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

Simon D. Hoyle[1], Yu-Min Yeh[2], Shu-Ting Chang[3], and Ren-Fen Wu[3].

Abstract

We analysed Taiwanese 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 tuna, 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, bluefin, southern bluefin tuna, skipjack tuna, other tuna, swordfish, striped marlin, black marlin, blue marlin, other marlin (mostly sailfish), sharks, and other species (mostly oilfish). 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 Taiwanese longline fleet. Complementary reports address the Japanese (Hoyle, Simon D. and Okamoto 2015) and Korean (Hoyle, Simon D., Lee et al. 2015) fleets. A further report (Hoyle, Simon D., Okamoto et al. 2015) addresses the main objectives of the study.

Methods

Full details of data preparation are included in Hoyle, Simon D., Okamoto 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).

The Taiwanese operational data were available 1979-2013, with fields year, month and day of operation; vessel call sign; operational area (a code indicating fishing location at 5 degree resolution); operation location at one degree resolution (from 1994); number of hooks between floats (from 1995); number of hooks per set; catches in number for the species albacore, bigeye, yellowfin, bluefin, southern bluefin (from 1994), other tuna, swordfish, striped marlin, blue marlin, black marlin, other billfish, skipjack, shark, and other species; equivalent values in weight for all species; SST; bait type fields for ‘Pacific saury’, ‘mackerel’, ‘squid’, ‘milkfish’, and ‘other’; depth of hooks (m); set type (type of target, from 2006); remarks (indicating outliers, from 2006); departure

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date from port; starting date of operations on a trip; stopping date of operations on a trip; arrival date at port.

International call sign was available for each set, and was selected as the vessel identifier. Call sign is unique to the vessel and held throughout the vessel's working life. The first digit of the Taiwanese callsign indicated the tonnage of the vessel. The vessel id was rendered anonymous by changing it to an arbitrary integer.

In most data from 1994, latitude and longitude were reported at 1 degree resolution, with a code to indicate north or south, west or east. Fishing locations were otherwise reported at 5 degree square resolution using a logbook code. All data were adjusted to represent the south-western corner of the 1 x 1 degree 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, A., Herrera et al. 2012) and a bigeye region (consistent with the bigeye assessment, Langley, Adam, Herrera et al. 2013), and data outside these areas ignored. Location information was used to calculate the 5 degree square (latitude and longitude).

Hooks per set was reported for all sets, and the few sets without hooks deleted. In the Taiwanese data hooks per set over 4500 and less than 200 were removed. A very high proportion of Taiwanese sets reported 3000 hooks per set, to an increasing degree through time, which may be genuine or may indicate a reporting problem.

The species and species groups were yellowfin tuna, bigeye tuna, albacore tuna, southern bluefin tuna, skipjack tuna, other tuna (mostly neritic), swordfish, striped marlin, black marlin, blue marlin, other marlin (mostly sailfish and possibly shortbill spearfish), sharks, and other species (mostly oilfish). Catch in weight was also reported, but we used only the number information. Columns for southern bluefin tuna were added in 1994, but prior to this southern bluefin tuna were only recorded in the database when individuals changed the heading in the logbook.

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).

SST was reported for many sets, but temperature information depends on the ship's measuring equipment, which may not be accurately calibrated. It may contain useful information but we did not have time to investigate its potential utility. SST from either vessels or oceanographic models is often used in standardizations that do not include 5 degree square. However, 5 degree square generally explains more variation and is preferred for several reasons, one of them being that the use of SST can bias abundance estimates (Hoyle, Simon D, Langley et al. 2014).

Bait type by set was a binomial variable that recorded whether Pacific saury, mackerel, squid, milkfish, and other species were used. More than one bait type could be used on each set. Bait was reported in almost all sets.

The remarks section (from 2006) indicated outliers and other anomalies. Codes and criteria for outliers changed in 2012. Before 2012 an outlier was flagged if there was catch of more than 5 tons of a species per set, or outliers in the distribution of species catch number per set. From 2012 an outlier was flagged according to the 'IQR rule'. 1. Arrange average catch numbers per set (within a

year) for all vessels in order. 2. Calculate first quartile (Q1), third quartile (Q3) and the interquartile range (IQR=Q3-Q1). 3. Compute Q1-1.5 x IQR and Compute Q3+1.5 x IQR. Anything outside this range is an outlier. This outlier information is used in the standard data cleaning procedures for Taiwanese standardisations. We did not use the outlier information in data cleaning for this paper.

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 - 4), hooks per set (Figure 5), hooks between floats (Figures 6 - 8), vessel characteristics and longevity (Figures 9 - 12), bait species (Figures 13 - 14), data reporting (Figures 15 - 19), catch (Figures 20 - 25), CPUE (Figures 26 - 31), proportions of sets with zero catch (Figures 32 - 34), species composition (Figures 35 - 45), catch by 5 degree square through time (Figures 46 - 63), and proportion of sets with zero catch by 5 degree square through time (Figures 64 - 81).

Acknowledgments

Thanks to the International Seafood Sustainability Foundation (ISSF) for funding this work. We are grateful to the IOTC for facilitating, and particularly Rondolph Payet, and David Wilson. Special thanks to Rishi Sharma of IOTC for facilitating, chairing the final meeting and for contributing substantially to the review and development of this work. Thanks to the Taiwanese Fisheries Agency, and the Taiwanese Overseas Fisheries Development Council for providing their facilities and support. Thanks to the Taiwanese fishing industry for providing their data.

References

Hoyle, S.D., Langley, A.D., Campbell, R.A. (2014) Recommended approaches for standardizing CPUE data from pelagic fisheries.

Hoyle, S.D., Lee, S.I., Kim, Z.G. (2015) Descriptive analyses of the Korean Indian Ocean longline fishery, focusing on tropical areas, IOTC–2015–WPTT17–INF04, IOTC–2015–WPTT17–INF04: 77 pp.,

Hoyle, S.D., Okamoto, H. (2015) Descriptive analyses of the Japanese Indian Ocean longline fishery, focusing on tropical areas, IOTC–2015–WPTT17–INF05, IOTC–2015–WPTT17–INF05: 54 pp.,

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, IOTC–2015–CPUEWS02–R[E]: 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*, IOTC–2012–WPTT14–38 Rev_1.

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. http://statistics.lazaridis.eu

R Core Team (2014) R: A Language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Figures

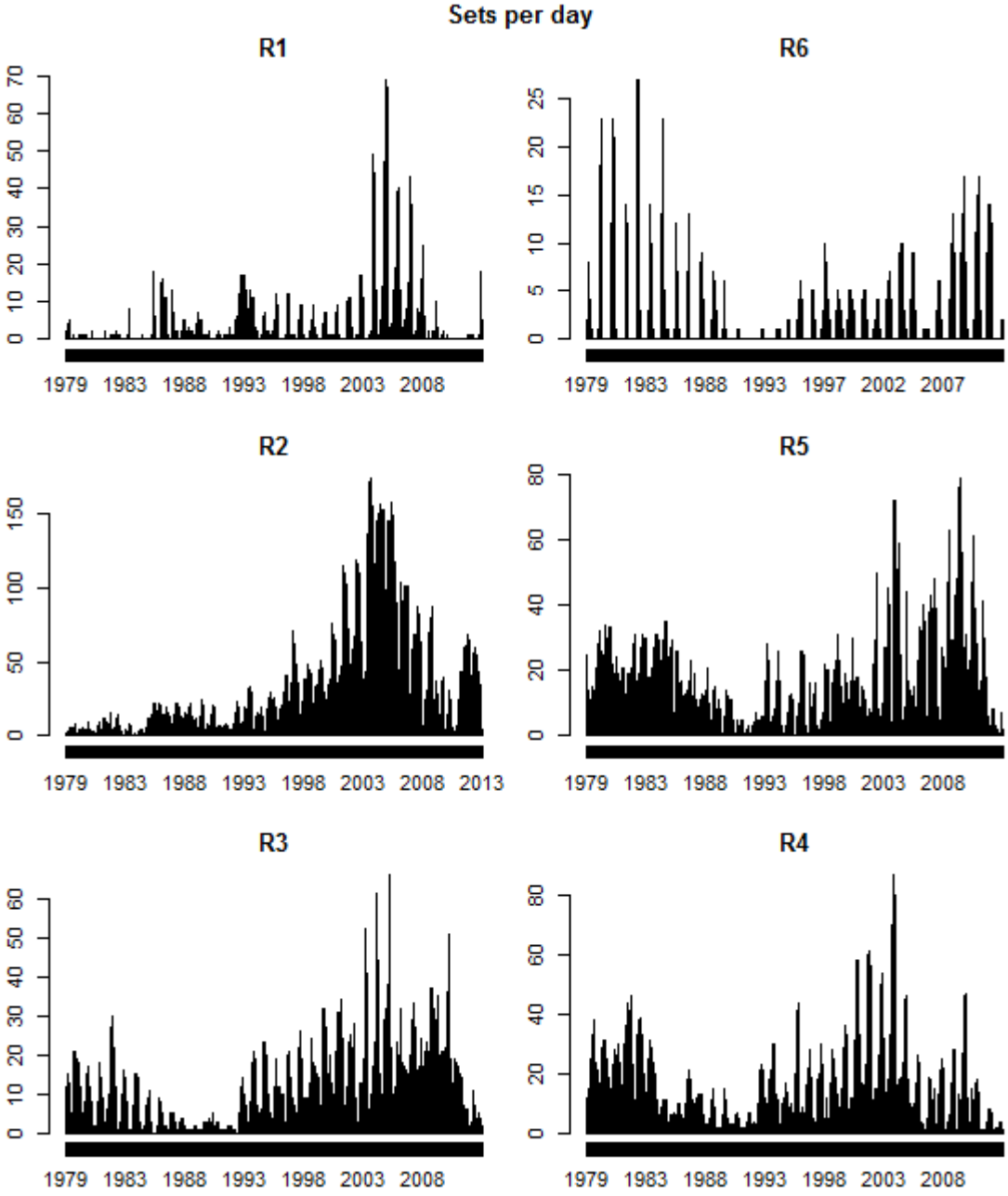

Figure 1: Sets per day by region.

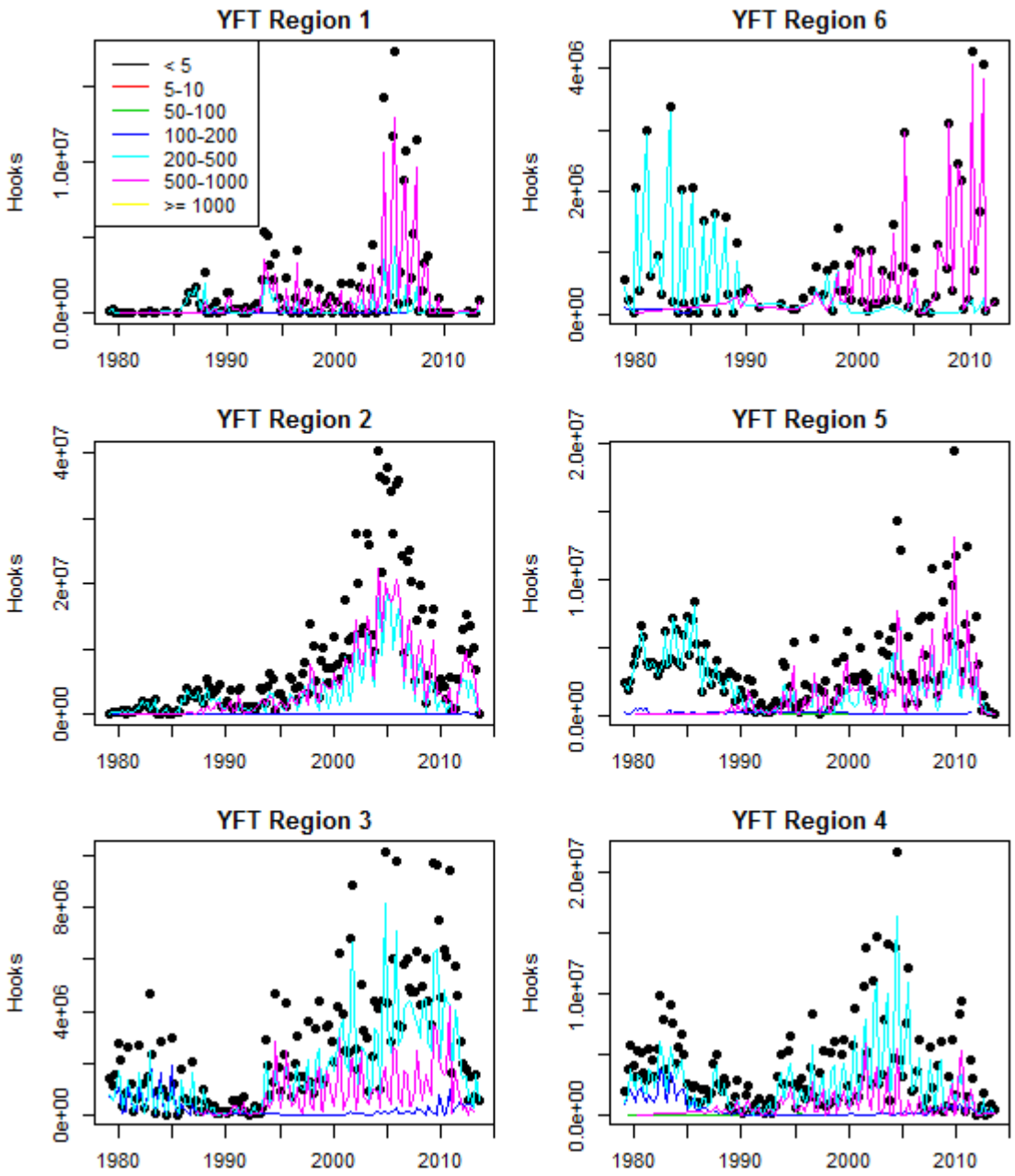

Figure 2: Hooks per year-qtr by region. Coloured lines represent different vessel tonnage classes, as indicated in the legend, and black circles represent the total effort.

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

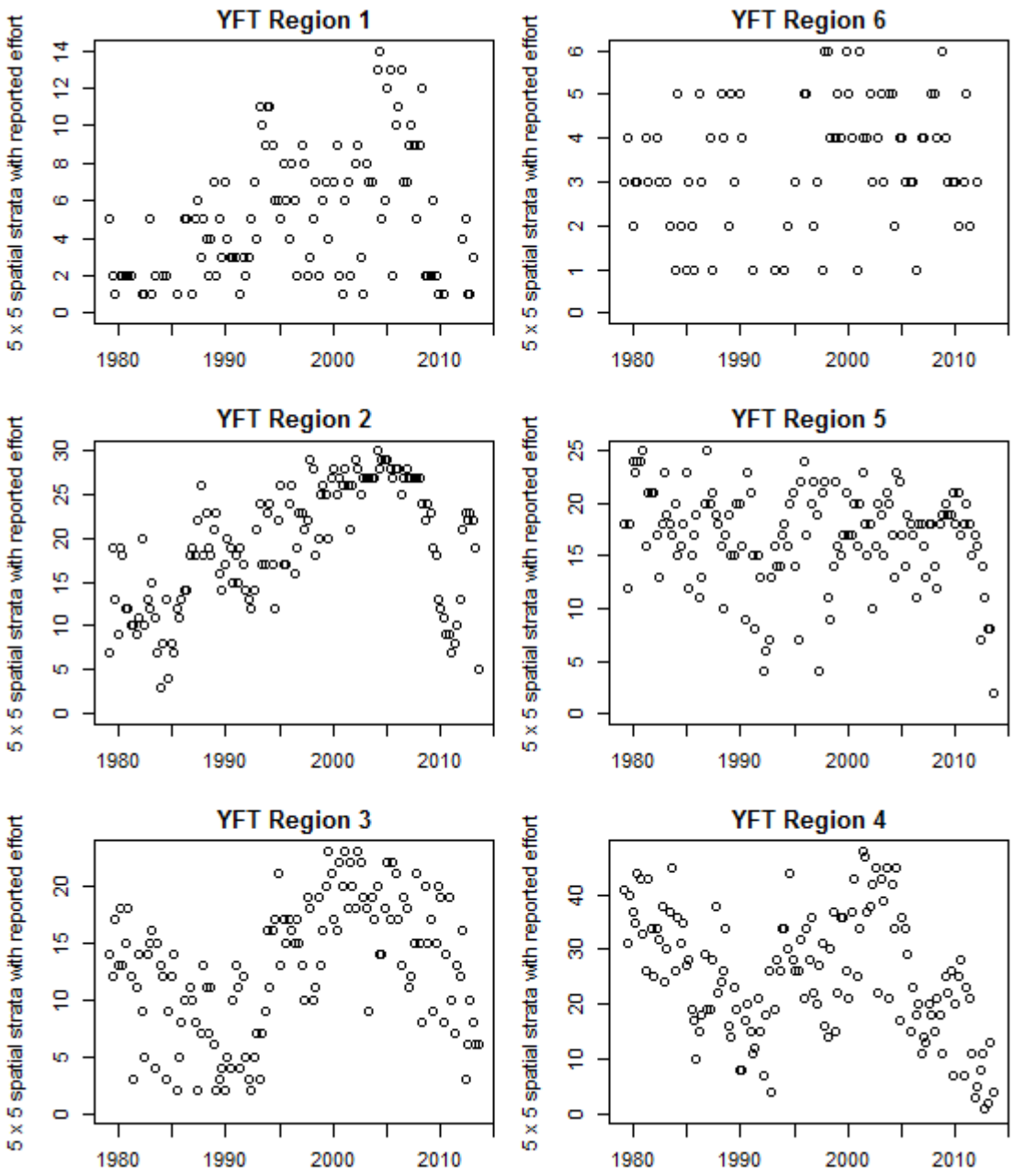

Figure 4: Spatial coverage through time, indicating the number of 5 degree cells with effort, by year-qtr and region.

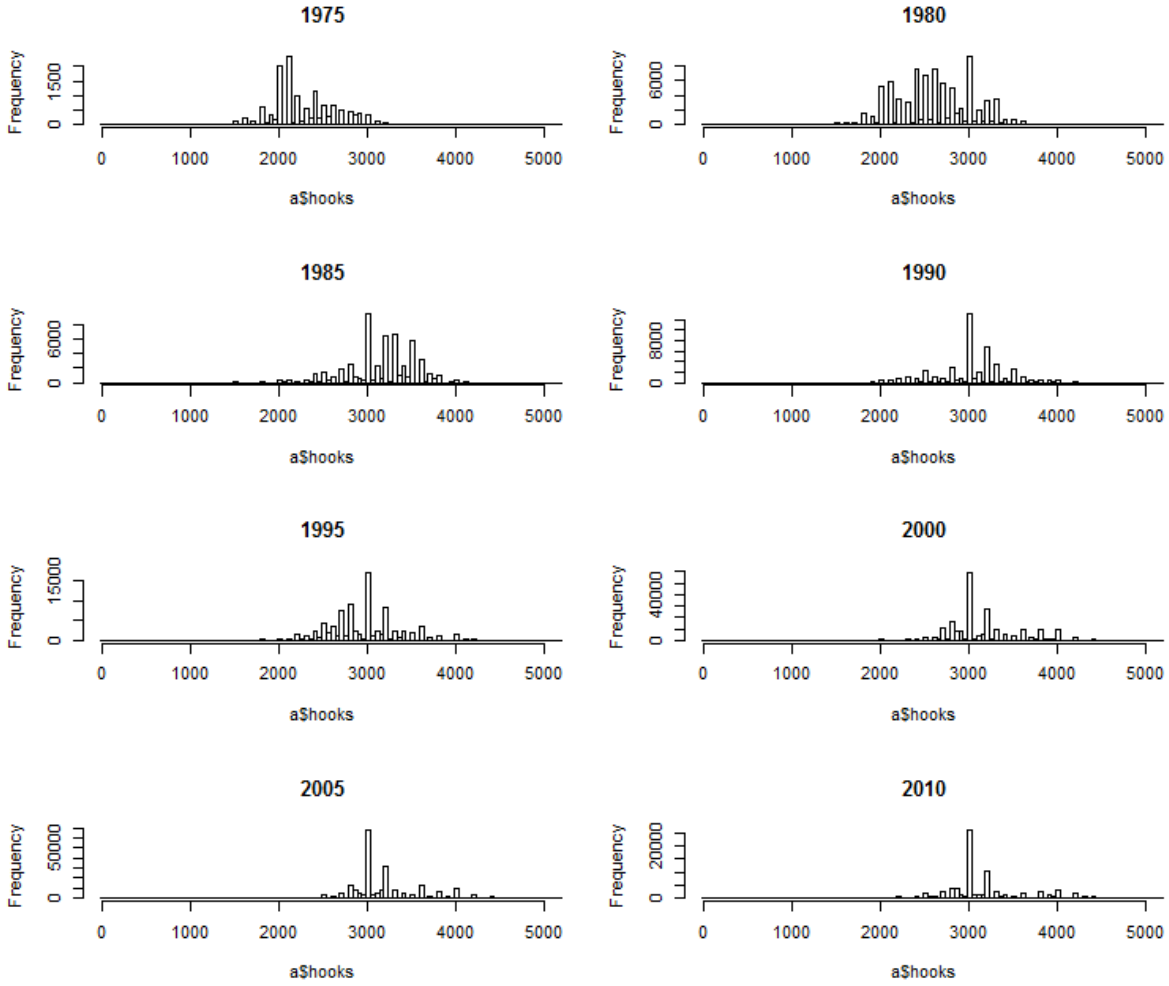

Figure 5: Frequency distribution of hooks per set by 5 year period.

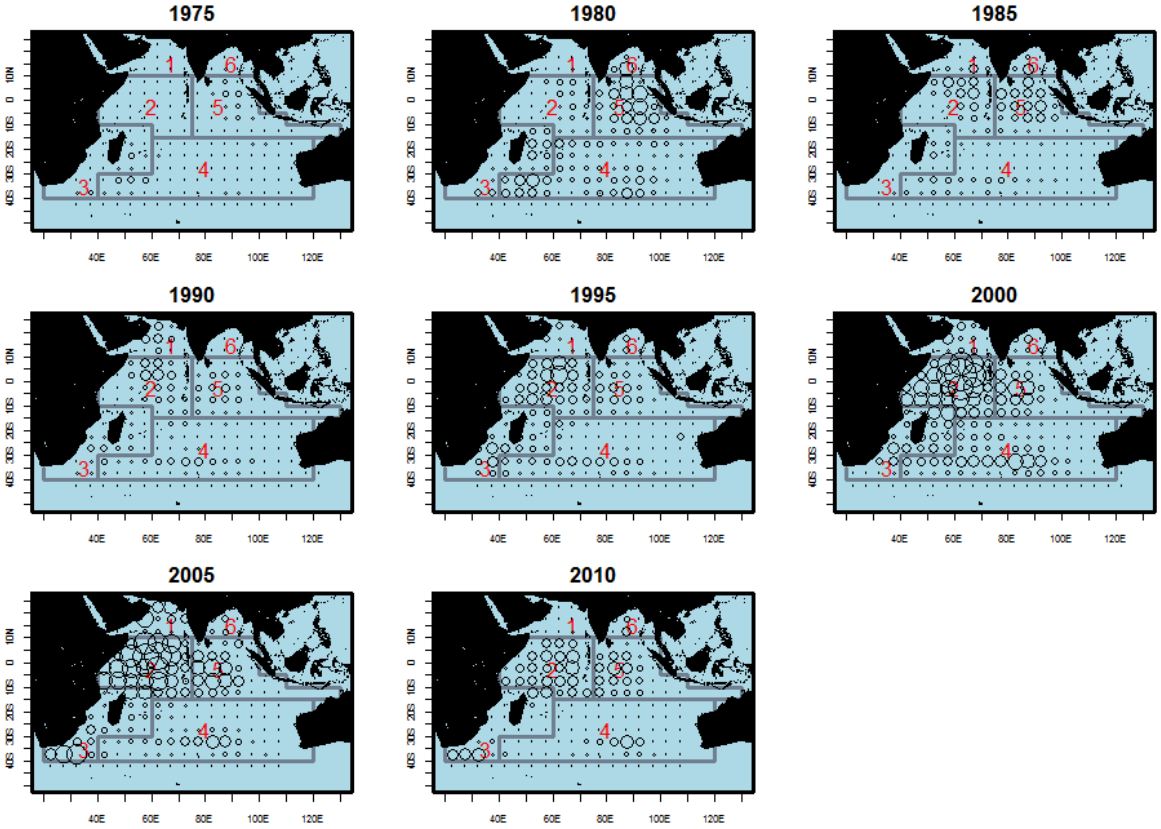

Figure 6: Spatial distribution of sets per 5 degree square by 5 year period. Circle area represents the relative number of sets.

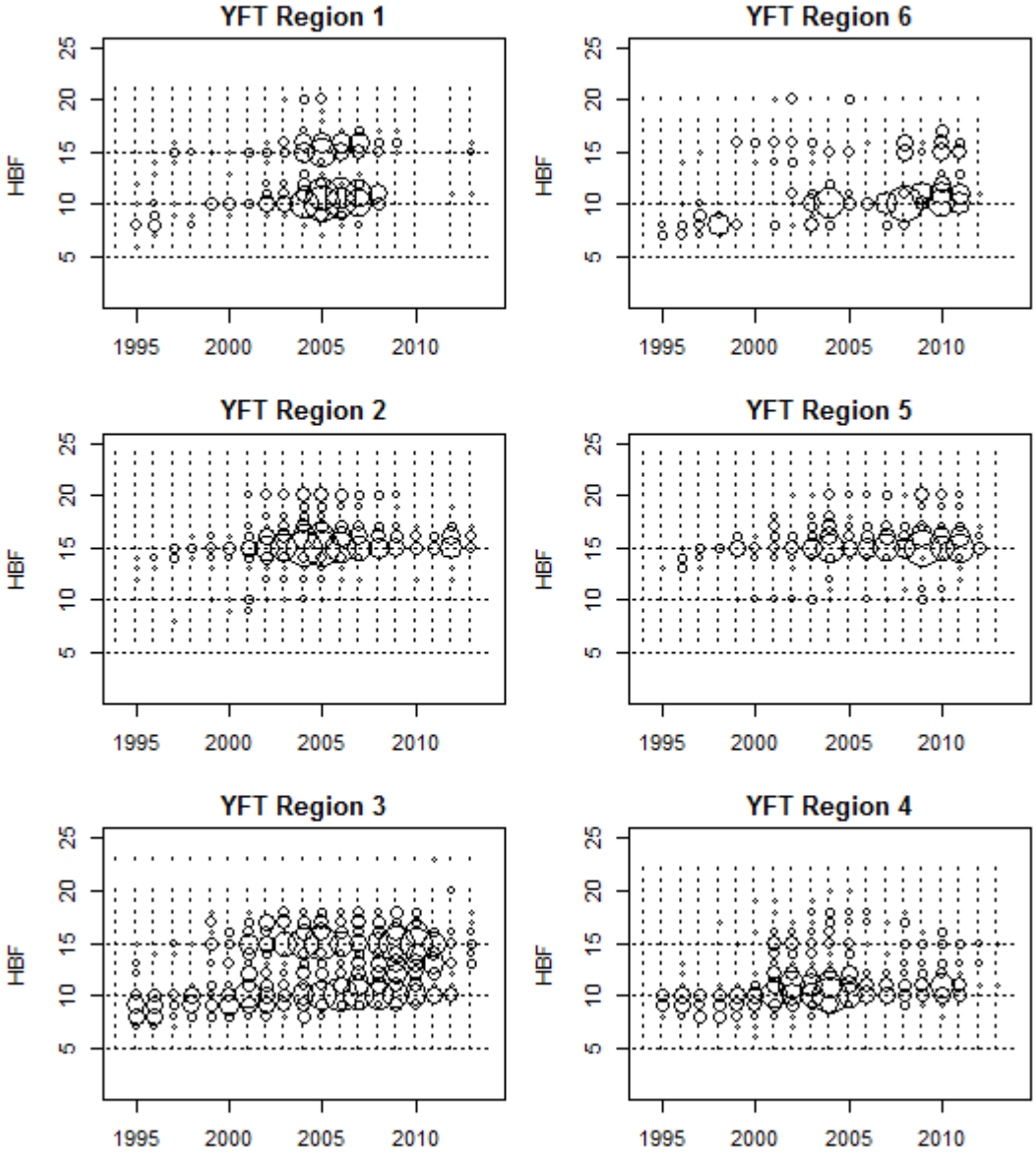

Figure 7: HBF by year and region. Circle area is proportional to effort in hooks.

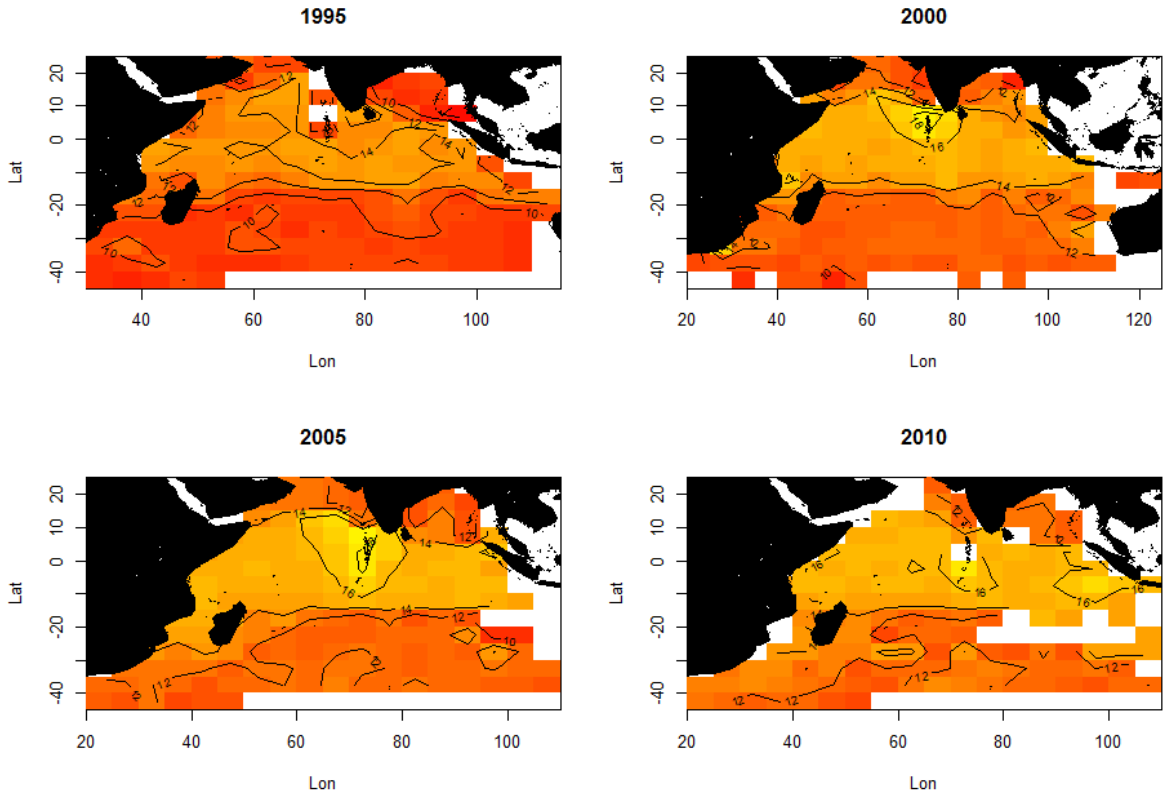

Figure 8: Maps of median HBF per 5 degree square across all sets, by 5 year period.

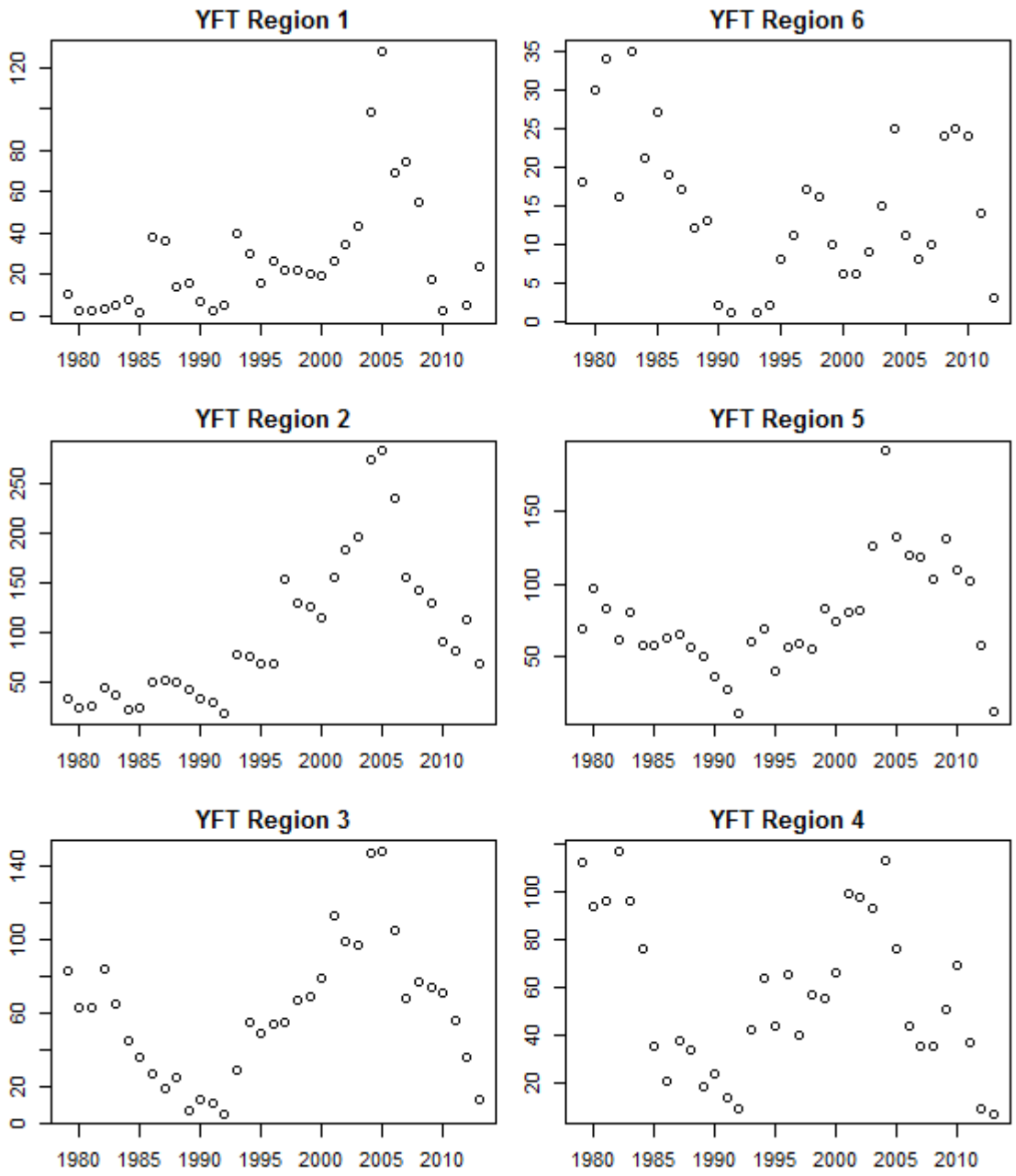

Figure 9: Unique vessels per year by region, according to vessel identifiers.

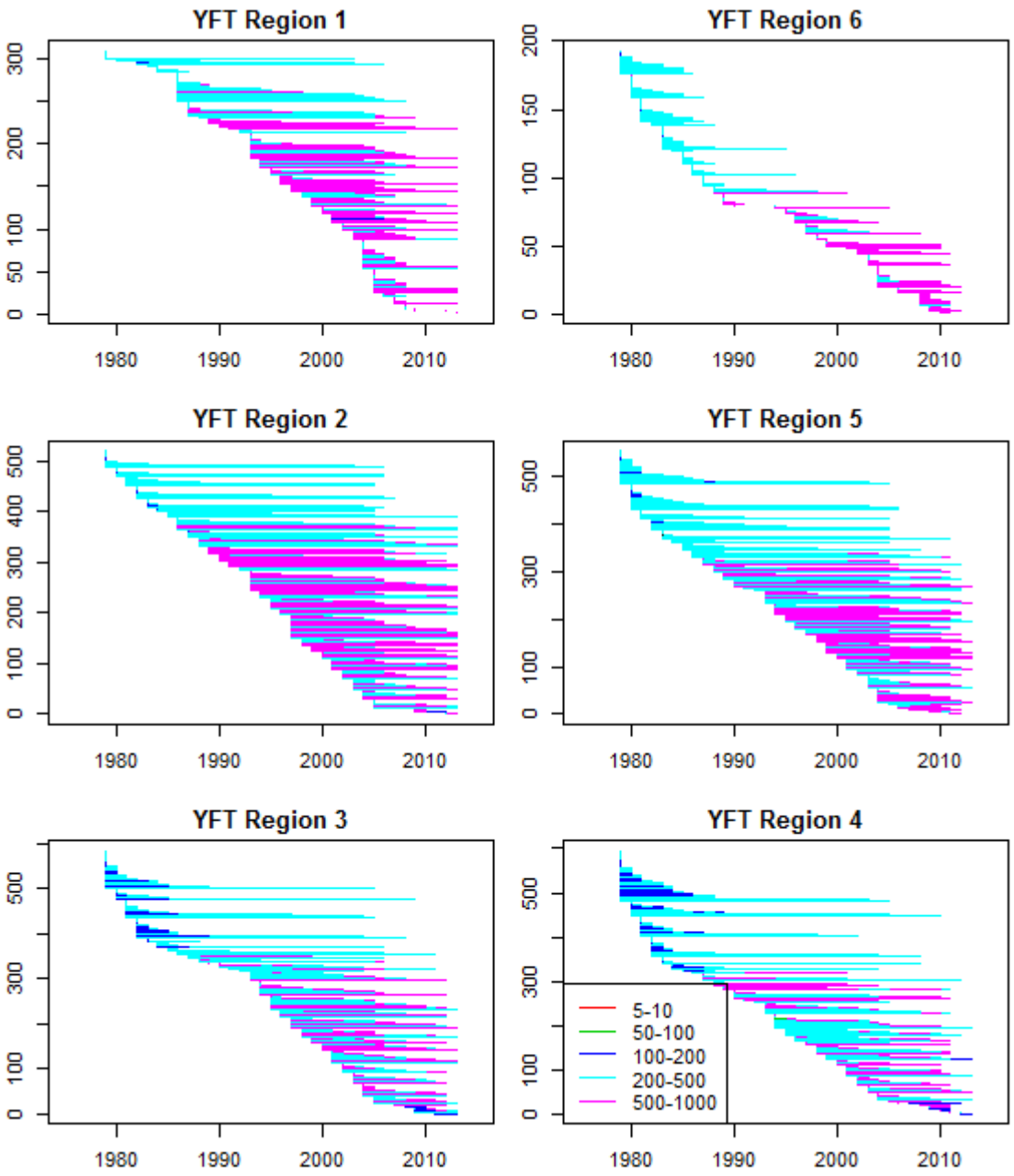

Figure 10: Vessels sorted by year of first set and last set, with a line between the years of first and last set by each vessel. Vessels are coloured by tonnage.

