A MODEL FOR THE POPULATION DYNAMICS OF *Crocodylus porosus* IN NORTHERN AUSTRALIA

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INTRODUCTION

In our chapter on the population status of *Crocodylus porosus* in northern Australia we describe the survey methods used in monitoring the populations and describe briefly the history of the surveys. More than 100 tidal river and creek systems were surveyed at least once between 1974 and 1979. In some cases the surveys have been continued over a period of ten years.

Intensive population surveys and studies were continued during 1980-1983 on some 330 km of tidal waterways (Figs. 1-3) centered on the Liverpool-Tomkinson and Blyth-Cadell Rivers Systems in northern Arnhem Land and on some 59.3 km of associated alternative habitat. These relatively undisturbed waterways constituted our population dynamics and status monitoring systems. In addition Ngandadauda Creek and the Glyde River with its associated Arafura Swamp were resurveyed twice in 1983 (Figs. 1, 4-5). All these latter surveys are analyzed in great detail in Messel et al. (1979-1984, 18).

The results of our survey and studies have allowed a picture of *C. porosus* population dynamics in northern Australia to be developed, and this picture is presented in some detail. It enables us to account in a consistent fashion for the results of the surveys and to predict results to be expected on future surveys.

One implication of the picture was that recovery of the crocodile population should occur more rapidly in areas where the TYPE 1 rivers (see Point 1 in the population model) have closely associated extensive freshwater complexes. One of the best such areas remaining in northern Australia is the Alligator Region, where there is the largest concentration of TYPE 1 *C. porosus* systems in northern Australia. For this reason the waterways of the Alligator Region and the Adelaide River were resurveyed in July 1984.

The Adelaide, East Alligator South Alligator, West Alligator, and Wildman River Systems and Murgenella Creek-- all TYPE 1 systems (Fig. 6)--were first systematically surveyed in 1977 (the Wildman in 1978) and then resurveyed in 1978 and again in 1979. Just to the north of the Alligator Region, the largest assemblage of TYPE 3 waterways in northern Australia--the Cobourg Complex consisting of the Ilamaryi and Minimini Complexes and Saltwater Creek--were surveyed for the first time in 1979 (Fig. 6). Our results and discussions of the surveys were presented in Messel et al. (1979-1984, 1, 3, 18) for the Adelaide River System and Messel et al. (1979-1984, 1, 4, 14) for the Alligator Region River Systems and the Cobourg Complex. Detailed descriptions of the waterways were given in those citations also and full work maps in Messel et al. (1979-

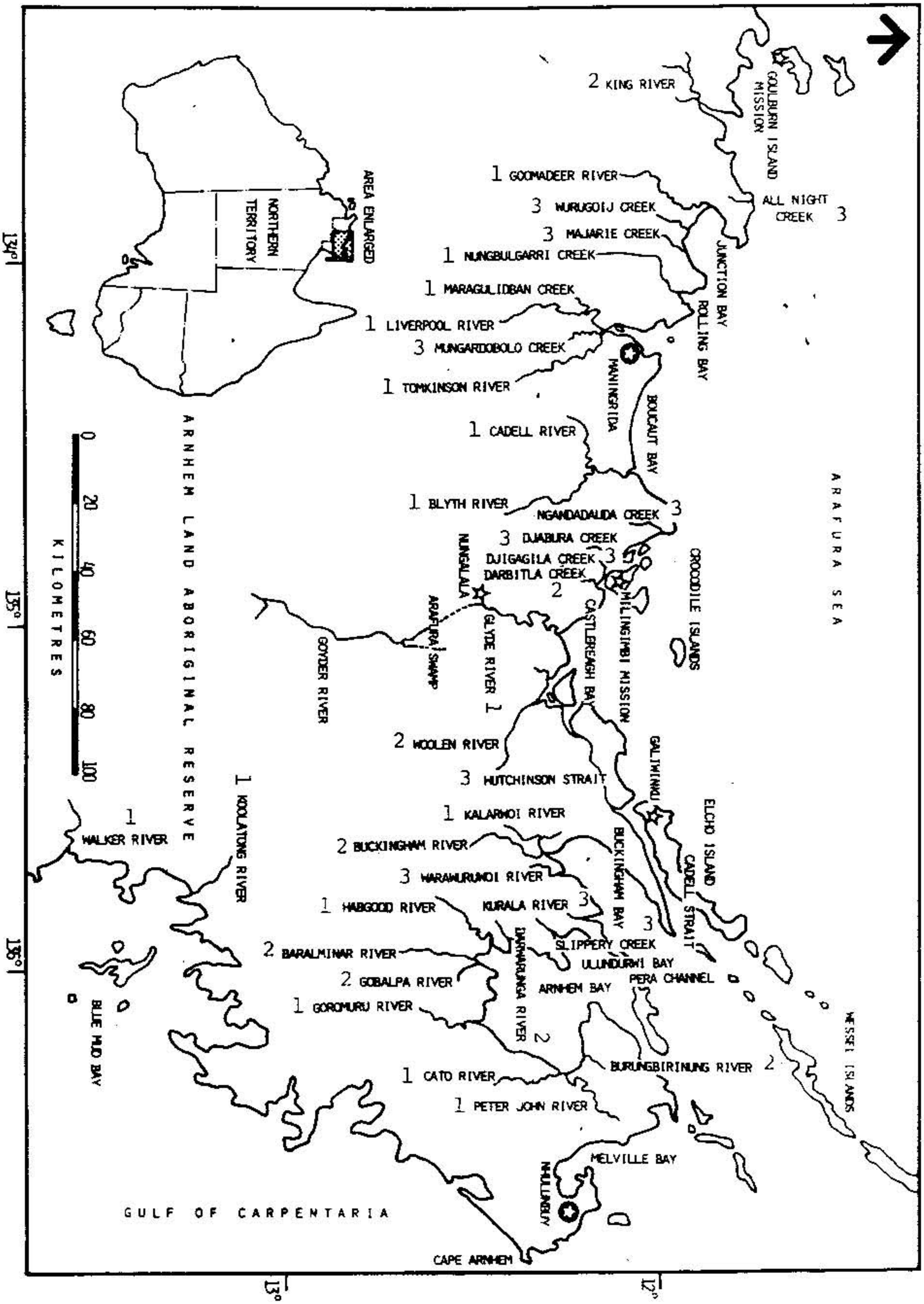

Figure 1. General area map showing the waterways of the monitored area, with their TYPE classifications.

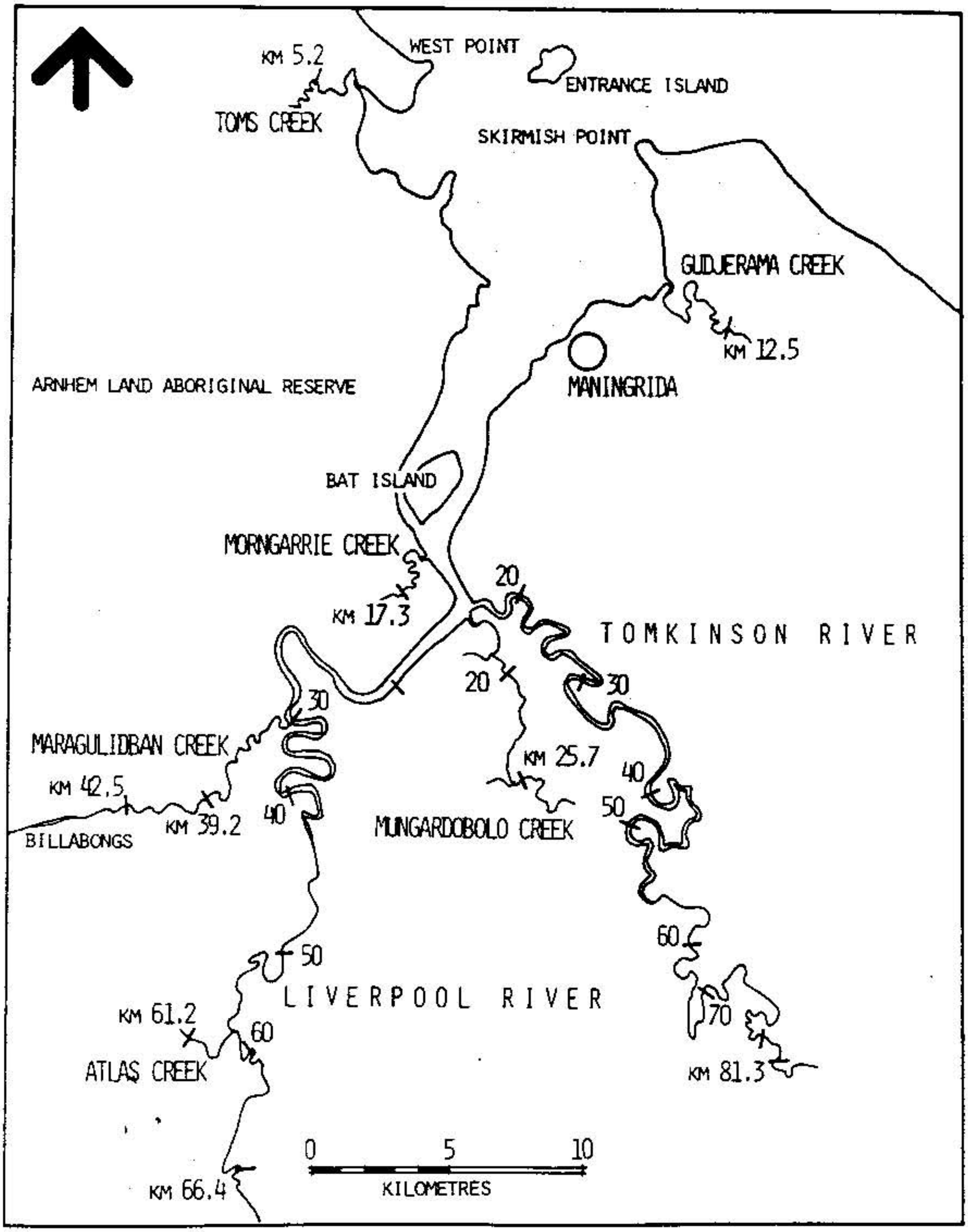

Figure 2. The Liverpool-Tomkinson Rivers.

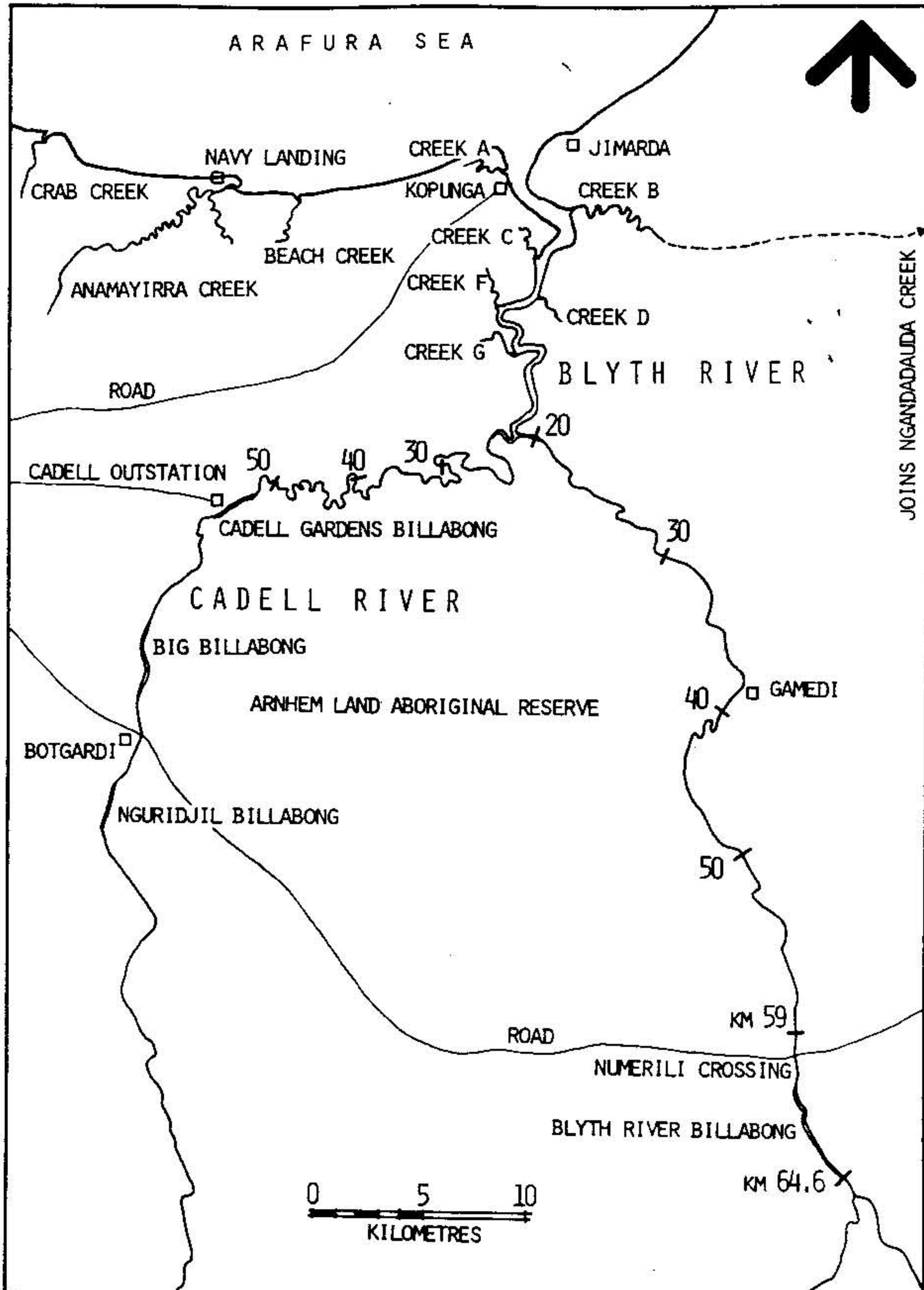

Figure 3. The Blyth-Cadell Rivers.

