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Time series of relative abundance indices from aerial sightings data for some important pelagic schooling species

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1. EXECUTIVE SUMMARY

This report summarises the most recent updates of relative abundance indices for blue mackerel in QMA 1, jack mackerel in JMA 1 and 7, kahawai in KAH 1, 2, and 3, skipjack tuna in QMA 1, and trevally in TRE 1 and 2. The estimated indices are presented as time-series plots of annual means of tonnage and school number for all sightings of a particular species by fishing year. Estimates based on trimmed means (trim factor = 0.25) and untrimmed means are compared and a brief note on their relative benefits is included.

Notable features of the time-series are as follows.

- Blue mackerel sightings in QMA 1 have followed a steadily increasing trend, both in total tonnage and number of schools, since 1995–96.
- Jack mackerel sightings in JMA 1 are highly variable.
- Kahawai sightings appear to be variable but it is often unclear how real the fluctuations are based on uncertainty in the estimates.
- Skipjack tuna time series show some major peaks and troughs which, to some degree, follow a pattern that is opposite to that of jack mackerel; a peak in 1985 is particularly significant.
- Trevally time series display less contrast than the other species.
- There is clear independence between tonnage and number of schools for trevally and skipjack in TRE 1 and QMA 1 — this is less clear in other areas.
- There are few instances of species in areas other than QMA 1 where there are sufficient data to provide time series of indices; where there are, levels of uncertainty are high.

2. INTRODUCTION

2.1 Scope of the Document

This document has two objectives. Firstly, it presents time series of relative abundance indices of schooling pelagic species to satisfy the requirement of Objective 2 of MFish Research Project PEL9701,

- To update the relative abundance indices for kahawai in KAH 1, 2, 3, and 9; jack mackerel in JMA 1, 3, and 7; blue mackerel in QMAs 1, 2, 3, 7, 8, and 9; and trevally in TRE 1, 2, and 7; from the aerial sightings database with inclusion of data up to the end of the 1997–98 year.

Its second objective is to summarise the value of the aerial sightings data collected from different areas and their effectiveness in providing reliable relative abundance indices.

NIWA's intention was to estimate relative abundance based on trimmed means. At the request of MFish, indices based on untrimmed means are also provided. The relative merits of the two methods are discussed.

2.2 Aerial Sightings Data

Aerial sightings data are collected for schooling pelagic species by pilots flying light aircraft in support of domestic purse-seine vessels. These data have been collected since 1976 and give time series of surface abundance for blue mackerel (*Scomber australasicus*), jack mackerels (*Trachurus declivis*, *T. symmetricus murphyi*, and *T. novaezelandiae*), kahawai (*Arripis trutta*), skipjack tuna (*Katsuwonus pelamis*), and trevally (*Pseudocaranx dentex*).

The aerial sightings data reside in a relational database, administered by NIWA for MFish. The structure and content of the database, and the pre-processing of data before being loaded onto the database, have been documented by Taylor (1995).

Until recently, most pilots recorded positions of sightings with a precision of half a degree of latitude and longitude. This has limited the data's potential because summaries could only be as fine as a half degree. During the last 12 months the data collection forms have been redesigned to incorporate global positioning system (GPS) information. This increases the potential of the data by allowing more refined school sighting positions, and summaries that are more meaningful in time and space.

2.3 Data used in the analysis

Aerial sightings to 30 September 1998 were used to estimate the time series of relative abundance indices.

2.4 Previous Research

Aerial sightings data were first published as summaries of the schools observed on research flights during the late 1970s in a series of *Catch* articles listed by Bradford & Taylor (1995). In the mid 1980s, annual summaries of aerial sightings by species were reported by Wood & Fisher (1983, 1984) and Swanson & Wood (1986a, 1986b).

Several studies of the MFish aerial sightings data have been completed. Bradford & Taylor (1995) explored several methods of estimating relative abundance indices from the data; one used the chance of sighting a species in an area, and the others used estimates of the tonnage and schools sighted. These indices were based on the median as a measure of central tendency in the distribution because it is generally more robust than the mean, particularly with skewed data.

A series of investigations during the early to mid 1990s were recorded by Taylor (in press). This work resulted from discussions held by staff in the MAF Fisheries Pelagic and Modelling Research Groups who were interested in developing reliable, cost-effective stock indices for inshore schooling pelagic species in the absence of anything better than purse-seine catch per unit effort indices. This work included extensive exploratory analysis of the aerial sightings data and their potential to provide estimates of fish density based on the tonnage of a species sighted per hour of search (i.e., flying) time.

Based on these results, Taylor (1997) used the tonnes-per-hour index as the basis for a regression analysis to determine how much of the variance in the index could be explained by such environmental variables as sea surface temperature, moonphase, visibility, and wind speed and direction. The aim was to produce a time series of standardised annual indices of relative abundance for each of the main species, but "year" was not statistically significant, thus precluding the possibility of producing a series of "year effects". Few of the environmental variables were statistically significant either, often because some data series were patchy and sparse.

It has been suggested that using the ratio between the amount of fish sighted and the time spent searching results in increased bias in the relative abundance estimates (Elizabeth Bradford, NIWA, pers. comm.). NIWA has thus adopted simple estimators for relative abundance, at least until this suggestion is investigated. Bradford (pers. comm.) also suggested that there are analyses available that could provide insight into how more sophisticated indices could be developed from the data.

3. RESEARCH

3.1 Distribution of flying effort

Flying effort since 1976 was summarised and plotted on a map of New Zealand (Figure 1).

3.2 Indices of Relative Abundance

The indices of relative abundance presented here are based on two simple measures — the total tonnage and the number of schools of a particular species in a particular sighting. These indices were summarised by fishing year using both trimmed and untrimmed means. Because the mean school number may vary independently of tonnage (Taylor in press), probably because there is a change in mean school size, both are required for interpreting variation in relative abundance.

Counts of the data were examined to determine their ability to provide time series of relative abundance indices for kahawai in KAH 1, 2, 3,and 9, jack mackerel in JMA 1, 3, and 7, blue mackerel in QMAs 1, 2, 3, 7, and 8, trevally in TRE 1, 2, and 7, and skipjack tuna in QMA 1.

To simplify reference in general terms, the quota management areas KAH 1, JMA 1, TRE 1, and QMA 1 are sometimes referred to collectively in the text as Area 1; KAH 2, TRE 2, and QMA 2 as Area 2; KAH 3, JMA 3, and QMA 3 as Area 3; and JMA 7, TRE 7, and QMA 7 as Area 7.

Data counts showed sufficient sightings (more than 30) for all species in all years in Area 1, but in other areas there were some years with no sightings of particular species. Sometimes only one sighting was made, which was included as a point in the appropriate time series of relative abundance indices. Standard error could not be calculated so these points do not have accompanying error bars. This applies to the following series:

- jack mackerel in JMA 3;
- blue mackerel in QMAs 2, 3, 7, and 8;
- trevally in TRE 7;
- kahawai in KAH 9.

Other series could be formulated to replace annual indices that are missing, by aggregating data from various areas, but it is unclear whether this would improve their usefulness in stock assessments. In their present form they refer directly to particular Fishstocks and quota management areas.

3.1.1 Sighting tonnage

Estimates of sightings tonnage were based on methods described by Taylor (in press), who showed that estimates based on the geometric mean are more reliable than those based on an arithmetic mean. Therefore, tonnage ($\hat{T}$) of the *i*th sighting of the *j*th species in the *k*th area was estimated using the geometric mean of the maximum and minimum tonnage, and the number of schools

$$\hat{T}_{ijk} = n_{ijk} \cdot \left(x_{1_{ijk}} + x_{2_{ijk}}\right)^{\frac{1}{2}}$$

where n is the number of schools sighted, and x_1 and x_2 are the pilot's estimates of the minimum and maximum school size.

3.1.2 Number of schools

The values for the number of schools in each sighting used in the estimates are those recorded by the pilot.

3.1.3 Estimating the trimmed mean

A symmetrically trimmed mean (Staudte & Sheather 1990) was used to estimate the two relative abundance indices for each year (Appendix 1). Estimation incorporated either total tonnage or number of schools for all sightings of the year, and was executed at a trim level of 0.25.

A confidence interval of ± 2 standard errors was estimated for each year based on the method in Appendix 1.

4. RESULTS

4.1 Distribution of Flying Effort

Most flying effort is centred in QMA 1 between North Cape and East Cape, and in the northern South Island between Westhaven Inlet and Kaikoura (*see* Figure 1).

4.2 Time Series of Indices

To provide a finer level of detail in Area 1, estimates were summarised as time series for East Northland, the Bay of Plenty (BOP), and for QMA 1 as a whole. There are no subarea summaries of data in the other areas. The various quota management areas and Fishstocks are summarised in Figure 2.

4.2.1. QMA 1, JMA 1, KAH 1, and TRE 1

For some species there are different trends between East Northland and the BOP.

Blue mackerel sightings in QMA 1 (Figures 3 & 4) have been variable throughout the time series. Since 1995–96, the trend has increased steadily, both in total tonnage and number of schools, mainly from increases in East Northland. Generally, fluctuations seem to be much greater in East Northland, while the BOP remains more stable, although much of the variability in the East Northland estimates is within the error bound and is therefore not statistically significant. The contrast in variability between the two areas expressed by the length of the error bars is probably a result of more sightings of blue mackerel and fewer extreme values in the BOP.

Sightings of jack mackerel in JMA 1 (Figures 5 & 6) are highly variable, both in total tonnage and number of schools. This applies to East Northland and the BOP. The plots show a period between 1984 and 1990 when the variance in the estimates for East

Northland was extremely high. This may be the result of too few sightings or non-recording of a low value species.

The arrival of *T. symmetricus murphyi* in the early 1990s and the major decrease in jack mackerel since 1994 are major features of the time series. The increase in 1998 in the BOP appears significant in terms of the non-overlap between the error bars, although the result is less clear in the "tonnage sighted" index than "number of schools". It is interesting that there is no similar event in East Northland, particularly if the preference of *T. symmetricus murphyi* for cooler water is considered in association with recent variations in water temperatures.

Sightings of kahawai in Bay of Plenty and KAH 1 (Figures 7 & 8) are variable, but frequent overlapping error bounds in the East Northland series suggest that it is not statistically significant there at the approximate level of 95% confidence that the ± 2 standard errors provides.

Sightings of skipjack tuna in QMA 1 (Figures 9 & 10) show significant peaks in the tonnage index about every 6 or 7 years. Increases in the last two years are an important feature of the time series. The extreme peak in 1984–85 is strongly represented in both East Northland and the BOP. The clear increase in tonnage in the Bay of Plenty during the last two years is not relected by the number of schools, suggesting that mean school size was larger in those years. The lack of similarity overall between corresponding series for skipjack in QMA 1 indicates that variation in school size are generally independent of tonnage for this species.

Sightings of trevally in TRE 1 (Figures 11 & 12) are remarkably flat compared with the other species. This seems to be driven by sightings in the BOP. In East Northland the series has more contrast with an increasing trend from 1985–86 to what appears to be a major peak in 1990–91. Both areas show declining trends around 1992–94 with no recovery apparent for the series in East Northland. The trend of increasing school number during 1997–98 in East Northland is not coupled with a similar increase in the tonnage index, and suggests a smaller mean school size. The poor relationship for corresponding series in QMA 1 suggests independence for tonnage and school number.

A comparison of the tonnage index for jack mackerel and skipjack tuna in Area 1 reveals some tendency for converse patterns of peaks and troughs. The large peak in 1985 is coincident with a particularly low tonnage for jack mackerel. A similar relationship is also evident in 1978 and the reverse is true for 1980. Although these features are obvious in the plots, the data are too different to use correlation analysis to quantify the negative correlation in these occasional converse data points.

This is also true of comparisons between the "tonnage sighted" and "number of schools" series. Similarities in peaks and troughs identified from an examination of the plots cannot be quantified by correlation analysis.

4.2.2. QMA 2, KAH 2, and TRE 2

Sightings of blue mackerel in QMA 2 (Figure 13) are variable, with independence between tonnage and school number apparent in some years. This time series contains years of zero sightings. The major peak in 1988–89 is based on a single sighting and has no variance associated with it.

Kahawai sightings in KAH 2 (Figure 14) appear to follow an overall increasing trend., which is particularly obvious over the three most recent years. Statistically, however, these last three points are not significantly different from one another, and, if we restrict the argument to the two plots of tonnage sighted, neither are they different from the series of points between 1988–89 and 1992–93. There is also some evidence, based on the untrimmed mean plot of tonnage sighted, that there was a decline in 1993–94 which persisted for two years, and since then there has been an increase that has persisted for three years. This conclusion cannot be reached from the three other plots because overlapping error bars suggest no statistically significant difference.

Sightings of trevally in TRE 2 (Figure 15) in the most recent years seem variable, particularly in the tonnage index, but it is dampened by the uncertainty in the estimates expressed by the error bars. There are no obvious similarities with trends in TRE 1, but there is much less evidence of the independence between the two indices.

4.2.3. QMA 3, JMA 3, and KAH 3

Sightings of blue mackerel in QMA 3 (Figure 16) are flat. The time series is short because of the high of years with zero sightings, and a number of the annual indices are based on single sightings.

Sightings of jack mackerel in JMA 3 (Figure 17) are variable. The large peak in 1984–85 is a single sighting of 35 schools giving a total of 700 t. The rising trend after 1989–90 is similar to that in JMA 1 where it has been interpreted as an increase in *T. symmetricus murphyi* .

Generally, the trend in sightings of kahawai in KAH 3 (Figure 18) show a gradual increase in the early years to a peak in the early 1980s with a decline to a statistically significant minimum in 1985–86. The tonnage series shows a second gradual increase from this point to a second peak in 1994–95. A third peak in 1997–98 is extreme, and is caused by five unusually large sightings in the South Taranaki Bight on 27 and 29 October 1997.

