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Annual waterfowl counts in south-west Western Australia - 1990/91

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ABSTRACT

A total of 200 443 waterfowl were counted in 1044 wetlands in south-west Western Australia in November 1990 and 314 244 birds were counted in 1115 wetlands in March 1991 in a program conducted jointly by the Department of Conservation and Land Management and the Royal Australasian Ornithologists Union. Species counted were the Black Swan, Eurasian Coot, 11 species of native duck, and four species of exotic duck, goose and swan. Extrapolation of the data suggests that the number of waterfowl in the south-west of Western Australia was approximately 1 500 000 over the 1990/91 summer. Grey Teal were the most abundant species in November (286 643 ± 96 477) and March (447 248 ± 222 228). During both surveys approximately 70 per cent of waterfowl occurred on lakes. Esperance and Wagin regions contained the bigger proportions of the total estimated waterfowl population. Totals of 96 waterfowl nests and 824 broods were recorded in November, mostly on lakes.

INTRODUCTION

In the late 1960s and early 1970s, annual counts of waterfowl made during aerial surveys in September or October were used to determine duration of the duck-hunting season and bag limits in south-west Western Australia (WA). Subsequently, measuring depths of selected wetlands replaced waterfowl counts as the method of determining duck-hunting seasons (Lane and Munro 1983; Lane 1985).

There has been a hunting season in only one of the last four years. A moratorium on hunting was declared in 1987/88 and 1988/89 and there was no announcement about a season in 1990/91. However, from 1986 to 1988 inclusive, the Department of Conservation and Land Management (CALM) funded March counts of ducks, swans and coots in south-west WA by the Royal Australasian Ornithologists Union (RAOU) to provide baseline data for management of duck hunting, if hunting seasons were declared, and to help identify important wetland habitat for waterbirds (Jaensch and Vervest 1988a,b). In the RAOU counts, volunteers surveyed a large number of wetlands from the ground while CALM staff surveyed some of the larger or more inaccessible wetlands from the air.

In November 1988, funding was obtained to continue a modified CALM-RAOU program of annual waterfowl counts until 1991/92. The modified program uses a fixed set of wetlands for survey, includes a larger aerial survey component and, most importantly, consists of November as well as March surveys (Halse *et al.* 1990, 1992). The program has three objectives: (1) to estimate actual numbers of ducks, swans and coots in south-west WA, (2) to examine regional distribution of the species each year in relation to wetland conditions, and (3) to compare regional distribution and types of wetlands used during the breeding season and in late summer. This paper reports results for 1990/91 and makes limited comparisons with counts and wetland conditions in 1988/89 and 1989/90.

There are currently three other large-scale waterfowl counting programs in Australia. The Conservation Commission of the Northern Territory conducts annual aerial surveys of major waterfowl habitats in the northern part of the Northern Territory (Bayliss and Yeomans 1990a,b). Aerial surveys of the eastern third of Australia are co-ordinated by the National Parks and Wildlife Service of New South Wales (Kingsford *et al.* 1992). In Victoria the RAOU, assisted by the Victorian Field and Game Association, is funded by the Department of Conservation and Environment to make annual ground counts of waterfowl at selected wetlands (Peter 1992).

SURVEY DESIGN

Species counted

Thirteen native and four exotic species of waterfowl were counted: Black Swan (*Cygnus atratus*), Freckled Duck (*Stictonetta naevosa*), Australian Shelduck (*Tadorna tadornoides*), Pacific Black Duck (*Anas superciliosa*), Grey Teal (*A. gibberifrons*), Chestnut Teal (*A. castanea*), Australasian Shoveler (*A. rhynchotis*), Pink-eared Duck

(*Malacorhynchus membranaceus*), Hardhead (*Aythya australis*), Maned Duck (*Chenonetta jubata*), Blue-billed Duck (*Oxyura australis*), Musk Duck (*Biziura lobata*), exotic ducks, geese and swans [domestic varieties of Mallard (*Anas platyrhynchos*), Muscovy (*Cairina moschata*), Greylag Goose (*Anser anser*) and Mute Swan (*Cygnus olor*)] and Eurasian Coot (*Fulica atra*).

Counting dates

Counts were made during nine-day periods (two weekends and the intervening week) towards the end of the breeding season, *viz* 17-25 November 1990, and in early autumn when waterfowl were congregated in 'summer' refuges, *viz* 9-17 March 1991.

Wetlands surveyed

Using map co-ordinates, the area to be surveyed in the South-west and the south-western part of the Eucla Land Divisions was divided into 20' blocks (Fig. 1)(Halse *et al.* 1990). The inland limit of the surveyed area generally corresponded with the extent of predictably filled wetlands in the south-western part of the State. Wetlands in the area are described briefly by Halse *et al.* (1990, 1993a).

As far as possible, the set of 1247 wetlands chosen for survey for the duration of the current project consisted of two permanent lakes with potential as drought refuges, two lakes (often seasonal) with potential as breeding sites, five farm dams and two sections of river in each 20' block (Halse *et al.* 1990,1992). Three extra dams were added to the wetland set in November 1990 to improve coverage of farm dams in blocks where none had been surveyed previously.

In addition to the lakes, dams and river sections surveyed, all major estuaries[1] between Perth and Esperance were surveyed because in some years they contain very large numbers of birds in November or March (Jaensch and Vervest 1988a,b; Halse *et al.* 1990). It is difficult to devise a method of counting only some estuaries and yet obtaining a meaningful estimate of waterfowl abundance in all estuarine systems. For the same reason, provided we were left with a reasonable mix of wetland types and did not exceed 11 wetlands per block, all wetlands known at the outset of the project to support large aggregations of waterfowl or high numbers of one species (Jaensch and Vervest 1988a,b) were included in the wetland set to be surveyed. Table 1 shows the number of wetlands surveyed in November 1990 and March 1991.

For analysis of the distribution of waterfowl and its relation to rainfall, 11 'regions' were delineated (Fig. 1). Each region consisted of 14-16 blocks containing surveyed wetlands, except for Walpole region, which contained 13 full blocks and five part blocks on the coast.

Survey methods

Most wetlands were surveyed from the ground by 160 volunteer RAOU observers or by CALM staff using binoculars or a telescope. In some cases a boat or canoe was used to traverse the wetlands. Some of the larger inland lakes, some lakes and river sections with difficult access, and all the larger estuaries were surveyed from the air over a four-day period using a Cessna Cutlass 172 flying at about 70 knots at a height of 30 m. Wetlands counted from the air are marked in Appendix 1[2]; the survey route is shown by Halse *et al.* (1990). Observers recorded the number of birds, the number of nests containing eggs and the number of broods at each wetland. They also recorded water depth (dry, <0.5 m, <1.0 m, ≥1.0 m). Emergent vegetation in the inundated part of each wetland had been recorded during earlier surveys (Halse *et al.* 1992).

Estimating numbers

Number of waterfowl in each region was estimated separately for lakes, rivers and dams by multiplying the mean numbers of birds counted per wetland by the total number of wetland units of that type in the region. Waterfowl counts in estuaries were not extrapolated: all major estuaries were surveyed and our observations showed that most, if not all, of the remainder did not support significant numbers of waterfowl. Approximately 30 lakes and river sections supported much larger waterfowl populations than other wetlands in the same region. These 'atypical' wetlands were excluded from extrapolations and counts in them were added directly to population estimates.

Topographic maps (1:100 000) were used to estimate the total number of lakes and river sections in each region. Sometimes groups of small salt lakes were counted as one 'unit' because this reflected the nature of the surveyed wetlands more closely than counting individual lakes. Similarly, long sections of flowing river were broken into several units or, in some cases, small pools were combined (Halse *et al.* 1992). Estimates of the numbers of lake and river units per region are shown in Table 1. Because of grouping, our estimates were substantially lower for some regions than the number of lakes and river sections shown on topographic maps (Halse *et al.* 1992).

Anon. (1971) was used to calculate the number of farm dams in each region (Table 1). However, comparison between duck numbers on randomly chosen dams counted from the air and numbers on dams counted from the ground suggested that the choice of dams for ground surveys was biased towards dams that were likely to contain waterfowl. To correct this bias, we halved Anon.'s (1971) figure for number of dams when calculating number of dam units in regions with fewer than 2000 dams. In

[1] We use the term 'estuary' colloquially to include several wetlands, most notably Vasse-Wonnerup Estuary, that are not truly estuarine.

[2] Appendices 1 and 2 are lodged in the Wildlife Sciences Library, Department of Conservation and Land Management, PO Box 51, Wanneroo 6065.

