Descriptive analyses of the Korean Indian Ocean longline fishery, focusing on tropical areas

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Abstract

We analysed Korean operational longline catch and effort data in order to describe and characterize the fishery, and to increase understanding of both the fishery and the species caught. The primary interest is in the tropical tuna species, bigeye and yellowfin, but information on other species is included because their catches are important for the fishery, and provide valuable information on fishing methods and ecological patterns. Species and species groups included are yellowfin tuna, bigeye tuna, albacore tuna, southern bluefin tuna, skipjack tuna, black marlin, blue marlin, striped marlin, sailfish, shark, swordfish, and other species. We provide temporal and spatial plots of catch, effort, catch rate, fishing patterns, fleet composition, reporting patterns, gear usage, proportions of zero sets, and species composition.

Introduction

This report is an output of an Indian Ocean Tuna Commission project to explore factors affecting the catch rates of Japanese, Taiwanese, and Korean longline fleets fishing for bigeye and yellowfin tunas in the Indian Ocean. The work was funded by the International Seafood Sustainability Foundation (ISSF).

This report provides detailed information on the Korean longline fleet. Complementary reports address the Japanese and Taiwanese fleets. A further report (Hoyle et al., 2015) addresses the main objectives of the study.

Methods

Full details of data preparation are included in Hoyle et al. (2015), some of which is repeated here. Data preparation and analyses were carried out using R version 3.1.2 (R Core Team, 2014).

Korean operational data were available for 1971 to 2014 , with fields vessel id, operation date, operation location to 1 degree, number of hooks, number of floats, and catch by species in number for albacore, bigeye, black marlin, blue marlin, striped marlin, other species, southern bluefin, sailfish, shark, skipjack, swordfish, and yellowfin.

In the Korean data the callsigns were understood to have changed through time to some extent, and so vessel ids were assigned based on a combination of vessel names and vessel callsigns. For all fleets, the vessel id was rendered anonymous by changing it to an arbitrary integer. Sets without a vessel call sign were allocated a vessel id of '1'. For joint analyses, care was taken to assign different vessel ids to vessels from different fleets.

Latitude and longitude were reported at 1 degree resolution, with a code to indicate north or south, west or east. All data were adjusted to represent the south-western corner of the 1 x 1 degree

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square, and longitudes translated into 360 degree format. Each set was allocated to a yellowfin region (consistent with the definitions in the yellowfin stock assessment, Langley et al., 2012) and a bigeye region (consistent with the bigeye assessment, Langley et al., 2013), and data outside these areas ignored. Location information was used to calculate the 5 degree square (latitude and longitude).

The few sets without hooks were deleted. For the purposes of further analyses, we cleaned the data by removing data likely to be in error. The criteria were selected after discussion with experts. Hooks per set above 5000 and less than 200 were removed.

Korea reported catch by species in numbers, for bigeye, yellowfin, albacore, southern bluefin tuna, swordfish, striped marlin, blue marlin, black marlin, skipjack, sailfish, sharks, and other species. The sailfish category may include shortbill spearfish (Uozumi, 1999).

Some very large catches were reported at times for individual species, but were not removed since there was anecdotal evidence that they may be genuine, and because they are unlikely to affect results substantially.

Hooks between floats (HBF) was not directly available in the logbooks, but the number of floats was reported, so we calculated HBF by dividing the number of hooks by the number of floats and rounding it to a whole number.

Dates of sets were used to calculate the years and quarters (year-quarter) in which the sets occurred. They were also used to calculate the level of illumination from the moon, using the function lunar.illumination() from the lunar package in R (Lazaridis, 2014). Moon phase has often been observed to affect catchability of pelagic fish, and is associated in some cases with changing targeting practices (Poisson et al., 2010).

Plotting

The plots provided are designed to provide an overview of the characteristics of the fishery through time. They address the temporal and spatial distribution of fishing effort (Figures 1 - 5), hooks per set (Figure 6), hooks between floats (Figures 7 - 9), vessel characteristics and longevity (Figures 10 - 13), catch (Figures 14 - 19), CPUE (Figures 20 - 25), proportions of sets with zero catch (Figures 26 - 28), species composition (Figures 29 - 36), catch by 5 degree square through time (Figures 37 - 48), and proportion of sets with zero catch by 5 degree square through time (Figures 49 - 60).

Acknowledgments

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References

Hoyle, S.D., Okamoto, H., Yeh, Y.-m., Kim, Z.G., Lee, S.I., Sharma, R. (2015) IOTC–CPUEWS02 2015: Report of the 2nd CPUE Workshop on Longline Fisheries, 30 April – 2 May 2015. 126.

Langley, A., Herrera, M., Million, J. (2012) Stock assessment of yellowfin tuna in the Indian Ocean using MULTIFAN-CL. Working Party on Tropical Tuna.

Langley, A., Herrera, M., Sharma, R. (2013) Stock assessment of bigeye tuna in the Indian Ocean for 2012. *IOTC Working Party Document*.

Lazaridis, E. (2014) lunar: Lunar Phase & Distance, Seasons and Other Environmental Factors (Version 0.1-04). Available from http://statistics.lazaridis.eu.

Poisson, F., Gaertner, J.-C., Taquet, M., Durbec, J.-P., Bigelow, K. (2010) Effects of lunar cycle and fishing operations on longline-caught pelagic fish: fishing performance, capture time, and survival of fish. *Fishery Bulletin* **108,** 268-281.

R Core Team (2014) R: A Language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Uozumi, Y. (1999) BBRG-6. Review of Problems on Stock Assessment of Marlins Laying Stress on the Coverage of landing and Catch and Effort Information in the Pacific Ocean. In: *12th Standing Committee on Tuna and Billfish (SCTB)*. Tahiti, French Polynesia, p. 9 pages.

Figures

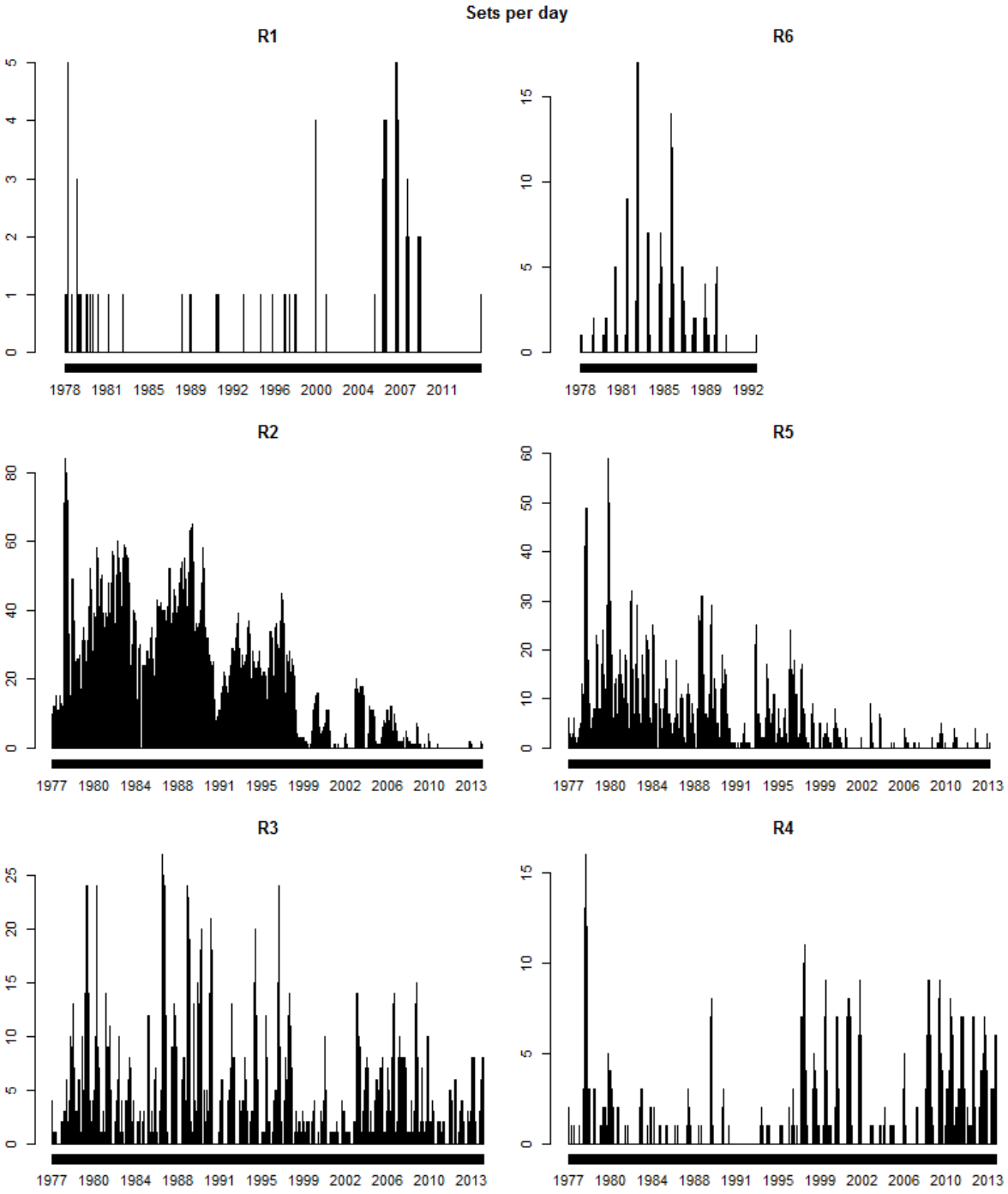


Figure 1: Sets per day by region.

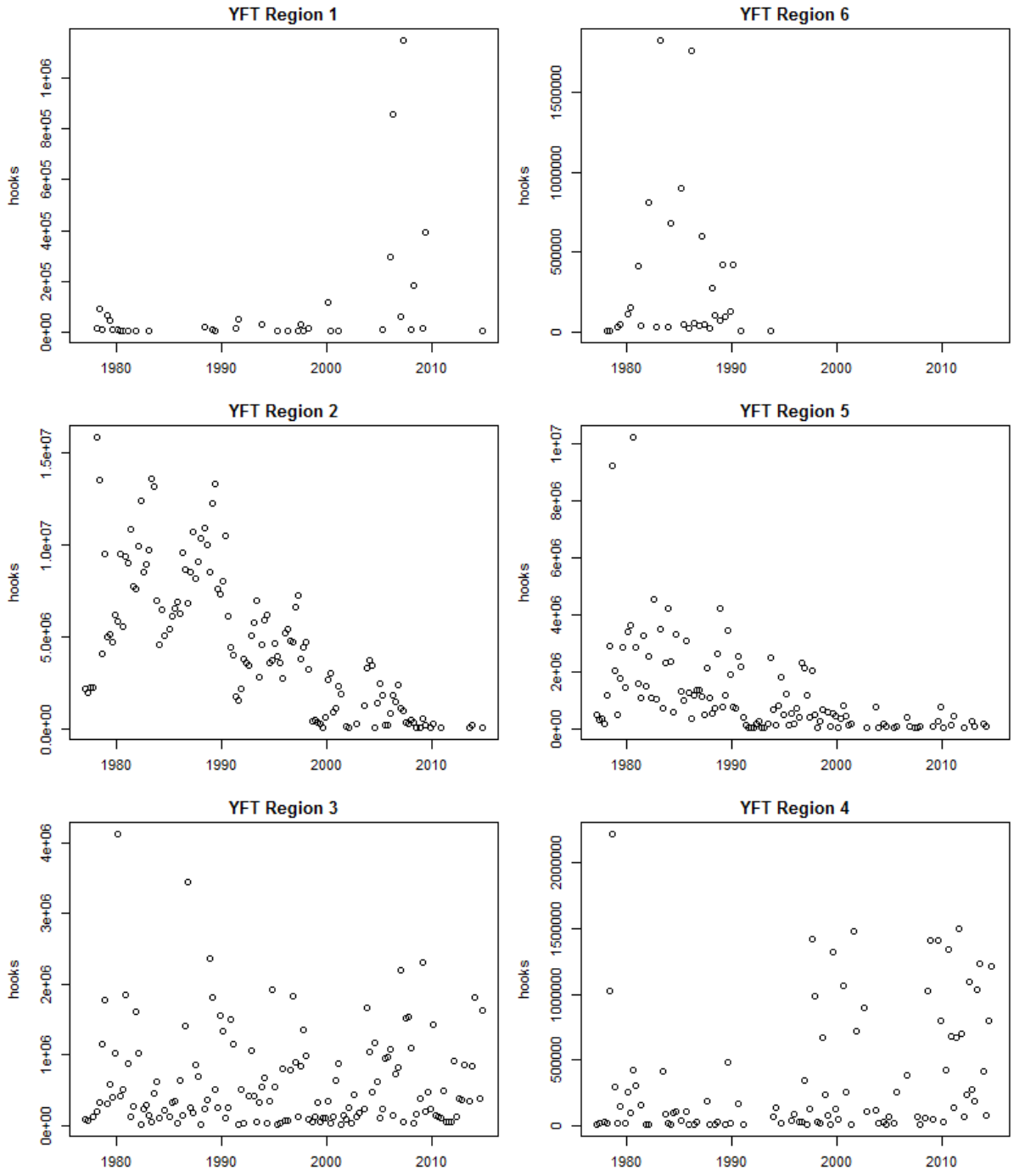


Figure 2: Hooks per year-qtr by region.

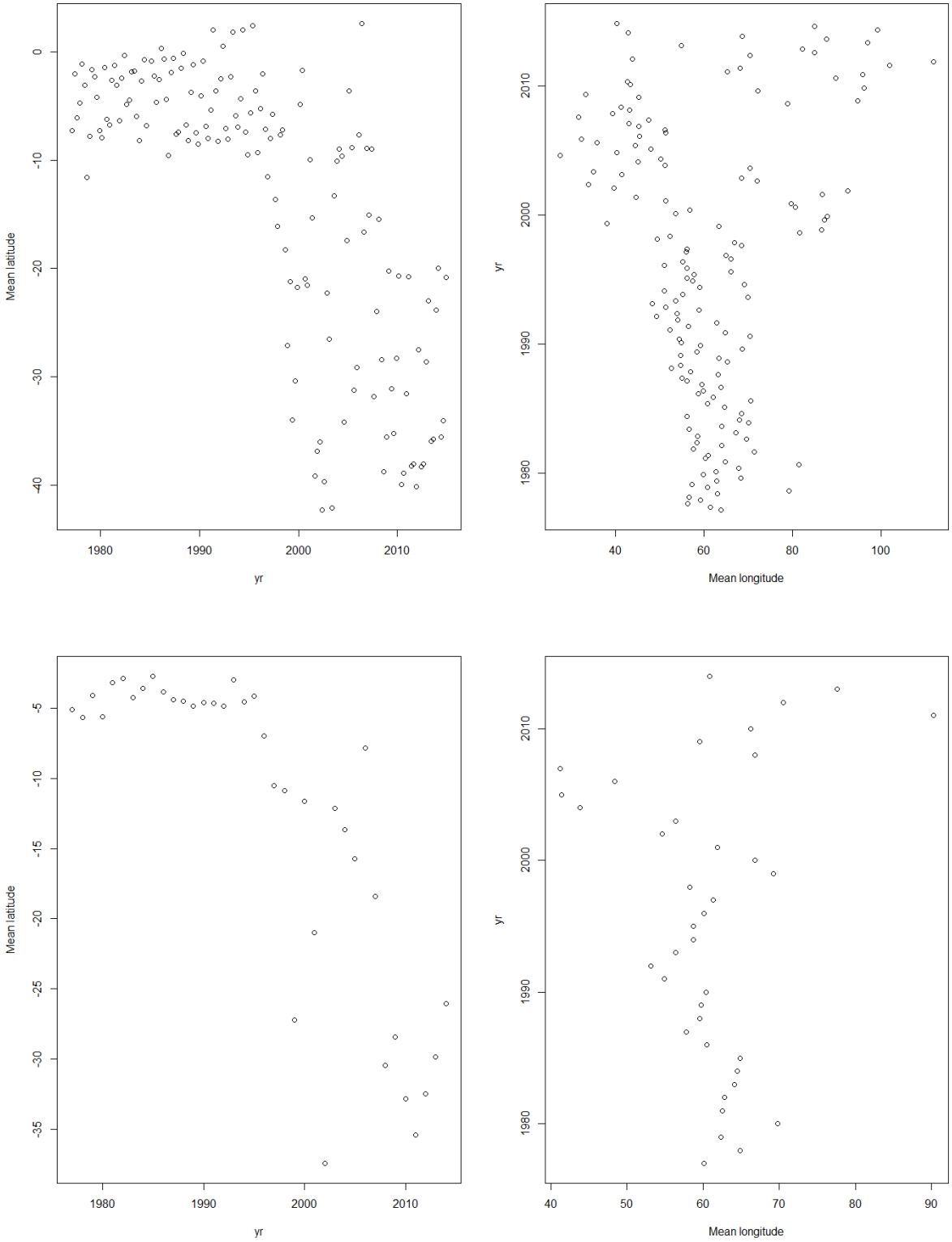


Figure 3: Median location of effort by year-qtr across the Indian Ocean, by year and either latitude (left) or longitude (right).

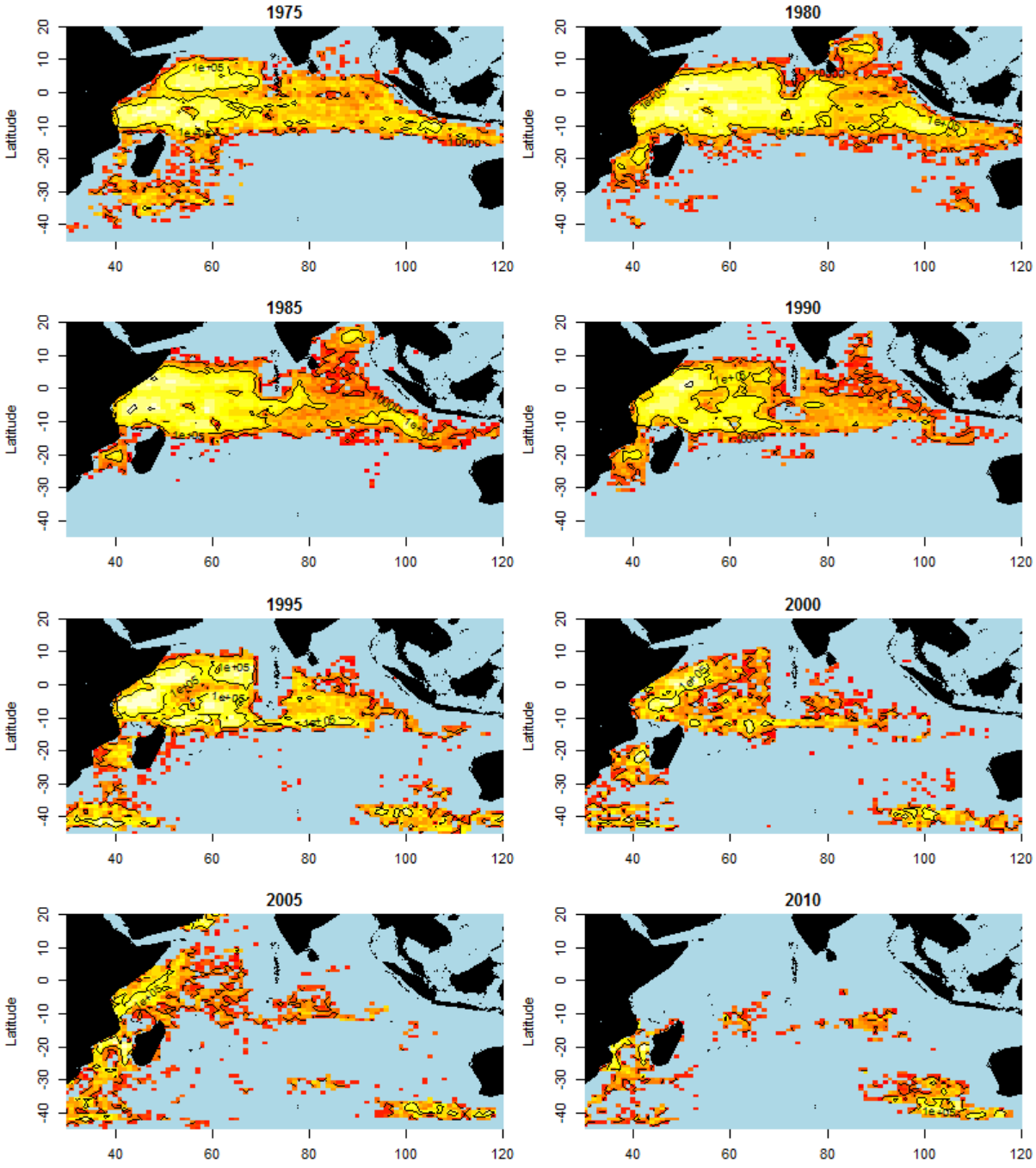


Figure 4: Spatial distribution of effort in total number of hooks per 5 year period. Yellow colour indicates higher effort. Contour intervals are at 10^3, 10^4, 10^5, etc.

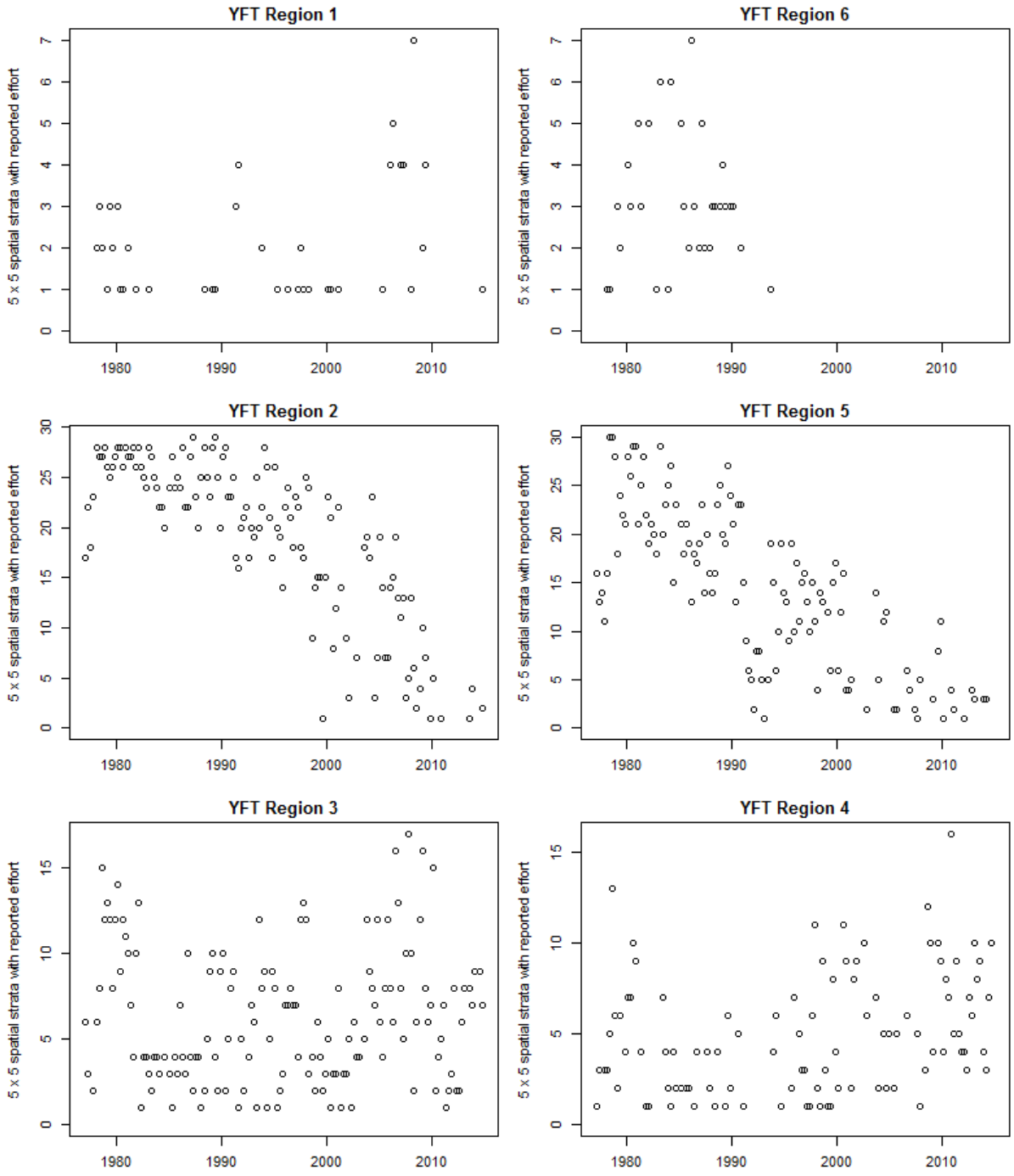


Figure 5: Spatial coverage through time, indicating the number of 5 degree cells with effort by year-qtr and region.

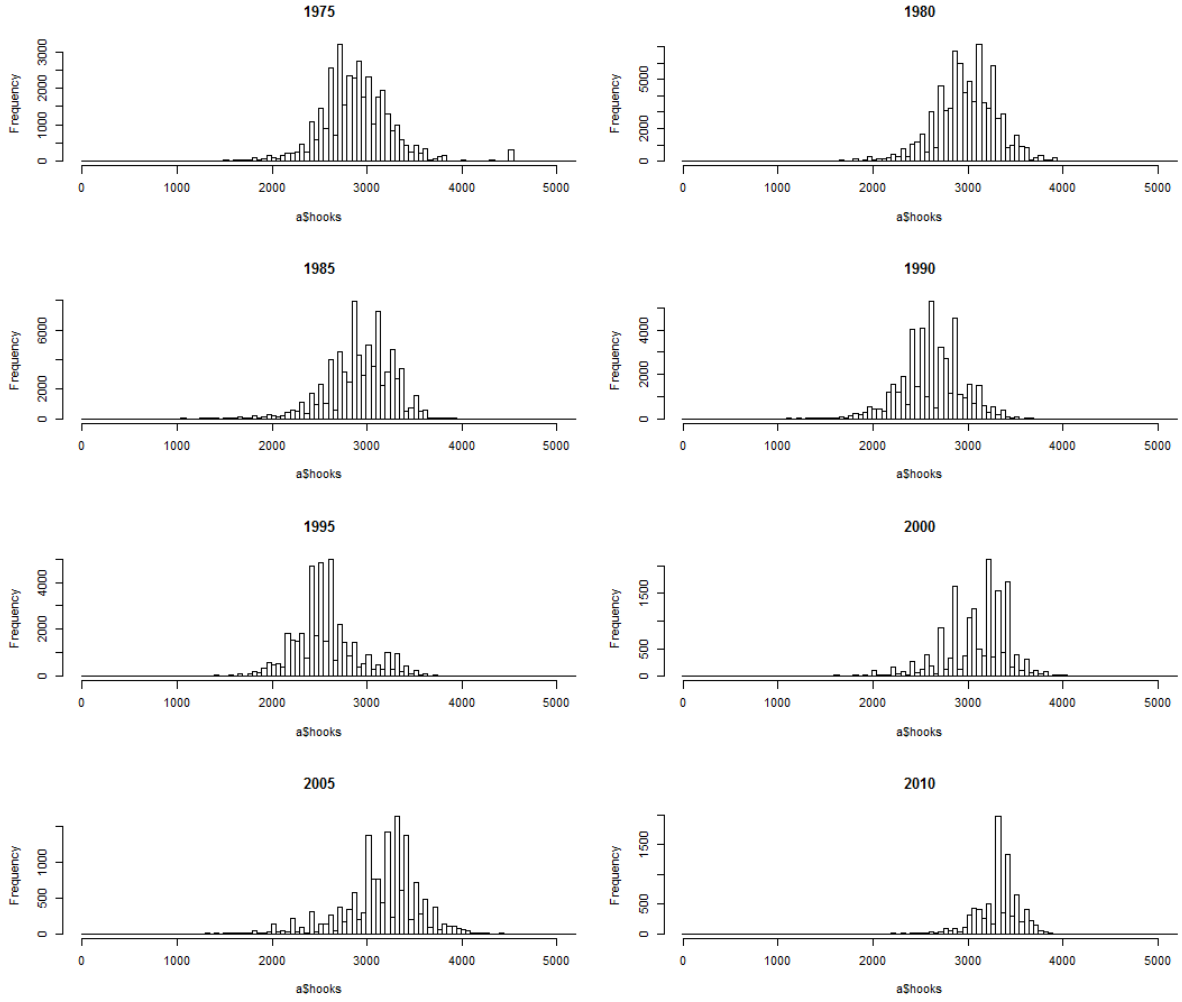


Figure 6: Frequency distribution of hooks per set by 5 year period.

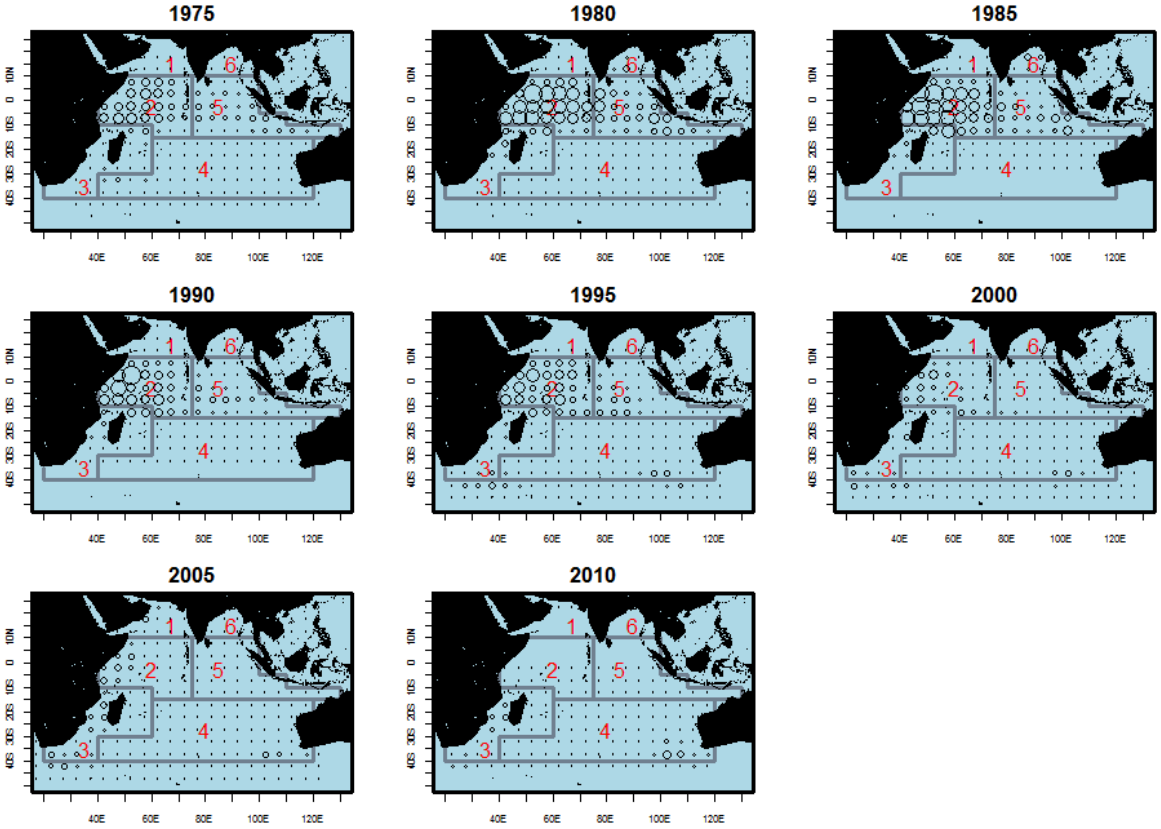


Figure 7: Spatial distribution of sets per 5 degree square by 5 year period.

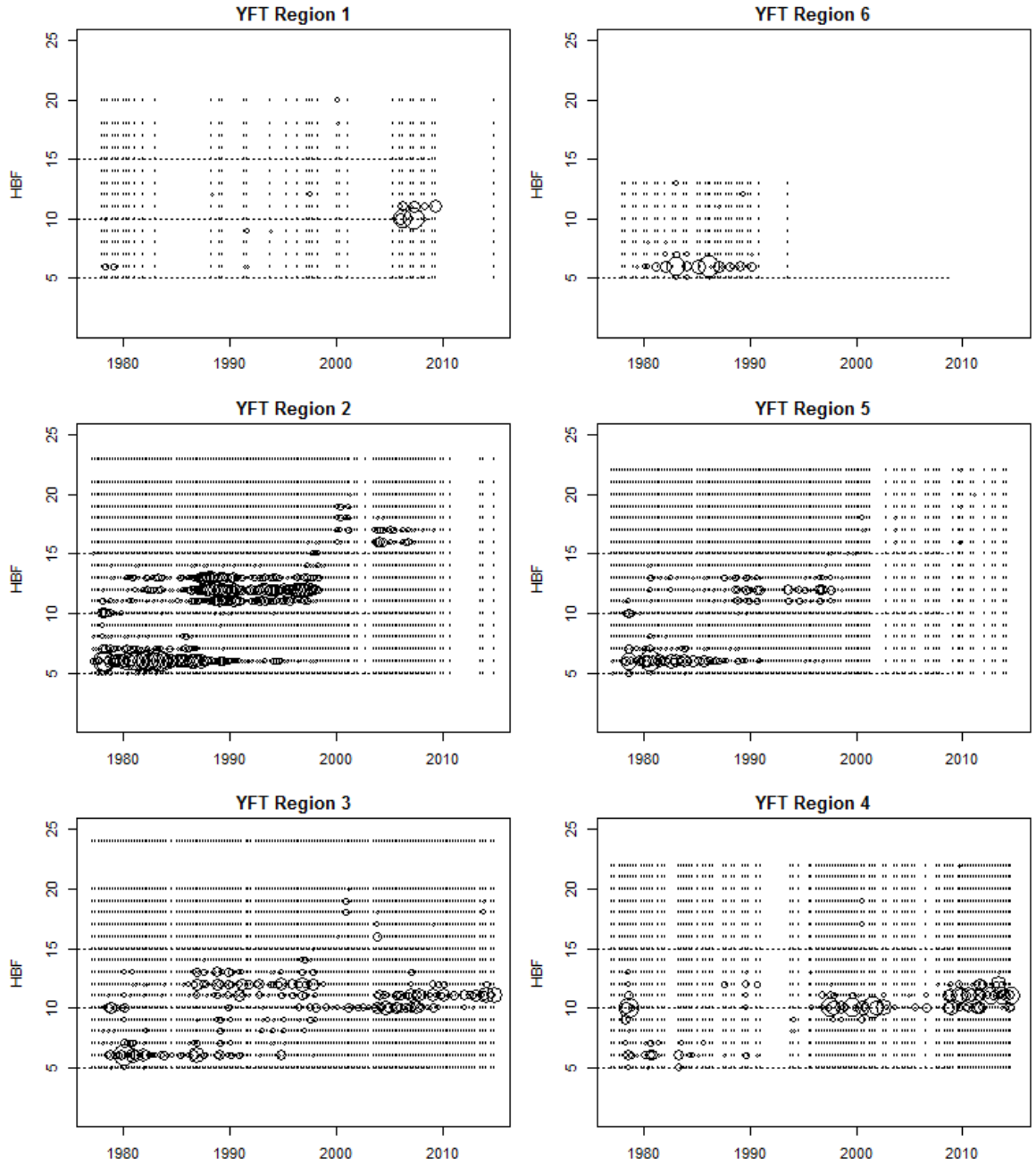


Figure 8: Hooks between floats by year and region. Circle area is proportional to effort in hooks.

