Australian Sea Lion Monitoring Framework: statistical model

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# Introduction

The Australian sea lion (ASL - Neophoca cinerea) is endemic to Australia with a breeding range from Houtman Abrohlos (Western Australia (WA)) to The Pages Island (South Australia (SA)). Breeding occurs on islands or sections of remote coastline that are often difficult to access. The breeding season is difficult to track due to the unusual asynchronous nature (approx. 17-18 month breeding cycle), which differs by colony/location. Females exhibit a high amount of site fidelity; to the point of the colonies effectively representing closed populations. These factors combined with the estimated small population size resulted in ASL being listed as Vulnerable under the threatened species category of the Commonwealth Environment Protection and Biodiversity Act 1999 (EPBC Act), Vulnerable under the South Australian National Parks and Wildlife Act (1972) and Endangered under the International Union for the Conservation of Nature (IUCN) Redlist (Goldsworthy et al. 2015).

In managing the recovery of a species like ASL, it is critical to be able to track changes in the size of the population through time. The expense and difficulty in obtaining accurate estimates of abundance mean that in the past, except for a small number of colonies, data has been sparse and collected using varying methodologies (even at a given site). However, recently Goldsworthy et al. 2015 published the results of a comprehensive survey of the SA ASL population, including pup estimates for most colonies within an 18 month period (one breeding cycle). The most accurate way to track the status of ASL through time would be to survey each colony every breeding season, however this is impossible from both a monetary and logistical perspective. This level of accuracy would also not be warranted given the rate of the estimated decline of the overall population (~2.9% per year or 4.4% per breeding cycle Goldsworthy et al. 2015). An alternative is to develop a monitoring regime with sufficient precision to estimate substantial (specified) changes in abundance over a prescribed time period.

A draft statistical monitoring framework for ASL was discussed at a workshop of key stakeholders in April 2014. The goal of the statistical framework is to develop a means of testing different monitoring designs and assess whether, if there is a substantial change in abundance, the designs will be able to detect it. The benefit of using a tool such as this is that most of the available data can be examined, despite the different estimation methods and sparcity at some sites, and a range of designs assessed. The remainder of this report details a statistical model that may form the basis of a statistical monitoring framework for ASL, the estimation process and the results of using the model to test the degree to whether several hypothetical future sampling schedules are able to detect changes in ASL abundance. This is a small study and as such we have not attempted to explore many design options or to second-guess the monitoring objectives. Instead we have focused on setting up an appropriate monitoring framework, including R scripts, and populate it with data. We hope that these tools will make exploring different sampling schedules, monitoring objectives and statistics to report on, relatively straightforward for others to undertake in the future.

# Methodology

### Data

The available ASL monitoring data was compiled and provided separately by SA and WA.

*SA Data*

The SA monitoring dataset contains surveys dating back to as early as 1965. However, in the early years the surveys are sparse in space and time. In consultation with SARDI, we compiled a subset of the dataset that was considered accurate (in terms of survey timing) and consistent (in terms of methodology). The dataset is similar to that used by SARDI in the analysis described in Goldsworthy 2015 et al., but it includes multiple measures of abundance (rather than selecting the most accurate) where multiple methods were used at a site in a given season. These multiple measures are important as this data allows us to estimate the bias factors described in the model below. A copy of the data is provided in Appendix 1.

The counts in the SA monitoring dataset are collected using three methods (further details described in Goldsworthy et al. 2015):

Direct count (Count) – direct counts of live and dead pups. This method underestimates total pup production, as pups that are hidden from view or absent from the colony are not counted. This method is considered to be more accurate for small colonies (most sites) than large ones. As the colony gets larger the breeding season gets longer and the estimates of this method compared to the others diverge.

Mark-recapture (MR) – individual pups are tagged using numbered plastic tags and individual re-sights are recorded for each field trip. The number of pups tagged, untagged and recorded dead are noted on each survey and then a variation of the Peterson method (formula) is used to arrive at an estimate of abundance. The dataset contains estimates of this method for Dangerous Reef, Olive, Lilliput and Blefuscu Islands.

Cumulative pup production (CPP) – this method builds on the MR by estimating the number of pup births that occur between consecutive mark-recapture surveys through the use of multiple Peterson estimates. Total cumulative pup production is then the sum of the Peterson estimate for the first survey, the cumulative number of dead pups recorded up to the end of the first survey and the estimates of pup births between each subsequent survey. The dataset contains estimates of this method for Dangerous Reef, Seal Bay, Olive, Lilliput and Blefuscu Islands.

*WA Data*

The WA monitoring dataset is very sparse (1998-2015). Beagle and Nth fish are the only two colonies (out of 23) with more than a couple of data points. Many of the recorded counts may not be accurate due to missing season timing. Due to the level of sparcity and the small proportion of the population that the WA data represents (~15%) we have not incorporated the WA monitoring data into the statistical model. If a baseline survey of ASL in WA were completed it would be relatively simple to then incorporate the WA data into the model that follows.

### Statistical Model

The monitoring framework is centered on a statistical model. The model is described here in generic terms as the proposed model is very flexible meaning that different factors thought to be related to ASL abundance or recovery could be incorporated into the model as further data is collected. The model is also very flexible in that it does not require a rigid monitoring protocol eg. Equally spaced sampling. The point of this model is to let observations “borrow strength” from each other. If most colonies have been trending in some direction, then it may be a reasonable assumption that an unmonitored but “similar” colony has been going the same way. Of course, the only way to be absolutely sure is to sample that colony. However, it is not feasible to sample every colony, every season, and nor is it necessary if the objective is to be able to estimate total or regional level ASL numbers within tolerable precision levels. The statistical model encapsulates these ideas.

The model is a special case of a Generalized Linear Mixed Model (GLMM);

Where:

is the site label

is the sampling date (with 0 standing for an arbitrary "reference date" for the monitoring program);

is an abundance estimate obtained for that site in that year

is a "bias" factor that depends on the method of survey

is the abundance of colony at the reference date.

is the rate-of-Change for colony thatcan be allowed to depend on various factors

is the noise/error associated with that particular measurement, which includes measurement error, natural variability in abundance (e.g. proportion of females actually breeding that season). The likely magnitude of will depend on the colony and the survey method used.

Statistically, the *Y* ’s are the observations, the ε ’s are the errors, and the linear predictor is given by

is a mixed effect that (i) allows for various factors such as colony size or exposure to gillnetting, as specified through a design matrix *X* and captured through appropriate components of the estimable parameters , and (ii) allows each colony to have its own additional trend.

We implemented the statistical model using the R v3.2.3 (R Core Team 2015) statistical software (available online at <http://www.r-project.org/>) and a pre-release version (provided by the author) of the mgcv package (v1.8\_13 Wood 2016, Wood 2011).

We modeled the estimated number of pups ‘Estimate’ as:

Estimate = Site + count\_bias + extra\_seal\_bay\_bias + MR\_bias + s( ID\_im, by=RE\_im, bs='re')

+ s( ID\_noim, by=RE\_noim, bs='re')+ y2000 %in% Region +ypost\_mgmt

In this model Site is the name of the individual site, count\_bias is a bias factor applied to ‘big’ sites when the ‘Count’ method is used, extra\_sealbay\_count\_bias is a bias factor applied to Seal Bay only, MR\_bias is a bias factor only when the ‘MR’ method is used, ID\_im and ID\_ noim indicate separate random effects for sites that do/don’t experience immigration/emigration, y2000 %in% Region is the long term trend at the Region level and ypost\_mgmt is the trend to indicate when changes in abundance may be expected due to management actions (currently post 2016).

More details on how these variables were constructed are described below.

* *count\_bias* : If the MR or CPP method have ever been used at a site, the site is classified as ‘big’. This factor was introduced as the bigger sites have longer breeding seasons and so the direct count method is more likely to result in an underestimate (the extent of which is estimated via this effect).
* *extra\_sealbay\_count\_bias:* A preliminary analysis involving a calibration of Count vs CPP, at sites where data were available for both methods in a given season, revealed that the method bias is similar for Lilliput, Olive and Dangerous reef but Seal Bay was significantly different. We introduced this factor just for Seal Bay to account for this difference.
* *MR\_bias:* A bias factor to account for the use of this method
* *s( ID\_noim, by=RE\_im, bs='re'):* Gaussian random effects for sites that do not experience immigration/emigration. We used these random effects as a means of allowing the immigration/no immigration sites to have different (unknown) variances. The sites were Seal Bay, Dangerous Reef, Liguanea, Cap, Rocky South, West Waldegrave, Pearson, Nicolas Baudin, Olive, Breakwater/Gliddon and Nuyts Reef. Note: the ability to incorporate random effects in this manner is new to mgcv and so this term will only work for mgcv 1.8 – 13 or later.
* *s( ID\_im, by=RE\_im, bs='re'):* Gaussian random effects for sites that experience immigration/emigration. Colonies subject to immigration from nearby earlier-breeders, should have higher variance in count data. The sites were all those not listed in *ID\_count\_noim* and were estimated separately to allow for movement between sites.
* *y2000 %in% Region:* the trend estimated at the Region level using the year 2000 as the baseline.
* *ypost\_mgmt:* A trend, post the year 2016, designed to detect a change in trend due to management action. The year can be changed depending when you could expect changes in abundance due to management actions likely to take effect.

The model was fitted using the ‘REML’ method with a Tweedie distribution (p=1.2, link=’log’) to account for overdispersion. The Tweedie is an exponential family distribution for which the variance of the response is given by the mean response to the power p where p is between 1 and 2.

### Monitoring framework

The above statistical model can be fitted to the existing monitoring data. To move beyond estimating a statistical model, into creating a monitoring framework, we created an R function that allowed us to combine the existing data with hypothetical future sample schedules to allow us to test the impact of differing sampling schedules (Scenarios outlined below) on various estimates of precision (such as the coefficient of variation of the estimate of ASL for a given Region in a given year).

The R function goes through the following sequence of steps:

(1) Form a dataset of past surveys including estimates based on different methods for the same site and season

(2) Fit the statistical model, estimating all variances and all coefficients

(3) Form a design data frame containing both the past data and a sampling schedule relating to the scenario being tested (with missing data for the estimates)

(4) Get the predictions for the model fitted above for all observations in the design data frame

(5) Refit the model to estimate coefficients, but with all the variances fixes at their original estimated values from step (2)

(6) Compute the precision on quantities of interest. For example, Coefficient of Variation (CV) of abundance or standard error of log-trend

The results should then mimic the information content (and thus the precision of any inferences) that will be possible once the extra data (future samples) are collected.

### Scenarios

The following sampling schedules were considered. These test scenarios are intended to show how our software could be used to decide on monitoring. We are not trying to evaluate every possible option, nor to second-guess what questions are most important nor how much the answers are “worth”, but rather to show how this can be done fairly systematically and easily, and to provide a software framework for doing so.

***1. Main colony in each region every 3 years***

Bunda Cliffs – Bunda09 in 2017, 2020, 2023, ….,2044

Chain of Bays – Olive in 2017, 2020, 2023, ….,2044

Kangaroo Island – Seal Bay in 2017, 2020, 2023, ….,2044

Nuyts-Archipelago – Lilliput in 2017, 2020, 2023, ….,2044

Spencer gulf – Dangerous Reef in 2017, 2020, 2023, ….,2044

SW Eyre – Rocky North in 2017, 2020, 2023, ….,2044

***2. Main colony in each region every 6 years***

Bunda Cliffs – Bunda09 in 2017, 2023, ….,2041

Chain of Bays – Olive in 2017, 2023, ….,2041

Kangaroo Island – Seal Bay in 2017, 2023, ….,2041

Nuyts-Archipelago – Lilliput in 2017, 2023, ….,2041

Spencer gulf – Dangerous Reef in 2017, 2023, ….,2041

SW Eyre – Rocky North in 2017, 2023, ….,2041

***3. Four key colonies every 3 years***

\* These are the four colonies identified in Goldsworthy et al. 2015

Chain of Bays – Jones and Olive in 2017, 2020, 2023, ….,2044

Kangaroo Island - Seal Bay and Seal Slide in 2017, 2020, 2023, ….,2044

***4. Rotating Regions***

Bunda Cliffs in years 2017, 2023, 2029, 2035 and 2041

*Bunda 00, Bunda02, Bunda04, Bunda06, Bunda08, Bunda09, Bunda12, Bunda18, Bunda 19, Bunda22*

Chain of Bays in years 2018, 2024, 2030, 2036 and 2042

*Jones, Nicolas Baudin, Olive, Pearson, Pt Labatt, Ward, West Waldegrave*

Kangaroo Island in years 2021, 2027, 2033 and 2039

*Cape Bouger, North Casuarina, Seal Bay, Seal Slide, The Pages*

Nuyts – Archipelago in years 2017, 20232029, 2035 and 2041

*Blefescu, Breakwater/Giddon, Fenelon, Lilliput, Lounds, Nuyts Reef, Purdie, West*

Spencer Gulf in years 2020, 2026, 2032, 2038 and 2044

*Albatross, Curta, Dangerous Reef, East, English, Lewis, Liguanea, North, Peaked Rocks, South Neptune, Williams*

SW Eyre in 2020 and 20262020, 2026, 2032, 2038 and 2044

*Cap, Four Hummocks, Little Hummock, Price, Rocky North, Rocky South*

**5. All colonies every 3 years**

Bunda Cliffs – All colonies in years 2017, 2020, 2023, ….,2044

Chain of Bays – All colonies in years 2017, 2020, 2023, ….,2044

Kangaroo Island – All colonies in years 2017, 2020, 2023, ….,2044

Nuyts – Archipelago – All colonies in years 2017, 2020, 2023, ….,2044

Spencer Gulf – All colonies in years 2017, 2020, 2023, ….,2044

SW Eyre – All colonies in years 2017, 2020, 2023, ….,2044

### Estimates of Interest

We looked at several estimates of interest to compare across the sampling scenarios, these are by no means exhaustive and have just been chosen as examples of metrics that one may wish to focus on when designing a sampling strategy. If an accurate estimate of the total number of ASL pups is of primary interest then you would look to minimise the coefficient of variation (CV) of the predicted total (after considering budget constraints). We used the delta-method (Oehlert 1992) to calculate the CV of the predicted total (as this is not calculated by the *mgcv* package in R).

