The Penguin Pressure Model

Below is a compilation of a presentation to the Small Pelagic Scientific Working Group on the 17th May 2011 and a document (FISHERIES/2011/SWG-PEL/30) tabled at that meeting.

ABBREVIATED from the report to the EAF SWG to serve as background information to Pel SWG -- Report from the Penguin Pressures Model Task Group of the Ecosystem Approach to Fisheries Scientific Working Group on progress being made on the "penguin pressures model"

November 2010

In April 2010, the Penguin Pressures Model Group was constituted, tasked with development of a system model of the various pressures acting on African penguins. This was in response to the decision taken at the joint meeting of the Pelagic and EAF SWGs on 13 January 2010 (2010-EAF01, Appendix 1) that fishery-penguin interactions will be dealt with primarily via the Pelagic SWG, whereas management advice relating to other detrimental factors acting to reduce the African penguin population off South Africa would be channelled through the EAF SWG. The Penguin Pressures Model Group operates as a Task Group under the EAF SWG. Its members are listed in Appendix 2.

The Penguin Pressures Model Group held several working sessions scoping the model aims, components and structure. The objective of the Penguin Pressures Model is to evaluate the likely performance of management strategies on penguin population dynamics, in view of the full suite of pressures acting on penguins, as a basis for recommending a suite of management measures for stabilisation and recovery of penguins in South Africa.

In terms of structure, the Penguin Pressures Model is a stochastic, stage-specific, spatially explicit population simulation model. Stages include eggs, chicks, immatures and adults. Interaction with food is modelled in two zones, one closely around a colony/island representing the foraging range of breeding penguins, the other corresponding to the region in which the penguins would forage to fatten up before and after moulting. The model runs in monthly time steps. It is explicitly designed to stay in line with current biological understanding of processes (even if qualitative or semi-quantitative). The general model framework includes all possible pressures, but for any specific colony/island, specific pressures can be switched off if penguin experts consider them not to be relevant. The monthly time-step allows the modelling of pressures less/more strongly depending on season. In terms of food availability, a scenarios approach is being used, which elucidates known relationships between food availability and specific population parameters, e.g. survival rates and breeding proportions.

The first prototype of the model has been implemented for Robben Island (see below). Expansion to the other six sites (Dassen Island, Dyer Island, Bird Island, St Croix Island, Stony Point (Betty's Bay), Boulders (Simon's Town)) is planned for the future. In May, Lee-Anne Rowbotham (co-supervised by Dr Leanne Scott and Prof Theo Stewart of the Statistical Sciences Department and Prof Astrid Jarre from MA-RE at UCT) took on development of the model as part of her Masters project in decision support. Penguin experts proposed the most appropriate data and relationships or use in the model and, by correspondence and through a series of meetings of the Penguin Pressures Model Group, advised on the biological processes underlying how each pressure affects which part(s) of the penguin life cycle. FISHERIES/2011/SWG_Pel/30 - 2 -

On 3 November 2010, Lee-Anne Rowbotham presented the first prototype of her “penguin pressures model” (Appendices 3,4). It was re-emphasised that this model is being developed with the aim of providing insights in a different paradigm (systems modelling) to that in which traditional stock assessment models are developed and that as such, it should be viewed and treated as complementary to the ongoing model development under the auspices of the Pelagic Scientific Working Group at DAFF. The model structure and aims received strong support from the various stakeholders present and much helpful advice was received in terms of finalizing the fish and fishing aspects of the model. The latter component of the model will be completed in the coming weeks and workshopped further with Janet Coetzee, Carl van der Lingen, Lauren Waller and Richard Sherley.

Appendix 1

Ecosystem Approach to Fisheries and Pelagic Scientific Working Group (EAF SWG & PEL SWG): Aide Memoire of the joint meeting on 13 January 2010, 2010-EAF01. Unpublished document of Marine and Coastal Management (now DAFF and DEA: Oceans and Coasts). 2pp.

Extract:

"Recommendations

A Task Team comprised of members of the pelagic SWG, industry and invited experts be formed to investigate further island closures or modifications to the island closure programme. This should commence immediately so that a considered recommendation may be included in advice to the Minister for 2011 fishing for sardine and anchovy, which is finalized at the end of 2010. The Task Team will consider penguin foraging tracks and industry fishing patterns. Furthermore, it is essential to establish a framework that will enable evaluation of the success/failure of island closures in preventing further declines in penguin numbers within a reasonable time frame.

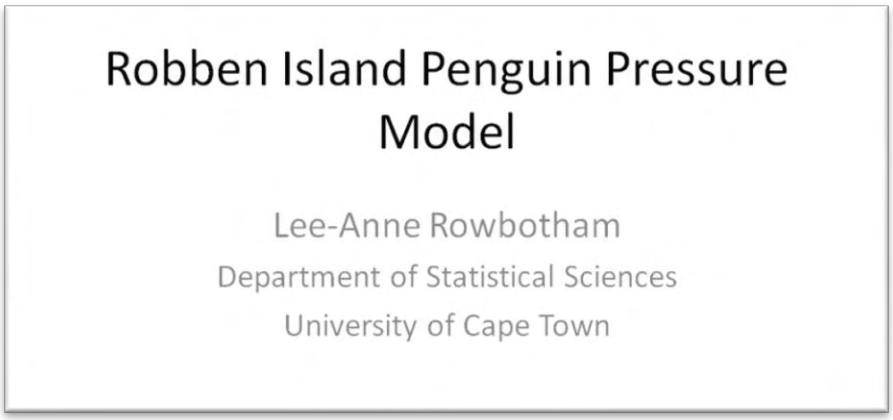
A second Task Team comprised of members of the EAF SWG and invited experts investigate measures relating to penguin conservation that are not related to forage fish abundance, such as seal predation, heat stress, new colony creation and a penguin recovery plan.

