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Catch history, CPUE analysis, and stock assessment of John dory (*Zeus faber*) around the North Island (Fishstocks JDO 1 and JDO 2)

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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1. EXECUTIVE SUMMARY

The catch histories of fisheries for John dory in JDO 1 and JDO 2 (i.e., QMAs 1, 2, 8, and 9) are described. Standardised estimates of relative abundance of John dory from trawl surveys are presented. Biological parameters are summarised or derived. A complete report of the analysis of CPUE data is presented in Appendix 1.

For the JDO 1 and JDO 2 assessments, all relevant biological parameters, the commercial catch history, and series of abundance indices from trawl surveys and CPUE analyses were incorporated into population models using the MIAEL estimation technique. This is the first model-based stock assessment of John dory. Four stocks were modelled: an eastern stock comprising QMA 1 (JDO 1E), a western stock comprising QMA 9 (JDO 1W), an eastern stock comprising QMA 2 (JDO 2E), and a western stock comprising QMA 8 (JDO 2W).

The model results suggest that the biomasses of all four stocks stocks have probably declined slightly (although JDO 1 may have increased) since fishing began. However, the estimates of virgin biomass had very low information indices (0–20%) and are therefore poorly estimated within the range of values estimated by the least squares method. The estimates of current biomass are better estimated for JDO 1E (information indices of 10–67%), but are very poorly estimated for the remaining stocks (information indices of 0–9%). The MIAEL estimates of current biomass as a percentage of B_0 range from 48 to 57% for the four stocks. However, the uncertainty on all these assessments is very high. More accurate productivity parameters, and estimates of year class strengths, will be necessary to produce more confident stock assessments.

The combined best estimate of MCY for the two JDO 1 stocks is about double the current TAC. The estimate of MCY for the JDO 2 stocks is at about the level of the current TAC. Current catch levels, or catches at the levels of the TACs, are probably sustainable, at least in the medium term.

2. INTRODUCTION

John dory (*Zeus faber*) is taken mainly as a bycatch of trawl and Danish seine fisheries. In recent years, total landings have been between 800 and 900 t. About 80% of the national landings are from QMAs 1 and 9. Annual landings have generally been less than the TAC, though in JDO 1 they have been close to the TAC since 1994–95.

Stock assessment information for John dory in New Zealand or on the world scene is scant. Probably the most definitive study available on New Zealand John dory growth and reproduction is contained in a thesis (Hore 1982). Research on John dory since 1982 has been limited to basic stock assessments (Hore 1985, Annala *et al.* 1998). John dory is a designated target species in North Island research trawl survey programmes. Data from these surveys, in conjunction with commercial catch statistics, is largely the only information available to assess John dory stocks

The aim of the current work was to draw together data on John dory from a variety of sources and produce assessments for JDO 1 and JDO 2 using population models. MCY for Fishstocks JDO 1 and JDO 2 have been estimated previously using the equation MCY = $c.Y_{av}$ (Annala *et al.* 1998), where Y_{av} is the average annual catch for the period 1983–84 to 1985–86 and *c* was set to 0.6 based on an estimate of *M* of 0.38. MCY estimates were 360 and 80 t for JDO 1 and JDO 2, respectively.

3. THE FISHERY

3.1 New Zealand catch history

Reported landings were generally less than 100 t annually until 1952 (Table 1). From 1953 they increased rapidly, and then more gradually, to 800 t by 1981. In the 1980s and 90s, landings ranged between 700 t and 900 t, and were always within the total TAC, which increased from 860 t in 1986–87 to about 1100 t from 1989–90 onwards (Table 2).

3.2 Fishstock catch histories

3.2.1 Background

From the fishing years 1989–90 to 1996–97, about 95% of New Zealand's total John dory landings have come from Fishstocks JDO 1 and JDO 2 (Figure 1). Between 70% and 80% have come from JDO 1 alone. JDO 1 landings from 1994–95 to 1996–97 have been close to the TACC. JDO 2 landings have declined slightly since 1992–93, and from 1994–95 have been about 50% of the TACC.

The remaining 5% of New Zealand landings have come mainly from JDO 7, with negligible landings from JDO 3.

3.2.2 JDO 1 and JDO 2 catch histories

Management areas JDO 1 and JDO 2 each have east coast and west coast components (*see* Figure 1). It is not known whether John dory populations on each coast constitute separate stocks. However, coastal stock separation in John dory is probably a reasonable assumption given that the adults are weak swimmers and the North Island coastal hydrology is not conducive to bulk inter-coastal larval transport. For the present purpose of stock assessment they are treated as different stocks: JDO 1E, JDO 1W, JDO 2E, JDO 2W (*see* Figure 1).

It is not easy to obtain a complete catch history for each of these four stocks, particularly since establishment of the QMS in 1986. There are two published (or otherwise readily available) time series of landings, with a gap of several years between them. The first comprises 1931 to 1982 landings by port (Annual Reports on Fisheries 1931 to 1973, King 1985). The second is a series from 1989–90 onwards of "estimated catches" (where John dory was one of the top five species in a tow, or during a day's fishing) by fishing return statistical area recorded in the QMS catch effort database. These estimated catches make up two-thirds to three-quarters of the actual catch, or landing (Table 3).

The absence of published landing data for the years 1983–89 is only partially covered (1984–87) by some unpublished data on landings by both port and statistical area, but these allow comparison of the two series. Catch by area is more suitable for stock assessment, and where possible these have been used. The following sections describe how the catch histories for the four areas (Table 4) were derived.

JDO 1

This Fishstock covers the entire Auckland Fisheries Management Area, combining QMA 1 and QMA 9, and extends around the northern North Island from Cape Runaway in the east to Tirua Point in the west. Its subdivision into east and west is made at the North Cape QMA boundary (*see* Figure 1).

From 1931 to 1982, the JDO 1E total was taken as the sum of landings at ports from Mangonui to Whakatane, and JDO 1W as the sum of landings at ports from Kawhia to Manukau. These totals are likely to be reasonably correct, given the following caveats:

(i) some Auckland-based boats may have fished both the east and west coasts, i.e., some JDO 1W catches would be included in JDO 1E landings;
(ii) some Auckland and Tauranga (JDO 1E) boats may also have fished southeast of Cape Runaway, in JDO 2E, with catches from here included in JDO 1E landings.

From 1983 to 1989 (1988–89), there are several unpublished data series of east and west coast catches, mainly by area, which match moderately well. A "best estimate" was made from these, using area rather than port where possible, and averaging some general trends. However, the JDO 1 totals derived this way for 1984–87 are lower than the totals in the Plenary Report (Annala *et al.* 1998), and are for calendar rather than fishing years, so the latter values have been used, and the east and west subtotals pro-rated up.

From 1988–89 to 1995–96, the "estimated catch" by statistical area values from CELR and TCEPR forms were used to obtain the proportion of JDO 1 catches taken on the east and west coasts (*see* Table 3). These estimated values were 70–90% of the landed values, and probably reasonable for this purpose; the only difficulty would be if John dory did not have an equal chance to be among the top five reported species on both coasts. The average split was 15% west coast, 85% east coast, but the values for individual years were used to subdivide JDO 1 landings into the two catch histories.

For 1996–97, the reported JDO 1 landings (QMS data) were subdivided 85:15 to the east and west coasts.

JDO 2

This Fishstock occupies the entire Central Fisheries Management Area, combining QMA 2 and QMA 8, and extends around the southern North Island from Cape Runaway in the east to Tirua Point in the west. Its subdivision into east and west is made at the Cook Strait (Mana Island) boundary between QMAs 2 and 8 (*see* Figure 1).

Catch totals compiled for the period 1931 to 1982 were based on the sum of landings at ports from Gisborne to Makara for JDO 2E, and on the sum of landings at ports from Paremata to New Plymouth for JDO 2W. These totals are assumed to be reasonably correct, given the following caveats:

(i) some Wellington-based boats may have fished both the east and west coasts, i.e., some JDO 2W catches would be included in JDO 2E landings;
(ii) some Gisborne and Napier (JDO 2E) boats may also have fished northwest of Cape Runaway, in JDO 1E, with catches from here included in JDO 2E landings.

However, from 1983 to 1989 (1988–89) there are several unpublished data series of east and west coast catches, mainly by area, which suggest that the port landings for this fishery are not reliable. The four-year mean from this period shows that JDO 2W port landings are 30% of JDO 2, while JDO 2W area landings are 45% of JDO 2 (the 45% value is reasonably close to the by-area value of 49% for the period 1989–90 to 1995–96). However, the JDO 2 total derived this way for 1984 is lower than the total in the Plenary Report (Annala *et al.* 1998), and is for the calendar rather than fishing year, so the latter value has been used, and the east and west coast subtotals pro-rated up.

From 1989–90 to 1996–97, the "estimated catch" by statistical area values from CELR and TCEPR forms were used to obtain the proportion of JDO 2 catches taken on the east and west coasts (*see* Table 3). The mean ratio for these years was 50:50, so reported landings were split in this proportion.

3.2.3 Spawning and pre-spawning catch

For future modelling it may be necessary to split the catch for each stock into a pre-spawning season and spawning season catch, though for the current modelling exercise, the Working Group chose to assume an instantaneous spawning season of zero length, with all catch taken in the home ground. John dory have a long spawning season extending from December to March (Hore 1982).

It was not possible to estimate the proportion of the annual catch taken in the spawning season for all years in the fishery. However, monthly landings reported on the QMRs by QMA since 1989–90 were analysed to determine the proportion taken during the spawning season. For JDO 1 as a whole, between 32% and 48% (mean 43%) of the annual catch was taken during the spawning season. For JDO 2 as a whole, between 36% and 55% (mean 47%) of the annual catch was taken during the spawning season. From estimated CELR and TCEPR data 36% of the JDO 1E catch, 45% of the JDO 1W, 48% of the JDO 2E catch, and 66% of the JDO 2W catch was taken during the spawning period. On this basis, the percentage of the catch taken in the spawning season is assumed to be 40% in areas JDO 1E and JDO 1W, 50% in area JDO 2E, and 65% in area JDO 2W.

4. CPUE ANALYSIS

Standardised CPUE analyses for various fishing methods from the four stocks are presented in Appendix 1. Catch rate data were examined using a linear (lognormal) model, and success rate (the number of days when John dory were caught) was examined using a binomial model. A combined model incorporating both sources of information was also run.

The Inshore Fishery Assessment Working Group examined the results and chose to use the linear model series for JDO 1E (bottom trawl and Danish seine), and JDO 1W (bottom trawl) in the stock modelling. These series are presented in Table 5. CPUE data from JDO 2 were not considered to be reliable indices of stock abundance because of low catch rates of only five to eight fish per tow (JDO 2E), and a very high proportion of zero catches (JDO 2W).

5. TRAWL SURVEY ANALYSIS

5.1 Biomass estimates

Biomass and *c.v.*s were calculated for all trawl surveys carried out by R.V. *Kaharoa* in the Bay of Plenty, west coast North Island (WCNI), east coast North Island (ECNI), and Hauraki Gulf, using a trawl survey analysis programme (Vignaux 1994b). Biomass from the WCNI surveys was calculated separately for QMAs 8 and 9. Steps were taken to ensure standardisation between surveys. These included: standardising stratum areas and total survey areas for each time series; estimating doorspread (from warp length or depth) for tows where doorspread had not been measured; using length-weight relationships appropriate for that season and area; calculating catch weight from length frequency data when weights were not available; and excluding stations with poor gear performance, or where fish were present but no catch or length frequency data were available. Details of standardisation steps for individual surveys are given in Appendix 2.

For most surveys, length-weight data were not available, and so the most appropriate length-weight relationship for that area and season had to be determined. To do this, biomass was calculated from recent surveys in each area using first, the recorded catch weights, and second, the length frequency data, the percent sampled, and various length-weight relationships calculated from individual surveys. The length-weight relationship which gave the biomass most similar to the one calculated using recorded catch weight was then used for that series of surveys.

The John dory biomass estimates from the time series of trawl surveys are shown in Table 6. The length frequency distributions for each series of surveys combined are presented in Figure 2. Length frequency distributions for individual surveys in each series are plotted in Appendix 3.

5.2 Estimation of 1 year old biomass from trawl surveys

The trawl survey length frequency data often have a small mode of 1 year old fish present, which may be indicative of year class strength (*see* Figure 2, Appendix 3). Length frequency data were examined from each survey, and from all surveys combined. The upper length of the 0+ mode was very consistent between surveys within each area. The following upper lengths were selected for the various survey series: Bay of Plenty, 32 cm; Hauraki Gulf, 29 cm; WCNI, 28 cm; ECNI, 32 cm. Biomass estimates of 1 year old fish are given in Table 6.

6. BIOLOGICAL PARAMETERS

6.1 Growth parameters

There was considerable uncertainty over age estimates obtained from recent readings of zones in whole and sectioned otoliths; between-reader variations were unacceptably high (Hanchet *et al.* unpublished results). All John dory length frequency data on the Ministry of Fisheries *trawl* database were extracted and combined by month (Figure 3). A clear modal progression was apparent, indicating a mean length of 20 cm at age 1 year for both sexes, and mean lengths of 34 and 36 cm for males and females respectively at age 2 (assuming a "birthday" around December-January). Growth curves were constructed by fixing the lower lengths at age based on modes in the length frequency data, and fixing the upper lengths at age by assigning an age to the maximum length in the population. The maximum lengths observed in the trawl surveys were 59 cm for females and 54 cm for males, but few females exceeded 54 cm and few males exceeded 50 cm. Growth curves were fitted assuming lengths at ages 1 and 2 as given above, and a length of 54 and 50 cm (for females and males respectively) at an age of either 4 or 8 years. [Ages 4 and 8 were chosen by the Working Group to be likely estimates of maximum age for this species.]

Von Bertalanffy growth curves were fitted to the estimated age-length data using the non-linear multivariate secant parameter estimation procedure (SAS Institute 1988). Growth curves were computed separately for males and females, and the parameters are listed in Table 7. It would appear that females are slightly longer than males of a comparable age, although, in general, growth differences between the sexes are not extreme.

6.2 Natural mortality

Estimates of instantaneous natural mortality (M) were calculated for male and female fish using the equation $M = [-\log_e(p)]/A$, where p is the proportion of the population that reaches age A (or older) in an unexploited stock (Annala *et al.* 1998). Although none of the stocks could be considered to be unexploited, they are assumed not to have been heavily exploited. Therefore, p was set to 0.01, and M was estimated under two assumptions about maximum age (see above). Maximum ages of 4 and 8 years gave estimates of natural mortality of 1.15 and 0.57, respectively. These values were applied to all assessed stocks.

6.3 Length-weight parameters

The method of estimating the most suitable length-weight parameters for each trawl survey series was described above (Section 5.1). It was found that a single length-weight relationship (that estimated from the 1997 Hauraki Gulf survey, KAH9720) was the best for all survey series (*see* Table 7).

7. SELECTIVITY OGIVES

Trawl survey vulnerability, maturity, and fishing selectivity ogives are required as input parameters for the stock assessment modelling. Length frequency distributions (*see* Figure 2) indicate that males and females are fully vulnerable to the Hauraki Gulf, Bay of Plenty, and WCNI trawl surveys by age 1. About 25% of fish on the ECNI appear to be recruited by age 1, and they appear to be fully recruited by age 2.

Hore (1982) examined the age at maturity of John dory in the Hauraki Gulf. One year old fish were all immature. About 50% of females were mature at a standard length of 31 cm (total length 38 cm), which equates to age 2. He was unable to determine the age at 50% maturity for males because of small sample sizes, so it has been assumed here that it is the same as for females. All 3 year old fish were mature. The same maturity ogive has been assumed for all John dory stocks assessed here.

Although 1 year old fish are available on the trawl grounds it is unclear at what length and age they recruit to the commercial fishery. Hore (1982) provided length frequency data from about 800 fish sampled from the commercial catch between February and October 1981. The fish ranged from 20 to 40 cm with a peak at about 32 cm, which indicated that some 1+ fish recruit to the fishery. The size distribution of fish caught on the ECNI trawl survey (using 100 mm codend) gives another distribution of the size of fish which may be taken in the commercial fishery. Based on the relative abundances of the assumed 1+ and 2+ year classes from the two areas, it is likely that about 25% of fish are recruited to the fishery by age 1, and that they are fully recruited by age 2.

The estimated trawl survey vulnerability, maturity, and fishing selectivity ogives are presented in Table 8.

8. STOCK ASSESSMENT

8.1 Model inputs

The least squares and single-stock MIAEL estimation procedures were used to model the respective John dory stocks. Full descriptions of these procedures were given by Cordue (1995, 1996, 1998). Although the single stock model allows the specification of spawning and non-spawning components of the catch, all John dory stocks were modelled assuming a spawning season of zero length, with all catch taken from the home ground.

Estimates of biological parameters and of model parameters used in the assessments are given in Tables 7 and 8 respectively. The steepness parameter is from the Beverton and Holt stock-recruitment relationship. The proportion spawning is assumed to be 0.9 in the absence of data to fix a figure. A series of trawl survey indices is available for each stock, with two series available for JDO 1E (*see* Table 6). The series of CPUE indices accepted by the Working Group for inclusion in the modelling process are listed in Table 5.

The maximum exploitation rate was taken as 0.5 on the home ground (r_{hm_max}) and on the spawning ground (r_{sp_max}). The values of r_{hm_max} and r_{sp_max} determine B_{min}, the lowest value of

B_0 that is consistent with the catch history. The minimum exploitation rates (r_{hm_mmx} and r_{sp_mmx}) are the lowest values that the exploitation rates are believed to have been in the year that the exploitation was highest. A value of 0.01 was used for all stocks. Assumptions about r_{hm_mmx} and r_{sp_mmx} determine the value of B_{max}, the highest level that is believed to be feasible for B_0. The values of B_{min} and B_{max} are used as bounds for estimates of B_0.

No proportion-at-age data are available. Estimates of the relative abundance of 1 year old fish were calculated from trawl surveys for all stocks (*see* Table 6), but the Working Group considered that these indices were based on unacceptably small sample sizes, so they were not included in the model.

For each stock, the base case was taken as the run using productivity parameters associated with a maximum age of 8 years, and relative abundance indices from trawl surveys only. Sensitivities to a decrease in r_{max} (i.e., setting it at 0.3 on both the home and spawning grounds) and the inclusion of CPUE data (where available) was tested. Because of the considerable uncertainties surrounding the productivity parameters for this species, a second set of comparable model runs (with similar sensitivity tests) were completed using productivity parameters associated with a maximum age of 4 years.

8.2 Biomass estimation

Estimates of mid-spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1997–98 (B_{mid98}), and mid-spawning season biomass as a percentage of B_0 were obtained for all four stocks using the least squares and MIAEL estimation techniques, and are listed in Table 9. Estimated biomass trajectories at B_{min} and B_{max} are shown in Figure 4. The model fits to the series of relative abundance estimates from trawl surveys and CPUE analyses, and the estimated values of q for each of these series, are plotted in Figures 5 and 6.

For JDO 1E, the base case (i.e., where A_{max} = 8 years) MIAEL estimate of current biomass (B_{mid98}) as a percentage of B_0 is 48%. The bounds for the estimated biomass are very wide and the information index is quite low (37%), so the uncertainly associated with this assessment should be considered to be high.

The base case (i.e., where A_{max} = 8 years) estimate of current biomass as a percentage of B_0 for the JDO 1W stock is 54%. Again, the bounds are wide and the information index is very low (6%), implying a very high uncertainty for this assessment.

