

Distribution and conservation status of the Green and Golden Bell Frog *Litoria aurea* in New South Wales

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ABSTRACT

The Green and Golden Bell Frog *Litoria aurea* has undergone a dramatic population decline in New South Wales. During this time the species' status in this state has changed from being common in the 1960s to endangered in 1992. To assess the present population numbers and environmental pressures, 31 sites within the Greater Sydney region and 61 sites from regional areas of New South Wales were surveyed. The sites consisted of previously known but no longer used localities prior to 1990, as well as more recently discovered localities. Since 1990, only 38 localities have been recorded for Green and Golden Bell Frogs, 19 of these are in the Greater Sydney region. Since the 1960s Green and Golden Bell Frogs have disappeared completely from all highland areas above 250 m a.s.l. Coastal populations have been reduced in number and are more isolated from other extant populations. Many of the extant sites are new sites (post 1990) for this species and occur in highly disturbed environments. The ecological niche of this species is discussed in the light of new observations on these frogs. The introduction of Mosquito Fish *Gambusia holbrooki* may be one of the factors limiting the recovery of Green and Golden Bell Frog populations in New South Wales.

INTRODUCTION

The Green and Golden Bell Frog *Litoria aurea* (Lesson) is a relatively conspicuous species and consequently, changes in its distribution and abundance are reasonably obvious. It is a large, strikingly-marked species and was one of the first frog species to be described from Australia (Lesson 1829). It has featured prominently in many general natural history books and articles about Australia's fauna (e.g., Fleay 1952; Clyne 1969; McAuley 1995). In New South Wales, this species was familiar because of its distinctive markings and its abundance in coastal areas near Sydney and Wollongong.

Until recently, the Green and Golden Bell Frog was regarded as being common throughout its range and as having a secure population. Barker and Grigg (1977) described the species as being "common" in coastal New South Wales. Tyler (1992) described the abundance of the species nationally as "common" and its status as "secure", this latter assessment of abundance and status being influenced markedly by the more secure populations of Green and Golden Bell Frogs in Victoria (Tyler, pers. comm.).

Since about 1960, declines in the distribution and abundance of the Green and Golden Bell Frog have been noticed. Osborne (1990), for example, observed that a number of frog species, including the Green and Golden Bell Frog, have declined in the Australian Capital Territory to the extent that they are probably now extinct in this region (see also Osborne *et al.* 1996). Similar declines in the abundance of the species have been observed in other parts of

its distribution (e.g., Cogger 1993; Robinson 1993; Greer 1994; Daly 1995; White 1995a). Because of these apparent declines the species was listed as "threatened" in New South Wales (i.e., on part 1 of Schedule 12 of the NSW *National Parks and Wildlife Act* 1974, where part 1 species are considered to be under greater threat of extinction than species included on part 2 of the Schedule).

Although many people have noticed and commented upon the apparent declines in the distribution and abundance of the Green and Golden Bell Frog (e.g., Cogger 1993; Robinson 1993; Greer 1994; Daly 1995; White 1995a; Pyke 1995), there has so far been no published review of the species in terms of its overall distribution, abundance and conservation status. This paper aims to provide such a review for New South Wales. The situation for the species in Victoria is discussed by Gillespie (1996).

METHODS

Distributional and Abundance Records

Distributional records have been obtained from a variety of sources, including government agencies, universities, museums, herpetological groups and individuals. Such records were sought from the following institutions: Australian Museum (AM), National Museum of Victoria (MV), Queensland Museum (QM), University of Canberra (UC), NSW National Parks and Wildlife Service's Wildlife Atlas, Australian National Parks and Wildlife Service, New South Wales's State Forests, American Museum of Natural History (AMNH) and the National

Museum of Natural History — Smithsonian (NMNH). In addition, requests have been made to various Australian herpetological groups soliciting information about Green and Golden Bell site localities, dates, estimates of frog numbers and history of the site. Some individuals who have had experience with this species have also provided records.

The majority of sites given as a result of these enquiries have subsequently been visited and surveyed for frogs by either or both authors (see Tables 1–4). With some old historical sites, the location of the sighting could not be determined with certainty. In these instances, a search was undertaken of the local area and the most likely looking habitat was accepted as the intended site. From 1990 onwards, intensive searches have taken place and are still continuing for prospective Green and Golden Bell Frog sites in New South Wales. The majority of site discoveries since 1990 are the result of these latter surveys.

Site Descriptions

Each site was assessed for various habitat characteristics regardless of whether the site still had extant populations of Green and Golden Bell Frogs. By also assessing past sites it was hoped that the reasons for their disappearance would become apparent. The habitat characteristics that were recorded included the nature of water present (i.e., permanent, fluctuating, ephemeral), aquatic plant species present, adjacent and nearby vegetation types (sensu Specht 1970), extent to which the site is shaded, the nature of the water source, the nature and extent of available shelter sites, species of fish present (see below), species of frogs present, description of frog breeding areas, records of successful spawning or tadpole sightings and soil characteristics of pond substrate. It was not always possible to obtain all of the required data for each site but, at more than 90% of the sites complete records were collated.

The habitat requirements of the Green and Golden Bell Frog, as revealed by analysis of these data, are discussed in Pyke and White (1996).

Frog abundance

In order to obtain an index of relative frog abundance at each site, the numbers of Green and Golden Bell Frogs that were detected (i.e., observed or heard using standard frog survey techniques: e.g., White 1995b) during each visit to a site was recorded. In some cases published information of this kind provides some indication of relative population sizes of the species during visits by other researchers.

These standard frog survey techniques may underestimate the actual numbers of frogs present since many frogs remain hidden and do

not call. In the case, for example, of the population of Green and Golden Bell Frogs at Rosebery (see Table 4), standard survey techniques only yielded up to 6 adult frogs, whereas excavation of the ground where they were sheltering resulted in the location of 33 individuals (A. White, unpubl. obs. reported in Pyke 1995). However, so long as the same techniques are employed during each visit, the resulting data should permit comparisons of relative numbers of frogs.

Fish Records

Records of the fish species present at the visited sites were obtained using the following techniques. Baited fish traps were used at all sites that had sufficient water. In ephemeral sites, small scoop nets were used to sample fish and tadpoles. Fish of taxonomic uncertainty were identified by the Australian Museum.

RESULTS

Regional Trends

Since half of the records for the Green and Golden Bell Frog in New South Wales come from the Greater Sydney Area (i.e., area bounded by the Hawkesbury River to the north, the Nepean River to the west, Port Hacking to the south, and the Pacific Ocean to the east), this area is considered separately from the rest of New South Wales in the following analysis and discussion.

