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**Summary of historical size data of North Pacific albacore (*Thunnus alalunga*)
caught by Japanese fisheries**

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Summary

1. Using area definition of the last stock assessment of North Pacific albacore, we summarized the length composition data of North Pacific albacore caught by Japanese fisheries between 1966 and 2018.
2. There are three major sources of albacore size composition data that are "Size original", "Size csv", and "SKJ database". In the last stock assessment, ALBWG used only length data in the "Size original" and "SKJ database".
3. The length frequency of longline fishery was smaller in area 1 with mode between 70 and 80cm FL than other areas with mode between 90 and 110cm, and represented a seasonal change in the northern areas (Area 1, 3, 5).
4. The length frequency of pole and line fishery represented a trend that was smaller in the northern area ($>30^{\circ}\text{N}$) than the southern area ($\leq 30^{\circ}\text{N}$) with a seasonal change between 1-2 quarters and 3-4 quarters of Area 6.
5. There are no clear trends in the length frequency of driftnet fishery because of the small and fragmentary data.
6. In the previous stock assessment, the ALBWG pointed out that the 1990s-length data might be biased sampling or measuring large fish. To verify the presence or absence of bias, we tabulated the weight and the mean body weight of the logbook data annually.
7. The weight data and logbook data represented similar trend to that of original length composition. Hence the trend, large albacore was caught by longline fishery in area 2, would be accurate.

Introduction

For the stock assessment, the size data is fundamental and important information. In the last stock assessment of North Pacific albacore, the historical change of size composition, which large albacore had been caught by Japanese longline (LL) fishery in southern part of North Pacific (Area 2, 4), was presented (Ijima et al., 2017). Because data source of the large albacore was based on measuring at a single fishing port, the trend might have been due to anthropogenic factors or sampling bias. Finally, the length composition data was utilized from 1993 to 2015 in the last stock assessment, and the data between 1966 and 1992 was excluded because it conflicted with the adult albacore indices such as growth model (ISC, 2017). We summarize the length data of albacore caught by Japanese longline, pole and line (PL), and drift net (DN) fisheries from 1966 to 2018 and re-consider validity of the 1990s-data using the weight data.

Material and methods

Data sets

This study utilized size data sets managed by National Research Institute of Far Seas Fisheries (NRIFSF). Data of albacore collected by Japanese LL, PL, and DN fisheries in the Northern Pacific were selected and utilized for analyses (**Table 1,2**). Measurements have been mainly conducted by observer program, training vessel of

fishery high schools, NRIFSF, and prefectural fishery research institutes. Measurements by NRIFSF and prefectural fishery research institutes have been mainly conducted in some fishing ports such as “Kamaishi”, “Kesenuma”, “Yaizu”, and “Kii-Katsuura”.

Reconsideration of weight/length relationship of albacore

To compare with length and weight data, we converted weight data to length-frequency data using length-weight relationship equation as:

$$W = a \times L^b,$$

where w is total weight (kg), L is fork length (m), and a and b are coefficient, respectively. To estimate parameters, we used R function `nls`. The data source for parameter estimation is “Size csv” data that records individual fork length and weight. The Smirnov grubbs’ test was adopted to exclude outliers of this data.

Logbook data information

We summarized logbook data to follow the annual changes in albacore size caught by Japanese longline vessels. In detail, we calculate mean body weight (total catch weight / total catch number) by 1 x 1 grid annually.

Area definition

Considering the fisheries activity, it was divided into five areas for LL (**Fig. 1**), and two areas on 30°N for PL and DN (**Fig. 2**).

Result and Discussion

Length composition of albacore caught by Japanese LL fishery was smaller in area 1 with mode between 70-80cm FL than other areas with mode between 90 and 110cm (**Fig. 3**). Seasonal change of size composition was recognized in the northern areas (Area 1, 3, 5). The length composition in such areas was smaller in the first half (quarter 1-2) than the second half (quarter 3-4) (**Fig. 4**). The length composition of PL fishery represented similar trend to LL fishery. It was smaller in the northern area (Area6: >30°N) than southern area (Area7: ≤30°N) (**Fig. 5**). Similar trend of seasonal change was also recognized between 1-2 quarters and 3-4 quarters of Area6 (**Fig. 6**). The length composition of DN fishery did not clearly differ between areas (**Fig. 7**). It looked a little different seasonally, however, more obscure than the LL and PL fisheries (**Fig. 8**). It is necessary to keep in mind that the data is fragmentary and the measurement number is much smaller than that of other fisheries.

Historical change of frequency of length compositions by LL, PL, and DN fisheries were summarized in Figs. 9-11, respectively. Larger size albacore was caught between 1984-1993 in area 2 and 4 by LL fishery (>110cm FL) (**Fig. 9**).

Regarding Area2, the length composition shifted prominently smaller from 1994 (**Fig. 10**). However, since the length data of large albacore before 1994 in the area strongly depended on measuring at a single fishing port (Port Yaizu) (**Fig. 13**), sampling bias and anthropogenic error should be also assumed.

To consider validity of the trend described above, we confirmed the weight/length relationship of albacore based on data of 68,168 individuals with both length and weight information collected 2004-2018 (size csv) (**Table 2**). The relational equation was showed as

$$W = 1.92 \times 10^{-1} L^{2.48}.$$

Consequently, estimated length of 4,325,166 individuals with only weight data (**Table 2**) was calculated by following equation as:

$$L = \exp(\log(W - 2.96 - error) / 2.48).$$

The “error” was calculated based on standard deviation (SD = 0.00319) of error between estimated length and true length using the 68,168 individuals with both length and weight information (**Table 2**). The historical change of estimated length composition represented trends similar to the original length composition despite not including data of Port Yaizu (**Fig. 14**). Therefore, the trend of original size data, representing large albacore by LL fishery before 1994, would not be due to bias or errors.

The mean body weight calculated by the Japanese longline logbook shows the existence of big albacore (30kg>, 110cm>) in 1993 and 1994 (**Fig. 15**). In this way, all data sources indicated that the Japanese longline catch size changed between the middle of the 1990s. Thus we considered that the length data of the Japanese longline is reasonable. To reflect this shift, we recommend using a larger CV of the growth curve, and big albacore still lives in the central Pacific Ocean (**Fig. 1**).

References

- Ijima, H., Ochi, D., and Kiyofuji, H. 2017. Estimation for Japanese catch at length data of North Pacific albacore tuna (*Thunnus alalunga*). ISC/17/ALBWG/04. Work. Doc. Submitt. to ISC Albacore Work. Gr. Meet. 11-19 April 2017, Southwest Fish. Sci. Center, La Jolla, California, USA.
- ISC. 2017. Stock assessment of albacore tuna in the North Pacific Ocean in 2017. Report of the albacore working group. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean.

Table 1. Available Japanese size composition data for stock assessment of North Pacific albacore tuna.

