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# Fishery characterisation and Catch-Per-Unit-Effort indices for John dory in JDO 1

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**TABLE OF CONTENTS**

## Executive Summary

**Langley, A.D. (2015). Fishery characterisation and Catch-Per-Unit-Effort indices for John dory in JDO 1.**

***New Zealand Fisheries Assessment Report 2015/47.* 76 p.**

John dory (*Zeus faber*) in JDO 1 is predominantly caught as a bycatch of the main inshore trawl fisheries operating around the northern North Island. There is also a considerable catch of John dory taken by the Danish seine fisheries in the Hauraki Gulf and, to a lesser extent, the Bay of Plenty.

Previous studies have partitioned JDO 1 into three sub-areas based on spatial differences in CPUE trends from the main fisheries: Bay of Plenty (BPLE), Hauraki Gulf and east Northland (HG-ENLD), and west coast North Island (WCNI). During the mid 1990s, annual catches from JDO 1 were at a historically high level and a substantial proportion (55–60%) of the total catch was taken from the HG-ENLD area. Annual catches from HG-ENLD fluctuated during the late 1990s–mid 2000s and then declined considerably during 2006/07–2012/13 and remained low in 2013/14. Annual catches of John dory catches from WCNI and BPLE were generally lower than HG-ENLD, but remained relatively stable over the last 20 years, with a general decline in the annual catch from BPLE from 2004/05. Recent (2009/10–2013/14) annual JDO 1 catches were about 360 t, approximately half of the TACC level.

This study updates area-specific CPUE indices derived from the event based catch and effort records from the main northern inshore trawl fisheries, including data to the end of the 2013/14 fishing years. The CPUE indices were derived using a delta-lognormal approach that incorporated Generalised Linear Models of the occurrence of John dory in the trawl catch (binomial model) and the magnitude of positive John dory catches (lognormal model). For the WCNI fishery, there is an indication that the reporting of small catches of John dory from individual trawls had increased over the study period. A simulation study was conducted to investigate potential biases in the CPUE indices resulting from changes in catch reporting comparable to those observed. The study concluded that any biases in the delta-lognormal CPUE indices were likely to be trivial; with changes in catch reported resulting in contradictory biases in the time-series of binomial and lognormal indices, which were ultimately cancelled in the combined delta-lognormal indices.

The area-specific CPUE indices are the accepted indices of abundance used for monitoring John dory abundance in JDO 1. The CPUE series for John dory in the HG-ENLD area steadily declined from the mid-2000s, and in 2013–14 the index was 56% of the target CPUE. In the Bay of Plenty the CPUE series declined from 2010–11 and the 2013–14 index was at 70% of the target biomass level. The trends in the CPUE indices from these areas are also generally consistent with CPUE indices derived from the corresponding Danish seine fisheries. The decline in the HG-ENLD trawl CPUE indices is also generally consistent with the decline in annual catch from the area. Previously, it was concluded that the decline in abundance in Hauraki Gulf–east Northland and Bay of Plenty was likely to be due to lower recruitment during the last decade, although there are no additional data available to confirm this conclusion (e.g. from catch sampling). For the WCSI area, John dory abundance fluctuated without trend during the last two decades; the indices from recent years (2010/11–2013/14) were above the average of the entire series.

# 1 INTRODUCTION

John dory (*Zeus faber*) in JDO 1 is predominantly caught by the inshore trawl and Danish seine fleets operating around the northern North Island. The Total Allowable Commercial Catch (TACC) for JDO 1 has been maintained at 704 t since 1989/90. During the early 1990s, annual catches from JDO 1 increased to about the level of the TACC and remained at that level during 1994/95–1998/99 (Ministry for Primary Industries 2014). During the following years, annual catches have fluctuated with a general declining trend. Recent (2009/10–2013/14) annual catches were about 360 t, approximately half of the TACC level.

Bentley & Kendrick (2011) summarised trends in the JDO 1 fishery from 1989/90–2008/09. The analysis partitioned the JDO 1 fishstock into three areas: Bay of Plenty, Hauraki Gulf and east Northland (East), and west coast North Island (West). For each area, the trends in the main method fisheries were summarised and standardised CPUE analyses were conducted for the main fishing methods in each area (i.e. bottom trawl in all areas and Danish seine in the East and Bay of Plenty). The CPUE analyses were conducted using aggregated catch and effort data ("trip strata") and, for the trawl fisheries, separate analyses were conducted using the event based ("tow-by-tow") data which were available from a substantial proportion of the fleet from 1994/95 (Bentley & Kendrick 2011).

The analyses yielded different CPUE trends amongst the three areas, while trends for alternate CPUE series within each area tended to be similar. Bentley & Kendrick (2011) recommended a preferred CPUE series for the monitoring of John dory abundance in each area. In each of the three areas the preferred CPUE indices were based on data from inshore single trawl fisheries targeting a similar suite of species (snapper, John dory, trevally, tarakihi, red gurnard, and barracouta), and were based on "trip strata" analyses, thereby including all available data.

Dunn & Jones (2013) adopted similar fishery definitions to conduct an updated CPUE analysis for the three JDO 1 areas, extended to the 2010/11 fishing year. The standardised CPUE analyses derived combined delta-lognormal CPUE indices from the event based trawl catch and effort records. The resulting indices were adopted by the Inshore Stock Assessment Working Group as the main indices for monitoring the abundance of the three components of the JDO 1 fishstock (Ministry for Primary Industries 2014).

The current study updates the previous characterisations of the JDO 1 fishery to include catch and effort data from the 1989/90–2013/14 fishing years. For each of the three fishery areas, the time-series of area specific CPUE indices was extended to include the 2013/14 fishing year. The study was funded by MPI under Research Contract JDO2014-01.

# 2 DATA SETS

Commercial catch and effort data from the JDO 1 fishery were sourced from the Ministry for Primary Industries (MPI) database *warehou*. The analysis maintained the spatial stratification of JDO 1 adopted by Dunn & Jones (2013), including the extended definition of the WCNI fishery to encompass the north-western area of the JDO 2 Fishstock (specifically Statistical Areas 040 and 041). On that basis, the data extract was primarily based on fishing trips that landed either JDO 1 or JDO 2. The initial data set also included any additional fishing trips that targeted a range of inshore species (SNA, JDO, TRE, TAR, GUR, BAR, and FLA) within a statistical area valid for the three subareas of JDO 1 and the north-western area of JDO 2 (Statistical Areas 001–010 and 040–048) (Figure 1). For the qualifying trips, all effort data records were obtained regardless of whether or not John dory was landed. The estimated catch and landed catch records of all finfish species were sourced for the qualifying fishing trips. Data were complete to the end of the 2013/14 fishing year.

From 1989/90, most inshore fishing vessels reported catch and effort data via the Catch Effort Landing Return (CELR), which records aggregated fishing effort and the estimated catch of the top five species. For the trawl and Danish seine fisheries, fishing effort and catch was required to be recorded for each target species and statistical area fished during each day, although typically catch and effort data were aggregated by fishing day (Langley 2014). The verified landed green weight that is obtained at the end of the trip was recorded on the Landings section of the CELR form.

From 1994/95, many of the inshore trawlers operating in JDO 1 reported fishing effort and catch data for individual trawls via the Trawl, Catch, Effort and Processing Return (TCEPR). In 2007/08, the Trawl, Catch and Effort Return (TCER) was introduced specifically for the inshore trawl fisheries and has been subsequently adopted by many of the vessels in the JDO 1 inshore trawl fishery. The TCER form records detailed fishing activity, including trawl start location and depth, and associated catches from individual trawls. Landed catches associated with trips reported on TCEPR and TCER forms is reported at the end of a trip on the Catch Landing Return (CLR).

The Danish seine fleet continued to report catch and effort data via the CELR for the entire study period.

The Quota Management System (QMS) totals are collected from fishing permit holders on a monthly basis (Monthly Harvest Return, MHR) and are subjected to a different regime of storage and checking.

## 2.1 Data processing

### 2.1.1 Fishery characterisation data set

The overall characterisation data set included all fishing trips that landed John dory (either JDO 1 or JDO 2) associated with fishing effort from within the statistical areas that approximate the area of JDO 1 or the north-western area of the JDO 2 (Statistical Areas 001–010 and 040–048) (Figure 1). The initial set of JDO landed catch records was screened to retain the records that represented the final destination of the JDO catch (destination codes L, A, C, E, and O). This resulted in a trivial reduction in the total JDO 1 landed catch included in the landings data set (Table 1). The landed catch from JDO 2 represented a very small proportion (0.9%) of the total John dory catch within the characterisation data set.

**Table 1: Total John dory (JDO 1 only) landed catch included in the fishery characterisation data set at each step of the catch grooming process.**

| Criterion | Landed catch (t) | Percent of total landed catch |
|---|---|---|
| All landing records | 12 976.6 | 100.0% |
| Destination codes (L, A, C, E, O) | 12 929.9 | 99.6% |
| Exclude landed catch outliers | 12 811.2 | 98.7% |
| Associated effort records | 12 625.4 | 97.3% |

Potential landed catch outliers were examined by comparing the corresponding landed catches and aggregated estimated catches from individual fishing trips. In most cases, the ratio of the trip landed catch to the estimated catch approximated 1.0 indicating a good correspondence between the landed catch and estimated catch (Figure 2).

Potentially erroneous landed catch records were identified based on the ratio of the trip landed catch to the aggregated estimated catch; i.e. where the ratio exceeded a factor of 4.0 and landed catches exceeded 250 kg. A total of 324 trips (of a total of 122 254 trips) met these criteria and the landed catches for these trips were further examined by comparing the landed catch with the corresponding processed catch weight multiplied by the conversion factor of the associated state code. A subset of those trips (105 of 324 trips) had catch values derived from the processed catch data that were considerably lower than the landed catch. For these trips, the landed catches were corrected using the green weight equivalent of the processed catches. This resulted in a small reduction in the total JDO 1 catch included in the data set (Table 1).

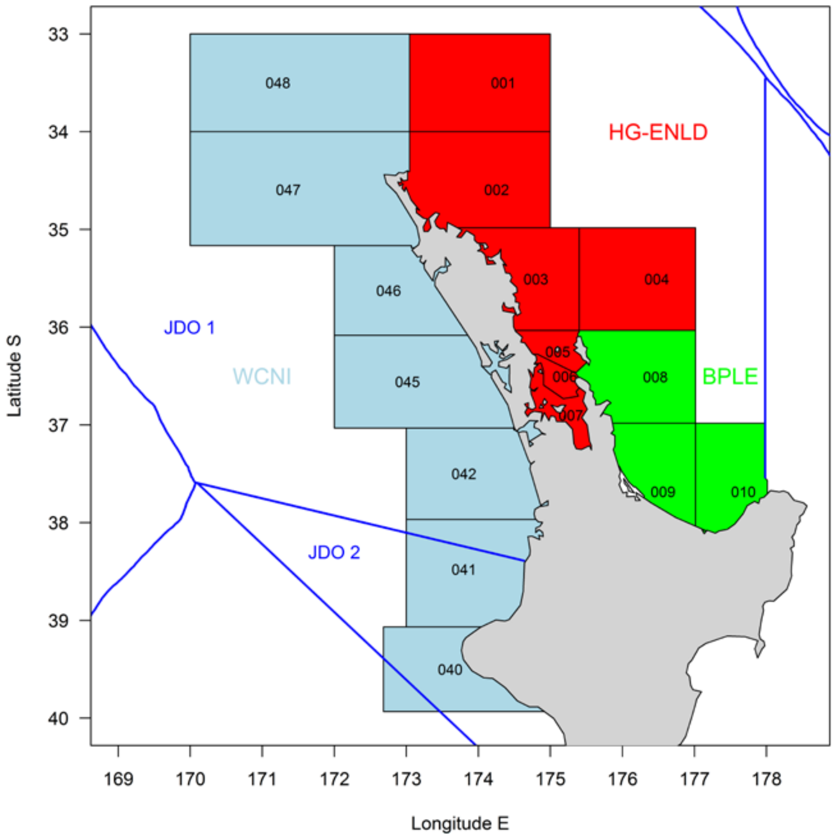



**Figure 1: Map of JDO 1 fishery areas defined based on Statistical Areas.**

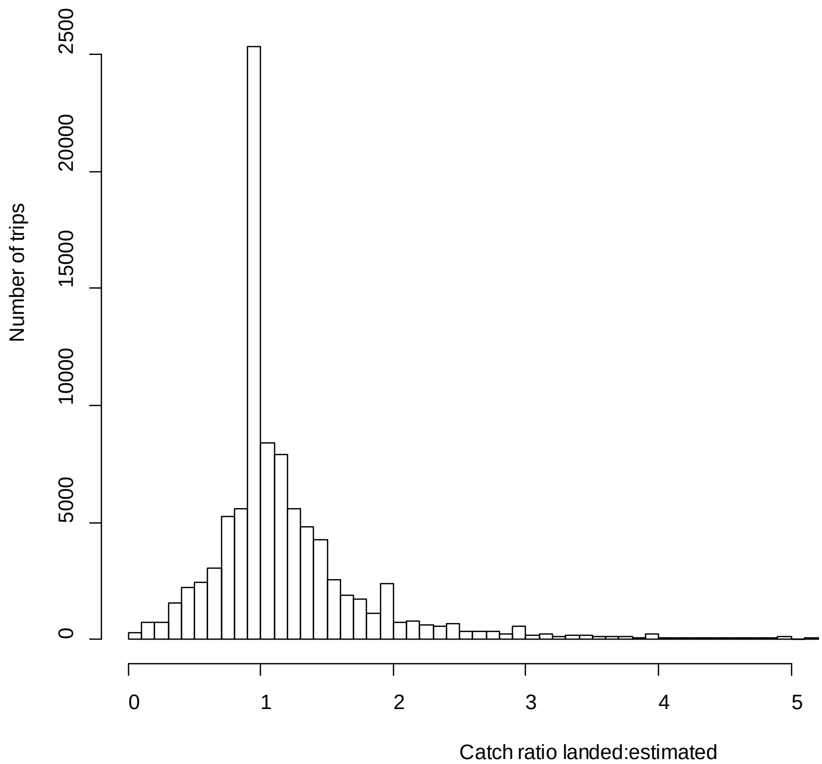



**Figure 2: Ratio of the JDO 1 landed catch and the sum of John dory estimated catches from individual fishing trips.**

During 1989/90–1993/94, most (93–99%) of the JDO 1 landed catch was associated with fishing effort recorded in the Catch Effort Landing Return (CELR) format (Figure 3). From 1994/95, many of the larger inshore trawl vessels operating in the snapper (SNA 1) fishery were required to complete the more detailed Trawl Catch Effort Processing Return (TCEPR) and, consequently, approximately 50–65% of the JDO 1 landed catch was reported from the associated Catch Landing Return (CLR) during 1994/95–2006/07 (Figure 3). In 2007/08, the Trawl Catch Effort Return (TCER) was introduced to facilitate the collection of the fishing event based catch and effort data from the inshore trawl fleet. Since 2007/08, the JDO 1 landed catch reported from trawl vessels has been relatively equally divided between vessels completing either the TCEPR or TCER form (about 35–40% of the catch from each). The remainder of the JDO 1 catch, primarily from the Danish seine fishery, has continued to be reported in the CELR format (25% of landed catch).

For the main characterisation data set, catch and effort data from the qualifying fishing trips were aggregated in a manner that approximates the daily aggregate format of the CELR following the approach of Langley (2014). The approach aggregates method specific fishing effort (number of trawls and hours fished) for each fishing vessel and fishing day. The resulting records are assigned a statistical area and target species based on the predominant statistical area and declared target species from the day of fishing. The estimated species catches are also aggregated for the vessel fishing day and the aggregate catches are ranked based on species catch weight. The five species with the largest estimated catches are retained, replicating the recording of the top five species estimated catches from the CELR. The estimated catches of the remainder of the species (non top five) are not included in the subsequent analysis.

This aggregation approach reduces the potential for the catch and effort data set to be influenced by the changes in reporting formats (from CELR to TCEPR and then TCER). Given the high proportion of the landed catch reported in the CELR format prior to 1994/95 it was considered important to maintain a consistent reporting format in the subsequent years.

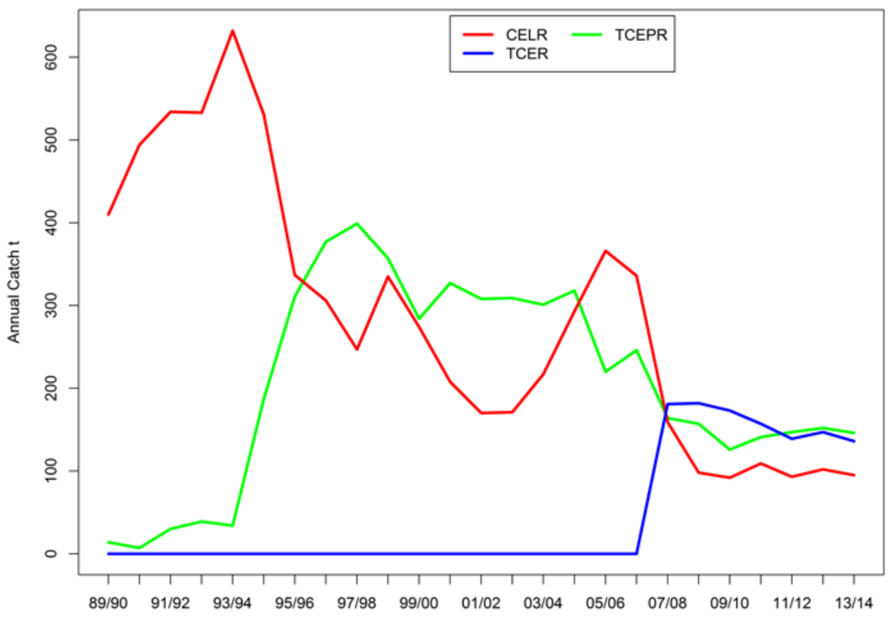



**Figure 3: Total annual JDO 1 landed catch associated with the statutory catch and effort reporting forms.**

A total of 120 793 trips (from 122 254 trips) with a landed catch of JDO 1 were successfully linked to the aggregated fishing effort records. However, the number of trips was reduced by the exclusion of effort records for fishing methods that would not be expected to catch John dory (e.g. surface longline and troll) and/or target species that are unlikely to be associated with John dory (e.g. ORH, SSO, and

BOE) (118 313 trips retained). There were also fishing effort records that were missing the data fields required to generate the aggregated effort records. The reduction in the number of fishing trips included in the final data set resulted in a small reduction in the overall quantity of JDO 1 landed catch (Table 1).

For 1989/90–2013/14, the JDO 1 landed catches included in the characterisation data set approximate the total annual JDO 1 catch reported in the MPI Plenary document (Figure 4).

The estimated catches of John dory represented about 85% of the annual landed catch from 1989/90–2006/07 (Figure 4). Since 2007/08, the estimated catches represented about 90% of the landed catch. The higher proportion of the total catch reported is likely to be due to the introduction of the TCER reporting form which enables the reporting of the catch of eight fish species from each trawl. Limiting the estimated catch to include only catches in the top five species per fishing day reduced the total estimated catch to approximately 75–80% of the annual landed catch (Figure 4).

The landed catches of JDO 1 from each fishing trip were apportioned to the aggregate fishing effort records following the approach developed by Starr (2007). For fishing trips that recorded at least one top five estimated catch of John dory, the JDO landed catch was allocated to the individual fishing effort records in proportion to the individual estimated catches (represented 91.4% of total landed catch). For fishing trips with no associated top five estimated catches, the landed catches were assigned to the daily fishing records in proportion to the number of trawls per day (represented 8.6% of total landed catch).

The characterisation data set was subdivided following the spatial stratification of JDO 1 adopted by Dunn & Jones (2013): West coast North Island (WCNI), Statistical Areas 040–048; Hauraki Gulf and east Northland (HG-ENLD), Statistical Areas 001–007; Bay of Plenty (BPLE) Statistical Areas 008–010 (Figure 1).

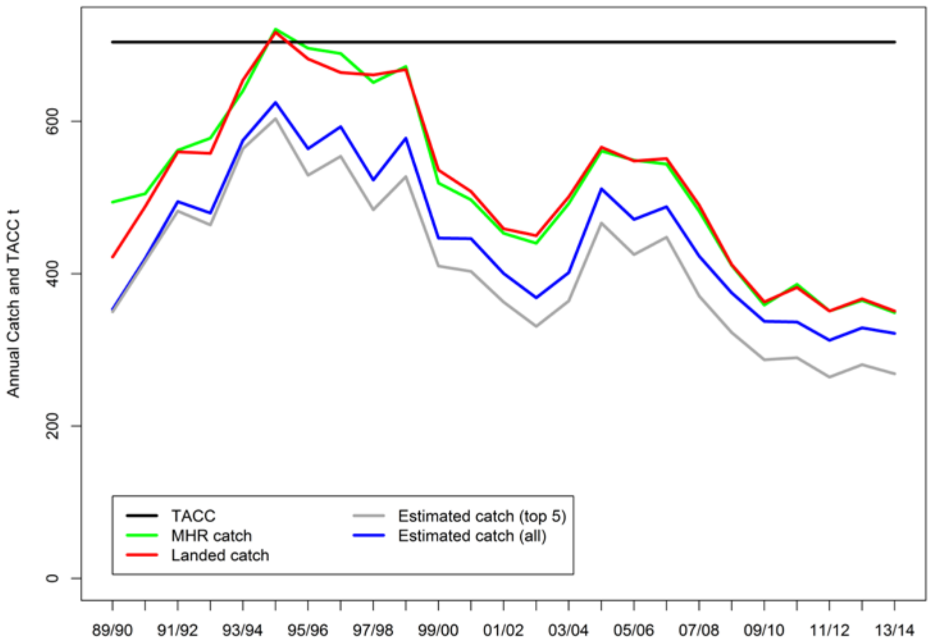



**Figure 4: Comparison of total annual JDO 1 estimated and landed catches (t) by fishing year from vessel trip landing returns and the total reported landings (t) to the QMS (MHR).**

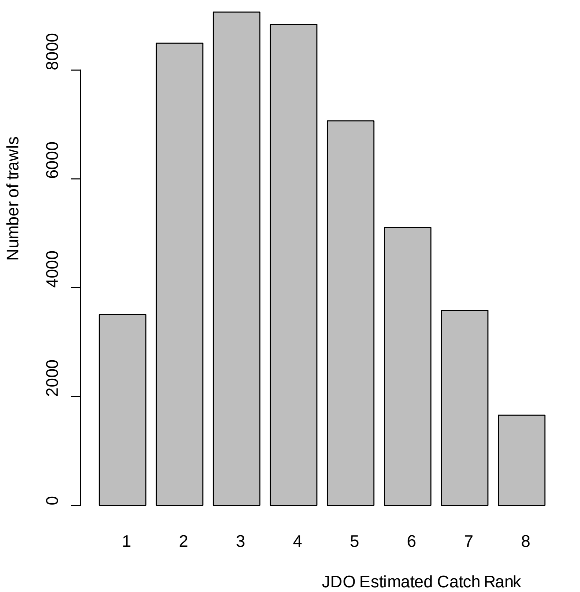
### 2.1.2 Individual trawl data set

From 1994/95, fishing event based catch and effort data are available from the northern inshore trawl fleet, accounting for a substantial proportion of the total JDO 1 catch. Detailed fishing event based catch and effort were collected in TCEPR format from 1994/95 and in both TCEPR and TCER formats from 2007/08 (Figure 3). The three sets of area specific CPUE indices derived by Dunn & Jones (2013) were based exclusively on the event based data from the trawl fishery.

For this study, the fishery definitions of Dunn & Jones (2013) were applied to derive a composite TCEPR and TCER trawl catch and effort data set. The initial data set included all TCEPR and TCER effort data from fishing trips that included at least one trawl (BT) that targeted one of the suite of inshore species (SNA, JDO, TRE, TAR, GUR, BAR) within the specified Statistical Areas (001–010 and/or 040–048).

The TCER records the details of individual trawls including start and end time, target species, trawl speed, and the location and bottom depth at the start of a trawl. This represents a comparable subset of the fishing event data recorded using the TCEPR format. A notable difference between the two formats is that the TCER form has the facility to record the estimated catch of the eight main species caught from the trawl, while only the trawl catch of the five main species can be recorded in the TCEPR format. This difference has the potential to result in a change in the reporting of the catch of the minor species, potentially increasing the number of small catches reported in the TCER format and, thereby, reducing the proportion of zero catch records. In turn, this has the potential to influence the allocation of the landed catches amongst fishing events from a fishing trip as this is usually based on the corresponding estimated catches from individual trawls.

For the composite TCEPR/TCER data set, estimated catches of John dory were associated with the individual trawl records and the ranking of John dory amongst the estimated species catches from the individual trawl was determined based on the reported estimated catch weight. Overall, 92% of the John dory estimated catch from the TCER data was included amongst the five main ("top 5") species reported, representing 78% of the TCER trawls that reported an estimated catch of John dory. Correspondingly, John dory was reported as the 6–8$^{th}$ ranked species for 22% of the TCER trawls that reported an estimated catch of John dory (Figure 5). The median catch of John dory reported amongst the 6–8$^{th}$ ranked species was 5 kg compared to a median catch of 20 kg in the "top 5" species.



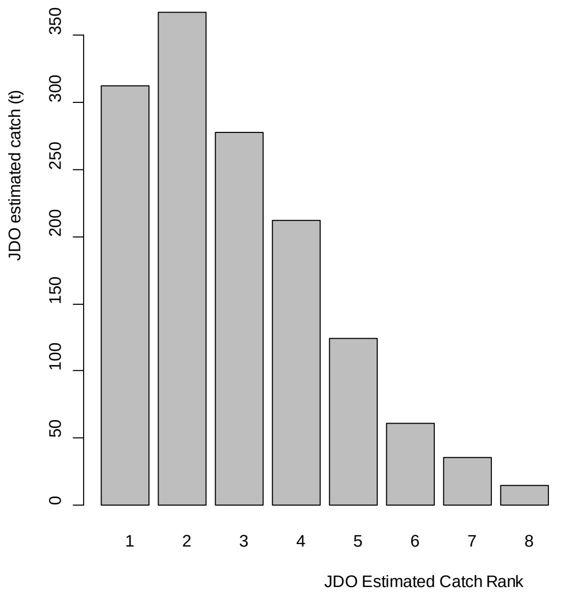




**Figure 5: Distribution of John dory effort records (left) and estimated catch (right) from individual TCER trawl records, ranked by the catch weight of all species recorded from each trawl. The data set includes all trawl records where an estimated catch of JDO was reported.**

For comparability with the TCEPR trawl records, John dory estimated catches from TCER records that were ranked lower than the 5th largest catch (i.e. the 6–8th ranked species) were reassigned an estimated catch of zero (0 kg). For each fishing trip, the aggregated top 5 estimated catch of John dory was determined. The landed catch of John dory from each fishing trip (from Section 2.1.1) was then allocated amongst the trawl records from the respective fishing trips in proportion to the estimated catches of John dory (top 5 species only). Virtually all of the qualifying fishing trips included at least one trawl with an estimated John dory catch, enabling all landed catches to be allocated in this manner.

The trawl based catch and effort data set was utilised to augment the fishery characterisations by providing information about the spatial distribution of the trawl catch of John dory for each of the main fisheries. The data set was also used to configure the area specific trawl CPUE data sets for each fishery area.

## 3 FISHERY CHARACTERISATION

From the early 1990s, annual catches of JDO 1 increased to about the level of the TACC and remained at about that level during 1994/95–1998/99 (Figure 4). Annual catches fluctuated over the subsequent years; catches were relatively low in 2001/02–2012/13, recovered in 2004/05–2006/07 and then declined considerably during 2006/07–2012/13. Recent (2009/10–2013/14) annual catches were about 360 t, approximately half of the TACC level (Figure 4).

The overall trends in JDO 1 annual catches are largely driven by the annual catch from the HG-ENLD area. During the 1990s, this area accounted for 50–60% of the total JDO 1 catch; however, in recent years the HG-ENLD area only accounted for 35% of the total catch (Figure 6). The secondary peak in the total catch during 2004/05–2006/07 was also attributable to catches from the area.

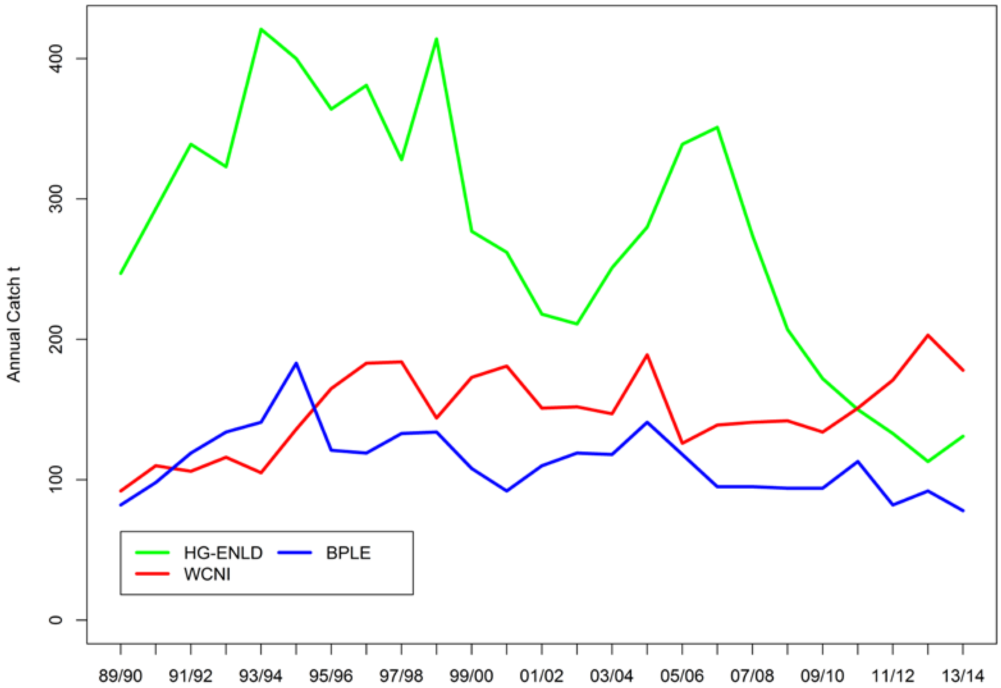



**Figure 6: Annual catches of John dory by fishery area.**

By comparison, the WCNI and BPLE areas each accounted for about 20–25% of the annual JDO 1 catches during the 1990s (Figure 6). Annual catches from the BPLE area tended to follow the trend in catches from the HG-ENLD area, increasing during the early 1990s to reach a peak in 1994/95 and generally declining over the remainder of the period. Recent annual catches from the BPLE area (approx. 100 t) were similar in magnitude to annual catches during the early 1990s (Figure 6).

Annual catches from the WCNI area increased from 1993/94 to 1995/96 and fluctuated about the higher level until 2004/05 (Figure 6). Annual catches were somewhat lower during 2005/06–2009/10 and then increased to a peak of about 200 t in 2012/13. This recent increase in annual catch meant that the WCNI area accounted for 45–50% of the annual JDO 1 catch during 2011/12–2013/14 (Figure 6).

The following sub-sections present separate fishery characterisations for each of the three fishery areas.

## 3.1 Bay of Plenty (BPLE)

Within the BPLE area, John dory was predominantly caught by single bottom trawl throughout the 1990s and 2000s with the method accounting for 70–80% of the annual catches (Figure 7). The annual catch from the bottom trawl fishery fluctuated about 80–100 t during this period but declined steadily from the mid 2000s to about 40 t in the most recent years (2012/13 and 2013/14) (Appendix 1 Table A1).

The remainder of the catch was mainly taken by pair trawl and Danish seine. The relative importance of the latter method has increased in recent years with the single trawl and Danish seine methods accounting for a similar magnitude of John dory catch in 2012/13 and 2013/14 (Figure 7). The Danish seine fishery also accounted for a comparable level of catch (about 25–40 t) during the mid 1990s.

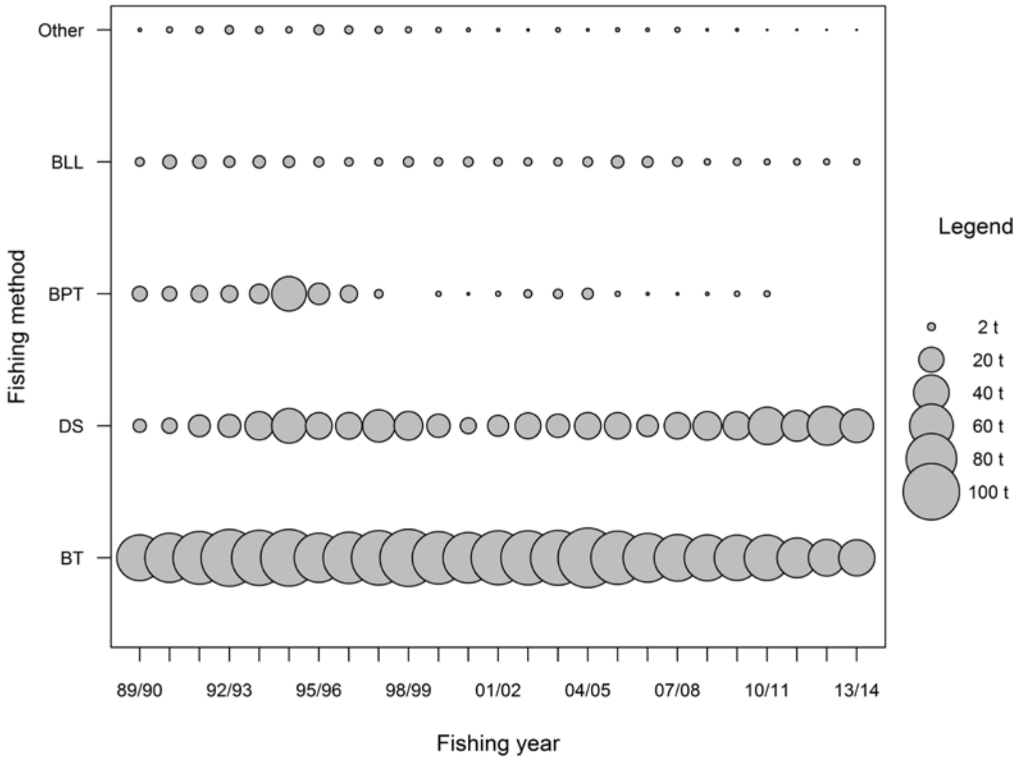



**Figure 7: Landed catch of John dory from the Bay of Plenty fishery, by fishing method and fishing year.**

The John dory catch from the single trawl fishery was taken by trawls targeting a range of species, principally snapper, John dory, trevally and tarahiki (Figure 8). The relative proportion of the John dory catch taken by the snapper target trawls declined during the 1990s with a corresponding increase in the proportion taken by the trevally and John dory target fishery species (Figure 8). In 2004/05, a considerable proportion of the John dory catch was taken by trawls targeting red gurnard; however, limited catch was taken from this fishery in subsequent years.

