# 結論與後續研究

本文使用動差法，針對取後放回與取後不放回兩種不同的抽樣方式，分別提出 、 以及 三種估計式，用以修正兩群落間共同物種豐富度的估計。並依據電腦模擬，在不同模型假設以及物種分配的模擬群落，以及使用真實數據做為模擬群落的情境下，重複進行1000次的隨機抽樣。針對本文所提出的共同物種數估計方法與現有的方法，取後放回的估計方式*Pan*與針對取後不放回的估計方式 ，進行比較，評估新提出的估計式。最後以紅杉國家公園的苔蘚資料，作為分析依據，對該地區不同海拔之間群落中的共同物種數進行估計，並以此計算Jaccard相異性指標作為兩群落間*Beta*多樣性的量化指標。

透過第4章使用電腦模擬群落進行估計中，無論是使用模擬群落或是真實資料作為群落使用的情況下，綜合各項指標的結果，在本文分別針對兩種抽樣形式的樣本所提出的新的估計方法與，比起原有的估計方法與，皆取得更接近真值的估計表現，但具有更大的變異。此外，在使用RMSE與95% CI Coverage評估估計式時，與相較於現有方法，具有較小的RMSE與較精確的95% CI Coverage。引此可推斷，本文所提出的估計方法在估計兩群落間的共同物種時，相較於現有方法具有更精確且穩定的表現。

值得注意的是，在取後不放回的多次模擬結果中，於小樣本的情境下，當其中一個估計的群落變異係數 () 小於0.4時，容易在估計共同種時發生高估的現象。因此，當該情境發生時，可能採用本文所提出的取後放回估計方法，會比使用取後放回的估計方式獲得更優秀的估計表現。除此之外，在標準差的估計方面，無論是何種取樣方法與估計方法下，估計標準差相較於樣本標準差皆有低估的現象發生，有期再取後放回的小樣本中更加明顯。

因此針對以上現象，提出兩個議題：首先，針對取後不放回的小樣本中，共同種結果發生高估的情境，在本文模擬中，為其中一群落的 小於0.4時較為容易發生。而當該結果發生時，或許使用取後放回修正估計式來進行估計，可能會得到較好的估計表現。然而，針對該現象所提出的評估標準「群落物種出現率之變異係數小於0.4」是藉由多次電腦模擬所推算出的平均結果，相對而言較為主觀。故針對該現象的發生，出了修正估計式以確保其穩定性之外，可能須另尋其他更明確且具有理論基礎的標準，來評估估計式的使用時機。此外，對於標準差估計的部分，由於所假設分佈為多項分佈，然而可能存在不同的分佈假設。是否能使用其他假設分佈近一步的修正，或是採用其他估計方法，例如：拔靴法 (Bootstrapping)，以更精確的估計標準差，也將成為未來在物種估計方面的一大挑戰。

最後，雖然共同物種數在作為評估兩群落間的物種相異性以及*Beta*多樣性的基礎之一，但若是想將估計後的截果運用於Jaccard相異性指標時，是針對兩群落間的共同物種以及混合群落物種數的比值作為標準。然而，並非在物種數估計準確的同時，多樣性的量化指標也會隨之準確。因此，若是想使用修正物種數去計算多樣性量化指標時，應注意修正後的估計結果合適的估計方式。

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# 附錄

針對的第4章電腦模擬結果，在不同抽樣方式，情境二至情境四的物種與區塊假設下之模擬。

**物種與區塊數的假設**

情境二：假設總物種數皆為700種物種 (700)，其中群落一與第二群落分別 存在400與600種物種 (400，600)，兩群落間共有300種共 同種(300)。且兩族群皆為100區塊 (100)，並從中依比 例抽取與個區塊作為樣本使用，且。

情境三：假設總物種數為500種物種 (500)，其中群落一與第二群落皆存在 400種物種 (400)，兩群落間共有300種共同種(300)； 兩族群皆為100區塊 (100)，並從中依比例抽取與個區塊 作為樣本使用，而 。

情境四：假設總物種數為500種物種 (500)，其中群落一與第二群落皆存在 400種物種 (400)，兩群落間共有300種共同種(300)。 且兩族群分別為100與200區塊 (100，200)，並從中依比例 抽取與 個區塊作為樣本使用。

而在每種群落假設下，樣本數的模擬次數為 1000次。

表S. 1、取後放回的抽樣方式在情境二下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 124.84 | 269.26 | -30.74 | 61.37 | 46.09 | 68.61 | 0.86 |
| Pan | 245.44 | -54.56 | 40.48 | 27.76 | 67.92 | 0.82 |
| 30 | 12.MoRE | 238.61 | 284.7 | -15.3 | 19.95 | 18.05 | 25.13 | 0.89 |
| Pan | 275.22 | -24.78 | 13.59 | 11.76 | 28.26 | 0.88 |
| 50 | 12.MoRE | 265.18 | 295.03 | -4.97 | 17.2 | 15.4 | 17.9 | 0.87 |
| Pan | 287.6 | -12.4 | 11.82 | 10.15 | 17.13 | 0.87 |
| 70 | 12.MoRE | 275.28 | 299.83 | -0.17 | 16.08 | 14.19 | 16.07 | 0.85 |
| Pan | 293.29 | -6.71 | 10.96 | 9.37 | 12.85 | 0.85 |

