Abundance Estimates and Diagnostics of Antarctic Minke Whales from the Historical IDCR/SOWER Survey Data Using the OK Method

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ABSTRACT

This document presents the specifications of the latest OK method and the results on the estimation of the abundances of Antarctic minke whales from the historical IDCR/SOWER survey data. The method is based on a design-based approach with the revised hazard probability model, which was applied to the data obtained by the surveys from 1985/86 to 2003/04. We changed the three points from the previous model: (1) the adoption of radial distance and sighting angles for the Q function, (2) mean school size dependent on the stratum, and (3) detection functions estimated separately for each Area and circumpolar set. The abundance for each management area was estimated using the "survey-once" method. The total abundances in the survey areas were 1,286,589 (CV: 0.202) for CPII and 688,389 (CV: 0.182) for CPIII with the actual northern boundary of the surveyed strata, when we use the definite duplicates only. We calculated the abundance estimate when using the definite and possible duplicates as a sensitivity test. The difference between the two results was not so large, but the abundance estimates including the possible duplicates were slightly lower as expected.

1. INTRODUCTION

The International Decade of Cetacean Research - Southern Ocean Whale and Ecosystem Research (IDCR/SOWER) surveys have been conducted annually in the Antarctic since the 1970s. The sightings data of Southern Hemisphere minke whales (*Balaenoptera bonaerensis*) have been collected as one of main purposes of the IDCR/SOWER surveys. The sightings data consist of three circumpolar sets of cruises: 1978/79-1983/84 (1st circumpolar: CPI), 1985/86-1990/91 (2nd circumpolar: CPII), and 1991/92-2003/04 (3rd circumpolar: CPIII). The abundance estimates for Southern Hemisphere minke whales (*Balaenoptera bonaerensis*) were estimated by conventional line transect methods (Branch and Butterworth, 2001; Matsuoka et al., 2003; Branch, 2006). The abundance estimates for the 3rd circumpolar surveys obtained from the IDCR/SOWER data showed a dramatic decrease compared with the 2nd circumpolar surveys. Some members in the Scientific Committee of International Whaling Commission (IWC/SC) doubted whether it was the true decrease. Consequently, IWC/SC has listed a number of possible causes that might result in the change in estimates (IWC, 2002).

One of the important assumptions in conventional line transect sampling is that all animals on the line are detected without failure, i.e., the probability of seeing an animal if it occurs on the survey trackline, commonly called $g(0)$, is equal to 1. However, the diving behaviour of cetaceans can lead to this assumption being violated, even if the animal occurs on the trackline. Since minke whales are relatively small baleen whales, it is often difficult for observers on the sighting vessel to detect

them so that $g(0)$ tends to be less than 1 (Schweder et al., 1997; Skaug et al., 2004; Okamura et al., 2003, 2005). IWC (2002) suggested that the difference of the abundance estimates of Branch and Butterworth (2001) would possibly be attributed to changes in $g(0)$ to some extent. Fortunately, the IDCR/SOWER surveys have conducted double-platform line transect sampling with independent observers, which gives the information needed to estimate $g(0)$. In this paper, we provide the revised abundance estimates of CPII and CPIII with $g(0)$ estimation by independent observer data.

There is a remarkable difference in mean school sizes between CPII and CPIII data (Branch and Butterworth, 2001; IWC, 2002). Mean school sizes could be overestimated if one uses a conventional line transect method with $g(0) = 1$ when $g(0)$ is in fact less than 1. Since $g(0)$ and mean school size are closely related to each other (Cooke, 1985; Butterworth, 2002), the trend and abundance estimates of Southern Hemisphere minke whales could be miscalculated unless there is an appropriate allowance for $g(0)$ and bias in mean school size. The survey effort of IDCR/SOWER surveys is divided into the Closing and Passing modes. In the Closing mode, when a school of whales is detected, the vessel turns off the trackline and closes with the sighting to confirm the school size and species. The Closing mode data therefore provide more accurate information on school size, while the Passing mode data are representative of double-platform line transect sightings collected by independent observers. Okamura et al. (2005) gave a basic model to estimate $g(0)$ and a school size distribution for IDCR/SOWER data dealing with the Closing and Passing mode data together in their analysis method. Okamura and Kitakado (2008a) modified their model and showed that it could provide relatively small bias of abundance estimates for the simulated data produced by IWC (Palka and Smith, 2004, 2005). We use the hazard probability model used in Okamura and Kitakado (2008a) for the real IDCR/SOWER datasets to estimate the abundance estimates. We added the three main changes to the model: (1) the adoption of radial distance and sighting angles for the Q function, (2) mean school size dependent on the stratum, and (3) detection functions estimated separately for each Area and circumpolar set.

The next section describes the data and the methodology used in this paper. The mathematical details of the model are given in Appendices. Section 3 presents the results and discussion.

2. MATERIALS AND METHODS

2.1. The data

We use the IDCR/SOWER standard dataset extracted from DESS by M. L. Burt (July 27, 2005). We basically follow the procedure in Branch and Butterworth (2001, 2006) as far as possible to process data for analysis. However, when we have some differences in the procedure due to the difference of the analysis methods, we handle the data in a fashion unique to ourselves. For example, we use duplicate sightings to estimate $g(0)$ and confirmed school sizes in the Passing and Closing modes to estimate school size distribution unlike Branch and Butterworth (2001). The details of our procedure are given below.

Circumpolar set

We use 1985/86 - 2003/04 data, which correspond to CPII and CPIII.

Vessel Speed

The vessel speeds recorded in the effort records are used. Notice that they are not constant during

the surveys. When the value is 888 (variable speed) or 999 (missing), we use the preset speed, 12 knot (before 1986/87) and 11.5 knot (after 1987/88).

Survey effort

The survey effort is calculated by the vessel speed times the traveled time in the effort records. We use all the data with different activity codes without excluding the codes "BH" and "BL" according to Branch (2006).

Species

We use data with the species code 04, 91, 92, 39. "Like minke" is included.

Sea state

We use a new category for simplicity in that 0-2 is good (0) and 3-5 is bad (1).

Platform

The original category is the following: 1 - topman in standard barrel, 2 - topman in IO position, 3 - upper bridge, primary observer, 4 - upper bridge, not primary observer, 5 - 1 and 4 simultaneously, 6 - 2 and 4 simultaneously.

We use a new category in that 1 & 5 $\rightarrow$ A, 2 & 6 $\rightarrow$ B, and 3 & 4 $\rightarrow$ C as in Appendix B.

Sighting distances and angles

Bias-corrected distances and angles are used. Angles are truncated at 90 degrees and transformed to radian. We use the perpendicular and forward distances transformed from the radial distances and angles in the analysis. The perpendicular distances transformed are truncated at 1.5 nautical miles, while the forward distances are not truncated.

School size

Best school size estimates are used.

Duplicate

Duplicate sightings in the IO-tracking searching under closing mode in 1987/88 are removed.

We adopt "definite" duplicates as the true duplicates under passing mode. However, we also use "definite + possible" duplicates as a sensitivity test. When any covariate other than sighting distances and angles is different in a duplicate sighting, we conform to the following rules:

- School size: If confirmed school size is only one, we used the value. If there are multiple confirmed school sizes or no confirmed school size, we then used the value of the platform with the highest sighting position based on the notion that a topman was the most reliable.
- Confirmation status of school size: If we have at least one confirmed school size, it was defined as confirmed.
- Sea state: When the sea states were different, we adopted the sea state with the earlier record time.
- Vessel speed: When the vessel speed was different, we used the averaged value.

The case with different covariates by different platforms in a duplicate sighting is few and therefore the above minor adjustment will have little effect on abundance estimation.

Truncation

Perpendicular distances are truncated at 1.5 nautical miles according to conventional method (Branch and Butterworth, 2001). When the sightings are duplicates, we use the averaged distances for the simultaneous duplicates and the distances of later sightings for the delayed duplicates.

2.2. The hazard probability model and the likelihood function

The detection probability density function of the animal positioned at the perpendicular distance x and the forward distance y assuming a Poisson surfacing pattern with the mean surfacing rate λ is

$$p(x,y) = \frac{\lambda}{v} Q(x,y) \exp\left\{ -\frac{\lambda}{v} \int_y^\infty Q(x,y')dy' \right\}, \tag{1}$$

where v is the vessel speed, and $Q(x,y)$ is a hazard probability function based on a logistic function (Appendix A). The parameters in Eq. (1) are linked to various factors such as school size, weather condition (Beaufort Sea State), platform type, circumpolar set, and survey area, which are potentially important on abundance estimation (Appendices A and B). We use 6 point Gaussian integration for all the integrals hereafter. In addition, we replace $\sum_{s=1}^{\infty}$ by $\sum_{s=1}^{s_{max}}$ with $s_{max} = 30$ for the application to the real data.

We construct a likelihood function conditioned on detection patterns and confirmation status of school size (Appendix B). For the confirmed school size, the likelihood function is

$$P_C(x_i, y_i, u_i, s_i) = \frac{c_k p_k(x_i, y_i, u_i | s_i)\pi(s_i)}{\mathrm{esw}_k}, \tag{2}$$

and for the unconfirmed school size, the likelihood function is

$$P_U(x_i, y_i, u_i, z_i) = \frac{\sum_{s=1}^{\infty}(1-c_k)\rho(z_i|s)p_k(x_i, y_i, u_i|s)\pi(s)}{\mathrm{esw}_k}, \tag{3}$$

where k is an index that denotes Passing/Closing mode, c_k is the probability of school size confirmation dependent on some covariates such as true school size, $\rho(z_i|s)$ is the probability that the school size is recorded as z_i given the true school size is s and the observed school size z_i is unconfirmed. u_i is a type of detection pattern, p_k is a detection probability density function given the mode k and the detection pattern u_i, and $\pi(s)$ is a probability mass function of true school size, and esw_k is

$$\mathrm{esw}_k = \int_0^{x_{max}} \int_0^\infty \sum_{s=1}^{\infty} \sum_{u}^{\text{all patterns}} p_k(x, y, u|s)\pi(s)dxdy. \tag{4}$$

For the simplification of calculation, when $z_i \geq z_{max}$, the above probability for the unconfirmed school size is modified to

$$P_U(x_i, y_i, u_i, z_i \geq z_{max}) = \frac{\sum_{s=1}^{\infty}(1-c_k)\{1 - \sum_{z=1}^{z_{max}-1} \rho(z|s)\}p_k(x_i, y_i, u_i|s)\pi(s)}{\mathrm{esw}_k}. \tag{5}$$

The mean value of true school size distribution, $\pi(s)$, is linked to the interaction of circumpolar set and survey area, and the logarithm of distance from the ice edge (Appendix C). The confirmation probability is dependent on survey mode, weather condition, perpendicular distance (for Passing mode) and radial distance (for Closing mode) (Appendix C).

The total likelihood function is then given by

$$L = \prod_{i=1}^{n_C} P_C(x_i, y_i, u_i, s_i) \times \prod_{i=1}^{n_U} P_U(x_i, y_i, u_i, z_i), \tag{6}$$

where n_C and n_U are the numbers of the sightings with confirmed and unconfirmed school size, respectively. We estimate parameters by maximizing the logarithm of the total likelihood function. The maximization of the likelihood function is conducted separately for each Management Area and Circumpolar Set.

2.3. Abundance estimation

We use only the Passing mode data in abundance estimation to circumvent possible biases that the Closing mode data involve (Kishino and Kasamatsu, 1987; Branch and Butterworth, 2001), while we use both of the Closing and Passing mode data for parameter estimation as above mentioned. The population size is then estimated with a Horvitz-Thompson-like estimator,

$$\hat{P} = \frac{A}{2L} \sum_{i=1}^{n_P} \frac{\phi_1(\eta_i) + 1}{\sum_{s=1}^{\infty} \hat{\mathrm{esw}}_{A \cup B \cup C}(s|\eta_i)\hat{\pi}(s|\eta_i)}, \tag{7}$$

where n_P is the number of the sightings in the Passing mode, L is total survey distance, A is the size of survey area, η_i is a vector of covariates except for school sizes, and the numerator corresponds to the mean school size derived from a parametric distribution of school size (Appendix C).

An estimator for the unconditional asymptotic variance of $\hat{P}$ is then

$$\hat{\mathrm{var}}(\hat{P}) = \left[\left\{ \frac{d\hat{P}(\theta)}{d\theta} \right\}^T I(\theta)^{-1} \frac{d\hat{P}(\theta)}{d\theta} \right]_{\theta=\hat{\theta}} + \frac{A^2}{J-1} \sum_{j=1}^{J} \frac{l_j}{L} (\hat{D}_j - D)^2, \tag{8}$$

where θ is a vector of estimated parameters, $I(\theta)$ is the Fisher information matrix obtained from the second derivative of the log-likelihood function that is often substituted by the Hessian matrix, and l_j ($j = 1, \ldots, J$; $\sum l_j = L$) is a replicated line. $\hat{D}_j$ is the density on replicate line j. If there is no sighting on replicate line j, $\hat{D}_j$ is defined as being equal to zero.

When the abundance estimates are obtained by strata, taking account of common estimated parameters across strata, the abundance estimate and its variance for the whole area are given by

$$\hat{P}_{\text{all strata}} = \sum_h A_h \hat{D}_h, \tag{9}$$

$$\hat{\mathrm{var}}(\hat{P}_{\text{all strata}}) = \left[\left\{ \frac{d\hat{P}_{\text{all strata}}(\theta)}{d\theta} \right\}^T I(\theta)^{-1} \frac{d\hat{P}_{\text{all strata}}(\theta)}{d\theta} \right]_{\theta=\hat{\theta}} + \sum_h \frac{A_h^2}{J_h - 1} \sum_{j=1}^{J_h} \frac{l_{j,h}}{L_h} (\hat{D}_{j,h} - D_h)^2, \tag{10}$$

where the subscript h is the index of stratum.

The covariance between abundance estimates with different years taking account of common parameters is calculated by

$$\hat{\text{cov}}(\hat{P}_1, \hat{P}_2) = \left[\left\{ \frac{d\hat{P}_1(\theta)}{d\theta} \right\}^T I(\theta)^{-1} \frac{d\hat{P}_2(\theta)}{d\theta} \right]_{\theta=\hat{\theta}}, \tag{11}$$

where the subscripts denote different years and areas. The correlation matrix is obtained from the estimated variances and covariances.

3. RESULTS AND DISCUSSION

We used the model given in Appendices A-C for abundance estimation. According to the SOWER abundance workshop held in St. Andrews, we provided the abundance estimates and the diagnostics (Tables 1-14 and Figs. 1-16: The "D+number" in Tables and Figs shows the corresponding diagnostics in Annex C of the SOWER abundance workshop report and the "A+number" shows the corresponding option in abundance estimates). The model was modified according to the comments made in the 2008 IWC/SC meeting (IWC, 2009). The use of radial distances and sighting angles instead of perpendicular and forward distances greatly improved the goodness of fit for the data (Figs 1-6). The use of mean school size dependent on the western and east strata enabled us to trace the variation on the mean school sizes well (Table 1).

Vessel speeds, school sizes, weather conditions, platforms, circumpolar sets, Areas, and distances from the ice edge were employed as the covariates or the factors. See the Appendices for the mathematical details. Although thorough model selection was not carried out because of time constraint, the preliminary assessments (not shown here) show the robustness of the results, at least about the total abundance estimates.

We provided the results for the definite duplicates only as a default according to the so far convention (Tables 1-7 and Figs. 1-8). However, according to the recommendation from the SOWER abundance workshop, we provided the results using the definite and possible duplicates (Tables 8-14 and Figs. 9-16). The use of the possible duplicates did not produce dramatic changes of the results.

The survey-once abundance estimates taking account of additional variance (Kitakado and Okamura 2009) were 1,286,589 (CV: 0.202) for CPII and 688,389 (CV: 0.182) for CPIII with the actual northern boundary of the surveyed strata, when we use the definite duplicates only (Table 4). When using the possible duplicates, the resultant abundances became slightly lower as expected. The two duplicates option (Dup only and Dup+Pos) had the similar ratios of the CPIII total abundance to the CPII total abundance (Table 4).

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Appendix A detection probability function of sighting cues

The hazard probability model is given by a logistic form,

$$Q(x,y) = \frac{1}{1+\exp[\tau_r R^{\gamma_r} + \tau_a A^{\gamma_a} + \omega]} \tag{A.1}$$

where $R = \sqrt{x^2+y^2}$, $A = \mathrm{atan}(x/y)$, x is the perpendicular distance, y is the forward distance, τ_r, τ_a, γ_r, and γ_a are scalar parameters with positive values. The parameters, τ_r, τ_a, and ω, are related to several covariates through a link function as follows:

$\log(\tau_r) \sim$ Platform + log(School.size) + Weather,

$\log(\tau_a) \sim$ Platform + log(School.size) + Weather,

$\omega \sim$ Platform + log(School.size) + Weather + Vessel.

In addition, the surfacing rate λ in Eq. (1) is modeled to be a function of school size,

$\log(\lambda) \sim$ log(School.size),

where the coefficient of log(School.size) is constrained to be positive.

Appendix B Specification of detection function for each sighting pattern

There are three platforms with two independent observers and one semi-independent observer in the Passing mode while there are two platforms with no independent observer in the Closing mode. The detection pattern in the Passing mode is therefore complicated by taking account of duplicate sightings.

B-1. Passing mode

Passing mode has three sighting platforms, the top barrel and the IO booth with independent observers, and the upper bridge with semi-independent observers or researchers. We can have information needed to estimate $g(0)$ from the sighting patterns of independent observers (Schweder et al., 1997; Cooke, 1997; Cooke, 2001; Okamura et al., 2003, 2005). The probability density function for each sighting pattern is given below. The contribution to the likelihood function of detection with each sighting pattern is calculated by each probability density times the probability mass density of school size (Appendix C) divided by $\mathrm{esw}_{A\cup B\cup C}$ when school sizes are confirmed. When school sizes are unconfirmed, the numerator is summed up over all school sizes. $\mathrm{esw}_{A\cup B\cup C}$ is given by

$$\begin{aligned}\mathrm{esw}_{A\cup B\cup C} = \sum_{s=1}^{\infty}\Bigg[\int_0^{x_{max}}\int_0^{\infty}\frac{\lambda}{v}Q_{A\cup B\cup C}(x,y|s) \\ \times\exp\left\{-\frac{\lambda}{v}\int_y^{\infty}Q_{A\cup B\cup C}(x,y'|s)dy'\right\}dxdy\Bigg]\pi(s),\end{aligned} \tag{B.1}$$

which is equal to Eq. (4) when $k =$ Passing mode.

We have two distances by independent observers in the delayed duplicates. We use the averaged distances for the simultaneous duplicates and the distances of the latter sightings for the delayed duplicates, since the latter sightings tend to have the distances closer to the vessel which are generally likely to be more accurate. The distances of the first sightings are calculated by adding the vessel speeds times the differences of the recorded times between the two sightings to the distances of the latter sightings.

In the IDCR/SOWER surveys before 1988/89, the sighting time was recorded in a "minute" unit, and "second" was omitted. We therefore add to the model to apply to the data before 1988/89 the additional sturcture taking account of uncertainty by rounding the sighting time to the nearest minute.

1. A

$$p(x,y,A) = \frac{\lambda}{v}\left\{Q_{A\cup B}(x,y) - Q_B(x,y)\right\}\exp\left\{-\frac{\lambda}{v}\int_0^y Q_B(x,y')dy'\right\}$$
$$\times\exp\left[-\frac{\lambda}{v}\left\{\int_y^\infty Q_{A\cup B}(x,y')dy' + \int_{y+vT}^\infty Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\}\right], \tag{B.2}$$

where $T = 90/3600$h (before 1988/89) and $T = 60/3600$h (after 1989/90).

2. B

Same as A except for exchanging the symbols A and B.

3. C

$$p(x,y,C) = \frac{\lambda}{v}\left\{Q_{A\cup B\cup C}(x,y) - Q_{A\cup B}(x,y)\right\}$$
$$\times\exp\left[-\frac{\lambda}{v}\left\{\int_0^y Q_{A\cup B}(x,y')dy' + \int_y^\infty Q_{A\cup B\cup C}(x,y')dy'\right\}\right]. \tag{B.3}$$

4. $A\times B$

$$p(x,y,AB) = \frac{\lambda}{v}\left(Q_A(x,y)Q_B(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_{A\cup B}(x,y')dy'\right\}\right.$$
$$+Q_A(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_A(x,y')dy'\right\}$$
$$\times\left[\exp\left\{-\frac{\lambda}{v}\int_{y+vT}^\infty Q_{A\cup B\setminus A}(x,y')dy'\right\} - \exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_{A\cup B\setminus A}(x,y')dy'\right\}\right]$$
$$+Q_B(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_B(x,y')dy'\right\}$$
$$\left.\times\left[\exp\left\{-\frac{\lambda}{v}\int_{y+vT}^\infty Q_{A\cup B\setminus B}(x,y')dy'\right\} - \exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_{A\cup B\setminus B}(x,y')dy'\right\}\right]\right) \tag{B.4}$$

where $T = 90/3600$h (before 1988/89) and $T = 60/3600$h (after 1989/90).

5. $A\to B$

For the dataset before 1988/89,

$$p(x,y,A\to B) = \frac{\lambda}{v}$$
$$\times\left[\exp\left\{-\frac{\lambda}{v}\int_{y+v(\tau_{AB}+T)}^\infty Q_{A\cup B\setminus B}(x,y')dy'\right\} - \exp\left\{-\frac{\lambda}{v}\int_{y+v(\tau_{AB}-T)}^\infty Q_{A\cup B\setminus B}(x,y')dy'\right\}\right]$$
$$\times Q_B(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^\infty Q_B(x,y')dy'\right\} \tag{B.5}$$

where $T = 30/3600$h and $\tau_{AB} \geq 120/3600$h.