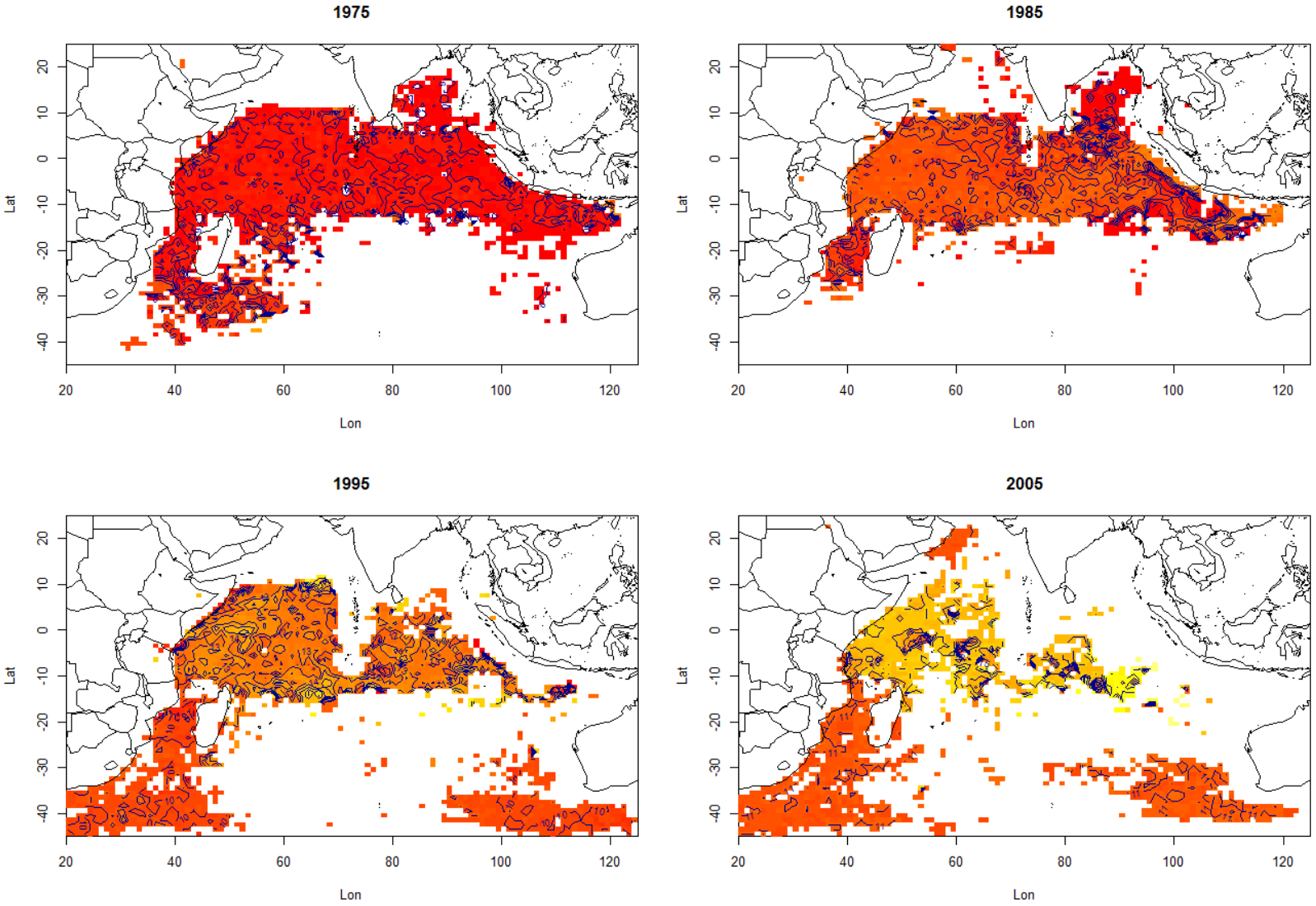


Figure 9: Median HBF per 5 degree square, by 5 year period.

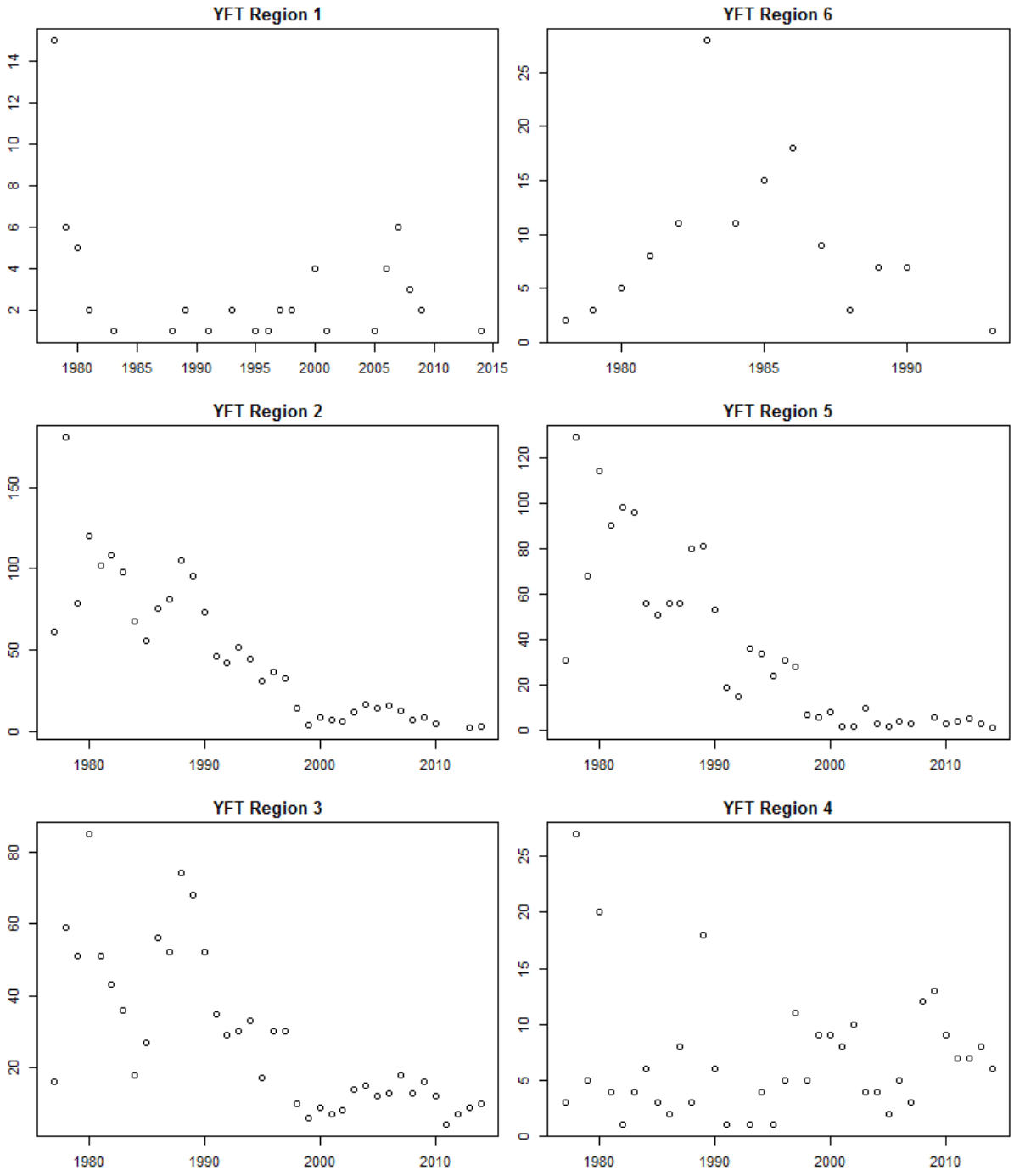


Figure 10: Unique vessels per year by region.

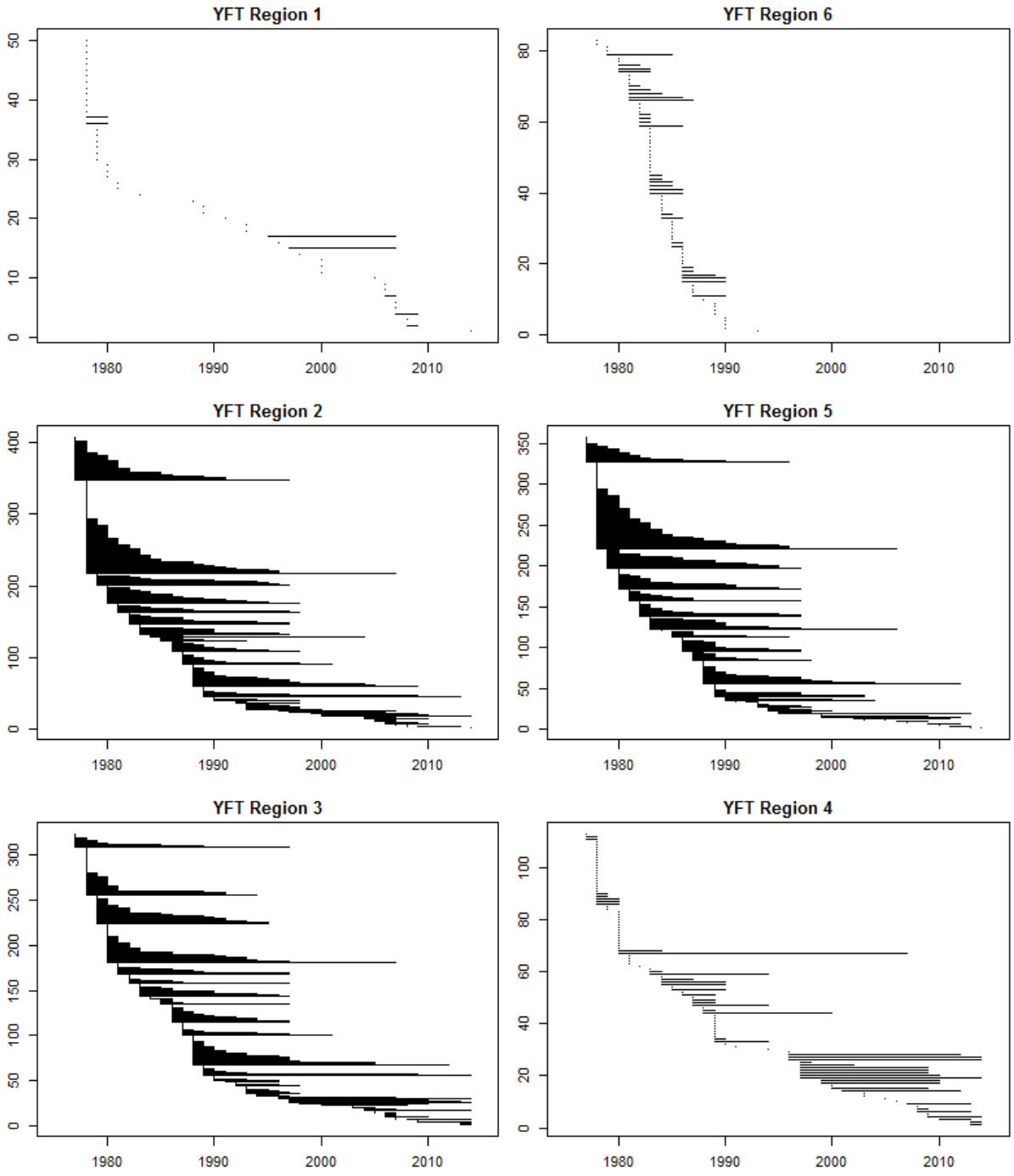


Figure 11: Vessel sorted by year of first set, with a line between the years of first and last set by each vessel.

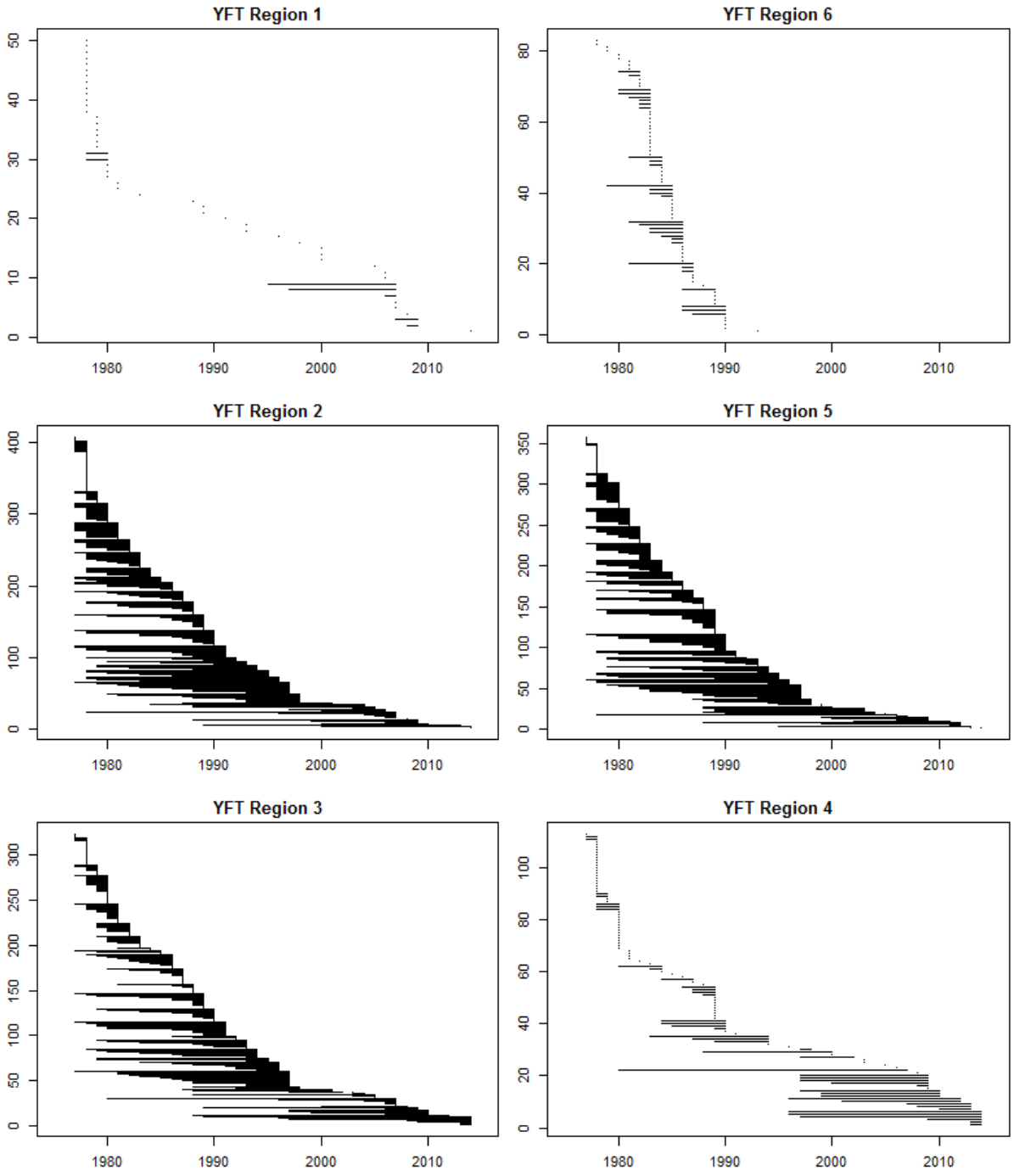


Figure 12: Vessel sorted by year of last set, with a line between the years of first and last set by each vessel.

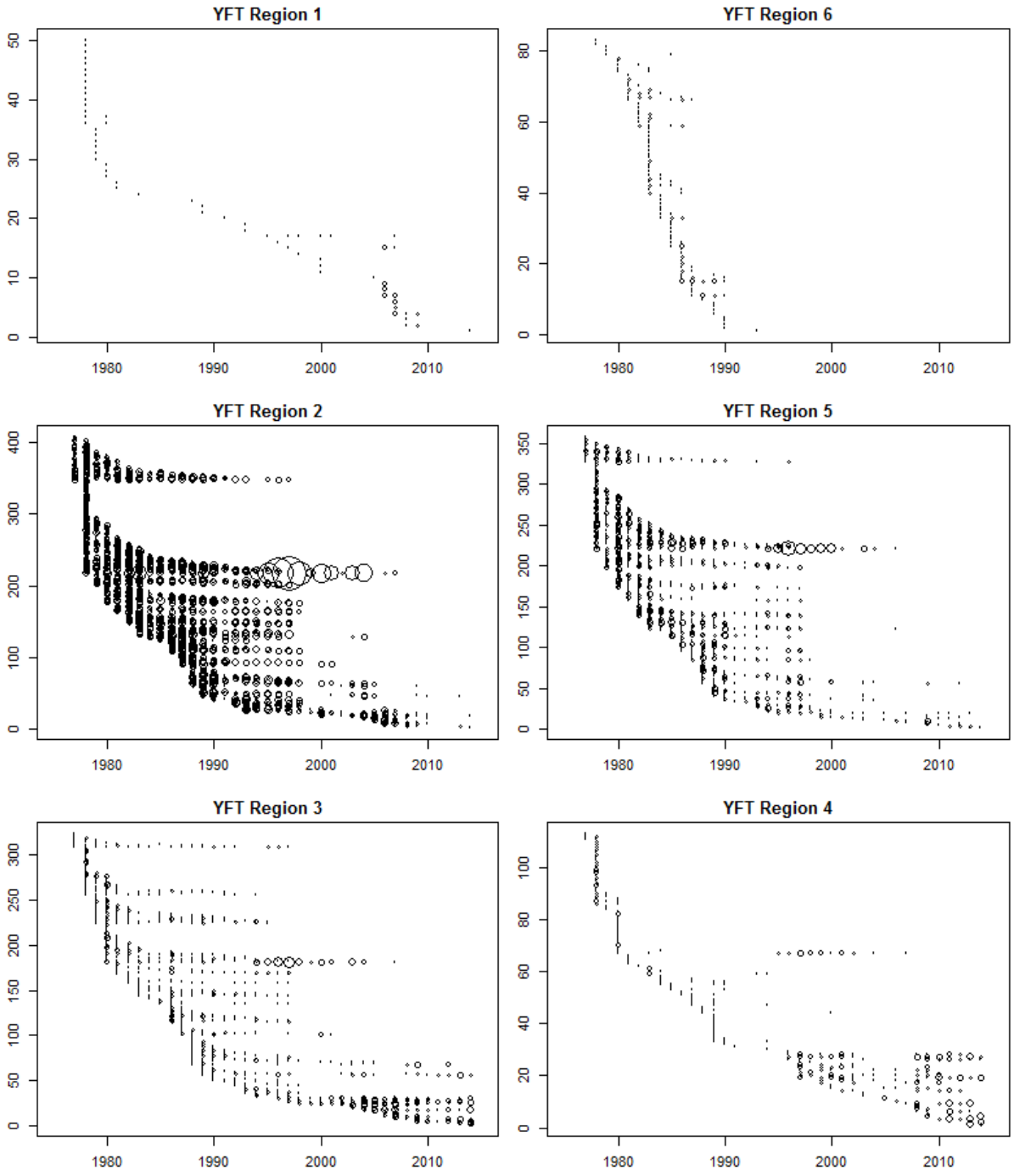


Figure 13: Vessel sorted by year of first set, with circles proportional to number of sets by each vessel.

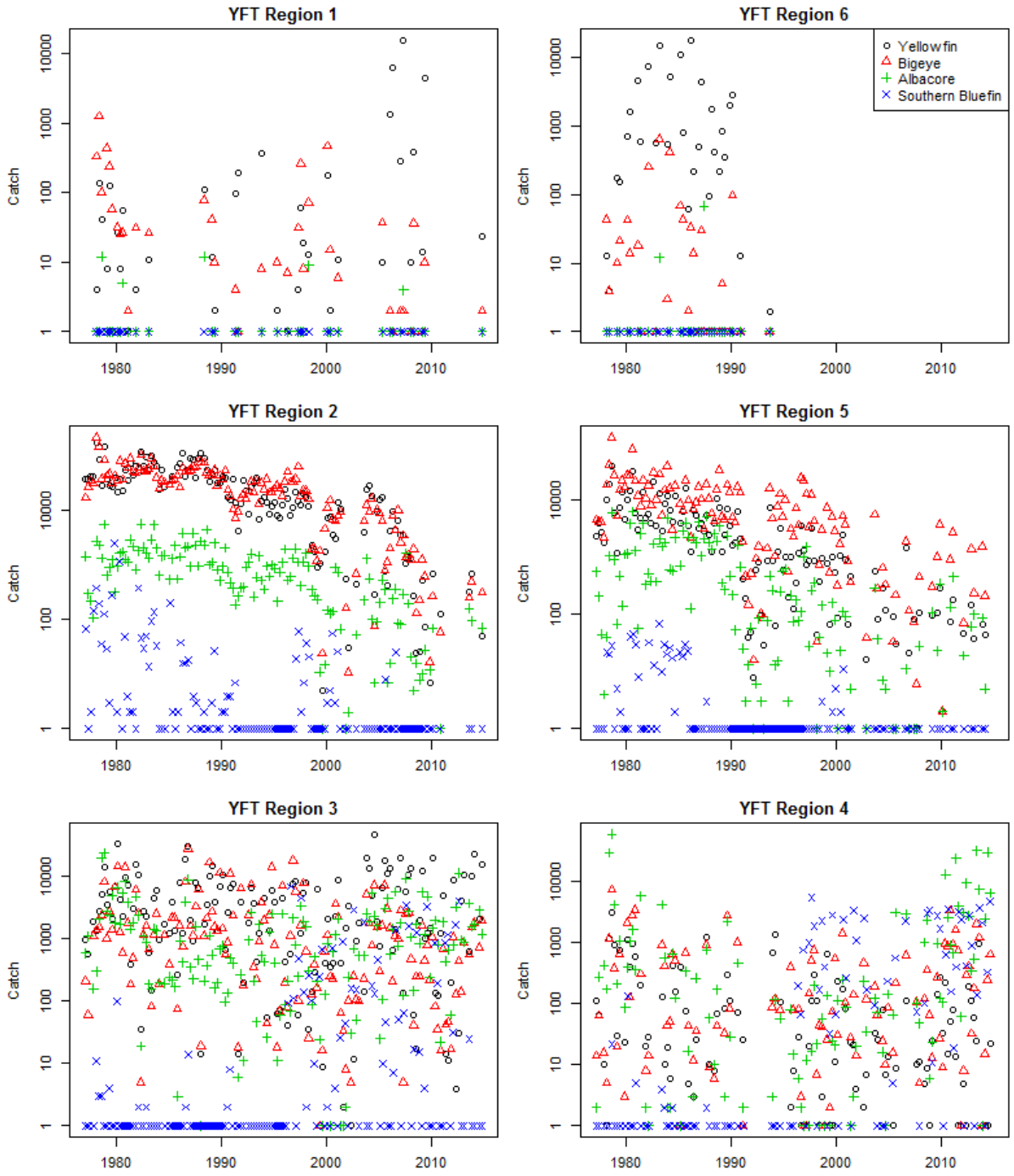


Figure 14: Log scale catch by year-qtr and region for bigeye, yellowfin, albacore and SBT.

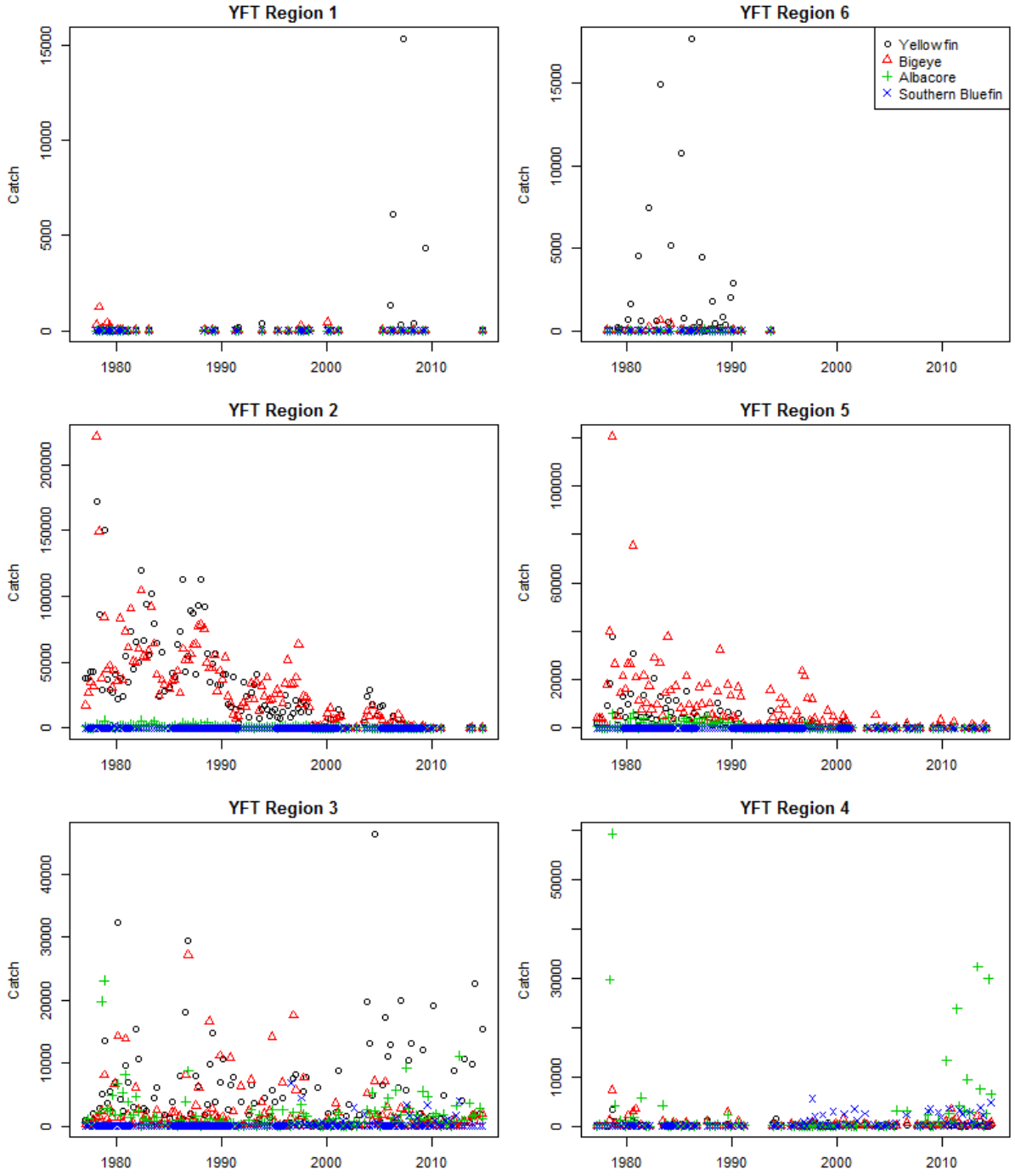


Figure 15: Catch by year-qtr and region for bigeye, yellowfin, albacore and SBT

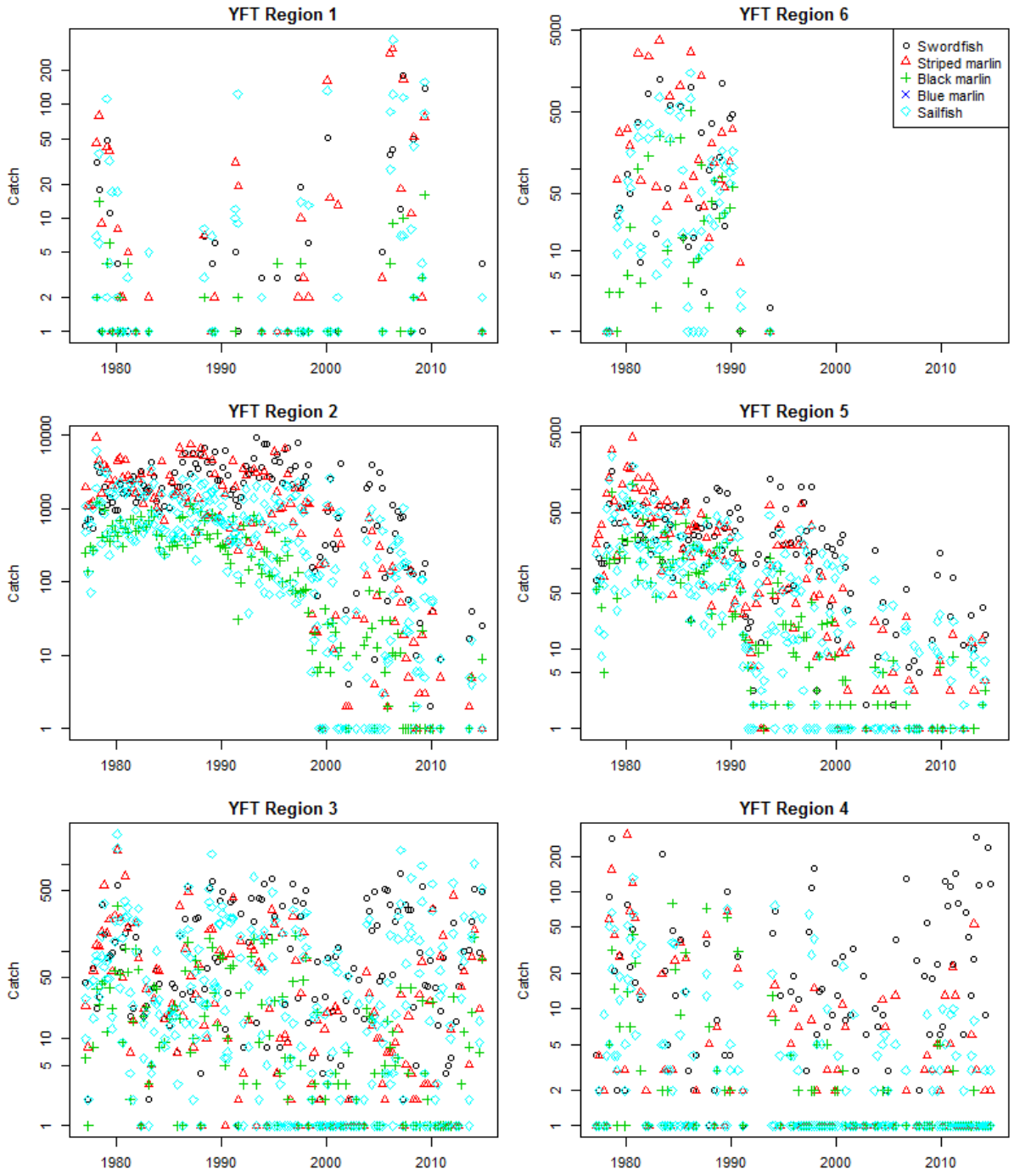


Figure 16: Log scale catch by year-qtr and region for swordfish, striped marlin, black marlin blue marlin and sailfish.

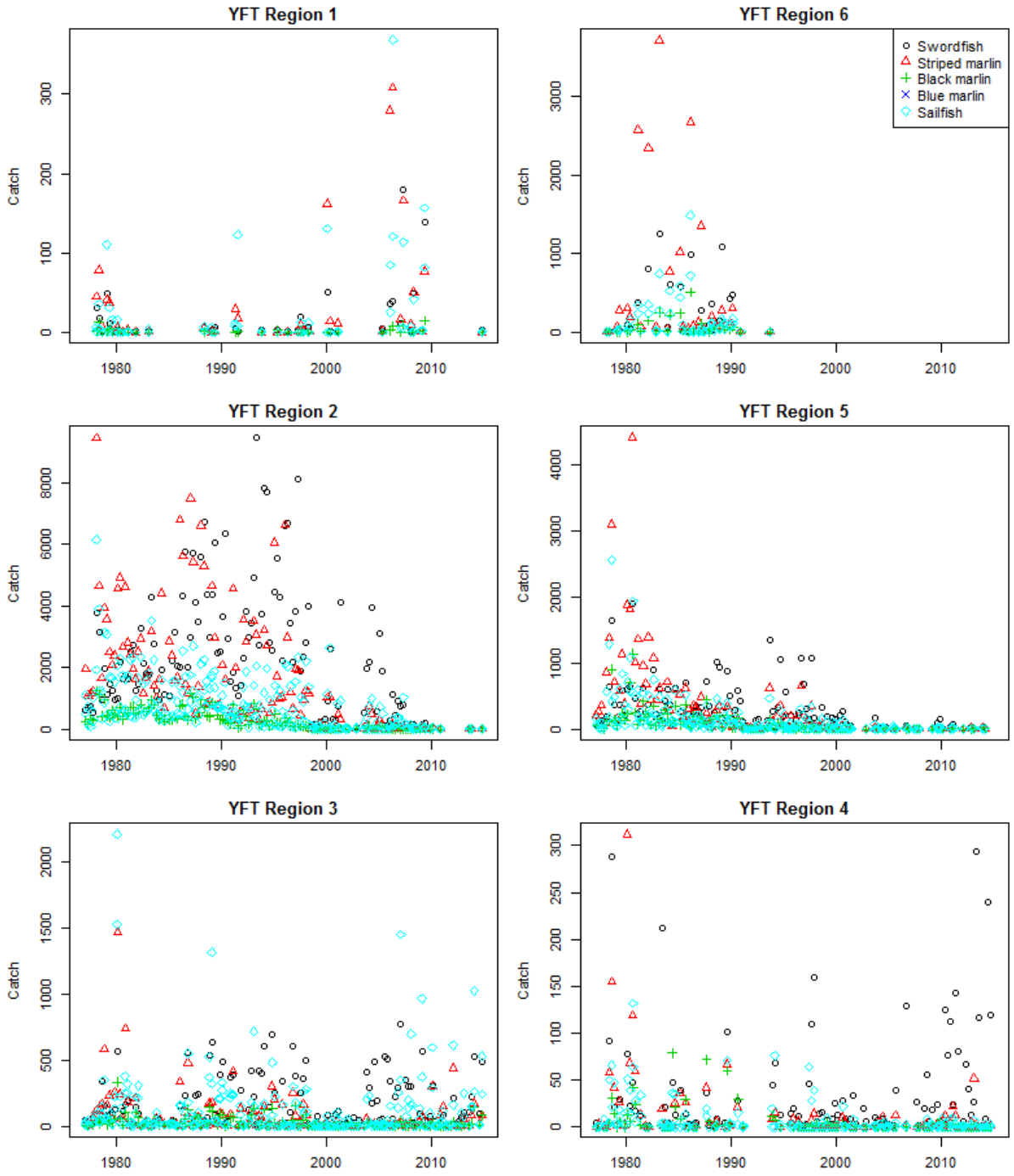


Figure 17: Catch by year-qtr and region for swordfish, striped marlin, black marlin blue marlin and sailfish.

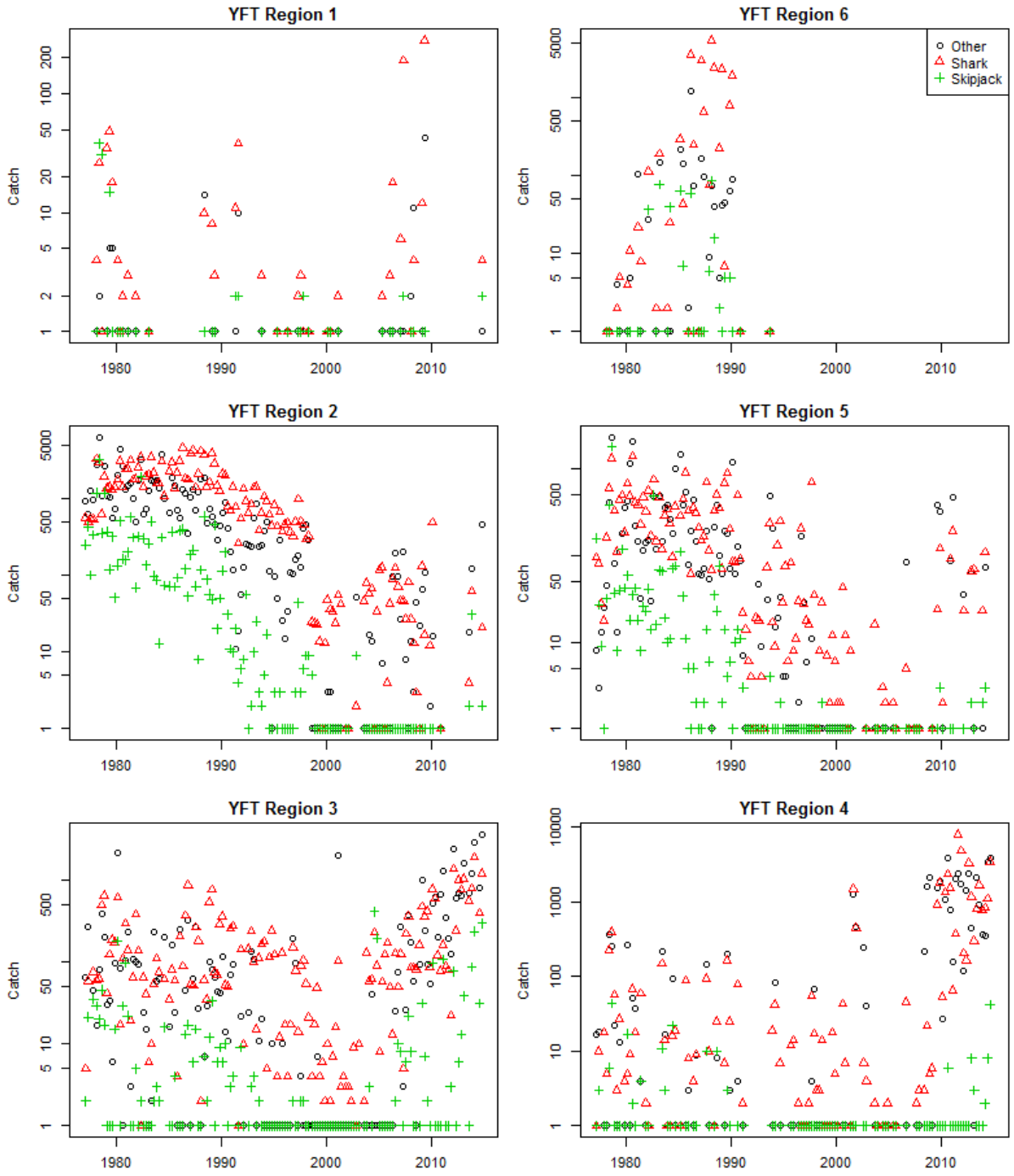


Figure 18: Log scale catch by year-qtr and region for other species, shark, and skipjack.