Point estimates of current biomass that are higher than estimated virgin biomass may appear to be in conflict with the plotted biomass trajectories at B_{max} which never rise above 100% B_0 (Figure 4). However, this is not so. No proportion-at-age data are available for the John dory stocks, so year class strengths are all assumed to be equal. Therefore, even if no catches are taken from the stock, there will never be any larger-than-average year classes to drive the biomass above its equilibrium virgin level. However, the MIAEL estimate of current biomass can be higher than the MIAEL estimate of virgin biomass, with both values still within their calculated bounds. This has arisen for both JDO 1 stocks.

The model fits to the abundance series (all of which had equal weighting in the model) for both JDO 1 stocks were essentially horizontal lines. This may appear incongruous, as linear regressions to all four series for JDO 1E showed an increasing trend (*see* Figure 5), while the CPUE series for JDO 1W exhibited a decreasing trend (*see* Figure 6). As noted above, projected biomass is based on catch histories and constant recruitment, so the biomass trajectories will always be declining (unless negligible catch levels allow some stock rebuilding). If the abundance index series have an increasing trend (as in JDO 1E), then they will always fit the model badly, and the best fit will be close to a horizontal line.

For JDO 1W, both abundance series were given equal weighting in the model, though individual *c.v.*s were greater for the CPUE data (*see* Table 8). The CPUE series covers a shorter time period (1990–97) than the trawl survey series (1986–96). The almost horizontal fit to the trawl survey data minimises the residuals for this series. Adding the CPUE data to the model did not influence the model fit much, because even though a downward-sloping line would minimise the residuals for the CPUE series, such a fit would have resulted in very high residuals for the first three points of the trawl survey series.

The model indicates that the JDO 2 stocks have probably declined since the fishery began. The base case (i.e., where A_{max} = 8 years) MIAEL estimate of current biomass (B_{mid98}) as a percentage of B_0 is 57% for JDO 2E and 53% for JDO 2W. For both these stocks, the bounds around the estimated biomass are very wide and the information indices are very low, indicating that the uncertainty associated with the assessments is very high.

The estimated CPUE catchability (q) values are quite consistent for the three series incorporated into the models, ranging from 2.3–3.7 $\times 10^{-5}$ (*see* Figures 5 and 6). The estimated q values from 4 of the 5 trawl surveys are also quite consistent, but are lower than expected (range 0.0024–0.0094). They imply that less than 1% of John dory in front of the trawl are actually caught. The exception to this is the q for the survey in QMA 8, which was 0.87. It was expected that all the trawl q values would be quite similar as they are derived from surveys using similar trawl gear. However, the estimates of trawl q are driven largely by the best estimate of current biomass. Where the best model fit to the abundance indices is essentially a horizontal line it indicates a high current biomass (relative to B_0), and consequently, a low q. For JDO 2W and the QMA 8 survey, the best model fit has a downward slope, indicating a reduced (lower than B_0) biomass, and, consequently, a higher q. It is believed that the 'true' value of trawl q for the surveys is likely to be between the 87% and under 1% values obtained from this analysis.

Estimates of B_0 under the assumption of a maximum age of 8 years were generally two to three times larger than those from similar runs under an assumption of a 4 year maximum. Estimates of B_0 for all stocks were found to be relatively insensitive to the tested change in r_{max} for either assumption of maximum age. The inclusion of CPUE data in the two JDO 1 assessments resulted in a marked improvement in the information indices. However, information indices for all B_0 runs ranged between 0 and 20%, indicating that the point estimates of virgin biomass are very poorly known. The information indices for B_{mid98} are generally much better than those for B_0, but with the exception of some for JDO 1E, they are still very low (i.e., less than 10%).

8.3 Yield estimates

The method used to estimate MCY was MCY = $p.B_0$ (Annala *et al.* 1998), where p is determined for each stock using the method of Francis (1992) such that the biomass does not drop below 20% B_0 more than 10% of the time. Estimates of MCY (Table 10) are shown to be much larger than values calculated previously (i.e., 360 and 80 t for JDO 1 and JDO 2, respectively, from Annala *et al.* (1998)). Base case estimates of MCY are 1910 t (range 370–7450 t) for JDO 1, and 350 t (range 120–2100 t) for JDO 2. For both administrative Fishstocks, reported landings, including estimated levels of recreational catch (see below), have never exceeded these MCY estimates. Current TACs are lower than the estimated MCYs. The best estimates of current stock size (B_{mid98}) are higher than estimates of B_{MCY}.

8.4 Management implications

This is the first assessment of John dory stocks using a population model. The model results suggest that fishing levels to date have had a small effect on the biomass levels of JDO 1 and JDO 2. MIAEL estimates of current biomass as a percentage of virgin biomass are at about 50% for all stocks, while point estimates of current biomass are higher than estimates of virgin biomass for JDO 1, but lower for JDO 2. Historic annual catch levels, and the current TACs, are lower than the estimates of MCY, so continued catches at current levels or at levels of the TACs should allow the stocks to move towards a size that will support the MSY. However, all the assessments presented here must be considered to have a very high level of uncertainty.

The lack of validated productivity parameters for John dory adds to the uncertainty of the assessments. The two different assumptions about maximum age gave markedly different estimates of virgin and current biomass for all stocks. The derivation of more accurate growth parameters is essential to the production of a more confident assessment.

The model was also restricted because of the lack of year class strength data, and the subsequent necessity to assume average recruitment in all years. This resulted in poor model fits to the abundance index series for JDO 1E. The survey and CPUE indices all indicated an increasing biomass, but other input data precluded the fitting of an increasing line to these series. Hence, it is difficult to evaluate the usefulness of the two trawl survey series in assessments of John dory in JDO 1E until catch-at-age data are available. Model fits to the trawl survey series for stocks JDO 1W and JDO 2W appear to be relatively good and have clearly influenced the assessment (i.e., indicating little change from B_0 in JDO 1W, and a biomass decline in JDO 2W). The JDO 2E trawl survey series covers a short time, so its use as an index of abundance may be limited at present. The availability of year class strength data could greatly enhance the usefulness of the trawl survey indices of abundance, particularly as the apparent high productivity of John dory could result in marked fluctuations in biomass if its recruitment success is variable.

None of the assessments presented here incorporated a recreational catch in the catch history. Recreational fishing surveys have indicated that landings from this source are probably insignificant for the JDO 2 stocks. However, it is estimated that at least since 1992, recreational landings from JDO 1 have been between 75 and 100 t annually (Annala *et al.*

1998). This represents about 10% of the total annual harvest. Future assessments of John dory stocks should incorporate some recreational catch component.

9. ACKNOWLEDGMENTS

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Table 1: Reported landings (t) of John dory, New Zealand total, from 1931 to 1997. Values from 1931 to 1983 are for calendar years; those from 1984 to 1997 are for fishing years (October–September)

1930		1940	4	1950	81	1960	292	1970	419	1980	741	1990	701
1931	70	1941	11	1951	45	1961	274	1971	413	1981	835	1991	730
1932	59	1942	13	1952	88	1962	274	1972	369	1982	767	1992	837
1933	58	1943	21	1953	233	1963	255	1973	388	1983	780	1993	853
1934	42	1944	24	1954	256	1964	227	1974	471	1984	826	1994	865
1935	92	1945	19	1955	237	1965	244	1975	374	1985	766	1995	894
1936	110	1946	35	1956	235	1966	296	1976	551	1986	735	1996	877
1937	84	1947	50	1957	167	1967	304	1977	531	1987	638	1997	864
1938	81	1948	43	1957	226	1968	312	1978	457	1988	758		
1939	46	1949	103	1959	270	1969	304	1979	647	1989	684		

Table 2: Reported landings and TACs (t) of John dory by Fishstock, 1986–87 to 1996–97 (Annala *et al.* 1998)

Fishstock		JDO1		JDO2		JDO3		JDO7		Total
QMA(s)		1&9		2&8		3–6		7		NZ
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	659	–	131	–	1	–	35	–	826	–
1984–85*	620	–	110	–	0	–	36	–	766	–
1985–86*	531	–	158	–	1	–	45	–	735	–
1986–87†	409	510	168	240	3	30	57	70	638	860
1987–88†	476	633	192	246	1	30	89	75	758	994
1988–89†	480	662	151	253	6	30	47	82	684	1037
1989–90†	494	704	152	262	1	30	54	88	701	1094
1990–91†	505	704	171	269	1	31	53	88	730	1102
1991–92†	562	704	214	269	1	31	60	88	837	1102
1992–93†	578	704	217	269	8	31	50	91	853	1105
1993–94†	640	704	186	269	2	32	37	91	865	1106
1994–95†	721	704	140	270	3	32	30	91	894	1107
1995–96†	696	704	139	270	<1	32	42	91	877	1107
1996–97†	689	704	140	270	<1	32	35	91	864	1107

* FSU data
† QMS data
Total includes 10 t TAC for QMA 10 (Kermadec Is) where no landings have ever been reported

Table 3: Estimated catches of John dory by east and west subdivisions of JDO 1 and JDO 2, and reported landings of John dory from JDO 1 and JDO 2, 1989–90 to 1995–96. Estimated data from catch effort database (CELR and TCEPR forms), landed data from QMS (Annala *et al.* 1998)

	JDO 1E		JDO 1W		JDO 1			JDO 2E		JDO 2W		JDO 2		
	Estimated		Estimated		Estimated		Landed	Estimated		Estimated		Estimated		Landed
	t	%*	t	%*	t	%†	t	t	%*	t	%*	t	%†	t
1989-90	292	85	51	15	343	69	494	55	52	51	48	106	70	152
1990-91	347	83	69	17	416	82	505	85	65	45	35	130	76	171
1991-92	421	87	61	13	482	86	562	81	55	66	45	147	69	214
1992-93	404	88	56	12	460	80	578	68	43	89	57	157	72	217
1993-94	502	89	63	11	565	88	640	57	50	58	50	115	62	186
1994-95	524	84	99	16	623	86	721	42	48	46	52	88	63	140
1995-96	420	79	111	21	531	76	696	47	41	69	59	116	83	139

* Percentage of *estimated* catch for entire QMA
† Percentage of *landed* catch for QMA

Table 4: Estimated catches (t) of John dory by east (E) and west (W) subdivisions of JDO 1 and JDO 2, and reported landings (Total) of John dory from JDO 1 and JDO 2, 1931 to 1995–96. For derivation of data, see text and footnotes

Year	JDO 1			JDO 2			Year	JDO 1			JDO 2		
	E	W	Total	E	W	Total		E	W	Total	E	W	Total
1931	70		70				1965	92	12	104	62	27	89
1932	58		58				1966	118	26	144	65	28	93
1933	56		56				1967	133	26	159	57	24	81
1934	42		42				1968	165	34	199	46	20	66
1935	92		92				1969	152	31	183	64	27	91
1936	105		105	4		4	1970	205	46	251	91	39	130
1937	80		80	3		3	1971	171	53	224	89	38	127
1938	78		78	2		2	1972	159	47	206	72	31	103
1939	40		40	5		5	1973	193	60	253	61	26	87
1940	0		0	1		1	1974	292	43	335	61	26	87
1941	1		1	5		5	1975	205	48	253	60	26	86
1942	4		4	2		2	1976	277	80	357	74	32	106
1943	12		12	2		2	1977	246	62	308	72	31	103
1944	10		10	4		4	1978	301	84	385	74	32	106
1945	12		12	5		5	1979	384	106	490	78	34	112
1946	26		26	6		6	1980	408	142	550	99	43	142
1947	23		23	6		6	1981	377	171	548	111	47	158
1948	18		18	22		22	1982	427	121	548	95	41	136
1949	15		15	77	7	84	1983	375	85	460	50	22	72
1950	12		12	62	5	67	1984	584	75	659	72	59	131
1951	1		1	38	3	41	1985	528	92	620	61	50	110
1952	28	1	29	51	4	55	1986	442	89	531	87	71	158
1953	145	13	158	60	5	65	1986–87	321	88	409	92	76	168
1954	170	7	177	38	3	41	1987–88	381	95	476	106	86	192
1955	143	14	157	38	6	44	1988–89	384	96	480	83	68	151
1956	145	28	173	31	5	36	1989–90	420	74	494	76	76	152
1957	82	26	108	27	4	31	1990–91	419	86	505	86	86	171
1958	98	31	129	30	5	35	1991–92	489	73	562	107	107	214
1959	132	23	155	34	6	40	1992–93	509	69	578	109	109	217
1960	118	38	156	49	8	57	1993–94	570	70	640	93	93	186
1961	128	25	153	46	7	53	1994–95	606	115	721	70	70	140
1962	121	25	146	58	10	68	1995–96	550	146	696	70	70	139
1963	91	18	109	64	10	74	1996–97	583	103	689	70	70	140
1964	89	17	106	50	22	72							

Notes:

1. Two assumptions were made when reconstructing the catch histories for JDO 2 East and West:
   (a) JDO 2W port values understate the (true) by-area catch by about one-third.
   (b) JDO 2W catches (or landings) have increased over time as a percentage of total JDO 2 catches.
2. The following adjustments and interpolations, rounded to the nearest tonne, are incorporated:
   1949 to 1954: JDO 2W listed port values (mean = 6% of JDO 2) have been increased to 8%.
   1955 to 1963: JDO 2W listed port values (mean = 11% of JDO 2) have been increased to 14%.
   1964 to 1982: JDO 2W listed port values (mean = 22% of JDO 2) have been increased to 30%.
   1983: Values not available; JDO 2W set at 30% of JDO 2, from trend.
   1984 to 1987: JDO 2W set at 45% of JDO 2, from mean of recorded area values.
   1987–88 and 1988–89: Values not available; JDO 2W set at 45% of JDO 2, from trend.
   1989–90 to 1996–97: JDO 2W set at 50% of JDO 2, from mean of recorded area values.

Table 5: Standardised CPUE indices for John dory incorporated into the population models, by stock and fishing method

Year	JDO 1E bottom trawl	JDO 1E Danish seine	JDO 1W bottom trawl
1990	1.000	1.000	1.000
1991	0.911	1.029	0.985
1992	0.927	0.950	0.952
1993	1.046	1.119	0.645
1994	1.168	1.171	0.644
1995	1.533	1.031	0.766
1996	1.295	1.115	0.757
1997	1.162	1.047	0.705

Table 6: Estimation of total John dory biomass (t) from *Kaharoa* trawl surveys. Total biomass is also separated into biomass of the assumed 1+ year class, and all other year classes combined (≥2+)

Year	Trip code	Total		1+		≥2+	
		Biomass	*c.v.*%	Biomass	*c.v.*%	Biomass	*c.v.*%
Bay of Plenty (JDO 1E)							
1983	KAH8303	113	24	18	29	96	28
1985	KAH8506	128	12	35	18	93	15
1990	KAH9004	157	16	37	14	121	20
1992	KAH9202	236	12	41	28	195	14
1996	KAH9601	193	44	18	22	175	46
North Island west coast FMA 9 (JDO 1W)							
1986	KAH8612	155	35	8	40	147	36
1987	KAH8715	160	16	3	34	157	17
1989	KAH8918	148	16	8	22	140	17
1991	KAH9111	216	37	13	44	203	37
1994	KAH9410	102	47	13	39	89	49
1996	KAH9615	147	15	7	19	140	15
North Island west coast FMA 8 (JDO 2W)							
1989	KAH8918	68	25	2	30	65	25
1991	KAH9111	142	62	1	77	141	62
1994	KAH9410	33	47	1	63	32	47
1996	KAH9615	19	38	< 1	64	19	39
Hauraki Gulf (JDO 1E)							
1984	KAH8421	281	22	35	41	242	20
1985	KAH8517	236	20	14	28	222	21
1986	KAH8613	211	25	24	28	187	28
1987	KAH8716	181	12	18	37	164	10
1988	KAH8810	477	32	10	22	462	33
1989	KAH8917	251	21	5	32	246	21
1990	KAH9016	322	13	18	46	304	13
1992	KAH9212	227	35	13	21	214	37
1993	KAH9311	374	24	17	29	355	25
1994	KAH9411	288	17	17	13	271	18
1997	KAH9720	387	18	17	21	371	18
North Island east coast (JDO 2E)							
1993	KAH9304	265	17	8	20	258	18
1994	KAH9402	268	31	6	73	261	31
1995	KAH9502	170	18	1	59	169	18
1996	KAH9605	172	48	5	31	166	49

Table 7: Biological parameters (instantaneous natural mortality, von Bertalanffy growth parameters, and length-weight coefficients) for all John dory stocks, under the two assumptions of maximum age

Parameter	Maximum age 4		Maximum age 8	
	Males	Females	Males	Females
M	1.15	1.15	0.57	0.57
L_∞	63.8	68.9	50.4	54.4
K	0.39	0.40	0.62	0.63
t_0	0.02	0.14	0.18	0.27
a	0.012	0.012	0.012	0.012
b	3.114	3.114	3.114	3.114

Table 8: Model input parameters for the assessment of all John dory stocks

Parameter		Estimate		
Steepness		0.95		
Recruitment variability		0.6		
Proportion spawning		0.9		
Spawning season length		0.0		
Maximum exploitation: $r_{hm\text{-}max}$, $r_{sp\text{-}max}$		0.5, 0.5		
Minimum exploitation at highest catch: $r_{hm\text{-}mmx}$, $r_{hm\text{-}mmx}$		0.01, 0.01		
Model *c.v.* for trawl survey indices		0.25		
Model *c.v.* for CPUE indices		0.35		
Maturity ogive	Age	1	2	3
	All stocks	0.00	0.50	1.00
Home ground selectivity	Age	1	2	
	All stocks	0.25	1.00	
Trawl survey selectivity	Age	1	2	
	JDO 2E	0.25	1.00	
	All other stocks	1.00	1.00	

Table 9: Least squares (LSQ) and best k estimates of biomass, and MIAEL estimates of *p*, biomass (MIAEL) and information indices (Info.), for base case and sensitivity model runs. All biomass estimates are in tonnes. MIAEL estimates of B_{mid98} as a percentage of virgin biomass (% B_0) are also presented. A_{max}, assumed maximum age. For each stock, the base case assumed a maximum age of 8 years, but because of uncertainties about productivity parameters, sets of comparable runs using an A_{max} of 4 years were conducted

