Corella, 1985, 9 (4): 108-113

SEASONAL CHANGES IN ABUNDANCE AND POND PREFERENCES OF WATERBIRDS AT MOITAKA SEWERAGE WORKS, PORT MORESBY, PAPUA NEW GUINEA

H. L. BELL

Department of Zoology, University of New England
Armidale, N.S.W. 2351

Received 10 November, 1983

Revised 1 April, 1985

Data are given on abundance of the more common waterbirds at Moitaka sewerage works, Port Moresby. Egrets and Pied Herons showed few seasonal fluctuations whereas Australasian Grebes, Black-winged Stilts and Masked Lapwings increased after the breeding-season. Terns were annual passage migrants. Jacanas occurred only when the south-east trade winds accumulated scum into firm mats. Species favouring anaerobic ponds were: terns and Pied Herons, because dead fish and cockroaches were present; Jacanas, which walked on the floating faeces; and Masked Lapwings, which foraged along the shallow shore-lines. Grebes only frequented aerobic ponds, and Stilts preferred them where the shoreline was sufficiently shallow. Egrets showed no preferences.

The attraction of waterbirds to sewerage works is well known (e.g. Glue and Bodenham 1974, 1977 in Britain; Heron 1970 and Boekel 1976 in Australia). Mackay (1967) first drew attention to the abundant bird life at the Moitaka severage works, Port Moresby, Papua New Guinea. The works adjoin the Waigani Swamps, which cover hundreds of square kilometres, where large assemblages of birds can be seen e.g. 3 000 Little Black Cormorants *Phalacrocorax sulcirostris* and 2 000 Wandering Whistling Ducks *Dendrocygna arcuata* (pers. obs.).

The aim of this paper is to show how the abundance of certain species at the sewerage works is related to season and to local conditions. The paper does not discuss seasonality and abundance of birds of Waigani Swamp in detail because others have collected data there over many years.

STUDY AREA AND METHODS

Technical details of the sewerage works are from a report to the PNG Public Works Department (1975, 1976). Figure 1 depicts the plan. Sewage receives little treatment before entering the ponds; but faeces are mechanically broken up into small pieces. Sewage flows directly into Anaerobic Ponds 1, 2 and 3, although Pond 1 was inoperative for most of the study period. The sewage contains a large and apparently constant supply of large dead cockroaches, *Blattoidea*. After break-down in the anaerobic ponds the sewage is released into Aerobic Pond 1, thence to Aerobic Pond 2, after which the effluent flows into the swamps. Ponds are steep-sided, with banks *ca.* 4 m wide, covered by mown grass. Because there are sludge deposits the banks of anaerobic ponds sloped away gradually

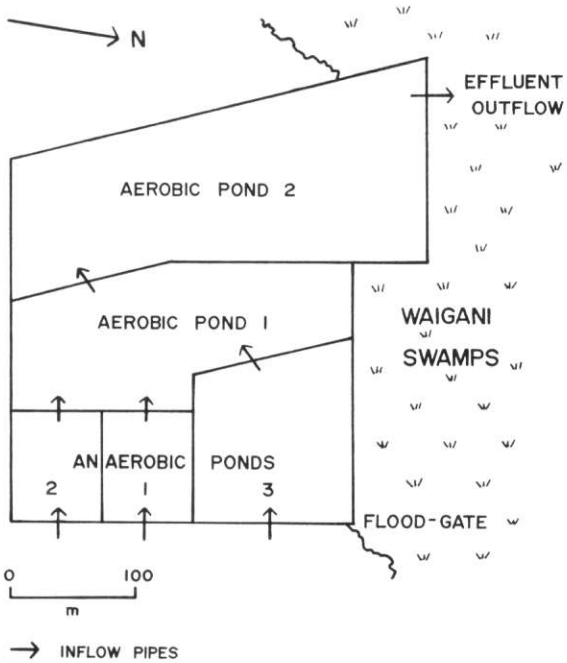

Figure 1. *Lay-out of Moitaka sewerage works, Port Moresby. Embankments dividing ponds are not drawn to scale.*

but in the aerobic ponds, particularly Pond 2, the water was much deeper close (< 0.5 m) to the banks, about 15-30 cm deep compared to 5 cm in anaerobic ponds.

