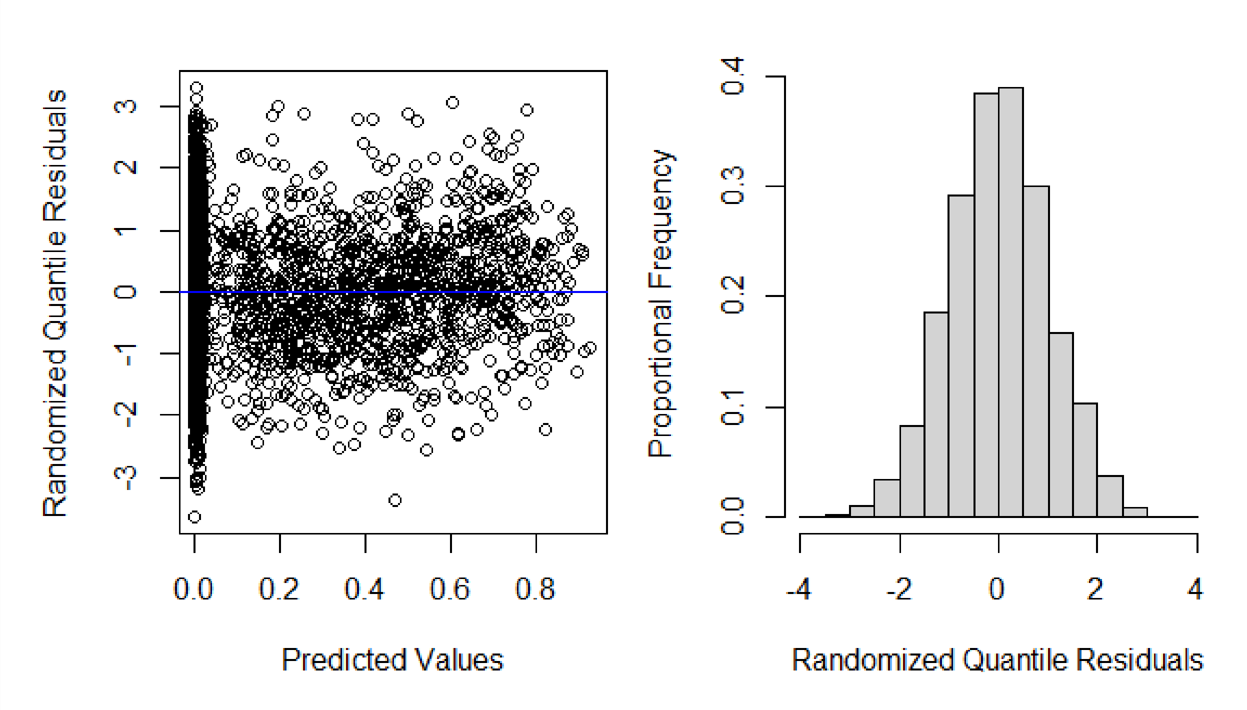

Figure 43. Residual distributions of the presence/absence process model selected for the *P. zonatus* CPUE standardization.

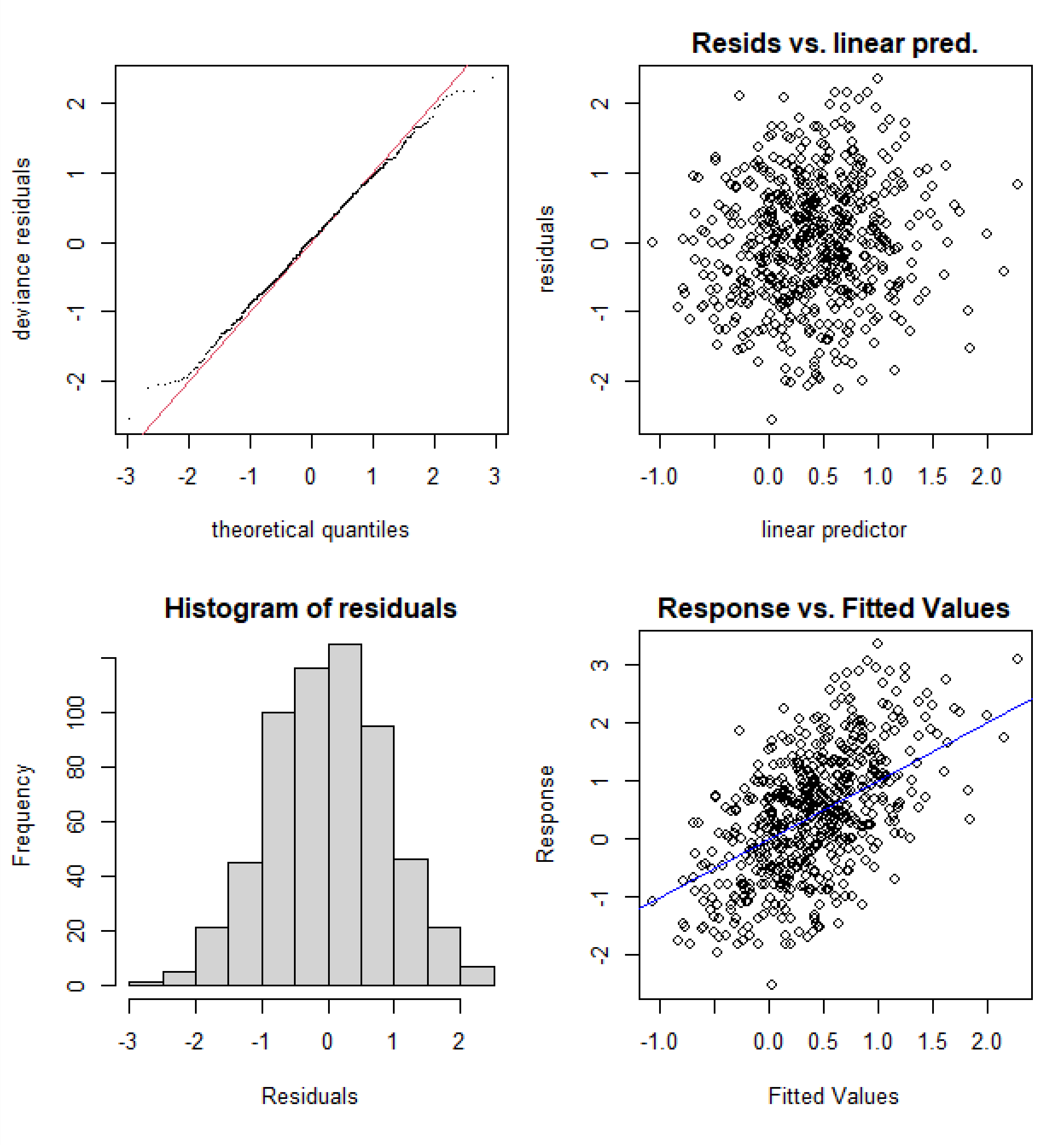

Figure 44. Residual distributions of the positive process model selected for the *P. zonatus* CPUE standardization.

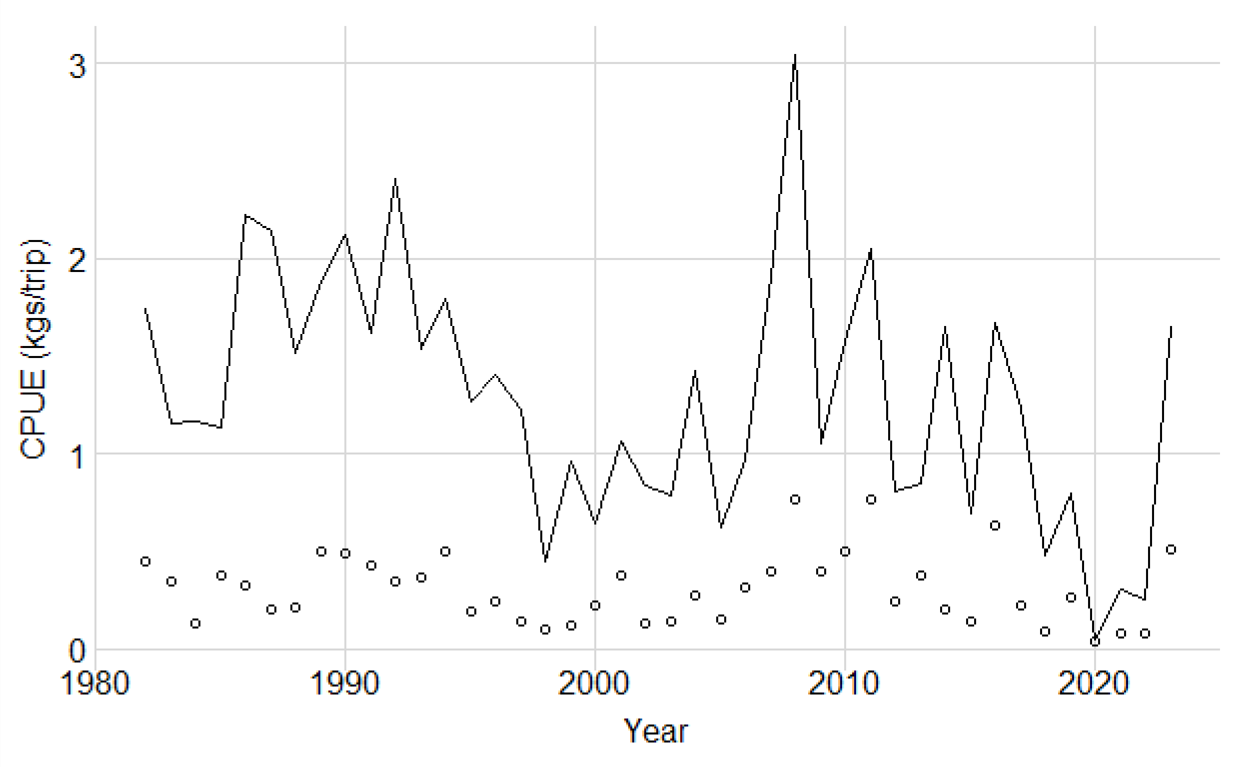

Figure 45. Standardized CPUE index (line) and nominal CPUE (points) of *P. zonatus*.

Variola louti

V. louti was moderately represented in the BBS, occurring in 10.5% of interviews over all years, ranging from 4–32 positive interviews per year (Figure 45). There were sufficient data to included 5 levels of area, and a year × area interaction, for both the presence/absence and positive processes (Table 13). A random vessel effect was included for the presence/absence process only. The selected CPUE standardization models explained 24.9% and 29.0% of deviance in the data for the presence/absence and positive processes, respectively. Model residual diagnostics do not indicate any notable degree of overdispersion or heteroskedasticity (Figure 46Figure 47), and predictive checks indicate model error assumptions were appropriate (Appendix, Supplemental Results for *V. louti*). CPUE was highest in the Southwest Banks region and lowest in the Southwest Nearshore region (Appendix, Supplemental Results for *V. louti*). Overall, CPUE of *V. louti* is low in the BBS and there was no clear trend over time (Figure 48).

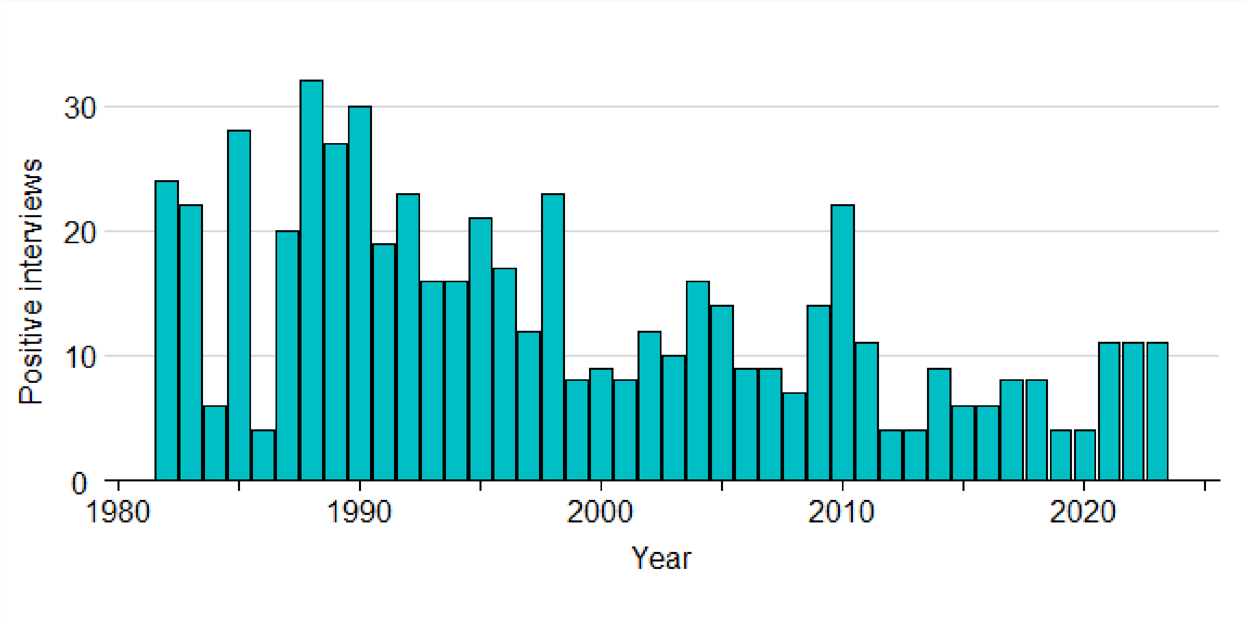

Figure 46. Number of bottomfishing interviews positive for *V. louti* by year. The nominal probability of occurrence for 1982–2023 was 0.1048.

Table 15. Selected models for the presence/absence and positive processes for *V. louti* with the number of interviews used in the model (n), the number of parameters in the model (nparm), and the deviance explained relative to the intercept only model (Dev. Expl.).

Process	Formula	n	nparm	Dev. Expl.
Presence/ Absence	z ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + DEPTH + s(VESSEL_ID_2, bs = "re")	4717	1561	0.2486
Positive	log(catch_kgs) ~ year_fac + AREA_E + s(AREA_E, year_fac, bs = "re") + s(yday, bs = "cc") + HOURS_FISHED + tod_quarter + num_gear_fac	505	271	0.2894

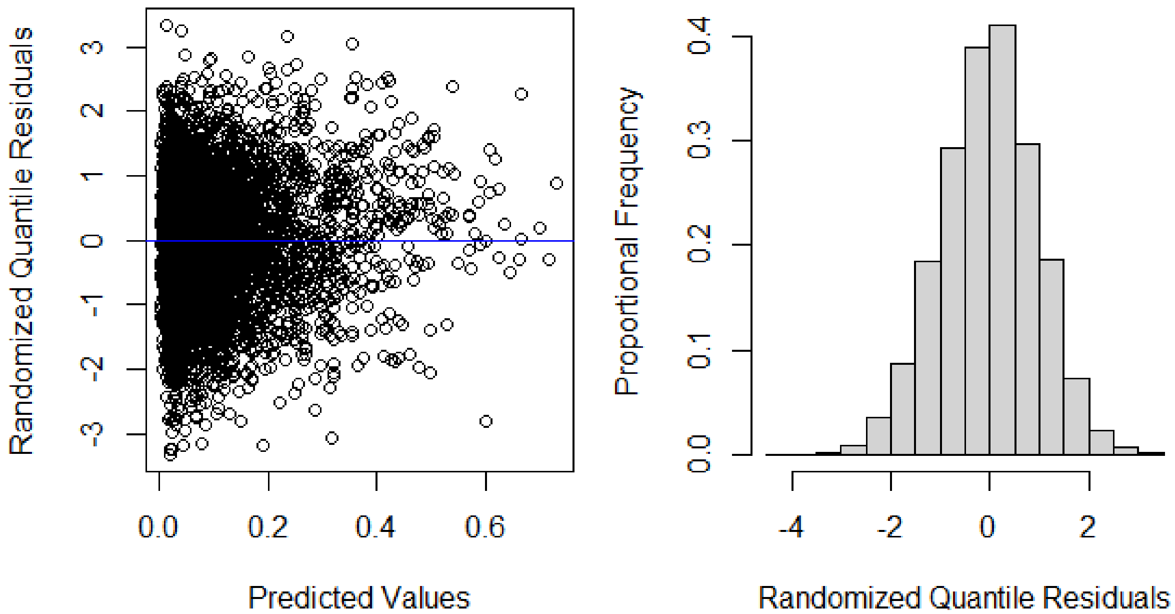

Figure 47. Residual distributions of the presence/absence process model selected for the *V. louti* CPUE standardization.

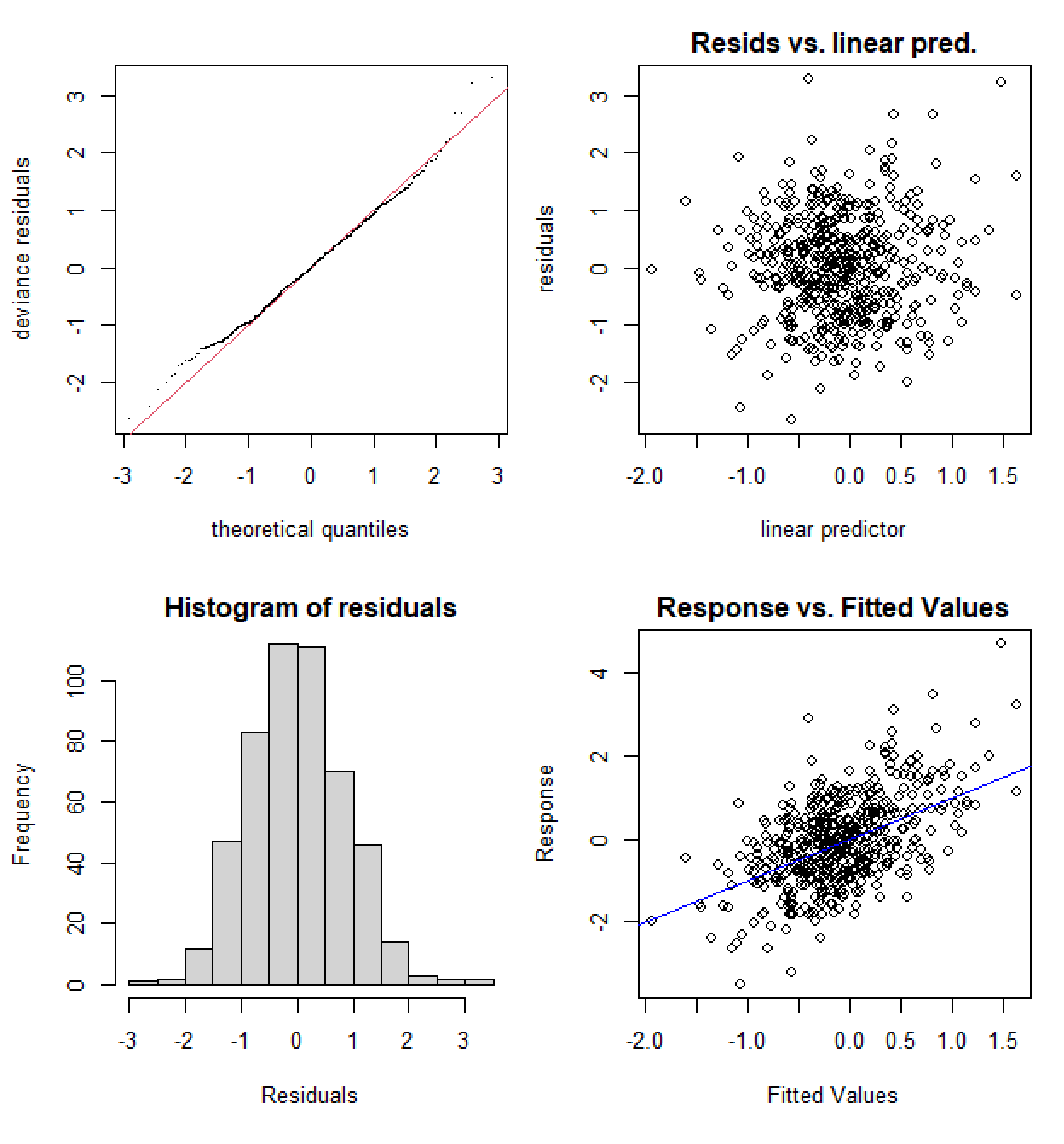

Figure 48. Residual distributions of the positive process model selected for the *V. louti* CPUE standardization.

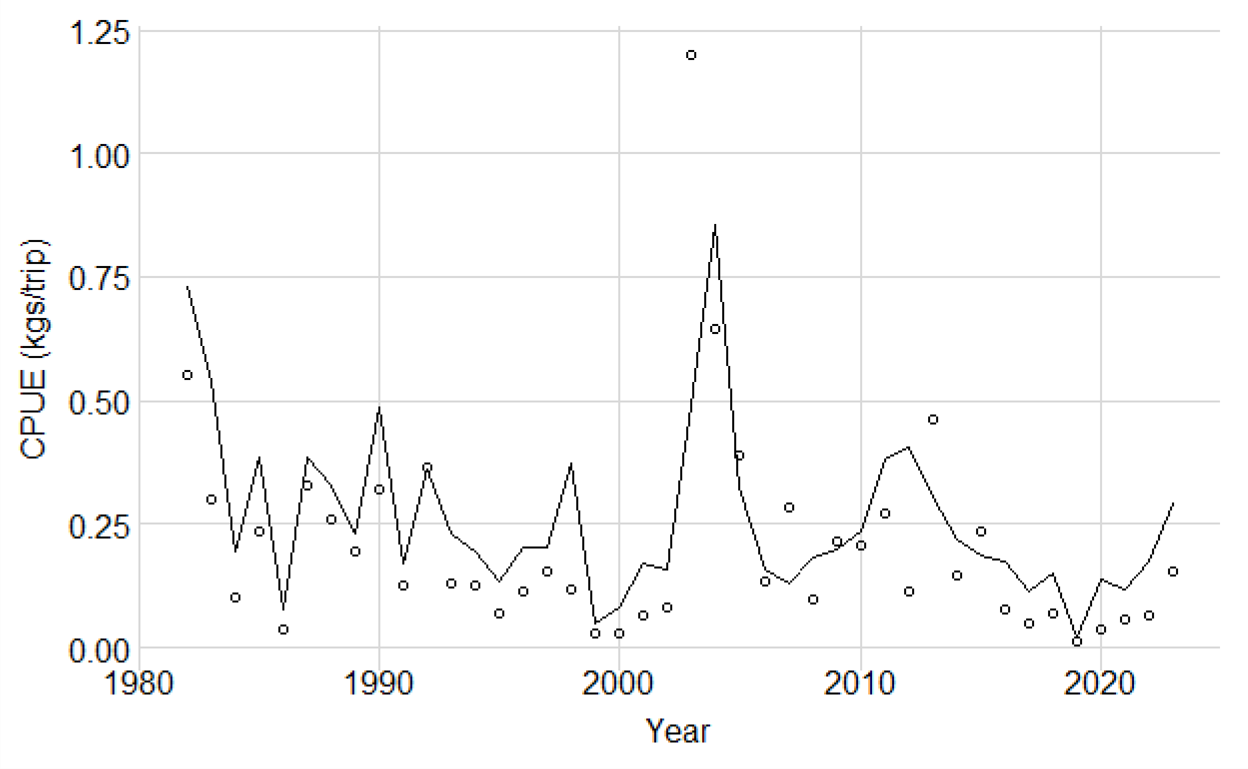

Figure 49. Standardized CPUE index (line) and nominal CPUE (points) of *V. louti*.

Acknowledgments

The authors thank many staff at the Guam Division of Aquatic & Wildlife Resources who collect the creel survey data as well as all fishermen of Guam who have volunteered to participate in creel survey interviews over the years. We also appreciate Guam fishermen and community members who provided us further knowledge informally and through the BMUS data workshops held on Guam in order to improve our analyses of the data. We thank the NOAA Pacific Islands Fisheries Science Center Western Pacific Fisheries Information Network for managing this large dataset and working with us to access and understand the creel survey interview data. We would also like to recognize several staff at the Pacific Islands Fisheries Science Center for their contributions to the writing of this working paper and the information and analyses presented herein: Robert Ahrens, Felipe Carvalho, Eric Cruz, Nicholas Ducharme-Barth, Mia Iwane, Megumi Oshima, and Marlowe Sabater.

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Appendix: Supplemental Results

Aphareus rutilans

Presence/Absence Model

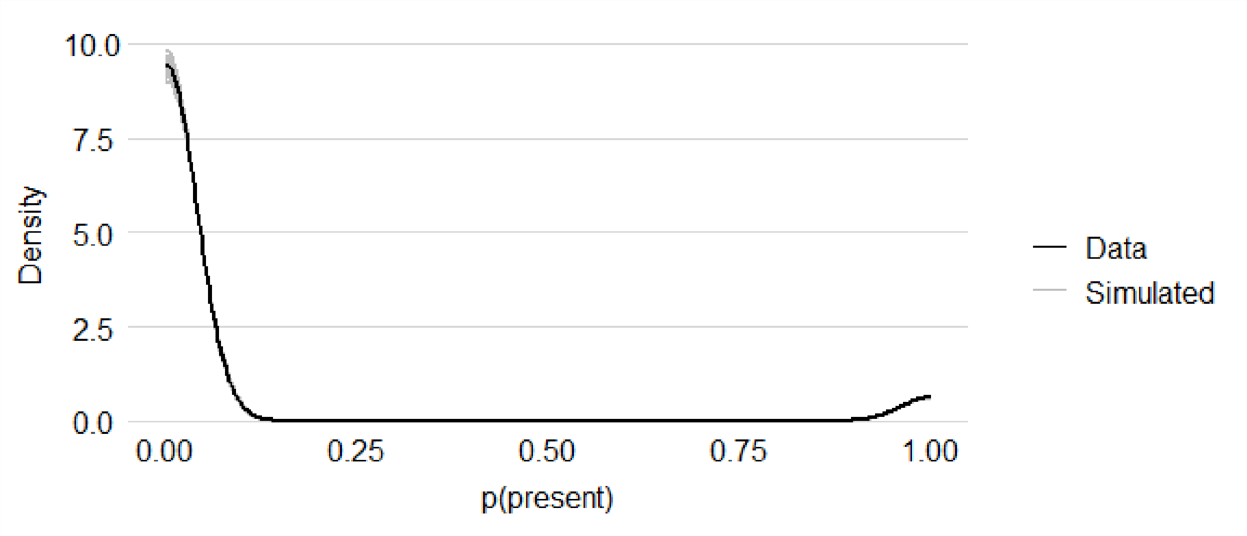


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *A. rutilans* CPUE standardization.

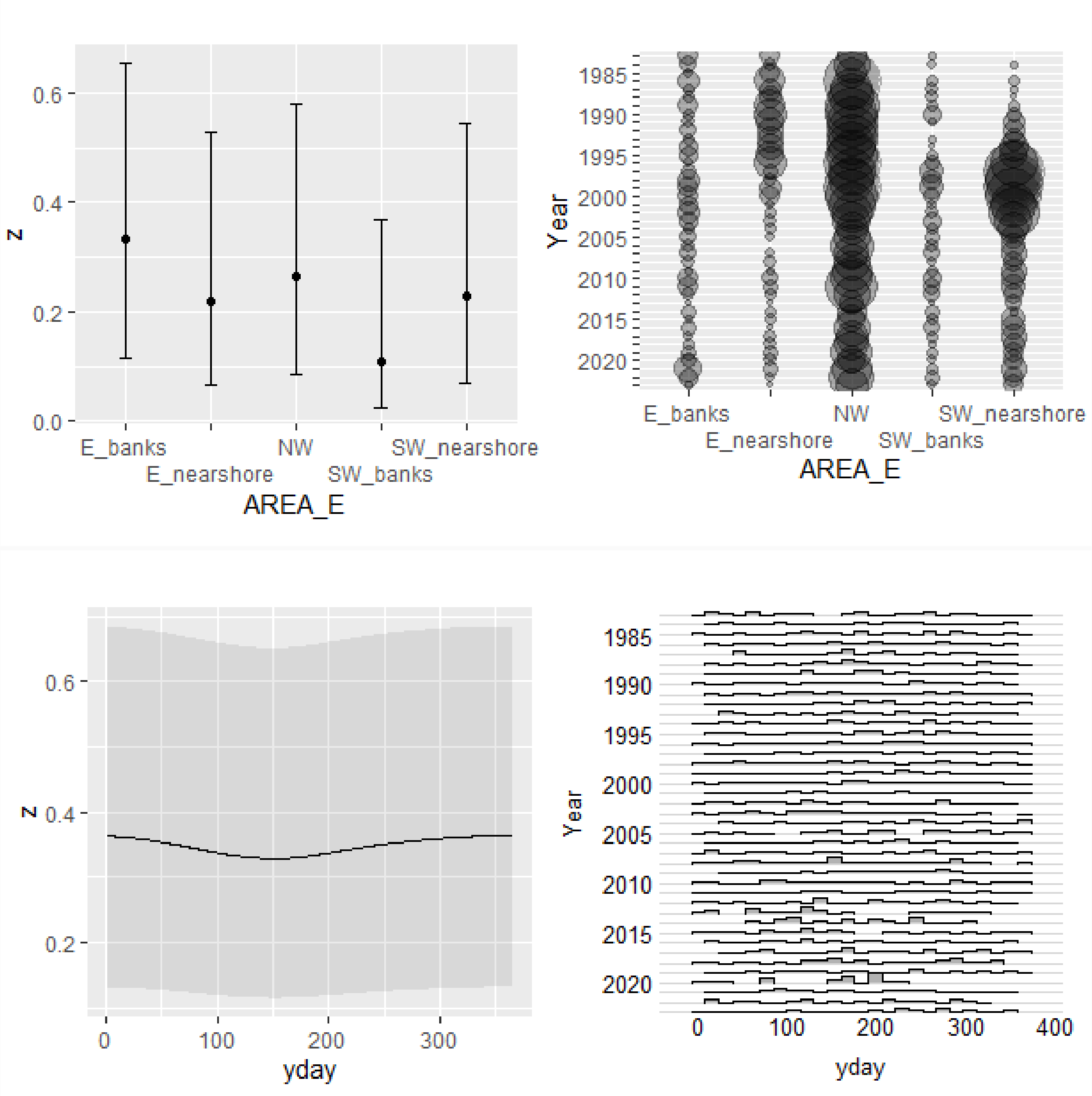


Figure 2. Partial effects of area and time of year on probability of presence in the *A. rutilans* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

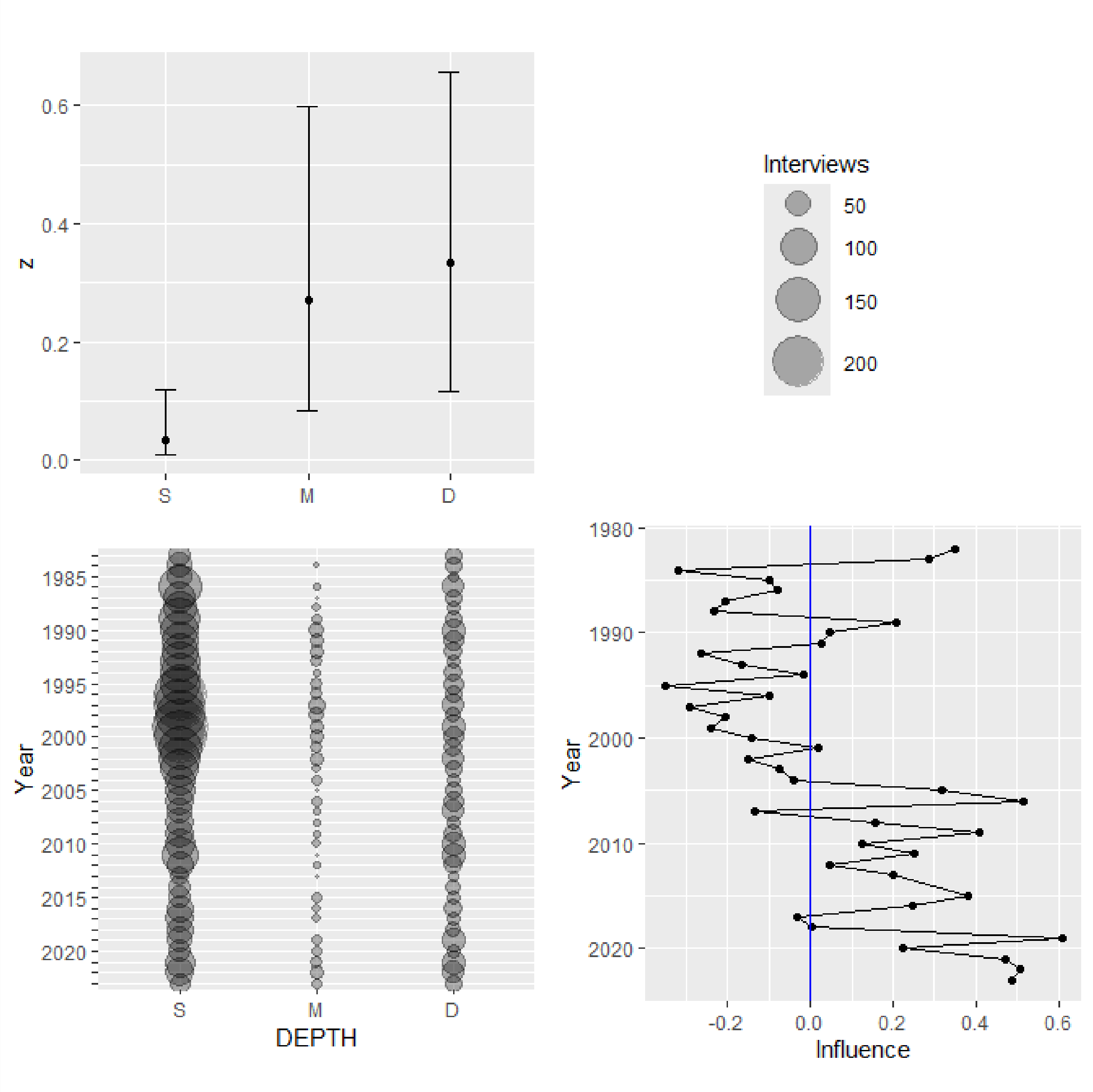


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *A. rutilans* CPUE standardization.

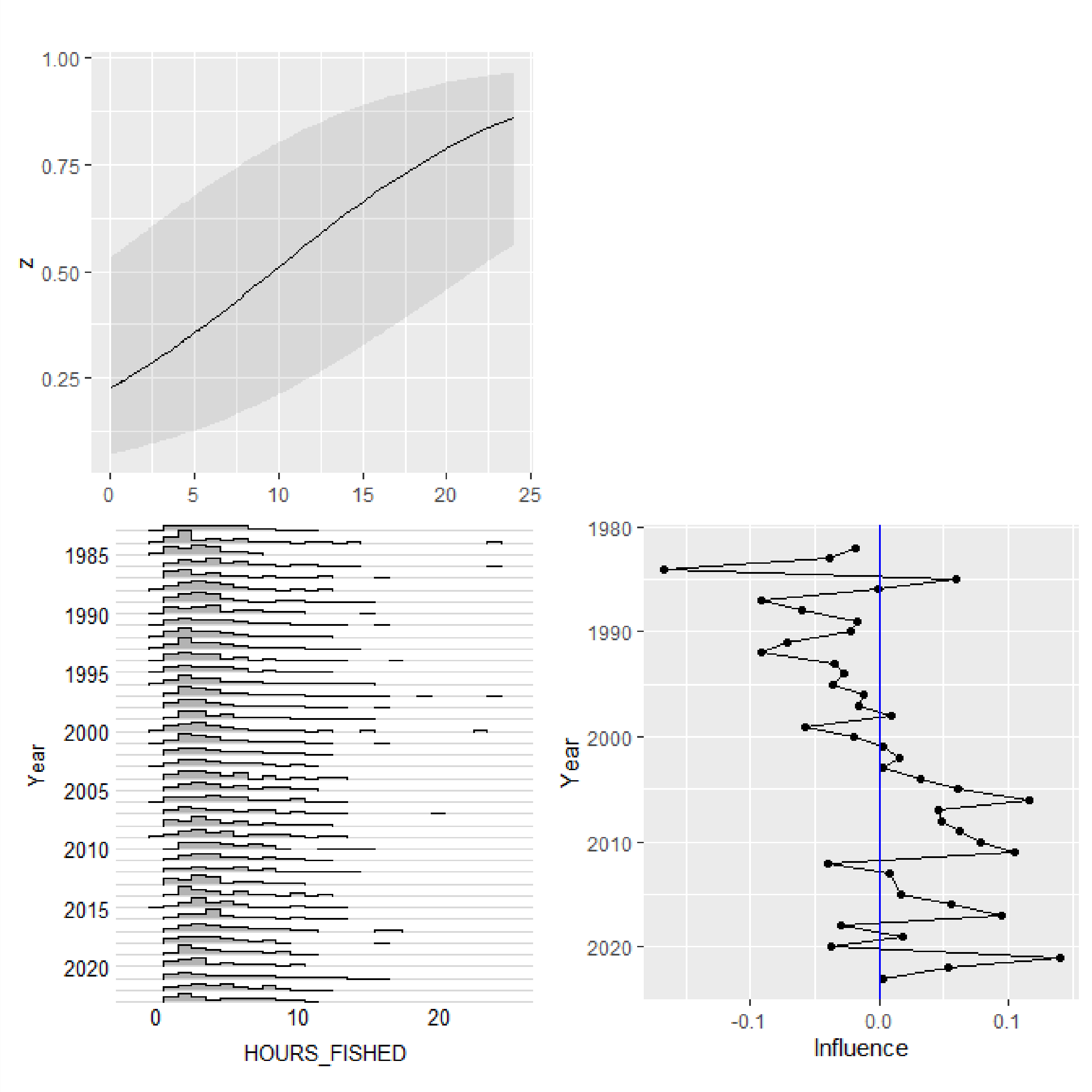


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on probability of presence in the *A. rutilans* CPUE standardization.

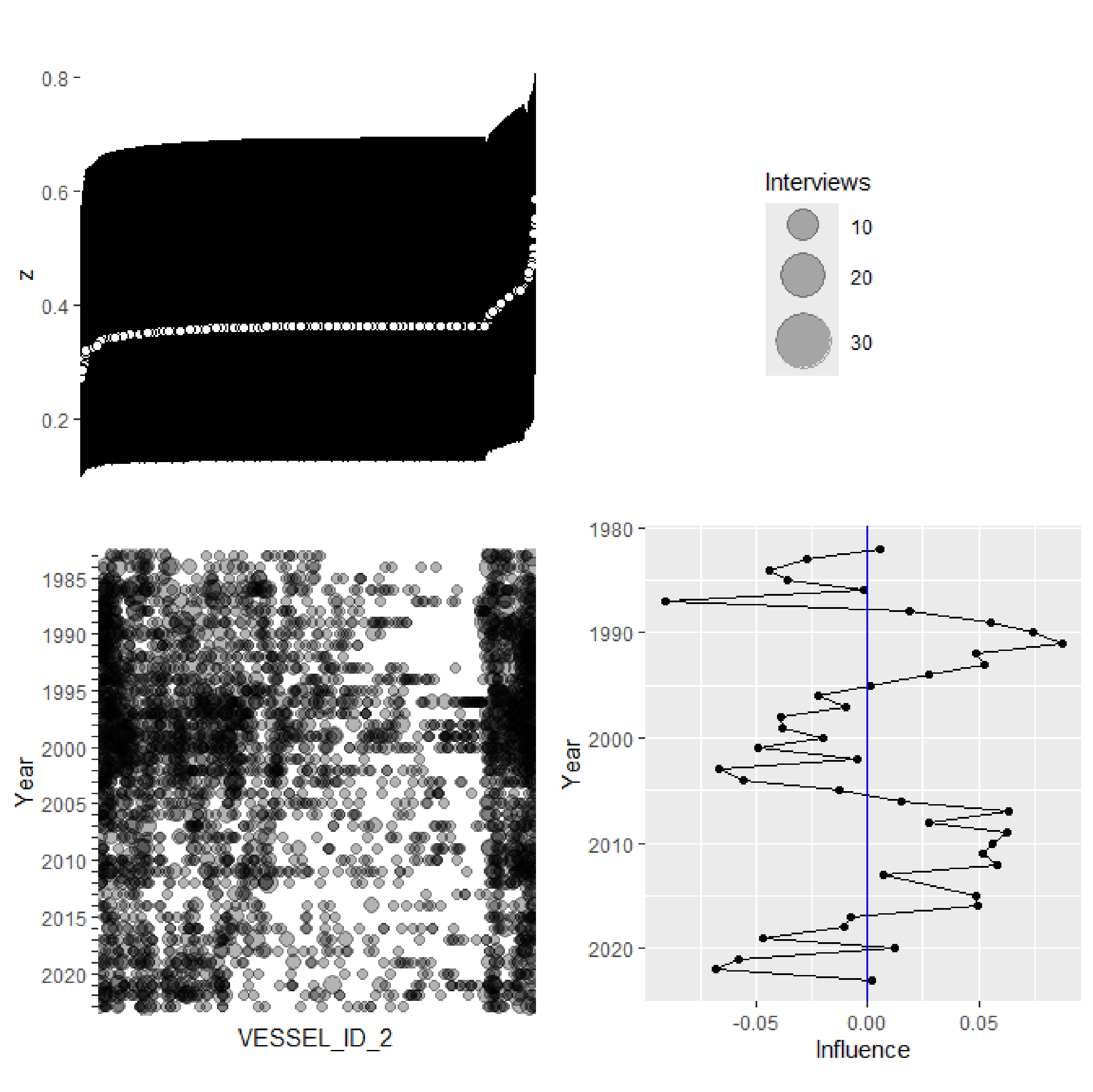


Figure 5. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *A. rutilans* CPUE standardization.

Positive Process Model

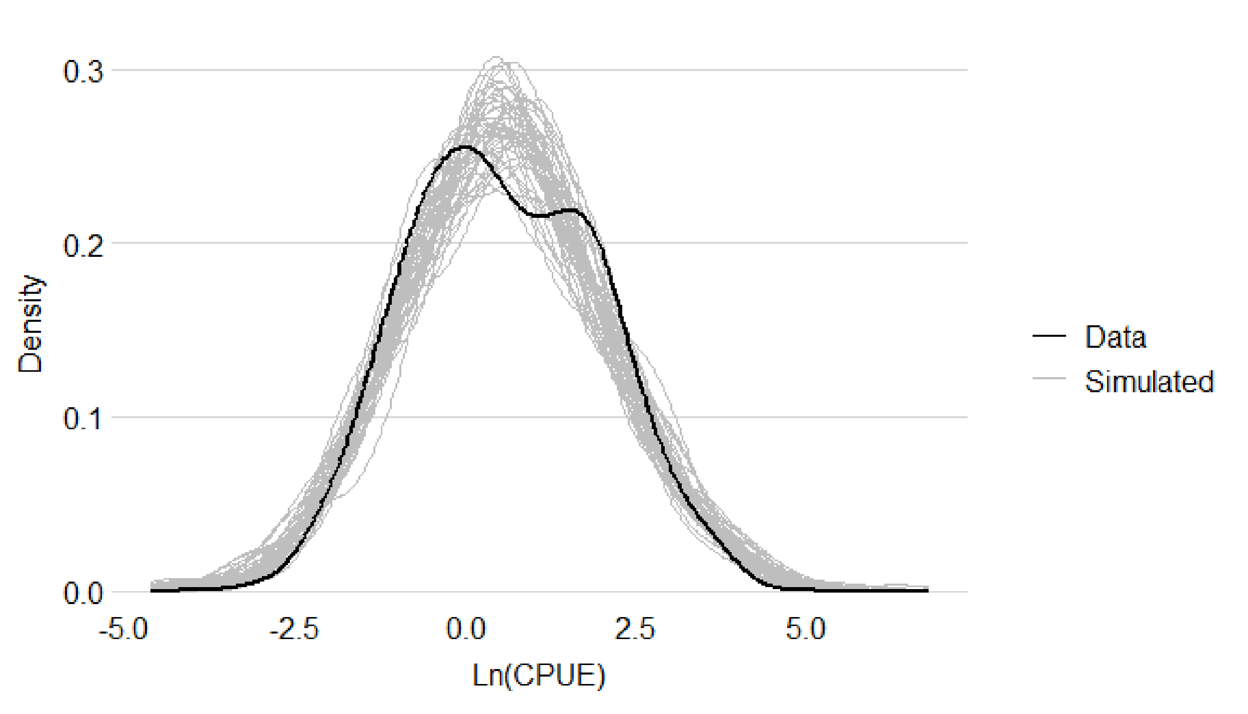


Figure 6. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *A. rutilans* CPUE standardization.

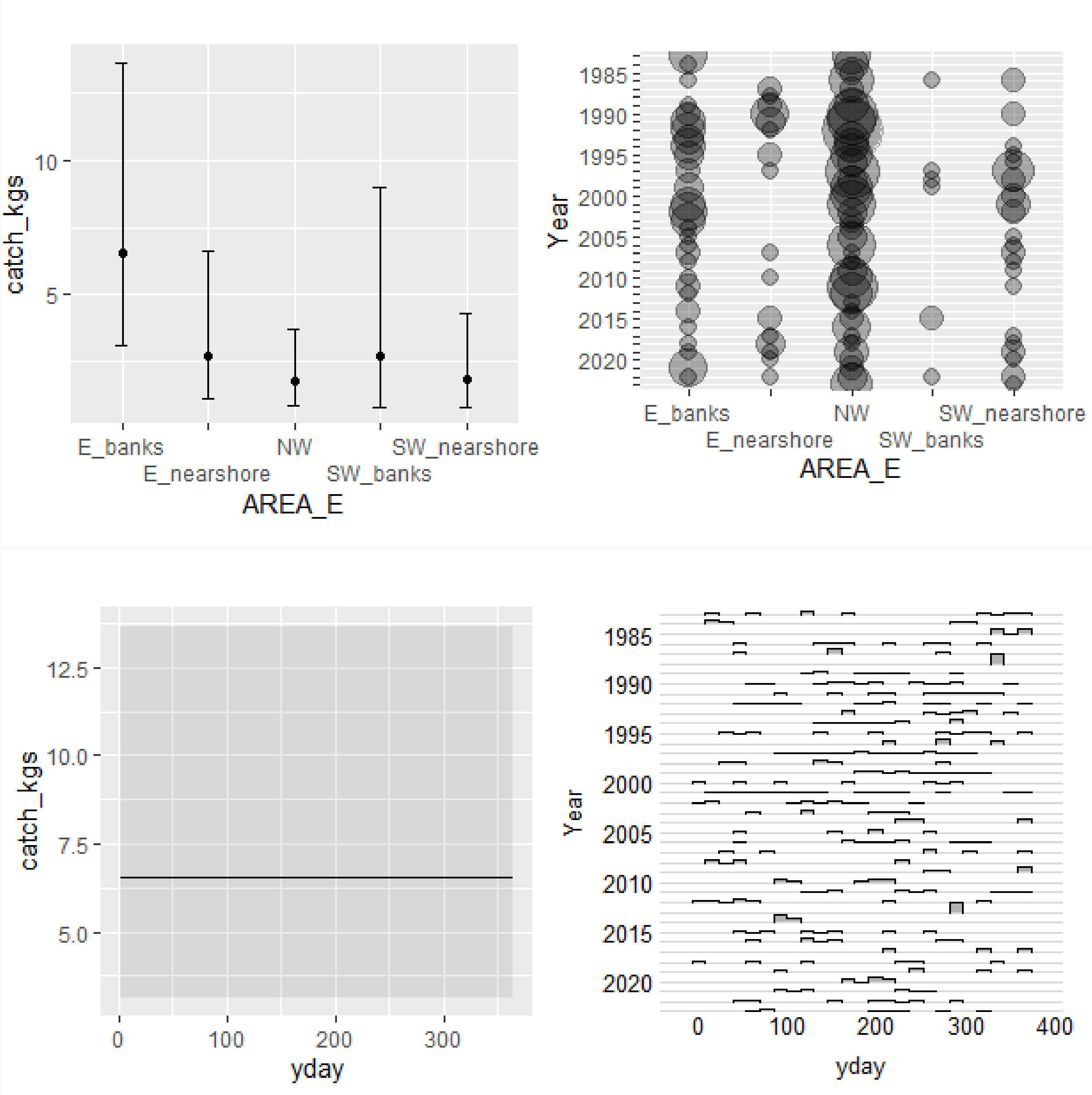


Figure 7. Partial effects of area and time of year on CPUE (kg per trip) in the *A. rutilans* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

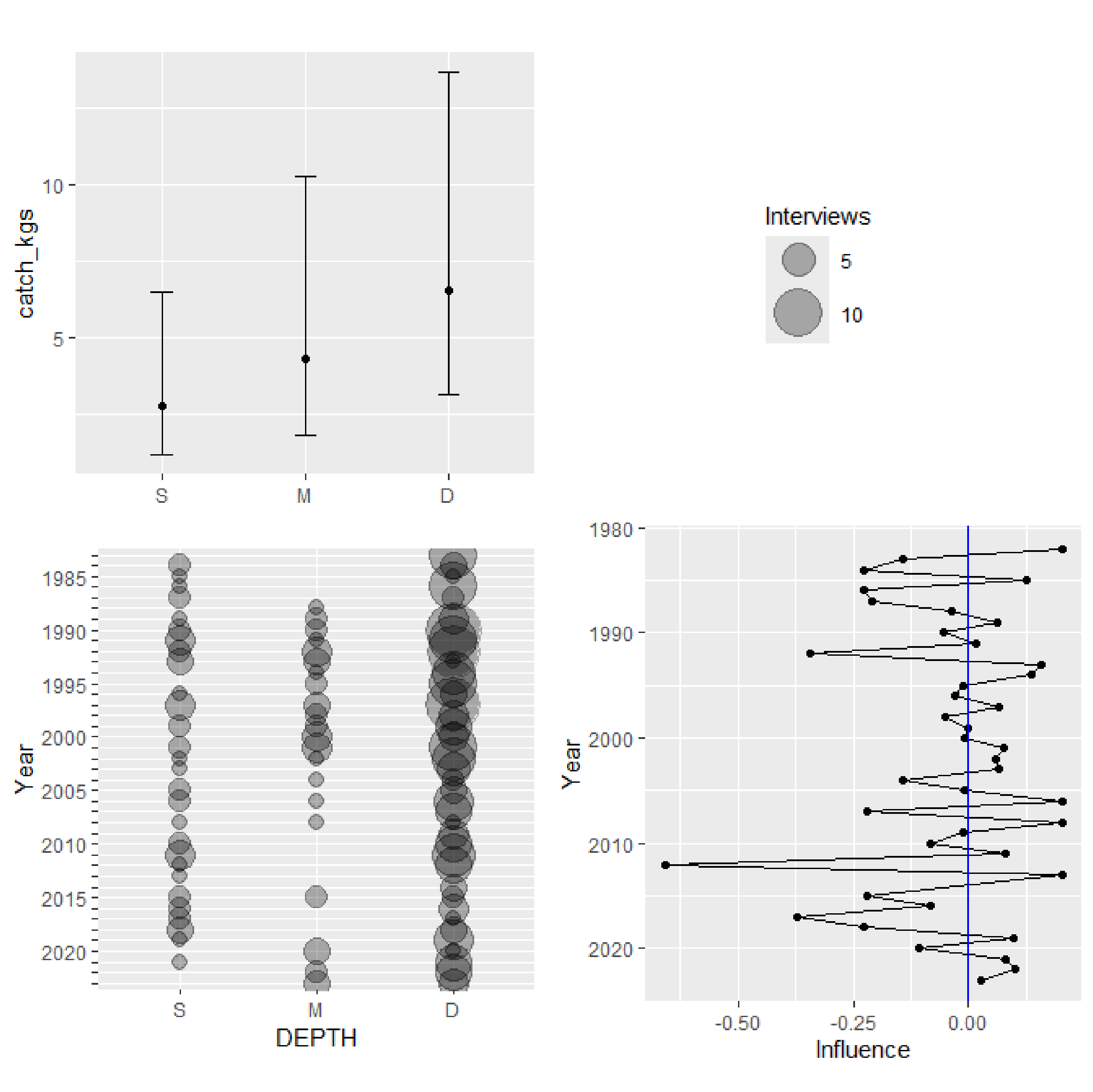


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on CPUE (kg per trip) in the *A. rutilans* CPUE standardization.

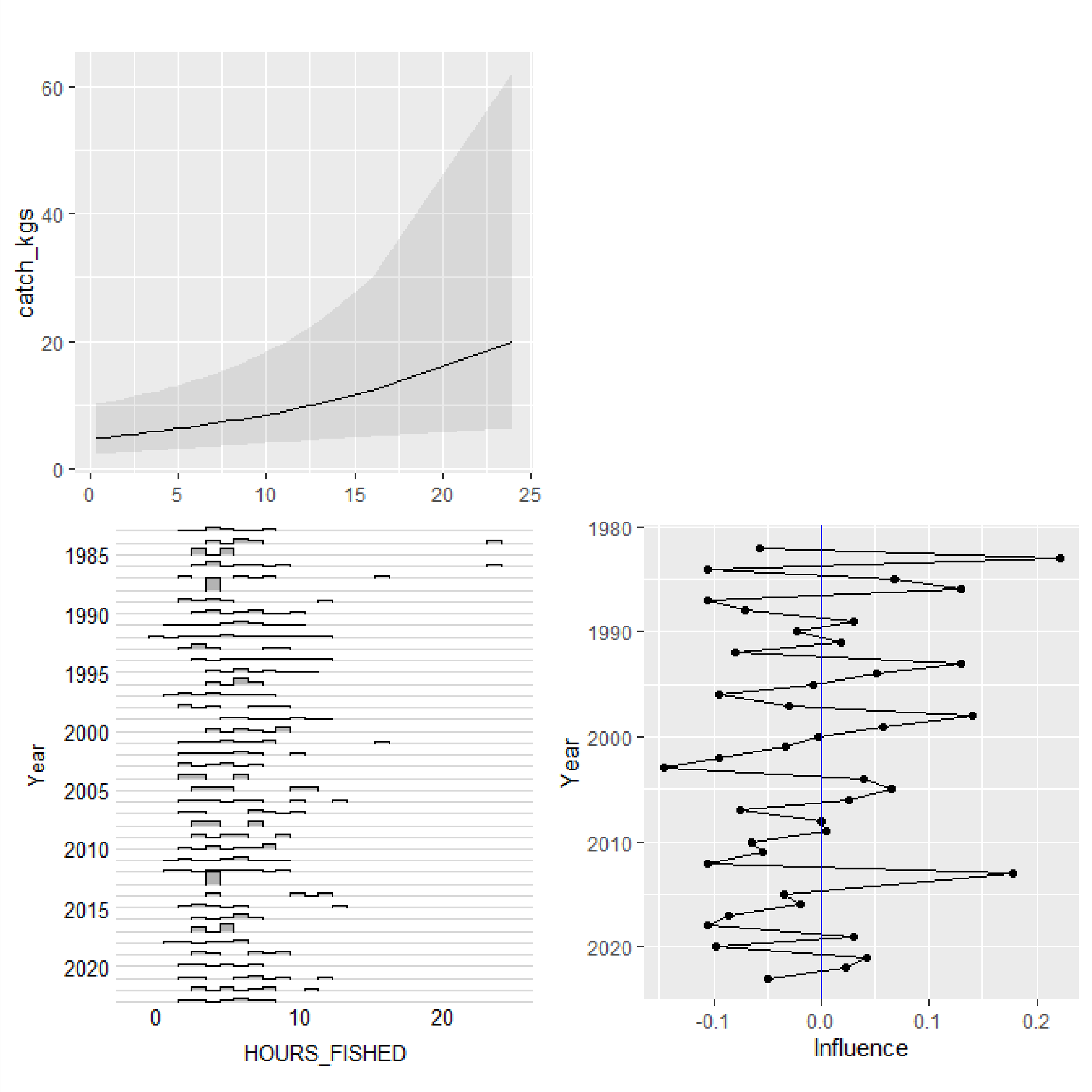


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on CPUE (kg per trip) in the *A. rutilans* CPUE standardization.

