# 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*New*、*wNew1*以及*wNew2*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況下，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*wChao2*，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指標作為兩群落間*Beta*多樣性的量化指標。

透過第4章前半段使用電腦模擬群落進行估計中，綜合各項指標的結果，在本文所提出之新的估計方法中，比起原有的估計方法，皆取得偏誤更小的結果，具有更好的估計表現。值得注意的是，在取後不放回的模擬結果中，於小樣本的情況下，當其中一個群落的變異數小於0.4時，容易在估計共同種時發生高估的現象，特別是在某群落為同質群落的情況下更容易發生此現象。因此，當該情況發生時，可能採用取後放回的估計方法*New*，會比使用*wNew1*或是*wNew2*獲得更優秀的估計表現。除此之外，在標準差的估計方面，無論是在取後放回或是取後不放回的模擬估計中，所得到的結果顯示在新提出的估計方法所估計的結果皆比現有結果還要大，尤其在小樣本方面的情況更甚。

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況，在本文模擬中，為其中一群落變異係數小於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*New*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「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，或是在針對估計式進行近一步的修正，以更精準地估計標準差，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似性以及*Beta*多樣性的基礎之一，但在物種相似性以及*Beta*多樣性的量化指標上，往往是針對兩群落間的共同物種以及兩群落間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，情況二至情況四的物種與區塊假設下之模擬。

**物種與區塊數的假設**

情況二：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。

情況三：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 。

情況四：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。

Table S. 1取後放回的抽樣方式在情況二下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 2取後放回的抽樣方式在情況二下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 3取後放回的抽樣方式在情況二下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 4取後放回的抽樣方式在情況二下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 5取後放回的抽樣方式在情況三下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 6取後放回的抽樣方式在情況三下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 7取後放回的抽樣方式在情況三下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 8取後放回的抽樣方式在情況三下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 9取後放回的抽樣方式在情況四下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 10取後放回的抽樣方式在情況四下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 11取後放回的抽樣方式在情況四下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 12取後放回的抽樣方式在情況四下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 10 | New | 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 | New | 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 | New | 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 | New | 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 |

Table S. 13取後不放回的抽樣方式在情況二下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 130.68 | 363.05 | 63.05 | 57.26 | 51.85 | 85.15 | 0.92 |
| wNew2 | 367.87 | 67.87 | 67.21 | 56.68 | 95.49 | 0.91 |
| wChao2 | 246.5 | -53.5 | 30.8 | 24.32 | 61.73 | 0.87 |
| New | 281.9 | -18.1 | 57.45 | 45.58 | 60.21 | 0.89 |
| 0.3 | wNew1 | 251.46 | 311.01 | 11.01 | 12.82 | 9.77 | 16.9 | 0.87 |
| wNew2 | 313.66 | 13.66 | 16.61 | 14.97 | 21.5 | 0.93 |
| wChao2 | 281.44 | -18.56 | 9.7 | 9.14 | 20.94 | 0.91 |
| New | 300.09 | 0.09 | 19.47 | 19.1 | 19.46 | 0.93 |
| 0.5 | wNew1 | 277.73 | 299.59 | -0.41 | 6.85 | 7.51 | 6.86 | 0.96 |
| wNew2 | 297.84 | -2.16 | 6.14 | 5.89 | 6.5 | 0.94 |
| wChao2 | 293 | -7 | 6.28 | 5.83 | 9.4 | 0.89 |
| New | 313.52 | 13.52 | 16.8 | 16.91 | 21.56 | 0.91 |
| 0.7 | wNew1 | 289.07 | 299.79 | -0.21 | 3.77 | 4.05 | 3.77 | 0.97 |
| wNew2 | 298.57 | -1.43 | 3.41 | 3.51 | 3.7 | 0.96 |
| wChao2 | 298.03 | -1.97 | 3.72 | 3.73 | 4.2 | 0.9 |
| New | 324.13 | 24.13 | 14.71 | 17.16 | 28.25 | 0.94 |

