Evaluating the state of knowledge on fishing exclusions around major African Penguin colonies

Christina Hagen[1]*, Astrid Jarre[2,3,4], Lynne Shannon[2,3], Richard B. Sherley[5,6], Antje Steinfurth[7], Robert J.M. Crawford[8], Lize van der Merwe[9], Ross Wanless[1,7], Herman Oosthuizen[8], Lorien Pichegru[7], Kate Robinson[5], Florian Weller[2,3], Alistair McInnes[7], Henning Winker[4,10], Res Altwegg[4,11], Katrin Ludynia[5], Lauren Waller[12], Azwianewi B. Makhado[8]

[1]Seabird Conservation Programme, BirdLife South Africa, PO Box 7119, Rogge Bay, 8012, South Africa
[2]Marine Research (MA-RE) Institute University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[3]Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[4]Centre for Statistics in Ecology, Environment and Conservation, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[5]Animal Demography Unit, Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[6]Environment and Sustainability Institute, University of Exeter, Penryn, Cornwall, TR10 9FE, United Kingdom
[7]Percy FitzPatrick Institute, DST/NRF Centre of Excellence, University of Cape Town, Rondebosch 7701, South Africa
[8]Department of Environmental Affairs, Oceans and Coasts, PO Box 52126, Cape Town 8000, South Africa
[9]Independent Biostatistcian; Extraordinary Professor: Statistics, University of the Western Cape, Cape Town
[10]South African National Biodiversity Institute, Kirstenbosch Research Centre, Private Bag X7, Claremont, Cape Town 7735, South Africa
[11]Department of Statistical Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[12]CapeNature, Scientific Services, 16 Seventeenth Avenue, Voëlklip, Hermanus 7200, South Africa

*Corresponding author: christina.hagen@birdlife.org.za

Executive summary

The primary purpose of this paper is to summarise analyses and to ensure that the best available data and the most appropriate methods are used to determine whether short-term purse-seine fishing closures around islands are beneficial to African Penguin demographics.

A large-scale study was established, with two pairs of islands (Bird and St Croix, Eastern Cape, and Dassen and Robben, Western Cape) used, and within-pair islands alternately closed in a 20 km radius or open to small pelagic purse-seine fishing. A suite of possible penguin response parameters were proposed and discussed at various meetings of the Small Pelagic Scientific Working Group (SWG-PEL) and its subsidiary body, the Island Closures Task Team (ICTT). Those parameters included foraging metrics from tracking studies, and measures of various life-history variables (chick growth, chick condition, breeding success, etc.). The intention was that models would be constructed that analyse the annual patterns in the various penguin parameters in response to islands' open/closed status.

Currently there is some uncertainty around the modelling approach from MARAM (hereafter the MARAM models) which casts some doubt around the reported outcomes from those models. First, the models do not use the best available data. Instead they use unweighted, annual means for many response variables, which in many cases exclude any variance or error estimates. In addition, using single data points for each year has the effect of creating over-parameterised models (because, for example, the degrees of freedom for a string of 14 numbers is only 13), with in many cases too few

degrees of freedom to allow robust estimates of model error parameters. This is unfortunate, because much richer, raw datasets exist and have been available for use, but were not requested by MARAM. Suggestions from penguin biologists to MARAM that these datasets should be considered were routinely ignored. A second significant concern is that the core MARAM models use catch instead of closure as a predictor. Thus these models fail to address the fundamental aim of isolating the closure effect.

An alternative approach is presented, using linear-mixed-effects models, with closure as a categorical variable. This analysis uses the full data set available, accounting for any correlation between parameters by using year (and month and penguin/nest ID where appropriate) as random effects. Most of the traits investigated in this study indicate a positive effect of closures on penguins, (15 positive and 5 negative results, of those 5 are significant; 4 positive and 1 negative). In addition, a separate analysis has indicated a benefit in chick survival of the three years of closure around Robben Island (Sherley et al. submitted). Generally, the results of the study would benefit from more years of closure, especially Dassen Island as it has been closed for only two consecutive years in which data collection was sparse due to logistical difficulties and financial constraints. Data from the latest year of closure (2014) are not yet available. The benefit of island closure has been demonstrated for the East coast by Pichegru et al. (2010, 2012), who report positive impacts of closures around St Croix Island on penguin fitness components.

