Analysis on fishing strategy for target species for Taiwanese large-scale longline fishery in the Indian Ocean

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Paper submitted to the 19th meeting of the Working Party on Billfish, Indian Ocean Tuna Commission, 13-16 September, 2021.

ABSTRACT

The cluster analysis approach was utilized to account for the patterns of the fishing strategy for target species for Taiwanese large-scale longline fishery in the Indian Ocean. The analyses were separately conducted for 4 sub-areas defined for the stock assessment for billfishes. For each sub-area, data from two different time periods of 1979-2020 and 2005-2020 were used. In general, the clustering approach was able to explicitly and clearly identify the targeting of each set. The cluster analysis suggested that main target species would be yellowfin tuna and bigeye tuna in the two northern sub-areas, while albacore and other species were the major targe species in the two southern sub-areas, with some bigeye tuna also included.

1. INTRODUCTION

Taiwanese longline fishery in the Indian Ocean commenced in the mid-1950s. In the beginning, the target species was yellowfin tuna. Following the development of the fishery, two different operation patterns were currently established: the first targets albacore for canning and the other on tropical tuna species, including bigeye tuna and yellowfin tuna, for the sashimi market. In addition, since the early 1990s, catches of swordfish also increased sharply as a result of changes in targeting from tunas to swordfish by part of the Taiwanese longline fleets. Southern bluefin tuna has been a seasonal target species by some vessels with super cold freezers from 1989 onwards.

Due to the decrease of profit margins, some tuna longliners started shifting to the south-west Indian Ocean for fishing oilfish seasonally after 2005 to obtain extra earnings (Anon, 2021).

The characters of fishing operation, such as the number of hooks between floats (NHBF), material of line, bait and etc., are known to be informative to describe the change in target species. The model performance for CPUE standardization can be generally improved when including the NHBF as a covariate for explaining the target (e.g. Wang and Nishida, 2011). However, NHBF data were only available since 1995 and the absence of NHBF information precluded the incorporation of the NHBF as a targeting effect when conducting the CPUE standardization with data before 1995.

Previous studies suggested alternative approaches to account for targeting in multispecies CPUE based on species composition, such as the cluster analysis and principal component analysis (e.g. Ortega-García and Gómez-Muňoz, 1992; He et al., 1997; Pech and Laloë, 1997; Hoyle et al., 2004; Winker et al., 2013; Winker et al., 2014). These approaches have been applied to conduct the CPUE standardization for billfishes in the Indian Ocean (Wang, 2015, 2016, 2017, 2018, 2019). The cluster analysis was adopted as a standard method to derive targeting strategies and include targeting effects in the standardization for main species in the Indian Ocean since the Second IOTC CPUE Workshop on Longline Fisheries in 2015 (Hoyle et al., 2015, 2018, 2019).

In this study, the cluster analysis was applied to explore the targeting strategies of fishing operations, which can be included in a further step for CPUE standardization.

2. MATERIALS AND METHODS

2.1. Data used

In this study, daily operational catch and effort data (logbook) by 5x5 degree longitude and latitude grid for Taiwanese longline fishery during 1979-2020 were used. These data were provided by Oversea Fisheries Development Council of Taiwan (OFDC). It should be noted that the data in 2020 remains preliminary.

More specifically, the dataset used for conducting the clustering consisted of *r* (the number of fishing set) x *c* (the number of species) data frame. Albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT) and sharks (SKX) were selected as main species, and the catches of fishes other than these species were aggregated into a single category of others (OTH). In addition, the data were aggregated by 10-days duration (1st-10th, 11th-20th, and 21st~ in each month) based on the agreement of the trilateral collaborative working group (Kitakado et al., 2021).

2.2. Cluster analysis

He et al. (1997) proposed a two-step cluster analysis (K-means clustering was conducted first and then hierarchical clustering was applied to the outcomes from K-means clustering) to classify the targeting for high dimensional fishery data with species composition because a large number of data sets precluded direct hierarchical cluster analysis. This approach was also used in previous studies for analyzing the targeting strategies of longline fisheries in the Indian Ocean (e.g. Wang, 2020; Kitakado et al., 2021).

However, the K-means method needs to pre-specify the number of clusters. Furthermore, relatively robust results also need to be obtained through a sufficient number of iterations of random processes, which lead to the calculation process to being quite time-consuming. Therefore, this study adopted a direct hierarchical clustering with agglomerative algorithm, which brings a fast and efficient implementation through features of memory-saving routines in hierarchical clustering of vector data (Müllner, 2013). The trials conducted using R function “hculst.vector” of package “fastcluster” (Müllner 2021) with Ward's minimum variance linkage methods (“ward.D” for the argument “method” in “hclust.vector” of R function) applied to the squared Euclidean distances between data points calculated based on the species composition.

The number of clusters was commonly selected based on the elbow method, i.e. the change in deviance between/within clusters against different numbers of clusters in previous studies (e.g. He et al., 1997; Hoyle et al., 2015; Matsumoto et al., 2018; Wang, 2019; Wang, 2020). The elbow method was also adopted in this study and the number of clusters was determined when the improvement in the sum of within-cluster variations was less than 10%.

However, observing the patterns from the elbow method may be relatively subjective. In this study, the diagnostics of the homogeneity of species compositions between clusters were also conducted using the nonparametric comparison of multivariate samples with permutation test (Burchett et al., 2017). The global tests of the significance among clusters were performed using function “nonpartest” of R package “npmv” (Burchett and Ellis, 2017) and detailed comparisons with combinations between 2, 3, …, all clusters were performed using function “ssnonpartest” with subset algorithm. In addition, the visual diagnostic for multivariate dispersions of the centroids by clusters was conducted based on the plots from PCA derived with the variance-covariance matrix of species compositions by clusters. All of these analyses were performed by four fishing areas separately (Fig.

1).

3. RESULTS AND DISCUSSION

3.1. Time series of 1979-2020

Based on the patterns from the elbow method, a total of 4 clusters were determined for all sub-areas and the improvements in the sum of within-cluster variations were obviously lower than 10% when increasing the number of clusters from 3 to 4 (Fig. 2). Plots of PCA for the multivariate dispersions indicated that the centroids of species compositions were distinct by clusters but the ranges of 95% confidence intervals overlapped among clusters for most areas (Fig. 3). The global tests of nonparametric comparisons indicated that the multivariate distributions of species compositions were statistically significant among clusters for all areas (P-value < 0.01 for all ANOVA type, Lawley Hotelling and Wilks Lambda tests). The statistical tests based on detailed comparisons rejected the hypothesis of equality of multivariate distributions between clusters for all sub-areas.

For each sub-area, the species compositions revealed different patterns by clusters (Fig. 4). The main target species, such as yellowfin tuna, bigeye tuna and albacore, can be grouped by clusters and some other species can be also grouped in a particular area (e.g. other species and sharks in the area SW). In general, clusters mainly consisted of yellowfin tuna and bigeye tuna in the northern areas (NW and NE), while albacore, other species (oilfish since the mid-2000s) were the major species accompanied some bigeye tuna in the southern areas (SW and SE).

Figs. 5 and 6 show the annual trends of catches of striped and black marlins and fishing efforts. Because striped and black marlins were caught as bycatches, their catches were grouped into different clusters when the levels of fishing efforts changed with time periods. In addition, the proportions of zero-catch were very high for both striped and black marlins in all areas and the proportions for striped marlin gradually increased by years in northern areas (Figs. 7 and 8).

3.2. Time series of 2005-2020

As the suggestion of WPTT (IOTC, 2021), the cluster analyses were also conducted using the data from 2005 to 2020. Based on the patterns from the elbow method, the determined numbers of clusters were 4 for areas NE and SE, 5 for area NW and 3 for area SW (Figs. 9 and 10). The global and detailed tests of nonparametric comparisons indicated statistical significance in the hypothesis of equality of multivariate distributions among and between clusters for all areas.

The species compositions by clusters indicated that clustering can not only identify the groups for the main target species but also can explicitly provide groups for other species in a particular area when data of 2005-2020 were used. (Fig. 11). For instance, the fishing sets targeted the other species (oilfish) in area SW and southern bluefin tuna in area SE can be explicitly identified by clustering. The annual trends of catches of striped and black marlins and fishing efforts were shown in Figs. 12-13.

REFERENCE

Anon, 2021. National Report of Chinese Taipei to the SIOFA Scientific Committee, 2021. 6th Meeting of the Southern Indian Ocean Fisheries Agreement (SIOFA) Scientific Committee, SC-06-20.

Burchett, W., Ellis, A., 2017. Package ‘npmv’. https://cran.r-project.org/web/packages/npmv/npmv.pdf

Burchett, W.W., Ellis, A.R., Harrar, S.W., Bathke, A.C., 2017. Nonparametric Inference for Multivariate Data: The R Package npmv. Journal of Statistical Software, 76(4): 1-18.

He, X., Bigelow, K.A., Boggs, C.H., 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. Fish. Res. 31: 147-158.

Hoyle, S.D., Fu, D., Kim, D.N., Lee, S.I., Matsumoto, T., Satoh, K., Wang, S.P., Kitakado, T., 2019. Collaborative study of albacore tuna CPUE from multiple Indian Ocean longline fleets in 2019. IOTC-2019-WPTmT07(AS)-10

Hoyle, S.D., Kitakado, T., Yeh, Y.M., Wang, S.P., Wu, R.F., Chang, F.C., Matsumoto, T., Satoh, K., Kim, D.N., Lee, S.I., Chassot, E., Fu, D., 2018. Report of the Fifth IOTC CPUE Workshop on Longline Fisheries, May 28th–June 1st, 2018. IOTC–2018–CPUEWS05–R[E].

Hoyle, S.D., Langley, A.D., Campbell, R.A., 2014. Recommended approaches for standardizing CPUE data from pelagic fisheries. WCPFC-SC10-2014/ SA-IP-10.

Hoyle, S.D., Okamoto, H., Yeh, Y.M., Kim, Z.G., Lee, S.I., Sharma, R., 2015. Report of the 2nd CPUE Workshop on Longline Fisheries, April 30th – May 2nd, 2015. IOTC–2015–CPUEWS02–R[E]

IOTC, 2021. Report of the 23th Session of the IOTC Working Party on Tropical tunas, Data Preparatory Meeting. IOTC-2021-WPTT23(DP)-R[E].

Kitakado, T., Wang, S.P., Satoh, K., Lee, S.I., Tsai, W.P., Matsumoto, T., Yokoi, H., Okamoto, K., Lee, M.Y., Lim, J.H., Kwon, Y., Su, N.J., Chang, S.T., Chang, F.C., 2021. Report of trilateral collaborative study among Japan, Korea and Taiwan for producing joint abundance indices for the yellowfin tunas in the Indian Ocean using longline fisheries data up to 2019. IOTC–2021-WPTT23(DP)-14.

Matsumoto, T., Satoh, K. Hoyle, S., 2018. Standardization of bigeye and yellowfin tuna CPUE by Japanese longline in the Indian Ocean which includes cluster analysis. IOTC–2018–WPTT20–37.

Müllner, D., 2013. fastcluster: Fast Hierarchical, Agglomerative Clustering Routines for R and Python. Journal of Statistical Software, 53(9): 1-18.

Müllner, D., 2021. The fastcluster package: User’s manual, Version 1.2.3. https://cran.r-project.org/web/packages/fastcluster/vignettes/fastcluster.pdf

Ortega-García, S., Gómez-Muňoz, V., 1992. Standardization of fishing effort using principle component analysis of vessel characteristics: the Mexican tuna purse-seiners. Sci. Mar. 56: 17-20.

Pech, N., Laloë, F., 1997. Use of principal component analysis with instrumental variables (PCAIV) to analyse fisheries catch data. ICES J. Mar. Sci. 54: 32-47.

Wang, S.P., 2015. CPUE standardization of striped marlin (*Kajikia audax*) caught by Taiwanese longline fishery in the Indian Ocean using targeting effect derived from cluster and principle component analyses. IOTC–2015–WPB13–31 Rev_1.

Wang, S.P., 2016. CPUE standardization of blue marlin (*Makaira nigricans*) caught by Taiwanese longline fishery in the Indian Ocean using targeting effect derived from principle component analyses. IOTC–2016–WPB14–23.

Wang, S.P., 2017. CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese longline fishery in the Indian Ocean. IOTC–2017–WPB15–17_Rev1.

Wang, S.P., 2018. CPUE standardization of striped marlin (*Tetrapturus audax*) caught by Taiwanese large scale longline fishery in the Indian Ocean. IOTC–2018–WPB16–18_Rev1.

Wang, S.P., 2020. CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese large scale longline fishery in the Indian Ocean. IOTC-2020-WPB18-15_Rev.

Wang, S.P., Nishida, T., 2011. CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese longline fishery in the Indian Ocean. IOTC-2011-WPB09-12.

Winker, H., Kerwath, S.E., Attwood, C.G., 2013. Comparison of two approaches to standardize catch-per-unit-effort for targeting behaviour in a multispecies hand-line fishery. Fish. Res. 139: 118-131.

Winker, H., Kerwath, S.E., Attwood, C.G., 2014. Proof of concept for a novel procedure to standardize multispecies catch and effort data. Fish. Res. 155: 149-159.

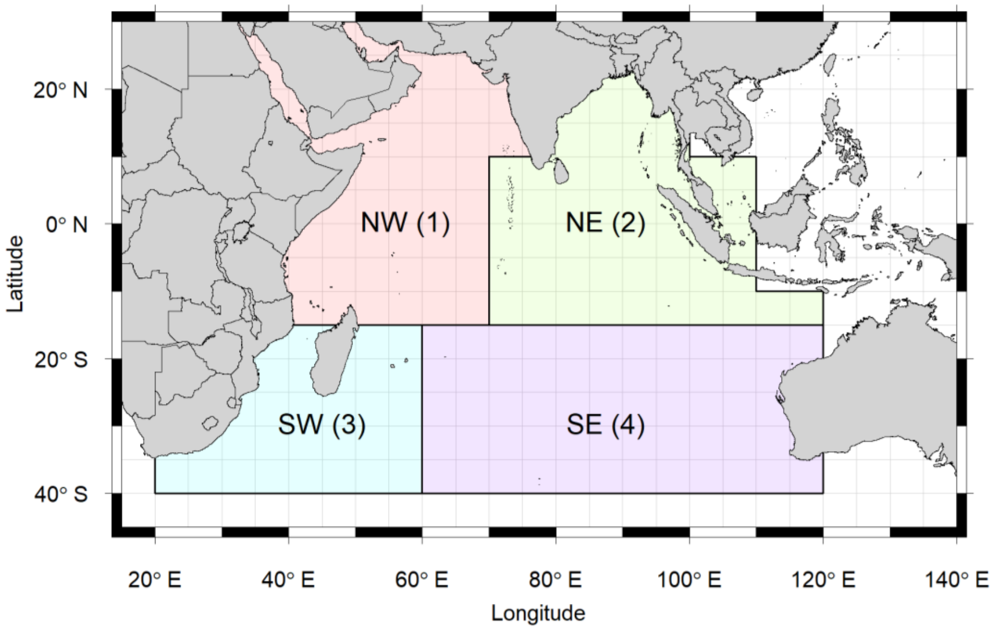
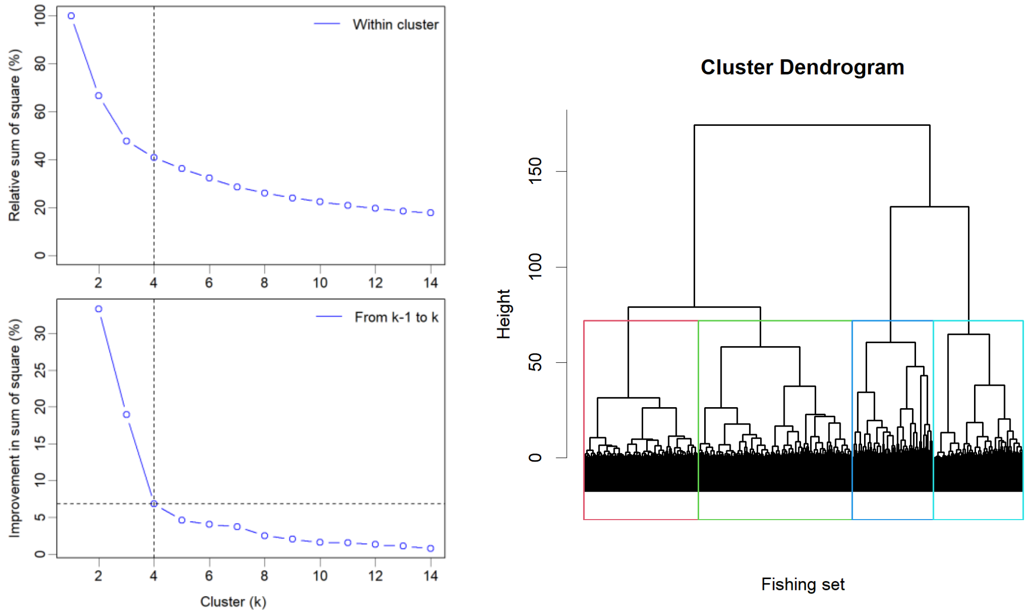


Fig. 1. Area stratification for swordfish in the Indian Ocean.