Fishstock	Estimate	Model run	$B_{min} - B_{max}$	LSQ	best k	*p*	MIAEL	Info. (%)	% B_0
JDO 1E	B_0	Base (A_{max}= 8)	1 430 – 27 720	27 720	4 470	0.146	7 860	12.0	
		r_{max} = 0.3	1 670 – 27 720	27 720	4 990	0.105	7 380	6.8	
		+ CPUE	1 430 – 27 720	27 720	4 470	0.198	9 070	17.8	
		A_{max} = 4	470 – 10 820	10 820	1 540	0.130	2 750	10.4	
		r_{max} = 0.3	600 – 10 820	10 820	1 840	0.081	2 560	4.5	
		+ CPUE	470 – 10 820	10 820	1 540	0.214	3 530	20.1	
	B_{mid98}	Base (A_{max}= 8)	60 – 26 470	26 470	370	0.411	11 090	37.4	48
		r_{max} = 0.3	330 – 26 470	26 470	1 470	0.274	8 320	18.1	54
		+ CPUE	60 – 26 470	26 470	370	0.691	18 400	67.1	70
		A_{max} = 4	10 – 10 310	10 310	70	0.135	1 450	11.1	18
		r_{max} = 0.3	110 – 10 310	10 310	500	0.187	2 340	9.7	49
		+ CPUE	10 – 10 310	10 310	70	0.581	6 020	57.9	58
JDO 1W	B_0	Base (A_{max}= 8)	350 – 7 770	7 770	1 140	0.019	1 260	0.4	
		r_{max} = 0.3	410 – 7 770	7 770	1 270	0.008	1 320	0.1	
		+ CPUE	350 – 7 770	7 770	1 140	0.043	1 420	1.4	
		A_{max} = 4	160 – 3 030	3 030	500	0.010	520	0.1	
		r_{max} = 0.3	170 – 3 030	3 030	520	0.080	720	0.9	
		+ CPUE	160 – 3 030	3 030	500	0.034	580	1.0	
	B_{mid98}	Base (A_{max}= 8)	90 – 7 520	7 520	400	0.140	1 400	5.8	54
		r_{max} = 0.3	150 – 7 520	7 520	600	0.091	1 230	2.4	62
		+ CPUE	90 – 7 520	7 520	400	0.188	1 740	9.3	56
		A_{max} = 4	60 – 2 930	2 930	240	0.111	540	3.5	63
		r_{max} = 0.3	70 – 2 930	2 930	270	0.031	350	0.5	62
		+ CPUE	60 – 2 930	2 930	240	0.181	730	8.1	65
JDO 2E	B_0	Base (A_{max}= 8)	290 – 5 030	5 030	880	–0.016	810	0.3	
		r_{max} = 0.3	350 – 5 030	5 030	1 000	–0.021	920	0.4	
		A_{max} = 4	70 – 880	880	190	–0.024	180	0.4	
		r_{max} = 0.3	80 – 880	880	210	–0.024	190	0.4	
	B_{mid98}	Base (A_{max}= 8)	100 – 4 870	4 870	400	0.044	590	0.7	57
		r_{max} = 0.3	170 – 4 870	4 870	590	0.034	740	0.3	68
		A_{max} = 4	30 – 840	840	100	0.018	120	0.1	2
		r_{max} = 0.3	40 – 840	840	130	0.022	140	0.2	38
JDO 2W	B_0	Base (A_{max}= 8)	290 – 4 960	290	870	0.044	850	1.7	
		r_{max} = 0.3	300 – 4 960	300	900	0.040	870	1.4	
		A_{max} = 4	130 – 1 950	130	380	–0.006	380	0.0	
		r_{max} = 0.3	140 – 1 950	140	400	–0.006	400	0.0	
	B_{mid98}	Base (A_{max}= 8)	110 – 4 800	110	430	0.192	360	9.3	53
		r_{max} = 0.3	120 – 4 800	120	450	0.172	400	7.6	56
		A_{max} = 4	70 – 1 890	70	240	0.070	230	1.4	68
		r_{max} = 0.3	80 – 1 890	80	260	0.070	250	1.4	71

Table 10: MIAEL estimates and information indices (Info.) of B_{MCY} (as % of B_0), B_{MCY} (t), MCY (as % of B_0) and MCY (t), for all model runs for the John dory stocks. A_{max}, assumed maximum age

Fishstock	Model run	B_{MCY} (%B_0)	B_{MCY}	MCY (%B_0)	MCY	Info. (%)	MCY range
JDO 1E	Base (A_{max}= 8)	47.6	3740	21.0	1650	12.0	300 – 5820
	r_{max} = 0.3	48.0	3540	21.1	1560	6.8	350 – 5850
	+ CPUE	47.5	4310	21.0	1900	17.8	300 – 5820
	A_{max}= 4	59.3	1630	45.9	1260	10.4	220 – 4970
	r_{max} = 0.3	59.0	1510	46.3	1190	4.5	280 – 5010
	+ CPUE	59.3	2090	45.9	1620	20.1	220 – 4970
JDO 1W	Base (A_{max}= 8)	47.6	600	21.0	260	0.4	70 – 1630
	r_{max} = 0.3	48.0	630	21.1	280	0.1	90 – 1640
	+ CPUE	47.5	670	21.0	300	1.4	70 – 1630
	A_{max}= 4	59.3	310	45.9	240	0.1	70 – 1390
	r_{max} = 0.3	59.0	420	46.3	330	0.9	80 – 1400
	+ CPUE	59.3	340	45.9	270	1.0	70 – 1390
JDO 2E	Base (A_{max}= 8)	47.5	380	21.0	170	0.3	60 – 1060
	r_{max} = 0.3	48.0	440	21.1	190	0.4	70 – 1060
	A_{max}= 4	59.3	110	45.9	80	0.4	30 – 400
	r_{max} = 0.3	58.9	110	46.3	90	0.4	40 – 410
JDO 2W	Base (A_{max}= 8)	47.5	400	21.0	180	1.7	60 – 1040
	r_{max} = 0.3	48.0	420	21.1	180	1.4	60 – 1050
	A_{max}= 4	59.3	230	45.9	170	0.0	60 – 900
	r_{max} = 0.3	58.9	240	46.3	190	0.0	60 – 900

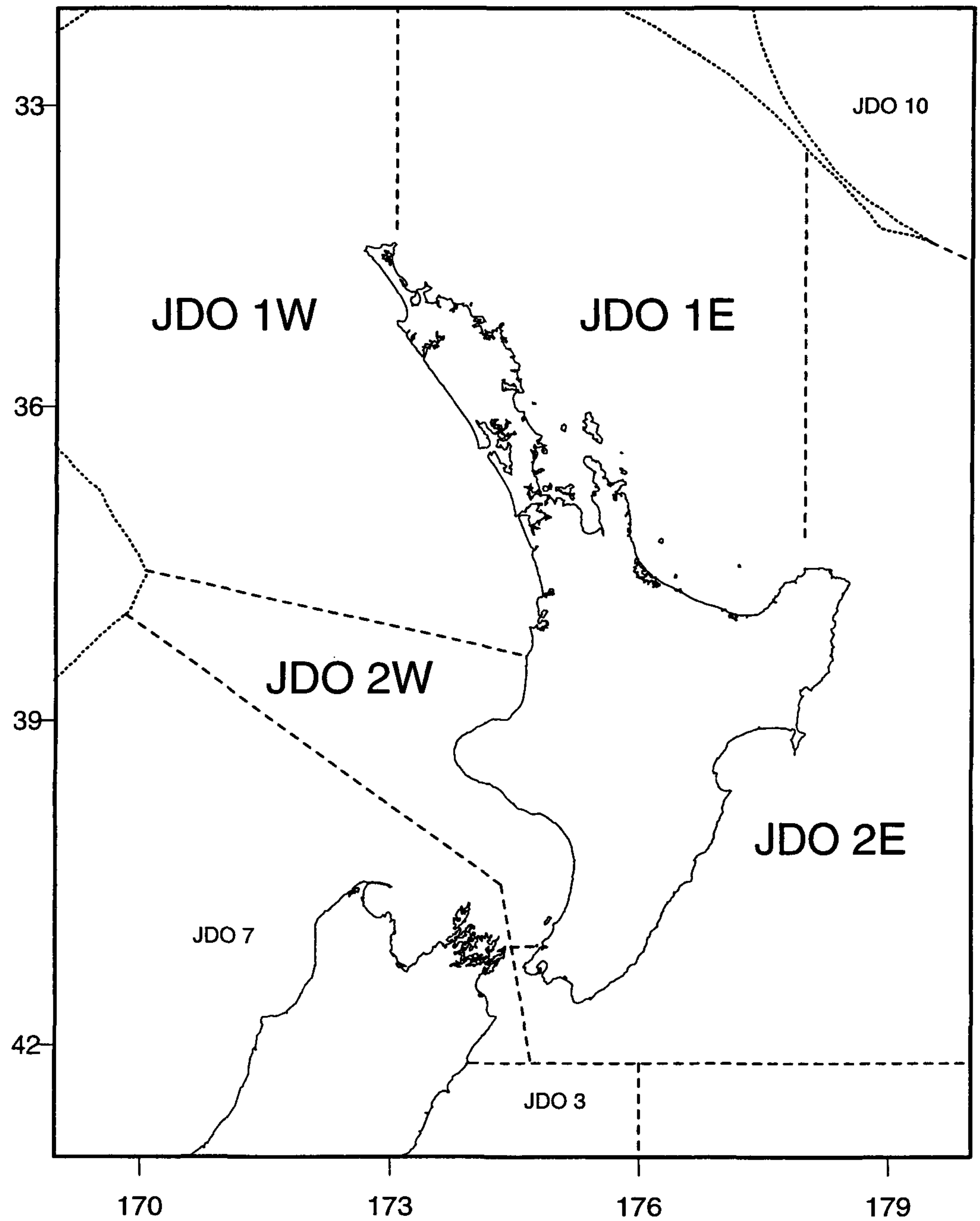


Figure 1: Areas of Fishstocks JDO 1 and JDO 2, separated into the eastern and western sections used in the current assessment. Adjacent John dory fishstock areas are also labelled.

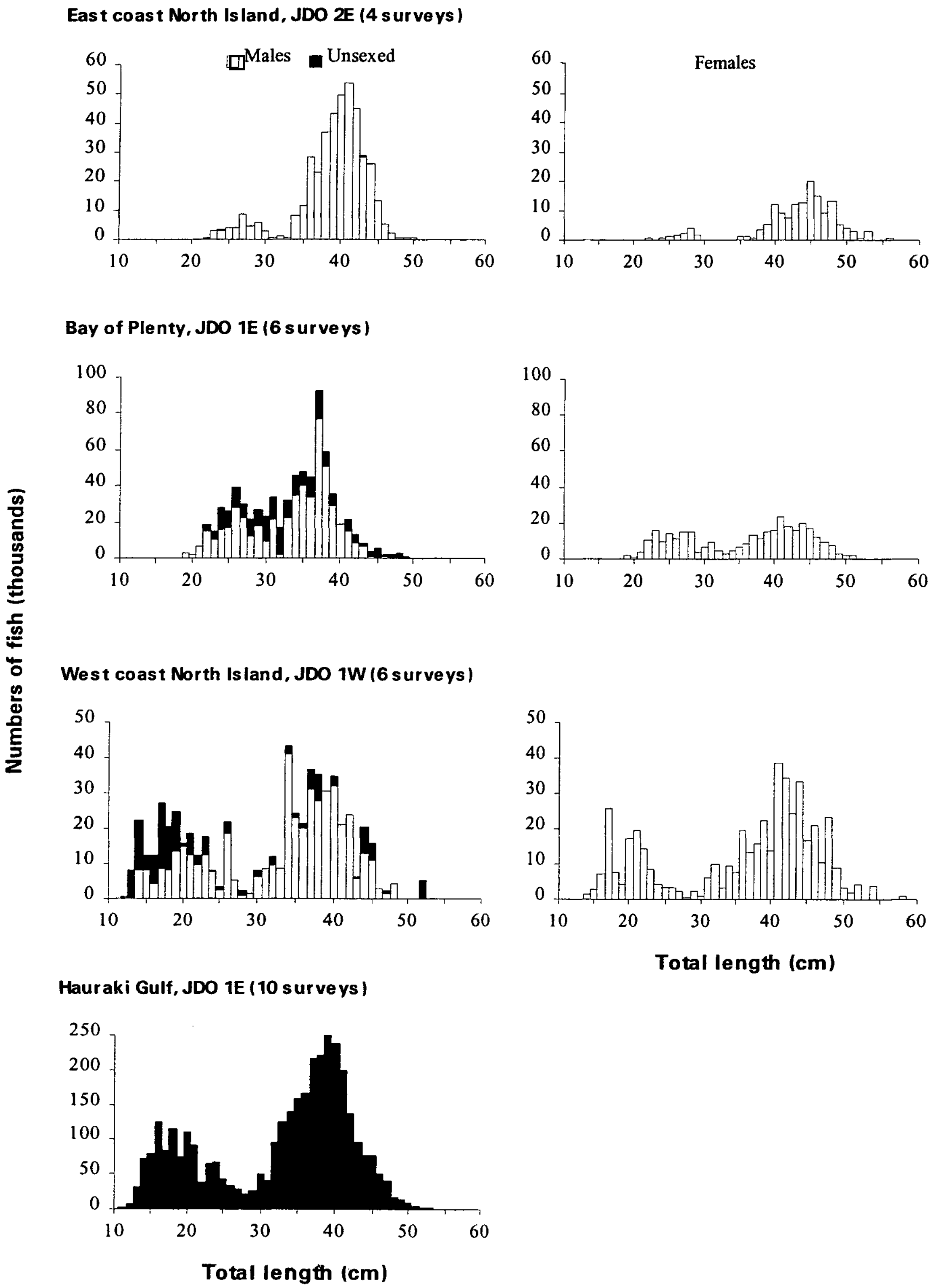


Figure 2: Combined length frequency distributions (by sex where data available) for John dory from each trawl survey series.

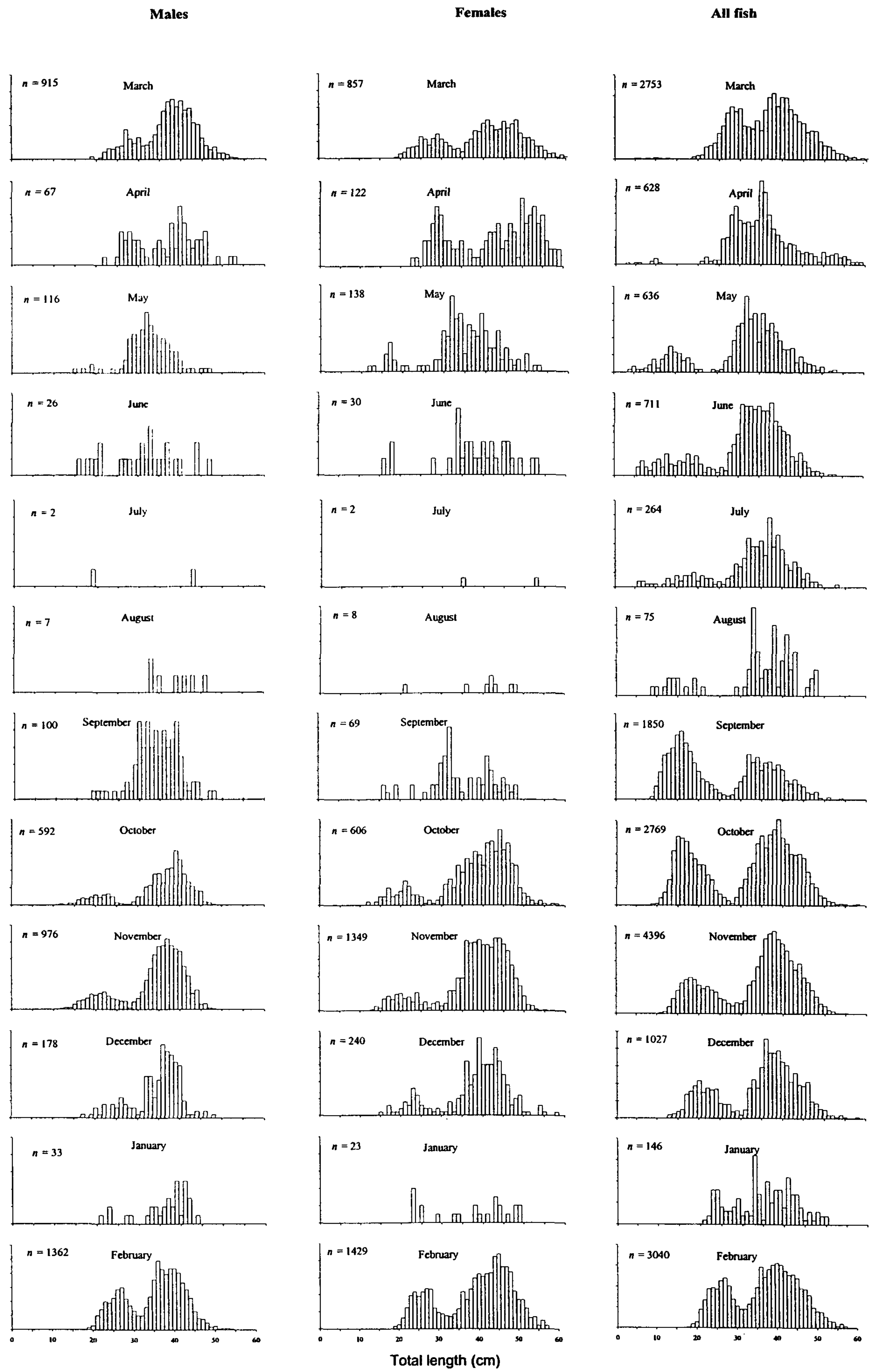


Figure 3: Summed length frequency distributions by month, for male, female, and all John dory caught during trawl surveys and recorded in the *trawl* database.