The Robben Island “pressures model” (Weller et al. 2014) is a process model, incorporating a wide range of potential pressures acting on the penguin population on that island. Simulations of a closure effect also suggest a positive impact of closures, but that the closures need to be in place for longer periods of time to become effective at the population level.

The African Penguin Biodiversity Management Plan (BMP-AP) was gazetted in 2013 (DEA 2013) and aims to halt the decline in African Penguins within two years of implementation. The plan outlines various actions to be taken to improve the conservation status of the African Penguin and it is anticipated that all of these in combination will need to play a part in achieving the aims of the BMP-AP. Scientific results from available analyses thus far, suggest that there is some benefit to penguins of purse-seine fishing closures around islands, even with the limited duration of the study and remaining uncertainty in the process model. This lays the foundation for several candidate strategies to be suggested for further evaluation.

Introduction

African Penguins and management

The African Penguin *Spheniscus demersus* underwent a large decrease in numbers in the past 80 years and now has a Red List status of "Endangered" in terms of criteria of the International Union for the Conservation of Nature (IUCN). The South African population of the species collapsed dramatically during the present century and in 2013 attained its lowest recorded level (Crawford et al. 2014). Whereas in South Africa more than 900,000 pairs may have bred at just one locality in the 1920s (Dassen Island, Crawford et al. 2007), the most recent estimates suggest that the current number of breeding pairs has dropped below 20 000 for all South African colonies combined (DEA unpublished data).

In South Africa's Western Cape, the number breeding decreased from 38 000 pairs in 2004 to 23,500 pairs in 2006. It is thought that this decrease was likely influenced by food scarcity along the West Coast (Crawford et al. 2008), especially following shifts to the south and east in the distributions of the spawner biomass of both anchovy and sardine and in the catches of sardine (Fairweather et al. 2006, van der Lingen et al. 2006, Roy et al. 2007, Coetzee et al. 2008). Therefore, in 2006 the Small Pelagic Scientific Working Group (SWG–PEL) of the present Department of Agriculture, Forestry and Fisheries (DAFF) was requested to incorporate spatial considerations in management of South Africa's purse-seine fisheries for anchovy and sardine to reduce competition between the penguins and fisheries for food, including precautionary closures around penguin colonies.

In 2013, the South African government adopted an African Penguin Biodiversity Management Plan (AP-BMP), in terms of its National Environmental Management: Biodiversity Act (No. 10 of 2004) (DEA 2013). The aim of the AP-BMP is "to halt the decline of the African Penguin population in South Africa within two years of the implementation of the management plan and thereafter achieve a population growth which will result in a down listing of the species in terms of its status in the IUCN Red List of Threatened Species". Various actions to improve the conservation status of the African Penguin are listed in the plan, and it is hoped that by acting in concert they may achieve the aim of the plan.

Island Closures Task Team

A combined meeting of the SWG-PEL and the SWG-EAF in January 2010 recommended that two task teams be formed (MCM 2010). The first task team was asked "to investigate further island closures or modifications to the island closure programme" and report to the SWG-PEL (Chair: J Coetzee, MCM). It was to become the ICTT (Island Closure Task Team), whose deliberations formed the basis for the roster of island closures (DAFF 2010) under review at present. It is here important to recall

that MCM (Marine and Coastal Management) was split in April 2010 into DAFF: Fisheries and DEA: Oceans & Coasts, with the former mandated with fisheries management, and the latter with conservation management. This task team generated the data used in Robinson (2013). Although reporting to the SWG-PEL (now under DAFF), the ICTT was chaired by H. Oosthuizen (DEA) from 2011.

