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Annex 3: Working document 7 for ple.27.21-32 presented at WKBPLAICE

Survey indices for Plaice in ICES areas 21-32.

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October 8, 2024

1 Summary

This document compares nine age-based survey indices for plaice in ICES areas 21-32 in connection with the benchmark of this stock. Several surveys (BITS Q1 and Q4, NS-IBTS Q1 and Q3, and the Cod survey in Q4)) are considered. Various gears are used in the surveys, which means gear effects must be considered. Delta-GAM models are used for estimating gear effects and standardized indices of abundance by age. All indices considered show quite similar trends and have high internal and external consistencies indicating good and consistent cohort tracking. The proposed model (base.noDTU70noShip), has the highest average internal and external consistencies of all models.

2 Data

Five trawl surveys are considered:

- BITS Q1 (TVS and TVL gear)
- BITS Q4 (TVS and TVL gear)
- NS-IBTS Q1 (GOV gear)
- NS-IBTS Q3 (GOV gear)
- Danish-Swedish Cod survey (DTU70 gear)

Estimation of gear and ship effects is challenging for this stock because of limited spatio-temporal overlap between the gears/ships and because systematic differences the in spatial distribution of plaice coincide with spatial distribution of gear types. The TVS gear is mostly used in areas with depths less than 50 meters, whereas the TVL and GOV gears sample more at depths greater than 50 meters. Juvenile plaice are more abundant at shallower depths, which means a model containing coefficients for conversion between TVS/TVL/GOV may erroneously explain the higher number of juveniles in TVS samples (partly) by the gear effect rather than the spatial effect. Also, the abundance of plaice is lower in the eastern part of the stock area where the TVL gear is used, which also may confound the gear and spatial effects in the models. The TVS gear is a smaller version of the TVL, so it is reasonable to assume that the expected catch per minute trawled scales with the width of the gear (DoorSpread). The GOV gear has approximately the same DoorSpread as the TVL gear, so similarly we may assume that the GOV gear has the same catchability as the TVL gear. The DTU70 gear used in the Cod survey is a commercial fishing gear with larger mesh sizes, so catchability for this gear cannot be assumed the same as the other gear types. The spatio-temporal overlap between the DTU70 gear and TVS/GOV is however much better so the DTU70 gear effect can be more reliably estimated.

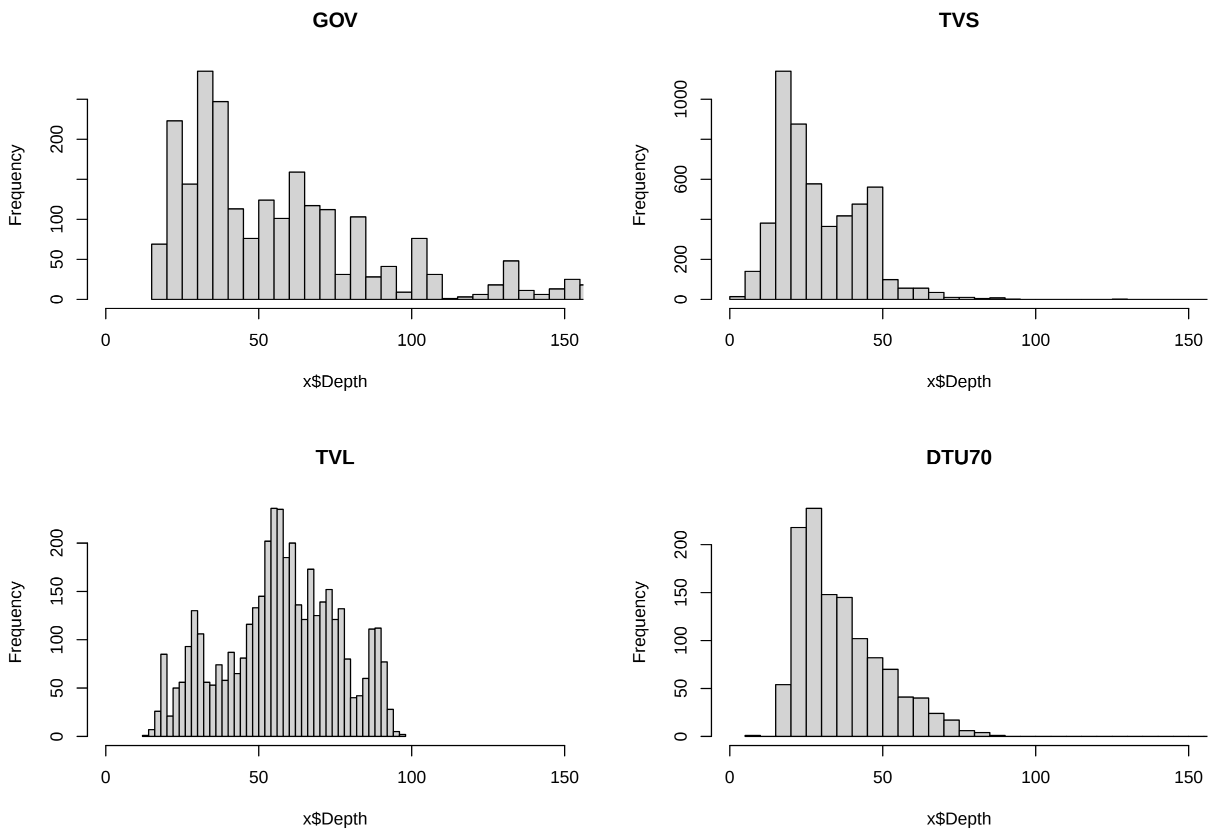


Figure 1: Distribution of sampling depths by gear.

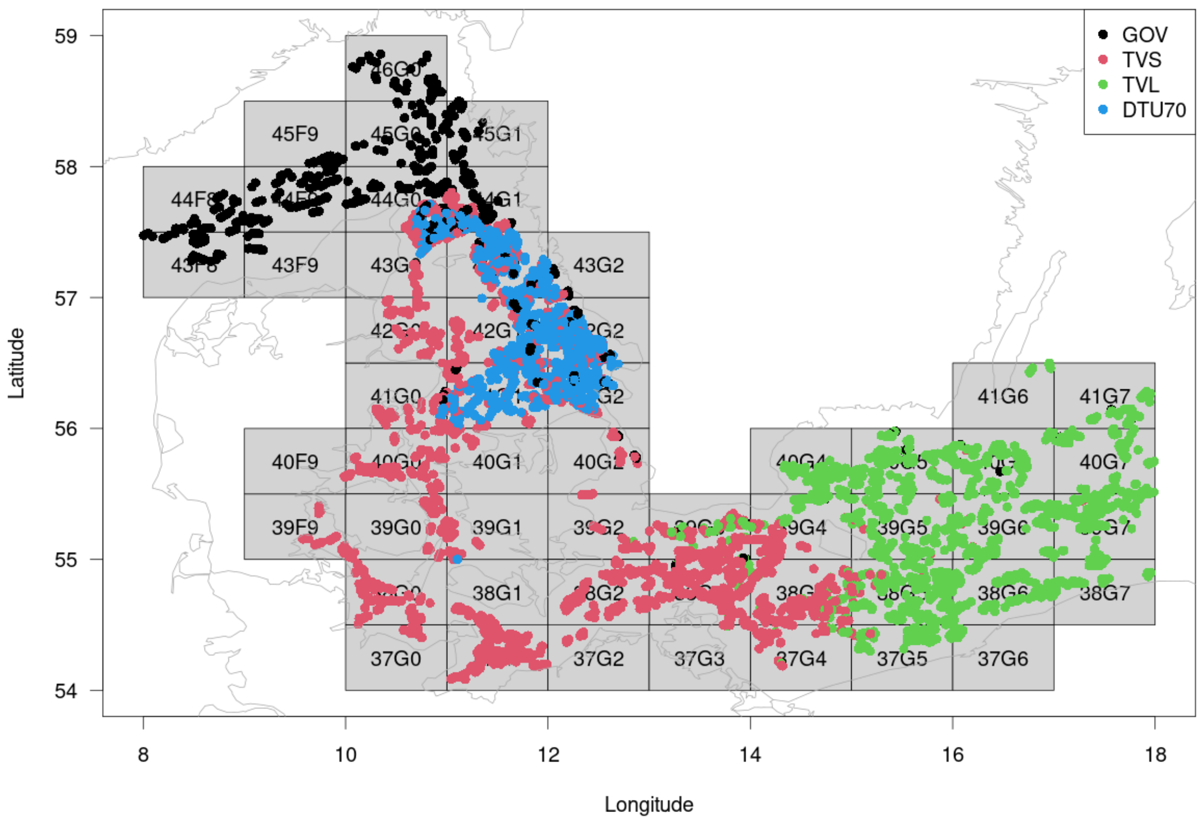


Figure 2: Hauls by gear type

3 Survey Index Models

Nine Delta-GAM models are considered and compared. The methodology is described in [2], except we consider model formulas with space-time interactions here. Briefly, we model numbers-at-age converted from numbers-at-length using smooth anually and spatially varying age-length keys ([1]). Each age-group is modelled independently. Standardized survey indices including CV estimates are produced from the model by performing a virtual experiment, where numbers-at-age are predicted from the model in a fixed grid of spatial points using a fixed gear. This procedure accounts for year-by-year changes in survey coverage and gear changes which could bias conventional design-based estimators.

The Delta-GAM model consists of two independent models, one binomial model for presence/absence and another model for positive observations only. Both models have the following structure:

$$
\begin{aligned}
g(\mu_i) = & \text{YearSemester(i)} + f_1(\sqrt{\text{depth}_i}, \text{Semester}_i) + \text{U(i)}_{\text{ship}} && (1) \\
& + f_2(\text{Semester}_i, \text{lon}_i, \text{lat}_i) + f_3(\text{YearSemester}_i, \text{lon}_i, \text{lat}_i) && (2) \\
& + \text{Gear(i)} + \log(\text{HaulDur}_i) && (3)
\end{aligned}
$$

where g is the link function, which is the logit function for the binomial model, the natural logarithm for positive part of the Delta-Gamma model, while the postivie part of the Delta-LogNormal is estimated using log-transformed response and a identity link. YearSemester(i) maps the ith haul to a categorical effect for each combination of Year and semester (Quarter 1 is semester 1, and Quarter 3 and 4 is semester 2), and Gear(i) maps the ith haul to a categorical geareffect (not present in all models). $\text{U(i)}_{\text{ship}} \sim N(0, \sigma_u^2)$ is a random Gaussian effect for each vessel. f_1 to f_3 are smooth Duchon splines with first derivative penalization. f_1 and f_2 are Semester-specific but time-invariant splines decribing the average plaice distribution, while f_3 describes Year and semester specific deviations from the average pattern.
In R syntax:

```
Model base: YearSemester + s(sqrt(Depth),k=5,bs='ds',m=c(1,0),by=Semester) + Gear2 + s(Ship,bs='re')
          + s(lon,lat,bs='ds',m=c(1,0.5),k=80,by=Semester) + s(lon,lat,bs='ds',m=c(1,0.5),by=YearSemester,k=6,id=1) + offset(log(HaulDur2))
```

The following nine models are compared:

1. **base** : All data. TVL effort assumed to be 1.33*TVS and GOV = TVL. Only DTU70 gear effects estimated.
2. **gearEstAll** : All data. Gear effects estimated for all gears.
3. **gearEstGOV** : All data. TVL effort assumed to be 1.33*TVS, but GOV and DTU70 gear effects estimated.
4. **base.noship** : As base, but without ship effects estimated.
5. **base.gamma** : As base, but Delta-Gamma instead of Delta-Lognormal.
6. **base.noDTU70** : As base, but without DTU70 gear (Cod survey).
7. **base.noQ3** : As base, but with Q3 IBTS data.
8. **base.noGOV** : As base, but without Q1 and Q3 IBTS data.
9. **base.noDTU70noShip** : As base, but without DTU70 gear and no ship effects.

Models 1 to 5 are fit on the same data but with different assumptions regarding Gear and Ship effects in the model. The assumption that the TVL catches 1.33 times more than TVS per minute trawled is based on the average door spread ratio of the two trawls. The average door spread ratio between TVL and GOV is very close to 1, which warrants the assumption that GOV and TVL gears should be approximately the same. Models 6 to 9 are fit on subsets of the full data set and can therefore not be compared in terms of model likelihood and AIC. Internal consistency and external consistency statisticis however can be compared across all models and is used for selection of the final model.

4 Results

The AIC criterion points towards model 2 as the best model among models 1-5, while model 5 has the least support. However, the gear effects estimated in model 2 do not seem plausible and seem to be confounded with the space-time effects. The TVS gear is estimated to have higher catch per minute trawled than TVL and the other gears for the youngest age groups, which contradicts expectations since TVL is a larger version of the same gear, and is likely an artifact stemming from TVS operating on shallower depths. The uncertainties of the estimated gear effects are also considerable, and do generally not exclude the assumption that TVL catches 1.33 times TVS. The internal/external consistencies are high for all models, but slightly better overall for model 9, which does not include any gear or ship effects. The indices and their trends are quite similar for all models though, as they are mainly driven by increasing catches found in the area covered by the TVS gear. The residual QQ-plots from model 9 do not indicate serious violations of the model assumptions, and the residuals versus gear and versus ship plots show that the model is able to explain apparant gear/ship differences by space-time effects as well. A retrospective analysis with 3 peels using model 9 show that the indices from the model are stable when updated with new data. In conclusion, model 9 is proposed as the final model for this stock.