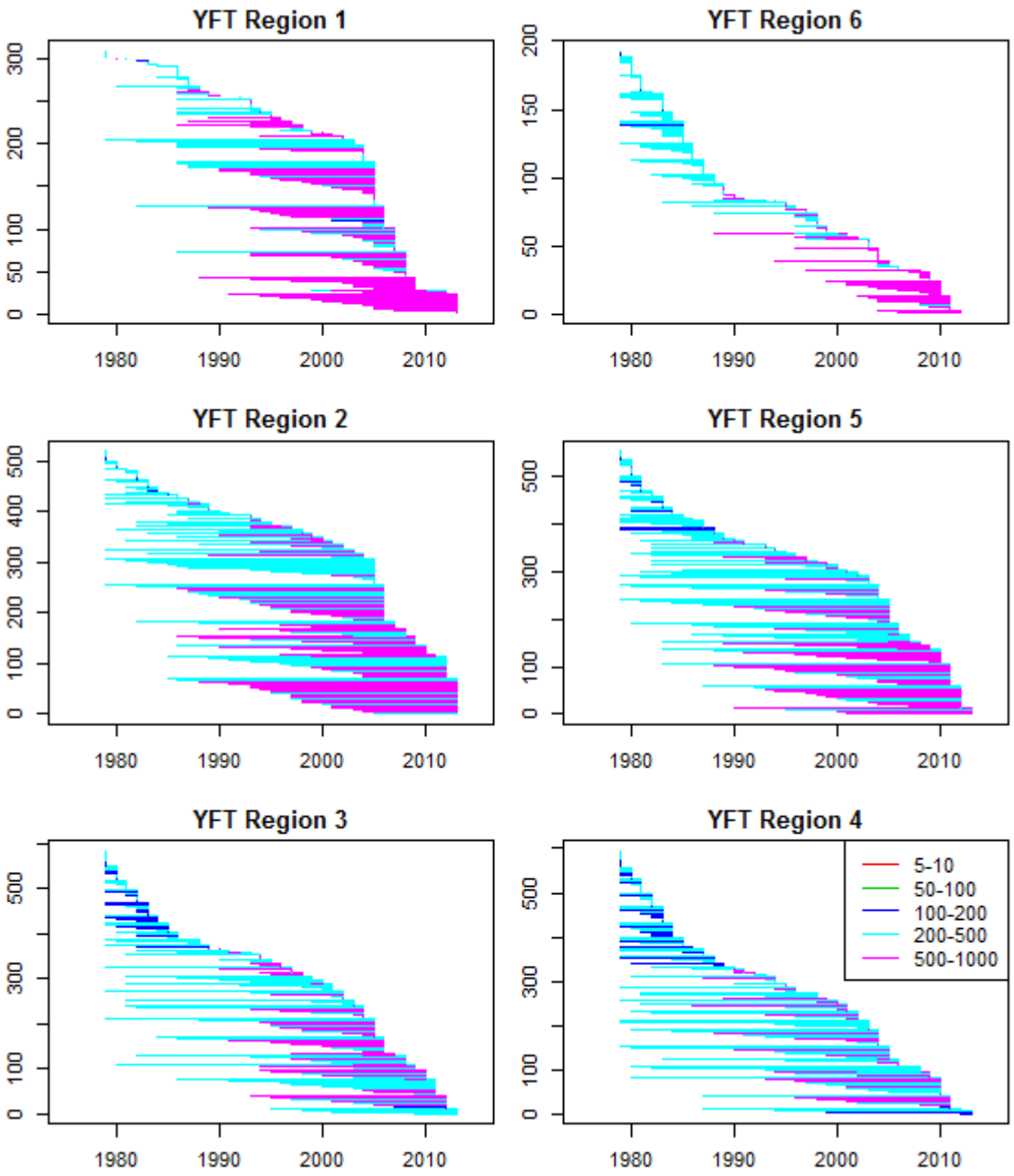

Figure 11: Vessel sorted by year of last set and first set, with a line between the years of first and last set by each vessel. Vessels are coloured by tonnage.

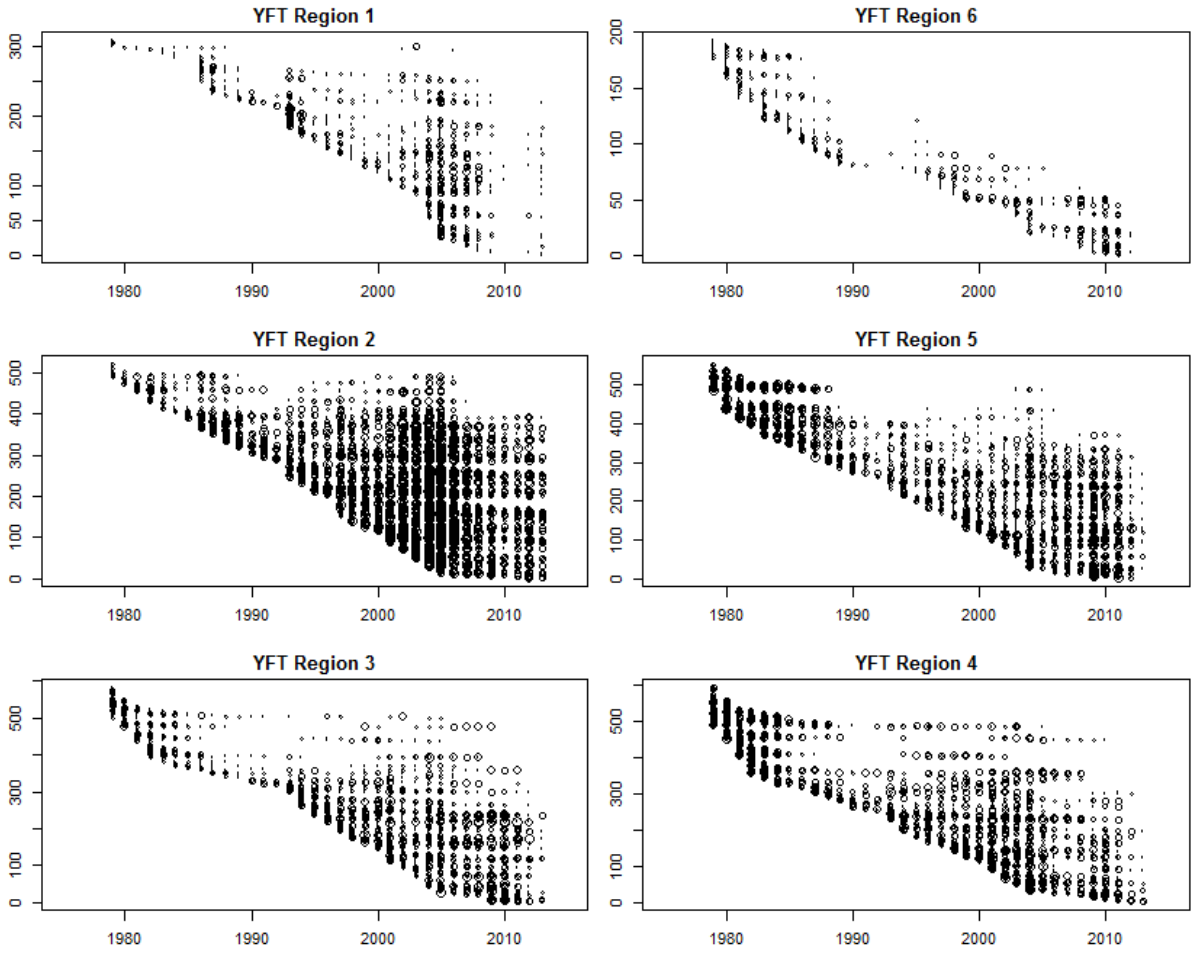

Figure 12: Vessel sorted by year of first set and last set, with circles proportional to number of sets by each vessel.

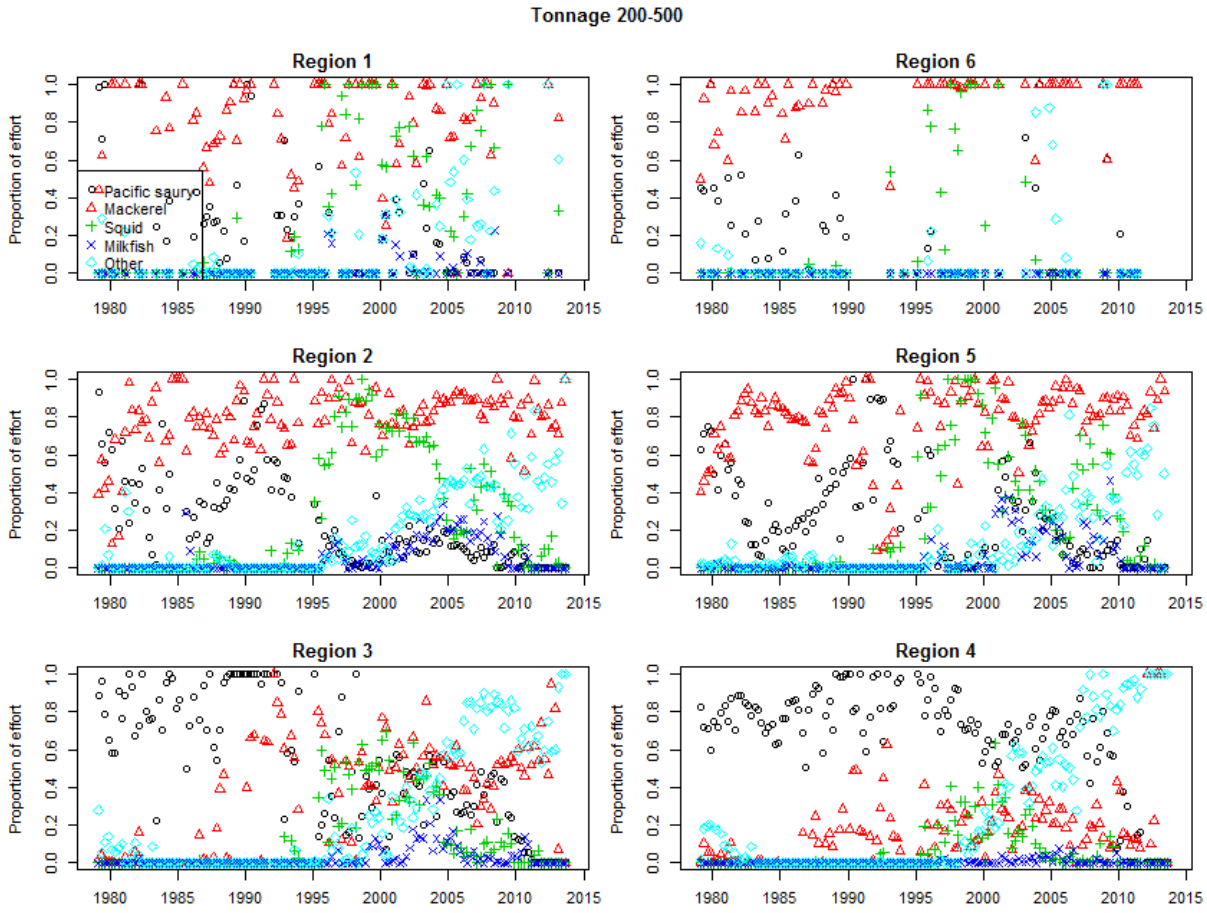

Figure 13: Proportions of effort reporting each bait type, by year-qtr and region, for vessels between 200 and 500 tonnes.

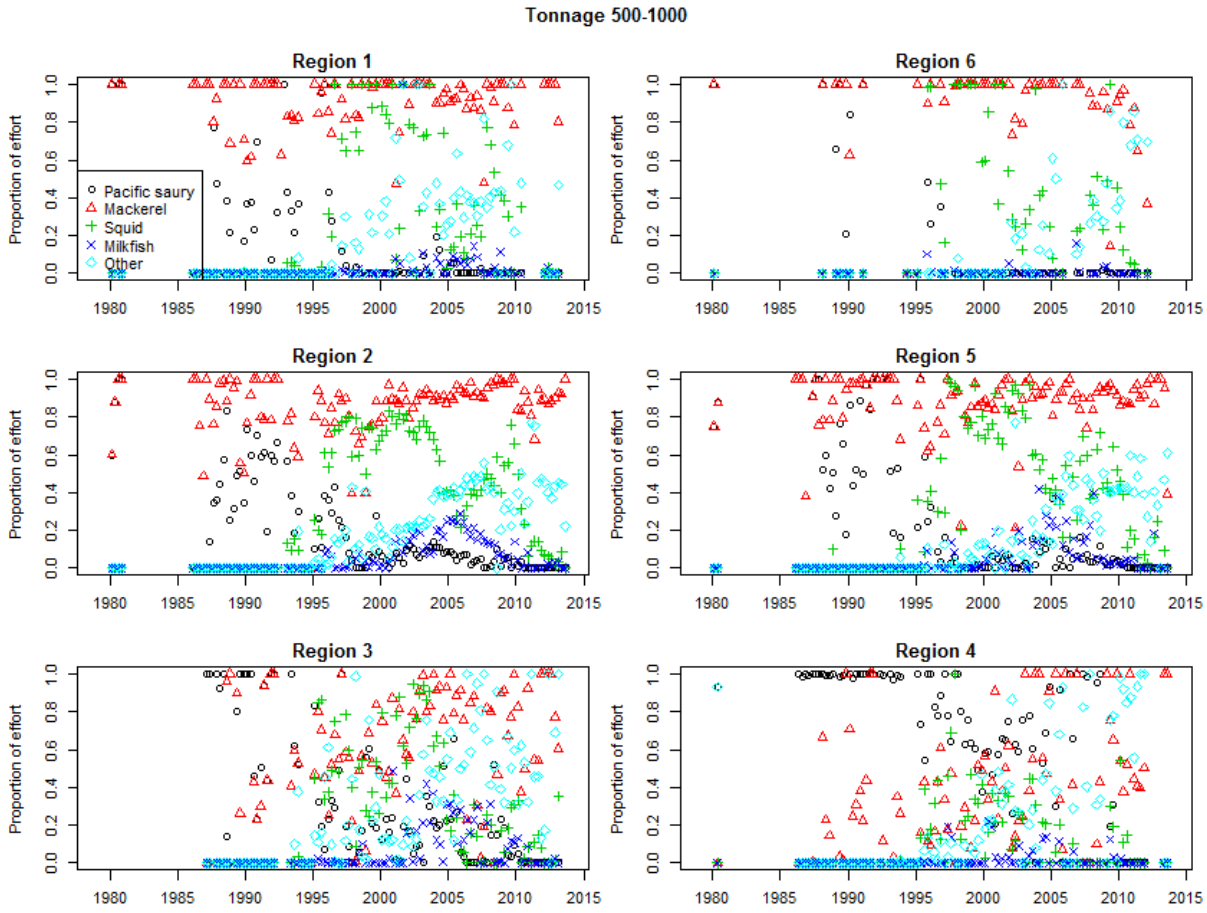

Figure 14: Proportions of effort reporting each bait type, by year-qtr and region, for vessels between 500 and 1000 tonnes.

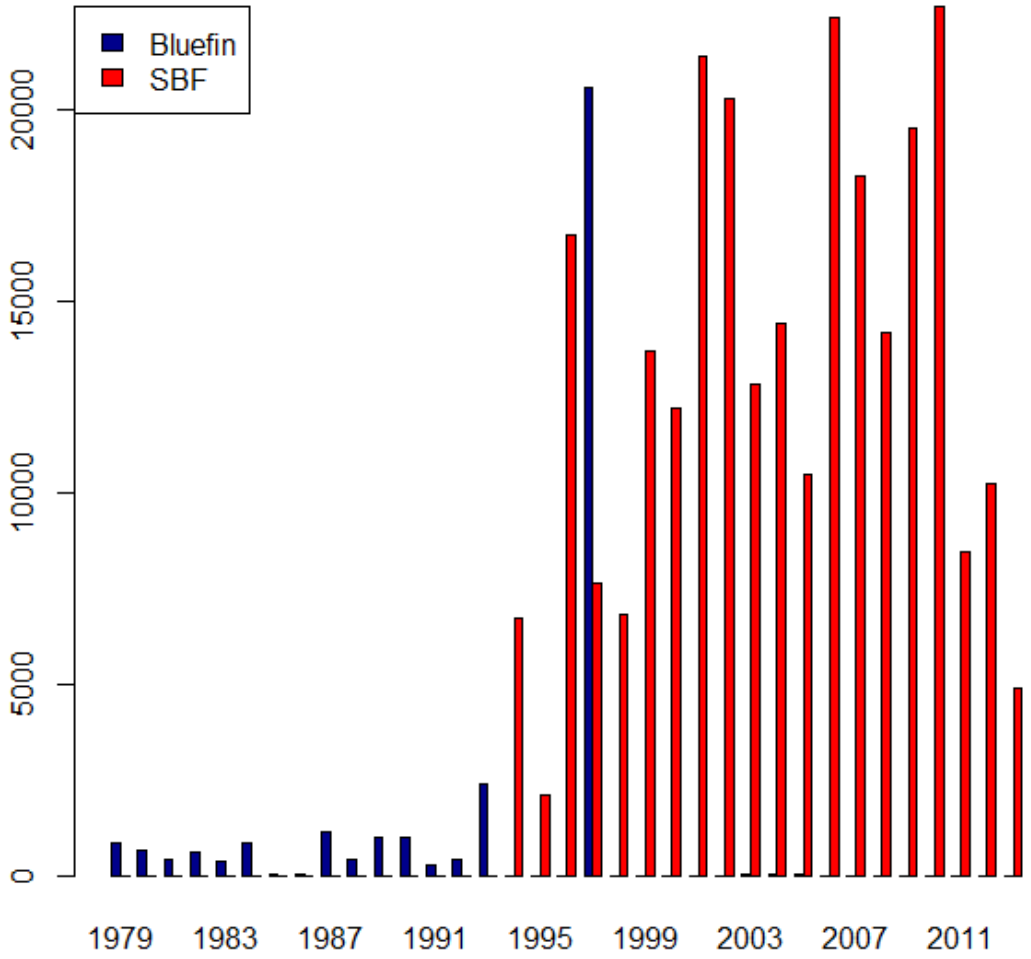

Figure 15: Catch in numbers reported as SBF (southern bluefin tuna) or 'bluefin', by year. The SBF category was introduced in 1994.

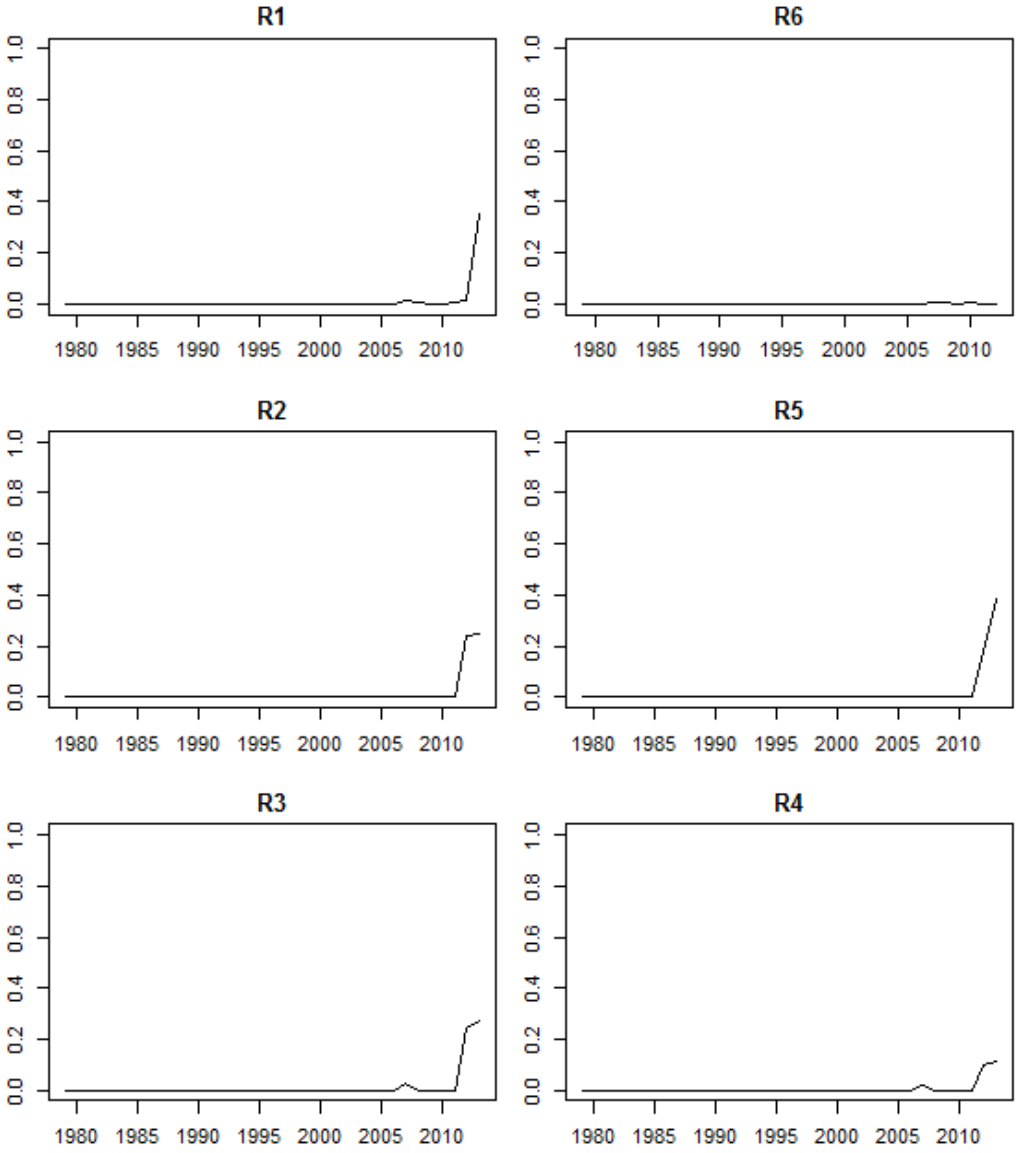

Figure 16: Proportions of sets designated by OFDC as outliers by according to current data cleaning procedures.

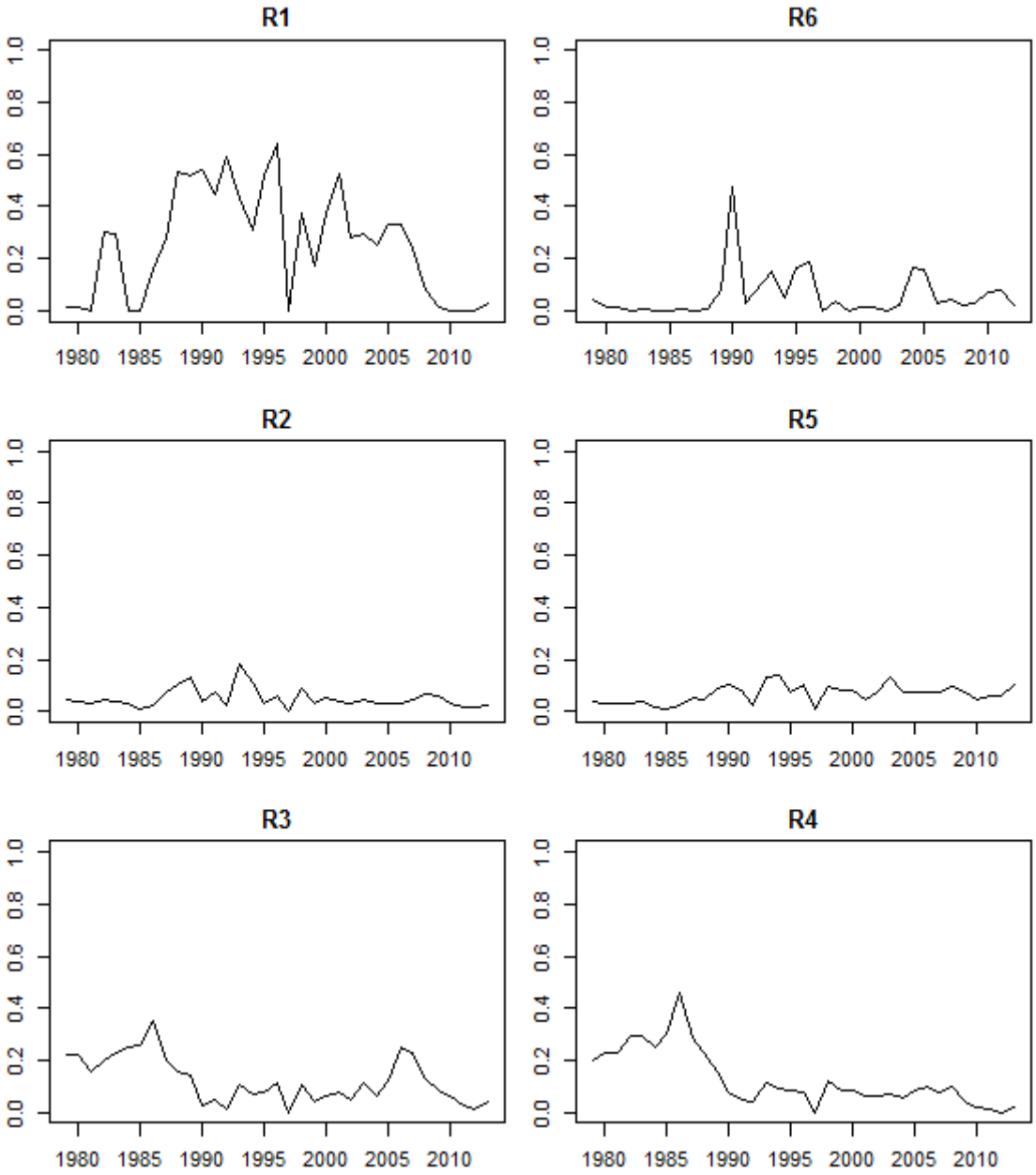

Figure 17: Proportion of sets reported as catching one species only, by year and region.

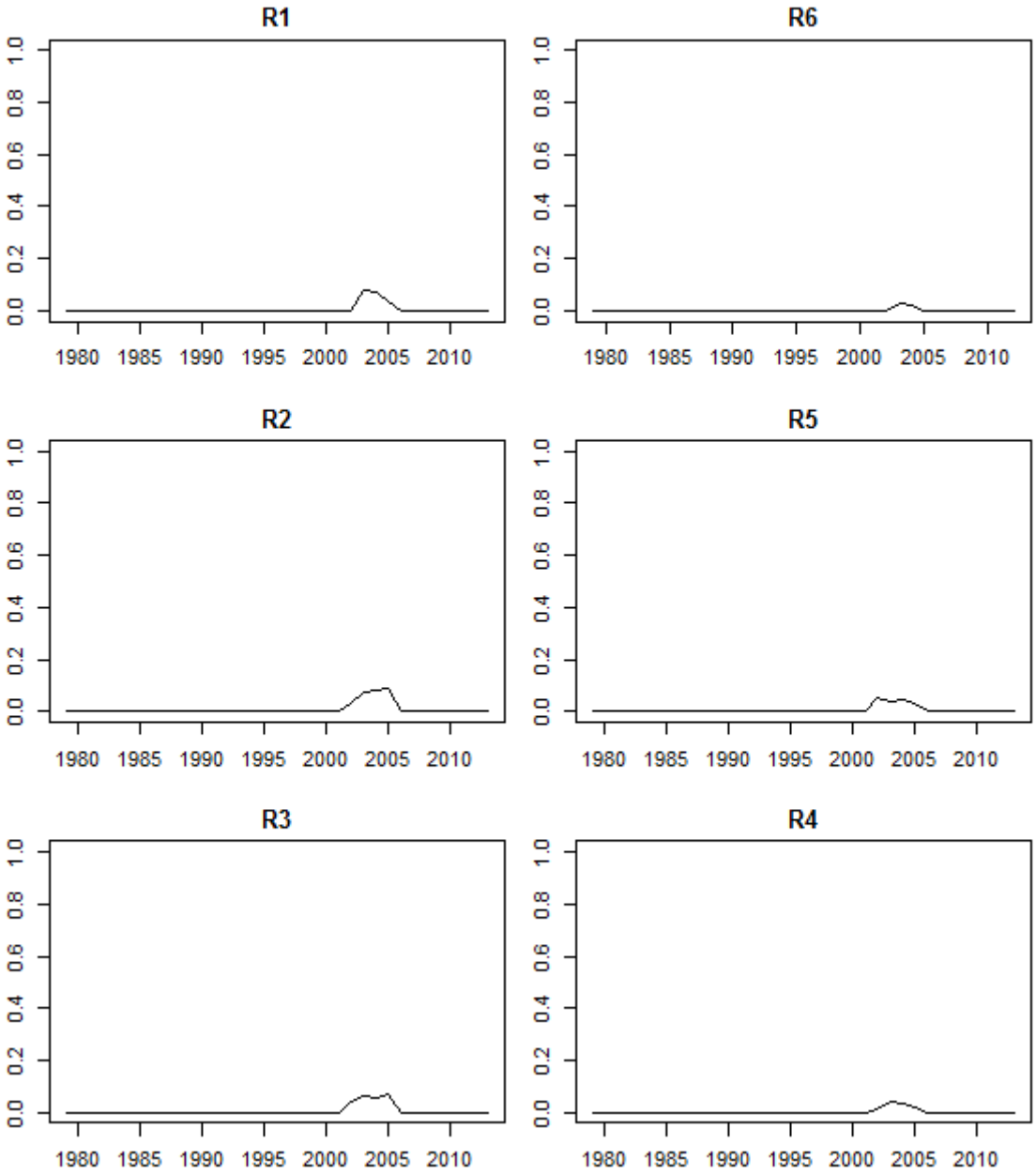

Figure 18: Proportion of sets by vessels designated by OFDC as flag of convenience vessels, by year and region.

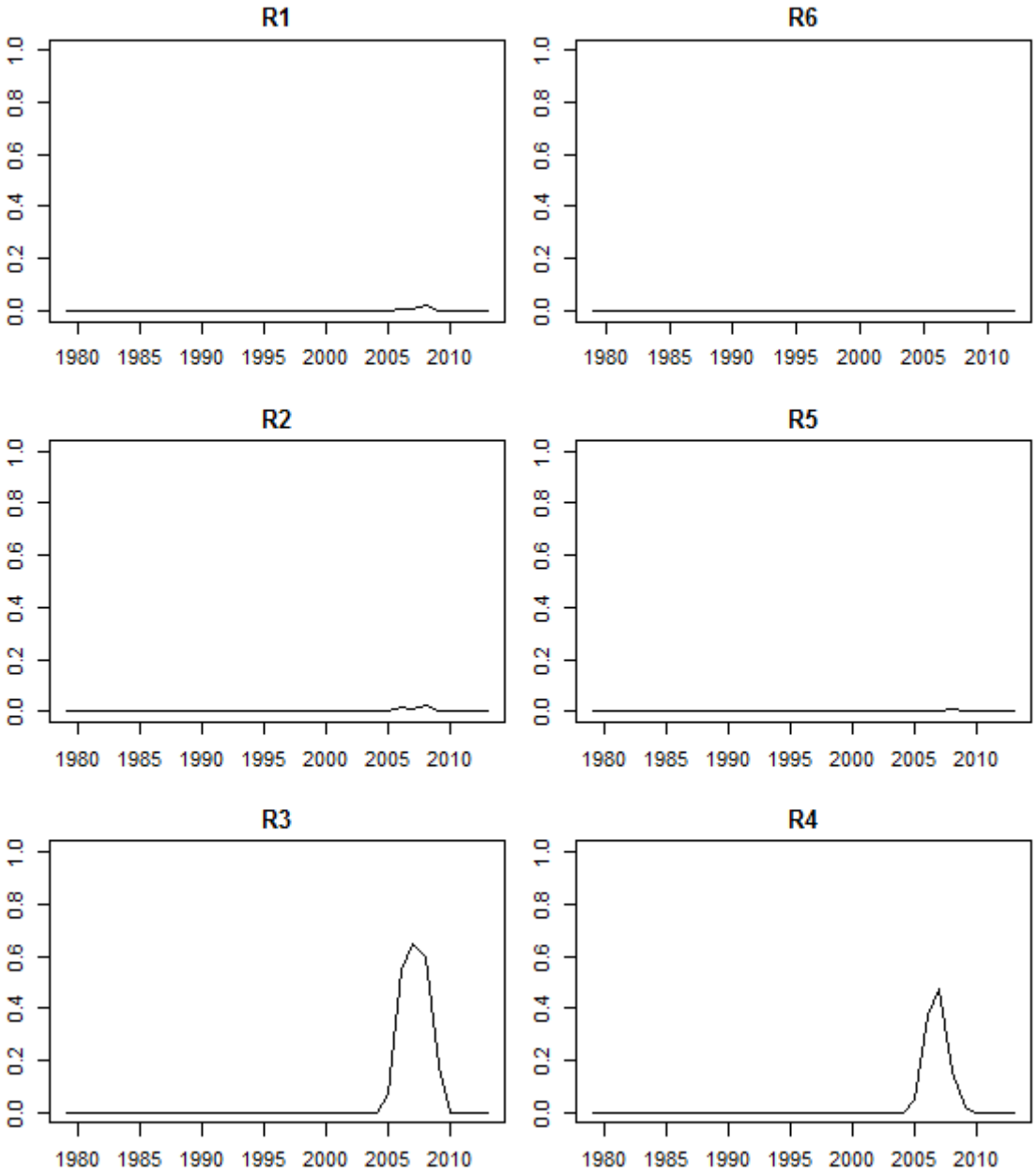

Figure 19: Proportion of sets by vessels designated by OFDC as oilfish vessels, by year and region.

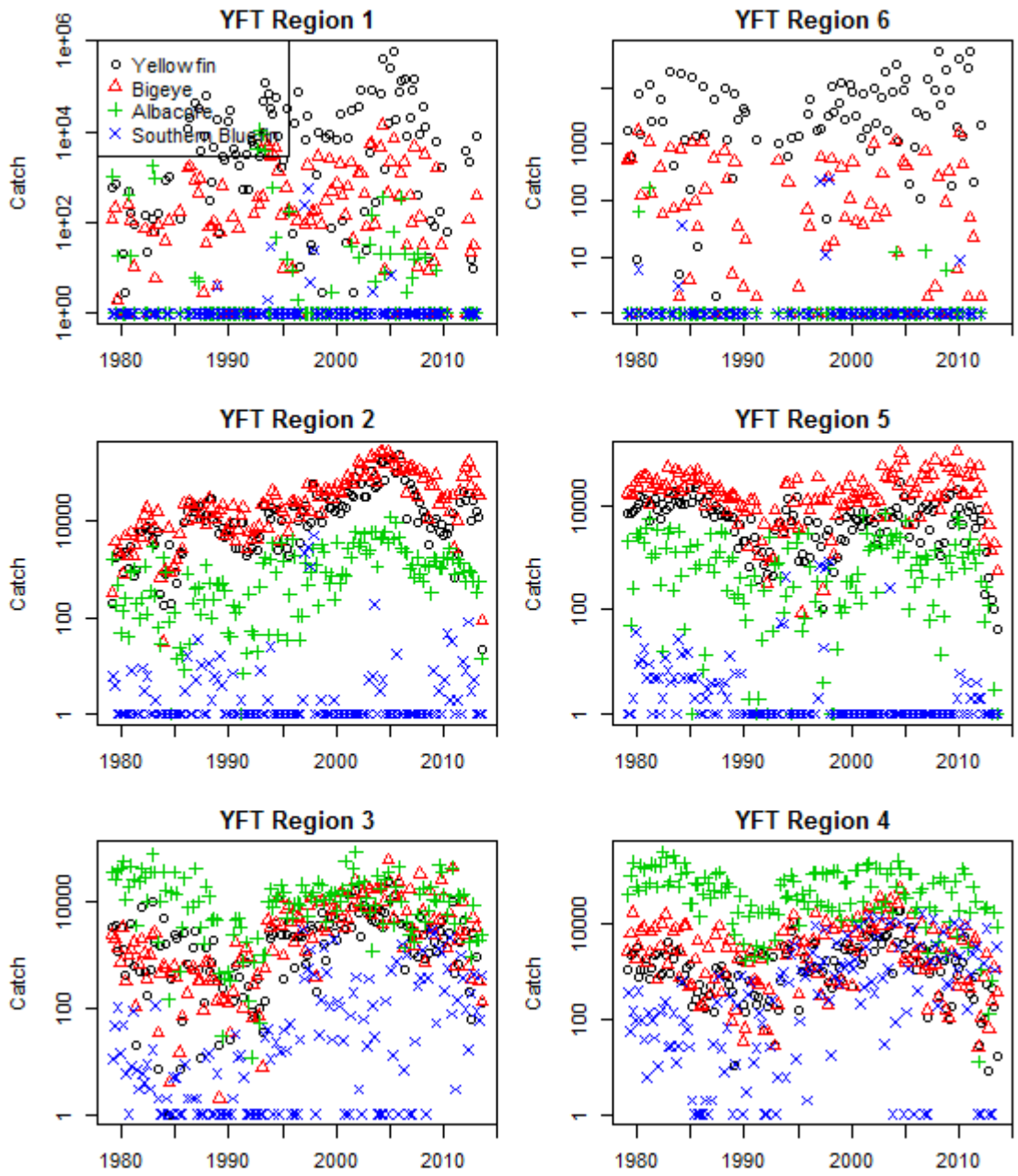

Figure 20: Catch in numbers plotted on log scale, by year-qtr and region for bigeye, yellowfin, albacore and SBT.