表S. 2、取後放回的抽樣方式在情境二下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 118.72 | 239.86 | -60.14 | 54.85 | 40.74 | 81.37 | 0.87 |
| Pan | 215.07 | -84.93 | 33.16 | 22.92 | 91.17 | 0.83 |
| 30 | 12.MoRE | 222.32 | 276.8 | -23.2 | 21.96 | 20.52 | 31.94 | 0.9 |
| Pan | 264.23 | -35.77 | 14.67 | 12.74 | 38.66 | 0.88 |
| 50 | 12.MoRE | 252.94 | 289.31 | -10.69 | 17.5 | 16.05 | 20.5 | 0.88 |
| Pan | 280.84 | -19.16 | 12 | 10.54 | 22.61 | 0.88 |
| 70 | 12.MoRE | 267.23 | 295.18 | -4.82 | 14.71 | 13.98 | 15.47 | 0.88 |
| Pan | 288.57 | -11.43 | 10.33 | 9.39 | 15.4 | 0.87 |

表S. 3、取後放回的抽樣方式在情境二下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 119.37 | 229.87 | -70.13 | 48.08 | 38.03 | 85.02 | 0.86 |
| Pan | 204.97 | -95.03 | 29.66 | 21.54 | 99.54 | 0.84 |
| 30 | 12.MoRE | 214.79 | 272.01 | -27.99 | 24.65 | 21.57 | 37.29 | 0.88 |
| Pan | 258.13 | -41.87 | 16.59 | 13.56 | 45.03 | 0.87 |
| 50 | 12.MoRE | 244.86 | 289.81 | -10.19 | 20.88 | 19.23 | 23.23 | 0.88 |
| Pan | 278.69 | -21.31 | 14.38 | 12.54 | 25.7 | 0.87 |
| 70 | 12.MoRE | 260.18 | 296.43 | -3.57 | 18.26 | 17.32 | 18.59 | 0.89 |
| Pan | 287.62 | -12.38 | 12.68 | 11.42 | 17.72 | 0.88 |

表S. 4、取後放回的抽樣方式在情境二下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 115.86 | 229.83 | -70.17 | 50.19 | 40.94 | 86.26 | 0.87 |
| Pan | 201.22 | -98.78 | 30.98 | 22.83 | 103.52 | 0.85 |
| 30 | 12.MoRE | 209.58 | 275.15 | -24.85 | 29.75 | 24.58 | 38.75 | 0.88 |
| Pan | 259.48 | -40.52 | 19.16 | 15.05 | 44.81 | 0.87 |
| 50 | 12.MoRE | 242.73 | 291.06 | -8.94 | 21.86 | 20.18 | 23.61 | 0.88 |
| Pan | 279.33 | -20.67 | 14.79 | 12.93 | 25.41 | 0.89 |
| 70 | 12.MoRE | 259.41 | 297.41 | -2.59 | 19.32 | 17.82 | 19.49 | 0.88 |
| Pan | 288.54 | -11.46 | 13.44 | 11.66 | 17.66 | 0.87 |

表S. 5、取後放回的抽樣方式在情境三下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 151.89 | 291.68 | -8.32 | 55.83 | 43.77 | 56.42 | 0.87 |
| Pan | 270.85 | -29.15 | 37.98 | 27.72 | 47.87 | 0.84 |
| 30 | 12.MoRE | 229.94 | 295.36 | -4.64 | 25.16 | 21.78 | 25.57 | 0.9 |
| Pan | 285.24 | -14.76 | 17.63 | 14.62 | 22.99 | 0.89 |
| 50 | 12.MoRE | 262.44 | 300.04 | 0.04 | 18.16 | 16.1 | 18.15 | 0.89 |
| Pan | 293.07 | -6.93 | 12.65 | 10.84 | 14.42 | 0.88 |
| 70 | 12.MoRE | 276.46 | 300.61 | 0.61 | 14.48 | 12.96 | 14.49 | 0.86 |
| Pan | 295.85 | -4.15 | 10.32 | 8.84 | 11.12 | 0.85 |

表S. 6、取後放回的抽樣方式在情境三下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 154.86 | 253.01 | -46.99 | 38.53 | 32.68 | 60.76 | 0.88 |
| Pan | 233.32 | -66.68 | 25.11 | 19.11 | 71.24 | 0.86 |
| 30 | 12.MoRE | 218.3 | 275.39 | -24.61 | 22.88 | 21.29 | 33.59 | 0.92 |
| Pan | 262.64 | -37.36 | 15.29 | 13.13 | 40.36 | 0.9 |
| 50 | 12.MoRE | 244.6 | 285.93 | -14.07 | 18.46 | 17.49 | 23.2 | 0.9 |
| Pan | 276.47 | -23.53 | 12.69 | 11.24 | 26.73 | 0.89 |
| 70 | 12.MoRE | 258.78 | 291.59 | -8.41 | 15.85 | 15.3 | 17.94 | 0.9 |
| Pan | 283.96 | -16.04 | 11.14 | 10.1 | 19.53 | 0.88 |