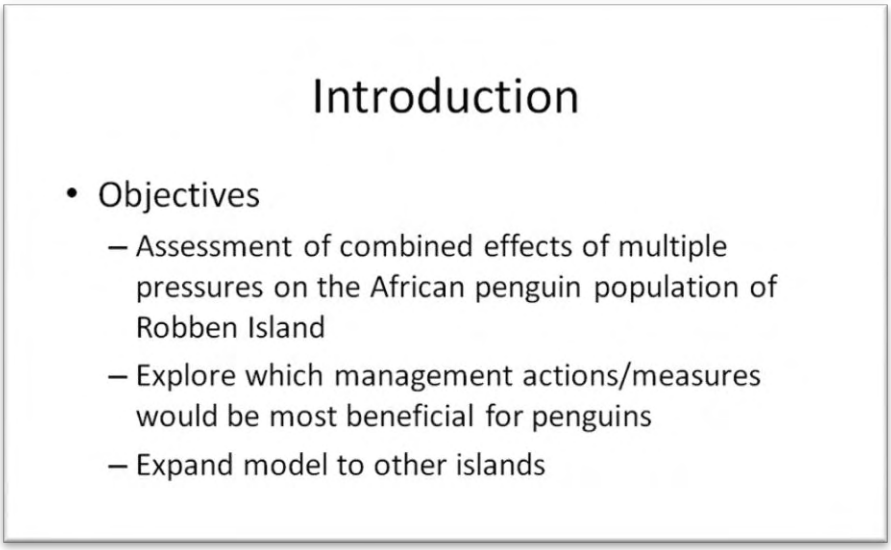
The EAF SWG oversee the work of the two Task Teams." FISHERIES/2011/SWG_Pel/30 - 4 -

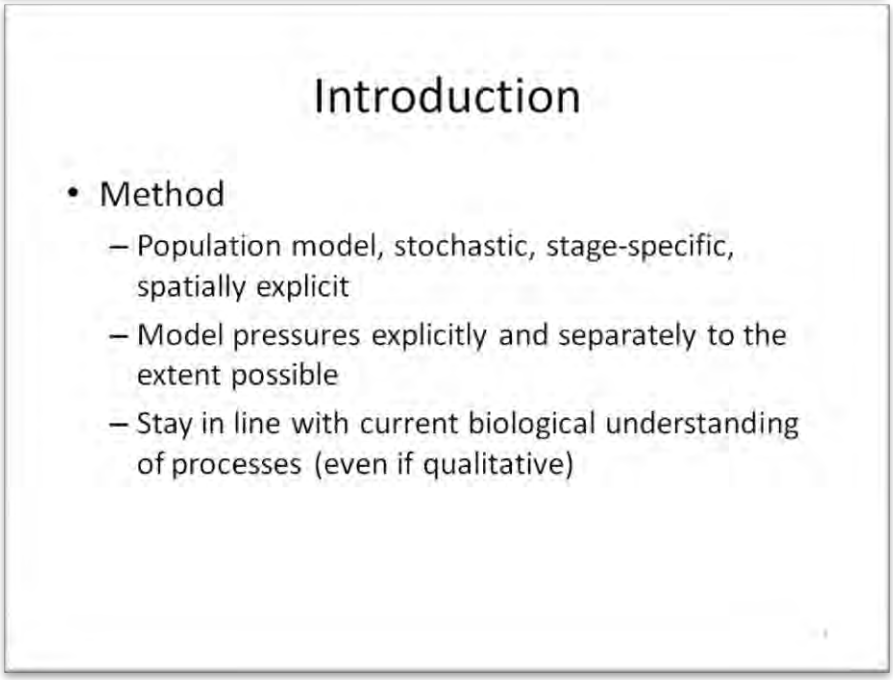
Appendix 2:

Composition of Penguin Pressure Model Task Group
Res Altwegg (SANBI)
Rob Crawford (DEA)
Fitsum Gebreselassie (SANBI)
Edward Hill (MA-Re Institute & Zoology Department, UCT)
Astrid Jarre (MA-RE Institute & Zoology Department, UCT)
Katta Ludynia (ADU, UCT)
Azikanewi Makhado (DEA)
Herman Oosthuizen (DEA)
Lorien Pichegru (Percy FitzPatrick Institute, UCT)
Lee-Anne Rowbotham (Department of Statistical Sciences, UCT)
Leanne Scott (Department of Statistical Sciences, UCT)
Lynne Shannon (MA-RE Institute & Zoology Department, UCT; Chair)
Richard Sherley (ADU, UCT)
Les Underhill (ADU, UCT)
Lauren Waller (Cape Nature)
Ross Wanless (BirdLife) FISHERIES/2011/SWG_Pel/30 - 5 -

Appendix 3:
Presentation of the Penguin Pressures Model (work in progress) by Lee-Anne Rowbotham on 3 November 2010.