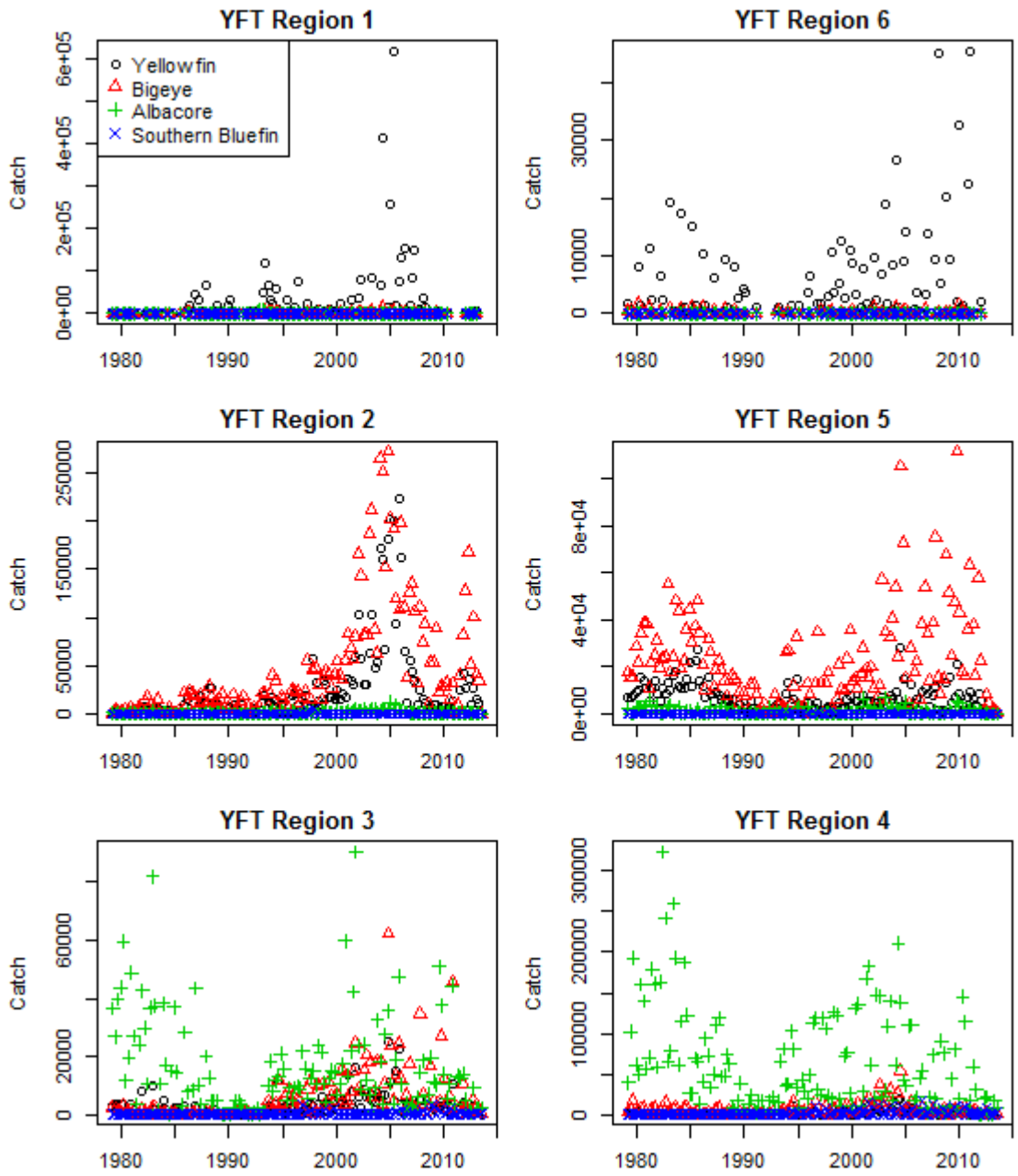

Figure 21: Catch in numbers plotted on nominal scale, by year-qtr and region for bigeye, yellowfin, albacore and SBT

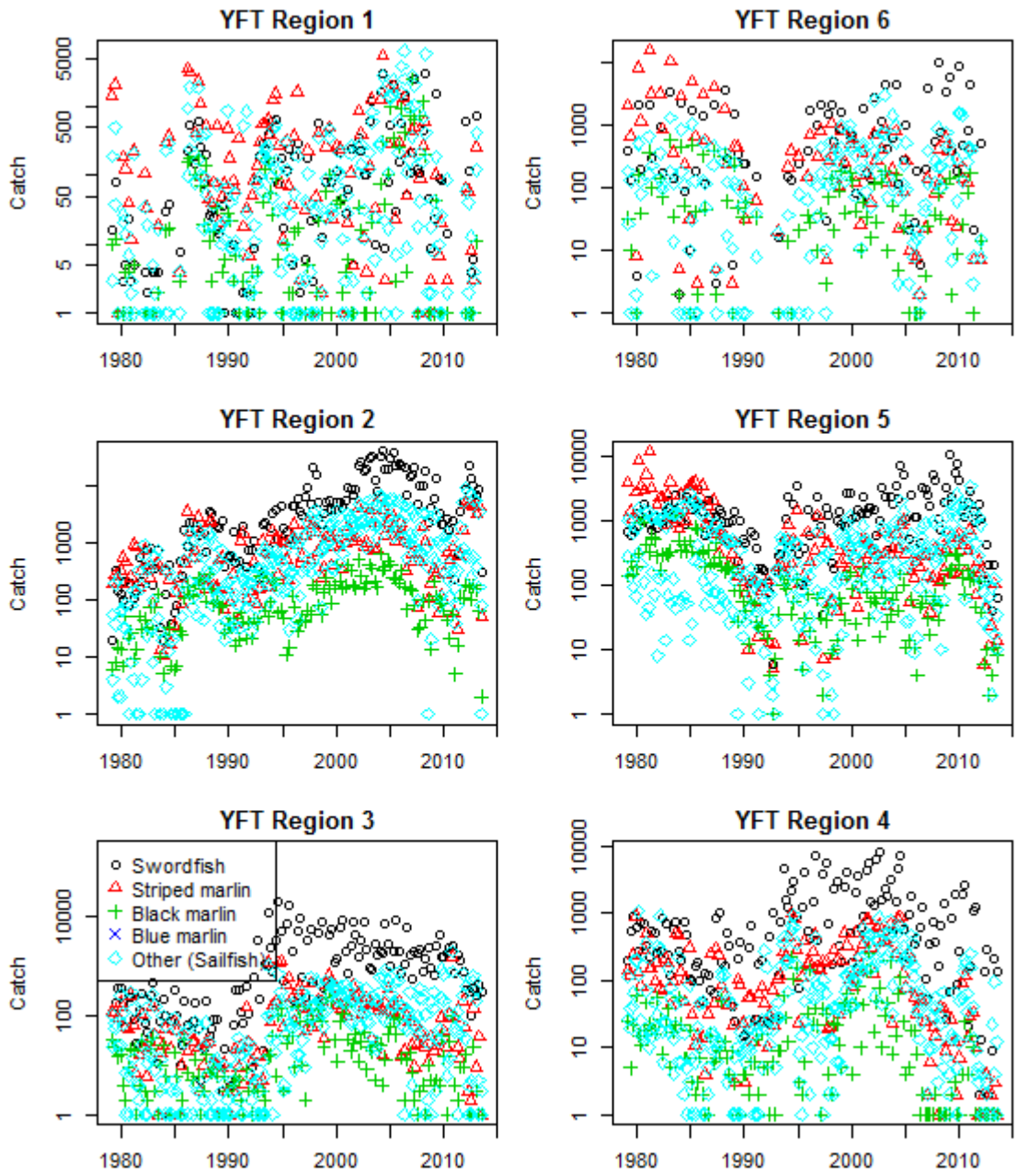

Figure 22: Catch in numbers plotted on log scale, by year-qtr and region for swordfish, striped marlin, black marlin blue marlin and other billfish.

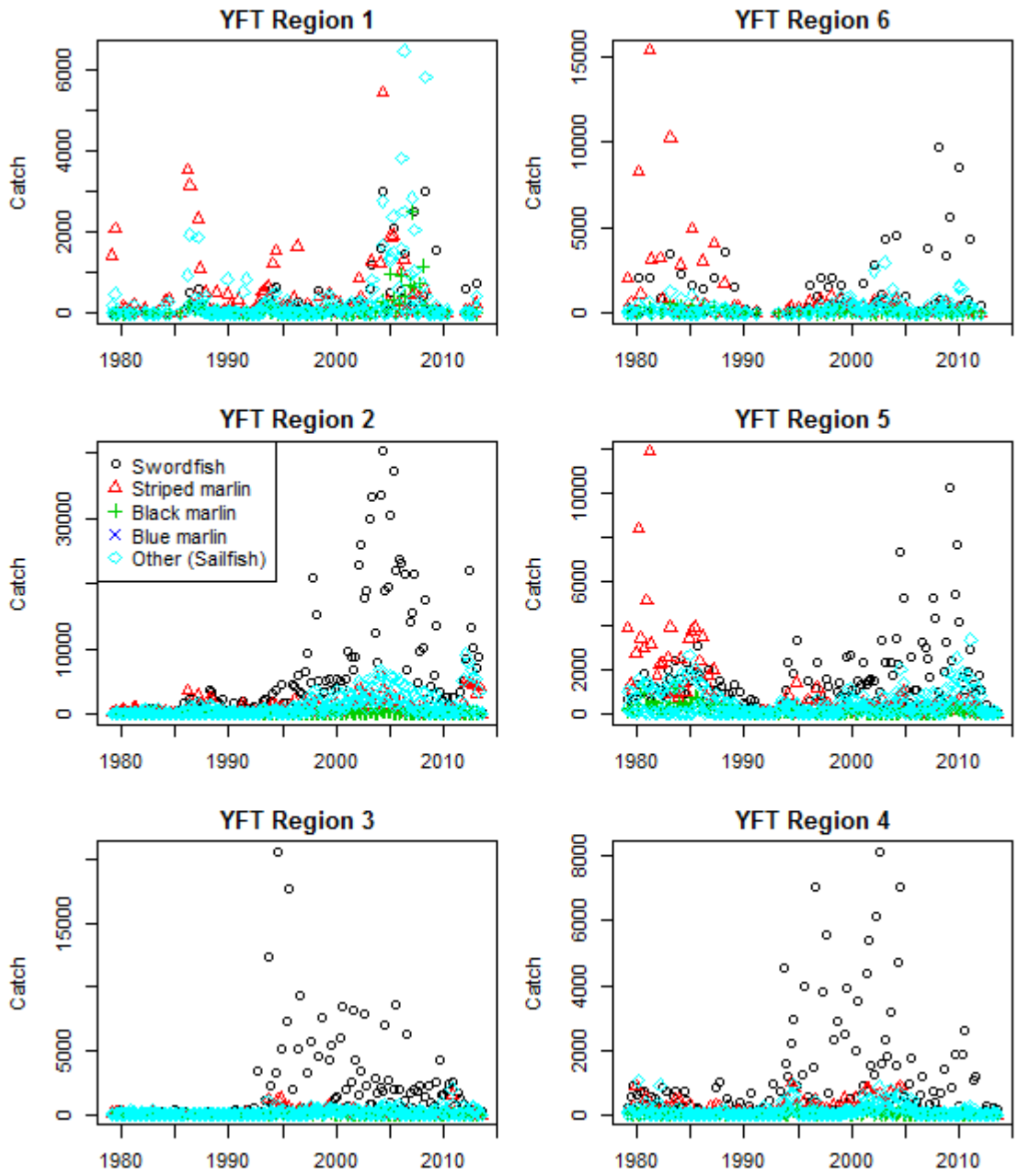

Figure 23: Catch in numbers plotted on nominal scale, by year-qtr and region for swordfish, striped marlin, black marlin blue marlin and other billfish.

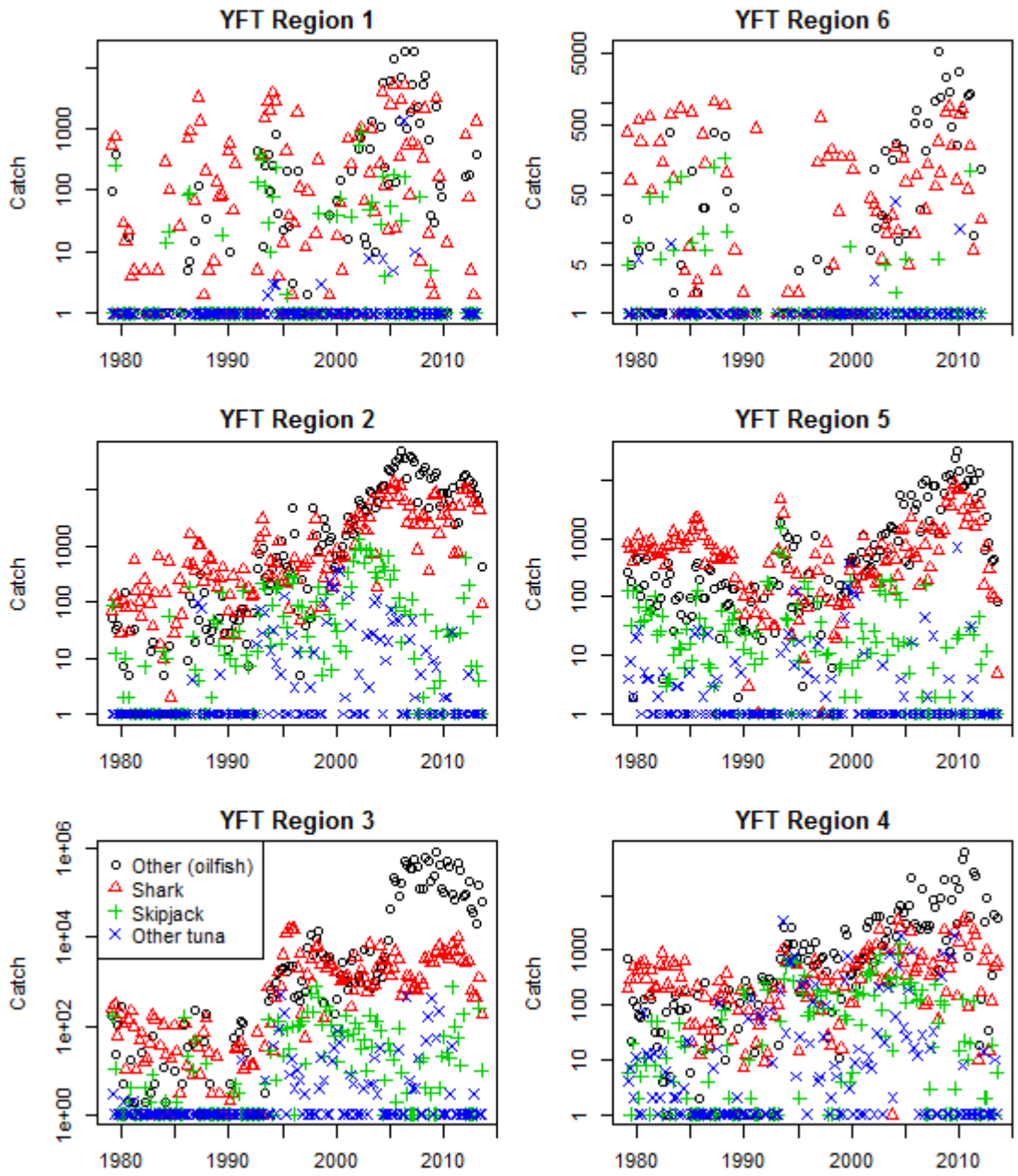

Figure 24: Catch in numbers plotted on log scale, by year-qtr and region for Other species (mostly oilfish and escolar), shark, skipjack, and other tunas.

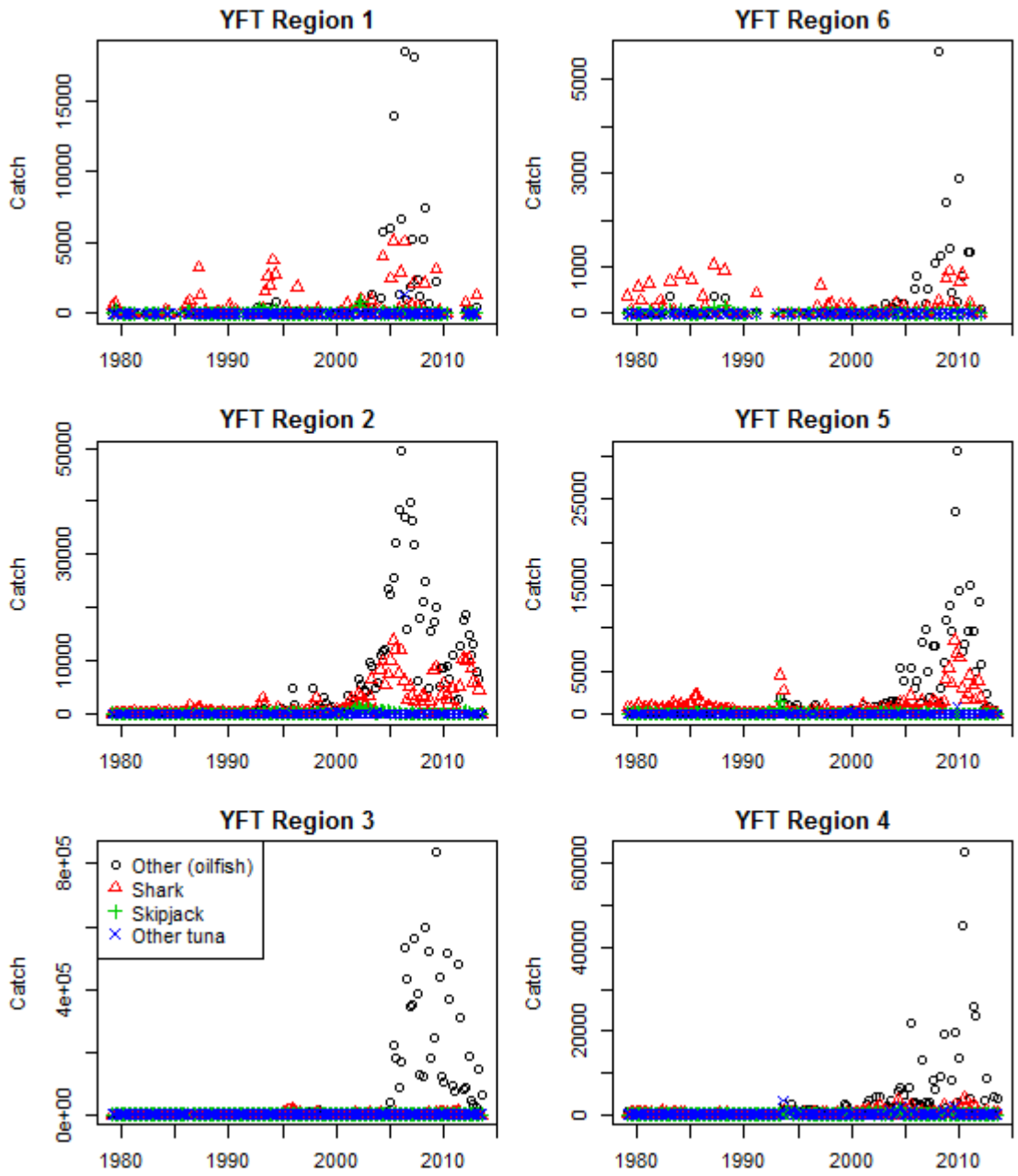

Figure 25: Catch in numbers plotted on nominal scale, by year-qtr and region for Other species (mostly oilfish and escolar), shark, skipjack, and other tunas.

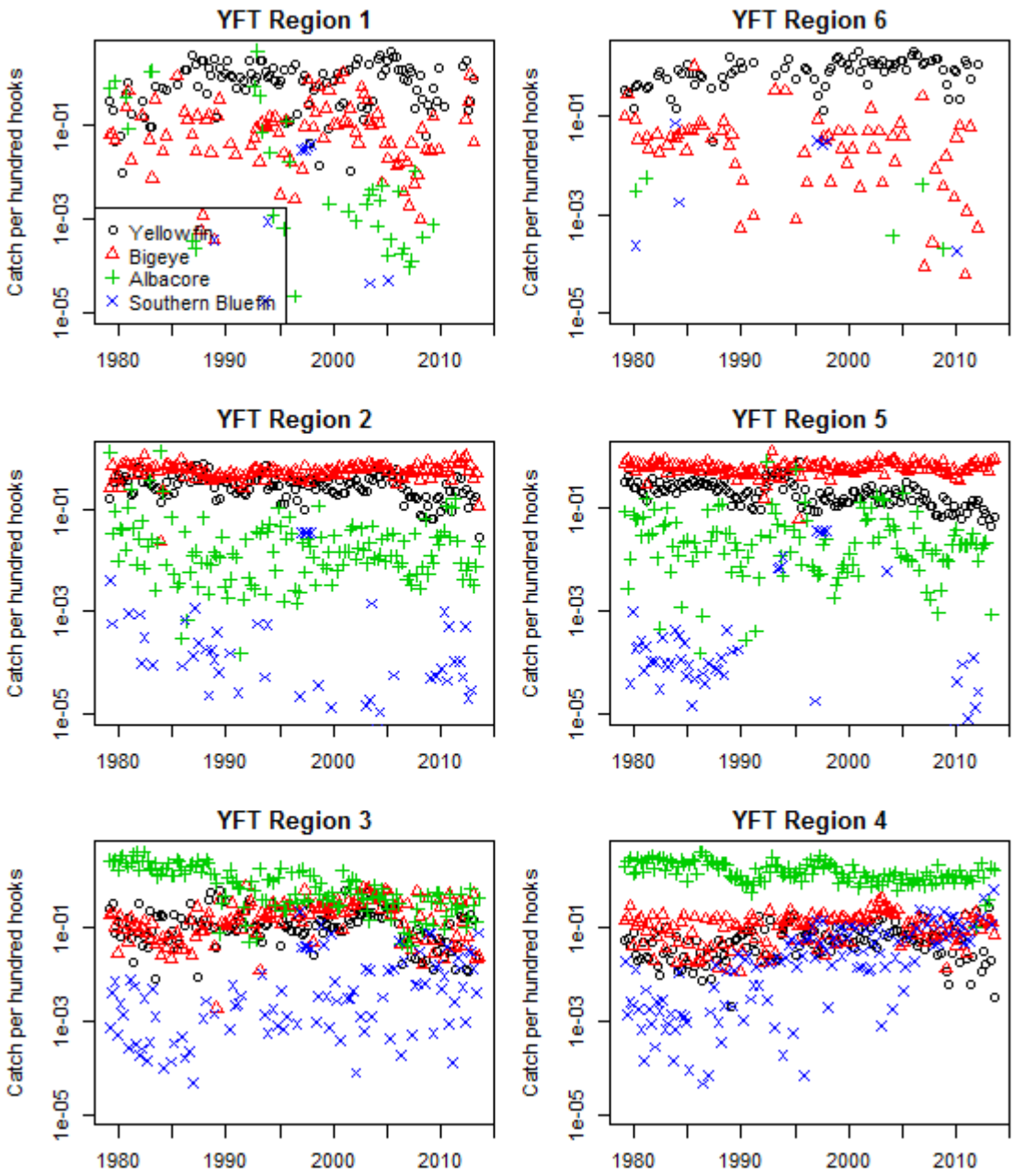

Figure 26: CPUE plotted on log scale, by year-qtr and region for yellowfin, bigeye, albacore, and SBT.

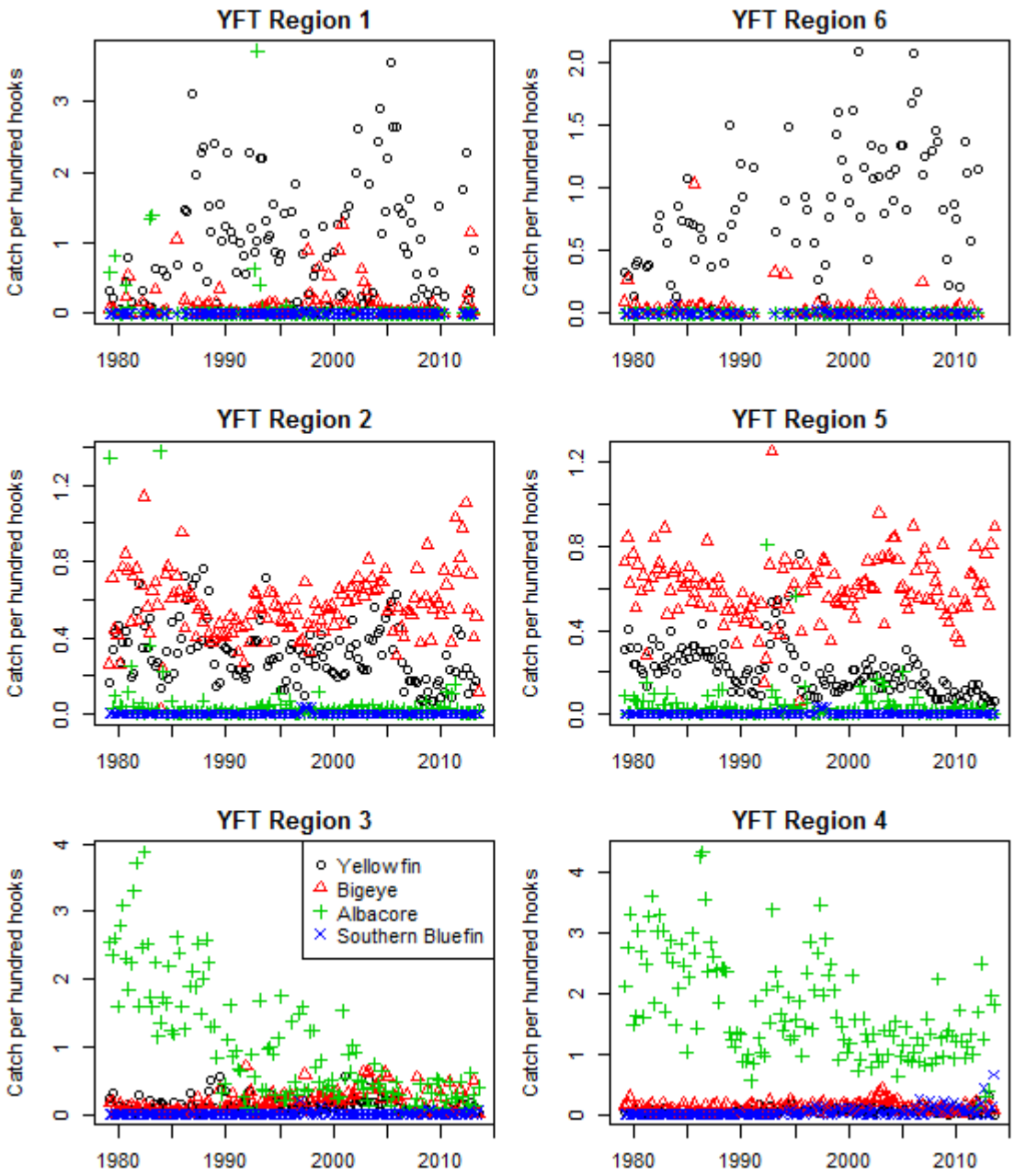

Figure 27: CPUE plotted on nominal scale, by year-qtr and region for yellowfin, bigeye, albacore, and SBT

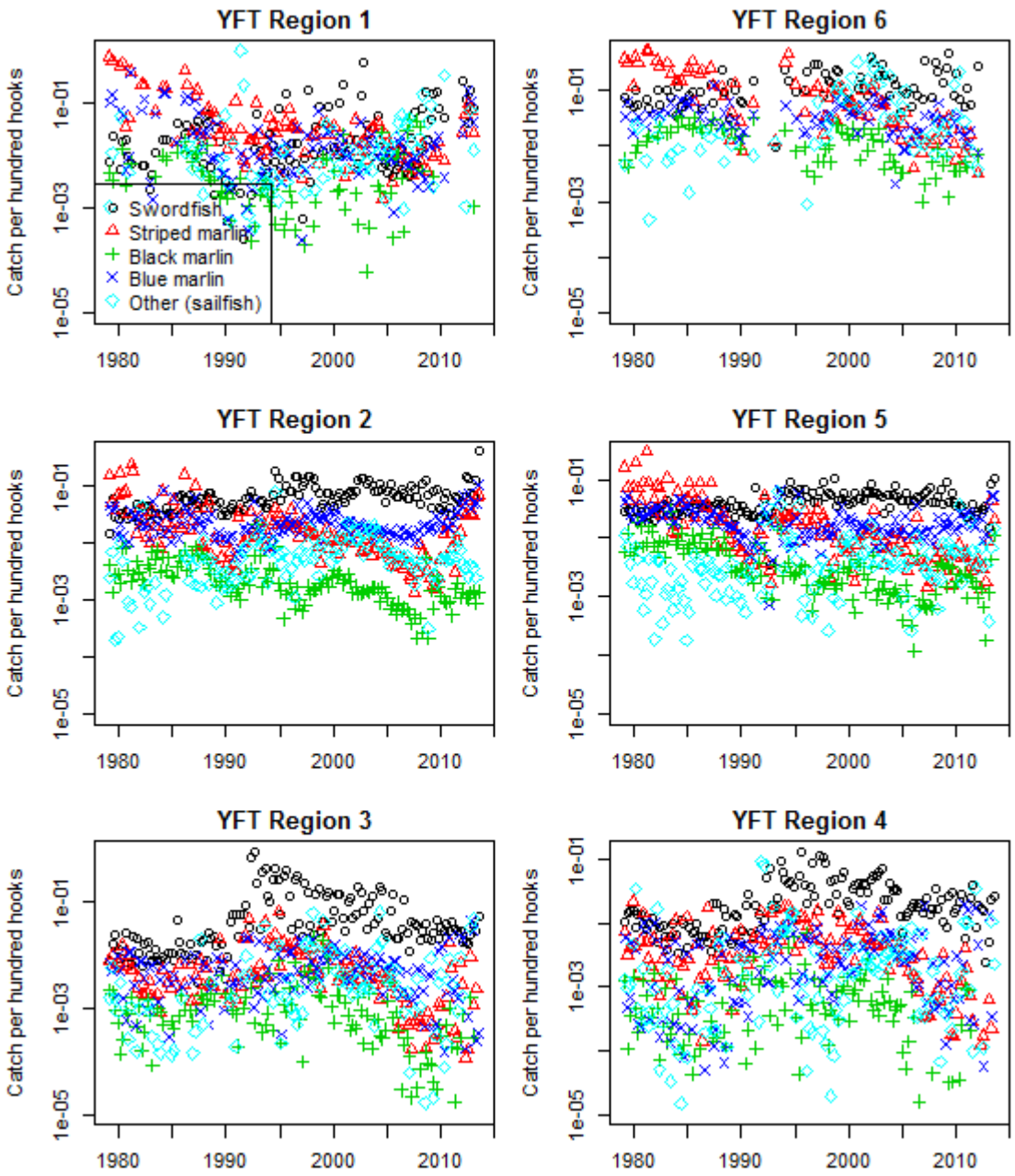

Figure 28: CPUE plotted on log scale, by year-qtr and region for billfish.

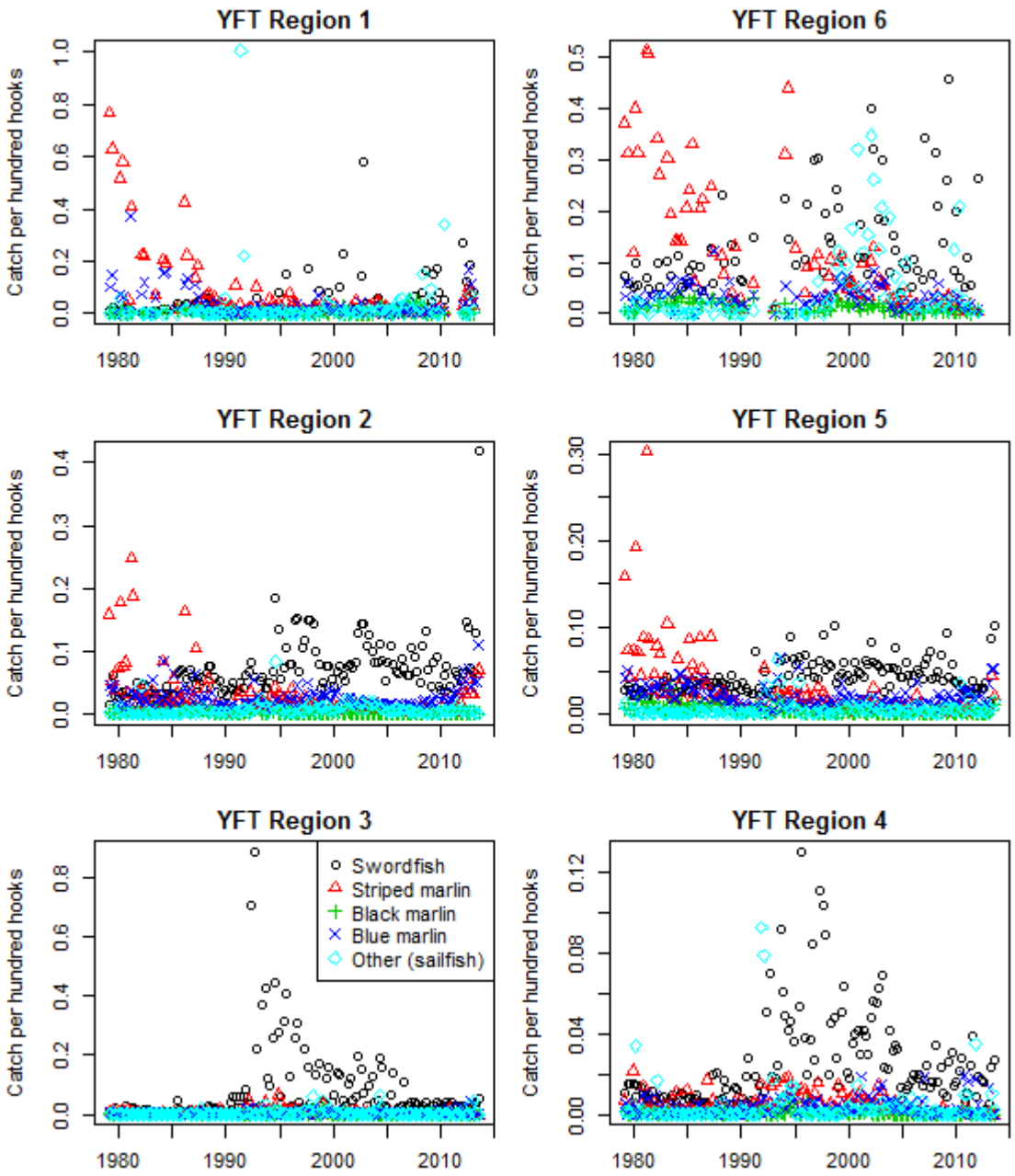

Figure 29: CPUE plotted on nominal scale, by year-qtr and region for billfish.

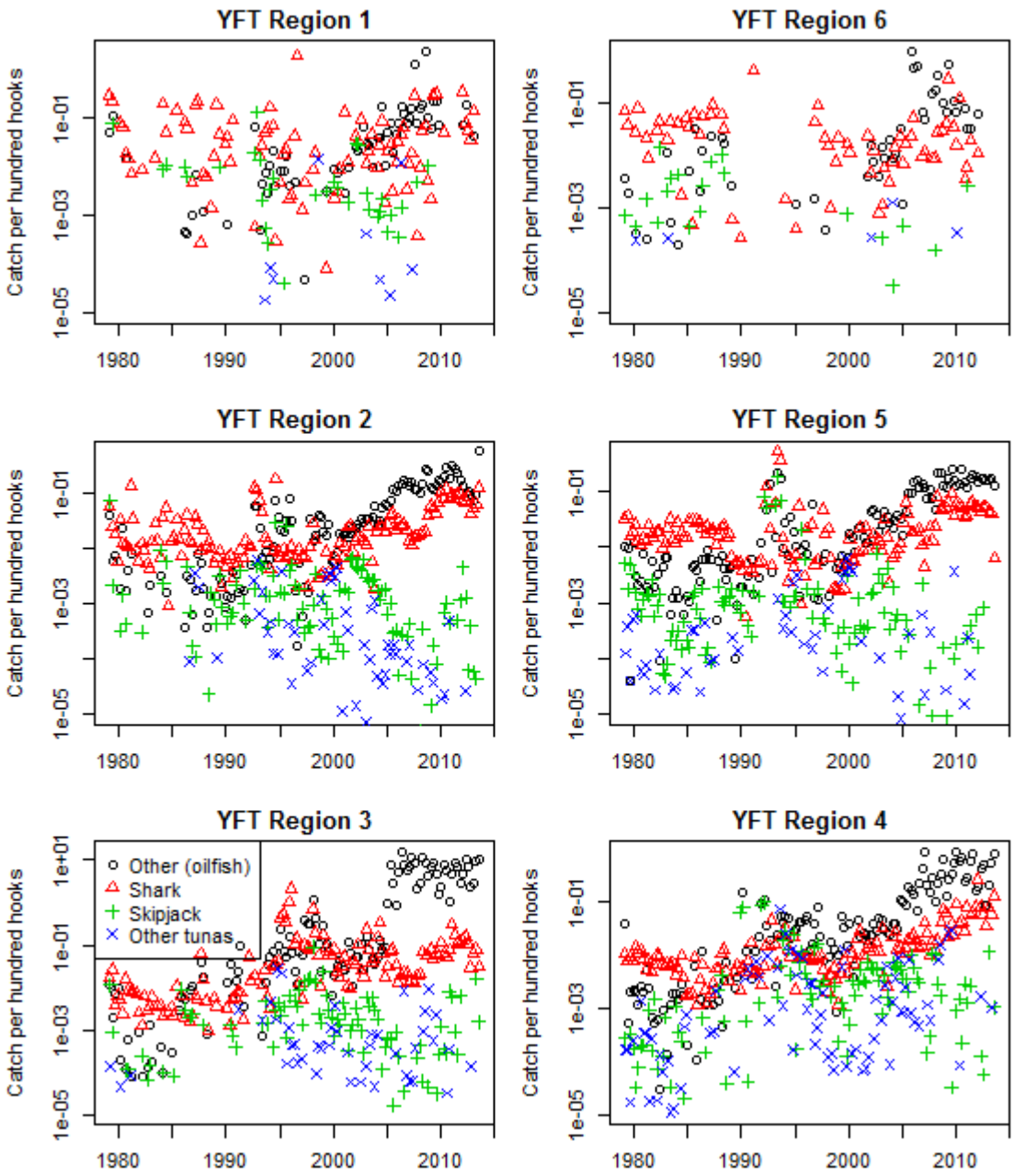

Figure 30: CPUE plotted on log scale, by year-qtr and region for oilfish, shark, skipjack, and other tunas.

