APPENDIX A

Supplementary report

Climate of the Bird Islands (Algoa Bay) South Africa

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INTRODUCTION

Algoa Bay is a large, crenulated embayment facing the south-west Indian Ocean on the south-east coast of South Africa (Goschen & Schumann, 1988). Cape Recife forms the western boundary of Algoa Bay and the less prominent Cape Padrone forms the eastern boundary, with the port installations and the city of Port Elizabeth in the western section. Large columns of fresh water flow offshore from the Swartkops, Coega and Sundays rivers. The bay is characterised by a narrow continental shelf area and the Agulhas Current (Schumann, 1987; Goschen & Schumann, 1988). The sea surface temperature (SST) of the Agulhas Current varies seasonally with a maximum of 26°C in summer and 3–4°C less in winter (Schumann, 1987). There is a gradual cooling (3°C drop) of the surface waters of the Agulhas Current as it flows southwards (Schumann, 1987).

Westerly winds have a dominant influence over the inshore shelf areas throughout most of the year. However, in summer, strong easterly winds are dominant. Strong easterly winds induce upwelling of cold nutrient rich water (Beckley, 1983; Goschen, 1988; Goschen & Schumann, 1988; Schumann, Ross & Goschen, 1988). Surface flow is generally in the direction of the wind, parallel with the coast-line (Harris, 1978; Hunter, 1981). Large scale weather patterns are dominated by the eastward-moving anticyclones from the South Atlantic high-pressure cell (Hunter, 1987). Coastal lows have a marked influence on the coastal environment (Hunter, 1987).

There are two island groups in Algoa Bay: the Islets of St Croix (Jahleel and Brenton Islets; St Croix Island) and the Bird Islands (Bird, Stag and Seal Islands; Black Rocks). These islands support significant bird breeding colonies, notably the Cape penguin, *Spheniscus demersus*, Cape gannet, *Morus capensis*, and roseate tern, *Sterna dougallii*; and a breeding colony of South African (Cape) fur seals, *Arctocephalus pusillus pusillus*. The seals breed on Black Rocks which is the eastern most extreme of their breeding range, and the only breeding colony in the Eastern Cape.

Although climate data are collected daily at the Port Elizabeth Airport (33° 59'S, 25° 36'E; height 60 m), which is representative of the general climatic conditions of the Port Elizabeth coast-line, a unique micro-climate exists at the Bird Island complex due to its positioning. Bird Island (33° 50.67'S, 26° 17.34'E), the largest of the 4 outcrops, is situated 63 km from the Port Elizabeth Airport, and 8–9 km from the mainland.

In June 1992, a seal research program was established in the Eastern Cape to examine the biology and conservation of the Cape fur seal (WWF project ZA-348). Previous studies in the area suggested that storm induced pup mortality may significantly influence the population dynamics of the Black Rocks seal colony (Shaughnessy, 1982). Therefore it was necessary to collect information on the intensity and frequency of storms during the pupping season (November/December). Subsequently, a temporary weather station was errected on Bird Island. Information on storms, and the general climatic conditions of the area, was collected daily from this station over a 3 year period.

This report describes the general climatic conditions of the Bird Islands for the 3 year period, from December 1992 to January 1996. Information on the impact of storms on seal pups is presented elsewhere (Stewardson, 1999).

MATERIALS AND METHODS

Study site

Bird Island is *c*. 9 m above sea level and measures *c*. 19 ha in area. Much of the island is covered by a thick growth of *Mesembryan themum*, *Tetragonia* and *Chenopodium* (Rand, 1963).

Stag Island (33° 50.00'S, 26° 17.00'E) lies *c*. 450 m NW of the northern coast of Bird Island, and measures 1 129 m² in area. It has a raised central shingle beach which is sparely vegetated. Seal Island (33° 50.00'S, 26° 17.00'E) is larger in size (6 479 m² in area) and lies *c*. 720 m NW of the NW corner of Bird Island. The two islands are joined by a reef which extends westward from Stag Island (Rand, 1963; Chart SAN 1025).

Black Rocks (33° 50.25'S, 26° 15.87'E) lies *c*. 1 080 m W-SW of Seal Island and consists of 5 small outcrops partially joined together by a reef of drying and submerged rocks. It is: situated 8–9 km off-shore (not sheltered by headlands); small in size (the largest rocky outcrop is 8 360 m²); and low-lying (the largest outcrop is 6 m above mean sea level) (Rand, 1963, 1972; Chart SAN 1025). Therefore it is particularly susceptible to high seas. In 1992 the estimated seal population was 2 315 seals, and in 1996 it was 1 480 seals (Marine & Coastal Management, Unpubl. data).

The island complex is composed of quartzitic sandstones of the Table Mountain Group, of the Cape Supergroup. The sandstones are essentially Palaeozoic (Ordovician) (Sven Coles, pers. comm.; Bremner & Day, 1991).

Collection of data

On November 26, 1992 a temporary weather station was established on Bird Island. Information on air temperature, SST, rainfall, wind direction, wind speed and swell height, was collected daily from December 9, 1992 to January 31, 1996.

Maximum and minimum air temperatures (°C) were read once daily at 0800 hrs from a standard mercury thermometer exposed in a Stevenson screen. Sea surface temperature (°C) measurements

Fig. 1 Map of Algoa Bay, showing the Bird Islands including Black Rocks seal colony.

were read once daily at 0800 hrs from a standard mercury thermometer, and rainfall (mm) measurements were read once daily at 0800 hrs from a standard measuring cylinder.

Wind speed (knots) and direction were measured using a pressure plate anemometer. This instrument was erected on the centre of the island (on the north-east side of the path between the headman's house near the jetty and the helipad). Observations of wind activity were recorded thrice daily at 0800 hrs, 1400 hrs and 1800 hrs. The anemometer was monitored for 1–2 minutes before each reading was taken.

Swell height was recorded thrice daily at 0800 hrs, 1400 hrs and 1800 hrs. 'Subjective estimates' were based on visual observation of the water surface within several meters of the island.

Statistical analysis

Statistical analysis and graphics were implemented in Microsoft ® Excel 97 (Microsoft Corp., Seattle, 1997) and S-PLUS (MathSoft, Inc., Seattle, 1999, 5.1). Smooth curves for air temperature and SST were produced using the S-PLUS function ksmooth which performs scatter-plot smoothing using kernel estimates (Venables & Ripley, 2000). The standard normal density was used for the smoothing kernel. The kernel bandwidth smoothing parameter *h* controlled the degree of smoothing applied to the data and was set at 30 days (1 month).

RESULTS

Air temperature

Daily air temperature[1] ranged from 9⁰C to 33⁰C. Minimum temperate was recorded in winter (June 29–30, 1994; July 18, 1995; August 6 & 22, 1993) and maximum temperature was recorded in summer (February 21, 1994).

