Responses to preliminary questions from the Annual International Stock Assessment Workshop Panel, 2014

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Each question is reproduced in blue italics and our responses follow in black text.

Question 1

It would be helpful for both parties to formulate analyses as a test of formal hypotheses. This will help the Panel interpret analyses, understand positions, and identify differences as well as common ground. There are several response variables that can be analysed separately and also together (MANOVA or similar). The main factors would be closure status and island, but other factors can also be considered (adjacent catch levels, estimates of local biomass):

All our statistical analyses were based on the null hypothesis that the mean penguin response would be the same regardless of whether the 20 km area around the relevant island was closed to fishing or not. This was tested against the alternative hypothesis that the mean response would differ between years when the area around the island was closed to fishing and when it remained open to fishing.

In order to do that, we modelled several response variables: chick body condition; chick growth rates; and the foraging parameters maximum distance from the colony, trip duration and foraging path length at the penguin's four main breeding sites Dassen, Robben, Bird and St. Croix islands.

Each model contained data on a pair of islands, as described in the individual documents. All p-values presented are those for the comparison of closed years versus open years, stratified by island, from that specific model.

We used linear mixed-effects (LME) models, which enabled us to adjust for known confounds, by including them in the models as fixed effects, as well as adjusting for known correlation between groups of observations, such as year, by including them in the models as random effects. We used one LME for each combination response variable and island pair, as described in the individual documents. We used individual models, because each model was adjusted for the specific confounders we decided were appropriate for each individual outcome.

Response variables that produced positively skewed residual distributions were log-transformed to approximate normality for analyses. All effect estimates are the difference between closed and open years, with their 95% confidence intervals. These effect estimates are from the models described above. The estimates are in the original unit of measurement where response variables were not transformed, or as a percentage change when log-transformed data were used.

Question 2

"It would be helpful to have basic summary statistics (annual means and SDs) of the response data presented in relation to the factors of analysis (closure status, local fish catch, available fish biomass). Clarification: Jason Link is looking for bar plots w/ SE bars across closure status & island of all the response metrics (not catch)".

Unless stated, point estimates in Figures 1 to 12 are the arithmetic mean and error bars show 1 standard error of the mean. Please send questions or further requests regarding these figures to richard.sherley@gmail.com.

Chick Condition

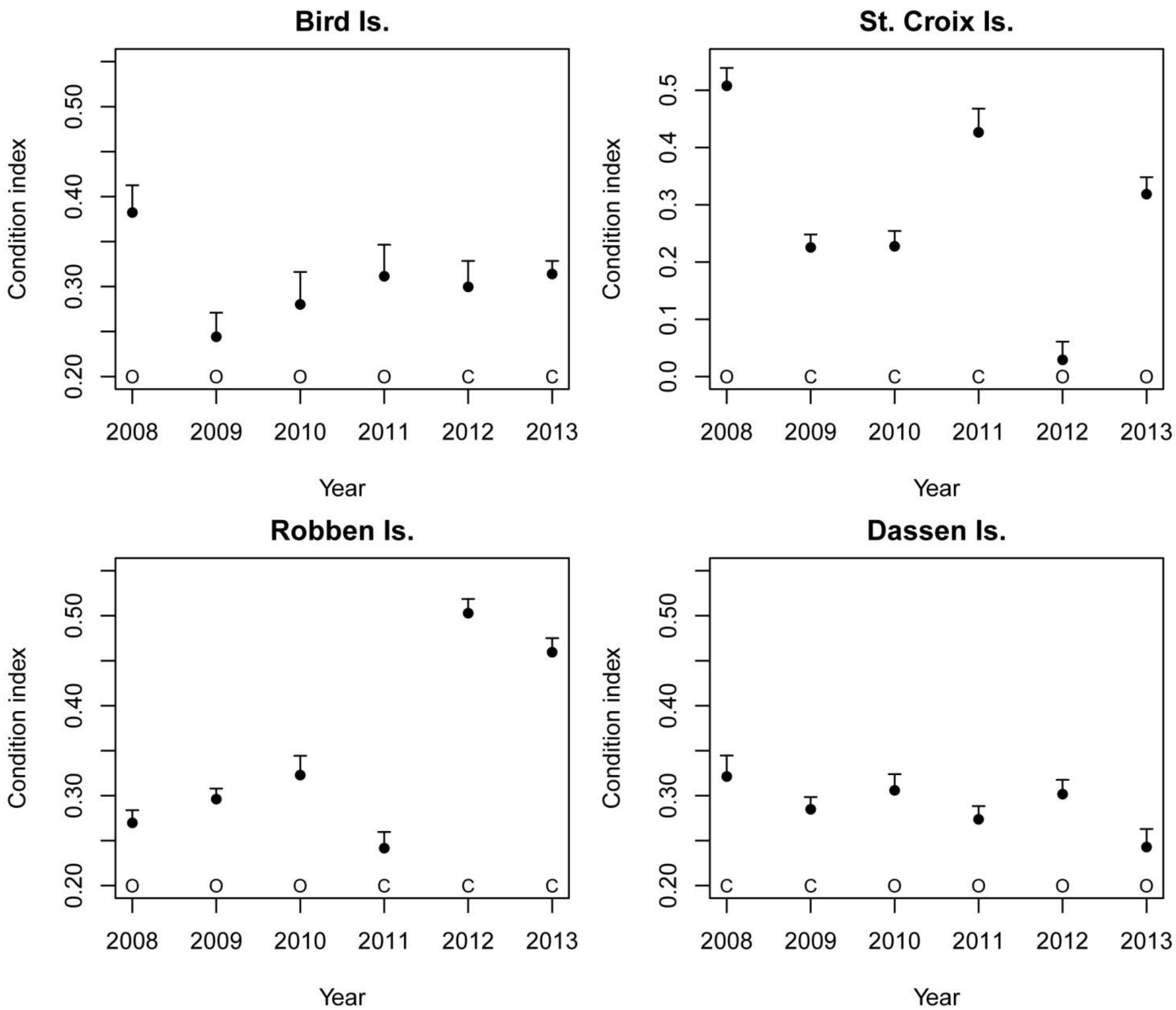

Figure 1: African penguin *Spheniscus demersus* chick condition by year (2008 to 2013). The condition index is a relative index based on data collected at Robben Island in 2004 where the average chick condition was 0.51. "C" and "O" above the x-axis indicate the annual closure status. Note the y-axis scale for Bird Island and St. Croix Island are not the same.