	IC	ICQ4	EC	avg
base	0.903	0.873	0.893	0.890
gearEstAll	0.911	0.870	0.897	0.893
gearEstGOV	0.908	0.869	0.893	0.890
base.noship	0.920	0.878	0.899	0.899
base.gamma	0.914	0.863	0.898	0.891
base.noDTU70	0.901	0.881	0.901	0.895
base.noQ3	0.902	0.866	0.886	0.885
base.noGOV	0.920	0.876	0.903	0.900
base.noDTU70noShip	0.918	0.888	0.907	0.904

Table 1: Average internal (IC) and external consistency (EC) for ages 1-6 and grand average (avg) for all models.

References

[1] Casper W Berg and Kasper Kristensen. Spatial age-length key modelling using continuation ratio logits. *Fisheries Research*, 129:119–126, 2012.

[2] Casper W Berg, Anders Nielsen, and Kasper Kristensen. Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. *Fisheries Research*, 151:91–99, 2014.

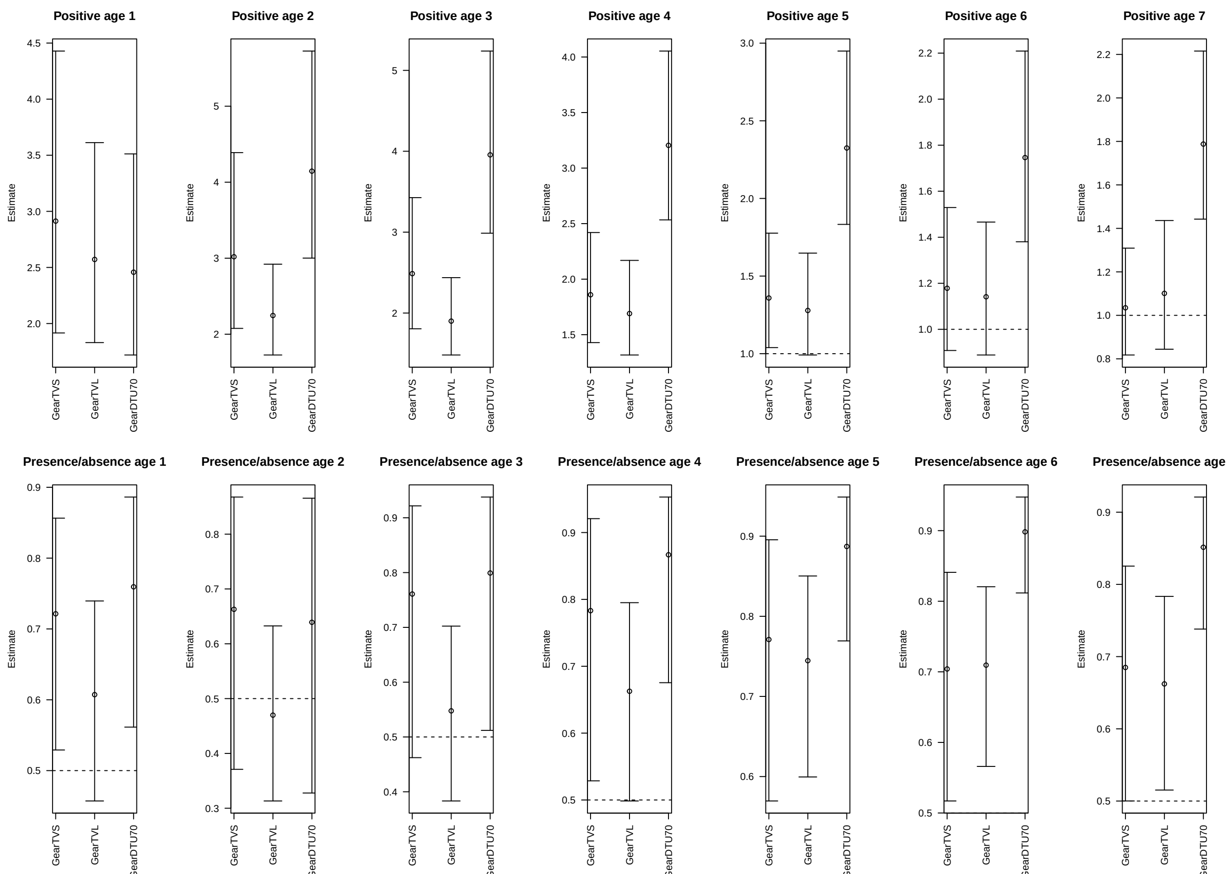


Figure 3: Estimated gear effects from model 2 with 95% confidence intervals. Top row is for the positive part of the model, and is on natural (multiplicative) scale relative to the GOV gear (GOV=1). Bottom row is from the binomial models, and is on probability scale relative to GOV (GOV = 0.5).

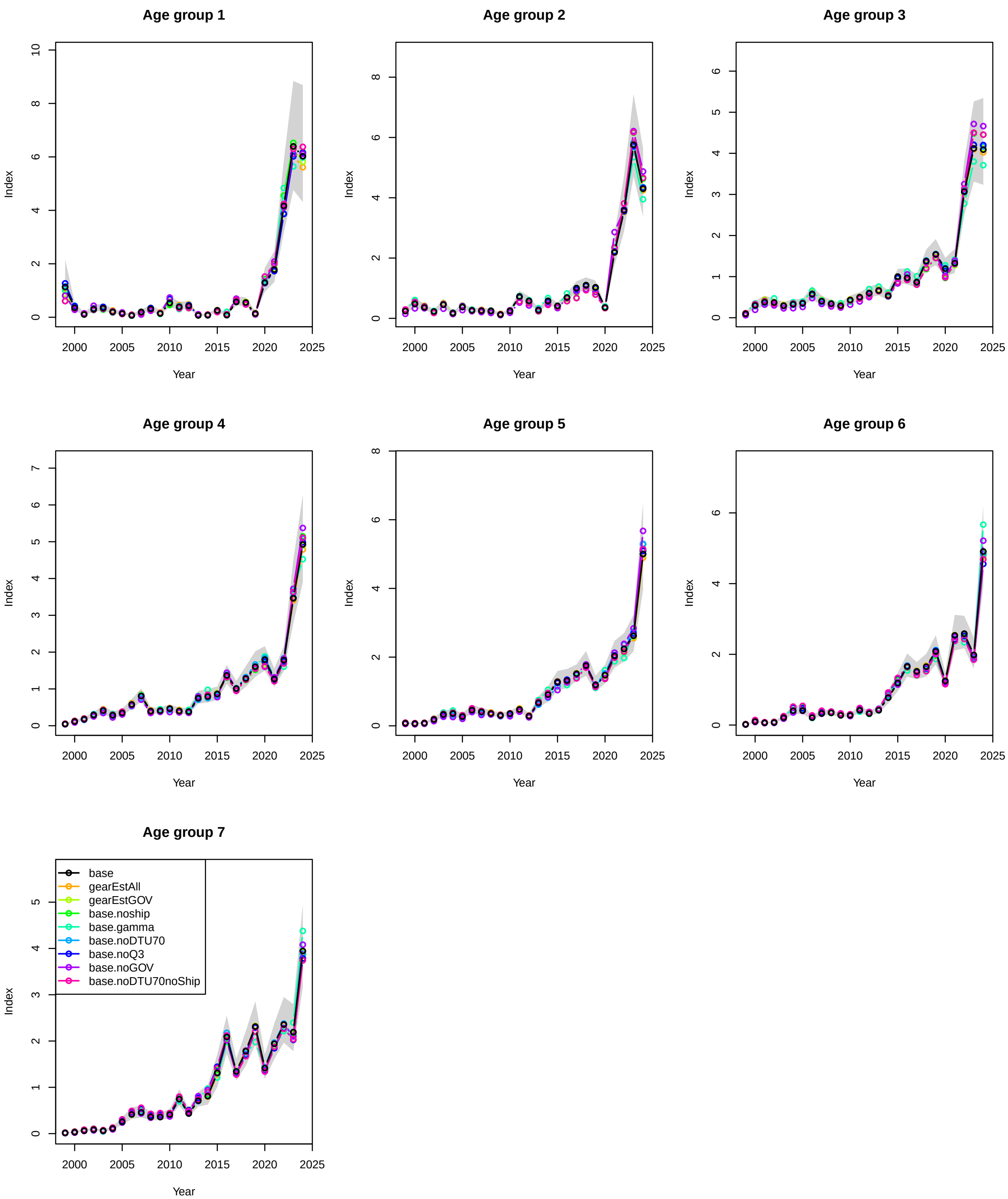


Figure 4: Q1 indices.

