

The distribution and status of the Giant Burrowing Frog *Heleioporus australiacus* in the Shoalhaven region of south-eastern New South Wales

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ABSTRACT

Surveys were conducted for the Giant Burrowing Frog *Heleioporus australiacus* within 50 km of Nowra, on the south coast of New South Wales using a variety of methods. Thirty-eight 250 m transects were surveyed at night for 30 min each and 0-12 adult frogs were detected during these searches. Additional diurnal searches for tadpoles proved to be the most efficient method to detect the species and locate breeding sites. Of 102 sites surveyed, fragmented populations were found at 27 by the presence of tadpoles and adult frogs. The vegetation at these sites was woodland and open forest with a dense shrublayer of heath, but was often ecotonal. Forty-six percent of the sites were within 100 m of cliff edges/waterfalls. The lithology of sites where the frog was found varied from Hawkesbury, Nowra and Snapper Point sandstones. The exception was a population south of Ulladulla that occurs on undifferentiated sediments, but at that site exposed sandstone and a sandy overlay was present. The location of tadpoles indicated that adults were highly selective of the section of drainage line used for breeding. Often these sites consisted of a few small pools in non-perennial creeks. Breeding behaviour was associated with late summer and autumn rain, but in some sites reproduction did not occur annually. Based on distribution and habitat preference, the region has five discrete populations. Urban development has fragmented populations.

Key words: *Heleioporus australiacus*, populations, habitat preference, Nowra, New South Wales

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Introduction

The Giant Burrowing Frog *Heleioporus australiacus* (Gray, 1835) is listed in New South Wales (NSW) as vulnerable under the *Biodiversity Conservation Act, 2016* and the *Environment Protection and Biodiversity Conservation Act, 1999*. The species distribution lies between Traralgon, Victoria to central (Putty State Forest) NSW (Atlas of Living Australia accessed 1/7/16). However, within this area the populations are highly fragmented and a major disjuncture occurs for 100 km between Narooma and Nowra (Daly 1996), suggesting the species may consist of two taxa (Daly 2006, Penman *et al.* 2004, 2005). This suggestion has been supported by genetic and morphometric evidence (M.J. Mahony and S.C. Donnellan, unpubl. data cited in Penman *et al.* 2005).

The Giant Burrowing Frog occupies a range of substrates and vegetation communities and this wide variation in habitat is profoundly different for that occupied by the southern and northern taxa. The southern species is found in montane sclerophyll woodland, montane riparian woodland, lowland-near coastal woodland, wet, damp and dry sclerophyll forest (Penman *et al.* 2004, 2008, Gillespie 1990, Littlejohn and Martin 1967) on a range of substrates, but absent from large river valleys (Penman *et al.* 2005). In contrast, populations north of Ulladulla (including

those studied here) are associated with first order streams on sandstone shelves and heath/woodland (Daly 1996, Rescei 1996, Webb 1993, Stauber 2006).

In view of the species status and its reputation as being difficult to detect (Gillespie 1990, Daly 1996, Lemckert *et al.* 1998, Penman *et al.* 2006a) I conducted targeted surveys in the Shoalhaven local government area in south-eastern NSW, being the southern limit of the northern taxa. The primary aims were to better inform the distribution and population size in this area, and to describe the floristics and the geology of occupied sites.

Methods

Study area

Survey sites were within Beecroft Peninsula (5250 ha), Booderee National Park (NP) plus associated freehold land (6380 ha), Bomaderry Creek bushland (230 ha), Bugong NP (1007 ha), Cambewarra Range NP (1680 ha), Colymea State Conservation Area (1671ha), Conjola NP (11593 ha), Jerrawangala NP (4026 ha), Jervis Bay NP (5000 ha), Kangaroo River NR (118 ha), Parma Creek Nature Reserve (3642 ha), Morton NP (199667 ha),

McDonald State Forest (3788 ha) and adjoining crown lands (Table 1). These sites are located within 50 km of Nowra on the south coast of NSW (Figure 1).

Booderee NP adjoins a portion of Jervis Bay NP to form a near contiguous block of bushland. Bugong NP and Cambewarra Range NP and similarly Colymea SCA, Parma Creek NR, and Jerrawangala NP are also linked by native vegetation. Bomaderry Ck bushland is isolated by surrounding urban and agricultural development. The Shoalhaven River separates Bugong NP and Cambewarra Range NP from Colymea SCA, Parma Creek NR and Jerrawangala NP. Portions of Morton NP are located north and south of the Shoalhaven River and adjoin Bugong NP and Jerrawangala NP. Booderee NP is a Federal National Park, whereas the other parks and forest are state managed.