For the dataset after 1989/90,

$$p(x,y,A\to B)=\left(\frac{\lambda}{v}\right)^2 Q_B(x,y)\{Q_{A\cup B}(x,y+v\tau_{AB})-Q_B(x,y+v\tau_{AB})\}$$
$$\times\exp\left[-\frac{\lambda}{v}\left\{\int_{y+v\tau_{AB}}^{\infty}Q_{A\cup B\setminus B}(x,y')dy'+\int_y^{\infty}Q_B(x,y')dy'\right\}\right] \tag{B.6}$$

where $\tau_{AB}>60/3600$h.

6. $B\to A$

Same as $A\to B$ for exchanging the symbols A and B.

7. $C\to A$

For the dataset before 1988/89,

$$p(x,y,C\to A)=\frac{\lambda}{v}\left[\exp\left\{-\frac{\lambda}{v}\int_{y+v(\tau_{CA}+T)}^{\infty}Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\}-\right.$$
$$\left.\exp\left\{-\frac{\lambda}{v}\int_{y+v(\tau_{CA}-T)}^{\infty}Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\}\right]$$
$$\times\{Q_{A\cup B}(x,y)-Q_B(x,y)\}$$
$$\exp\left[-\frac{\lambda}{v}\left\{\int_y^{\infty}Q_{A\cup B}(x,y')dy'+\int_0^{y}Q_B(x,y')dy'\right\}\right] \tag{B.7}$$

where $T=30/3600$h and $\tau_{AB}\geq 120/3600$h.

For the dataset after 1989/90,

$$p(x,y,C\to A)=\left(\frac{\lambda}{v}\right)^2\{Q_{A\cup B}(x,y)-Q_B(x,y)\}$$
$$\times\{Q_{A\cup B\cup C}(x,y+v\tau_{CA})-Q_{A\cup B}(x,y+v\tau_{CA})\}$$
$$\times\exp\left\{-\frac{\lambda}{v}\int_{y+v\tau_{CA}}^{\infty}Q_{A\cup B\cup C\setminus A\cup B}(x,y')dy'\right\}$$
$$\times\exp\left[-\frac{\lambda}{v}\left\{\int_y^{\infty}Q_{A\cup B}(x,y')dy'+\int_0^{y}Q_B(x,y')dy'\right\}\right] \tag{B.8}$$

where $\tau_{CA}>60/3600$h.

8. $C\to B$

Same as $C\to A$ for exchanging the symbols A and B.

B-2. Closing mode

We have two platforms, top barrel and upper bridge, for Closing mode. Once any observer on either platform detect the animal, the sighting is communicated to other observers by the researcher immediately. Hence, there are no duplicates in the Closing mode. The detection function is given by

$$p(x,y,A\cup C)=\frac{\lambda}{v}Q_{A\cup C}(x,y)\exp\left\{-\frac{\lambda}{v}\int_y^{\infty}Q_{A\cup C}(x,y')dy'\right\}. \tag{B.9}$$

The contribution to the likelihood function of detection with each sighting pattern is calculated by the above probability density times the probability mass density of school size (Appendix C) divided

by $\mathrm{esw}_{A\cup C}$ when school sizes are confirmed. When school sizes are unconfirmed, the numerator is summed up over all school sizes. $\mathrm{esw}_{A\cup C}$ is given by

$$\mathrm{esw}_{A\cup C} = \sum_{s=1}^{\infty} \left[\int_0^{x_{xmax}} \int_0^{\infty} \frac{\lambda}{v} Q_{A\cup C}(x, y|s) \right.$$
$$\left. \times \exp\left\{ -\frac{\lambda}{v} \int_y^{\infty} Q_{A\cup C}(x, y'|s) dy' \right\} dxdy \right] \pi(s), \tag{B.10}$$

which is equal to Eq. (4) when k = Closing mode.

Appendix C Scool size distribution

The probability mass function of true school size is given by a truncated negative binomial distribution,

$$\pi(s) = \frac{\Gamma(\phi_0 + s - 1)}{\Gamma(\phi_0)\Gamma(s)} \left(1 - \frac{\phi_0}{\phi_0 + \phi_1}\right)^{s-1} \left(\frac{\phi_0}{\phi_0 + \phi_1}\right)^{\phi_0}, \tag{C.1}$$

where $\phi_0 > 0$, $\phi_1 > 0$, and the parameter ϕ_1 is linked to the following covariates,

$\log(\phi_1) \sim$ W/E Strata +W/E Strata $\times \log(d_{\mathrm{ice}} + 1.0)$,

where W/E Strata is the difference of the western and east stratum, and d_{ice} is the distance from the ice edge, which is used to represent the latitudinal gradient of school size. Note that $\mathrm{E}(s) = \phi_1 + 1$.

The probability mass function of unconfirmed school size given true school size is also given by a truncated Poisson distribution,

$$\rho(z|s) = \frac{\mu^{z-1} \exp(-\mu)}{\Gamma(z)}, \tag{C.2}$$

where $\mu = \beta(s - 1) > 0$ and the parameter β is linked to the following covariates,

$\log(\beta) \sim$ Survey.mode.

Note that $\mathrm{E}(z) = \mu + 1$.

The probability of confirmation status c_k, which is given separately for each survey mode, is linked to the following covariates,

$\mathrm{logit}(c_k) \sim \log(s) + \sqrt{x^2 + y^2}$ + Weather (for Closing mode),

$\mathrm{logit}(c_k) \sim \log(s) + x$ + Weather (for Passing mode).

Table 1a. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 1 using the strata boundaries in the standard dataset. Only the definite duplicates were used. See the text for the detailed explanation of parameters. The symbols used in this table denote the following:

Area: stratum area (n.miles2)
L: line length (primary search effort, n.miles)
nL: number of transects
ns: number of schools sighted (primary effort)
E(s): estimated mean school size
g0: g(0) for the combined platforms
esw_s: effective strip-half width for schools by the combined platforms
esw_w: effective strip-half width for whales by the combined platforms
P: abundance estimate
D: density of whales
CV: coefficient of variation of abundance estimate

Area 1	Stratum	Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=4269.38											
1989/90	EN	153,029	750.2	7	60	1.617	0.610	0.301	0.394	33,389	0.218	0.257
	ESBA	62,594	821.1	14	74	3.060	0.739	0.496	0.696	17,159	0.274	0.492
	WN	168,761	577.9	6	35	3.336	0.741	0.503	0.727	33,905	0.201	0.554
	WS	45,128	830.9	15	214	2.392	0.673	0.377	0.542	37,010	0.820	0.222
	Total	429,512	2980.1	42	383					121,463	0.283	0.219
CP III	AIC=2822.98											
1993/94	EN	293,196	749.6	10	17	1.625	0.587	0.314	0.542	17,203	0.059	0.769
	ES	72,249	544.8	9	84	1.594	0.475	0.221	0.404	41,029	0.568	0.437
	WN	251,735	459.6	8	9	1.101	0.432	0.156	0.180	17,910	0.071	0.402
	WS	50,596	566.6	12	80	1.432	0.576	0.287	0.442	17,898	0.354	0.244
	Total	667,776	2320.6	39	190					94,040	0.141	0.303
1999/00	EN	57,309	241.1	5	9	1.534	0.576	0.298	0.494	5,498	0.096	0.392
	ES	23,632	179.8	7	9	1.543	0.476	0.216	0.384	4,313	0.182	0.307
	WN	110,906	349.9	6	2	1.476	0.409	0.182	0.317	2,575	0.023	0.683
	WS	20,506	243.0	7	7	1.237	0.583	0.267	0.352	1,385	0.068	0.432
	Total	212,353	1013.8	25	27					13,771	0.065	0.276
2000/01	EN	127,789	378.3	12	2	1.537	0.516	0.253	0.429	2,133	0.017	0.612
	ES	29,080	303.8	10	19	2.619	0.483	0.285	0.613	8,155	0.280	0.415
	Total	156,869	682.2	22	21					10,288	0.066	0.366

Table 1b. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 2 using the strata boundaries in the standard dataset. Only the definite duplicates were used. The symbols are the same as in the caption of Table 1a.

Area 2	Stratum	Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=5580.7											
1986/87	EBAY	15,242	125.8	4	40	2.021	0.503	0.353	0.695	13,860	0.909	0.379
	EM	69,908	431.2	3	75	1.892	0.450	0.251	0.504	45,900	0.657	0.308
	EN	124,057	427.7	3	45	1.854	0.421	0.226	0.464	53,486	0.431	0.390
	ES1	23,142	277.4	5	20	1.979	0.434	0.237	0.496	6,958	0.301	0.638
	ES2	44,975	710.0	16	114	1.966	0.516	0.342	0.654	20,735	0.461	0.265
	WBAY	11,505	31.8	1	11	1.555	0.507	0.285	0.448	10,667	0.927	0.513
	WN	95,361	201.0	2	2	1.609	0.475	0.309	0.551	2,469	0.026	1.121
	WS1	10,270	91.7	2	14	1.248	0.364	0.163	0.237	5,991	0.583	0.473
	WS2	21,143	259.6	4	7	3.211	0.410	0.217	0.269	3,443	0.163	0.722
	WS3	79,605	839.0	14	82	1.444	0.376	0.198	0.347	28,465	0.358	0.297
	Total	495,208	3395.1	54	410					191,973	0.388	0.182
CP III	AIC=2594.04											
1996/97	EN	241,928	660.7	17	25	1.172	0.184	0.104	0.160	51,735	0.214	0.508
	ES	67,072	665.6	18	37	1.408	0.269	0.188	0.348	14,139	0.211	0.514
	WN	113,687	194.0	5	8	1.212	0.256	0.156	0.238	18,271	0.161	0.785
	WS	23,028	230.0	8	40	1.307	0.206	0.130	0.238	20,209	0.878	0.416
	Total	445,715	1750.3	48	110					104,353	0.234	0.421
1997/98	ES1	47,036	385.2	8	48	1.384	0.227	0.147	0.283	27,892	0.593	0.574
	ES2	10,451	142.8	5	24	1.499	0.302	0.214	0.406	6,197	0.593	0.831
	WN	52,135	253.3	4	5	1.092	0.160	0.085	0.112	6,615	0.127	0.599
	WS	32,620	303.2	10	1	1.362	0.281	0.186	0.326	394	0.012	0.984
	EN1	84,726	345.1	6	9	1.174	0.227	0.137	0.202	9,597	0.113	0.531
	EN2	80,013	258.6	4	7	1.129	0.175	0.099	0.139	12,912	0.161	0.613
	Total	306,981	1688.3	37	94					63,607	0.207	0.436
1999/00	ENA	7,361	34.2	2	0	-	-	-		0	0	
	ESA	6,494	54.6	2	0	-	-	-		0	0	
	Total	13,855	88.8	4	0					0	0	

Table 1c. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 3 using the strata boundaries in the standard dataset. Only the definite duplicates were used. The symbols are the same as in the caption of Table 1a.

Area 3		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=2497.44											
1987/88	EN	168,881	514.5	7	8	1.477	0.441	0.232	0.317	8,344	0.049	0.510
	ES	87,677	666.3	8	48	1.458	0.586	0.355	0.446	13,765	0.157	0.485
	WN	148,821	358.0	7	35	2.465	0.581	0.371	0.590	51,695	0.347	0.583
	WS	74,351	486.9	9	121	2.136	0.561	0.354	0.544	59,125	0.795	0.281
	Total	479,730	2025.8	31	212					132,929	0.277	0.292
CP III	AIC= 4162.54											
1992/93	EN	150,547	562.2	5	10	1.357	0.488	0.301	0.421	6,045	0.040	0.565
	ES	23,207	478.3	12	18	1.596	0.563	0.374	0.561	1,858	0.080	0.406
	WN	210,035	784.3	8	42	1.593	0.561	0.384	0.582	23,331	0.111	0.376
	WS	61,527	893.7	15	157	1.529	0.514	0.329	0.502	25,108	0.408	0.254
	Total	445,316	2718.4	40	227					56,342	0.127	0.220
1994/95	WN	148,803	457.9	7	21	1.170	0.447	0.261	0.319	15,269	0.103	0.381
	WS	51,938	505.3	11	52	1.705	0.564	0.390	0.594	11,536	0.222	0.448
	ESW	33,854	234.2	4	32	1.437	0.497	0.315	0.461	10,561	0.312	0.529
	ENW	69,342	318.0	4	17	1.285	0.523	0.332	0.434	7,174	0.103	0.527
	Total	303,937	1515.4	26	122					44,540	0.147	0.257

Table 1d. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 4 using the strata boundaries in the standard dataset. Only the definite duplicates were used. The symbols are the same as in the caption of Table 1a.

Area 4		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=3557.52											
1988/89	BN	17,486	412.9	10	28	2.497	0.651	0.571	0.835	2,590	0.148	0.275
	BS	6,520	144.5	3	50	2.937	0.479	0.285	0.521	11,605	1.780	0.804
	EN	181,166	606.0	6	17	1.985	0.420	0.221	0.370	22,889	0.126	0.317
	ES	52,441	255.8	7	49	2.137	0.641	0.556	0.788	19,346	0.369	0.261
	WN	156,617	716.6	6	5	2.244	0.638	0.546	0.784	2,244	0.014	0.451
	WS	58,693	245.7	5	23	2.386	0.448	0.251	0.446	26,054	0.444	0.388
	Total	472,923	2381.6	37	172					84,728	0.179	0.235
CP III	AIC=1883.762.											
1994/95	PRYD	21,096	203.5	4	48	1.249	0.585	0.388	0.454	8,014	0.380	0.363
	ESE	26,192	225.3	4	17	1.275	0.591	0.395	0.469	3,190	0.122	0.629
	ENE	77,339	312.7	4	5	1.308	0.530	0.324	0.401	2,494	0.032	0.471
	Total	124,627	741.4	12	70					13,698	0.110	0.304
1998/99	EN	169,387	578.7	14	21	1.104	0.483	0.303	0.326	11,248	0.066	0.349
	ES	70,193	685.9	25	34	1.176	0.534	0.376	0.421	5,452	0.078	0.270
	WN	105,396	377.9	10	29	1.718	0.607	0.443	0.627	15,660	0.149	1.077
	WS	42,605	472.4	15	32	2.830	0.570	0.457	0.725	8,764	0.206	0.531
	Total	387,581	2114.8	64	116					41,124	0.106	0.458

Table 1e. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 5 using the strata boundaries in the standard dataset. Only the definite duplicates were used. The symbols are the same as in the caption of Table 1a.

Area 5		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC= 8162.72											
1985/86	EM	165,912	1041.2	10	182	2.003	0.439	0.251	0.431	116,945	0.705	0.338
	EN	279,611	844.0	8	68	2.007	0.401	0.194	0.348	116,781	0.418	0.359
	ES	107,717	739.2	8	191	2.003	0.434	0.226	0.396	124,035	1.151	0.313
	WM	166,349	492.0	4	53	1.717	0.422	0.217	0.345	71,195	0.428	0.543
	WN	139,065	357.6	3	59	1.618	0.394	0.189	0.294	98,911	0.711	0.492
	WS	104,814	647.6	13	103	2.038	0.401	0.205	0.368	83,457	0.796	0.209
	Total	963,468	4121.6	46	656					611,324	0.635	0.188
CP III	AIC=13160.54											
1991/92	EN	165,429	505.8	8	118	2.000	0.596	0.479	0.692	80,528	0.487	0.195
	ES	82,039	687.5	10	106	1.947	0.503	0.346	0.532	35,645	0.434	0.384
	WN	137,734	337.1	5	9	2.227	0.510	0.364	0.588	11,259	0.082	0.748
	WS	58,643	470.8	5	174	2.233	0.608	0.501	0.745	48,287	0.823	0.508
	Total	443,845	2001.3	28	407					175,719	0.396	0.196
2001/02	EN	83,082	295.0	4	4	1.968	0.479	0.331	0.520	3,342	0.040	0.405
	ES	26,099	231.9	8	39	1.445	0.560	0.410	0.516	7,984	0.306	0.279
	WN	46,333	184.1	3	4	1.059	0.394	0.227	0.239	2,354	0.051	0.778
	WS	34,886	301.6	11	25	2.367	0.621	0.514	0.739	6,495	0.186	0.542
	Total	190,400	1012.7	26	72					20,175	0.106	0.241
2002/03	EN	135,038	541.3	16	16	1.259	0.470	0.299	0.358	8,627	0.064	0.197
	ES	126,870	536.0	12	39	1.539	0.583	0.440	0.565	16,097	0.127	0.446
	W1N	75,395	244.6	7	25	1.288	0.453	0.280	0.345	17,777	0.236	0.209
	W1S	101,237	228.5	7	27	4.181	0.647	0.567	0.761	42,174	0.417	0.521
	W2N	22,128	284.4	9	13	1.631	0.529	0.382	0.526	2,215	0.100	0.537
	W2S	21,327	257.1	14	20	1.492	0.468	0.303	0.413	4,105	0.192	0.205
	Total	481,995	2091.9	65	140					90,994	0.189	0.262
2003/04	MID	131,782	909.9	21	235	2.281	0.571	0.444	0.676	89,532	0.679	0.212
	N1	123,227	167.7	7	4	3.270	0.590	0.461	0.752	10,414	0.085	0.403
	N2	95,445	288.7	9	25	2.378	0.645	0.537	0.781	18,247	0.191	0.508
	N3	14,598	112.6	4	42	2.073	0.602	0.486	0.700	11,571	0.793	0.183
	ROSS	56,444	575.8	19	139	1.973	0.545	0.404	0.597	34,027	0.603	0.149
	Total	421,496	2054.6	60	445					163,791	0.389	0.144

Table 1f. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 6 using the strata boundaries in the standard dataset. Only the definite duplicates were used. The symbols are the same as in the caption of Table 1a.

Area 6		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=1352.098											
1990/91	EN	191,954	473.6	4	24	1.309	0.349	0.183	0.235	34,903	0.182	0.725
	ES	108,268	476.3	4	27	1.613	0.312	0.149	0.224	33,493	0.309	0.468
	WN	211,788	551.4	4	19	1.516	0.317	0.149	0.216	37,107	0.175	0.515
	WS	45,414	645.9	9	42	2.088	0.401	0.233	0.366	13,506	0.297	0.378
	Total	557,424	2147.2	21	112					119,009	0.213	0.399
CP III	AIC=2456.3											
1995/96	EN	242,073	533.5	11	32	1.886	0.724	0.519	0.681	27,262	0.113	0.274
	ES	72,349	561.8	10	46	1.414	0.532	0.310	0.380	14,116	0.195	0.378
	WN	97,945	280.3	5	13	1.401	0.482	0.259	0.321	12,300	0.126	0.414
	WS	34,051	314.1	9	5	1.508	0.679	0.445	0.547	945	0.028	0.327
	Total	446,418	1689.7	35	96					54,623	0.122	0.226
2000/01	WN	252,078	459.2	13	18	1.905	0.642	0.430	0.584	23,214	0.092	0.379
	WS	43,916	417.6	17	48	1.741	0.706	0.523	0.664	9,458	0.215	0.265
	Total	295,994	876.8	30	66					32,672	0.110	0.295

Table 2a. (A2) Abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks with the common northern boundary for additional variance estimation. Only the definite duplicates were used.

		CPII						CPIII											
Area	Sector	1986	1987	1988	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	W					31,166										9,912			
						0.365										0.377			
	M					70,860			33,497										
						0.283			0.496										
	E					23,221			64,977						8,260				
						0.324			0.345						0.316				
2	W		38,141										60,955						
			0.270										0.440						
	E		147,086									83,870							
			0.204									0.440							
3	W			113,588				34,785											
				0.326				0.207											
	E			12,335						41,098									
				0.434						0.269									
4	W				26,482					13,760									
					0.440					0.297									
	E				58,407									39,445					
					0.227									0.466					
5	W	137,349															20,169		
		0.283															0.241		
	M	157,164																43,448	
		0.351																0.199	
	E	326,088																	159,771
		0.191																	0.146
6	W						54,401				55,459								
							0.592				0.230								
	E						70,272									28,231			
							0.401									0.296			

Table 2b. (A2) Variance-covariance matrix for abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks for additional variance estimation. Only the definite duplicates were used.

Area I/CPII	1990.1M	1990.1W
1990.1E	0.107	0.238
1990.1M	1.000	0.120

Area I/CPIII	1994.1M	2000.1E	2001.1W
1994.1E	0.145	0.119	0.068
1994.1M	1.000	0.605	0.355
2000.1E	-	1.000	0.282

Area II/CPII	1987.2W
1987.2E	0.255

Area II/CPII	1998.2W
1997.2E	0.695

Area III/CPII	1988.3W
1988.3E	0.142

Area III/CPII	1995.3E
1993.3W	0.273

Area IV/CPII	1989.4W
1989.4E	0.268

Area IV/CPII	1999.4E
1995.4W	0.218

Area V/CPII	1986.5M	1986.5W
1986.5E	0.196	0.193
1986.5M	1.000	0.329

Area V/CPII	2003.5M	2004.5E
2002.5W	0.093	0.101
2003.5M	1.000	0.126

Area VI/CPII	1991.6W
1991.6E	0.341

Area VI/CPII	2001.6E
1996.6W	0.398

Table 3. (A3) Abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks without the common northern boundary. Only the definite duplicates were used.