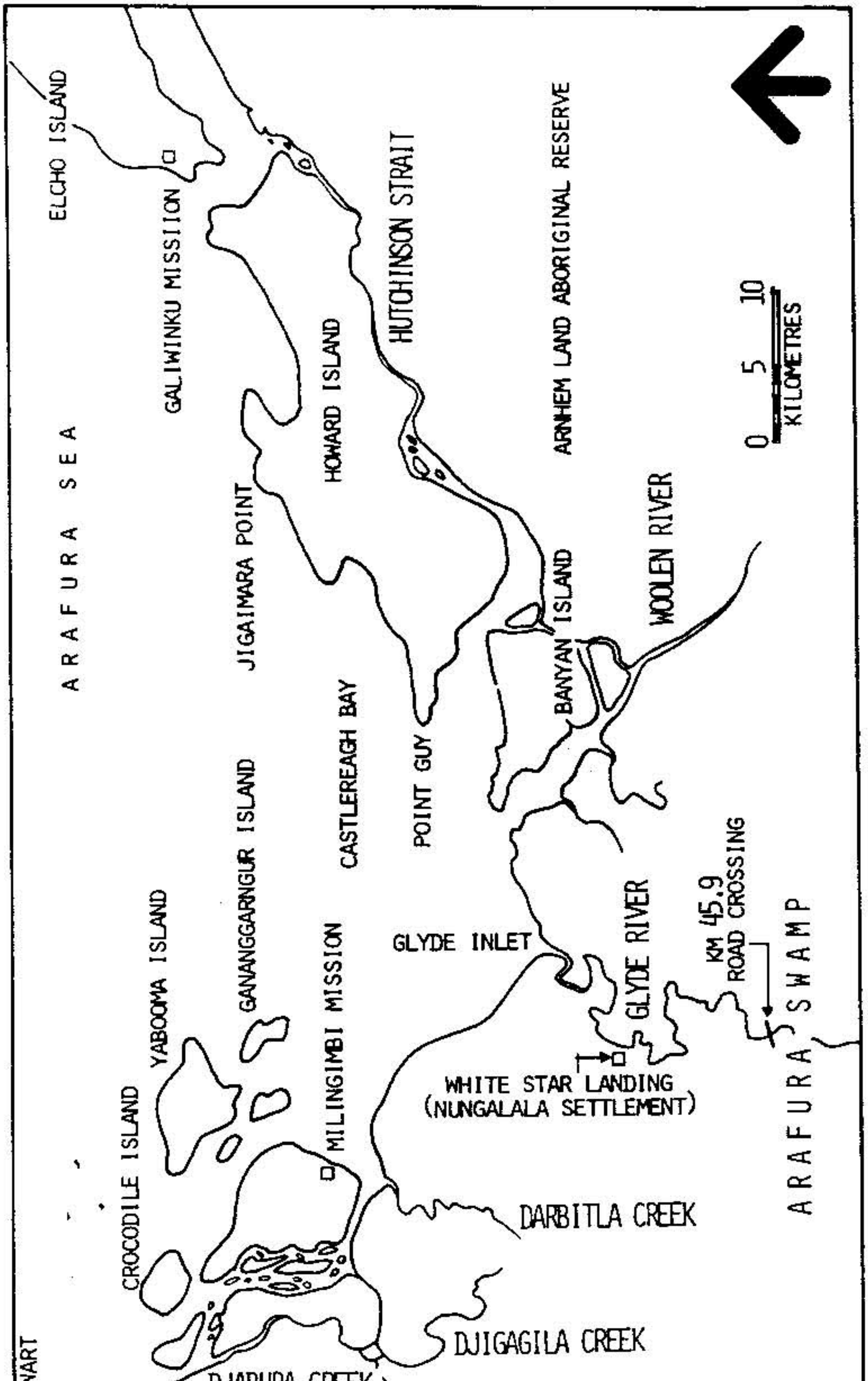

Figure 4. General area map showing the tidal waterways of the Milingimbi Complex and Castlereagh Bay.

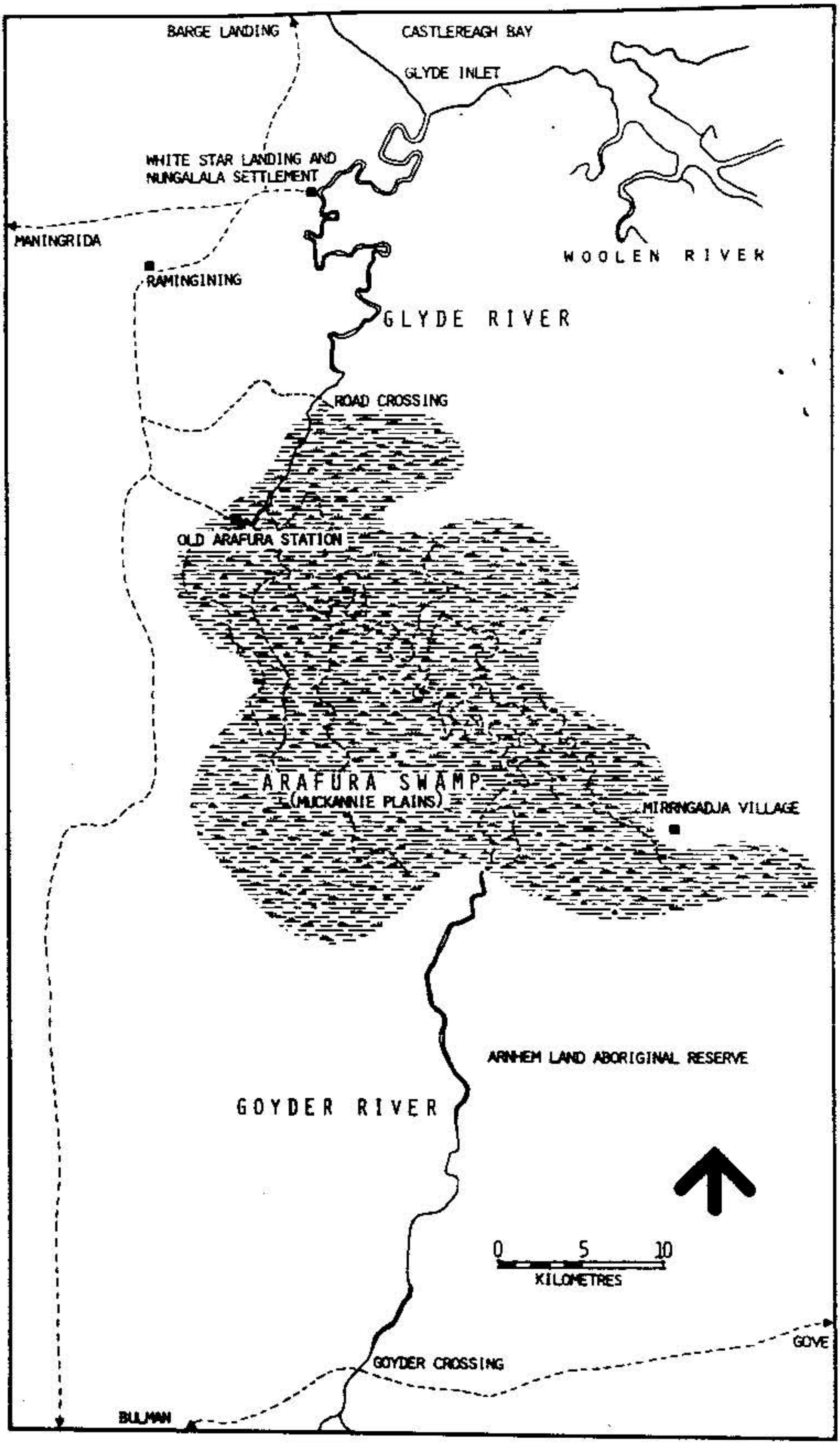

Figure 5. The Glyde-Arafura and Goyder Areas.

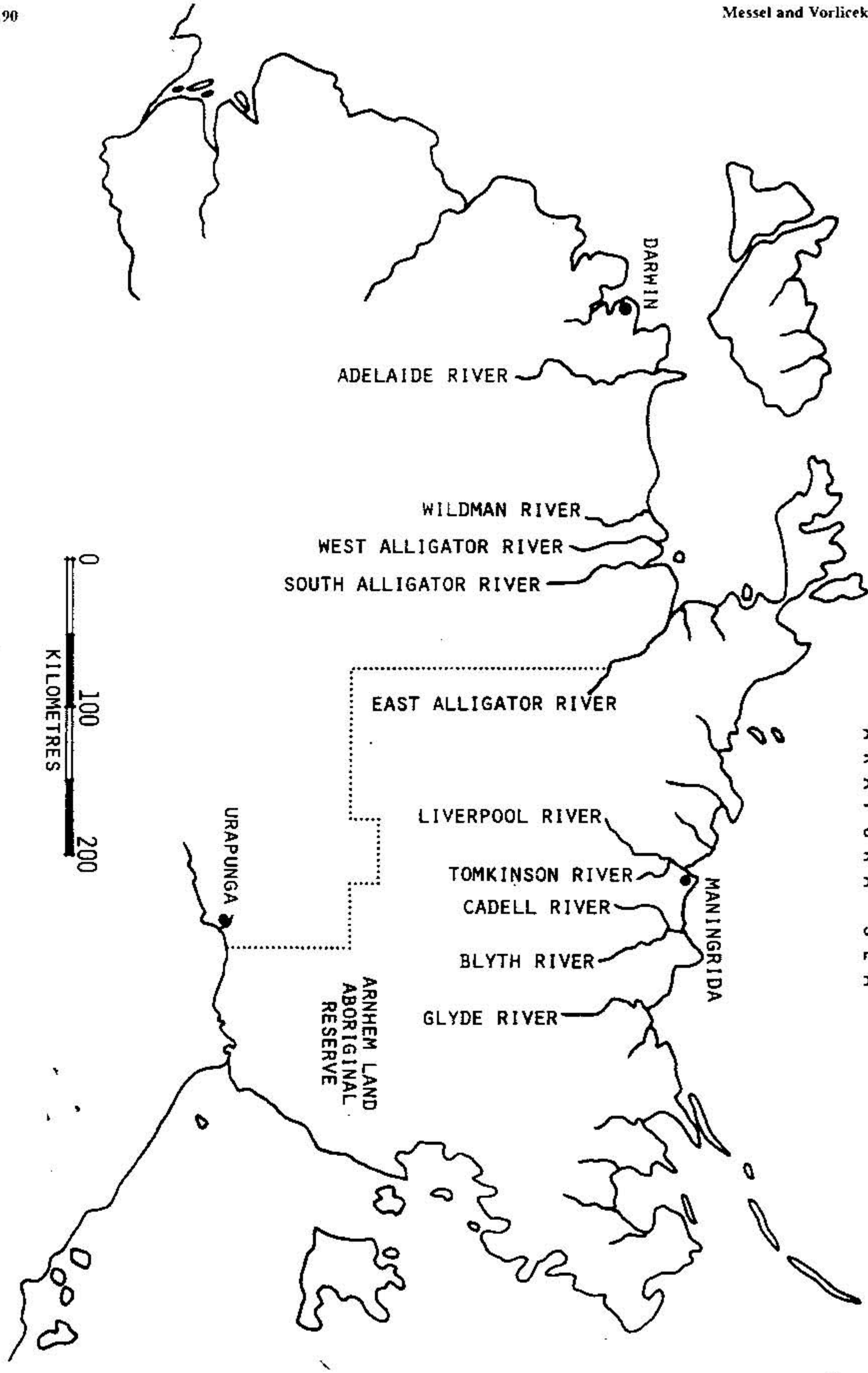

Figure 6. General area map showing rivers and creeks on the Cobourg Peninsula and the Alligator Region. The dotted area shows the Cobourg Mangrove Complex which is one of the largest in Australia.

1984, 15). The results and analysis of the July 1984 surveys is presented in detail in Messel et al. (1979-1984, 19).

Our approach in this chapter is to present the model we have developed and describe how the results obtained In the Maningrida monitored area and Alligator Rivers Region fit the model. This of course is a somewhat circular process, since the model was derived partly from consideration of these results. Other evidence is also presented to support the basic ideas of the model.

We believe that the construction of a mathematical model of *C. porosus* population dynamics would be premature at this stage. There are far too many uncertainties in values for basic biological parameters to allow a sensible predictive model. Examples of such uncertainties include: percentage of mature females in a given population; percentage of mature females nesting; variability in nesting in different years and different rivers; detailed understanding of territorial requirements and so on.

RESULTS

As we describe in our chapter on population status, when discussing population changes it is essential to consider results for broad groups of waterways as well as those for individual waterways. In Table 1A we present results for each survey of the tidal waterways of the monitored area from 1974 to 1983. The table is in our standard format, which is described in the Results section of the chapter on Population Status, and the reader should refer to this.

In Table 1B we present the results for all surveys carried out in the Alligator Region, Cobourg Complex, and Adelaide River, in the same form as Table 1A. Tables 2 and 3 are obtained using Table 1A, and highlight a number of salient features of the data for the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems. In Tables 4 and 5 we show summary results for the number of crocodiles sighted in the hatchling, small (3-6'), and large size classes during the general night-time surveys of the major components of the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems. The more important size classes are the 3-6'), large, and ≥3'. Interpretation of small and non-hatchling numbers can be distorted temporarily because of variations arising from the input of 2-3' animals after a heavy hatchling recruitment year. This variation appears to soon disappear once the animals reach the ≥3-4' size classes.

Table 6 gives summary results in the different size classes for the waterways of Rolling and Junction Bays. Table 7 does likewise for each of the major components of our monitoring area and for their combined total. Table 8 gives the results for the surveys of the main alternative *C. porosus* habitats associated with the monitored area. The reader is asked to spend a few minutes looking down the columns in Tables 4 to 7 before proceeding. Table 9 for the Alligator Region and Adelaide River Systems has been obtained using Table 1B and presents the results in similar form to Tables 2 and 3, with the sightings grouped into important size classes.

We draw attention to two important points when considering and comparing the results shown in the Tables. The first relates to the matter of errors in size class estimation. We discussed this matter in some detail in Messel et al. (1979-1984, 1:80, 335, 389 and 18:117) and refer the reader to these. The second matter concerns the importance of comparing results for equivalent survey seasons; that is, breeding versus breeding and non-breeding versus non-breeding periods whenever possible (Messel et al. 1979-1984, 18:124-125). For example, October-November surveys should, if possible, be compared with other October-November surveys and not June-July

Table 1A. Number of *C. porosus* sighted within each size class on tidal waterways of the 130 km of control systems in the Maningrida area of northern Arnhem Land and on Ngandadauda Creek and the Glyde River draining the Arafura Swamp, during night time spotlight surveys[1,2].