Site selection

Since the Giant Burrowing Frog occurs in the upper reaches of small drainage lines (Webb 1987, Daly 1996, Rescei 1996, Webb 1993, Stauber 2006) a search site was defined by the specific arm of that drainage line. Sites were targeted to include those with historic occurrences of the frog (Daly 1996, 2006 and Murphy and Daly 1998) or the presence of first order creeks that flowed over sandstone in open forests with a xeric shrublayer. Sites were often selected by reviewing topographic and geological maps and searching for the appropriate sized drainage line in relation to road or

track access. Most sites that were subject to nocturnal searches were selected on the basis that they supported tadpoles that were observed during diurnal surveys conducted prior to spotlight searches.

Survey methods

A total of 102 sites (nocturnal plus diurnal) were searched over a 25 year period (Table 2). Diurnal surveys involved walking beside creeks looking for tadpoles and spawn. Nocturnal stream-side surveys were primarily conducted within the accepted calling period for the species that is between December and June (Daly 1996, Lemckert and Mahony 2008), often after periods of intense rain to enhance detection. Additional streamside searches conducted outside the known calling period focused on detecting tadpoles.

Thirty-eight 250 m long stream side transects were sampled for 30 min each along select creeks at night (NPWS 1997). Some of these sites were surveyed repeatedly over a number of years. A total of 94 (i.e. 47 hrs with 56 being replicate surveys) nocturnal stream-side transects were conducted by the use of 50 watt, 12volt spotlights or LED spotlights from 1994 to 2017. These transects were usually separated by a distance of at least 1 km. In addition, some night-time surveys did not conform with the standard 30 min search. These so - called aural spot-searches were conducted for periods of between 5-15 min during the accepted calling period. A total of about 62 hrs were

Table 1. Areas of reserves and State Forest surveyed, elevation range, and numbers of frog survey sites in the Shoalhaven Area.

Note: data on Bomaderry Creek bushland includes the regional park. (n) = number of sites where Giant Burrowing Frogs detected either by the presence of tadpoles and or adults. * indicated data from other parties.

Reserve or State Forest	Area (ha)	Number of sites	Min. elevation (m AHD)	Max. Elevation (m AHD)
Becroft Peninsula	5250	10 (0)	5	80
Booderee NP	6380	19 (7)	20	130
Bomaderry Creek bushland	230	2 (1)	30	30
Bugong NP	1007	3 (1)	180	190
Cambewarra Range NP	1680	1 (1)	570	570
Colymea SCA	1671	1 (0)	1010	1010
Conjola NP	11593	24 (0)	20	390
Crown Land	10	5 (4)	180	310
Freehold	29	2 (2)	100	160
Jerrawangala NP	4026	3 (2)	90	370
Jervis Bay NP	5000	7 (1)	30	80
Kangaroo River NR	118	1 (0)	100	100
Parma Creek NR	3642	3 (0)	125	125
Morton NP	199667	10 (5)	380	700
McDonald State Forest	3788	3 (1)	20	150
Local Government*	30	8 (2)	30	160
Total	244121	102 (27)		