		CPII						CPIII											
Area	Sector	1986	1987	1988	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	W					31,166										10,287			
						0.338										0.375			
	M					71,719			48,598										
						0.239			0.429										
	E					23,474			48,066						13,930				
						0.330			0.431						0.275				
2	W		38,982										63,603						
			0.289										0.436						
	E		154,190									86,886							
			0.194									0.438							
3	W			115,101				56,637											
				0.325				0.225											
	E			13,513						44,541									
				0.404						0.257									
4	W				27,041					14,198									
					0.425					0.324									
	E				58,874									41,015					
					0.226									0.441					
5	W	152,066															20,174		
		0.272															0.241		
	M	162,324																43,436	
		0.343																0.189	
	E	320,310																	158,964
		0.187																	0.150
6	W						55,165				53,448								
							0.579				0.226								
	E						62,665									32,674			
							0.360									0.288			

Table 4. (A4, 5) Abundance estimates for each Management Area and the circumpolar estimates for CP II and III with the additional CV. Only the definite duplicates were used.

additional CV 0.576

survey once	Area	I	II	III	IV	V	VI	Total
CP II	Area size	429,522	492,155	479,763	472,924	961,100	557,426	3,392,888
	Abundance	**126,359**	**193,171**	**128,614**	**85,915**	**634,699**	**117,830**	**1,286,589**
	Density	0.294	0.393	0.268	0.182	0.660	0.211	0.379
	CV	0.193	0.181	0.300	0.231	0.175	0.384	0.104
	CV with add.var	0.369	0.364	0.422	0.385	0.362	0.479	0.202
CP III	Area size	816,788	669,874	749,253	512,163	828,276	742,425	4,318,779
	Abundance	**72,814**	**150,489**	**101,178**	**55,213**	**222,574**	**86,122**	**688,389**
	Density	0.089	0.225	0.135	0.108	0.269	0.116	0.159
	CV	0.345	0.406	0.191	0.355	0.122	0.208	0.114
	CV with add.var	0.451	0.497	0.368	0.458	0.347	0.375	0.182
Ratio of abund.		0.58	0.78	0.79	0.64	0.35	0.73	0.54
Ratio of dens.		0.30	0.57	0.50	0.59	0.41	0.55	0.42

Table 5. (D3) Effective strip half widths for schools in Passing mode, where only the definite duplicates were used.

		School size category				
CP series	Condition	1	2	3-4	5-9	10-30
CP II	good	0.203	0.389	0.588	0.840	1.121
	bad	0.168	0.337	0.508	0.718	0.971
CP III	good	0.263	0.509	0.768	1.072	1.339
	bad	0.219	0.448	0.697	1.005	1.315

Table 6. (D4) g(0)s for schools in Passing mode, where only the definite duplicates were used.

			School size category				
CP series	Condition	Platform-comb.	1	2	3-4	5-9	10-30
CP II	good	AB	0.055	0.157	0.282	0.423	0.505
		Ab	0.096	0.179	0.243	0.287	0.280
		aB	0.087	0.151	0.192	0.211	0.146
		Cab	0.087	0.134	0.159	0.165	0.193
	bad	AB	0.036	0.139	0.272	0.407	0.534
		Ab	0.085	0.175	0.241	0.279	0.298
		aB	0.079	0.150	0.193	0.210	0.208
		Cab	0.083	0.134	0.160	0.164	0.157
CP III	good	AB	0.046	0.151	0.303	0.451	0.628
		Ab	0.111	0.211	0.286	0.323	0.361
		aB	0.102	0.179	0.225	0.236	0.248
		Cab	0.100	0.158	0.184	0.184	0.188
	bad	AB	0.034	0.125	0.259	0.391	0.598
		Ab	0.098	0.192	0.264	0.306	0.355
		aB	0.090	0.166	0.212	0.229	0.247
		Cab	0.091	0.150	0.178	0.181	0.188

Table 7. (D13) Comparison between the SSE data and the model predicted values, where 2007 SSE data were used and only the definite duplicates were used.

a) x <= 0.3 & good

SSE

True/Obs	1	2	3	4	5	6+
1	0.727	0.273	0.000	0.000	0.000	0.000
2	0.500	0.438	0.063	0.000	0.000	0.000
3	0.000	0.667	0.333	0.000	0.000	0.000
4	0.000	0.500	0.500	0.000	0.000	0.000
5	0.000	1.000	0.000	0.000	0.000	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.290	0.573	0.101	0.028	0.006	0.001
3	0.128	0.214	0.497	0.100	0.042	0.019
4	0.056	0.141	0.177	0.458	0.093	0.076
5	0.025	0.082	0.137	0.153	0.433	0.171

b) x <= 0.3 & bad

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.667	0.333	0.000	0.000	0.000	0.000
3	1.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	1.000	0.000	0.000	0.000
5	0.000	0.000	1.000	0.000	0.000	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.252	0.629	0.088	0.025	0.005	0.001
3	0.112	0.187	0.561	0.087	0.036	0.017
4	0.049	0.123	0.155	0.525	0.081	0.066
5	0.022	0.072	0.120	0.134	0.502	0.150

b) x > 0.3 & good

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.500	0.500	0.000	0.000	0.000	0.000
3	0.500	0.250	0.250	0.000	0.000	0.000
4	0.500	0.250	0.250	0.000	0.000	0.000
5	0.250	0.250	0.250	0.000	0.250	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.390	0.427	0.136	0.038	0.008	0.002
3	0.170	0.285	0.331	0.133	0.056	0.025
4	0.074	0.186	0.234	0.282	0.123	0.100
5	0.032	0.108	0.181	0.202	0.251	0.225

b) x > 0.3 & bad

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.400	0.600	0.000	0.000	0.000	0.000
3	0.250	0.500	0.250	0.000	0.000	0.000
4	0.000	0.000	0.571	0.143	0.286	0.000
5	0.000	0.333	0.333	0.000	0.333	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.374	0.449	0.131	0.036	0.008	0.001
3	0.164	0.274	0.356	0.128	0.053	0.024
4	0.072	0.180	0.226	0.307	0.118	0.097
5	0.031	0.105	0.175	0.195	0.275	0.218

Table 8a. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 1 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. See the text for the detailed explanation of parameters. The symbols used in this table denote the following:

Area: stratum area (n.miles2)
L: line length (primary search effort, n.miles)
nL: number of transects
ns: number of schools sighted (primary effort)
E(s): estimated mean school size
g0: g(0) for the combined platforms
esw_s: effective strip-half width for schools by the combined platforms
esw_w: effective strip-half width for whales by the combined platforms
P: abundance estimate
D: density of whales
CV: coefficient of variation of abundance estimate

Area 1	Stratum	Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=4269.38											
1989/90	EN	153,029	750.2	7	59	1.620	0.631	0.316	0.413	31,145	0.204	0.263
	ESBA	62,594	821.1	14	74	3.191	0.755	0.511	0.711	17,313	0.277	0.498
	WN	168,761	577.9	6	34	3.372	0.756	0.516	0.740	32,398	0.192	0.543
	WS	45,128	830.9	15	212	2.388	0.691	0.391	0.557	35,151	0.779	0.223
	Total	429,512	2980.1	42	379					116,007	0.270	0.216
CP III	AIC=2822.98											
1993/94	EN	293,196	749.6	10	16	1.709	0.657	0.364	0.613	14,679	0.050	0.658
	ES	72,249	544.8	9	82	1.670	0.568	0.275	0.486	33,310	0.461	0.407
	WN	251,735	459.6	8	9	1.106	0.514	0.190	0.218	14,476	0.058	0.358
	WS	50,596	566.6	12	79	1.484	0.643	0.328	0.497	15,884	0.314	0.222
	Total	667,776	2320.6	39	186					78,348	0.117	0.264
1999/00	EN	57,309	241.1	5	9	1.585	0.646	0.344	0.554	4,927	0.086	0.381
	ES	23,632	179.8	7	9	1.603	0.562	0.263	0.454	3,619	0.153	0.282
	WN	110,906	349.9	6	2	1.548	0.515	0.241	0.408	2,037	0.018	0.657
	WS	20,506	243.0	7	7	1.253	0.643	0.298	0.389	1,244	0.061	0.412
	Total	212,353	1013.8	25	27					11,827	0.056	0.252
2000/01	EN	127,789	378.3	12	2	1.470	0.590	0.286	0.441	1,769	0.014	0.593
	ES	29,080	303.8	10	18	3.776	0.585	0.375	0.666	8,030	0.276	1.032
	Total	156,869	682.2	22	20					9,799	0.062	0.846

Table 8b. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 2 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. The symbols are the same as in the caption of Table

Area 2	Stratum	Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=5580.7											
1986/87	EBAY	15,242	125.8	4	39	2.070	0.515	0.372	0.731	13,145	0.862	0.371
	EM	69,908	431.2	3	75	1.899	0.445	0.251	0.512	46,042	0.659	0.307
	EN	124,057	427.7	3	45	1.850	0.416	0.226	0.470	53,441	0.431	0.388
	ES1	23,142	277.4	5	20	2.014	0.432	0.240	0.511	6,996	0.302	0.638
	ES2	44,975	710.0	16	109	1.997	0.528	0.361	0.688	19,081	0.424	0.254
	WBAY	11,505	31.8	1	11	1.557	0.521	0.302	0.472	10,078	0.876	0.520
	WN	95,361	201.0	2	2	1.609	0.485	0.322	0.574	2,369	0.025	1.121
	WS1	10,270	91.7	2	14	1.245	0.358	0.161	0.237	6,060	0.590	0.473
	WS2	21,143	259.6	4	7	3.300	0.404	0.216	0.266	3,532	0.167	0.744
	WS3	79,605	839.0	14	81	1.442	0.368	0.194	0.347	28,589	0.359	0.297
	Total	495,208	3395.1	54	403					189,332	0.382	0.182
CP III	AIC=2594.04											
1996/97	EN	241,928	660.7	17	25	1.185	0.200	0.115	0.177	47,517	0.196	0.500
	ES	67,072	665.6	18	36	1.439	0.290	0.205	0.378	12,855	0.192	0.501
	WN	113,687	194.0	5	8	1.220	0.265	0.162	0.247	17,693	0.156	0.790
	WS	23,028	230.0	8	38	1.335	0.228	0.146	0.268	17,405	0.756	0.406
	Total	445,715	1750.3	48	107					95,470	0.214	0.414
1997/98	ES1	47,036	385.2	8	48	1.399	0.242	0.158	0.300	26,310	0.559	0.563
	ES2	10,451	142.8	5	24	1.520	0.313	0.223	0.420	6,037	0.578	0.816
	WN	52,135	253.3	4	5	1.093	0.174	0.093	0.122	6,046	0.116	0.581
	WS	32,620	303.2	10	1	1.372	0.288	0.190	0.333	388	0.012	0.981
	EN1	84,726	345.1	6	9	1.179	0.242	0.146	0.214	8,984	0.106	0.520
	EN2	80,013	258.6	4	7	1.133	0.191	0.108	0.152	11,681	0.146	0.595
	Total	306,981	1688.3	37	94					59,445	0.194	0.427
1999/00	ENA	7,361	34.2	2	0	-	-	-		0	0	
	ESA	6,494	54.6	2	0	-	-	-		0	0	
	Total	13,855	88.8	4	0					0	0	

Table 8c. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 3 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. The symbols are the same as in the caption of Table 8a.

Area 3		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=2497.44											
1987/88	EN	168,881	514.5	7	8	1.488	0.453	0.242	0.328	8,071	0.048	0.507
	ES	87,677	666.3	8	48	1.468	0.608	0.382	0.474	12,877	0.147	0.482
	WN	148,821	358.0	7	34	2.540	0.601	0.396	0.622	48,317	0.325	0.590
	WS	74,351	486.9	9	121	2.173	0.574	0.369	0.560	57,725	0.776	0.278
	Total	479,730	2025.8	31	211					126,990	0.265	0.289
CP III	AIC= 4162.54											
1992/93	EN	150,547	562.2	5	9	1.401	0.553	0.349	0.483	4,838	0.032	0.509
	ES	23,207	478.3	12	18	1.642	0.609	0.409	0.603	1,749	0.075	0.403
	WN	210,035	784.3	8	42	1.652	0.599	0.411	0.618	22,600	0.108	0.373
	WS	61,527	893.7	15	153	1.586	0.576	0.379	0.565	22,032	0.358	0.243
	Total	445,316	2718.4	40	222					51,220	0.115	0.215
1994/95	WN	148,803	457.9	7	21	1.182	0.504	0.300	0.361	13,455	0.090	0.378
	WS	51,938	505.3	11	52	1.766	0.601	0.416	0.625	11,186	0.215	0.452
	ESW	33,854	234.2	4	32	1.476	0.555	0.359	0.514	9,514	0.281	0.523
	ENW	69,342	318.0	4	17	1.304	0.559	0.354	0.460	6,831	0.099	0.525
	Total	303,937	1515.4	26	122					40,985	0.135	0.252

Table 8d. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 4 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. The symbols are the same as in the caption of Table 8a.

Area 4		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=3557.52											
1988/89	BN	17,486	412.9	10	28	2.583	0.705	0.626	0.886	2,447	0.140	0.271
	BS	6,520	144.5	3	50	3.051	0.527	0.315	0.553	10,897	1.671	0.801
	EN	181,166	606.0	6	17	2.044	0.470	0.248	0.406	20,937	0.116	0.305
	ES	52,441	255.8	7	47	2.206	0.696	0.613	0.847	17,360	0.331	0.250
	WN	156,617	716.6	6	5	2.313	0.693	0.599	0.837	2,107	0.013	0.449
	WS	58,693	245.7	5	23	2.465	0.496	0.281	0.481	24,103	0.411	0.377
	Total	472,923	2381.6	37	170					77,851	0.165	0.223
CP III	AIC=1883.762.											
1994/95	PRYD	21,096	203.5	4	46	1.268	0.633	0.436	0.508	6,929	0.328	0.357
	ESE	26,192	225.3	4	17	1.292	0.639	0.444	0.523	2,880	0.110	0.623
	ENE	77,339	312.7	4	5	1.324	0.565	0.349	0.428	2,348	0.030	0.462
	Total	124,627	741.4	12	68					12,157	0.098	0.293
1998/99	EN	169,387	578.7	14	21	1.109	0.516	0.324	0.348	10,542	0.062	0.334
	ES	70,193	685.9	25	34	1.184	0.580	0.420	0.468	4,923	0.070	0.251
	WN	105,396	377.9	10	28	1.776	0.655	0.496	0.688	13,953	0.132	1.065
	WS	42,605	472.4	15	32	2.972	0.604	0.488	0.756	8,614	0.202	0.547
	Total	387,581	2114.8	64	115					38,032	0.098	0.438

Table 8e. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 5 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. The symbols are the same as in the caption of Table

Area 5		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC= 8162.72											
1985/86	EM	165,912	1041.2	10	171	2.092	0.517	0.310	0.528	93,142	0.561	0.301
	EN	279,611	844.0	8	68	2.072	0.457	0.221	0.400	106,205	0.380	0.354
	ES	107,717	739.2	8	189	2.092	0.483	0.247	0.444	117,688	1.093	0.306
	WM	166,349	492.0	4	51	1.773	0.497	0.269	0.426	57,462	0.345	0.523
	WN	139,065	357.6	3	59	1.679	0.440	0.207	0.332	94,256	0.678	0.494
	WS	104,814	647.6	13	101	2.063	0.456	0.232	0.417	73,380	0.700	0.200
	Total	963,468	4121.6	46	639					542,133	0.563	0.180
CP III	AIC=13160.54											
1991/92	EN	165,429	505.8	8	116	1.994	0.600	0.485	0.701	77,985	0.471	0.198
	ES	82,039	687.5	10	104	1.946	0.505	0.349	0.539	34,597	0.422	0.385
	WN	137,734	337.1	5	9	2.219	0.511	0.366	0.594	11,144	0.081	0.748
	WS	58,643	470.8	5	173	2.236	0.613	0.508	0.755	47,429	0.809	0.506
	Total	443,845	2001.3	28	402					171,156	0.386	0.197
2001/02	EN	83,082	295.0	4	4	1.996	0.482	0.336	0.532	3,343	0.040	0.406
	ES	26,099	231.9	8	37	1.461	0.565	0.418	0.529	7,534	0.289	0.262
	WN	46,333	184.1	3	4	1.058	0.396	0.228	0.240	2,339	0.050	0.778
	WS	34,886	301.6	11	24	2.438	0.627	0.525	0.754	6,274	0.180	0.544
	Total	190,400	1012.7	26	69					19,490	0.102	0.239
2002/03	EN	135,038	541.3	16	16	1.256	0.473	0.302	0.362	8,527	0.063	0.197
	ES	126,870	536.0	12	38	1.551	0.589	0.449	0.579	15,456	0.122	0.436
	W1N	75,395	244.6	7	25	1.285	0.454	0.282	0.347	17,628	0.234	0.210
	W1S	101,237	228.5	7	27	4.205	0.651	0.577	0.771	41,710	0.412	0.527
	W2N	22,128	284.4	9	13	1.627	0.531	0.386	0.532	2,190	0.099	0.540
	W2S	21,327	257.1	14	20	1.489	0.470	0.305	0.416	4,077	0.191	0.204
	Total	481,995	2091.9	65	139					89,589	0.186	0.264
2003/04	MID	131,782	909.9	21	235	2.275	0.574	0.449	0.684	88,362	0.671	0.212
	N1	123,227	167.7	7	4	3.260	0.592	0.466	0.761	10,283	0.083	0.405
	N2	95,445	288.7	9	25	2.372	0.650	0.547	0.794	17,862	0.187	0.508
	N3	14,598	112.6	4	42	2.069	0.606	0.493	0.710	11,383	0.780	0.185
	ROSS	56,444	575.8	19	139	1.968	0.548	0.409	0.606	33,510	0.594	0.149
	Total	421,496	2054.6	60	445					161,400	0.383	0.144

Table 8f. (D1, 2; A1) Abundance estimates of minke whales obtained from the Passing mode data in Area 6 using the strata boundaries in the standard dataset. Definite and Possible duplicates were used. The symbols are the same as in the caption of Table

Area 6		Area	L	nL	ns	E(s)	g0	esw_s	esw_w	P	D	CV
CP II	AIC=1352.098											
1990/91	EN	191,954	473.6	4	24	1.291	0.339	0.177	0.232	35,576	0.185	0.732
	ES	108,268	476.3	4	27	1.590	0.312	0.152	0.236	32,021	0.296	0.465
	WN	211,788	551.4	4	19	1.491	0.313	0.148	0.220	36,795	0.174	0.513
	WS	45,414	645.9	9	41	2.086	0.413	0.249	0.402	12,035	0.265	0.352
	Total	557,424	2147.2	21	111					116,427	0.209	0.406
CP III	AIC=2456.3											
1995/96	EN	242,073	533.5	11	32	1.844	0.693	0.495	0.669	28,276	0.117	0.277
	ES	72,349	561.8	10	46	1.396	0.562	0.340	0.420	12,947	0.179	0.368
	WN	97,945	280.3	5	13	1.380	0.502	0.273	0.344	11,473	0.117	0.399
	WS	34,051	314.1	9	5	1.480	0.643	0.416	0.522	1,005	0.030	0.334
	Total	446,418	1689.7	35	96					53,701	0.120	0.223
2000/01	WN	252,078	459.2	13	17	1.906	0.643	0.438	0.614	21,333	0.085	0.353
	WS	43,916	417.6	17	47	1.719	0.708	0.535	0.692	8,804	0.200	0.254
	Total	295,994	876.8	30	64					30,138	0.102	0.275

Table 9a. (A2) Abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks with the common northern boundary for additional variance estimation. Definite and Possible duplicates were used.

		CPII						CPIII											
Area	Sector	1986	1987	1988	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	W					30,702										9,838			
						0.361										0.855			
	M					68,593			30,022										
						0.286			0.415										
	E					22,504			55,383						6,990				
						0.330			0.348						0.284				
2	W		37,945										56,846						
			0.275										0.432						
	E		146,208									78,287							
			0.203									0.432							
3	W			109,759				31,649											
				0.319				0.197											
	E			11,676						37,965									
				0.436						0.264									
4	W				24,665					12,517									
					0.432					0.283									
	E				54,059									36,990					
					0.216									0.458					
5	W	128,522															20,094		
		0.272															0.243		
	M	139,763																43,038	
		0.346																0.200	
	E	294,297																	157,429
		0.182																	0.145
6	W						52,855				54,474								
							0.585				0.227								
	E						69,478									27,435			
							0.414									0.280			

Table 9b. (A2) Variance-covariance matrix for abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks for additional variance estimation. Definite and Possible duplicates were used.

Area I/CPII	1990.1M	1990.1W
1990.1E	0.093	0.209
1990.1M	1.000	0.108

Area I/CPIII	1994.1M	2000.1E	2001.1W
1994.1E	0.119	0.097	0.028
1994.1M	1.000	0.506	0.030
2000.1E	-	1.000	0.025

Area II/CPII	1987.2W
1987.2E	0.261

Area II/CPII	1998.2W
1997.2E	0.683

Area III/CPII	1988.3W
1988.3E	0.137

Area III/CPII	1995.3E
1993.3W	0.238

Area IV/CPII	1989.4W
1989.4E	0.215

Area IV/CPII	1999.4E
1995.4W	0.184

Area V/CPII	1986.5M	1986.5W
1986.5E	0.163	0.161
1986.5M	1.000	0.312

Area V/CPII	2003.5M	2004.5E
2002.5W	0.093	0.098
2003.5M	1.000	0.123

Area VI/CPII	1991.6W
1991.6E	0.363

Area VI/CPII	2001.6E
1996.6W	0.394

Table 10. (A3) Abundance estimates of minke whales obtained from the Passing mode data using the additional variance blocks without the common northern boundary. Definite and Possible duplicates were used.

