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Peer-review of the report - Analysis of possible change in ecological character of Roebuck Bay and Eighty Mile Beach Ramsar sites – Version 1

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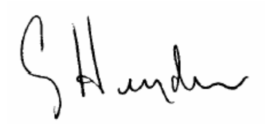

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1. EXECUTIVE SUMMARY

- Here, we review critically a recent document concluding a change in ecological character owing to a decline of shorebirds below the limit of acceptable change at Eighty Mile Beach, a Ramsar site of high significance in the East Asian-Australasian Flyway. The document also concludes that there has been no change in the ecological character of Roebuck Bay, at least in terms of shorebird numbers. Our review covers a review of the suitability of the analysis methods, a judgement on the strength of the results and conclusions drawn, a comment on the limits of acceptable change set in the ecological character descriptions, and a description of any further work required at the two sites.

- We found the analysis methods to be inadequately described, the assumptions of the methods to be untested, the choice of their use not justified, and the extent of the analyses incomplete.

- Despite this, we agree with the main conclusions of the report. Visual inspection of Roebuck Bay data supports no other conclusion than no change, even if analysis methods were substantially revisited. In our view, the Eighty Mile Beach count data support no other conclusion than a decline in ecological character below the limit of acceptable change, most notably because summer counts in several recent years fell below the limits of acceptable change in the 5-60 km stretch for great knot, bar-tailed godwit, terek sandpiper and greater sand plover.

- Limits of acceptable change are inherently hard to set because of natural fluctuations in population abundances. We suggest incorporating proportional rates of decline into the criteria to allow more flexibility in diagnosing declines in shorebird numbers, and also a more statistical approach to determining whether unacceptable changes have occurred.

- Although the case for a change in ecological character for Eighty Mile Beach would be made more scientifically rigorous by incorporating various improvements, such changes will not alter the conclusions, and so we recommend that the focus of future work should be on conservation action and monitoring, given that a change in ecological character has occurred.

2. INTRODUCTION

The purpose of this report is to provide a critical review of Bennelongia (2010) *Analysis of possible change in ecological character of Roebuck Bay and Eighty Mile Beach Ramsar sites*. The primary finding from Bennelongia (2010) is that a change in the ecological character of Eighty Mile Beach has occurred, evidenced by a decline in several species of migratory shorebirds beyond their limit of acceptable change in the northern part of the Bay.

2.1 Consultancy Objectives

The actions listed below were performed to achieve the Consultancy Objectives.

1. Advise on the suitability of the method of analysis used based on the task and the available data;

2. Comment on the strength of the results and conclusions drawn;

3. Form a reasoned judgement of the suitability of the limits of acceptable change set in the Ecological Character Descriptions; and

4. Determine what further analysis/work/data collection may be required to assess whether a change in ecological character has occurred or is occurring at the sites.

We devote a section of our review to each of these objectives, and then provide a series of detailed point-by-point comments on specific issues. We provide a full electronic appendix with PDF documents of all material cited.

3. SUITABILITY OF METHODS

3.1 Analysis Methods are not Specified or Justified

It is difficult to comment on the suitability of the analysis methods applied as they are only scantily outlined in the report. A clear and full description of the analysis methods is unfortunately missing from the draft report and needs to be inserted before the report is finalised. Also, there are two plots labelled figure 14, and figure captions are vague in places, e.g. it is not clear from the captions of many figures whether they refer to summer or winter data. The description of methods should be sufficiently comprehensive to allow the analysis to be repeated by a third party. Section 3.3 of the draft report refers to “correlations”, but the presence of equations in many of the figures suggest that standard linear regression has been the primary analysis method underpinning the results and conclusions, and we proceed with our assessment on this basis.

3.2 Assumptions of the Methods are not Tested

Full description of the methods employed is particularly important because any analysis method makes a number of assumptions about the data, which need to be checked so that use of the method can be justified. The major assumptions of standard linear regression are (i) homoscedasticity (residuals constant for each value of x), (ii) linearity of the relationship between independent and dependent variables (see figure 8 for a case where this might be a problem), (iii) normally distributed residuals, and (iv) independence of residuals, e.g. that successive residuals are not correlated. To deal with this, we suggest including a quantitative assessment of whether the data meet these assumptions to justify the use of linear regression. There are appropriate ways to deal with failure to meet most of these assumptions, either by incorporating additional data into the model, or by choosing another model structure (see section 2.4).

