Wildlife Research, 1996, **23**, 557–69

Waterbird Surveys of the Middle Fly River Floodplain, Papua New Guinea

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Abstract

In total, 58 species of waterbird were recorded on the grassed floodplain of the Middle Fly during surveys in December 1994 and April 1995. The floodplain is an important dry-season habitat both in New Guinea and internationally, with an estimated (± s.e.) 587249 ± 62741 waterbirds in December. Numbers decreased 10-fold between December and April to 54914 ± 9790: the area was less important during the wet season when it was more deeply inundated. Only magpie geese, comb-crested jacanas and spotted whistling-ducks were recorded breeding on the floodplain. The waterbird community was numerically dominated by fish-eating species, especially in December. Substantial proportions of the populations of many species that occurred on the Middle Fly in December were probably dry-season migrants from Australia, suggesting that migration across Torres Strait is important to the maintenance of waterbird numbers in both New Guinea and Australia.

Introduction

About 700 species of bird occur on the island of New Guinea (Coates 1985; Beehler *et al.* 1986). Many of those at lower altitudes, especially in the Trans-Fly ornithological region in the southernmost part of New Guinea, occur also in Australia. New Guinea is separated from Australia by Torres Strait, which is only 150 km wide at its narrowest point, and at least 102 species of bird migrate annually between the two land masses (Draffan *et al.* 1983). Although the population size, distribution and migratory status of many species still need to be determined (Ashford 1979), large numbers of Australian waterbirds occur in the Trans-Fly region during the dry season (Beehler *et al.* 1986). The Trans-Fly ornithological region encompasses much of the lowland part of the Fly River.

The lowland part of the Fly River has very little gradient; Kiunga, which is 800 km from the sea, is only 20 m above sea level (Smith and Bakowa 1994). This has resulted in an extensive floodplain, especially on the middle reaches of the river, that is referred to hereafter as the grassed floodplain of the Middle Fly (Jaensch 1994). Together with Bensbach River to the south-west of the Fly River (Finch 1980), the grassed floodplain of the Middle Fly has long been recognised as an important habitat for waterbirds (Rand 1942; Simpson 1990, 1994) and among the most significant wetlands in Papua New Guinea (Scott 1989).

In 1981, Ok Tedi Mining Ltd began construction of a large gold and copper mine at Mt Fubilan on the upper reaches of the Ok Tedi, a tributary of the Fly River (Fig. 1). Production began in 1984 and, because of construction difficulties, the mine has operated without a tailings

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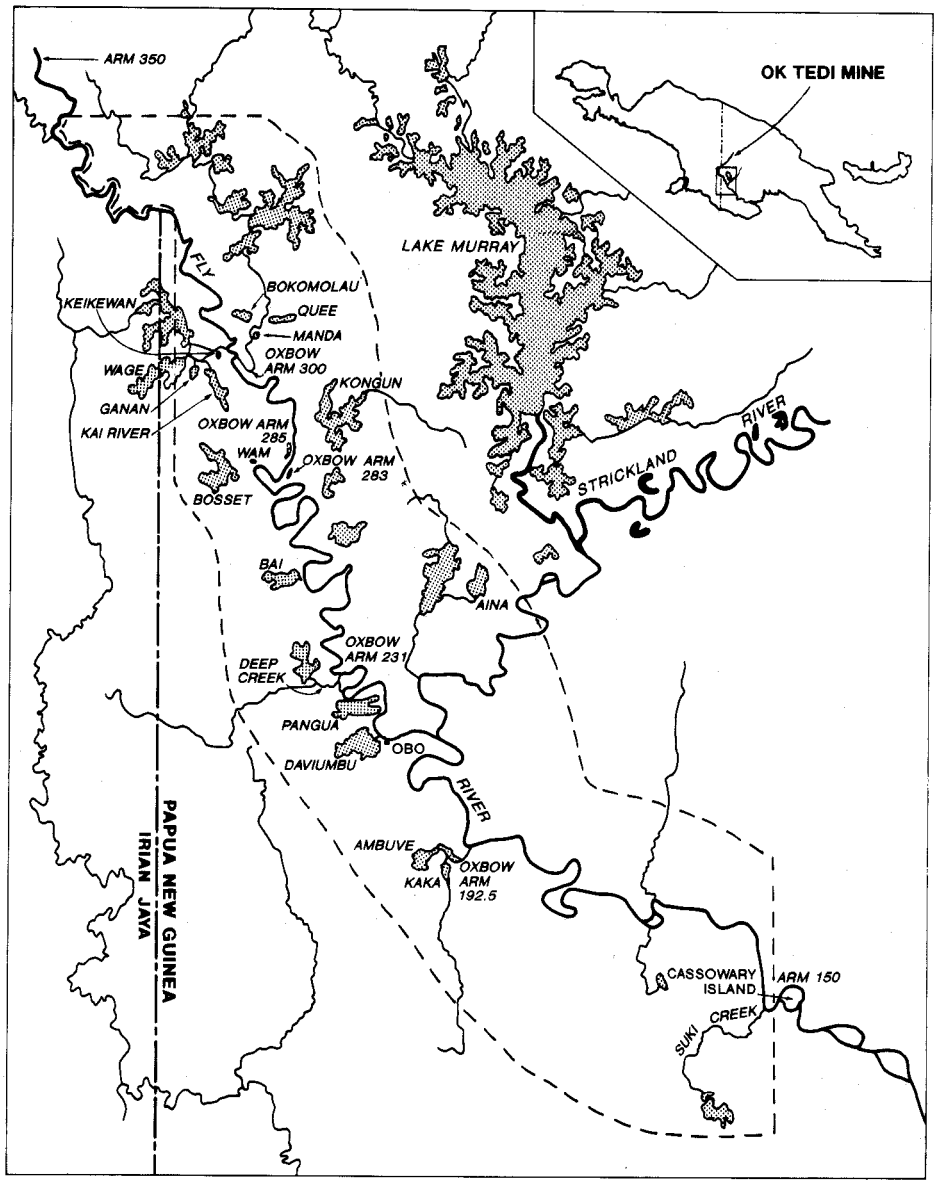

