PROJECT TITLE:	**POP 2019-02 Fish shoal dynamics in north eastern New Zealand; Objective 2, exploring distributions of pelagic fish using aerial sightings data**
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DATE:	**2 December 2020**
THIS DOCUMENT:	**Progress report on work since 12 August 2020**

OVERVIEW

Overall objective

To analyse fish shoal data from the aerial sightings database (aer_sight) and, for the study area in East Northland, Hauraki Gulf and Bay of Plenty (BOP), develop a model of temporal variability in surface schools of the pelagic shoaling finfish species targeted by the domestic purse-seine fishery in terms of relevant environmental variation as a first step in better understanding fisheries pressures on seabird population trends.

Tasks in progress this period

This report aims to provide an update on work currently being carried out, which was begun after the interim report dated 12 August 2020. The current work is of an exploratory nature, to analyse certain aspects of the data as a preliminary to beginning the analysis proper outlined in the objective above.

- Investigate the links between environmental features and distribution of fish schools from *aer_sight*.
- To continue examining changes in schooling aggregations over time i.e., size of schools, tonnage of sightings, number of schools.

Ongoing development of the methodology to complete the first of these tasks is of prime importance. This requires several steps. In particular during this period has been development of a method for projecting observations from the *aer_sight* database onto the same coordinate space as the raster-based environmental variables (see interim report dated 10/03/20) and code for manipulating the data as raster stacks within R. Completion of these tasks still requires some work.

Underlying these tasks is the need for reliable data from *aer_sight*. Direct access to the database has been available for previous work contracted by NIWA (e.g., Taylor, 2014; Taylor & Doonan, 2014), but is not possible for the current work, so extracts must be requested from Fisheries NZ. Exploratory data analysis is necessary to ensure that the expected content of data provided is received. This process of data access has been complicated by the general level of unfamiliarity with the *aer_sight* database and the constraints Fisheries NZ necessarily impose on the data to satisfy privacy terms for contributing fishers. Consequently, discussion and several variations on an evolving data request have been required to produce the current dataset.

The analysis described here under the second task above explores the hypothesis that the aggregation size of surface schooling pelagic finfish species has decreased appreciably over the years since the advent of the purse-seine fishery in 1975–76. The analysis is not designed to provide biomass estimates, only to investigate possible changes in aggregation size of the various species. It does not include mixed schools of these species, but focuses on sightings of mono-specific or single-species schools. To maximise the basis for detecting changes in size, the dataset includes sightings from the entire northeast coast, from North Cape to East Cape.

Sightings are mainly of 8 species: the coastal schooling species trevally (*Pseudocaranx dentex*), blue mackerel (*Scomber australasicus*), three species of jack mackerel (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*), and kahawai (*Arripis trutta*), and the highly migratory species skipjack tuna (*Katsuwonas pelamis*); sightings of blue maomao (*Scorpis violaceus*) have also been reasonably high, though at a much lower rate than the other species listed here.

Data selection

A dataset was created in R (R Core Team (2019) based on the revised extract of schools data from the *aer_sight* database. For each sighting, spotter pilots record details that include species composition, the total number of schools, tonnages of the smallest and largest schools (= range of school sizes), as well as the geographical position of the sighting. These were included in the dataset along with date and area (east Northland and Bay of Plenty); annual and "decadal" references (1976–83, 1984–93, 1994–03, 2004–13) were also created. The dataset was restricted to the six senior pilots contributing to the database (pilot codes 1, 2, 6, 9, 50, 87: see interim report dated 12/08/20) and to the eight main species, although sightings of the three jack mackerel species are included as the singular species, jack mackerel because they are not always recorded separately by the spotter pilots.

Also included in the dataset was the calculated sighting tonnage. The three measures related to sighting size recorded by the spotter pilots are minimum school size (*ton_min*), maximum school size (*ton_max*), and number of schools in the sighting (*num_of_schools*). These measures are combined to provide a simple estimate of the size of the sighting as the calculated tonnage (*ton_tot_calc*):

$$ton\_tot\_calc = num\_of\_schools((ton\_min + ton\_max)/2)$$

Examining school size and number of schools

Some exploratory analyses were carried out to characterise the descriptors of sighting size, *ton_max* and *num_of_schools*. These included a plot of ton_max on ton_min (Figure 1), box and whisker plots of ton_max by species for each of the senior pilots (Figure 2), ton_max by species for the two areas (Figure 3), ton_max by decade for each species in the two areas (Figure 4), num_of_schools by species for the two areas (Figure 5), num_of_schools by decade for each species in the two areas (Figure 6) and calculated tonnage by species for the senior pilots.

The two measures, ton_min and ton_max express the range of sizes in the sighting. Figure 1 is a summary of data for all sightings of the main species by the senior pilots and shows that the majority of ton_max values are less than 100t. The skewness in the data is a feature of the *aer_sight* data and is strongly evident in the plots shown here.

