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SPATIAL AND TEMPORATL TRENDS IN YELLOWIFN AND BIGEYE LONGLINE CPURE FOR THE JAPANESE FLEET IN WCPO

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1. Introduction

Catch and effort data from the Japanese longline fleet represent a key input into the stock assessments of yellowfin and bigeye for the WCPO (Hampton et al 2005a, 2005b). The assessments encompass separate regions and for the 2005 assessment an equivalent regional structure, comprising six regions, was used for both yellowfin and bigeye tuna (Figure 1). These regions were defined based on the distribution of catch and spatial distributions in CPUE aggregated over time.

For the yellowfin and bigeye stock assessments, catch and effort data from the Japanese longline fleet represent the key index of stock abundance in each of the six regions. These data are used in a generalised linear model (GLM) to derive a standardised effort series for the key longline fisheries in each region (Langley et al. 2005). These fisheries are incorporated in the assessment model with a constant catchability throughout the model period and, consequently, the standardised effort series represents an index of the longline exploitable biomass in each region.

A key assumption of the regional structure of the assessments is that the population dynamics are relatively homogeneous within a region, i.e., trends in both fish size and relative abundance are broadly consistent throughout a region. During the first Scientific Committee meeting (SC1) of the WCPFC there was considerable discussion regarding the GLM longline CPUE indices derived for yellowfin and bigeye. One of the specific recommendations from SC1 was to investigate the homogeneity of the CPUE trends within each region. This paper examines the issue by undertaking an analysis of the time-series of CPUE data from the Japanese longline fleet at the finest level of spatial resolution available for the entire model period (five degrees of latitude and longitude).

2. Methods

Catch and effort data for the Japanese longline fleet are available for the period 1952 to 2005. These data are available aggregated by year, month and spatial cell. Prior to 1966, the data are available at a 5-degree spatial resolution, i.e., aggregated by spatial cells of dimensions five (5) degrees of latitude and longitude. From 1996 onwards, data are available at 1-degree spatial resolution. For years 1975 onwards, data are also stratified by the gear configuration of the longline (number of hooks between floats, HBF). Catch was recorded as the number of fish caught and effort in the number of hooks set.

The analysis was conducted using the data set stratified at the finest resolution available for the entire time period (1952–2005) — 5-degree resolution. An example of the subdivision of an individual region by 5-degree cells is presented in Figure 2. While a similar analysis could be undertaken using 1-degree data it was considered important to capture the earlier period of the fishery as there were some large scale changes in CPUE during that period.

A separate analysis was conducted for each species in each of the six model regions. Each analysis involved calculating the nominal CPUE (number of fish per 100 hooks set) by year and quarter for the species in the individual 5-degree squares comprising the region. Only 5-degree cells with at least 50 year/quarter records were included in the analysis and only year/quarters with at least 2000 hooks set were included.

The resulting CPUE indices were normalised to the mean of the series. The indices were then smoothed using a lowess function and the resulting CPUE trends compared to determine the degree of spatial heterogeneity in the CPUE trend for the region.

3. Results

3.1. Yellowfin

For region 1, yellowfin CPUE tended to be high in most 5-degree cells during the late-1950s–early-1960s and subsequently declined through the 1960s, remaining relatively low through the 1970s (Figure 3). For most of the cells comprising region 1, yellowfin CPUE increased from the late 1970s to relatively high levels, particularly in the east of the region, and then declined sharply over the last decade.

Within region 2, two distinct trends in yellowfin CPUE are evident. In the northern area (north of 30°N), CPUE was generally low in the early period (pre 1965) and increased strongly from the 1970s to a peak in the mid-1980s–mid-1990s (Figure 4). This trend was steadier in the 30°–35°N latitudinal band, while in the northern latitudes the trend occurred later and was more extreme. In both latitudinal bands, there was a strong decline in CPUE from about the early–mid 1990s to very low levels in recent years.

A contrasting trend in yellowfin CPUE is evident in the southern area of region 2 (20°–30°N). CPUE was relatively high through the 1970s and 1980s and then declined rapidly in the late 1970s–early 1980s (Figure 4). Catch rates were relatively stable for the remainder of the period. The exception is within 25°–30°N where CPUE declined very rapidly from the late 1990s; similar to the trend observed in the more northern areas of the region.

For yellowfin in region 3, there is a consistent decline in CPUE in the each of the 5-degree cells that comprise the equatorial region (between 10°S and 10°N), with CPUE declining by about 70% over the study period (Figure 5). Higher declines are evident in the western extremity of the region, particularly during the late 1970s–early 1980s. This may relate to a decline in the number of records from this area in the latter period of the study. CPUE trends differed in the area north of 10°N. CPUE trends from individual 5-degree cells in this area were relatively variable prior to 1980, although since 1990 most cells have exhibited a strong decline in CPUE.

For yellowfin in region 4, there are two distinct CPUE trends in the individual 5-degree cells (Figure 6). In the core equatorial region, between 5°S and 5°N, there is a consistent trend with a strong initial decline in CPUE until the mid 1970s followed by a period of relatively stable CPUE and then a steady decline from about 1990 to current. There is a different trend in the higher latitudes (north and south). In these cells, CPUE trends were more variable but tended to fluctuate throughout 1952–mid-1980s with no strong trends evident within and between individual cells. However, since the early 1990s, there has been a consistent decline in all cells and this decline has been particularly marked in the last decade.

For region 5, yellowfin CPUE tended to steadily decline from the mid 1950s to the mid-1970s in all 5-degree squares north of 30°S — the area where most of the yellowfin catch is taken from the region (Figure 7). For the remainder of the period, yellowfin CPUE remained relatively stable or tended to increase slightly during the 1980s. In the more southern areas of the region, yellowfin CPUE was highly variable among 5-degree cells, probably due to low levels of fishing effort and yellowfin catch.

In region 6, yellowfin CPUE generally declined rapidly from the mid-1950s to mid-1970s in all 5-degree cells north of 30°S (Figure 8). Limited catch and effort data are available from these cells from the subsequent period and the CPUE trends are highly variable among cells. Similarly, limited catch and effort data are available from the southern area of the region and the CPUE trends are poorly determined.

3.2. Bigeye

In region 1, the 5-degree cells within the latitudinal range 25°–35°N all show a consistent decline in bigeye catch rates over the time period, with CPUE declining by about 50% (Figure 9). By comparison, the more northern area (35°–40°N) reveals a strong initial decline in CPUE between 1955 and 1970, particularly in the eastern area of region 1. Catch rates were relatively stable for the remainder of the period (Figure 9). CPUE trends in the more southern latitude of region 1 were more variable, but generally exhibit a decline in CPUE in the 1960s, low CPUE in the 1970s, an increase in the 1980s, and a recent decline. This trend is generally consistent with the CPUE observed in the adjacent area within region 3, i.e., the northern area of region 3 (Figure 11).

For bigeye in region 2, there is a generally consistent trend in CPUE in all 5-degree cells (Figure 10). CPUE declines sharply during the initial period of the fishery, up to the mid 1970s. Over the remainder of the study period, there is a general and much more gradual decline in CPUE. The only exceptions to this trend are the increasing trends in CPUE observed in the south-western cells of the region (west of 160°W and south of 25°N).

For bigeye in region 3, two different trends in CPUE are evident delineated by the equator (Figure 11). In the south, CPUE was relatively constant up to the mid 1970s before increasingly sharply from the mid 1970s to 1990. Since 1990, bigeye CPUE in the cells in the southern area has tended to decline. To the north of the equator, CPUE in most cells exhibited a sharp initial decline and has tended to fluctuate at a relatively constant level over the subsequent period, with peaks in CPUE evident in both the mid 1970s and late 1980s–early 1990s.