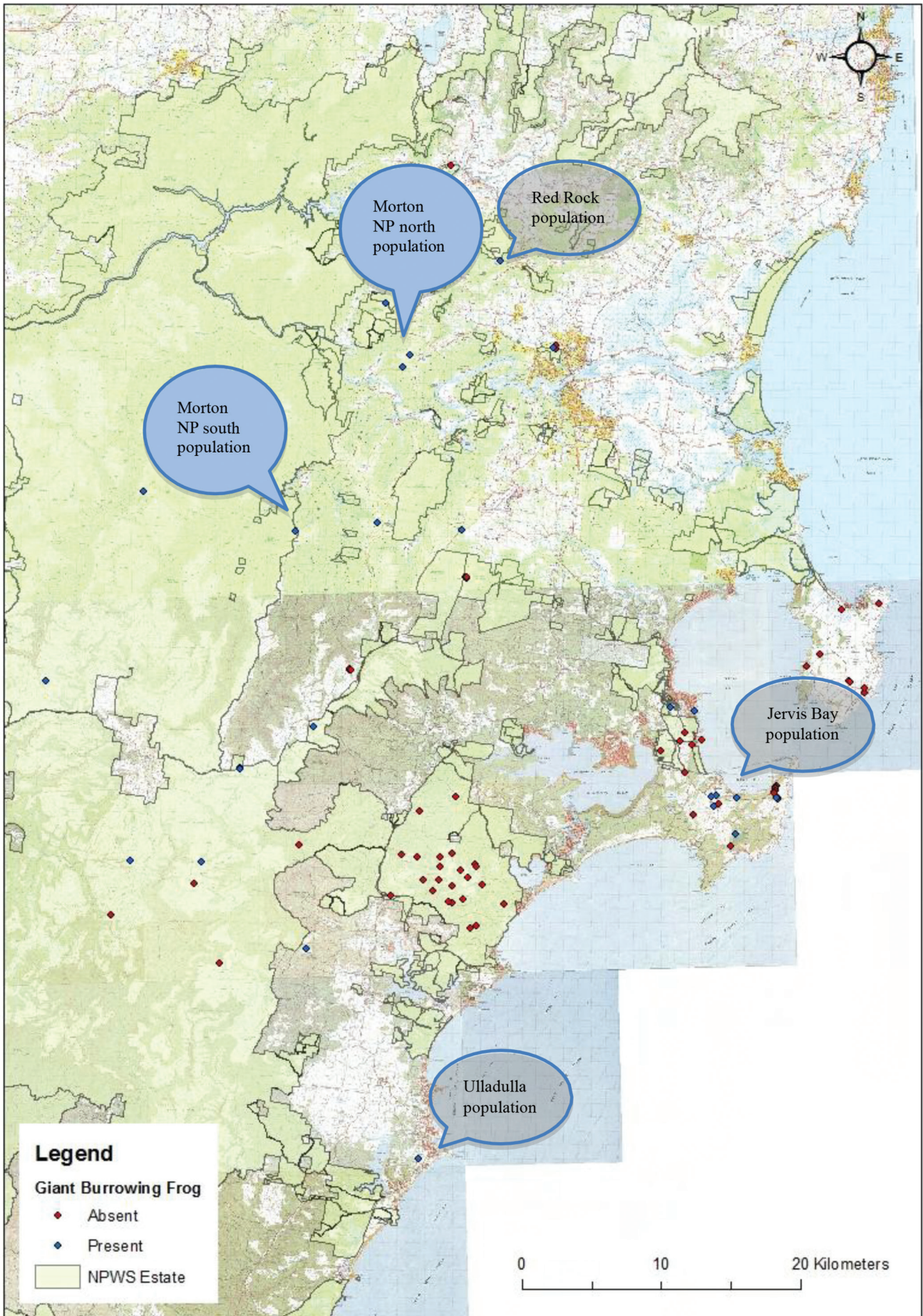


Figure 1. Giant Burrowing Frog survey sites and populations

Table 2. Site locations, date and effort for surveys.
Eastern Standard Time used for search periods.

Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
1	Beecroft Peninsula	5	16.3.95	0	Nocturnal survey
2	Beecroft Peninsula	15	16.3.95	0	Nocturnal survey
3	Beecroft Peninsula	80	16.3.95	0	Nocturnal survey
4	Beecroft Peninsula	80	16.3.95	0	Nocturnal survey
5	Beecroft Peninsula	80	8.11.95	0	Nocturnal survey
6	Beecroft Peninsula	80	16.3.95	0	Nocturnal survey
6	Beecroft Peninsula	80	19.3.95	0	Nocturnal survey
6	Beecroft Peninsula	80	27.8.95	0	Nocturnal survey
7	Beecroft Peninsula	10	16.3.95	0	Nocturnal survey
7	Beecroft Peninsula	10	19.3.95	0	Nocturnal survey
8	Beecroft Peninsula	80	22.5.95	0	Nocturnal survey
9	Beecroft Peninsula	20	-.3.95	0	Diurnal survey
10	Beecroft Peninsula	25	-.3.95	0	Diurnal survey
11	Booderee NP	20	3.3.94	tadpoles	Diurnal survey
12	Booderee NP	40	23.3.94	tadpoles	Diurnal survey
12	Booderee NP	40	9.5.94	tadpoles	Diurnal survey
12	Booderee NP	45	22.2.05	0	19.30-20.00
13	Booderee NP	45	22.2.05	1 adult female on road	Nocturnal dive transect
14	Booderee NP	40	22.2.05	tadpoles	Diurnal survey
15	Booderee NP	140	22.2.05	2 calling	20.16-20.46hrs
16	Booderee NP	140	22.2.05	0	20.56-21.26 hrs
16	Booderee NP	140	26.4.15	1 calling not seen	Nocturnal survey
17	Booderee NP	75	22.2.05	0	22.05-22.35 hrs
18	Booderee NP	40	23.5.05	0	19.40-20.10 hrs
19	Booderee NP	60	23.5.05	0	Nocturnal survey
20	Booderee NP	40	24.7.16	0	Diurnal survey
21	Booderee NP	40	24.7.16	0	Diurnal survey
22	Booderee NP	40	24.7.16	0	Diurnal survey
23	Booderee NP	40	24.7.16	0	Diurnal survey
24	Booderee NP	40	24.7.16	0	Diurnal survey
25	Booderee NP	40	24.7.16	0	Diurnal survey
26	Booderee NP	40	24.7.16	6 tadpoles	Diurnal survey
27	Booderee NP	40	24.7.16	0	Diurnal survey
28	Booderee NP	40	24.7.16	0	Diurnal survey
29	Booderee NP	30	1.4.17	0	Diurnal survey