Mean monthly maximum temperature increased slightly in November; peaked in January/February (26⁰C); and then declined slowly throughout autumn, reaching a low in winter and early/mid spring (21⁰C to 22⁰C) (Table 1).

Table 1 ***Mean monthly maximum and mean monthly minimum air temperature (˚C) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)[1]***

			Minimum temp. (˚C)		Maximum temp. (˚C)	
Month	***n***	**NR**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**
Summer						
December	93	0	16.0 ± 0.2	12–19	23.8 ± 0.3	18–29
January	93	0	17.7 ± 0.2	14–22	25.8 ± 0.2	21–32
February	84	0	18.1 ± 0.2	14–21	26.0 ± 0.2	19–33
	270	**0**	**17.2 ± 0.1**	**12–22**	**25.2 ± 0.2**	**18–33**
Autumn						
March	92	1	17.2 ± 0.2	13–22	25.3 ± 0.3	20–31
April	88	2	15.3 ± 0.2	11–19	23.2 ± 0.3	18–31
May	93	0	14.7 ± 0.2	10–18	22.5 ± 0.3	14–30
	273	**3**	**15.7 ± 0.1**	**10–22**	**23.7 ± 0.2**	**14–31**
Winter						
June	90	0	13.4 ± 0.2	9–18	21.9 ± 0.3	13–30
July	93	0	12.5 ± 0.2	9–16	21.7 ± 0.3	14–32
August	93	0	12.8 ± 0.2	9–16.5	21.0 ± 0.3	14–29
	276	**0**	**12.9 ± 0.1**	**9–18**	**21.5 ± 0.2**	**13–32**
Spring						
September	90	0	13.9 ± 0.2	10–17	21.2 ± 0.2	15–27
October	93	0	14.0 ± 0.2	10–17	21.3 ± 0.2	17–26
November	90	0	16.0 ± 0.2	11–19	23.5 ± 0.2	18–28
	273	**0**	**14.6 ± 0.1**	**10–19**	**22.0 ± 0.1**	**15–28**
Total	**1092**	**3**	**15.1 ± 0.1**	**9–22**	**23.1 ± 0.1**	**13–33**
December 1992	23	0	18.5 ± 0.2	17–20	26.4 ± 0.3	23–28
January 1996	30	1	18.1 ± 0.3	14–20	26.4 ± 0.3	22–31

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

Table 2 ***Mean maximum and mean minimum air temperature (˚C) recorded at 0800 hrs daily at Bird Island according to season and year (January 1, 1993 to December 31, 1995, n = 1 095 days)***

			Minimum temp. (˚C)		Maximum temp. (˚C)	
Month	***n***	**NR**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**
Summer						
1993	90	0	18.5 ± 0.2	14–22	26.1 ± 0.2	19–33
1994	90	0	16.7 ± 0.2	13–20	24.6 ± 0.2	18–30
1995	90	0	16.5 ± 0.2	12–20	24.8 ± 0.3	18–31
	270	**0**	**17.2 ± 0.1**	**12–22**	**25.2 ± 0.2**	**18–33**
Autumn						
1993	89	3	16.7 ± 0.2	13–22	24.6 ± 0.3	18–31
1994	92	0	16.0 ± 0.2	10–19	23.9 ± 0.3	16–31
1995	92	0	14.6 ± 0.2	11–18.5	22.6 ± 0.3	14–30
	273	**3**	**15.7 ± 0.1**	**10–22**	**23.7 ± 0.2**	**14–31**
Winter						
1993	92	0	13.3 ± 0.2	9–18	22.1 ± 0.3	15–32
1994	92	0	13.0 ± 0.2	9–18	21.4 ± 0.4	13–30
1995	92	0	12.4 ± 0.2	9–16.5	21.0 ± 0.3	14–29
	276	**0**	**12.9 ± 0.1**	**9–18**	**21.5 ± 0.2**	**13–32**
Spring						
1993	91	0	14.5 ± 0.2	12–19	21.7 ± 0.2	15–26
1994	91	0	14.3 ± 0.2	10–19	21.9 ± 0.2	16–27
1995	91	0	15.0 ± 0.2	11–19	22.3 ± 0.2	17–28
	273	**0**	**14.6 ± 0.1**	**10–19**	**22.0 ± 0.1**	**15–28**
All seasons						
1993	362	3	15.7 ± 0.1	9–22	23.6 ± 0.2	15–33
1994	365	0	15.0 ± 0.1	9–20	23.0 ± 0.2	13–31
1995	365	0	14.6 ± 0.1	9–20	22.6 ± 0.2	14–31
Total	**1092**	**3**	**15.1 ± 0.1**	**9–22**	**23.1 ± 0.1**	**13–33**

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that year.

[1] The air temperature data set was based on 1 092 days of records, i.e., data was not recorded during 3 days of the study

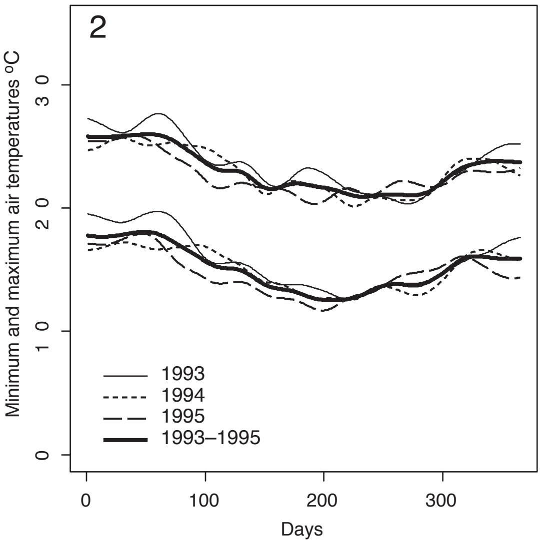

Fig. 2 Daily maximum and minimum air temperature (°C) recorded at 0800 hrs at Bird Island (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

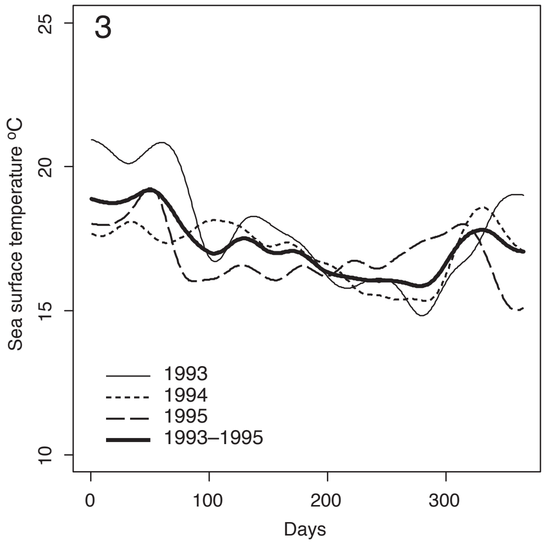

Fig. 3 Daily sea surface temperature (°C) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

Mean monthly minimum temperature increased slightly in September/October (14°C) and November (16°C); peaked in January/February (18°C); and then declined slowly throughout autumn, reaching a low in winter (12°C to 13°C) (Table 1).