Standardized CPUE Index

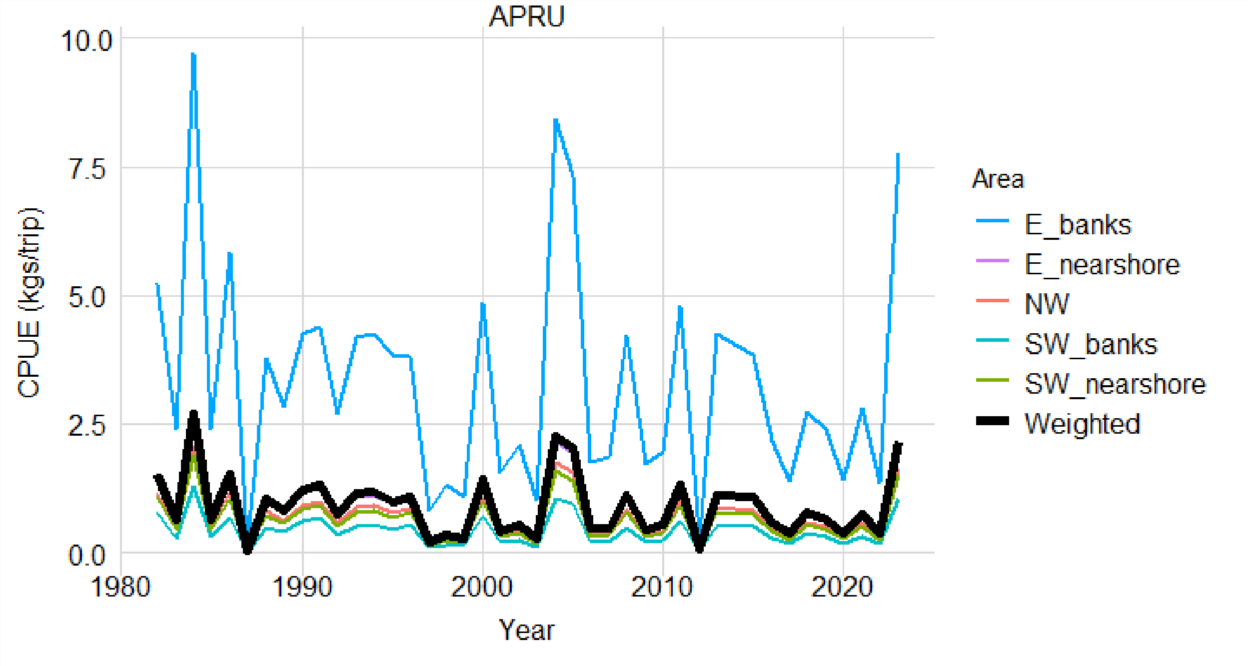


Figure 10. Standardized CPUE index (kg per trip) of *A. rutilans* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *A. rutilans*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	1.53	1.19	1996	1.09	0.73	2010	0.54	0.44
1983	0.64	0.80	1997	0.21	0.25	2011	1.32	1.25
1984	2.70	5.05	1998	0.35	0.33	2012	0.07	0.36
1985	0.65	0.54	1999	0.28	0.29	2013	1.13	1.82
1986	1.53	2.15	2000	1.41	0.98	2014	---	---
1987	0.05	0.27	2001	0.42	0.37	2015	1.08	1.04
1988	1.04	1.00	2002	0.56	0.62	2016	0.58	0.63
1989	0.81	0.56	2003	0.27	0.43	2017	0.36	0.60
1990	1.22	0.86	2004	2.28	2.64	2018	0.78	0.75
1991	1.30	0.85	2005	2.01	1.75	2019	0.64	0.62
1992	0.75	0.73	2006	0.46	0.51	2020	0.38	0.51
1993	1.14	1.05	2007	0.49	0.80	2021	0.73	0.81
1994	1.18	0.95	2008	1.10	1.52	2022	0.36	0.34
1995	0.99	1.43	2009	0.46	0.45	2023	2.18	2.06

Caranx ignobilis

Presence/Absence Model

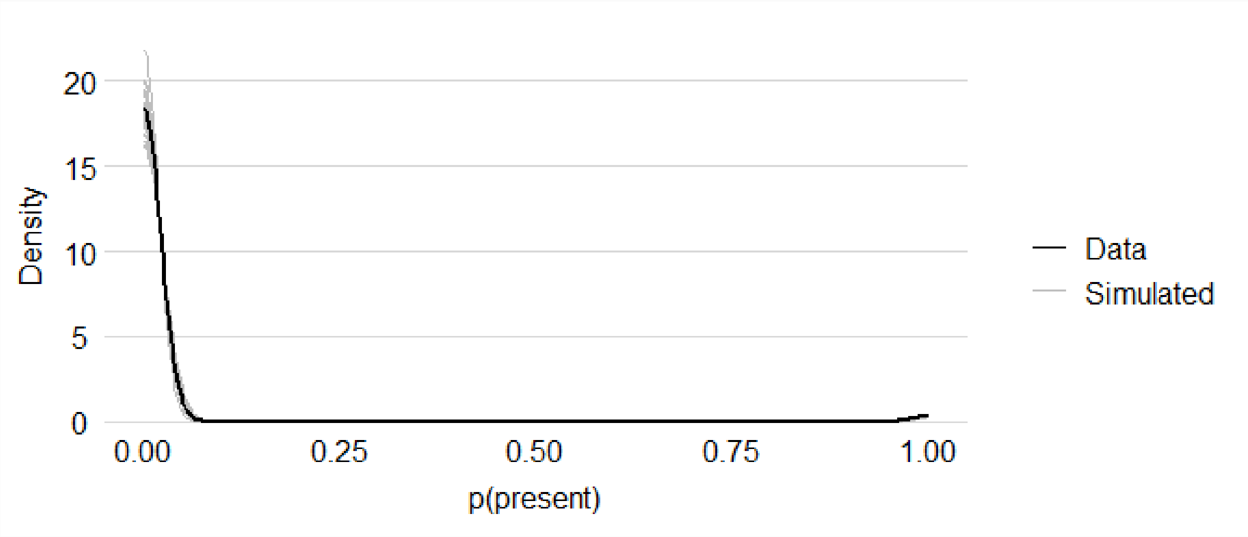


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *C. ignobilis* CPUE standardization.

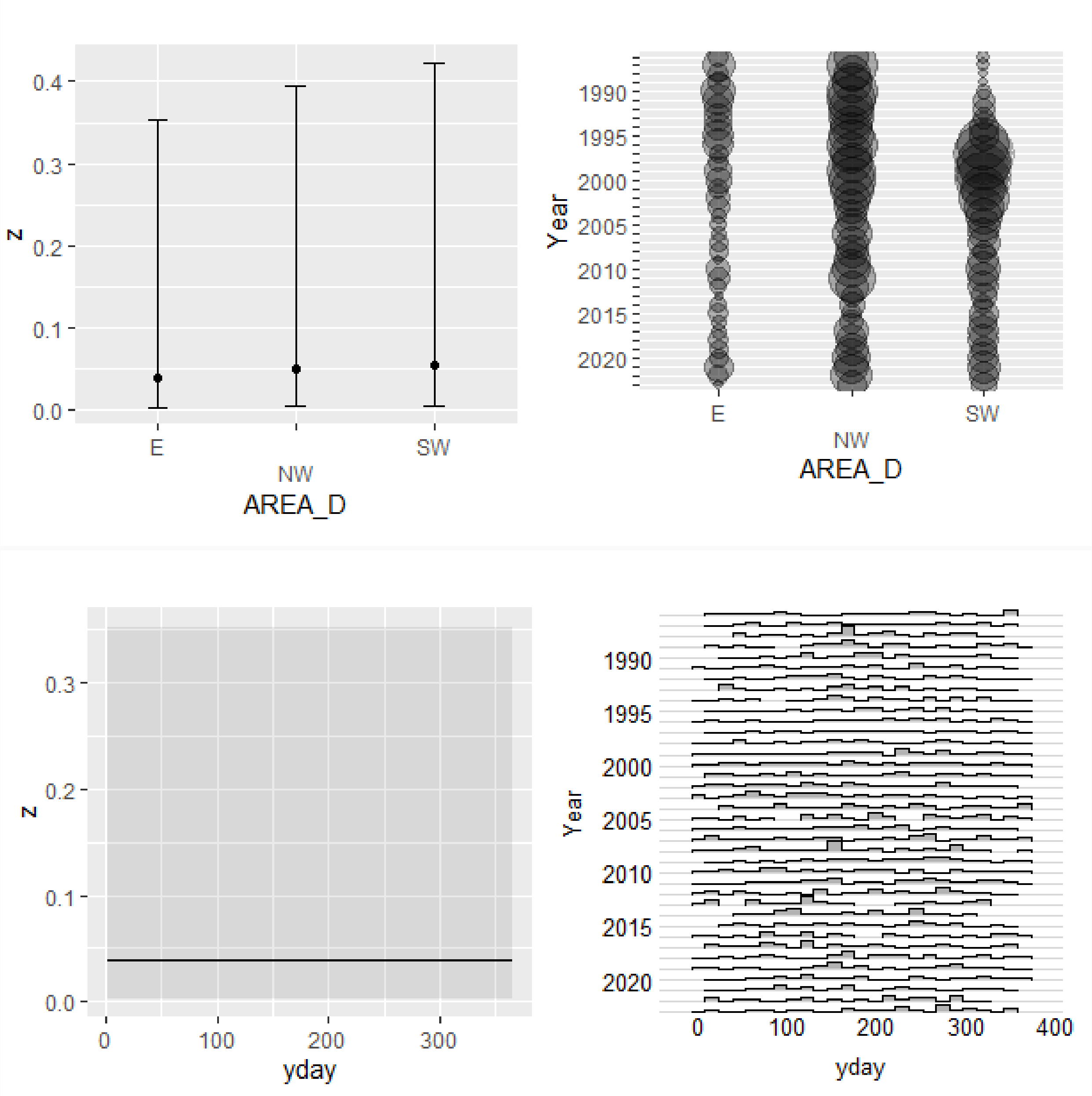


Figure 2. Partial effects of area and time of year on probability of presence in the *C. ignobilis* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

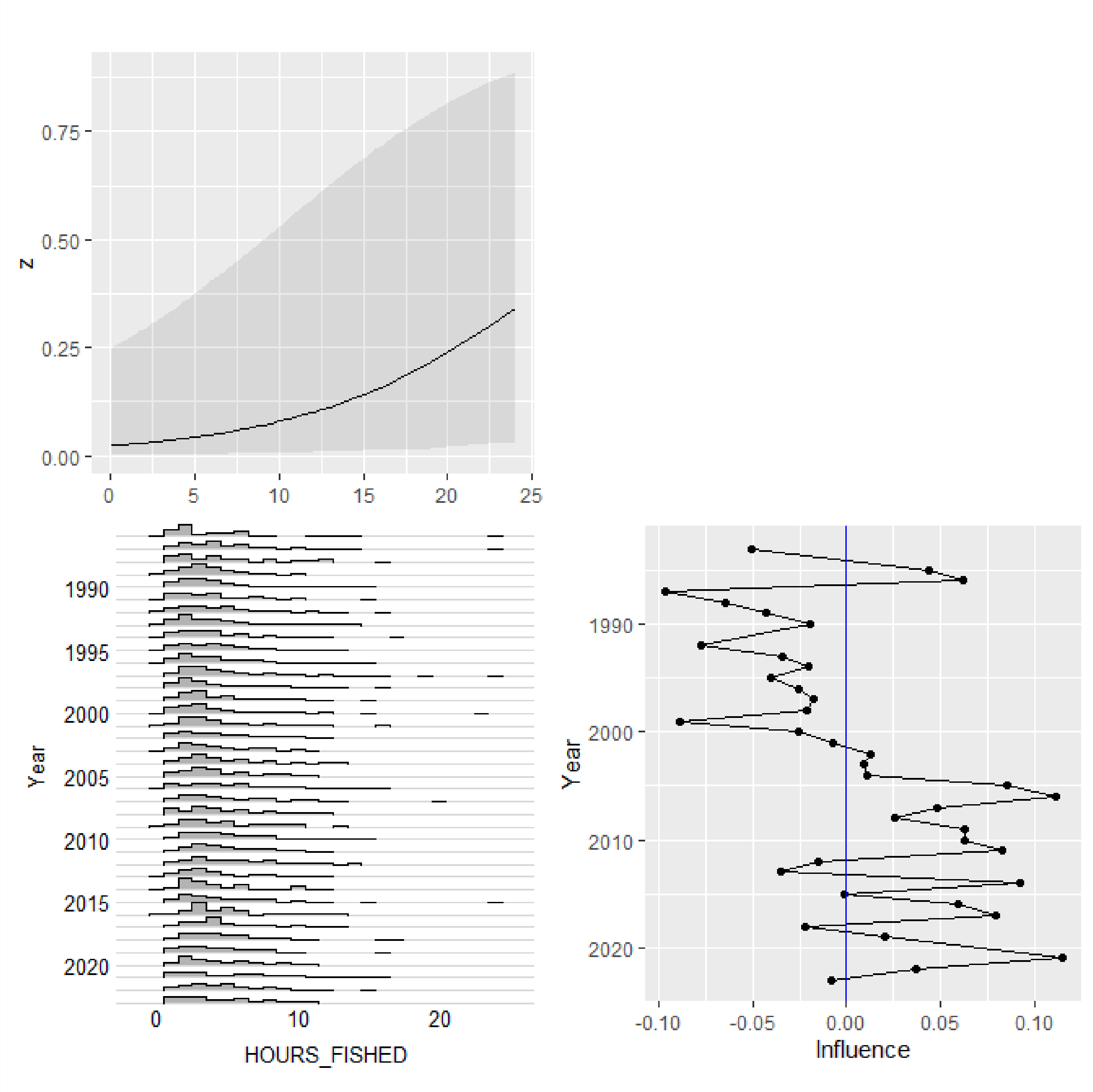


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on probability of presence in the *C. ignobilis* CPUE standardization.

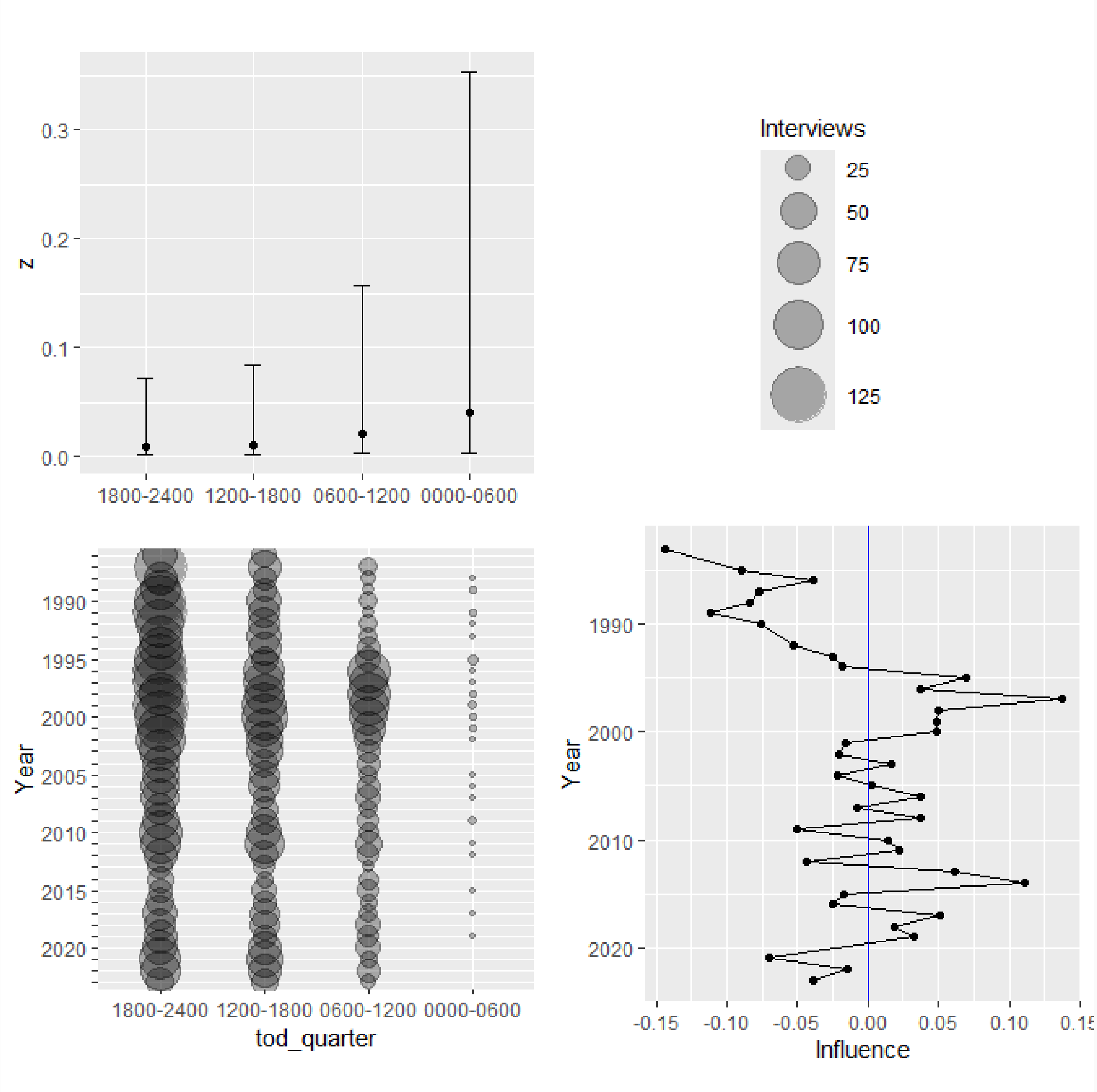


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of time of day on probability of presence in the *C. ignobilis* CPUE standardization.

Positive Process Model

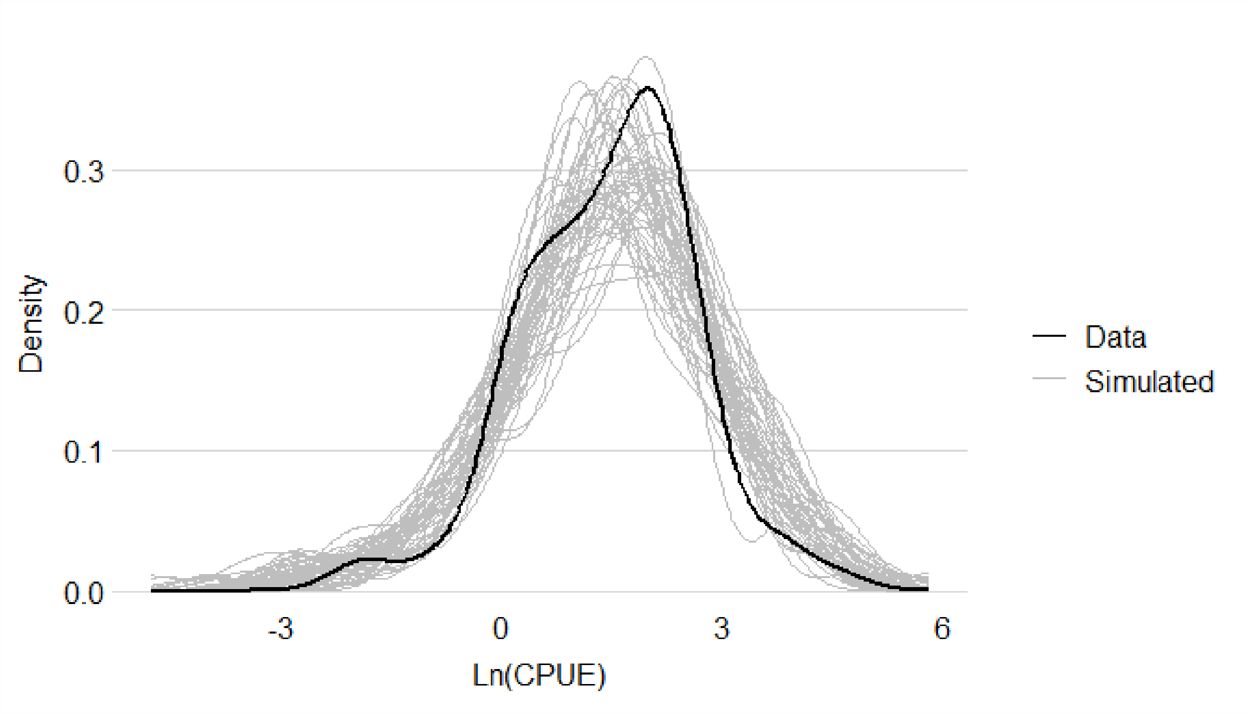


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *C. ignobilis* CPUE standardization.

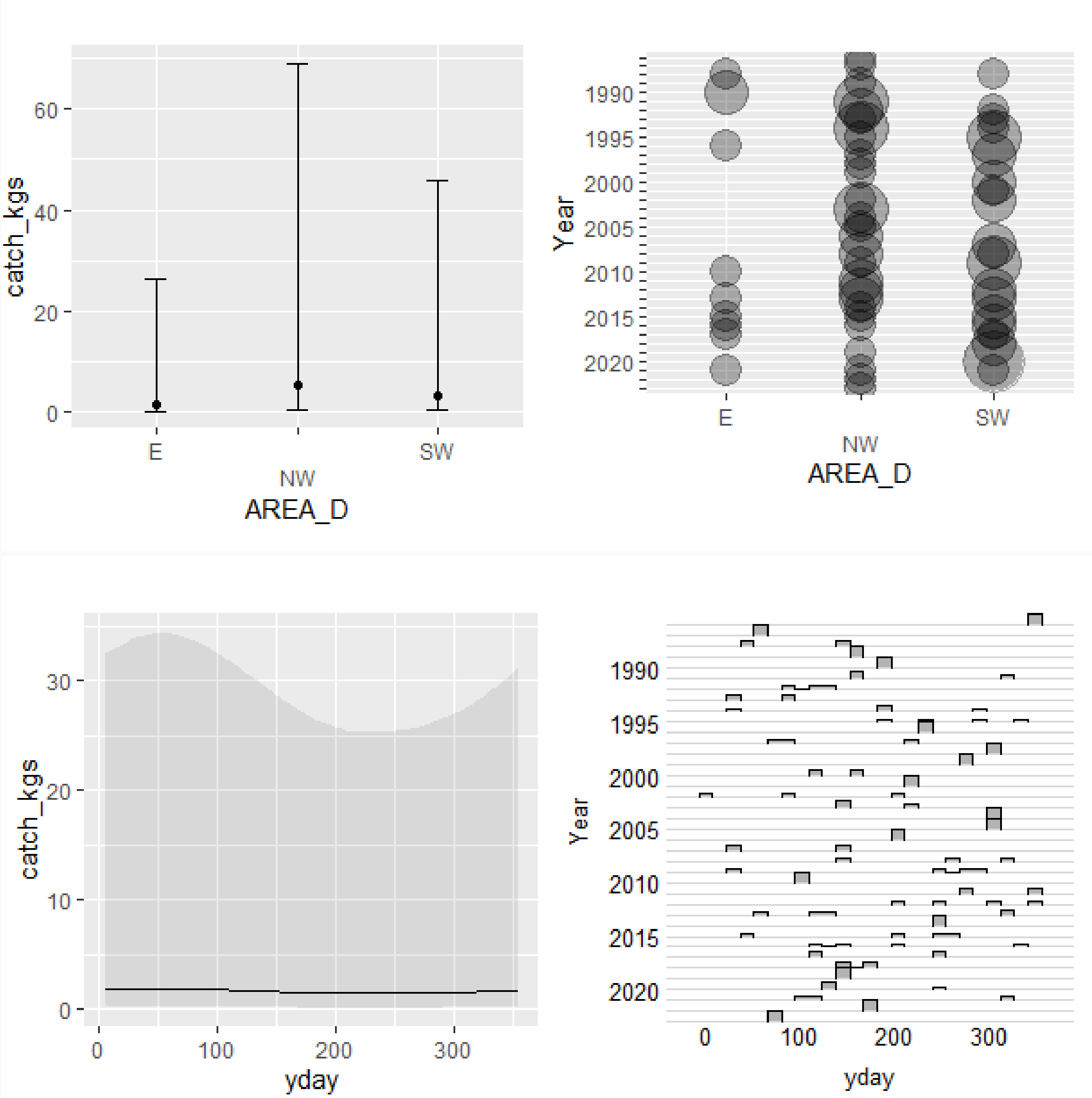


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *C. ignobilis* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

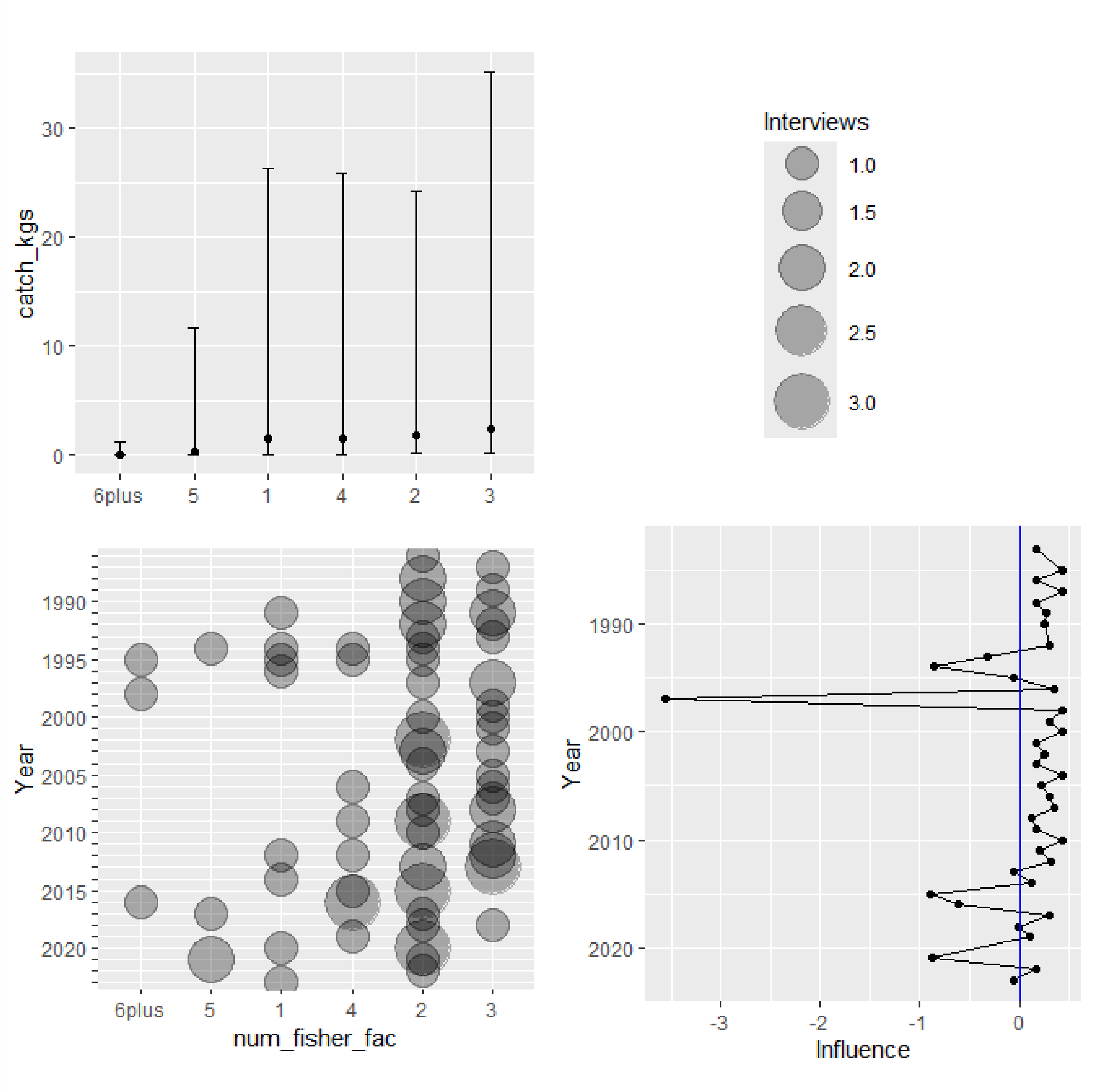


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of number of fishers on CPUE (kg per trip) in the *C. ignobilis* CPUE standardization.

Standardized CPUE Index

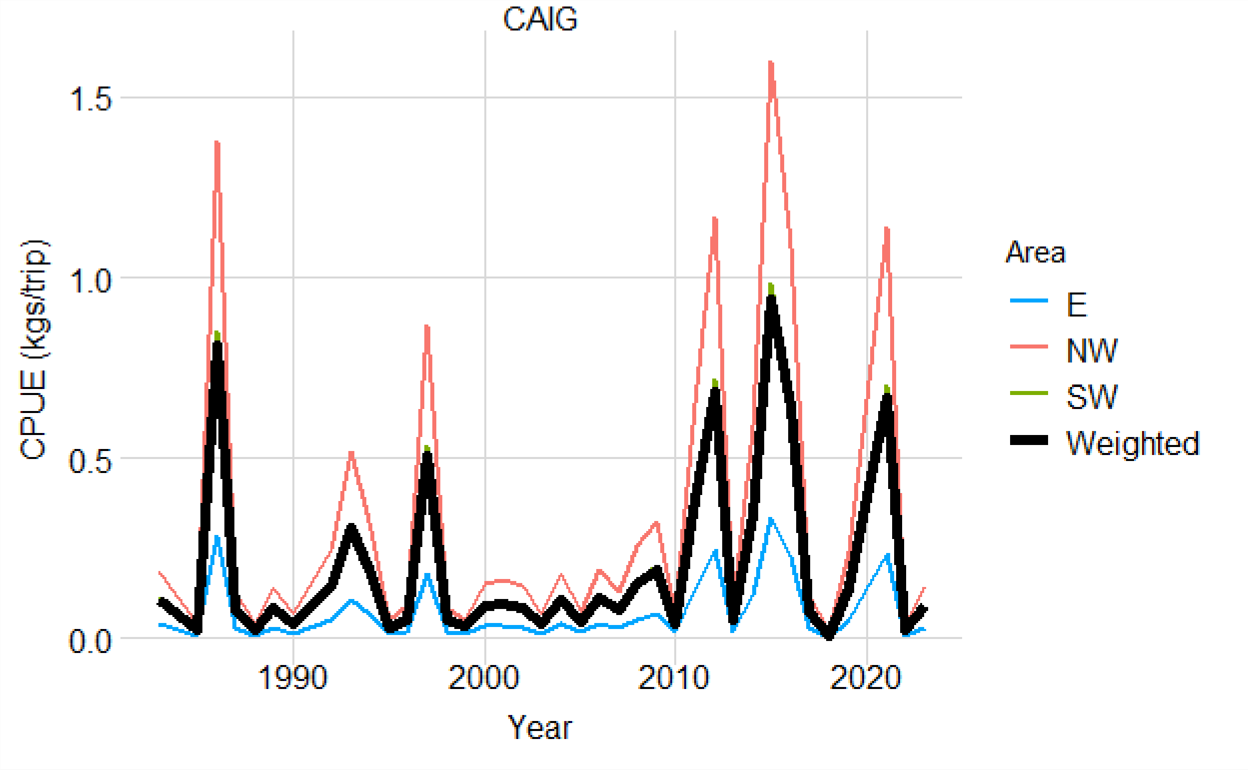


Figure 8. Standardized CPUE index (kg per trip) of *C. ignobilis* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *C. ignobilis*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	--	--	1996	0.05	0.08	2010	0.04	0.10
1983	0.11	0.57	1997	0.51	6.01	2011	0.38	0.51
1984	--	--	1998	0.05	0.29	2012	0.69	0.71
1985	0.02	0.14	1999	0.03	0.07	2013	0.05	0.33
1986	0.81	1.76	2000	0.09	0.54	2014	0.35	0.42
1987	0.08	0.45	2001	0.10	0.13	2015	0.94	1.57
1988	0.02	0.06	2002	0.09	0.13	2016	0.64	1.77
1989	0.08	0.14	2003	0.04	0.20	2017	0.07	0.16
1990	0.04	0.06	2004	0.10	0.62	2018	0.01	0.06
1991	--	--	2005	0.04	0.11	2019	0.14	0.17
1992	0.15	0.31	2006	0.11	0.24	2020	--	--
1993	0.30	0.40	2007	0.08	0.12	2021	0.67	1.47
1994	0.19	0.26	2008	0.15	0.18	2022	0.02	0.11
1995	0.03	0.27	2009	0.19	1.21	2023	0.09	0.60

Caranx lugubris

Presence/Absence Model

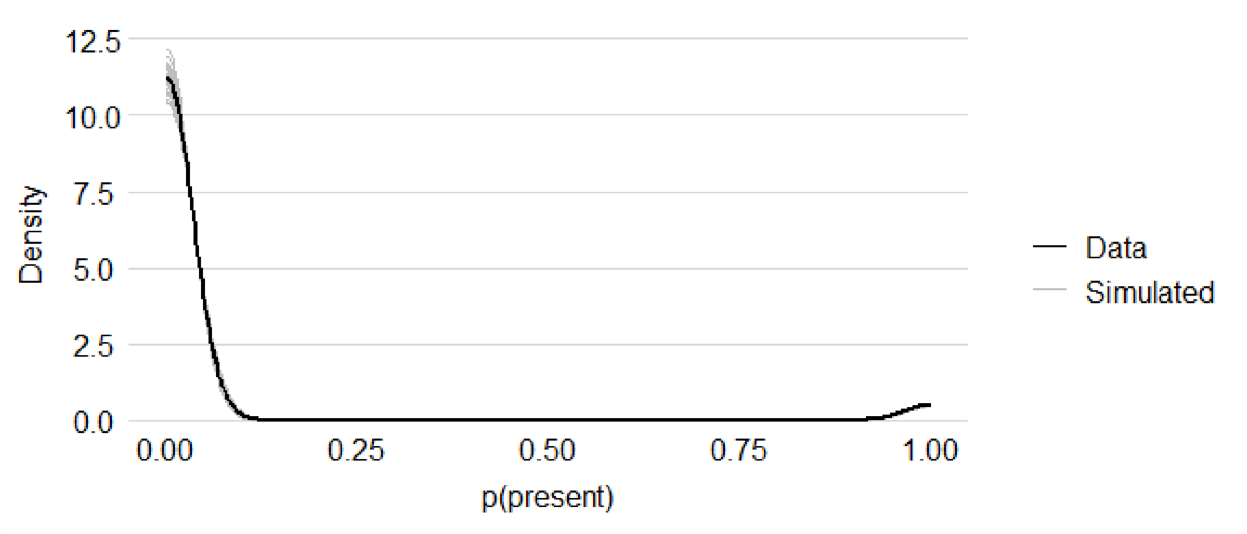


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *C. lugubris* CPUE standardization.

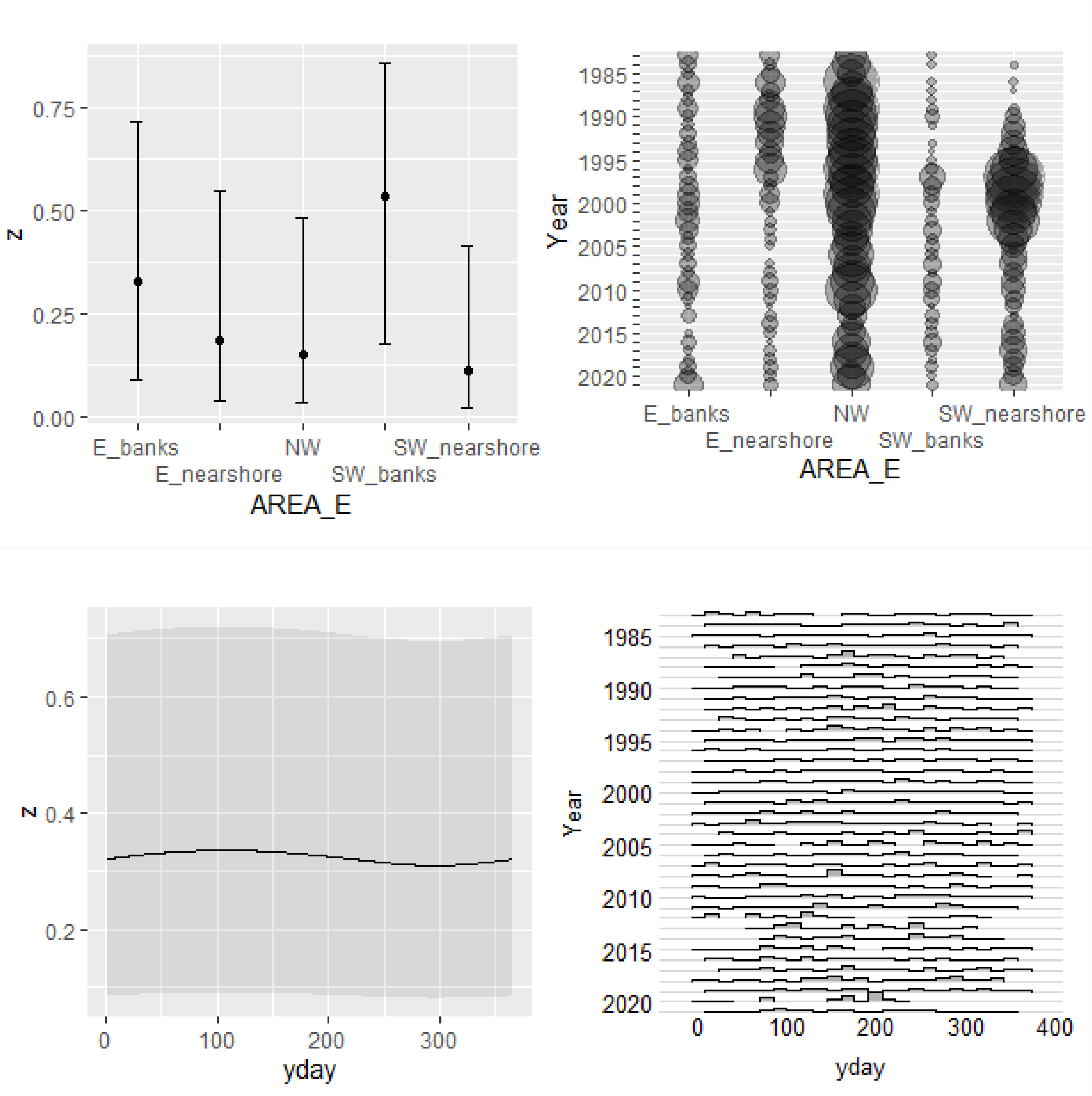


Figure 2. Partial effects of area and time of year on probability of presence in the *C. lugubris* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

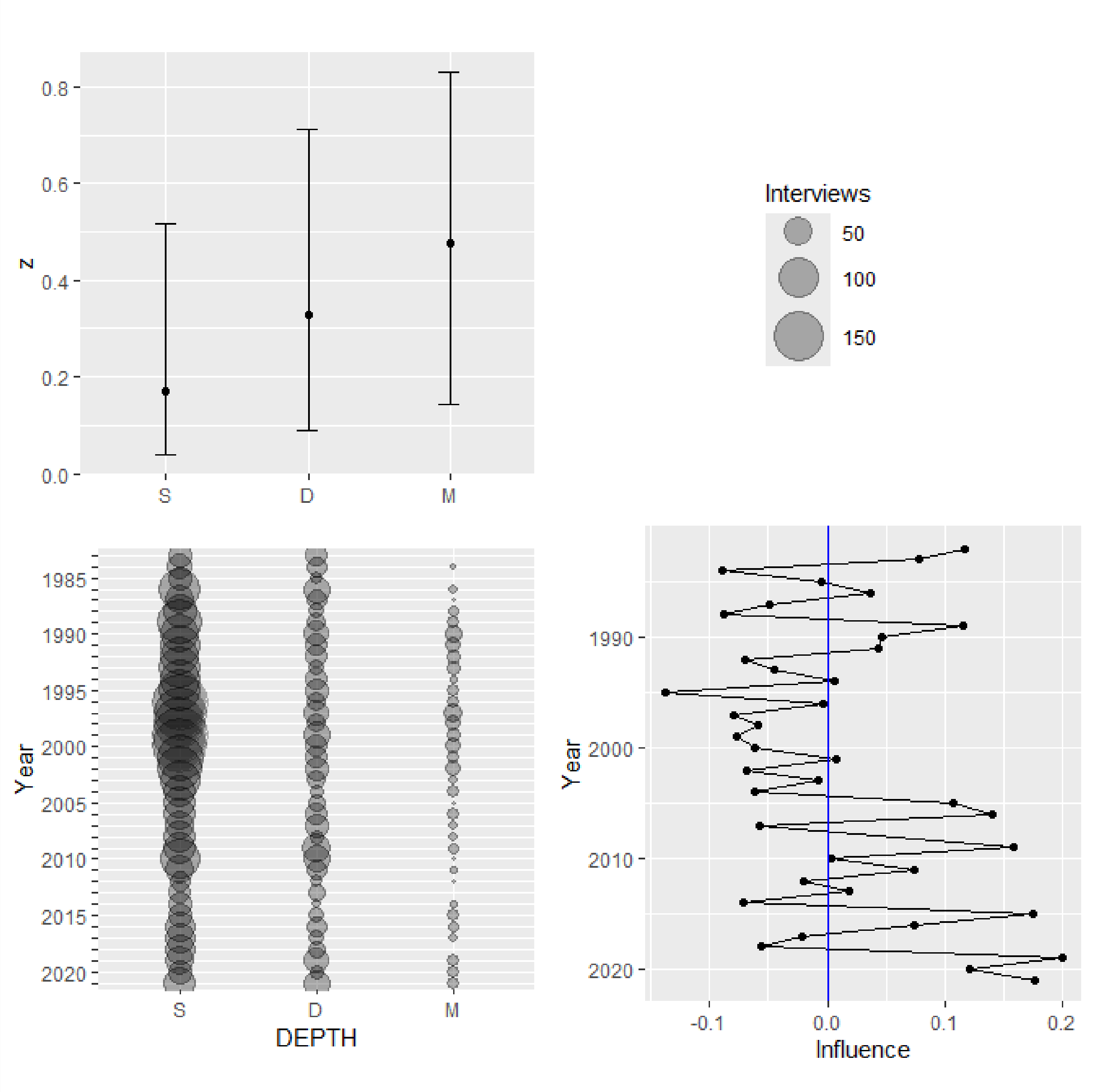


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *C. lugubris* CPUE standardization.

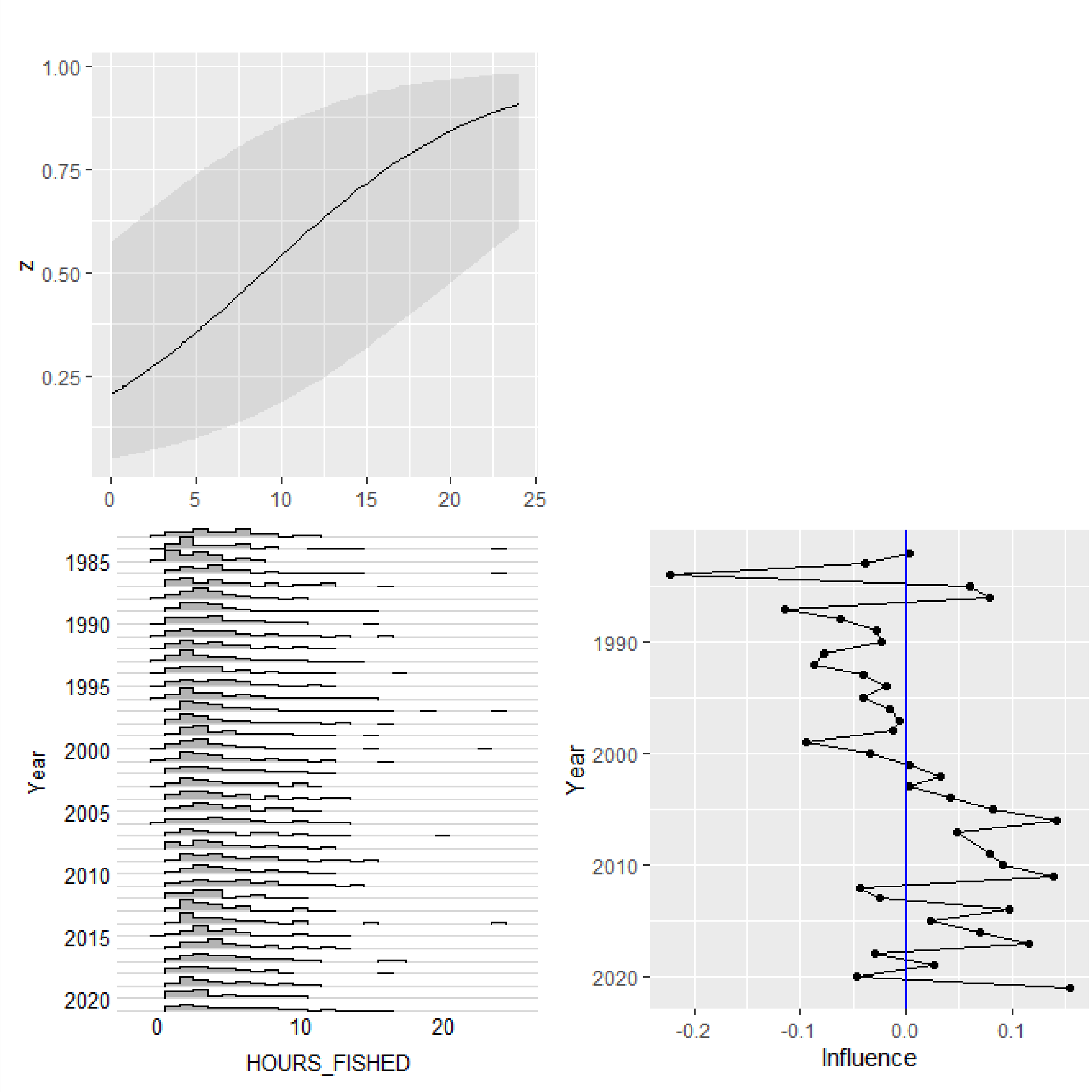


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on probability of presence in the *C. lugubris* CPUE standardization.

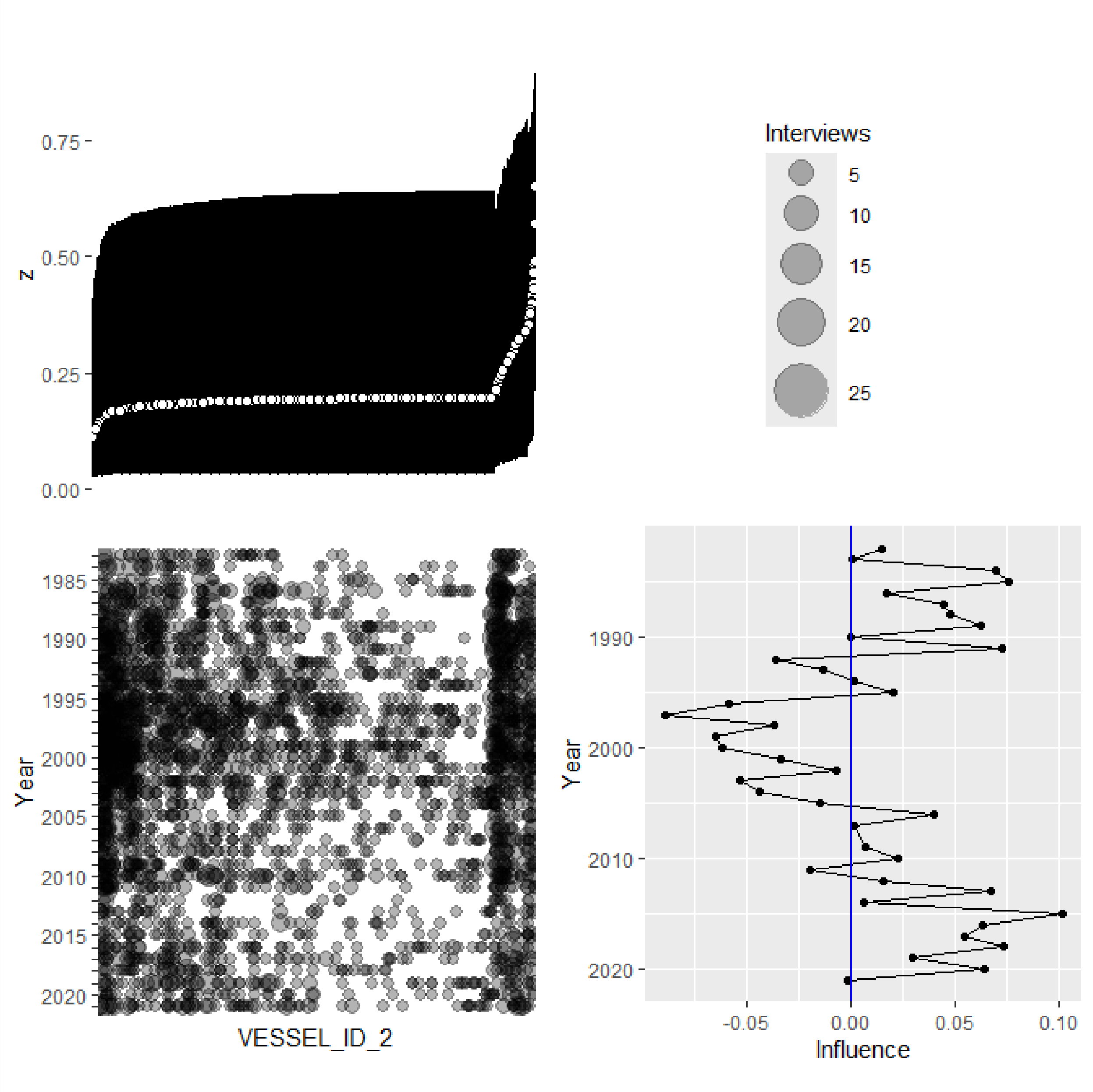


Figure 5. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *C. lugubris* CPUE standardization.

Positive Process Model

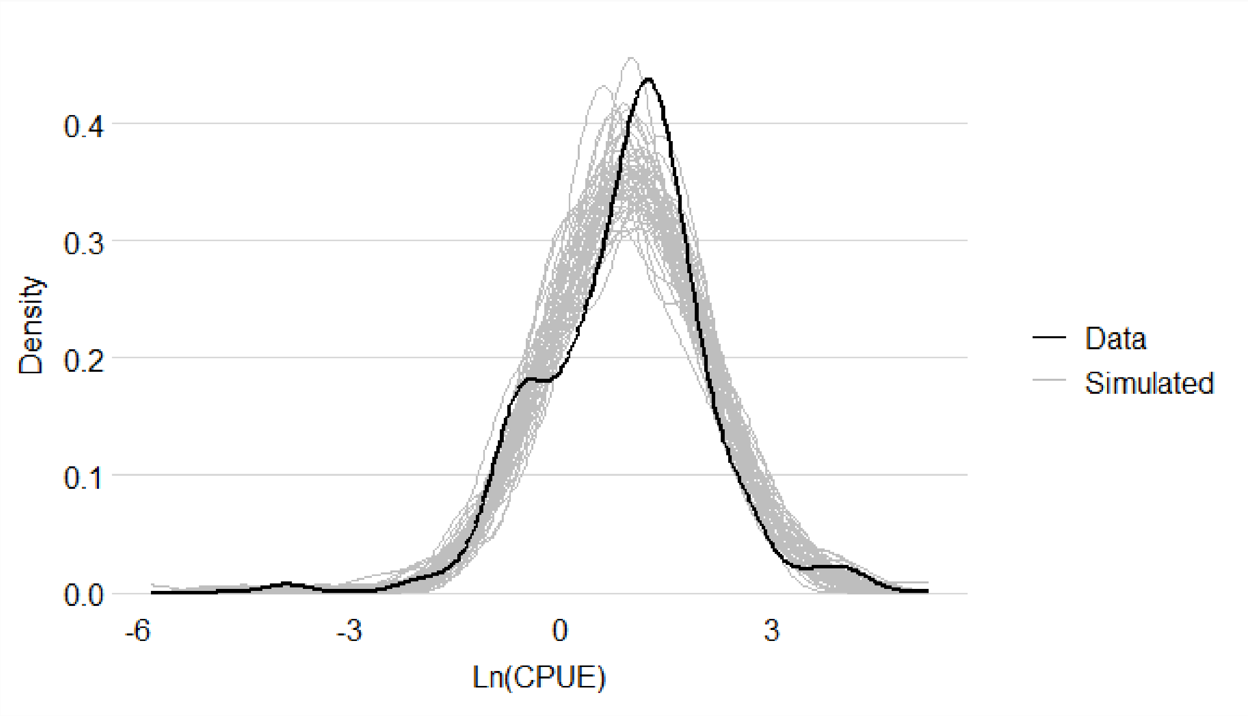


Figure 6. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *C. lugubris* CPUE standardization.