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Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
30	Local government	30	16.5.92	1	Nocturnal survey
31	Local government	30	30.3.93	0	Diurnal survey
31	Local government	30	3.4.93	0	Nocturnal survey
31	Local government	30	9.7.93	0	Diurnal survey
31	Local government	30	21.2.96	0	22.00-22.15 hrs
31	Local government	30	4.3.96	0	22.00-22.15 hrs
31	Local government	30	2.5.96	0	Nocturnal survey
31	Local government	30	6.5.96	0	19.00-19.15 hrs
31	Local government	30	7.5.96	0	20.00-20.30 hrs
32	Local government	159	18.4.02	1 adult male	Nocturnal (M. Norton pers. comm.)
33	Local government	30	10.2.97	3 active during day	Diurnal (K. Mills, pers. comm.)
34	Local government	30	4.5.16	0	Diurnal survey
35	Local government	30	19.8.16	0	Diurnal survey
36	Local government	30	25.3.17	0	Nocturnal survey
37	Local government	30	25.3.17	0	Nocturnal survey
38	Bomaderry Ck RP	30	25.3.08	0	19.57-20.27 hrs
39	Bomaderry Ck RP	30	12.2.94	0	Nocturnal survey
39	Bomaderry Ck RP	30	22.1.15	0	19.52-20.22 hrs
39	Bomaderry Ck RP	30	8.2.15	0	19.36-20.46 hrs
39	Bomaderry Ck RP	30	18.3.15	0	18.47-19.07 hrs
39	Bomaderry Ck RP	30	23.3.15	0	18.24-19.54 hrs
39	Bomaderry Ck RP	30	23.4.15	0	20.00-21.00 hrs
40	Bugong NP	190	6.1.95	0	Nocturnal search
40	Bugong NP	190	10.7.94	tadpoles	Diurnal survey
40	Bugong NP	190	6.1.95	0	Nocturnal search
40	Bugong NP	190	6.3.95	2 calling not seen	c. 19.30 hrs
40	Bugong NP	190	24.2.96	0	Nocturnal search
40	Bugong NP	190	27.2.96	0	21.00-21.15 hrs
40	Bugong NP	190	28.2.96	0	c. 21.00-21.15 hrs
40	Bugong NP	190	4.3.96	0	21.00-21.15 hrs
40	Bugong NP	190	29.3.96	0	Diurnal search
40	Bugong NP	190	14.4.96	0	21.00-21.15 hrs
40	Bugong NP	190	2.5.96	0	Nocturnal survey
40	Bugong NP	190	6.5.96	0	20.00-20.15 hrs
40	Bugong NP	190	5.6.96	0	Nocturnal survey
40	Bugong NP	190	13.2.97	0	Nocturnal survey