$\hat{T}$	Number of schools	Minimum tonnage	Maximum tonnage
1549	200	3	20
306	25	5	30
1186	125	3	30
1472	85	5	60
450	30	5	45

These sightings produce uncharacteristically high mean values for $\hat{T}$ and the number of sighted schools for kahawai in this area.

4.2.4. QMA 7, JMA 7, and TRE 7

Sightings of blue mackerel in QMA 7 (Figure 19) show a generally flat trend with relatively high, but non-significant, peaks in 1981–82, 1983–84, and 1989–90. These peaks are evident in both the tonnage and the "school number" time series.

Sightings are quite variable in JMA 7 (Figure 20) with a large amount of uncertainty in the indices in some years.

Sightings of trevally in TRE 7 (Figure 21) show an increasing trend during the early years to a peak in the early 1980s. The time series contain a number of years of zero and single sightings because of low flying effort in this area since the mid 1980s.

4.2.5. QMA 8

Sightings of blue mackerel in QMA 8 (Figure 22) are flat with peaks in 1978–79, 1982–83, and 1990–91. These maxima appear to decline over time, but this conclusion is uncertain, given that their apparent differences are not statistically significant. The sparse data for this species is probably related to reduction in flying effort in this area since 1985–86.

4.2.6. KAH 9

Sightings of kahawai in KAH 9 (Figure 23) show peaks in 1982–83 and in 1991–93. Again, these peaks are not statistically significant, although they are considerably higher than the general trend, which is flat.

5. DISCUSSION

5.1. The Updated Indices

The predominance of flying effort in Area 1 allows estimation of indices for all species, and with less uncertainty than in other areas. The summarised trends are similar to those presented by Bradford & Taylor (1995). The jack mackerel increase in the early 1990s in JMA 1 has decreased more recently, probably as a result of water temperatures higher than those associated with *T. symmetricus murphyi*.

Trends in sightings of kahawai in KAH 3 may be a result of different recording methods for different pilots. A complicating factor in the Kaikoura area is the presence of a large aggregation of fish, presumably kahawai, which extends northwards along the beach from the northern end of the Kaikoura township, to at least the Hapuka River mouth. According to anecdotal accounts, these fish are a perennial feature of the area, but the reason for their presence is unclear. Because of high but varying levels of water turbidity in the area, consistent assessment of the amount present is probably impossible.

Different pilots have taken different approaches to these aggregations, and the large peaks in the indices between 1981 and 1984 are the result of a pilot attempting to provide estimates. Since then the pilots have not included any estimates in their records, and there is neither recent anecdotal nor aerial sightings information on the presence/absence of this feature.

The decreasing trend for trevally that is evident from other indices (Taylor & Bradford 1995, Taylor in press), and is well known from anecdotal information, is absent in these indices.

The peaks for blue mackerel in 1988–89 (QMA 2) and 1991–92 (QMA 1) are interesting, but require more investigation to determine their cause.

5.2. Trimmed versus untrimmed means

A trimmed mean for the relative abundance indices gives a more robust measure of central tendency that is unaffected by outliers. Generally, this strategy is successful and in some cases (e.g., jack mackerel in JMA 1 and blue mackerel in East Northland, plots of tonnage sighted by year) is useful in maintaining similar scales for examination. However, the loss of information from reduced, or even eliminated, annual fluctuations might not always be desirable. After all, the best estimate of the maximum amount accessible to the fishery is the single largest sighting during a given period of a particular species.

A comparison of the plots shows that the trimmed mean does little to reduce the relative degree of variance compared with estimates using the untrimmed mean. There is some benefit from the smoothing which helps in the interpretation of some cases (e.g., KAH 3, *see* Figure 18), but this is far from being the general case, and trends can usually be seen in the plots based on untrimmed means. In conclusion, it is useful to have both so that all the information is available for interpretation.

5.3 Uses of the Aerial Sightings Data

Developing methods for estimating stock indices from aerial sightings data has met with strong criticism, particularly in two areas. First, we cannot know what proportion of the total population of a species appears at the surface, and second, the lack of independence of the data collection method from the commercial fishery is often considered limiting, particularly by some recreational fishers.

Both are valid concerns and should be considered in using summaries from the data, but they should not become the sole factors in deciding the utility of the data. There are instances where empirical information shows variations in environmental features that are coincidental with major features in the aerial sightings data, suggesting that these data are sensitive to changes in the appearance of fish at the surface, albeit as a result of behavioural responses in the fish.

For example, the arrival of *T. symmetricus murphyi* in JMA 1 is strongly reflected in sightings of jack mackerel, and more recent declines can be related to water temperatures higher than are normally associated with this species. This response to water temperature may also account for the converse patterns in increases and decreases of sightings of jack mackerel and skipjack tuna referred to above.

Other more subtle events have also been identified, such as the increased occurrence of some species in mixed schools during particular seasons, which also seems to be influenced by proximity (in time) to an El Niño event (Taylor, unpublished data). There is also evidence in the present indices to suggest changes in the mean school size that is independent of changes in the total sighted tonnage.

In the final analysis most criticisms that can be made of indices from the aerial sightings data can be made equally well of indices from CPUE data (Hilborn & Walters 1992). And, while the limitations of these latter data are well known, their continued use in stock assessments offers support for a similar use of aerial sightings data, especially considering the absence of reliable indices from purse-seine catch and effort data.

6. DATA

The data are located on the MFish aerial sightings database *aer_sight*, currently administered by NIWA for MFish.

7. ACKNOWLEDGMENTS

Thanks to the spotter pilots all of whom have contributed to the database voluntarily, particularly Red Barker and John Reid who have committed a lot of time and experience, and Brian Decke who has become involved more recently. Thanks to Elizabeth Bradford for the methodology for symmetrically trimmed means and templates for some of the S functions used in these estimations, and to Talbot Murray for reviewing the manuscript. This work was funded by MFish as research project PEL9701.

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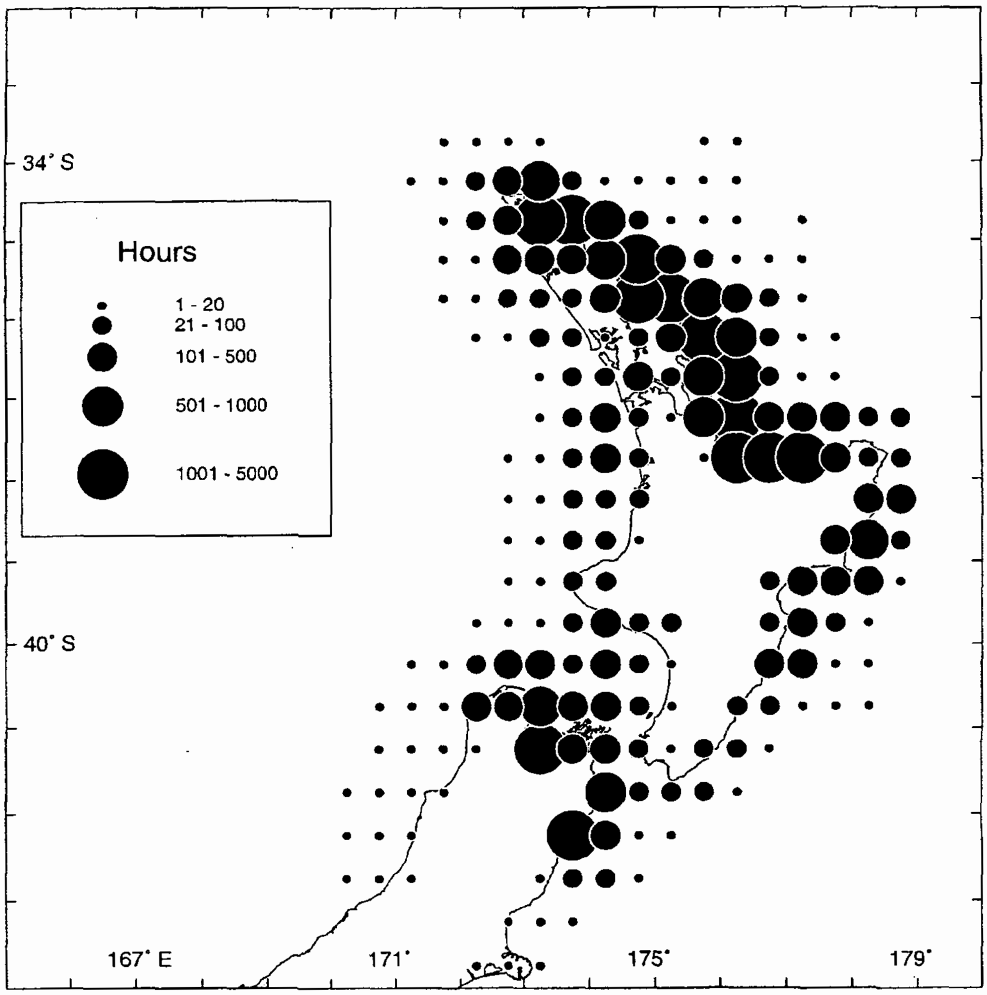


Figure 1: Distribution of flying effort since 1976, total hours flown by half degree square. Circles are centred on half degree squares, which may have only a small proportion of their total area over the sea resulting in the appearance of their being erroneously referenced to the land.

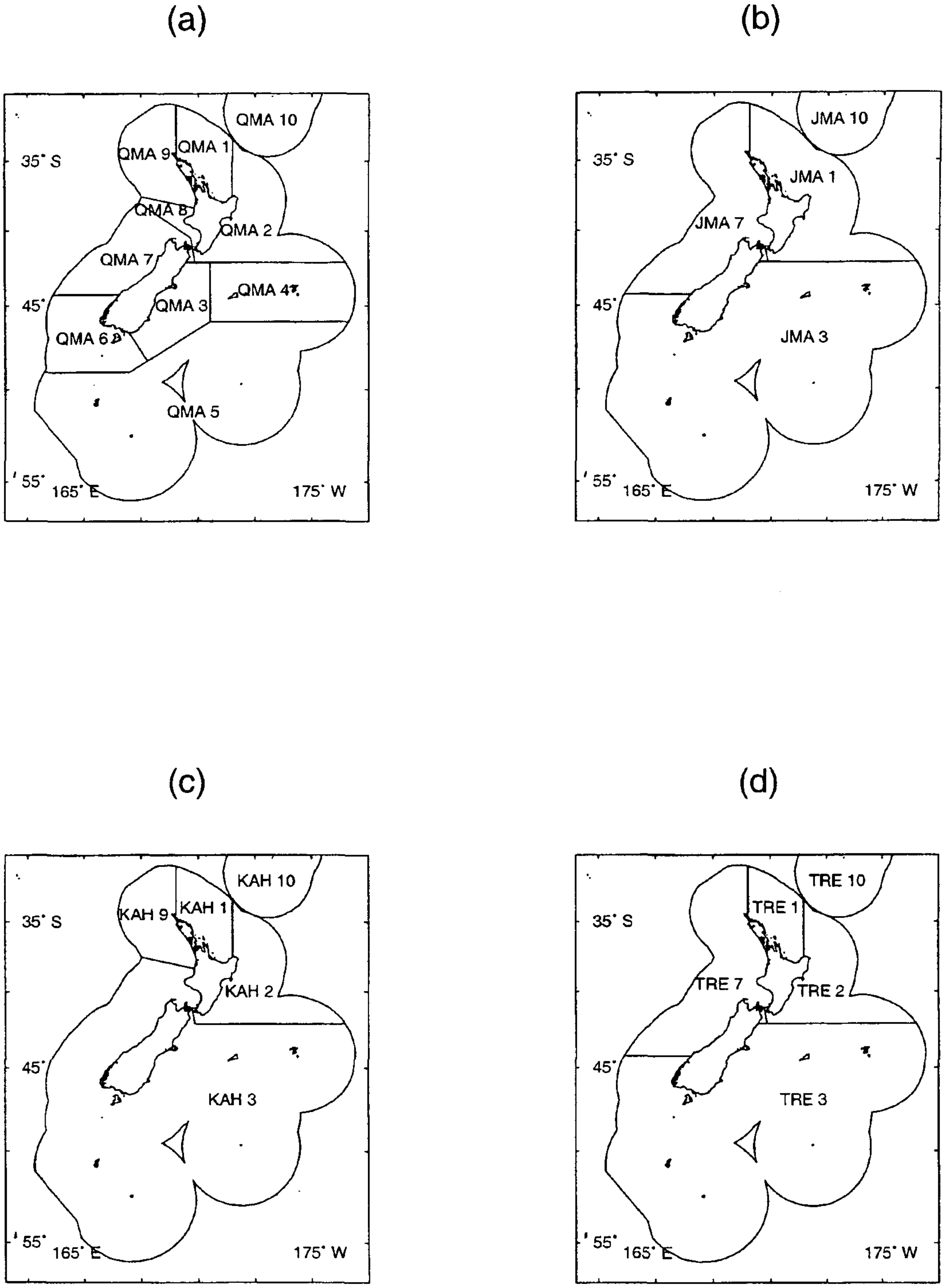


Figure 2: Boundaries for (a) general Quota Management Areas (QMAs), and Fishstocks for (b) jack mackerel (JMA 1, 3, 7, 10), (c) kahawai (KAH 1, 2, 3, 9, 10), and (d) trevally (TRE 1, 2, 3, 7, 10).