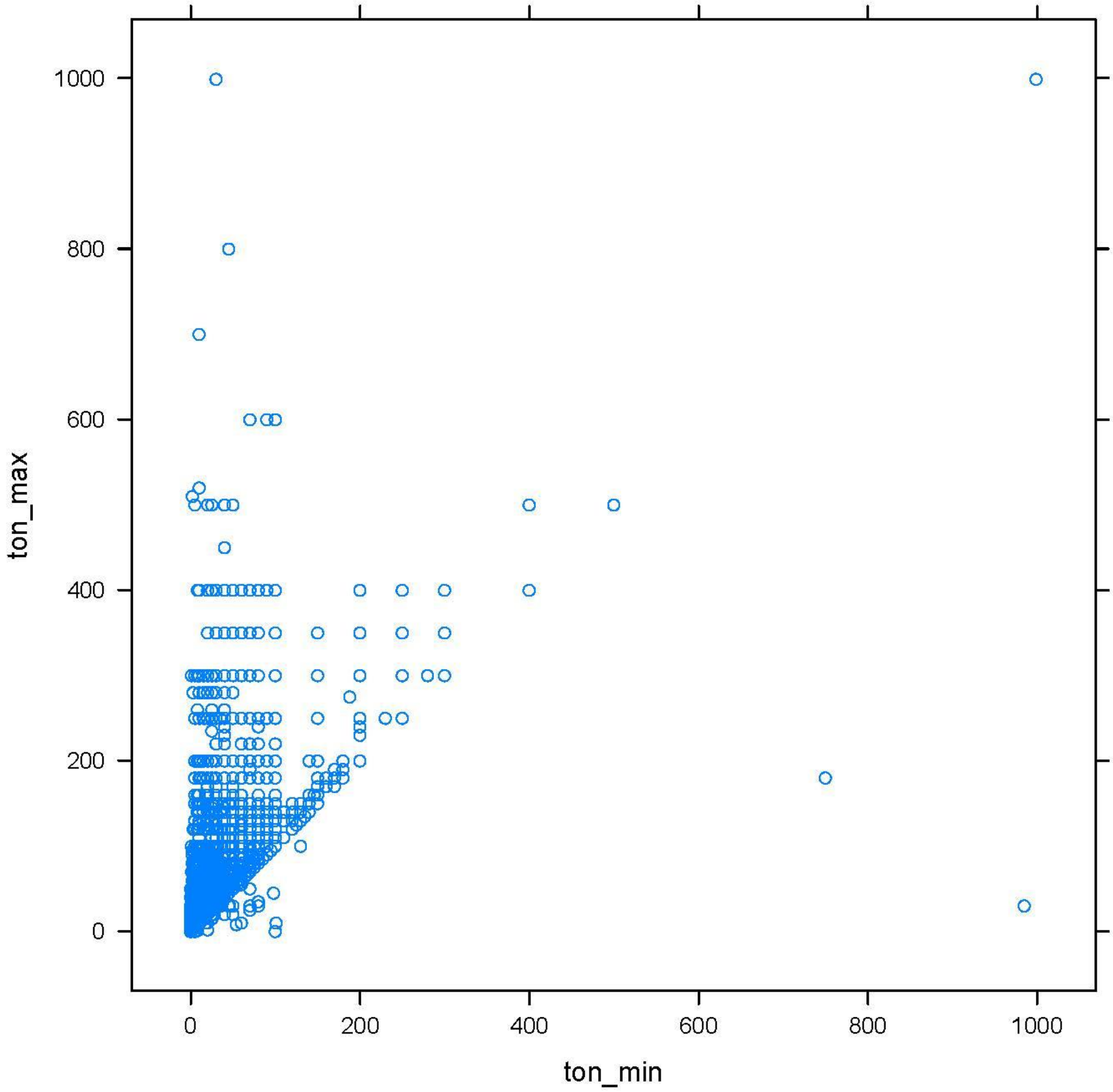

Figure 1: Maximum tonnage on minimum tonnage. Source: Fisheries NZ *aer_sight* database.

Pilots #2 and #9 have collected data over many years. Pilot #9 appears to have a cut-off value for ton_max of about 500t (Figure 2), a feature that is not evident in the data from Pilot #2. The distribution for blue maomao (BMA) is quite different for pilot #9 compared with the other 4 pilots recording observations. Generally the between-pilot patterns of medians and interquartile ranges are similar for the other 5 species, although there are some clear differences e.g., interquartile range of blue mackerel (EMA) for Pilot #9.

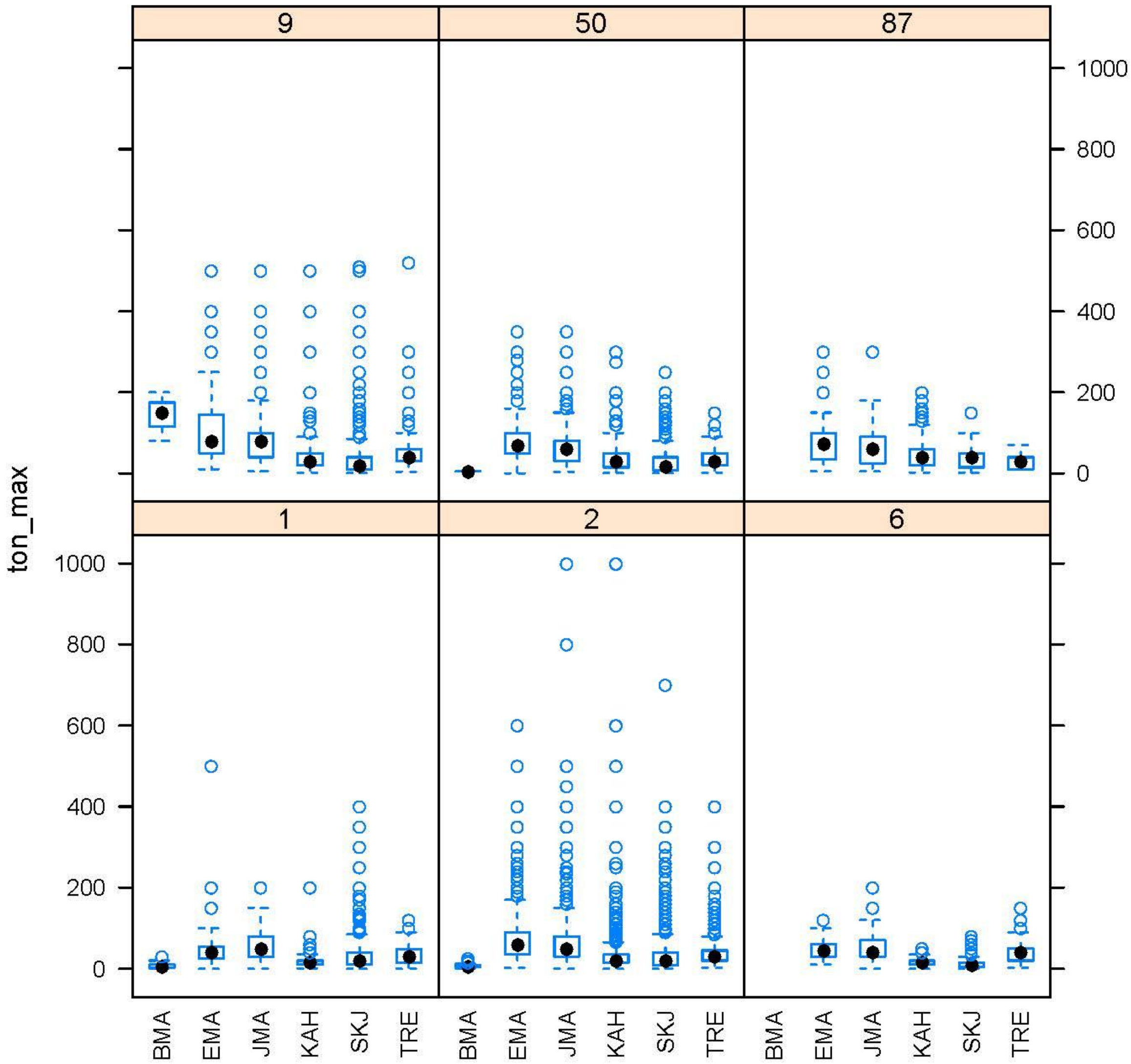

Figure 2: Maximum tonnage by the main species for the senior spotter pilots. Source: Fisheries NZ *aer_sight* database.