Even small amounts of noise caused by underlying environmental variation (see Larsen *et al*. 2001) will lead to positively correlated residuals and invalidate the use of linear regression. Correlated residuals are commonly a feature of this type of data, and it occurs when environmental conditions in one year are not completely independent of conditions in the previous or next year (Fuller *et al*. 2009). Such effects can be dealt with relatively easily by incorporating the autocorrelation structure of the data into the model.

3.3 Power to Detect Trends is not Reported

With any time series analysis, a conclusion of no change might simply be a consequence of low power to detect a trend, rather than a trend not existing. For example, declines in migratory shorebirds are visually apparent in the data shown in figures 3-5 for total numbers of migratory shorebirds in both bays in summer and winter, and for great knot in summer, but none of these trends was statistically significant. Many of the trends for the northern part of Eighty Mile Beach are downward but again several are not statistically significant (presumably at the $p < 0.05$ level, although this isn't specified in the report). To interpret these results as "no change" requires knowledge of the power of the analysis, and a reasoned method for setting alpha. This said, several of the declines are highly statistically significant, and count data show unequivocally that numbers of some species have dropped below their LAC, and so the argument is to some extent academic (see section 3.1.2).

In Bennelongia (2010), results where a trend is not statistically significant are often reported as showing no trend (see e.g. figure legends for figures 3,4). There is an important difference between these two types of statement, because not finding a trend could be a type II error, i.e. overlooking a trend that is really there either because of low statistical power or setting the burden of proof (alpha) too high. The type II error rate depends on the power of the analysis and the level at which the p value or alpha is set. Power depends most notably on sample size, and alpha should be set to correctly balance type I and type II errors. P=0.05 is conventional, but entirely arbitrary, and we recommend a power analysis that formally determines the appropriate level of alpha, or at least reports actual values of alpha for all the analyses.

It is beyond the scope of our review to work directly on the data, but we suspect that the power to detect trends in these data is rather low, given the relatively small number of years that have been sampled. Some discussion of the relevance of this and how to interpret results in the light of low power is important, given that the aim of the limits of acceptable change process is to detect changes in ecological character *before* they cause irrevocable changes in system ecology (Hale & Butcher 2009). Waiting for 95% confidence that an observed trend is not due to chance may lead to important biological change being overlooked. Setting the criteria for limits of acceptable change might benefit from adjustment in the light of the low power attainable in analyses of much ecological survey data (see section 4).

We include here some general notes on power analysis by way of background. In determining whether the data statistically support the existence of a trend or do not support the existence of a trend, there are two errors that can be made. The first type of error is when there is actually no trend, but we falsely determine that a trend is present. This is known as a Type I error and has probability, α. The second type of error is when there actually is a trend, but we fail to detect it. This is known as a Type II error and has probability, β. The power of a statistical test, which is $1 - \beta$, is the probability that we detect a trend, given that a trend is actually occurring. If power is low then we are unlikely to be able to detect a real trend that is occurring and we might falsely conclude that no change is occurring.

Usually, the level of α is fixed at a low value and specified in the statistical test, often at 0.05, although other values may commonly be more sensible and we urge they are explored in future shorebird monitoring work of this type (for a discussion of these issues see Field *et al*. 2007; Field *et al*. 2004; Mapstone 1995). The power to detect a trend then depends primarily on the size of the trend that needs to be detected, and the variability inherent in the survey data. Power increases with the size of the trend that is required to be detected, and also as the variability in the data declines. Power will also increase over time as more surveys are conducted; in a long term monitoring program, the power to detect trends will always be low to start with and then increase as the number of years surveyed increases (Field *et al*. 2007).