Fig. 1. Areas surveyed for waterbirds on the grassed floodplain of the Middle Fly in 1994–95. The approximate boundary of the area covered by transects, and the major waterbodies, are shown. Adopted River Mileage (ARM) 350, at northern end of survey area, and ARM 150, at southern end, are marked.

dam and without waste retention (Smith and Bakowa 1994). Gold is no longer mined and the principal environmental concerns are the elevated sediment and copper levels in discharge water from the mine (Smith and Hortle 1991). Since 1983, Ok Tedi Mining Ltd has conducted extensive biological monitoring, focused on maintaining biomass and diversity of fish species in the Ok Tedi and Fly River (Smith and Hortle 1991). In 1994–95, the company commissioned

waterbird surveys of the grassed floodplain of the Middle Fly during the dry and wet seasons as part of its programme to document the biology of the Fly River system and to expand the range of organisms monitored.

Methods

Study Area

The Fly River lies in the Western Province of Papua New Guinea, arising in the Star Mountains at an altitude of 3500–4000 m above sea level and distance from the sea of approximately 1000 km. For a short distance, it forms the border between Papua New Guinea and Irian Jaya (Fig. 1). Of the world's major rivers, the Fly has the highest run-off per unit area and 23rd-highest discharge (6000 cumecs year^{-1}) (Welcomme 1985; Smith and Hortle 1991). Annual rainfall in the headwaters of the system is about 10 m; it is 4 m at the river port of Kiunga near the junction of the Ok Tedi and Fly River and 2 m at Obo on the Middle Fly floodplain (Ok Tedi Mining Ltd 1995). Rainfall in the headwaters is usually evenly distributed through the year but about 75% of rain on the grassed floodplain falls between December and May. Water levels on the grassed floodplain were 3·3 m lower during December 1994 than in April 1995, when most of the floodplain was deeply inundated.

The grassed floodplain of the Middle Fly begins about 600 km from the river mouth and extends downstream almost 350 km (Fig. 1). The floodplain is up to 30 km wide and there is little longitudinal variation in habitat as the river meanders through the floodplain. Upstream from the Middle Fly, land adjacent to the river has more relief and the river floodplain is reduced to a comparatively narrow terrace. Downstream from the Middle Fly, the river is influenced by tides, and various types of forest (often mangroves) grow to the river's edge. Several tributaries join the Middle Fly, the most significant being the Strickland River. Lake Murray, the largest lake in the region, is on the floodplain of the Strickland River but was not surveyed (Fig. 1).

Most of the grassed floodplain is covered by reeds, *Phragmites karka*, with smaller areas of wild rice, *Oryza rufipogon*, near the outer edge of the floodplain and pit-pit, *Saccharum robustum*, lining the river channels (Scott 1989). The whole floodplain is inundated during the wet and early dry seasons. Some low-lying areas, usually tributaries that have been blocked off from the main channel by levees, contain a mosaic of open water and mats of floating grasses, *Echinochloa praestans* and *Leersia hexandra*, all year and are referred to herein as blocked valley lakes. Lotus, *Nelumbo nucifera*, waterlilies, *Nymphaea* and *Nymphoides* spp., mats of spiny mudgrass, *Pseudoraphis spinescens*, and red water fern, *Azolla pinnata*, also occur in blocked valley lakes. Oxbows containing deep water occur on the floodplain where the river has changed course; their banks are higher than the surrounding floodplain and support riparian forest dominated by *Barringtonia acutangula*, *Nauclea orientalis* and *Terminalia* sp., interspersed with occasional sections of bare bank. River channels have a bank structure similar to that of oxbows; the chief difference between the two habitats is the strong current in river channels. Swamps of *Melaleuca leucadendra* occur at the edge of the floodplain and other areas where water is shallow. Swamps of sago palm, *Metroxylon sagu*, also occur towards the edge of the floodplain.

A high species richness and biomass of fish occurs on the grassed floodplain (Smith and Hortle 1991; Smith and Bakowa 1994). By contrast, the invertebrate fauna appears to be depauperate in both biomass and numbers of species (Chambers 1988).

Surveys

Waterbirds were surveyed at the end of the dry season (2–7 December 1994), when they were congregated on residual water in blocked valley lakes and oxbows, and near the end of the wet season (25–30 April 1995), when most of the floodplain was inundated, birds were dispersed and breeding was likely to be maximal (Coates 1985). For the first three days of each survey, two teams of three observers counted from boats or on foot in accessible areas of open water and adjacent vegetation. Ground counts provided comprehensive species lists and information about species that were difficult to distinguish from the air (e.g. crakes, shorebirds, egrets).