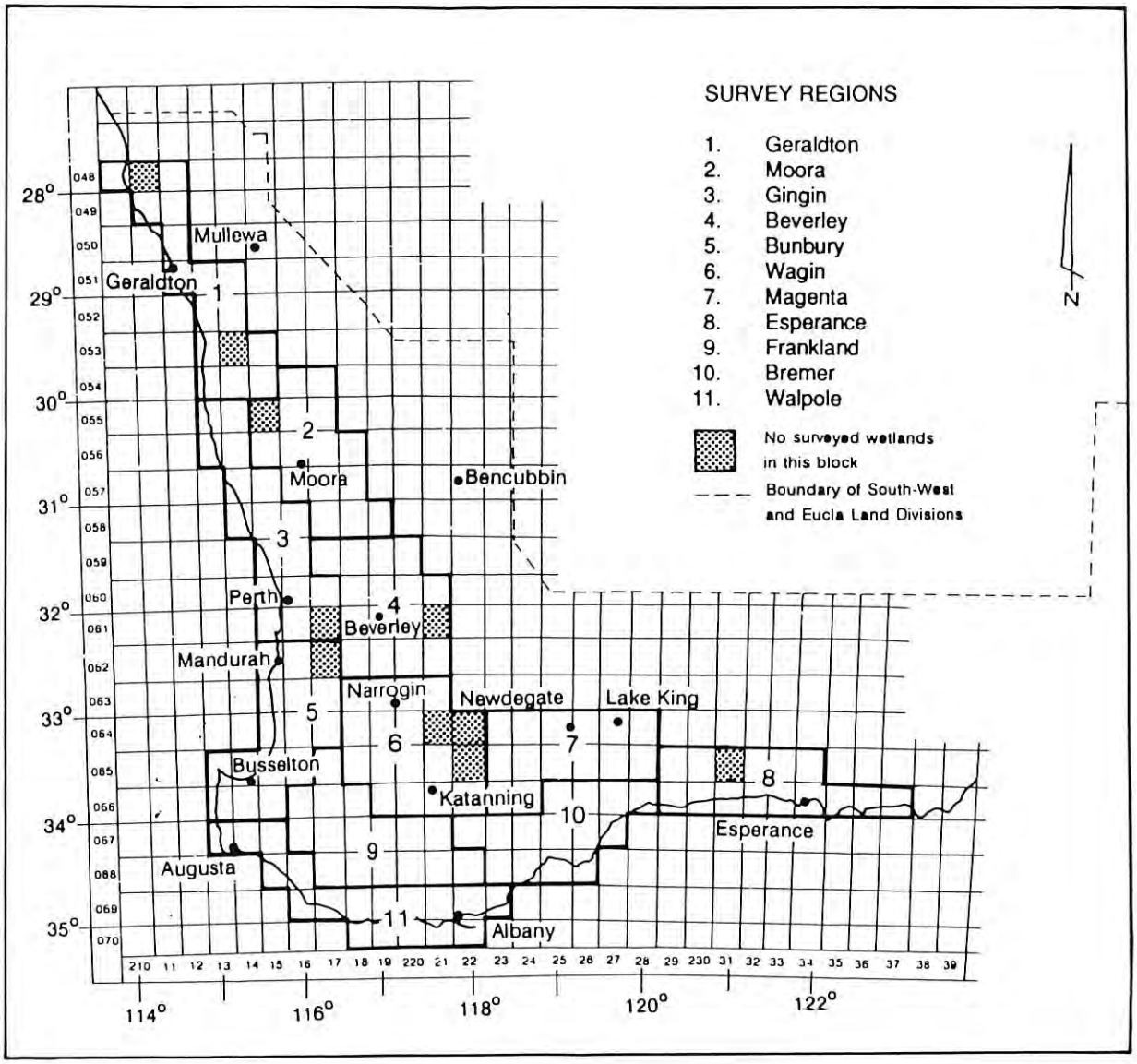

Figure 1. The area surveyed in the annual waterfowl counts and the regions recognized within the surveyed area. The 20' blocks comprising the regions are marked.

TABLE 1

Number of waterbodies of each type surveyed in each region in November 1990 and March 1991 compared with the number of wetland 'units' (see text) of each type identified from the topographic maps. Figures in parentheses represent numbers of atypical waterbodies counted. Counts from atypical wetlands were added directly to the extrapolations.

REGION	LAKE			RIVER			DAM			ESTUARY		
	Nov 90	Mar 91	Units	Nov 90	Mar 91	Units	Nov 90	Mar 91	Units	Nov 90	Mar 91	Units
Geraldton	27	35	464	6	10	69	12	19	100	1	2	6
Moora	53(2)	50(2)	651	2	2	42	51	54	1000	-	-	-
Gingin	80(5)	76(5)	400	14	11	110	28	28	100	1	-	3
Beverley	27(2)	30(2)	102	16	15	105	58	62	1500	-	-	-
Bunbury	36(4)	37(4)	384	15(2)	15(2)	198	37	40	200	3	3	6
Wagin	37(8)	37(7)	209	12(1)	18(1)	112	47	63	1500	-	-	-
Magenta	38	38	350	1	1	5	52	54	1500	-	-	-
Esperance	48(5)	51(5)	650	6(3)	7(3)	57	35	36	1500	4	4	4
Frankland	36(2)	45(2)	343	20	21	288	52	61	3000	-	-	-
Bremer	35	37	232	18(3)	19(3)	219	37	34	1500	10	10	10
Walpole	36	33	206	10(1)	12(1)	135	35	37	2000	8	8	13
TOTAL	453(28)	469(27)	3991	120(10)	131(10)	1340	444	488	13900	27	27	42

regions with more than 2000 dams we used a value that was one-quarter of Anon.'s (1971) figure (Halse *et al.* 1992).

The formula used for extrapolations is given below, estimating number of Grey Teal on lakes in Beverley region as an example

$$\text{Estimated number} = \frac{\text{Count}}{N_S} \times N_T + C_A$$

where Count = number of Grey Teal counted in typical lakes in Beverley, N_T = total number of lake units in Beverley, N_S = number of typical lakes surveyed in Beverley, and C_A = number of Grey Teal counted in atypical lakes in Beverley.

Ninety-five per cent confidence limits (CL) of estimates of waterfowl numbers were calculated using formulae derived from Snedecor and Cochran (1967, p. 520-523) for standard errors associated with stratified sampling

$$S(\text{mean no of birds/wetland}) = \frac{\sqrt{MS_{error}}}{\sqrt{N_S}} \times \sqrt{1 - \frac{N_S}{N_T}}$$

$$CL = 1.96N_T \times S(\text{mean no of birds/wetland})$$

where MS_{error} = mean square of the within-regions term in a one-way ANOVA of number of birds per wetland according to region.

RESULTS

Rainfall and wetland conditions

Approximately 80 per cent of rainfall in south-west WA falls between April and October so annual rainfall is essentially a measure of 'winter' rainfall. Wetland conditions in November are primarily a reflection of winter rainfall but they are also influenced by water levels at the start of winter, which are determined by summer rainfall and, for permanent lakes, by rainfall during the previous winter. Summer rainfall occurs as storm events that can generate run-off from comparatively little rain.

Annual rainfall in 1990 in the area covered by the annual waterfowl counts was mostly average or below the long-term average (Table 2), except along the eastern edge of the survey area where it was in the eighth and ninth deciles (Fig. 2). In absolute terms, the wettest areas were the extreme south-west of the study area in the Walpole region and an area south-west of Perth in the Bunbury region (Fig. 3). Rainfall decreased along a north-easterly gradient.

Ninety-two per cent of waterbodies (lakes, dams, etc.) contained water in November 1990. By comparison, 85 per cent contained water in November 1989 and 96 per cent in November 1988 (Halse *et al.* 1990,1992). The regions where the largest numbers of waterbodies held water in November 1990 were Walpole, Frankland and Bremer, while the driest regions were Geraldton, Moora and Gingin (Fig. 4).

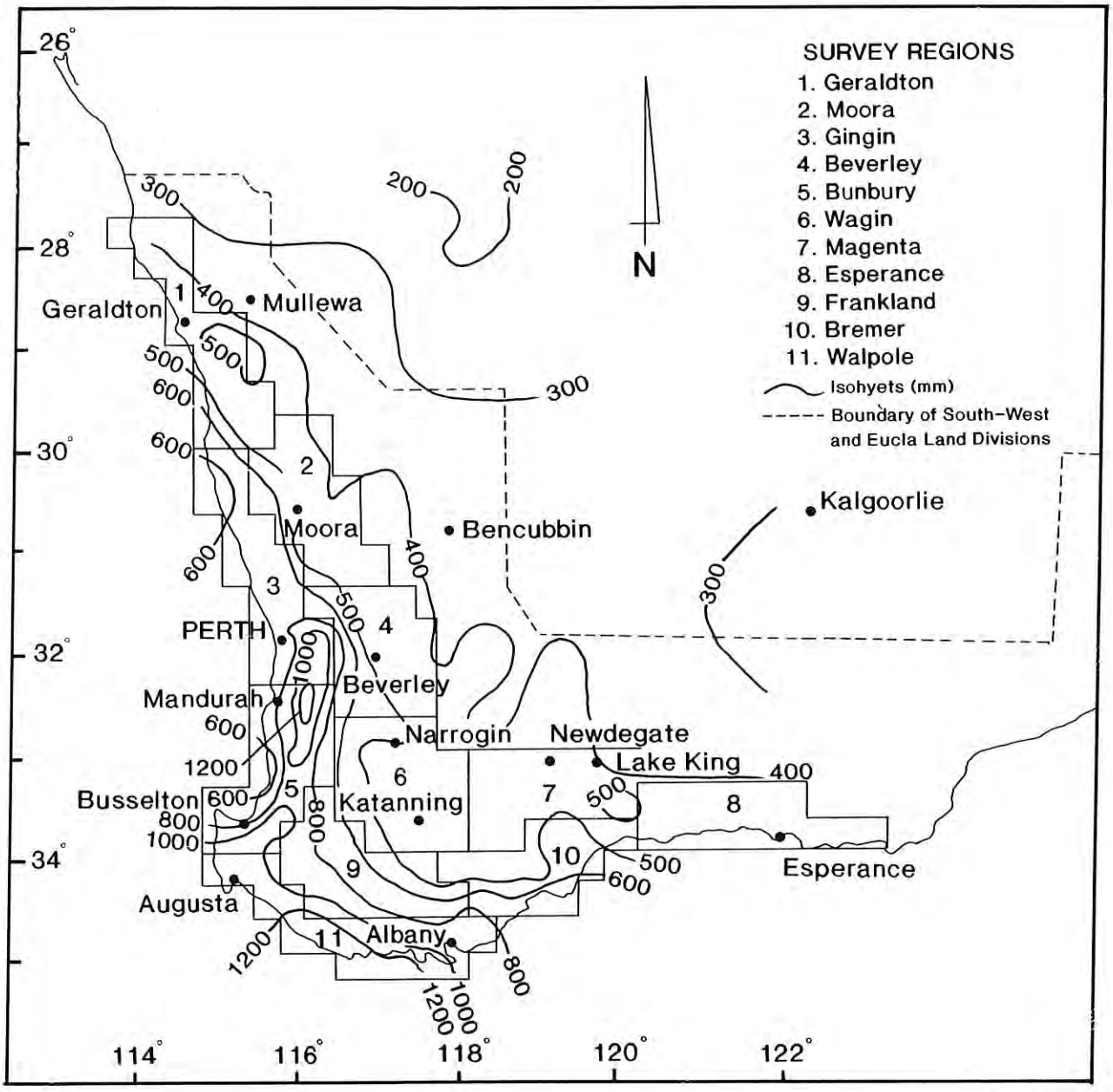

Figure 2. Decile ranges for the rainfall between January and December 1990 (inclusive) in south-west WA.