		CPII						CPIII											
Area	Sector	1986	1987	1988	1989	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	W					30,702										9,797			
						0.332										0.855			
	M					68,500			41,892										
						0.237			0.355										
	E					22,249			38,015						11,962				
						0.342			0.397						0.251				
2	W		38,496										59,441						
			0.293										0.427						
	E		152,032									79,958							
			0.194									0.431							
3	W			110,137				51,506											
				0.321				0.222											
	E			12,775						40,985									
				0.405						0.252									
4	W				25,184					12,574									
					0.417					0.313									
	E				53,740									37,935					
					0.214									0.422					
5	W	141,826															19,490		
		0.259															0.239		
	M	142,310																43,027	
		0.339																0.190	
	E	282,282																	156,625
		0.174																	0.150
6	W						53,339				52,696								
							0.574				0.224								
	E						61,786									30,140			
							0.373									0.269			

Table 11. (A4, 5) Abundance estimates for each Management Area and the circumpolar estimates for CP II and III with the additional CV. Definite and Possible duplicates were used.

additional CV 0.583

survey once	Area	I	II	III	IV	V	VI	Total
CP II	Area size	429,522	492,155	479,763	472,924	961,100	557,426	3,392,888
	Abundance	**121,451**	**190,529**	**122,912**	**78,924**	**566,418**	**115,125**	**1,195,359**
	Density	0.283	0.387	0.256	0.167	0.589	0.207	0.352
	CV	0.190	0.181	0.296	0.219	0.164	0.390	0.099
	CV with add.var	0.376	0.373	0.428	0.388	0.367	0.492	0.200
CP III	Area size	816,788	669,874	749,253	512,163	828,276	742,425	4,318,779
	Abundance	**63,651**	**139,399**	**92,491**	**50,509**	**219,142**	**82,836**	**648,028**
	Density	0.078	0.208	0.123	0.099	0.265	0.112	0.150
	CV	0.296	0.398	0.186	0.340	0.122	0.202	0.109
	CV with add.var	0.428	0.498	0.374	0.456	0.355	0.381	0.185
Ratio of abund.		0.52	0.73	0.75	0.64	0.39	0.72	0.54
Ratio of dens.		0.28	0.54	0.48	0.59	0.45	0.54	0.43

Table 12. (D3) Effective strip half widths for schools in Passing mode, where definite and Possible duplicates were used.

		School size category				
CP series	Condition	1	2	3-4	5-9	10-30
CP II	good	0.219	0.425	0.641	0.900	1.158
	bad	0.178	0.360	0.539	0.750	0.989
CP III	good	0.282	0.542	0.804	1.101	1.353
	bad	0.233	0.473	0.726	1.032	1.332

Table 13. (D4) g(0)s for schools in Passing mode, where definite and Possible duplicates were used.

			School size category				
CP series	Condition	Platform-comb.	1	2	3-4	5-9	10-30
CP II	good	AB	0.059	0.170	0.308	0.450	0.518
		Ab	0.103	0.193	0.260	0.294	0.280
		aB	0.093	0.161	0.203	0.214	0.192
		Cab	0.093	0.142	0.166	0.165	0.145
	bad	AB	0.039	0.151	0.291	0.422	0.542
		Ab	0.091	0.186	0.252	0.283	0.298
		aB	0.083	0.158	0.200	0.211	0.207
		Cab	0.087	0.141	0.165	0.164	0.156
CP III	good	AB	0.051	0.166	0.321	0.460	0.632
		Ab	0.119	0.223	0.295	0.326	0.360
		aB	0.108	0.188	0.229	0.236	0.247
		Cab	0.107	0.165	0.187	0.183	0.187
	bad	AB	0.038	0.135	0.275	0.408	0.605
		Ab	0.106	0.203	0.274	0.312	0.355
		aB	0.096	0.174	0.218	0.232	0.246
		Cab	0.097	0.156	0.182	0.183	0.186

Table 14. (D13) Comparison between the SSE data and the model predicted values, where 2007 SSE data were used and definite and Possible duplicates were used for model analysis.

a) x <= 0.3 & good

SSE

True/Obs	1	2	3	4	5	6+
1	0.727	0.273	0.000	0.000	0.000	0.000
2	0.500	0.438	0.063	0.000	0.000	0.000
3	0.000	0.667	0.333	0.000	0.000	0.000
4	0.000	0.500	0.500	0.000	0.000	0.000
5	0.000	1.000	0.000	0.000	0.000	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.296	0.576	0.096	0.026	0.005	0.001
3	0.135	0.218	0.498	0.094	0.038	0.016
4	0.061	0.148	0.179	0.457	0.087	0.067
5	0.028	0.089	0.144	0.154	0.430	0.155

b) x <= 0.3 & bad

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.667	0.333	0.000	0.000	0.000	0.000
3	1.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	1.000	0.000	0.000	0.000
5	0.000	0.000	1.000	0.000	0.000	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.260	0.628	0.084	0.023	0.005	0.001
3	0.119	0.192	0.557	0.083	0.034	0.015
4	0.054	0.131	0.159	0.519	0.077	0.060
5	0.025	0.079	0.128	0.137	0.493	0.138

b) x > 0.3 & good

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.500	0.500	0.000	0.000	0.000	0.000
3	0.500	0.250	0.250	0.000	0.000	0.000
4	0.500	0.250	0.250	0.000	0.000	0.000
5	0.250	0.250	0.250	0.000	0.250	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.401	0.426	0.130	0.035	0.007	0.001
3	0.181	0.291	0.329	0.126	0.051	0.022
4	0.081	0.197	0.238	0.279	0.116	0.089
5	0.037	0.118	0.190	0.204	0.246	0.205

b) x > 0.3 & bad

SSE

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.400	0.600	0.000	0.000	0.000	0.000
3	0.250	0.500	0.250	0.000	0.000	0.000
4	0.000	0.000	0.571	0.143	0.286	0.000
5	0.000	0.333	0.333	0.000	0.333	0.000

Model Predicted

True/Obs	1	2	3	4	5	6+
1	1.000	0.000	0.000	0.000	0.000	0.000
2	0.386	0.447	0.125	0.034	0.007	0.001
3	0.175	0.281	0.352	0.122	0.049	0.021
4	0.079	0.191	0.230	0.302	0.112	0.087
5	0.036	0.114	0.184	0.198	0.269	0.199

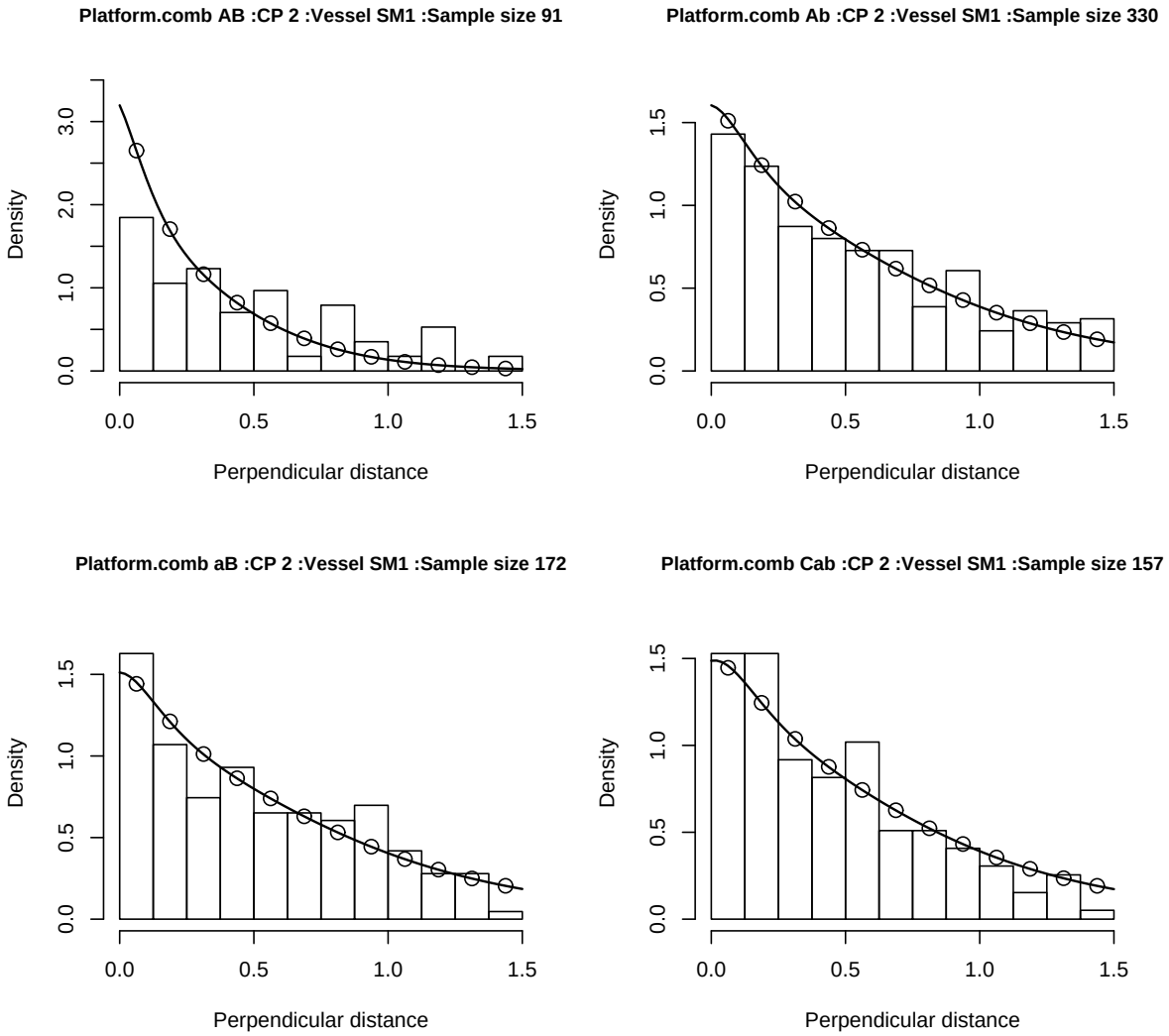

Fig. 1a. (D6) The plot of perpendicular distances in the Passing mode with the definite duplicates only by platform combination for SM1 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

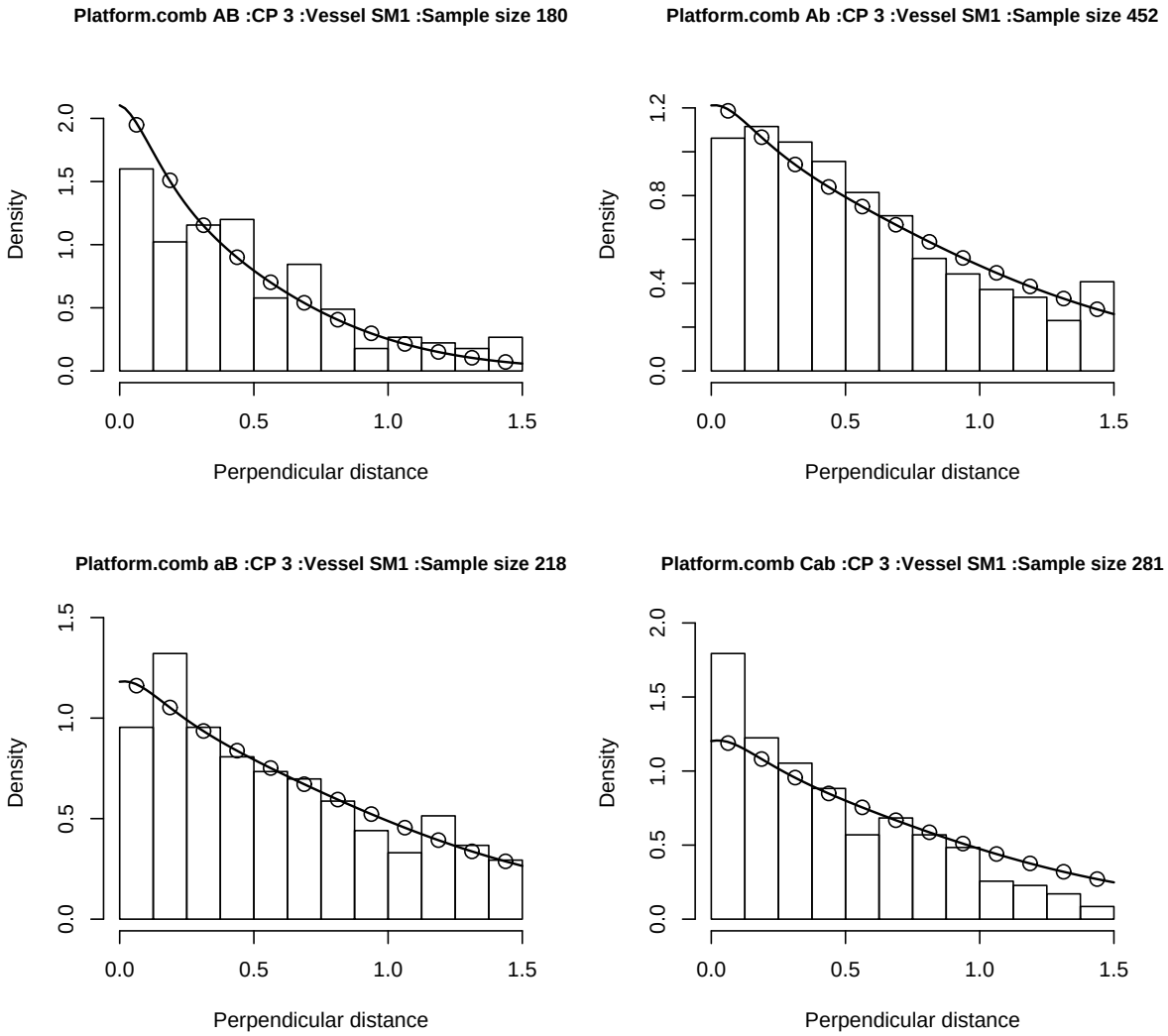

Fig. 1b. (D6) The plot of perpendicular distances in the Passing mode with the definite duplicates only by platform combination for SM1 and CPIII. The histogram is observed, while the open circles and the solid line are predicted.

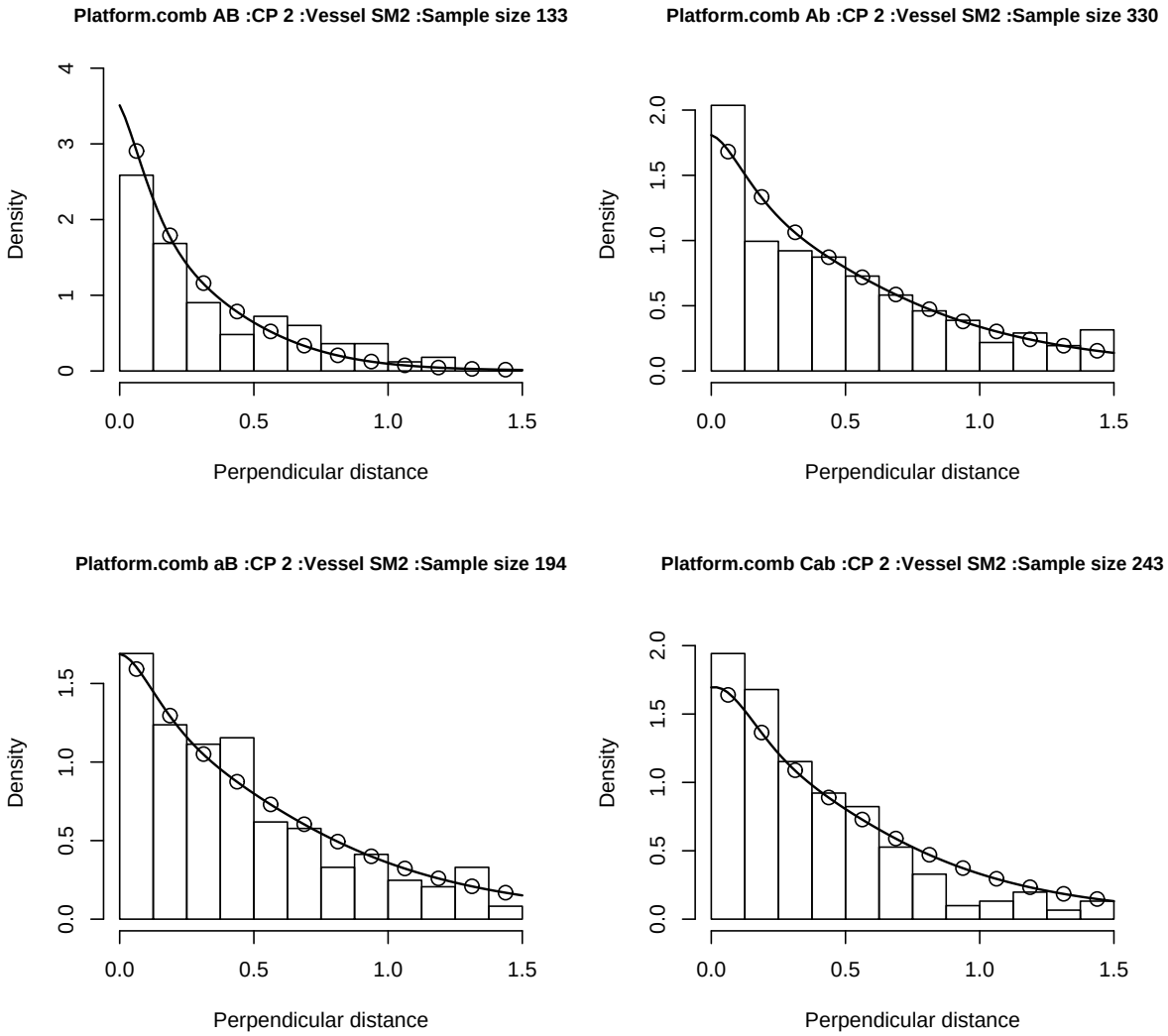

Fig. 2a. (D6) The plot of perpendicular distances in the Passing mode with the definite duplicates only by platform combination for SM2 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

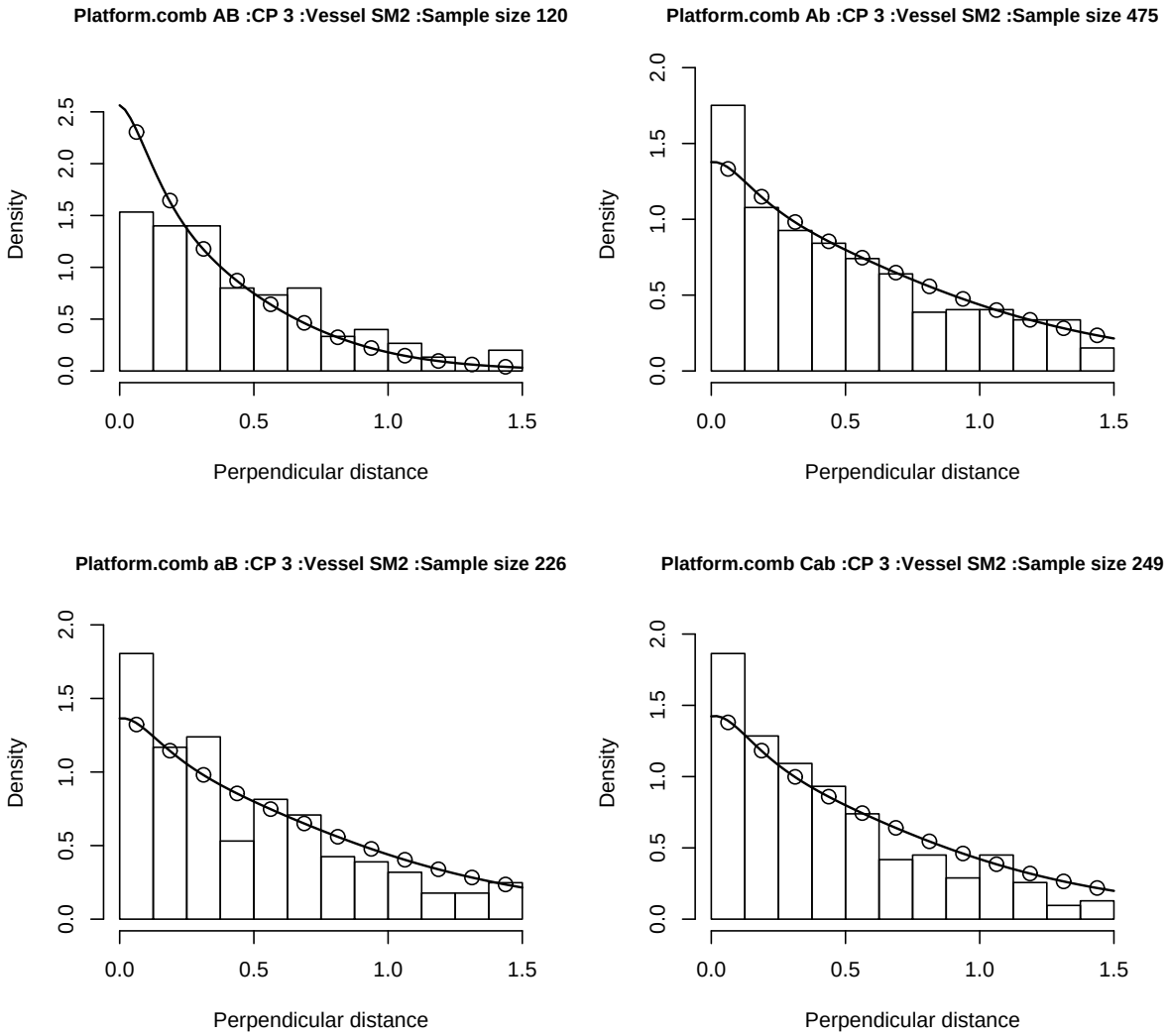

Fig. 2b. (D6) The plot of perpendicular distances in the Passing mode with the definite duplicates only by platform combination for SM2 and CPIII. The histogram is observed, while the open circles and the solid line are predicted.