Data	Unit	Year	Source	Gear	Trip ID
Size original	Fork length	1966-2018	Port sampling by NRIFSF	LL	No
	Body weight		Observer	PL	
			Training vessel	DN	
Size csv ¹	Fork length / Body weight ²	1998-2018	Port sampling by NRIFSF	LL	Yes ³
			Observer	PL	
			Training vessel	DN	
Skj database	Fork length	2000-2018	Port sampling by NRIFSF	LL	No
			Port sampling by Prefecture	PL	
			Training vessel		
Logbook data ⁴	Body weight	1994-2018	One individual catch data	LL	Yes

1: After 1998, "Size original" data has been made by the "Size csv" data. However, there is some inconsistency between "Size original" and "Size csv" in the early period.

2: Fork length and whole the weight of one individual fish measured, but some survey data had just one measurement data.

3: Coverage and accuracy are very low.

4: It needs to evaluate the represents of albacore catch.

Table 2. Summary of data source for North Pacific albacore stock assessment.

Data base	Unit	Gear	1966	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015
Size original	Fork length	LL	Available for the stock assessment										
		PL	Available for the stock assessment										
	DN	Available for the stock assessment											
Size original	Body weight	LL	Used for calculation of estimated length in this document										
		PL	Used for calculation of estimated length in this document										
	DN	Used for calculation of estimated length in this document											
Size csv	Fork length	LL	Available for the stock assessment										
		PL	Available for the stock assessment										
	DN	Available for the stock assessment											
Size csv	Body weight	LL	Used for confirming of weight/length relationship in this document										
		PL	Used for confirming of weight/length relationship in this document										
	DN	Used for confirming of weight/length relationship in this document											
Skj database	Fork length	LL	Available for the stock assessment										
		PL	Available for the stock assessment										
	DN	Available for the stock assessment											
Logbook data	Body weight	LL	Used for considering validity of trend of length composition										

Available for the stock assessment
 Used for calculation of estimated length in this document
 Used for confirming of weight/length relationship in this document
 Available for the stock assessment, and used for confirming of weight/length relationship in this document
 Used for considering validity of trend of length composition

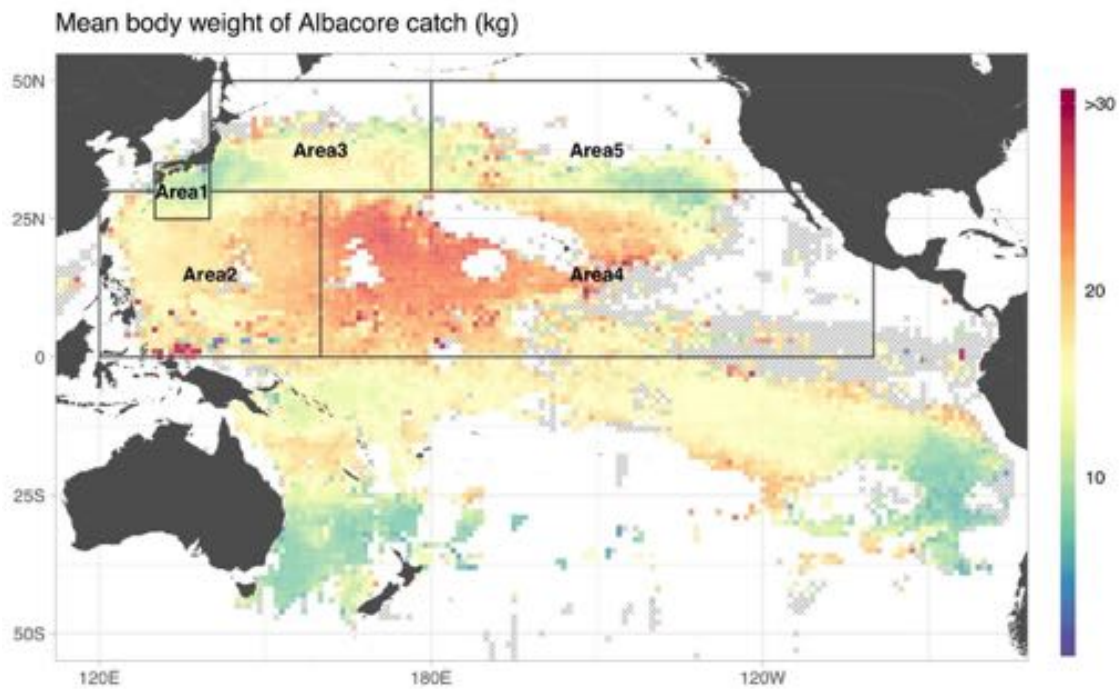


Figure 1. Area definition of Japanese longline fishery considering spatially size selectivity of North Pacific albacore. The mean body weight of albacore catch was calculated by Japanese logbook data (1994-2018).

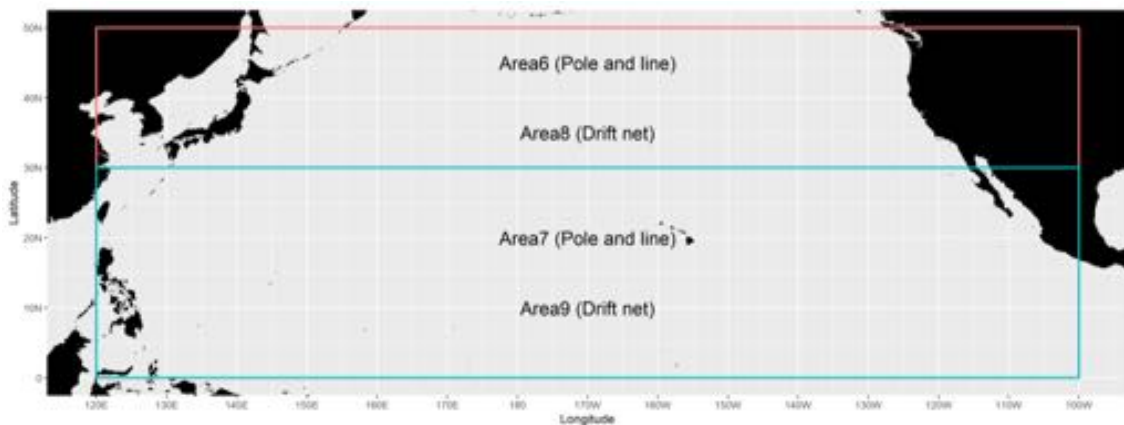


Figure 2. Area definition of Japanese pole and line and drift net fisheries considering spatially size selectivity of North Pacific albacore.