NW



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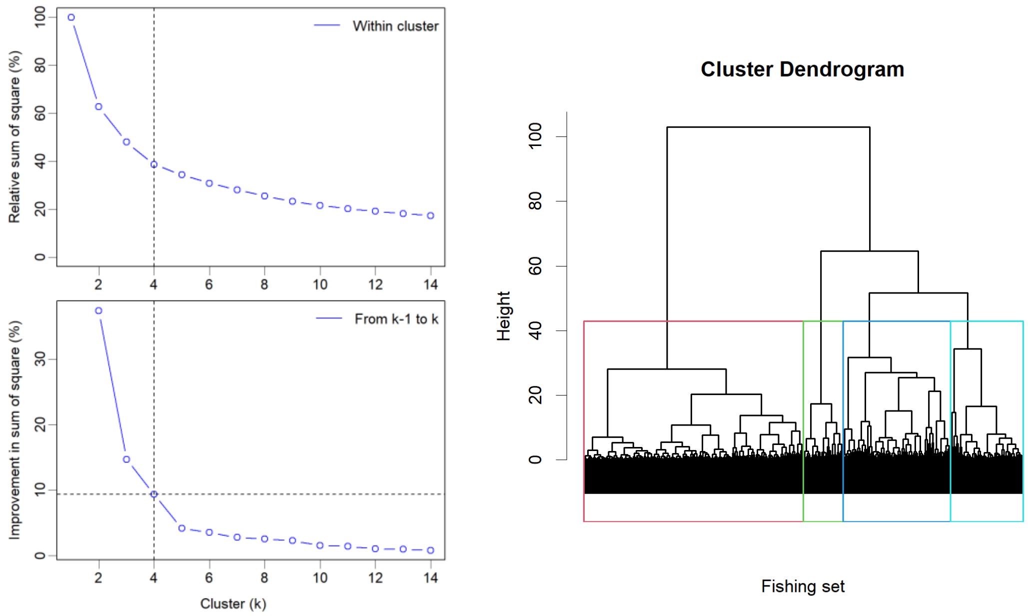
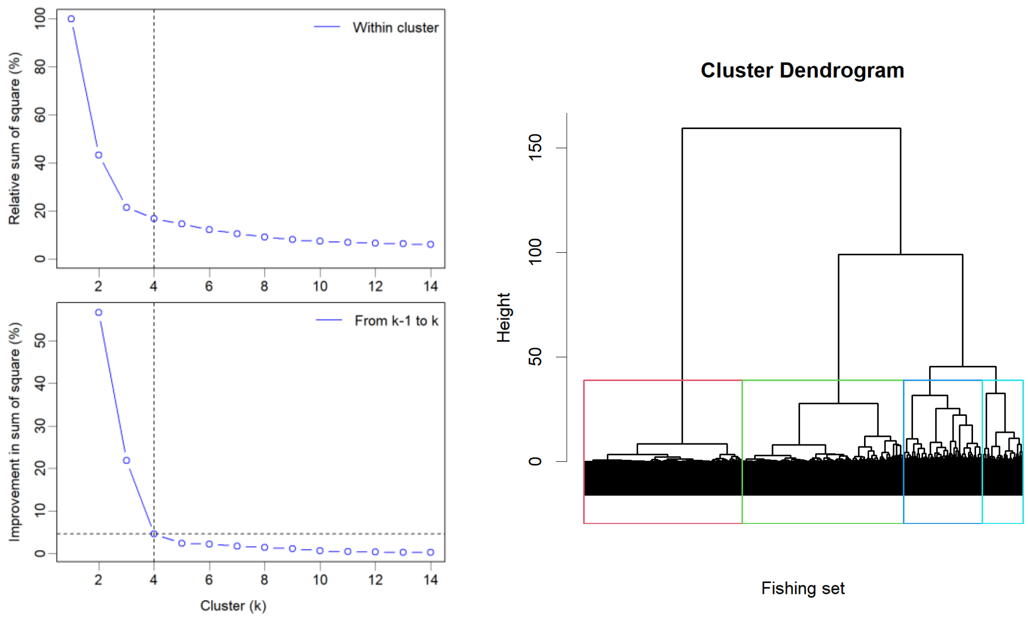


Fig. 2. Sum of squares within clusters for the data of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

SW



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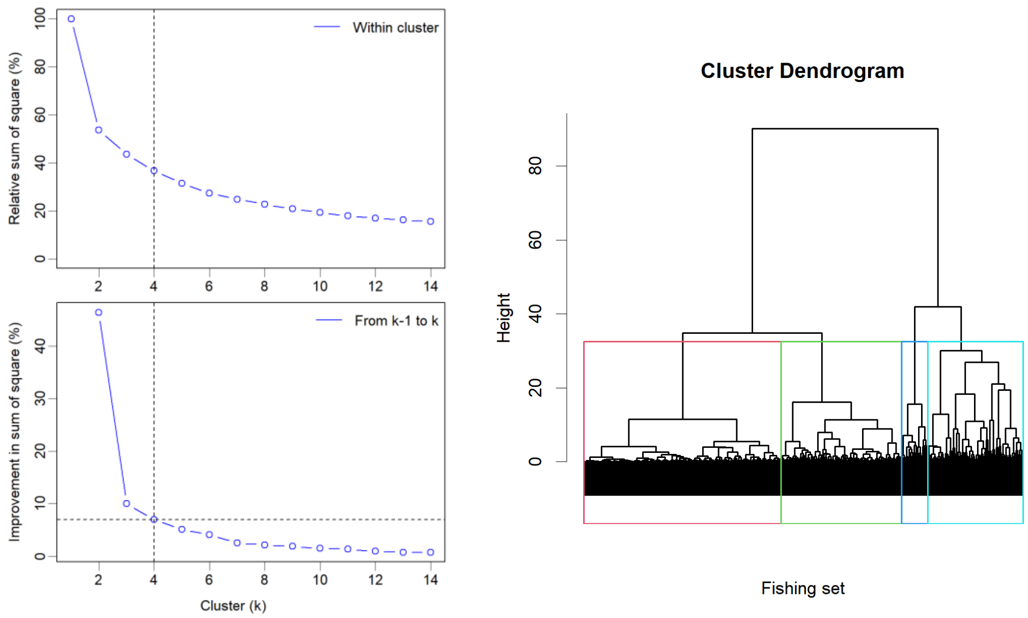

Fig. 2. (Continued).

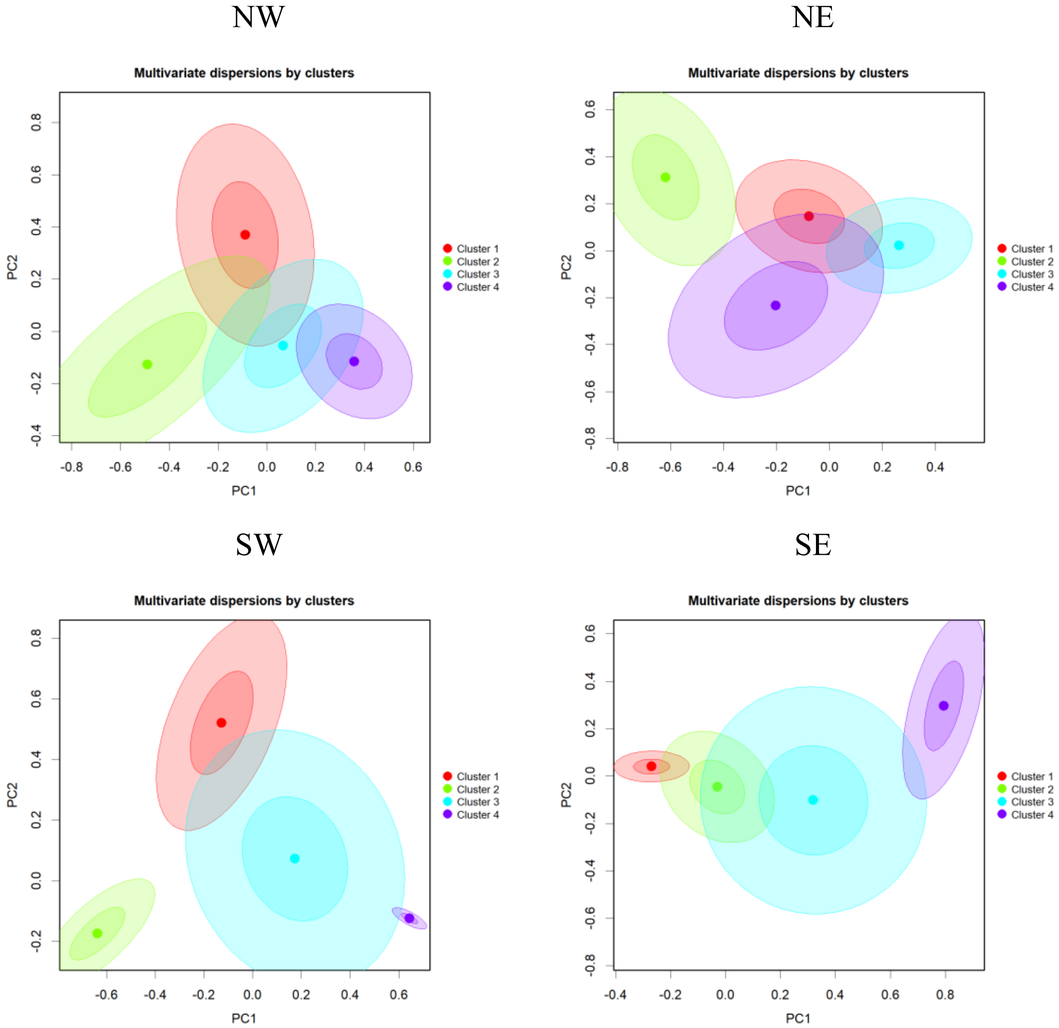

Fig. 3. Multivariate dispersions of the centroids by clusters derived from PCA for the data of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

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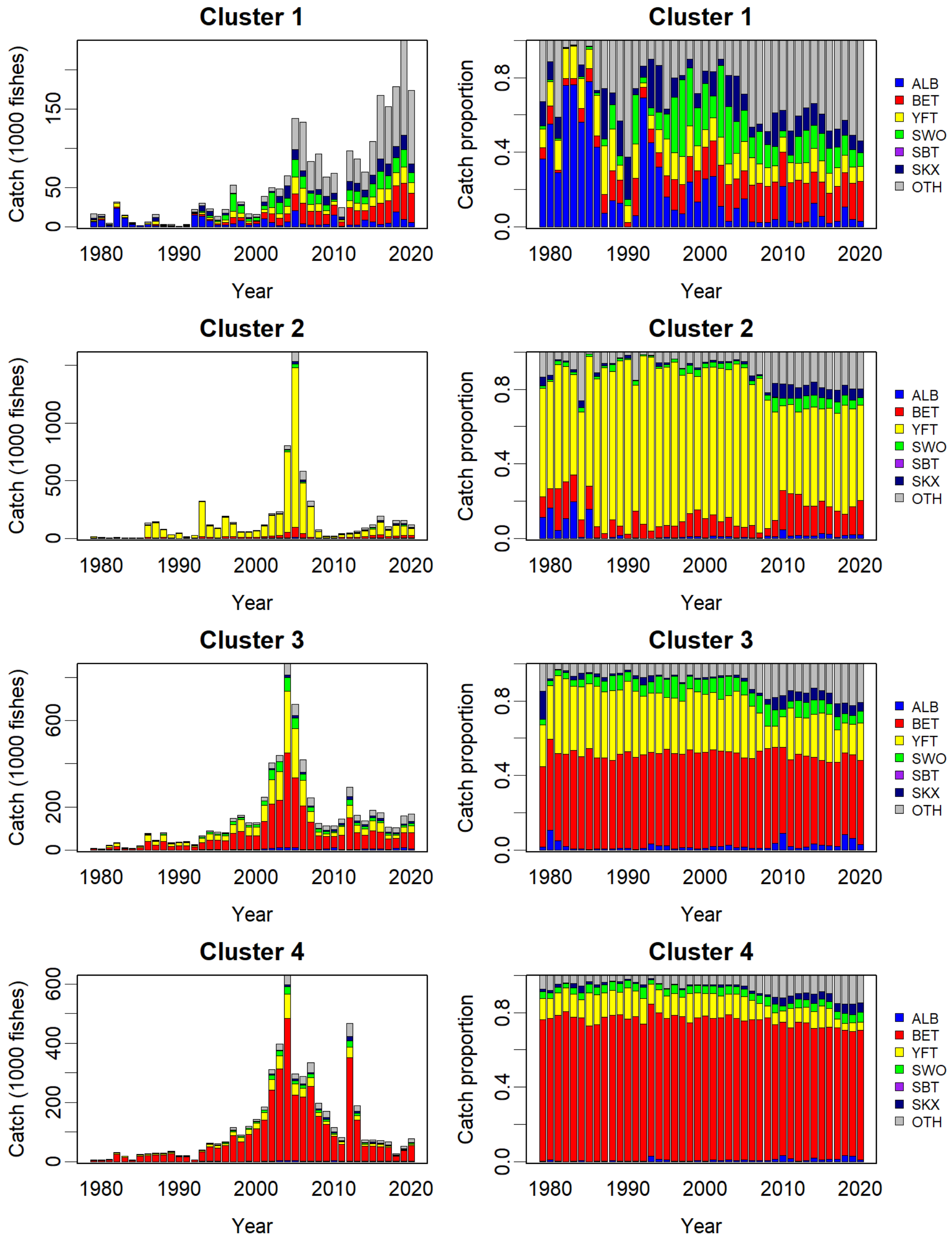

Fig. 4. Annual catches and compositions by species for each cluster of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

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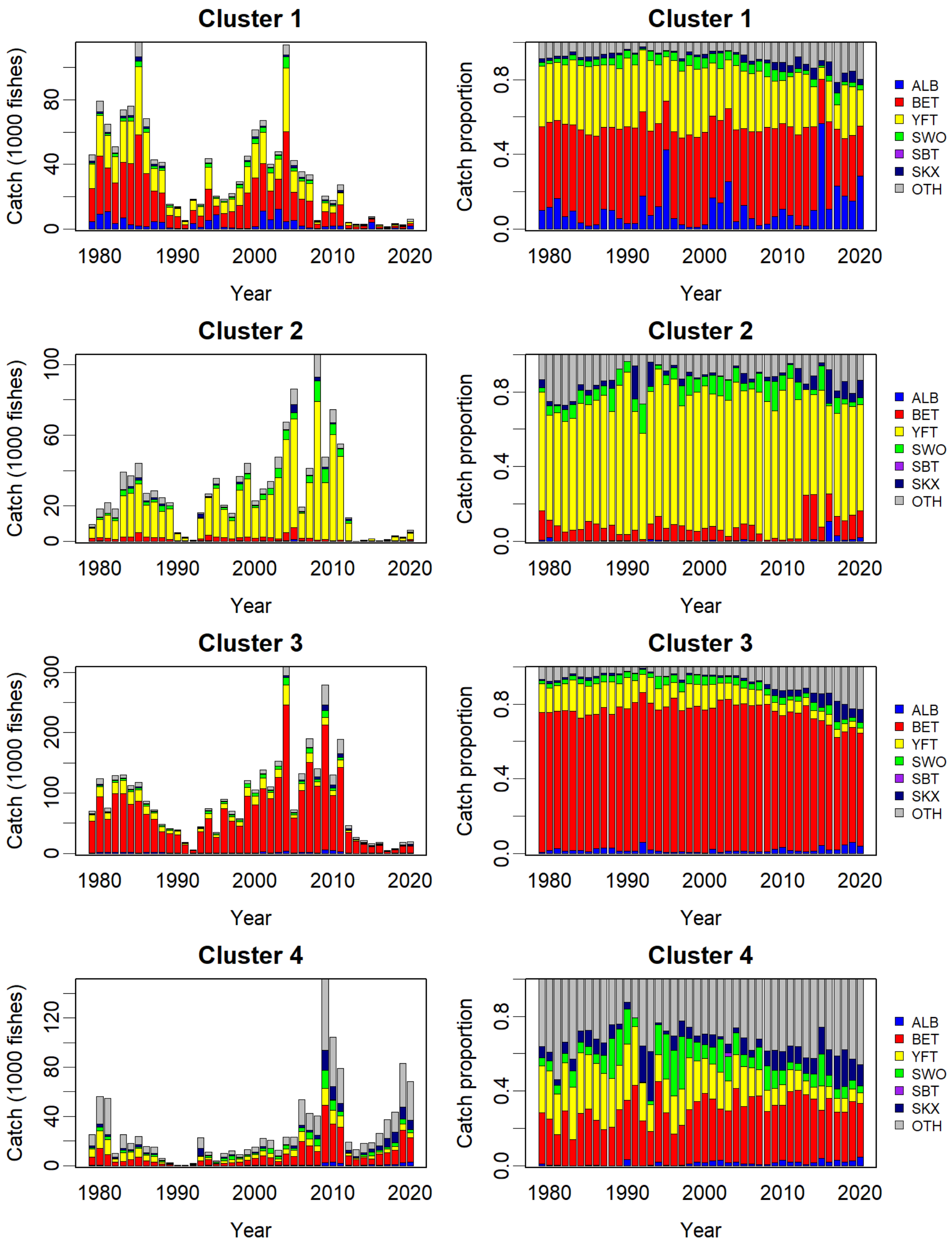

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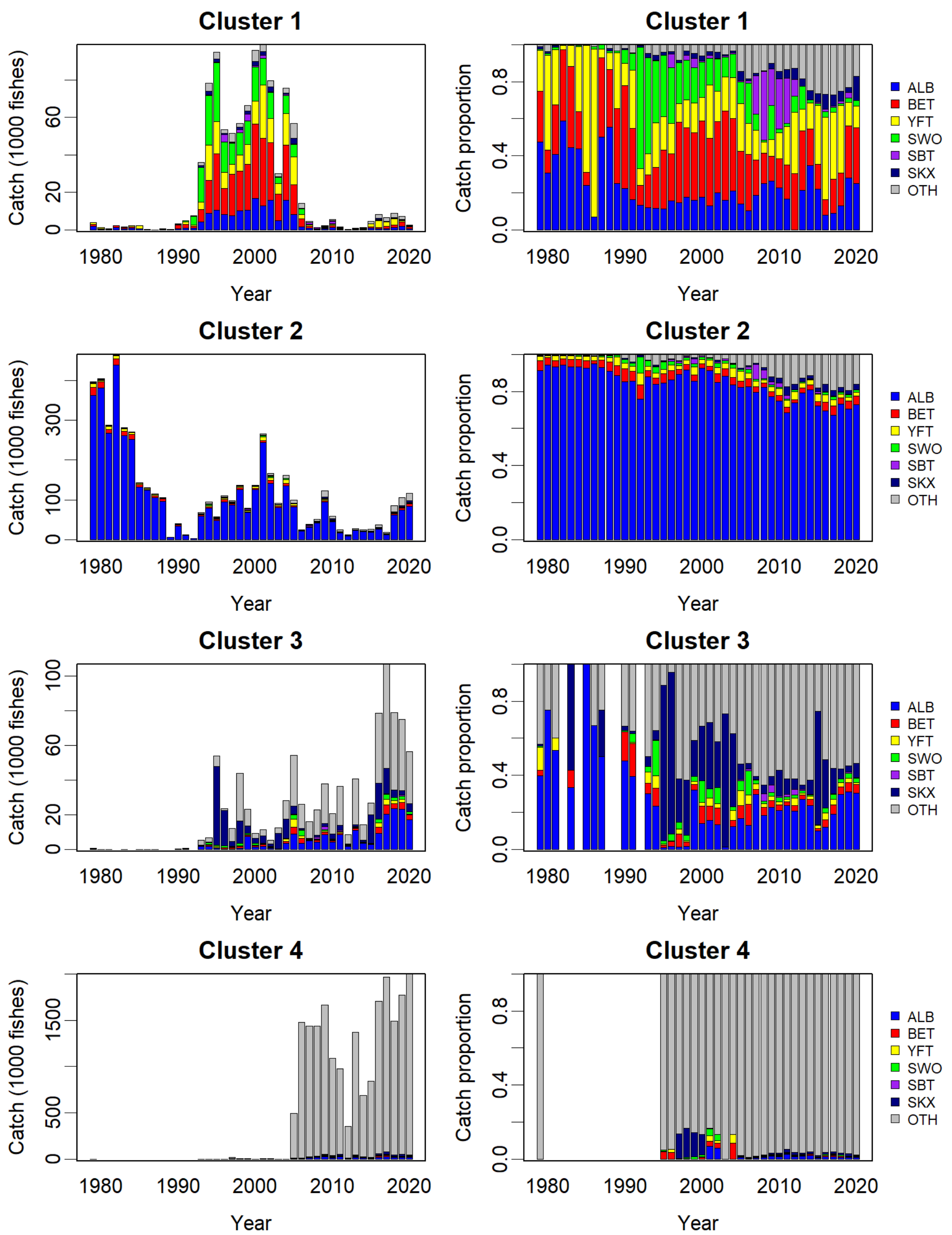

Fig. 4. (Continued).