The median pattern for ton_max is also similar between the two areas, BOP and ENL (Figure 3), although maximum school size of EMA may tend to be higher in ENL. Apart from 4 sightings in the BOP with ton_max > 600t (2 for blue mackerel, and 1 each for kahawai (KAH) and skipjack tuna (SKJ), the overall spread in the two areas is similar. However, the distribution of ton_max for kahawai is clearly different in the two areas.

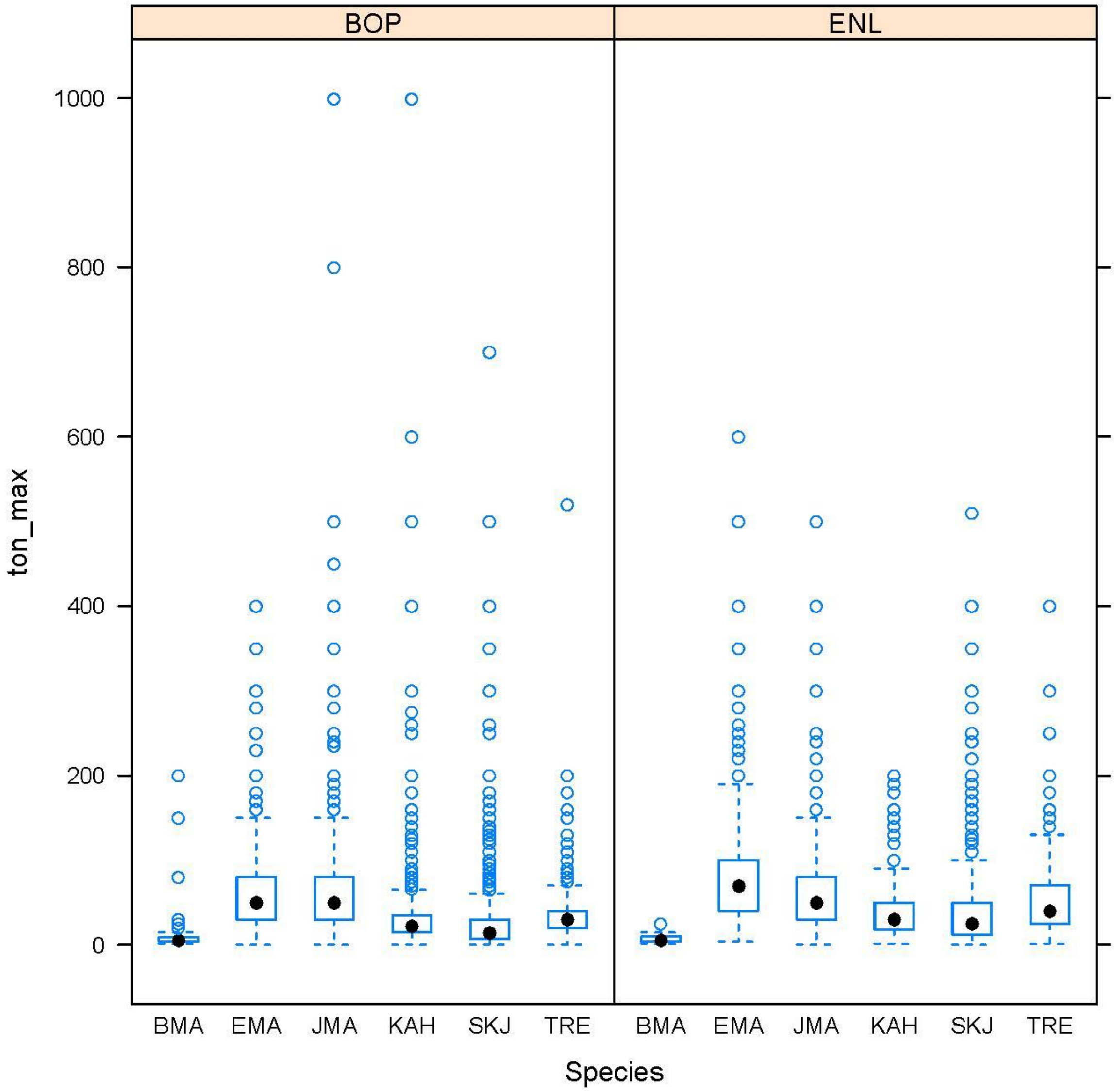

Figure 3: Maximum tonnage by species for the two areas, Bay of Plenty (BOP) and east Northland (ENL). Source: Fisheries NZ *aer_sight* database.

Adding the time factor “decade” (Figure 4) reveals a little more. The higher variability of ton_max for blue mackerel in ENL is largely from decades 2 and 3; otherwise the patterns are similar for this species between the two areas. The pattern of decadal medians is similar for jack mackerel (JMA) in the two areas. The interquartile ranges for kahawai are similarly tight for the two areas and through time, although there is much wider variation in the recorded larger ton_max values in the BOP. The patterns for skipjack are fairly consistent between the two areas and through time. There is little actual difference in the trevally (TRE) distributions between the two areas.

