ISNR: Effect of environment and fishing on Albacore CPUE levels in the southern area of the Cook Islands EEZ

At a regional level, the 2011 stock assessment indicates that south Pacific albacore tuna (*Thunnus alalunga*) is not overfished and overfishing is not occurring. In the Cook Islands EEZ, albacore represents on average over 80% of the total longline tuna catch indicated in logbook returns, while recorded catches have increased rapidly since 2001 (Figure 1). Analyses for the Cook Island EEZ has been divided into northern and southern areas, as the catch rate of albacore shows considerable local patterns, both across the EEZ and within these areas (Figure 2). This report covers the analysis for the southern area (below 15°S).

The aims of this Issue-Specific National Report (ISNR) were to:

- identify factors affecting albacore catch rates within EEZs;
- identify the specific influence of factors that can be controlled by fisheries managers, and variables that are outside their control but can be monitored;
- examine the potential implications for future albacore fishery CPUE levels.

Previous work has identified a number of variables that affect PICT fishery albacore CPUE levels:

- vessel effects: the differing ability of vessels to catch albacore. These effects can be managed;
- regional albacore abundance: this effect can be managed at the regional scale, e.g. through WCPFC CMMs, and monitored through stock assessments;
- oceanographic effects: affecting the availability of albacore to the fishing gear. These influences cannot be directly managed, but some can be monitored.

In addition, on a shorter time scale:

- local depletion effects: the potential short-term impact of fishing on the albacore population at a local level. These effects can be controlled, e.g. through local licensing limits or spatial management measures.

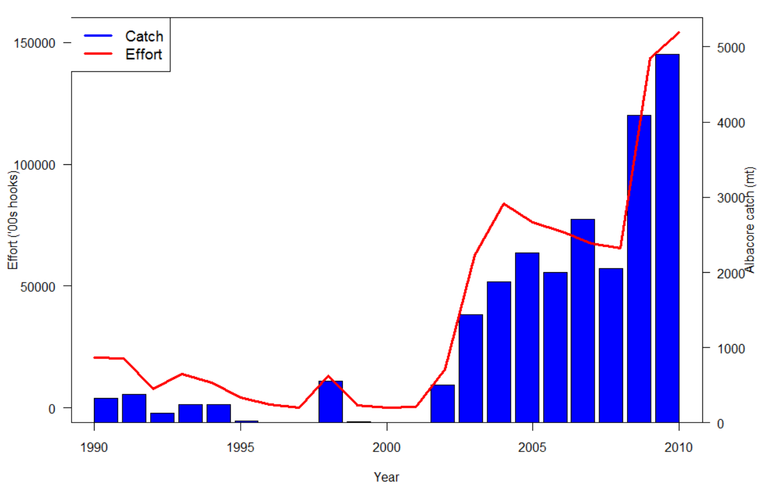

Figure 1. Cook Island EEZ total fishing effort ('00s hooks) and albacore catch (mt) by year since 1990, from logbook data.

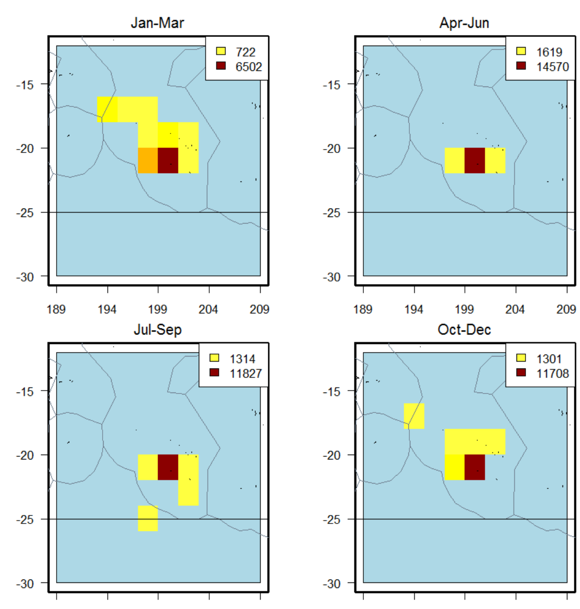

Figure 2. Chart of overall fishing intensity within the southern Cook Islands EEZ area, by quarter of the year (measured in total '00s hooks recorded between 1998 and 2009). Darker squares indicate highest number of records in each quarter (see legend for level).