表S. 7、取後放回的抽樣方式在情境三下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 149.91 | 250.1 | -49.9 | 39.71 | 34.31 | 63.76 | 0.89 |
| Pan | 228.42 | -71.58 | 25.27 | 19.96 | 75.9 | 0.87 |
| 30 | 12.MoRE | 210.79 | 275.31 | -24.69 | 27.07 | 23.77 | 36.63 | 0.89 |
| Pan | 260.27 | -39.73 | 17.73 | 14.62 | 43.5 | 0.89 |
| 50 | 12.MoRE | 238.46 | 287 | -13 | 21.37 | 19.78 | 25 | 0.9 |
| Pan | 275.48 | -24.52 | 14.5 | 12.64 | 28.48 | 0.88 |
| 70 | 12.MoRE | 253.86 | 291.79 | -8.21 | 17.98 | 17.07 | 19.76 | 0.89 |
| Pan | 283.04 | -16.96 | 12.63 | 11.19 | 21.14 | 0.86 |

表S. 8、取後放回的抽樣方式在情境三下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 145.97 | 243.51 | -56.49 | 41.24 | 33.87 | 69.92 | 0.88 |
| Pan | 219.83 | -80.17 | 25.29 | 19.35 | 84.06 | 0.86 |
| 30 | 12.MoRE | 203.73 | 270.95 | -29.05 | 28.84 | 24.61 | 40.92 | 0.88 |
| Pan | 254.7 | -45.3 | 18.87 | 15.08 | 49.07 | 0.87 |
| 50 | 12.MoRE | 231.27 | 282.68 | -17.32 | 23.18 | 20.65 | 28.93 | 0.88 |
| Pan | 270.41 | -29.59 | 15.53 | 13.09 | 33.42 | 0.86 |
| 70 | 12.MoRE | 247.5 | 290.08 | -9.92 | 19.83 | 18.4 | 22.16 | 0.89 |
| Pan | 279.96 | -20.04 | 13.62 | 11.94 | 24.23 | 0.88 |

表S. 9、取後放回的抽樣方式在情境四下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 150.09 | 305.42 | 5.42 | 60.34 | 46.78 | 60.55 | 0.87 |
| Pan | 283.4 | -16.6 | 41.32 | 28.51 | 44.52 | 0.81 |
| 30 | 12.MoRE | 273.08 | 301.7 | 1.7 | 12.44 | 11.78 | 12.55 | 0.91 |
| Pan | 297.95 | -2.05 | 9.09 | 8.35 | 9.32 | 0.91 |
| 50 | 12.MoRE | 293.35 | 300.54 | 0.54 | 5.19 | 5.32 | 5.22 | 0.86 |
| Pan | 299.45 | -0.55 | 4.01 | 3.96 | 4.05 | 0.87 |
| 70 | 12.MoRE | 297.44 | 299.97 | -0.03 | 3.08 | 3.08 | 3.08 | 0.78 |
| Pan | 299.4 | -0.6 | 2.41 | 2.27 | 2.48 | 0.77 |

表S.10、取後放回的抽樣方式在情境四下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 189.35 | 292.07 | -7.93 | 35.51 | 30.45 | 36.37 | 0.89 |
| Pan | 278.38 | -21.62 | 24.72 | 18.7 | 32.83 | 0.85 |
| 30 | 12.MoRE | 284.54 | 301 | 1 | 8.81 | 8.7 | 8.86 | 0.9 |
| Pan | 298.27 | -1.73 | 6.39 | 6.11 | 6.61 | 0.88 |
| 50 | 12.MoRE | 296.12 | 300.51 | 0.51 | 4.03 | 4.08 | 4.06 | 0.83 |
| Pan | 299.73 | -0.27 | 3.09 | 3.05 | 3.1 | 0.82 |
| 70 | 12.MoRE | 298.58 | 300.06 | 0.06 | 2.09 | 2.24 | 2.09 | 0.77 |
| Pan | 299.73 | -0.27 | 1.66 | 1.69 | 1.68 | 0.75 |

表S.11、取後放回的抽樣方式在情境四下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 179.09 | 280.11 | -19.89 | 39.18 | 31.17 | 43.92 | 0.86 |
| Pan | 262.25 | -37.75 | 25.55 | 18.42 | 45.58 | 0.83 |
| 30 | 12.MoRE | 274.47 | 300.73 | 0.73 | 13.23 | 11.92 | 13.24 | 0.88 |
| Pan | 295.92 | -4.08 | 9.39 | 8.01 | 10.23 | 0.86 |
| 50 | 12.MoRE | 291.63 | 301.1 | 1.1 | 6.6 | 6.55 | 6.69 | 0.87 |
| Pan | 299.63 | -0.37 | 5.02 | 4.78 | 5.03 | 0.86 |
| 70 | 12.MoRE | 296.42 | 300.37 | 0.37 | 3.98 | 4.04 | 3.99 | 0.81 |
| Pan | 299.7 | -0.3 | 3.13 | 3.06 | 3.14 | 0.81 |