Trends in CPUE for bigeye in region 4 are more complex. The cells in the southwest of the region display similar trends in CPUE to those cells south of the equator within region 3, that is, a general increase in CPUE from the mid 1970s to 1990 (Figure 12). This trend is strongest to the west of 160°W and south of 5°S. In the core equatorial area (within 5°S and 5°N), CPUE has been relatively constant throughout the study period, with a period of higher CPUE during the mid 1980s. To the north of 5°N, the CPUE trend is more comparable to the trend in CPUE observed throughout region 2, i.e., a strong decline in CPUE from 1952 to mid 1970s, followed by a more gradual decline in CPUE over the subsequent period.

Trends in bigeye CPUE within region 5 vary with respect to latitude (Figure 13). In the northern Coral Sea (10°–15°S), CPUE remained relatively constant until the mid 1970s before increasing steadily over the following decade. CPUE remained high until the late 1980s–early 1990s and subsequently declined. In the southern area of the Coral Sea (15°–25°S), there was a strong decline in CPUE from the commencement of fishing in the late 1950s until the mid-1980s (Figure 13). CPUE in the 5-degree cells that comprise this area generally increased during the 1990s. A similar trend is also observed in the more southern areas of region 5, although the trends are much more variable, at least partly due to the lower level of fishing effort in the constituent 5-degree cells.

For region 6, bigeye CPUE tends to decline in most 5-degree cells north of 30°S from the mid-1950s to the mid-1970s (Figure 14). However, CPUE trends were highly variable between cells for the remainder of the period. The high level of variation is likely to reflect the relatively low level of fishing effort by the Japanese fleet in these areas during this period, partly due to the exclusion of the fleet from historical areas of operation.

4. Conclusions

For both species, there is considerable spatial heterogeneity in the CPUE trend within each of the main regions defined for the 2005 stock assessments of yellowfin and bigeye. This qualitative analysis was useful in the process of reconsidering the regional stratification of the models for the 2006 assessment (Langley 2006a). In addition, this approach was supported by a more quantitative analysis of the same data, whereby, a clustering technique was applied to determine the regional boundaries that minimised the variation in the CPUE trends from each 5-degree cell in a region (Langley 2006a).

The other important consideration in the definition of the regional boundaries is the size structure of the yellowfin and bigeye within each region. Size frequency data (length and weight) from the Japanese longline fleet are available at a larger spatial resolution than the catch and effort data. However, the resolution provides an opportunity to examine the homogeneity of the size composition within a region. These data are analysed in a separate paper (Langley 2006b).

While CPUE trends varied among the 5-degree cells within a region, there was generally a consistent CPUE trend within each latitudinal band comprising the region. This latitudinal structure in the CPUE trends may indicate that trends in relative abundance, largely attributable recruitment processes and exploitation rates, are broadly consistent throughout a latitudinal zone. This may be due to recruitment and movement of tuna being largely driven by oceanographic processes that are structured latitudinally (e.g. equatorial current flows) and/or differential rates of exploitation with respect to latitude. An example of the latter may be the differential impact on the yellowfin stock in the western equatorial waters (5°S–10°N) due to the concentration of the operation of the purse-seine fleet in this area.

The CPUE indices presented in this paper are nominal indices and no attempt has been made to standardise the indices for changes in catchability that may have occurred through the time-series. For a number of the core regions, the analysis was repeated using a GLM model to include additional variables such as gear configuration (HBF) and associated catch of the other species, essentially replicating the GLM approach in Langley et al. (2005). There was no substantive difference in the resulting trends in the CPUE indices for the individual 5-degree cells and the observations regarding the spatial variation in CPUE trends were consistent between the two approaches. However, considerable further work is required to improve the standardisation of longline CPUE in general and a more detailed study may provide some insight into the causes of the spatial variation described in this paper.

5. References

Hampton, J., P. Kleiber, A. Langley, Y. Takeuchi, and M. Ichinokawa. 2005a. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia. SC1 SA WP-1.

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Langley, A., Bigelow, K., Maunder, M., Miyabe, N. 2005. Longline CPUE indices for yellowfin and bigeye in the Pacific Ocean using GLM and statistical habitat standardisation methods. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia. SC1 SA WP-8.

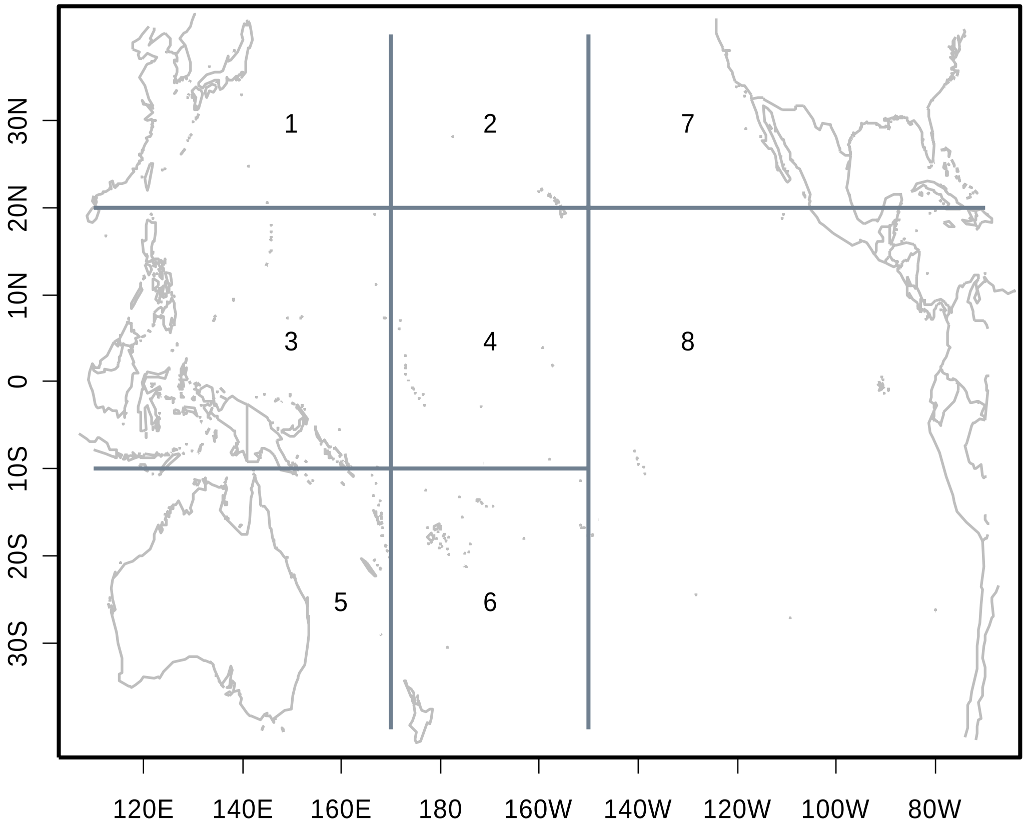

Figure 1. Definitions of the regions included in the WCPO yellowfin and bigeye and Pacific-wide bigeye MFCL assessments. The WCPO assessments encompass the area west of 150°W.

