Fishery characterisations and catch-per-unit-effort indices for three sub-stocks of John dory in JDO 1, 1989–90 to 2008–09

T.H. Kendrick
N. Bentley

Trophia Limited
PO Box 60
Kaikoura 7340

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EXECUTIVE SUMMARY

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This study was contracted as MFish project JDO 2009–01 with the general objective: To characterise the John dory (*Zeus faber*) fishery and undertake a CPUE analysis in JDO 1.

The annual landed greenweight of JDO 1 is described by fishing method in three substock areas; the west coast (FMA 9), and FMA 1 divided at the Coromandel Peninsula into east coast and Bay of Plenty. The main fishing methods in each substock are further described for fishing year by target species, statistical area, and month. Catch rates, encounter rates, and distribution of the John dory catch component of the main target fisheries are compared and contrasted in a consideration of appropriate fisheries in which abundance might best be monitored.

JDO 1 is mainly a bycatch of bottom trawl in the west coast substock, associated with catches of snapper, trevally and gurnard. It is rarely targeted in this substock, and neither is there yet a useful time series of catch effort from the developing Danish seine fishery. In the east coast substock, there is a well-delineated target bottom trawl fishery, but it is also taken as bycatch of snapper and gurnard tows, and as both a target and a bycatch of snapper and gurnard Danish seine sets. In the Bay of Plenty bottom trawl fishery it is associated with catches of snapper, trevally and tarakihi, but also targeted. There is very little targeting of John dory by Danish seine in the Bay of Plenty and it is largely taken as bycatch from sets made on snapper or gurnard.

Exploratory work examining the utility of Danish seine and targeted bottom trawl was done, but the Stock Assessment Working Group preferred the series based on mixed species trawl fisheries in each substock. The Danish seine fisheries operated in fewer statistical areas than did the trawl fisheries and, for this reason, are less likely to represent the overall stock trends, but more likely to track trends in local abundance. Indices based on data sets restricted to target fishing often had similar trends to the trends estimated from the full data set, but with exaggerated peaks and troughs. Mixed species analyses tended to produce more stable and plausible CPUE indices. Comparisons are made with the CPUE series from analyses based on target trawl and mixed and target Danish seine, but the discarded analyses are not described here in detail.

Positive catches of JDO 1 in the mixed species bottom trawl fisheries in each sub-area were modelled assuming log-normal distribution. Data were summarised at the trip-stratum level and data from both form types (CELR and TCEPR/TCER) were combined by “rolling up” the more detailed data to match the CELR stratification. Comparisons were made between the “rolled up” series which combined all the form types with the series estimated from the disaggregated tow-by-tow data in each sub-area. These comparisons showed strong similarity between the two sets of series in the period of overlap, indicating that the aggregation had not affected the overall estimated trend.

Landings of JDO 1 have varied in a cyclical manner, peaking at just above the TACC in 1994–95 (the only year in which the TACC has been caught), and at their lowest since its introduction into the Quota Management System, in 2008–09. Catches of JDO 1 have not therefore been constrained by the TACC, but may have been constrained to some extent by the limits set on snapper, with which it is associated.

The lognormal CPUE indices for JDO 1W depict a trend that reached its lowest point for the series in 1992–93. This was followed by a recovery almost to original levels over the following seven years, and a three year plateau at the new level. The series subsequently returned to about the mean of the series by 2004–05 and has been relatively stable since then.

The lognormal CPUE indices for JDO 1E depict a trend with a pronounced cyclical pattern that has lows in the early 1990's and early 2000's and peaks in the middle of each decade. The annual landings of JDO 1 track this index, which is currently at a low point.

The lognormal CPUE indices for JDO 1BP depict a trend that shows more stability than the other two sub stocks, and an overall decrease. It currently sits just below the mean for the series.

1 INTRODUCTION

1.1 The fishery

John Dory (*Zeus faber*; JDO) is an important component of commercial, recreational and customary fisheries in the northern half of New Zealand. The commercial fishery in JDO 1 is the largest in the country accounting for 50–80% of total national landings over the last decade (Ministry of Fisheries, 2009). Landings have varied widely, peaking at about 700 t in 1983–84 and in 1994–95 and declining to levels around 400 t in 1986–87, and in 2002–03. A subsequent increase over two years was sustained for two years and has since reversed, with catches in 2008–09 being the lowest for the study period. The TACC has not been caught since 1994–95 (Figure 1).

The JDO 1 Fishstock encompasses the upper halves of both the west and east coasts of the North Island. The fisheries for John Dory on each coast are quite different. In the west coast fishery (FMA 9) John dory is mainly a bycatch of bottom trawls targeted at trevally, snapper or tarakihi. There is very little targeting of John dory with bottom trawl, and only a small developing Danish seine fishery. East Northland (subarea of FMA 1) accounts for most of the landings of JDO 1, mainly by bottom trawl with most of the balance by Danish seine. For both gear types, the catch of John dory is largely targeted, with the balance taken largely as a bycatch of snapper targetting. In the Bay of Plenty sub-area of FMA 1, John dory is taken mostly by bottom trawl in both a well-defined target fishery and as bycatch of a wide range of species. Danish seine accounts for most of the balance, which is taken as a bycatch of snapper and gurnard targetting.

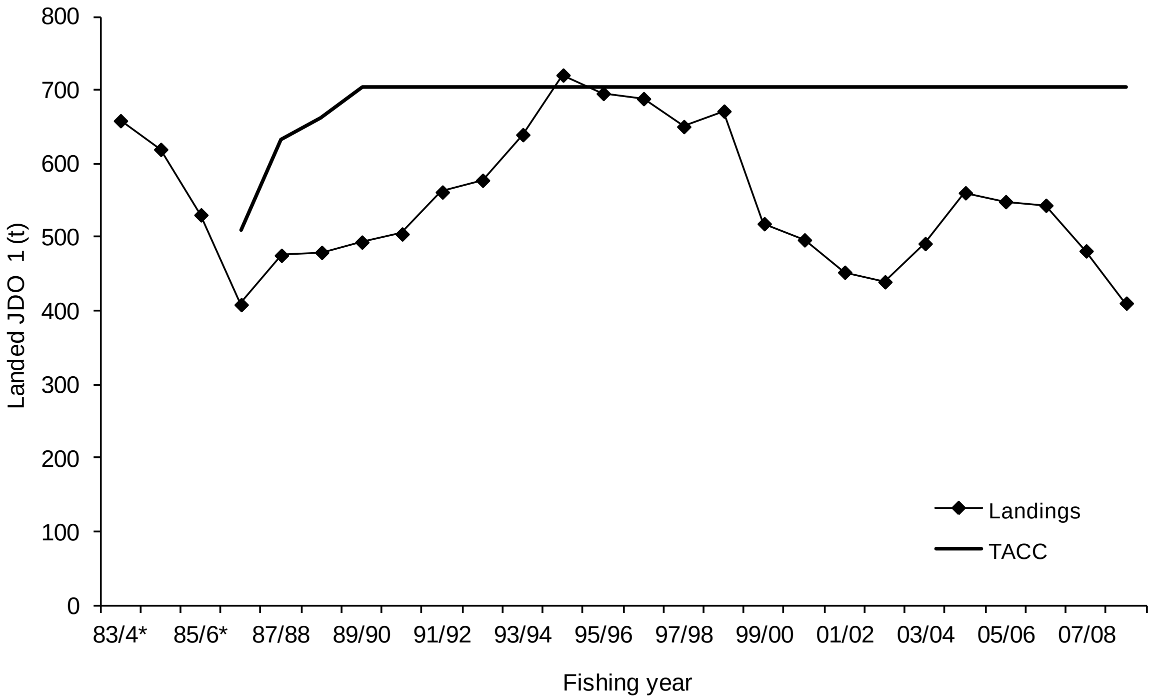

Figure 1: Reported landings of John dory (t) in JDO 1 from 1983–84 to 2008–09 and gazetted and actual TACCs (t) for 1986–87 to 2008–09. QMS data from Ministry of Fisheries 2009.

1.2 Previous work

There have been two attempts at standardising CPUE for JDO 1 in the last 10 years: Horn et al. (1999) and Fu et al. (2008). Each study used similar criteria to define three separate CPUE datasets, splitting JDO 1 into two substocks (east and west) with a boundary at North Cape, and standardising John dory CPUE in bottom trawl (in each substock) and in Danish seine (east coast only). Neither study produced series that were accepted by the Stock Assessment Working Group for monitoring abundance of JDO.

The Inshore bottom trawl fishery on the west coast, targeted at snapper, trevally, tarakihi, gurnard or barracouta, described as accounting for a low proportion of the JDO 1 landings and, being almost entirely a bycatch fishery, was comprised of a large proportion of records with zero catches of John dory (usually more than 40%, Horn et al 1999, Fu et al 2008). The series from the east coast inshore bottom trawl fishery, which includes some targeted effort, in contrast accounted for most of the landings of JDO 1, and included a high proportion of successful (with respect to John dory) records, but was likewise discounted due to the perceived sparse and patchy spatial distribution of the species indicated by high interannual variance in the annual indices. The east coast Danish seine fishery was considered to be limited in its spatial representativeness, being concentrated in a few statistical areas.

The original specification of this project (JDO 2009-03) called for an evaluation of the utility of Danish seine CPUE to monitor abundance of John dory, but this was subsequently expanded to include a re-examination of the usefulness of bottom trawl CPUE, especially for the west coast substock.

The approach taken in this study does not differ markedly from the previous project, except in further splitting JDO 1 East in to east Northland and Bay of Plenty substock areas, but it has the benefit of longer time series of catch effort data and better core fleets selection.

2 DATA SOURCES AND METHODS

The catch effort data extract (from the MFish database “warehou”) defined qualifying trips as those that landed to JDO 1, or that had fishing events in a statistical area valid for JDO 1, and used bottom single or pair trawl, bottom longline or Danish seine method, and targeted any species excluding the following deepwater species (ORH, OEO, SOE, SOR, SSO, BOE, WOE, CDL, BYX, HOK, SCI, SQU, HAK, JMA).

For the trips thus defined we obtained all effort data whether or not John dory was landed, so that all, and not just successful effort could be included in the calculation of CPUE. Landings and estimated catch data for any JDO Fishstock associated with those trips were also obtained.

The fishery characterisations and CPUE analyses for this study were done on landed greenweight of JDO 1 as reported at the end of the fishing trip, either on the bottom part of the general Catch Effort Landing Returns (CELR) or, where fishing was reported on the more detailed Trawl Catch Effort and Processing Return (TCEPR/TCE), on the associated Catch Landing Return (CLR). The CELR form summarises the estimated catch and effort for a day or part day of fishing. It may therefore generalise the species targeted for the day. The TCEPR/TCE form reports catch and effort for each individual tow and includes more detail to describe fishing practice.

Landed greenweight of John dory was linked to effort strata (unique combinations of trip, method, target species and statistical area) proportionate to estimated catch using the method of Starr (2007). For the shorter time series based on TCEPR/TCER format data, landed greenweight was linked to individual tows proportionate to estimated catch, and the data retained in their original resolution.

2.1 Methods used for grooming and collation of MFish catch and effort data

2.1.1 Grooming effort data

Commonly transposed effort fields (such as number of hooks and number of sets for longline) were corrected. Other outlier values in the effort data were identified from empirical distributions derived from the effort variable (duration or number of tows) by identifying records where the values for these variables were in the extreme upper and lower tails of the distribution, and replacing them with the median value for the effort field for the affected vessel. Missing effort data were treated similarly. Missing values for statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Trips with all fields missing for one of these descriptors were dropped entirely.

2.1.2 Grooming landings data

Outlier values in the landings data were identified by finding the trips with very high landings for John dory based on limit values supplied by the Ministry of Fisheries data unit. The effort data for these trips were then used to calculate the trip CPUE and the associated estimated catch. Trips which had a ratio of landed to estimated catch which exceeded 4 and a CPUE which exceeded two times the 95th percentile of the trip CPUE distribution for the entire dataset, were excluded from the analysis.

Most John dory were landed to destination code "L" (landed to a Licensed Fish Receiver in New Zealand), but there were also some landings reported to destination code "R", meaning that they were retained on board; "Q", meaning they were held in a receptacle on land for subsequent landing or "T", meaning they were transferred to another vessel. These fish are not identifiable when subsequently landed and there is therefore a risk of double counting. Where these destination codes were reported, the entire trip was dropped with the loss of just over 35 t of John dory from the analysis dataset.

Almost all JDO 1 are landed green (more than 99% in each year) with most of the balance being dressed. The conversion factor used to back-calculate greenweight from landed (dressed) weight changed from 1.7 to 1.85 for dressed fish in 1995–96, but as the actual tonnage of fish landed to that state was less than 4 t, changes in conversion factors were not corrected for.

2.1.3 Linking and allocating landed catch to effort

For both the characterisation and CPUE analysis datasets the allocation of landed catch to effort is done by first summarising effort and estimated catch data for a fishing trip, for every unique combination of fishing method, statistical area, and target species (referred to as a "trip-stratum"). This reduces both CELR and TCEPR format records to lower resolution "amalgamated" data, giving fewer records per trip, but retains the original method, area, and target species recorded by the skipper. The landed greenweight, declared at the end of the trip, is then allocated to the trip strata in proportion to the estimated catch. Where there are no estimated catches during the trip, the allocation is proportionate to the amount of effort.

Trips landing to more than one fishstock of John dory from the straddling statistical area (041), or that used multiple fishing methods with incompatible measures of effort, were entirely dropped.
The total landed greenweight available from the bottom of the form and obtained in the "*warehou*" extract differs slightly from the total landings of John dory reported in MFish 2009 due to the different error checking routines used. This method of using allocated landings retained for analysis more than 95% of landed JDO 1 in the last half of the time series, but with more of a

shortfall in the mid to late 1990s . The estimated catch in the groomed dataset represented generally more than 80% of the allocated landings (Table 1, Figure 2).

The data available for each trip included estimated and landed catch of John dory, total hours fished, total number of tows/sets/hooks (depending on fishing method), fishing year, statistical area, target species, month of landing, and a unique vessel identifier. Data retained for the analyses might not represent an entire fishing trip, but just those portions of it that qualified, but the amount of landed catch assigned to the part of the trip that was kept would be proportional to the total landed catch for the trip. Trips were not dropped because they targeted more than one species or fished in more than one statistical area.

Alternative datasets delineated by formtype and analysed at original resolution were also based on landed rather than estimated catch, but were allocated to effort at the resolution at which effort was recorded, not amalgamated to trip-stratum. The TCEPR series thus included more detailed variables, such as bottom depth and tow speed, that are only reported for tow-by-tow data.

Landings were re-scaled in the dataset to equal the verified totals from Monthly Harvest Returns (MHR) or, before October 2001, from Quota Management Returns (QMR). For the CPUE standardisation part of this study, records for which any field had been corrected or replaced during grooming were dropped.

Table 1: Comparison of JDO 1 TACC and landed catch totals (t) from the MFish catch and effort forms by fishing year with the total reported landings (t) to the QMS. Also shown are the catch totals (t) which remain after the dataset has been prepared for analysis by dropping trips which reported to more than one John dory fishstock and fished in a straddling statistical area or that used multiple and incompatible gear types. The estimated catch total is the sum from all trips with matching landing data.

Fishing year	TACC (t)	Landed catch (t) from catch effort forms	Landed catch (t) reported to the QMS	Landed catch retained for analysis (t)	Estimated catch in dataset (t)	% analysis catch of landed catch	% analysis catch of QMR	% estimated catch of analysis
89–90	704	422	493	412	342	97	83	83
90–91	704	489	500	479	405	90	88	85
91–92	704	560	566	538	475	95	96	88
92–93	704	561	578	546	456	91	95	84
93–94	704	657	642	644	559	85	85	87
94–95	704	722	731	703	617	74	87	88
95–96	704	686	696	654	535	93	98	82
96–97	704	667	689	639	549	88	83	86
97–98	704	659	651	594	486	85	81	82
98–99	704	671	674	652	530	97	98	81
99–00	704	537	519	518	405	98	98	78
00–01	704	510	497	493	399	95	99	81
01–02	704	460	453	436	348	95	99	80
02–03	704	451	440	436	329	99	104	75
03–04	704	503	492	485	371	99	100	76
04–05	704	568	561	555	454	99	98	82
05–06	704	552	549	537	427	100	101	80
06–07	704	553	544	540	448	96	99	83
07–08	704	493	482	472	390	98	96	83
08–09	704	414	411	396	328	99	96	83

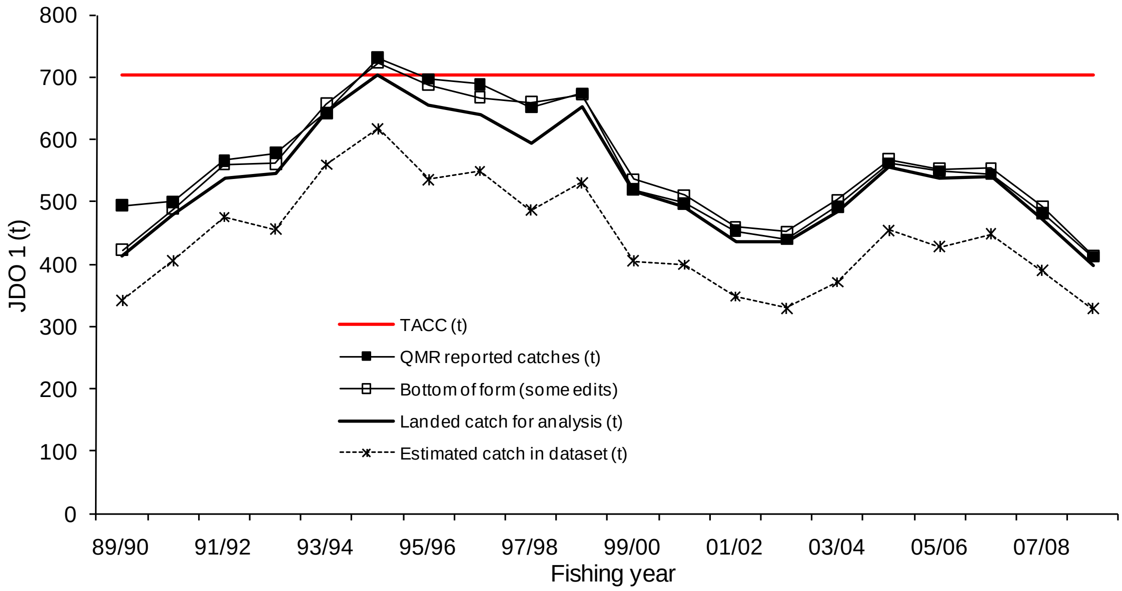

Figure 2: Plot of catch datasets presented in Table 1. The landings are totals reported on Catch Effort forms with some editing; the analysis dataset excludes all landings from trips that landed more than one John dory fishstock and fished in a straddling statistical area or that used multiple incompatible fishing methods. The estimated catch total is the sum of all estimated catch in the analysis dataset.

2.2 Methods used for catch-per-unit-effort analysis

The methodology for standardising CPUE inherently involves a selection of effective effort and of models appropriate to that selection. There are a suite of issues to be considered. Initially this involves a search for adequate time series of data in each substock area in appropriate (for sampling) fishing methods; a consideration of whether to monitor in target or bycatch fisheries; whether to base the analysis on landed or estimated catch, whether and how zero catches might best be handled, and the advantages and disadvantages of including data from the various form types.

2.2.1 Landed greenweight versus estimated catch

The estimated catch of the top five species (top eight species in recent years) in the catch is reported (for a day's fishing) on Catch Effort Landing Returns (CELRs), or for individual tows on Trawl Catch Effort and Processing Returns (TCEPRs). The estimated catch is often therefore an underestimate, and zero catches are as likely to mean the species was caught, but was not among the top five species, as that it wasn't caught at all. The shortfall was first acknowledged as a serious problem for monitoring bycatch species, but with the trend towards monitoring many species in mixed target fisheries, it is becoming acknowledged as a more general problem.

The degree to which the estimated catch is representative of the actual landed catch depends on the consistency of the reporting rate (the proportion of the landed catch that was estimated among the top five species caught), and bias can result if the shortfall comes from specific parts of the fleet or varies between target fisheries. Any variation from year to year in the reporting rate will compromise an annual index based on estimated catch, and the problem is more serious, and more obvious, when there is a trend in the reporting rate over time. Also, the estimated catch of well reported, or even targeted, species is still biased towards large catches, with smaller catches making the top five species less often. This is a potentially serious source of bias that could mask the magnitude of a decline in abundance.

Only the landings values, reported on the bottom part of the CELR, or on Catch Landing Returns (CLRs) respectively, represent total catches. These values are trip-based (available only at the end of the fishing trip), and are not directly linkable to individual fishing events or even to a single day's fishing. The linkage can be simulated by apportioning the landed catch at the end of each trip to effort strata within the corresponding trip using procedures that were comprehensively described by Starr (2007).

The main assumption made in this allocation procedure is that the reporting of estimated catch is consistent across statistical areas and target species within a trip. In contrast, if estimated catches were used directly, the assumption must be made that reporting rates are constant across the entire fleet and all statistical areas for all years.

Another advantage to using landed, rather than estimated catch, is that the catches from ambiguous statistical areas (statistical areas shared by more than one Fishstock) can often be assigned to a Fishstock and retained in the analysis dataset. Without the benefit of Fishstock information, all data from straddling areas must be excluded.

2.2.2 Combining data across form types

Danish seine has been consistently reported on CELRs in daily format, but trawl effort has variously been reported on the CELR and the more detailed TCEPR (or more recently the new TCER) form. There is considerable structure to the use of these forms, historically it was the larger vessels that completed tow-by-tow forms, but in the mid 1990s, the main operator in the northern inshore trawl fishery made reporting on the TCEPR form mandatory for all its vessels. The proportion of data in tow-by-tow format has therefore varied with the participation of that operator, and representative time series of catch effort requires data from the different formtypes to be combined.

Trawl effort reported on the daily CELR form generally summarises a day’s fishing in a single record, and therefore includes an unknown proportion of unsuccessful effort associated with each estimated catch. The amalgamation of TCEPR data to trip-stratum mimics that of the CELR format, by including qualifying effort whether successful or not, and allows data in both formats to be combined in a defensible manner.

There remains, however, concern about defining fisheries based on data in both formats in the northern inshore trawl fishery because of the almost total shift from CELR daily reporting to TCEPR tow-by-tow reporting that has resulted in a systematic improvement in the definition of target effort.

CELRs may report a mixture of fishing practices over a day’s fishing, using a single target species. For example, Field & Hanchet (2001) in describing TAR 1 in this same inshore trawl fishery, reported that fishers were usually targeting a species mix, and that fishing strategies were aimed at maximising the catch of the quota mix rather than maximising the tarakihi catch. Therefore, on any particular day they may have tows targeting tarakihi, tows targeting a 50% tarakihi and 50% mix, and tows actively avoiding tarakihi. Unfortunately, this level of detail is not easily captured on CELRs, and was often combined into a daily record with a single reported target species.

The reporting behaviour on TCEPRs, however, is quite different, with a nominal target species recorded for each individual tow, and targeting potentially better defined.

In a study of TAR 1 in this same inshore trawl fishery, Kendrick (2009) reported catch rates for targeted tarakihi to be lower on CELRs than on TCEPRs, presumably because CELRs include this other effort, and that, as the proportion of data reported on TCEPRs increased, so too did the annual simple catch rate.

The current understanding of this problem (which will become relevant to many other fisheries as they switch from CELR to the new TCE form) is that it will have the greatest effect on time series based on a single target species, and is best allayed by monitoring abundance in fisheries that are defined across a wider range of target species.

To examine the effect of this shift in reporting practice during the mid 1990s (which is peculiar to this northern inshore trawl fishery) on CPUE for John dory, a shorter series based on TCEPR format data was collated for each trawl fishery and a standardisation was done that included such potential explanatory variables as bottom depth, and tow speed as are available for tow-by-tow resolution catch effort records. The annual indices from the shorter time series in each substock are presented without detailed diagnostics and compared, for the years they have in common, with the combined form series.

2.2.3 Inclusion of zero catch information

Where a species is monitored in a well defined target fishery, zero catches are rare, and historically have been excluded. However, it is acknowledged that in many mixed species fisheries the reported target species can indicate: 1) the single species targeted, 2) the main of several species targeted, 3) the species for which the most quota is held (especially before the introduction of the current Actual Catch Entitlement (ACE) regime), 4) the main species actually caught (whether it was targeted or not), 5) the species which legalises a subsequent bycatch trade, or 6) simply a logical species for that area and fishery (Paul & Bradford 2000), rather than any predetermined fishing behaviour. For this reason it would be spurious to consider only the target tows, or indeed to exclude them. This is a particular problem in CELR format data, as an entire day's fishing can be reported to a single target species.

Current practice in monitoring inshore species in New Zealand is to define a fishery that expends effective effort with respect to the species of interest, based on a single fishing method, a group of associated target species, and sometimes season or location. The fishery definition includes target species that are often caught together (associated), have a common depth range preference, and have similar catch and encounter rates for the species of interest.

When a fishery is thus defined, it is logical that all qualifying effort, including unsuccessful effort, is included in the calculation of catch rate, but it is essential when using either CELR format catch-effort, or allocated landings, because the method for linking landed greenweight with effort amalgamates records to trip-stratum resolution and, therefore, incorporates zero-catches, i.e., effort for tows that were unsuccessful. CELR data are also amalgamated, being reported at the resolution of a fishing day, and they also include an unknown amount of unsuccessful effort: there is a potential for bias to be introduced through any systematic and undetectable change in success rate.

The most defensible way to standardise the measure of CPUE in non-target (or mixed target) fisheries is to include all qualifying effort, and to employ a model that can cope with zero catch information. Currently this is done using a two-part model that combines indices from a lognormal model of catch rate in successful events and a binomial model of success rate.

