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QUANTIFYING VESSEL PERFORMANCE IN THE CCAMLR TAGGING PROGRAM: SPATIALLY AND TEMPORALLY CONTROLLED MEASURES OF TAG-DETECTION RATES

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Abstract

A reliable commercial fish tagging program is critical to the successful management of a number of toothfish fisheries in Antarctica. In particular, tag-detection rates are directly linked to stock size estimated from the tag data in an integrated stock assessment. Previous attempts to assess the relative reliability of vessels in detecting tagged fish have been inconclusive due to low numbers of recaptures after controlling for spatial and temporal confounding. This paper presents a method that utilised most of the data while also controlling for spatial and temporal variables using a case-control study design, and uses this method to develop relative indices for detection rate performance for vessels involved in the Antarctic toothfish tagging in CCAMLR Subareas 88.1 and 88.2.

The index derived provides evidence of significant differences in the relative performance of vessels in the Antarctic toothfish fishery in CCAMLR Subareas 88.1 and 88.2, as well as changes in the performance of some vessels over time. Further investigations show that these indices appear robust to the assumptions made, in particular the choice of the control group and the maximum distance between fishing events compared. The results suggest that the method can be useful for assessing the relative vessel tagging performance across all CCAMLR fisheries, and may potentially be developed as a more general method for comparing relative performance of spatially and temporally heterogeneous datasets.

Introduction

In CCAMLR Subareas 88.1 and 88.2, tag-release and -recapture data are used in an integrated age-structured stock assessment model of Antarctic toothfish (*Dissostichus mawsoni*) to determine sustainable yields (Mormede et al., 2011a, 2011b; Mormede, 2011). In those analyses, the assumed values of mortality of tagged fish and the subsequent detection rate of recaptured tagged fish are important input parameters. For example, underestimating the tag-detection rate of the fleet will result in an overestimate of the stock biomass. The assessment model assumes that all vessels have equal tag-detection rates, and therefore, including observations from vessels with low detection rates, could lead to an overestimate of the stock biomass.

Comparison of the raw recapture rates of different vessels has suggested that there may be important differences between vessels in their respective detection rates of tagged fish (Agnew et al., 2005; Dunn et al., 2009; Mormede et al., 2011c). However, after controlling for the time and location of recapture effort through disaggregating the data into temporal and location subsets, low sample sizes have meant that it was not possible to conclude if there were significant differences in the relative performance between vessels.

In this analysis a case-control study design is used to develop an index of relative performance of the detection rate of each vessel with the rest of the fleet. The scaled number of tags recaptured by a given vessel (case) is divided by the number of tags recaptured by a subset of the data (control). Scaling is carried out for each fishing event to account for the difference in the number of fish scanned by the case and the control fishing events. Spatial and temporal variability of the recapture rates are accounted for in the calculation by using different levels of aggregation in the control subset (i.e. within x months and y km around the case). This method is applied to vessels in the Antarctic toothfish fishery in Subareas 88.1 and 88.2. This paper investigates the robustness of the method to assumptions around the size of the aggregation and the choice of control data. Further, it investigates if the performance of each vessel has changed over time by applying the method to the annual fishing trips for each vessel.

Methods

Initially, the case is defined as an individual vessel, but the analysis is later extended to vessel-season (trip), and to vessel-seasons aggregated in three-season bins in order to investigate changes in performance of individual vessels between seasons. Note that the fishing season in Subareas 88.1 and 88.2 starts on 1 December each year, and ends when the quota has been fully caught which, in recent years, has been between 15 January and 28 February. Each vessel is assigned a unique trip number for each season, which corresponds to a vessel-season identifier.

The analysis was carried out on a haul basis, defined as a fishing event. The location of each fishing event was approximated as the midpoint of each haul. Each fishing event of the case was paired with fishing events from all other vessels that were carried out within a defined distance (space window) and time (time window) of the case fishing event. Then, using all fishing events of the case that were matched with at least one control event, the ratio of the scaled number of tags recaptured by the case fishing events to the number of tags recaptured by the matched control fishing events was calculated. This ratio provides an index of relative performance of the case compared with the control. Aggregating the data over all fishing events provides the statistical power that can be lacking in analyses that disaggregate the data into spatial or temporal subsets. By iterating over all events for all vessels, a relative index of tag-detection rate for each vessel is generated, with a value of one representing the average performance of all vessels.