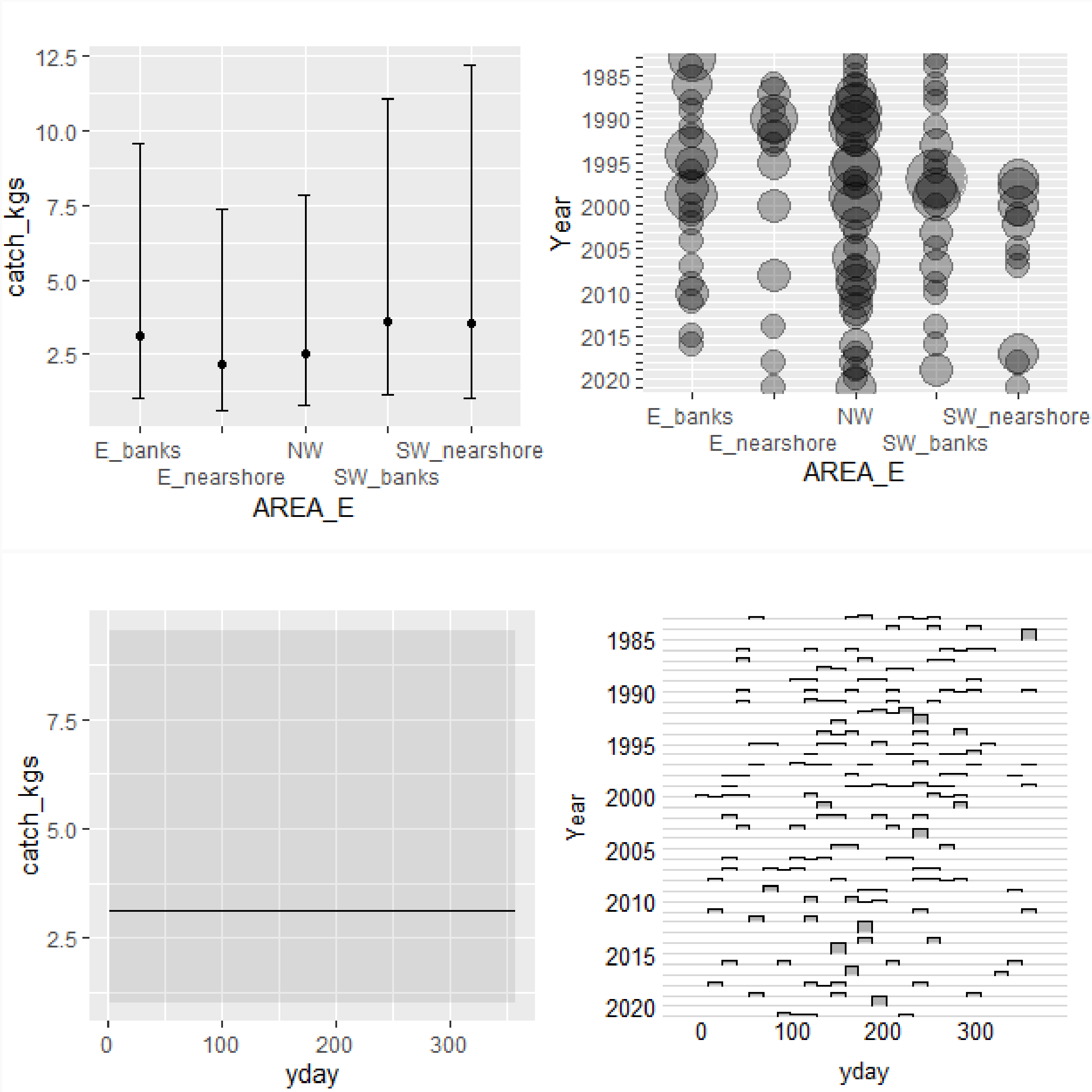


Figure 7. Partial effects of area and time of year on CPUE (kg per trip) in the *C. lugubris* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

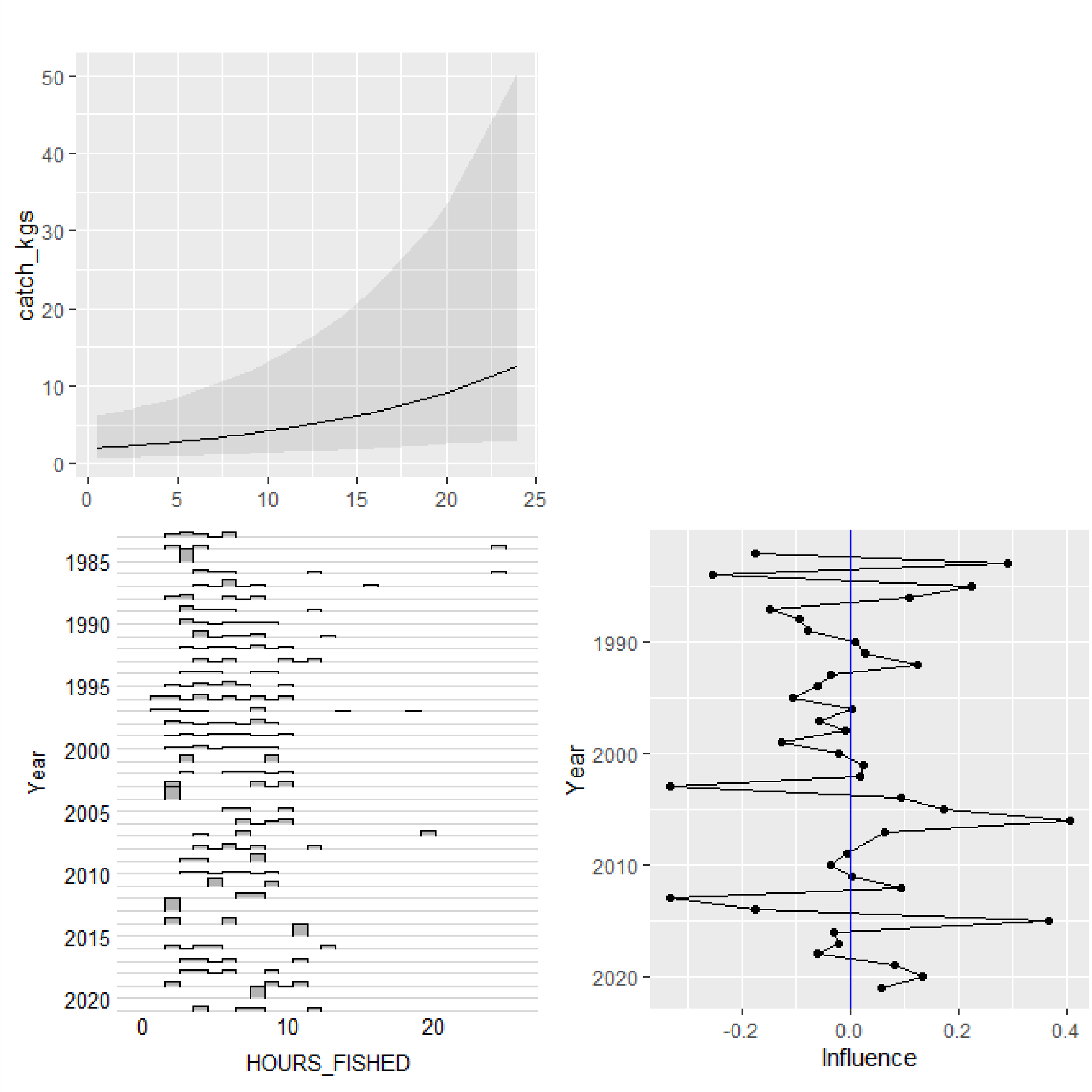


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *C. lugubris* CPUE standardization.

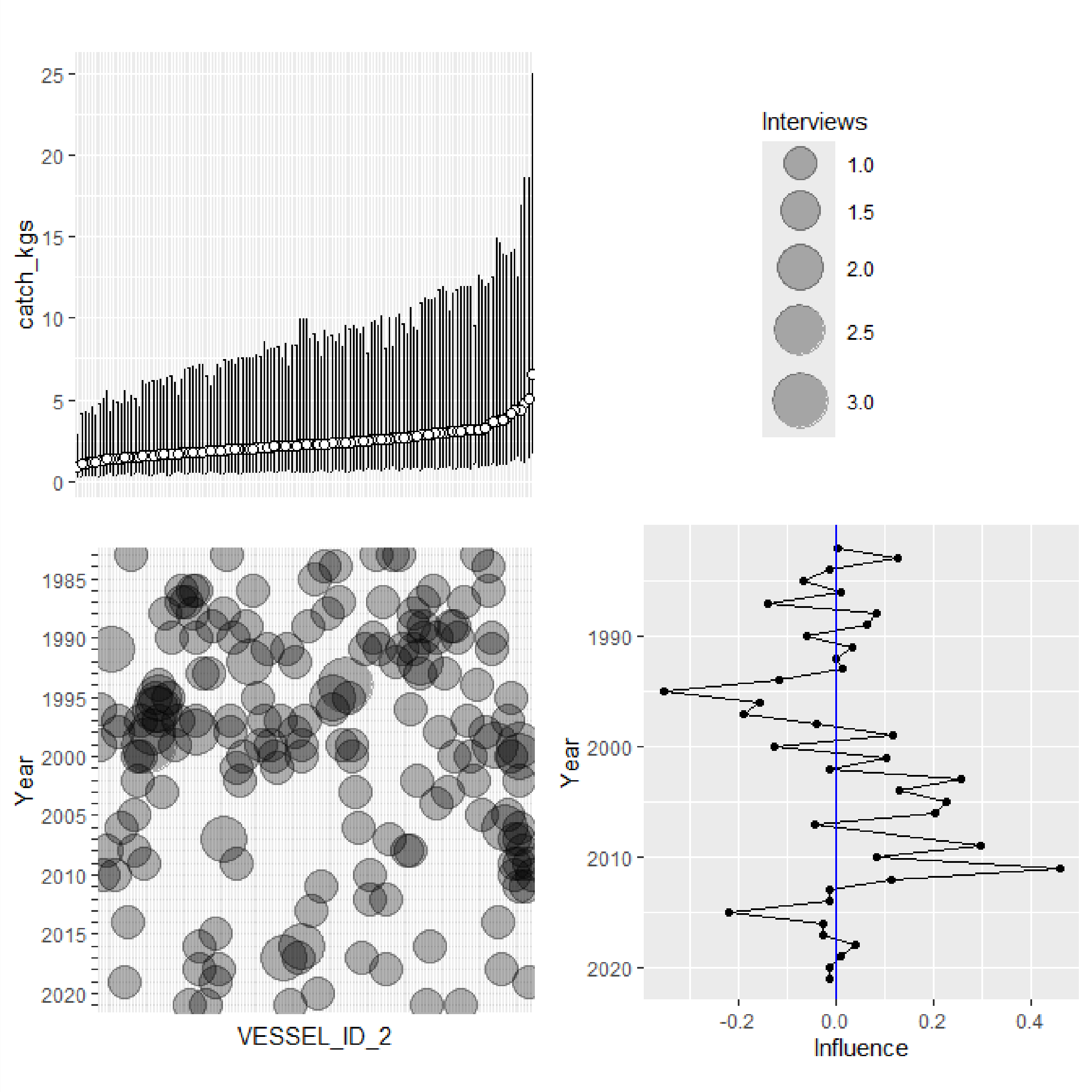


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *C. lugubris* CPUE standardization.

Standardized CPUE Index

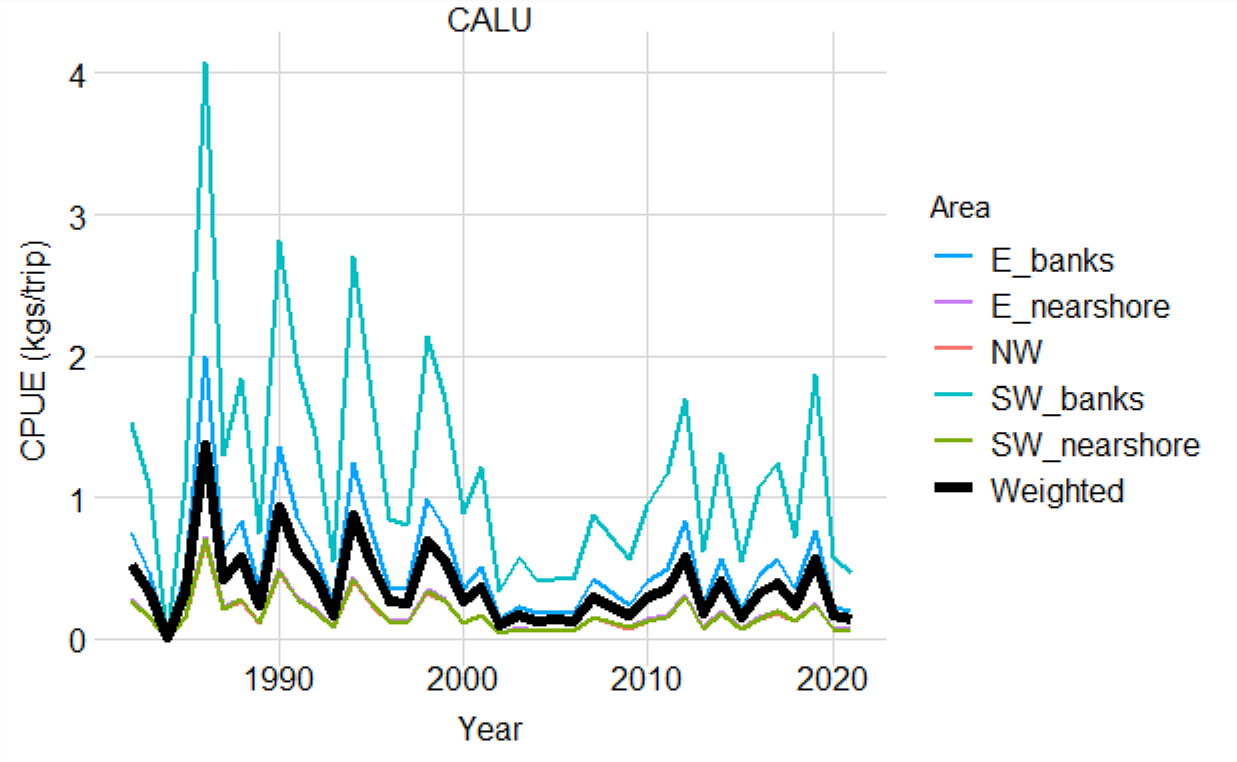


Figure 10. Standardized CPUE index (kg per trip) of *C. lugubris* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *C. lugubris*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	0.51	0.77	1996	0.26	0.37	2010	0.29	0.51
1983	0.33	0.71	1997	0.25	0.36	2011	0.35	0.76
1984	0.00	0.02	1998	0.69	0.91	2012	0.57	1.27
1985	0.33	0.57	1999	0.54	0.71	2013	0.18	0.67
1986	1.36	2.02	2000	0.26	0.82	2014	0.40	1.11
1987	0.43	0.67	2001	0.37	0.64	2015	0.16	1.05
1988	0.58	0.87	2002	0.10	0.24	2016	0.33	0.62
1989	0.23	0.35	2003	0.17	0.97	2017	0.40	0.73
1990	0.94	1.28	2004	0.12	0.26	2018	0.24	0.39
1991	0.61	1.00	2005	0.13	0.22	2019	0.56	1.26
1992	0.44	0.84	2006	0.13	0.24	2020	0.17	1.07
1993	0.17	0.32	2007	0.29	0.46	2021	0.14	0.26
1994	0.87	1.21	2008	--	--	2022	--	--
1995	0.54	0.83	2009	0.17	0.30	2023	--	--

Etelis coruscans

Presence/Absence Model

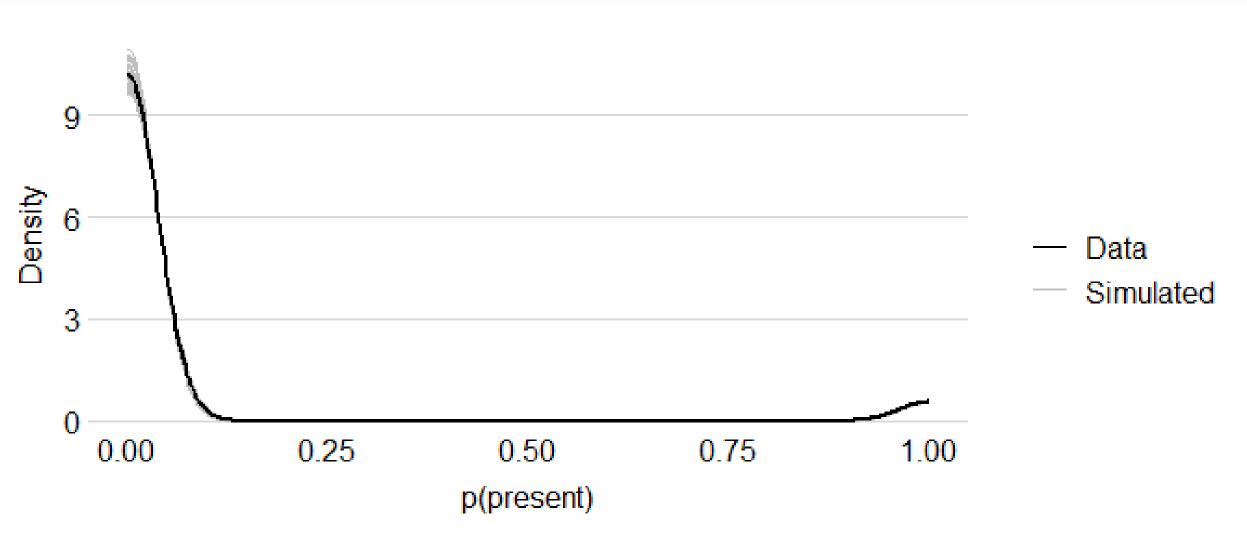


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *E. coruscans* CPUE standardization.

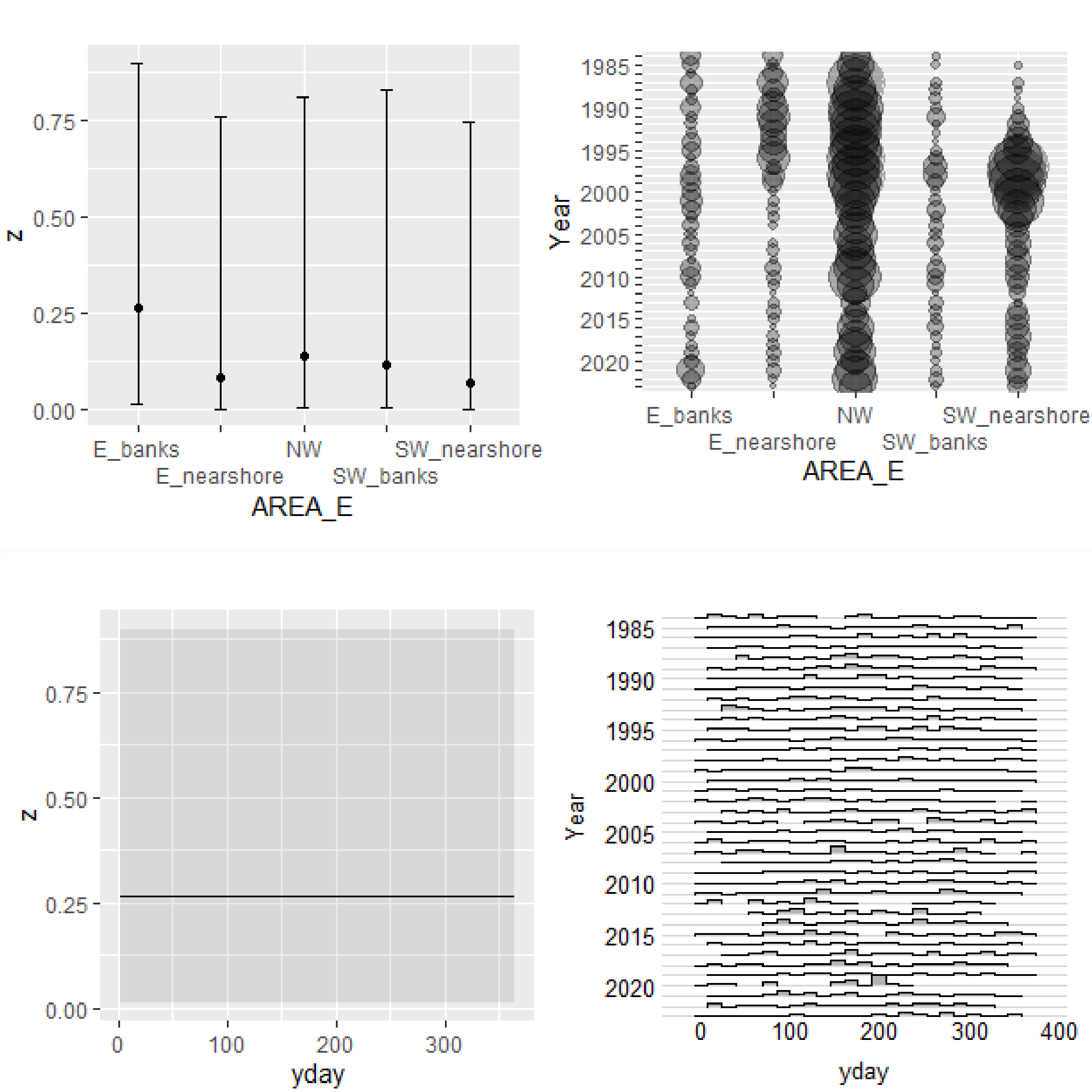


Figure 2. Partial effects of area and time of year on probability of presence in the *E. coruscans* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

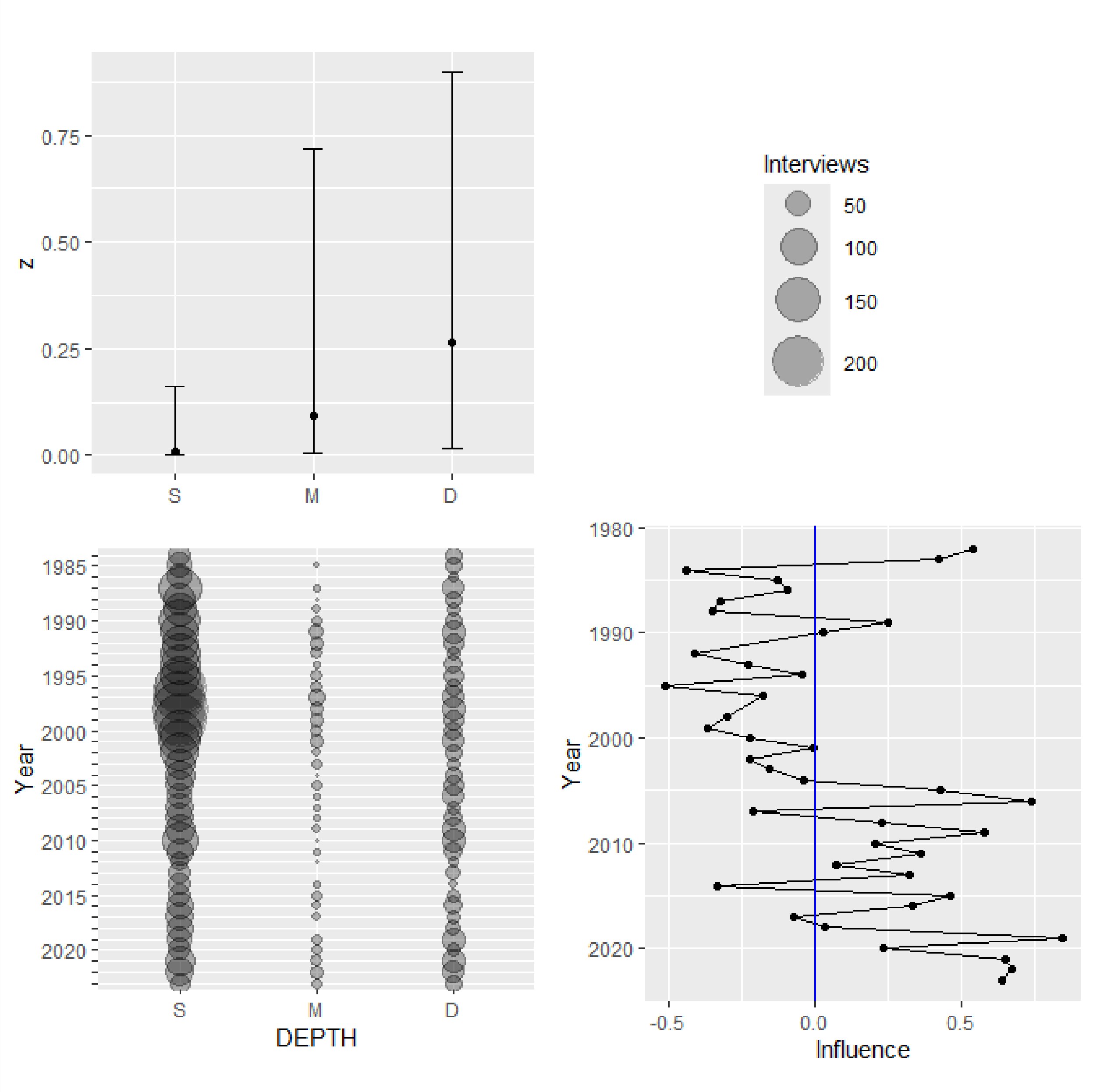


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *E. coruscans* CPUE standardization.

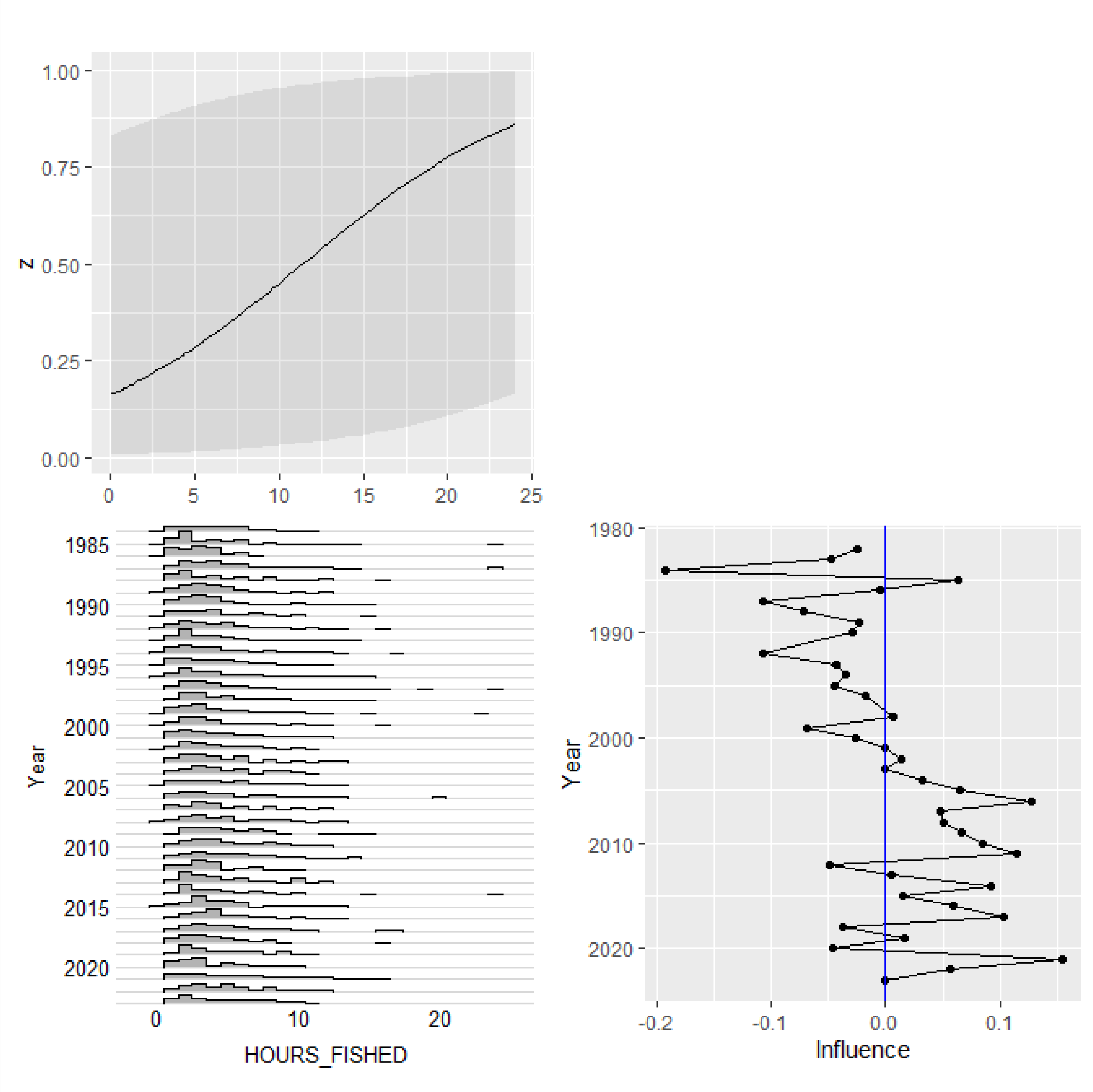


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on probability of presence in the *E. coruscans* CPUE standardization.

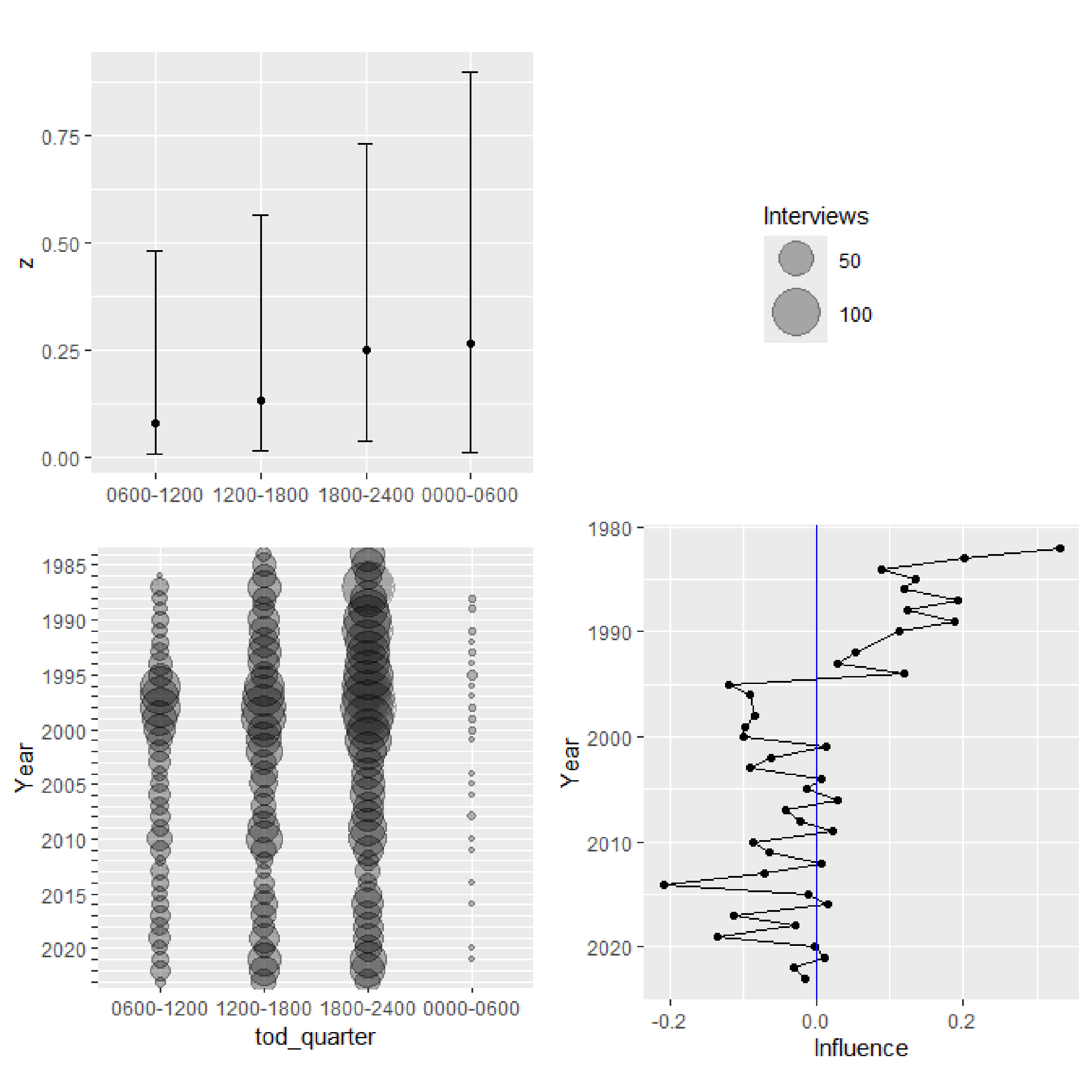


Figure 5. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of time of day (quarter) on probability of presence in the *E. coruscans* CPUE standardization.

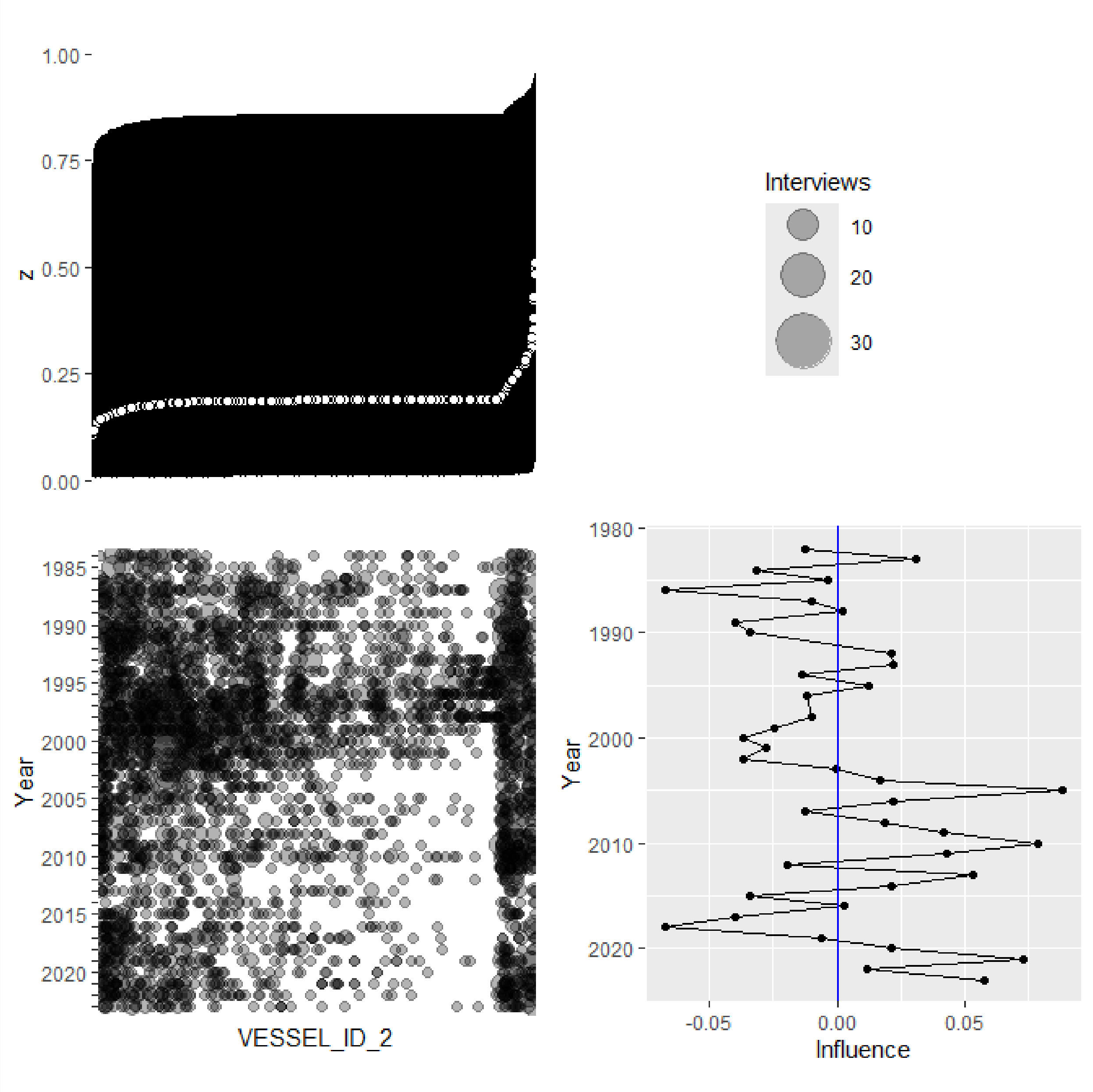


Figure 6. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *E. coruscans* CPUE standardization.

Positive Process Model

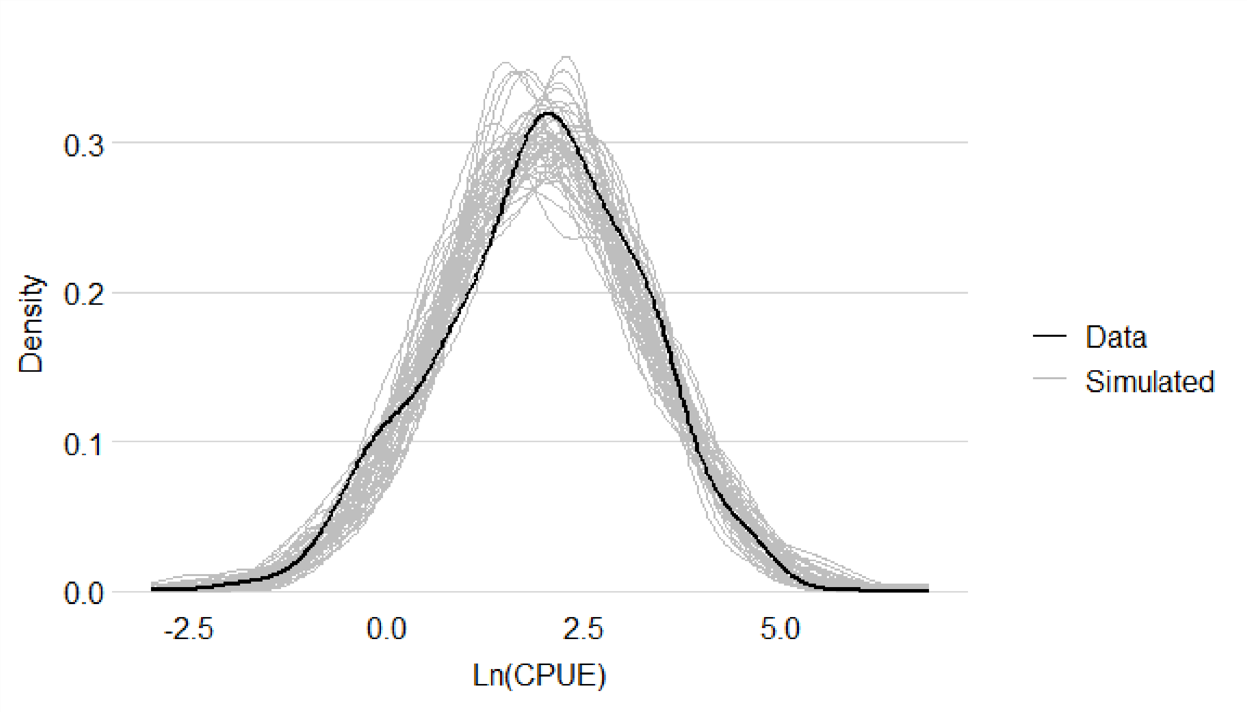


Figure 7. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *E. coruscans* CPUE standardization.

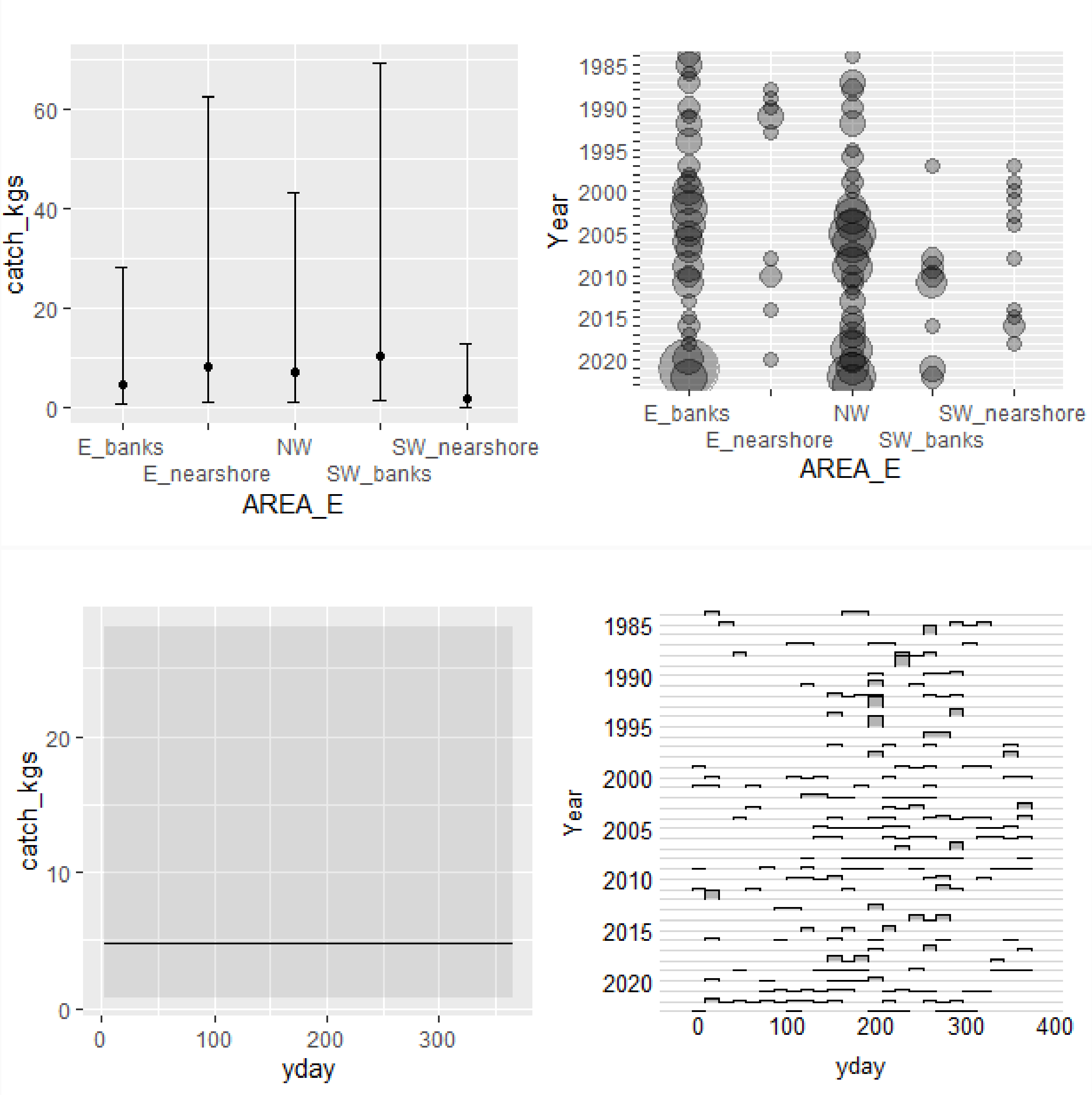


Figure 8. Partial effects of area and time of year on CPUE (kg per trip) in the *E. coruscans* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

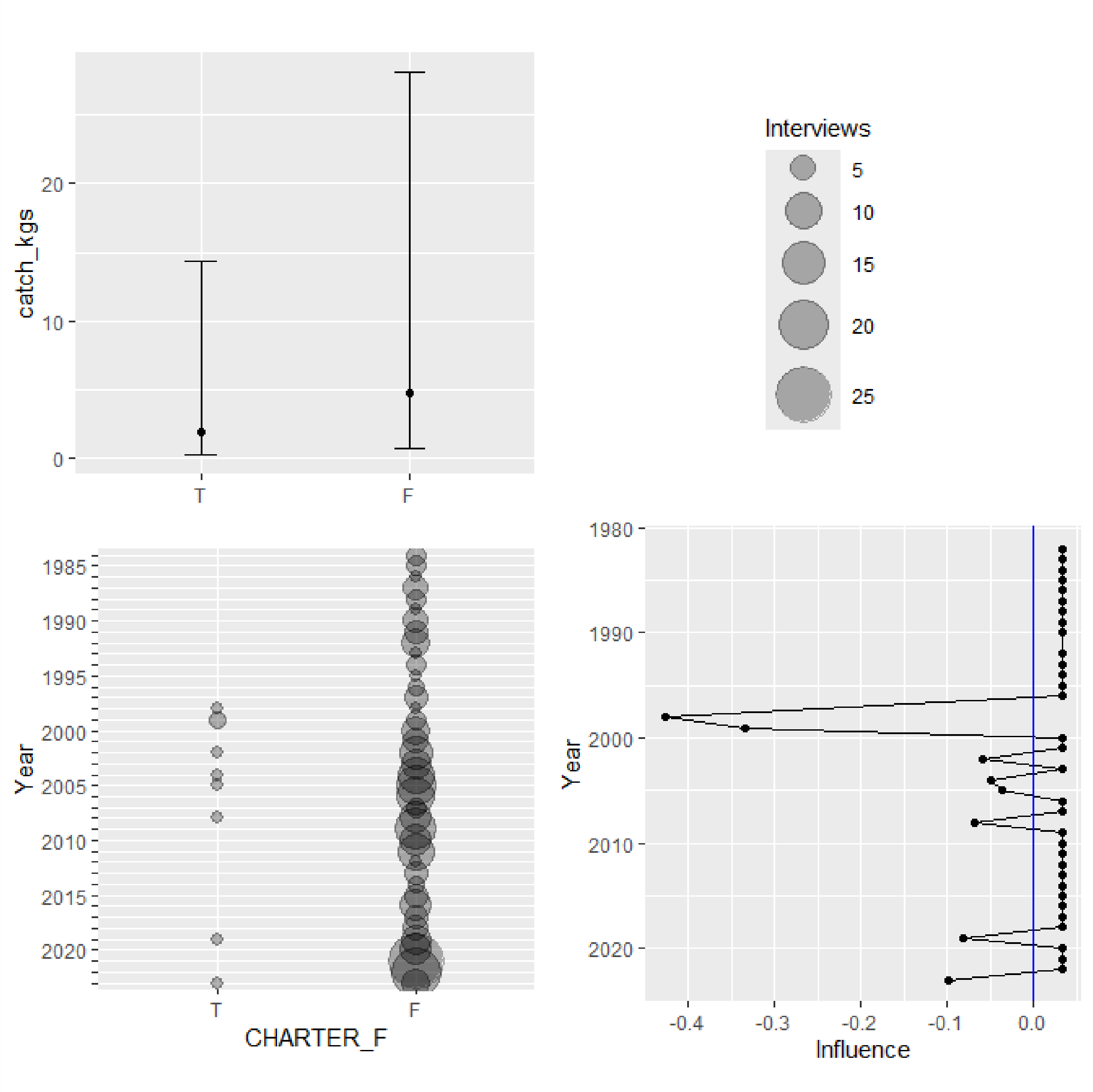


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of charter status on CPUE (kg per trip) in the *E. coruscans* CPUE standardization.

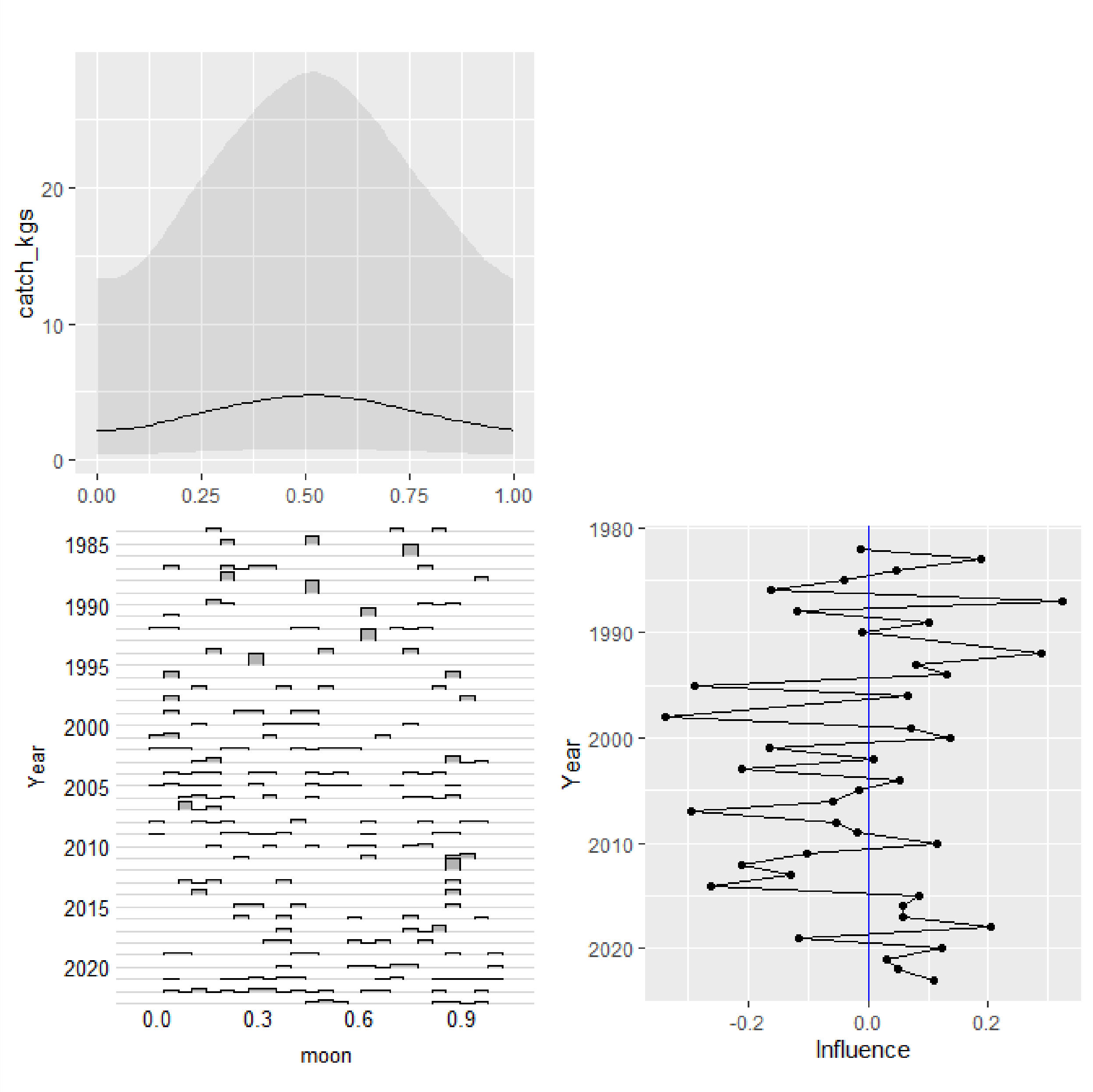


Figure 10. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of moon phase on CPUE (kg per trip) in the *E. coruscans* CPUE standardization.

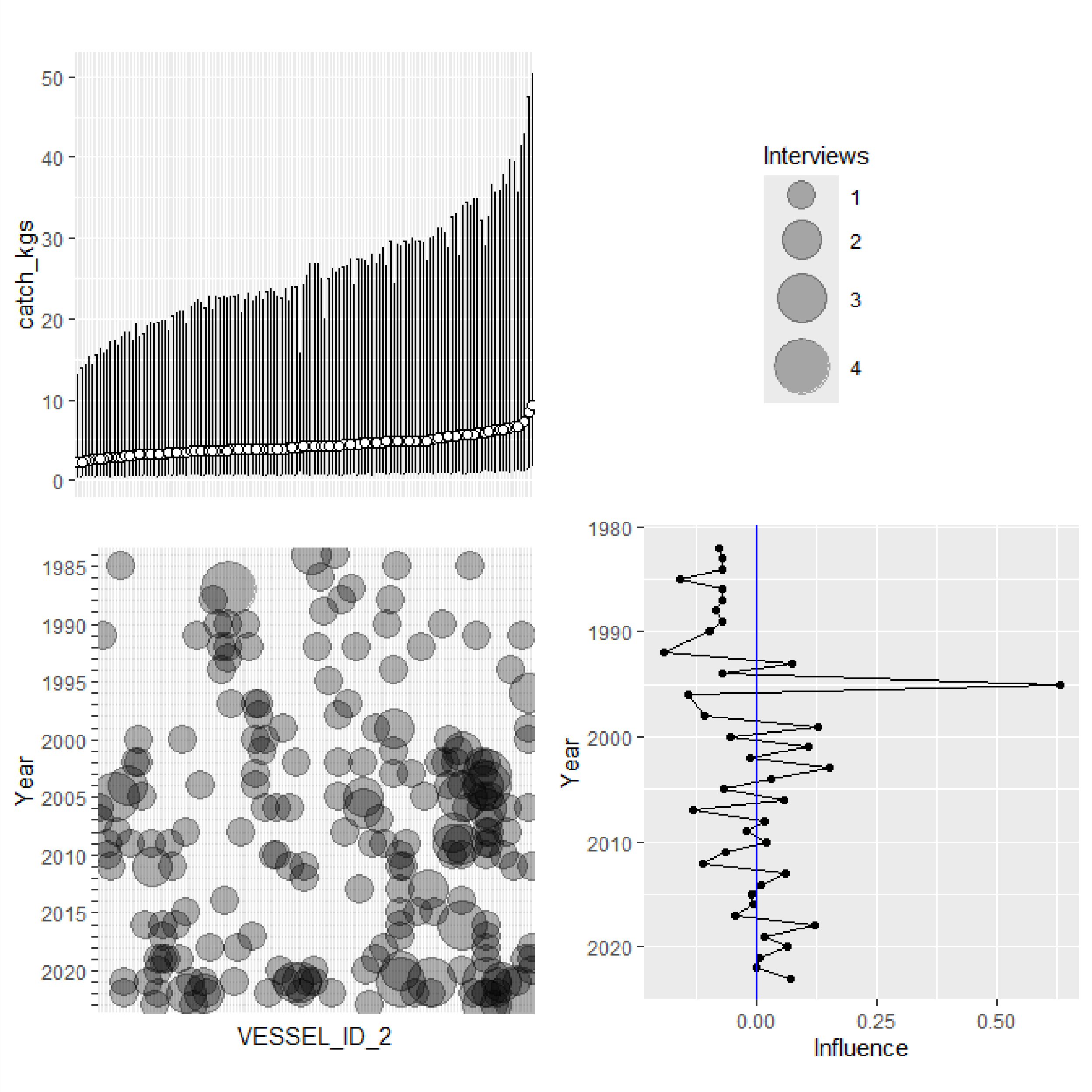


Figure 13. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *E. coruscans* CPUE standardization.