Catches of John dory from the Danish seine fishery were predominantly taken as a bycatch of snapper and red gurnard (Figure 8). A small John dory catch is taken by the snapper longline fishery and minor catches are also taken by the set net method.

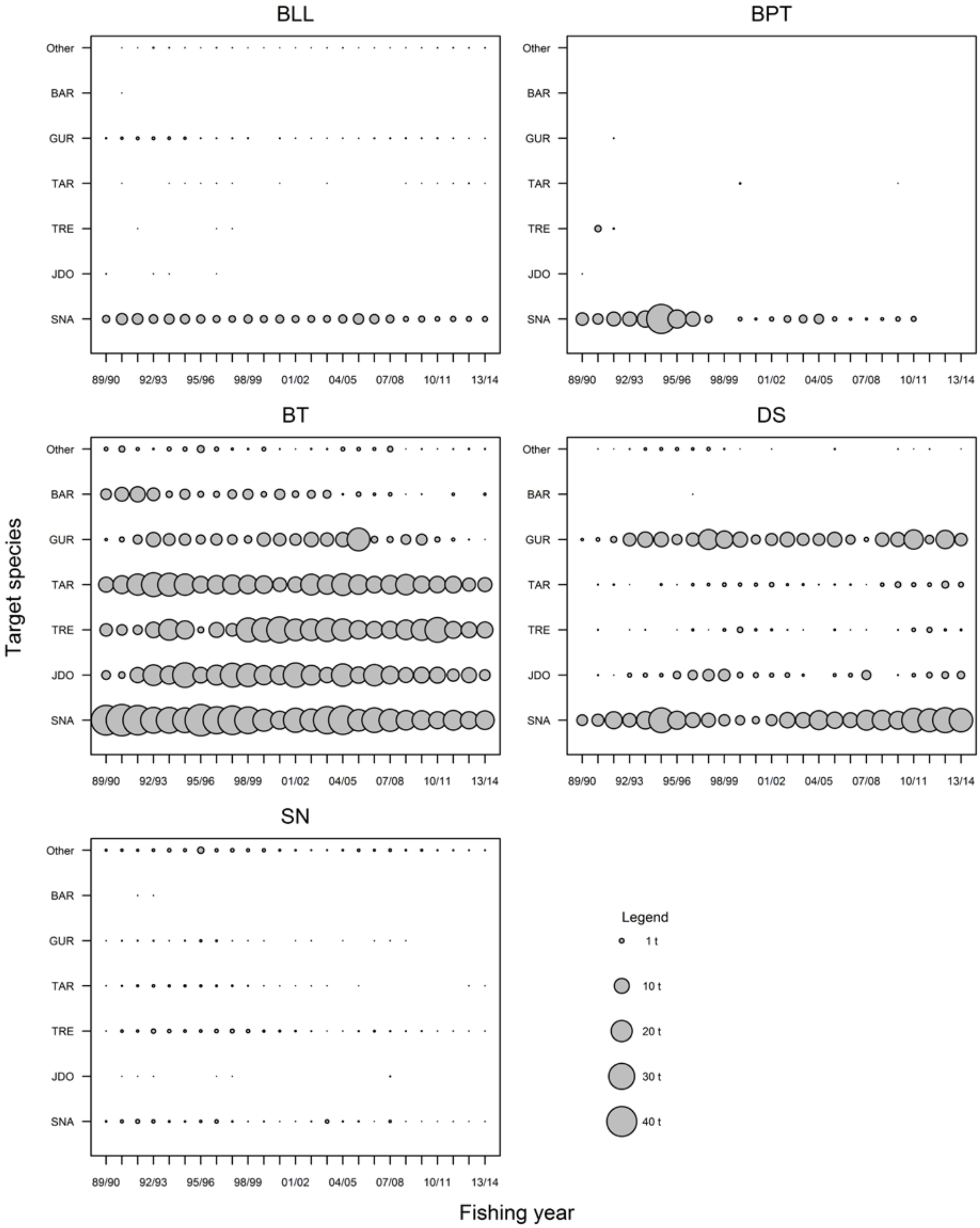



**Figure 8: Landed catch of John dory from the Bay of Plenty fishery, by fishing method, target species and fishing year.**

The data collected from TCER and TCEPR forms during 1994/95–2013/14 were used to characterise the depth distribution of the John dory catch from the BPLE single trawl fishery. Most of the catch was taken in the 20–120 m depth range corresponding to the depth range of the main target species (snapper and trevally) (Figure 9). The peak in catches at a depth of 100 m corresponds to a large number of trawls being conducted along the 100 m depth contour. Target John dory trawls tended to catch the species in a more restricted depth range (40–100 m). Overall, catches of John dory were minimal from trawls in depths greater than 150 m (Figure 9) despite a considerable proportion of fishing effort (primarily targeting tarakihi) occurring in depths exceeding 150 m.

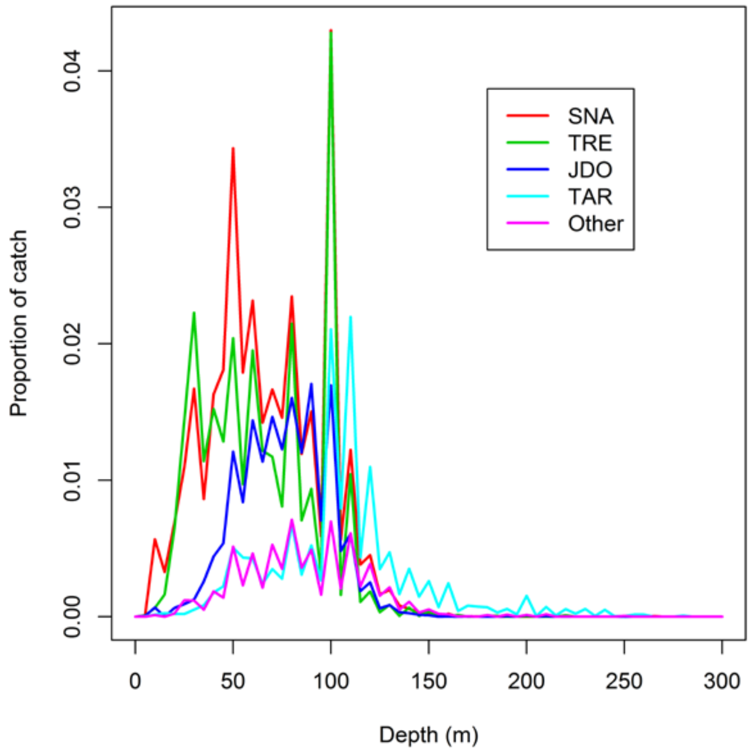



**Figure 9: Proportional depth distribution of John dory single trawl catch from the BPLE fishery by bottom depth (5 metre depth intervals) and target species from 1994/95 to 2013/14 for the main bottom trawl target species (TCEPR or TCER records, all years combined).**

The catch of John dory by the main fishing methods (BT and DS) is distributed throughout the Bay of Plenty (Figure 10). The recent decline in the catch by the single trawl fishery has occurred throughout the three Statistical Areas that comprised the fishery area. Overall, the John dory trawl catch is relatively evenly distributed throughout the Bay of Plenty within the 30–120 m depth range (Figure 11), although there are a number of localised areas which have supported higher catches, specifically to the east of Great Barrier Island, westward of Mayor Island, and in the eastern Bay of Plenty off the coast from Opotiki.

The recent increase in the Danish seine catch has primarily occurred in the central and eastern area of the Bay of Plenty (Statistical Areas 009 and 010), while annual catches have remained relatively stable in the western Bay of Plenty (008) (Figure 10).

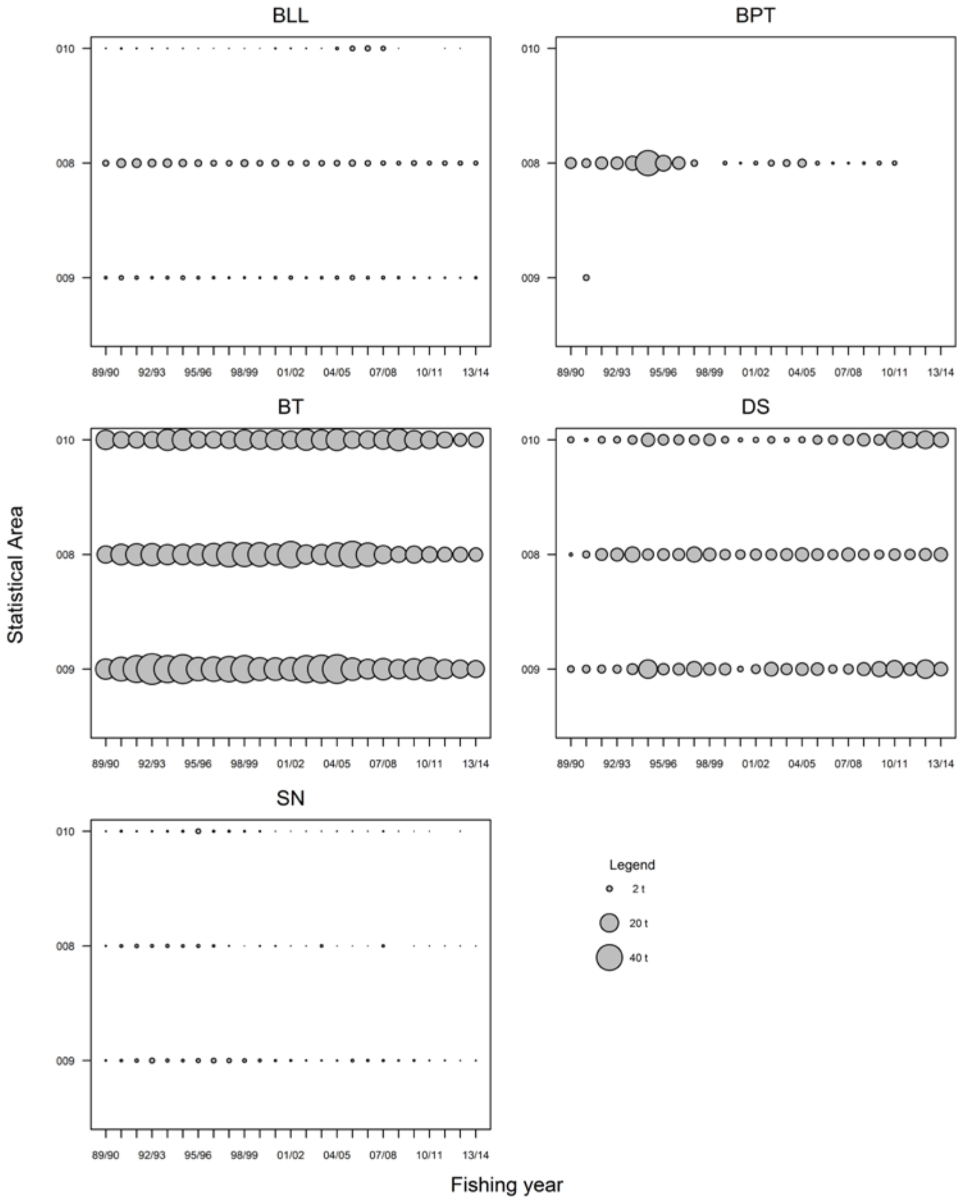



**Figure 10: Annual distribution of John dory catch from BPLE by fishing method and statistical area. The area of the circle is proportional to the catch.**

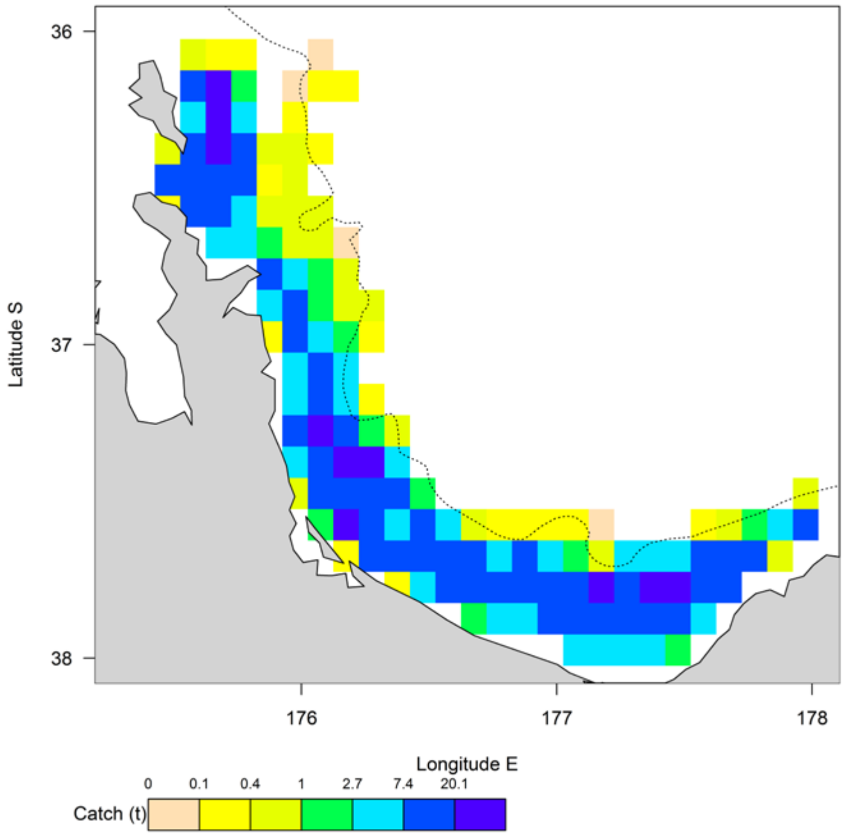



**Figure 11: Spatial distribution of John dory single trawl catch from the Bay of Plenty for 1994/95–2013/14 fishing years (derived from TCER and TCEPR records). The catch data are aggregated by 0.1 lat/long spatial cells. The dashed line represents the 200 m depth contour.**

The seasonal distribution in the catch of John dory from the trawl fishery has changed considerably over the study period (Figure 12), primarily in response to changes in the seasonal distribution of fishing effort. Trawl catch rates of John dory tend to be highest during December–March and low during April–June. During the early 1990s, trawl effort was concentrated during June–September and, consequently, most of the John dory catch was taken during that period (Figure 12). Since then, trawl effort tended to be more evenly distributed throughout the year and a higher proportion of the annual catches has been taken during December–March (Figure 12).

A similar pattern is evident for the Danish seine fishery. During the 1990s, fishing effort was concentrated during June–September resulting in moderate catches during that period (Figure 12). From 2007/08, fishing effort was more evenly distributed throughout the year and most of the Danish seine catch was taken during October–March (Figure 12) when catch rates are relatively high.

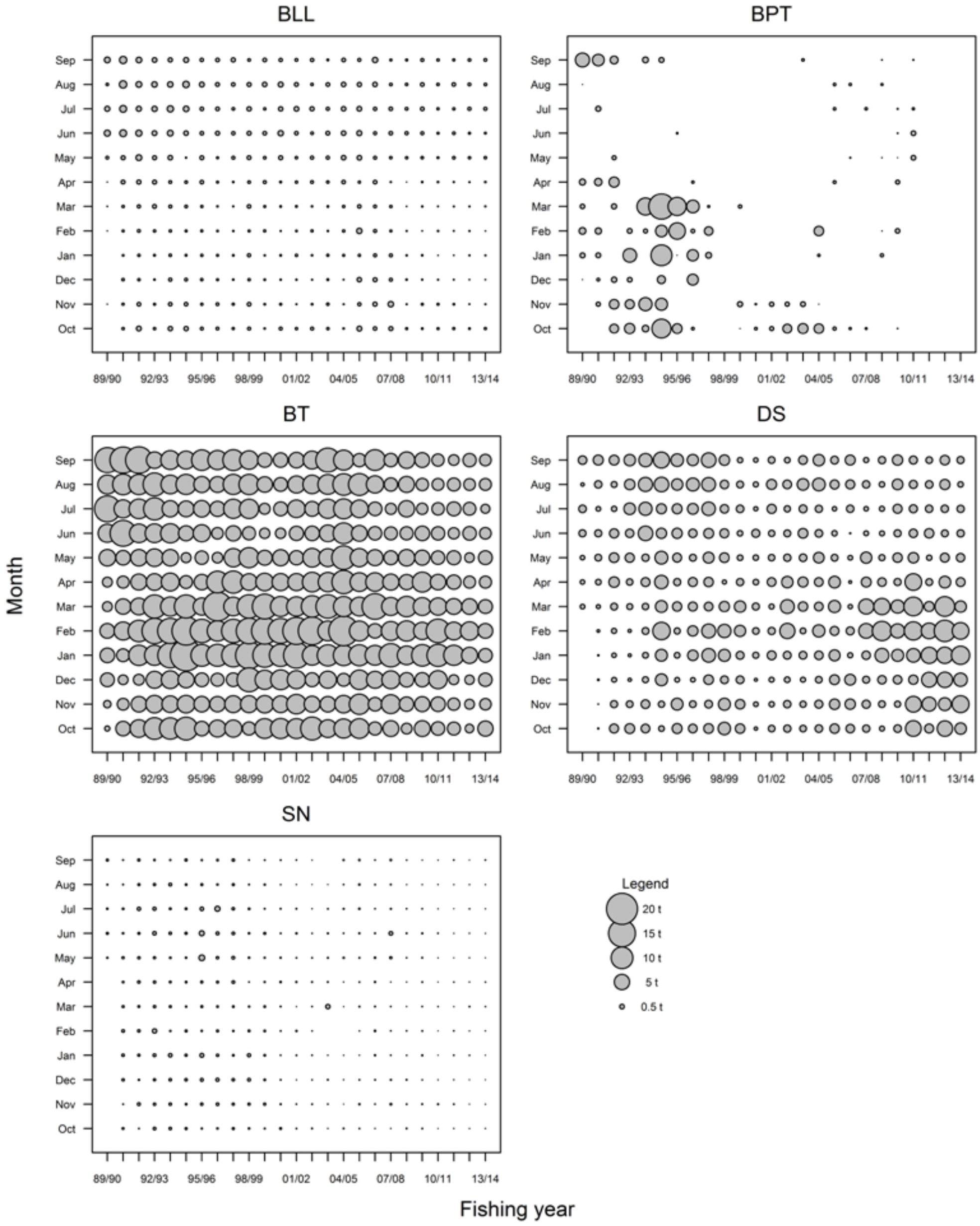



**Figure 12: The monthly distribution of John dory catches from BPLE by method and fishing year. Circle areas are proportional to the catch.**

## 3.2 Hauraki Gulf and east Northland (HG-ENLD)

The catch from the HG-ENLD fishery was predominantly taken by the single bottom trawl (61%) and Danish seine (32%) methods (Figure 13). The annual catch from both methods declined from the late 1990s, recovered during the mid 2000s and then continued to decline over the remainder of the period. In recent years (2012/13 and 2013/14), annual catches from both methods were 33% of the annual catch from the period of peak catch during the mid 1990s (1993/94–1998/99) (Appendix 1 Table A2).

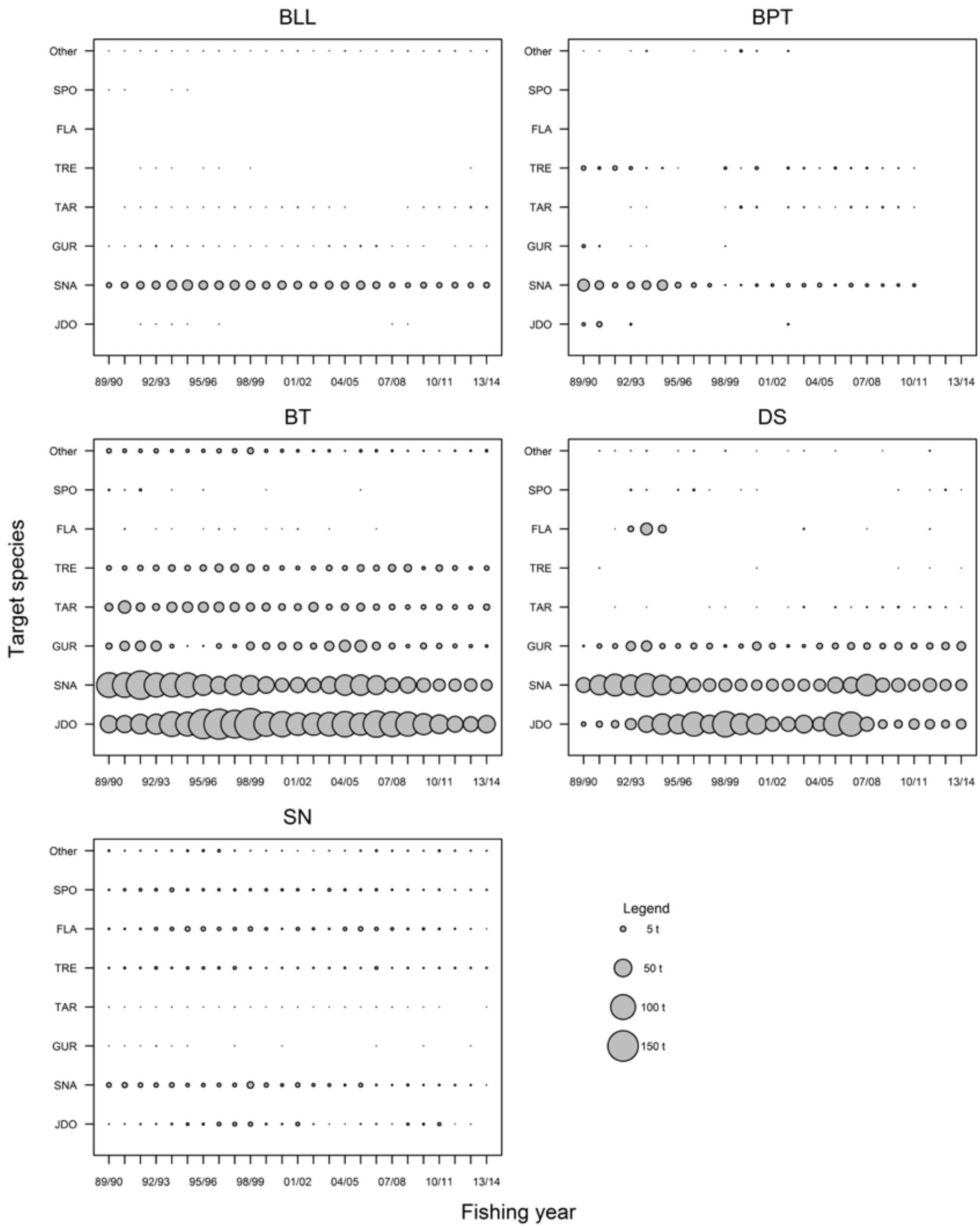



**Figure 13: Landed catch of John dory from the HG-ENLD fishery by fishing method, target species and fishing year.**

For both the single trawl and Danish seine fisheries, John dory is predominantly caught either by target fishing or associated with targeting snapper (Figure 13). For both methods, annual catches were dominated by snapper target fishing during the early 1990s but were more equally distributed between the John dory and snapper target fisheries in the subsequent years.

Minor catches of John dory from HG-ENLD have also been taken by the snapper longline fishery and as a bycatch of the pair trawl fishery (Figure 13).

Most of the John dory catch from the Danish seine fishery is taken from the central Hauraki Gulf (Statistical Area 006) (Figure 14), while the single trawl catch is predominantly taken from the outer Hauraki (005) and outer Bream Bay (003) (Figure 14 and Figure 15). Limited catch of John dory was taken by the single trawl fishery operating in the north of the HG-ENLD area.

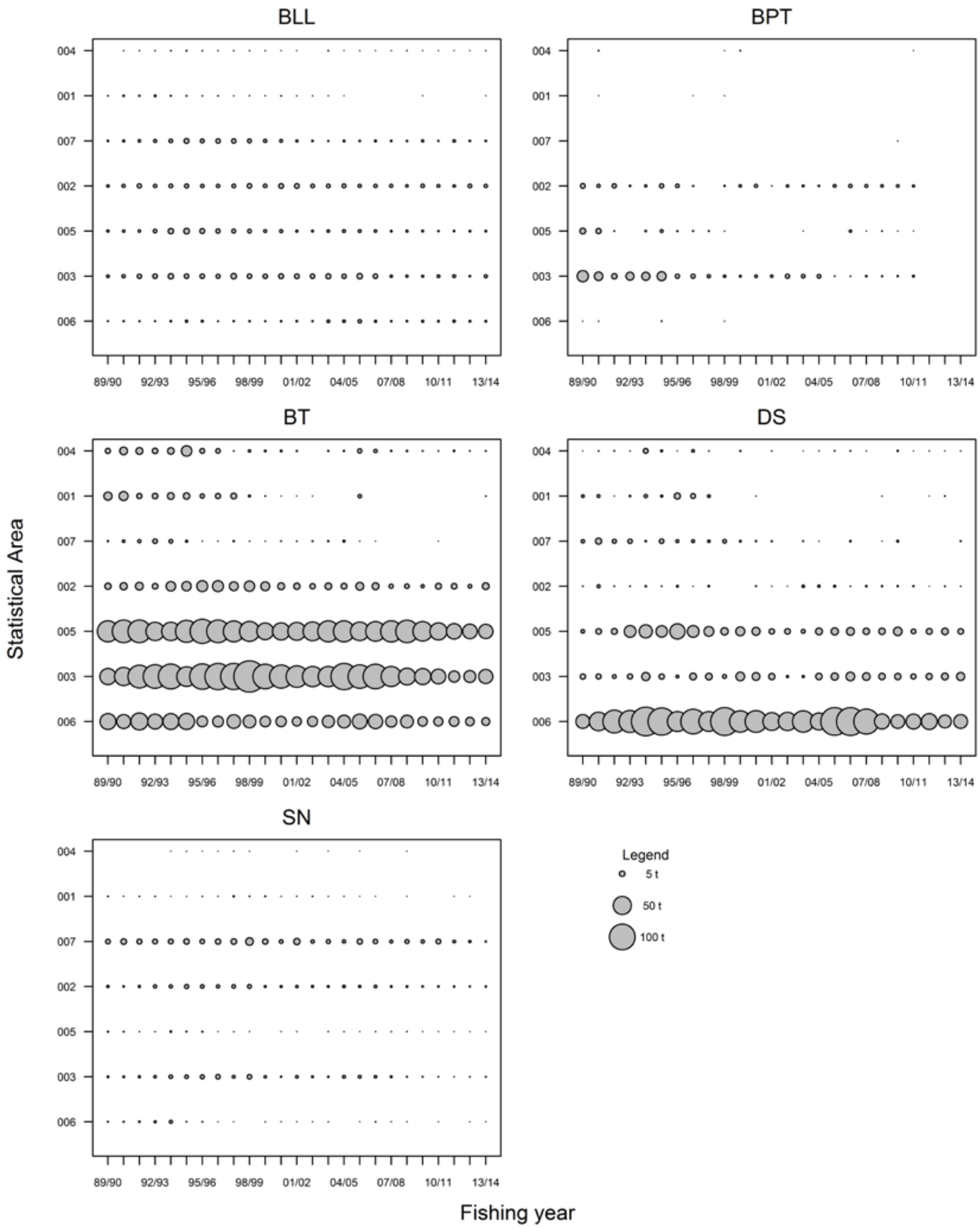



**Figure 14: Annual distribution of John dory catch from HG-ENLD by fishing method and statistical area. The area of the circle is proportional to the catch.**

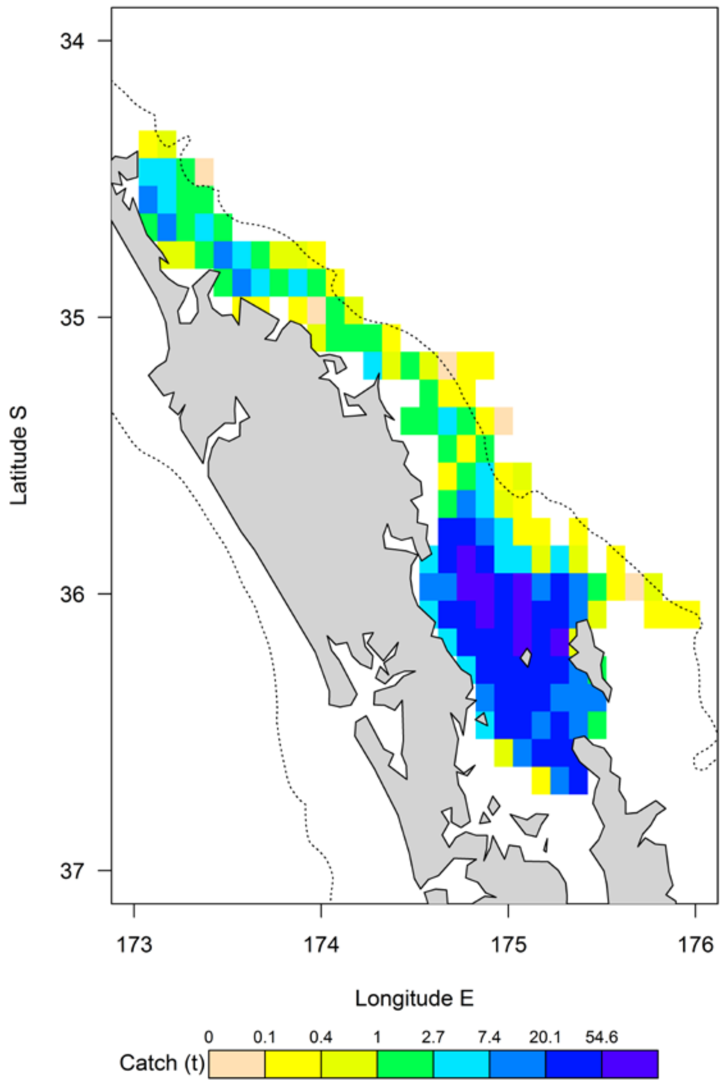



**Figure 15: Spatial distribution of John dory single trawl catch from the HG-ENLD for 1994/95–2013/14 fishing years (derived from TCER and TCEPR records). The catch data are aggregated by 0.1 lat/long spatial cells. The dashed line represents the 200 m depth contour.**

Most of the John dory trawl catch was taken in the 40–100 m depth range by the target fishery (Figure 16). The distribution of John dory catch from the snapper trawl fishery was concentrated about the 50 m depth contour. The depth distribution of catches is truncated at about 45–50 m which approximates the depth of the outer boundary of the Hauraki Gulf trawl exclusion zone.

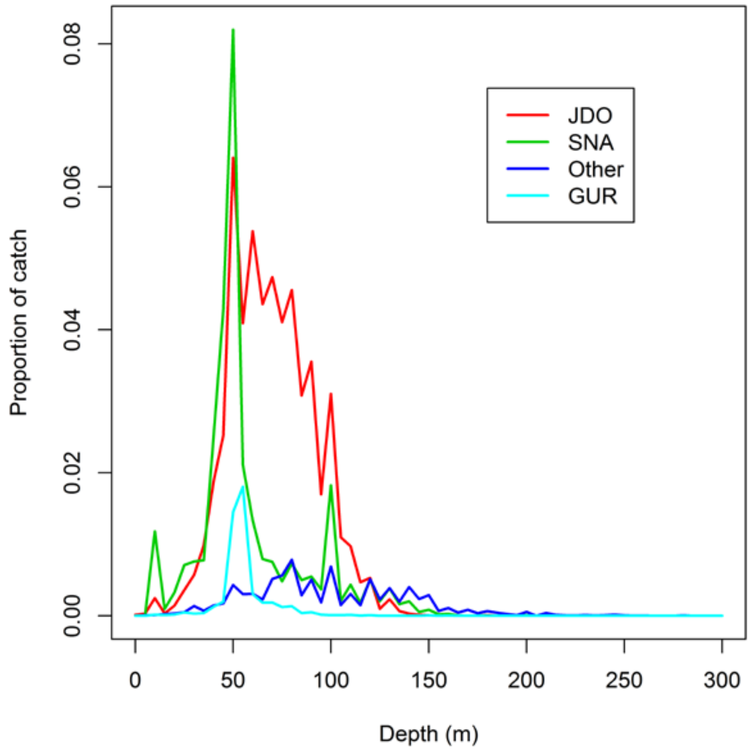



**Figure 16: Proportional depth distribution of John dory single trawl catch from the HG-ENLD fishery by bottom depth (5 metre depth intervals) and target species from 1994/95 to 2013/14 for the main bottom trawl target species (TCEPR or TCER records, all years combined).**

Monthly catches of John dory from the HG-ENLD single trawl fishery were generally highest during December–March and low during April–June, while the seasonal distribution of catch from the Danish seine fishery was variable amongst years (Figure 17). The variability in monthly catch from the Danish seine fishery is related to variability in the period of higher catch rates, rather than changes in the monthly distribution of fishing effort. This indicates that the effective targeting of John dory by the Danish seine method can be conducted throughout the year.