The key assumption is that within the same space and time window, the spatial and temporal factors that may affect fish behaviour and probability of capture are identical, and therefore any differences in the observed rate of recapture can be attributed to differences in the relative detection rates of the vessels. The index for each vessel is also dependent on the performance of the vessels it is compared with, whereby a performance higher than one might be due to a vessel being only compared with vessels of lower performance.

The method is applied to fishing effort in Subareas 88.1 and 88.2. The reference group is defined as all fishing events carried out by all vessels which had fished in Subareas 88.1 or 88.2, but data from vessels that were in their first season of tagging were excluded. The premise is that vessels in their first season might be in a learning phase and may not have fully developed their tag-detection process. This assumption was tested by running a sensitivity trial whereby the reference group included the first season of tagging. Results were mostly similar, apart from a few vessels with little information. Note that the case vessel is excluded from the reference group so that it is not in the reference group and hence not compared to itself.

A time window of one season is used, as fish movement is not expected to be significant over the relatively short fishing season. Also, it is plausible that recapture rates may differ between case and controls due to individual fish movement or tag-loss effects over periods longer than one season. Short time windows may be considered if fish were thought to move rapidly. This would reduce the number of available controls for each case and therefore reduce the power of the analysis to detect a difference. The analysis assumed that the sequence in which the case and controls recapture tagged fish does not materially change the probability of recapture due to the large number of tags available for recapture in any location. The within-season tag recaptures are ignored in the analysis, as these would be sensitive to the order of release and therefore that of the case and control fishing events.

The space window used was a circle with a radius of 20 km, centred on the location of the case fishing event. This assumes that the recapture events within the area defined by the space window have the same probability of recapture for both the case and the controls, irrespective of fish movement or tag loss rates. Sensitivities that used space windows of 10, 50, 100 and 200 km were also investigated. The space window of 20 km was chosen because this value corresponded to the maximum

Table 1: Simulation results for three vessels (the number of the vessel corresponds to the number in further figures) when randomly retaining 25 to 75% of their recaptures. The range of the relative detection rate index corresponds to the 10 simulations carried out, excluding confidence intervals.

Vessel	% recaptures	Range index
24	25	0.05–0.20
	50	0.28–0.46
	75	0.47–0.63
	100	0.72
15	25	0.19–0.75
	50	0.54–1.21
	75	1.13–1.43
	100	1.66
10	25	0.19–0.43
	50	0.44–0.77
	75	0.73–1.01
	100	1.2

median distance between the release and recapture of tagged toothfish within season for most years (Figure 1).

The method is applied in three scenarios: the first to all vessels (across all seasons); and, as sensitivities, the second to each individual vessel-season; and the third to the individual vessel-seasons aggregated into three-season bins. Note that the method can be applied to any subset of effort as the case, against any comparable subset of effort for the control group. With larger subsets, the larger sample size will improve the statistical power to detect differences between the relative indices, but with a corresponding reduction in resolution.

The relative detection rate is calculated as the sum of the number of tags recaptured by the case vessel ($recaptures_{case}$) scaled by fishing event, and divided by the sum of the number of tags recaptured by the matched control fishing events ($recaptures_{control}$). For each fishing event, the number of tags reported by the case was scaled to give the expected number of tags that they would have recaptured if they had scanned the same number of fish as the paired control fishing events by multiplying it by the number of scanned fish by the matched control fishing events ($scanned_{MatchedControl}$) and dividing by the number of scanned fish by the case fishing event ($scanned_{case}$) (Equation 1). The number of fish scanned were the total number of fish caught that were checked for tags, and included fish that were caught untagged and subsequently released with a tag.

$$index = \frac{\sum_{case} recaptures_{case} \times scanned_{MatchedControl} / scanned_{case}}{\sum_{matched} recaptures_{control}} \quad (1)$$

Approximate 90% confidence intervals were calculated for each case-control comparison by parametric bootstrap using 1 000 replicates, and by assuming that the number of tags recaptured within each fishing event followed a Poisson distribution with rate equal to the number of tags recaptured.