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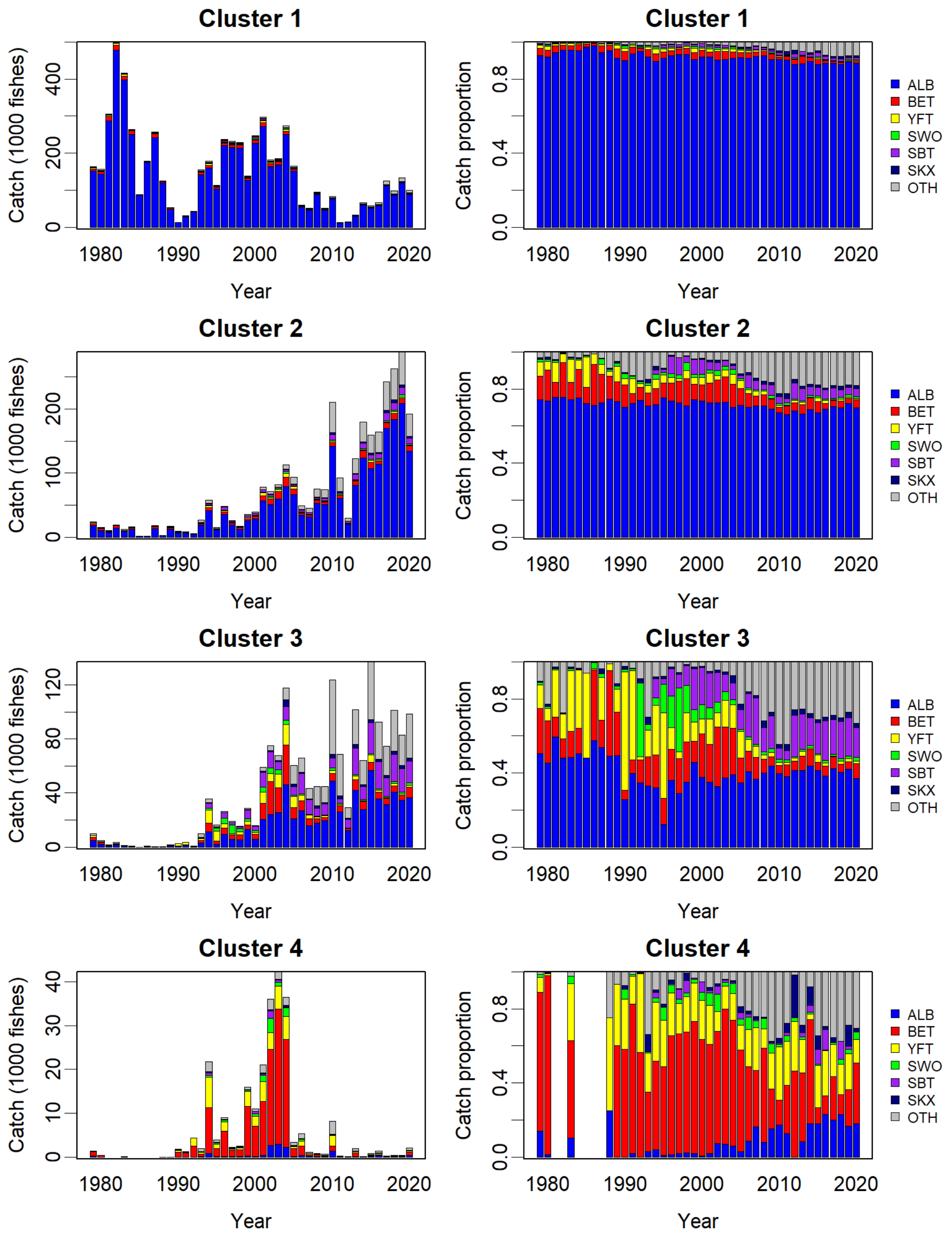

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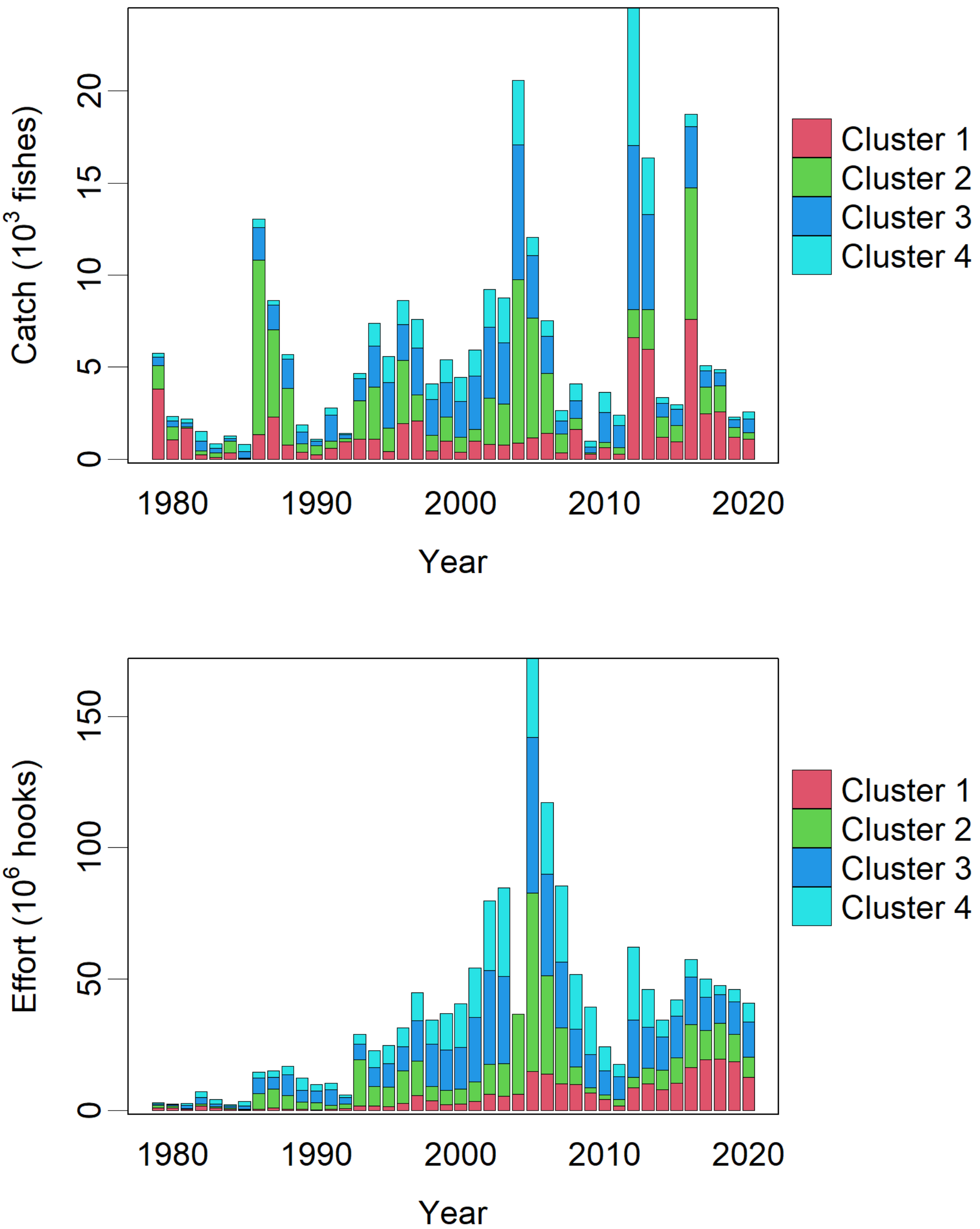

Fig. 5. Annual striped marlin catches and efforts for each cluster of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

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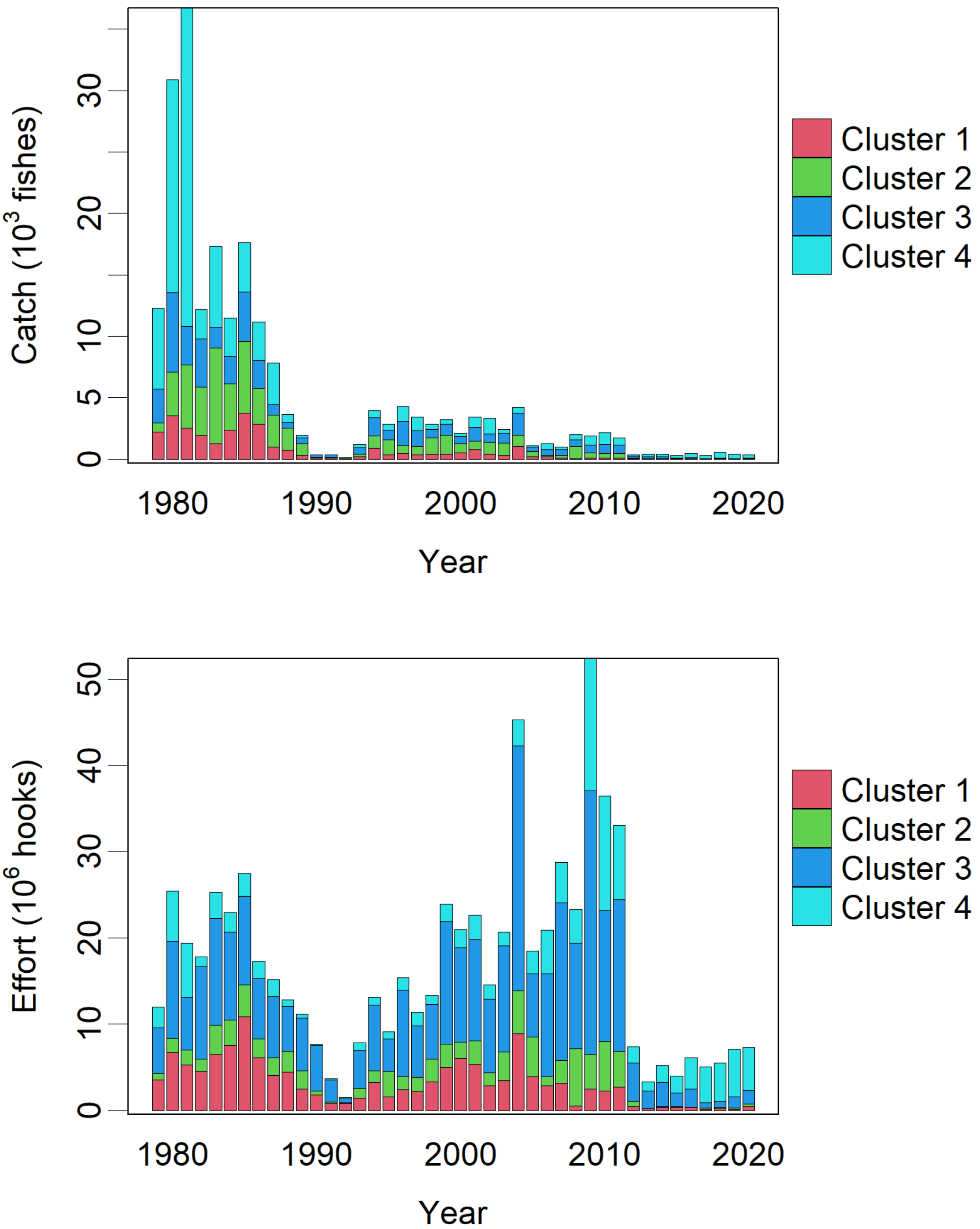

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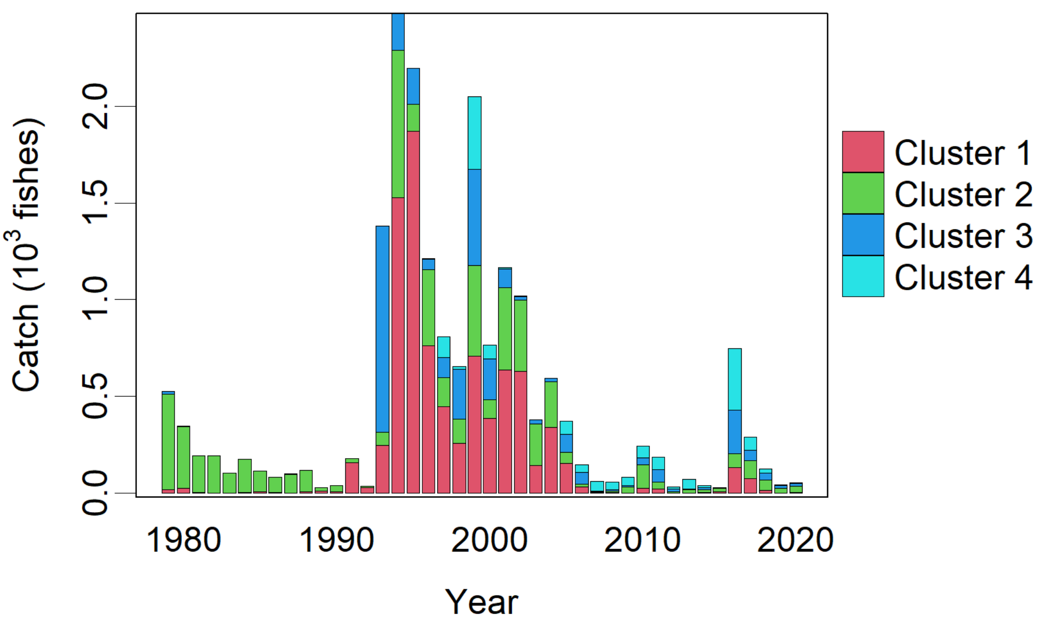

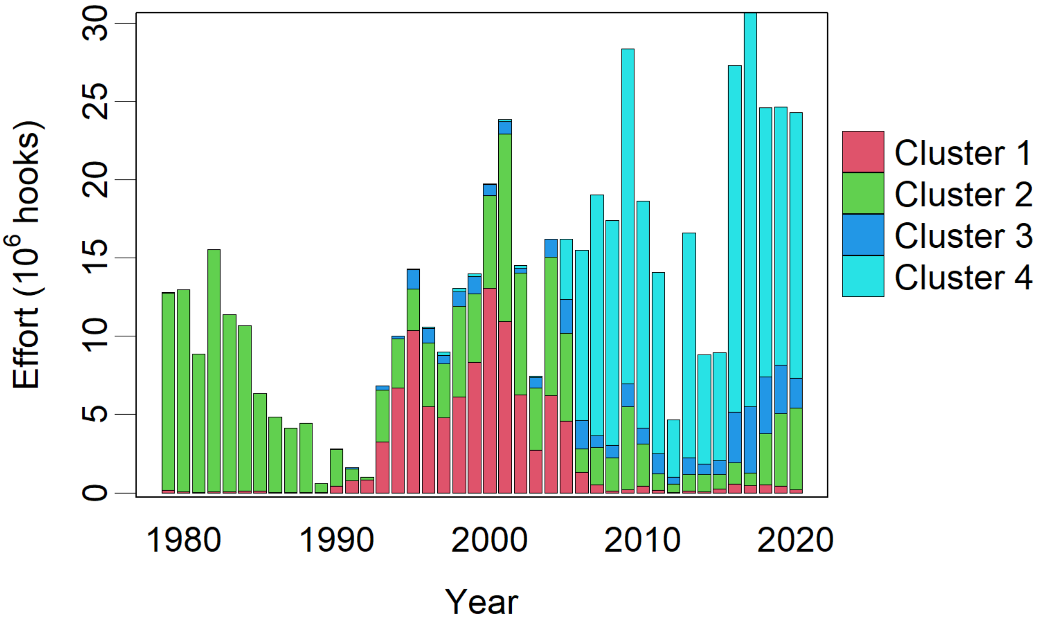

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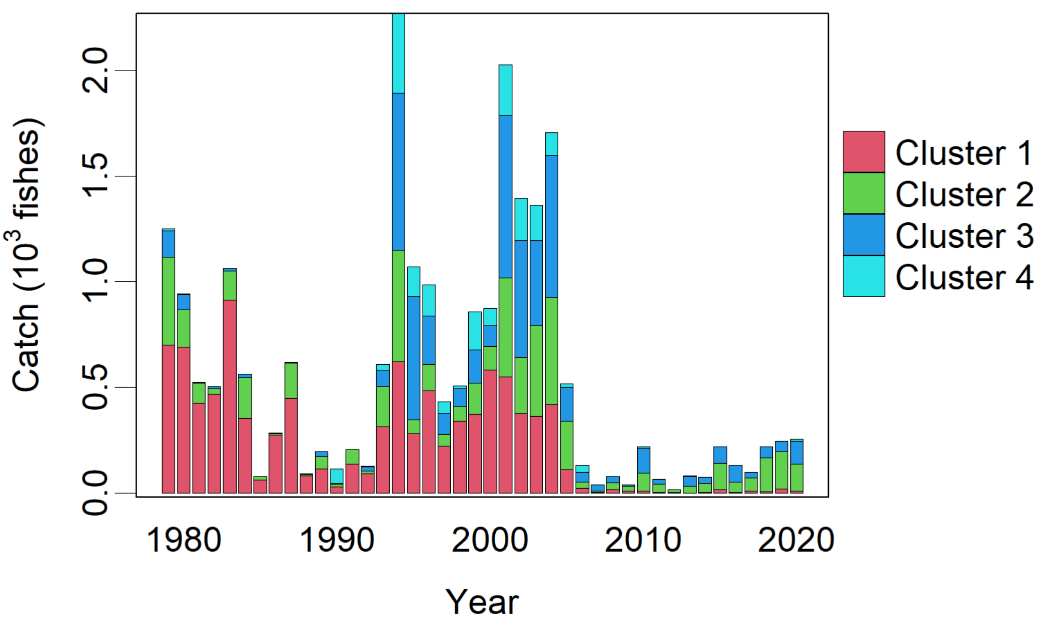

