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Progress with in-season modelling of squid within New Zealand's EEZ and Management strategy evolution (MSE)

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Progress with in-season modelling of squid within New Zealand's EEZ and Management Strategy Evaluation (MSE)

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1. Introduction

Modelling population size in fish typically relies on a mathematical model that keeps track of the number of fish in each age class across years. As fish grow older in the model, they move from one age class to the next, subject to assumed or estimated patterns of growth and mortality. For a typical, relatively long-lived fish with low natural mortality, there will be many age classes in the water and the population size will tend to change relatively slowly, with incoming recruitment providing only a small increment to the stock size in most years. Management of these types of fish stocks tend to be informed by assessments and population modelling approaches that are carried out on an annual basis.

Squid have a very different life-cycle that does not fit with standard fish population modelling approaches. Most squid live for around one year, spawn and then die. The result of this is an entirely new stock each year, the size of which tends to be driven by environmental factors. With a more-or-less annual life-cycle and lack of a stock that spans more than one year, squid fisheries require a different management approach to most fish species, which are longer lived. Essentially, the setting of a fixed annual or multiyear total allowable catch (TAC) is inappropriate for squid fisheries as this will fail to protect the stock in years of low recruitment and will also lead to under-exploitation in years with very large recruitments. Using a stock assessment for an annual species to provide advice for management implies the development of a different management paradigm.

There are approaches to management that can provide for sustainable exploitation. These include, a very precautionary fixed TAC, a TAC that is updated within the season based on some assessment of the stock early in the season (typically a pre-recruit or new recruit vessel-based survey), or updated by an in-season stock assessment. Approaches that do not apply a strict TAC approach are also possible, where relative or absolute levels of escapement of spawning squid are set based on survey or assessment results.

Within season stock assessments require a different, more flexible and focussed approach to data collection from the fishery through to data preparation for the assessment. Strictly, the population is largest when it exists as eggs, and the earliest estimation of population size can be made on recruits using either a recruit survey or back-calculating from the fishery driven depletion. The fishery data (catch, effort, location) and observer data (mean length by date and location, weight at length) require near-real time processing to support a within season assessment to provide timely advice to managers. It is this approach that we are investigating for the New Zealand Snares and Auckland Islands squid fisheries.

Assessing squid stocks in-season is possible and has been done for a small number of fisheries. Hurst et al. (2012) carried out a detailed characterisation of SQU6T (Auckland Islands) and SQU1T (Snares Islands) fisheries and a preliminary evaluation of potential in-season management approaches. McGregor (2013) and McGregor & Tingley (*in press*) further developed these analyses and the depletion method as described in Roa-Ureta (2012), in particular applying a preliminary model to 2008 Aucland Islands data . We apply and further refine this approach in each fishery (the Snares and Auckland Islands) and each fishing year (1991-2014).

2. Methods: Depletion model

2.1. Determine standardised catch in numbers

The depletion model requires an abundance index and a catch history, both in numbers. We used TCEPR data supplied by the New Zealand Ministry for Primary Industries for the Hurst et. al. (2012) study (1990 to 2008 fishing seasons), updated to the end of the 2014 fishing season, along with length-frequency data from the New Zealand Government Observer Programme.

We applied a minimal automatic grooming algorithm using the methods of Hurst et al (2012). This identified and either deleted or corrected gross errors in locations (latitudes and longitudes), and the catch and effort values using range checking and imputed these from the values of nearby records.

We obtained catch in tonnes per tow duration (CPUE_t) by fitting a standardised CPUE to a data subset, selected to sufficiently capture the trends in abundance of the fished population as it responds to fishing. We used this to produced a time-series of standardised catch-in-numbers per tow (CPUE_n) using length-frequency data (from the Observer Programme) and length-weight conversion parameters.

2.2. Estimate timings of possible recruitment pulses

We located all local maxima of a smoothed line fitted to the CPUE_n. Those maxima that are sufficiently spaced and sufficiently higher than the previous local minima were offered to the depletion model as potential timings of recruitment pulses. Recruitment, in this case, means new fish added to the fished population, i.e., a recruitment pulse may represent something other than juveniles, e.g. migration.