As the effort spent surveying for the Green and Golden Bell Frog in New South Wales has increased markedly since 1990, the time period up to and including 1990 is considered separately from the period after 1990 in the analysis and discussion below. Since about 1990 the species has been included in surveys carried out by environmental consultants (e.g., White 1993), university researchers (e.g., Osborne *et al.* 1996), members of the Frog and Tadpole Study Group of New South Wales Inc. (FATS Group), and others. Sites where the species has been recorded during both periods are considered only with regard to the later period.

a) Distribution up to and including 1990, outside of the Greater Sydney Area:

There are presently 97 known locations for New South Wales outside of the Greater Sydney Area where the Green and Golden Bell Frog has been recorded during the period up to and including 1990, but not since then (Table 1, Fig. 1). From these records, it is apparent that during the earlier period:

- (i) the distribution of the species was reasonably continuous along the New South Wales coast from about Byron Bay in the north to the Victorian border in the south;

Table 1. Known localities for *Litoria aurea* prior to 1990 outside of the Greater Sydney Area.

Location	Year of record	Nature of record	Altitude m (a.s.l.)	Site Description	Year location revisited
Armidale	1971	AM R33417	850		
Ballina	1972	MV D18194	10	Swamp at back of mangrove	1993
	1973	QM J27995, 29932			
Barrengarry	1947	AM R74556	50	Farm dam	1991
Bateman's Bay	1964	MV D19640	15	Coastal paperbark swamp	1990
	1968	MV D19707.19709			
Bateman's Bay South	1964	MV D19618-19	20	Farm dam and creek	1990
Bathurst	1829	FMNH	730	River	1993
Bendalong	1988	A. White	80	Ephemeral creek and soak	1993
Bodalla	1953	AMNH 64857-61			
	1964	MV D19620			
	1968	AM R71874			
Bombah Point (Myall Lakes)	1971	AM R99662	0	Lake overflow	1994
Bombala	1953	P. Johnson			
Braidwood	1977	AM R119329	650	Farm dam	1993
Braidwood (Clyde Mtn)	1966	MV D19700			
Brunswick Heads	1972	QM J22708	50	Ephemeral swamp	1994
Buladelah	1920	AMNH 12948-49	50	River overflow	1993
Bulli	1910	AM R4665-8	40	Ephemeral creek	1991
Bundanoon	1939	AM R74552-3, 84809	540	Farm dam	1991
Burradoo	1952	AMNH 64843			
Burrawang	unknown	AM R7376			
Byron Bay	1982	P. Parker	30	Dredge pond in coastal heath	1994
Camden	1970	AM R110675	370	Farm dam	1991
Campbelltown	unknown	AM R1630			
Canberra	1964	MV D19617	580	Farm dam	1993
	1974	UC C/A 313-29,40-43	650	Perched swamp	1993
Capertee	unknown	AM R7325			
Cobargo	1968	AM R27635			
Cooma	1963	P. Johnson	890	Farm dam	1991
Cowra	1972	D. McEvoy			
Currumbene S.F.	1979	R. Braithwaite			
Darkes Forest	1976	AM R117916,119330	550	Ephemeral swamp in heath	1995
Delegate	1965	MV D59248			
Digger's Camp	1982	NPWS, G. Clancy	50	Paperbark swamp	1994
Dungog	1977	Wildl. Atlas, A. Heinrich	150	Farm dam	1991
Ebor	1972	AM R118494			
Eden	1953	AMNH 64852-56	35	Coastal swamp	1991
	1969	MV D19636			
	1980	Wildl. Atlas, C. Webb			
Erina	1972	AM R37392-4	80	Farm dam	1992
Fitzroy Falls	1941	AM R74555	560	Farm dam	1991
Ginninderra Ck. (ACT)	1967	M. Robinson	580	Ephemeral creek	1993
Gosford	unknown	AM R16041			
Hat Head	1964	MV D19695-99	25	Ephemeral swamp	1991
Helensburg	1970	AM R110694	440	Ephemeral creek	1994
	1972	AM R78912			
Henty	1979	Wildl. Atlas, J. Brickhill			
Hillgrove	unknown	AM R19428			
Jackadgery	1975	A. Manning			
Jervis Bay	1963	MV D19623-35	20	Permanent swamp	1993
(Ryan's Swamp)	1965	MV D18907-8, 19722-23			
	1969	MV D19712-19			
	1972	ANWC			
	1974	UC C/A 155,305			
Jervis Bay (Marshall's Beach)	1972	ANWC	30	Permanent swamp	1993
Jibbon Lagoon	1970	P. Morris	20	Permanent swamp in heath	1989
Jindabyne	1964	UC specimen			
Kioloa	1986	Wildl. Atlas, F. Lemckert	50	Permanent lagoon/dam	1992
Lake Conjola	1978	R. Williams	10	Edge of lake	1991
Lake George	1975	UC C/A 414-422	370	Ephemeral swamp	1993
Lake Liddell	1971	AM R31788	80	Permanent lake	1991
	unknown	AM R71689-99			
Macksville (Gurravembi)	unknown	AM R6824			
Macksville	1975	A. White	50	Paperbark swamp	1994
	1975	AM R49784			
Maitland	1976	AM R99430	50	Farm dams	1991
Mangrove Mountain	1970	MV D19715			

Table 1 — continued.

Location	Year of record	Nature of record	Altitude m (a.s.l.)	Site Description	Year location revisited
Mimosa Rocks	1928	Wildl. Atlas, J. Wombey	20	Ephemeral swamp	1991
Moruya	1953	AM R47566-71	60	Farm dam	1991
Moruya Heads	1954	AM R47572-85	25	Permanent swamp	1991
(Pedro's Swamp)	1963	AM R89809-10			
Moss Vale	1964	MV D19621			
Nadgee	1973	AM R3735847952-3			
	1974	AM R45739-56			
	1980	AM R97609-10			
Nowra	1969	G. Daly	30	River overflow	1993
Oakdale	1975	MV D62457			
Oberon	1977	R. Hoser	760	Ephemeral creek	1994
Ourimbah	1970	AM R42156	75	Creek overflow/dam	1994
	1972	AM R42156, 71961			
Picton (Razorback Mtn)	1938	AM R74545-51, 84805-8	730	Farm dam	1991
Queanbeyan	1979	Wildl. Atlas, J. Wombey			
Ravensworth	1963	MV D18931	60	Ephemeral creek	1994
Raymond Terrace	1973	A. White	50	Paperbark Swamp	1994
Shellharbour	1987	C. Schafer	10	Storm water drain	1995
Shoalhaven Heads	unknown	AM R18768			
Singleton	1958	AM R19669-81			
Somersby	1969	MV D19710-11	270	Perched swamp in heath	1992
Smith's Lake	1972	AM R111716	10	Reed swamp in heath	1994
St Albans	1972	G. Grigg	80	Permanent lagoon	1991
Tallong	1939	AM R74554	450	Perched swamp/dam	1991
Taylor's Arm	1982	Wildl. Atlas, T. Evans	280	Permanent creek	1992
Telegraph Point	1974	P. Williams	50	River overflow/swamp	1991
Termeil	1965	MV D19720	80	farm dam	1994
	1986	Wildl. Atlas, F. Lemckert			
Thirroul	1920	L. Harrison	10	Ephemeral creek/pond	1991
Tianjara	1980	Wildl. Atlas, G. Meredith	350	Permanent creek	1991
Tomerong	1964	MV D19622	25	Coastal swamp	1992
Tumut (Mt Horeb)	unknown	AM R8422			
Twofold Bay	1982	Wildl. Atlas, A. Mednis	25	Coastal swamp	1991
Ulong	1947	AM R13817			
Upper Colo	unknown	AM R7974	120	River overflow	1991
Uriarra (ACT)	1963	AM R90718-20	430	River edges	1993
Warrell Creek	1908	AM R4251	100	Permanent swamp	1994
Watagan S. F. (Basin)	1967	M. Robinson	80	Permanent creek	1995
Wiseman's Ferry	1963	QM J16986-87, 89-90	75	Permanent creek	1991
	1987	QM J48519			
Wollombi	1975	AM R46067	150	Permanent creek	1992
Wollongong	1840	NMMH 15478	20	Coastal lagoon	1991
Wollongong (Mt Keira)	unknown	AM R18484	140	Perched swamp	1994
Womboyn (Narrabarba Ck)	1974	MV D62411			
Woonona	1910	AM R4665-68	40	Permanent creek	1994
Woragi Swamp	1969	K. Griffiths	30	Permanent swamp	1993
Wyee	1976	R. Hoser	50	Farm dam	1994
Wyoming (Reptile Park)	1967	M. Robinson	75	Dam	1994
Wyang	1976	AM R70202	50	Permanent swamp	1993