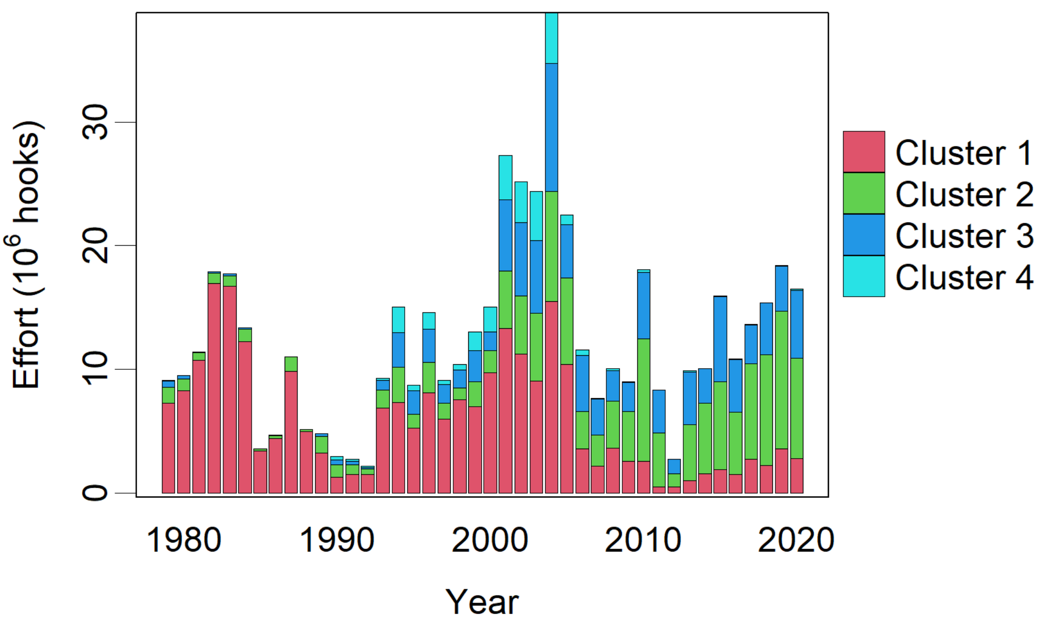

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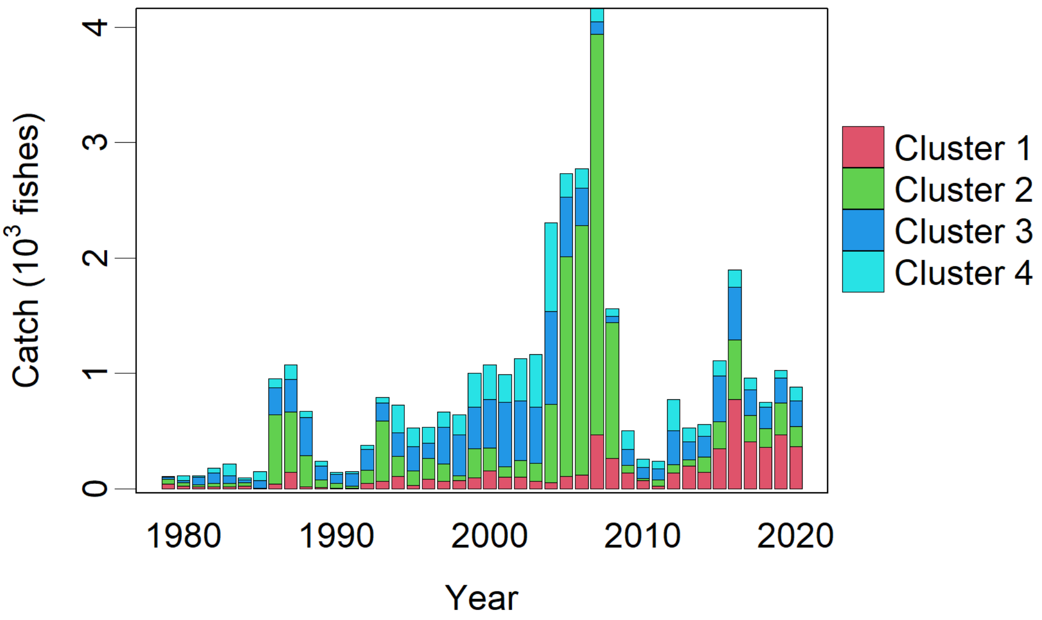

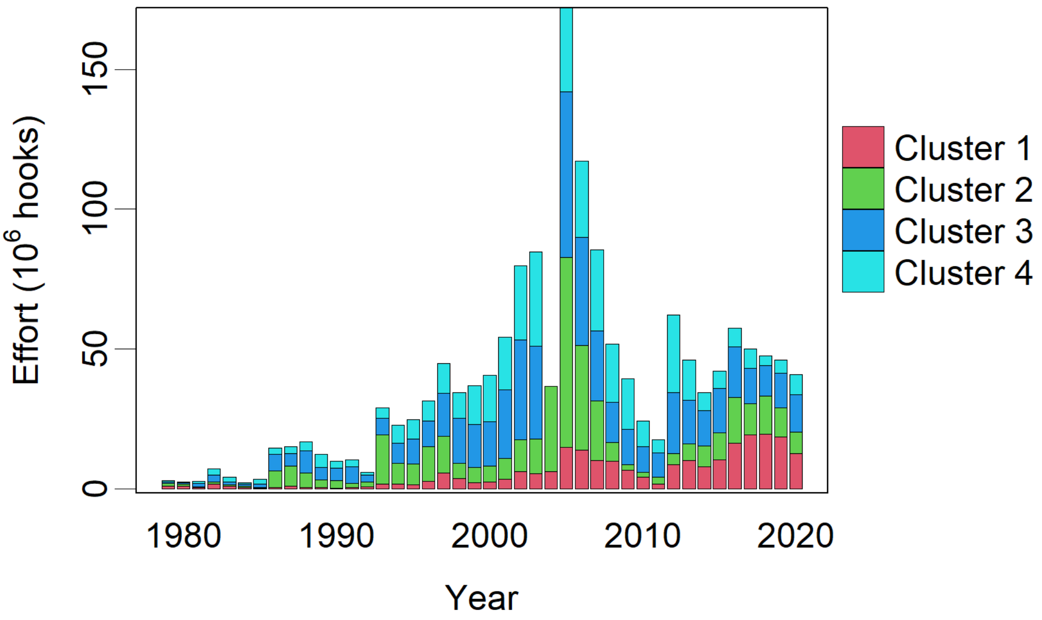

Fig. 6. Annual black marlin catches and efforts for each cluster of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

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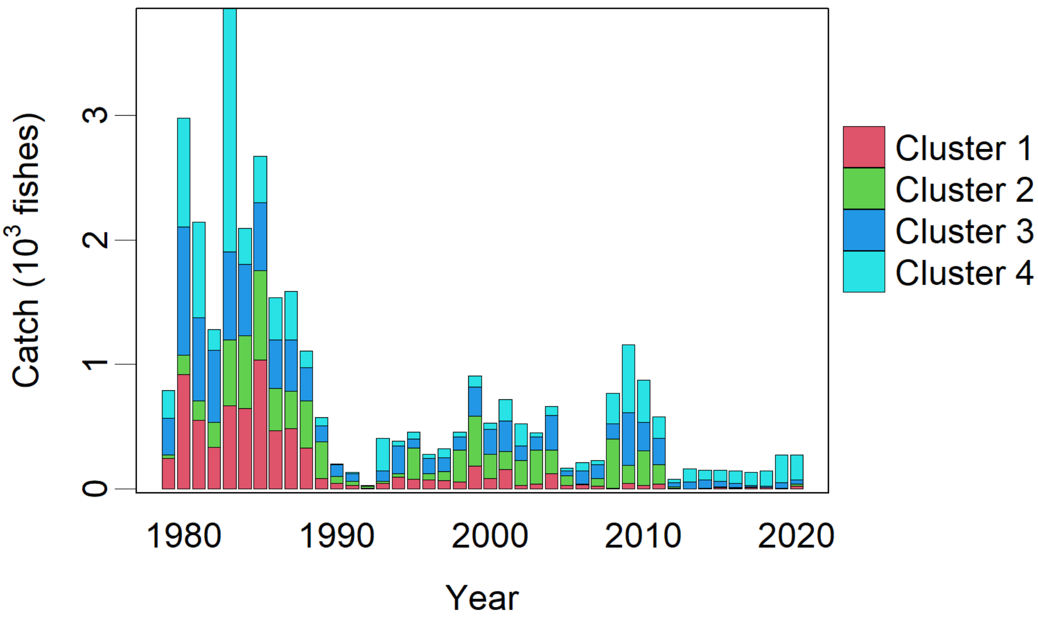

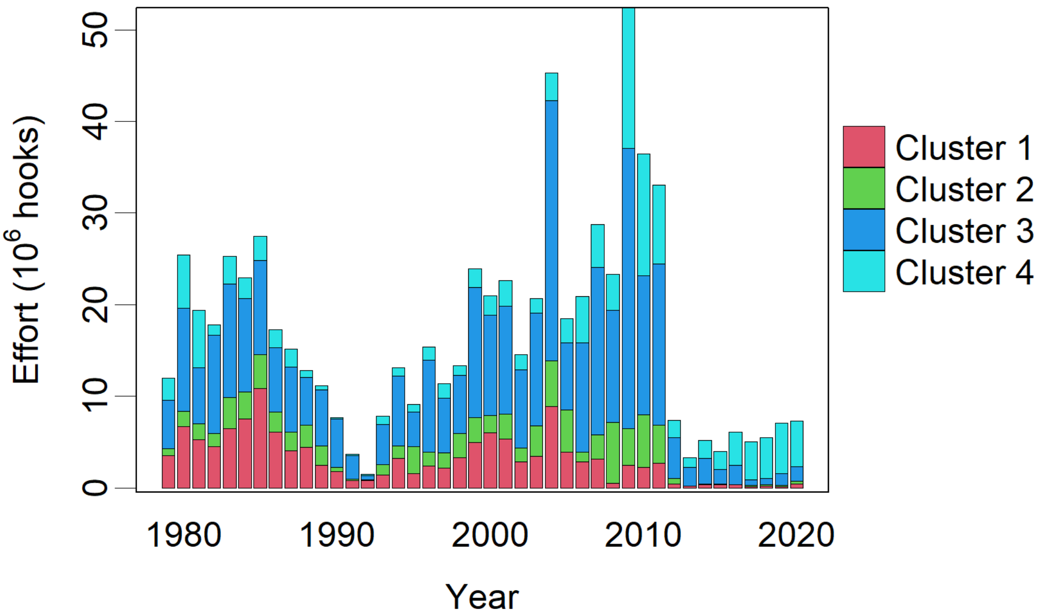

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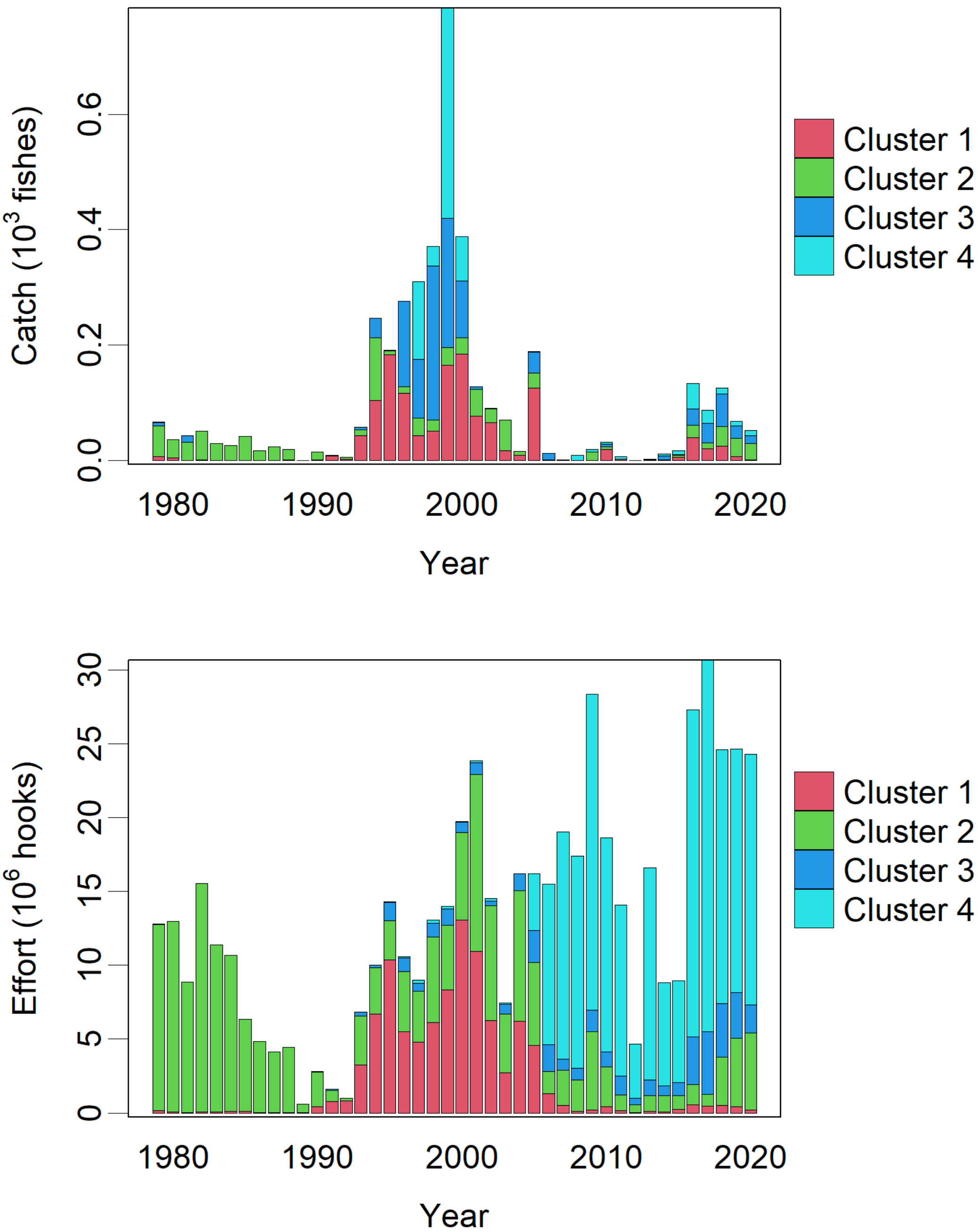

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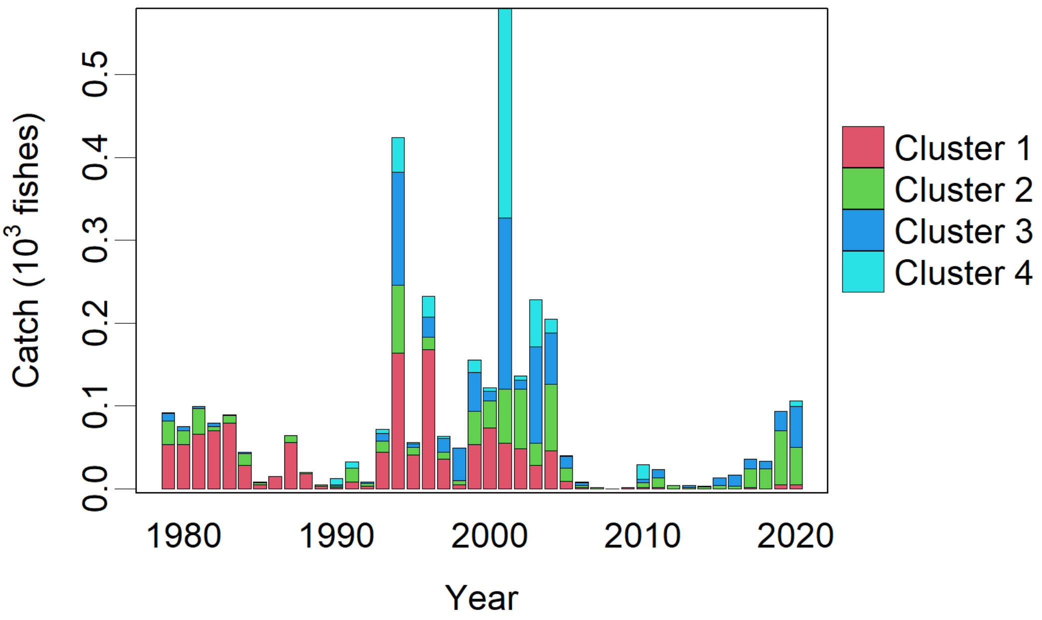

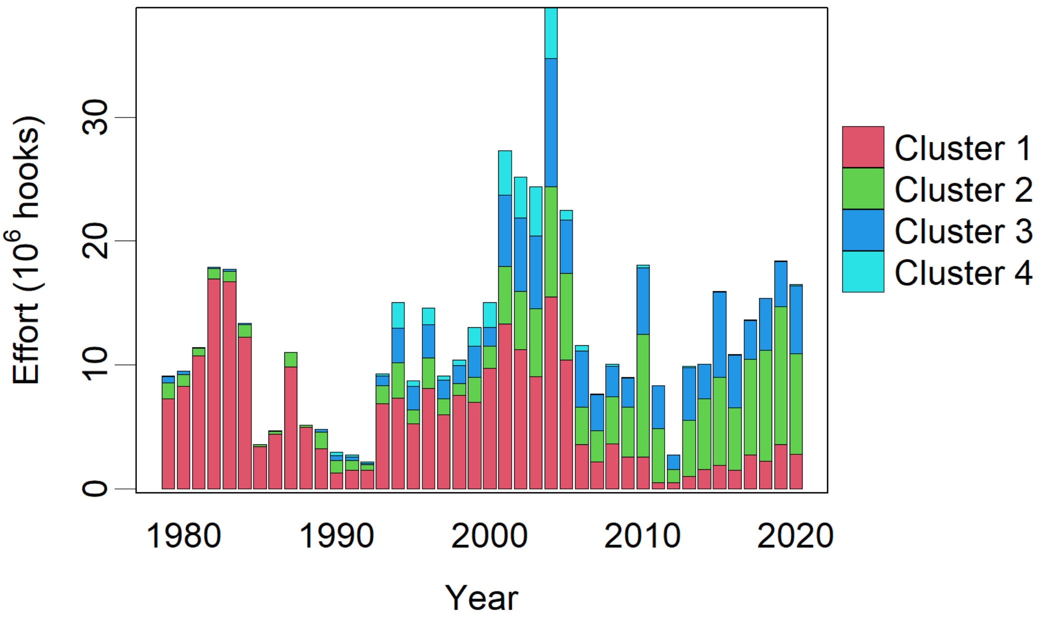

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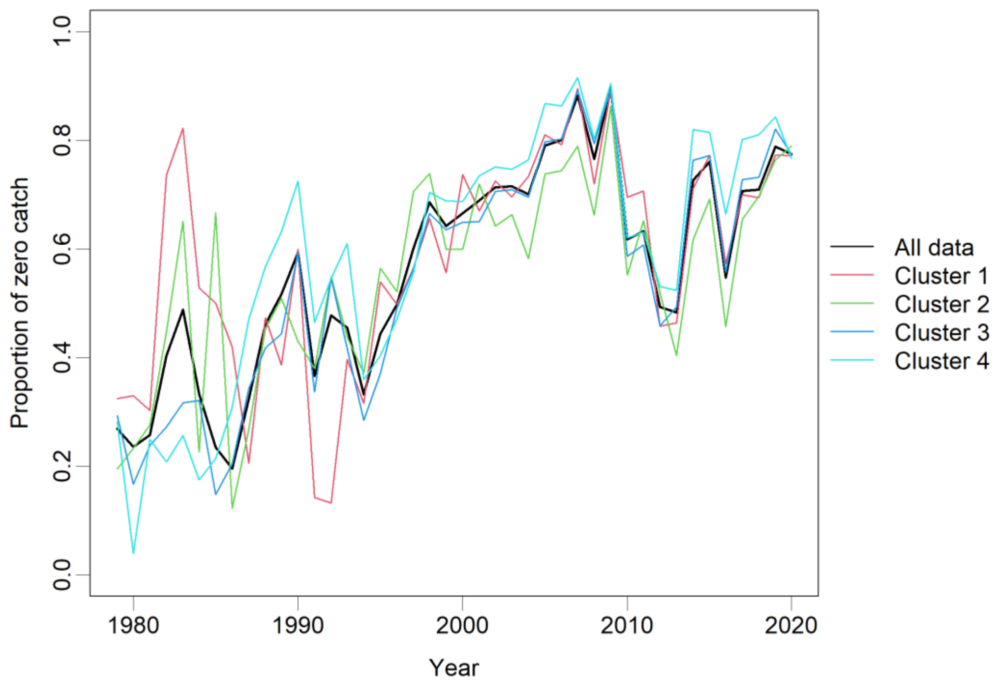