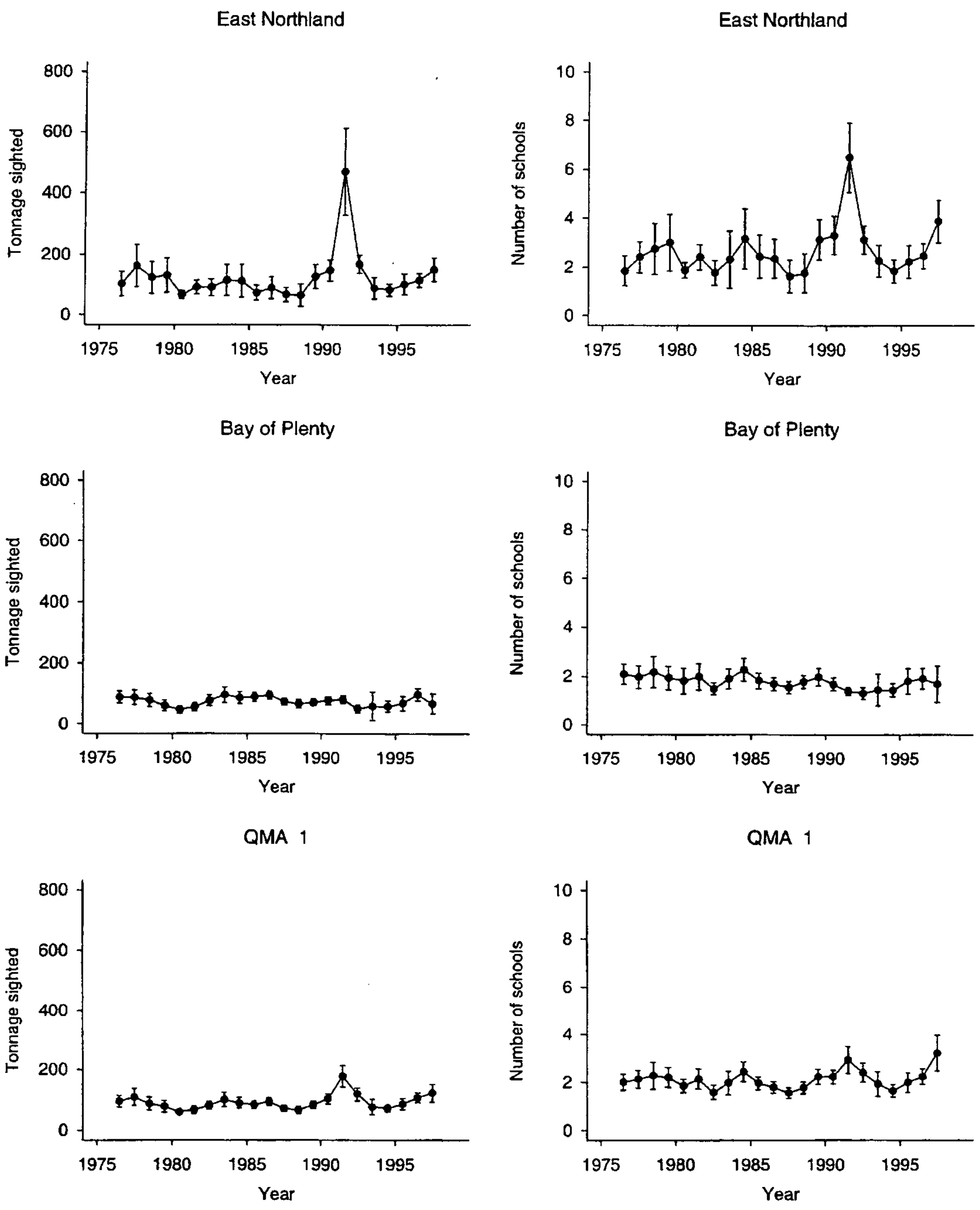


Figure 3: Time series of relative abundance indices for blue mackerel in QMA 1, based on 25% symmetrically trimmed means.

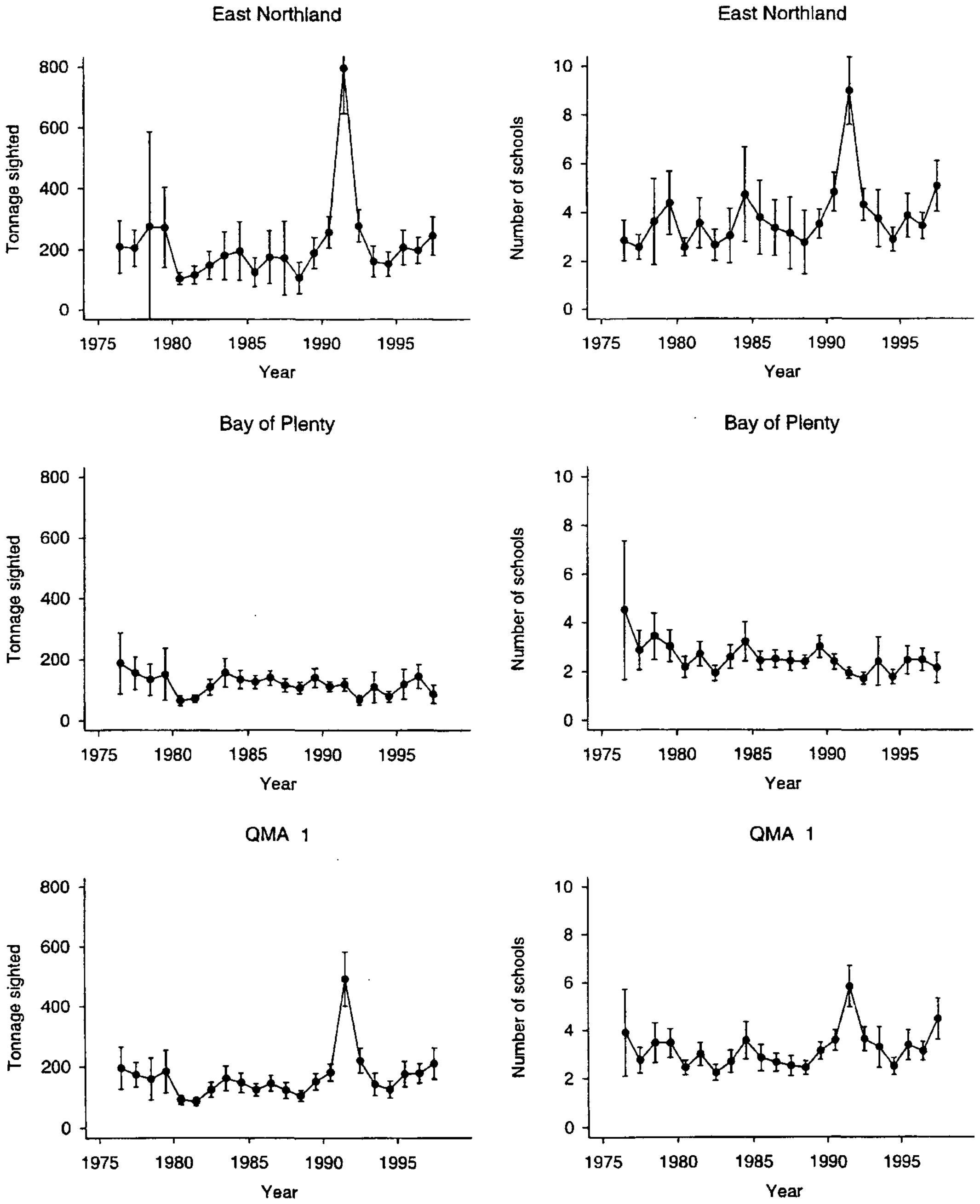


Figure 4: Time series of relative abundance indices for blue mackerel in QMA 1, based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

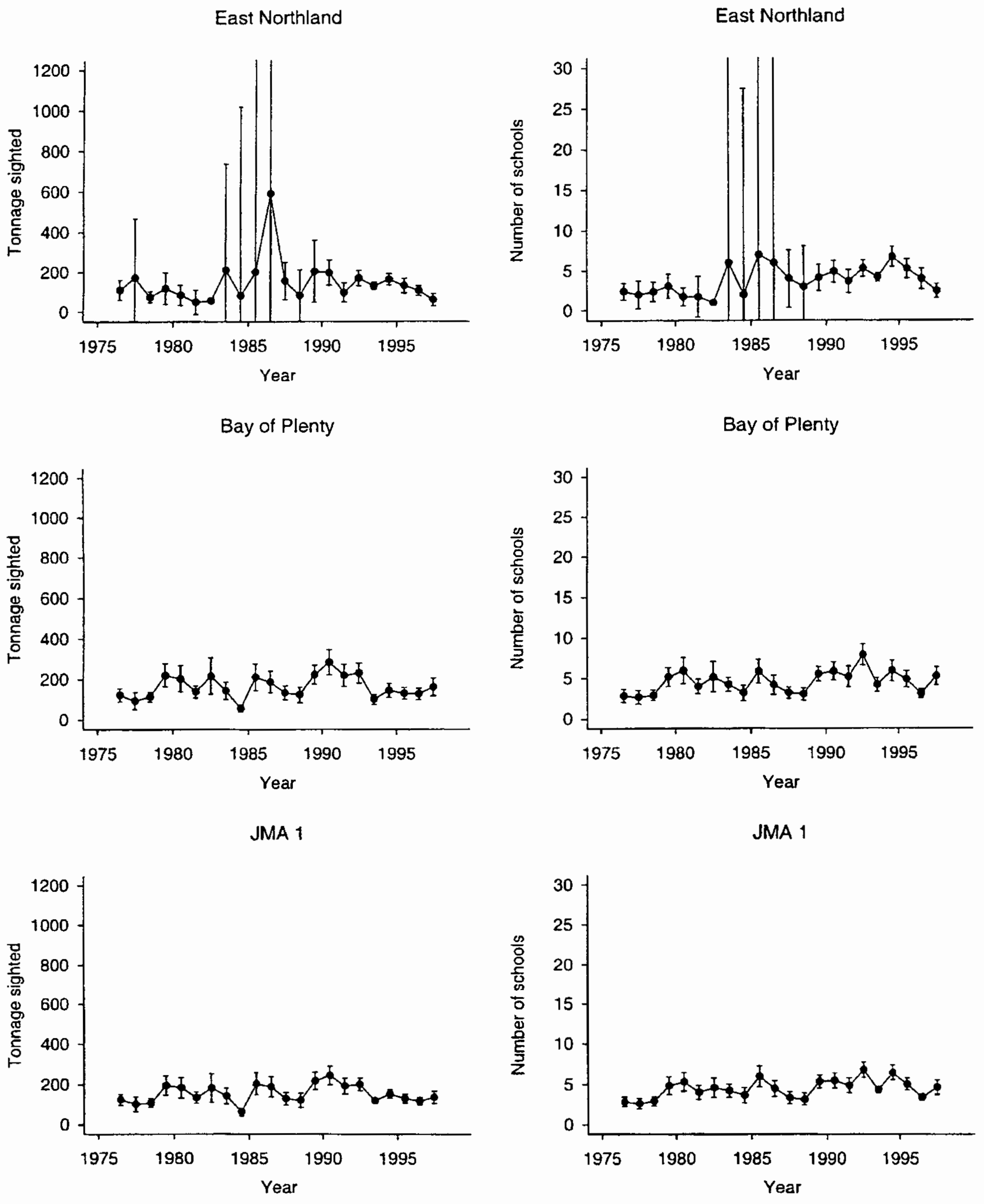


Figure 5: Time series of relative abundance indices for jack mackerel (all species combined) in JMA 1, based on 25% symmetrically trimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

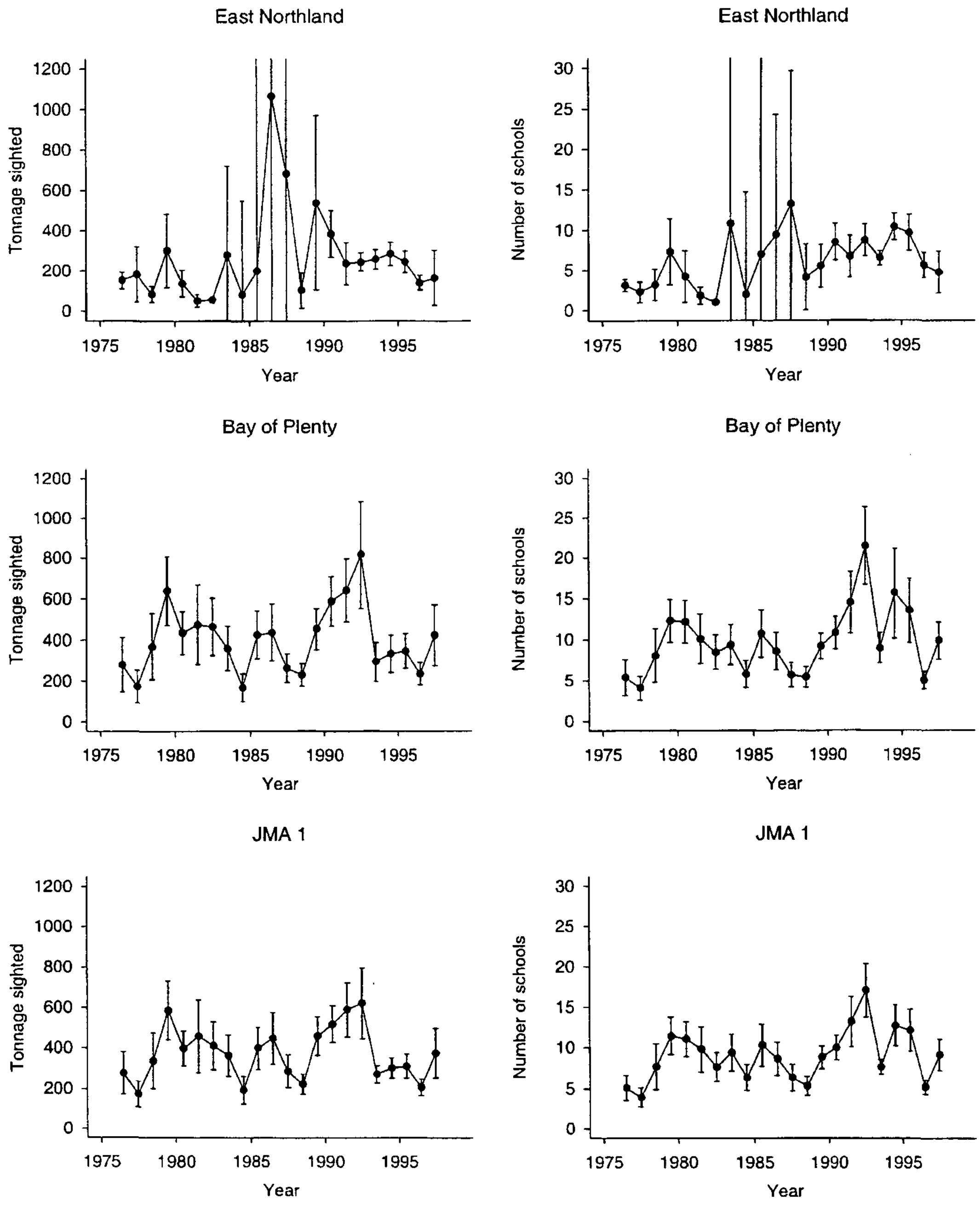


Figure 6: Time series of relative abundance indices for jack mackerel (all species combined) in JMA 1, based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