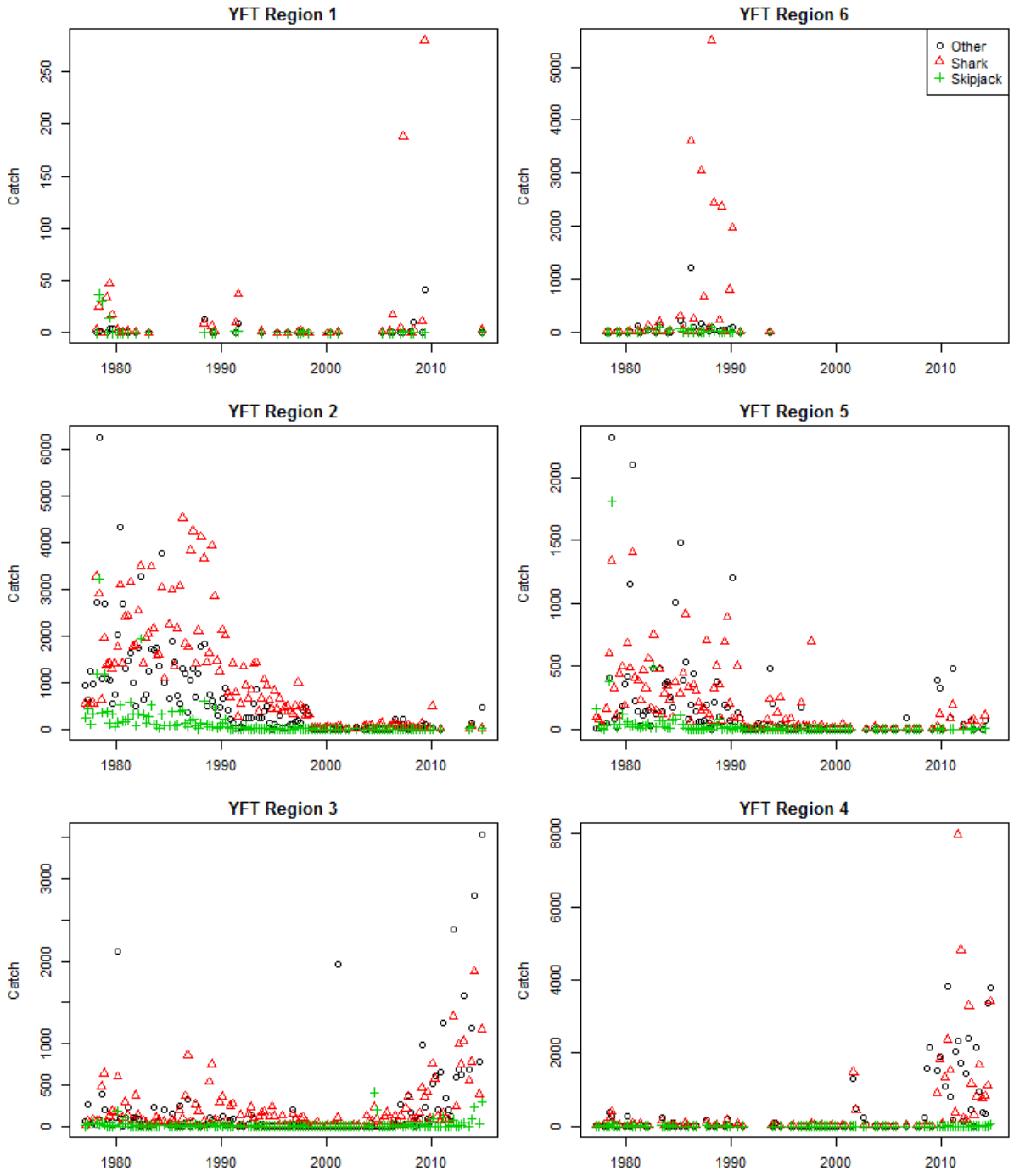


Figure 19: Catch by year-qtr and region for other species, shark, and skipjack.

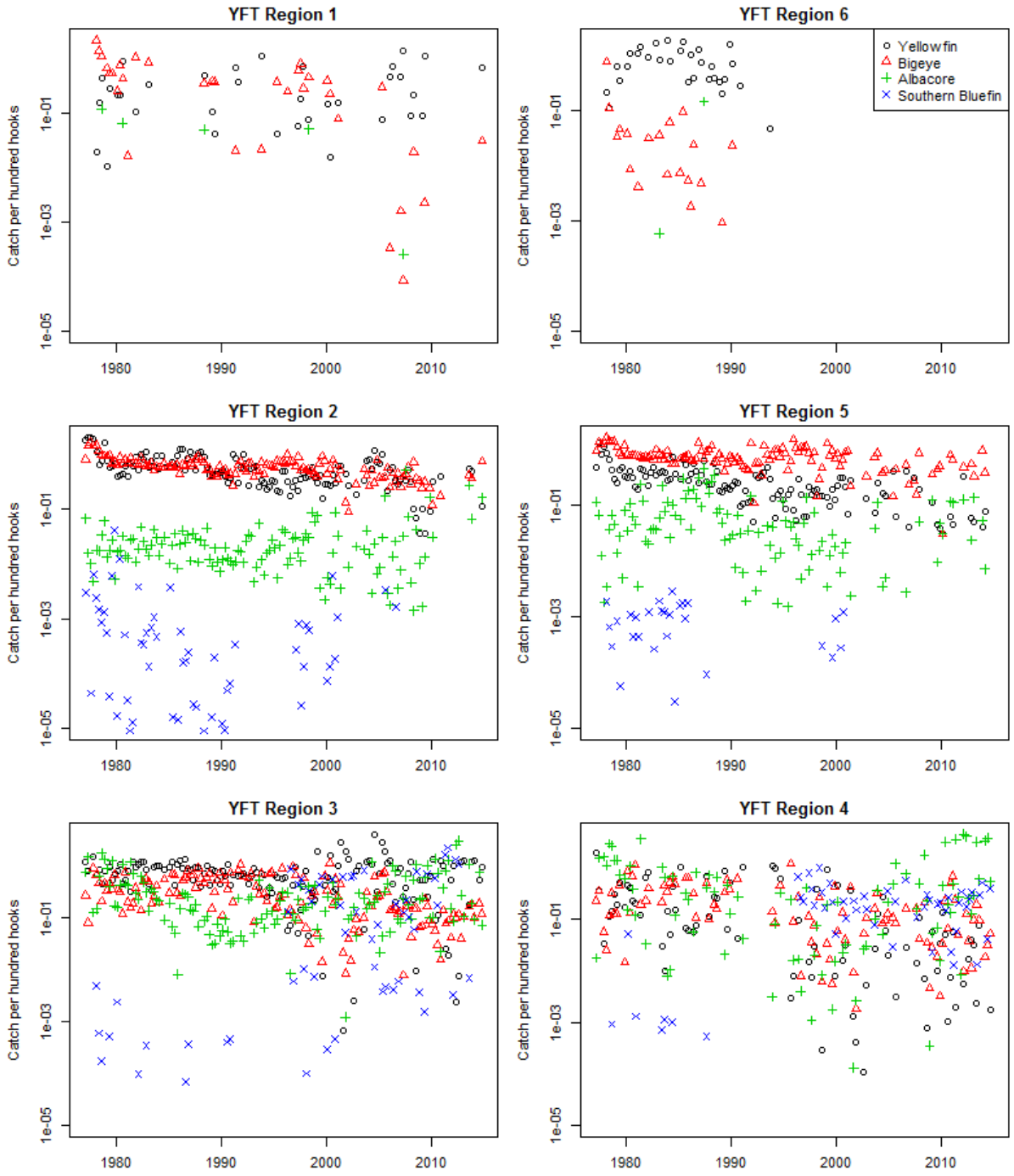


Figure 20: Log scale CPUE by year-qtr and region for yellowfin, bigeye, albacore, and SBT.

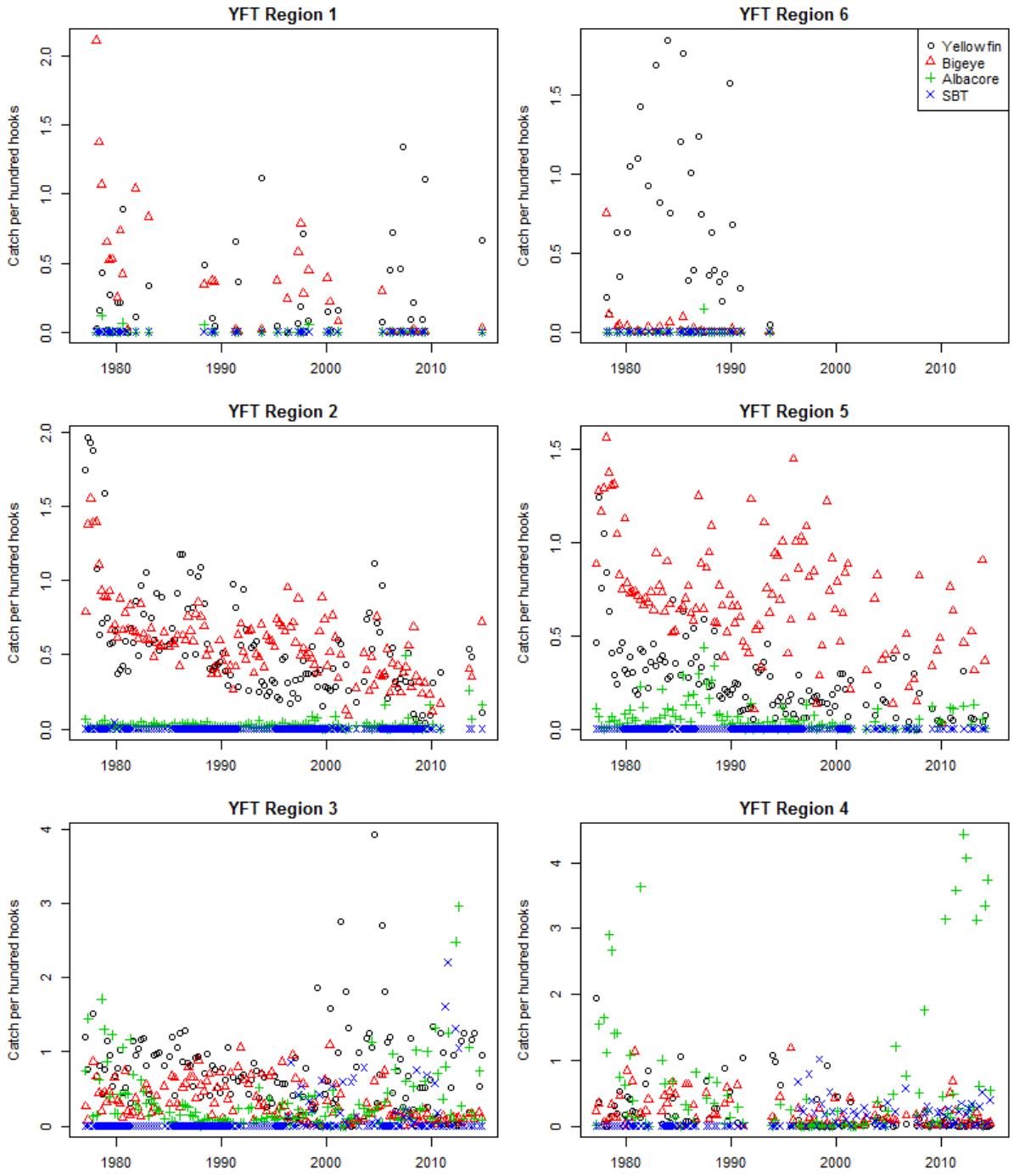


Figure 21: CPUE by year-qtr and region for yellowfin, bigeye, albacore, and SBT

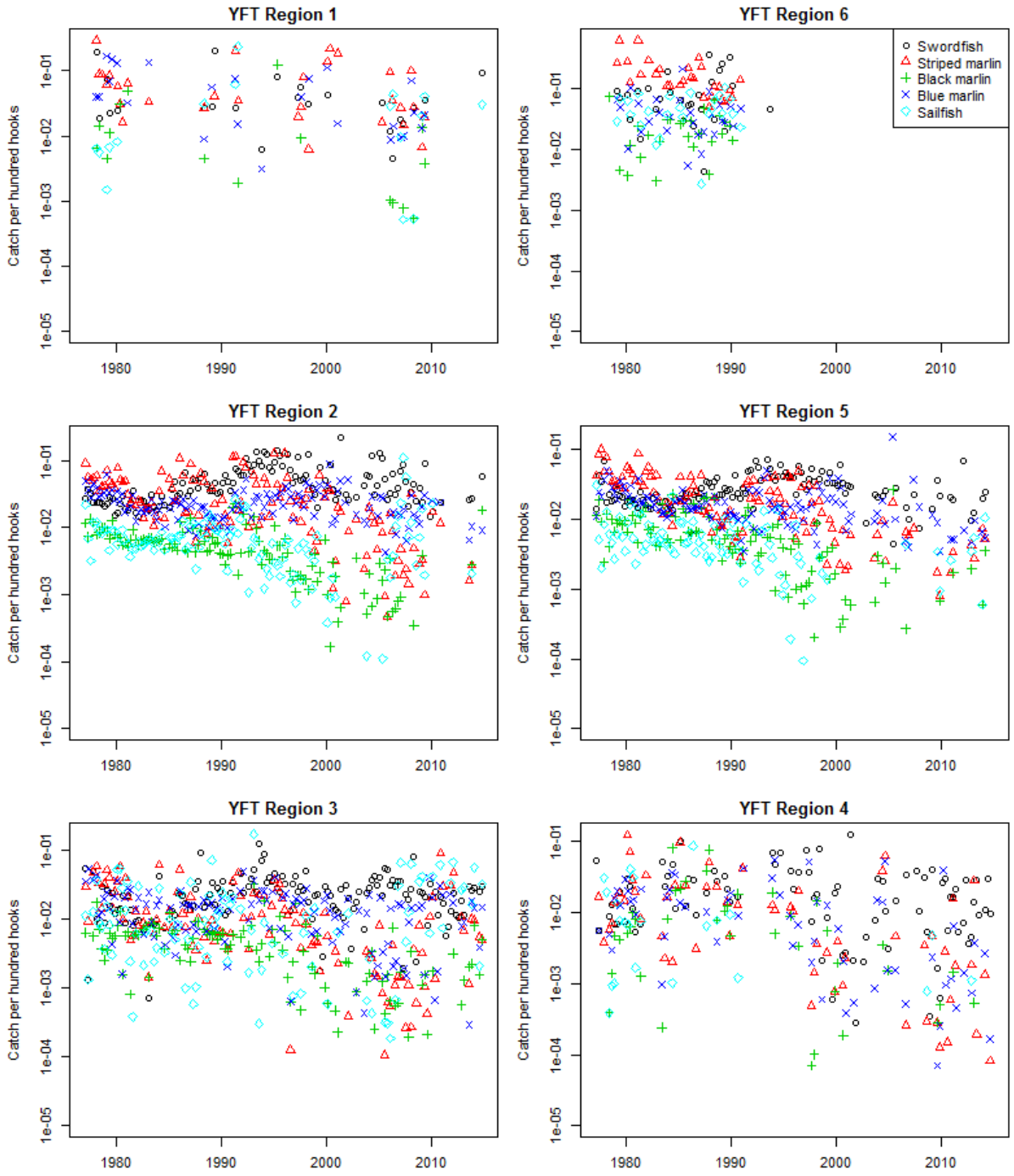


Figure 22: Log scale CPUE by year-qtr and region for billfish.

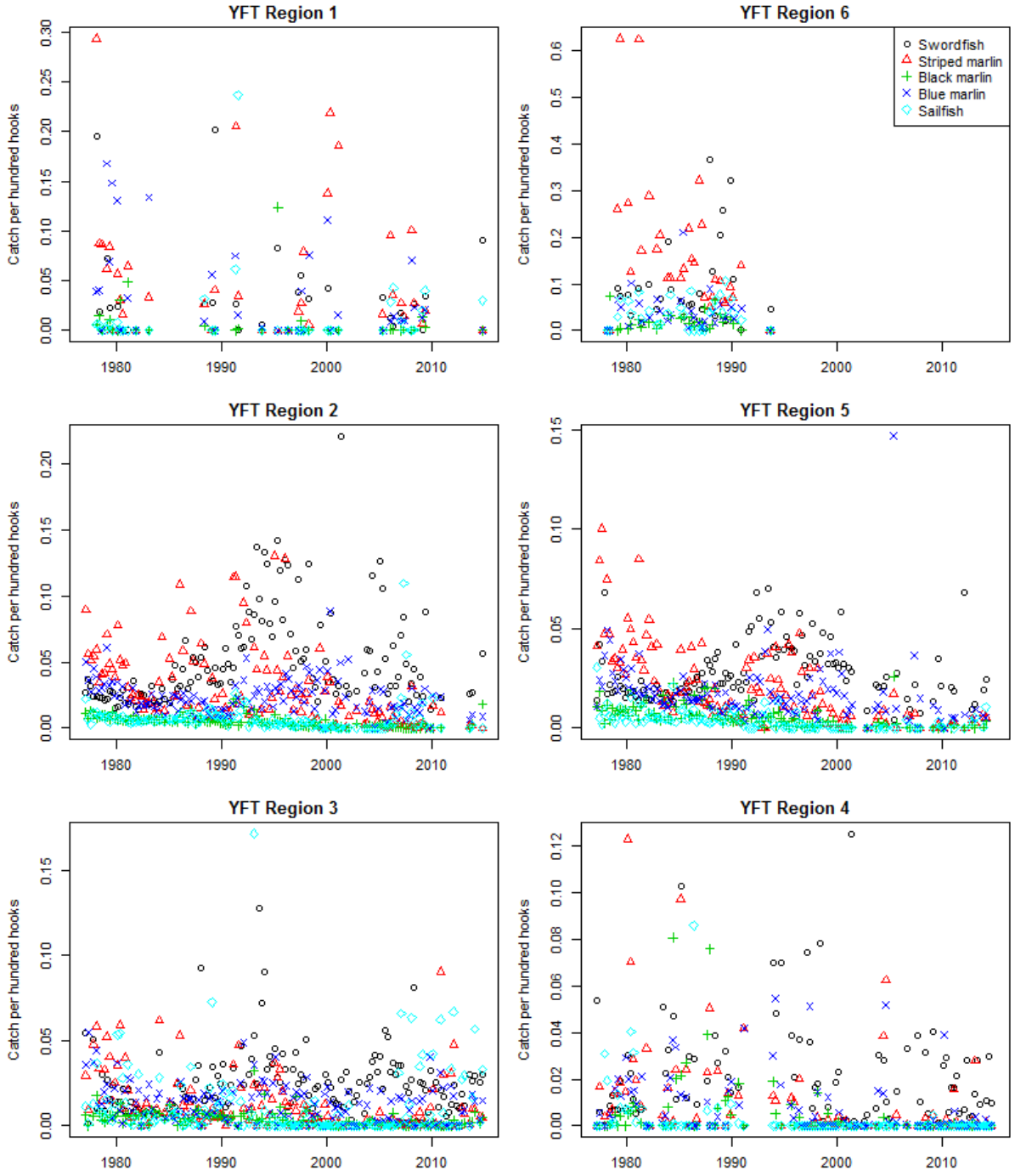


Figure 23: CPUE by year-qtr and region for billfish.

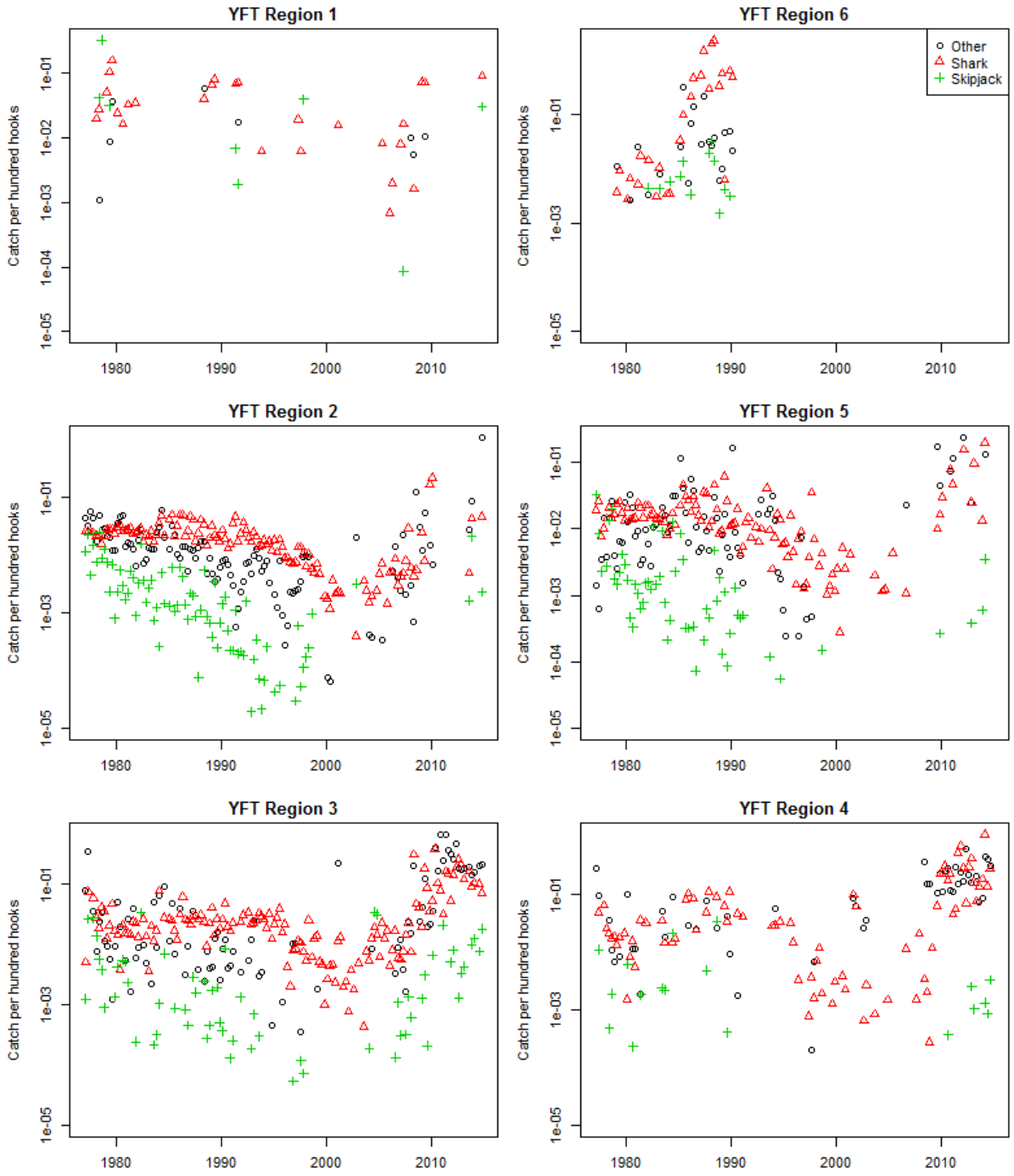


Figure 24: Log scale CPUE by year-qtr and region for shark, skipjack, and other species.

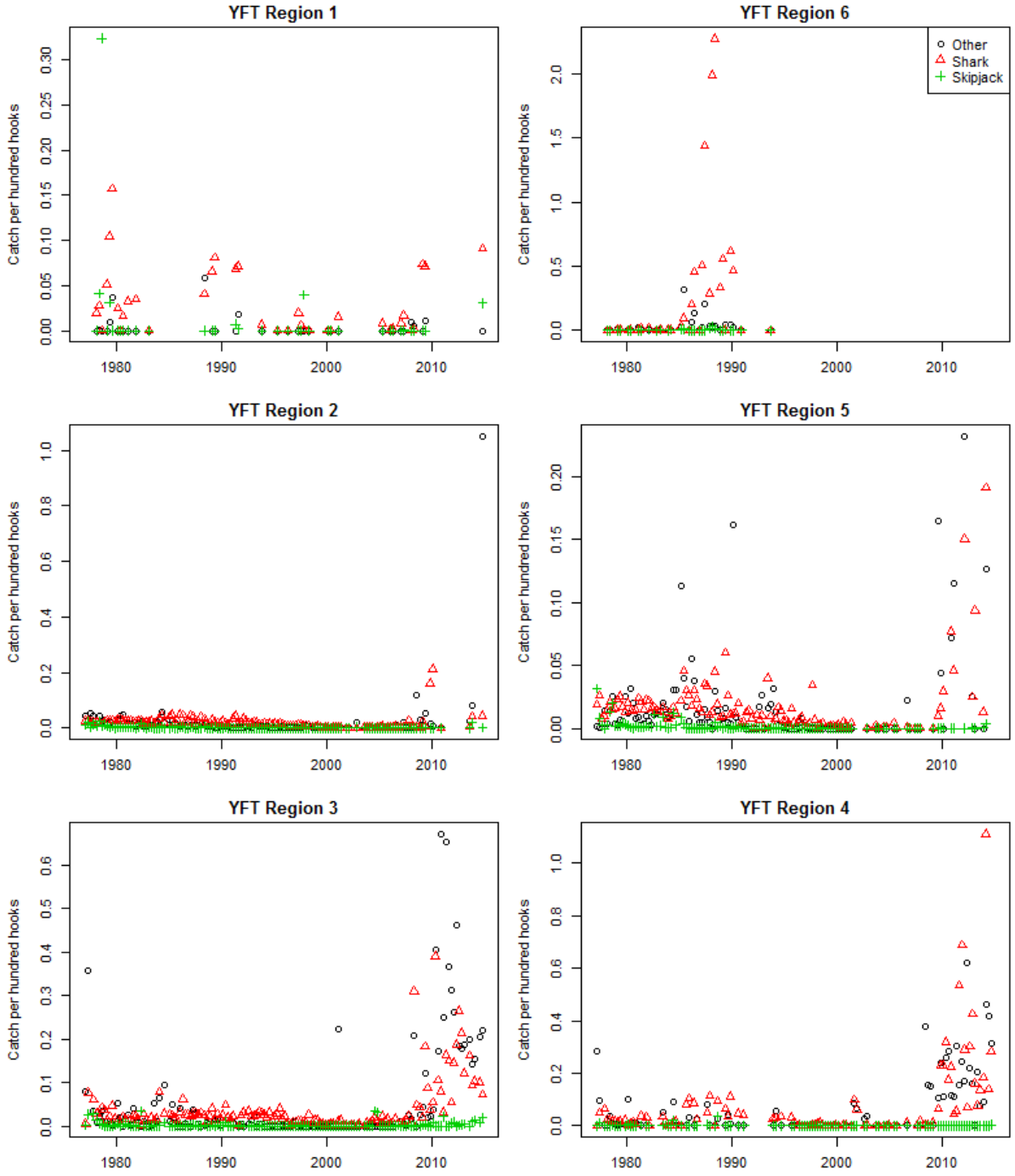


Figure 25: CPUE by year-qtr and region for shark, skipjack, and other species.

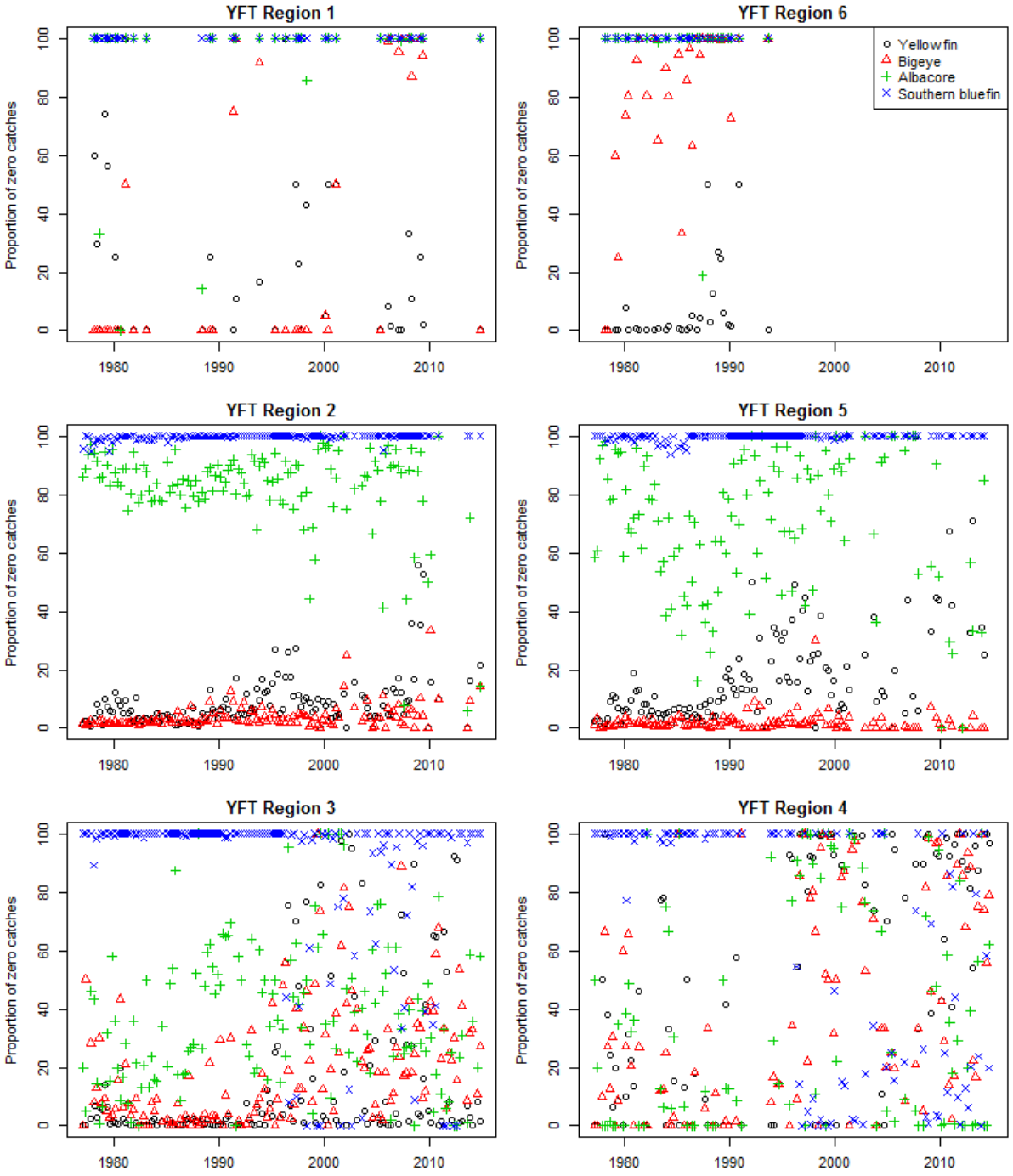


Figure 26: Proportion of zero catches by year-qtr and region for bigeye, yellowfin, albacore, and SBT.

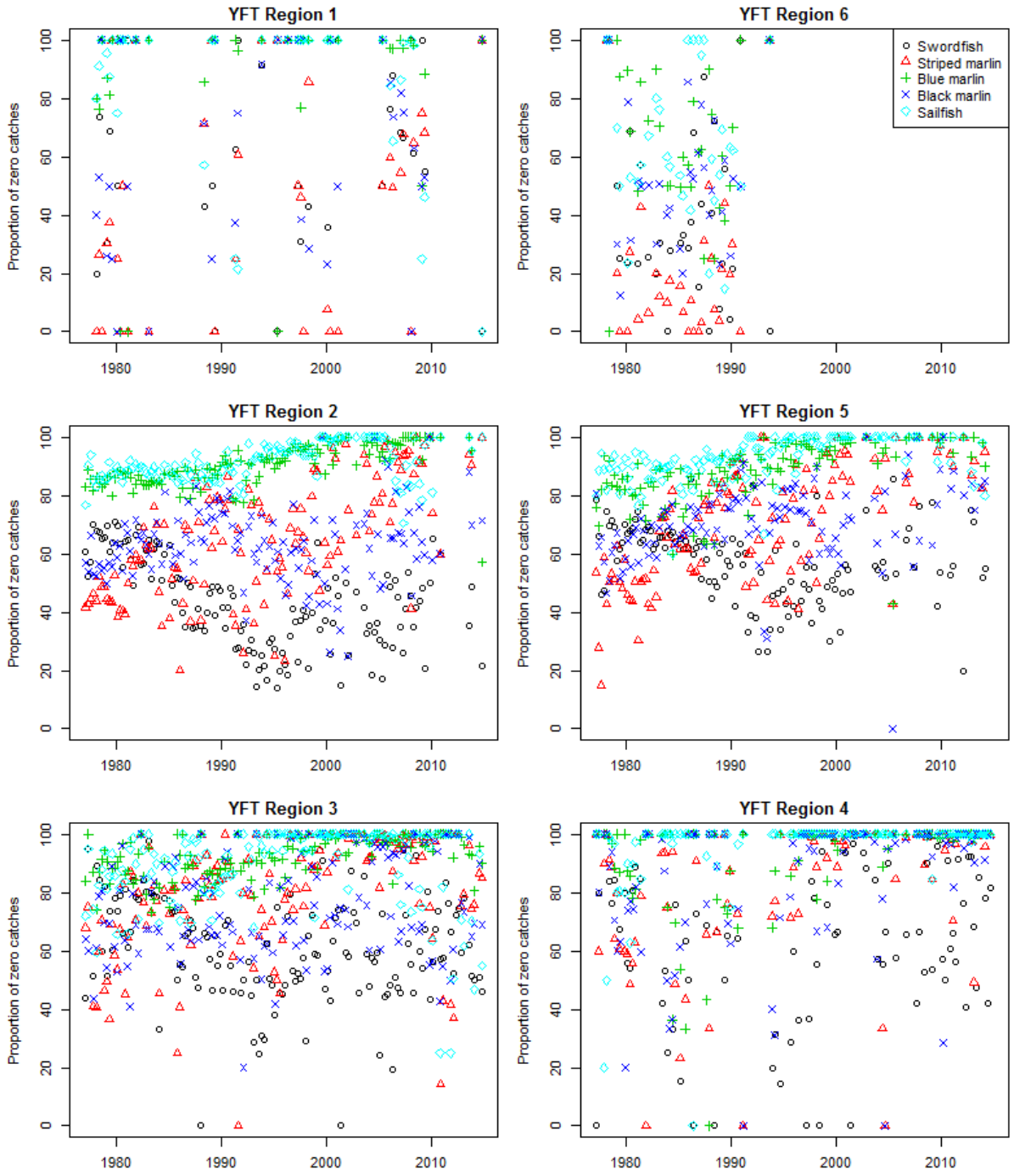


Figure 27: Proportion of zero catches by year-qtr and region for billfish.