Overall, mean annual air temperatures were slightly higher in 1993 and lowest in 1995. However, in spring, mean temperature recorded in 1995 exceeded mean temperatures recorded 1993 and 1994 (Table 2; Fig. 2).

Sea surface temperature

Sea surface temperatures[2] ranged from 12°C to 23°C. Minimum SST was recorded in summer (December 19 & 26, 1995). Maximum SST was recorded in autumn (March 7, 1993) and summer (January 3, 1993).

Mean monthly SST increased in November; peaked in January/February (19°C); and then declined slowly throughout autumn, reaching a low in July–October (16°C) (Table 3).

Overall, mean annual SST was slightly higher in 1993. However, in spring, mean SST recorded in 1995 exceeded mean temperatures recorded in 1993 and 1994 (Table 4; Fig. 3).

During summer, mean monthly SST was 17°C to 19°C; however, on two occasions, SST fell by 5°C due to wind induced upwelling:

(i) On December 12, 1995, strong easterly winds (up to 25 knots) were recorded, resulting in SST to fall to 13°C on December 13–14. By December 17, SST gradually increased to 14°C. Strong easterly winds (up to 20 knots) blew in the afternoon/evening causing SST to drop to 12.5°C on December 18, and to 12°C on December 19.

(ii) On December 24, 1995, strong easterly winds (up to 28 knots) were recorded, resulting in SST to fall from 17°C to 12.5°C on December 25, and to 12°C on December 26.

Table 3 ***Mean monthly sea surface temperature (°C) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)[1]***

Month	*n*	NR	SST (°C) Mean ± SE	Range
Summer				
December	93	0	17.4 ± 0.2	12–22
January	93	0	18.8 ± 0.2	15–23
February	84	0	19.2 ± 0.2	15.5–22
	270	**0**	**18.4 ± 0.1**	**12–23**
Autumn				
March	92	1	18.1 ± 0.2	14–22.5
April	90	0	17.0 ± 0.1	13.5–19.5
May	93	0	17.4 ± 0.1	15–19
	275	**1**	**17.5 ± 0.1**	**13.5–22.5**
Winter				
June	82	8	17.1 ± 0.1	15–19
July	92	1	16.4 ± 0.1	14.5–18
August	93	0	16.1 ± 0.1	14–18
	267	**9**	**16.5 ± 0.1**	**14–19**
Spring				
September	90	0	16.0 ± 0.1	14–18
October	93	0	16.0 ± 0.2	13–19.5
November	89	1	17.7 ± 0.1	14.5–20
	272	**1**	**16.6 ± 0.1**	**13–20**
Total	**1084**	**11**	**17.3 ± 0.1**	**12–23**
December 1992	22	1	20.7 ± 0.2	19–22
January 1996	30	1	19.4 ± 0.4	14–22

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

[2] The SST data set was based on 1 084 days of records, i.e., data was not recorded during 11 days of the study.

Table 4 *Mean sea surface temperature (˚C) recorded at 0800 hrs daily at Bird Island according to season and year (January 1, 1993 to December 31, 1995, n = 1 095 days)*

Month	*n*	NR	SST (˚C) Mean ± SE	Range
Summer				
1993	90	0	20.0 ± 0.1	15.5–23
1994	90	0	17.8 ± 0.1	15–20
1995	90	0	17.5 ± 0.2	12–21
	270	**0**	**18.4 ± 0.1**	**12–23**
Autumn				
1993	92	0	18.4 ± 0.2	14.5–22.5
1994	92	0	17.7 ± 0.1	15–19.5
1995	91	1	16.4 ± 0.1	13.5–20.5
	275	**1**	**17.5 ± 0.1**	**13.5–22.5**
Winter				
1993	85	7	16.5 ± 0.1	15–18.5
1994	92	0	16.6 ± 0.1	14–19
1995	90	2	16.4 ± 0.1	14.5–18
	267	**9**	**16.5 ± 0.1**	**14–19**
Spring				
1993	91	0	15.9 ± 0.1	13–19
1994	90	1	16.4 ± 0.2	13–20
1995	91	0	17.4 ± 0.1	15–20
	272	**1**	**16.6 ± 0.1**	**13–20**
All seasons				
1993	358	7	17.7 ± 0.1	13–23
1994	364	1	17.1 ± 0.1	13–20
1995	362	3	16.9 ± 0.1	12–21
Total	**1084**	**11**	**17.3 ± 0.1**	**12–23**

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that year.

Rainfall

Daily rainfall[3] ranged from 0–98 mm. Maximum rainfall was recorded on December 28, 1994 (65 mm), January 14, 1995 (98 mm) and September 22, 1993 (83 mm).

Mean monthly rainfall was very low (0.9 mm) in July and October, and peaked (2.2–3.0 mm) in December, January and September (Table 5).

Mean annual rainfall was 1.7 mm in 1993 and 1995, and slightly lower (1.6 mm) in 1994 (Table 6). Although mean monthly rainfall varied considerably between years, total annual rainfall was *c.* 600 mm (Table 7).

Wind direction

When all wind direction[4] data were combined, irrespective of time of day or season, it was apparent that wind direction had a westerly dominance, with a shift towards the easterly-component winds in summer (Fig. 4–7; Appendix 1–3).

Northerly-component winds (N, N-NE, N-NW)

N-NW winds were the most dominant of the northerly-component winds. N-NW winds generally developed in the mornings (land breeze) and were most frequent in winter.

Table 5 *Mean monthly rainfall (mm) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)[1]*

Month	*n*	NR	Rainfall (mm) Mean ± SE	Range
Summer				
December	93	0	3.0 ± 0.9	0.0–65.0
January	92	1	2.3 ± 1.1	0.0–98.4
February	84	0	1.2 ± 0.4	0.3–0.8
	269	**1**	**2.2 ± 0.5**	**0.0–98.4**
Autumn				
March	93	0	1.2 ± 0.5	0.0–31.7
April	90	0	1.6 ± 0.4	0.0–18.4
May	92	1	1.2 ± 0.3	0.0–22.9
	275	**1**	**1.3 ± 0.2**	**0.0–31.7**
Winter				
June	90	0	1.8 ± 0.7	0.0–48.5
July	93	0	0.9 ± 0.4	0.0–20.6
August	93	0	1.5 ± 0.4	0.0–23.2
	276	**0**	**1.4 ± 0.3**	**0.0–48.5**
Spring				
September	90	0	2.5 ± 1.0	0.0–83.0
October	93	0	0.9 ± 0.3	0.0–16.5
November	90	0	1.6 ± 0.6	0.0–41.0
	273	**0**	**1.7 ± 0.4**	**0.0–83.0**
Total	**1093**	**2**	**1.6 ± 0.2**	**0.0–98.4**
December 1992	23	0	0.3 ± 0.3	0.0–6.1
January 1996	30	1	1.1 ± 0.4	0.0–9.0

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

Table 6 *Mean annual rainfall (mm) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)*

Year	*n*	NR	Rain (days)	No rain (days)	Rainfall mean ± SE (mm)	Range (mm)	Total
1993	365	0	87 (24%)	278 (76%)	1.7 ± 0.4	0–83.0	621.3
1994	365	0	101 (28%)	264 (72%)	1.6 ± 0.3	0–65.0	587.3
1995	363	2	109 (30%)	254 (70%)	1.7 ± 0.3	0–98.4	573.7

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.