2.3. Fitting the depletion model

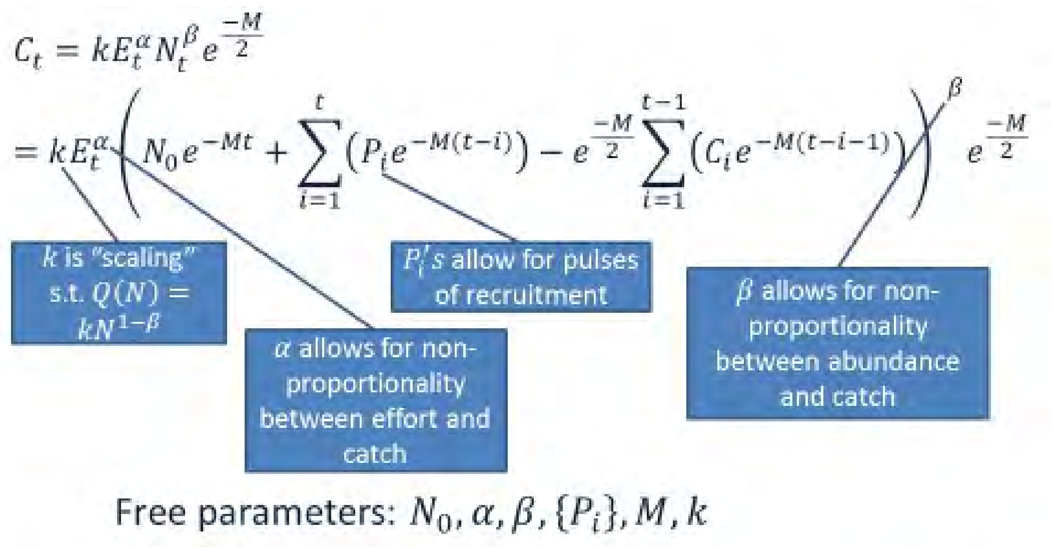
For each of the two stocks and for each fishing year, the model was run for each week, with the depletion at the end of each week calculated as,

$$depletion_w = 1 - \frac{population|fishing}{population|nofishing} \tag{1}$$

The depletion is not a prediction of the final depletion for the season, but an estimation of what the depletion was at the conclusion of each week of fishing.

The depletion model fitted was based on that used in the Falkland Islands (Roa-Ureta, 2012) and allows for pulses of recruitment (cohorts) to enter the population. The timing of recruitment of each cohort was estimated prior to fitting the depletion model. The depletion model (represented by Equation 2) estimated the number of squid in each cohort.

The model can incorporate the relaxation of the assumption that response of catch to effort and abundance is directly proportional, through the hyper-parameters and in Equation 2. These parameters allow for hyperstability and hyperdepletion.



$$C_t = kE_t^{\alpha} N_t^{\beta} e^{\frac{-M}{2}}$$

$$= kE_t^{\alpha} \left(N_0 e^{-Mt} + \sum_{i=1}^{t} \left(P_i e^{-M(t-i)} \right) - e^{\frac{-M}{2}} \sum_{i=1}^{t-1} \left(C_i e^{-M(t-i-1)} \right) \right)^{\beta} e^{\frac{-M}{2}}$$

Free parameters: $N_0, \alpha, \beta, \{P_i\}, M, k$

Figure 1: The depletion model, Equation 2.

Table 1: List of symbols used in Equation 2

Description	Symbol
Expected catch (millions of animals)	C
Effort (number of tows)	E
Abundance (millions of animals)	N
Time-step (days)	t
Scaling (1/number of tows)	k
Abundance response (days)	α
Effort response	β
Natural mortality (1/day)	M
Initial abundance (millions of animals)	N_0
Perturbation index	i
Abundance perturbations (cohorts) (millions of animals)	$\{P_i\}$

3. Results

3.1. Data grooming

We compared our minimal grooming process to the full grooming applied in Hurst et al (2012). The catch and effort (number of tows) from tows that targeted squid remained very similar (Figure 2). We carried out a CPUE for the minimally groomed datasets. These were sufficiently similar to those fitted to the fully groomed datasets to support the use of the minimal grooming process for in-season modelling, for example CPUE for Auckland Islands for fishing year 2008 (Figure 3).