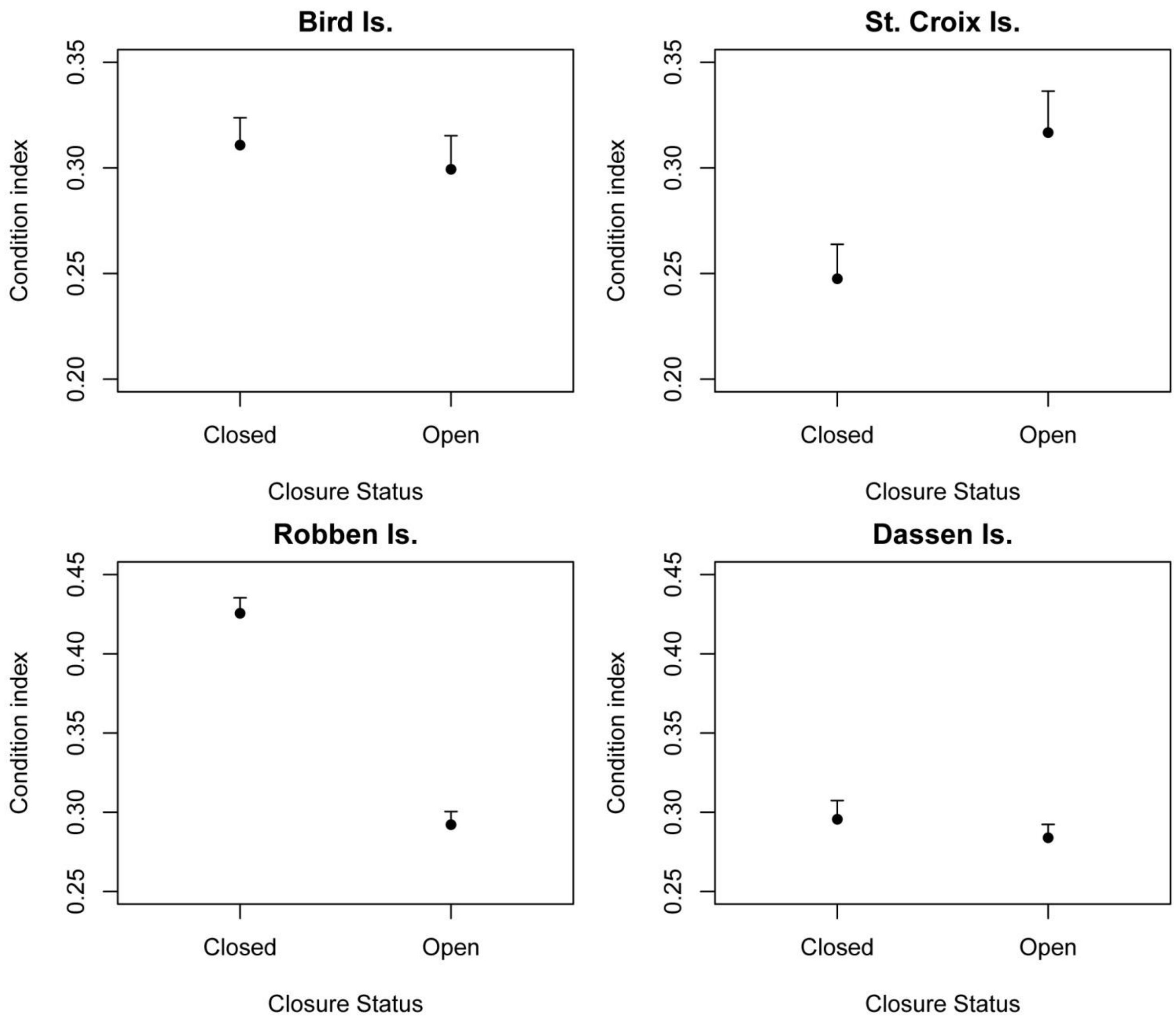

Figure 2: African penguin chick condition by Closure status. The condition index is a relative index based on data collected at Robben Island in 2004 where the average chick condition was 0.51. “C” and “O” above the x-axis indicate the annual closure status. Only the 2008 to 2013 data were used here.

Chick Growth

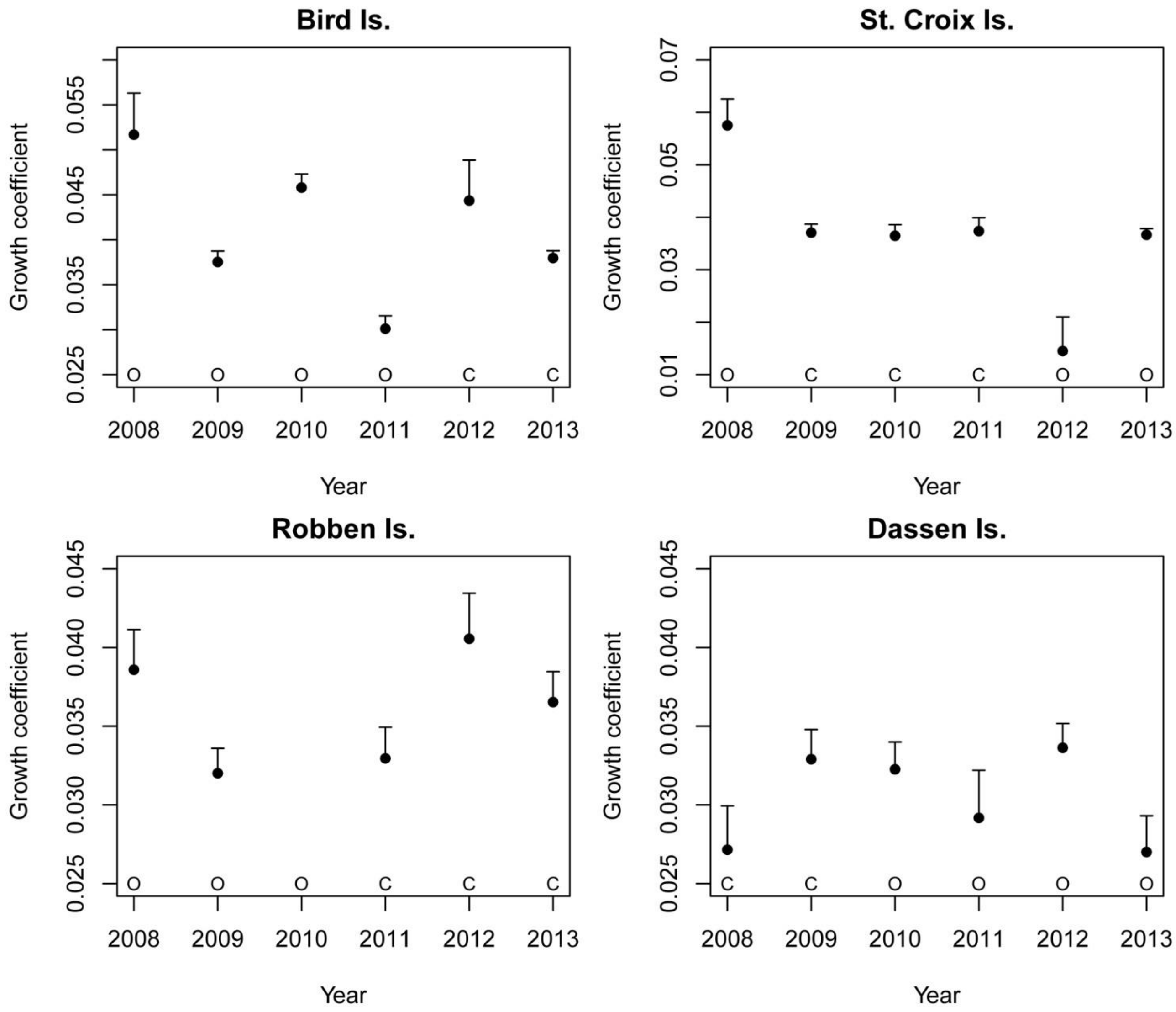

Figure 3: African penguin chick growth by year (2008 to 2013). Growth rates are expressed as a Gompertz growth coefficient. Note the y-axis scale for Bird Island and St. Croix Island are not the same. Growth data were not collected at Robben Island in 2010.

