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Preliminary Investigation into Australian Surface Fishery CPUE Data

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BRS Report

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Abstract

The surface (purse seine) fishery to supply SBT ‘farming’ operations commenced in the 1991-92 season and has accounted for more than 90% of Australia’s SBT catches since the 1998-99 season. Statistical analysis of surface fishery CPUE has not been attempted to date due to difficulties in quantifying fishing effort and reported changes in selectivity.

A preliminary analysis of CPUE data from the surface fishery is presented. Generalised Additive Models (GAMs) were used to investigate the influence of variables such as spotter plane assistance, month of capture, latitude, longitude, and environmental factors on CPUE. A time series of standardised CPUE showed very similar trends to the nominal CPUE values for the period 1998 to 2007. The usefulness of the CPUE analysis for assessment of stock abundance is affected by the limited geographic range of the surface fishery and effort data limitations. Possible improvements to catch and effort data collection and analysis are discussed although the utility of CPUE data from the surface fishery is likely to remain in doubt.

Introduction

Troll catches of SBT were reported as early as the 1920s off the east coast of Australia but significant commercial fishing for SBT commenced in the early 1950s with the establishment of a pole-and-live-bait fishery off New South Wales, South Australia and, later (1970), Western Australia. Purse seine gear overtook pole as the predominant method and catches peaked at 21 500 t in 1982. Following quota reductions in 1983–84, the Western Australian pole fishery for very small juveniles closed down. Between 1989 and 1995 about half of the Australian total allowable catch (TAC) was taken by Australia–Japan joint venture longliners in the Australian Fishing Zone (AFZ).

In 1990-91 about 20 tonnes of southern bluefin tuna (SBT) were caught for farming in cages off Port Lincoln, South Australia. Utilisation of the Australian SBT total allowable catch (TAC) for farming increased from 3% of the 5265 tonnes TAC in 1991-92 to over 92% in every fishing season since 1998-99. The Australian farm fishery (refered to as the surface fishery) targets the one to five year old juvenile SBT that surface school in the waters of the eastern Great Australian Bight, South Australia. The farmed SBT are caught with the purse seine method from late spring to autumn, by a small number of vessels (seven in 2005-06).

The analysis of catch and effort trends from commercial purse seine fisheries is associated with a number of potential biases that are generally not as evident in the analysis of longline data. Purse seine targets aggregations of fish with a highly selective fishing gear and a diverse range of inputs, the impact of which are often difficult to quantify (Maunder & Hoyle 2006). As a consequence CPUE is often not proportional to the underlying stock abundance (Gaertner & Dreyfus-Leon 2004).

The Australian SBT fishery has a number of characteristics that are unique. The fishery is managed under Individual Transferable Quotas (ITQs) with a restricted Total Allowable Catch (TAC) and as a result the operators are able to take their time to catch their TAC without risk of losing catch to other operators. This is quite different from fisheries managed under competitive systems where maximising the tonnage of catch is the main objective. The Australian quota management arrangements aim to reduce operators' incentive to increase capacity, when compared to other volume driven purse seine fisheries. The quota system may also increase incentive for operators to be more selective of the fish caught and as a result the operators may choose not to catch particular schools of fish if doing so will maximise profits.

Surface fishery effort in the Australian farming fishery is particularly difficult to quantify. Unlike traditional purse seine fisheries where catch storage is located on the vessel, surface fishery catch must be transferred to a tow cage. The interaction of fishing vessels with aerial spotting planes adds an additional dimension to the surface fishery effort. In essence, the real effort in the surface fishery is a combination of the interactions of aerial spotting planes, purse seine and assisting vessels as well as the availability of tow cages and the fishers experience. Although the presence-absence of spotting craft has been included in this analysis of CPUE, any changes in aerial spotting or tow cage availability and other inputs have largely been ignored.
Many of these issues associated with analysis of purse seine CPUE data are not as pronounced in longline fisheries and as a result, longline data is usually used as the index of abundance forming the base of highly migratory tuna stock assessments (Hampton 2002a; Hampton 2002b; Hampton 2002c; Nishida & Shono 2002). In response to CCSBT member requests, the following report details preliminary analysis of trends in the Australian surface fishery catch and effort data.

Due to the problems associated with analysis of the surface fishery CPUE, the results of the analysis are preliminary and require substantial further investigation. Any trends presented in this report should be interpreted with caution and not used as an indication of the SBT recruitment or stock abundance.

Catch and Effort Data

Operational level catch and effort logbook data from the Australian surface fishery provided the basis for this analysis. Annual surface fishery reported catches since the farm-based fishery began are presented in Figure 1. The catch data used in this analysis are the fishing master estimated catch in kilograms; the estimates are the provisional estimate of tonnage caught, prior to the formal quota reconciliation at the farm gate.

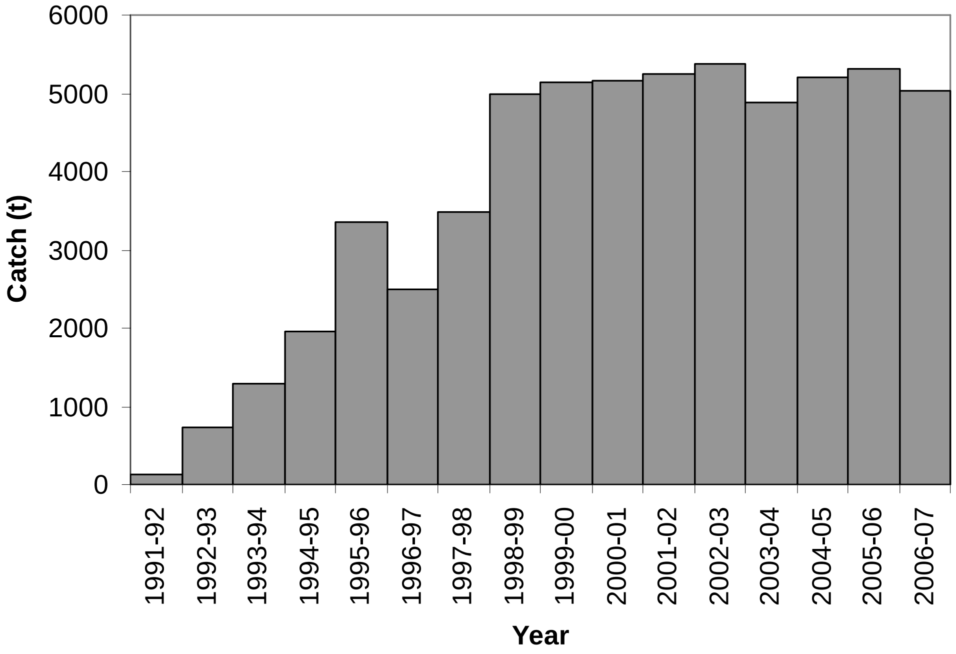

Figure 1. Annual surface fishery catch since the start of SBT farming in Australia. Note: the 2006-07 data is preliminary as the fishing season is not complete.

The surface fishery developed rapidly during the 1990s. The analysis of CPUE was limited to post 1998 as this was the year, beyond which over 50% of the Australian TAC was caught for farming purposes. Trends in CPUE prior to1998 are likely to be influenced by the rapid development of the farming industry. In future analysis it may be more appropriate to limit any analysis to post 1998-99 fishing seasons where more than 90% of the TAC has been caught for farming purposes.