An important consequence of combining form types and amalgamating data, however, is that the coarser resolution of the data compromises the utility of modelling the probability of capture. Catch and effort data reported on CELRs (or data amalgamated to be compatible with CELR data) commonly represent totals for an entire day of fishing (unless there was a change in statistical area or of target species). Unsuccessful tows are unavoidably included in those totals, and, while they may have the effect of lowering the nominal catch rate, they are not individually identifiable. Catch rates calculated from CELR or otherwise amalgamated data therefore inherently include much of the zero catch information and any signal it contains about abundance, so that separate analyses of the probability of capture rarely yields much additional information.

Binomial and combined models were fit to all fisheries examined, but they added little value to the lognormal series and the resultant indices are presented here, but without detailed diagnostics of comment.

2.2.4 Substock areas

Previous work has described JDO 1 as comprising two substocks (JDO 1W and JDO 1E), and MFish (2009) reported that there is no new information to suggest any changes to that structure. However, other species in this same northern inshore bottom trawl fishery are monitored in three substocks, with the eastern part being further divided by the Coromandel Peninsula. It seems appropriate to do the same for John dory, which is a fairly sedentary fish. In any case, whether or not John dory exists as separate biological substocks in the eastern part of JDO 1, the fisheries operate with some independence and for that reason are best described separately.

The three substocks for descriptive and CPUE analyses were defined on the basis of statistical area, as detailed in Table 2 with boundaries at Cape Reinga and Coromandel–Great Barrier Island. Where offshore statistical areas have been amalgamated with adjacent inshore areas they are referred to as zones.

Table 2: Statistical area definitions of JDO 1 substock areas used in the distribution tables and plots in this report.

Substock area	Statistical areas
West	041 042 043 044 045 046 047 048 101 102 103 104
East	001 002 003 004 005 006 007 105 106
Bay of Plenty	008 009 010 107

2.2.5 Defining fisheries

Fisheries are identified in the characterisation as likely candidates in which to monitor abundance of John dory based on a consideration of whether: 1) effort is effective with respect to John dory (accounts for a significant proportion of landed JDO 1), 2) the gear type is suitable for sampling, 3) the selected target fisheries are equally effective with respect to John dory (similar depth, catch rates, encounter rates, and – or other evidence of association), and 4) there has been reasonable stability in the operation of the fishery (based on examination of the areal and seasonal distribution of effort).

A clear definition of the fishery is also important if a meaningful analysis of success rate (probability of capture) is to be modelled separately to the catch rate in positive tows, because it defines how much unsuccessful effort is relevant and should be included in the analysis. Where only the lognormal model is used, effective effort is redefined as the successful effort only, in the delineated fishery.

For JDO 1 the preferred series monitor CPUE in single bottom trawl tows targeted at a suite of closely associated species (snapper, trevally, gurnard and John dory) that are considered to be effectively the same fishery with respect to JDO 1. The definition was broadened to include deeper tows targeted at tarakihi and barracouta to cover more completely the spatial distribution of John dory, despite demonstrable differences in the way those fisheries operate.

This trend towards using a broader fishery definition reflects an increasing confidence in the models to account for operational differences between target fisheries as the datasets grow larger. The consequential inclusion of a lot of unproductive effort is of less concern when only the lognormal model of positive catches is used.

2.2.6 Core fleet definitions

The data sets used for the standardised CPUE analyses were further restricted to those vessels that participated with some consistency in the defined fishery. Core vessels were selected by specifying two variables: the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery.

The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of John dory. This selection process generally reduces the number of vessels in the dataset by about 70–80% while reducing the amount of landed John dory catch by about 10–20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching John dory. The variables used to select core vessels, and the participation across years of the vessels selected is given in Appendix A. All datasets were examined for adequate overlap of vessels across years.

2.2.7 Models

A lognormal General Linear Model was fitted to successful catches of JDO 1, excluding zero catches, for each of the fisheries defined, and a binomial model which predicted success or failure of JDO 1 catch was fitted to the total dataset, including records that reported a zero catch of John dory. These two models were combined into a single set of indices using the method of Vignaux (1994). Only the results from the lognormal models were informative, however, and the combined indices are included without detailed diagnostics or comment in this report.

Catches were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting until the improvement in model R^2 was less than 0.01. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

The dependent variable for the lognormal models based on allocated landings was the log of landed weight of JDO 1 per stratum. The explanatory variables offered to the model were: fishing year (always forced as the first variable) and month (of landing), statistical area, target species, form type, and a unique vessel identifier. The logs of the total number of tows and of total duration of fishing were included as measures of effort to explain catch per trip-stratum.

For models based on TCEPR data in its original resolution, the dependent variable was the log of estimated catch per trawl tow, and bottom depth, tow speed, and the log of tow distance (calculated from speed and duration) were also offered as potential explanatory factors.

The dependent variable for the binomial model was a binary variable set to ‘1’ for records which had associated JDO 1 catch and set to ‘0’ for records with no catch. This model was offered the same explanatory variables as the lognormal model.

The two models were combined using;

$$C_i = \frac{L_i}{\left(1 - P_0\left[1 - \frac{1}{B_i}\right]\right)}$$

where C_i = combined index for year i
L_i = lognormal index for year i
B_i = binomial index for year i
P_0 = proportion zero for base year 0

It is relatively straightforward to calculate standard errors for the indices L_i and B_i. However, this is not so for the combined index C_i because the standard errors of the two sets of indices are likely to be correlated as they come from the same dataset. Francis et al. (2001) suggested that a bootstrap procedure is the appropriate way to estimate the variability of the combined index, but this was not done for this paper.

3 RESULTS

3.1 Characterisation of JDO 1

Catches from the east coast of Northland dominate the landings of JDO 1 (47–66% annually) with the balance in each year taken almost equally from the west coast and the Bay of Plenty. Catches increased during the early 1990s in all three substocks, but while landings from the west coast and Bay of Plenty have been relatively stable since then, landings from the east coast have varied considerably; declining by about 50% over four consecutive years to their lowest level in 2002–03, then increasing to peak again in 2006–07. Landings from the East coast substock, and from JDO 1 overall, have since declined from that peak and in 2008–09 were the lowest for the study period (Table 3, Figure 3).

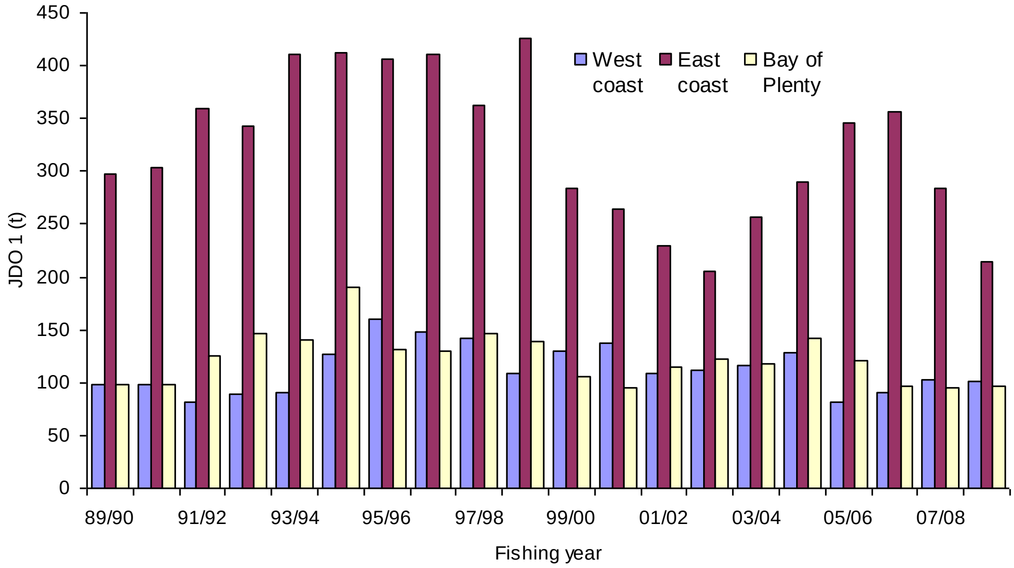

Figure 3: Landed catch of JDO 1 by substock area and fishing year.

Table 3: Distribution of landed John dory by substock area and fishing year, in tonnes and percentage, from trips which landed JDO 1 for 1989–90 to 2008–09. Catches are scaled up to equal the annual QMS catch (Table 1). Percentages sum to 100 by year.

	Substock area (t)			Substock area (%)		
Fishing year	West Coast	East Coast	Bay of Plenty	West Coast	East Coast	Bay of Plenty
89–90	98	297	99	20	60	20
90–91	98	304	98	20	61	20
91–92	81	359	126	14	63	22
92–93	88	342	147	15	59	25
93–94	91	410	141	14	64	22
94–95	128	413	190	17	57	26
95–96	160	406	131	23	58	19
96–97	148	411	130	21	60	19
97–98	143	362	146	22	56	22
98–99	109	426	139	16	63	21
99–00	129	285	106	25	55	20
00–01	138	264	95	28	53	19
01–02	109	229	115	24	51	25
02–03	112	206	122	25	47	28
03–04	116	257	119	24	52	24
04–05	129	290	143	23	52	25
05–06	82	346	121	15	63	22
06–07	91	357	96	17	66	18
07–08	103	284	95	21	59	20
08–09	101	214	97	25	52	24

3.2 Characterisation of the west coast JDO 1 fisheries

Historically, more than 70% of the catch of JDO 1 in the western substock has been taken by bottom single trawl, with most of the balance taken by bottom pair trawl and small amounts (less than 10 t annually each) by Danish seine and by set net (Table 4). There has been some decline in the importance of bottom trawl since 2004–05, particularly in the northern areas 046 and 047 as the result of contraction of the snapper fishery, and a small recent increase in the amount taken by the Danish seine fishery developing in Area 047 (Figure 4).

3.2.1 West coast (single) bottom trawl

The bottom trawl catch of JDO 1 from the west coast substock has largely been a bycatch of the trevally (18–62 % annually) and snapper fisheries (10–44%) with most of the balance taken as a bycatch of gurnard tows. It was more often reported as a bycatch of snapper tows during the first half of the time series and increasingly as a bycatch of trevally tows in the last half. John dory is only rarely a target species in the west coast substock (Table 5).

The seasonality of the five most important fisheries taking JDO 1 by bottom trawl is shown in Figure 5. The greatest catches from the snapper fishery are taken in spring and early summer and traditionally from the trevally fishery during the summer months, though they have shifted into spring as bycatch from the snapper fishery has declined. Bycatch from gurnard and tarakihi tows is more evenly distributed year round, and the barracouta fishery lands John dory mainly in the last three months of the fishing year.

Table 4: Distribution of landed John dory by method and by fishing year for the west coast substock of JDO 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMS catch (Table 1): 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; DS, Danish seine; BPT, bottom pair trawl; SN, setnet.

Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BPT	SN	Other	BT	DS	BPT	SN	Other
89–90	82		16	0	0	84	0	16	0	0
90–91	76		22	0	0	77	0	23	0	0
91–92	66		16	0	0	80	0	19	0	0
92–93	77	0	10	0	0	87	0	12	0	0
93–94	76	1	14	0	0	83	1	15	0	0
94–95	113	0	14	0	0	89	0	11	0	0
95–96	126	11	22	0	0	79	7	14	0	0
96–97	134	5	7	1	0	91	3	5	1	0
97–98	136	1	5	1	0	95	1	3	1	0
98–99	96	1	11	1	0	88	1	10	1	0
99–00	113	1	14	0	0	88	1	11	0	0
00–01	109	4	24	1	1	79	3	17	0	0
01–02	95	7	6	0	0	87	6	6	0	0
02–03	95	6	11	0	0	85	5	9	0	0
03–04	90	14	9	0	2	78	12	8	0	2
04–05	101	6	20	0	1	78	5	16	0	1
05–06	66	6	8	0	1	81	7	10	0	2
06–07	71	8	12	1	0	77	9	13	1	1
07–08	74	14	14	0	0	72	14	14	0	0
08–09	77	14	10	0	0	76	13	10	0	0

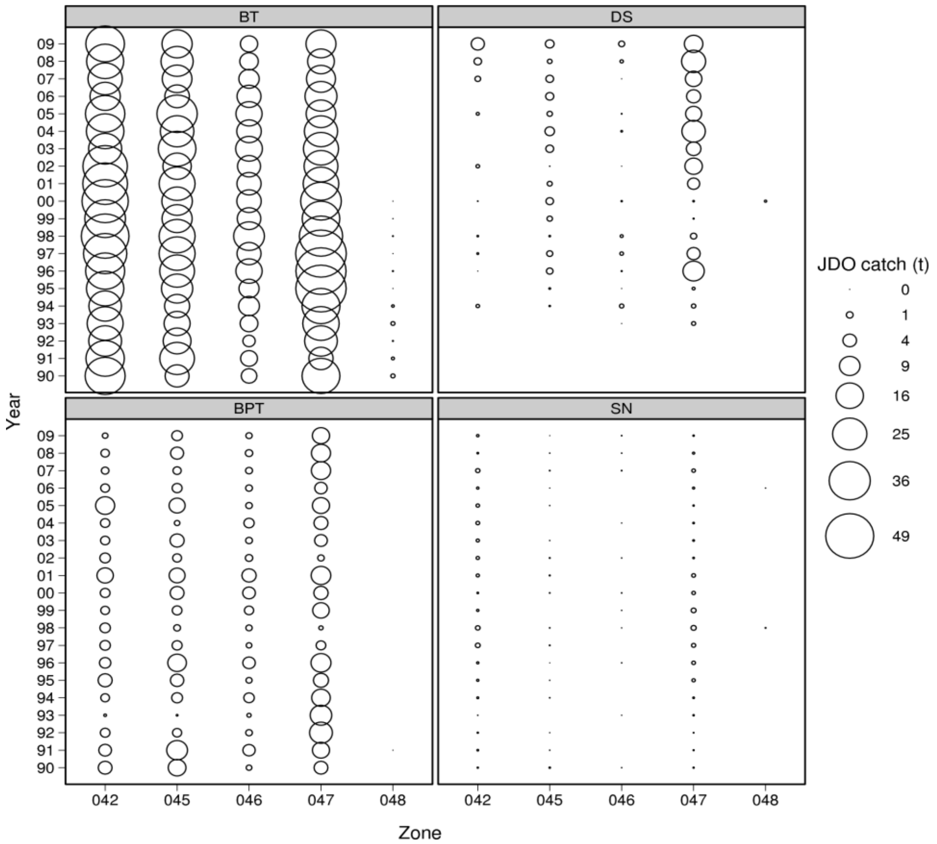

Figure 4: Spatial distribution of John dory catches in the west coast substock for the four main methods by fishing year. Zones amalgamate offshore statistical areas with adjacent inshore areas.

The spatial distribution of JDO 1 is similar among the main target fisheries (Figure 6), with all inshore statistical areas being important for John dory (areas 043 and 044 are harbours that are protected from commercial trawling), except that tarakihi and barracouta fisheries are more confined to area 047. Bycatch from snapper tows has declined in all areas while bycatch from trevally tows has increased to compensate. Despite the shifts in target species used to describe the catch of John dory, catches have been maintained from the traditional areas and seasons.

Annual average catch rates (total catch per year/total tows per year) of John dory in tows targeted at snapper, gurnard, tarakihi or trevally are similar in magnitude and show similar trends. Catch rates vary between 10 kg and 40 kg per tow. Catch rates in tows targeted at barracouta show an anomalous increase over the time series to about 70 kg per tow by 2008–09. The encounter rates (of John dory) also suggest similarities between target fisheries for gurnard, barracouta, trevally and snapper, with John dory caught in 70–100 % of strata with no apparent trend. In contrast, John dory is reported in a declining proportion (from 70 down to 40%) of tows targeted at tarakihi (Figure 7).

It is defensible to consider all bottom trawls targeted at snapper, trevally, or red gurnard in this substock area to be effectively the same fishery with respect to John dory, and the utility of target species as an explanatory variable to be doubtful. Successful tows (with respect to gurnard) in the three main target fisheries are also made in much the same depth range (at least for that subset reported on TCEPRs (Figure 8). The fisheries for barracouta and tarakihi are substantially different in that they are more confined to statistical area 047; operate at greater depths and in the case of barracouta, at a different time of the year, than the other target fisheries. They nevertheless account for a considerable amount of John dory. Data are mainly reported on TCEPR after 1995–96 (Figure 9) and these data can be used in their original (tow-by-tow) resolution to standardise positive catches for bottom depth and tow speed, rather than for fisher-nominated target species.

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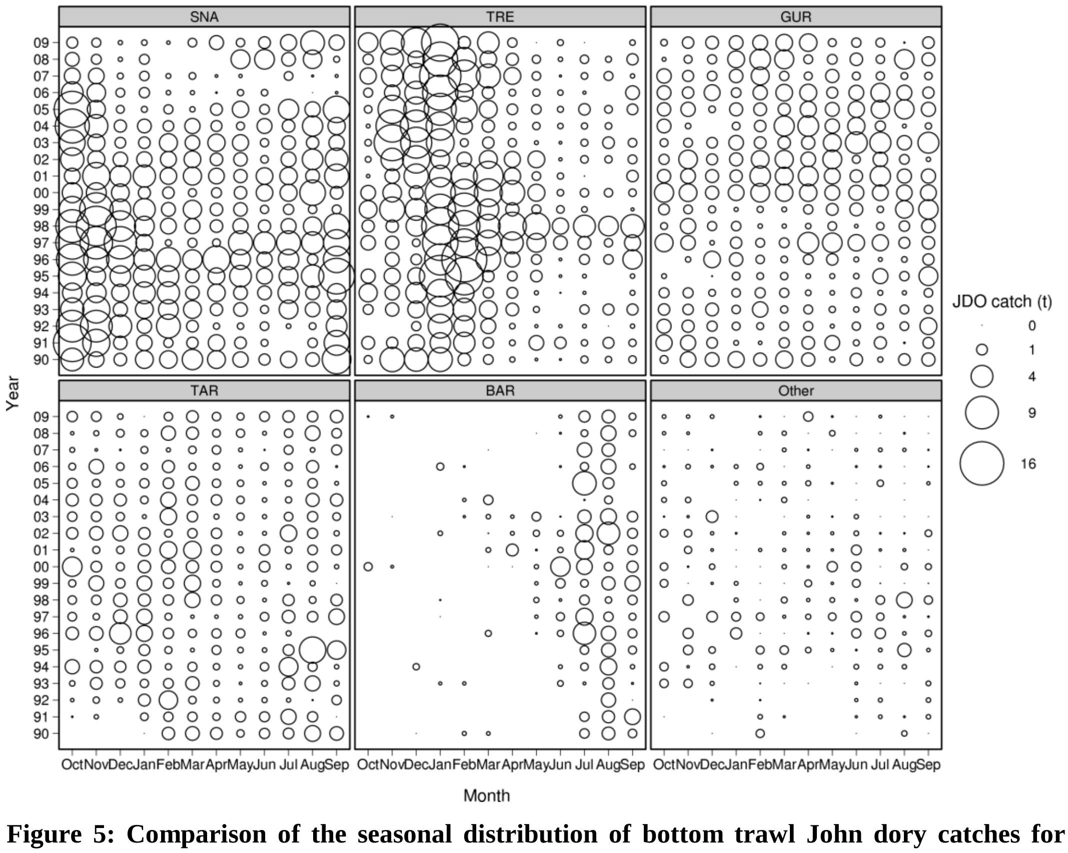

Figure 5: Comparison of the seasonal distribution of bottom trawl John dory catches for the four main target fisheries taking JDO 1 from the west coast substock area, by fishing year. Other includes small amounts of targeted catch. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 5.

Table 5: Distribution of bottom trawl caught John dory by target species (snapper, John dory, trevally, gurnard, tarakihi, and other) and by fishing year for the west substock of JDO 1 in tonnes and percentage. Catches are scaled up to the annual QMS catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

Fishing	Target species (t)						Target species (%)					
year	SNA	JDO	TRE	GUR	TAR	Other	SNA	JDO	TRE	GUR	TAR	Other
89–90	33		19	16	10	4	40	0	23	20	12	5
90–91	33	0	18	12	7	4	44	0	24	16	10	6
91–92	35	0	12	10	7	2	53	0	18	16	10	3
92–93	32	0	22	10	9	3	42	0	29	13	12	4
93–94	33	1	20	7	12	4	43	1	26	9	15	6
94–95	49	2	36	8	13	6	43	1	32	7	11	5
95–96	54	1	41	9	12	10	42	1	32	7	10	8
96–97	54	3	39	21	10	6	40	3	29	16	8	5
97–98	52	3	57	8	11	4	38	2	42	6	8	3
98–99	33	1	36	12	9	6	34	1	37	13	9	6
99–00	26	1	36	27	12	10	23	1	32	24	11	9
00–01	36	1	28	26	11	7	33	1	26	24	10	7
01–02	28	0	24	20	12	10	30	0	26	21	12	11
02–03	25	1	31	24	8	6	26	1	32	25	9	6
03–04	31	0	30	16	12	2	34	0	33	18	13	2
04–05	31	1	34	21	7	6	31	1	34	21	7	6
05–06	10	1	24	21	8	4	14	1	37	32	11	5
06–07	7	0	44	13	4	3	10	0	62	18	5	5
07–08	15	0	29	18	9	3	20	0	39	25	12	5
08–09	15	0	34	14	9	4	20	0	44	19	12	5

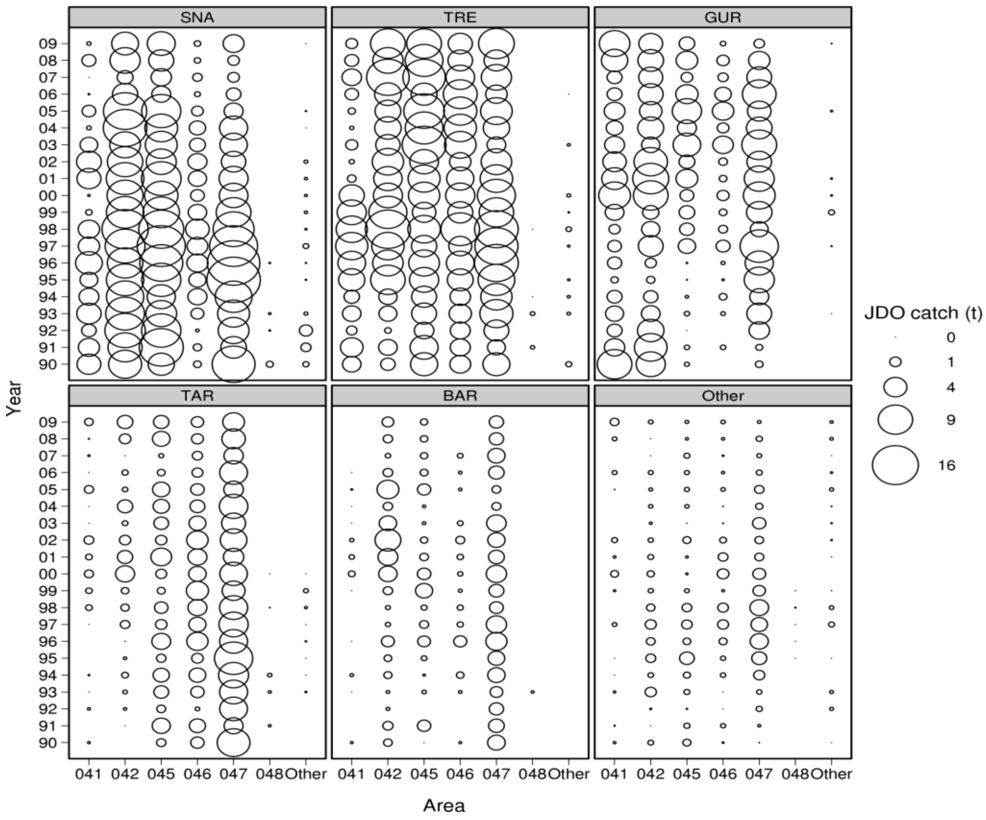

Figure 6: Comparison of the spatial distribution of bottom trawl John dory catches for the five main target fisheries taking JDO 1 from the west coast substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species summing to the annual totals given in Table 5.

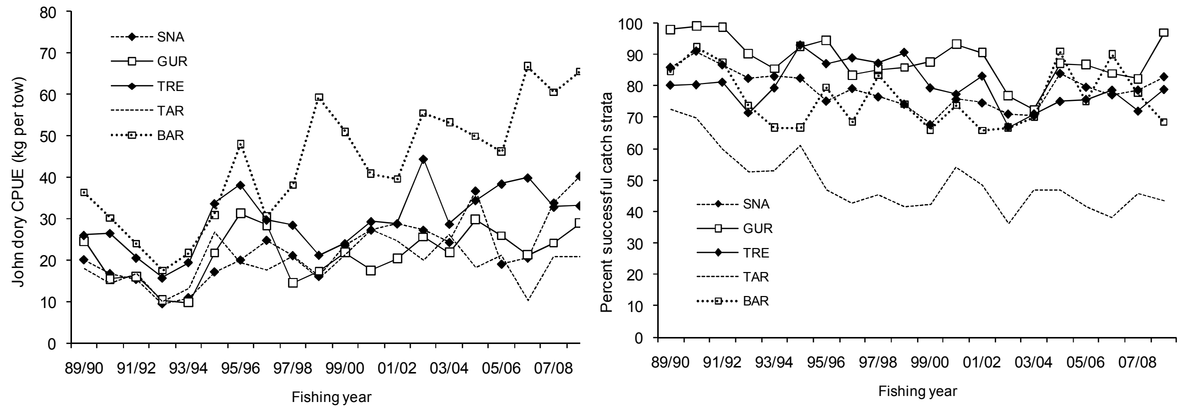

Figure 7: Unstandardised CPUE (kg/tow, across total effort) and percent successful strata for John dory in the main target fisheries using single bottom trawl tows in the west coast substock of JDO 1. All forms and statistical areas combined.