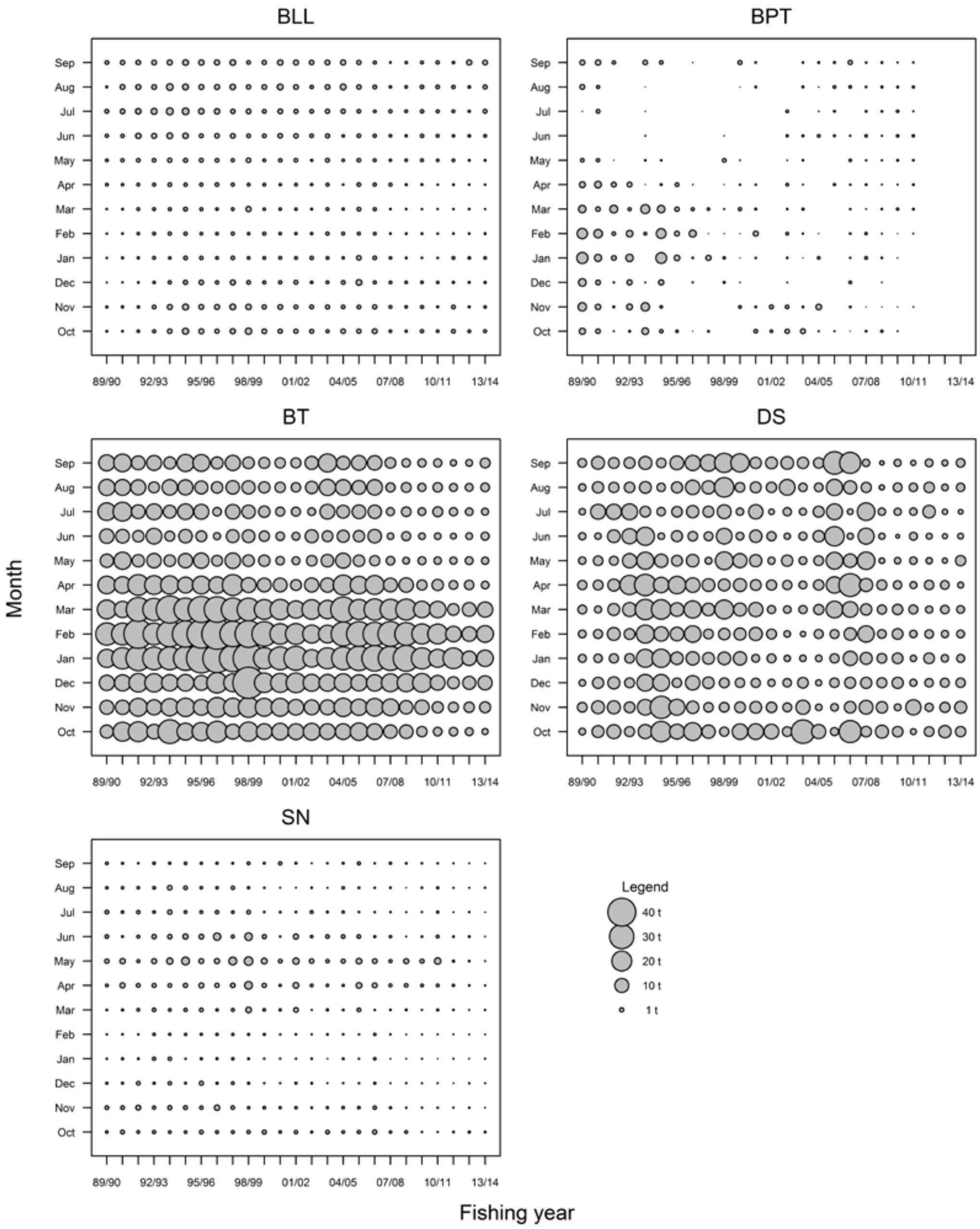



**Figure 17: The monthly distribution of John dory catches from the HG-ENLD fishery by fishing method and fishing year. Circle areas are proportional to the catch.**

## 3.3 West coast North Island (WCNI)

Most of the catch from the WCNI John dory fishery was taken by the single bottom trawl method (83%) with minor catches also taken by the pair trawl (8%) and Danish seine (4%) methods (Figure 18 and Appendix 1 Table A3). The trawl catch is predominately a bycatch from trawls targeting a range of inshore species: trevally, snapper, red gurnard and, to a lesser extent tarakihi. Since 2004/05, John dory catches from the snapper target trawl fishery have been relatively low, while catches from trawls targeting trevally and red gurnard have increased (Figure 18). This component of the fishery accounted for most of the increased level of the overall catch from the WCNI fishery during 2011/12–2013/14. A small proportion of the catch was also taken by John dory target trawls during that period. Most of the Danish seine catch was taken as a bycatch of red gurnard (Figure 18).

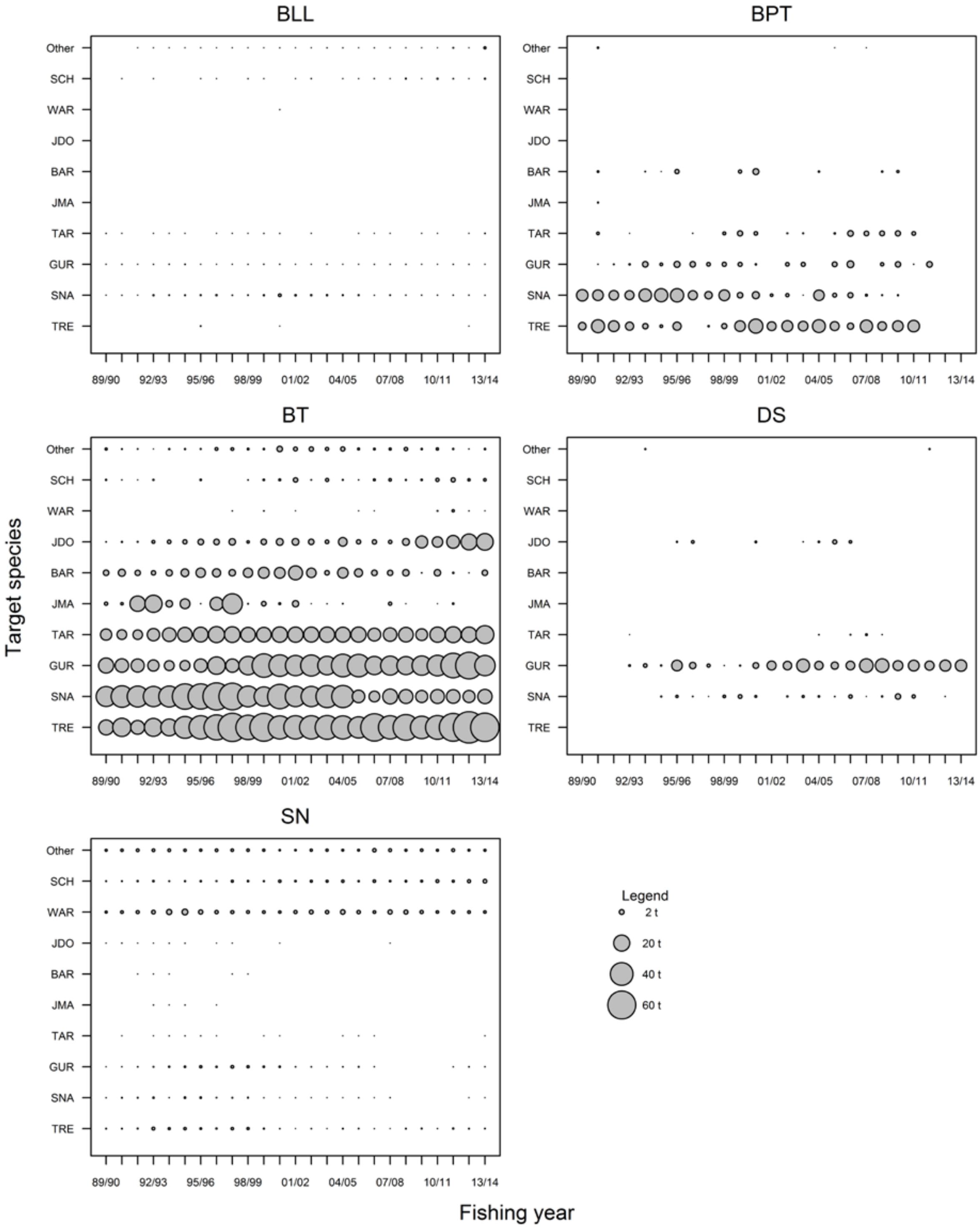



**Figure 18: Landed catch of John dory from the WCNI fishery by fishing method, target species and fishing year.**

The John dory catch from the trawl fishery is taken throughout the WCSI fishery area between Cape Reinga and Cape Egmont, with the highest catches taken in North Taranaki Bight (Statistical Area 041), Ninety Mile Beach (047) and between the entrances of Kaipara and Manukau Harbours (042 and 045) (Figure 19 and Figure 20). The Danish seine fishery primarily operates in the northern WCNI fishery area (047) (Figure 19).

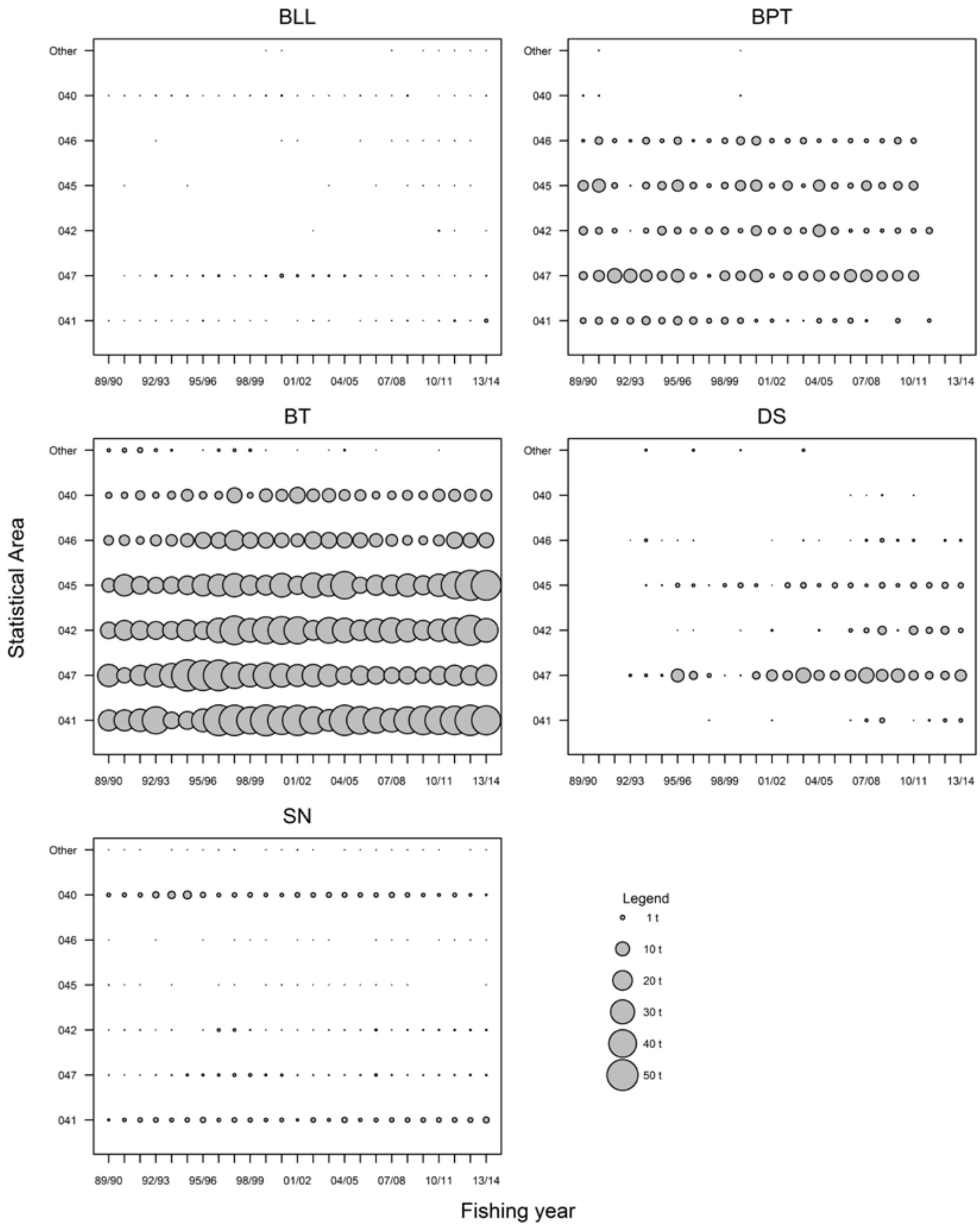



**Figure 19: Annual distribution of John dory catch from the WCNI fishery by fishing method and statistical area. The area of the circle is proportional to the catch.**

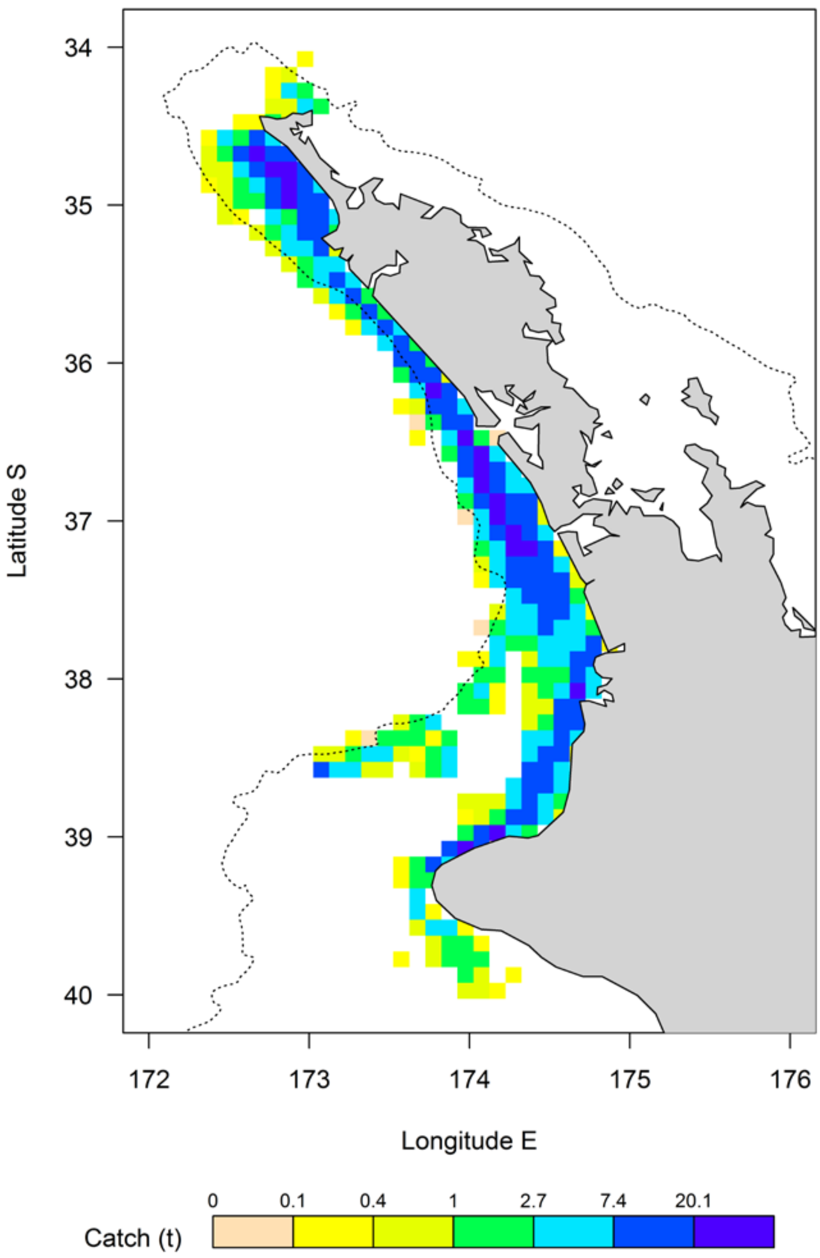



**Figure 20: Spatial distribution of John dory single trawl catch from the WCNI fishery for 1994/95–2013/14 fishing years (derived from TCER and TCEPR records). The catch data are aggregated by 0.1 lat/long spatial cells. The dashed line represents the 200 m depth contour.**

Most of the John dory trawl catch was taken in the 25–100 m depth range from trawls targeting trevally, snapper and red gurnard (Figure 21). The tarakihi trawl fishery occurs in deeper water and moderate catches of John dory are taken in 100–160 m depth range. Catches are small from the tarakihi trawls conducted in deeper water (Figure 21) (typically to depths of about 200 m).

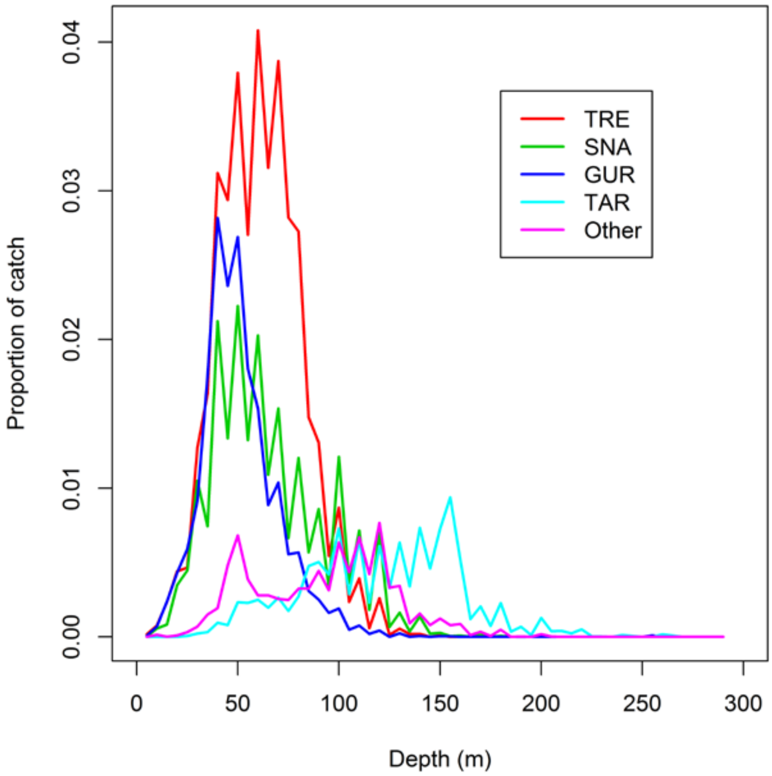



**Figure 21: Proportional depth distribution of John dory single trawl catch from the WCNI fishery by bottom depth (5 metre depth intervals) and target species from 1994/95 to 2013/14 for the main bottom trawl target species (TCEPR or TCER records, all years combined).**

Most of the John dory catch is taken during December–March and catches tend to be lowest during April–July (Figure 22). The seasonal distribution in catch tends to correspond with the seasonal pattern in both the distribution of the trawl effort in the WCNI fishery and the relative catch rate of John dory by the trawl fleet.

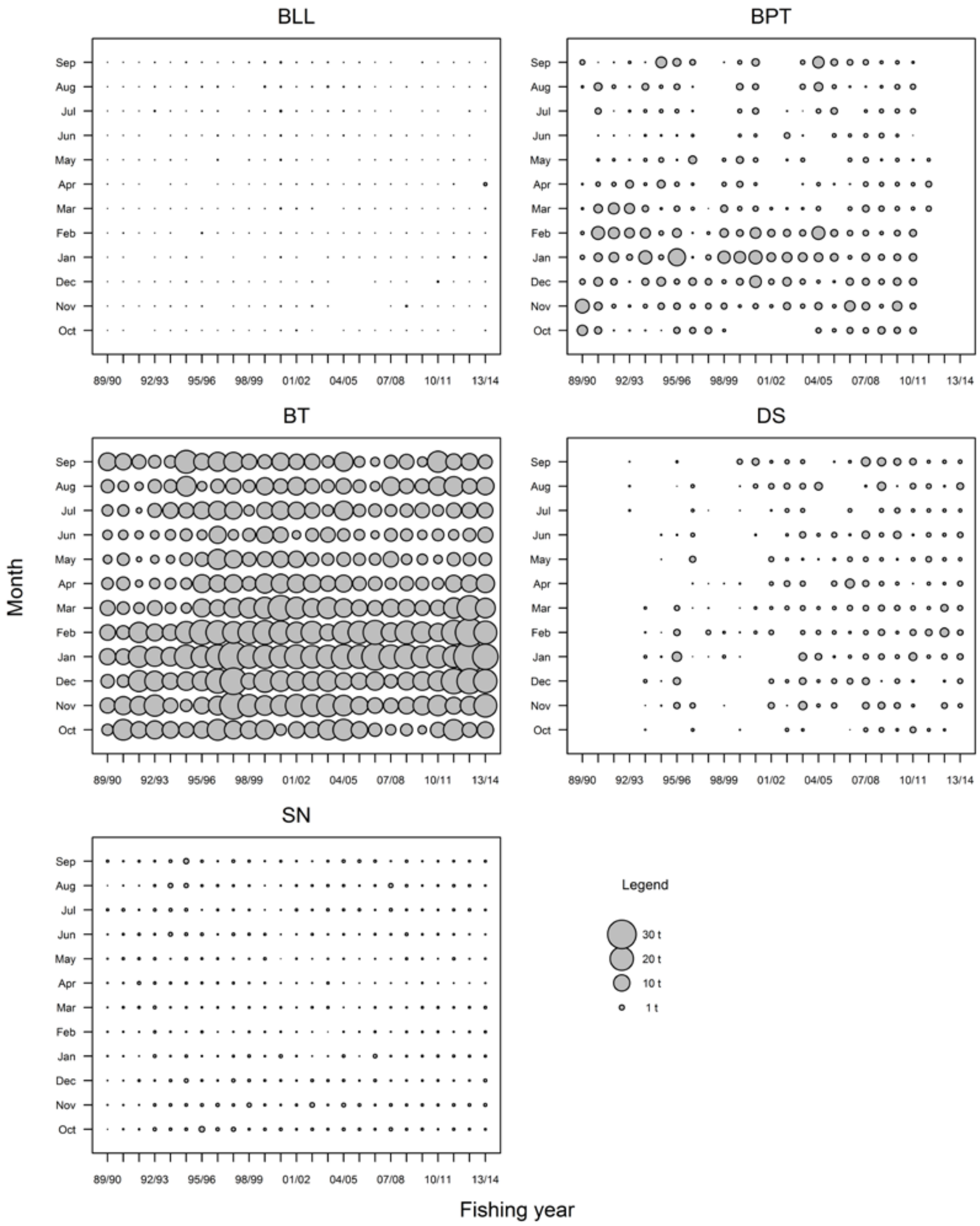



**Figure 22: The monthly distribution of John dory catches from WCNI by fishing method and fishing year. Circle areas are proportional to the catch.**

# 4 CPUE Analyses

## 4.1 Methodology

### 4.1.1 Single trawl CPUE

For the three sub-areas of JDO 1, standardised CPUE analyses of the event based catch and effort data from the inshore trawl fisheries were conducted following the approach of Dunn & Jones (2013). The CPUE analyses were based on the trawl catch and effort data set configured in Section 2.1.2. The data set was partitioned by fishery area and restricted to 1994/95–2013/14 as very limited trawl based (i.e., tow by tow) catch and effort data are available from the preceding years. Each area specific data set was further limited to a set of (core) vessels that completed a minimum of 5 fishing trips in a minimum of five years (in the specific area). Fishing effort records were also restricted to the depth range of the John dory catches determined from the respective fishery area characterisations (Table 2).

A Generalised Linear Modelling (GLM) approach was applied to model the occurrence of John dory catches (presence/absence) and the magnitude of positive John dory catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch and a lognormal error structure was assumed. The presence/absence of John dory catch was modelled based on a binomial distribution. The potential explanatory variables available for inclusion in each CPUE model are presented in Table 2.

Fishing location was categorised by assigning the trawl start location to a grid of 0.2 degree latitude/longitude cells (*Loc2* variable). The spatial resolution of the 0.2 degree grid approximates the average trawl distance (based on time speed and trawl duration). To reduce the number of spatial cells included in the WCNI CPUE models, the spatial categorisation was limited to 0.2 degree bands of latitude (*Lat2* variable) (Table 2).

The dimensions of the trawl net (gear width and headline height) were also available for each fishing record. For most of the vessels included in the final CPUE analyses, the recorded trawl gear width and headline height were relatively constant throughout the study period.

**Table 2: The variables included in the single trawl CPUE analyses for the three areas.**

| Variable | Definition | Data type | Range |
|---|---|---|---|
| *Vessel* | Fishing vessel category | Categoric | |
| *FishingYear* | Fishing year | Categoric (20) | 1994/95–2013/14 |
| *Month* | Month | Categoric (12) | 1–12 |
| *StatArea* | Statistical area of trawl | Categoric | 008–010 (BPLE)<br>001–007 (HG-ENLD)<br>040–048 (WCNI) |
| *Loc2* | Start location of trawl categorised by 0.2 degree latitude/longitude cell. | Categoric | |
| *Lat2* | Start location of trawl categorised by 0.2 degree latitude. | Categoric | |
| *TargetSpecies* | Declared target species for trawl. | Categoric | SNA,GUR,JDO,TRE,BAR,TAR |
| *Duration* | Natural logarithm of trawl duration | Continuous | Ln(0.5–6) |
| *Depth* | Fishing depth (m) | Continuous | < 150 (BPLE)<br>< 200 (HG-ENLD)<br>< 200 (WCNI) |
| *StartTime* | Hour at the start of trawl. | Continuous | 0–23 |
| *Speed* | Trawl speed (knots) | Continuous | 2.0–5.0 |
| *GearWidth* | Wingspread of trawl gear (m) | Continuous | |
| *GearHeight* | Headline height of trawl gear (m) | Continuous | |
| *JDOcatch* | Scaled estimated JDO trawl catch (kg). | Continuous | 0–1000 kg |
| *JDObin* | Presence (1) or absence (0) of JDO catch in trawl. | Categoric | |

A step-wise fitting procedure was implemented to configure each of the CPUE models. The procedure included all of the potential explanatory variables (Table 2) with the continuous variables parameterised as a third order polynomial function. The categoric variable *FishingYear* was included in the initial model and subsequent variables were included in the model based on the improvement in the AIC. Additional variables were included in the model until the improvement in the Nagelkerke pseudo-$R^2$ was less than 0.5%.

For each area, lognormal and binomial CPUE indices were calculated from the respective CPUE models. The delta-lognormal indices were determined from the product of the positive catch (lognormal) and binomial indices, following the approach of Stefansson (1996). The confidence intervals associated with the combined delta-lognormal indices were determined using a bootstrapping approach.

### 4.1.2 Danish seine CPUE

For the HG-ENLD and BPLE areas, a substantial proportion of the John dory catch is taken by the Danish seine fishery. Supplementary CPUE analyses were conducted for these two area specific Danish seine fisheries.

All catch and effort data from the Danish seine fishery were reported in CELR format. The area specific data sets were extracted from the fishery characterisation data set (Section 2.1.1) with catches scaled to represent the overall landed catch per trip. Each record represented the daily fishing activity (total fishing duration and number of sets) and John dory catch of a vessel associated with the statistical area and target species.

The area specific CPUE data sets were each limited to a set of (core) vessels that had completed a minimum of five trips in a minimum of five years. The John dory catch from the core vessel sets generally represented about 80–100% of the total Danish seine catch from each area.

The CPUE data sets were limited to records with a catch of John dory. For the HG-ENLD fishery, there was a relatively small (5–10%) proportion of fishing days with no associated catch of John dory (Appendix 2 Table A7). The proportion of zero catch records excluded from the BPLE data set is considerably higher at 20–35% (Appendix 2 Table A8).

For each area, standardised CPUE indices were determined using a GLM approach. The dependent variable was the natural logarithm of the John dory catch and potential explanatory variables are presented in Table 3. A step-wise fitting procedure was implemented to configure each of the CPUE models. The categoric variable *FishingYear* was included in the initial model and subsequent variables were included in the model based on the improvement in the AIC. Additional variables were included in the model until the improvement in the Nagelkerke pseudo-$R^2$ was less than 0.5%.

**Table 3: The variables included in the Danish seine CPUE analyses for BPLE and HG-ENLD areas.**

| Variable | Definition | Data type | Range |
|---|---|---|---|
| *Vessel* | Fishing vessel category | Categoric | |
| *FishingYear* | Fishing year | Categoric (25) | 1989/90–2013/14 |
| *Month* | Month | Categoric (12) | 1–12 |
| *StatArea* | Main statistical area fished in fishing day | Categoric | 001–007 (HG-ENLD)<br>008–010 (BPLE) |
| *TargetSpecies* | Main species targeted in fishing day | Categoric | SNA,GUR,JDO |
| *EffortNum* | Number of fishing events | Continuous | 1–7 |
| *JDOcatch* | Scaled estimated JDO catch (kg). | Continuous | 1–1000 kg |

## 4.2 Bay of Plenty

### 4.2.1 Single trawl CPUE

The BPLE trawl CPUE analysis was based on the trawl event catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 008–010 (Table 2). Catch and effort records were included regardless of whether or not there was an associated reported catch of John dory. The initial data set accounted for about 70–80% of the John dory catch from the BPLE trawl fishery from 1995/96–2006/07 (Figure 23). From 2007/08, almost all of the John dory trawl catch has been reported in event based format (i.e. TCEPR or TCER format).

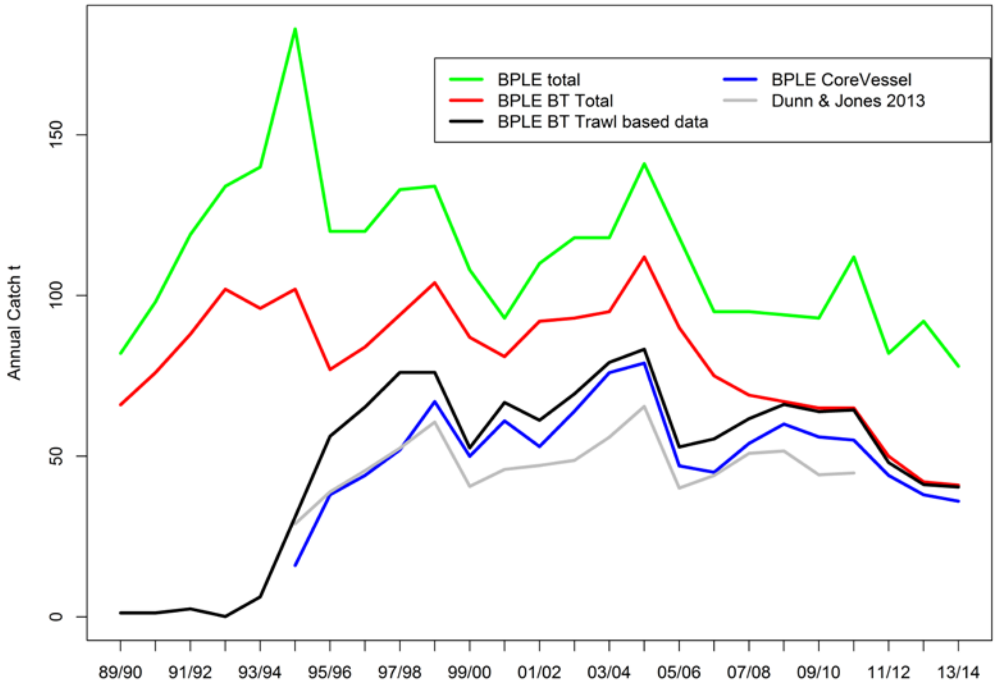



**Figure 23: A comparison of the total Bay of Plenty (BPLE) annual JDO 1 catch and various subsets of the catch and effort data set, including the final trawl CPUE data set for the core fleet (BPLE CoreVessel). For comparison, the annual catch included in the CPUE analysis of Dunn & Jones (2013) is also presented.**

The core fleet, defined based on continuity criteria of a minimum of five trips in at least five years, accounted for 85% of the total John dory catch included in the trawl event based data set (from 1994/95 to 2013/14) (Figure 23). The criteria resulted in the selection of 30 unique vessels including three vessels that had operated in the fishery for at least 15 years (Figure 24). Approximately half of the John dory catch included in the data set was taken by six vessels.