System dynamics

- Used to further understanding of a system
- Focus on long term potential for structural change, not short term prediction
- Chosen as it bridges the gap between quantitative and qualitative modelling
- Involves people of all backgrounds
- Does not ignore impact of relationships for which there is little or no quantitative data
- Not for detailed prediction – understand system behaviour

Omitting structures or variables known to be important because numerical data are unavailable is actually less scientific and less accurate than using your best judgment to estimate their values.

''To omit such variables is equivalent to saying they have zero effect—probably the only value that is known to be wrong!''- Forrester (1961)

– John Sterman in his Jay Wright Forrester Prize lecture, 2002

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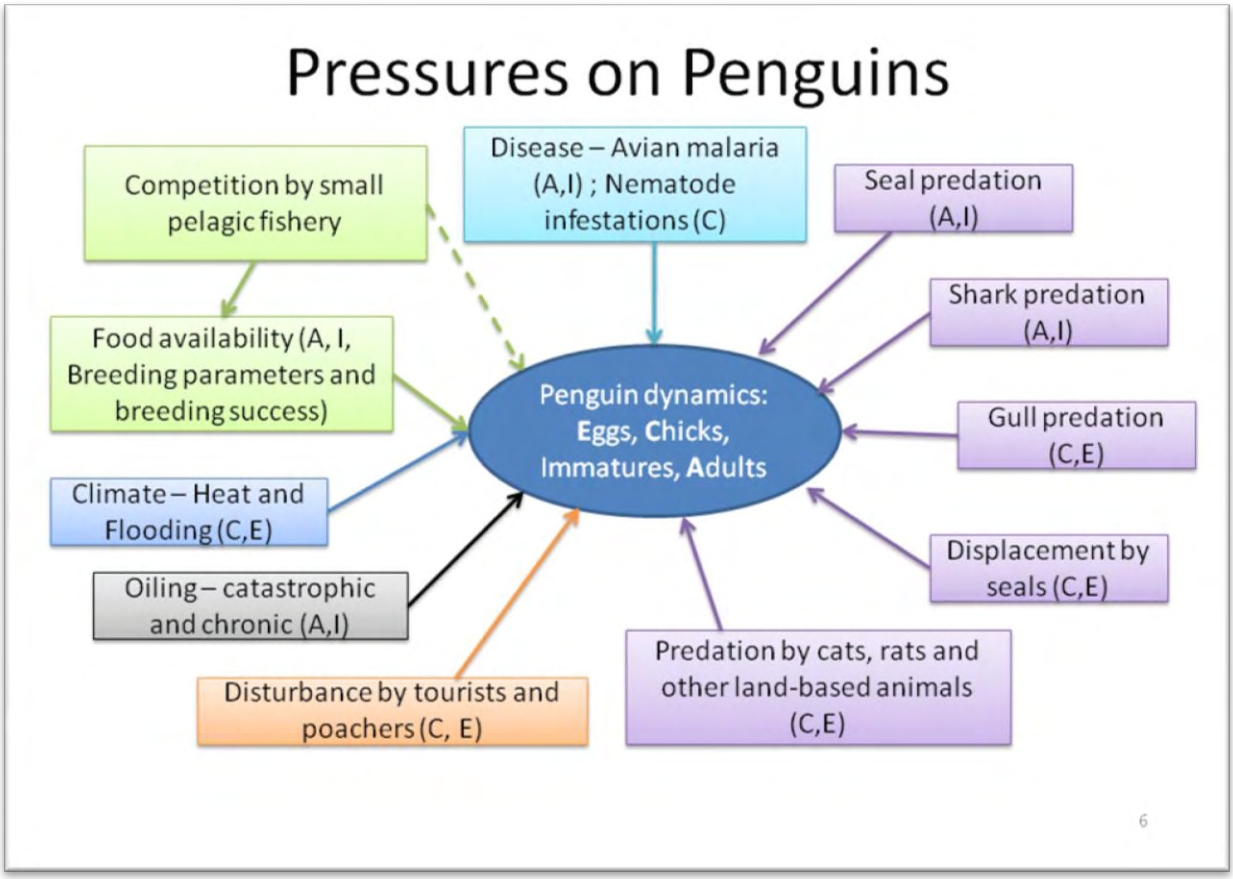
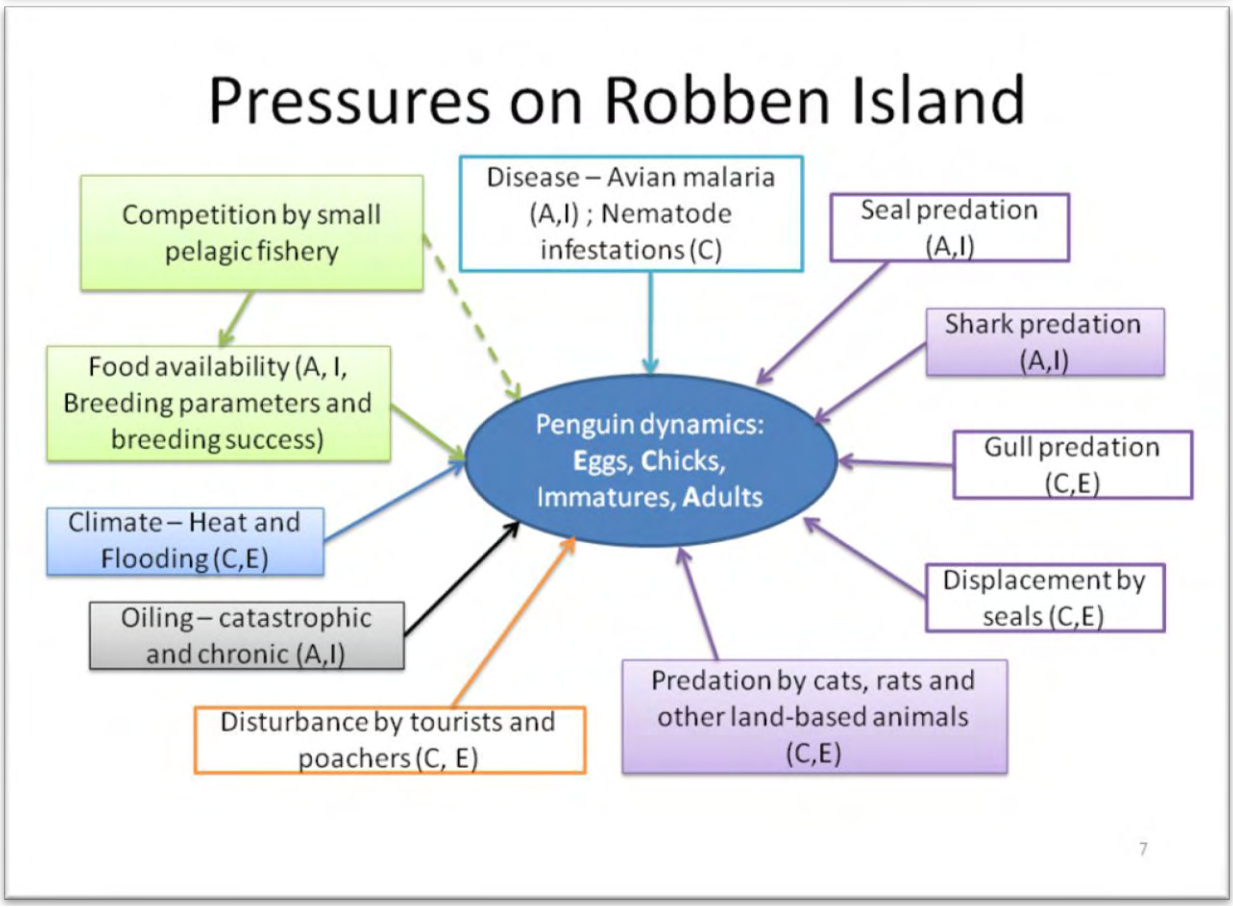