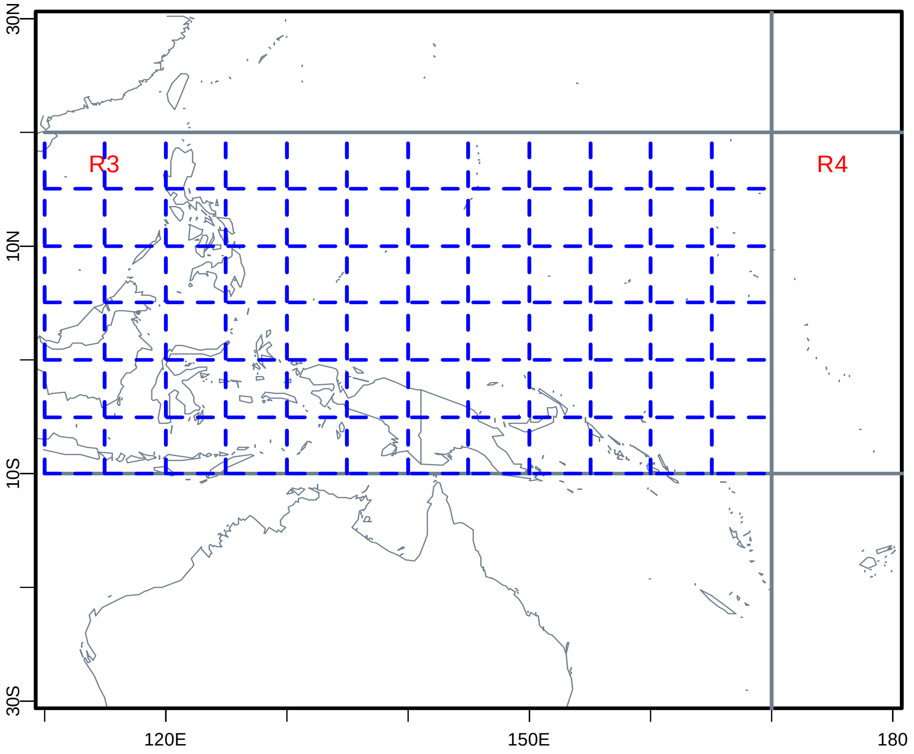

Figure 2. Subdivision of region 3 into 5-degree cells.

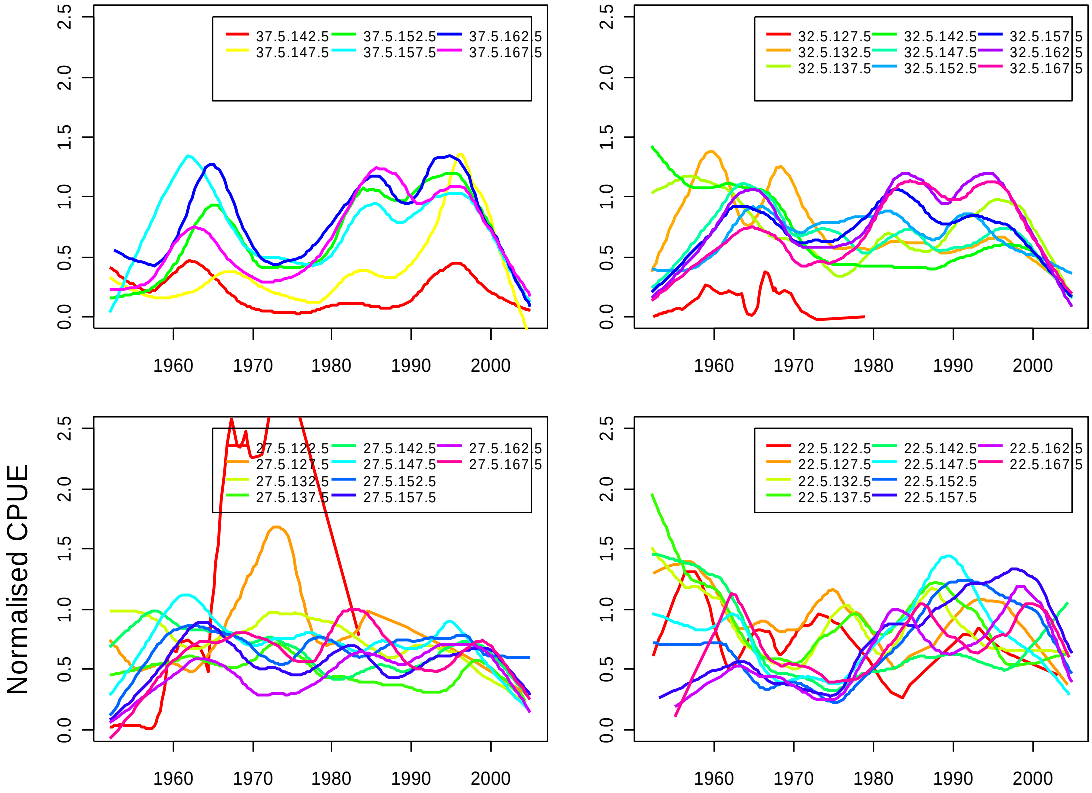

Figure 3. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 1. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

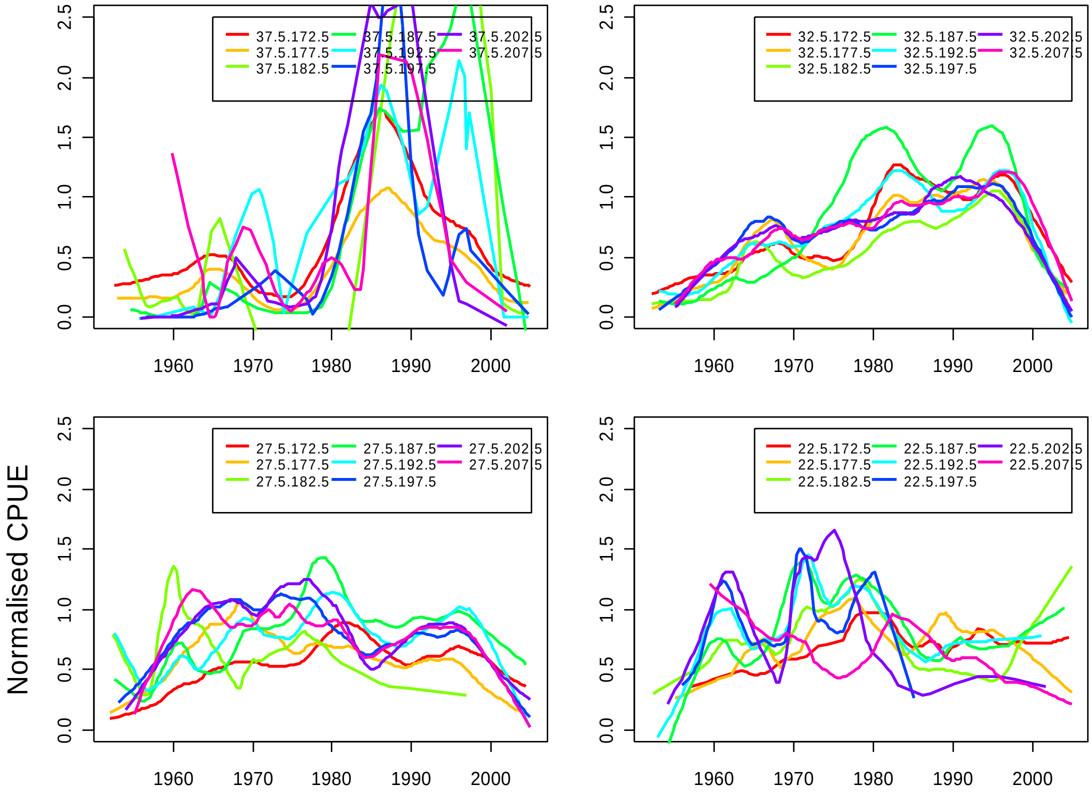

Figure 4. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 2. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