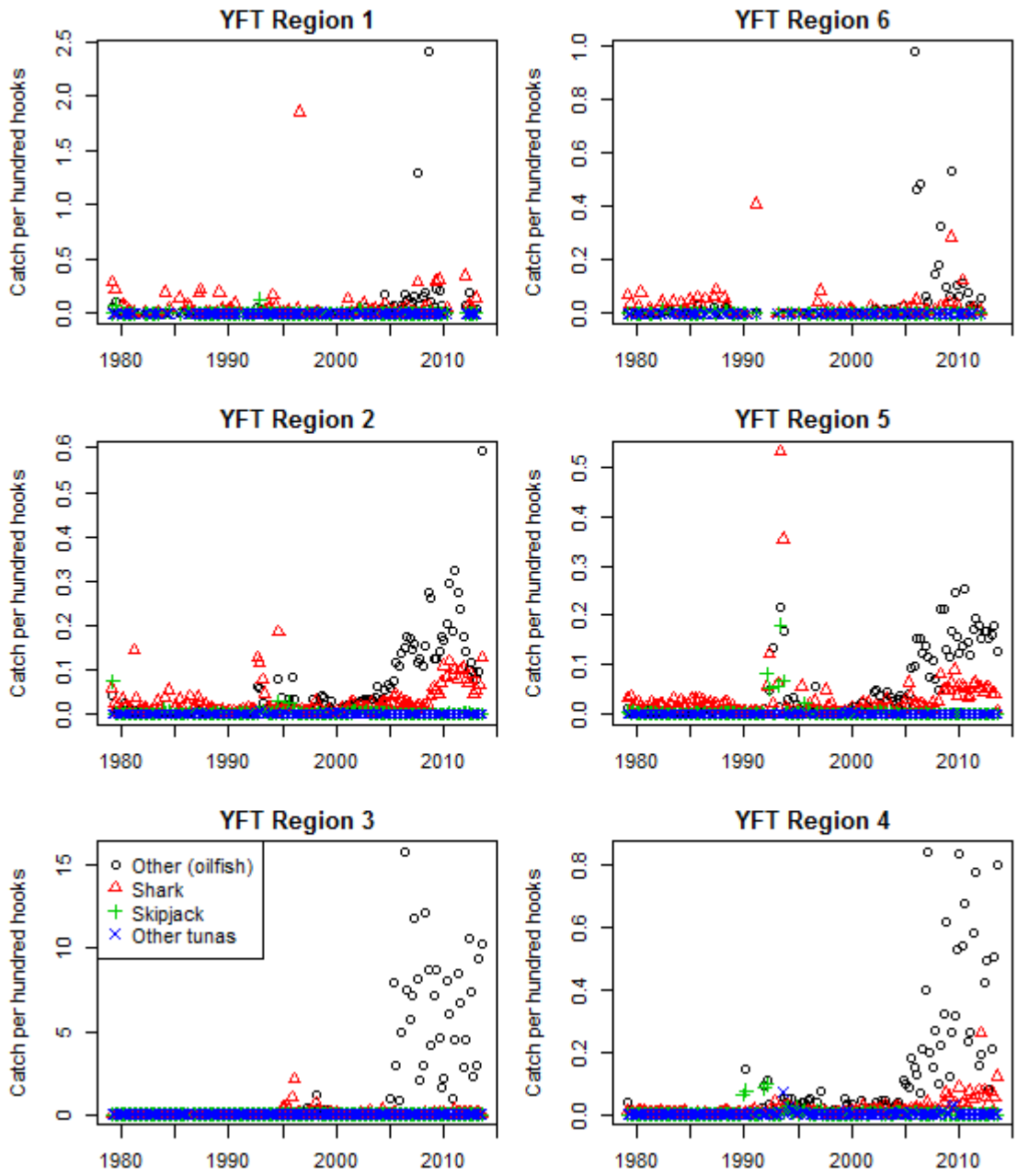

Figure 31: CPUE plotted on nominal scale, by year-qtr and region for oilfish, shark, skipjack, and other tunas.

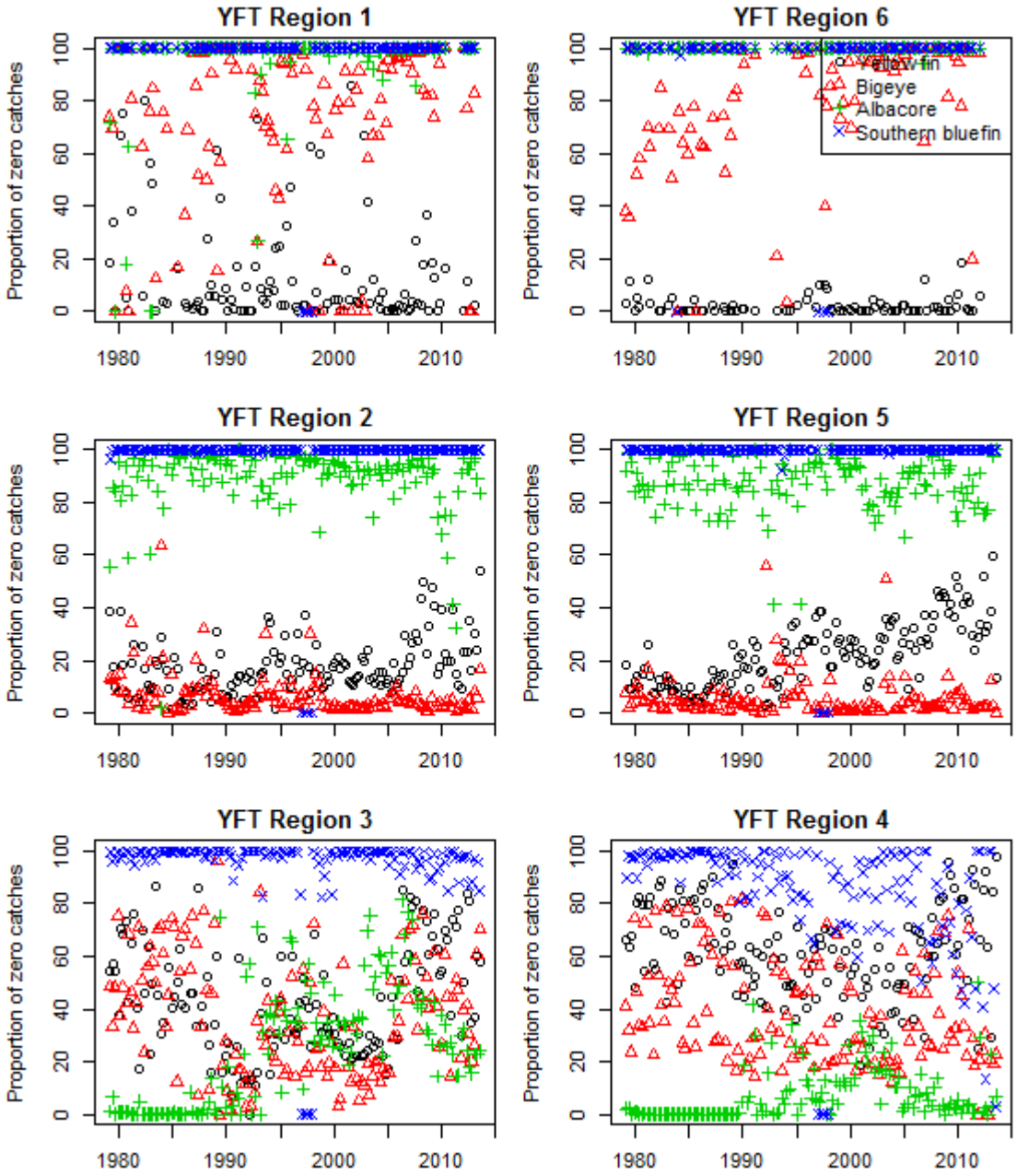

Figure 32: Proportion of zero catches by year-qtr and region for bigeye, yellowfin, albacore, and SBT.

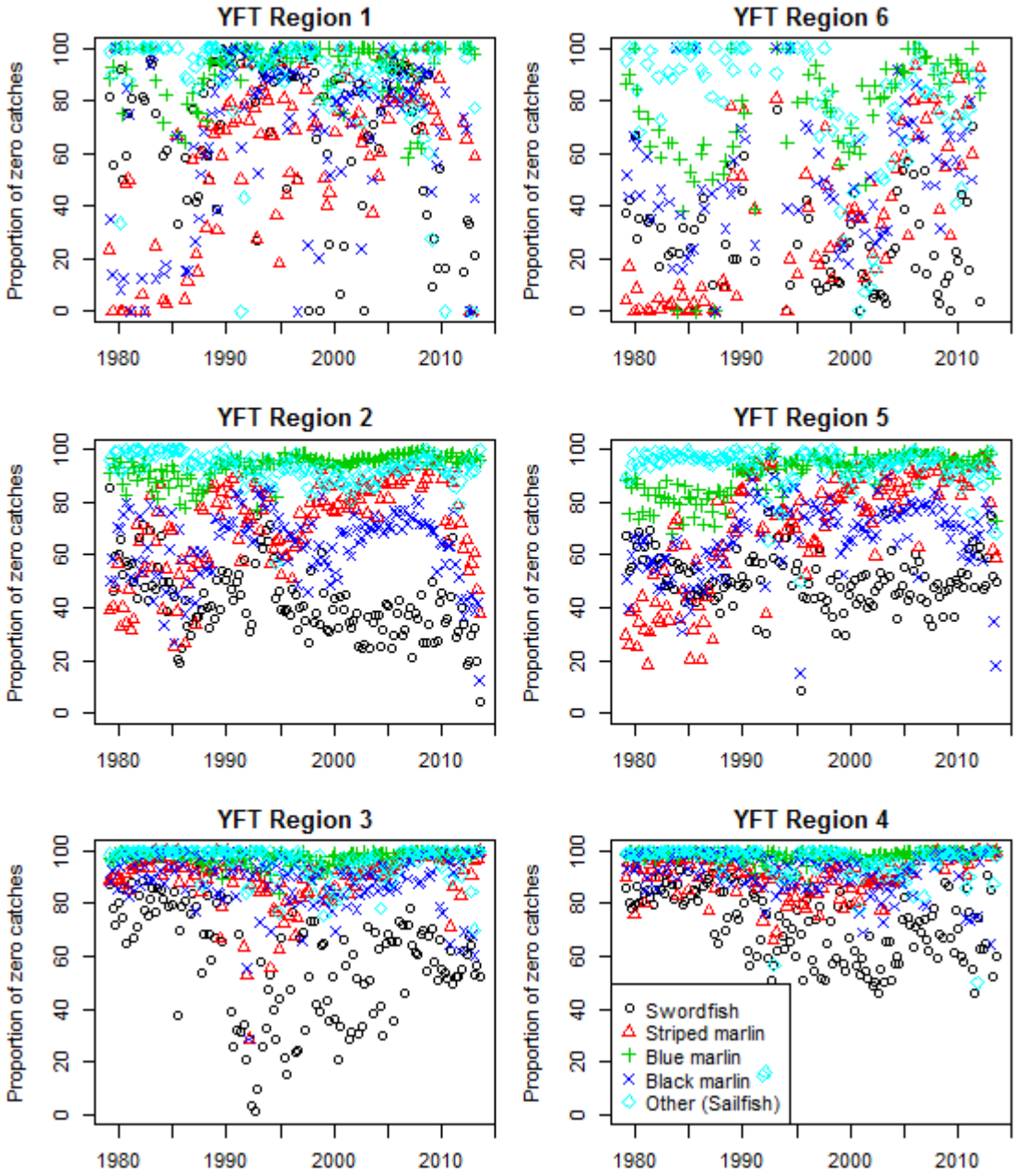

Figure 33: Proportion of zero catches by year-qtr and region for billfish.

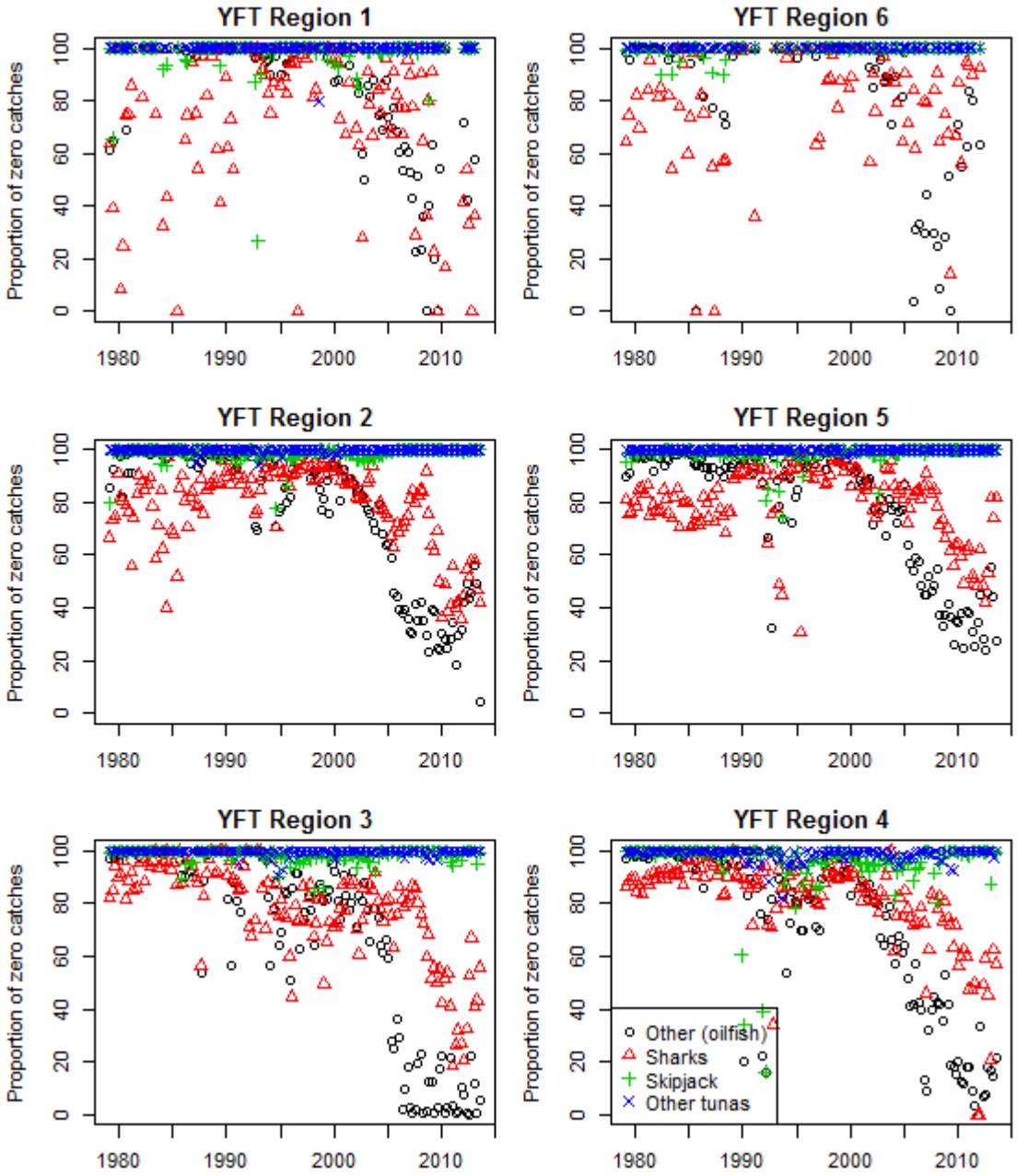

Figure 34: Proportion of zero catches by year-qtr and region for oilfish, shark, skipjack, and other tunas.

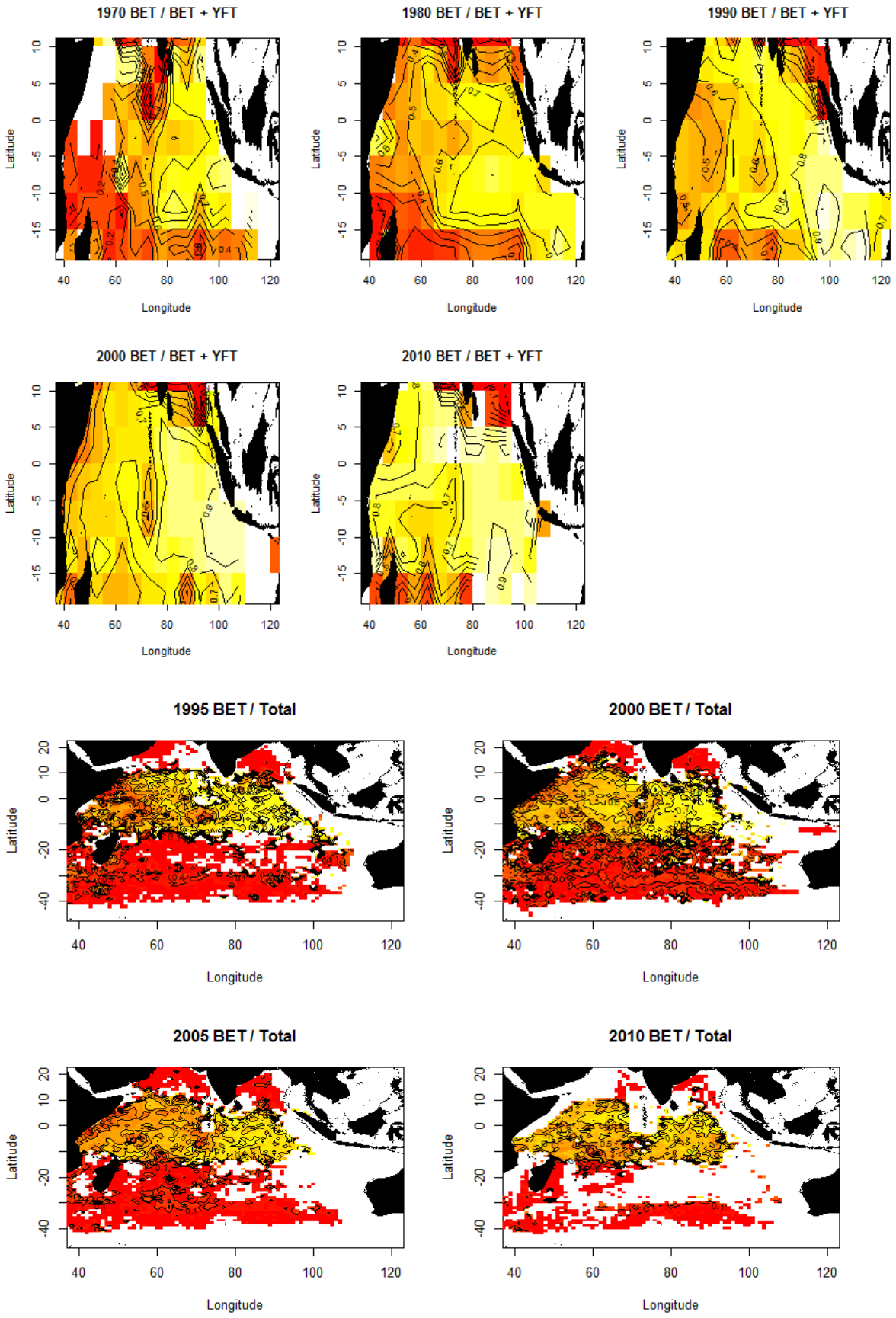

Figure 35: Proportion bigeye in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

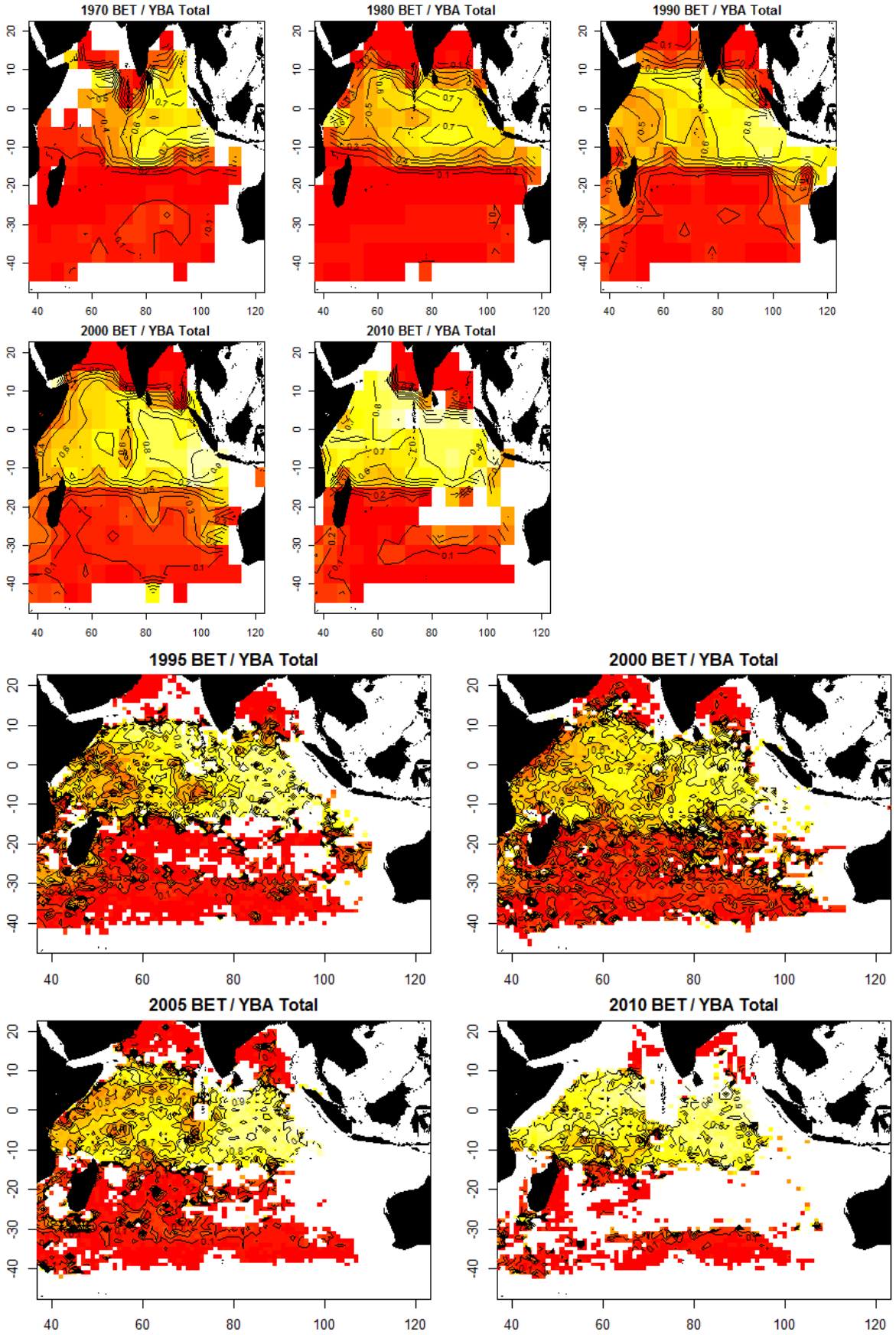

Figure 36: Proportion bigeye in the catch of yellowfin, bigeye, and albacore (YBA) by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

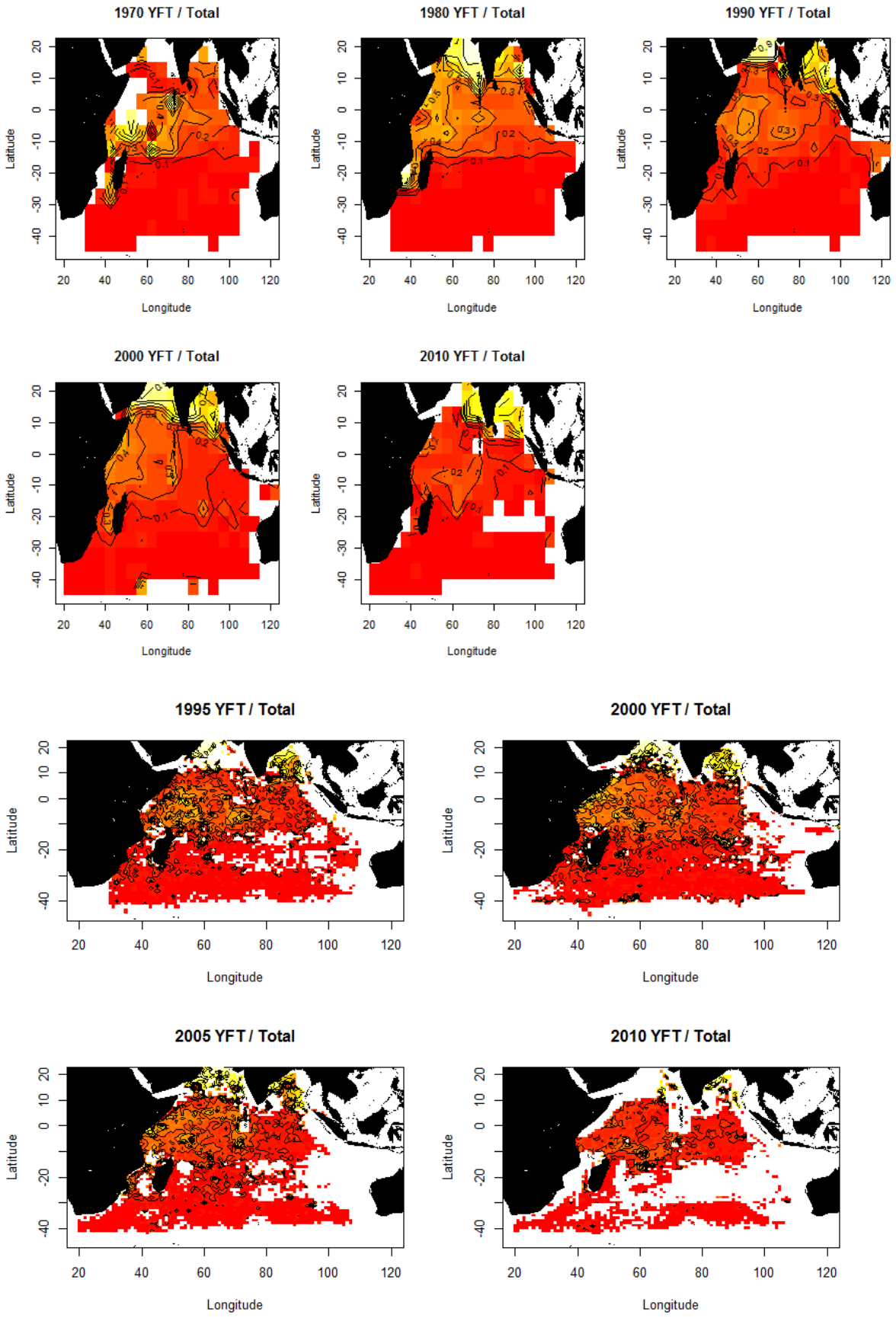

Figure 37: Proportion yellowfin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

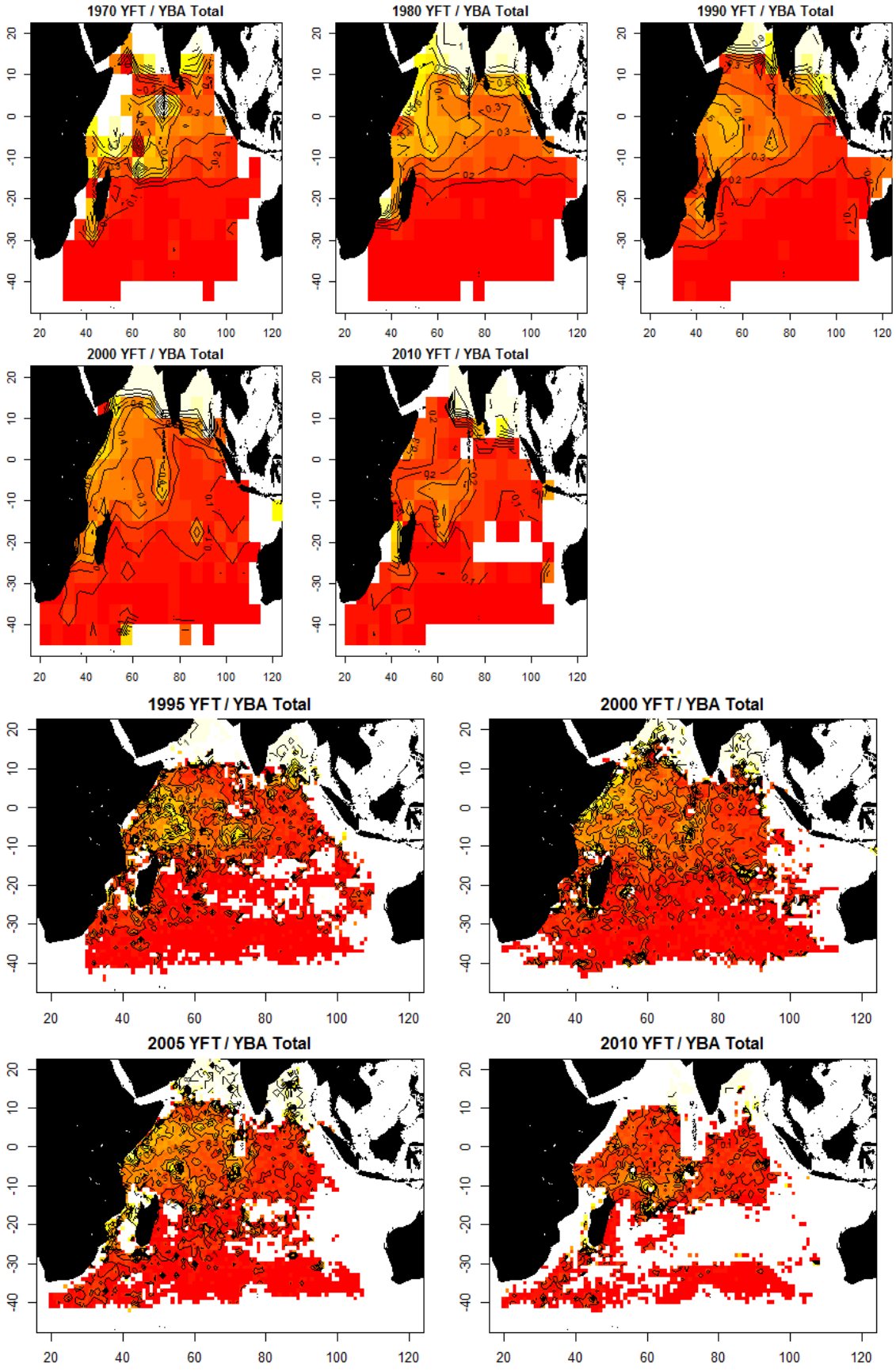

Figure 38: Proportion yellowfin in the catch of yellowfin, bigeye, and albacore (YBA) by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

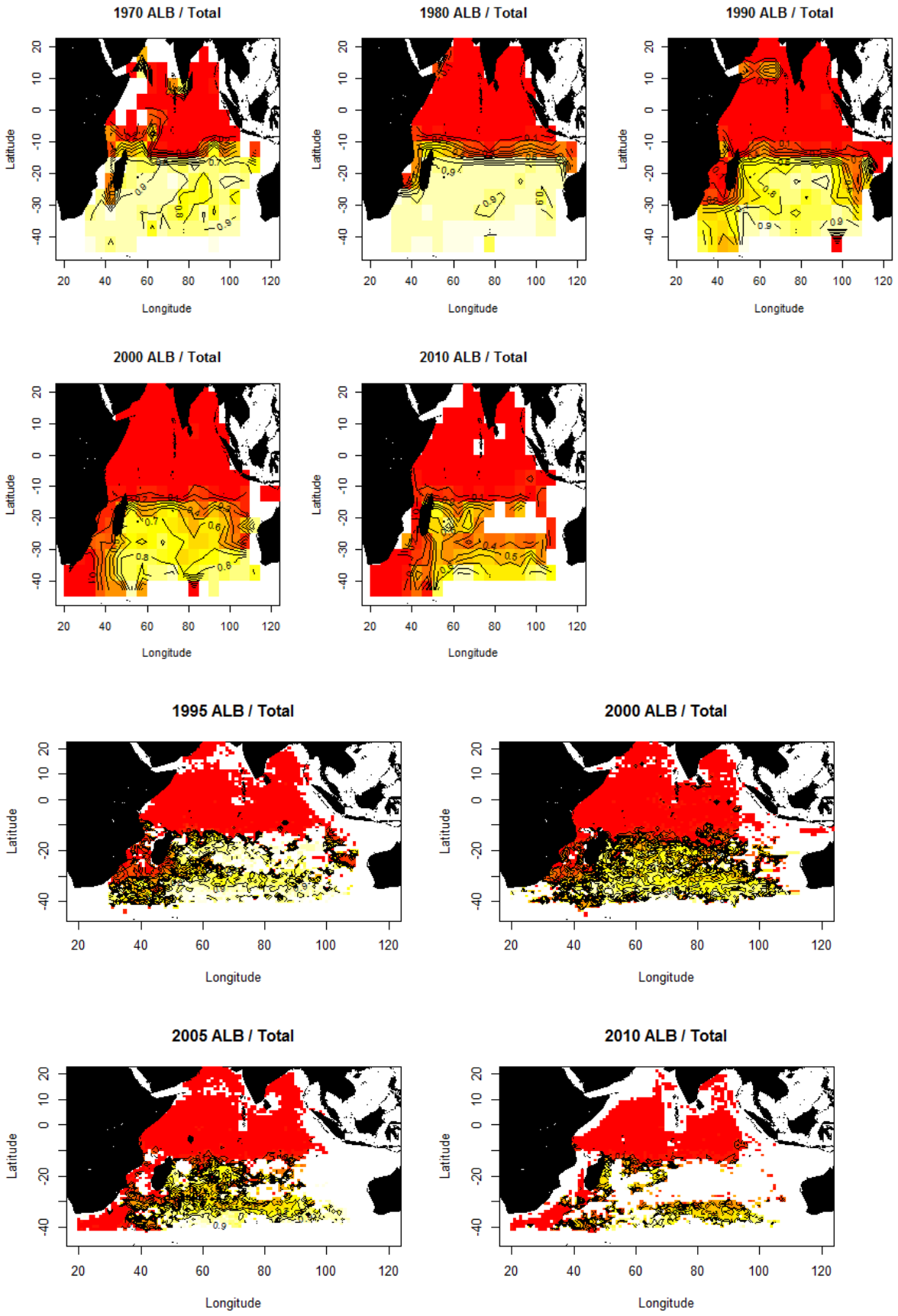

Figure 39: Proportion albacore in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

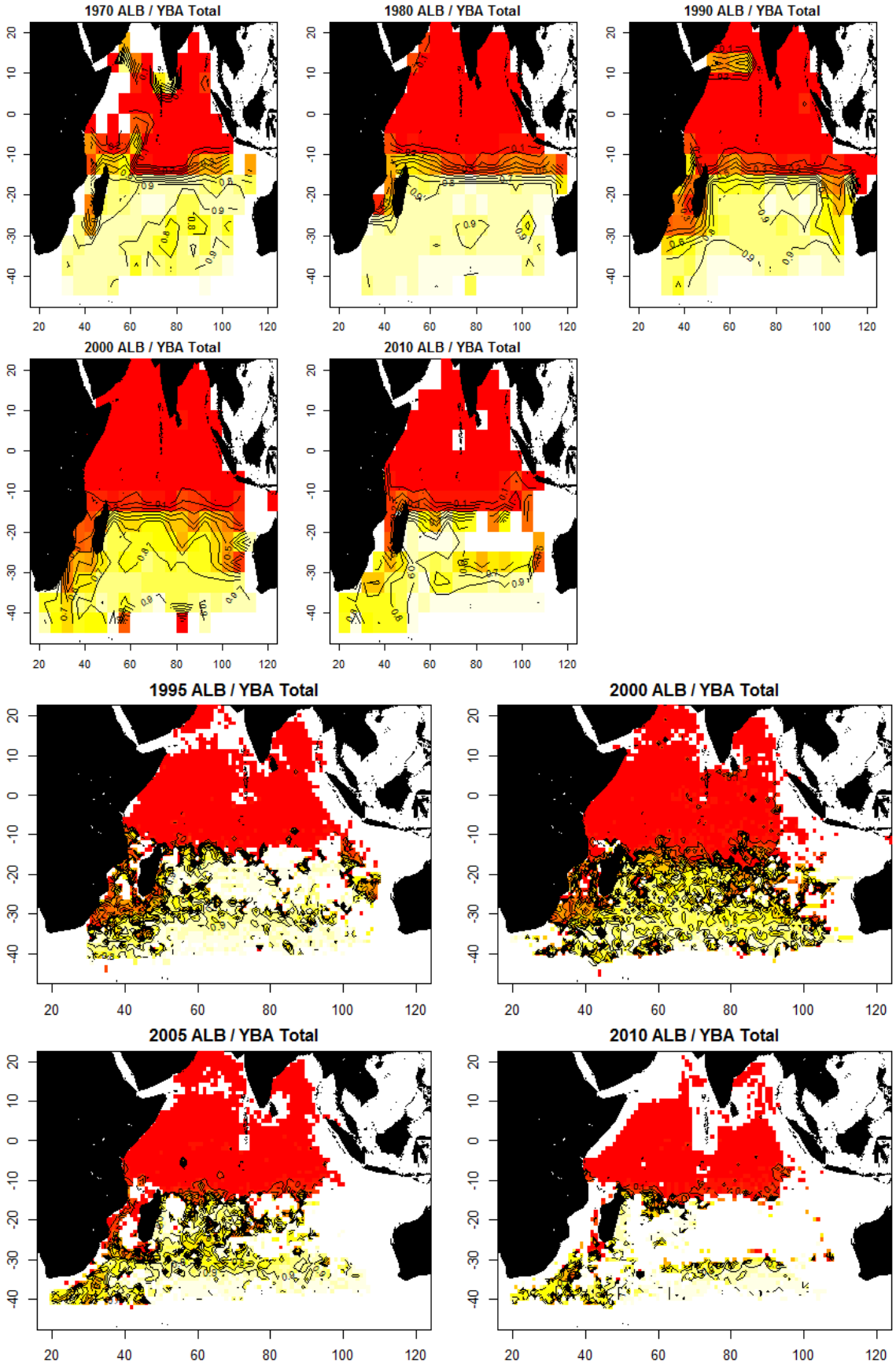

Figure 40: Proportion albacore in the catch of yellowfin, bigeye, and albacore (YBA) by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

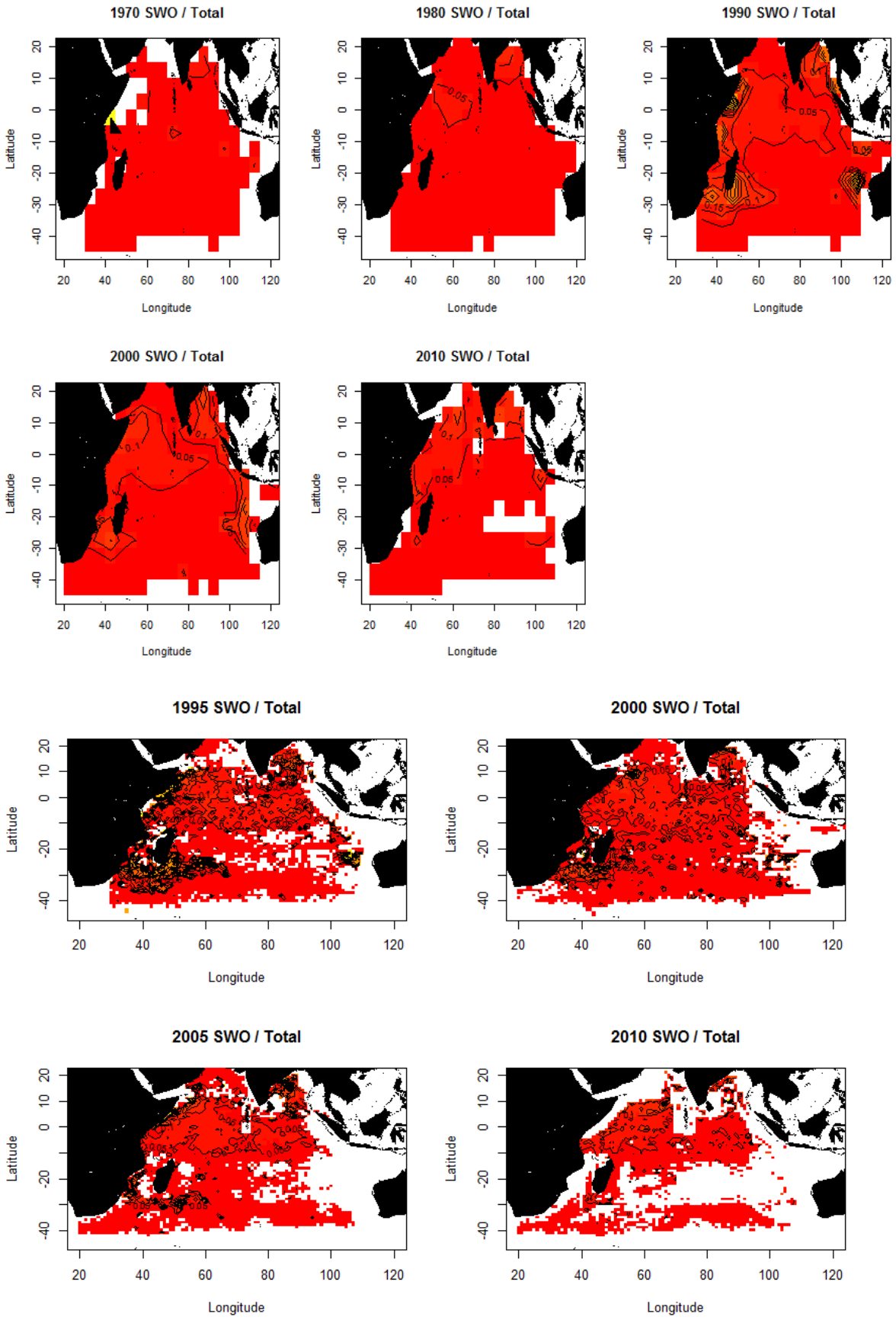

Figure 41: Proportion swordfish in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.1 intervals.