The second task team was asked "to investigate measures relating to penguin conservation that are not related to forage fish abundance, such as seal predation, heat stress, new colony creation and a penguin recovery plan" (MCM 2010). This task team was asked to report to the SWG-EAF (then Chair: R. Crawford, MCM), and was to become the Penguin Pressures Model Task Group (Chair: L. Shannon, UCT). Acknowledging that penguin population dynamics could not be modelled without the inclusion of food, this group proceeded to generate the Penguin Pressures Model for Robben Island (DAFF 2011, Weller et al. 2014).

The difference in the outcome in the two modelling approaches pursued was discussed in the ICTT from February to April 2014, but the discussions failed to reach a constructive resolution. The diverging argument is outlined in Cherry (2014) and forms one basis for the terms of reference for the International Stock Assessment Review Panel meeting in December 2014 (DAFF 2014).

Unresolved discussions in the ICTT are not a novelty. As part of the feasibility study aiming to inform on possible future experimental island closures, in 2008 and 2009, a radius of 20 km around Dassen Island was closed to purse-seine fishing and an area of the same radius around Robben Island was open to purse-seine fishing. In the Eastern Cape, St Croix Island was closed to fisheries in 2009 while nearby Bird Island was open. As not enough data had been collected by the end of 2009 to make any decisions about whether to begin an experiment or not, in 2010, existing closure status was maintained in the Eastern Cape but both Robben and Dassen islands were open to fishing while decisions were made regarding the future of the feasibility study. Two positions were put forward: Butterworth (2010) advocated alternating closures on a short time scale (every year) while others (Pichegru et al. 2010, Crawford 2010, Wanless and Moseley 2010 and Altwegg 2010) supported longer term closures (at least 5 years). For resolution, these arguments were presented to the International Stock Assessment Review Panel in 2010, who recommended using a compromise between the two positions, which was subsequently implemented (Parma et al. 2010, DAFF 2010). It is along these lines that the International Stock Assessment Review Panel meeting in December 2014 is hoped to fulfil a similar role.

Current status of analyses

The MARAM group has analysed the data from the island closures thus far and presented GLMs (Robinson 2013) and a power analysis (Robinson and Butterworth 2014). The methods and interpretations of the results of these analyses are examined in Annex 1. The models use annual unweighted mean values for penguin response variables for which more data are available, and results in the models being over-parameterised. Another concern is the use of pelagic catches as a predictor, instead of closure status. However, a positive correlation between catch and biomass at the macro level confirms that causality is from biomass to catch at this resolution, and it is likely also to be the case at the local level. When an island is closed, the normal positive relationship between prey biomass and catch breaks down, since in this situation catch can and is reduced without an associated reduction in prey biomass. Therefore the behaviour of the closed system cannot be predicted by studying the relationship between prey biomass, catch and penguin response under normal fishing conditions, and setting catches to zero in prediction equations to estimate the closed island situation for penguins. Under circumstances of unresolved controversy of this nature, it is safest to exclude catch from the GLMs and use closure status and prey biomass as the relevant predictors.

Robinson (2013) interprets observed positive relationships between catch and some penguin fitness components to mean that fishing in the 20 km closure does not affect penguins and in some cases may even have a positive effect. The mechanism suggested is that fishing breaks up shoals of fish, making it easier for penguins and other predators to catch them. However, there is no observational or past evidence that catch benefits penguins; rather the converse has applied with regard to catch and many studies have indicated a positive relationship between estimates or proxies of forage fish biomass and numbers of African Penguins breeding and their demographic parameters. Studies conducted elsewhere have demonstrated both the importance of sufficient availability of prey to sustain seabird processes at colonies and a negative impact of local depletion of prey by fishing on foraging parameters of seabirds that compete with fisheries for anchovy. Therefore, it is not defensible at present to expect fishing to benefit penguins.

Linear-mixed-effect models were used to analyse the effect of alternating closures in the Western Cape around Dassen and Robben islands, and in the Eastern Cape around Bird and St. Croix islands, on the response variables (traits): (1) chick condition, (2) chick growth, and the foraging related responses: (3) trip duration (h), (4) foraging path length (km) and (5) maximum foraging distance from the colony (km). For details on methodology, see Annex 2.

