CHAPTER 4: ENVIRONMENTAL, SPATIAL AND TEMPORAL VARIATION

INTRODUCTION

Quantification of environmental, spatial and temporal variation in animal behaviour may provide insight into the behaviour in question. However, these may vary greatly both on the population and the individual level.

It has been established that seal-seabird predation is not a common, stereotyped behaviour, but rather that a few individuals develop their own preferences and techniques (see Chapter 2). Therefore, environmental, spatial and temporal aspects of predation may vary with individual predators, and would not necessarily be reflected as trends in overall predation. Nevertheless, bird activity is constrained by these factors, such that seals may encounter different bird species (or age classes of birds) depending on environmental conditions, location and season or time of day. For instance, seasonal variation in predation may be attributed to prey availability, especially newly fledged gannets and cormorants, which form a third of predations noted (see Results). Furthermore, observed environmental, spatial and temporal variation in seal-seabird predation is likely to be influenced not only by seal and bird behaviour, but also by the method of observation (see Chapter 3).

There is little quantitative information available in the literature concerning factors that influence seal-seabird predation. Penney & Lowry (1967) found that surf and sea conditions influence predation by leopard seals on Adelie penguins, but no diurnal pattern was evident. They made use of continuous observations, which are quantifiable (see Chapter 3). Other accounts of seal-seabird predation in the literature (see Chapter 2 for references) are descriptive rather than quantitative, primarily due to the incidental nature of the observations.

However, in the present study (as shown in Chapter 3), incidental observations – which form the bulk of the data – may reveal trends in predation despite the biases inherent in this sampling technique. The present attempt at quantifying aspects of seal-seabird predatory activity serves as an exploratory investigation to gain insight into the differences between prey species with respect to various factors, and is the subject of this chapter.

METHODS

The methods of observation and recording of predatory activity are described in Chapter 3. Because environmental, spatial and temporal parameters are valid as measured for each event, regardless of the method of observation, all records of predation were grouped and these trends investigated.

Various environmental factors were recorded daily. The sea surface temperature (SST) was measured every morning at 08:00 by collecting a sample of seawater and measuring the temperature to the closest 0.1°C. The wind speed (according to the Beaufort Scale (BS)), and wind direction were recorded daily at 08:00, 14:00 and 20:00. For each predation record, the BS recorded at the time (08:00, 14:00 or 20:00) closest to the time of the predation was entered for the historical incidental data, whereas the BS at the time of the predation was used for the other methods.

Database

The database used for the investigation of above-mentioned trends consists of 2989 individual records of seal-seabird predation, noted between 21 September 1991 and 17 May 2001 at Ichaboe Island. BS data were available for the period 16 July

1993 to 31 May 2000; these values were averaged to obtain a single value per day. Daily SST measurements from 6 September 1991 to 14 August 2001 were used.

SST anomalies were calculated as the difference between the individual value of a particular day within a year and the average SST of that day over the years. Therefore, a positive anomaly indicates that the temperature was warmer on the day in question than the average value for that day over the years for which the data is available. These records of ambient environmental conditions are referred to as "overall" conditions.

Selection of records

Records were grouped according to the parameter being investigated. A year was chosen such that it started on 1 July and ended on 30 June in order to incorporate the annual peak in predation. The years were numbered '1' to '10', such that year '1' runs from 1 July 1991 to 30 June 1992, year '2' from 1 July 1992 to 30 June 1993, and so forth. Each year was further divided into three periods (referred to as seasons): 1) July to October (winter); 2) November to February (breeding season); 3) March to June (fledging season).

Where bird ages are compared within species, only those records for which the age class of the bird was known, were used. Small sample sizes resulted for those species (such as penguins) where the age of the bird is difficult to determine during a predation.

Statistical analyses

Where more than two independent frequency distributions were compared, the Kruskal Wallis ANOVA was used; for only two groups the Kolmogorov-Smirnov

Test was used. Categorical variables were compared using the Spearman Chi-squared Test. Fisher's exact test was used to test for significance in 2 x 2 contingency tables (Summers & Underhill, 1987; see Table 4.2). Statistical significance was set at $p < 0.05$.

Assumptions

Individual records of predation are assumed to be independent. However, this assumption is violated on account of the fact that some seals may have been responsible for more than one predation. This departure from assumption will result in the calculated significance levels being too small, but the extent of the problem is impossible to quantify, due to the difficulty in identifying individual seals.

While observer effort is known to be inconsistent (see Chapter 3), it is assumed that there is adequate representation of sampling throughout the relevant environmental, spatial and temporal ranges under investigation.

RESULTS

The prey could be identified in 96% (n = 2876) of predatory events; of these, 75.6% of the victims could be allocated into age classes (Table 4.1).

Table 4.1. Number of adult and juvenile birds of each species preyed upon by seals between 21 September 1991 and 17 May 2001 at Ichaboe Island (n = 2876). % - percentage of n. The sum of adults and juveniles differ from the total in cases where the species, but not the age of the bird, was identified.

	Adults	Juveniles	Total	%
Cape gannets	569	449	1021	35.5
African penguins	384	44	549	19.1
Cormorants	183	545	1306	45.4
of which:				
Cape cormorants	99	456	555	19.3
Bank cormorants	53	89	142	4.9

Temporal factors

- Annual

There was marked inter-annual variation in the number of birds preyed upon (Kruskal-Wallis ANOVA: H (9, n = 2904) = 586.48; $p < 0.001$) (Figure 4.1). Four distinct phases are evident in the annual pattern of predation:

- years 1 and 2, where 93.5% of predations noted involved adult birds;
- years 3 and 4, which together account for only 2.1% of predations and where 96.7% of birds preyed upon were adults;
- years 5 to 8, which incorporate a peak in predatory activity, and where predation on juveniles (71.6%) exceeds that of adults;
- years 9 and 10, during which more adult birds (54.7%) were preyed upon than juveniles.

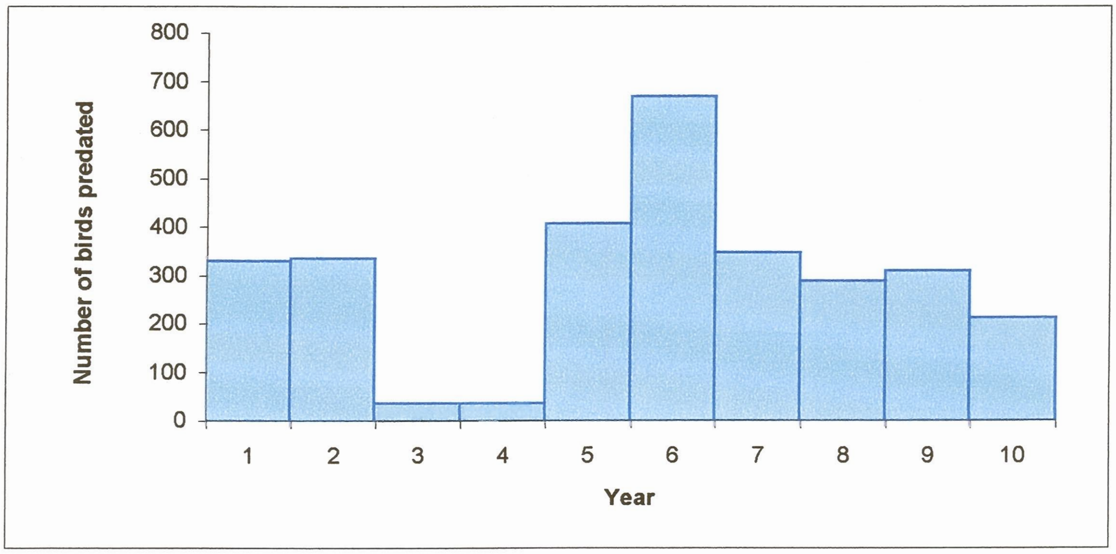


Figure 4.1. Frequency distribution of the number of birds preyed upon by seals at Ichaboe Island per year, where year '1' runs from 1 July 1991 to 30 June 1992, year '2' from 1 July 1992 to 30 June 1993, and so forth.