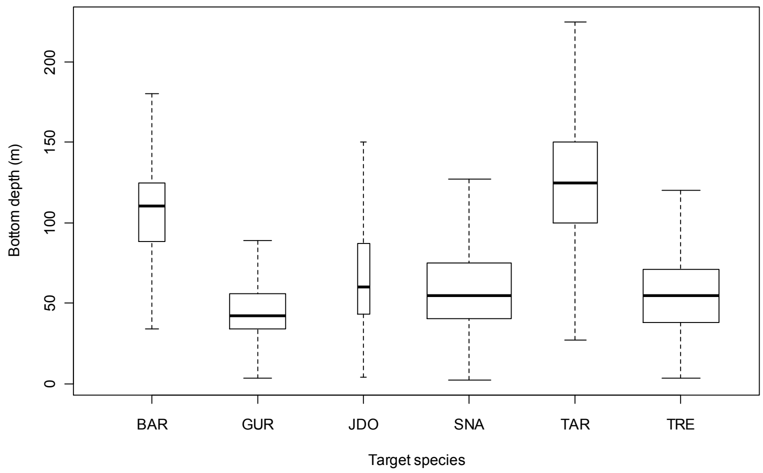

Figure 8: Box plot distributions (median and interquartiles) of bottom depth from TCEPR or TCE records of the single bottom trawl method for the main six target species where a catch of John dory was reported (positive tows). All years and statistical areas for the western substock are combined. The width of the boxes is proportionate to the number of records.

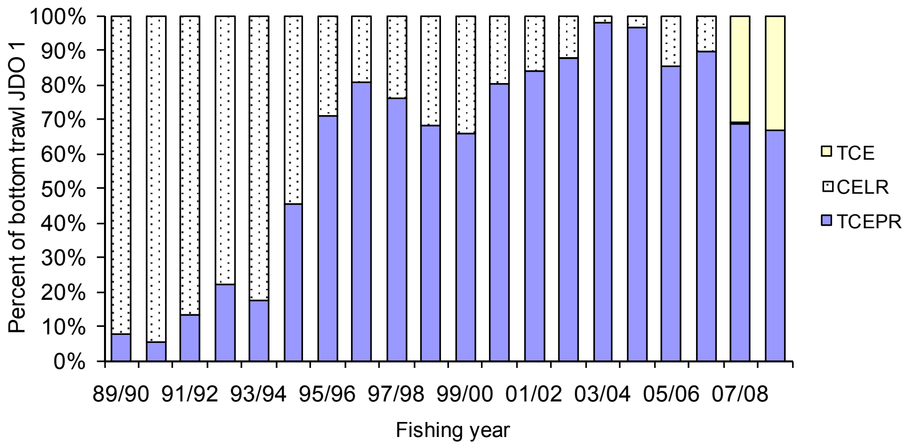

Figure 9: Change in reporting practice in the west coast trawl fishery. The percentage of bottom trawl caught JDO 1 (by landed weight) reported on the tow-by-tow forms (TCEPR or TCE) and on the daily form (CELR) by fishing year.

3.2.2 West coast bottom pair trawl

The catch of John dory by west coast pair trawl fishery resembles that from single trawl with John dory mainly a bycatch of tows targeted at snapper, trevally and gurnard and to a lesser extent from tarakihi and barracouta tows (Figure 10). The inshore statistical areas 042, 045, 046, and 047 are all important for John dory, with most of the catch taken in the spring and summer months (Figure 11). A similar shift away from snapper target towards more trevally target, to that seen in bottom single trawl, is also evident for this gear type.

3.3 Characterisation of the east coast JDO 1 fisheries

On the east coast, bottom single trawl tows accounted for 50–72 % of the landings of John dory from this substock annually, followed by Danish seine (16–40 % annually). Bottom pair trawl and bottom longline each accounted for about 10 t in most years (Table 6).

Most Danish seine-caught John dory comes out of Statistical Area 005, but there has also been consistent small amounts landed by Danish seine in areas 003 and 002. Bottom trawl catches are more equally distributed between areas 005 and 003, with smaller amounts from 002. Large and cyclical variations are a feature of the catch by Danish seine, and also by bottom trawl in area 003, but bottom trawl catches in area 005 have been much more consistent from year to year (Figure 12).

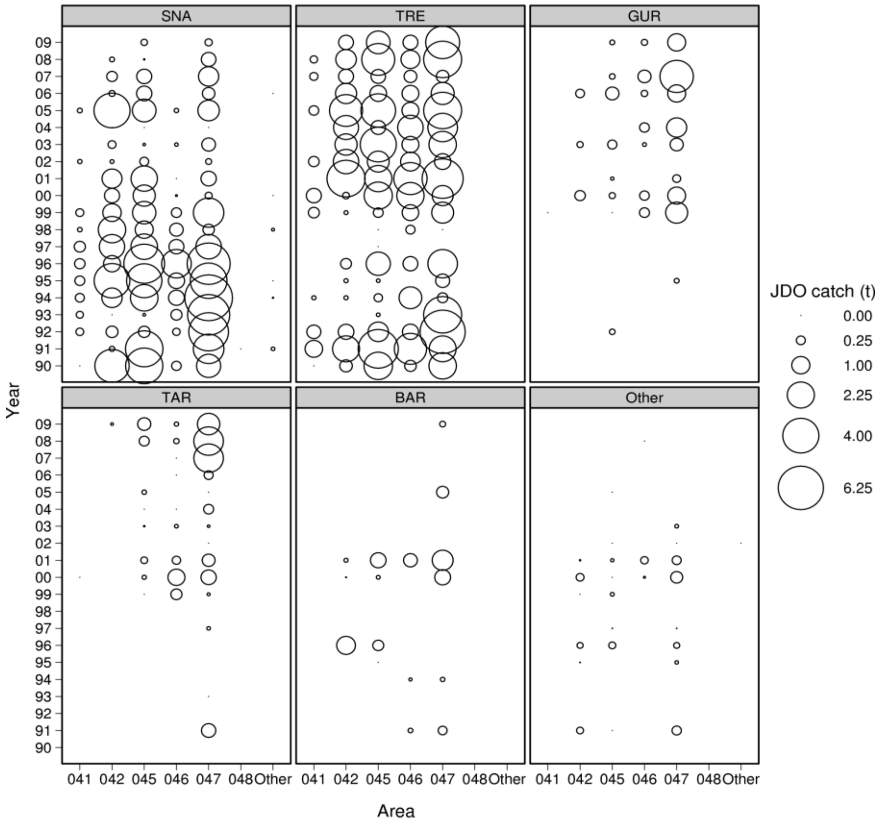

Figure 10: The distribution across statistical area, fishing year, and target species of catches of John dory by bottom pair trawl in the west coast substock.

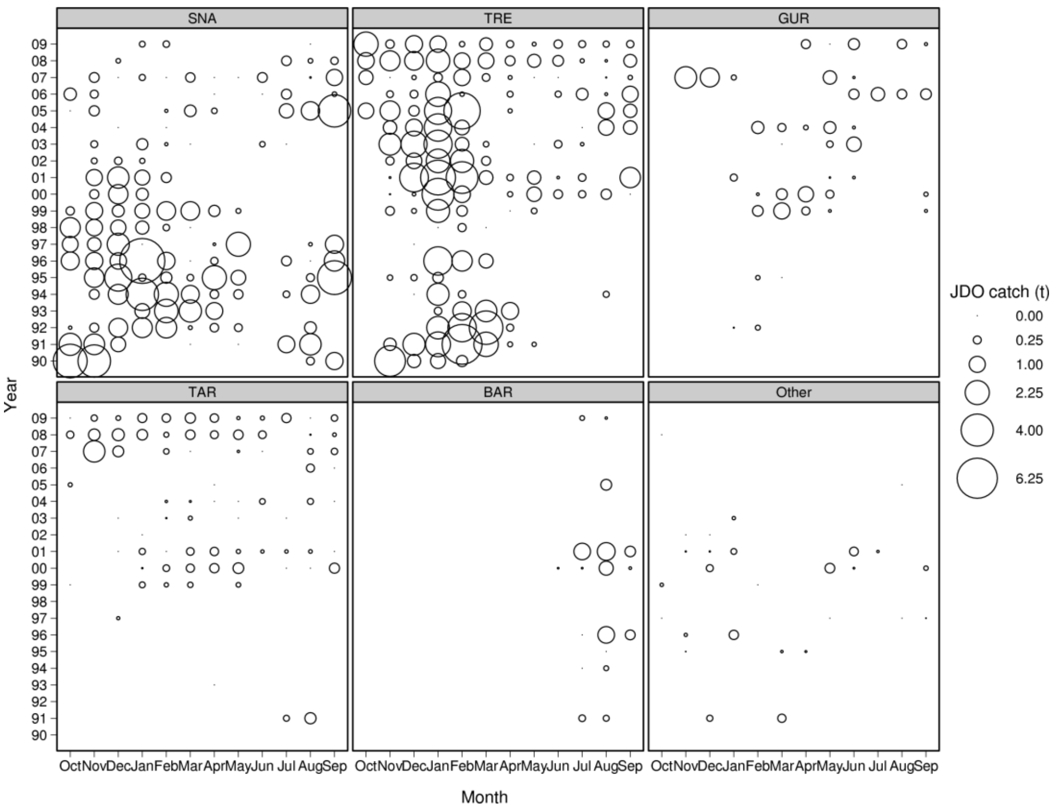

Figure 11: The seasonal distribution by fishing year and target species of catches of John dory by bottom pair trawl in the west coast substock.

Table 6: Distribution of landed John dory by method and by fishing year for the east coast substock of JDO 1 in tonnes and in percentage of substock annual landings. Catches are raised to the annual QMS catch (Table 1); 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; DS, Danish seine; BPT, bottom pair trawl; BLL, bottom longline. Other includes set net.

										East coast
Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BPT	BLL	Other	BT	DS	BPT	BLL	Other
89–90	202	47	35	5	7	68	16	12	2	2
90–91	196	76	18	7	7	65	25	6	2	2
91–92	238	96	8	10	7	66	27	2	3	2
92–93	199	112	11	11	10	58	33	3	3	3
93–94	205	168	12	14	11	50	41	3	4	3
94–95	217	150	18	17	11	53	36	4	4	3
95–96	248	126	7	13	12	61	31	2	3	3
96–97	239	143	4	13	13	58	35	1	3	3
97–98	236	99	2	15	11	65	27	0	4	3
98–99	257	138	1	13	17	60	32	0	3	4
99–00	163	98	2	9	13	57	34	1	3	5
00–01	152	93	3	11	5	58	35	1	4	2
01–02	146	62	2	10	10	64	27	1	4	4
02–03	132	58	4	7	5	64	28	2	3	2
03–04	163	77	3	9	5	63	30	1	4	2
04–05	208	65	3	9	6	72	22	1	3	2
05–06	188	137	2	11	8	54	40	0	3	2
06–07	193	142	3	8	11	54	40	1	2	3
07–08	158	115	3	4	3	56	41	1	2	1
08–09	154	51	1	4	4	72	24	1	2	2

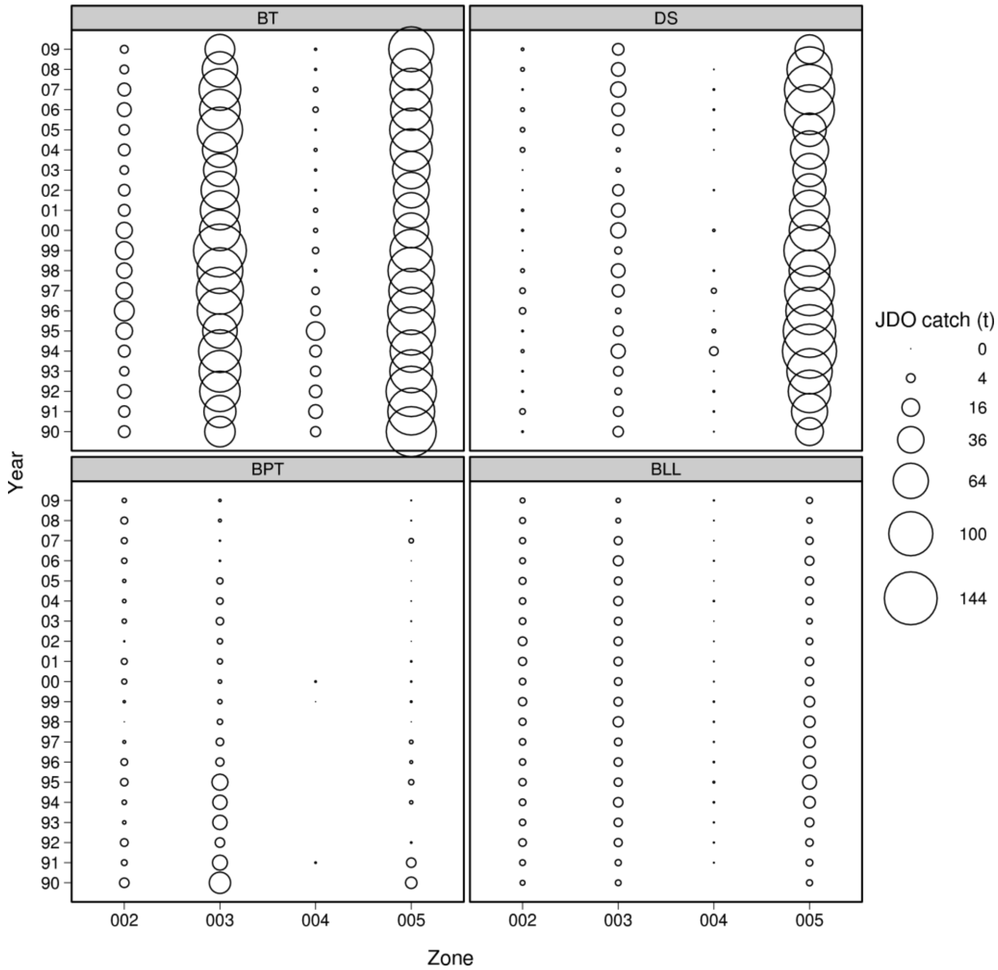

Figure 12: Spatial distribution of catches of John dory by the four main methods in the east coast substock by fishing year. Zones amalgamate some offshore areas into adjacent inshore statistical areas.

3.4 Characterisation of the Bay of Plenty JDO 1 fisheries

JDO is landed from the Bay of Plenty mainly by bottom trawl (54–87% annually) with most of the balance in each year taken by Danish seine (7–28% annually). Bottom pair trawl was briefly important in the mid 1990s, accounting for a maximum of 21% of the catch from this substock in 1994–95, but has since almost disappeared. Bottom longline has consistently landed small amounts (less than 7 t) of John dory in each year (Table 7). Both bottom trawl and Danish seine have landed John dory almost equally from the three inshore statistical areas (008, 009, and 010) in every year. Bottom pair trawl is mostly confined to Area 008, and bottom longline mostly to 008 and 009 (Figure 13).

3.4.1 Bay of Plenty bottom trawl

The bottom trawl fishery in Bay of Plenty lands similar quantities of John dory in each year from several target fisheries; snapper, John dory, trevally and tarakihi, with smaller amounts from tows targeted at gurnard and barracouta (Table 8). The transition from reporting of trawl fishing on CELRs to reporting on TCEPRs is also marked for this substock and the greater detail in which tows are described on the TCEPR form may have had some effect on the apparent distribution of catch with target species (Figure 14).

The target fishery operates mainly in Area 008 during the summer months, but John dory is landed throughout the year as a bycatch from all three inshore areas (Figure 15, Figure 16). There have been considerable shifts over time in the relative importance of target species.

Annual average catch rates are relatively stable in the main bycatch fisheries at between 10 to 40 kg per tow, with higher rates of up to 60 kg per tow in the barracouta fishery, and higher but much more variable rates in the target fishery, peaking in 1994–95 and 2008–09 at more than 120 kg per tow compared to a low of nearer 20 kg per tow in 2001–02. Encounter rates are high (generally greater than 70 of strata are successful with respect to a catch of John dory) for all targets except that the tarakihi fishery catches John dory on average in only about 50% of strata (Figure 17).

A series of CPUE indices from bottom trawl across all effort in the four main target fisheries (JDO, SNA, TRE and GUR) should be useful for monitoring abundance of John dory. The similarity in bottom depth for successful tows in the three main fisheries (Figure 18) also supports the concept of them being effectively one fishery with respect to John dory. The fisheries for barracouta and tarakihi are substantially different in that they operate at greater depths. They nevertheless account for a considerable amount of John dory.

Table 7: Distribution of landed John dory by method and by fishing year for the Bay of Plenty substock of JDO 1 in tonnes and in percent of substock annual landings. Catches are raised to the annual QMS catch (Table 1) 0, less than 0.5 t. Percentages sum to 100 by year. BT, bottom trawl; BPT, bottom pair trawl; BLL, bottom longline; SN, setnet; DS, Danish seine.

	Bay of Plenty									
Fishing	Fishing method (t)					Fishing method (%)				
year	BT	DS	BPT	BLL	Other	BT	DS	BPT	BLL	Other
89/90	81	7	8	2	1	82	7	9	2	1
90/91	76	7	7	6	2	77	7	7	6	2
91/92	93	15	9	6	2	74	12	7	5	2
92/93	113	18	9	4	3	77	12	6	3	2
93/94	96	26	12	5	3	68	18	8	3	2
94/95	102	42	40	4	2	54	22	21	2	1
95/96	83	25	16	4	3	63	19	12	3	3
96/97	91	24	10	3	2	70	19	7	2	2
97/98	102	37	3	2	2	70	25	2	2	1
98/99	107	27		3	1	77	20	0	2	1
99/00	83	17	1	2	2	79	16	1	2	2
00/01	83	9	0	3	1	87	9	0	3	1
01/02	96	15	1	2	0	84	13	1	2	0
02/03	94	23	2	2	0	77	19	2	2	0
03/04	95	18	3	2	1	80	15	2	2	1
04/05	112	23	4	3	0	79	16	3	2	0
05/06	92	23	1	5	1	76	19	1	4	1
06/07	76	15	0	4	1	79	15	0	4	1
07/08	68	23	0	3	1	72	24	0	3	1
08/09	68	27	0	1	0	70	28	0	1	0

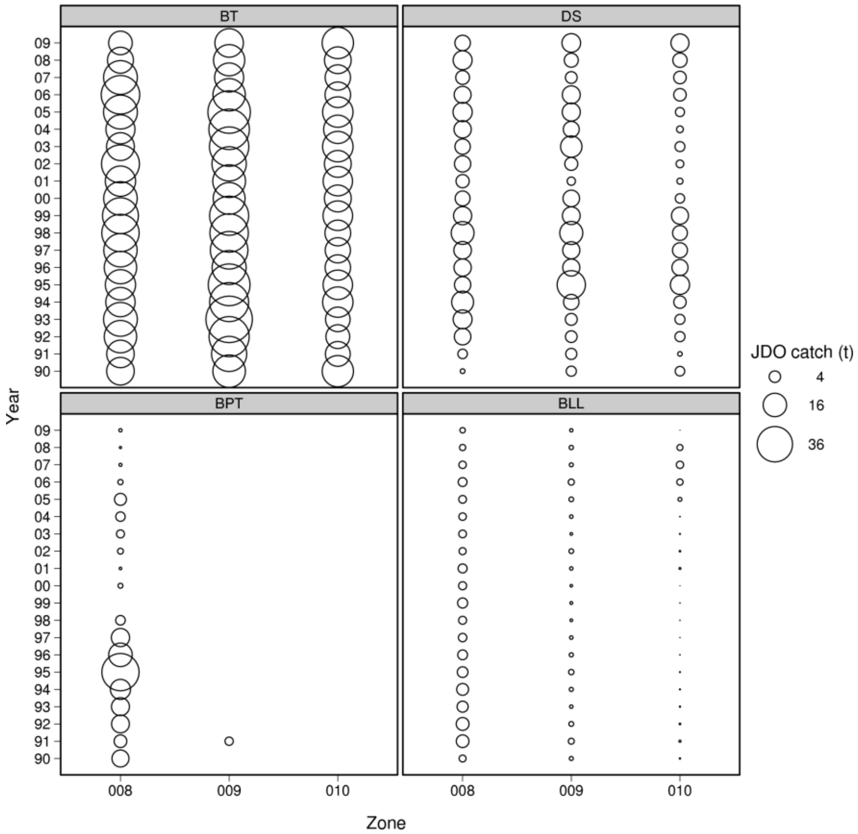

Figure 13: Spatial distribution of John dory catches by the four main methods in the Bay of Plenty substock by fishing year. Zones amalgamate some adjacent statistical areas.

Table 8: Distribution of bottom trawl caught John dory by target species (snapper, John dory, trevally, red gurnard, tarakihi, or other) and by fishing year for the Bay of Plenty substock of JDO 1 in tonnes and percentage. Catches are scaled up to the annual QMS catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

	Bay of Plenty bottom trawl											
Fishing	Target species (t)						Target species (%)					
year	SNA	JDO	TRE	GUR	TAR	Other	SNA	JDO	TRE	GUR	TAR	Other
89/90	47	4	8	0	13	9	58	5	10	0	15	11
90/91	45	2	5	1	15	7	60	3	7	2	19	9
91/92	40	11	4	4	20	14	43	12	4	4	22	15
92/93	31	20	12	10	26	14	28	18	10	8	23	12
93/94	29	14	19	6	23	3	31	15	20	7	24	3
94/95	29	26	15	6	19	8	28	26	14	6	18	8
95/96	48	13	2	2	11	7	58	16	3	3	13	8
96/97	36	21	10	4	14	6	39	23	11	5	15	7
97/98	40	30	8	3	15	6	40	29	8	3	14	6
98/99	33	25	28	3	12	5	31	24	26	3	11	5
99/00	21	16	23	9	11	4	25	20	27	10	13	4
00/01	13	15	32	8	10	5	16	18	39	9	11	6
01/02	26	27	22	6	12	3	27	28	23	6	12	4
02/03	23	17	23	10	17	4	25	18	25	10	18	4
03/04	34	11	25	8	13	4	35	12	27	8	14	4
04/05	38	23	23	9	18	1	34	21	20	8	16	1
05/06	22	13	17	23	15	2	23	14	18	26	17	2
06/07	29	21	14	2	9	1	38	28	18	3	12	2
07/08	21	16	15	1	12	4	30	23	22	2	17	5
08/09	17	13	17	6	15	0	25	19	26	8	21	0

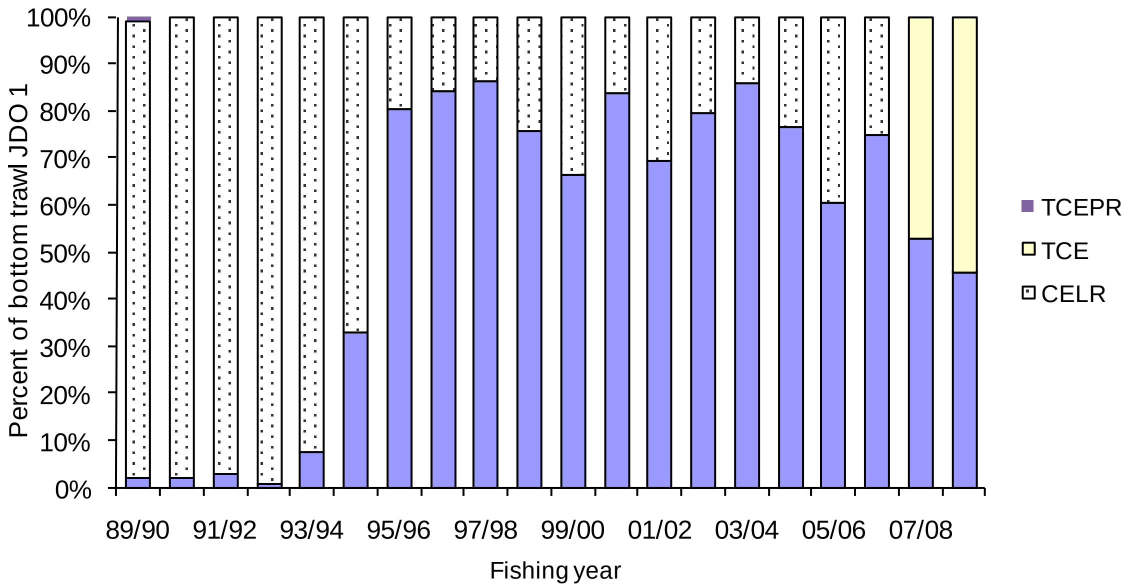

Figure 14: Change in reporting practice in the Bay of Plenty trawl fisheries. The percentage of bottom trawl caught JDO 1 (by landed green-weight) reported on the tow-by-tow forms (TCEPR and TCE) and the daily form (CELR) by fishing year.

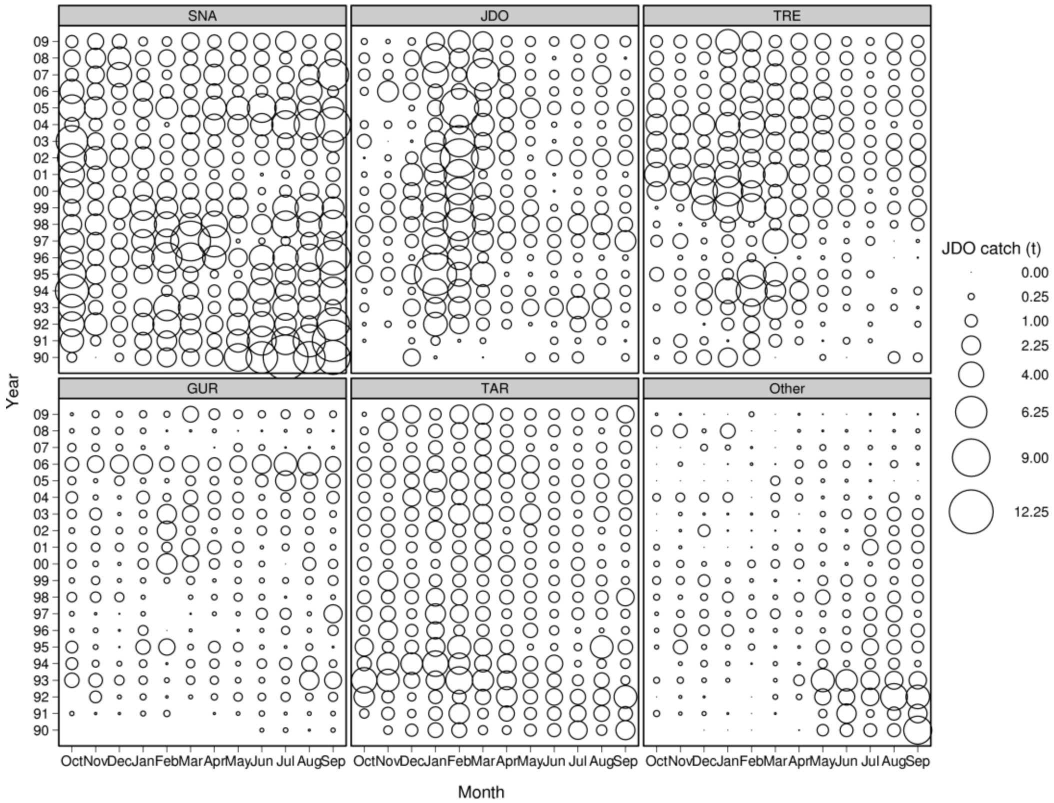

Figure 15: Comparison of the seasonal distribution of bottom trawl John dory catches for the five main target fisheries taking JDO 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 11.

