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Wind
currents
Water levels
Nutrients
Birds.

Wind-induced water level changes and waterbird ecology at Lake St. Lucia

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Introduction

Lake St. Lucia (Natal, South Africa) is a large, shallow lake joined to the sea by a permanent, narrow channel 21 km in length (Fig. 1). The lake has a water surface area of 328 km^2 and an average depth of less than 1 m at mean sea level (msl) (Hutchison 1976). Lake water levels and salinities are variable, and are a consequence of the relative inputs of fresh water and sea water (Hutchison 1976). Tidal water level changes occur in the channel (Narrows), but not in the main lake. In the absence of tidal water level changes, wind-inducdd water level changes apparently play an important rôle in the lake ecology.

The lake is an important nursery for juvenile marine fishes (Wallace 1975), and supports a commercial prawn industry (Joubert and Davies 1966). The lake supports important populations of many animal species including waterbirds (Berruti 1980a).

Wind-induced water level changes

Wind data (four hourly averages of wind speed and direction) are taken from Hutchison and Pitman (1973). During January 1970 to December 1972, winds blew most frequently from the N-NE sector (35,6%) and the SW-W sector (33%) (Table 1). The windiest months in 1972 were January and February, and September to December (Table 2).

In 1972, average wind strength was greatest between 12.00-16.00 hrs, then decreased in strength to a minimum between 04.00-08.00 hrs, and increased rapidly between 20.00-08.00 hrs (Table 3). In 1972, winds blew from the W-SW sector mainly between 20.00-08.00 hrs (land breeze), whereas winds from the N-NE sector blew mainly between 08.00-20.00 hrs (sea breeze) (Table 4). A feature of wind patterns at Lake St. Lucia is the movement of cold fronts from the south west, which may bring strong winds and rain for 2-3 days.

The long axes of the two arms of the lake (False Bay and the eastern arm) lie in a north-south direction. Thus northerly and southerly winds produce the greatest water level changes, which are recorded at the southern and northern ends of the lake. Easterly and westerly winds cause relatively small water level changes. The amplitude of water level change is dependent on wind direction, speed and duration (Fig. 2 and Hutchison 1976). Most of the lake is subject to wind-induced water level changes of 10-20 cm (Fig. 2).

Extensive shallows (water depth usually less than 20 cm below msl) are located on the lake periphery and within the Lane, Bird and Fanies islands. Water exchange between these shallows and the main lake is usually restricted to channels through enclosing banks, and water level changes lag behind those in the main lake. Wind-induced water level changes occur more rapidly in the main lake, where water movement is unrestricted. The difference in water levels produces scour currents in the linking channels. This was seen at Bird Island on 3 March 1978. Bird Island (area 186 ha) has a raised periphery enclosing a central shallows on all sides except the north-east, where a channel was set in a lower lying marshy periphery. The channel was about 1.5 m deep and 2 m wide at msl. The channel substrate was sundry, whereas the substrate elsewhere at Bird Island is mainly fine silt and clay. A strong south westerly wind (up to m/sec) had been blowing since 2 March, raising the water level in the northern lake around Bird Island. On 3 March 1978, wind direction changed to north-east. A current was flowing in the channel, at an estimated speed of 1 m/sec, in a north-easterly direction into the wind. The water level in the island shallows was higher than in the lake, where the water level had receded rapidly.

Wind-induced water level changes may expose or inundate large areas of mud flats unrestricted by enclosing banks (Mauge Flats, Southern Shallows), or within the larger shallows (Northern Shallows).

Development and importance of scour channels relative to water level

Development of scour channels relies on the frequent differentials in water level between two areas with restricted water exchange. Thus scour channels are likely to occur in shallows experiencing restricted water exchange with the main lake at the most frequent water levels - -30 cm to +10 cm relative to msl (Table 5). However, many shallows are dry below 20 cm less than msl. Buildup of enclosing banks at these low levels may be unfavourable because plants are less able to colonise these areas, and very low water levels are generally associated with hypersaline conditions (Hutchison 1976). Unstabilised enclosing banks at low water levels are susceptible to erosion, as they are inundated for greater than 70% of the time (Table 5). Scour channels are more likely to occur where water level changes, and hence water movements, are greatest, at the northern and southern ends of the lake, and at Fanies Island, where the main lake is constricted to a narrow channel. The Hluhluwe and Nyalazi rivers have created levees partially isolating adjacent shallows from the rivers and the lake. The Mzinene river has a large floodplain area (1 136 ha) with a very narrow connection to the lake. The channel is so narrow, that wind-induced water movement is unimportant in the Mzinene floodplain. Some shallows (e.g. Sengwana), primarily on the Eastern shores, are fed by small freshwater seeps which may help maintain the scour channels.