The analysis presented in the report is based on calendar year, not fishing season. Figure 2 presents the frequency of effort by month. In the future data will be altered to allow simple analysis by fishing season, which aligns better with the seasonal migration of SBT across the GAB. As the majority of records from one fishing season are in one calendar year, the trends presented in this report are unlikely to substantially change when presented by fishing season in the future.

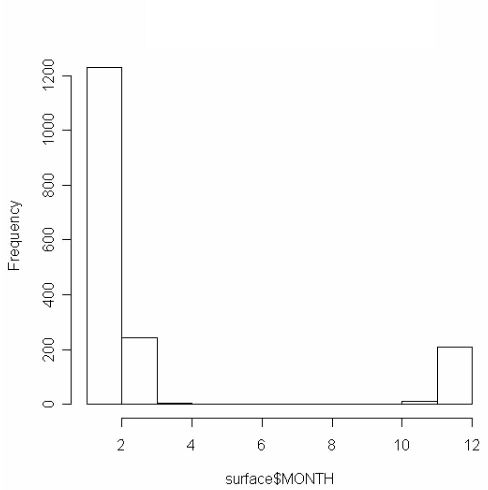

Figure 2. Frequency of records of effort by month from 1998-2007.

The effort measure used in this analysis is purse seine vessel search hours. Search hours are recorded by vessel Masters in logbooks; however it does not appear to have been collected in a standardized manner. A series of assumptions have been made to allow analysis of the data. Detailed discussion with vessel Master's has not been completed to ensure that these assumptions are valid and reasonable.

The measure of effort (hours searched) has a number of important limitations that must be noted. A visual inspection of Figure 3 shows peaks in search hours at twelve, six and four hours. These appear to be a result of the majority of vessels normally recording twelve hours of searching as a full day. As a result, two or three sets in a day result in six or four search hours if the effort is allocated evenly. Analysis has included both searching when fish were captured as well as search hours when fish were not captured. It is also important to note that search hours do not appear to be recorded in a standardized manner. Some vessels Masters recorded a daily single search hour estimate irrespective of the number of sets in a day, while others recorded individual search hours for each set. The daily search hour estimates were transcribed into the database for multiple sets in a day which resulted in a number of vessels recording more search hours than available daylight and in some cases more than 24 search hours in a day.

For this preliminary analysis, if a vessel recorded more than one set in a day and the search hours for each set were identical, and totalled more than the estimated 15 hours of daylight, the search hours for each set were divided by the number of sets in that day. The search time data manipulations appears to have rectified the total quantum of search hours per vessel, per day, however it has not completely resolved the distribution of search hours per set. In addition, the manipulation assumes that days with less than 15 hours of total searching are correct. These data recording inconsistencies and the data grooming detailed above requires discussion with individual vessel Masters to ensure the assumptions applied are valid.

If search hours were blank and one set was undertaken that day, the search hours were set as the hours between 6am and the set. If more than one set was completed and the search hours were not recorded, the search time was set as the time between the two sets. If both search hours and set time were not recorded, the data was excluded from the analysis. Records where environmental data was not available were also excluded (see below). In total 50 records were excluded from the 1751 operations available in the database.

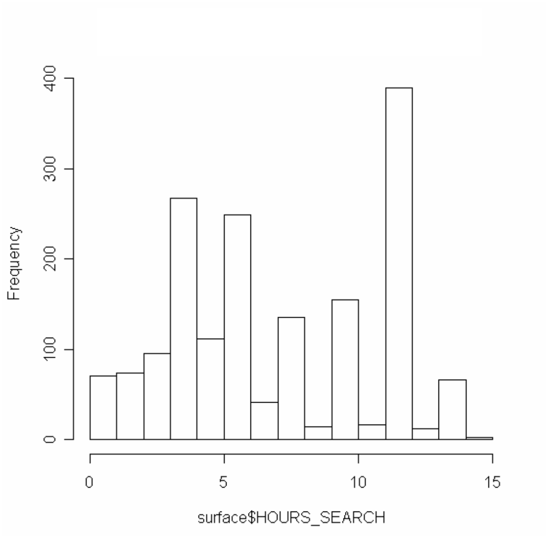

Figure 3. Frequency of hours searched for records in the surface fishery between 1998-2007 after data grooming as detailed.

In some instances effort was reported but not attributed to a geographical location. The inclusion of this data was seen as important as the majority of the effort reported without a location was search time with no catch (zero sets). Where effort was recorded but not attributed to a geographical location, the location of the set closest in time was used (Note: this assumption affects on Figures 4 and 5 below). This was achieved manually and in the majority of circumstances there were additional operations close in both time and location. The spatial distribution of records of surface fishery effort is presented in Figure 4 and Figure 5.

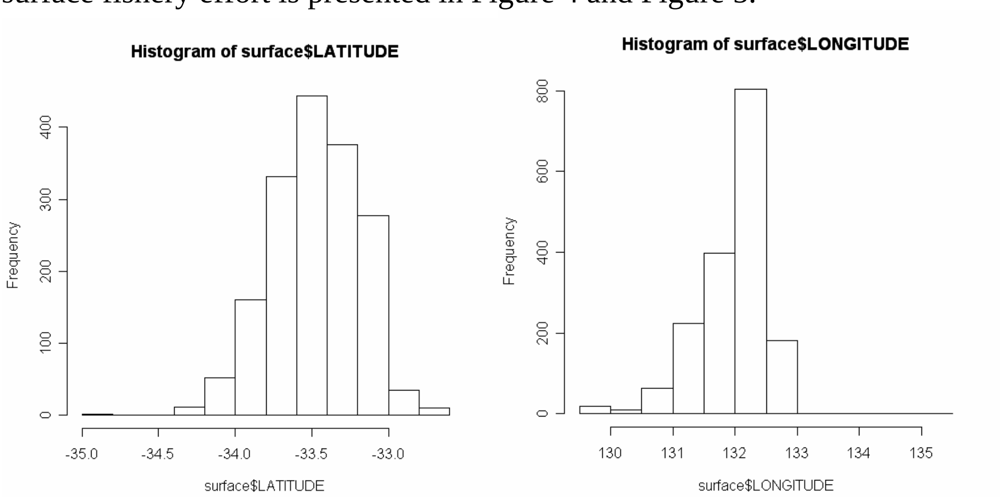

Figure 4. Frequency of records in relation to latitude and longitude in the surface fishery from 1998-2007.

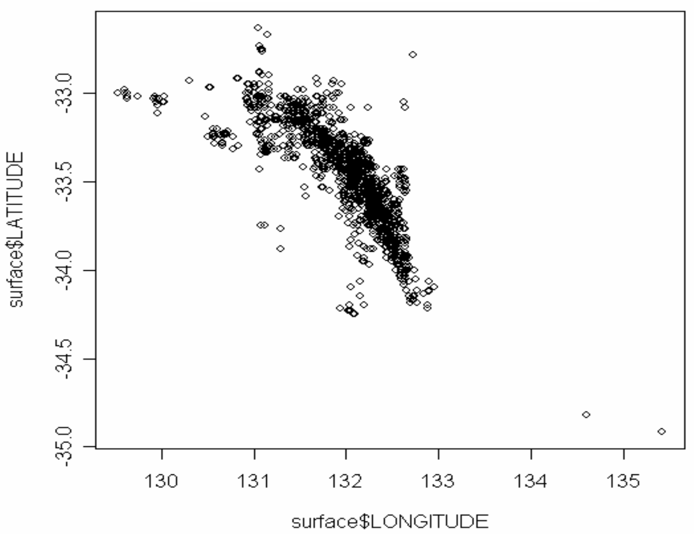

Figure 5. Spatial distribution of surface fishery effort between 1998-2007.