表S.12、取後放回的抽樣方式在情境四下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | 12.MoRE | 173.62 | 275.55 | -24.45 | 42.65 | 33.45 | 49.14 | 0.87 |
| Pan | 252.91 | -47.09 | 26.06 | 18.94 | 53.82 | 0.85 |
| 30 | 12.MoRE | 267.04 | 299.99 | -0.01 | 15.73 | 14.21 | 15.72 | 0.89 |
| Pan | 294.02 | -5.98 | 10.84 | 9.28 | 12.38 | 0.88 |
| 50 | 12.MoRE | 287.71 | 300.53 | 0.53 | 8.33 | 7.85 | 8.34 | 0.88 |
| Pan | 298.39 | -1.61 | 6.08 | 5.6 | 6.29 | 0.87 |
| 70 | 12.MoRE | 294.25 | 300.18 | 0.18 | 4.78 | 5.08 | 4.78 | 0.85 |
| Pan | 299.23 | -0.77 | 3.72 | 3.81 | 3.79 | 0.85 |

表S. 13、取後不放回的抽樣方式在情境二下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 130.68 | 363.05 | 63.05 | 57.26 | 51.85 | 85.15 | 0.92 |
| 12.wMoRE2 | 367.87 | 67.87 | 67.21 | 56.68 | 95.49 | 0.91 |
| wChao2.12 | 246.5 | -53.5 | 30.8 | 24.32 | 61.73 | 0.87 |
| 12.MoRE | 281.9 | -18.1 | 57.45 | 45.58 | 60.21 | 0.89 |
| 0.3 | 12.wMoRE1 | 251.46 | 311.01 | 11.01 | 12.82 | 9.77 | 16.9 | 0.87 |
| 12.wMoRE2 | 313.66 | 13.66 | 16.61 | 14.97 | 21.5 | 0.93 |
| wChao2.12 | 281.44 | -18.56 | 9.7 | 9.14 | 20.94 | 0.91 |
| 12.MoRE | 300.09 | 0.09 | 19.47 | 19.1 | 19.46 | 0.93 |
| 0.5 | 12.wMoRE1 | 277.73 | 299.59 | -0.41 | 6.85 | 7.51 | 6.86 | 0.96 |
| 12.wMoRE2 | 297.84 | -2.16 | 6.14 | 5.89 | 6.5 | 0.94 |
| wChao2.12 | 293 | -7 | 6.28 | 5.83 | 9.4 | 0.89 |
| 12.MoRE | 313.52 | 13.52 | 16.8 | 16.91 | 21.56 | 0.91 |
| 0.7 | 12.wMoRE1 | 289.07 | 299.79 | -0.21 | 3.77 | 4.05 | 3.77 | 0.97 |
| 12.wMoRE2 | 298.57 | -1.43 | 3.41 | 3.51 | 3.7 | 0.96 |
| wChao2.12 | 298.03 | -1.97 | 3.72 | 3.73 | 4.2 | 0.9 |
| 12.MoRE | 324.13 | 24.13 | 14.71 | 17.16 | 28.25 | 0.94 |

表S. 14、取後不放回的抽樣方式在情境二下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 127.75 | 307.14 | 7.14 | 45.84 | 44.82 | 46.37 | 0.96 |
| 12.wMoRE2 | 310.97 | 10.97 | 51.61 | 43.1 | 52.74 | 0.93 |
| wChao2.12 | 216.34 | -83.66 | 24.65 | 19.44 | 87.21 | 0.87 |
| 12.MoRE | 246.24 | -53.76 | 46.83 | 38.83 | 71.28 | 0.9 |
| 0.3 | 12.wMoRE1 | 234.05 | 295.24 | -4.76 | 13.56 | 14.3 | 14.37 | 0.96 |
| 12.wMoRE2 | 301.76 | 1.76 | 18.12 | 16.94 | 18.2 | 0.95 |
| wChao2.12 | 269.31 | -30.69 | 10.75 | 9.88 | 32.52 | 0.91 |
| 12.MoRE | 294.08 | -5.92 | 22.85 | 21.09 | 23.6 | 0.9 |
| 0.5 | 12.wMoRE1 | 266.21 | 297.06 | -2.94 | 8.33 | 8.51 | 8.83 | 0.95 |
| 12.wMoRE2 | 300.6 | 0.6 | 9.74 | 8.98 | 9.75 | 0.94 |
| wChao2.12 | 287.46 | -12.54 | 7.63 | 6.76 | 14.68 | 0.9 |
| 12.MoRE | 314.96 | 14.96 | 20.43 | 19.06 | 25.31 | 0.91 |
| 0.7 | 12.wMoRE1 | 282.98 | 299.11 | -0.89 | 5.14 | 4.97 | 5.21 | 0.95 |
| 12.wMoRE2 | 299.58 | -0.42 | 5.23 | 4.84 | 5.24 | 0.93 |
| wChao2.12 | 296.37 | -3.63 | 5.05 | 4.55 | 6.22 | 0.89 |
| 12.MoRE | 338.29 | 38.29 | 20.47 | 21.34 | 43.42 | 0.94 |