- (ii) although the distribution along the coast was reasonably continuous there are more records from south of Sydney than north of Sydney (i.e., 34 locations or 35% of sites north of Sydney and 63 locations or 65% of sites south of Sydney; see Fig. 1);
- (iii) most of the records are from low elevations, below 100 metres a.s.l. (Table 1);
- (iv) the species was recorded from a number of highland sites, in particular, the Canberra-Braidwood district of the Southern Tablelands; and

- (v) to the north of Sydney there were few high elevation sites and almost all sites were east of the Great Divide (the only discrepant records for both these parameters are from Armidale and Ebor).

In Victoria, the Green and Golden Bell Frog has been found throughout the Gippsland Lakes and East Gippsland coast areas (e.g., Hero *et al.* 1991; Gillespie 1996). In some areas, such as West Gippsland, the species hybridizes with its close relative, *Litoria raniformis* (W. Sherwin, pers. comm.).

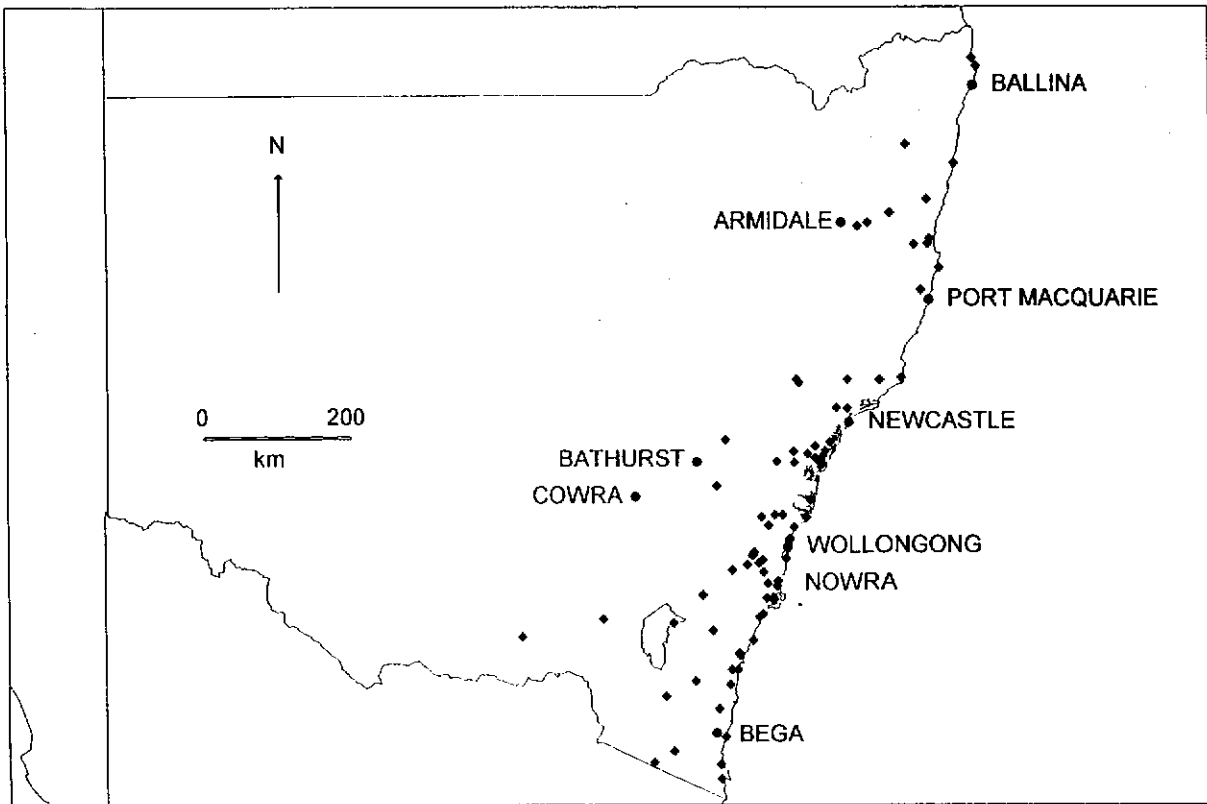


Fig. 1. Localities for *Litoria aurea* in New South Wales prior to 1990.