If the CCSBT SAG sees benefit in the analysis of the surface CPUE, changes to the way in which effort data are recorded in the future should be considered. Alternatively a measure of the number of days at sea will be investigated to determine the suitability of the alternate measure of effort.

Environmental Data

The surfacing behaviour of SBT schools and the ease of spotting surface schools of SBT has been shown to correlate with warm calm conditions (Everson *et al*. 2007). Weather data at daily intervals was obtained from the Australian Bureau of Meteorology from the closest sites. Data from Ceduna were used for air temperature, barometric pressure, wind speed and direction, while ocean conditions of sea and swell were provided from Cape Borda on Kangaroo Island. The environmental conditions at the sample sites are likely to be similar to those on the fishing grounds (pers. comm.. Bureau of Meteorology). In situations where data was not available for specific days, the entire record was excluded from the analysis.

Sea surface temperature (SST) weekly means for 1x1 degree square were attained from the National Oceanic and Atmospheric Administration (NOAA NCEP EMC CMB GLOBAL Reyn_SmithOIv2). The SST data was linked to the catch and effort data as well as the weather data for analysis.

CPUE Data Analysis

In order to investigate the influence of variables on catch and effort, a range of variables were plotted against nominal CPUE (calculated as catch in kg divided by total hours searched). Appendix 1 presents a series of box-plots and frequency histograms that show the impact of factors of interest on CPUE and provide an indication of sample size. Figure 6 presents the nominal mean CPUE trends for both total effort (right) and only sets where some catch was obtained (left). Both series show an increase in nominal CPUE between 1998 and 2001 with a declining CPUE between 2001 and 2007. The 2007 level of CPUE is roughly equal to the 1998 level. Figure 7 presents the nominal CPUE as a series of box plots.

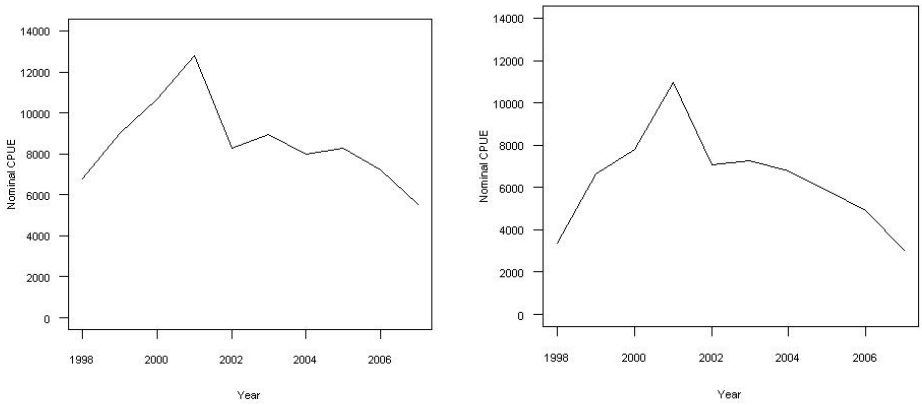

Figure 6. Nominal mean CPUE with only non-zero catches (left) and nominal mean CPUE with zero and non-zero catches.

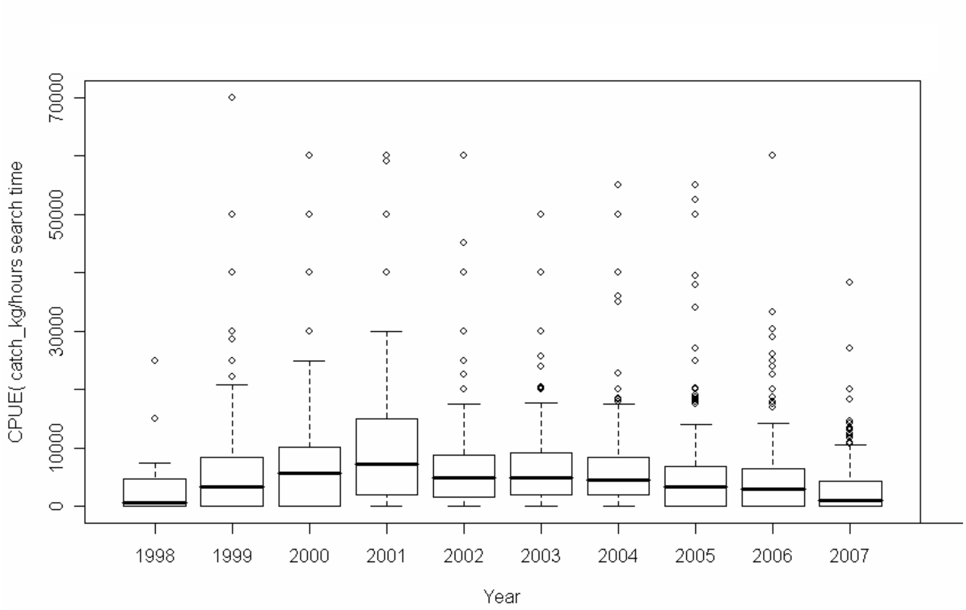

Figure 7. The nominal CPUE by year for the Australian surface fishery presented by calendar year with both zero and non-zero sets.

Generalised Additive Models (GAMs) were used to provide an indication of the relationship between explanatory variables and the logarithm of CPUE (for non-zero catch sets) using a Gaussian error distribution. These relationships were then considered to inform the inclusion of factors in the CPUE standardisation. The relationship between factors of interest and nominal CPUE are presented in Figure 8.