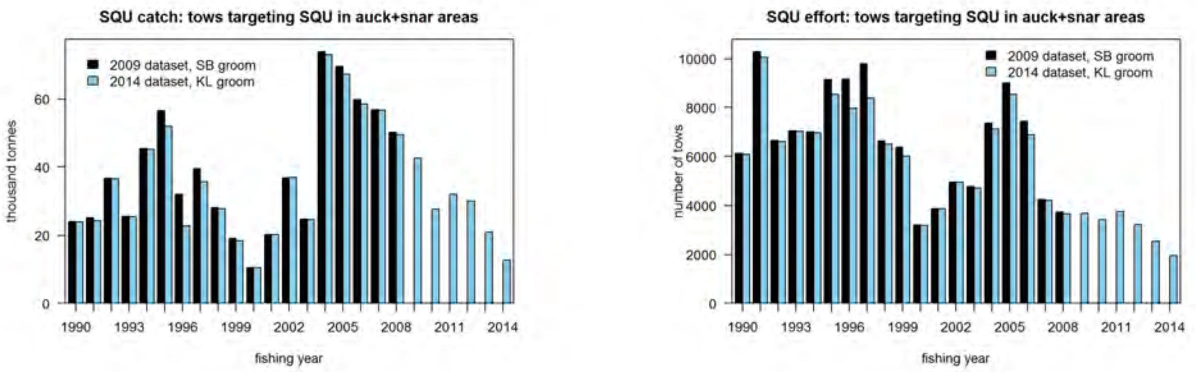


Figure 2: Catch in tonnes (left) and number of tows (right) that targeted squid for each fishing year 1990-2008 for the fully groomed dataset from Hurst et al. (2012) (black bars) and the dataset following the minimal grooming algorithm for fishing years 1990-2014 (blue bars).

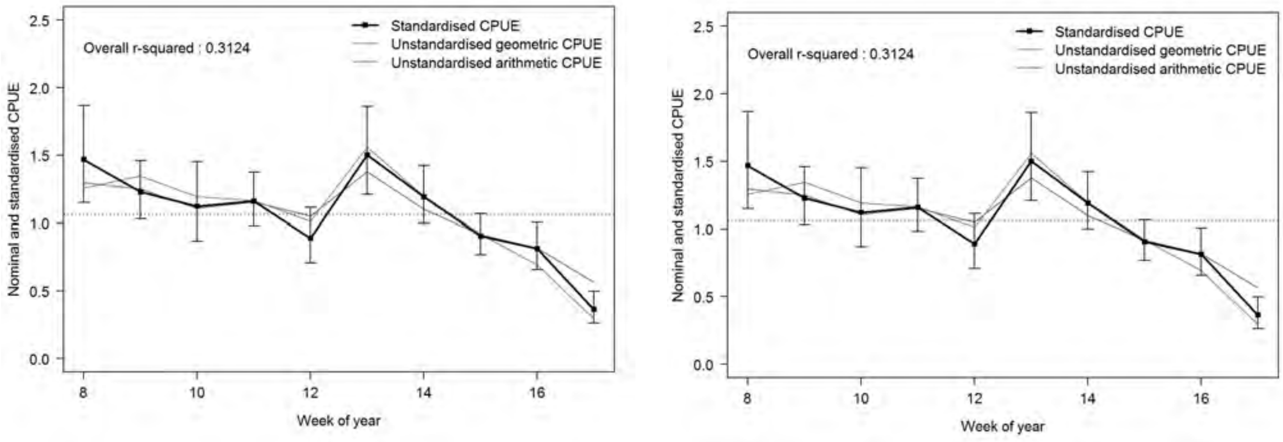


Figure 3: CPUE for the Auckland Islands, fishing year 2008 for the fully groomed dataset (left) and the minimally groomed dataset (right).

3.2. Fitting CPUE

Catch and effort data from tows that target squid were selected, and excluded little data from the weeks where most of the catch was taken. From this subset of the data, core vessels were then selected using the criteria of at least four tows recorded in each of at least four weeks.