There are a number of methods for estimating the power to detect trends. These range from standard power equations for simple statistical models such as linear regression (Gerrodette 1987) to simulation approaches for more complex statistical models (Field *et al*. 2005; Rhodes *et al*. 2006). The requirements for conducting a power analysis include: (1) defining the minimum trend magnitude that one wants to be able to detect with confidence; and (2) an estimate of the variability in the data that will be collected during the monitoring program. Defining the minimum trend magnitude that one wishes to detect is relatively straightforward and will depend in this case on the position of the limits of acceptable change (see section 4). Obtaining estimates of the variability in the data one will collect prior to collecting that data can be more difficult. However it is usually possible to estimate this variability from existing surveys. Importantly, as data are collected, more information on the variability in the data will be obtained, which will allow subsequent power analysis to be conducted to improve on the estimates of sample size required. The sampling design can then be adjusted accordingly through time in an adaptive fashion (Ringold *et al*. 1996; Ringold *et al*. 1999). We have found with analysis of shorebird monitoring data in Queensland, that multiple surveys within a year can help reduce overall variability (Fuller *et al*. 2009).

3.4 Model Choice has not been Justified

Linear regression is probably the simplest type of model that could be fit to time series data of the type available for Roebuck Bay and Eighty Mile Beach. However, there are a number of considerations that would benefit from expanded discussion in the draft report. Notably in the context of analysing shorebird count data, it assumes that all the deviation from the model fit is due to measurement error, and thus underestimates the uncertainty in a trend and overestimates the degree of significance and power. Variability in survey data arises principally from two sources, namely measurement error and natural environmental variability (process error). Both of these are expected to be high for counts of migratory birds and correctly accounting for the two distinct sources of error might be more appropriate than considering either in isolation. This said, a better estimated, simpler model, even when wrong, may prove more accurate in forecasting population declines than a more complicated model with less precision (Dennis *et al*. 1991; Sabo *et al*. 2004), but an analysis of this issue would be appropriate to ensure the most suitable models are being fitted to the data. Simple models are particularly important where time series are relatively short; more data-hungry methods will often have unacceptably low power.

Fuller *et al*. (2009) found inflated rates of false alarms when using standard linear regression to analyse shorebird count data in Queensland. However, given (i) the context of the Bennelongia (2010) analysis, (ii) the paucity of data, and (iii) the precautionary principle that encompassed the setting of limits of acceptable change for these sites (Bennelongia 2009; Hale & Butcher 2009), we find the use of linear regression models appropriate, providing the relevant assumptions have been met (see section 2.2).

4. STRENGHT OF RESULTS AND CONCLUSIONS

4.1 Overall Conclusions

There are two major planks to the conclusion of the report, which we deal with in turn here.

4.1.1. Roebuck Bay

First, the authors conclude there has been "no decline in use of Roebuck Bay by migratory shorebirds, over the past decade and also over the past 25 years, although this is based principally on data from the northern part of the Bay". Visual inspection of the figures and the results of the presumed linear regressions lead us to agree with this conclusion. The limit of acceptable change is 99,400 waterbirds, or, under the assumption that shorebirds constitute 75% of waterbirds, 74,550 shorebirds. The limit of acceptable change was approached during the 2006 count of shorebirds throughout the whole of Roebuck Bay, which totalled 74,664 individuals, but since then counts have been substantially larger and there is no obvious downward trend apparent in the data shown in table 2, figures 14-21, or figures 26-29. Despite our reservations about the rigour of the statistical analysis (see section 2), we cannot envisage how any improvements, refinements, or even wholesale replacement of the analytical approach would lead to any conclusion other than that shorebirds have not breached the limit of acceptable change in Roebuck Bay.

Our only concern with the Roebuck Bay conclusion is the assumption that 75% of waterbirds are shorebirds. This appears to be based on the difference between the average of the two counts in table 23 of Bennelongia (2009) based on all waterbirds ((170,915 + 154,643)/2 = 162,779)) and the two counts based on shorebirds with or without terns ((144,300 + 146,200 + 96486 + 104306)/4 = 122,823), yielding an estimated percentage of all waterbirds that are shorebirds of 75.45%. This figure is based on a very small sample of highly variable counts and would perhaps be better based on the average proportion of birds counted in the all-waterbird counts that were shorebirds. These data are not available in table 23 of Bennelongia (2009) and in any case should be calculated directly from all available counts of all waterbirds from Roebuck Bay. If this calculation yields a lower estimate of the proportion of waterbirds that are shorebirds, there is potential that the limit of acceptable change has been breached. This is the only threat to the validity of the "no change" conclusion that we can see.