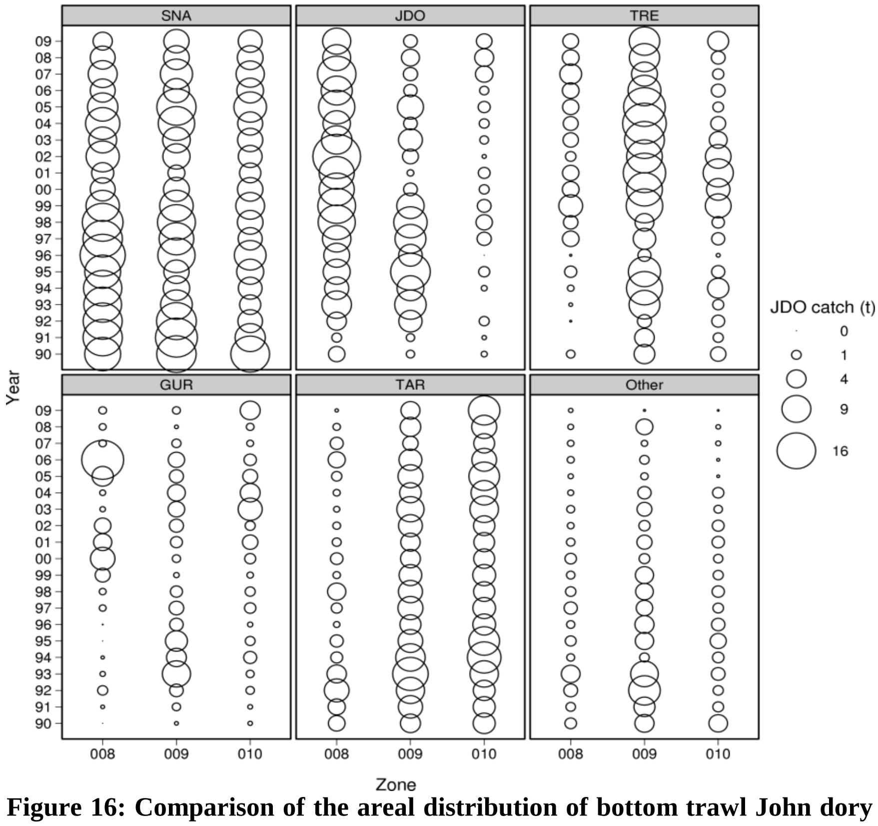

Figure 16: Comparison of the areal distribution of bottom trawl John dory catches among Statistical Areas for the five main target fisheries taking JDO 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 1

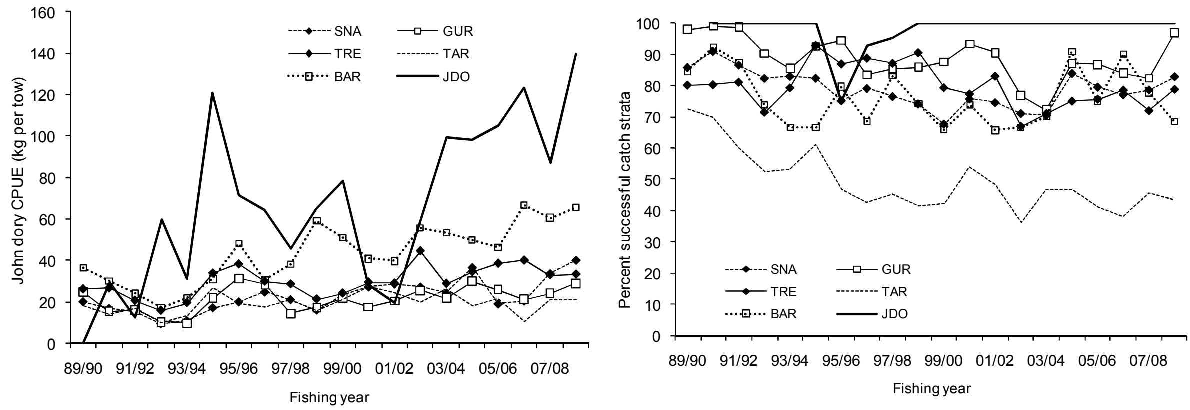

Figure 17: Unstandardised CPUE (kg/tow) and percentage successful strata for John dory in the main target fisheries using single bottom trawl tows in the Bay of Plenty substock of JDO 1. All forms and statistical areas combined.

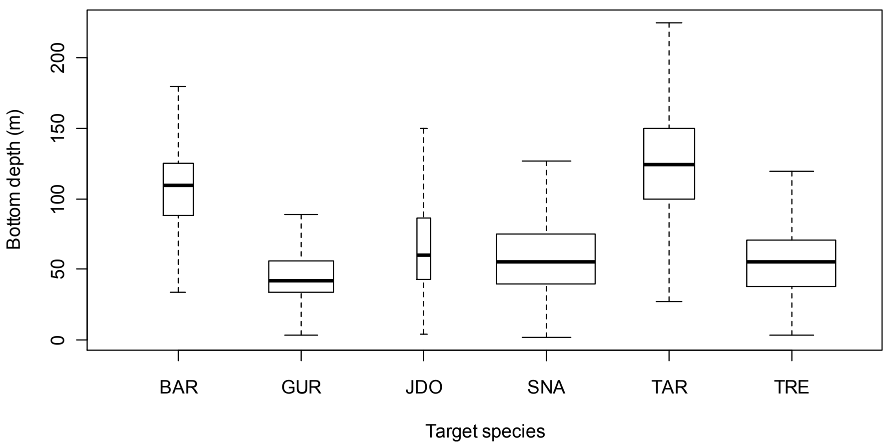

Figure 18: Box plot distributions (median and interquartiles) of bottom depth from TCEPR or TCE records of the single bottom trawl method for the main six target species where a catch of John dory was reported (positive tows). All years and statistical areas for the Bay of Plenty substock combined. The width of the boxes is proportionate to the number of records.

3.4.2 Bay of Plenty Danish seine

Danish seine in this substock takes small amounts of John dory in each year (up to about 40 t) mainly as a bycatch of sets targeted at snapper or gurnard. John dory is a part of the catch of almost all sets (about 90% of strata) at average annual rates of 10–40 kg per set, but there is very little targeting of John dory (Table 9).

John dory is taken by Danish seine almost equally from the three inshore Statistical Areas and with little evidence of seasonality (Figure 19, Figure 20), but considerable shifts over time in the relative importance of the main target species.

Most Danish seine is reported on CELR and there is little depth information available, but catch and encounter rates for John dory are similar between the main target fisheries (Figure 21).

Table 9: Distribution of Danish seine caught John dory by target species (snapper, gurnard, John dory, trevally, tarakihi, or other) and by fishing year for the Bay of Plenty substock of JDO 1 in tonnes and percentage. Catches are scaled up to the annual QMS catch (Table 1). 0, less than 0.5 tonne. Percentages sum to 100 by year.

							Bay of Plenty Danish seine					
Fishing	Target species (t)						Target species (%)					
year	SNA	GUR	JDO	TRE	TAR	Other	SNA	GUR	JDO	TRE	TAR	Other
89/90	6	0	-	-	-	0	94	6	0	0	0	0
90/91	6	1	0	0	0	0	87	9	1	1	1	0
91/92	13	2	0		0	0	86	13	0	0	1	0
92/93	9	8	1	0	0	0	50	44	5	0	0	1
93/94	14	11	1	0	-	0	54	41	3	0	0	2
94/95	31	10	1	-	0	0	73	24	2	0	1	1
95/96	17	5	3	0	0	0	66	20	11	0	0	2
96/97	11	8	4	0	0	0	44	34	17	1	1	2
97/98	10	20	6	0	0	1	26	53	17	0	1	2
98/99	6	14	6	0	1	0	21	52	22	2	3	0
99/00	4	10	1	1	1	0	23	57	8	9	3	0
00/01	3	4	1	0	0	0	30	47	14	3	6	0
01/02	6	7	1	0	1	0	40	46	6	2	7	0
02/03	13	9	1	0	0	0	54	41	4	0	1	0
03/04	11	7	0	0	0	0	60	37	1	0	1	0
04/05	16	6	-	-	0	0	72	28	0	0	0	0
05/06	12	10	0	0	0	0	54	43	2	1	1	0
06/07	10	4	1	0	0	0	67	27	5	0	1	0
07/08	18	1	4	0	0	0	79	4	17	0	0	0
08/09	18	8	-	-	1	0	68	30	0	0	2	0

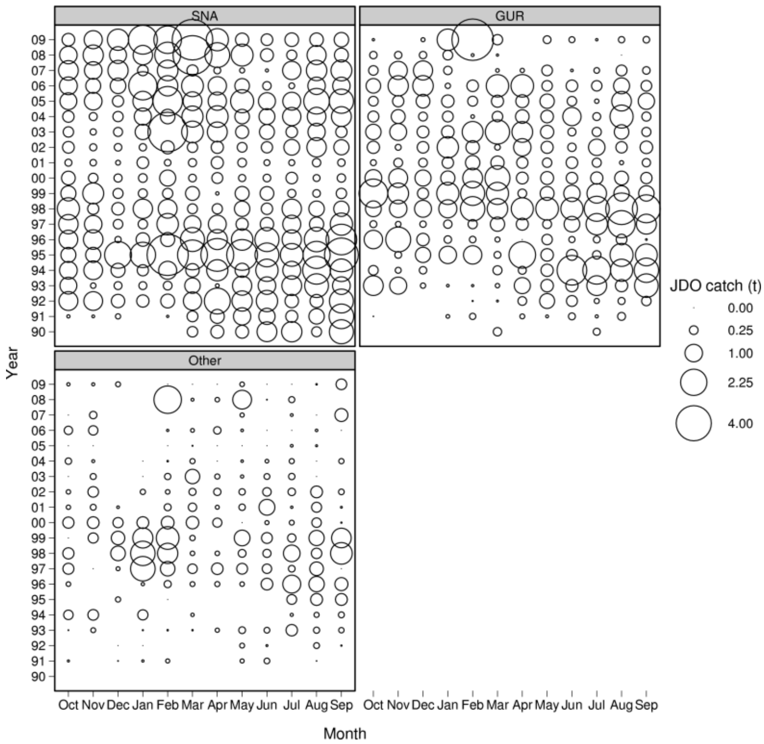

Figure 19: Comparison of the seasonal distribution of Danish seine John dory catches for the two main target fisheries taking JDO 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by month, target species, summing to the annual totals given in Table 12.

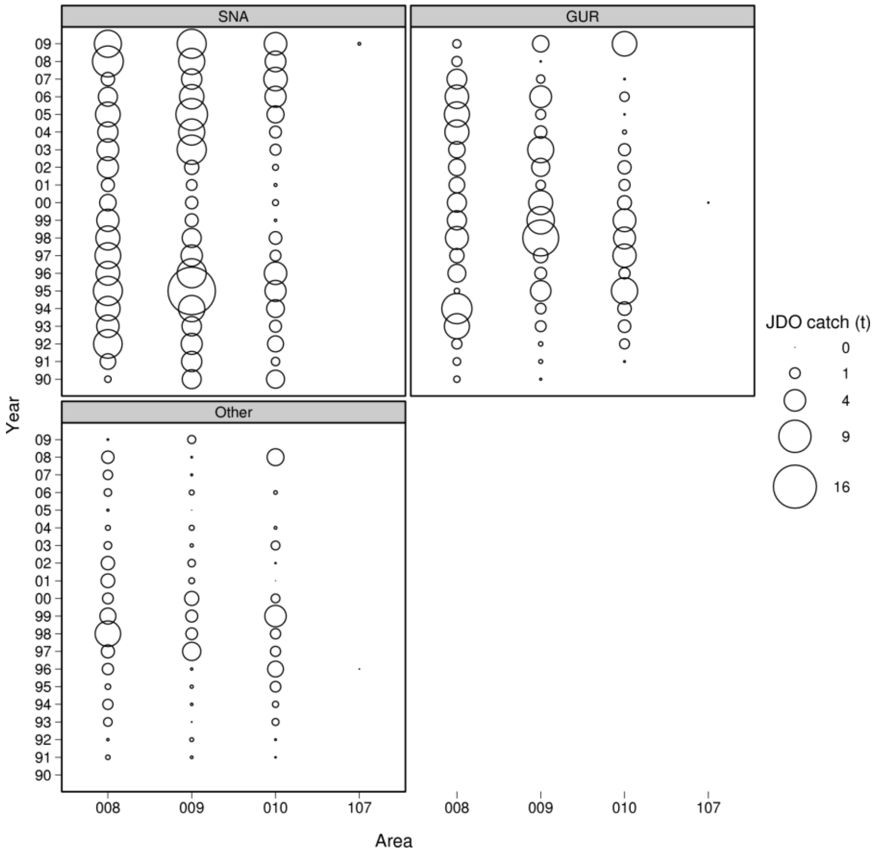

Figure 20: Comparison of the areal distribution of Danish seine John dory catches among statistical areas for the two main target fisheries taking JDO 1 from the Bay of Plenty substock area, by fishing year. Circle areas are proportional to the catch totals by statistical area, and target species, summing to the annual totals given in Table 12.

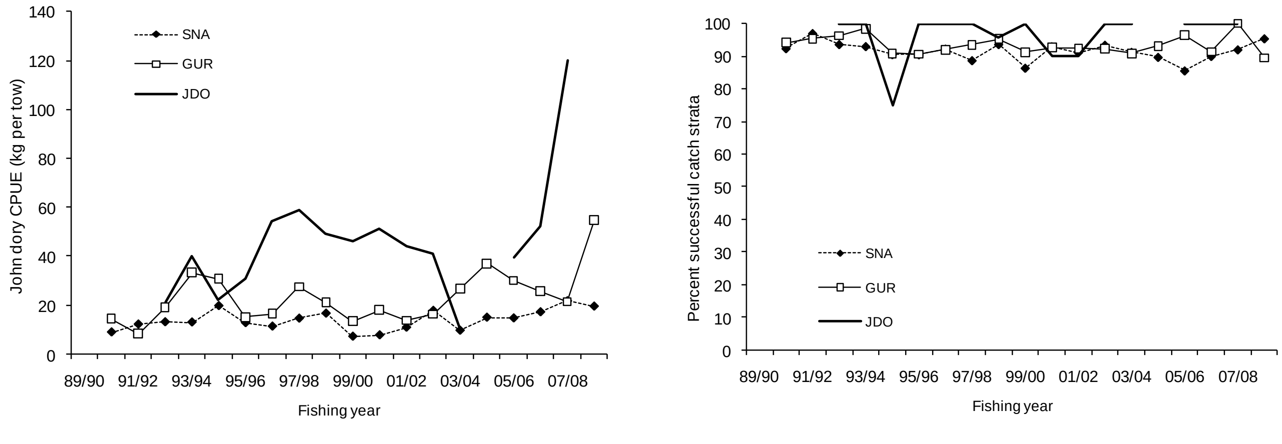

Figure 21: Unstandardised CPUE (kg/tow) and percentage unsuccessful tows for John dory in the main target fisheries using Danish seine in the Bay of Plenty substock of JDO 1.

3.5 Standardised CPUE analysis

3.5.1 Fishery definitions and models fitted

The fisheries selected as potentially adequate in which to monitor JDO 1 are referred to by substock and fishing gear, and then by some descriptor of target (MIX or TARG), formtype (TCE), or subarea (KM or NMB). The same identifiers refer to the models used to standardise CPUE in those fisheries. A brief summary of the thirteen fisheries examined is given in Table 10. All analyses have been presented in detail to the Stock Assessment Working group, but only the preferred series (bolded in Table 12) are described in detail in this report.

Lognormal and binomial models were fitted to all bycatch fishery–datasets, and combined using the method of Vignaux (1994). The binomial series generally supported the trends in the lognormal series and the combined series did not differ markedly from the lognormal so that they were not considered to be additionally informative. It should be remembered that catch effort in CELR format is effectively amalgamated data, and much of the zero catch information is already incorporated into the catch per day so that the binomial and combined models might be expected to be less informative for the CELR datasets than for the TCEPR datasets.

For each substock area there is an adequate time series of bottom trawl targeted at a mix of species and reported on CELR, TCEPR, or TCE forms. These BT_MIX analyses are done on landed catch allocated to effort that has been amalgamated to trip-stratum. The lognormal models of positive catches yielded the series preferred by the Northern Inshore Working Group for monitoring the abundance of John dory in each of the three sub stock areas.

Other models fitted during the exploratory work done for this project were presented to a meeting of the Working Group and described in a Progress Report for this project. Comparisons of the annual indices with the preferred series are summarised here for the benefit of future researchers, but without any detailed diagnostics. They include the following;

- Comparisons with Danish seine in the same substock areas; east and Bay of Plenty substocks only.

- Utility of target only fisheries; For bottom trawl in the east coast and Bay of Plenty substocks; for Danish seine in the east coast substock..

- Possible substocks on the west coast; The bottom trawl dataset for the west coast substock, was further split into Ninety Mile Beach (statistical areas 047 and 048) and Kaipara/Manakau (areas 041 – 046) and the annual indices compared for any contrast in trends.

- Potential bias from systematic shift in formtype; For bottom trawl in each substock a shortened series of catch effort based on TCEPR/TCE form only was standardised in original resolution, and compared to the MIX series for the years they have in common.

Table 10: Description of the fisheries defined and the datasets collated for standardised CPUE analyses. The preferred series are bolded and described in detail in the results. Comparisons with the other series are described in a later section.

Substock	Areas	Gear	Target	Formtype	Resolution	Dataset label
West	**040-048**	**BT**	**SNA,JDO,TRE,TAR,GUR,BAR**	**Combined**	**trip-strata**	**W_BT_MIX**
“	“	“	SNA,JDO,TRE,TAR,GUR,BAR	TCE/TCEPR	Tow-by-tow	W_BT_TCE
“	047-048	“	SNA,JDO,TRE,TAR,GUR,BAR	Combined	trip-strata	W_BT_NMB
“	041-042	“				
	045-047		SNA,JDO,TRE,TAR,GUR,BAR	Combined	trip-strata	W_BT_KM
East	**001-007**	**BT**	**SNA,JDO,TRE,TAR,GUR,BAR**	**Combined**	**trip-strata**	**E_BT_MIX**
“	“	“	SNA,JDO,TRE,TAR,GUR,BAR	TCE/TCEPR	Tow-by-tow	E_BT_TCE
“	“	“	JDO	Combined	trip-strata	E_BT_TARG
East	“	DS	SNA,JDO,GUR	Combined	trip-strata	E_DS_MIX
“	“	“	JDO	Combined	trip-strata	E_DS_TARG
BoP	**008-010**	**BT**	**SNA,JDO,TRE,TAR,GUR**	**Combined**	**trip-strata**	**BP_BT_MIX**
“	“	“	SNA,JDO,TRE,TAR,GUR	TCE/TCEPR	Tow-by-tow	BP_BT_TCE
“	“	“	JDO	Combined	trip-strata	BP_BT_TARG
BoP	“	DS	JDO,GUR,SNA	Combined	trip-strata	BP_DS_MIX

3.5.2 Model selection and model fits

The final lognormal models for each substock are described in Table 11–15 and the datasets to which they were fit are described in Tables B1–B3. Fits of the models to the lognormal assumption were examined by plotting the residuals (Figure C1, Figure C3). The fit of the data to the lognormal assumption is reasonable for each model, though the standardised residuals display slight skewing and departure in the extreme ends of the distribution.

The lognormal models explained 43% (WC), 57% (EC), and 43% (BP) of the deviance in log catch. Fishing year was forced as the first variable in each case to facilitate the extraction of canonical year effects, and explained 1–5 % of the deviance. Effort was included as the factor with greatest explanatory power in all three models, with log duration the preferred measure in both the west and east coast fisheries and the number of tows selected into the Bay of Plenty model. Vessel entered third in the west coast model followed by target species, and in the opposite order in the east coast and Bay of Plenty models. There was no significant seasonal effect in the west coast fishery, but month entered both the east coast and Bay of Plenty models as the last variable. Statistical area did not have significant explanatory power in any of the bottom trawl fisheries, though target species was possibly an effective proxy, accounting for any variance among areas.

The cumulative effect as each variable was added to the lognormal model is shown in Figures 22–24. These plots emphasise the relative importance of each variable in moving the standardised series away from the unstandardised and contributing to the final trend. An understanding of why is best gained by examining the influence plots (Jiang & Bentley 2008) in Appendix D. They illustrate the combined effect of (a) the expected log catch for each level of the variable (model coefficients) and (b) the distribution of the levels of the variable in each year, and therefore describe the influence that the variable has on the unstandardised CPUE which must be accounted for by the standardisation.

West coast substock

Log duration enters the W_BT_MIX model with the most explanatory power, explaining 27% of the deviance in log catch, but without markedly changing the annual indices from their annual geometric means. Although there is a positive relation between catch and effort, shifts in effort have varied in direction from year to year without trend so that the adjustments made by the model do not change the overall trajectory.

Vessel enters the model after log duration, explaining a further 10% of the deviance, and dramatically lifts the first three points and lowers the series in the last six years, effectively changing the trajectory from one that increases to one that declines overall. Changes in the core fleet have had a strongly positive influence on observed CPUE because poorer vessels have dropped out of the fishery and better performing vessels have entered the fishery over time. The model adjusts the earlier CPUE upwards, and more recent CPUE downwards to account for the improvements in the fleet.

Target enters the model with little explanatory power, and without further altering the annual indices discernibly. Shifts in targeting have had a positive influence on observed CPUE overall, but mainly to adjust for increased targeting of trevally, which is predicted to have slightly higher than average catches of John dory.

Table 11: Summary of final lognormal model for the W_BT_MIX fishery based on the vessel selection criteria of at least ten trips per year in at least three or more fishing years. Independent variables are listed in the order of acceptance to the model. AIC, Akaike Information Criterion; R^2, proportion of deviance explained at each step and in the final model (bold); Final, Whether or not variable was included in final model; Fishing year was forced as the first variable.

Lognormal Term	DF	Deviance	AIC	R^2	Final
None	0	22 194	42 897	0.0000	
fyear	20	21 132	42 317	0.0478	*
poly(log(duration) 3)	23	15 291	38 247	0.3110	*
vessel	54	12 974	36 238	0.4154	*
target	59	12 735	36 013	**0.4262**	*
month	70	12 553	35 854	0.4344	
zone	74	12 414	35 721	0.4407	
poly(log(num) 3)	77	12 387	35 700	0.4419	

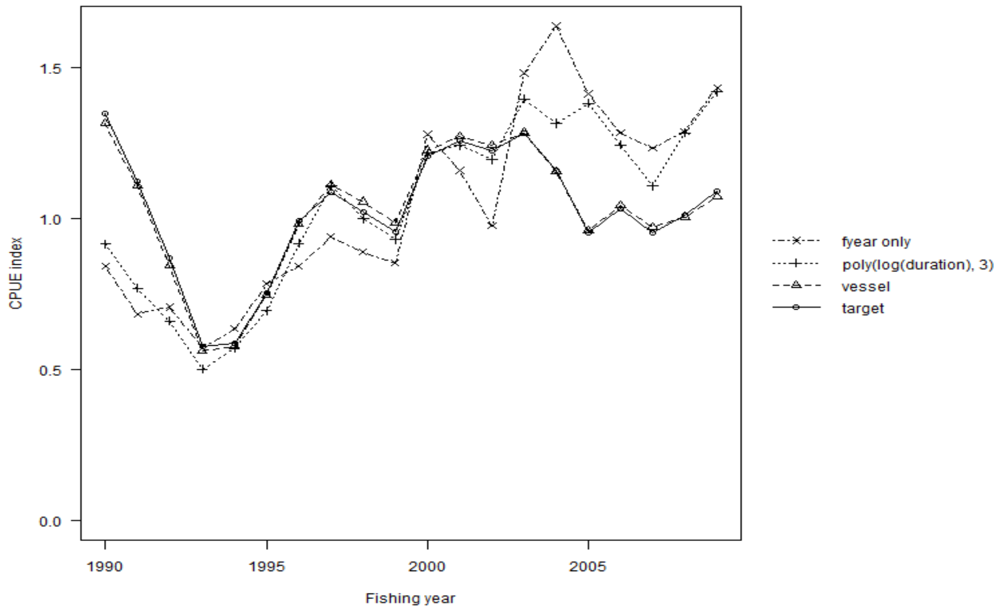

Figure 22: Annual indices from the W_BT_MIX lognormal model at each step in the variable selection process.