CPUE$_t$ ($tonnes.hour^{-1}$) was fitted for each fishery and fishing year. The variables offered and selected for each of the models are in Figure 4. An example of the CPUE with identified recruitment pulses in 2009 is shown in Figure 5.

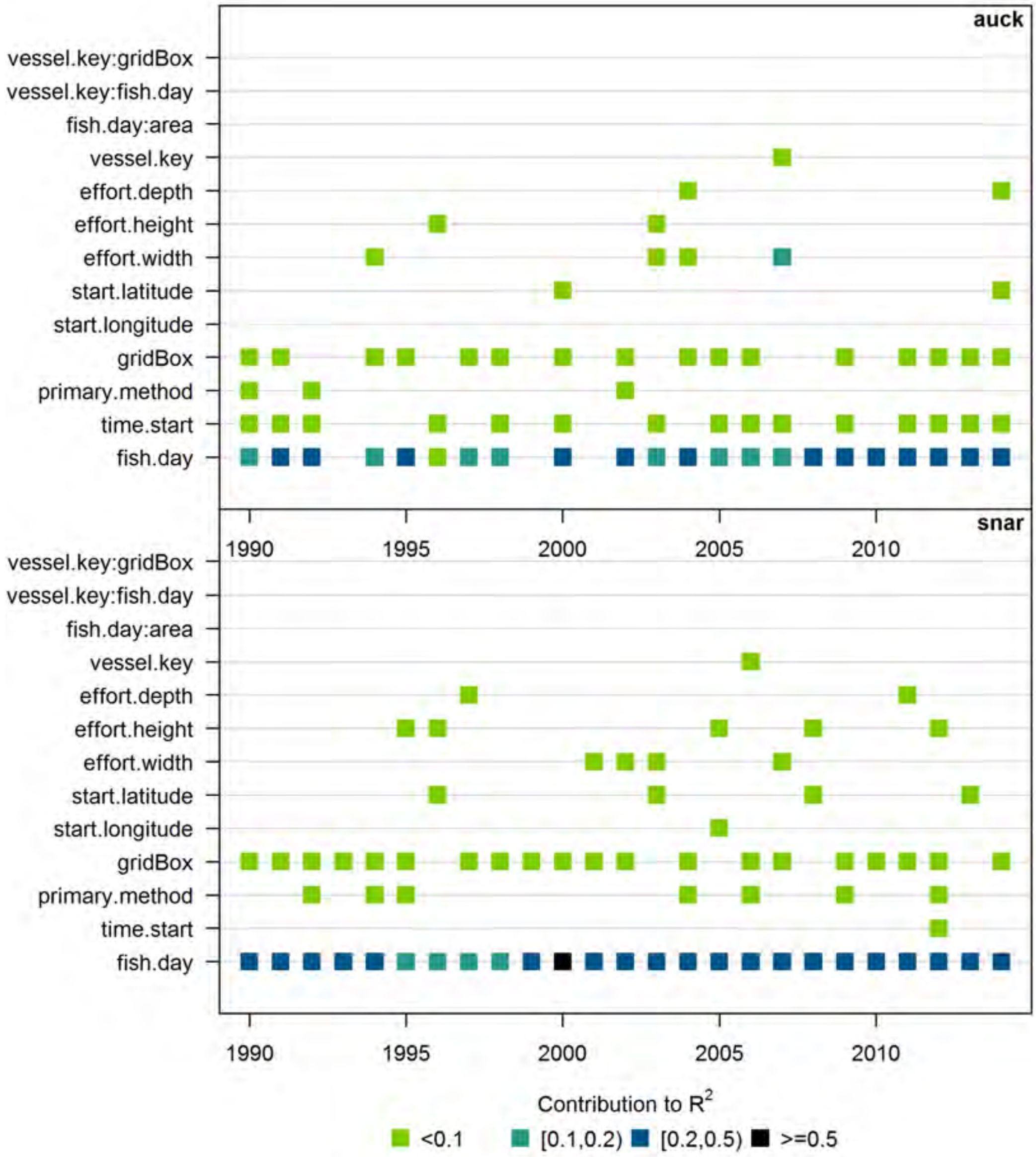


Figure 4: CPUE variables offered (y-axis) and selected (coloured squares) for Auckland Islands (top) and the Snares (bottom). A CPUE was fitted for each fishing year (x-axis) for each fishery.