Results

Simple simulations of the index were used to determine the sensitivity of the method to detect changes in performance with real changes in underlying performance. A trial dataset was created, whereby the number of tags recaptured by a single vessel was artificially reduced through the random removal of recaptured tags prior to running the analysis. This process was carried out for three different vessels of different performance, removing 25, 50 or 75% of their recaptures randomly, repeating each process 10 times. Results showed that, as the number of tags removed from the analysis increased, the relative performance of that vessel deteriorated, capturing in effect the artificial reduction in tag detection of that vessel. The reduction in the index value was directly proportional to the reduction in the number of tags recaptured (Table 1).

Indices of relative detection rates of recaptured fish were calculated for Subareas 88.1 and 88.2 by vessel for a space window of 20 km and time window of one season (Figure 2). The amount of fishing effort covered by this analysis is expressed on the right-hand side of the figure as the number of fish scanned by each vessel that are included in the analysis, and in brackets the percentage of the total effort of that fishing vessel that is included in the analysis. For most vessels, that number is less than 100%, reflecting that not all fishing events could be paired with fishing events from the control group.

Sensitivities of the results to the choice of the size of the space window were investigated (Figure 3). As the space window increased, the number of available controls increased and there was a corresponding small reduction in the width of the confidence intervals. With size widows of 40 km or greater, some indices changed dramatically (e.g. vessels 10 and 18 in Figure 3). This may reflect bias that was introduced from fish that were within the chosen distance from the case fishing event not being equally likely to be recaptured. At distances of 20 km and lower, the relative values for the indices were unchanged; hence 20 km was chosen as the balance between reducing the width of the confidence intervals in the indices and introducing possible bias.

The index was calculated for each vessel, each vessel-season, and for vessel-seasons aggregated in three-season bins. The analyses for vessel-seasons and vessel-seasons aggregated in three-season bins were to investigate changes in performance of vessels between years.

Due to the limited sample size at vessel-season level, it was impossible to conclude whether there was a real change in performance of the vessels through time, or in performance between vessels. Aggregation into three-season bins (Figure 4) showed that significant changes in performance over time for a few individual vessels could be detected; the relative performance of two vessels improved with time in the fishery (vessels 6 and 7 in Figure 4) and two decreased (vessels 15 and 22 in Figure 4). The performance of the remaining vessels did not change significantly over time in the fishery.

The sensitivity of the index to the possible choices of the control fishing events was investigated in two ways. In the first, all fishing events from all vessels were included (but excluded the case vessel). In the second, only fishing events from vessels which had been fishing for more than three seasons were included, representing a stable component of the fishing fleet. In both, the indices were similar for almost all vessels. Where there was a difference, the effect appeared to be due to the limited sample size rather than a real change in performance.

Discussion

Previous comparisons of recapture rates of different vessels suggested that there may be important differences between vessels in their respective detection rates of tagged fish (Agnew et al., 2005; Dunn et al., 2009; Mormede et al., 2011c). However, the relatively small numbers of recaptured tagged fish in the program and the confounding effect of spatially and temporally variable fishing effort prevent simple analyses.

The case-control approach presented in this paper can allow the development of spatially and temporally controlled measures of performance indicators for use in tag-based assessments of CCAMLR fisheries. The method controls for spatial and temporal differences in the fish population and the distribution of fishing effort, whilst the aggregation across seasons conserves the statistical power of the analysis.

In applying this approach to the analysis of detection rates of tagged fish, it is concluded that there are significant differences in the relative tagging performance of different vessels in the toothfish fishery in Subareas 88.1 and 88.2, and that the performance of some of these vessels has changed over time.

Although this methodology requires an assumption of control group and maximum distance between fishing events to be compared, sensitivity analyses suggest that the index was unchanged under different assumptions. However, the ability to draw substantive conclusions was limited when the analysis was carried out for individual vessel-seasons due to the low sample size. Therefore, some aggregation is required.

This analysis derived performance indices calculated for all vessels but only provides a relative ranking between vessels. For such an analysis to be used to inform stock assessment (Mormede et al., 2011a, 2011b), a decision on a level of acceptable performance would be required to use in the stock assessment model as the entire fleet in the model has a single tag-detection rate. It is suggested that vessels with performance indices that were low or with very large confidence intervals (very uncertain) be excluded as they reflect very large uncertainty in the index.