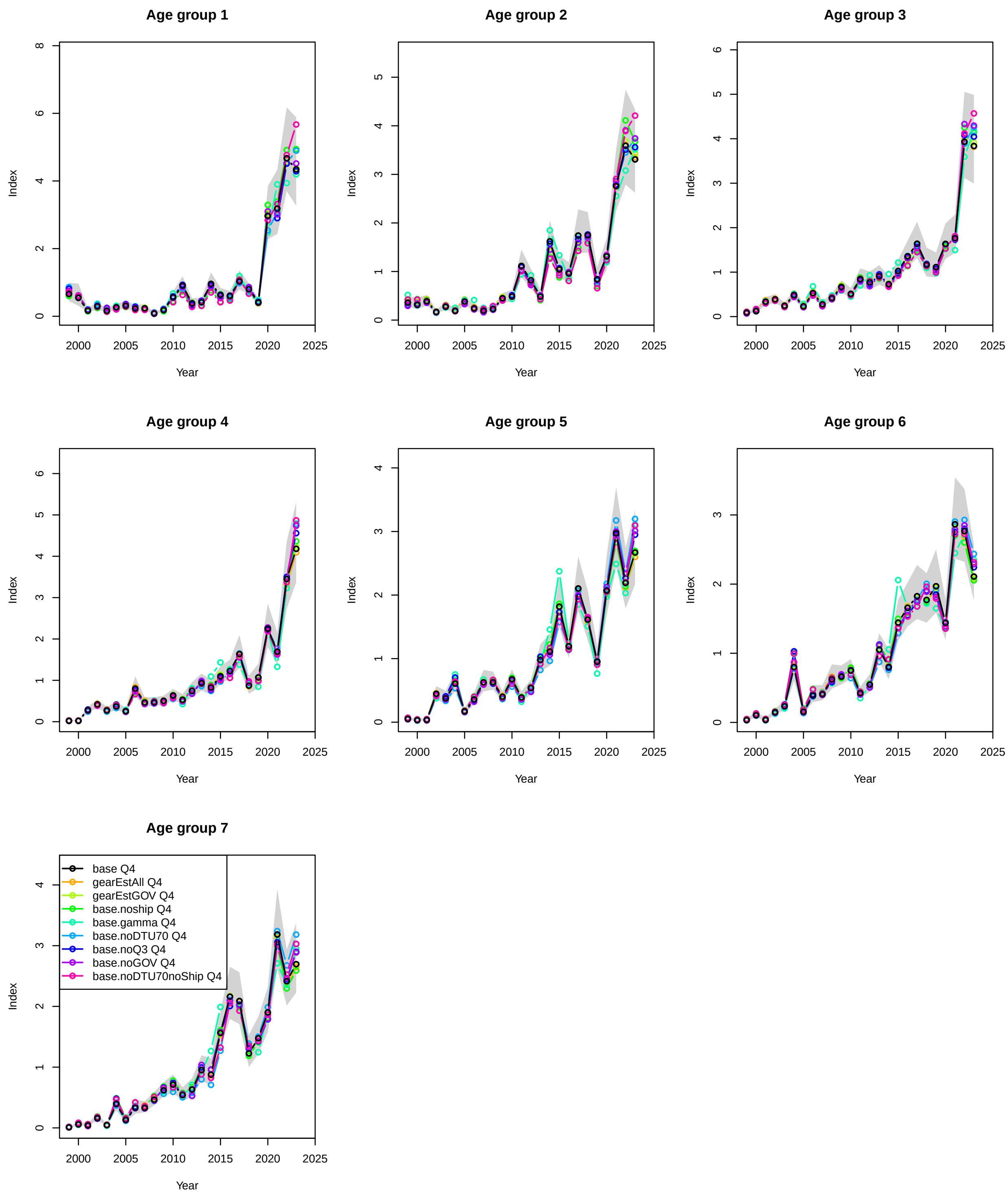


Figure 5: Q4 indices

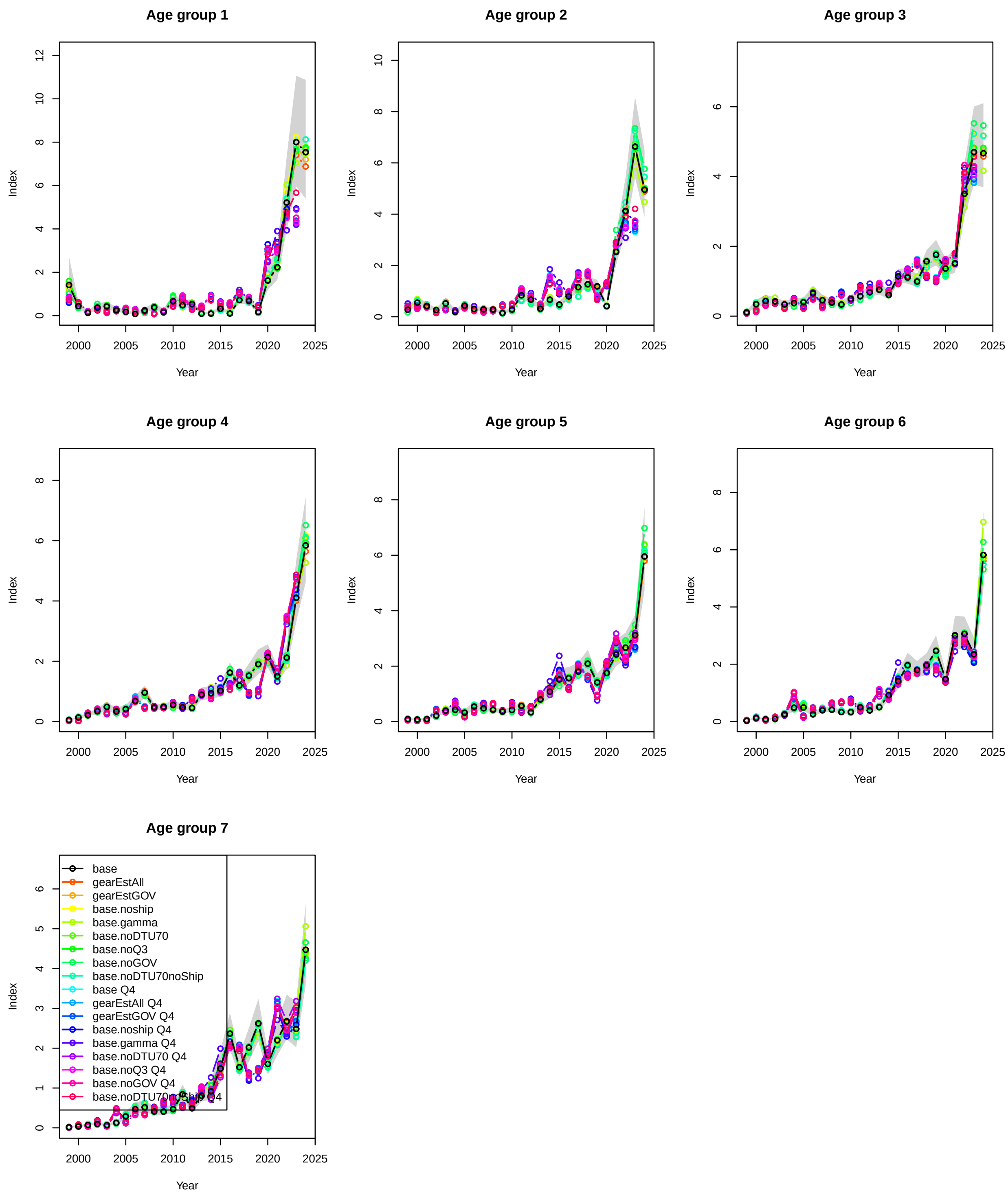


Figure 6: All indices.

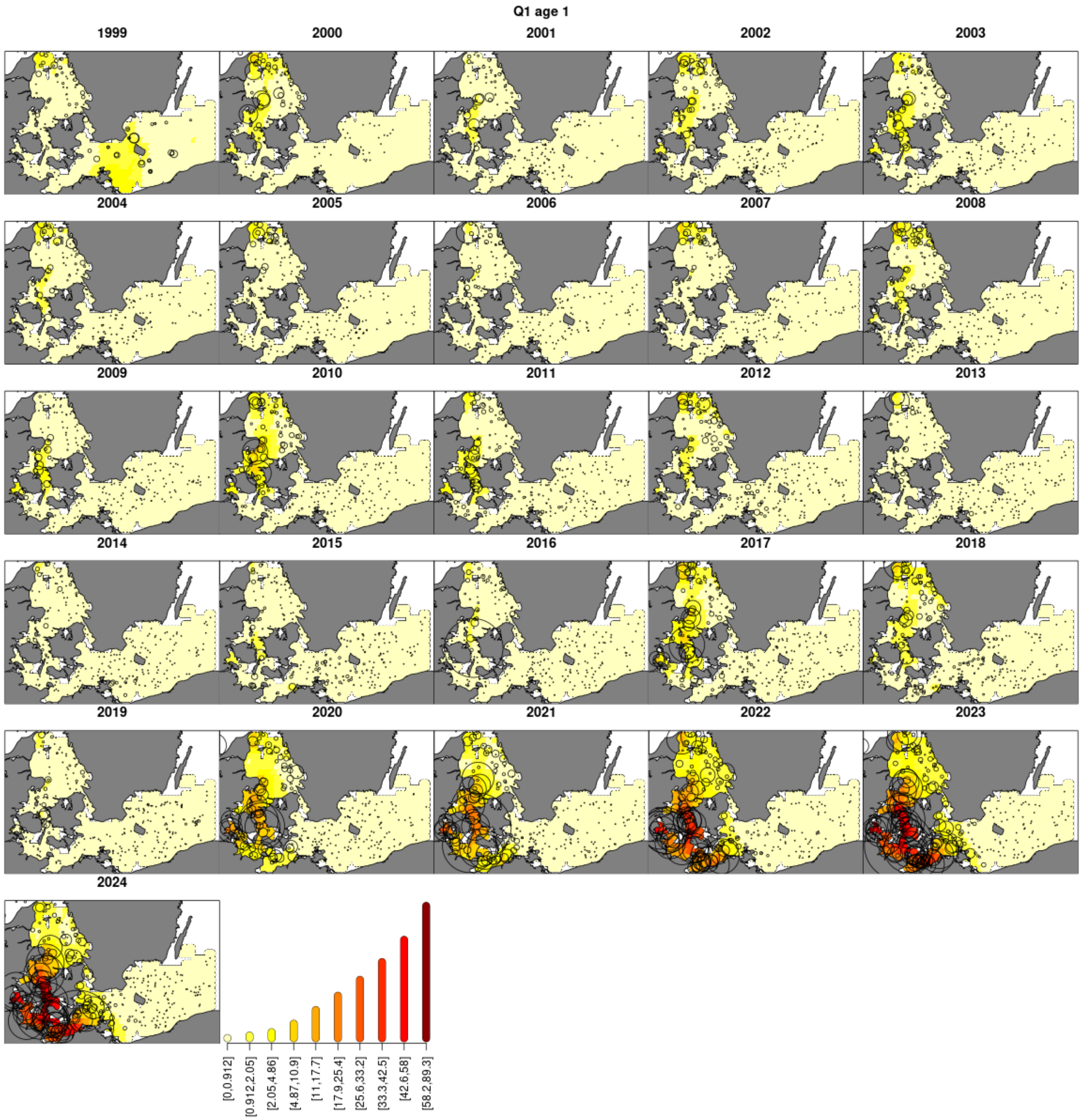
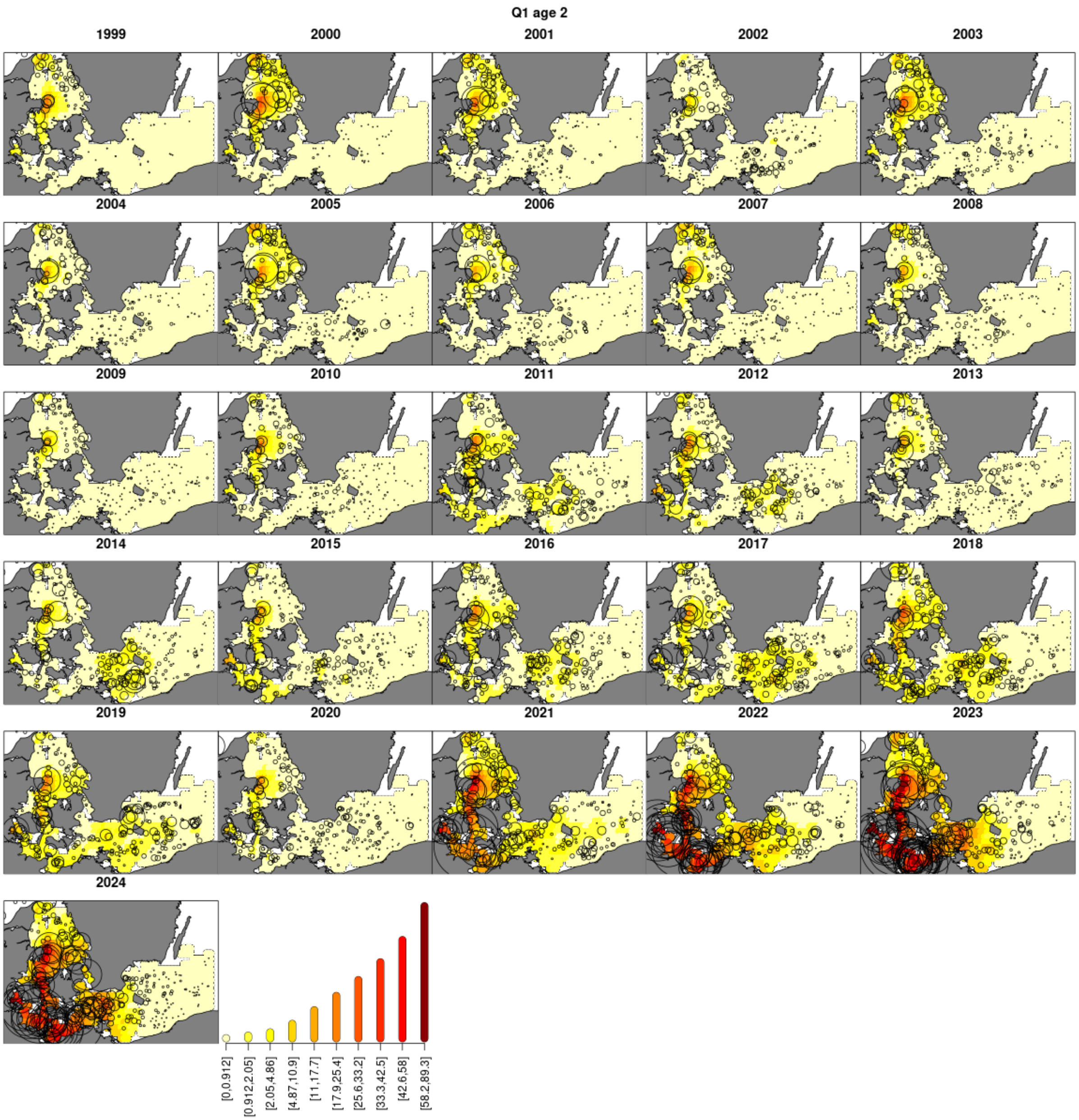


Figure 7: Distribution map (model 9). Black bubbles indicate observations and their area is proportional to observed CPUE.



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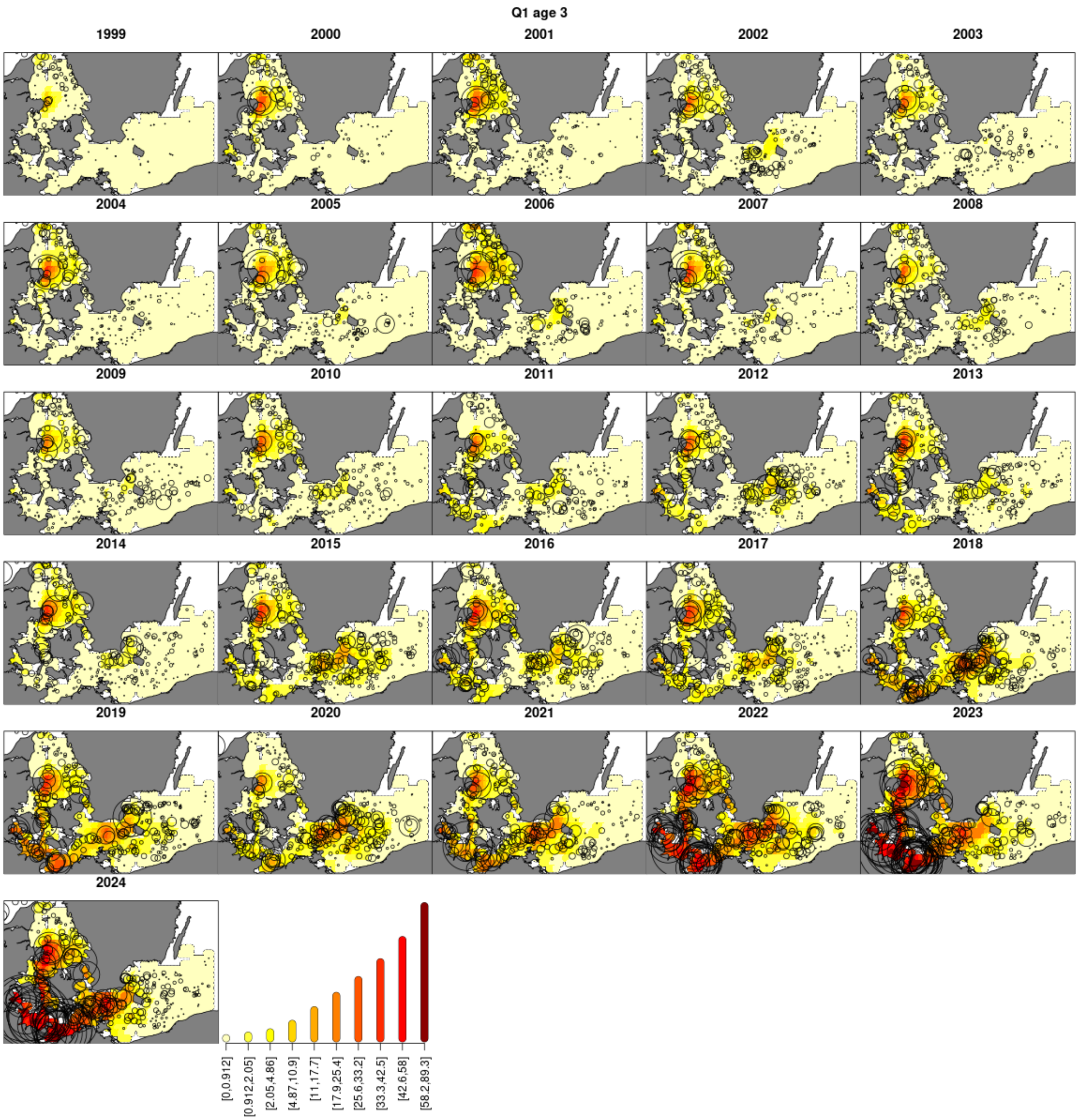
[0.912,2.05]
[2.05,4.86]
[4.87,10.9]
[11,17.7]
[17.9,25.4]
[25.6,33.2]
[33.3,42.5]
[42.6,58]
[58.2,89.3]