表S. 15、取後不放回的抽樣方式在情境二下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 126.46 | 290.65 | -9.35 | 43.42 | 38.73 | 44.39 | 0.92 |
| 12.wMoRE2 | 299.29 | -0.71 | 55.46 | 44.91 | 55.44 | 0.92 |
| wChao2.12 | 208.76 | -91.24 | 24.23 | 19.12 | 94.4 | 0.87 |
| 12.MoRE | 243.6 | -56.4 | 47.84 | 38.78 | 73.94 | 0.88 |
| 0.3 | 12.wMoRE1 | 226.84 | 293.38 | -6.62 | 16.14 | 14.9 | 17.43 | 0.94 |
| 12.wMoRE2 | 296.97 | -3.03 | 21.04 | 17.76 | 21.24 | 0.92 |
| wChao2.12 | 266.22 | -33.78 | 12.58 | 10.78 | 36.04 | 0.88 |
| 12.MoRE | 296.13 | -3.87 | 27.57 | 24.19 | 27.82 | 0.89 |
| 0.5 | 12.wMoRE1 | 261.66 | 297.43 | -2.57 | 8.65 | 9.23 | 9.02 | 0.96 |
| 12.wMoRE2 | 298.04 | -1.96 | 9.33 | 9.33 | 9.53 | 0.95 |
| wChao2.12 | 286.87 | -13.13 | 7.84 | 7.46 | 15.29 | 0.9 |
| 12.MoRE | 321.63 | 21.63 | 21 | 22.07 | 30.14 | 0.94 |
| 0.7 | 12.wMoRE1 | 281.01 | 299.5 | -0.5 | 5.31 | 5.33 | 5.33 | 0.95 |
| 12.wMoRE2 | 298.91 | -1.09 | 5.21 | 5.09 | 5.32 | 0.94 |
| wChao2.12 | 296.41 | -3.59 | 5.23 | 4.89 | 6.34 | 0.89 |
| 12.MoRE | 342.5 | 42.5 | 20.79 | 23.2 | 47.31 | 0.95 |

表S. 16、取後放回的抽樣方式在情境二下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 121.46 | 282.28 | -17.72 | 44.81 | 41.19 | 48.17 | 0.94 |
| 12.wMoRE2 | 290.34 | -9.66 | 55.69 | 47.56 | 56.5 | 0.93 |
| wChao2.12 | 202.71 | -97.29 | 25.03 | 19.93 | 100.45 | 0.86 |
| 12.MoRE | 243.35 | -56.65 | 50.83 | 41.75 | 76.09 | 0.87 |
| 0.3 | 12.wMoRE1 | 223.8 | 300.92 | 0.92 | 17.6 | 19.65 | 17.62 | 0.97 |
| 12.wMoRE2 | 304.37 | 4.37 | 22.81 | 19.48 | 23.22 | 0.93 |
| wChao2.12 | 270.02 | -29.98 | 13.43 | 11.79 | 32.85 | 0.9 |
| 12.MoRE | 305 | 5 | 31.71 | 27.54 | 32.09 | 0.9 |
| 0.5 | 12.wMoRE1 | 262.84 | 301.43 | 1.43 | 8.93 | 9.83 | 9.04 | 0.97 |
| 12.wMoRE2 | 303.64 | 3.64 | 10.47 | 9.93 | 11.08 | 0.94 |
| wChao2.12 | 289.22 | -10.78 | 8.19 | 7.55 | 13.54 | 0.9 |
| 12.MoRE | 321.8 | 21.8 | 22.39 | 22.04 | 31.24 | 0.92 |
| 0.7 | 12.wMoRE1 | 283.23 | 300.86 | 0.86 | 4.84 | 5.18 | 4.92 | 0.96 |
| 12.wMoRE2 | 301.34 | 1.34 | 5 | 5.12 | 5.18 | 0.95 |
| wChao2.12 | 296.91 | -3.09 | 4.79 | 4.59 | 5.7 | 0.91 |
| 12.MoRE | 330.09 | 30.09 | 17.81 | 19.61 | 34.97 | 0.95 |

表S. 17、取後不放回的抽樣方式在情境三下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 159.06 | 373.25 | 73.25 | 47.31 | 39.17 | 87.18 | 0.91 |
| 12.wMoRE2 | 382.25 | 82.25 | 70.75 | 56.44 | 108.47 | 0.92 |
| wChao2.12 | 271.82 | -28.18 | 27.94 | 23.77 | 39.67 | 0.9 |
| 12.MoRE | 308.83 | 8.83 | 56.2 | 44.22 | 56.86 | 0.9 |
| 0.3 | 12.wMoRE1 | 243.7 | 330.38 | 30.38 | 13.99 | 12.84 | 33.45 | 0.94 |
| 12.wMoRE2 | 334.38 | 34.38 | 18.56 | 17.4 | 39.06 | 0.94 |
| wChao2.12 | 289.62 | -10.38 | 11.8 | 10.95 | 15.71 | 0.92 |
| 12.MoRE | 312.97 | 12.97 | 23.34 | 21.64 | 26.69 | 0.92 |
| 0.5 | 12.wMoRE1 | 277.54 | 315.42 | 15.42 | 7 | 7.6 | 16.93 | 0.96 |
| 12.wMoRE2 | 316.22 | 16.22 | 8 | 8.6 | 18.09 | 0.96 |
| wChao2.12 | 296.67 | -3.33 | 6.05 | 5.99 | 6.9 | 0.91 |
| 12.MoRE | 322.72 | 22.72 | 18.08 | 18.55 | 29.03 | 0.94 |
| 0.7 | 12.wMoRE1 | 291.93 | 304.46 | 4.46 | 3.47 | 4.16 | 5.65 | 0.98 |
| 12.wMoRE2 | 304.6 | 4.6 | 3.6 | 4.29 | 5.84 | 0.98 |
| wChao2.12 | 299.35 | -0.65 | 3.02 | 3.18 | 3.09 | 0.91 |
| 12.MoRE | 329.92 | 29.92 | 14.28 | 18.41 | 33.14 | 0.96 |