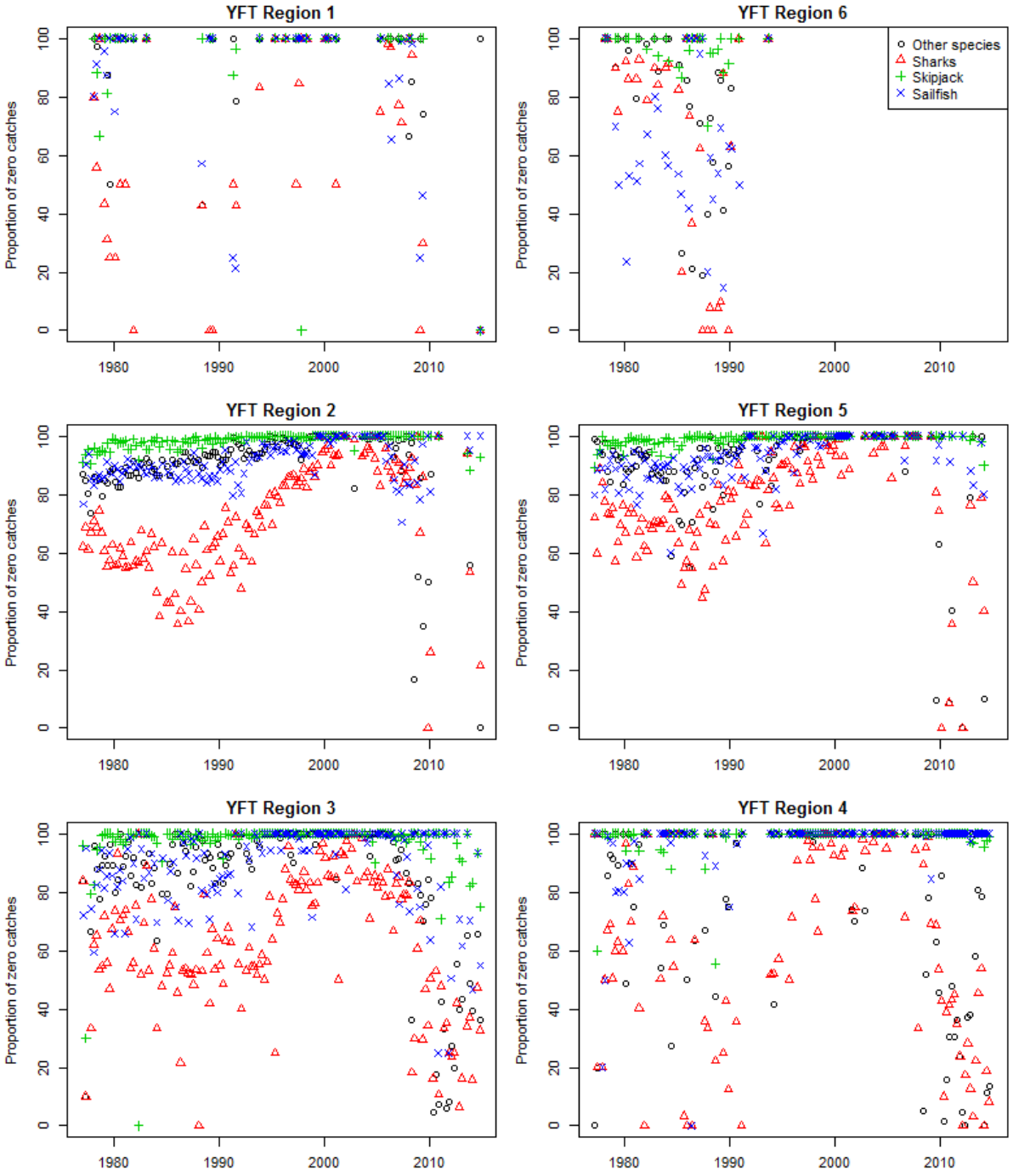
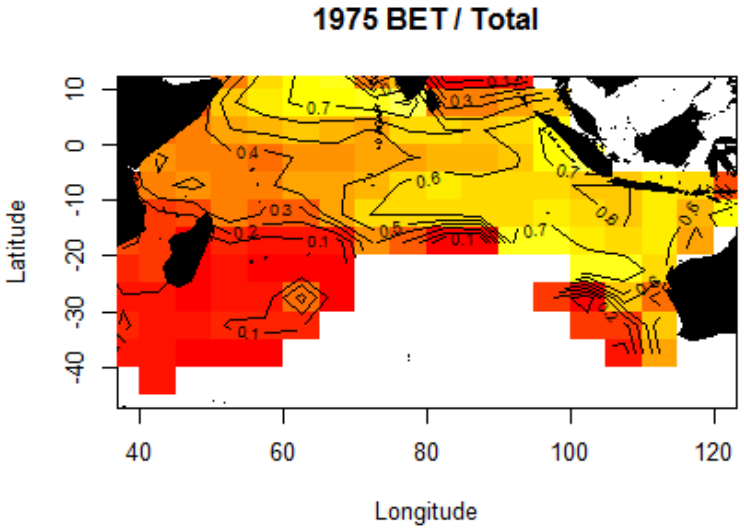


Figure 28: Proportion of zero catches by year-qtr and region for shark, skipjack, and other species.


1975 BET / Total
Latitude
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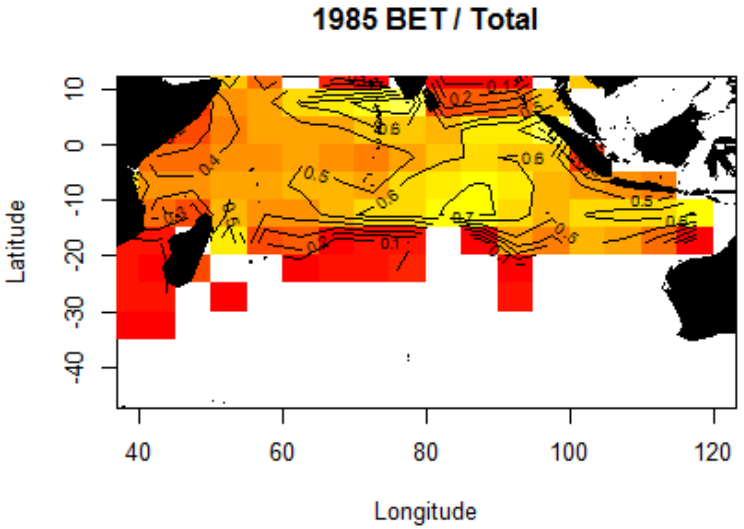
1985 BET / Total
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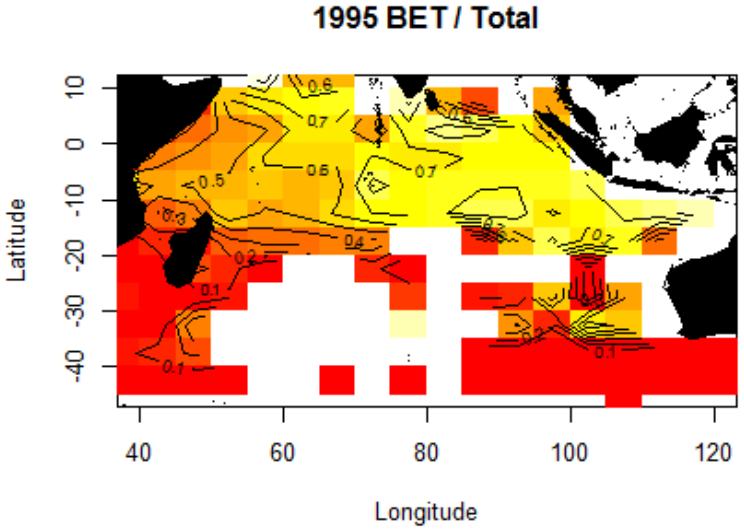
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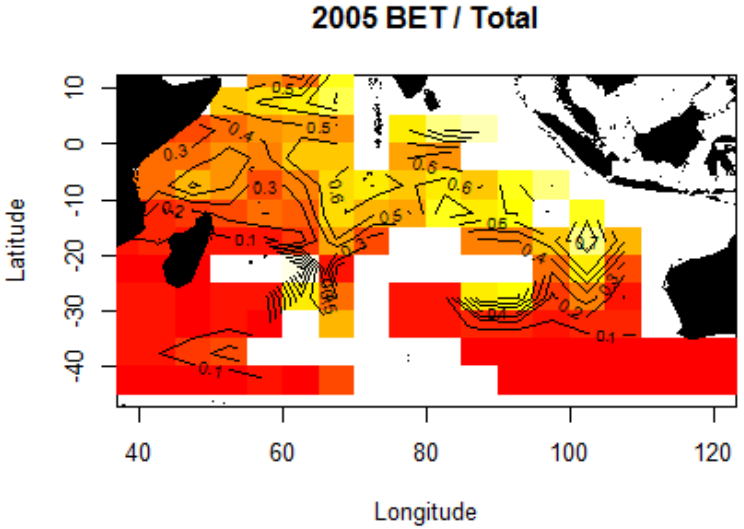
2005 BET / Total
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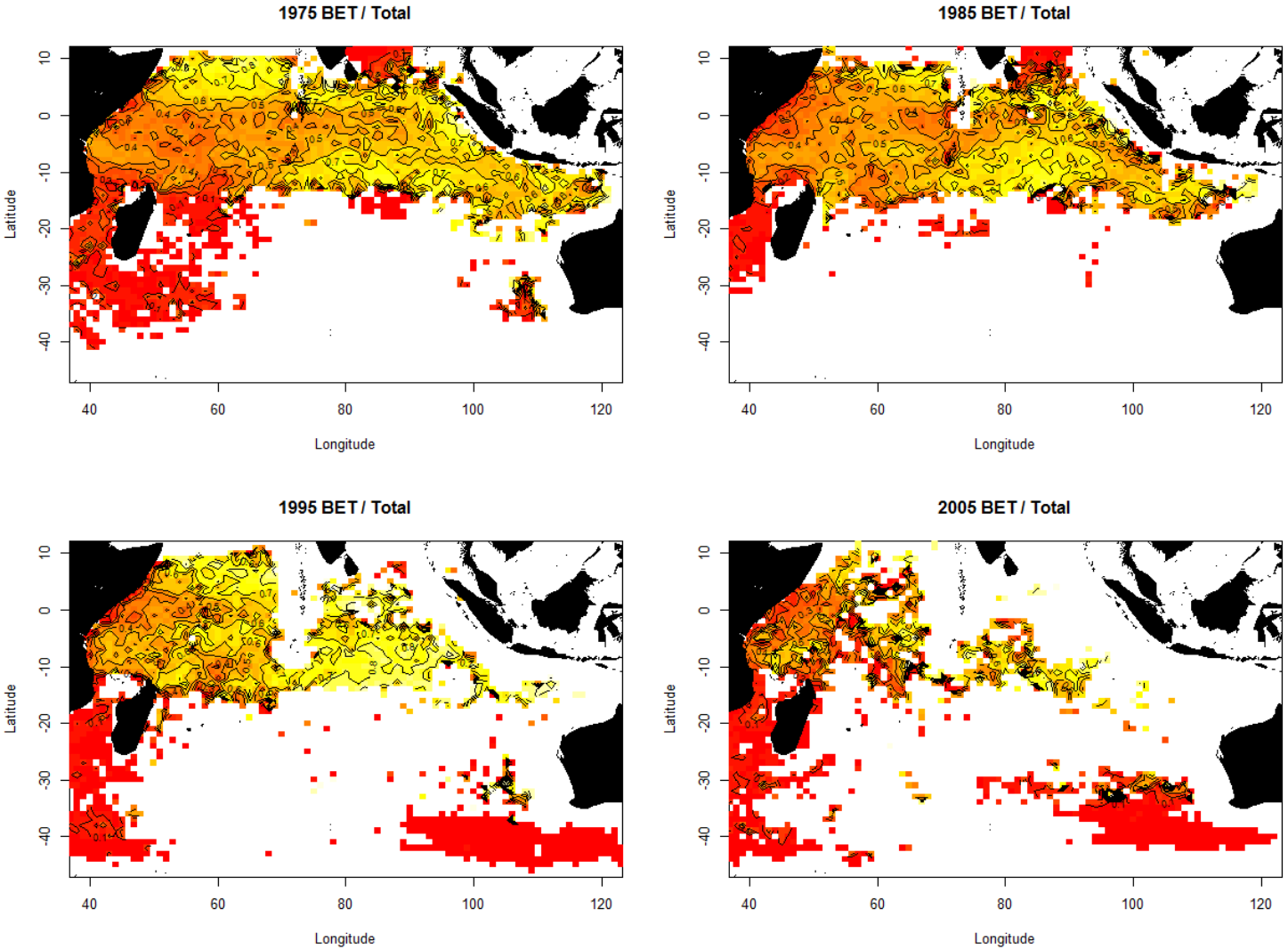
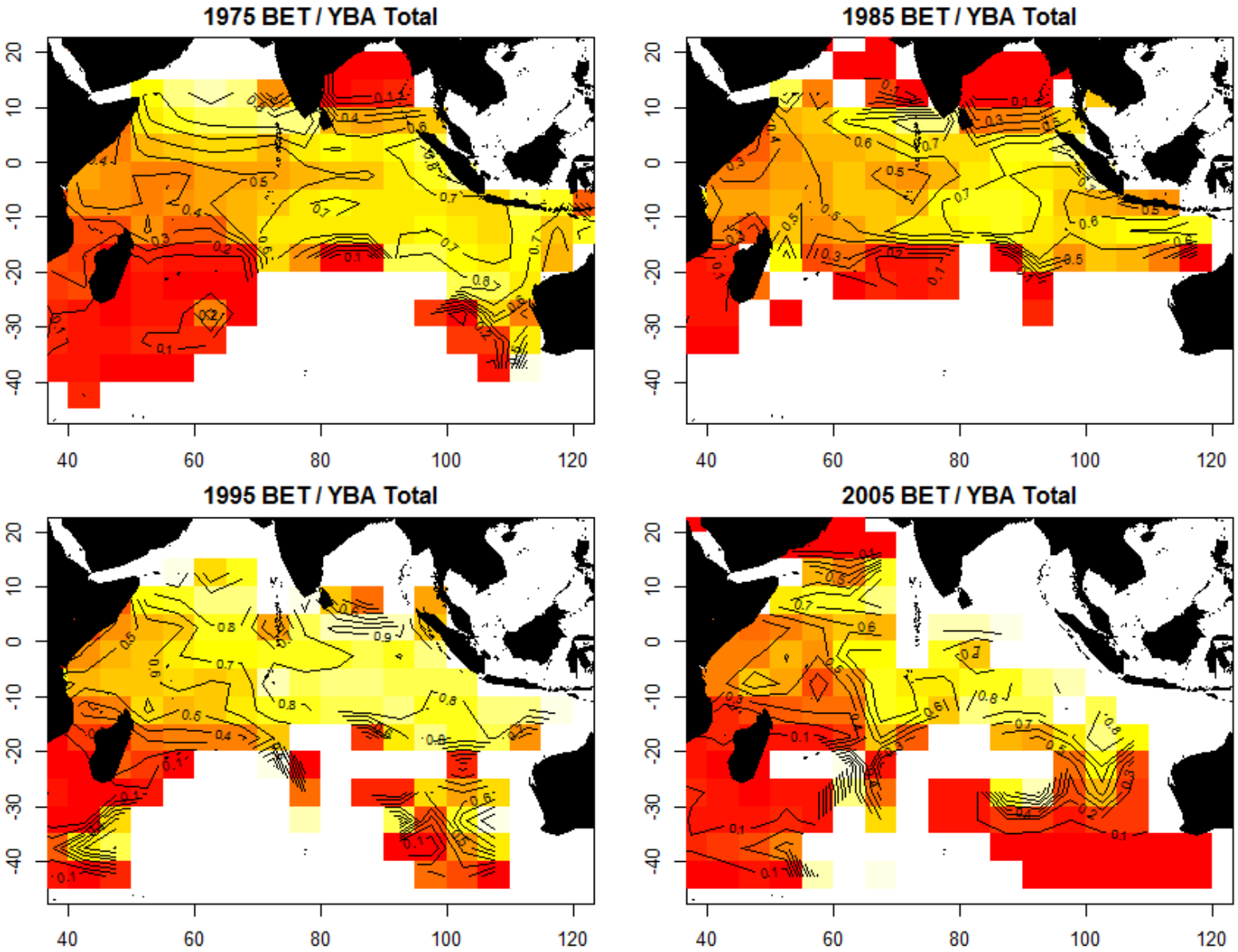


Figure 29: Proportion bigeye in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.


1975 BET / YBA Total
1985 BET / YBA Total
1995 BET / YBA Total
2005 BET / YBA Total
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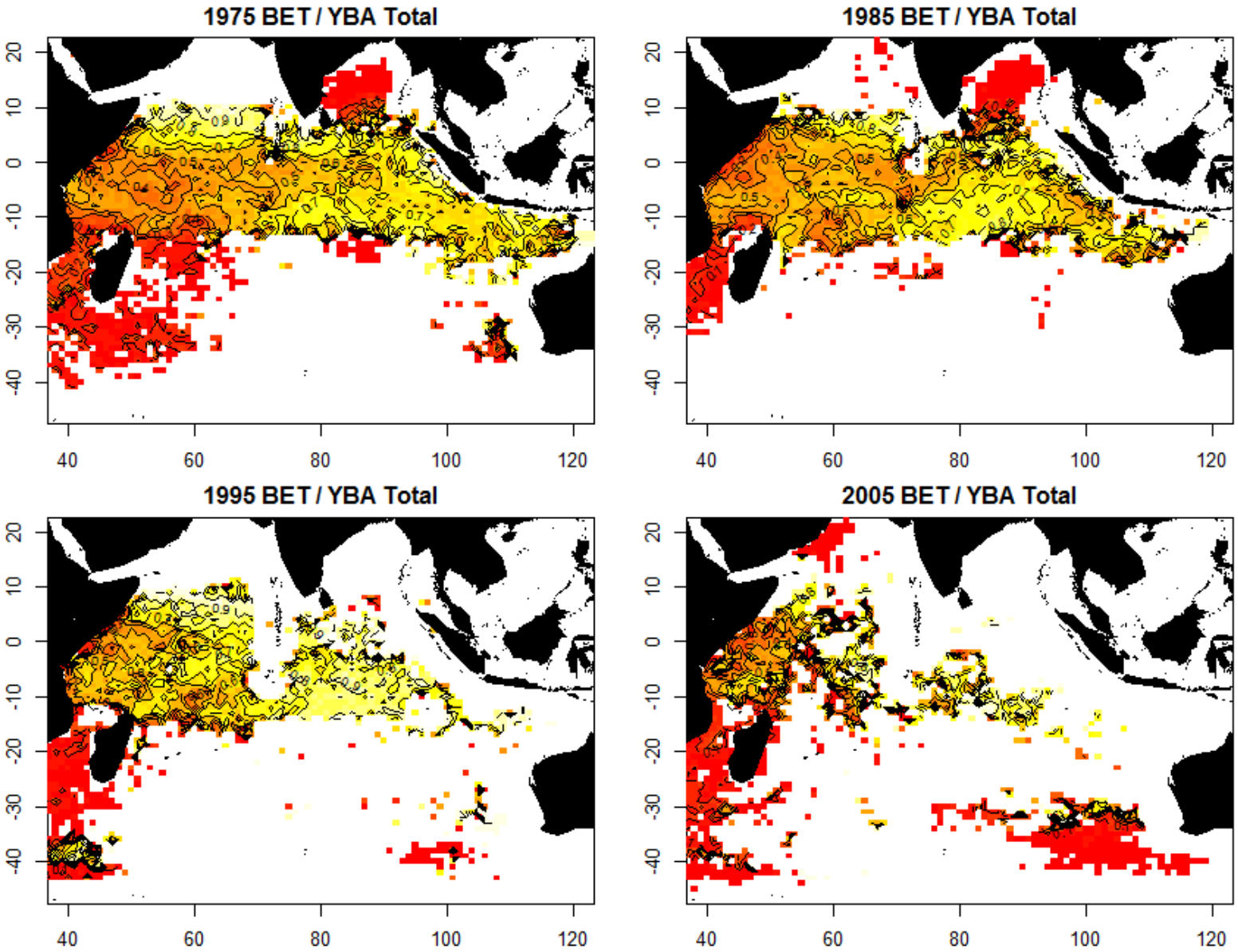
1975 BET / YBA Total
1985 BET / YBA Total
1995 BET / YBA Total
2005 BET / YBA Total
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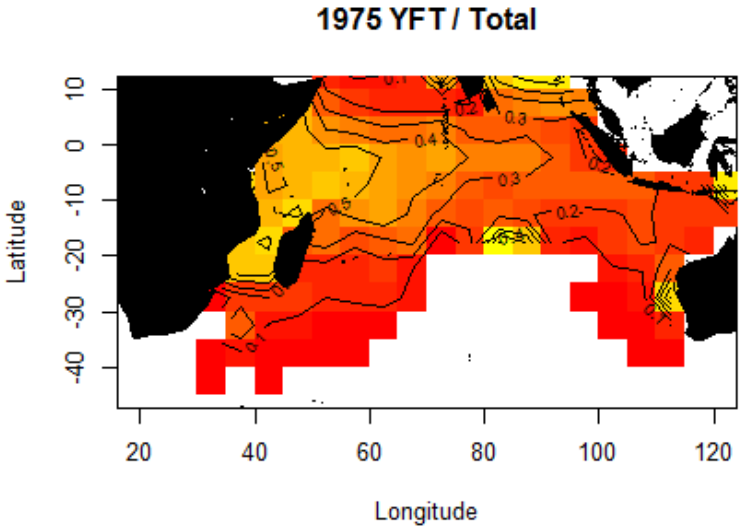
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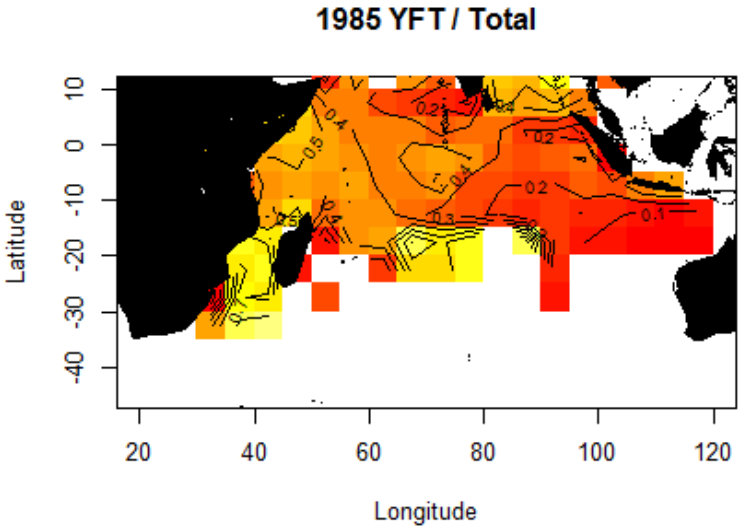
1985 YFT / Total
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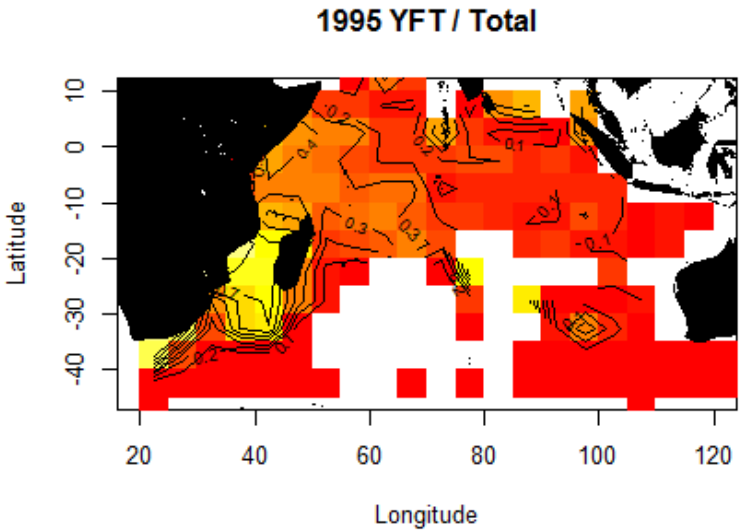
1995 YFT / Total
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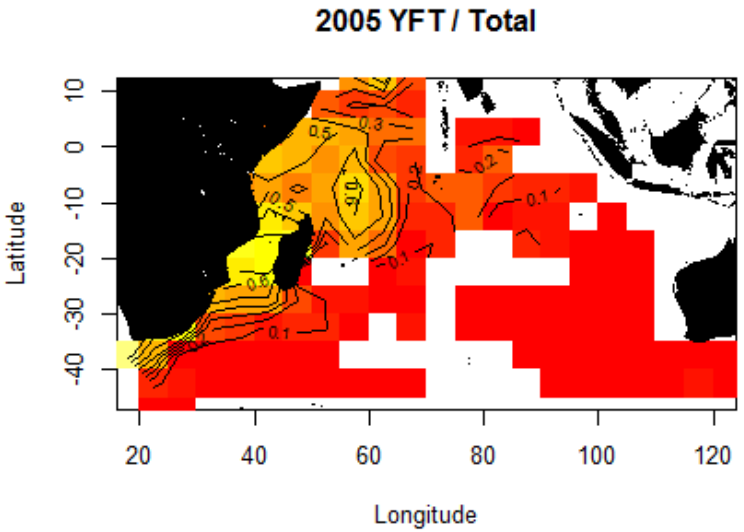
2005 YFT / Total
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100
120

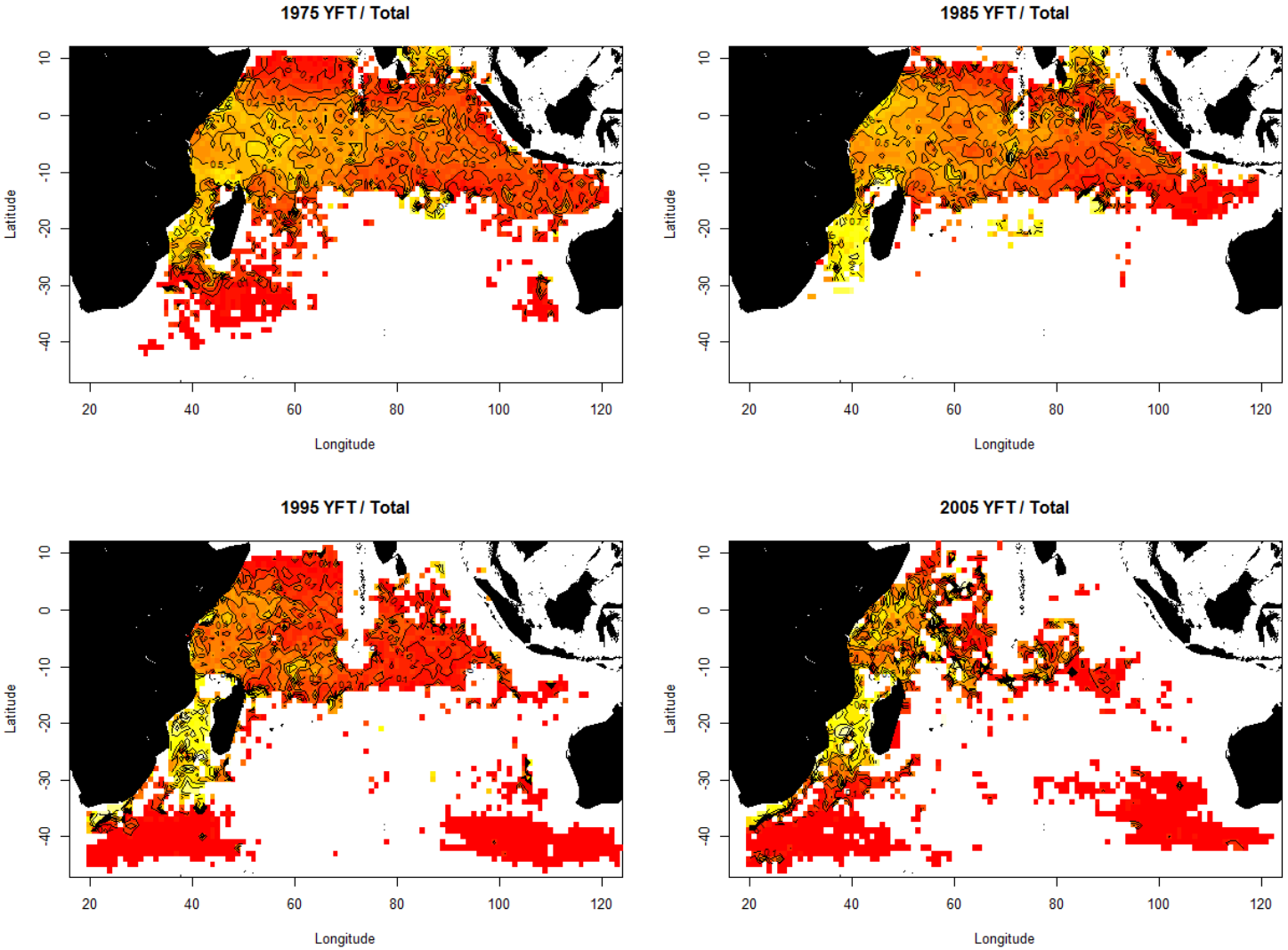
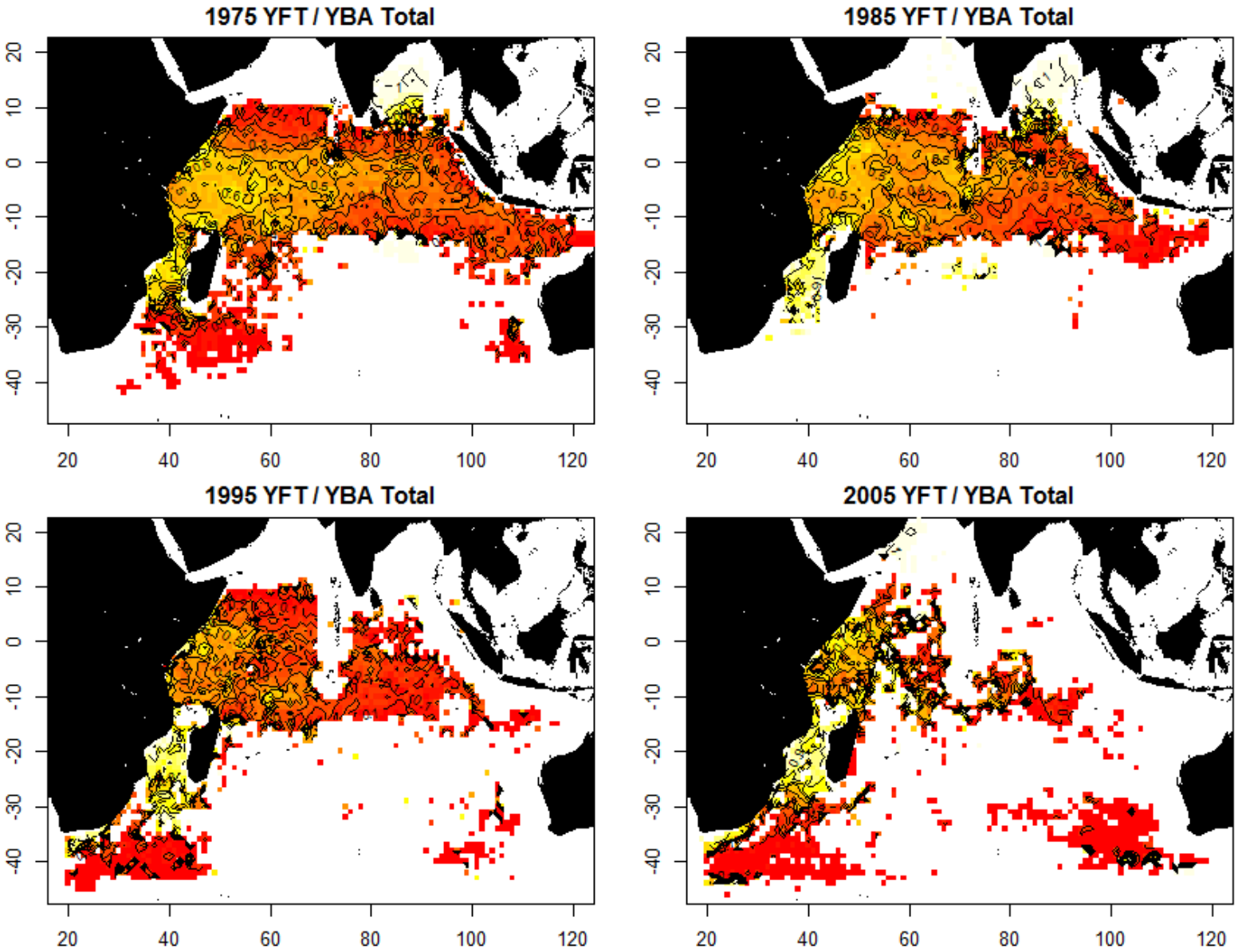
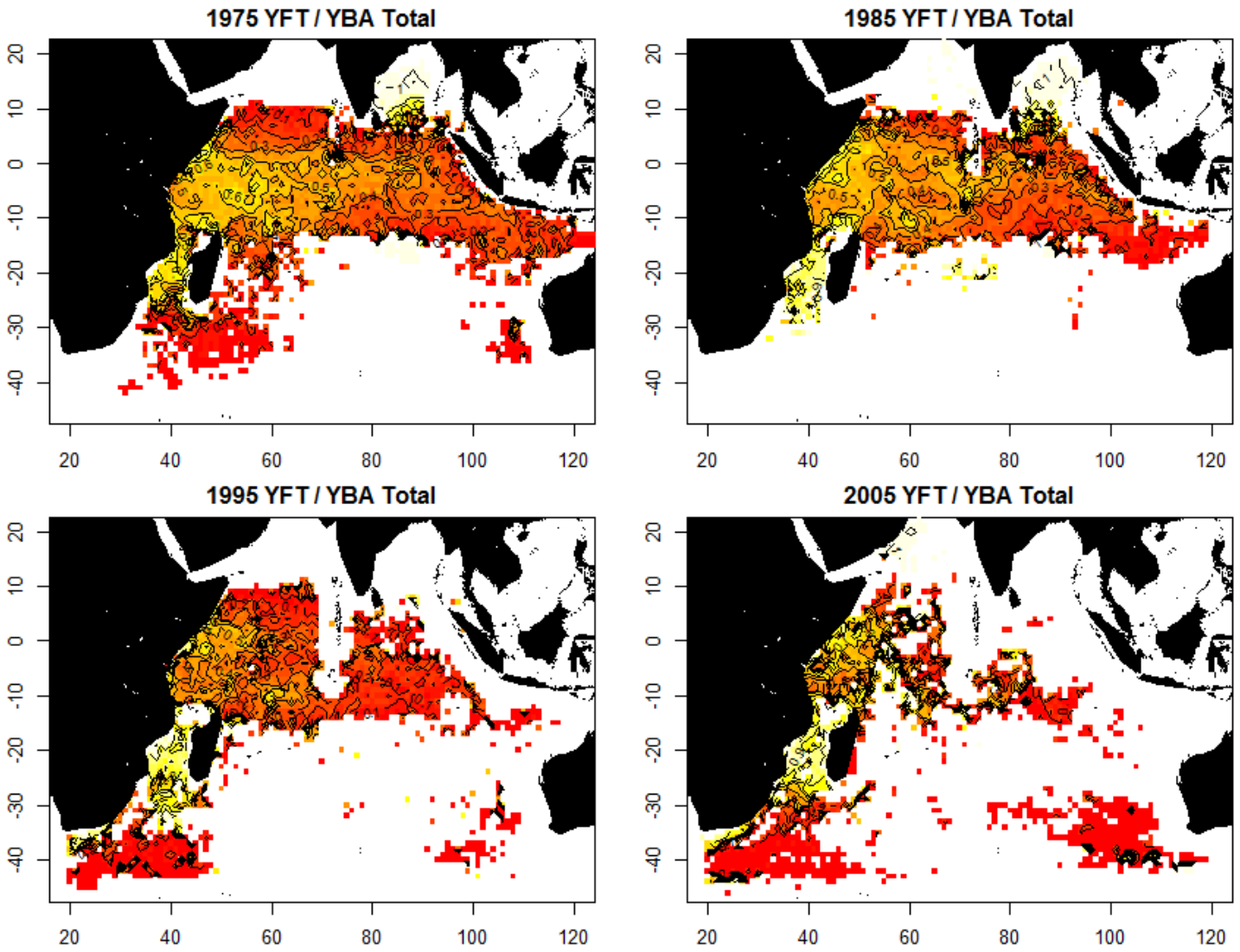
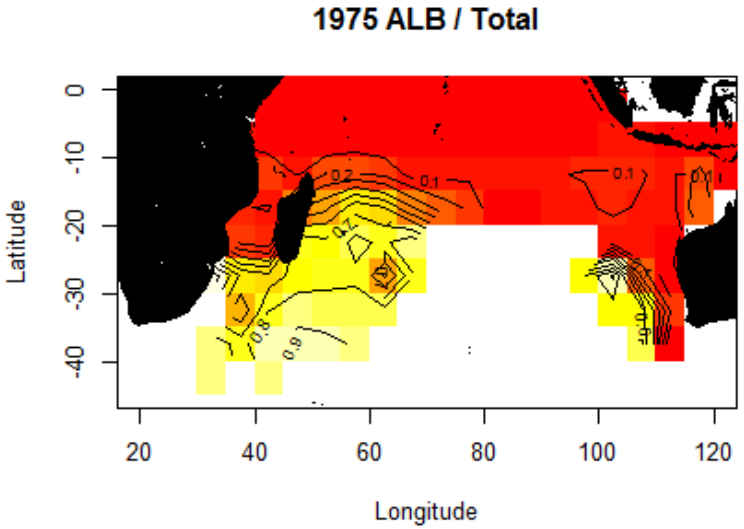
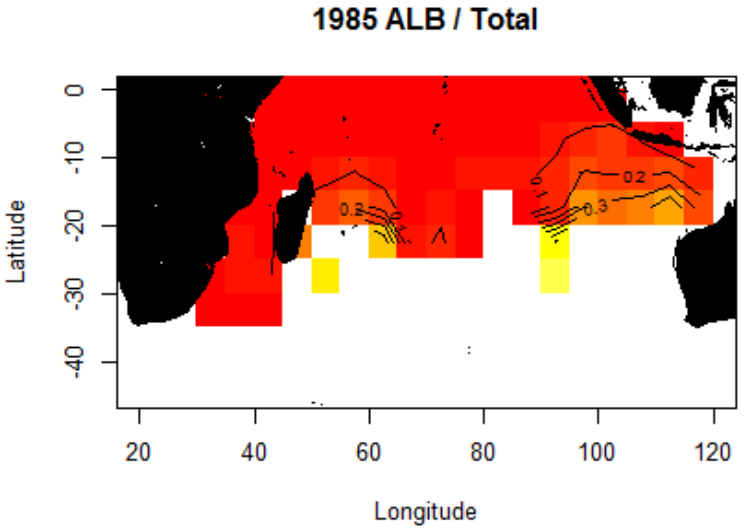