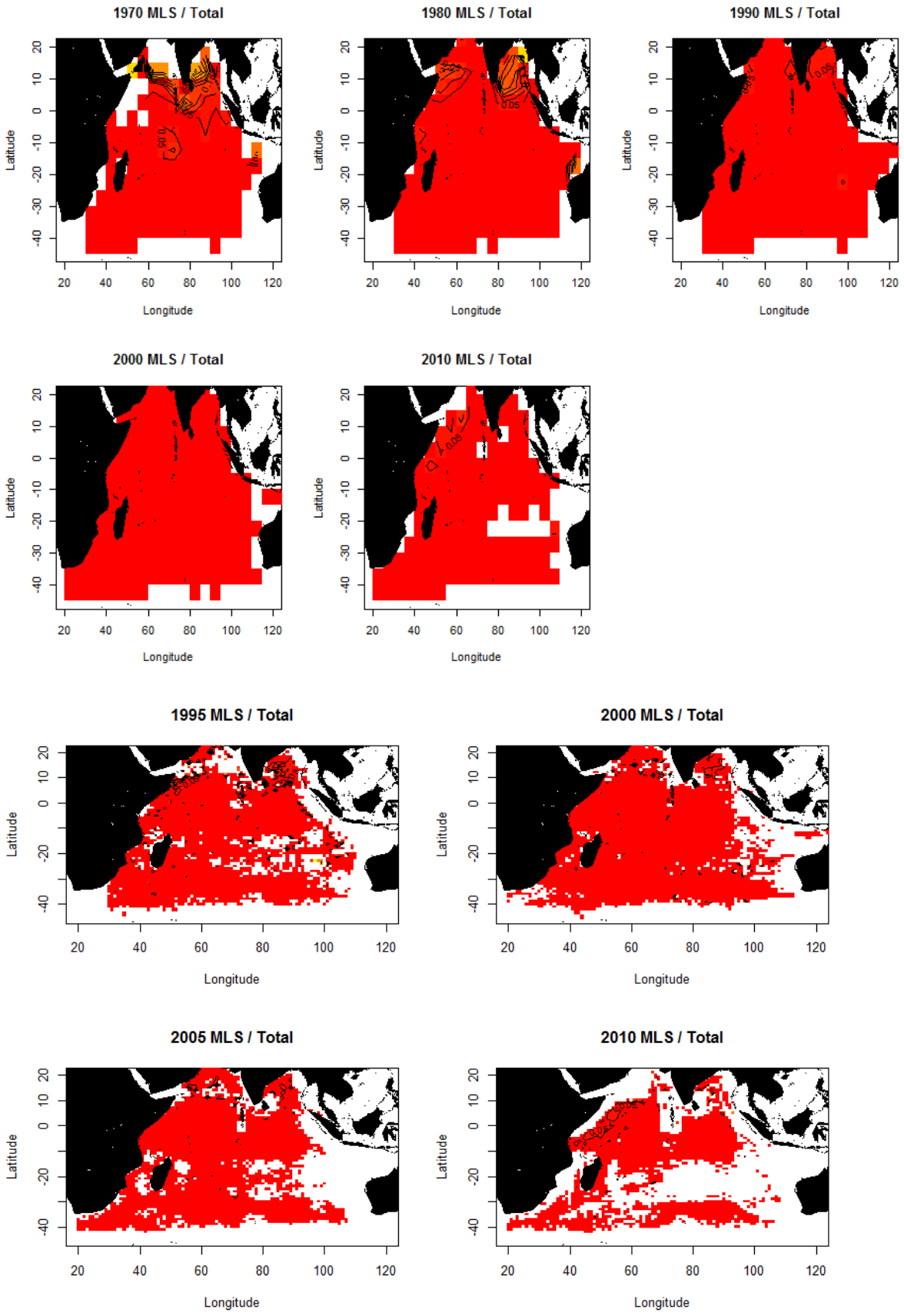

Figure 42: Proportion striped marlin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.

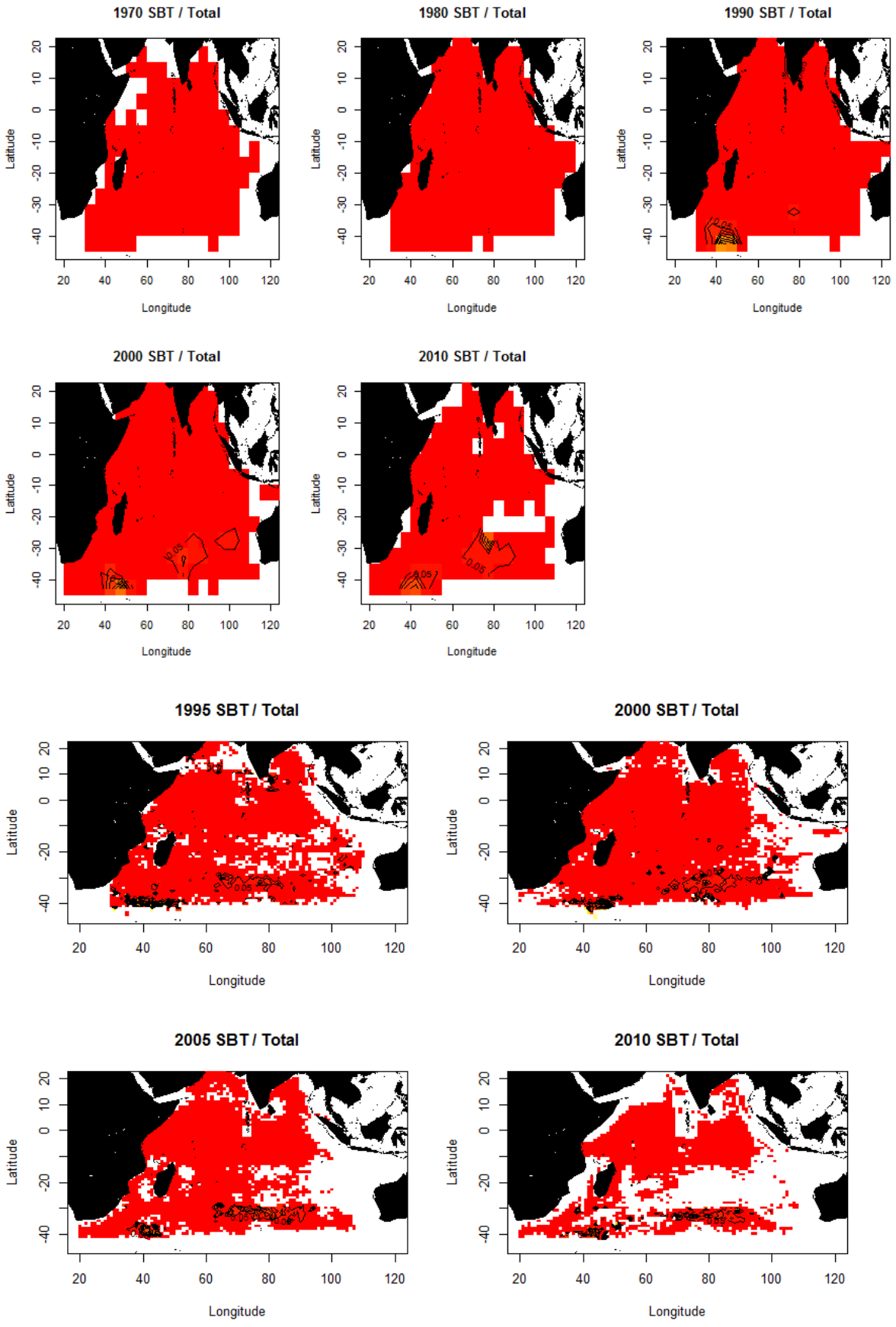

Figure 43: Proportion SBT in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.

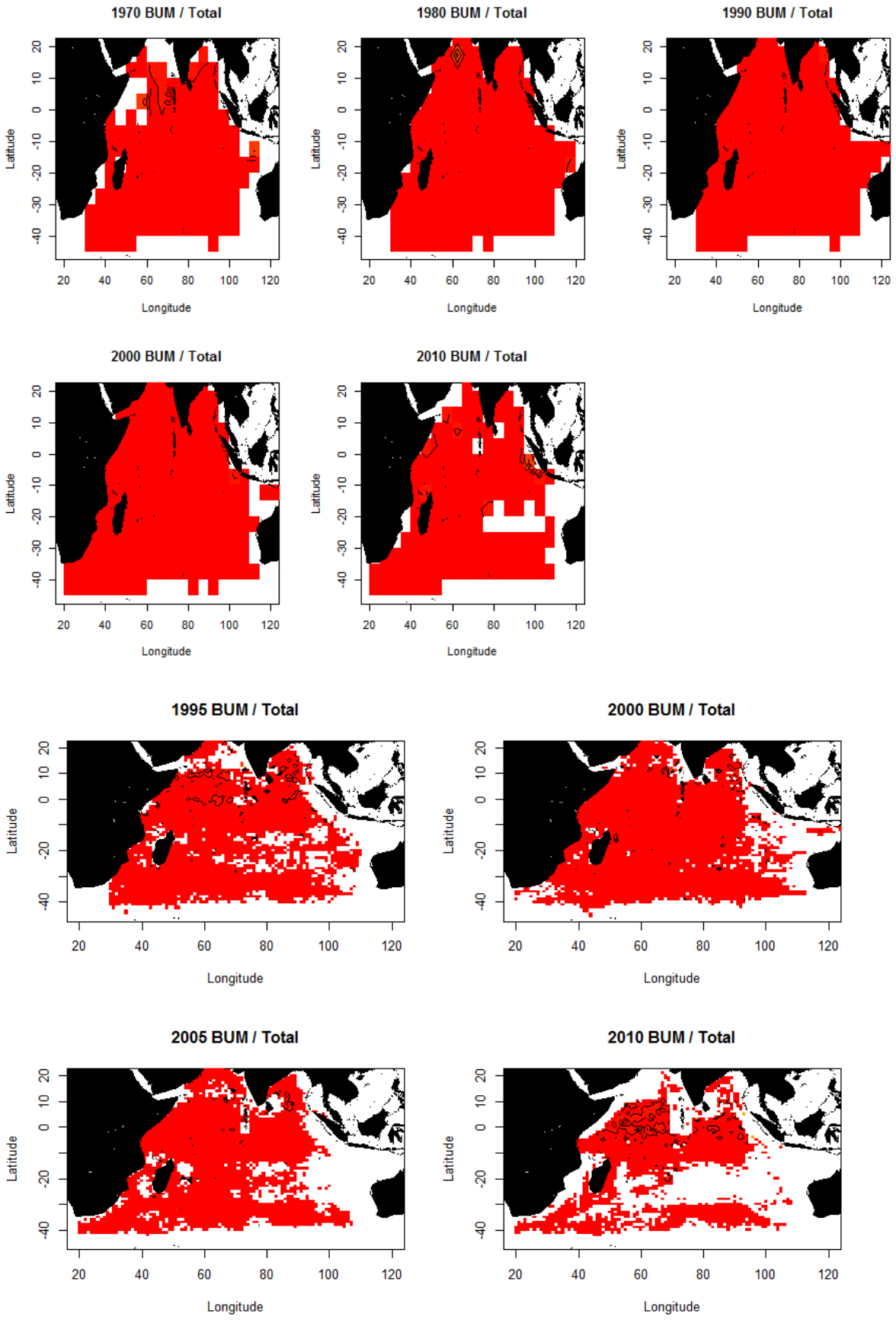

Figure 44: Proportion blue marlin in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.

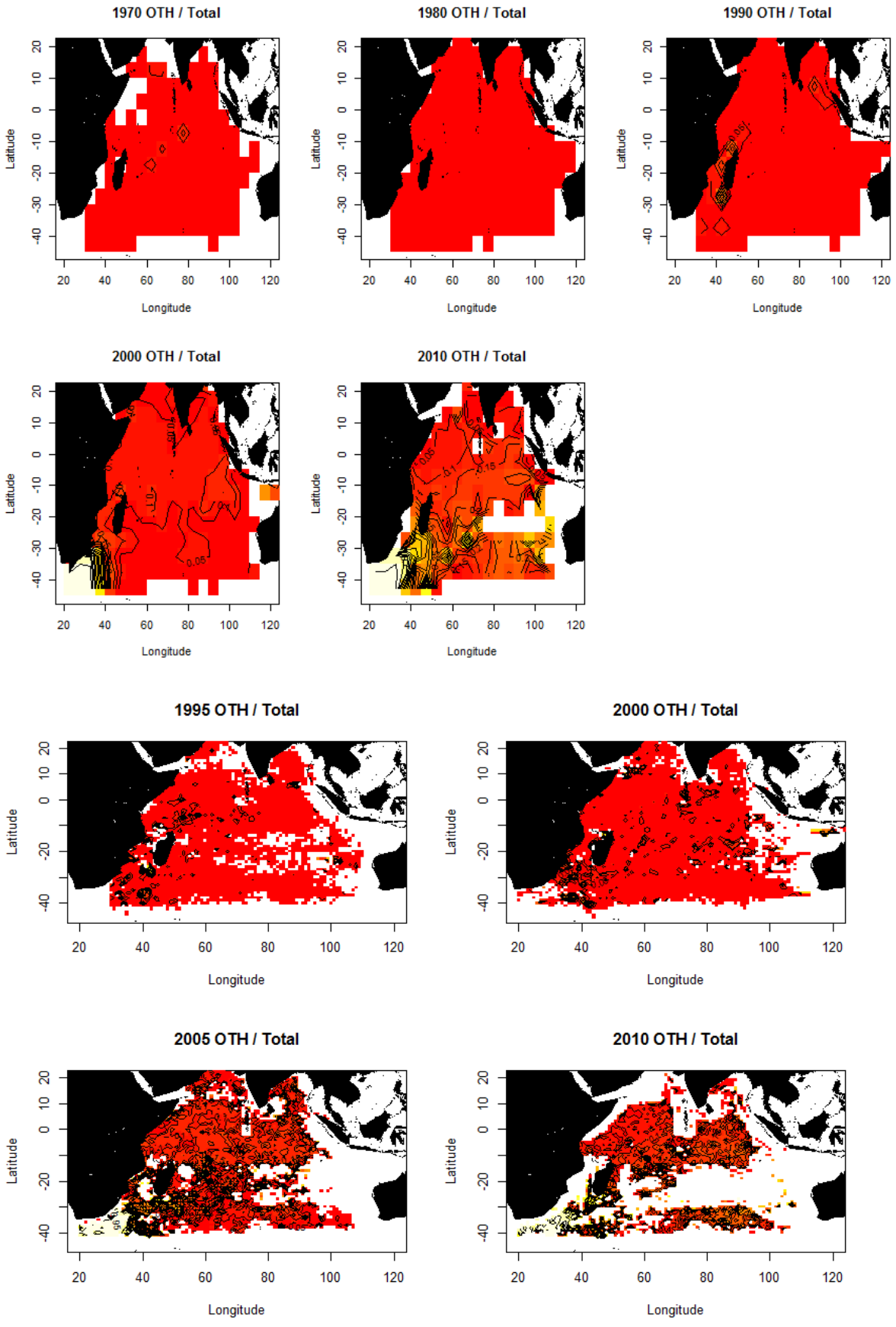

Figure 45 Proportion other species in total catch by decade and 5 degree square (top) and by 5 year period and 1 degree square (bottom). Yellow indicates higher proportion. Contour lines are at 0.05 intervals.

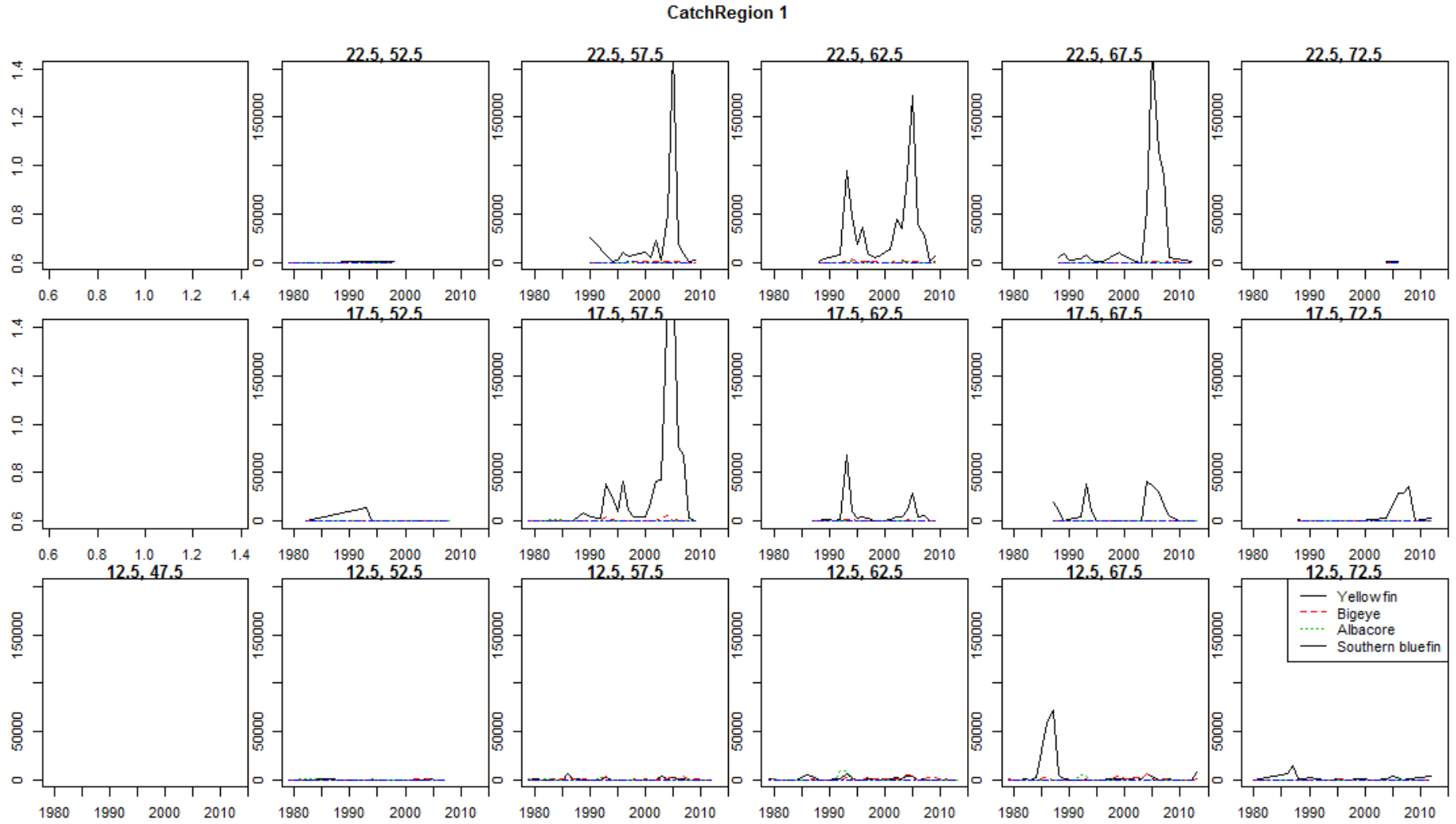

Figure 46: Catch by year-qtr and 5 degree square in region 1 for bigeye, yellowfin, albacore and SBT.

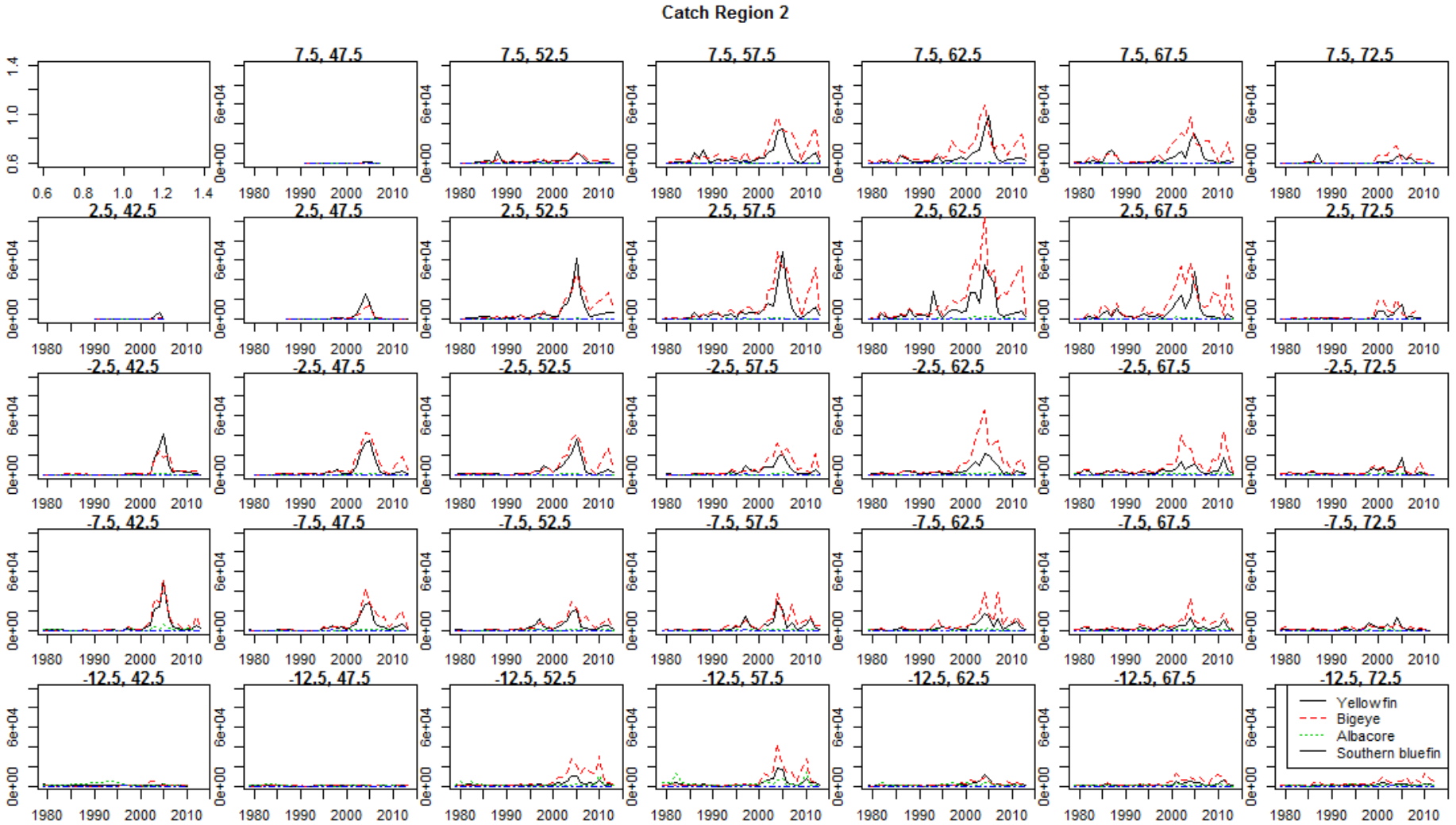

Figure 47: Catch by year-qtr and 5 degree square in region 2 for bigeye, yellowfin, albacore and SBT.

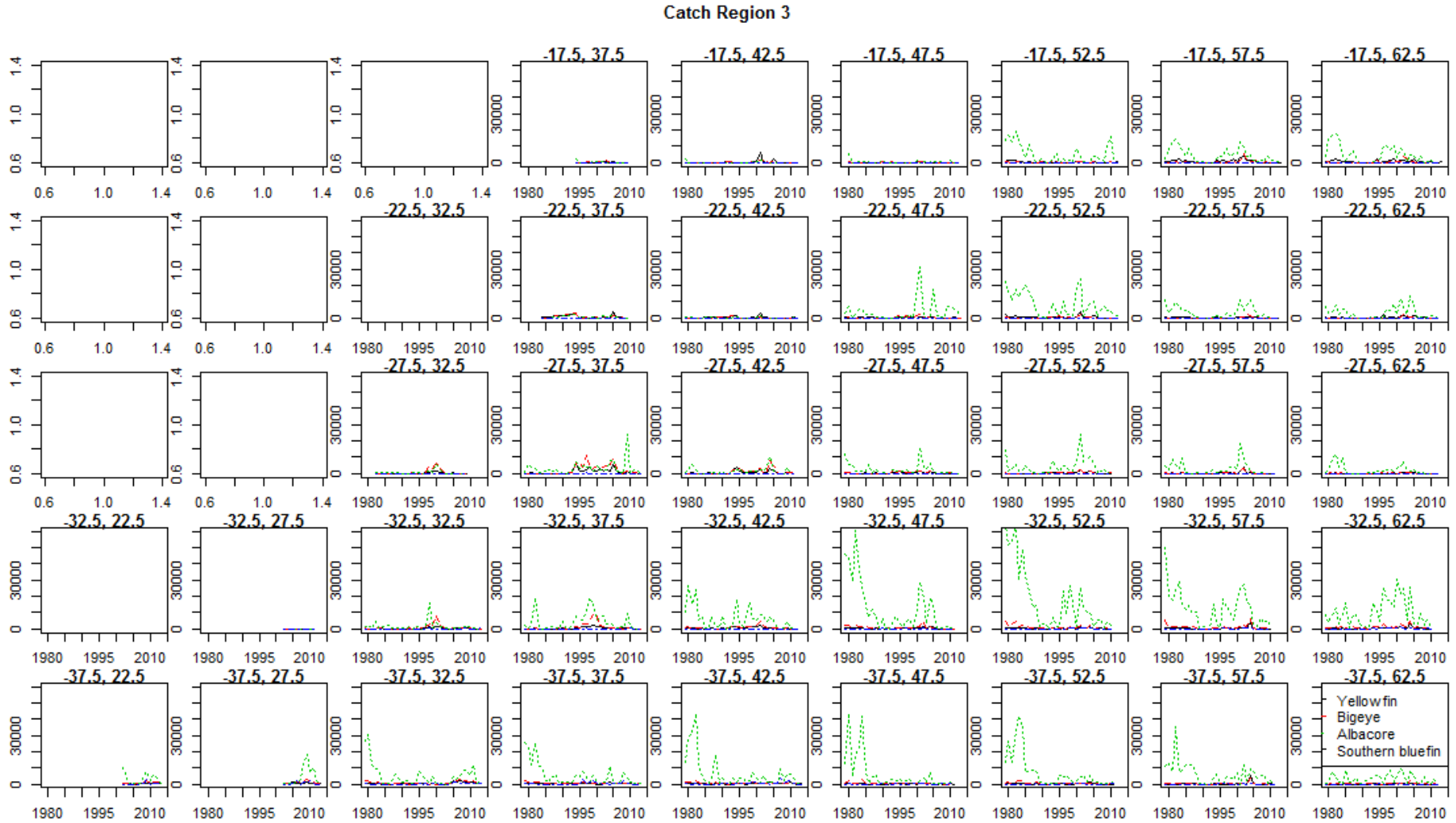

Figure 48: Catch by year-qtr and 5 degree square in region 3 for bigeye, yellowfin, albacore and SBT.

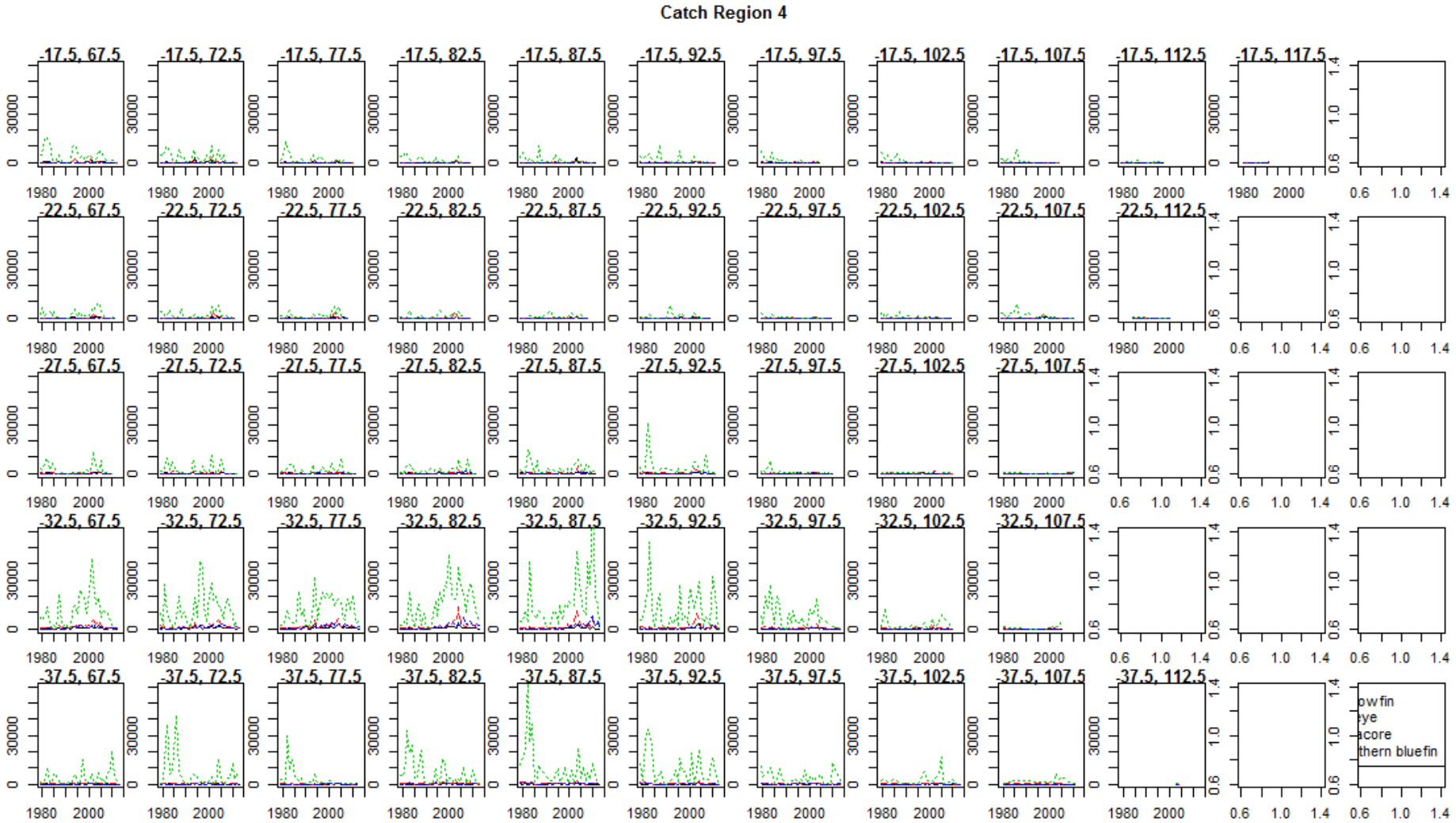

Figure 49: Catch by year-qtr and 5 degree square in region 4 for bigeye, yellowfin, albacore and SBT.

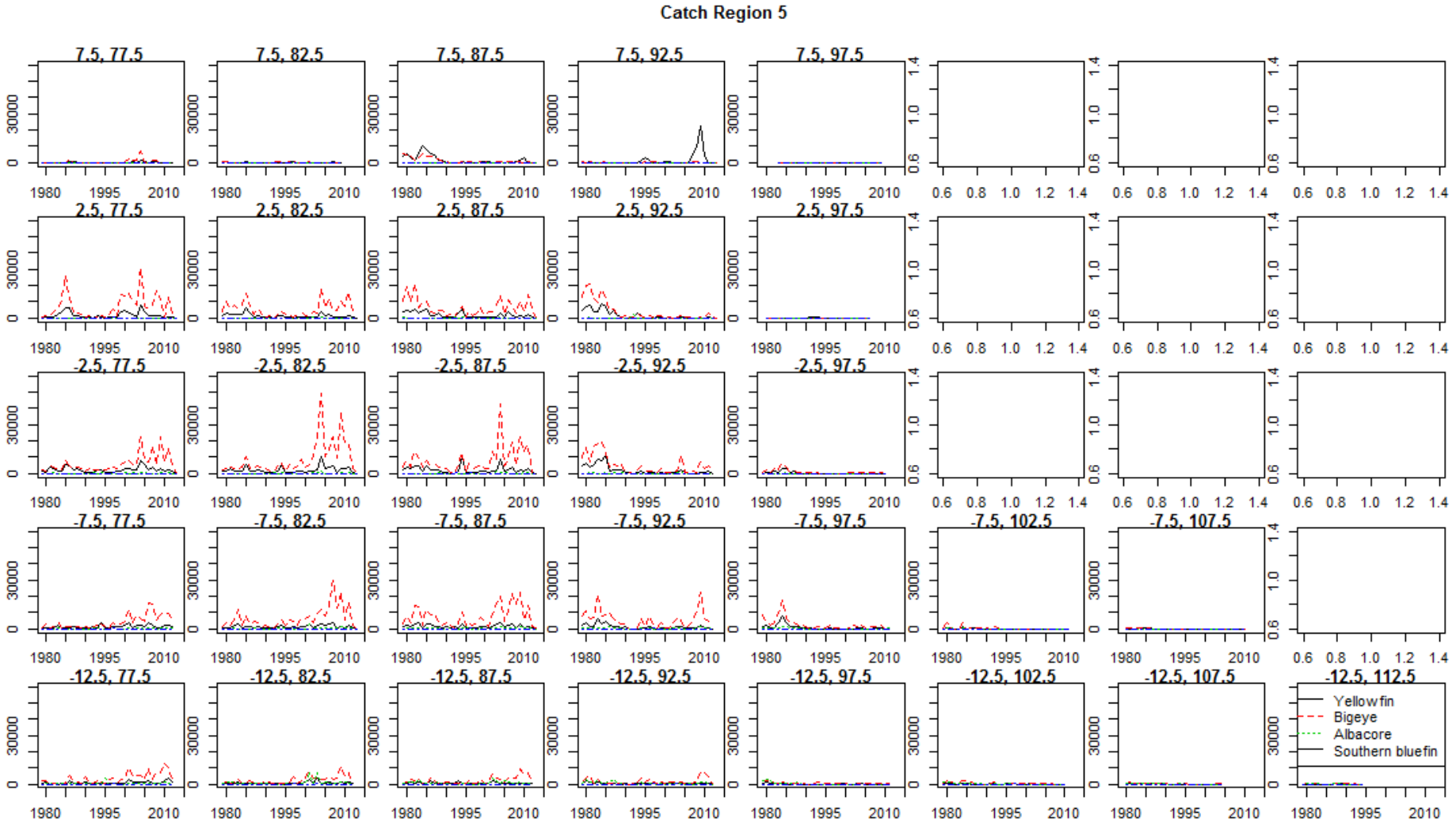

Figure 50: Catch by year-qtr and 5 degree square in region 5 for bigeye, yellowfin, albacore and SBT.

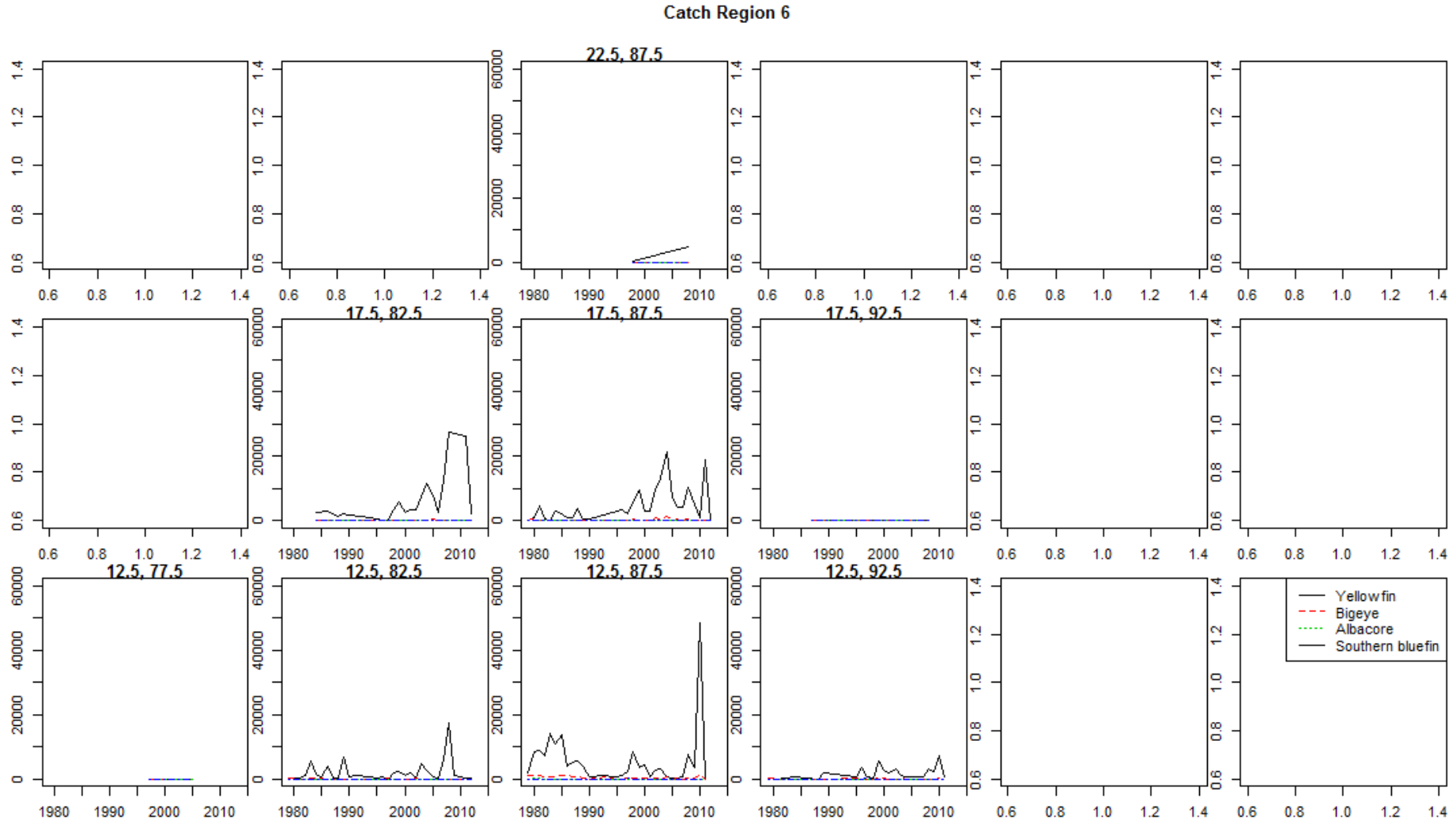

Figure 51: Catch by year-qtr and 5 degree square in region 6 for bigeye, yellowfin, albacore and SBT.