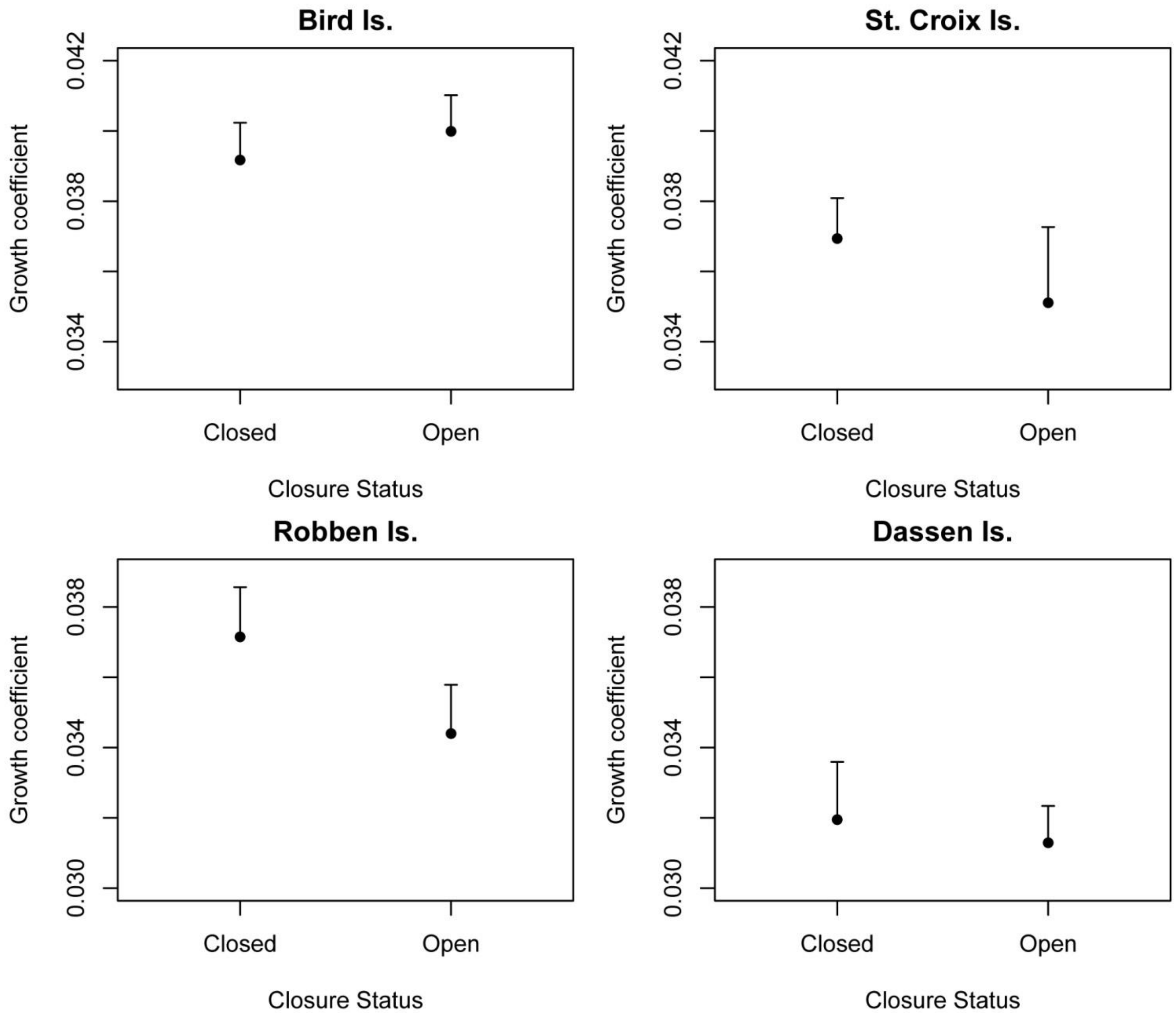

Figure 4: African penguin chick growth by Closure status. Growth rates are expressed as a Gompertz growth coefficient. “C” and “O” above the x-axis indicate the annual closure status. Only the 2008 to 2013 data were used here.

Foraging Behaviour – Maximum Distance

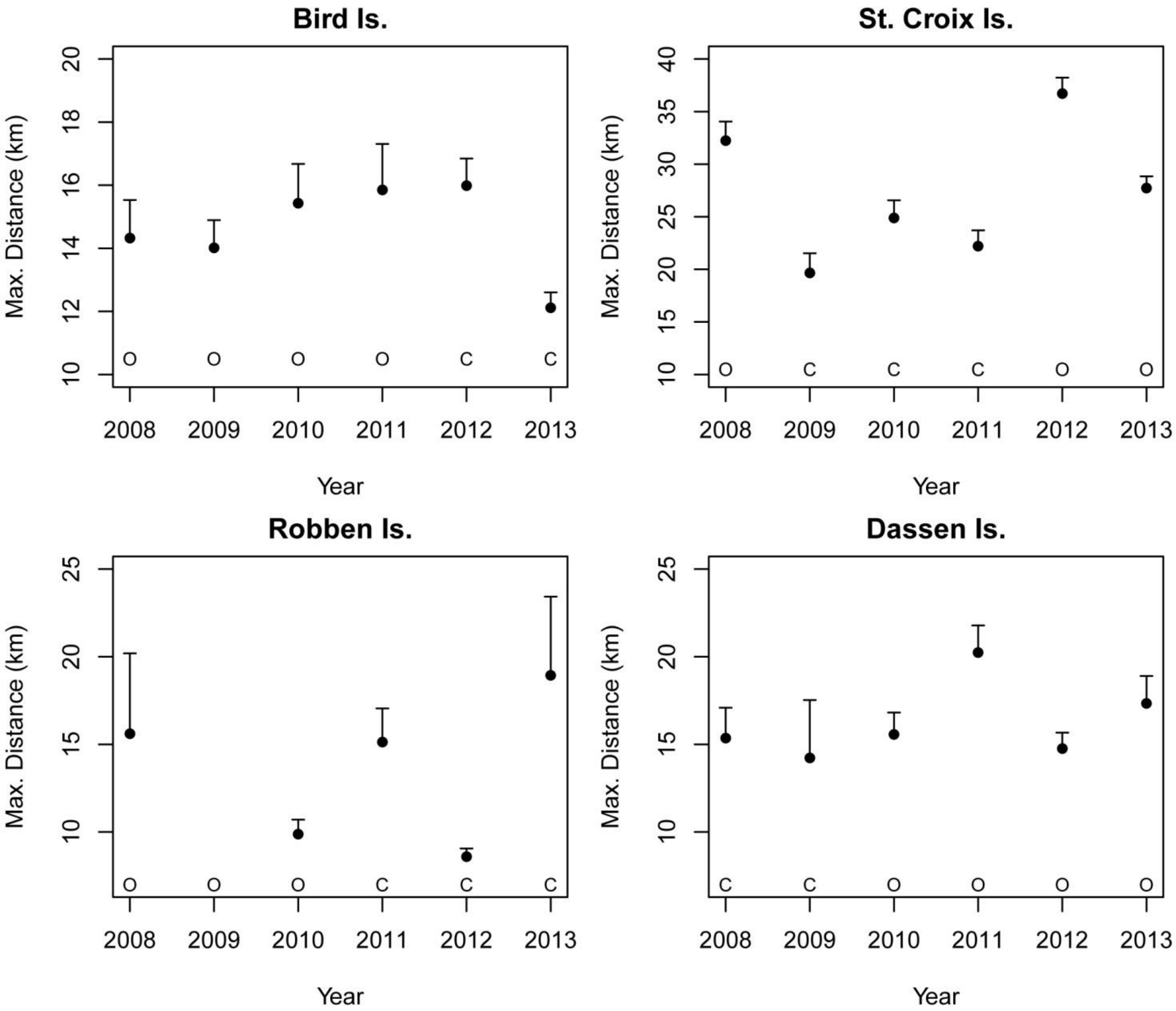

Figure 5: Maximum foraging distance (km) by year (2008 to 2013). This is the mean maximum distance from the colony reached by breeding African penguins. Note the y-axis scale for Bird Island and St. Croix Island are not the same. Foraging data were not collected at Robben Island in 2009.