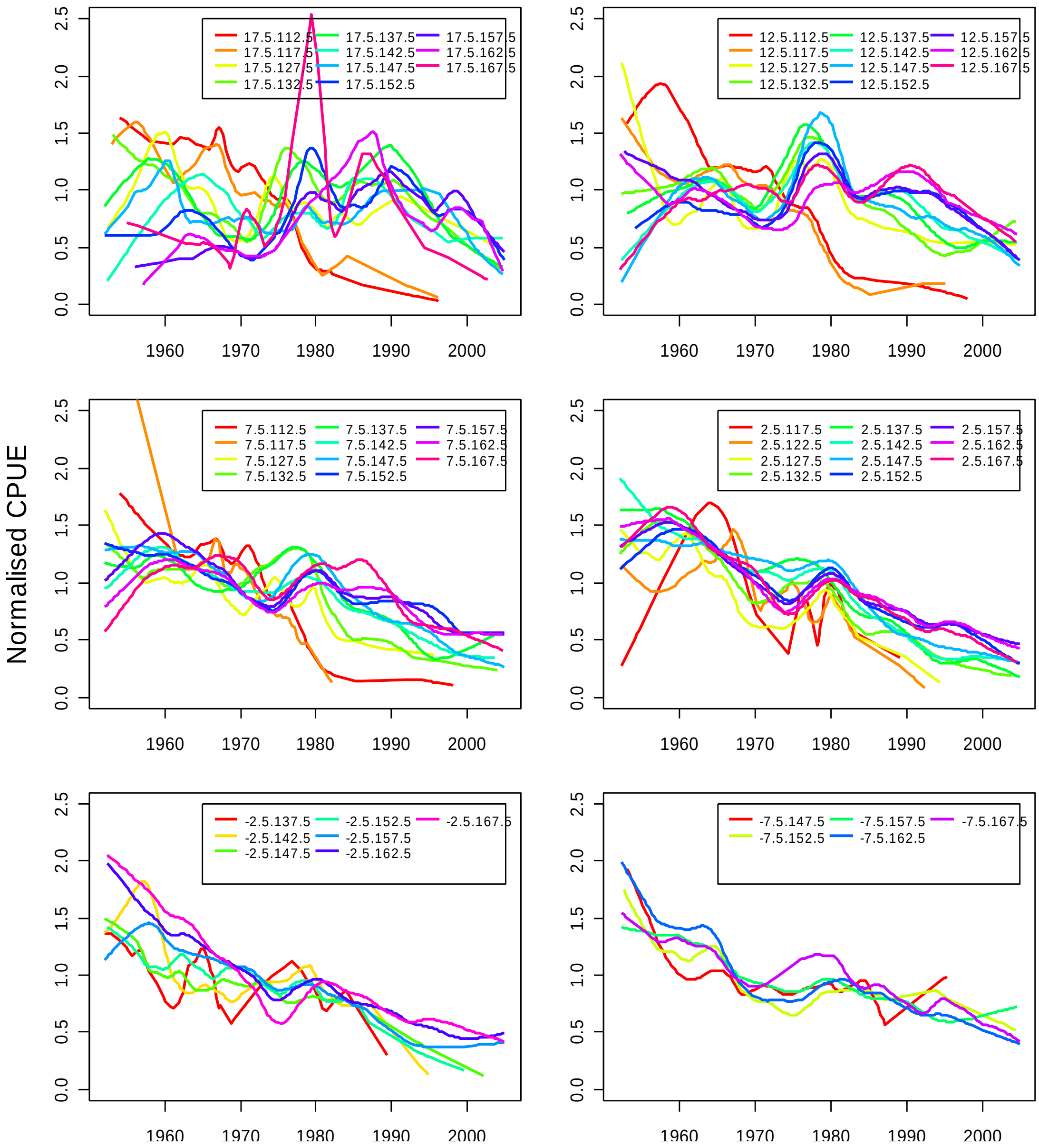

Figure 5. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 3. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

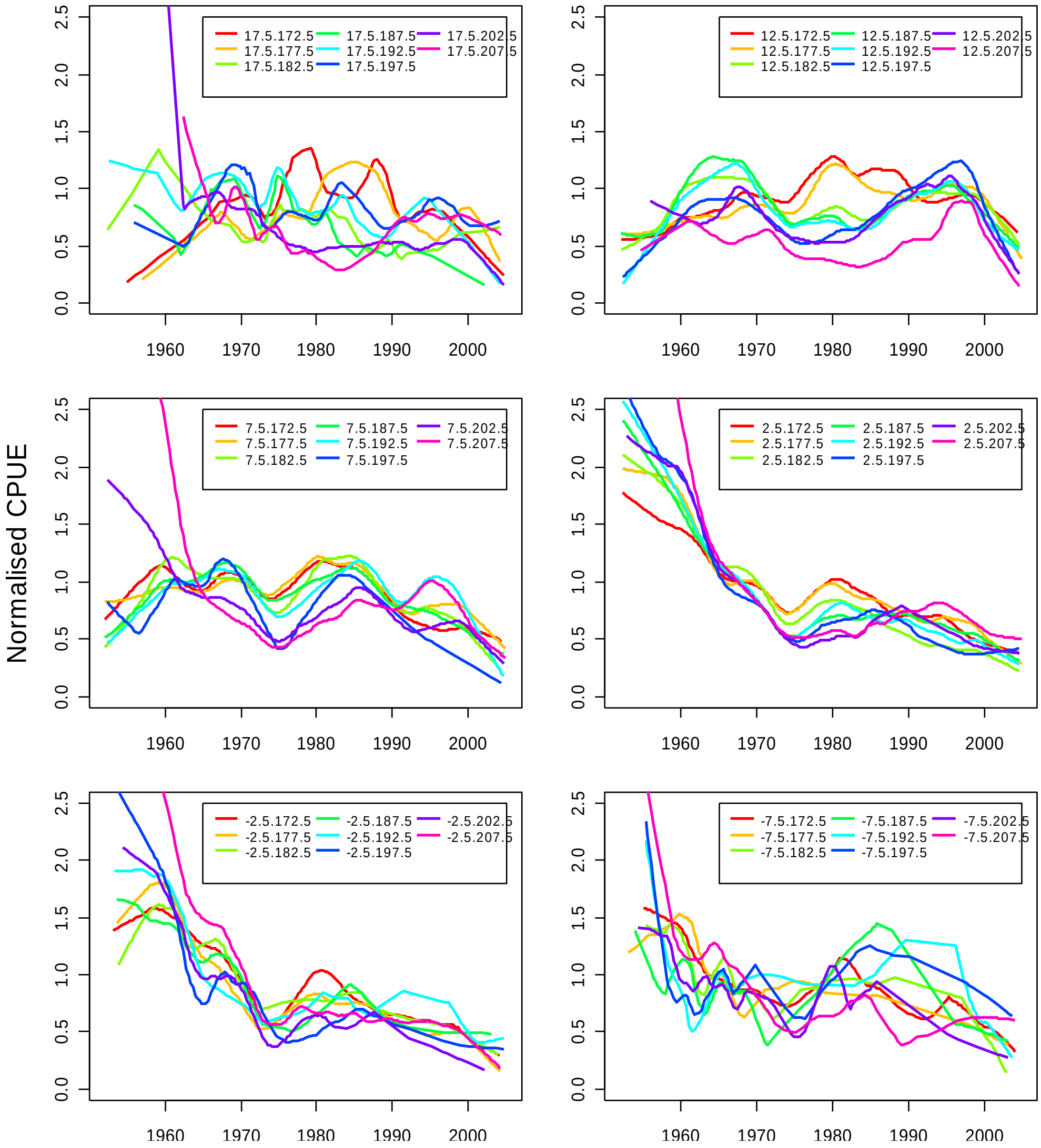

Figure 6. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 4. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