The results suggest that the method can be useful for assessing the relative performance of vessels in tag detection across all CCAMLR fisheries. Further, it may be possible to extend the methods to investigate the relative performance of other spatially and temporally heterogeneous datasets, including for example comparison of by-catch reporting rates or relative catch-per-unit-effort.

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References

Agnew, D.J., G.P. Kirkwood, J. Pearce and J. Clark. 2005. Investigation of bias in the mark-recapture estimate of toothfish population size at South Georgia. Document *WG-FSA-SAM-05/06*. CCAMLR, Hobart, Australia: 16 pp.

Dunn, A., S.M. Hanchet and J. Devine. 2009. Descriptive analysis of the toothfish (*Dissostichus* spp.) tagging program in Subareas 88.1 and 88.2 for the years 2000/01 to 2008/09. Document *WG-FSA-09/38*. CCAMLR, Hobart, Australia: 28 pp.

Mormede, S. 2011. Investigation of the sensitivity of the Ross Sea toothfish assessment to withholding subsets of the available data. Document *WG-SAM-11/17*. CCAMLR, Hobart, Australia: 8 pp.

Mormede, S., A. Dunn and S.M. Hanchet. 2011a. Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 88.2 SSRUs 88.2C–G for the years 2002–03 to 2010–11. Document *WG-FSA-11/43*. CCAMLR, Hobart, Australia: 17 pp.

Mormede, S., A. Dunn and S.M. Hanchet. 2011b. Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea for the years 1997–98 to 2010–11. Document *WG-FSA-11/42*. CCAMLR, Hobart, Australia: 40 pp.

Mormede, S., A. Dunn and S.M. Hanchet. 2011c. Descriptive analysis of the toothfish (*Dissostichus* spp.) tagging programme in Subareas 88.1 & 88.2 for the years 2000–01 to 2010–11. Document *WG-FSA-11/46*. CCAMLR, Hobart, Australia: 32 pp.

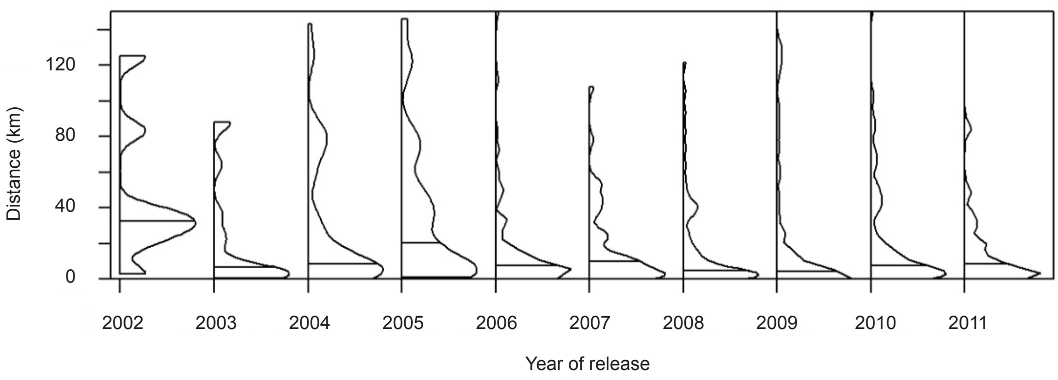

Figure 1: Distribution of distances between release and recapture locations of tagged toothfish recaptured within season, presented by year of release. The horizontal line indicates the median of each distribution.