Aerial counts were made from a helicopter by two observers (front left, S.A.H., and rear right, G.B.P.) during the second three days. The survey area was divided into 786 transects 200 m wide, located perpendicular to the river channel. Every 23rd transect (36 in total at 4·6-km intervals) was surveyed at a height of 25 m in December and 15 m in April and a speed of *c.* 90 km h^{-1}. Transects were flown at a lower height in April because many birds occurred in denser habitat and flushed less readily. Each observer counted all waterbirds in a 100-m strip either side of the helicopter, using a line on the window to mark off

100 m. Length of the transects varied from 24 to 46 km. The overall area divided into transects was 5957 km^2, calculated from 1:100000 topographic maps. This encompassed the Papua New Guinean portion of the Middle Fly River floodplain, except that we stopped short of the border with Irian Jaya between the northern end of Bosset Lagoon and the point where the border is defined by the Fly River (Fig. 1). At its northern end, the river floodplain extends a short distance into Irian Jaya.

Six blocked valley lakes were surveyed from the air in December and April to check the feasibility of estimating waterbird abundance from surveys of blocked valley lakes rather than transects of the whole floodplain. Because of their diffuse nature and irregular shapes, it was impossible to survey in a standardised way, but, in general terms, the outer parts of each lake were covered in one circuit and the central area was covered in one or more passes. Two of the lakes (Ambuve and Daviumbu) were also counted from the ground for comparison with the aerial surveys.

The amount of water present on each transect of the floodplain was scored on a scale of 1–4 during aerial surveys (1, floodplain dry except for river channels and oxbows; 2, most of floodplain dry but blocked valley lakes contain water; 3, most of floodplain inundated; 4, whole floodplain inundated).

Analyses

Use of systematically selected transects to estimate abundance provides precise estimates but standard errors that may be biased (Caughley 1977*a*). Random sampling was inappropriate, however, because transects needed to be spaced several kilometres apart to ensure that birds disturbed on the previous transect were not recounted and because we wanted data on distribution of birds on the floodplain (Caughley 1977*a*, 1977*b*). The distribution of birds did not appear related in any way to the spacing of transects, so it is unlikely that bias of standard errors was significant (Caughley 1977*a*).

Population estimates ($\hat{Y}$) were calculated as follows:

$$\hat{Y} = (\Sigma y/\Sigma z)\, Z,$$

where y is the number of waterbirds in a given transect of area z, and Z is the overall area covered by transects. When the number of birds counted from the ground exceeded the estimate based on transect data, we used the ground count as an estimate of abundance. Standard errors of the transect-based estimates were calculated as follows:

$$\text{s.e.}_{\hat{Y}} = \sqrt{\frac{N(N-n)\left(\sum y^2 + R^2 \sum z^2 - 2R\sum yz\right)}{n(n-1)}},$$

where N is the total number of possible transects in the survey area, n is the number selected for survey and $R = \hat{Y}/Z$. Population estimates in December and April were compared by t-tests (Zar 1974, pp. 105–7). When the April population estimate for a species was too low to calculate a meaningful variance, we used a 1-sample hypothesis and calculated the probability that the April estimate was drawn from the same population as the December estimate.

Counting Efficiency

Aerial counts of waterbirds on floodplain habitats in northern Australia have substantially underestimated the number of birds present (Bayliss and Yeomans 1990; Morton *et al.* 1990*a*, 1990*b*, 1993*a*, 1993*b*). To check the completeness of our counts, the transects were flown again by helicopter in October 1995 at a height of 20 m and speed of 110 km h^{-1} with front (S.A.H.) and rear (W.R.K.) observers on the left side. The rear observer recorded birds missed by the front observer. To increase the chance of seeing birds overlooked by the front observer, the rear observer flew with the door open and limited his checks to a single species or a group of related species on each transect, whereas the front observer counted all species. Counts of comb-crested jacanas, cormorants and darters, and ducks were checked. Densities of waterbirds were approximately midway between those of December 1994 and those of April 1995.

The proportion of birds seen by the front observer (p) was calculated as follows (Pollock and Kendall 1987):

$$p = 1 - [n_2 / (n_1 + 1)],$$

where n_1 is the number of birds seen by the front observer and n_2 is the number of birds missed by the front but seen by the rear observer.

Results

In total, 58 species of waterbird were recorded on the grassed floodplain of the Middle Fly. In December 1994, at the end of the dry season, 57 species were recorded and the estimated waterbird population was 587249 ± 62 741 (Table 1) (all errors stated are standard errors). The most abundant species were egrets (great egret, intermediate egret, little egret) with 231052 ± 44718 individuals, glossy ibis 60332 ± 28589, Australian white ibis 50420 ± 15054 and magpie geese 47976 ± 15774 (scientific names are given in Table 1). Based on the relative proportions among the egrets identified to species level during ground counts, there were about 130 000 intermediate egrets, 90000 great egrets and 1500 little egrets. One cattle egret was seen. All transects were scored as 2 for wetness in December, indicating that water was present in all blocked valley lakes and oxbows but that most of the surrounding floodplain was dry.

A dramatic reduction in numbers occurred during the wet season, with an estimated population in April 1995 of only 54914 ± 9790 waterbirds of 36 species. The most abundant species were magpie geese with 18670 ± 4770 individuals, egrets 17923 ± 5743, darters 4684 ± 1147 and comb-crested jacanas 3394 ± 735 (Table 1). Based on relative proportions in the ground counts, there were about 16000 great egrets and 2000 intermediate egrets. Most transects were scored as 4 for wetness in April (mean = 3·9 ± 0·04), with almost the entire floodplain inundated.

Most species mirrored the decline seen in overall waterbird numbers between December and April but the statistical certainty attached to the changes in abundance varied greatly between species. *P*-values in Table 1 reflect both the magnitude of the seasonal changes in abundance and the size of December standard errors. Many species were recorded occasionally in large flocks, which increased the variance of population estimates, and meant that only extreme changes in numbers were statistically significant (Fig. 2).