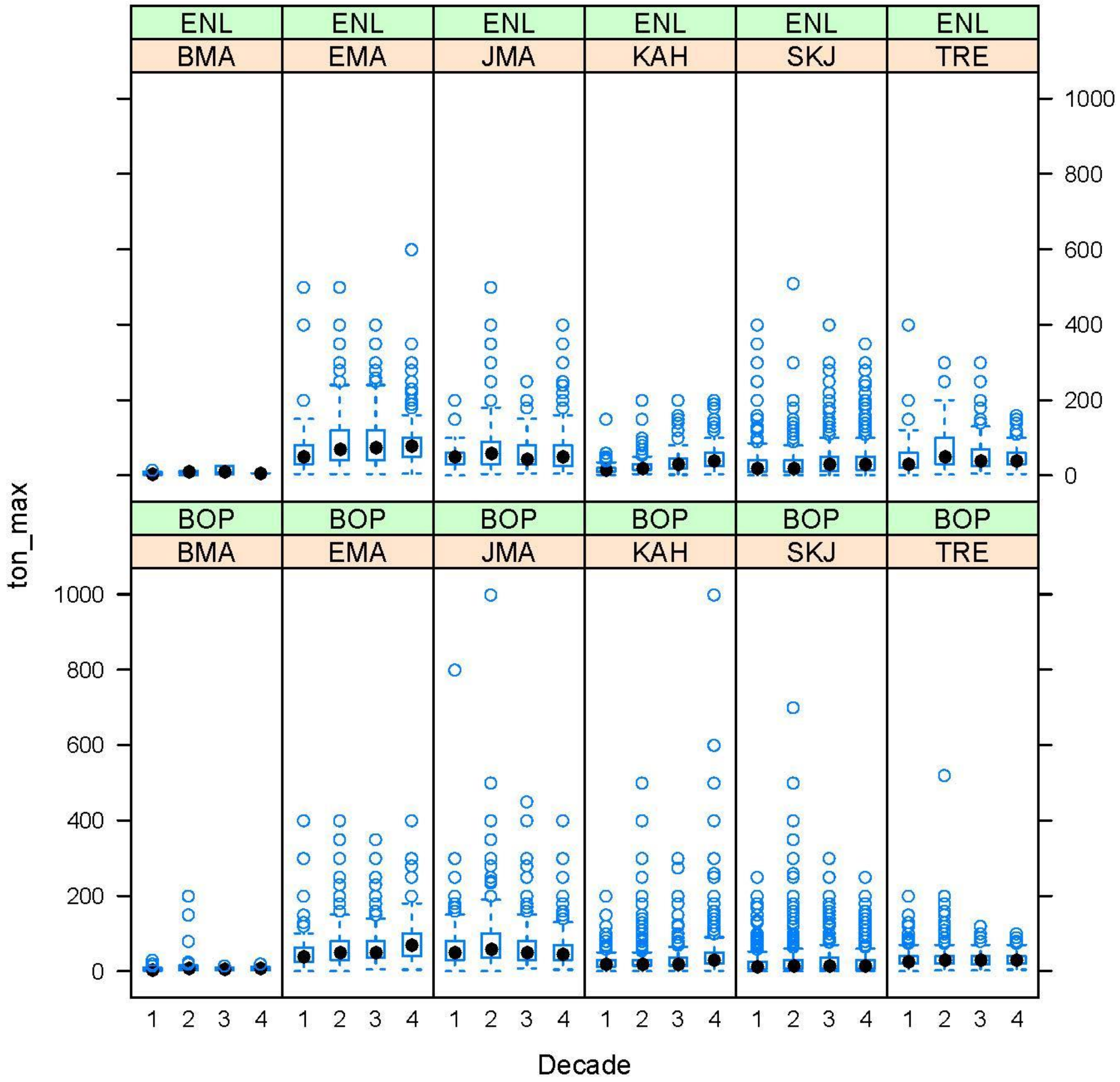

Figure 4: Maximum tonnage by decade (1976–83, 1984–93, 1994–03, 2004–13) for each species in the two areas, Bay of Plenty (BOP) and east Northland (ENL). Source: Fisheries NZ *aer_sight* database.

Because of the low values for the majority of the data and the degree of skewness for 3 species, jack mackerel, kahawai and skipjack tuna in the BOP, the plots of num_of_schools are a little more difficult to read (Figure 5). This skewness represents a much larger variations for this factor in the BOP. Highest degree of skew in ENL is for skipjack, which is the species more often targeted in that at area.

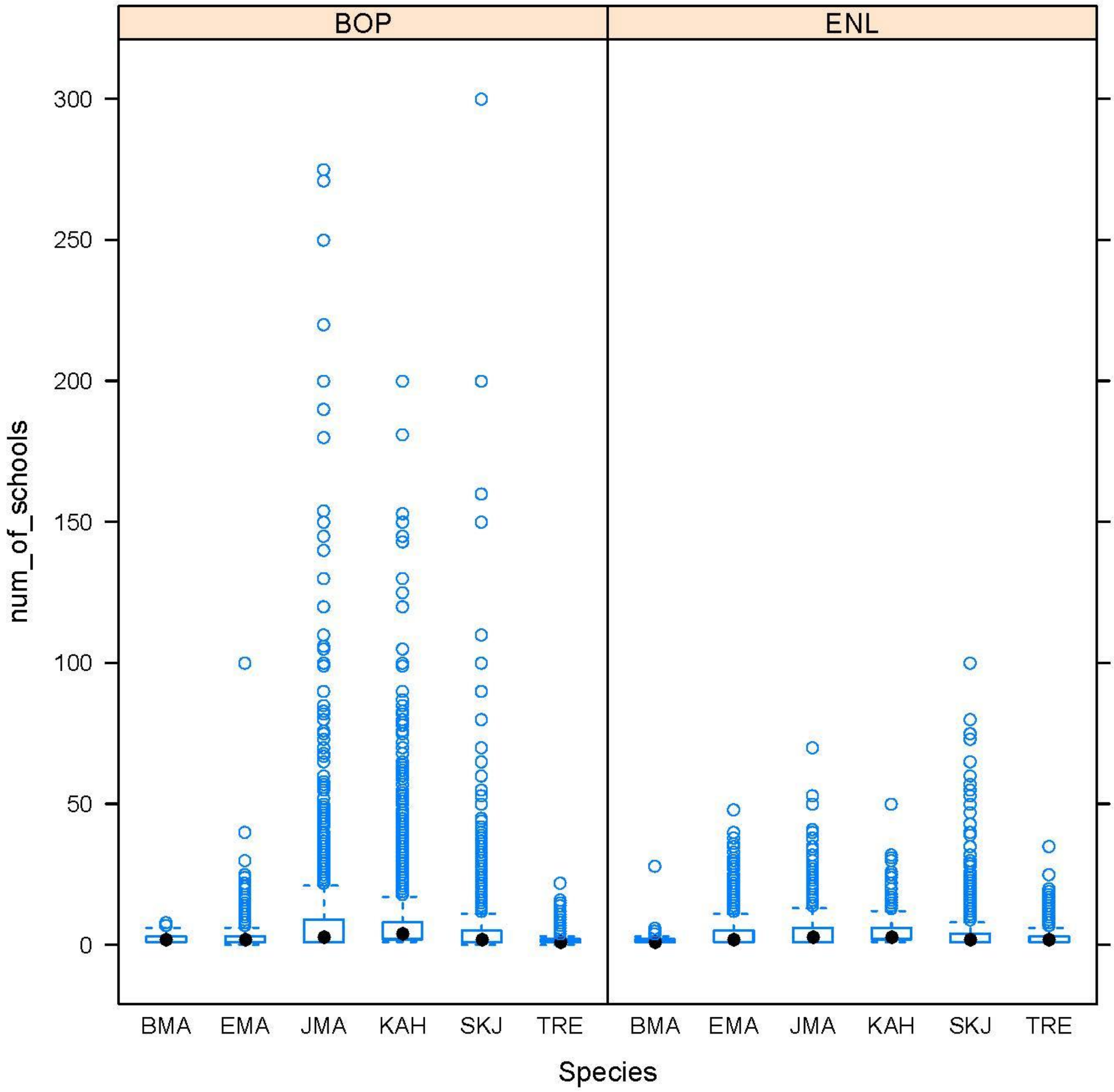

Figure 5: Number of schools by species for the two areas, Bay of Plenty (BOP) and east Northland (ENL). Source: Fisheries NZ *aer_sight* database.