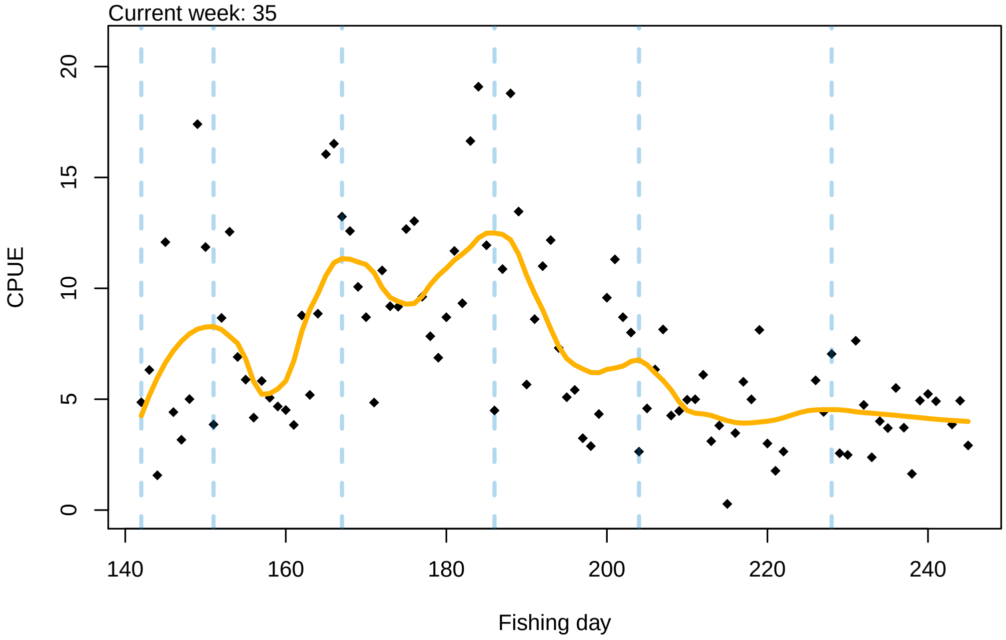


Figure 5: CPUE fitted for the Auckland Islands 2009 catch and effort data (black dots), with a smoother (yellow line) and located potential recruitment pulse timings (blue vertical dashed lines).

3.3. Fitting the depletion model

Modelling depletion was successful (model was able to fit to the data) for different weeks in different years for the two areas, and tended to be successful in later weeks (Figure 6). For example, the 2009 Auckland Islands fishery, the relative abundance and depletion rates by fishing day are plotted for depletion model runs with data up to fishing weeks 24, 26, 30 and 38 (Figure 7). These figures illustrate the potential usefulness of the model in indicating abundance levels in real-time as the fishing season progresses.