Table S. 14取後不放回的抽樣方式在情況二下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 127.75 | 307.14 | 7.14 | 45.84 | 44.82 | 46.37 | 0.96 |
| wNew2 | 310.97 | 10.97 | 51.61 | 43.1 | 52.74 | 0.93 |
| wChao2 | 216.34 | -83.66 | 24.65 | 19.44 | 87.21 | 0.87 |
| New | 246.24 | -53.76 | 46.83 | 38.83 | 71.28 | 0.9 |
| 0.3 | wNew1 | 234.05 | 295.24 | -4.76 | 13.56 | 14.3 | 14.37 | 0.96 |
| wNew2 | 301.76 | 1.76 | 18.12 | 16.94 | 18.2 | 0.95 |
| wChao2 | 269.31 | -30.69 | 10.75 | 9.88 | 32.52 | 0.91 |
| New | 294.08 | -5.92 | 22.85 | 21.09 | 23.6 | 0.9 |
| 0.5 | wNew1 | 266.21 | 297.06 | -2.94 | 8.33 | 8.51 | 8.83 | 0.95 |
| wNew2 | 300.6 | 0.6 | 9.74 | 8.98 | 9.75 | 0.94 |
| wChao2 | 287.46 | -12.54 | 7.63 | 6.76 | 14.68 | 0.9 |
| New | 314.96 | 14.96 | 20.43 | 19.06 | 25.31 | 0.91 |
| 0.7 | wNew1 | 282.98 | 299.11 | -0.89 | 5.14 | 4.97 | 5.21 | 0.95 |
| wNew2 | 299.58 | -0.42 | 5.23 | 4.84 | 5.24 | 0.93 |
| wChao2 | 296.37 | -3.63 | 5.05 | 4.55 | 6.22 | 0.89 |
| New | 338.29 | 38.29 | 20.47 | 21.34 | 43.42 | 0.94 |

Table S. 15取後不放回的抽樣方式在情況二下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 126.46 | 290.65 | -9.35 | 43.42 | 38.73 | 44.39 | 0.92 |
| wNew2 | 299.29 | -0.71 | 55.46 | 44.91 | 55.44 | 0.92 |
| wChao2 | 208.76 | -91.24 | 24.23 | 19.12 | 94.4 | 0.87 |
| New | 243.6 | -56.4 | 47.84 | 38.78 | 73.94 | 0.88 |
| 0.3 | wNew1 | 226.84 | 293.38 | -6.62 | 16.14 | 14.9 | 17.43 | 0.94 |
| wNew2 | 296.97 | -3.03 | 21.04 | 17.76 | 21.24 | 0.92 |
| wChao2 | 266.22 | -33.78 | 12.58 | 10.78 | 36.04 | 0.88 |
| New | 296.13 | -3.87 | 27.57 | 24.19 | 27.82 | 0.89 |
| 0.5 | wNew1 | 261.66 | 297.43 | -2.57 | 8.65 | 9.23 | 9.02 | 0.96 |
| wNew2 | 298.04 | -1.96 | 9.33 | 9.33 | 9.53 | 0.95 |
| wChao2 | 286.87 | -13.13 | 7.84 | 7.46 | 15.29 | 0.9 |
| New | 321.63 | 21.63 | 21 | 22.07 | 30.14 | 0.94 |
| 0.7 | wNew1 | 281.01 | 299.5 | -0.5 | 5.31 | 5.33 | 5.33 | 0.95 |
| wNew2 | 298.91 | -1.09 | 5.21 | 5.09 | 5.32 | 0.94 |
| wChao2 | 296.41 | -3.59 | 5.23 | 4.89 | 6.34 | 0.89 |
| New | 342.5 | 42.5 | 20.79 | 23.2 | 47.31 | 0.95 |