Estimating the number of pups at the region level may also be important for some or all regions, particularly those with quickly declining or growing populations. We calculated the CV of the predicted number of pups by region and year, for each of the scenarios, also using the delta method. Finally, it may be of primary interest to obtain an accurate estimate of the trend so we have also estimated the standard error (SE) of the trend by region and across all regions.

# Results

Below is a summary of the model fitted to the existing data. The regional trend terms (y2000:Region) show that the trend is downward in all regions with the slowest decrease in Kangaroo Island (~0.5% per year) and the greatest in SW Eyre (~5.4% per year). The standard GLM diagnostics did not show a lack of fit and that the Tweedie parameter fixed at 1.2 was adequate.

Family: Tweedie (1.2)

Link function: log

Formula:

Estimate ~ Site + count\_bias + extra\_sealbay\_count\_bias + MR\_bias + s(ID\_im, by = RE\_im, bs = "re") + s(ID\_noim, by = RE\_noim, bs = "re") + y2000 %in% Region + ypost\_mgmt

Parametric coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 4.458879 0.176055 25.327 < 2e-16 \*\*\*

SiteBlefuscu 0.800824 0.238054 3.364 0.000975 \*\*\*

SiteBreakwater/Gliddon -0.845634 0.294429 -2.872 0.004667 \*\*

SiteBunda 00 (B1) -2.156451 0.480982 -4.483 1.45e-05 \*\*\*

SiteBunda 02 (B1.1) -2.966043 0.640617 -4.630 7.85e-06 \*\*\*

SiteBunda 04 (B2) -3.525644 0.530112 -6.651 5.07e-10 \*\*\*

SiteBunda 06 (B3) -1.992279 0.264725 -7.526 4.45e-12 \*\*\*

SiteBunda 08 (B4) -3.919597 0.741001 -5.290 4.25e-07 \*\*\*

SiteBunda 09 (B5) -1.775726 0.270944 -6.554 8.42e-10 \*\*\*

SiteBunda 12 (B6) -3.359948 0.383727 -8.756 3.88e-15 \*\*\*

SiteBunda 18 (B7) -2.714364 0.433434 -6.262 3.77e-09 \*\*\*

SiteBunda 19 (B8) -2.218308 0.319332 -6.947 1.05e-10 \*\*\*

SiteBunda 22 (B9) -2.577418 0.413999 -6.226 4.55e-09 \*\*\*

SiteCap -0.192292 0.887094 -0.217 0.828684

SiteCape Bouguer -2.198406 0.541356 -4.061 7.84e-05 \*\*\*

SiteCurta -2.183936 0.587230 -3.719 0.000282 \*\*\*

SiteDangerous Reef 2.087028 0.170294 12.255 < 2e-16 \*\*\*

SiteEast -1.815666 0.367633 -4.939 2.07e-06 \*\*\*

SiteEnglish -0.870035 0.218836 -3.976 0.000109 \*\*\*

SiteFenelon -0.568912 0.321519 -1.769 0.078846 .

SiteFour Hummocks -1.525025 0.843245 -1.809 0.072523 .

SiteJones -1.392942 0.251772 -5.533 1.37e-07 \*\*\*

SiteLewis 0.411114 0.203515 2.020 0.045152 \*

SiteLiguanea -0.884212 0.257662 -3.432 0.000775 \*\*\*

SiteLilliput 0.457526 0.242133 1.890 0.060740 .

SiteLittle Hummock -1.793253 0.945475 -1.897 0.059789 .

SiteLounds -0.653341 0.326978 -1.998 0.047506 \*

SiteNicolas Baudin 0.281520 0.255175 1.103 0.271682

SiteNorth -1.088135 0.295933 -3.677 0.000328 \*\*\*

SiteNorth Casuarina -1.997735 0.505275 -3.954 0.000118 \*\*\*

SiteNuyts Reef 0.881730 0.343463 2.567 0.011229 \*

SiteOlive 1.147976 0.210838 5.445 2.07e-07 \*\*\*

SitePeaked Rocks -0.157145 0.300257 -0.523 0.601487

SitePearson -0.687730 0.257834 -2.667 0.008483 \*\*

SitePrice -0.182652 1.005349 -0.182 0.856078

SitePt Labatt -3.079051 0.492406 -6.253 3.96e-09 \*\*\*

SitePurdie 0.530815 0.240706 2.205 0.028955 \*

SiteRocky North -0.083190 0.823745 -0.101 0.919693

SiteRocky South -1.289632 0.920819 -1.401 0.163415

SiteSeal Bay 1.142620 0.186364 6.131 7.33e-09 \*\*\*

SiteSeal Slide -2.030144 0.238357 -8.517 1.57e-14 \*\*\*

SiteSouth Neptune -2.378924 0.441803 -5.385 2.74e-07 \*\*\*

SiteThe Pages 1.690406 0.179272 9.429 < 2e-16 \*\*\*

SiteWard -0.186877 0.263642 -0.709 0.479527

SiteWest -0.413082 0.268432 -1.539 0.125937

SiteWest Waldegrave 0.595476 0.226057 2.634 0.009316 \*\*

SiteWilliams -2.520409 0.664079 -3.795 0.000213 \*\*\*

count\_biasTRUE -0.371025 0.056916 -6.519 1.01e-09 \*\*\*

extra\_sealbay\_count\_biasTRUE -0.328846 0.096011 -3.425 0.000792 \*\*\*

MR\_biasTRUE -0.155511 0.044578 -3.489 0.000637 \*\*\*

ypost\_mgmt 0.000000 0.000000 NA NA

y2000:RegionBunda Cliffs -0.052504 0.014703 -3.571 0.000478 \*\*\*

y2000:RegionChain of Bays -0.040404 0.010170 -3.973 0.000110 \*\*\*

y2000:RegionKangaroo Island -0.004865 0.003638 -1.337 0.183079

y2000:RegionNuyts-Archipelago -0.045777 0.013021 -3.516 0.000580 \*\*\*

y2000:RegionSpencer Gulf -0.021935 0.005718 -3.836 0.000184 \*\*\*

y2000:RegionSW Eyre -0.054033 0.062618 -0.863 0.389567

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:

edf Ref.df F p-value

s(ID\_im):RE\_im 6.757 90 0.101 0.11144

s(ID\_noim):RE\_noim 13.828 46 0.594 0.00216 \*\*

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Rank: 699/700

R-sq.(adj) = 0.951 Deviance explained = 98.6%

fREML = 400.68 Scale est. = 1.4766 n = 227

Figure 1 (and Table 1) show how the CV of the predicted total ASL pup count varies by year under each of the scenarios. Scenario 5, which involves sampling every site every 3 years, is the best scenario for obvious reasons. Scenario 4 which involves sampling the sites on a 6-year rotations is the next best and outperforms sampling the key colonies every 3 years. Note that regardless of the chosen scenario, the predicted value is the same (it is jut the CV that varies; Table 1).

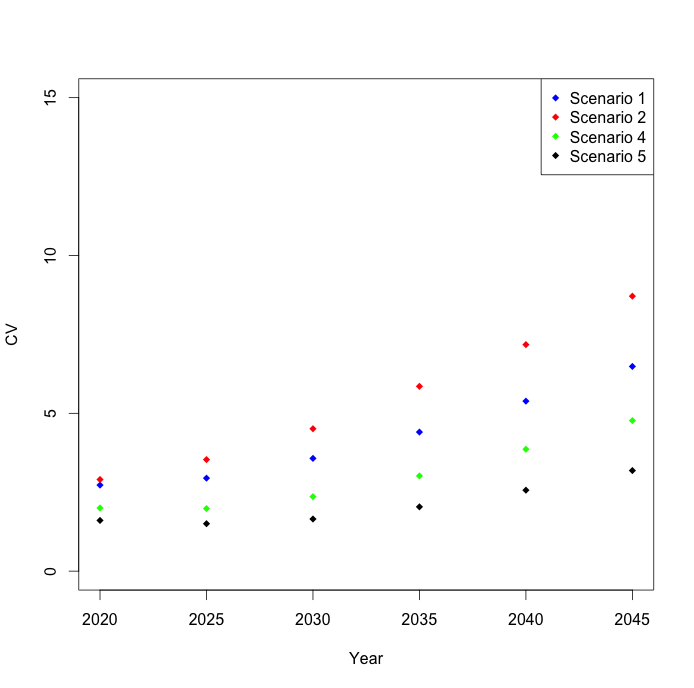


Figure 1 CV of predicted total ASL pup count for each of the sampling scenarios

Table 1 Predicted total and CV (%) by scenario

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Prediction** | 2244.00 | 1983.00 | 1765.00 | 1582.00 | 1428.00 | 1297.00 | 1186.00 |
| **Scenario 1 CV** | 2.67 | 2.73 | 2.95 | 3.57 | 4.41 | 5.39 | 6.48 |
| **Scenario 2 CV** | 2.75 | 2.90 | 3.53 | 4.51 | 5.85 | 7.17 | 8.71 |
| **Scenario 4 CV** | 2.15 | 2.00 | 1.98 | 2.36 | 3.02 | 3.86 | 4.77 |
| **Scenario 5 CV** | 1.80 | 1.61 | 1.50 | 1.65 | 2.04 | 2.56 | 3.19 |

Table 2 to Table 6 summarise the predicted number of pups at the region level, and CVs under each of the scenarios. While Bunda Cliffs and SW Eyre have the smallest estimates, they have the largest CV’s. If, for example, a minimum CV was required for each region then more sampling effort may need to be directed to these two areas. There are no results reported for Scenario 3 as the model did not fit, due to a lack of information about four of the six regions.

Table 2 Predicted number of pups at the region level

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Bunda Cliffs** | 31.76 | 24.43 | 18.79 | 14.45 | 11.11 | 8.55 | 6.57 |
| **Chain of Bays** | 327.07 | 267.24 | 218.36 | 178.42 | 145.78 | 119.11 | 97.32 |
| **Spencer Gulf** | 655.41 | 587.33 | 526.32 | 471.65 | 422.66 | 378.75 | 339.41 |
| **SW Eyre** | 124.37 | 94.93 | 72.45 | 55.30 | 42.21 | 32.22 | 24.59 |
| **Kangaroo Island** | 717.54 | 700.30 | 683.47 | 667.04 | 651.01 | 635.37 | 620.10 |
| **Nuyts-Archipelago** | 387.82 | 308.48 | 245.37 | 195.17 | 155.24 | 123.48 | 98.22 |

Table 3 CV (%) for regional level predictions for Scenario 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Bunda Cliffs** | 13.89 | 17.28 | 21.18 | 25.37 | 29.73 | 34.18 | 38.70 |
| **Chain of Bays** | 5.28 | 6.23 | 7.65 | 9.50 | 11.54 | 13.69 | 15.90 |
| **Spencer Gulf** | 3.94 | 4.30 | 5.00 | 5.90 | 6.94 | 8.05 | 9.22 |
| **SW Eyre** | 11.03 | 11.72 | 14.13 | 17.62 | 21.65 | 25.99 | 30.49 |
| **Kangaroo Island** | 4.32 | 4.45 | 4.62 | 5.43 | 6.55 | 7.85 | 9.25 |
| **Nuyts-Archipelago** | 7.45 | 8.61 | 10.52 | 12.92 | 15.59 | 18.40 | 21.29 |

Table 4 CV (%) for regional level predictions for Scenario 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Bunda Cliffs** | 15.45 | 19.73 | 24.50 | 29.52 | 34.68 | 39.93 | 45.24 |
| **Chain of Bays** | 5.58 | 7.10 | 9.38 | 11.99 | 14.92 | 17.79 | 20.73 |
| **Spencer Gulf** | 4.21 | 4.95 | 6.01 | 7.35 | 8.78 | 10.26 | 11.80 |
| **SW Eyre** | 11.12 | 12.81 | 16.98 | 22.27 | 28.08 | 34.13 | 40.29 |
| **Kangaroo Island** | 4.47 | 4.60 | 5.42 | 6.66 | 8.66 | 10.40 | 12.12 |
| **Nuyts-Archipelago** | 7.66 | 9.53 | 12.40 | 15.77 | 19.52 | 23.31 | 27.06 |

Table 5 CV (%) for regional level predictions for Scenario 4

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Bunda Cliffs** | 8.67 | 9.98 | 12.07 | 14.59 | 17.37 | 20.30 | 23.31 |
| **Chain of Bays** | 4.00 | 4.03 | 4.69 | 5.89 | 7.37 | 9.01 | 10.69 |
| **Spencer Gulf** | 2.92 | 2.95 | 3.37 | 4.07 | 4.92 | 5.87 | 6.87 |
| **SW Eyre** | 8.57 | 7.23 | 7.44 | 9.14 | 11.68 | 14.64 | 17.81 |
| **Kangaroo Island** | 3.48 | 3.37 | 3.47 | 4.13 | 5.12 | 6.33 | 7.56 |
| **Nuyts-Archipelago** | 4.43 | 4.19 | 4.65 | 5.78 | 7.26 | 8.93 | 10.68 |

Table 6 CV (%) for regional level predictions for Scenario 5

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** |
| **Bunda Cliffs** | 7.29 | 7.64 | 8.80 | 10.49 | 12.51 | 14.73 | 17.05 |
| **Chain of Bays** | 3.52 | 3.24 | 3.50 | 4.27 | 5.33 | 6.55 | 7.84 |
| **Spencer Gulf** | 2.52 | 2.38 | 2.60 | 3.10 | 3.78 | 4.55 | 5.38 |
| **SW Eyre** | 7.30 | 5.86 | 5.63 | 6.75 | 8.71 | 11.08 | 13.64 |
| **Kangaroo Island** | 2.88 | 2.62 | 2.49 | 2.71 | 3.26 | 3.99 | 4.82 |
| **Nuyts-Archipelago** | 3.88 | 3.39 | 3.41 | 4.00 | 4.98 | 6.15 | 7.43 |

The predicted numbers of ASL at each site, in each year under each scenario are provided in Appendix 3.