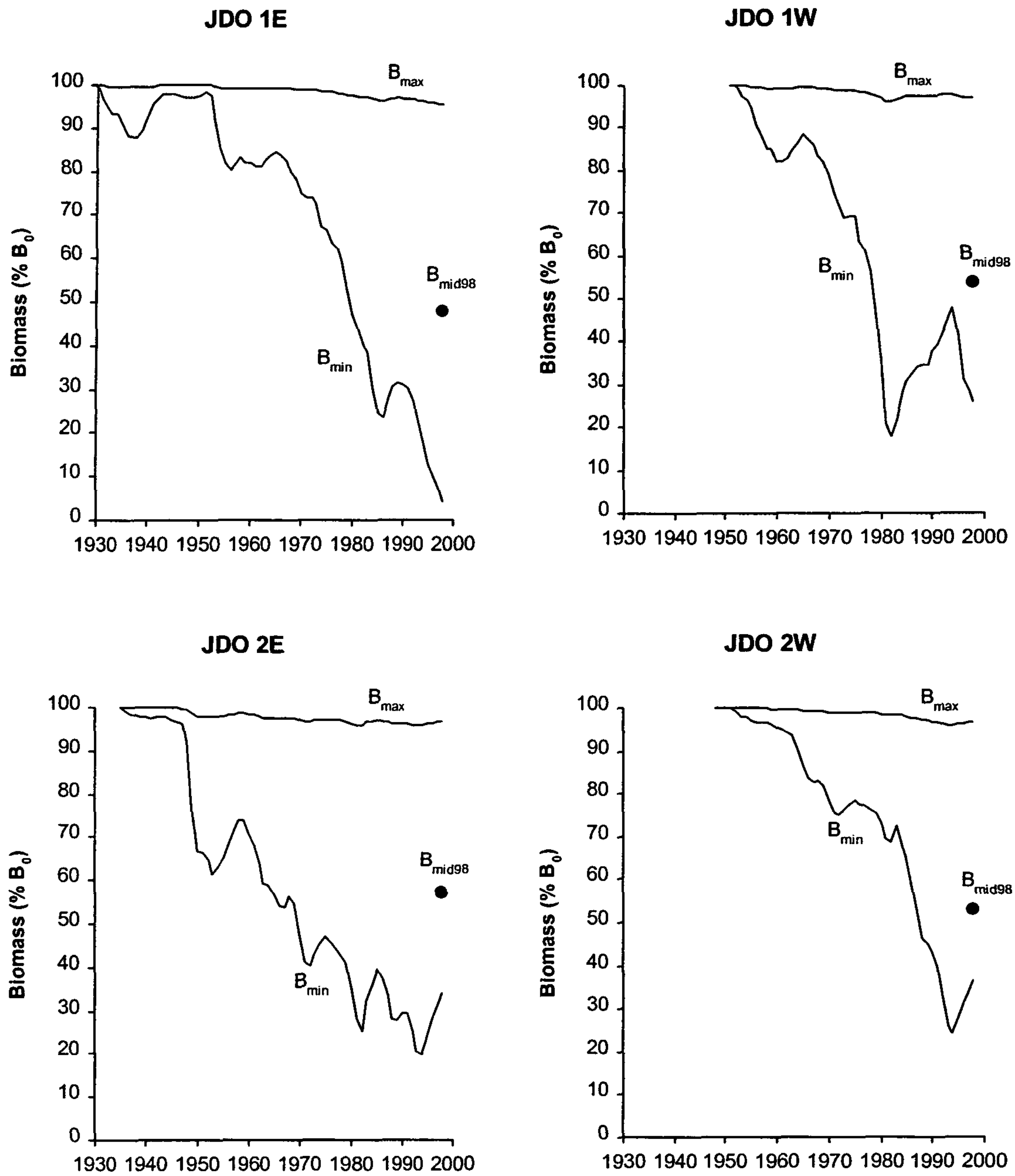
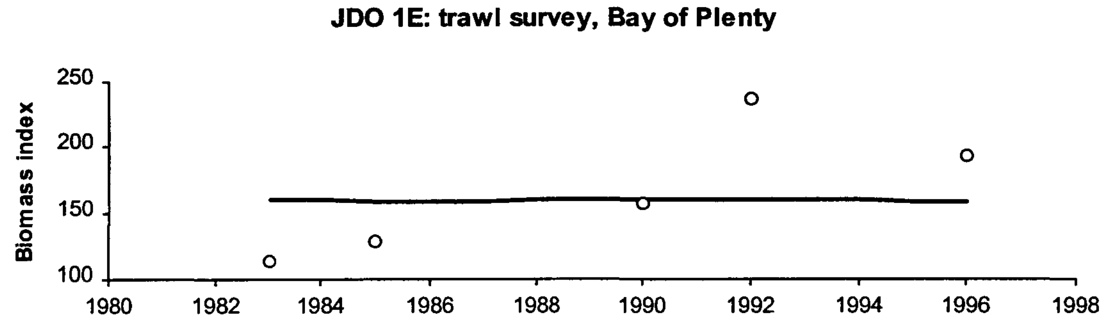
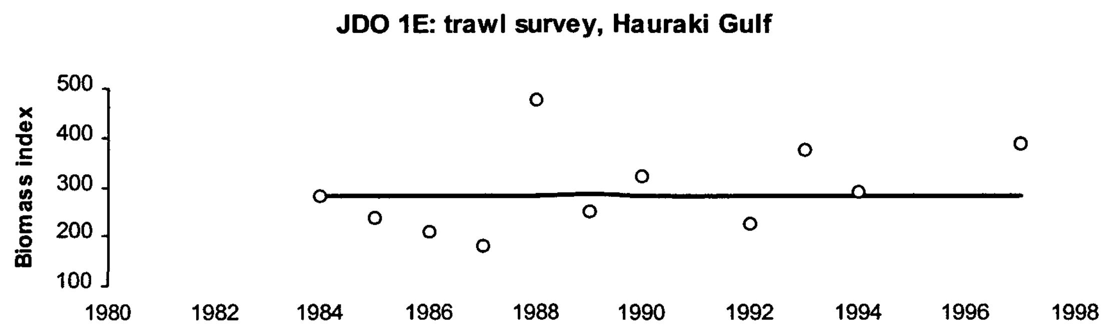
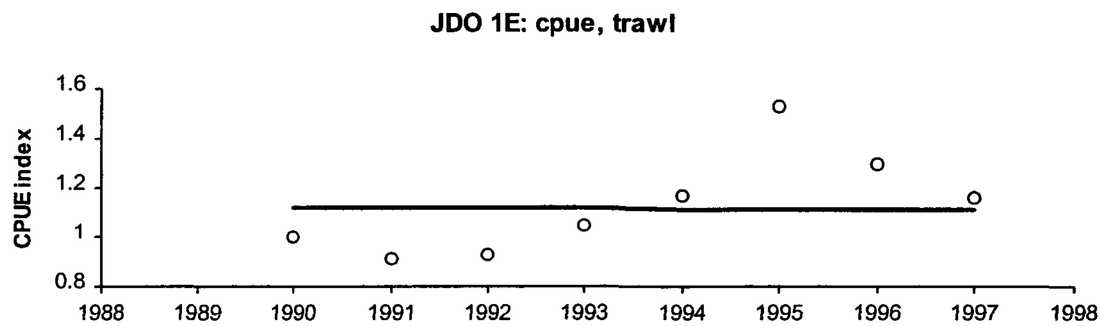


Figure 4: Trajectories for minimum (B_{min}) and maximum (B_{max}) estimates of biomass for base case John dory assessments. MIAEL estimates of current biomass (B_{mid98}) as a percentage of B_0 are shown as black circles.







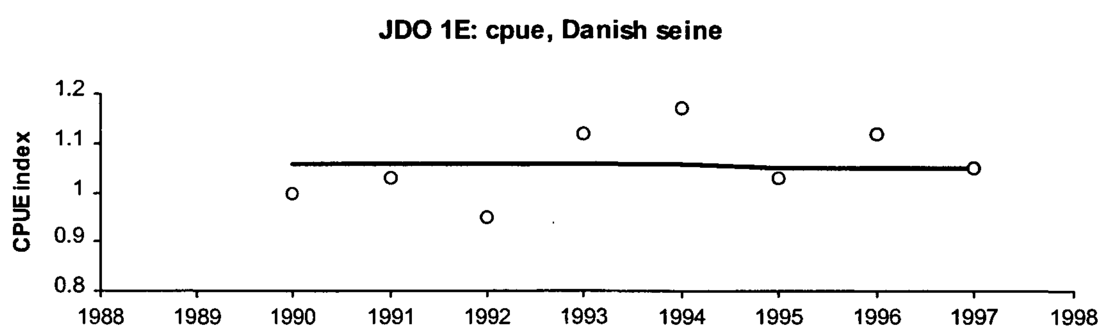


Figure 5: Model fits (solid lines) to the series of observed relative abundance indices (open circles) from trawl survey series and CPUE analyses, for John dory stock JDO 1E. Model estimates of q (catchability) for each series are shown on the plots.

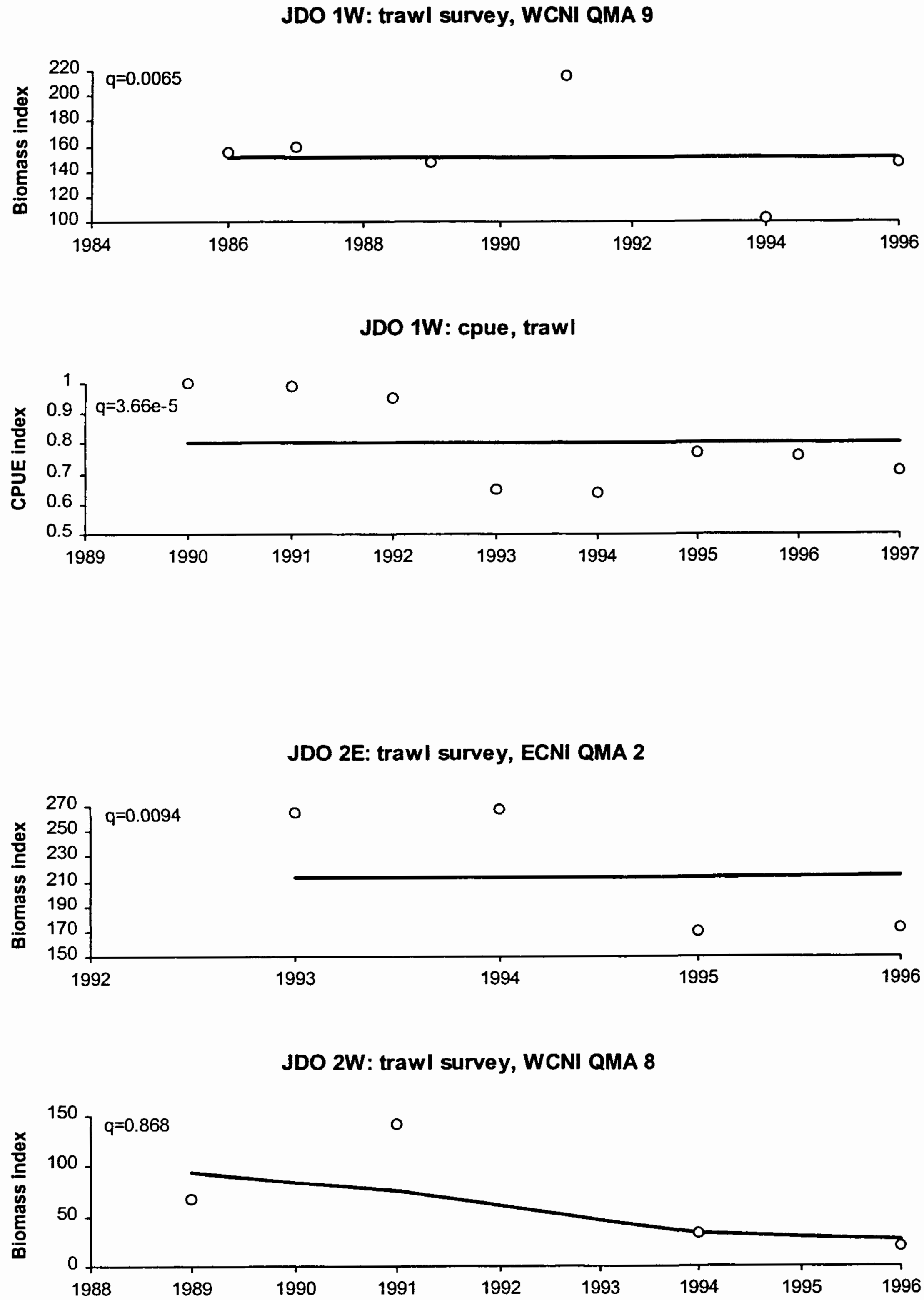


Figure 6: Model fits (solid lines) to the series of observed relative abundance indices (open circles) from trawl survey series and CPUE analyses, for John dory stocks JDO 1W, JDO 2E, and JDO 2W. Model estimates of *q* (catchability) for each series are shown on the plots.

Appendix 1

CPUE analyses for John dory stocks JDO 1 and JDO 2

Terese H. Kendrick & L. J. Paul

1 Executive Summary

John dory are taken mainly as a bycatch of trawl and Danish seine fisheries. About 80% of the national landings are from QMAs 1 and 9. Annual landings have generally been less than the TAC, though in JDO 1 they have been close to the TAC since 1994–95.

Fishstocks JDO 1 and JDO 2 each have an eastern and western component. It is not known whether these are separate stocks, although given the limited swimming ability of John dory it is probable that the eastern and western populations are reasonably separate. For the present purpose of stock assessment they are treated as different sub stocks. Within these eastern and western substocks, representative fisheries are selected from which to calculate CPUE of John dory.

CPUE from successful days only in each fishery, from 1989 to 1997, are standardised using a lognormal linear model, and combined mathematically with indices of success rate (of tows) from a logistic model; this is the combined model (Vignaux 1993), currently favoured for application to fisheries with high proportions of zero catches.

The catch per unit effort (CPUE) time-series for John dory has problems as an index of abundance because the species is usually a very minor component of mixed species trawl catches, and is often not reported due to it not being among the top five species caught. The necessity for combining records from both CEL and TCP databases has resulted in some contamination of both series by the problem of genuine non reporting.

The Stock Assessment Working Group chose to accept the linear component series for JDO 1E (single trawl, and Danish seine), and JDO 1W (single trawl). CPUE data from JDO 2 were not considered to be reliable indices of stock abundance because of low catch rates of only five to eight fish per tow (JDO 2E), and a very high proportion of zero catches (JDO 2W).

2 Introduction

No assessments of John dory stocks using population models have been completed previously. The aim of this study was to provide standardised CPUE indices of abundance where feasible, for incorporation into population models for the 1998 stock assessment. Results of those analyses, along with commercial catch histories, abundance indices from trawl surveys, and other biological parameters for John dory are presented elsewhere in this document.

Three indices calculable from the raw data which might indicate changes in stock size are raw CPUE, success rate, and catch rate when successful.

- The raw CPUE is total catch divided by total effort (e.g., tows or days fished), and in bycatch fisheries, where the proportion of zero catches of the species of interest can be high and can vary significantly, raw CPUE can be completely dominated by those reported zero catches.

- The ratio of successful to unsuccessful effort (success rate), can itself indicate a change in abundance, but it is susceptible to genuine non-reporting as when the species of interest is not among the top five species caught.

- The catch rate for only those records that did include the species of interest (catch rate when successful), is the third possible index. It is useful to look at both success rate and catch rate (rather than raw CPUE which may be one confounded by the other) to see whether they each send the same signal about the fishstock.

The combined model described by Vignaux (1993, 1994a) was applied here to commercial catch and effort data. This model actually consists of two separate models; a logistic model, and a lognormal linear model, fitted consecutively. The resulting indices are combined mathematically.

3 Data availability and quality

Vessels participating in the fisheries described here have tended to change their reporting of catch and effort from CELR to TCEPR forms in recent years. This is a reflection of company policy rather than of changes in fishing practice, so it has been necessary to combine information extracted from both MFish databases.

The main difference between the two sources of information is that the catch and number of tows on CELR forms are totals for the day, whereas TCEPR catch and effort is recorded on a tow by tow basis. To combine them, the TCEPR records were summarised by vessel/day to resemble CELR data. This loss of precision means that success rate is described as days, rather than tows, in which John dory were caught, and CPUE (kg/tow) for the linear model is calculated on the total number of tows completed by the vessel on a successful day, not on the number of those tows that were successful in catching John dory. Similarly, "proportion zero" refers to unsuccessful days not to unsuccessful tows.

John dory catches were small, always less than 2 t, and always less than the total catch, so there was no reason to eliminate any records from the datasets on the basis of catch. The number of tows per day contained errors, the causes of which were not obvious enough to allow them to be corrected. Frequency histograms suggested that 7 tows per day was the maximum practically possible (95% of the observations): records of more than 10 tows per day were assumed to be errors and were deleted. Also, tows with zero total catch were assumed to be gear failures and were deleted.

4 The variables

The response variable, CPUE, is taken to be average catch (kg) per tow for those days on which a catch of John dory was recorded (successful days). The logarithm of CPUE was used in the linear part of the combined model. A binary variable success (whether a catch of John dory was recorded or not) was the response variable for the logistic part of the combined model.

Dummy variables were created for each level of the categorical explanatory variables year, target species, and formtype. The other explanatory variables were treated as continuous variables, and offered for inclusion in the model as linear terms.

The choice of software (SAS v6.12) allowed use of an automatic stepwise selection tool for multiple regression. Some trade-offs against the expedience were accepted in this study; a low selection criterion for acceptance of variables (0.5% improvement in R^2) leading to the models possibly being over-specified, a reluctance to offer variables as categorical, yielding less information about area and month (season) effects, and year being added to the model last. However, these are unlikely to have affected the resulting indices.

The necessary resolution of one day (rather than one tow) for CELR data, meant that tow or gear characteristics could not be included in the analysis. Variables are given in Table 1.

Table 1: Explanatory variables considered for inclusion in the model. Variables in bold were offered as categorical, the others as continuous variables (linear terms only).

Variable	Description
year	Fishing year
month	Month of year
target	Target species
area	Statistical area
tottows	Total tows by that vessel on the day
totcatch	Total catch of all species by that vessel on the day
yrbuilt	Year the vessel was built
draught	Draft of vessel
length	Overall length of vessel
tonnage	Gross tonnage of vessel
kilowats	Power of vessel engine in kilowatts
crewno	Number of crew carried
formtype	Whether from CELR or TCEPR

5 The model

A feature of bycatch fisheries, where tows targeted on other species are selected as representative of the fishery for the species of interest, is a high proportion of zero catches. Although a problem mathematically, zero John dory catches in tows from the representative fisheries may nevertheless offer important information on John dory abundance. A linear (lognormal) model fitted to all the data would require the addition of an arbitrary value to catch to avoid attempting to take the logarithm of zero: the resultant distortion of the regression can yield unreliable results. The combined model was proposed by Vignaux (1994a) as a means of better combining catch rate information from successful tows with the proportion of tows that were unsuccessful.

The combined model splits the problem in two: first, how the success rate of tows has changed from year to year (where success is a non-zero tow), and second, how the catch rate in the successful tows has changed from year to year. It thus has two components fitted consecutively: a logistic regression on the success or otherwise (1 or 0) of each vessel-day, and a lognormal linear regression on CPUE from just those vessel-days that were successful (thus no zeros to contend with). Hence a change in abundance might be detected in either index. When the two indices are combined as described by Vignaux (1994a) the effect is to modify the CPUE index (for successful vessel-days only) by the ratio of successful to unsuccessful vessel-days.

The two series (success rate and catch rate) are each standardised using a multiple regression technique (Vignaux 1994a) to remove the effects of other explanatory variables. In the linear component of the combined model (of catch rate), forward stepwise selection of variables (as linear terms until there was less than a 0.5% improvement in R^2) has been retained. The variables for year were then added to the model. This permitted use of an automatic stepwise selection tool in SAS v6.12 without risking the exclusion of some or all of those years.

The criteria for selection of variables into the logistic model differed from that of the loglinear model. For the logistic model, significance of the improvement to the log likelihood was tested using the chi-square distribution, taking into account the degrees of freedom. Variables were accepted if the significance level was greater than 0.05. The score chi-square therefore reports the improvement to the log likelihood with the addition of the variable, much as the change in R^2 used for selection of variables in the log linear model indicates the relative improvement in the model as a result of each variable added.

In the logistic component of the combined model, variables were selected in a stepwise fashion as above. The criterion for entry into the model was a significance level of 0.05. The year effect must be calculated by applying the inverse of the logit function to the coefficients of the model, that is, 1/(1+exp(coeff.)). The pattern of these year effects is similar to that of the proportion of tows for which a zero catch of John dory was reported. In this study, the procedures were carried out using SAS v6.12 (proc reg for the linear and proc logistic for the logistic).

The combined index was calculated from that of the linear component (of catch rate of successful days), and that of the logistic component, using the proportion of zero days in the first year ($P0_1$), in the following manner:

$$\text{Combined index} = (1/(1-P0_1 * (1- \text{logistic index}))) * \text{linear index}$$

where the logistic index is the exponential of the negative relative year effect coefficient from the logistic model, and the linear index is the exponential of the relative year effect coefficient from the linear model of non-zero catches. For those years with a higher than mean proportion of zero catches, the effect is to modify the CPUE index downwards and in years with a higher success rate, to modify it upwards.

6 The datasets

Fishstocks JDO 1 and JDO 2 each have an eastern and western component. It is not known whether these are separate stocks, although given the limited swimming ability of John dory it is probable that the eastern and western populations are separate. For the present stock assessment they are treated as different substocks.

Within these eastern and western substocks, data were included in the dataset if visual examination of the raw CPUE showed no contradictory trends among statistical areas and target species fisheries, and if the major proportion of the John dory catch was represented.

JDO 1

This Fishstock covers the entire Auckland Fisheries Management Area, combining QMA 1 and QMA 9, and extends around the northern North Island from Cape Runaway in the east to Tirua Point in the west. Its subdivision into east and west is made at the North Cape QMA boundary.

JDO 2

This Fishstock occupies the entire Central Fisheries Management Area, combining QMA 2 and QMA 8, and extends around the southern North Island from Cape Runaway in the east to Tirua Point in the west. Its subdivision into east and west is made at the Cook Strait (Mana Island) boundary between QMAs 2 and 8.

6.1 JDO 1E (East Northland, Hauraki Gulf, Bay of Plenty)

6.1.1 The Fishery

This region contains the main fishing grounds for John dory. Recorded landings reached 100 t in the 1930s, but were negligible (apparently from lack of market demand) in the 1940s. From the mid 1950s to the mid 60s landings were 100–150 t, then increased steadily to about 600 t in the mid 1990s.

There is moderate seasonality in landings, the peak months (January–March) being about twice as great as the low months (June–August).