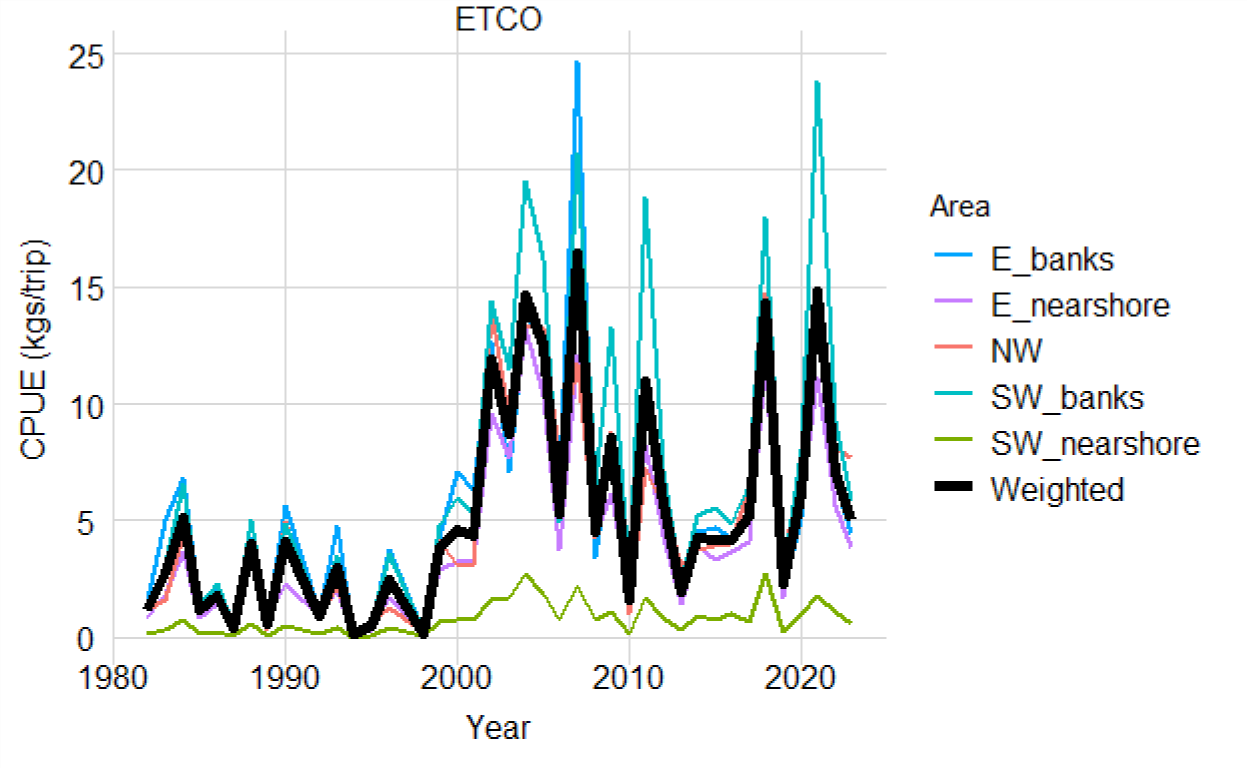


Figure 14. Standardized CPUE index (kg per trip) of *E. coruscans* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *E. coruscans*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	1.17	3.99	1996	2.46	5.71	2010	1.59	2.54
1983	2.74	9.17	1997	--	--	2011	10.92	13.88
1984	5.10	28.20	1998	0.19	1.02	2012	5.68	35.61
1985	1.19	3.70	1999	3.85	8.68	2013	1.98	4.77
1986	1.81	4.40	2000	4.65	8.16	2014	4.29	10.89
1987	0.41	3.42	2001	4.30	10.80	2015	4.21	7.36
1988	3.98	7.49	2002	11.93	16.13	2016	4.17	6.30
1989	0.59	1.45	2003	8.68	11.97	2017	5.21	10.63
1990	4.10	7.47	2004	14.67	17.99	2018	14.30	23.31
1991	--	--	2005	12.50	17.51	2019	2.30	4.19
1992	0.93	7.33	2006	5.29	8.26	2020	6.13	8.01
1993	2.94	11.42	2007	16.42	40.34	2021	14.79	16.78
1994	0.11	0.95	2008	4.51	5.92	2022	7.09	8.18
1995	0.50	2.61	2009	8.58	11.51	2023	5.05	8.36

Lethrinus rubrioperculatus

Presence/Absence Model

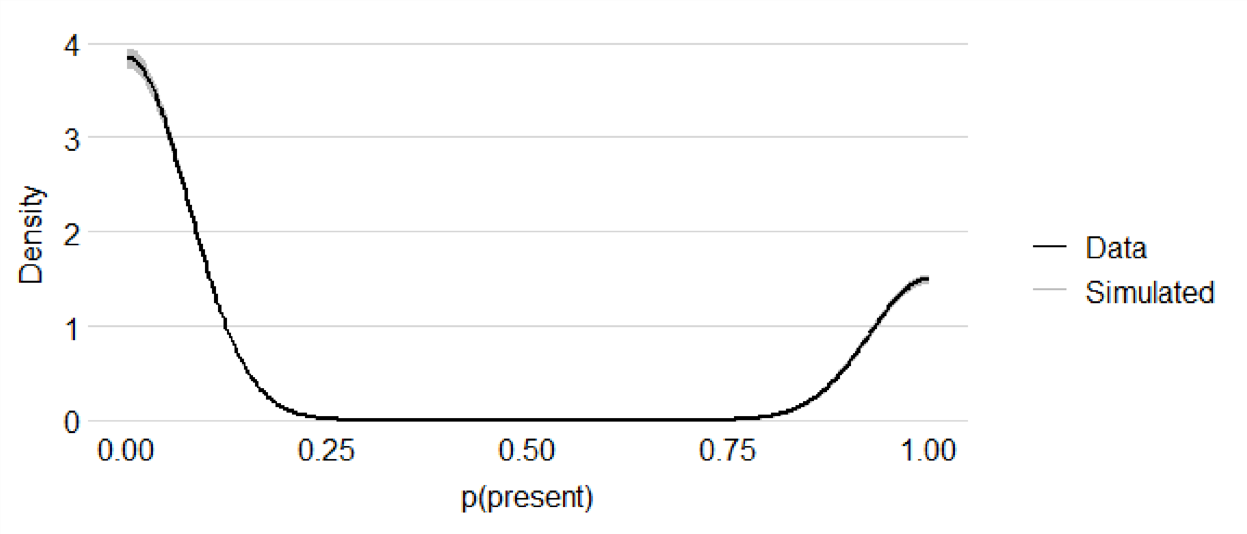


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *L. rubrioperculatus* CPUE standardization.

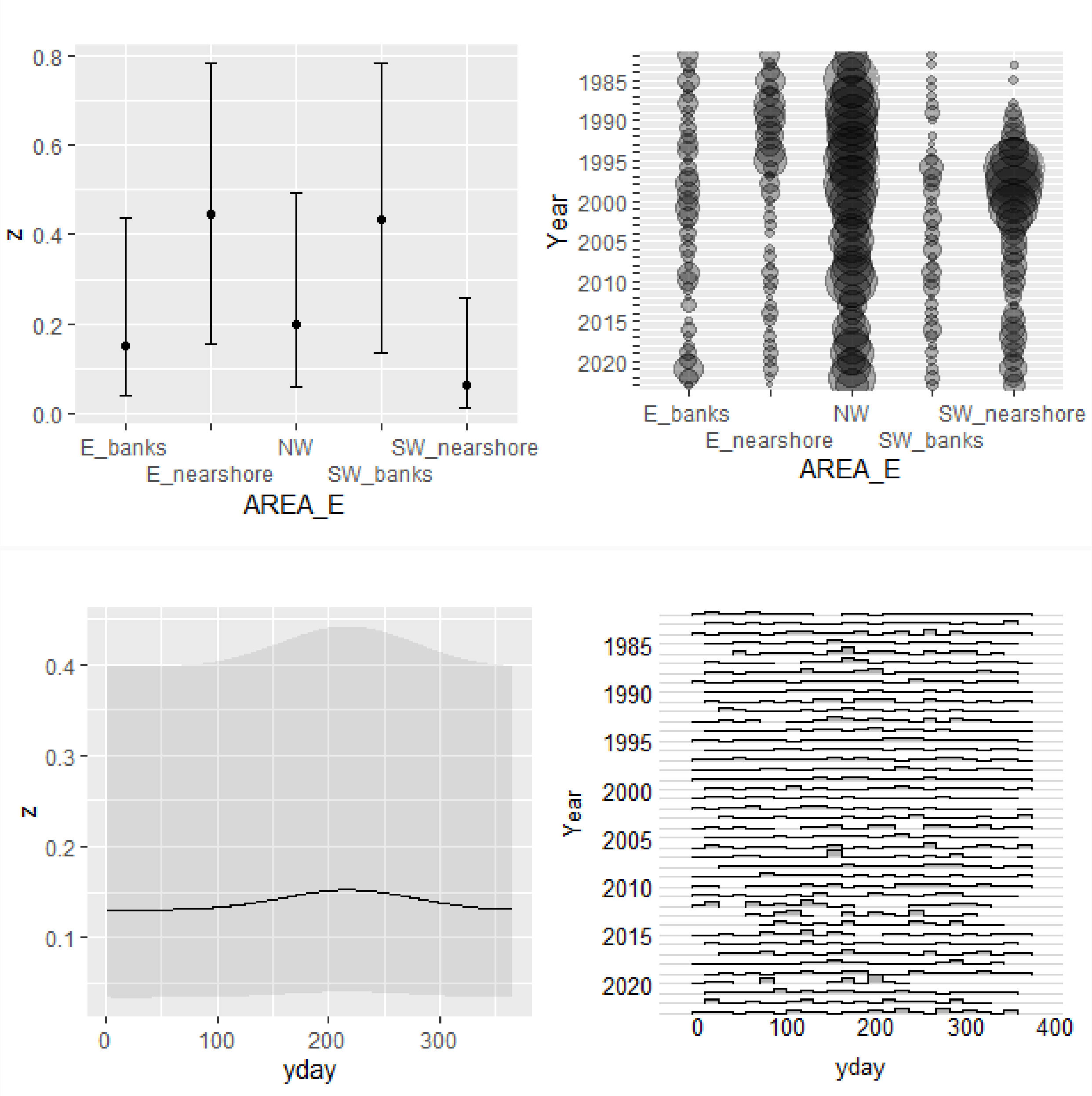


Figure 2. Partial effects of area and time of year on probability of presence in the *L. rubrioperculatus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

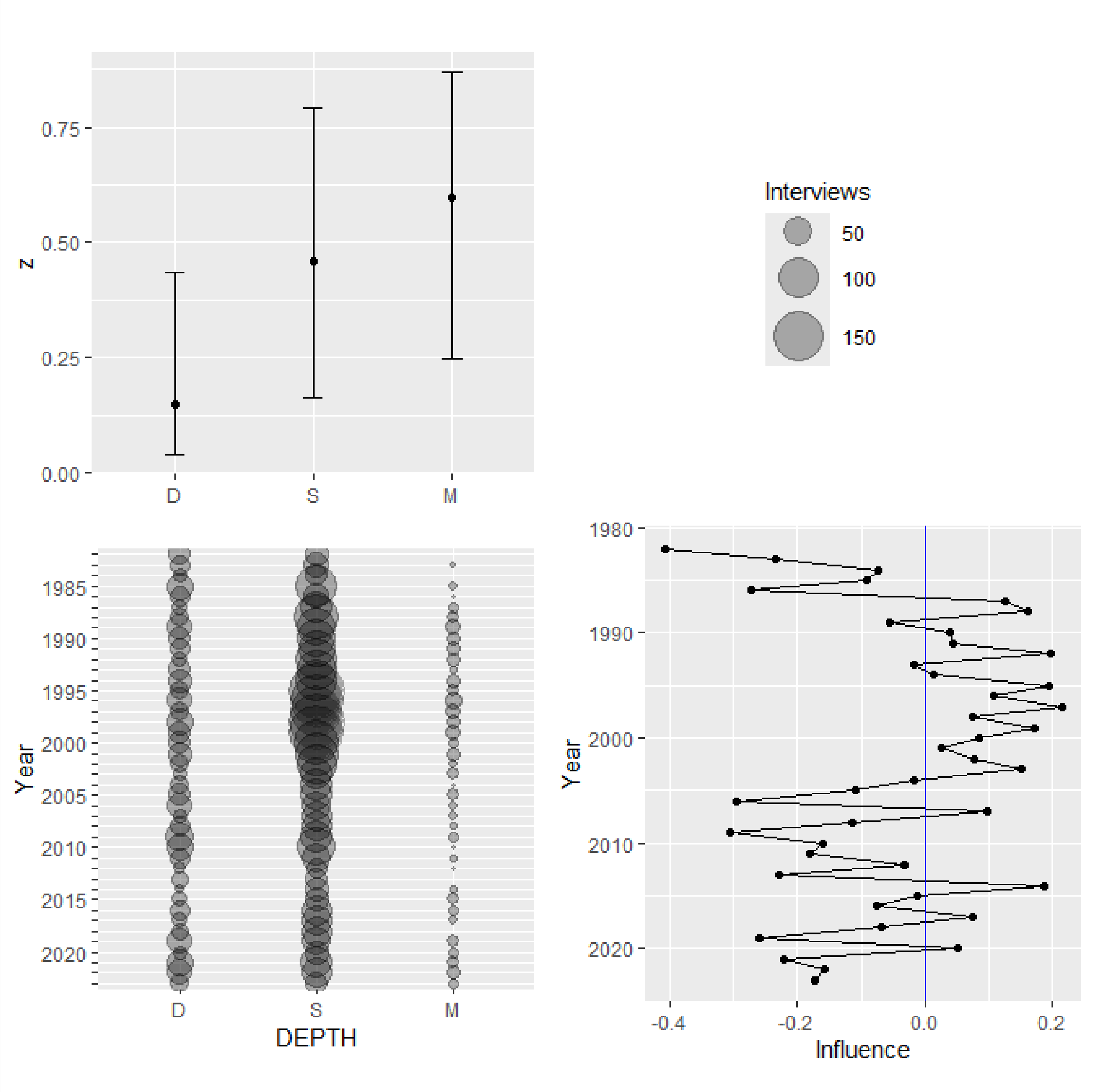


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *L. rubrioperculatus* CPUE standardization.

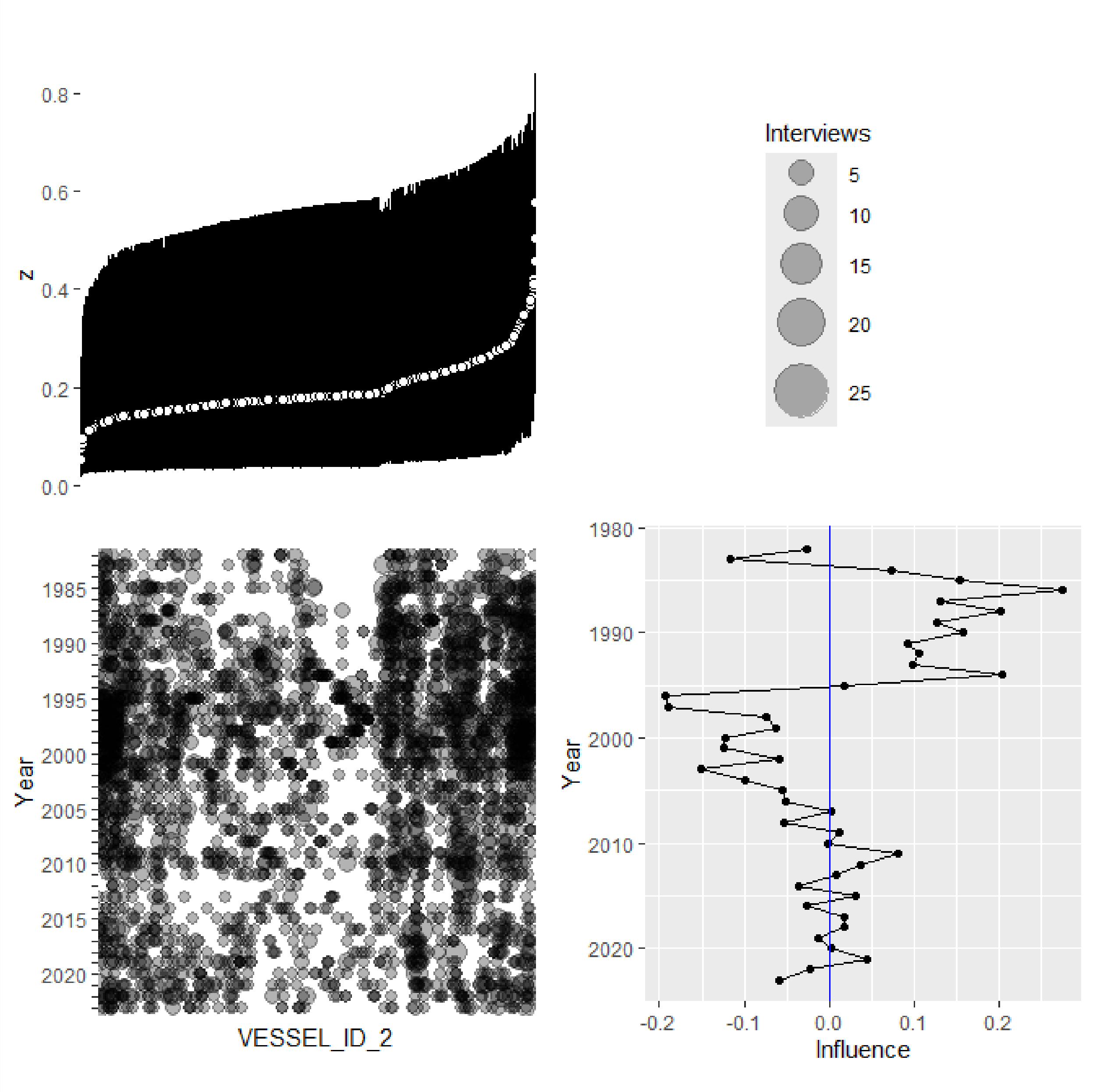


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *L. rubrioperculatus* CPUE standardization.

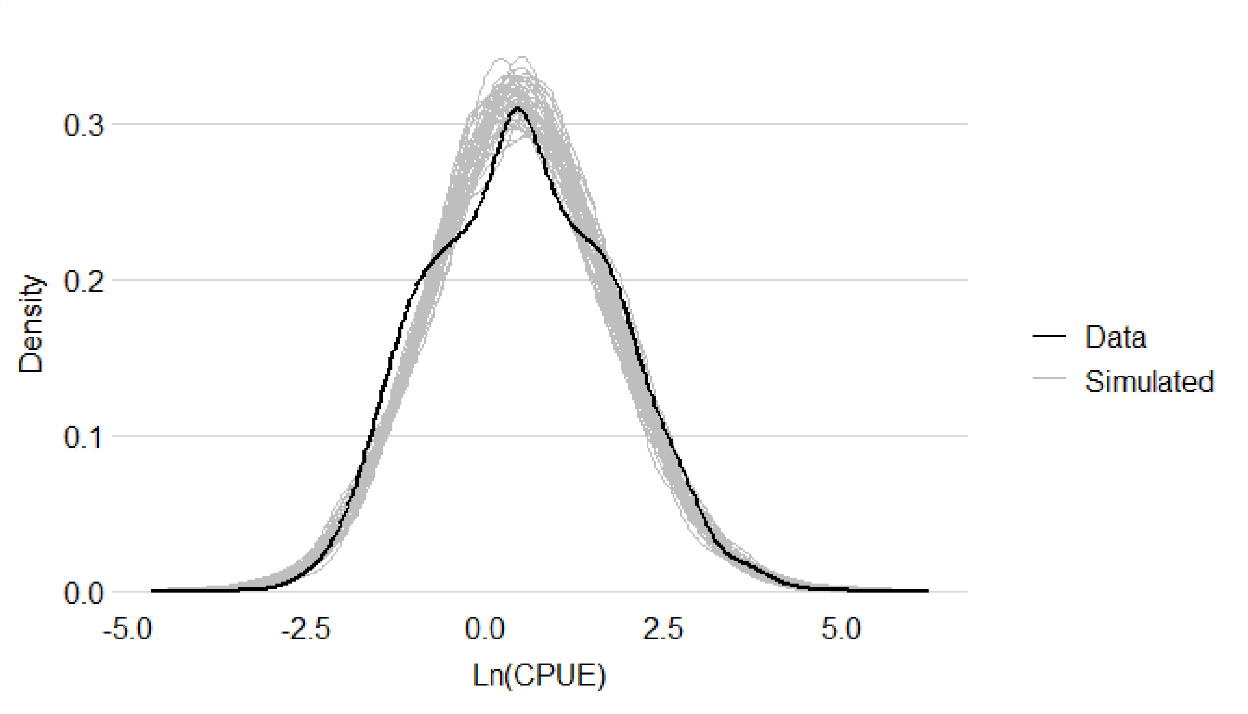


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *L. rubrioperculatus* CPUE standardization.

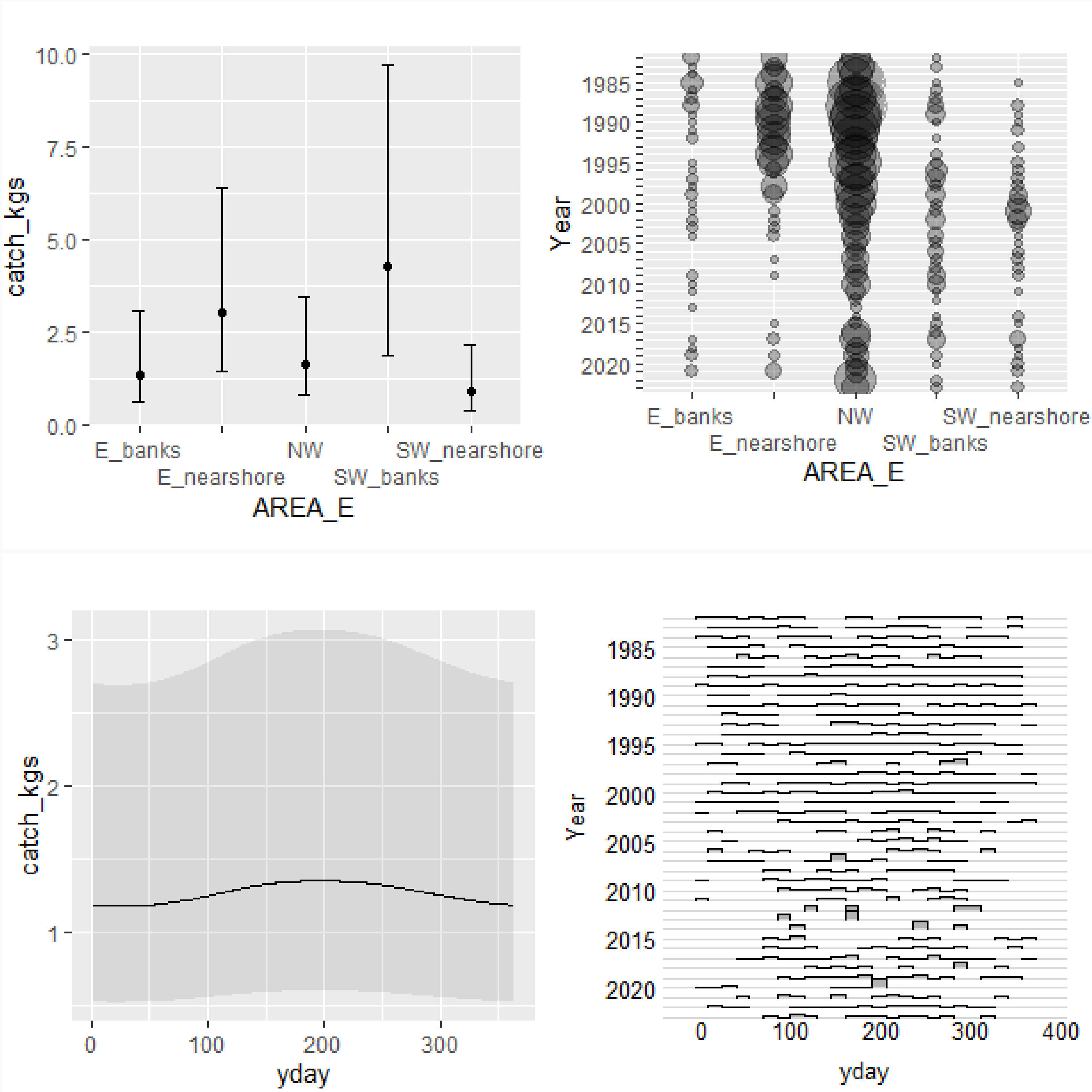


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *L. rubrioperculatus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

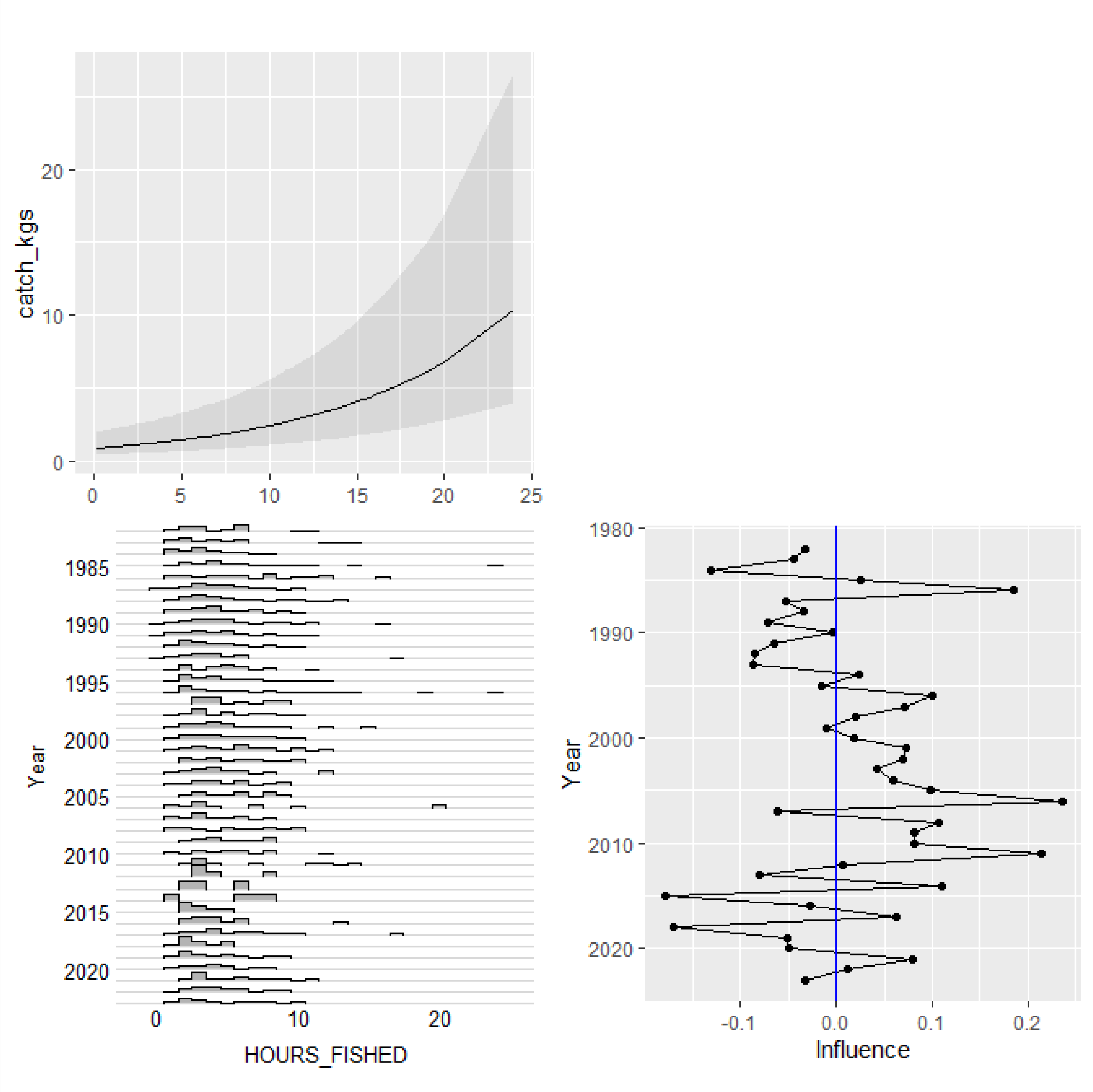


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *L. rubrioperculatus* CPUE standardization.

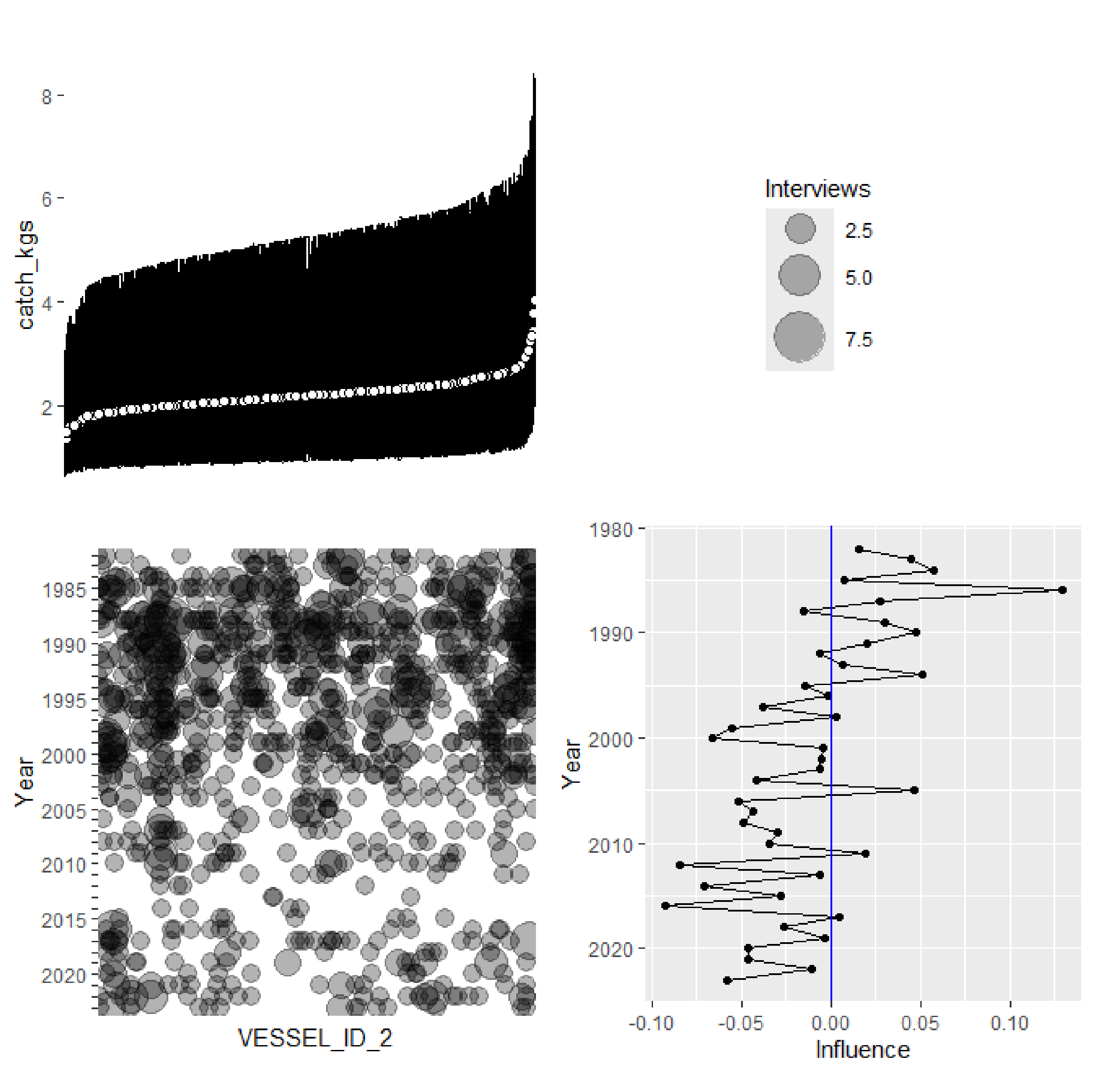


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *L. rubrioperculatus* CPUE standardization.

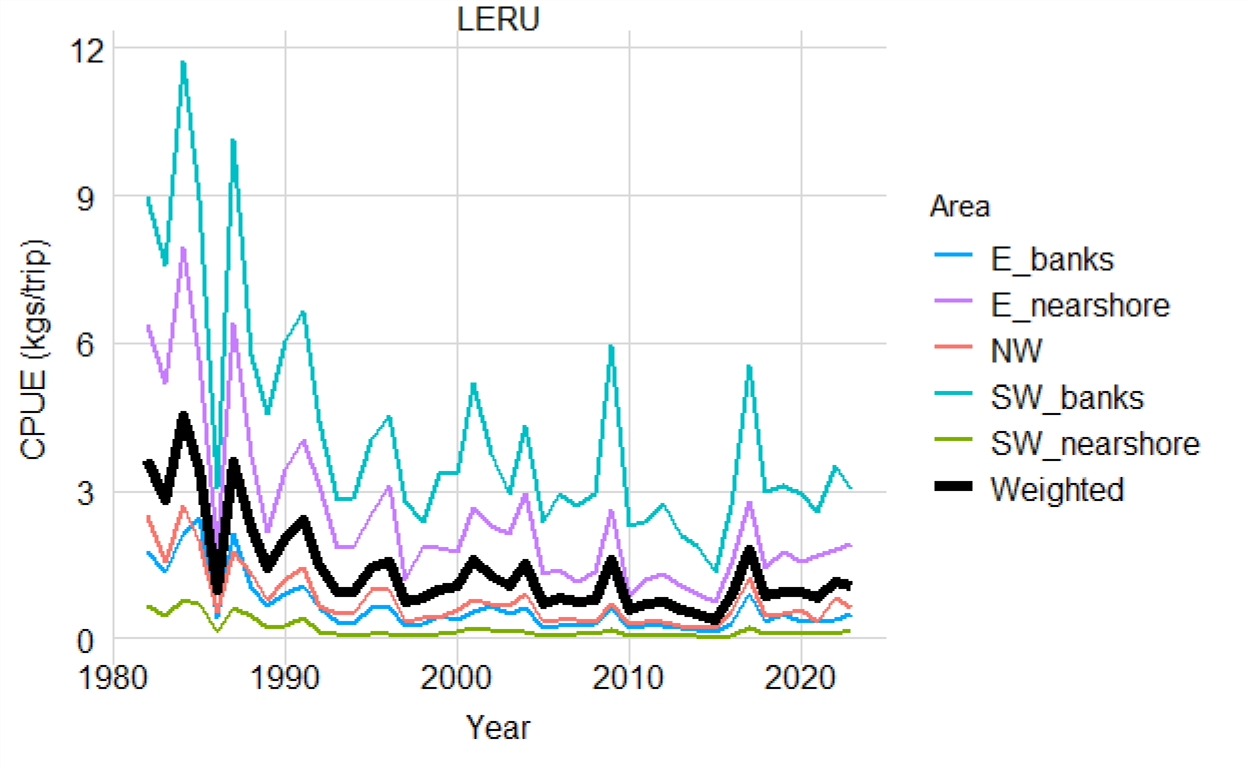


Figure 9. Standardized CPUE index (kg per trip) of *L. rubrioperculatus* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *L. rubrioperculatus*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	3.64	2.05	1996	1.55	0.99	2010	0.59	0.47
1983	2.83	1.66	1997	0.73	0.54	2011	0.69	0.72
1984	4.53	2.59	1998	0.85	0.55	2012	0.75	0.95
1985	3.42	1.78	1999	0.97	0.61	2013	0.59	1.08
1986	1.01	0.63	2000	1.07	0.71	2014	0.52	0.77
1987	3.60	1.95	2001	1.61	0.99	2015	0.39	0.42
1988	2.24	1.12	2002	1.28	0.80	2016	0.86	0.68
1989	1.42	0.77	2003	1.09	0.80	2017	1.80	1.04
1990	2.04	1.13	2004	1.51	1.00	2018	0.86	0.84
1991	2.42	1.29	2005	0.70	0.62	2019	0.96	0.72
1992	1.48	0.86	2006	0.81	0.69	2020	0.95	0.80
1993	0.96	0.61	2007	0.76	0.56	2021	0.84	0.65
1994	0.94	0.57	2008	0.80	0.60	2022	1.15	0.81
1995	1.42	0.90	2009	1.59	1.22	2023	1.08	0.73

Lutjanus kasmira

Presence/Absence Model

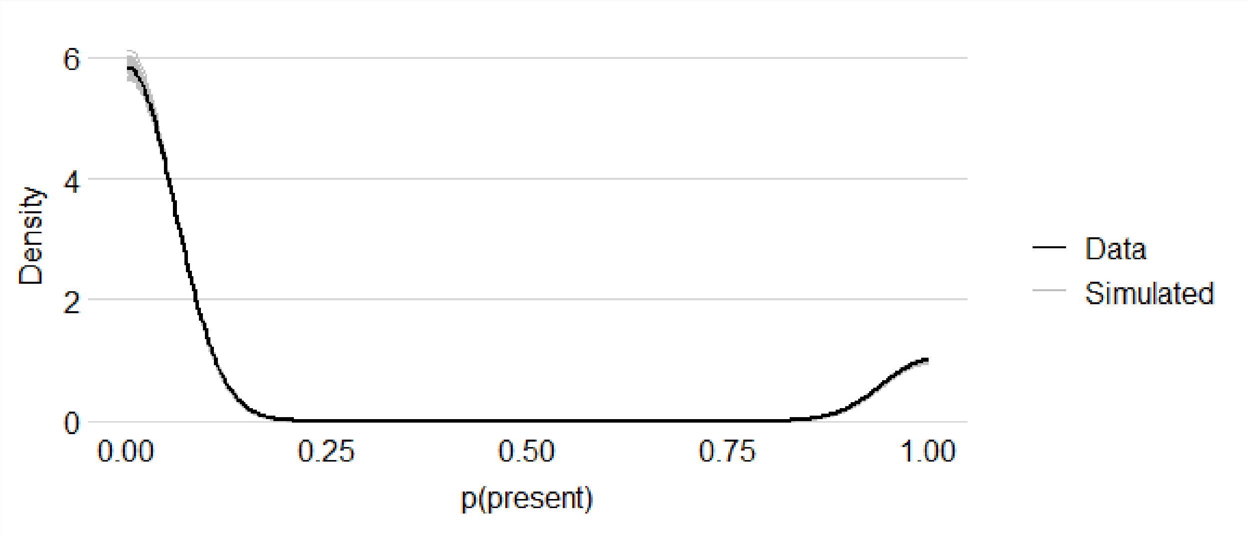


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *L. kasmira* CPUE standardization.

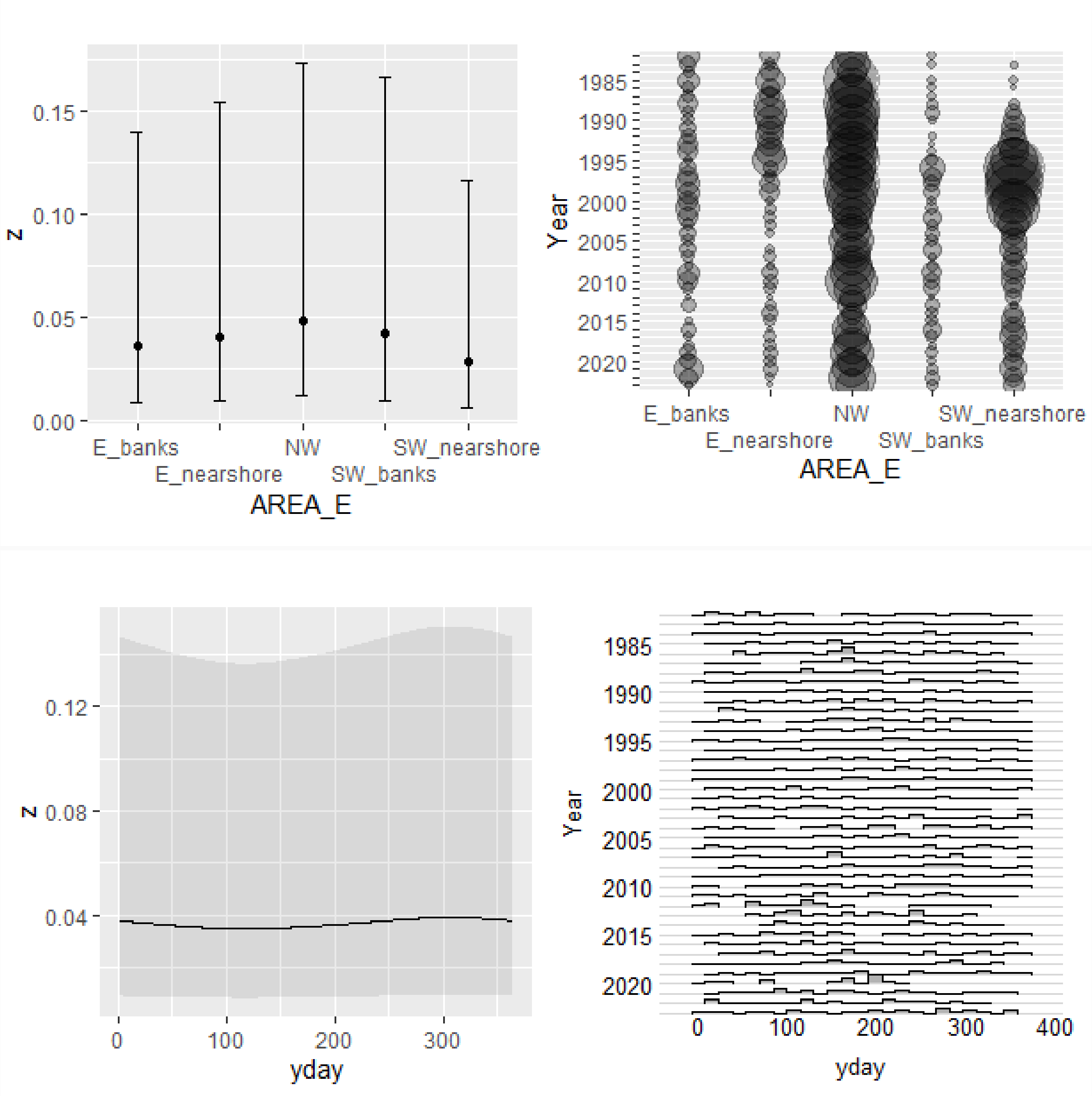


Figure 2. Partial effects of area and time of year on probability of presence in the *L. kasmira* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

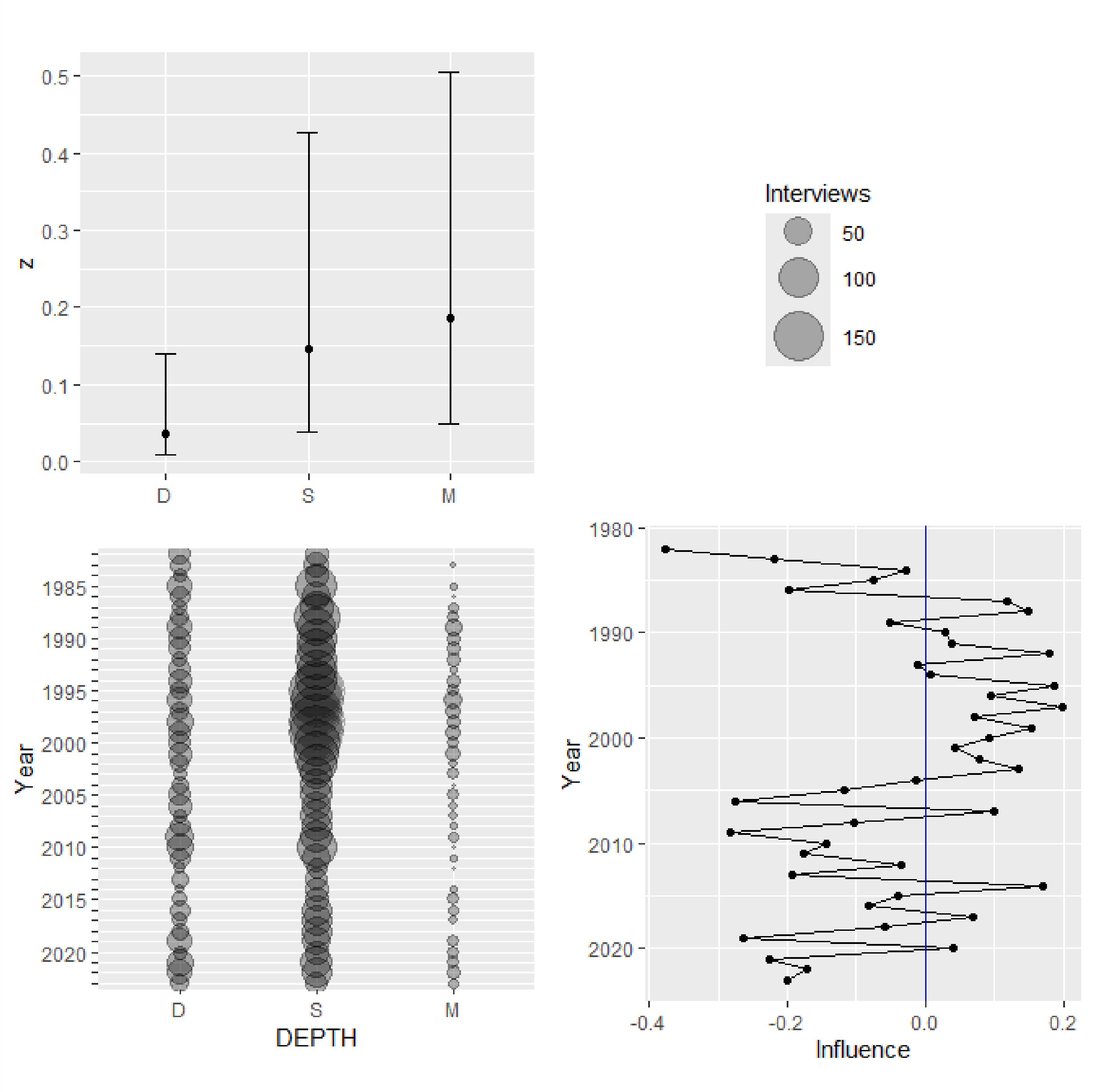


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *L. kasmira* CPUE standardization.

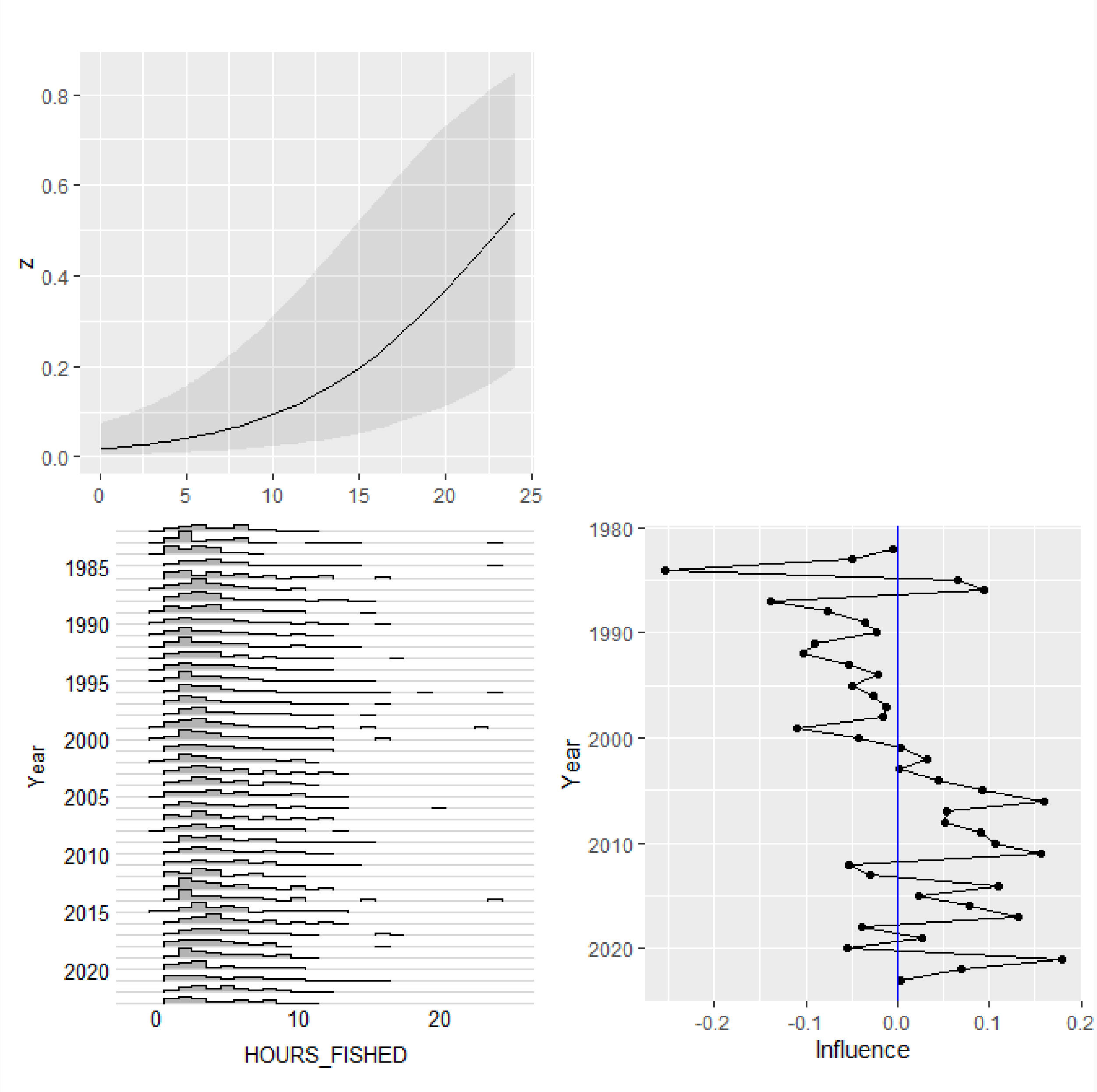


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on probability of presence in the *L. kasmira* CPUE standardization.

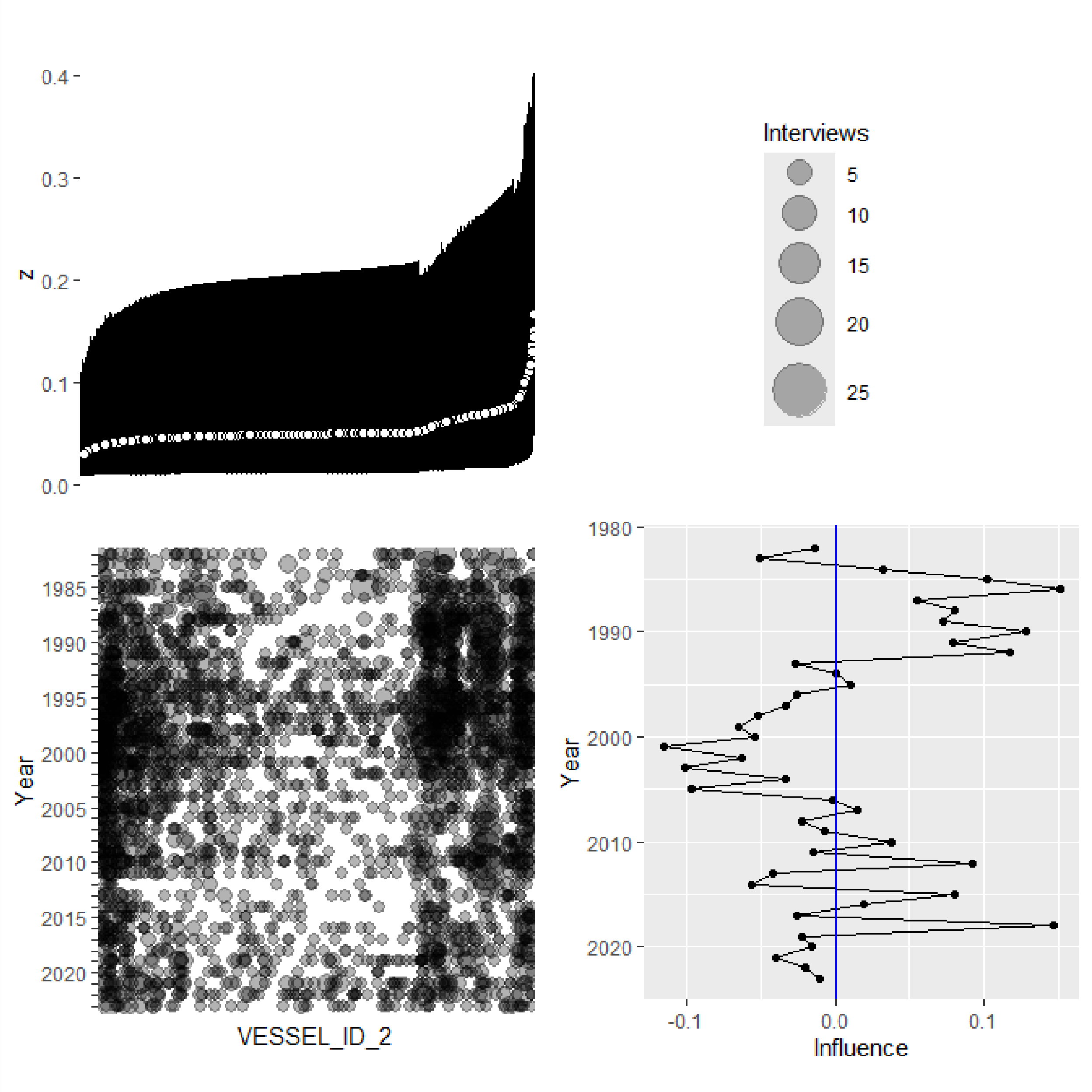


Figure 5. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *L. kasmira* CPUE standardization.