Figure 8


Q1 age 3
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[0,0.912]
[0.912,2.05]
[2.05,4.86]
[4.87,10.9]
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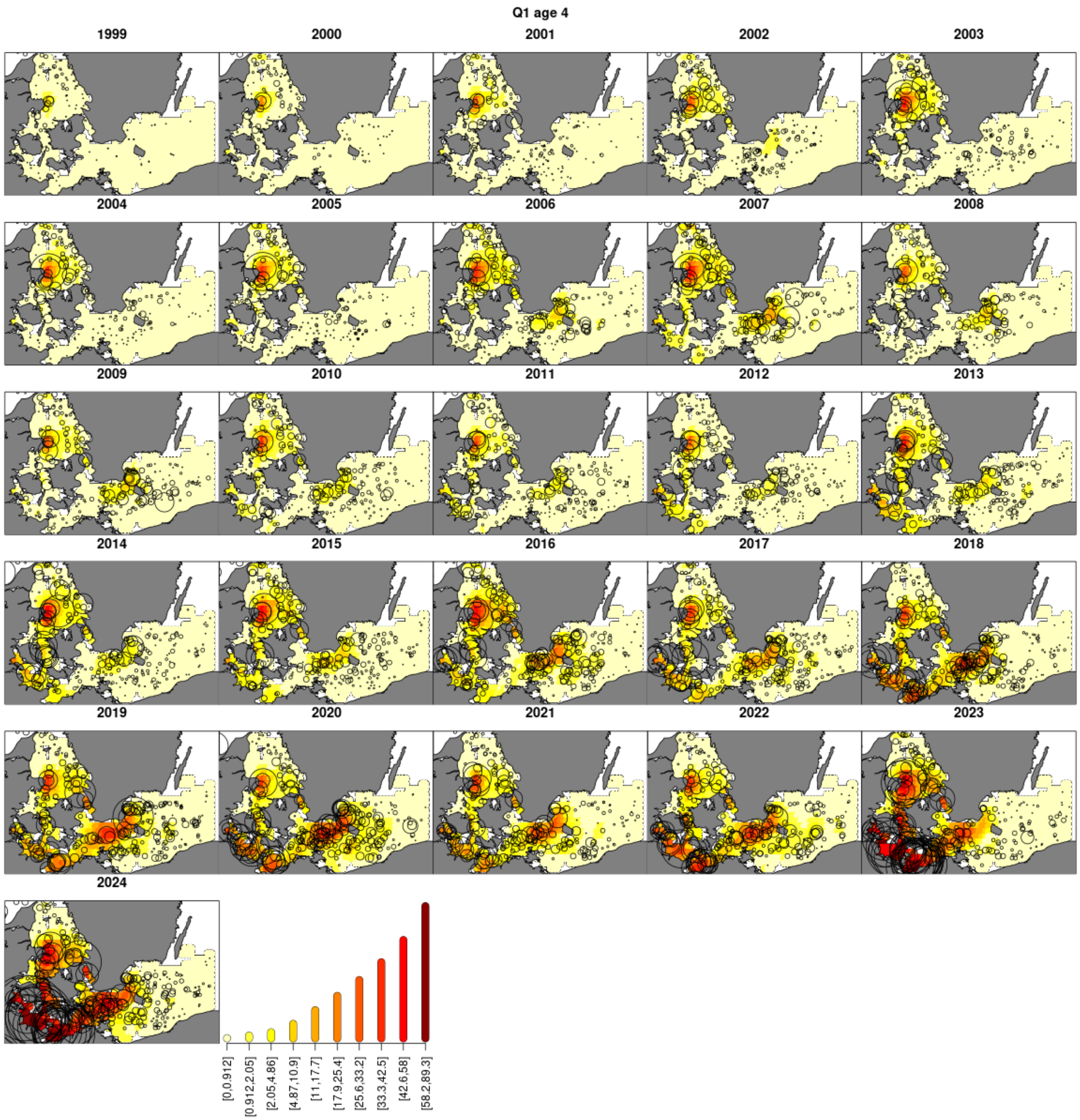
[17.9,25.4]
[25.6,33.2]
[33.3,42.5]
[42.6,58]
[58.2,89.3]

Figure 9


Q1 age 4
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[0,0.912]
[0.912,2.05]
[2.05,4.86]
[4.87,10.9]
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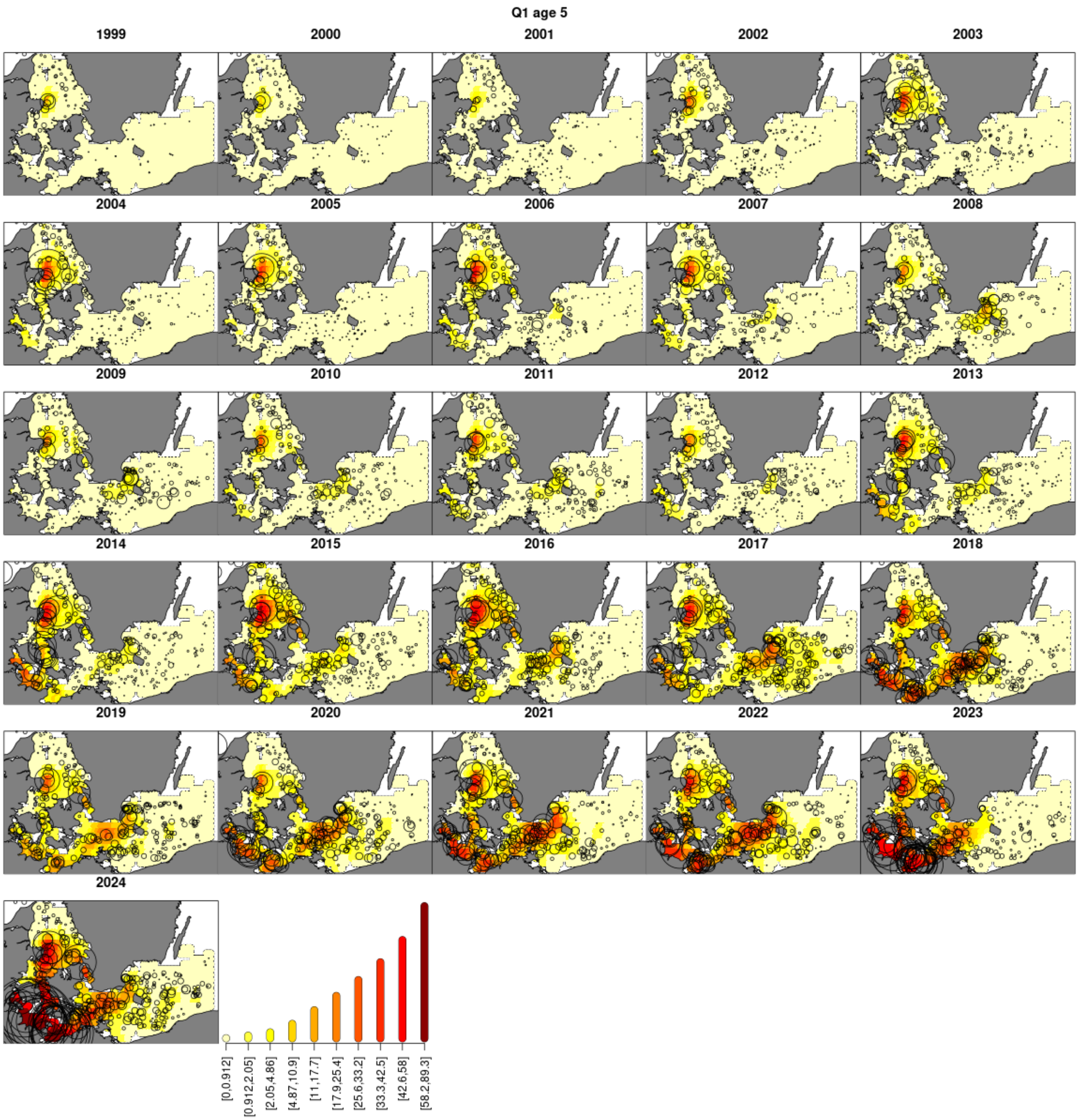
[17.9,25.4]
[25.6,33.2]
[33.3,42.5]
[42.6,58]
[58.2,89.3]

Figure 10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[2.05,4.86]
[4.87,10.9]
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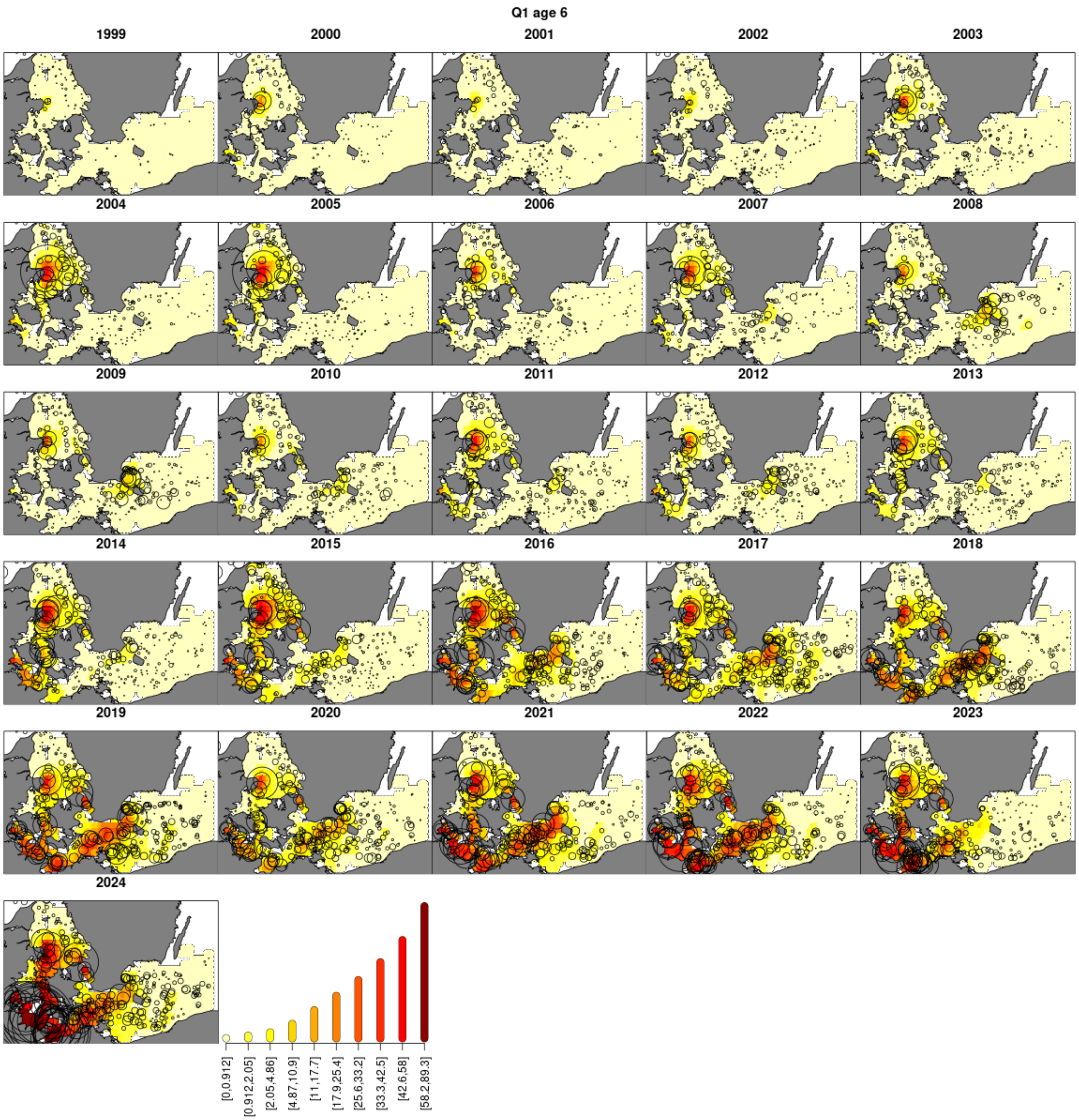
[17.9,25.4]
[25.6,33.2]
[33.3,42.5]
[42.6,58]
[58.2,89.3]