[3] The SST data set was based on 1 093 days of records, i.e., data was not recorded during 2 days of the study.
[4] Wind speed/direction data set was based on 3 272 recording periods, i.e., data was not recorded during 13 recording periods. Zero wind speed was recorded on 49 recording periods.

Table 7 ***Total monthly rainfall (mm) recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)[1]***

Month	*n*	NR	Total rainfall (mm)			
			1993	**1994**	**1995**	**1993–1995**
Summer						
December	93	0	86.6	157.5	32.7	**276.8**
January	92	1	52.8	39.3	115.5	**207.2**
February	84	0	22.1	40.3	35.8	**98.2**
	269	**1**	**161.5**	**237.1**	**184.0**	**582.6**
Autumn						
March	93	0	7.2	46.2	60.3	**113.7**
April	90	0	41.6	23.1	76.6	**141.3**
May	92	1	16.0	37.0	55.4	**108.4**
	275	**1**	**64.8**	**106.3**	**192.3**	**363.4**
Winter						
June	90	0	129.6	21.5	6.4	**157.5**
July	93	0	8.0	48.5	30.9	**87.4**
August	93	0	56.1	69.4	13.0	**138.5**
	276	**0**	**193.7**	**139.4**	**50.3**	**383.4**
Spring						
September	90	0	148.9	33.5	40.9	**223.3**
October	93	0	11.6	48.3	24.3	**84.2**
November	90	0	40.8	22.7	81.9	**145.4**
	273	**0**	**201.3**	**104.5**	**147.1**	**452.9**
Total	**1093**	**2**	**621.3**	**587.3**	**573.7**	**1782.3**
December 1992	23	0	–	–	–	6.5
January 1996	30	1	–	–	–	31.8

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

Southerly-component winds (S, S-SE, S-SW)

S-SW winds were the most dominant of the southerly-component winds. S-SW winds generally developed in the afternoons (sea breeze) and were most frequent in spring and summer.

Easterly-component wind (E, E-SE, E-NE)

E-NE winds were the most dominant of the easterly-component winds. E-NE winds were frequent throughout the year; E winds were frequent in spring, summer and autumn; while E-SE winds were frequent in spring and summer. E winds were more dominant than E-NE winds in summer.

Westerly-component winds (W, W-NW, W-SW)

W-SW winds were the most dominant westerly-component winds. W-SW and W-NW winds were frequent throughout the year, especially in winter; while W winds were most frequent in autumn. W-NW winds generally blew in the mornings, whereas W-SW winds tended to blow throughout the day. This was enhanced and by the land/sea breeze effect.

Other wind directions (NW, NE, SE, SW)

SW winds were frequent throughout the year, especially in summer, autumn and spring. NW winds were frequent in winter (mornings).

Wind speed

Spring was the windiest season. Wind speed of 0–5 knots (calm to slight breeze) were most frequent in autumn and least frequent in spring (Fig. 4–7).

Wind speeds[4] ≥ 28 knots (near gale or greater) were recorded in all seasons (Table 8). Gales were most frequent in May–August and October. Gales were predominantly westerly (W-SW) in autumn and winter; and easterly (E-ENE) and westerly (W-SW) in spring.

Median wind speed was consistently stronger in the afternoons (*c.* 14.0 knots)/evenings (*c.* 13.0 knots) than in the mornings (*c.* 11.0 knots). In the mornings, median monthly wind speed was highest in June (15.0 knots); in the afternoons, median speed was highest in June (15.5 knots) and October (15.0 knots); and in the evenings, median speed was highest in November (16.0 knots) (Appendix 1–3).

Table 8 ***Gale force winds (days) recorded at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)***

Wind direction	Component winds	Number of days with gales			
		Summer	**Autumn**	**Winter**	**Spring**
N	N	0	0	0	0
	N-NE	0	0	0	0
	N-NW	0	0	0	0
	NW	0	0	2	0
	NE	0	1	0	0
E	E	0	1	0	5
	E-SE	1	0	0	1
	E-NE	2	0	1	5
	SE	0	0	0	0
S	S	0	0	0	0
	S-SW	0	0	0	0
	S-SE	1	0	0	0
	SW	2	1	1	2
W	W	1	2	3	1
	W-NW	0	0	4	0
	W-SW	2	14	15	6
Total		**9[1] (0)**	**19[2] (3)**	**26[3] (7)**	**20[4] (3)**

(), number of consecutive days (2/3 days) with gale force winds.
Wind data for December 9–31, 1992 and January 1–31, 1996 was excluded from analysis.
During the 3 year study: [1]gales occurred on 6 days in December; [2]gales occurred on 16 days in May; [3]gales were distributed equally winter; [4]gales occurred on 15 days in October.