- *Seasonal*

When the total number of predations noted per year, as illustrated in Figure 4.1, is separated according to season as well as the respective prey species and ages (Figure 4.2), further differences are evident.

For each prey species, the number of adults and juveniles preyed upon, differed significantly with respect to season (Kolmogorov-Smirnov Tests: gannets: $p < 0.001$; penguins: $p < 0.05$; Cape cormorants: $p < 0.001$; bank cormorants: $p < 0.001$). Whereas 92.8% of predations involving a juvenile bird occurred in season 3 (March to June), the majority (65.5%) of adult birds fell prey to seals in season 2 (November to February). This, together with the four phases mentioned earlier, is illustrated in Figure 4.2.

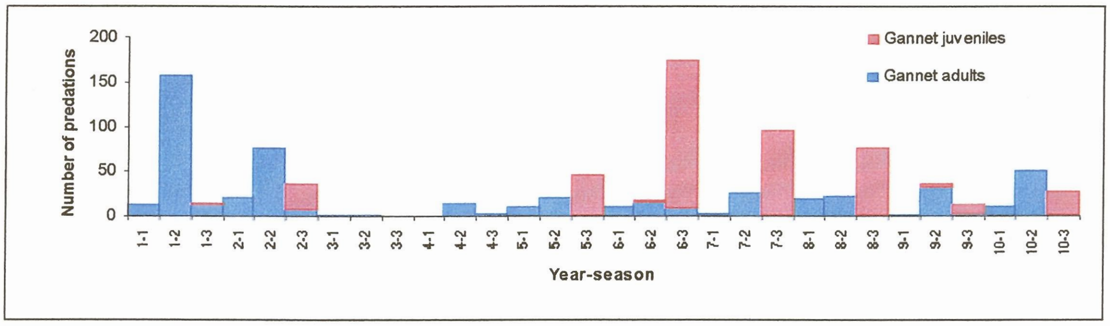


Figure 4.2a

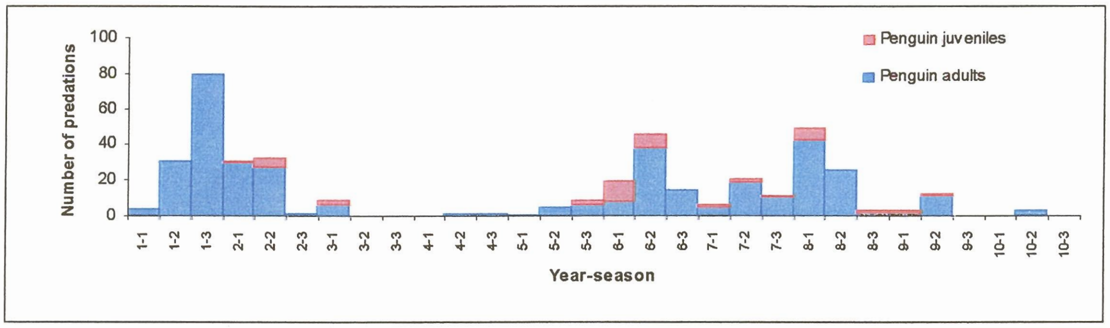


Figure 4.2b

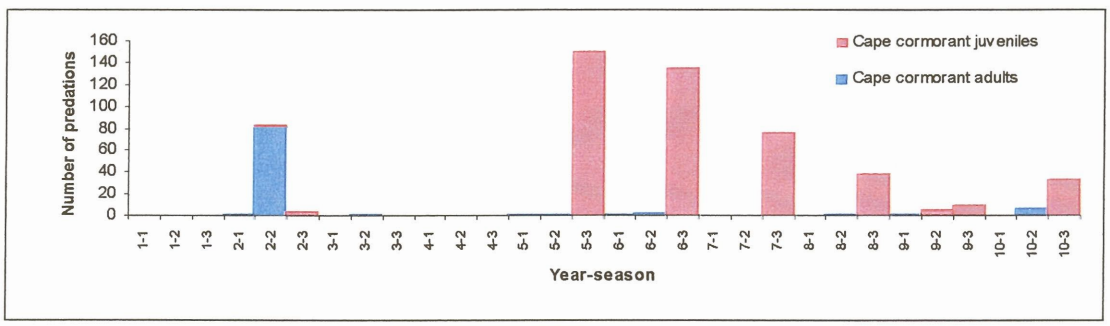


Figure 4.2c

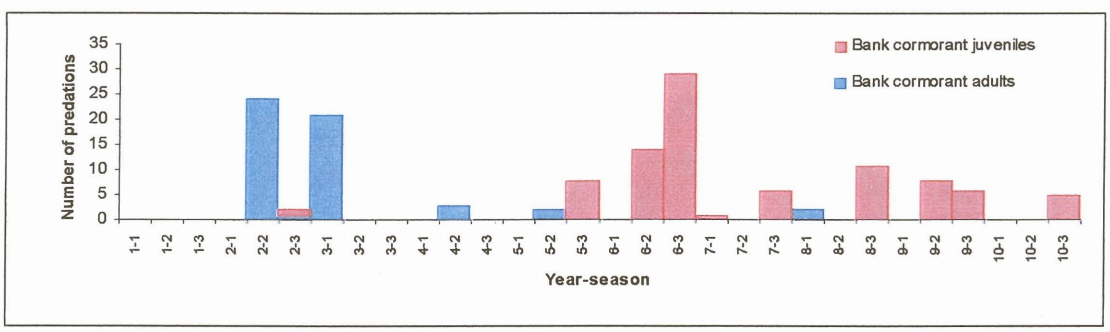


Figure 4.2d

Figure 4.2. Number of adult and juvenile birds preyed upon by seals in each season over ten years (see text for details). Bird species predated: **a** – gannets; **b** – penguins; **c** – Cape cormorants; **d** – Bank cormorants.

Peaks in predatory activity were evident during those times when the four seals that were individually identifiable (see Chapter 2) were actively preying upon birds. During year 2, seasons 2 and 3, at least 68.9% of Cape cormorant and 76.9% of bank cormorant predations were carried out by "U" (2-2 to 2-3, Figure 4.2c,d). Broad Flipper was active during the peak in penguin predation in year 1, seasons 2 and 3 (1-2 to 1-3, Figure 4.2b). The 1996/1997 peak in predatory activity falls within the period when both Blunt Flipper and Ragged Flipper were active. Blunt Flipper was observed killing all four bird species, and contributed to the number of predations from year 5, season 3 to year 8, season 2 (5-3 to 8-2, Figure 4.2). Ragged Flipper was seen preying on penguins only, and was active between season 2 of year 6 to season 1, year 8 (6-2 to 8-1, Figure 4.2b). The predations on gannet fledglings in April and May 1993 (2-3, Figure 4.2a) are likely to have been carried out by an individual seal which only removed the viscera of the birds.

- Diurnal

Within each prey species, the time of day that adults and juveniles were taken by seals differs significantly (Kolmogorov-Smirnov Tests: gannets: $p < 0.001$; penguins: $p < 0.05$; Cape cormorants: $p < 0.001$; bank cormorants: $p < 0.05$) (Figure 4.3). While gannet fledglings were taken predominantly at midday, adult gannets were seen to fall prey to seals throughout the day, peaking after midday (Figure 4.3a). Over 85% of penguins identified as adults fell prey to seals after midday; juveniles of the same species were also preyed upon predominantly in the afternoon (Figure 4.3b). Adult Cape and bank cormorants were preyed upon in the morning, and again in the late afternoon. Juvenile Cape cormorants were preyed upon by seals throughout the day; predations on bank cormorant juveniles peak at midday (Figures 4.3c, d).