System	Date	Total	H	2-3	3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels	Type
					Numbers in size class									
							MONOGRAPH 1							
BLYTH-CADELL	Oct. 74	387	89	81	147	58	6	2		4	91.9	3.2	454- 524	1
	Nov. 75	353	50	106	81	72	23	4	2	15	94.9	3.2	462- 532	
	Sept. 76	348	82	63	104	46	14	7	6	26	92.0	2.9	403- 469	
	Nov. 76	307	61	61	103	47	10	4	2	19	92.0	2.7	371- 435	
	Apr. 77	327	72	70	108	48	10	2	4	13	92.0	2.8	386- 450	
	May 77	333	88	60	94	55	13	4	1	18	92.0	2.7	370- 432	
	June 77	365	108	36	102	69	13	10	3	24	90.5	2.8	389- 453	
	Sept. 77	386	105	45	132	47	17	4	4	32	90.5	3.1	427- 495	
	Oct. 77	360	112	68	83	47	18	8	3	21	90.5	2.7	375- 439	
	June 78	432	173	65	81	67	15	6	4	21	90.5	2.9	393- 457	
	Sept. 78	399	155	60	79	56	18	8	6	17	90.5	2.7	369- 431	
	June 79	465	123	91	93	59	31	16	26	26	94.5	3.6	524- 598	
	Oct. 80	400	119	89	71	48	22	9	4	38	92.9	3.0	427- 495	
	July 81	366	76	86	84	43	24	11	9	33	90.1	3.2	442- 510	
	Oct. 81	315	72	77	60	32	20	16	7	31	89.9	2.7	367- 430	
	June 82	408	136	42	59	49	31	22	20	49	91.9	3.0	413- 479	
	Nov. 82	347	111	43	66	46	28	15	10	28	92.5	2.6	356- 418	
	July 83	465	157	98	61	48	30	19	9	43	91.8	3.4	470- 540	
	Oct. 83	354	73	95	69	45	24	11	10	27	92.8	3.0	427- 495	
							MONOGRAPH 5							
GOOMADEER	Aug. 75	46		27	7	5	4			3	45.3	1.0	61- 89	1
	Sept. 76	52	18	5	8	5	1	3	3	9	45.3	0.8	44- 68	
	June 77	50	2	9	13	10	6	2	1	7	45.3	1.1	65- 83	
	July 79	90	29	14	7	14	10	6	1	9	45.3	1.4	84- 116	
	June 81c	43	6	5(3)	11(3)	8(1)	4	3	1	5	45.0	0.8	49- 73	
	Oct. 81	45	17	3	13	6	1			5	45.0	0.6	35- 47	
	June 82	61	18	5	12	5	2	4	4	11	45.3	0.9	58- 84	
	Oct. 82	54	9	7	9	11	5	4	3	6	45.3	1.0	61- 87	
	June 83	63	24	5	6	8	3	3	4	10	45.3	0.9	51- 77	
	Oct. 83	73	33	8	5	8	5	4	3	7	45.3	0.9	53- 79	
MARJARIE	Aug. 75	12	1	1	2	2	1	1	2	2	20.1	0.5	11- 25	3
	Aug. 76	7			3					4	20.1	0.4	7	
	July 79	18			1	7	4	1	3	2	24.1	0.7	21- 39	
	June 81	19			2	2	4	2	3	6	21.1	0.9	22- 40	

System	Date		Total	H	2-3	3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels		Type
					Numbers in size class											
MARJARIE	Oct.	81	17			3	4	2	1		7	22.0	0.8	20-	36	
	June	82	17	2	1	1	2	2	1	3	5	23.8	0.6	17-	33	
	Oct.	82	12				4	5	1	1	1	23.3	0.5	13-	27	
	June	83	24	4		4	4	5	2		5	24.1	0.8	24-	42	
	Oct.	83	19		1	4	1	6	3	1	3	24.1	0.8	22-	40	
WURUGOIJ	Aug.	75	4				3	1				16.4	0.2	4		3
	Aug.	76	1								1	16.4	0.1	1		
	July	79	9					2	2	4	1	16.4	0.5	9		
	June	81	6			1	1	1	1	1	1	16.4	0.5	6		
	Oct.	81	8		1	1	1	3			2	16.4	0.5	8		
	June	82	7					2		2	3	16.2	0.4	7		
	Oct.	82	8	1			2	2	1	1	1	16.4	0.4	7		
	June	83	6		1		1	2	1		1	16.4	0.4	6		
	Oct.	83	11			2	3	1	2		3	16.4	0.7	11-	25	
								MONOGRAPH 7								
LIVERPOOL-TOMKINSON	July	76	228	19	39	56	27	13	3	3	68	152.2	1.4	314-	372	1
	May	77	245	40	6	51	59	30	13	5	41	145.1	1.4	307-	365	
	Oct.	77	228	56	7	39	62	24	9	1	30	123.4	1.4	256-	308	
	Sept.	78	233	37	18	37	65	19	14	8	35	141.4	1.4	293-	349	
	Oct.	79	335	161	16	36	37	29	17	23	36	141.1	1.4	290-	346	
	July	79	515	289	11	39	43	34	29	20	50	150.0	1.5	341-	401	
	Oct.	80	295	71	51	37	32	29	12	14	49	140.6	1.6	337-	397	
	July	81	256	26	52	48	29	23	15	15	48	140.6	1.6	347-	407	
	Oct.	81	254	34	33	50	34	23	14	14	52	141.1	1.6	331-	391	
	June	82	467	193	29	64	50	37	23	17	54	141.1	1.9	416-	482	
	Oct.	82	384	144	16	48	51	25	21	17	62	141.1	1.7	363-	425	
	July	82	432	121	83	64	56	32	17	15	44	141.1	2.2	475-	466	
	Oct.	83	327	63	77	47	39	34	8	14	45	141.1	1.9	400-	466	
NUNGBULGARRI	Aug.	75	29		4	11	3		1		10	15.0	1.9	37-	59	1
	July	76	15	2		3	5	1	1		3	13.6	1.0	14-	28	
	June	77	14	2	2		6	1	1		2	13.6	0.9	13-	27	
	July	79	35	10		4	4	6	5	12	4	14.8	1.7	31-	51	
	June	81	27	2	4	10	4		1		6	14.8	1.7	31-	51	
	Oct.	81	25		2	12	4	2			5	14.8	1.7	31-	51	
	June	82	23		2	8	4	3	1	1	4	14.8	1.6	28-	48	
	Oct.	82	29		1	9	8	2	2	4	3	14.4	2.0	37-	59	

Table 1A. cont.

System	Date	Total	H	2-3	Numbers in size class 3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels	Type
					MONOGRAPH 9									
NUNGBULGARRI	June 83	55	34	2	6	5	5			3	14.4	1.5	25- 43	
	Oct. 83	38	15	1	5	4	6	1	1	5	14.4	1.6	28- 48	
NGANDADAUDA	Sept. 75	19	3	2	5	1	1	2	1	4	22.6	0.7	18- 34	3
	June 79	21			2	3	3	4	4	5	23.9	0.9	25- 43	
	June 83	30			2	5	7	1	2	13	23.6	1.3	38- 60	
	Oct. 83	21				5	8	4	2	2	23.6	0.9	25- 43	
GLYDE	Sept. 75	28			3	6	2	1	4	12	45.9	0.6	35- 57	1
	July 79	100	36	9	10	9	10	6	6	14	45.9	1.4	89- 121	
	July 83	118	5	9	35	16	8	6	10	29	45.9	2.5	164- 206	
	Oct. 83	91		3	22	12	11	5	11	27	45.9	2.0	130- 168	

1. The midstream distance surveyed and density of non-hatchling crocodiles sighted on each waterway is shown, as are the 95% confidence limits for the estimate of the actual number of non-hatchlings present. The TYPE classification of each waterway is given also.

2. The 1976 results for the Liverpool-Tomkinson given here differ by 20 from those in Table 9.2.1 (Monograph 1) because these animals are now included in the upstream Tomkinson (km 73.7-80.1) on Table 8.

3. Numbers in brackets give numbers of crocodiles removed by Biology researchers before survey.

Table 1B. Number of C. porosus sighted within each size class on tidal waterways of Van Diemen Gulf, during night-time spotlight surveys carried out between 1977 and 1984.

System	Date		Total	H	2-3	Numbers in size class 3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels	Type
								MONOGRAPH 3							
ADELAIDE	July	77	417	48	24	88	116	47	35	33	26	226.3	1.6	556- 644	1
	Sept.	78	381	62	24	71	90	43	33	32	26	221.0	1.4	487- 559	
	Sept.	79	374	53	8	46	75	58	47	64	23	231.6	1.4	490- 562	
	July	84	602	60	36	105	79	64	78	120	60	231.6	2.3	842- 936	
								MONOGRAPH 4 (14)							
MURGENELLA	Oct.	77	95	1	1	8	33	13	6	18	15	45.9	2.0	135- 173	1
	June	78	173	48	16	4	17	24	23	30	11	44.9	2.8	183- 227	
	Aug.	79	198	47	24	12	22	24	27	26	16	45.6	3.3	223- 273	
	July	84	236	7	17	61	28	21	31	57	14	45.6	5.0	346- 406	
EAST ALLIGATOR	Oct.	77	318	53	18	37	57	41	40	34	38	114.9	2.3	402- 468	1
	June	78	329	39	14	63	51	42	31	51	38	118.9	2.4	442- 510	
	Aug.	79	393	53	30	44	58	28	58	64	58	119.2	2.9	521- 595	
	July	84	411	22	51	72	35	24	47	60	100	119.2	3.3	598- 678	
SOUTH ALLIGATOR	Oct.	77	142			12	24	24	25	31	26	113.8	1.2	209- 257	1
	July	78	157	6	3	4	14	43	24	38	25	113.2	1.3	223- 273	
	Aug.	79	164	4	1	4	12	24	31	51	37	114.0	1.4	237- 287	
	July	84	279	39	15	17	18	25	38	91	36	114.0	2.1	363- 425	
WEST ALLIGATOR	Oct.	77	83	9	2	14	14	15	10	10	9	42.2	1.8	104- 138	1
	July	78	85	23	5	12	9	13	10	6	7	40.4	1.5	86- 118	
	Aug.	79	96	12	9	13	14	7	12	14	15	42.2	2.0	120- 156	
	June	84	120	17	2	33	21	18	6	12	11	42.2	2.4	149- 189	
WILDMAN	Sept.	78	118	53	16	6	8	10	9	7	9	33.5	1.9	91- 123	1
	Aug.	79	155	21	34	15	14	7	17	31	16	33.5	4.0	197- 243	
	June	84	226	26	60	46	20	23	24	13	14	33.5	6.0	300- 356	
ALLIGATOR REG. EXCL. WILDMAN	Oct.	77	638	63	21	71	128	93	81	93	88	316.8	1.8	895- 991	1
	June	78	744	116	38	83	91	122	88	125	81	317.4	2.0	980- 1080	
	Aug.	79	851	116	64	73	106	83	128	155	126	321.0	2.3	1151-1259	
	July	84	1046	85	85	183	102	88	122	220	161	321.0	3.0	1514-1638	

Table 1B. cont.

System	Date		Total	H	2-3	3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels	Type
				Numbers in size class											
ALLIGATOR REG. WITH WILDMAN	June	78	862	169	54	89	99	132	97	132	90	350.9	2.0	1084-1190	1
	Aug.	79	1006	137	98	88	120	90	145	186	142	354.5	2.4	1366-1484	
	July	84	1272	111	145	229	122	111	146	233	175	354.5	3.3	1836-1972	
SALTWATER	Aug.	79	29		1	1	6	4	6	9	2	14.1	2.1	37- 59	3
	July	84	25	6		4	3	3	1	6	2	14.1	1.3	22- 40	
MINIMINI	Aug.	79	11			1	4	3	1	2		43.8	0.3	11- 25	3
	July	84	9					2	3	1	3	43.8	0.2	9	
MIDDLE ARM	Aug.	79	6				3	2	1			28.5	0.2	6	3
	July	84	10			1	1	4	2	1	1	28.5	0.4	10- 22	
IWALG	Aug.	79	10				3	1	2	2	2	53.5	0.2	10- 22	3
	July	84	25			3	3	6	5	5	3	53.5	0.5	31- 51	
MINIMINI COMPLEX	Aug.	79	27			1	10	6	4	4	2	125.8	0.2	34- 54	
	July	84	44			4	4	12	10	7	7	125.8	0.3	59- 85	
ARM A	Aug.	79	5				3		1		1	26.7	0.2	5	3
	July	84	9				1		4	4		26.7	0.3	9	
ARM B	Aug.	79	3				1		1	1		15.0	0.2	3	3
	July	84	4						1	3		15.0	0.3	4	
ARM C	Aug.	79	7				3	1	1		2	29.3	0.2	7	3
	July	84	5				2			2	1	29.3	0.2	5	
ARM D	Aug.	79	9				1		3	2	3	19.8	0.5	9	3
	July	84	7					1	1	3	2	19.8	0.4	7	
ILAMARYI	Aug.	79	16				3	4	3	3	3	44.4	0.4	18- 34	3
	July	84	7				1	1	1	2	2	44.4	0.2	7	
ILAMARYI COMPLEX	Aug.	79	40				11	5	9	6	9	135.2	0.3	53- 79	3
	July	84	32				4	2	7	14	5	135.2	0.2	41- 63	
COBOURG COMP.	Aug.	79	67			1	21	11	13	10	11	261.0	0.3	94- 126	3
	July	84	76			4	8	14	17	21	12	261.0	0.3	107- 143	
COBOURG COMP. & SALTWATER	Aug.	79	96		1	2	27	15	19	19	13	275.1	0.3	137- 177	3
	July	84	101	6		8	11	17	18	27	14	275.1	0.3	136- 176	

Table 1B. cont.

System	Date		Total	H	2-3	3-4	4-5	5-6	6-7	>7	E.O.	Kilometers surveyed	Density	95% levels	Type
						Numbers in size class									
ALLIGATOR REG. +COBOURG COMP. & SALTWATER	Aug.	79	1102	137	99	90	147	105	164	205	155	629.6	1.5	1521-1645	1 & 3
	July	84	1373	117	145	237	133	128	164	260	189	629.6	2.0	1989-2131	
ADELAIDE + ALLIGATOR REG. EXCL. WILDMAN	July & Oct.	77	1055	111	45	159	244	140	116	126	114	543.1	1.7	1486-1610	1
	Sept. & June	78	1125	178	62	154	181	165	121	157	107	538.4	1.8	1491-1615	
	Sept. & Aug.	79	1225	169	72	119	181	141	175	219	149	552.6	1.9	1667-1797	
	July	84	1648	145	121	288	181	152	200	340	221	552.6	2.7	2387-2543	
ADELAIDE + ALLIGATOR REGION INCL. WILDMAN	Sept. & June	78	1243	231	78	160	189	175	130	164	116	571.9	1.8	1596-1724	1
	Sept. & Aug.	79	1380	190	106	134	195	148	192	250	165	586.1	2.0	1883-2021	
	July	84	1874	171	181	334	201	175	224	353	235	586.1	2.9	2710-2876	
ABOVE + COBOURG COMP. & SALTWATER	Sept. & Aug.	79	1476	190	107	136	222	163	211	269	178	861.2	1.5	2037-2181	1 & 3
	July	84	1975	177	181	342	212	192	242	380	249	861.2	2.1	2864-3034	

Table 2A. Blyth-Cadell Rivers System. Table for the Blyth-Cadell Rivers System showing various size class groupings[a].

Survey		Total	H	2-5 ft	≥5 ft	2-6 ft (S)	≥6ft (L)	3-6 ft (M)	S:L	M:L
26 Oct.	74	387	89	286	12	292	6	211	48.7	35.2
1 Nov.	75	353	50	263	40	289	14	183	20.6	13.1
				Major flooding						
23 Sept.	76	348	82	221	45	240	26	177	9.2	6.8
4 Nov.	76	307	61	217	29	230	16	169	14.4	10.6
11 Apr.	77	327	72	230	25	242	13	172	18.6	13.2
3 May	77	333	88	215	30	231	14	171	16.5	12.2
8 June	77	365	108	215	42	232	25	196	9.3	7.8
16 Sept.	77	386	105	234	47	257	24	212	10.7	8.8
23 Oct.	77	360	112	204	44	226	22	158	10.3	7.2
10 June	78	432	173	219	40	238	21	173	11.3	8.2
12 Sept.	78	399	155	200	44	221	23	161	9.6	7.0
				No flooding - driest wet on record						
10 June	79	465	123	251	91	287	55	196	5.2	3.6
4 Oct.	80	400	119	220	61	249	32	160	7.8	5.0
				Heavy flooding						
9 July	81	366	76	223	67	253	37	167	6.8	4.5
19 Oct.	81	315	72	179	64	204	39	127	5.2	3.3
				Dry wet - minor flooding only						
25 June	82	408	136	166	106	205	67	163	3.1	2.4
6 Nov.	82	347	111	164	72	197	39	154	5.1	3.9
				Dry wet - minor flooding only						
15 July	83	465	157	221	87	258	50	160	5.2	3.2
26 Oct.	83	354	73	217	64	246	35	151	7.0	4.3

[a] The 2-3', 3-4' and 4-5 size classes are grouped together (2-5') and the size classes above those in another group (≥5'). We have also grouped the crocodiles sighted into small (2-6'), medium (3-6') and large (≥6'). Also shown are the ratios small/large and medium/large. This Table was obtained by using the data given in Table 1. See caption to Table 3 for division of the EO crocodiles among the various size classes.

Table 2B Liverpool-Tomkinson Rivers System. Equivalent Table for the overall Liverpool-Tomkinson Rivers System[a].