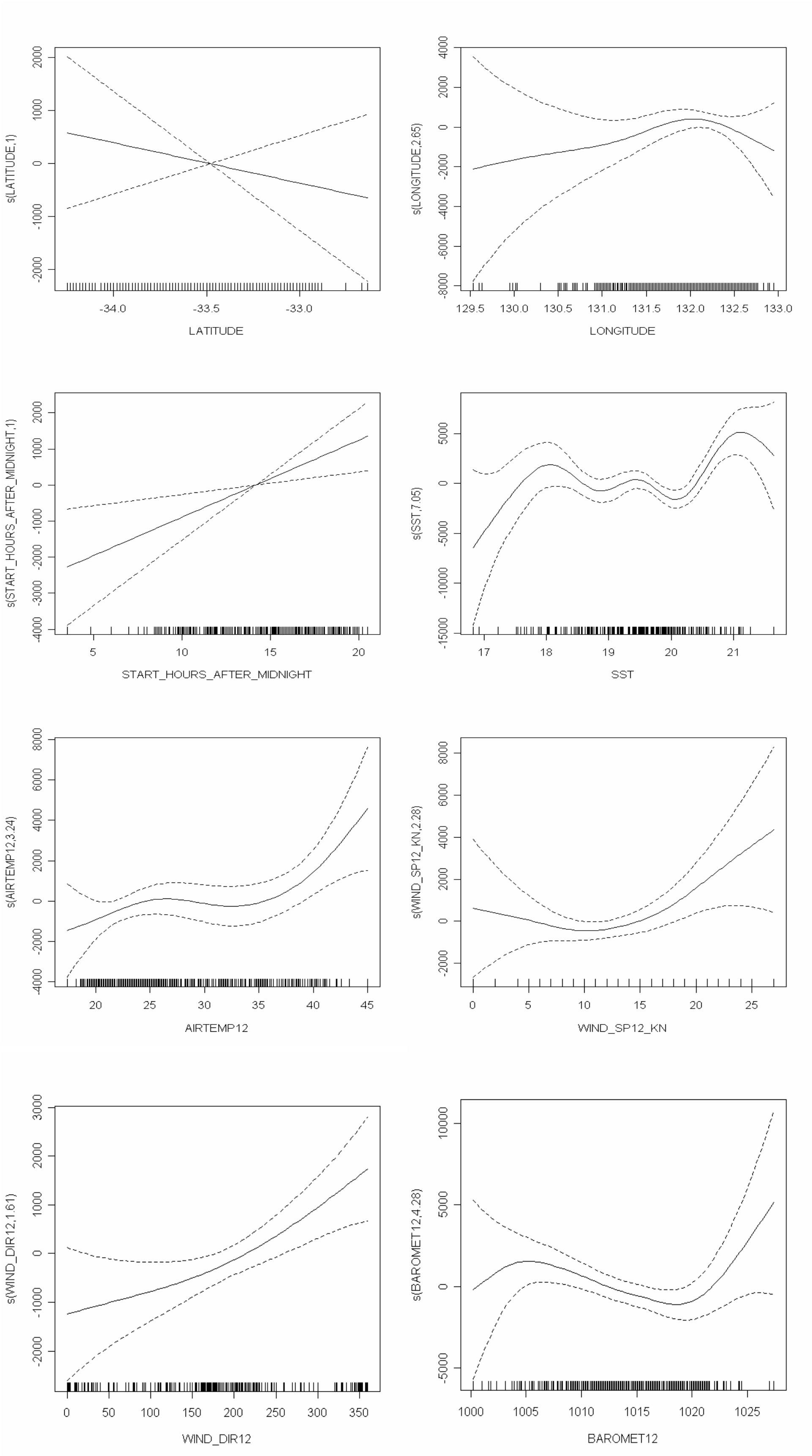

Figure 8. A series of Generalised Additive Models (GAMs) presenting the relationship of variables to surface fishery CPUE with 95% confidence intervals.

The results of the GAMs presented in Figure 8 were visually inspected to determine whether the apparent relationships were valid and warranted inclusion in the CPUE standardisation. The interpretation of the GAMs have been useful in raising number of concerns with the measure of effort (search time) not being applied when the weather is poor and the vessel sits idle. A summary of the interpretation of the GAMs follows:

- Latitude and longitude were excluded as the spatial range of sets was very small;
- Hours after midnight was excluded as the trend is likely to be driven by the hours of night as well as the catch rate of twilight sets. In addition the linear trend is likely to be driven by sets later in the day, likely to be a second or third set, where the vessel has already located schools. l;
- Sea surface temperature was not used in the model as large portion of the sets took place in the central range of sea surface temperature where the trend was largely flat;
- Air temperature was included as the relationship was in line with fishers observations of higher catch rates with high temperatures (associated with high barometric pressure). We separated air temperature into three categories based on the underlying relationship for inclusion in the model;
- The influence of wind speed was included in the model. The GAM showed catch rates increasing with increasing wind speed up to ~25knots, beyond which no effort was allocated. The lack of search time (effort data) at speeds above 25 knots is due to operators stopping to search once winds increase above the threshold where purse seine is not possible. This is very likely to have influenced the relationship. The relationship of wind speed to CPUE is in conflict with the observation that SBT are harder to locate and capture with purse seine in higher winds. This unexpected trend is possibly a result of the SBT taking time to form large surface schools in the morning when winds are low (causing lower catch rates). Once the fish have schooled the wind often increases in the afternoon. By this time the schools have been located causing higher catch rates;
- Wind direction was not incorporated in the model as there was no continuity between 360 degrees and 0 degrees. This is not logical and potentially driven by the small number of sets in the 0 to 100 degree range; and
- Barometric pressure was not incorporated in the model as it was highly confounded with air temperature which was included.

The catch and effort data for the Australian surface fishery is “zero inflated”. This means that the data contain more zeros (*i.e.*search time where no SBT were caught) than might be predicted from standard error models used with GLMs (Ridout *et al*. 1998). If this feature of the data is ignored problems with inference may occur as the assumptions eg. a lognormal error distribution, may not be an adequate approximation to the distribution of the catch data (McCullagh and Nelder 1989).

One solution to analysing this type of data is to use the delta approach (Maunder and Punt 2004) which models the probability of obtaining a non-zero catch and the catch rate for nonzero catches separately. This methodology was used here to model the data in these two steps. Firstly the presence or absence of SBT catch was modelled in terms of the chosen explanatory variables to obtain the probability of a non-zero catch. Then the relationship between catch rate and the explanatory variables, conditional on at least on SBT being caught was modelled. The two models were fitted and predictions were obtained based on a standard set of factors (the most common value of each explanatory variable in each model) for each year for both models. These predictions were multiplied together to obtain an expected catch rate index for each observation for each year. The average index was calculated for each year to give the standardized catch rate for that year.

The presence/absence model was based on a binomial error distribution with a logistic link function. The factors considered in the model were year, month, pole boat, spotter plane, air temperature and wind speed. The factors that were included in the final CPUE standardisation were year, month and spotter plane

The logarithm of the catch rate was modelled using a Gaussian error distribution. The factors considered in the model were year, month, pole boat, air temperature, windspeed and a random effect for vessel. The factors that were included in the final CPUE standardisation were year, month and wind speed.

The uncertainty around the index was calculated using a parametric bootstrap with two levels. For each bootstrap sample, a presence-absence random variable and a catch rate random variable was generated. The two sets of simulated predictions were multiplied together for each bootstrap sample to give the predicted catch rate indices for each observation for each year. The average abundance index was calculated for each year for each of the 500 bootstrap iterations. A 95% confidence interval was then calculated for each year by taking the 0.025% and the 0.975% percentiles from the bootstrap distribution for each year.

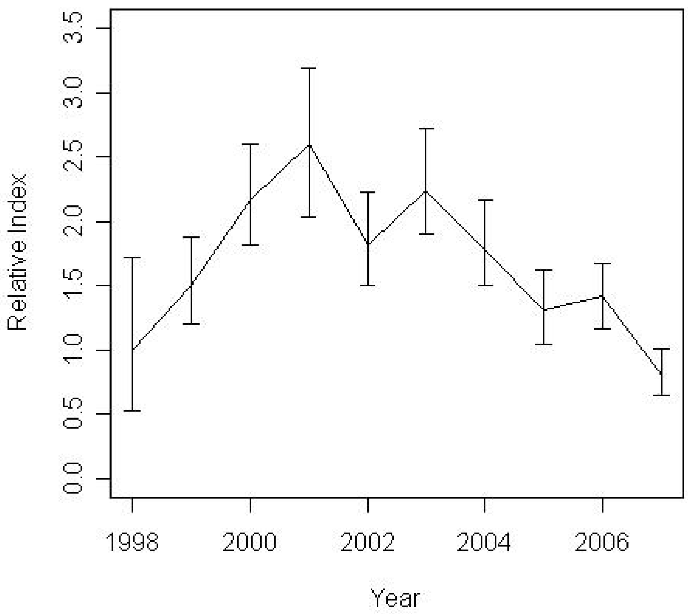

Figure 9 Preliminary standardized CPUE for 1998-2007 from surface fishery logbook data with approximate 95% confidence intervals.