Table S. 16取後放回的抽樣方式在情況二下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 121.46 | 282.28 | -17.72 | 44.81 | 41.19 | 48.17 | 0.94 |
| wNew2 | 290.34 | -9.66 | 55.69 | 47.56 | 56.5 | 0.93 |
| wChao2 | 202.71 | -97.29 | 25.03 | 19.93 | 100.45 | 0.86 |
| New | 243.35 | -56.65 | 50.83 | 41.75 | 76.09 | 0.87 |
| 0.3 | wNew1 | 223.8 | 300.92 | 0.92 | 17.6 | 19.65 | 17.62 | 0.97 |
| wNew2 | 304.37 | 4.37 | 22.81 | 19.48 | 23.22 | 0.93 |
| wChao2 | 270.02 | -29.98 | 13.43 | 11.79 | 32.85 | 0.9 |
| New | 305 | 5 | 31.71 | 27.54 | 32.09 | 0.9 |
| 0.5 | wNew1 | 262.84 | 301.43 | 1.43 | 8.93 | 9.83 | 9.04 | 0.97 |
| wNew2 | 303.64 | 3.64 | 10.47 | 9.93 | 11.08 | 0.94 |
| wChao2 | 289.22 | -10.78 | 8.19 | 7.55 | 13.54 | 0.9 |
| New | 321.8 | 21.8 | 22.39 | 22.04 | 31.24 | 0.92 |
| 0.7 | wNew1 | 283.23 | 300.86 | 0.86 | 4.84 | 5.18 | 4.92 | 0.96 |
| wNew2 | 301.34 | 1.34 | 5 | 5.12 | 5.18 | 0.95 |
| wChao2 | 296.91 | -3.09 | 4.79 | 4.59 | 5.7 | 0.91 |
| New | 330.09 | 30.09 | 17.81 | 19.61 | 34.97 | 0.95 |

Table S. 17取後不放回的抽樣方式在情況三下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 159.06 | 373.25 | 73.25 | 47.31 | 39.17 | 87.18 | 0.91 |
| wNew2 | 382.25 | 82.25 | 70.75 | 56.44 | 108.47 | 0.92 |
| wChao2 | 271.82 | -28.18 | 27.94 | 23.77 | 39.67 | 0.9 |
| New | 308.83 | 8.83 | 56.2 | 44.22 | 56.86 | 0.9 |
| 0.3 | wNew1 | 243.7 | 330.38 | 30.38 | 13.99 | 12.84 | 33.45 | 0.94 |
| wNew2 | 334.38 | 34.38 | 18.56 | 17.4 | 39.06 | 0.94 |
| wChao2 | 289.62 | -10.38 | 11.8 | 10.95 | 15.71 | 0.92 |
| New | 312.97 | 12.97 | 23.34 | 21.64 | 26.69 | 0.92 |
| 0.5 | wNew1 | 277.54 | 315.42 | 15.42 | 7 | 7.6 | 16.93 | 0.96 |
| wNew2 | 316.22 | 16.22 | 8 | 8.6 | 18.09 | 0.96 |
| wChao2 | 296.67 | -3.33 | 6.05 | 5.99 | 6.9 | 0.91 |
| New | 322.72 | 22.72 | 18.08 | 18.55 | 29.03 | 0.94 |
| 0.7 | wNew1 | 291.93 | 304.46 | 4.46 | 3.47 | 4.16 | 5.65 | 0.98 |
| wNew2 | 304.6 | 4.6 | 3.6 | 4.29 | 5.84 | 0.98 |
| wChao2 | 299.35 | -0.65 | 3.02 | 3.18 | 3.09 | 0.91 |
| New | 329.92 | 29.92 | 14.28 | 18.41 | 33.14 | 0.96 |

Table S. 18取後不放回的抽樣方式在情況三下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 160.17 | 302.73 | 2.73 | 33.67 | 28.43 | 33.77 | 0.9 |
| wNew2 | 308.52 | 8.52 | 40.33 | 35.82 | 41.2 | 0.93 |
| wChao2 | 233.84 | -66.16 | 20.05 | 16.93 | 69.13 | 0.89 |
| New | 262.46 | -37.54 | 37.84 | 32.68 | 53.29 | 0.9 |
| 0.3 | wNew1 | 225.7 | 294.97 | -5.03 | 16.21 | 14.21 | 16.97 | 0.93 |
| wNew2 | 301.87 | 1.87 | 22.21 | 19.5 | 22.28 | 0.93 |
| wChao2 | 264.79 | -35.21 | 12.57 | 10.53 | 37.39 | 0.87 |
| New | 289 | -11 | 26.09 | 21.81 | 28.3 | 0.88 |
| 0.5 | wNew1 | 254.95 | 296.39 | -3.61 | 10.88 | 10 | 11.46 | 0.93 |
| wNew2 | 301.25 | 1.25 | 14.7 | 12.97 | 14.75 | 0.93 |
| wChao2 | 280.67 | -19.33 | 9.33 | 7.9 | 21.46 | 0.87 |
| New | 307.28 | 7.28 | 22.1 | 19.68 | 23.26 | 0.89 |
| 0.7 | wNew1 | 271.15 | 297.59 | -2.41 | 8.2 | 7.62 | 8.54 | 0.92 |
| wNew2 | 300.09 | 0.09 | 9.54 | 8.39 | 9.54 | 0.92 |
| wChao2 | 289.4 | -10.6 | 7.38 | 6.26 | 12.91 | 0.87 |
| New | 331.18 | 31.18 | 24.84 | 23.16 | 39.86 | 0.91 |