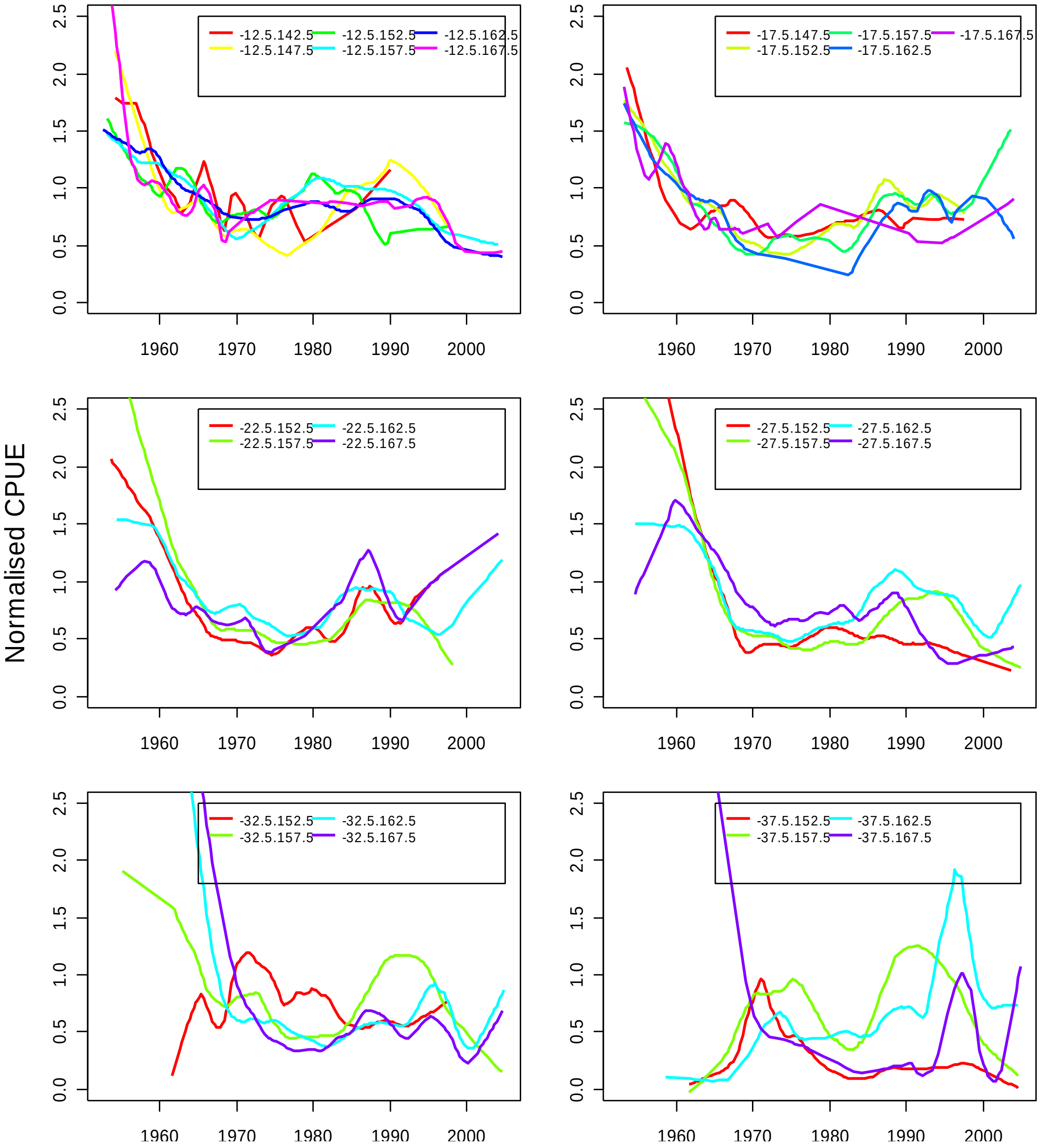

Figure 7. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 5. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

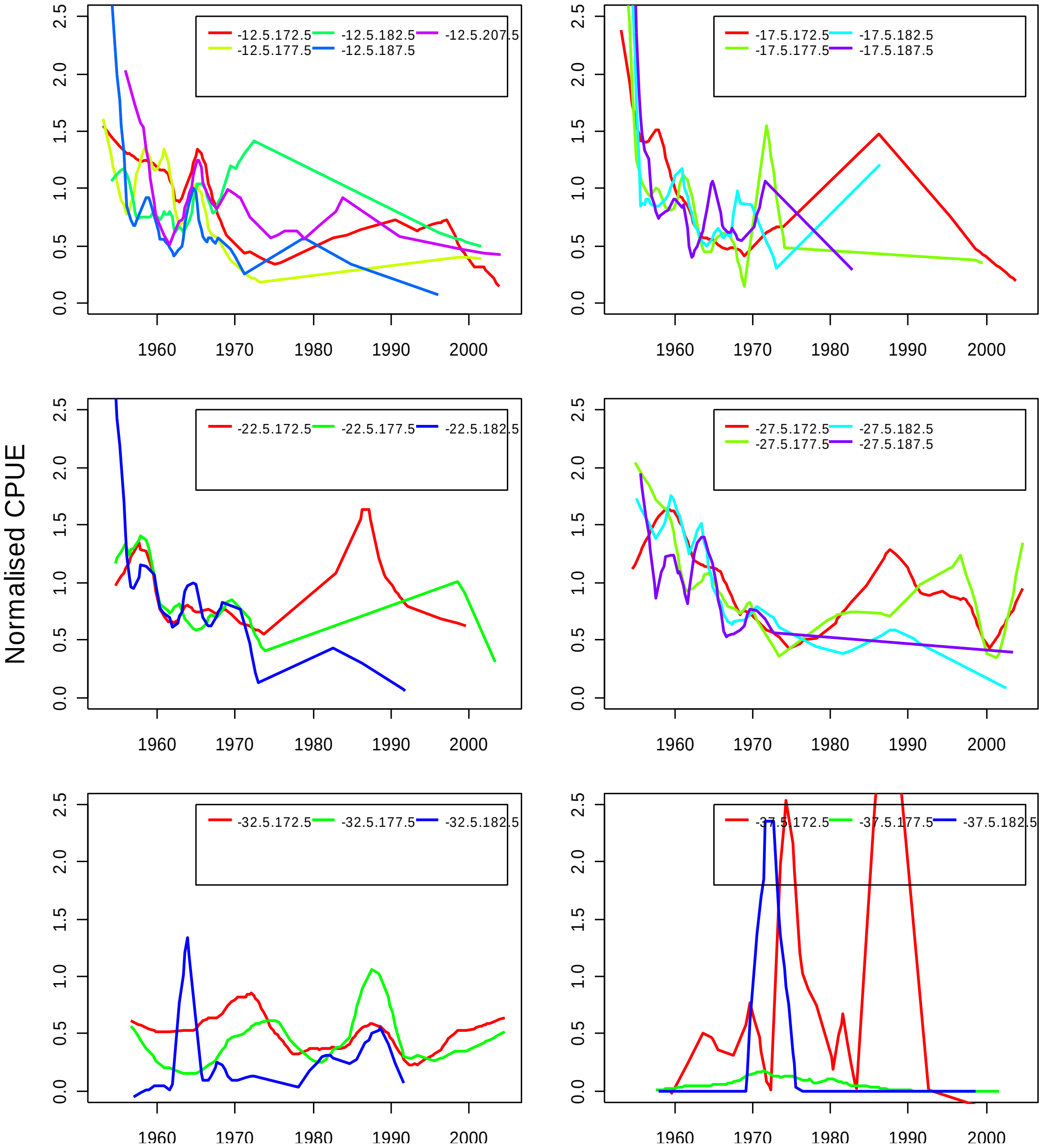

Figure 8. Smoothed trends in nominal CPUE for yellowfin for each of the 5*5 latitude/longitude cells that comprise YFT MFCL region 6. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