The results of the CPUE standardisation are presented in Figure 9. The standardised CPUE is relative to 1998.

Note that the trend in the standardised CPUE series does not differ significantly from that of the nominal CPUE series, indicating that the nominal series provides a fairly good indication of the trend over the 1998-2007 period.

Catch at Size Data Analysis

In recent years, Australian industry has noted an increase in the number of schools with mixed size classes of fish. To maximise profits from farming, industry prefer schools of similar sized fish. As a result industry has reported sighting many mixed schools that have not been captured due to the reduced profits. Avoiding the capture of mixed schools would result in a depression of CPUE trends.

As information of passed schools is not recorded in logbook data and has only recently been recently recorded by observers, there was no data available to standardize the CPUE data. A visual investigation of size frequency in the Australian surface fishery catches in Figure 10, does indicate a change in the size composition of captures in the Australian surface fishery after 2002-03.

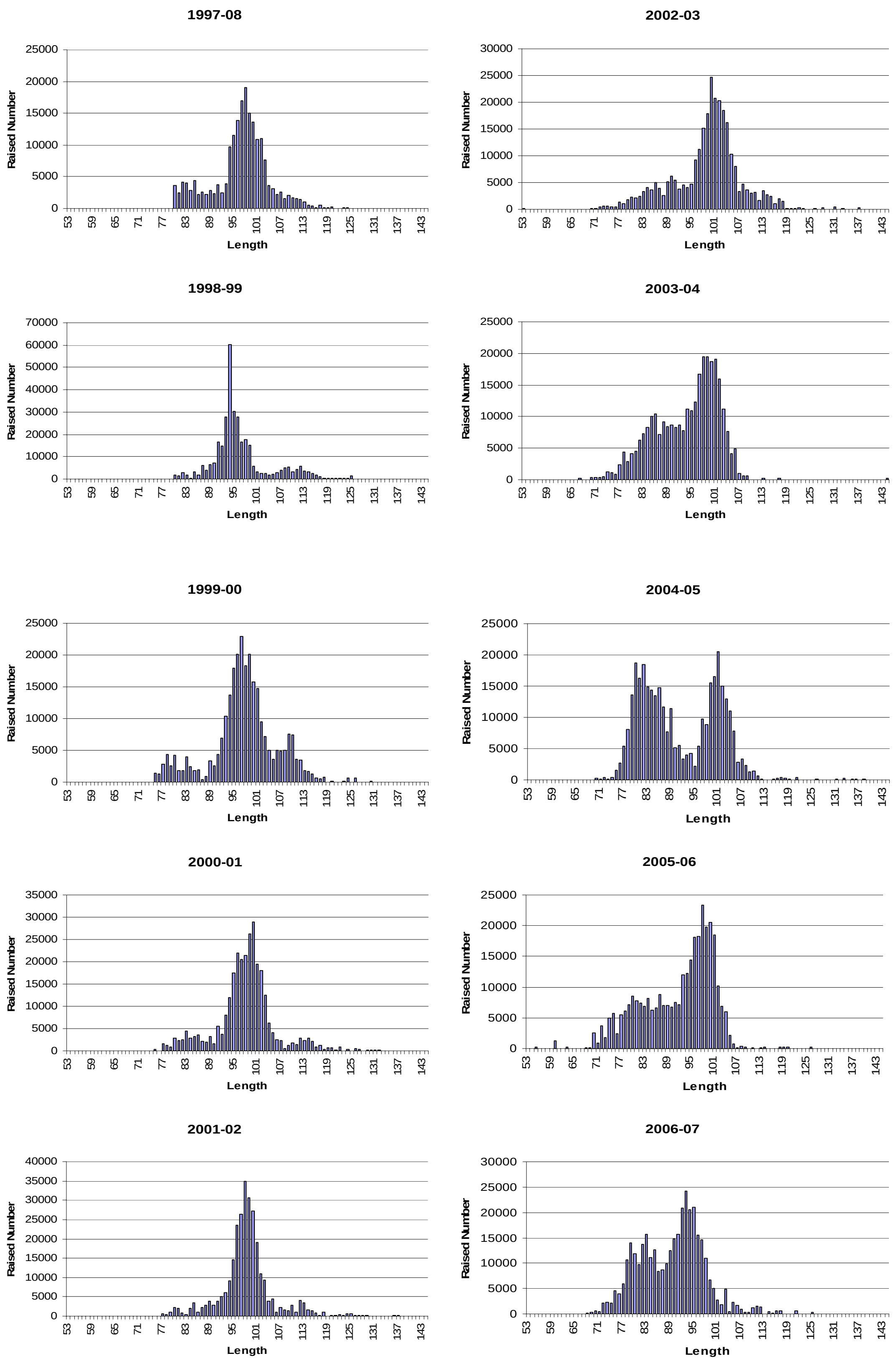

Figure 10. Size frequency distribution of Australian surface fishery between 1997-08 and 2006-07 fishing seasons.

Discussion

The surface fishery effort has proven difficult to quantify. The use of hours searched has proven problematic mostly due to inconsistent data recording. Hours searched does not incorporate times of unfavourable whether where the vessel sits idle. Inclusion of the times of bad weather is likely to assist future attempts to standardise the CPUE series. Any future analysis should compare hours searched with the number of days on the fishing grounds. This time series was not analysed during the preliminary investigation as it currently does not exist and will need to be created. In-depth consultation with vessel masters was not undertaken in this preliminary analysis, such input is vital to gain more insight into the effort data.

The preliminary analysis of factors influencing effort has been relatively successful. Due to the small spatial area of captures the influence of location on CPUE was limited. The influence of month was however seen as important.

The influence of a range of environmental variables on CPUE were analysed with mixed success. The climatic variables of wind speed, direction, barometric pressure and air temperature are all related to the movement of high and low pressure systems across southern Australia. Fishers have reported increased surfacing of SBT during high temperature days, which are also often relatively calm for a period of the day (pers. comm. Findlay, J. 2007.). The analysis of a range of environmental factors, found air temperature and wind speed were significant and as a result were incorporated into the standardisation.

The availability of spotter aircraft was clearly associated with increased CPUE. This is likely a combination of spotter aircraft being unable to fly in periods of high wind, as well as their ability to rapidly locate suitable schools. The influence of chum vessels were not included due to the very small amount of effort applied in the absence of a chum vessel.

Future analysis would need to investigate the influence of tow cage operations on CPUE. A tow cage is the equivalent of a fish hold on a traditional fishing vessel. If a purse seine vessel does not have the capacity to store fish as a tow cage if not in the vicinity, the vessel will not catch schools it sights. There is potential to model the interactions of the purse seine vessels, spotter craft and tow cages in an effort to provide a more suitable estimate of effort in the surface fishery.