The higher numbers of schools recorded for skipjack are most evident in the third decade (1994–03) (Figure 6). Generally the higher values in the BOP for jack mackerel, kahawai and skipjack continue throughout the time series, although there are some variations e.g., the fourth decade for jack mackerel.

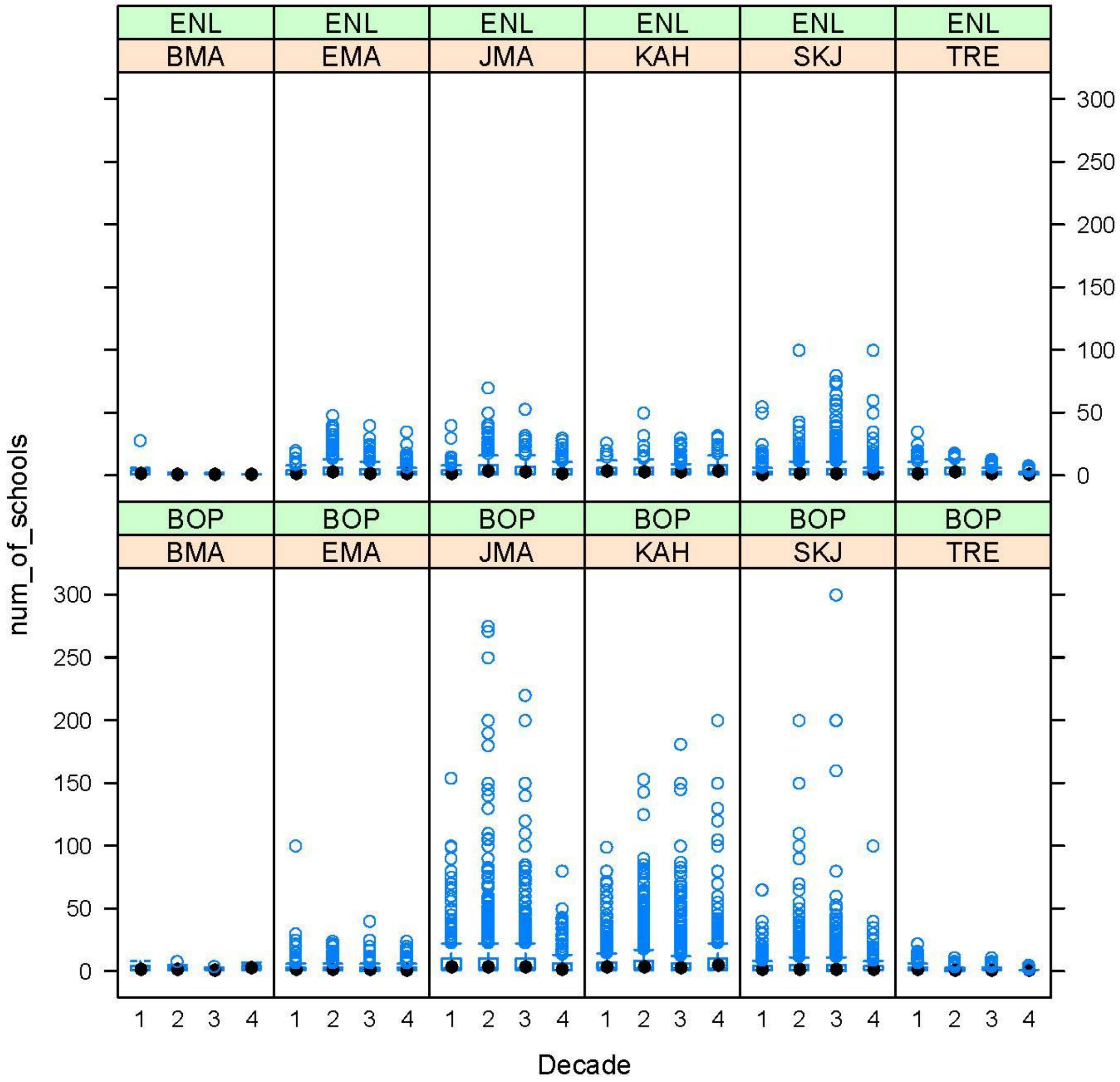

Figure 6: Number of schools by decade (1976–83, 1984–93, 1994–03, 2004–13) for the main species in the two areas, Bay of Plenty (BOP) and east Northland (ENL). Source: Fisheries NZ *aer_sight* database.

Estimates of ton_tot_calc are calculated from ton_min, ton_max and num_of_schools. In two cases the values are very high (Figure 7), suggesting that one or more of the contributing values are incorrect. Several other variations between pilots are of interest: the jack mackerel distribution for Pilot #9 is considerably wider than for the other pilots (apart from the gross outlier for Pilot #2); similarly for KAH/Pilot #50 and SKJ/Pilot #2.