Glossy ibis, radjah shelducks, black-winged stilts, pied herons, Australian white ibis and migrants from the Northern Hemisphere were among the species showing the most pronounced exodus from the Middle Fly during the wet season; they were either absent in April or only a few vagrant individuals were recorded (Table 1). Other species, including intermediate egrets, green pygmy-geese, nankeen night herons and wandering whistling-ducks, were seen regularly in April but at only 1–4% of December abundance. A third group, including magpie geese, comb-crested jacanas, great egrets, darters and spotted whistling-ducks, occurred in April at 17–52% of December abundance, which sometimes was not a statistically significant reduction. A few species showed no reduction in numbers; in fact, clamorous reed-warblers and white-browed crakes defied the overall trend and were recorded in higher numbers in April than in December.

Little consistency existed in species distribution along the length of the Middle Fly in either December or April (Fig. 2). This presumably reflected lack of longitudinal pattern in habitat, although the mix of blocked valley lakes, oxbows, dense reeds and other habitat types caused substantial variation between transects. Waterbird abundance was greater in blocked valley lakes in both the wet and dry seasons than in oxbows or river sections (Table 2) and it was apparent during the aerial transects that few birds occurred in *Melaleuca* swamps or sago swamps, even when they were flooded. Large numbers of magpie geese, often with nests, were seen from the air in areas of *Oryza rufipogon*, *Echinochloa praestans* and *Phragmites karka* in April, but few other large waterbirds were seen in dense areas of reeds or grass.

The correlation between numbers of waterbirds counted on the same transects in December and April was poor (r_s = 0·015, d.f. = 35, not significant). This was probably due to microhabitats within each transect changing between surveys, because of increased flooding in April and substantial changes in size and position of floating grass mats in some blocked valley lakes.

Counting efficiencies of the left and right observers in the helicopter in December and April were similar (Table 3), which is consistent with them counting almost all birds present (the

Table 1. Estimates of abundance of each species on the floodplain of the middle Fly River based on aerial transects, aerial counts and ground counts

Actual numbers counted are shown in parentheses when estimates from transects were less than 500 (or when counts were greater than estimates) and standard errors are shown when estimates were more than 500. Ratios between estimates (*A/D*) in December 1994 (*D*) and April 1995 (*A*) are shown when one estimate was greater than 500 or actual count was more than 25. Significance levels of changes in abundance between seasons are presented if one estimate was more than 500: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; n.s., not significant

Species	December 1994	April 1995	Ratio	Significance
Magpie goose, *Anseranas semipalmata*	47976 ± 15774	18670 ± 4770	0·39	*
Wandering whistling-duck, *Dendrocygna arcuata*	23218 ± 12044	362 (44)	0·02	*
Spotted whistling-duck, *Dendrocygna guttata*	21996 ± 11244	3666 ± 1029	0·17	n.s.
Radjah shelduck, *Tadorna radjah*	1358 ± 527	–	0	*
Pacific black duck, *Anas superciliosa*	12809 ± 3215	136 (6)	0·01	***
Grey teal, *Anas gibberifrons*	113 (38)	–	0	–
Garganey, *Anas querquedula*	46 (176)	–	0	–
Hardhead, *Aythya australis*	– (14)	–	–	–
Green pigmy-goose, *Nettapus pulchellus*	28152 ± 8642	475 (84)	0·02	**
Unidentified duck	10953	–	–	–
Australasian grebe, *Tachybaptus novaehollandiae*	– (16)	–	–	–
Darter, *Anhinga melanogaster*	26070 ± 4773	4684 ± 1147	0·18	***
Little pied cormorant, *Phalacrocorax melanoleucos*	9278 ± 2000	724 ± 273	0·08	***
Little black cormorant, *Phalacrocorax sulcirostris*	12628 ± 2518	2535 ± 1336	0·20	***
Unidentified cormorant	543	– (2)	–	–
Australian pelican, *Pelecanus conspicillatus*	3213 ± 1697	113 (8)	0·04	*
White-faced heron, *Ardea novaehollandiae*	294 (13)	–	–	–
Little egret, *Ardea garzetta*	+	–	0[A]	–
Great-billed heron, *Ardea sumatrana*	23 (4)	136 (8)	5·91	–
Pied heron, *Egretta picata*	22358 ± 7490	23 (19)	0·00	**
Great egret, *Egretta alba*	+	+	0·17[A]	–
Intermediate egret *Egretta intermedia*	+	+	0·02[A]	–
Unidentified egret	231052 ± 44718	17923 ± 5743	0·08	***
Cattle egret, *Egretta ibis*	– (1)	–	–	–
Striated heron, *Ardeola striata*	181 (26)	23 (1)	0·13	–
Nankeen night heron, *Nycticorax caledonicus*	9437 ± 3798	136 (9)	0·01	*
Little bittern, *Ixobrychus minutus*	– (2)	– (2)	–	–
Black bittern, *Dupetor flavicollis*	23 (10)	23 (15)	–	–
Glossy ibis, *Plegadis falcinellus*	60332 ± 28589	– (1)	0·00	*
Australian white ibis, *Threskiornis aethiopicus*	50420 ± 15054	68 (4)	0·00	**
Royal spoonbill, *Platalea regia*	23 (8)	–	–	–
Black-necked stork, *Xenorhynchus asiaticus*	317 (24)	249 (13)	–	–
Osprey, *Pandion haliaetus*	–	– (3)	–	–
White-bellied sea-eagle, *Haliaeetus leucogaster*	158 (23)	226 (49)	2·1	–
Swamp harrier, *Circus approximans*	46 (5)	– (1)	–	–
Eastern marsh harrier, *Circus spilonotus*	90 (11)	68 (9)	–	–
Unidentified harrier	–	– (2)	–	–
White-browed crake, *Porzana cinerea*	– (28)	– (44)	1·22	–
Unidentified crake or rail	430	68	–	–
New Guinea flightless rail, *Megacrex inepta*	45 (2)	23 (1)	–	–
Purple swamphen, *Porphyrio porphyrio*	– (1)	23 (2)	–	–
Swinhoe's snipe, *Gallinago megala*	23 (12)	–	–	–
Little curlew, *Numenius minutus*	23 (2)	–	–	–
Whimbrel, *Numenius phaeopus*	–	– (1)	–	–
Marsh sandpiper, *Tringa stagnatilis*	23 (70)	–	0	–
Common greenshank, *Tringa nebularia*	204 (37)	–		–
Wood sandpiper, *Tringa glareola*	23 (40)	–	0	–