METHODOLOGY

The effect of a range of factors on albacore CPUE levels was analysed using generalised linear models (GLMs).

Longline logbook catch and effort data available from SPC member countries (including DWFNs fishing in those waters) were collated at a 2° square geographic resolution (e.g. Figure 2). Each vessel-specific record was linked to:

- the corresponding relative albacore regional biomass estimate (see table below); and,
- corresponding oceanographic variables from the GODAS (NCEP Global Ocean Data Assimilation System) database for that 2° square.

Analyses focused on the period 1998 – 2008, due to limitations in the environmental data time series and logbook returns prior to this period. The oceanographic variables selected for modeling were known to influence albacore CPUE in general, and had minimal interaction with each other. These variables are described in the table below. All averages were calculated at the temporal scale of year and month, and unless otherwise stated, by 2° square.

Variable	**Code**	**Description**
Vessel	vessel	Each vessel (name) operating in the fishery
Regional albacore biomass	regB_alb	The relative regional biomass of albacore, based on MULTIFAN-CL assessment sub-areas, from the standardised catch rate of the Korean fleet
Average sea surface temperature (SST)	sstavg	The average SST (°C)
Depth of 20°C isotherm	depth20C	The average depth (m) of the 20°C water layer
Average temperature at 155m depth	temp155avg	The average temperature at 155m depth
Average ocean colour	colavg	The average ocean chlorophyll-a level (in mg/m^3), a measure related to ocean productivity
Range of altimetry	altrange	The range in height of the sea surface relative to a standard sea surface height
Average salinity deviation	salavg	The average annual deviation of surface salinity from 35ppt
Current	current	The average overall current velocity
Easterly component of the current direction	currente	The average overall east/west current velocity. +ive values = easterly flow, -ive values = westerly flow
Southerly component of the current direction	currents	The average overall north/south current velocity. +ive values = northerly flow, -ive values = southerly flow
Southern Oscillation Index	SOI	Regional value, calculated from fluctuations in the air pressure difference between Tahiti and Darwin. +ive values = La Niña conditions, -ive values = El Niño conditions

The modeling approach then compared the outputs of alternative models that incorporated vessel, regional biomass, and:

- all oceanographic variables ("Oceanographic model");
- specific oceanographic variables (SST, depth 20°C) that can easily be monitored or purchased commercially ("Strategic model"); or
- the Southern Oscillation Index ("SOI model").

For each, two model types were implemented. The first examined the likelihood of achieving a catch (thereby taking into account that not all sets are successful, identified as 'presence/absence' in the following results). Given that the set had been successful, the second examined the likely level of albacore CPUE achieved ('positive CPUEs'). Model outputs identified the relationships between variables and albacore fishing success.

These models were implemented for the following PICTs and sub-areas:

New Caledonia, Vanuatu, Fiji, Samoa, American Samoa, Cooks Islands (EEZ separated into north and south areas), and French Polynesia (EEZ separated into northwest and southeast areas).

Results - Influence of different factors on albacore CPUE

For the southern area of the Cook Islands EEZ, 18% of the variation in presence or absence of albacore catches can be explained by the 'vessel' factor (see table of model outputs below), implying that in this area, the ability of different vessels to find albacore was quite comparable. The level of albacore regional biomass has a small but significant influence on the likelihood of finding fish on a longline (over the range of regional biomass levels seen in the data), while the general oceanography also explains some of the variation.

Where fish are found (positive CPUEs only), the variation in catch rates are strongly related to the vessel fishing (47% of the variability explained, i.e. some vessels perform better than others). Regional biomass explains over 2% of the variation in CPUE, while over 8% is explained by oceanography.

Data	Total deviance	% deviance explained by				
		Vessel	Regional biomass	Oceanographic variables	Strategic Variables	SOI
Presence/absence	745.6	18.2	0.9	3.0	3.0	0.0
Positive CPUEs	1856.6	46.6	2.2	8.2	3.1	0.4

While oceanography explains relatively low levels of the variation in albacore CPUE in the southern Cook Islands EEZ, models indicate that the impact is significant. The full oceanographic model examines the potential influence of nine different variables. 38% of their explanatory power is gained through monitoring sea surface temperature and the depth of the 20°C thermocline alone (i.e. the strategic model), while the SOI level alone explains only 5% of that variation attributed to all oceanographic variables.