表S. 18、取後不放回的抽樣方式在情境三下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 160.17 | 302.73 | 2.73 | 33.67 | 28.43 | 33.77 | 0.9 |
| 12.wMoRE2 | 308.52 | 8.52 | 40.33 | 35.82 | 41.2 | 0.93 |
| wChao2.12 | 233.84 | -66.16 | 20.05 | 16.93 | 69.13 | 0.89 |
| 12.MoRE | 262.46 | -37.54 | 37.84 | 32.68 | 53.29 | 0.9 |
| 0.3 | 12.wMoRE1 | 225.7 | 294.97 | -5.03 | 16.21 | 14.21 | 16.97 | 0.93 |
| 12.wMoRE2 | 301.87 | 1.87 | 22.21 | 19.5 | 22.28 | 0.93 |
| wChao2.12 | 264.79 | -35.21 | 12.57 | 10.53 | 37.39 | 0.87 |
| 12.MoRE | 289 | -11 | 26.09 | 21.81 | 28.3 | 0.88 |
| 0.5 | 12.wMoRE1 | 254.95 | 296.39 | -3.61 | 10.88 | 10 | 11.46 | 0.93 |
| 12.wMoRE2 | 301.25 | 1.25 | 14.7 | 12.97 | 14.75 | 0.93 |
| wChao2.12 | 280.67 | -19.33 | 9.33 | 7.9 | 21.46 | 0.87 |
| 12.MoRE | 307.28 | 7.28 | 22.1 | 19.68 | 23.26 | 0.89 |
| 0.7 | 12.wMoRE1 | 271.15 | 297.59 | -2.41 | 8.2 | 7.62 | 8.54 | 0.92 |
| 12.wMoRE2 | 300.09 | 0.09 | 9.54 | 8.39 | 9.54 | 0.92 |
| wChao2.12 | 289.4 | -10.6 | 7.38 | 6.26 | 12.91 | 0.87 |
| 12.MoRE | 331.18 | 31.18 | 24.84 | 23.16 | 39.86 | 0.91 |

表S. 19、取後不放回的抽樣方式在情境三下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 153.34 | 299.93 | -0.07 | 36.54 | 28.54 | 36.53 | 0.89 |
| 12.wMoRE2 | 306.95 | 6.95 | 48.58 | 41.09 | 49.05 | 0.93 |
| wChao2.12 | 230.42 | -69.58 | 21.62 | 17.94 | 72.86 | 0.88 |
| 12.MoRE | 266.17 | -33.83 | 45.96 | 36.79 | 57.05 | 0.89 |
| 0.3 | 12.wMoRE1 | 219.68 | 295.52 | -4.48 | 16.77 | 15.01 | 17.35 | 0.92 |
| 12.wMoRE2 | 300.87 | 0.87 | 23.68 | 20.31 | 23.68 | 0.94 |
| wChao2.12 | 263.91 | -36.09 | 12.81 | 11.37 | 38.29 | 0.89 |
| 12.MoRE | 296.76 | -3.24 | 28.32 | 25.95 | 28.49 | 0.9 |
| 0.5 | 12.wMoRE1 | 251.18 | 296.83 | -3.17 | 10.52 | 10.46 | 10.98 | 0.95 |
| 12.wMoRE2 | 299.4 | -0.6 | 13.31 | 12.65 | 13.32 | 0.94 |
| wChao2.12 | 280.36 | -19.64 | 8.98 | 8.37 | 21.6 | 0.91 |
| 12.MoRE | 315.41 | 15.41 | 22.86 | 23.04 | 27.55 | 0.94 |
| 0.7 | 12.wMoRE1 | 269.77 | 297.88 | -2.12 | 7.64 | 7.88 | 7.92 | 0.96 |
| 12.wMoRE2 | 299 | -1 | 8.42 | 8.35 | 8.48 | 0.96 |
| wChao2.12 | 289.27 | -10.73 | 6.85 | 6.43 | 12.73 | 0.89 |
| 12.MoRE | 331.2 | 31.2 | 20.99 | 22.91 | 37.59 | 0.95 |