Figure 11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[0,0.912]
[0.912,2.05]
[2.05,4.86]
[4.87,10.9]
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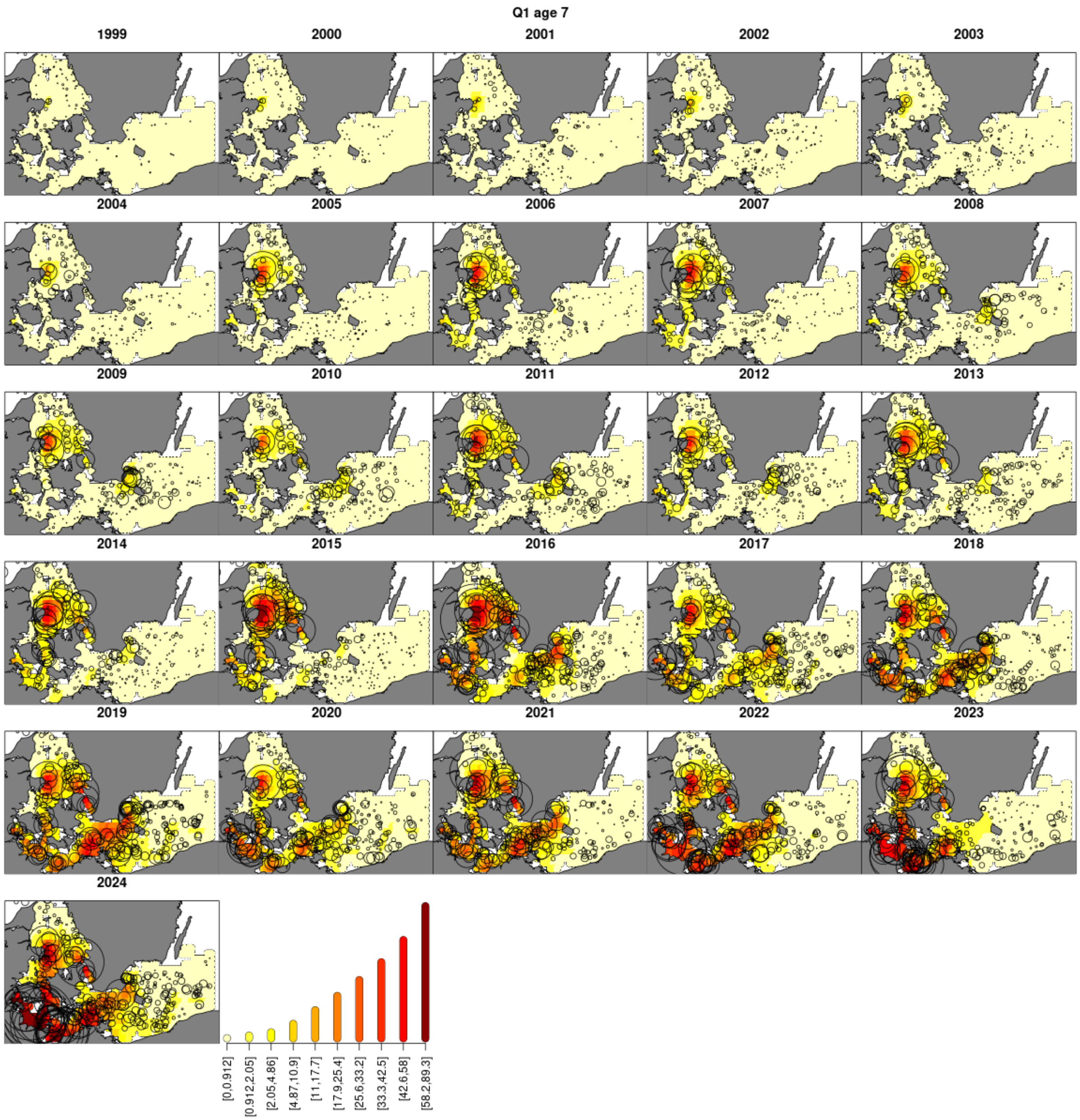
[17.9,25.4]
[25.6,33.2]
[33.3,42.5]
[42.6,58]
[58.2,89.3]

Figure 12



Q1 age 7
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[17.9,25.4]
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[33.3,42.5]
[42.6,58]
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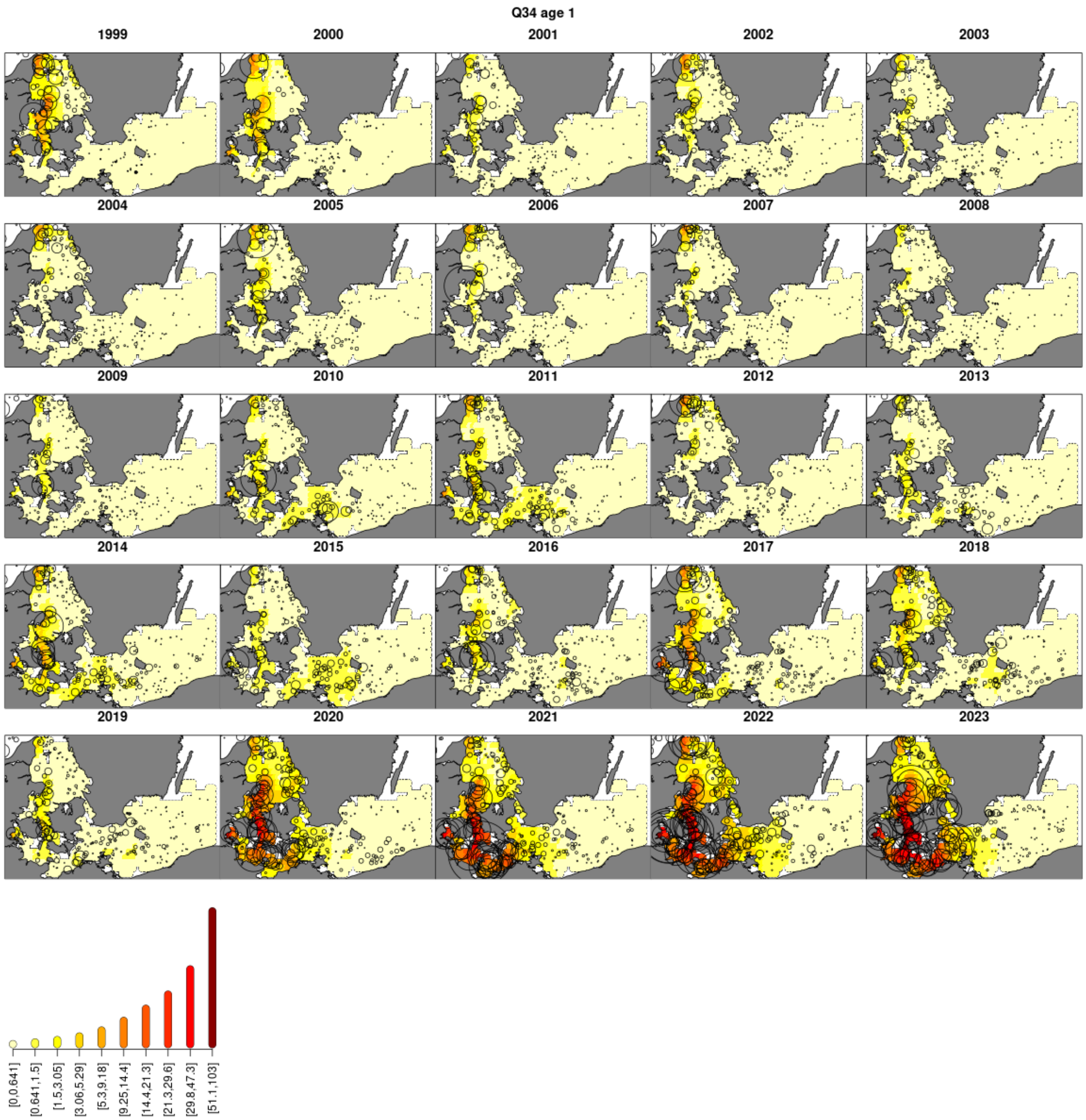
Figure 13



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[9.25,14.4]
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[21.3,29.6]
[29.8,47.3]
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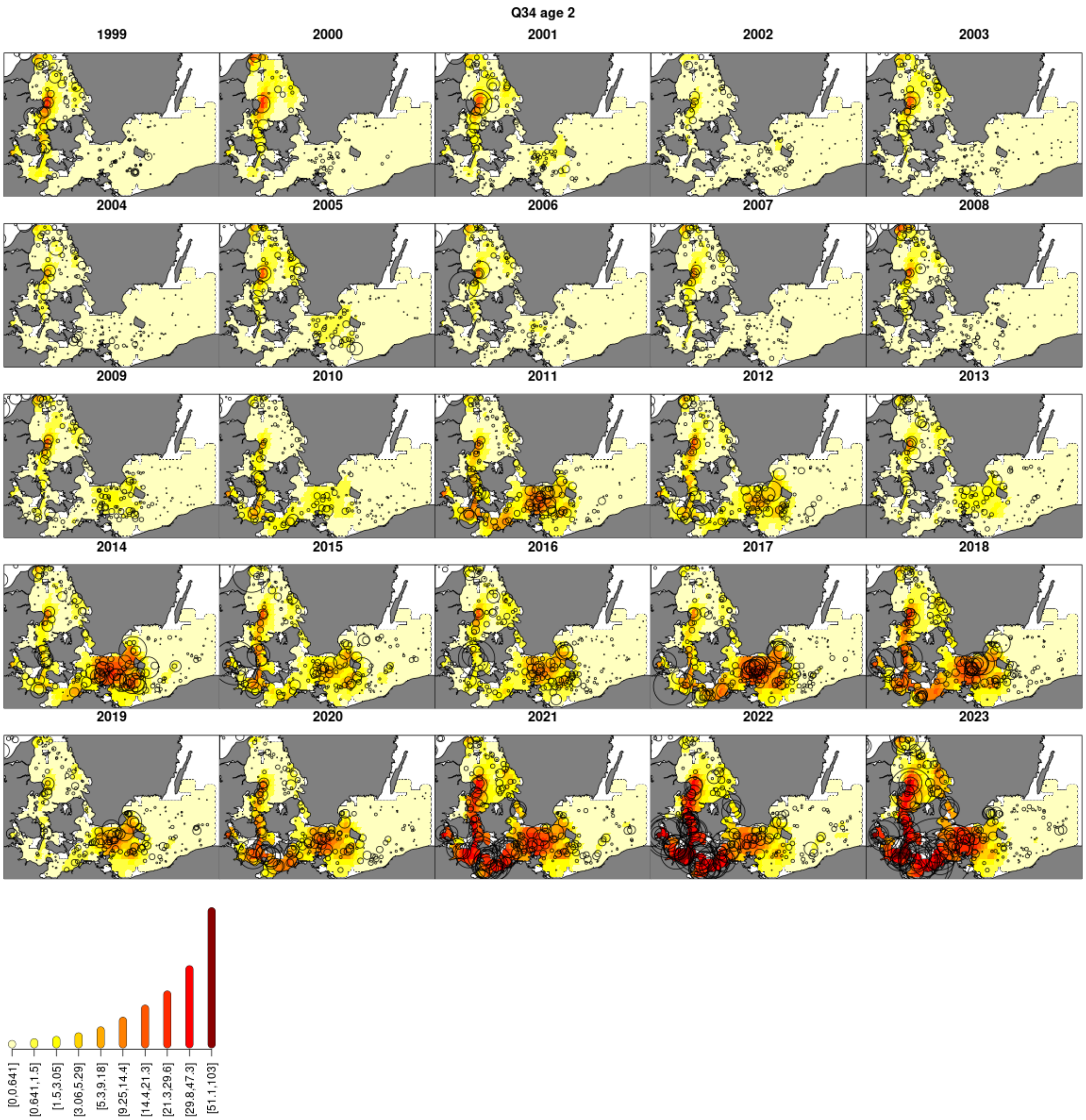
Figure 14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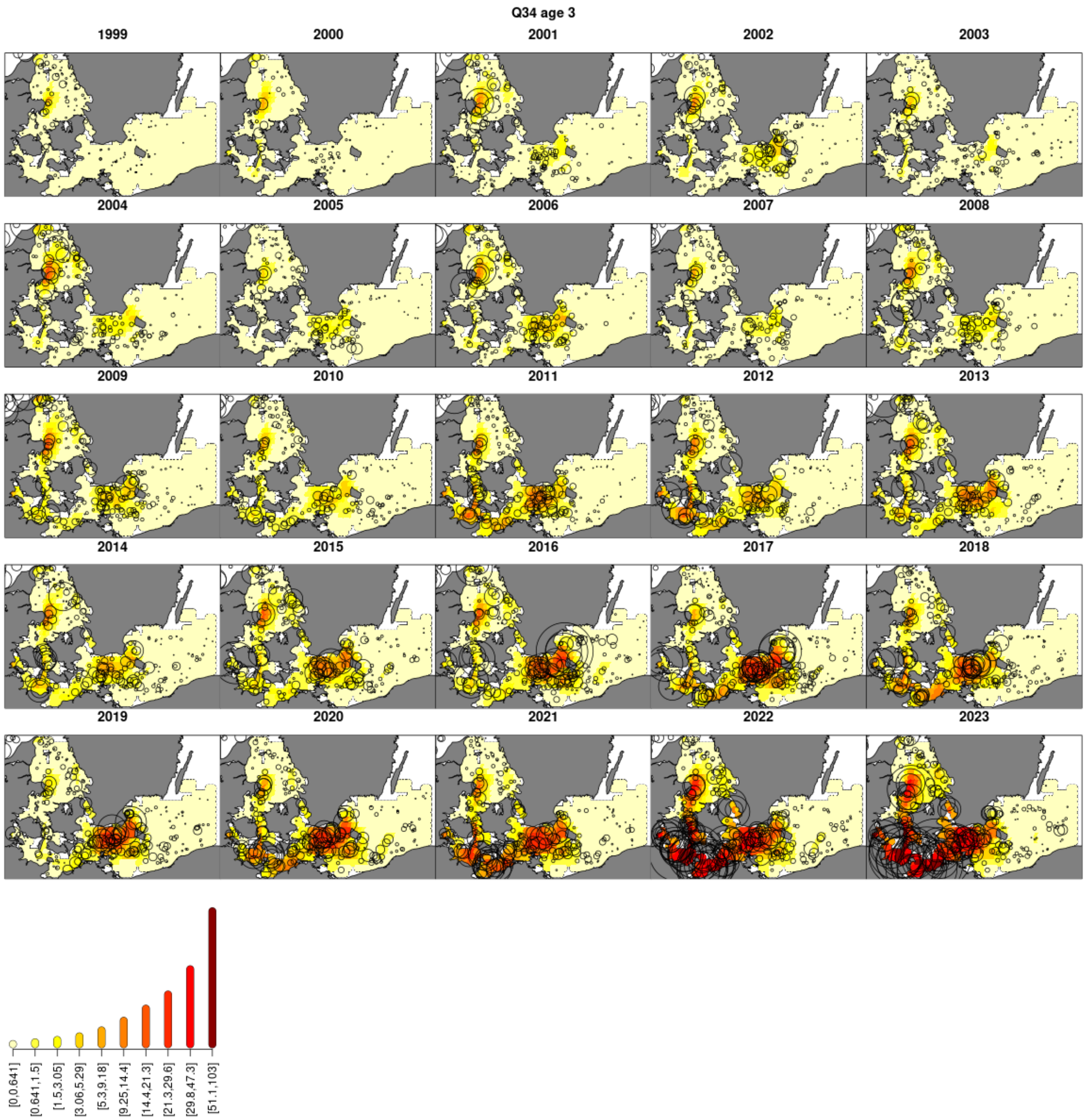
[51.1,103]