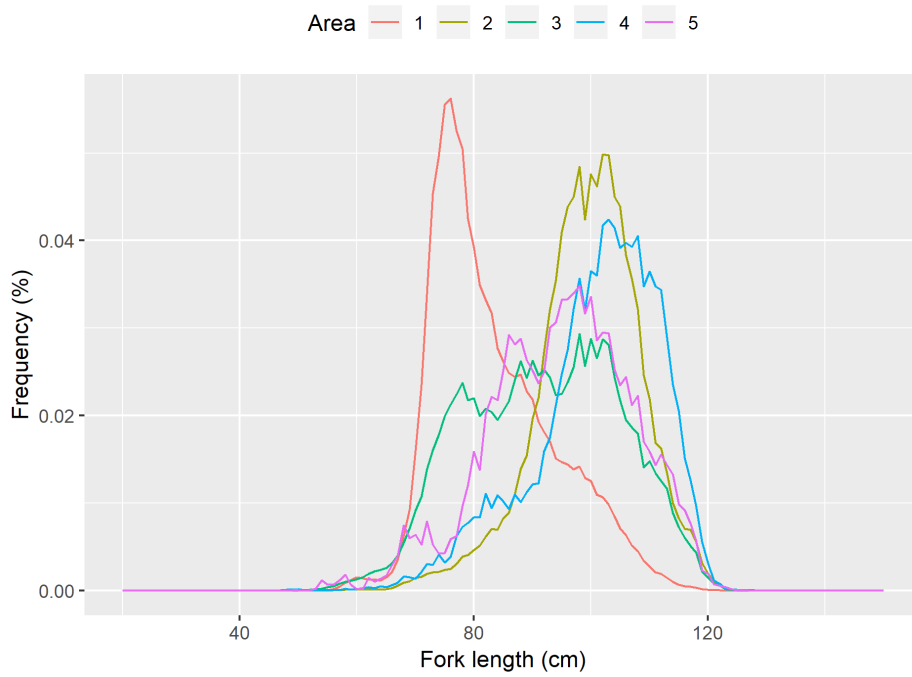


Figure 3. Length frequency data of each area (Japanese longline fishery)

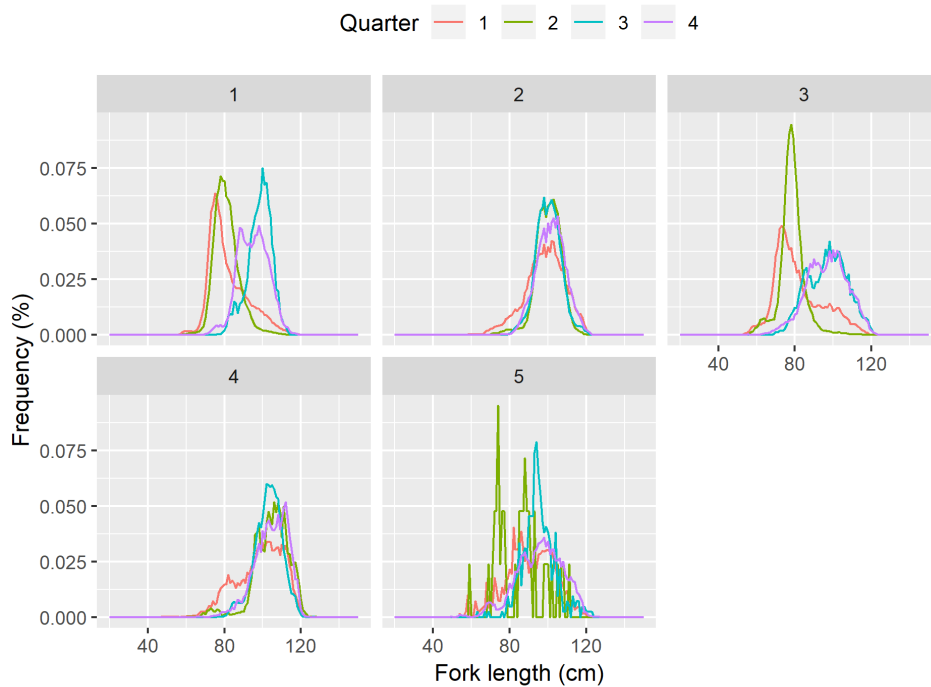


Figure 4. Seasonal difference of length frequency data (Japanese longline fishery)

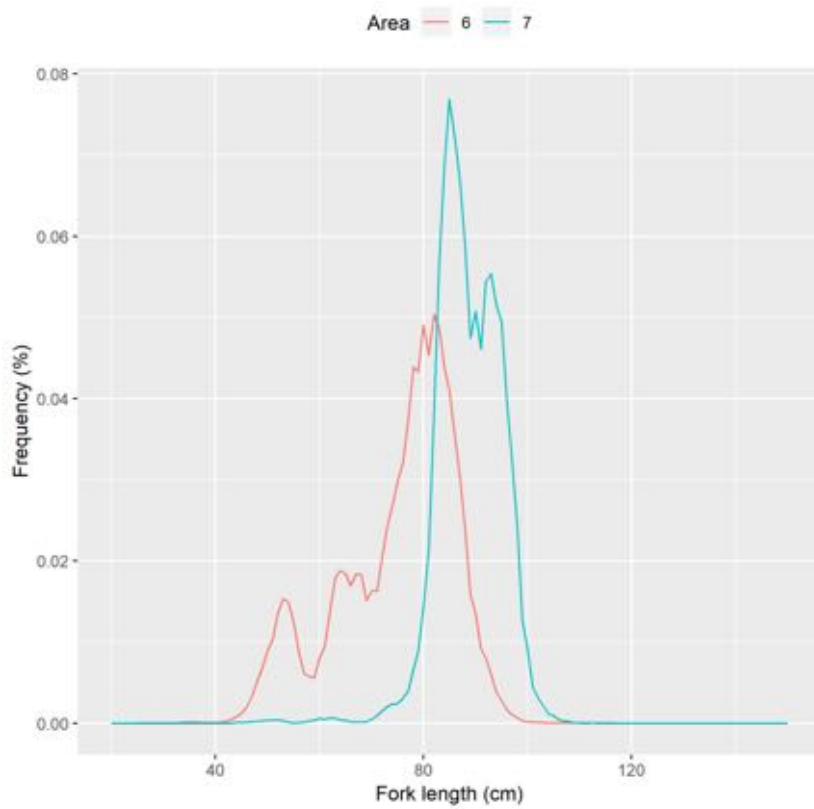


Figure 5. Length-frequency of each area (Japanese pole and line fishery)