The system originally was designed for a human population of 26 000 but by 1975 was coping with the sewage of 57 500 people. In September/November, 1976, Anaerobic Pond 3 overflowed directly into the swamp. By March, 1976, Aerobic Pond 1 had become anaerobic owing to inflow from the anaerobic ponds. Scum cover, mainly of partly-dissolved faeces and toilet paper, was dense on the anaerobic ponds and from June to November, when the south-east trade wind blew, it accumulated in the north-west corners of ponds. In Anaerobic Pond 3 during the trade wind season the scum was a firm, heavily fly-blown layer, covering *ca.* 0.5 ha. At other times scum was evenly dispersed and not a solid mass. By contrast, the aerobic ponds, at least until March, 1976, were clear of scum, rich in algae and with clear water. The

TABLE 1

Biological Oxygen Demand loadings of sewerage ponds in tests at Moitaka December, 1975 (PNG Public Works Department 1975).

Pond	Loading	BOD Reduction % (mean)
Anaerobic 1	Closed	
Anaerobic 2	1 301 kg O_2/ha/day	68.7
Anaerobic 3	1 023 kg O_2/ha/day	42.6
Aerobic 1	89 kg O_2/ha/day	50.6*
Aerobic 2	37 kg O_2/ha/day	31.3

*Note that by March, 1976, Aerobic 1 had become anaerobic owing to overloading.

The Biological Oxygen Demand is the quantity of oxygen required to oxidize a unit volume or area of material.

Biological Oxygen Demands of each pond are depicted in Table 1. The African fish *Tilapia mossambica* was abundant in all ponds and the swamps. Those in anaerobic ponds, however, were breathing at the surface and many floating dead fish were seen.

The rainfall during the study period is shown in Table 2, data being taken from Port Moresby regional Forestry office.

I visited Moitaka seventeen times between September, 1975 and November, 1976, in all seasons except for the wettest period (late Dec.-Feb.). All birds seen were counted, by pond, or by bank on which they were seen. I present data only for the more abundant species, but will refer briefly to others.

RESULTS

Figure 2 shows the abundance, on all ponds, of several species or groups. These need not indicate relative abundance in the neighbouring swamps. For example Comb-crested Jacanas *Irediparra gallinacea* were abundant year-round in the swamps, but not so on the sewerage ponds.

Fewer Masked Lapwings *Vanellus miles* occurred during the dry season (July-November). Black-winged Stilts *Himantopus himantopus* disappeared, both from the works and the neighbouring swamps, during the wet season. Jacanas left the ponds during the wet season but were breeding in the nearby swamps then.

TABLE 2

Rainfall, Jackson's Aerodrome, Port Moresby, September, 1975-November, 1976.

MONTH	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Rainfall (mm)	63	77	137	227	378	161	136	103	159	144	8	12	0	129	96

Australasian Grebes *Tachybaptus novaehollandiae* declined in the wet season. Whiskered *Chlidonias hybrida,* White-winged *C. leucoptera* and Gull-billed Terns *Gelochelidon nilotica* occurred only in late spring and early summer, in both 1975 and 1976. Great *Egretta alba,* Intermediate *E. intermedia* and Little Egrets *E. garzetta* appeared to show a wet season peak but this was not statistically significant. The Pied Heron *Ardea picata* appeared to be present year-round, but in greater numbers in the early wet season. However, on three occasions, in October, 1975 and 1976, and August, 1976, they were virtually absent, but in each case were present in either the preceding or following week.