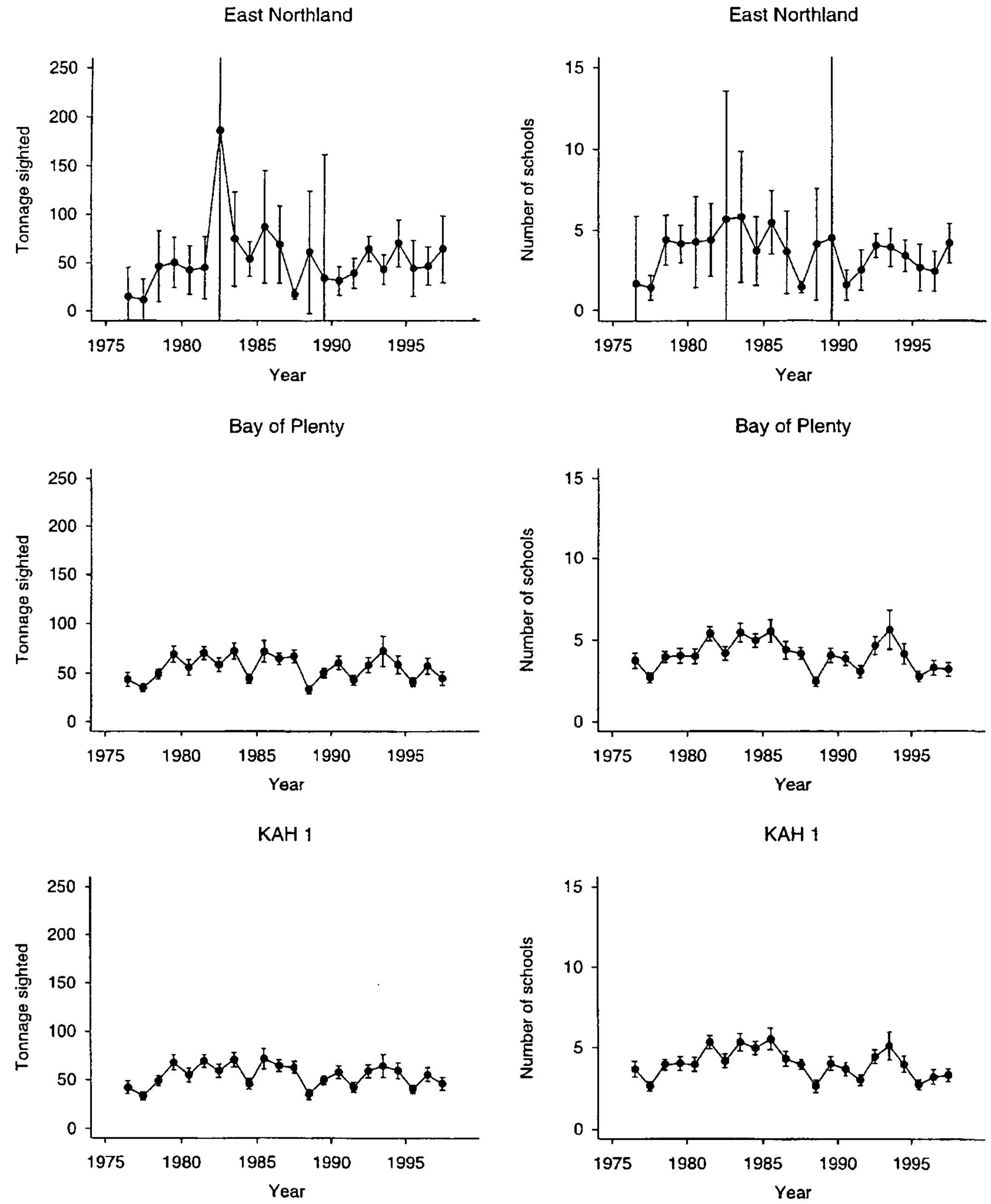


Figure 7: Time series of relative abundance indices for kahawai in KAH 1, based on 25% symmetrically trimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

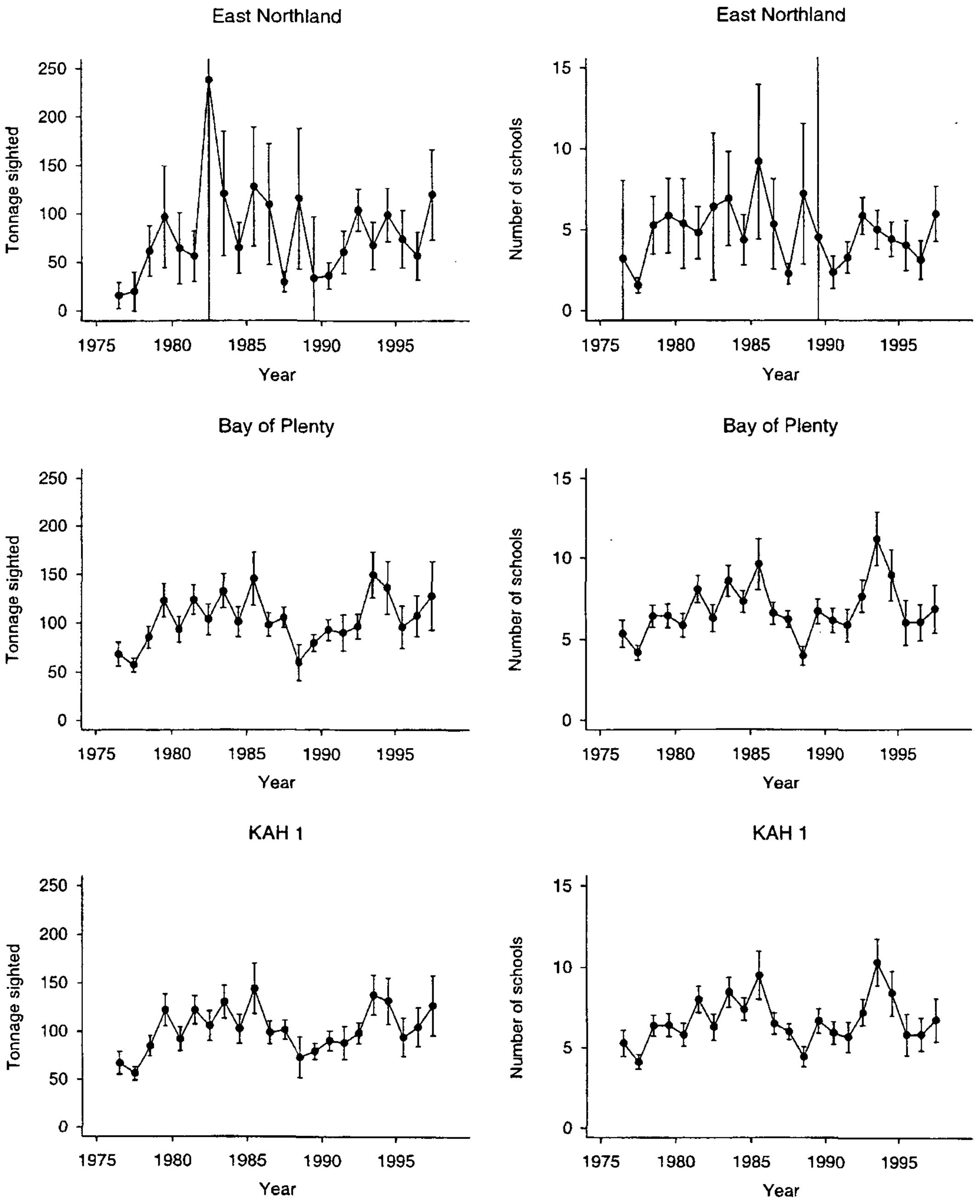


Figure 8: Time series of relative abundance indices for kahawai in KAH 1, based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

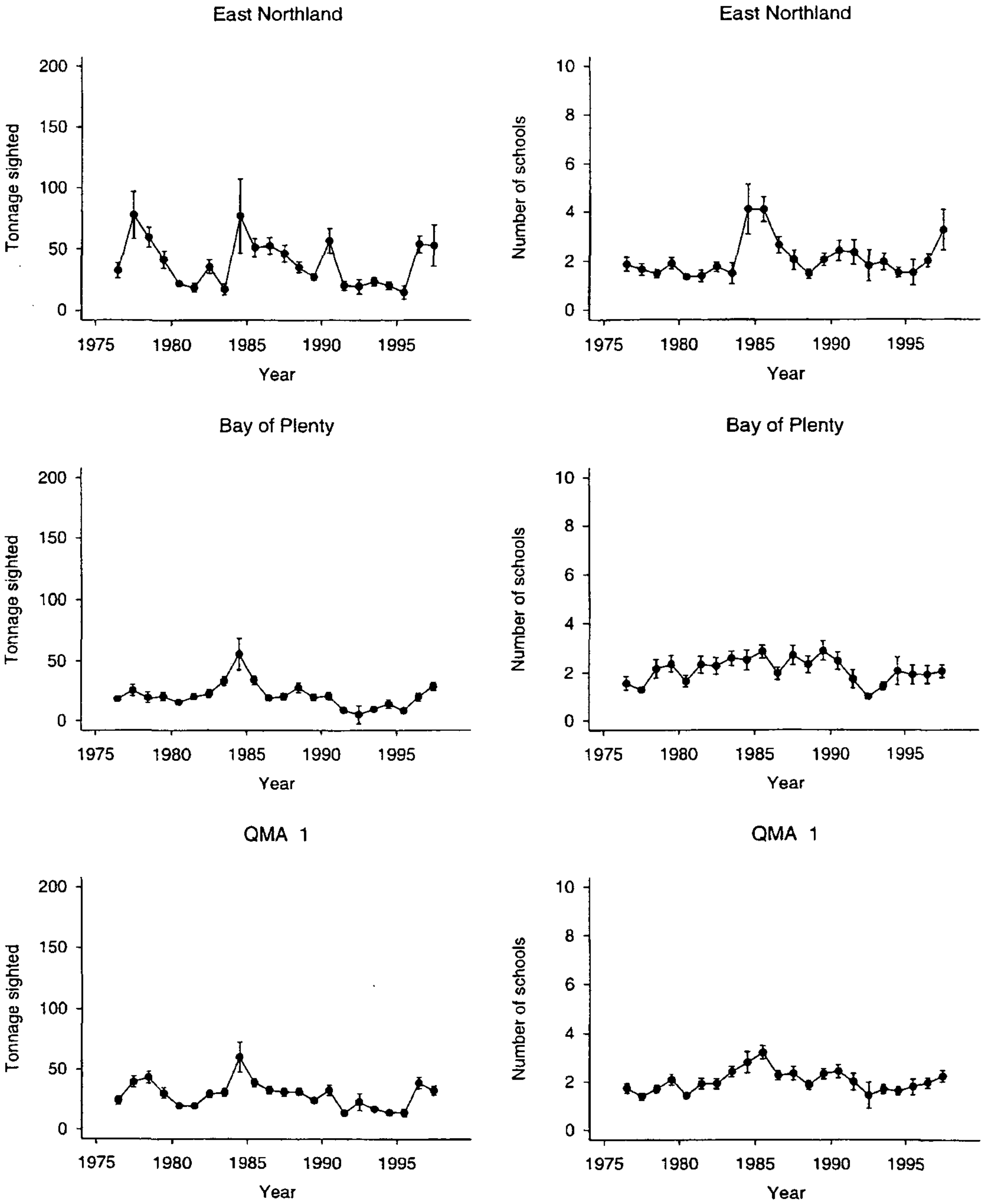


Figure 9: Time series of relative abundance indices for skipjack tuna in QMA 1, based on 25% symmetrically trimmed means.