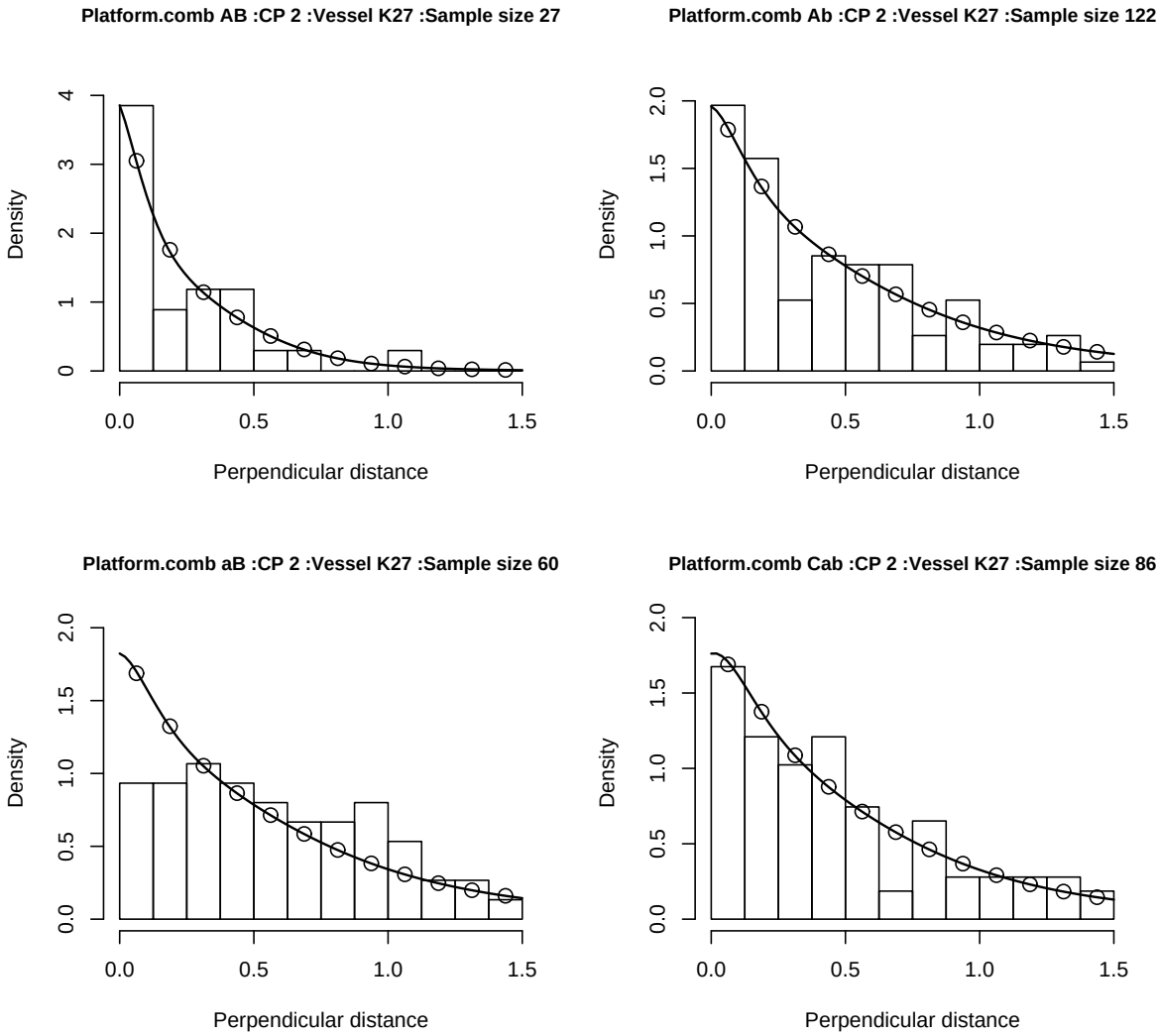

Fig. 3. (D6) The plot of perpendicular distances in the Passing mode with the definite duplicates only by platform combination for K27 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

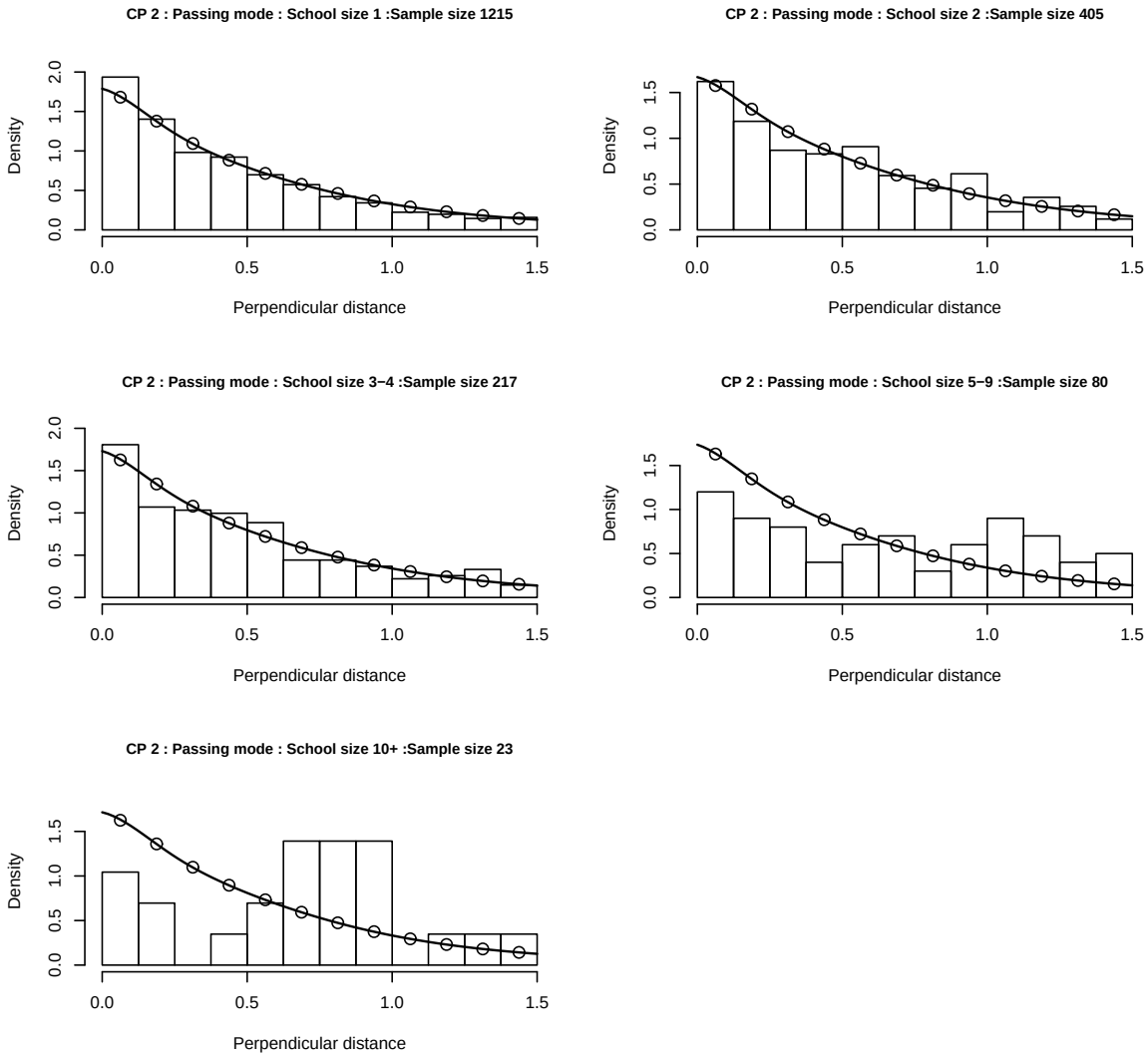

Fig. 4a. (D7) The plot of perpendicular distances in the Passing mode with the definite duplicates only by observed school size class for CPII. The histogram is observed, while the open circles and the solid line are predicted.

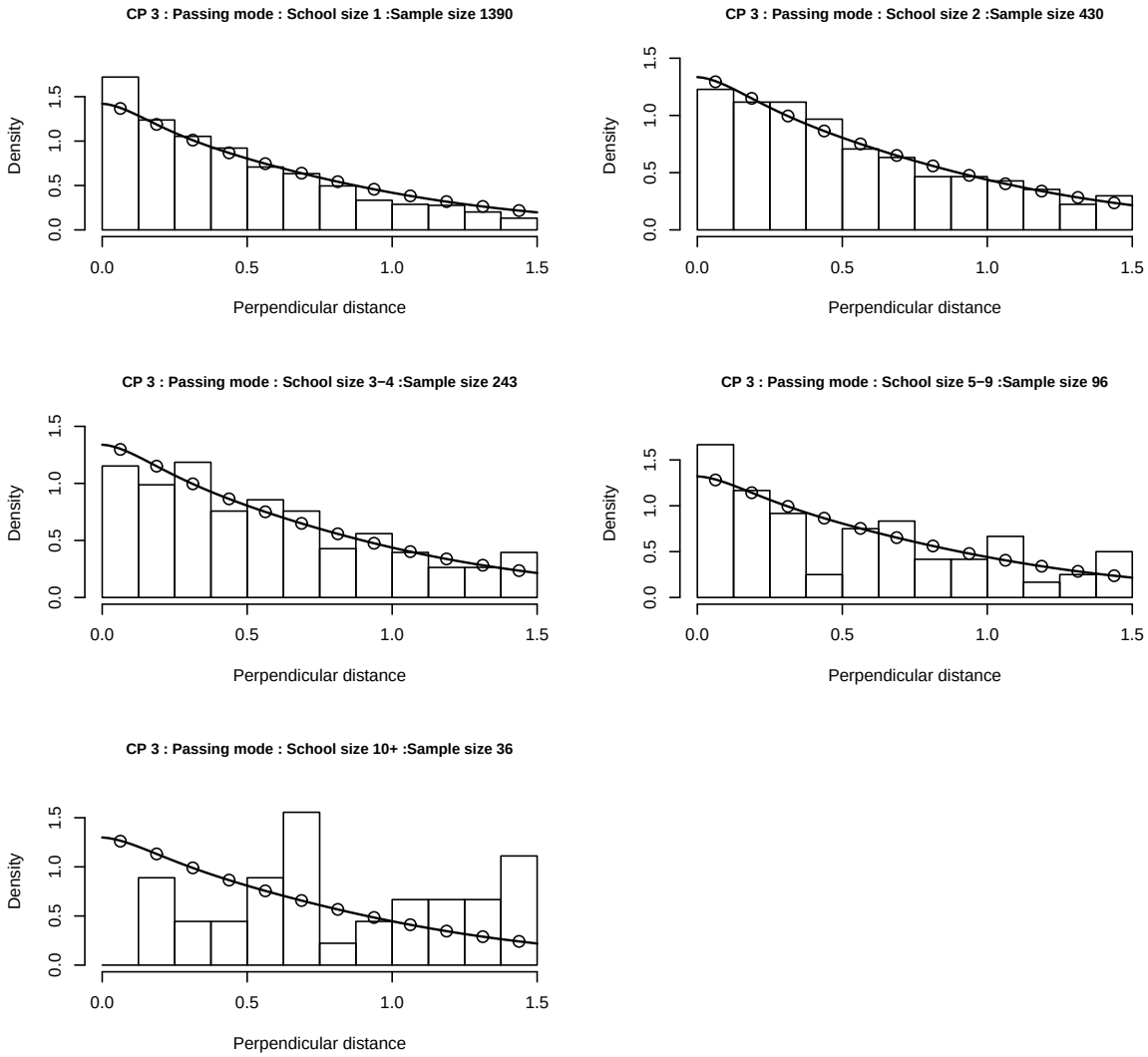

Fig. 4b. (D7) The plot of perpendicular distances in the Passing mode with the definite duplicates only by observed school size class for CPIII. The histogram is observed, while the open circles and the solid line are predicted.

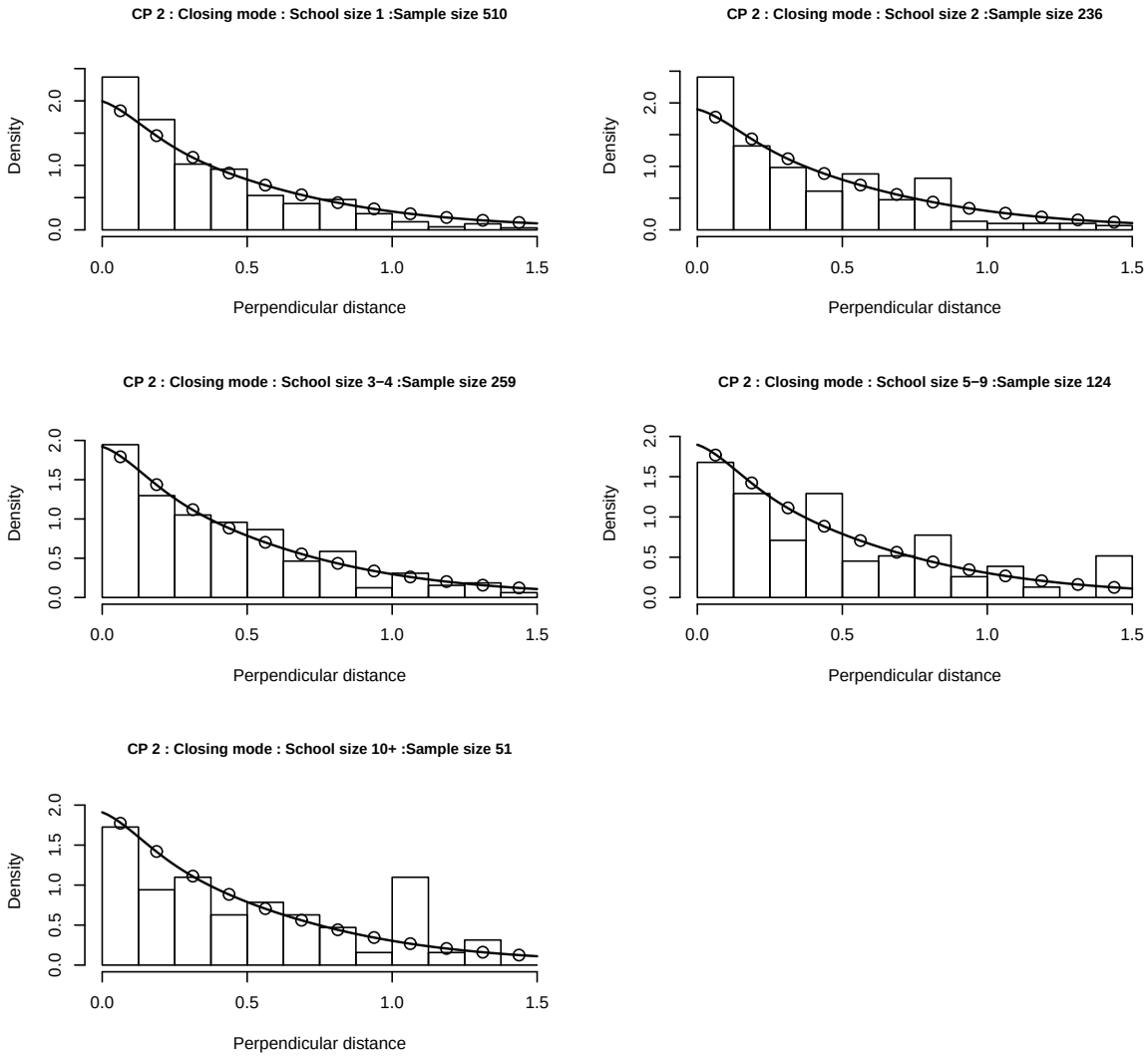

Fig. 5a. (D8) The plot of perpendicular distances in the Closing mode with the definite duplicates only by observed school size class for CPII. The histogram is observed, while the open circles and the solid line are predicted.

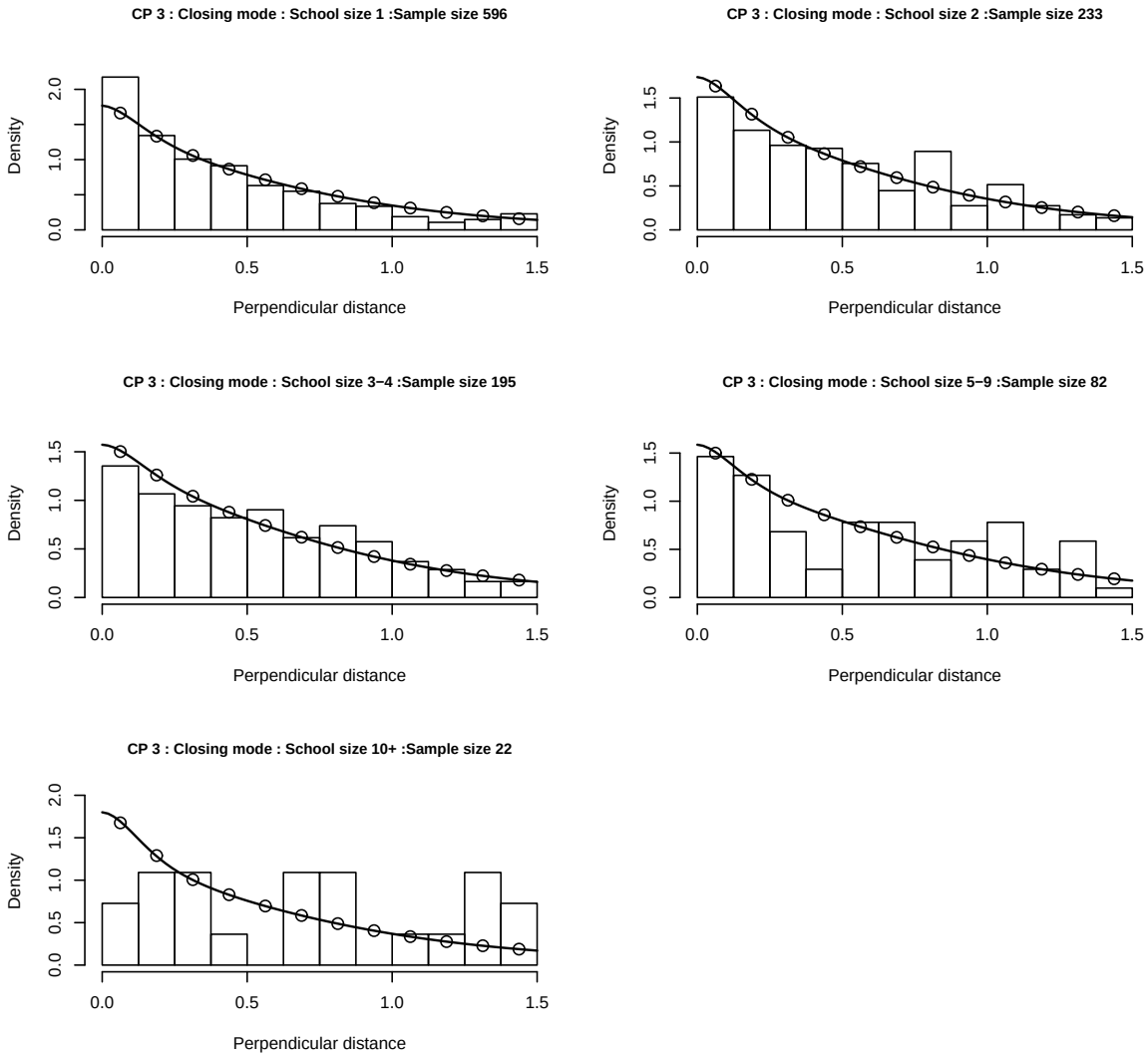

Fig. 5b. (D8) The plot of perpendicular distances in the Closing mode with the definite duplicates only by observed school size class for CPIII. The histogram is observed, while the open circles and the solid line are predicted.