Table 1. continued

Species	December 1994	April 1995	Ratio	Significance
Common sandpiper, *Tringa hypoleucos*	68 (54)	91 (8)	0·15	–
Sharp-tailed sandpiper, *Calidris acuminata*	248 (249)	–	0	–
Comb-crested jacana, *Irediparra gallinacea*	6404 ± 2572	3394 ± 735	0·52	n.s.
Black-winged stilt, *Himantopus leucocephalus*	656 ± 656	–	0	n.s.
Pacific golden plover, *Pluvialis fluva*	– (7)	–	–	–
Little ringed plover, *Charadrius dubius*	– (1)	–	–	–
Lesser sand plover, *Charadrius mongolus*	– (2)	–	–	–
Greater sand plover, *Charadrius leschenaultii*	– (3)	–	–	–
Masked lapwing, *Vanellus miles*	3259 ± 542	588 ± 374	0·18	***
Unidentified wader	950	45	–	–
Little tern, *Sterna albifrons*	– (7)	–		–
Whiskered tern, *Chlidonias hybrida*	630 (1422)	317 (105)	0·22	–
White-winged black tern, *Chlidonias leucopterus*	– (2)	– (4)	–	–
Unidentified tern	–	– (2)	–	–
Clamorous reed-warbler, *Acrocephalus stentoreus*	– (16)	– (36)	2·25	–
Oriental reed-warbler, *Acrocephalus orientalis*	– (1)	–	–	–
Little grassbird, *Megalurus gramineus*	– (2)	– (1)	–	–
Fly River grassbird, *Megalurus albolimbatus*	– (25)	– (11)	0·44	–
Zitting cisticola, *Cisticola juncidis*	– (11)	– (19)	–	–
Total	587219 ± 62741	54915 ± 9790	0·09	***

[A]Totals of 1025 great egrets, 1531 intermediate egrets and 19 little egrets were counted on the ground in December; 482 great egrets and 63 intermediate egrets were counted in April.

alternative is that both observers had the same large error). Checks on the front left observer in October 1995 suggested that he detected at least 89% of birds, excluding passerines and crakes (Table 4). Most of the discrepancy resulted from missing 30 magpie geese on Transect 32. The most probable explanations are either that the front observer thought the geese were more than 100 m from the helicopter (the rear observer thought they were close to the boundary) or he did not operate the tape recorder properly and failed to record a count of 30 geese. It is unlikely that 30 geese were missed completely and, if they are excluded from the analysis, 95% of birds were detected.

Comparison of gound and aerial surveys of Lakes Ambuve and Daviumbu also suggested that the level of detection from the air was high. Except for grassbirds, warblers, cisticolas and, sometimes, crakes, more species as well as more birds were counted aerially. Even at Lake Daviumbu in December, the aerial count was higher than the ground count three days earlier if 900 glossy ibis flying across the wetland during the ground count were excluded (1812 *v.* 1345: Table 2).

Many magpie geese were either breeding or had bred in April. One unfledged magpie goose was caught during ground surveys and another was recorded on an aerial transect. Villagers caught four goslings at Bosset Lagoon on 27 April. Five nests with eggs were recorded on aerial transects, another two were recorded during the aerial survey of Lake Daviumbu and one was found during ground surveys of Deep Creek. Several nests without eggs were seen during ground and aerial surveys and a colony of about 200 nests was seen south of Lake Pangua, although most birds at the colony had finished breeding. Hundreds of pairs of magpie geese would have nested on the grassed floodplain of the Middle Fly during the 1994–95 wet season.

Comb-crested jacanas and spotted whistling-ducks also were breeding or had bred in April, although probably in low numbers. Two young comb-crested jacanas, one flightless and one