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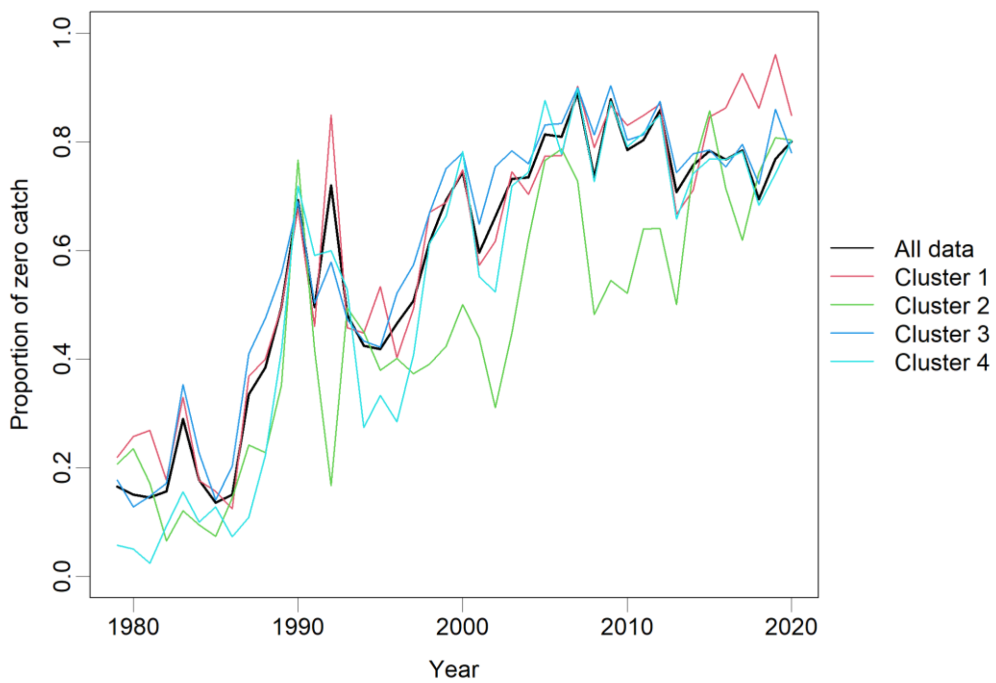
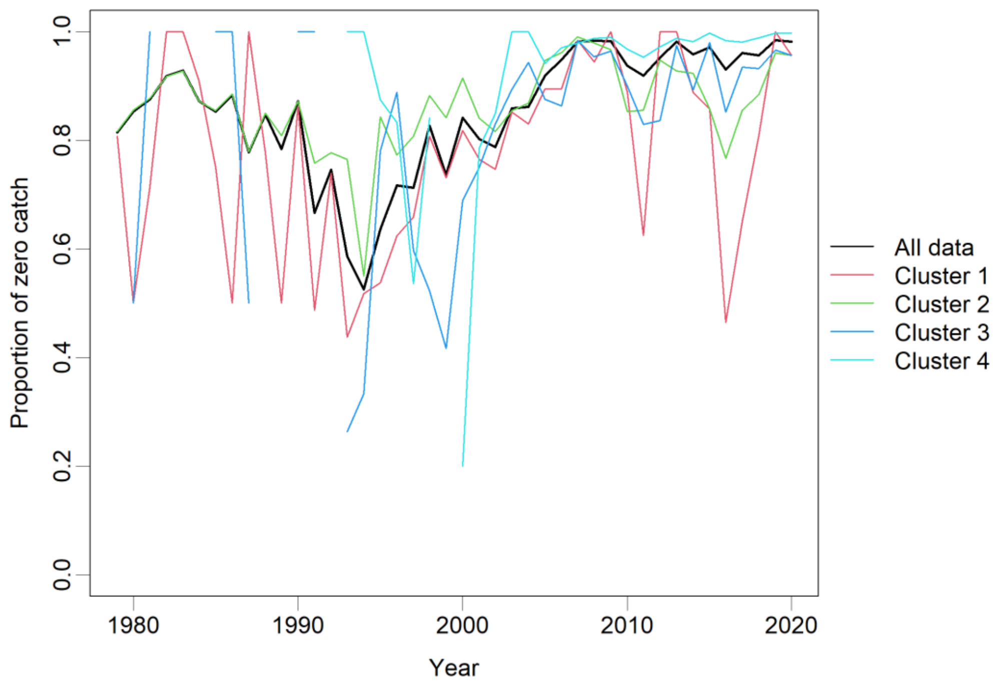


Fig. 7. Annual zero proportion of striped marlin catches for each cluster of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

SW



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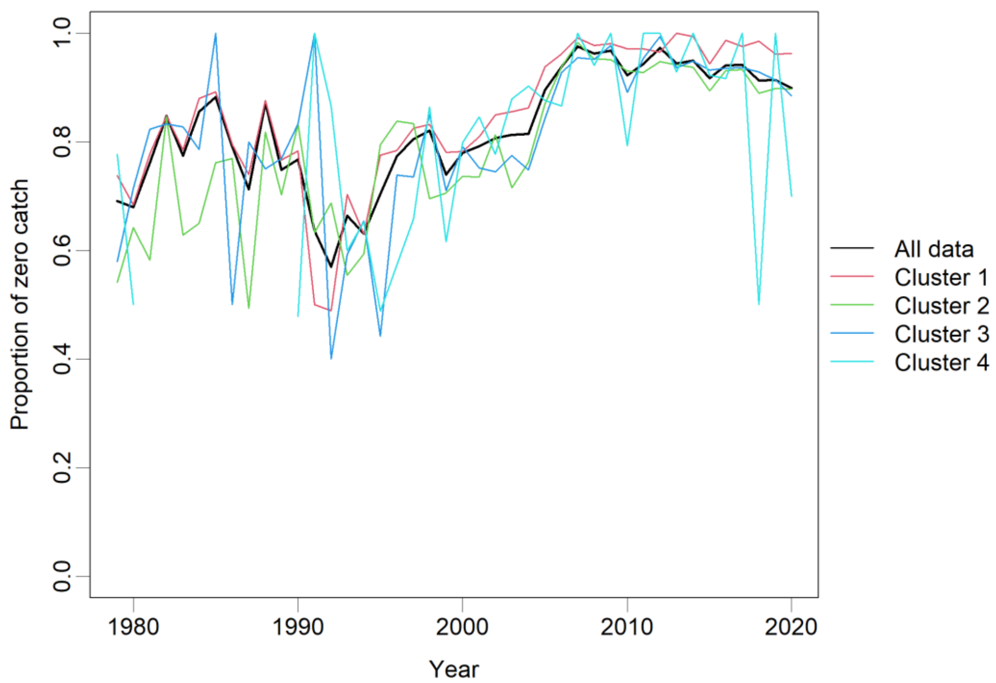

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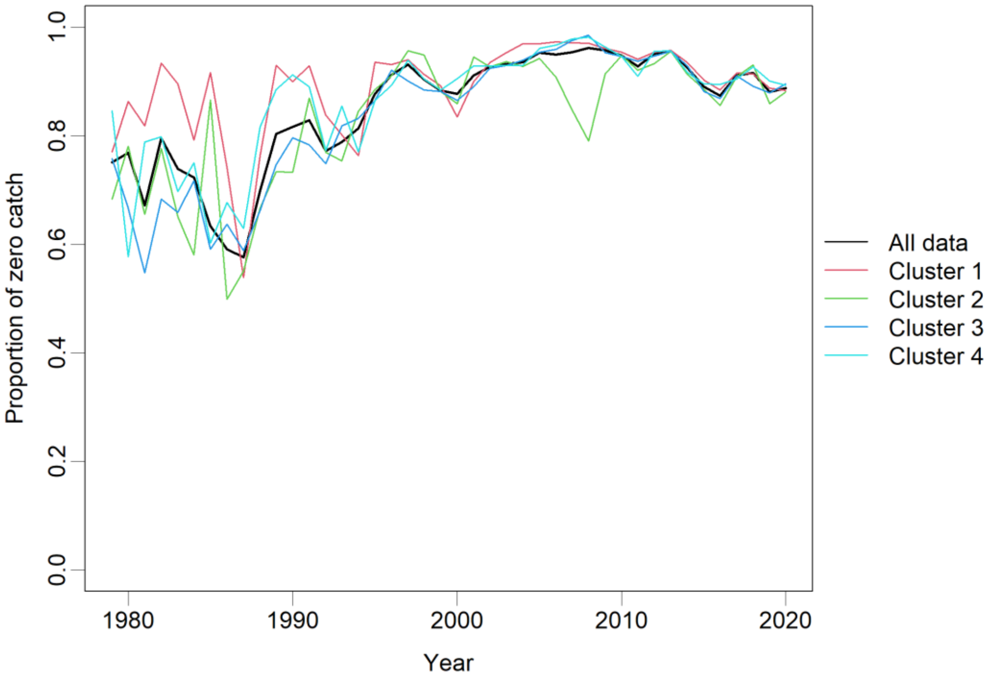

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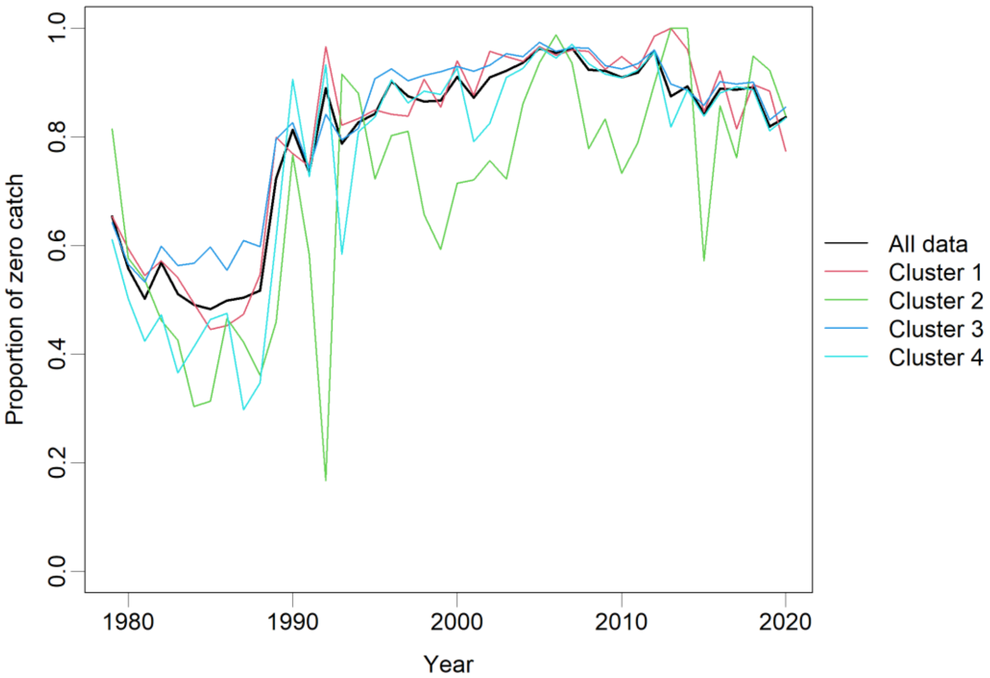
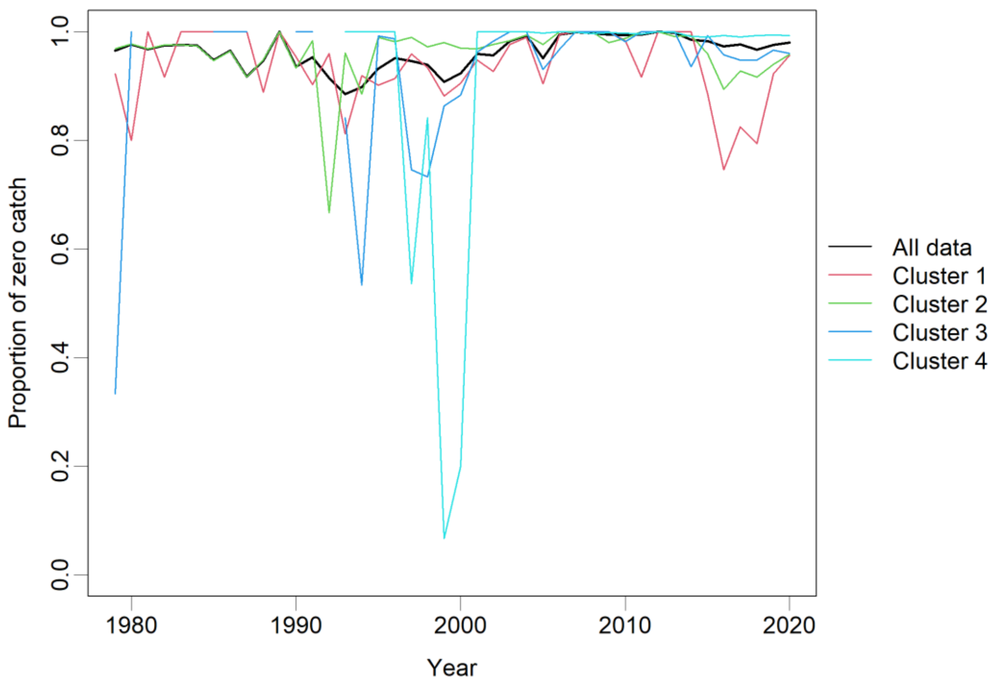


Fig. 8. Annual zero proportion of black marlin catches for each cluster of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 1979 to 2020.

SW



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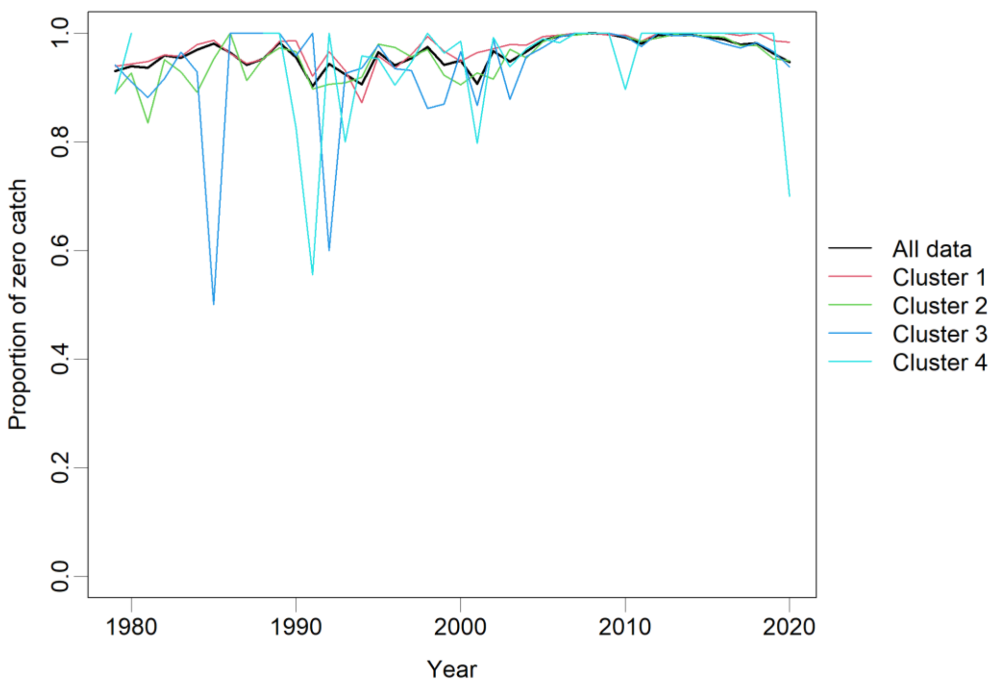

Fig. 8. (Continued).

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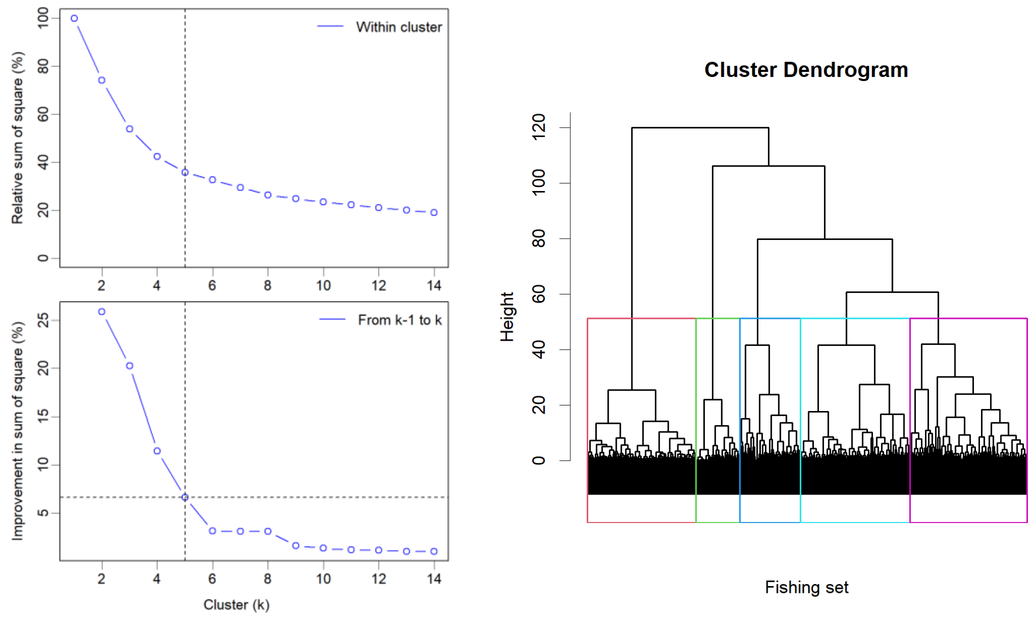