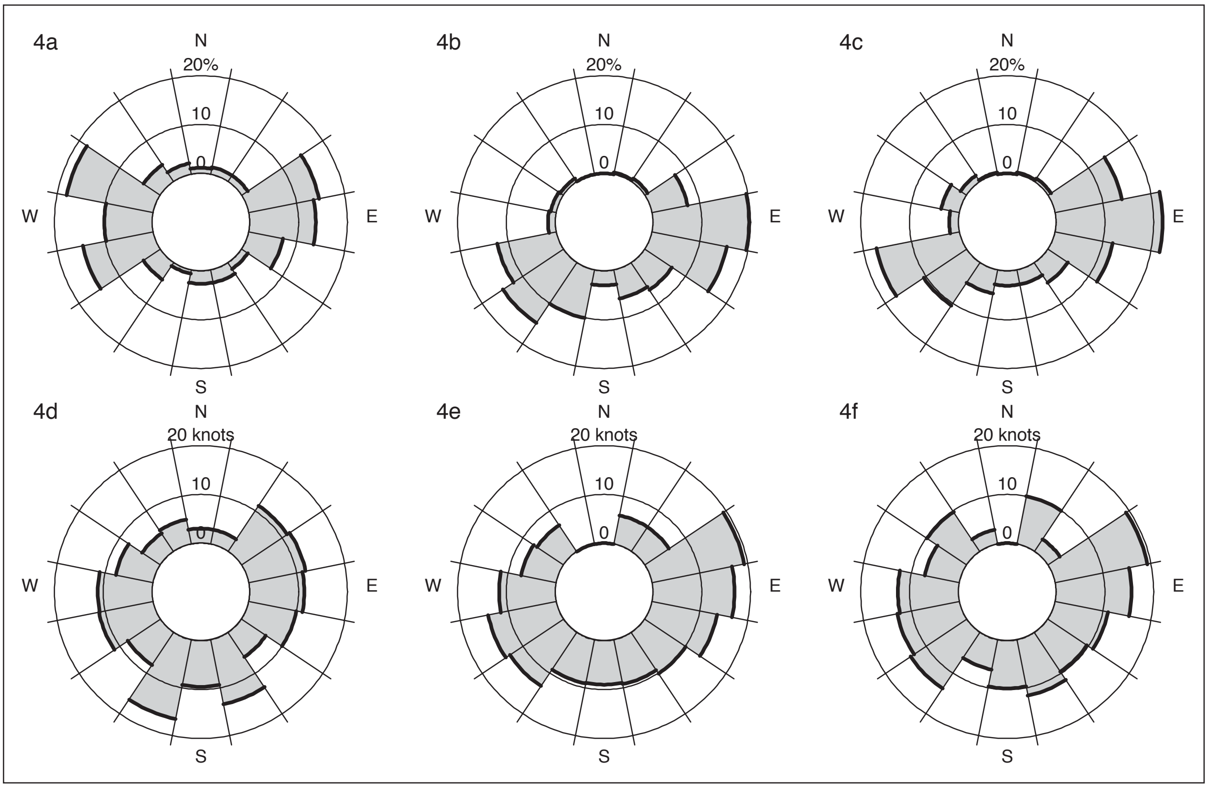

Fig. 4 Wind-rose diagrams for Bird Island for summer showing wind frequency (%) in various directions* at: (a) 0800 hrs, (b) 1400 hrs and (c) 1800 hrs; and mean wind speed (knots) in various directions at: (d) 0800 hrs, (e) 1400 hrs and (f) 1800 hrs (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

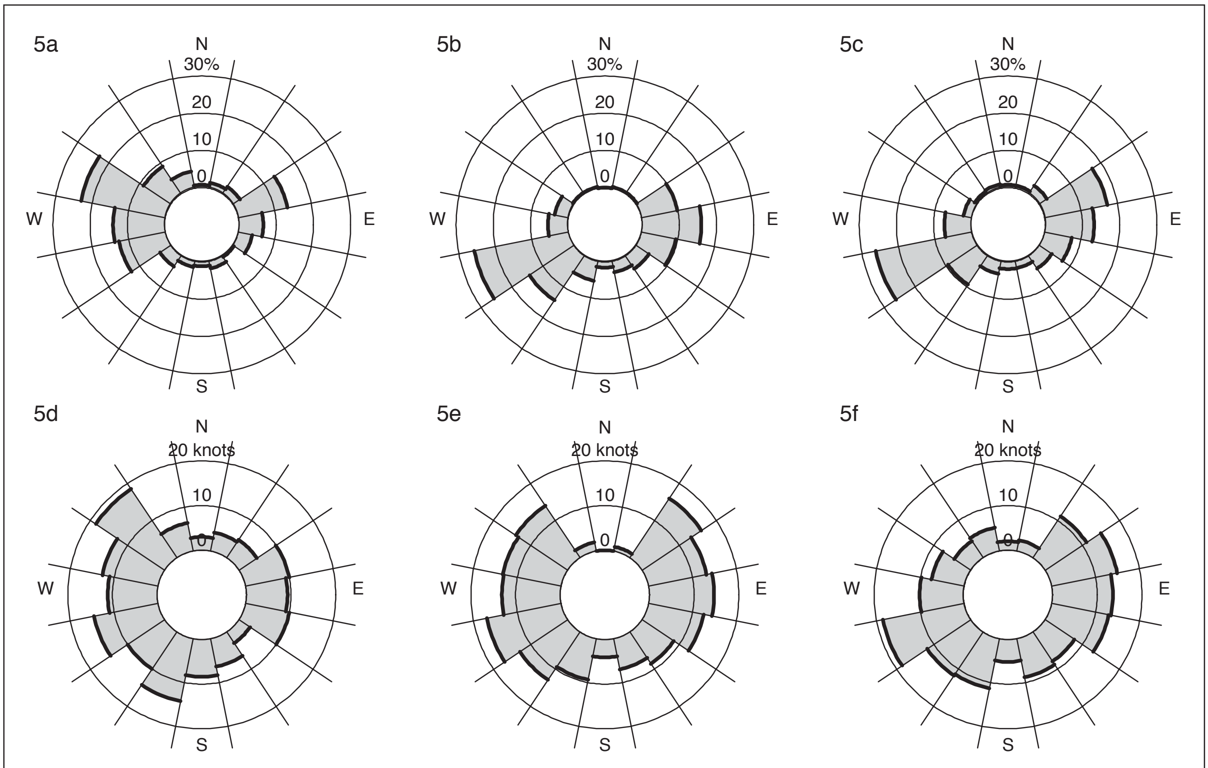

Fig. 5 Wind-rose diagrams for Bird Island for autumn showing wind frequency (%) in various directions at: (a) 0800 hrs, (b) 1400 hrs and (c) 1800 hrs; and mean wind speed (knots) in various directions at: (d) 0800 hrs, (e) 1400 hrs and (f) 1800 hrs (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

* Wind direction was classified as follows: N (360°), NNE (22.5°), NE (45.0°), ENE (67.5°), E (90.0°), ESE (112.5°), SE (135.0°), SSE (157.5°), S (180.0°), SSW (202.5°), SW (225.0°), WSW (247.5°), W (270.0°), WNW (292.5°), NW (315.0°) or NNW (337.5°).