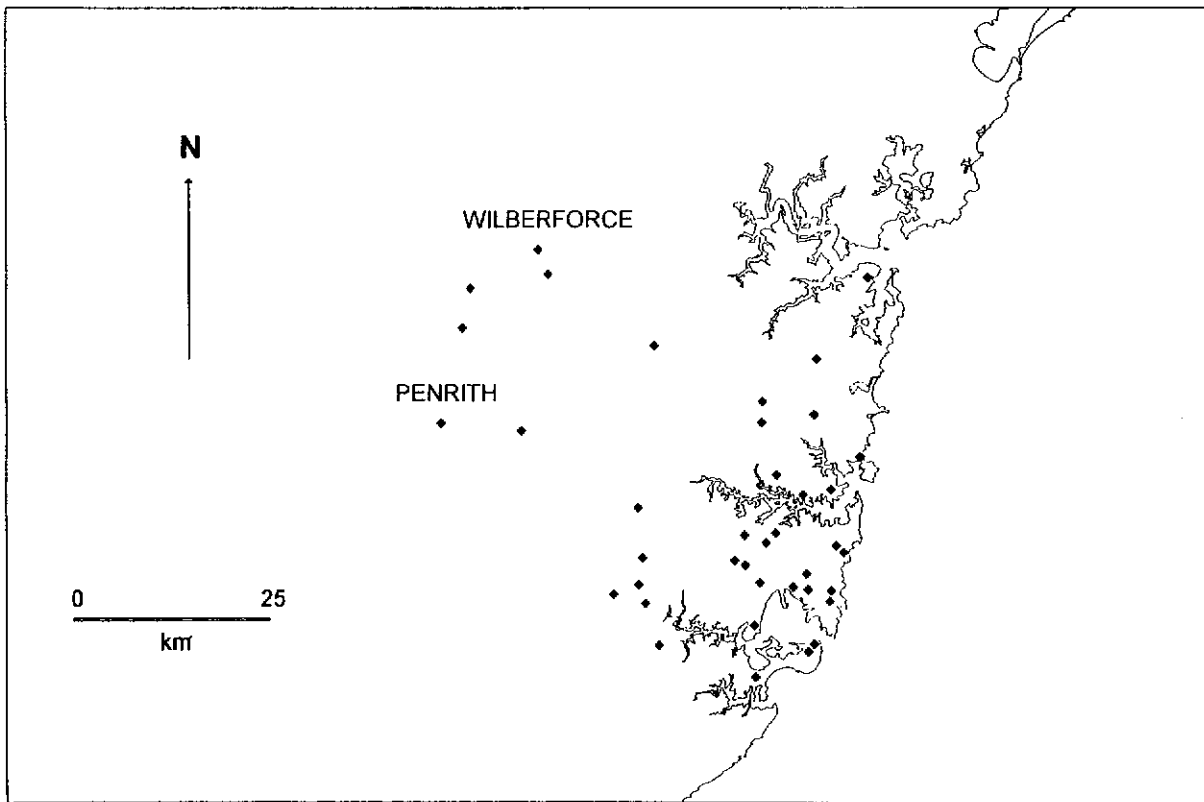


Fig. 2. Localities for *Litoria aurea* in the Greater Sydney Region prior to 1990.

Table 2. Known localities for *Litoria aurea* prior to 1990 in the Greater Sydney Area.

Location	Year of record	Nature of record	Altitude m (a.s.l.)	Site Description	Year site revisited
Annandale	unknown	AM R1682			
Arncliffe	1981	A. White	10	Storm water basin	1995
Ashfield	unknown	AM R1516			
Botany Swamps	unknown	AM R8256, 9532			
	1949	J. Cann	10	Remnant swamp	1982
	1967	AM R90702-7			
Bronte	1967	AM R90702-7	10	Ephemeral creek	1985
Canterbury	1968	AM R99664	40	Permanent pond (racecourse)	1987
	1972	V. Giniunas	40	Ephemeral pond	1993
Cook's River	1900	AM R3012	20	Ephemeral soak	1990
East Hills	1963	AM R74641	40	Golf course pond	1991
Eastlakes	1952	AM R14529	35	Permanent swamp	1968
	1952	AMNH 64844-51			
French's Forest	1970	AM R29441-3			
George's Hall	1975	S. Howard	40	River overflow	1974
Gordon	1920	L. Harrison			
Guildford	1969	G. Husband	35	Permanent pond	1992
Holsworthy	1975	K. Griffiths	45	Permanent creek	1989
Kenthurst	1977	R. Hoser			
Kurnell — North	1975	A. White	25	Ephemeral swamp	1975
Kurnell — South	1977	K. Griffiths	25	Ephemeral swamp	1977
La Perouse	1969	A. White	25	Ephemeral swamp	1969
Lane Cove	1977	D. Tyrell	25	Permanent creek/dam	1994
Londonderry	unknown	AM R24555			
Long Neck Lagoon	1973	P. Wettin	45	Permanent lagoon/swamp	1973
Manly	1890	AM R19643	10	Permanent swamp	1971
Maroubra	1908	AM R4194-206	10	Permanent lagoon	1965
Menai	1972	AM R119327-8			
Milperra	1980	Wildlife Atlas	25	Permanent ponds	1980
Mosman	unknown	AM R5963-65			
Mount Druitt	1973	G. Husband	35	Ephemeral ponds	1992
North Sydney	unknown	AM R5388-9			
Penrith	1960	H. Ehmann	50	Permanent lakes	1990
Petersham	unknown	AM R8454			
Pitt Town	1974	A. White	45	Ephemeral lagoon	1974
Richmond	1890	AM R19424-7	45	Permanent lagoon	1978
	1971	AM R50626			
Sans Souci	1909	AM R4452	10	Paperbark swamp	1988
Terrey Hills	1975	R. Hoser	130	Permanent pond	1992
Waverley	unknown	AM R1876-8, 1897-8			
	1953	AM R74558			
West Head	c.1950	Ranleigh House Museum			
Wilberforce	1975	S. Thompson	35	Permanent lagoon	1991

(b) Distribution up to and including 1990, Greater Sydney Area:

There are 37 known sites in the Greater Sydney Area where the Green and Golden Bell Frog has been recorded during the period to 1990, but not since then (Table 2, Fig. 2). Populations were widely scattered across the Sydney Metropolitan Area and outlying districts with the majority of sites being in the southern half of the region (Fig. 2). Several large population centres were known in the Richmond/Windsor/Wilberforce area along the Hawkesbury River, around the George's River in the Liverpool area, in the southeastern suburbs of Botany, Eastlakes, Mascot and La Perouse, and on the Kurnell Peninsula. Smaller populations were known from along sections of the Cook's River. Specific site location data can be obtained from the authors.

(c) Distribution since 1990, outside Greater Sydney Region:

Since 1990, records of the Green and Golden Bell Frog in New South Wales have been obtained for only 22 sites outside of the Greater Sydney Region (Table 3; Fig. 3). These include a concentration of five locations around the Shoalhaven River (i.e., Brundee, Coomonderry Swamp, Greenwell Point, West Nowra and Shoalhaven Heads) and another four locations in the Wollongong Area (i.e., Coomaditchy Swamp, Korrungulla Swamp, Primbee and Port Kembla).

Given that there have been extensive searches for the Green and Golden Bell Frog since 1990, the number and distribution of records obtained during this period indicate that there has been a contraction in the distribution of the species

Table 3. Locations and maximum recorded populations of *Litoria aurea* outside of the Greater Sydney region after 1990.