The main fishing method (Table 2) is single bottom trawl, followed by Danish seine and then by bottom pair trawl. The two main fishing methods were analysed separately.

Table 2: Estimated catches (t) of John dory by fishing method (single trawl, pair trawl, Danish seine, "other") in JDO 1E, 1989–90 to 1996–97

Method	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	Total (%)
S. Trawl	210	231	288	260	275	279	267	229	62
Pr Trawl	32	26	16	13	26	58	18	10	6
D. Seine	40	73	98	110	174	158	97	109	26
Other	9	16	18	21	26	28	38	45	6
Total	292	346	421	404	502	524	420	394	

6.1.2 Selecting single trawl fisheries in JDO 1E, by area and target species

Trawl catches were made in all statistical areas (1–10), predominantly in areas 3, 5, 6, and 9, but there were regular though small catches in all others except 7, where trawling is prohibited and only a few tonnes were recorded, presumably in error.

Patterns of raw CPUE by statistical area are shown in Figure 1. Some areas had few data points and hence a lot of variation, but the areas generally all show an increasing trend.

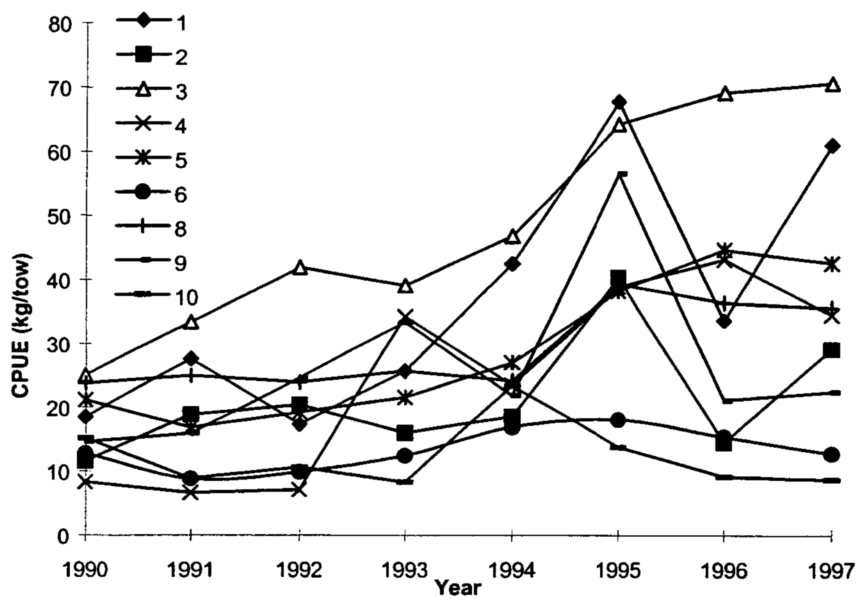


Figure 1: Raw CPUE of John dory by statistical area in JDO 1E.

All areas except 7 were included in the data set, and the model was allowed to account for differences between them.

Within these areas, John dory were taken mainly in two target fisheries, for snapper (44%), and John dory itself (34%). Other fisheries taking John dory were tarakihi (10%), red gurnard (4%), and barracouta (2%). The John dory catch in the snapper and John dory target fisheries was 1600 t, 79% of the total estimated JDO 1E trawl catch.

Raw CPUE of John dory in the two target fisheries are shown in Figure 2 There was no decrease evident in either, and even a slight overall increase in the John dory target fishery.

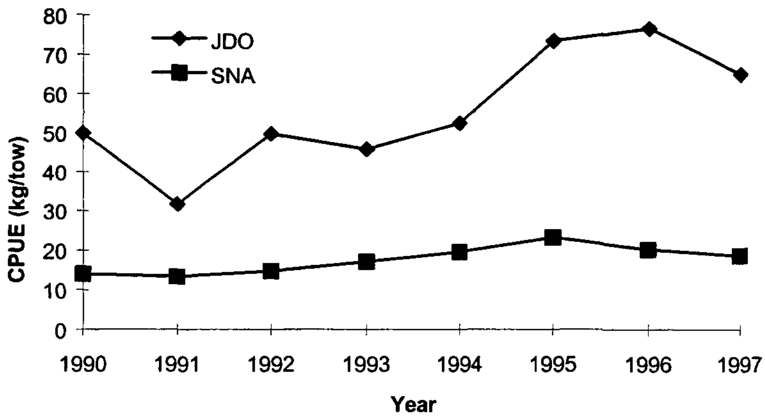


Figure 2: Raw CPUE of John dory by target species in JDO 1E (single trawl).

The patterns of success rate for each fishery (Figure 3), although different from each other in magnitude, confirm the slightly increased abundance seen in the raw CPUE of John dory in the snapper and John dory fisheries, with the proportion of unsuccessful days declining in the JDO target fishery and showing no overall increase in the snapper fishery.

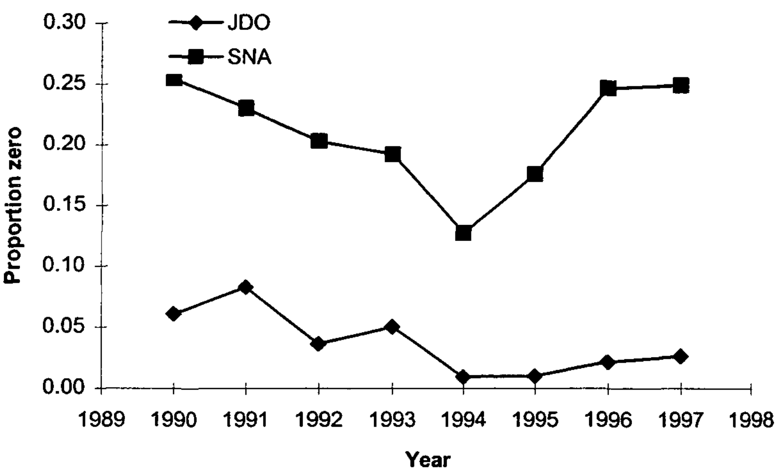


Figure 3: Proportion of days with zero reported catch of John dory in JDO 1E by target species.

The target and the bycatch fisheries within each fishing method obviously perform quite differently from each other in terms of John dory catch: nevertheless, for all practical purposes they are considered to be one and the same fishery, with the target species being chosen on the basis of catch composition and quota.

Single trawls targeted on snapper (SNA) or John dory (JDO) in statistical areas 1 to 10 (except 7) were accepted by the Stock Assessment Working Group as likely to be representative of the eastern fishery for JDO 1, and were combined to describe the single trawl JDO 1E fishery.

6.1.3 Standardised CPUE for JDO 1E (Single Trawl)

Data for the two target fisheries and for all statistical areas were combined to describe the single trawl JDO 1E fishery, and the success and catch rates modelled in order to obtain a possible index of abundance. A summary of the data included in the CPUE analysis is given in Table 3.

Table 3: Summary of catch data, raw CPUE (kg/tow), and success rate for John dory in the target snapper and John dory fisheries in JDO 1E (single trawl). Prop. zero is the proportion of days on which zero catch of John dory was reported

Year	Catch (kg)	Total no. tows	Raw CPUE (kg/tow)	Days fished	Days successful	Prop. zero
1989–90	169 244	9 535	17.75	2 631	603	0.229
1990–91	168 961	10 826	15.61	2 972	621	0.209
1991–92	223 009	11 863	18.80	3 232	579	0.179
1992–93	184 701	7 971	23.17	2 267	357	0.157
1993–94	211 393	7 687	27.50	2 471	228	0.092
1994–95	215 375	6 285	34.27	2 017	273	0.135
1995–96	233 318	6 594	35.38	2 621	481	0.184
1996–97	204 115	5 848	34.90	2 330	371	0.159

Target species was the most important explanatory variable in both the linear (Table 4) and the logistic (Table 5) components of the model. Statistical area entered the models of both catch rate and success rate, and the different patterns of CPUE among statistical area, largely in 1995–96 and 1996–97 indicates that an area × year interaction term might have been appropriate here.

Table 4: JDO 1E (single trawl) – The order in which the variables were selected into the linear model (of catch rate) and the model R^2 at each step

Variable		Model R^2
TARGET	1	0.1742
TOTTOWS	2	0.2286
TOTCATCH	3	0.2706
YRBUILT	4	0.2937
DRAUGHT	5	0.3090
AREA	6	0.3247
MNTH	7	0.3284
LENGTH	8	0.3318
TONNAGE	9	0.3380
KILOWATS	10	0.3383
FORMTYPE	11	0.3385
CREWNO	12	0.3386
YEAR		0.3557

Table 5: JDO 1E (single trawl) – The order in which the variables were selected into the logistic model (of success rate) and the chi-square score for the improvement to the log likelihood at the inclusion of each variable

Variable		Chi-square
TARGET	1	1206.73
DRAUGHT	2	594.19
TOTTOWS	3	355.00
YRBUILT	4	186.63
CREWNO	5	106.50
TONNAGE	6	73.88
TOTCATCH	7	42.85
AREA	8	21.30
FORMTYPE	9	12.28
MNTH	10	6.40
LENGTH	11	0.91
YEAR		

Table 6: CPUE indices for JDO 1E (single trawl) from the linear component, the logistic component and the combined model

Year	Linear	Logistic	Combined
1989–90	1.000	1.000	1.00
1990–91	0.911	1.038	0.93
1991–92	0.927	1.136	0.98
1992–93	1.046	1.137	1.11
1993–94	1.168	1.412	1.35
1994–95	1.533	1.330	1.73
1995–96	1.295	1.286	1.44
1996–97	1.162	1.294	1.30

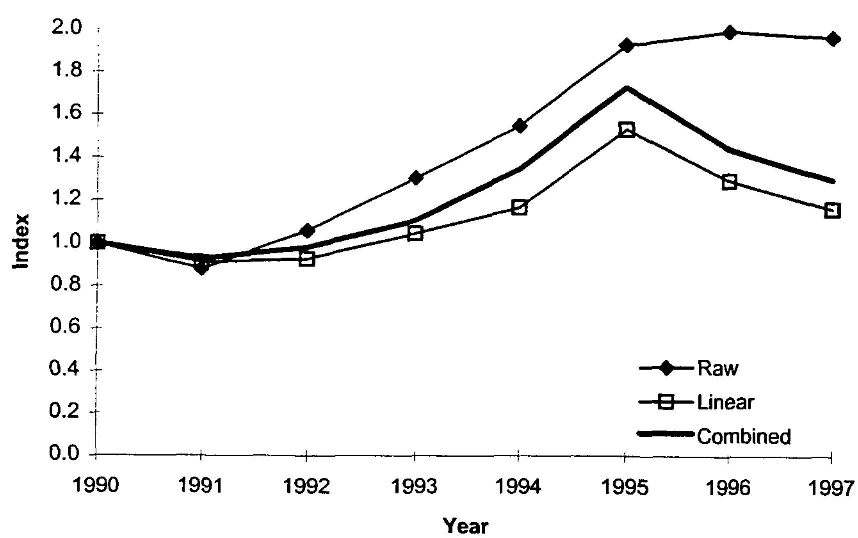


Figure 4: Relative CPUE indices for JDO 1E (single trawl) from the raw catch and effort, from the model of successful days, and from the combined model.

The CPUE index from the linear model (catch rate in successful tows), shows a slight increase, peaking in 1994–95 and declining in 1996 and 1997 (Figure 4). The decline seen in the subsequent years is not evident in the raw CPUE because it coincides with a decline in zero catches.

The index from the logistic model of success rate (Table 6) also gives a signal of increased abundance stabilising in later years. The index from the combined model tracks that from the linear, but it is modified upward by the increased success rate since 1989–90 (Figure 4).

6.1.4 Selecting Danish seine fisheries in JDO 1E by area and target species

Danish seine catches were made in all statistical areas (1–10), but predominantly (76%) in areas 5 and 6, the outer and central Hauraki Gulf. Only these two were included in the data set. The estimated John dory catch for all target species in these two areas, 1989–90 to 1996–97, was 656 t.

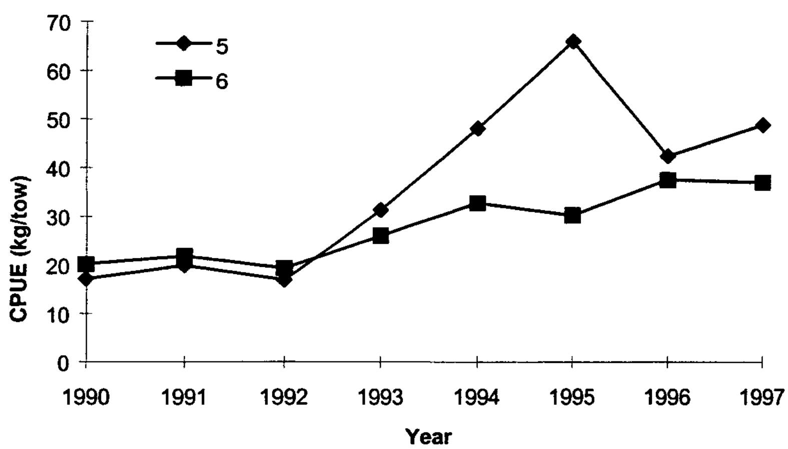


Figure 5: Raw CPUE of John dory by statistical area in the Danish seine fishery in JDO 1E.

Within these two areas John dory were mainly taken in two target fisheries, for snapper (54%), and John dory itself (37%). Other fisheries taking John dory were flatfish (4%) and red gurnard (3%). The John dory catch in the snapper and John dory target fisheries was 597 t, 69% of the total estimated JDO 1E Danish seine catch.

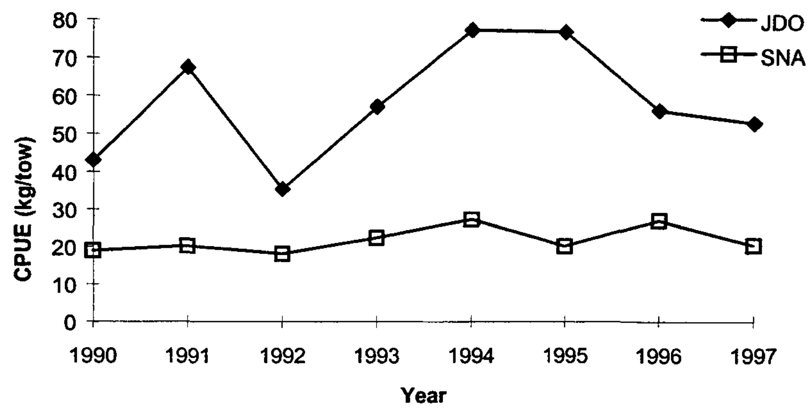


Figure 6: Raw CPUE of John dory by target species in the Danish seine fishery in JDO 1E.

Trends in raw CPUE between statistical areas and target fisheries were similar and are shown in Figures 5 and 6. Overall raw CPUE appears to have increased over the time series, but this mostly reflects the decrease in the proportion of days for which a zero John dory catch was reported (Figure 7).

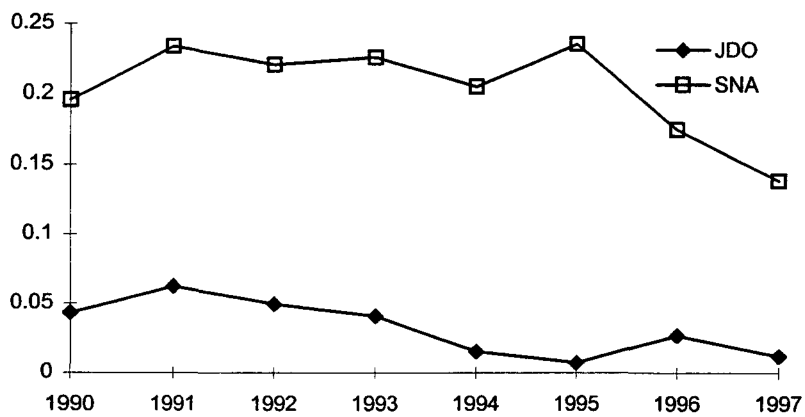


Figure 7: Proportion of days with zero reported catch of John dory by target species in the Danish seine fisheries in JDO 1E.

The target and the bycatch fisheries within each fishing method obviously perform differently from each other in terms of John dory catch. Nevertheless, for all practical purposes they are considered to be one and the same fishery, with the target species being chosen on the basis of catch composition and quota.

Danish seines targeted on snapper (SNA) or John dory (JDO) in statistical areas 5 and 6 were accepted by the Stock Assessment Working Group as likely to be representative of the Danish seine fishery for JDO 1E.

6.1.5 Standardised CPUE for JDO 1E (Danish seine)

Data for the two target fisheries and for the two statistical areas (5 & 6) were combined to describe the Danish seine JDO 1E fishery, and the success and catch rates modelled in order to obtain a possible index of abundance.

A summary of the data included in the CPUE analysis is given in Table 7.

Table 7: Summary of TCEP and CELR catch data and raw CPUE (kg/tow) for John dory in the target snapper and John dory fisheries in JDO 1E (Danish seine). Prop. zero is the proportion of days on which zero catch of John dory was reported

Year	Catch (kg)	Total no. tows	Raw CPUE (kg/tow)	Days fished	Days Successful	Prop. zero
1989–90	28 253	1 418	19.92	646	123	0.19
1990–91	50 646	2 337	21.67	1 007	230	0.23
1991–92	76 017	3 966	19.17	1 529	320	0.21
1992–93	72 916	2 743	26.58	977	198	0.20
1993–94	106 577	3 106	34.31	1 142	197	0.17
1994–95	104 620	3 188	32.82	1 107	196	0.18
1995–96	82 600	2 112	39.11	896	102	0.11
1996–97	92 907	2 412	38.52	1 078	74	0.07

Target species was the most important explanatory variable in both the linear (Table 8) and the logistic model (Table 9) components. Statistical area also entered the models of both catch rate and success rate, and exploration of a year × statistical area interaction might have been appropriate here.

Table 8: JDO 1E Danish seine – The order in which the variables were selected into the linear model (of catch rate) and the model R^2 at each step

Variable		Model R^2
TARGET	1	0.1132
TOTTOWS	3	0.1473
TOTCATCH	4	0.1525
BREADTH	5	0.1566
LENGTH	6	0.1654
TONNAGE	7	0.1727
KILOWATS	8	0.1777
DRAUGHT	8	0.1816
AREA	9	0.1839
MNTH	10	0.1845
YEAR		0.1881

Table 9: JDO 1E Danish seine – The order in which the variables were selected into the logistic model (of success rate) and the chi-square score for the improvement to the log likelihood at the inclusion of each variable

Variable		Chi-square
TARGET	1	664.76
YRBUILT	2	462.79
TOTTOWS	3	280.02
KILOWATS	4	167.36
LENGTH	5	128.74
TONNAGE	6	44.89
BREADTH	7	20.76
DRAUGHT	8	8.36
AREA	9	4.10
YEAR		

Table 10: CPUE indices for JDO 1E (Danish seine) from the linear component, the logistic component, and the combined model

Year	Linear	Logistic	Combined
1989–90	1.000	1.00	1.000
1990–91	1.029	0.95	0.963
1991–92	0.950	0.92	0.860
1992–93	1.119	0.92	1.014
1993–94	1.171	1.02	1.195
1994–95	1.031	0.92	0.925
1995–96	1.115	1.15	1.325
1996–97	1.047	1.30	1.461

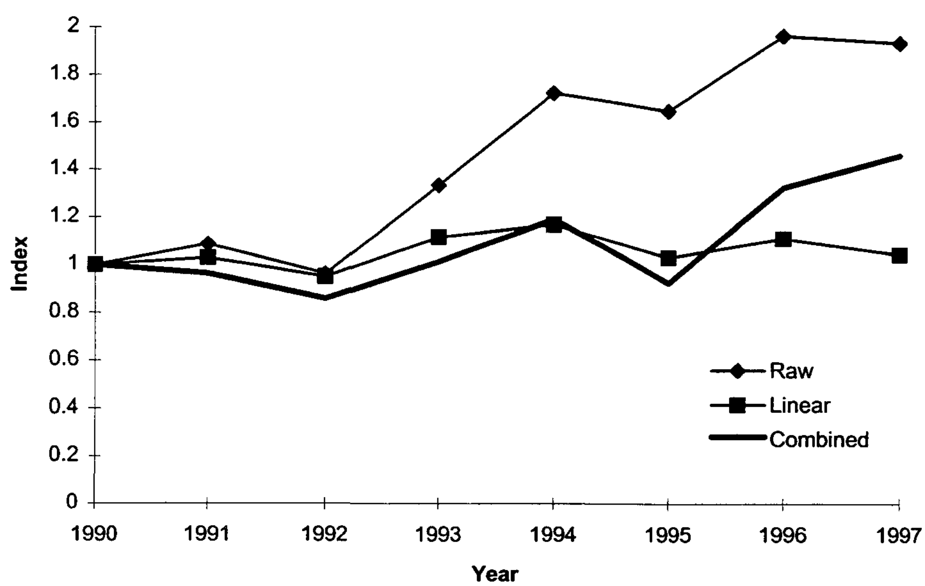


Figure 8: Relative CPUE indices for JDO 1E (Danish seine).