Compared to other EEZs (Figure 3), vessels explain less of the likelihood of catching albacore (presence/absence) but slightly more of the variation in those CPUEs where a catch was achieved than found in other EEZs, while regional biomass and oceanographic variables explain around the average across EEZs.

- The vessel fishing has a significant effect on catch rates - can be influenced through licensing;
- regional albacore biomass has a significant but low influence on CPUE variability;
- oceanographic influences are significant. Monitorable variables explain small amounts of the variation in CPUE;
- compared to other EEZs, the level of variability explained differs between the variables examined.

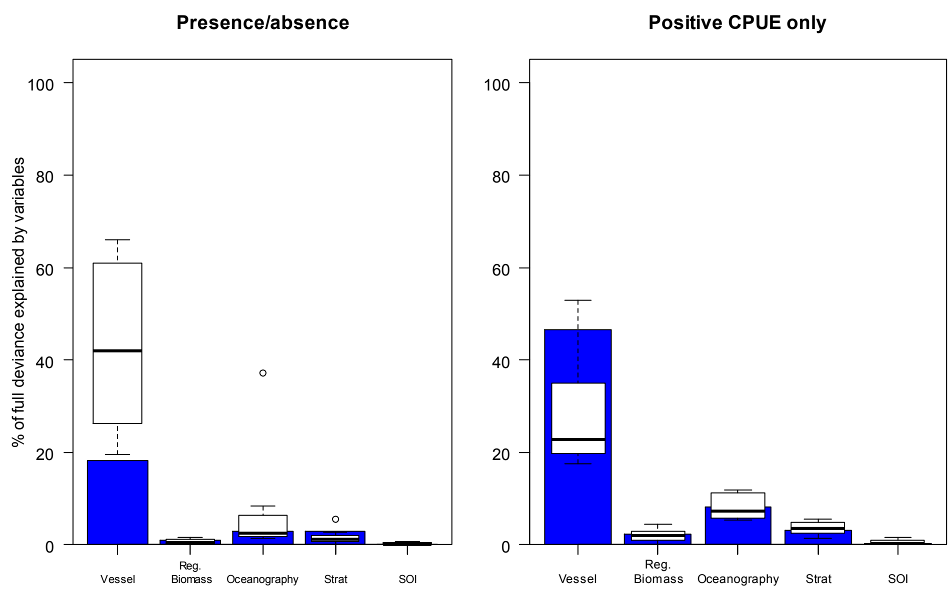

Figure 3. Graphical comparison of the % total model deviance explained by different model components for the southern Cook Islands EEZ (blue bars). Box and whiskers plots show the median and range identified from the models for the other EEZs examined.

Results – Oceanographic and regional biomass effects

The likelihood of a vessel catching albacore was positively influenced by:

- increasing depth of the 20°C thermocline
- increasing regional biomass

and negatively influenced by:

- increasing sea surface temperatures

The 'form' of the effect of each significant variable modelled within the GLMs for positive CPUEs is presented in Figure 4. Where albacore was caught, catch rates were positively influenced by:

- increasing regional albacore biomass
- increases in depth of the 20°C thermocline
- increasing altimetry range, up to a value of 0.05
- increasing ocean colour (above 0.04)
- a northerly flow in current direction
- negative SOI levels (El Niño), although extreme La Niña conditions had a similar effect.

negatively influenced by:

- increasing sea surface temperature
- increases in the temperature at 155m depth, up to around 22°C
- increasing overall current, up to 0.04
- an increasing easterly directional component to the current

and a variable influence was found for:

- increasing with average salinity up to a median level, then decreasing.

The model indicated that of the variables examined, the average salinity, easterly and overall current directions, and depth of the 20°C thermocline, had a relatively notable influence on CPUE levels.