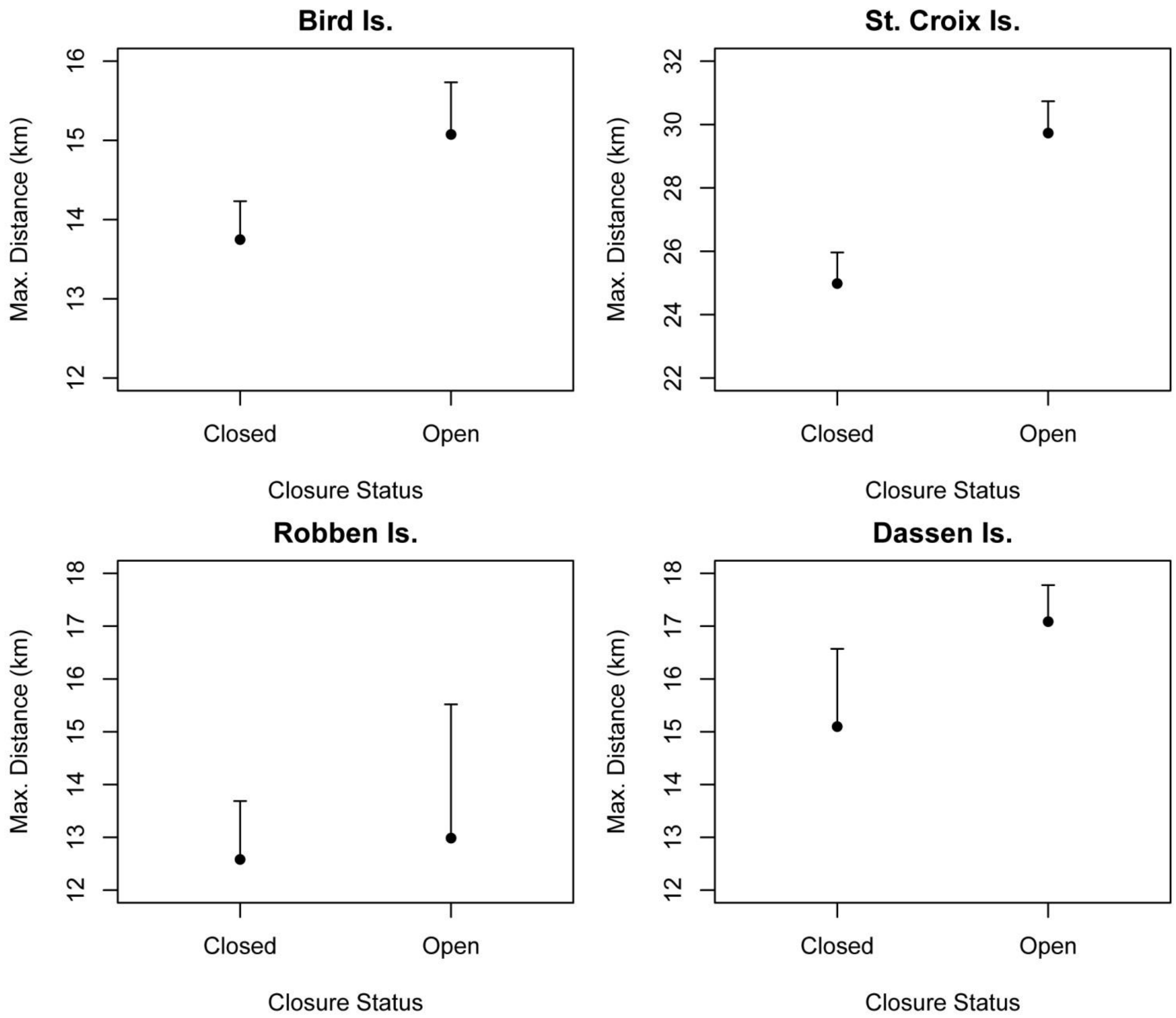

Figure 6: Maximum foraging distance (km) by closure status. This is the mean maximum distance from the colony reached by breeding African penguins. Note the y-axis scale for Bird Island and St. Croix Island are not the same. Only the 2008 to 2013 data were used here.

Foraging Behaviour – Path Length

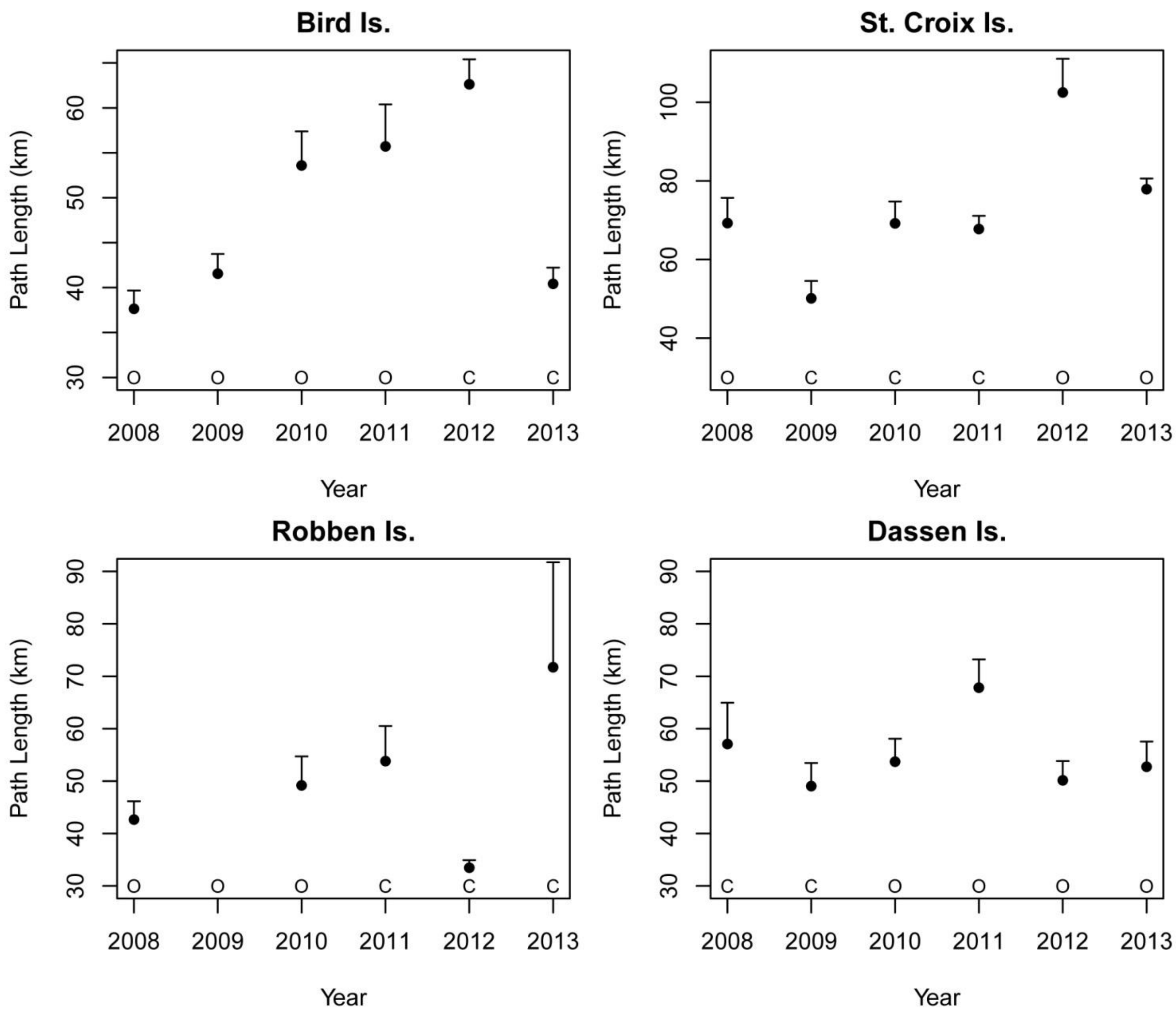

Figure 7: Foraging path length (km) by year (2008 to 2013). This is the mean distance travelled during a foraging trip by breeding African penguins. Note the y-axis scale for Bird Island and St. Croix Island are not the same. Foraging data were not collected at Robben Island in 2009.