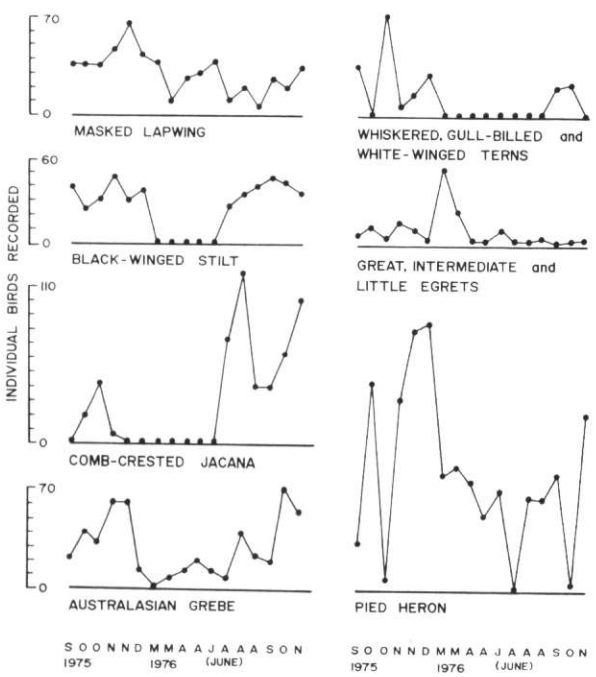

Figure 2. *Numbers of Masked Lapwings, Black-winged Stilts, Comb-crested Jacanas, Australasian Grebes, Terns, Egrets and Pied Herons recorded at visits to Moitaka sewerage works, September, 1975 to November, 1976.*

Several species prefered particular ponds for foraging. To determine such preferences it was necessary to distinguish between those species that forage on or over the open water, such as grebes, jacanas and terns, and those whose foraging area is determined by the amount of shore-line, such as lapwings, stilts, egrets and Pied Herons (although Pied Herons and egrets will also hover and take fish over open water, W. Filewood, pers comm.).

Table 3 shows the numbers of grebes, jacanas and terns seen in each pond at Moitaka. Australasian Grebes clearly avoided the anaerobic ponds and from March, 1976, when Aerobic Pond 1 became anaerobic, they abandoned it. Jacanas occurred predominantly on Anaerobic Pond 3, but occurred twice on the aerobic ponds, feeding on the shore-line. Possibly there was a concentration of food there at such times, because Jacanas rarely forage along shore-lines. Anaerobic Pond 3 was the only pond with a large surface area of firm scum and the jacanas walked upon it searching for maggots. Sharp-tailed Sandpipers *Calidris acuminata* also foraged on the scum but many were found dead, not obviously killed by predators, on nearby embankments. Terns foraged only over Anaerobic Ponds 2 and 3 (Pond 1 was inoperative). All three species take aerial or surface prey and were seen to take flying insects, particularly over the floating scum, or floating dead fish and cockroaches.

Table 4 shows the frequency of occurrence, of shore-birds at each pond. Egrets showed no preferences; but were seldom common (Figure 2) in contrast to their status in the neighbouring swamps. Pied Herons, while present at all ponds, favoured the anaerobic ones. The Black-winged Stilt favoured Anaerobic Pond 1 (the inoperative one) and Aerobic Pond 1 but avoided Aerobic Pond 2. Masked Lapwings favoured

TABLE 3

Numbers of grebes, jacanas and terns seen, by ponds, at Moitaka sewerage works, September, 1975 to November, 1976

POND	1975					1976											
*	25ix	3x	10x	21xi	28xi	12xii	5iii	23iii	2iv	23iv	24vi	6viii	20viii	28viii	24iv	1x	21xi
Australasian Grebe																	
Anaerobic 1																	
Anaerobic 2									1								
Anaerobic 3																	
Aerobic 1	2	2	2	25	23	3			2			1					
Aerobic 2	20	38	30	36	28	10		9	9	20	12	8	40	24	20	70	55
Comb-crested Jacana																	
Anaerobic 1																	
Anaerobic 2																1	
Anaerobic 3		20	42	6								73	60	40		40	101
Aerobic 1													40			18	
Aerobic 2													20			4	
Whiskered, White-winged and **Gull-billed Terns**																	
Anaerobic 1															5		
Anaerobic 2	12		22	8	8	10									12	8	
Anaerobic 3	25	52		8	20										8	14	
Aerobic 1																	
Aerobic 2																	

* (Day, month in Roman)

Anaerobic Ponds 1 (inoperative) and 3, but avoided Aerobic Pond 2, though frequencies differed little between all ponds.

TABLE 4

Abundance of wading species at different ponds of Moitaka sewerage works (birds per 100 m of shoreline, for visits when the species was recorded).