The estimated trend between 2045 and 2015 is a decline of 2.12% per year. The associated standard errors by scenario are Scenario 1: 0.23%, Scenario 2: 0.30%, Scenario 4: 0.18% and Scenario 5: 0.13%. The SE of the trend is clearly the lowest for Scenario 5, however Scenario 4 only involves half the sampling for a relatively minor increase in SE.

The regional level trends and SE’s are summarized in Table 7. Increasing sampling effort obviously reduces the SE on the trend in all regions (Scenario 2 least effort, Scenario 5 most). The SE for the trend for Kangaroo Island is obviously the smallest for all scenarios. However, the trend is also the smallest by at least a factor of 4. In Scenario 1 only Seal Bay is sampled every 3 years while in Scenario 5 all of the sites are sampled every 3 years, which reduces the SE for the trend by 0.13% for the Kangaroo Island region. Whether or not the extra sampling warrants this size decrease depends entirely on the monitoring goals.

Table 7 Trend (2045 compared to 2015) and associated SE’s under each of the scenarios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Trend** | **SE 1** | **SE 2** | **SE 4** | **SE 5** |
| **Bunda Cliffs** | -5.25% | 0.95% | 1.10% | 0.65% | 0.52% |
| **Chain of Bays** | -4.04% | 0.47% | 0.62% | 0.37% | 0.29% |
| **Spencer Gulf** | -2.19% | 0.26% | 0.33% | 0.22% | 0.19% |
| **SW Eyre** | -5.40% | 0.98% | 1.30% | 0.70% | 0.57% |
| **Kangaroo Island** | -0.49% | 0.32% | 0.40% | 0.28% | 0.19% |
| **Nuyts-Archipelago** | -4.58% | 0.62% | 0.80% | 0.38% | 0.29% |

Discussion

The model proposed is very flexible, in that it does not require any particular rigid design, no need for equally spaced sampling, etc. Also, if circumstances change and the monitoring design needs to be changed, there is no problem in accommodating the new data nor in re-planning future data collection. This flexibility does not, of course, mean that common-sense principles of good design can be discarded; "bad" designs (unbalanced and/or too sparse) will still unavoidably give imprecise estimates. However, the use of a model should make a bad design fairly obvious from the numerical results.

Clearly, there is a huge range of possible designs that couldbe explored using this framework. Although there is in principle a suite of techniques for "optimal design" which aim to choose *automatically* the best amongst possible designs, in practice these techniques are unlikely to be much use for ASLs. First, there will be a number of "givens" in the design process (e.g. desire to sample some colonies regularly for other reasons) that may be hard to incorporate into an optimal design algorithm, but that are easy to just impose manually. Second, optimality has to be aimed at one specific criterion, e.g. change in overall abundance of ASLs, or detecting the effects of some management action; it is unlikely that there will be consensus in advance about what "the" goal should be, and it is more important to be able to explore interactively the extent of trade-offs between different criteria. Third, optimality algorithms require either a predefined cost-benefit trade-off or an explicit budget; for ASL monitoring, though, there is currently no clear notion of how much money is "available" and how it might be broken down.

The process of exploration of future monitoring regimes for ASL will be best handled interactively, so that scientists and managers can develop some feel for what precision about various quantities-of-interest is, and is not, actually achievable over various timescales, and at what financial cost. We hope that this project will help narrow down the candidate designs and provide a means for testing further designs to find a sampling regime that adequately meets the chosen monitoring objectives and logistical constraints for ASL.

While we tried to incorporate the most critical terms into the model, the small scale of this project prevented us from incorporating all terms that might be worth exploring. In particular it would be useful to investigate incorporating the regional level trends as a random-effect ie. turning y2000 %in% region into a random effect. Including the trends in such a manner would make more use of the notion of ‘borrowing strength’ across regions and time. Once future data is collected, and the model updated, changes in trend should be reported and in particular the post management trend will become relevant (currently incorporated but has a value of 0 as no data post 2015).

There was insufficient WA data to incorporate in the statistical model but should a baseline study be conducted in WA it would be relatively straightforward to update the R code and model to reflect the new data.

We have downloaded the version of R and associated packages and will archive these alongside the project code to ensure that the R code remains useable in the future and is robust to future package changes.