Positive Process Model

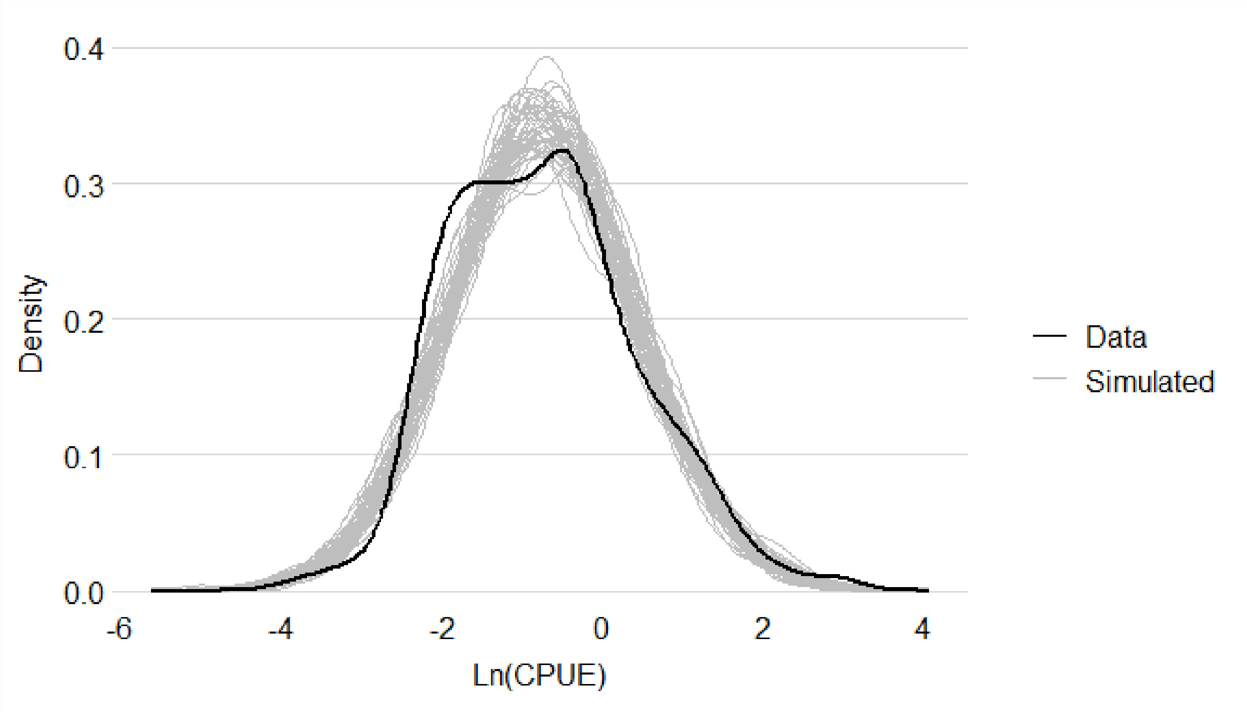


Figure 6. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *L. kasmira* CPUE standardization.

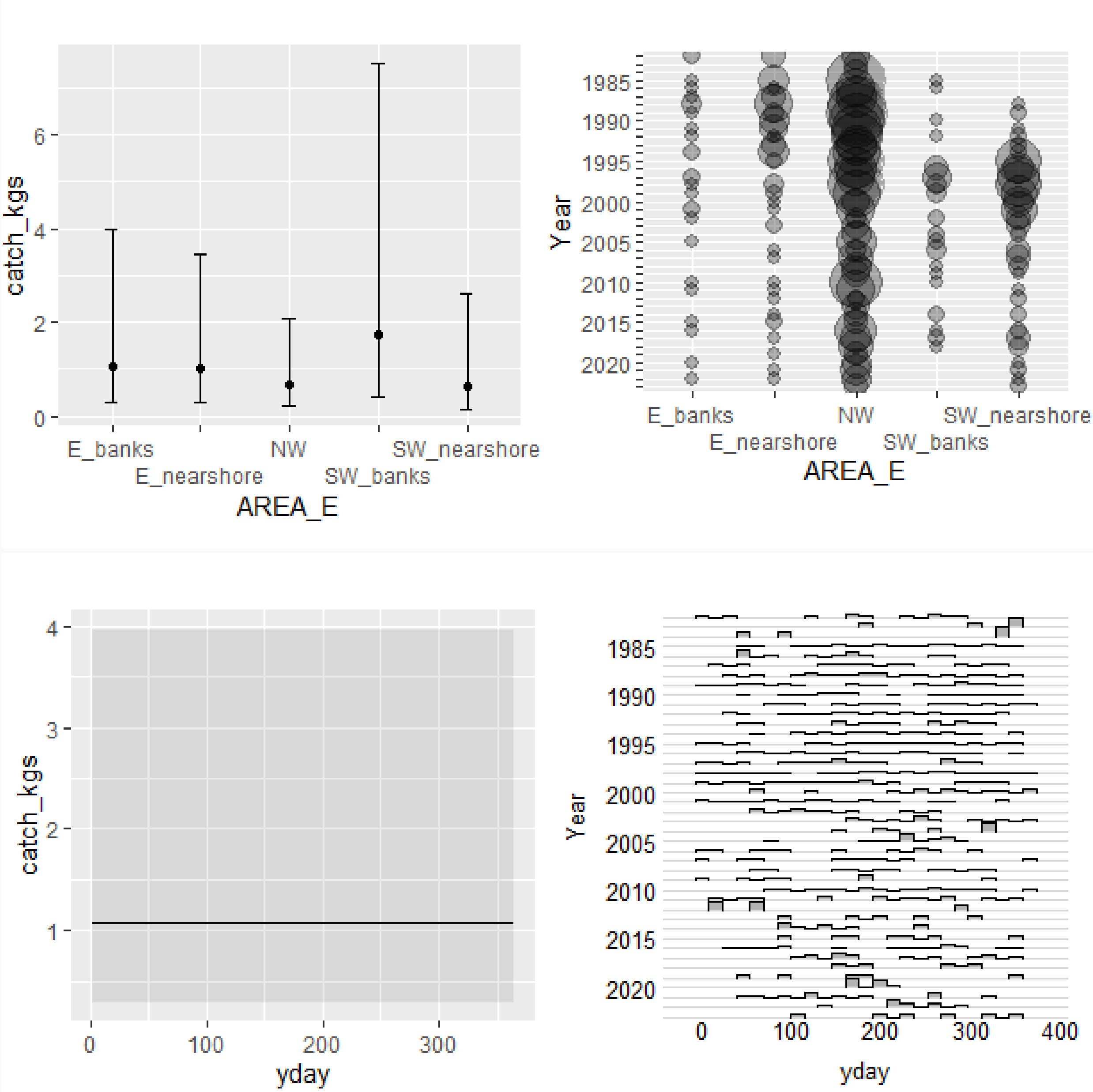


Figure 7. Partial effects of area and time of year on CPUE (kg per trip) in the *L. kasmira* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

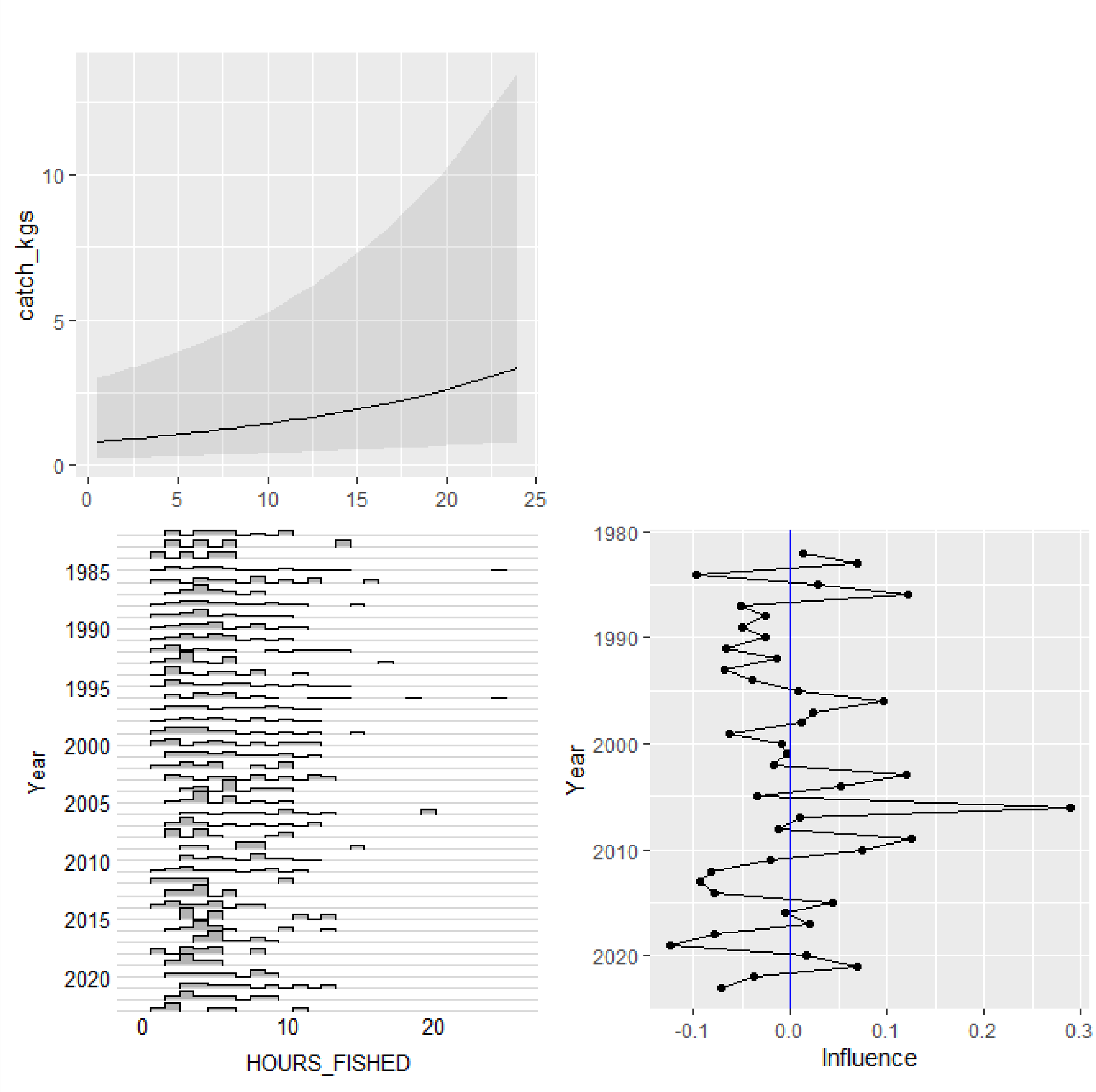


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on CPUE (kg per trip) in the *L. kasmira* CPUE standardization.

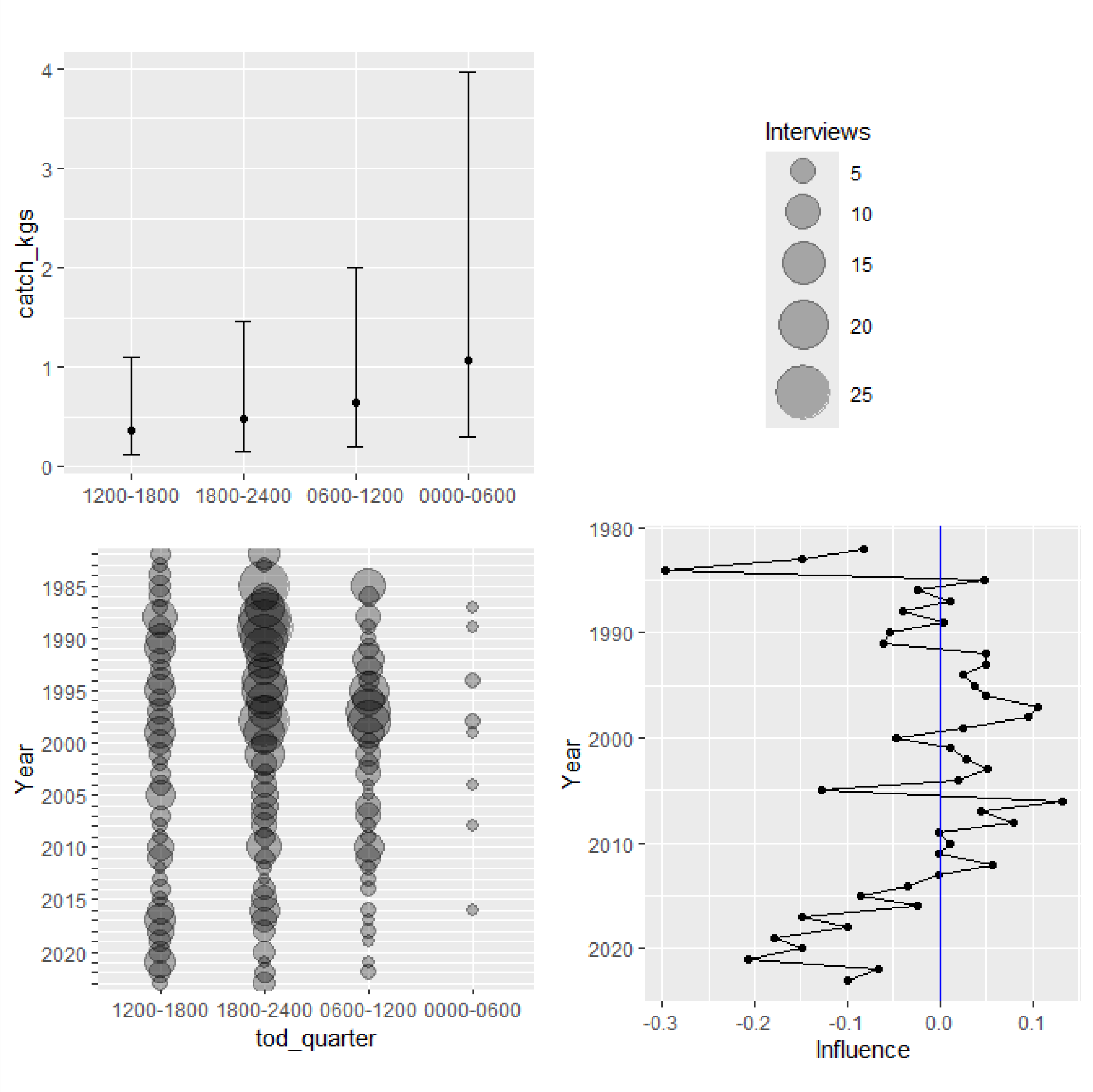
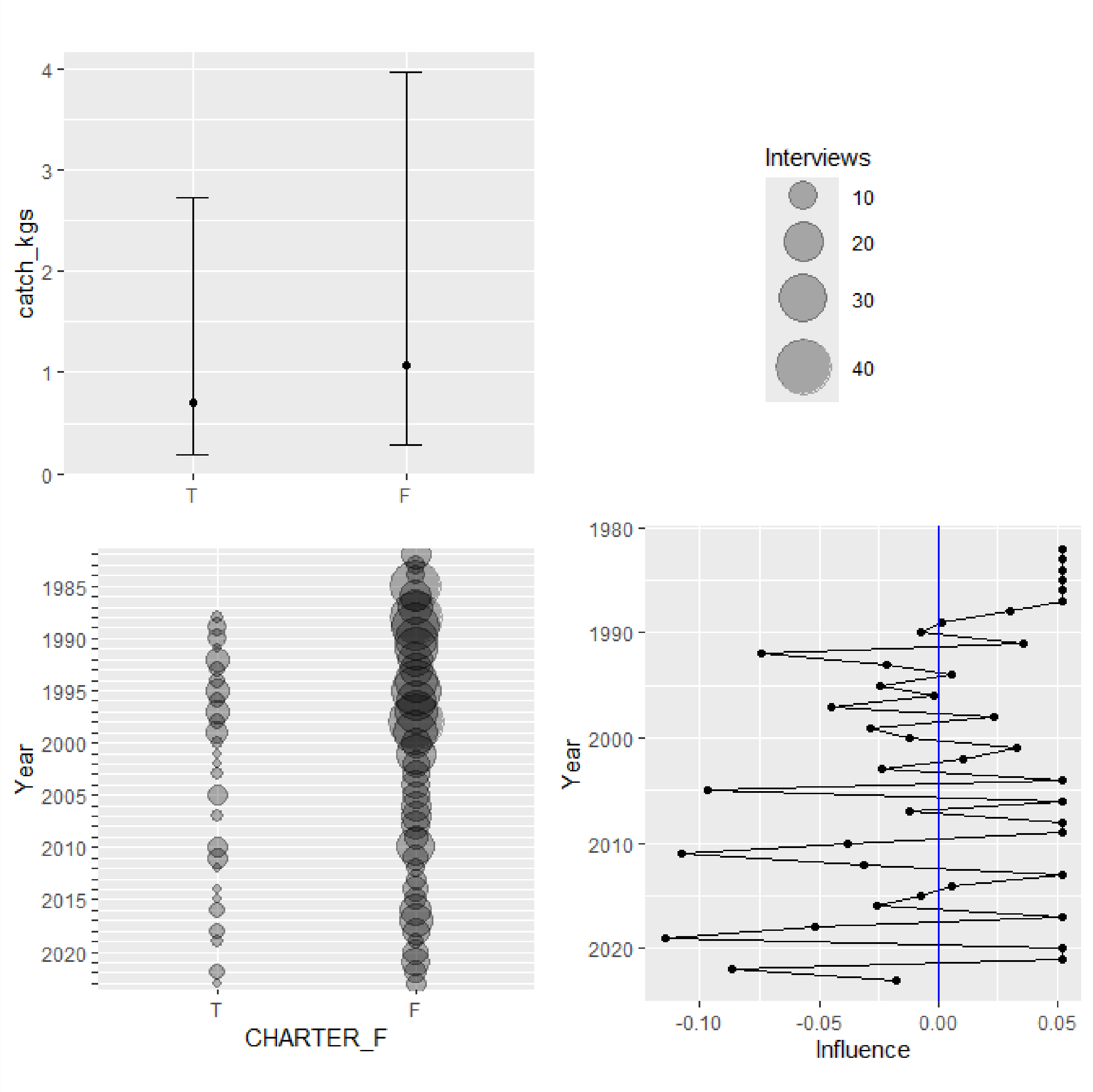


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of time of day (quarter) on CPUE (kg per trip) in the *L. kasmira* CPUE standardization.



Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of charter status on CPUE (kg per trip) in the *L. kasmira* CPUE standardization.

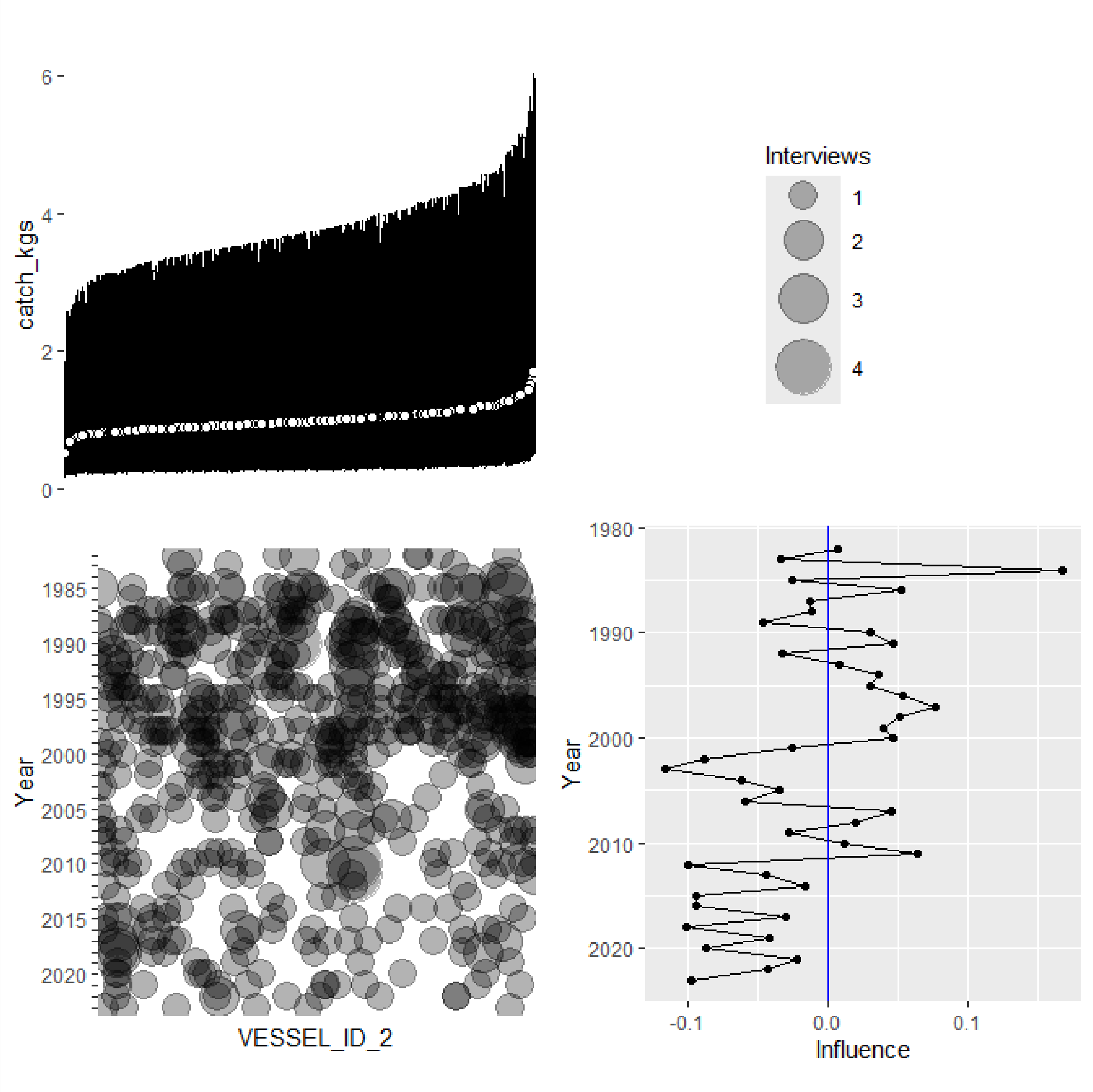


Figure 11. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *L. kasmira* CPUE standardization.

Standardized CPUE Index

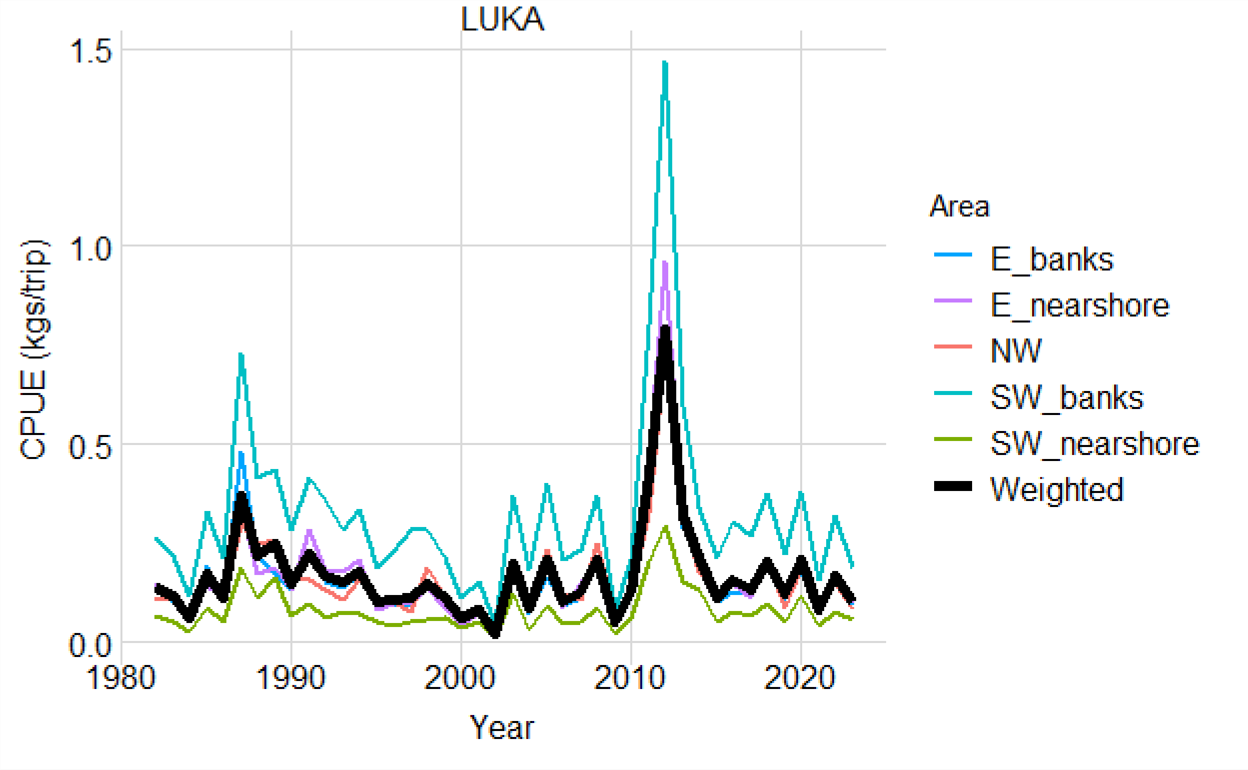


Figure 12. Standardized CPUE index (kg per trip) of *L. kasmira* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *L. kasmira*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	0.14	0.14	1996	0.11	0.11	2010	0.13	0.13
1983	0.12	0.22	1997	0.11	0.10	2011	0.42	0.46
1984	0.06	0.12	1998	0.15	0.12	2012	0.79	1.01
1985	0.17	0.15	1999	0.11	0.10	2013	0.32	0.50
1986	0.11	0.12	2000	0.06	0.07	2014	0.21	0.21
1987	0.37	0.37	2001	0.08	0.08	2015	0.11	0.15
1988	0.22	0.19	2002	0.02	0.03	2016	0.16	0.16
1989	0.25	0.22	2003	0.20	0.21	2017	0.13	0.13
1990	0.15	0.13	2004	0.08	0.10	2018	0.20	0.21
1991	0.22	0.21	2005	0.21	0.22	2019	0.12	0.20
1992	0.17	0.17	2006	0.10	0.11	2020	0.21	0.25
1993	0.15	0.15	2007	0.13	0.13	2021	0.08	0.10
1994	0.18	0.16	2008	0.21	0.23	2022	0.17	0.21
1995	0.10	0.09	2009	0.05	0.07	2023	0.10	0.14

Pristipomoides auricilla

Presence/Absence Model

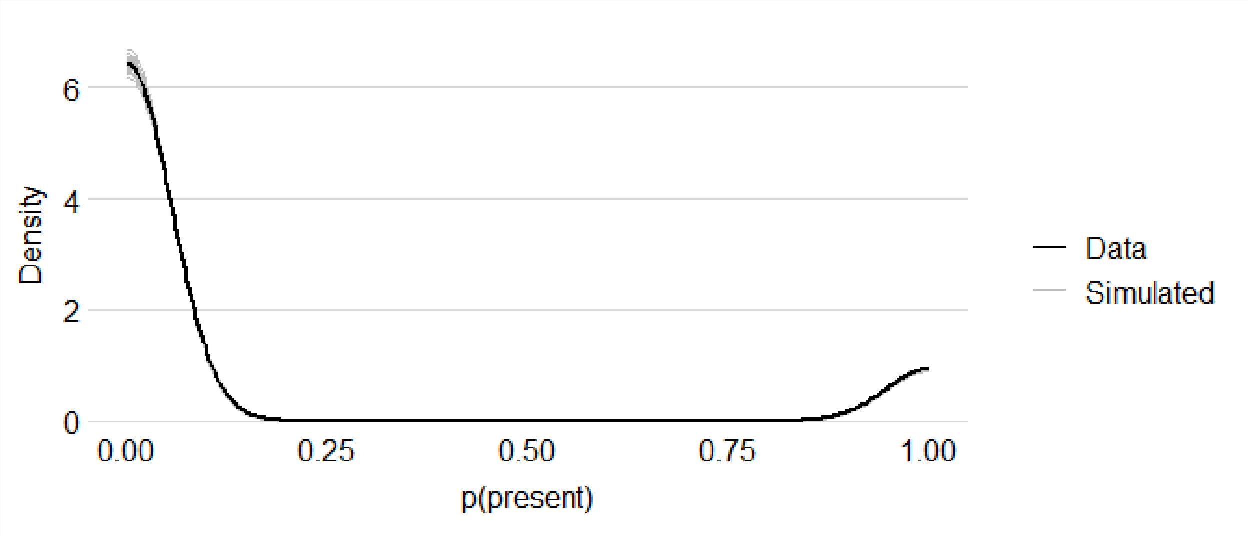


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *P. auricilla* CPUE standardization.

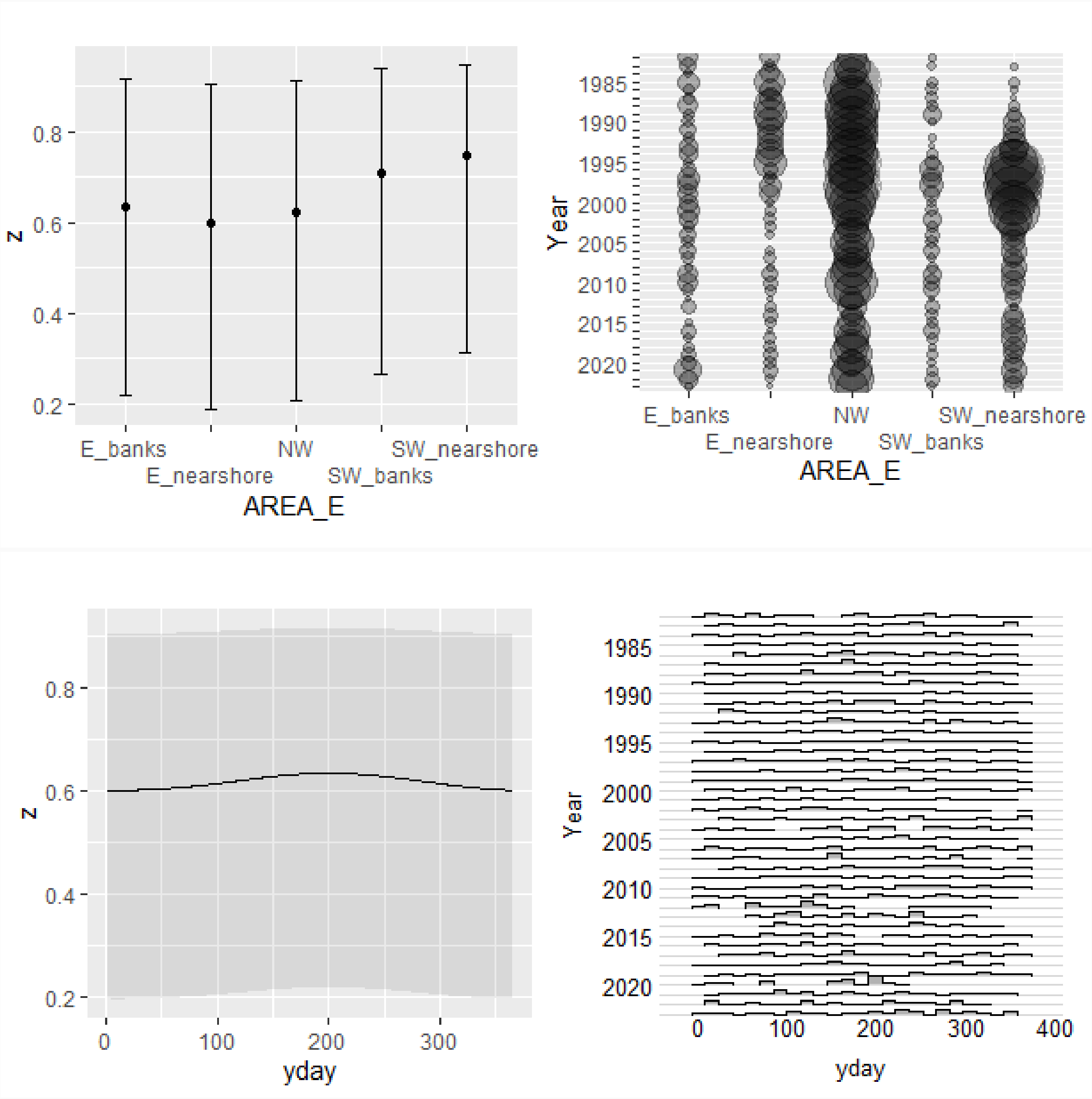


Figure 2. Partial effects of area and time of year on probability of presence in the *P. auricilla* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

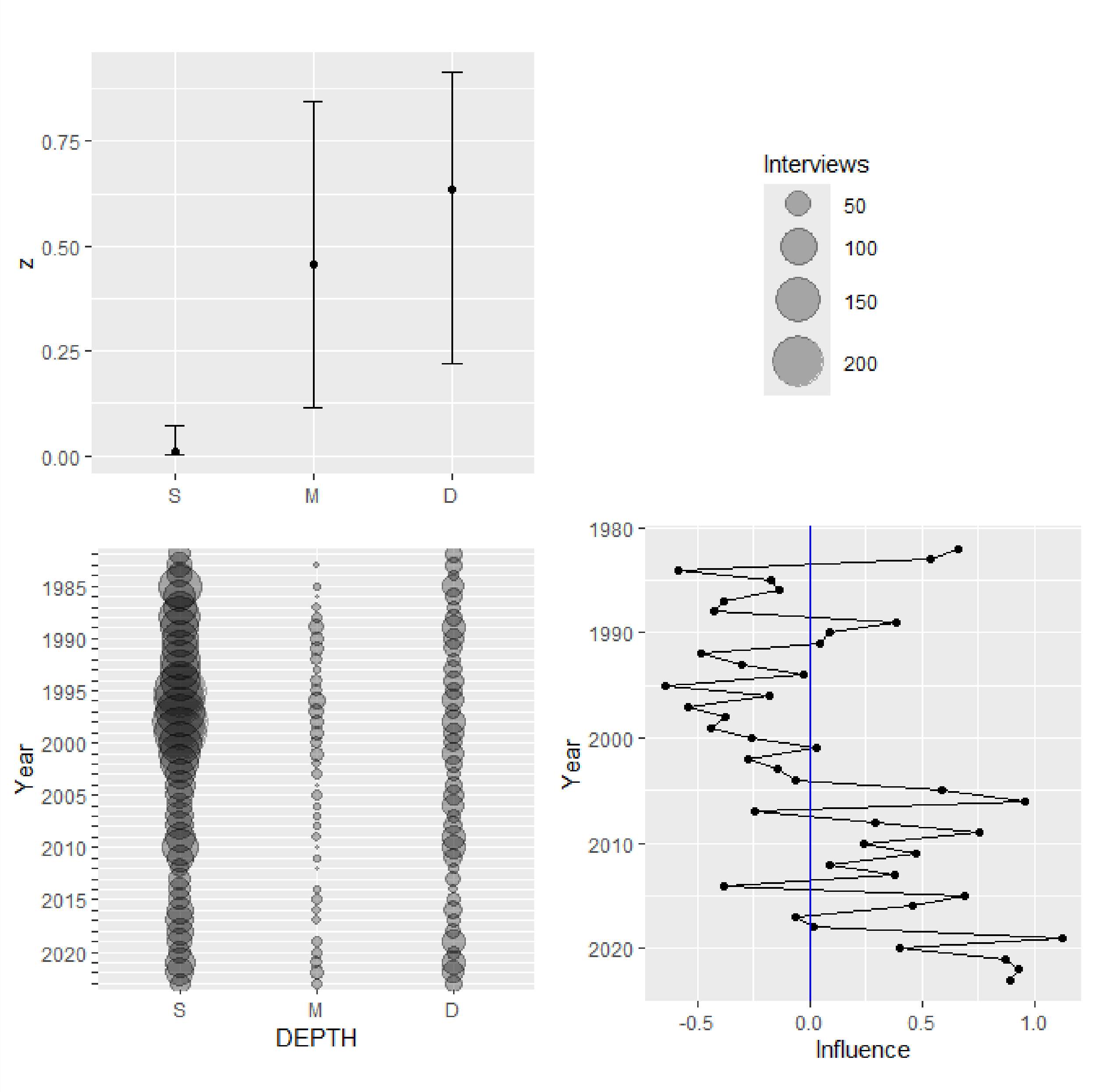


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *P. auricilla* CPUE standardization.

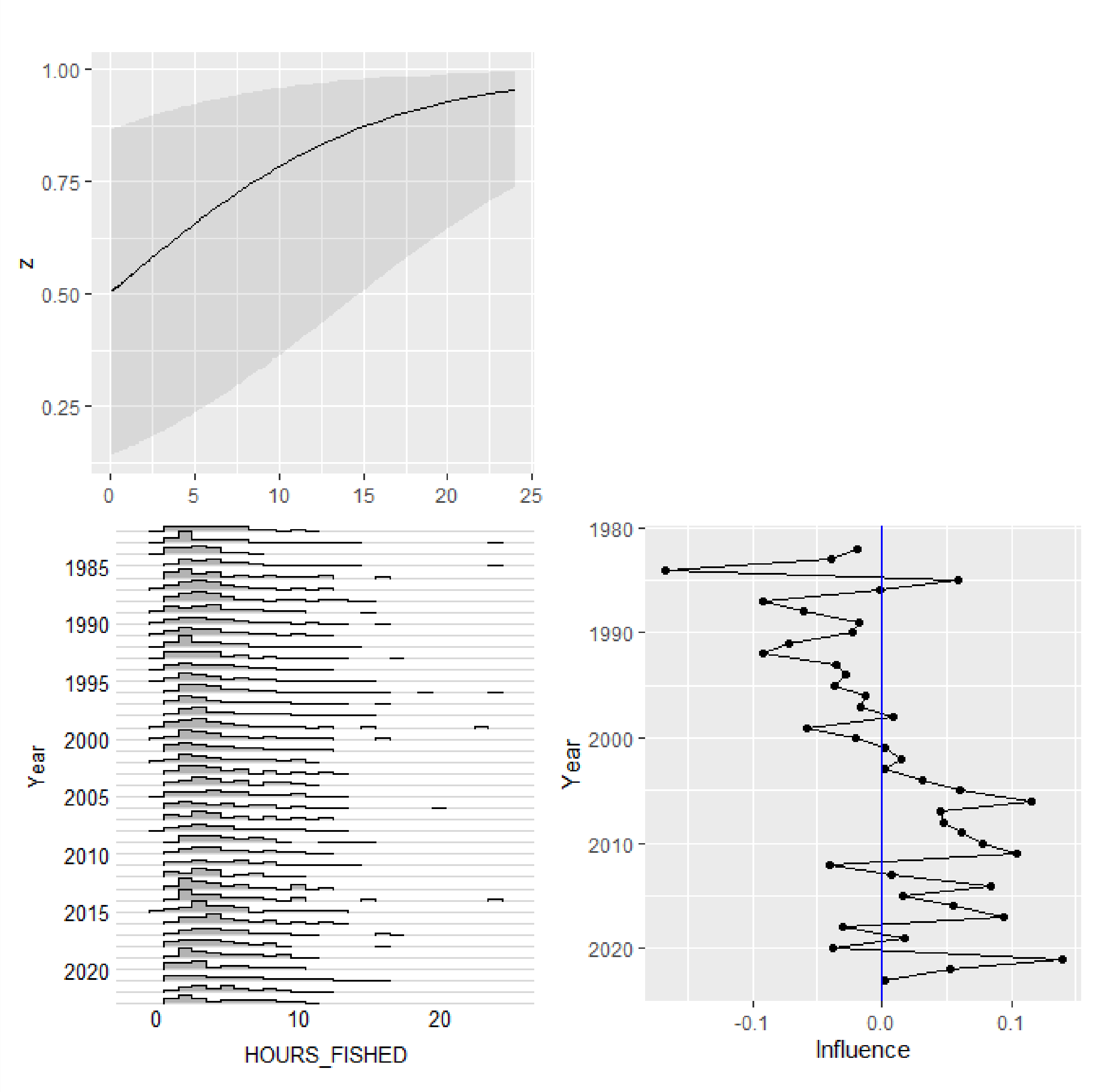


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on probability of presence in the *P. auricilla* CPUE standardization.

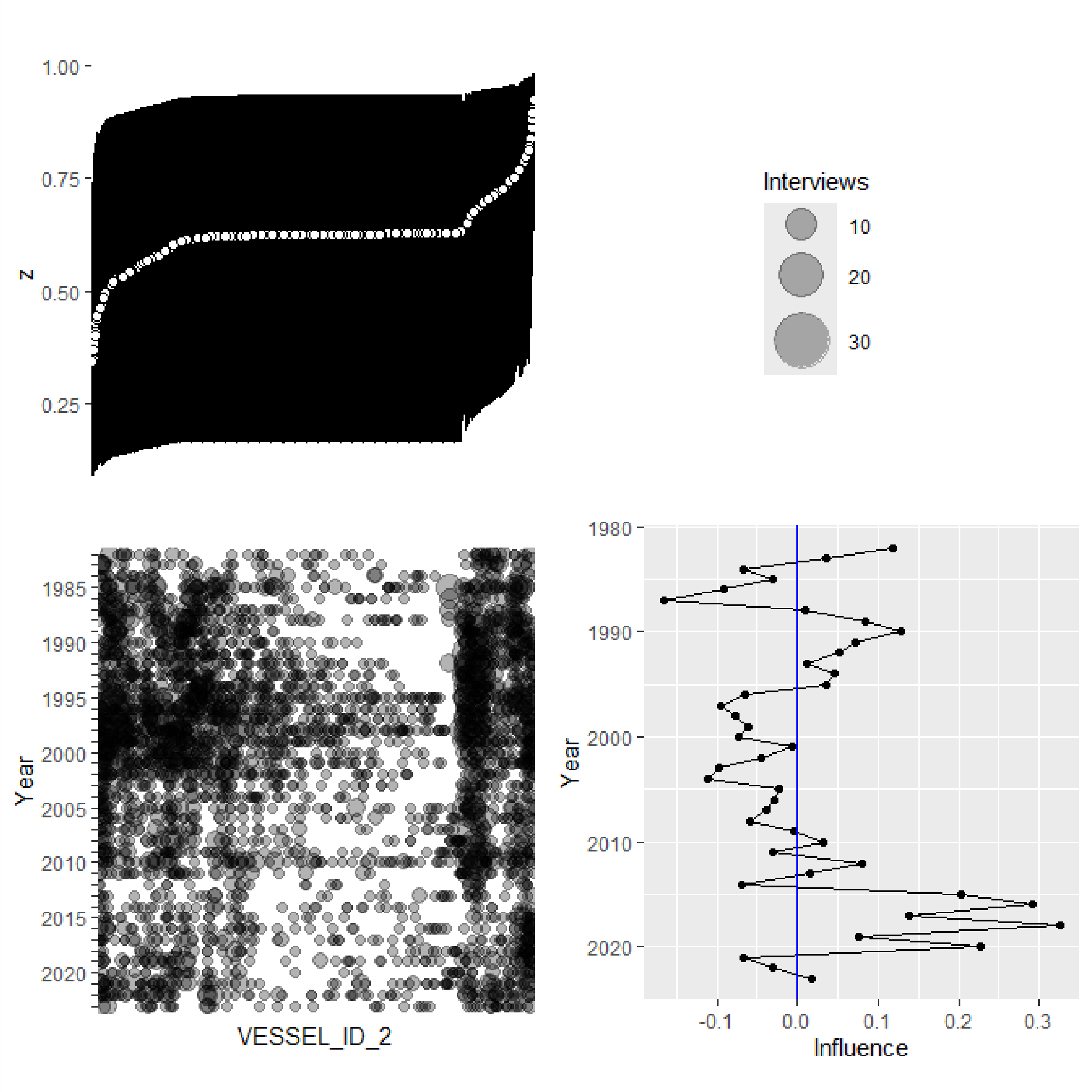


Figure 5. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *P. auricilla* CPUE standardization.

Positive Process Model

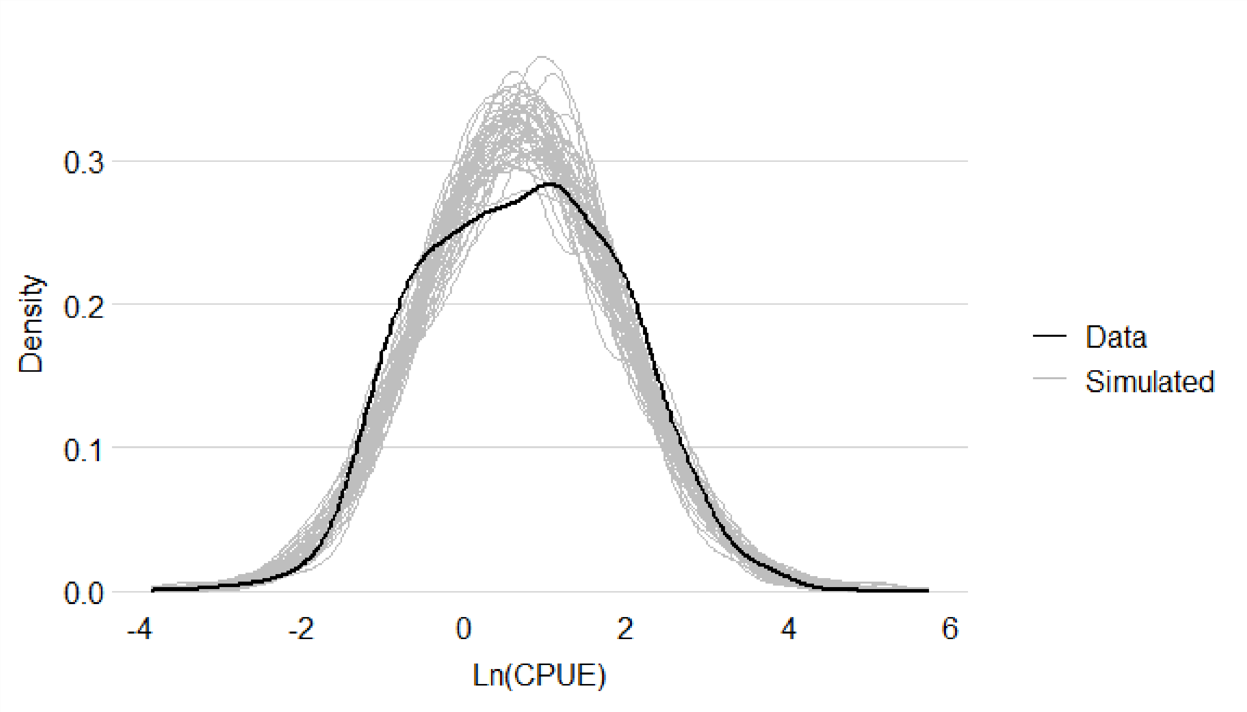


Figure 6. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *P. auricilla* CPUE standardization.

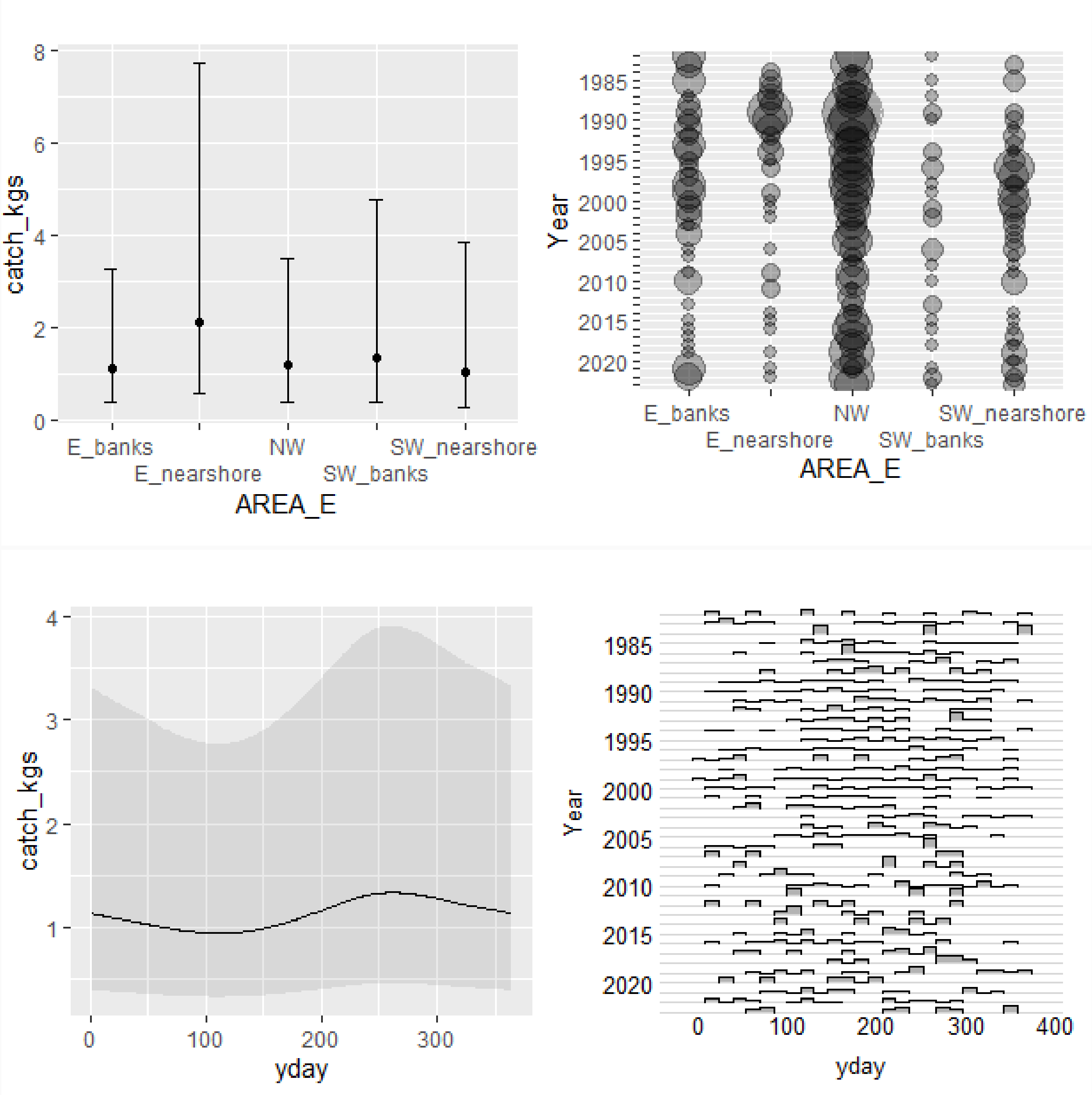


Figure 7. Partial effects of area and time of year on CPUE (kg per trip) in the *P. auricilla* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

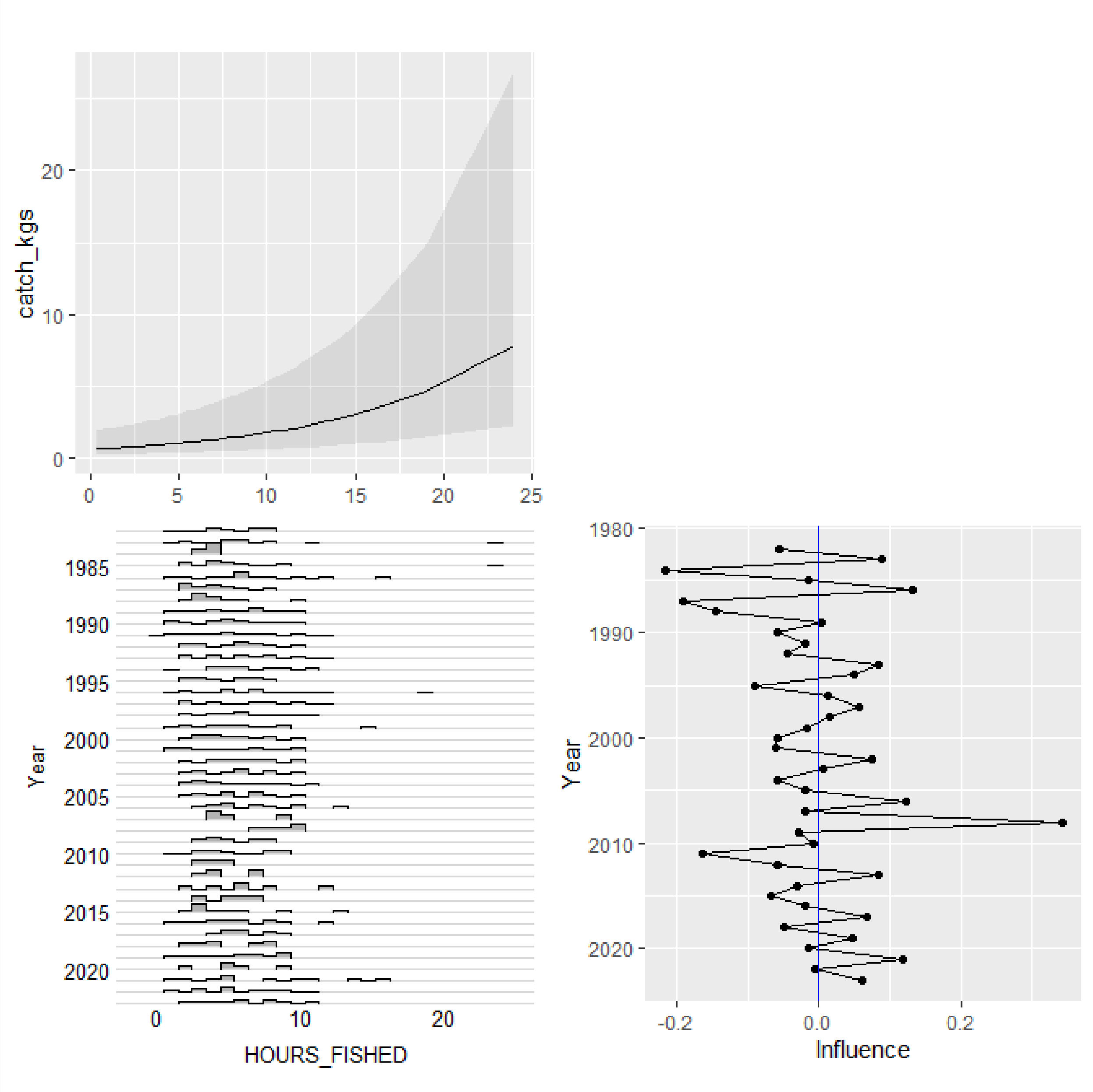


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of hours fished on CPUE (kg per trip) in the *P. auricilla* CPUE standardization.