	Egrets	Pied Heron	Black-winged Stilt	Masked Lapwing
Anaerobic 1	0.3	3.4+	1.1+	1.0+
Anaerobic 2	0.2	2.8+	0.9	0.8
Anaerobic 3	0.1	3.0+	0.7	0.7
Aerobic 1	0.2	1.1—	1.2+	0.7
Aerobic 2	0.2	1.1—	0.2—	0.4—
$\chi^2_{(3)}$	8.12 ns	344.5 $p<0.001$	126.6 $p<0.001$	45.50 $p<0.001$

+ indicates significantly more than expected, — indicates significantly fewer than expected (all $p<0.01$). Expected values calculated from total numbers of birds divided by proportion of total shore-line for each pond.

DISCUSSION

The apparent seasonal changes in Figure 2 can be mostly explained. Although Mayr (1941) claimed that the Masked Lapwing was a wintering migrant in Papua New Guinea we now know it to be a breeding resident. The higher numbers at Moitaka are at times when wintering migrants should be absent. A few breed on the embankments at Moitaka in the dry season but the high numbers in the wet season have probably dispersed from other breeding areas

Black-winged Stilts disappeared, from both sewerage works and swamps, in the late wet season, as they did in subsequent years. Stilts breed locally (Finch 1982, first noted by R. H. Donaghey in 1967-68) but need shallow water with small islands, which is not present at Moitaka. On return their numbers included many immature birds; so they presumably disperse to breed. Similarly, Australasian Grebes probably disperse to breed during the wet season, there being no water-weed for nest-building in the sewerage works.

Jacanas were always present near the works, but preferred to feed on the ponds when prevailing winds provided a firm scum-cover for foraging. The low numbers in 1975, compared to 1976, were probably due tothe direct release of sewage into the swamps from Anaerobic Pond 3 in September, 1975.

The seasonal pattern for terns suggests that they are passage migrants. Whiskered and Gull-billed Terns in Papua New Guinea are probably wintering migrants from Australia, while White-winged Terns are Palaearctic wintering migrants to Australia. The pattern is probably one of both north-bound and south-bound passage migration through Moitaka.

I cannot explain the pattern for egrets; they are abundant year-round in the neighbouring swamps. Australian breeding Great and Little Egrets do move to Papua New Guinea (Bird Banders' Association of Australia 1962, 1964) but local informants claim that all three egrets breed in Papua New Guinea and the Great Egret is definitely known to do so.

Pied Herons are supposed to migrate to northern Australia from Papua New Guinea (Hancock and Elliot 1978). This idea, current for years in the Australian literature (e.g. Cayley 1931), seems unsupported by evidence. Why a bird should migrate from waterbodies in Papua New Guinea, to those in Australia, when both undergo similar seasonal patterns of rainfall, seems mystifying. There were sudden absences at Moitaka but all within a week or two of subsequent increases. Pied Herons are gregarious; I counted a flock, most likely heading for a roost of *Melaleuca* trees, of 1 150 birds, at Balimo, Western Province (Bell 1967). The species quickly congregates at an ephemeral food source, as it does in the Western Province after dry grasslands have been fired (Rand 1942, Bell 1967). I believe that the temporary absences at Moitaka are caused by birds moving off a temporary food source or perhaps temporary changes in the contents of sewage outflows (e.g. a lack of cockroaches) at Moitaka.

The quality of the ponds has a direct bearing on which species use them. Anaerobic ponds, with their high scum cover, lack of oxygen and high density of solid matter in the water would discourage diving species. So it is not surprising that not only did Grebes avoid anaerobic ponds; they quickly abandoned Aerobic Pond 1 when it, too, turned anaerobic. In contrast, jacanas can only forage on anaerobic ponds when seasonal conditions pack up the surface scum. Presumably, had the sewage works not been grossly overloaded, there would have been no jacanas at all. The deaths of Sharp-tailed Sandpipers, which foraged on the same floating scum as jacanas, may have resulted from botulism as found at sewerage works elsewhere (e.g. Moulton *et al.*, 1976). If so then it is strange that no jacanas were found dead. The partiality by terns for Anaerobic Ponds 2 and 3 was because dense clouds of insects hovered over the scum in Pond 3 and dead *Tilapia* and cockroaches floated on both ponds.