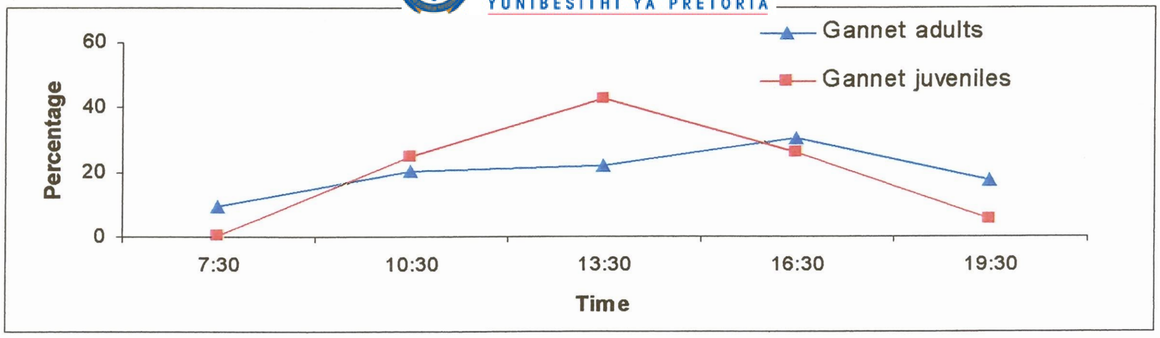


Figure 4.3a

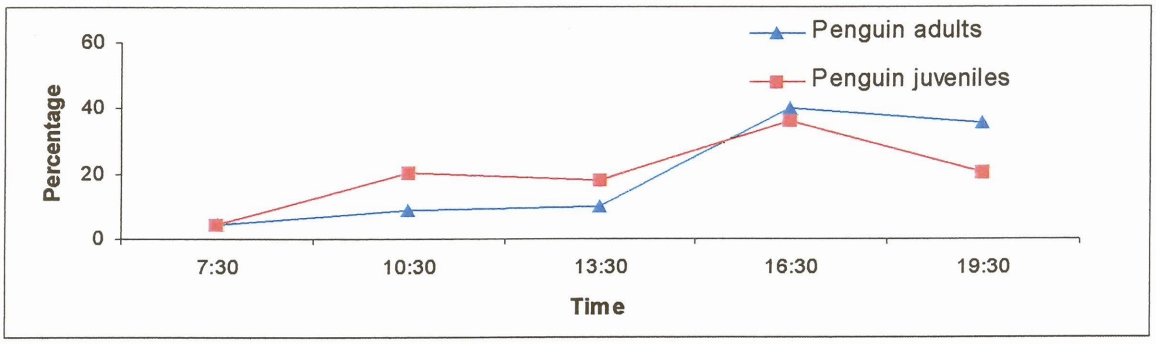


Figure 4.3b

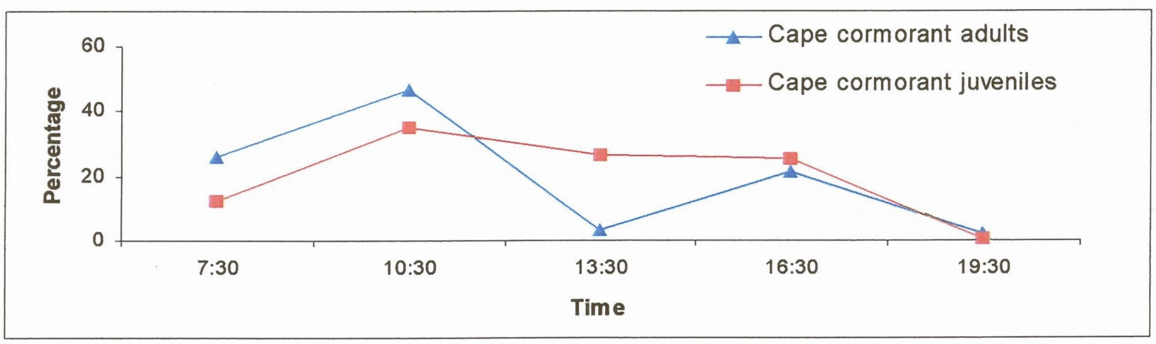


Figure 4.3c

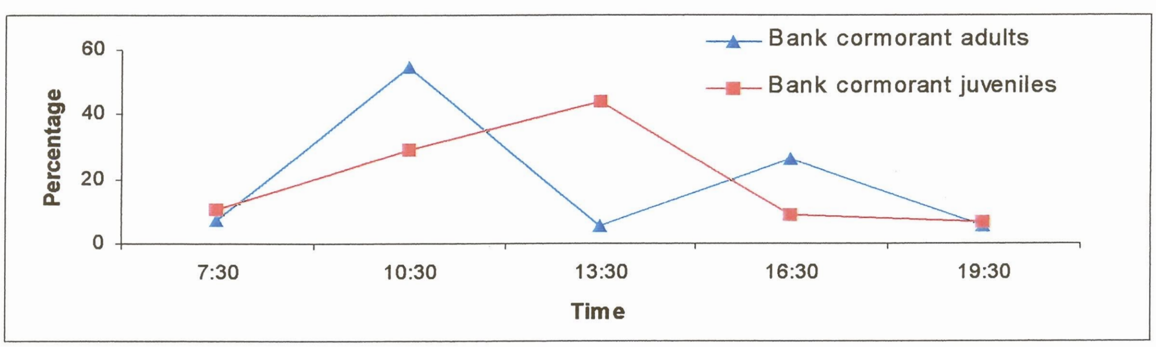


Figure 4.3d

Figure 4.3. Percentage distributions of the number of adult and juvenile birds preyed upon by seals throughout the day. Bird species: **a** – gannets; **b** – penguins; **c** – Cape cormorants; **d** – bank cormorants.

Environmental factors

- Beaufort Scale

While the Beaufort Scale of wind speed as measured during gannet and cormorant predations differed significantly from the overall BS (Kolmogorov-Smirnov Test; $p < 0.001$ in each case), this was not the case for penguin predations (Kolmogorov-Smirnov Test; p = n.s.) (Figure 4.4). A peak in predatory activity was noted at BS 4 for each prey species. A greater percentage of gannet predations occurred in conditions of high wind speed than both penguin and cormorant predations; this is also evident in Figure 4.5.

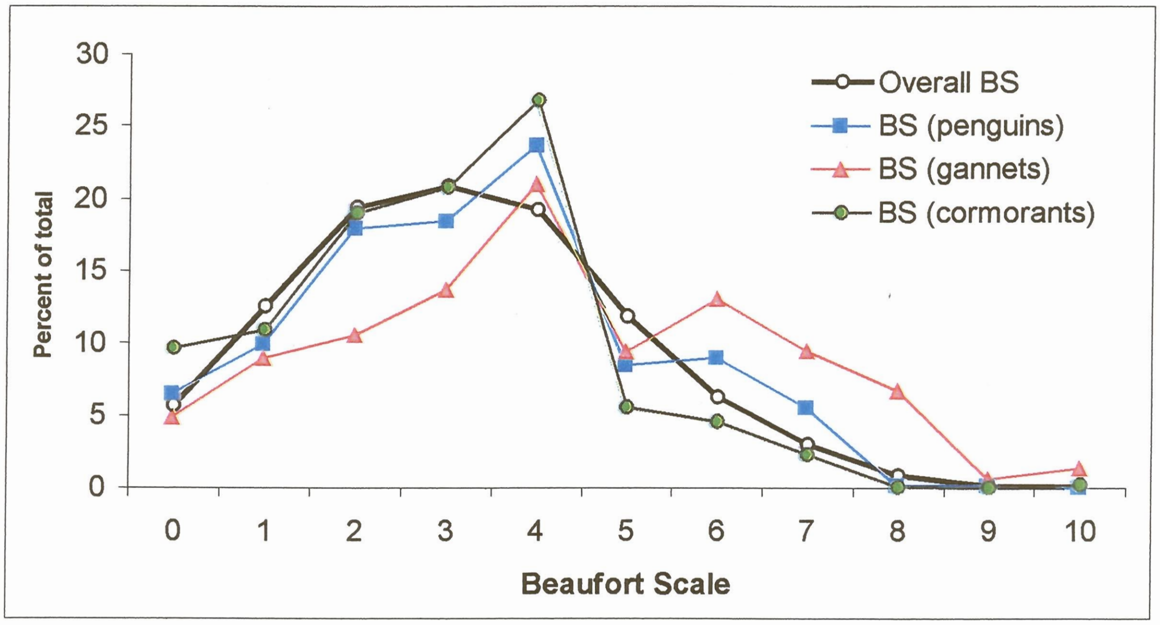


Figure 4.4. Comparison between overall Beaufort Scale and Beaufort Scale associated with predations by seals involving penguins, gannets and cormorants.