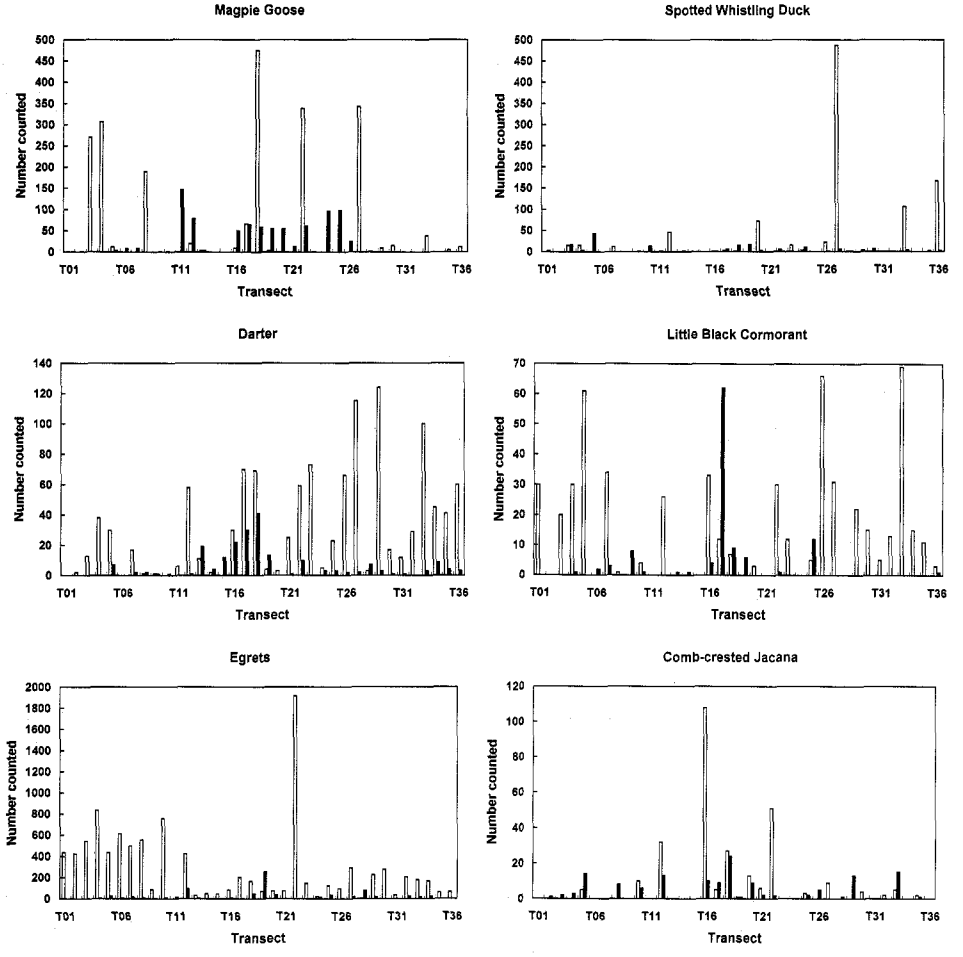

Fig. 2. Counts of some common waterbird species on 36 transects across the grassed floodplain of the Middle Fly in December 1994 (open bars) and April 1995 (solid bars).

just flying, were seen during ground surveys and one nest with eggs was found. One brood of spotted whistling-ducks was seen during the aerial survey of Lake Kongun. White-bellied sea-eagles were displaying vigorously in April and one was seen attending a nest. No breeding was recorded in December.

Interesting records during the surveys included sightings of two little grassbirds in December at Bosset Lagoon and one in April on a backwater of the Kai River. Previous records in New Guinea have been from Irian Jaya and a breeding population at the montane Wissel Lakes (Coates 1985; Beehler *et al.* 1986). The species occurs in temperate and some tropical wetlands in Australia. A single Oriental reed-warbler was seen at Oxbow ARM (Adopted River Mileage) 192.5 in December; the few previous records of this Asian species in New Guinea have mostly been around Port Moresby, although there is one record from the Bensbach River (Coates 1985). Zitting cisticolas were abundant in both December and April in the vicinity of Obo. Previous records from New Guinea of this widespread species were only from the Bensbach and Morehead Rivers (Finch 1980; Coates 1985). Little bitterns were seen in both December and April. Combined with previous records from the Middle Fly in June 1994 (R. P. Jaensch, unpublished data) and September (Rand 1942), the sightings suggest there is a resident

Table 2. Numbers of waterbird species and individual birds counted at sites on the Middle Fly River floodplain in December 1994 and April 1995

Survey method: a, aerial; g, ground. Habitat type: H1, river channel; H2, blocked valley lake; H3, oxbow. ARM, Adopted River Mileage

Site	Habitat type	Survey method	December 1994		April 1995	
			No. of species	No. of birds	No. of species	No. of birds
Agu River ARM 302–306	H1	g	9	75	8	182
Aina Lagoon	H2	a	12	320	10	617
Bai Lagoon	H2	a	21	6067	12	282
Be Oxbow	H3	g	10	115	7	149
Bokomolau Lagoon[A]	H2	g	31	1706	5	6
Bosset Lagoon	H2	g	24	2633	11	67
Deep Creek	H3	g	–	–	12	235
Fly River ARM 300–302	H1	g	2	35	–	–
Fly River ARM 280–300	H1	g	–	–	6	44
Fly River ARM 280–285	H1	g	4	16	–	–
Fly River ARM 224–231	H1	g	–	–	5	35
Fly River ARM 214–224	H1	g	8	65	4	21
Fly River ARM 192–214	H1	g	6	18	9	42
Ganan Lagoon	H2	g	1	1	6	59
Kai River ARM 302–307	H1	g	14	115	13	151
Kai River Lagoon[B]	H2	a	11	603	11	113
	–	g	–	–	5	26
Keikewan Lagoon	H2	g	4	27	3	8
Lake Ambuve	H2	a	25	9327	11	376
	–	g	20	662	12	89
Lake Daviumbu[C]	H2	a	20	1812	11	660
	–	g	22	2245	15	128
Lake Kaka[D]	H2	g	–	–	12	84
Lake Kongun	H2	a	20	6631	11	332
Lake Pangua	H2	g	30	591	20	459
Manda Lagoon	H2	g	23	932	7	25
Oxbow ARM 192.5	H3	g	40	2165	12	72
Oxbow ARM 231	H3	g	–	–	8	40
Oxbow ARM 283	H3	g	6	48	1	2
Oxbow ARM 285	H3	g/a	23	1171	7	132
Oxbow ARM 300	H3	g	12	108	7	44
Quee Lagoon	H2	g	–	–	5	28
Wage Lagoon	H2	g	18	1025	4	144
Wam Lake	H2	g	9	344	5	25
Total[E]	–	–	55	36383	33	4535

[A]Very limited access in April.