Pressures on Penguins
Competition by small pelagic fishery
Disease – Avian malaria (A,I) ; Nematode infestations (C)
Seal predation (A,I)
Shark predation (A,I)
Food availability (A, I, Breeding parameters and breeding success)
Penguin dynamics: Eggs, Chicks, Immatures, Adults
Gull predation (C,E)
Climate – Heat and Flooding (C,E)
Displacement by seals (C,E)
Oiling – catastrophic and chronic (A,I)
Predation by cats, rats and other land-based animals (C,E)
Disturbance by tourists and poachers (C, E)
6


Pressures on Robben Island
Competition by small pelagic fishery
Disease – Avian malaria (A,I) ; Nematode infestations (C)
Seal predation (A,I)
Shark predation (A,I)
Food availability (A, I, Breeding parameters and breeding success)
Penguin dynamics: Eggs, Chicks, Immatures, Adults
Gull predation (C,E)
Climate – Heat and Flooding (C,E)
Displacement by seals (C,E)
Oiling – catastrophic and chronic (A,I)
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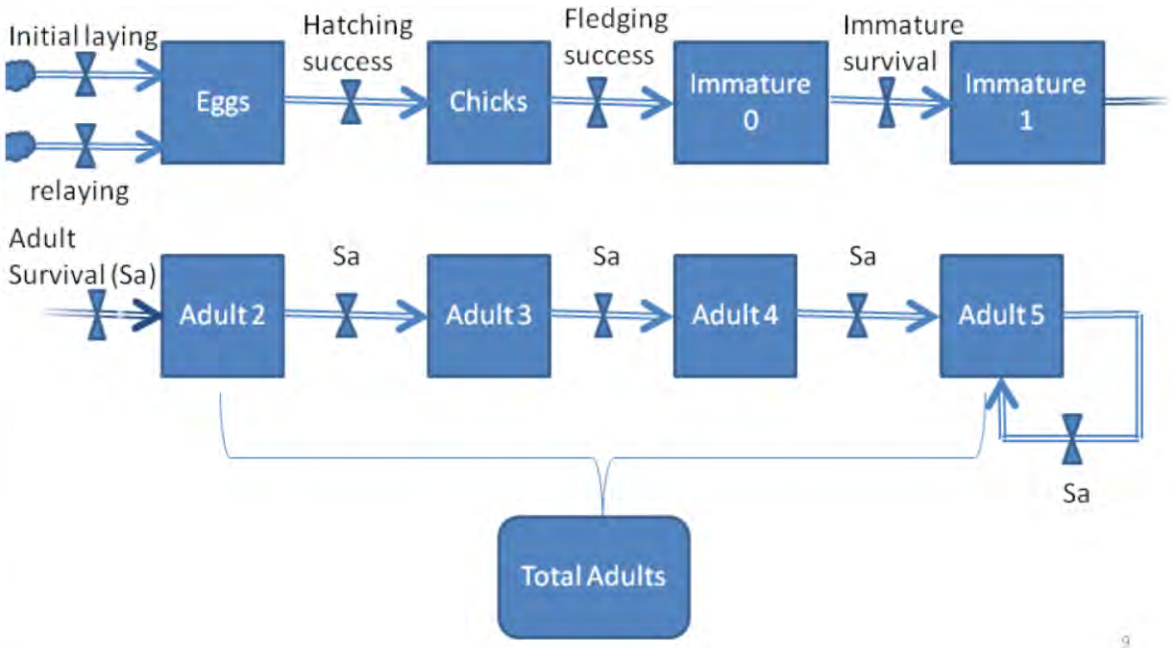
Disturbance by tourists and poachers (C, E)
7