East coast substock

In the E_BT_MIX model, the annual geometric means (fyear only) describe a trajectory that declines through the study period, and the inclusion of log duration drops the early points and lifts the most recent points effectively changing the trajectory to one that increases overall. The subsequent inclusion of target species and vessel, each moderate those shifts somewhat without changing the main features of the series (a peak in 1994–95 and a low in 2000–01), so that the final model describes a flat trajectory overall,

The influence of shifts in log duration on observed catches is predicted to have been negative overall, largely because of a decline in total duration during the first decade, and another sharp decline in the early 2000s. The model adjusts the series upwards in those years to account for fewer hours towed. In contrast, a trend away from snapper and towards more targeting of John dory is predicted to have increased catches, and changes in the core fleet towards better performing vessels is also credited with increasing catches. The adjustments made by the model to account for these shifts therefore move the series back towards its original trajectory such that the final series is effectively flat. The influence of months fished varies from year to year without trend and with little influence.

Table 12: Summary of final lognormal model for the E_BT_MIX fishery based on the vessel selection criteria of at least 10 trips per year in at least five or more fishing years. See caption to Table 11 for details.

Lognormal Term	DF	Deviance	AIC	R^2	Final
None	0	23 730	52 153	0.0000	
fyear	20	23 371	51 944	0.0151	*
poly(log(duration) 3)	23	14 694	44 434	0.3808	*
target	28	11 901	41 029	0.4985	*
vessel	65	10 802	39 534	0.5448	*
month	76	10 191	38 613	**0.570**6	*
poly(log(num) 3)	79	10 017	38 340	0.5779	
zone	83	9 887	38 137	0.5834	

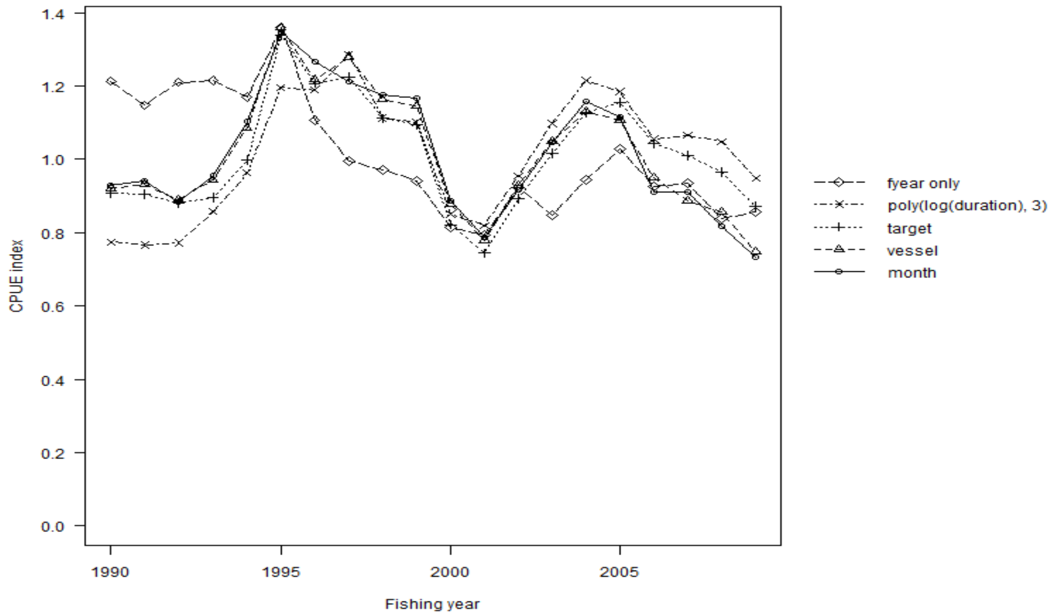

Figure 23: Annual indices from the E_BT_MIX lognormal model at each step in the variable selection process.

Bay of Plenty substock

There is less effect of standardisation in the Bay of Plenty model, but the inclusion of effort (log tows), removes an initial decline and lifts some recent points. The inclusion of target species as the next most important variable does not change the series much, but when vessel enters the model as the third variable, it moderates the dip in the mid 1990s and drops recent points, neutralising some of the effect that effort had. The final series declines overall but not from so high a level. A shift towards fewer tows per stratum is predicted to have caused much of the decline observed in CPUE over the first seven years of the study period, and the adjustment for this trend lessens the initial decline. The influence of changes in targeting is not great, but is positive overall, and improvements in the core fleet are also predicted to have improved catches. The period of poor performing vessels in the mid 1990s, and the improvement in the fleet since then, can be clearly seen.

Table 13: Summary of final lognormal and binomial models for the BP_BT_MIX fishery based on the vessel selection criteria of at least 5 trips per year in at least five or more fishing years. See caption to Table 12 for details.

Lognormal Term	DF	Deviance	AIC	R2	Final
None	0	17 820	39 860	0.0000	
fyear	20	17 257	39 497	0.0316	*
poly(log(num) 3)	23	13 044	36 011	0.2680	*
target	27	11 523	34 472	0.3533	*
vessel	65	10 458	33 338	0.4131	*
month	76	10 145	32 980	**0.4307**	*
poly(log(duration) 3)	79	10 022	32 834	0.4376	
zone	81	9 952	32 750	0.4416	

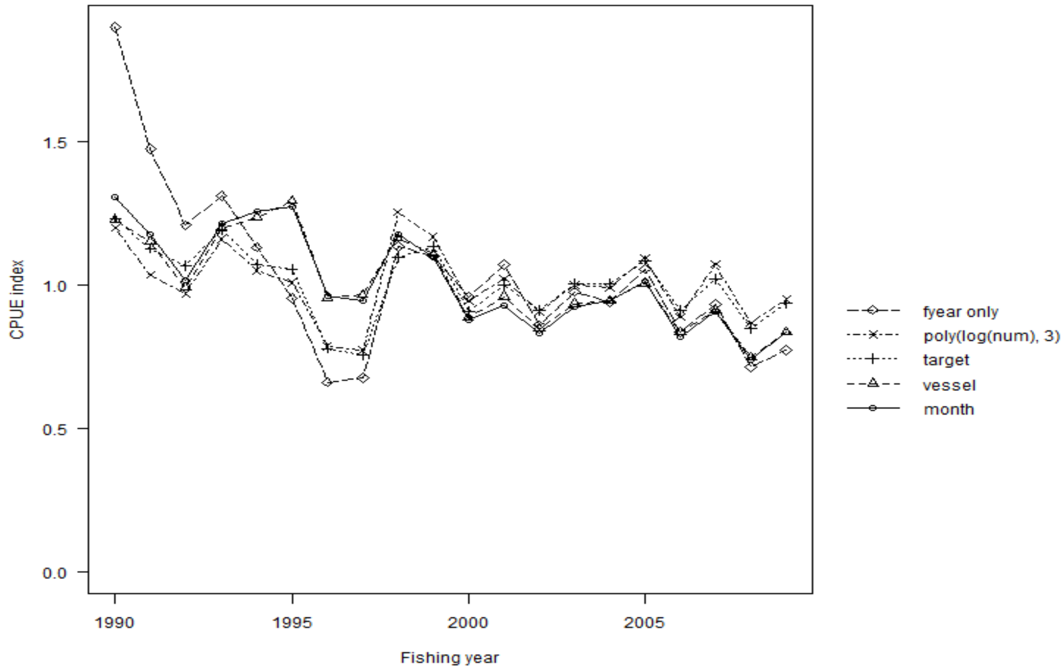

Figure 24: Annual indices from the BP_BT_MIX lognormal model at each step in the variable selection process.

3.5.3 Trends in model year effects

The year effects from lognormal models for each fishery are plotted in Figures 25, 26, and 27. They show a) the effect of core vessel selection on unstandardised CPUE, b) the effect of standardisation of catch rate in successful tows, and c) the effect of combining the binomial and lognormal indices. The unstandardised and the standardised CPUE indices with 95% confidence intervals are tabled in Appendix E.

For each fishery, the arithmetic CPUE for core vessels tracks similarly to that from the overall fleet and gives no concern about the representativeness of the core fleet selected. The trends in the standardised CPUE indices are well determined in that there are small confidence intervals around each point and the changes in direction are sustained over several consecutive years rather than manifesting as interannual variance. The effect of standardising the probability of capture (binomial model) was not great in any fishery, and the effect of combining lognormal and binomial indices was likewise slight.

The effect of standardisation of catch rates was marked in each fishery, in each case lifting early points and dropping recent points compared with the unstandardised CPUE and changing the trajectory from increasing (west and east substocks) or flat (Bay of Plenty substock), to one that declines overall. Each series of standardised CPUE therefore shows a less optimistic trend than the unstandardised series, as the result of the models accounted for a trend towards shorter or fewer tows, and improved performance in the core fleets.

In the west coast substock the BT_MIX series declines over three years from its highest level in 1989–90 to reach its lowest level in 1992–93, then recovers over ten years to near its original level in 2002–03. It has fallen since then back to about the mean for the series where it has been relatively stable over the five most recent years (Figure 25).

In the east coast substock the BT_MIX series resembles the pattern of landings of JDO 1, increasing from below the mean for the series in 1989–90 to reach its highest level in 1994–95. It has generally declined since then except that there was a pronounced dip and recovery in the early 2000s. The 2008–09 point is the lowest for the series and follows five consecutive years of decline (Figure 26).

The Bay of Plenty's BT_MIX series has generally declined over the period, without the large cycles of change in abundance that are the main features in the other two substocks (Figure 27).

A comparison with the indices from the previous project is given in Appendix F. In those plots the current series have been rescaled relative to the years in common. Differences will be due to slightly different fishery definitions and core fleet selections used this study. There is good agreement with the previous series for the east coast, but for the west substock the magnitude of the trends is greater in this study than was reported by Fu et al. (2008).

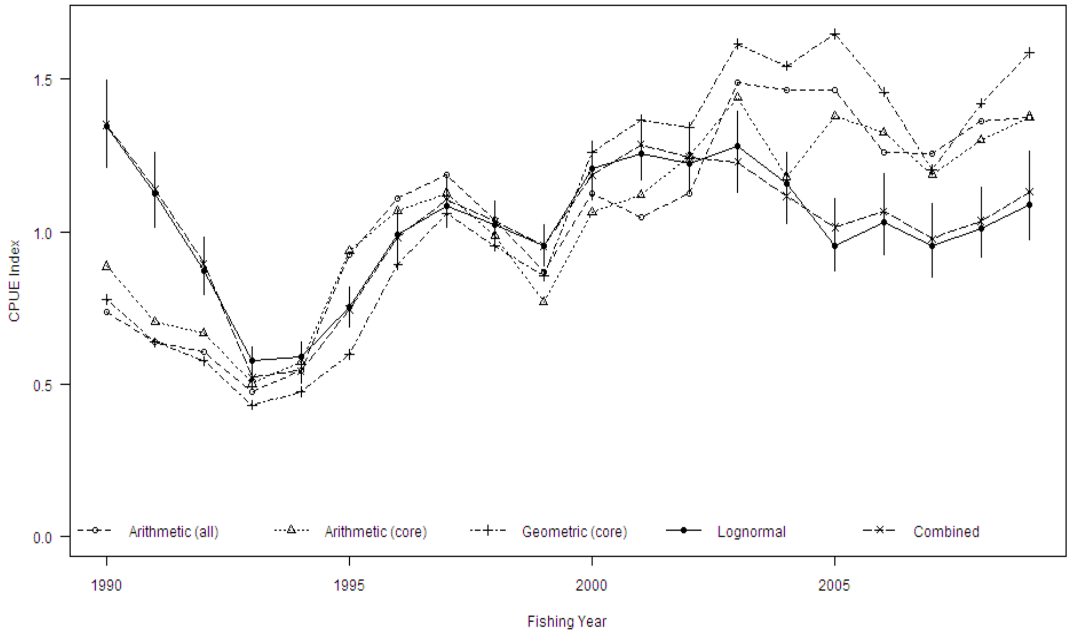

Figure 25: The effect of core vessel selection, lognormal standardisation, and combining of lognormal and binomial indices on the raw CPUE of John dory in the W_BT_MIX fishery. The year effects from the lognormal model are shown ±2 SE. Unstandardised (arithmetic) CPUE is based on kg/tow.

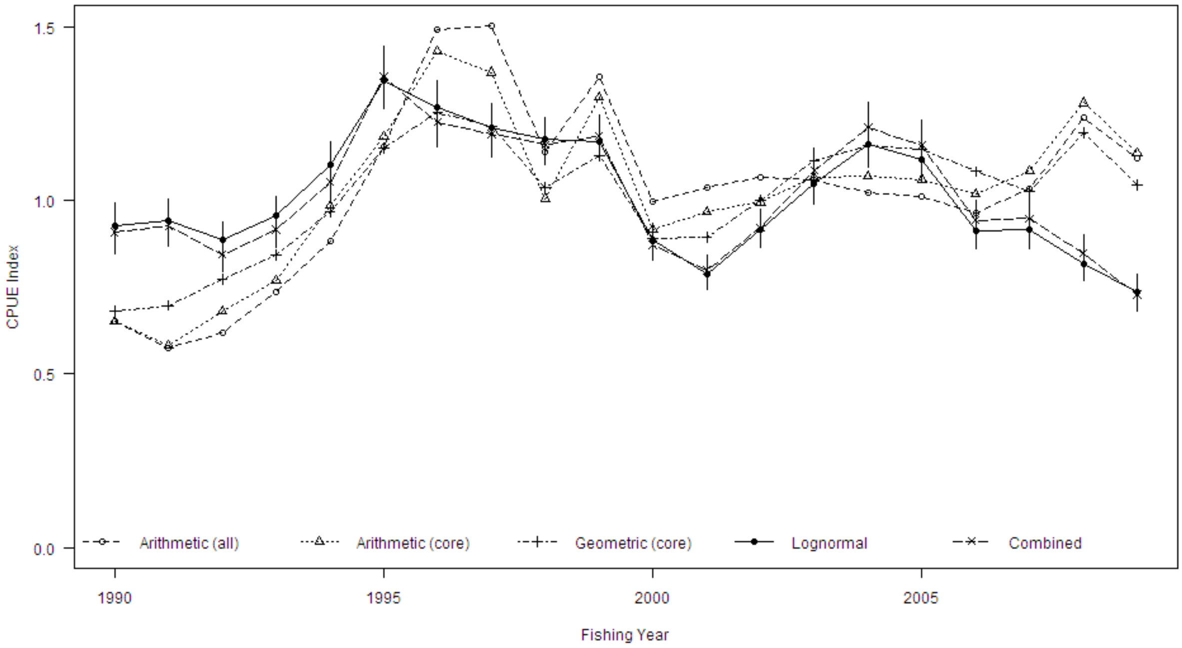

Figure 26: The effect of core vessel selection, lognormal standardisation, and combining of lognormal and binomial indices on the raw CPUE of John dory in the E_BT_MIX fishery. The year effects from the lognormal model are shown ±2 SE. Unstandardised (arithmetic) CPUE is based on kg/tow.

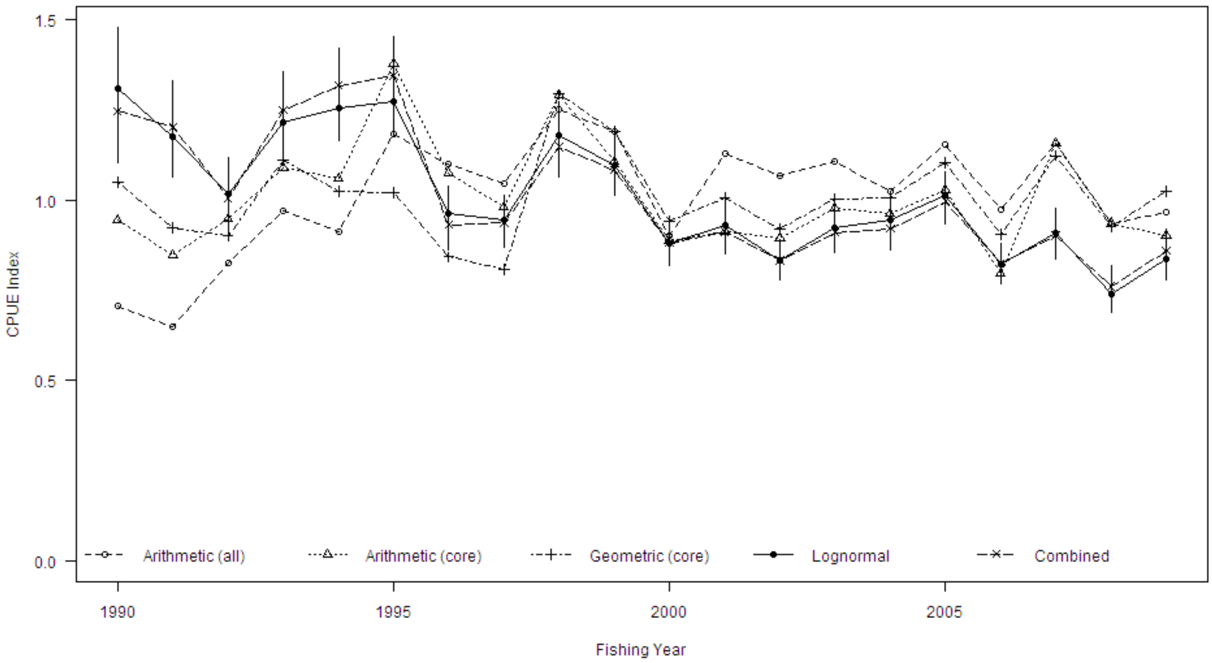

Figure 27: The effect of core vessel selection, lognormal standardisation, and combining of lognormal and binomial indices on the raw CPUE of John dory in the BP_BT_MIX fishery. The year effects from the lognormal model are shown ±2 SE. Unstandardised (arithmetic) CPUE is based on kg/tow.

3.5.4 Comparisons with other models

The following analyses were considered by the Stock Assessment Working Group and subsequently dropped in favour of the BT_MIX series in each of the three substocks, mainly because they were considered to be less representative of the Fishstock, as demonstrated by exaggerated peaks and troughs, and also to suffer from the lack of precision expected from smaller datasets. It is understandable that a target fishery for a species that is distributed sparsely and erratically might yield a spiky index as areas of higher local abundance are exploited opportunistically, whereas a well-reported bycatch from an extensive bottom trawl fishery is more likely to be an appropriate (passive) sampling method. The following comparisons are included here for completeness, and for the benefit of future researchers, but without any detailed diagnostics.

West coast substock

Annual indices from lognormal models of two sub areas of JDO 1 W are overlaid for comparison in

Figure 28. They show that the overall series is dominated by trends in the Kaipara/Manakau part of the fishery (Statistical Areas 042, 045, and 046; the actual harbours 043 and 044 are closed to trawl), but that the series produced for the northern areas described as Ninety-mile beach (Statistical Areas 047 and 048) is not dissimilar, and supports the analysis of CPUE at the QMA level for this substock of John dory.

There is very little targeting of John dory by bottom trawl, and likewise, very little Danish seine catch of John dory in this substock (although a developing fishery using this gear type should be re-examined when the time series is longer), limiting the comparisons that can be made among alternative fisheries.

A shorter series based only on tow-by-tow data was produced and is overlaid for comparison with the BT_MIX series in Figure 29. It confirms the large magnitude cycles that are a feature of that series. There is divergence in the final year which is curious because all catch effort in the last two years are reported in tow-by-tow format due to the introduction of the new TCE form, so that we might expect there to be little difference between the two datasets in those years. Nevertheless, there is a different core fleet selection done for each analysis, and although it uses the same definition (minimum of 10 trips per year in at least 3 years) it results in a slightly different set of vessels because of the shorter time series.

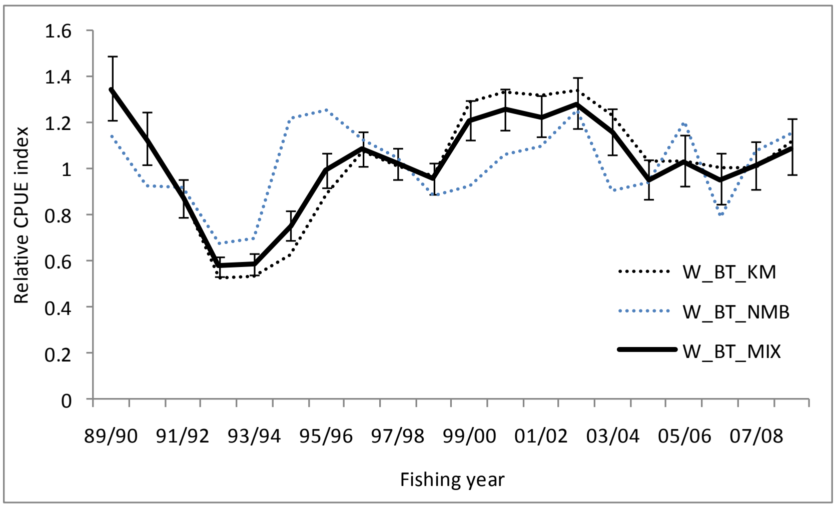

Figure 28: Comparison of annual indices from lognormal models of the west coast bottom trawl fishery W_BT_MIX (±2 SE) and two subareas; (KM), Kaipara-Manakau (Areas 042, 045, 046); (NMB), Ninety mile beach (Areas 047 & 048).

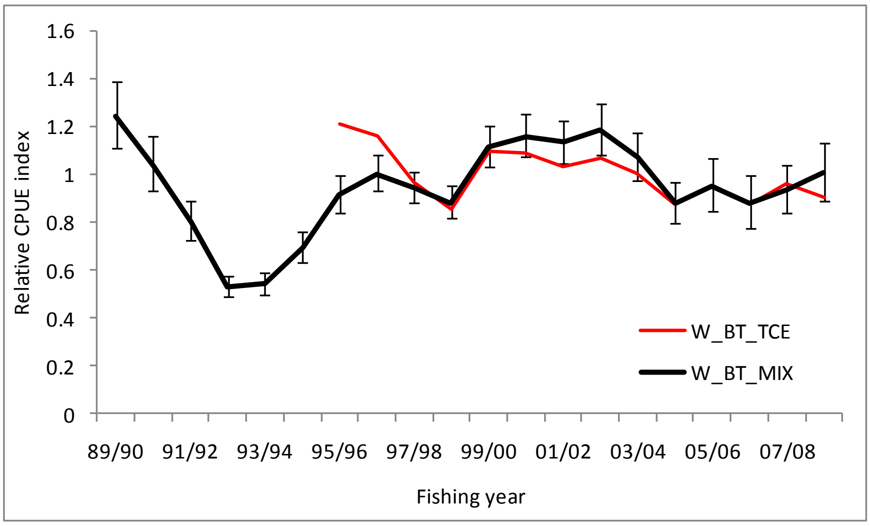

Figure 29: Comparison of annual indices from lognormal models of the west coast bottom trawl fishery W_BT_MIX (±2 SE) and a shorter time series that uses only tow-by-tow resolution data W_BT_TCE (recorded on TCEPR or TCER forms). W_BT_MIX series rescaled relative to the geometric mean for the years in common.

East coast substock

In the east coast substock there is a well-determined target bottom trawl fishery, in that it operates seasonally and is largely confined to a single Statistical Area. A series of standardised CPUE from a lognormal model of that fishery was produced and is overlaid for comparison with the BT_MIX series in Figure 30.

There is very good agreement between them with the only point of difference being the greater magnitude of the peak in 1995–96 in the target fishery. There is also considerable Danish seine catch of John dory including targeted catch, and alternative analyses done for Danish seine targeted at gurnard, snapper or John dory and for targeted Danish seine produced series that are compared in Figure 31. They resemble the BT_MIX series only in that the lows in the early 1990s and in the early 2000s coincide, and in describing a steep decline in the most recent three years, but the first peak seen in the trawl indices during the mid 1990s is not evident, while the second peak is a year or two later and considerably greater than that seen in the trawl series.

A shorter series based only on tow-by-tow data was produced and is overlaid for comparison with the BT_MIX series in Figure 32.Figure 29 There are some differences in the later years when there are no CELR data to differentiate the two datasets, which will be due to the different core fleets selected. The TCE series confirms the large magnitude cycles that are a feature of the BT_MIX series and shows overall the same trends thereby allaying concerns about combining data in the different formats.

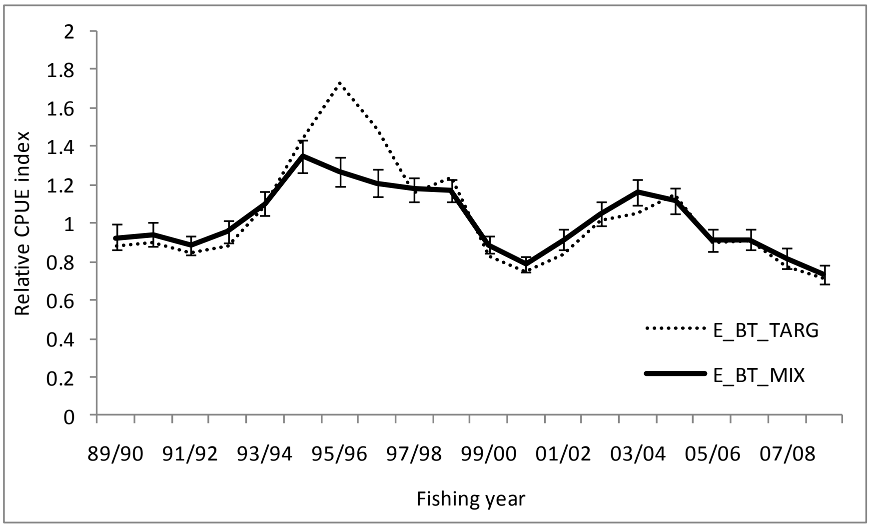

Figure 30: Comparison of annual indices from lognormal models of the east coast bottom trawl fishery E_BT_MIX (±2 SE) and from the subset of those tows that targeted John dory E_BT_TARG.