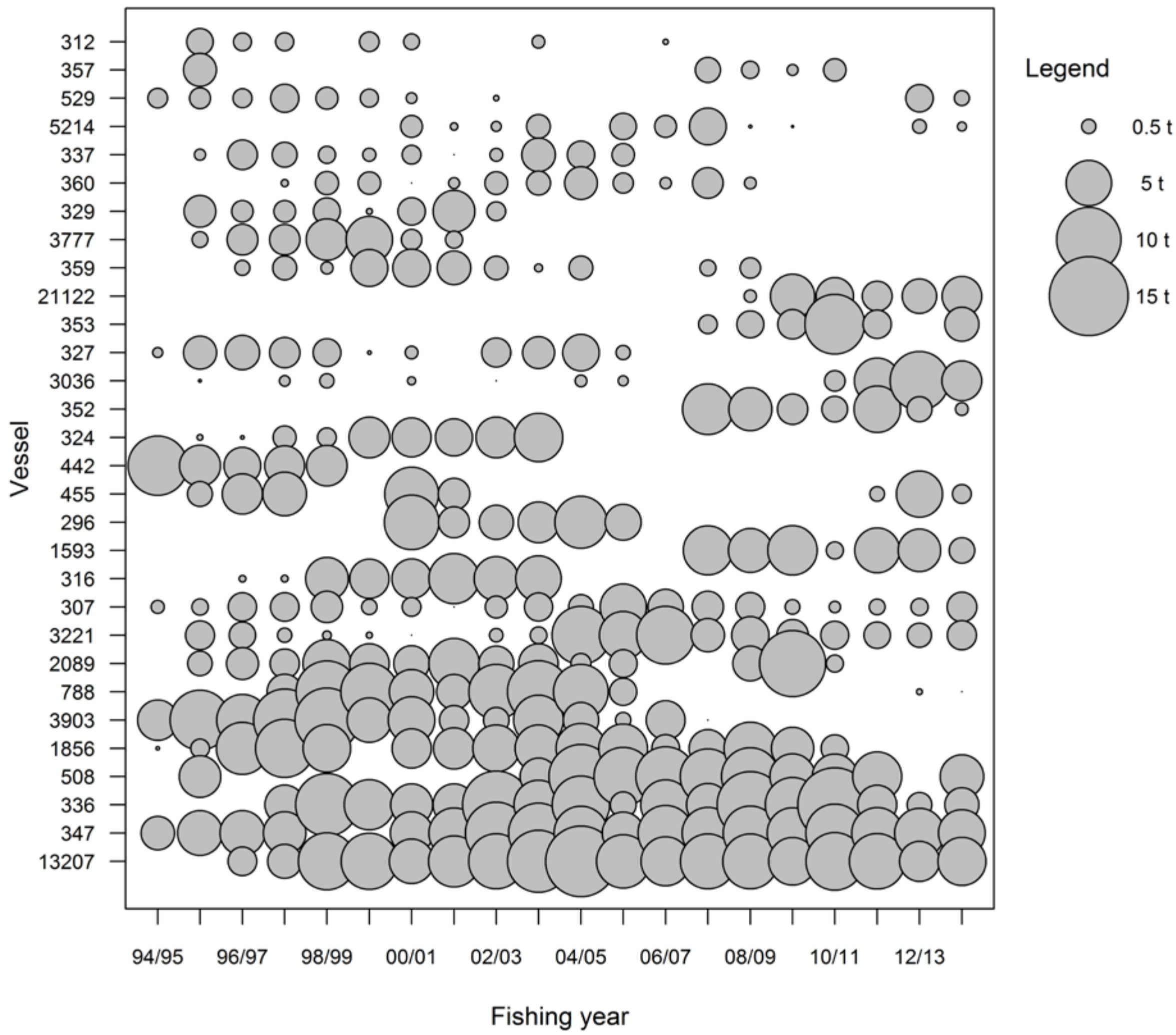



**Figure 24: Distribution of John dory BPLE trawl catch by year and fishing vessel for the core fleet included in the final trawl based CPUE data set.**

The annual distribution of John dory catch and trawl effort by target species, month and statistical area are generally consistent with the trends described in the characterisation of the BPLE trawl fishery (Section 3.1). From the early 2000s, the distribution of fishing effort amongst the main target species (snapper, trevally and tarakihi) remained relatively stable (Figure 25). There was a decline in the proportion of tarakihi trawls from 2009/10 with a corresponding decline in the depth fished (Figure 26).

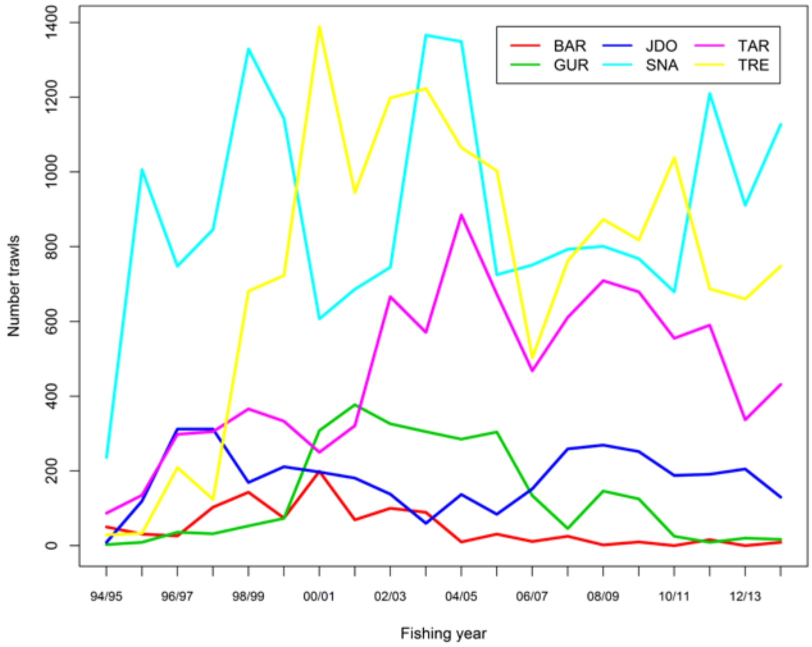



**Figure 25: Annual distribution of trawl effort records by target species for the BPLE core vessel CPUE data set.**

The spatial distribution of fishing effort within the Bay of Plenty was characterised by determining the distance of individual trawls from the western boundary of Statistical Area 008 (i.e. Cape Colville). From 1996/97 to 2001/02, the distribution of fishing effort shifted eastwards and was increasingly concentrated in the eastern Bay of Plenty (Figure 26) in the area between Whakatane and Te Kaha. This corresponded with a shift from targeting snapper to targeting trevally (Figure 25). Fishing effort remained concentrated in the eastern Bay of Plenty in the subsequent years (Figure 26).

Trawl duration tended to be shorter during the mid–late 1990s than during the subsequent years (Figure 26) when there was an increase in the proportion of longer trawls (primarily targeting tarakihi). The diurnal distribution of fishing effort remained relatively constant throughout the study period (Figure 26).

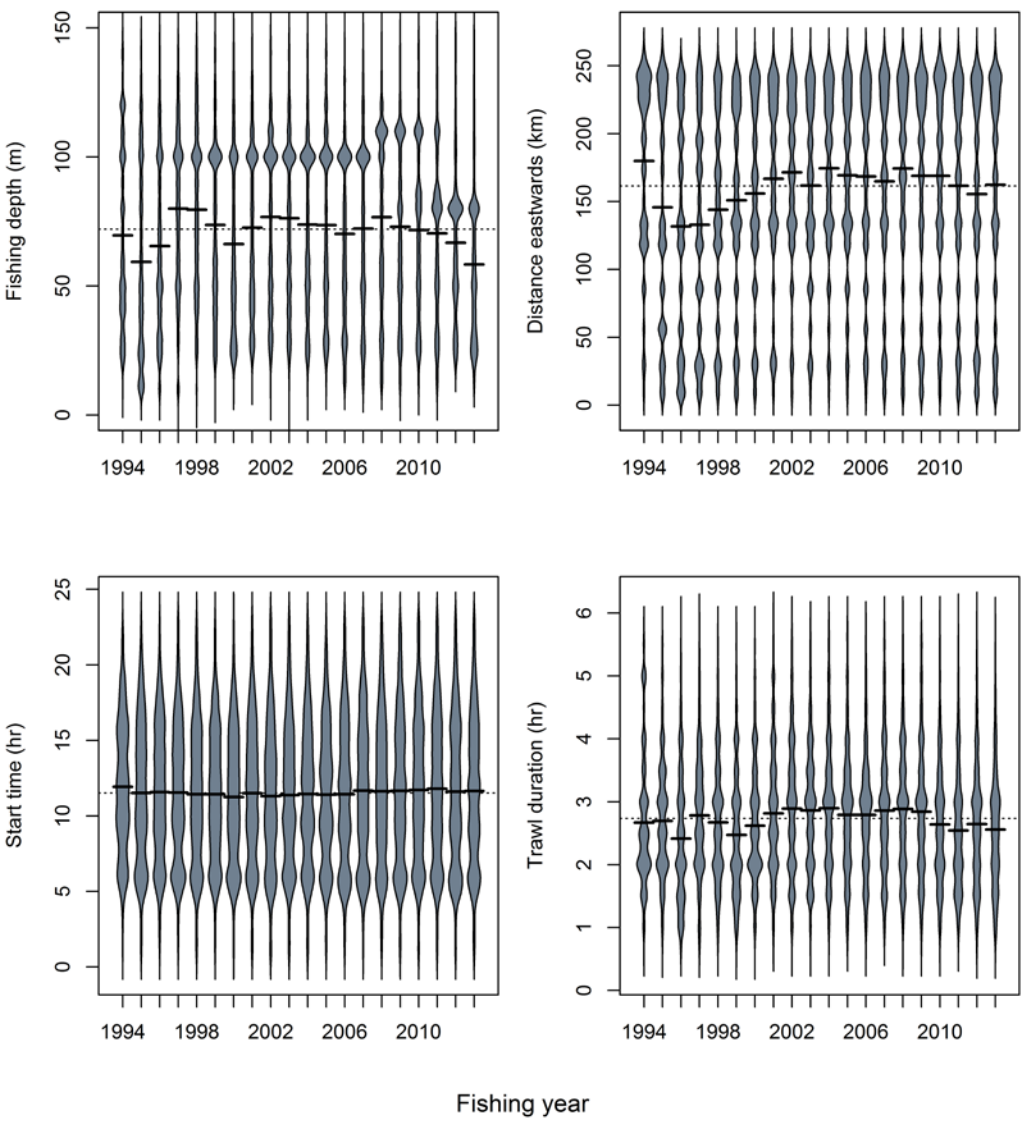



**Figure 26: Beanplots of a range of descriptive variables characterising the fishing effort data included in the BPLE trawl CPUE data set (core vessels). The "beans" represent the distribution of the yearly data and the solid horizontal line represents the median value. The fishing year is denoted by the calendar year at the start of the fishing year (e.g. 1994 represents the 1994/95 fishing year).**

The CPUE data set included a large proportion (50–60%) of trawl records with no John dory catch (Appendix 2 Table A4). From 2008/09, the proportion of trawls that caught John dory declined throughout the Bay of Plenty, although the trend was most pronounced in the eastern Bay of Plenty (Figure 27). The overall proportion of trawls with no associated John dory catch was highest in 2011/12–2013/14.

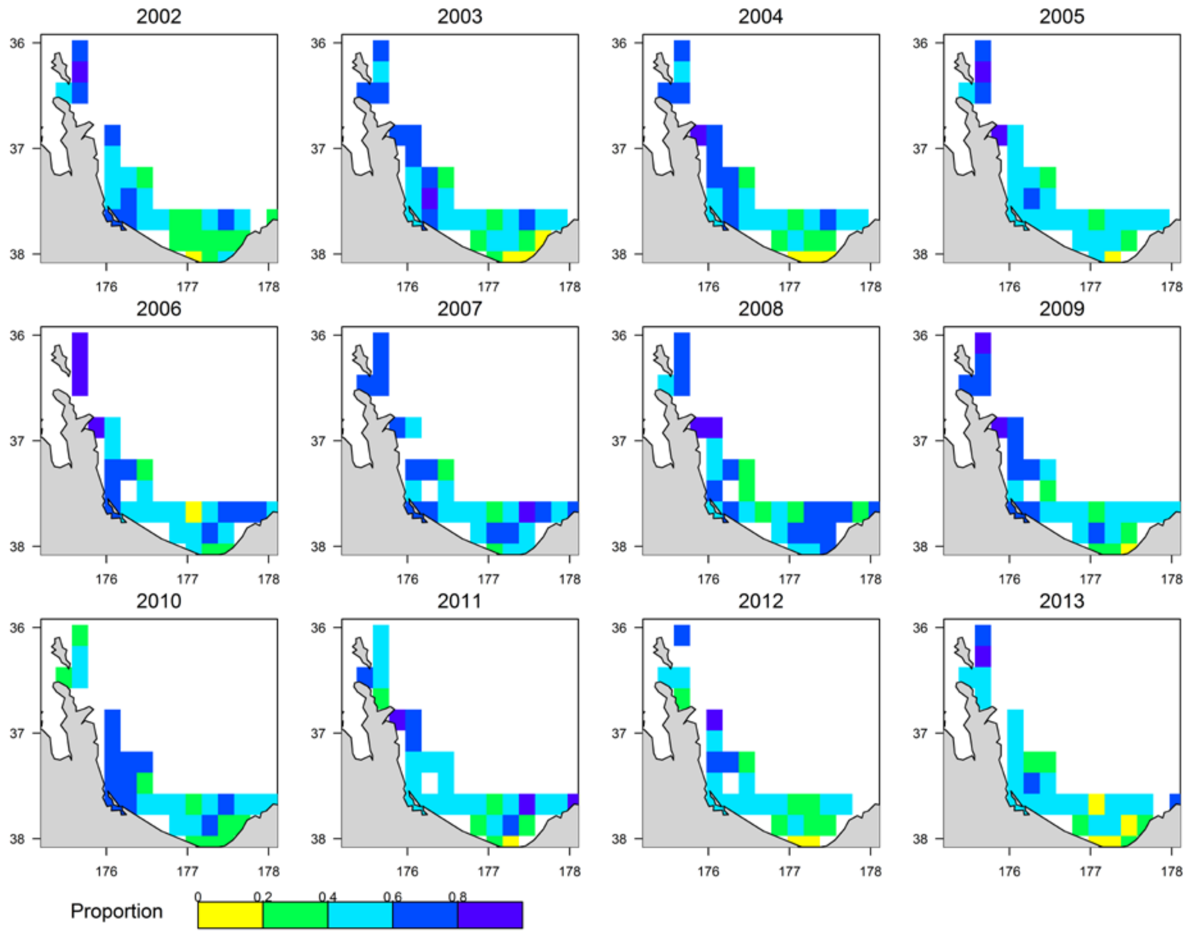



**Figure 27: Proportion of BPLE trawls reporting a catch of John dory by fishing year and location (core vessel CPUE data set). Data are aggregated by 0.2 latitude/longitude cell. The fishing year is denoted by the calendar year at the start of the fishing year (e.g. 2002 represents the 2002/03 fishing year).**

The lognormal (positive catch) CPUE model included the predictor variables *FishingYear*, *Vessel*, *Loc2*, natural logarithm of *Duration*, *TargetSpecies*, *Month*, *Depth* and *StartTime* (Table 4). Overall, the model explained 27.8% of the variation in the positive catch of John dory (Nagelkerke pseudo-$R^2$), while the *FishingYear* variable accounted for a small proportion of the variation (2.1%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality, with the exception of a relatively small number of observations with a small JDO catch which are not well estimated by the model (Figure 28).

**Table 4: Summary of stepwise selection of variables in the BPLE trawl positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -113 558 | 227 157 | 2.1 * |
| *Vessel* | 29 | -111 987 | 224 075 | 13.8 * |
| *Loc2* | 32 | -111 196 | 222 557 | 19.2 * |
| *Duration* | 3 | -110 751 | 221 672 | 22.1 * |
| *TargetSpecies* | 5 | -110 356 | 220 892 | 24.5 * |
| *Month* | 11 | -110 033 | 220 268 | 26.5 * |
| *Depth* | 3 | -109 904 | 220 016 | 27.2 * |
| *StartTime* | 3 | -109 801 | 219 816 | 27.8 * |
| *GearWidth* | 3 | -109 739 | 219 699 | 28.2 |
| *Speed* | 3 | -109 729 | 219 684 | 28.3 |
| *GearHeight* | 3 | -109 721 | 219 673 | 28.3 |
| *StatArea* | 2 | -109 711 | 219 663 | 28.4 |

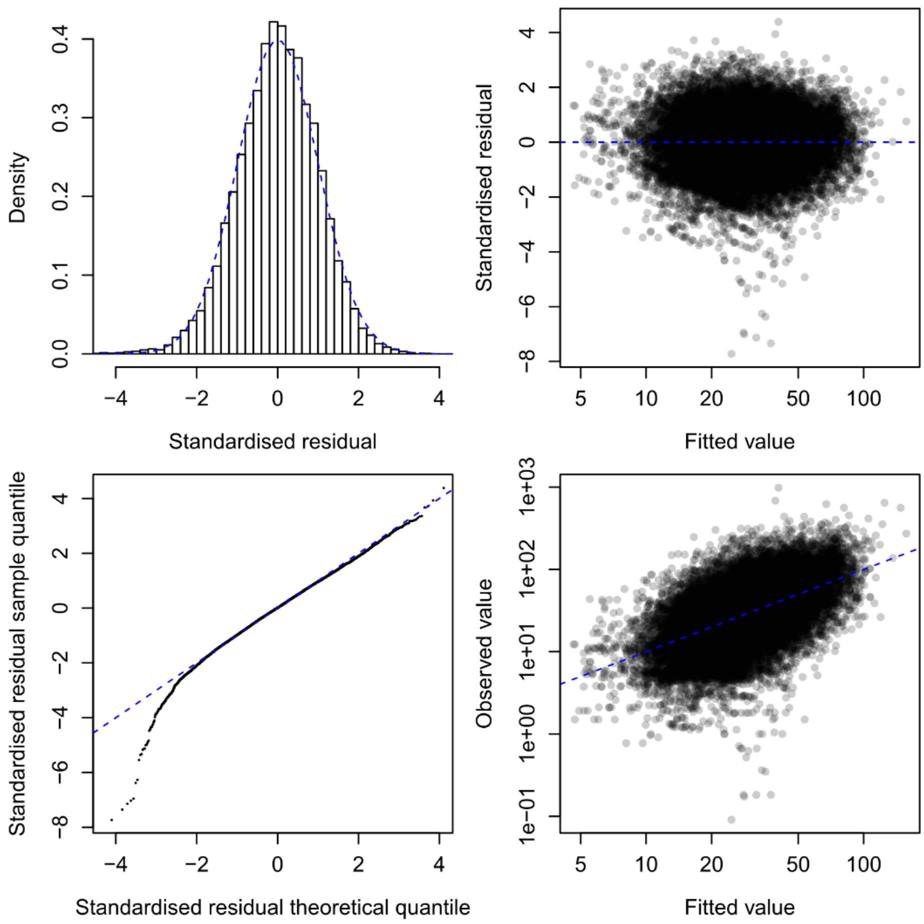



**Figure 28: Residual diagnostics for the lognormal CPUE model for the BPLE trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.**

The annual indices derived from the lognormal CPUE model decline considerably during 1994/95–2001/02 and continued to decline at a lower rate for the remainder of the period (Figure 29). The initial decline in the CPUE indices was also evident in the unstandardized annual catch rate. The *Vessel* variable was the most influential variable included in the CPUE model, resulting in a reduction in the CPUE indices from 2005/06 relative to the unstandardized catch rates (Figure 30).

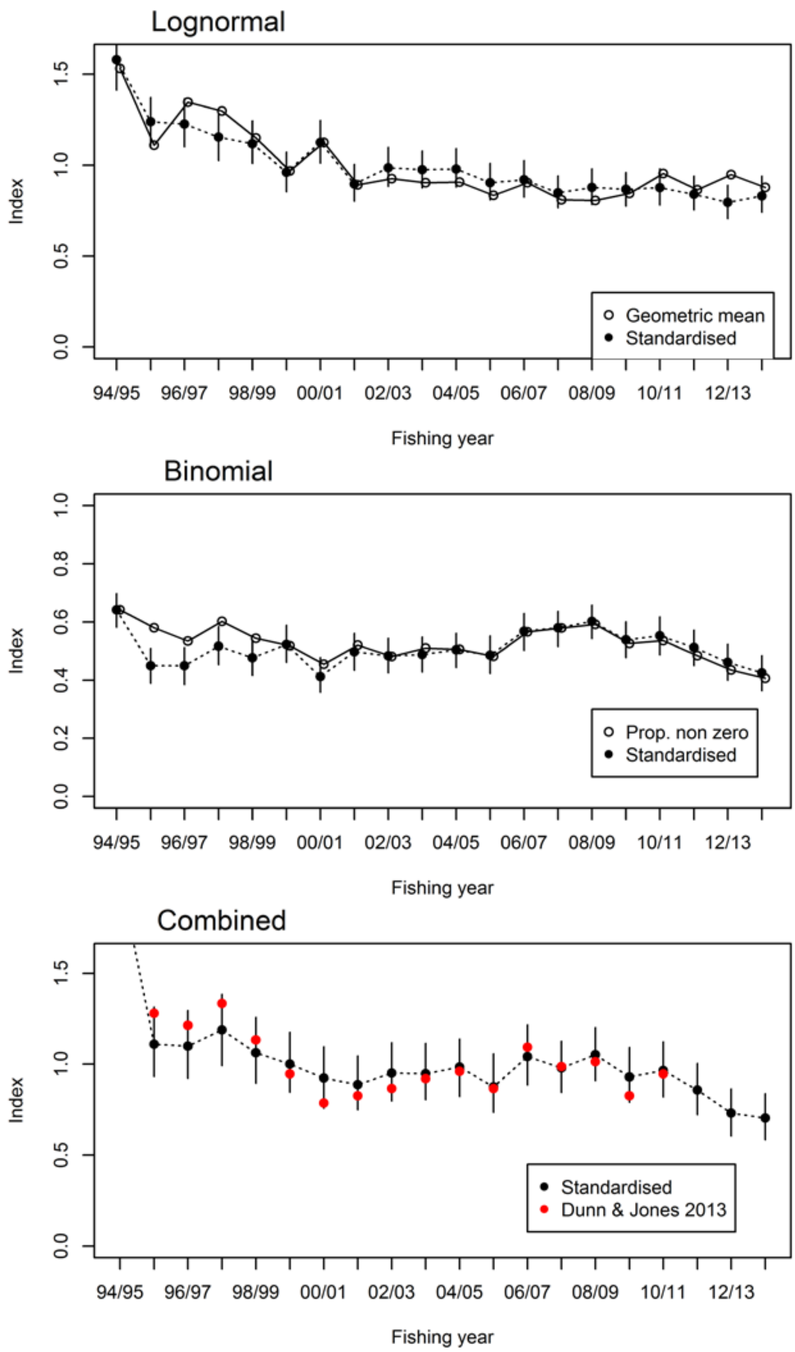



**Figure 29: A comparison of the BPLE trawl standardised CPUE indices and the geometric mean of the annual catch per day (unstandardised) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A9 (Appendix 3).**

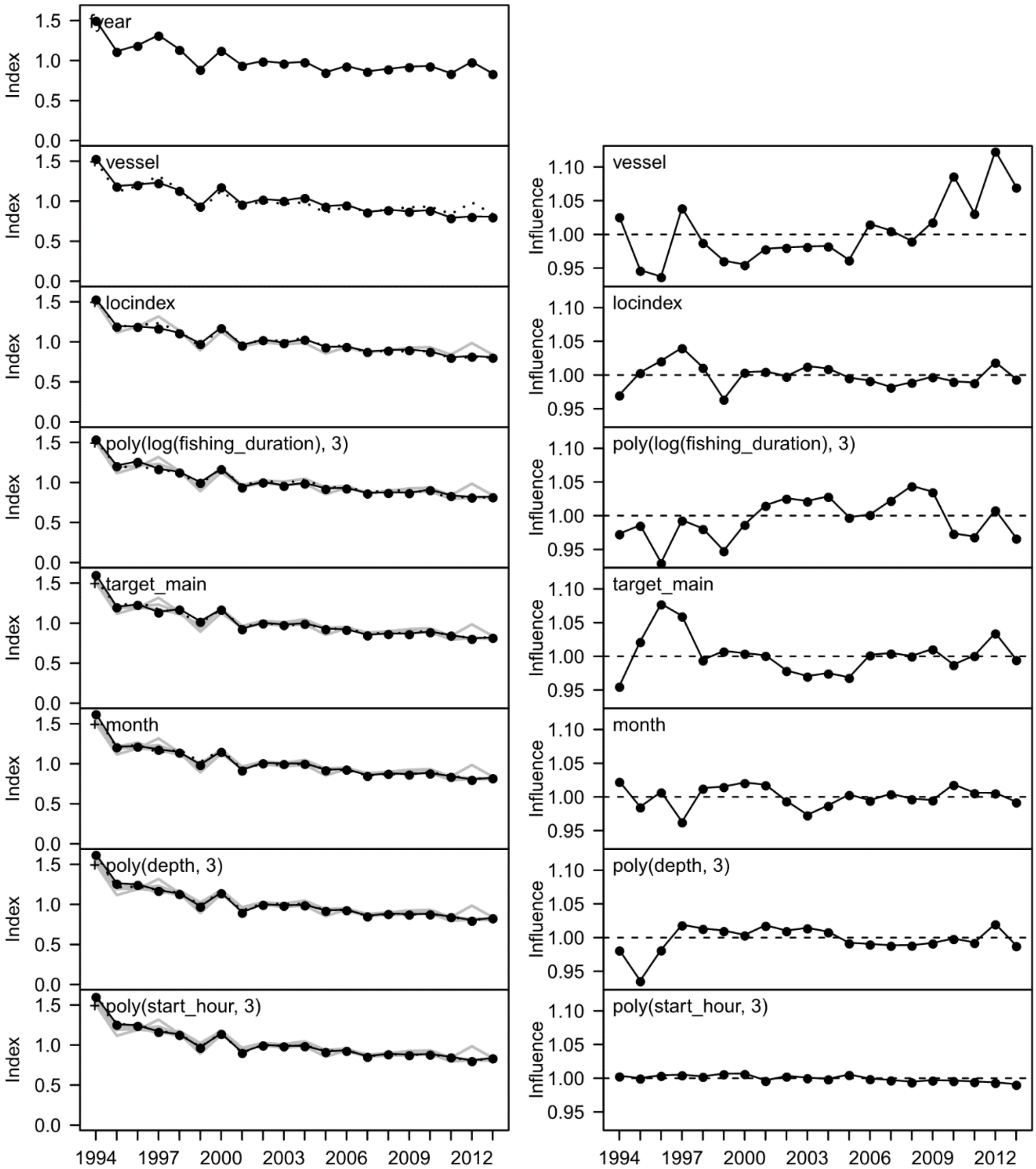



**Figure 30: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the lognormal CPUE model for the BPLE trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1994 denotes the 1994/95 fishing year).**

The occurrence of John dory in the BPLE trawl catch was predicted by the binomial model including the explanatory variables *FishingYear, Vessel, TargetSpecies, Loc2*, *Depth* and *Duration* (Table 5).

The resulting annual indices derived from the binomial model were generally comparable to the annual proportion of positive catch records. The indices were relatively stable during 1995/96–2005/06, increased in 2006/07 and then declined from 2008/09 to 2013/14 (Figure 29). The recent decline in the binomial CPUE indices was primarily driven by a decline in the occurrence of John dory catches from trawls targeting snapper and trevally.

The combined BPLE trawl CPUE indices declined considerably during 1994/95–2000/01, remained relatively stable throughout 1994/95–2008/09 and then declined by about one third from 2008/09 to 2013/14 (Figure 29, Appendix 3 Table A9). The combined CPUE indices were comparable to the corresponding CPUE indices derived by Dunn & Jones (2013) for the overlapping period (Figure 29).

**Table 5: Summary of stepwise selection of variables in the BPLE John dory catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -32 852 | 65 743 | 1.36 * |
| *Vessel* | 29 | -31 213 | 62 524 | 10.11 * |
| *TargetSpecies* | 5 | -30 082 | 60 272 | 15.81 * |
| *Loc2* | 32 | -29 068 | 58 308 | 20.7 * |
| *Depth* | 3 | -28 877 | 57 931 | 21.59 * |
| *Duration* | 3 | -28 714 | 57 611 | 22.36 * |
| *StartTime* | 3 | -28 613 | 57 416 | 22.82 |
| *Month* | 11 | -28 529 | 57 271 | 23.21 |
| *Speed* | 3 | -28 486 | 57 190 | 23.41 |
| *GearWidth* | 3 | -28 456 | 57 137 | 23.54 |
| *GearHeight* | 3 | -28 439 | 57 108 | 23.62 |
| *StatArea* | 3 | -28 430 | 57 096 | 23.66 |

### 4.2.2 Danish seine CPUE

The Danish seine fishery accounts for a relatively small proportion of the John dory catch from the Bay of Plenty, although the relative importance of the fishery has increased from 2006/07 (Figure 31). The fishery has been comprised of a consistent fleet of vessels with most of the participants attaining the criteria for inclusion within the core vessel set (Appendix 2 Table A8).

The level of John dory catch and fishing effort from the Danish seine fishery was low relative to the Bay of Plenty trawl fishery. However, it was considered that a supplementary set of CPUE indices derived from the Danish seine fishery may provide some corroboration of the recent declining trend in the CPUE indices from the trawl fishery.

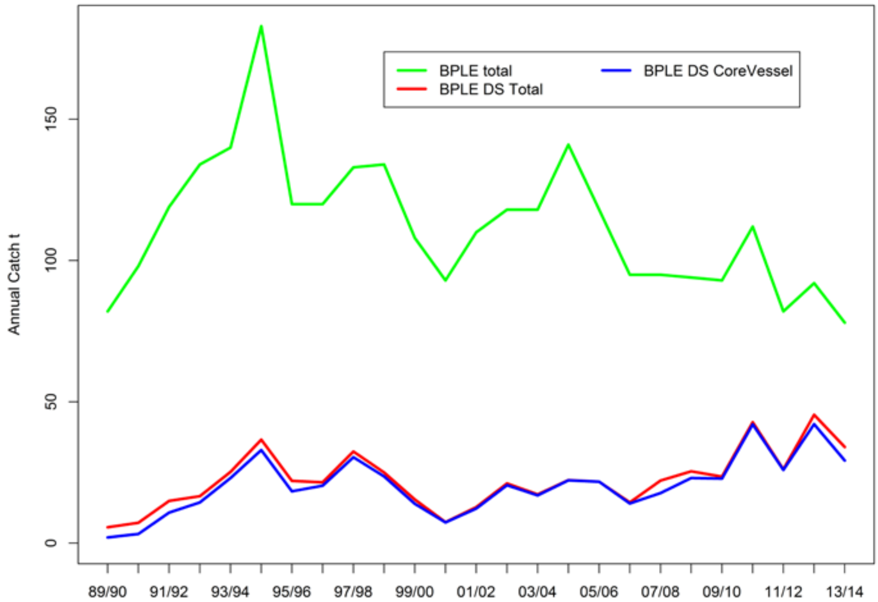



**Figure 31: Annual catch of John dory from the Bay of Plenty Danish seine fishery relative to the total John dory catch from the area.**

The Danish seine CPUE indices were derived from daily aggregated catch and effort data, excluding days that did not record a catch of John dory. Nil catch records were predominantly associated with snapper target fishing effort and represented a variable proportion of the annual effort records (Appendix 2, Table A8). The exclusion of these records from the CPUE analysis has the potential to introduce a source of bias in the annual CPUE indices derived from the fishery.

The final CPUE model included all the available explanatory variables with the number of sets (*EffortNum*) accounting for most of the explained variability in John dory catch (Table 6).

**Table 6: Summary of the variables included in the BPLE Danish seine John dory lognormal CPUE model. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model. Fishing year was forced as the first variable.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 25 | -44 476 | 89 004 | 6.9 * |
| *EffortNum* | 3 | -43 674 | 87 406 | 21.9 * |
| *Vessel* | 19 | -43 211 | 86 518 | 29.5 * |
| *Month* | 11 | -42 989 | 86 096 | 32.9 * |
| *TargetSpecies* | 2 | -42 896 | 85 914 | 34.2 * |
| *StatArea* | 2 | -42 847 | 85 821 | 34.9 * |

The resulting standardised CPUE indices differ considerably from the annual trend in unstandardized catch rates, which tended to increase during 2000/01–2013/14 (Figure 32). The standardised indices deviated from 2005/06 with the CPUE model attributing the recent increase in John dory catch rate to the increased dominance of the fishery by the more efficient vessels in the fleet (Figure 33).

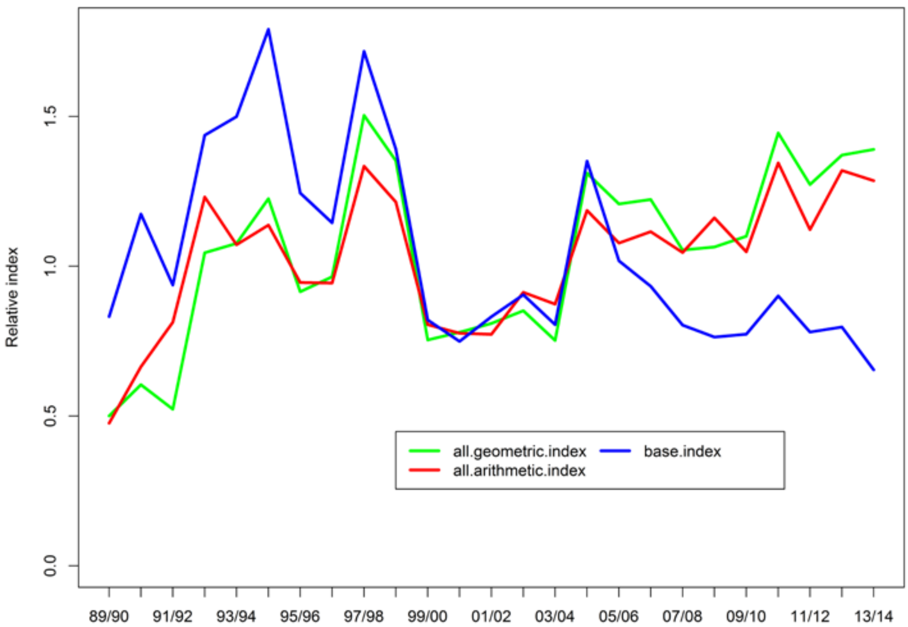



**Figure 32: A comparison of the BPLE Danish seine CPUE indices (base.index) and the unstandardized average (arithmetic and geometric mean) catch rate of John dory. Each series is normalised to the average of the series.**

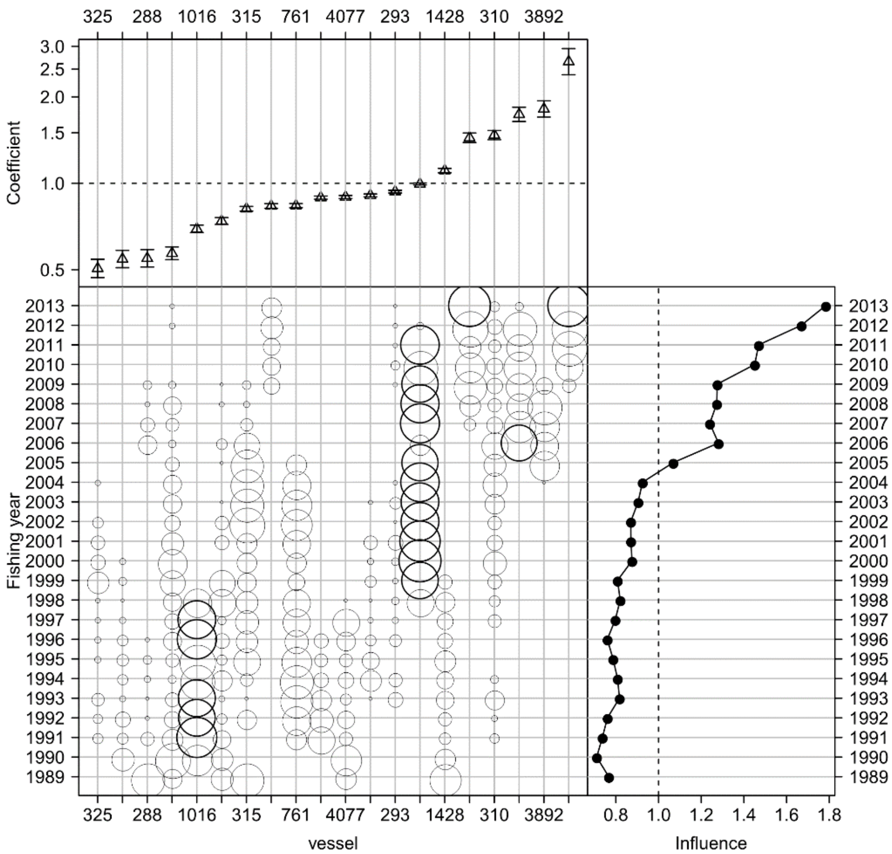



**Figure 33: Influence plot (Bentley et al 2011) of the *Vessel* variable for the BPLE Danish seine CPUE model.**

The Danish seine CPUE indices fluctuated about a relatively high level during the 1990s. From 1999/2000, the CPUE indices were generally lower than the preceding period, with the exception of higher indices for 2004/05 (Figure 34).