Survey		Total	H	2-5 ft	≥5 ft	2-6 ft (S)	≥6 ft (L)	3-6 ft (M)	S:L	M:L
					Major flooding					
18 July	76	228	19	144	65	169	40	130	4.2	3.3
25 May	77	245	40	129	76	166	39	160	4.3	4.1
27 Oct.	77	228	56	118	54	147	25	140	5.9	5.6
27 Sept.	78	233	37	131	65	156	40	138	3.9	3.5
					No flooding - driest wet on record					
16 July	79	515	289	109	117	152	74	141	2.1	1.9
19 Oct.	79	355	161	101	93	136	58	120	2.3	2.1
15 Oct.	80	295	71	136	88	173	51	122	3.4	2.4
					Heavy flooding					
2 July	81	256	26	145	85	176	54	124	3.3	2.3
5 Oct.	81	254	34	134	86	166	54	133	3.1	2.5
					Dry wet - minor flooding only					
12 June	82	467	193	161	113	207	67	178	3.1	2.7
16 Oct.	82	384	144	135	105	171	69	155	2.5	2.2
					Dry wet - minor flooding only					
1 July	83	432	121	217	94	257	54	174	4.8	3.2
13 Oct.	83	327	63	177	87	219	45	142	4.9	3.2

[a] Note that the 1976 survey shows 68 (EO) crocodiles sighted and 34 of these were taken to be large. This is probably too high a figure for the large animals. An intensive recapture programme was carried out in 1975 thus making many more animals more wary then normal. Most of the animals involved in the recapture programme were small. It is thus likely that the true ratios for 1976 are somewhat higher than those shown.

Table 3A. Summary Table showing for each suvey of the overall Blyth-Cadell Rivers System the number of crocodiles in the size classes indicated[a].

Survey Date		Total	H	≥2 ft	≥3 ft	≥4 ft	≥5 ft	≥6 ft	≥7 ft	Kilometers Surveyed	Density
26 Oct.	74	387	89	298	217	70	12	6	4	91.9	3.24
1 Nov.	75	353	50	303	197	114	40	14	7	94.9	3.19
					Major flooding						
23 Sept.	76	348	82	266	203	95	45	26	15	92.0	2.89
4 Nov.	76	307	61	246	185	79	29	16	6	92.0	2.67
11 Apr.	77	327	72	255	185	75	25	13	9	92.0	2.77
3 May	77	333	88	245	185	88	30	14	7	92.0	2.66
8 June	77	365	108	257	221	115	42	25	11	90.5	2.84
16 Sept.	77	386	105	281	236	99	47	24	15	90.5	3.10
23 Oct.	77	360	112	248	180	94	44	22	10	90.5	2.74
10 June	78	432	173	259	194	110	40	21	11	90.5	2.86
12 Sept.	78	399	155	244	184	103	44	23	12	90.5	2.70
					No flooding - driest wet on record						
10 June	79	465	123	342	251	154	91	55	35	94.5	3.62
4 Oct.	80	400	119	281	192	115	61	32	17	92.9	3.02
					Heavy flooding						
9 July	81	366	76	290	204	115	67	37	20	90.1	3.22
19 Oct.	81	315	72	243	166	101	64	39	18	89.2	2.70
					Dry wet - minor flooding only						
25 June	82	408	136	272	230	163	106	67	37	91.9	2.96
6 Nov.	82	347	111	236	193	123	72	39	19	92.5	2.55
					Dry wet - minor flooding only						
15 July	83	465	157	308	210	142	87	50	24	91.8	3.36
26 Oct.	83	354	73	281	186	113	64	35	19	92.8	3.03

[a] The EO (eye reflection only was seen) classes have been added together in each survey and 50% of these have been distributed equally among the 3-4', 4-5' and 5-6' size classes; the remaining 50% have been distributed to the ≥6 size classes with 1/3 being allocated to the 6-7' size class and 2/3 to size class ≥7. This weights the distribution heavily in favor of large crocodiles, which are known to normally be the most wary. When the EO is an odd number, the bias is also given to the large size classes. For 1974, all EO crocodiles were put in the ≥7 size class.

Table 3B. Equivalent Table for Liverpool-Tomkinson System.

Survey Date		Total	H	≥2 ft	≥3 ft	≥4 ft	≥5 ft	≥6 ft	≥7 ft	Kilometres Surveyed	Density
					Major Flooding						
18 July	76	228	19	209	170	103	65	40	26	152.5	1.37
25 May	77	245	40	205	199	142	76	39	19	145.1	1.41
27 Oct.	77	228	56	172	165	121	54	25	11	123.4	1.39
27 Sept.	78	233	37	196	178	136	65	40	20	141.4	1.39
					No flooding - driest wet on record						
16 July	79	515	289	226	215	168	117	74	37	150.0	1.51
19 Oct.	79	355	161	194	178	136	93	58	35	141.1	1.38
15 Oct.	80	295	71	224	173	128	88	51	31	140.6	1.59
					Heavy flooding						
2 July	81	256	26	230	178	122	85	54	31	140.6	1.64
5 Oct.	81	254	34	220	187	129	86	54	32	141.1	1.56
					Dry wet - minor flooding only						
12 June	82	467	193	274	245	172	113	67	35	141.1	1.94
16 Oct.	82	384	144	240	224	166	105	69	38	141.1	1.70
					Dry wet - minor flooding only						
1 July	83	432	121	311	228	157	94	54	30	141.1	2.20
13 Oct.	83	327	63	264	187	133	87	45	29	141.1	1.87

Table 4. Sightings on the three major components of the Blyth-Cadell Rivers System[a].

Survey Date	Blyth Mainstream				Blyth Sidecreeks				Cadell				Totals			
	H	S	M	L	H	S	M	L	H	S	M	L	H	S	M	L
26 Oct. 74	41	207	151	6	1	3	3	0	47	82	57	0	89	292	211	6
1 Nov. 75	41	177	120	11	3	11	7	2	6	101	56	1	50	289	183	14
							Major flooding									
23 Sept. 76	48	159	108	14	2	16	14	5	32	65	55	7	82	240	177	26
4 Nov. 76	40	142	108	10	3	16	13	1	18	72	48	5	61	230	169	16
11 Apr. 77	65	142	104	6	3	17	14	3	4	83	54	4	72	242	172	13
3 May 77	74	144	111	10	0	15	15	3	14	72	45	1	88	231	171	14
8 June 77	88	129	107	19	2	23	20	4	18	80	69	2	108	232	196	25
16 Sépt. 77	75	164	139	19	2	18	15	2	28	75	58	3	105	257	212	24
23 Oct. 77	76	136	94	14	3	15	11	2	33	75	53	6	112	226	158	22
10 June 78	136	148	99	14	1	21	18	4	36	69	56	3	173	238	173	21
4 Oct. 80	86	171	106	40	1	15	14	9	37	101	76	6	123	287	196	55
							Heavy flooding									
9 July 81	48	144	97	27	2	25	22	3	26	84	48	7	76	253	167	37
19 Oct. 81	37	127	75	28	3	13	12	2	32	64	40	9	72	204	127	39
							Dry wet - minor flooding only									
25 June 82	84	118	94	41	1	14	13	6	51	73	56	20[b]	136	205	163	67[b]
6 Nov. 82	55	116	93	26[b]	0	9	9	3	56	71	51	11[b]	111	197	154	39
							Dry wet - minor flooding									
15 July 83	146	127	84	35[b]	2	10	10	2	9	121	66	13	157	258	160	50[b]
26 Oct. 83	70	140	84	23	0	10	10	2[b]	3	96	57	10	73	246	151	35[b]

[a] The table shows the number of *C. porosus* sighted within the hatchling, small 2-6', medium 3-6' and large $\geq$6 size classes on the three major components of the Blyth-Cadell Rivers System: Blyth mainstream, Blyth sidecreeks and Cadell River; 49.8, 12.5 and 29.7 km respectively.

[b] Bias to large.

Table 5. Sightings on the three major components of the Liverpool-Tomkinson Rivers System[a]

Survey Date		Liverpool Mainstream H	S	M	L	Liverpool Sidecreeks H	S	M	L	Tomkinson H	S	M	L	Totals H	S	M	L
									Major flooding								
18 July	76	11	64	51	14	4	27	22	7[b]	4	77	56	20[b]	19	169	130	40
25 May	77	13	67	64	12	4	28	27	7[b]	23	71	69	20	40	166	160	39[b]
27 Oct.	77	23	77	73	13[b]	5	20	20	4*	28	49	46	9	56	147	140	25
27 Sept.	78	13	69	63	21	7	20	17	5	17	67	58	14[b]	37	156	138	40[b]
									No flooding - driest wet on record								
16 July	79	24	63	59	29	5	24	20	21	260	65	62	24	289	152	141	74
19 Oct.	79	17	63	51	32	2	21	20	5	142	52	49	21	161	136	120	58
15 Oct.	80	28	61	51	25	17	25	23	7[b]	26	87	48	19	71	173	122	51[b]
									Heavy flooding								
2 July	81	8	75	47	23	1	23	18	8[b]	17	77	58	24[b]	26	176	124	54
5 Oct.	81	2	74	54	19	2	26	22	9[b]	30	65	57	27[b]	34	166	133	54
									Dry wet - minor flooding only								
12 June	82	7	66	59	30	8	36	34	10	178	105	85	27	193	207	178	67
16 Oct.	82	6	82	78	27[b]	3	32	28	18	135	56	48	25[b]	144	171	155	69
									Dry wet - minor flooding								
1 July	83	27	74	67	20	3	37	35	11[b]	91	145	71	24[b]	121	257	174	54
13 Oct.	83	21	70	64	19	2	28	25	9	40	121	53	17[b]	63	219	142	45[b]

[a] Number of *C. porosus* sighted within the hatchling, small 2-6', medium 3-6' and large ≥6 size classes on the three major components of the Liverpool-Tomkinson Rivers System: Liverpool mainstream, Liverpool sidecreeks and Tomkinson (normally 57.0, 27.4 and 56.7 km respectively, but distances can vary from year to year - see page 16, Monograph 7).
Note specially that during the 1977 and 1978 Tomkinson surveys, the river was surveyed to km 70 only and that a number of small and large crocodiles were thus not counted. Probably not more than 3 or 4 of each were thus omitted. Normally the Tomkinson is surveyed to km 73.7. Also see Table 8.

[b] Bias to large.

Table 6. Sighting on the waterways of Junction and Rolling Bays[a]

Survey Date	Goomadeer H	S	L	Wurugoij H	S	L	Majarie H	S	L	Nungbulgarri H	S	L	Totals H	S	M	L	S/L	M/L
Aug. 75	–	44	2	–	4	–	1	7	4	--	23[b]	6	1	78[b]	46	12	6.5	3.8
Major flooding																		
July-Sept. 76	18	23	11	–	–	1	–	5	2	2	1-	3	2-	38	33	17	2.2	1.9
June 77	2	41	7	No survey	No survey	2	10	2	4	51	40	9	5.7[c]	4.4[c]				
No flooding - driest wet on record																		
July 79	29	49	12	–	2	7	–	13	5	10	16	9	39	80	66	33	2.4	2.0
Heavy flooding																		
June 81	6	30(7)[d]	7	–	3	3	–	11	8	2	21	4	8	65(7)[d]	56(4)[d]	22	3.0	2.5
Oct. 81	17	25	3	–	7	1	--	12	5	–	22	3	17	66	60	12	5.5	5.0
Dry wet - minor flooding only																		
June 82	18	29	14	–	3	4	2	8	7	–	19	4	20	59	51	29	2.0	1.8
Oct. 82	9	35	10	1	4	3	–	9	3	–	21	8	10	69	61	24	2.9	2.5
Dry wet - minor flooding only																		
June 83	24	27	12	--	4	2	4	15	5	34	19	2	62	65	57	21	3.1	2.7
Oct. 83	33	29	11	–	7	4	--	13	6	15	18	5	48	67	57	26	2.6	2.2

[a] The table shows the number of *C. porosus* sighted within the hatchling (H), small (S) and large (L) size classes on the tidal waterways of Junction and Rolling Bays, which are within the Maningrida monitoring area. Also shown is the number of medium crocodiles and the ratios of small to large and medium to large for the overall systems.

[b] This relatively high number may have resulted from animals leaving the Liverpool System after our intensive catching effort on it during the period of 1973-1975. See page 75, Monograph 7.

[c] Wurugoij and Marjarie Creeks were not surveyed resulting in the omission of a few small and large animals. Hence the value of S/L and M/L are probably slightly TOO HIGH.

[d] Numbers in brackets give number of crocodiles removed by Biology researchers before survey.

Table 7. Sightings within the Maningrida monitoring area[a].

Survey Date	Blyth-Cadell System H	S	M	L	Liverpool-Tomkinson System H	S	M	L	Rolling & Junction Bays H	S	M	L	H	S	M	L	>3'	S/L	M/L
Aug./Nov. 75	50	289	183	14	Data unusable		1	78	46	12									
									Major flooding										
July/Sept. 76	82	240	177	26	19	169	130	40[c]	20	38	33	17	121	447	340	83	423	5.4	4.1
May/June 77	108	232	196	25	40	166	160	39	4	51[d]	40[d]	9[d]	152	449d	396[d]	73[d]	369[d]	6.2[d]	5.4[d]
October 77	112	226	158	22	56	147	140	25	No surveys				168	373	298	47	345	7.9	6.3[e]
September 78	155	221	161	23	37	156	138	40	No surveys				192	377	299	63	362	6.0	4.7[e]
									No flooding - driest wet on record										
June/July 79	123	287	196	55	289	152	141	74	39	80	66	33	451	519	403	162	565	3.2	2.5
October 80	119	249	160	32	71	173	122	51	No surveys				190	422	282	83	365	5.1	3.4[e]
									Heavy flooding										
June/July 81	76	253	167	37	26	176	124	54	8	67(7)[b]	56(4)[b]	22	110	494(7)[b]	347(4)[b]	113	460	4.4	3.1
October 81	72	204	127	39	34	166	132	54	17	66	60	12	123	436	320	105	425	4.2	3.0
									Dry wet - minor flooding										
June/July 82	136	205	163	67	193	207	178	67	20	59	51	29	349	471	392	163	555	2.9	2.4
Oct./Nov. 82	111	197	154	39	144	171	155	69	10	61	24		265	437	370	132	502	3.3	2.8
									Dry wet - minor flooding										
June/July 83	157	258	160	50	121	257	174	54	62	65	57	21	340	580	391	125	516	4.6	3.1
October 83	73	246	151	35	63	219	142	45	48	67	57	26	184	532	350	106	456	5.0	3.3

[a] The table shows the number of *C. porosus* sighted within the hatchling, small (2-6'), medium (3-6') and large (>6) size classes on the major component tidal systems within the Maningrida monitoring area. Also shown is the ratio of small to large and madium to large crocodiles and the total number of medium plus large animals (that is animals >3).

[b] Numbers in brackets give numbers of crocodiles removed by Biology researchers before survey.

[c] See caption to Table 2B for the Liverpool-Tomkinson.

[d] See Table 6, footnote c.

[e] Because the four waterways of Rolling and Junction Bays were not surveyed in October 1977, September 1978 and October 1980 the totals for those surveys are TOO LOW. Inspection of the results for immediately preceding and succeeding surveys indicates that the totals for the three missing cases are too low by a MAXIMUM of 40(H), 80(S), 66(M), 33(L) and 99(>3'). The ratios shown for these surveys are thus probably TOO HIGH.

Table 8. Sightings on alternative habitats[a].