Figure 15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[9.25,14.4]
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[21.3,29.6]
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Figure 16

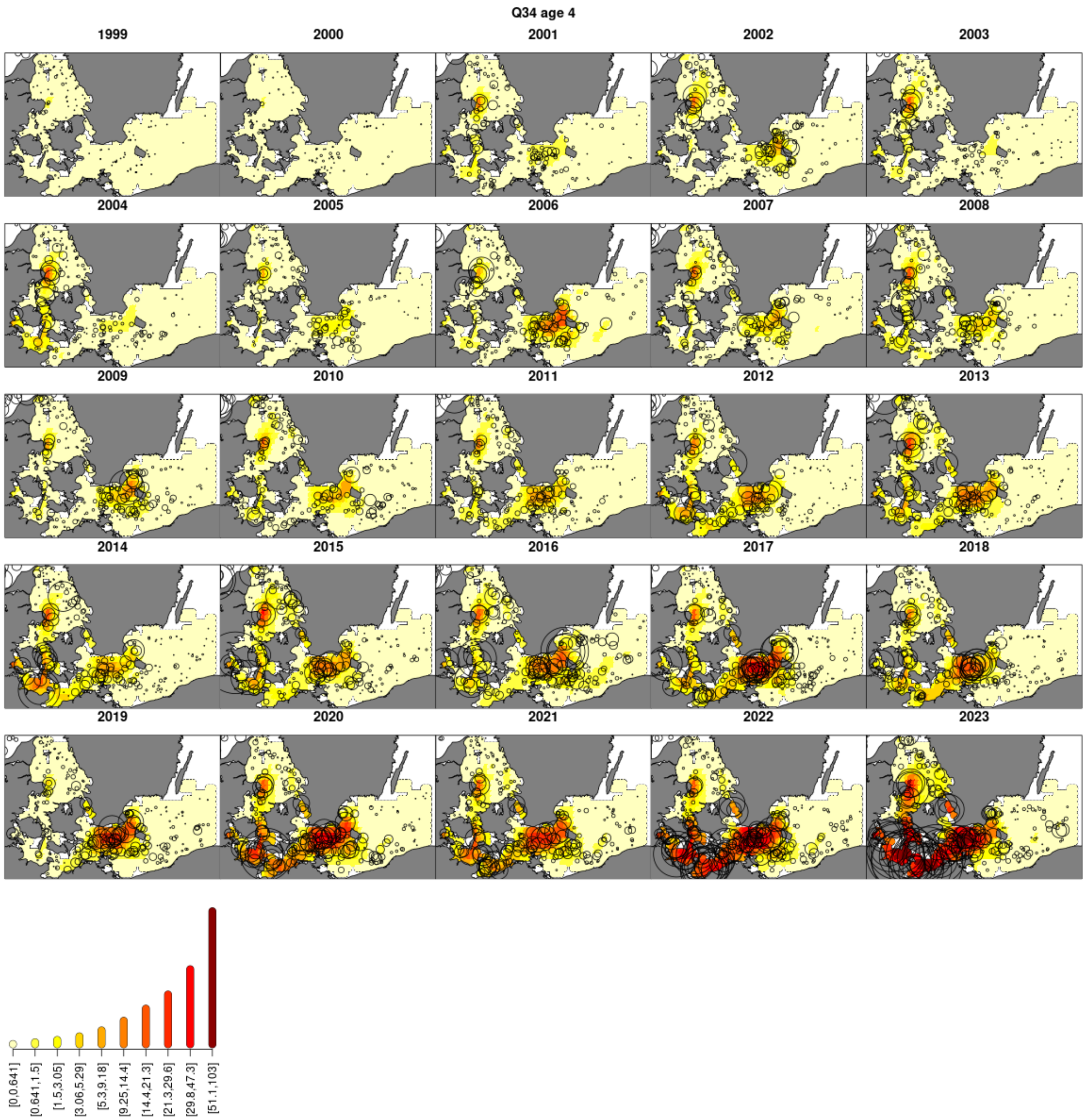
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Figure 17

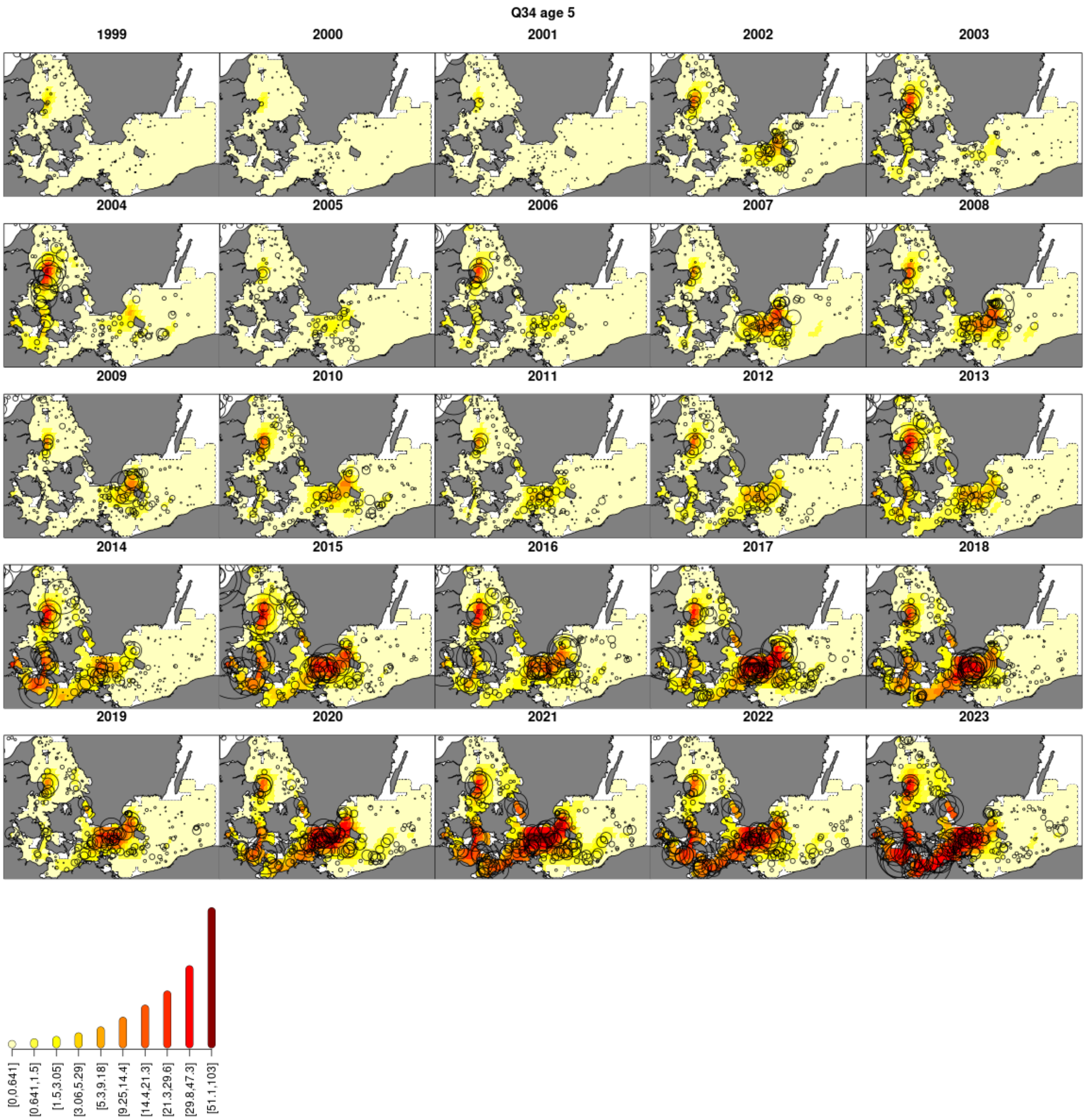
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Figure 18

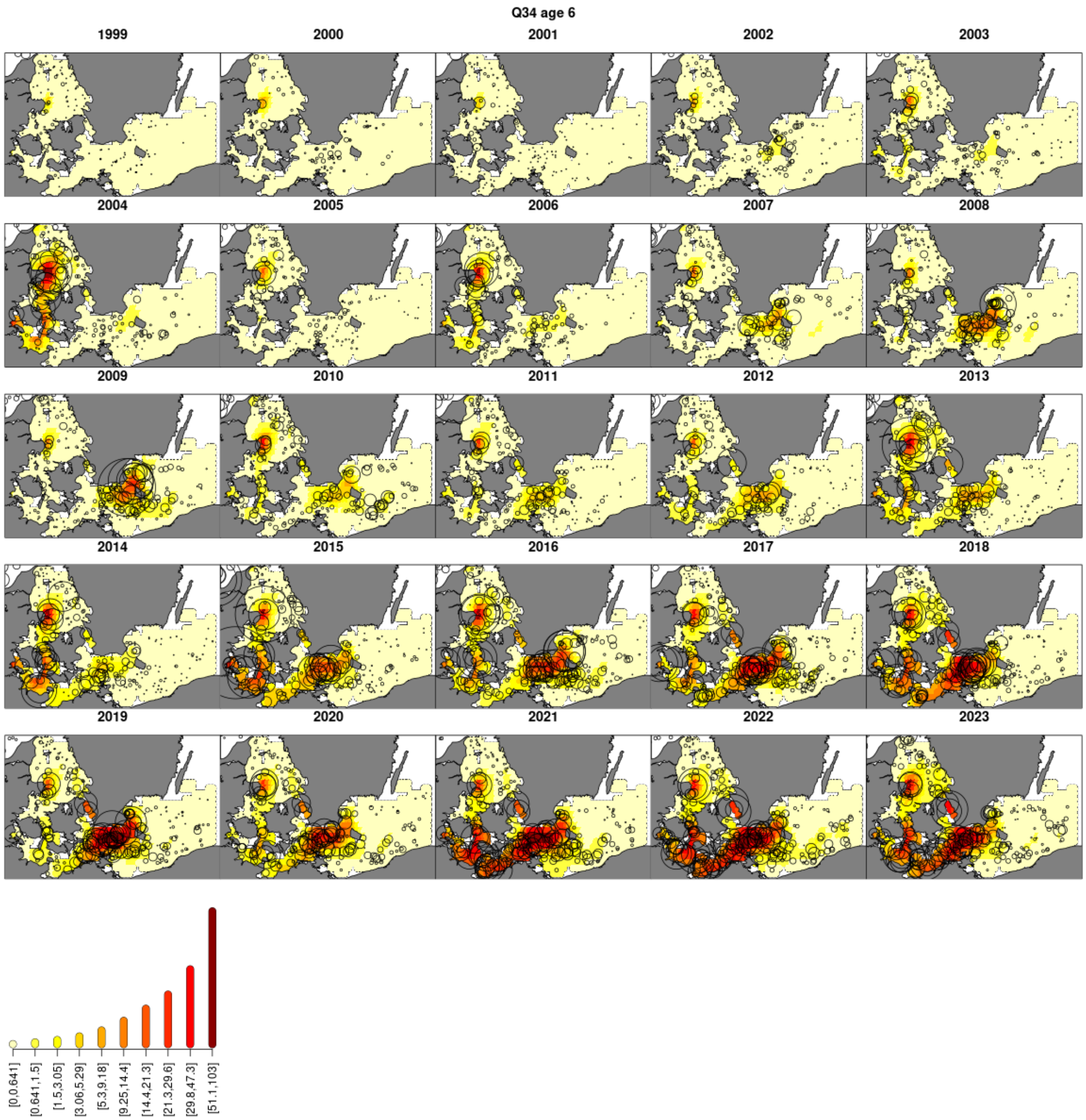
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Figure 19