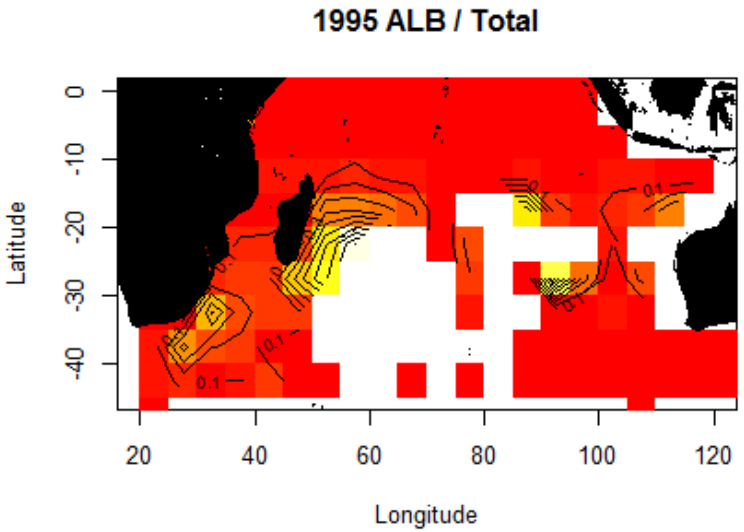
Figure 30: Proportion yellowfin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

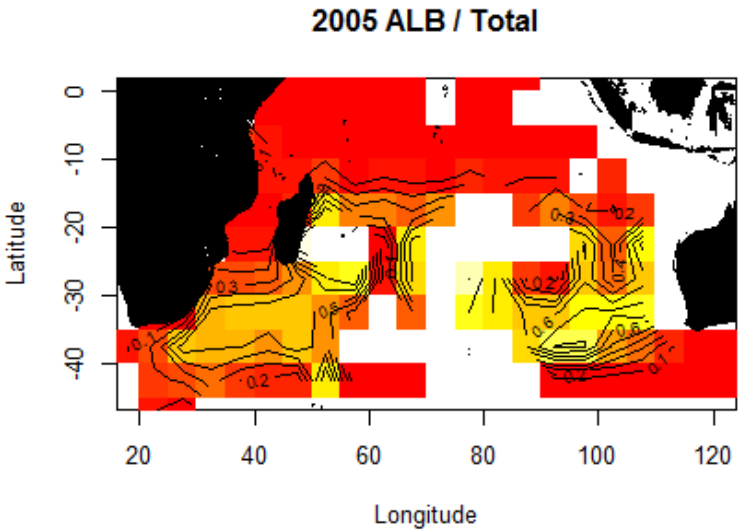

1975 YFT / YBA Total
1985 YFT / YBA Total
1995 YFT / YBA Total
2005 YFT / YBA Total
20
10
0
-10
-20
-30
-40
20
40
60
80
100
120


1975 YFT / YBA Total
1985 YFT / YBA Total
1995 YFT / YBA Total
2005 YFT / YBA Total
20
10
0
-10
-20
-30
-40
20
40
60
80
100
120


1975 ALB / Total
Latitude
Longitude
0
-10
-20
-30
-40
20
40
60
80
100
120


1985 ALB / Total
Latitude
Longitude
0
-10
-20
-30
-40
20
40
60
80
100
120


1995 ALB / Total
Latitude
Longitude
0
-10
-20
-30
-40
20
40
60
80
100
120


2005 ALB / Total
Latitude
Longitude
0
-10
-20
-30
-40
20
40
60
80
100
120

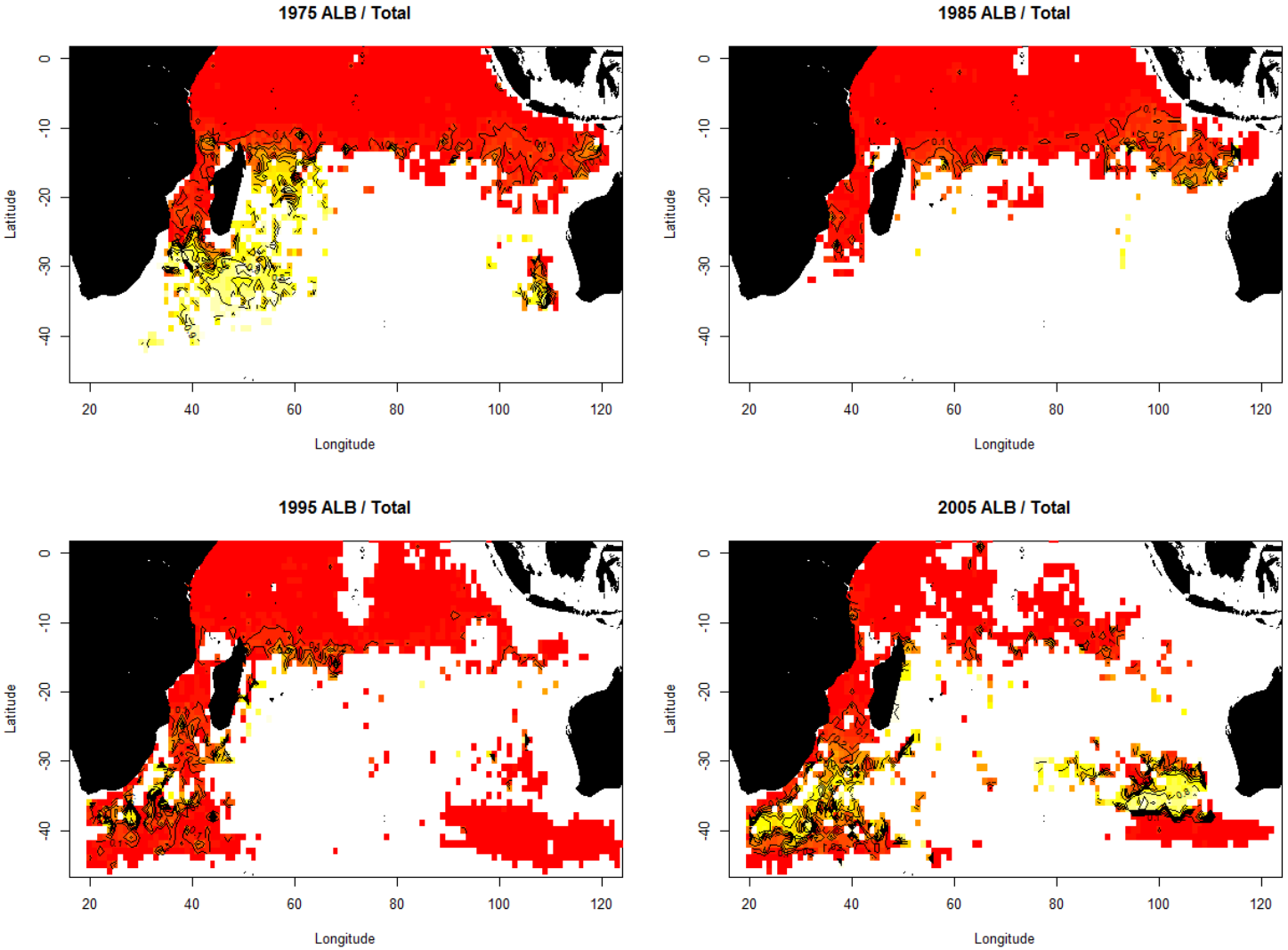
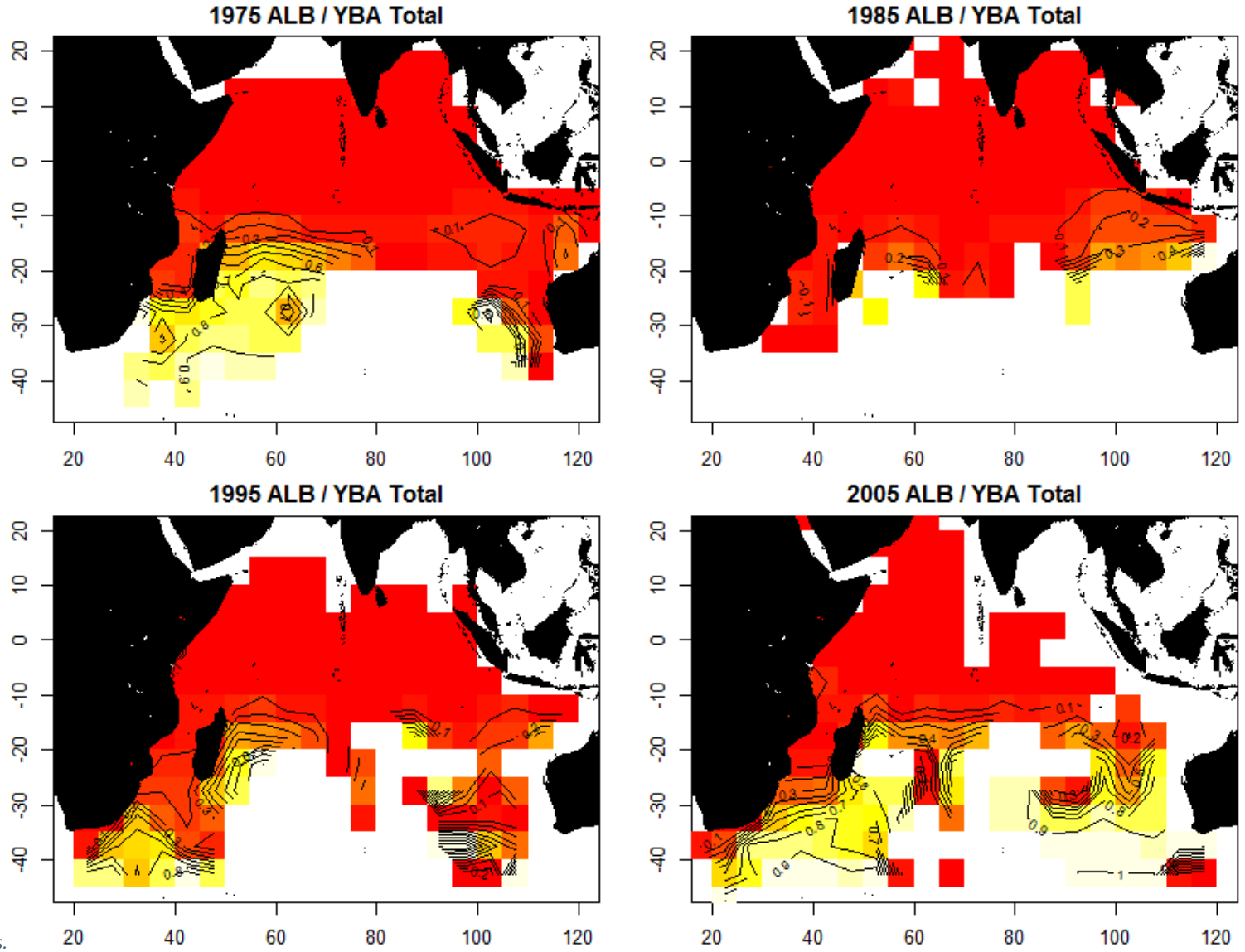
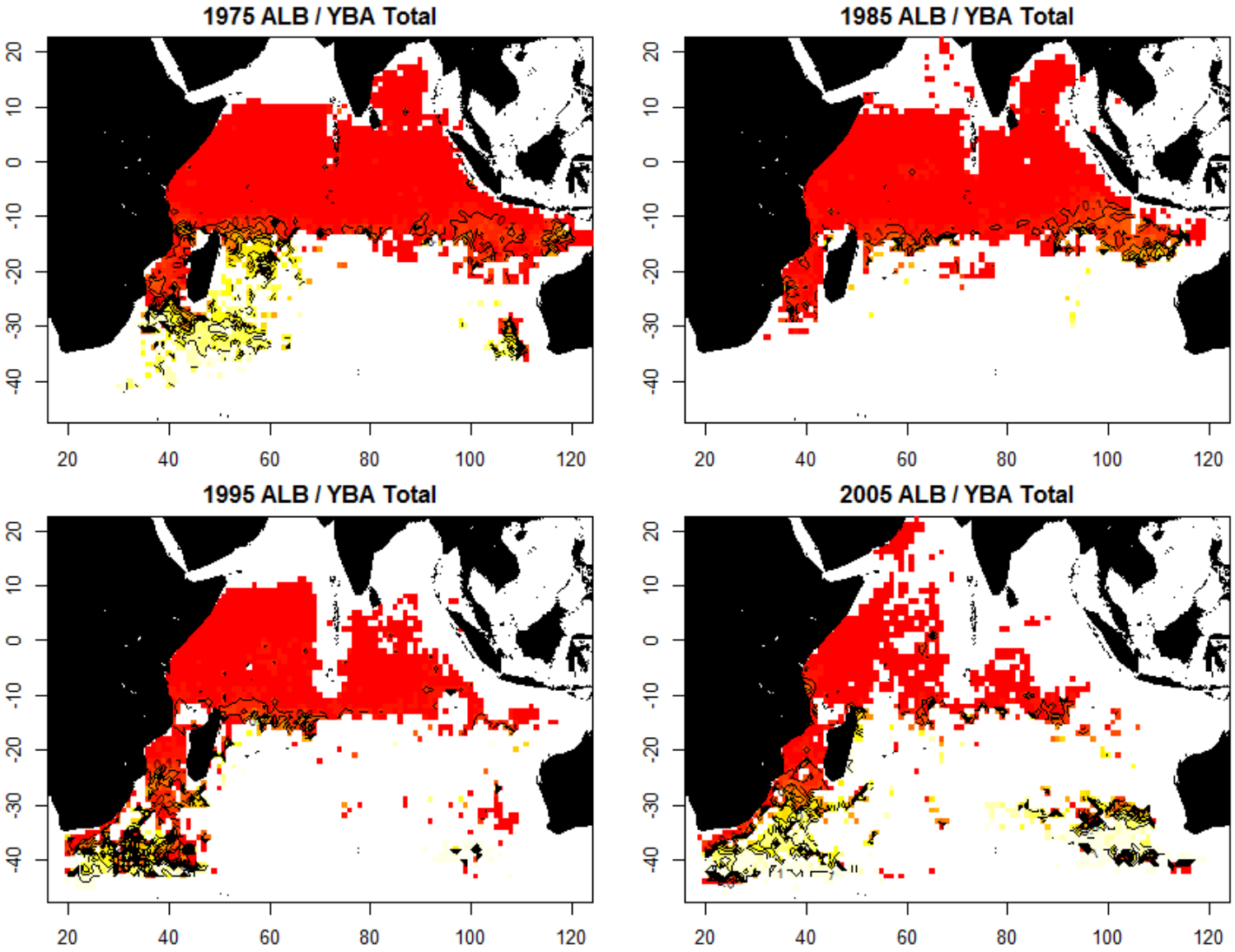
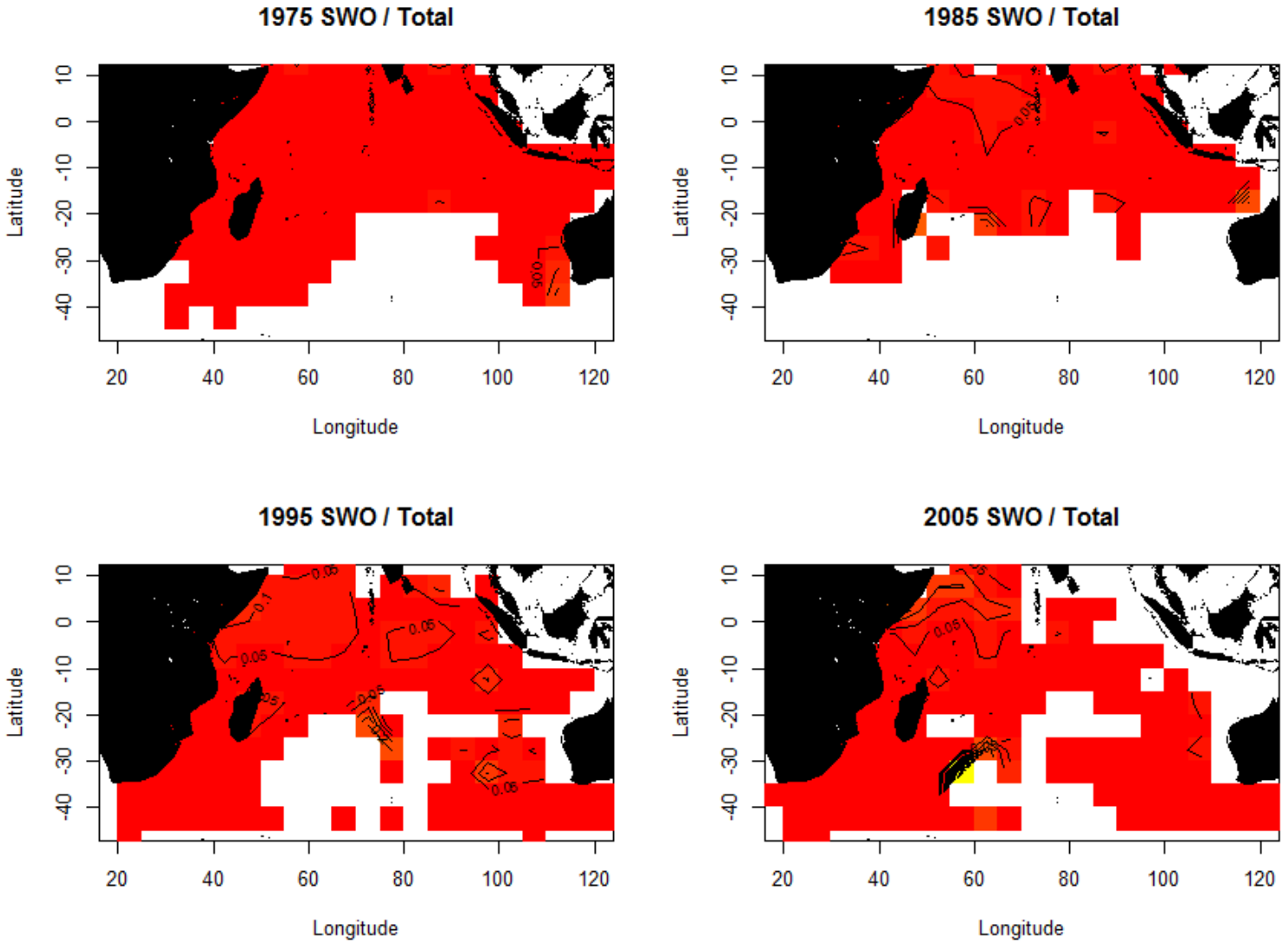

1975 ALB / Total
1985 ALB / Total
1995 ALB / Total
2005 ALB / Total
Latitude
Longitude
0
-10
-20
-30
-40
20
40
60
80
100
120

Figure 31: Proportion albacore in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.




1975 ALB / YBA Total
1985 ALB / YBA Total
1995 ALB / YBA Total
2005 ALB / YBA Total
20
10
0
-10
-20
-30
-40
20
40
60
80
100
120


1975 SWO / Total
1985 SWO / Total
1995 SWO / Total
2005 SWO / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120

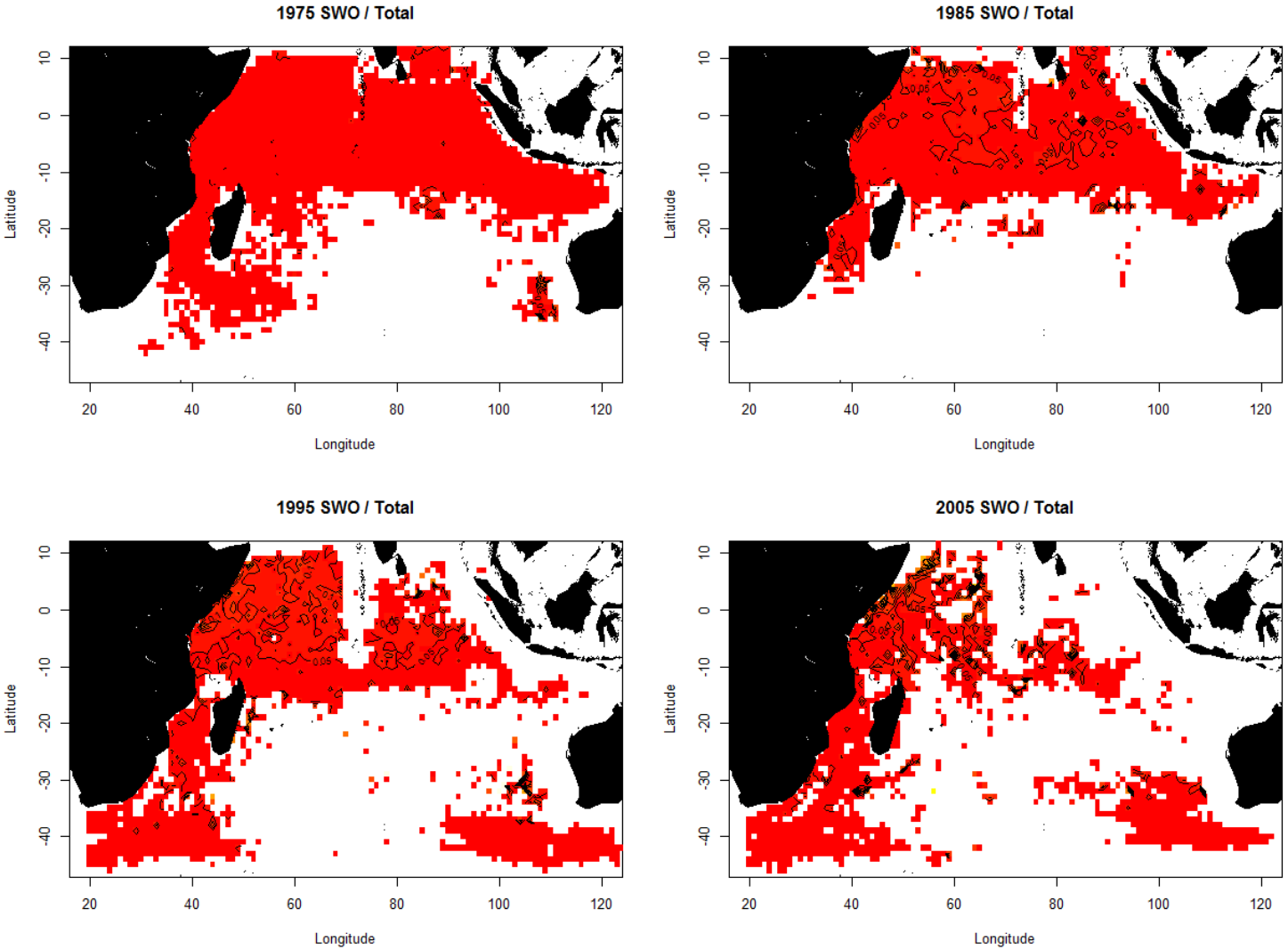
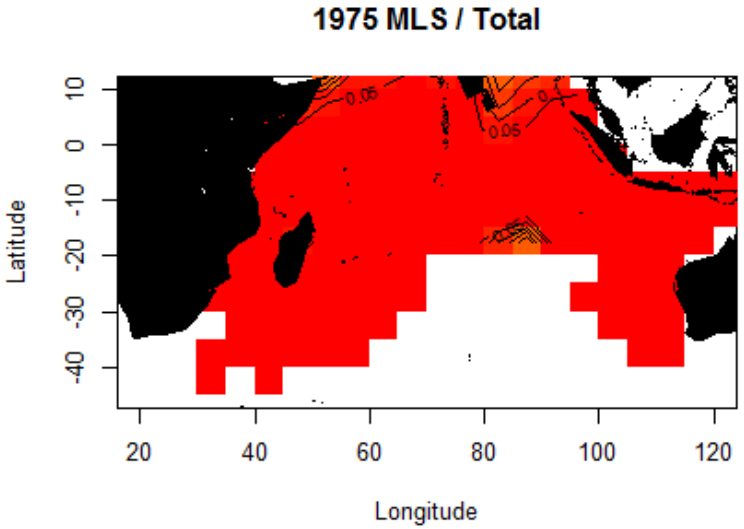
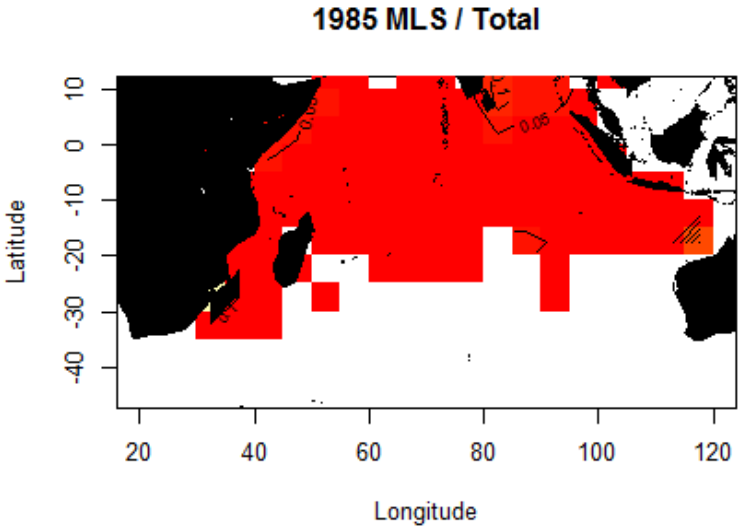
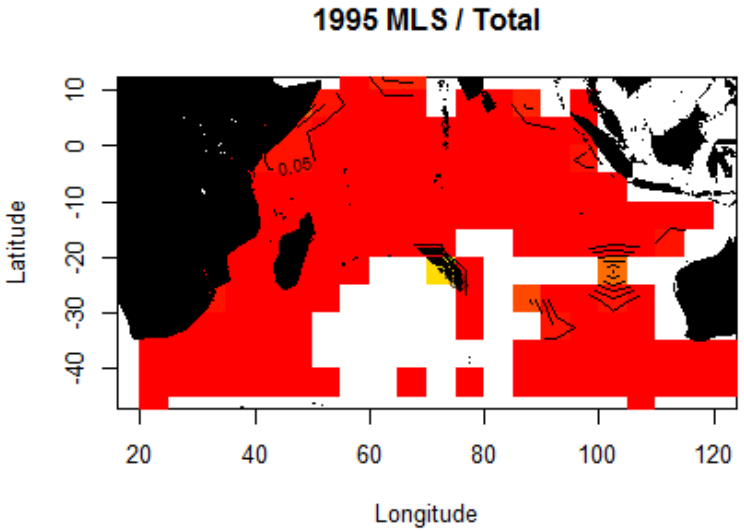
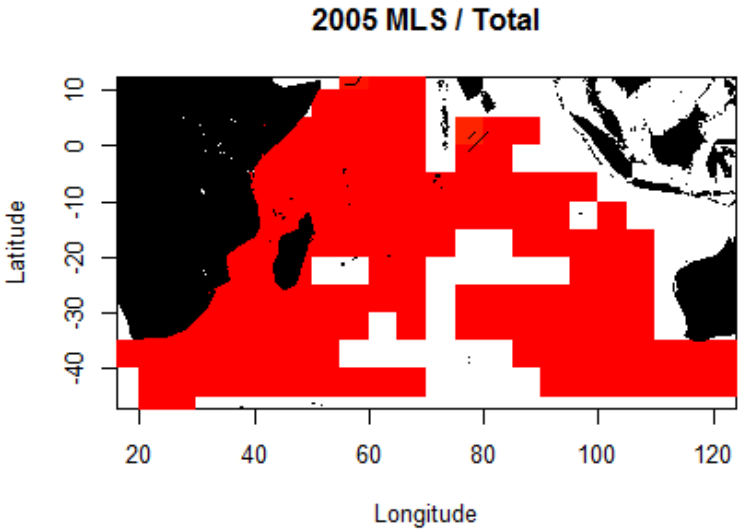


Figure 32: Proportion swordfish in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.


1975 MLS / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120
0.05


1985 MLS / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120
0.05


1995 MLS / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120
0.05


2005 MLS / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120

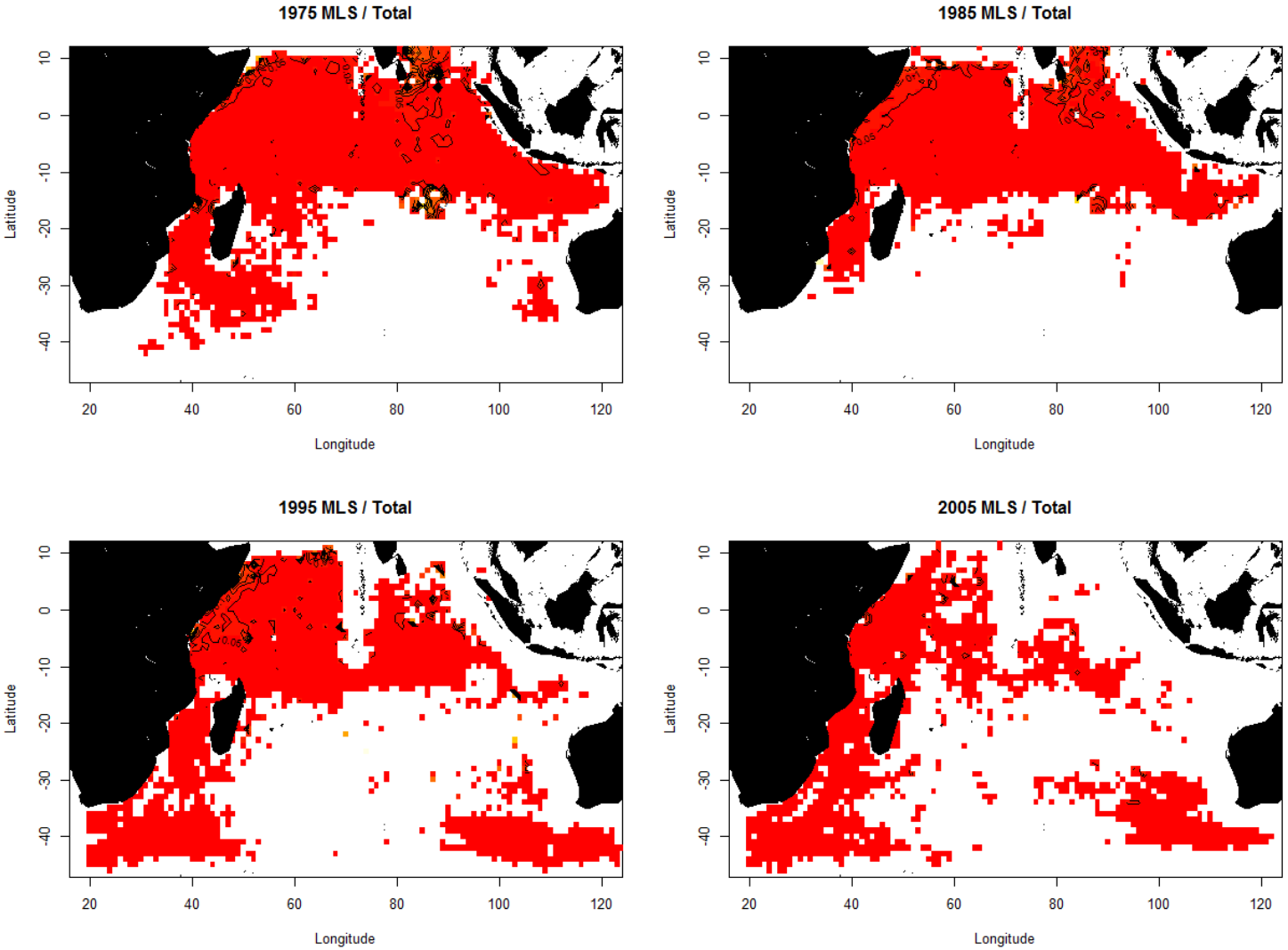
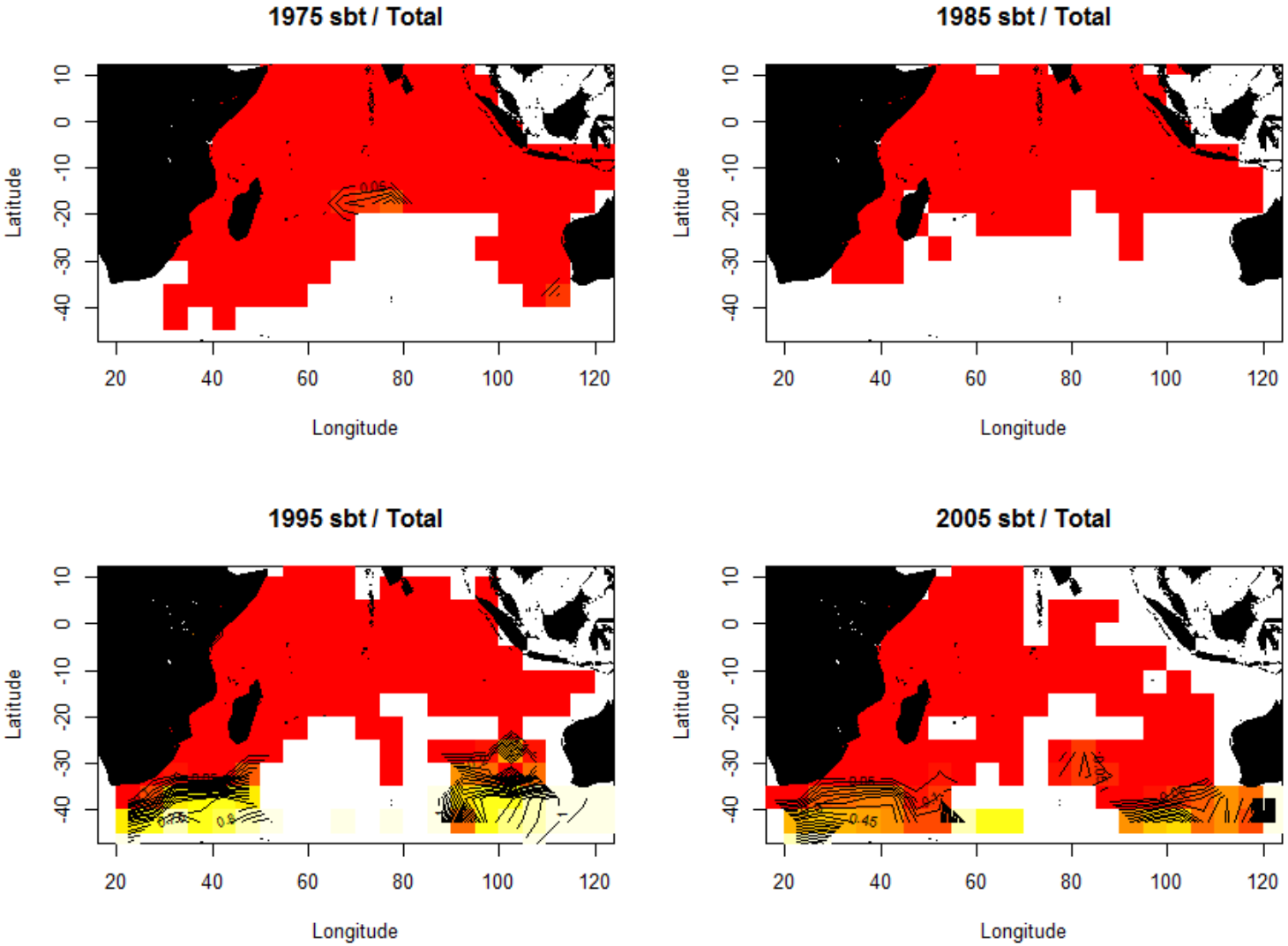


Figure 33: Proportion striped marlin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.