	Kilometers Surveyed		Oct.-Nov 1981		July-July 1982		Oct.-Nov. 1982		June-July 1983		October 1983					
			H	S	L	H	S	L	H	S	L	H	S	L	H	S	L
Liverpool River	6.4	No survey			No survey			--	5	3	--	5	1	--	1	4	
Maragulidban Ck.	4.9	No survey			--	--	1	--	1	1	--	1	--	--	--	1	
Tomkinson River km 73.7 - 81.3	7.6	-- July 1976 to km 80.1	11	9	--	18	14	--	11	13	2	18_1	9	--	8	9	
Tom's Creek	8.9	1 July 1979	--	2	No survey		1	2	--	--	5	1	--	2_1	2		
Crab Creek	3.0	--	--	2	No survey		--	--	1	--	--	2	--	1	1		
Anamayirra Creek	7.3	No survey		--	9	7	--	11	5	--	10	6	--	5	3		
Beach Creek	2.2	No survey		--	3	3	--	3	--	--	6	1	--	2	--		
Blyth R. + Billabong km 49.8 - 64.6		13.2	1	2_2	3	1	1	3	5	7_2	7	1	4_2	1	--	8_4	4
Cadell Gardens Billabong	2.0	-- Oct. 1980	1	3	No survey		--	2	1	--	2	1	--	2	1		
Cadell Big	4.0	No survey		--	2	3	No survey			--	--	3	--	--	3		

[a] The table shows the number of *C. porosus* sighted within the hatchling, small and large size classes on the amin alternative habitats of the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems, such as various fresh and saltwater complexes and the exterme upstream sections of the Systems.

The results for these 59.3 km of waterways are not included in Tables 1 to 7. The first seven habitats listed appear to provide alternative habitat largely for animals from the Liverpool-Tomkinson and Rolling and Junction Bay Systems. Subscripts show the number of 2-3' animals included.

Table 9. Sightings on waterways of Van Dieman Gulf[a].

Survey		Totals	Hatchlings	(2-3')	(3-6')	Large (≥6)	3-6' / Large
ADELAIDE							
July	77	417	48	24	264	81	3.26
Sept.	78	381	62	24	217	78	2.78
Sept.	79	374	53	8	190	123	1.54
July	84	602	60	36	278	228	1.22
MURGENELLA							
Oct.	77	95	1	1	61	32	1.91
June	78	173	48	16	50	59	0.85
Aug.	79	198	47	24	66	61	1.08
July	84	236	7	17	117	95	1.23
EAST ALLIGATOR							
Oct.	77	318	53	18	154	93	1.66
June	78	329	39	14	175	101	1.73
Aug.	79	393	53	30	159	151	1.05
July	84	411	22	51	181	157	1.15
SOUTH ALLIGATOR							
Oct.	77	142	--	--	73	69	1.06
June	78	157	6	3	73	75	0.97
Aug.	79	164	4	1	58	101	0.57
July	84	279	39	15	78	147	0.53
WEST ALLIGATOR							
Oct.	77	83	9	2	47	25	1.88
June	78	85	23	5	37	20	1.85
Aug.	79	96	12	9	41	34	1.21
June	84	120	17	2	77	24	3.21
WILDMAN							
Sept.	78	118	53	16	28	21	1.33
Aug.	79	155	21	34	44	56	0.79
June	84	226	26	60	96	44	2.18
ALLIGATOR REGION EXCL. WILDMAN							
Oct.	77	638	63	21	336	218	1.54
June	78	744	116	38	336	254	1.32
Aug.	79	851	116	64	325	346	0.94
July	84	1046	85	85	453	423	1.07
ALLIGATOR REGION WITH WILDMAN							
June	78	862	169	54	365	274	1.33
Aug.	79	1006	137	98	369	402	0.92
July	84	1272	111	145	549	467	1.18

Table 9. continued.

Survey		Totals	Hatchlings	(2-3')	(3-6')	Large (≥6)	3-6' / Large
SALWATER							
Aug.	79	29	--	1	12	16	0.75
July	84	25	6	--	11	8	1.38
MINIMINI							
Aug.	79	11	--	--	8	3	2.67
July	84	9	--	--	6	3	2.00
MIDDLE ARM							
Aug.	79	6	--	--	5	1	5.00
July	84	10	--	--	6	4	1.50
IWALG							
Aug.	79	10	--	--	5	5	1.00
July	84	25	--	--	13	12	1.08
MINIMINI COMPLEX							
Aug.	79	27	--	--	18	9	2.00
July	84	44	--	--	23	21	1.10
ARM A							
Aug.	79	5	--	--	3	2	1.50
July	84	9	--	--	1	8	0.13
ARM B							
Aug.	79	3	--	--	1	2	0.50
July	84	4	--	--	--	4	0.00
ARM C							
Aug.	79	7	--	--	5	2	2.50
July	84	5	--	--	2	3	0.67
ARM D							
Aug.	79	9	--	--	2	7	0.29
July	84	7	--	--	2	5	0.40
ILAMARYI							
Aug.	79	16	--	--	8	8	1.00
July	84	7	--	--	3	4	0.75
ILAMARYI COMPLEX							
Aug.	79	40	--	--	20	20	1.00
July	84	32	--	--	8	24	0.33
COBOURG COMPLEX							
Aug.	79	67	--	--	38	29	1.31
July	84	76	--	--	31	45	0.69

Table 9. continued.

Survey		Totals	Hatchlings	(2-3')	(3-6')	Large (≥6)	3-6' / Large
COBOURG COMPLEX & SALTWATER							
Aug.	79	96	--	1	50	45	1.11
July	84	101	6	--	43	52	0.83
ALLIGATOR REGION + COBOURG COMPLEX & SALTWATER							
Aug.	79	1102	137	99	419	447	0.94
July	84	1373	117	145	592	519	1.14
ADELAIDE + ALLIGATOR REGION EXCL. WILDMAN							
July & Oct.	77	1055	111	45	600	299	2.01
Sept. & June	78	1125	178	62	553	332	1.67
Sept. & Aug.	79	1225	169	72	515	469	1.10
July	84	1648	145	121	731	651	1.12
ADELAIDE + ALLIGATOR REGION WITH WILDMAN							
Sept. & June	78	1243	231	78	582	352	1.65
Sept. & Aug.	79	1380	190	106	559	525	1.06
July	84	1874	171	181	827	695	1.19
ABOVE + COBOURG COMPLEX & SALTWATER							
Sept. & Aug.	79	1476	190	107	610	569	1.07
July	84	1975	177	181	870	747	1.16

[a] This Table was prepared using the results given in Table 1B and groups the crocodiles sighted into the important size classes shown.

Table 10. Sightings in 1979 and 1983 for combined systems[a].

Survey	Total	H	Size Class Numbers 2-3	3-4	4-5	5-6	6-7	>7	km EO	Surveyed	95%	Density Levels	TYPE
June & July 1979	1253	487	125	156	139	100	69	66	111	414.9	1.8	1201-1312	1 & 3
July & July 1988	1199	345	198	180	145	92	49	40	150	411.5	2.1	1342-1459	

Survey	Totals	H	2-3	Large 3-6	3-6 / ≥6	Large
June & July 1979	1253	487	125	450	191	2.36
June & July 1983	1199	345	198	492	164	3.00

[a] The table shows combined results for the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems, Goomadeer and Glyde Rivers, and Nungbulgarri, Majarie, Wurugoij and ngandadauda Creeks (obtained usir Table 1A). The results are given first in the form of Table 1 and then in the form of Table 9 to facilitate comparisons. Note that the 1983 survey was made after the 'dry wet' of 1982-1983 and hence animals wei again concentrated into the tidal waterways, but not to the same degree as in 1979 when surveys were carried out after the 'driest wet' on record.

ones. In the case of the 1984 June-July surveys of the tidal waterways in the Alligator Region, results can be most meaningfully compared with those for the June-July 1978 and August 1979 surveys rather than the October 1977 one. However, even in the case of the 1979 results, considerable caution must be used, for the 1978-1979 wet season was the driest on record and many of the animals that would have normally been in the associated freshwater complexes at the time of the survey were forced back into the tidal waterways (see Messel et al. 1979-1984:1, 4, 14, and specially 18 where this matter is discussed in detail). In the case of Murgenella Creek, the concentration appears to have taken place in 1978 (Messel et al. 1979-1984, 4:18 and 14:76).

A MODEL FOR THE DYNAMICS OF *C. porosus* POPULATIONS

As stated previously, the model which we have built up and have been refining (specially see Messel et al. 1979-1984[1 and 18]) as more data are obtained not only enables us to account in a consistent fashion for the vast store of field observations and results we have accumulated for some 100 tidal waterways in northern Australia, but also enables us to predict successfully results to be expected on future individual surveys. The model runs as follows:

1. The tidal waterways of northern Australia have been classified according to their salinity signatures into TYPE 1, TYPE 2, and TYPE 3 systems shown in Fig. 7 (see our chapter on ecology of *C. porosus* for more detail on this). TYPE 1 systems are the main breeding ones and non-TYPE 1 systems are usually poor or non-breeding systems. It is the TYPE 1 systems and the freshwater billabongs and semipermanent and permanent freshwater swamps associated with them which account for the major recruitment of *C. porosus*; the other systems contribute to a lesser degree and they must depend largely upon TYPE 1 systems and their associated freshwater complexes for the provision of their crocodiles. Non-TYPE 1 systems also sometimes have freshwater complexes associated with them but these are normally quite minor.

2. As indicated in Fig. 7, our results show that in TYPE 1 systems some 27% of the crocodiles sighted are hatchlings (of which some 50% are normally lost between June of one year and June of the next, Messel et al. 1979-1986, 1:394), whereas in TYPE 2-3 systems this figure falls to 14% and in TYPE 3 systems down to 4%, showing a much decreased hatchling recruitment in non-TYPE 1 systems. In TYPE 3 systems the percentage of crocodiles in the hatchling, 2-3', and 3-4' size classes combined is some 11% whereas in TYPE 1 systems it is at least 52%. On the other hand the percentage of crocodiles in the ≥4-5' size classes is some 39% in TYPE 1 systems and 73% on TYPE 3 systems. Some 79% of the non-hatchling crocodiles are sighted on TYPE 1 waterways and 21% on non-TYPE 1 waterways (Messel et al. 1979-1986, 1:419).

3. The relatively few large, and more frequent small freshwater billabongs and semipermanent and permanent freshwater swamps associated with tidal waterways are known to contain *C. porosus* but have not been inventoried systematically, except in a few cases. The accurate extent of their non-hatchling *C. porosus* populations is unknown. Based upon the fact that the number of large freshwater swamp areas, with substantial perennial water (normally bordering old river channels), in northern Australia is very limited--perhaps 400 km^2 maximum--and upon limited observations, we estimated that in 1979 the non-hatchling *C. porosus* population was less than 20% of the non-hatchling population sighted in tidal systems. We now believe that the 20% figure was an overestimate for 1979--an unusual year associated with one of the "driest wet" seasons on record.

4. It appears that the populating of non-TYPE 1 systems (hypersaline or partially hypersaline coastal and non-coastal waterways) results mostly from the exclusion of a large fraction of the sub-adult crocodiles from TYPE 1 systems and any freshwater complexes associated with them. Adult

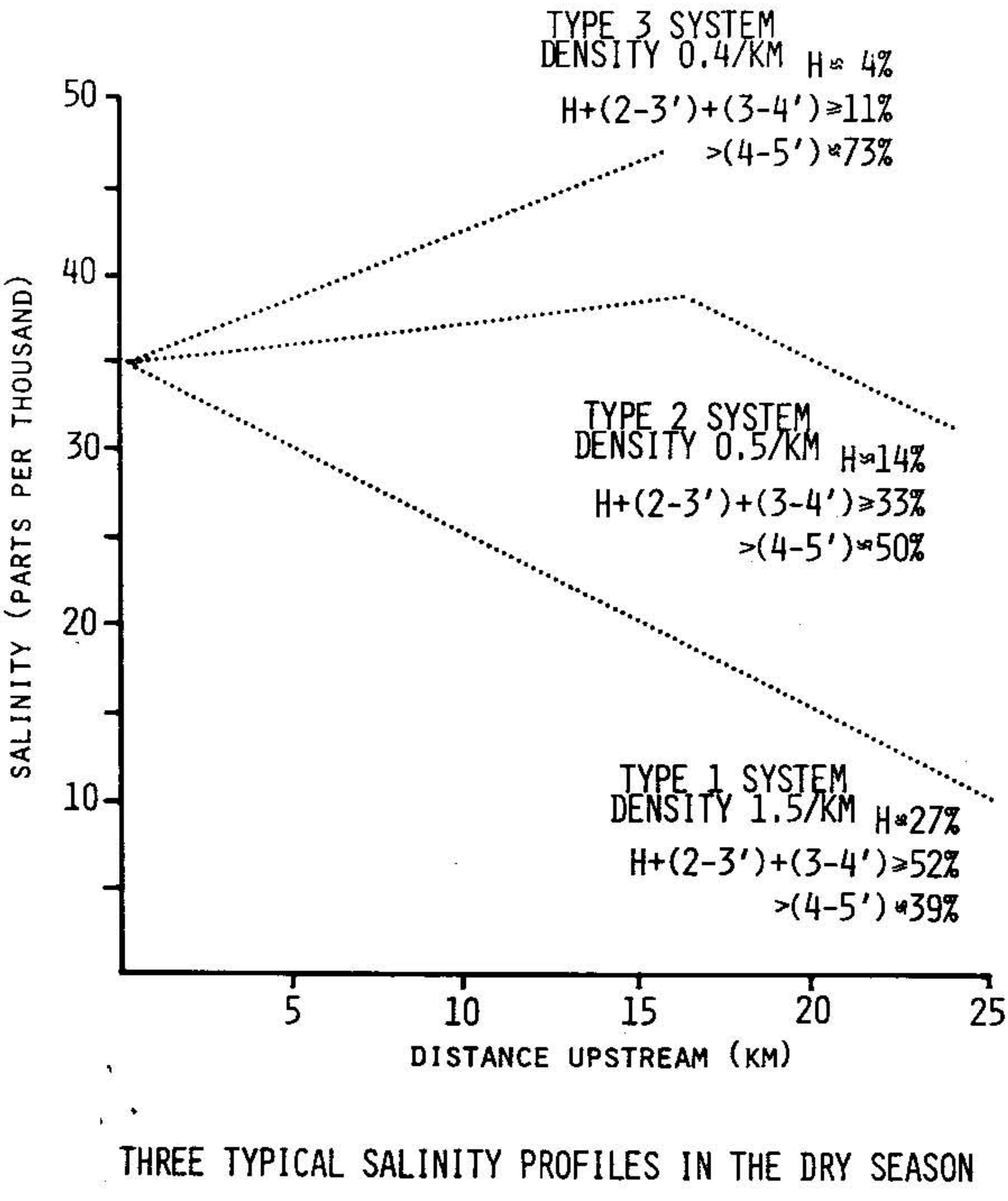

Figure 7. Typical dry season salinity profiles for the three types of tidal river systems occurring in the model's classification scheme. In a TYPE 1 system the salinity decreases steadily as one progresses upstream from that of seawater measured at the mouth of the waterway (=35o/oo). In contrast, the salinity in a TYPE 3 system increases steadily as one progresses upstream. TYPE 2 systems fall somewhere between TYPE 1 and TYPE 3 systems and tend to show hypersaline tendencies as the dry season progresses. As shown above, the non-hatchling density and size structure of the crocodiles sighted in the three kinds of systems differ strikingly.

crocodiles appear generally to tolerate hatchlings, 2-3', and sometimes even 3-4' sized crocodiles in their vicinity (but not always--they sometimes eat them, Messel et al. 1979-1986, 14:43, or kill them, [1]:334), but not larger crocodiles. Thus once a crocodile reaches the 3-4' and 4-5' size classes, it is likely to be challenged increasingly not only by crocodiles near or in its own size class (Messel et al. 1979-1986, 1:454-458) but by crocodiles in the larger size classes and to be excluded from the area it was able to occupy when it was smaller. A very dynamic situation prevails with both adults and sub-adults being forced to move between various components of a system and between systems. Crocodile interactions or aggressiveness between crocodiles in all size classes increases around October--during the breeding season (Messel et al. 1979-1986, 1:445 and 18:109) and exclusions, if any, normally occur around this period. A substantial fraction (~80%) of the sub-adults, mostly in the 3-6' size classes but also including immature larger crocodiles, are eventually excluded from the river proper or are predated upon by larger crocodiles.