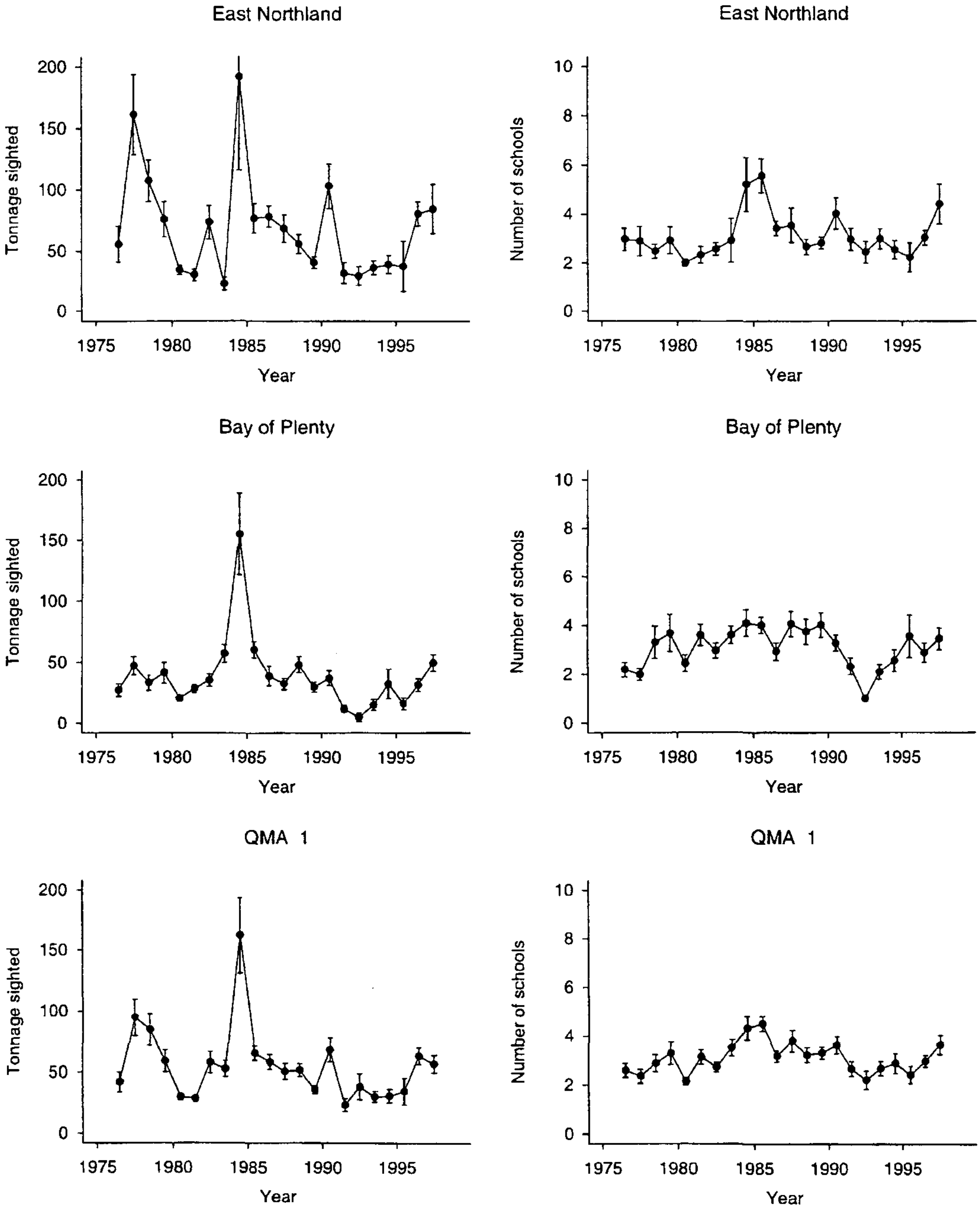


Figure 10: Time series of relative abundance indices for skipjack tuna in QMA 1, based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

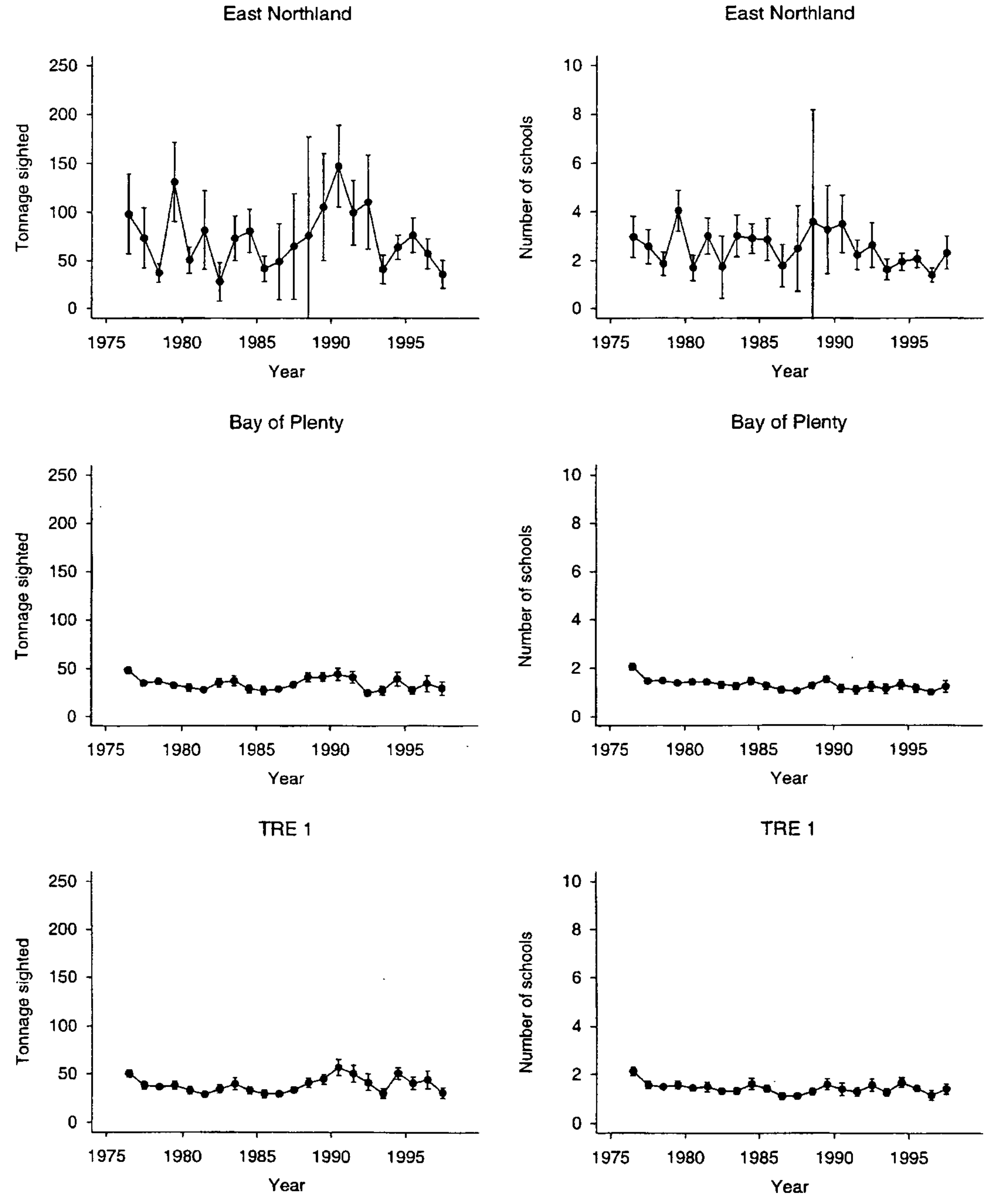


Figure 11: Time series of relative abundance indices for trevally in TRE 1, based on 25% symmetrically trimmed means.

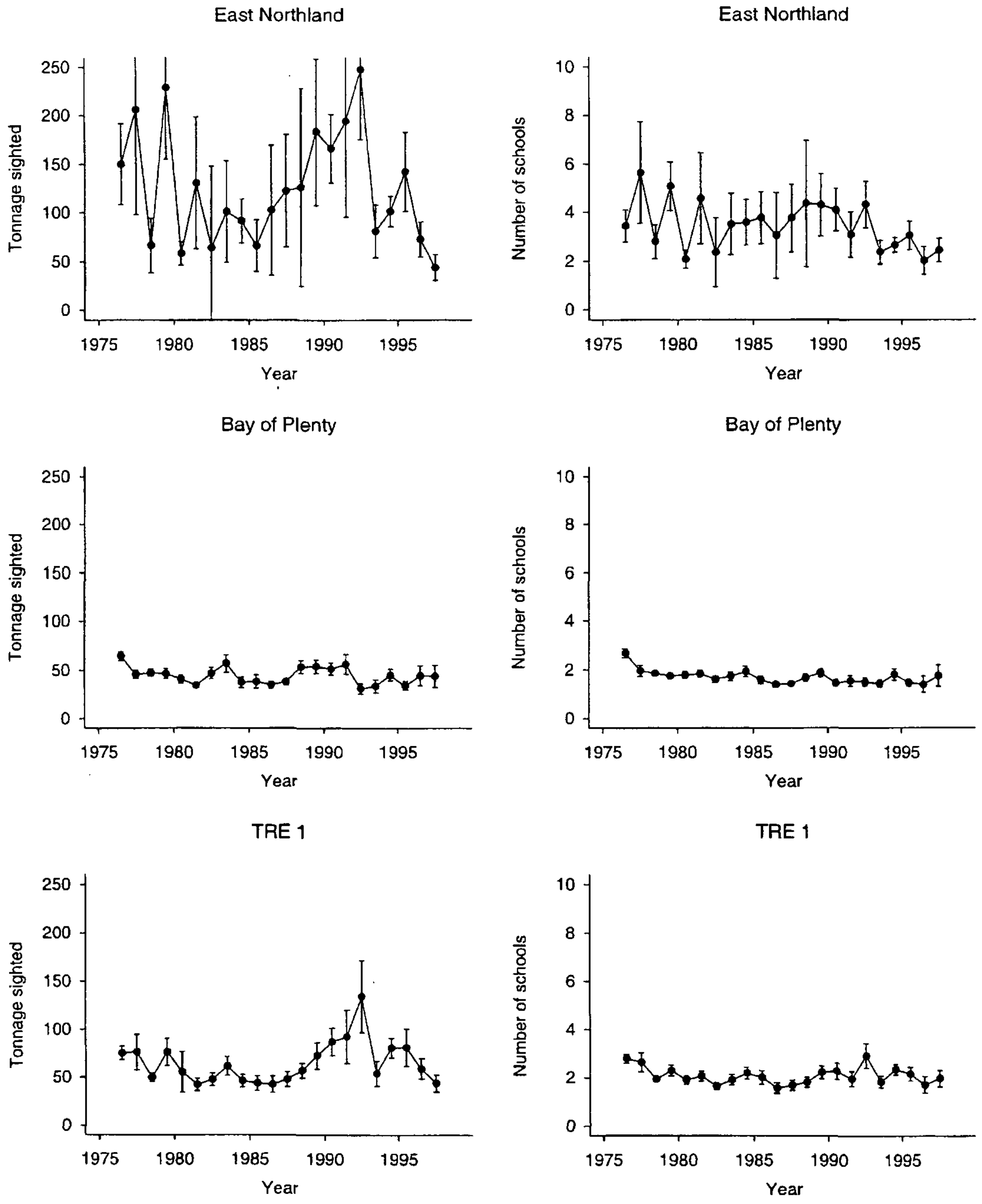


Figure 12: Time series of relative abundance indices for trevally in TRE 1, based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

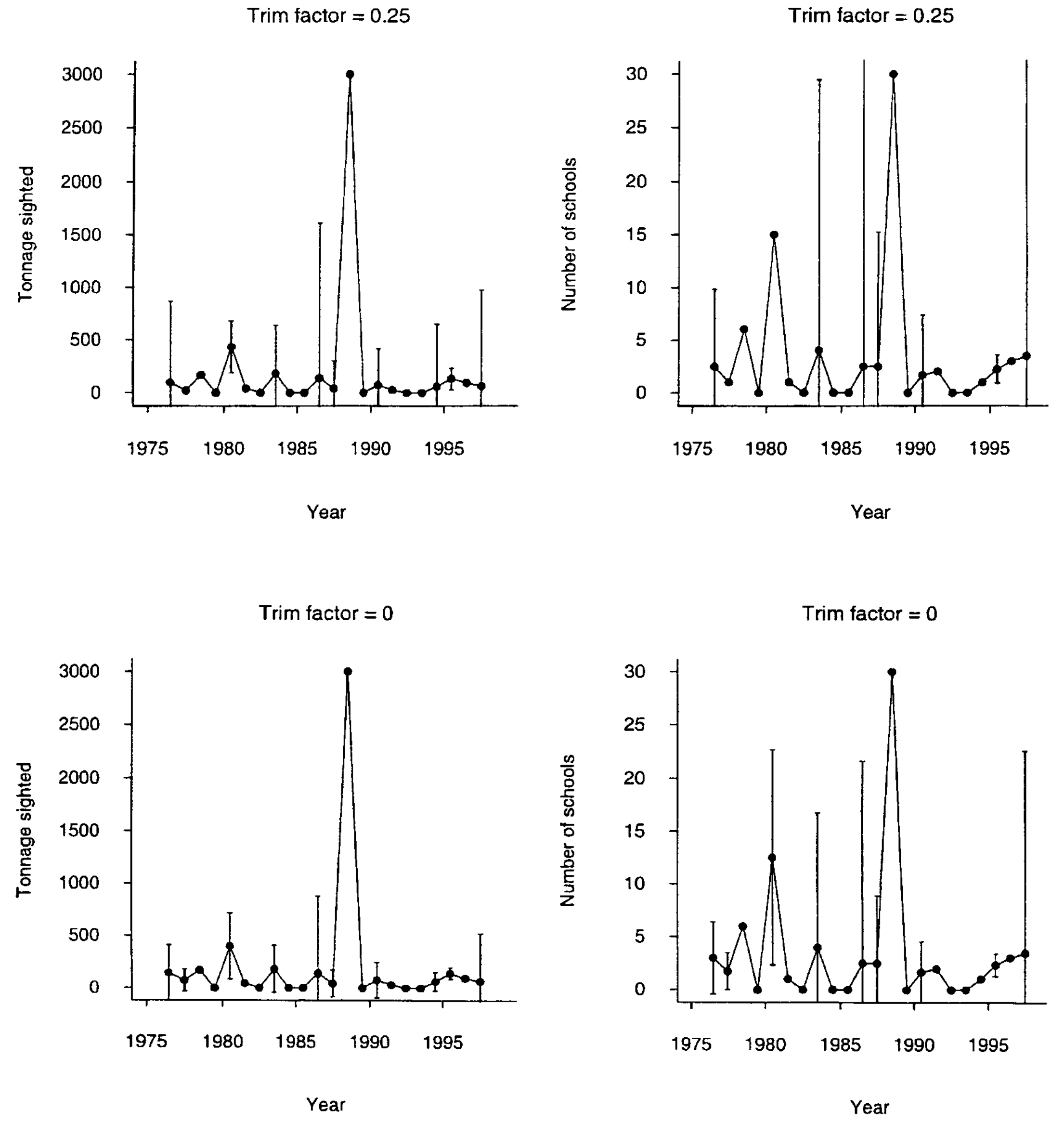


Figure 13: Time series of relative abundance indices for blue mackerel in QMA 2—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