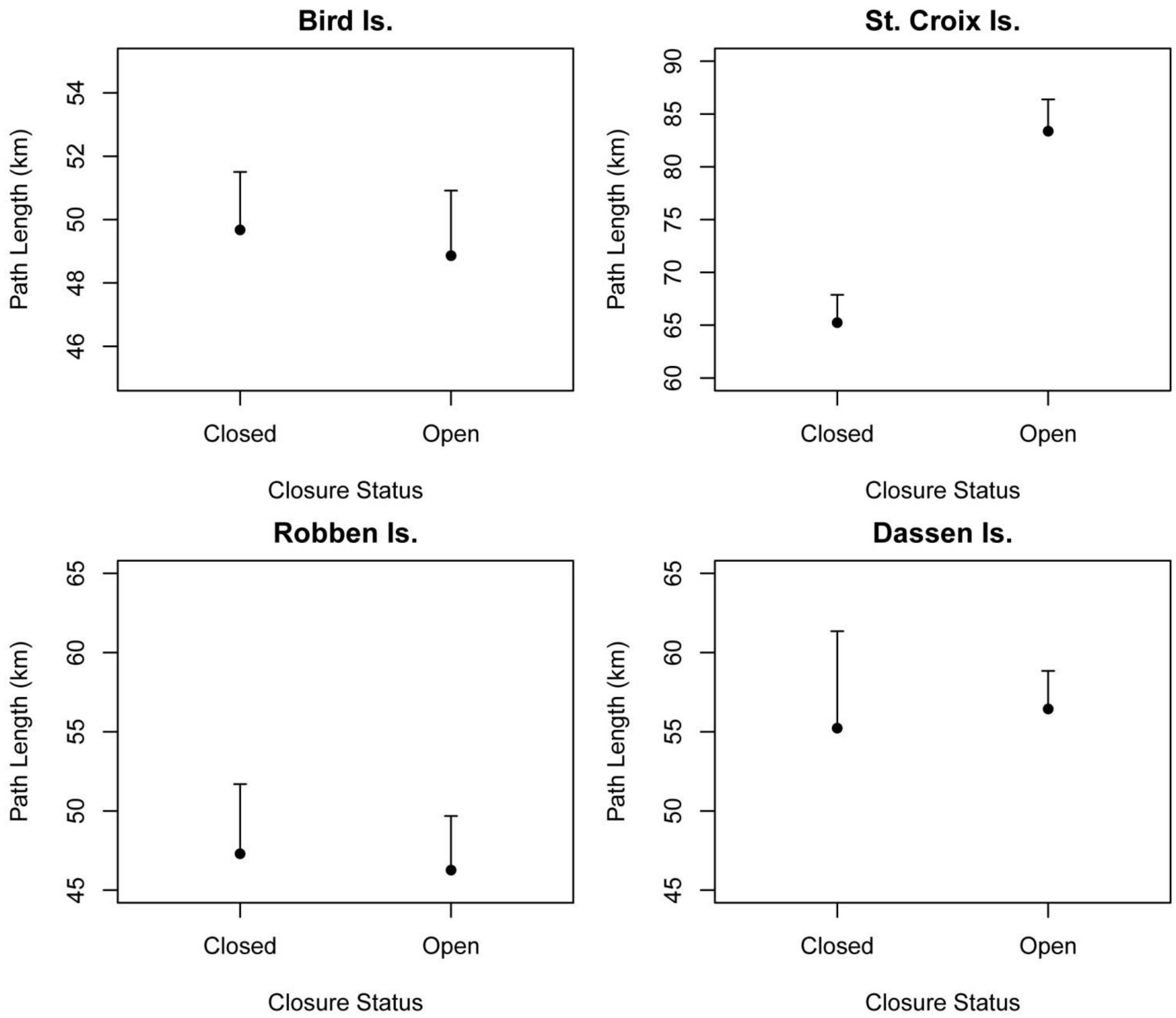

Figure 8: Foraging path length (km) by closure status. This is the mean distance travelled during a foraging trip by breeding African penguins. Note the y-axis scale for Bird Island and St. Croix Island are not the same. Only the 2008 to 2013 data were used here.

Foraging Behaviour – Trip Duration

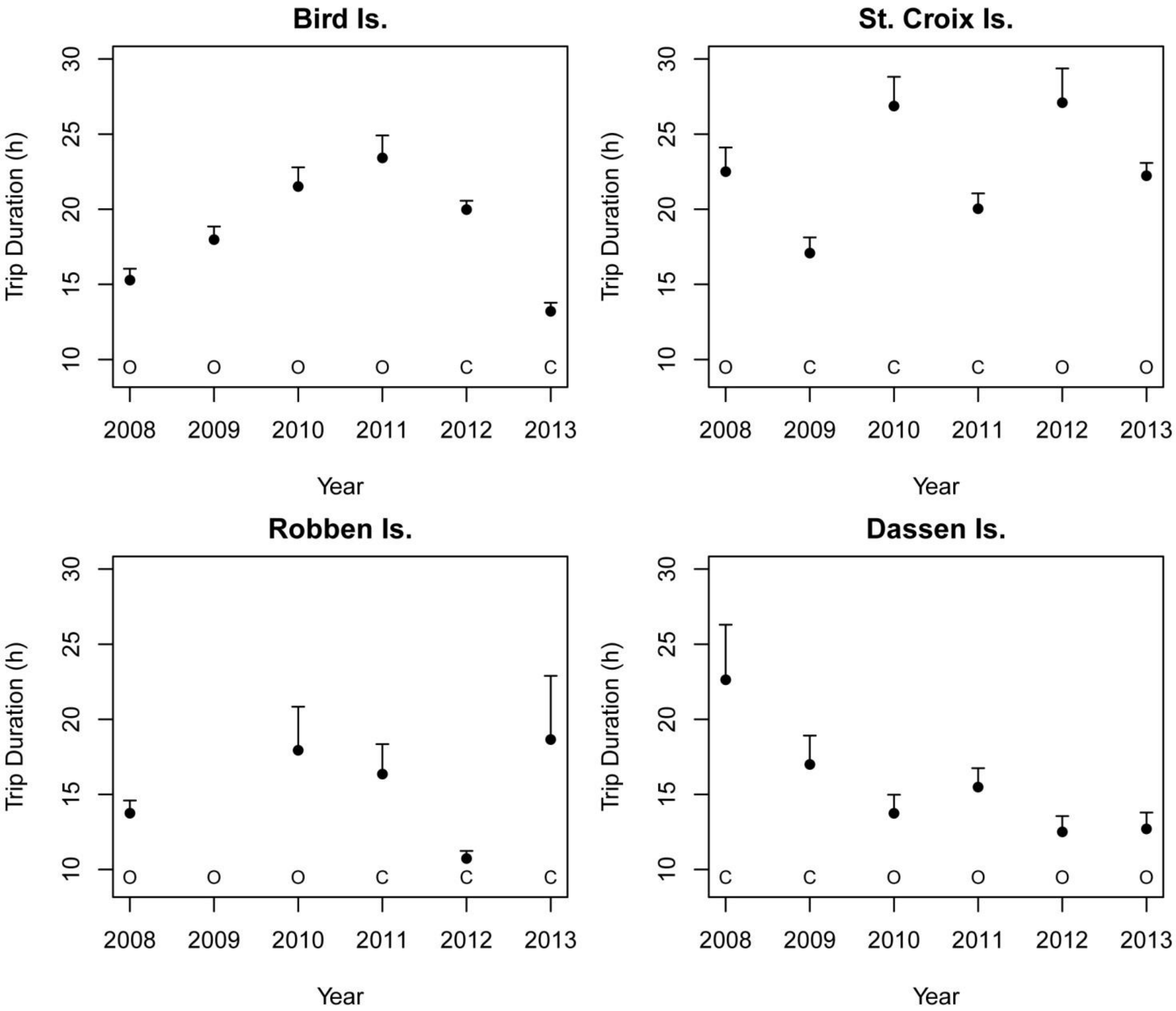

Figure 9: Foraging trip duration (h) by year (2008 to 2013). This is the mean time spent at sea on a foraging trip by breeding African penguins. Foraging data were not collected at Robben Island in 2009.