表S. 20、取後放回的抽樣方式在情境三下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 154.28 | 288.19 | -11.81 | 33.85 | 30.26 | 35.84 | 0.92 |
| 12.wMoRE2 | 296.9 | -3.1 | 44.25 | 37.21 | 44.34 | 0.93 |
| wChao2.12 | 225.06 | -74.94 | 20.74 | 16.82 | 77.76 | 0.88 |
| 12.MoRE | 262.05 | -37.95 | 42.71 | 35.21 | 57.12 | 0.88 |
| 0.3 | 12.wMoRE1 | 218.34 | 295.64 | -4.36 | 18.74 | 17.87 | 19.23 | 0.94 |
| 12.wMoRE2 | 300.33 | 0.33 | 25.28 | 21.32 | 25.27 | 0.94 |
| wChao2.12 | 263.33 | -36.67 | 13.56 | 11.91 | 39.1 | 0.9 |
| 12.MoRE | 295.2 | -4.8 | 30.68 | 25.92 | 31.03 | 0.9 |
| 0.5 | 12.wMoRE1 | 248.75 | 297.2 | -2.8 | 12.83 | 12.29 | 13.13 | 0.94 |
| 12.wMoRE2 | 298.45 | -1.55 | 15.46 | 13.78 | 15.53 | 0.94 |
| wChao2.12 | 279.09 | -20.91 | 10.32 | 9.11 | 23.32 | 0.88 |
| 12.MoRE | 305.35 | 5.35 | 23.07 | 21.46 | 23.67 | 0.9 |
| 0.7 | 12.wMoRE1 | 266.82 | 298.09 | -1.91 | 8.5 | 9.04 | 8.71 | 0.96 |
| 12.wMoRE2 | 298.04 | -1.96 | 9.71 | 9.4 | 9.9 | 0.94 |
| wChao2.12 | 287.74 | -12.26 | 7.36 | 7.17 | 14.3 | 0.91 |
| 12.MoRE | 310.82 | 10.82 | 17.42 | 18.4 | 20.5 | 0.92 |

表S. 21、取後不放回的抽樣方式在情境四下，群落一為同質模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 159.21 | 379.59 | 79.59 | 48.65 | 39.61 | 93.27 | 0.89 |
| 12.wMoRE2 | 391.99 | 91.99 | 92.69 | 60.95 | 130.55 | 0.92 |
| wChao2.12 | 272.87 | -27.13 | 28.1 | 24.33 | 39.05 | 0.9 |
| 12.MoRE | 304.06 | 4.06 | 51.66 | 42.84 | 51.79 | 0.9 |
| 0.3 | 12.wMoRE1 | 271.94 | 314.85 | 14.85 | 10.24 | 8.33 | 18.03 | 0.89 |
| 12.wMoRE2 | 317.52 | 17.52 | 12.44 | 11.8 | 21.48 | 0.94 |
| wChao2.12 | 291.25 | -8.75 | 7.89 | 7.03 | 11.78 | 0.88 |
| 12.MoRE | 300.94 | 0.94 | 14.23 | 13.25 | 14.25 | 0.9 |
| 0.5 | 12.wMoRE1 | 288.99 | 300.51 | 0.51 | 4.81 | 5.12 | 4.83 | 0.96 |
| 12.wMoRE2 | 299.28 | -0.72 | 4.15 | 3.99 | 4.21 | 0.93 |
| wChao2.12 | 296.71 | -3.29 | 4.41 | 4.11 | 5.51 | 0.86 |
| 12.MoRE | 305.96 | 5.96 | 10.79 | 10.9 | 12.32 | 0.88 |
| 0.7 | 12.wMoRE1 | 294.62 | 299.87 | -0.13 | 2.75 | 2.84 | 2.75 | 0.95 |
| 12.wMoRE2 | 299.3 | -0.7 | 2.53 | 2.46 | 2.62 | 0.95 |
| wChao2.12 | 298.96 | -1.04 | 2.71 | 2.59 | 2.9 | 0.85 |
| 12.MoRE | 310.06 | 10.06 | 9.8 | 10.72 | 14.04 | 0.91 |

表S. 22、取後不放回的抽樣方式在情境四下，兩群落皆為均勻模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 157.26 | 306.13 | 6.13 | 36.13 | 29.39 | 36.63 | 0.88 |
| 12.wMoRE2 | 309.38 | 9.38 | 44.84 | 37.29 | 45.78 | 0.92 |
| wChao2.12 | 231.82 | -68.18 | 21.15 | 17.38 | 71.38 | 0.88 |
| 12.MoRE | 256.95 | -43.05 | 38.25 | 32.16 | 57.57 | 0.88 |
| 0.3 | 12.wMoRE1 | 250.49 | 298.19 | -1.81 | 12.04 | 10.69 | 12.17 | 0.92 |
| 12.wMoRE2 | 303.26 | 3.26 | 16.27 | 15.34 | 16.59 | 0.94 |
| wChao2.12 | 277.91 | -22.09 | 9.81 | 8.74 | 24.16 | 0.9 |
| 12.MoRE | 295.75 | -4.25 | 19.08 | 17.75 | 19.53 | 0.9 |
| 0.5 | 12.wMoRE1 | 275.77 | 299.32 | -0.68 | 7.08 | 6.74 | 7.11 | 0.95 |
| 12.wMoRE2 | 299.32 | -0.68 | 7.23 | 6.97 | 7.25 | 0.94 |
| wChao2.12 | 291.99 | -8.01 | 6.51 | 5.92 | 10.32 | 0.89 |
| 12.MoRE | 311.21 | 11.21 | 15.68 | 15.64 | 19.27 | 0.92 |
| 0.7 | 12.wMoRE1 | 288.22 | 299.73 | -0.27 | 4.17 | 4.08 | 4.18 | 0.94 |
| 12.wMoRE2 | 298.94 | -1.06 | 3.96 | 3.81 | 4.1 | 0.94 |
| wChao2.12 | 297.66 | -2.34 | 4.12 | 3.82 | 4.74 | 0.88 |
| 12.MoRE | 323.15 | 23.15 | 14.83 | 16.28 | 27.49 | 0.93 |