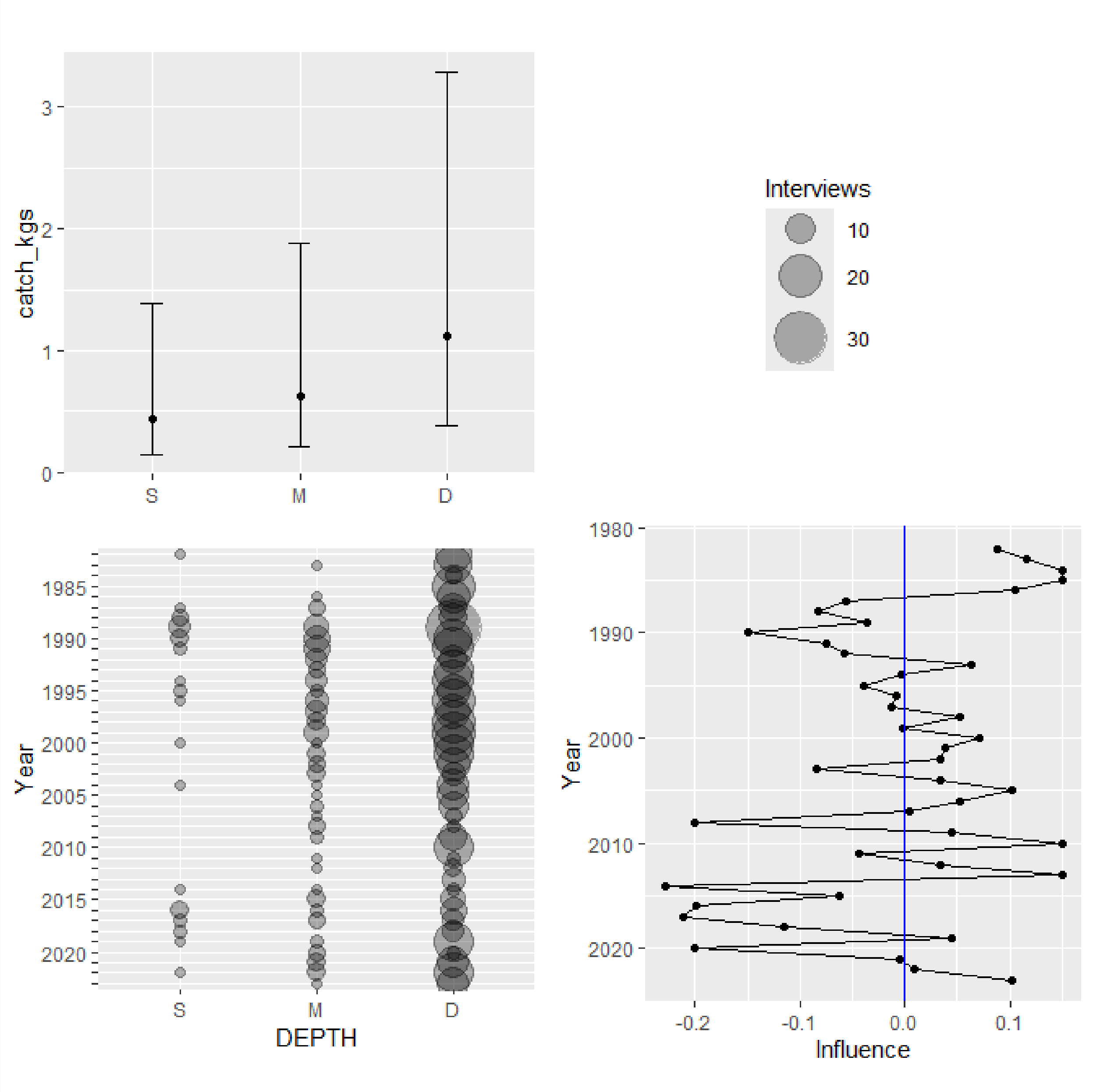


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on CPUE (kg per trip) in the *P. auricilla* CPUE standardization.

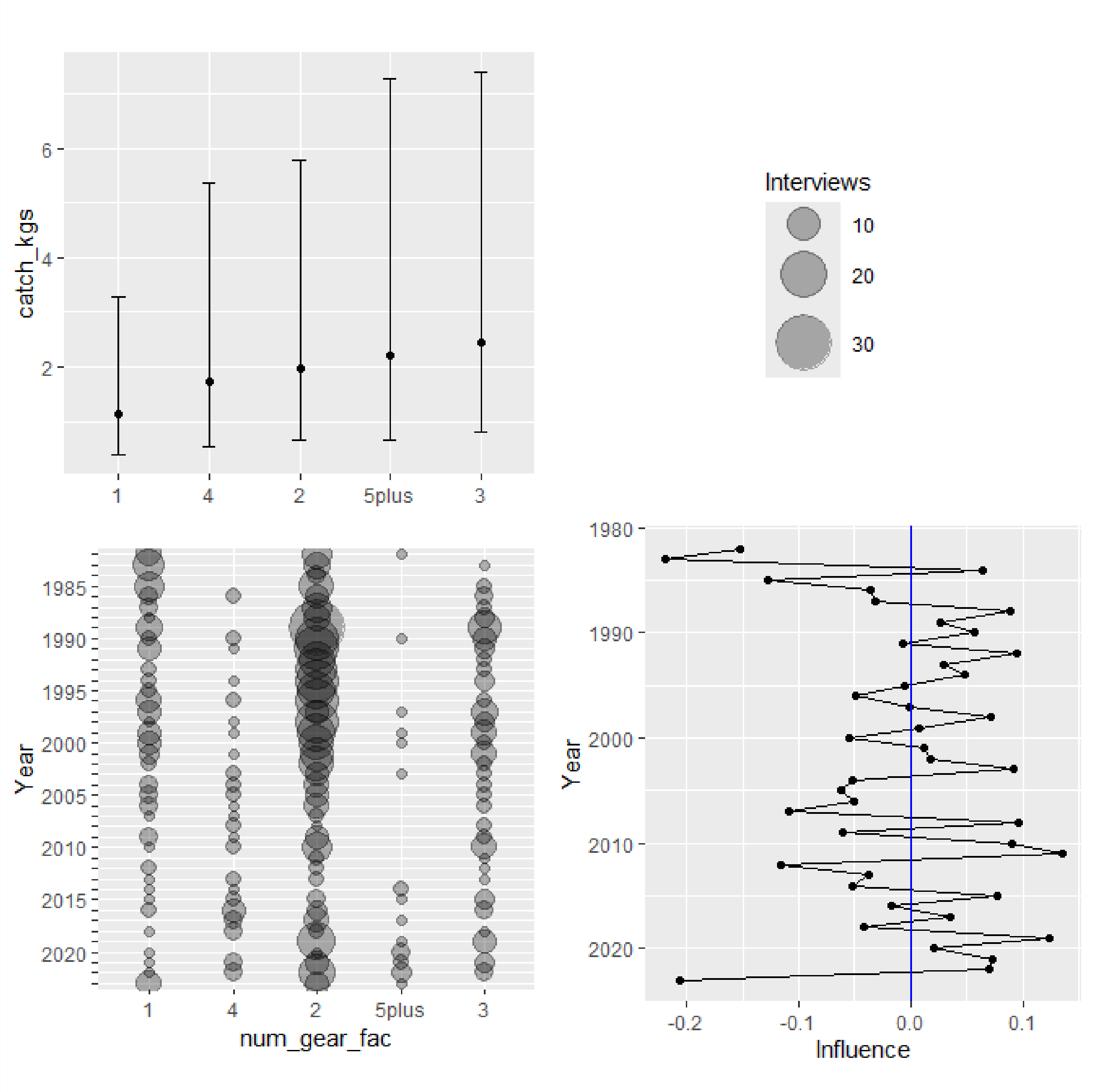


Figure 10. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (number of gears) on CPUE (kg per trip) in the *P. auricilla* CPUE standardization.

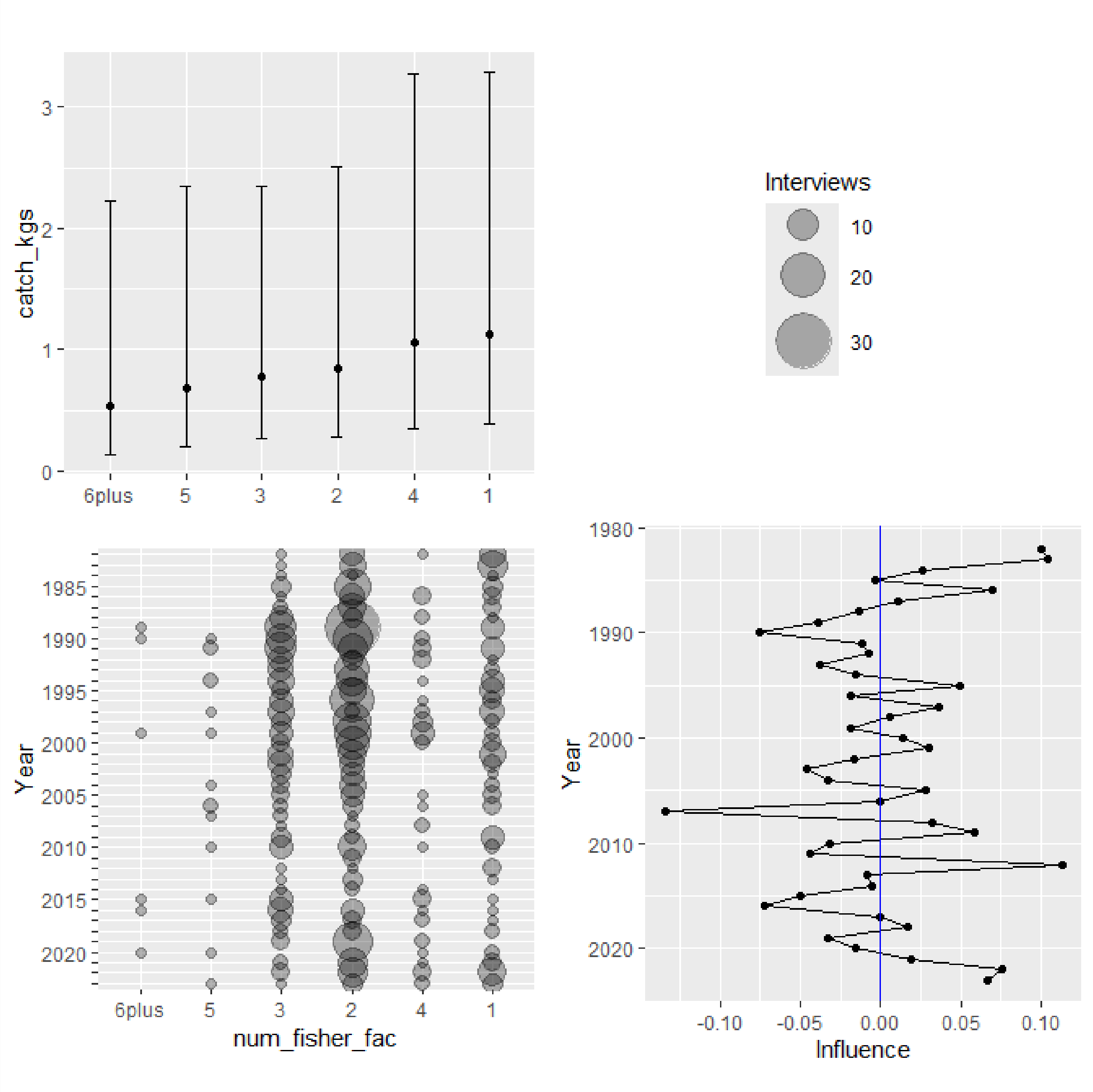


Figure 11. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (number of fishers) on CPUE (kg per trip) in the *P. auricilla* CPUE standardization.

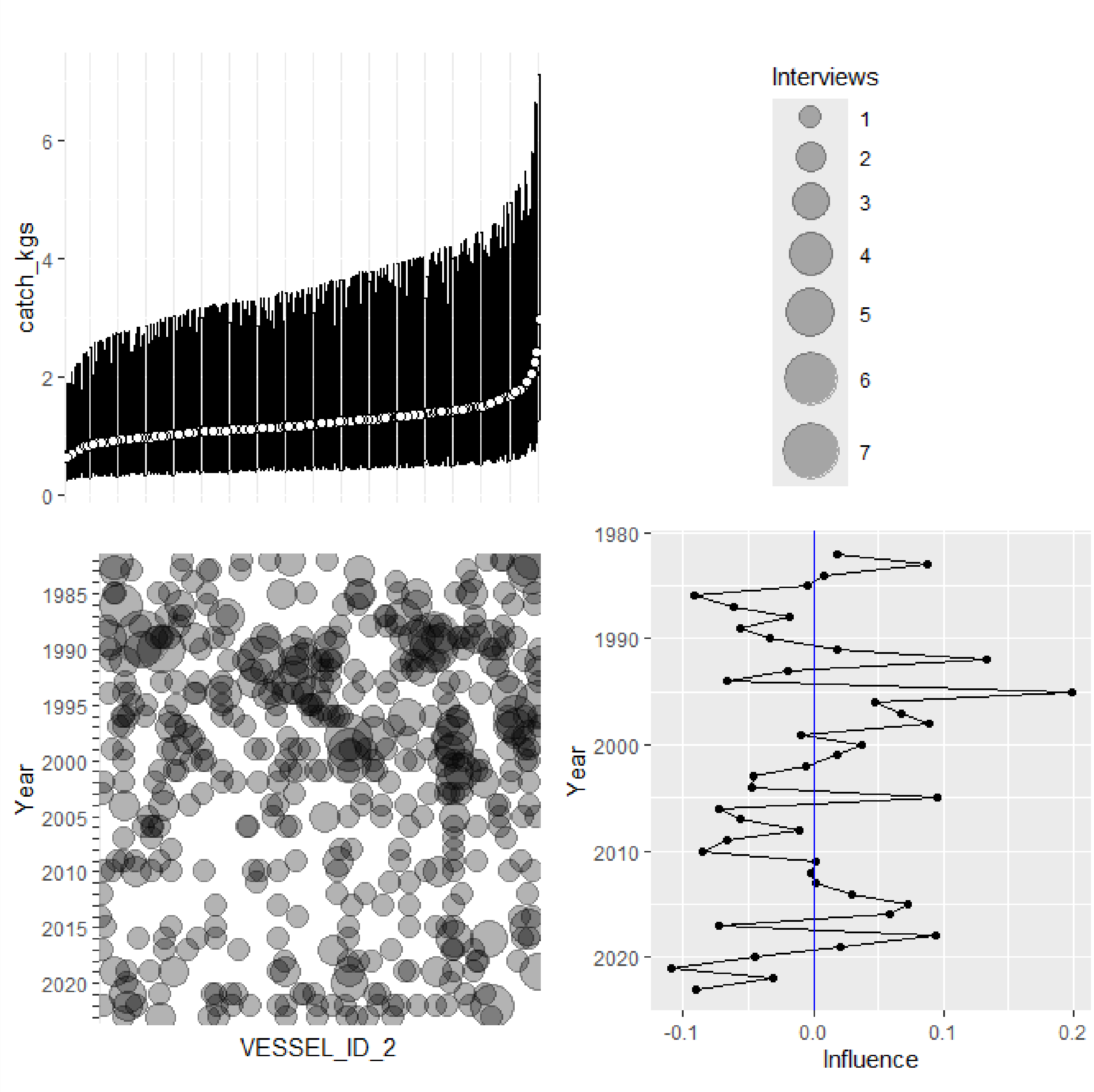


Figure 12. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *P. auricilla* CPUE standardization.

Standardized CPUE Index

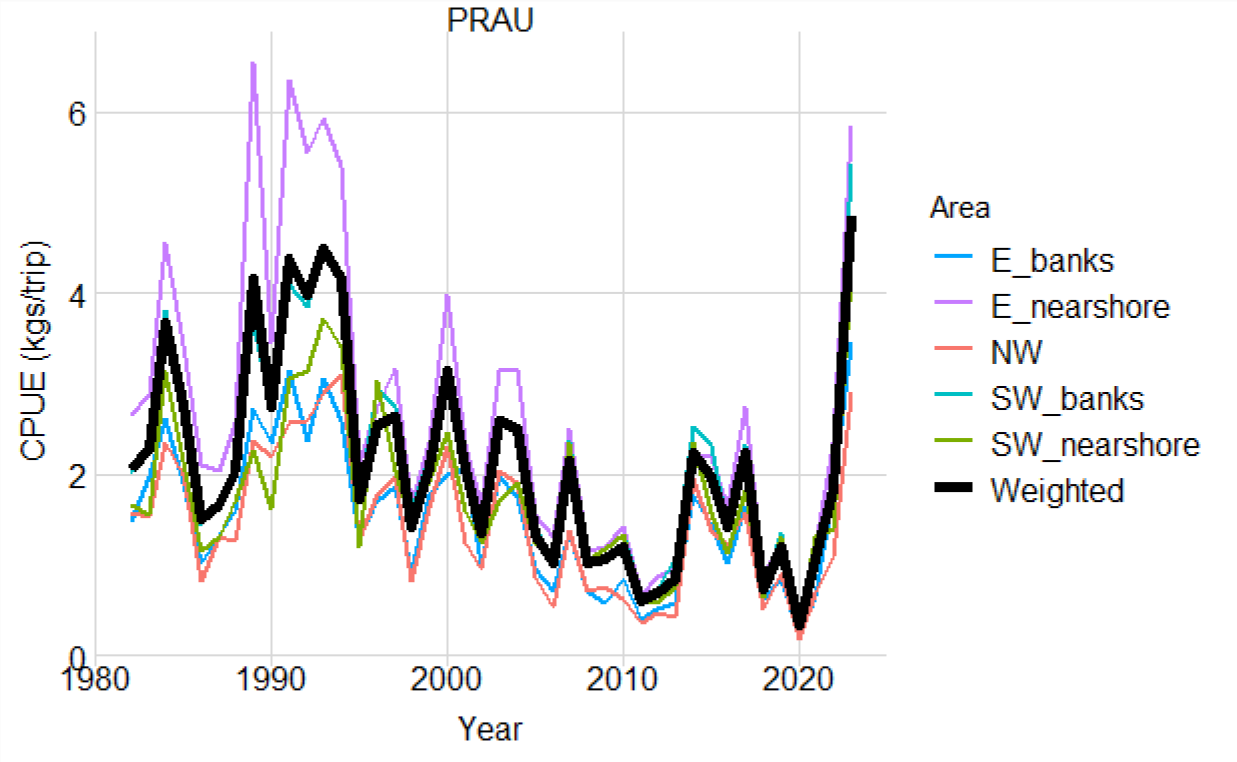


Figure 13. Standardized CPUE index (kg per trip) of *P. auricilla* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *P. auricilla*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	2.07	1.81	1996	2.55	2.12	2010	1.20	1.20
1983	2.28	2.00	1997	2.63	2.47	2011	0.59	1.32
1984	3.67	5.09	1998	1.41	1.37	2012	0.69	0.85
1985	2.78	2.31	1999	2.09	1.66	2013	0.85	1.05
1986	1.50	1.37	2000	3.14	2.77	2014	2.24	2.80
1987	1.67	1.33	2001	2.06	1.83	2015	1.99	1.97
1988	2.04	1.83	2002	1.36	1.18	2016	1.42	1.45
1989	4.15	2.59	2003	2.58	2.53	2017	2.25	2.29
1990	2.75	2.00	2004	2.49	2.21	2018	0.74	0.95
1991	4.38	3.23	2005	1.34	1.54	2019	1.21	1.14
1992	3.99	3.41	2006	1.03	1.15	2020	0.33	0.57
1993	4.49	3.68	2007	2.16	3.17	2021	1.08	1.16
1994	4.17	3.19	2008	1.02	1.68	2022	1.85	1.56
1995	1.74	1.62	2009	1.06	1.34	2023	4.86	4.75

Pristipomoides filamentosus

Presence/Absence Model

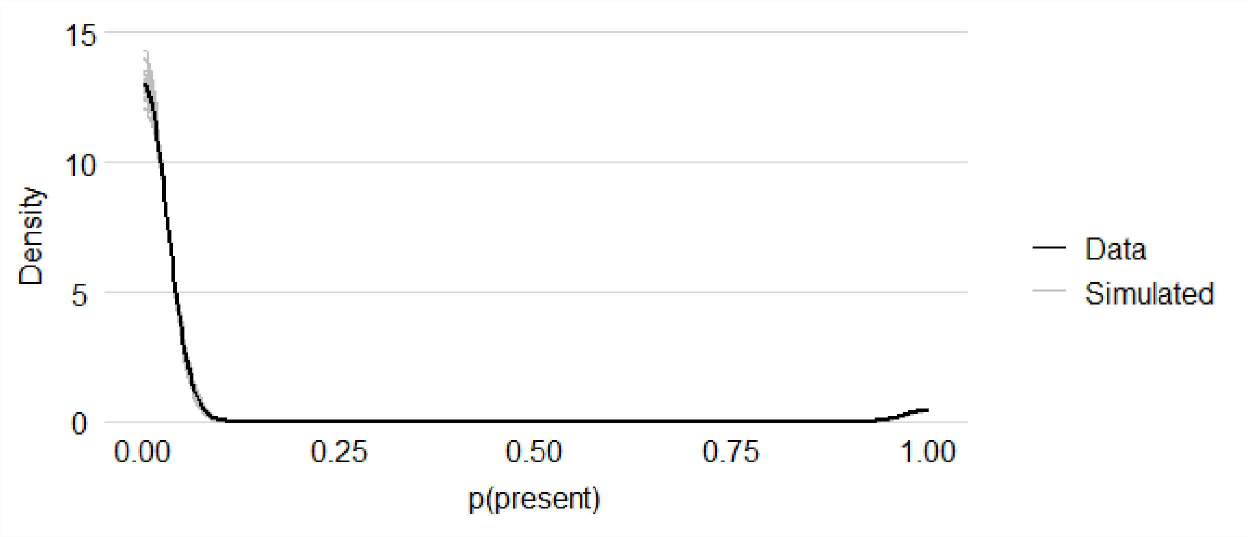


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *P. filamentosus* CPUE standardization.

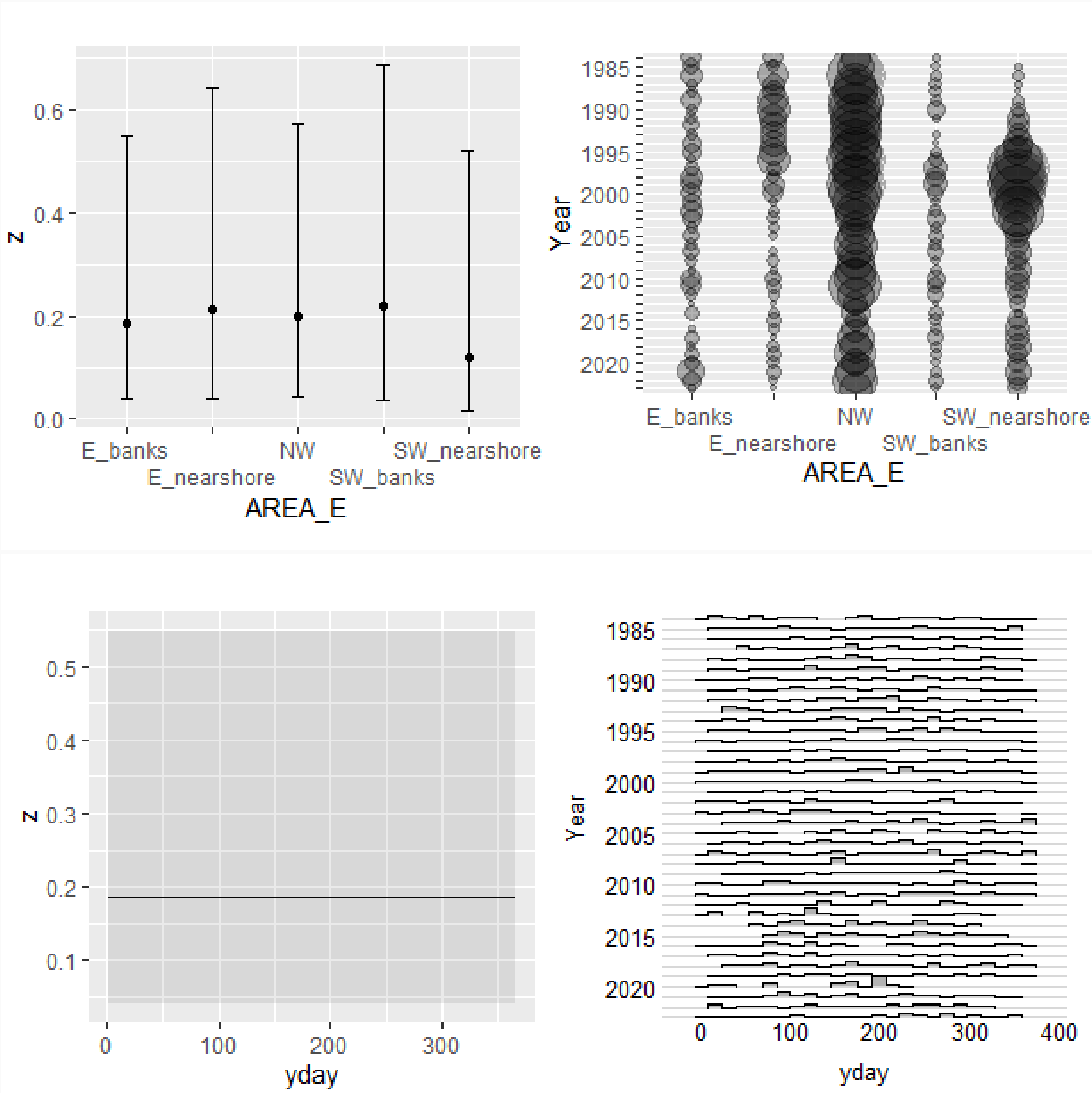


Figure 2. Partial effects of area and time of year on probability of presence in the *P. filamentosus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

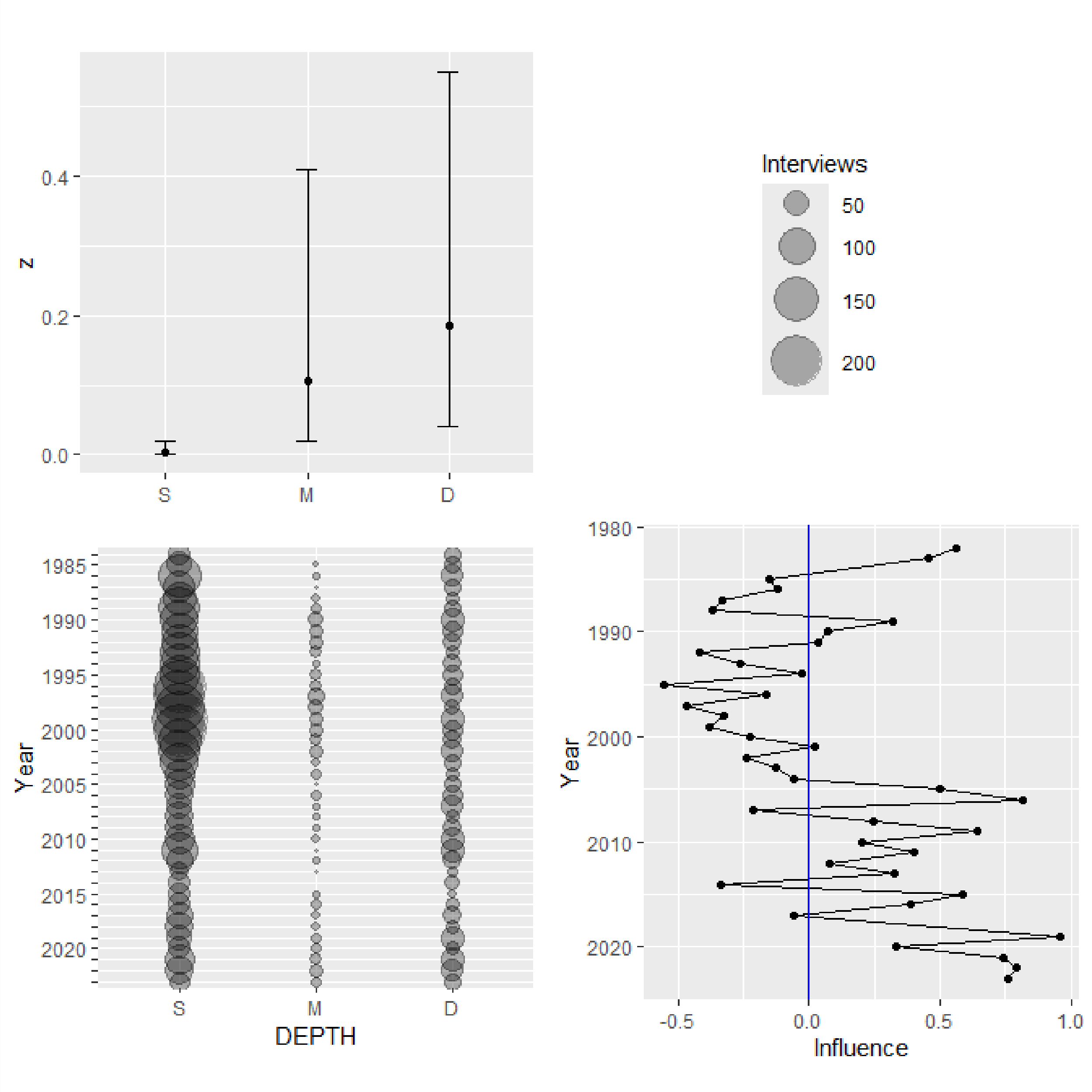


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *P. filamentosus* CPUE standardization.

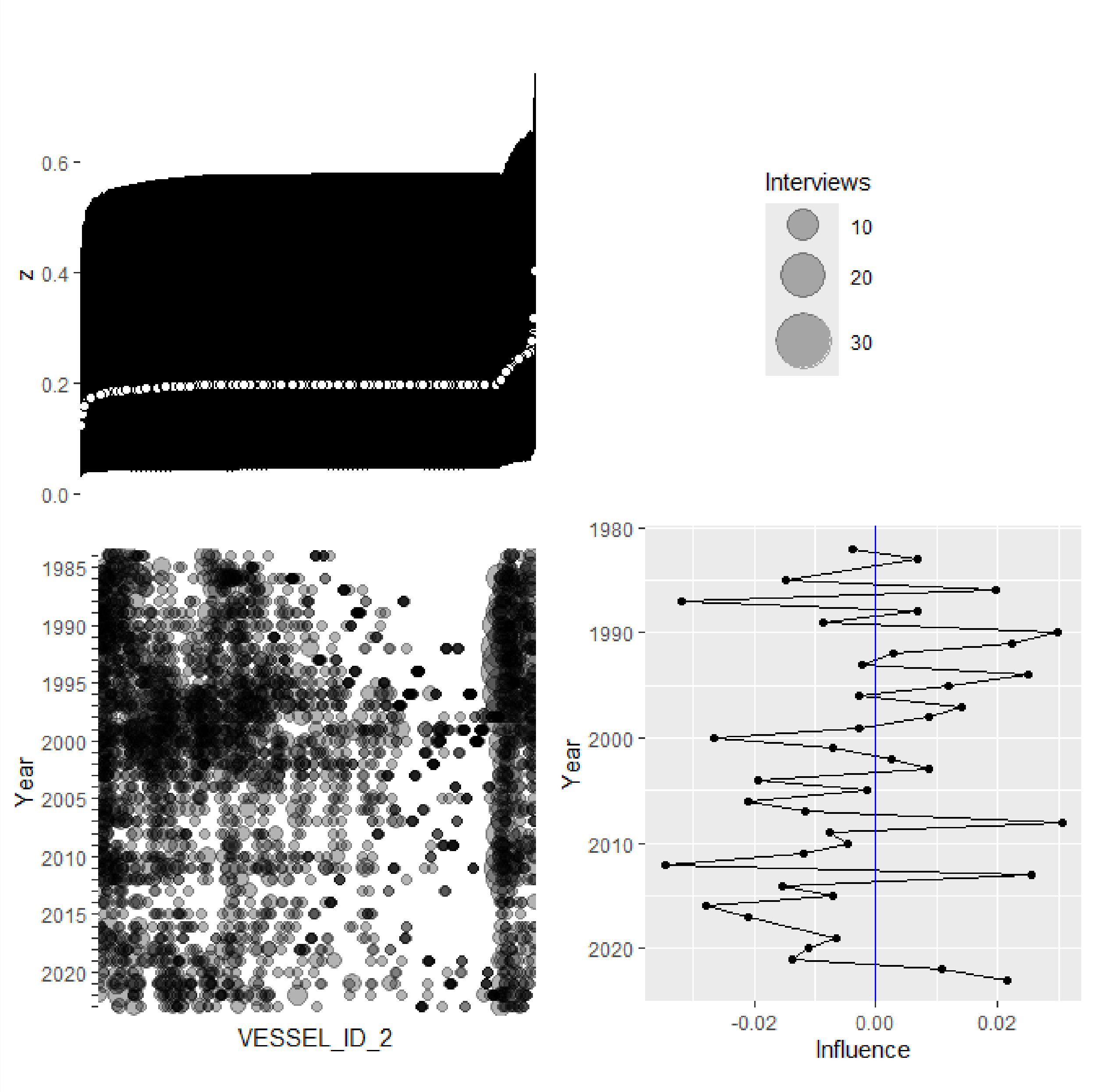


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *P. filamentosus* CPUE standardization.

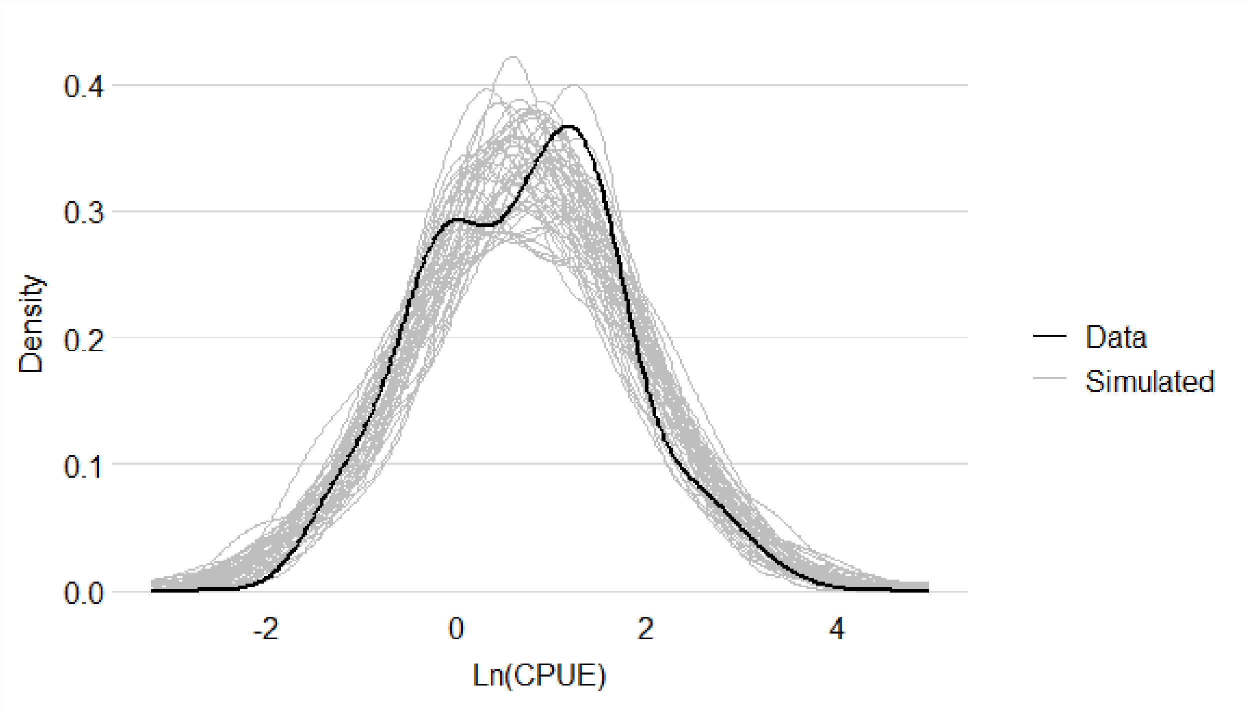


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *P. filamentosus* CPUE standardization.

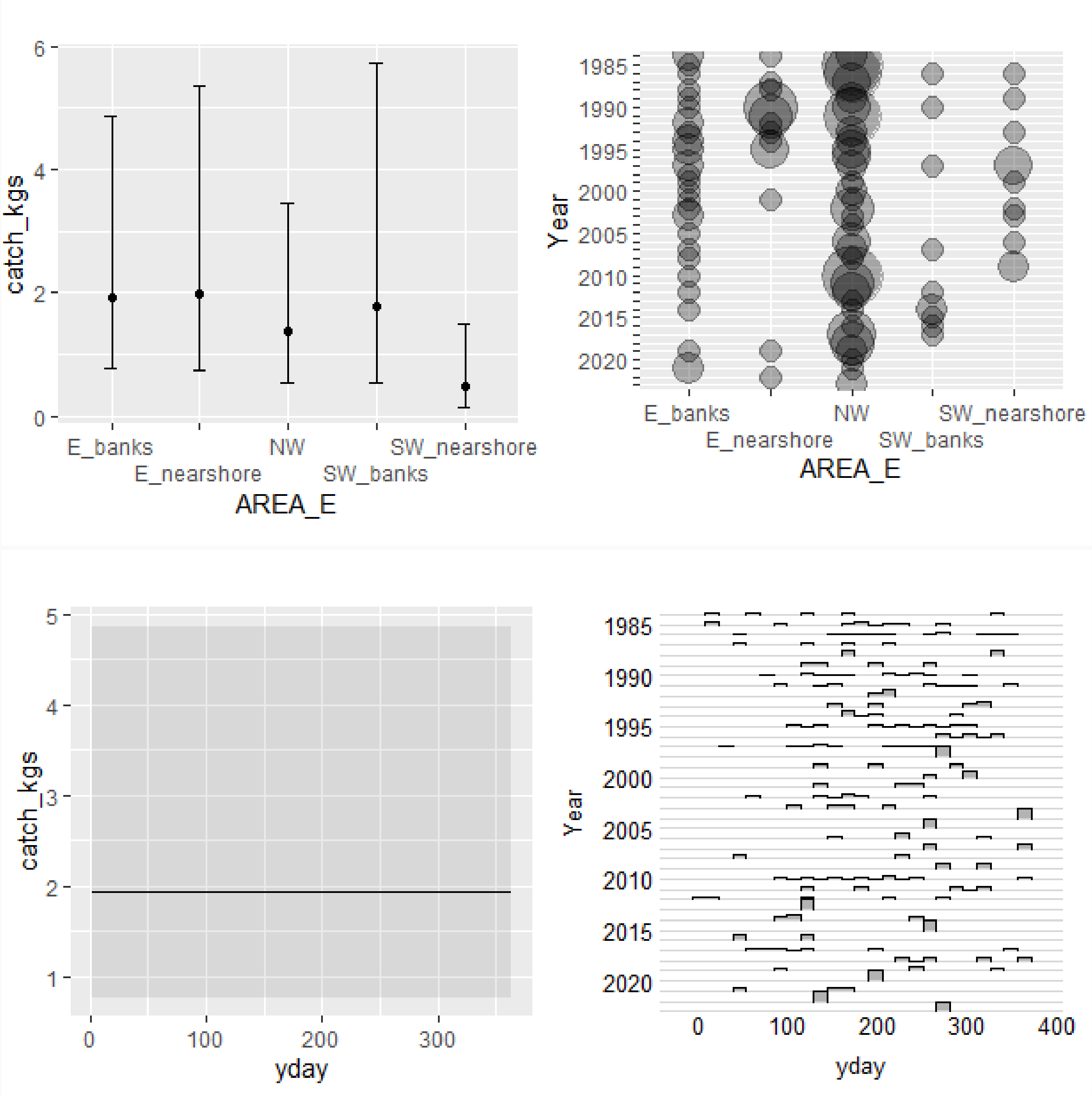


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *P. filamentosus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

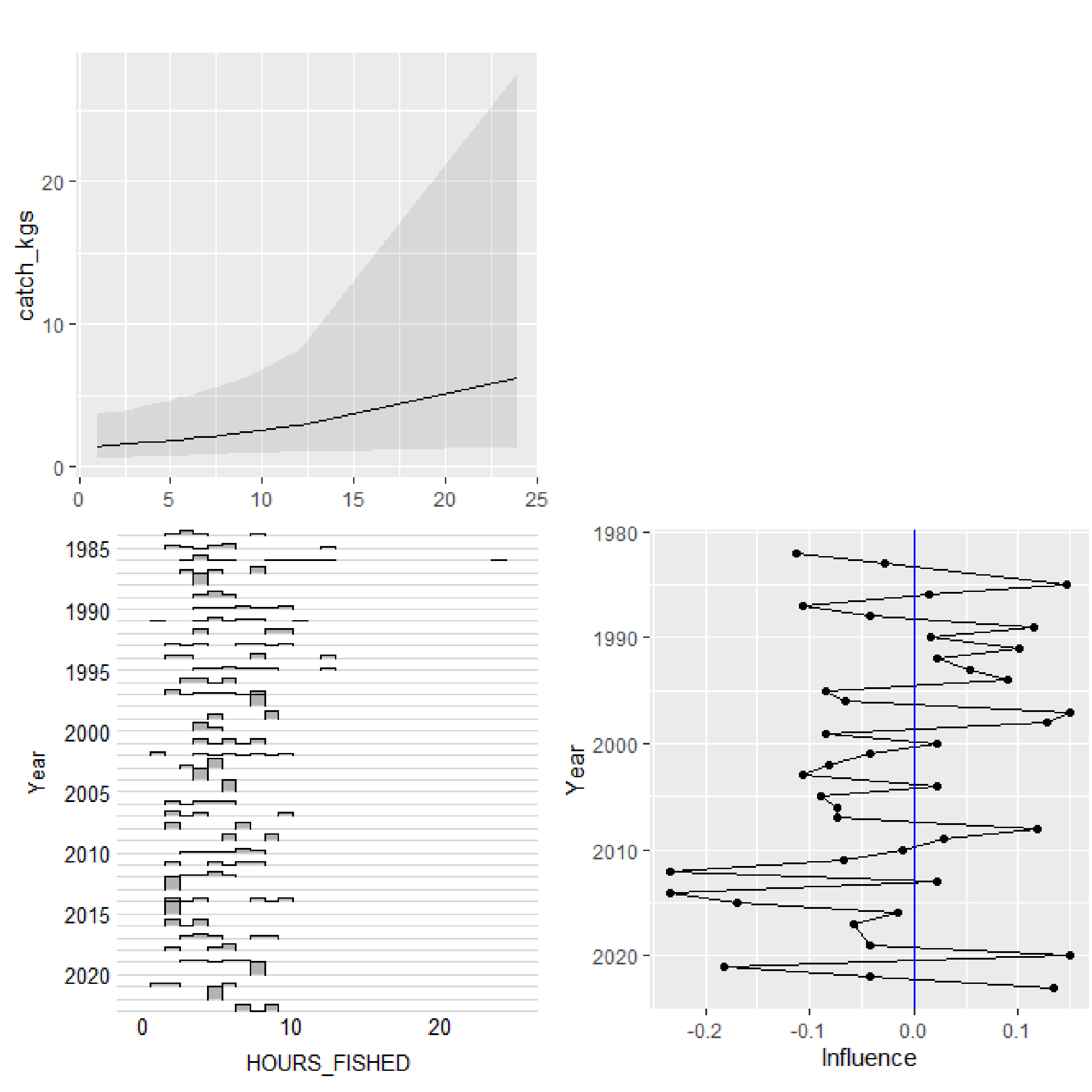


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *P. filamentosus* CPUE standardization.

Standardized CPUE Index

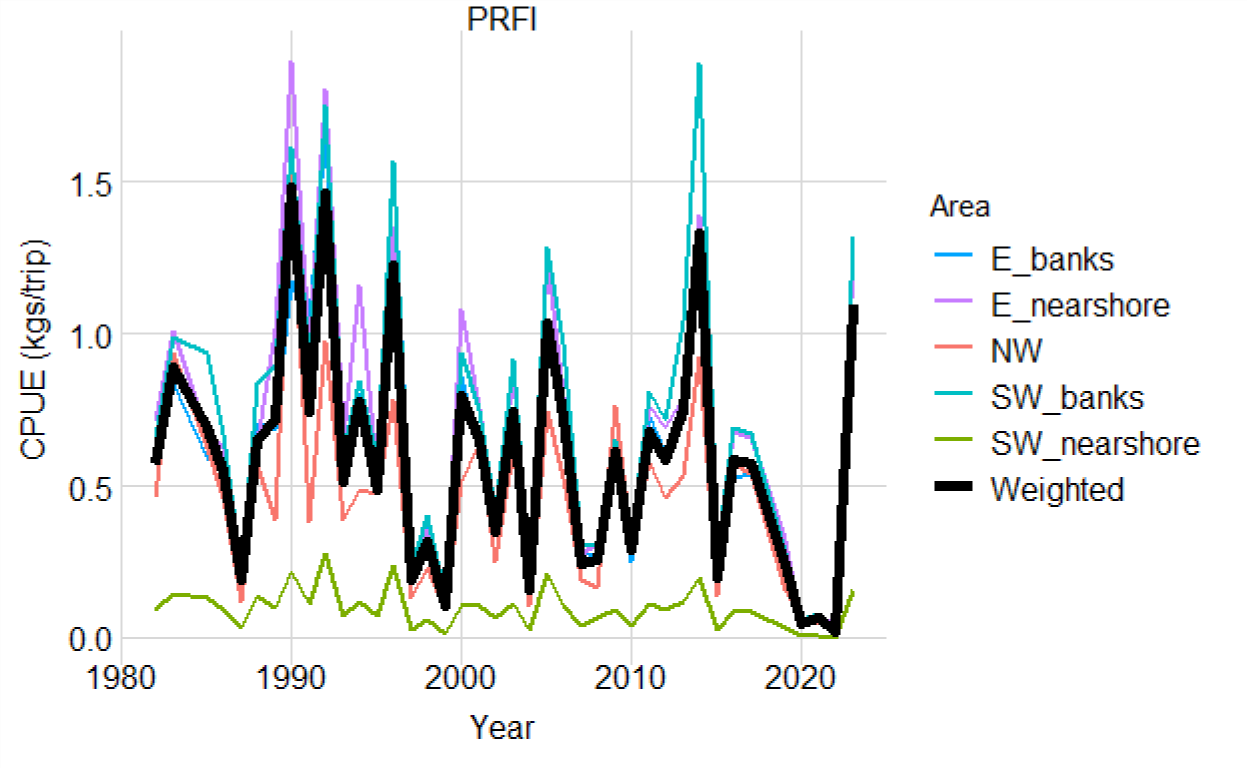


Figure 8. Standardized CPUE index (kg per trip) of *P. filamentosus* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *P. filamentosus*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	0.57	0.60	1996	1.23	1.28	2010	0.29	0.46
1983	0.89	0.70	1997	0.19	1.08	2011	0.68	0.75
1984	---	---	1998	0.32	0.65	2012	0.59	2.14
1985	0.69	0.57	1999	0.11	0.20	2013	0.75	0.82
1986	0.55	0.69	2000	0.79	1.28	2014	1.33	4.21
1987	0.19	0.35	2001	0.65	0.77	2015	0.20	0.39
1988	0.65	0.84	2002	0.35	0.47	2016	0.59	0.60
1989	0.72	0.56	2003	0.74	3.63	2017	0.57	0.67
1990	1.48	1.17	2004	0.16	0.79	2018	---	---
1991	0.74	1.22	2005	1.03	1.52	2019	0.24	0.35
1992	1.46	1.40	2006	0.72	1.01	2020	0.05	0.22
1993	0.52	0.58	2007	0.25	0.47	2021	0.07	0.13
1994	0.78	0.70	2008	0.26	0.66	2022	0.02	0.13
1995	0.49	0.89	2009	0.62	0.62	2023	1.09	2.54

Pristipomoides flavipinnis

Presence/Absence Model

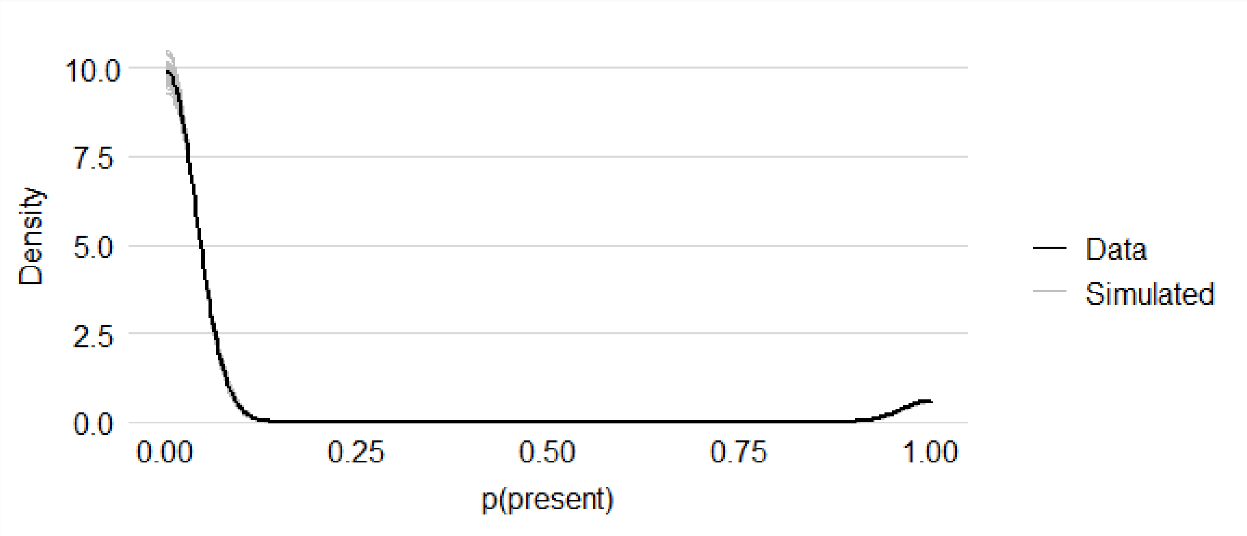


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *P. flavipinnis* CPUE standardization.