1975 sbt / Total
1985 sbt / Total
1995 sbt / Total
2005 sbt / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120

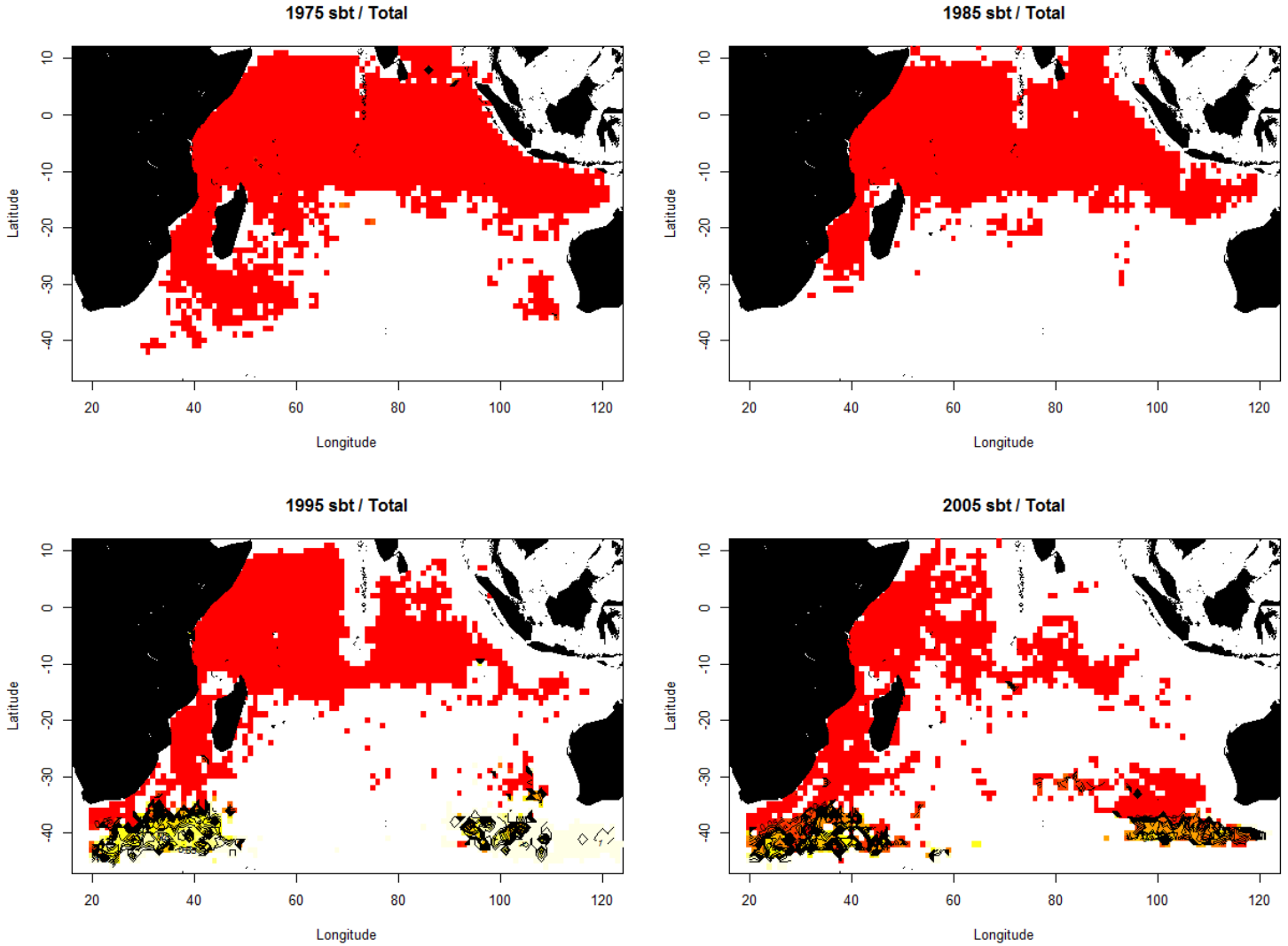
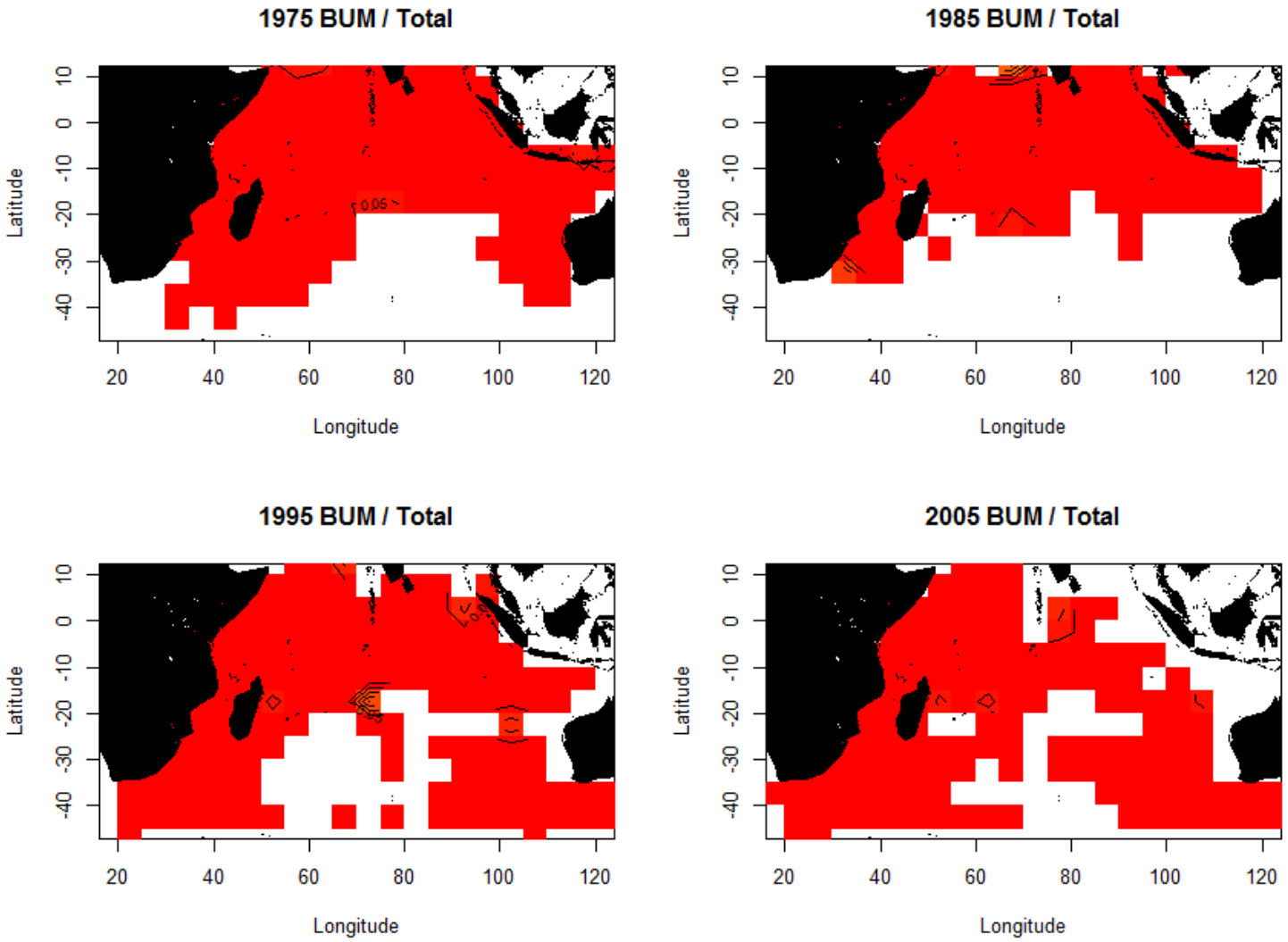


Figure 34: Proportion SBT in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.


1975 BUM / Total
1985 BUM / Total
1995 BUM / Total
2005 BUM / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120
0.05

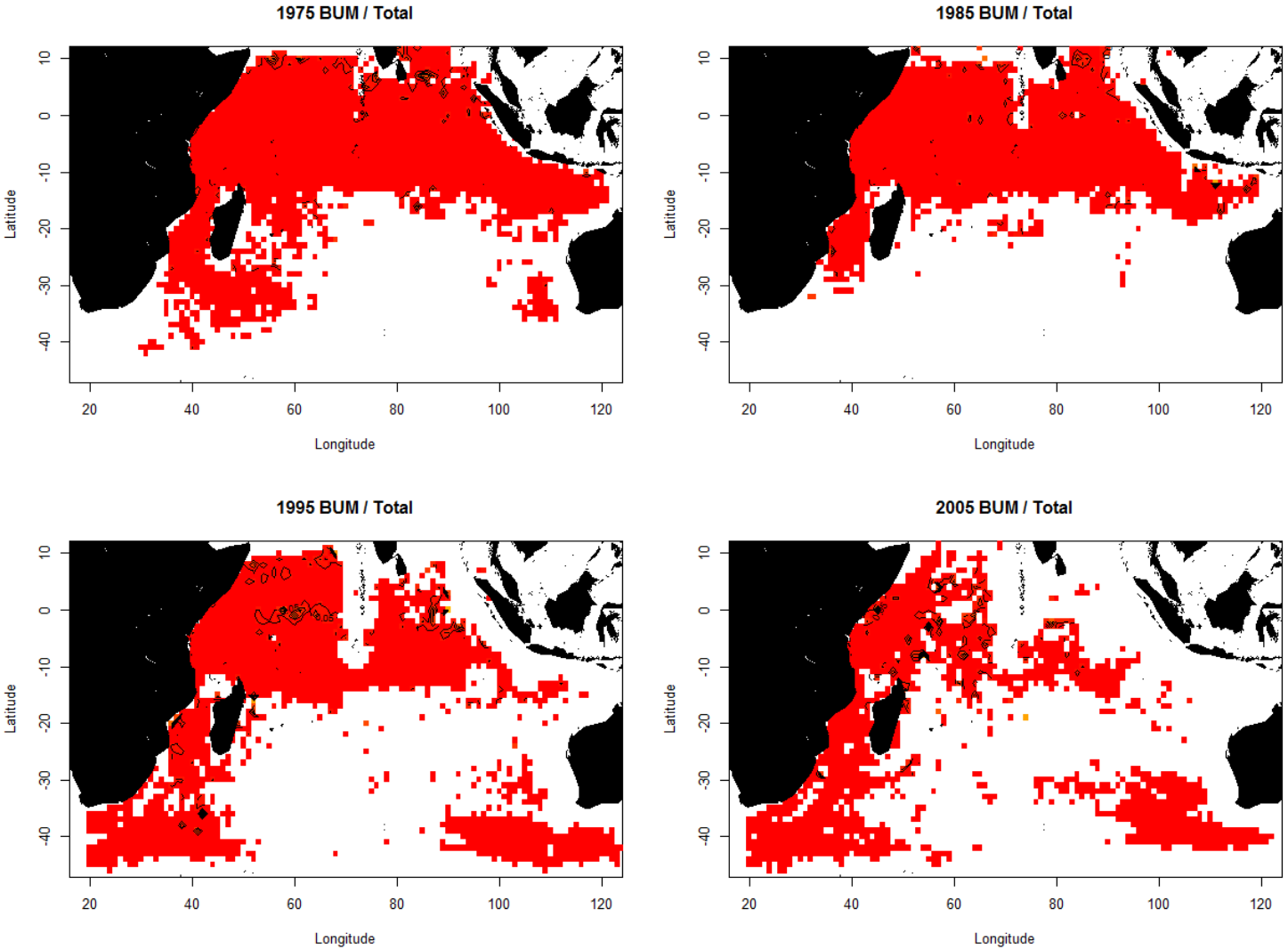
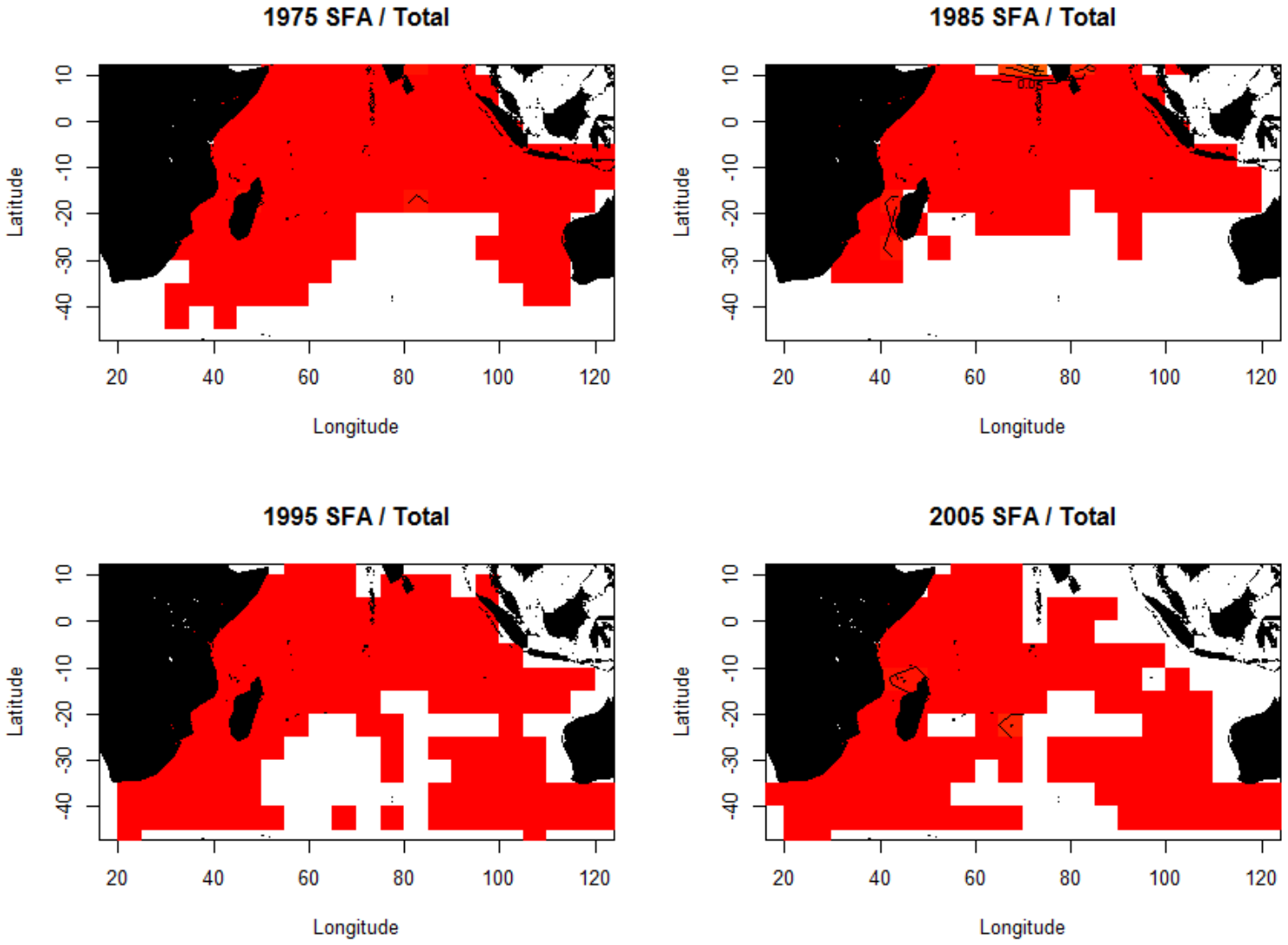


Figure 35: Proportion blue marlin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.


1975 SFA / Total
1985 SFA / Total
1995 SFA / Total
2005 SFA / Total
Latitude
Longitude
10
0
-10
-20
-30
-40
20
40
60
80
100
120

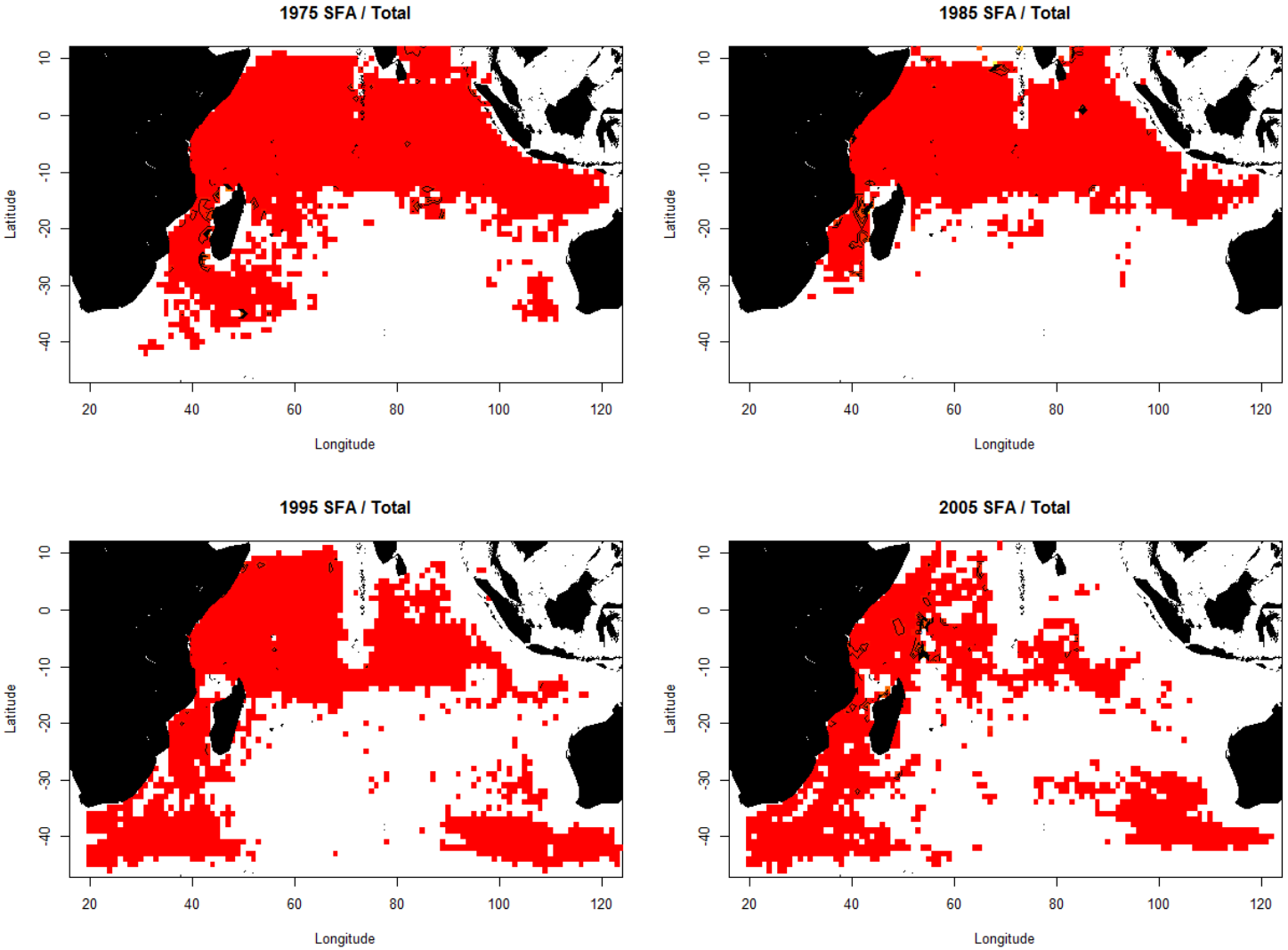


Figure 36 Proportion sailfish in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.

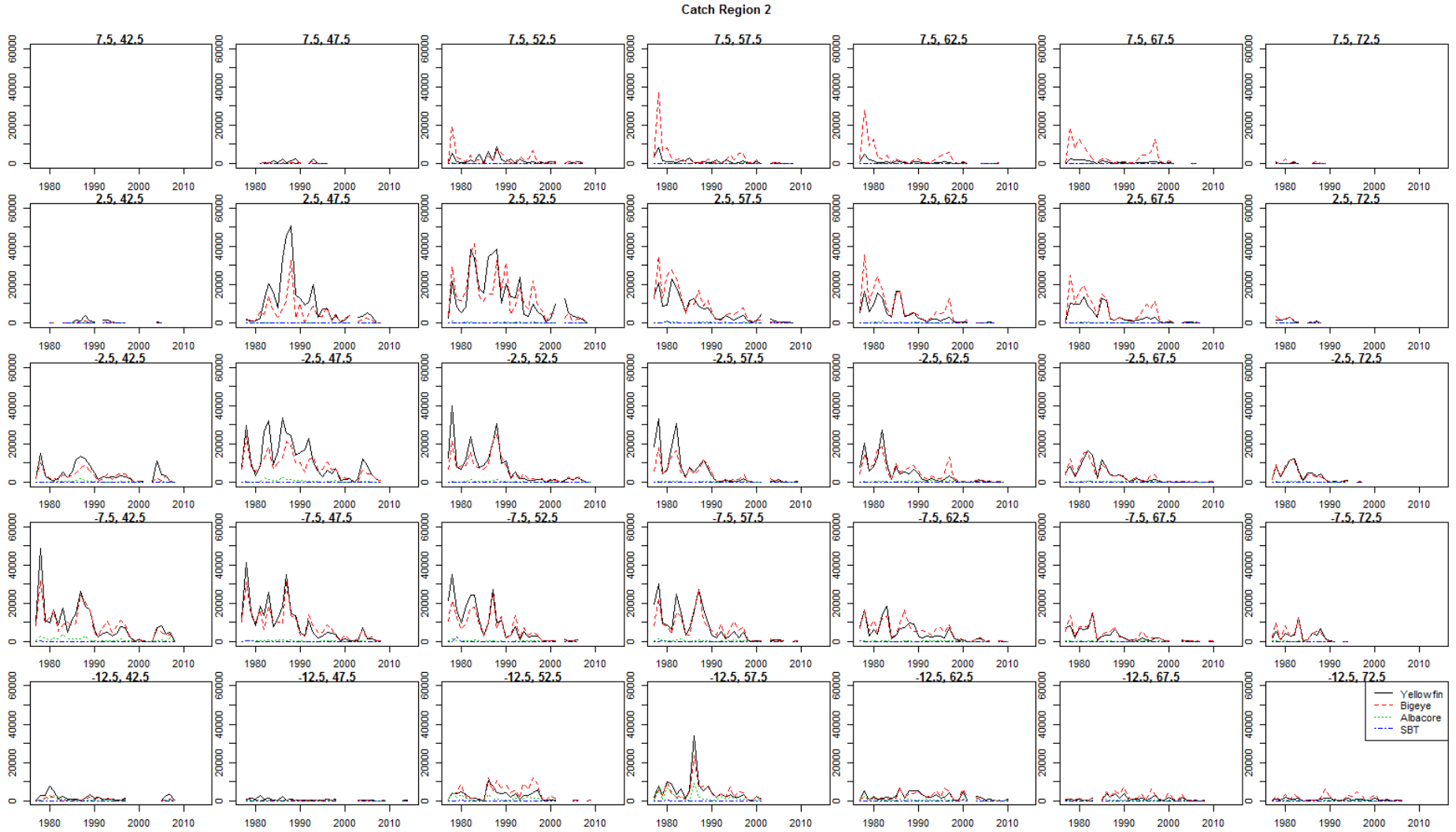


Figure 37: Catch by year-qtr and 5 degree square in region 2 for bigeye, yellowfin, albacore and SBT.

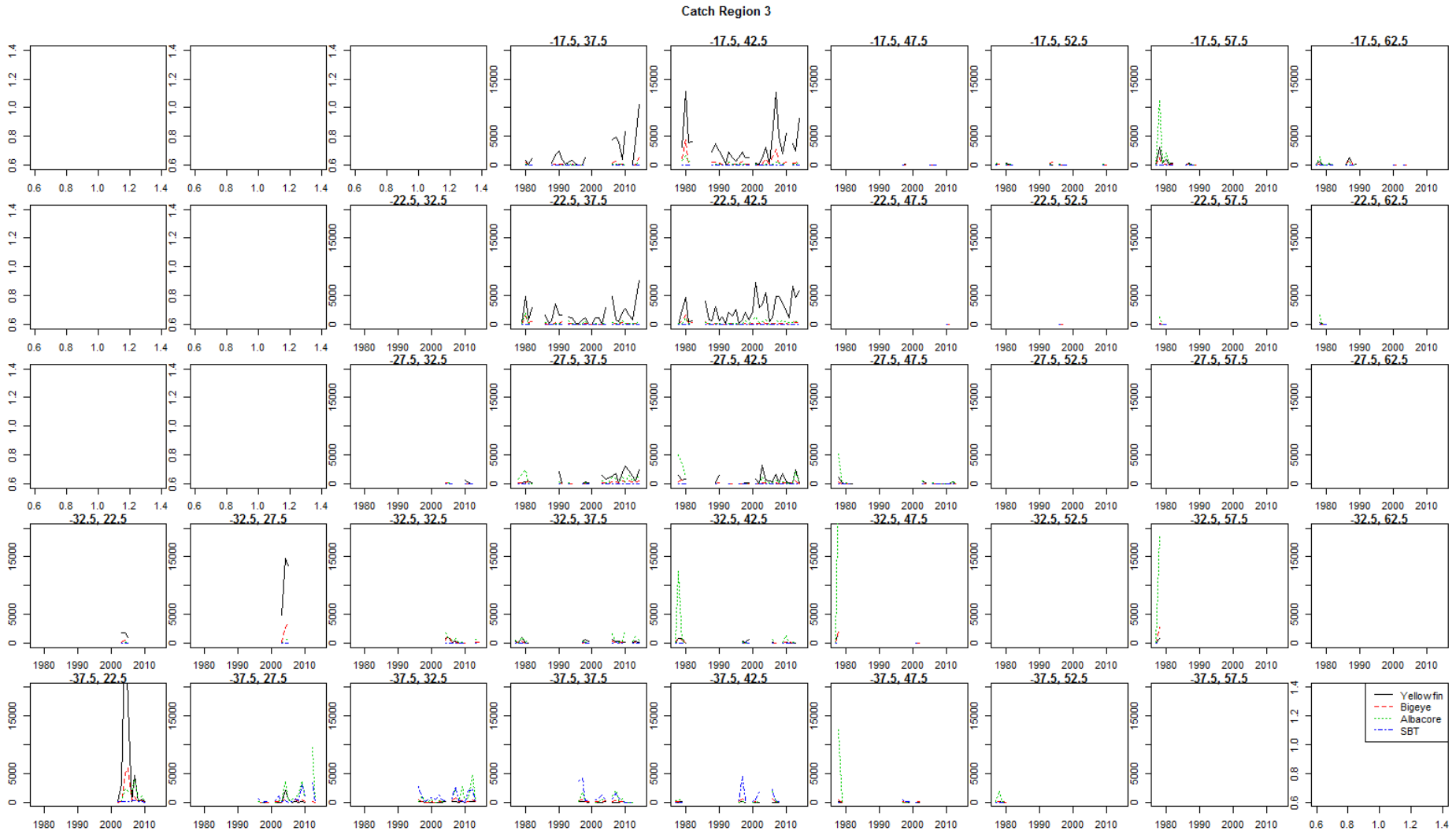


Figure 38: Catch by year-qtr and 5 degree square in region 3 for bigeye, yellowfin, albacore and SBT.

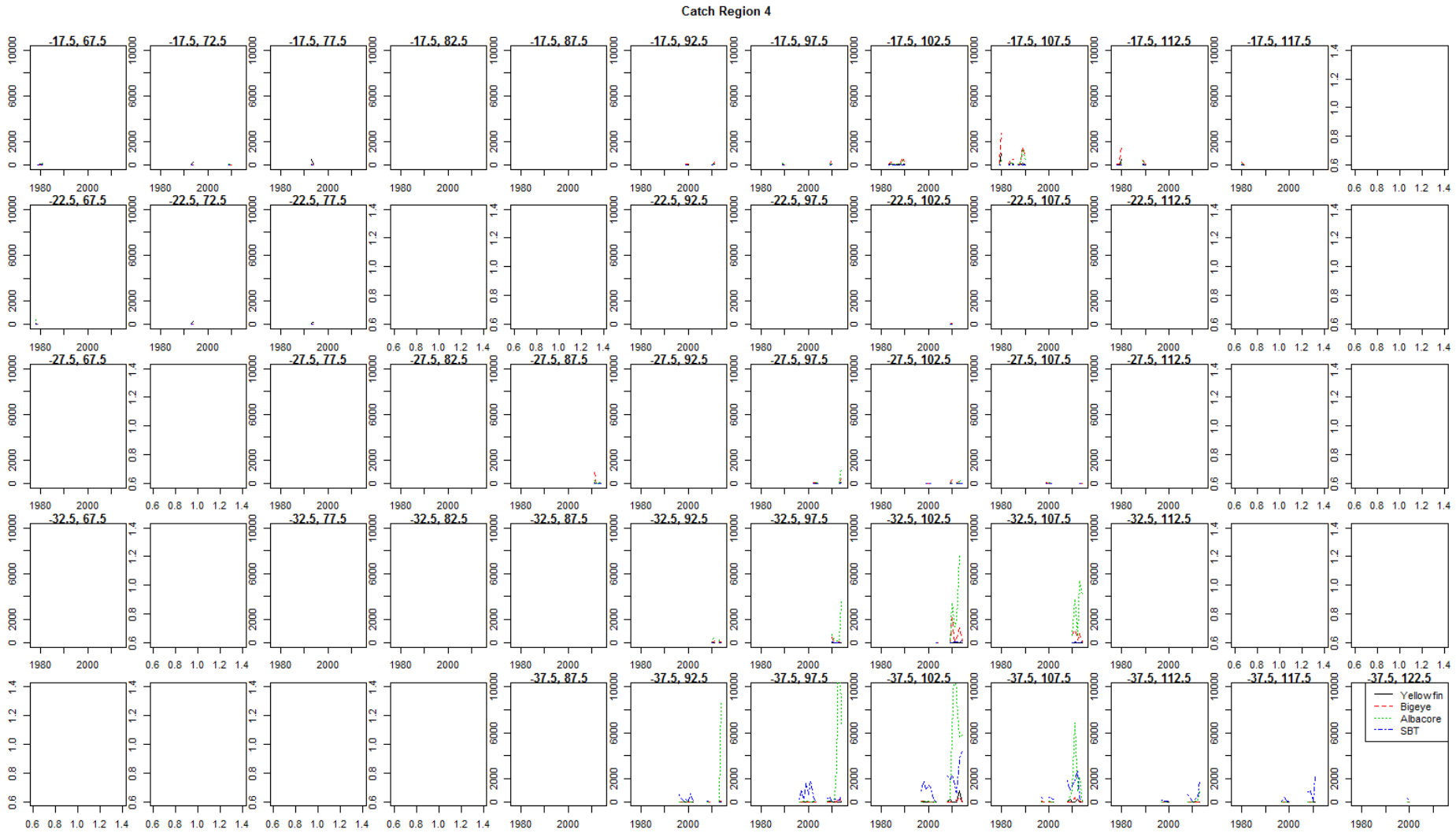


Figure 39: Catch by year-qtr and 5 degree square in region 4 for bigeye, yellowfin, albacore and SBT.

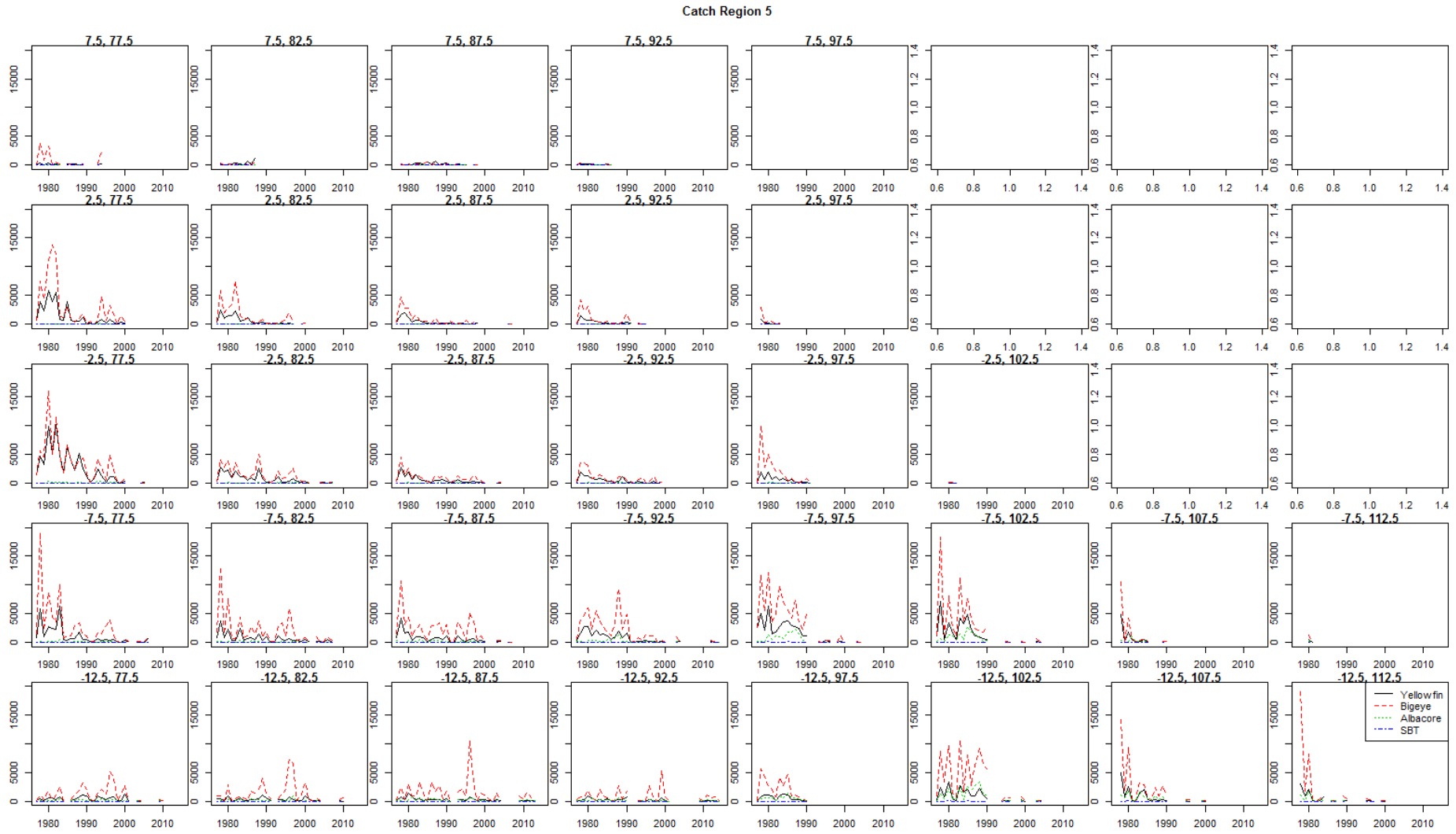


Figure 40: Catch by year-qtr and 5 degree square in region 5 for bigeye, yellowfin, albacore and SBT.