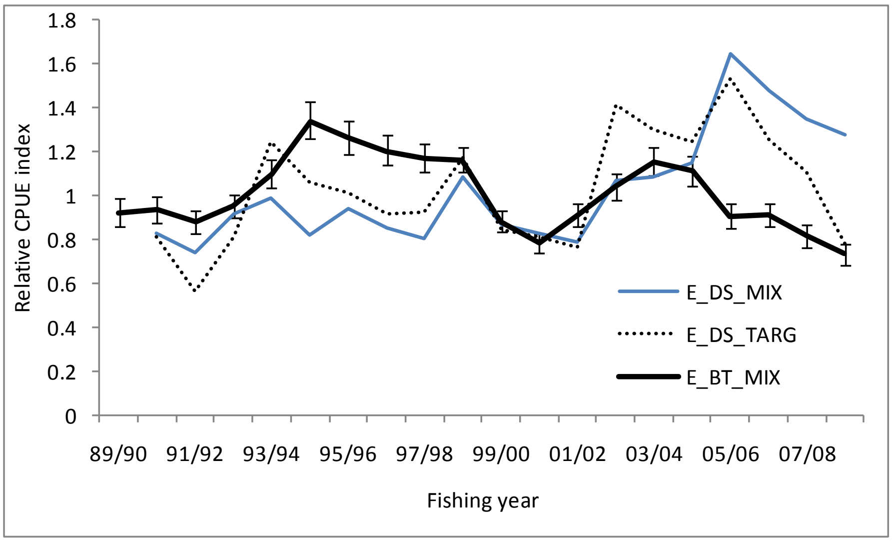

Figure 31: Comparison of annual indices from lognormal models of the east coast bottom trawl fishery E_BT_MIX (±2 SE), the east coast Danish seine fishery, E_DS_MIX (SNA, JDO, GUR target), and from the subset of those sets that targeted John dory, E_DS_TARG.

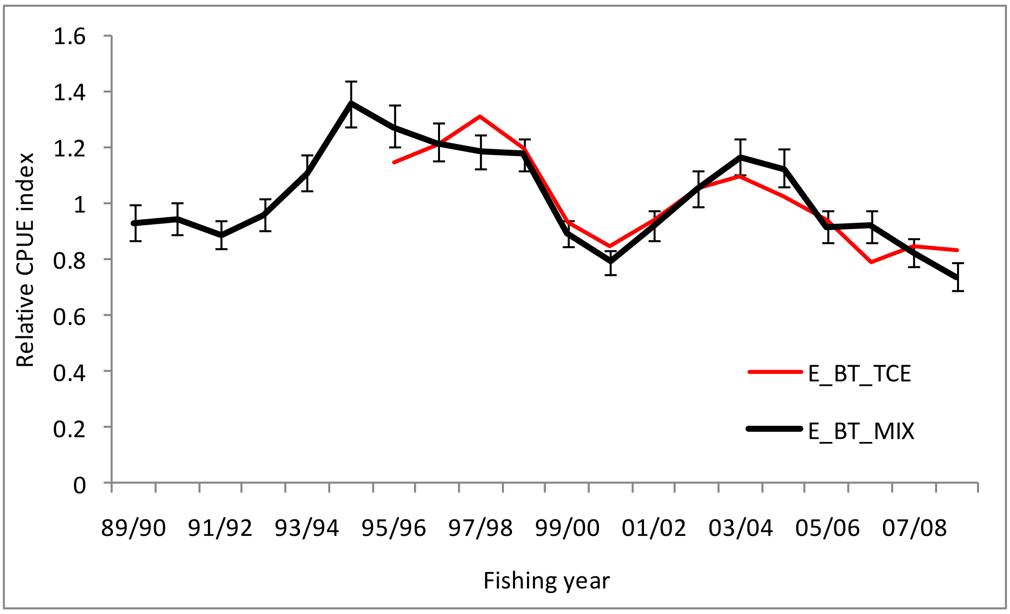

Figure 32: Comparison of annual indices from lognormal models of the east coast bottom trawl fishery E_BT_MIX (±2 SE) and a shorter time series that uses only tow-by-tow resolution data E_BT_TCE (recorded on TCEPR or TCER forms). W_BT_MIX series rescaled relative to the geometric mean for the years in common.

Bay of Plenty substock

In the Bay of Plenty substock, there is some targeting of John dory by bottom trawl, but it is not well delineated as a target fishery, in that there are no obvious differences in season or area between target and bycatch of John dory by this method. It is likely that sets in this mixed species fishery are described as target tows on the basis of catch rather than intention. The indices from the target fishery are not dissimilar to those from the mixed target fishery, but with exaggerated peaks and troughs (Figure 33). This may be the result of using smaller data sets or because JDO are often targeted in restricted spatial areas and may therefore produce hypo-stable indices. Experience with monitoring other inshore species indicates that mixed species analyses tend to produce more stable and plausible CPUE indices.

A series produced for Danish seine likewise resembled the BT_MIX series but with exaggerated peaks and troughs. Despite not being a target fishery, it resembles the BT_TARG series, probably for similar reasons (Figure 34).

Comparisons were made between the "rolled up" series which combined all the form types with the series estimated from the disaggregated tow-by-tow data in each sub-area. These comparisons showed strong similarity between the two sets of series in the period of overlap, indicating that the aggregation had not affected the overall estimated trend (Figure 35).

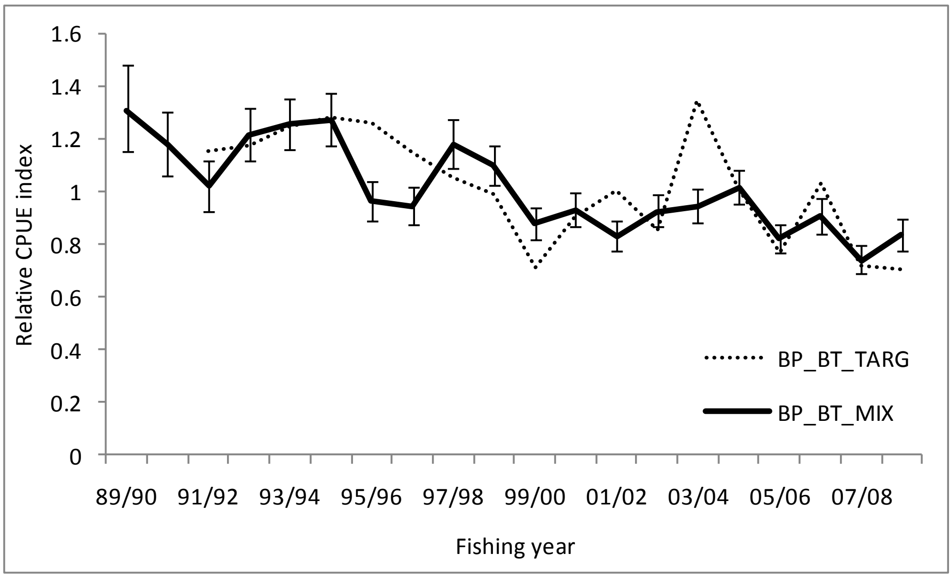

Figure 33: Comparison of annual indices from lognormal models of the Bay of Plenty bottom trawl fishery, BP_BT_MIX (±2 SE) and from the subset of those tows that targeted John dory, BP_BT_TARG.

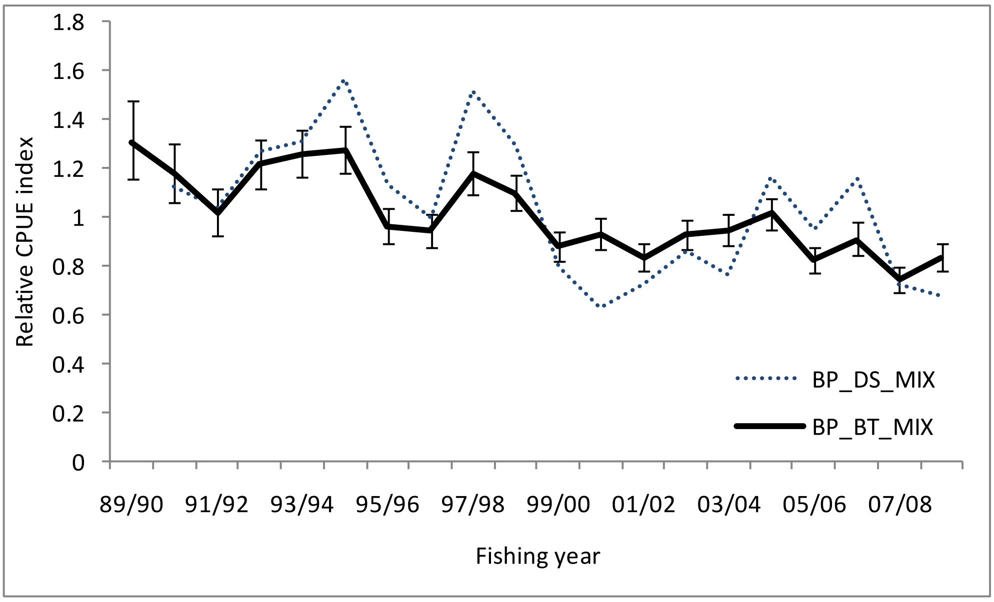

Figure 34: Comparison of annual indices from lognormal models of the Bay of Plenty bottom trawl fishery BP_BT_MIX (±2 SE) and the Bay of Plenty Danish seine fishery BP_DS_MIX (SNA, JDO, GUR target).

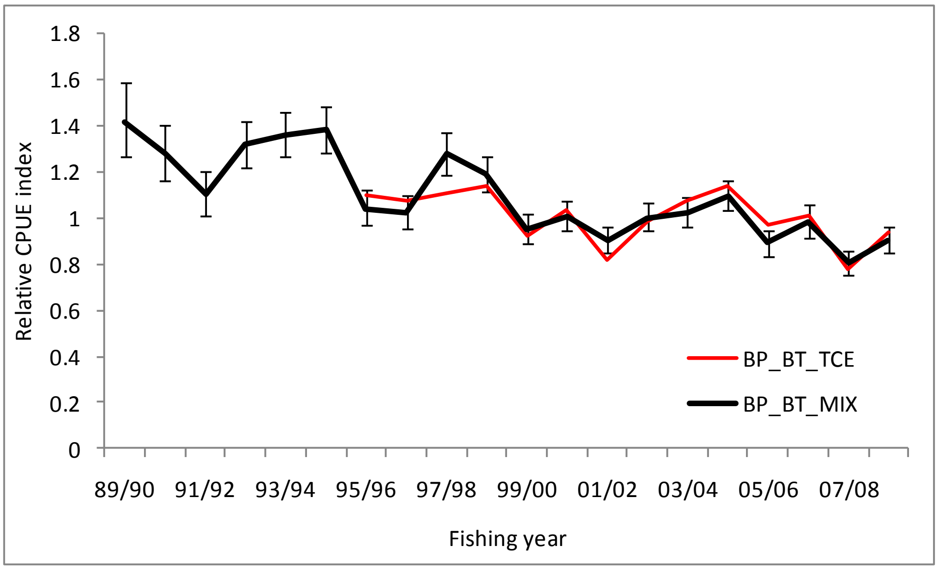

Figure 35: Comparison of annual indices from lognormal models of the Bay of Plenty bottom trawl fishery BP_BT_MIX (±2 SE) and a shorter time series that uses only tow-by-tow resolution data BP_BT_TCE (recorded on TCEPR or TCER forms). BP_BT_MIX series rescaled relative to the geometric mean for the years in common.

4 CONCLUSIONS

John dory is a short-lived, fast growing species and abundance is therefore likely to fluctuate widely with year class strength. It is caught as a bycatch in most bottom trawl tows targeted at the main inshore species, and the extensive nature of that fishery (both spatially and seasonally), makes it a potentially better sampling method for John dory than targeted effort. John dory is considered to have a patchy and erratic distribution, and target fishing can opportunistically exploit peaks in local abundance. Expansion of the definition of the fishery in which CPUE is monitored to include a wider range of target species appears to have improved the utility of the bottom trawl indices.

The trends in the standardised CPUE indices are well determined in that there are small confidence intervals around each point and the changes in direction are sustained over several consecutive years rather than manifesting as interannual variance and the diagnostics are acceptable. There is a marked effect of standardisation on each series of CPUE as the models adjust for trends in effort per stratum, and demonstrable improvement in the core fleets as well. Where target species is significant it has not had a marked effect on the annual indices and the debate about whether or not it should even be offered as a potential explanatory variable can perhaps be deferred.

Abundance in all three sub-stocks appears to be cyclical, probably in response to recruitment variation, and the trajectories describe several large changes in availability over the study period with a net gain on the west coast where John dory is only a by catch; effectively constrained by the TACC of snapper, and a net loss in both east coast substocks where it is also targeted. There is less evidence of large recruitment pulses in the Bay of Plenty.

The lognormal CPUE indices for JDO 1W depict a trend that reached its lowest point for the series in 1992–93. This was followed by a recovery almost to original levels over the following seven years, followed by a three year plateau at the new level. The series subsequently returned to about the mean of the series by 2004–05 and has been relatively stable since then. The lognormal CPUE indices for JDO 1E depict a trend with a pronounced cyclical pattern that has lows in the early 1990's and early 2000's and peaks in the middle of each decade. The index is currently at a low point. The lognormal CPUE indices for JDO 1BP depict a trend that shows more stability than the other two sub stocks and an overall decrease. It currently sits just below the mean for the series.

5 ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries as project JDO2009–03. Thanks to members of the Northern Inshore Fishery Assessment Working Group, particularly Paul Starr and Malcolm Francis, for methodology and helpful suggestions.

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APPENDIX A: CORE VESSEL SELECTION

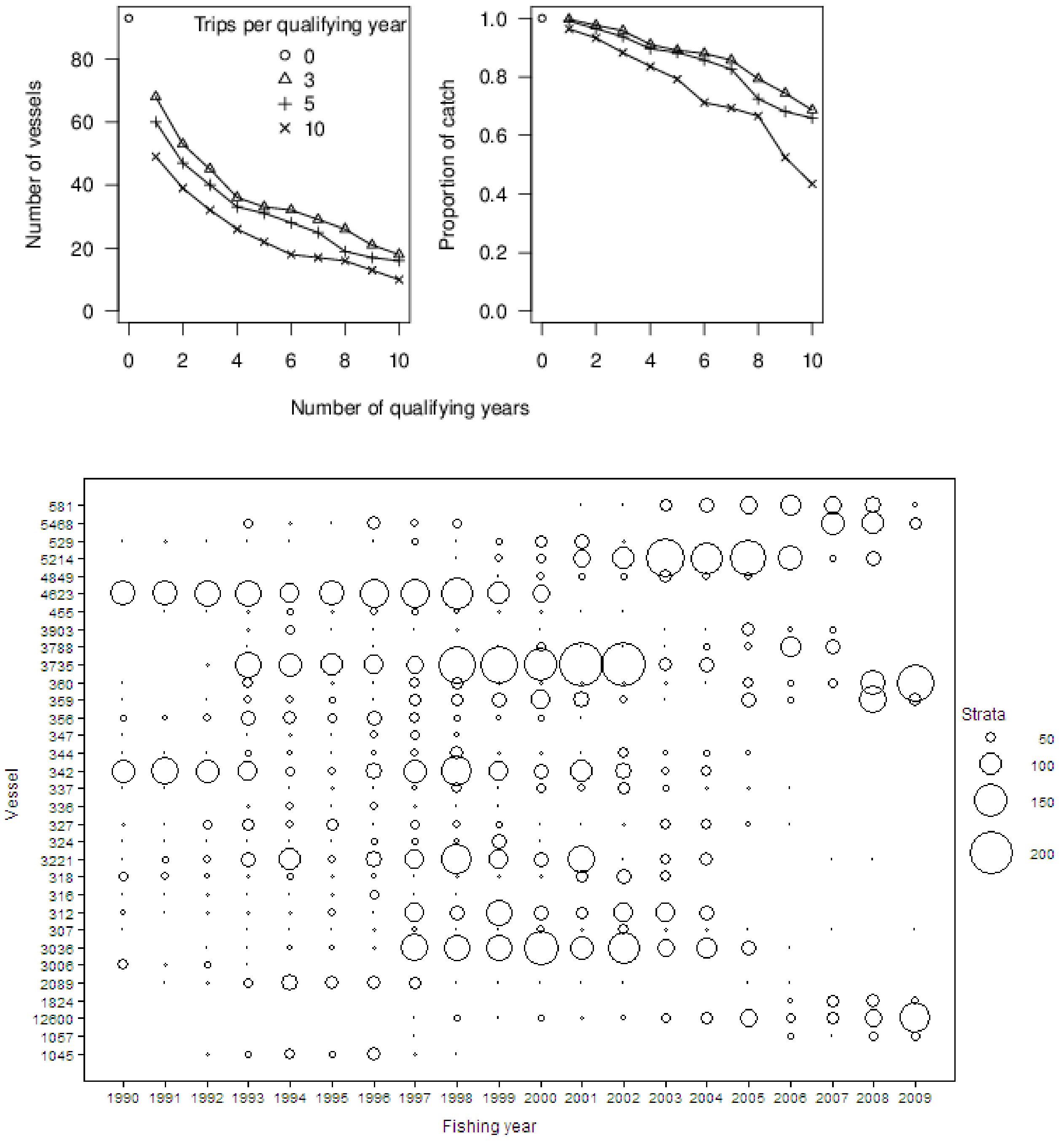
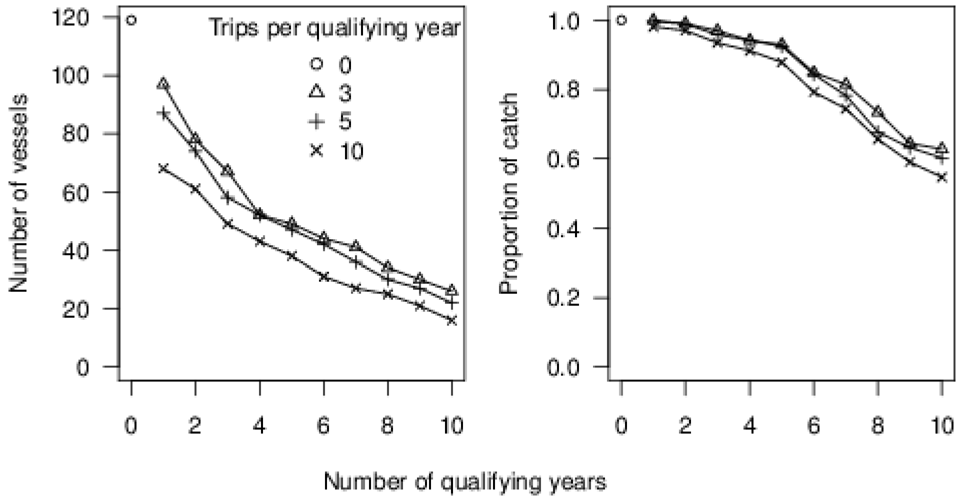


Figure A.1: The number of vessels [top left] and the proportion of landed JDO 1 [top right] retained in the W_BT_MIX dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 10 trips per year in at least three years) and the number of records for each vessel in each fishing year [bottom].



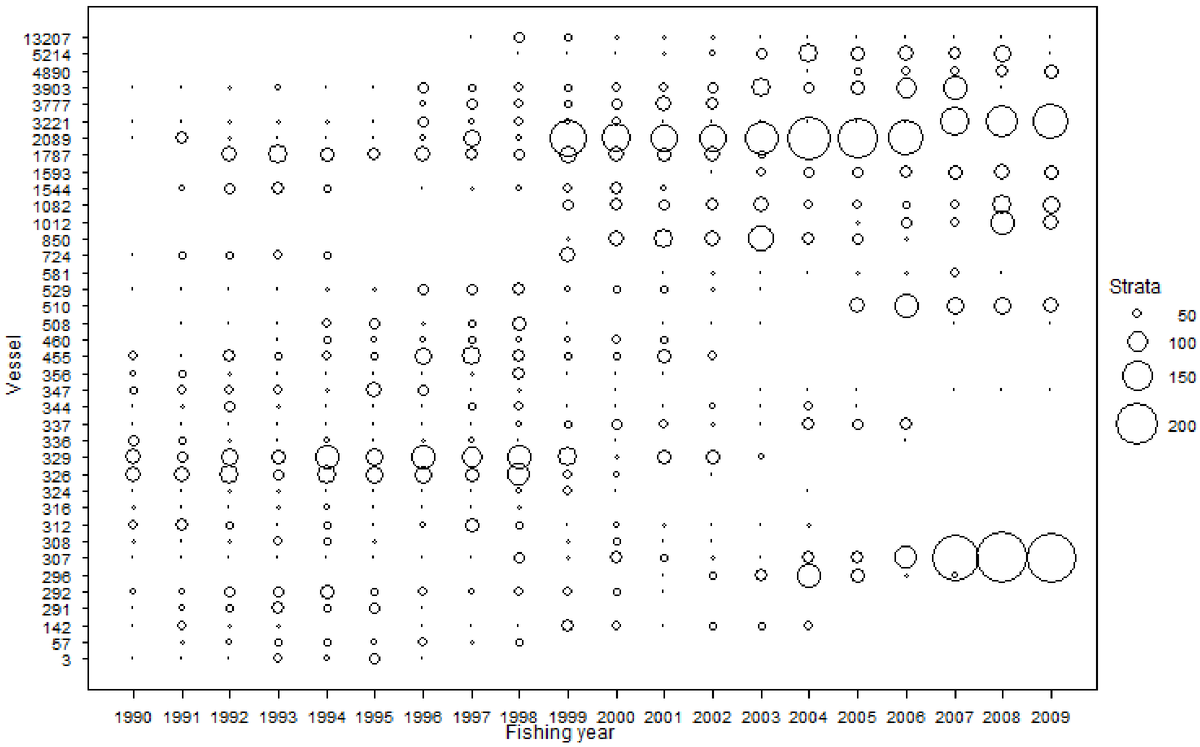


Figure A.2: The number of vessels [top left] and the proportion of landed JDO 1 [top right] retained in the E_BT_MIX dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 10 trips per year in at least five years) and the number of records for each vessel in each fishing year [bottom].

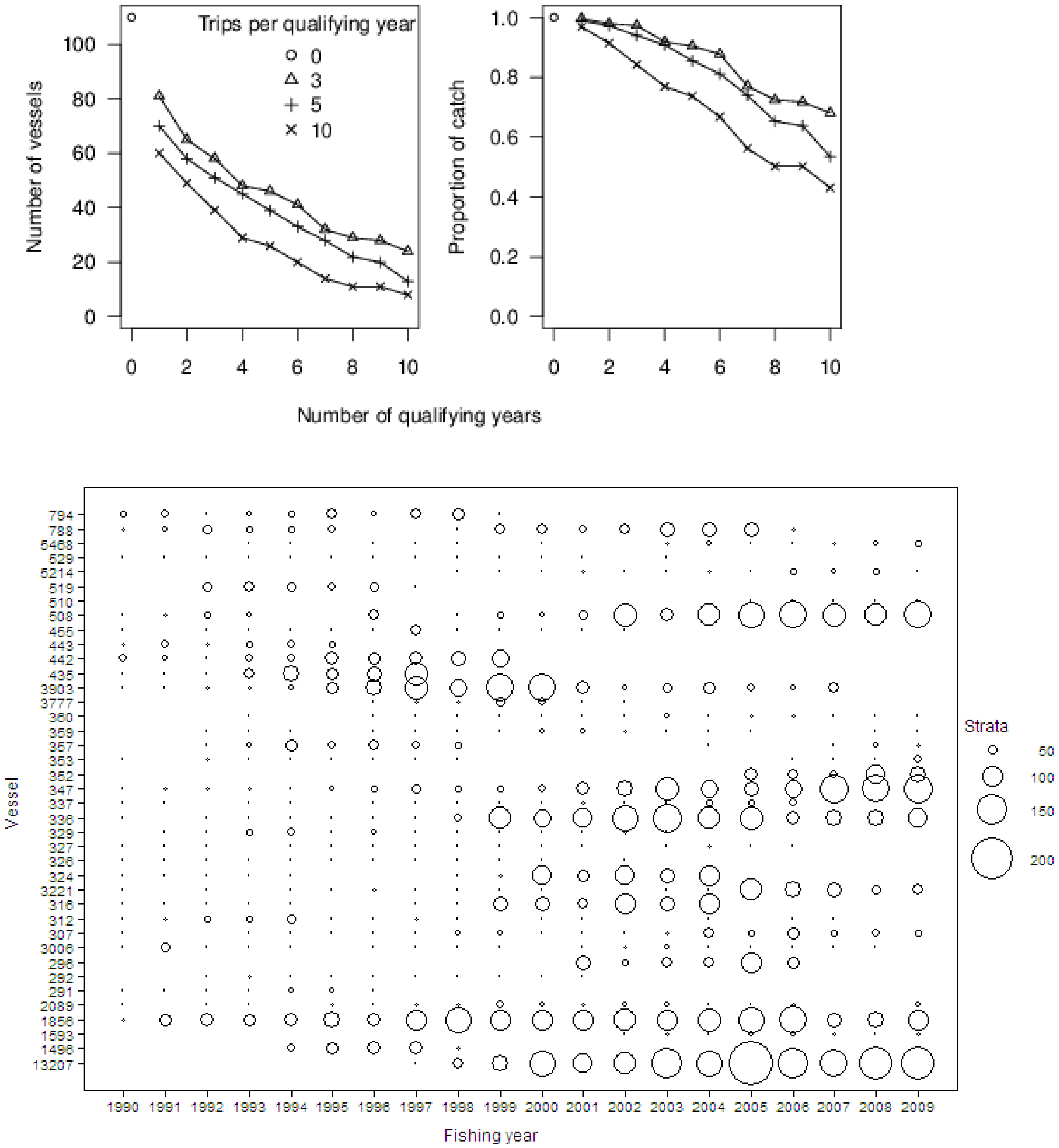


Figure A.3: The number of vessels [top left] and the proportion of landed JDO 1 [top right] retained in the BP_BT_MIX dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 5 trips per year in at least 5 years) and the number of records for each vessel in each fishing year [bottom].