表S. 23、取後不放回的抽樣方式在情境四下，群落一為均勻模型，群落二為Broken-stick模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 156.58 | 300.09 | 0.09 | 35.8 | 27.9 | 35.78 | 0.89 |
| 12.wMoRE2 | 310.17 | 10.17 | 52.07 | 42.92 | 53.03 | 0.94 |
| wChao2.12 | 229.88 | -70.12 | 20.99 | 17.59 | 73.19 | 0.89 |
| 12.MoRE | 256.18 | -43.82 | 40.83 | 33.23 | 59.88 | 0.89 |
| 0.3 | 12.wMoRE1 | 246.82 | 295.82 | -4.18 | 13.73 | 10.71 | 14.35 | 0.88 |
| 12.wMoRE2 | 305.03 | 5.03 | 20.11 | 17.09 | 20.73 | 0.92 |
| wChao2.12 | 275.39 | -24.61 | 11.32 | 8.99 | 27.09 | 0.86 |
| 12.MoRE | 295.65 | -4.35 | 23.25 | 19.35 | 23.65 | 0.86 |
| 0.5 | 12.wMoRE1 | 272.32 | 298.08 | -1.92 | 7.63 | 7.05 | 7.86 | 0.93 |
| 12.wMoRE2 | 298.96 | -1.04 | 8.02 | 7.79 | 8.09 | 0.95 |
| wChao2.12 | 290.34 | -9.66 | 6.92 | 6.29 | 11.88 | 0.89 |
| 12.MoRE | 314.46 | 14.46 | 17.74 | 17.83 | 22.88 | 0.92 |
| 0.7 | 12.wMoRE1 | 286.38 | 299.73 | -0.27 | 4.58 | 4.43 | 4.59 | 0.94 |
| 12.wMoRE2 | 299.05 | -0.95 | 4.42 | 4.23 | 4.52 | 0.94 |
| wChao2.12 | 297.47 | -2.53 | 4.49 | 4.15 | 5.15 | 0.89 |
| 12.MoRE | 330.72 | 30.72 | 17.57 | 19.77 | 35.39 | 0.94 |

表S. 24、取後放回的抽樣方式在情境四下，群落一為Broken-stick模型，群落二為對數常數模型之情境下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | 12.wMoRE1 | 172.25 | 289.62 | -10.38 | 28.85 | 25.08 | 30.65 | 0.92 |
| 12.wMoRE2 | 297.81 | -2.19 | 44.89 | 37.64 | 44.92 | 0.93 |
| wChao2.12 | 232.28 | -67.72 | 17.57 | 15.58 | 69.96 | 0.9 |
| 12.MoRE | 256.73 | -43.27 | 32.13 | 29.1 | 53.89 | 0.9 |
| 0.3 | 12.wMoRE1 | 250.99 | 297.87 | -2.13 | 13.14 | 12.23 | 13.31 | 0.93 |
| 12.wMoRE2 | 301.84 | 1.84 | 17.17 | 16.48 | 17.26 | 0.95 |
| wChao2.12 | 279.12 | -20.88 | 10.51 | 9.23 | 23.38 | 0.88 |
| 12.MoRE | 298.74 | -1.26 | 21.2 | 19.82 | 21.23 | 0.89 |
| 0.5 | 12.wMoRE1 | 274.96 | 298.83 | -1.17 | 6.95 | 7.14 | 7.04 | 0.96 |
| 12.wMoRE2 | 296.82 | -3.18 | 6.29 | 6.43 | 7.04 | 0.96 |
| wChao2.12 | 291.84 | -8.16 | 6.42 | 6.12 | 10.38 | 0.9 |
| 12.MoRE | 313.39 | 13.39 | 17 | 17.48 | 21.63 | 0.92 |
| 0.7 | 12.wMoRE1 | 287.79 | 299.7 | -0.3 | 3.97 | 4.2 | 3.98 | 0.95 |
| 12.wMoRE2 | 298.47 | -1.53 | 3.6 | 3.74 | 3.9 | 0.95 |
| wChao2.12 | 297.65 | -2.35 | 3.94 | 3.91 | 4.58 | 0.9 |
| 12.MoRE | 325.28 | 25.28 | 15.77 | 17.75 | 29.79 | 0.93 |