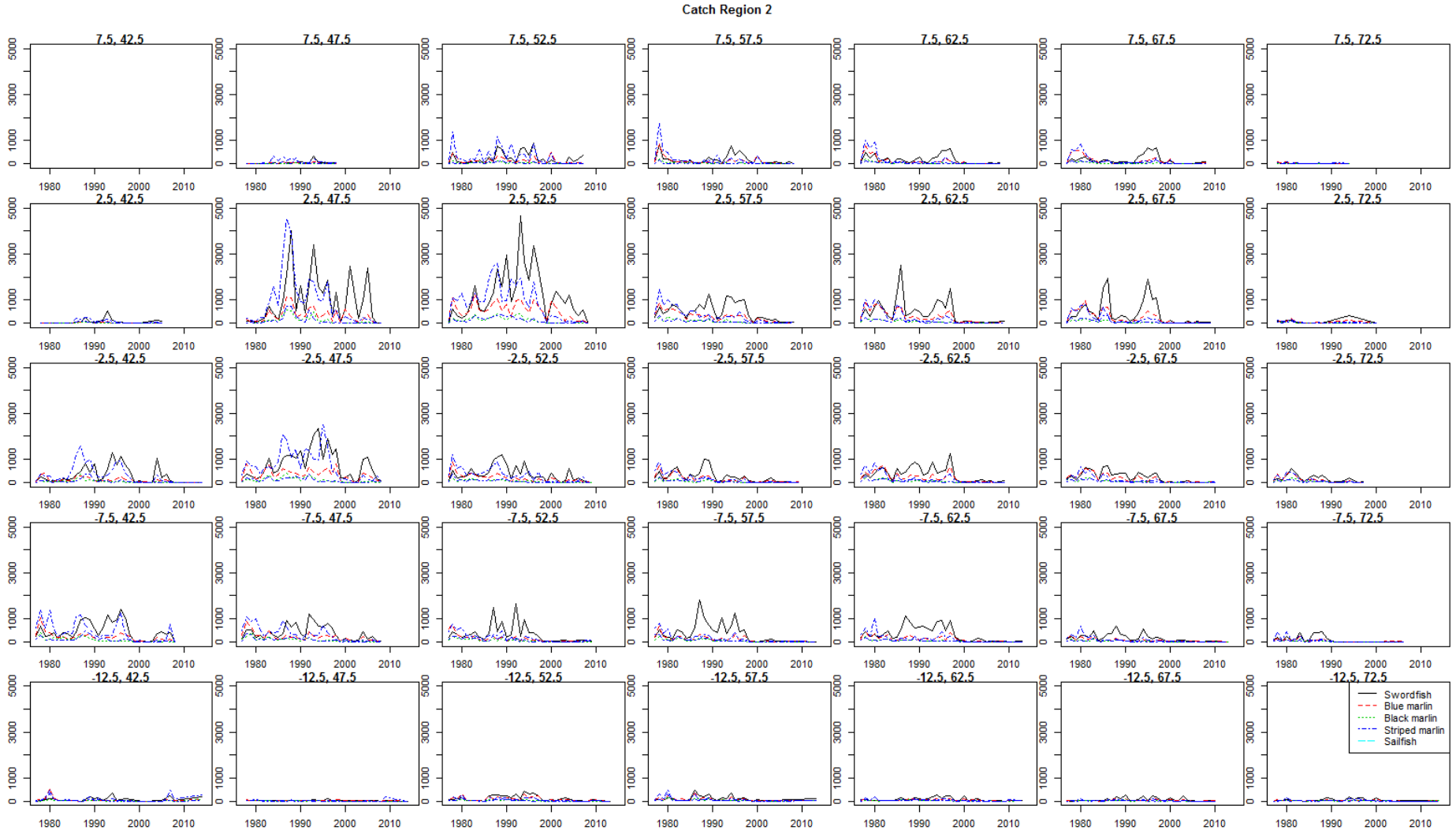


Figure 41: Catch by year-qtr and 5 degree square in region 2 for Swordfish, striped marlin, black marlin, blue marlin, and sailfish

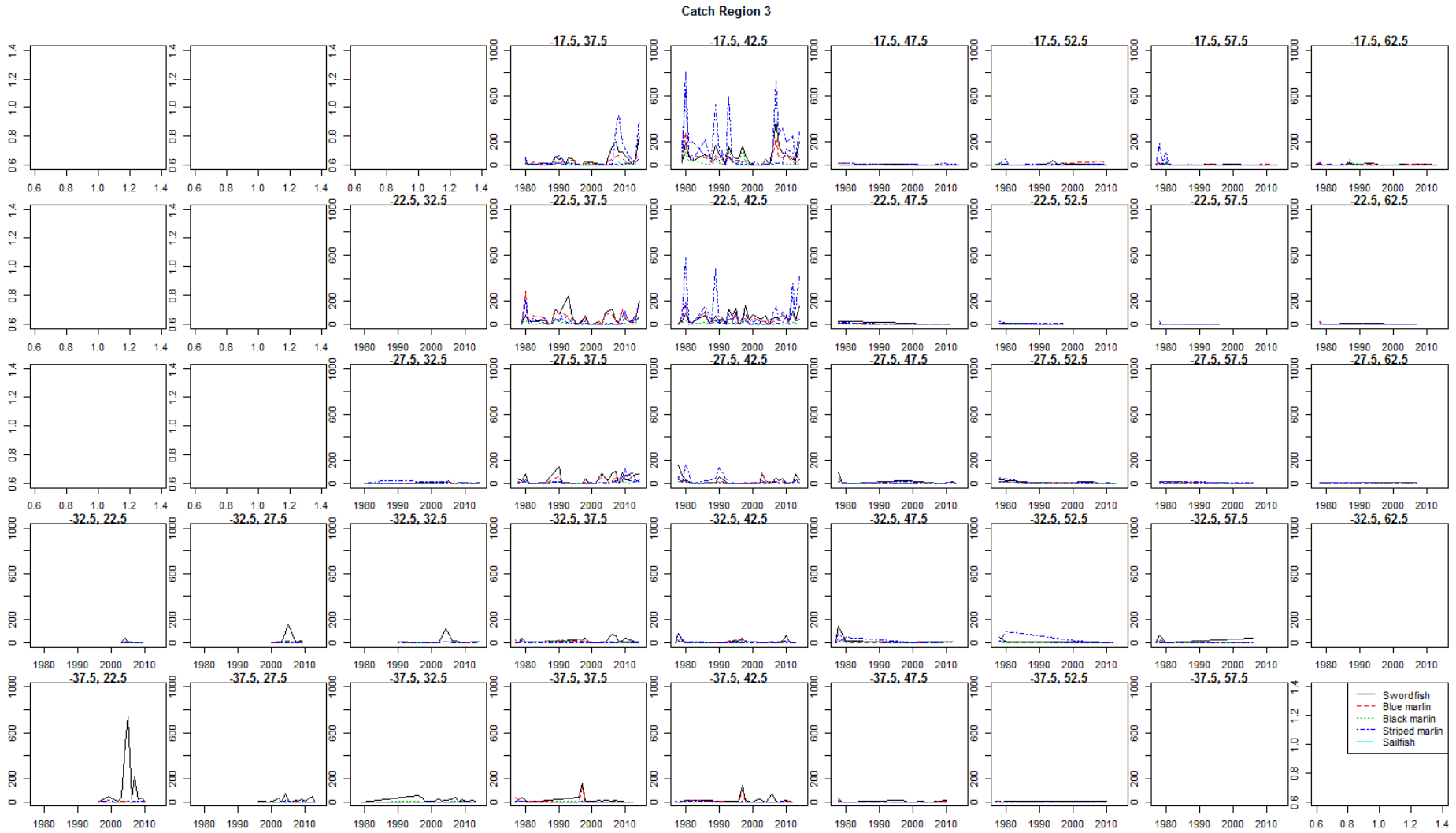


Figure 42: Catch by year-qtr and 5 degree square in region 3 for Swordfish, striped marlin, black marlin, blue marlin, and sailfish.

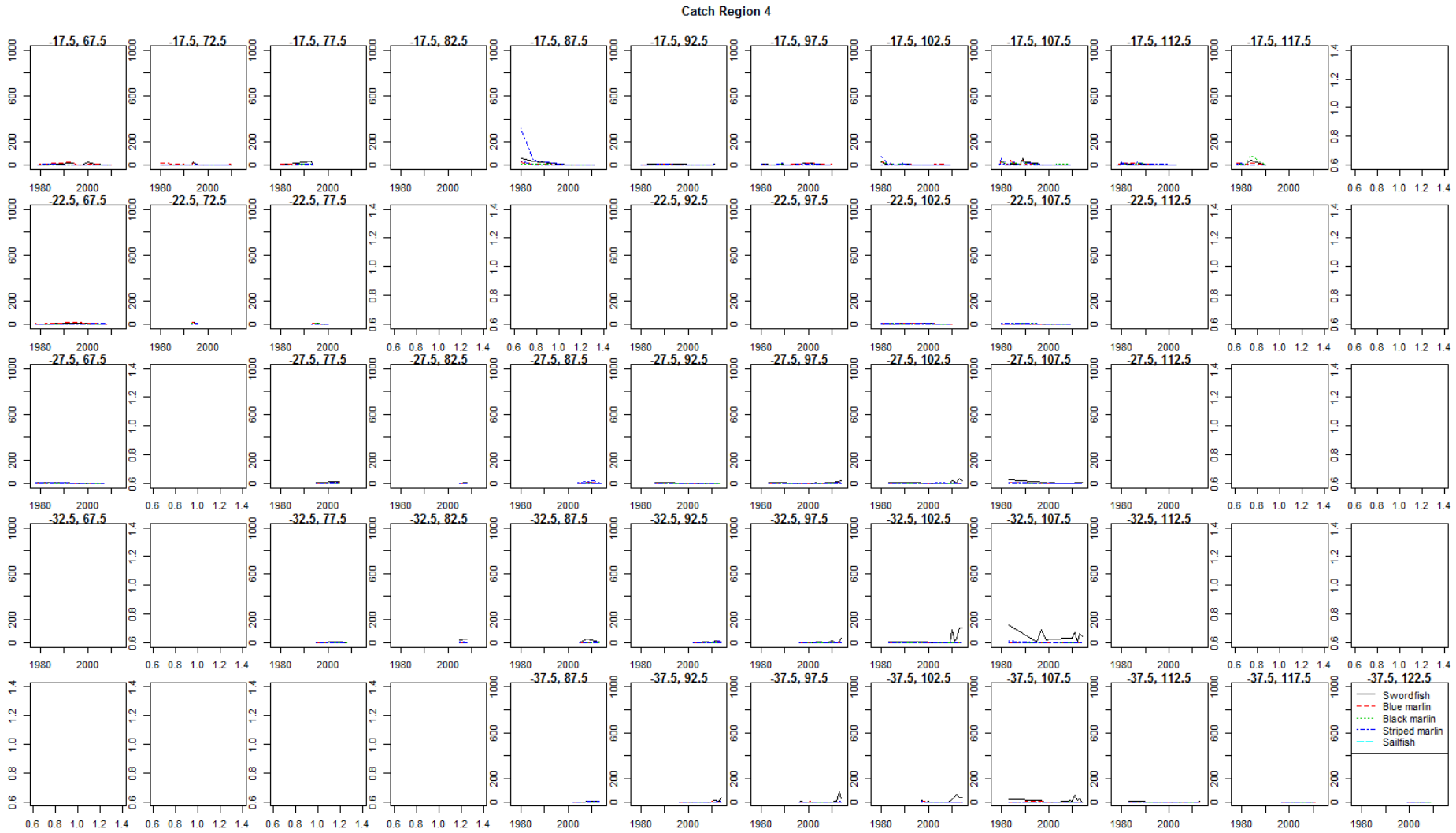


Figure 43: Catch by year-qtr and 5 degree square in region 4 for Swordfish, striped marlin, black marlin, blue marlin, and sailfish.

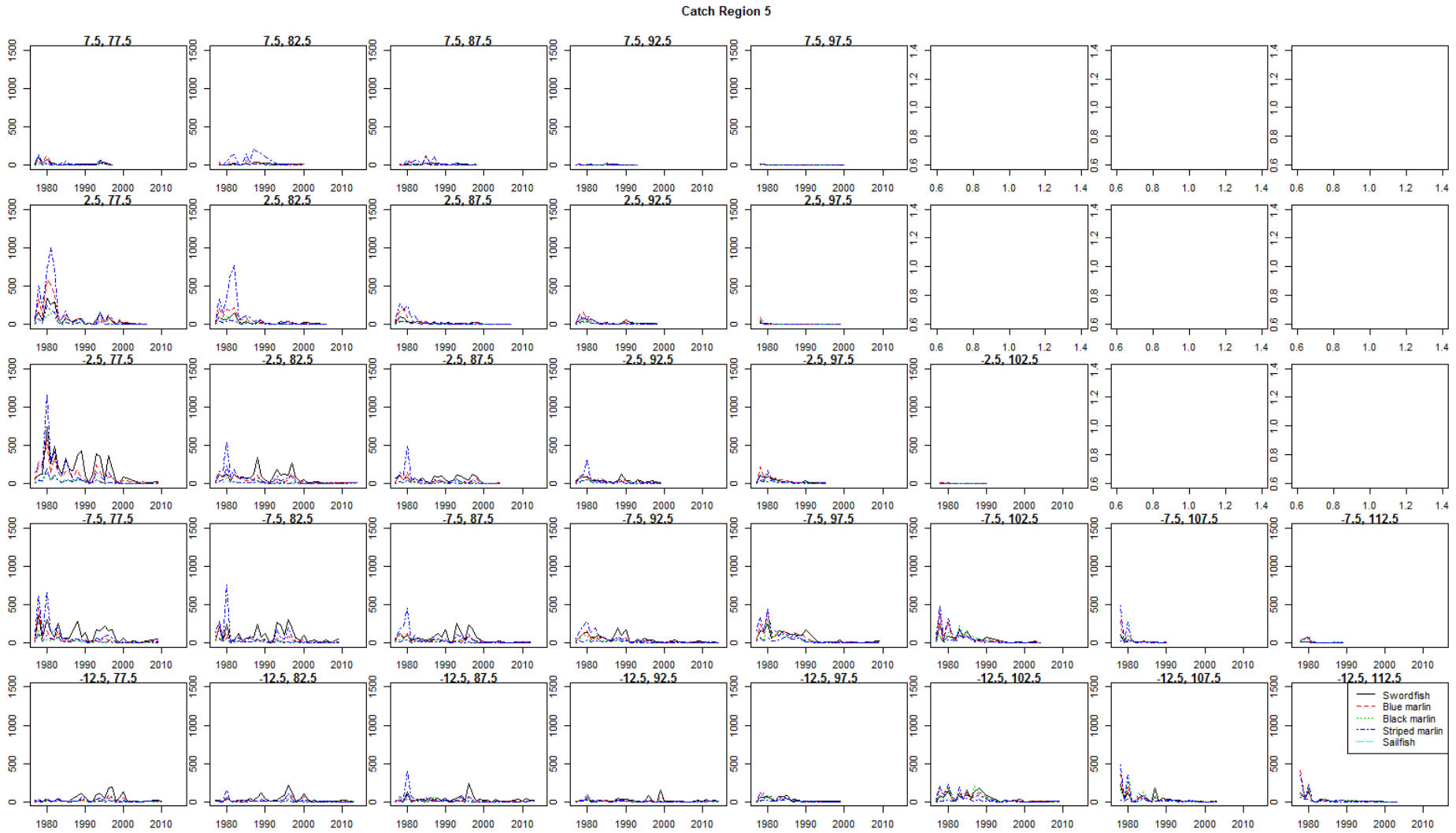


Figure 44: Catch by year-qtr and 5 degree square in region 5 for Swordfish, striped marlin, black marlin, blue marlin, and sailfish

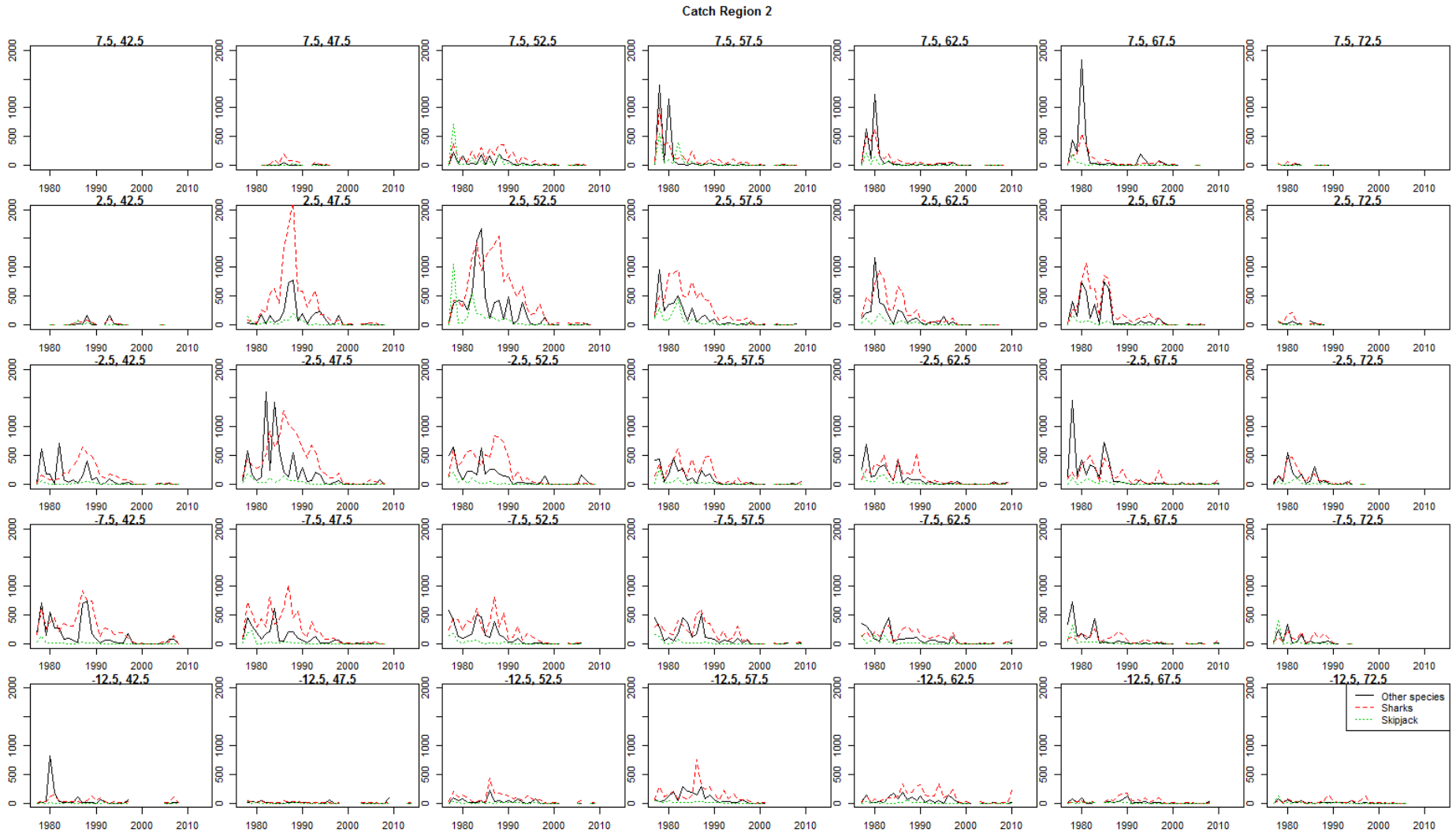


Figure 45: Catch by year-qtr and 5 degree square in region 2 for shark, skipjack, and other species.

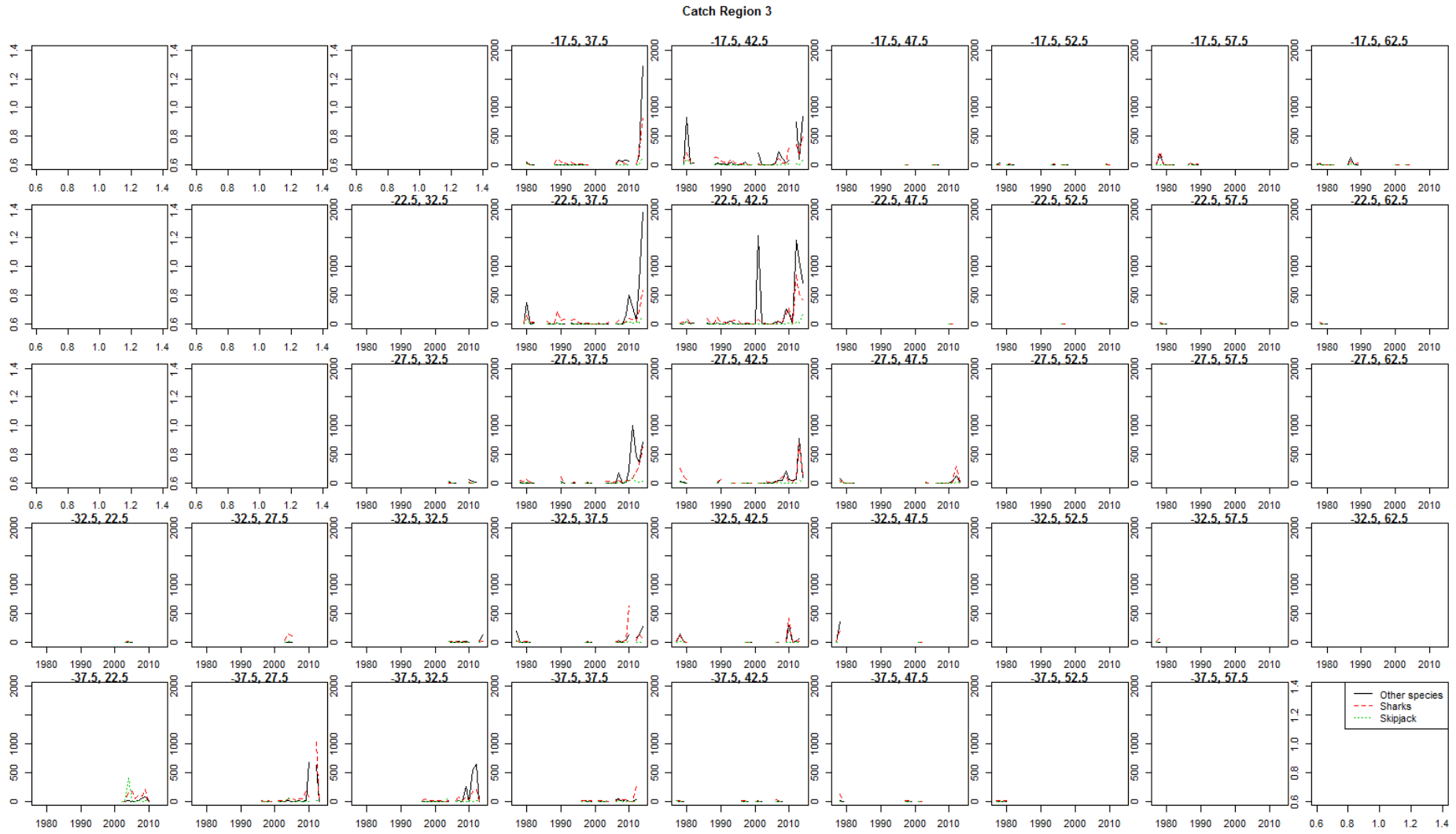


Figure 46: Catch by year-qtr and 5 degree square in region 3 for shark, skipjack, and other species.

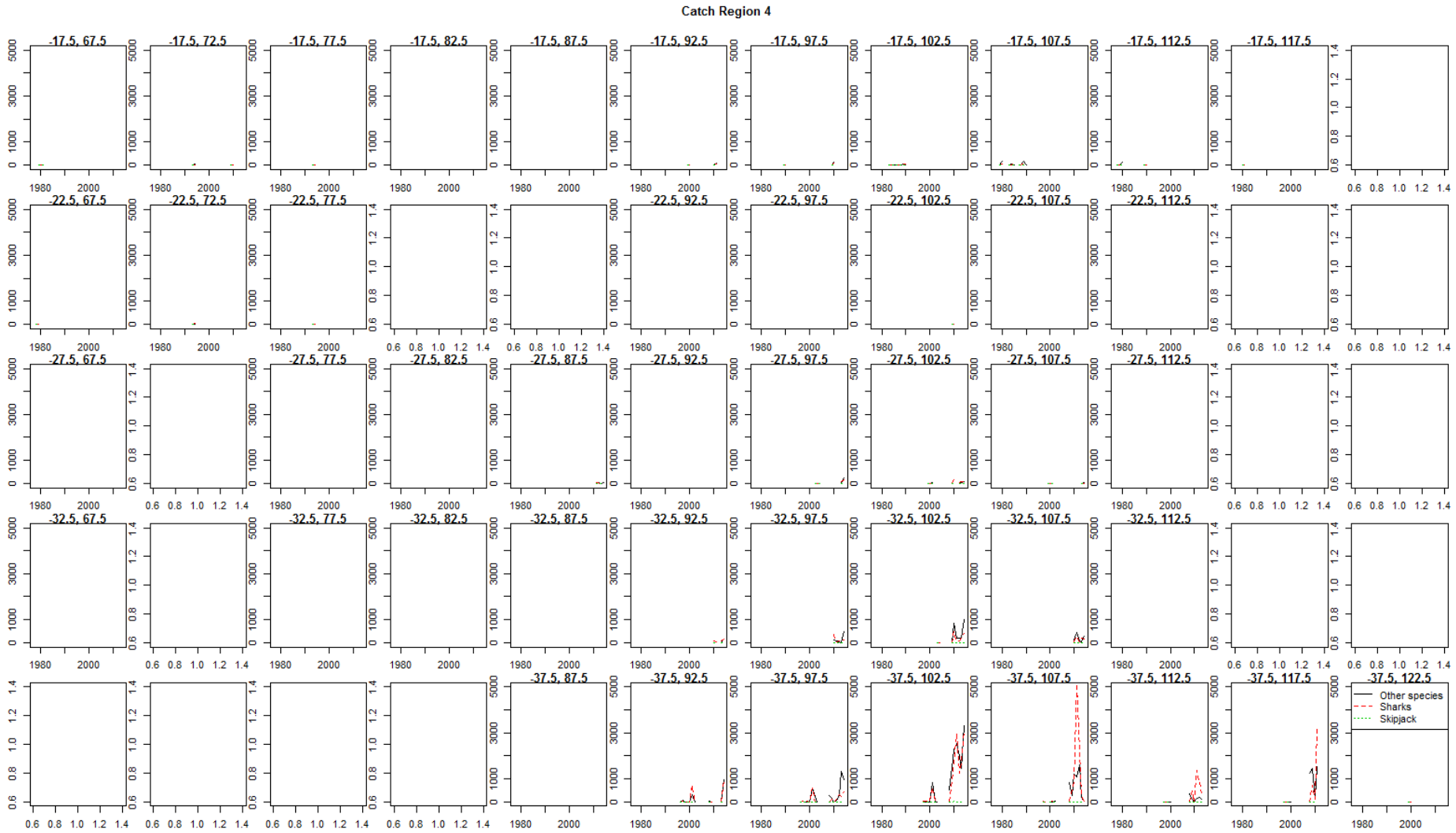


Figure 47: Catch by year-qtr and 5 degree square in region 4 for shark, skipjack, and other species.

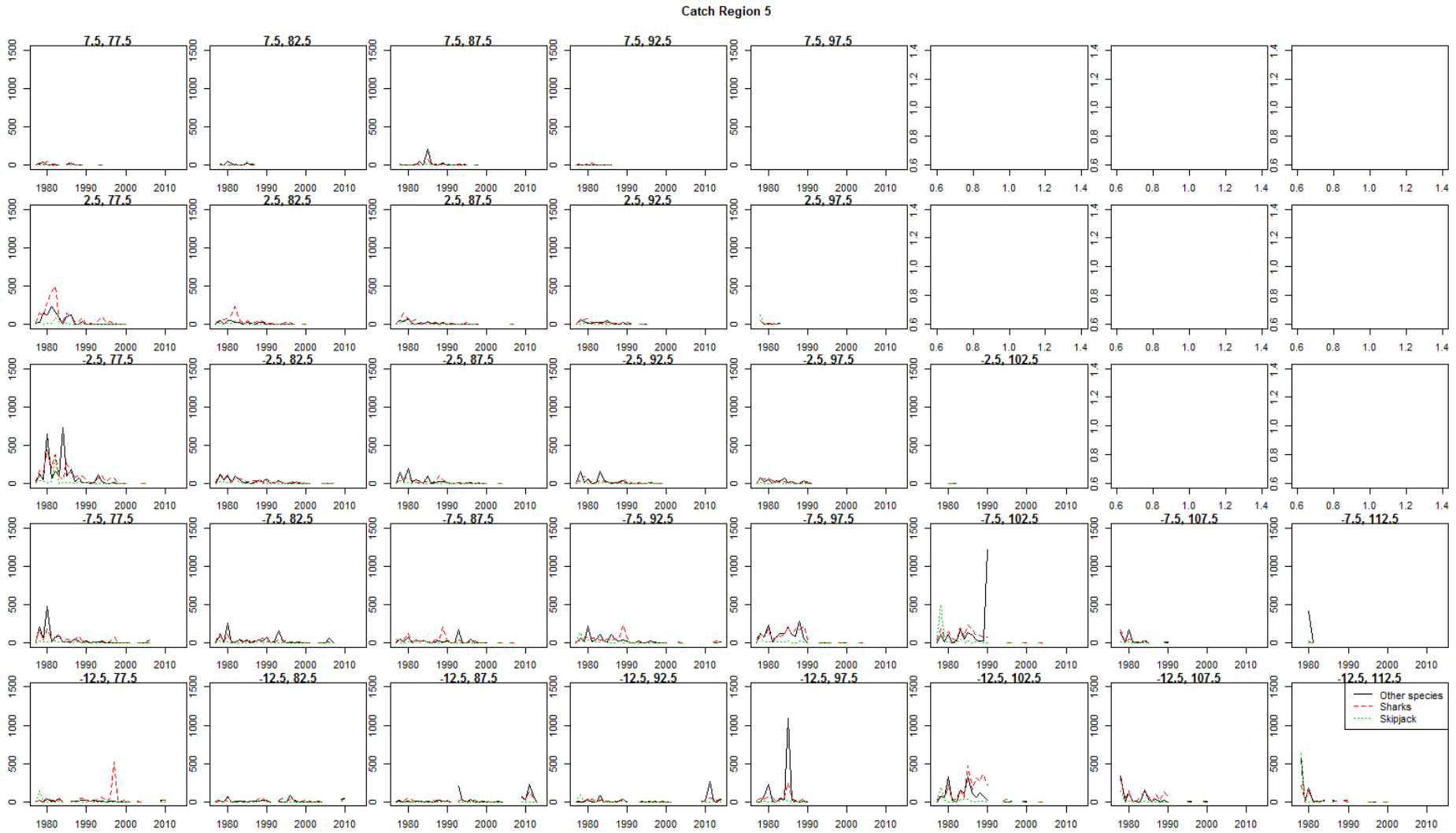


Figure 48: Catch by year-qtr and 5 degree square in region 5 for shark, skipjack, and other species.

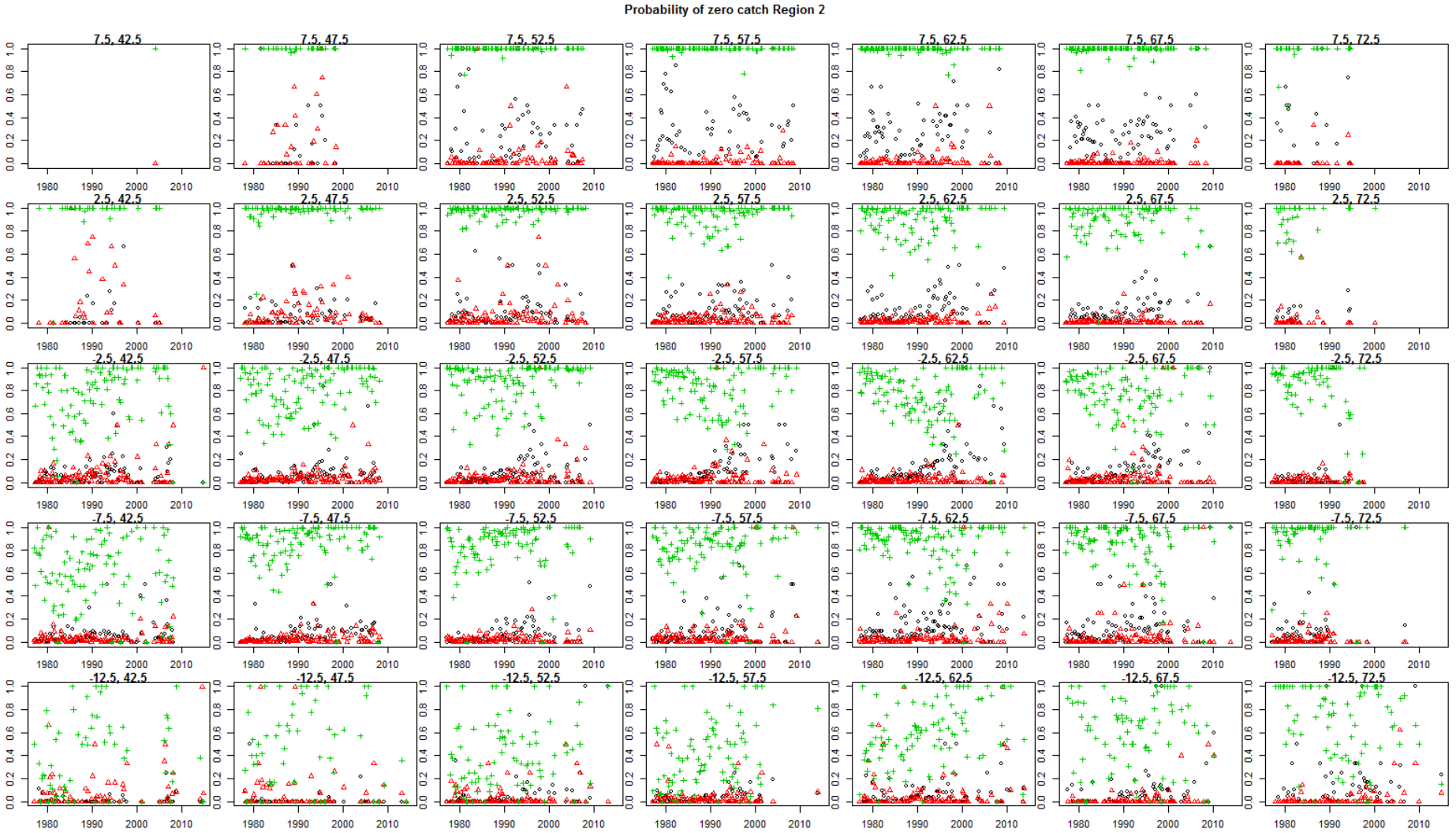


Figure 49: Probability of zero catch by year-qtr and 5 degree square in region 2 for bigeye, yellowfin, albacore, and SBT.

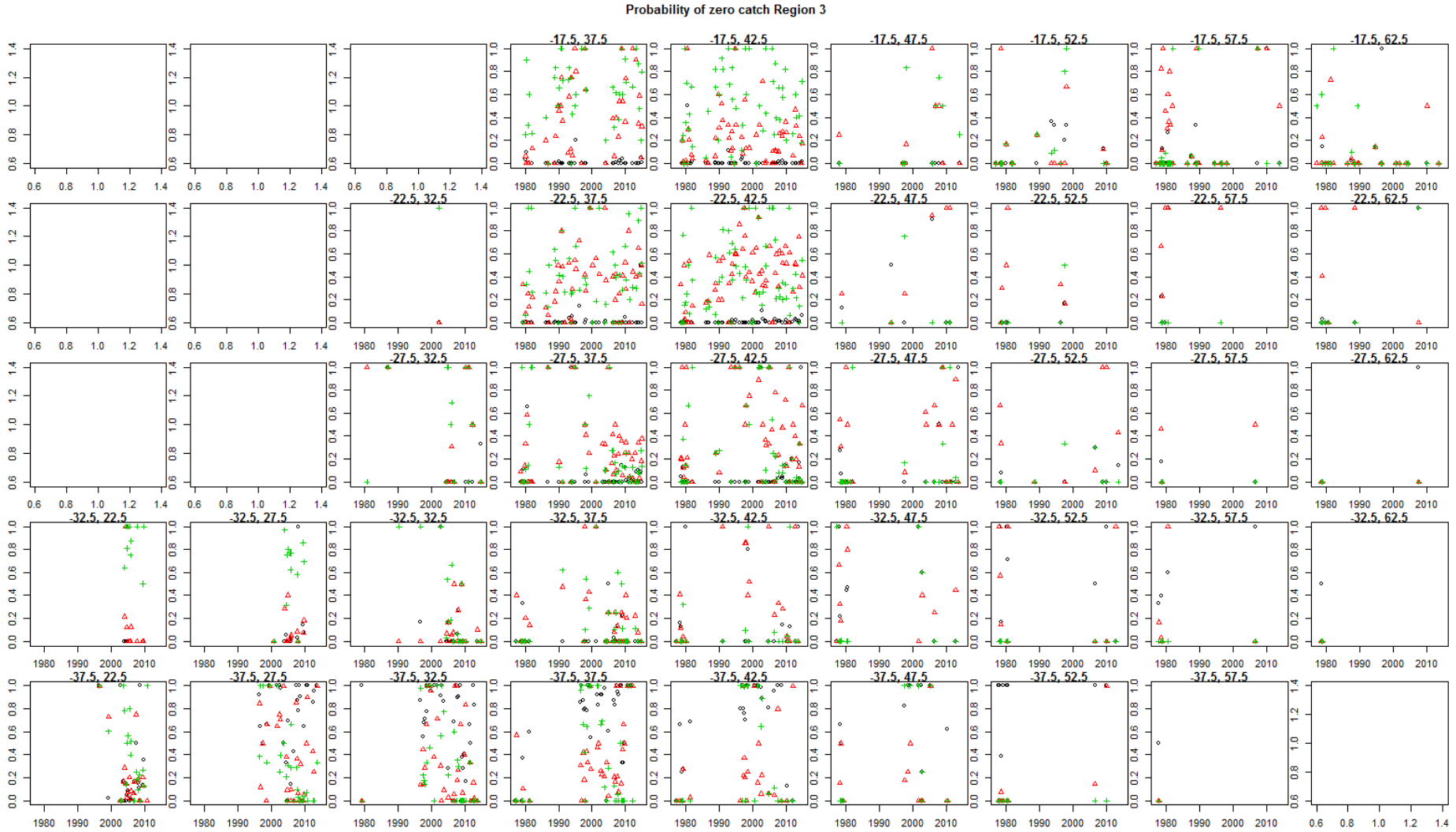


Figure 50: Probability of zero catch by year-qtr and 5 degree square in region 3 for bigeye, yellowfin, albacore, and SBT.