Table S. 19取後不放回的抽樣方式在情況三下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 153.34 | 299.93 | -0.07 | 36.54 | 28.54 | 36.53 | 0.89 |
| wNew2 | 306.95 | 6.95 | 48.58 | 41.09 | 49.05 | 0.93 |
| wChao2 | 230.42 | -69.58 | 21.62 | 17.94 | 72.86 | 0.88 |
| New | 266.17 | -33.83 | 45.96 | 36.79 | 57.05 | 0.89 |
| 0.3 | wNew1 | 219.68 | 295.52 | -4.48 | 16.77 | 15.01 | 17.35 | 0.92 |
| wNew2 | 300.87 | 0.87 | 23.68 | 20.31 | 23.68 | 0.94 |
| wChao2 | 263.91 | -36.09 | 12.81 | 11.37 | 38.29 | 0.89 |
| New | 296.76 | -3.24 | 28.32 | 25.95 | 28.49 | 0.9 |
| 0.5 | wNew1 | 251.18 | 296.83 | -3.17 | 10.52 | 10.46 | 10.98 | 0.95 |
| wNew2 | 299.4 | -0.6 | 13.31 | 12.65 | 13.32 | 0.94 |
| wChao2 | 280.36 | -19.64 | 8.98 | 8.37 | 21.6 | 0.91 |
| New | 315.41 | 15.41 | 22.86 | 23.04 | 27.55 | 0.94 |
| 0.7 | wNew1 | 269.77 | 297.88 | -2.12 | 7.64 | 7.88 | 7.92 | 0.96 |
| wNew2 | 299 | -1 | 8.42 | 8.35 | 8.48 | 0.96 |
| wChao2 | 289.27 | -10.73 | 6.85 | 6.43 | 12.73 | 0.89 |
| New | 331.2 | 31.2 | 20.99 | 22.91 | 37.59 | 0.95 |

Table S. 20取後放回的抽樣方式在情況三下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 154.28 | 288.19 | -11.81 | 33.85 | 30.26 | 35.84 | 0.92 |
| wNew2 | 296.9 | -3.1 | 44.25 | 37.21 | 44.34 | 0.93 |
| wChao2 | 225.06 | -74.94 | 20.74 | 16.82 | 77.76 | 0.88 |
| New | 262.05 | -37.95 | 42.71 | 35.21 | 57.12 | 0.88 |
| 0.3 | wNew1 | 218.34 | 295.64 | -4.36 | 18.74 | 17.87 | 19.23 | 0.94 |
| wNew2 | 300.33 | 0.33 | 25.28 | 21.32 | 25.27 | 0.94 |
| wChao2 | 263.33 | -36.67 | 13.56 | 11.91 | 39.1 | 0.9 |
| New | 295.2 | -4.8 | 30.68 | 25.92 | 31.03 | 0.9 |
| 0.5 | wNew1 | 248.75 | 297.2 | -2.8 | 12.83 | 12.29 | 13.13 | 0.94 |
| wNew2 | 298.45 | -1.55 | 15.46 | 13.78 | 15.53 | 0.94 |
| wChao2 | 279.09 | -20.91 | 10.32 | 9.11 | 23.32 | 0.88 |
| New | 305.35 | 5.35 | 23.07 | 21.46 | 23.67 | 0.9 |
| 0.7 | wNew1 | 266.82 | 298.09 | -1.91 | 8.5 | 9.04 | 8.71 | 0.96 |
| wNew2 | 298.04 | -1.96 | 9.71 | 9.4 | 9.9 | 0.94 |
| wChao2 | 287.74 | -12.26 | 7.36 | 7.17 | 14.3 | 0.91 |
| New | 310.82 | 10.82 | 17.42 | 18.4 | 20.5 | 0.92 |