Locaton	Year first recorded after 1990	Maximum No. of Bell Frogs	Source	Site description
Bowen Island	1995	1 (1995)	G. Daly (ANCA)	Overgrown ponds.
Brundee Swamp	1993	6 (1993)	A. White	Ephemeral creek
Brundee West	1994	1 (1994)	G. Daly	Ponds in rubbish tip
Coomonderry Swamp	1993	20 (1993)	H. Ehmann	Permanent swamp
Greenwell Point	1992	6 (1993)	A. White	Permanent swamp
Hexham (Shortlands Wetl.)	1990	2 (1990)	M. Robinson	Permanent swamp
Jervis Bay (Ryan's Swamp)	1993	5 (1993)	ANWC	Permanent swamp
Kemblawarra (Coomaditchy)	1992	8 (1994)	T. van de Mortel	Permanent swamp
Kilalea Lagoon	1992	10 (1993)	T. van de Mortel	Permanent lagoon
Kioloa	1992	12 (1992)	F. Lemckert	Permanent ponds
Nadgee	1993	4 (1993)	NPWS	Swamps in heath
Nowra (Ben's Walk)	1994	4 (1994)	G. Daly	Ephemeral ponds
Ocean Shores	1992	2 (1992)	G. Schmida	Ephemeral pools
Port Kembla	1992	22 (1994)	B. Buttermer	Ephereral pond
Primbee (Korrungulla)	1992	6 (1994)	T. van de Mortel	Permanent swamp
Primbee Golf Course	1994	2 (1994)	T. van de Mortel	Golf course ponds
Ravensworth	1994		G. Pyke	Ephemeral creek
Shoalhaven Heads	1992	4 (1992)	G. Daly	Farm dam
Smith's Lake	1993	1 (1993)	A. White	Permanent swamp
Yuragir (Blue Lagoon)	1994	6 (1994)	G. Clancy	Permanent lagoon
Yuragir (Station Creek)	1993	2 (1993)	G. Clancy	Permanent creek

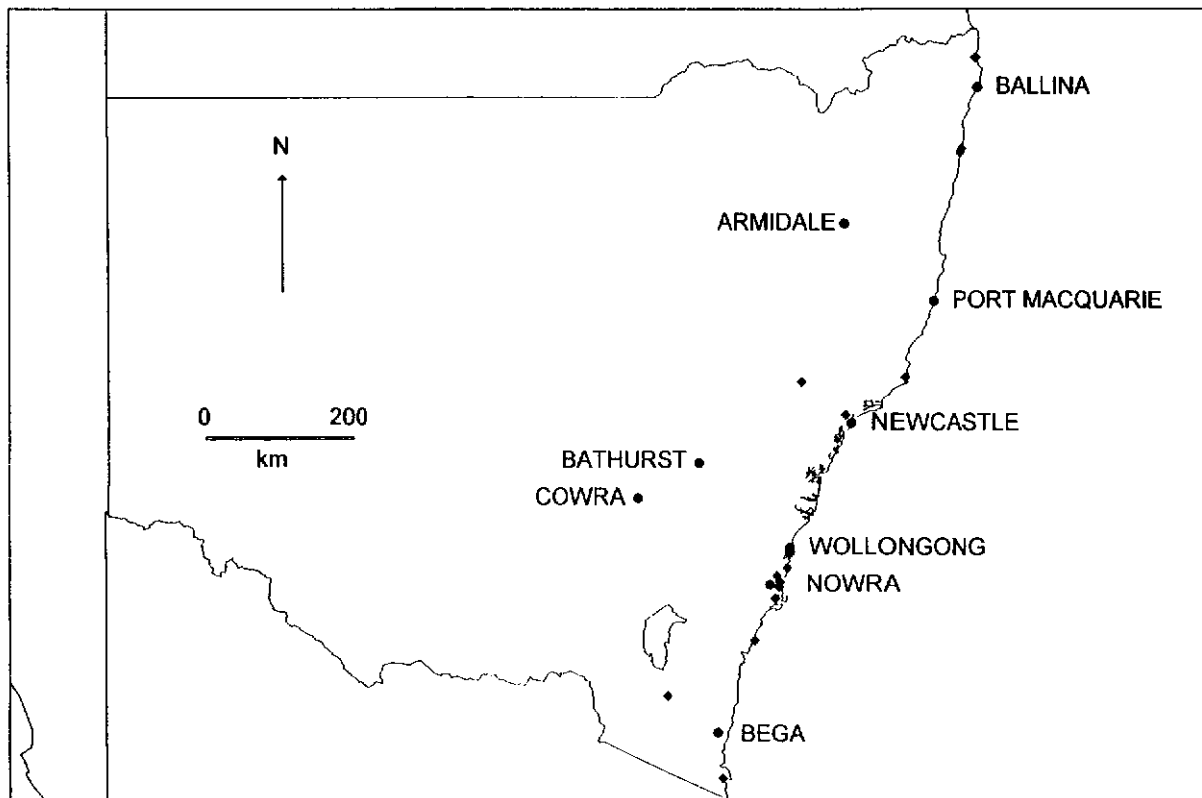


Fig. 3. Localities for *Litoria aurea* in New South Wales post-1990.

Table 4. Locations and maximum recorded populations of *Litoria aurea* inside the Greater Sydney Area after 1990.

Locaton	Year first recorded after 1990	Maximum No. of Bell Frogs	Source	Site description
Arncliffe	1991	6 (1992)	A. White	Storm water basin
East Hills	1993	4 (1993)	A. White	Golf course ponds
Eastlakes	1993	3 (1993)	A. White	Storm water channel
Enfield (Marshalling Yds)	1994	2 (1994)	A. Greer	Temporary ponds
Greenacre (Cox's Creek)	1991	4 (1993)	A. White	Permanent creek
Greenacre (Brick Pit)	1994	4 (1994)	A. Greer	Brick pit basin
Hammondville	1993	6 (1993)	A. White	Permanent dam
Holsworthy	1993	2 (1993)	K. Griffiths	Permanent creek
Homebush (Brick Pit)	1992	50* (1992)	A. Greer	Brick pit basin
Kurnell — North	1993	2 (1993)	A. White	Ephemeral swamp
Kurnell — South	1993	5 (1993)	A. White	Ephemeral swamp
La Perouse	1993	1 (1993)	A. White	Ephemeral swamp
Liverpool	1992		Wildlife Atlas	River overflow ponds
Mascot	1993	2 (1993)	A. White	Permanent ponds
Milperra	1992		Wildlife Atlas	Temporary ponds
Mount Druitt	1994	2 (1994)	A. White/G. Pyke	Temporary ponds
Newington	1993	12 (1993)	A. Greer	Various water bodies
North Ryde	1992	4 (1992)	J. Joss	Artificial ponds
Rosebery	1993	6** (1992)	A. White	Mining dredge pond
Wanda	1994	50* (1994)	A. Greer	Mining dredge ponds
Woolooware	1994	2 (1994)	A. White	Temporary ponds

*minimum population estimates

**33 Green and Golden Bell frogs found using non-standard counting techniques in 1993.

and the disappearance of many known populations. Specifically, it appears (see Table 3 and Fig. 3) that:

- (i) the species has disappeared from 92 of the 96 locations included in Table 1 and Figure 1; there are only five locations (Jervis Bay, Nadgee, Kioloa, Shoalhaven Heads and Smith's Lake) where the species has been found during both time periods. Since 1990 the species has been found in 18 previously unknown sites;
- (ii) the species is now probably extinct in New South Wales in all areas west of the coastal plain and in the Southern Tablelands (see also Osborne *et al.* 1996);
- (iii) the species is still known in New South Wales from about Byron Bay in the north (i.e., Ocean Shores) to the Victorian border in the south, but sites are now widely separated;
- (iv) the proportion of known New South Wales locations that lie to the south of the Greater Sydney Area rather than to the north has increased (i.e., six locations or 27% of sites lie north of Sydney compared to 16 locations or 73% of sites that occur south of Sydney for period up to and including 1990);

(d) Distribution since 1990, Greater Sydney Region:

Since 1990 only 21 sites have been found in the Greater Sydney Area (Table 4 and Fig. 4). These sites are not evenly scattered across the

metropolitan area. The main centres of population are the Kurnell Peninsula and the Liverpool/George's River area. Only one site is known from the northern suburbs of Sydney (North Ryde). This site is a newly created site (Lungfish ponds on the campus of Macquarie University) and frogs were first recorded here in 1992.