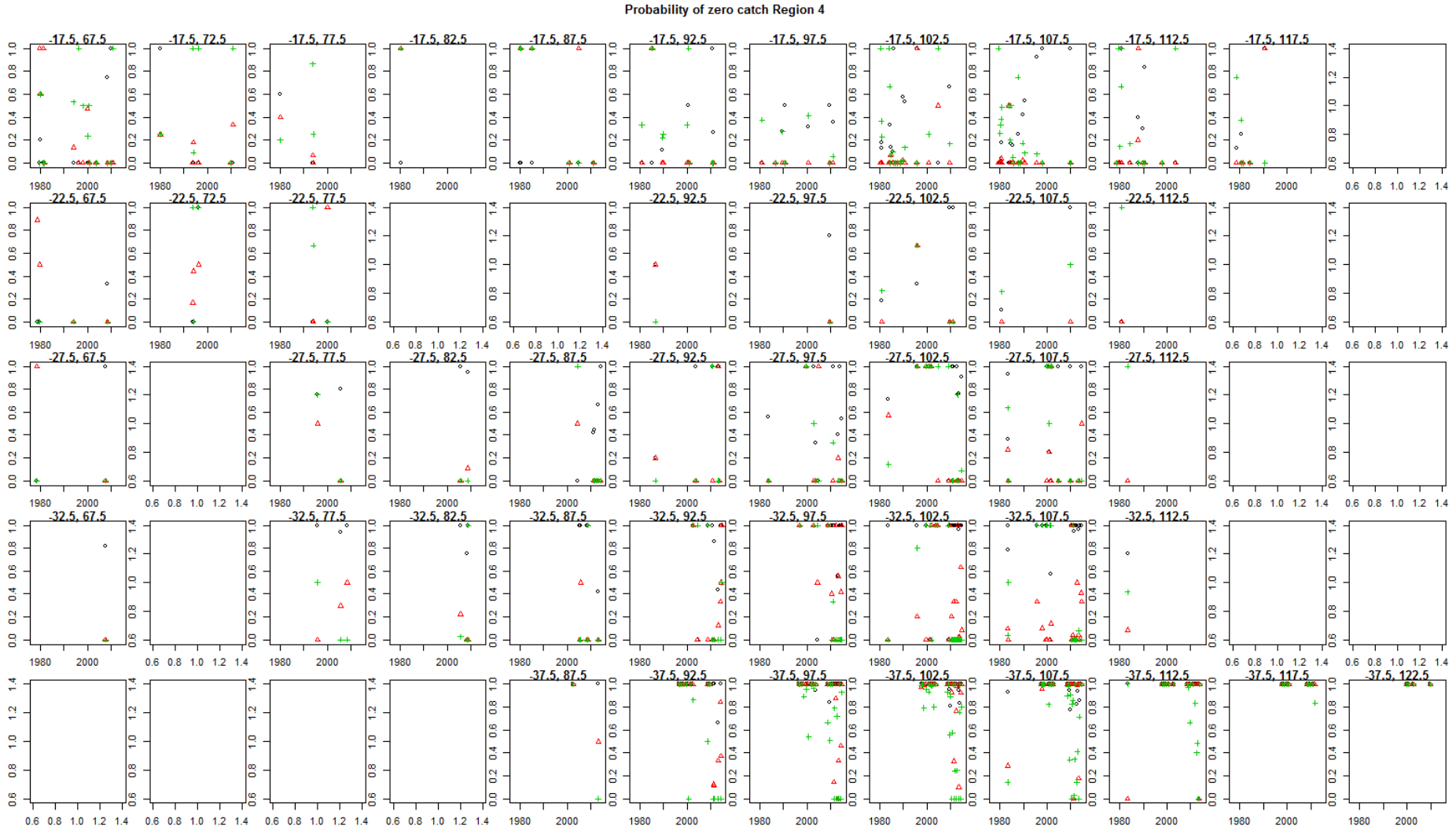


Figure 51: Probability of zero catch by year-qtr and 5 degree square in region 4 for bigeye, yellowfin, albacore, and SBT.

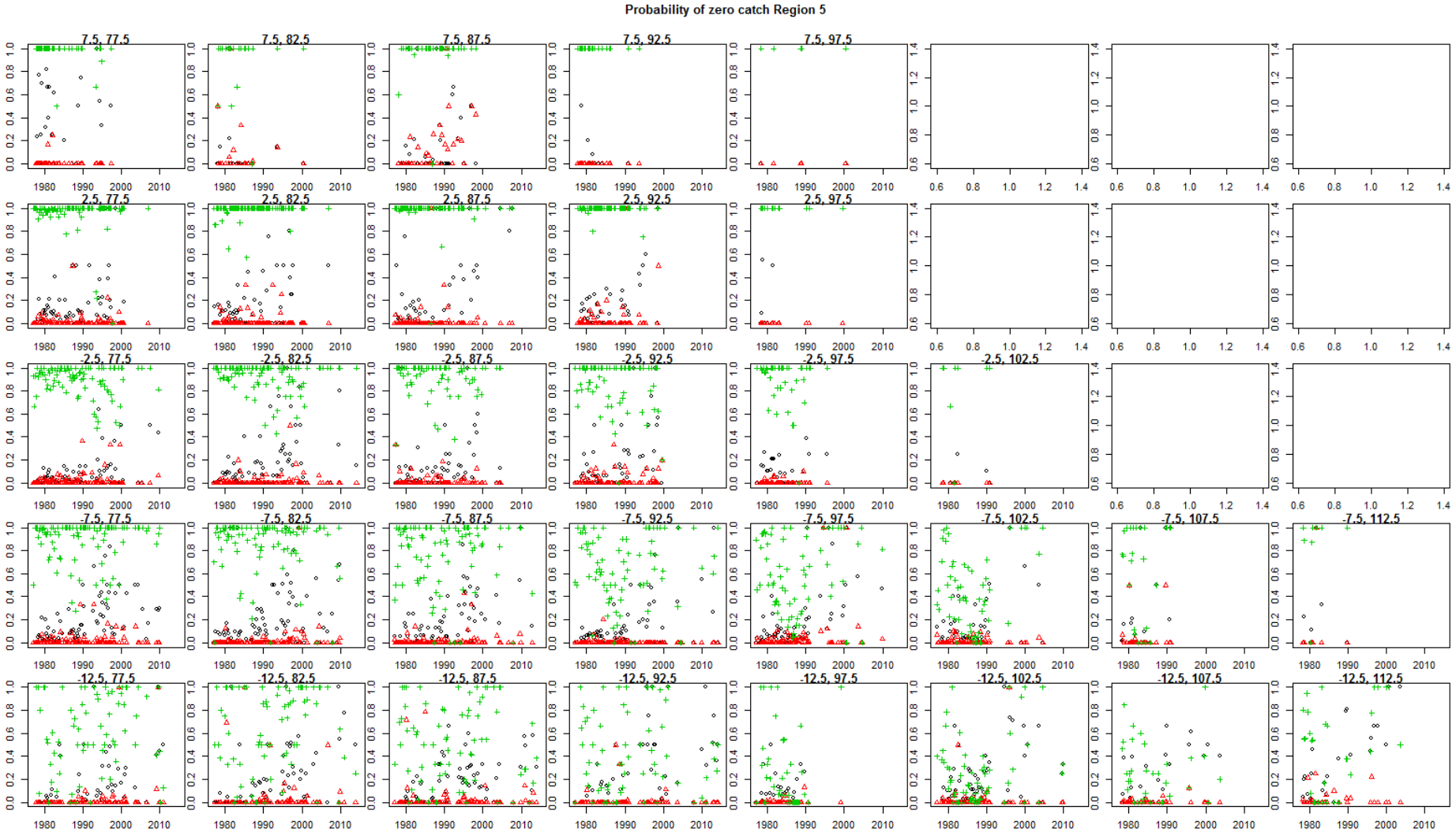


Figure 52: Probability of zero catch by year-qtr and 5 degree square in region 5 for bigeye, yellowfin, albacore, and SBT.

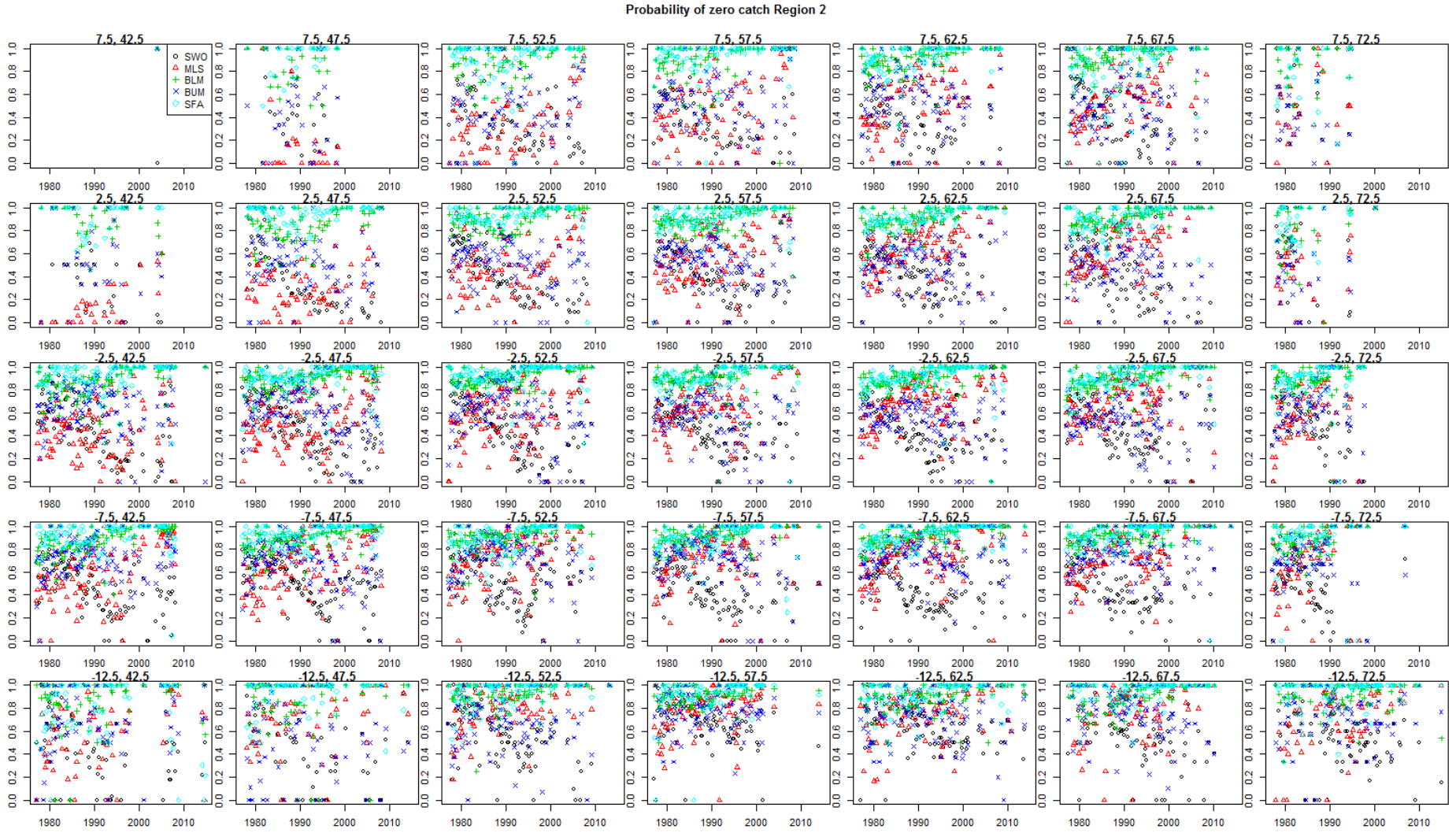


Figure 53: Probability of zero catch by year-qtr and 5 degree square in region 2 for swordfish, striped marlin, black marlin, blue marlin, and sailfish.

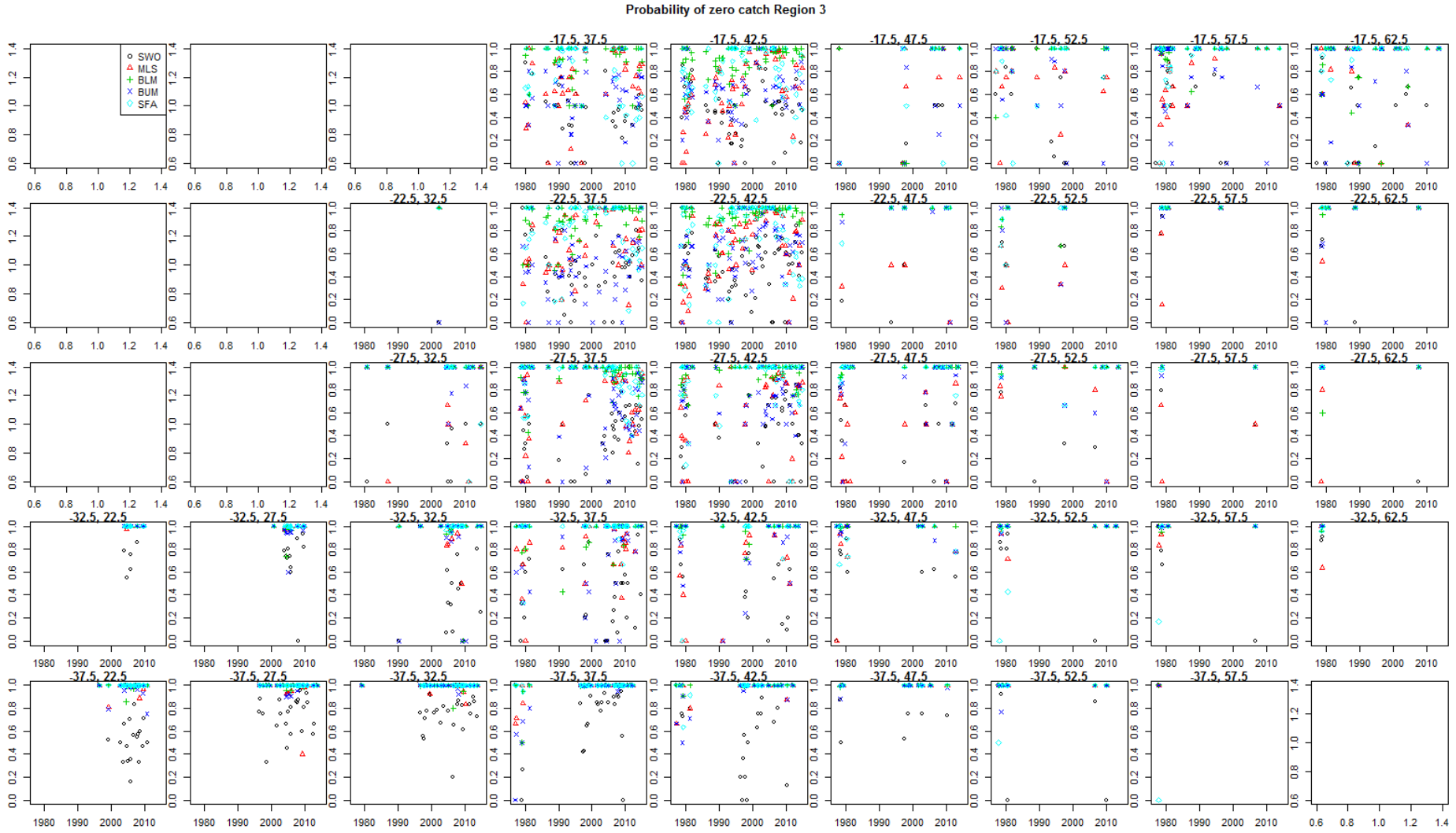


Figure 54: Probability of zero catch by year-qtr and 5 degree square in region 3 for swordfish, striped marlin, black marlin, blue marlin, and sailfish.

Figure 55: Probability of zero catch by year-qtr and 5 degree square in region 4 for swordfish, striped marlin, black marlin, blue marlin, and sailfish.

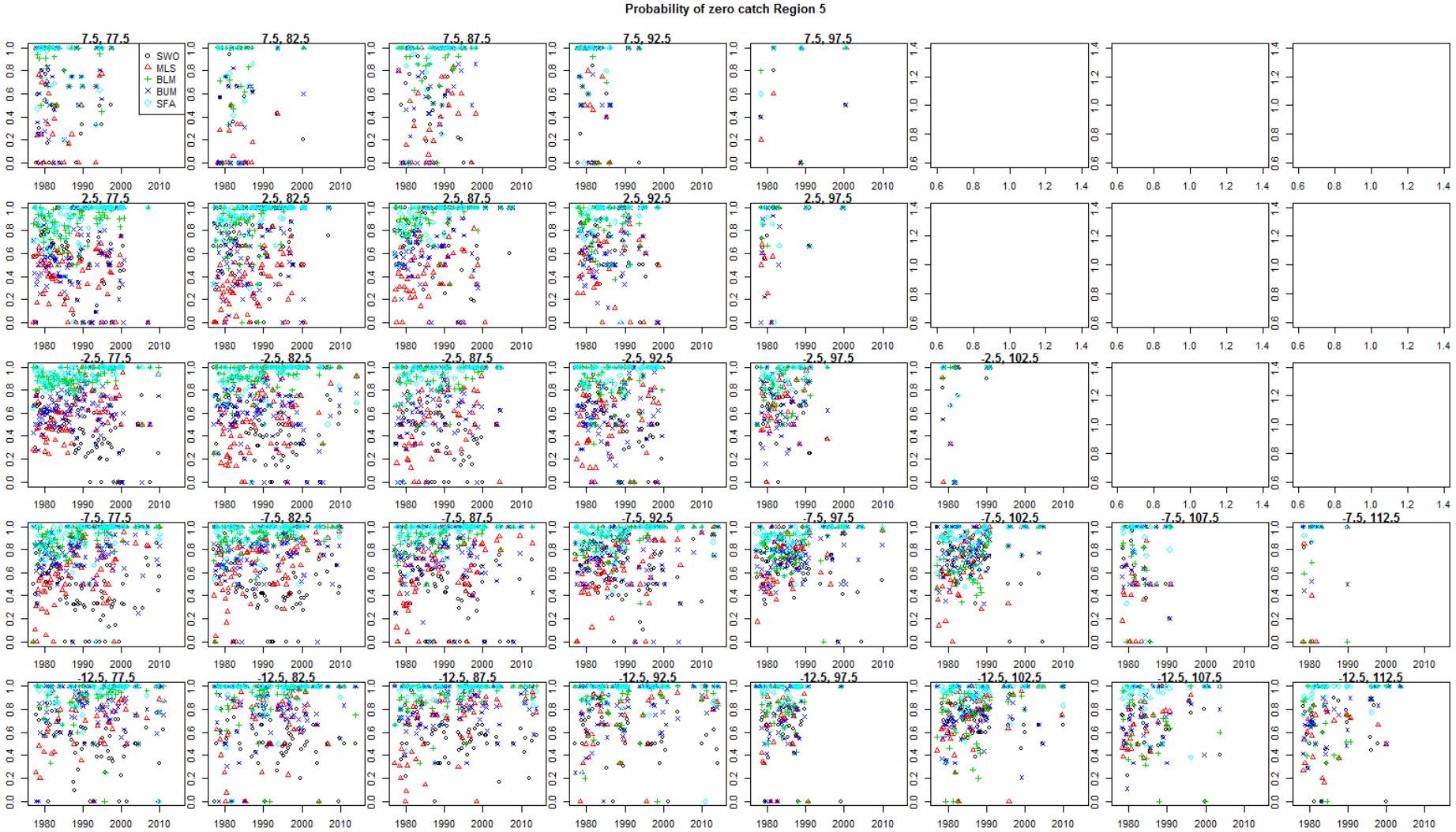


Figure 56: Probability of zero catch by year-qtr and 5 degree square in region 5 for swordfish, striped marlin, black marlin, blue marlin, and sailfish.

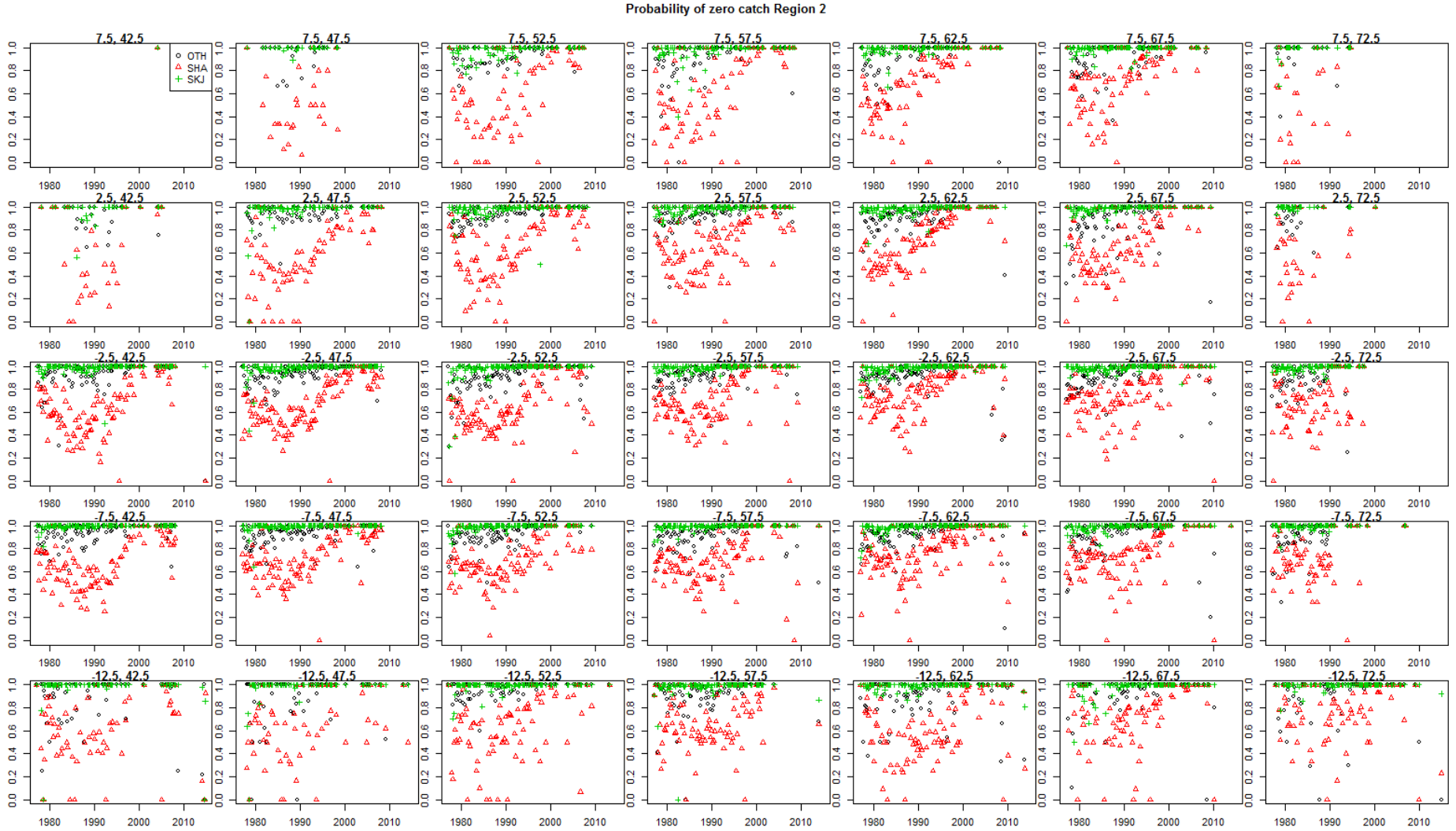


Figure 57: Probability of zero catch by year-qtr and 5 degree square in region 2 for sharks, skipjack, and other species.

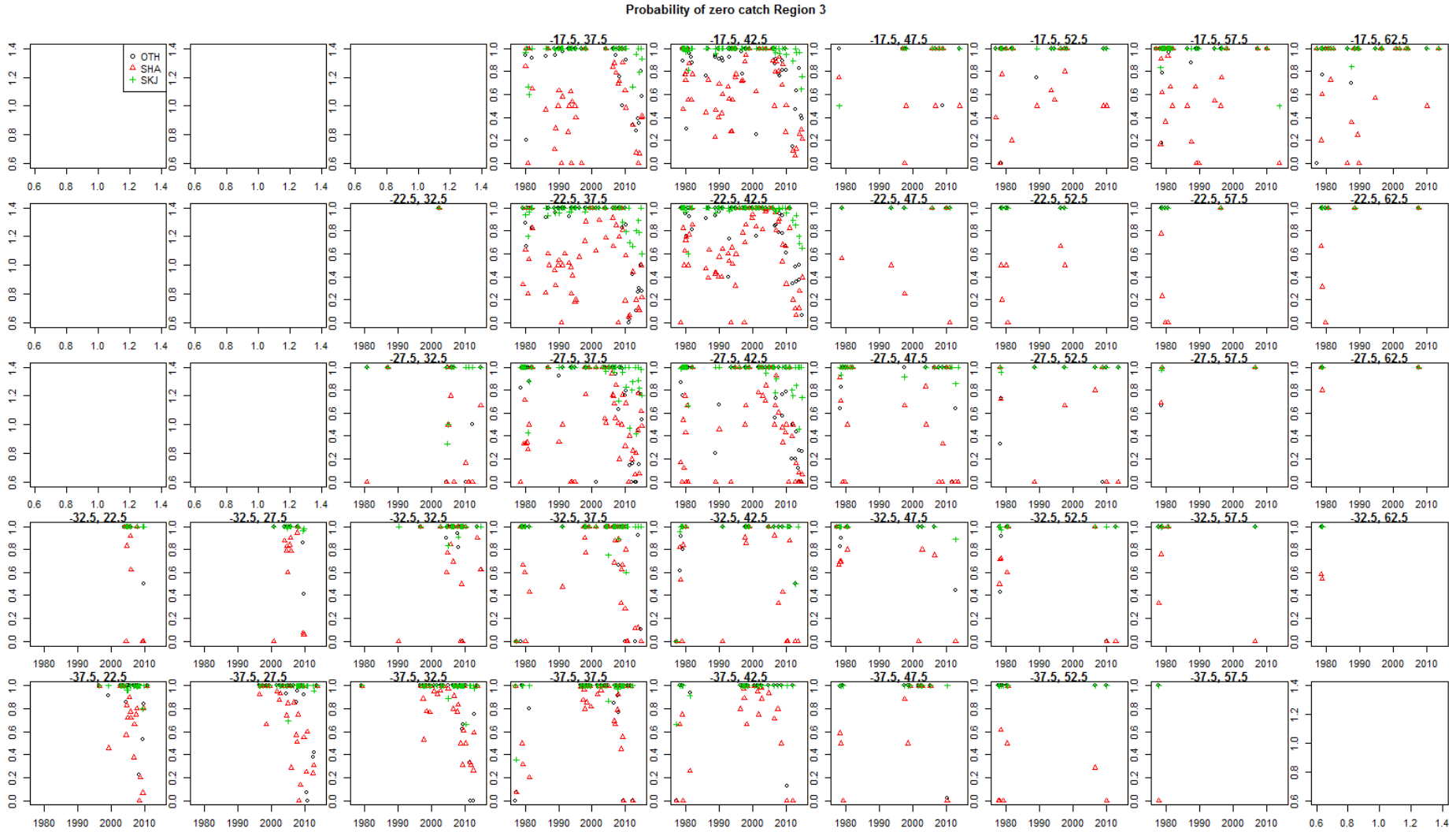


Figure 58: Probability of zero catch by year-qtr and 5 degree square in region 3 for sharks, skipjack, and other species.

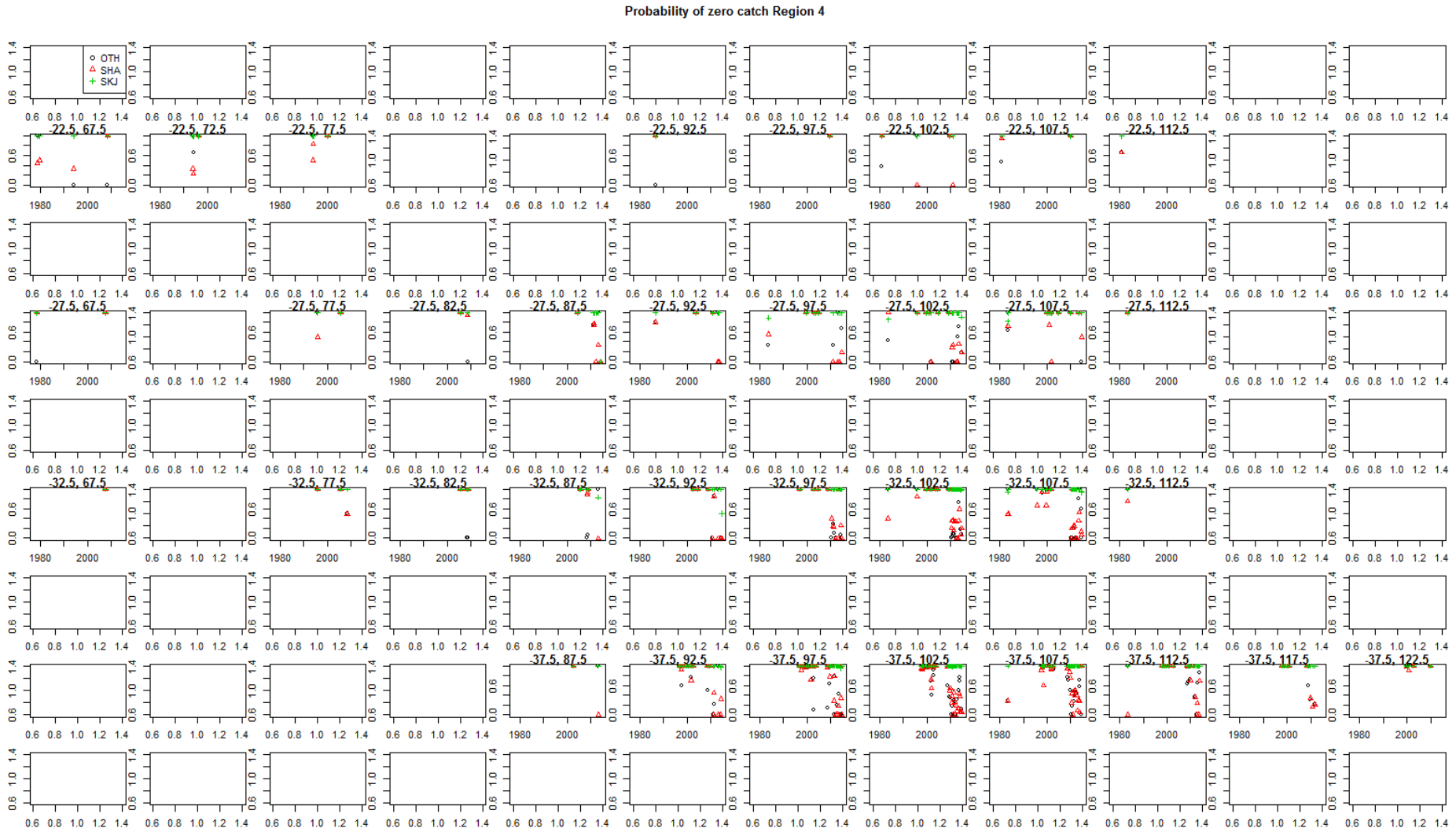


Figure 59: Probability of zero catch by year-qtr and 5 degree square in region 4 for sharks, skipjack, and other species.

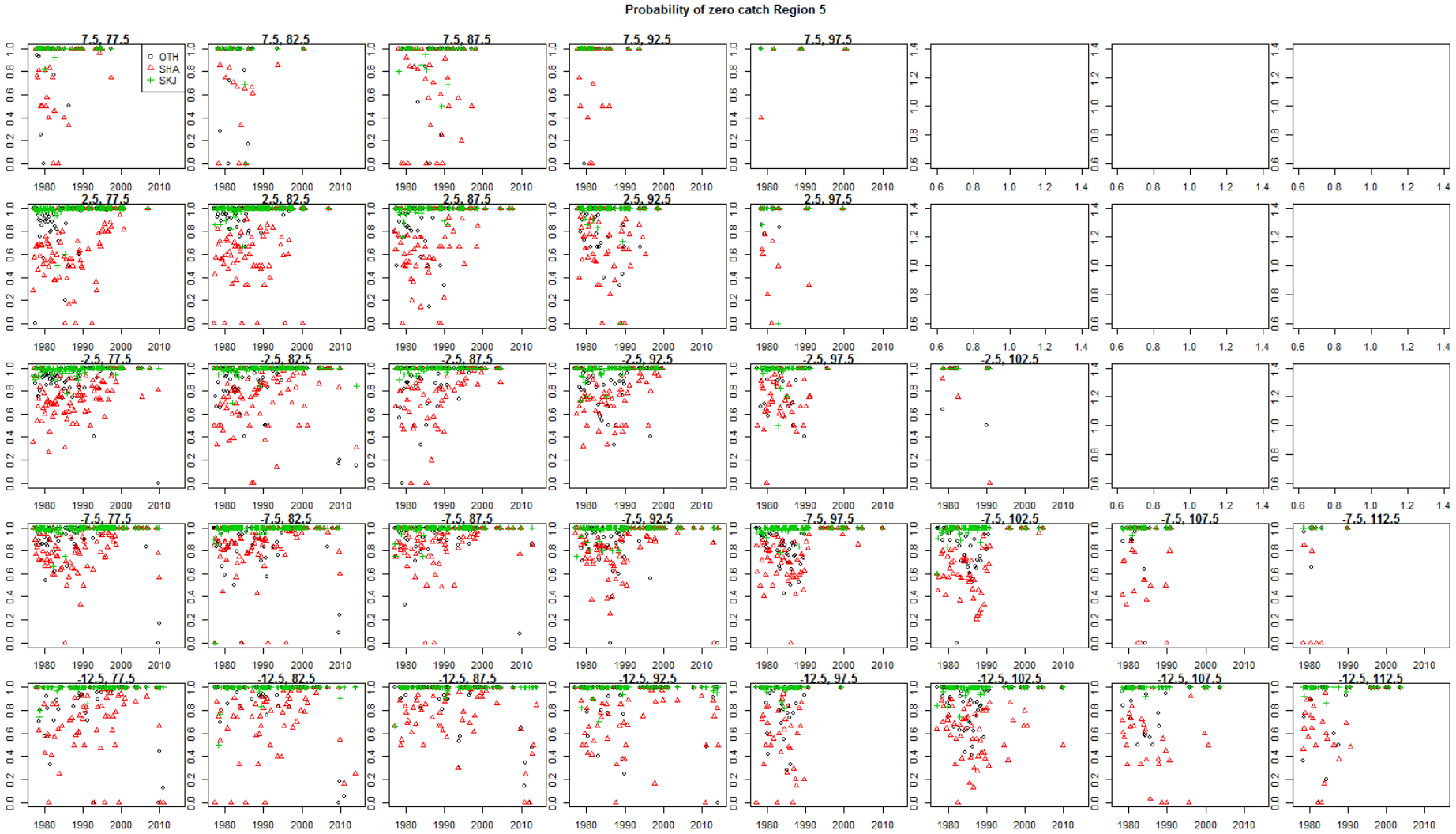


Figure 60: Probability of zero catch by year-qtr and 5 degree square in region 5 for sharks, skipjack, and other species.