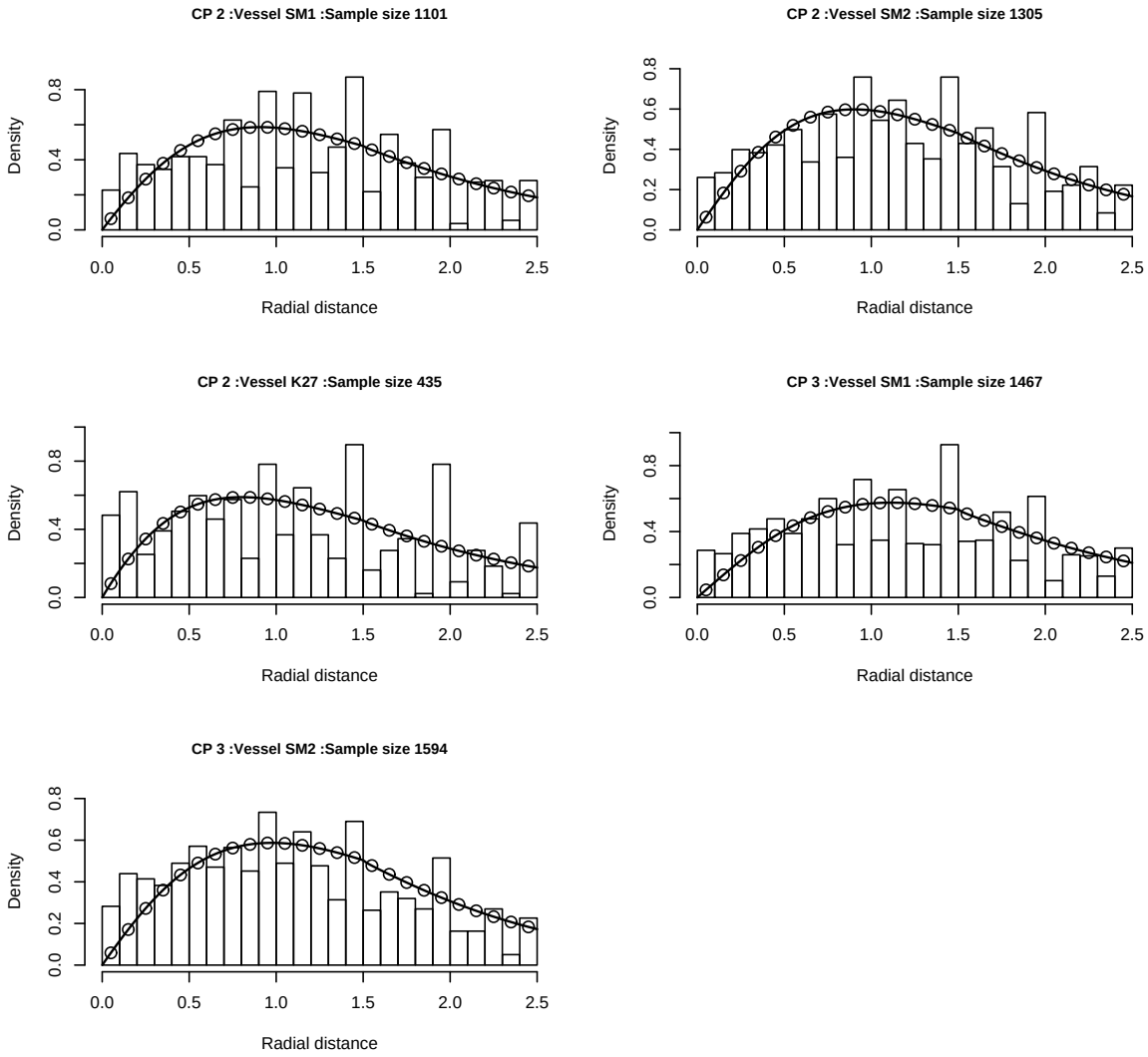

Fig. 6. (D9) The plot of radial distances with the definite duplicates only. The histogram is observed, while the open circles and the solid line are predicted.

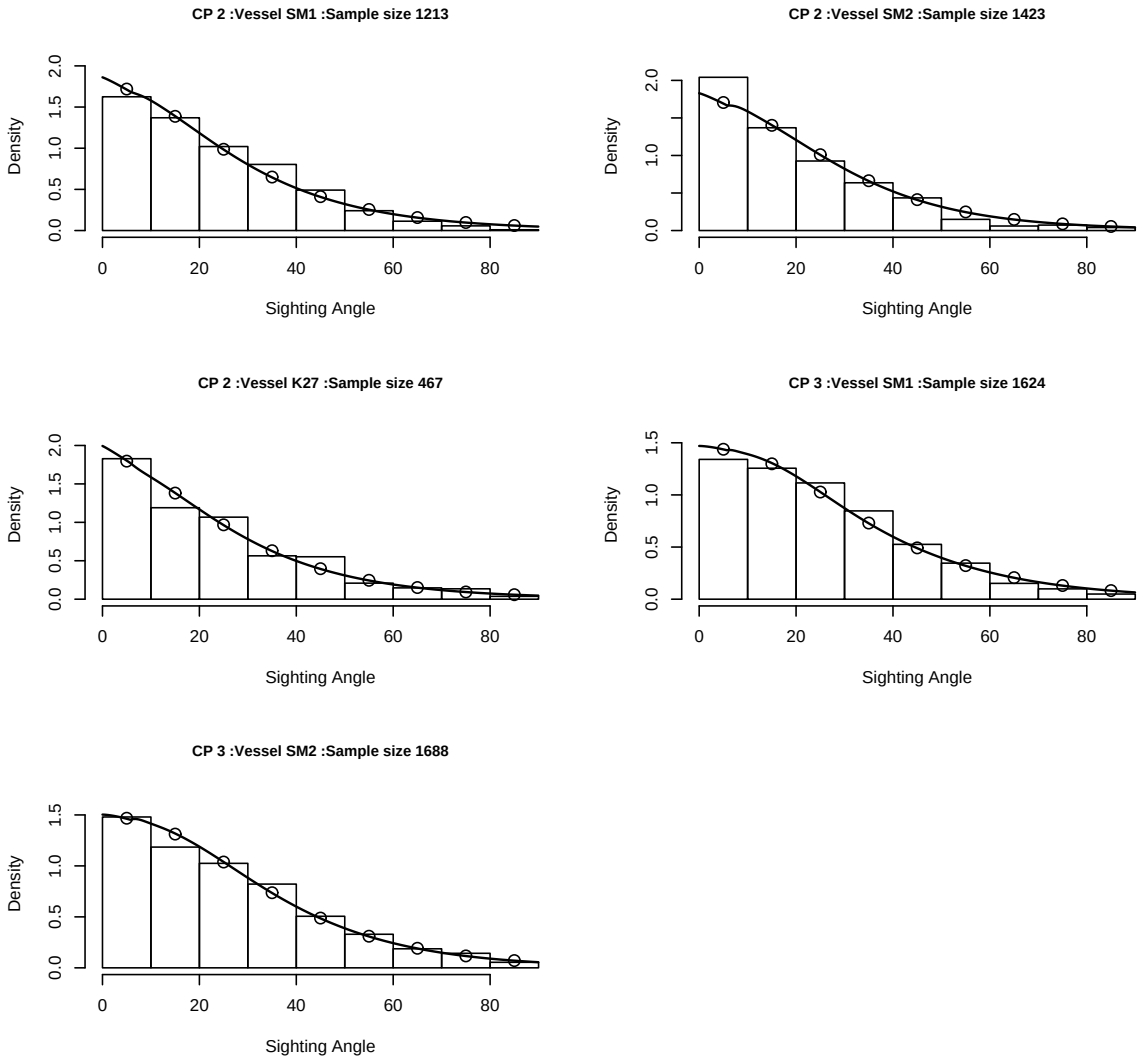

Fig. 7. (D10) The plot of sighting angles with the definite duplicates only. The histogram is observed, while the open circles and the solid line are predicted.

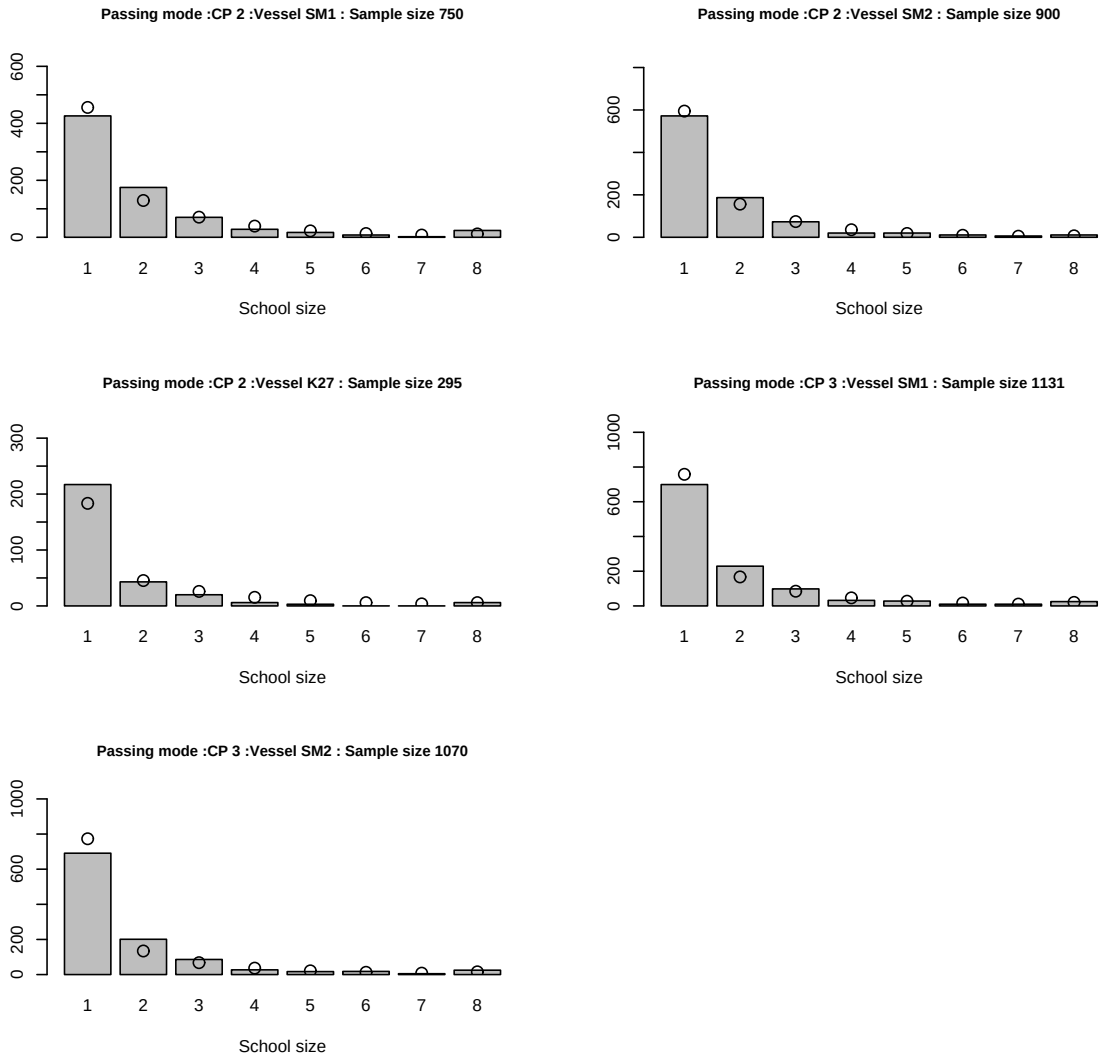

Fig. 8a. (D11) The plot of school size estimates with the definite duplicates only in the Passing mode. The histogram is observed, while the open circles are predicted.

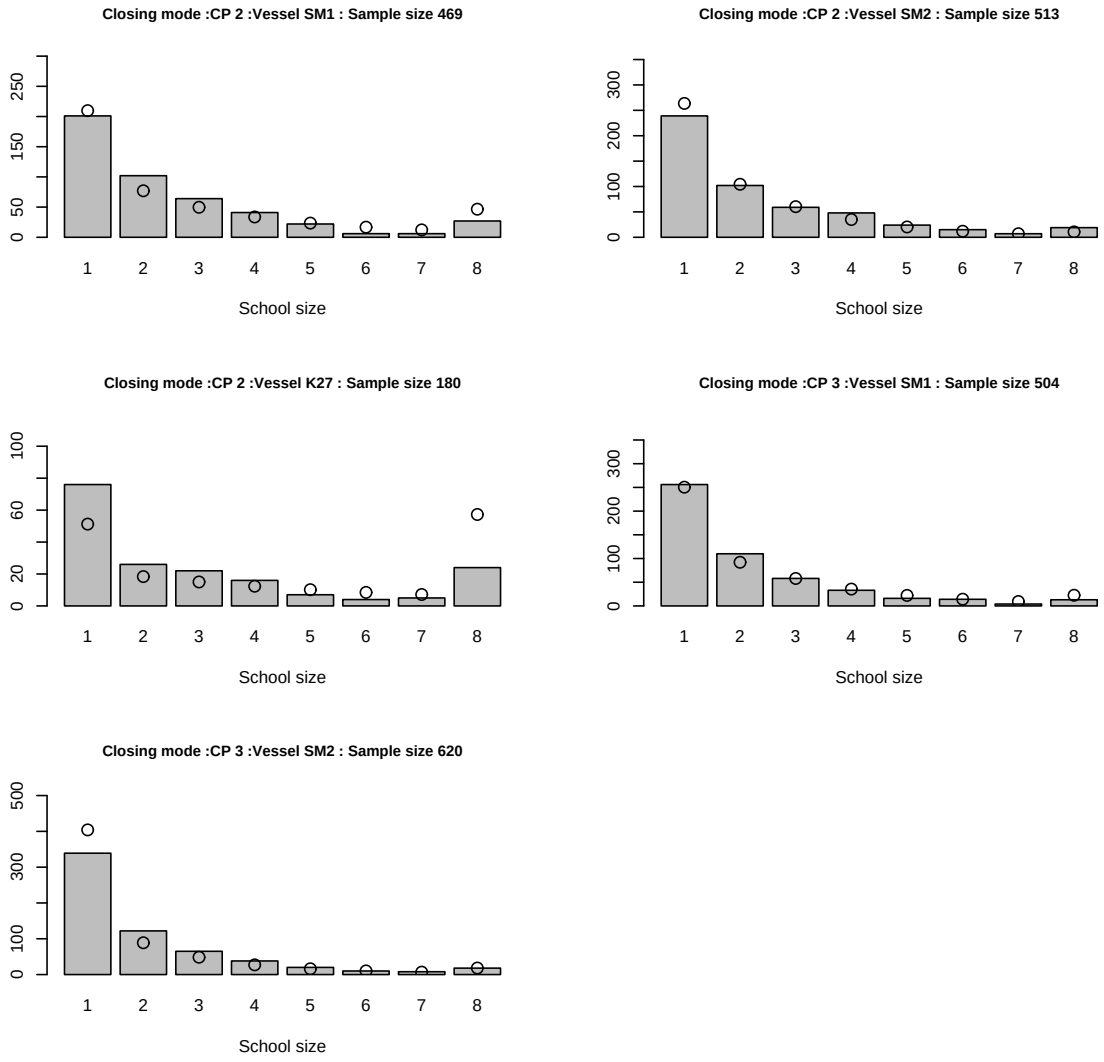

Fig. 8b. (D12) The plot of school size estimates with the definite duplicates only in the Closing mode. The histogram is observed, while the open circles are predicted.

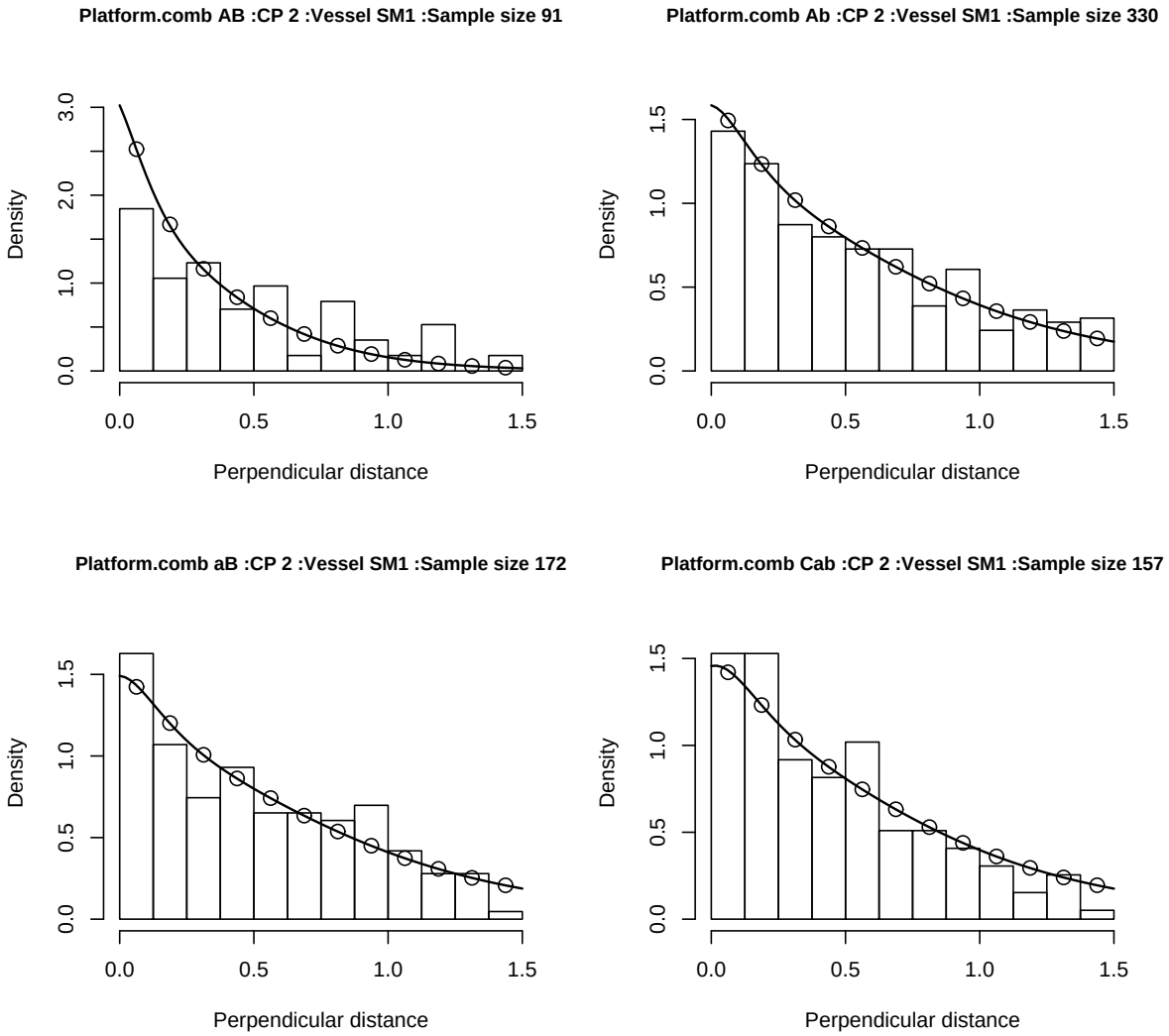

Fig. 9a. (D6) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by platform combination for SM1 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

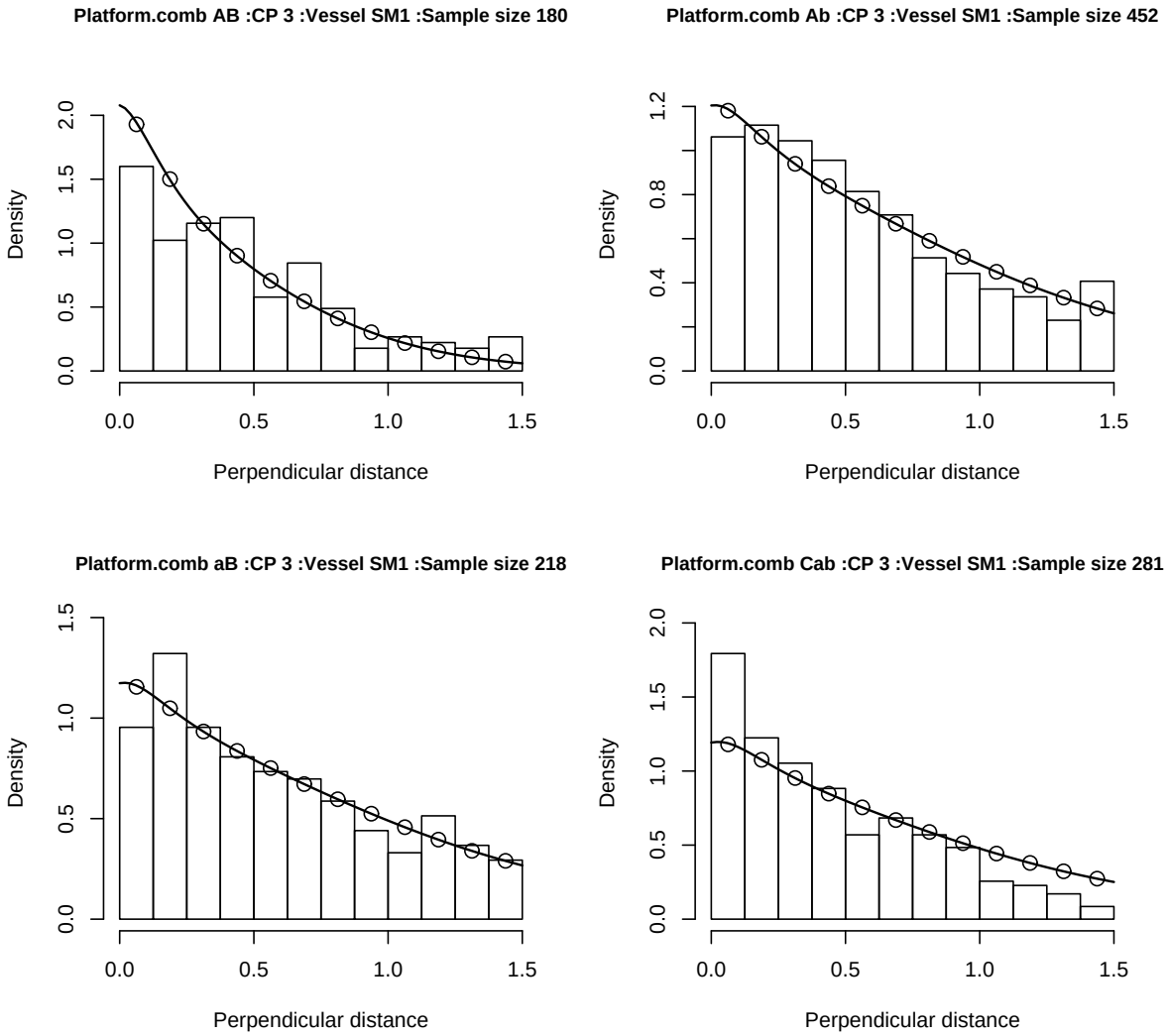

Fig. 9b. (D6) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by platform combination for SM1 and CPIII. The histogram is observed, while the open circles and the solid line are predicted.