Model Structure

Population Dynamics



Assumptions

- Immature penguins are counted as age 1 on the 1st of January the year after they fledge.
- Each age class experiences monthly mortality
- At the end of each year, surviving penguins move to the next age class or stay in the last age class.
- Eggs take 1 month to hatch
- Chicks take 3 months to fledge

Assumptions

- Immature 0 survival rate is lower than adult survival rate
- Immature 1 survival rate is the same as adult survival rate
- Initial penguins in adult age classes and immature 1 are set so that population is in equilibrium
- Eggs, chicks and immature 0 are set to zero

Breeding assumptions

- Only adult penguins are able to breed
- The proportion of penguins able to breed in each age class is different
- Represents age at first breeding
- Indication of potential to breed

Age class:	Adult 2	Adult 3	Adult 4	Adult 5
Mean	0.05	0.33	0.74	1.00
Range	0.00 – 0.10	0.30 – 0.36	0.675 – 0.805	0.00

Breeding assumptions

- Breeding proportion indicates proportion of pairs that actually breed
- Between 0.7 and 1
- Set annually
- Dependent on food

- Average clutch size is also dependent on food

Breeding assumptions

- Pairs lay initial clutches from February to August according to the table below:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.23	0.23	0.23	0.09	0.09	0.09	0.04	0	0	0	0

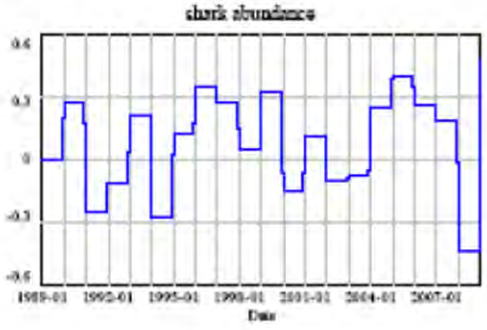
- Pairs may lay a second clutch if the first clutch or brood is lost or if the brood is successfully fledged

Survival rates

- Survival rates for all classes are based on a logit function
- Logit(survival) = base survival + effect of pressure on survival*value of pressure
- Survival = $\frac{1}{1+exp(-logit)}$
- Ensures survival remains between 0 and 1

Predator abundance

- Predator abundance varies annually
- The mean value is set to zero with minimum and maximum values of -1 and 1



Oiling

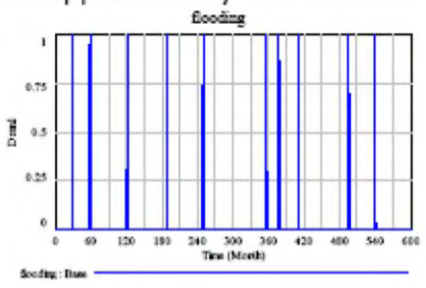
- Oiling is split into catastrophic and chronic oiling
- Catastrophic oil spills occur on average every 50 years and affect approximately half of adults and immature penguins
- Eggs and chicks are also affected as oiling removes parents
- Chronic oil spills occur on average every 2 years but have a smaller impact

Weather events

- Flooding affect chicks and eggs
- A flood will kill a proportion of chicks and eggs
- Both excessive heat and extreme cold are factors
- Excessive heat has a larger effect on hatching and fledging success than extreme cold

Flooding

- Flooding affect chicks and eggs
- It occurs on average every 5 years
- A flood will kill approximately 40% of chicks and eggs



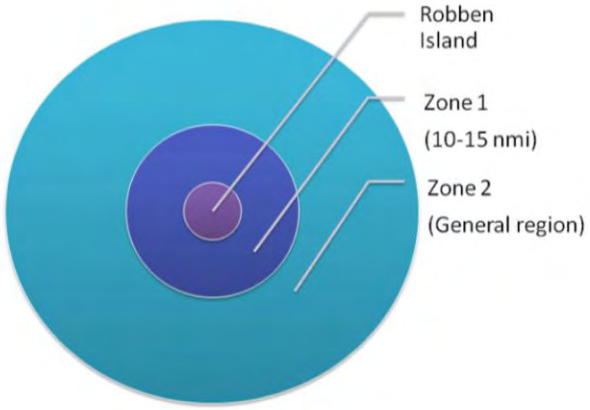
Climate

- Both excessive heat and extreme cold are factors
- Excessive heat can cause hatching and fledging success to halve
- Extreme cold has a smaller effect – hatching and fledging success is reduced to 70% of normal