The component indices for the combined model are given in Table 10. A comparison between raw CPUE, standardised CPUE from successful days, and the combined model indices can be seen in Figure 8.

The CPUE index from the linear model (catch rate in successful tows) is relatively flat, with years not significantly different from each other. The index of success rate wanders around unity with no clear trend over time. When the models are combined, the resultant index resembles more the pattern shown by raw CPUE, suggestive of a slight overall increase.

6.2 JDO 1W (West coast of Auckland/Northland)

6.2.1 The fishery

Recorded landings from this area start in 1952, when the port of Manukau reported catches separately from Auckland, but small catches (mainly from Ninety Mile Beach) would have been made in earlier years. Landings were less than 50 t until the mid 1970s, increased rapidly to 171 t in 1981, then remained at 70–80 t until 1993–94. In the subsequent three years estimated landings have been 100–150 t. The seasonality of landings is not known.

The main fishing method (Table 11) is single bottom trawl.

Table 11: Estimated catches (t) of John dory by fishing method (single trawl, pair trawl, Danish seine, "other") in JDO 1W, 1989–90 to 1996–97

Method	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	Total (%)
S. Trawl	44	55	51	47	49	86	83	85	83
Pr Trawl	7	14	10	8	13	12	17	4	14
D. Seine	0	0	0	0	1	0	7	5	2
Other	0	0	0	0	0	0	0	1	<1
Total	51	69	61	56	63	99	111	97	

6.2.2 Selecting single trawl fisheries in JDO 1W by area and target species

Trawl catches were made in all statistical areas (42–48), but mainly in 42 and 45–47. Only these areas were included in the data set. Small catches in areas 43 and 44 (harbours) where trawling is prohibited were considered erroneous, and there were negligible catches from the northernmost area (48). The estimated John dory catch for all target species in these four areas, 1989–90 to 1996–97, was 497 t, 99% of the estimated JDO 1W trawl catch.

Within these areas, John dory were mainly taken in three target fisheries, for snapper (44%), trevally (25%), and red gurnard (11%). Other fisheries taking John dory were tarakihi (12%) and barracouta (4%). The John dory catch in the snapper and John dory target fisheries was 400 t, 80% of the total estimated JDO 1W single trawl catch.

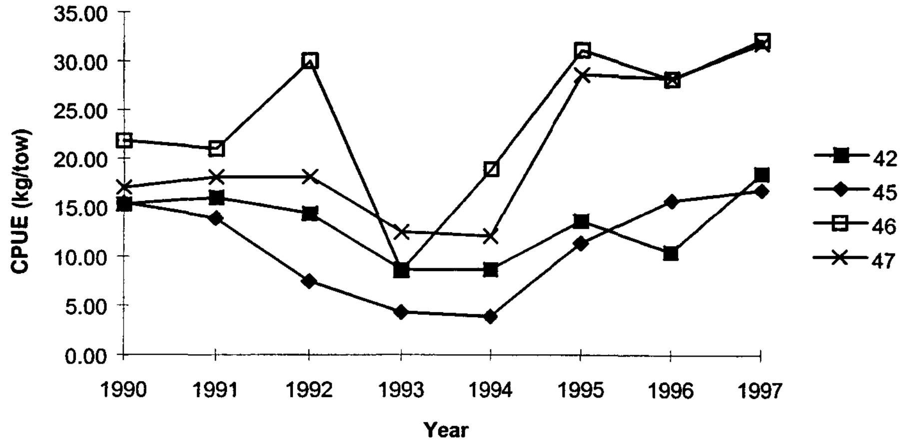


Figure 9: Raw CPUE of John dory by statistical area in JDO 1W.

The patterns of CPUE by statistical area (Figure 9) show some evidence of a north-south grouping. Though the trends are similar, the two northern statistical areas (46 and 47) show a greater recovery than the southern two (42 and 45).

Trends in raw CPUE between target fisheries are similar (Figure 10). The patterns of CPUE are largely a reflection of the changes in the proportion of days with zero reported catch of John dory (Figure 11). Those patterns are also similar for both target fisheries.

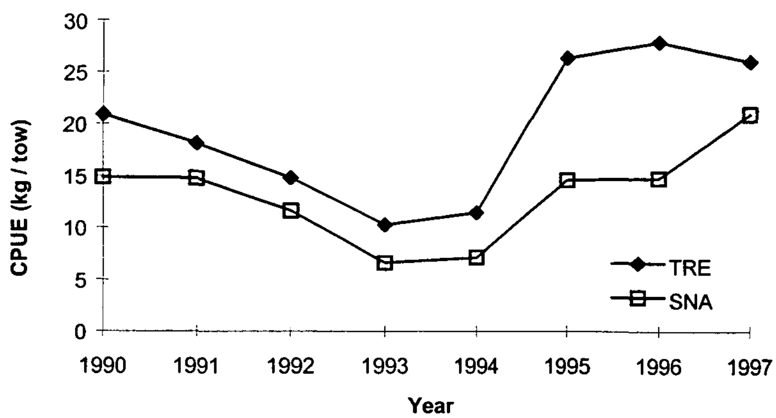


Figure 10: Raw CPUE of John dory by target species in JDO 1W.

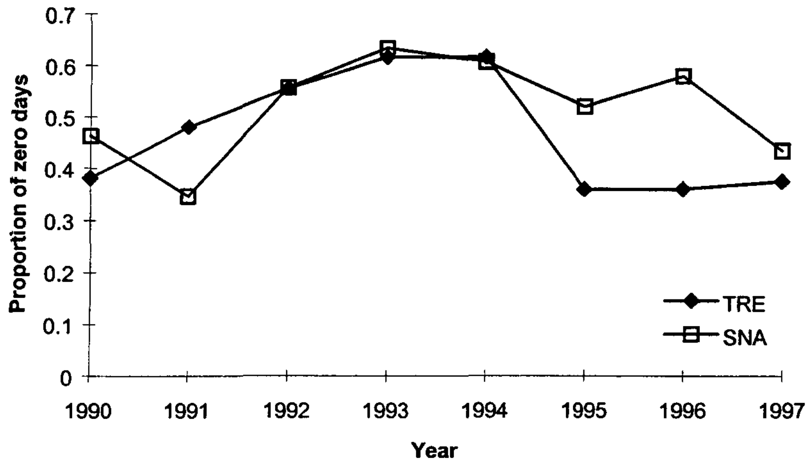


Figure 11: Proportion of days with zero reported catch of John dory in JDO 1W by target species.

Bottom trawls targeted on snapper (SNA) or trevally (TRE) in statistical areas 42, 45, 46 and 47 were accepted by the Stock Assessment Working Group as likely to be representative of the western fishery for JDO 1.

7 Standardised CPUE for JDO 1W (single trawl)

Data from the two target fisheries (snapper and trevally) and the four statistical areas (42, 45, 46 and 47) were combined to describe the JDO 1W substock, and the success and catch rates modelled in order to obtain a possible annual index of abundance for John dory in QMA 9. A summary of data included in the CPUE analysis is given in Table 12.

Table 12: Summary of catch data, raw CPUE (kg/tow), and success rate for John dory in the target snapper and trevally fisheries in JDO 1W. Prop. zero is the proportion of days on which zero catch of John dory was reported

Year	Catch (kg)	Total no. tows	Raw CPUE (kg/tow)	Days fished	Days successful	Prop. zero
1989–90	29 257	1 767	16.56	575	253	0.44
1990–91	35 283	2 260	15.61	678	264	0.39
1991–92	34 918	2 844	12.28	865	481	0.56
1992–93	32 783	4 271	7.68	1 246	781	0.63
1993–94	32 258	3 976	8.11	1 134	690	0.61
1994–95	62 299	3 523	17.68	1 066	505	0.47
1995–96	59 099	3 238	18.25	1 259	647	0.51
1996–97	65 447	2 889	22.65	1 173	485	0.41

Target species entered the logistic model (Table 14) predicting success rate, but did not significantly improve the linear model (Table 13) predicting catch rate. Statistical area, by contrast, was significant in explaining variation in catch rate but not success rate.

Table 13: JDO 1W Single trawl – The order in which the variables were selected into the linear model (of catch rate) and the model R^2 at each step

Variable		Model R^2
FORMTYPE	1	0.1064
TOTTOWS	2	0.1666
TOTCATCH	3	0.2297
AREA	4	0.2808
LENGTH	5	0.2859
TONNAGE	6	0.2941
YRBUILT	7	0.2976
CREWNO	8	0.3010
KILOWATS	9	0.3033
BREADTH	10	0.3064
DRAUGHT	11	0.3075
YEAR		0.3273

Table 14: JDO 1W Single trawl – The order in which the variables were selected into the logistic model (of success rate) and the chi-square score for the improvement to the log likelihood at the inclusion of each variable

Variable		Chi square
TOTCATCH	1	199.51
KILOWATS	2	177.32
LENGTH	3	135.05
TONNAGE	4	77.41
YRBUILT	5	38.28
FORMTYPE	6	24.25
TARGET	7	12.97
TOTTOWS	8	7.15
YEAR		

Table 15: CPUE indices for JDO 1W (single trawl) from the linear component, the logistic component and the combined model

Year	Linear	Logistic	Combined
1989-90	1.000	1.000	1.000
1990-91	0.985	1.133	1.098
1991-92	0.952	0.770	0.754
1992-93	0.645	0.646	0.435
1993-94	0.644	0.678	0.454
1994-95	0.766	0.949	0.731
1995-96	0.757	0.948	0.723
1996-97	0.705	1.198	0.825

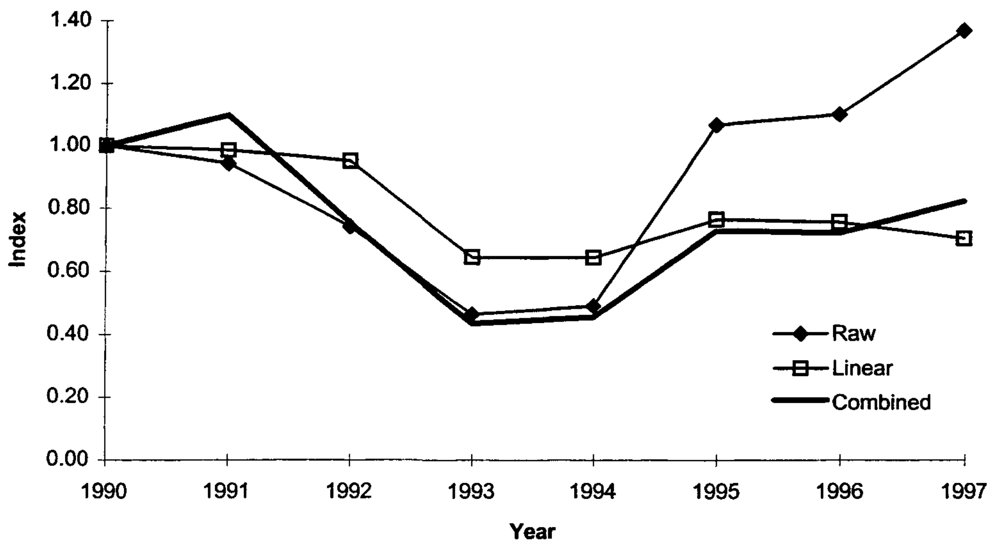


Figure 12: Relative CPUE indices for JDO 1W (single trawl).

The component indices for the combined model are shown in Table 15. A comparison between raw CPUE, standardised CPUE from successful days, and the combined model indices can be seen in Figure 12.

Raw CPUE declined to about 50% of its 1989–90 level in 1992–93 and then recovered dramatically, suggesting, overall, a marked increase in abundance. This is largely due to the influence of success rate, which also reflects this pattern. The CPUE index from the linear model (catch rate on successful days) shows only a moderate decline to 1992–93 and then is relatively flat, though precision is good and the year effects are significant. The index from the combined model shows a slight decline overall, but with steady recovery since 1992–93.

7.1 JDO 2E (East Cape to Cook Strait)

7.1.1 The fishery

Landings were negligible until the late 1940s, then rose slowly and with large fluctuations from about 50 t in the early 1950s to 80–90 t in the 1980s and 1990s.

Almost the entire John dory catch in JDO 2E is taken by single bottom trawl (99% of the estimated catch from 1989–90 to 1996–97), with 1% by setnet.

There is moderate seasonality in landings for JDO 2, the peak months (December–February) being about twice as great as the low months (April–August).

7.1.2 Selecting fisheries in JDO 2E, by area and target species

Trawl catches were made in all statistical areas (11–16), but predominantly (81%) in areas 13 and 14, centred on Hawke Bay. However, because areas 11 and 12 are part of the same fishing ground they were included in the data set. The two southernmost areas, 15 and 16, are part of the Cook Strait fishery and were excluded. The estimated John dory catch for all target species in areas 11 to 14, 1989–90 to 1996–97, was 436 t, 93% of the estimated JDO 2E trawl catch.

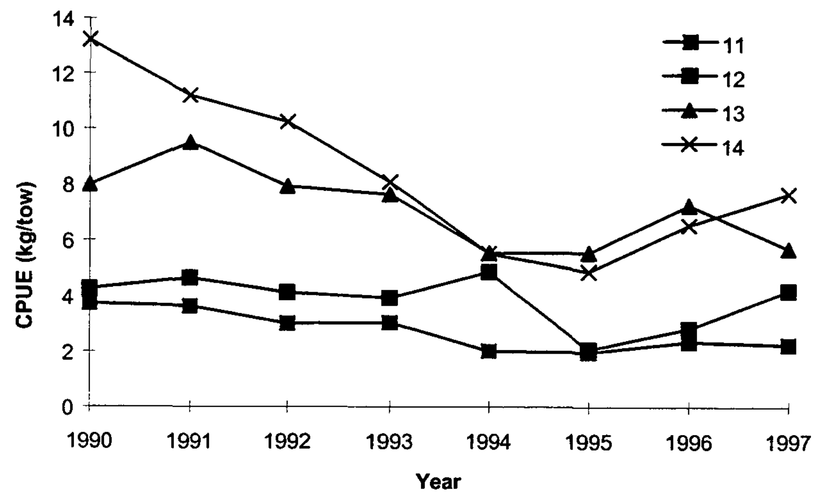


Figure 13: Raw CPUE of John dory by statistical area in JDO 2E.

Within these areas John dory were taken mainly in three target fisheries, for gurnard (34%), tarakihi (33%), and John dory itself (12%). Other fisheries taking John dory were barracouta (5%), trevally (4%), flatfish and snapper (each 3%), and hoki, gemfish and warehou (each 2% or less). The John dory catch in the gurnard, tarakihi, and John dory target fisheries was 292 t, 62% of the total estimated JDO 2E trawl catch.

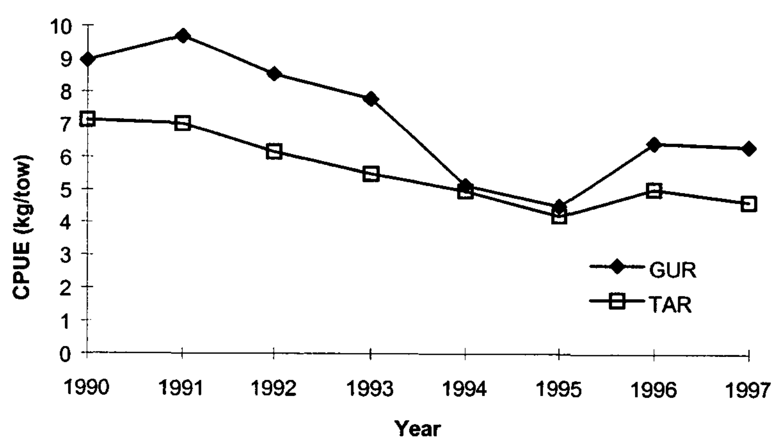


Figure 14: Raw CPUE of John dory by target species in JDO 2E.

The overall pattern in raw CPUE among statistical areas (Figure 13) and target species (Figure 14) is one of steady decline, but this mostly reflects an increased proportion of zero days reported (Figure 15). This is seen most strongly in the gurnard fishery, and to a lesser extent in the tarakihi fishery.

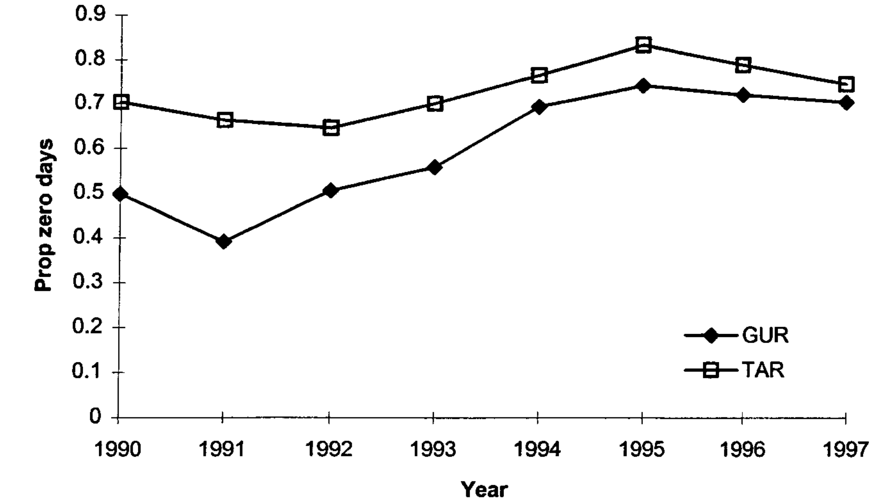


Figure 15: Proportion of days with zero reported John dory catch by target species in JDO 2E.

Single trawls targeted on tarakihi or gurnard in statistical areas 11 to 14 were initially accepted by the Stock Assessment Working Group as likely to be representative of the eastern fishery for JDO 2.

7.1.3 Standardised CPUE for JDO 2E

Data from the two target fisheries (tarakihi or gurnard) and the four statistical areas (11 to 14) were combined to describe the JDO 2E substock, and the success and catch rates modelled to provide a possible index of abundance. A summary of data included in the CPUE analysis is given in Table 16.