For the West Coast, no foraging traits differed significantly between ‘Open’ and ‘Closed’ years, but the trend was for lower effort for penguins breeding on Robben Island during ‘Closed’ years with a

discernible decrease in all three traits (foraging trip duration (h), foraging path length (km), and max distance to colony (km)). However, on Dassen Island during 'Closed' years, birds were foraging closer to the island but stayed at sea for longer periods of time and travelled longer overall distances.

This trend was mirrored in the chick condition which was higher in 'Closed' years at Robben Island than during 'Open' years (0.14 ± 0.03; t_{8003} = 4.91; $p < 0.001$) but did not differ significantly between 'Closed' and 'Open' years at Dassen Island. The effect size at Robben Island was 59% of the mean for 'Open' years and the effect of the closure was sufficient to produce condition indices for 2012 and 2013 that approached the reference level from Robben Island in 2004. The effect was also significant despite 2011 having the poorest condition so far measured for a West Coast colony. This was likely driven by the fact that birds breeding at Robben Island fed on < 38% sardine and anchovy that year (Crawford et al. 2012). This is the lowest percentage on record since diet sampling began in 1989 (Crawford et al. 2011). Thus, the closure benefited chick condition at Robben Island despite one year having unusually poor prey availability. At the same time chick growth rates did not differ significantly between 'Closed' and 'Open' years at either Dassen Island or Robben Island. In both cases, however, the trend showed faster growth during 'Closed' than 'Open' years.

On the East Coast, foraging effort for penguins breeding at Bird and St. Croix islands was consistently lower in 'Closed' years than during 'Open' years with a discernible decrease in all three traits (see above). The effect of closure was significant on foraging trip duration for penguins breeding on Bird Island (-0.44 ± 0.17; t_{415}= -2.56; p = 0.011) and for foraging path length for penguins breeding on St Croix Island ((-0.31 ± 0.14; t_{411}= -2.28; p = 0.023), with birds spending less time at sea (on Bird Island) and performing shorter trips (on St. Croix Island) during the closed years.

In addition, chick condition was better in 'Closed' years at Bird Island than during 'Open' years (0.11 ± 0.04; t_{2421} = 2.50; p = 0.013). However at St. Croix, condition was better during 'Open' years than 'Closed' years (p = 0.047). The latter was marginally significant. Thus, the closure benefitted chick condition at Bird Island, but not at St. Croix Island. Growth rates did not differ significantly between 'Closed' and 'Open' years at either Bird Island or St. Croix Island and the trends were the same as for chick condition.

An overall positive effect of closures on the foraging behaviour and chick condition of African Penguins (15 positive and 5 negative results, of those 5 are significant; 4 positive and 1 negative) has been shown in this study. This supports published evidence of benefits from fishing closures to penguin foraging behaviour (Pichegru et al. 2010, 2012) and a separate study showing a benefit of closure on chick survival at Robben Island (Sherley et al. submitted).

Weller et al. (2014) developed a systems dynamic (process-based) model of the pressures acting on African Penguin demographics, and parameterised this for Robben Island. This model is strategic and not intended for prediction purposes. The model showed a weak benefit to the penguin colony of short-term (three-year) closure to purse-seining around Robben Island, which would be strengthened with longer and more continuous periods of closure. The approach highlighted the importance of managing the combined negative pressures acting on the population, including oiling. The model was parameterised based on the best available biological estimates for the locality (Annex 3) and is being adapted for application to the Dyer Island African Penguin colony, for which sparser data are available. In light of analyses currently underway and which are suggesting existence of an asymptotic relationship between food availability and penguin survival (R. Sherley pers. comm.), the model will be refined accordingly once the relationship has been finalized.

Further work

The alternating closures around the four islands have given penguin biologists a unique opportunity to study the causal link between fishing in the vicinity of islands and penguin fitness components. These fitness components are linked and together determine population growth (Figure 1 in Annex 2). Research is currently underway that aims to address remaining gaps. These will be filled in the coming years and will substantially improve our understanding of how these components are linked, and thus will help to provide a holistic view on the African Penguin's current precarious population status.