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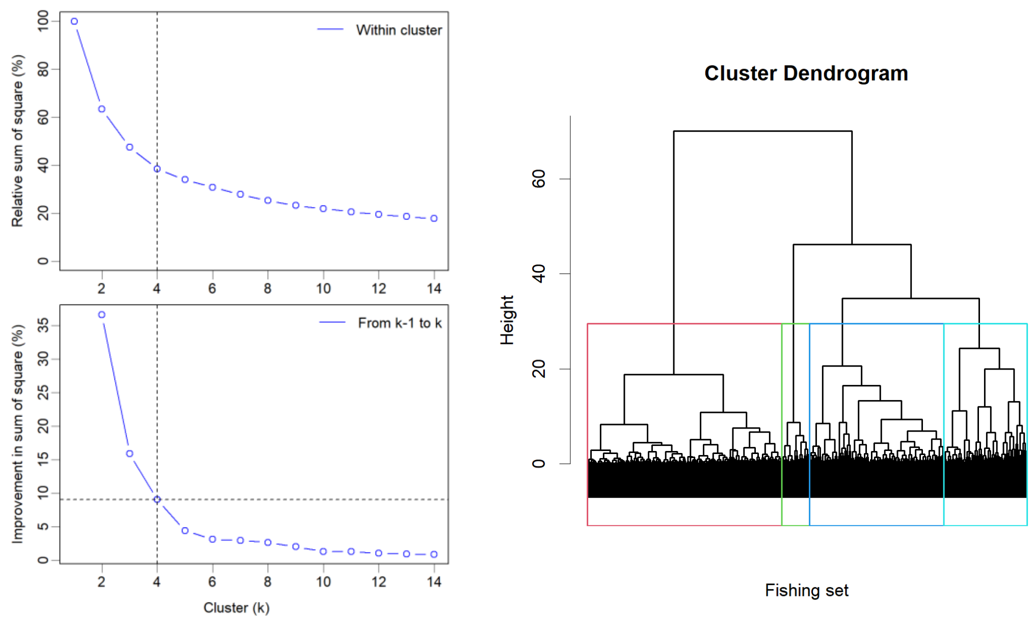
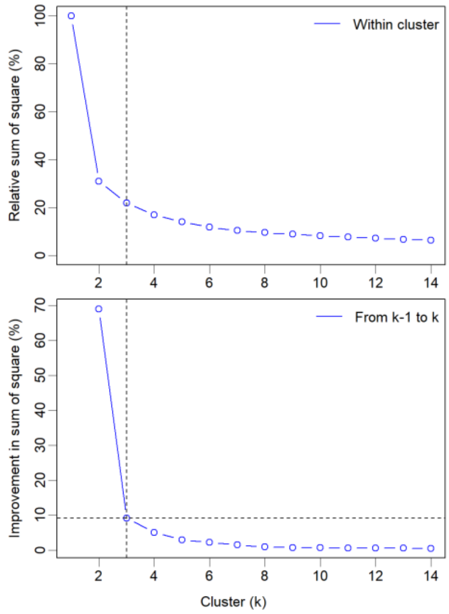
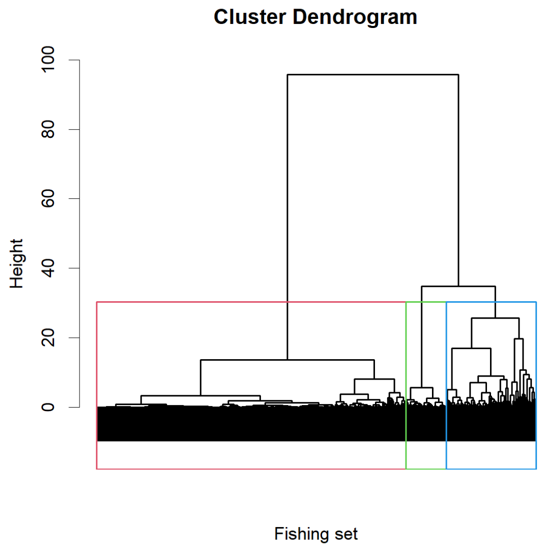


Fig. 9. Sum of squares within clusters for the data of Taiwanese large-scale longline fishery in Billfish Area NE of the Indian Ocean from 2005 to 2020.

SW





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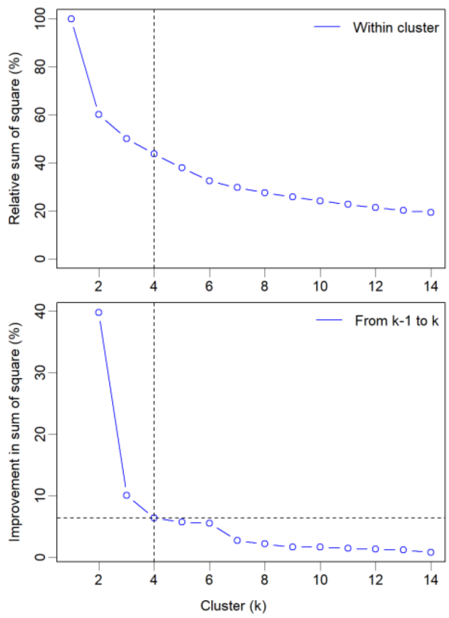


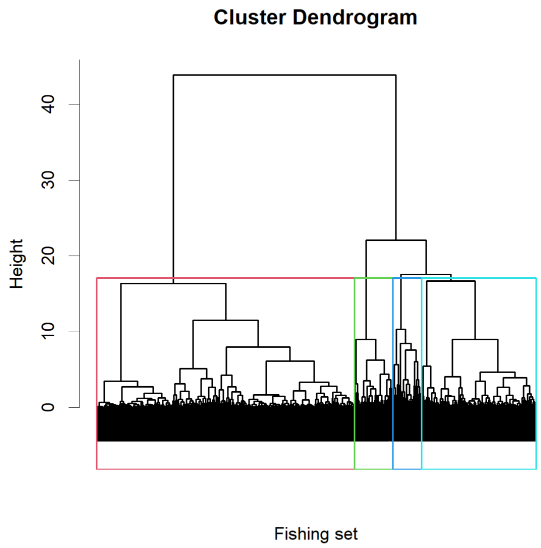


Fig. 9. (Continued).

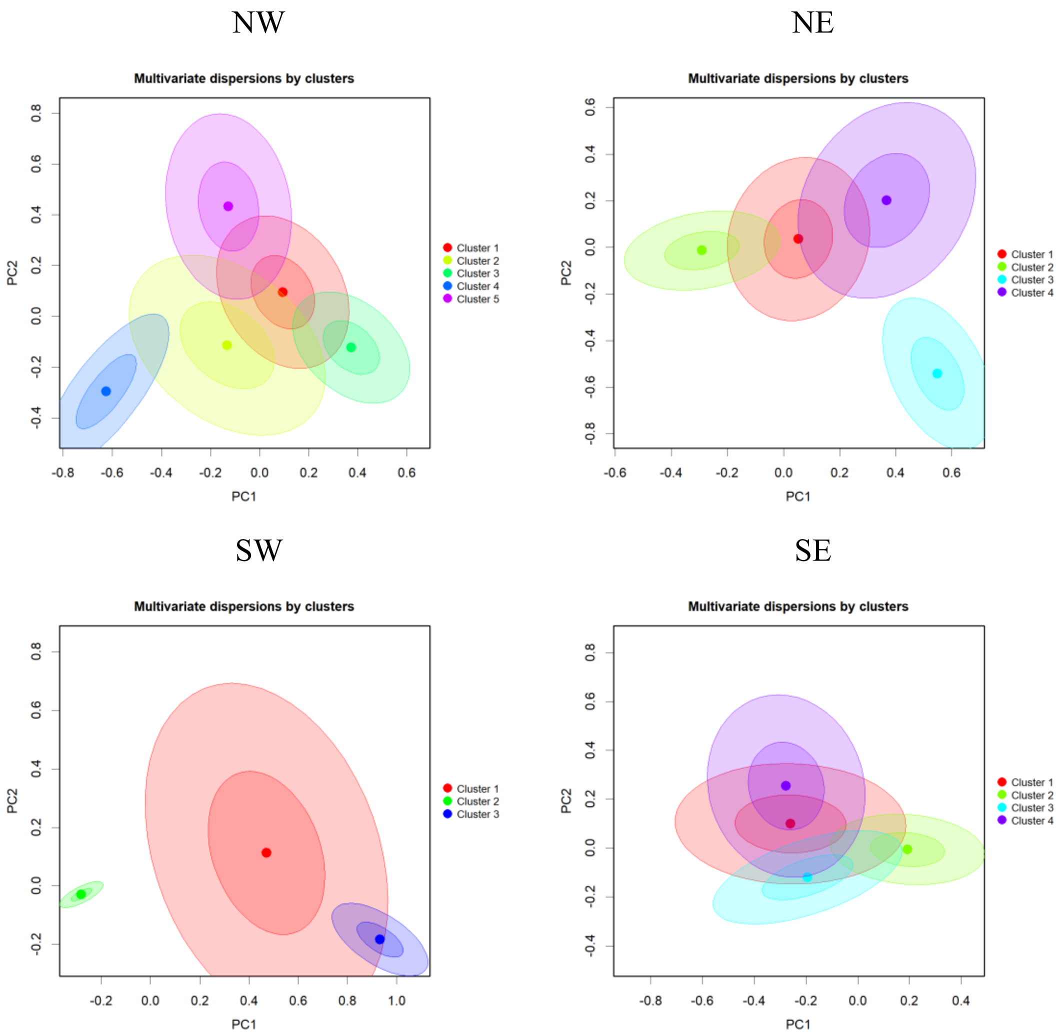


Fig. 10. Multivariate dispersions of the centroids by clusters derived from PCA for the data of Taiwanese large-scale longline fishery in Billfish Area of the Indian Ocean from 2005 to 2020.

NW

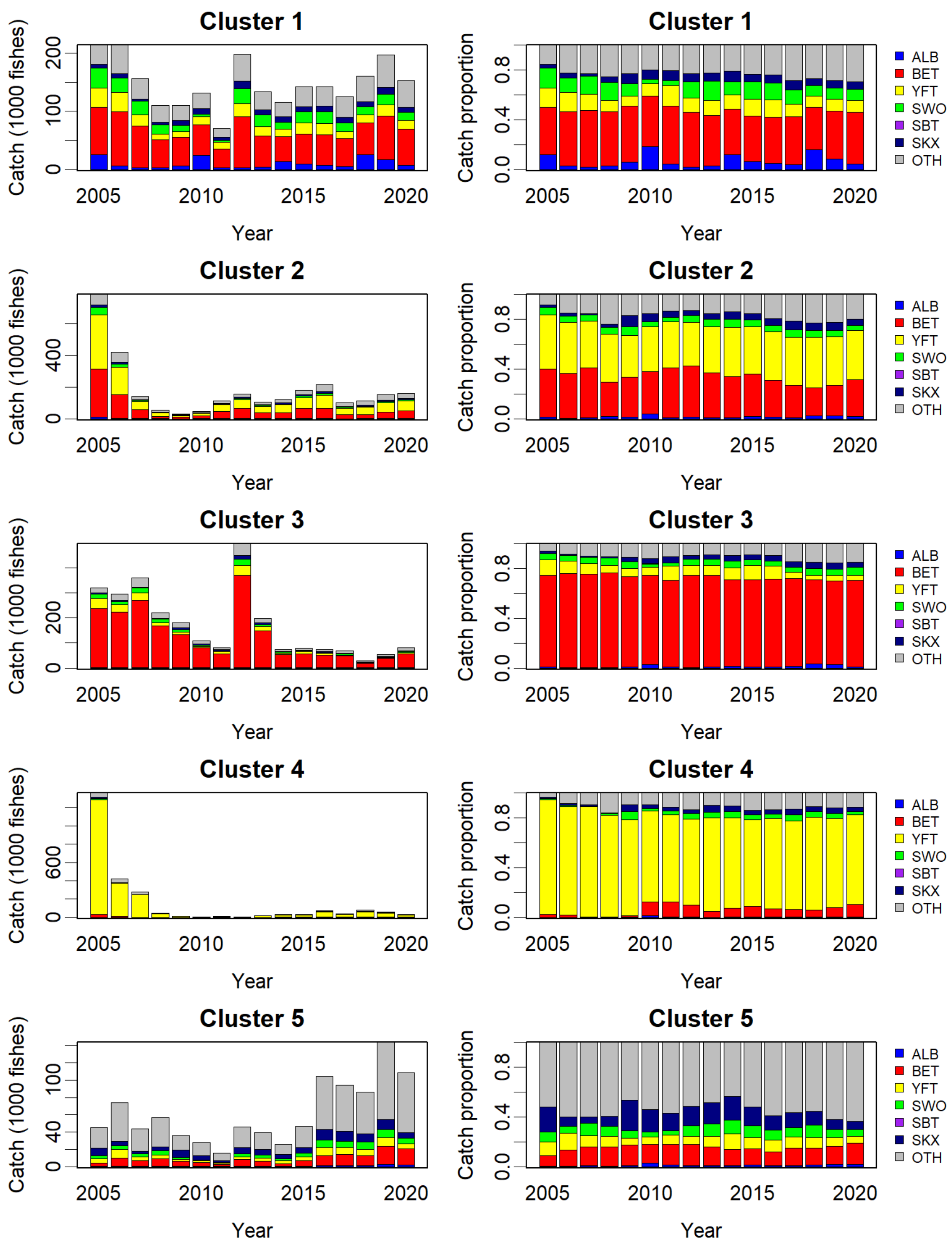


Fig. 11. Annual catches and compositions by species for each cluster of Taiwanese large-scale longline fishery in Billfish Area NE of the Indian Ocean from 2005 to 2020.

NE

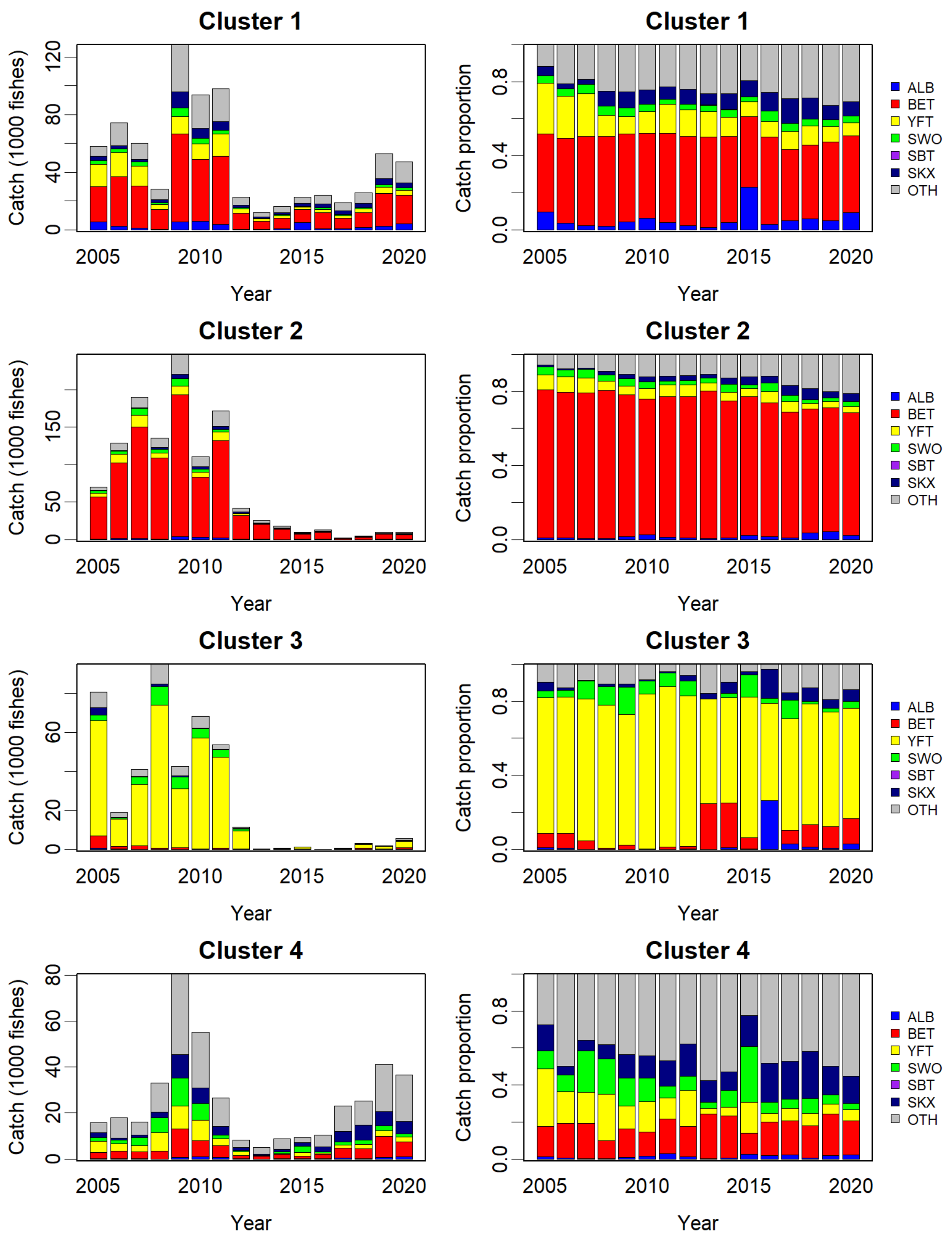


Fig. 11. (Continued).

SW

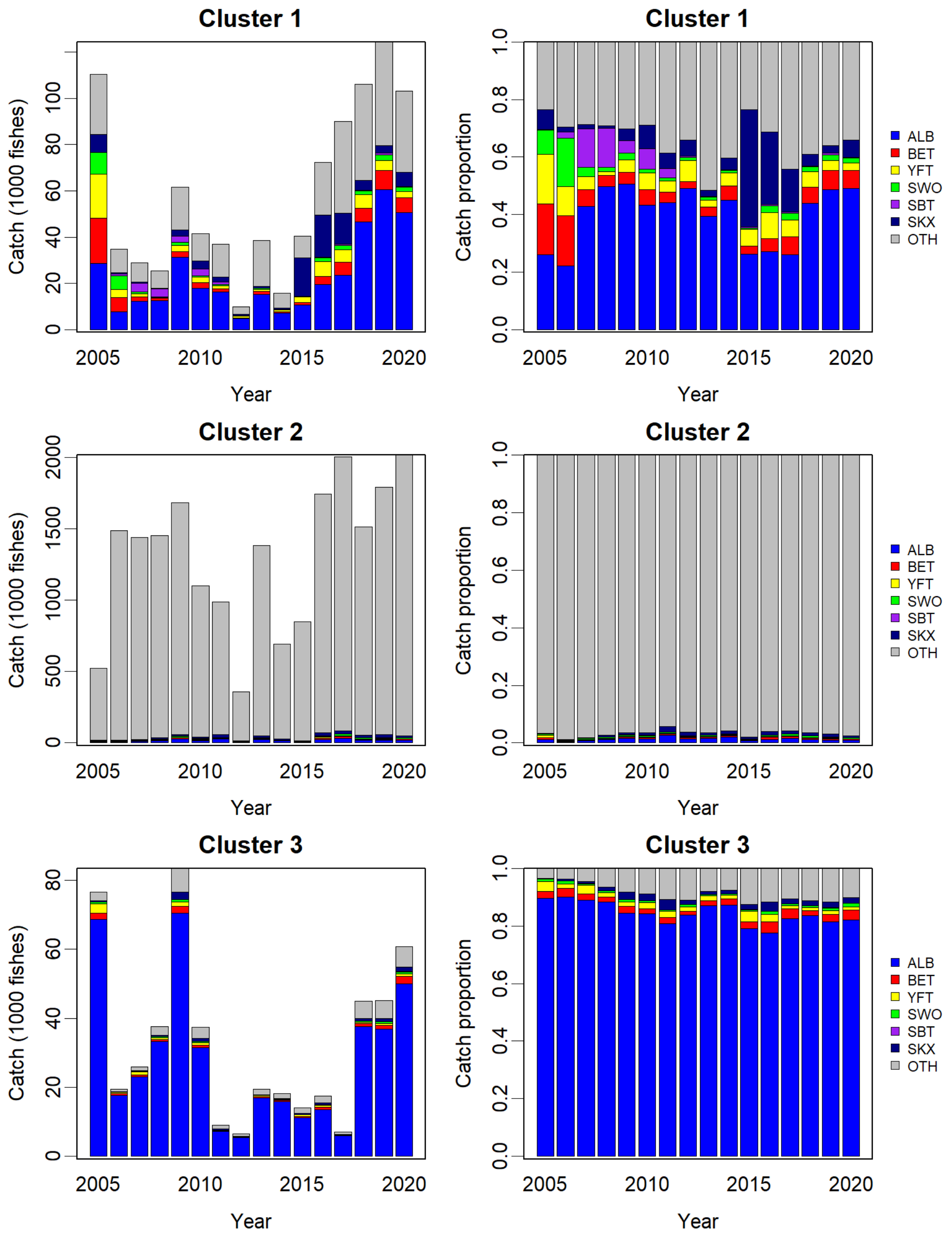


Fig. 11. (Continued).