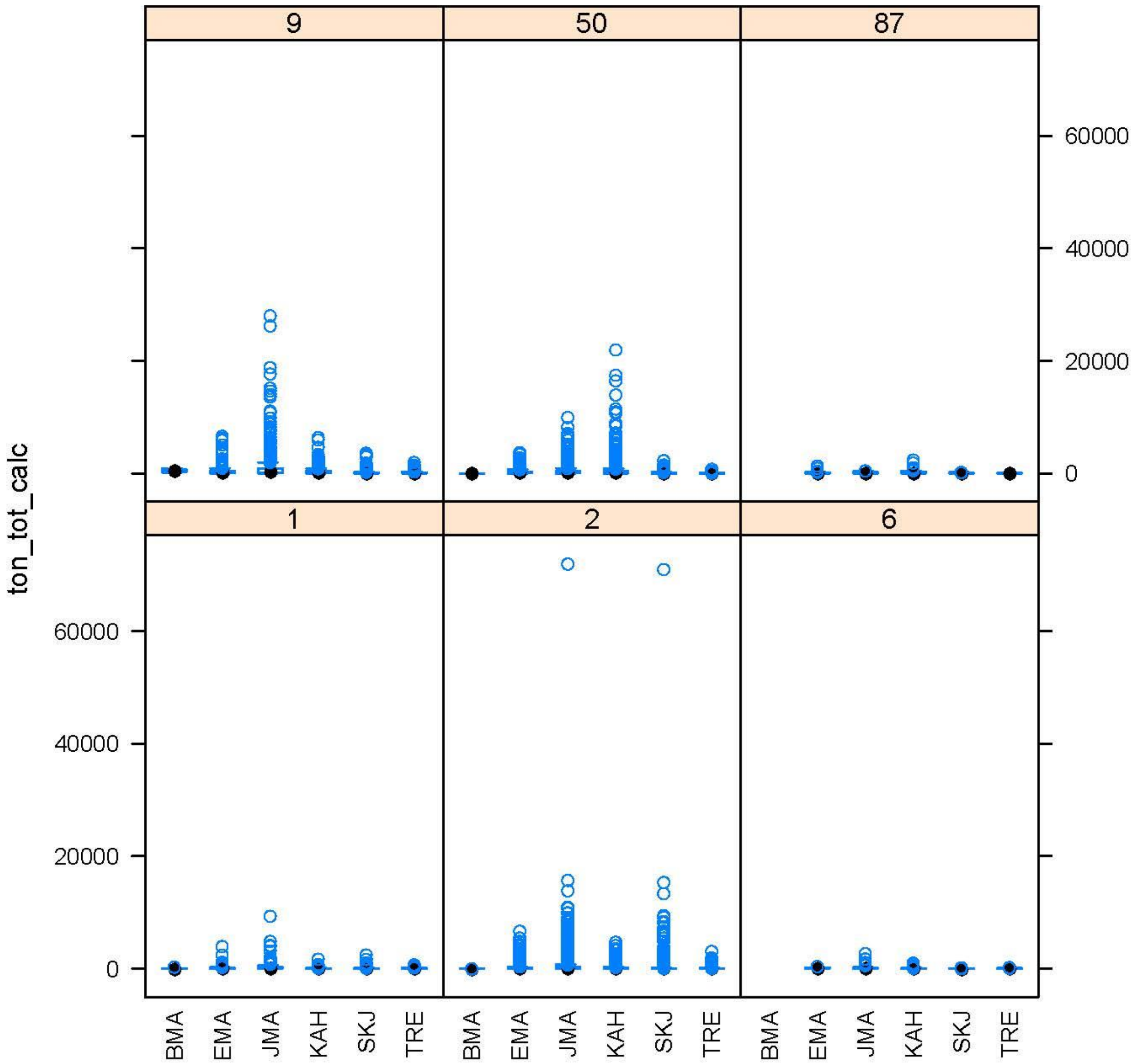

Figure 7: Calculated tonnage by species for the senior pilots. Source: Fisheries NZ *aer_sight* database.

Examining changes in school size, number of schools and calculated tonnage

Methods

The dataset referred to previously was separated by species and the measures of school size (ton_max, num_of_schools and ton_tot_calc) were examined for trends using the time series analysis package TTR. Two aspects of the time series of raw data for these measures were investigated: 1) the likelihood of trend through the sequence and 2) a difference between the first half of the sequence (before 1995) and the second half of the sequence (after 1994). These were examined for five of the main species: blue maomao (BMA) was omitted from these analyses because of a high frequency of missing data.

For the time series analyses, sequences of monthly means of the three measures were created for each species. To provide perspective two series were produced in each case: a series for all pilots and a series for Pilot #2. Missing data were replaced by the preceding value, which was repeated in the case of multiple missing values. For the statistical testing, values of the particular measure for all sightings of a given species in all years were included.

For the examination of trend, the linear model in R (lm) was used to produce t-test/p-value for the time variable (year) which provided the test for the null hypothesis (no trend in the sequence) vs the alternative. In each case a test for normality in the distribution of the sequence was carried out using the R function qqplot to determine whether applying the linear model was appropriate.

For the comparison of the first and second halves of the sequence, data for the species and measure of interest were selected as being either <1995 or >1994 and the t-test applied. Once again, normality was tested using qqplot.

Results

Generally, the time series plots were highly variable. The clearest indication of a positive trend was for ton_max and kahawai (Figure 8) and the clearest negative trend was for number of schools and trevally (Figure 9), the latter also suggested in the ton_tot_calc plot for trevally (Figure 10). Other trends are a little more subtle. For example, the ton_max curve for jack mackerel (Figure 8) shows an increase from 1985 which peaks and declines from about 1992. This trend is also evident in the num_of_schools plot for jack mackerel (Figure 9), although it begins a little later in the sequence.

The results of the linear model and t-testing are shown in Table 1. Empty cells are where simple data transforms would not comply with the normal assumption. All successful transformations were logarithmic. Note that the trend estimates for jack mackerel are both negative, which reflects the trend in Figure 8, though perhaps not so clearly the curve in Figure 10. The highest positive estimates are for both kahawai cases and for ton_max/blue mackerel which also reflect the curves in Figure 8 (ton_max) and Figure 10 (ton_tot_calc).

Note that in some cases however, the lack of normality in the testing data precluded carrying out the testing, while a clear trend is evident in the time series plot. This is perhaps clearest in the blue mackerel plot for ton_tot_calc (Figure 10). In this case it is interesting to note that the t-test on the first-half vs second half of the data (sequence halves) tested significant at the 0.05 level on normal data.

Table 1: Estimates and significance levels (SL) from the trend analysis and comparison of sequence halves. Source: Fisheries NZ *aer_sight* database

Analysis (statistic)	Sighting measure	SKJ	TRE	EMA	JMA	KAH
Trend (estimates)	ton_max	6.27e-3	9.193e-3	1.306e-2	-3.613e-3	1.810e-2
	num_of_schools					
	ton_tot_calc		†	7.123e-3	-19361e-2	1.964e-2
Trend (SL)	ton_max	0.001	0.001	0.001	0.001	0.001
	num_of_schools					
	ton_tot_calc			0.001	0.001	0.001
Sequence halves (SL)	ton_max	0.001		0.001	0.001	0.001
	num_of_schools			0.05	0.001	
	ton_tot_calc		0.001		0.001	0.001

†estimate = -1.176e-2 with no transformation or 7.024e-4 with a log transformation; the original distribution is closer to normal; neither are significant.