Table S. 21取後不放回的抽樣方式在情況四下，群落一為同質模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 159.21 | 379.59 | 79.59 | 48.65 | 39.61 | 93.27 | 0.89 |
| wNew2 | 391.99 | 91.99 | 92.69 | 60.95 | 130.55 | 0.92 |
| wChao2 | 272.87 | -27.13 | 28.1 | 24.33 | 39.05 | 0.9 |
| New | 304.06 | 4.06 | 51.66 | 42.84 | 51.79 | 0.9 |
| 0.3 | wNew1 | 271.94 | 314.85 | 14.85 | 10.24 | 8.33 | 18.03 | 0.89 |
| wNew2 | 317.52 | 17.52 | 12.44 | 11.8 | 21.48 | 0.94 |
| wChao2 | 291.25 | -8.75 | 7.89 | 7.03 | 11.78 | 0.88 |
| New | 300.94 | 0.94 | 14.23 | 13.25 | 14.25 | 0.9 |
| 0.5 | wNew1 | 288.99 | 300.51 | 0.51 | 4.81 | 5.12 | 4.83 | 0.96 |
| wNew2 | 299.28 | -0.72 | 4.15 | 3.99 | 4.21 | 0.93 |
| wChao2 | 296.71 | -3.29 | 4.41 | 4.11 | 5.51 | 0.86 |
| New | 305.96 | 5.96 | 10.79 | 10.9 | 12.32 | 0.88 |
| 0.7 | wNew1 | 294.62 | 299.87 | -0.13 | 2.75 | 2.84 | 2.75 | 0.95 |
| wNew2 | 299.3 | -0.7 | 2.53 | 2.46 | 2.62 | 0.95 |
| wChao2 | 298.96 | -1.04 | 2.71 | 2.59 | 2.9 | 0.85 |
| New | 310.06 | 10.06 | 9.8 | 10.72 | 14.04 | 0.91 |

Table S. 22取後不放回的抽樣方式在情況四下，兩群落皆為均勻模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 157.26 | 306.13 | 6.13 | 36.13 | 29.39 | 36.63 | 0.88 |
| wNew2 | 309.38 | 9.38 | 44.84 | 37.29 | 45.78 | 0.92 |
| wChao2 | 231.82 | -68.18 | 21.15 | 17.38 | 71.38 | 0.88 |
| New | 256.95 | -43.05 | 38.25 | 32.16 | 57.57 | 0.88 |
| 0.3 | wNew1 | 250.49 | 298.19 | -1.81 | 12.04 | 10.69 | 12.17 | 0.92 |
| wNew2 | 303.26 | 3.26 | 16.27 | 15.34 | 16.59 | 0.94 |
| wChao2 | 277.91 | -22.09 | 9.81 | 8.74 | 24.16 | 0.9 |
| New | 295.75 | -4.25 | 19.08 | 17.75 | 19.53 | 0.9 |
| 0.5 | wNew1 | 275.77 | 299.32 | -0.68 | 7.08 | 6.74 | 7.11 | 0.95 |
| wNew2 | 299.32 | -0.68 | 7.23 | 6.97 | 7.25 | 0.94 |
| wChao2 | 291.99 | -8.01 | 6.51 | 5.92 | 10.32 | 0.89 |
| New | 311.21 | 11.21 | 15.68 | 15.64 | 19.27 | 0.92 |
| 0.7 | wNew1 | 288.22 | 299.73 | -0.27 | 4.17 | 4.08 | 4.18 | 0.94 |
| wNew2 | 298.94 | -1.06 | 3.96 | 3.81 | 4.1 | 0.94 |
| wChao2 | 297.66 | -2.34 | 4.12 | 3.82 | 4.74 | 0.88 |
| New | 323.15 | 23.15 | 14.83 | 16.28 | 27.49 | 0.93 |