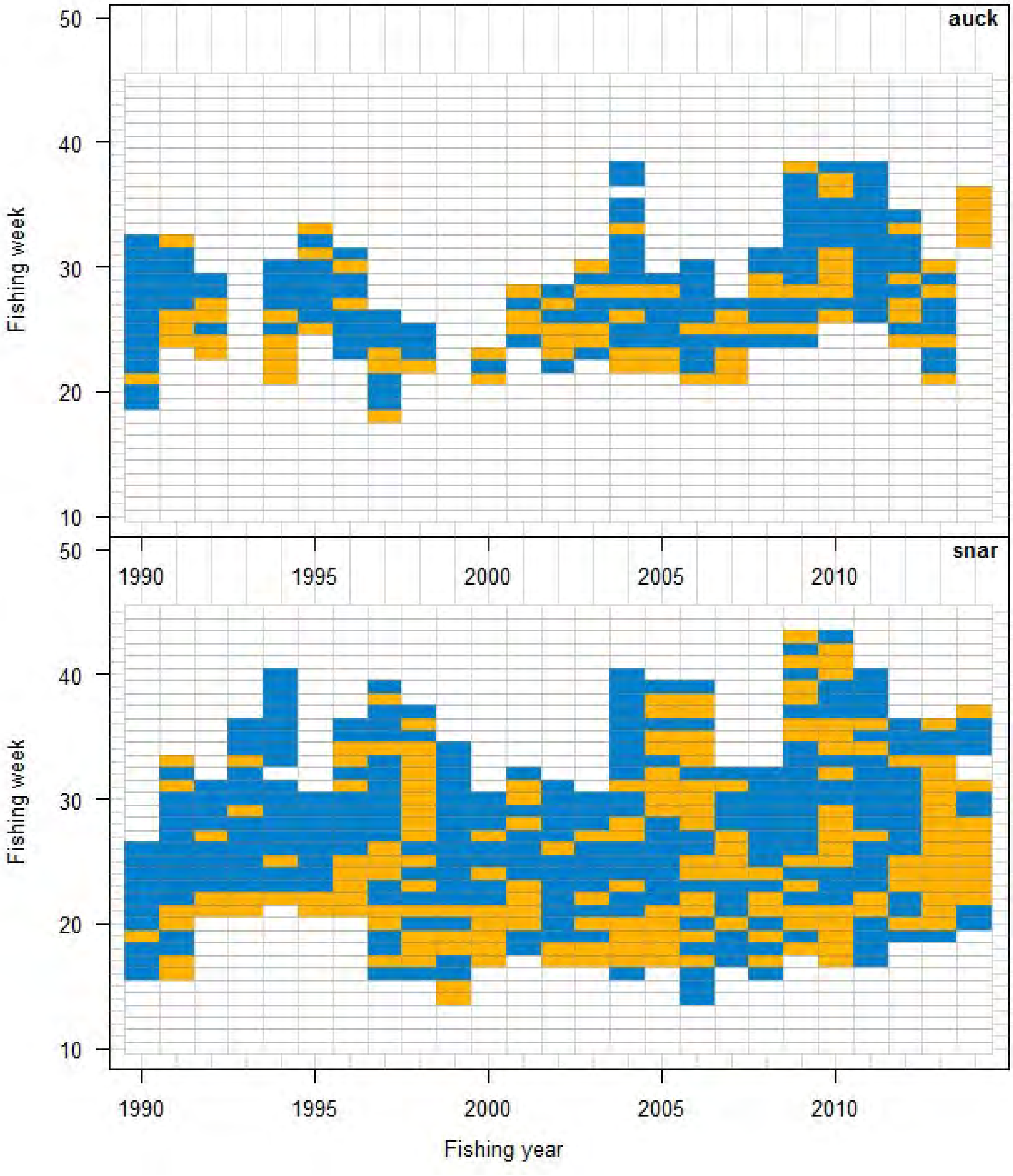


Figure 6: Depletion modelling success by fishing year, fishing week and area. Blue boxes: Depletion model successful (i.e., CPUE and depletion model fitted the data); Yellow boxes: Depletion model tried and failed (i.e., the CPUE fitted, but the depletion model did not.)