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# Appendix 1 – Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Site** | **Region** | **Year** | **Estimate** | **Method** | **Gillnet\_exposure** |
| Seal Bay | Kangaroo Island | 1985.5 | 154 | Count | High |
| Seal Bay | Kangaroo Island | 1987 | 166 | Count | High |
| Seal Bay | Kangaroo Island | 1988.5 | 136 | Count | High |
| Seal Bay | Kangaroo Island | 1990 | 162 | Count | High |
| The Pages | Kangaroo Island | 1990 | 522 | Count | High |
| Seal Bay | Kangaroo Island | 1991.5 | 128 | Count | High |
| The Pages | Kangaroo Island | 1991.5 | 431 | Count | High |
| Seal Bay | Kangaroo Island | 1993 | 153 | Count | High |
| The Pages | Kangaroo Island | 1993 | 448 | Count | High |
| Seal Bay | Kangaroo Island | 1994.5 | 124 | Count | High |
| The Pages | Kangaroo Island | 1994.5 | 439 | Count | High |
| Bunda 08 (B4) | Bunda Cliffs | 1995 | 1 | Count | Low |
| Bunda 04 (B2) | Bunda Cliffs | 1995 | 2 | Count | Low |
| Bunda 12 (B6) | Bunda Cliffs | 1995 | 5 | Count | Low |
| Bunda 22 (B9) | Bunda Cliffs | 1995 | 7 | Count | Low |
| Bunda 00 (B1) | Bunda Cliffs | 1995 | 13 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 1995 | 13 | Count | Low |
| Bunda 19 (B8) | Bunda Cliffs | 1995 | 16 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 1995 | 18 | Count | Low |
| Seal Bay | Kangaroo Island | 1996 | 145 | Count | High |
| The Pages | Kangaroo Island | 1996 | 381 | Count | High |
| Seal Bay | Kangaroo Island | 1997.5 | 149 | Count | High |
| The Pages | Kangaroo Island | 1997.5 | 445 | Count | High |
| Seal Bay | Kangaroo Island | 1999 | 148 | Count | High |
| Dangerous Reef | Spencer Gulf | 1999 | 383 | Count | Low |
| Dangerous Reef | Spencer Gulf | 1999 | 425 | MR | Low |
| The Pages | Kangaroo Island | 1999 | 438 | Count | High |
| Dangerous Reef | Spencer Gulf | 2000.5 | 393 | Count | Low |
| Bunda 04 (B2) | Bunda Cliffs | 2001 | 3 | Count | Low |
| Bunda 12 (B6) | Bunda Cliffs | 2001 | 3 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 2001 | 16 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 2001 | 16 | Count | Low |
| Seal Bay | Kangaroo Island | 2001 | 135 | Count | High |
| The Pages | Kangaroo Island | 2001 | 461 | Count | High |
| English | Spencer Gulf | 2002 | 32 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2002 | 426 | Count | Low |
| Seal Slide | Kangaroo Island | 2002.5 | 9 | Count | High |
| Seal Bay | Kangaroo Island | 2002.5 | 147 | Count | High |
| The Pages | Kangaroo Island | 2002.5 | 609 | Count | High |
| Pt Labatt | Chain of Bays | 2003.5 | 1 | Count | High |
| Pearson | Chain of Bays | 2003.5 | 29 | Count | High |
| West Waldegrave | Chain of Bays | 2003.5 | 157 | Count | High |
| Dangerous Reef | Spencer Gulf | 2003.5 | 499 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2003.5 | 507 | MR | Low |
| Seal Slide | Kangaroo Island | 2004 | 11 | Count | High |
| Seal Bay | Kangaroo Island | 2004 | 148 | Count | High |
| Seal Bay | Kangaroo Island | 2004 | 272 | CPP | High |
| The Pages | Kangaroo Island | 2004 | 490 | Count | High |
| Bunda 06 (B3) | Bunda Cliffs | 2004.5 | 10 | Count | Low |
| Pt Labatt | Chain of Bays | 2005 | 6 | Count | High |
| East | Spencer Gulf | 2005 | 14 | Count | High |
| Jones | Chain of Bays | 2005 | 15 | Count | High |
| Breakwater/Gliddon | Nuyts-Archipelago | 2005 | 24 | Count | High |
| English | Spencer Gulf | 2005 | 27 | Count | Low |
| North | Spencer Gulf | 2005 | 28 | Count | Low |
| Pearson | Chain of Bays | 2005 | 35 | Count | High |
| Liguanea | Spencer Gulf | 2005 | 43 | Count | High |
| West | Nuyts-Archipelago | 2005 | 56 | Count | High |
| West Waldegrave | Chain of Bays | 2005 | 104 | Count | High |
| Blefuscu | Nuyts-Archipelago | 2005 | 124 | Count | High |
| Purdie | Nuyts-Archipelago | 2005 | 132 | Count | High |
| Dangerous Reef | Spencer Gulf | 2005 | 574 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2005 | 585 | Count | Low |
| Seal Slide | Kangaroo Island | 2005.5 | 10 | Count | High |
| Seal Bay | Kangaroo Island | 2005.5 | 125 | Count | High |
| The Pages | Kangaroo Island | 2005.5 | 543 | Count | High |
| South Neptune | Spencer Gulf | 2006.5 | 6 | Count | High |
| Jones | Chain of Bays | 2006.5 | 15 | Count | High |
| Ward | Chain of Bays | 2006.5 | 45 | Count | High |
| Nicolas Baudin | Chain of Bays | 2006.5 | 98 | Count | High |
| Lewis | Spencer Gulf | 2006.5 | 149 | Count | Low |
| Olive | Chain of Bays | 2006.5 | 197 | MR | High |
| Olive | Chain of Bays | 2006.5 | 200 | CPP | High |
| Dangerous Reef | Spencer Gulf | 2006.5 | 575 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2006.5 | 709 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2006.5 | 831 | CPP | Low |
| Bunda 18 (B7) | Bunda Cliffs | 2007 | 1 | Count | Low |
| Bunda 12 (B6) | Bunda Cliffs | 2007 | 2 | Count | Low |
| Bunda 19 (B8) | Bunda Cliffs | 2007 | 4 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 2007 | 7 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 2007 | 11 | Count | Low |
| Seal Slide | Kangaroo Island | 2007 | 15 | Count | High |
| Seal Bay | Kangaroo Island | 2007 | 154 | Count | High |
| Seal Bay | Kangaroo Island | 2007 | 254 | CPP | High |
| The Pages | Kangaroo Island | 2007 | 403 | Count | High |
| Bunda 12 (B6) | Bunda Cliffs | 2008 | 1 | Count | Low |
| Bunda 02 (B1.1) | Bunda Cliffs | 2008 | 2 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 2008 | 5 | Count | Low |
| Bunda 19 (B8) | Bunda Cliffs | 2008 | 8 | Count | Low |
| Bunda 18 (B7) | Bunda Cliffs | 2008 | 9 | Count | Low |
| Jones | Chain of Bays | 2008 | 15 | Count | High |
| Breakwater/Gliddon | Nuyts-Archipelago | 2008 | 22 | Count | High |
| English | Spencer Gulf | 2008 | 23 | Count | Low |
| Lounds | Nuyts-Archipelago | 2008 | 34 | Count | High |
| West | Nuyts-Archipelago | 2008 | 39 | Count | High |
| Fenelon | Nuyts-Archipelago | 2008 | 40 | Count | High |
| Lilliput | Nuyts-Archipelago | 2008 | 55 | Count | High |
| Lilliput | Nuyts-Archipelago | 2008 | 66 | MR | High |
| Lilliput | Nuyts-Archipelago | 2008 | 70 | CPP | High |
| Purdie | Nuyts-Archipelago | 2008 | 95 | Count | High |
| Blefuscu | Nuyts-Archipelago | 2008 | 113 | MR | High |
| Olive | Chain of Bays | 2008 | 162 | MR | High |
| Olive | Chain of Bays | 2008 | 169 | CPP | High |
| Dangerous Reef | Spencer Gulf | 2008 | 335 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2008 | 520 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2008 | 543 | CPP | Low |
| Seal Slide | Kangaroo Island | 2008.5 | 12 | Count | High |
| Seal Bay | Kangaroo Island | 2008.5 | 122 | Count | High |
| Seal Bay | Kangaroo Island | 2008.5 | 268 | CPP | High |
| The Pages | Kangaroo Island | 2008.5 | 478 | Count | High |
| Bunda 12 (B6) | Bunda Cliffs | 2009.5 | 1 | Count | Low |
| Jones | Chain of Bays | 2009.5 | 11 | Count | High |
| English | Spencer Gulf | 2009.5 | 39 | Count | Low |
| Albatross | Spencer Gulf | 2009.5 | 69 | Count | Low |
| Olive | Chain of Bays | 2009.5 | 221 | CPP | High |
| Olive | Chain of Bays | 2009.5 | 221 | MR | High |
| Dangerous Reef | Spencer Gulf | 2009.5 | 435 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2009.5 | 488 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2009.5 | 629 | CPP | Low |
| Seal Slide | Kangaroo Island | 2010 | 10 | Count | High |
| Seal Bay | Kangaroo Island | 2010 | 119 | Count | High |
| Seal Bay | Kangaroo Island | 2010 | 267 | CPP | High |
| The Pages | Kangaroo Island | 2010 | 478 | Count | High |
| Jones | Chain of Bays | 2010.5 | 12 | Count | High |
| Four Hummocks | SW Eyre | 2010.5 | 14 | Count | High |
| Rocky North | SW Eyre | 2010.5 | 34 | Count | High |
| Lilliput | Nuyts-Archipelago | 2010.5 | 47 | Count | High |
| Lilliput | Nuyts-Archipelago | 2010.5 | 66 | MR | High |
| Blefuscu | Nuyts-Archipelago | 2010.5 | 120 | MR | High |
| Olive | Chain of Bays | 2010.5 | 173 | MR | High |
| Olive | Chain of Bays | 2010.5 | 199 | CPP | High |
| Bunda 22 (B9) | Bunda Cliffs | 2011 | 1 | Count | Low |
| Bunda 04 (B2) | Bunda Cliffs | 2011 | 2 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 2011 | 2 | Count | Low |
| Bunda 08 (B4) | Bunda Cliffs | 2011 | 2 | Count | Low |
| Bunda 12 (B6) | Bunda Cliffs | 2011 | 2 | Count | Low |
| Bunda 18 (B7) | Bunda Cliffs | 2011 | 3 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 2011 | 9 | Count | Low |
| North | Spencer Gulf | 2011 | 21 | Count | Low |
| English | Spencer Gulf | 2011 | 34 | Count | Low |
| Peaked Rocks | Spencer Gulf | 2011 | 58 | Count | Low |
| Albatross | Spencer Gulf | 2011 | 69 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2011 | 329 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2011 | 399 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2011 | 413 | CPP | Low |
| Seal Slide | Kangaroo Island | 2011.5 | 13 | Count | High |
| Seal Bay | Kangaroo Island | 2011.5 | 84 | Count | High |
| Seal Bay | Kangaroo Island | 2011.5 | 249 | CPP | High |
| Four Hummocks | SW Eyre | 2012 | 9 | Count | High |
| Little Hummock | SW Eyre | 2012 | 10 | Count | High |
| Jones | Chain of Bays | 2012 | 12 | Count | High |
| Rocky South | SW Eyre | 2012 | 12 | Count | High |
| Cap | SW Eyre | 2012 | 38 | Count | High |
| Rocky North | SW Eyre | 2012 | 44 | Count | High |
| Lilliput | Nuyts-Archipelago | 2012 | 69 | Count | High |
| Lilliput | Nuyts-Archipelago | 2012 | 70 | MR | High |
| Blefuscu | Nuyts-Archipelago | 2012 | 80 | MR | High |
| Olive | Chain of Bays | 2012 | 101 | MR | High |
| Olive | Chain of Bays | 2012 | 109 | Count | High |
| Olive | Chain of Bays | 2012 | 135 | CPP | High |
| Bunda 18 (B7) | Bunda Cliffs | 2012.5 | 1 | Count | Low |
| Bunda 12 (B6) | Bunda Cliffs | 2012.5 | 2 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 2012.5 | 5 | Count | Low |
| Bunda 19 (B8) | Bunda Cliffs | 2012.5 | 7 | Count | Low |
| South Neptune | Spencer Gulf | 2012.5 | 7 | Count | High |
| Bunda 06 (B3) | Bunda Cliffs | 2012.5 | 8 | Count | Low |
| Lewis | Spencer Gulf | 2012.5 | 79 | Count | Low |
| Cape Bouguer | Kangaroo Island | 2013 | 9 | Count | High |
| Seal Slide | Kangaroo Island | 2013 | 10 | Count | High |
| North Casuarina | Kangaroo Island | 2013 | 11 | Count | High |
| Seal Bay | Kangaroo Island | 2013 | 99 | Count | High |
| Seal Bay | Kangaroo Island | 2013 | 259 | CPP | High |
| Pt Labatt | Chain of Bays | 2013.5 | 2 | Count | High |
| Jones | Chain of Bays | 2013.5 | 16 | Count | High |
| Liguanea | Spencer Gulf | 2013.5 | 17 | Count | High |
| Pearson | Chain of Bays | 2013.5 | 27 | Count | High |
| Ward | Chain of Bays | 2013.5 | 46 | Count | High |
| Rocky North | SW Eyre | 2013.5 | 47 | Count | High |
| Nicolas Baudin | Chain of Bays | 2013.5 | 57 | Count | High |
| Lilliput | Nuyts-Archipelago | 2013.5 | 68 | MR | High |
| Lilliput | Nuyts-Archipelago | 2013.5 | 73 | Count | High |
| Olive | Chain of Bays | 2013.5 | 76 | Count | High |
| Lilliput | Nuyts-Archipelago | 2013.5 | 78 | CPP | High |
| Blefuscu | Nuyts-Archipelago | 2013.5 | 86 | CPP | High |
| West Waldegrave | Chain of Bays | 2013.5 | 91 | Count | High |
| Olive | Chain of Bays | 2013.5 | 139 | MR | High |
| Olive | Chain of Bays | 2013.5 | 150 | CPP | High |
| Bunda 19 (B8) | Bunda Cliffs | 2014 | 0 | Count | Low |
| Bunda 02 (B1.1) | Bunda Cliffs | 2014 | 3 | Count | Low |
| Bunda 09 (B5) | Bunda Cliffs | 2014 | 7 | Count | Low |
| Bunda 22 (B9) | Bunda Cliffs | 2014 | 7 | Count | Low |
| Bunda 06 (B3) | Bunda Cliffs | 2014 | 9 | Count | Low |
| East | Spencer Gulf | 2014 | 9 | Count | High |
| Lewis | Spencer Gulf | 2014 | 82 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2014 | 288 | Count | Low |
| Dangerous Reef | Spencer Gulf | 2014 | 408 | MR | Low |
| Dangerous Reef | Spencer Gulf | 2014 | 485 | CPP | Low |
| Seal Slide | Kangaroo Island | 2014.5 | 8 | Count | High |
| Seal Bay | Kangaroo Island | 2014.5 | 103 | Count | High |
| Seal Bay | Kangaroo Island | 2014.5 | 239 | CPP | High |
| Little Hummock | SW Eyre | 2015 | 4 | Count | High |
| Williams | Spencer Gulf | 2015 | 5 | Count | High |
| Four Hummocks | SW Eyre | 2015 | 6 | Count | High |
| Curta | Spencer Gulf | 2015 | 7 | Count | High |
| Rocky South | SW Eyre | 2015 | 11 | Count | High |
| Jones | Chain of Bays | 2015 | 19 | Count | High |
| Fenelon | Nuyts-Archipelago | 2015 | 19 | Count | High |
| Lounds | Nuyts-Archipelago | 2015 | 20 | Count | High |
| West | Nuyts-Archipelago | 2015 | 20 | Count | High |
| Liguanea | Spencer Gulf | 2015 | 25 | Count | High |
| Breakwater/Gliddon | Nuyts-Archipelago | 2015 | 27 | Count | High |
| Pearson | Chain of Bays | 2015 | 30 | Count | High |
| Cap | SW Eyre | 2015 | 31 | Count | High |
| Price | SW Eyre | 2015 | 32 | Count | High |
| Rocky North | SW Eyre | 2015 | 35 | Count | High |
| Ward | Chain of Bays | 2015 | 44 | Count | High |
| Lilliput | Nuyts-Archipelago | 2015 | 52 | Count | High |
| Nicolas Baudin | Chain of Bays | 2015 | 63 | Count | High |
| Lilliput | Nuyts-Archipelago | 2015 | 67 | MR | High |
| Purdie | Nuyts-Archipelago | 2015 | 67 | Count | High |
| Lilliput | Nuyts-Archipelago | 2015 | 72 | CPP | High |
| West Waldegrave | Chain of Bays | 2015 | 89 | Count | High |
| Blefuscu | Nuyts-Archipelago | 2015 | 97 | CPP | High |
| Olive | Chain of Bays | 2015 | 103 | Count | High |
| Nuyts Reef | Nuyts-Archipelago | 2015 | 105 | Count | High |
| Olive | Chain of Bays | 2015 | 131 | MR | High |
| Olive | Chain of Bays | 2015 | 142 | CPP | High |

# Appendix 2 – R Code

**‘ASL Main Script.R’**

###THIS IS THE MAIN SCRIPT

#Set working directory to an appropriate location and make sure all of your scripts and Excel files are in that directory

setwd("~//Documents/Data/ASL/Mark")

#If you have not installed the mgcv and mvbutils packages previously you will need to do so by saving the packages to a directory and then choosing the 'browse' option for installing a package.

#install.packages("mgcv")

#install.packages("mvbutils")

require( mgcv, quietly=TRUE)

require(mvbutils, quietly=TRUE)

#Source R scripts

source("prepare\_fn3.R")

source("prepare\_frame2.R")

source("Other\_functions.R")

# List sites with no immigration (this is here so it can be used across all scripts)

nonimsus <- c(

"Seal Bay", "Dangerous Reef", "Liguanea", "Cap", "Rocky South", "West Waldegrave",

"Pearson", "Nicolas Baudin", "Olive", "Breakwater/Gliddon", "Nuyts Reef")

# Prepare the prediction frame first

## Just need to change filename here. This should contain all sites for each year a prediction value may be required

# (Variables: Site, Region, Year (eg. 2020, 2025), Method, Gillnet\_exposure)

Frame <- prepare\_frame2( filename='Pred\_frame\_AllSites.csv',

nonimsus=nonimsus)

# Fit Model to data. To change the scenario you just need to change the filename where the file has the future sampling schedule

Model<- prepare\_fn3(filename='Scenario\_all\_every3.csv',

nonimsus=nonimsus,

predlevs\_im=levels( Frame$ID\_im),

predlevs\_noim=levels( Frame$ID\_noim))

#Predictions at the colony/site by year level

Pred\_yearcol <- predict(Model$refit, newdata=Frame, type="response", se=TRUE)

Pred\_yearcol <- cbind(Frame[,1:6],Pred\_yearcol)

Pred\_yearcol

#CV of Total (or regional level total) for a particular year using the delta method. region="NA" if you want the Total across all regions otherwise enter region name in ""

# The chosen year must be in the prediction frame (Frame)

delta\_method(year="2020",region="Kangaroo Island")

#CV of Trend from "yearNow" to "yearFuture". region="NA" if you want the Total across all regions otherwise enter region name in ""

# The chosen years must be in the prediction frame

delta\_method\_trend(data=Frame,yearFuture="2045",yearNow="2000",region="NA")

**############################################################################**

**‘prepare\_3.R’**

prepare\_fn3 <- function ( filename= 'Scenario\_keycol.csv', nonimsus, predlevs\_im, predlevs\_noim) {

# the main function that prepares the data and fits the model

asl.data <- read.table( filename, sep=',', header=TRUE, row=NULL, stringsAsFactors=FALSE)

asl.data$Site<-as.factor(asl.data$Site)

# Big sites assumed to have count bias due to long season--- based on a "big-site" method having ever been used there

asl.data$sites\_mrcpp <- with(asl.data, ifelse (Method %in% c('MR','CPP'),1,0))

test <- with(asl.data, tapply(sites\_mrcpp,Site,sum))

big\_sites <- names(test[test>0])

# only use sites with at least one obs

usable <- with(asl.data %where% (Year<2016 & Estimate>0),tapply(Estimate,Site,length))

usable.sites <- names(usable[usable>0])

data.usable <- asl.data %where% (Site %in% usable.sites)

# Now add columns for fitting

data.usable <- within(data.usable, {

count\_bias <- (Site %in% big\_sites) & (Method=='Count') # small sites (short season): count OK if timed right

extra\_sealbay\_count\_bias <- count\_bias & (Site=='Seal Bay') # Seal Bay clearly has a different amount of bias associated with it