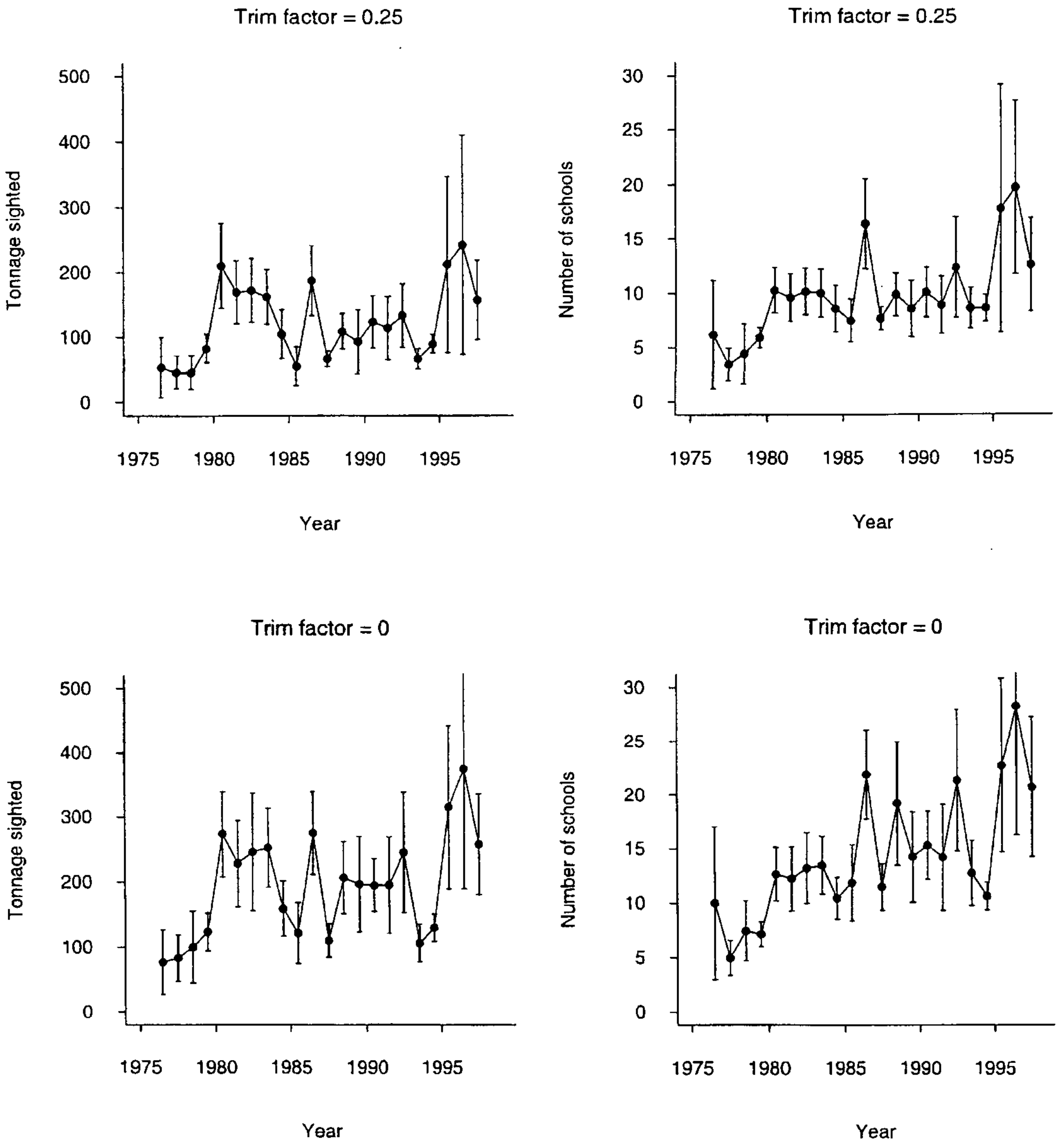


Figure 14: Time series of relative abundance indices for kahawai in KAH 2—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

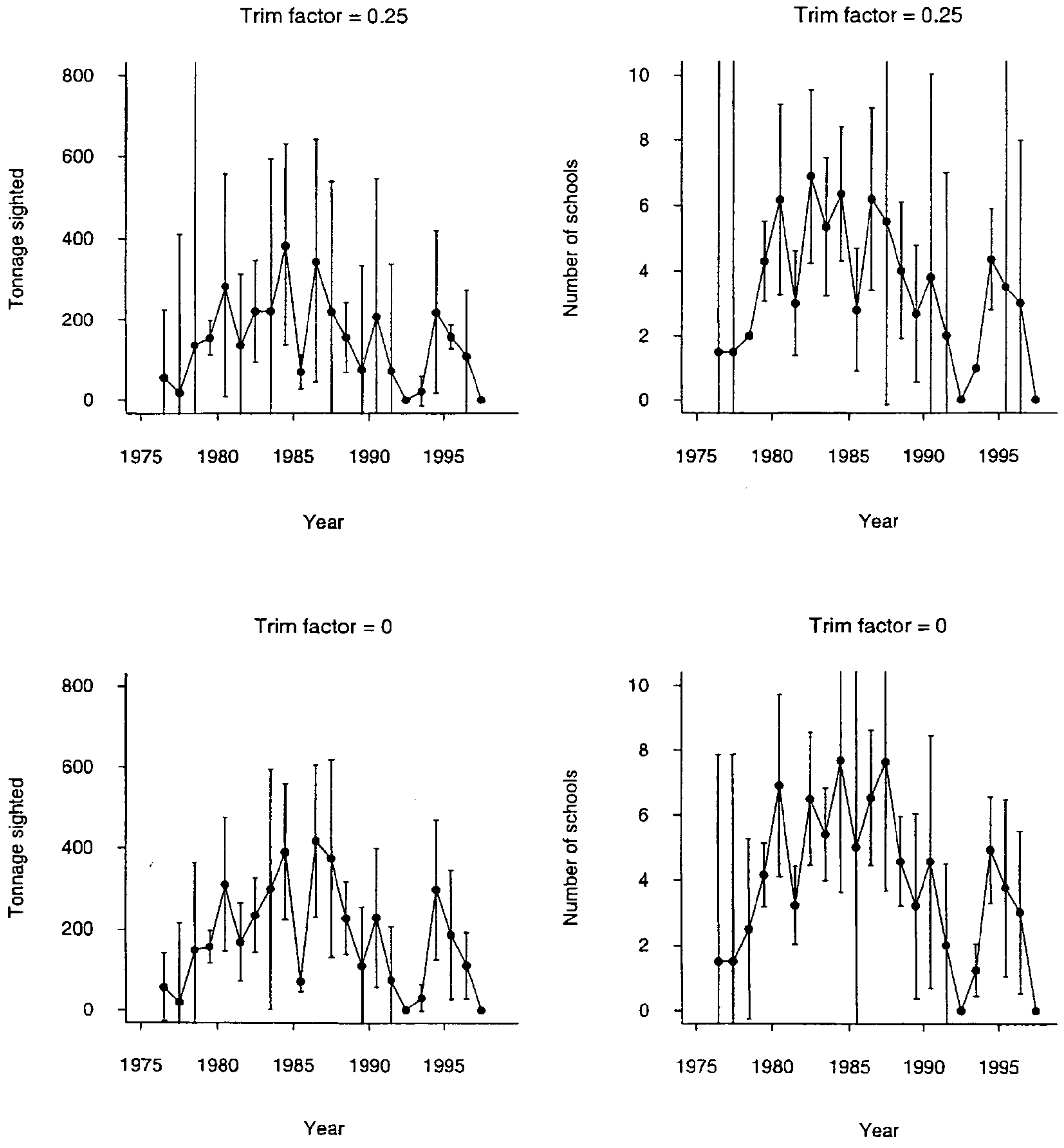


Figure 15: Time series of relative abundance indices for trevally in TRE 2—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

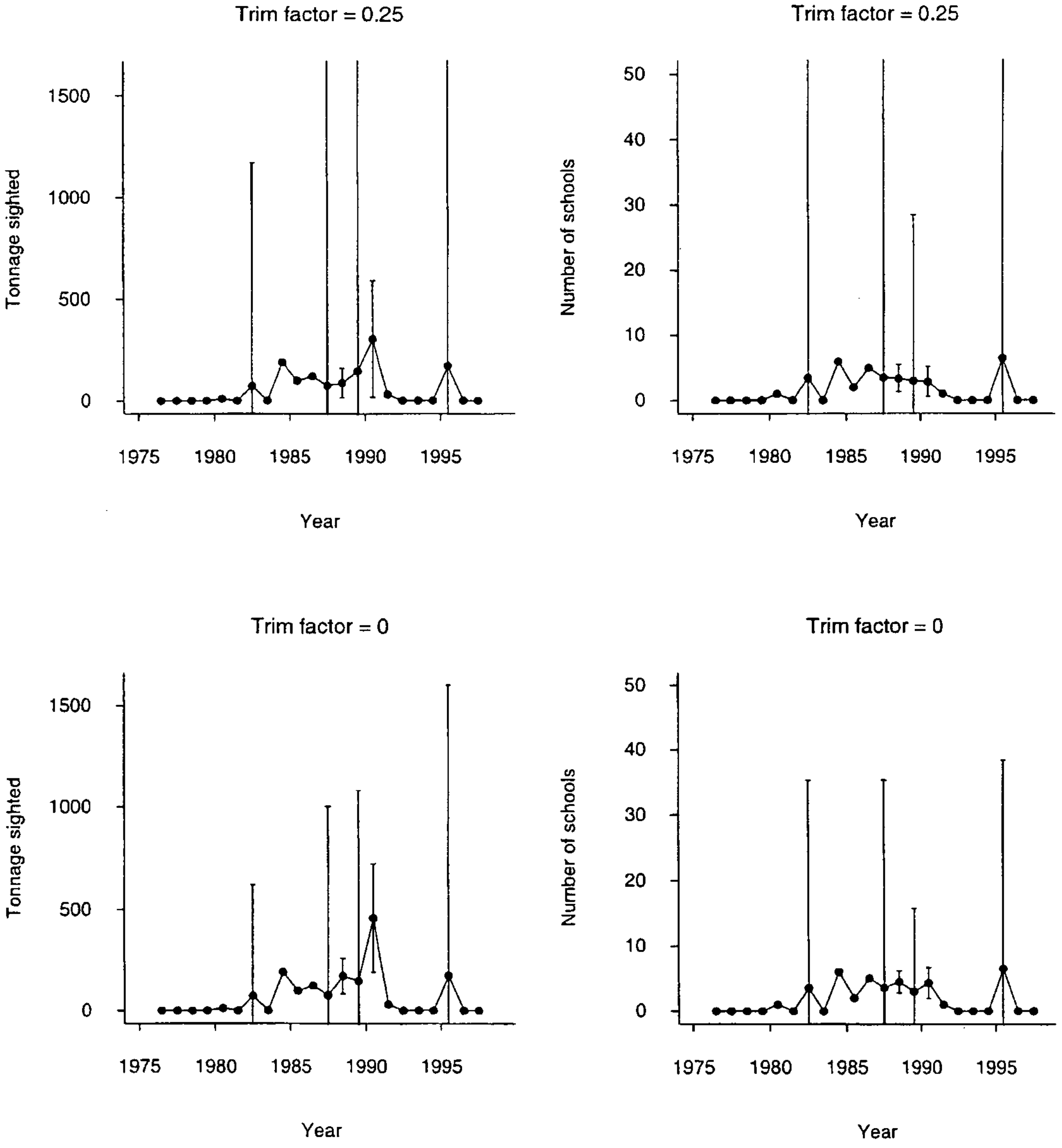


Figure 16: Time series of relative abundance indices for blue mackerel in QMA 3—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