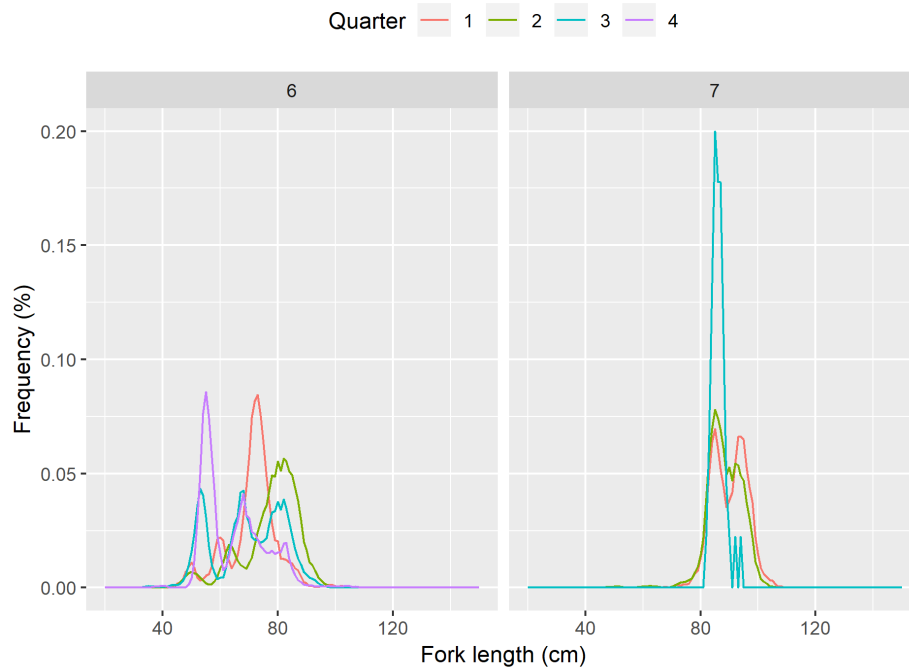


Figure 6. Seasonal difference of length-frequency (Japanese pole and line fishery)

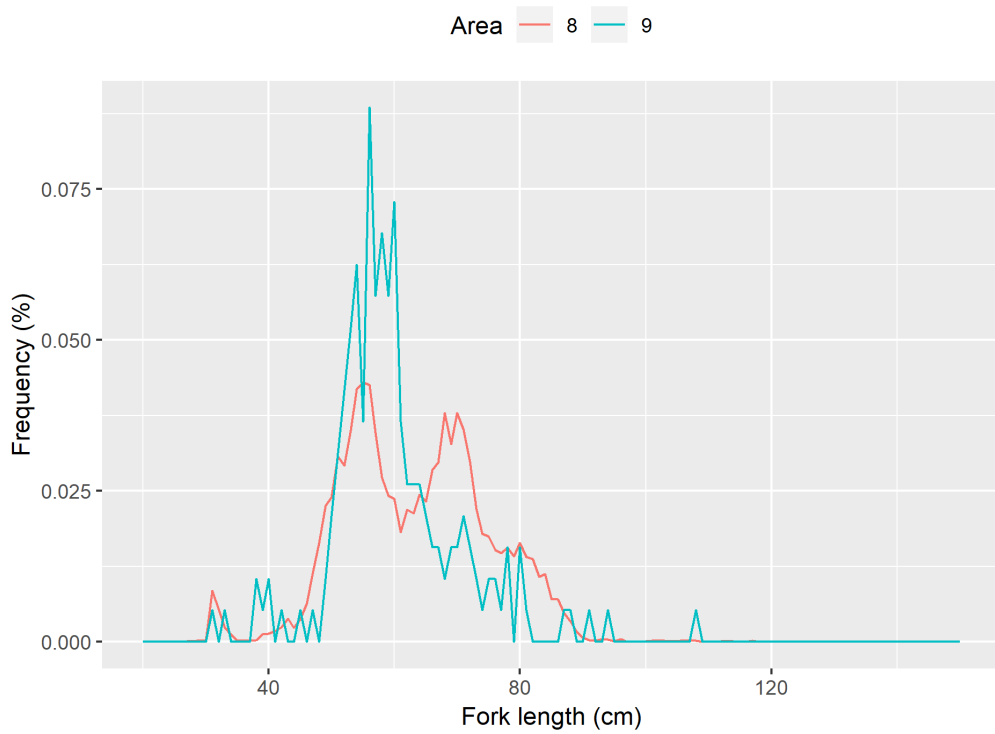


Figure 7. Length-frequency of each area (Japanese drift net fishery)