What were once extensive populations, have been reduced, in some cases, to a small number of isolated remnants. Only two populations may remain from the original Botany Swamps (Eastlakes: at Eastlakes Golf Course and at Rosebery). However, no Green and Golden Bell Frogs were found at Eastlakes in the summer of 1994/95. Only one population remains in the Cook's River valley at Greenacre, although the isolated Green and Golden Bell Frog populations at Homebush Bay and Arncliffe may have once formed part of the original Cook's River population. No known Green and Golden Bell Frog populations still exist in the Windsor, Richmond, Hawkesbury or Penrith areas.

Statewide trend

During the period since 1990 the Green and Golden Bell Frog has apparently disappeared from at least 113 locations (see Tables 1-4).

Relatively recent observations indicate that this decline in distribution is continuing. The best evidence of this comes from population records for the species at Eastlakes, in Sydney, which have been carried out by one of us (A.W.) since 1967. These records show that there has been a consistent decline in the size of the

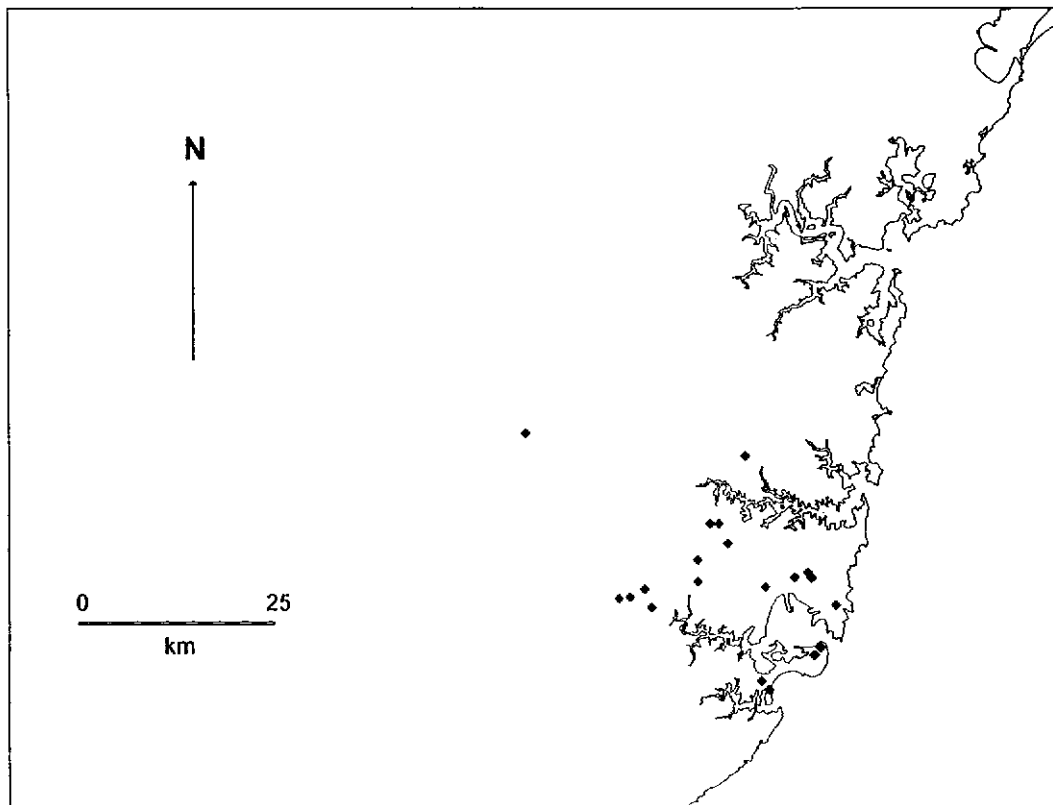


Fig. 4. Localities for *Litoria aurea* in the Greater Sydney Region post-1990.

population over the ensuing period with 138 adults detected in 1968, but only three adults in November 1993 and none found since (Fig. 5). In addition, despite breeding in the Macquarie University lungfish ponds during the 1992/93 and 93/94 summer breeding periods, the species was not recorded there during the 94/95 season.

It appears, therefore, that the decline in the distribution of the frog species is continuing in some parts of New South Wales.

(e) Abundance up to and including 1990:

It is difficult to gauge the sizes of the populations of Green and Golden Bell Frogs that were encountered up to and including 1990 because the numbers of frogs observed or heard was not generally reported. However, as the following discussion indicates, it is possible to gain some idea of these populations from published and unpublished accounts.

Reported observations indicate that Green and Golden Bell Frogs were present in large numbers in the Botany Swamps area of Sydney prior to the 1960s. It is widely reported that Green and Golden Bell Frogs were collected from this part of Sydney for University class dissections and for food for captive snakes. For example, during the 1950s between 50 and 100 individuals of the species could be collected for such purposes, two or three times a year, without any perceptible effect on the numbers

present (J. Cann, pers. comm.). Since then low-lying sites in the area have been developed for industrial occupation and the species has almost completely disappeared from it.

Large populations of Green and Golden Bell Frogs were also known from other parts of the Sydney Metropolitan area. Populations from the George's River in the Liverpool–Chipping Norton area (S. Howard, W. Bartolo, pers. comm.) and Milperra and Hammondville (S. Howard, K. Griffiths, pers. comm.) have been described as being in the "hundreds". Other apparently large but more scattered populations were known from the Hawkesbury River around Richmond, Windsor, Wilberforce (T. Wiley, pers. comm.; P. Armstrong, pers. comm.; A. White, pers. obs.) and the from the Nepean Lakes (H. Ehmann, pers. comm.; A. White, pers. obs.). Populations of between 25 and 50 frogs were known from the Cook's River valley at Canterbury and Arncliffe (V. Giniunas, pers. comm.; A. White, pers. obs.).

Some parts of Sydney apparently supported populations of Green and Golden Bell Frogs which were relatively small. Beach suburbs of Bronte, Waverley, Maroubra and La Perouse had established Bell Frog populations that were "not very large" (J. Cann, pers. comm.; A. Crollick, pers. comm.).