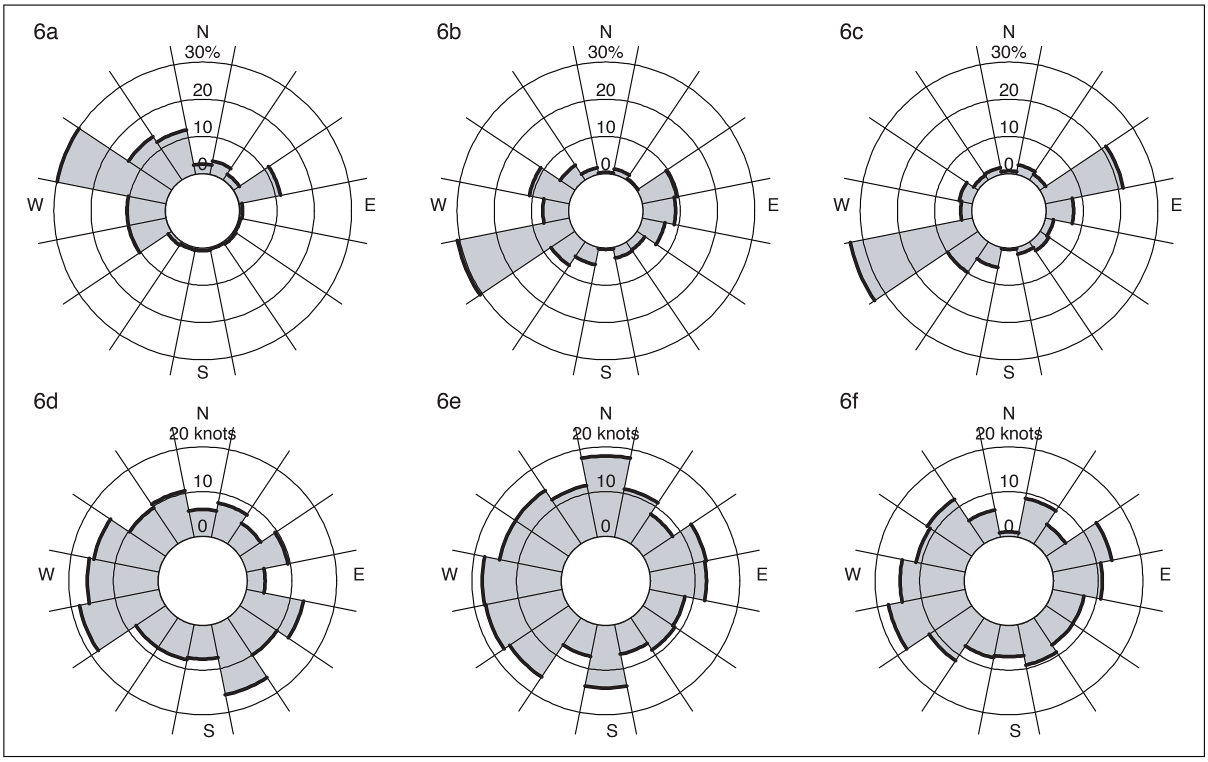

Fig. 6 Wind-rose diagrams for Bird Island for winter showing wind frequency (%) in various directions at: (a) 0800 hrs, (b) 1400 hrs and (c) 1800 hrs; and mean wind speed (knots) in various directions at: (d) 0800 hrs, (e) 1400 hrs and (f) 1800 hrs (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

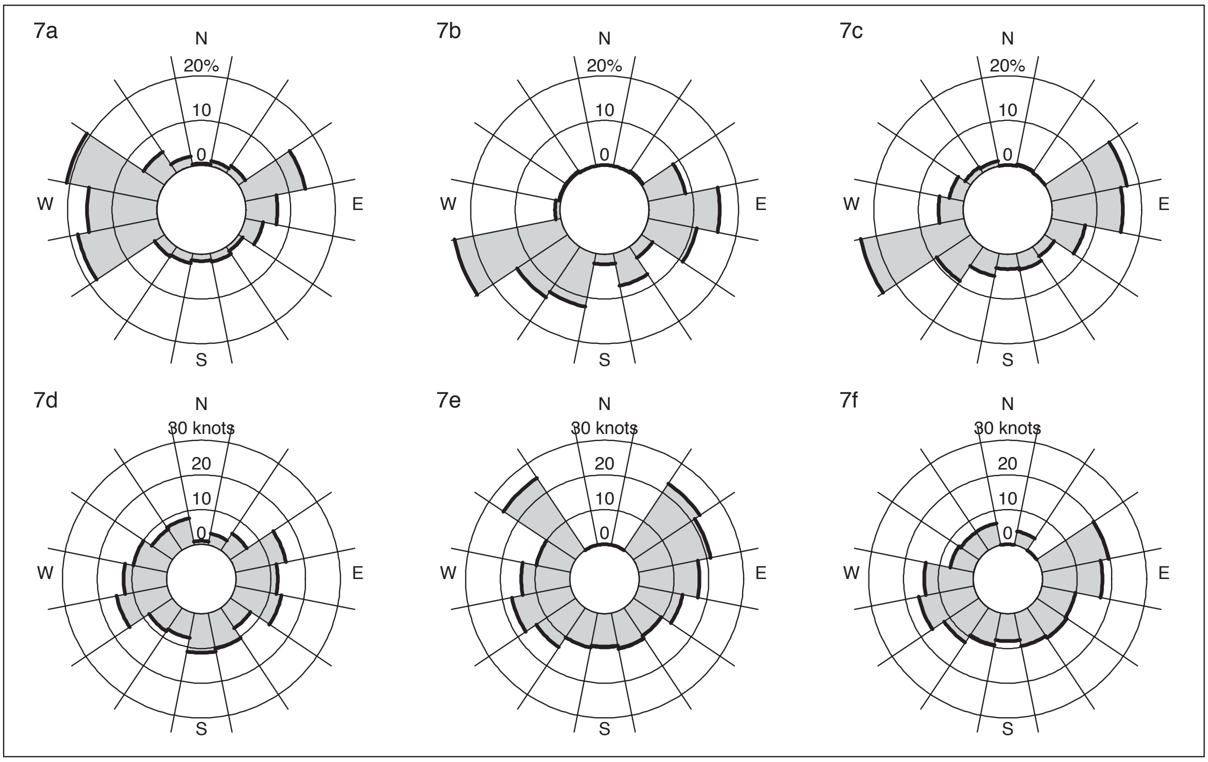

Fig. 7 Wind-rose diagrams for Bird Island for spring showing wind frequency (%) in various directions at: (a) 0800 hrs, (b) 1400 hrs and (c) 1800 hrs; and mean wind speed (knots) in various directions at: (d) 0800 hrs, (e) 1400 hrs and (f) 1800 hrs (January 1, 1993 to December 31, 1995, *n* = 1 095 days).

Swell height

'Estimated' swell height[5] ranged from 0.5–6.0 m (Table 9). Large swells (5–6 m) were recorded in March (4 days), April (3 days), July (2 days), September (2 days), October (6 days) and December (2 day).