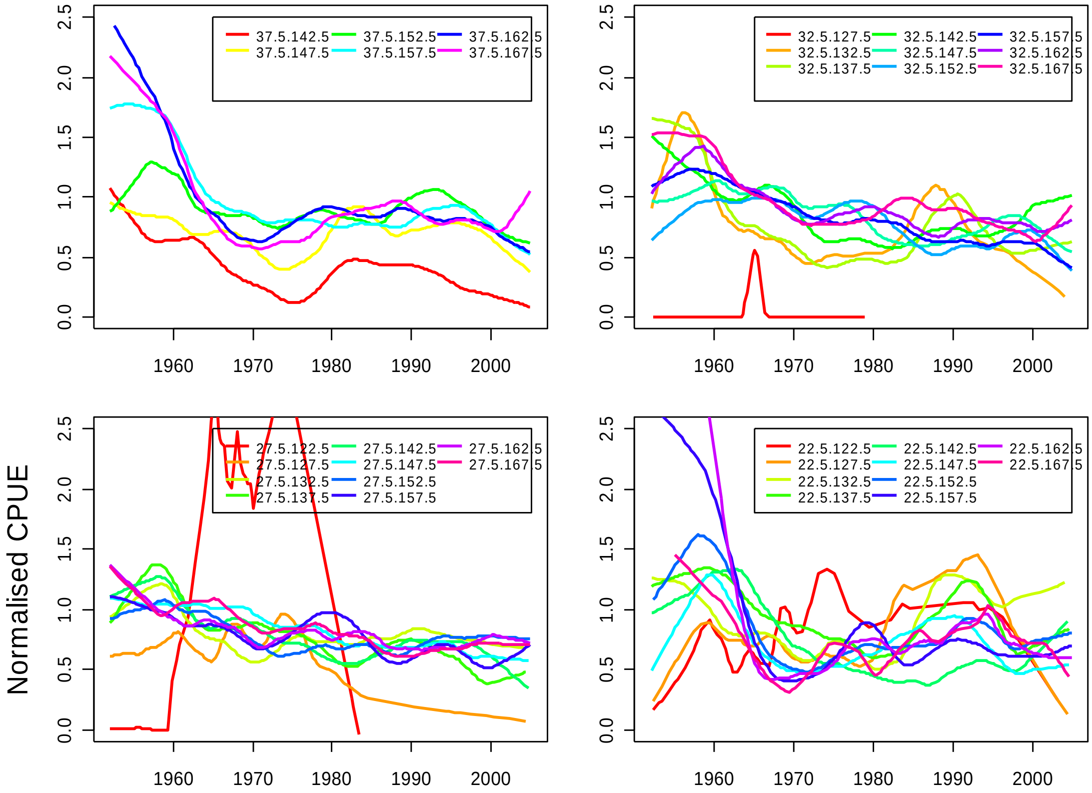

Figure 9. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 1. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

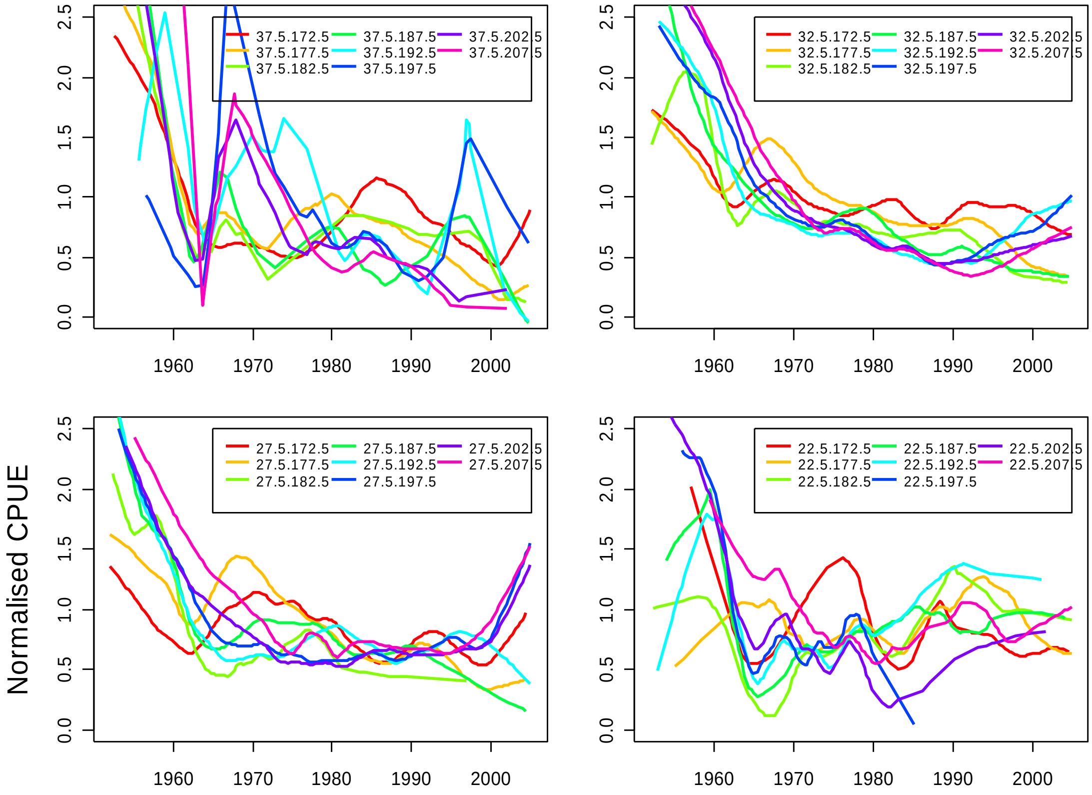

Figure 10. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 2. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