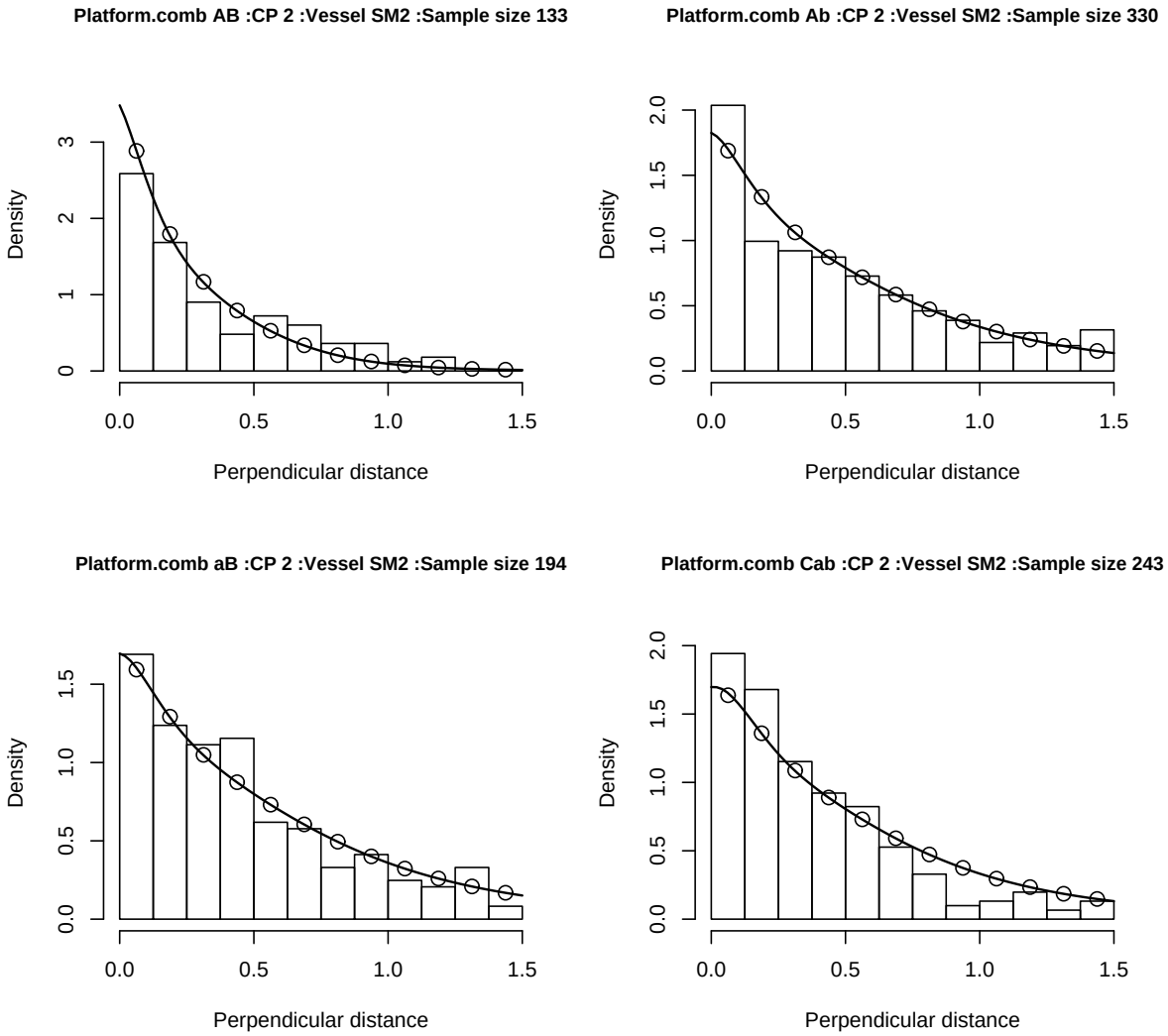

Fig. 10a. (D6) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by platform combination for SM2 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

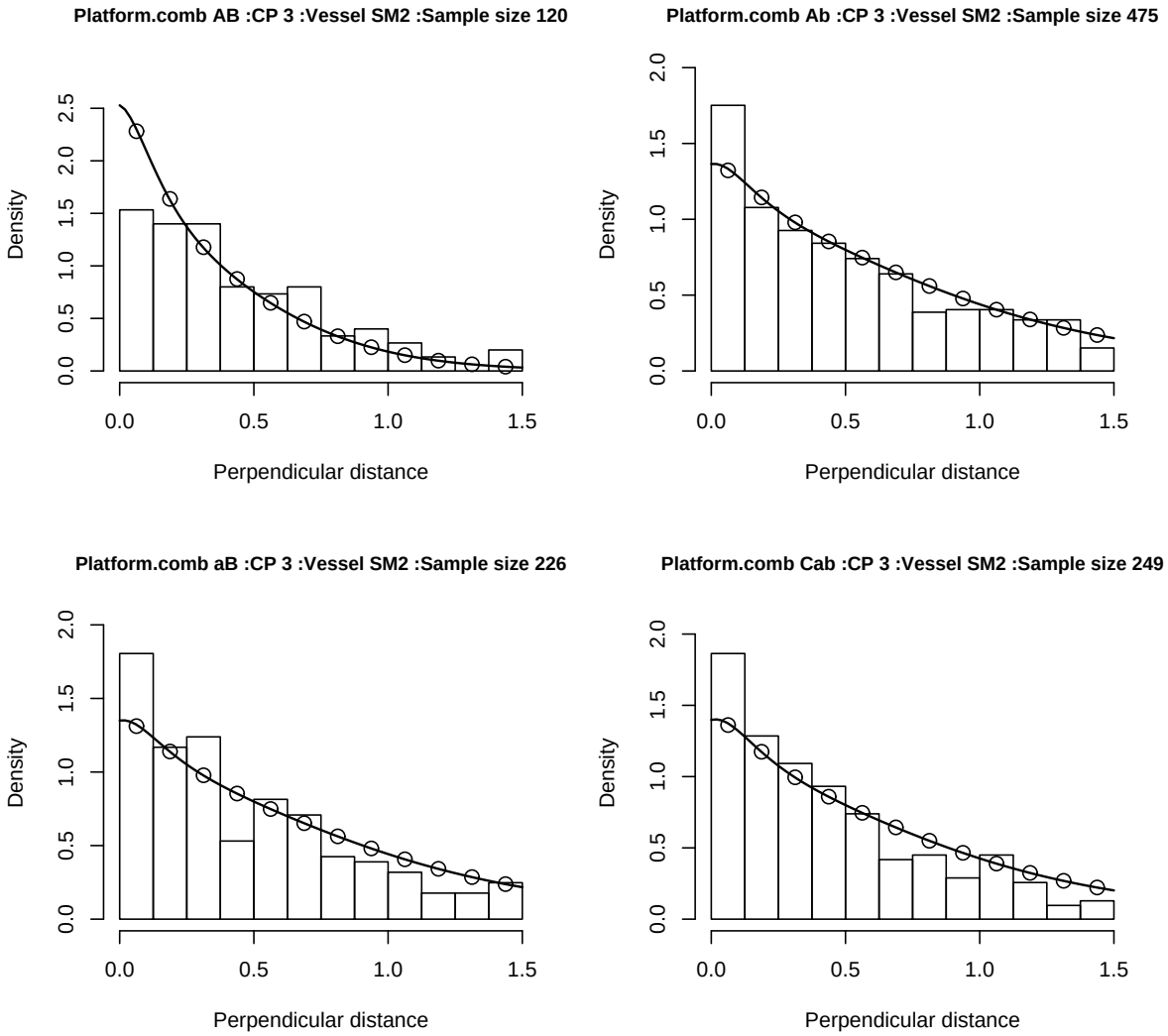

Fig. 10b. (D6) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by platform combination for SM2 and CPIII. The histogram is observed, while the open circles and the solid line are predicted.

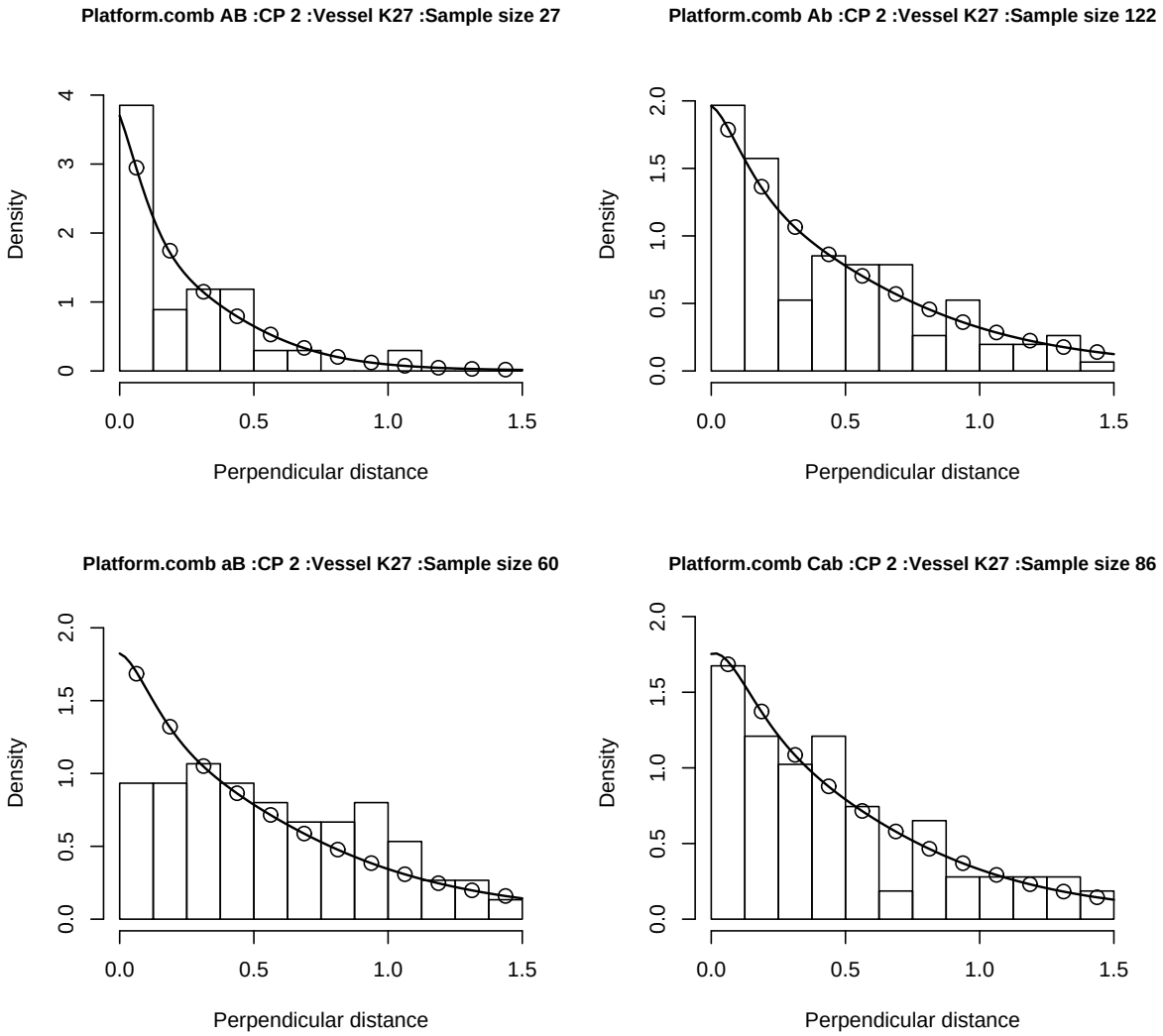

Fig. 11. (D6) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by platform combination for K27 and CPII. The histogram is observed, while the open circles and the solid line are predicted.

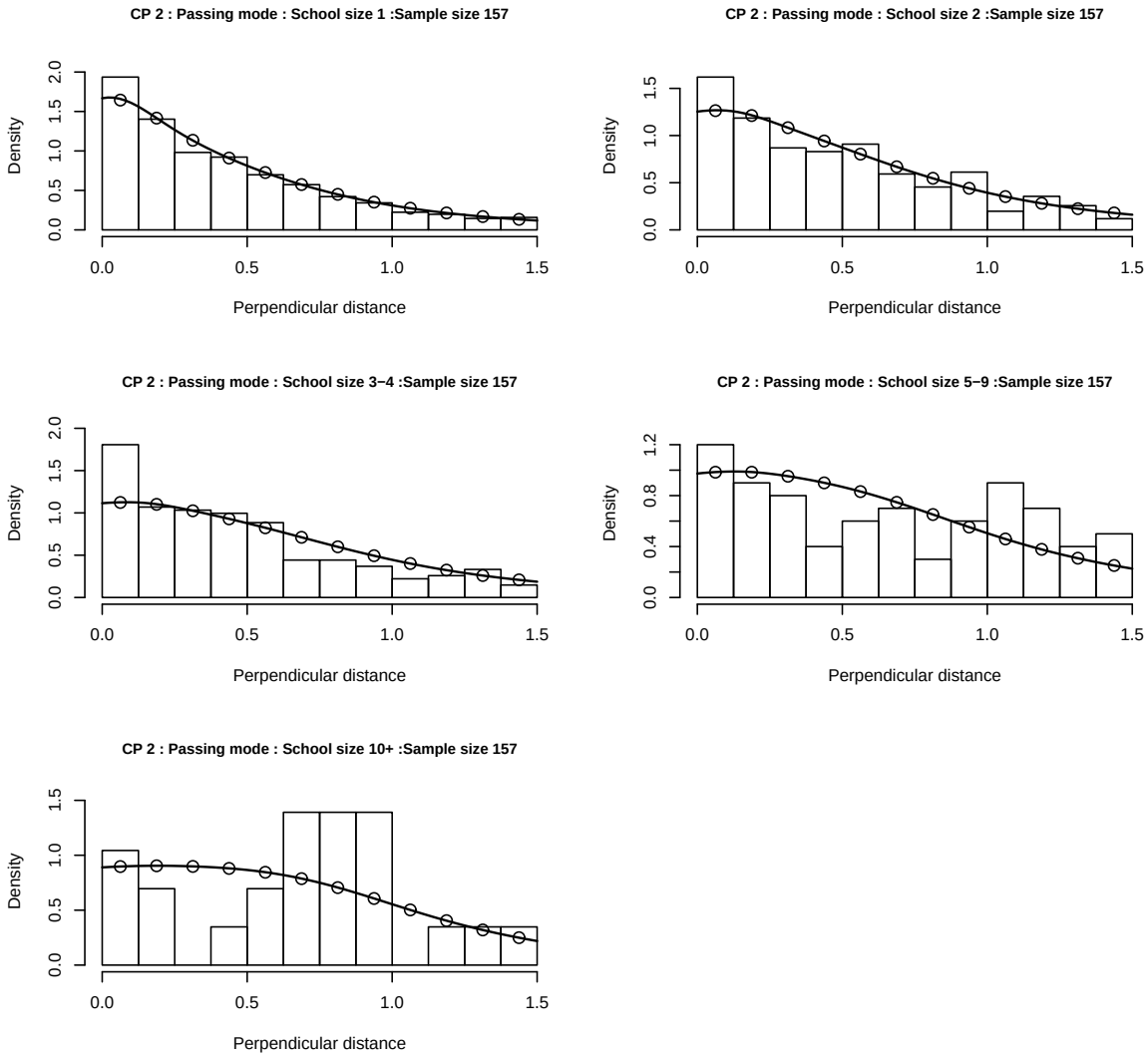

Fig. 12a. (D7) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by observed school size class for CPII. The histogram is observed, while the open circles and the solid line are predicted.

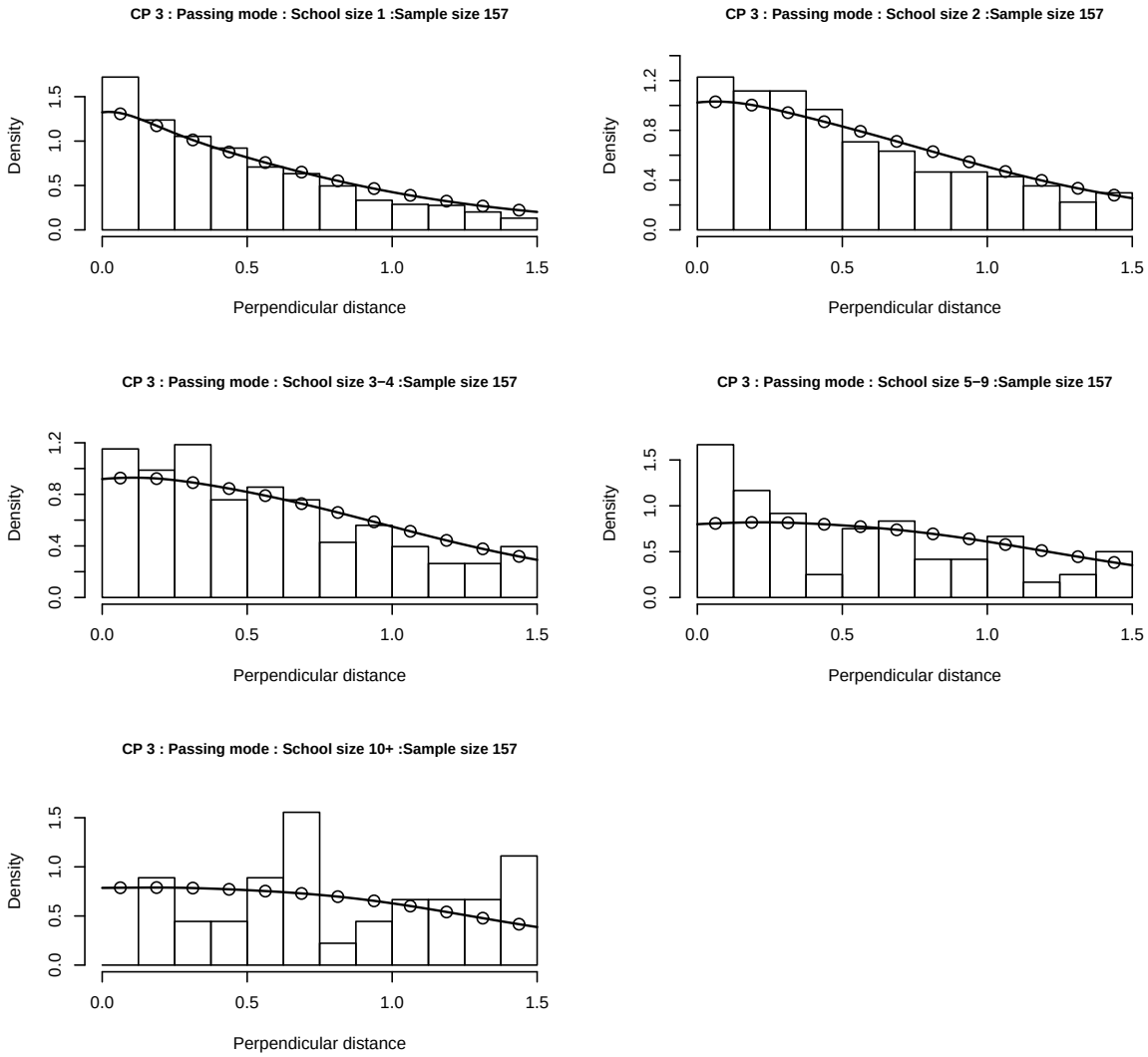

Fig. 12b. (D7) The plot of perpendicular distances in the Passing mode with the definite and possible duplicates by observed school size class for CPIII. The histogram is observed, while the open circles and the solid line are predicted.