APPENDIX B: DATA SUMMARIES

Table B.1: Data summary for the W_BT_MIX bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 10 trips per year for at least 3 years); Number of trips, percentage of strata that recorded a zero catch of John dory, number of core vessels, total number of tows, landed weight of JDO 1 (tonnes), and the simple catch rate of JDO 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	367	14	17	2 002	42	21
1990/91	374	10	15	2 167	38	18
1991/92	445	12	18	2 913	47	16
1992/93	627	22	25	5 373	59	11
1993/94	594	23	23	5 152	64	12
1994/95	510	17	23	4 062	90	22
1995/96	596	26	25	3 747	89	24
1996/97	676	25	26	4 273	111	26
1997/98	791	23	26	4 902	115	23
1998/99	608	23	23	4 467	80	18
1999/00	559	29	23	4 368	106	24
2000/01	479	24	21	3 744	98	26
2001/02	467	26	20	3 102	87	28
2002/03	299	37	18	2 857	88	31
2003/04	258	34	16	3 191	84	26
2004/05	199	27	14	2 534	81	32
2005/06	205	28	13	1 843	55	30
2006/07	190	27	11	1 923	53	28
2007/08	223	30	9	2 276	67	29

Table B.2: Data summary for the E_BT_MIX bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 10 trips per year for at least 5 years); Number of trips, percentage of strata that recorded a zero catch of JDO, number of core vessels, total number of tows, landed weight of JDO 1 (tonnes), and the simple catch rate of JDO 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	403	9	22	5 096	109	21
1990/91	498	9	25	6 322	119	19
1991/92	612	11	26	7 378	160	22
1992/93	636	12	27	6 715	162	24
1993/94	618	16	26	6 048	181	30
1994/95	491	13	24	4 824	180	37
1995/96	472	17	26	4 249	186	44
1996/97	494	17	25	4 525	190	42
1997/98	609	19	26	5 961	184	31
1998/99	570	11	26	5 493	228	42
1999/00	544	16	26	5 306	151	28
2000/01	476	12	25	4 624	143	31
2001/02	453	12	23	4 191	134	32
2002/03	395	11	20	3 507	120	34
2003/04	454	11	18	4 067	141	35
2004/05	407	11	17	3 911	133	34
2005/06	440	14	16	4 207	134	32
2006/07	454	12	14	4 788	165	34
2007/08	356	12	12	3 493	141	40

Table B.3: Data summary for the BP_BT_MIX bottom trawl fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 5 trips per year for at least 5 years); Number of trips, percentage of strata that recorded a zero catch of JDO, number of core vessels, total number of tows, landed weight of JDO 1 (tonnes), and the simple catch rate of JDO 1 across qualifying tows (kg/tow).

Fishing year	Trips	% zero strata	Vessels	Number of tows	Catch (t)	CPUE kg / tow
1989/90	175	18	24	2 031	40	20
1990/91	269	14	19	2 651	46	17
1991/92	310	19	27	2 648	49	19
1992/93	408	14	29	3 152	71	22
1993/94	496	12	29	3 666	83	23
1994/95	437	14	24	2 789	80	29
1995/96	411	23	29	2 657	57	21
1996/97	471	22	29	3 210	62	19
1997/98	355	27	31	2 742	69	25
1998/99	408	27	26	3 833	82	21
1999/00	388	25	25	3 967	70	18
2000/01	412	25	24	3 913	71	18
2001/02	454	23	22	3 865	67	17
2002/03	528	27	23	4 389	83	19
2003/04	508	29	23	4 629	84	18
2004/05	493	27	21	5 097	100	20
2005/06	487	27	22	4 176	64	15
2006/07	321	29	18	3 033	63	21
2007/08	352	24	17	3 142	56	18

Appendix C: Residual plots

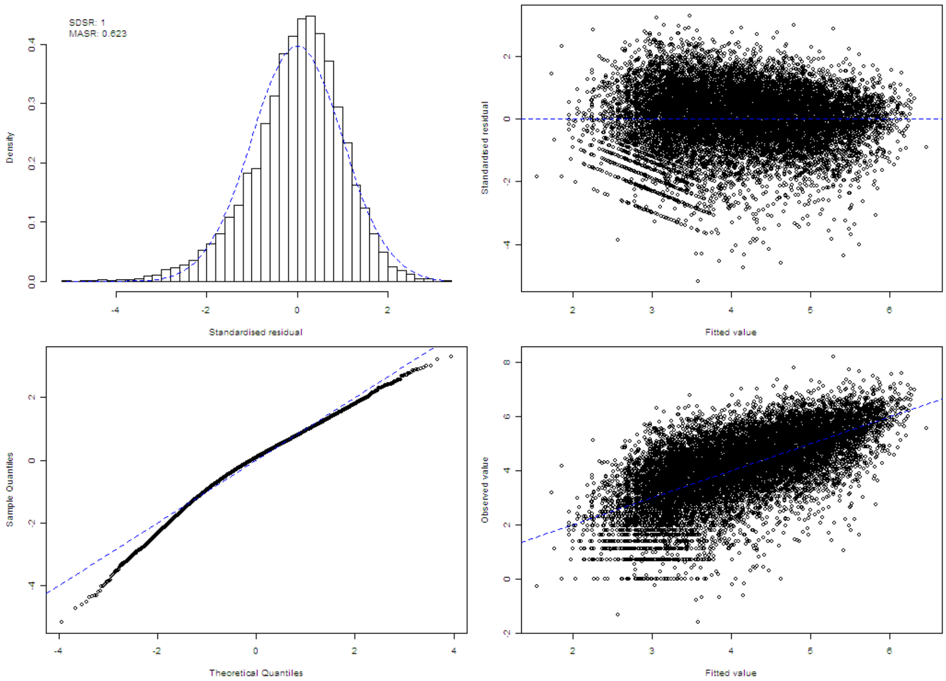


Figure C1: Plots of the fit of the standardised CPUE model to successful catches of John dory in the JDO 1 W_BT_MIX fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

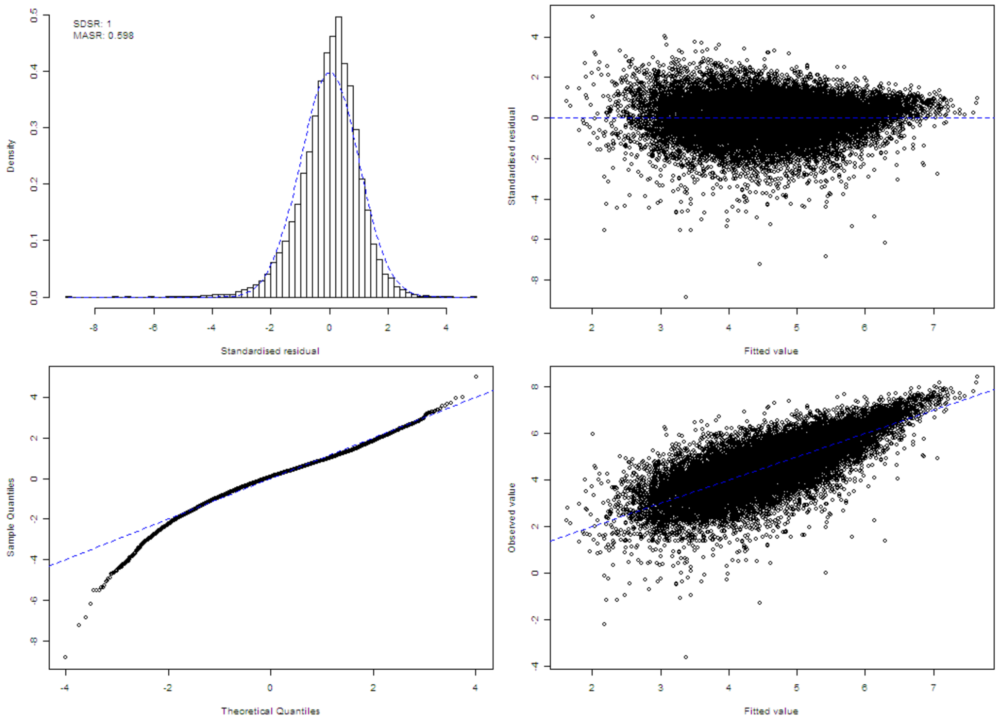


Figure C2: Plots of the fit of the standardised CPUE model to successful catches of John dory in the JDO 1 E_BT_MIX fishery. See caption of C1 for details.

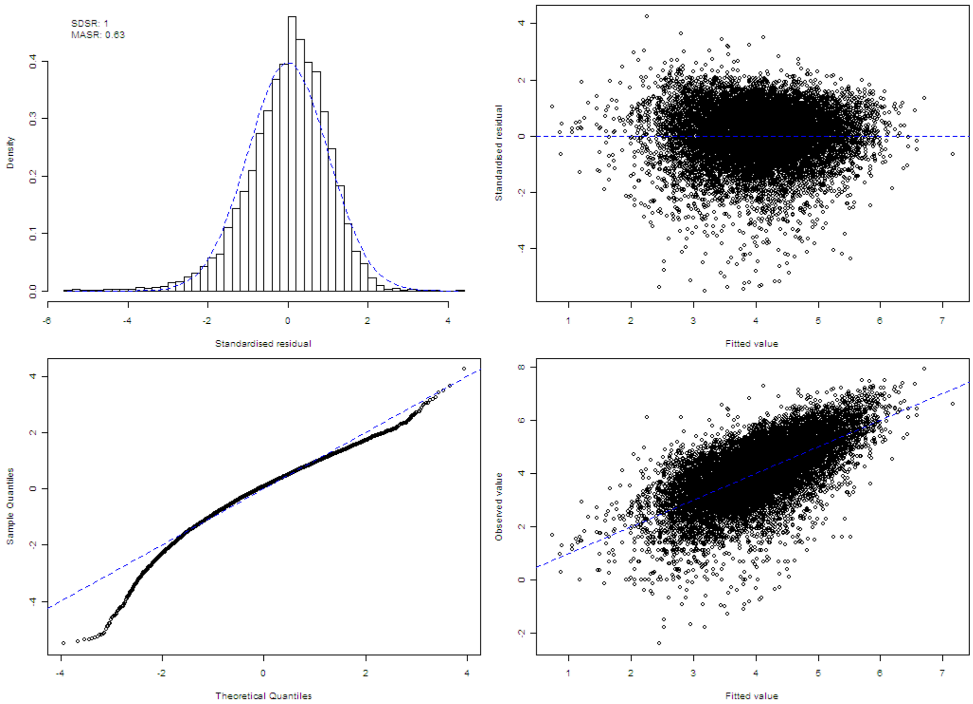


Figure C3: Plots of the fit of the standardised CPUE model to successful catches of John dory in the JDO 1 BP_BT_MIX fishery. See caption of C1 for details.

APPENDIX D: MODEL COEFFICIENT INFLUENCE PLOTS

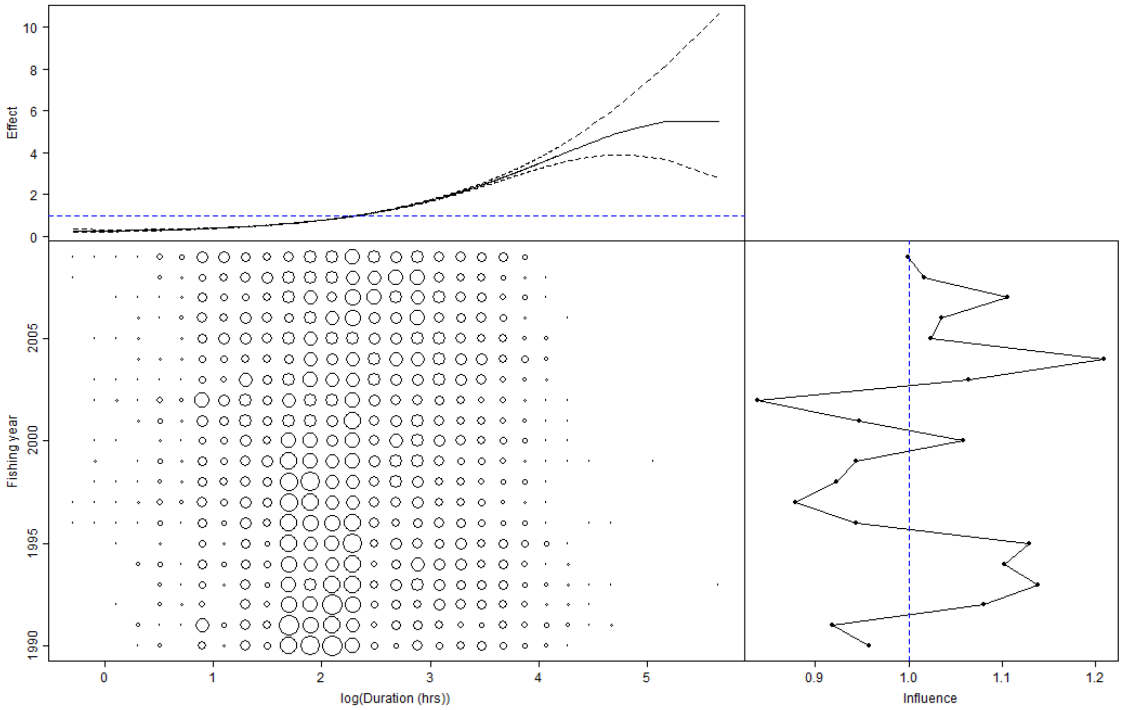


Figure D.1: Effect and influence of log(duration) in the W_BT_MIX lognormal model. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

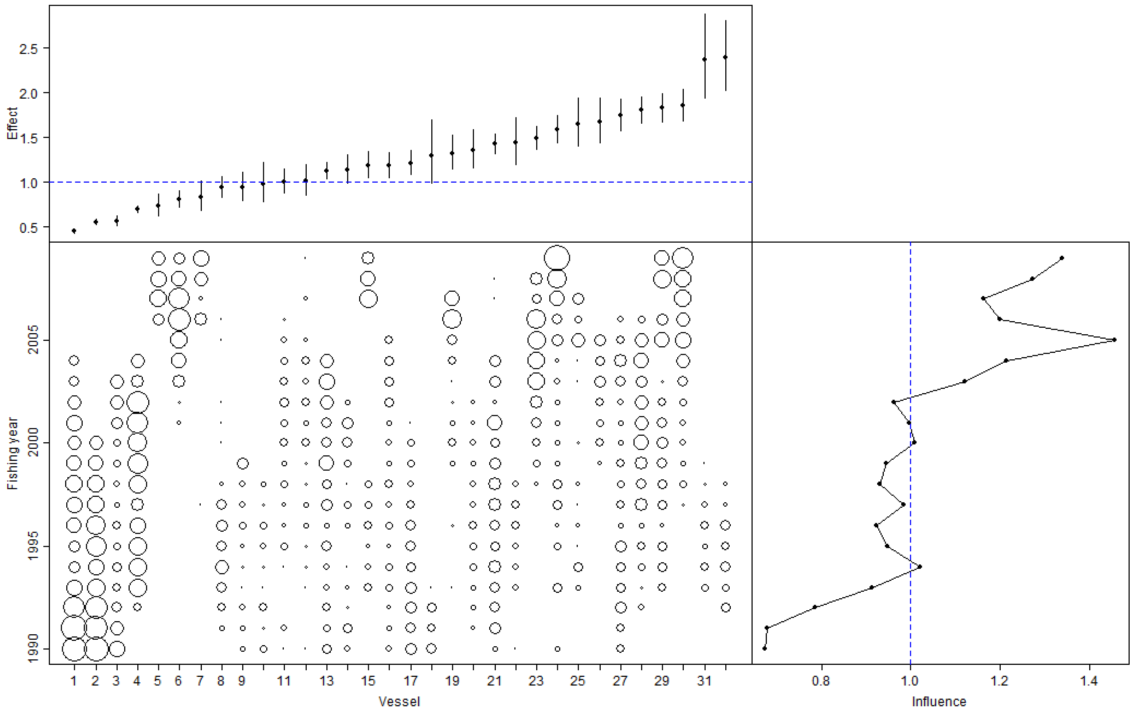


Figure D.2: Effect and influence of vessel in the W_BT_MIX lognormal model. See caption of Figure D.1 for details.

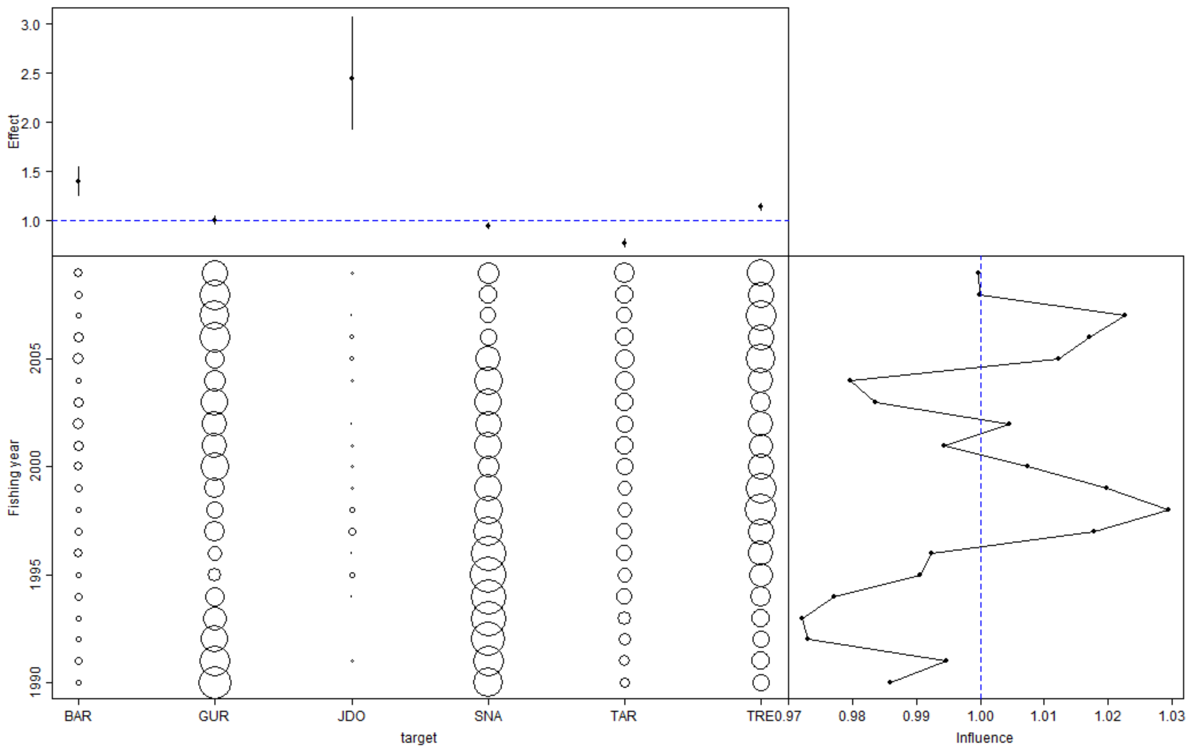


Figure D.3: Effect and influence of target species in the W_BT_MIX lognormal model. See caption of Figure D.1 for details.

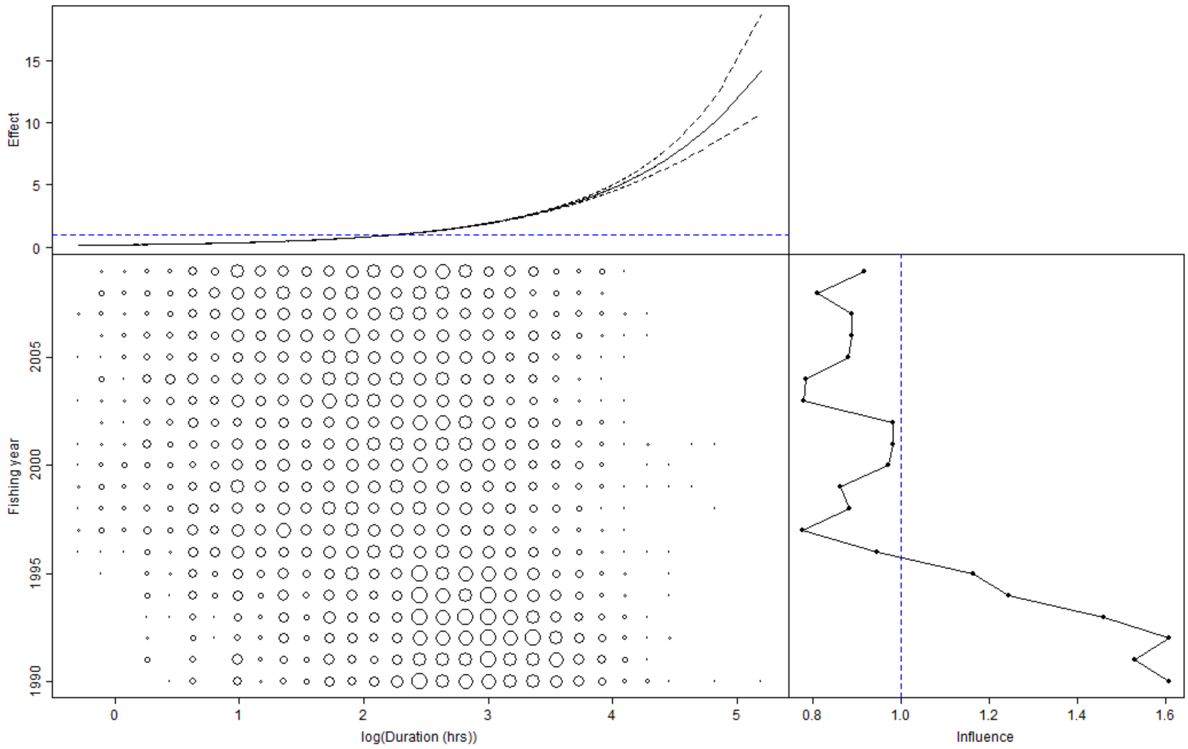


Figure D.4: Effect and influence of log(duration) in the E_BT_MIX lognormal model. See caption ofFigure D.1 for details.

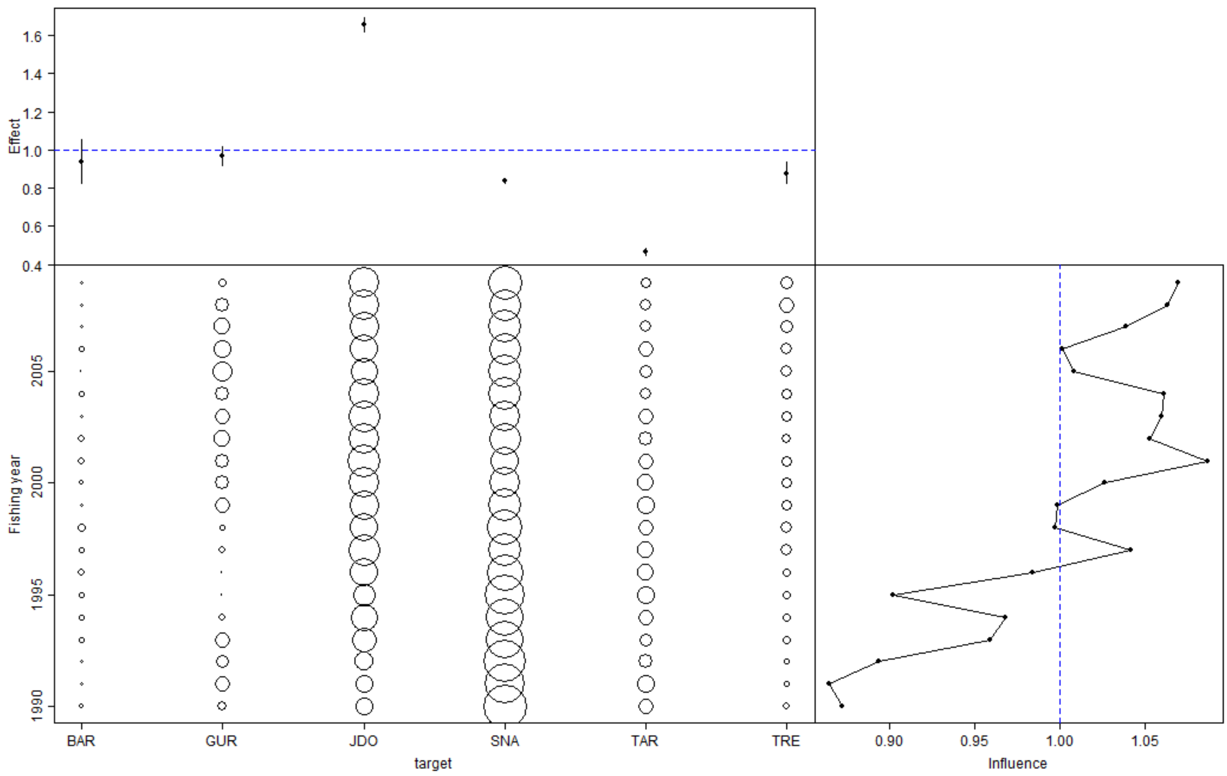


Figure D.5: Effect and influence of target species in the E_BT_MIX lognormal model. See caption of Figure D.1 for details.