4.1.2. Eighty Mile Beach

The second major conclusion is that “a change in the ecological character of Eighty-mile Beach, as defined by the ecological character description, is occurring as a result of declining numbers of shorebirds using the 0-60 km sector of the Beach during the last decade”. Given that this conclusion raises a serious conservation concern, and will trigger action under legislation, this is clearly the most important part of the report, and so we consider the strength of this result in some depth.

There are four main individual results arising from analysis of the Eighty-mile Beach data, (i) the count data for all shorebirds in table 1 that show a close approach to the limit of acceptable change for all shorebirds (ii) downward trends over the past decade in the 5-40 km stretch are significant at the 1% level for all migratory shorebirds shown in figure 6, (iii) there are similar individual downward trends for great knot, bar-tailed godwit, terek sandpiper, greater sand plover, and red-necked stint, and (iv) summer counts in several recent years fell below the limits of acceptable change in the 5-60 km stretch for great knot, bar-tailed godwit, terek sandpiper and greater sand plover (figures 8-12 and table 1). As an aside, figures in the right hand columns of tables 1 and 2 are referred to as percentages but they are proportions or ratios.

Presentation and analysis of the combined count data for the 5-40 km and 40-60 km sections would have been useful despite the fact that only five years have been counted in the latter (2001, 2004, 2007-2009) because these would align almost exactly with the limits of acceptable change set out in Hale & Butcher (2009). However, it is clear to us from visual inspection of the plots that numbers of several listed species have consistently been below those set out in Hale & Butcher (2009) and we agree that several of the limits of acceptable change have been breached in the reportable section of Eighty-mile Beach, most obviously those for bar-tailed godwit, greater sand plover and terek sandpiper, which show downward trends over a decade and counts consistently below the LAC for the past few years. Bearing in mind that direct analysis of the data are outside the scope of this work, and in spite of our reservations about the rigour of the statistical analysis, we agree with the general conclusion that limits of acceptable change have been breached for Eighty-mile Beach.

The raw count data alone indicate a breach of LAC, even without any statistical analysis. The only possible concern is that in common with any ecological survey, it is unlikely that all individuals are detected during a shorebird count, and it is possible that the true number of birds using the 0-60 km stretch of Eighty Mile Beach is higher than the counted number.

However, these errors are also inherent in the data used to set the LAC in the first place, so the numbers are at least comparable even if underestimated, and it is also possible that numbers are overestimated.

Although we support the conclusion that several LACs have been breached for shorebirds in the northern part of Eighty Mile Beach, the data seem to indicate that these trends are not representative of the Beach as a whole. There are three broad explanations for this. First, declines could be happening in the north of the Bay but not in the south. The relatively stable counts in the southern part of the Bay evident from figures 6-14 seem to support this possibility. A second explanation is that birds have redistributed themselves to the southern portion of the Beach. If this has occurred, one would expect increases there that compensate for declines in the north, an effect which is not apparent in the data. A third possibility is that birds have redistributed themselves outside the Bay. We are not aware of any external data suggesting this is the case, but even if it were, it would still represent a change in ecological character of the site and thus does not alter the validity of the conclusion.

4.1.3. Expected frequency of counts below the LAC

According to Hale & Butcher (2009), the LAC for Eighty Mile Beach is based on the mean of some counts, seemingly those from 2002 to 2008 ± 1 standard deviation. Assuming a normal stationary distribution for the population abundance indeed gives a probability of 1/6 for any count to be below this threshold, as mentioned in Bennelongia (2010) in section 4.4.1. However, something approximating a log-normal population distribution is more common in biological data (a normal distribution for log population size). This means that crossing the threshold is actually less likely than 1/6, but within the same order of magnitude, and so the observation that counts have been below the LAC for several years recently is more significant than a 1/6 expectation would suggest.