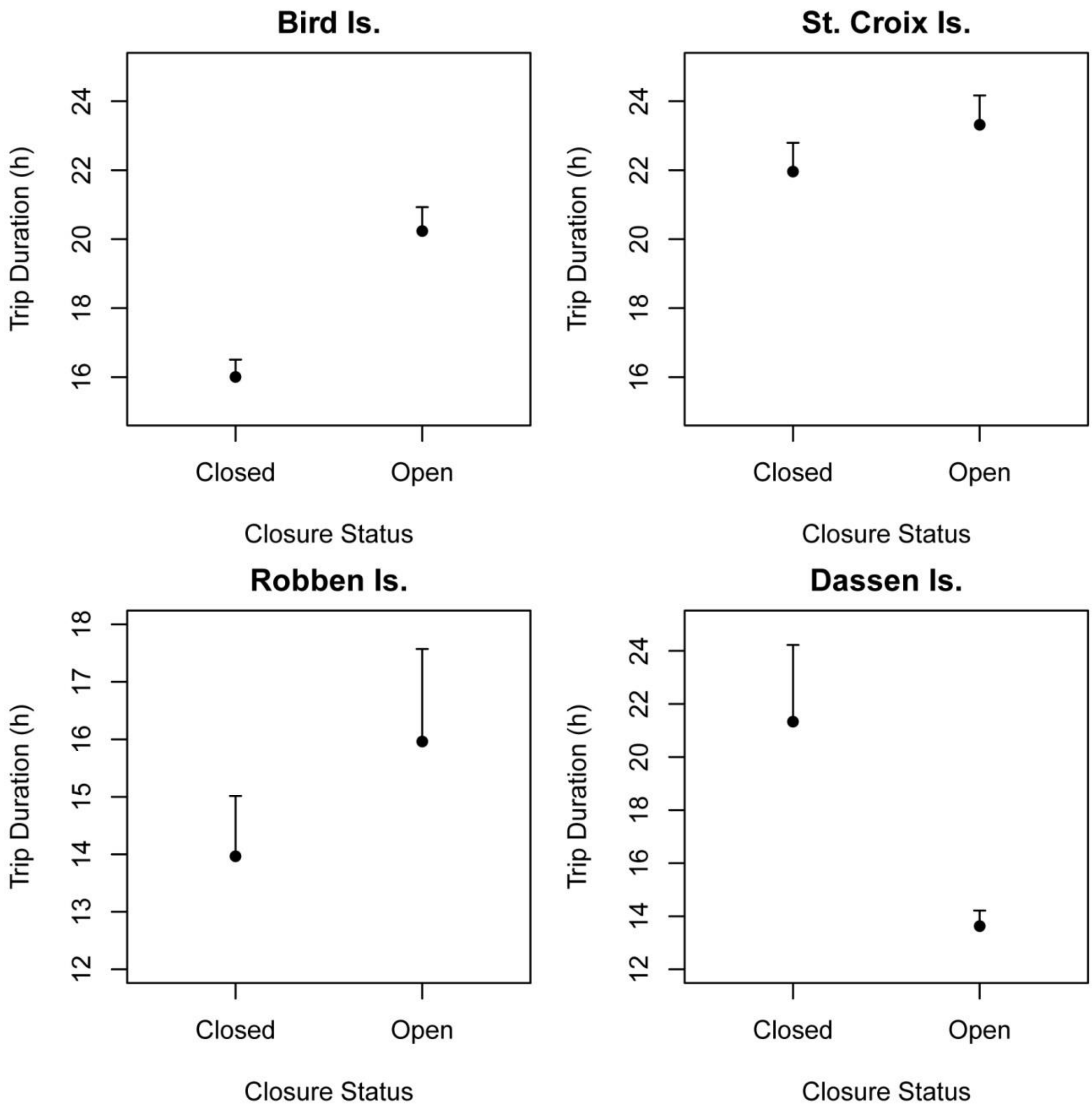

Figure 10: Foraging trip duration (h) by closure status. This is the mean distance travelled during a foraging trip by breeding African penguins. Note the y-axis scale for Robben Island and Dassen Island are not the same. Only the 2008 to 2013 data were used here.

Breeding Success

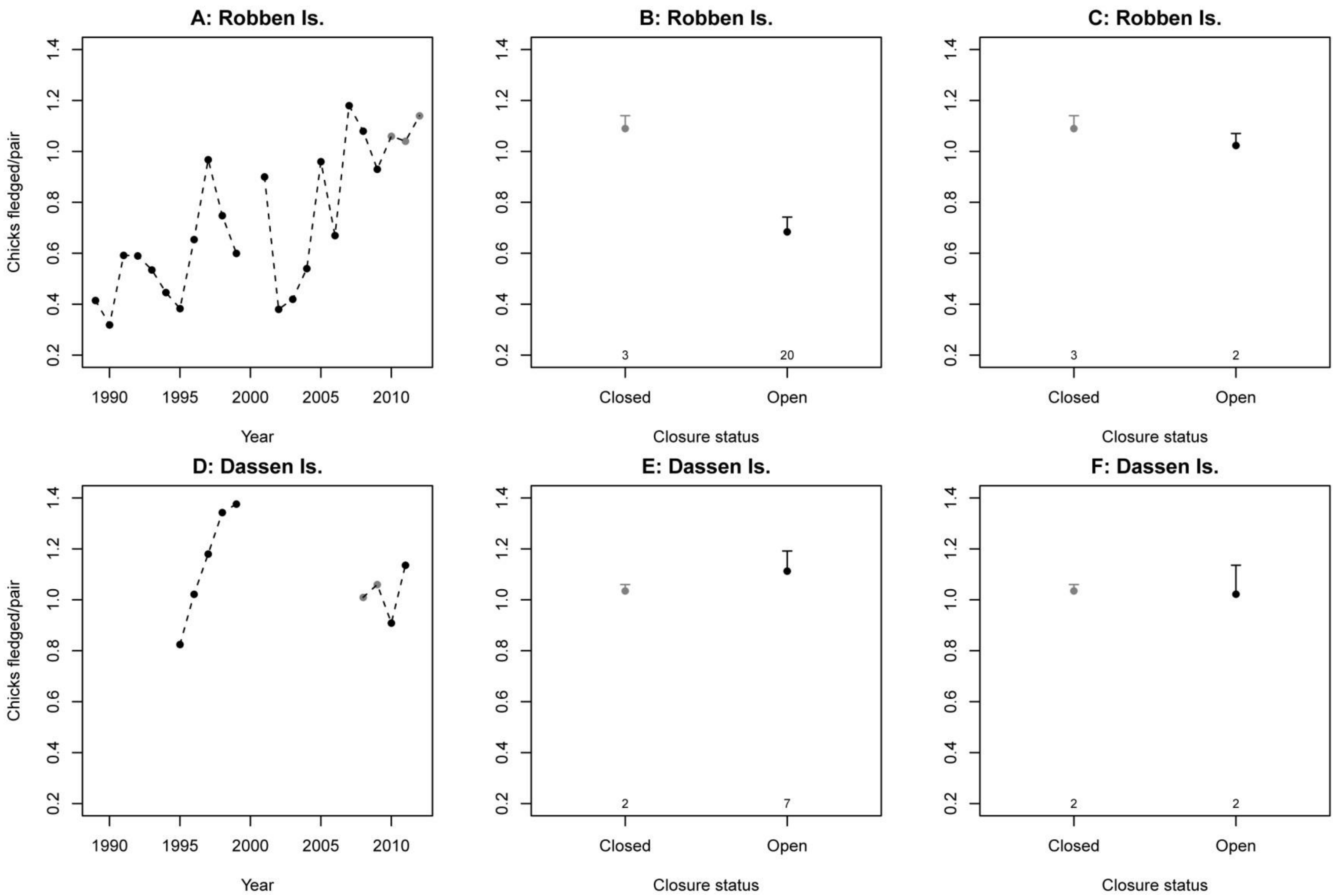

Figure 11: African penguin breeding success (chicks fledged/pair/year) by year at Robben Island (A: 1989–1999 and 2001–2012) and Dassen Island (D: 1995–1999 and 2008–2011), the mean and 1 S.E. by island closure status using all the available data (B and E) and for only 2008 to 2012 at Robben Island (C) and 2008 to 2011 at Dassen Island (F). ‘Closed’ years are shown in grey and ‘Open’ years in black.