MR\_bias <- Method=='MR'

count\_noise <- Method=='Count' # regardless of site type

ID <- seq\_along( Site) # 1:"n"; MVB taking advantage of new mgcv

ID[ !count\_noise] <- 1L # reduce unused factor levels

RE\_im <- (count\_noise & (Site %not.in% nonimsus)) \* 1

RE\_noim <- (count\_noise \* (Site %in% nonimsus)) \* 1

# Seems to run into trouble if same ID is used for im and noim smooths

ID\_im <- ifelse( RE\_im, ID, 1L)

ID\_noim <- ifelse( RE\_noim, ID, 1L)

#Set up two basline year variables - Year 2000 and Year 2016 (post-management action)

y2000 <- Year-2000

ypost\_mgmt <- (Year>2015) \* (Year-2016) \* (Gillnet\_exposure=='High') # should quantify old per cap exposure; 2016 is arguably first year that effects might be seen

FUTURE <- Year > 2015

})

factorify <- function( vals, prefix, extralevs) {

vals <- prefix %&% vals

vals <- factor( vals, levels=c( unique( vals), extralevs))

return( vals)

}

data.usable$ID\_im <- factorify( data.usable$ID\_im, 'IX', predlevs\_im)

data.usable$ID\_noim <- factorify( data.usable$ID\_noim, 'NX', predlevs\_noim)

# Real stuff (plus fake rows...)

data.real <- data.usable %where% !FUTURE

data.future <- data.usable %where% FUTURE # for making up data later

data.future$count\_noise <- FALSE # turn off for predicting mean

# We are using bam from mgcv 1.8.13 not gam, with new miracle feature to allow "more coefficients than data"

fit <- bam( Estimate ~

Site

+ count\_bias

+ extra\_sealbay\_count\_bias

+ MR\_bias

+ s( ID\_im, by=RE\_im, bs='re')

+ s( ID\_noim, by=RE\_noim, bs='re')

+ y2000 %in% Region

+ ypost\_mgmt,

family=Tweedie( p=1.2, link='log'),

discrete=TRUE,

drop.unused.levels=FALSE,

data=data.real)

data.future$Estimate <- 1 # for 'predict', this has to be there (Any non-NA value is ok)

#data.future$RE\_noim<-0 # For no random effect remove comment

#data.future$RE\_im<-0 # For no random effect remove comment

preddo <- predict( fit, newdata=data.future, type='response')

data.future$Estimate <- preddo

data.both <- rbind( data.real, data.future)

refit <- update( fit, sp=fit$sp, scale=fit$sig2,data=data.real) # just a check; should be the same as fit;

refit <- update( fit, sp=fit$sp, scale=fit$sig2, data=data.both) # past & future together

Vfuture <- vcov( refit)

Vnow <- vcov( fit)

returnList( data.usable, Vfuture, Vnow, fit, refit)

}

**############################################################################**

**‘prepare\_frame2.R’**

prepare\_frame2 <- function(filename='Pred\_frame\_Allsites.csv', nonimsus){

### Function to prepare the prediction frame

Pred\_frame\_AllSites <- read.csv(filename)

big\_sites <- c("Blefuscu","Dangerous Reef","Lilliput","Olive","Seal Bay" )

Pred\_frame\_AllSites <- within(Pred\_frame\_AllSites, {

count\_bias <- (Site %in% big\_sites) & (Method=='Count') # small sites (short season): count OK if timed right

extra\_sealbay\_count\_bias <- count\_bias & (Site=='Seal Bay') # SB has clearly...

# ... different q cf

MR\_bias <- Method=='MR'

count\_noise <- Method=='Count' # regardless of site type

#Change the \*0 to \*1 to put the REs back into the prediction

RE\_im <- (count\_noise & (Site %not.in% nonimsus)) \* 0

RE\_noim <- (count\_noise \* (Site %in% nonimsus)) \* 0

y2000 <- Year-2000

ypost\_mgmt <- (Year>2015) \* (Year-2016) \* (Gillnet\_exposure=='High') # should quantify old per cap exposure; 2016 is arguably first year that effects might be seen

FUTURE <- Year > 2015

ID <- seq\_along( Site) # 1:"n"; MVB taking advantage of new mgcv

ID[ !count\_noise] <- 1L # reduce unused factor levels. This line is otiose

ID\_im <- ifelse( RE\_im, ID, 1L)

ID\_noim <- ifelse( RE\_noim, ID, 1L)

ID\_im <- factor( 'IY' %&% ID\_im) # called 'X' in fit-frame

ID\_noim <- factor( 'NY' %&% ID\_noim)

})

return(Pred\_frame\_AllSites)

}

**############################################################################**

**‘Other\_functions.R’**

# Function to sum the predictions on the response scale

TotalPredict<-function (coefs,lpmatrix)

{

# This gives the sum of predictions (which are medians)

temp <- lpmatrix %\*% coefs # on the predictor scale

temp<- exp(temp) # inverse log to get to the response scale

temp<- sum(temp)

return(temp)

}

# Mark's function to calculate the numerical derivative

Numderiv<-function(f,x0,eps=0.0001,...) {

#Mark's function

f0 <- f(x0,...)

n <- length( x0)

m <- matrix( 0, length(f0), n)

for( i in 1:n) {

this.eps <- eps \* if( x0[ i]==0) 1 else x0[ i]

m[,i] <- ( f( x0+this.eps \* (1:n==i), ...) - f0) / this.eps }

if( !is.null( dim( f0)))

dim( m) <- c( dim( f0), n)

return(m)

}

#Now need a function to use delta-method to calculate Total or Regional estimates by year. For total by year then region="NA"

delta\_method <- function(data=Frame,year="2025",region="Kangaroo Island"){

temp <- if(region=="NA") subset(Frame, Year==year) else subset (Frame, Year==year & Region==region)

Vfuture <- vcov(Model$refit) # This give the variance-covariance matrix

coefs <- Model$refit$coefficients # GAM coefficients

lpmatrix <- predict(Model$refit, newdata=temp, type='lpmatrix') #Prediction matrix

deriv <- Numderiv( TotalPredict, coefs, lpmatrix=lpmatrix)# Calculate the derivative

Variance <- deriv%\*%Vfuture%\*%t(deriv) # Calculate the variance

pred <- TotalPredict( coefs, lpmatrix=lpmatrix)

CV <- (sqrt(Variance)/TotalPredict( coefs, lpmatrix=lpmatrix))\*100 # Calculate the CV (sd/mean)

returnList (CV, pred, Variance)

#want to calculate total and variance by year

}

#Function to calculate the trend (Number of seals)

delta\_method\_trend <- function(data=Frame,yearFuture="2025",yearNow="2015",region="Kangaroo Island"){

temp <- if(region=="NA") subset(Frame, Year %in% c(yearNow,yearFuture)) else subset (Frame, Year %in% c(yearFuture,yearNow) & Region==region)

n\_sites <- nrow(temp)/2

Trend<-function (coefs,lpmatrix,yearNow,yearFuture)

{

ans<- (log(sum(exp(lpmatrix[1:n\_sites,] %\*% coefs)))-log(sum(exp(lpmatrix[(n\_sites+1):(n\_sites\*2),] %\*% coefs))))/(as.numeric(yearFuture)-as.numeric(yearNow))

return(ans)

}

Vfuture <- vcov(Model$refit) # This give the variance-covariance matrix

coefs <- Model$refit$coefficients # GAM coefficients

lpmatrix <- predict(Model$refit, newdata=temp, type='lpmatrix') #Prediction matrix

deriv <- Numderiv( Trend, coefs, lpmatrix=lpmatrix, yearFuture=yearFuture,yearNow=yearNow)# Calculate the derivative

Variance <- deriv%\*%Vfuture%\*%t(deriv) # Calculate the variance

log\_trend <- Trend( coefs, lpmatrix=lpmatrix, yearFuture=yearFuture,yearNow=yearNow)

SE<- sqrt(Variance)

trend <- (sum(exp(lpmatrix[1:n\_sites,] %\*% coefs))-sum(exp(lpmatrix[(n\_sites+1):(n\_sites\*2),] %\*% coefs)))/(as.numeric(yearFuture)-as.numeric(yearNow))

returnList (SE, trend, log\_trend)