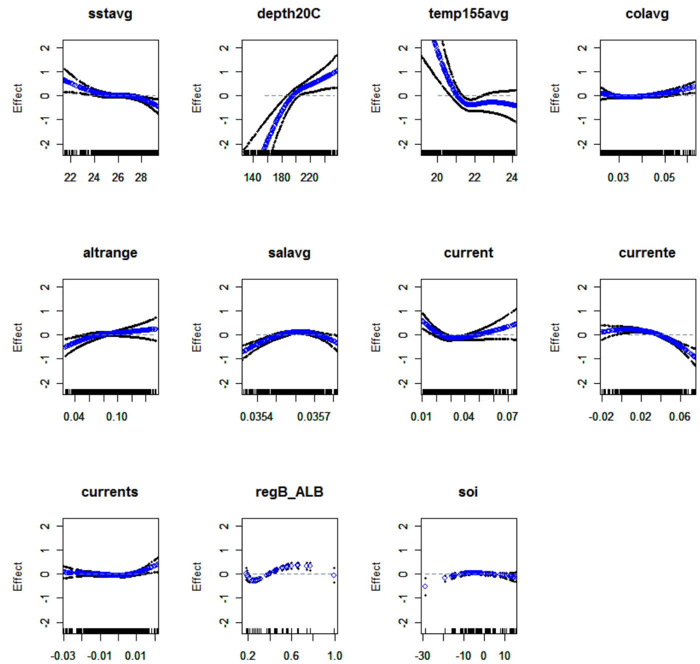

Figure 4. Effect of significant biological and environmental variables on positive albacore CPUE levels only.

Examining those environmental variables that can be more easily be monitored (‘strategic’ and 'SOI' models), the table below indicates what states have a positive (green) and negative (red) effect on albacore CPUEs in this region.

Effect on CPUE	General status of 'strategic' variables
Positive	• neutral SOI conditions • lower SSTs • deeper 20°C thermocline
Negative	• strong El Niño/La Niña conditions • higher SSTs • shallower 20°C thermocline

Implications of model outputs

Outputs of models developed for EEZs across the south Pacific region allow us to examine the pattern in the impact of monitorable environmental variables on albacore catch rates at a regional scale. Figure 5 shows the influence of SOI state on catch rates by EEZ or EEZ area. In western EEZs, an El Niño state has a positive influence on albacore catch rates (shown by the green colour). In eastern EEZs, a La Niña state has a positive influence on catch rates. For the southern Cook Island EEZ, mild El Niño through neutral conditions positively influence catch rates, while strong El Niño and La Niña conditions have a negative effect. This pattern is consistent with the geographic pattern across the region, perhaps due to its more southerly location, in contrast to that seen for the northern area of the Cook Islands EEZ. It should be noted that the extremes of the SOI range have fewer data points to underpin the modelling process, and hence SOI impacts are more uncertain at these levels.