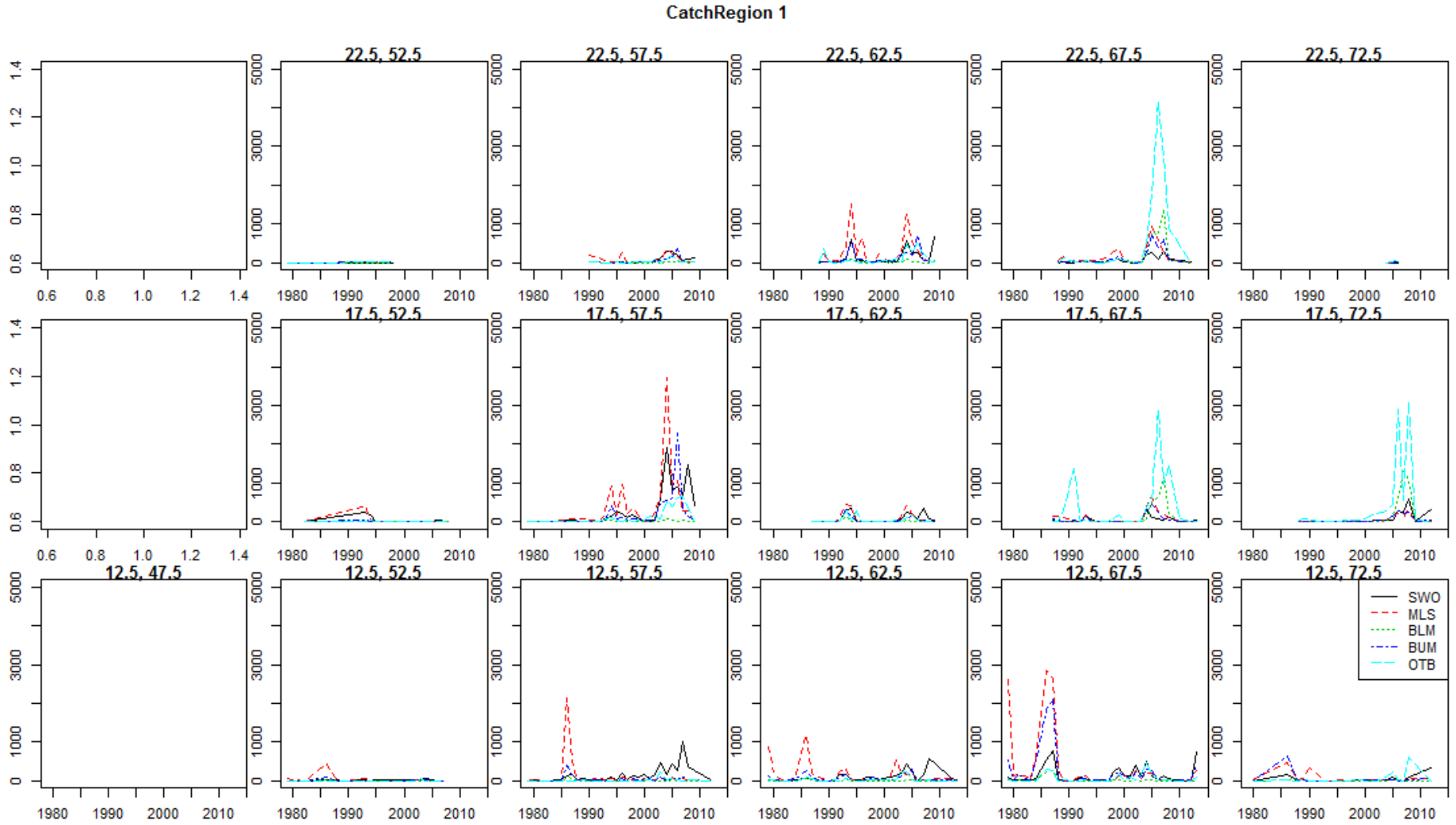

Figure 52: Catch by year-qtr and 5 degree square in region 1 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish.

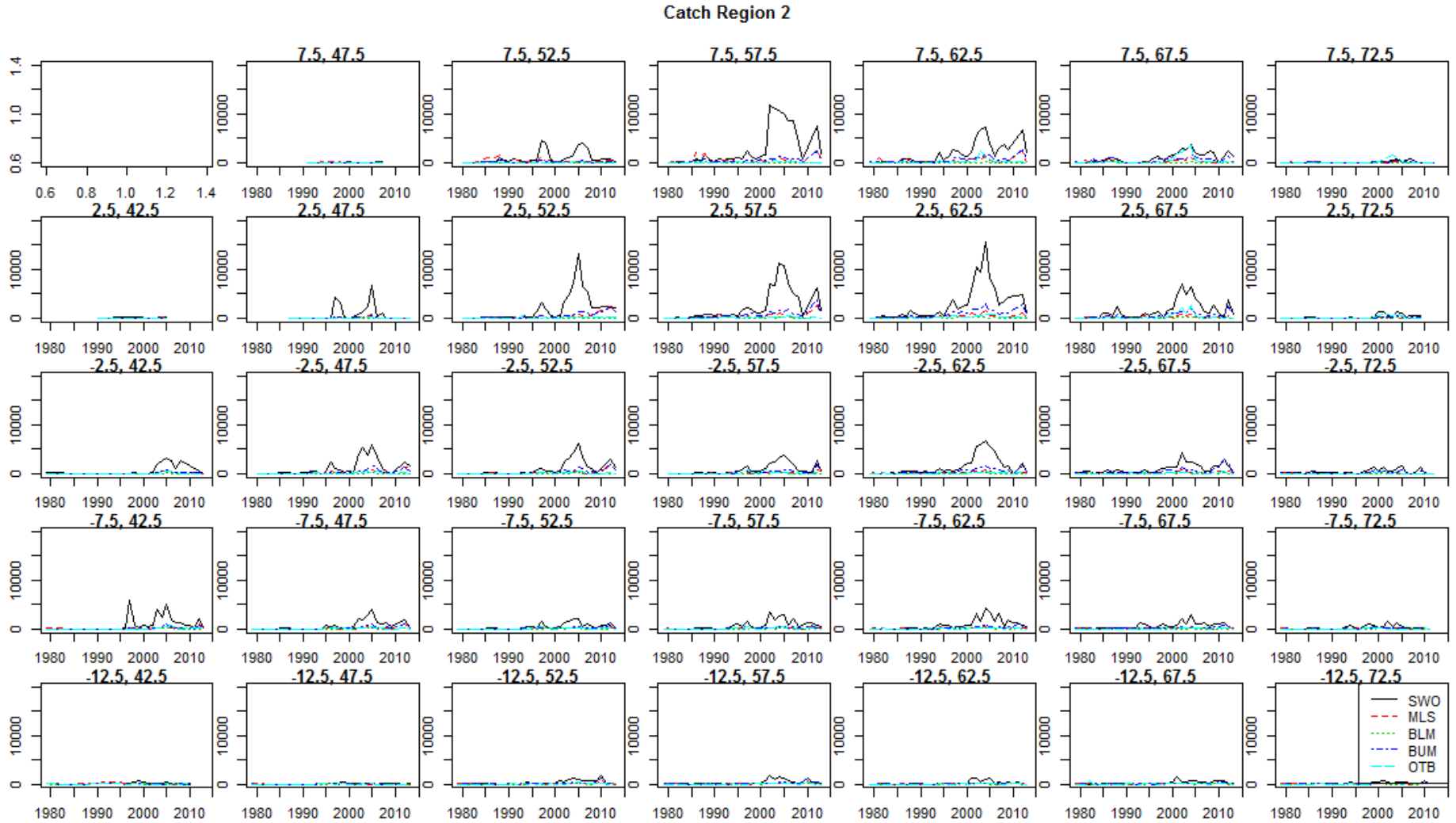

Figure 53: Catch by year-qtr and 5 degree square in region 2 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish

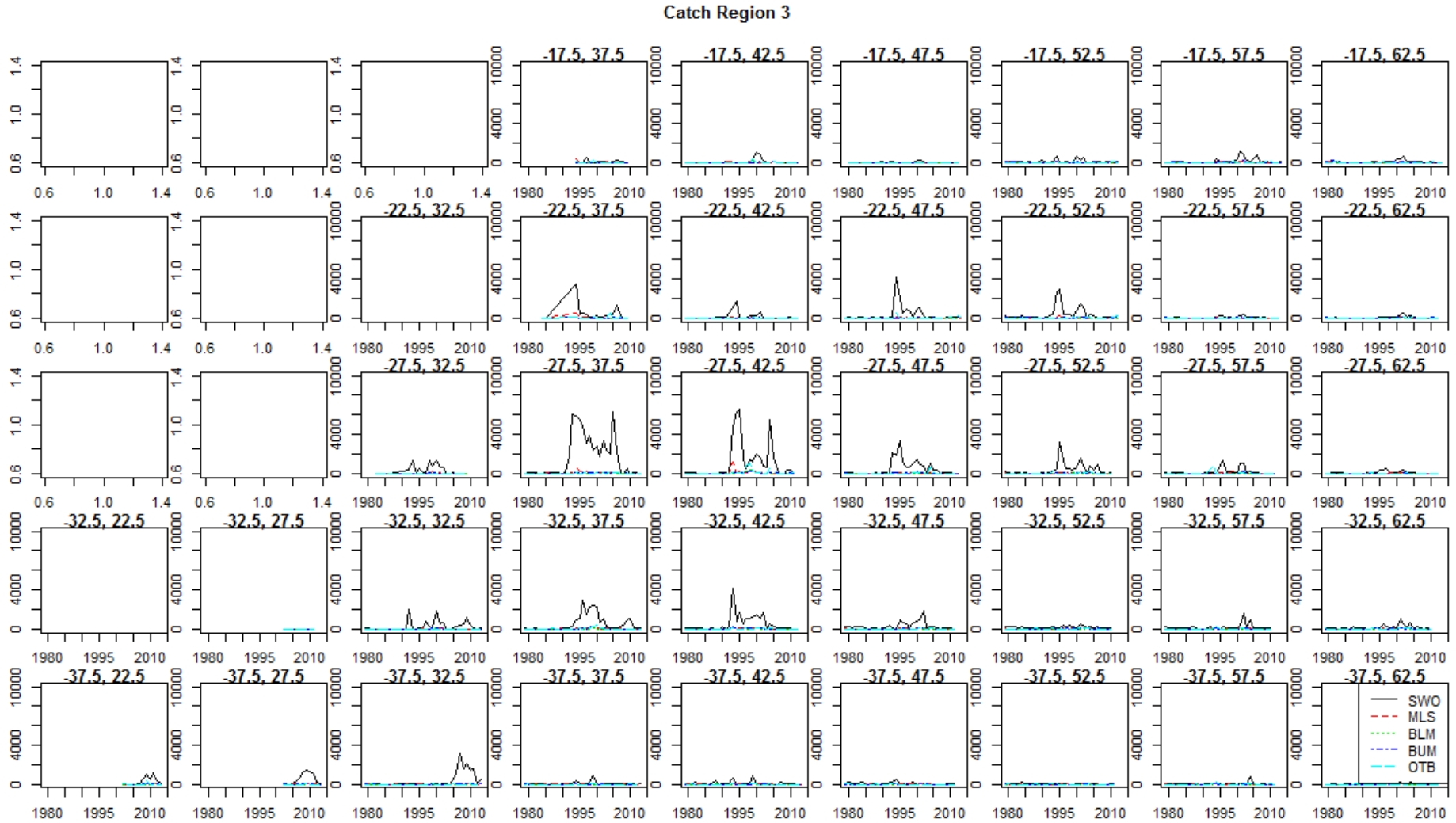

Figure 54: Catch by year-qtr and 5 degree square in region 3 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish.

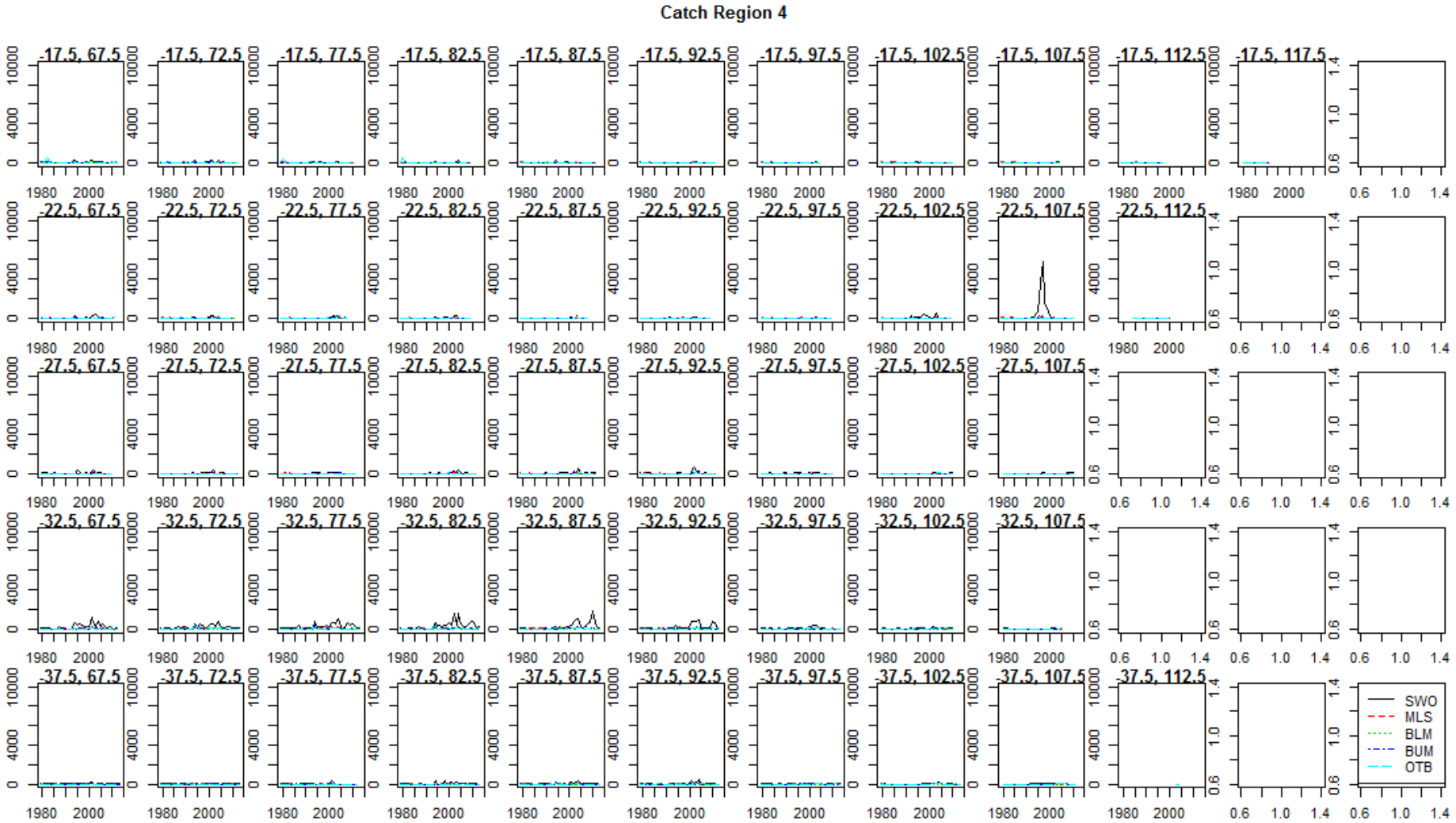

Figure 55: Catch by year-qtr and 5 degree square in region 4 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish.

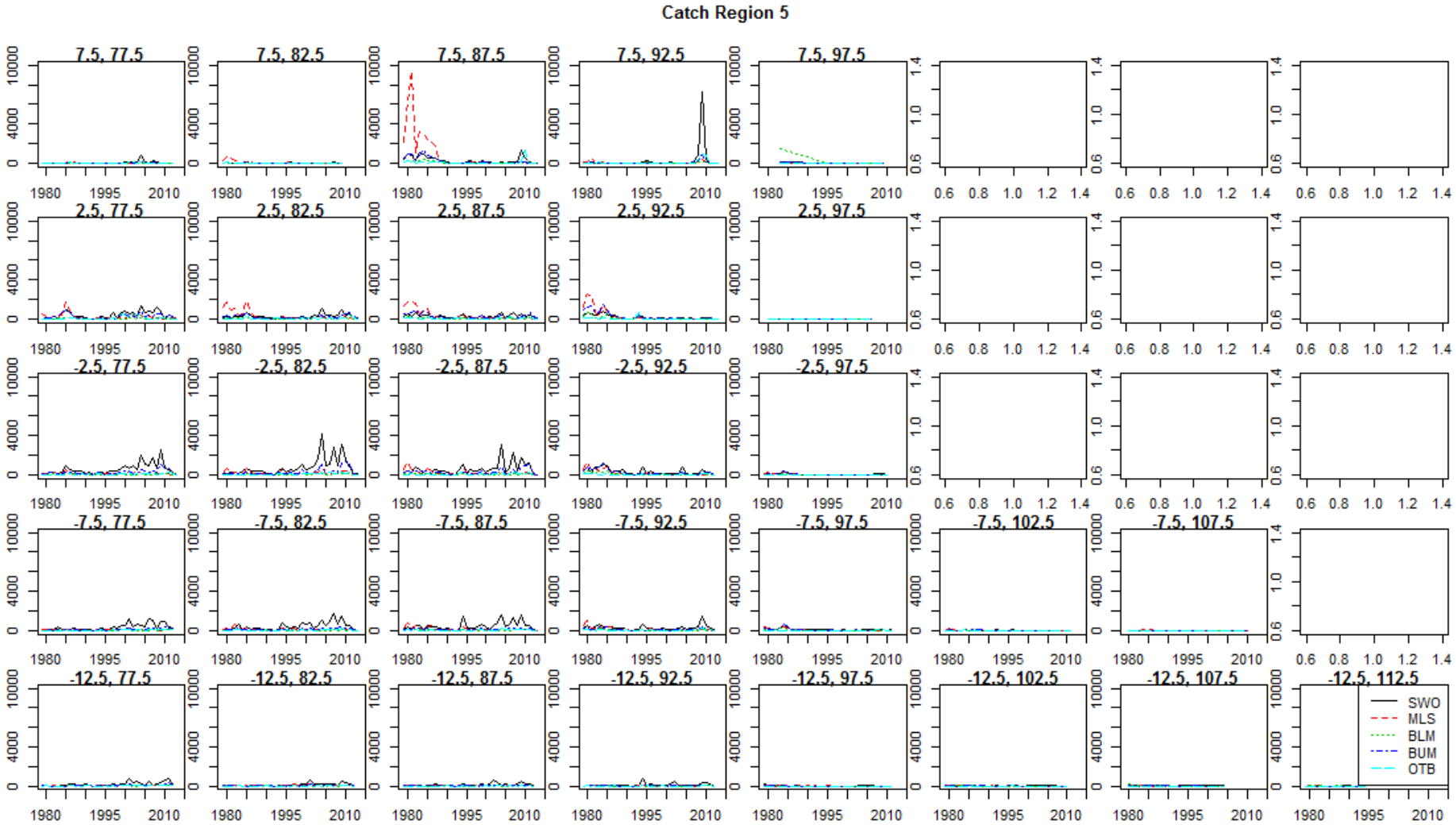

Figure 56: Catch by year-qtr and 5 degree square in region 5 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish

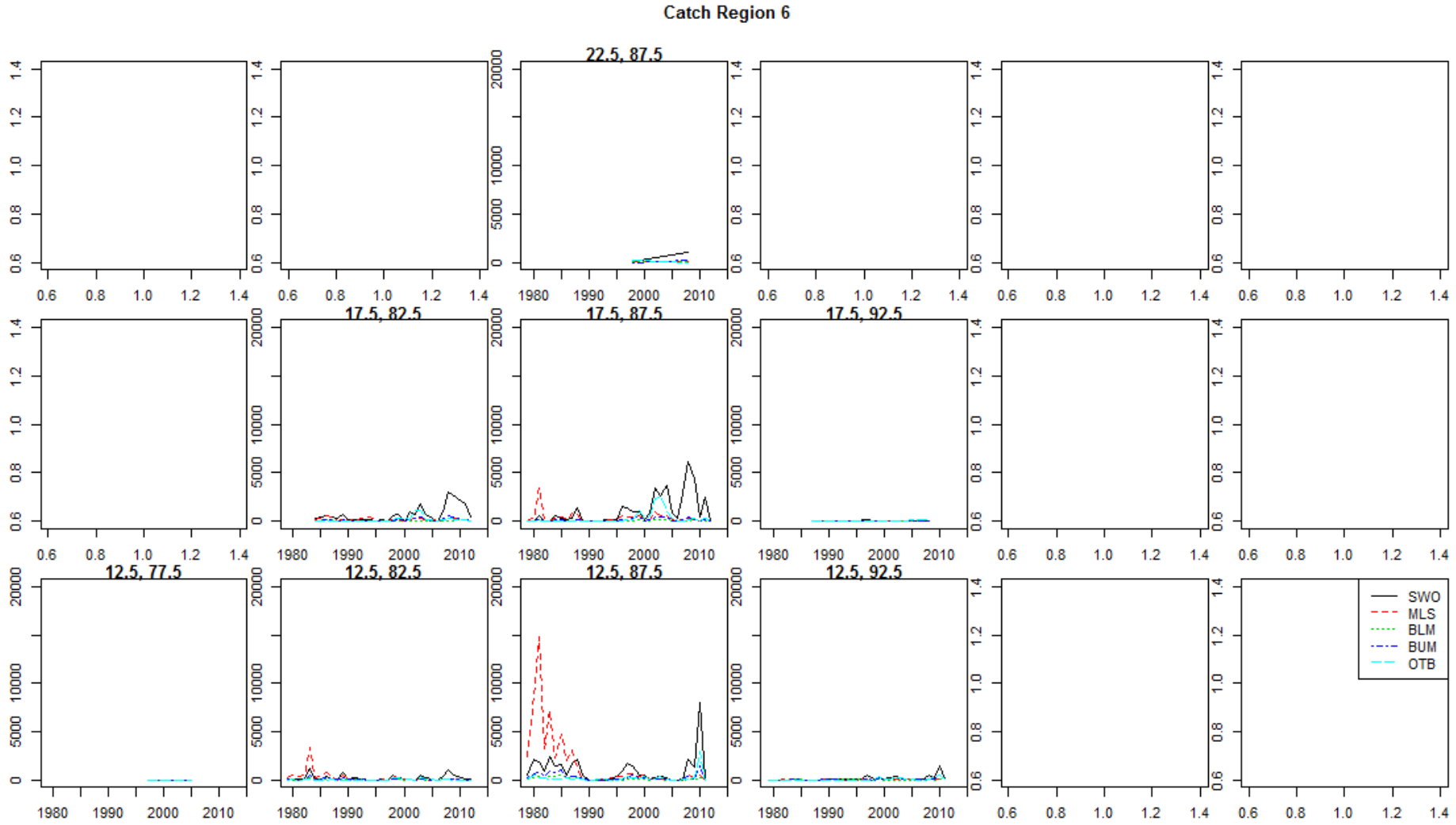

Figure 57: Catch by year-qtr and 5 degree square in region 6 for Swordfish, striped marlin, black marlin, blue marlin, and other billfish.

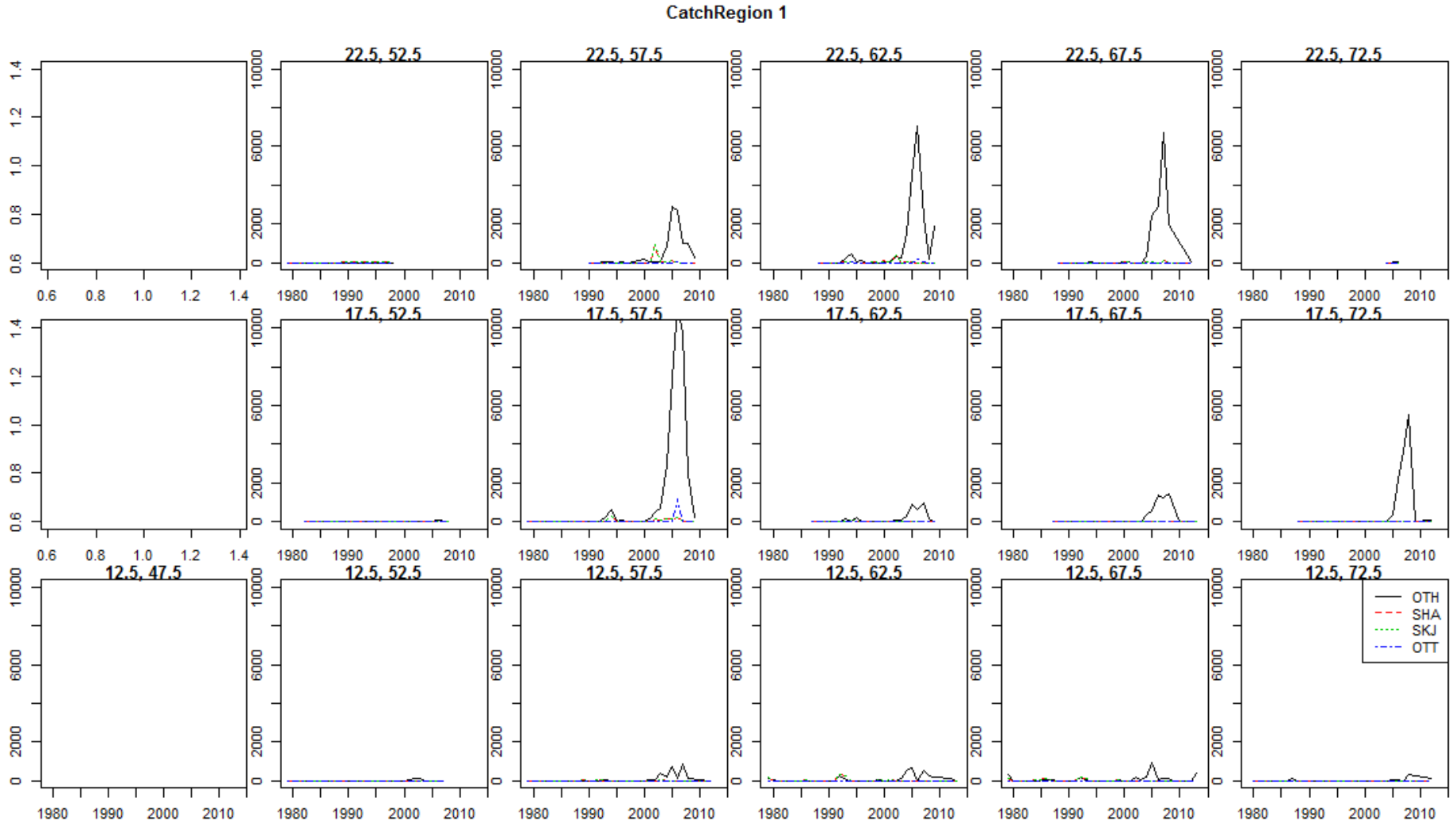

Figure 58: Catch by year-qtr and 5 degree square in region 1 for shark, skipjack, other tunas, and other species.

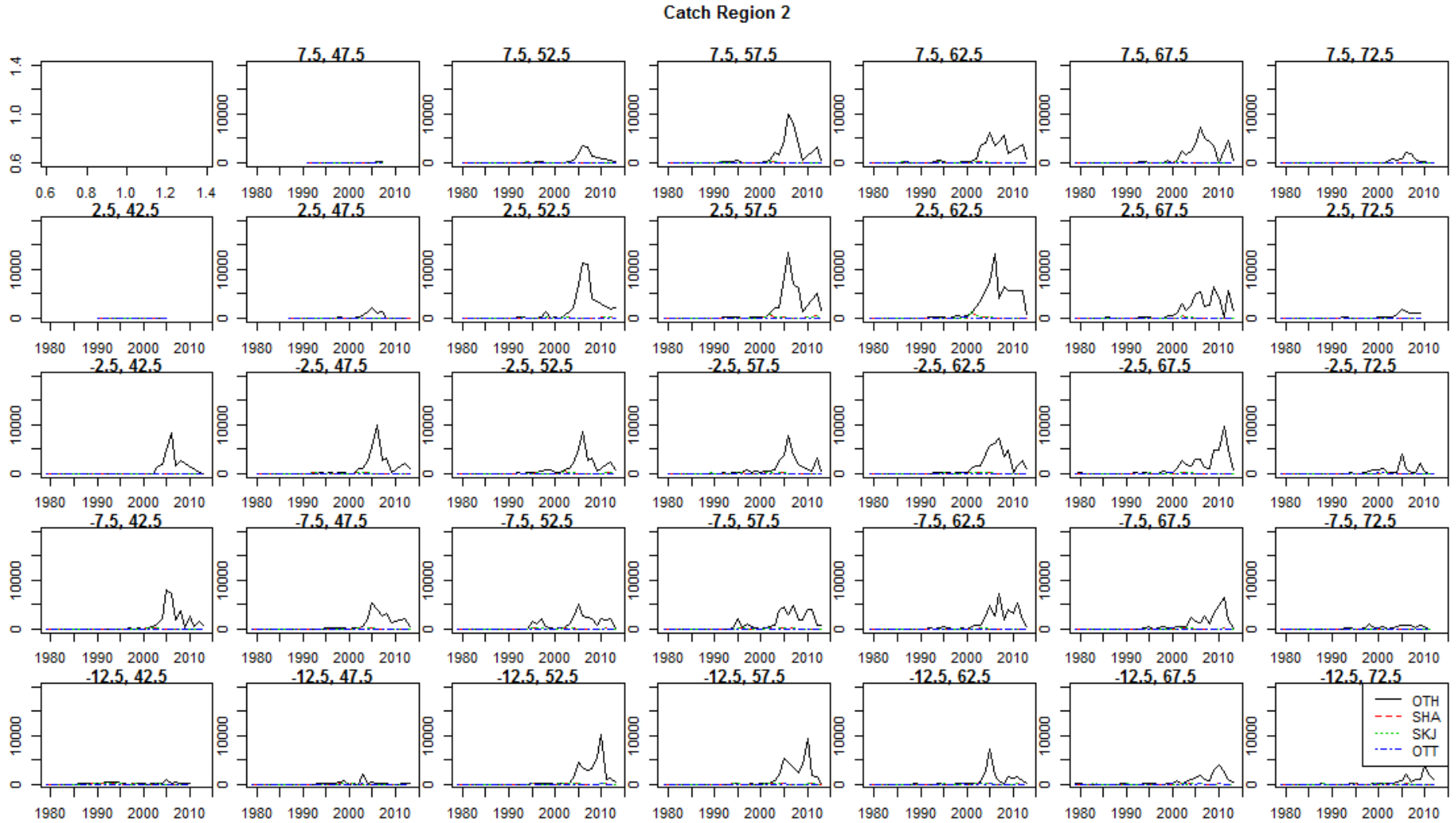

Figure 59: Catch by year-qtr and 5 degree square in region 2 for shark, skipjack, other tunas, and other species.

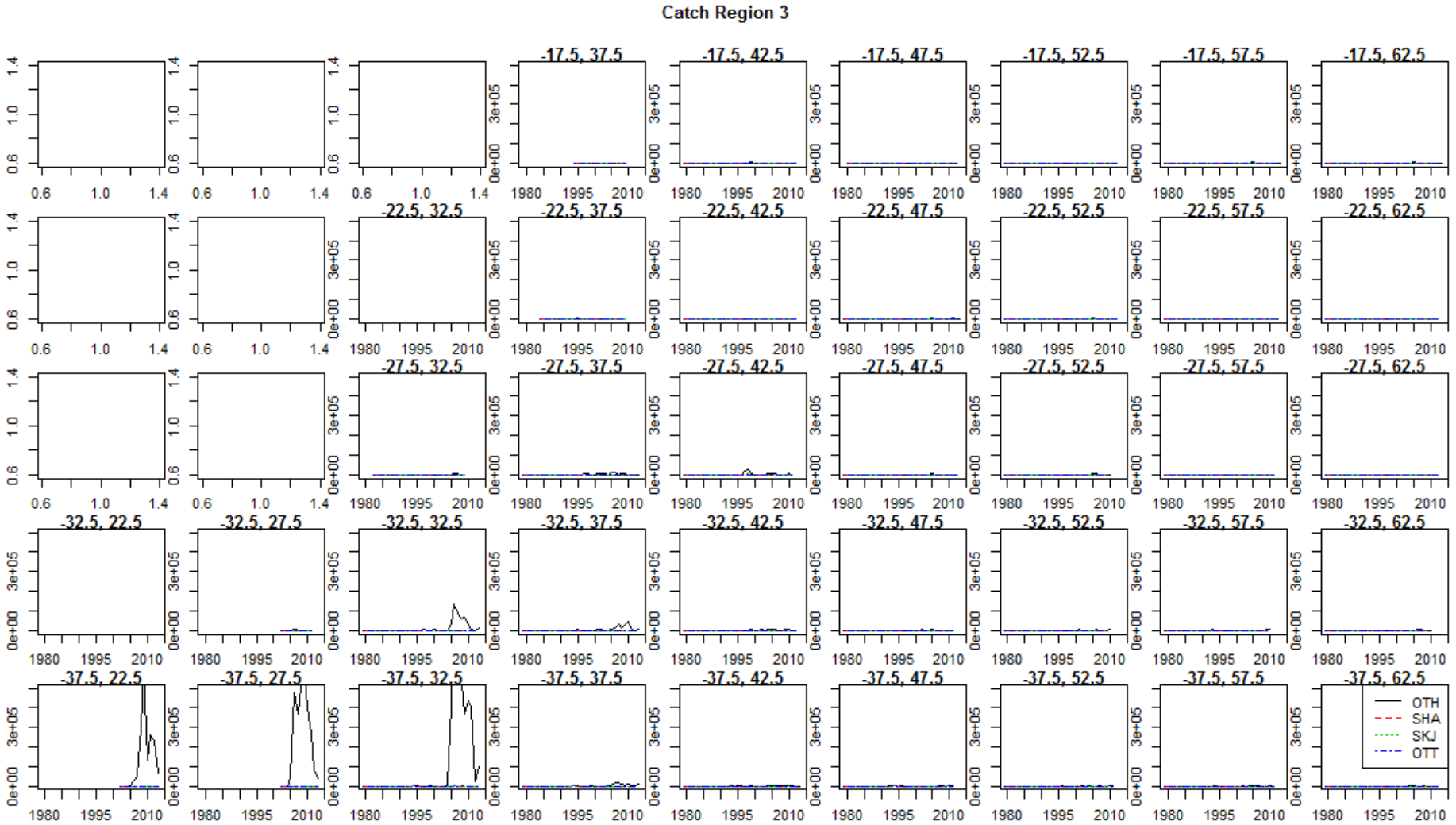

Figure 60: Catch by year-qtr and 5 degree square in region 4 for shark, skipjack, other tunas, and other species.

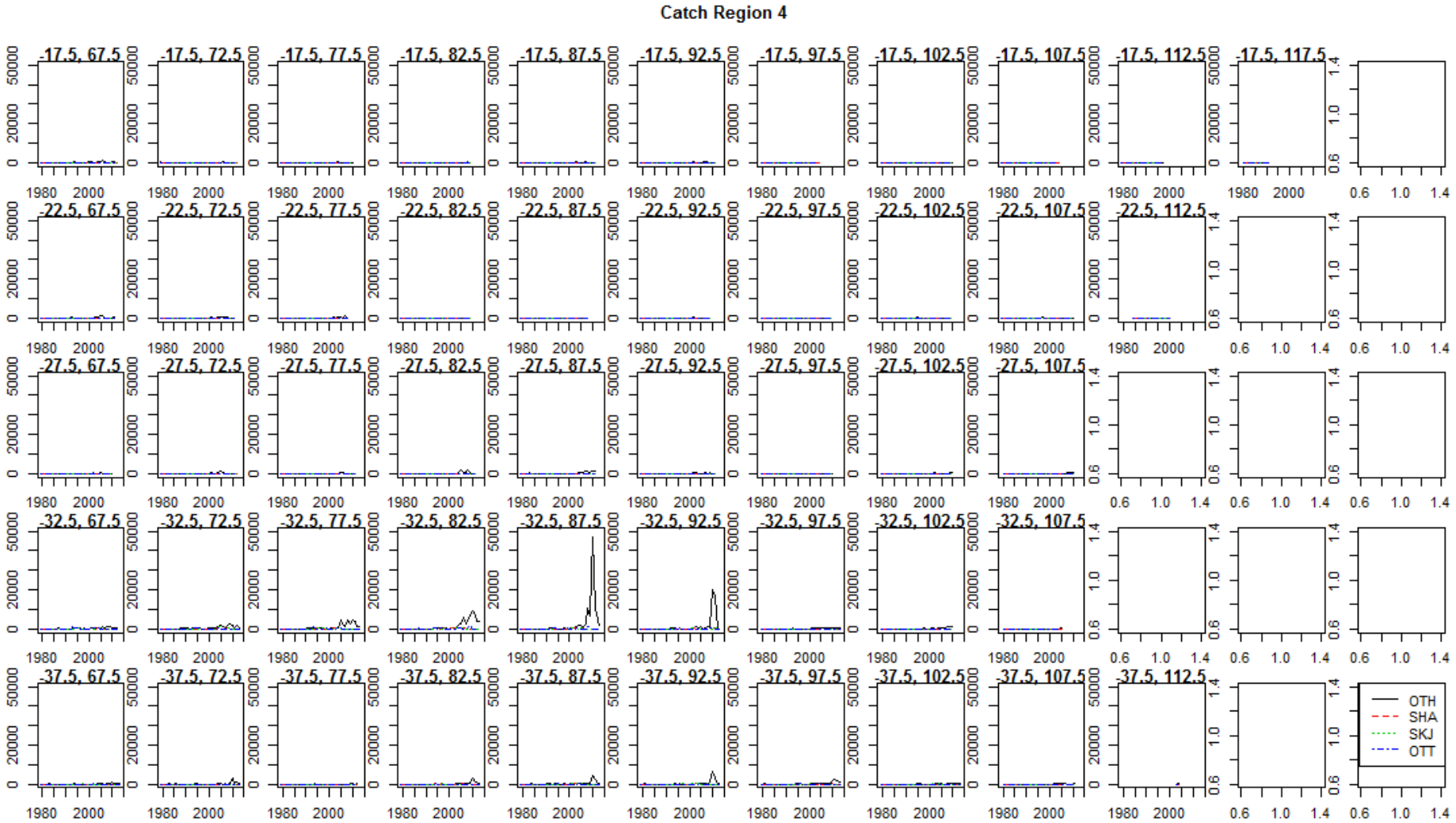

Figure 61: Catch by year-qtr and 5 degree square in region 5 for shark, skipjack, other tunas, and other species.