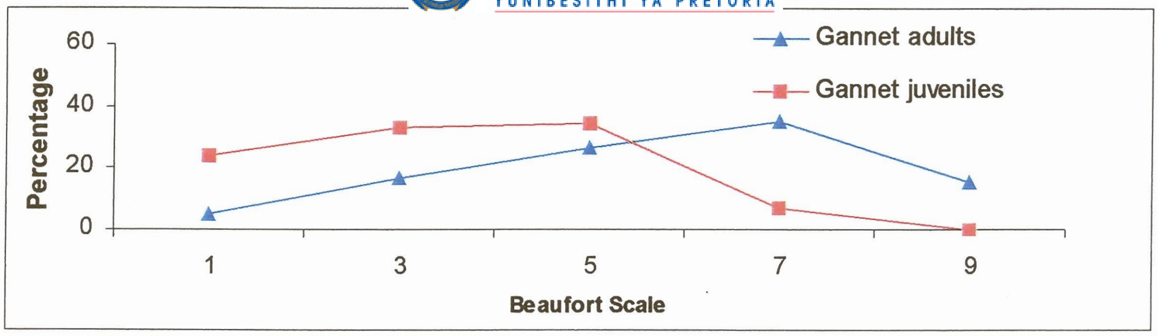
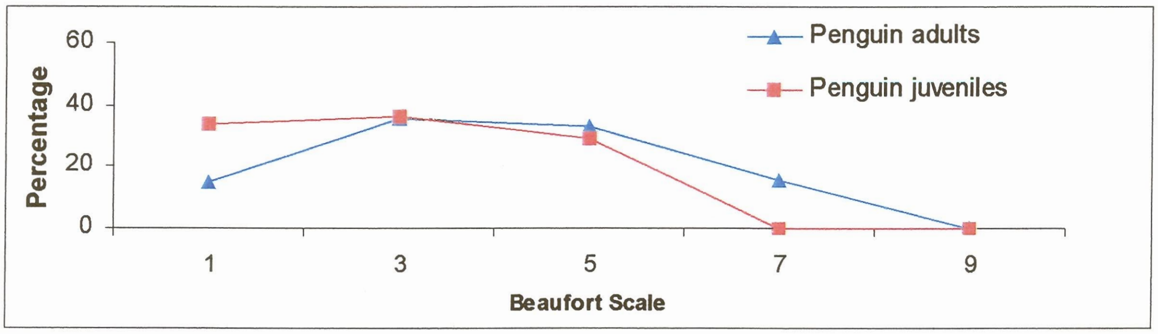


Figure 4.5a



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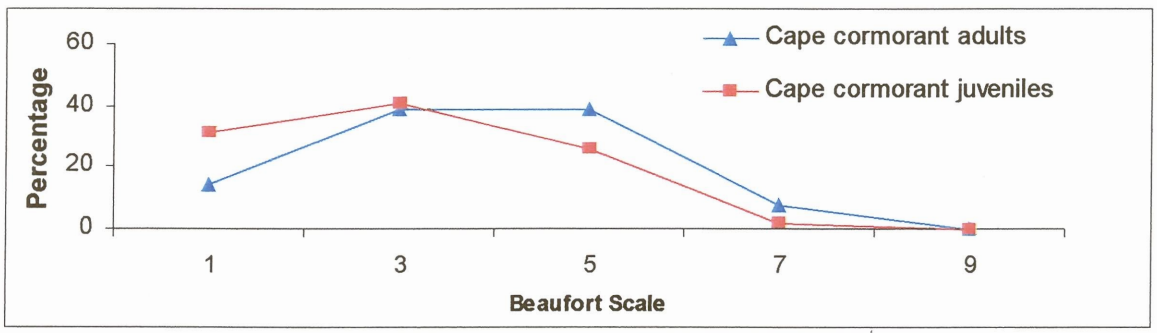

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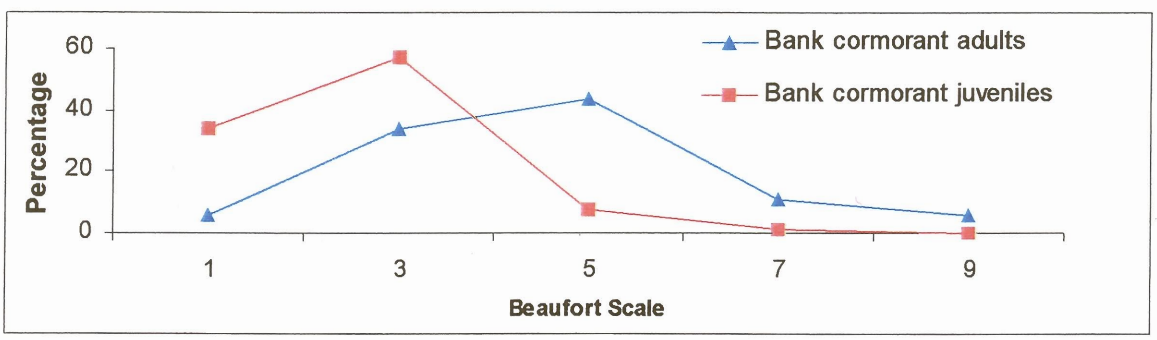


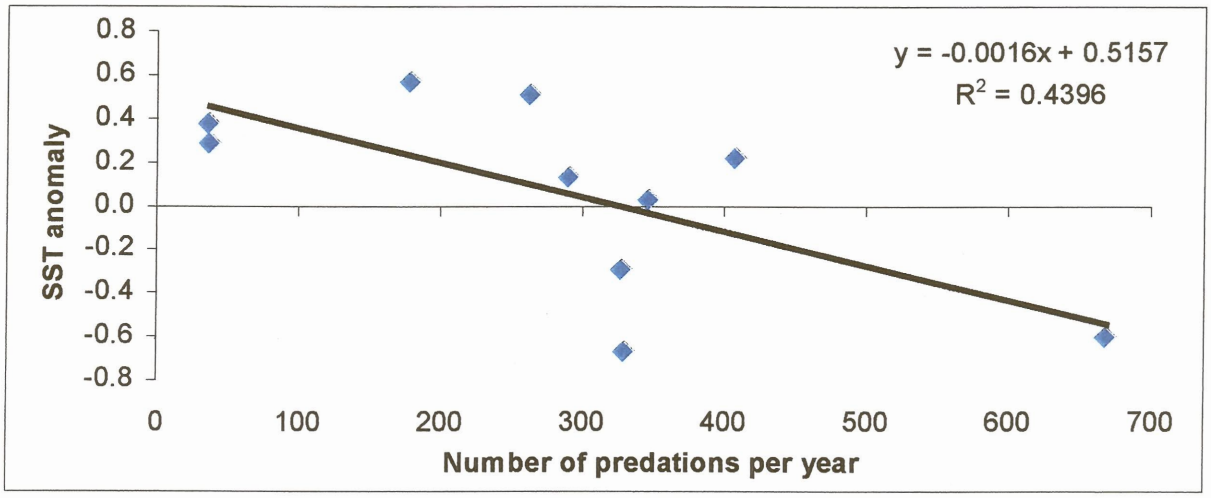
Figure 4.5d

Figure 4.5. Percentage distributions of the number of adult and juvenile birds preyed upon by seals at different wind speeds, as measured by the Beaufort Scale. Bird species: **a** – gannets; **b** – penguins; **c** – Cape cormorants; **d** – bank cormorants.