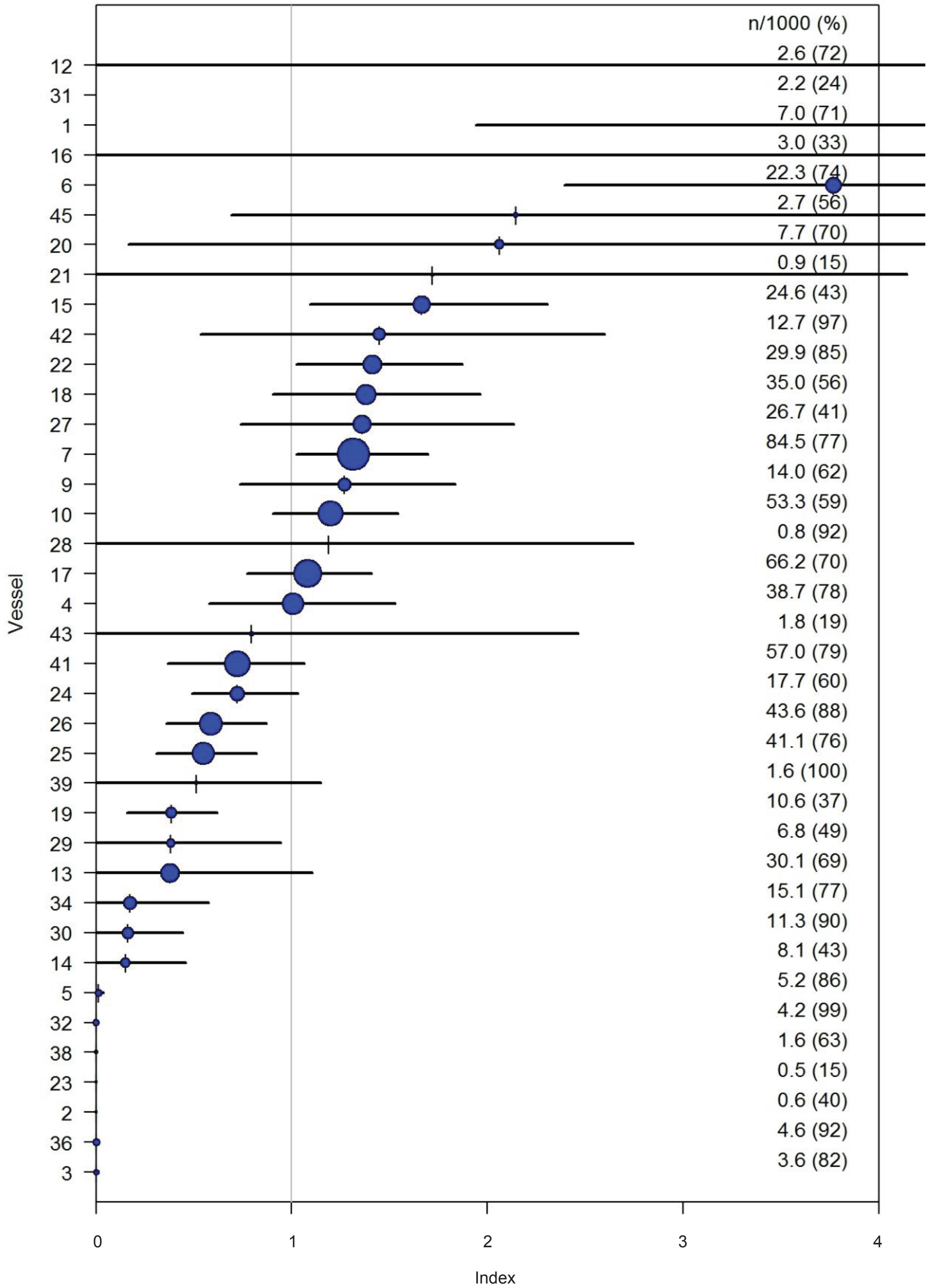

Figure 2: Indices of relative detection rates of tagged fish by vessel. The circle and vertical bars indicate the index value. The area of each circle is proportional to the number of fish scanned by each vessel in the analysis. The grey vertical line represents an index of 1, where case and control performed identically (i.e. had the same recapture rate). Horizontal bars show the 90% confidence interval, with confidence intervals ≥4 truncated at 4. The numbers on the right represent the number (and percentage of the scanned fish included in the analysis for each vessel) of scanned fish from the case fishing events in the analysis.