Table 9 ***Estimated mean monthly swell height recorded thrice daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)[1]***

Month	*n*	Swell height (m) NR	Mean ± SE	Range
Summer				
December	277	2	1.6 ± 0.05	0.5–5.0
January	277	2	1.2 ± 0.04	0.5–4.0
February	250	2	1.5 ± 0.05	0.5–4.0
	804	**6**	**1.4 ± 0.03**	**0.5–5.0**
Autumn				
March	279	0	1.8 ± 0.08	0.5–5.0
April	269	1	1.7 ± 0.07	0.5–5.0
May	278	1	1.4 ± 0.04	0.5–4.0
	826	**2**	**1.7 ± 0.04**	**0.5–5.0**
Winter				
June	269	1	1.7 ± 0.05	0.5–4.0
July	278	1	1.7 ± 0.05	0.5–5.0
August	277	2	1.5 ± 0.04	0.5–4.0
	824	**4**	**1.6 ± 0.03**	**0.5–5.0**
Spring				
September	270	0	1.7 ± 0.05	0.5–5.0
October	279	0	1.6 ± 0.07	0.5–6.0
November	268	2	1.3 ± 0.05	0.5–4.0
	817	**2**	**1.5 ± 0.03**	**0.5–6.0**
Total	**3271**	**14**	**1.6 ± 0.02**	**0.5–6.0**
December 1992	67	2	1.0 ± 0.05	0.5–2.0
January 1996	92	1	2.3 ± 0.09	1.0–4.5

n, number of observations at 0800 hrs, 1400 hrs and 1800 hrs.
NR, number of observations for 0800 hrs, 1400 hrs and 1800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

DISCUSSION

Air temperature

At the Bird Islands, daily air temperature ranged from 9ºC to 33ºC, with mean monthly temperatures peaking in summer and reaching a low in winter and early/mid spring (present study). Daily change in air temperature is primarily attributed to radiation changes, with temperatures generally rising between dawn and midafternoon. Nocturnal cooling continues until about dawn.

Previous studies within Algoa Bay indicate that incoming solar radiation varies from *c.* 350 Wm^{-2} in summer to *c.* 140 Wm^{-2} in winter (Goschen, 1991). Therefore, at the Birds Islands, mean maximum and mean minimum air temperatures may differ by 4ºC or 5ºC in mid-summer and in mid-winter (present study).

Sea surface temperature

Sea surface temperature within Algoa Bay decreases from the shoreline to the shelf, and then increase again to the Agulhas Current (Goschen, 1991). A strong thermocline (surface layer 15–20ºC; bottom layer 9–12ºC) is present over the continental shelf off Algoa Bay (Goschen, 1991). However, the shallow inshore waters are generally well mixed due to wind-forcing (Goschen & Schumann, 1988).

At the Bird Islands, daily SST ranged from 12ºC to 23ºC and varied seasonally, with mean monthly temperatures remaining low from July to October, and peaking in January/February (present study). Seasonal variability in the surface heat fluxes, and mass transports of water, are the primary factors influencing temperature structure within Algoa Bay (Goschen, 1991).

Minimum SST's within Algoa Bay are usually caused by one of the following. Firstly, localised easterly winds can cause upwelling at Cape Recife and Cape Padrone, resulting in advection of the cold bottom water into adjacent areas (Schumann, Perrins & Hunter, 1982; Goschen, 1991; present study). Secondly, upwelling associated with the inshore boundary of the Agulhas Current (*c.* 44 km off Cape Padrone and *c.* 60 km off Cape Recife) can introduce cold water (12ºC or 13ºC) into Algoa Bay (Walker, 1986; Schumann, 1987; Goschen, 1988; Dr Ian Hunter, pers. comm.). Thirdly, upwelling forced by the Agulhas Current can introduce cold water onto the shelf which may occasionally penetrate Algoa Bay (Eagle & Orren, 1985; Schumann, 1987; Swart & Largier, 1987; Goschen & Schumann, 1988; Schumann, Ross & Goschen, 1988).

Maximum SST's within Algoa Bay are generally associated with the Agulhas Current. The core of this current (max. temp 26ºC) generally flows just beyond the shelf break, i.e., 70 km off shore for Algoa Bay (Pearce, 1977; Gründlingh, 1983). The Agulhas Current separates from the shelf break west of Algoa Bay. Downstream of this region, meanders and frontal eddies of the Agulhas Current increase in dimension (Goschen, 1991). Plumes of warmer water attached to eddies may cross the shelf edge over the continental shelf, advecting warmer water across the Agulhas Bank, causing SST to rise to 24ºC+, from Cape Agulhas to Algoa Bay (Eagle & Orren, 1985; Swart & Largier, 1987; Goschen & Schumann, 1988; Lutjeharms, 1981; Dr Ian Hunter, pers. comm.). East London does not benefit from these large episodic core meanders, i.e., maximum SST's are in the low 20's.

[5]Swell height data set was based on 3 273 recording periods, i.e., data was not recorded during 12 recording periods.

Rainfall

The southwestern Cape has winter rainfall, while the east coast has a summer rainfall. The Eastern Cape coast lies in an intermediate situation (Schultze, 1965). At the Bird Islands, rain falls through out the year with highest rainfall in summer (present study). Total annual rainfall (*c*. 600 mm) is similar to the mainland (e.g., *c*. 624 mm at Port Elizabeth; Garth Sampson, pers. comm.).

Wind speed and direction

At the Bird Islands, the prevailing winds (W-SW and E-NE) are parallel with the general orientation of the coast (Illenberger 1986; Goschen, 1988, 1991; Schumann & Martin, 1991; present study). Westerly-component winds are common for most of the year, with easterly-component winds dominate in summer (Schumann, 1992; present study). The seasonal dominance of easterly- and westerly-component winds at the Bird Islands is caused by the semipermanent South Atlantic and South Indian anticyclones which form part of the belt of anticyclonic centers occurring within the average limits of *c*. 27^0–38^0S. This belt moves seasonally by 4–6^0 (latitude) causing the South Atlantic anticyclone to ridge eastward over the southern tip of Africa in winter and lie further south in summer (Schumann, 1992).

Land/sea breezes form an important component of local winds at the Bird Islands (Roberts, 1990; Goschen, 1991; present study). At these islands the sea breeze (S-SW) is most frequent in spring and summer, and the land breeze (N-NW) is most frequent in winter (present study). Considering that variation in air temperature is large if the wind is off the land, and small if wind is off the sea, diurnal air temperatures at these islands are more variable in winter (9^0C to 32^0C) than in spring (10^0C to 28^0C) and summer (12^0C to 33^0C) (present study).

Water movement in the nearshore region of Algoa Bay is mainly due to wind forcing (Roberts, 1990). In summer, easterly component winds increase in strength and frequency causing localised upwelling at the major Capes and a subsequent fall is SST (Schumann, Ross & Goschen, 1988; Goschen, 1991). Localised upwelling enhances primary productivity by bringing nutrients into the euphotic zone, promoting the growth of plankton which indirectly benefits large predators by increasing prey availability. In the present study, SST fell to 12^0C in summer in association with strong easterly winds. No case of upwelling was observed in the absence of easterly-component winds in the summer months (present study). In winter, the frequency of easterly-component winds decreases (Goschen, 1991; present study), and the depth of the surface isothermal layer over the shelf increases, resulting in a reduction in wind driven upwelling (Goschen, 1991).