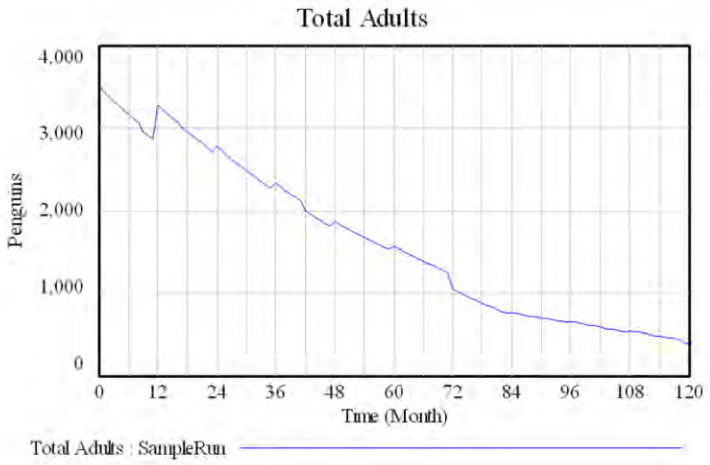
Food availability

- Zone 1 influences hatching and fledging success, and clutch size
- Zone 2 influences adult and immature survival as well as proportion of adults choosing to breed
- Zone 2 is currently based on Stratum C – relationship between lagged kj values and breeding proportion

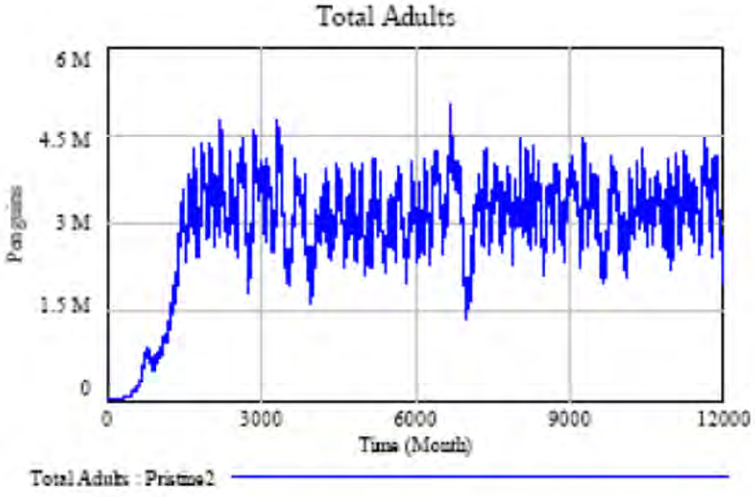
Food Zones



Sample run

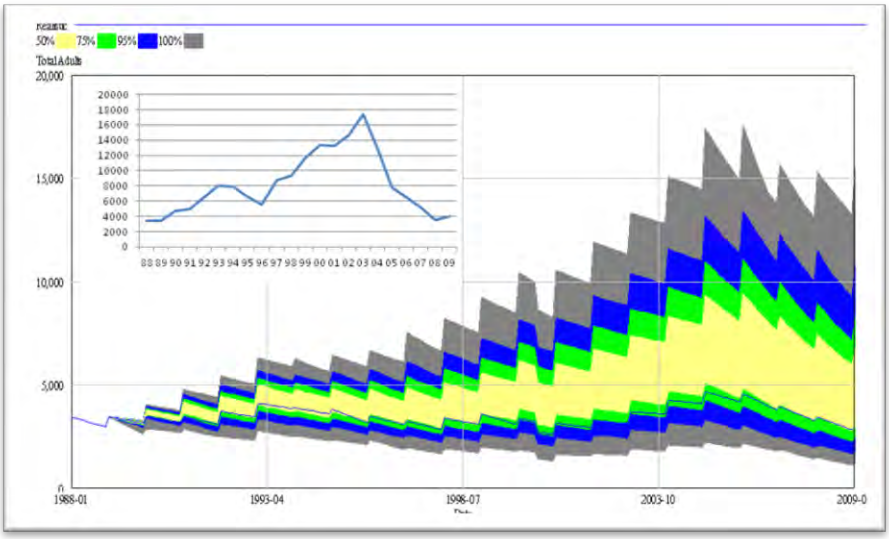


Pristine run



'Realistic' run

- Attempt to replicate period from 1988 to 2009 as closely as possible
- Realistic food data is used as well as timing of major oil spills
- Investigate what other factors must be to achieve close fit



Parameters that changed

- Predators have forced low abundance until 2003 then forced high abundance
- Other catastrophes turned off
- Immature 0 survival is varied between 0.51 and 1
- High immature survival results in a close fit to real data
- This replicates a situation with immigration (into Immature 1 age class)

Management strategy

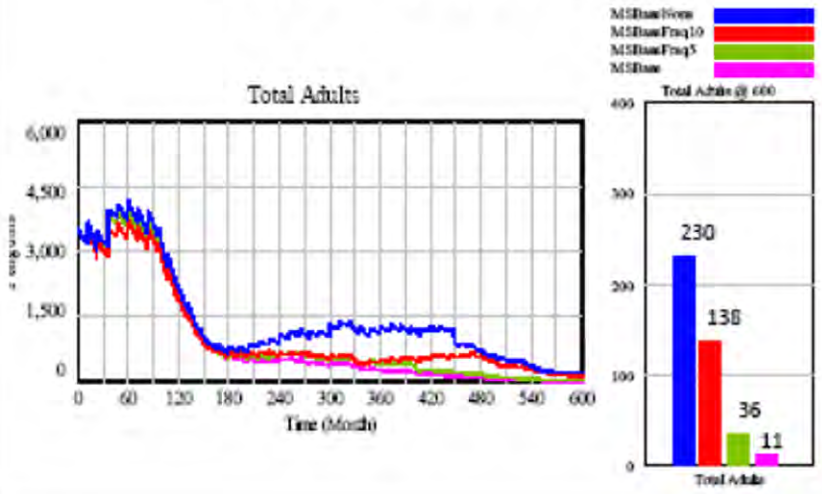
- Example: Reduce chronic oiling
  - Reduce frequency of oiling
  - Remove chronic oiling