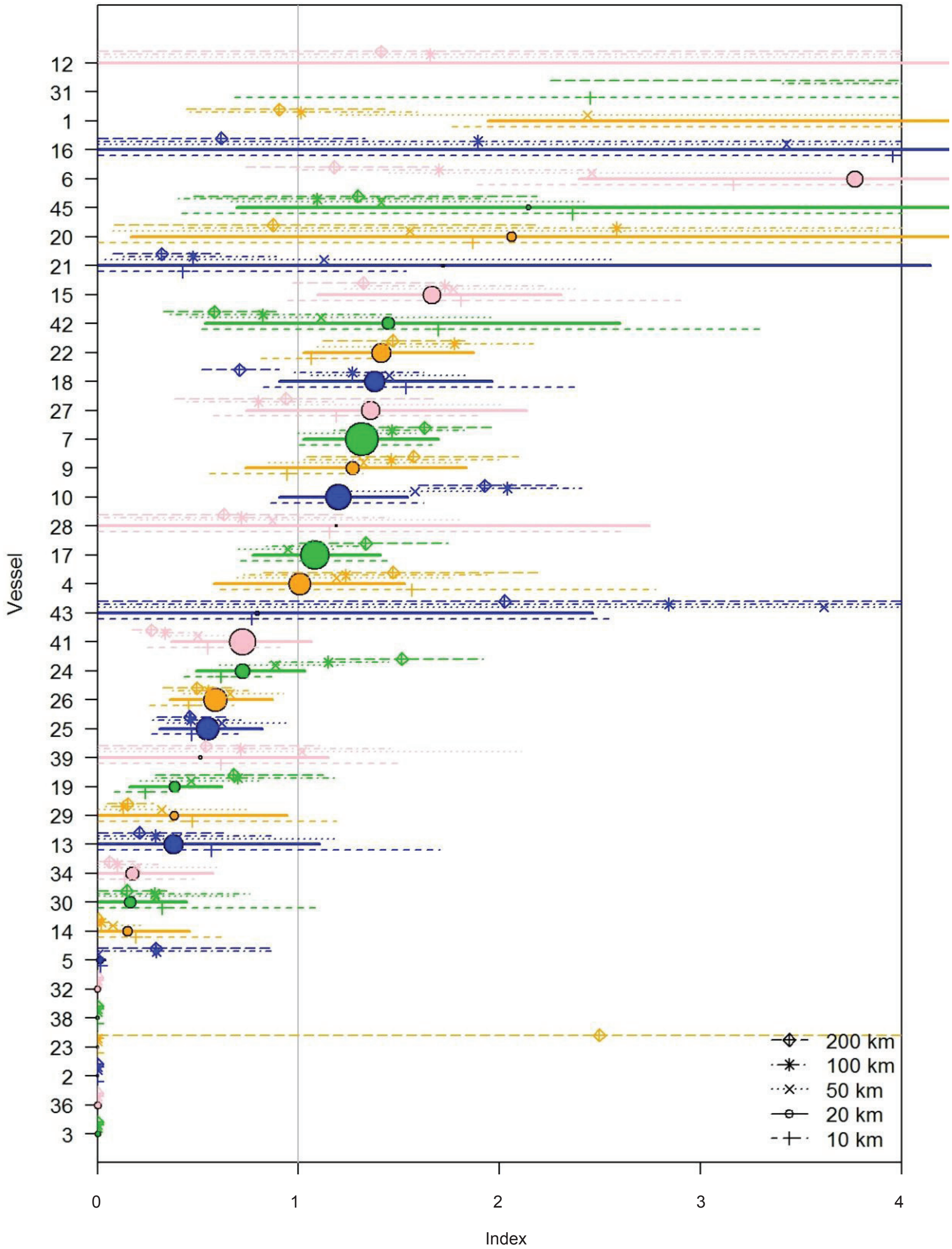

Figure 3: Indices of relative tag-detection rates of tagged fish by vessel for various space windows. The area of each circle is proportional to the number of fish scanned by each vessel which could be paired with a control fishing event. The grey line represents a ratio of 1, where case and control performed identically (i.e. had the same recapture rate). Horizontal bars show the 90% confidence intervals with confidence intervals ≥4 truncated at 4. Vessels are plotted in different colours to help the reader.