SE

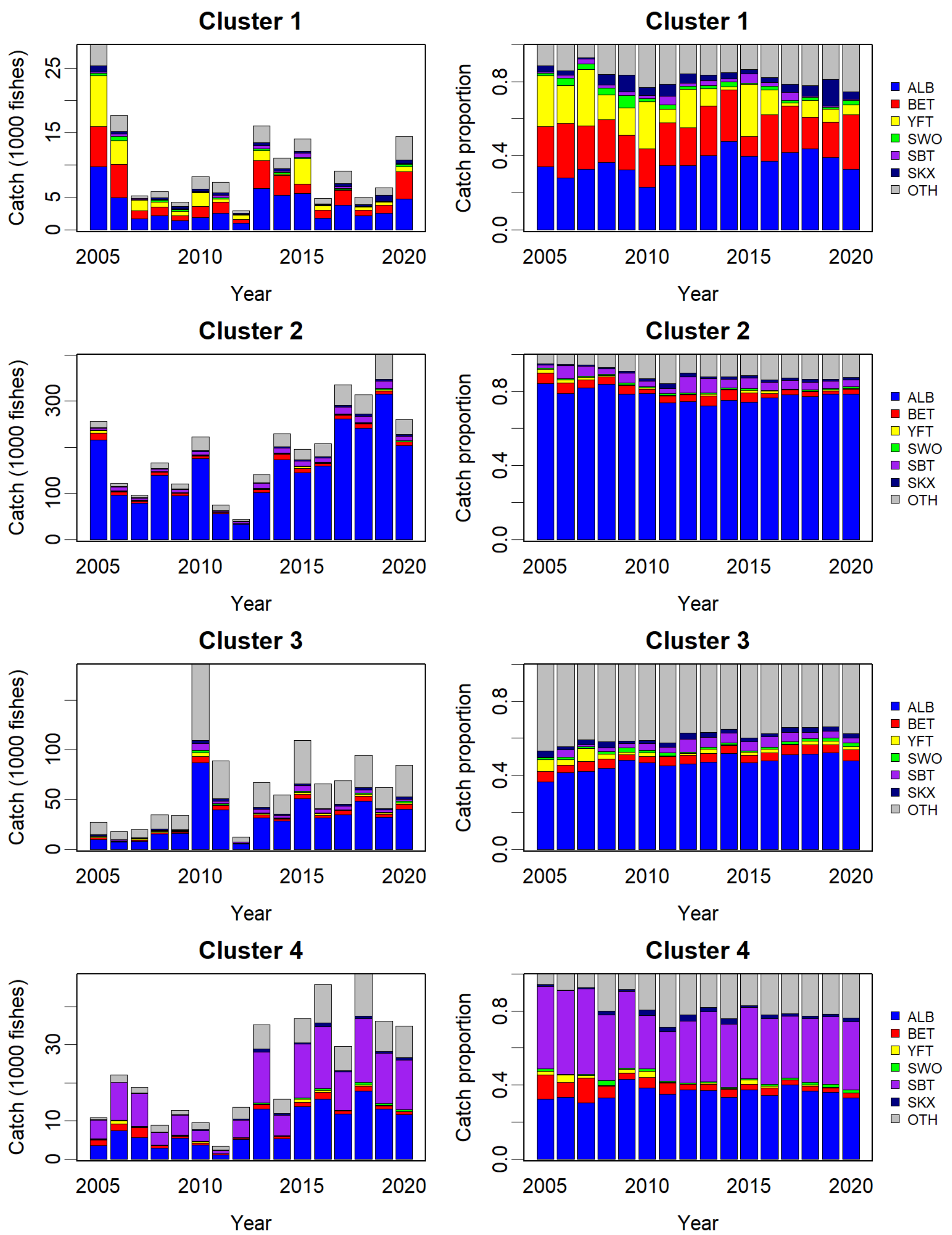
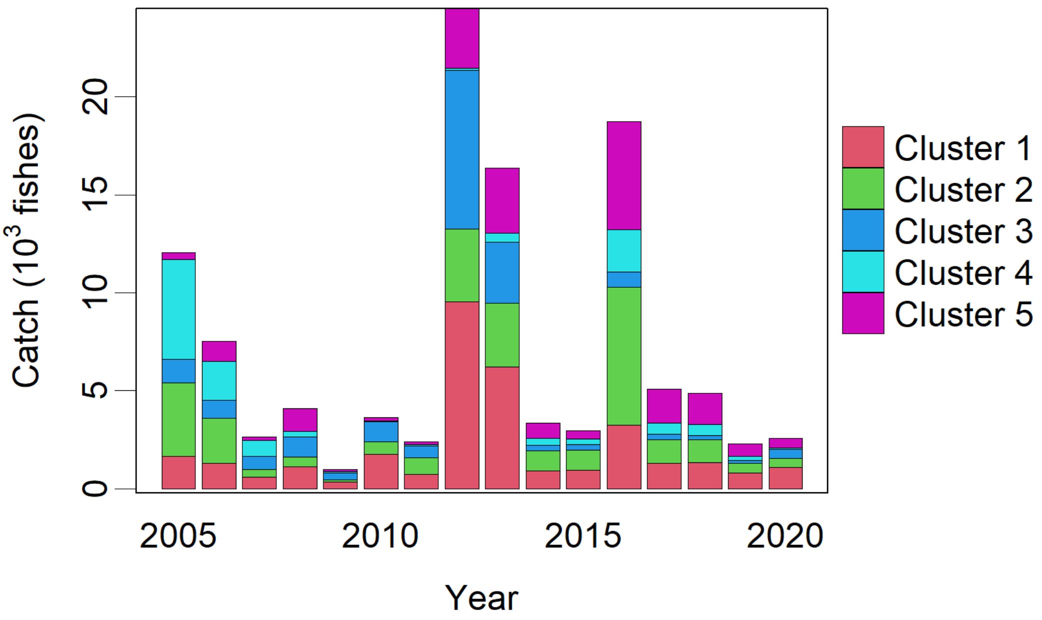


Fig. 11. (Continued).

NW



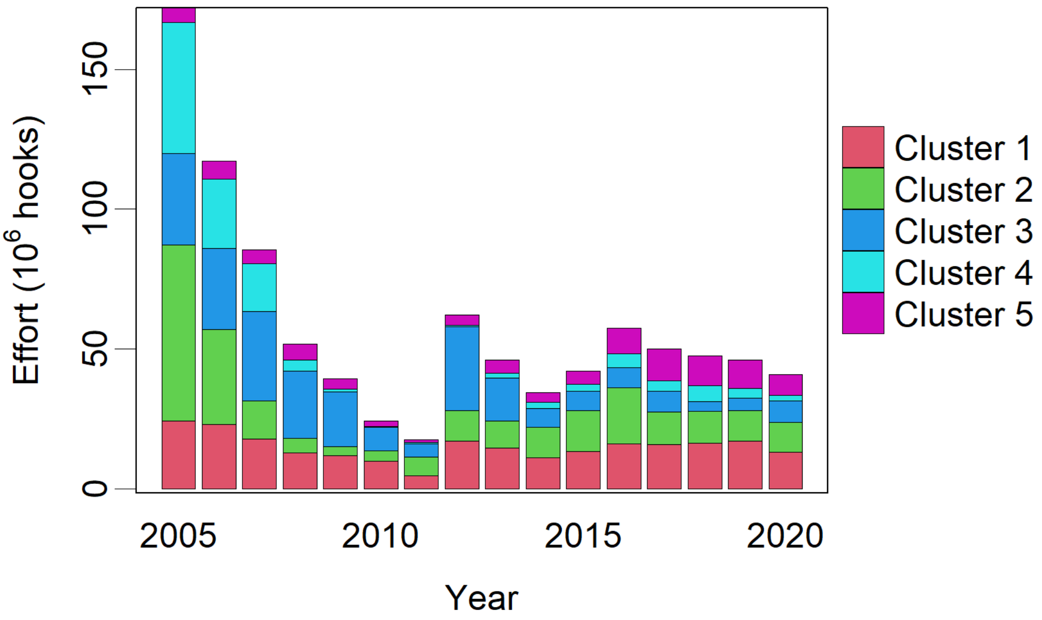
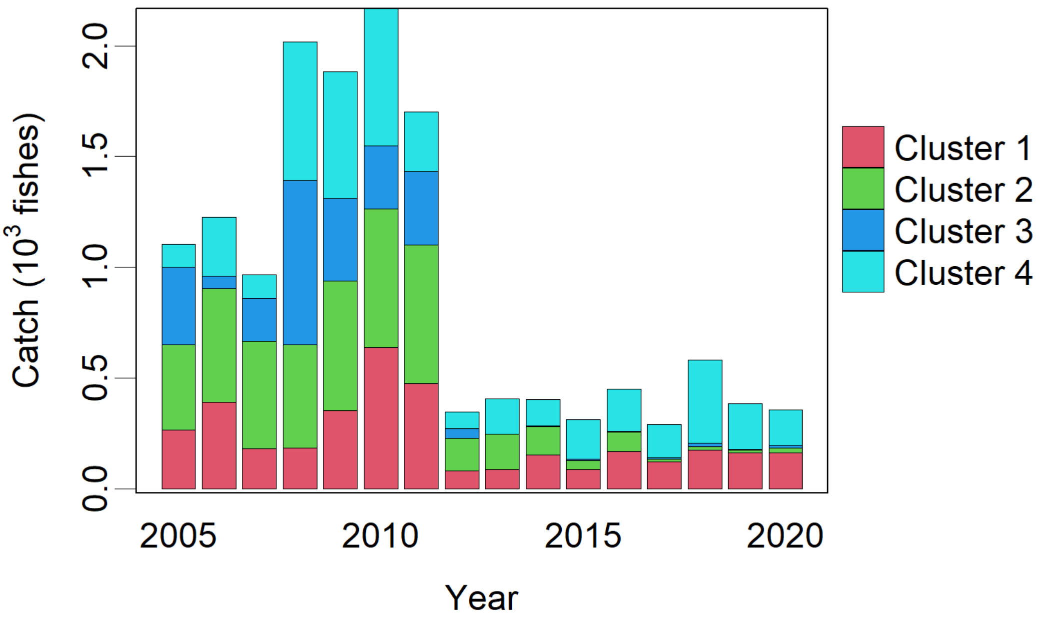


Fig. 12. Annual striped marlin catches and efforts for each cluster of Taiwanese large-scale longline fishery in Billfish Area NE of the Indian Ocean from 2005 to 2020.

NE



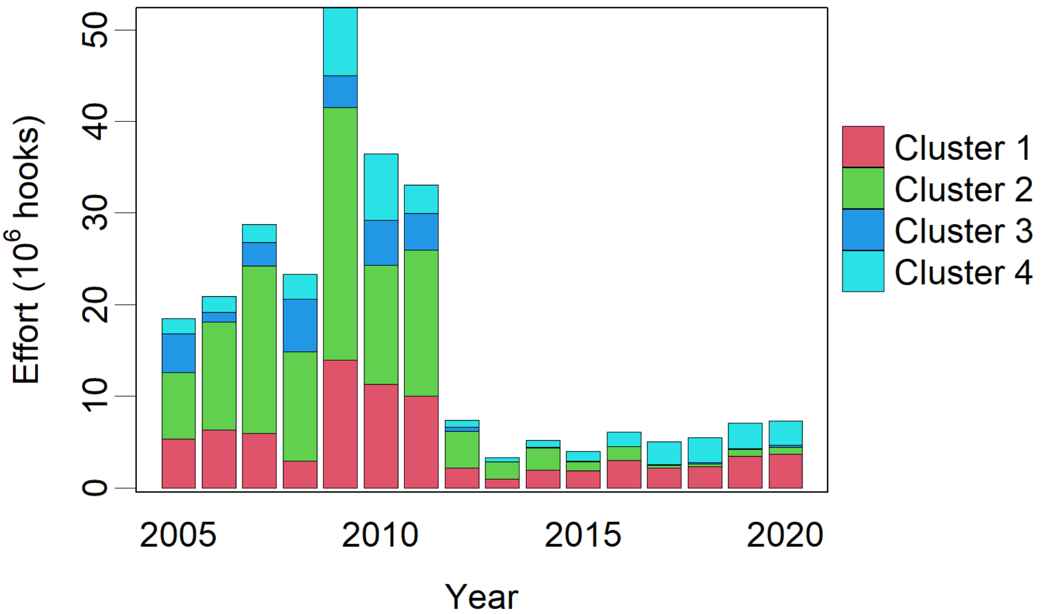


Fig. 12. (Continued).

SW

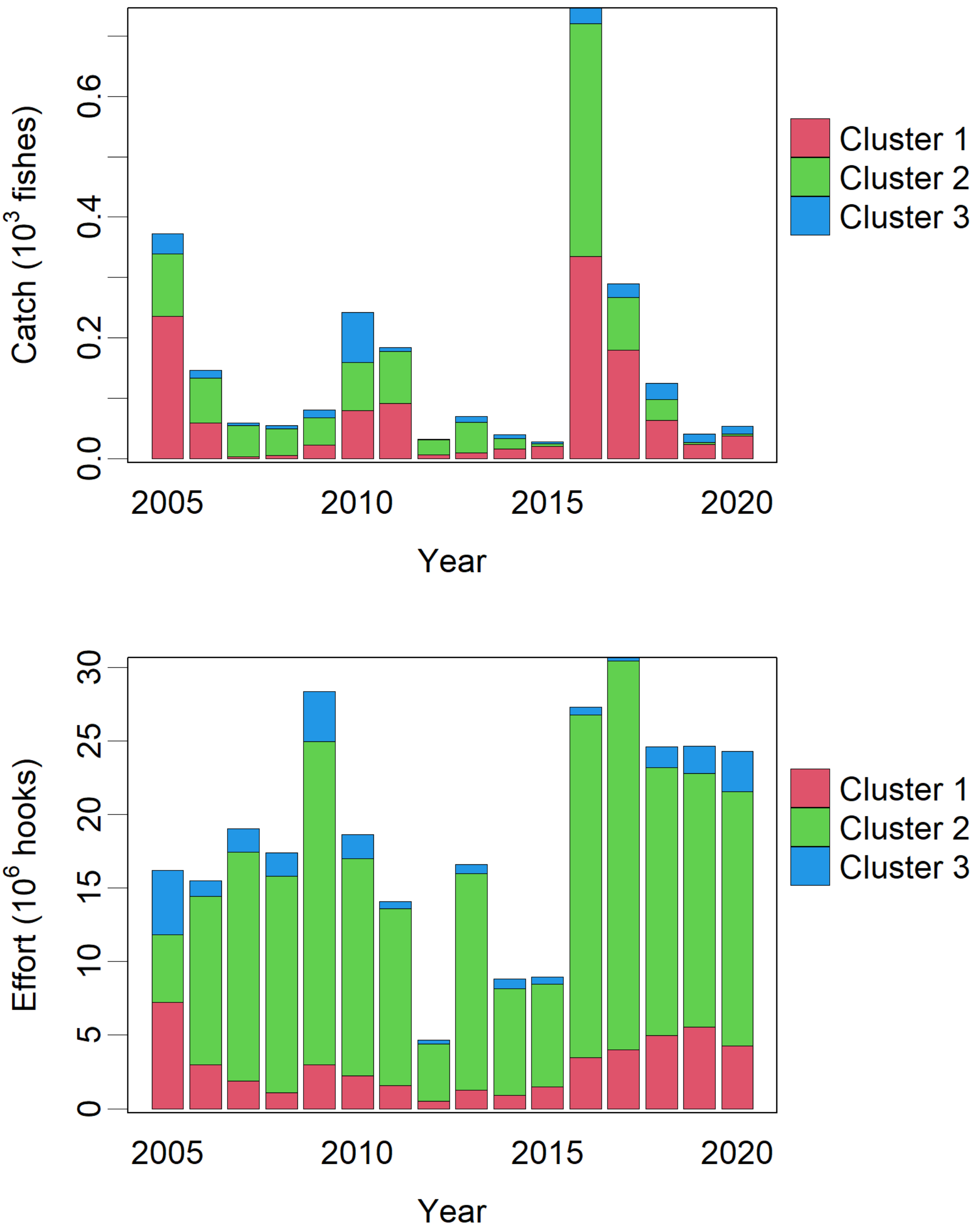
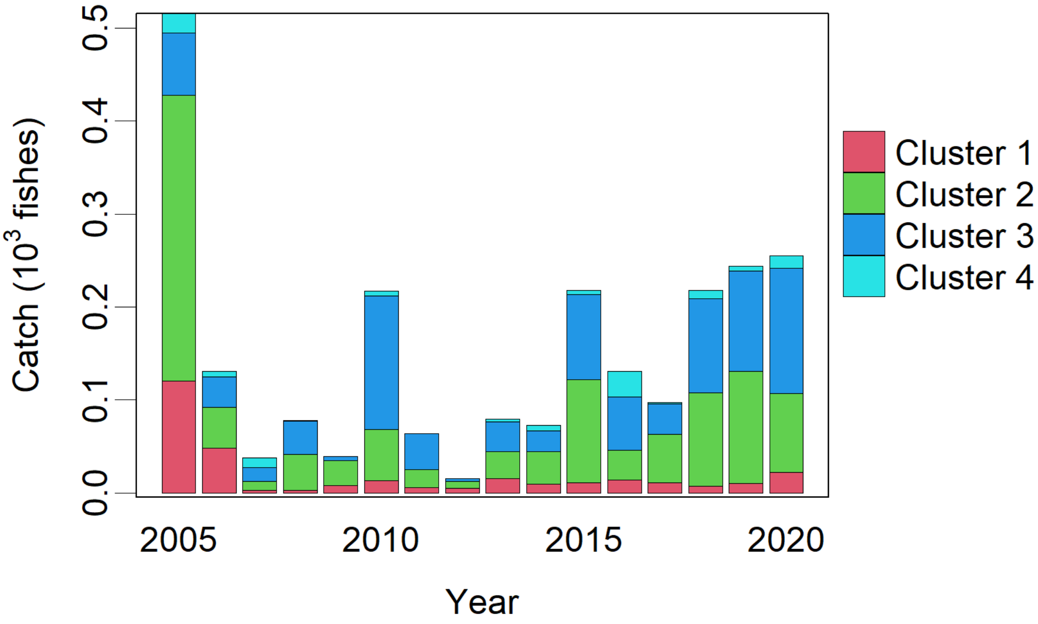


Fig. 12. (Continued).