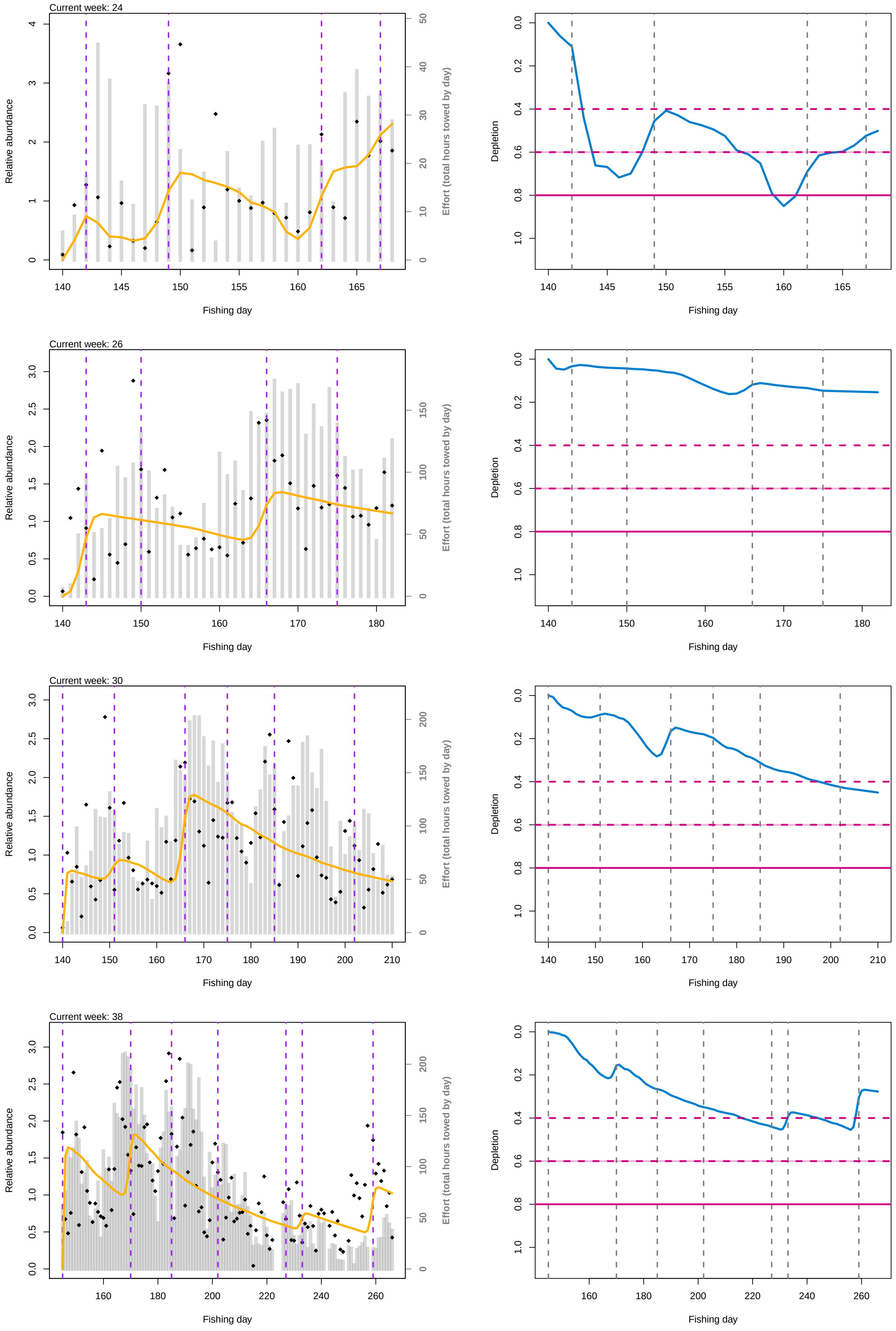


Figure 7: Relative abundance (left) and depletion rates (right) for four depletion models fitted to Auckland Islands data for the 2009 fishing year where the data is available to the current week: week 24 (top), week 26 (second from top), week 30 (second from bottom), week 38 (bottom) . Vertical dotted line indicate the timing of the recruitment pulses.

4. Discussion

This approach to stock assessment has been successfully applied to the squid stocks around the Falkland Islands (Rosenberg et al 1990; Beddington et al 1990, Basson et al 1996, Agnew et al 1998), hence, has the potential to be applied to New Zealand squid stocks to allow for in-season catch-limit management.

We found that the CPUE from various fishing seasons in both fish stock areas has sufficient signal to enable the depletion model to be fitted, a core requirement of this approach. The model was able to fit to the data in many area/year/current fishing week instances, important if this method is to be adopted for management purposes.

Further investigation is required to determine how best to fit the depletion model through the extent of the season when there are breaks in effort, a main challenge in fitting the model. Other investigation includes: the sensitivity of the model to variation in natural mortality; whether chlorphyll is useful as a pre-season indicator; and developing predictive capability within the model (using historical data to estimate probabilities that depletion will go below a certain point given the current state).

While this analysis is in the early stages, the in-season CPUE trends show declines as the season progresses .The fits from depletion model to these data suggests this approach has the potential to provide in-season management advice. We note that additional analyses and evaluations of this strategy are required to determine optimal threshold limits and decision rules.

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