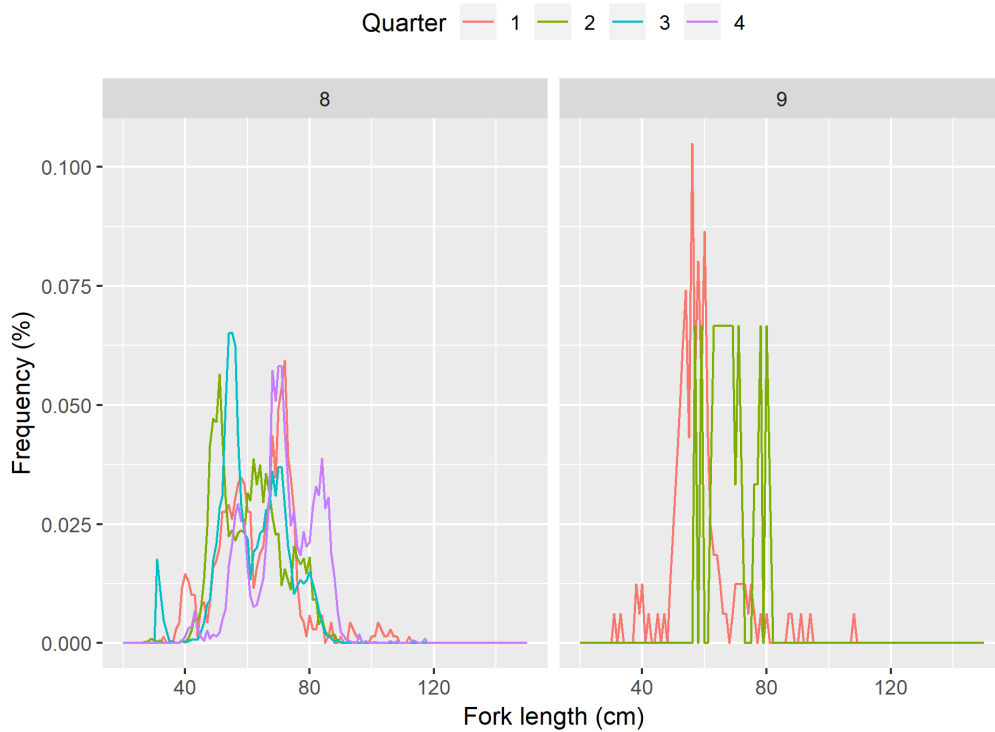


Figure 8. Length-frequency of Japanese drift net fishery

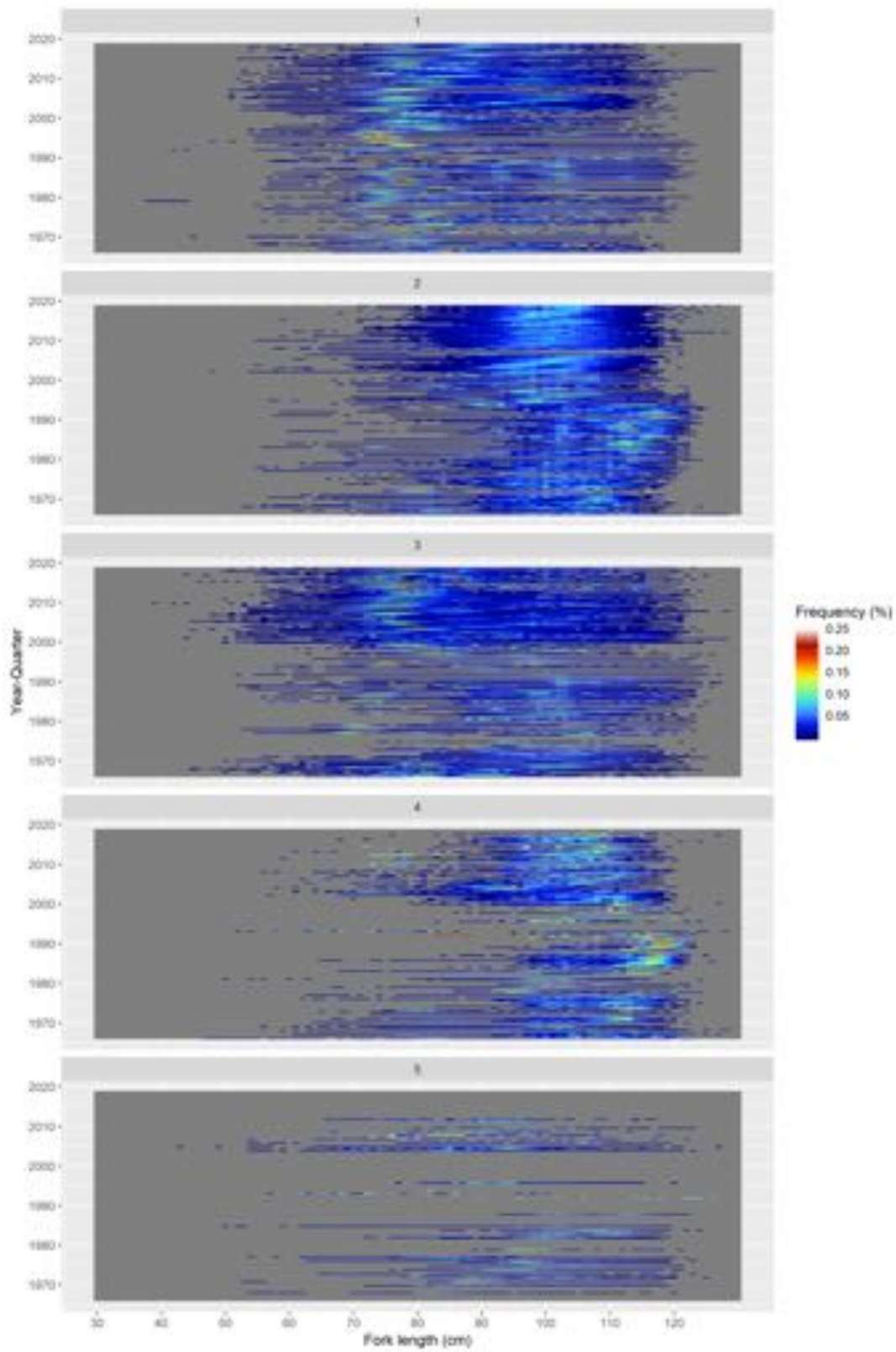


Figure 9. Historical change of length-frequency data (Japanese longline fishery)

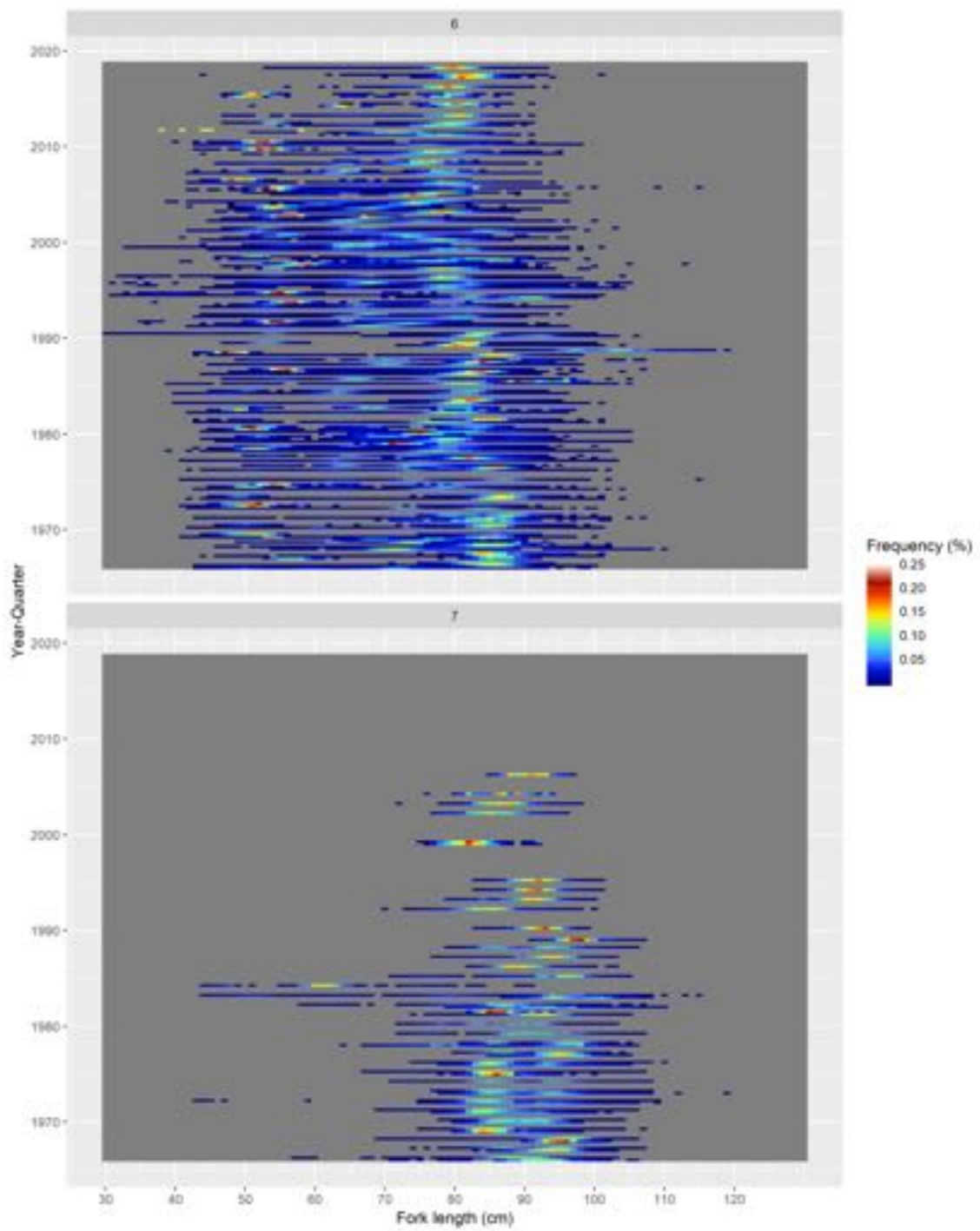


Figure 10. Historical change of length-frequency data (Japanese pole and line fishery)