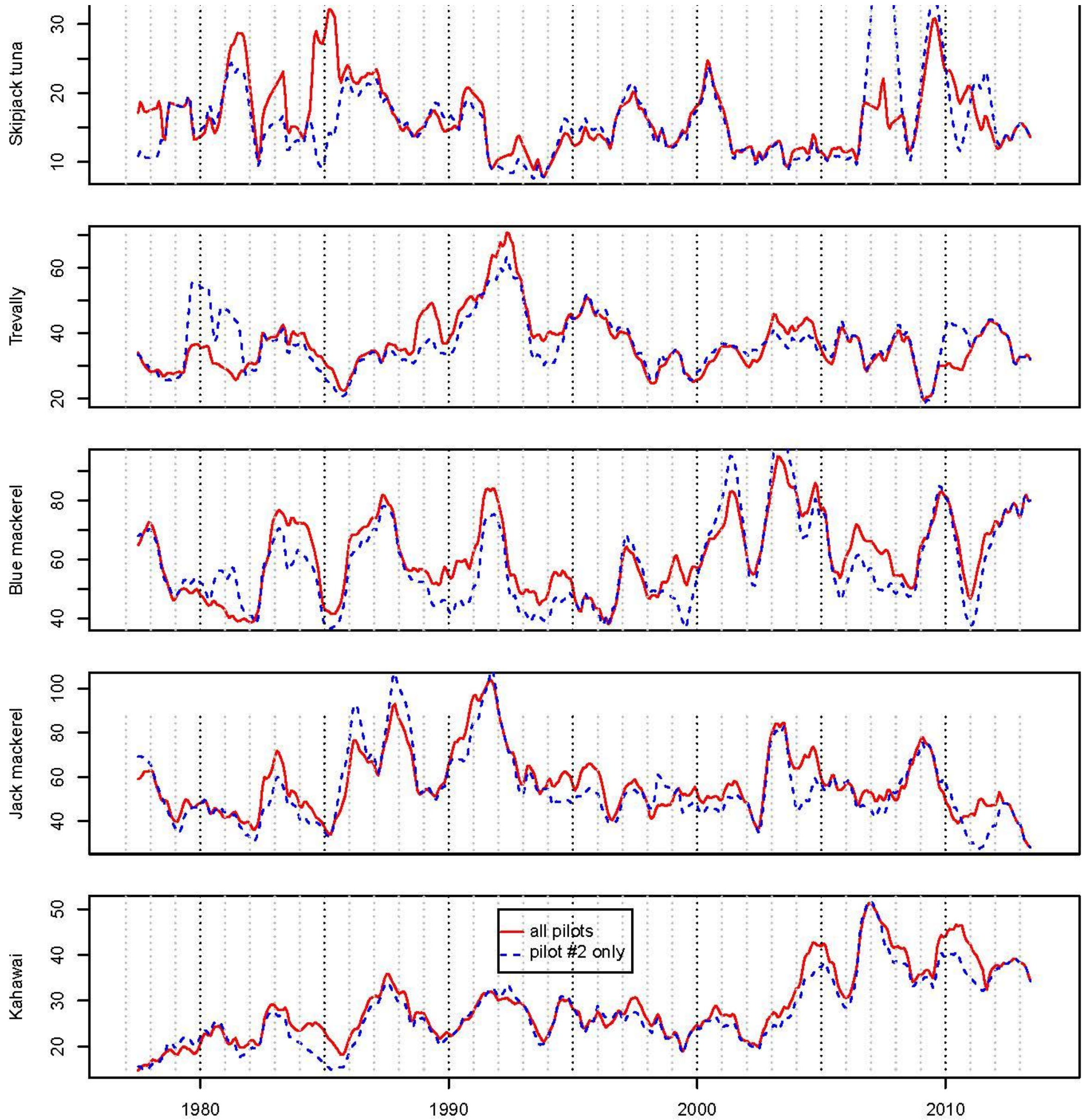

Figure 8: Time series plots of maximum sighting tonnage. Source: Fisheries NZ *aer_sight* database.