Adult gannets were preyed upon at higher wind speeds than juveniles (Kolmogorov-Smirnov Test, $p < 0.001$; Figure 4.5a); over 94% of predations noted at BS 8 and 9 involved adult gannets. Penguin predations were noted predominantly at BS 2 to 5; adults and juveniles differ significantly (Kolmogorov-Smirnov Test, $p < 0.01$; Figure 4.5b). Predation on newly fledged as well as adult Cape cormorants differ significantly (Kolmogorov-Smirnov Test, $p < 0.01$; Figure 4.5c) but were both noted almost exclusively at wind speeds of less than 27 knots (BS 6). Adult bank cormorants were seen to be taken by seals at higher BS than juveniles of the same species (Kolmogorov-Smirnov Test, $p < 0.001$; Figure 4.5d).

- Sea Surface Temperature

There is an inverse relationship between the annual average SST anomalies and the number of seal-seabird predations per year (Figure 4.6a). Annual predation rates of less than 300 birds all correspond with positive annual average SST anomalies, while during those years with a negative average SST anomaly, over 300 birds fell prey to seals. Figure 4.6b illustrates the annual trends in predation and SST anomalies. This relationship was found not to be significant when using high-low categories but significant when using the change between years, when examined using 2x2 contingency tables (Table 4.2).



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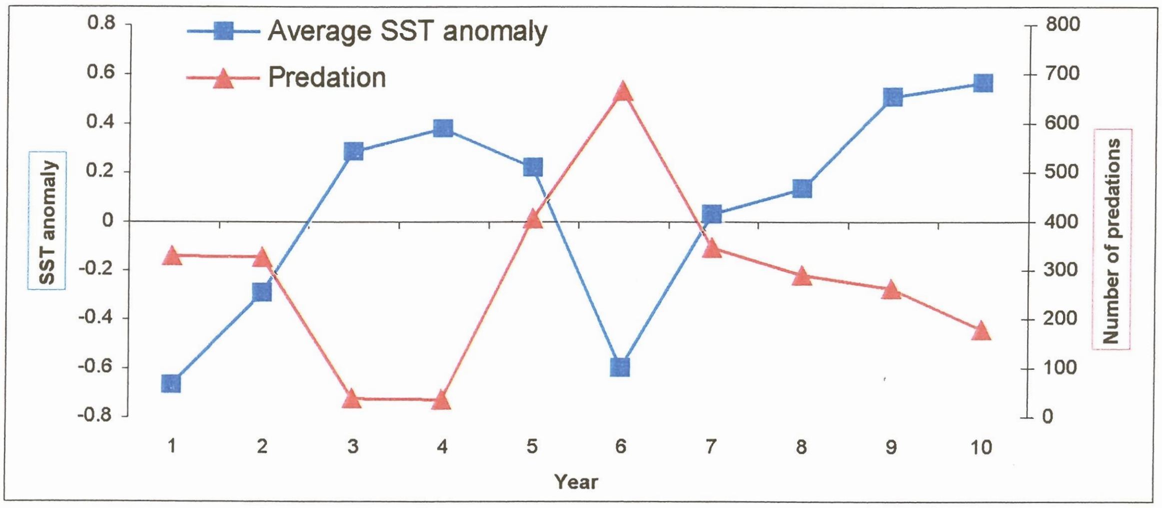

b

Figure 4.6. The relationship between the annual average sea surface temperature (SST) anomalies and the number of seal-seabird predations noted per year. **a** – linear relationship; **b** – plot per annum.

Table 4.2. Relationships between the annual average SST anomaly and the number of predations per year. Contingency tables: **A** – using high-low categories, **B** – using change. Probabilities are based on Fisher's exact test (two-tailed).

A

	Annual predation	
SST anomaly	High (>300)	Low (<300)
High (>0.2)	1	4
Low (<0.2)	4	1
Probability	0.2064	

B

	Annual predation	
SST anomaly	Rise	Fall or same
Rise	0	7
Fall	2	0
Probability	0.0138	

Spatial factors

While the majority of penguin and cormorant predations was noted less than 200 m from the island, this is not the case for gannets, which were noted to fall prey to seals as far as 1000 m from the island. Over 42% of adult gannet predations (for which distance data is available) occurred at a distance greater than 400 m from the island (Figure 4.7a). In contrast, only 3.5% of predations on newly fledged gannets were recorded in this distance class (Kolmogorov-Smirnov Test, $p < 0.001$) (Figure 4.7a).