[B]Ground count was incomplete and in part of wetland not surveyed from the air.

[C]The ground count in December included 900 glossy ibis flying over Lake Daviumbu; the aerial count in April extended north-east towards Lake Pangua (there was no obvious boundary between these lakes).

[D]No access in December.

[E]Some 2474 birds in Lakes Ambuve and Daviumbu in December and 160 in April may have been counted twice and were excluded from the total.

Table 3. Comparison of mean number of birds counted per transect by S.A.H. and G.B.P. in December 1994 and April 1995

Numbers in parentheses exclude Transect 30 in December 1994, where G.B.P. recorded 3628 birds compared with 1057 by SAH. *P*-values for paired *t*-tests of the counts are shown

	SAH	GBP	*P*
December	315 ± 51 (293 ± 47)	411 ± 105 (319 ± 53)	0·24 (0·53)
April	32 ± 42	35 ± 42	0·54

Table 4. Percentage of birds present counted from the air in October 1995 by front left observer

Numbers in parentheses exclude 30 magpie geese missed on Transect 32, which was an atypical event (see text)

Variable	Ducks	Cormorants, darter	Comb-crested jacana	All transects
No. missed (n_2)	38 (8)	19	1	58 (28)
No. seen (n_1)	185	304	21	510
Percentage counted	80 (96)	94	95	89 (95)

population. Beehler *et al.* (1986) and Coates (1985) provide rather contradictory accounts of the status of little bitterns in New Guinea.

Two intermediate egrets that had been wing-tagged as nestlings at the Macquarie Marshes, south-eastern Australia, in the summer of 1993–94 were seen at Bokomolau Lagoon in December. Intermediate egrets tagged in Australia have been seen elsewhere in New Guinea (Coates 1985; M. Maddock, D. Geering, G. Cam, C. Ireland, S. Halse and G. Pearson unpublished data).

Discussion

The December 1994 survey shows that, with a population of 587 249 ± 62 741 at the end of the dry season, the grassed floodplain of the Middle Fly is an internationally important area for waterbirds, and further justifies Scott's (1989) inclusion of the area on the list of most significant wetlands in Papua New Guinea. However, the relative value of the Middle Fly for waterbirds cannot be fully assessed without better knowledge of other New Guinean wetland systems, especially the similar floodplains in Irian Jaya (Silvius *et al.* 1989).

Higher numbers of waterbirds were recorded on the Middle Fly in December than have been recorded on the Bensbach River (Finch 1980, 1982; Stronoch 1981), which is the only Ramsar-listed wetland in Papua New Guinea. The Bensbach system is probably poorer dry-season habitat than is the Middle Fly, but at least part of the populations of some species absent from the Middle Fly in April, such as Australian white ibis and radjah shelducks, may move onto the Bensbach during the wet season (see Stronoch 1981). The greatest value of the Middle Fly to waterbird conservation appears to be during the dry season, although our surveys are based on a single year when water levels during the dry season were comparatively low. According to local villagers, waterbird numbers are highest during dry seasons with low water levels.

The significance of the grassed floodplain of the Middle Fly as waterbird habitat is highlighted by comparison with the Alligator Rivers floodplain in northern Australia. This area, which is of similar size to the Middle Fly and includes part of Kakadu National Park, supports uniquely high numbers in Australia with maximum dry-season populations of magpie geese of 1 600 000 birds, wandering whistling-ducks 400 000, egrets 300 000 (mostly intermediate egrets), glossy ibis 60 000, Australian pelicans 55 000 and pied herons 50 000 (Morton *et al.*

1990*a*, 1990*b*, 1993*a*, 1993*b*). Numbers of Australian white ibis, darters and cormorants on the Middle Fly in December 1994 were higher than maximum numbers recorded on the Alligator Rivers, while numbers of egrets, pied herons and glossy ibis were similar on the two floodplains. The Middle Fly appeared to be characterised by a high proportion and high numbers of fish-eating species.

Checks on counting efficiency in October 1995 suggested that we recorded 89–95% of birds present during aerial surveys of the Middle Fly, assuming the rear observer saw at least as high a proportion of birds as did the front observer. This is realistic, given the extra time available to the rear observer because counts were limited to a single species or species-group. Whatever the exact proportion of birds counted, it is clear that population estimates derived from the counts were reasonably accurate and correction factors were unnecessary. By contrast, Morton *et al.* (1990*b*) detected as few as one-tenth of some common species, such as plumed whistling-ducks, and Bayliss and Yeomans (1990) detected less than half the magpie geese and one-sixth the whistling ducks present on floodplains in northern Australia. The large number of birds overlooked by Morton *et al.* was accompanied by differences between observers in counting efficiency. For example, there was an almost 5-fold difference between observers in numbers of straw-necked ibis counted (Morton *et al.* 1993*a*). There was no significant difference between the counts of S.A.H. and those of G.B.P. on the Middle Fly.