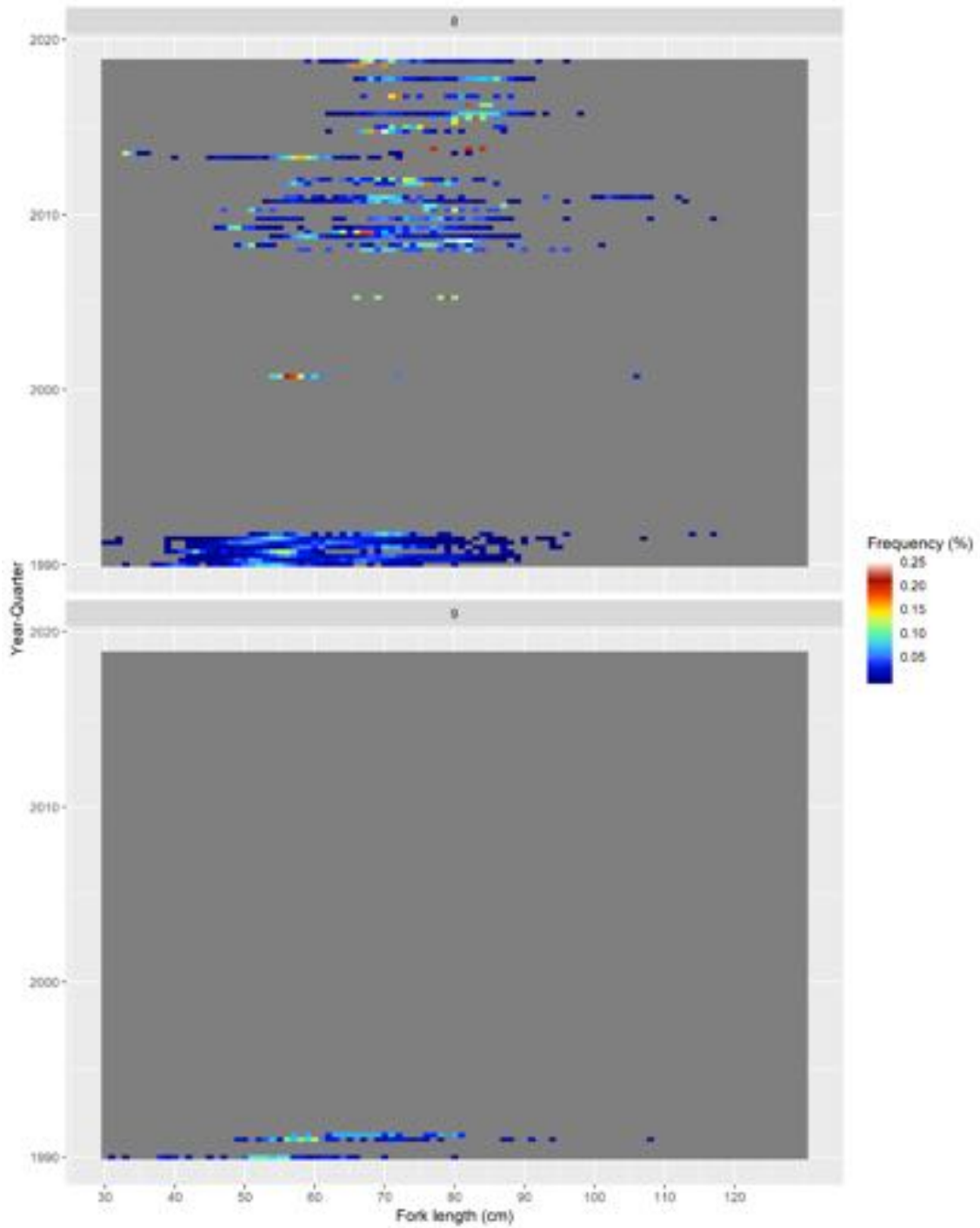


Figure 11. Historical change of length-frequency data (Japanese drift net fishery)