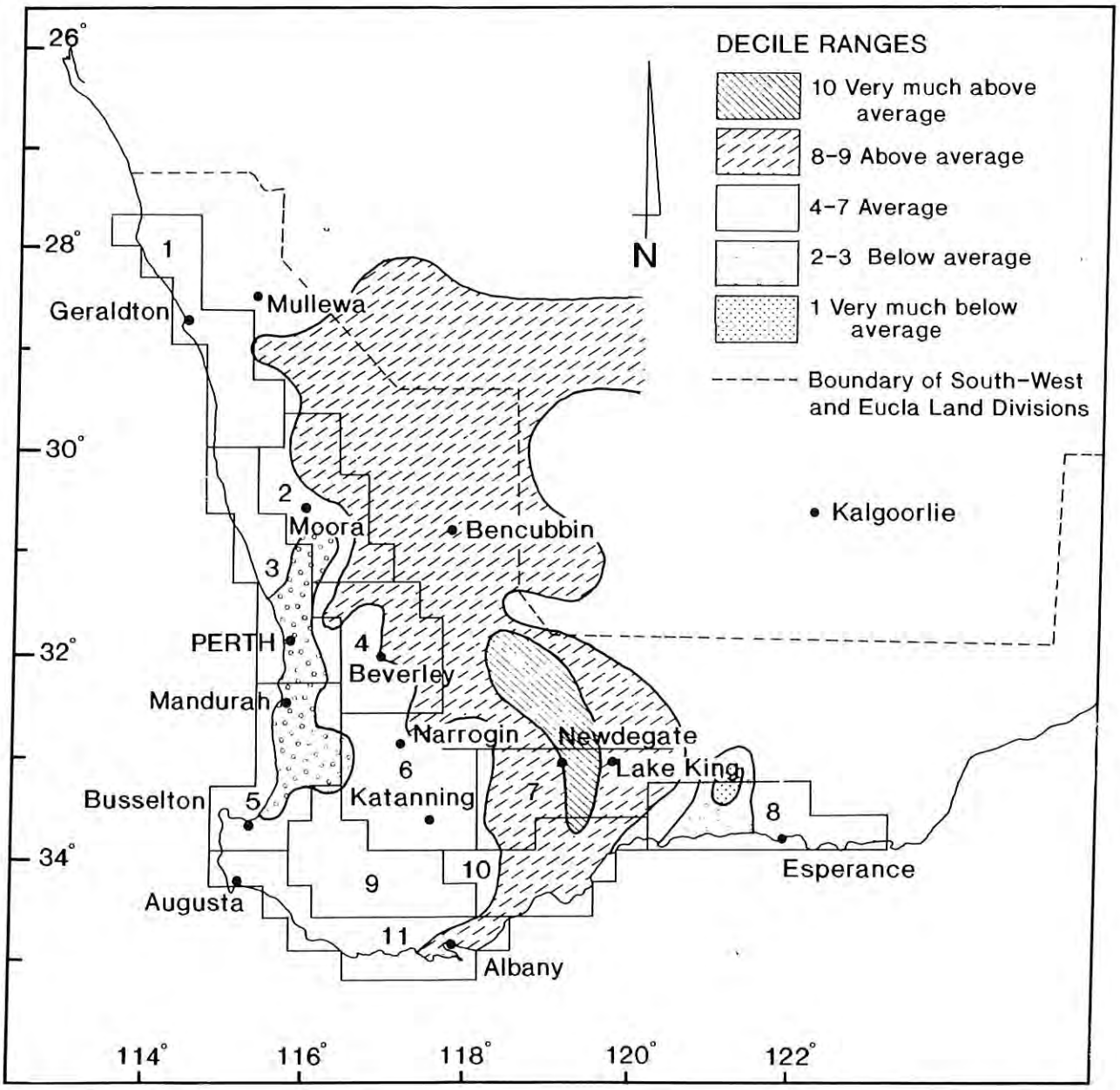

Figure 3. Rainfall (mm) in south-west WA between January and December 1990.

TABLE 2

Annual rainfall for 1990 in the five meteorological districts in south-west WA within the area of the annual waterfowl count (Bureau of Meteorology 1991).

DISTRICT	1990 RAINFALL (mm)	AVERAGE RAINFALL (mm)	DECILE RANGE[a]
North Coastal	391	396	6
Central Coastal	737	849	3
South Coastal	819	909	3
North Central	368	357	6
South Central	427	435	5

[a]decile range 5-6 = average rainfall
3 = below average rainfall

Surface water was comparatively scarce in March 1991 with only 73 per cent of waterbodies containing water. By comparison, 86 per cent held water in March 1990 after substantial summer rainfall and 81 per cent in March 1989 (Halse *et al.* 1990, 1992). Lakes were the wetland type showing greatest reduction in water levels over summer of 1990/91 (Fig. 5). Thirty-four per cent of lakes containing water in November were dry by March, compared with 17 per cent of dams, 5 per cent of rivers and 4 per cent of estuaries.

Number of waterfowl

Totals of 200 443 waterfowl were counted in 1044 wetlands in November 1990, and 314 244 in 1115 wetlands in March 1991, respectively (Table 3). Extrapolations suggested that there were 945 376 ± 135 348 waterfowl in the surveyed area in November and 1 510 963 ± 65 792 in March (Table 4). The six more abundant species during both surveys were Grey Teal, Australian Shelduck, Pacific Black Duck, Eurasian Coot, Maned Duck and Black Swan. They accounted for 94 per cent of the estimated waterfowl population in November and 90 per cent of the estimated March population (Table 4).

Differences between the November and March population estimates of most species were not significant because confidence limits were broad[3], but estimates were noticeably higher in March for Chestnut Teal (5.4 times more, t=3.88, P<0.001), Blue-billed Ducks (3.5, t=1.68, *NS*), Musk Ducks (3.2, t=2.32, P<0.05), Eurasian Coots (2.9, t=2.50, P<0.05), Australasian Shovelers (2.7, t=1.81, *NS*) and Pacific Black Ducks (1.9, t=2.06, P<0.05).

[3] The comment in Halse *et al.* (1992) that confidence limits were generally <10 per cent was based on a computing error.

TABLE 3

Number of birds, nests and broods counted for each waterfowl species in November 1990 and March 1991 in south-west WA.

	NOVEMBER 1990			MARCH 1991		
SPECIES	Birds counted	Nests counted	Broods counted	Birds counted	Nests counted	Broods counted
Black Swan	17808	16	268	18700	-	1
Freckled Duck	2	-	-	-	-	-
Australian Shelduck	83681	1	19	66198	-	-
Pacific Black Duck	21951	4	101	30168	-	-
Grey Teal	47431	9	98	124387	-	1
Chestnut Teal	1084	-	8	8670	-	-
Australasian Shoveler	689	-	2	2336	-	-
Pink-eared Duck	5054	13	35	7510	-	-
Hardhead	1206	-	12	858	-	-
Maned Duck	4830	3	37	6282	-	3
Blue-billed Duck	631	2	2	687	-	3
Musk Duck	801	-	19	2918	-	-
Exotic ducks	358	-	4	362	-	1
Unidentified ducks	31	-	-	335	-	-
Eurasian Coot	14886	48	219	44833	-	4
TOTAL	200443	96	824	314244	-	13