5. Of those crocodiles that have been excluded, some may take refuge in freshwater swamp areas and billabongs associated with the waterway from which they were excluded or in the waterways' non-TYPE 1 creeks if it has any. Others may travel along the coast until by chance they find a non-TYPE 1 or another TYPE 1 waterway, however in this latter case they may again be excluded from it; others may go out to sea and possibly perish, perhaps because of lack of food, as they are largely shallow water on edge feeders, or they may be taken by sharks. Those finding non-TYPE 1 systems, or associated freshwater complexes frequent these areas, which act as rearing stockyards, for varying periods, until they reach sexual maturity, at which time they endeavor to return to a TYPE 1 breeding system. Since a large fraction of the crocodiles sighted in non-TYPE 1 systems must be derived from TYPE 1 systems and their associated freshwater complexes, they are, as seen in (2) above, predominantly sub-adults in the ≥3' size classes or just mature adults (Messel et al. 1979-1986, 1:431). Both sub-adults and just mature adults might attempt to return and be forced out of the system many times before finally being successful in establishing a territory in a TYPE 1 system or in its associated freshwater complex. Crocodiles may have a homing instinct (this important point requires further study) and even though a fraction of crocodiles may finally return to and remain in a TYPE 1 system or in its associated freshwater complex, the overall sub-adult numbers missing-- presumed dead--remain high and appear to be at least 60-70%.

6. Normally, the freshwater complexes (swamps and/or billabongs) associated with tidal systems, are found at the terminal sections of small and large creeks running into the main waterway, or at the terminal sections of the mainstream(s). Though this alternative habitat is usually very limited in extent, sporadic (and sometimes extensive yearly) nesting does take place on it. There are, however, several fairly extensive freshwater complexes associated with TYPE 1 tidal systems and these are important as they may act both as rearing stockyards and as breeding systems, just as the TYPE 1 waterway does itself. Examples of these are the Glyde River with the Arafura Swamp (Messel et al. 1979-1986, 9), the Alligator Region Rivers with their wetlands (Messel et al. 1979-1986, 4, 14), and the Daly, Finniss, Reynolds, and Moyle rivers with their wetlands (Messel et al. 1979-1986, 2). Not only can the loss factor, which appears to occur during the exclusion stage, be expected to be lower for movements into and out of swamp areas associated with a TYPE 1 waterway than for movement into and out of coastal non-TYPE 1 systems, but the loss of nests due to flooding can also be expected to be less. We have observed nests made of floating grass cane mats in the Daly River Aboriginal Reserve area. Thus recovery of the *C. porosus* population on TYPE 1 tidal waterways, with substantial associated freshwater complexes, can be expected to be faster than on other systems (Messel et al. 1979-1986, 1:445, 14:98 and also see important results for the 1984 resurvey of Alligator Region and Adelaide River systems appearing in 19 and discussed here later).

7. Because of the ~80% exclusion and at least 60-70% losses of sub-adult crocodiles as they proceed toward sexual maturity, there appears to have been no significant sustained increase in the

non-hatchling *C. porosus* population on the some 500 km of tidal waterways monitored in the Maningrida area of northern Australia since the commencement of our systematic surveys in 1974, a period of ten years (Messel et al. 1979-1986, 18). With the exception of the Glyde River, these waterways have only minor freshwater complexes associated with them.

8. Though there appears to have been no sustained significant increase in the number of non-hatchling crocodiles sighted on the tidal waterways of the Maningrida area since our surveys started in 1974, the size structure of the animals sighted appears to have been changing slowly. Notwithstanding substantial fluctuations, the ratios of small (2-6') to large (≥6'), and 3-6' to large animals was decreasing on the Blyth-Cadell, may have been decreasing on the Liverpool-Tomkinson and was decreasing overall on the tidal waterways of the Maningrida monitoring area. Thus there was some indication of the commencement of a slow recovery phase.

9. For the 861 km of tidal waterways of the Alligator Region, with their substantial freshwater complexes, and the Adelaide River System, there was strong evidence, as of July 1984, that an important and sustained recovery was underway (as predicted in 6 above).

10. Though there are wide fluctuations, specially after "dry wet" seasons when the animals are concentrated into the tidal waterways, it appears that as the number of large crocodiles in a tidal waterway increases, there is a tendency for the number of sub-adults in the 3-6' size classes to decrease or only increase marginally. Thus the total number of 3-6' and large animals sighted appears generally to be holding steady or only increasing slowly. This density dependent behavior has an important bearing on the rate of population growth and on the size structure of the population.

11. When a steady state is reached in a "recovered" population, the ratio of 3-6' to large animals might be considerably less than one.

12. An important and remarkable fact becomes evident if one excludes the 3-4' size class and focuses on the 4-5' and 5-6' size classes only. Regardless of how large the recruitment may be, the number of animals sighted in the 4- 5' and 5-6' size classes seems to remain essentially constant or only increases slowly. Thus a major bottleneck occurs for these size classes. It is as if there are a definite number of slots for these animals on a given river system and that the number of these slots only increases slowly--if at all (note specially the results for the Blyth-Cadell and Liverpool-Tomkinson waterways in Messel et al. 1979-1986, 1, 18 and the 1984 results for the Alligator Region and Adelaide River systems appearing in 19). The crocodiles themselves appear to be primarily responsible for the very heavy losses of ≈70 percent that occur in the process of trying to secure these slots or to increase them in number.

13. If one considers a group of 100 of the sub-adult crocodiles in a TYPE 1 tidal system without a substantial freshwater complex associated with it, one can expect some 80 to be excluded from it, at least 60-70 to end up missing--presumed dead--fewer than 15-20 to successfully establish territories on the system without having to leave it, and the remainder might eventually also return and establish a territory, specially after becoming sexually mature. The very nature of this matter is such as to preclude precise figures and they must be looked upon as broad estimates only, however detailed study of our results (Messel et al. 1979-1986, 18) now indicates that the missing--presumed dead figure is likely to be in excess of 70. For systems with substantial freshwater complexes associated with them, this figure is likely to be considerably less.

14. When there is an exclusion of sub-adult animals, mostly 3-6' in size but also including immature larger animals, this takes place mainly in the breeding season, normally commencing around September-October and apparently lasting throughout the wet season. Any influx of

animals, in the 3-6' and/or large size classes, appears to occur mainly in the early dry season and to be completed in the June-early September period, but in some years may be earlier.

15. After a single "dry wet" season there is a substantial influx of large and sometimes 3-6' animals, forced out of freshwater complexes, into the tidal waterways and these are sighted during June-July surveys. Surveys made in October-November of the same year, usually reveal a substantial decrease in the number of 3-6' and/or large animals sighted; however, the number of large animals sighted sometimes remains higher than previously seen and hence a number of the new large animals do not return from whence they came. These animals appear successful in establishing a territory on the waterway, and it could be the waterway from which they had originally been excluded. The "dry wet" variation in the number of animals sighted appears to be superimposed upon the variations normally found during surveys following usual wet seasons--which generally result in extensive flooding on the upstream sections of the tidal waterways. Hatchling recruitment on the tidal waterways is generally greatly enhanced during "dry wet" seasons but appears to be greatly reduced in major swamp habitat. The reverse appears to be true during normal or heavy wet seasons.

DISCUSSION

The Monitored Area

The results of our surveys in our monitored area centered on Maningrida have been essentially summarized in points 9 to 15 of our model and are discussed in detail in Messel et al. (1979-1986, 18).

In Fig. 8 we have plotted, using Table 8, the number of 3-6', large and their sum, 3-6' plus large, or ≥3' animals sighted on surveys over the past 8 years of the Liverpool-Tomkinson, Blyth-Cadell, and the 4 waterways of Rolling and Junction Bays. The waterways of Rolling and Junction Bays would not be surveyed every time the Blyth-Cadell and Liverpool-Tomkinson were, thus resulting in a number of incomplete totals. These cases are referred to in the caption of Table 7, and certain corrections are suggested. The number of large crocodiles sighted on the overall Systems during the surveys of 1976 was 83 and the number of 3-6' animals was 340. The number of both 3-6' and large crocodiles sighted then essentially held steady or even declined slightly until June-July 1979 when there was a dramatic jump following the "driest wet" on record of 1978- 1979. In Messel et al. (1979-1986, 18) we discuss in detail where these additional animals may have come from and show that the results are explicable on the basis of their being forced out of the Arafura Swamp which was being used both as a breeding system and a rearing stockyard. By the time of the June-July 1981 surveys the number of 3-6' animals sighted was back to almost the same figure as in 1976 (347 versus 340), whereas the number of large crocodiles remained at a higher level, 113 versus 83. Obviously a number of the returning large animals were being successful in establishing a territory for themselves, probably in the very waterways from which they had been excluded, but many of their less successful rivals were)joining the ranks of the missing--presumed dead in the process. Then came the two "dry wets" of 1981-1982 and 1982-1983. Again there was an influx, this time of 72 3-6' and 58 large animals: 392 3-6' and 163 large animals (amazingly the number for 1979 had been 162) were sighted. Again a substantial fraction of the increase, specially for large animals could only have been derived from animals excluded from the Arafura Swamp. In June of both 1979 and 1982, concentrations of large animals were sighted at the mouth of the Blyth River, showing that they were entering and leaving the System through the mouth. By the time or the June-July 1983 surveys the number of large animals sighted had dropped to 125

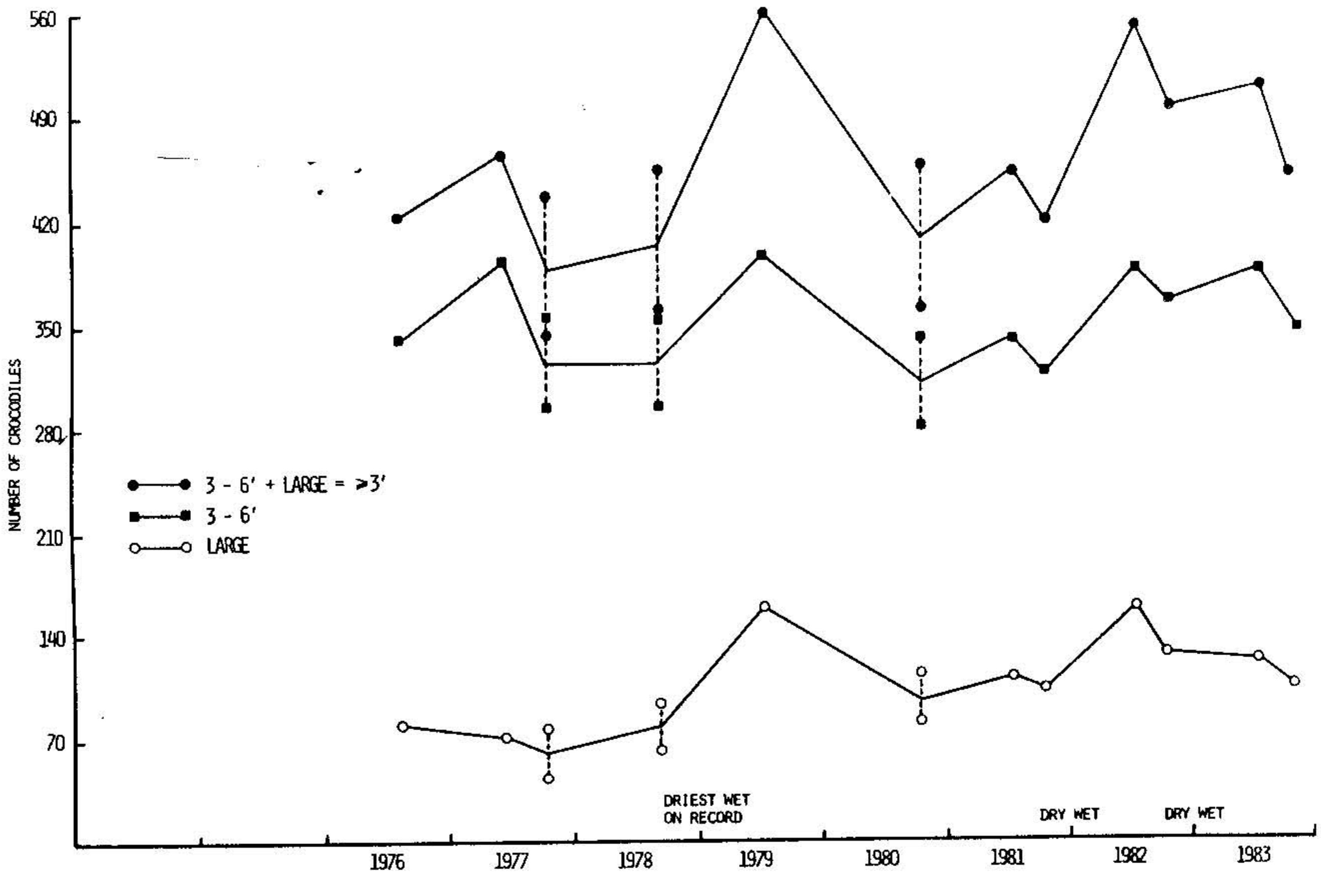

Figure 8. A plot of the number of 3-6', large (≥6)' and their sum, 3-6' plus large or ≥3' animals for surveys carried out on the Liverpool-Tomkinson. Blyth-Cadell and Rolling and Junction Bays Rivers Systems during the eight years 1976 to 1983. For those years in which the waterways of Rolling and Junction Bays were not surveyed, we have plotted the numbers shown in Table 7 and the maximum figures also, but have drawn the line through the average value only.

whereas the number of (3-6') animals remained almost constant (392 versus 391). Then came the expected drop in numbers for the October 1983 survey when 350 3-6' and 106 large animals were spotted.

Obviously only a relatively small number of additional 3-6' animals may have been successful in establishing a territory for themselves during the 8 year period: it is as if there were a fairly definite number of slots or territories on the waterways for the 3-6' animals and the number and size of those slots can vary depending upon a complex set of factors of which food supply is one. Of course the 3-6' animals utilizing these in 1983 were not the same animals which filled those slots in 1976. Superimposed upon this is the increasingly aggressive behavior of the animals as the October-November period approaches and the more aggressive behavior of the large animals towards the 3- 6' ones during the breeding season.