Active Nest Proportion

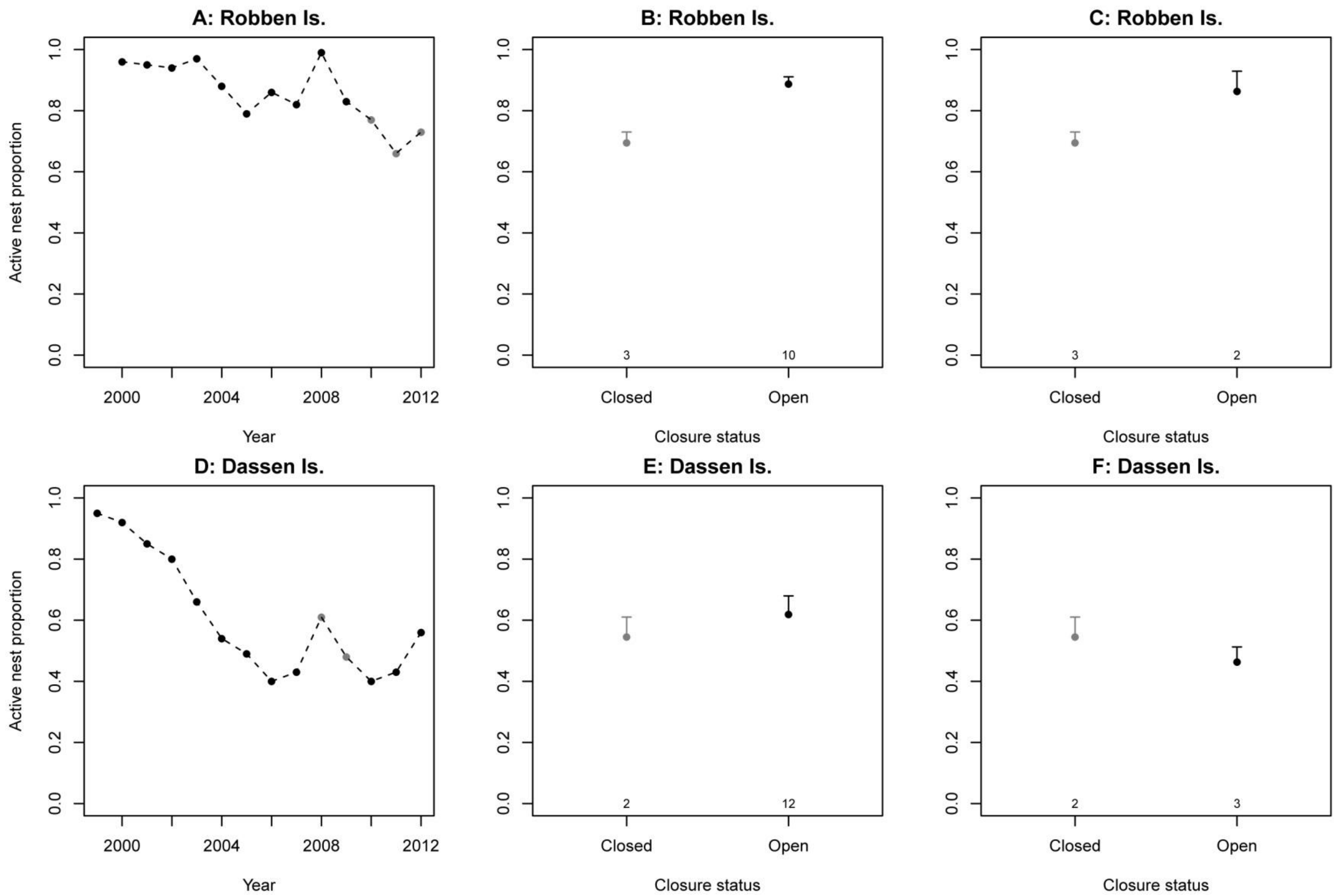

Figure 12: African penguin active nest proportion (occupied nests/all nests judged to be active) by year at Robben Island (A: 2000–2012) and Dassen Island (D:1999–2012), the mean and 1 S.E. by island closure status using all the available data (B and E) and for only 2008 to 2012 (C and F). 'Closed' years are shown in grey and 'Open' years in black

Question 3

"As background for Panel members not familiar with African penguins or local ecosystems, and to help understand the "energetics" of the situation, tables or summaries of the following information would be helpful (noting that some of this information is already available in various papers already distributed, but it would be helpful to have it synthesized – averages for the recent period would be fine)":

a. African Penguin population abundance (and biomass) around the islands and for the whole population.

The most recent publication on African penguin *Spheniscus demersus* population numbers is Crawford et al. (2014). The penguin population in South Africa decreased from a mean of 48 000 ± 7 000 breeding pairs between 1979 and 2004 to ca. 17 000 pairs in 2013 (Crawford et al. 2014). Updated (but still unpublished) numbers for Dassen and Robben islands in the Western Cape and St. Croix and Bird islands in the Eastern Cape are shown in Figure 13 and 14.

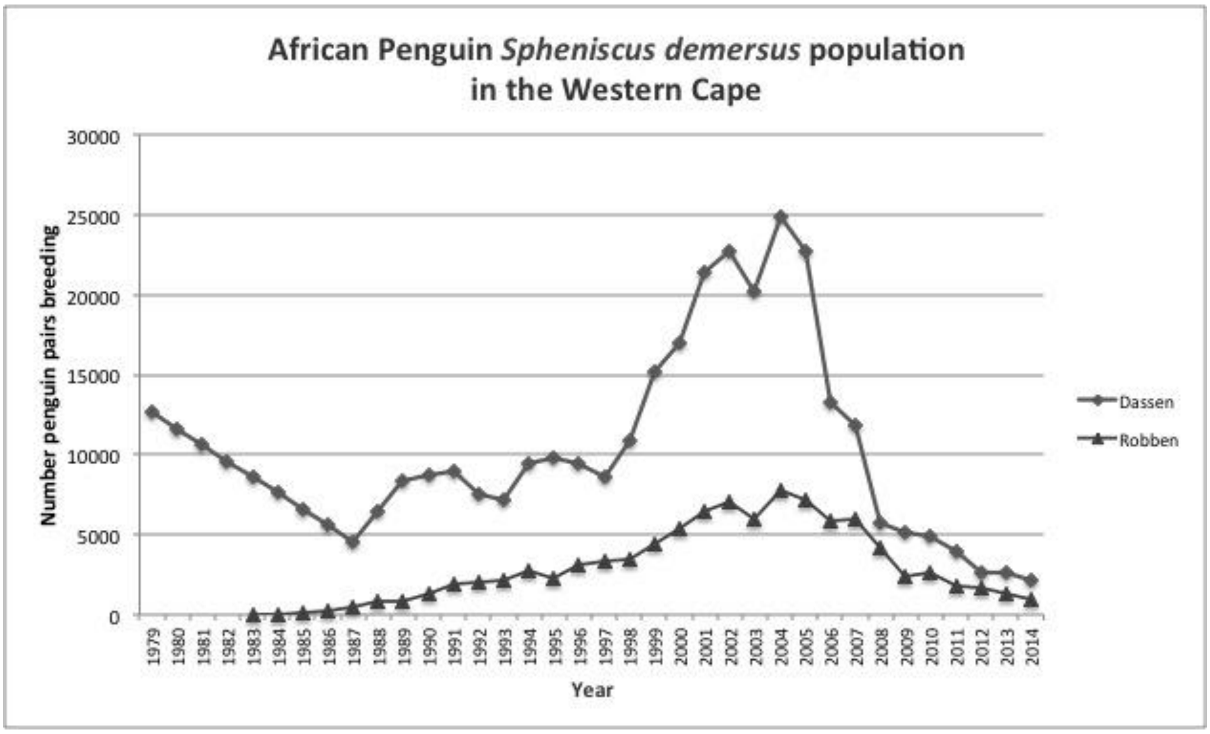

Figure 13: Trends in counts of African penguin breeding pairs at Robben and Dassen islands in the Western Cape, South Africa.