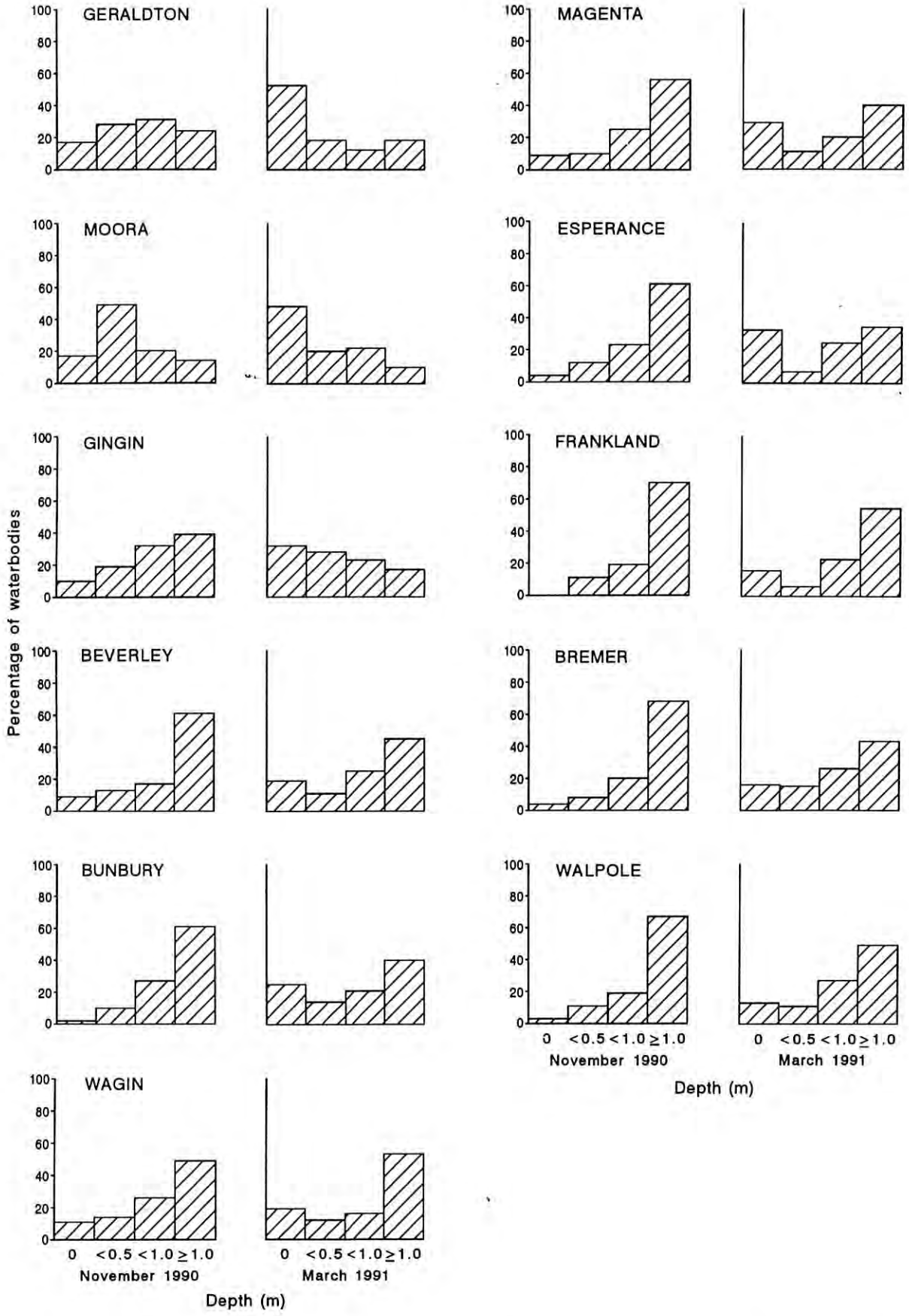

Figure 4. Percentage of waterbodies containing various depths of water in different regions in November 1990 and March 1991.

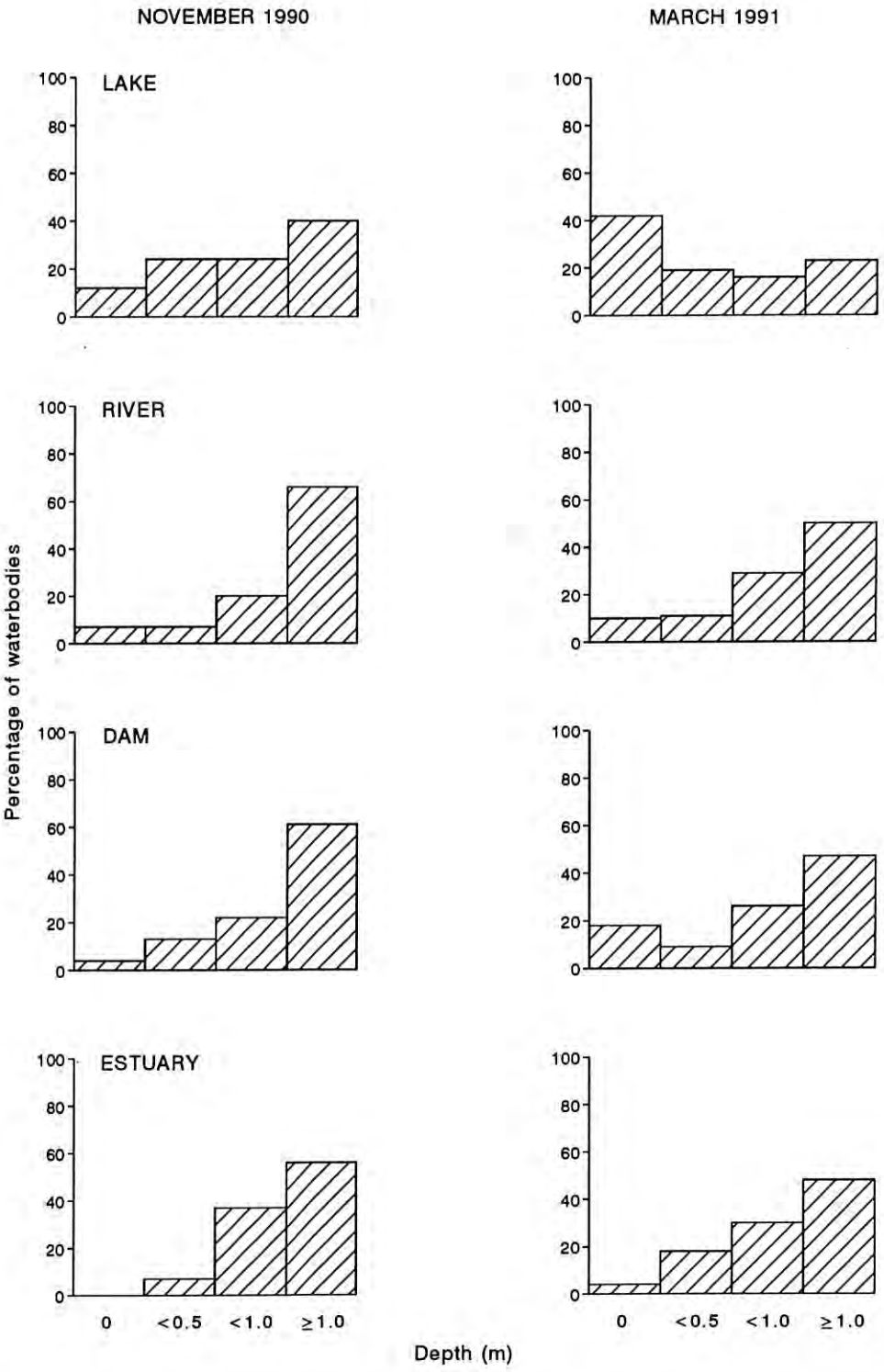

Figure 5. Percentage of waterbodies of each type containing various depths of water in November 1990 and March 1991.

TABLE 4
Estimated number of birds (± 95% confidence limits) of each waterfowl species in November 1990 and March 1991 in south-west WA.

SPECIES	NOVEMBER 1990	MARCH 1991
Black Swan	52814 ± 14415	61232 ± 27046
Freckled Duck[a]	-	-
Australian Shelduck	247671 ± 62449	253488 ± 76816
Pacific Black Duck	119236 ± 37969	230828 ± 99003
Grey Teal	286643 ± 96477	447248 ± 222288
Chestnut Teal	7989 ± 4420	42724 ± 17021
Australasian Shoveler	5209 ± 3660	13870 ± 8673
Pink-eared Duck	28126 ± 13380	54324 ± 23702
Hardhead	7780 ± 4360	5957 ± 4098
Maned Duck	95984 ± 24073	127925 ± 44608
Blue-billed Duck	1975 ± 1326	6824 ± 5524
Musk Duck	6795 ± 1906	21979 ± 12731
Exotic ducks	2485 ± 1804	2484 ± 2375
Unidentified ducks[a]	206	3143
Eurasian Coot	82437 ± 28436	238937 ± 119581
TOTAL	945376 ± 65792	1510963 ± 135348

[a] Confidence limits could not be calculated because of too few occurrences.

Distribution between wetland types

In November 1990 and March 1991, 78 and 68 per cent, respectively, of the estimated waterfowl population in south-west WA occurred on lakes, 13 and 19 per cent on dams, 5 and 10 per cent on river pools and <5 per cent on estuaries (Table 5). Maned Ducks were the only species that occurred mostly outside lakes - more than 70 per cent were in dams on both counting dates. Pacific Black Ducks were probably the most flexible species in use of wetland types: in March 54 per cent of them occurred in lakes, 28 per cent in rivers, 16 per cent in dams and 2 per cent in estuaries. Other species, especially Australasian Shovelers, Pink-eared Ducks, Blue-billed Ducks and Musk Ducks, were restricted mainly to lakes (Table 5).

Distribution between regions

The important regions for waterfowl in 1990/91 were Esperance and Wagin (Tables 6 and 7). In November, the Wagin region contained 17 per cent of the estimated population in south-west WA, Esperance 15 per cent and Frankland 12 per cent. In March, all native species, except Maned Ducks, were most abundant in Esperance, which contained 25 per cent of the total waterfowl population, while Wagin held 15 per cent and Gingin and Beverley each had 12 per cent.

Chestnut Teal exhibited the most pronounced geographical bias in distribution, with approximately 75 per cent of the species occurring in the Esperance region and 15 per cent in the Bremer region in both November and March (Tables 6 and 7). Maned Ducks were most numerous in the Wagin, Beverley, Frankland and Gingin regions, which accounted for approximately 75 per cent of the species population during both surveys. Blue-billed Ducks exhibited a substantial shift towards Esperance during summer 1990/91: in November 67 per cent occurred in the Gingin region and only 8 per cent in Esperance, but by March 68 per cent of the population was in Esperance.

Distribution between habitats

The number of waterfowl counted in 1990/91 in wetlands with different categories of vegetation is shown in Table 8; there appeared to be preferences for wetlands in the 'dead trees' and 'sedges' categories (each represented approximately 11 per cent of wetlands and supported 25 and 26 per cent, respectively, of birds in November and 18 and 40 per cent of birds in March[4]). There was avoidance of 'open' wetlands, which represented approximately 45

[4] Results of statistical tests of habitat preferences are not presented because valid hypotheses could not be constructed. If occurrence of each bird was treated as an independent event, then deviations from expected frequencies were significant even when they constituted a very small percentage deviation. Analysis based on presence/absence also seemed flawed because if only one bird of a species was seen in a wetland that supported vast numbers of other waterfowl, the habitat was probably less suitable for the rare species than for the abundant ones.