The measure of catch in the preliminary analysis is not ideal. The vessel master estimates of catch do not include the number of schools sighted but not captured. Industry has noted an increase in the number of schools with mixed size composition and, as a result an increase in the number of schools sighted but not captured. A visual analysis of the size distribution of the forty fish sample supports a shift in the size distribution of the SBT surface schools. Any change in the selectivity of the surface fishery will influence the CPUE series. In future, it may be possible to quantify the number of passed schools by the addition of a field in the logbook. Alternatively it may be possible to quantify a change in selectivity be comparing the surface fishery captures to the commercial spotting craft school sightings to determine the ratio of schools sighted to schools captured.

The preliminary analysis of the surface fishery CPUE data has provided some useful insights into the surface fishery catch and effort data. While it may be possible to develop a better series of surface fishery CPUE and remove the influence of a range of factors through standardisation, it is still unclear if the trends from the small spatial area of the surface fishery will provide an indication of the underlying stock abundance.

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Appendix 1. Series of figures used to investigate the relationship of catch and effort to other factors.

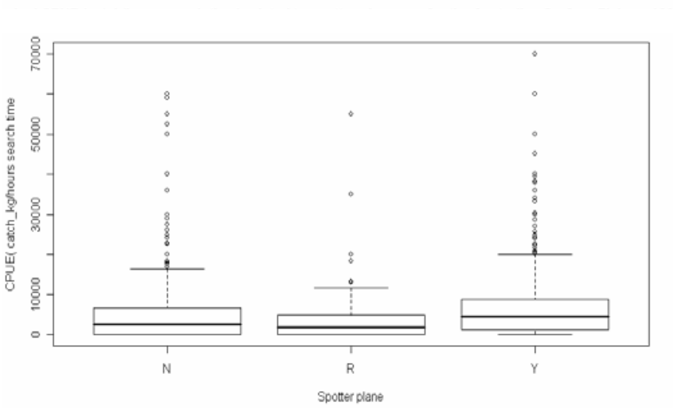

Figure 11. Box plot of CPUE related to the presence (Y), absence (N) or not recorded (R) of a spotter plane between 1998-2007.

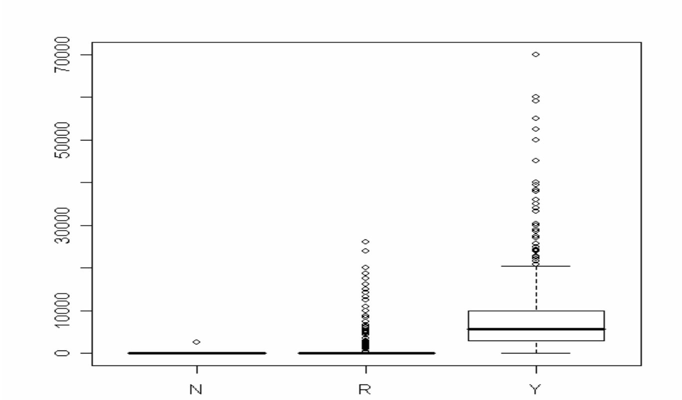

Figure 12. Box plot of CPUE related to the presence (Y), absence (N) or not recorded (R) of a chum vessel between 1998-2007.

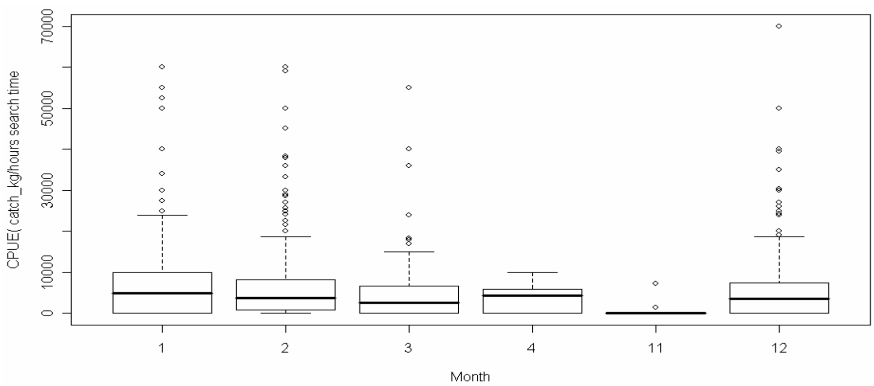

Figure 13. Nominal CPUE (catch/hours seached) in relation to month for the Australian surface fishery from 1998-2007.

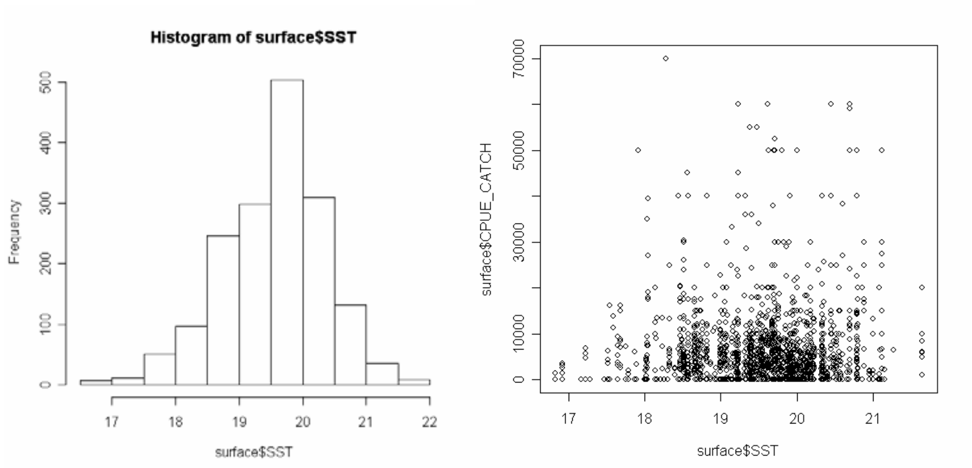

Figure 14. Histogram of the number of operations related to sea surface temperature (left) and a scatter plot of sea surface temperature related to CPUE.

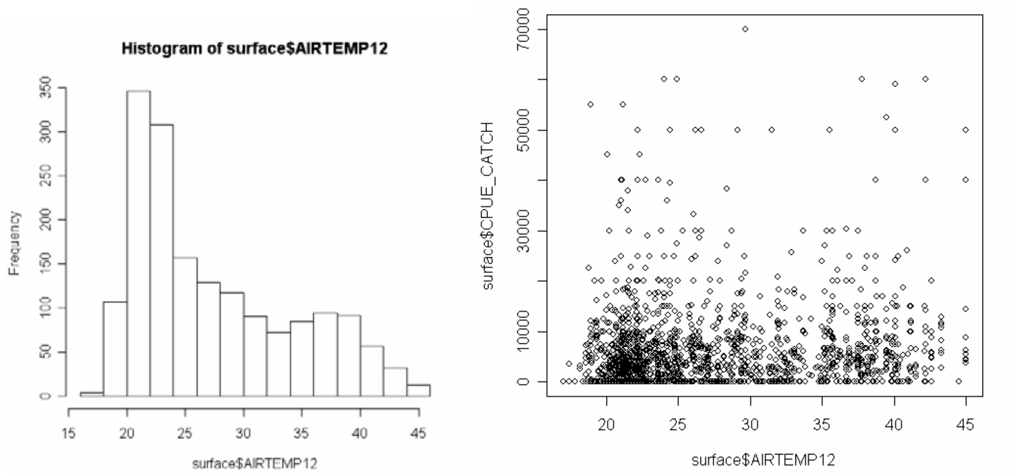

Figure 15. Histogram of the number of operations related to air temperature (left) and a scatter plot of air temperature related to CPUE.