Swell height

The most common swell along the Eastern Cape coast is from the SW, usually originating from low pressure systems moving from west to east, over the southern ocean (Dr Ian Hunter, pers. comm.).

Strong, persistent south westerly winds, with a fetch of ≥ 1200 nautical miles in the Southern Ocean, generate a fully developed sea with waves reaching maximum height and length by the time they reach Algoa Bay (Bremner, 1991). Abnormal waves in excess of 18 m have been reported in the vicinity of the shelf break. Occasionally waves ≥ 10 m enter Algoa Bay (Bremner, 1991). In the present study abnormally large waves were not recorded. Maximum wave height was 6 m.

CONCLUSION

Overall, climate at the Bird Islands is not severe, with moderate air temperatures ranging from 9^0C to 33^0C; SST's ranging from 12^0C to 23^0C; a total annual rainfall of c. 600 mm; and relatively strong winds predominantly W-SW and E-NE.

In order to fully understand the complex interactions between climate and the resident seal population, continued monitoring of climatic conditions at the Bird Islands is required. Particular attention should be given to: (i) pup mortality relative to storms; (ii) the timing of the pupping season relative to upwelling events; and (iii) the effects of climate on prey species relative to the distribution/abundance patterns of seals throughout their breeding range.

Considering that Black Rocks is often surrounded by heavy breakers, ongoing behavioural studies examining the impact of high temperatures on: (i) daily activities of seals, (ii) pup survival, and (iii) duration of territorial tenure, would not be feasible.

Climate data collected at the offshore Bird Islands (present study) should be compared with climate data collected from the mainland (at Port Elizabeth Airport). Similarities and differences between the two sites can then be quantified, increasing our overall understanding of the climate in this region.

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Appendix 1 ***Mean monthly wind speed recorded at 0800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)***[1]

			Wind speed (knots)		
Month	***n***	**NR**	**Mean ± SE**	**Median**	**Range**
Summer					
December	93	0	10.4 ± 0.6	11.0	1–20
January	93	0	9.6 ± 0.7	10.0	0–30+
February	84	0	8.9 ± 0.6	8.0	0–20
	270	**0**	**9.7 ± 0.4**	**10.0**	**0–30+**
Autumn					
March	92	1	8.5 ± 0.5	8.0	0–24
April	90	0	10.2 ± 0.7	10.0	0–30+
May	93	0	11.7 ± 0.8	12.0	0–30+
	275	**1**	**10.1 ± 0.4**	**10.0**	**0–30+**
Winter					
June	90	0	14.4 ± 0.8	15.0	1–30+
July	92	1	12.0 ± 0.7	11.0	0–30+
August	93	0	10.8 ± 0.7	10.0	0–30+
	275	**1**	**12.4 ± 0.4**	**12.0**	**0–30+**
Spring					
September	90	0	11.3 ± 0.8	10.0	0–30+
October	93	0	11.6 ± 0.6	11.0	0–30+
November	90	0	11.7 ± 0.7	12.0	1–30+
	273	**0**	**11.5 ± 0.4**	**11.0**	**0–30+**
Total	**1093**	**2**	**10.9 ± 0.2**	**11.0**	**0–30+**
December 1992	22	1	11.2 ± 0.9	10.0	4–20
January 1996	31	0	8.1 ± 0.7	9.0	3–17

n, number of observations at 0800 hrs.
NR, number of observations for 0800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

Appendix 2 ***Mean monthly wind speed recorded at 1400 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)***[1]

			Wind speed (knots)		
Month	***n***	**NR**	**Mean ± SE**	**Median**	**Range**
Summer					
December	93	0	13.7 ± 0.6	13.0	2–30+
January	93	0	12.5 ± 0.6	12.0	1–30+
February	84	0	13.7 ± 0.7	14.0	0–28
	270	**0**	**13.3 ± 0.4**	**13.0**	**0–30+**
Autumn					
March	90	3	12.2 ± 0.7	11.5	0–30+
April	88	2	13.9 ± 0.7	14.5	0–30+
May	93	0	13.2 ± 0.9	13.0	0–30+
	271	**5**	**13.1 ± 0.4**	**13.0**	**0–30+**
Winter					
June	90	0	15.0 ± 0.7	15.5	2–30+
July	93	0	14.0 ± 0.7	14.0	2–30+
August	91	2	13.5 ± 0.8	12.0	2–30+
	274	**2**	**14.1 ± 0.4**	**14.0**	**2–30+**
Spring					
September	90	0	14.5 ± 0.8	13.0	4–30+
October	93	0	15.4 ± 0.7	15.0	3–30+
November	89	1	14.7 ± 0.7	14.0	2–30+
	272	**1**	**14.9 ± 0.4**	**14.0**	**2–30+**
Total	**1087**	**8**	**13.8 ± 0.2**	**14.0**	**0–30+**
December 1992	23	0	13.8 ± 0.9	14.0	6–22
January 1996	30	1	12.0 ± 1.0	11.0	3–25

n, number of observations at 1400 hrs.
NR, number of observations for 1400 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.

Appendix 3 ***Mean monthly wind speed recorded at 1800 hrs daily at Bird Island (January 1, 1993 to December 31, 1995, n = 1 095 days)***[1]

			Wind speed (knots)		
Month	***n***	**NR**	**Mean ± SE**	**Median**	**Range**
Summer					
December	93	0	13.4 ± 0.7	13.0	1–30+
January	93	0	12.7 ± 0.7	12.0	0–30+
February	83	1	13.0 ± 0.8	12.0	0–30+
	269	**1**	**13.1 ± 0.4**	**12.0**	**0–30+**
Autumn					
March	92	1	12.2 ± 0.7	12.5	0–30+
April	90	0	13.9 ± 0.8	14.0	0–30+
May	93	0	13.5 ± 0.9	12.0	0–30+
	275	**1**	**13.2 ± 0.5**	**13.0**	**0–30+**
Winter					
June	89	1	13.5 ± 0.8	14.0	0–30+
July	93	0	13.4 ± 0.8	12.0	1–30+
August	93	0	12.1 ± 0.8	10.0	1–30+
	275	**1**	**13.0 ± 0.5**	**12.0**	**0–30+**
Spring					
September	90	0	13.8 ± 0.7	14.0	1–30+
October	93	0	14.9 ± 0.8	14.0	0–30+
November	90	0	14.2 ± 0.8	16.0	2–30+
	273	**0**	**14.3 ± 0.4**	**14.0**	**0–30+**
Total	**1092**	**3**	**13.4 ± 0.2**	**13.0**	**0–30+**
December 1992	22	1	12.5 ± 1.1	11.0	6–25
January 1996	31	0	13.0 ± 1.0	11.0	4–25

n, number of observations at 1800 hrs.
NR, number of observations for 1800 hrs not recorded for that month.
[1] Data for December 9–31, 1992 and January 1–31, 1996 is presented separately at the end of this table.