TABLE 5
Distribution of estimated numbers of waterfowl species by wetland type in November 1990 and March 1991.

	NOVEMBER 1990				MARCH 1991			
SPECIES	Lake	River	Dam	Estuary	Lake	River	Dam	Estuary
Black Swan	46261 ±14086	105 ± 114	312 ± 215	6136	51140 ± 25334	1103 ± 1053	1248 ± 659	7740
Freckled Duck	26	-	-	-	-	-	-	-
Australian Shelduck	222078 ± 58728	1747 ± 1635	4774 ± 2086	19072	203405 ± 59543	5058 ± 3957	41024 ± 13316	4002
Pacific Black Duck	85278 ± 21881	14309 ± 10317	14230 ± 5771	5419	124475 ± 43535	64601 ± 42985	37078 ± 12483	4674
Grey Teal	243099 ± 75721	11840 ± 7668	26380 ± 13088	5325	348853 ± 195054	18015 ± 7778	61588 ± 19456	18792
Chestnut Teal	6242 ± 2828	901 ± 507	608 ± 1085	238	30364 ± 11728	4680 ± 1907	3715 ± 3386	3964
Australasian Shoveler	4985 ± 3055	201 ± 484	14 ± 121	10	13554 ± 8526	40 ± 93	40 ± 54	235
Pink-eared Duck	28000 ± 13165	59 ± 94	68 ± 121	-	53058 ± 23038	14 ± 8	1251 ± 656	1
Hardhead	6298 ± 2928	349 ± 497	1122 ± 935	11	5691 ± 3619	61 ± 158	203 ± 321	2
Maned Duck	18100 ± 7384	10095 ± 4300	67761 ± 12389	28	14513 ± 8561	17130 ± 13842	96262 ± 22205	20
Blue-billed Duck	1935 ± 1054	13 ± 32	27 ± 240	-	6732 ± 5324	49 ± 146	41 ± 54	2
Musk Duck	6482 ± 1713	187 ± 108	96 ± 85	30	20729 ± 11519	286 ± 334	789 ± 878	176
Exotic ducks	1577 ± 1158	236 ± 278	613 ± 368	59	1840 ± 1395	606 ± 742	38 ± 238	-
Unidentified ducks	186	15	-	5	3143	-	-	-
Eurasian Coot	70979 ± 18026	4956 ± 7299	5700 ± 3111	802	149148 ± 46110	36600 ± 56228	41057 ± 17243	12132
TOTAL	741524 ± 221727	45013 ± 33333	121704 ± 39615	37135	1026245 ± 443286	148243 ±129231	284334 ± 90949	51740

TABLE 6
Estimated number of birds of each species in each region in November 1990.

SPECIES	REGION										
	Geraldton	Moora	Gingin	Beverley	Bunbury	Wagin	Magenta	Esperance	Frankland	Bremer	Walpole
Black Swan	165	6502	5628	668	6626	3532	5324	17230	2852	997	3291
Freckled Duck	-	26	-	-	-	-	-	-	-	-	-
Australian Shelduck	1507	27227	23758	10355	26084	23422	17778	65719	18142	23144	10535
Pacific Black Duck	3462	7946	18643	4626	23246	2029	6899	11502	24272	4140	12473
Grey Teal	20426	28752	17957	22812	25591	73894	33600	12308	45009	4073	2222
Chestnut Teal	-	51	11	-	-	55	18	5982	409	1432	30
Australian Shoveler	-	-	497	-	108	597	18	2652	20	1180	137
Pink-eared Duck	2612	1804	3059	343	48	7300	2339	9591	383	624	23
Hardhead	310	829	699	1200	1370	278	1953	925	-	-	219
Maned Duck	3094	2464	9109	14664	5608	28812	1307	3309	18720	1800	7095
Blue-billed Duck	-	25	1319	38	112	-	18	151	71	-	240
Musk Duck	258	345	1180	29	815	53	129	2298	925	186	579
Exotic ducks	-	217	1490	-	37	606	-	-	-	-	135
Eurasian Coot	3479	6000	16880	4331	4348	17681	9588	10243	4808	2176	2903
TOTAL[a]	35347	82188	100230	59066	93993	158259	78971	142066	115611	39752	39897

[a] Includes unidentified waterfowl

TABLE 7

Estimated number of birds of each species in each region in March 1991.

	REGION										
SPECIES	Geraldton	Moora	Gingin	Beverley	Bunbury	Wagin	Magenta	Esperance	Frankland	Bremer	Walpole
Black Swan	573	3228	13296	2211	3091	3751	847	21782	3767	1992	6694
Freckled Duck	-	-	-	-	-	-	-	-	-	-	-
Australian Shelduck	7441	27254	8270	32702	6263	53036	16810	73762	19664	3950	4337
Pacific Black Duck	4748	5130	39379	15006	52090	12681	457	57685	18649	3439	21567
Grey Teal	16470	19192	29467	88692	30346	98442	59891	78497	7753	8801	9697
Chestnut Teal	140	80	-	-	51	1206	-	31532	2972	6361	382
Australasian Shoveler	93	345	3650	736	60	581	138	6506	734	701	325
Pink-eared Duck	592	3733	12982	1543	234	754	2036	29558	72	2596	225
Hardhead	41	13	1437	14	-	239	-	3898	40	40	234
Maned Duck	686	4291	15437	25809	10574	36890	3319	5503	17640	3791	3986
Blue-billed Duck	-	93	1014	231	-	-	46	4673	671	2	94
Musk Duck	385	93	3553	26	1033	-	83	14314	1209	295	989
Exotic ducks	-	239	1916	42	164	-	-	-	-	-	123
Eurasian Coot	2314	19158	49350	7970	3600	23498	7820	56906	25685	15409	27228
TOTAL[a]	33483	84178	179751	174982	107506	231078	91447	384616	100451	47596	75881

[a] includes unidentified waterfowl

TABLE 8

Number of waterfowl counted in each habitat type in 1990/91.

HABITAT	NOVEMBER	MARCH
Live trees	53845	72772
Trees/sedges	26564	47029
Sedges	50504	56673
Dead trees	52904	127257
Samphire	9173	2871
Open	7453	7642
TOTAL	200443	314244

per cent of all waterbodies but supported only 4 per cent of waterfowl in November and 2 per cent in March. Vegetation categories were confounded with wetland types, however. Most 'open' wetlands were dams and low numbers of waterfowl may have been counted in open wetlands because dams, rather than open habitats, were avoided.

The distribution of waterfowl among lakes, which had the most diverse vegetation of all the types of wetland surveyed, showed that all species had strong associations with some vegetation categories (Fig. 6). Grey Teal appeared to prefer lakes with dead trees during both surveys, Chestnut Teal preferred live trees, Maned Ducks preferred sedges and Musk Ducks showed a positive association with lakes containing trees and sedges. Open lakes were avoided by all species, except Maned Ducks during November. In March all species avoided lakes that were dominated by samphire. Habitat associations must be interpreted cautiously, however, because they were not always consistent with results from earlier years (see Halse *et al.* 1992) and changed according to wetland conditions. For example, in November 1990 Black Swans and Pacific Black Ducks were associated with lakes containing samphire but they quit these lakes before March 1991 because the lakes had dried out or, perhaps, become too saline (Halse *et al.* 1993b).

Numbers on individual wetlands

The number of wetlands without waterfowl increased between November 1990 and March 1991 (usually because the wetlands were dry), as did the number of wetlands supporting large numbers of birds (Fig. 7a). Almost 40 per cent of waterfowl occurred in wetlands containing 10 000 or more birds in March (Fig. 7b).

Wetlands with high numbers of waterfowl

The 15 wetlands supporting highest numbers of waterfowl in November 1990 and March 1991, respectively, are listed in Table 9. Lake Gore had most birds in November (12 172) and Coyrecup Lake contained most in March (20 486). Lake Gore, Peel-Harvey Estuary, Lake Dumbleyung, Culham Inlet, Lake Clifton, Lake Eganu and Lake Gundaring were in the top 15 wetlands in both surveys. Twelve of the wetlands in the November list were lakes and three were estuaries; there were two estuaries and thirteen lakes on the March list. Wetlands with high numbers of birds were concentrated in the Wagin region in March (six of the top 15 occurred there) but were spread more evenly in November.

Wetlands with the three highest counts for each species in November and March, respectively, are listed in Appendix 2[5]. Thirty-eight of the wetlands were lakes, six were estuaries, four were river sections and one was a dam. All regions except Geraldton and Walpole were represented on the list although listed wetlands were concentrated in Gingin and Esperance.

Breeding

Ninety-six nests and 824 broods were found in November 1990. No nest and only 13 broods were recorded in March 1991 (Table 3). No nest of Freckled Duck, Chestnut Teal, Australasian Shoveler, Hardhead, Maned Duck, Musk Duck, Blue-billed Duck or exotic duck was found in either survey. The most commonly found nests belonged to Eurasian Coots, Black Swans, Pink-eared Ducks and Grey Teal.

The most commonly seen broods in November belonged to Black Swans, Eurasian Coots, Pacific Black Ducks and Grey Teal. In relation to number of birds counted, Musk Ducks broods were found most frequently (ratio of 1 brood : 42 adults). Broods of Black Swans (1:66) and Eurasian Coots (1:67) were common. Broods of exotic ducks (1:90), Hardheads (1:100), Maned Ducks (1:130), Chestnut Teal (1:136), Pink-eared Ducks (1:144), Pacific Black Ducks (1:217), Blue-billed Ducks (1:316)and and Grey Teal (1:484) were less common while Australian Shelduck broods (1:4404) were scarce. No brood of Freckled Duck was seen.