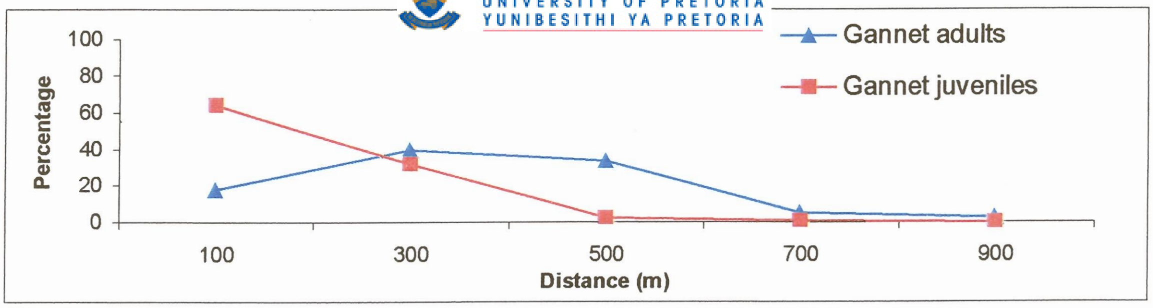

Figure 4.7a

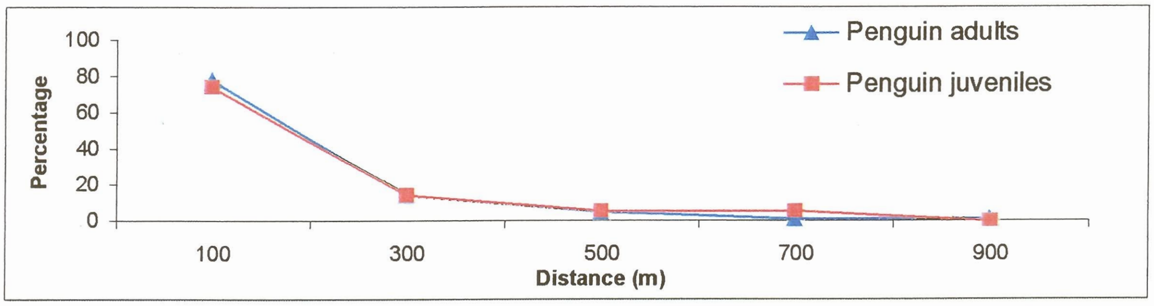

Figure 4.7b

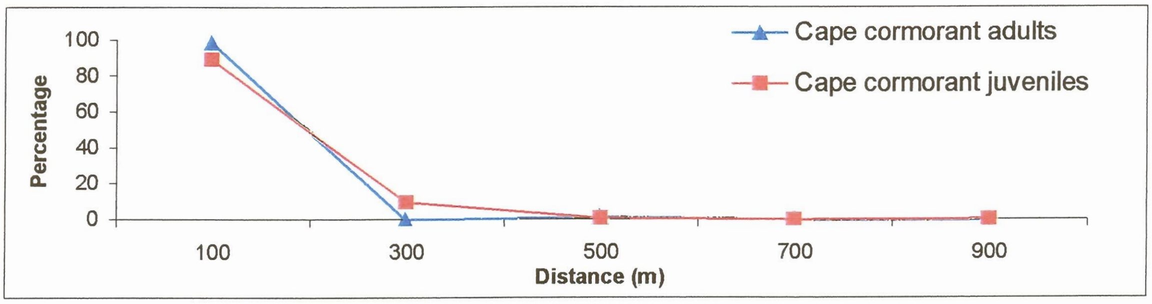

Figure 4.7c

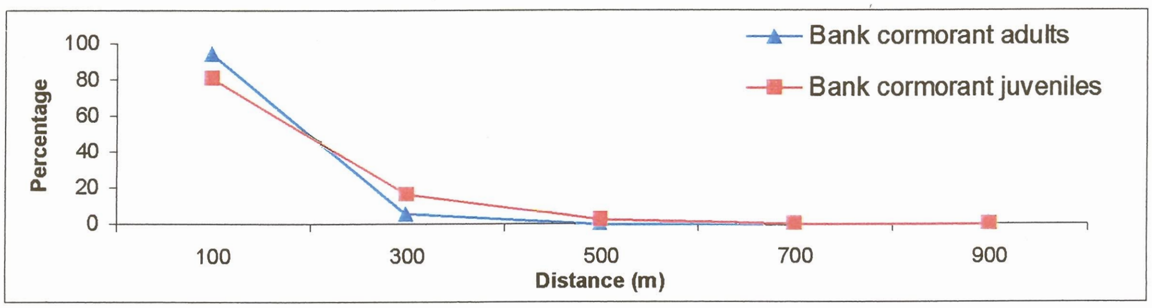

Figure 4.7d

Figure 4.7. Percentage distributions of the number of adult and juvenile birds preyed upon by seals at different distances from the island. Bird species: **a** – gannets; **b** – penguins; **c** – Cape cormorants; **d** – bank cormorants.

DISCUSSION

Bird species preyed upon

During the seal's thrashing action, and when the bird is tossed in an arc through the air, the prey may be identified by its size, shape and colour. For instance, the flailing wings of a cormorant being thrashed and its relatively small size confirms the genus but not the species of bird preyed upon. Only if the carcass is collected can the species and age be determined. Gannets, on the other hand, are easier to identify during a predatory event, or even when a drifting carcass is seen from a distance, due to their large size, and distinct colour difference between adults and fledglings. Penguins have a characteristic silhouette that can be identified at a distance if tossed by the seal; because this does not always occur, the identification of penguins falling prey to seals may be under-represented. Furthermore, adult penguins can be identified by the presence of white colouration on the carcass, while juveniles can only be positively identified upon inspection of the carcass.

Due to these differences in the probability of identifying the age and species of birds falling prey to seals, the numbers given in Table 4.1 are not an accurate reflection of the actual numbers of birds taken. Moreover, because the majority of the observations were incidental, this may further skew the observed numbers of different bird species preyed upon. Nevertheless, the environmental, spatial and temporal parameters recorded for each event are relevant to the particular prey species, the analysis of which may reveal biologically significant trends.

Annual trends in predation

The large annual variation in the number of records of seal-seabird predation may be partly ascribed to the incidental nature of the majority of the observations.

However, this variation also serves to confirm that birds do not form part of the normal prey of these seals – opportunistic predation is bound to be variable. Despite this, a decrease in predatory activity is noted between years 6 and 10, which may coincide with the decline in bird populations over this time (see Chapter 5), as well as SST anomalies (see later). Furthermore, seals specialising in seabird predation and taking large numbers of birds in a particular year or season (see Chapter 2) may contribute to the annual and seasonal variation noted, especially if a particular prey species is targeted. It is likely that peaks in predation of a particular prey species and age – such as in year 1, season 2, where the highest number of adult gannet predations was recorded (Figure 4.2a) – are due to one or more seals targeting this prey. Such behaviour may also explain the predominantly adult prey prior to year 5. The small number of seal-seabird predations noted in years 3 and 4 may be linked to a rise in sea temperature at this time (see later). The removal of seals specialising in taking seabirds has unnaturally contributed to the seasonal and annual variation in predation.

The seal population at Little Ichaboe has grown over the past 10 years, with increased recruitment of young seals as well as an increase in pup production (MFMR, unpublished data), resulting in a larger subadult age-group around Ichaboe. Concomitant with the increase in breeding activity by seals on Little Ichaboe, larger numbers of subadult seals are displaced each year. As this age-group was responsible for the most seabird predations, an increase in predatory activity over the 10-year period is expected. That this was not the case suggests that not all seals prey on seabirds.

Seasonal trends

The seasons defined for this study, namely winter (July to October), breeding season (November to February) and fledging season (March to June), proved useful in highlighting the seasonality in the pattern of predation. Figure 4.2 shows that newly-fledged gannets and Cape cormorants fall prey to seals almost exclusively in season 3 (fledging season), while bank cormorants sometimes fledge earlier in the year. Penguins, on the other hand, are not as synchronised in their breeding, and juvenile penguins are present year-round. The paucity of juvenile penguin predations may be attributed to the difficulty in identifying the age of these birds during a predatory event. Trends may be obscured by the large variation resulting from small sample sizes.

Fledgling gannets and cormorants are easy prey for seals (see Chapter 2), and may be both targeted and taken opportunistically; hence their large representation in the predation records.

Diurnal trends

The large number of adult gannet predations in the afternoon may be linked to wind speed (see below). Newly fledged gannets leave the island throughout the morning, and are at peak numbers on the water at midday, returning to the island or swimming beyond the area of predatory activity by late afternoon. Their diurnal pattern of predation therefore corresponds with the number of birds sitting on the water and available for seals to take as prey.

Penguins return to the island in the late afternoon in groups, satiated and probably swimming more slowly than usual. Some seals capitalise on this (see

Chapter 2), ambushing these birds close to their haul-out sites on the island, hence the increase in observed penguin predations at this time.

The activity of adult cormorants diving for nesting material peaks at mid-morning (pers. obs); the number of these birds falling prey to seals follows the same trend. The second spurt of predation on adult cormorants in the late afternoon may be attributable to the presence on the water of birds washing themselves after being relieved from their nests by partners that have returned from a day's fishing (pers. obs).

Juvenile cormorants gather in groups on the beaches in the morning, and are present in large numbers on the water by mid-morning, hence the observed peak in predatory activity. As the juvenile Cape cormorants disperse later in the day, or take off from the water, aided by an increase in wind, a peak in predation on newly-fledged bank cormorants is noted, which are heavier and possibly have more difficulty in take-off. A further consideration in the observed diurnal pattern of juvenile cormorant predation is the collection of carcasses by the observer. Juvenile cormorants can only be accurately identified upon inspection of the carcass; the peak in mid-morning predations of these may be partially attributable to the preferred time of the observer to go out onto the water and collect carcasses preyed upon by seals.

Beaufort Scale

Newly-fledged gannets are unable to take off from the water unless aided by wind, due to their heavy fledging weight (Navarro 2000), so at low wind speeds cannot escape predation by seals. Adult gannet fishing activity increases with wind speed (Nelson 1978; pers. obs), which generally increases through the day. Furthermore, gannet clouds tend to form in conditions of strong wind; because these are highly visible cues mostly indicating gannet predations (see Chapter 2), observed predation in these conditions may be biased toward gannets.

Because penguin activity is not influenced by wind to the same extent as the activity of flying birds, predation on this species at different BS is not expected to differ from overall conditions, which was indeed found to be the case (see Figure 4.4).

During conditions of strong wind, sea conditions may obscure cormorant predations, which are of short duration and not associated with conspicuous cues (see Chapter 2). These may therefore be under-represented at high BS. However, cormorant activity also increases with wind, such that these birds may be further afield during conditions of greater wind speed.

The observed peak in predatory activity for each prey species at BS 4 is an artefact of the method of recording this data for the records during the historical incidental observations, which form the bulk of the data. Predation events occurring between 11:00 and 17:00 (which constitute the majority of the records) would have been assigned the BS as recorded at 14:00. The general increase in wind speed after 14:00 would therefore not be reflected in predation records.

Sea surface temperature

The differences in the p-values as calculated using Fisher's exact test, in Table 4.2 are ascribed to the small sample size; however, the biological significance is of more importance.