Table S. 23取後不放回的抽樣方式在情況四下，群落一為均勻模型，群落二為Broken-stick模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 156.58 | 300.09 | 0.09 | 35.8 | 27.9 | 35.78 | 0.89 |
| wNew2 | 310.17 | 10.17 | 52.07 | 42.92 | 53.03 | 0.94 |
| wChao2 | 229.88 | -70.12 | 20.99 | 17.59 | 73.19 | 0.89 |
| New | 256.18 | -43.82 | 40.83 | 33.23 | 59.88 | 0.89 |
| 0.3 | wNew1 | 246.82 | 295.82 | -4.18 | 13.73 | 10.71 | 14.35 | 0.88 |
| wNew2 | 305.03 | 5.03 | 20.11 | 17.09 | 20.73 | 0.92 |
| wChao2 | 275.39 | -24.61 | 11.32 | 8.99 | 27.09 | 0.86 |
| New | 295.65 | -4.35 | 23.25 | 19.35 | 23.65 | 0.86 |
| 0.5 | wNew1 | 272.32 | 298.08 | -1.92 | 7.63 | 7.05 | 7.86 | 0.93 |
| wNew2 | 298.96 | -1.04 | 8.02 | 7.79 | 8.09 | 0.95 |
| wChao2 | 290.34 | -9.66 | 6.92 | 6.29 | 11.88 | 0.89 |
| New | 314.46 | 14.46 | 17.74 | 17.83 | 22.88 | 0.92 |
| 0.7 | wNew1 | 286.38 | 299.73 | -0.27 | 4.58 | 4.43 | 4.59 | 0.94 |
| wNew2 | 299.05 | -0.95 | 4.42 | 4.23 | 4.52 | 0.94 |
| wChao2 | 297.47 | -2.53 | 4.49 | 4.15 | 5.15 | 0.89 |
| New | 330.72 | 30.72 | 17.57 | 19.77 | 35.39 | 0.94 |

Table S. 24取後放回的抽樣方式在情況四下，群落一為Broken-stick模型，群落二為對數常數模型之情況下的估計結果。

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| q | Estimator | Obs | AVG Estimate | Bias | Sample SE | Est. SD | RMSE | 95% CI Coverage |
| 0.1 | wNew1 | 172.25 | 289.62 | -10.38 | 28.85 | 25.08 | 30.65 | 0.92 |
| wNew2 | 297.81 | -2.19 | 44.89 | 37.64 | 44.92 | 0.93 |
| wChao2 | 232.28 | -67.72 | 17.57 | 15.58 | 69.96 | 0.9 |
| New | 256.73 | -43.27 | 32.13 | 29.1 | 53.89 | 0.9 |
| 0.3 | wNew1 | 250.99 | 297.87 | -2.13 | 13.14 | 12.23 | 13.31 | 0.93 |
| wNew2 | 301.84 | 1.84 | 17.17 | 16.48 | 17.26 | 0.95 |
| wChao2 | 279.12 | -20.88 | 10.51 | 9.23 | 23.38 | 0.88 |
| New | 298.74 | -1.26 | 21.2 | 19.82 | 21.23 | 0.89 |
| 0.5 | wNew1 | 274.96 | 298.83 | -1.17 | 6.95 | 7.14 | 7.04 | 0.96 |
| wNew2 | 296.82 | -3.18 | 6.29 | 6.43 | 7.04 | 0.96 |
| wChao2 | 291.84 | -8.16 | 6.42 | 6.12 | 10.38 | 0.9 |
| New | 313.39 | 13.39 | 17 | 17.48 | 21.63 | 0.92 |
| 0.7 | wNew1 | 287.79 | 299.7 | -0.3 | 3.97 | 4.2 | 3.98 | 0.95 |
| wNew2 | 298.47 | -1.53 | 3.6 | 3.74 | 3.9 | 0.95 |
| wChao2 | 297.65 | -2.35 | 3.94 | 3.91 | 4.58 | 0.9 |
| New | 325.28 | 25.28 | 15.77 | 17.75 | 29.79 | 0.93 |