Distribution of breeding between wetland types

Lakes were the most important breeding areas surveyed in 1990/91: 79 per cent of nests and 75 per cent of broods found in November occurred there. River sections contained 7 per cent of nests and 8 per cent of broods, dams contained 14 per cent of nests and 6 per cent of broods. No nest was seen in estuaries but 11 per cent of broods (mostly Black Swans) were recorded on them (Table 10).

Distribution of breeding between regions

Most nests and broods seen in November 1990 occurred in the Gingin (35 per cent of records) and Bunbury (19 per cent) regions. The importance of Gingin and Bunbury was

[5] Appendices 1 and 2 are lodged in the Wildlife Sciences Library, Department of Conservation and Land Management, PO Box 51, Wanneroo 6065.

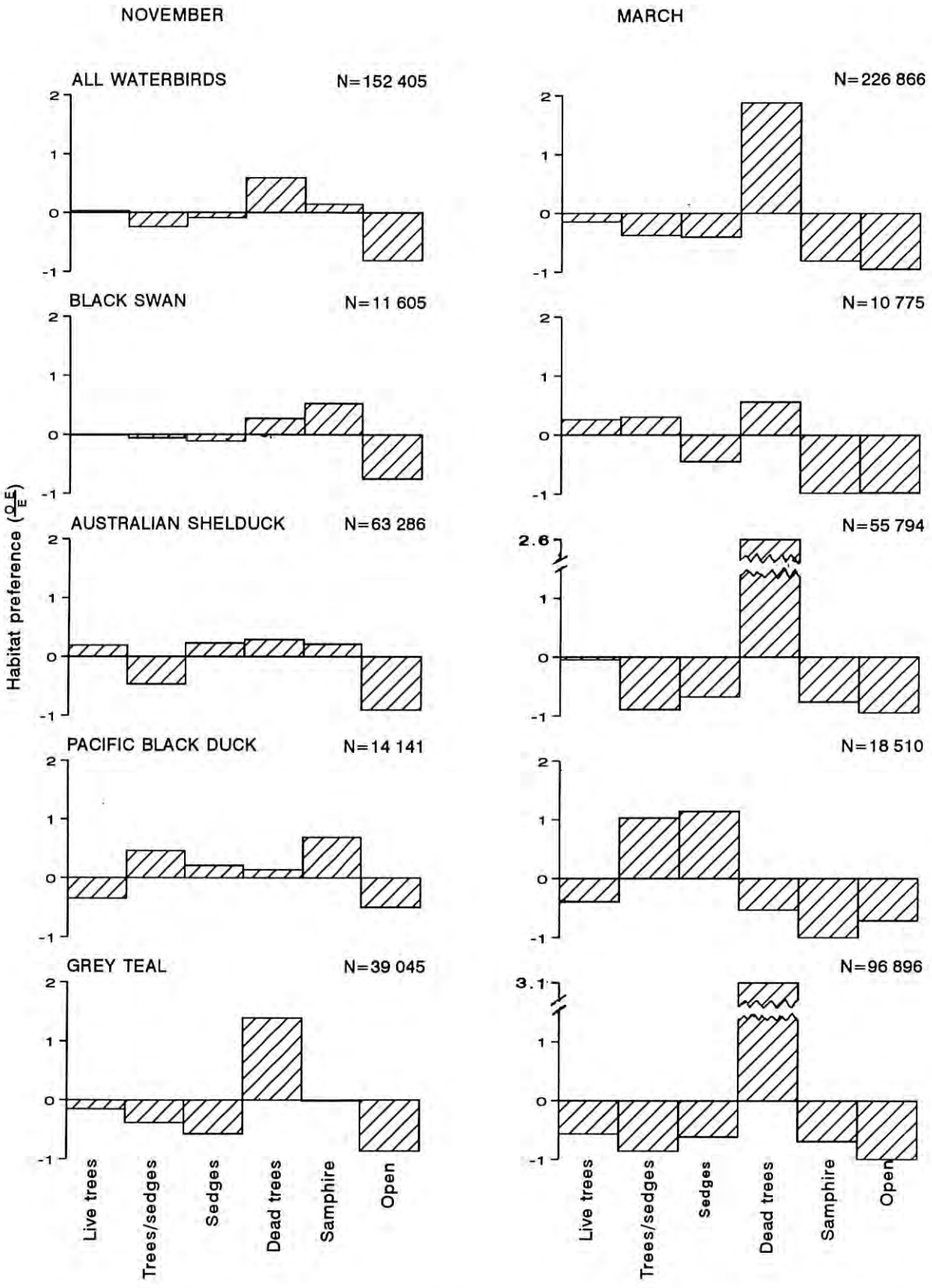

Figure 6. Habitat preferences of waterfowl species during the annual waterfowl counts in 1990/91. Preference for each vegetation type calculated as (O-E)/E where O was number of birds counted in each vegetation type and E was number expected if occurrences were proportional to the number of waterbodies of each vegetation type. Values of (O-E)/E are not symmetrical about zero.

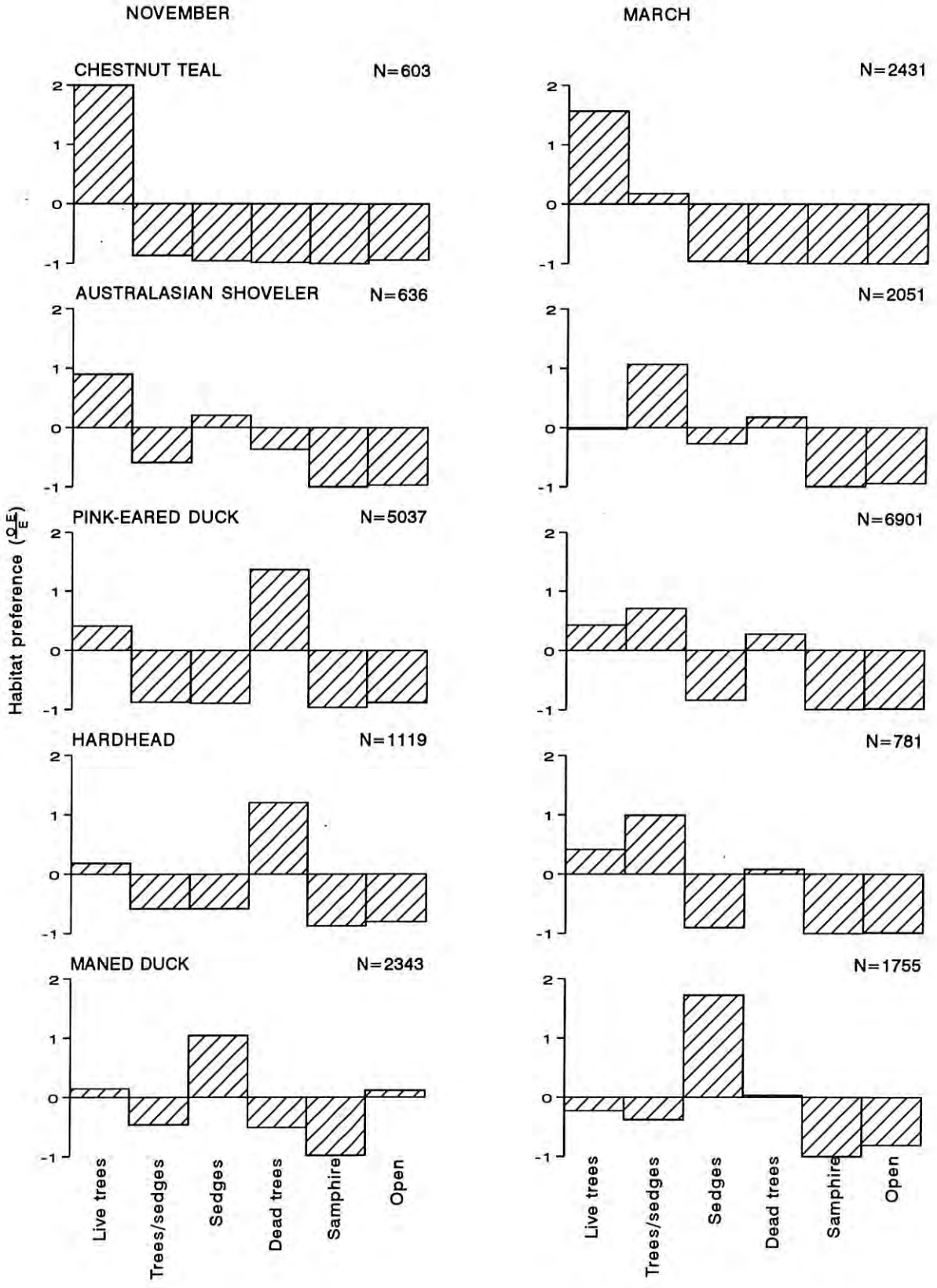

Figure 6 (continued)