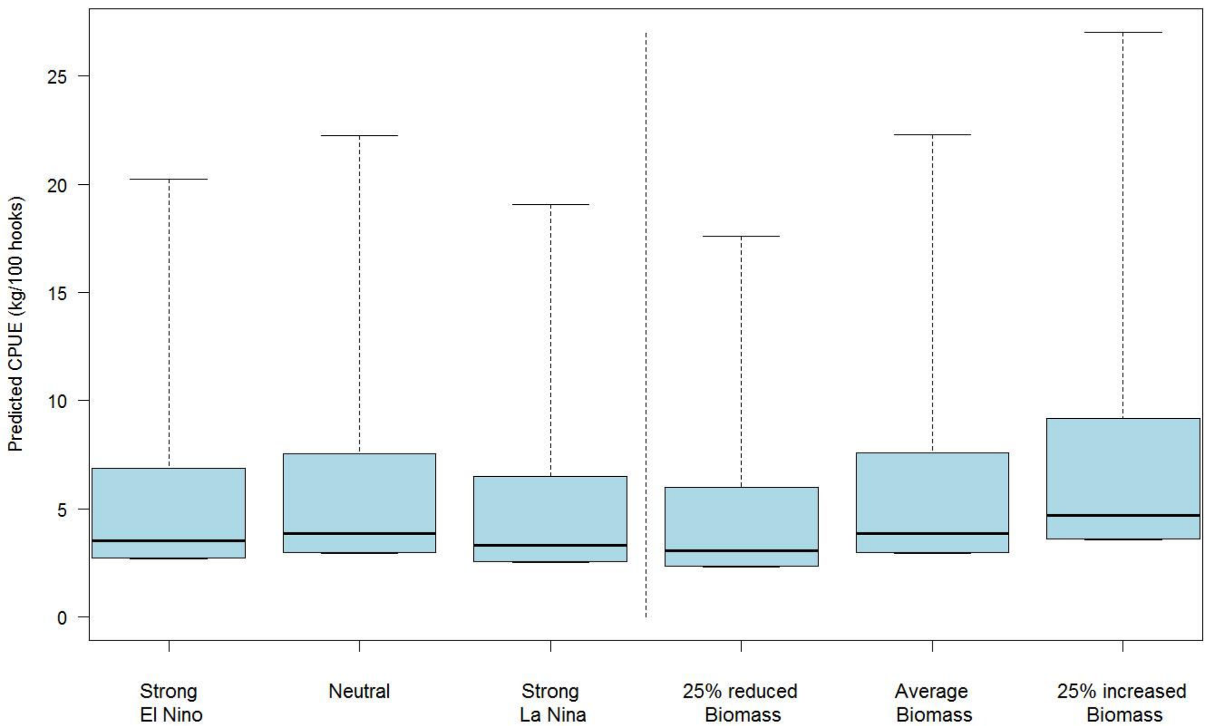

Figure 5. General predicted effect of SOI state on albacore CPUE levels, by EEZ/EEZ area.

- The impact of El Niño/La Niña on albacore CPUE levels within the region shows trends from west to east.
- El Niño has a positive influence in the west, and negative in the east, with La Niña showing the opposite effect.
- In the centre of the region, the impact is variable.
- For the southern Cook Islands EEZ, strong El Niño and La Niña conditions have negative influences on CPUE levels; the 2011, strong La Niña should therefore reduce albacore catch rates in the southern area.
- Neutral to mild El Niño conditions have a positive influence on albacore catch rates.

Depletion analysis

The potential impact of localised effort on catch rate was examined. The difference in albacore catch rate between successive 10-day periods was calculated, and related to the catch taken and effort applied in the previous 10-day period, using statistical models.

Figure 6 (top) indicates that high catch levels in one 10 day period within the southern Cook Islands EEZ relate to lower catch rates in the following 10 day period. At relatively low catch levels (>20 mt) a decrease in subsequent catch rates of about 5% are seen. Such catch events are rare in the less productive southern Cook Islands EEZ area, as shown by the few points at this level in the graph. This was confirmed by the model, which predicted high catches in a 10 day period leading to another relatively high (but reduced) catch rate in the next period, perhaps reflecting relative high stock abundance in the region. High effort levels in the first 10 day period were significantly related to lower catch rates in the following 10 day period, although as seen from Figure 6, the % decrease in catch rates was generally lower than that accompanying high catch levels.

- minor local (short term) depletion effects have been seen in the southern Cook Islands EEZ;
- very high catch levels may result in up to a 5% decline;
- the impact of high effort, while significant, is small;
- these effects can be managed.

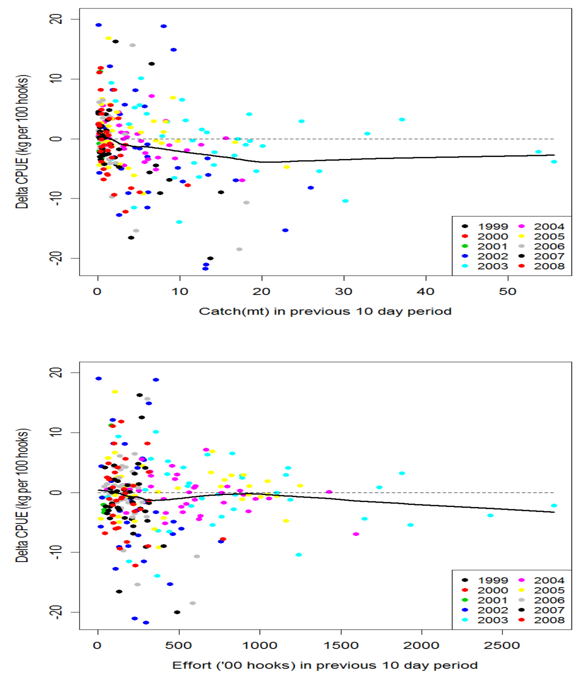

Figure 6. Change in overall albacore CPUE in the southern Cook Islands EEZ between two 10-day periods, relative to the total catch level (mt, top) and effort ('00 hooks, bottom) in the first 10-day period.