5. SUITABILITY OF LIMITS OF ACCEPTABLE CHANGE

There are two distinct issues treated in Bennelongia (2010), first deciding whether there has been a statistically significant decline in numbers of birds and second working out if the numbers of birds present in the Bay in recent years has breached the limits of acceptable change, which are based on numerical thresholds. There is a strong focus in the report on the former type of analysis, but only the latter consideration really has any bearing on the narrow question of whether LAC has been breached and thus the ecological character of a site has changed. As currently framed in the ecological character descriptions, trends are much less important. A decline could be highly statistically significant without resulting in a drop below the LAC and conversely a non-significant change in bird numbers could culminate in one or more counts being below the LAC.

There is much variability inherent in natural population abundances, and it will always be fundamentally challenging to be certain when a particular threshold has been crossed that should trigger conservation action. One of the most widely accepted systems for triggering conservation concern globally has been the IUCN Red List, which operates according to a clear set of quantitative criteria based on a combination of observed or estimated proportional declines and fixed numerical thresholds. A single documentation that reasonably indicates a numerical threshold has been crossed is sufficient to warrant listing (IUCN 2001).

The time period over which limits of acceptable change have to be breached to trigger an alert is unclear to us from the documentation in Bennelongia (2009) or Hale & Butcher (2009), despite the useful discussion of spatial and temporal considerations in those documents. Clearly, setting such limits is a complex issue, and ultimately several arbitrary judgements have to be made. Our main concern though is the simple reliance on a single figure as a numerical threshold. We offer two suggestions in relation to this.

First, examples of limits of acceptable change given in Department of the Environment, Water, Heritage and the Arts (2008) include proportional declines, which are probably more ecologically relevant than a fixed threshold value, and remain valid over a much longer period. A range of conservation-relevant values for proportional declines underpin the process for IUCN Red Listing, augmented with fixed numerical thresholds for very low population sizes (see IUCN 2001 for full details). Crucial to the IUCN process is that a species can qualify for red listing by meeting just one of a whole range of criteria, and such a model might serve the LAC process better than simple numerical thresholds. Given the difficulty of deciding whether to interpret a single count that drops slightly below the LAC as a cause for concern, statistical estimates of proportional declines over longer periods, where suitable data are exist might prove more useful. If statements that incorporate uncertainty can be constructed, these could be particularly useful, e.g. we are 80% confident that there has been a 7% annual decline in shorebirds over 15 years.

Where numerical thresholds are used, we wonder if it might be more sensible to set the criteria for meeting them more statistically rather than based on individual counts to determine whether they have been breached. For example one could fit trends to time series data using any appropriate statistical technique, and quantitatively estimate the predicted number of birds present for the most recent year or group of years, together with associated confidence intervals. This could lead to a clear statement of the form “we are 80% certain that the number of birds using the site has dropped below the limit of acceptable change for three of the last four years”.

6. FURTHER WORK NEEDED

We believe the case for a change in ecological character for Eighty Mile Beach would be made more scientifically rigorous by incorporating the improvements we have suggested above (section 2). However, it is our judgement that such changes will not alter the conclusions presented in Bennelongia (2010), and therefore we recommend that the focus of future work should be on conservation action and monitoring rather than additional work on the question of change in ecological character of the sites.

As Bennelongia (2010) point out, declines in shorebirds in Eighty Mile Beach are most likely to be driven by impacts outside the Bay, and probably outside Australia. Important stopover sites for migratory shorebirds in eastern Asia are diminishing rapidly in both area and quality, as a result of economic development, climate change and human disturbance. Given the speed and scale of loss of habitat, it is almost certain that this is one of the key drivers of population change. For example, construction of a 33 km seawall has reclaimed over 40,000 ha of estuarine habitat at Saemangeum in South Korea (Rogers *et al*. 2006). Analysis of bird numbers at Saemangeum and neighbouring areas before and after construction has correlated the loss of habitat with a loss of approximately 100,000 birds, and mark-recapture work has tied the loss of birds at Saemangeum with losses in North-West Australia (D.I. Rogers pers. comm.). Formal scientific analysis of this issue would seem to be a priority, along with the identification of advocacy activities aimed at arresting future wetland loss throughout the East-Asian-Australasian migratory flyway.

Ongoing monitoring activity in Eighty Mile Beach will be crucial to keep track of shorebird populations using the Ramsar site. The utility of the monitoring will be maximised by careful analysis of the best way to allocate sampling activity to maximise statistical power given the resources available (Field *et al*. 2007).

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