Our results show that aerial surveys can provide a rapid and accurate method of estimating numbers of waterbirds. We suggest that differences in survey techniques were responsible for the comparatively poor detection rates of Bayliss and Yeomans (1990) and Morton *et al.* (1990*a*, 1990*b*, 1993*a*, 1993*b*). We flew in a helicopter at a height of 15–25 m and a speed of 90–110 km h^{-1} with each observer counting a 100-m strip, whereas Morton *et al.* (1990*a*, 1990*b*, 1993*a*, 1993*b*) and Bayliss and Yeomans (1990) used fixed-wing aeroplanes flying at 30 m and 140 km h^{-1}, and 61 m and 185 km h^{-1}, respectively. Bayliss and Yeomans (1990) counted 200-m strips. Johnson *et al.* (1989) found that helicopter surveys recorded three times more mottled ducks, *Anas fulvigula*, than did fixed-wing surveys, although height and speed probably affect detection rates more than does type of aircraft, and that the proportion of ducks counted declined with transect width. More birds are flushed and detection is easier when flying low (see Johnson 1989; Bayliss and Yeomans 1990). Densities on the Middle Fly fell well short of the density of approximately 40 birds ha^{-1} (or 10 000 birds in a lake) at which Kingsford *et al.* (1994) found under-counting became pronounced.

Dispersal from the grassed floodplain of the Middle Fly between December and April was probably the result of both local movements to areas such as the Bensbach River (Stronoch 1981) and regular migrations to Australia (Warham 1962; Ashford 1979; Draffan *et al.* 1983), although the limited ornithological work in New Guinea and northern Australia makes it difficult to evaluate the relative importance of the two dispersal patterns. Australia is the most probable source of migrants for most species found on the Middle Fly (Warham 1962; Draffan *et al.* 1983), apart from palaearctic shorebirds and garganey, which are known to be summer migrants from more northern latitudes (Coates 1985). The number of Australian waterbirds migrating onto the Middle Fly during the dry season would be affected by conditions in Australia (Frith 1982; Woodall 1985).

The dramatic decline in numbers of glossy ibis, radjah shelducks, black-winged stilts, Australian white ibis and pied herons by April (Table 1) suggests that the December populations of these species probably consisted mostly of dry-season migrants from Australia. Local nomadism is unlikely to have led to such pronounced reductions but more information is required. The occurrence of 37 000 Australian white ibis and small numbers of radjah shelducks on the Bensbach River in May 1980 (Stronoch 1981) shows that significant proportions of the populations of some species may remain in New Guinea during the wet season.

Although low numbers of intermediate egrets, green pygmy-geese, nankeen night herons and wandering whistling-ducks remained on the grassed floodplain of the Middle Fly and on adjacent wetlands during April, we suggest that breeding adults had returned to Australia. For

example, only two of the nine nankeen night herons seen in April had adult plumage and even they were not fully coloured. Although birds in non-breeding plumage have been recorded breeding in Australia (Braithwaite 1976), it is an unusual event. There are no known breeding colonies of intermediate egrets in New Guinea (Coates 1985; Simpson 1994). Coates (1985) regards the other species occurring in low numbers in April (wandering whistling-ducks, Pacific black ducks and green pygmy-geese) as having populations consisting of resident breeding birds as well as Australian migrants, although evidence for breeding of green pygmy-geese is inconclusive. All the species occurring in low numbers during April are conspicuous migrants across Torres Strait (Warham 1962; Ashford 1979).

Magpie geese, comb-crested jacanas, great egrets, darters and wandering whistling-ducks are also known to move to Australia (Warham 1962; Ashford 1979; Draffan *et al.* 1983), but substantial numbers remained in April (Table 1). We suggest they were locally nomadic, with birds moving onto adjacent wetland habitats in the same way that most birds move away from the Alligator Rivers floodplain (Morton *et al.* 1990*a*, 1990*b*, 1993*a*, 1993*b*). Stronoch (1981) found a substantial increase in numbers of magpie geese on the Bensbach River during the early wet season.

Many of the species that remained moderately common on the Middle Fly in April probably bred locally, although we found evidence of breeding only for magpie geese, comb-crested jacanas and spotted whistling-ducks. There are other records of darters, masked lapwings and clamorous reed-warblers breeding on the Middle Fly (Coates 1985). Discussions with villagers indicated that the breeding season varies between waterbird species, although late in the wet season is probably the time of most activity (see Coates 1985). More fieldwork is required to document breeding patterns of New Guinean waterbirds.

In summary, the surveys in 1994–95 showed that the grassed floodplain of the Middle Fly was an internationally important area for waterbirds, especially fish-eating species, during the dry season. Our analysis of migratory status of waterbirds of the Fly River is preliminary and intended to complement the data provided by Coates (1985), but it is obvious that patterns of movement are complex. At times, substantial proportions of the populations of many species may be dry-season migrants from Australia, and the Middle Fly appears to be an important dry-season refuge for Australian waterbirds.

Acknowledgments

We thank Bruce Cameron and Gerard Cattana for skilful flying during the aerial surveys, and Andy Maie, Peter Stewart and Ron Clarke for logistical support and hospitality on the Ok Tedi Mining Ltd research vessels, MV *Archimedes* and MV *Western Venturer*. Ian Wood, Environmental Manager at Ok Tedi Mining Ltd, supported and encouraged the project; Dr Monica Rau identified the floodplain plants and Dr Richard Kingsford commented on a draft of the manuscript.

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Manuscript received 4 December 1995; revised and accepted 26 April 1996