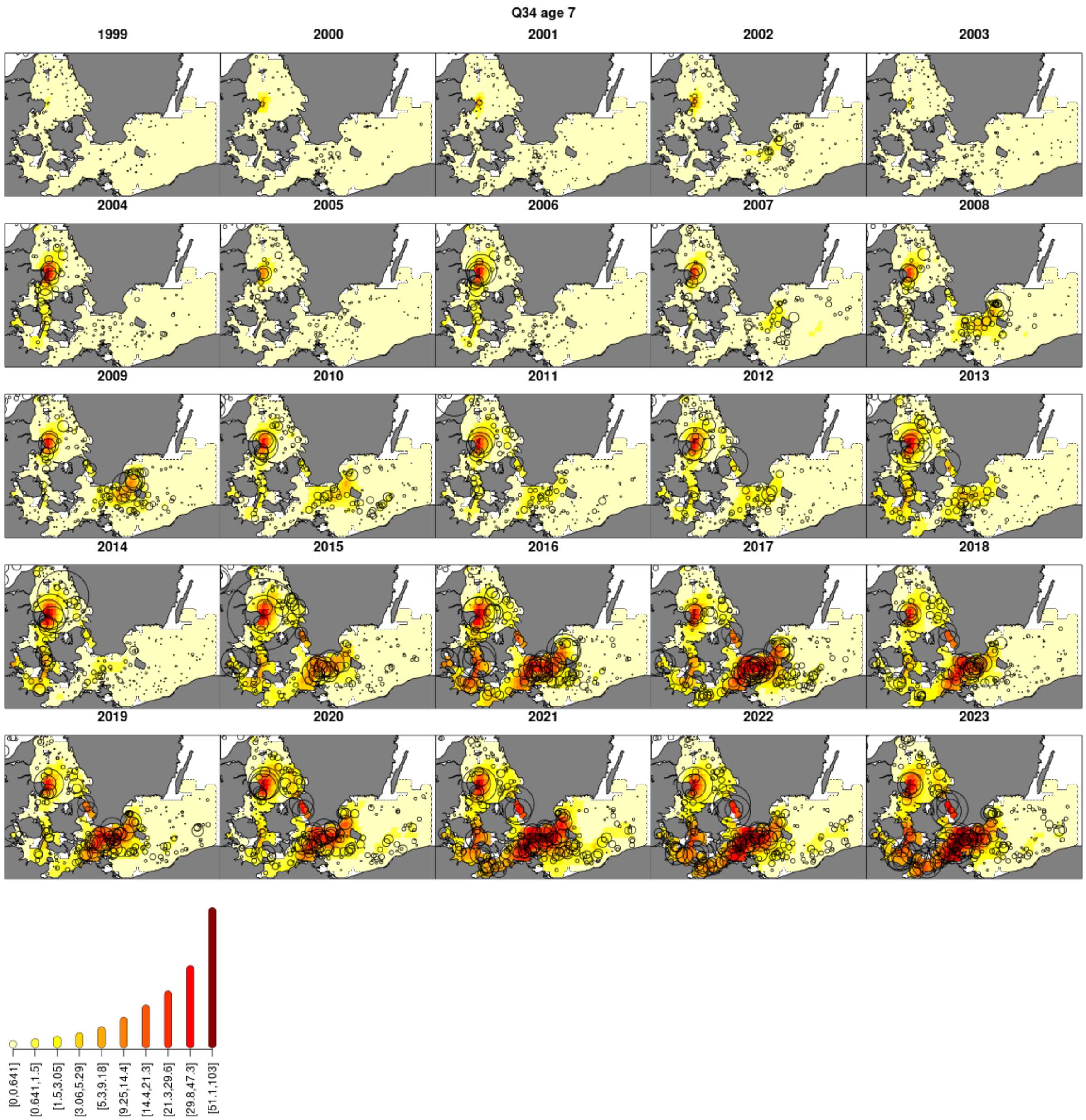
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Figure 20

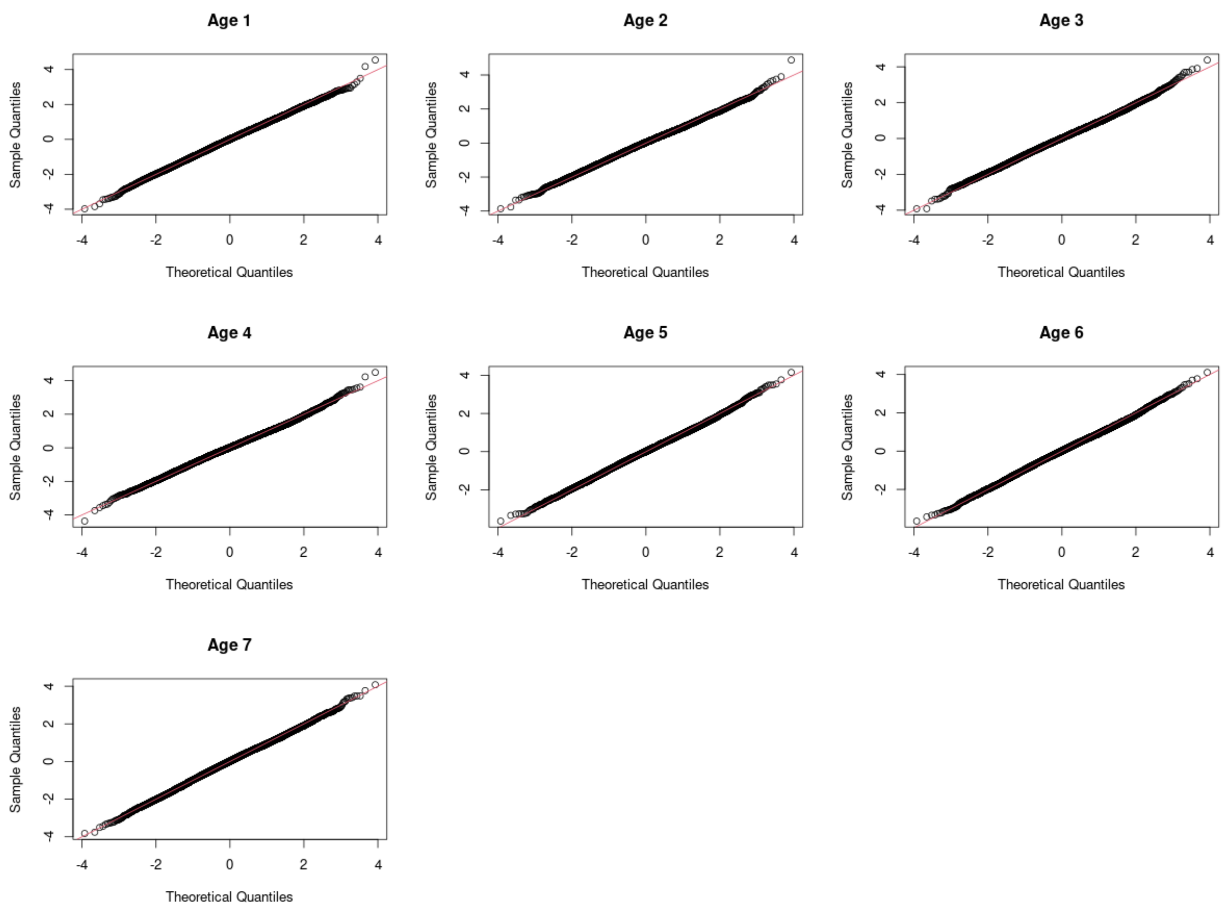

Figure 21: QQ-plots from model 9.

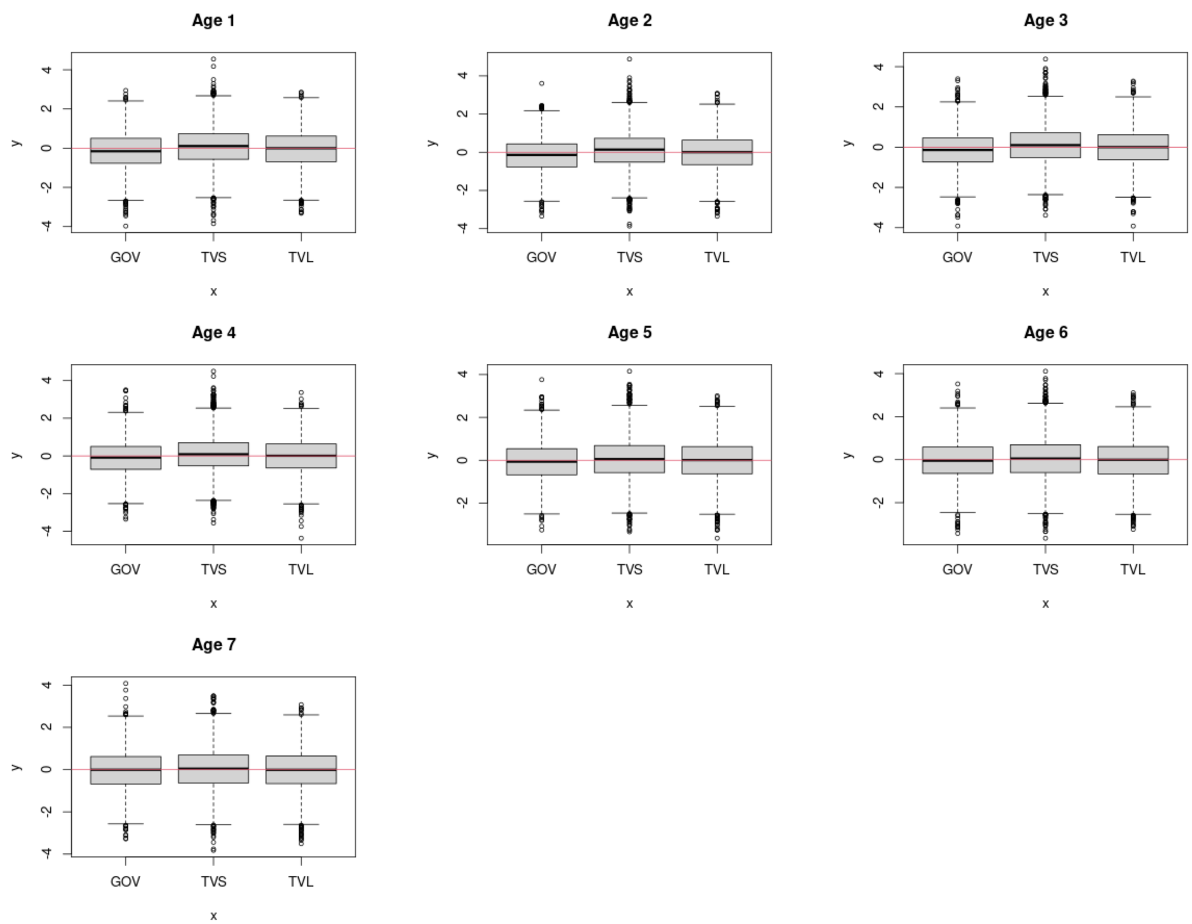

Figure 22: Residuals versus gear (model 9)