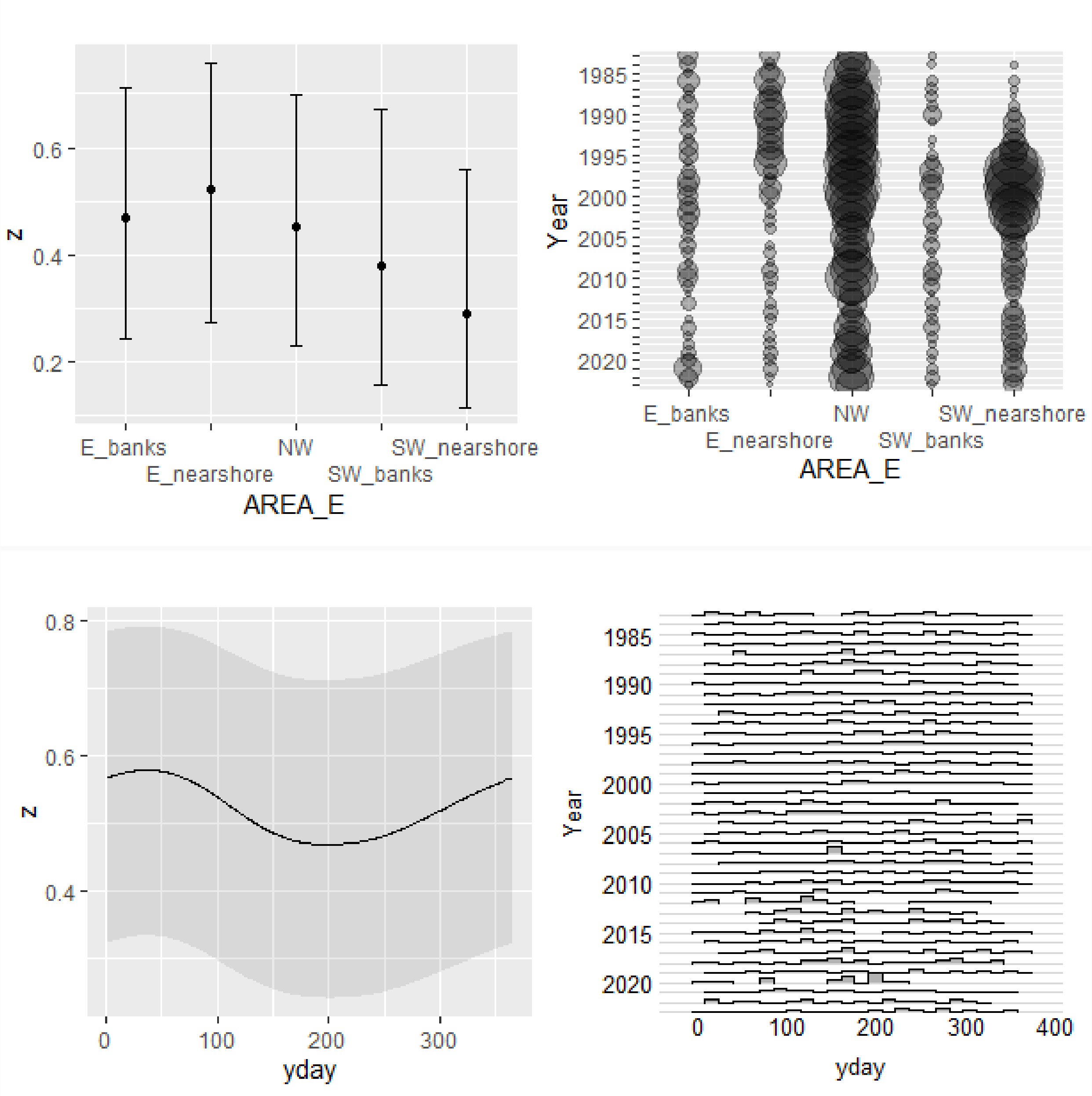


Figure 2. Partial effects of area and time of year on probability of presence in the *P. flavipinnis* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

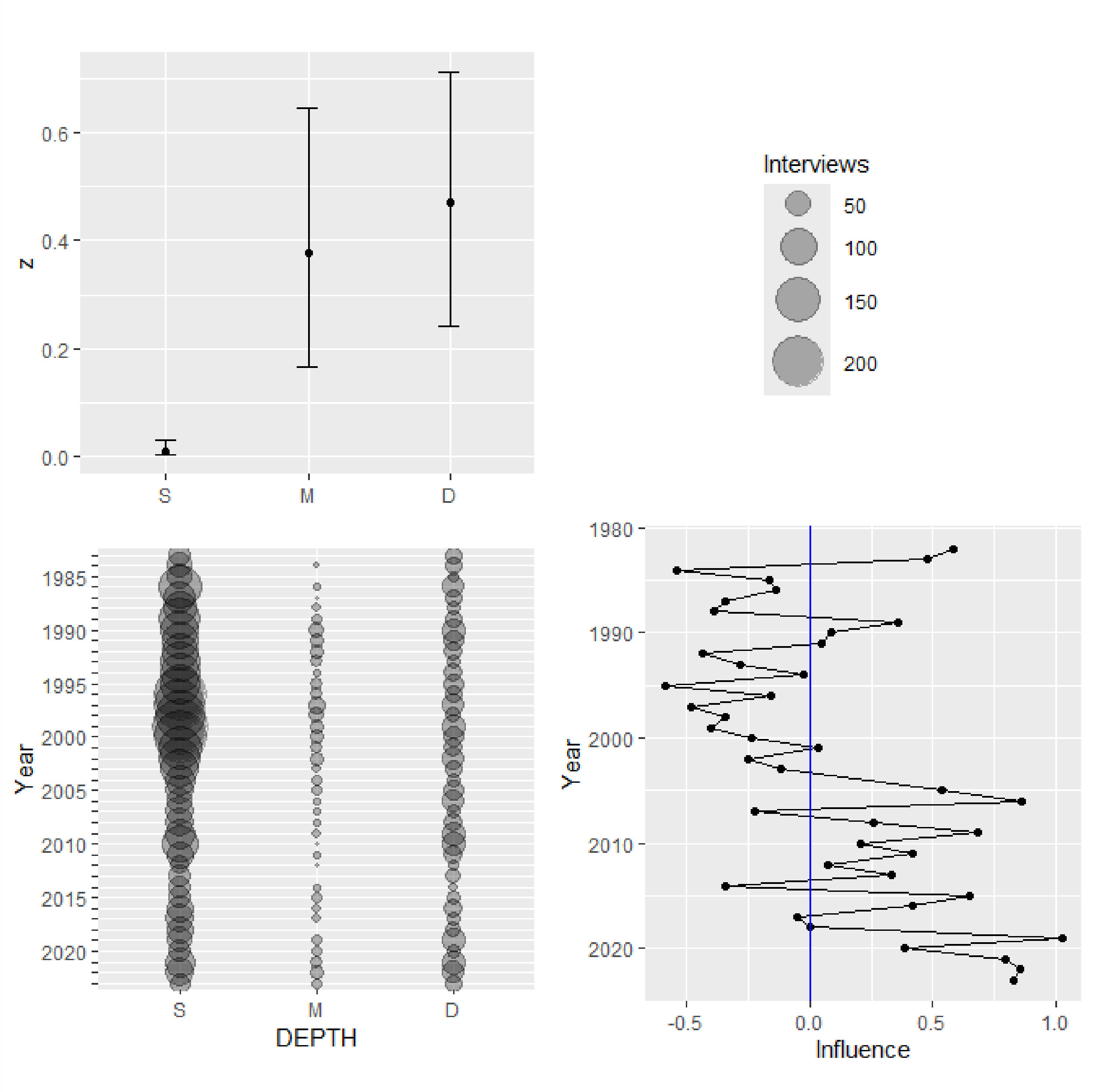


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *P. flavipinnis* CPUE standardization.

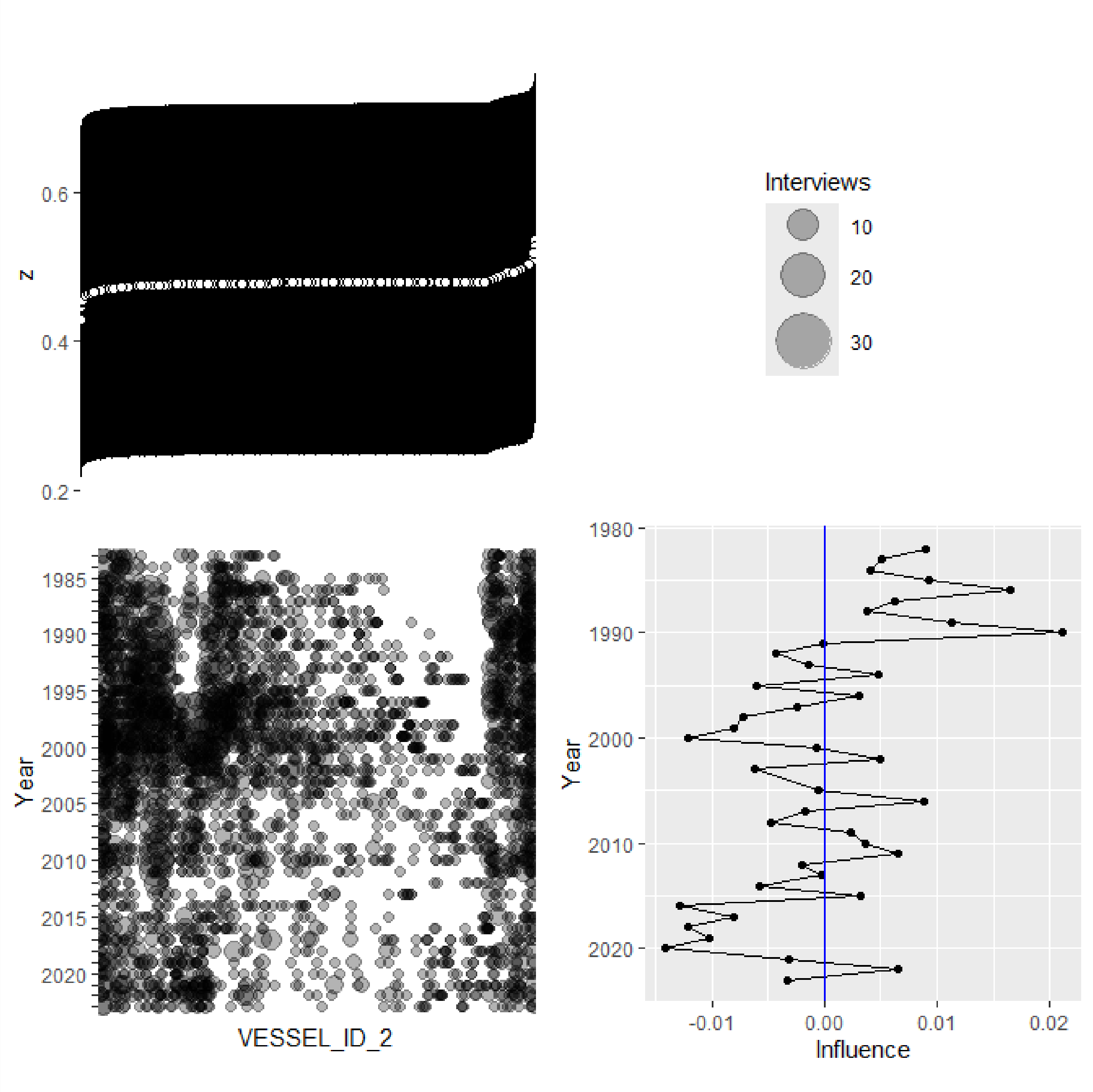


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *P. flavipinnis* CPUE standardization.

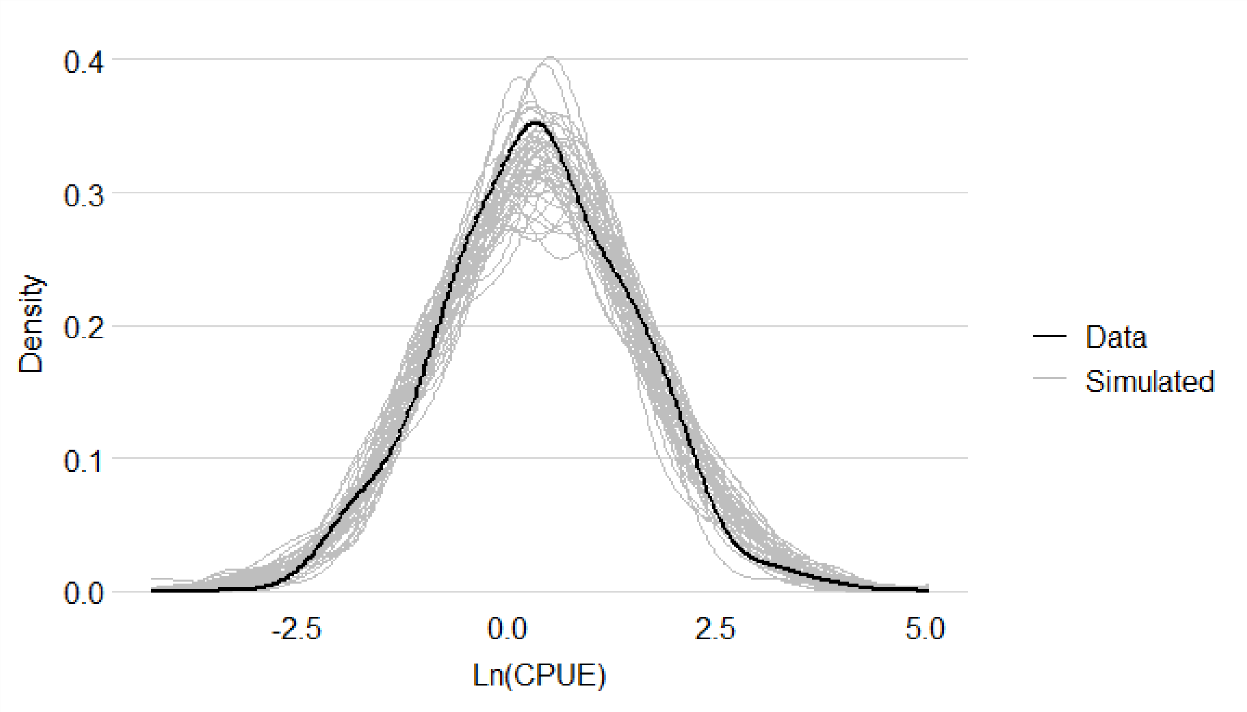


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *P. flavipinnis* CPUE standardization.

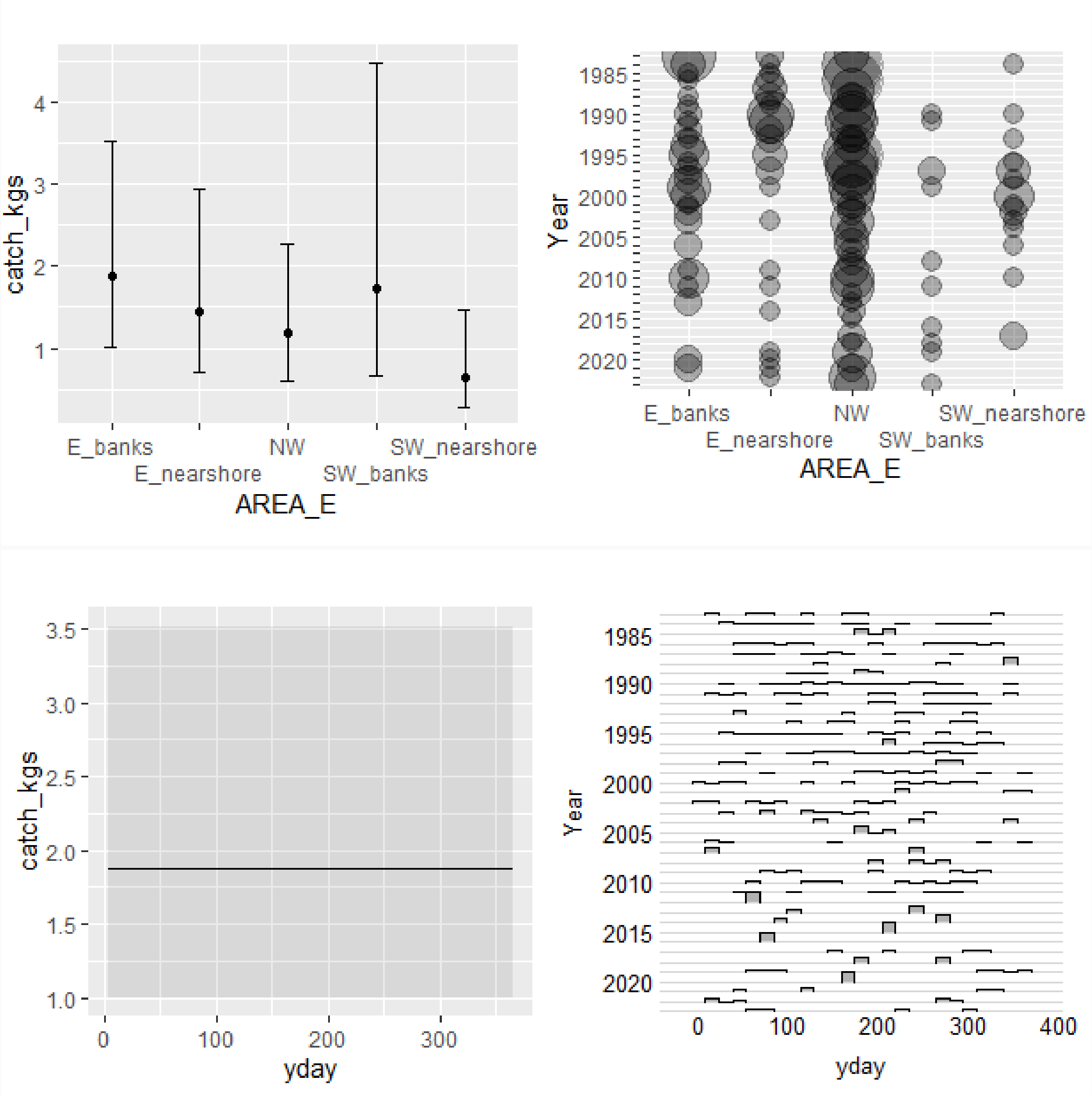


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *P. flavipinnis* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

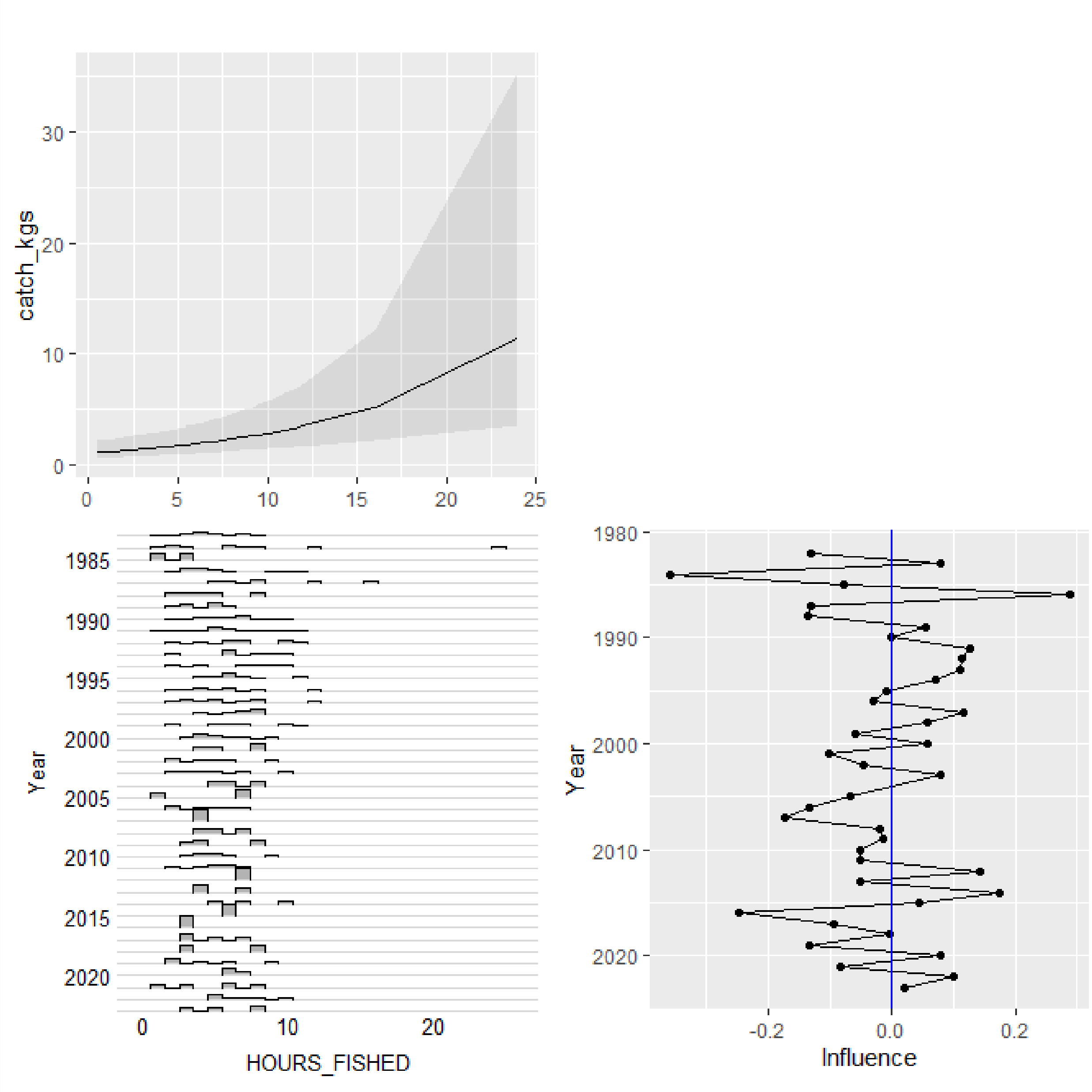


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *P. flavipinnis* CPUE standardization.

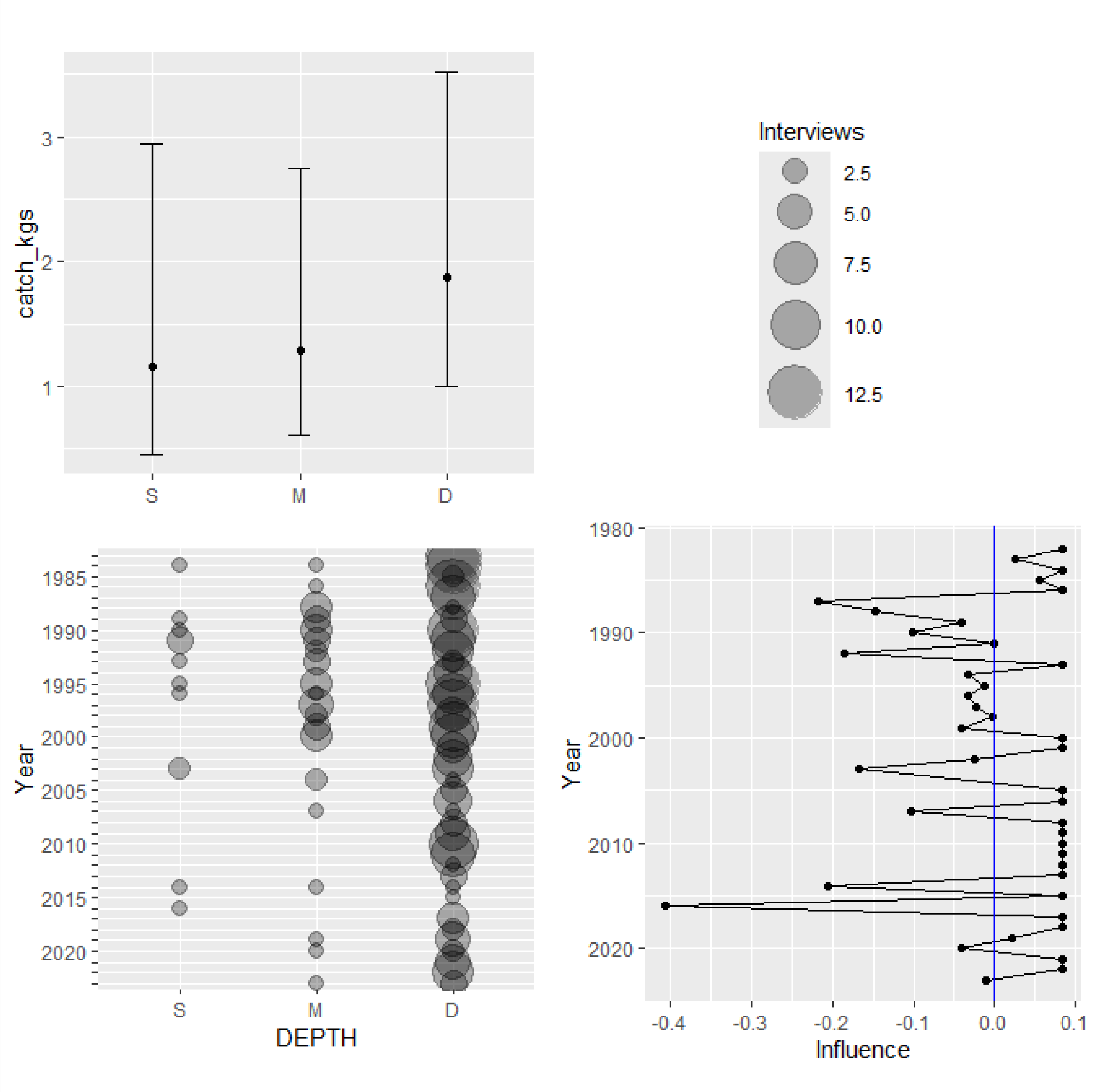


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on CPUE (kg per trip) in the *P. flavipinnis* CPUE standardization.

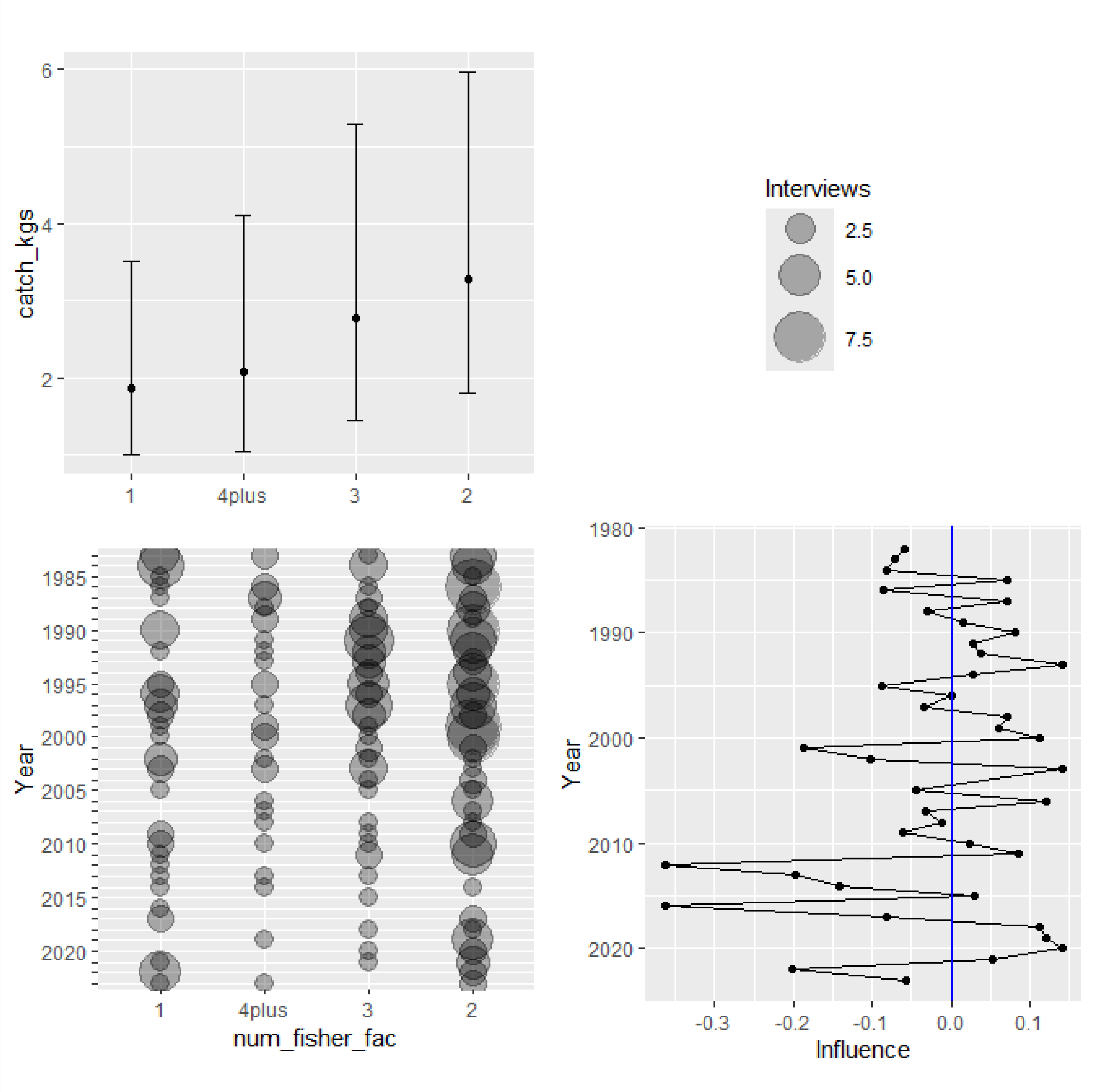


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (number of fishers) on CPUE (kg per trip) in the *P. flavipinnis* CPUE standardization.

Standardized CPUE Index

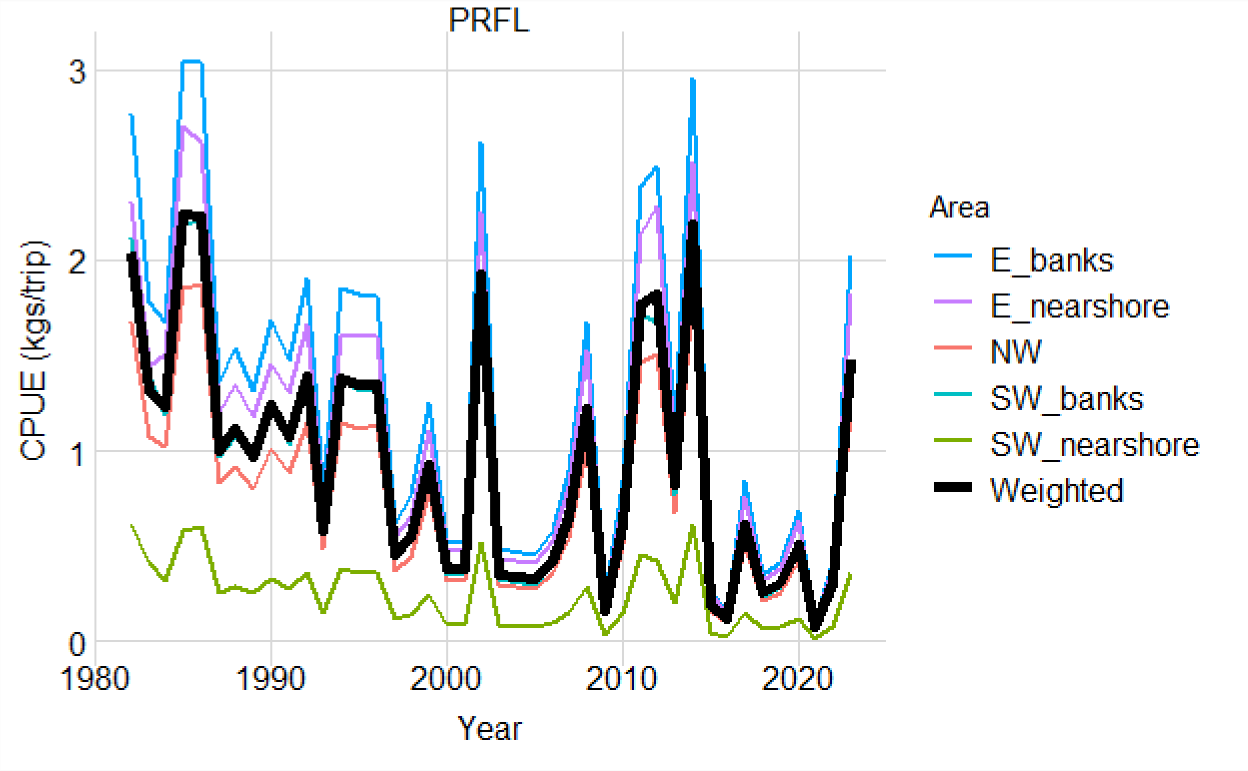


Figure 10. Standardized CPUE index (kg per trip) of *P. flavipinnis* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *P. flavipinnis*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	2.04	1.05	1996	1.35	0.68	2010	0.61	0.39
1983	1.31	0.63	1997	0.45	0.33	2011	1.76	1.14
1984	1.23	1.77	1998	0.55	0.31	2012	1.82	6.18
1985	2.24	1.26	1999	0.93	0.54	2013	0.82	0.95
1986	2.23	1.49	2000	0.38	0.39	2014	2.18	2.24
1987	1.00	0.84	2001	0.38	0.32	2015	0.19	0.75
1988	1.12	0.82	2002	1.92	1.22	2016	0.11	0.54
1989	0.97	0.51	2003	0.35	0.42	2017	0.62	0.65
1990	1.24	0.66	2004	---	---	2018	0.25	0.40
1991	1.08	0.70	2005	0.33	0.43	2019	0.30	0.24
1992	1.39	1.07	2006	0.42	0.35	2020	0.50	0.59
1993	0.58	0.46	2007	0.65	1.08	2021	0.07	0.07
1994	1.38	0.68	2008	1.22	1.45	2022	0.30	0.24
1995	1.34	0.87	2009	0.16	0.15	2023	1.47	1.42

Pristipomoides zonatus

Presence/Absence Model

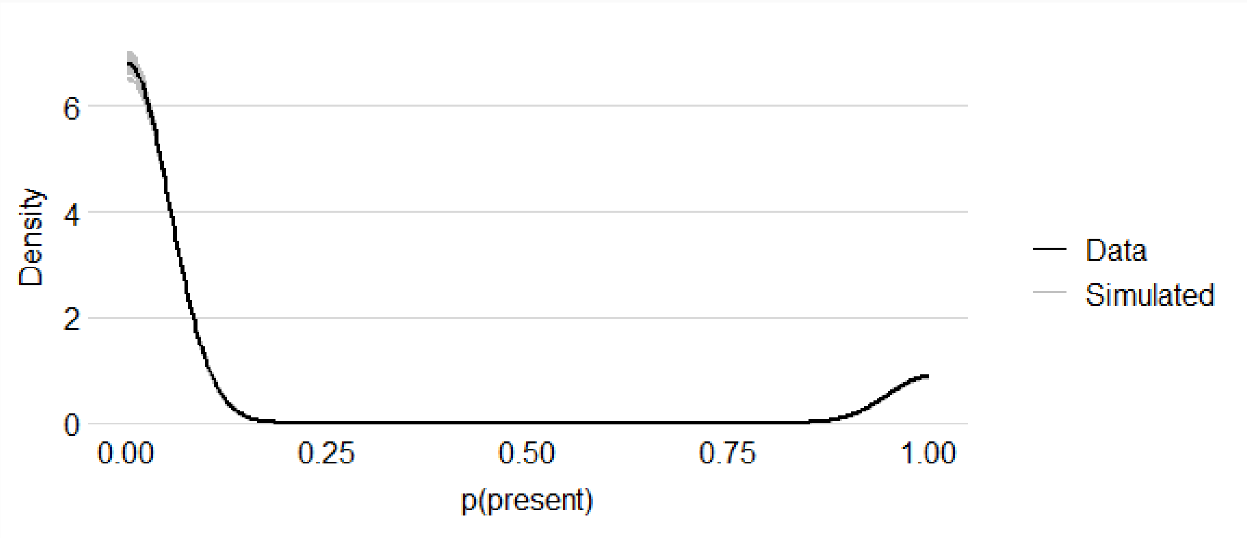


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *P. zonatus* CPUE standardization.

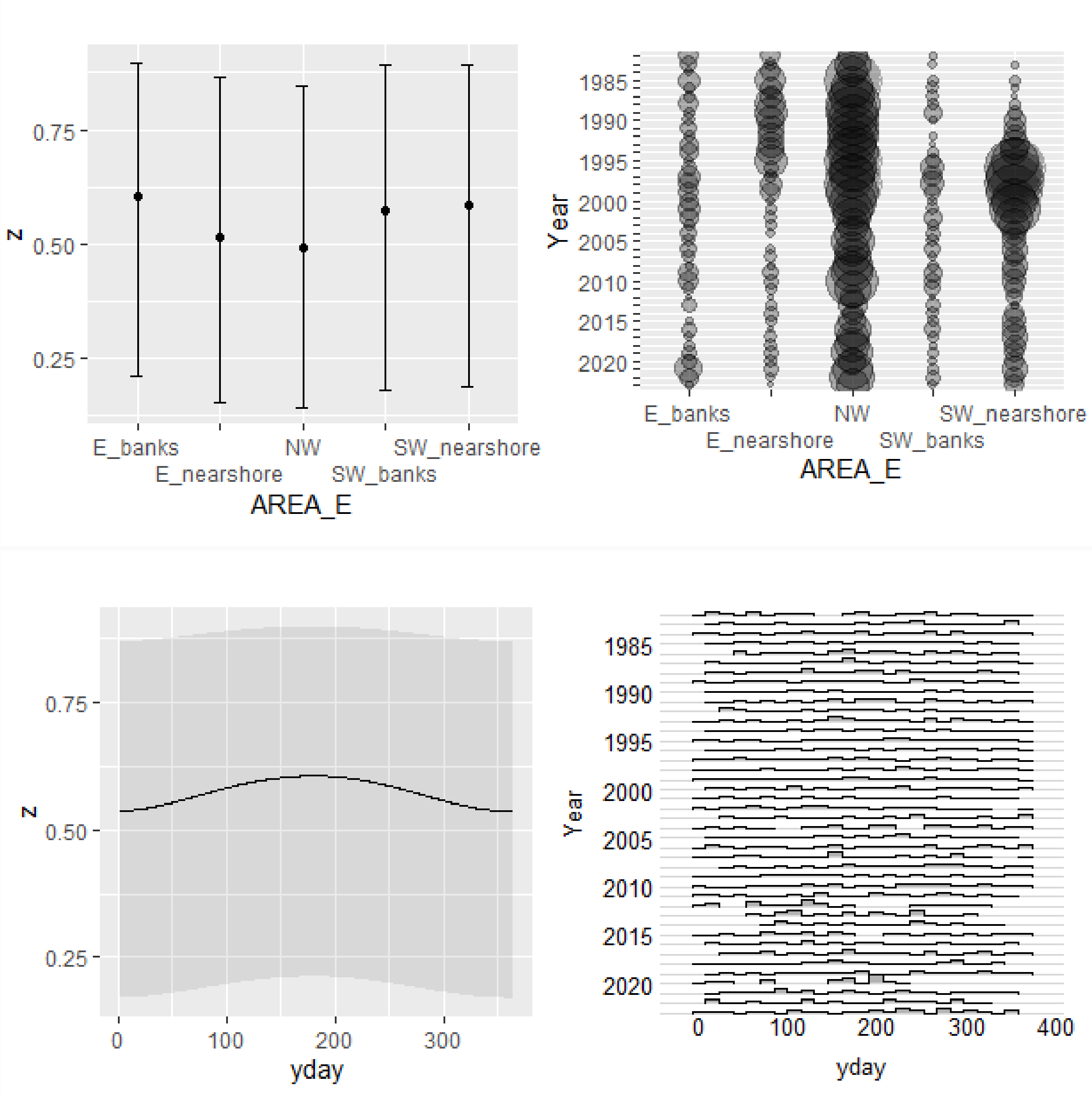


Figure 2. Partial effects of area and time of year on probability of presence in the *P. zonatus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

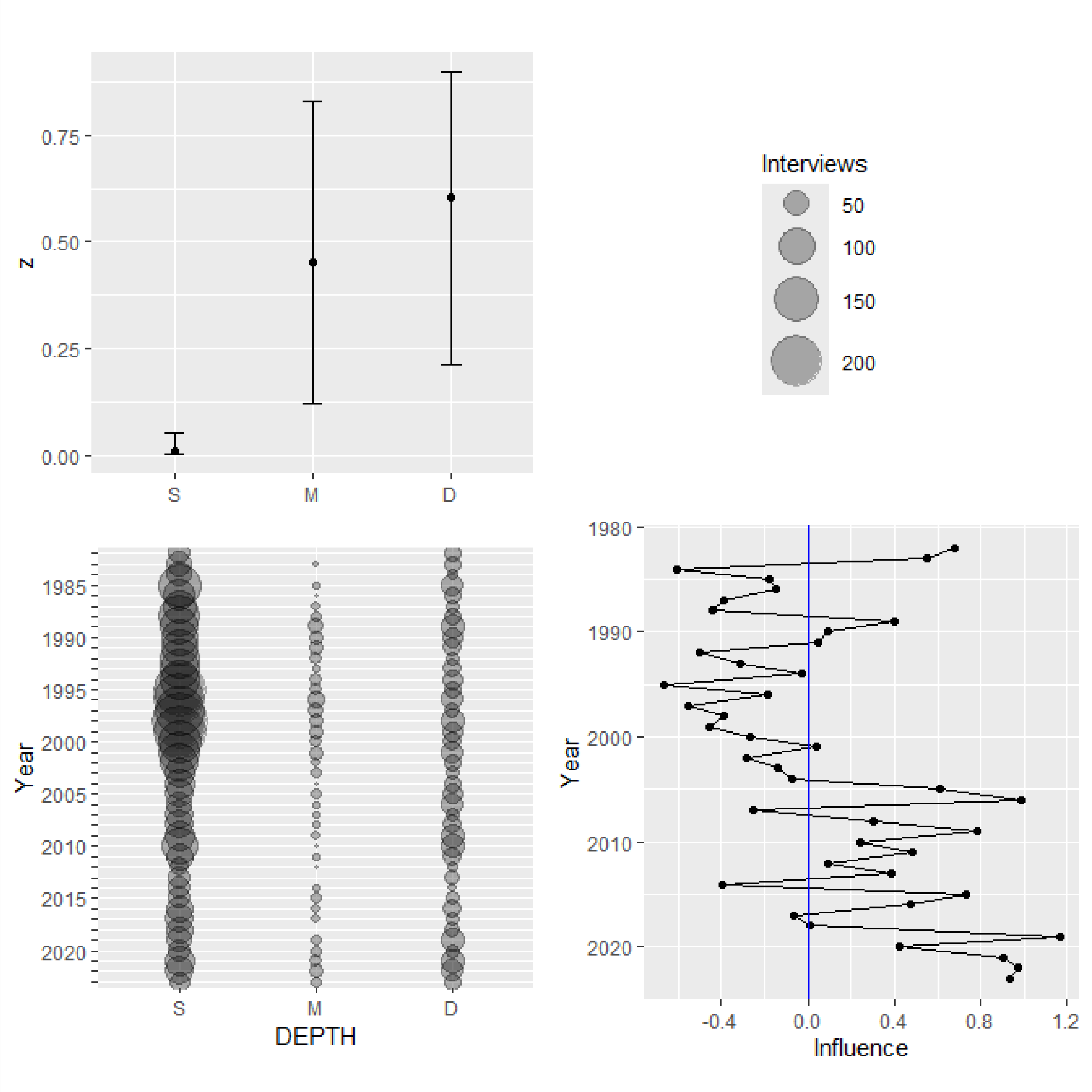


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *P. zonatus* CPUE standardization.

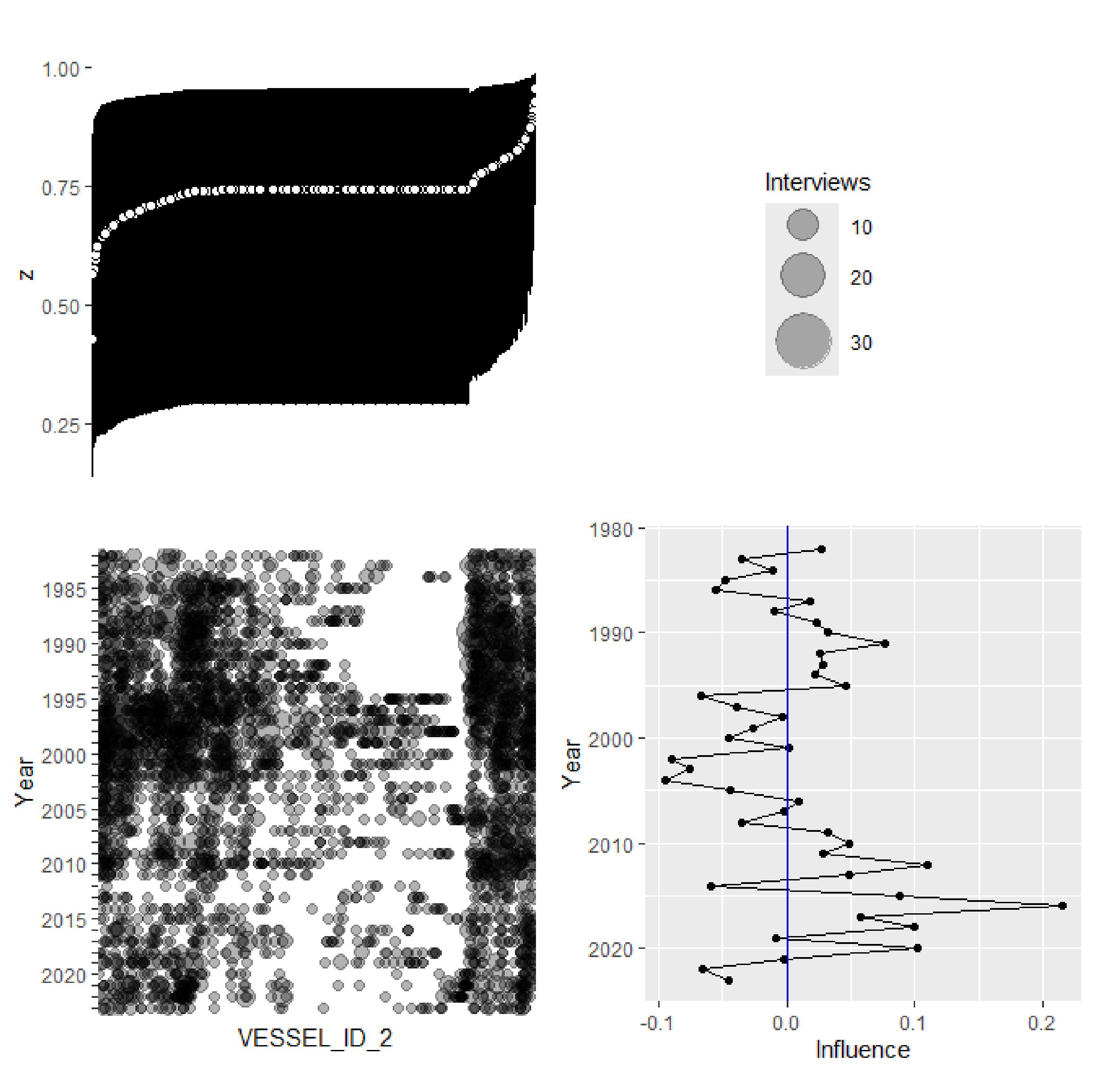


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *P. zonatus* CPUE standardization.

Positive Process Model

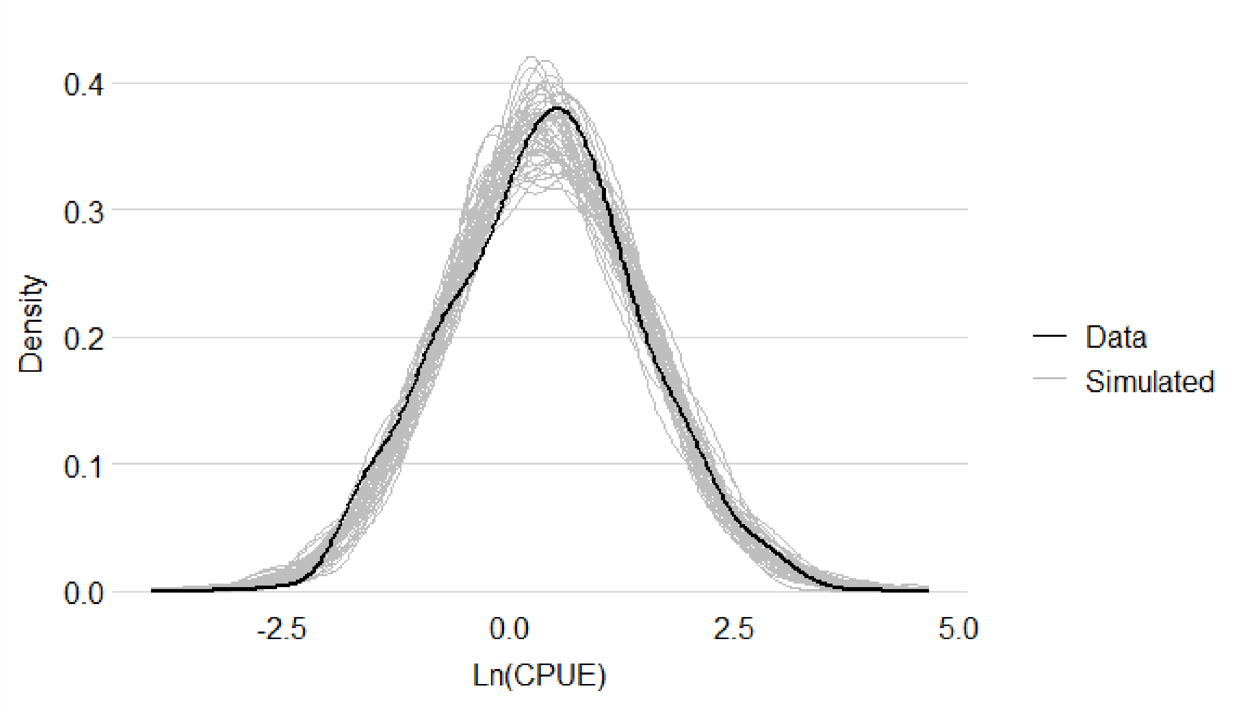


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *P. zonatus* CPUE standardization.

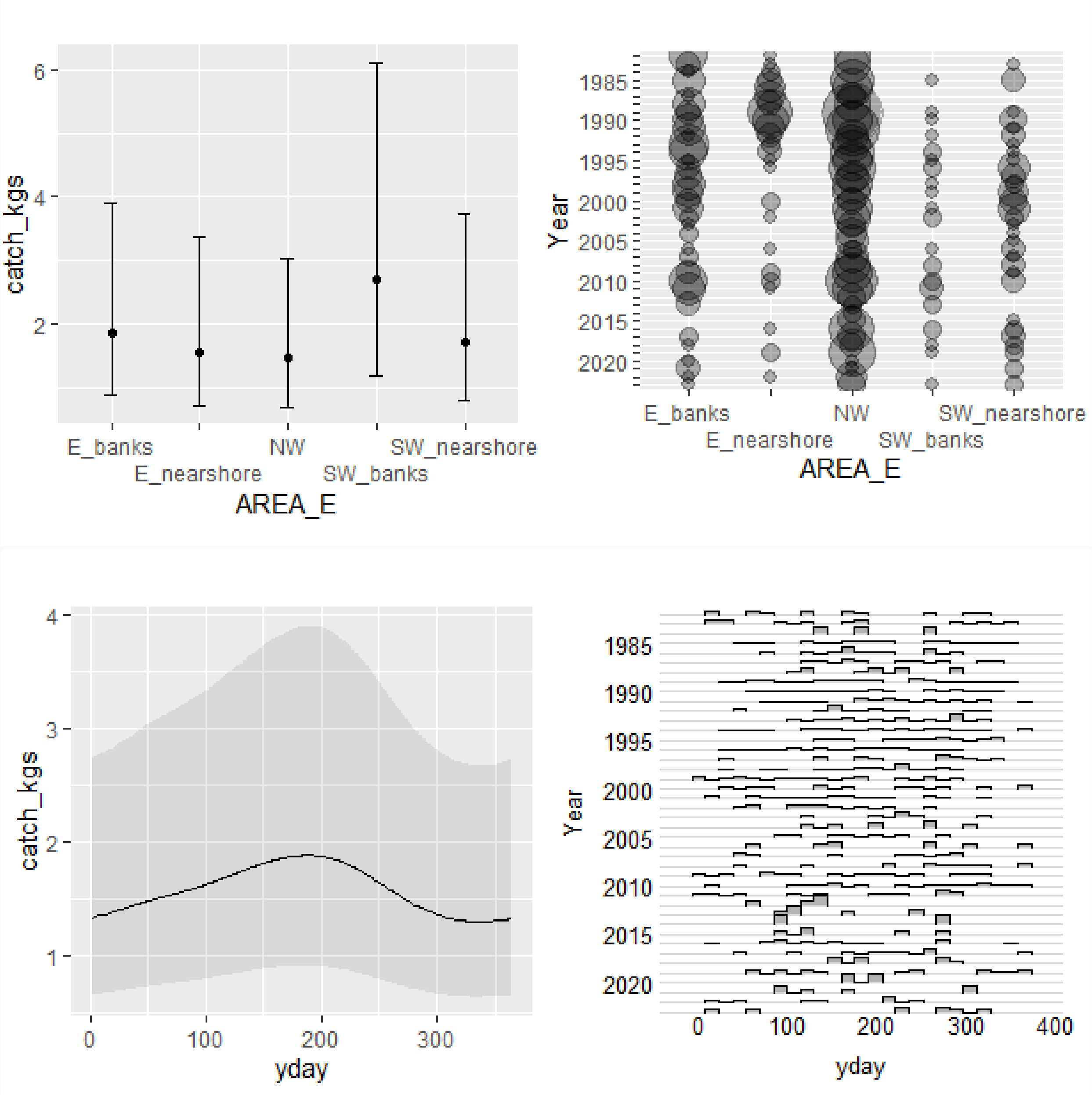


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *P. zonatus* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right). Error bars and the shaded ribbon represent the 95% confidence intervals.

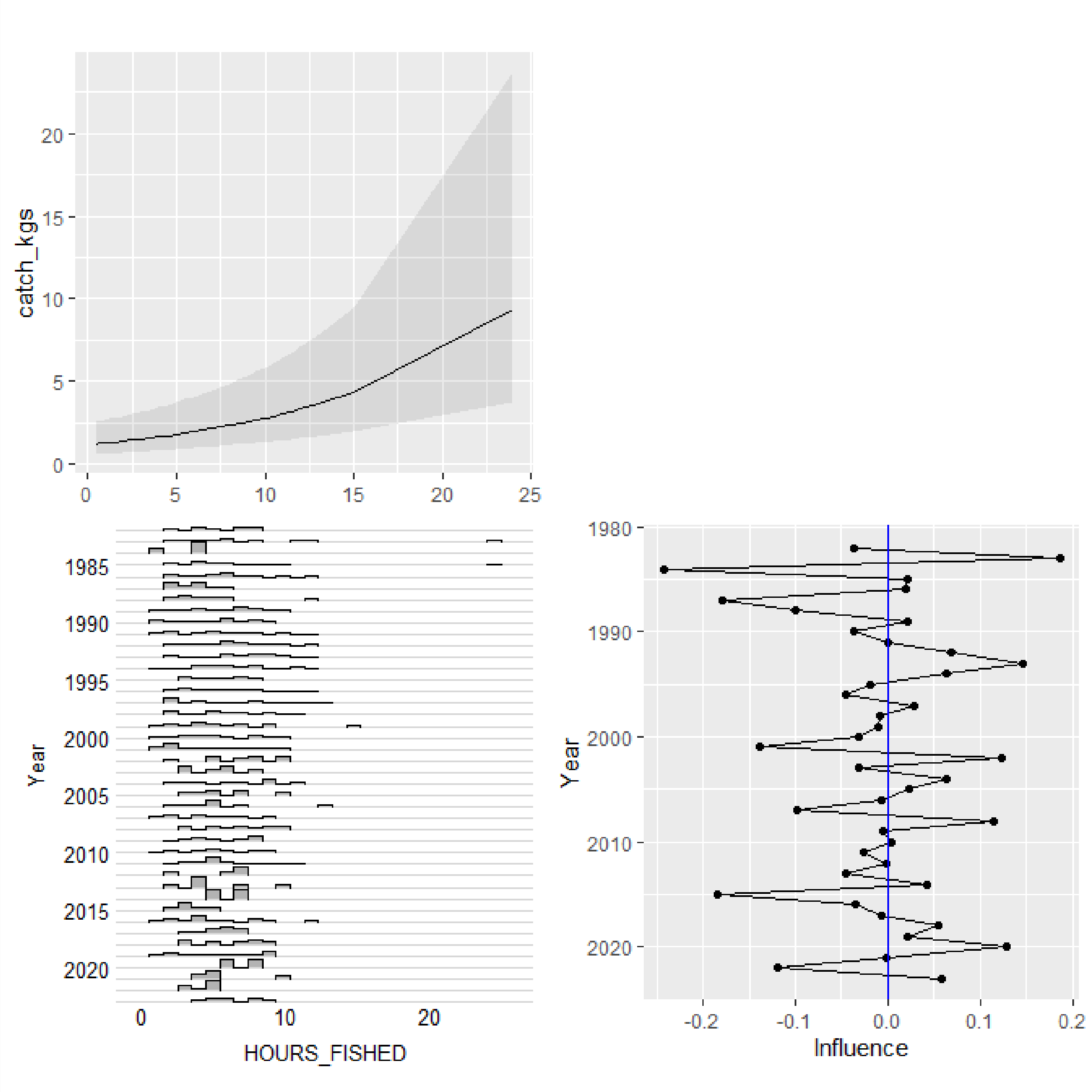


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *P. zonatus* CPUE standardization.