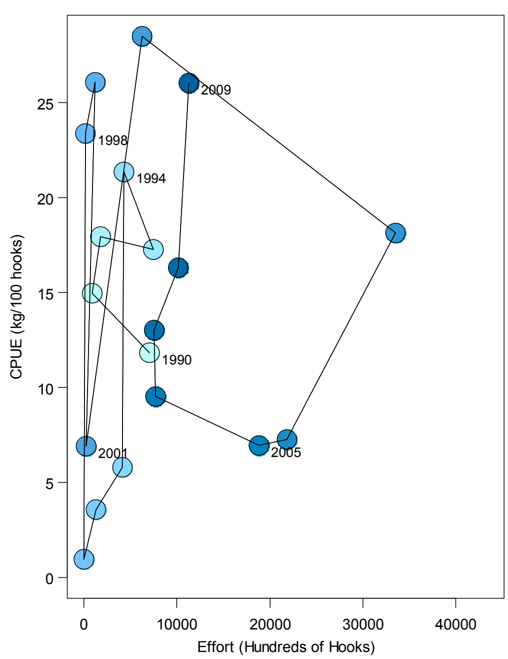

Figure 7. Overall annual albacore CPUE in the southern Cook Islands EEZ, relative to the total effort ('00 hooks) in each year (raw data from logbooks, not standardised).

Longer-term effects of effort on catch rates

While high fishing effort may influence catch rates in the short term, longer-term effort levels may have longer-lasting implications for catch rates, and hence fishery profitability. Figure 7 shows the pattern in un-standardised annual effort and CPUE for the period of logsheet data available from the southern Cook Islands fishery.

Effort levels have fluctuated over time, with high variability in the resulting catch rate. The highest un-standardised effort level seen (2003) resulted in average overall CPUE levels. Compared to effort levels in the northern Cook Islands EEZ, effort in the south is low and the resulting CPUEs comparable (up to 25-30 kg/100 hooks at those effort levels).

- There is insufficient time period and range of effort and catch rate data to identify patterns in effort and CPUE;
- Further increases in effort should continue to be monitored.

Projecting the potential implications of future conditions

The models developed allowed the potential impact of alternative states of regional albacore biomass and the Southern Oscillation Index on future catch levels to be examined.

These scenarios were developed based upon the 'median' vessel within the fleet (reflecting 'average' vessel performance), the median SOI/regional albacore biomass (dependent upon the scenario), and a set value for the other of those two variables. Confidence intervals around these predictions were developed by randomly selecting 100 individual vessels from those operating within the fishery in the last five years, weighted by the number of sets they had performed during that period (i.e. those vessels that set more longlines in the last five years would have a greater chance of being selected), and predicting the resulting CPUE level.

For the southern Cook Islands area, slightly higher catch rates are predicted where neutral SOI conditions occur (Figure 8). Increasing average regional albacore biomass leads to a consistent increase in the albacore CPUE in the southern Cook Islands area. In both cases, there is considerable variability in the future CPUE dependent upon the vessel fishing (shown by the 5th and 95th percentiles), such that differences in the median catch rates seen are likely to be masked by that vessel-specific variability. The vessel variability examined also indicates that relatively high CPUE events may occur (note the skewed nature of the median versus upper 95th quartile values). On average, however, catch rates are predicted to be low, consistent with the fact that few vessels choose to operate in the southern Cook Island EEZ area.

- average catch rates of albacore are low in this region;
- increased regional albacore biomass has a significant and positive effect on CPUE levels, and can be managed. Increased biomass levels may offset the impacts of oceanographic change;
- the effect of SOI is variable. This is monitorable but not controllable;
- different vessels achieve very different CPUE levels, which are likely to mask overall trends.