SE



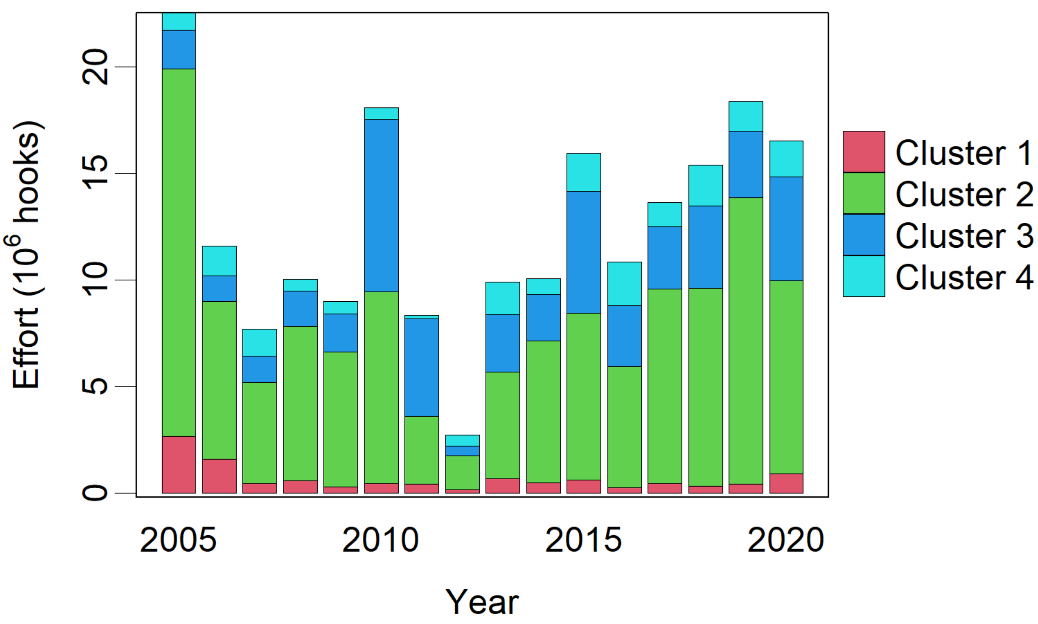


Fig. 12. (Continued).

NW

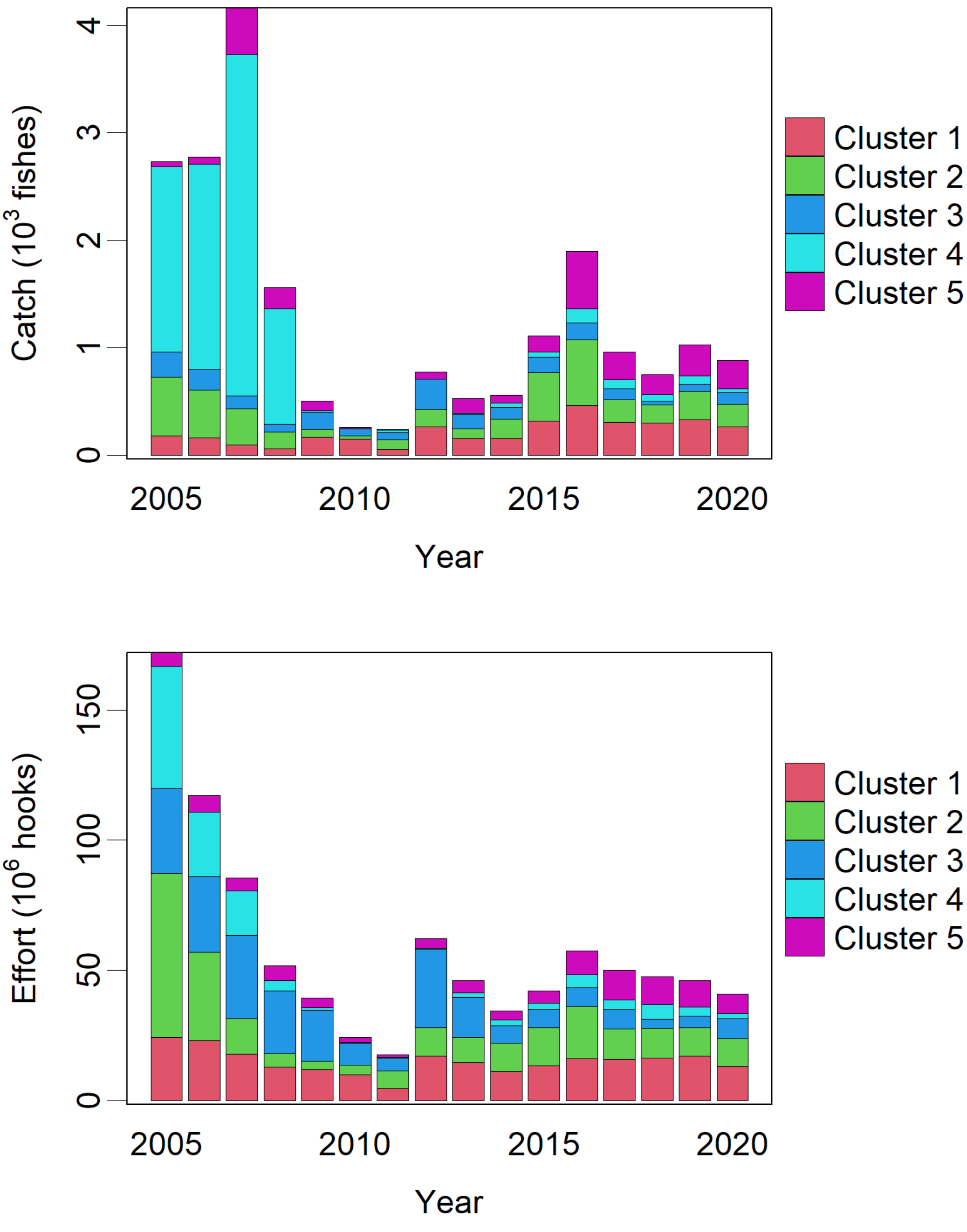
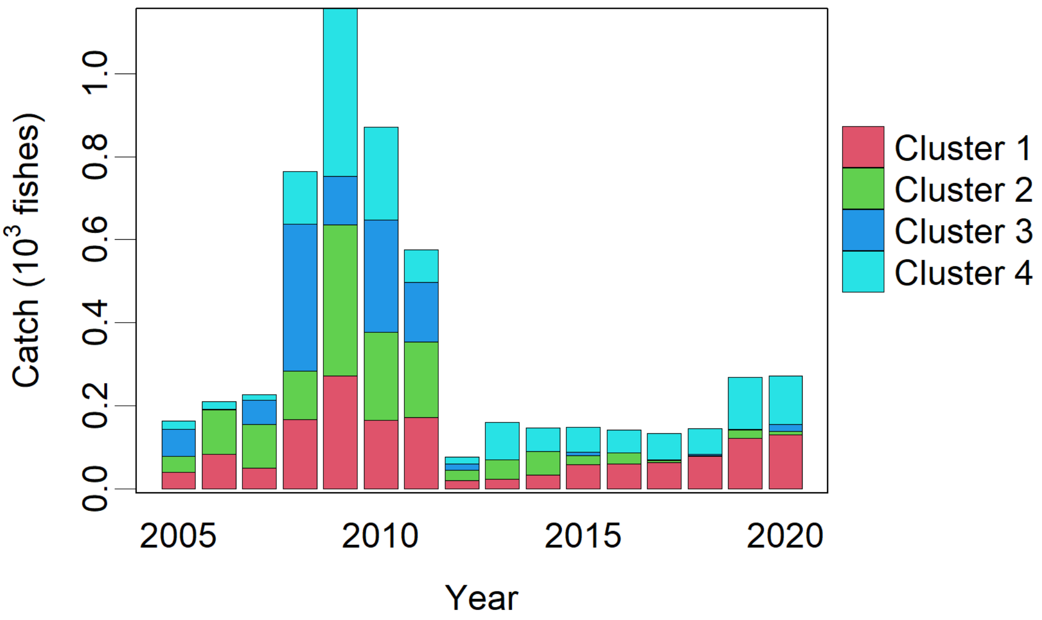


Fig. 13. Annual black marlin catches and efforts for each cluster of Taiwanese large-scale longline fishery in Billfish Area NE of the Indian Ocean from 2005 to 2020.

NE



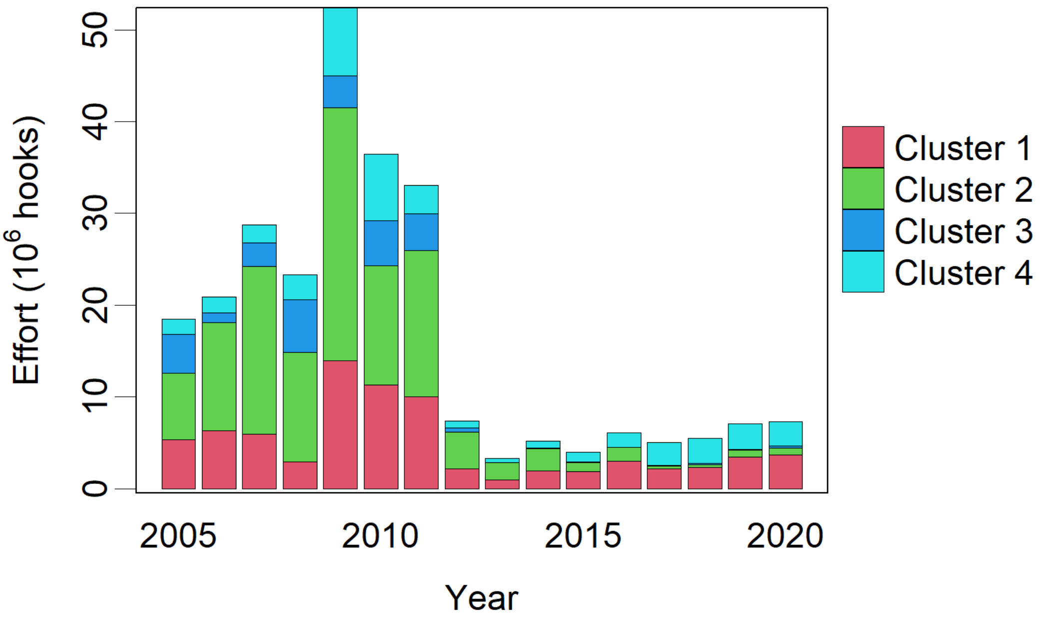
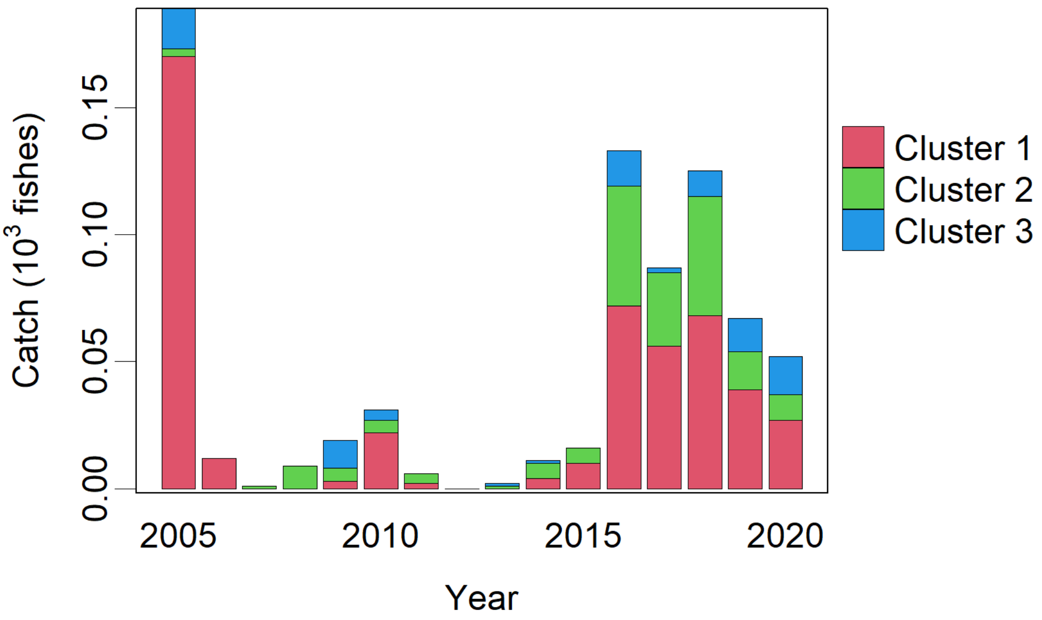


Fig. 13. (Continued).

SW



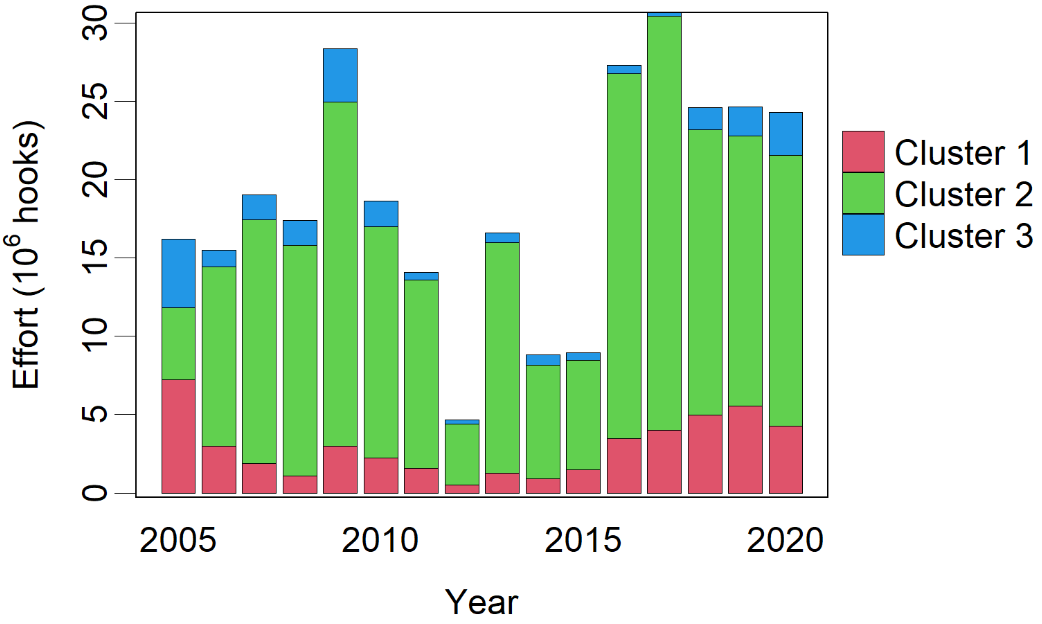


Fig. 13. (Continued).

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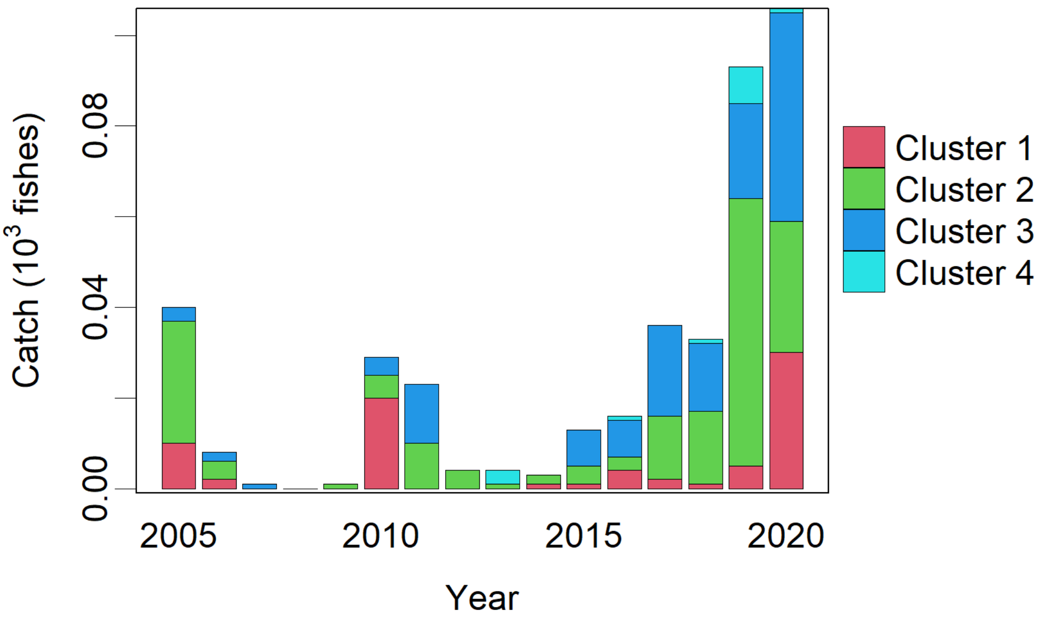

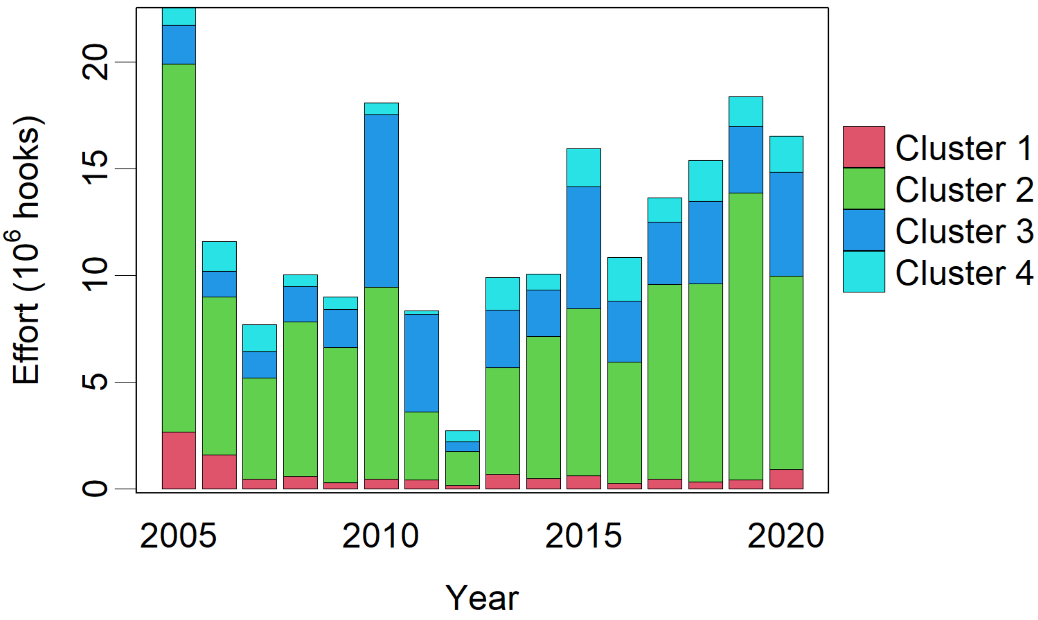

Fig. 13. (Continued).