The Danish seine CPUE indices are not entirely consistent with the combined BPLE trawl CPUE indices, although both sets of indices do indicate that John dory catch rates since 1999/2000 were lower than the preceding period (Figure 34). The two sets of indices also suggest that catch rates declined further during 2010/11–2013/14. Of the two sets of indices, the trawl indices are considered to be more indicative of trends in stock abundance due to the broader spatial extent of the trawl fishery, the higher overall level of fishing effort (and catch) included within the trawl data set and the limited targeting of John dory by the trawl fleet. The Danish seine indices are strongly dependent on the estimated influence of the recent changes in the composition of the fleet and, consequently, the recent CPUE indices may be less well determined than the trawl based CPUE indices.

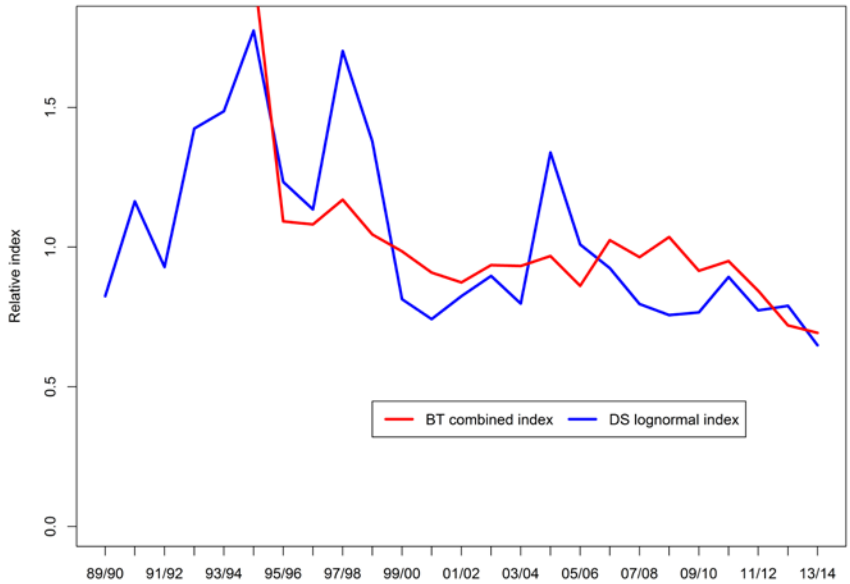



**Figure 34: A comparison of the combined CPUE indices from the BPLE trawl fishery and the CPUE indices from the BPLE Danish seine fishery.**

## 4.3 Hauraki Gulf – east Northland

### 4.3.1 Single trawl CPUE

The HG-ENLD trawl CPUE analysis was based on the trawl event catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 001–007 (Table 2). Catch and effort records were included regardless of whether or not there was an associated reported catch of John dory. The initial data set accounted for about 70–90% of the John dory catch from the HG-ENLD trawl fishery JDO 1 from 1995/96 to 2002/03 (Figure 35). During 2004/05–2006/07, a high proportion of the John dory trawl catch was associated with CELR data and, consequently, a lower proportion of the data was available for inclusion within the trawl event based data set. From 2007/08, almost all of the John dory trawl catch has been reported in event based format (i.e. TCEPR or TCER format) (Figure 35).

The core fleet accounted for 90% of the total John dory catch included in the trawl event based data set (from 1994/95 to 2013/14) (Figure 35). The criteria resulted in the selection of 31 unique vessels including two vessels that operated in the fishery for at least 15 of the 20 years (Figure 36). Approximately half of the John dory catch included in the core vessel data set was taken by six vessels.

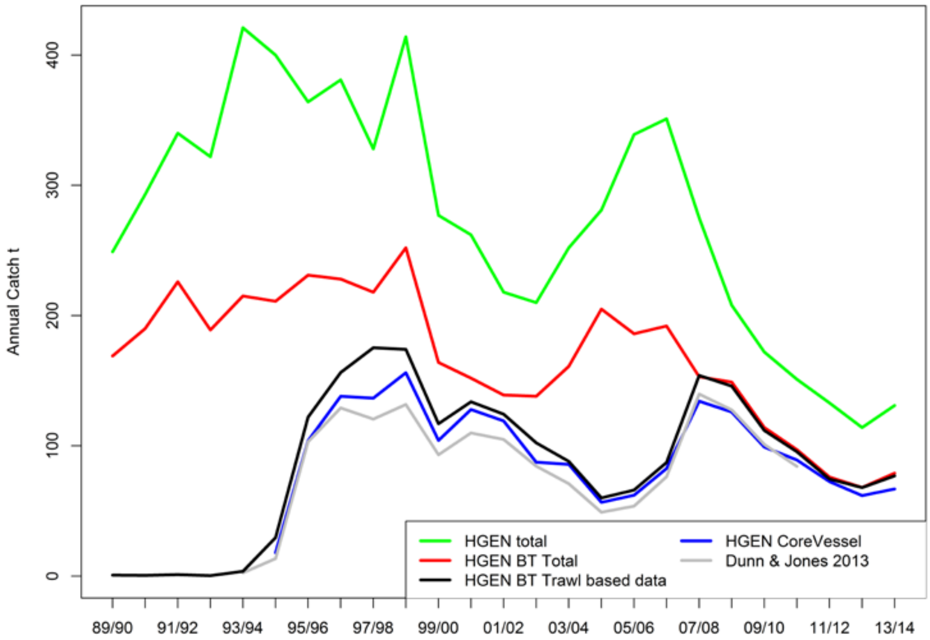



**Figure 35: A comparison of the total Hauraki Gulf and east Northland (HG-ENLD) annual JDO 1 catch and various subsets of the catch and effort data set, including the final trawl CPUE data set for the core fleet (HG-ENLD CoreVessel). For comparison, the annual catch included in the CPUE analysis of Dunn & Jones (2013) is also presented.**

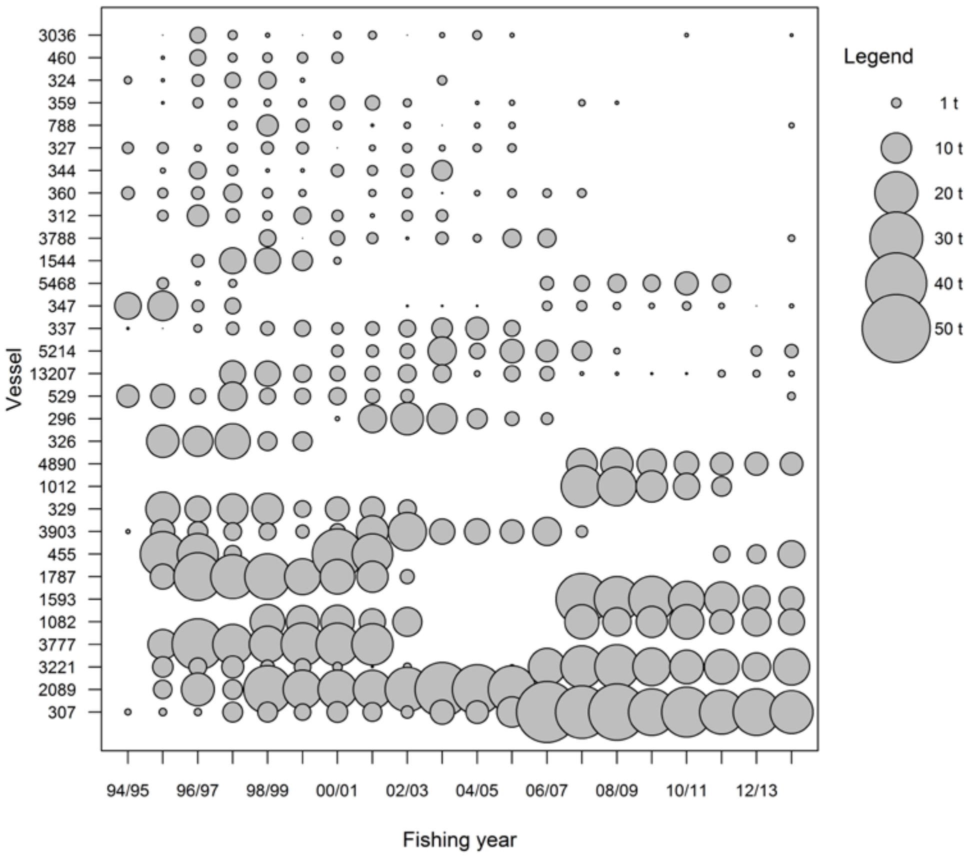



**Figure 36: Distribution of John dory HG-ENLD trawl catch by year and fishing vessel for the core fleet included in the final trawl based CPUE data set.**

The annual distribution of John dory catch and trawl effort by target species, month and statistical area is generally consistent with the trends described in the characterisation of the HG-ENLD trawl fishery (Section 3.2). Most of the trawl records were associated with targeting snapper or John dory, although there was considerable variability in the annual distribution of fishing effort amongst the two target species (Figure 37). Snapper target trawls dominated the data set during the late 1990s, while John dory trawls accounted for a higher proportion of fishing effort during 2000/01–2002/03 and 2007/08–2009/10.

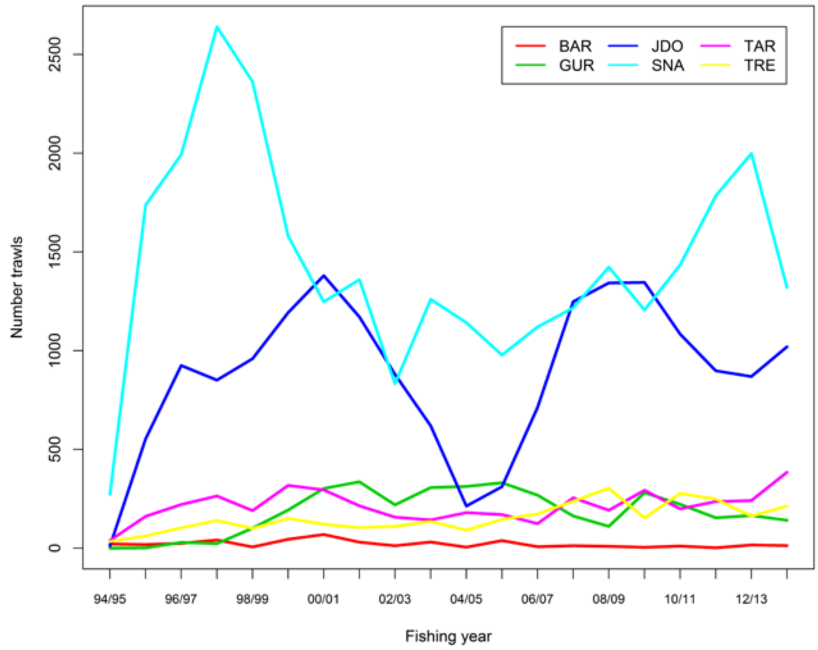



**Figure 37: Annual distribution of trawl effort records by target species for the HG-ENLD core vessel CPUE data set.**

There was considerable variability in trawl duration amongst years (Figure 38), primarily due to the proportion of tarakihi trawls in the data set. These trawls were considerably longer in duration than the trawls targeting the range of other species.

Fishing effort was concentrated in the outer Hauraki Gulf extending north to Bream Head around the 50 m depth contour (Figure 38). Limited fishing effort also occurred in the northern area of HG-ENLD (i.e. Great Exhibition Bay).

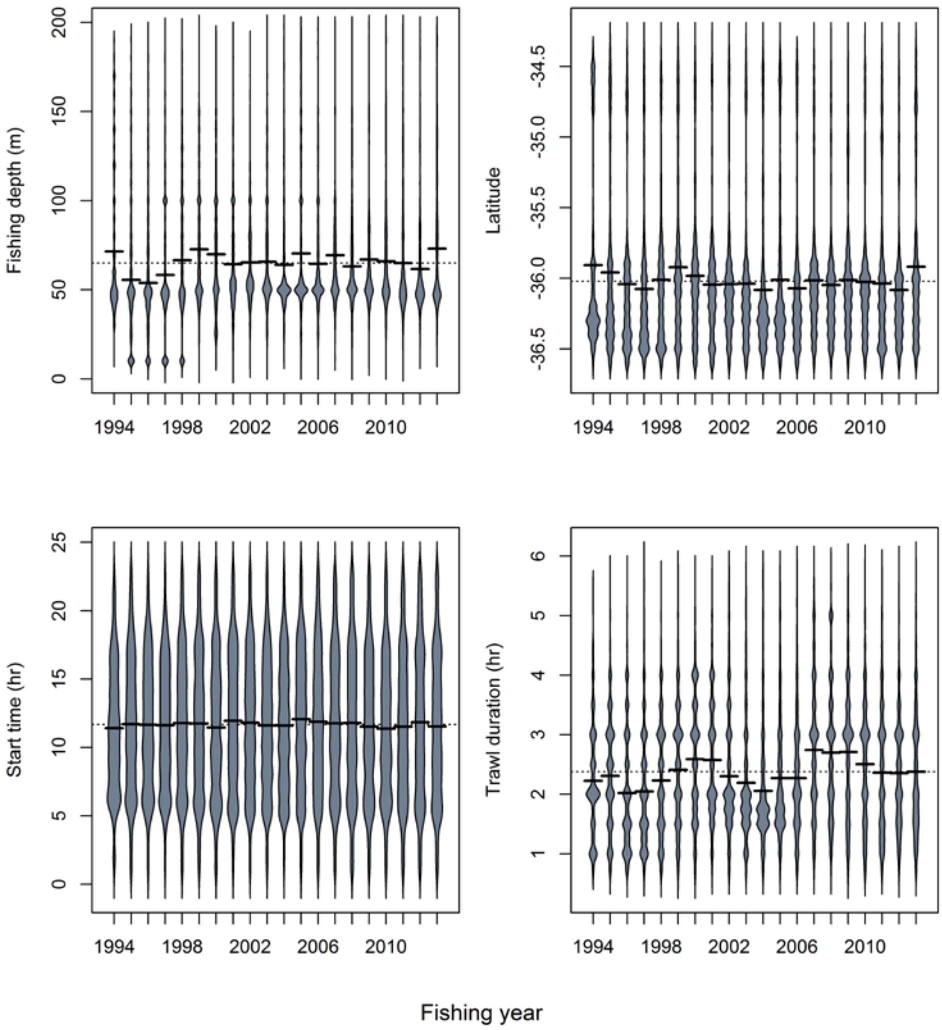



**Figure 38: Beanplots of a range of descriptive variables characterising the fishing effort data included in the HG-ENLD trawl CPUE data set (core vessels). The "beans" represent the distribution of the annual data and the solid horizontal line represents the median value. The fishing year is denoted by the calendar year at the start of the fishing year (e.g. 1994 represents the 1994/95 fishing year).**

The lognormal (positive catch) CPUE model included the predictor variables *FishingYear*, *Loc2, Vessel, Month,* natural logarithm of *Duration, TargetSpecies* and *StartTime* (Table 7). Overall, the model explained 41.4% of the variation in the positive catch of John dory (Nagelkerke pseudo-$R^2$), while the *FishingYear* variable accounted for a small proportion of the variation (3.8%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality, with the exception of a relatively small number of observations with a small JDO catch which are not well estimated by the model (Figure 39).

**Table 7: Summary of stepwise selection of variables in the HG-ENLD trawl positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -189 461 | 378 963 | 3.8 * |
| *Loc2* | 50 | -185 380 | 370 901 | 21.6 * |
| *Vessel* | 30 | -183 589 | 367 379 | 28.3 * |
| *Month* | 11 | -182 141 | 364 503 | 33.3 * |
| *Duration* | 3 | -180 592 | 361 412 | 38.3 * |
| *TargetSpecies* | 5 | -179 802 | 359 843 | 40.7 * |
| *StartTime* | 3 | -179 546 | 359 335 | 41.4 * |
| *Depth* | 3 | -179 443 | 359 137 | 41.7 |
| *StatArea* | 5 | -179 376 | 359 012 | 41.9 |
| *GearHeight* | 3 | -179 340 | 358 946 | 42.0 |
| *GearWidth* | 3 | -179 312 | 358 895 | 42.1 |
| *Speed* | 3 | -179 299 | 358 876 | 42.2 |

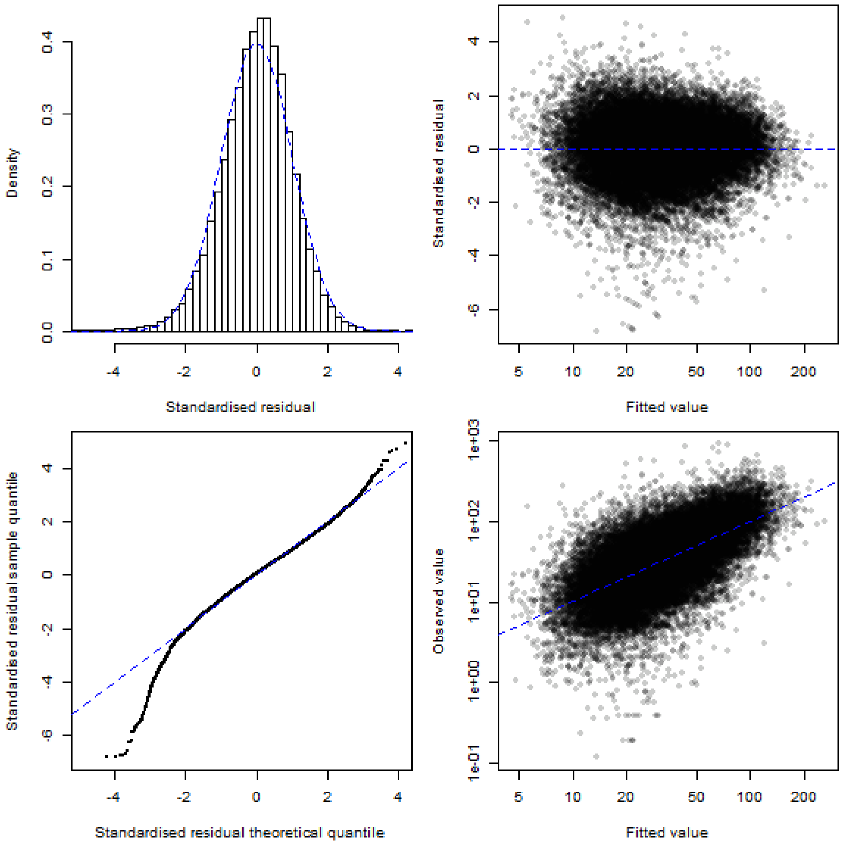



**Figure 39: Residual diagnostics for the lognormal CPUE model for the HG-ENLD trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.**

The annual indices derived from the lognormal CPUE model generally declined over the study period, from a relatively high level in 1995/96–1998/99 (Figure 40). There was a brief recovery in the CPUE indices during 2002/03–2004/05 and then the CPUE indices declined steadily from 2004/05 to 2011/12 and remained at the lower level during the two subsequent years (Figure 40).

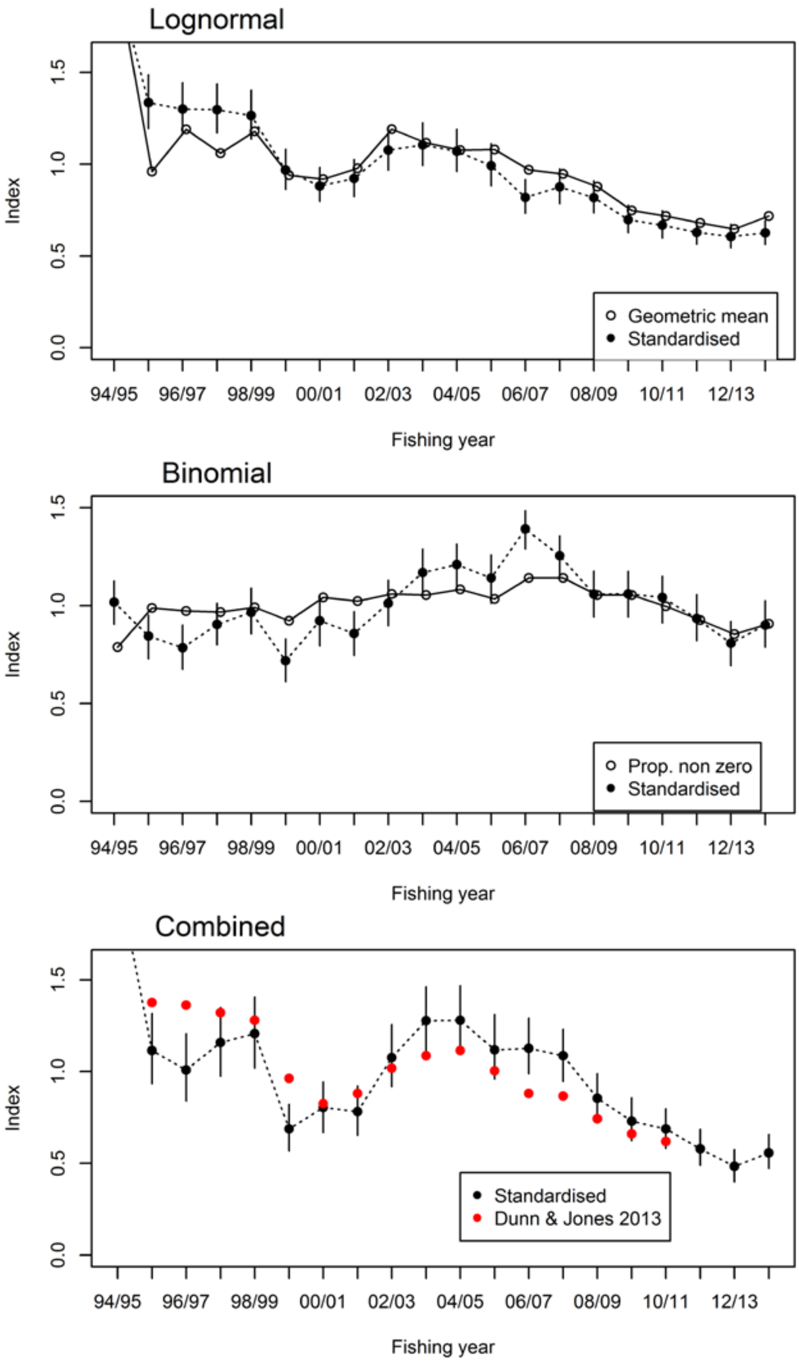



**Figure 40: A comparison of the HG-ENLD trawl standardised CPUE indices and the geometric mean of the annual catch per day (unstandardised) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A10 (Appendix 3).**

The trends in the standardised CPUE indices are comparable to the trend in the unstandardized catch rates of John dory (Figure 40). The main deviation between the two sets of indices is attributable to a change in the composition of the fleet during 1995/96–1998/99 (Figure 41). A number of the main vessels operating in the fishery at that time tended to have lower overall catch rates of John dory.

Standardised and unstandardised CPUE indices for 1994/95 were exceptionally high (Figure 40). The constituent data set included a small number of vessels and a relatively low proportion of the John dory catch and fishing effort compared to the following years. There were also a higher proportion of zero John dory catch records reported from 1994/95 (Appendix 2 Table A5). Consequently, the indices from 1994/95 are considered to be less reliable than for the other years.

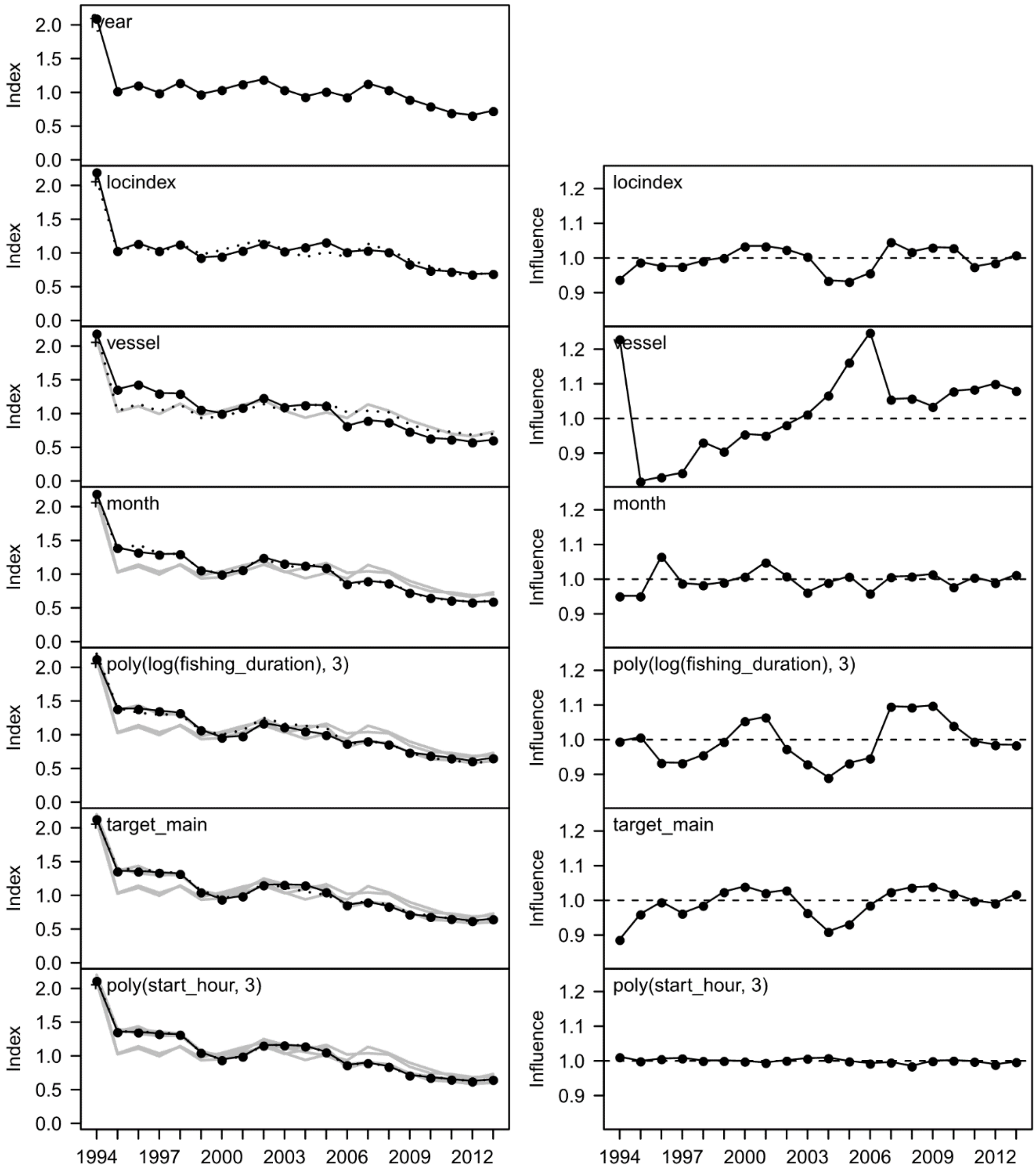



**Figure 41: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the lognormal CPUE model for the HG-ENLD trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1994 denotes the 1994/95 fishing year).**

The HG-ENLD CPUE data set included a considerable proportion (30–40%) of trawl records with no John dory catch, particularly in 2011/2012–2013/14 (Appendix 2 Table A5). The occurrence of John dory in the trawl catch was predicted by the binomial model including the explanatory variables *FishingYear, TargetSpecies, Vessel, Loc2, Month* and *Duration* (Table 8).

The annual indices derived from the binomial model increased from 2001/02 to 2006/07 to account for a shift towards target species and fishing vessels with a lower expectation of catching John dory (Figure 40). The probability of catching John dory is predicted to have declined during 2007/08–2013/14.

The higher binomial indices in 2006/07–2007/08 and lower indices in 1995/96–1998/99 tend to contradict the lognormal indices from the corresponding periods (Figure 40) although the trends in the two sets of indices are comparable during the remainder of the years.

The combined HG-ENLD trawl CPUE indices fluctuated during 1995/96–2004/05 and then steadily declined to a relatively low level in 2011/12–2013/14 (Figure 40, Appendix 3 Table A10). The combined CPUE indices were comparable to the corresponding CPUE indices derived by Dunn & Jones (2013) (Figure 40).

**Table 8: Summary of stepwise selection of variables in the HG-ENLD John dory catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -35 476 | 70 992 | 1.8 * |
| *TargetSpecies* | 5 | -30 653 | 61 356 | 23.1 * |
| *Vessel* | 30 | -28 888 | 57 885 | 30.1 * |
| *Loc2* | 49 | -28 187 | 56 582 | 32.7 * |
| *Month* | 11 | -27 771 | 55 771 | 34.3 * |
| *Duration* | 3 | -27 522 | 55 279 | 35.2 * |
| *StartTime* | 3 | -27 409 | 55 060 | 35.6 |
| *Depth* | 3 | -27 335 | 54 919 | 35.9 |
| *GearWidth* | 3 | -27 306 | 54 865 | 36.0 |
| *GearHeight* | 3 | -27 281 | 54 822 | 36.1 |
| *StatArea* | 4 | -27 275 | 54 818 | 36.1 |

### 4.3.2 Danish seine CPUE

The Danish seine fishery accounted for about 25–35% of the annual John dory catch from the Hauraki Gulf and east Northland area (Figure 42). The fishery has been comprised of a consistent fleet of vessels with most of the participants attaining the criteria for inclusion within the core vessel set (Appendix 2 Table A7).

The level of John dory catch and fishing effort from the Danish seine fishery was lower than the HG-ENLD trawl fishery. However, it was considered that a supplementary set of CPUE indices derived from the Danish seine fishery might provide some corroboration of the recent declining trend in the CPUE indices from the trawl fishery.

The Danish seine CPUE indices were derived from daily aggregated catch and effort data, excluding days that did not record a catch of John dory. Nil catch records were predominantly associated with snapper target fishing effort; the proportion of nil catch records was considerably higher during 1989/90–1995/96 than during the following years (Appendix 2 Table A7).

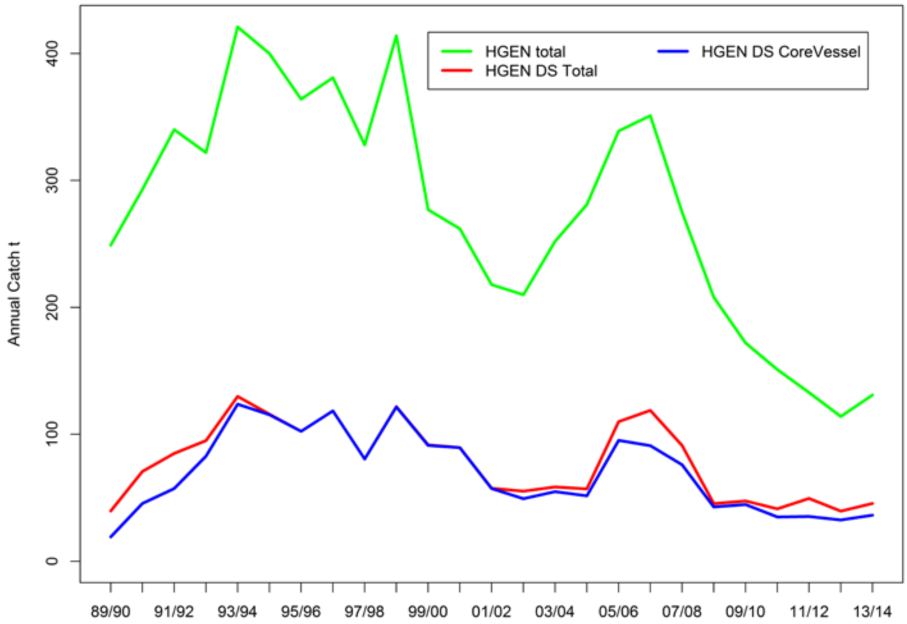



**Figure 42: Annual catch of John dory from the Hauraki Gulf and east Northland Danish seine fishery relative to the total John dory catch from the area.**

The CPUE model included all the available explanatory variables with the exception of Statistical Area (*StatArea*) (Table 9). The standardised CPUE indices derived from the model are comparable with the annual trend in unstandardized catch rates from the fishery (Figure 43). The CPUE indices fluctuated without trend during 1989/90–2000/01, increased to a reach a peak in 2006/07 and then steadily declined to 2011/12. The most recent indices (2011/12–2013/14) are at a similar level to the 1989/90–2000/01 indices (Figure 43).