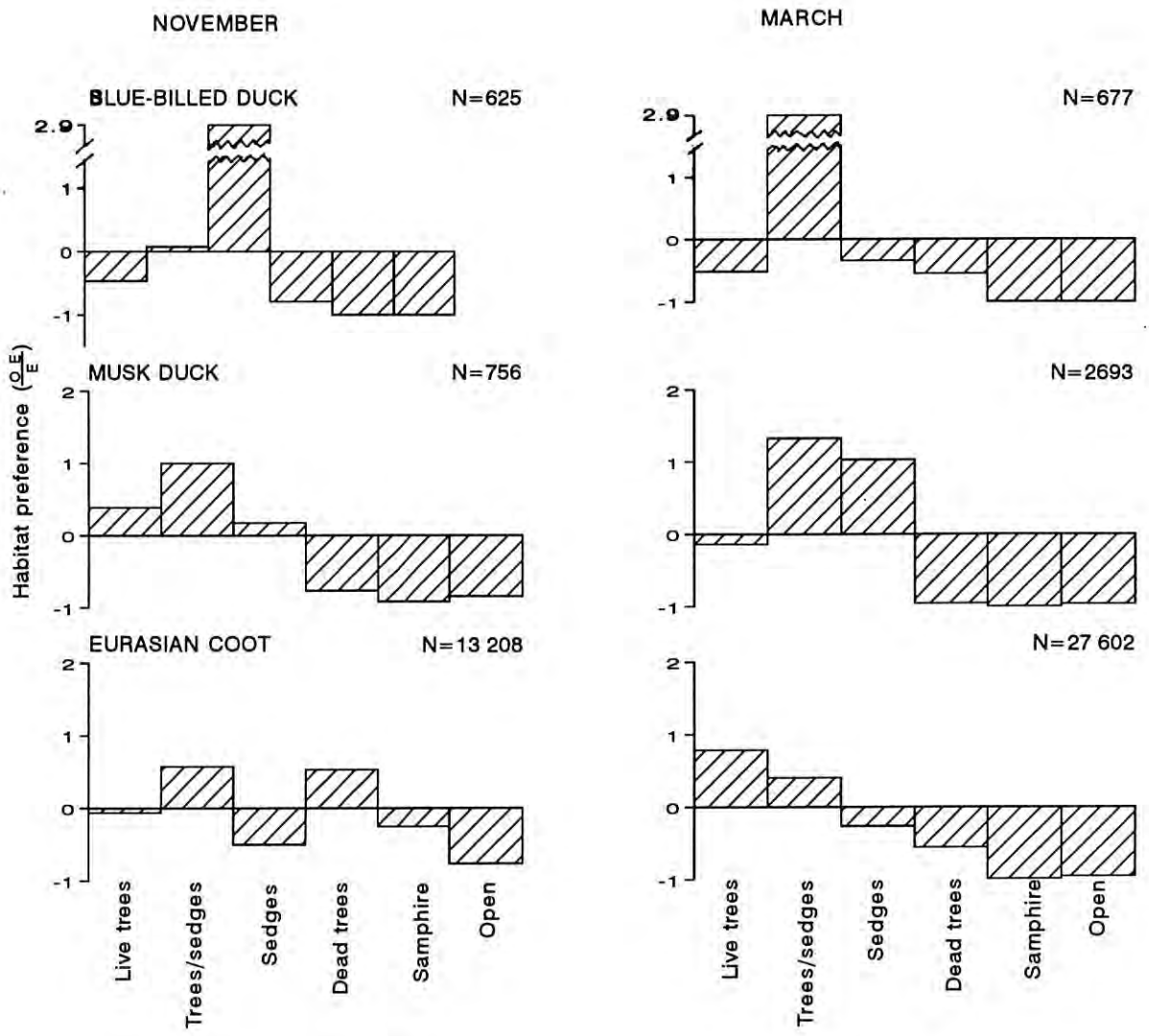

Figure 6 (continued)

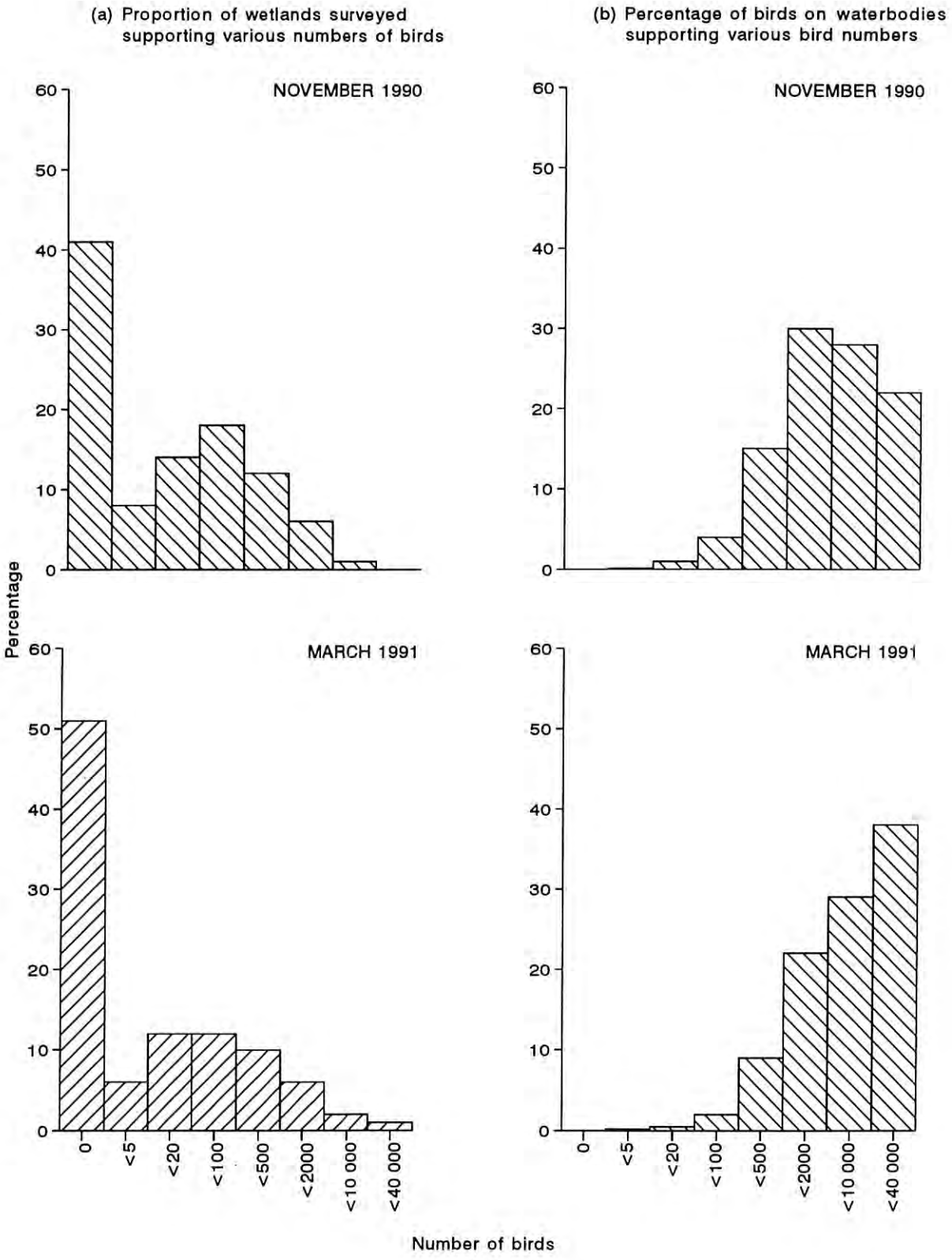

Figure 7. Number of birds in surveyed wetlands during the 1990/91 annual waterfowl counts. (a) The percentage of waterbodies supporting various numbers of birds. (b) The percentage of birds on waterbodies supporting various bird numbers.

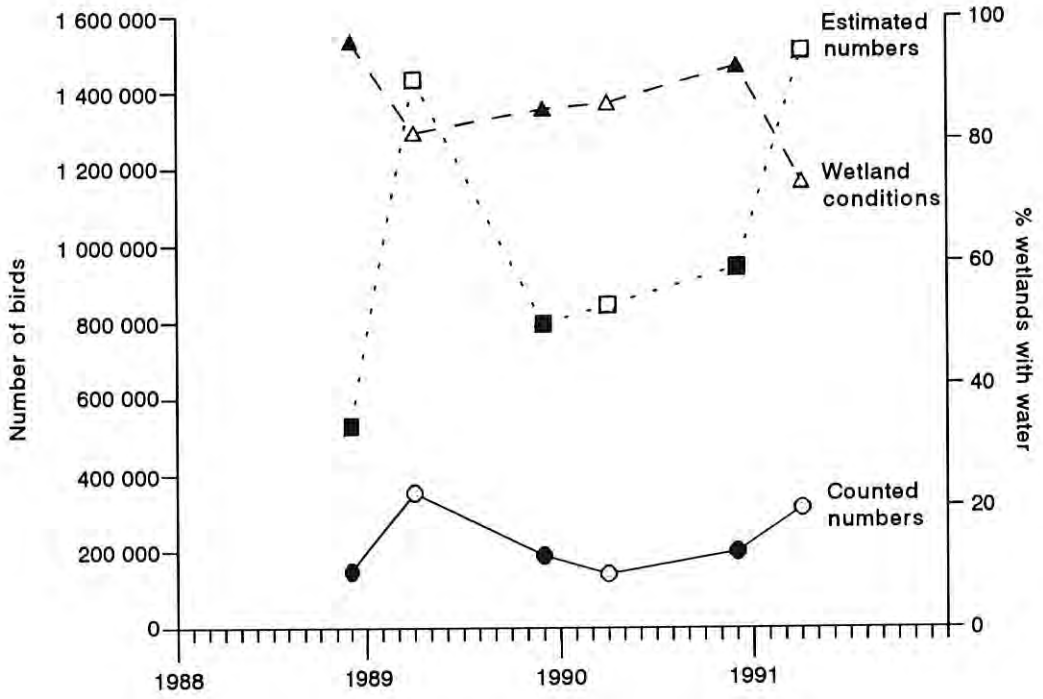

Figure 8. Numbers of birds counted, estimated numbers of birds in the surveyed area and percentage of wetlands surveyed that contained water during November and March waterfowl surveys between 1988/89 and 1990/91 in south-west WA.

a consequence of large numbers of Eurasian Coot breeding records in Gingin and Black Swan breeding records in Bunbury. Esperance supported more breeding by most other species (Table 11).