There are considerably fewer recorded sites for Green and Golden Bell Frogs in the northern suburbs of Sydney. Populations were

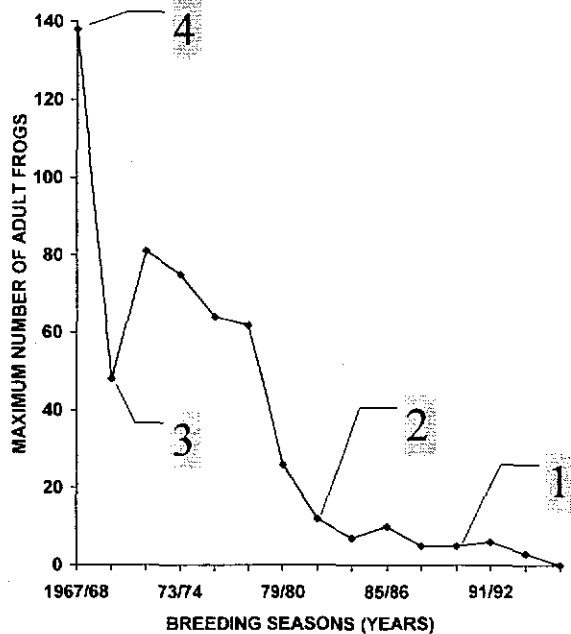


Fig. 5. Changes in the maximum population numbers of *Litoria aurea* at Eastlakes, New South Wales since 1967/1968. The circled numbers refer to the number of water bodies being used by the Green and Golden Bell Frogs at Eastlakes.

known at Gordon (Harrison 1922), French's Forest and the Terrey Hills area (R. Hoser, pers. comm.). In addition some sites, such as West Head and Manly, are only known from single specimens in museum collections.

In New South Wales populations of the Green and Golden Bell Frog away from the Greater Sydney area were apparently generally smaller than most in the Greater Sydney Area. Populations on the south coast, near Wollongong, Jervis Bay, Kioloa and Bega are believed to have generally numbered less than 100 frogs (Harrison 1922; J. Barker, pers. comm.; A. White, pers. obs.). Of the highland populations, only the one at Cooma has been reported to contain more than 50 individuals (P. Johnston, pers. comm.). Along the coast to the north of Sydney the species was rarely seen in numbers greater than 20 animals (J. Barker, pers. comm.; A. White, pers. obs.).

Observed populations of the Green and Golden Bell Frog in Victoria have apparently been of comparable size to those in the Greater Sydney Area. Populations exceeding 100 individuals have been reported from the Gippsland Lakes area and the river valleys north of there (W. Sherwin, pers. comm.; G. Gillespie, pers. comm.).

(f) Abundance after 1990

Since 1990 there is more information available regarding the numbers of Green and Golden Bell Frogs observed or detected at a site.

This enables a clearer picture of present abundance patterns to be assessed.

Most presently-known populations of the Green and Golden Bell Frog in New South Wales are apparently quite small. Since 1990 there are only four locations where more than 20 individuals were detected using standard methods of sampling (Tables 3 and 4). These somewhat exceptional sites are at Coomonderry Swamp, Homebush Bay Brick Pit, Port Kembla and Wanda (Tables 3 and 4).

(1) Abundance since 1990 in Greater Sydney Area

The largest known extant populations of Green and Golden Bell Frogs in New South Wales occur in the Greater Sydney region and inhabit highly disturbed sites. The disused State Brick Pit site at Homebush Bay appears to have the largest population with estimates of frog numbers exceeding 50 frogs (Greer 1994, pers. comm.; Pyke 1995; M. Christie, pers. comm.). The other large population of Bell Frogs found in Sydney occurs at Wanda in flooded sand dredge pits at an old sand mining site. The population here has been estimated at about 50 frogs (A. Greer, pers. comm.).

Other smaller populations are known in areas that have historically had larger populations in the past in close proximity. For example, in the Liverpool region, there are still small populations of Bell Frogs known from Milperra to Hammondville. None of the populations in this area are known to exceed six animals (A. White, pers. obs.).

Not all extant populations of Green and Golden Bell Frogs can be traced to a historical source. An unusual population of Bell Frogs appeared at North Ryde in 1992 in newly constructed lungfish ponds. There are no records of Bell frogs from this area prior to this date and the source of these animals remains undetermined. These frogs, numbering only four adults, spawned at this site in 1992/93 and again in 1993/94, but were absent from the site in 1994/95 (J. Joss, pers. comm.).

The assessment of Bell Frog population sizes based on the number of animals sighted or heard calling using standard techniques can be misleading. The Rosebery population in eastern Sydney was surveyed a number of times in 1992 and 1993 using traditional, non-invasive methods. The maximum number of adult frogs observed was six. This site is small, well-demarcated and has little ground vegetation. It was suitable for an intensive survey that involved the physical removal (and later replacement) of all shelter materials. During this survey, which was conducted in September 1993, 33 adult frogs were found by the Frog and Tadpole Study

Group of New South Wales (FATS). The Rosebery site has recently been approved for residential subdivision and this site will be destroyed as frog habitat in the next few years (A. White, pers. obs.).

(2) Abundance since 1990 outside of the Greater Sydney Area

Most populations of Green and Golden Bell Frogs outside of Sydney are small (less than 10 adult frogs observed at one time; Table 4). The exceptions are Coomonderry Swamp, near Nowra, and Port Kembla. In November 1993, 20 calling or breeding Green and Golden Bell Frogs were observed in cattle pasture on the western edge of Coomonderry Swamp (H. Ehmann, pers. comm.). Other smaller breeding aggregations have been recorded elsewhere around the edge of the swamp (Murphy 1995). Coomonderry Swamp is a large freshwater lagoon and is relatively undisturbed. The Port Kembla site, in contrast, is an artificial and greatly confined site. Despite this, 22 adult Bell Frogs were observed in December 1994 (T. van de Mortel, pers. comm.).

(g) Inter-connected Populations

The four large extant populations of Green and Golden Bell Frogs are surrounded by other smaller Bell Frog localities. For example, the Homebush Bay population lies less than a kilometre from another breeding Bell Frog population (at Newington). Recent observations on these two populations (White, unpubl. data) has revealed that migration of animals occurs between these two localities.

Observations in the Kurnell area indicate that there is probable movement of individuals between the Wanda population of Green and Golden Bell Frogs and other smaller populations scattered throughout the Kurnell Peninsula. In 1992, 12 adults of the species were located in the Botany Bay National Park (Carbon Black site, see Table 4) in 1992 (K. Griffiths, pers. comm.) but none were located at Wanda (A. White, pers. obs.). On the other hand, during the 1994/95 breeding season, the majority of Bell Frogs found in the Kurnell area were at Wanda while fewer individuals were found at North Kurnell, South Kurnell and Woolooware. These observations suggest that sites vary in the area and over time with regard to their suitability for breeding by the Green and Golden Bell Frog and that there is likely to be dispersal of frogs from successful sites to others.

A similar inter-connected population of the species apparently occurs around the less disturbed site at Coomonderry Swamp. In this case the species has been found in a number of distinct but nearby locations (e.g., Murphy 1994; Daly 1994) The Coomonderry population is

within easy dispersal distance of the population known from Shoalhaven Heads on the north side of the Shoalhaven River (A. White, pers. comm.; G. Daly, pers. comm.).