Various factors affect the preferences by shoreline species. Egrets, in view of their abundance in the swamps, treated the sewerage works as only a secondary habitat. They appeared to forage on all ponds. The deep water of the two aerobic ponds would not inhibit Egrets, with their long legs, as it did Masked Lapwings. Pied Herons, also long-legged, clearly favoured anaerobic ponds, perhaps due to their predilection for the numerous cockroaches and dead *Tilapia* on these ponds. Pied Herons hovered at the inflow pipes (2 m above water level) to take cockroaches, and above the water to take dead fish and cockroaches. Strictly, in this setting, they were not wading birds. Anaerobic Pond 1, being located between Ponds 2 and 3, was used as a base for sallying over those ponds.

Stilts appeared to prefer the inoperative Anaerobic Pond 1 and Aerobic Pond 1. Probably the micro-organisms on which stilts feed need clear water. Aerobic Pond 2 was probably too deep for Stilts and was avoided. Lapwings clearly favoured anaerobic ponds except Pond 2. Pond 2 is nearest the car-park and works depot so human disturbance may have reduced the presence of this wary species. I believe that Masked Lapwings prefer the anaerobic ponds because the water is shallow there.

Many migratory waders visited the area and whereas almost all Sharp-tailed Sandpipers, Pectoral Sandpipers *Calidris melanotus* and Red-necked Stints *Calidris ruficollis* were on the anaerobic ponds with their shallow shores, long-legged species such as the Ruff *Philomachus*

pugnax and Black-tailed Godwit *Limosa limosa* were only ever seen at the deeper aerobic ponds.

While sewerage works everywhere seem to provide habitat for waterbirds it should be borne in mind that the species likely to be attracted, in any numbers, will depend upon the management of the works, the different types of ponds employed, and the rate of sewage inflow in relation to the size of the works.

ACKNOWLEDGEMENTS

I thank Mr R. D. Mackay for his assistance in many field trips to Moitaka. Dr H. A. Ford and Mr R. C. Nias criticized the drafts. Mr S. Ferrier gave advice on the appropriate statistical methods. Ms L. Bridges drew the figures, Mrs V. Watt and Miss S. Pont typed the manuscript.

REFERENCES

Bell, H. L. (1967). Bird life of the Balimo Sub-district, Papua. *Emu* 67: 57-79.

Bird Banders' Association of Australia (1962). Recovery Round-up. *Aust. Bird Bander* 1: 39-41.

Bird Banders' Association of Australia (1964). Recovery Round-up. *Aust. Bird Bander* 2: 115-117.

Boekel, C. (1976). Ten months on Gove Peninsula. *Aust. Bird Watcher* 6: 231-245.

Cayley, N. W. (1931). What bird is that? Sydney, Angus and Robertson.

Finch, B. W. (1982). Black-winged Stilt (*Himantopus himantopus*) nesting at Kanosia Lagoon, Central Province — a new breeding species for the island of New Guinea. *PNG Bird Soc. Newsl.* 193-194: 10.

Glue, D. and Bodenham, D. (1974). Bird-life at a modern sewage farm. *Bird Study* 21: 229-237.

Glue, D., and Bodenham D. (1977). Sewage farm bird-life increases during 1976 summer drought. *Bird Study* 24: 200-209.

Hancock, J. and Elliot, H. (1978). The herons of the world. London, London Editions.

Heron, S. J. (1970). Birds of the sewerage works at Armidale, N.S.W. *Aust. Bird Watcher* 8: 269-272.

Mackay, R. D. (1967). Birds catching fish in Papua. *Aust. Bird Watcher*: 2: 46-48.

Mayr, E. (1941). List of New Guinea birds, New York Am. Mus. nat. Hist.

Moulton, D. W., Jensen, W. I. and Low, J. B. (1976). Avian botulism epizootiology on sewage oxidation ponds in Utah. *J. Wildl. Mgmt.* 40: 735-742.

PNG Public Works Department (1975). Port Moresby sewerage system. Report on sewage lagoons Waigani and Gerehu. Scott Furphy Pty Ltd.

PNG Public Works Department (1976). Waigani sewage lagoons. Supplementary Report June, 1976. Camp Scott Furphy Lty Ltd.

Rand, A. L. (1942). Results of the Archbold Expeditions. No. 42. Birds of the 1936-1937 New Guinea expedition. *Bull. Am. Mus. Nat. Hist.* 79: 289-366.