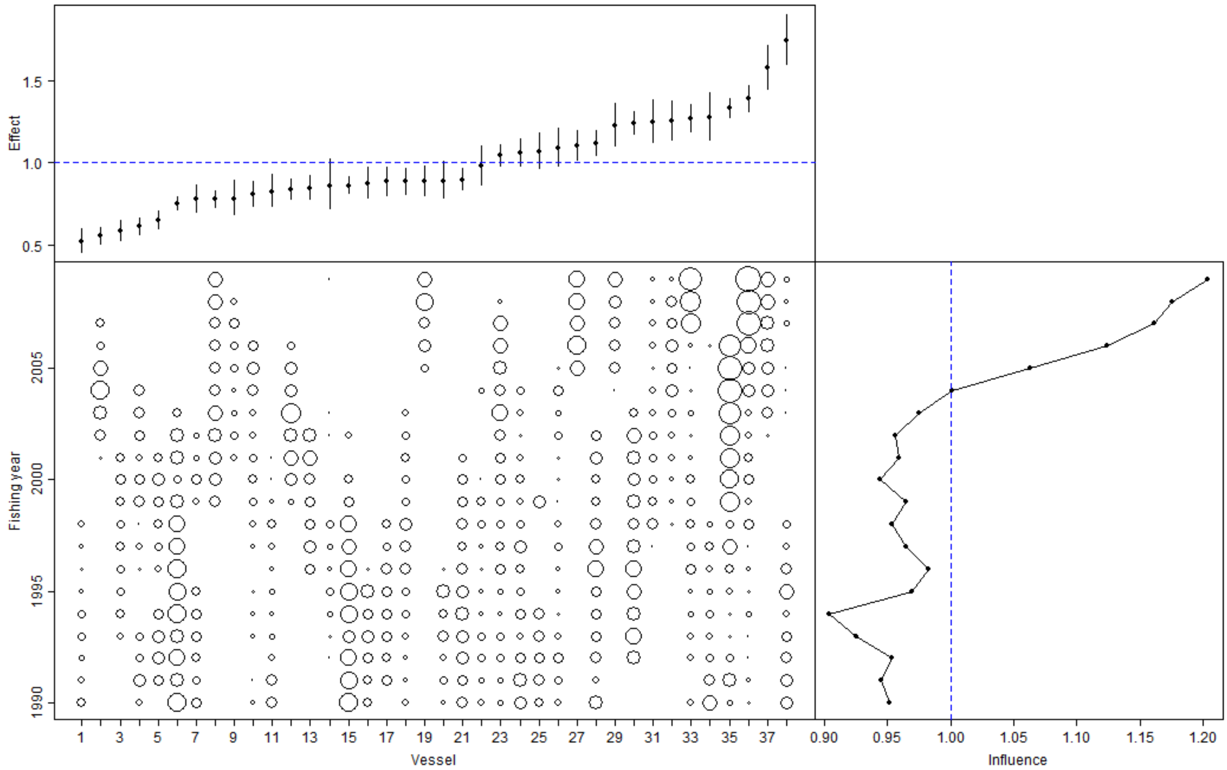


Figure D.6: Effect and influence of vessel in the E_BT_MIX lognormal model. See caption of Figure D.1 for details.

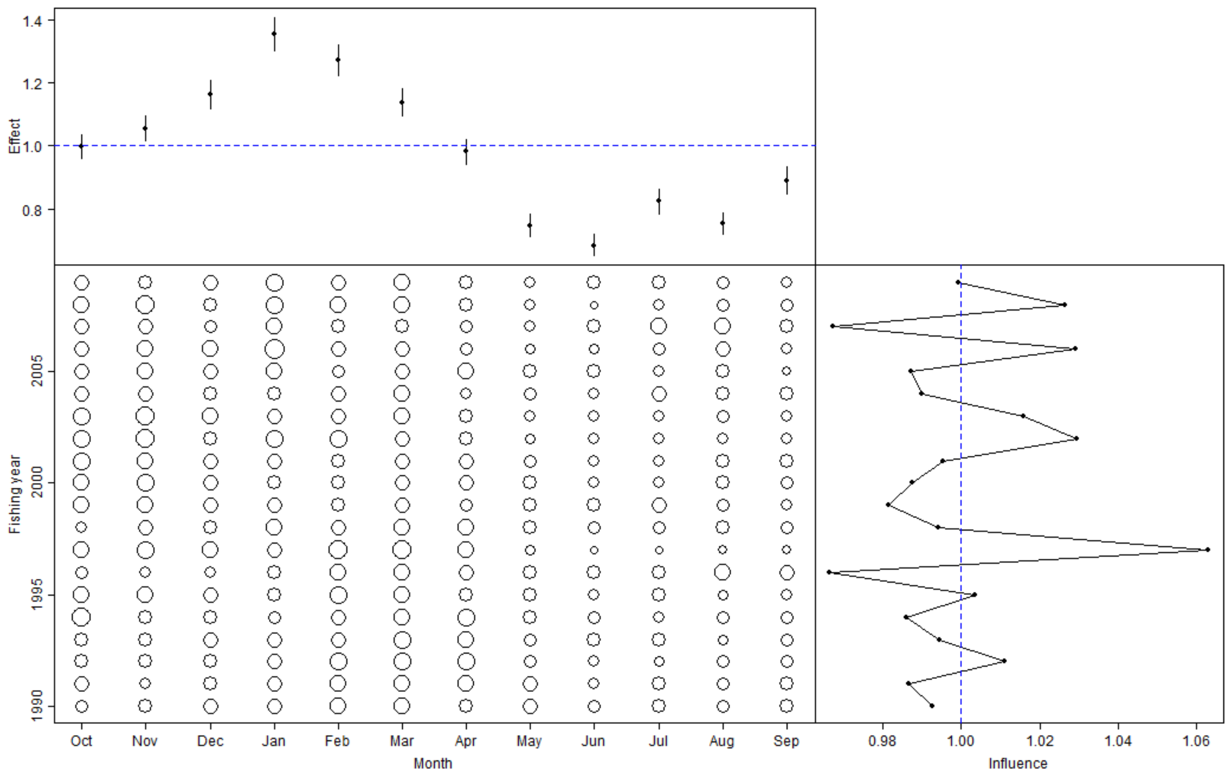


Figure D.7: Effect and influence of month in the E_BT_MIX lognormal model. See caption of Figure D.1 for details.

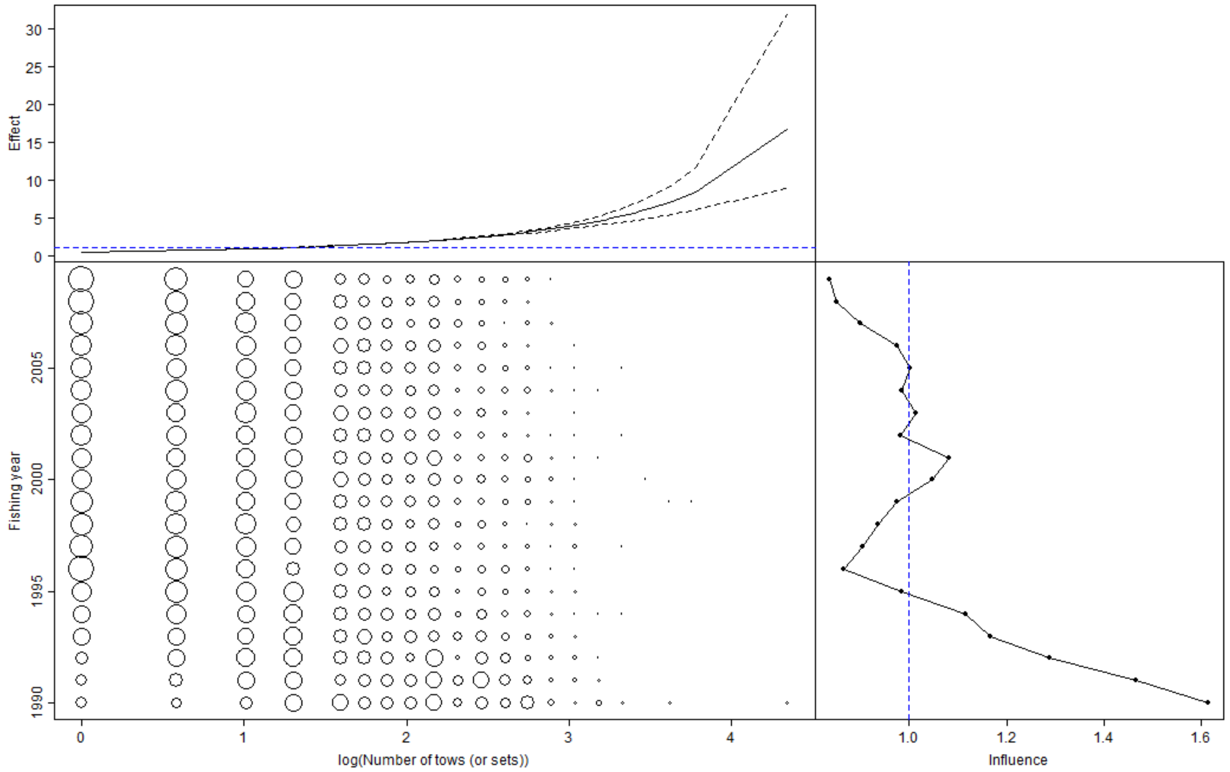


Figure D.8: Effect and influence of log(tows) in the BoP_BT_MIX lognormal model. See caption of Figure D.1 for details.

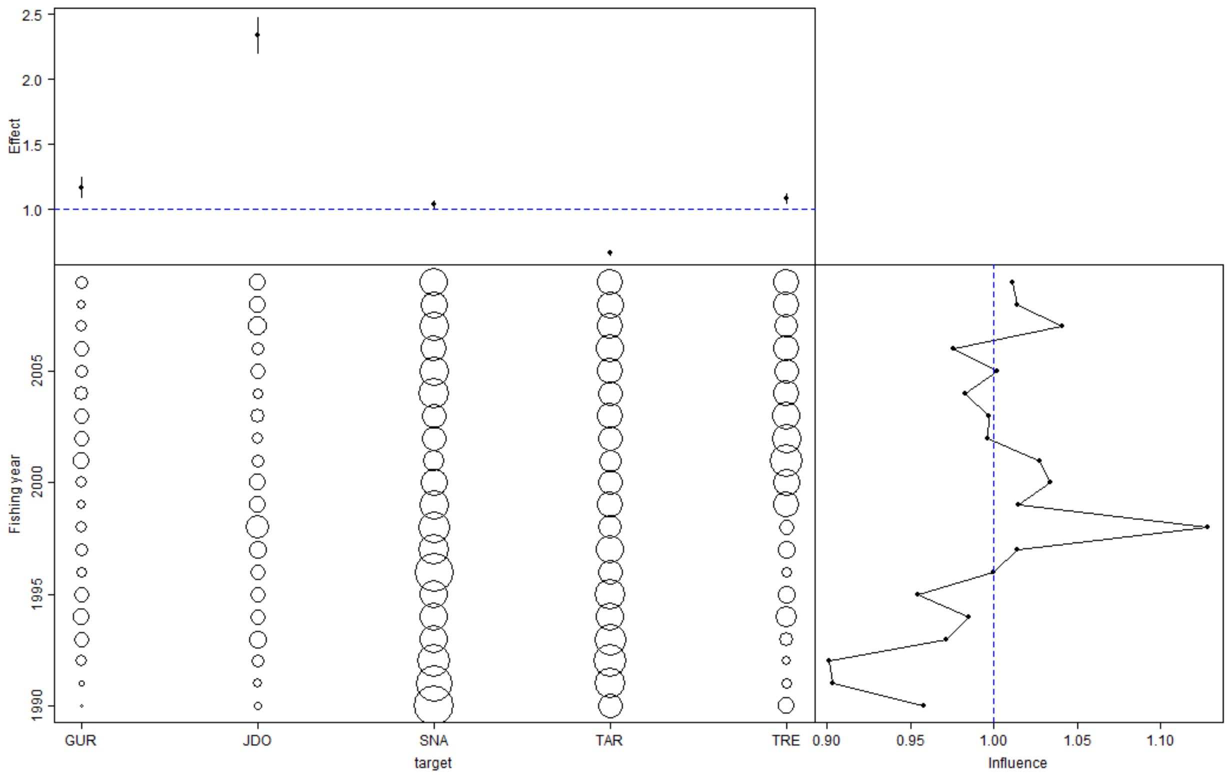


Figure D.9: Effect and influence of target species in the BoP_BT_MIX lognormal model. See caption of Figure D.1 for details.

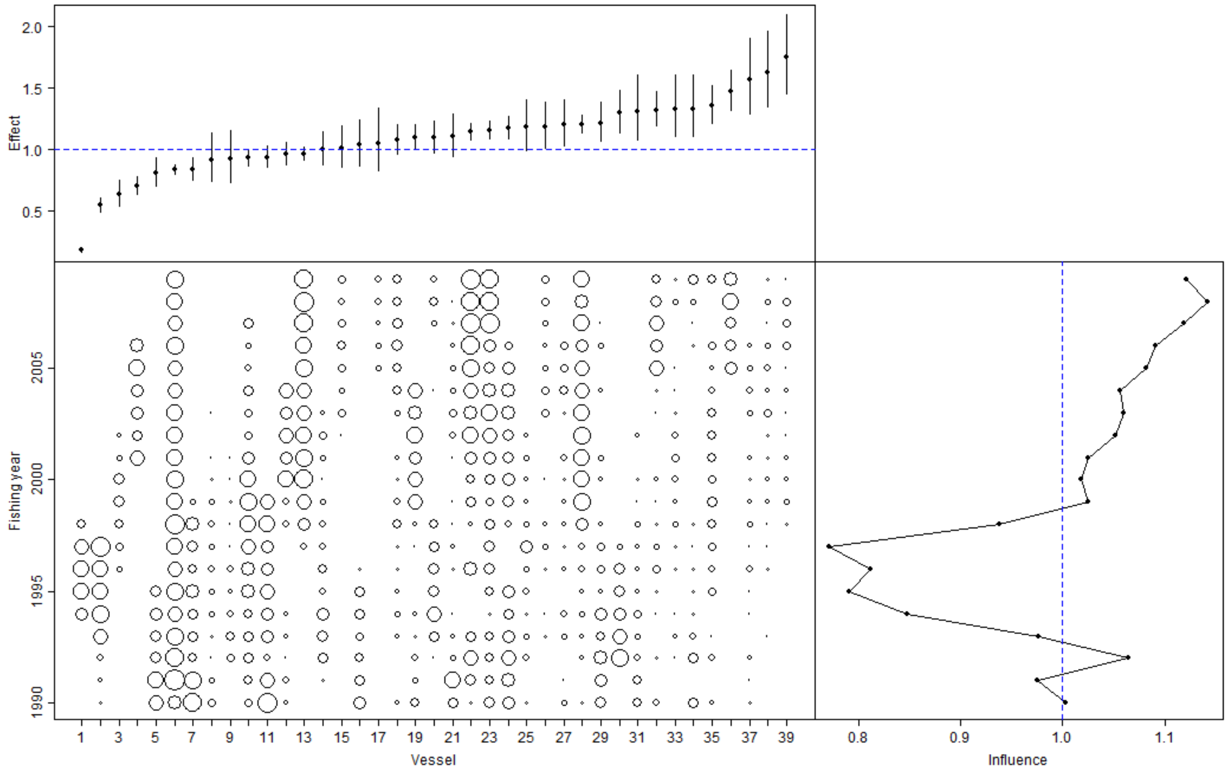


Figure D.10: Effect and influence of vessel in the BoP_BT_MIX lognormal model. See caption of Figure D.1 for details.

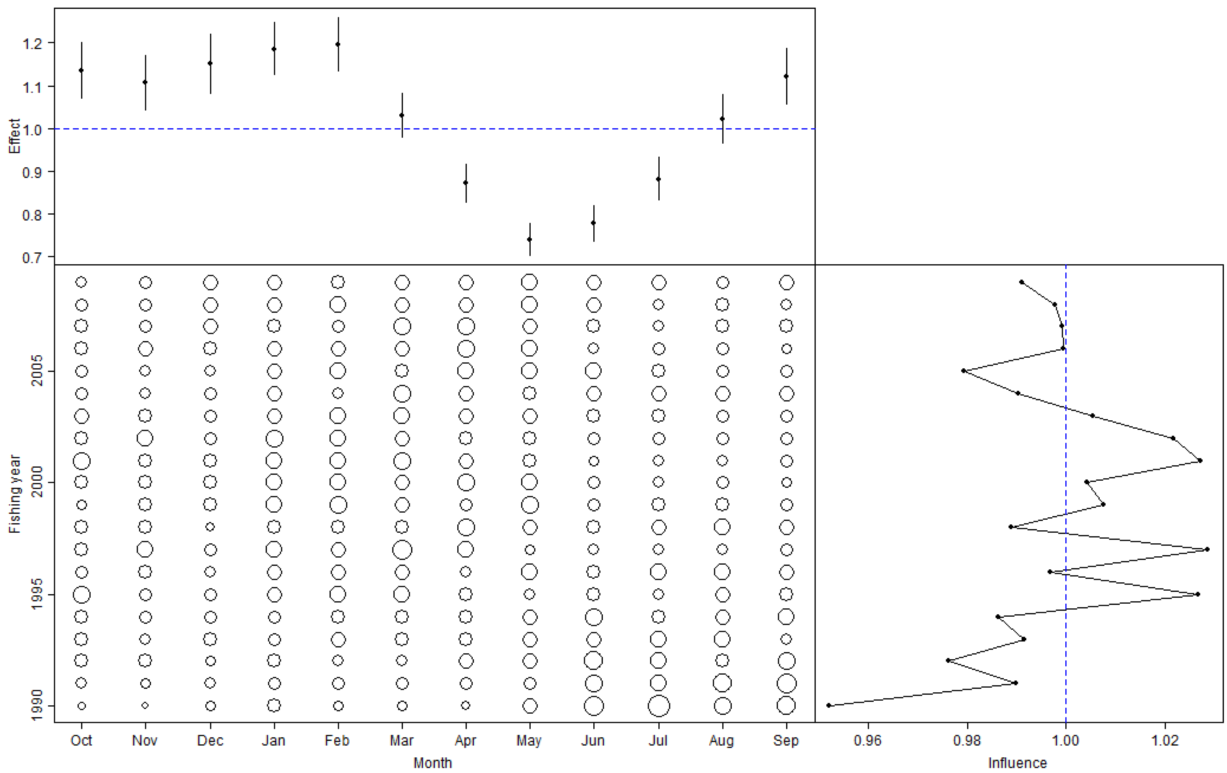


Figure D.11: Effect and influence of month in the BoP_BT_MIX lognormal model. See caption of Figure D.1 for details.

APPENDIX E: CPUE INDICES

Table E.1: Relative year effects (unstandardised and standardised) and confidence intervals (±2 SE) for the lognormal model fitted to the W_BT_MIX bottom trawl dataset for JDO 1.

Fishing year	Geometric mean	Lognormal standardisation
1989/90	0.778	1.345 (1.213-1.492)
1990/91	0.636	1.124 (1.016-1.244)
1991/92	0.574	0.870 (0.792-0.955)
1992/93	0.431	0.577 (0.535-0.622)
1993/94	0.473	0.589 (0.544-0.637)
1994/95	0.597	0.753 (0.693-0.817)
1995/96	0.891	0.992 (0.918-1.071)
1996/97	1.058	1.085 (1.015-1.161)
1997/98	0.952	1.021 (0.958-1.088)
1998/99	0.855	0.955 (0.890-1.024)
1999/00	1.260	1.207 (1.124-1.297)
2000/01	1.367	1.255 (1.169-1.348)
2001/02	1.343	1.225 (1.138-1.319)
2002/03	1.618	1.282 (1.178-1.396)
2003/04	1.544	1.157 (1.062-1.261)
2004/05	1.649	0.953 (0.871-1.042)
2005/06	1.459	1.030 (0.924-1.149)
2006/07	1.204	0.952 (0.850-1.066)
2007/08	1.422	1.012 (0.915-1.118)
2008/09	1.588	1.089 (0.974-1.217)

Table E.2: Relative year effects and confidence intervals (±2 SE) for the lognormal model fitted to the E_BT_MIX bottom trawl dataset for JDO 1.

Fishing year	Geometric mean	Lognormal standardisation
1989/90	0.683	0.928 (0.865-0.996)
1990/91	0.697	0.941 (0.883-1.002)
1991/92	0.772	0.884 (0.835-0.936)
1992/93	0.844	0.957 (0.903-1.014)
1993/94	0.965	1.104 (1.042-1.169)
1994/95	1.150	1.347 (1.265-1.434)
1995/96	1.253	1.267 (1.195-1.343)
1996/97	1.212	1.211 (1.145-1.281)
1997/98	1.039	1.176 (1.117-1.239)
1998/99	1.129	1.168 (1.112-1.228)
1999/00	0.890	0.887 (0.842-0.935)
2000/01	0.894	0.788 (0.746-0.832)
2001/02	1.001	0.916 (0.865-0.969)
2002/03	1.115	1.046 (0.987-1.109)
2003/04	1.158	1.159 (1.095-1.228)
2004/05	1.147	1.117 (1.052-1.187)
2005/06	1.083	0.910 (0.858-0.966)
2006/07	1.026	0.912 (0.859-0.969)
2007/08	1.195	0.817 (0.767-0.870)
2008/09	1.043	0.734 (0.686-0.785)

Table E.3: Relative year effects and confidence intervals (±2 SE) for the lognormal model fitted to the BP_BT_MIX bottom trawl dataset for JDO 1.

Fishing year	Geometric mean	Lognormal standardisation
1989/90	1.049	1.308 (1.157-1.480)
1990/91	0.924	1.177 (1.063-1.302)
1991/92	0.900	1.019 (0.927-1.120)
1992/93	1.112	1.215 (1.120-1.319)
1993/94	1.024	1.256 (1.164-1.355)
1994/95	1.022	1.274 (1.179-1.376)
1995/96	0.843	0.962 (0.891-1.040)
1996/97	0.807	0.944 (0.877-1.016)
1997/98	1.294	1.178 (1.091-1.273)
1998/99	1.192	1.098 (1.025-1.176)
1999/00	0.941	0.880 (0.820-0.944)
2000/01	1.007	0.930 (0.866-1.000)
2001/02	0.920	0.832 (0.778-0.891)
2002/03	1.002	0.925 (0.867-0.987)
2003/04	1.007	0.946 (0.887-1.009)
2004/05	1.104	1.014 (0.952-1.080)
2005/06	0.905	0.822 (0.769-0.879)
2006/07	1.124	0.908 (0.842-0.979)
2007/08	0.928	0.740 (0.689-0.795)
2008/09	1.024	0.835 (0.780-0.895)

APPENDIX F : COMPARISON WITH PREVIOUS SERIES

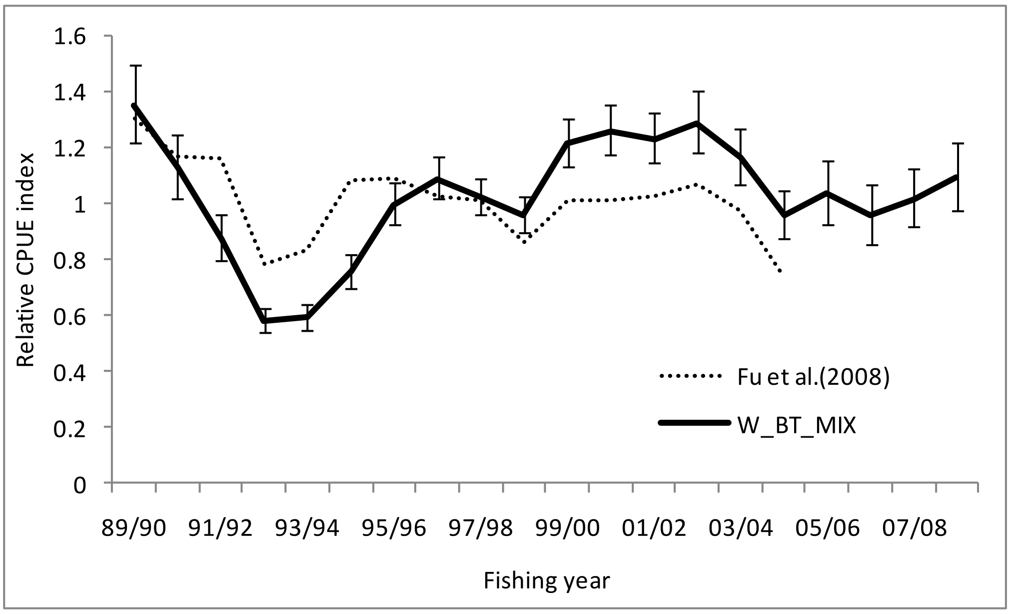


Figure F1: Annual indices from lognormal model of bottom trawl in the west coast substock (W_BT_MIX; this study) compared to a previous series from a similar model (Fu et al. 2008).

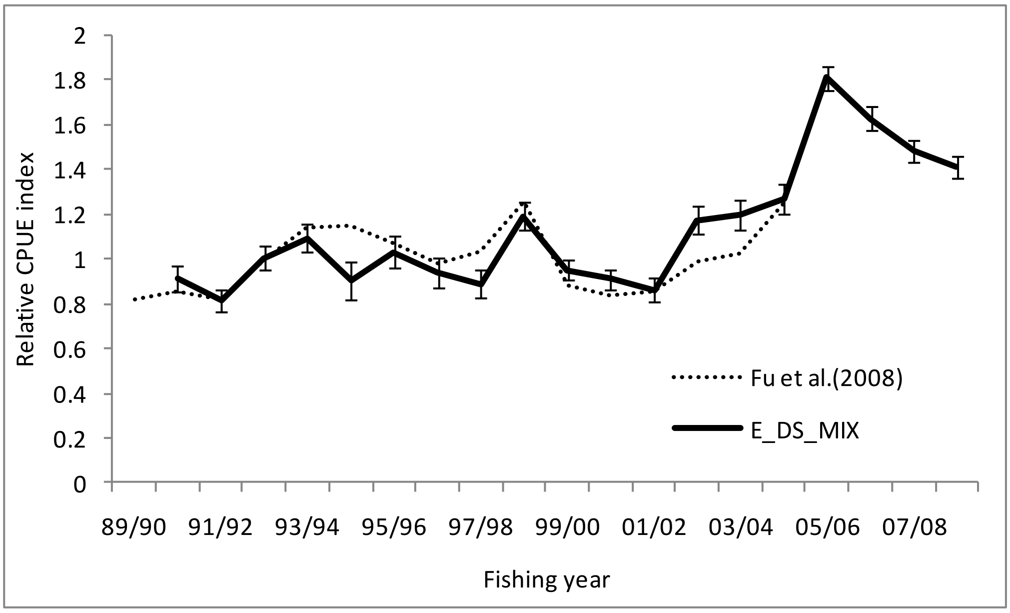


Figure F2: Annual indices from lognormal model of Danish seine in the east coast substock (E_DS_MIX; this study) compared to a previous series from a similar model (Fu et al. 2008).