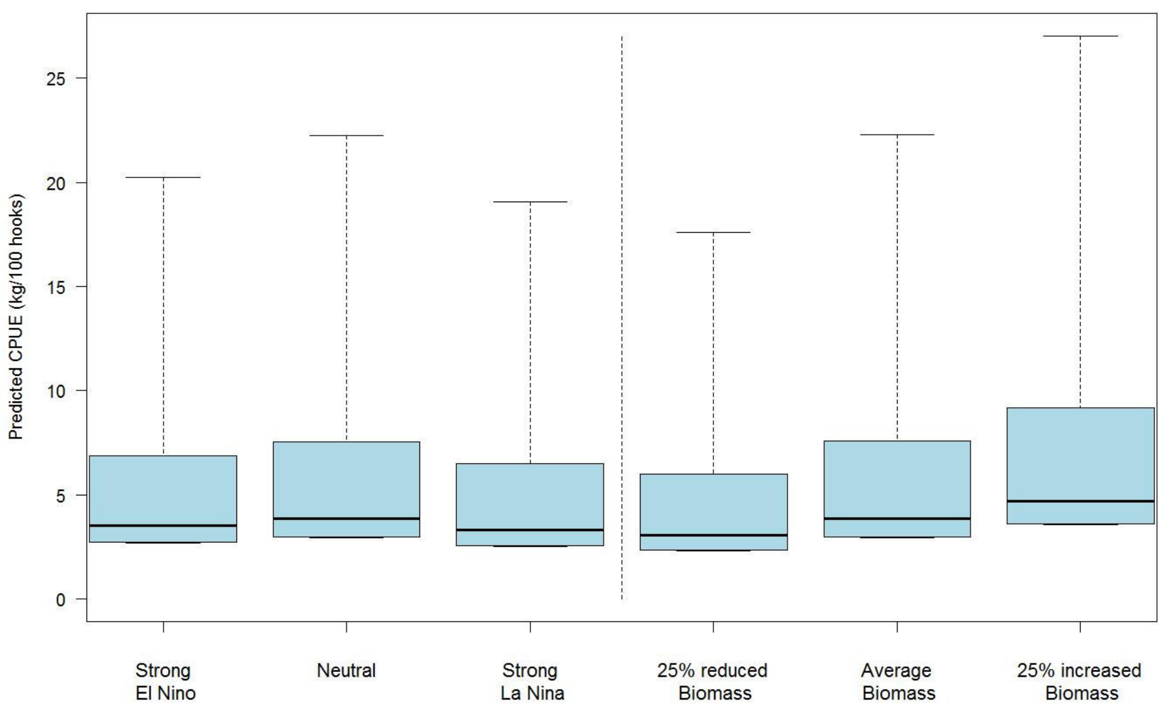

Figure 8. Predicted average and range of albacore CPUE (kg/100 hooks) under different SOI and regional albacore biomass states (positive catches only). Box represents 25th and 75th quartiles, horizontal line represents the median CPUE, extremes represent the 5th and 95th quartiles.

CONCLUSIONS

This ISNR examined the effect of environment, stock abundance and fishing practices on albacore CPUE levels in the southern area of the Cook Islands EEZ. It identifies the influence of those factors that can be controlled by fisheries managers, and those variables that can be monitored but not influenced by them.

- All factors examined affect catch rates to some extent:
  - Some of the variability in finding albacore, and much of that in the level of subsequent catch, was explained by the vessel doing the fishing. This can be influenced through licensing.
  - Increased regional albacore biomass had a positive and significant effect on CPUE levels. This is controllable through regional management measures.
  - Oceanographic factors had variable influences on albacore CPUE levels. Of those that can be easily monitored by managers, lower sea surface temperatures, deeper 20°C thermoclines and neutral SOI conditions positively influenced albacore CPUE levels.
  - the regional impact of the southern oscillation index (SOI) varied between EEZs. In the west, El Niño conditions positively influenced albacore CPUE levels, while La Niña positively influenced CPUE levels in the eastern EEZs. The influence of SOI on Cook Islands albacore catch rates is consistent with this regional pattern.
- Evidence of local depletion, resulting from high effort levels in the EEZ, were identified.
  - High catches were likely to result in lower (but still relatively high) catches in subsequent periods, with decreases of up to 5% in catch rates.
  - High effort levels were also likely to reduce catches in subsequent periods, to a lesser degree.
- Longer-term effects of effort on catch rates were seen in unstandardised logsheet data. Effort levels fluctuated over time, with high variability in resulting catch rates. The highest effort level seen (2003) resulted in average overall CPUE levels. There were insufficient data to show whether increases in effort above 2003 levels (the historical high) would lead to declines in overall CPUE levels.
- The potential implications of future environmental and biological conditions were examined.
  - average catch rates predicted for an 'average' vessel varied around 5kg/100 hooks, a comparatively low catch rate.
  - increased regional albacore biomass levels has a significant positive influence on CPUE.
  - the impact of SOI was, as already noted, variable but significant, with neutral SOI conditions resulting in slightly higher CPUE levels.
  - variability in CPUE due to the vessel fishing was high; this variability in catch rates could result in over 20kg/100 hooks being achieved under higher than average regional biomass levels. The variability may mask the influence of other factors in the southern Cook Islands EEZ region.

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