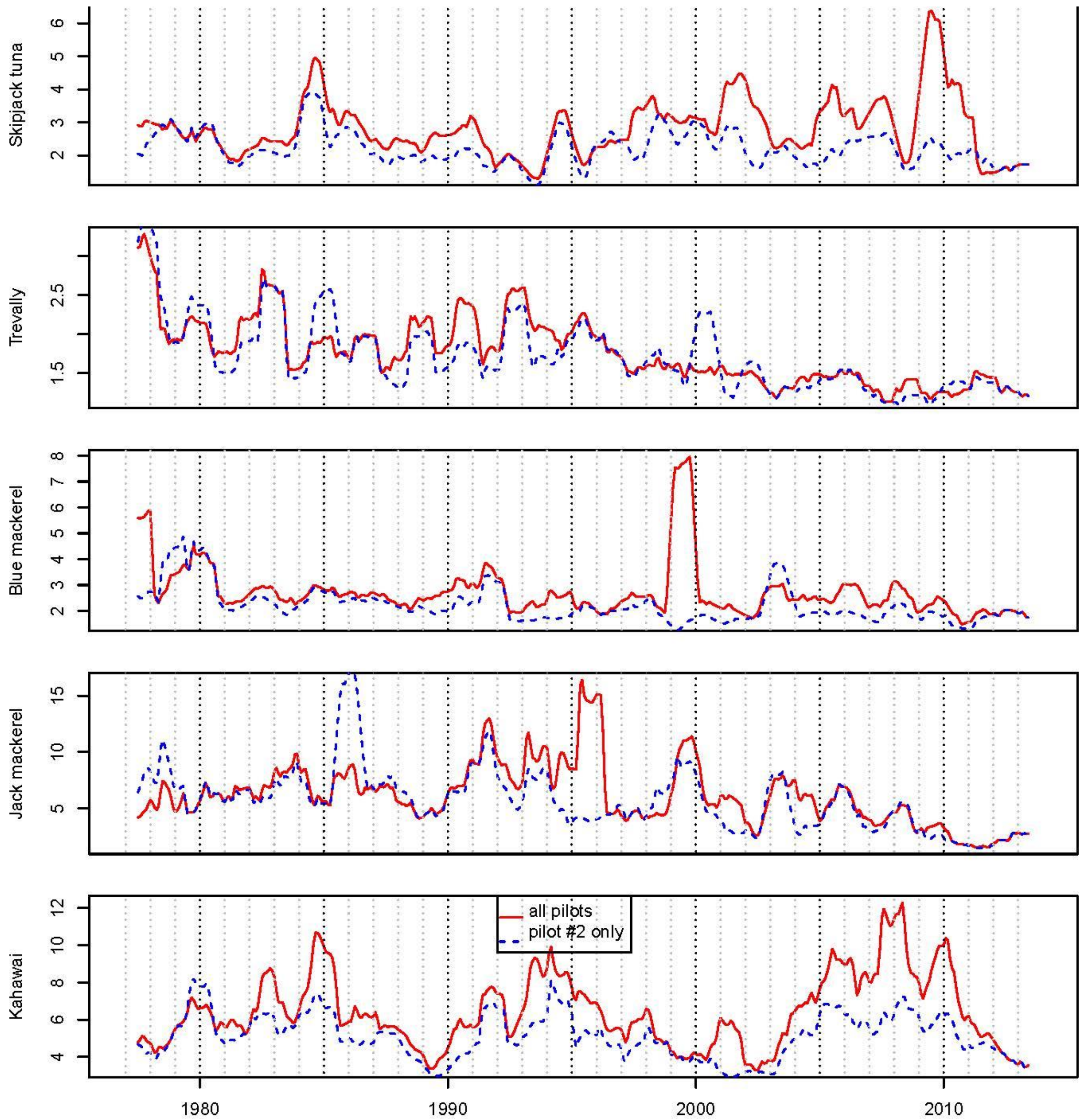

Figure 9: Time series plots of the number of schools by sighting for each of the main species. Source: Fisheries NZ *aer_sight* database.

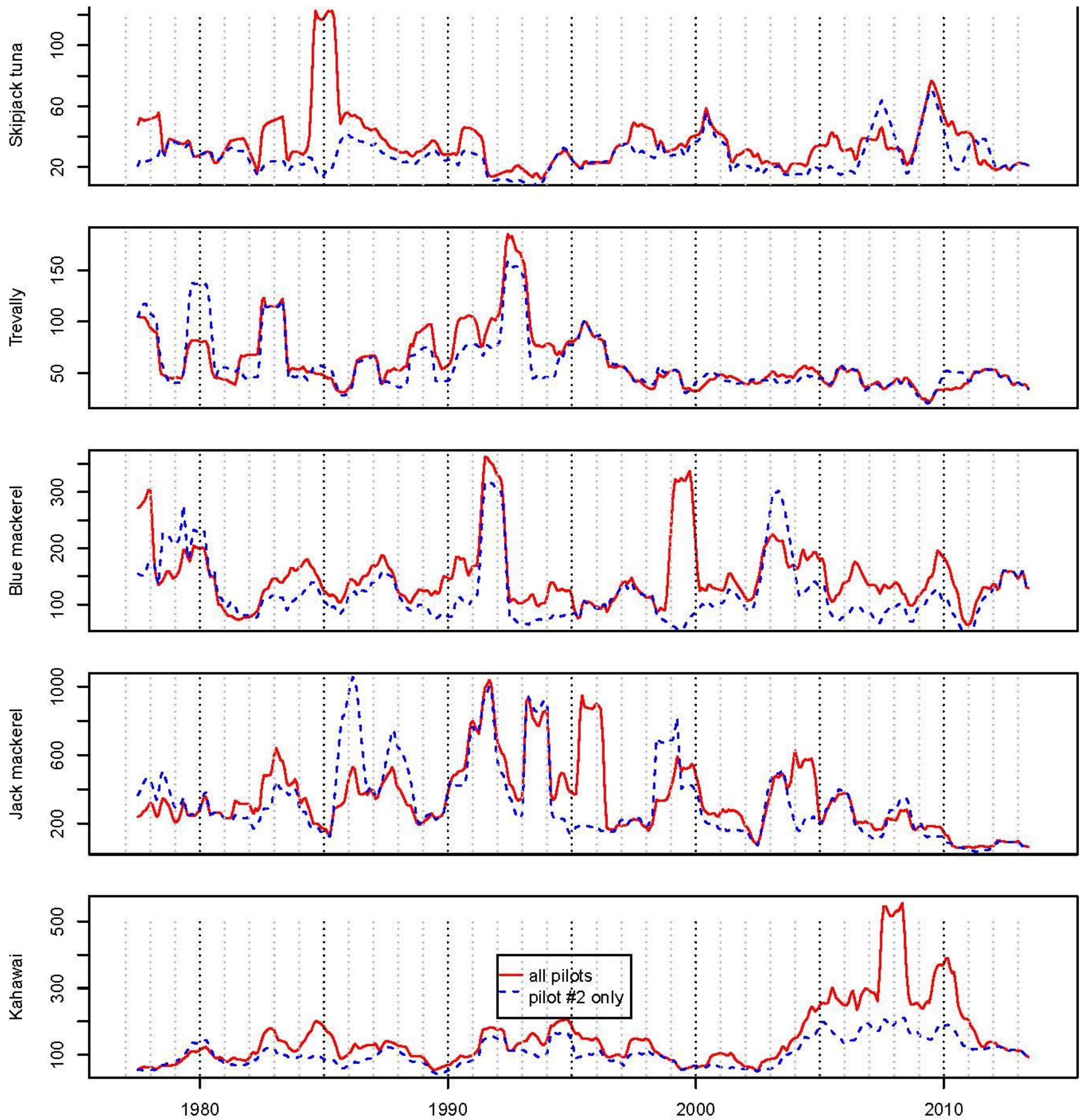

Figure 10: Time series plots of maximum sightings tonnage for each of the main species.

Discussion

The aim here was to examine whether there was any obvious evidence to support the hypothesis that school size in surface schooling finfish species had declined over time since the advent of the purse-seine fishery. Although there is clear evidence of downward trends in the measures of school and sighting size, it is also clear that time series plots of the measures are highly variable. Moreover, in the case of kahawai for example, a clear positive trend is evident in at least one of the measures, possibly as a result of the management of this species.

There are other patterns that are interesting. One example is that of the calculated tonnage for trevally, where the high variability that is a feature of the first half of the series is reduced considerably and accompanied with what appears to be a reduction in calculated tonnage of the sighting as well as num_of_schools. The lesson here, perhaps, is that this is not reflected in the ton_max time series, indicating that it is the number of schools that is more revealing in this case.

Generally, the analyses presented here are useful groundwork in understanding the information contained in the *aer_sight* data.

ACKNOWLEDGEMENTS

Many thanks to the team at Fisheries Data Management of FNZ for providing the data for this work, in particular to Tyler Northern for the revised extract. Thanks also to John Leathwick for discussion on various aspects of the proposed modelling methods, and to Chris Gaskin for managing the project and keeping me on track.

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