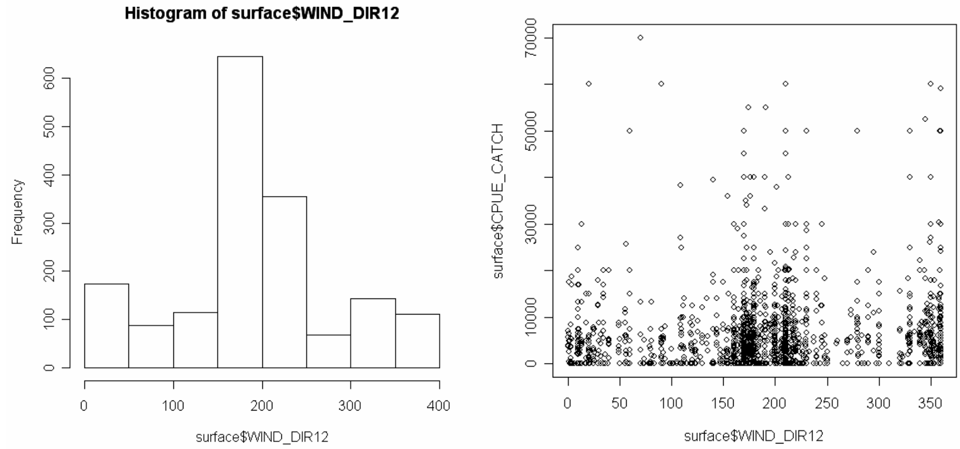

Figure 16. Histogram of the number of operations related to wind direction (left) and a scatter plot of wind direction related to CPUE.

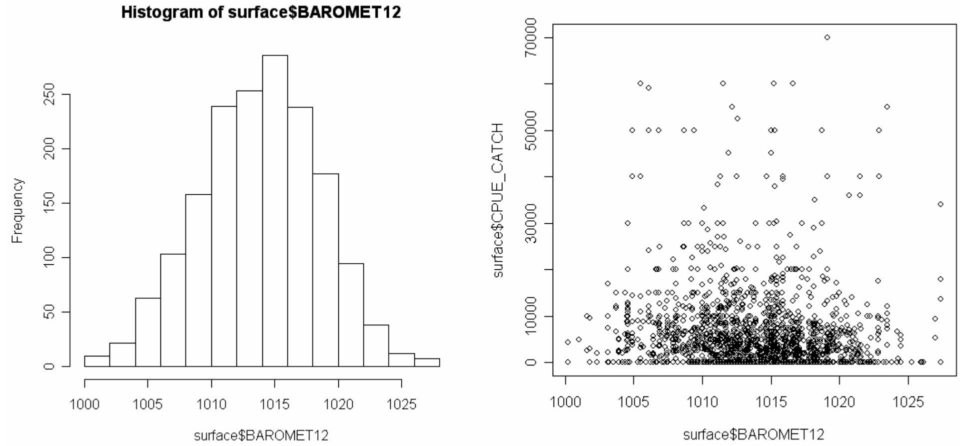

Figure 17. . Histogram of the number of operations related to barometric pressure (left) and a scatter plot of barometric pressure related to CPUE.

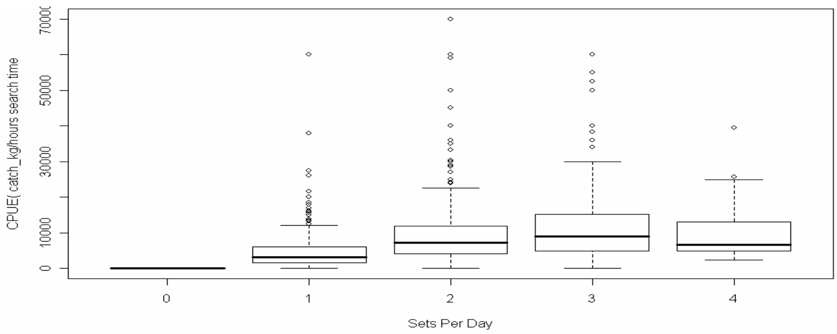

Figure 18. Nominal CPUE (catch/hour search time) related to sets per day for the Asutralian surface fishery 1998-2007.

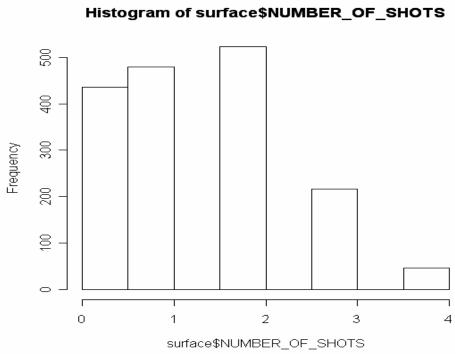

Figure 19. A Frequency histogram of the number of shots per day for vessels in the surface fishery between 1998-2007.

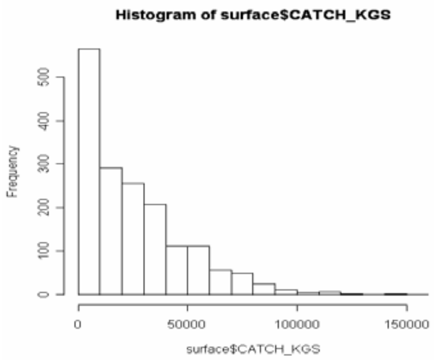

Figure 20. A Frequency histogram of the estimated kilograms of catch per shots per day for vessels in the surface fishery between 1998-2007.

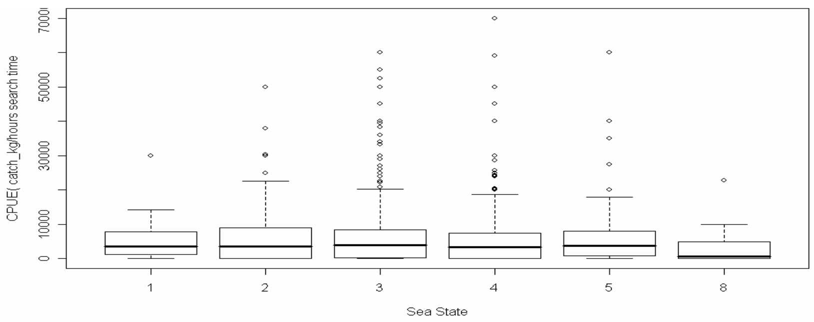

Figure 21. Nominal CPUE (catch/hours seached) in relation to the sea state for the Australian surface fishery from 1998-2007.