**Table 9: Summary of the variables included in the HG-ENLD Danish seine John dory lognormal CPUE model. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model. Fishing year was forced as the first variable.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 25 | -101 013 | 202 078 | 4.7 * |
| *EffortNum* | 3 | -99 490 | 199 039 | 19.2 * |
| *TargetSpecies* | 2 | -98 677 | 197 415 | 26.0 * |
| *Vessel* | 24 | -98 126 | 196 363 | 30.3 * |
| *Month* | 11 | -98 002 | 196 136 | 31.2 * |
| *StatArea* | 6 | -97 941 | 196 026 | 31.7 |

Overall, the general trends in the CPUE indices from the Danish seine fishery are comparable to the HG-ENLD trawl CPUE indices (Figure 44). Both sets of indices increased during the early 2000s to reach a peak in the mid 2000s and then subsequently declined. These recent trends in the Danish seine indices tended to follow the trawl CPUE indices with a 1–2 year lag period (Figure 44). The lag period may indicate a difference in the age specific selectivity of the two fishing methods with the Danish seine fishery harvesting a higher proportion of older John dory than the trawl method.

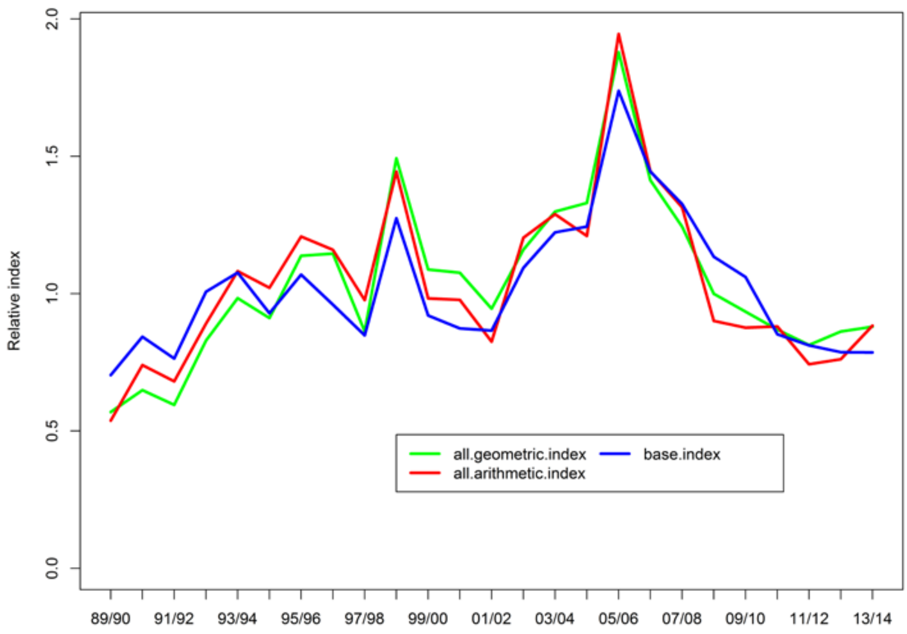



**Figure 43: A comparison of the HG-ENLD Danish seine CPUE indices (base.index) and the unstandardized average (arithmetic and geometric mean) catch rate of John dory. Each series is normalised to the average of the series.**

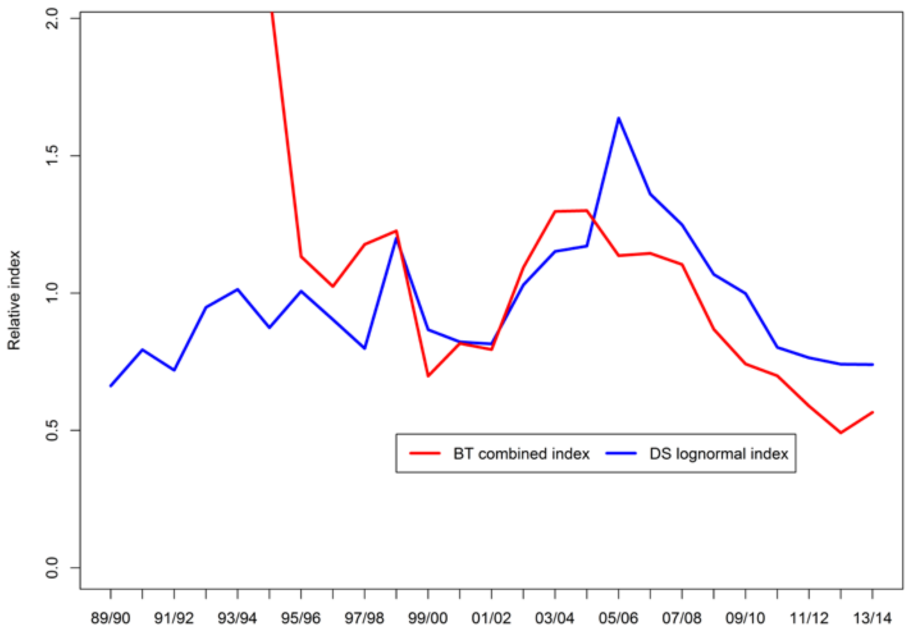



**Figure 44: A comparison of the combined CPUE indices from the HG-ENLD trawl fishery and the CPUE indices from the HG-ENLD Danish seine fishery.**

## 4.4 West coast North Island

### 4.4.1 Single trawl CPUE

The WCNI trawl CPUE analysis was based on the trawl event catch and effort data for the inshore bottom trawl fishery targeting the suite of inshore species within Statistical Areas 040–048 (Table 2). Catch and effort records were included regardless of whether or not there was an associated reported catch of John dory. The proportion of the total John dory trawl catch included within the trawl event based data set increased from about 60% in 1995/96–1997/98 to 80–90% in 2002/03–2006/07 (Figure 45). From 2007/08, almost all of the John dory trawl catch has been reported in event based format (i.e. TCEPR or TCER format).

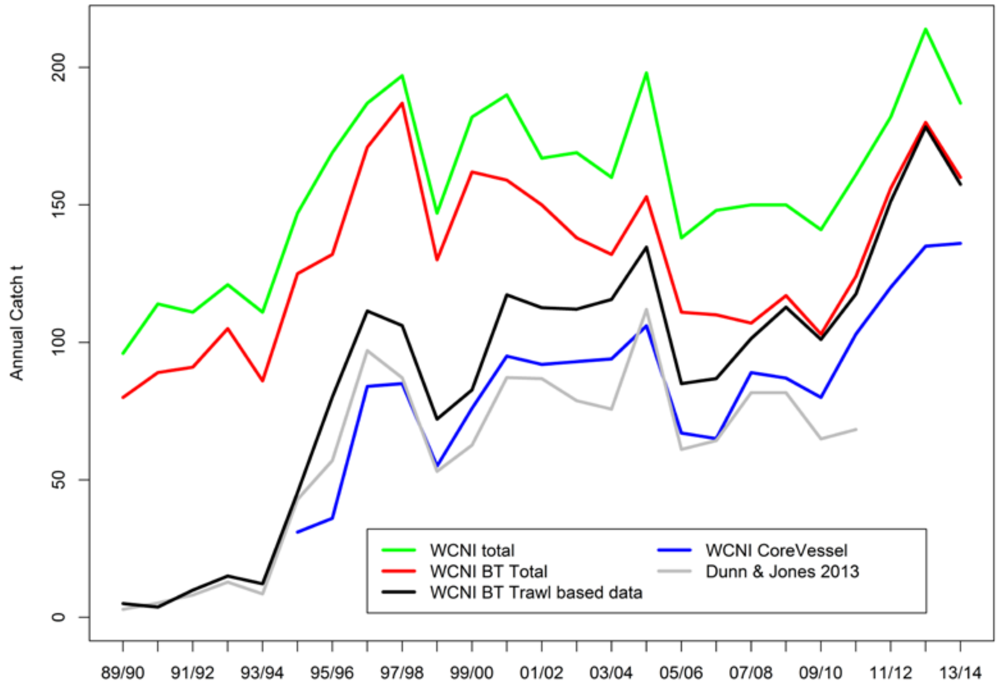



**Figure 45: A comparison of the total West coast North Island (WCNI) annual JDO 1 catch and various subsets of the catch and effort data set, including the final trawl CPUE data set for the core fleet (WCNI CoreVessel). For comparison, the annual catch included in the CPUE analysis of Dunn & Jones (2013) is also presented.**

The core fleet accounted for 79% of the total John dory catch included in the trawl event based data set (from 1994/95 to 2013/14) (Figure 45). The continuity criteria resulted in the selection of 28 unique vessels including two vessels that operated in the fishery for at least 15 of the 20 years (Figure 46). Approximately half of the John dory catch included in the data set was taken by six vessels.

In recent years, an increasing proportion of the total John dory catch was caught by a single vessel (12600); the vessel accounted for 30–35% of the catch during 2010/11–2013/14 (Figure 46).

For 1995/96–2003/04, a high proportion of the records included within the data set were from trawls targeting snapper and trevally (Figure 47). Since 2005/06, the number of trawls targeting snapper was considerably lower while the number (and proportion) of trawls targeting trevally and red gurnard increased. The number of trawls targeting tarakihi remained relatively stable over the study period (Figure 47).

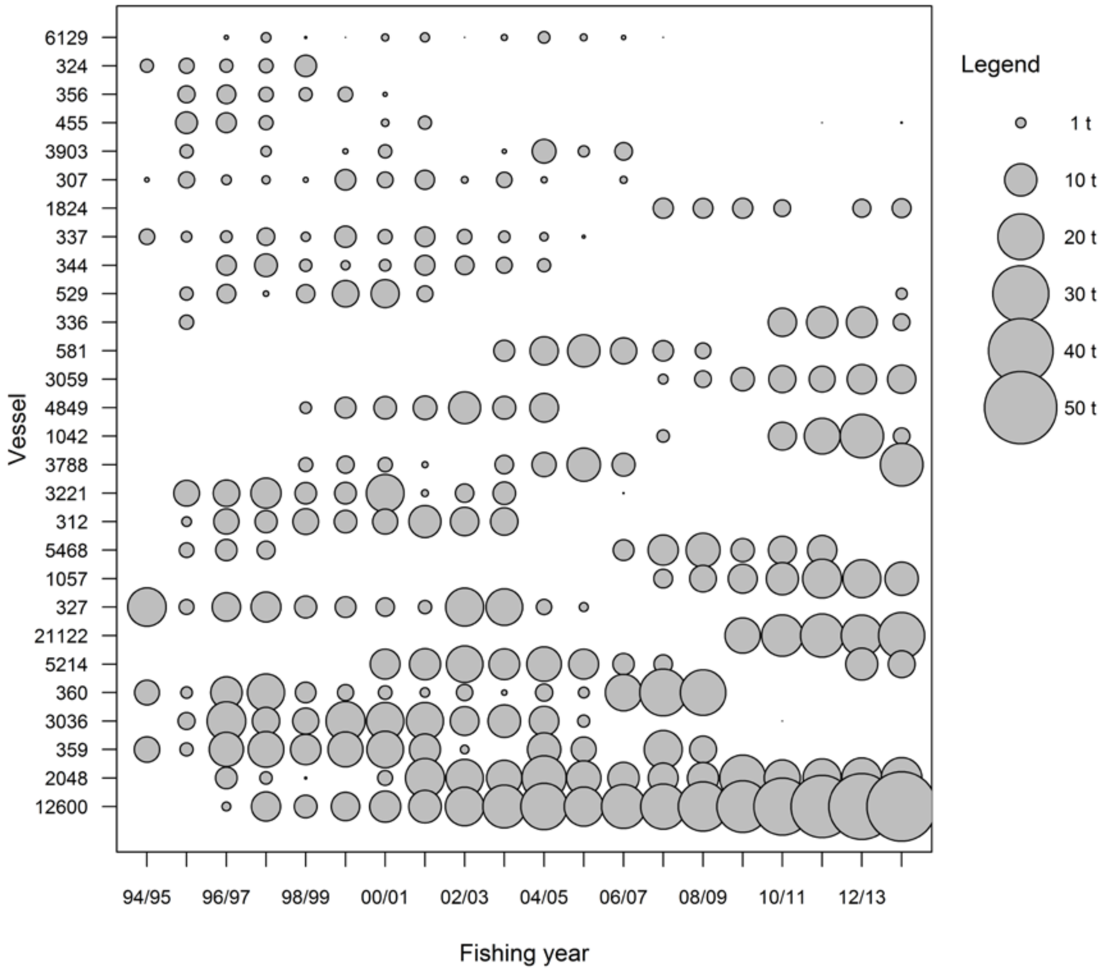



**Figure 46: Distribution of John dory WCNI trawl catch by year and fishing vessel for the core fleet included in the final trawl based CPUE data set.**

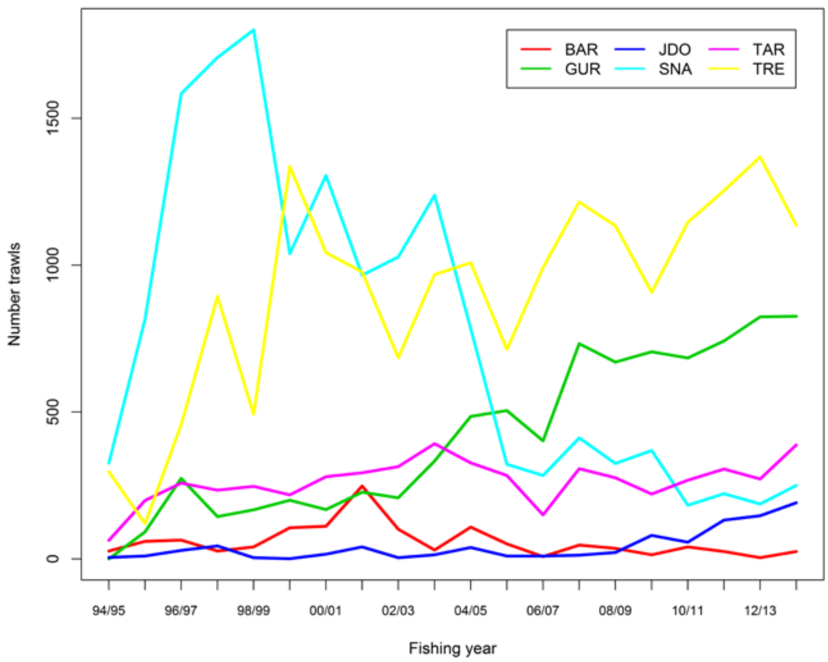



**Figure 47: Annual distribution of trawl effort records by target species for the WCNI core vessel CPUE data set.**

Within the WCSI area, fishing effort and John dory catch was concentrated in three main sub-areas: Ninety Mile Beach, North Taranaki Bight and the area adjacent to Kaipara and Manukau Harbours (Figure 20 and Figure 48). Since 1998/99, there was considerably less effort off Ninety Mile Beach, while from 2007/08 there was an increase in the proportion of effort within the Northern Taranaki Bight (Figure 48). Trawl duration was generally longer during the early–mid 2000s, primary due to a higher proportion of trawls targeting red gurnard during that period (Figure 48).

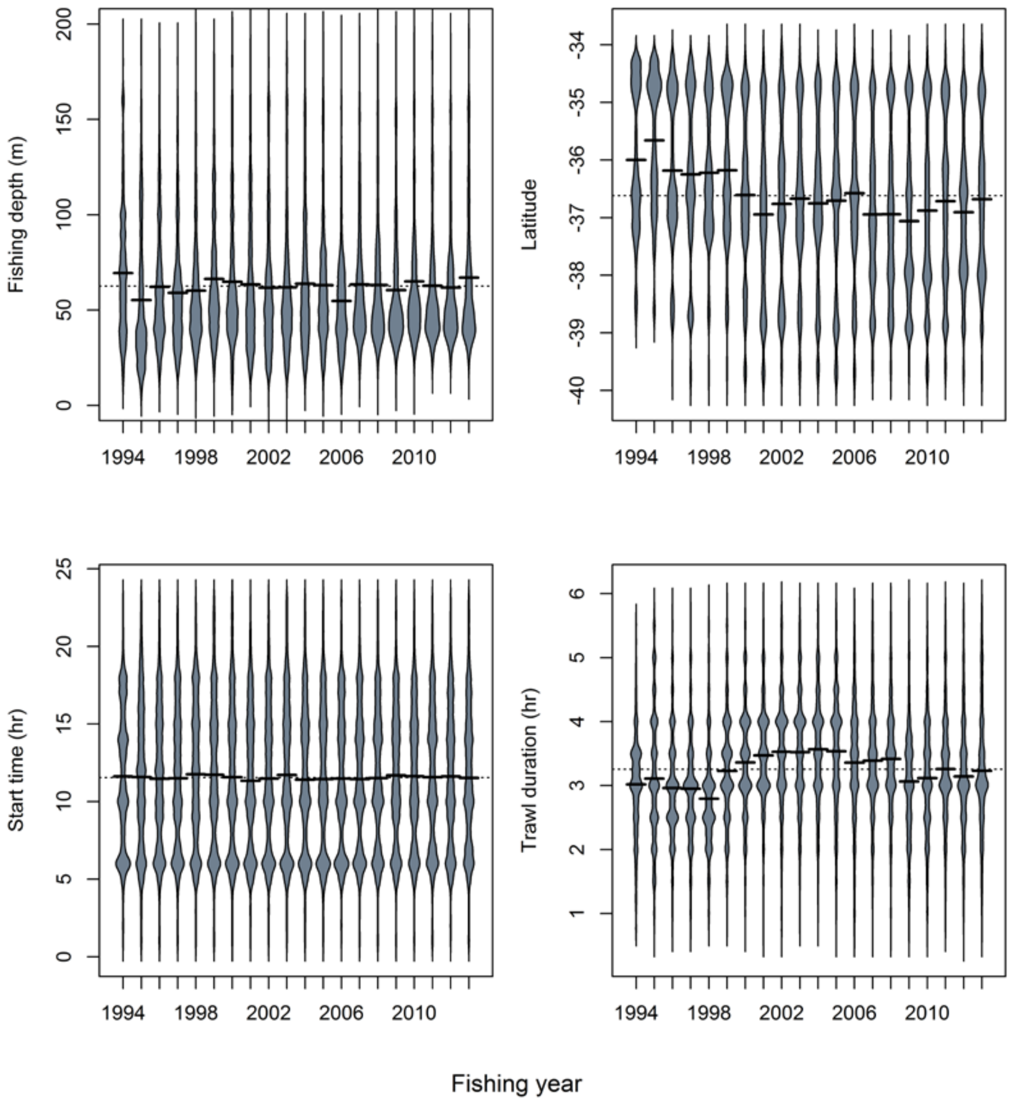



**Figure 48: Beanplots of a range of descriptive variables characterising the fishing effort data included in the WCNI trawl CPUE data set (core vessels). The "beans" represent the distribution of the yearly data and the solid horizontal line represents the median value. The fishing year is denoted by the calendar year at the start of the fishing year (e.g. 1994 represents the 1994/95 fishing year).**

The CPUE data set included a relatively high proportion of trawl records with no associated John dory catch (Appendix 2 Table A6), although the overall proportion of nil catch records declined steadily from 60–70% in 1994/95–1999/2000 to 40–45% in 2010/11–2013/14. Overall, there tended to be a lower frequency of nil catch records from the Northern Taranaki Bight area, although the occurrence of John dory catches appears to have increased in all areas in recent years (Figure 49).

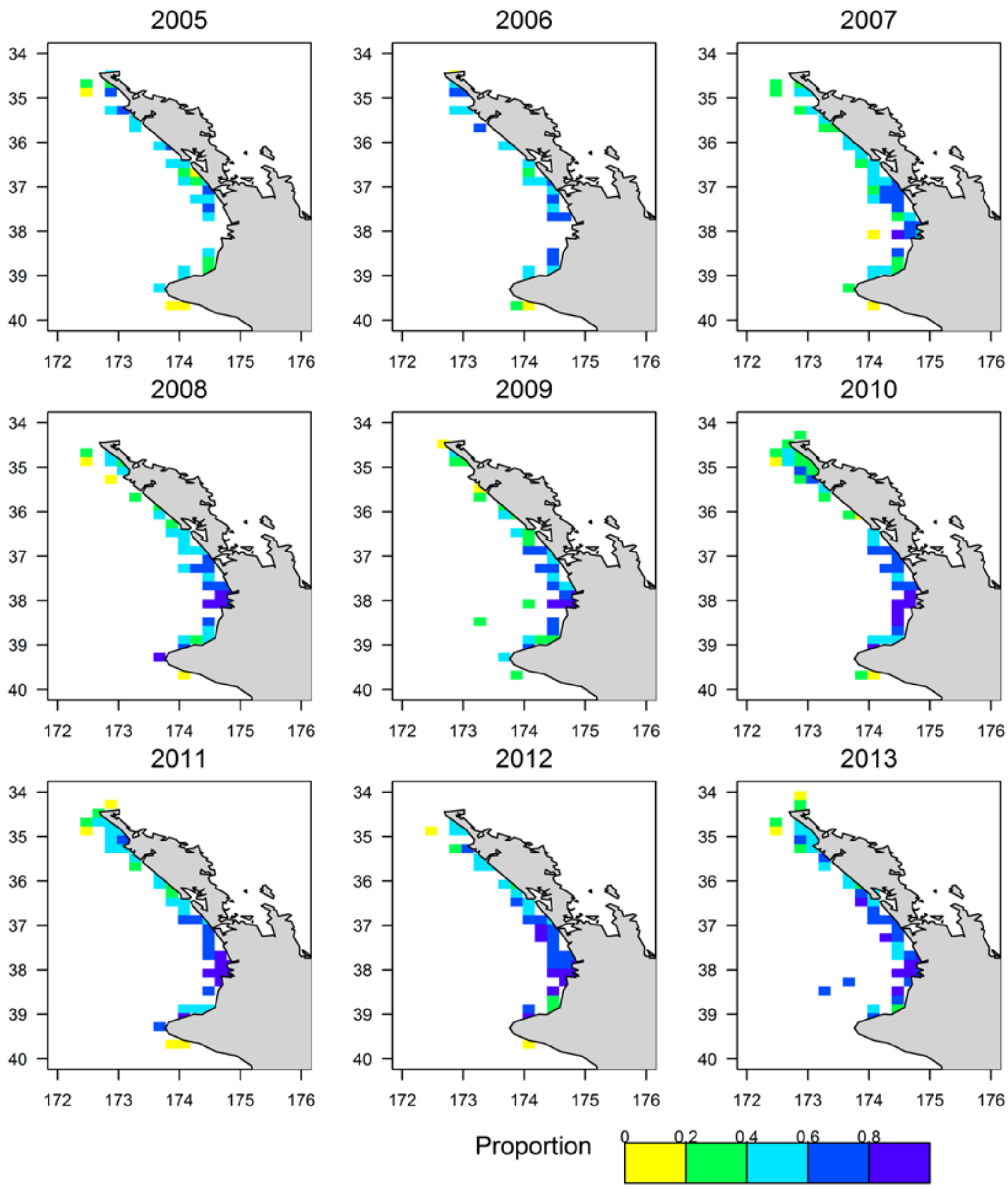



**Figure 49: Proportion of WCNI trawls reporting a catch of John dory by fishing year and location (core vessel CPUE data set). Data are aggregated by 0.2 latitude/longitude cell. The fishing year is denoted by the calendar year at the start of the fishing year (e.g. 2002 represents the 2002/03 fishing year).**

Initial CPUE modelling yielded indices for 2010/11–2013/14 that were substantially higher than the indices for the preceding period. An examination of the CPUE indices revealed that the recent indices were strongly influenced by catch and effort data from the single vessel that had accounted for a substantial proportion of the John dory catch in those years (i.e., vessel 12600). The increase in CPUE coincided with a change in the vessel's trawl net in 2009/10; the new trawl net had a larger wingspread (14 m compared to 20 m) and lower headline height. The operational manager of the vessel considered that the change in fishing gear had considerably improved the performance of the vessel. The gear parameters (*GearWidth* and *GearHeight*) were available for inclusion in the CPUE models, although these variables were not selected in the initial CPUE models. Instead, the improvement in fishing power appears to have been incorporated in the model estimates of the year coefficients for 2010/11–2013/14.

To more explicitly account for the recent increase in the fishing power of vessel 12600, the catch and effort data from the vessel were partitioned into two discrete time blocks demarcated by the start of the 2009/10 fishing year (i.e., pre 2009/10 and 2009/10 onwards). The data from each time block were treated as separate vessel factors in the subsequent CPUE modelling.

The lognormal (positive catch) CPUE model included the predictor variables *FishingYear*, *Vessel*, *Depth*, *Lat2* (0.2 degree of latitude, categoric variable), natural logarithm of *Duration* and *TargetSpecies* (Table 10). Overall, the model explained 35.0% of the variation in the positive catch of John dory (Nagelkerke pseudo-$R^2$), while the *FishingYear* variable accounted for a small proportion of the variation (1.9%). The distribution of the CPUE model residuals is generally consistent with the assumption of normality, with the exception of a relatively small number of observations with a small JDO catch which are not well estimated by the model (Figure 50).

**Table 10: Summary of stepwise selection of variables in the WCNI trawl positive catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -122 085 | 244 213 | 1.9 * |
| *Vessel* | 28 | -118 580 | 237 258 | 27.5 * |
| *Depth* | 3 | -118 166 | 236 436 | 30.1 * |
| *Lat2* | 30 | -117 794 | 235 753 | 32.3 * |
| *Duration* | 3 | -117 542 | 235 253 | 33.7 * |
| *TargetSpecies* | 5 | -117 315 | 234 810 | 35.0 * |
| *StatArea* | 6 | -117 262 | 234 716 | 35.3 |
| *Speed* | 3 | -117 221 | 234 639 | 35.5 |
| *StartTime* | 3 | -117 188 | 234 579 | 35.7 |
| *Month* | 11 | -117 154 | 234 534 | 35.9 |
| *GearWidth* | 3 | -117 135 | 234 501 | 36.0 |

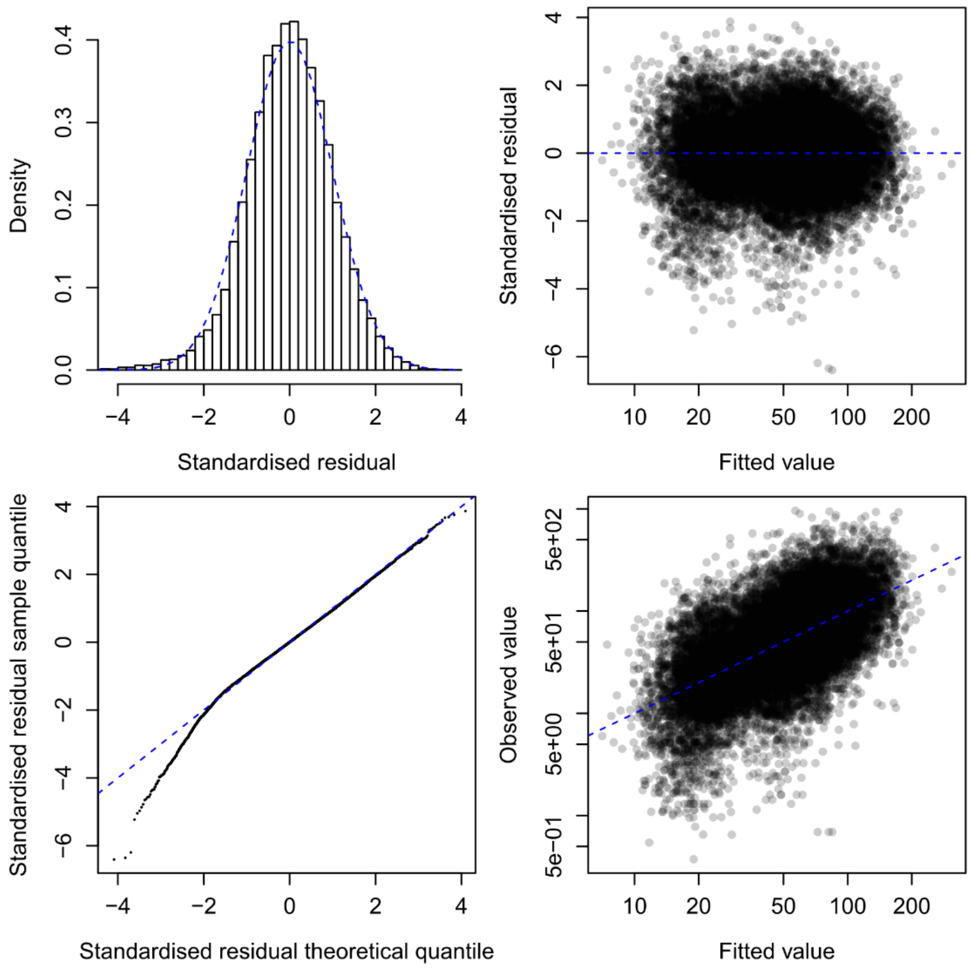



**Figure 50: Residual diagnostics for the lognormal CPUE model for the WCNI trawl fishery. Top left: histogram of standardised residuals compared to standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.**

The annual indices derived from the lognormal CPUE model declined considerably during 1994/95–2008/09, partially recovered in 2010/11 and remained relatively stable during the subsequent years (2011/12–2013/14) (Figure 51). The annual trends in the unstandardized average annual catch rates were similar to the standardised CPUE indices. Deviations between the two sets of indices were primarily attributable to changes in the composition of the fishing fleet accounted for by the inclusion of the *Vessel* variable in the CPUE model (Figure 52).

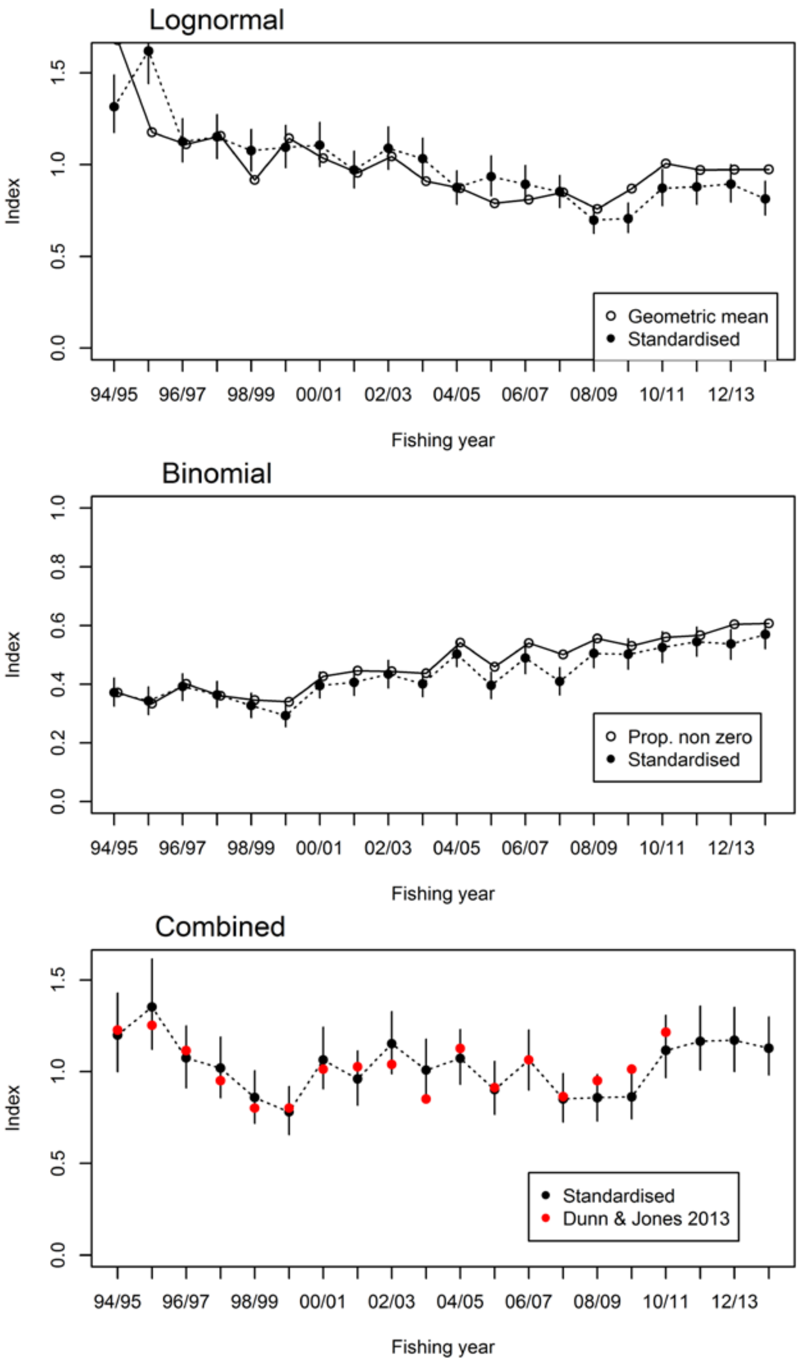



**Figure 51: A comparison of the WCNI trawl standardised CPUE indices and the geometric mean of the annual catch per day (unstandardised) (top panel), a comparison of the binomial indices and the annual proportion of positive catch records in the data set (middle panel) and the combined index (bottom panel) . The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A11 (Appendix 3).**

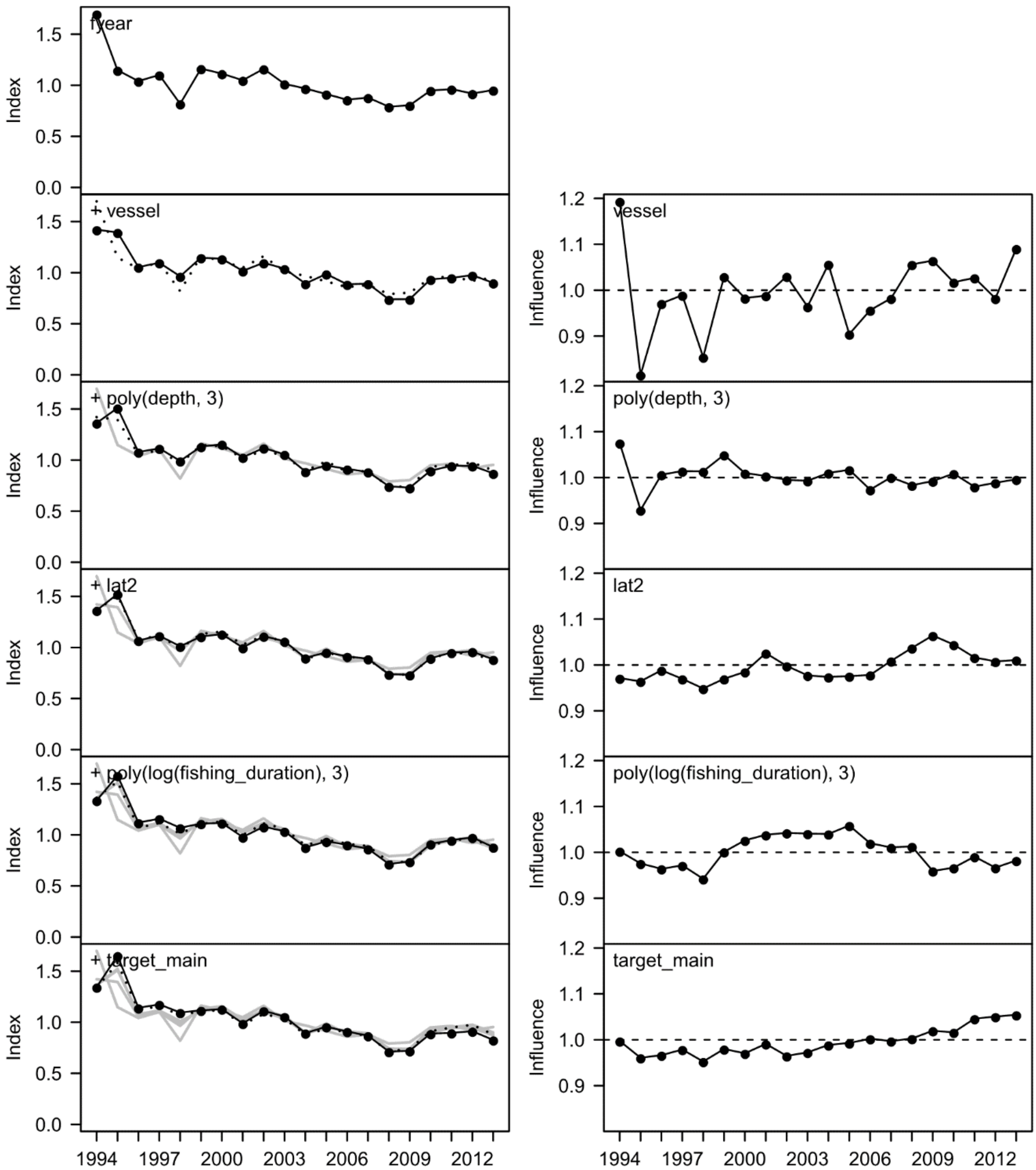



**Figure 52: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the lognormal CPUE model for the WCNI trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1994 denotes the 1994/95 fishing year).**

The occurrence of John dory in the WCNI trawl catch was predicted by the binomial model including the explanatory variables *FishingYear, Vessel, TargetSpecies, Loc2, Depth* and *Duration* (Table 11). The annual indices derived from the binomial model generally increased from 1999/2000 to 2013/14 (Figure 51), similar to the increase in the (unstandardized) proportion of positive catch records in the data set.