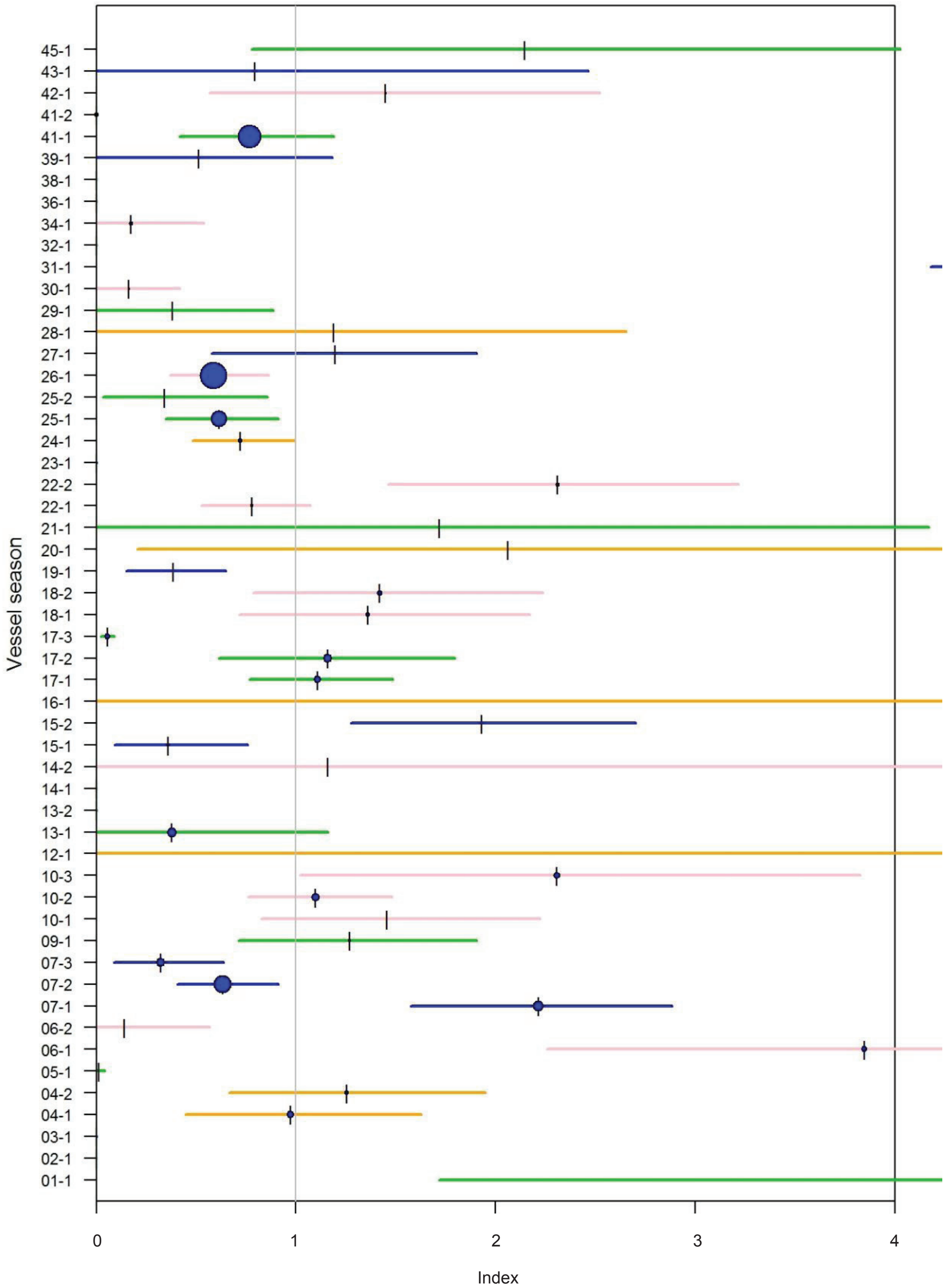

Figure 4: Indices of relative tag-detection rates of tagged fish by vessel in three-year blocks. The area of each circle is proportional to the number of fish scanned by each vessel which could be paired with a control fishing event. The grey line represents a ratio of 1, where case and control performed identically (i.e. had the same recapture rate). Horizontal bars show the 90% confidence intervals with confidence intervals ≥4 truncated at 4. For each vessel, 1 is the most recent three years of data, 2 is the previous three years and 3 the oldest three years where applicable, the oldest block of data might include less than three years of data (e.g. if the vessel fished 4 years in total). Vessels are plotted in different colours to help the reader.