(h) The Eastlakes Population

The population of Green and Golden Bell Frogs at Eastlakes in the south-east of Sydney is the only site that has been monitored over a long period of time. The first quantitative records were made (by A.W.) in October 1967 and the area has been surveyed (by A.W.) a number of times each year since.

This population has shown declines in both the abundance of the species and in the number of occupied water bodies (Fig. 5). In the summer of 1967/68 138 adult Bell Frogs were located in four major water bodies at Eastlakes. At that time the largest assemblage of calling males was from the marsh land below the main weir and from channels near the northern end of the Eastlakes system. In addition, just four calling males were heard in the pond to the south of Wentworth Road. However, the 1968/69 season was the last time that the species was heard calling from this last mentioned pond. After that, the number of occupied ponds had fallen to three. By 1981/82 Green and Golden Bell Frogs could only be found in two of the four water bodies. At this time the two most northern water bodies were still being used by the Bell Frogs as shelter, basking and calling sites, but the maximum number of active frogs had fallen to 15. Subsequently, the summer of 1987/88 was the last time that the species was seen or heard in the marsh land below the weir. During that season seven adult Bell Frogs were observed in the northern channel. Since the 1994/95 summer Bell Frogs have not been found anywhere in the area, and the species may be locally extinct in the area.

The Eastlakes population of Green and Golden Bell Frogs would previously have been connected with other nearby populations of the species. Prior to 1945 it was continuous with the Botany Swamps, a region noted above for its large populations of the species. More recently, the Eastlakes system was surrounded by a number of artificial sites at which the species was found. These sites had been created on surrounding golf courses, sand mining sites and the Kingsford Smith Airport.

Most of these other nearby populations of the species declined and disappeared over the same time period as the decline in the main Eastlakes population. For example, within the land occupied by Kingsford Smith Airport two calling males Green and Golden Bell Frogs were found during the 1992/93 season. However, the species has not been found there since then.

The only population of the original Eastlakes system that has apparently survived is located in a highly disturbed site at Rosebery. This population has probably been isolated from the rest of the Eastlakes population since the Southern Cross Freeway was built in the 1960s and must have persisted for about 30 years. This site remained free from invasion by Mosquito Fish and water weeds, and has no visible signs of eutrophication; these factors have probably contributed to the survival of the population. By comparison, other water bodies in the Eastlakes area have suffered extensively from these adverse impacts:

(i) Breeding of Green and Golden Bell Frogs

For Green and Golden Bell Frogs to be able to persist at a location, they must be able to breed successfully. There are, however, only 14 locations known where breeding has been observed (i.e., eggs, tadpoles or young of that year found) after 1990. These locations, and the attributes they share, are discussed further in Pyke and White (1996).

DISCUSSION

The results indicate that the broad distribution of the Green and Golden Bell Frog, and possibly its local abundance, have declined since 1960 and that this decline may be continuing, and that the species may now be considered rare. There is therefore ample justification for the present inclusion of the species on Schedule 1 of the *Threatened Species Conservation Act 1995* in New South Wales. If the decline is still continuing a recovery plan will be required soon for the species in New South Wales to attempt to ensure that it does not become extinct in this state.

The Green and Golden Bell Frog is presently very poorly conserved in New South Wales. Of the 43 locations for the species that have been recorded since 1990, only nine occur in conservation reserves (i.e., Station Creek and Blue Lake in Yuragir National Park; Bowen Island and Murray Beach in Jervis Bay National Park, Coomonderry Swamp (part of which lies in the Seven Mile Beach National Park), Nadgee Nature Reserve, Kilalea State Recreational Reserve, Myall Lakes National Park and the Botany Bay National Park) and the populations at all of these locations appear to be relatively small (see Tables 3 and 4). None of the four large populations are presently protected in conservation reserves. Breeding sites for the Coomonderry Swamp Green and Golden Bell Frogs are on private land, although the swamp does extend into the Seven Mile Beach National Park. No breeding was observed in the national park (Murphy 1995). The Homebush Bay locations occur on land managed by the Olympic Co-ordination Agency (see Greer 1994; Pyke

1995). The Wanda Beach location occurs on disused sand mining areas that are privately owned.

The decline in the distribution and abundance of the Green and Golden Bell Frog in New South Wales is probably the result primarily of alterations to drainage patterns and of the introduction and spread of the Mosquito Fish *Gambusia holbrooki*. In New South Wales the species apparently requires, in order to breed successfully, ponds which are ephemeral or fluctuate significantly in water level and which receive reasonably unpolluted water (Pyke and White 1996). Such ponds have, to a large degree, been replaced with ponds which are polluted, relatively permanent or both. In order to breed successfully, the species also requires ponds that are free of predatory fish, especially the introduced Mosquito Fish (Pyke and White 1996). This fish, which readily consumes eggs or tadpoles of the Green and Golden Bell Frog (White, unpubl. obs.; Webb 1994; Morgan 1995), was initially introduced into New South Wales in 1925 and has increased greatly in distribution and abundance, especially since about 1950 (Myers 1965). By the 1980s these fish were present in New South Wales in all of the major drainage systems east of the Great Divide and in a number of rivers west of the Divide (Merrick and Schmida 1984). The decline of this frog species, which apparently occurred most severely during the 1960s and 1970s, appears to have lagged behind but coincided with the expansion of populations of Mosquito Fish in eastern New South Wales.

No similar decline in distribution and/or abundance of the Green and Golden Bell Frog in Victoria is so far apparent (Gillespie 1996). There are no known Victorian populations of the species that have disappeared and no populations are known to have declined in abundance (Gillespie 1996). However, the species has not been subject to the same survey effort in Victoria as in New South Wales and further surveys are necessary in Victoria before the status of the species there will be clear (Gillespie 1996). The east Gippsland region of Victoria has been generally spared from the introduction of *Gambusia* and efforts are being made in that state to prevent these fish from invading natural waterways. The Green and Golden Bell Frog locations in Victoria are also rather different to those in New South Wales in that many of them are in low altitude coastal river valleys surrounded by relatively untouched forestland.

The overall dynamics of the populations of Green and Golden Bell Frogs that are presently centred on a few relatively large known populations in New South Wales may be typical of what used to occur throughout the range of the

species and may indicate what will be required for conservation of the species. Essentially, each of these large populations consists of a number of locations where the abundance and breeding of the species fluctuates widely and between which there is movement of individuals. In these cases, long-term survival of each population may be enhanced through dispersal from locations that are temporarily very suitable for the species to locations that are less suitable. Small, isolated populations may ultimately perish because they are not recolonized. Conservation of the species may therefore require its protection and maintenance in areas that are large enough to always have locations within them that are suitable for the species and within dispersal distances of other temporarily unsuitable locations.

ACKNOWLEDGEMENTS

Recent collaborative research by the authors was supported by the Australian Museum and the Olympic Co-ordination Agency. Earlier research by A. White was supported by personal funds. We appreciate the many helpful comments and suggestions that we have received with regard to this paper, in particular, from Dr Allen Greer, John Barker and Dr Will Osborne.

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