**Table 11: Summary of stepwise selection of variables in the WCNI John dory catch occurrence CPUE model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: Term included in final model.**

| Term | DF | Log likelihood | AIC | Nagelkerke pseudo-$R^2$ (% Improvement) |
|---|---|---|---|---|
| *FishingYear* | 20 | -33 132 | 66 304 | 4.2 * |
| *Vessel* | 28 | -31 563 | 63 222 | 12.2 * |
| *Depth* | 3 | -30 629 | 61 359 | 16.7 * |
| *Lat2* | 30 | -30 041 | 60 243 | 19.5 * |
| *TargetSpecies* | 5 | -29 807 | 59 785 | 20.6 * |
| *Month* | 11 | -29 691 | 59 576 | 21.1 * |
| *StartTime* | 3 | -29 615 | 59 430 | 21.4 |
| *Duration* | 3 | -29 566 | 59 338 | 21.7 |
| *GearHeight* | 3 | -29 541 | 59 295 | 21.8 |
| *GearWidth* | 3 | -29 532 | 59 281 | 21.8 |
| *Speed* | 6 | -29 524 | 59 277 | 21.9 |

The increase in the binomial indices during 1999/2000–2008/09 contradicted the declining trend in the lognormal indices during the same period. An examination of the vessel coefficients from the two CPUE models revealed that there was a negative correlation between the two sets of vessel coefficients (Figure 53). This suggested that there may have been differences in the reporting of John dory catches by individual vessels; for example, vessels at one end of the continuum may have tended to be more inclined to report larger catches of John dory resulting in a high vessel coefficient from the lognormal model and a lower coefficient from the binomial model. This is contrasted by vessels more accurately reporting the smaller catches of John dory resulting in a lower vessel coefficient from the lognormal model and a higher coefficient from the binomial model.

Further, an examination of the proportional distribution of the estimated catches from trawl records revealed that from 2009/10 onwards there was an increase in the proportion of John dory catches in the 10–29 kg catch range with a corresponding decline in the proportion of zero catch records (Figure 54). There was no substantial change in the proportion records with catches exceeding 30 kg. This observation may indicate that over time the fishing fleet was more accurately recording the smaller catches (under 30 kg) of John dory.

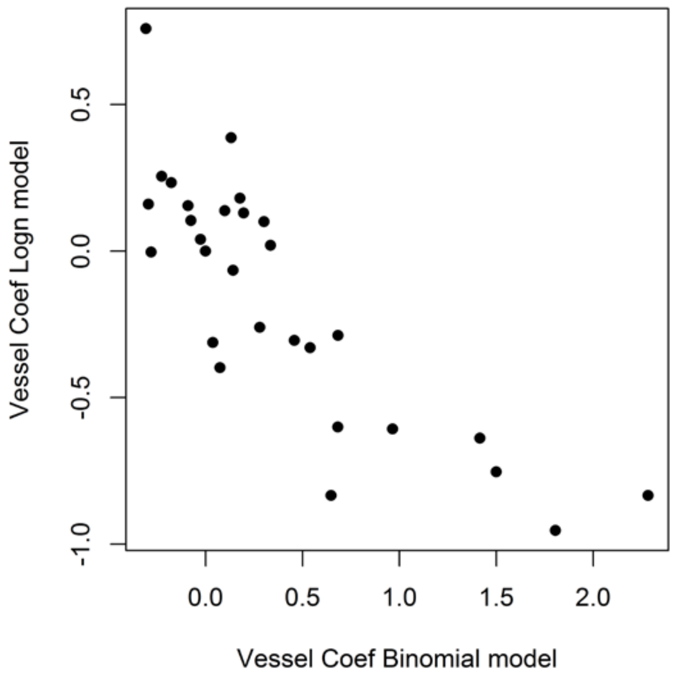



**Figure 53: A comparison of the corresponding vessel coefficients derived from the WCNI lognormal CPUE model and the binomial CPUE model.**

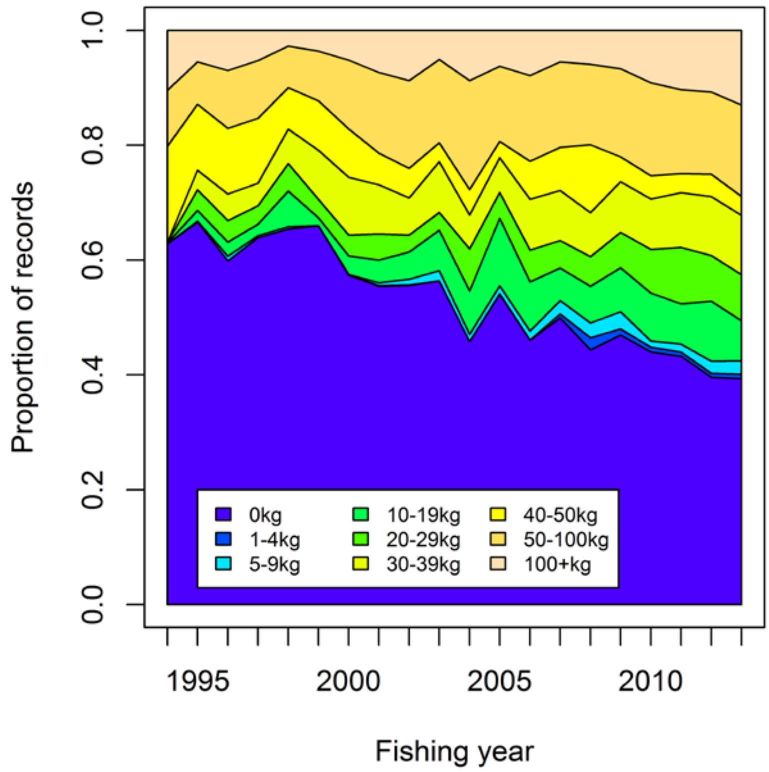



**Figure 54: Proportional distribution of the annual WCNI trawl records by John dory catch category (estimated catches, top 5 species only). The fishing year is labelled by the calendar year at the start of the fishing year (e.g. 1995 represents the 1995/96 fishing year).**

The annual trends in catch reporting by individual vessels were examined by determining the annual proportion of the landed catch of John dory that was reported from individual trawls (estimated catches, top five species only). The proportion of the total catch reported from trawl catches varied amongst vessels and varied over time for individual vessels (Figure 55). For individual vessels, there was no indication of an increasing trend in the proportion of the landed catch reported from individual trawl catches.

An examination of the proportion of the records reporting a small catch (10–29 kg) of John dory indicates that the proportion of smaller reported catches differs amongst vessels and may vary over time for an individual vessel (Figure 56).

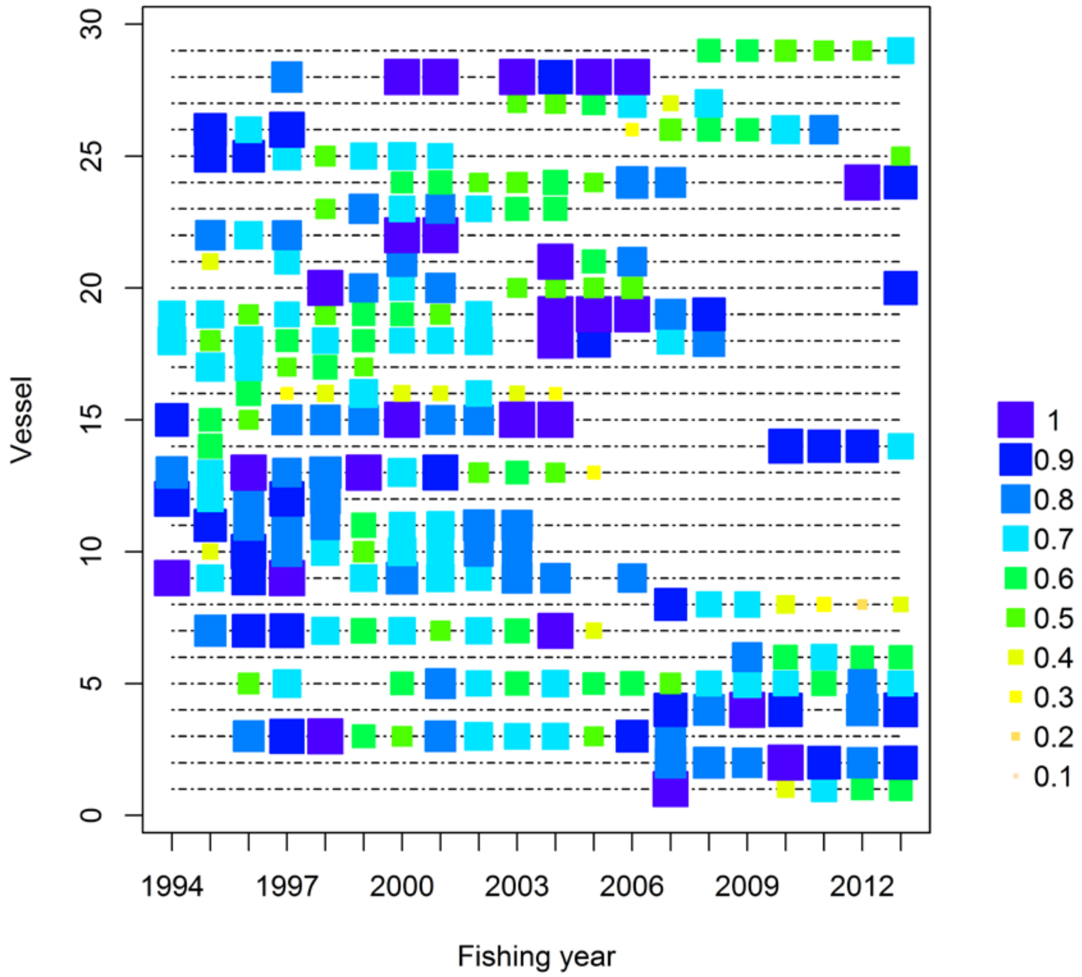



**Figure 55: Proportion of the John dory landed catch reported from WCNI trawl records (estimated catch, top five species only) by vessel and fishing year. The sides of the square boxes are proportional to the ratio of the summation of trawl catches and landed catches; the legend represents the lower bound of each colour category. The fishing year is labelled by the calendar year at the start of the fishing year (e.g. 1994 represents the 1994/95 fishing year).**

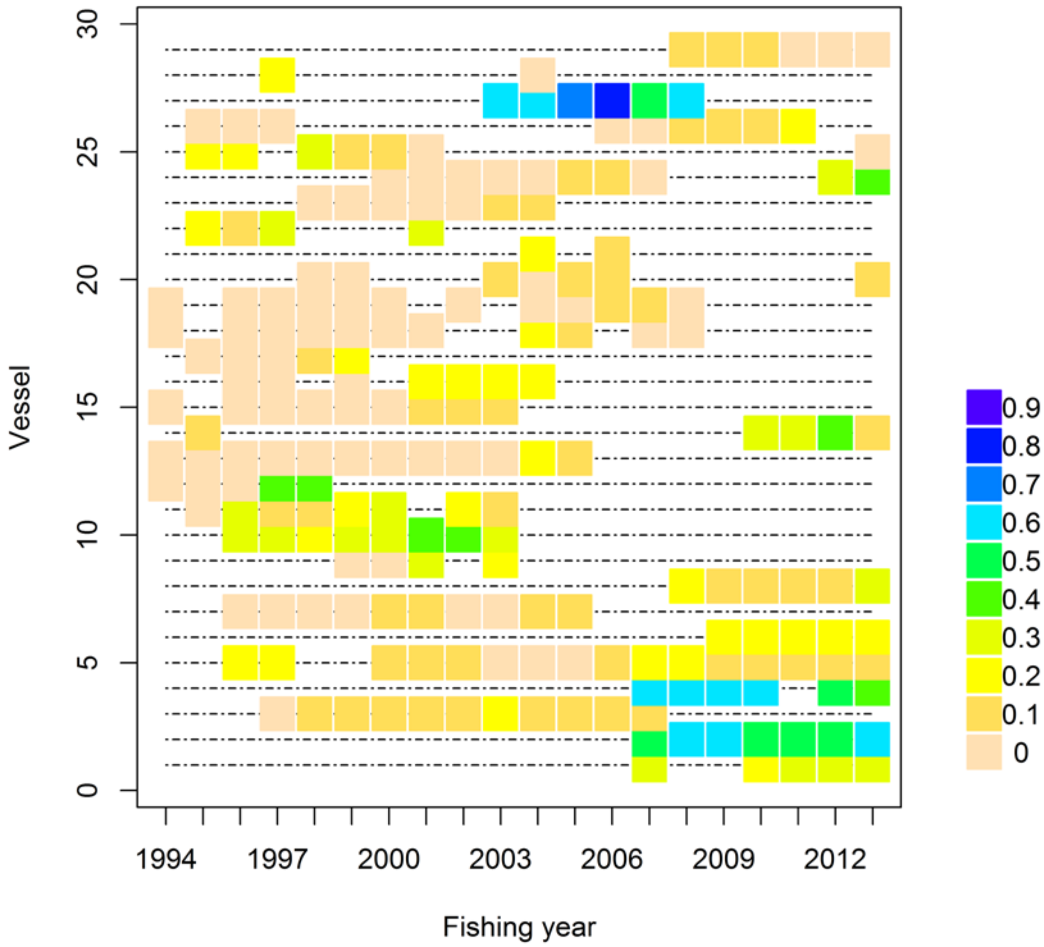



**Figure 56: Proportion of WCNI trawl CPUE records reporting an estimated John dory catch of 1-29 kg (top 5 species only) by vessel and fishing year. The legend represents the lower bound of each category. The fishing year is labelled by the calendar year at the start of the fishing year (e.g. 1994 represents the 1994/95 fishing year).**

These observations indicate that the reporting of small John dory trawl catches is variable amongst individual vessels although there may be considerable inter-annual variation in the reporting of small catches by individual vessels.

Collectively, there was an increase in the proportion of small catches of John dory reported by the fleet over time. There is an inherent linkage between the magnitude of the positive catch trawl records and the reporting of small trawls catches due to the apportionment of the landed catches amongst the effort records from an individual fishing trip. This has the effect of inflating the trawl catches from trips that do not report a high proportion of the smaller trawl catches of John dory; i.e., the entire landed catch gets allocated to the small number of trawl records that recorded a catch of John dory. An increasing trend in the relative reporting of smaller trawl catches will result in an increasing proportion of the landed catches being distributed amongst a larger number of trawls, resulting in a lower average positive catch.

This is a likely explanation for the contradicting annual trends in the CPUE indices obtained from the lognormal and binomial WCNI trawl CPUE models. It is considered that changes in the reporting of small catches has the potential to bias both sets of indices. This was further investigated via a simple simulation study (Appendix 4). The results of the simulation study were consistent with the positive and negative biases introduced by changes in reporting of smaller catches described above. The simulation study also highlighted that these biases were effectively cancelled when the two sets of indices were multiplied to derive the combined indices.

On that basis, it was considered that the combined indices represent the most reliable CPUE indices for the WCNI trawl fishery. The combined indices moderated the contrasting trends in the lognormal and binomial CPUE indices; the combined indices fluctuated over the study period with higher indices during 1994/95–1996/97, 2000/01–2006/07 and 2010/11–2013/14 and lower indices during 1998/99–1999/2000 and 2007/08–2009/10 (Figure 51, Appendix 3 Table A11). The combined CPUE indices were comparable to the corresponding CPUE indices derived by Dunn & Jones (2013) (Figure 51).

The combined indices were also comparable to an additional set of CPUE indices that were derived from the trawl data set aggregated by fishing trip (Figure 57). The data aggregation removes the potential for the introduction of biases associated with changes in the frequency of the reporting of small catches from individual trawls.

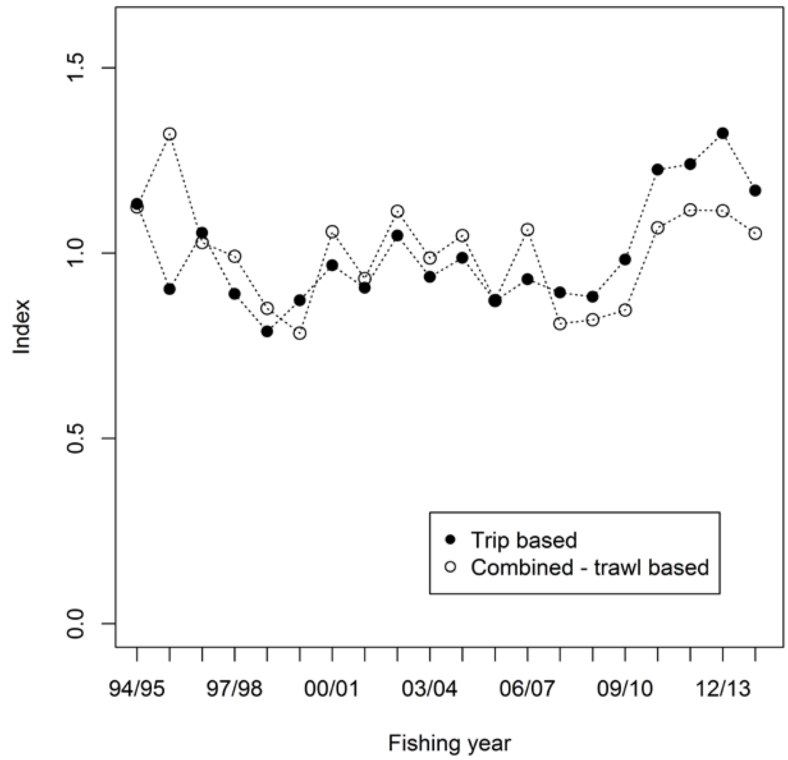



**Figure 57: A comparison of the combined WCNI trawl based CPUE indices and comparative CPUE indices derived from the catch and effort data aggregated by fishing trip.**

## 5 DISCUSSION

Previously, the area specific trawl CPUE indices have been accepted for monitoring of the relative abundance of John dory within the sub-areas of JDO 1. Limited data are available to validate this assumption. Inshore trawl surveys were conducted in each of the three sub-areas although the time-series of surveys ceased in 1999 (west coast North Island and Bay of Plenty) and 2000 (Hauraki Gulf) (MPI 2014). Consequently, there is insufficient temporal overlap between the John dory trawl survey biomass estimates and the current time-series of CPUE indices to directly compare trends in relative abundance of the respective sets of indices (Figure 58). However, the CPUE indices derived from a previous study (Bentley & Kendrick 2011) included earlier years (extending back to 1989) and provide increased overlap with the trawl survey biomass estimates. The area-specific trends in these CPUE indices are generally comparable with the trawl survey biomass estimates (Figure 58).

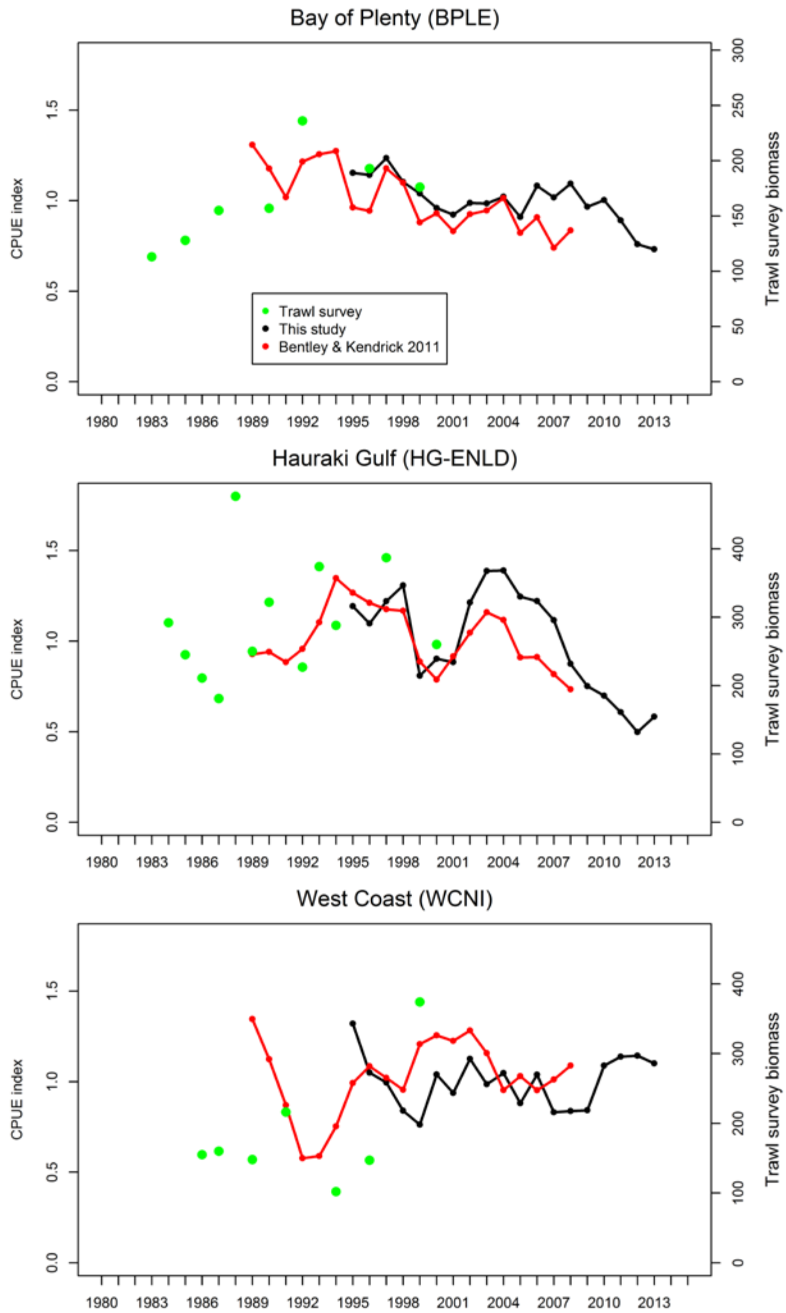



**Figure 58. A comparison between the combined trawl CPUE indices from the current study and CPUE indices from Bentley & Kendrick (2011) and the time series of area specific trawl survey biomass indices (MPI 2014).**

In addition, a complementary set of John dory CPUE indices and trawl survey biomass estimates is available from the west coast South Island inshore fishery (JDO 7). There is a good correspondence between these two sets of indices (Langley 2014) indicating that trawl CPUE is probably sufficiently reliable to monitor John dory abundance.

The catch rates of John dory from trawl surveys and commercial trawling indicate that the species tends to occur at relatively low densities and the distribution of the species is relatively homogeneous within the main fishery areas. The relatively low fish densities mean that John dory within the JDO 1 sub-areas is generally not considered a primary target species of the trawl fishery. The annual catches in JDO 1 are generally not constrained by the JDO 1 TACC and, consequently, there is unlikely to be any direct avoidance of the species by the trawl fleets. These characteristics suggest that annual catch rates of John dory are unlikely to be strongly influenced by changes in the operation of the fishery in response to changes in the availability of the species. On that basis, catch rates of John dory are likely to be primarily a function of stock abundance and, hence, trawl CPUE can probably be expected to provide a reasonable indicator of relative stock abundance. This assertion is further supported by the broadly comparable trends in the trawl and Danish seine CPUE indices from the Hauraki Gulf (HG-ENLD) and Bay of Plenty fisheries.

In each of the trawl fisheries, John dory represents a relatively small component of the total catch (e.g., about 2.5% of the main species catch from the WCNI fishery) and individual trawl catches of John dory are typically small (less than 100 kg). Consequently, there is the potential for small trawl catches to routinely be unreported, particularly when only the catches of the five main species were reported from each trawl. For the WCNI trawl fishery, there also appears to have been considerable variability in the reporting of the smaller (under 30 kg) John dory trawl catches amongst vessels and over time. The current study indicates that it is necessary to incorporate both the positive John dory catch component and the presence/absence of John dory in the derivation of CPUE indices to minimise potential biases attributable to changes in the reporting of smaller John dory catches.

There are marked differences in the trends in the CPUE indices from the three areas of JDO 1 (Figure 59). This result is consistent with the previous CPUE studies and supports the conclusion that JDO 1 needs to be monitored at the regional scale rather than as a single entity (Bentley & Kendrick 2011, Dunn & Jones 2013).


**Figure 59: A comparison of the combined trawl based CPUE indices derived for each of the three fishery areas of JDO 1.**

The trawl CPUE indices from HG-ENLD indicate that the abundance of John dory decreased considerably during 2004/05–2013/14 (Figure 59). John dory are relatively short lived (maximum age 9 years) and there appears to be considerable inter-annual variability in recruitment (Hanchet et al 2001). Consequently, stock abundance may be expected to be fluctuate over relatively short periods (5–10 years). The time series of Hauraki Gulf trawl survey biomass indices reveal considerable variability in abundance, generally increasing by about 100% (two fold) from the late 1980s to the late 1990s (Figure 58).

The magnitude of the recent decline in HG-ENLD CPUE indices represents a three-fold change in stock abundance, exceeding the degree of the variability observed in the trawl survey biomass indices. Nonetheless, the two sets of indices are not directly comparable as the trawl fishery is excluded from the inner and central Hauraki Gulf. These areas have accounted for a substantial proportion of the total John dory trawl survey biomass estimates.

For the HG-ENLD and BPLE areas, exceptionally high CPUE indices were estimated for 1994/95 (Figure 59). The indices were inconsistent with the indices from the subsequent year (1995/96) and were also not comparable with the corresponding indices derived from the Danish seine fisheries. The 1994/95 indices were derived from a relatively small proportion of total John dory trawl catch and fishing effort. Further, it has been speculated that there may have been some issues related to the reliability of the reporting of catch and effort data during the transitional period when TCEPR forms were being introduced to the northern inshore trawl fleet. Therefore, it is recommended that the 1994/95 CPUE indices should not be included in the time-series of indices used for the purpose of monitoring trends in stock abundance in each area.

## 6 MANAGEMENT IMPLICATIONS

The area specific CPUE indices represent the primary monitoring tool for JDO 1. During the 2015 assessment process, the Northern Inshore Fishery Assessment Working Group accepted the updated time-series of CPUE indices for the three areas of JDO 1. The CPUE indices indicate that John dory abundance in the Hauraki Gulf-east Northland area is at a relatively low level, while abundance of John dory in the Bay of Plenty has also declined over the last five years. Annual catches of John dory from the Hauraki Gulf-east Northland area have also declined in recent years and are substantially lower than the annual catches during the 1990s. It is considered that the decline in abundance in Hauraki Gulf-east Northland and Bay of Plenty is due to lower recruitment during the preceding period (MPI 2014); however, there are no additional data available to confirm this conclusion (e.g. from catch sampling). John dory abundance in the WCSI area has fluctuated without trend over the last two decades. It is anticipated that the JDO 1 CPUE indices will be further updated in 2017.

## 7 ACKNOWLEDGMENTS

This study was funded by the Ministry for Primary Industries under research project JDO2014-01. Members of the Northern Inshore Fishery Assessment Working Group provided input during the development of the standardised CPUE indices. Software developed by Nokome Bentley was utilised for conducting the standardised CPUE analyses and the presentation of CPUE model diagnostics.