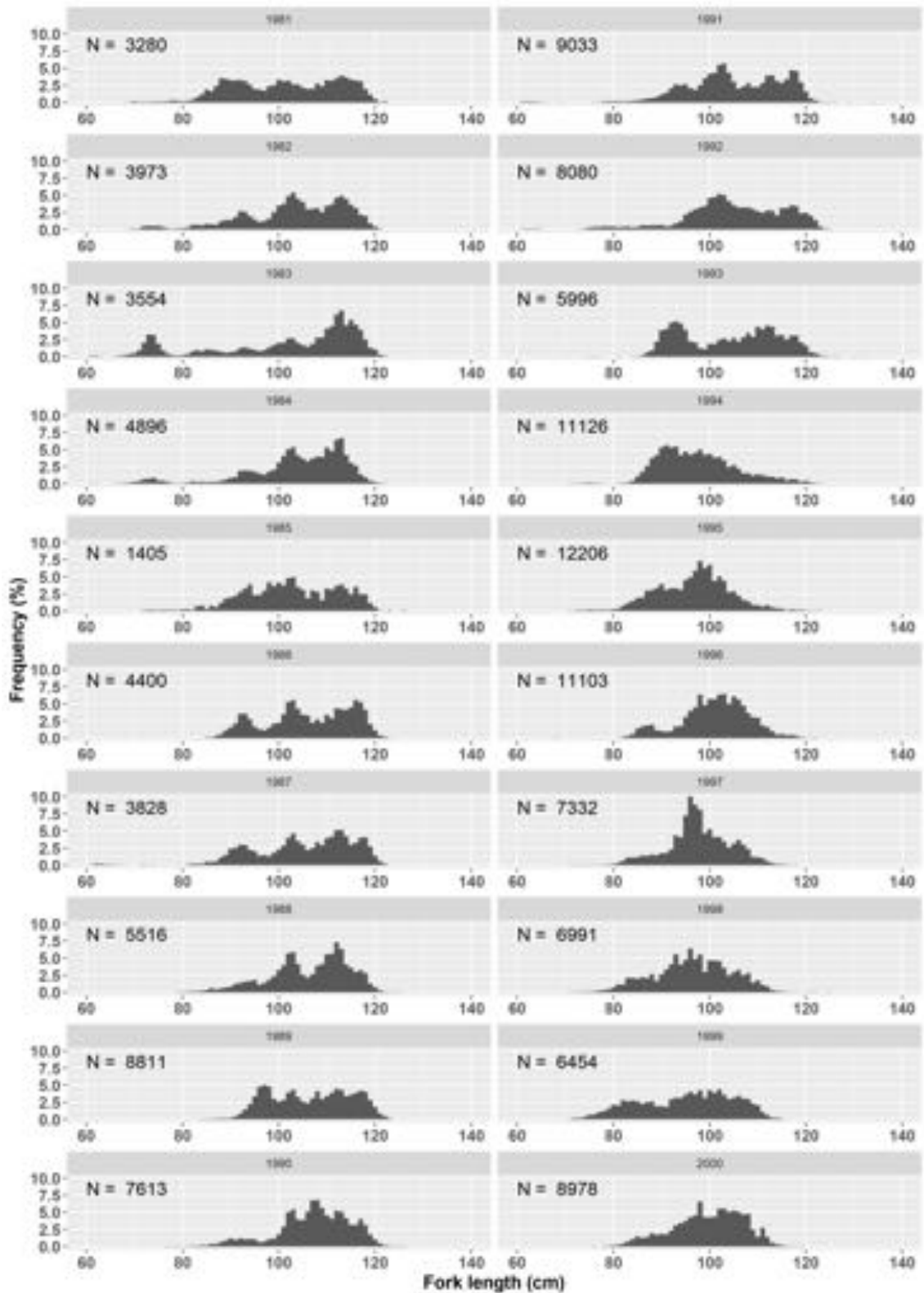


Figure 12. Original size composition of albacore caught by Japanese longline fishery in Area2 between 1981-2000.

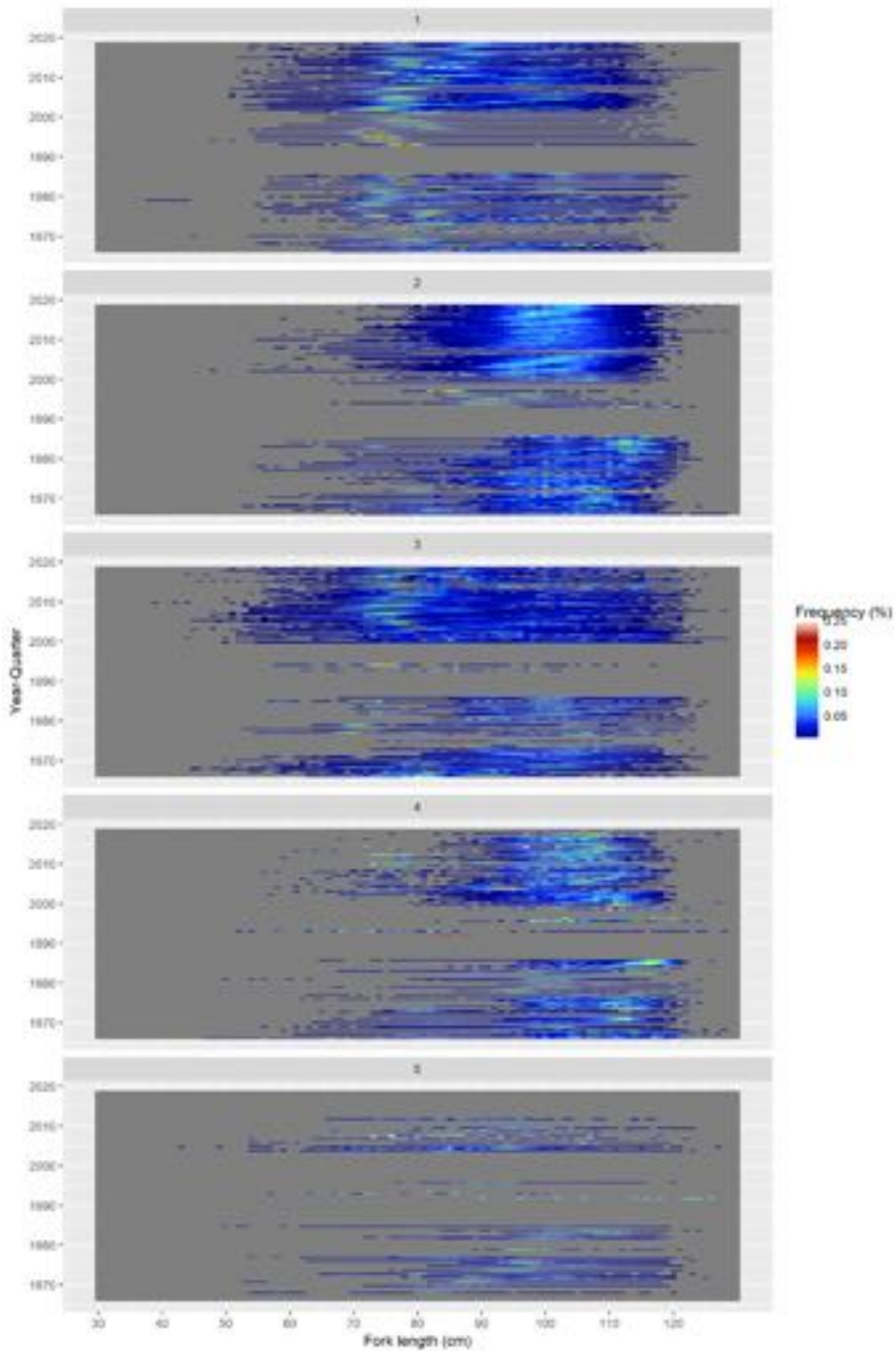


Figure 13. Historical size composition by longline fishery (excluded measurement result in Port Yaizu).