Distribution of breeding between habitats

Only 8 per cent of breeding records were from open wetlands or those with only samphire in the inundated area. In general, suitable wetlands for breeding had more complex vegetation. The distribution of breeding by individual species was examined for lakes. There were more breeding records of all native species, other than Black Swans, Chestnut Teal and Blue-billed Ducks, in lakes with live trees than in other habitats (Table 12). Black Swans appeared to prefer lakes with dead trees for breeding, most breeding records of Chestnut Teal were from open lakes, while the few breeding records of Blue-billed Ducks were scattered among habitats.

DISCUSSION

The patterns of counts, estimated numbers of birds and wetland conditions in south-west WA in 1988/89, 1989/90 and 1990/91 are shown in Figure 8. Estimated numbers of waterfowl in both March 1989, after a wet winter, and March 1991, after an average winter, were approximately 1 500 000. The estimate in March 1990, after a dry winter and extensive summer rainfall, was about 800 000.

The similarity of the total population estimates in March 1991 and March 1989 suggests that the lower estimate in March 1990 was a result of sampling problems and/or temporary dispersal of waterfowl out of the surveyed area. It is unlikely that there was a real reduction in population size, owing to hunting prior to the March 1990 count (see Halse *et al.* 1992) or some other factor, followed by a population recovery because there were comparatively few breeding records in November 1990 (49 per cent fewer than in 1988/89, Halse *et al.* 1990).

Population estimates and calculations of confidence limits assumed that surveys had a stratified random design with: (1) all wetland types used by waterfowl being sampled, (2) all wetlands of a particular type having equal probability of being sampled, and (3) the total number of wetlands of each type in south-west WA being known. The first condition was violated in November 1990 because many roadside pools and flooded paddocks, which were not surveyed, were used by waterfowl. This was part of the reason the total population estimate in November 1990 was lower than in March 1991 (see Halse *et al.* 1992). The extent to which the other assumptions were violated is unknown. Bias in wetland sampling was reduced by removing wetlands that supported large numbers of birds ('atypical' wetlands, which were not randomly selected) from the extrapolation process. Accuracy of estimates of total numbers of wetlands was discussed by Halse *et al.* (1992).

TABLE 9

The 15 wetlands supporting the highest number of waterfowl in November 1990 and March 1991.

	NOVEMBER 1990				MARCH 1991			
	Wetland	Number	Region	Type	Wetland	Number	Region	Type
1	Lake Gore	12172	Esperance	L[a]	Coyrecup Lake	20486	Wagin	L
2	Vasse-Wonnerup Estuary	11179	Bunbury	E	Peel-Harvey Estuary	17795	Bunbury	E
3	Peel-Harvey Estuary	10773	Bunbury	E	Lake Dumbleyung	13285	Wagin	L
4	Lake Dumbleyung	10154	Wagin	L	Beverley Lakes	13149	Beverley	L
5	Lake Preston	7086	Bunbury	L	Lake Gore	11767	Esperance	L
6	Culham Inlet	5064	Bremer	E	Jerdercuttup West Lake	11629	Esperance	L
7	Lake Muir	4705	Frankland	L	Lake Brown	11134	Beverley	L
8	Lakes Gidong and Carbul	4552	Esperance	L	Lake Gundaring	10960	Wagin	L
9	Lake Clifton	4543	Bunbury	L	Culham Inlet	10476	Bremer	E
10	Lake Forrestdale	4099	Gingin	L	Lake Parkeyerring	8697	Wagin	L
11	Lake Pinjarrega	3800	Moora	L	Lake Yealering	6984	Beverley	L
12	Lake Eganu	3600	Moora	L	Lake Norring	6389	Wagin	L
13	Martagallup Lake	3037	Frankland	L	Lake Clifton	6340	Bunbury	L
14	Fitzes Swamp	3007	Wagin	L	Lake Eganu	5502	Moora	L
15	Lake Gundaring	2543	Wagin	L	Lake Coomelberrup	4850	Wagin	L

[a]Wetland types: E = estuary, L = lake, R = river

TABLE 10

Distribution of breeding by waterfowl species among wetland types in south-west WA in November 1990.

	LAKE		RIVER		DAM		ESTUARY	
SPECIES	Nests	Broods	Nests	Broods	Nests	Broods	Nests	Broods
Black Swan	16	178	-	4	-	2	-	84
Freckled Duck	-	-	-	-	-	-	-	-
Australian Shelduck	1	17	-	1	-	1	-	-
Pacific Black Duck	3	70	-	18	1	11	-	2
Grey Teal	5	67	-	12	4	18	-	1
Chestnut Teal	-	7	-	1	-	-	-	-
Australasian Shoveler	-	2	-	-	-	-	-	-
Pink-eared Duck	13	35	-	-	-	-	-	-
Hardhead	-	11	-	1	-	-	-	-
Maned Duck	-	15	-	13	3	8	-	1
Blue-billed Duck	2	2	-	-	-	-	-	-
Musk Duck	-	19	-	-	-	-	-	-
Exotic ducks	-	2	-	2	-	-	-	-
Eurasian Coot	36	196	7	18	5	5	-	-
TOTAL	76	621	7	70	13	45	-	88

TABLE 11

Distribution of breeding (nests and broods combined) by waterfowl species among regions in south-west WA in November 1990.

	REGION										
SPECIES	Geraldton	Moora	Gingin	Beverley	Bunbury	Wagin	Magenta	Esperance	Frankland	Bremer	Walpole
Black Swan	2	5	51	41	111	21	17	4	15	1	16
Freckled Duck	-	-	-	-	-	-	-	-	-	-	-
Australian Shelduck	1	1	3	-	5	1	-	8	1	-	-
Pacific Black Duck	1	-	50	3	20	-	-	12	12	-	7
Grey Teal	6	1	20	12	16	9	2	25	13	-	3
Chestnut Teal	-	-	-	-	-	-	-	6	1	1	-
Australasian Shoveler	-	-	-	1	-	1	-	-	-	-	-
Pink-eared Duck	-	3	11	11	-	2	2	14	-	5	-
Hardhead	-	-	7	1	4	-	-	-	-	-	-
Maned Duck	-	3	5	15	4	2	-	6	2	-	3
Blue-billed Duck	-	-	3	-	-	-	-	-	1	-	-
Musk Duck	-	-	4	1	1	-	1	12	-	-	-
Exotic ducks	-	-	2	-	-	-	-	-	-	-	2
Eurasian Coot	6	5	167	23	17	16	1	24	2	5	1
TOTAL	37	13	274	72	331	70	21	42	33	21	41

TABLE 12

Distribution of breeding within lakes according to vegetation category in south-west WA in November 1990. N = nests, B = broods.

	LIVE TREES		TREES/SEDGES		SEDGES		DEAD TREES		SAMPHIRE		OPEN	
SPECIES	N	B	N	B	N	B	N	B	N	B	N	B
Black Swan	4	31	5	52	1	17	6	67	-	8	-	3
Freckled Duck	-	-	-	-	-	-	-	-	-	-	-	-
Australian Shelduck	-	12	-	3	-	-	1	2	-	-	-	-
Pacific Black Duck	-	39	3	18	-	9	-	3	-	-	-	1
Grey Teal	-	43	-	1	-	11	5	9	-	-	-	3
Chestnut Teal	-	-	-	1	-	-	-	-	-	-	-	6
Australasian Shoveler	-	2	-	-	-	-	-	-	-	-	-	-
Pink-eared Duck	2	26	-	-	2	1	9	8	-	-	-	-
Hardhead	-	8	-	2	-	-	-	1	-	-	-	-
Maned Duck	-	7	-	1	-	5	-	2	-	-	-	-
Blue-billed Duck	-	1	-	1	1	-	1	-	-	-	-	-
Musk Duck	-	15	-	2	-	1	-	1	-	-	-	-
Exotic ducks	-	-	-	2	-	-	-	-	-	-	-	-
Eurasian Coot	21	113	6	32	3	23	6	12	-	-	-	16
TOTAL	27	297	14	115	7	67	28	105	-	8	-	29

Ninety-five per cent confidence limits for species population estimates in 1990/91 ranged from 25 per cent of the population estimate for Australian Shelducks and Maned Ducks in November to 81 per cent for Blue-billed Ducks in March. For most species, confidence limits were smaller relative to population estimates in November than March, which reflected the more clumped distribution of birds in March (Fig. 7).

One implication of the comparatively large confidence limits associated with population estimates of most species is that only large changes in populations between years can be detected. No suitable way of reducing confidence limits has been identified. Most sampling error was associated with lakes but 2.5 times more lakes (30 per cent of lakes in south-west WA) would need to be surveyed to halve confidence limits of estimates of lake populations.

In practice, confidence limits of population estimates probably do not limit interpretation of population trends as much as wetland conditions. For example, as a result of different depths in wetlands during the two surveys, statistically higher population estimates were obtained for several species, including Chestnut Teal, in March 1991 than November 1990. The higher estimates must have been the result of birds concentrating in the types of wetlands being sampled or more birds moving into the survey area. There is little breeding during summer (Halse and Jaensch 1989) and, Australia-wide, populations must have remained static or decreased. By analogy with the November 1990 and March 1991 counts, comparing March estimates of consecutive years may result in spurious conclusions unless wetland conditions are identical. A long-term data set is required to detect changes in the abundance of species.

Wetland conditions in the Esperance region appeared particularly favourable to waterfowl during the 1990/91 surveys, especially in March when 25 per cent of the estimated waterfowl population in south-west WA and highest numbers of all species other than Maned Duck occurred there. Half the native species recorded breeding in November bred in greatest numbers in Esperance.

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