The picture in the Maningrida area for the large animals is along the same lines. Comparing the surveys of July-September 1976 with those of June-July 1983 indicates that an additional (125 versus 83) 42 large animals had or were well on the way to establishing a territory for themselves. Study of Tables 4, 5, and 6 reveals that, as expected, those territories were in the TYPE 1 waterways. On the other hand, since only 106 large animals were sighted during the October 1983 survey, it is apparent that a number of large animals which held a territory in the July 1983 period could not do so once the breeding season commenced. Again one must realize that one is viewing a highly dynamic situation: a large animal may be successful in holding a territory for only a limited period. Even the largest animals may eventually be deposed by younger and more aggressive ones. This continual battle for the eventual right to breed is documented for many species. The losses involved during this process in the case of *C. porosus* are startlingly high, and this includes the large size classes.

A broad estimate for the minimum percentage of 3-6' crocodiles which are excluded and/or lost from the monitored area may be obtained by noting (Table 7) that 340 3-6' and 83 large animals were sighted during the July 1976 survey and that the July 1983 surveys revealed 125 large crocodiles only. Each of the 3-6' animals Of 1976 would, if they survived, be in the large size class by 1983 and hence the minimum percentage which have been excluded and/or lost (minimum because we have assumed that all the increase originated from the 340) by July 1983 is (340-42)/340 or 88%. Again if we assume that the 'dry wet' of 1981-1982 had concentrated back into our monitored waterways nearly all of the surviving large animals originally recruited there--and none originating from elsewhere--then 76% becomes the estimate for the missing--presumed dead--3-6' animals ((340- 80)/340 or 76%).

Obviously the exclusions and/or losses of animals in all size classes have to date nearly equalled the input. It should be stressed that the large size classes are included; that they also suffer substantial exclusion and/or losses for we know from our recapture work (see Messel et al. 1979-1986, 18) that some 3-6' animals do enter the large size class and yet the overall number of large animals sighted only increases marginally.

In order to eliminate the various possibilities as to where the large number of apparently missing crocodiles could be, we surveyed, in 1982 and 1983, all of the alternative habitat (such as small coastal creeks and billabongs) in the monitoring area that we could gain entry to, using boats, vehicles, and a helicopter. This was a very expensive and time-consuming exercise, but one we felt had to be done. The results given in Table 8 show that the alternative habitat does provide some important rearing stockyards for both large and small animals, but the number of animals involved is small compared to the hundreds missing (much more detail on the alternative habitat may be found in Messel et al. 1979-1986, 18). As pointed out previously, the Arafura Swamp appears to be the main haven of refuge for the excluded crocodiles.

RESULTS IN VAN DIEMEN GULF

In Tables 1B and 9 we have combined the results from 1977 to 1984 for the tidal waterways surveyed, from the Ilamaryi River in the Cobourg Peninsula to the Adelaide River in Adams Bay. The various combinations shown allow one to view the results from a number of different angles and to assess the recovery of *C. porosus* in this broad geographical area of northern Australia. In Figs. 9 and 10 we have plotted, using Table 9, the results of the Van Diemen Gulf surveys in the same manner as in Fig. 8 for the monitored area.

1. One point which stands out strongly for each of the combinations shown is the inflated number of animals sighted during the July 1984 survey in the 3-4' size class (Table 1B) and that this in turn has inflated the 3-6' size class number count (Figs. 9 and 10) and the 3-6'/large ratio (Table 9). These animals in the 3-4' size class are the result of the excellent breeding season during the "dry wet" of 1981-1982 and a large fraction of them are unlikely to enter the 4-5' and 5-6' size classes. Excluding such fluctuations, which appear to level out rather quickly, the number of 3-6' animals sighted normally remains fairly constant (see Table 2). However, as we have accumulated more and more data, it has become clear that it is the 4-5' and 5-6' size classes which provide most of the bottleneck and that the neck size appears to remain surprisingly constant for a given tidal system. This appears to be as true for the waterways of Van Diemen Gulf as for those in the monitored area.

2. Examining the results in Table 1B for the "Alligator Region plus Cobourg Complex and Saltwater"--629.6 km--shows that the number of 4-5' plus 5-6' animals sighted during the 1979 and 1984 surveys were 252 and 261 respectively. Interestingly the number of (6-7') animals positively identified was 164 on each survey.

For the "Adelaide plus Alligator Region with Wildman"-- 586.1 km--the 4-5' plus 5-6' counts for 1978, 1979, and 1984 were 364, 343, and 376 respectively. Considering the errors- -of up to one size class--which can easily arise in size class estimation, this is an amazing constancy.

If one then adds in the results for the Cobourg Complex and Saltwater, the 4-5' plus 5-6' counts for 1979 and 1984 become 385 and 404 respectively--again surprisingly constant for the 861.2 km of tidal waterways surveyed.

The same exercise may be carried out for the Blyth- Cadell and the Liverpool-Tomkinson River Systems, using Table 1A and again one finds a similar constancy in the number of 4-5' plus 5-6' animals sighted.

3. Though the number count for the 4-5' plus 5-6' size classes appears to remain closely constant from survey to equivalent survey, this is not the case for large animals. Once the animals have passed through the bottleneck, their numbers appear to continue to increase--in spite of various and continuing losses within their size classes as well (Table 9 and Figs. 9 and 10).

For the "Alligator Region plus Cobourg Complex and Saltwater"--629.6 km--the numbers of large animals sighted on the 1979 survey was 447 while the 1984 survey yielded 519 large animals.

For the "Adelaide plus Alligator Region with Wildman"-- 586.1 km--the number of large animals sighted during the 1978, 1979, and 1984 surveys was 352, 525, and 695 respectively. And if

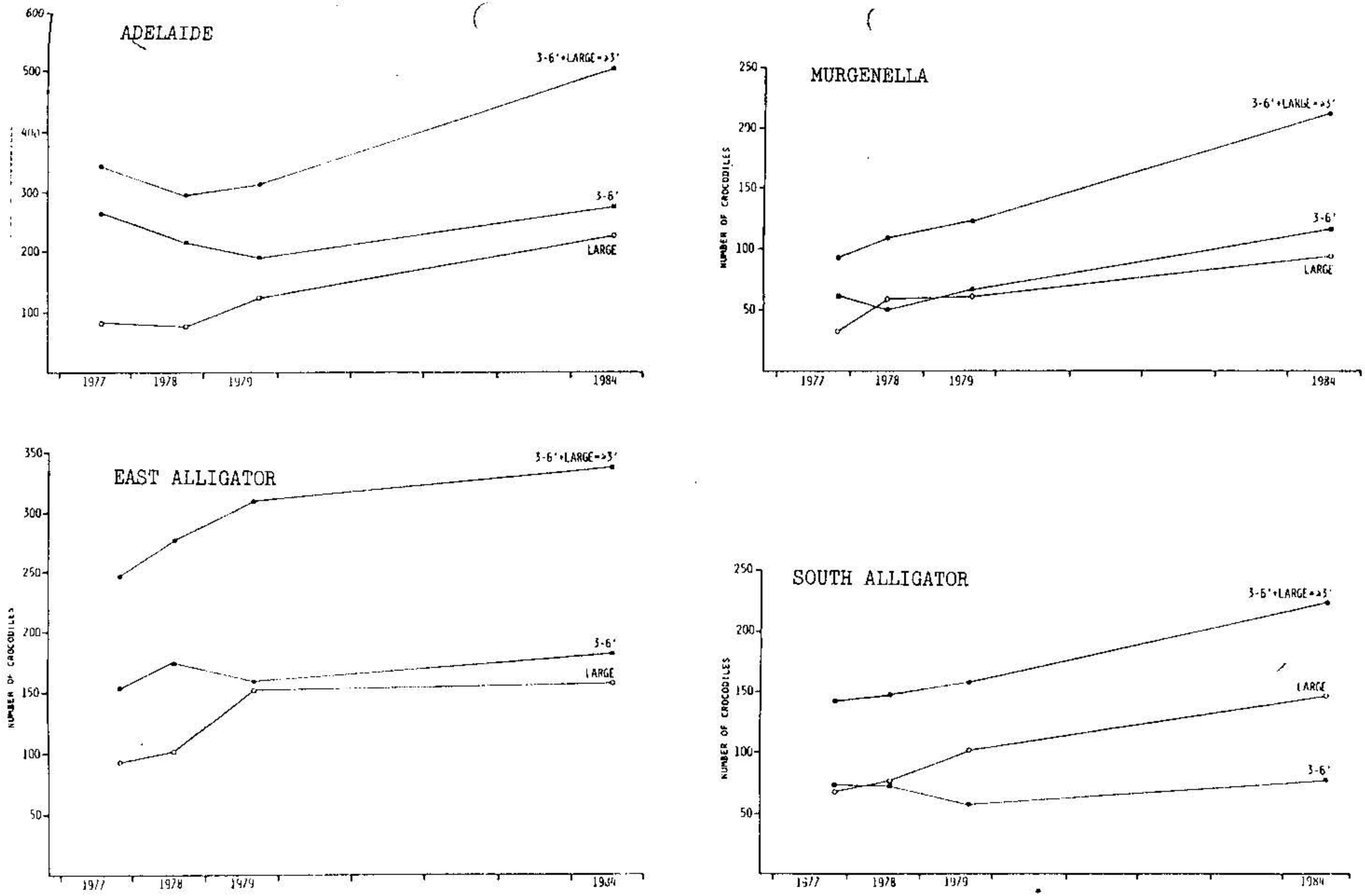

Figure 9. A plot of the number of 3-6', large (≥6)' and their sum, 3-6' plus large or ≥3' animals for surveys carried out on the Adelaide River, Murgenella Creek, East Alligator River, and South Alligator River.

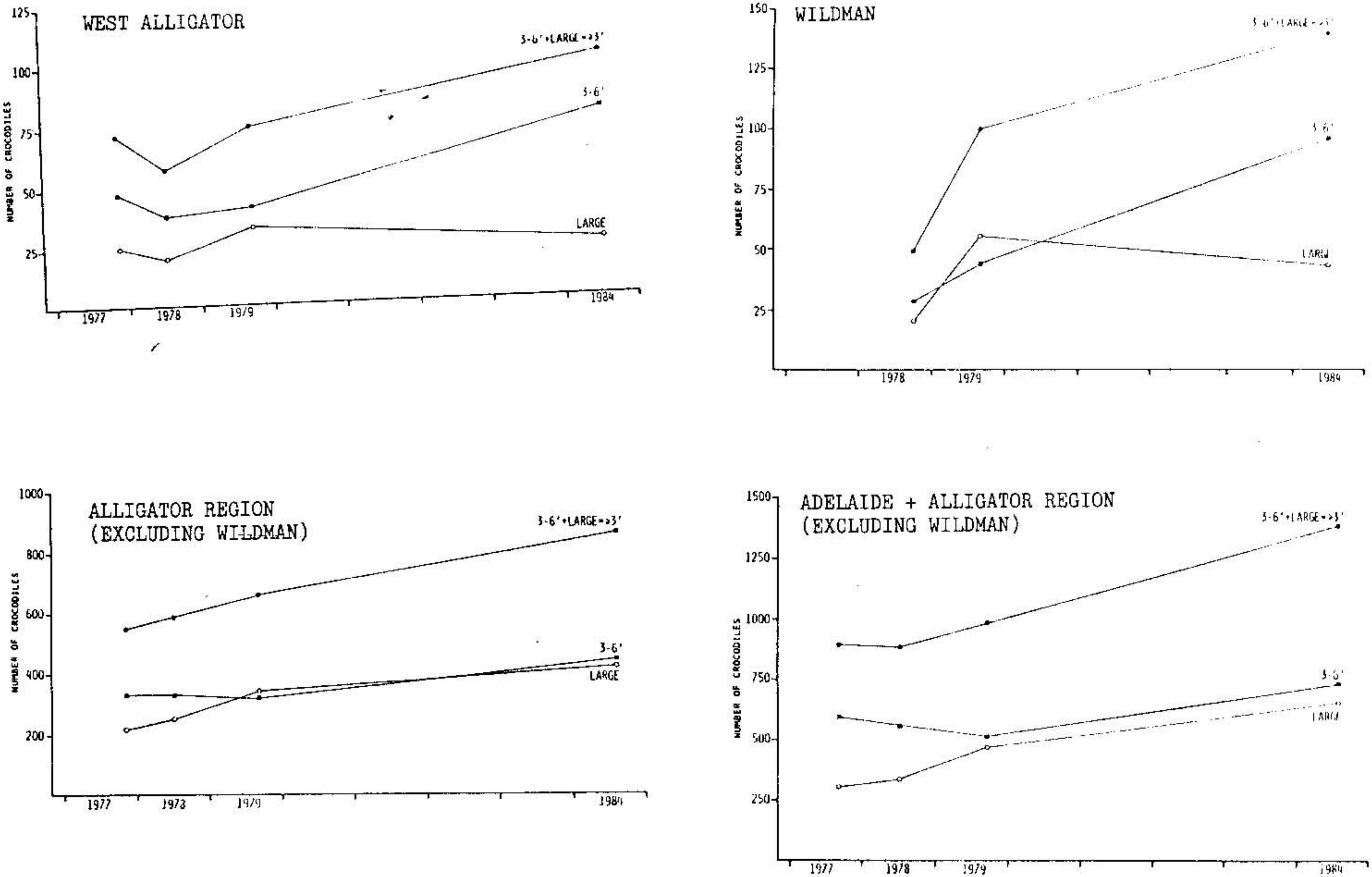

Figure 10. A plot of the number of 3-6', large (≥6)' and their sum, 3-6' plus large or ≥3' animals for surveys carried out on the West Alligator River, the Wildman River, and the combined results for the Alligator Region (excl 'ing the Wildman) and for the Adelaide RI plus the Alligator Region (excluding the Wildm.).

one adds in the Cobourg Complex and Saltwater Creek, then the number of large animals sighted on the 861.2 km of these tidal waterways during the 1979 and 1984 surveys is 569 and 747 respectively.

4. As already pointed out previously, the "dry wet" season of 1981-1982 apparently resulted in heavy hatchling recruitment and this in turn resulted in a high 3-4' animal count during the July 1984 survey. As has been shown during the course of our lengthy study on the Blyth-Cadell and Liverpool-Tomkinson Rivers Systems such fluctuations are soon smoothed out (Messel et al. 1979-1986, 1, 18 and Tables 1A and 2). The heavy 3-4' animal count in turn inflated the 3-6' count which in turn halted the decreasing 3-6'/large ratio (Table 9 and Figs. 9 to 10). Furthermore, the heavy losses of large animals through drowning in barramundi nets set in the tidal waterways of Kakadu National Park also leads to an artificially high ratio. Some idea of the impact of net fishing may be gained by comparing the results in Table 9 for Murgenella Creek, where net fishing is not allowed, and the West Alligator River, where it is allowed. If commercial net fishing was halted in the tidal waterways of the National Park, one could be confident that the ratio would continue to fall over the long term. However only repeated, careful, and systematic surveys of the overall waterways in the area can provide a long term check on this matter.

5. The density of non-hatchling crocodiles sighted during the 1984 resurvey increased in each of the systems and areas (Table 1B). For the overall 861.2 km of tidal waterways resurveyed, the increase was from 1.5/km for 1979 to 2.1 for 1984. This increase is significant statistically at >99% level of confidence and importantly the increase is not made up of increases in the 3-6' size classes (870 versus 610) only, but there was also a large increase in the number of large animals sighted (747 versus 569).

6. Along the waterways of the Alligator Region, there has been much destruction of riverine habitat by feral water buffalo. This is especially so for the South Alligator and accounts for the minimal hatchling recruitment. We believe that recruitment in the associated freshwater complexes must play an important role in the Alligator Region, especially for the South Alligator.