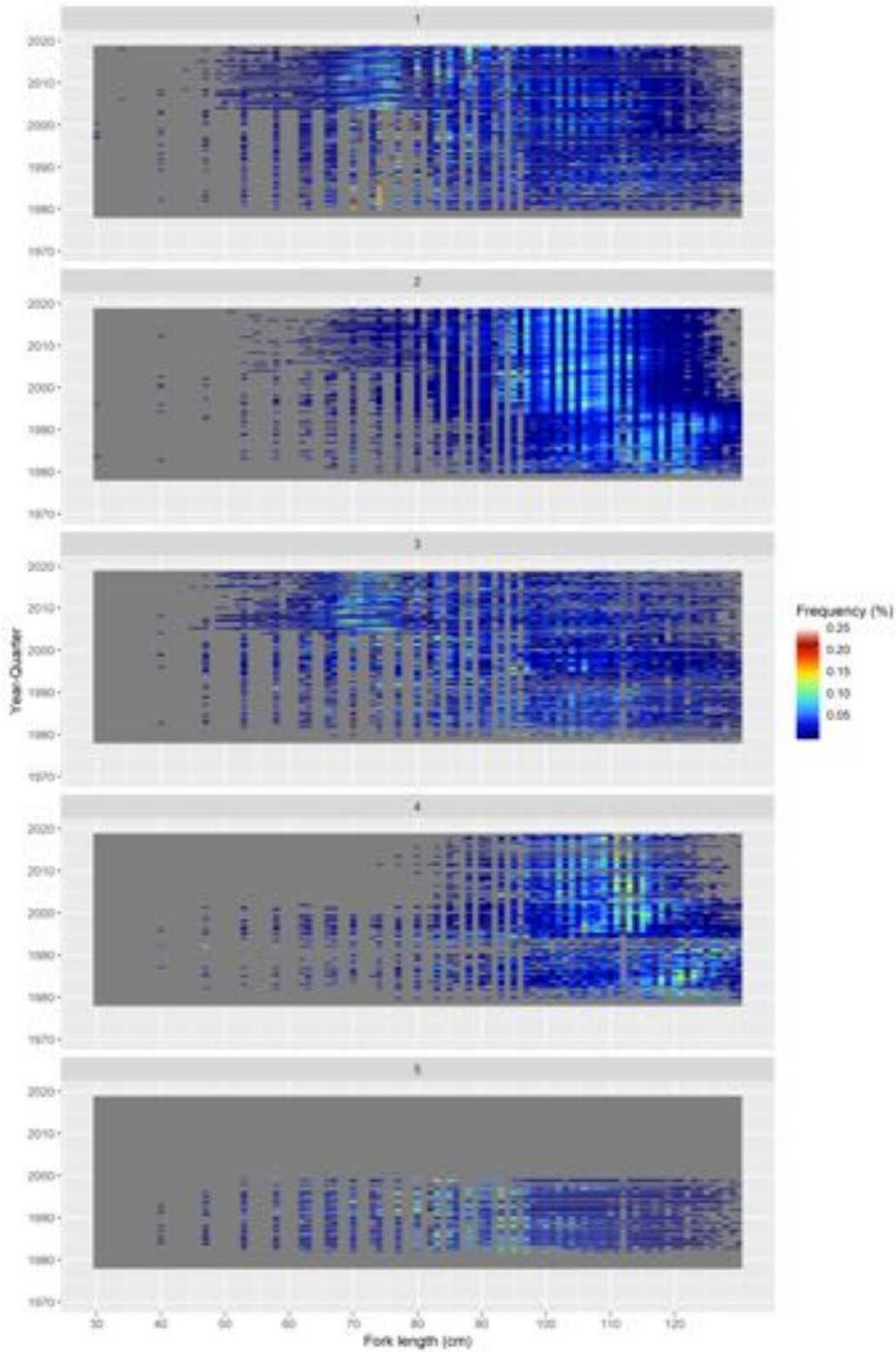


Figure 14. Historical size composition of longline fishery calculated by weight/length relationship (excluded measurement result in Port Yaizu).

Mean body weight of Albacore catch (kg)

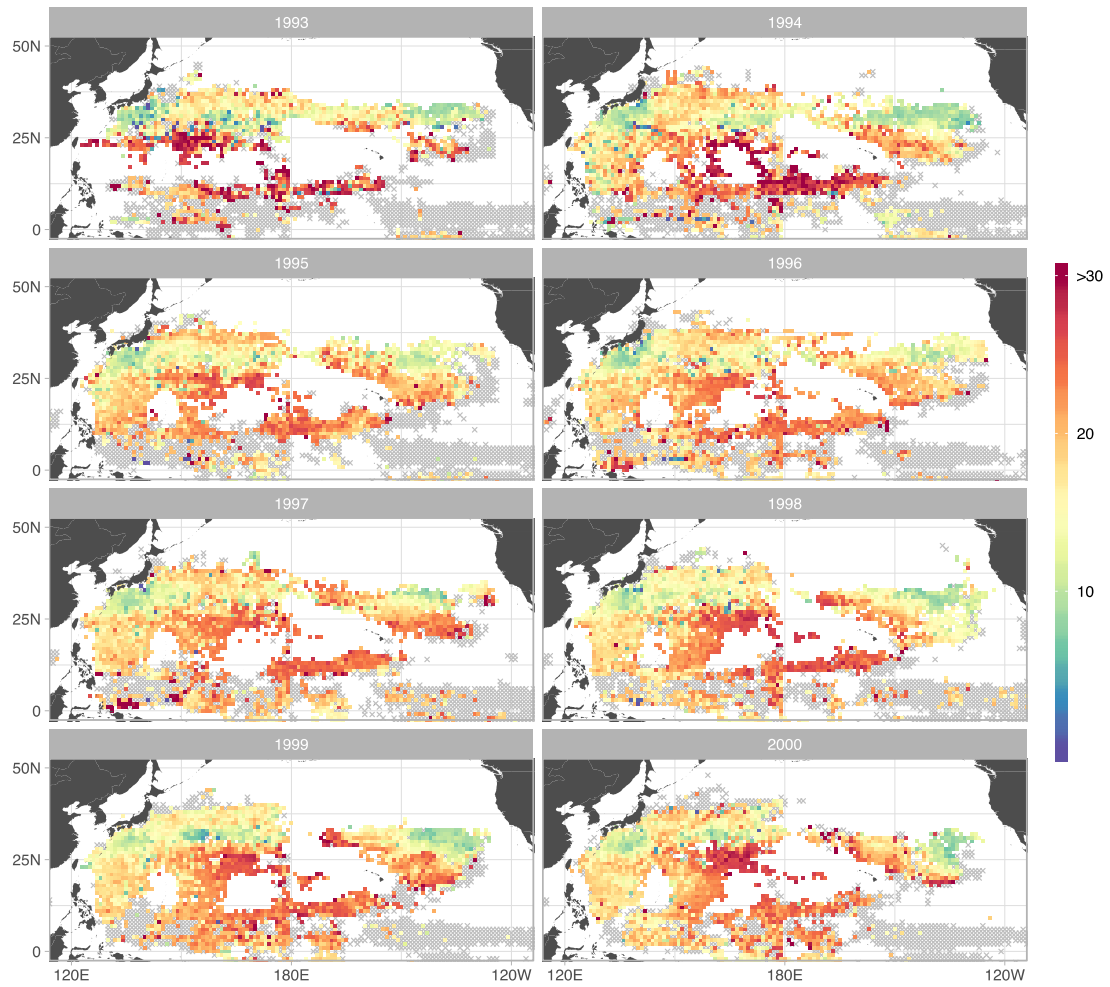


Figure 15. Historical change of North Pacific albacore mean body weight caught by Japanese longline fishery.