Reduce chronic oiling

Over a period of 10 years, changing the frequency of small oils results in:

Penguins less than x% of start	Average time between oil spills: 2 years	5 years	10 years	None
100%	1	1	1	1
75%	1	1	1	1
50%	1	1	1	1
25%	**0.985**	**0.86**	**0.675**	**0.255**
10%	0	0	0	0

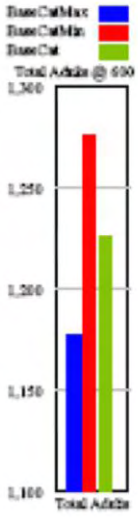
Reduce chronic oiling



Sensitivity analysis

- Only looked at one factor at a time
- Other factors were turned off
- Varied the effect that the factor had on the penguins
- Looked at maximum and minimum values with the base value as a comparison

Predators

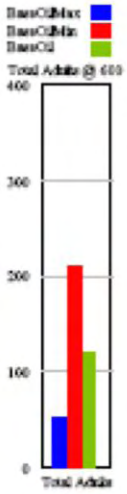


- Maximum difference of 100 penguins when the effect of land predators is varied
- Maximum difference of 338 when the effect of sharks is varied

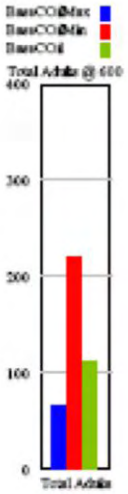
Climate and flooding

- Maximum difference of 238 penguins when the effect of climate (heat and cold) is varied
- Maximum difference of 111 when the effect of flooding is varied

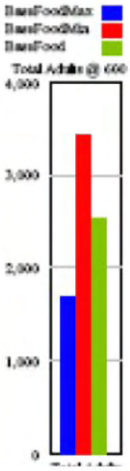
Oiling



- Maximum difference of 157 penguins when the effect of catastrophic oiling is varied
- Maximum difference of 156 when the effect of chronic oiling is varied
- Produce very similar results



Food



- Maximum difference of 1725 penguins when the effect of food availability is varied
- Largest effect as food also affects breeding proportion and clutch size
- Can change depending on food sample

Appendix 4:
Record of the discussion following the penguin pressure model presentation on 3 November 2010
Background and participation:

Meeting by invitation only, 10-13h30. 26 people present, composed of members of the Penguin Pressures Model Group ("Group") and staff of the following organisations ("Participants"): Penguin Datasystems (UK); Cape Nature, DAFF:Research, Percy FitzPatrick Institute (UCT), MA-RE Institute (UCT), BirdLife, WWF, Animal Demography Unit (UCT), Department of Statistical Sciences (UCT).
Apologies: DAFF:Management, SANParks:Table Mountain National Park
Welcome and context – Chair of Penguin Pressures Model Group
Powerpoint presentation – /Model developer on behalf of Penguin Pressures Model Group

Discussion
(Notes taken by Group members)

Particpant - Well done. Need recruit abundance – probably underestimating food abundance now from SSB alone. The distributional shift really only affected the adult fish.
Participant - Asked for parameter explanation re oiling. Modelling process seems to be ok, but catastrophic events maybe too frequent?
Participant - Clarification – how are relaying and feeding success related? Group member explains that there are timing issues – if first clutch laid too late, then second clutch will not be successful. 2nd clutch dependent on food availability as well.
Participant - Why are sardine and anchovy converted to calorific values for Zone 2 but not for Zone 1? Group member clarifies. Another group member comments on importance of SSB in Stratum C, data sources and background.
Participant - Questions whether there is really such a big difference in the calorific value of anchovy and sardine? Group member clarifies that the time lags in the penguin-sardine/anchovy relationships found are different.
Participant - Is there any consideration of foraging effort – net energetic gain? Potentially more expensive to feed on 100g of anchovy (requires catching more fish) than 100g of sardine. Another participant comments it is possibly rather a discussion of small to large fish – juvenile sardine vs adult anchovy probably not that different? Group member emphasises that we did not want to make the model unnecessarily complicated, so omitted differences at that level of detail.
Other important effects, e.g. allee effect – as the penguin numbers decrease, behavioural aspects probably more important than food availability alone, affecting survival rates and foraging. Group member explains how density dependence is modelled. Participant asks for thresholds. Seems satisfied with explanation received. Another group member adds that allee effects are likely nonlinear. Again, trading off investigating this vs. anchovy/sardine specificity.

Participant questions the plot of "oiling" results. Why the large decreases in penguin numbers? Group member explains that this is the (stochastically generated) coincidence of 1 catastrophic plus 2 chronic oiling events. Another group member explains how to interpret the plot. Participant insists on more sensitivity testing wrt oiling. Group member explains that parallel evaluations with different levels of food need to be done, because food availability currently is read into the model.
Participant - Were there no runs at all exploring the impacts of fishing? Clearly this is important wrt OMP testing. Group member explains that yes, runs have been carried out, but we did not want to show premature results given that food (recruits vs SSB) and catch (area specific rather than general) still need to be modelled better.
Participant - Is it actually fishing in Zone 1 or Zone 2 that affects the penguins? Clarification how both zones are regarded as important. Another particant points out that there were very few anchovy/sardine off Robben Island in the mid-2000s, probably hence the strong dependence on food. Might change when looking at the past 2 years.
Participant - It is important to capture the food availability properly. Anotherh participant answers that DAFF Fisheries does not have small scale high-resolution data of impact of industry on fish schools and these are unlikely to be available any time soon.
Participant - Questions where/what the food abundance time series are based upon. Group member explains - random selection of actual abundances of anchovy and sardine surveyed over the 25 years (species are coupled i.e. sampled in tandem for a year). Another