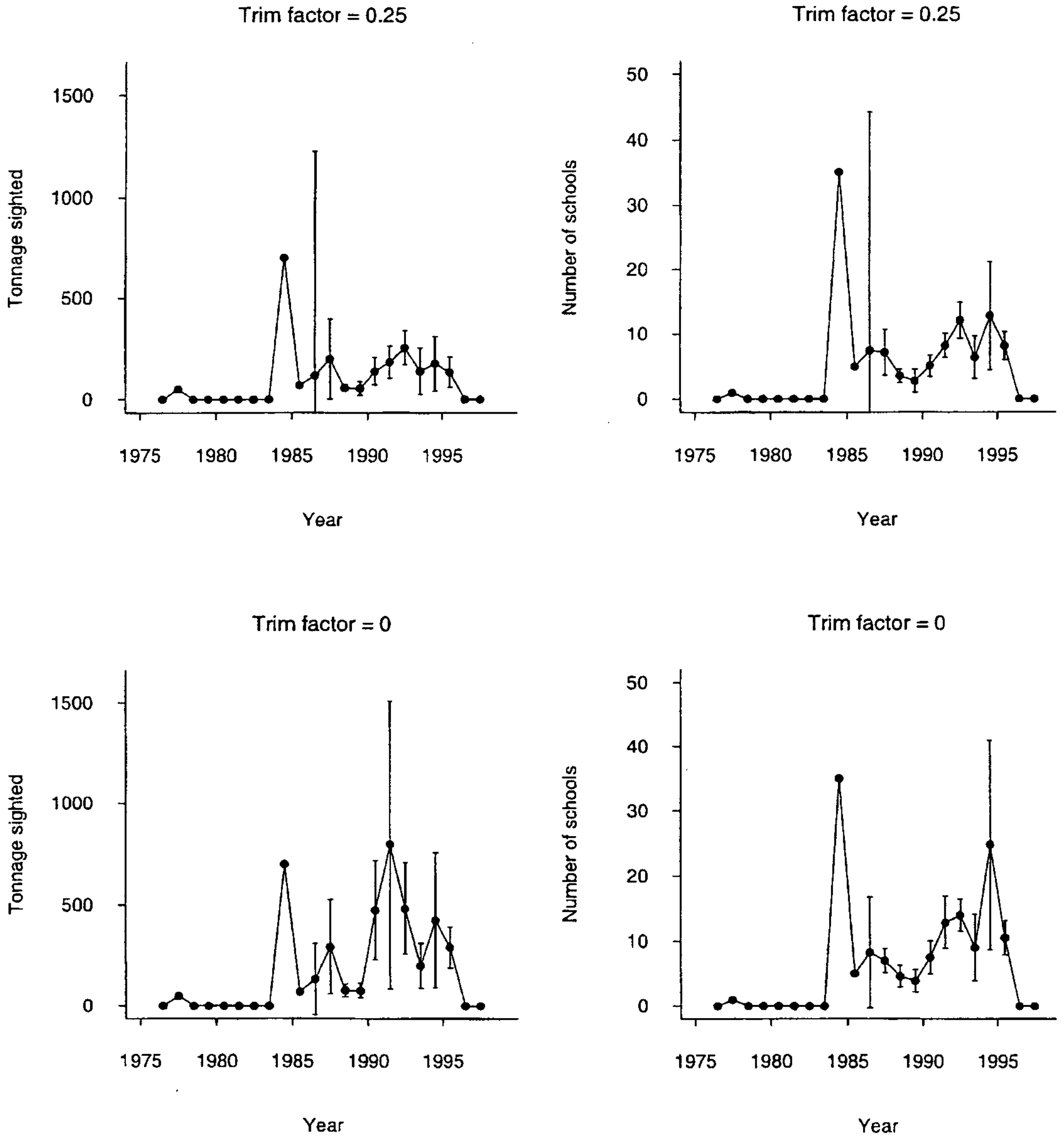
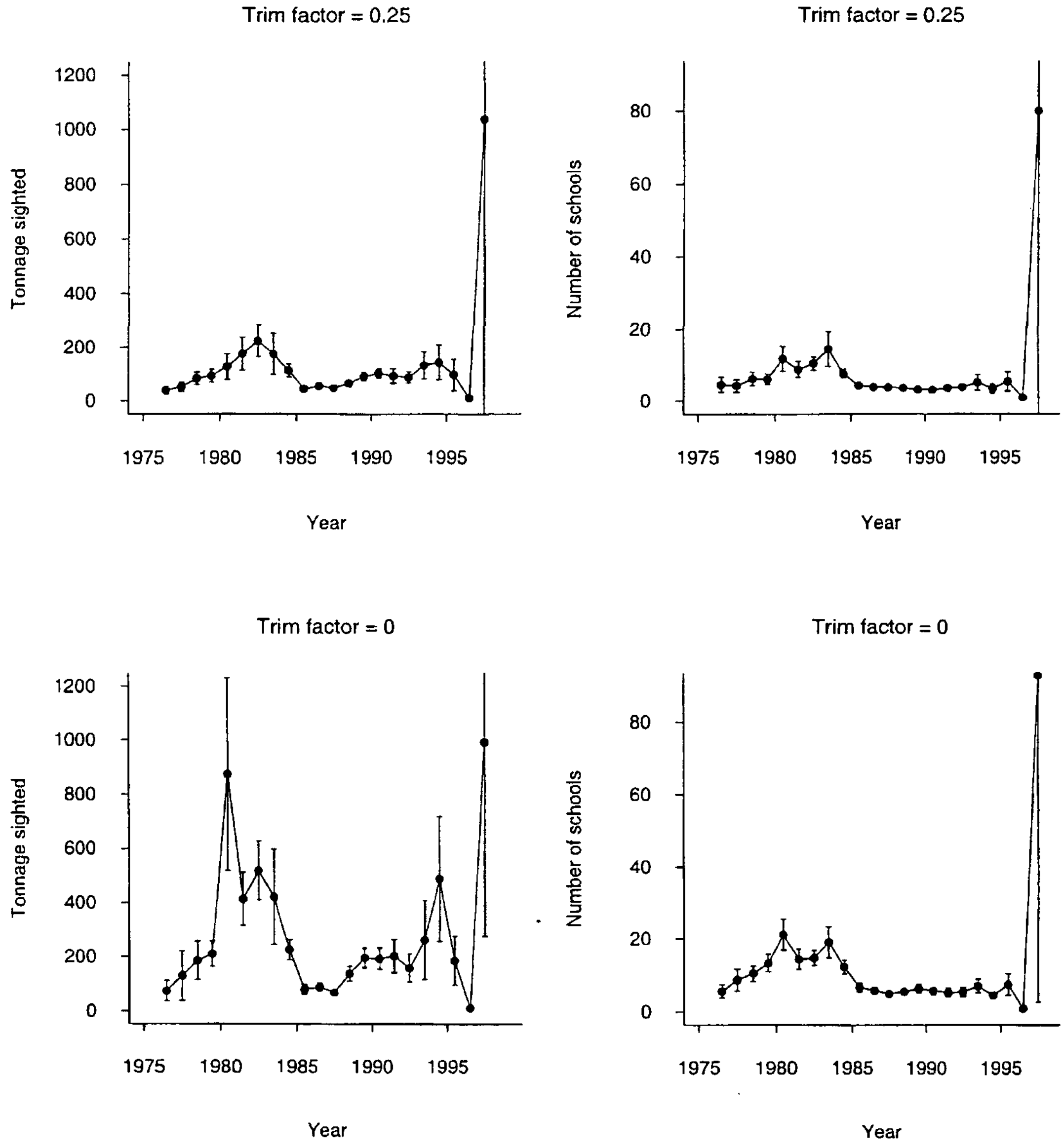


Figure 17: Time series of relative abundance indices for jack mackerel in JMA 3—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means.



Trim factor = 0.25

Trim factor = 0.25

Trim factor = 0

Trim factor = 0

Figure 18: Time series of relative abundance indices for kahawai in KAH 3—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

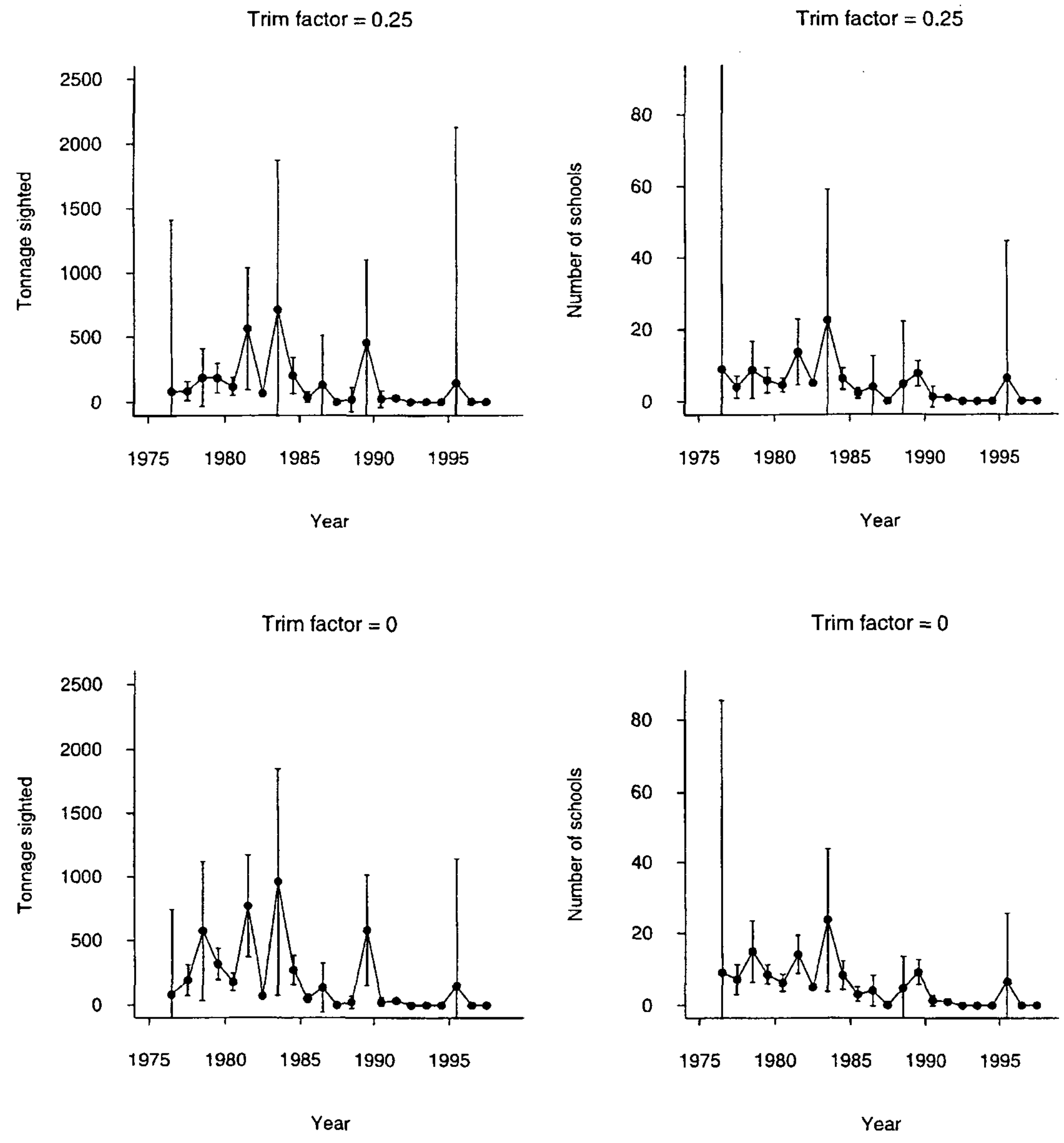


Figure 19: Time series of relative abundance indices for blue mackerel in QMA 7—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

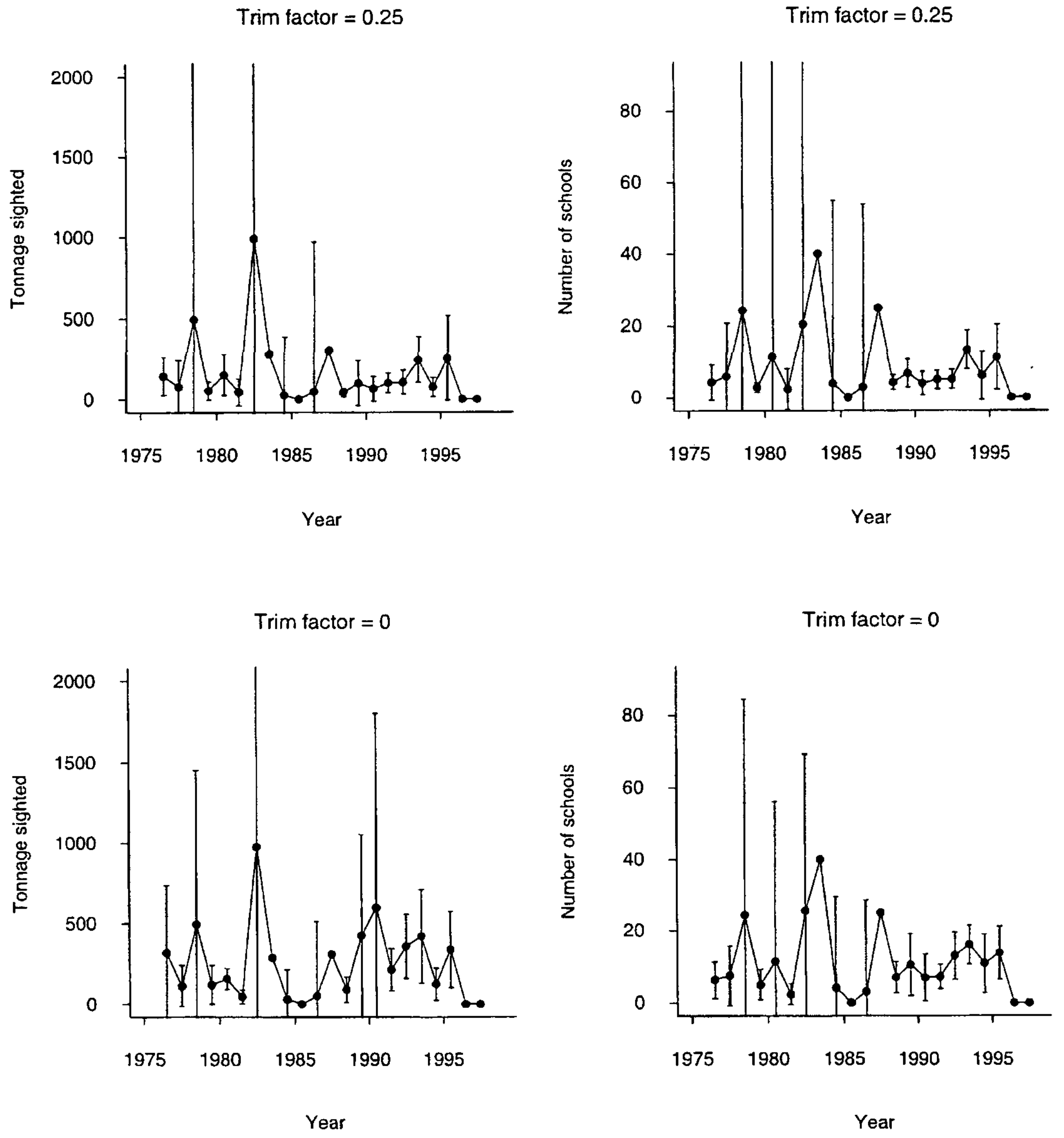


Figure 20: Time series of relative abundance indices for jack mackerel in JMA 7—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