Negative SST anomalies are associated with cold water upwelling, which culminates in large fish stocks (Boyera *et al.* 2000). When daily SST anomalies are averaged over a year, and the result is negative, this indicates that more upwelling occurred in that particular year than average. A negative annual average SST anomaly may therefore indicate that there was more fish available for both seals and birds during that year, and vice versa. If this is the case, predation on seabirds is apparently greater in years when there is abundant fish (see Figure 4.6). During years 3 and 4, when seal-seabird predation was at its lowest at Ichaboe, oxygen-poor water was widespread, and an estimated 300 000 seals – almost a third of the total Namibian population – died of malnutrition (Roux 1998). This may serve to confirm that seals do not prey on birds as an alternative food resource.

It is possible that seabird predation is energetically more costly for seals than preying on fish, and that in "poor" years (positive average SST anomaly) seals are searching for fish rather than taking birds. This also supports the hypothesis that seabird predation by seals may be an extension of play behaviour, which is energetically costly (Nunes, Muecke, Anthony & Batterbee 1999). King (1983) describes the young males in particular as active and noisy, also engaging in play.

Roux (1998) relates an incident in 1988 when an increase in the SST in the Lüderitz region due to a lack of wind resulted in seals being unable to find enough fish in the vicinity of their breeding colonies. Therefore, in "poor" years, both seals and birds would be searching further afield for fish, such that seal-seabird predatory interactions are unlikely to be observed from the island.

The above explanation for the relationship between the SST anomalies and the number of birds predated by seals per year is speculation, as no evidence of the same could be found in the literature.

Distance

Gannet clouds, being a highly visible cue to predatory activity (see Chapter 2), are likely to been seen at great distances. Because these are mostly associated with predatory events involving adult gannets, the distribution of observed predations may be skewed toward these birds at greater distances from the island. Furthermore, the large size and white colouring of adult gannets may make carcasses of these birds visible at up to 1000 m. However, the fishing activity of these birds occurs mostly farther than 500 m from the island, which may account for the observed distances at which these birds were seen to be taken by seals. Newly-fledged gannets were taken while swimming out from the island, or while sitting on the water, where they spend a large proportion of their time at this stage of their lives.

Though penguin and cormorant predations were less visible than those involving gannets, the large number of these birds falling prey to seals close to the island can be explained in terms of the birds' behaviour. Penguins were caught close to the island when leaving or returning in groups from their haul-out sites, and may form a larger target for seals, especially in the afternoon when satiated. Some seals ambushed and killed penguins close to these haul-out sites (see Chapter 2). Cormorant adults were taken while they are diving for nesting material in the shallows around the island, while the fledglings were targeted by seals while they are sitting on the water in large groups close to the island.

CHAPTER 5: IMPACT OF SEAL-SEABIRD PREDATION

INTRODUCTION

In order to investigate the impact of seal-seabird predation on populations at Ichaboe Island, it is important to compare this with other mortality factors that influence the bird populations. These include insufficient food resources, oiling, kelp gull predation, heat stress, diseases and deliberate or accidental human-induced mortalities (see Chapter 1). Seabirds have low adult mortality rates and are generally long-lived (Berruti *et al.* 1989). Factors contributing to the mortality of especially the breeding populations need to be addressed in attempting to improve the conservation status of these birds.

The predation impact by seals on penguins at Lambert's Bay (20% of chicks fledged and 4% of adults annually) is believed to be unsustainable, as recruitment to the breeding population is prevented. Seal predation alone may cause the extinction of this colony in 23 years' time. Therefore, predation by seals threaten the survival of small populations of seabirds (Crawford *et al.* 2001).

Cape cormorants were the most numerous seabird species breeding on Ichaboe for each of the ten years covered in this study, followed by Cape gannets, African penguins and Bank cormorants (MFMR unpublished data). The total observed predation by seals on gannets (n = 1021) exceeds that of Cape cormorants (n = 555) for this period, implying a greater predation pressure on the gannet population. However, predatory events involving cormorants are under-represented in the data at hand due to the inherent difficulties of observation at high wind speeds and possibly at greater distances from the island, whereas those involving gannets are more readily noted (see Chapter 4). Therefore, incidental observations would note a greater proportion of gannet than cormorant predations. It is necessary to address such bias in results when using the figures to calculate predation pressures. Furthermore, the number of birds that fledge per nest may be site specific and differ per season (MFMR, unpublished data); this may introduce further error in the calculation of predation pressure.

An unknown cause of mortality in gannets, particularly the adults, unknown (or unreported) except at Ichaboe Island, is that of "soaking", where these birds lose their waterproofing and may die of hypothermia and loss of condition (du Toit & Bartlett, 2001). This added mortality factor was investigated in order to assess its relative importance.

METHODS

Calculation of predation impact per species

The sum, over a one-year period (July to June), of counts of the number of adult penguins in the feather shedding stage of their moult, made at 14-day intervals, is used as a conservative estimate of the number of adult penguins (Crawford & Dyer 1995; Crawford *et al.* 1990). Peak active nest counts of Cape and bank cormorants (MFMR unpublished data) are used to estimate the numbers of these birds on the island. Active nest counts are multiplied by two to give a conservative estimate of the number of adult cormorants and gannets. It was assumed that 0.74 gannets fledged per nest (Nelson 1978), and 0.47 penguin chicks (Crawford & Boonstra 1994).

Aerial census counts of gannets on Ichaboe on 17 December 1999 were done by enlargement of black-and-white aerial photographs and counting individual birds (not flying) by marking each with a pen. These counts were compared with counts done on the same photographs that were scanned into computer on high resolution, and the zoom and contrast enhanced digitally to distinguish individual birds with greater accuracy.

The predation impact per species was calculated as the percentage of birds that fell prey to seals, using the adjusted values for predation numbers.

Other causes of mortality – soaked gannets

Between December 2000 and April 2001, an intensive ringing and retrap study was conducted on soaked gannets at Ichaboe Island. Soaked gannets can be recognised by their inability to take off from the water. They are less buoyant, and sit deeper in the water than healthy birds. If strong enough, they will swim to land, or even attempt to haul out on a boat. The plumage is wet, and often with a yellow tinge; severe contamination results in a deep yellow discolouration, with the feathers being sticky to the touch and smelling slightly fishy. The feathers do not interlock, and the birds have a scruffy appearance (Figure 5.1).

The number of soaked birds was recorded, with data concerning the environmental conditions, and the severity and localised area of soaking. A total of 93 soaked birds were ringed, and regular searches made for birds with rings, which were then caught and the ring number noted. Where feasible, the bird was weighed (n = 86) when wet, and in a few cases (n = 21) kept in a pen until dry, and weighed again.

A

B

C

D

Figure 5.1. Soaked, or waterlogged gannets. **a** – note the scruffy appearance and yellow discolouring of the feathers; **b** – the left-hand-side of this bird was contaminated and it died of poor condition; **c** – the neck of a gannet fledgling showing a severe case of soaking, where the feathers are sticky and do not interlock and the down has a deep yellow discolouring; **d** – this bird is soaked through but not discoloured.

RESULTS

Aerial census counts

The count from the aerial photographs done on enlarged prints, resulted in a total of 14 291 individual gannets. The same count done with the aid of a computer, totalled 16 453, representing a 13.1% discrepancy.

Impact of predation

In 1996, the breeding colony of gannets on Ichaboe occupied 0.56 ha (Crawford 2000c); density counts conducted on the same day (MFMR, unpublished data) gave a total of 25 034 nests. Therefore, 18 525 gannets would have fledged in the 1996-1997 season. A total of 167 gannet fledglings were taken by seals during this time, a predation rate of 0.9%; that for the adults was 0.08% (40 adult gannets fell prey to seals during this time). Using the higher of the aerial census counts for 1999 mentioned above, and interpreting these as representing nests, 11 517 gannets would have fledged from Ichaboe during the 1999-2000 season. During this time, 13 gannet fledglings fell prey to seals, a predation rate of 0.1%; the adult predation rate was the same.