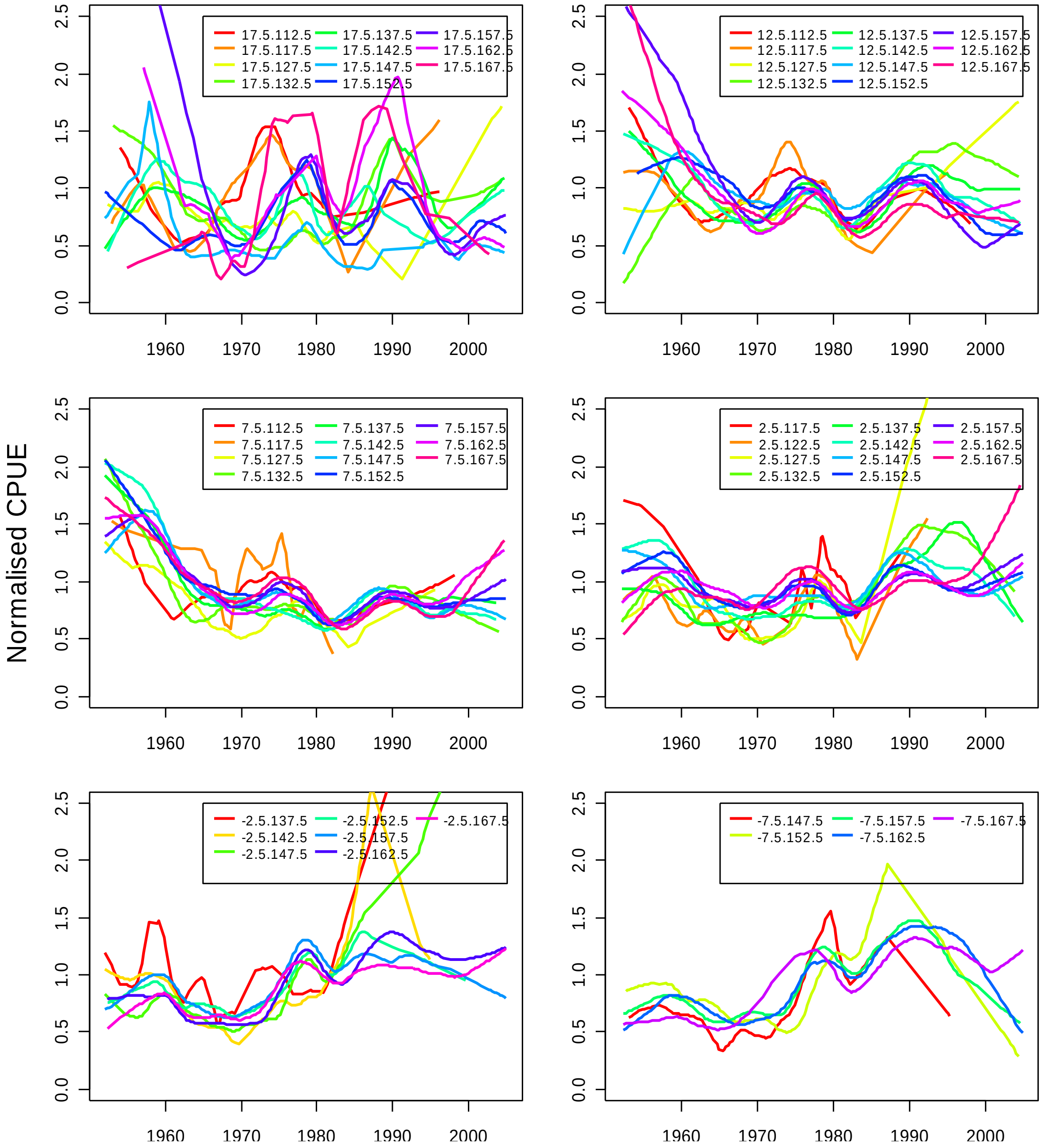

Figure 11. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 3. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

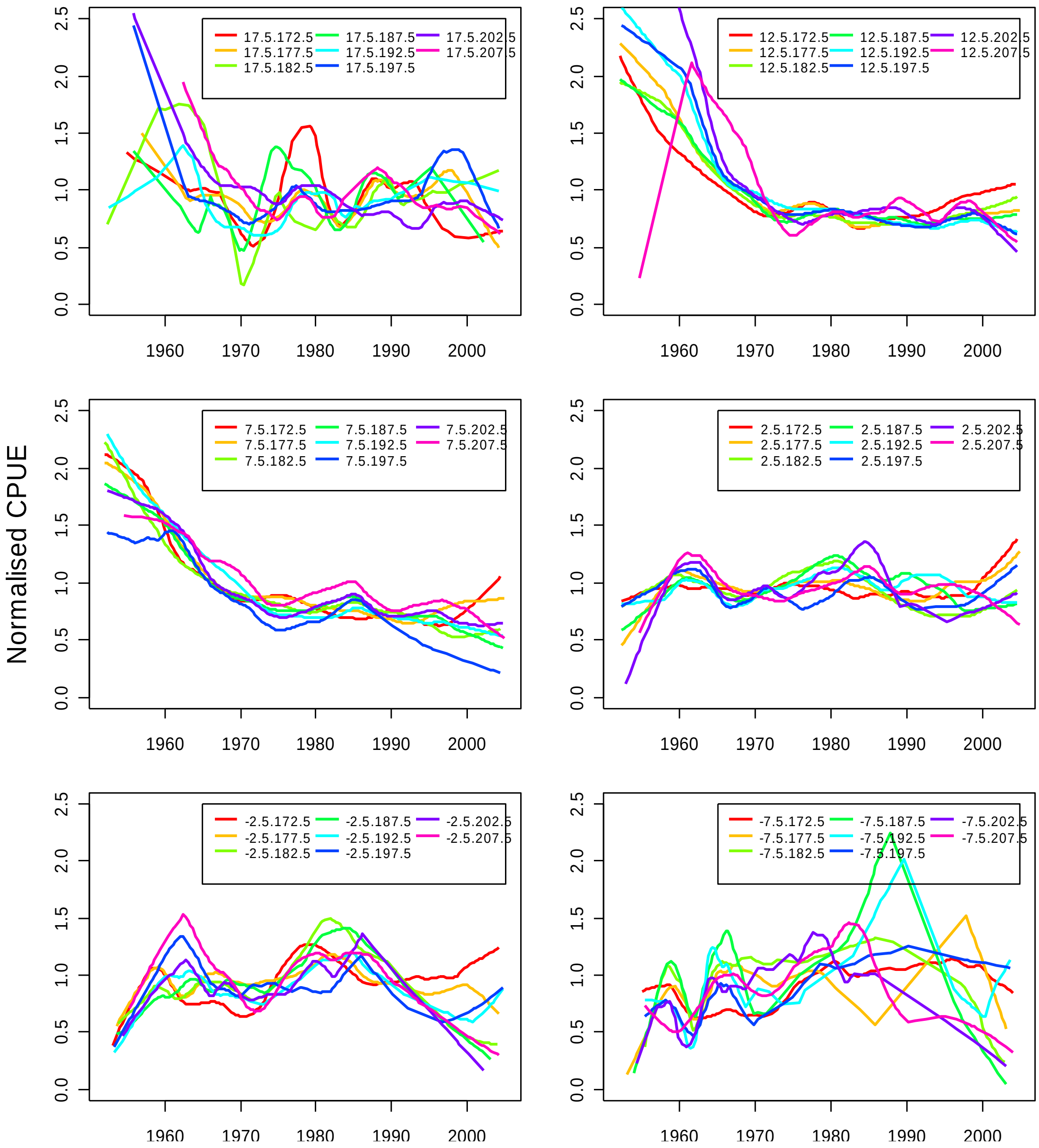

Figure 12. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 4. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