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## APPENDIX 1. SUMMARY OF ANNUAL CATCHES BY AREA AND METHOD

**Table A1: Annual catches (tonnes) of John dory from the Bay of Plenty (BPLE) fishery by fishing method.**

| Fishing year | Fishing method | | | | Total |
|---|---|---|---|---|---|
| | BT | DS | BPT | Other | |
| 1989/90 | 66.1 | 5.6 | 7.1 | 3.0 | 81.8 |
| 1990/91 | 76.5 | 7.3 | 6.8 | 7.1 | 97.7 |
| 1991/92 | 87.9 | 15.0 | 8.8 | 7.2 | 118.9 |
| 1992/93 | 102.3 | 16.7 | 8.9 | 6.3 | 134.2 |
| 1993/94 | 96.3 | 25.6 | 11.9 | 6.6 | 140.3 |
| 1994/95 | 101.6 | 38.4 | 37.8 | 5.6 | 183.3 |
| 1995/96 | 76.7 | 22.5 | 14.7 | 6.3 | 120.2 |
| 1996/97 | 83.6 | 22.4 | 9.2 | 4.5 | 119.8 |
| 1997/98 | 93.5 | 33.3 | 2.4 | 3.7 | 132.9 |
| 1998/99 | 103.5 | 26.2 | 0.0 | 4.4 | 134.2 |
| 1999/2000 | 86.9 | 17.4 | 0.9 | 3.1 | 108.3 |
| 2000/01 | 80.7 | 8.1 | 0.3 | 3.5 | 92.6 |
| 2001/02 | 92.3 | 13.9 | 0.8 | 2.6 | 109.5 |
| 2002/03 | 92.6 | 21.4 | 2.1 | 2.3 | 118.3 |
| 2003/04 | 95.0 | 17.4 | 2.8 | 2.8 | 118.0 |
| 2004/05 | 111.8 | 22.4 | 4.0 | 3.3 | 141.4 |
| 2005/06 | 89.8 | 22.0 | 0.9 | 5.4 | 118.2 |
| 2006/07 | 75.4 | 14.6 | 0.3 | 4.3 | 94.6 |
| 2007/08 | 68.7 | 22.1 | 0.3 | 3.6 | 94.7 |
| 2008/09 | 66.6 | 26.0 | 0.4 | 1.5 | 94.4 |
| 2009/10 | 65.1 | 25.1 | 0.9 | 2.1 | 93.2 |
| 2010/11 | 65.3 | 44.3 | 1.2 | 1.2 | 112.0 |
| 2011/12 | 50.2 | 30.3 | 0.0 | 1.5 | 82.0 |
| 2012/13 | 42.4 | 47.9 | 0.0 | 1.3 | 91.6 |
| 2013/14 | 41.4 | 35.3 | 0.0 | 1.3 | 78.0 |

**Table A2: Annual catches (tonnes) of John dory from the Hauraki Gulf and east Northland (HG-ENLD) fishery by fishing method.**

| Fishing year | Fishing method | | | | Total |
|---|---|---|---|---|---|
| | BT | DS | BPT | Other | |
| 1989/90 | 169.3 | 39.6 | 29.2 | 10.4 | 248.5 |
| 1990/91 | 190.0 | 71.4 | 17.7 | 13.5 | 292.7 |
| 1991/92 | 225.8 | 90.3 | 7.6 | 15.9 | 339.6 |
| 1992/93 | 189.3 | 103.5 | 10.7 | 18.2 | 321.7 |
| 1993/94 | 215.2 | 168.7 | 12.3 | 24.8 | 421.0 |
| 1994/95 | 211.3 | 144.1 | 17.5 | 26.6 | 399.5 |
| 1995/96 | 230.8 | 106.6 | 5.3 | 21.5 | 364.3 |
| 1996/97 | 227.5 | 127.9 | 3.6 | 21.5 | 380.5 |
| 1997/98 | 218.3 | 85.2 | 2.1 | 22.9 | 328.5 |
| 1998/99 | 252.3 | 132.4 | 1.5 | 27.5 | 413.7 |
| 1999/2000 | 164.4 | 95.4 | 2.2 | 15.6 | 277.5 |
| 2000/01 | 152.1 | 92.1 | 3.3 | 14.7 | 262.2 |
| 2001/02 | 139.2 | 59.6 | 1.2 | 18.5 | 218.5 |
| 2002/03 | 137.5 | 57.5 | 4.0 | 11.2 | 210.3 |
| 2003/04 | 160.8 | 74.4 | 2.8 | 13.7 | 251.6 |
| 2004/05 | 204.7 | 59.5 | 2.9 | 13.6 | 280.7 |
| 2005/06 | 185.5 | 134.1 | 1.6 | 18.2 | 339.4 |
| 2006/07 | 192.2 | 141.0 | 3.2 | 14.3 | 350.7 |
| 2007/08 | 153.3 | 112.0 | 2.3 | 7.6 | 275.1 |
| 2008/09 | 149.4 | 48.7 | 1.8 | 7.8 | 207.6 |
| 2009/10 | 113.7 | 48.1 | 1.8 | 8.3 | 171.9 |
| 2010/11 | 97.2 | 42.6 | 1.5 | 9.2 | 150.6 |
| 2011/12 | 75.5 | 50.3 | 0.0 | 7.1 | 133.0 |
| 2012/13 | 68.3 | 40.1 | 0.0 | 6.2 | 114.5 |
| 2013/14 | 79.2 | 45.5 | 0.0 | 6.7 | 131.4 |

**Table A3: Annual catches (tonnes) of John dory from the West Coast North Island (WCNI) fishery by fishing method.**

| Fishing year | Fishing method | | | | Total |
|---|---|---|---|---|---|
| | BT | DS | BPT | Other | |
| 1989/90 | 79.9 | 0.0 | 14.9 | 1.1 | 95.9 |
| 1990/91 | 88.9 | 0.0 | 23.3 | 1.6 | 113.9 |
| 1991/92 | 90.9 | 0.0 | 16.4 | 3.9 | 111.2 |
| 1992/93 | 104.7 | 0.3 | 12.1 | 3.5 | 120.6 |
| 1993/94 | 86.4 | 1.2 | 17.1 | 6.5 | 111.3 |
| 1994/95 | 125.5 | 0.3 | 15.0 | 6.3 | 147.1 |
| 1995/96 | 131.7 | 9.5 | 23.8 | 3.6 | 168.6 |
| 1996/97 | 170.9 | 4.2 | 9.2 | 2.8 | 187.1 |
| 1997/98 | 187.4 | 0.9 | 5.7 | 3.3 | 197.3 |
| 1998/99 | 130.1 | 0.6 | 13.6 | 2.9 | 147.3 |
| 1999/2000 | 162.4 | 1.4 | 16.0 | 2.0 | 181.8 |
| 2000/01 | 158.5 | 3.4 | 23.9 | 4.0 | 189.8 |
| 2001/02 | 149.8 | 6.5 | 6.7 | 3.8 | 166.9 |
| 2002/03 | 137.6 | 5.9 | 11.7 | 13.5 | 168.7 |
| 2003/04 | 131.7 | 13.5 | 8.8 | 6.2 | 160.2 |
| 2004/05 | 153.5 | 6.2 | 21.8 | 16.4 | 197.8 |
| 2005/06 | 111.5 | 5.6 | 9.9 | 11.4 | 138.4 |
| 2006/07 | 110.4 | 7.8 | 11.9 | 17.7 | 147.9 |
| 2007/08 | 106.9 | 14.6 | 14.1 | 14.1 | 149.7 |
| 2008/09 | 116.8 | 14.5 | 9.4 | 9.8 | 150.5 |
| 2009/10 | 102.8 | 10.0 | 14.1 | 13.9 | 140.8 |
| 2010/11 | 123.8 | 10.2 | 11.8 | 15.1 | 160.9 |
| 2011/12 | 156.2 | 6.9 | 2.7 | 16.6 | 182.4 |
| 2012/13 | 180.3 | 9.8 | 0.0 | 24.0 | 214.1 |
| 2013/14 | 159.7 | 10.1 | 0.0 | 16.9 | 186.8 |

## APPENDIX 2. CPUE DATA SETS

**Table A4: Summary of the catch and effort data from the Bay of Plenty (BPLE) single trawl CPUE data set (core vessels only).**

| Fishing year | Number vessels | Number trips | JDO catch (t) | Number trawls | Duration (hrs) | Percent zero catch |
|---|---|---|---|---|---|---|
| 1994/95 | 7 | 67 | 16.9 | 501 | 1 450 | 41.9 |
| 1995/96 | 18 | 187 | 40.1 | 1 534 | 4 342 | 47.3 |
| 1996/97 | 18 | 205 | 44.2 | 1 809 | 4 518 | 51.1 |
| 1997/98 | 22 | 248 | 58.0 | 2 138 | 6 316 | 45.3 |
| 1998/99 | 19 | 324 | 71.3 | 3 198 | 8 993 | 49.4 |
| 1999/2000 | 17 | 277 | 51.0 | 2 886 | 7 552 | 52.7 |
| 2000/01 | 23 | 358 | 63.0 | 3 335 | 9 157 | 58.3 |
| 2001/02 | 18 | 353 | 54.6 | 2 950 | 8 807 | 53.0 |
| 2002/03 | 20 | 412 | 64.5 | 3 514 | 10 713 | 55.8 |
| 2003/04 | 19 | 436 | 77.6 | 4 111 | 12 747 | 53.1 |
| 2004/05 | 16 | 390 | 80.0 | 4 158 | 12 938 | 53.2 |
| 2005/06 | 16 | 373 | 49.7 | 3 367 | 10 428 | 56.8 |
| 2006/07 | 11 | 247 | 46.2 | 2 453 | 7 525 | 50.8 |
| 2007/08 | 15 | 336 | 54.9 | 3 022 | 9 533 | 49.2 |
| 2008/09 | 16 | 372 | 61.7 | 3 475 | 10 939 | 49.9 |
| 2009/10 | 14 | 367 | 57.1 | 3 275 | 10 500 | 55.0 |
| 2010/11 | 14 | 318 | 55.8 | 2 994 | 8 953 | 54.4 |
| 2011/12 | 12 | 330 | 45.6 | 3 217 | 9 107 | 58.6 |
| 2012/13 | 13 | 291 | 38.3 | 2 538 | 7 351 | 62.9 |
| 2013/14 | 15 | 290 | 36.8 | 2 758 | 7 512 | 63.6 |

**Table A5: Summary of the catch and effort data from the Hauraki Gulf-East Northland (HG-ENLD) single trawl CPUE data set (core vessels only).**

| Fishing year | Number vessels | Number trips | JDO catch (t) | Number trawls | Duration (hrs) | Percent zero catch |
|---|---|---|---|---|---|---|
| 1994/95 | 8 | 51 | 17.9 | 419 | 992 | 49.6 |
| 1995/96 | 21 | 301 | 103.9 | 2 709 | 6 281 | 34.0 |
| 1996/97 | 22 | 387 | 138.0 | 3 482 | 7 076 | 34.5 |
| 1997/98 | 24 | 475 | 136.6 | 4 309 | 8 981 | 34.8 |
| 1998/99 | 23 | 391 | 156.1 | 4 072 | 9 231 | 31.5 |
| 1999/2000 | 23 | 355 | 104.2 | 3 667 | 8 946 | 37.2 |
| 2000/01 | 23 | 373 | 127.9 | 3 616 | 9 391 | 28.9 |
| 2001/02 | 22 | 369 | 119.1 | 3 328 | 8 675 | 30.2 |
| 2002/03 | 21 | 271 | 87.4 | 2 366 | 5 505 | 28.7 |
| 2003/04 | 17 | 297 | 85.8 | 2 696 | 5 972 | 29.4 |
| 2004/05 | 15 | 200 | 56.6 | 2 110 | 4 681 | 29.6 |
| 2005/06 | 14 | 225 | 62.1 | 2 298 | 6 115 | 36.9 |
| 2006/07 | 10 | 266 | 82.6 | 2 689 | 6 633 | 27.1 |
| 2007/08 | 13 | 341 | 134.3 | 3 364 | 9 588 | 25.5 |
| 2008/09 | 12 | 310 | 126.0 | 3 618 | 10 149 | 29.9 |
| 2009/10 | 9 | 297 | 99.1 | 3 473 | 9 646 | 29.4 |
| 2010/11 | 11 | 284 | 89.1 | 3 556 | 9 099 | 35.0 |
| 2011/12 | 10 | 289 | 72.5 | 3 519 | 8 493 | 38.1 |
| 2012/13 | 9 | 267 | 61.8 | 3 584 | 8 523 | 42.0 |
| 2013/14 | 13 | 301 | 66.9 | 3 350 | 8 352 | 40.4 |

**Table A6: Summary of the catch and effort data from the west coast North Island (WCNI) single trawl CPUE data set (core vessels only).**

| Fishing year | Number vessels | Number trips | JDO catch (t) | Number trawls | Duration (hrs) | Percent zero catch |
|---|---|---|---|---|---|---|
| 1994/95 | 6 | 50 | 33.2 | 788 | 2 446 | 62.9 |
| 1995/96 | 16 | 156 | 40.1 | 1 532 | 5 036 | 68.7 |
| 1996/97 | 17 | 281 | 88.6 | 2 883 | 8 730 | 60.9 |
| 1997/98 | 18 | 303 | 90.3 | 3 336 | 10 157 | 64.9 |
| 1998/99 | 17 | 221 | 62.3 | 3 008 | 8 775 | 65.9 |
| 1999/2000 | 16 | 239 | 82.2 | 3 140 | 10 557 | 66.7 |
| 2000/01 | 19 | 265 | 103.9 | 3 177 | 11 033 | 57.5 |
| 2001/02 | 17 | 284 | 97.8 | 3 024 | 10 896 | 57.0 |
| 2002/03 | 15 | 231 | 98.5 | 2 582 | 9 522 | 57.6 |
| 2003/04 | 16 | 264 | 103.1 | 3 258 | 11 942 | 57.1 |
| 2004/05 | 15 | 244 | 114.3 | 2 990 | 11 126 | 47.1 |
| 2005/06 | 12 | 200 | 70.0 | 2 036 | 7 433 | 55.2 |
| 2006/07 | 11 | 176 | 67.3 | 1 946 | 6 689 | 47.1 |
| 2007/08 | 13 | 279 | 92.4 | 2 895 | 10 141 | 51.4 |
| 2008/09 | 10 | 247 | 92.0 | 2 694 | 9 649 | 46.4 |
| 2009/10 | 8 | 241 | 85.0 | 2 441 | 7 707 | 47.8 |
| 2010/11 | 10 | 256 | 109.2 | 2 514 | 8 037 | 44.6 |
| 2011/12 | 9 | 266 | 125.0 | 2 866 | 9 692 | 44.9 |
| 2012/13 | 11 | 286 | 147.2 | 3 044 | 10 111 | 41.2 |
| 2013/14 | 12 | 328 | 150.0 | 3 172 | 10 954 | 42.3 |

**Table A7: Summary of the catch and effort data from the Hauraki Gulf-East Northland (HG-ENLD) Danish seine CPUE data set (core vessels only).**

| Fishing year | Num. records | Number vessels | Number trips | JDO catch (t) | Duration (hrs) | Percent zero catch |
|---|---|---|---|---|---|---|
| 1989/90 | 433 | 15 | 224 | 19.2 | 1 041 | 15.9 |
| 1990/91 | 808 | 16 | 450 | 45.5 | 1 945 | 18.2 |
| 1991/92 | 1 236 | 16 | 626 | 57.3 | 3 037 | 21.6 |
| 1992/93 | 1 099 | 19 | 553 | 82.8 | 2 905 | 17.4 |
| 1993/94 | 1 298 | 20 | 663 | 123.7 | 3 387 | 15.1 |
| 1994/95 | 1 194 | 18 | 644 | 115.5 | 3 329 | 14.5 |
| 1995/96 | 1 113 | 18 | 508 | 102.4 | 2 544 | 13.4 |
| 1996/97 | 1 321 | 20 | 609 | 118.5 | 2 899 | 7.6 |
| 1997/98 | 862 | 17 | 430 | 80.5 | 2 212 | 5.6 |
| 1998/99 | 855 | 13 | 415 | 121.6 | 2 162 | 4.1 |
| 1999/2000 | 909 | 14 | 442 | 91.3 | 2 276 | 4.3 |
| 2000/01 | 969 | 12 | 441 | 89.5 | 2 254 | 3.7 |
| 2001/02 | 678 | 11 | 348 | 57.3 | 1 707 | 4.4 |
| 2002/03 | 521 | 9 | 285 | 49.3 | 1 167 | 3.3 |
| 2003/04 | 547 | 9 | 269 | 54.8 | 1 129 | 3.5 |
| 2004/05 | 606 | 9 | 280 | 51.5 | 1 114 | 5.6 |
| 2005/06 | 676 | 11 | 305 | 95.2 | 1 318 | 4.7 |
| 2006/07 | 750 | 11 | 352 | 91.1 | 1 618 | 3.2 |
| 2007/08 | 734 | 13 | 378 | 76.0 | 1 558 | 3.8 |
| 2008/09 | 618 | 14 | 333 | 42.8 | 1 264 | 5.7 |
| 2009/10 | 696 | 15 | 346 | 44.7 | 1 442 | 5.6 |
| 2010/11 | 455 | 12 | 235 | 34.9 | 1 003 | 5.3 |
| 2011/12 | 568 | 10 | 275 | 35.3 | 1 229 | 6.0 |
| 2012/13 | 509 | 10 | 238 | 32.5 | 1 099 | 5.9 |
| 2013/14 | 712 | 9 | 233 | 36.3 | 1 098 | 7.3 |

**Table A8: Summary of the catch and effort data from the Bay of Plenty (BPLE) Danish seine CPUE data set (core vessels only).**

| Fishing year | Num. records | Number vessels | Number trips | JDO catch (t) | Duration (hrs) | Percent zero catch |
|---|---|---|---|---|---|---|
| 1989/90 | 111 | 6 | 48 | 2.0 | 284 | 34.2 |
| 1990/91 | 154 | 6 | 72 | 3.2 | 430 | 37.7 |
| 1991/92 | 384 | 11 | 186 | 10.8 | 2 069 | 22.1 |
| 1992/93 | 318 | 12 | 171 | 14.4 | 893 | 20.8 |
| 1993/94 | 467 | 14 | 220 | 23.0 | 1 444 | 21.8 |
| 1994/95 | 577 | 13 | 256 | 32.9 | 1 745 | 27.4 |
| 1995/96 | 669 | 12 | 229 | 18.3 | 1 354 | 36.2 |
| 1996/97 | 734 | 13 | 271 | 20.3 | 1 435 | 36.5 |
| 1997/98 | 682 | 12 | 242 | 30.4 | 1 461 | 34.2 |
| 1998/99 | 561 | 13 | 214 | 23.6 | 1 081 | 28.7 |
| 1999/2000 | 559 | 11 | 221 | 13.9 | 1 053 | 24.3 |
| 2000/01 | 353 | 9 | 134 | 7.3 | 575 | 34.8 |
| 2001/02 | 520 | 9 | 205 | 12.2 | 993 | 25.2 |
| 2002/03 | 624 | 8 | 225 | 20.5 | 1 238 | 25.3 |
| 2003/04 | 654 | 8 | 264 | 16.9 | 1 301 | 25.5 |
| 2004/05 | 603 | 8 | 258 | 22.2 | 1 226 | 25.9 |
| 2005/06 | 588 | 7 | 257 | 21.7 | 1 112 | 28.9 |
| 2006/07 | 305 | 8 | 155 | 14.0 | 709 | 23.9 |
| 2007/08 | 400 | 9 | 172 | 17.7 | 759 | 27.7 |
| 2008/09 | 484 | 9 | 190 | 23.0 | 878 | 27.7 |
| 2009/10 | 567 | 12 | 232 | 22.8 | 1 089 | 26.1 |
| 2010/11 | 630 | 8 | 257 | 42.0 | 1 393 | 21.4 |
| 2011/12 | 520 | 7 | 212 | 25.9 | 1 055 | 22.3 |
| 2012/13 | 491 | 8 | 228 | 42.1 | 1 344 | 18.1 |
| 2013/14 | 511 | 7 | 161 | 29.2 | 952 | 21.3 |

## APPENDIX 3. TABULATED CPUE INDICES

**Table A9: Annual BPLE trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.**

| Fishing | Combined | | | Binomial | | | Lognormal | | |
|---|---|---|---|---|---|---|---|---|---|
| year | Index | LCI | UCI | Index | LCI | UCI | Index | LCI | UCI |
| 94/95 | 0.644 | 0.554 | 0.740 | 0.642 | 0.582 | 0.698 | 1.000 | 0.894 | 1.124 |
| 95/96 | 0.352 | 0.296 | 0.417 | 0.450 | 0.389 | 0.509 | 0.784 | 0.698 | 0.868 |
| 96/97 | 0.349 | 0.293 | 0.411 | 0.450 | 0.385 | 0.512 | 0.775 | 0.696 | 0.864 |
| 97/98 | 0.377 | 0.315 | 0.439 | 0.517 | 0.453 | 0.585 | 0.730 | 0.649 | 0.811 |
| 98/99 | 0.337 | 0.284 | 0.399 | 0.477 | 0.417 | 0.538 | 0.707 | 0.639 | 0.786 |
| 99/00 | 0.318 | 0.268 | 0.373 | 0.523 | 0.462 | 0.589 | 0.608 | 0.540 | 0.678 |
| 00/01 | 0.293 | 0.241 | 0.348 | 0.412 | 0.358 | 0.478 | 0.712 | 0.640 | 0.788 |
| 01/02 | 0.282 | 0.238 | 0.332 | 0.497 | 0.434 | 0.561 | 0.567 | 0.507 | 0.635 |
| 02/03 | 0.302 | 0.253 | 0.355 | 0.484 | 0.425 | 0.544 | 0.624 | 0.559 | 0.694 |
| 03/04 | 0.301 | 0.256 | 0.354 | 0.488 | 0.428 | 0.548 | 0.617 | 0.554 | 0.681 |
| 04/05 | 0.312 | 0.261 | 0.361 | 0.504 | 0.444 | 0.561 | 0.619 | 0.557 | 0.690 |
| 05/06 | 0.278 | 0.233 | 0.336 | 0.486 | 0.423 | 0.552 | 0.572 | 0.512 | 0.639 |
| 06/07 | 0.331 | 0.281 | 0.386 | 0.568 | 0.503 | 0.630 | 0.582 | 0.521 | 0.648 |
| 07/08 | 0.311 | 0.268 | 0.357 | 0.580 | 0.516 | 0.637 | 0.536 | 0.485 | 0.595 |
| 08/09 | 0.334 | 0.289 | 0.381 | 0.602 | 0.543 | 0.658 | 0.555 | 0.496 | 0.620 |
| 09/10 | 0.295 | 0.251 | 0.347 | 0.538 | 0.478 | 0.601 | 0.548 | 0.490 | 0.608 |
| 10/11 | 0.306 | 0.260 | 0.356 | 0.553 | 0.487 | 0.618 | 0.554 | 0.494 | 0.620 |
| 11/12 | 0.272 | 0.229 | 0.319 | 0.512 | 0.451 | 0.572 | 0.532 | 0.477 | 0.595 |
| 12/13 | 0.232 | 0.192 | 0.274 | 0.461 | 0.399 | 0.523 | 0.503 | 0.447 | 0.563 |
| 13/14 | 0.224 | 0.186 | 0.266 | 0.426 | 0.364 | 0.484 | 0.525 | 0.469 | 0.595 |

**Table A10: Annual HG-ENLD trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.**

| Fishing | Combined | | | Binomial | | | Lognormal | | |
|---|---|---|---|---|---|---|---|---|---|
| year | Index | LCI | UCI | Index | LCI | UCI | Index | LCI | UCI |
| 94/95 | 0.545 | 0.460 | 0.635 | 0.542 | 0.478 | 0.607 | 1.000 | 0.896 | 1.106 |
| 95/96 | 0.299 | 0.250 | 0.352 | 0.466 | 0.401 | 0.527 | 0.642 | 0.578 | 0.711 |
| 96/97 | 0.275 | 0.231 | 0.329 | 0.429 | 0.369 | 0.494 | 0.640 | 0.576 | 0.713 |
| 97/98 | 0.306 | 0.259 | 0.360 | 0.486 | 0.427 | 0.555 | 0.629 | 0.562 | 0.698 |
| 98/99 | 0.327 | 0.279 | 0.383 | 0.525 | 0.463 | 0.585 | 0.623 | 0.559 | 0.692 |
| 99/00 | 0.203 | 0.166 | 0.243 | 0.407 | 0.343 | 0.467 | 0.499 | 0.448 | 0.554 |
| 00/01 | 0.226 | 0.191 | 0.266 | 0.506 | 0.439 | 0.570 | 0.447 | 0.400 | 0.497 |
| 01/02 | 0.221 | 0.183 | 0.261 | 0.470 | 0.403 | 0.536 | 0.471 | 0.425 | 0.521 |
| 02/03 | 0.304 | 0.259 | 0.356 | 0.555 | 0.489 | 0.622 | 0.547 | 0.491 | 0.609 |
| 03/04 | 0.347 | 0.298 | 0.396 | 0.631 | 0.567 | 0.693 | 0.551 | 0.495 | 0.610 |
| 04/05 | 0.348 | 0.300 | 0.399 | 0.643 | 0.579 | 0.706 | 0.541 | 0.488 | 0.602 |
| 05/06 | 0.312 | 0.268 | 0.361 | 0.623 | 0.563 | 0.682 | 0.501 | 0.449 | 0.560 |
| 06/07 | 0.306 | 0.268 | 0.348 | 0.744 | 0.691 | 0.794 | 0.411 | 0.367 | 0.455 |
| 07/08 | 0.279 | 0.240 | 0.320 | 0.654 | 0.595 | 0.713 | 0.427 | 0.384 | 0.478 |
| 08/09 | 0.219 | 0.187 | 0.255 | 0.549 | 0.485 | 0.610 | 0.399 | 0.357 | 0.448 |
| 09/10 | 0.188 | 0.159 | 0.221 | 0.553 | 0.489 | 0.616 | 0.340 | 0.306 | 0.378 |
| 10/11 | 0.175 | 0.148 | 0.204 | 0.540 | 0.480 | 0.604 | 0.324 | 0.289 | 0.361 |
| 11/12 | 0.152 | 0.125 | 0.182 | 0.490 | 0.421 | 0.560 | 0.311 | 0.277 | 0.346 |
| 12/13 | 0.125 | 0.103 | 0.149 | 0.420 | 0.357 | 0.488 | 0.297 | 0.266 | 0.329 |
| 13/14 | 0.146 | 0.121 | 0.173 | 0.472 | 0.403 | 0.537 | 0.309 | 0.278 | 0.343 |

**Table A11: Annual WCNI trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.**

| Fishing | Combined | | | Binomial | | | Lognormal | | |
|---|---|---|---|---|---|---|---|---|---|
| year | Index | LCI | UCI | Index | LCI | UCI | Index | LCI | UCI |
| 94/95 | 0.374 | 0.312 | 0.446 | 0.372 | 0.326 | 0.421 | 1.000 | 0.893 | 1.131 |
| 95/96 | 0.422 | 0.350 | 0.504 | 0.343 | 0.297 | 0.391 | 1.231 | 1.096 | 1.379 |
| 96/97 | 0.335 | 0.285 | 0.390 | 0.393 | 0.345 | 0.436 | 0.855 | 0.772 | 0.951 |
| 97/98 | 0.318 | 0.268 | 0.371 | 0.363 | 0.321 | 0.410 | 0.875 | 0.786 | 0.967 |
| 98/99 | 0.268 | 0.224 | 0.314 | 0.328 | 0.286 | 0.370 | 0.818 | 0.734 | 0.906 |
| 99/00 | 0.244 | 0.205 | 0.287 | 0.293 | 0.256 | 0.331 | 0.832 | 0.747 | 0.923 |
| 00/01 | 0.332 | 0.283 | 0.388 | 0.395 | 0.353 | 0.441 | 0.841 | 0.752 | 0.935 |
| 01/02 | 0.300 | 0.255 | 0.347 | 0.406 | 0.362 | 0.453 | 0.738 | 0.664 | 0.816 |
| 02/03 | 0.360 | 0.309 | 0.414 | 0.434 | 0.388 | 0.482 | 0.828 | 0.741 | 0.916 |
| 03/04 | 0.315 | 0.267 | 0.367 | 0.401 | 0.358 | 0.445 | 0.785 | 0.708 | 0.870 |
| 04/05 | 0.334 | 0.291 | 0.383 | 0.503 | 0.460 | 0.549 | 0.665 | 0.596 | 0.735 |
| 05/06 | 0.281 | 0.239 | 0.329 | 0.396 | 0.351 | 0.441 | 0.711 | 0.632 | 0.797 |
| 06/07 | 0.332 | 0.281 | 0.383 | 0.489 | 0.437 | 0.543 | 0.678 | 0.609 | 0.756 |
| 07/08 | 0.266 | 0.226 | 0.309 | 0.409 | 0.363 | 0.456 | 0.649 | 0.583 | 0.715 |
| 08/09 | 0.268 | 0.228 | 0.307 | 0.505 | 0.457 | 0.555 | 0.530 | 0.476 | 0.590 |
| 09/10 | 0.269 | 0.232 | 0.315 | 0.502 | 0.452 | 0.555 | 0.536 | 0.479 | 0.601 |
| 10/11 | 0.348 | 0.302 | 0.408 | 0.525 | 0.474 | 0.578 | 0.662 | 0.591 | 0.740 |
| 11/12 | 0.364 | 0.315 | 0.423 | 0.545 | 0.496 | 0.594 | 0.668 | 0.597 | 0.744 |
| 12/13 | 0.365 | 0.313 | 0.421 | 0.538 | 0.485 | 0.586 | 0.680 | 0.605 | 0.760 |
| 13/14 | 0.352 | 0.307 | 0.405 | 0.569 | 0.521 | 0.616 | 0.618 | 0.552 | 0.692 |

## APPENDIX 4. SIMULATING THE EFFECT OF CHANGES IN THE REPORTING OF SMALL TRAWL CATCHES ON STANDARDISED CPUE INDICES.

A simple simulation study was conducted to investigate the influence of the reporting of small catches from individual fishing effort event on the resulting CPUE indices derived from standardised CPUE models of catch occurrence and magnitude of catch.

A simulated catch and effort data set was generated based on the following specifications.

- The sampled population was at a constant level for a ten year period.
- The fishery was comprised of three vessels each with 100 fishing events from each year. The catchability of the three vessels was equivalent.
- For each vessel/year, the proportion of positive catches was randomly generated from a binomial distribution with a probability of 0.5. This corresponds to approximately 50% of the catch records having a positive catch.
- For each vessel/year, positive catches were randomly generated from a lognormal distribution with a mean of 100 kg and a CV of 0.2.

A standardised CPUE analysis was then conducted on the base simulation data set. The analysis included two components: a binomial model of the presence/absence of catch and a lognormal model of the magnitude of the positive catches. Both CPUE models included the categoric variables of vessel and year. Annual indices were derived from the two models and combined indices were derived from the product of the two sets of indices. All indices were normalised to the average of the series.

An alternative data set was then generated from the base data set which included a time variant bias in the reporting of smaller catches for one of the three vessels. The reporting bias was implemented by assigning annual positive catch records below a certain threshold to a zero catch. The deleted component of the catch was then reallocated to the remainder of the positive catch records for the vessel/year in proportion to the catch of the individual records. The initial catch threshold was set at the 30% quantile of the annual positive catches and was reduced by 5% over the successive years. Thus, the reporting bias was reduced to zero by the 7$^{th}$ year. The binomial and lognormal CPUE models were then rerun with the alternative data set and the resulting indices compared.

The binomial indices derived from the alternative data set were negatively biased, while the lognormal indices were positively biased over the time period. However, the combined indices from the base and alternative data sets were very similar as the multiplication of the two sets of indices countered the positive and negative biases introduced by the reporting bias (Figure A1). The larger sample of simulations (1000) indicated that a minor positive bias may remain in the final combined indices derived from the reporting bias data set; however, the magnitude of the bias is trivial compared to the binomial and lognormal indices (Figure A2).

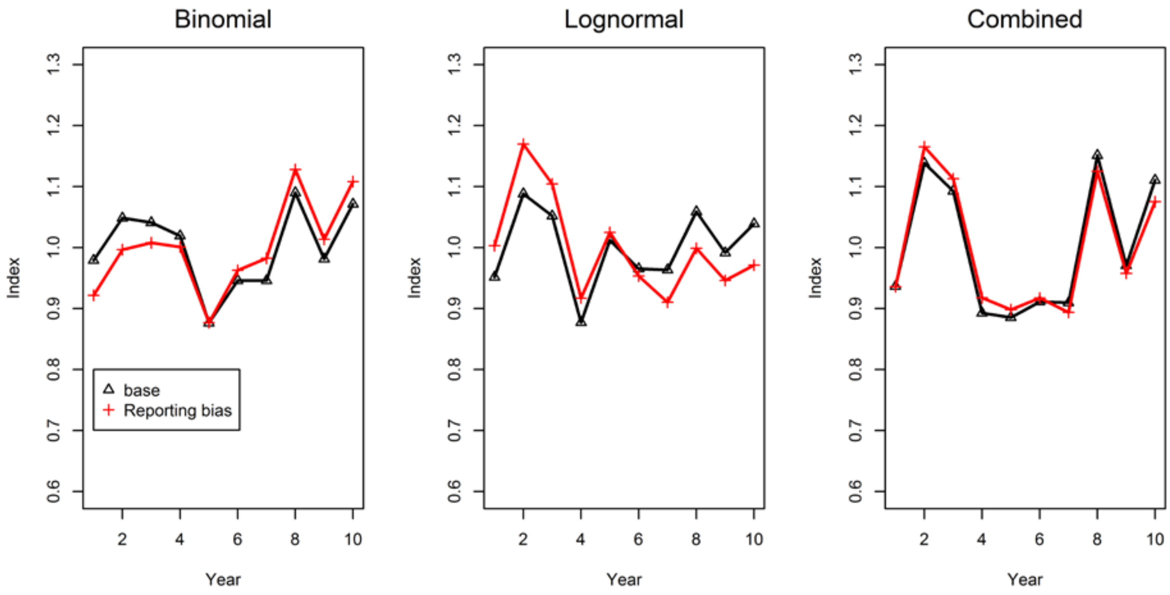


**Figure A1: An example of the comparison of the binomial, lognormal and combined CPUE indices derived data sets with and without (base) reporting bias (from a single iteration of the simulation study).**

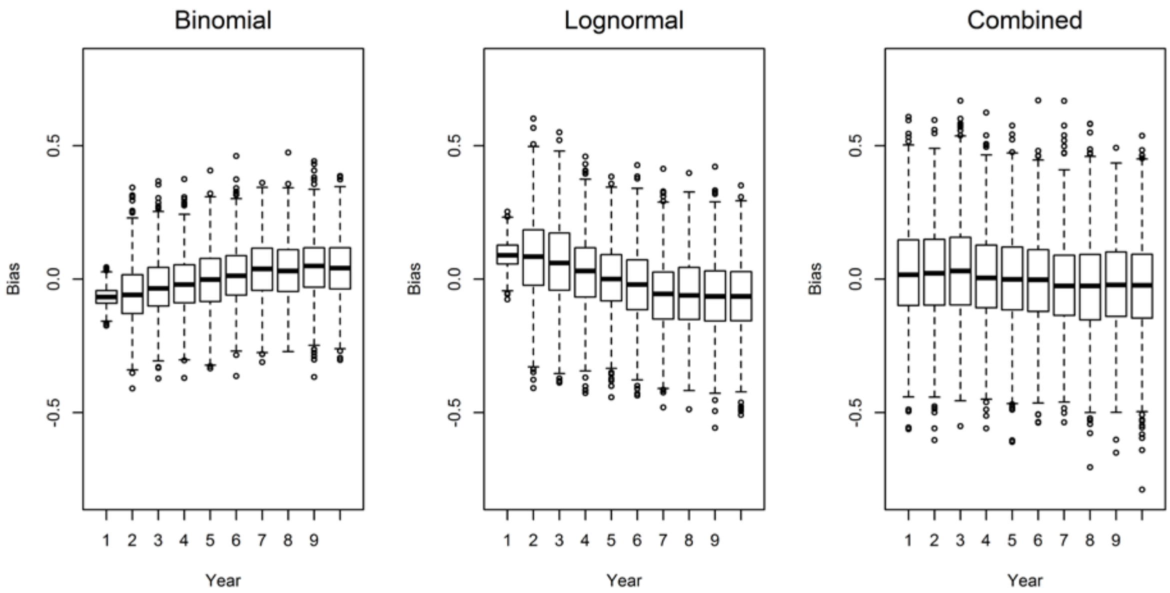


**Figure A2: Boxplots of the annual bias introduced to the binomial, lognormal and combined CPUE indices due to changes in the reporting of small positive catches (results from 1000 simulations).**