Table 16: Summary of catch data, raw CPUE (kg/tow), and success rate for John dory as bycatch of the target tarakihi and gurnard fisheries in JDO 2E (single trawl). Prop. zero is the proportion of days on which zero catch of John dory was reported

Year	Catch (kg)	Total no. tows	Raw CPUE (kg/tow)	Days fished	Days successful	Prop. zero
1989–90	32 021	4 147	7.72	1 639	1 022	0.62
1990–91	48 245	6 021	8.01	2 324	1 286	0.55
1991–92	52 919	7 298	7.25	2 914	1 677	0.58
1992–93	44 629	6 739	6.62	2 633	1 646	0.63
1993–94	34 101	6 775	5.03	2 853	2 067	0.72
1994–95	26 331	6 095	4.32	2 674	2 106	0.79
1995–96	30 037	5 303	5.66	2 250	1 697	0.75
1996–97	25 955	4 831	5.37	2 113	1 529	0.72

Target species was selected into the linear model (Table 17) predicting catch rate, and was the most important variable in the logistic model (Table 18) predicting success rate. Area was significant in explaining variation in both.

Table 17: JDO 2E single trawl – The order in which the variables were selected into the linear model (of catch rate) and the model R^2 at each step

Variable		Model R^2
DRAUGHT	1	0.1242
TOTTOWS	2	0.1537
TOTCATCH	3	0.1863
YRBUILT	4	0.1989
CREWNO	5	0.2061
LENGTH	6	0.2203
AREA	7	0.2313
TONNAGE	8	0.2409
KILOWATS	9	0.2418
TARGET	10	0.2421
YEAR		0.2432

Table 18: JDO 2E Single trawl – The order in which the variables were selected into the logistic model (of success rate) and the chi-square score for the improvement to the log likelihood at the inclusion of each variable

Variable		Chi-square
TARGET	1	249.87
AREA	2	149.08
KILOWATS	3	79.01
YRBUILT	4	45.81
TOTTOWS	5	35.85
TONNAGE	6	30.26
LENGTH	7	10.37
YEAR		

Table 19: CPUE indices for JDO 2E (single trawl) from the linear component, the logistic component and the combined model

Year	Linear	Logistic	Combined
1989–90	1.000	1.000	1.000
1990–91	0.967	1.166	1.175
1991–92	0.952	1.097	1.069
1992–93	1.014	0.975	0.983
1993–94	0.971	0.737	0.673
1994–95	0.948	0.612	0.531
1995–96	1.034	0.706	0.682
1996–97	0.902	0.793	0.682

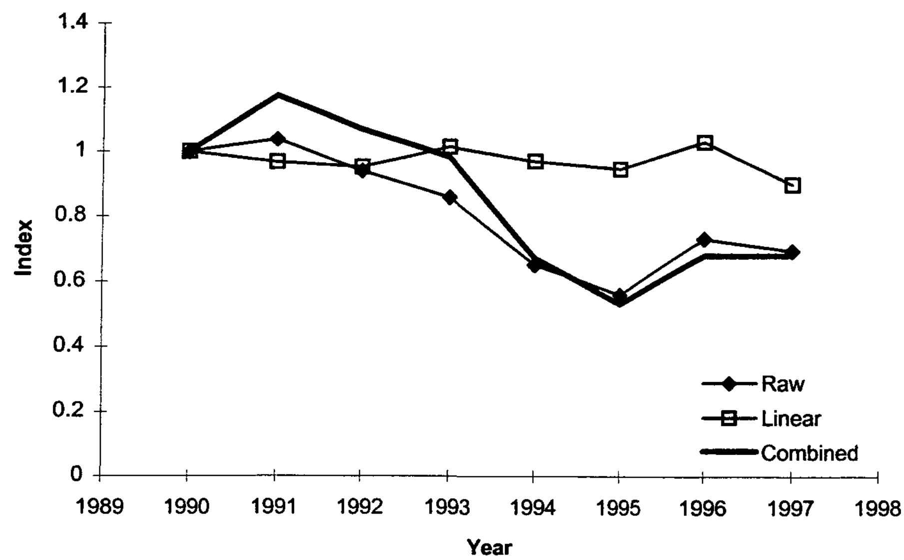


Figure 16: Relative CPUE indices for JDO 2E (single trawl).

The component indices for the combined model are shown in Table 19. A comparison between raw CPUE, standardised CPUE from successful days, and the combined model indices can be seen in Figure 16.

The index from the linear model of catch rate is quite flat with insignificant year effects. The combined index reflects the increase in unsuccessful days reported in the gurnard fishery and to a lesser extent in the tarakihi fishery. It suggests a decline in abundance.

7.2 JDO 2W (South Taranaki Bight and Cape Egmont)

7.2.1 The fishery

The main fishing method (Table 20) is single bottom trawl (93% of the estimated catch from 1989–90 to 1996–97). Bottom pair trawling took 3%, setnetting 3%.

Table 20: Estimated catches (t) of John dory by fishing method (single trawl, pair trawl, other) in JDO 2W, 1989–90 to 1996–97

Method	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97
S. Trawl	49	42	63	85	52	41	64	53
Pr Trawl	2	1	2	2	2	2	3	1
Other	1	2	1	2	3	3	2	1
Total	51	45	66	89	58	46	69	56

7.2.2 Selecting fisheries in JDO 2W, by area and target species

Trawl catches were made in all statistical areas (37, 39–41), but mainly in 41 (north of Cape Egmont), and all were included in the data set. The estimated John dory catch for all target species in these four areas, 1989–90 to 1996–97, was 449 t.

Within these areas, John dory were taken mainly in the target fishery for jack mackerel (41%), with much smaller catches when the target was trevally (13%), snapper, red gurnard (12% each), and barracouta (6%). Only the jack mackerel fishery was considered, in which the John dory catch was 182 t, 41% of the total estimated JDO 2W trawl catch.

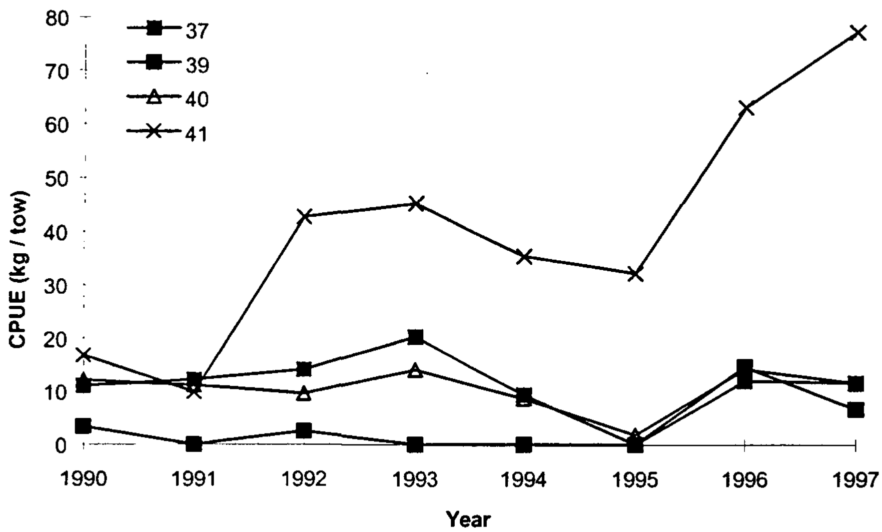


Figure 17: Raw CPUE of John dory by statistical area in JDO 2W.

Trends in raw CPUE among statistical areas are similar (Figure 17) though there are large differences in magnitude.

Bottom trawls targeted on jack mackerel only, in statistical areas 37, 39–41 were accepted by the Stock Assessment Working Group as likely to be representative of the western fishery for JDO 2.

8 Standardised CPUE for JDO 2W

Data from the four statistical areas were combined to describe the JDO 2W substock and the success and catch rates modelled to provide a possible index of abundance. A summary of data included is given in Table 21.

Table 21: Summary of catch data, raw CPUE (kg/tow), and success rate for John dory in the target jack mackerel fishery in JDO 2W (single trawl). Prop. zero is the proportion of days on which zero catch of John dory was reported

Year	Days fished	Days successful	Prop. zero	Catch (kg)	Total no. tows	Raw CPUE (kg/tow)
1989–90	808	629	0.78	16 920	1 548	10.93
1990–91	511	423	0.83	10 100	902	11.20
1991–92	786	601	0.76	44 050	1 522	28.94
1992–93	922	645	0.70	58 005	1 824	31.80
1993–94	622	474	0.76	29 020	1 314	22.09
1994–95	232	211	0.91	6 000	448	13.39
1995–96	339	299	0.88	10 960	644	17.02
1996–97	142	116	0.82	6 830	262	26.07

Bottom trawls targeted on jack mackerel only, in statistical areas 37, 39–41 were initially accepted by the Stock Assessment Working Group as likely to be representative of the western fishery for JDO 2.

The variables selected into the linear model predicting catch rate are given in Table 22. The logistic model of success rate included only two variables, Tottows, and area.

Table 22: JDO 2W Single trawl – The order in which the variables were selected into the linear model (of catch rate) and the model R^2 at each step

Variable		Model R^2
TOTTOWS	1	0.1808
TOTCATCH	2	0.3191
AREA	4	0.4123
DRAUGHT	6	0.4355
CREWNO	7	0.4439
MNTH	8	0.4473
LENGTH	9	0.4506
BREADTH	10	0.4541
YEAR		0.5302

Table 23: CPUE indices for JDO 2W (single trawl) from the linear component, the logistic component, and the combined model

Year	Linear	Logistic	Combined
1989-90	1.000	1.00	1.000
1990-91	1.388	0.90	1.216
1991-92	2.004	0.97	1.941
1992-93	2.053	1.13	2.396
1993-94	1.797	0.92	1.613
1994-95	2.328	0.45	0.927
1995-96	2.856	0.68	1.806
1996-97	1.920	0.91	1.714

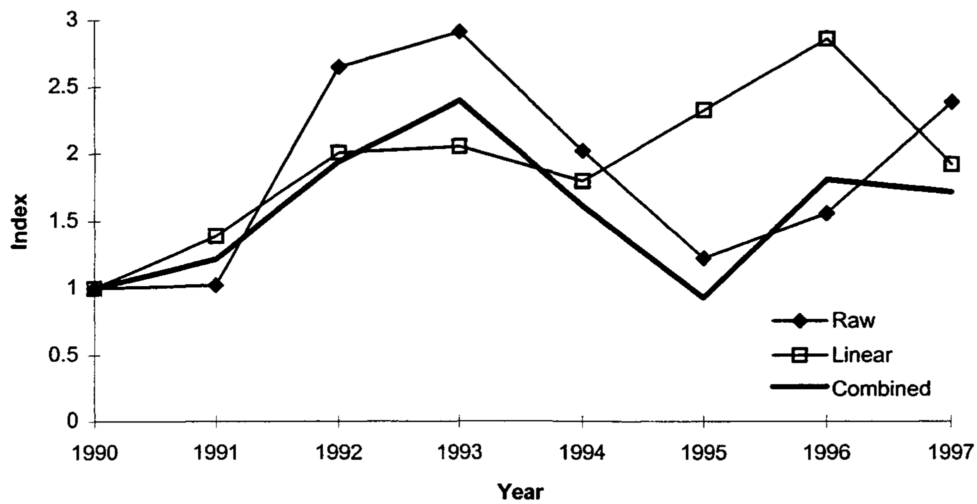


Figure 18: Relative CPUE indices for JDO 2W (single trawl).

For this fishery, the proportion of reported zero days is very high (Table 21) and completely dominates the raw CPUE and the combined model indices. When the unsuccessful days are removed, the pattern of (linear) CPUE is almost opposite in shape, so the two indicators are contradictory (Table 23, Figure 18). There is no evidence of a trend, up or down.

9 Discussion

Analysis of CPUE has been completed to obtain CPUE indices of abundance for the targeted and bycatch John dory fisheries around the North Island.

John dory usually constitutes a very minor part of the catch in coastal trawl fisheries, and representative fisheries, therefore, yield a high proportion of zero tows. The combined model (currently in vogue) considers both the success rate of tows and the catch rate of successful tows, and combines both sources of information in a standardised way. When this study was commissioned, the combined model was considered to be the most appropriate approach considering the statistical characteristics of the data. However, at the 1998 plenary there were serious reservations expressed about the information content of the zero reported catches, and there remain serious concerns about including zero reported catches at all in the calculation of CPUE for these fisheries.

Reporting for the Quota Monitoring System requires only that the weight of the top five species in a tow be estimated. In coastal trawl fisheries, such as those described here, it is not uncommon to catch up to 30 different species. Zero reported catches of John dory are therefore just as likely to indicate increased abundance of other species, or increased diversity of species, as they are a reduced abundance of John dory. Because of the way in which data have been collapsed to daily records for comparability between CELR and TCEPR records, however, CPUE for successful days also incorporate zero reported catches on those days. This is the reason that number of tows by the vessel on the day (tottows) was so consistently selected into the models of both catch and success rates. The linear model indices therefore, may also be tainted by this problem of genuine non reporting. The magnitude of their effect is unknown, and is not necessarily constant.

The working group examined the results and chose to accept the linear model series for JDO 1E (single trawl, and Danish seine), and JDO 1W (single trawl). CPUE data from JDO 2 were not considered to be reliable indices of stock abundance because of low catch rates of only 5-8 fish per tow (JDO 2E), and a very high proportion of zero catches (JDO 2W).

10 Acknowledgments

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Appendix 2

Parameters used for calculation of biomass and scaled length frequency distributions for John dory. For all surveys, gear performance was set to "less than 3", and the length-weight coefficients used were $a = 0.011988$ and $b = 3.113808$ (calculated from KAH9720, $n = 296$, length range = 13–52 cm).

Bay of Plenty surveys (JDO 1E)

KAH8303
Doorspreads were calculated from warp length using the equation from Langley (1994)
dist_doors = 88.8214 × (1–e(–0.00970 × (warp_lgth + 7.330)))
Because: Actual doorspreads were not available, and the constant doorspread used in previous analyses (79 m) inaccurately estimates area swept.
Stratum 9 excluded
Because: Area of 1987 survey was used for all analyses and stratum 9 is outside that area.
Biomass calculated from catch weights
Because: Catch weights were available for most stations and weights from remaining stations could be calculated from length frequency data.

KAH8506
Same as KAH8303 except:
Stratum 0090 excluded
Because: Area of 1987 survey was used for all analyses and stratum 0090 is outside that area.
Biomass calculated from length frequency and percent sampled
Because: Few catch weights were available.

KAH8711
Same as KAH8303 except:
Only strata 11, 12, 21, 22, 23, 30, 40, 51, 52, 360 were included
Because: Other strata were in the Hauraki Gulf (as part of a combined survey).
Biomass calculated from length frequency and percent sampled
Because: Few catch weights were available.

KAH9004
Same as KAH8303 except:
Biomass was always calculated from catch weights, and no strata were excluded

KAH9202
Same as KAH9004 except:
Stratum MNGM excluded
Because: Area of 1987 survey was used for all analyses and stratum MNGM is outside that area.

KAH9601
Doorspreads used were recorded doorspreads
Because: Actual doorspreads were recorded using Scanmar gear.
Catch weights were available, but biomass was calculated from length frequencies and percent sampled for consistency with other surveys.

Hauraki Gulf surveys (JDO 1E)

KAH8421
Areal availability changed as follows; bracketed pairs are stratum number, and area (km^2):
(21, 205), (22, 464), (23, 196), (24, 168), (25, 427), (31, 115), (32, 342), (41, 2124), (50, 1129), (60, 2063)
Because: Total area of survey reduced to match 1986 and later surveys, and some of the areas to be removed were at the boundaries between existing or new strata, so reductions had to be on a pro rata basis (Francis *et al.* 1995).
Biomass was calculated from length frequency data
Because: Catch weights were not available for 39 stations.
Stations 3, 4, 8, 9, 12, 15, 21, 23, 24, 25, 28, 34, 35, 37, 38, 39, 42, 43, 44, 45, 46, 49, 50, 52, 53, 54, 56, 57, 62, 63, 65, 66, 67, and 68 excluded
Because: No length frequency data were available from these stations.

KAH8517
Areal availability was changed as follows; bracketed pairs are stratum number, and area (km^2):
(23, 196), (27, 669), (28, 595), (31, 115), (32, 342), (41, 2124), (50, 1129), (60, 2063)
Because: Total area of survey reduced to match 1986 and later surveys, and some of the areas to be removed were at the boundaries between existing or new strata so reductions had to be on a pro rata basis (Francis *et al.* 1995).
Biomass was calculated from length frequency data
Because: First 5 surveys had lower mean headline height than later surveys.

KAH8613
All strata selected
Biomass estimates calculated from length frequency data
Because: First 5 surveys had lower mean headline height than later surveys.

KAH8716 & KAH8810
Same as KAH8613

KAH8917
Same as KAH8613 except:
Biomass estimates were calculated using catch weights

KAH9016, KAH9212, KAH9311, KAH9411 & KAH9720
Same as KAH8917

West coast North Island surveys (QMA9) (JDO 1W)

KAH8612
Strata A1, A2, A3, A4, G1, G2, G3, G4, H1, H2, H3, H4, and half of B1, B2, B3, and B4 excluded
Because: These strata are outside the area of the 1987 survey (which was used as the "base" survey).
Biomass was calculated from catch weights, with weights for stations 2. 30, 31, 35, 38, 41, 50, and 61 estimated from length frequency data

KAH8715
All strata were used with no change to areal availability (the "base" survey)
Biomass was calculated from length frequency data using length-weight regression equation
Because: Few catch weights are available

KAH8918
All of strata GEB1, GEB2, WCN2, WCN3, WCS4, WCS5, and 50% of WCN1 and WCS1, and 70% of WCS2 excluded
Because: These strata are outside area of 1987 survey.
Effective areas (km^2): WCN1 = 1177.0; WCS1= 1319.5; WCS2 = 649.5
Biomass estimates were calculated from catch weights

KAH9111
All of strata A25, A50, A100, A200, B25, B200, C200, E200, F50, F100, F200, G25, G50, G100, H25, H50, I25, I50, J25, and 50% of strata B100 excluded
Because: These strata are outside area of 1987 survey.
Effective area: B100 = 665.5 km^2
Biomass estimates were calculated from catch weights

KAH9410
All of strata A25, AA50, A100, A200, B25, B200, C200, E200, F50, F100, F200, G25, and 50% of strata B100 excluded
Because: These strata are outside area of 1987 survey.
Effective area: B100 = 665.5 km^2
Area of stratum BB50 set at 323 km^2
Biomass estimates were calculated from catch weights

KAH9615
Same as KAH9410 except
The effective area of stratum B100 is 666 km^2

West coast North Island surveys (QMA8) (JDO 2W)

KAH8918
Includes strata WCS4, WSC5, 50% of WCS1 and 70% of WCS2
Because: These strata cover the area of JDO 2W.
Effective areas (km^2): WCS1= 1319.5; WCS2 = 1515.5
Biomass estimates were calculated from catch weights

KAH9111
Includes strata F50, F100, and G25 only
Because: These strata cover the area of JDO 2W.
Biomass estimates were calculated from catch weights

KAH9410 & KAH9615
Same as KAH9111

East coast North Island surveys (JDO 2E)

KAH9304
Biomass calculated from catch weights
Strata 1, 2, 3, 4, 5, and 6 excluded
Because: Strata were outside the area of later surveys.
Areal availability for strata 14 and 18 reduced to match areas of later surveys
Effective areas (km^2): 14 = 655.2, 18 = 762.9

KAH9402
Same as KAH9304 except
All strata included and no change to areal availability

KAH9502 & KAH9602
Same as KAH9402

Appendix 3

Scaled length frequency distributions for John dory from five series of inshore trawl surveys around the North Island, by sex where data are available. (*n*, number of fish measured; N, estimated population size, *c.v.*, coefficient of variation)