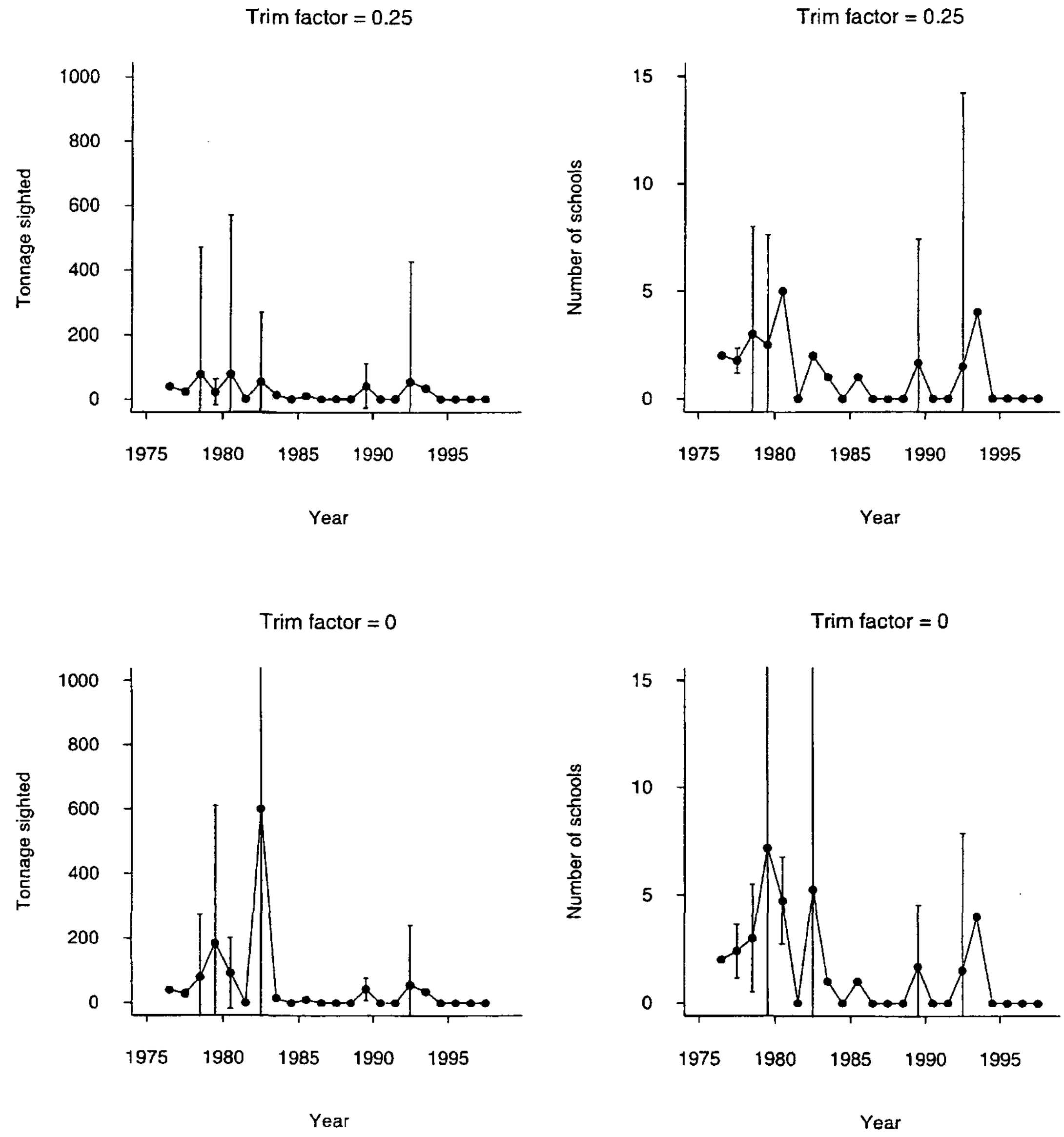


Figure 21: Time series of relative abundance indices for trevally in TRE 7—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

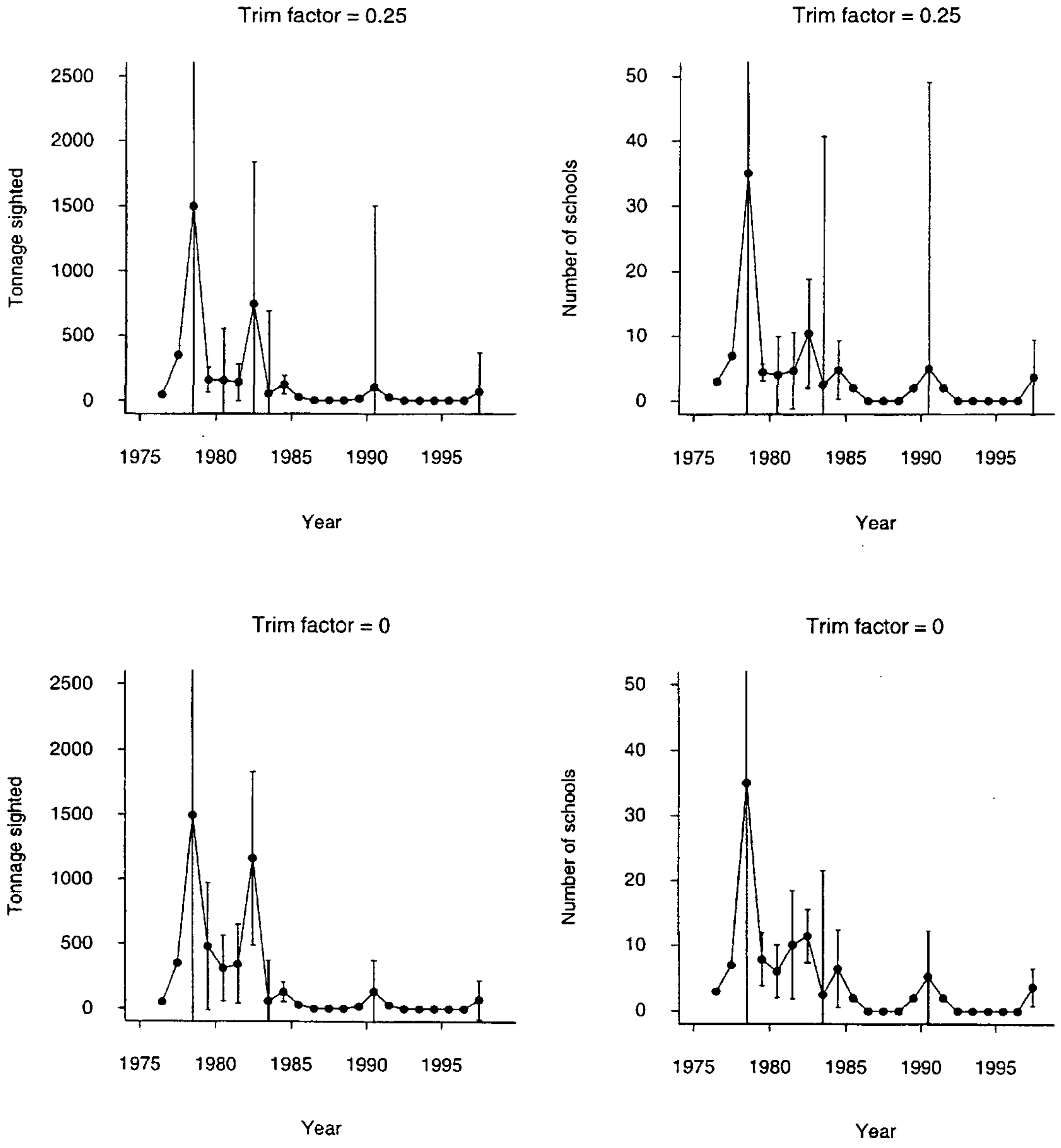


Figure 22: Time series of relative abundance indices for blue mackerel in QMA 8—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed means. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

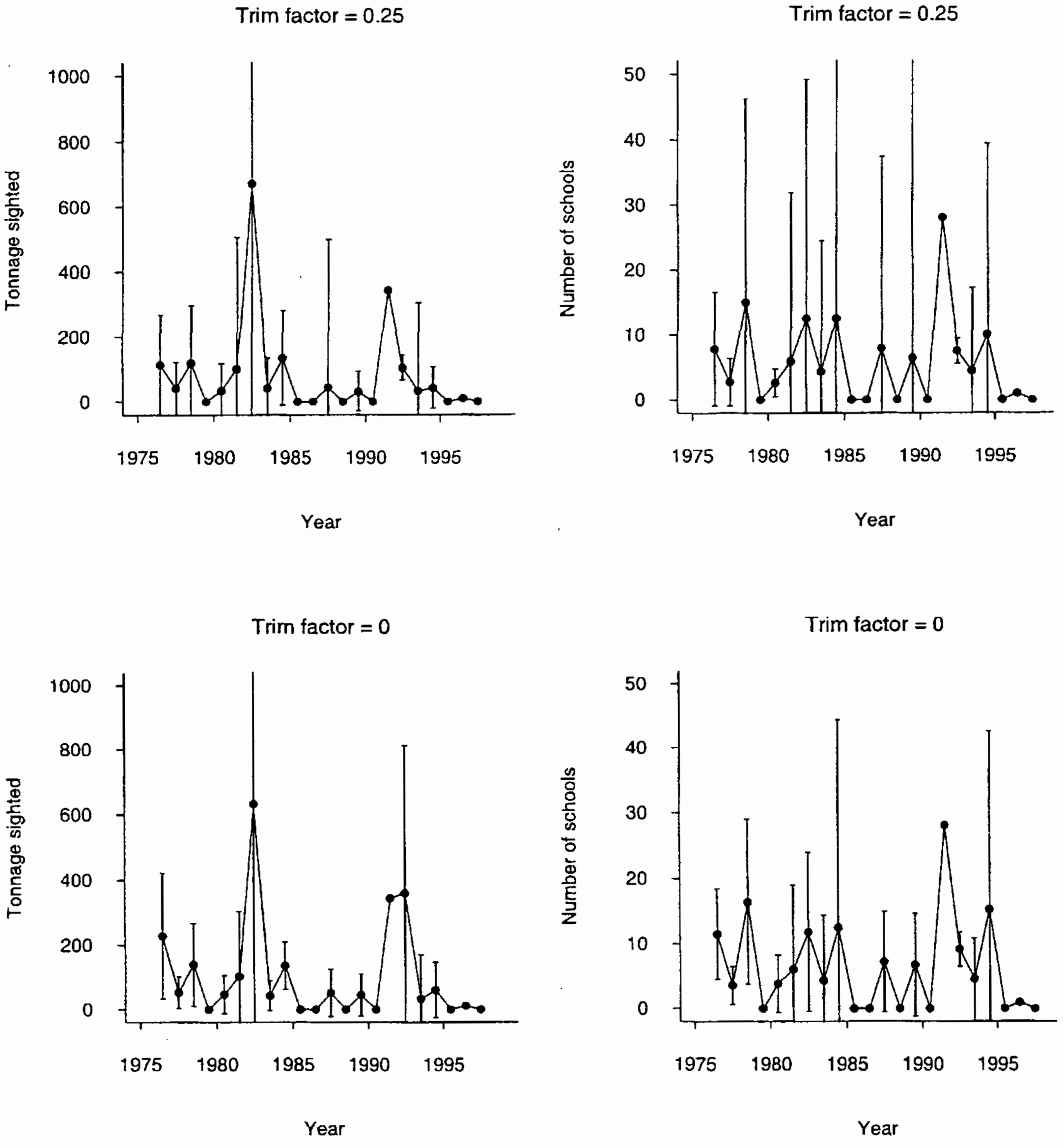


Figure 23: Time series of relative abundance indices for kahawai in KAH 9—plots at the top are based on 25% symmetrically trimmed means, plots at the bottom are based on untrimmed mean. Confidence intervals without horizontal bars have extremes that lie outside the limits of the y-axis, which were chosen to maximise contrast in the indices.

Appendix 1: Symmetrically trimmed means

The (α, β) trimmed mean (T) of x with distribution F is defined by

$$T_{\alpha,\beta}(F) = \int_{F^{-1}(\alpha)}^{F^{-1}(1-\beta)} \frac{x dF(x)}{1-\alpha-\beta} \qquad (1)$$

which is a descriptive measure of location provided that $\alpha = \beta$, when it is called the 2β trimmed mean, or the symmetrically trimmed mean (Staudte & Sheather 1990). Staudte & Sheather (1990) list four important properties of trimmed means:

1. They are robust to outliers, up to $100\beta\%$ on each side.
2. They have very strong nonparametric efficiency; namely, their asymptotic efficiency relative to the untrimmed mean never drops below $(1 - 2\beta)^2$.
3. They are simple to calculate, and their standard errors are easily estimated from the 2β-Winsorized* sample.
4. When the data are normally distributed, there is strong evidence that the distribution of the standardised trimmed mean has an approximate Student's t distribution with known degrees of freedom: hence robust confidence intervals of known coverage probability may be constructed for normal means, even when the sample is small.

The standard error is given by

$$\hat{\mathrm{SE}}[T_{2\beta}(F_n)] = \frac{1}{(1-2\beta)} \frac{s^2_{W_{2\beta}}}{\sqrt{n}} \qquad (2)$$

where $s^2_{W_{2\beta}}$ is the sample variance of the 2β Winsorized sample. That is, let $m = [n\beta]$, and define

$$Y_{(i)} = \begin{cases} X_{(m+1)}, i \le m \\ X_{(i)}, \quad m < i \le n-m \\ X_{(n-m)}, n-m < i \end{cases} \qquad (3)$$

Then the sample variance of the 2β trimmed mean is defined as

$$s^2_{W_{2\beta}} = \frac{1}{n-1} \sum_{i=1}^{n} (Y_i - \bar{Y})^2 . \qquad (4)$$

Reference

Staudte, R.G. & Sheather, S.J. 1990: Robust estimation and testing. John Wiley & Sons, New York. 351 p.

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[*] The Winsorised sample is where each observation below the first quartile is replaced with the value of the first quartile, each observation above the third quartile is replaced with the value of the third quartile, and all other observations remain unchanged.