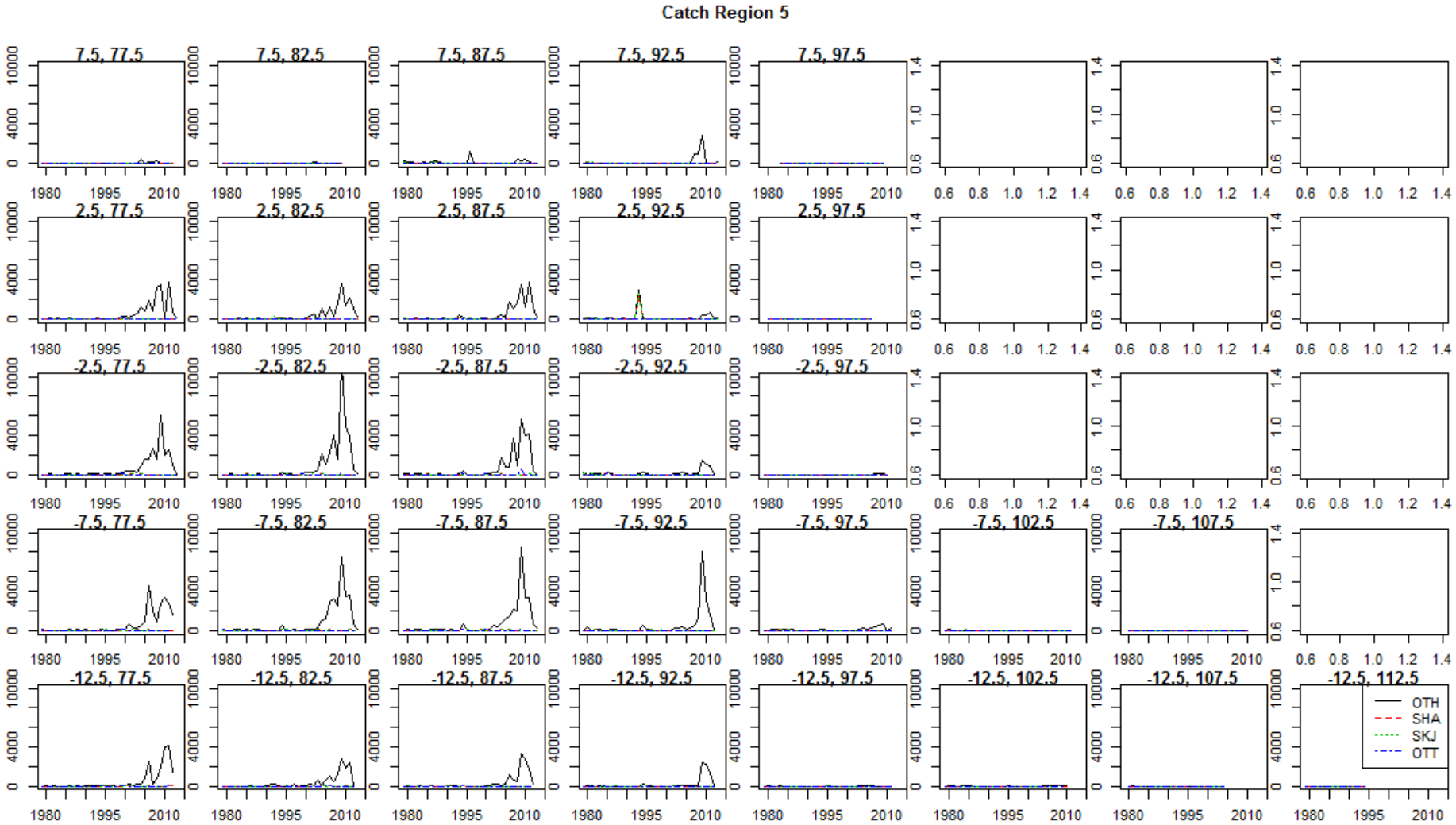

Figure 62: Catch by year-qtr and 5 degree square in region 6 for shark, skipjack, other tunas, and other species.

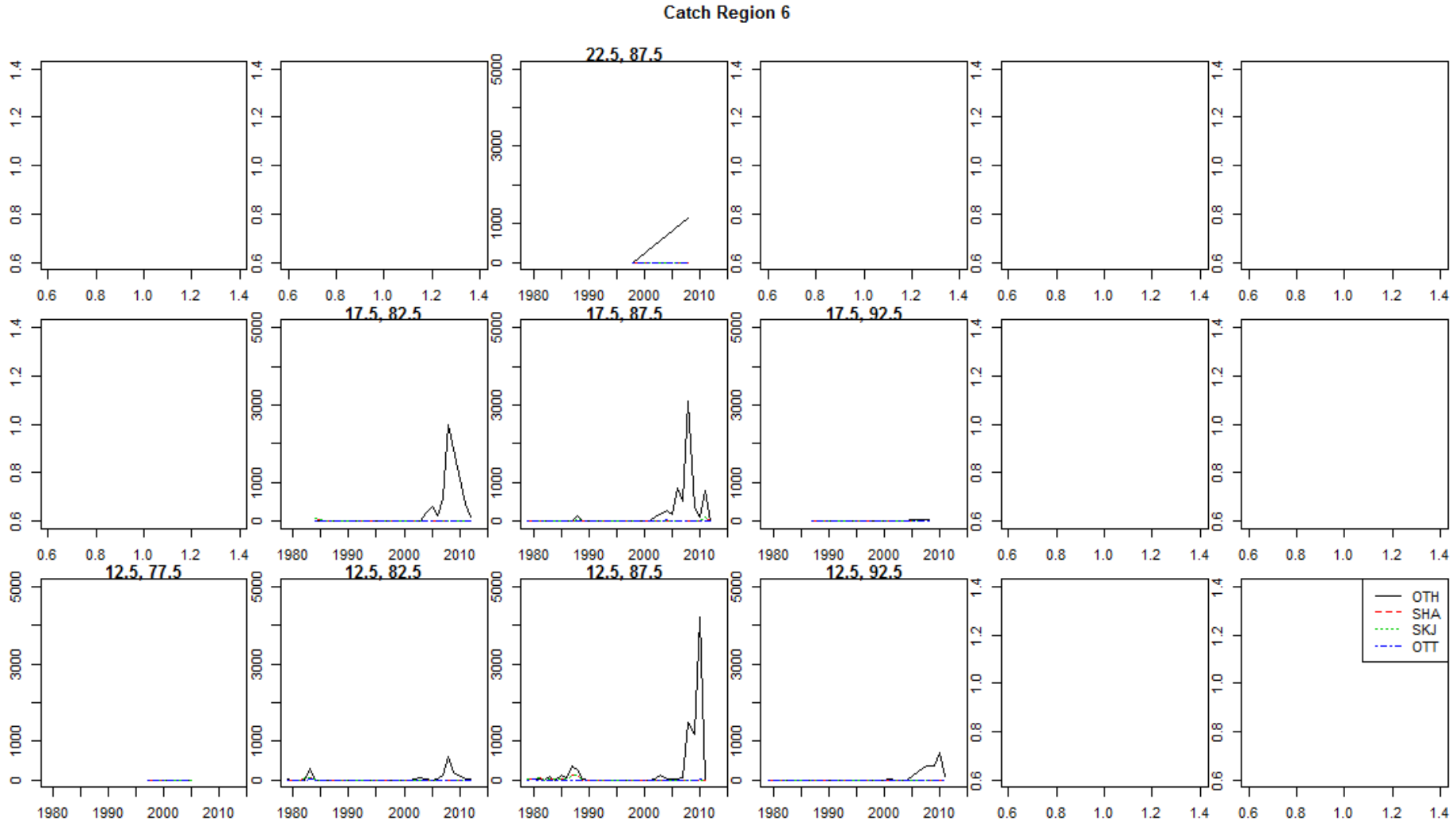

Figure 63: Catch by year-qtr and 5 degree square in region 6 for shark, skipjack, other tunas, and other species.

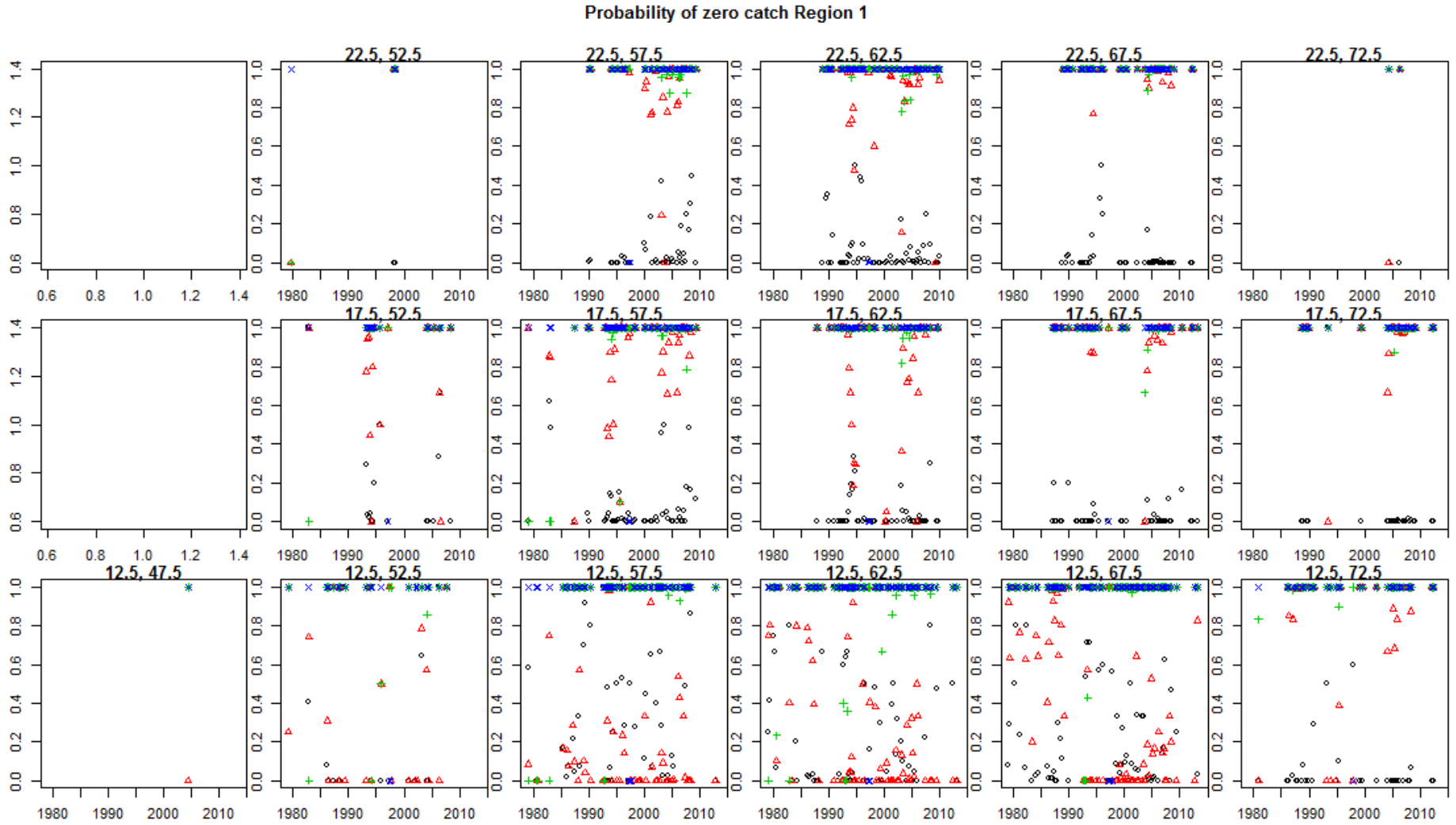

Figure 64: Probability of zero catch by year-qtr and 5 degree square in region 1 for bigeye, yellowfin, albacore, and SBT.

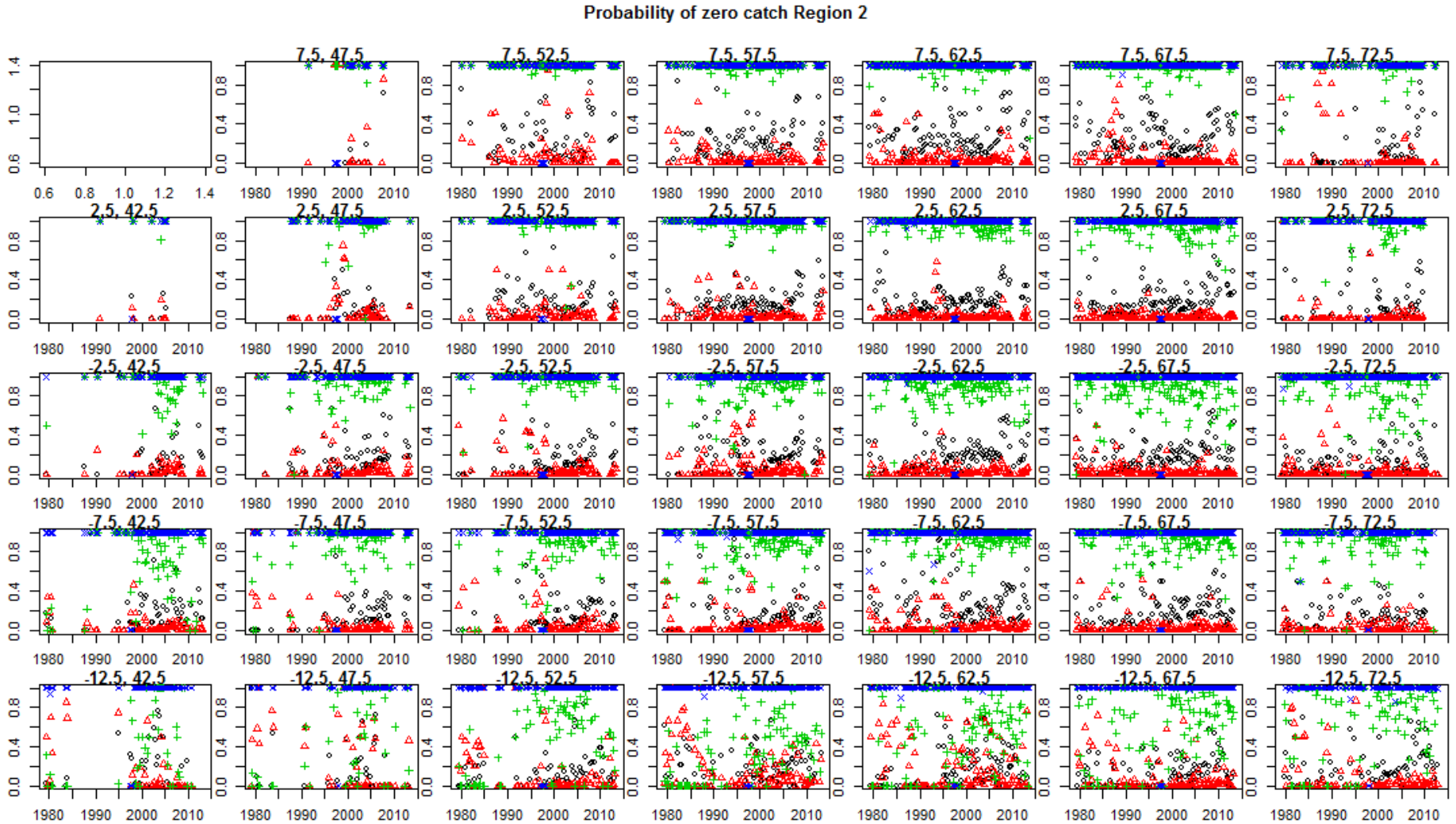

Figure 65: Probability of zero catch by year-qtr and 5 degree square in region 2 for bigeye, yellowfin, albacore, and SBT.

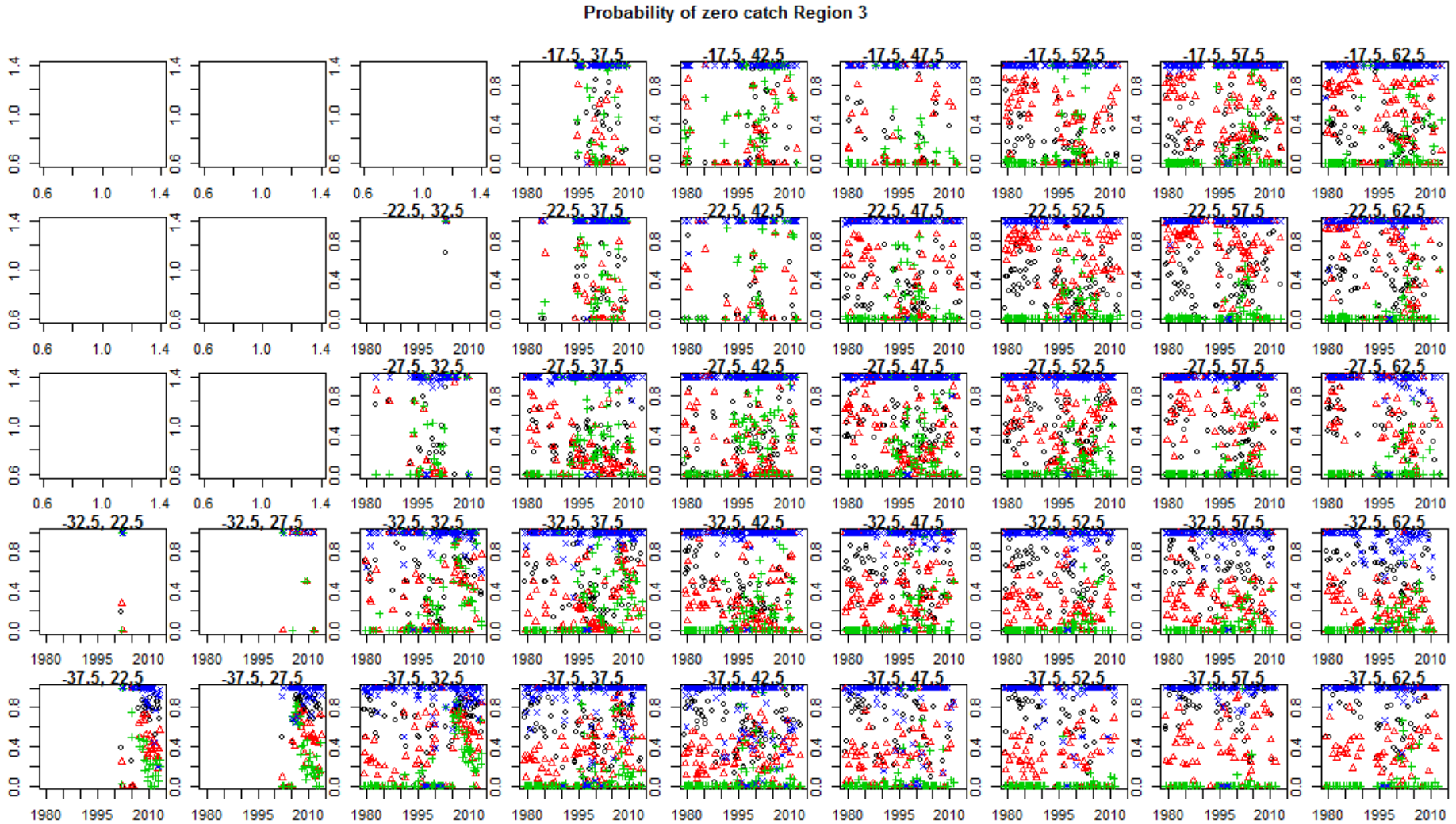

Figure 66: Probability of zero catch by year-qtr and 5 degree square in region 3 for bigeye, yellowfin, albacore, and SBT.

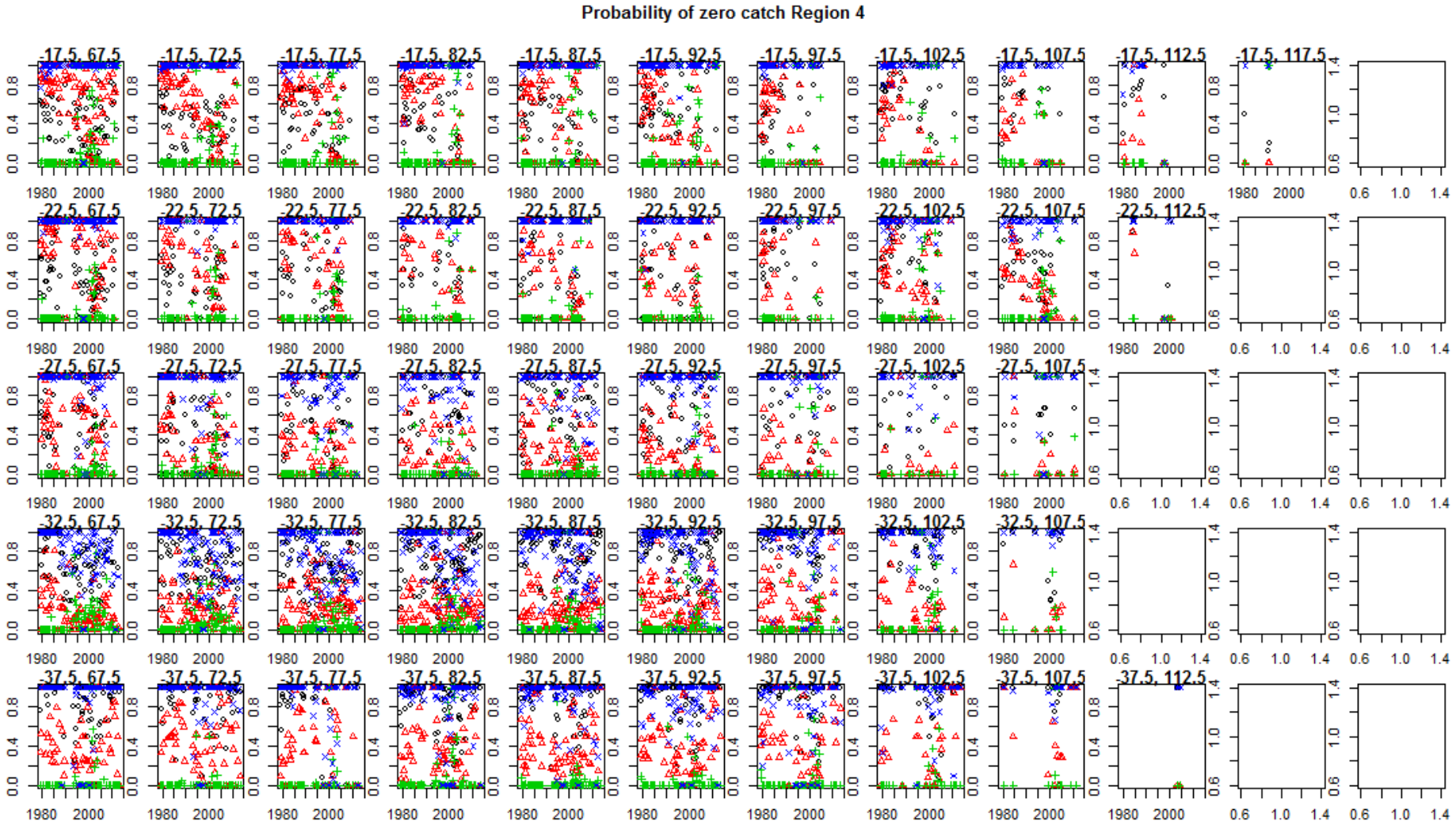

Figure 67: Probability of zero catch by year-qtr and 5 degree square in region 4 for bigeye, yellowfin, albacore, and SBT.

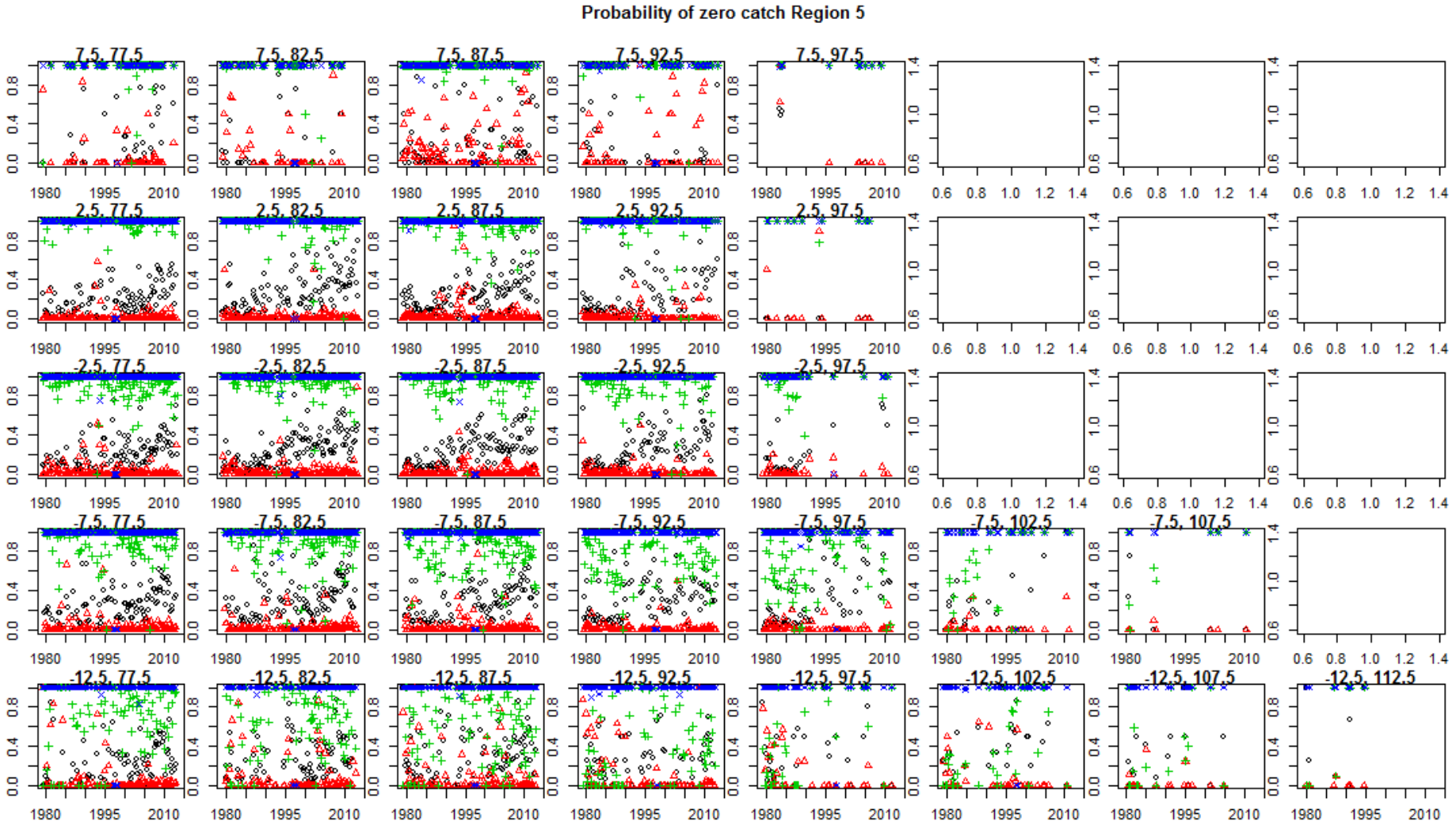

Figure 68: Probability of zero catch by year-qtr and 5 degree square in region 5 for bigeye, yellowfin, albacore, and SBT.

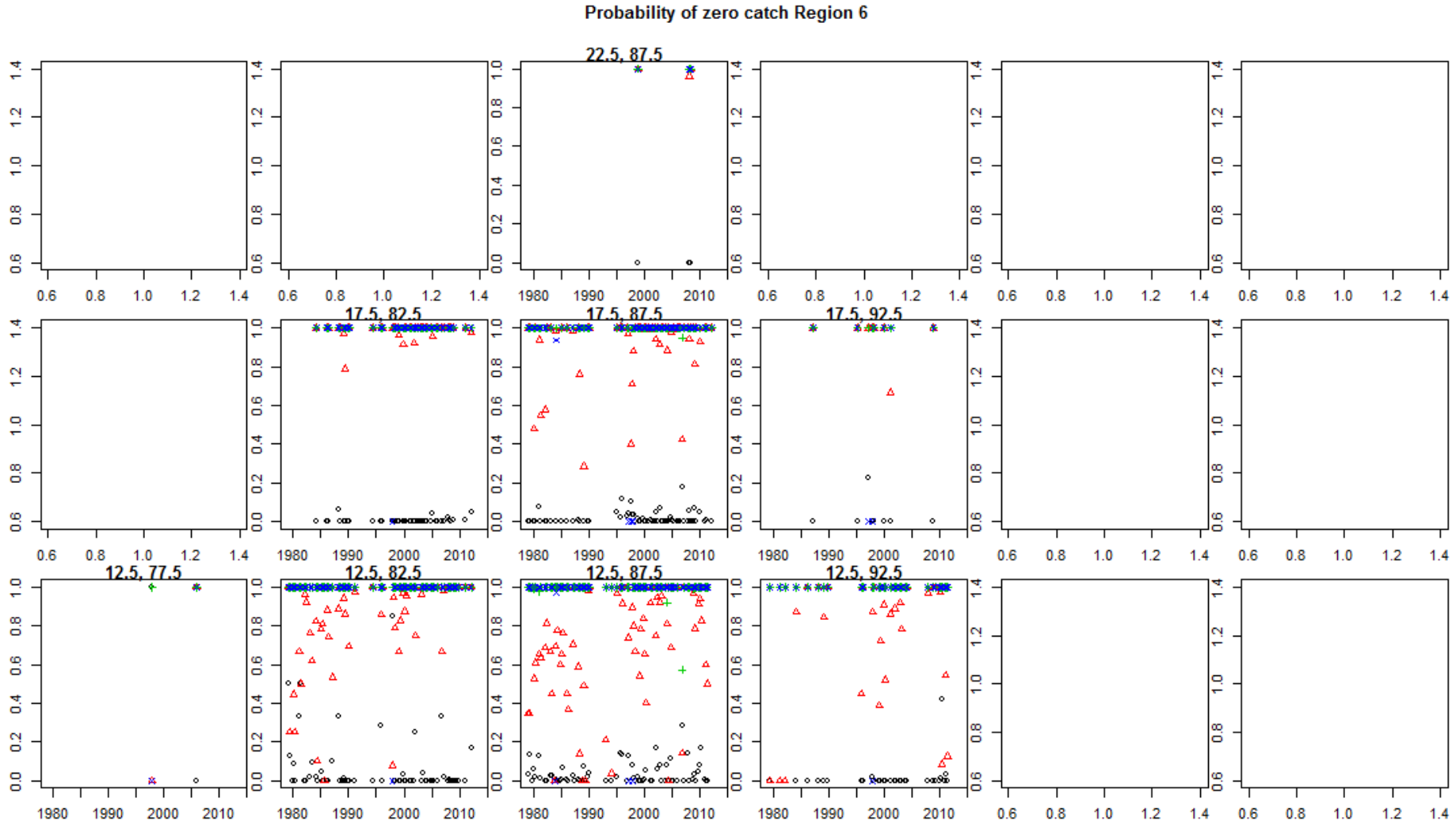

Figure 69: Probability of zero catch by year-qtr and 5 degree square in region 6 for bigeye, yellowfin, albacore, and SBT.

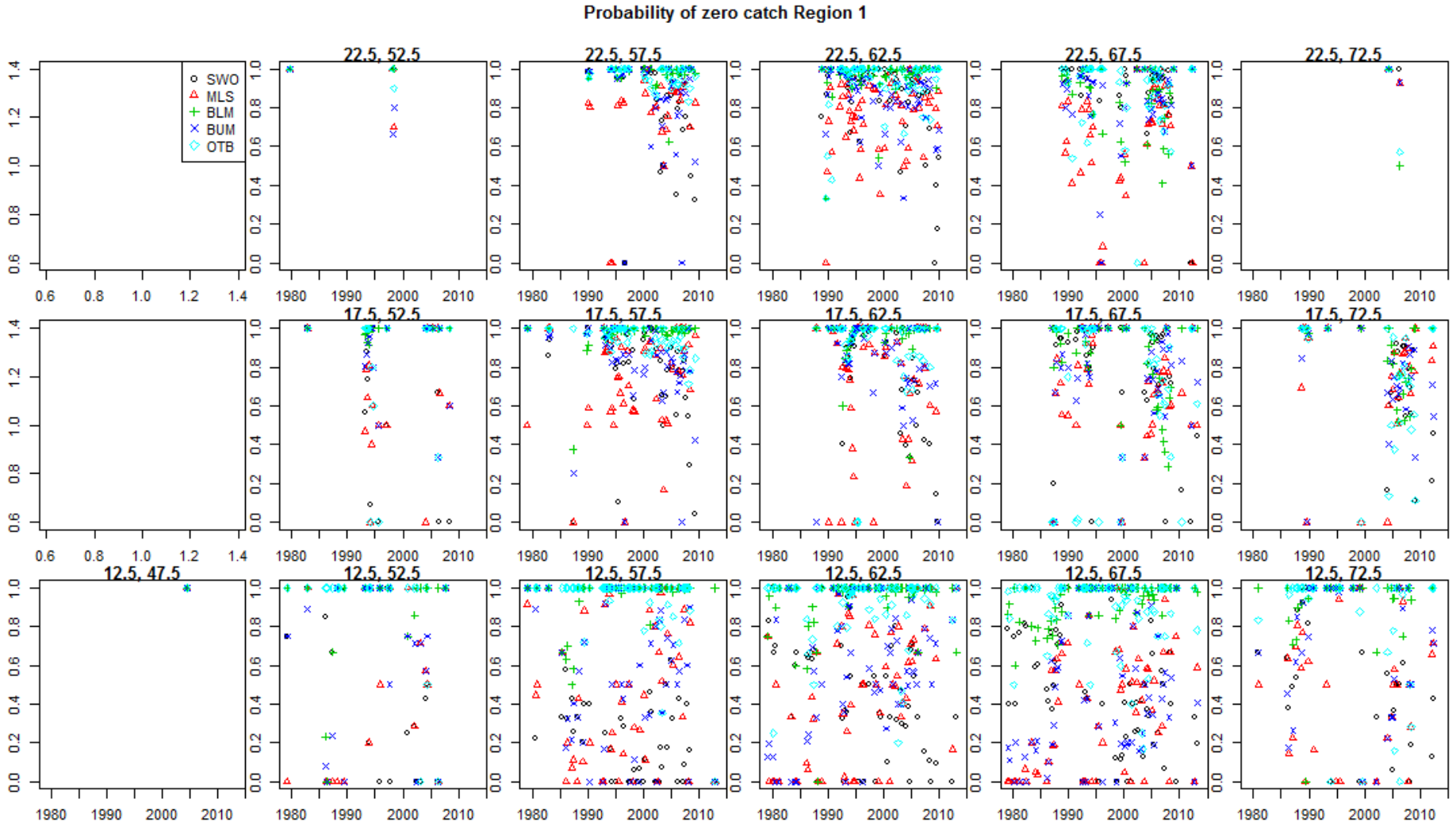

Figure 70: Probability of zero catch by year-qtr and 5 degree square in region 1 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

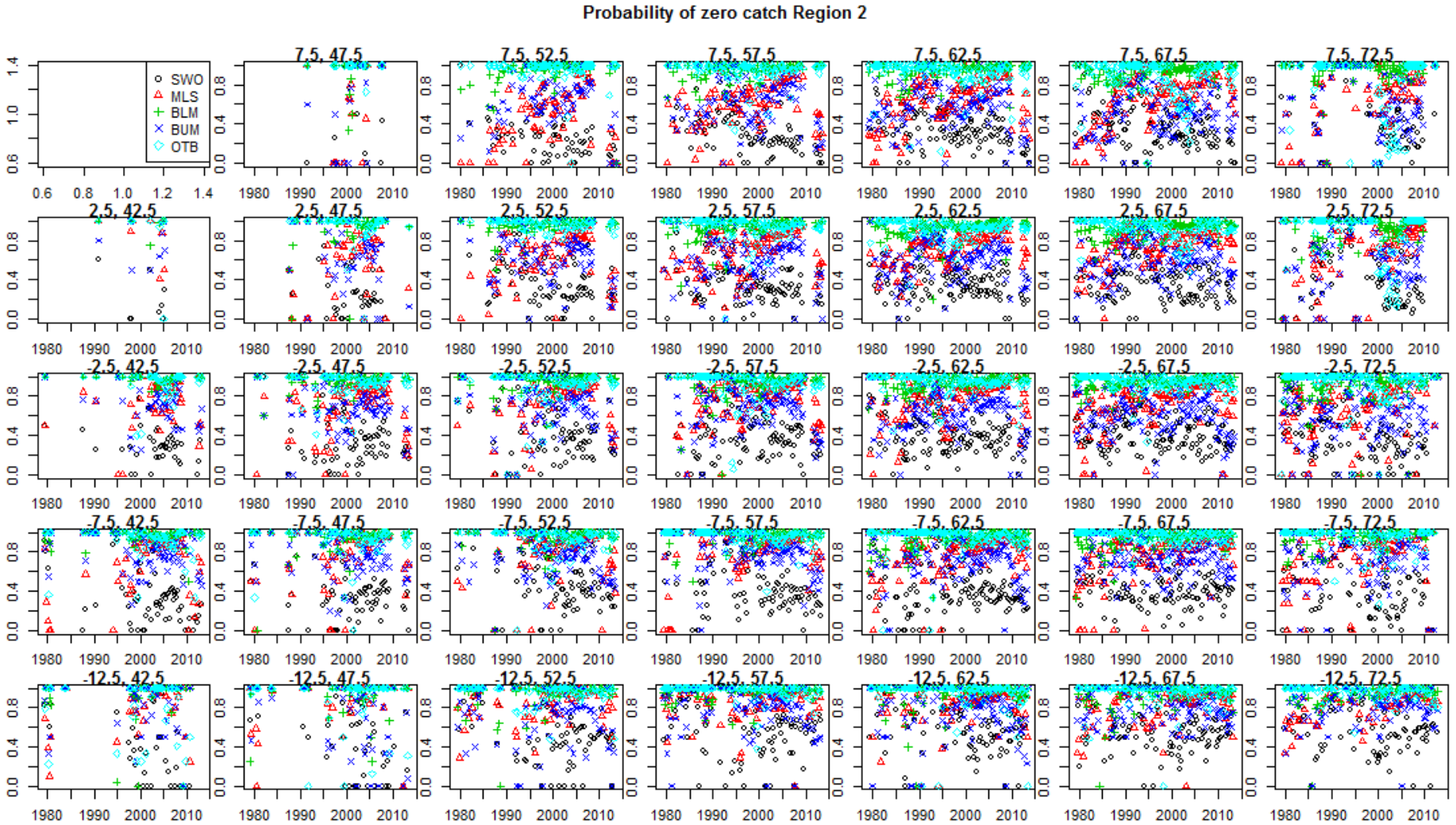

Figure 71: Probability of zero catch by year-qtr and 5 degree square in region 2 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