#want to calculate total and variance by year

# Appendix 3 – Model predictions

Table 8 Predictions by site for each year for each scenario. Estimate is the estimated pup count in that year for that site, and the SE variables correspond to the standard error of the prediction under each of the sampling scenarios.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Site** | **Region** | **Year** | **Method** | **Estimate** | **SE1** | **SE2** | **SE4** | **SE5** |
| Bunda 00 (B1) | Bunda Cliffs | 2015 | Count | 4.55 | 2.19 | 2.24 | 1.33 | 1.08 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2015 | Count | 2.02 | 1.21 | 1.21 | 0.81 | 0.66 |
| Bunda 04 (B2) | Bunda Cliffs | 2015 | Count | 1.16 | 0.60 | 0.61 | 0.46 | 0.40 |
| Bunda 06 (B3) | Bunda Cliffs | 2015 | Count | 5.36 | 1.10 | 1.14 | 0.90 | 0.81 |
| Bunda 08 (B4) | Bunda Cliffs | 2015 | Count | 0.78 | 0.57 | 0.58 | 0.41 | 0.35 |
| Bunda 09 (B5) | Bunda Cliffs | 2015 | Count | 6.66 | 1.01 | 1.17 | 1.13 | 1.01 |
| Bunda 12 (B6) | Bunda Cliffs | 2015 | Count | 1.37 | 0.47 | 0.48 | 0.40 | 0.37 |
| Bunda 18 (B7) | Bunda Cliffs | 2015 | Count | 2.60 | 0.98 | 0.98 | 0.77 | 0.67 |
| Bunda 19 (B8) | Bunda Cliffs | 2015 | Count | 4.28 | 1.16 | 1.18 | 0.92 | 0.82 |
| Bunda 22 (B9) | Bunda Cliffs | 2015 | Count | 2.99 | 1.15 | 1.17 | 0.86 | 0.74 |
| Jones | Chain of Bays | 2015 | Count | 11.70 | 1.79 | 1.80 | 1.53 | 1.36 |
| Nicolas Baudin | Chain of Bays | 2015 | Count | 62.45 | 9.08 | 9.12 | 6.47 | 5.36 |
| Olive | Chain of Bays | 2015 | Count | 102.49 | 5.11 | 5.53 | 5.34 | 4.80 |
| Pearson | Chain of Bays | 2015 | Count | 23.69 | 4.03 | 4.06 | 3.04 | 2.59 |
| Pt Labatt | Chain of Bays | 2015 | Count | 2.17 | 0.99 | 0.99 | 0.73 | 0.61 |
| Ward | Chain of Bays | 2015 | Count | 39.09 | 6.25 | 6.27 | 4.50 | 3.73 |
| West Waldegrave | Chain of Bays | 2015 | Count | 85.48 | 9.88 | 10.06 | 7.31 | 6.21 |
| Cape Bouguer | Kangaroo Island | 2015 | Count | 8.91 | 4.54 | 4.54 | 2.11 | 1.43 |
| North Casuarina | Kangaroo Island | 2015 | Count | 10.89 | 5.13 | 5.13 | 2.38 | 1.62 |
| Seal Bay | Kangaroo Island | 2015 | CPP | 251.77 | 10.79 | 11.56 | 11.06 | 9.35 |
| Seal Slide | Kangaroo Island | 2015 | Count | 10.55 | 1.68 | 1.68 | 1.41 | 1.18 |
| The Pages | Kangaroo Island | 2015 | Count | 435.42 | 26.11 | 26.51 | 19.26 | 15.60 |
| Blefuscu | Nuyts-Archipelago | 2015 | Count | 66.82 | 6.02 | 6.22 | 4.90 | 4.35 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2015 | Count | 18.66 | 3.94 | 3.98 | 2.83 | 2.38 |
| Fenelon | Nuyts-Archipelago | 2015 | Count | 24.61 | 5.67 | 5.68 | 3.67 | 3.01 |
| Lilliput | Nuyts-Archipelago | 2015 | Count | 47.41 | 2.91 | 3.12 | 3.05 | 2.81 |
| Lounds | Nuyts-Archipelago | 2015 | Count | 22.62 | 5.38 | 5.39 | 3.48 | 2.85 |
| Nuyts Reef | Nuyts-Archipelago | 2015 | Count | 105.00 | 23.39 | 23.39 | 11.68 | 9.17 |
| Purdie | Nuyts-Archipelago | 2015 | Count | 73.92 | 9.40 | 9.64 | 6.57 | 5.59 |
| West | Nuyts-Archipelago | 2015 | Count | 28.76 | 5.02 | 5.09 | 3.60 | 3.04 |
| Albatross | Spencer Gulf | 2015 | Count | 62.17 | 10.35 | 10.36 | 6.31 | 4.94 |
| Curta | Spencer Gulf | 2015 | Count | 7.00 | 3.94 | 3.94 | 1.84 | 1.36 |
| Dangerous Reef | Spencer Gulf | 2015 | Count | 345.80 | 11.86 | 13.76 | 13.16 | 11.46 |
| East | Spencer Gulf | 2015 | Count | 10.12 | 3.32 | 3.32 | 2.05 | 1.60 |
| English | Spencer Gulf | 2015 | Count | 26.04 | 3.72 | 3.74 | 2.85 | 2.41 |
| Lewis | Spencer Gulf | 2015 | Count | 93.78 | 11.08 | 11.10 | 7.57 | 6.14 |
| Liguanea | Spencer Gulf | 2015 | Count | 25.68 | 5.07 | 5.07 | 3.52 | 2.84 |
| North | Spencer Gulf | 2015 | Count | 20.94 | 5.14 | 5.14 | 3.15 | 2.46 |
| Peaked Rocks | Spencer Gulf | 2015 | Count | 53.13 | 13.30 | 13.31 | 6.76 | 5.09 |
| South Neptune | Spencer Gulf | 2015 | Count | 5.76 | 2.36 | 2.36 | 1.45 | 1.13 |
| Williams | Spencer Gulf | 2015 | Count | 5.00 | 3.21 | 3.21 | 1.49 | 1.11 |
| Cap | SW Eyre | 2015 | Count | 31.69 | 7.14 | 7.15 | 4.99 | 4.02 |
| Four Hummocks | SW Eyre | 2015 | Count | 8.36 | 2.41 | 2.42 | 1.82 | 1.51 |
| Little Hummock | SW Eyre | 2015 | Count | 6.39 | 2.55 | 2.55 | 1.74 | 1.38 |
| Price | SW Eyre | 2015 | Count | 32.00 | 9.99 | 9.99 | 5.73 | 4.35 |
| Rocky North | SW Eyre | 2015 | Count | 35.35 | 3.95 | 4.17 | 4.13 | 3.58 |
| Rocky South | SW Eyre | 2015 | Count | 10.58 | 3.54 | 3.54 | 2.42 | 1.93 |
| Bunda 00 (B1) | Bunda Cliffs | 2020 | Count | 3.50 | 1.75 | 1.82 | 1.03 | 0.83 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2020 | Count | 1.56 | 0.94 | 0.94 | 0.62 | 0.51 |
| Bunda 04 (B2) | Bunda Cliffs | 2020 | Count | 0.89 | 0.47 | 0.48 | 0.36 | 0.31 |
| Bunda 06 (B3) | Bunda Cliffs | 2020 | Count | 4.12 | 0.95 | 1.01 | 0.73 | 0.64 |
| Bunda 08 (B4) | Bunda Cliffs | 2020 | Count | 0.60 | 0.45 | 0.45 | 0.32 | 0.27 |
| Bunda 09 (B5) | Bunda Cliffs | 2020 | Count | 5.12 | 0.83 | 1.02 | 0.92 | 0.79 |
| Bunda 12 (B6) | Bunda Cliffs | 2020 | Count | 1.05 | 0.38 | 0.39 | 0.32 | 0.29 |
| Bunda 18 (B7) | Bunda Cliffs | 2020 | Count | 2.00 | 0.77 | 0.78 | 0.59 | 0.51 |
| Bunda 19 (B8) | Bunda Cliffs | 2020 | Count | 3.29 | 0.96 | 0.99 | 0.73 | 0.64 |
| Bunda 22 (B9) | Bunda Cliffs | 2020 | Count | 2.30 | 0.92 | 0.95 | 0.67 | 0.57 |
| Jones | Chain of Bays | 2020 | Count | 9.56 | 1.51 | 1.55 | 1.26 | 1.11 |
| Nicolas Baudin | Chain of Bays | 2020 | Count | 51.02 | 7.63 | 7.79 | 5.18 | 4.24 |
| Olive | Chain of Bays | 2020 | Count | 83.74 | 4.27 | 5.20 | 4.62 | 3.99 |
| Pearson | Chain of Bays | 2020 | Count | 19.36 | 3.44 | 3.52 | 2.49 | 2.09 |
| Pt Labatt | Chain of Bays | 2020 | Count | 1.77 | 0.81 | 0.82 | 0.60 | 0.50 |
| Ward | Chain of Bays | 2020 | Count | 31.94 | 5.22 | 5.32 | 3.63 | 2.98 |
| West Waldegrave | Chain of Bays | 2020 | Count | 69.84 | 8.56 | 9.00 | 5.94 | 4.94 |
| Cape Bouguer | Kangaroo Island | 2020 | Count | 8.70 | 4.44 | 4.44 | 2.04 | 1.39 |
| North Casuarina | Kangaroo Island | 2020 | Count | 10.63 | 5.01 | 5.01 | 2.31 | 1.57 |
| Seal Bay | Kangaroo Island | 2020 | CPP | 245.72 | 9.05 | 10.08 | 10.28 | 8.50 |
| Seal Slide | Kangaroo Island | 2020 | Count | 10.29 | 1.65 | 1.65 | 1.37 | 1.15 |
| The Pages | Kangaroo Island | 2020 | Count | 424.95 | 26.67 | 27.56 | 18.63 | 14.61 |
| Blefuscu | Nuyts-Archipelago | 2020 | Count | 53.15 | 5.35 | 5.88 | 3.97 | 3.42 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2020 | Count | 14.85 | 3.24 | 3.33 | 2.25 | 1.88 |
| Fenelon | Nuyts-Archipelago | 2020 | Count | 19.58 | 4.60 | 4.67 | 2.90 | 2.35 |
| Lilliput | Nuyts-Archipelago | 2020 | Count | 37.71 | 2.41 | 2.94 | 2.53 | 2.25 |
| Lounds | Nuyts-Archipelago | 2020 | Count | 17.99 | 4.36 | 4.42 | 2.75 | 2.23 |
| Nuyts Reef | Nuyts-Archipelago | 2020 | Count | 83.52 | 18.78 | 18.89 | 8.92 | 6.93 |
| Purdie | Nuyts-Archipelago | 2020 | Count | 58.80 | 8.14 | 8.70 | 5.22 | 4.34 |
| West | Nuyts-Archipelago | 2020 | Count | 22.88 | 4.18 | 4.35 | 2.86 | 2.39 |
| Albatross | Spencer Gulf | 2020 | Count | 55.71 | 9.35 | 9.41 | 5.57 | 4.33 |
| Curta | Spencer Gulf | 2020 | Count | 6.27 | 3.53 | 3.53 | 1.63 | 1.21 |
| Dangerous Reef | Spencer Gulf | 2020 | Count | 309.88 | 11.31 | 14.49 | 12.95 | 10.77 |
| East | Spencer Gulf | 2020 | Count | 9.07 | 2.99 | 3.00 | 1.82 | 1.41 |
| English | Spencer Gulf | 2020 | Count | 23.34 | 3.38 | 3.43 | 2.56 | 2.15 |
| Lewis | Spencer Gulf | 2020 | Count | 84.04 | 10.07 | 10.19 | 6.66 | 5.35 |
| Liguanea | Spencer Gulf | 2020 | Count | 23.01 | 4.59 | 4.61 | 3.08 | 2.47 |
| North | Spencer Gulf | 2020 | Count | 18.77 | 4.62 | 4.65 | 2.81 | 2.18 |
| Peaked Rocks | Spencer Gulf | 2020 | Count | 47.61 | 11.99 | 12.04 | 5.77 | 4.31 |
| South Neptune | Spencer Gulf | 2020 | Count | 5.16 | 2.12 | 2.12 | 1.29 | 1.00 |
| Williams | Spencer Gulf | 2020 | Count | 4.48 | 2.88 | 2.88 | 1.33 | 0.98 |
| Cap | SW Eyre | 2020 | Count | 24.19 | 5.66 | 5.82 | 3.62 | 2.87 |
| Four Hummocks | SW Eyre | 2020 | Count | 6.38 | 1.89 | 1.94 | 1.38 | 1.13 |
| Little Hummock | SW Eyre | 2020 | Count | 4.88 | 1.97 | 1.99 | 1.31 | 1.03 |
| Price | SW Eyre | 2020 | Count | 24.42 | 7.72 | 7.79 | 4.11 | 3.07 |
| Rocky North | SW Eyre | 2020 | Count | 26.98 | 2.59 | 3.07 | 3.08 | 2.57 |
| Rocky South | SW Eyre | 2020 | Count | 8.07 | 2.75 | 2.78 | 1.81 | 1.43 |
| Bunda 00 (B1) | Bunda Cliffs | 2025 | Count | 2.69 | 1.41 | 1.48 | 0.81 | 0.65 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2025 | Count | 1.20 | 0.73 | 0.74 | 0.48 | 0.39 |
| Bunda 04 (B2) | Bunda Cliffs | 2025 | Count | 0.68 | 0.38 | 0.39 | 0.28 | 0.24 |
| Bunda 06 (B3) | Bunda Cliffs | 2025 | Count | 3.17 | 0.83 | 0.90 | 0.61 | 0.52 |
| Bunda 08 (B4) | Bunda Cliffs | 2025 | Count | 0.46 | 0.35 | 0.35 | 0.25 | 0.21 |
| Bunda 09 (B5) | Bunda Cliffs | 2025 | Count | 3.94 | 0.73 | 0.92 | 0.76 | 0.64 |
| Bunda 12 (B6) | Bunda Cliffs | 2025 | Count | 0.81 | 0.31 | 0.32 | 0.25 | 0.22 |
| Bunda 18 (B7) | Bunda Cliffs | 2025 | Count | 1.54 | 0.62 | 0.63 | 0.46 | 0.40 |
| Bunda 19 (B8) | Bunda Cliffs | 2025 | Count | 2.53 | 0.80 | 0.85 | 0.59 | 0.50 |
| Bunda 22 (B9) | Bunda Cliffs | 2025 | Count | 1.77 | 0.75 | 0.78 | 0.53 | 0.44 |
| Jones | Chain of Bays | 2025 | Count | 7.81 | 1.29 | 1.36 | 1.05 | 0.92 |