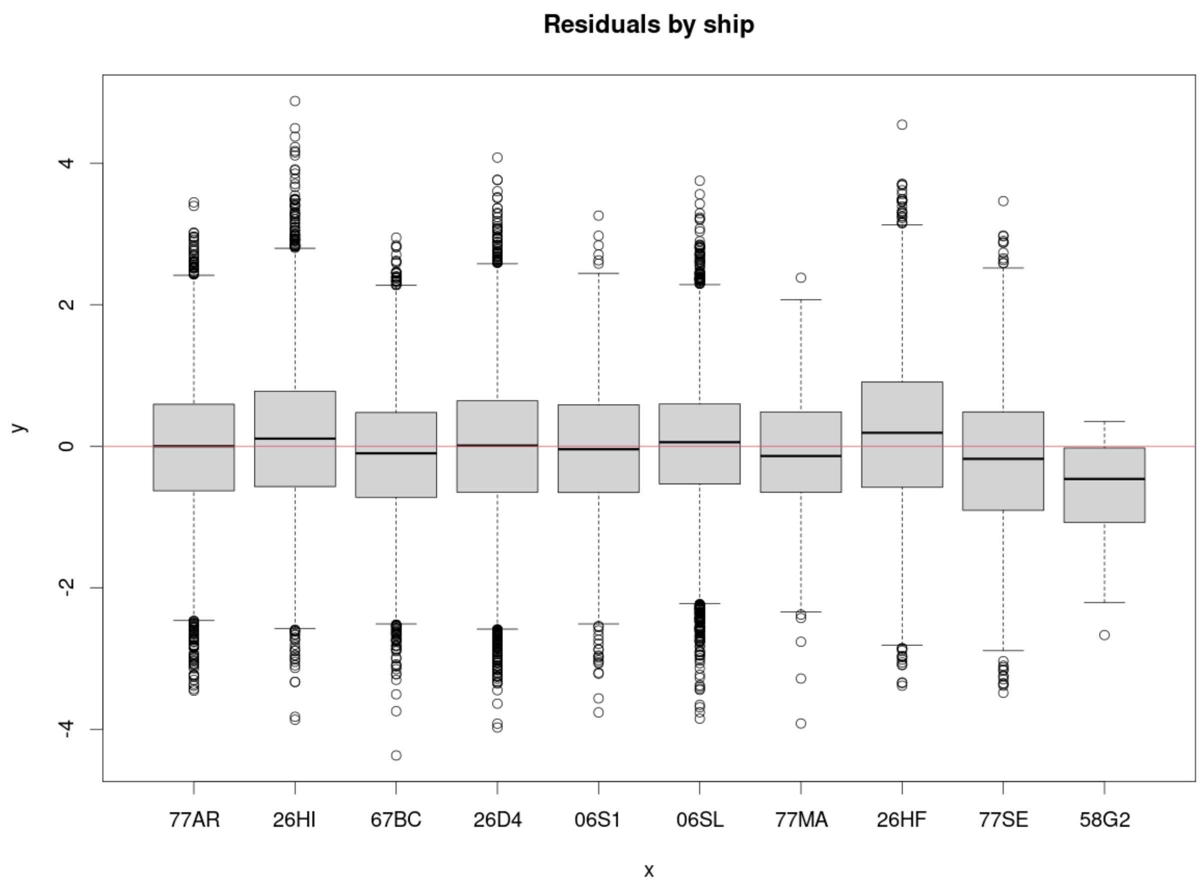

Figure 23: Residuals versus ship (model 9). Note there are only 3 data points for ship “58G2”.

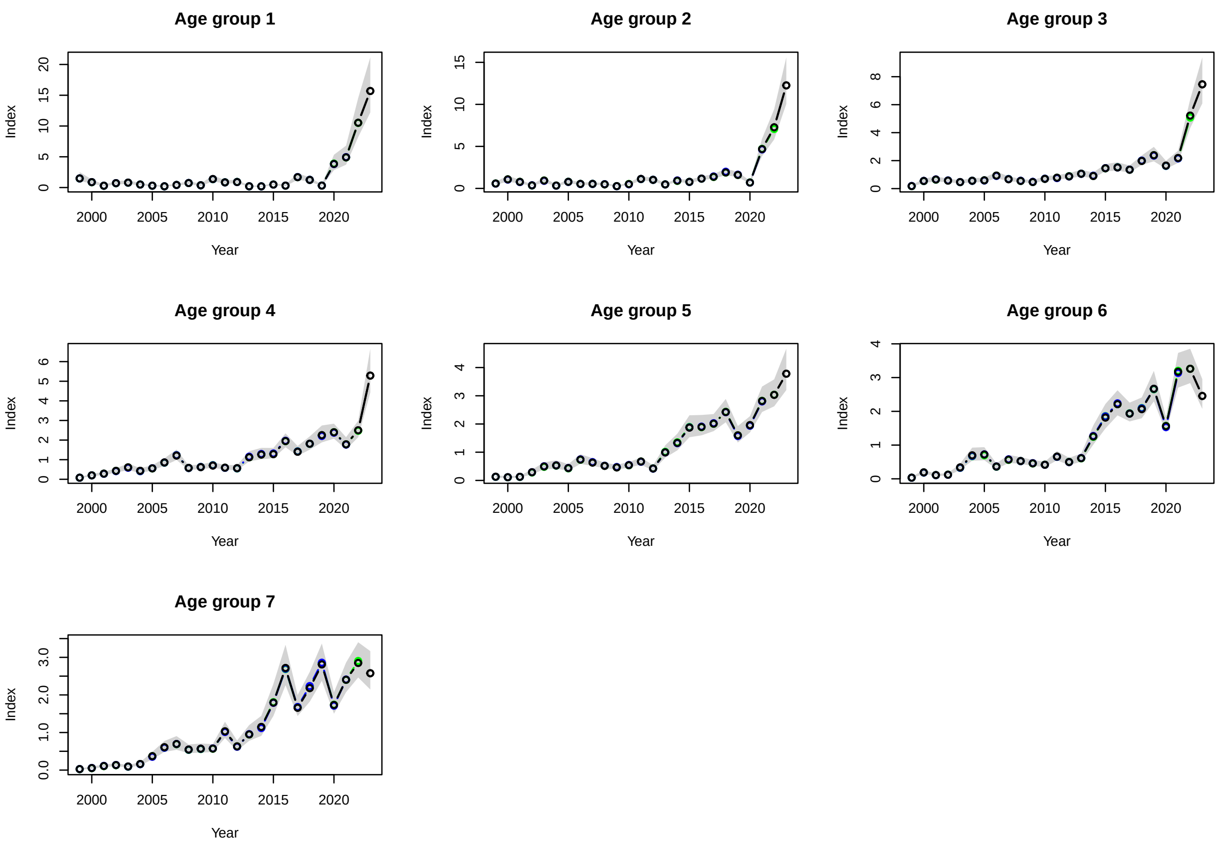

Figure 24: Retrospective analysis with 3 peels from model 9.

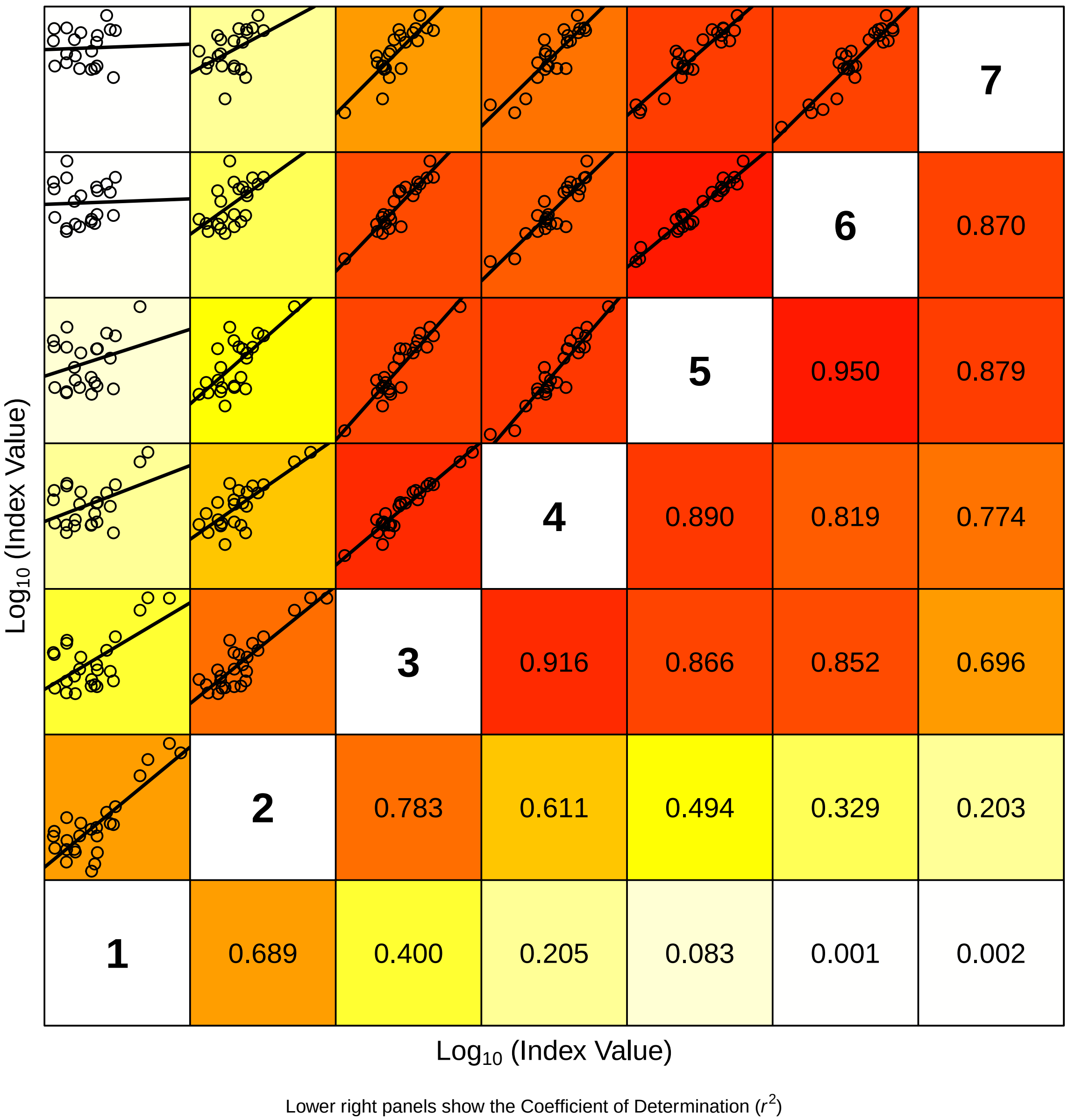

Figure 25: Internal consistency plot Q1 (model 9)

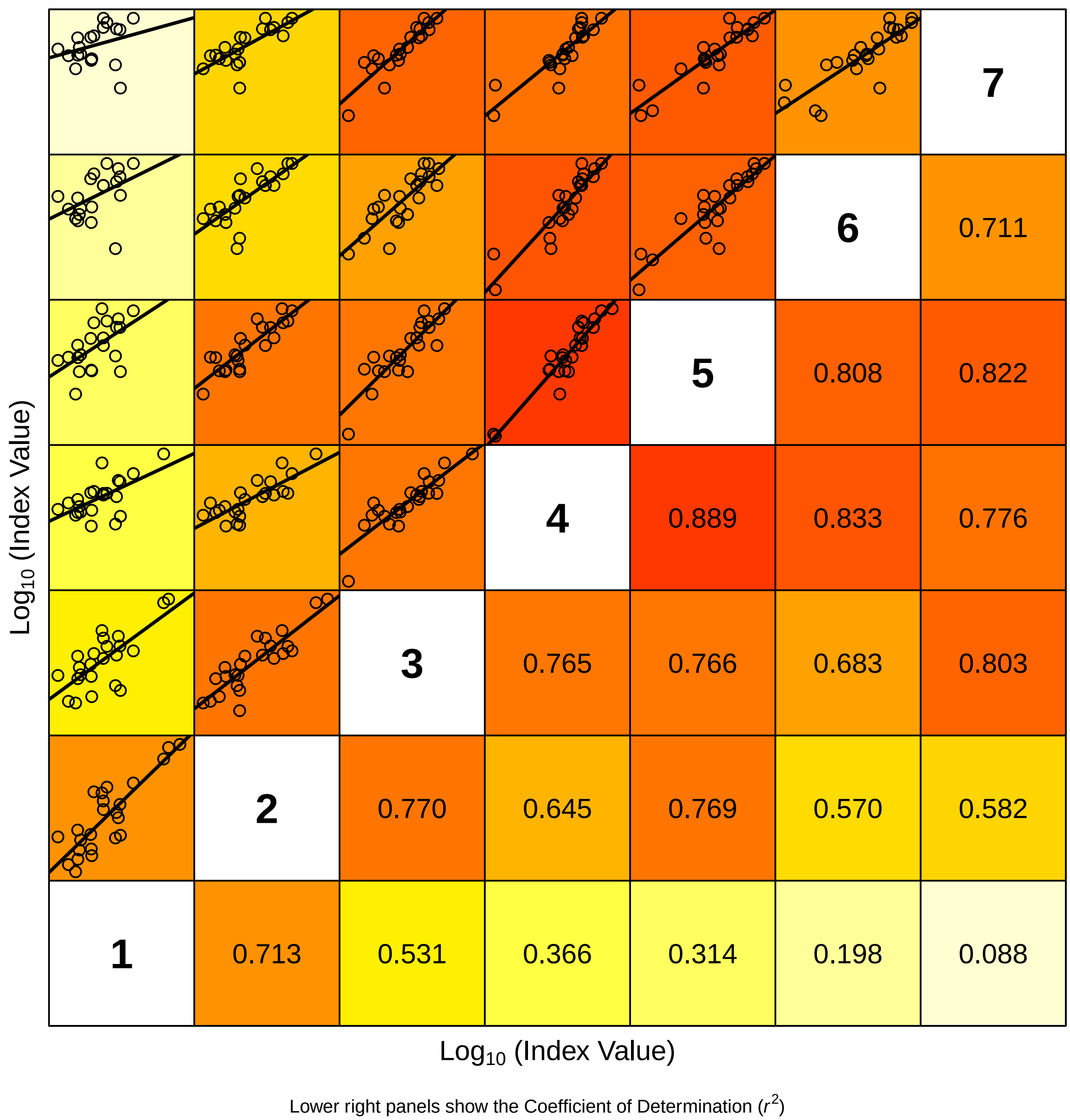

Figure 26: Internal consistency plot Q4 (model 9)