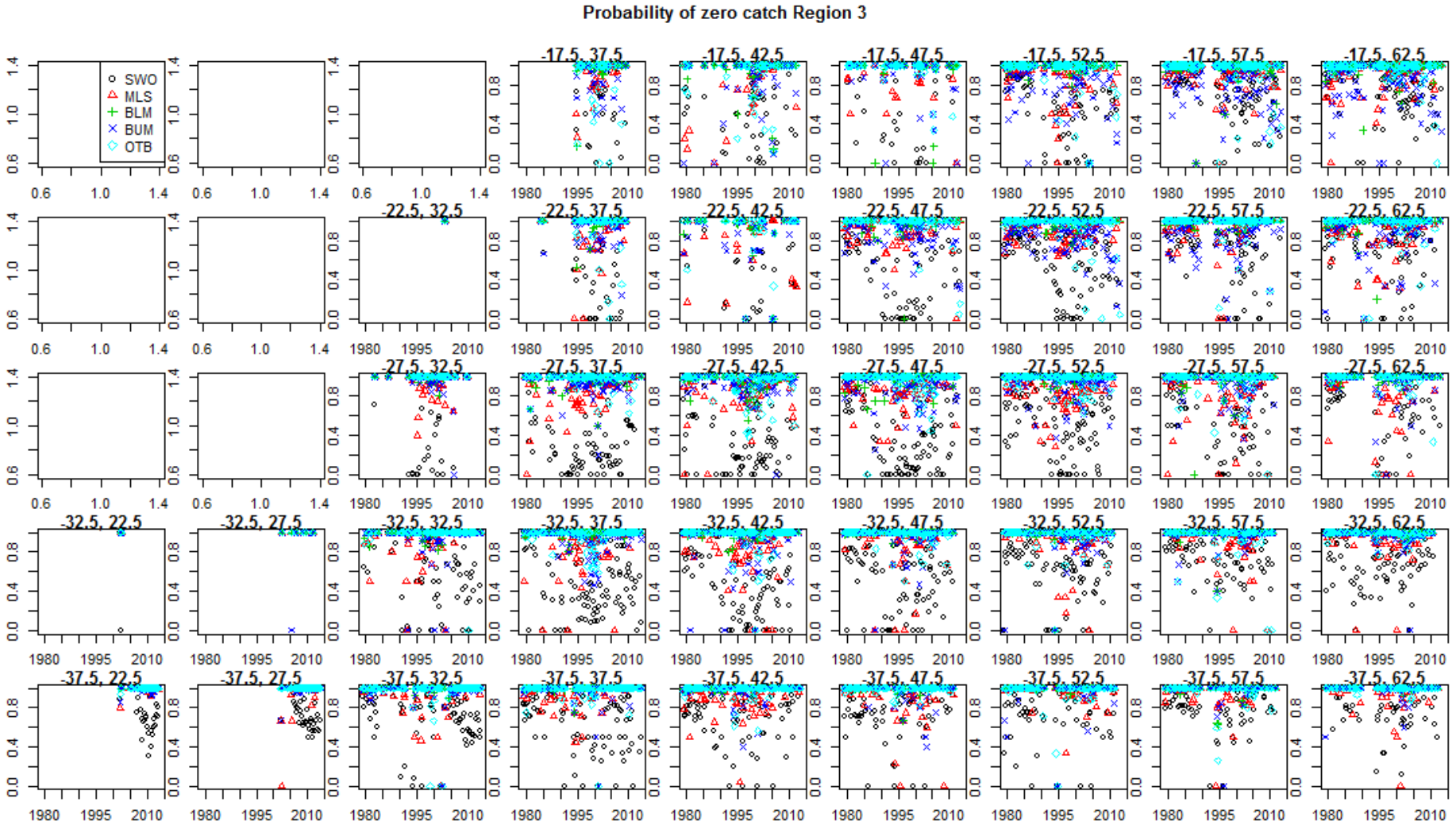

Figure 72: Probability of zero catch by year-qtr and 5 degree square in region 3 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

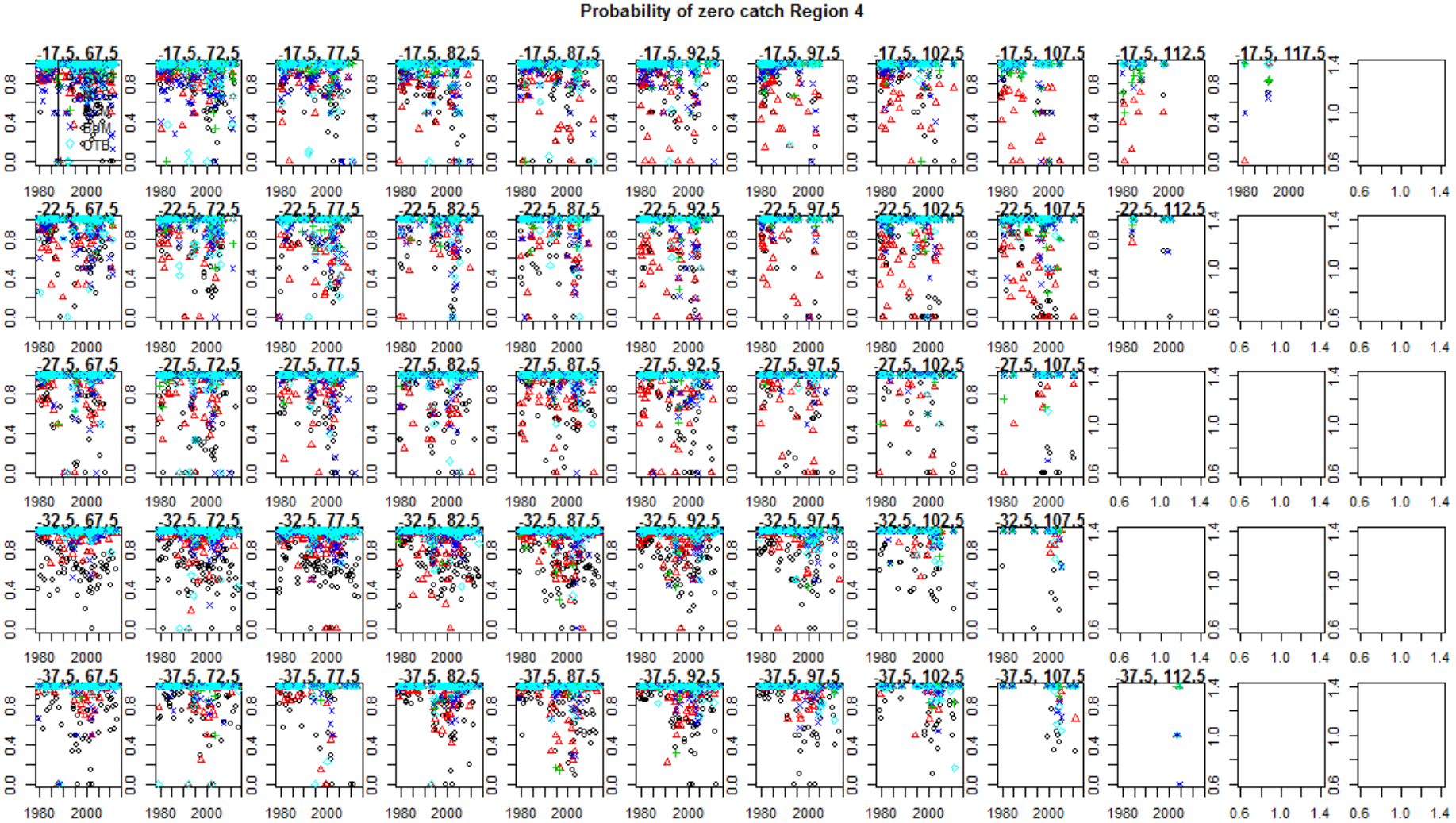

Figure 73: Probability of zero catch by year-qtr and 5 degree square in region 4 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

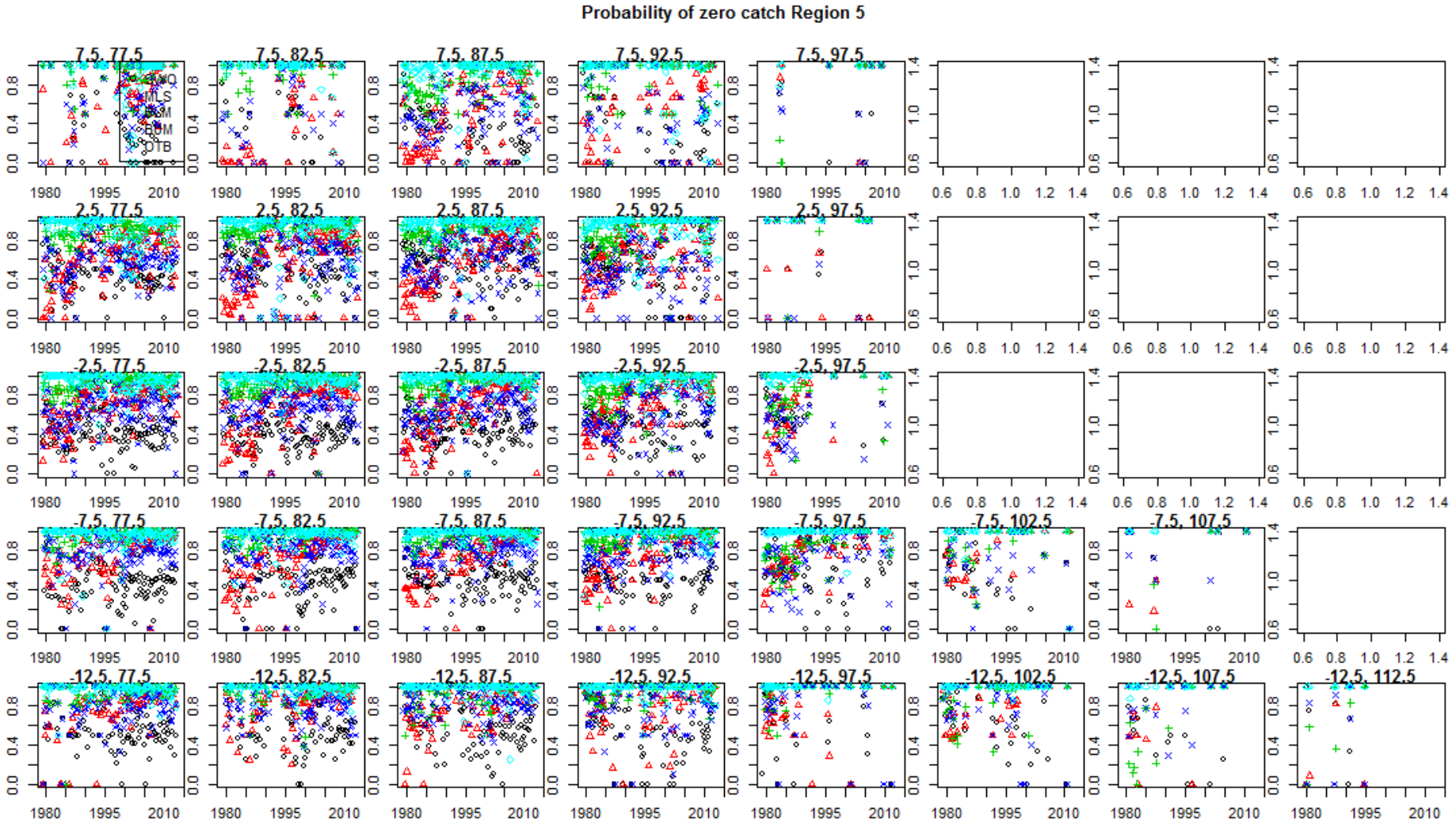

Figure 74: Probability of zero catch by year-qtr and 5 degree square in region 5 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

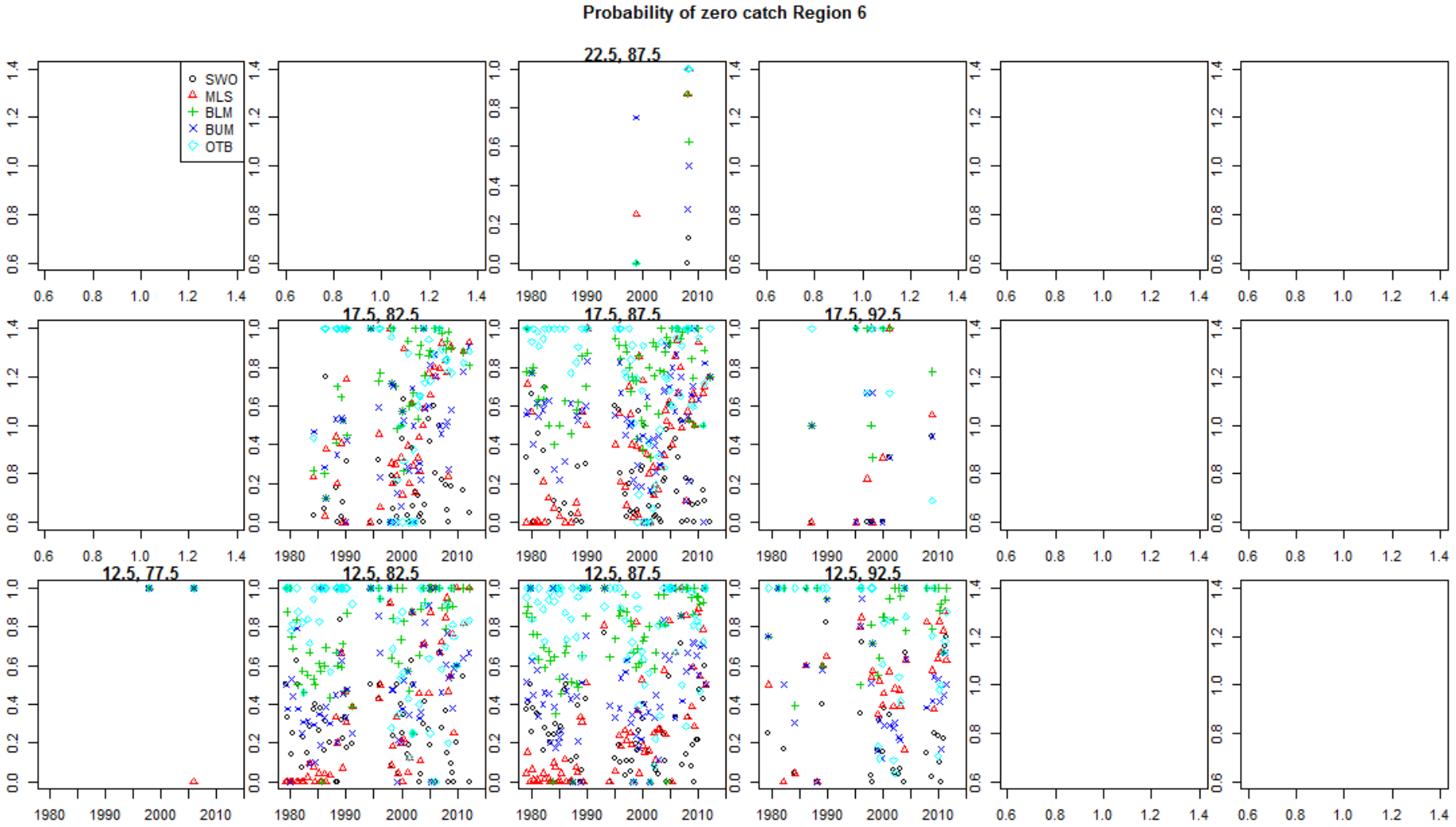

Figure 75: Probability of zero catch by year-qtr and 5 degree square in region 6 for swordfish, striped marlin, black marlin, blue marlin, and other billfish.

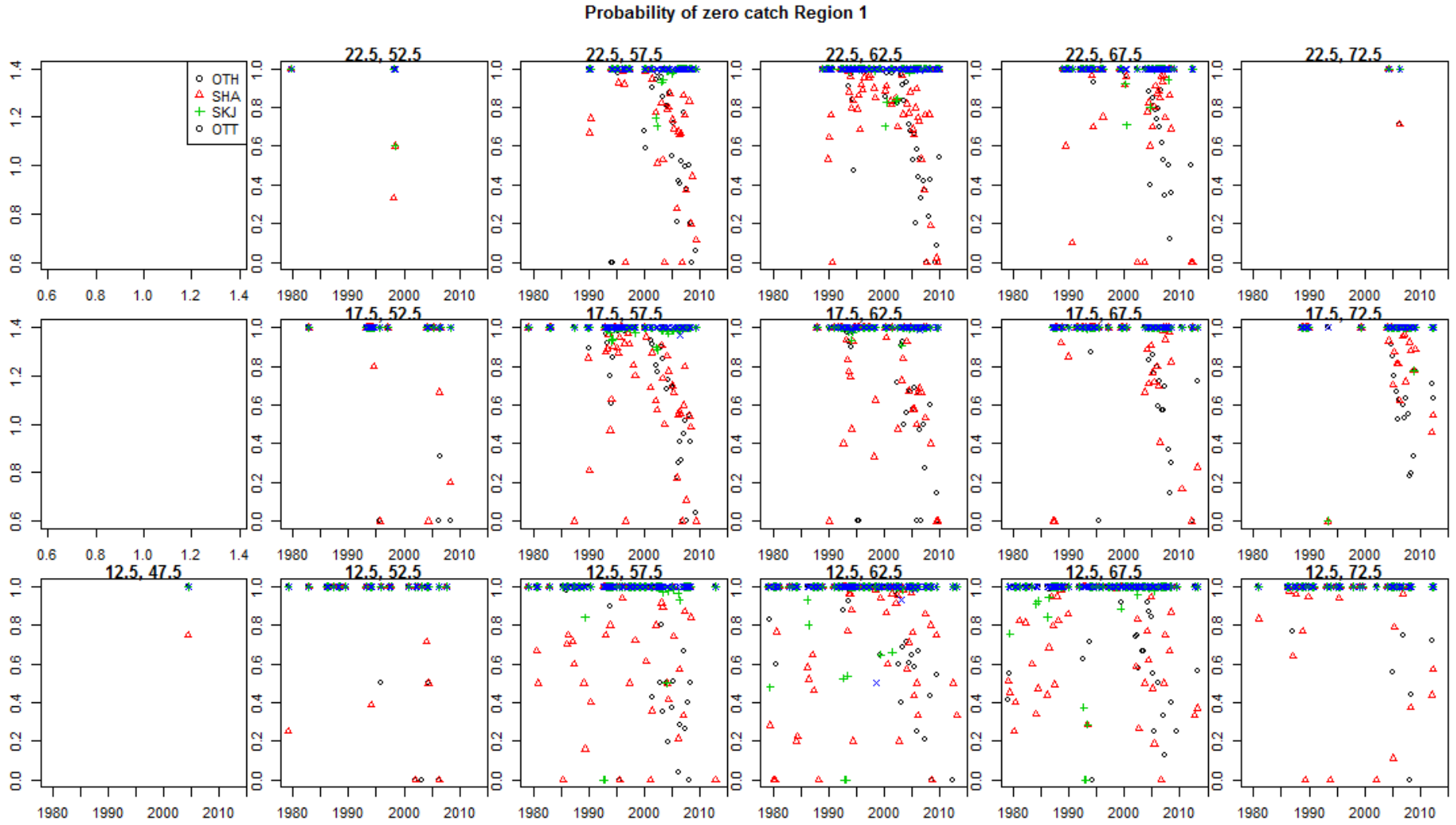

Figure 76: Probability of zero catch by year-qtr and 5 degree square in region 1 for sharks, skipjack, other tunas, and other species.

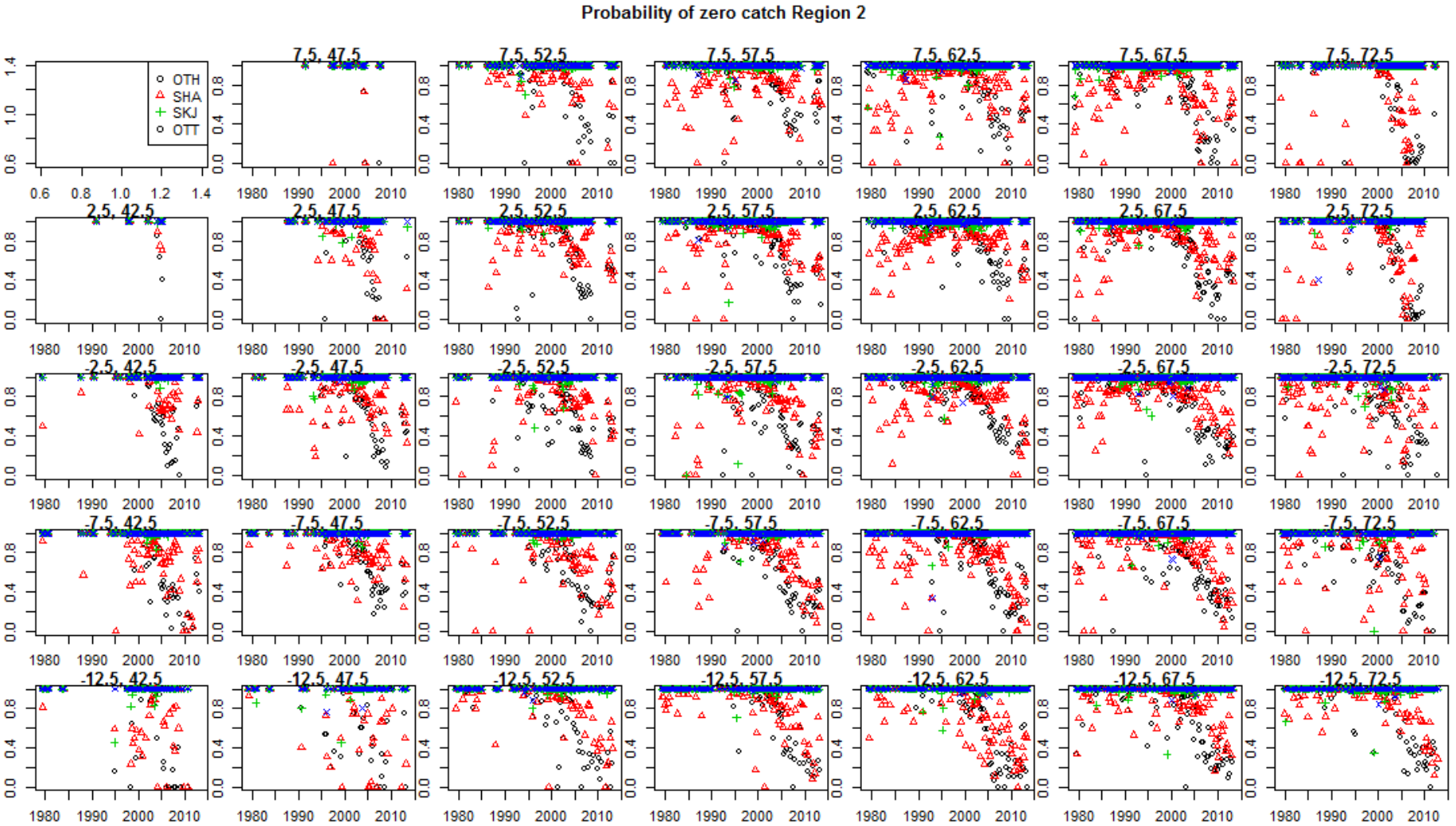

Figure 77: Probability of zero catch by year-qtr and 5 degree square in region 2 for sharks, skipjack, other tunas, and other species.

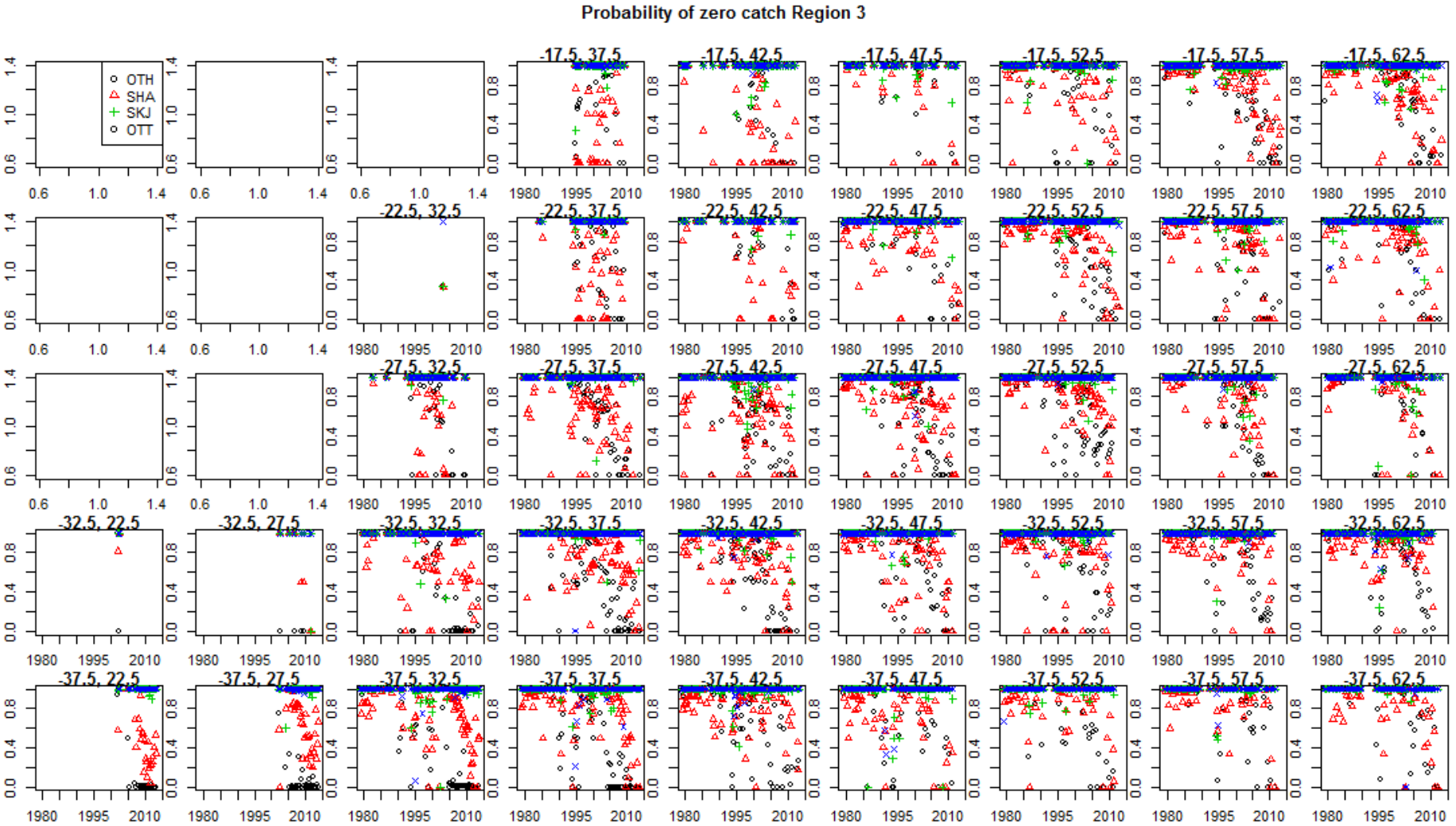

Figure 78: Probability of zero catch by year-qtr and 5 degree square in region 3 for sharks, skipjack, other tunas, and other species.

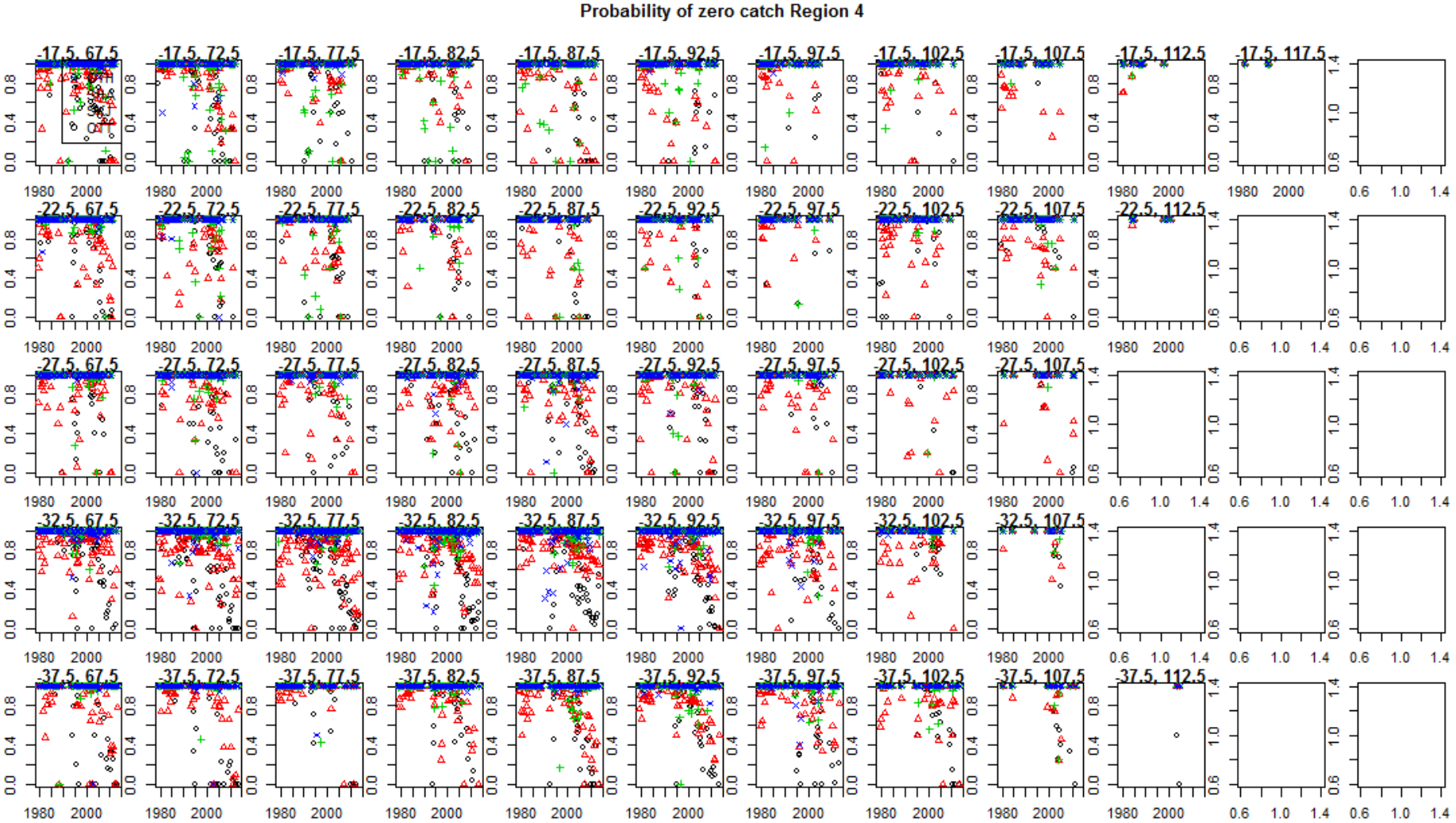

Figure 79: Probability of zero catch by year-qtr and 5 degree square in region 4 for sharks, skipjack, other tunas, and other species.

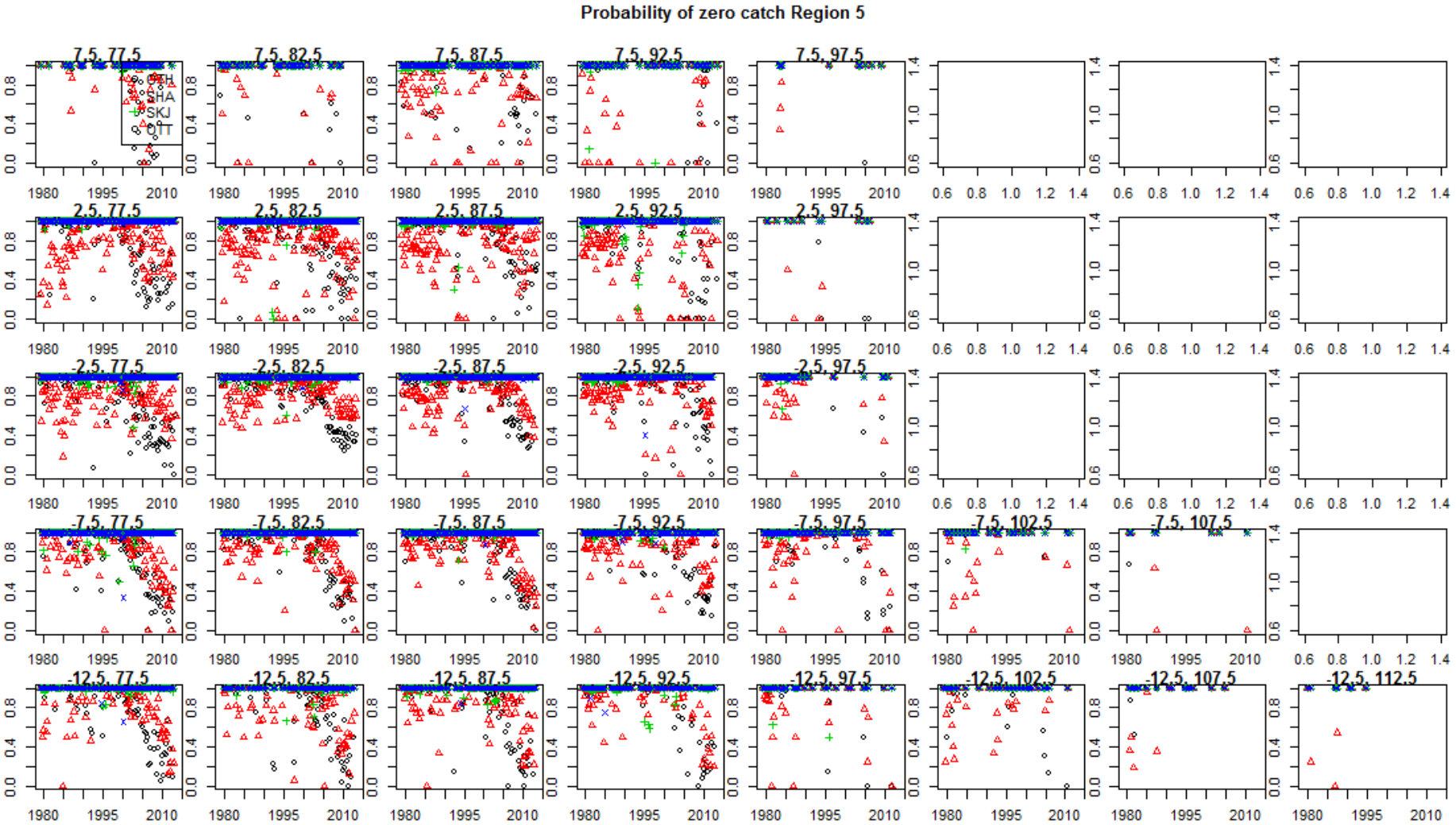

Figure 80: Probability of zero catch by year-qtr and 5 degree square in region 5 for sharks, skipjack, other tunas, and other species.

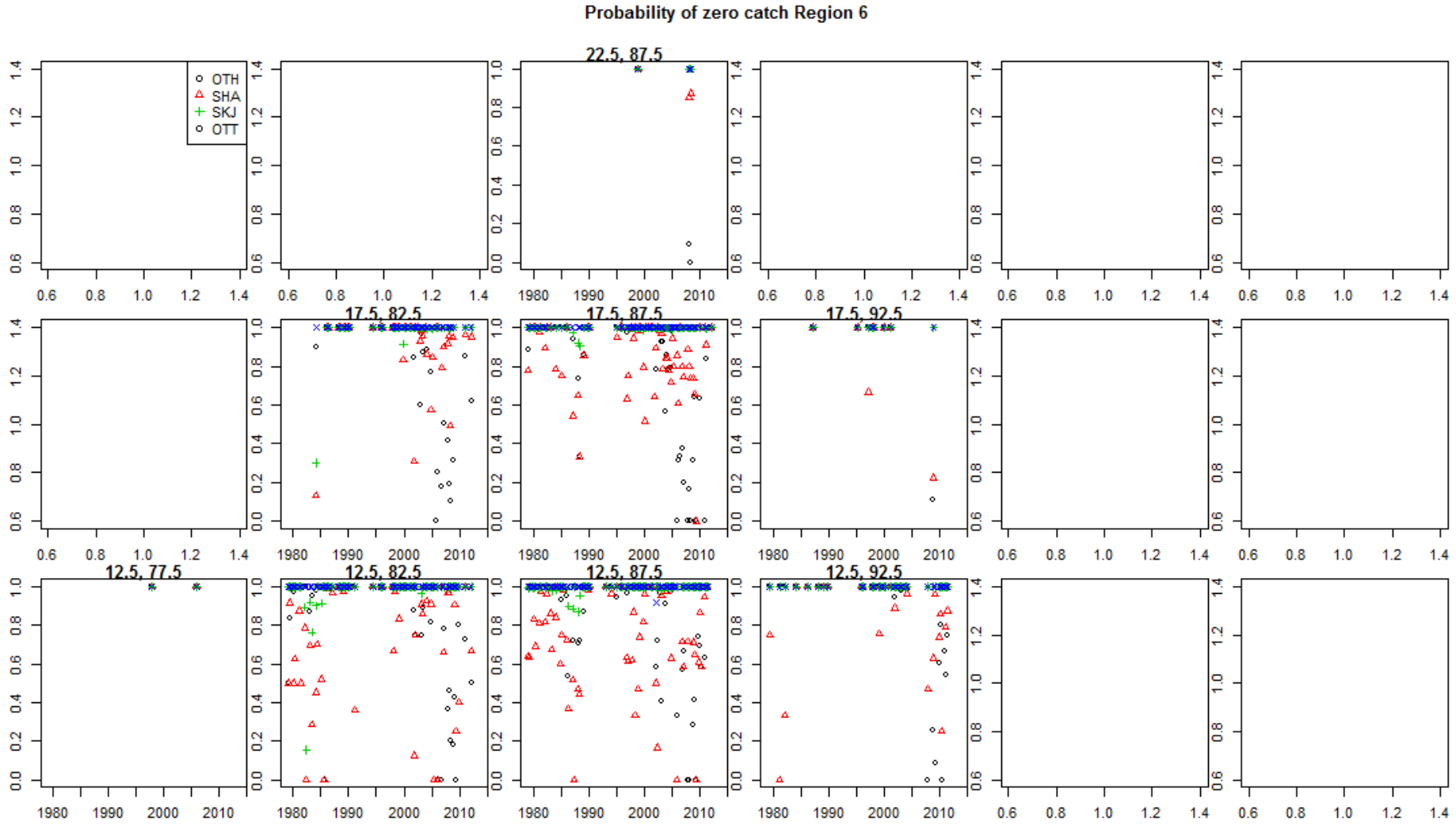

Figure 81: Probability of zero catch by year-qtr and 5 degree square in region 6 for sharks, skipjack, other tunas, and other species.