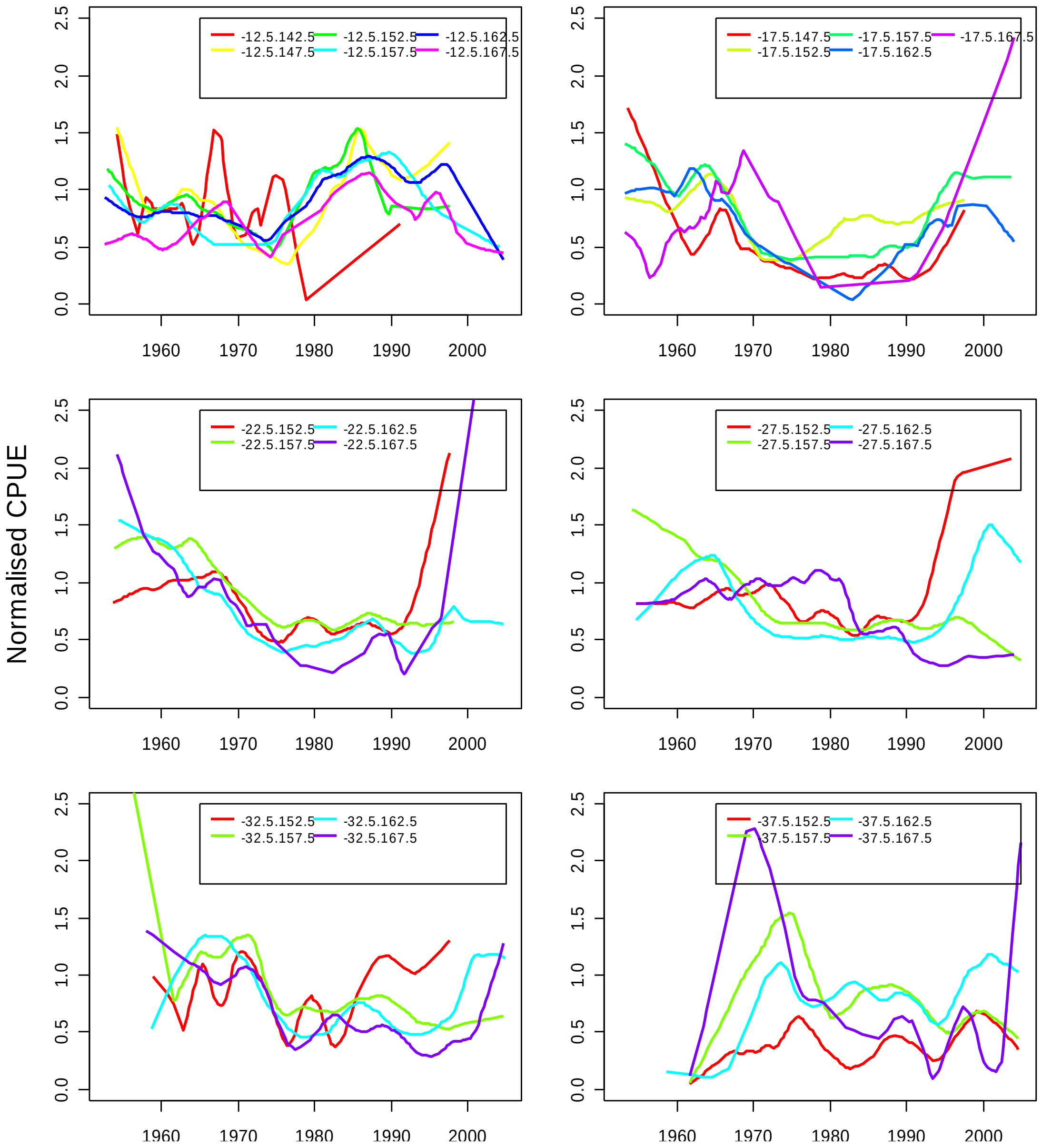

Figure 13. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 5. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.

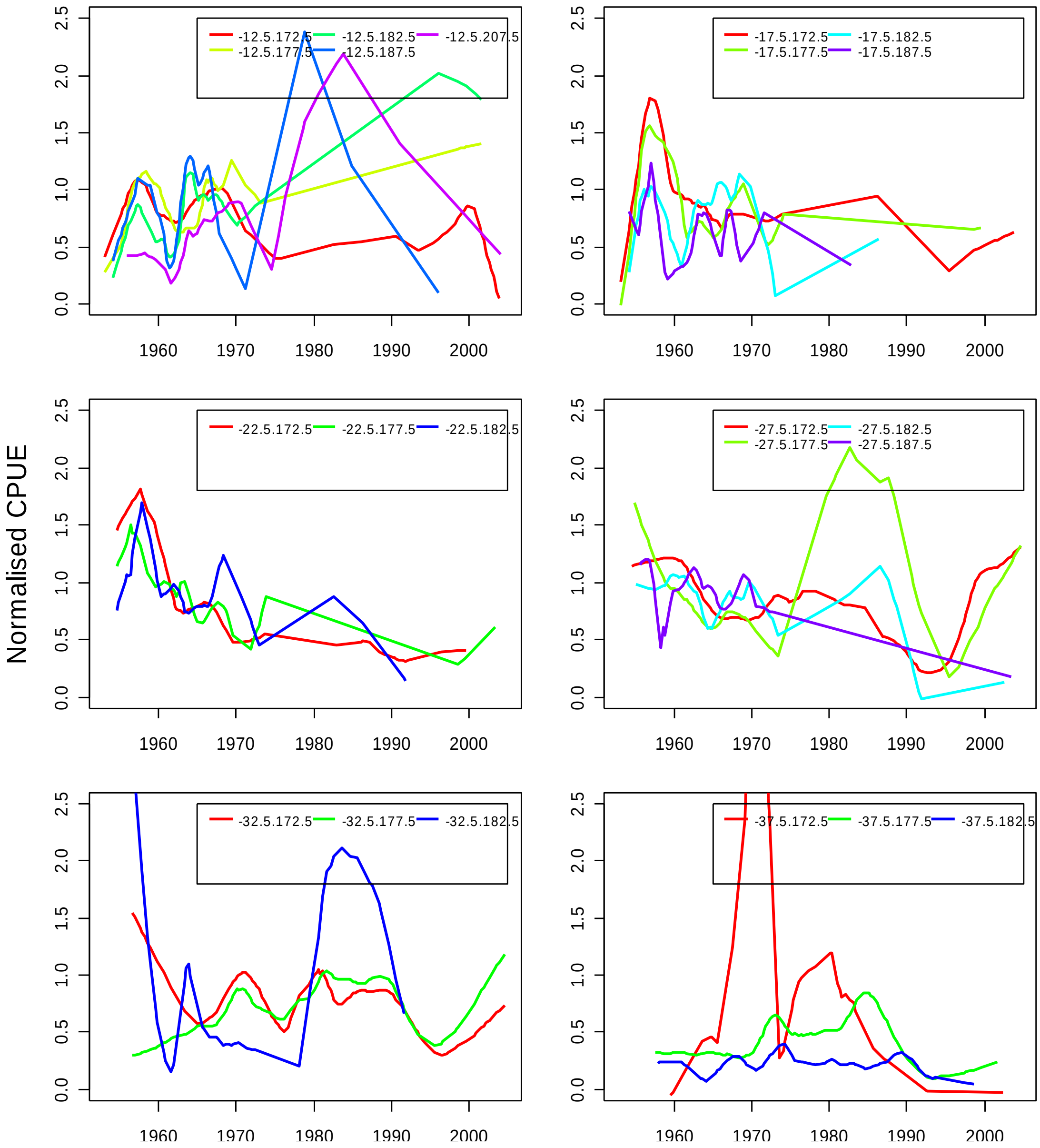

Figure 14. Smoothed trends in nominal CPUE for bigeye for each of the 5*5 latitude/longitude cells that comprise BET MFCL region 6. The indices are normalised to the mean of each series. Each set of plots represents a latitudinal band within the region.