Group member adds that it might be interesting to look at the probability of having consecutive years of good vs. bad food availability. Yet another Group member reiterates that the November SSB is linked to the decision to breed, whereas the recruit data are hoped to be more relevant for feeding the chicks.
Group member comments on errors / variance – We may well underestimate the importance of food because of the variance in the pelagic SSB surveys. Can we possibly use the model to explore this?
Participant - We also need to know how the fish move. Another participant explains that there are two approaches in connection with discussions at the Pel SWG, a) the "River" model, and b) a senior DAFF scientist is looking at small-scale temporal patterns in the available data.
A Group member reiterates that the systems dynamics modelling philosophy is neither to ignore an issue completely, nor to build a complete picture of what is going on. The model rather qualitatively aggregates (by means of expert inputs) what is going on so it can be interpreted. Questions like "Given a change of fishing pressure on anchovy and sardine, is there a change in survival/breeding success" is aiming at intermediate effects, and we do not need the full complexity of the real world.
Group members notes that already, the strong dependence on food is a major result, as opposed, e.g., to effects relating to predator pressure.

Participant - Has the amount of food that the seals (or other predators) will eat been incorporated in the model i.e. competition for forage fish? The effects could well be similar to fishing. Group member explains that, again, it is a compromise between what is realistic to model. Another Group member suggests that a mass-balance model might be better suited to estimate this sort of interaction. Participant explains that the small pelagics stock assessment models show that fishing has a minor impact on the dynamics of sardines (F's). Group member comments that this is where the spatial aspect becomes really important.
Participant - Is it possible to get an estimate of the number of recruits in Zone 1 from DAFF? This would be very helpful. Participant responds that the fishing industry will catch closest to their home port. Another participant highlights that catches cannot replace biomass estimates. Monthly breakdowns of catches are available, showing the seasonality of the anchovy fishery. Problem is the imprecise location of the catches, by 10*10 nmi_2 blocs, i.e. at a coarser resolution than the Zone 1 in the model.
Participant - Returning to food. Yes the spatial aspect is important, but also important is food availability at the right point in time (i.e temporal aspects important). Data suggest that the natural mortality rates of small pelagics increase when the fish population is small. How would one manage that? Probably by managing the fishing industry. How do other models (like those of MARAM) handle the presence of predation mortality? Could predation M be incorporated into the penguin pressure model in a similar way? When fish abundance is low, there is empirical evidence to suggest that natural mortality (predation) of fish is high, and thus we really need to manage the fish resources via reduced fishing mortality. Another participant responds that this is what the pelagic OMP attempts to do except that the reduction on F is capped to stabilize the catch for sustainability of the fishing industry. Group member points out that clearly the objectives of industry stability and that of penguin conservation can be conflicting, and there needs to be an explicit tradeoff discussion. Another participant responds that penguin conservation is an objective in the management of the small pelagics fishery, and that this discussion is happening.
Participant – questions shark predation in the model – based on lots of personal experience from the field, but has never seen a shark attack a penguin. Group member explains that there are data on shark attacks on penguins. Another Group member adds that based on work by Randall & ...., sharks definitely attack penguins, the wounds are different to those inflicted, e.g., by seals. Group member explains that the effect of shark predation currently is not strong in the model, but the pressure is retained in the model to enable assessment of the possible impact of cumulative effects. Yet another group member asks for details on how the effects of sharks are modelled. Would it be possible not to take a fraction of the population, but a constant number per unit of time? Group member agrees, but emphasizes that sharks to not have a huge effect at Robben Island, and alternative model versions could be sensitivity tested in the case that there is additional time for model development. Another participant - asks again how shark mortality is modelled. Group member explains that this is an average mortality, i.e. increased shark predation will increase penguin mortality and decrease their survival, on top of climate effects, oiling etc.
Participant - Why is tourism not included for Robben Island? Group member explains that it was expert judgment that tourism and research had a minor effect on penguins on Robben Island. This could be disputed, but the intention is to model major pressures at this stage.

Participant - Other predators – gulls are turned off on Robben? Group member – yes, but can be turned on for other islands, where gulls are known to be important for penguin dynamics.
Group member – Model developer has pointed out that the model is not designed for short term predictions. Is this a consequence of the high stochasticity in the model? Another group member - Lots of the relationships are qualitative which means the numerical outputs per se are not that useful. They have to be interpreted as outcome of a strategy, rather. Yet another group member – if we got the current situation and run the model for some period, we might see factors in the model that are important in the short term, and others that are important in the long term.
Group member - Would the model results likely still allow us to design the field sampling better? Another interesting thought is to use the model to generate data – e.g. exploring the question, how long do we need the time series to be to detect effects of changing pressures? (i.e. use the model for power analysis). Another group member -yes.
Participant - Can stakeholders play with the model? Group member- yes, after changes as discussed here are incorporated, but would need Reader Version of VenSim.
Participant - Getting back to the quotes in the presentation: This is a very nice compromise of keeping it simple and still having the important characteristics included.