7. The total number of *C. porosus* sighted on the 261.0 km of waterways comprising the Cobourg Complex increased from 67 for the 1979 survey to 76 for the 1984 one. This increase is not statistically significant and the density figure for the Complex increased from 0.26/km to 0.29/km only.

Thus the present results support the view that a sustainable recovery in the *C. porosus* population is in progress in the Adelaide River System and In the tidal waterways of the Alligator Region. Furthermore this recovery is very much in accord with the predictions of our model. The recovery is much stronger than that found for the tidal waterways in the Maningrida area. In Table 10, we have combined data for 1979 and 1983 from Table 1A for the 411.5 km of tidal waterways monitored in the Maningrida area, which encompass the Coomadeer, Liverpool-Tomkinson, Blyth-Cadell, and Glyde Rivers Systems and various TYPE 3 creeks in the area, and presented these in the same form as the results shown in Tables 1A and 9. This then permits us to compare survey results for the monitored tidal waterways In the Maningrida area with those for the 861.2 km of waterways bordering Van Diemen Gulf. Comparing Tables 9 and 10 highlights immediately and strongly the difference between the regions. The explanation for the difference in recovery rates is straightforward. Whereas the freshwater complexes associated with the TYPE 1 waterways in the Maningrida area are scant, and hence most of the animals excluded from the tidal systems in the area had little choice but to leave the systems (and later endeavor to return or to be killed if they remained). In this process the losses in the 3-6' and large size classes are very high. On the other hand, in the Alligator Region, there are substantial freshwater complexes associated with the TYPE 1 tidal waterways and many of the excluded animals take refuge in these and they are used both as rearing stockyards and as breeding systems. In freshwater complexes there are many more places for crocodiles to hide from other crocodiles than on a river with only two banks. The losses in this case could be expected to be lower (see points 5 and 6 of our model) and the recovery rate faster than on systems without associated freshwater complexes. For the overall waterways in the Alligator Region we found that the exclusion and/or loss factor varied between 47 and 82%. This latter high figure can probably be attributed largely to the loss of crocodiles through drowning in nets. Were it not for this, the figure would undoubtedly have been much lower and the recovery more spectacular.

For the Adelaide River System, two important factors appear to come into play. Though many of the former freshwater complexes associated with the System have been destroyed by feral water buffalo, the waterway has in addition an extensive (101.8 km) system of mostly TYPE 3 waterways on its downstream sections and hence when animals are excluded from the breeding sections they can take refuge in these without leaving the System. The exclusion and/or loss factor for the Adelaide System was only between 31 and 45%, compared to the 80 to 90% or more, for the waterways in the Maningrida area (Messel et al. 1979-1984, 18:127, 134, 155). The increase from only 81 large animals sighted on the Adelaide during the July 1977 survey to 228 large animals sighted on the July 1984 one is the consequence of these smaller losses. Given another decade or two of protection, the Adelaide System may begin approaching its former crocodile numbers.

An important implication of our results is that in much wetter climates than northern Australia, with much more extensive swamp areas (such as New Guinea, Malaysia, Thailand, Burma, for example) recovery could be expected to be faster, given enough animals to allow a recovery.

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APPENDIX--SUPPORTIVE EVIDENCE

In this appendix we summarize some of the data that provides additional support for our model. A full appreciation of course requires a complete reading of all the monographs and their analysis of individual systems (a somewhat daunting task admittedly!).

THE 1979 HATCHLING INPUT ON THE TOMKINSON

A spectacular illustration of the dramatic losses of small animals may be given by considering the fate of the very large hatchling input on the Tomkinson River in 1979. In June 1979, 289 hatchlings were sighted on the Liverpool-Tomkinson System; 260 of these were on the Tomkinson. There was an increase in the number of 3-6' animals on the Tomkinson from 62 in July 1979 to 85 in June 1982, which we believe was due to the return of some of the 1979 hatchlings to the mainstream from extreme upstream sections, because they were now in the size class to be excluded. By October many of these animals were gone from the system. In summary the number of 3-6' animals in the Liverpool-Tomkinson System was 120 in October 1979 and 142 in October 1983--the very large recruitment in 1979 had produced virtually no result.

RESULTS IN ARNHEM BAY

The waterways of Arnhem Bay (Messel et al. 1979-1984, 11) provide further evidence for the losses in the sub-adult size classes.

Arnhem Bay, because of the relatively narrow channel leading into it, is an enclosed system with three groups of waterways (Group 3 has the Goromuru River only). Each group has a major *C. porosus* breeding river in it, the Peter John, Habgood and Goromuru Rivers, which can supply *C. porosus* to adjacent waterways. Although we have no direct evidence, it would be surprising if there was no movement of *C. porosus* between the three groups.

We showed that there was a significant increase in the number of non-hatchling *C. porosus* sighted in the three groups of rivers from the October 1975 to the May-June 1979 surveys and hence that the population of *C. porosus* in Arnhem Bay is increasing (but see remarks on Arnhem Bay in Status Chapter). However, the increase is slow and there is strong evidence for continuing heavy losses (disappearance) in the transition from the 2-3', 3-4', and 4-5' size classes to the ≥5-6' size classes. Comparing the number of crocodiles in the 2-3', 3-4', and 4-5' size classes for the combined rivers of Arnhem Bay in October 1975 and the number in size classes ≥5-6' in May-June 1979 reveals that the loss (disappearance) of crocodiles in the transition from the 2- 3', 3-4', and 4-5' size classes to size classes ≥5-6' was some 88%.

There was no increase in large crocodiles sighted in Arnhem Bay in 1979, which is against the trend for most of the waterways surveyed in 1979. The reasons for this could be twofold: (a) the climate is wetter in the Arnhem Bay area; (b) there is only limited freshwater swamp.

DISTRIBUTION OF ANIMALS

In our ecology chapter we briefly discussed typical distributions of animals along a TYPE 1 waterway and how this fitted in with the idea of a movement of larger size classes downstream. Each system has of course its own peculiarities and we shall now give some examples, with references for the supportive details.

In 1979 we round for the overall Kalarwol River (Messel et al. 1979-1984, 10:28) that the losses of animals was considerably less than in other systems of similar type. The much lower percentage missing is undoubtedly connected with the fact that the Kalarwoi River has a TYPE 1 breeding, northern branch and a TYPE 2-TYPE 3 rearing stockyard adjoining it (the Kalarwoi mainstream). The subadult crocodiles displaced from the TYPE 1 breeding section need not travel out to sea (where a large fraction may perish) but can seek refuge in the adjoining TYPE 2-TYPE 3 mainstream. Since there is little or no breeding on this section, there is likely to be less competition between the sub-adult and adult size classes. The present result also provides additional evidence for the view that the high losses in the other TYPE 1 systems are associated with the sea movement of *C. porosus* from one system to another. A similar mechanism also applies for the Adelaide River, as we discussed in the results for Van Diemen Gulf.

The upstream section (km 73.7-81.3, Table 8) of the Tomkinson has a size class structure typical of a non-TYPE 1 system and appears to function as a refuge for larger animals excluded from the breeding sections of the river. The less desirable far upstream sections of the Liverpool and Blyth also appear to function in the same way, with higher numbers being sighted there in October surveys (excluded from main sections with onset of breeding season) than in June-July surveys (Messel et al. 1979-1984, 18:138).

The sighting of a different size class structure on each resurvey of TYPE 3 systems (but of course always mainly animals $\geq$4') fits in with these systems being mainly inhabited by itinerant animals that move in and out of such systems.

Webb and Messel (1978) classified crocodiles into short and long distance movers. In terms of our model the long distance movers are simply the crocodiles unable to secure a territory and we also see why there is an increasing number of long distance movers with increasing size of sub-adults.

INJURIES, DEATHS, AND INTERACTIONS

During a daytime survey of the Tomkinson River in May 1975 a freshly killed 5' *C. porosus* was found at km 22 and was preserved. This animal had been captured, marked and released 2 years previously. The dead animal had a distinct pattern of crocodile teeth punctures and was presumably bitten to death by a larger crocodile. During the night-time survey of km 73.7-81.3 section of the Tomkinson River on 1 November 1982 (breeding season) a 7-8' freshly dead male *C. porosus* was found floating in the water at km 73. It appeared to be in excellent condition and had blood coming from its nostrils--it was probably killed by a blow from a larger crocodile.

On the survey of the Cadell River carried out on 6 November 1982, a 7-8' crocodile was sighted at km 45.9 (the breeding area) with a near leg that was almost completely torn off--obviously done by a larger crocodile.

A 14' animal found drowned in a fisherman's net on the Wildman River in August 1979 had the remains of three small crocodiles in its stomach--possible direct evidence of the cannibalism which we strongly suspect is a major factor in *C. porosus* population dynamics and density control. In July 1983 on the Glyde River, the lower half of an 8-9' crocodile was seen floating in the river. As we approached, the carcass was attacked by a 9-10' crocodile. Considering the concentration of large crocodiles in the Glyde at this time, it is quite likely that the dead animal had been killed by another and that we witnessed another case of cannibalism.

Webb and Messel (1977) found that there was no significant increase in injury frequency in size classes up to 4-5'; however, in size classes above this, injury frequency was high. This of course fits in completely with our model.

Appendix A1.4 of Messel et al. (1979-1984, 1) gives a number of examples of observations of territorial behavior and displays, including a detailed account of the interaction of two 3-4' crocodiles over several months in 1976. A single example will be given here.

At 1334 hrs at km 22, on the Blyth River, on 16 September 1978, a 7-8' crocodile was sighted basking on a gently sloping mud bank, near low tide. We were approaching it slowly in the survey boat in order to get a photograph. When the survey boat was some 30 meters away, the crocodile started to move towards the water. Suddenly a 6-7' crocodile rushed out of the water and chased the 7-8' one, snapping at its tail. The 7-8' crocodile raced along the mud bank in a semicircular path into the water, with the 6-7' crocodile still chasing it. By this time, the survey boat was only 2 to 3 meters away from the 6-7' crocodile, which had its back arched well out of the water. As we approached closer, the crocodile blew a thin stream of water from its nostrils into the air. We could see no sign of the 7-8' crocodile. The 6-7' specimen gradually submerged its back and just the head was left visible.

OBSERVATIONS OF CROCODILES IN MUD

During the night-time surveys many crocodiles have been observed buried in mud (Messel et al. 1979-1984, 1:Chapter 7). Often the mud is very thin and physiologically a crocodile in mud is like one in the water. In most instances only the eyes, cranial platform, and snout are showing. The phenomenon is also observed during daytime. After examining and dismissing salinity and temperature as the reasons, the only explanation for the behavior that we could think of was that of camouflage. Crocodiles bury themselves in mud to hide from other crocodiles and so escape territorial interactions. The same mechanism is the basic explanation of the observation of crocodiles on the bank (Messel et al. 1979-1984, 1:Chapter 7). We have often witnessed crocodiles being chased out on the bank at night by other crocodiles.

DISPERSAL OP HATCHLINGS

In June 1978 all hatchlings on the Blyth-Cadell System that could be caught were marked and released. They were systematically recaptured in September 1978 and again in June 1979 (Messel et al. 1979-1984, 1:Chapter 8). A few recaptures of the same animals were made in October 1979 (Messel et al. 1979-1984, 1:Chapter 8) and October 1980 (Messel et al. 1979-1984, 18:Chapter 5). The pattern that emerges is again that of some animals hardly moving at all and some moving large distances. Looking at the 11 recaptures in October 1980, 3 animals on the Cadell were recaptured within 200 meters of their initial capture as hatchlings. Long distance movement is related to food supply but the number of male long distance movers is very significantly greater than the number of female long distance movers. Could interactions be greater for males even at this early stage? The fact that the males had more tail injuries than females supports this view. Webb et al. (1978) and Magnusson (1978) give further results on hatchling dispersal.

RECAPTURES OF 1980, 1981 AND 1983

These recaptures on the Liverpool-Tomkinson System were of animals initially captured in 1973-1976. The details are given in Messel et al. (1979-1984, 18:63-65 and in our chapter on Growth of *C. porosus*. One female (131) stayed in the same area on the upstream Tomkinson for two years and some time after reaching 4' moved to the midsection of the Liverpool--this agrees with our model. A male (517) was captured at 5' size at km 19 on the Tomkinson; one year later it was at km 73 on the Tomkinson; eight years later it was back at km 18. This is suggestive of the animal being excluded to the non-breeding section of the Tomkinson and returning when large enough to establish a territory. Animal 184 (a male) was captured as a hatchling on Maragalidban Creek and recaught three more times over a period of 10 years; all captures were within 1 km or the initial capture. This animal is one of the 10-15% we believe manage to establish a territory in the area where they were born and never leave. Animals 382 and 1059 also hardly moved over a period of six years.

CONCENTRATION OF LARGE ANIMALS AT MOUTHS OF RIVERS

It is unusual to see concentrations of large (or small) animals near the mouth of rivers. We have seen it, however, on a few occasions, and these observations are understandable in terms of our picture of movement between the Arafura Swamp and the monitored area.

On the June 1979 survey, on the Blyth mainstream, the number of large animals sighted increased dramatically from 15 to 40 and from 23 to 55 for the overall Blyth-Cadell System. For us it was exciting to see so many large animals; they were mostly concentrated at the mouth region of the Blyth River and on the sidecreeks of the downstream section of the river. Where had these animals come from and were they coming into the river or leaving it? Since they were not sighted during the September 1978 survey, the evidence points to these animals trying to gain entrance to the waterway.

By October 1980 most of these additional large animals were gone again. We interpret this to mean large animals excluded from the Arafura Swamp after the dry wet of 1978-1979 were trying to enter the Blyth. Exactly the same phenomenon occurred in June 1982 after the dry wet of 1981-1982; 31 large *C. porosus* were sighted on the km 0-15 section of the Blyth River and its sidecreeks. By November 1982 the number of large *C. porosus* on the Blyth-Cadell System had dropped by 15 and the decrease occurred almost exclusively on the mouth section.

In July 1979, on the Glyde River, we observed 12 animals between km 0 and km 1.2 in size classes $\geq$4'. This was the first occasion we had seen such a concentration of *C. porosus* at a river mouth. These would be largely animals excluded from the Arafura Swamp and leaving the river or waiting to return. Because of this 1979 observation we were expecting a similar observation in July 1983 after the "dry wet" of 1981-1982, and so it turned out. Furthermore, there were 19 animals sighted on the km 0- 5 mouth section and the majority of these were large; 15 of the animals were sighted between km 0 and 2, strongly indicating that they were either entering or leaving the river (in fact the October survey indicates they were entering the system). Three pairs of these large crocodiles were sighted interacting; that is, one was in the water directly facing one up on the bank. Further discussion may be found in Messel et al. (1979-1984, 18).

The large increase in the Milingimbi Complex (Messel et al. 1979-1984, 9) in 1979 also supports the idea of movement out of the Arafura Swamp via the Glyde River.

The idea of movement between the monitored area and the Glyde River is made more plausible by the sighting in 1976 in the Milingimbi Complex of a 12' male with a transmitter on its head that was originally caught at km 49 on the TomkInson one year earlier.

OBSERVATIONS WITH OTHER SPECIES

Cott (1961) remarked on the losses of small *C. niloticus* between the ages of about two and five years, crocodiles go into retreat in less desirable habitat and this cryptic behavior has probably been forced on them by the habit of cannibalism. Studies of *C. acutus* in Florida also indicate that a substantial fraction of sub-adult *C. acutus* remain unaccounted for (J. Kushlan, 5th Working meeting, Crocodile Specialist Group, 1980).