In January 1993, the peak count of active nests of bank cormorants numbered 5182; the predation impact on adults for year 3 equals 0.2%; these are believed to have been carried out by a single seal ("U"; see Chapter 2). After this seal was shot, predation on adult cormorants declined to less than five per year (see Figure 4.2c,d).

The predation pressure on adult penguins in year 9 equals 0.2% when using moult counts to estimate the number of these birds on the island during that time. That of fledgling penguins is estimated to be 0.25% for the same period.

Soaked birds

A total of 744 soaked gannets were recorded between April 1996 and May 2000. A further 97 gannets that were soaked, were found dead during this time. Out of 170 soaked birds noted between December 2000 and May 2001, two were Cape cormorants adults, 135 Cape gannet adults and 33 gannet fledglings. A total of 80 adult and 13 juvenile gannets were ringed. The average difference between the wet and dry weight (i.e. weight of water absorbed) was 191.67 g; the maximum was 400 g. On average, soaked birds weighed 266.6g less than healthy birds (which weigh, on average, 2645g; Maclean, 1985), despite being waterlogged.

The majority of the birds were contaminated on their wings, back and belly, with the sides and tail the next most abundant as areas of localised waterlogging. Seventeen birds were soaked on one side only; one bird in particular was discoloured, soaked through and sticky on only the left hand side – this bird was later found dead (see Figure 5.1b).

Out of the 93 birds ringed during this study, 14 were resighted. Of these, 11 birds were resoaked – one was resoaked three times – and two resoaked birds were found dead. Only one gannet that had been soaked was seen in good condition at least one month later. In addition to the live soaked birds, 14 soaked gannets were found dead on the island, and a further 11 adrift. Another soaked bird (not ringed) had a long-line hook embedded in its neck, and died one day later. Almost 90% of the soaked gannets observed were at wind speeds of less than 10 knots.

DISCUSSION

Bias in results

Though counting individual animals on aerial photographs may be more accurate than ground counts, while also allowing for repeat counts (Lowry 1999), the method used to count from the aerial photographs may affect the accuracy of the count. Counting birds on aerial photographs with the aid of a computer is believed to be more accurate than counting from enlarged photographs; the difference found between these methods indicate a potential source of error in such data. Due to the large temporal variation in predation by seals on seabirds at Ichaboe Island (see Chapter 4), the predation pressure calculated for one year cannot be extrapolated or used for predictive purposes. The number of predations that occurred cannot be accurately determined due to the bias in the methods of observation (see Chapter 3). The adjusted values of predation may be more realistic, but such extrapolation is similarly based on assumptions that introduces further bias. Furthermore, the number of birds that fledge per nest may differ seasonally and spatially (at different breeding localities). Therefore, the assumptions of accuracy of the data needed to calculate the predation pressures are violated. For the same reason, calculating a mean predation pressure for each prey species over the ten year period would not be meaningful. Values of predation pressure therefore need to be treated with caution.

In addition, the identification of the species (and age class) of cormorant is only possible upon collection and inspection of the carcass, which could not be carried out during systematic observations, as the observations would have to be interrupted. Therefore, the identification of cormorant species and age classes falling prey to seals were carried out when these predations were noted incidentally, as the observer was in a position to collect and identify the carcass. This involved donning a wetsuit and often single-handedly launching a vessel and paddling or motoring to where the predation event was seen and searching for the carcass.

Impact of seal-seabird predation

Though seal-seabird predation seems to have a minimal impact on the seabird populations at Ichaboe, the number of predations reported on here should be regarded as the minimum, because it is certain that predations would have been missed regardless of the method of observation. Furthermore, it cannot be assumed that seal-seabird predation is restricted to the area around breeding colonies, and a substantial number of such events probably occur farther offshore; such incidents would not be recorded in island-based observations. Additional losses of both eggs and chicks would result from the loss of breeding adults; this mortality is difficult to assess (Penney & Lowry 1967).

Individual seals that prey on seabirds sometimes display significant preference for specific species (see Chapter 2). During the time when such seals are active, they may have a significant impact on the species targeted (see Chapter 2; Williams 1988); the removal (under licence) of such seals, if positively identified, may be considered necessary in some cases. Best *et al.* (1997) maintain that "there is some potential for control through culling animals that feed on seabirds around breeding localities" (p. 198).

Due to the higher number of adult gannets that fell prey to seals, in comparison with the other bird species, predation pressure on gannets is believed to be greater, because factors influencing adult mortality are important. However, predatory events involving adult gannets are the most visible (see Chapter 2), such that the database may under-represent predations involving adults of the other bird species. For this reason, the impact of predation per species cannot be accurately calculated or compared amongst species. This is supported by a statement by Mann (1999), who explains that because the sampling effort during incidental observations is unquantified, rates, frequencies and proportions cannot be accurately calculated.

The local populations of gannets and bank cormorants at Ichaboe form substantial proportions of the global populations of these threatened species (see Chapter 1). As suggested by Williams *et al.* (1990), it may be necessary for conservation authorities to safeguard these populations from causes of population decline.

Kelp gull predation

In January 1993, there were 19 active nests of kelp gulls; this number has increased to 74 nests in December 1999. Kelp gulls take unguarded eggs of other birds, and also prey on young chicks. This is exacerbated by human disturbance (such as with tourism, uncontrolled access to breeding colonies of birds and other human activities in the vicinity), when birds desert their nests, leaving them exposed to kelp gulls (Cooper 1974; Simmons *et al.* 1998). This form of mortality has the greatest impact on gannets and penguins, which lay one and two eggs respectively. Though some birds may relay if a clutch or young chicks are lost, this is not always the case (Maclean 1985). The increase in kelp gull recruitment to the island through the increase in breeding numbers is cause for concern. Furthermore, kelp gull numbers are increasing as a result of the provisioning of additional food in the form of rubbish dumps, offal etc. Breeding kelp gulls as well as large numbers that roost on the island (up to 300) prey on eggs and chicks (pers. obs). Though difficult to quantify, kelp gull predation is another potentially important mortality factor that puts added pressure on already declining penguin and gannet populations.

Whereas birds do not form part of the natural diet of seals, the taking of eggs and chicks of other birds by kelp gulls forms part of their natural diet. As established in this investigation, not all seals prey on seabirds, and this behaviour seems to be restricted to certain localities. Therefore, it is believed that the impact of kelp gull predation on seabird populations may exceed that of seals; this needs further investigation.

Soaked gannets

It is suspected that the birds become contaminated by fish oil. Gannets often scavenge hake and other offal at demersal trawlers (Crawford *et al.* 1985), which forms an oily slick when dumped at sea. Feeding chicks with the same may be messy, resulting in the contamination of their plumage too. Repetitive contact with the contaminant may result in a loss of waterproofing.

The amount of time spent in the water plays an important role, as these birds find it difficult to take off from the water when there is little wind. On the other hand, whatever is contaminating the birds may remain longer on the surface of the water in the absence of wind. Guano on the feathers may aggravate the contamination and subsequent waterlogging. Dirty or soaked gannets often try to wash themselves, which is unsuccessful as it leads to becoming resoaked.

In the light of the number of dead soaked gannets found (n = 124), the general poor condition of soaked gannets, and the likelihood that a bird will become repetitively soaked, it may be speculated that a large proportion of soaked gannets that were ringed and are unaccounted for may have died out at sea. If birds that become soaked eventually die, this is an important mortality factor – that exceeds predation pressure – to consider in the decline of the Ichaboen gannet population.

It is interesting to note that seals specialising in seabird predation do not seem to target soaked gannets, which are vulnerable as they are unable to take off from the water.

Human-induced mortality

The exploitation of the prey of seabirds, commercial collection of guano, and deliberate or accidental pollution of the marine environment by humans are believed to be causing unsustainable declines in the population numbers of the seabirds under investigation (see Chapter 1). The impact of predation by seals at Ichaboe cannot account for the decline in seabird numbers and research efforts should be directed to at-sea factors such as fisheries interactions.