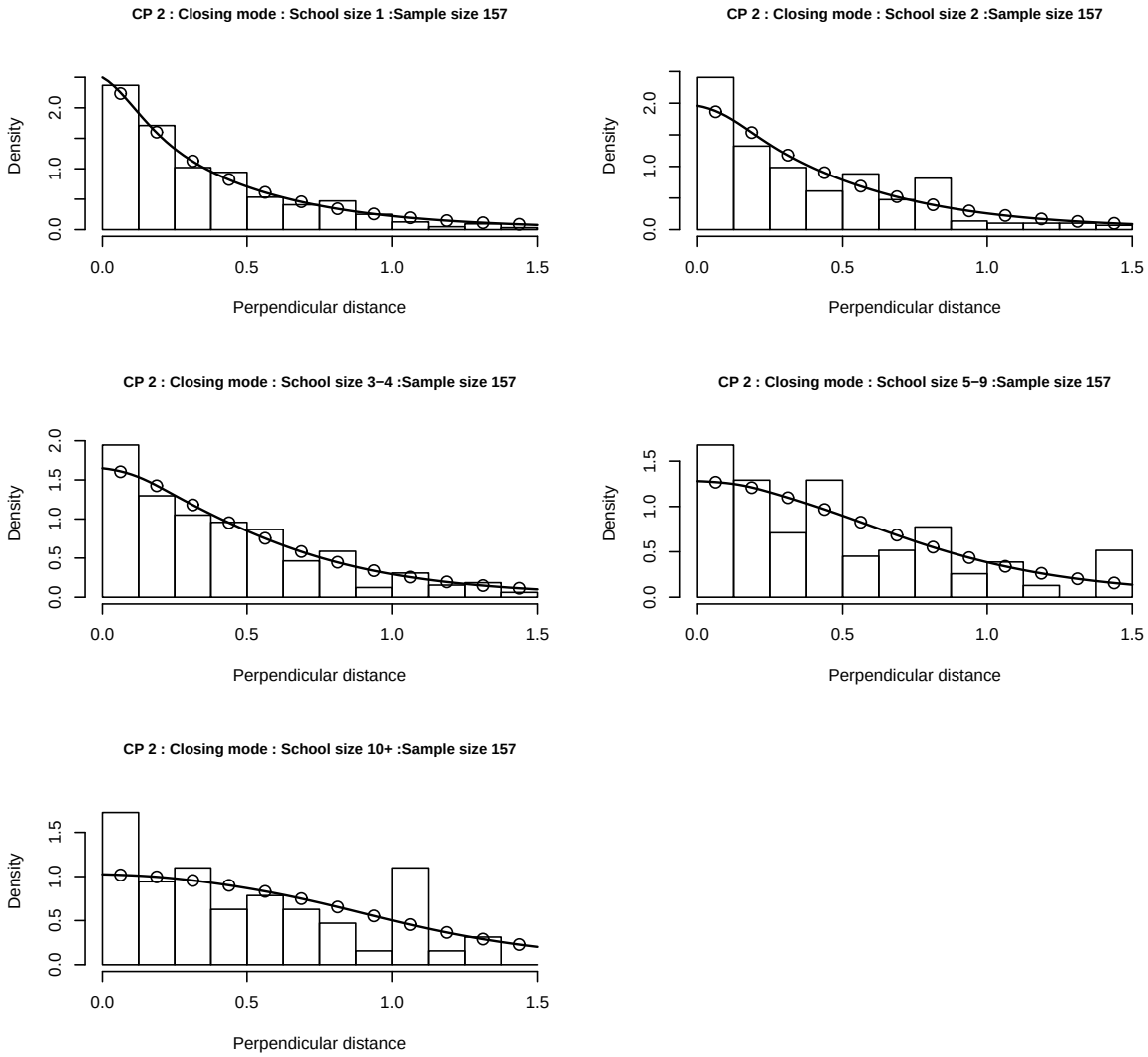

Fig. 13a. (D8) The plot of perpendicular distances in the Closing mode with the definite and possible duplicates by observed school size class for CPII. The histogram is observed, while the open circles and the solid line are predicted.

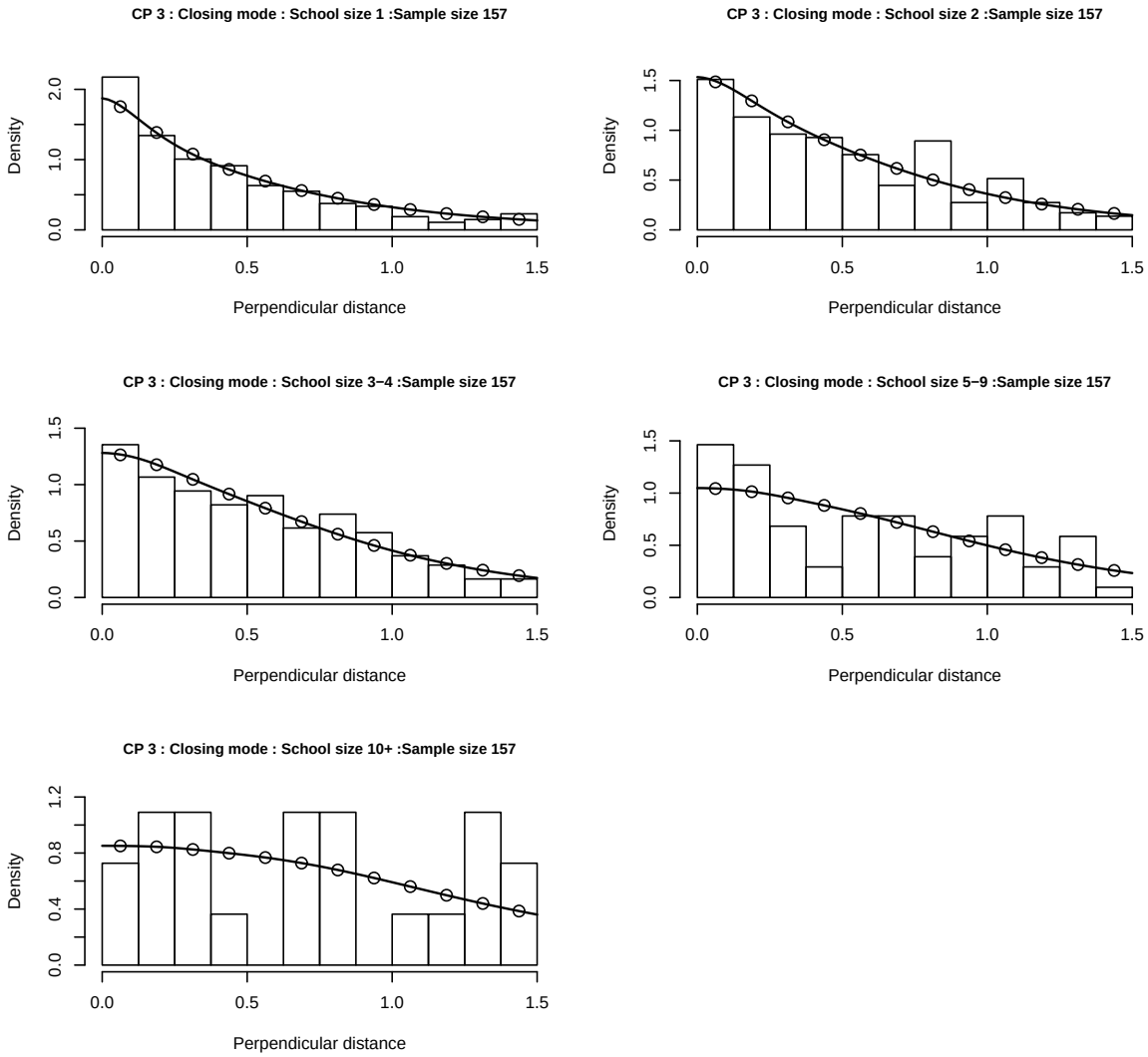

Fig. 13b. (D8) The plot of perpendicular distances in the Closing mode with the definite and possible duplicates by observed school size class for CPIII. The histogram is observed, while the open circles and the solid line are predicted.

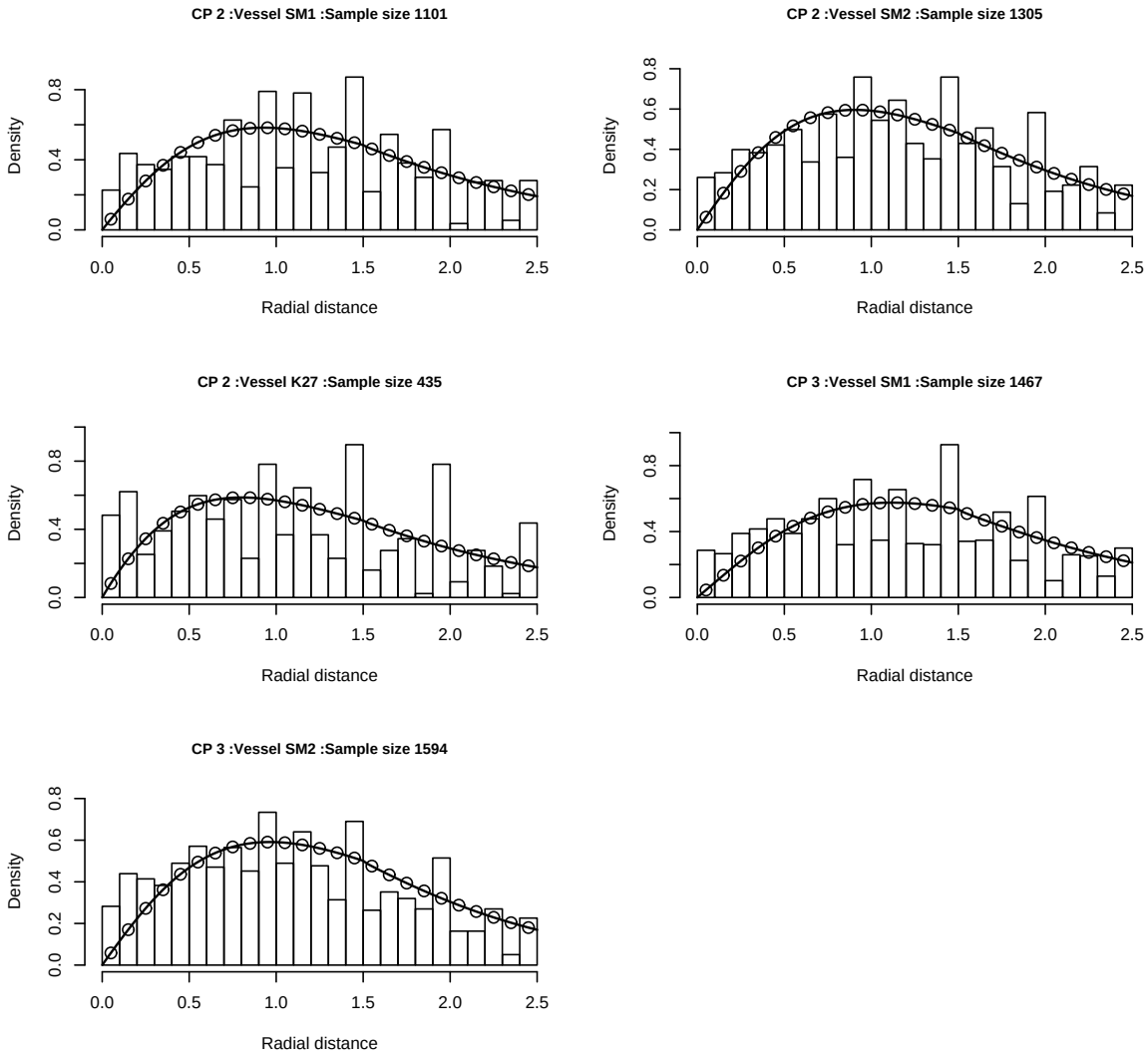

Fig. 14. (D9) The plot of radial distances with the definite and possible duplicates. The histogram is observed, while the open circles and the solid line are predicted.

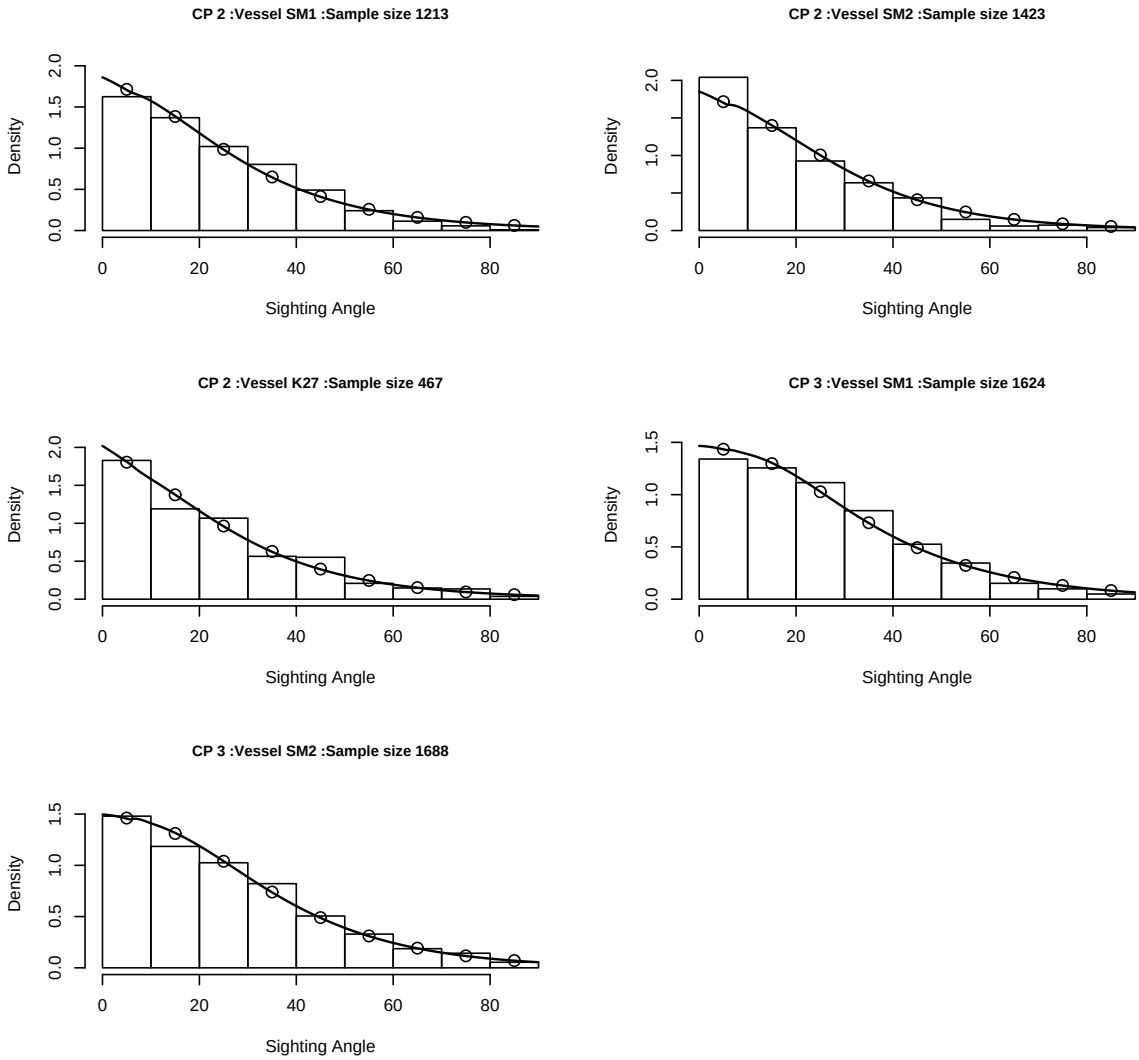

Fig. 15. (D10) The plot of sighting angles with the definite and possible duplicates. The histogram is observed, while the open circles and the solid line are predicted.

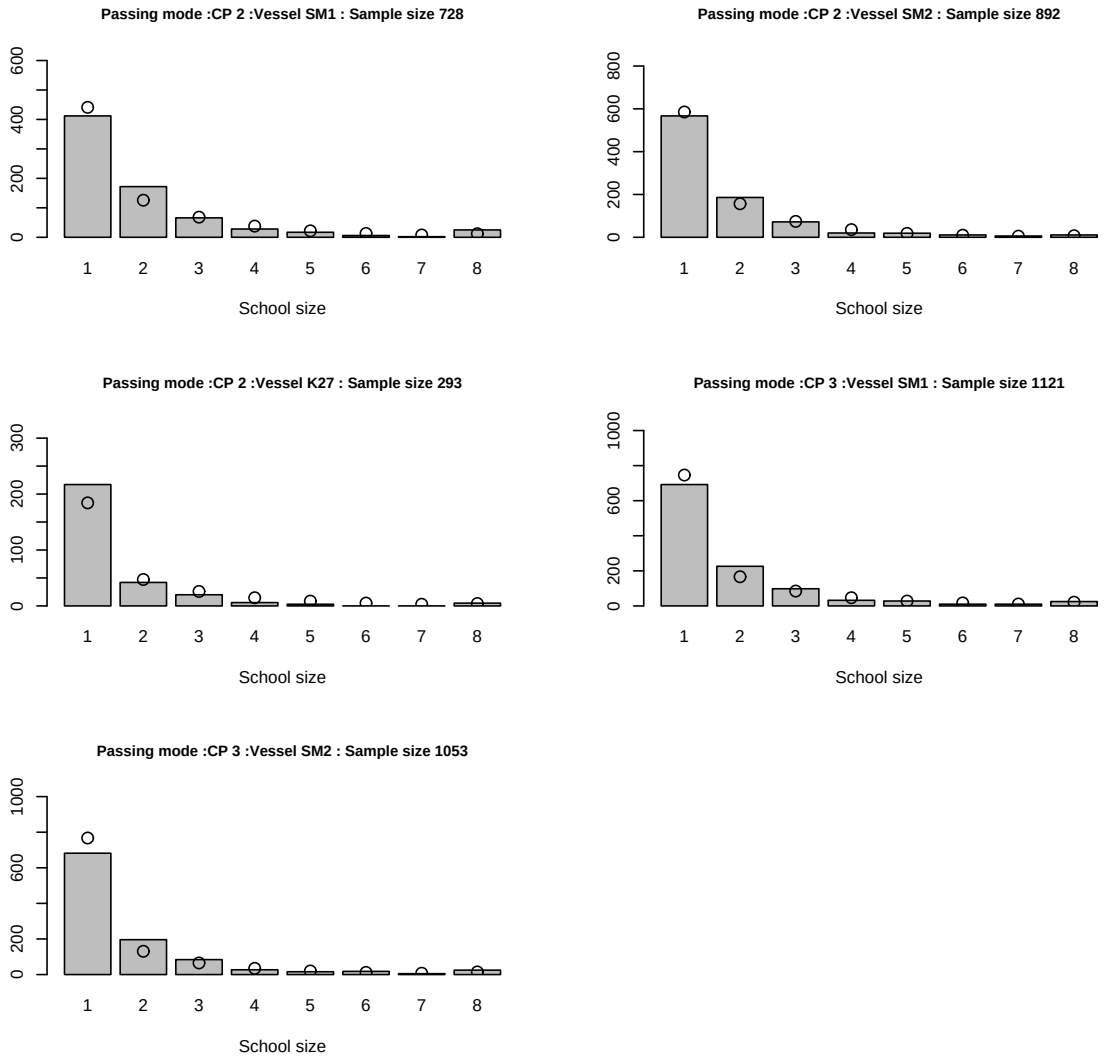

Fig. 16a. (D11) The plot of school size estimates with the definite and possible duplicates in the Passing mode. The histogram is observed, while the open circles are predicted.

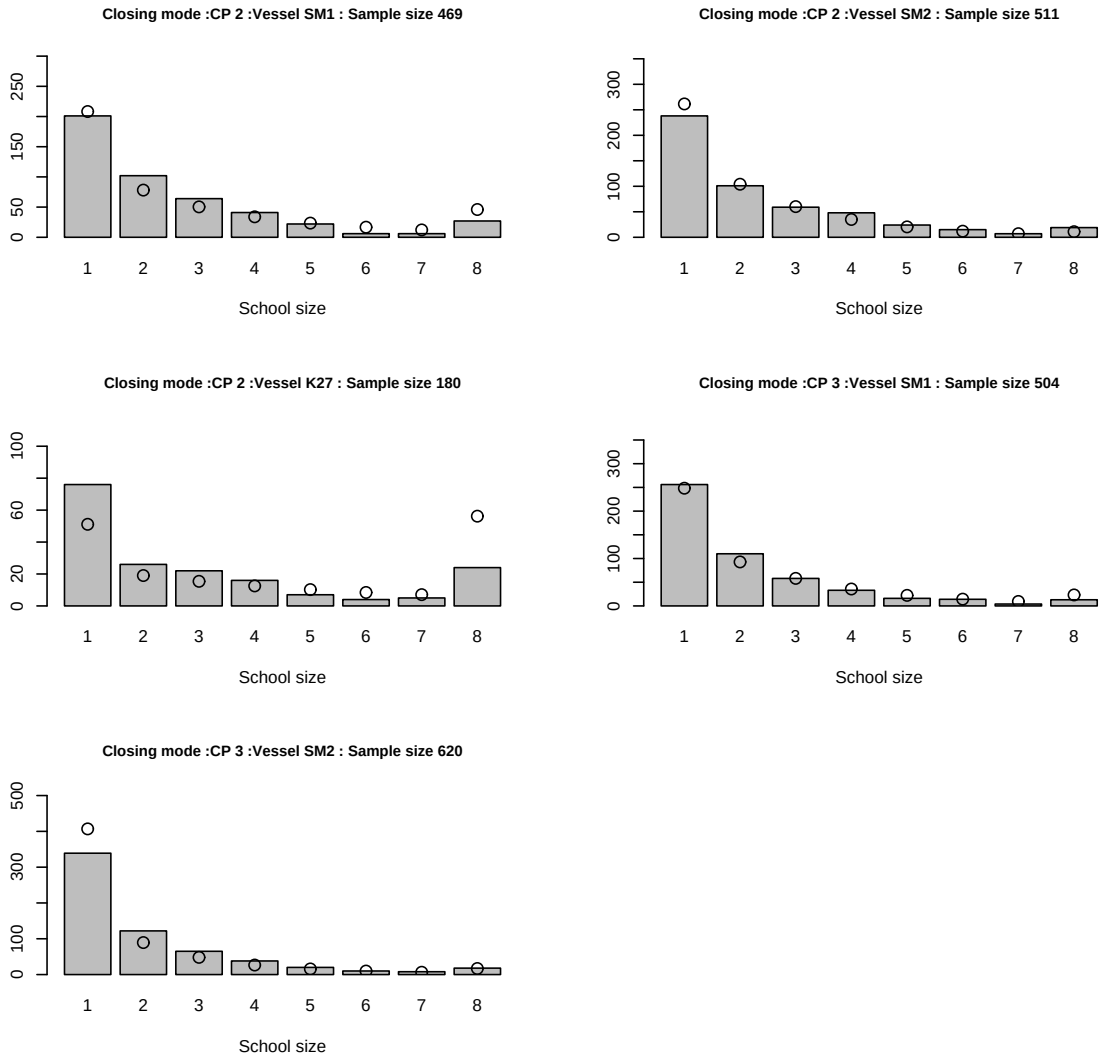

Fig. 16b. (D12) The plot of school size estimates with the definite and possible duplicates in the Closing mode. The histogram is observed, while the open circles are predicted.