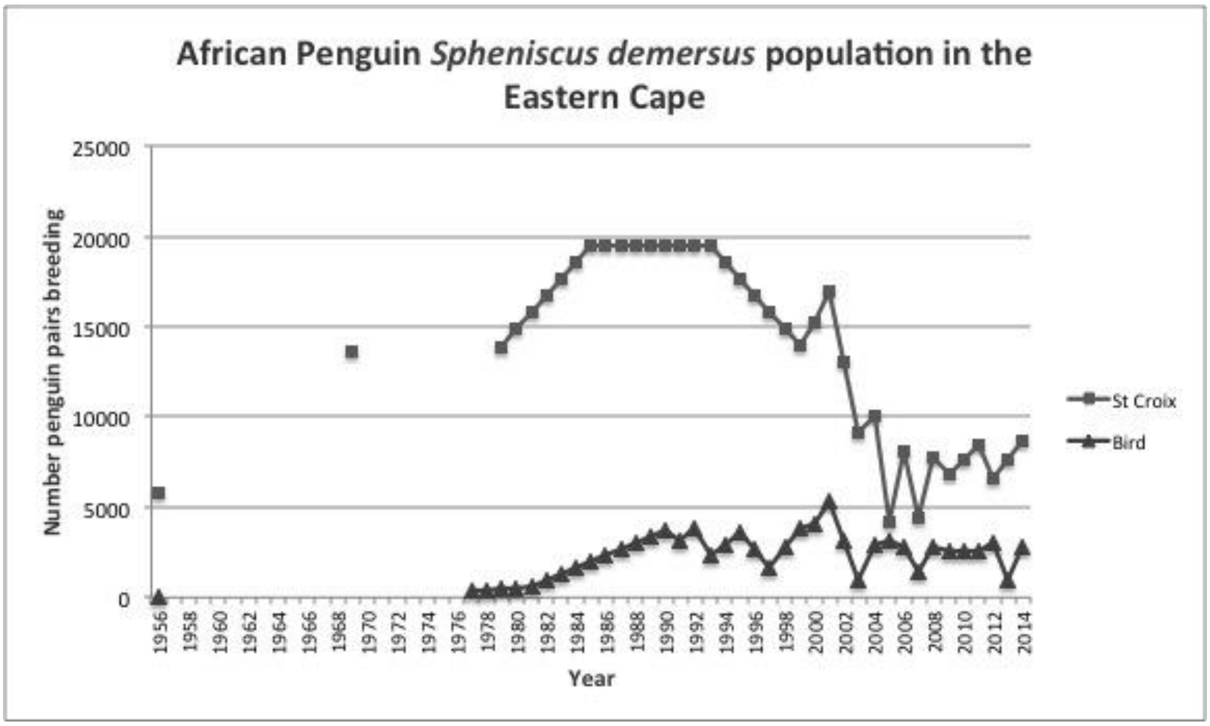

Figure 14: Trends in counts of African penguin breeding pairs at St. Croix and Bird islands in the Eastern Cape, South Africa.

b. Degree of movement / migration for African Penguins

After fledging, African Penguins leave their natal colony and spend 3-4 years prospecting. Many juvenile penguins from the west coast go north to forage in Namibia (Sherley et al. 2013) and many juveniles from the Eastern Cape go west to the Western Cape and onto the west coast of South Africa (RB Sherley, unpubl. data). Studies of banded birds show that juvenile penguins usually return to their natal colony but some do breed at non-natal colonies (Whittington et al. 2005a). Once a penguin has found a mate and bred at a specific colony, they show a high mate and site fidelity (Croxall and Davis 1999). There have been very few recorded instances of penguins breeding at more than one colony and all of those that had were previously cleaned following oil spills (Whittington et al. 2005a). Penguins may moult at colonies other than the one at which they breed (Whittington et al. 2005b), a trend which is becoming increasingly common in the Western Cape (L. Waller pers. comm.).

During breeding however, African Penguins are constrained by the need to return to their colony to incubate eggs or feed their chicks. This means that foraging ranges and search capabilities are correspondingly reduced (Wilson & Wilson 1995, Petersen et al. 2006, Ryan et al. 2007, Pichegru et al. 2009, 2010, 2012, Crawford et al. 2013). Outside of the breeding season, African Penguins are much more mobile and can travel several hundred kilometres from their breeding colony (Harding 2013).

c. *African Penguin per capita consumption and total population consumption of anchovy and sardine and related fish in South Africa (relevant to penguin diet)*

African penguins predominately eat sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus*. A recent summary of the diet fed to chicks can be found in Crawford et al. (2011).

Based on a recent study carried out by Cook et al. (in preparation) the following energy budgets were calculated for the African penguin population in South Africa:

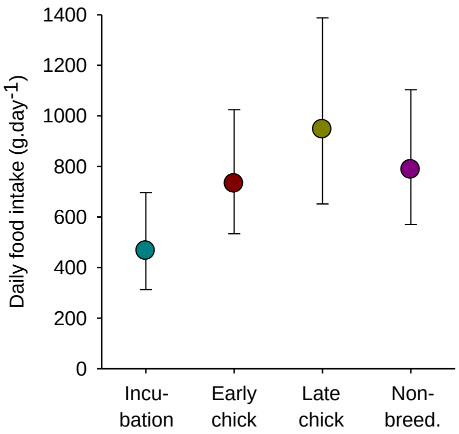

Figure 15: Food requirements of African Penguins in South Africa. Daily food intake (g of fish) is presented for all four phases of the annual cycle: incubation, early chick-rearing, late chick-rearing and non-breeding. Error-bars represent the range of variation of the time-energy-budget models based on the sensitivity analysis.

Table 1: Summary of values presented in Figure 15.

	DFI (g / day)	Max. DFI (g/day)	Min. DFI (g/day)
Incubation	466	696	312
Early-chick rearing	732	1024	534
Late chick-rearing	946	1388	652
Non-breeding	787	1103	571

Table 2: Annual consumption of fish (sardine or anchovy) by the African Penguin in South Africa over time.

Year	Fish per year (tons)	Max. fish per year (tons)	Min. fish per year (tons)
2013	17,395	24,313	14,002
2007-2011	23,113	32,304	16,739
1978-1982	55,839	78,045	40,441
1956/1957	125,960	176,051	91,225
1910	1,007,683	1,408,411	729,805
1500	1,511,525	2,112,617	1,094,708

Using these figures yields consumption by breeding birds and their chicks of 281 (Min. = 187, Max. = 418) tonnes for the 1364 breeding pairs at Robben Island in 2013 and 542 (Min. = 363, Max. = 807) for the 2633 breeding pairs at Dassen Island in 2013. For earlier studies also see Nagy et al. (1984) and Bouwhuis et al. (2007).

In this context however it is critical for the Panel to understand and consider the whole extent of the predator-prey relationship within the marine ecosystem dynamics. The effect of food abundance and seabird breeding success has been shown in several studies while Cury et al. (2011) identified the threshold in prey abundance below which seabirds experience consistently reduced and more variable productivity. This threshold was identified to be approximately one-third of the maximum prey biomass, the minimal prey biomass needed to sustain seabird productivty over a long term (Cury et al. 2011).

d. Landings of anchovy and sardine, both around the island and at stock level.

Detailed data on catches within 10, 20 and 30 nm around the islands as well as total biomass of anchovy and sardine on a yearly basis are provided in document MARAM_IWS_DEC14_PENG_C1 data tables.

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