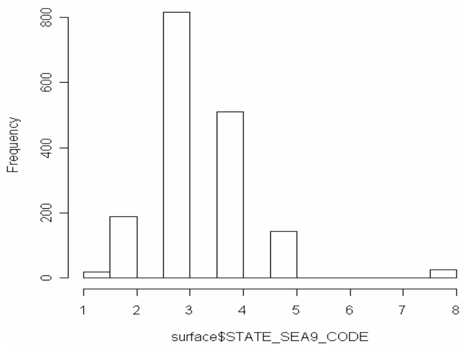

Figure 22. A Frequency histogram of the sea state code for operations of vessels in the surface fishery between 1998-2007.

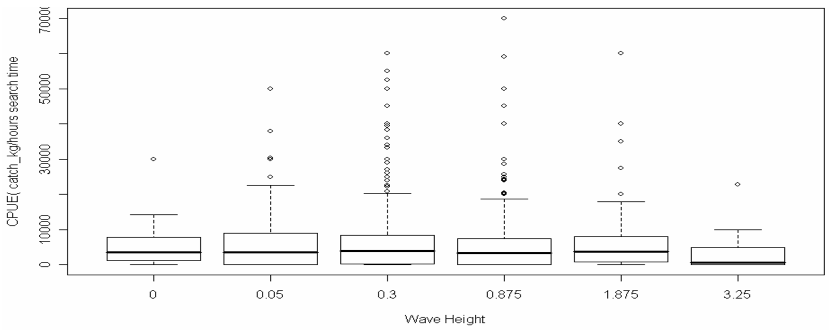

Figure 23. Nominal CPUE (catch/hours seached) in relation to the wave height for the Australian surface fishery from 1998-2007.

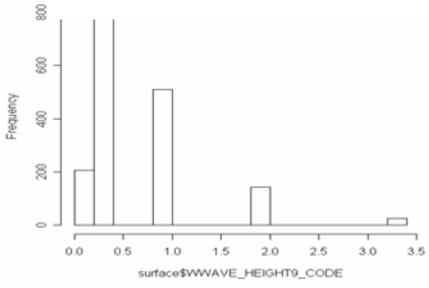

Figure 24. A Frequency histogram of the wave height code for operations of vessels in the surface fishery between 1998-2007.

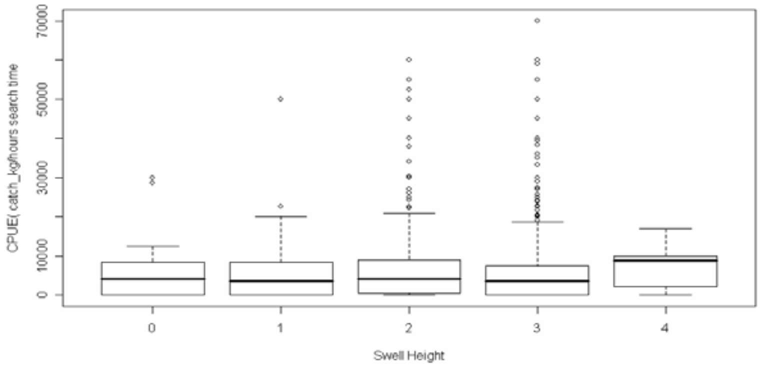

Figure 25. Nominal CPUE (catch/hours seached) in relation to the swell height for the Australian surface fishery from 1998-2007.

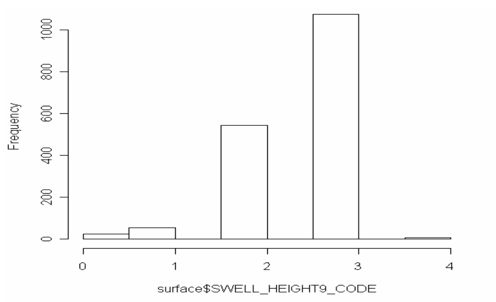

Figure 26. A Frequency histogram of the swell height code for operations of vessels in the surface fishery between 1998-2007.

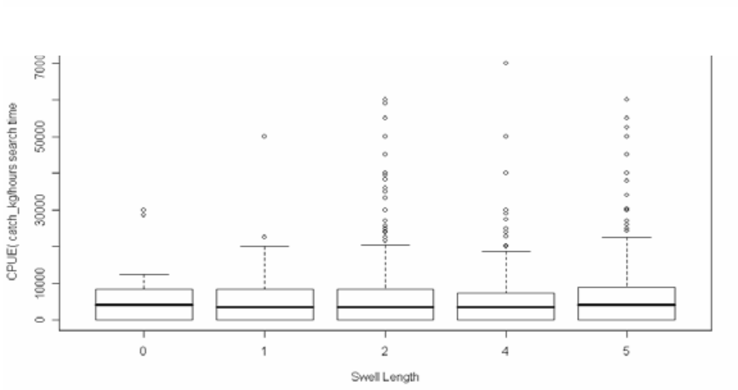

Figure 27. Nominal CPUE (catch/hours seached) in relation to the swell length for the Australian surface fishery from 1998-2007.

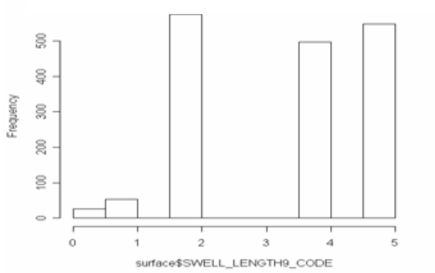

Figure 28. A Frequency histogram of the swell length code for operations of vessels in the surface fishery between 1998-2007.

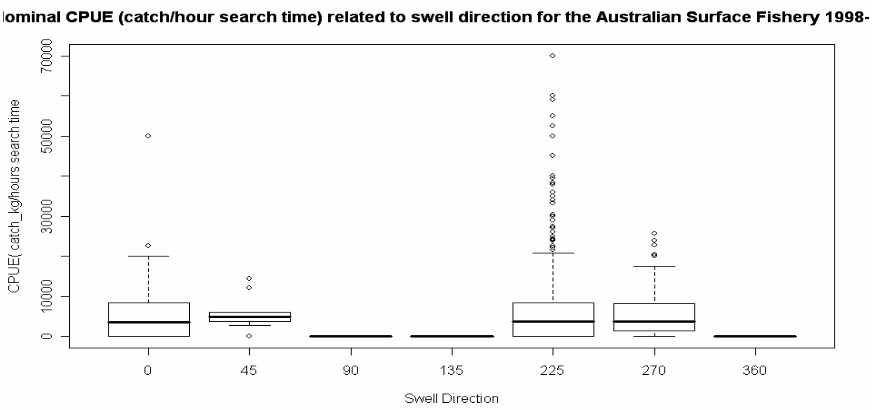

Figure 29. Nominal CPUE (catch/hours seached) in relation to the swell direction for the Australian surface fishery from 1998-2007.

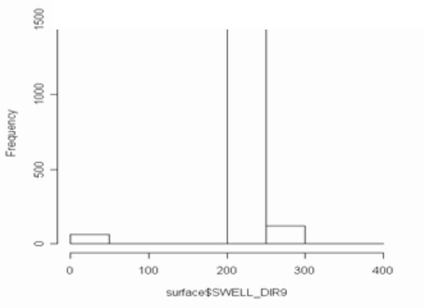

Figure 30. A Frequency histogram of the swell direction for operations of vessels in the surface fishery between 1998-2007.