The mean lake level determines the relative importance of water exchange between the lake and shallows via scour channels, and whether mud flats are exposed. At high water levels (greater than 10 cm above msl) banks enclosing shallows tend to be inundated, and water movement in scour channels alone may be unimportant relative to total water exchange. At intermediate lake levels (about +10 cm to -20 cm relative to msl) the scour channels are the most important medium of exchange. At low water levels (less than -20 cm relative to msl), many shallows are dry and there is no water exchange, but elsewhere large mud banks are exposed. The pattern of isolation and dry-down of each shallows differs temporally (Whitfield & Cyrus 1978) and may not even conform to the general pattern described here.

Waterbird ecology and wind-induced water level changes

In years of average or better rainfall, shallows are flooded in summer. Thereafter, water levels recede until the next summer flood. Shallows are highly productive areas, and are rapidly colonised by aquatic organisms after flooding (Whitfield & Cyrus 1978). Generally, dry-down of wetlands results in a concentration of foods which may be exploited by waterbird aggregations (Kushlan 1976, 1978). Waterbirds may be important consumers in such situations (Blaber 1973, Kushlan 1976, Whitfield & Cyrus 1978).

The scour channel is a path whereby pre-adult stages and adults of free-floating, mobile and sessile organisms can enter or leave the shallows. It allows exchange of water, which in this area of high productivity and organic content, could become depleted of oxygen. Two possible outcomes of no water exchange between shallows and lake at St. Lucia have been observed.

In 1976, a dense growth of aquatic macrophytes *Zostera capensis* and *Potomogeton pectinatus* covered the lake between the Vincent islands and eastern shoreline. In October, lake levels dropped so that the macrophytes filled the entire water column, drastically reducing water movement. The area thus functionally resembled a shallows area which had been isolated from the main lake. Dead patches of macrophytes were found in central areas and close to the eastern shoreline. The cause of the die-off is not unknown. Anaerobic conditions (black organic deposits and hydrogen sulphide gas) developed in these areas, with consequent lack of living organisms. I suggest this situation would develop in any relatively deep or slow-drying area with high organic content and no water exchange. Scour channels may thus increase the availability of food to waterbirds, by maintaining high productivity for longer periods than would occur with isolation of the shallows.

Whitfield and Cyrus (1978) documented a different ecological outcome resulting from the isolation of relatively small and rapidly drying backwaters from the main lake in western False Bay. The backwaters are dry at 5 cm above msl, and lie in the zone of smallest wind-induced water level changes. As predicted, scour channels have not developed, and dry down isolates the backwaters from the main lake. A succession of waterbird species exploits the foods concentrated in the backwater, which dries before oxygen supplies are depleted. Isolation in this case, of small rapidly drying ponds, increases the availability of food to waterbirds. Predation by waterbirds on mobile oxygen-consuming animals may delay the depletion of anaerobic conditions. Fish concentrated in a seasonally drying pond were exploited by waterbirds in one year, but not the next (Kushlan 1976). In the first instance, fish populations were reduced 70 % by waterbird predation. In the second instance a 96 % fish population reduction was followed depletion of oxygen supplies.

There will be irregular changes in water depth due to wind-induced changes in shallows linked to the lake. A decrease in water level will increase the availability of prey to waterbirds by decreasing the shelter available to prey and by allowing short legged wading birds to forage in the area. Mobile animals moving from the shallows via scour channels will be vulnerable to predation in narrow channels. This situation was seen on the Masege Flats in southern False Bay. This area had been inundated in the early morning of 27 January 1978 (C.J. Ward pers. comm.). By midday, a strong south westerly had lowered the water level, and only a few small pools linked to the lake by a single channel contained water. A flock of birds comprising 13 Spoonbills *Platuba alba*, 30-40 Little Egrets *Egretta garzetta* and one Black Heron *Egretta ardesiaca* were feeding actively in the pools. Their active hunting methods indicated pursuit of active prey such as prawns or fish. Ten Wood Storks *Ibis ibis*, 15 Great White Egrets *Egretta alba* and one Grey Heron *Ardea cinerea* were standing in the channel catching prey.

In a similar way, an increased water depth may provide increased shelter for prey and make the feeding zone too deep for short legged waders. The floods in February 1977 at Lake St. Lucia resulted in a great decrease in numbers of all waterbirds except those catching prey by underwater pursuit (cormorants, Darter *Anhinga rufa*) and from the air (Fish Eagle *Haliatis vocifer*) (Berruti in prep.).

Wind-induced water level changes decrease the spatial and temporal predictability of food availability. Species likely to be most affected are the short legged waders (Charadriidae). A water level rise of a few cm will greatly alter habitat availability to short-legged waders. A Charadrid wader breeding at St. Lucia may have to contend with reduced feeding habitat availability for several kilometres around the nest for several days, at a time when energetic demands are maximal. This may explain the rarity of breeding of small waders at Lake St. Lucia (Berruti 1980).