Another component of this work is the small scale pelagic fish abundance surveys around the islands. As shown in Figure 1 of Annex 2, the link between closure and local fish biomass is key to understanding the impacts of closures on African Penguins. On the West Coast, these small scale surveys were conducted by the DAFF and on the East Coast by Dr Lorien Pichegru and Alistair McInnes (University of Cape Town). Due to weather and logistical constraints, surveys on the west coast have been limited in frequency during the penguin breeding season. Nevertheless penguin tracking was achieved in conjunction with several of the small scale surveys. The small scale surveys show high variability in pelagic fish biomass, such that variability and the gaps between surveys would only allow for imprecise biomass estimates. Survey effort was not equal over the years of interest, for example in 2013 only one small scale survey was conducted around Robben Island. For these reasons the small scale data were not included in the analyses in Annex 2. The surveys on the East Coast were performed more regularly (once per month during the penguin breeding season) and often in conjunction with the tracking of breeding African Penguins. These data are currently being analysed as part of two PhD theses and show promise for use in linking the finer scale

movements of penguins to local fish abundance (A. McInnes and K. Robinson pers. comm.) Efforts should be made to continue conducting these surveys on both coasts, at a frequency which will allow insights into finer scale changes in fish abundance and thereby elucidate the links between fishing, available biomass and penguin parameters. If necessary, additional resources should be sought to do this.

Thus far there have been no economic studies on the impact of island closures to the purse-seine fishing industry, whereas there has been a study showing the economic benefit of ecotourism from penguins at Boulders Beach (Lewis et al. 2012).

Conclusion

The presented analyses show that in general, the direction of the relationship between closures and penguin parameters is positive, even though not significant in all responses measured. It is important to note however, that many other measures to improve African Penguin conservation are being implemented or explored. These include the continuous rescue and rehabilitation of oiled penguins, breeding habitat restoration that includes deployment of artificial nests, predator control, the rescue and rearing of abandoned eggs and chicks, and the potential establishment of a new colony closer to present supplies of food. To improve management advice on the state of the small pelagic fisheries resources, efforts are being made to implement a two-stock sardine fishery management approach, which has the potential to benefit the sardine stock and West Coast ecosystem as a whole, including the penguins. The island closures show promise as an important contribution to these efforts to improve the conservation status of the Endangered African Penguin. With the current rapid decline of the African Penguin population (in South Africa and globally), which has fragmented the population and made it increasingly sensitive to localised threats (e.g. Crawford et al. 2008, Ryan et al. 2012, Ludynia et al. 2014, Pichegru and Parsons 2014), there is urgent need to put in place all actions that are likely to have a positive effect on this species, in order to halt and reverse the decline as the BMP-AP requires. The four islands considered in this study are key colonies to protect as they collectively hold ~14 600 breeding pairs, i.e. 75% of the South African Penguin population (DEA, unpublished data).

In this context and in the absence of consensus or converging results showing that island closure is *not* beneficial to penguins, a precautionary approach to managing fishing around these islands is justified. However, without alternation of closures, simultaneous closures of all islands may not provide sufficient variability to show significant results, as there would be no reference point for general ecosystem conditions. In line with an Ecosystem Approach to Fisheries, there are three dimensions that need to be evaluated: the ecological dimension (maximum protection to penguins),

the human dimension (potential social and economic impacts), and the dimension of ability to achieve (which includes minimizing existing scientific uncertainty). An in-depth discussion is required regarding the trade-offs between these three dimensions namely (a) contributing to the conservation aims of the BMP-AP, (b) the scientific objective of generating statistically significant results and (c) potential social and economic impacts of closures. In the light of the above, a few strategies should be considered:

- Permanent precautionary closure of all four islands simultaneously (maximising conservation benefit to penguins);
- Continuing three year alternations of closure between island pairs in order to improve the sample size for detection of any significant effects (maximising scientific knowledge gain);
- Consecutive years of experimental closure (5 years) of all four islands, using each island as its own baseline (compromise).

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