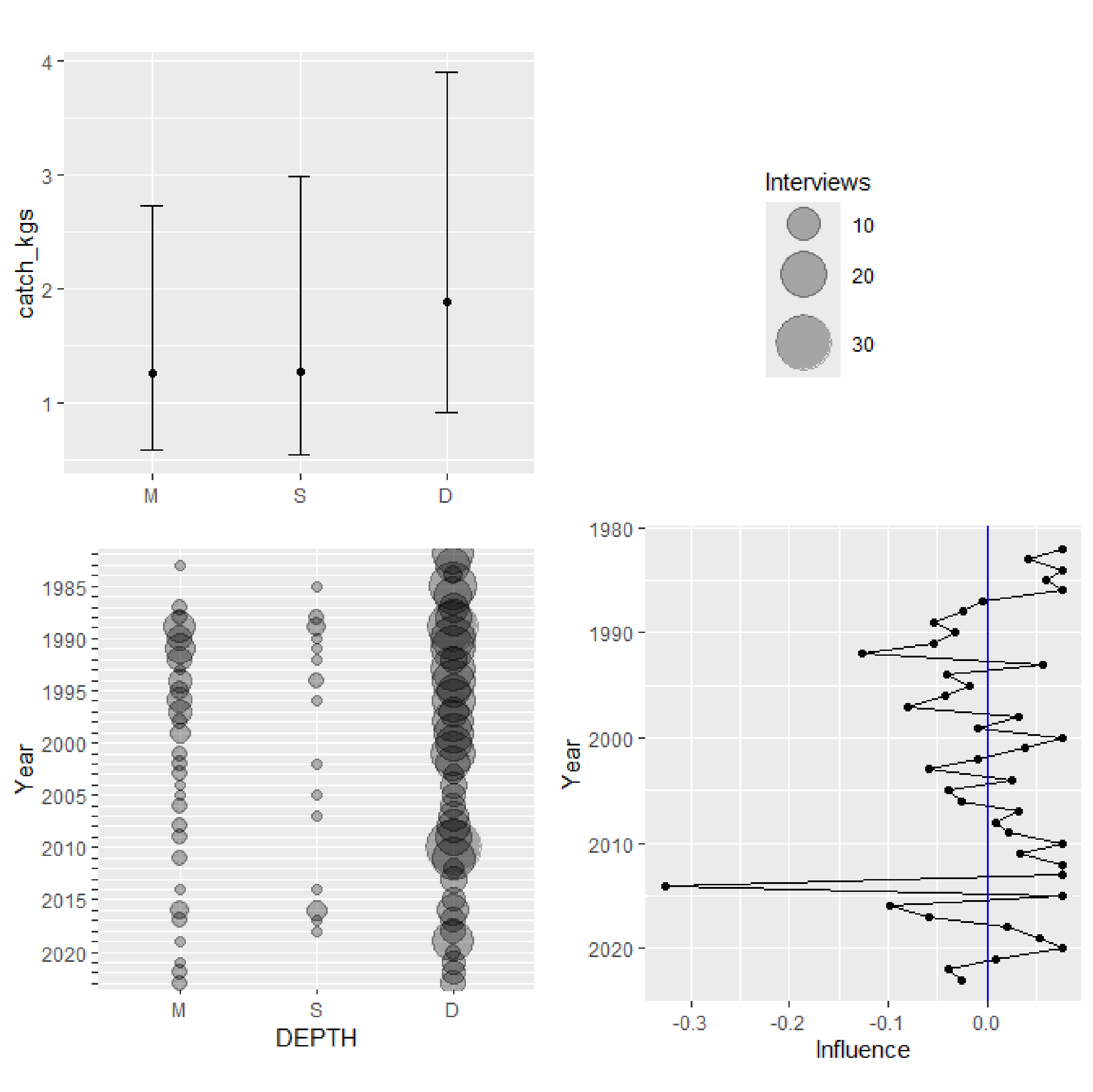


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on CPUE (kg per trip) in the *P. zonatus* CPUE standardization.

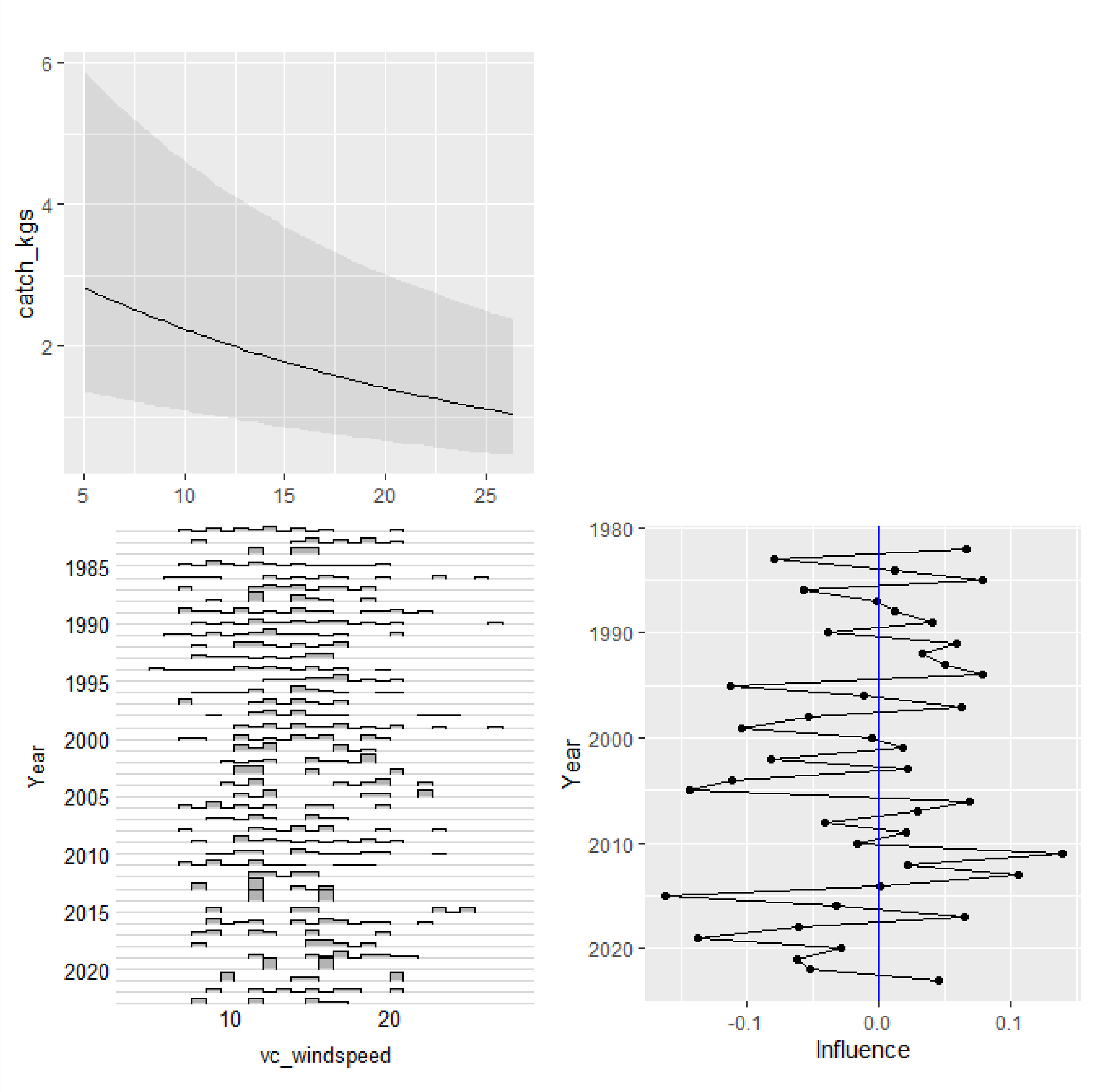


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of wind speed on CPUE (kg per trip) in the *P. zonatus* CPUE standardization.

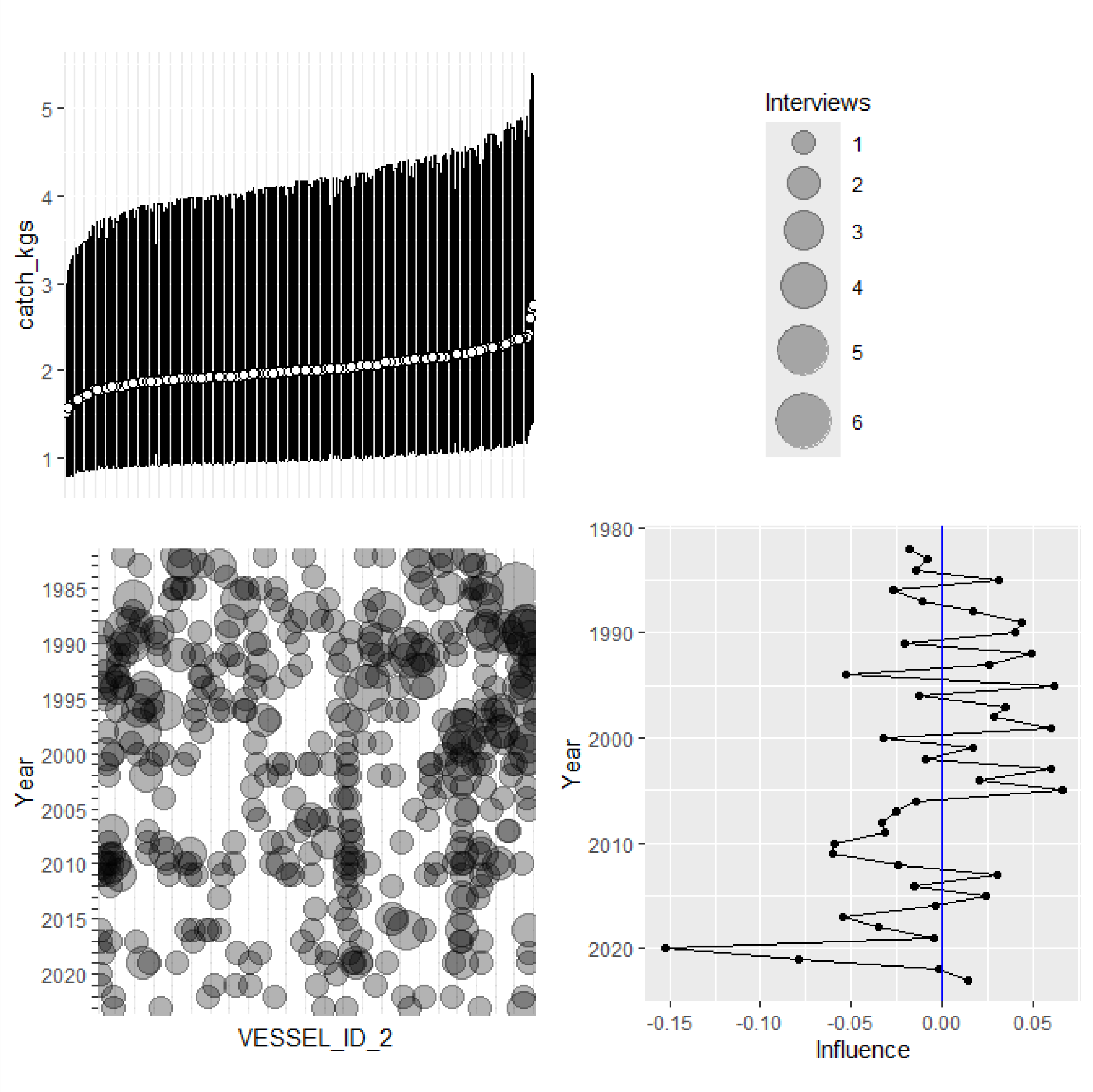


Figure 10. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on CPUE (kg per trip) in the *P. zonatus* CPUE standardization.

Standardized CPUE Index

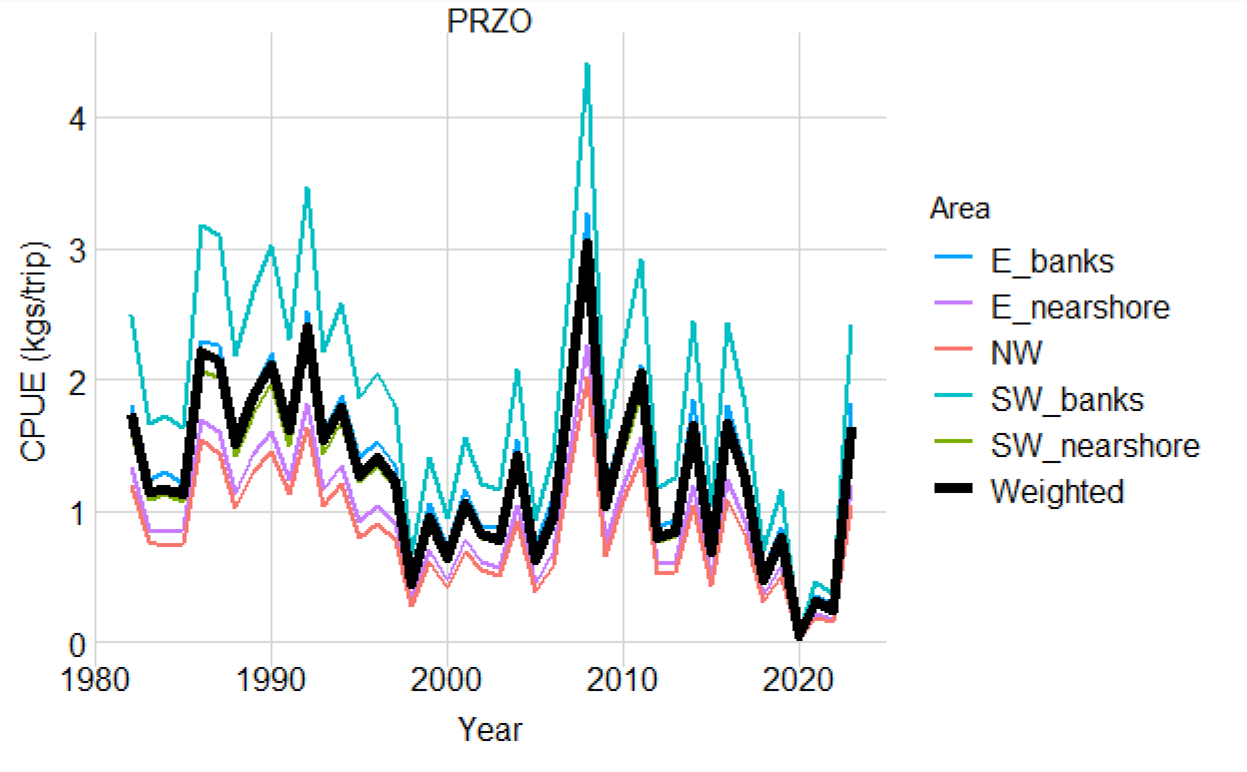


Figure 11. Standardized CPUE index (kg per trip) of *P. zonatus* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *P. zonatus*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	1.74	0.92	1996	1.40	0.85	2010	1.57	0.75
1983	1.15	0.73	1997	1.22	0.87	2011	2.05	1.02
1984	1.17	1.33	1998	0.44	0.36	2012	0.80	0.74
1985	1.14	0.62	1999	0.96	0.62	2013	0.85	0.68
1986	2.22	1.20	2000	0.65	0.48	2014	1.65	2.42
1987	2.14	1.35	2001	1.06	0.68	2015	0.69	0.79
1988	1.51	0.85	2002	0.83	0.51	2016	1.67	1.04
1989	1.88	0.86	2003	0.79	0.68	2017	1.24	0.84
1990	2.12	1.03	2004	1.42	1.06	2018	0.48	0.39
1991	1.62	0.76	2005	0.62	0.65	2019	0.80	0.53
1992	2.40	1.36	2006	0.97	0.98	2020	0.05	0.12
1993	1.54	0.82	2007	1.90	1.18	2021	0.31	0.43
1994	1.79	0.93	2008	3.04	1.88	2022	0.25	0.28
1995	1.26	0.93	2009	1.05	0.79	2023	1.64	1.31

Variola louti

Presence/Absence Model

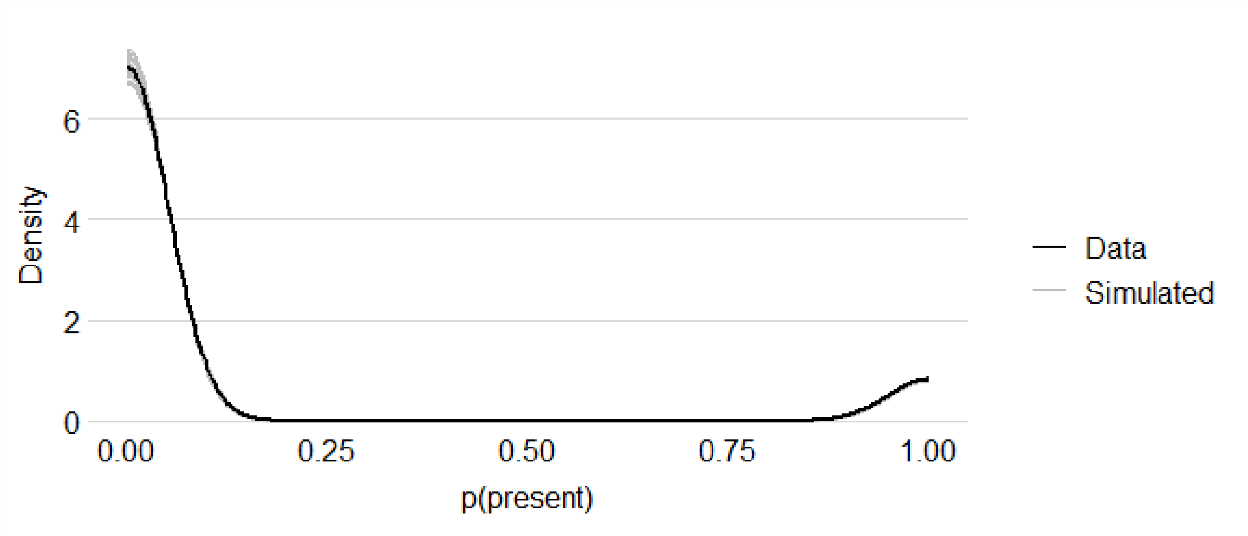


Figure 1. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) presence/absence for the *V. louti* CPUE standardization.

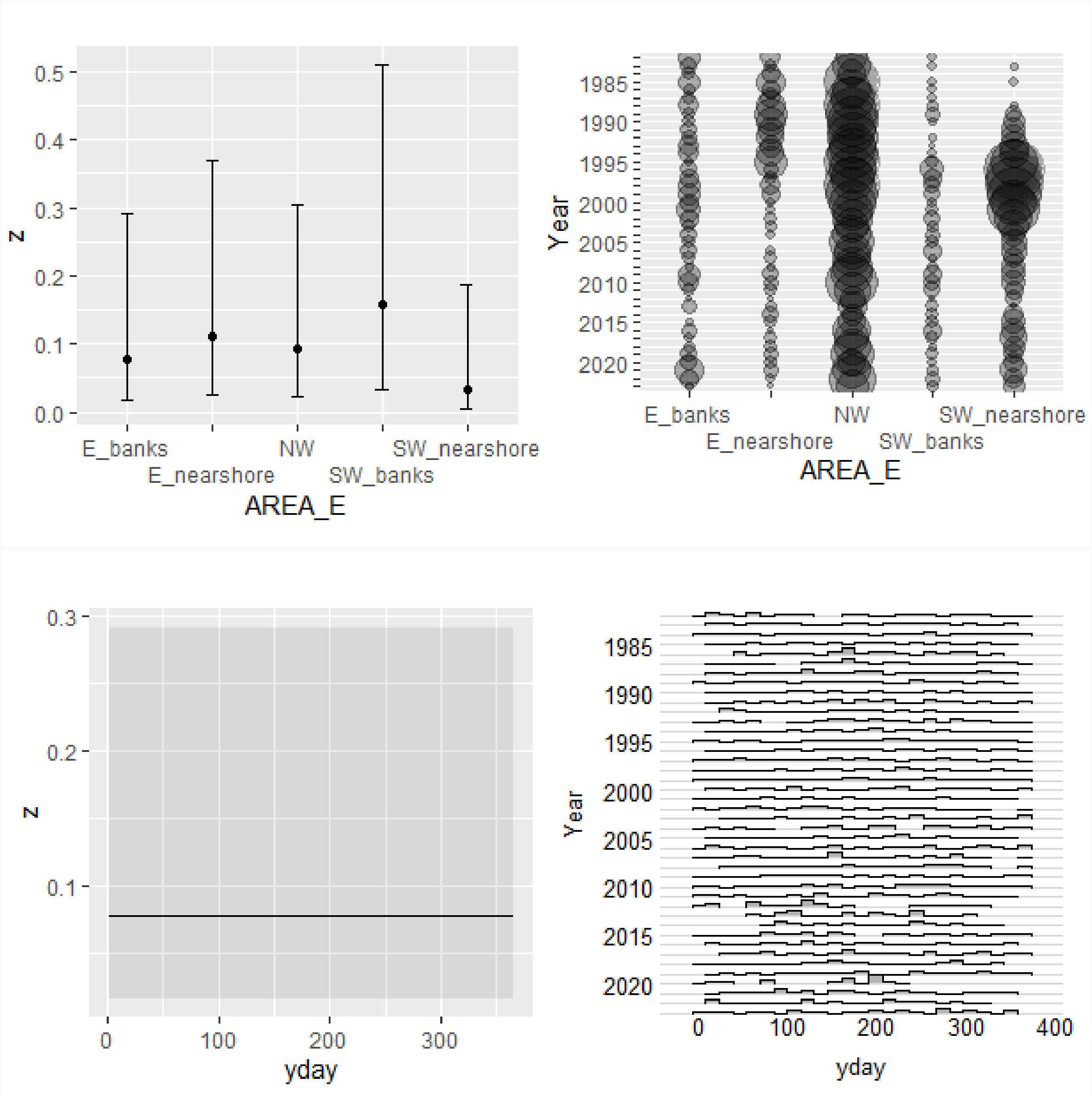


Figure 2. Partial effects of area and time of year on probability of presence in the *V. louti* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

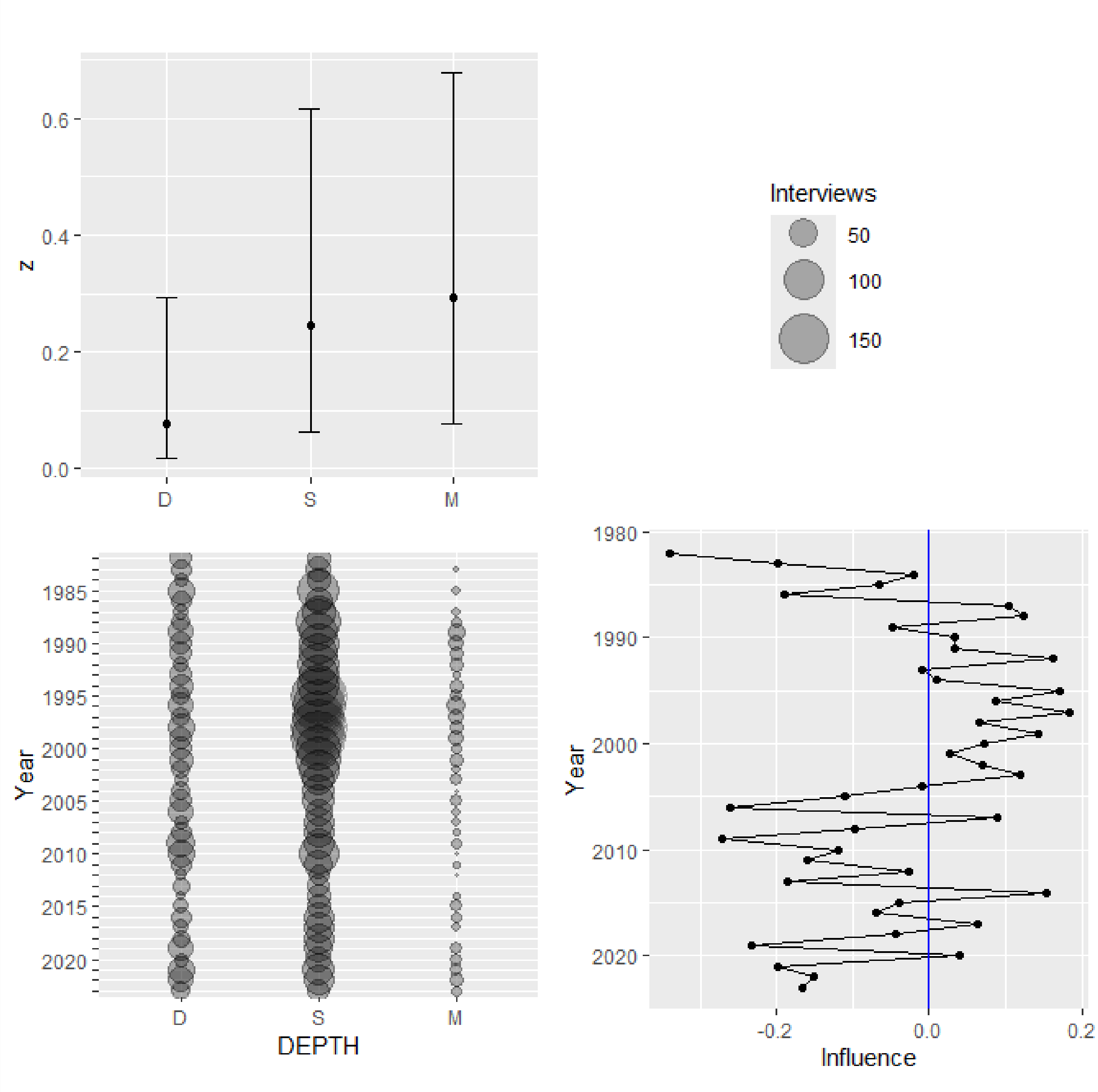


Figure 3. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of depth on probability of presence in the *V. louti* CPUE standardization.

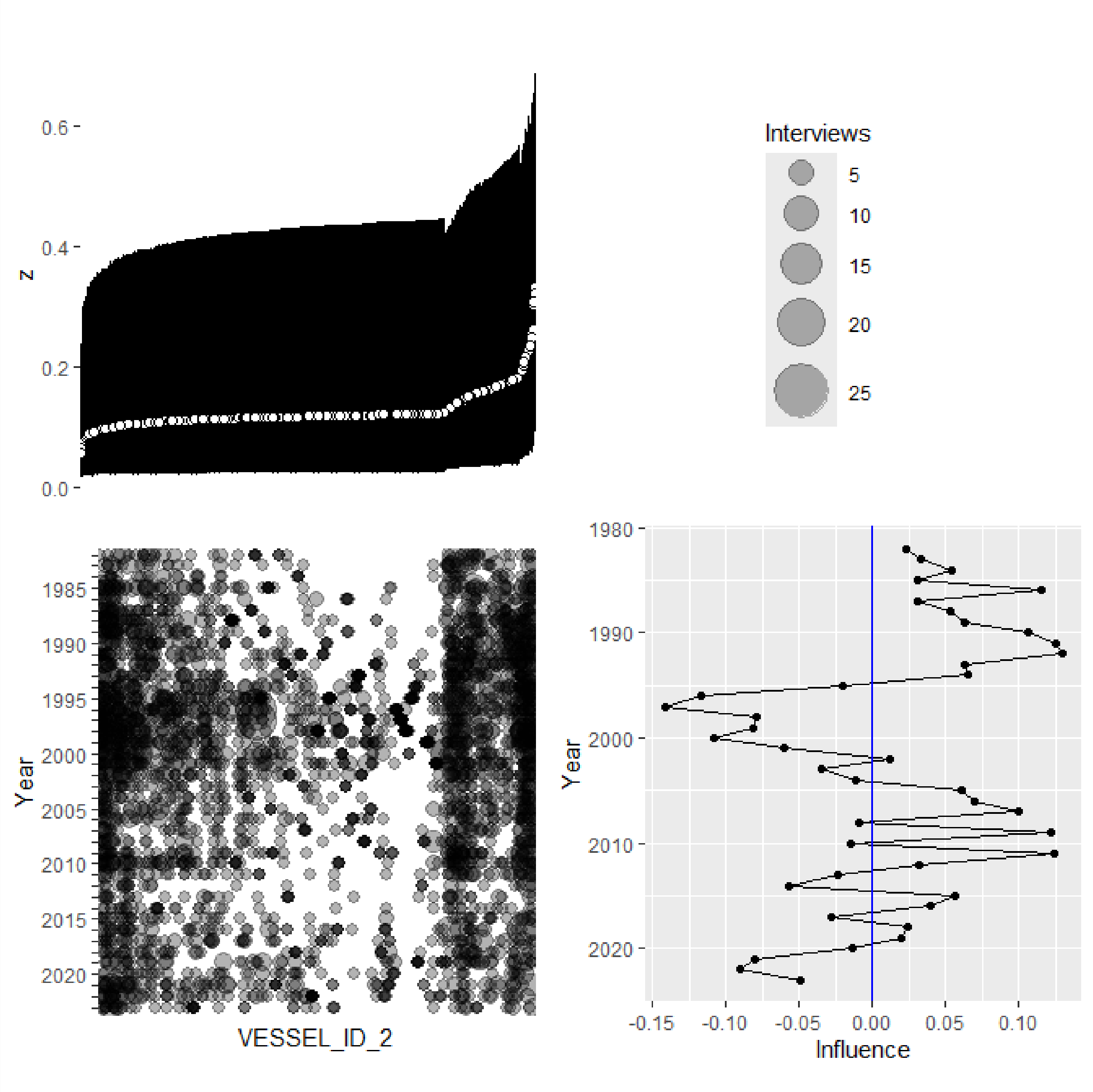


Figure 4. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of vessel on probability of presence in the *V. louti* CPUE standardization.

Positive Process Model

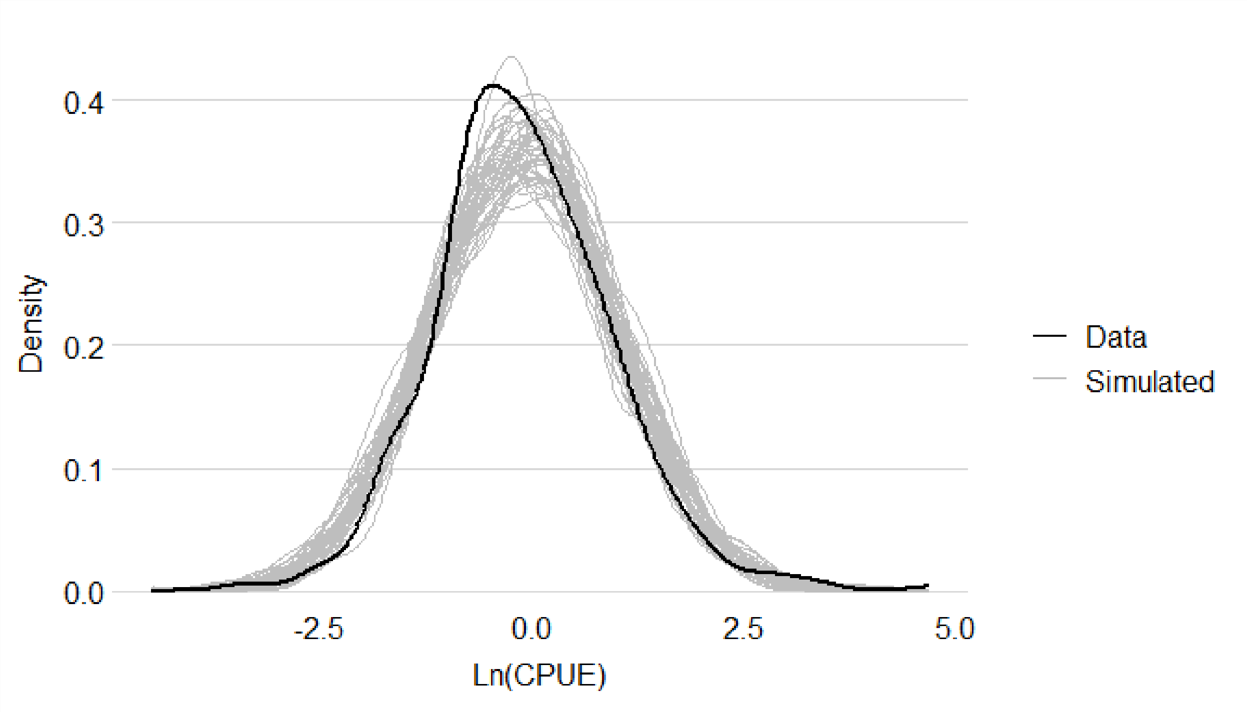


Figure 5. Density distributions of observed (black) and model-simulated (gray; 50 simulations shown) Ln(CPUE) for the *V. louti* CPUE standardization.

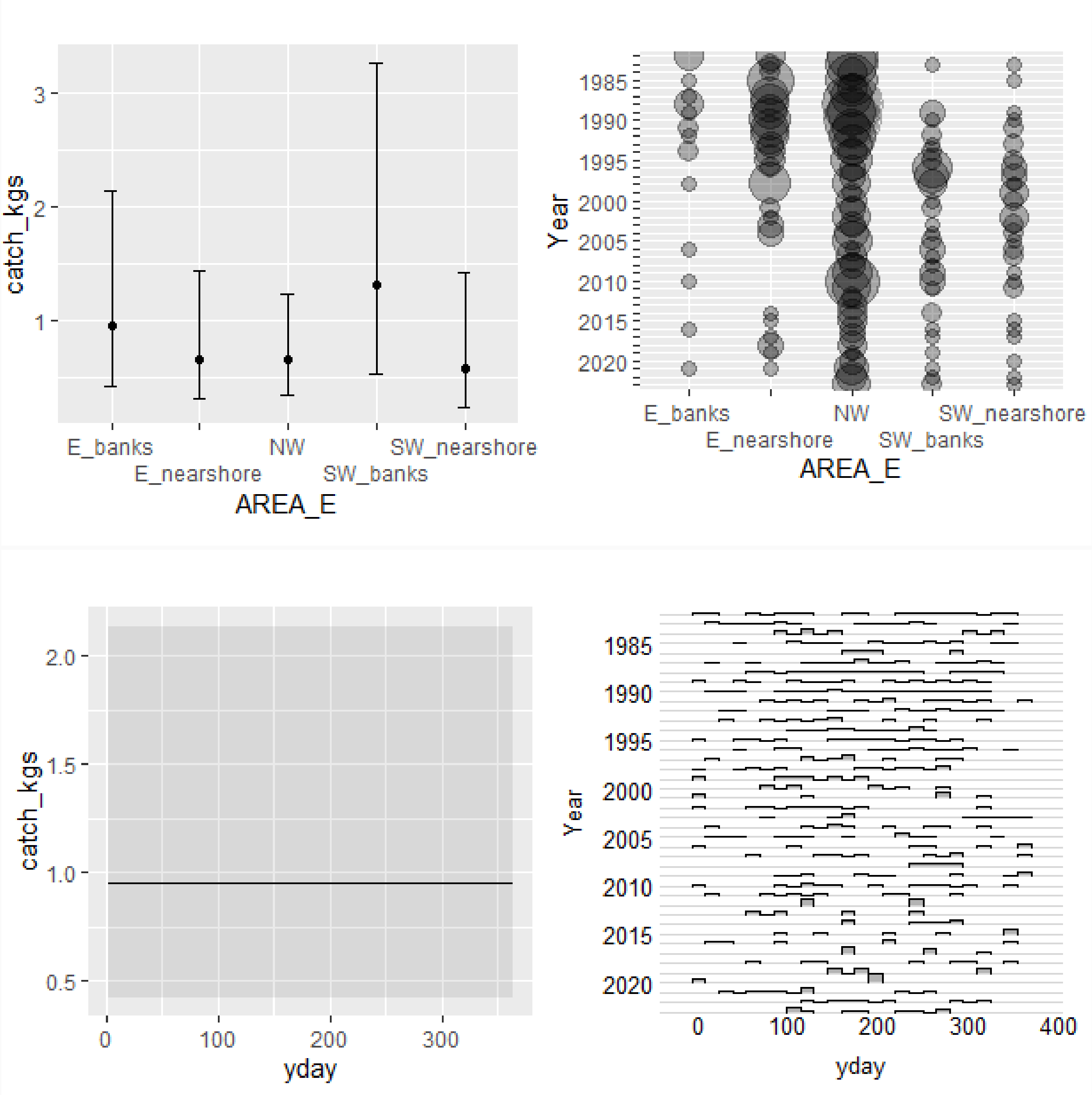


Figure 6. Partial effects of area and time of year on CPUE (kg per trip) in the *V. louti* CPUE standardization (left) and relative number of interviews by area and time of year 1982–2023 (right).

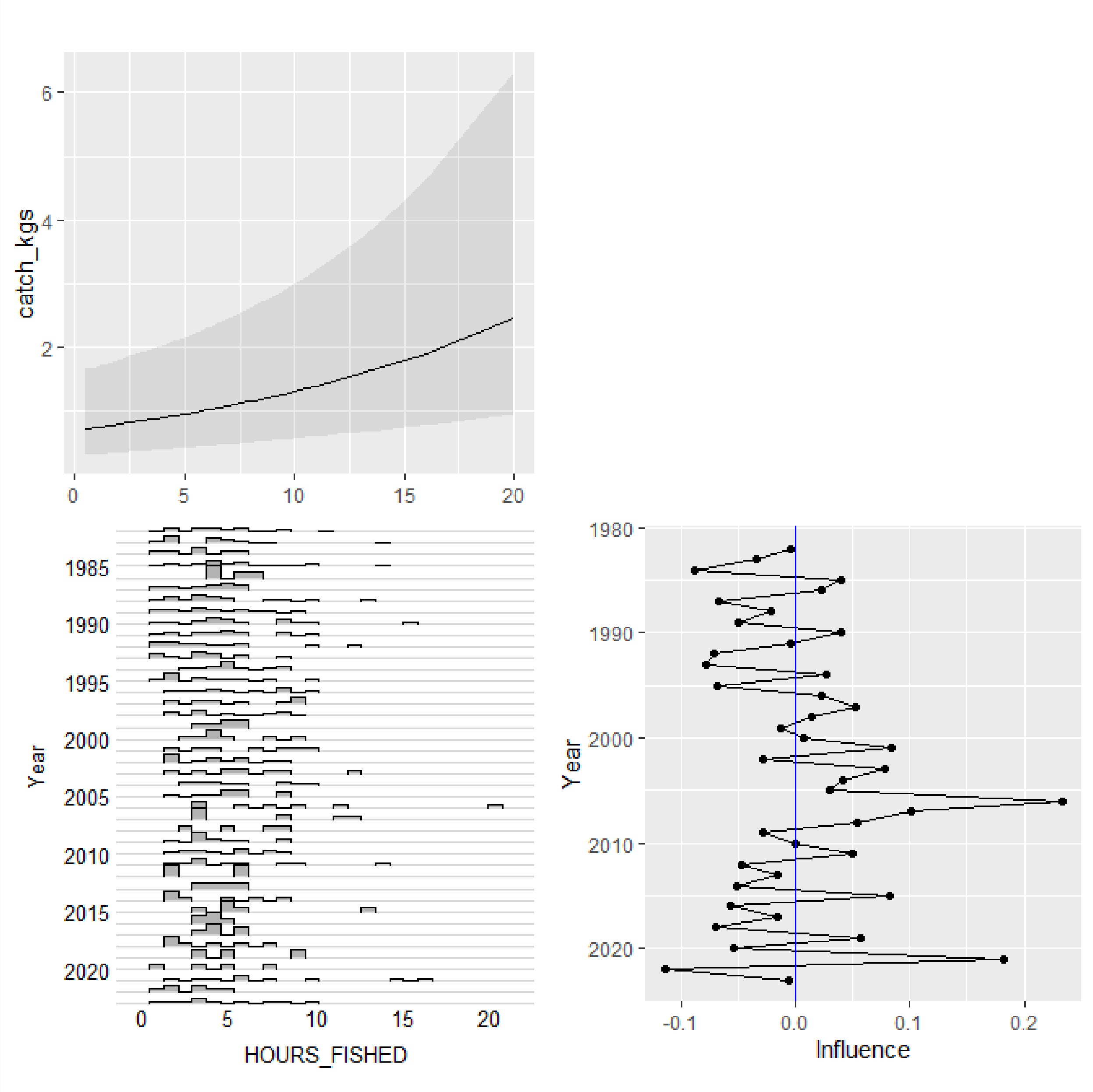


Figure 7. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (hours fished) on CPUE (kg per trip) in the *V. louti* CPUE standardization.

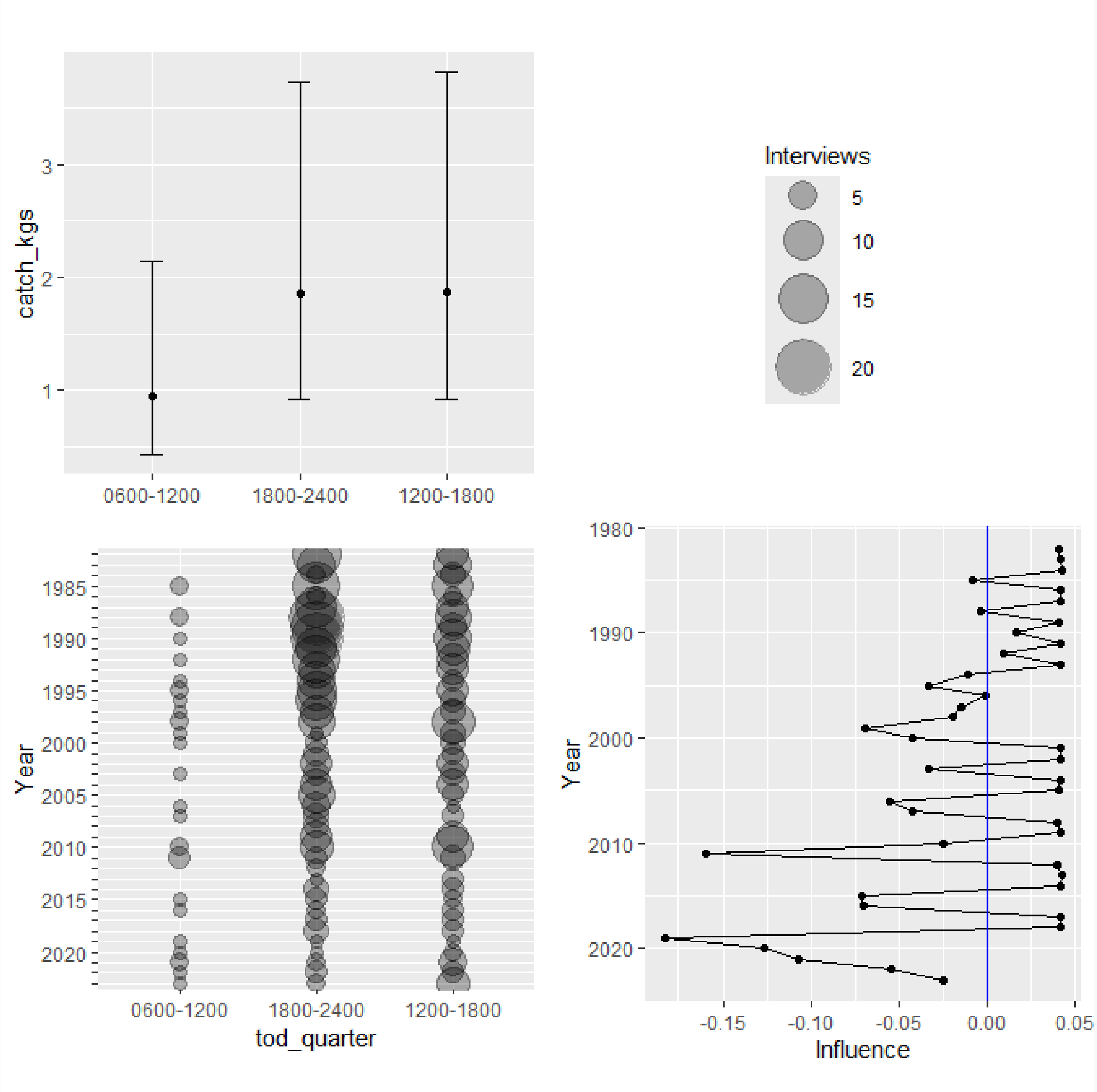


Figure 8. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of time of day on CPUE (kg per trip) in the *V. louti* CPUE standardization.

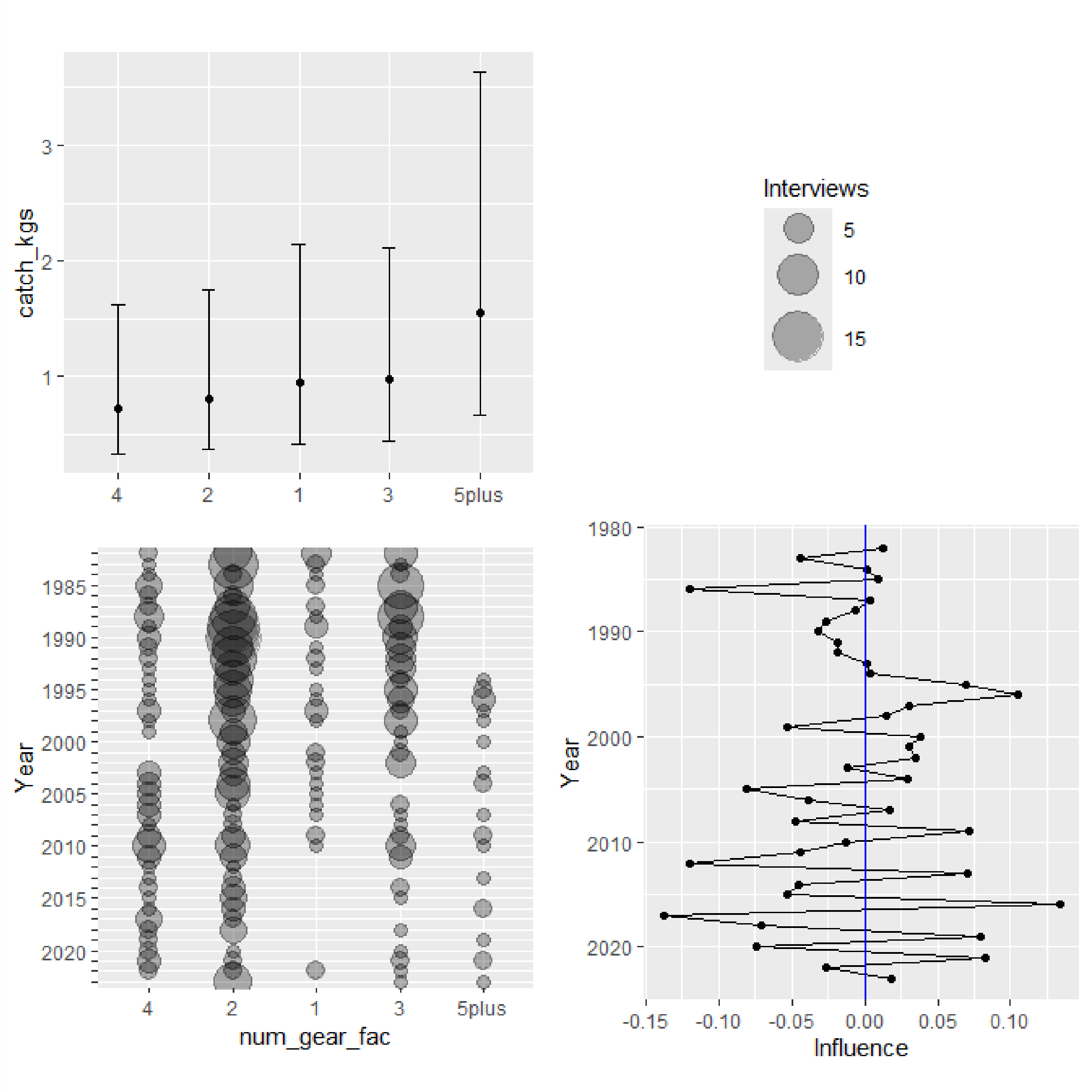


Figure 9. Partial effects (top left), number of observations (bottom left), and relative influence (bottom right) of effort (number of gears) on CPUE (kg per trip) in the *V. louti* CPUE standardization.

Standardized CPUE Index

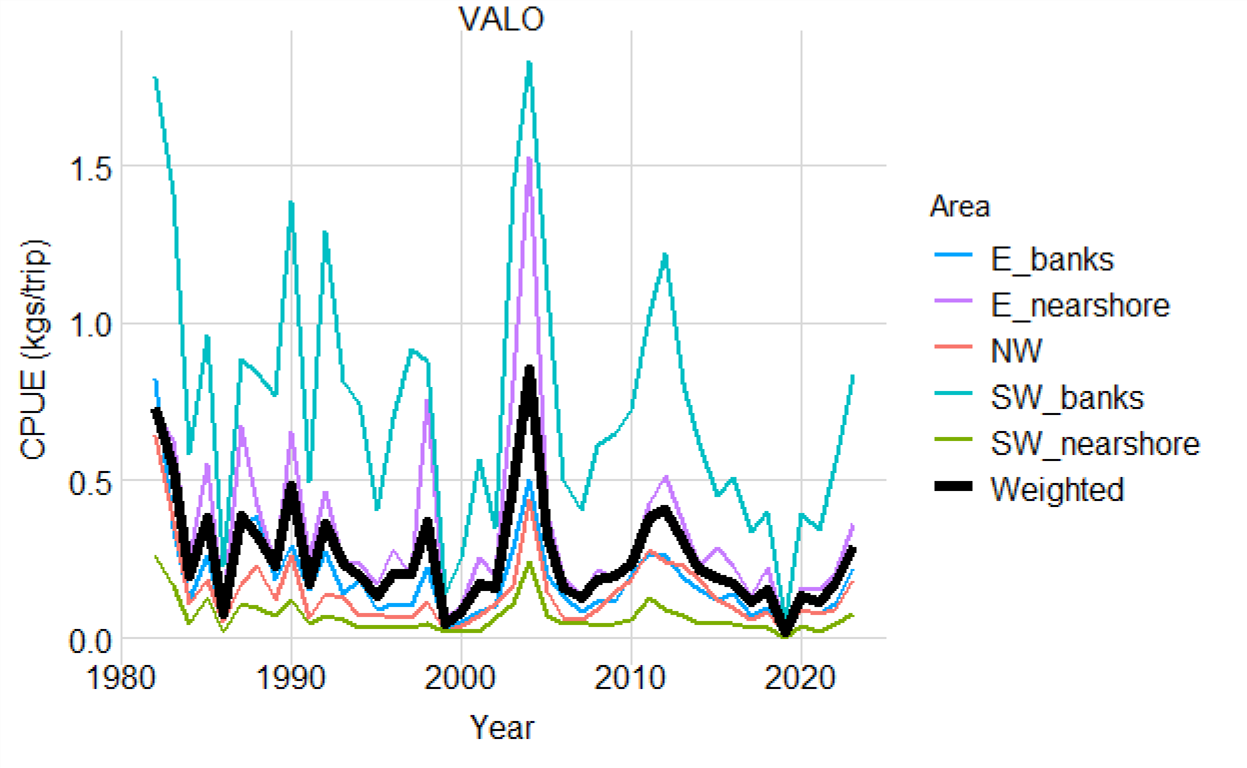


Figure 10. Standardized CPUE index (kg per trip) of *V. louti* by area and weighted by habitat extent.

Table 1. Standardized CPUE index (kg per trip) and standard deviation (sd) of *V. louti*.

Year	CPUE	sd	Year	CPUE	sd	Year	CPUE	sd
1982	0.73	0.45	1996	0.20	0.15	2010	0.24	0.19
1983	0.54	0.36	1997	0.20	0.18	2011	0.38	0.37
1984	0.20	0.23	1998	0.37	0.23	2012	0.41	0.85
1985	0.38	0.28	1999	0.05	0.07	2013	0.30	0.44
1986	0.08	0.13	2000	0.08	0.09	2014	0.22	0.20
1987	0.39	0.29	2001	0.17	0.17	2015	0.19	0.21
1988	0.33	0.26	2002	0.16	0.16	2016	0.17	0.21
1989	0.23	0.17	2003	0.49	0.42	2017	0.11	0.13
1990	0.49	0.32	2004	0.85	0.66	2018	0.15	0.15
1991	0.17	0.13	2005	0.32	0.29	2019	0.02	0.03
1992	0.36	0.26	2006	0.16	0.16	2020	0.14	0.20
1993	0.23	0.20	2007	0.13	0.13	2021	0.12	0.11
1994	0.20	0.17	2008	0.18	0.26	2022	0.17	0.20
1995	0.13	0.12	2009	0.20	0.19	2023	0.29	0.21