However, several thousand Palaearctic waders (Charadriidae) utilise St. Lucia in some years. These migrants, which feed primarily on mud substrates, begin to arrive in August. Lake levels are usually lowest in spring and early summer, and occasionally as late as February (Berruti 1980). At low lake levels, large areas of mudflats (preferred habitat for waders) are alternatively exposed and inundated. The period September to February is the windiest with most frequent water level changes. Lake St. Lucia is probably the most important feeding ground for migrant Charadriidae in south-eastern Africa in some years, and wind-induced water level changes are probably important in determining food availability. After summer floods, the feeding habitat of Charadriidae is submerged, and the birds depart. I suggest wind-induced water level changes provide more feeding habitat by alternatively exposing and inundating feeding areas, than would be available at the edge of a lake at constant, or constantly receding water levels.

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Figures

TABLE

AVERAGE PERCENTAGE WIND FREQUENCY BY DIRECTION JANUARY 1969 - FEBRUARY 1973

(TAKEN FROM HUTCHISON & PITMAN 1973)

Wind direction															
N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9,3	8,5	17,8	5.1	4,1	1,7	4,3	1,9	5,0	4,6	15,6	7,7	9,7	1,1	2,0	1,7

TABLE 2

AVERAGE PERCENTAGE FREQUENCY OF WIND STRENGTH PER MONTH DURING JANUARY 1969 – FEBRUARY 1972

(DATA FROM HUTCHISON AND PITMAN 1973)

Wind strength (m/sec)	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0 – 1	0,8	1,4	5,0	6,3	4,4	3,6	1,1	0,9	2,5	2,2	2,4	2,5
2 – 3	19,4	22,5	28,4	30,0	29,8	31,1	28,1	22,1	16,0	16,8	16,1	22,5
4 – 6	52,3	41,6	44,9	46,8	42,5	46,2	54,4	52,4	42,8	51,9	40,8	46,5
7 – 11	26,4	29,7	18,8	16,4	23,1	17,9	16,2	23,2	37,1	28,4	40,8	27,1
12 – 18	1,2	4,9	2,5	0,4	0,3	1,3	0,2	1,4	1,6	0,6	1,4	1,5
≥ 19	0	0	0,4	0	0	0	0	0	0	0	0	0

TABLE 3

AVERAGE PERCENTAGE FREQUENCY OF WIND STRENGTH PER FOUR HOURLY PERIODS OF THE DAY DURING 1972

(DATA FROM HUTCHISON AND PITMAN 1973)

Wind strength (m/sec)	Time period					
	0001-0400	0401-0800	0801-1200	1201-1600	1601-2000	2001-2400
0 - 1	6,3	5,0	4,0	1,1	2,0	4,6
2 - 3	30,4	35,8	20,8	14,9	20,4	29,0
4 - 6	41,8	38,4	40,6	39,0	39,7	41,4
7 - 11	20,6	19,1	31,4	41,8	35,4	24,1
12 - 18	0,9	1,7	3,2	2,9	2,5	0,9
⩾ 19	0	0	0	0	0	0

TABLE 4

AVERAGE PERCENTAGE WIND FREQUENCY PER FOUR HOURLY PERIODS OF THE DAY IN EACH WIND DIRECTION QUADRANT

DURING 1972

(DATA FROM HUTCHISON AND PITMAN 1973)

Time period	Wind direction															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0001-0400	24,4	20,22	8,33	1,3	3,7	7,1	2,9	2,4	2,4	4,1	20,4	25,8	35,9	30,9	31,8	30,6
0400-0800	23,4	22,5	9,6	1,3	1,9	3,6	2,9	7,3	4,9	4,8	21,3	21,5	30,1	30,9	20,6	30,6
0800-1200	11,4	16,1	19,6	18,4	31,5	10,7	17,4	17,1	28,1	33,3	14,5	10,8	7,8	7,3	6,4	11,1
1200-1600	3,5	11,0	21,8	48,7	31,5	60,7	43,5	48,8	34,1	22,4	10,1	7,5	2,9	7,3	4,7	2,8
1600-2000	9,0	13,8	27,9	26,3	22,2	17,9	26,1	12,2	20,7	26,9	13,8	8,6	7,8	7,3	6,4	8,3
2001-2400	28,4	16,5	12,8	3,9	9,2	0	7,3	12,2	9,8	8,2	20,0	25,8	15,6	16,4	30,2	16,7

TABLE 5

Percentage lake water levels (monthly averages at Charter's Creek) in each water depth class relative to msl at Lake St, Lucia March 1967 - Dec 1978.

	Water level (cm relative to msl)						
	<-40	-40 - -31	-30 - -21	-20 - -11	-100 - 0	1 - 10	11 - 200
%	3,6	6,4	18,0	15,2	23,2	11,6	8,4