| Nicolas Baudin | Chain of Bays | 2025 | Count | 41.69 | 6.54 | 6.88 | 4.28 | 3.44 |
| Olive | Chain of Bays | 2025 | Count | 68.42 | 4.18 | 5.59 | 4.33 | 3.57 |
| Pearson | Chain of Bays | 2025 | Count | 15.82 | 2.99 | 3.12 | 2.10 | 1.73 |
| Pt Labatt | Chain of Bays | 2025 | Count | 1.45 | 0.67 | 0.68 | 0.49 | 0.41 |
| Ward | Chain of Bays | 2025 | Count | 26.10 | 4.44 | 4.64 | 2.99 | 2.43 |
| West Waldegrave | Chain of Bays | 2025 | Count | 57.07 | 7.58 | 8.30 | 5.02 | 4.06 |
| Cape Bouguer | Kangaroo Island | 2025 | Count | 8.49 | 4.33 | 4.34 | 1.99 | 1.35 |
| North Casuarina | Kangaroo Island | 2025 | Count | 10.38 | 4.90 | 4.91 | 2.25 | 1.52 |
| Seal Bay | Kangaroo Island | 2025 | CPP | 239.81 | 8.14 | 10.49 | 10.25 | 7.96 |
| Seal Slide | Kangaroo Island | 2025 | Count | 10.05 | 1.63 | 1.65 | 1.35 | 1.12 |
| The Pages | Kangaroo Island | 2025 | Count | 414.74 | 27.59 | 30.07 | 18.77 | 13.85 |
| Blefuscu | Nuyts-Archipelago | 2025 | Count | 42.28 | 5.00 | 5.82 | 3.39 | 2.80 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2025 | Count | 11.81 | 2.70 | 2.85 | 1.81 | 1.50 |
| Fenelon | Nuyts-Archipelago | 2025 | Count | 15.57 | 3.79 | 3.93 | 2.32 | 1.86 |
| Lilliput | Nuyts-Archipelago | 2025 | Count | 29.99 | 2.36 | 3.14 | 2.22 | 1.89 |
| Lounds | Nuyts-Archipelago | 2025 | Count | 14.31 | 3.58 | 3.71 | 2.20 | 1.77 |
| Nuyts Reef | Nuyts-Archipelago | 2025 | Count | 66.43 | 15.35 | 15.72 | 7.01 | 5.37 |
| Purdie | Nuyts-Archipelago | 2025 | Count | 46.77 | 7.23 | 8.08 | 4.31 | 3.47 |
| West | Nuyts-Archipelago | 2025 | Count | 18.20 | 3.56 | 3.82 | 2.32 | 1.91 |
| Albatross | Spencer Gulf | 2025 | Count | 49.92 | 8.49 | 8.61 | 4.98 | 3.85 |
| Curta | Spencer Gulf | 2025 | Count | 5.62 | 3.18 | 3.18 | 1.45 | 1.07 |
| Dangerous Reef | Spencer Gulf | 2025 | Count | 277.69 | 11.77 | 15.92 | 13.34 | 10.76 |
| East | Spencer Gulf | 2025 | Count | 8.12 | 2.71 | 2.73 | 1.62 | 1.25 |
| English | Spencer Gulf | 2025 | Count | 20.91 | 3.10 | 3.19 | 2.33 | 1.93 |
| Lewis | Spencer Gulf | 2025 | Count | 75.31 | 9.25 | 9.48 | 5.99 | 4.76 |
| Liguanea | Spencer Gulf | 2025 | Count | 20.62 | 4.23 | 4.30 | 2.74 | 2.18 |
| North | Spencer Gulf | 2025 | Count | 16.82 | 4.18 | 4.21 | 2.51 | 1.95 |
| Peaked Rocks | Spencer Gulf | 2025 | Count | 42.66 | 10.94 | 11.06 | 5.01 | 3.71 |
| South Neptune | Spencer Gulf | 2025 | Count | 4.63 | 1.91 | 1.92 | 1.15 | 0.89 |
| Williams | Spencer Gulf | 2025 | Count | 4.02 | 2.59 | 2.59 | 1.18 | 0.87 |
| Cap | SW Eyre | 2025 | Count | 18.46 | 4.65 | 4.99 | 2.77 | 2.15 |
| Four Hummocks | SW Eyre | 2025 | Count | 4.87 | 1.52 | 1.61 | 1.07 | 0.86 |
| Little Hummock | SW Eyre | 2025 | Count | 3.72 | 1.54 | 1.59 | 1.00 | 0.79 |
| Price | SW Eyre | 2025 | Count | 18.64 | 6.10 | 6.30 | 3.06 | 2.27 |
| Rocky North | SW Eyre | 2025 | Count | 20.59 | 2.12 | 2.94 | 2.51 | 2.02 |
| Rocky South | SW Eyre | 2025 | Count | 6.16 | 2.17 | 2.26 | 1.38 | 1.08 |
| Bunda 00 (B1) | Bunda Cliffs | 2030 | Count | 2.07 | 1.14 | 1.21 | 0.65 | 0.51 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2030 | Count | 0.92 | 0.57 | 0.58 | 0.37 | 0.30 |
| Bunda 04 (B2) | Bunda Cliffs | 2030 | Count | 0.53 | 0.30 | 0.31 | 0.22 | 0.19 |
| Bunda 06 (B3) | Bunda Cliffs | 2030 | Count | 2.44 | 0.73 | 0.80 | 0.52 | 0.43 |
| Bunda 08 (B4) | Bunda Cliffs | 2030 | Count | 0.35 | 0.27 | 0.28 | 0.19 | 0.16 |
| Bunda 09 (B5) | Bunda Cliffs | 2030 | Count | 3.03 | 0.66 | 0.83 | 0.64 | 0.53 |
| Bunda 12 (B6) | Bunda Cliffs | 2030 | Count | 0.62 | 0.25 | 0.27 | 0.20 | 0.18 |
| Bunda 18 (B7) | Bunda Cliffs | 2030 | Count | 1.18 | 0.50 | 0.51 | 0.37 | 0.31 |
| Bunda 19 (B8) | Bunda Cliffs | 2030 | Count | 1.95 | 0.67 | 0.73 | 0.48 | 0.40 |
| Bunda 22 (B9) | Bunda Cliffs | 2030 | Count | 1.36 | 0.61 | 0.64 | 0.42 | 0.35 |
| Jones | Chain of Bays | 2030 | Count | 6.38 | 1.12 | 1.22 | 0.90 | 0.77 |
| Nicolas Baudin | Chain of Bays | 2030 | Count | 34.06 | 5.70 | 6.21 | 3.65 | 2.89 |
| Olive | Chain of Bays | 2030 | Count | 55.91 | 4.35 | 6.02 | 4.22 | 3.37 |
| Pearson | Chain of Bays | 2030 | Count | 12.92 | 2.63 | 2.80 | 1.81 | 1.47 |
| Pt Labatt | Chain of Bays | 2030 | Count | 1.18 | 0.55 | 0.56 | 0.40 | 0.33 |
| Ward | Chain of Bays | 2030 | Count | 21.32 | 3.84 | 4.14 | 2.54 | 2.03 |
| West Waldegrave | Chain of Bays | 2030 | Count | 46.63 | 6.83 | 7.78 | 4.42 | 3.48 |
| Cape Bouguer | Kangaroo Island | 2030 | Count | 8.29 | 4.24 | 4.25 | 1.94 | 1.31 |
| North Casuarina | Kangaroo Island | 2030 | Count | 10.13 | 4.79 | 4.81 | 2.19 | 1.48 |
| Seal Bay | Kangaroo Island | 2030 | CPP | 234.05 | 9.01 | 13.04 | 11.28 | 8.16 |
| Seal Slide | Kangaroo Island | 2030 | Count | 9.80 | 1.62 | 1.67 | 1.33 | 1.10 |
| The Pages | Kangaroo Island | 2030 | Count | 404.77 | 29.88 | 34.52 | 20.62 | 14.32 |
| Blefuscu | Nuyts-Archipelago | 2030 | Count | 33.63 | 4.73 | 5.72 | 3.01 | 2.40 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2030 | Count | 9.39 | 2.28 | 2.47 | 1.48 | 1.21 |
| Fenelon | Nuyts-Archipelago | 2030 | Count | 12.39 | 3.16 | 3.37 | 1.89 | 1.50 |
| Lilliput | Nuyts-Archipelago | 2030 | Count | 23.86 | 2.42 | 3.30 | 2.03 | 1.65 |
| Lounds | Nuyts-Archipelago | 2030 | Count | 11.38 | 2.98 | 3.17 | 1.79 | 1.42 |
| Nuyts Reef | Nuyts-Archipelago | 2030 | Count | 52.84 | 12.75 | 13.38 | 5.70 | 4.30 |
| Purdie | Nuyts-Archipelago | 2030 | Count | 37.20 | 6.51 | 7.54 | 3.70 | 2.89 |
| West | Nuyts-Archipelago | 2030 | Count | 14.48 | 3.07 | 3.41 | 1.93 | 1.56 |
| Albatross | Spencer Gulf | 2030 | Count | 44.74 | 7.75 | 7.93 | 4.51 | 3.47 |
| Curta | Spencer Gulf | 2030 | Count | 5.04 | 2.86 | 2.87 | 1.30 | 0.96 |
| Dangerous Reef | Spencer Gulf | 2030 | Count | 248.84 | 12.61 | 17.38 | 13.91 | 11.08 |
| East | Spencer Gulf | 2030 | Count | 7.28 | 2.47 | 2.51 | 1.46 | 1.13 |
| English | Spencer Gulf | 2030 | Count | 18.74 | 2.86 | 2.98 | 2.13 | 1.76 |
| Lewis | Spencer Gulf | 2030 | Count | 67.49 | 8.57 | 8.93 | 5.49 | 4.33 |
| Liguanea | Spencer Gulf | 2030 | Count | 18.48 | 3.96 | 4.09 | 2.50 | 1.98 |
| North | Spencer Gulf | 2030 | Count | 15.07 | 3.78 | 3.83 | 2.27 | 1.75 |
| Peaked Rocks | Spencer Gulf | 2030 | Count | 38.23 | 10.09 | 10.31 | 4.49 | 3.33 |
| South Neptune | Spencer Gulf | 2030 | Count | 4.14 | 1.73 | 1.75 | 1.04 | 0.80 |
| Williams | Spencer Gulf | 2030 | Count | 3.60 | 2.33 | 2.34 | 1.06 | 0.78 |
| Cap | SW Eyre | 2030 | Count | 14.09 | 3.90 | 4.38 | 2.23 | 1.72 |
| Four Hummocks | SW Eyre | 2030 | Count | 3.72 | 1.24 | 1.36 | 0.85 | 0.68 |
| Little Hummock | SW Eyre | 2030 | Count | 2.84 | 1.22 | 1.29 | 0.78 | 0.61 |
| Price | SW Eyre | 2030 | Count | 14.23 | 4.91 | 5.23 | 2.38 | 1.77 |
| Rocky North | SW Eyre | 2030 | Count | 15.72 | 2.04 | 2.99 | 2.17 | 1.70 |
| Rocky South | SW Eyre | 2030 | Count | 4.70 | 1.75 | 1.87 | 1.08 | 0.84 |
| Bunda 00 (B1) | Bunda Cliffs | 2035 | Count | 1.59 | 0.93 | 0.99 | 0.52 | 0.40 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2035 | Count | 0.71 | 0.45 | 0.46 | 0.29 | 0.24 |
| Bunda 04 (B2) | Bunda Cliffs | 2035 | Count | 0.40 | 0.24 | 0.25 | 0.18 | 0.15 |
| Bunda 06 (B3) | Bunda Cliffs | 2035 | Count | 1.88 | 0.63 | 0.71 | 0.44 | 0.36 |
| Bunda 08 (B4) | Bunda Cliffs | 2035 | Count | 0.27 | 0.22 | 0.22 | 0.15 | 0.12 |
| Bunda 09 (B5) | Bunda Cliffs | 2035 | Count | 2.33 | 0.59 | 0.75 | 0.54 | 0.44 |
| Bunda 12 (B6) | Bunda Cliffs | 2035 | Count | 0.48 | 0.21 | 0.22 | 0.16 | 0.14 |
| Bunda 18 (B7) | Bunda Cliffs | 2035 | Count | 0.91 | 0.40 | 0.42 | 0.29 | 0.25 |
| Bunda 19 (B8) | Bunda Cliffs | 2035 | Count | 1.50 | 0.57 | 0.62 | 0.40 | 0.33 |
| Bunda 22 (B9) | Bunda Cliffs | 2035 | Count | 1.04 | 0.50 | 0.53 | 0.34 | 0.28 |
| Jones | Chain of Bays | 2035 | Count | 5.22 | 0.99 | 1.11 | 0.78 | 0.66 |
| Nicolas Baudin | Chain of Bays | 2035 | Count | 27.83 | 5.03 | 5.65 | 3.19 | 2.49 |
| Olive | Chain of Bays | 2035 | Count | 45.68 | 4.46 | 6.22 | 4.12 | 3.22 |
| Pearson | Chain of Bays | 2035 | Count | 10.56 | 2.32 | 2.52 | 1.59 | 1.27 |
| Pt Labatt | Chain of Bays | 2035 | Count | 0.97 | 0.46 | 0.47 | 0.33 | 0.27 |
| Ward | Chain of Bays | 2035 | Count | 17.42 | 3.35 | 3.72 | 2.20 | 1.73 |
| West Waldegrave | Chain of Bays | 2035 | Count | 38.10 | 6.20 | 7.28 | 3.99 | 3.08 |
| Cape Bouguer | Kangaroo Island | 2035 | Count | 8.09 | 4.15 | 4.18 | 1.90 | 1.28 |
| North Casuarina | Kangaroo Island | 2035 | Count | 9.88 | 4.70 | 4.73 | 2.15 | 1.45 |
| Seal Bay | Kangaroo Island | 2035 | CPP | 228.43 | 11.07 | 16.57 | 13.00 | 8.93 |
| Seal Slide | Kangaroo Island | 2035 | Count | 9.57 | 1.63 | 1.71 | 1.34 | 1.08 |
| The Pages | Kangaroo Island | 2035 | Count | 395.05 | 33.07 | 40.00 | 23.57 | 15.76 |
| Blefuscu | Nuyts-Archipelago | 2035 | Count | 26.75 | 4.44 | 5.50 | 2.73 | 2.11 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2035 | Count | 7.47 | 1.94 | 2.16 | 1.23 | 0.99 |
| Fenelon | Nuyts-Archipelago | 2035 | Count | 9.85 | 2.67 | 2.91 | 1.56 | 1.22 |
| Lilliput | Nuyts-Archipelago | 2035 | Count | 18.98 | 2.42 | 3.32 | 1.88 | 1.48 |
| Lounds | Nuyts-Archipelago | 2035 | Count | 9.06 | 2.51 | 2.73 | 1.47 | 1.16 |
| Nuyts Reef | Nuyts-Archipelago | 2035 | Count | 42.03 | 10.71 | 11.55 | 4.77 | 3.55 |