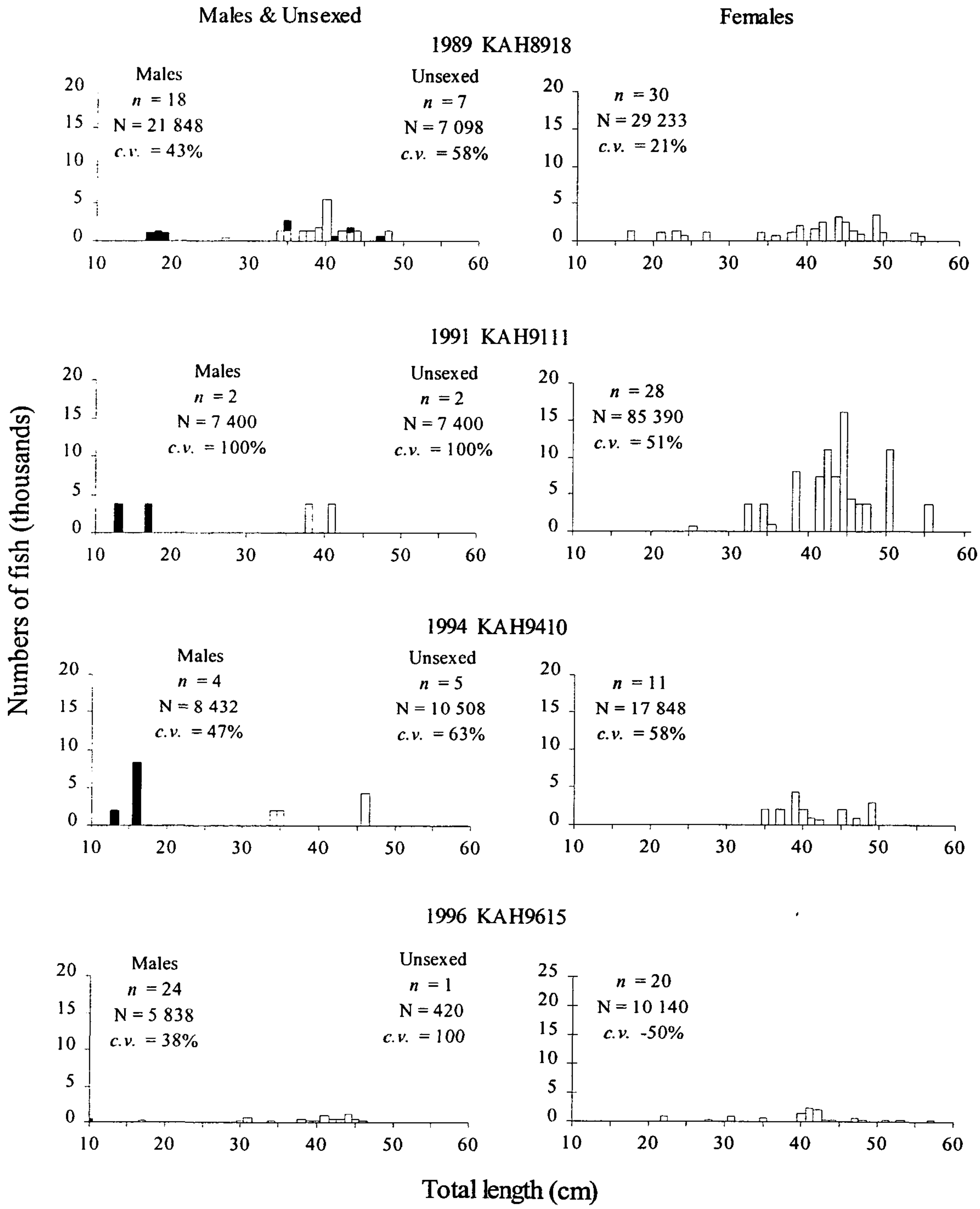

Figure A1: Scaled length frequency distributions for John dory from surveys off the west coast of the North Island (FMA 8) (JDO 2W).

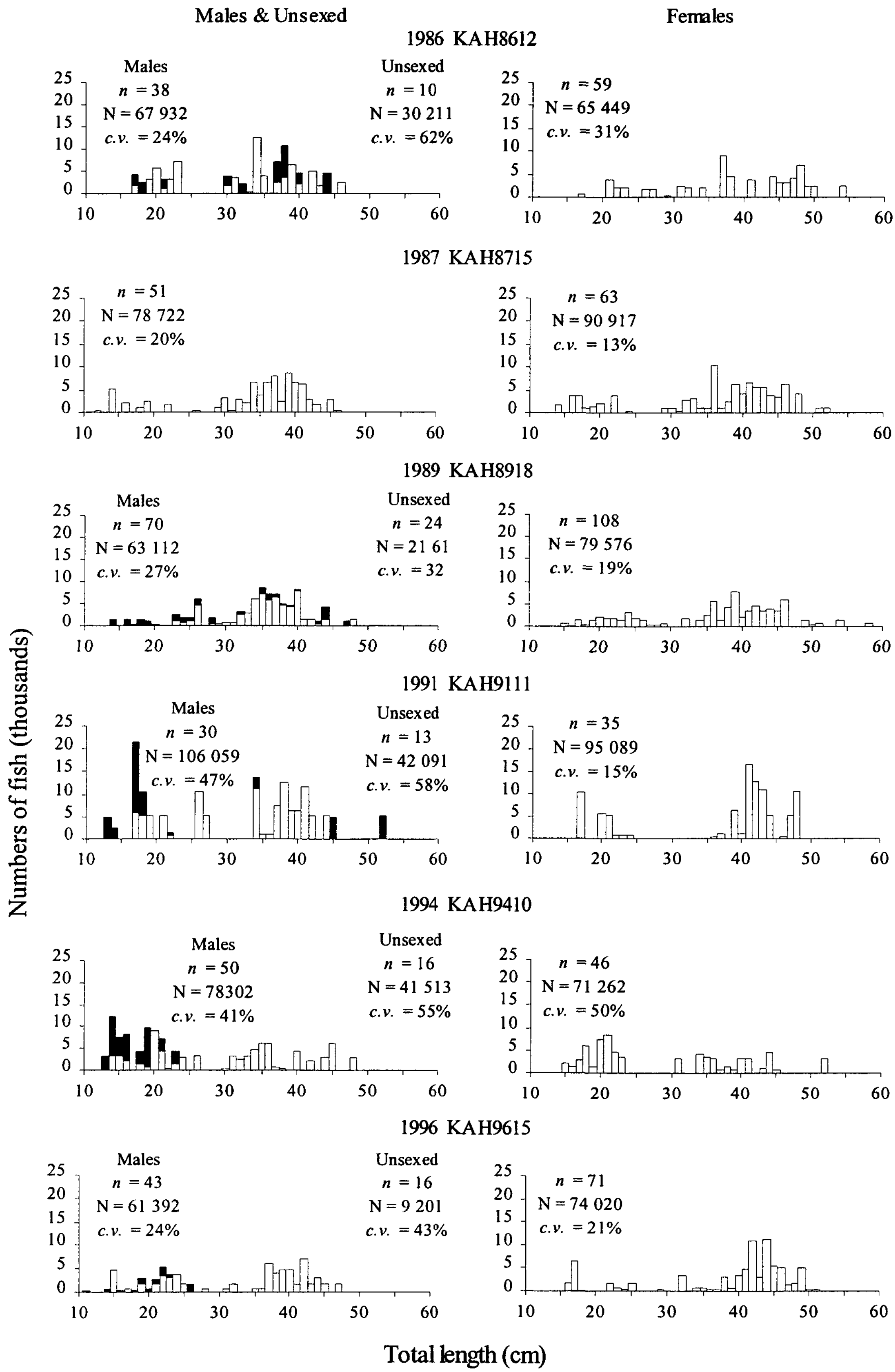

Figure A2: Scaled length frequency distributions for John dory from surveys off the west coast of the North Island (FMA 9) (JDO 1W).

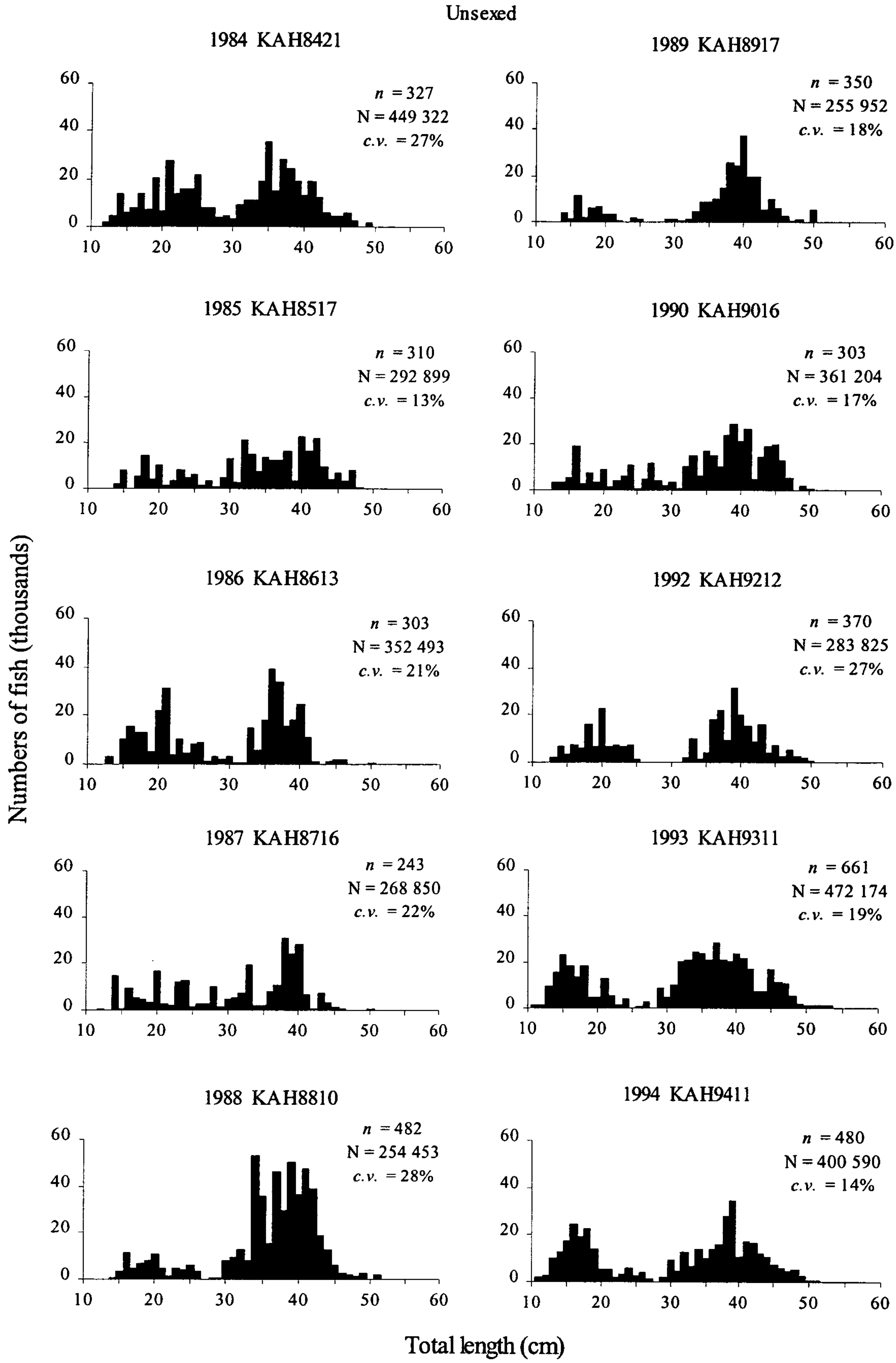

Figure A3: Scaled length frequency distributions for John dory from surveys in the Hauraki Gulf (JDO 1E).

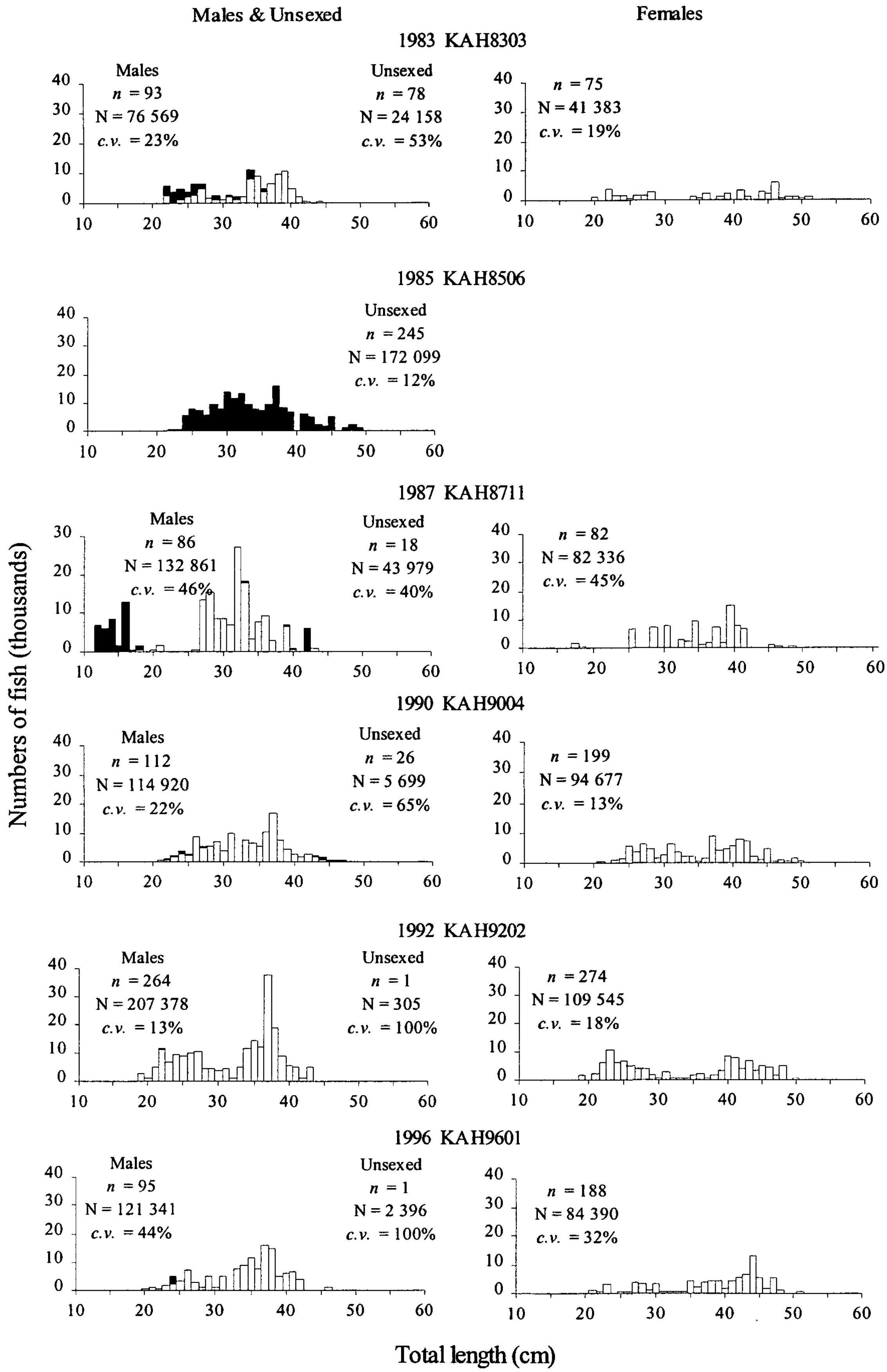

Figure A4: Scaled length frequency distributions for John dory from surveys in the Bay of Plenty (JDO 1E).

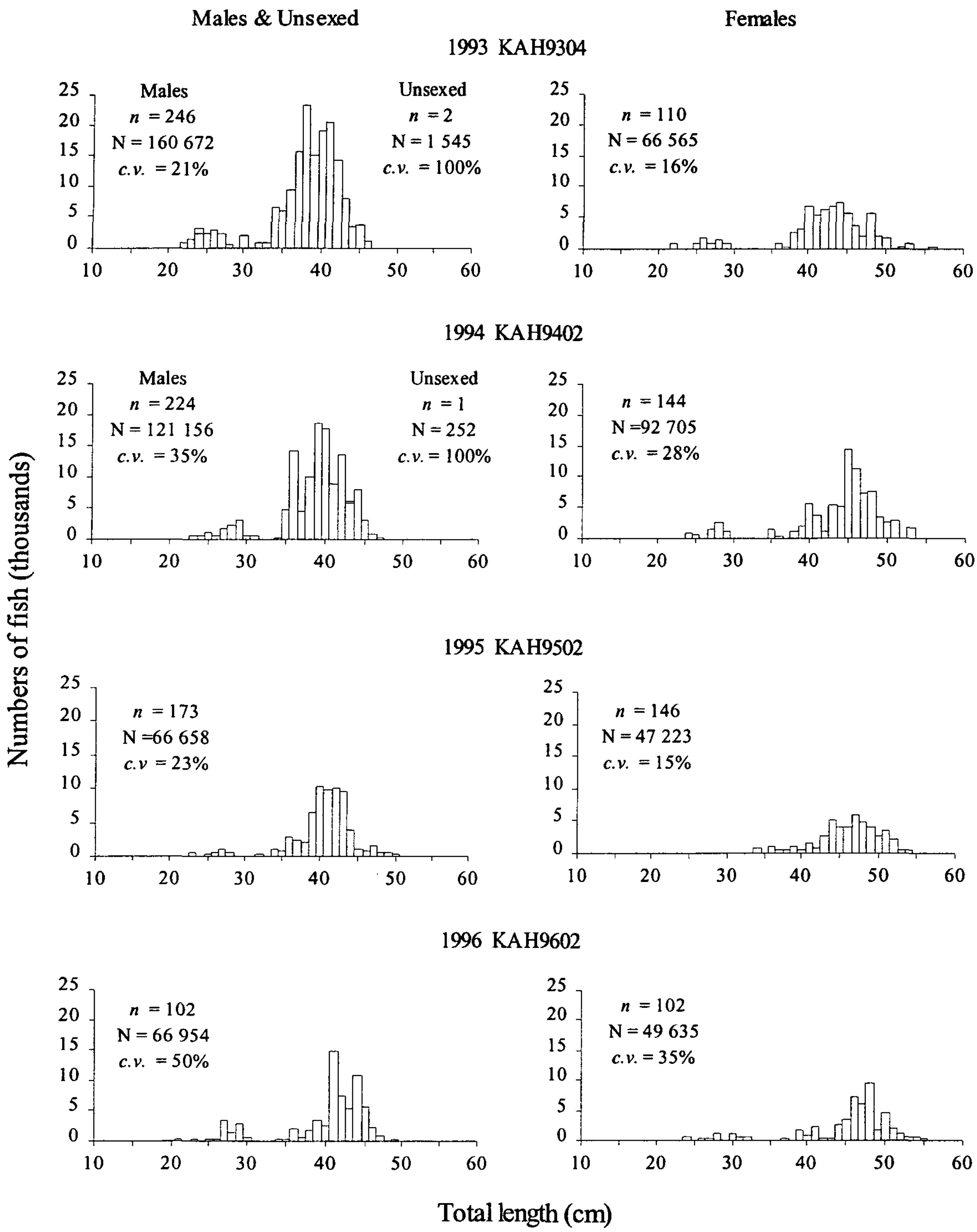

Figure A5: Scaled length frequency distributions for John dory from surveys off the lower east coast of the North Island (JDO 2E).