| Purdie | Nuyts-Archipelago | 2035 | Count | 29.59 | 5.86 | 6.98 | 3.24 | 2.47 |
| West | Nuyts-Archipelago | 2035 | Count | 11.51 | 2.67 | 3.05 | 1.62 | 1.29 |
| Albatross | Spencer Gulf | 2035 | Count | 40.09 | 7.10 | 7.35 | 4.13 | 3.18 |
| Curta | Spencer Gulf | 2035 | Count | 4.51 | 2.58 | 2.60 | 1.17 | 0.87 |
| Dangerous Reef | Spencer Gulf | 2035 | Count | 222.99 | 13.47 | 18.62 | 14.46 | 11.47 |
| East | Spencer Gulf | 2035 | Count | 6.52 | 2.27 | 2.32 | 1.33 | 1.03 |
| English | Spencer Gulf | 2035 | Count | 16.80 | 2.65 | 2.80 | 1.97 | 1.62 |
| Lewis | Spencer Gulf | 2035 | Count | 60.48 | 7.99 | 8.48 | 5.13 | 4.03 |
| Liguanea | Spencer Gulf | 2035 | Count | 16.56 | 3.75 | 3.94 | 2.34 | 1.84 |
| North | Spencer Gulf | 2035 | Count | 13.50 | 3.43 | 3.50 | 2.06 | 1.59 |
| Peaked Rocks | Spencer Gulf | 2035 | Count | 34.26 | 9.38 | 9.71 | 4.16 | 3.10 |
| South Neptune | Spencer Gulf | 2035 | Count | 3.71 | 1.58 | 1.60 | 0.94 | 0.73 |
| Williams | Spencer Gulf | 2035 | Count | 3.22 | 2.10 | 2.11 | 0.95 | 0.71 |
| Cap | SW Eyre | 2035 | Count | 10.76 | 3.31 | 3.86 | 1.87 | 1.43 |
| Four Hummocks | SW Eyre | 2035 | Count | 2.84 | 1.03 | 1.16 | 0.68 | 0.54 |
| Little Hummock | SW Eyre | 2035 | Count | 2.17 | 0.98 | 1.06 | 0.62 | 0.48 |
| Price | SW Eyre | 2035 | Count | 10.86 | 4.00 | 4.41 | 1.93 | 1.45 |
| Rocky North | SW Eyre | 2035 | Count | 12.00 | 2.00 | 2.95 | 1.93 | 1.50 |
| Rocky South | SW Eyre | 2035 | Count | 3.59 | 1.42 | 1.56 | 0.87 | 0.67 |
| Bunda 00 (B1) | Bunda Cliffs | 2040 | Count | 1.22 | 0.75 | 0.81 | 0.42 | 0.32 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2040 | Count | 0.54 | 0.36 | 0.37 | 0.23 | 0.18 |
| Bunda 04 (B2) | Bunda Cliffs | 2040 | Count | 0.31 | 0.19 | 0.21 | 0.14 | 0.12 |
| Bunda 06 (B3) | Bunda Cliffs | 2040 | Count | 1.44 | 0.55 | 0.61 | 0.37 | 0.30 |
| Bunda 08 (B4) | Bunda Cliffs | 2040 | Count | 0.21 | 0.17 | 0.18 | 0.12 | 0.10 |
| Bunda 09 (B5) | Bunda Cliffs | 2040 | Count | 1.79 | 0.52 | 0.66 | 0.46 | 0.37 |
| Bunda 12 (B6) | Bunda Cliffs | 2040 | Count | 0.37 | 0.17 | 0.19 | 0.13 | 0.11 |
| Bunda 18 (B7) | Bunda Cliffs | 2040 | Count | 0.70 | 0.33 | 0.35 | 0.23 | 0.20 |
| Bunda 19 (B8) | Bunda Cliffs | 2040 | Count | 1.15 | 0.48 | 0.53 | 0.33 | 0.27 |
| Bunda 22 (B9) | Bunda Cliffs | 2040 | Count | 0.80 | 0.41 | 0.44 | 0.27 | 0.22 |
| Jones | Chain of Bays | 2040 | Count | 4.26 | 0.87 | 1.01 | 0.68 | 0.57 |
| Nicolas Baudin | Chain of Bays | 2040 | Count | 22.74 | 4.46 | 5.16 | 2.84 | 2.19 |
| Olive | Chain of Bays | 2040 | Count | 37.32 | 4.46 | 6.20 | 3.97 | 3.07 |
| Pearson | Chain of Bays | 2040 | Count | 8.63 | 2.06 | 2.27 | 1.41 | 1.11 |
| Pt Labatt | Chain of Bays | 2040 | Count | 0.79 | 0.38 | 0.39 | 0.27 | 0.23 |
| Ward | Chain of Bays | 2040 | Count | 14.24 | 2.95 | 3.36 | 1.93 | 1.50 |
| West Waldegrave | Chain of Bays | 2040 | Count | 31.13 | 5.63 | 6.77 | 3.64 | 2.77 |
| Cape Bouguer | Kangaroo Island | 2040 | Count | 7.89 | 4.07 | 4.11 | 1.87 | 1.26 |
| North Casuarina | Kangaroo Island | 2040 | Count | 9.65 | 4.61 | 4.66 | 2.12 | 1.43 |
| Seal Bay | Kangaroo Island | 2040 | CPP | 222.94 | 13.65 | 20.41 | 15.07 | 10.09 |
| Seal Slide | Kangaroo Island | 2040 | Count | 9.34 | 1.65 | 1.78 | 1.35 | 1.08 |
| The Pages | Kangaroo Island | 2040 | Count | 385.55 | 36.78 | 45.94 | 27.11 | 17.82 |
| Blefuscu | Nuyts-Archipelago | 2040 | Count | 21.28 | 4.10 | 5.16 | 2.47 | 1.87 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2040 | Count | 5.94 | 1.66 | 1.90 | 1.03 | 0.82 |
| Fenelon | Nuyts-Archipelago | 2040 | Count | 7.84 | 2.26 | 2.53 | 1.30 | 1.01 |
| Lilliput | Nuyts-Archipelago | 2040 | Count | 15.09 | 2.35 | 3.22 | 1.72 | 1.33 |
| Lounds | Nuyts-Archipelago | 2040 | Count | 7.20 | 2.12 | 2.36 | 1.23 | 0.96 |
| Nuyts Reef | Nuyts-Archipelago | 2040 | Count | 33.43 | 9.08 | 10.05 | 4.08 | 3.00 |
| Purdie | Nuyts-Archipelago | 2040 | Count | 23.54 | 5.26 | 6.38 | 2.87 | 2.15 |
| West | Nuyts-Archipelago | 2040 | Count | 9.16 | 2.32 | 2.72 | 1.38 | 1.08 |
| Albatross | Spencer Gulf | 2040 | Count | 35.93 | 6.53 | 6.85 | 3.83 | 2.95 |
| Curta | Spencer Gulf | 2040 | Count | 4.05 | 2.34 | 2.37 | 1.06 | 0.79 |
| Dangerous Reef | Spencer Gulf | 2040 | Count | 199.83 | 14.19 | 19.53 | 14.88 | 11.81 |
| East | Spencer Gulf | 2040 | Count | 5.85 | 2.09 | 2.16 | 1.23 | 0.95 |
| English | Spencer Gulf | 2040 | Count | 15.05 | 2.46 | 2.64 | 1.84 | 1.50 |
| Lewis | Spencer Gulf | 2040 | Count | 54.19 | 7.49 | 8.10 | 4.85 | 3.81 |
| Liguanea | Spencer Gulf | 2040 | Count | 14.84 | 3.58 | 3.83 | 2.23 | 1.75 |
| North | Spencer Gulf | 2040 | Count | 12.10 | 3.11 | 3.20 | 1.87 | 1.45 |
| Peaked Rocks | Spencer Gulf | 2040 | Count | 30.70 | 8.79 | 9.22 | 3.96 | 2.97 |
| South Neptune | Spencer Gulf | 2040 | Count | 3.33 | 1.44 | 1.47 | 0.86 | 0.66 |
| Williams | Spencer Gulf | 2040 | Count | 2.89 | 1.90 | 1.91 | 0.86 | 0.64 |
| Cap | SW Eyre | 2040 | Count | 8.21 | 2.82 | 3.37 | 1.60 | 1.22 |
| Four Hummocks | SW Eyre | 2040 | Count | 2.17 | 0.85 | 0.99 | 0.56 | 0.44 |
| Little Hummock | SW Eyre | 2040 | Count | 1.66 | 0.79 | 0.87 | 0.49 | 0.38 |
| Price | SW Eyre | 2040 | Count | 8.29 | 3.29 | 3.73 | 1.61 | 1.22 |
| Rocky North | SW Eyre | 2040 | Count | 9.16 | 1.91 | 2.79 | 1.72 | 1.33 |
| Rocky South | SW Eyre | 2040 | Count | 2.74 | 1.16 | 1.31 | 0.70 | 0.55 |
| Bunda 00 (B1) | Bunda Cliffs | 2045 | Count | 0.94 | 0.61 | 0.66 | 0.34 | 0.26 |
| Bunda 02 (B1.1) | Bunda Cliffs | 2045 | Count | 0.42 | 0.28 | 0.30 | 0.18 | 0.15 |
| Bunda 04 (B2) | Bunda Cliffs | 2045 | Count | 0.24 | 0.16 | 0.17 | 0.11 | 0.09 |
| Bunda 06 (B3) | Bunda Cliffs | 2045 | Count | 1.11 | 0.47 | 0.53 | 0.32 | 0.25 |
| Bunda 08 (B4) | Bunda Cliffs | 2045 | Count | 0.16 | 0.13 | 0.14 | 0.09 | 0.08 |
| Bunda 09 (B5) | Bunda Cliffs | 2045 | Count | 1.38 | 0.46 | 0.58 | 0.39 | 0.31 |
| Bunda 12 (B6) | Bunda Cliffs | 2045 | Count | 0.28 | 0.14 | 0.16 | 0.11 | 0.09 |
| Bunda 18 (B7) | Bunda Cliffs | 2045 | Count | 0.54 | 0.27 | 0.29 | 0.19 | 0.16 |
| Bunda 19 (B8) | Bunda Cliffs | 2045 | Count | 0.89 | 0.40 | 0.45 | 0.27 | 0.22 |
| Bunda 22 (B9) | Bunda Cliffs | 2045 | Count | 0.62 | 0.33 | 0.36 | 0.22 | 0.18 |
| Jones | Chain of Bays | 2045 | Count | 3.48 | 0.77 | 0.91 | 0.59 | 0.49 |
| Nicolas Baudin | Chain of Bays | 2045 | Count | 18.58 | 3.96 | 4.69 | 2.54 | 1.94 |
| Olive | Chain of Bays | 2045 | Count | 30.50 | 4.33 | 6.00 | 3.76 | 2.90 |
| Pearson | Chain of Bays | 2045 | Count | 7.05 | 1.82 | 2.04 | 1.25 | 0.98 |
| Pt Labatt | Chain of Bays | 2045 | Count | 0.65 | 0.31 | 0.33 | 0.23 | 0.19 |
| Ward | Chain of Bays | 2045 | Count | 11.63 | 2.60 | 3.03 | 1.71 | 1.32 |
| West Waldegrave | Chain of Bays | 2045 | Count | 25.44 | 5.09 | 6.24 | 3.33 | 2.52 |
| Cape Bouguer | Kangaroo Island | 2045 | Count | 7.70 | 3.99 | 4.05 | 1.85 | 1.25 |
| North Casuarina | Kangaroo Island | 2045 | Count | 9.41 | 4.52 | 4.59 | 2.09 | 1.41 |
| Seal Bay | Kangaroo Island | 2045 | CPP | 217.58 | 16.41 | 24.29 | 17.30 | 11.45 |
| Seal Slide | Kangaroo Island | 2045 | Count | 9.11 | 1.68 | 1.85 | 1.37 | 1.08 |
| The Pages | Kangaroo Island | 2045 | Count | 376.29 | 40.75 | 52.01 | 30.91 | 20.20 |
| Blefuscu | Nuyts-Archipelago | 2045 | Count | 16.92 | 3.74 | 4.75 | 2.23 | 1.67 |
| Breakwater/Gliddon | Nuyts-Archipelago | 2045 | Count | 4.73 | 1.42 | 1.66 | 0.87 | 0.68 |
| Fenelon | Nuyts-Archipelago | 2045 | Count | 6.23 | 1.92 | 2.20 | 1.09 | 0.84 |
| Lilliput | Nuyts-Archipelago | 2045 | Count | 12.01 | 2.22 | 3.03 | 1.57 | 1.20 |
| Lounds | Nuyts-Archipelago | 2045 | Count | 5.73 | 1.80 | 2.05 | 1.03 | 0.79 |
| Nuyts Reef | Nuyts-Archipelago | 2045 | Count | 26.59 | 7.73 | 8.76 | 3.53 | 2.58 |
| Purdie | Nuyts-Archipelago | 2045 | Count | 18.72 | 4.68 | 5.76 | 2.55 | 1.89 |
| West | Nuyts-Archipelago | 2045 | Count | 7.29 | 2.02 | 2.41 | 1.18 | 0.91 |
| Albatross | Spencer Gulf | 2045 | Count | 32.19 | 6.03 | 6.40 | 3.58 | 2.77 |
| Curta | Spencer Gulf | 2045 | Count | 3.62 | 2.12 | 2.16 | 0.97 | 0.72 |
| Dangerous Reef | Spencer Gulf | 2045 | Count | 179.07 | 14.70 | 20.13 | 15.14 | 12.05 |
| East | Spencer Gulf | 2045 | Count | 5.24 | 1.93 | 2.02 | 1.14 | 0.88 |
| English | Spencer Gulf | 2045 | Count | 13.49 | 2.29 | 2.50 | 1.72 | 1.40 |
| Lewis | Spencer Gulf | 2045 | Count | 48.56 | 7.05 | 7.75 | 4.63 | 3.64 |
| Liguanea | Spencer Gulf | 2045 | Count | 13.30 | 3.43 | 3.73 | 2.15 | 1.68 |
| North | Spencer Gulf | 2045 | Count | 10.84 | 2.84 | 2.94 | 1.72 | 1.33 |
| Peaked Rocks | Spencer Gulf | 2045 | Count | 27.51 | 8.27 | 8.80 | 3.84 | 2.91 |
| South Neptune | Spencer Gulf | 2045 | Count | 2.98 | 1.32 | 1.36 | 0.79 | 0.61 |
| Williams | Spencer Gulf | 2045 | Count | 2.59 | 1.72 | 1.74 | 0.79 | 0.58 |
| Cap | SW Eyre | 2045 | Count | 6.27 | 2.39 | 2.92 | 1.37 | 1.06 |
| Four Hummocks | SW Eyre | 2045 | Count | 1.65 | 0.71 | 0.84 | 0.46 | 0.37 |
| Little Hummock | SW Eyre | 2045 | Count | 1.26 | 0.64 | 0.72 | 0.40 | 0.31 |
| Price | SW Eyre | 2045 | Count | 6.33 | 2.71 | 3.16 | 1.36 | 1.04 |
| Rocky North | SW Eyre | 2045 | Count | 6.99 | 1.77 | 2.56 | 1.51 | 1.17 |

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