Surveys of the Giant Burrowing Frogs in the Shoalhaven

Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
40	Bugong NP	190	29.5.97	50 tadpoles. Two size classes.	Diurnal survey
40	Bugong NP	190	12.6.97	0	Diurnal survey
40	Bugong NP	190	17.9.97	0	Nocturnal survey
40	Bugong NP	190	5.10.97	0	Nocturnal survey
40	Bugong NP	190	12.10.97	0	Nocturnal survey
40	Bugong NP	190	16.12.97	0	Nocturnal survey, creek dry
40	Bugong NP	190	8.5.98	0	Diurnal survey
40	Bugong NP	190	17.9.98	0	Diurnal survey
40	Bugong NP	190	9.3.02	0	20.32-21.02 hrs
40	Bugong NP	190	25.3.08	2 calling not seen	18.37-19.07 hrs
40	Bugong NP	190	8.2.10	0	19.28-29.58 hrs
40	Bugong NP	190	15.2.10	0	19.35-20.05 hrs
40	Bugong NP	190	26.2.13	0	19.24-19.54 hrs
40	Bugong NP	190	26.3.14	0	19.21-19.51 hrs
40	Bugong NP	190	23.4.15	0	19.09-19.19 hrs
40	Bugong NP	190	20.3.17	0	18.46-19.16 hrs
41	Bugong NP	200	13.2.97	0	Nocturnal search
41	Bugong NP	200	12.10.97	0	Nocturnal survey
41	Bugong NP	200	17.9.98	0	Diurnal survey
42	Bugong NP	160	6.1.95	0	Nocturnal search
42	Bugong NP	160	5.9.97	0	Diurnal search
42	Bugong NP	160	5.10.97	0	Nocturnal search
42	Bugong NP	160	17.9.98	0	Diurnal search
42	Bugong NP	160	26.2.13	0	21.02-21.32 hrs
43	Cambewarra Range NR	570	29.1.98	150 tadpoles	20.05-20.35 hrs
43	Cambewarra Range NR	570	-.1.10	0	Diurnal survey
43	Cambewarra Range NP	575	9.2.10	2 males one calling, one observed	20.08-20.38 hrs
44	Conjola NP	10	25.5.08	0	Diurnal survey
45	Conjola NP	70	26.3.08	0	Diurnal and nocturnal surveys
46	Conjola NP	30	26.3.08	0	Diurnal and nocturnal surveys
47	Conjola NP	20	26.3.08	0	19.46-20.06 hrs
48	Conjola NP	50	25.5.08	0	Nocturnal search
49	Conjola NP	290	25.5.08	0	Diurnal search
50	Conjola NP	60	25.5.08	0	Diurnal search
51	Conjola NP	30	25.5.08	0	Diurnal search
52	Conjola NP	40	25.5.08	0	Diurnal search
53	Conjola NP	100	25.5.08	0	Diurnal search

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Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
54	Conjola NP	70	23.5.08	0	Diurnal search
55	Conjola NP	60	23.5.08	0	Diurnal search
56	Conjola NP	40	23.5.08	0	Diurnal search
57	Conjola NP	30	23.5.08	0	Diurnal search
58	Conjola NP	40	23.5.08	0	Diurnal search
59	Conjola NP	50	23.5.08	0	Diurnal search
60	Conjola NP	50	23.5.08	0	Diurnal search
61	Conjola NP	30	25.5.08	0	Diurnal search
62	Conjola NP	50	25.5.08	0	Diurnal search
63	Conjola NP	50	25.5.08	0	Diurnal search
64	Conjola NP	70	25.5.08	0	Diurnal search
65	Conjola NP	40	24.5.08	0	Diurnal search
66	Conjola NP	30	24.5.08	0	Diurnal search
67	Conjola NP	10	24.5.08	0	Diurnal search
68	Crown land	300	17.2.09	0	17.29-17.59 hrs
69	Crown land	300	17.2.09	0	17.29-17.59 hrs
70	Crown land	220	16.2.10	1 adult male observed	19.37-20.07 hrs
71	Crown Land	220	28.3.96	24 tadpoles, one metamorphling	Diurnal search
71	Crown Land	220	11.3.96	20 tadpoles	Diurnal search
71	Crown Land	220	28.3.96	24 tadpoles plus metamorphs	Diurnal search
71	Crown Land	220	6.4.96	200 tadpoles	Nocturnal survey
71	Crown Land	220	12.6.97	0 - creek dry	Diurnal survey
71	Crown Land	220	8.5.98	0	Diurnal survey
71	Crown Land	220	8.2.10	0	20.25-20.40 hrs
71	Crown Land	220	15.2.10	0	20.30-20.40 hrs
71	Crown Land	220	23.4.15	0	19.33-19.43 hrs
71	Crown Land	220	22.9.15	15 tadpoles	Diurnal search
71	Crown Land	220	12.10.15	5 tadpoles	Diurnal search
71	Crown Land	220	23.3.17	0	19.34-19.43 hrs
72	Crown Land	190	28.3.96	16 tadpoles, one metamorphling	Diurnal search
72	Crown Land	190	2.4.96	1 tadpole	Diurnal search
72	Crown Land	190	6.5.96	0	Nocturnal search
72	Crown Land	190	5.6.96	100's of tadpoles	Diurnal search
72	Crown Land	190	12.6.97	0	Diurnal survey
72	Crown Land	190	8.5.98	0	Diurnal survey
72	Crown Land	190	8.2.10	0	20.45-20.50 hrs
73	Crown Land	310	10.9.03	2 tadpoles	19.45-20.15 hrs

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Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
74	Crown Land	180	6.1.95	0	Nocturnal survey
74	Crown Land	180	5.10.97	0	Nocturnal survey
74	Crown Land	180	12.10.97	0	Nocturnal survey
75	Freehold land	160	8.11.99	5 tadpoles	Diurnal survey
75	Freehold land	160	21.1.09	0	20.13-20.43 hrs
75	Freehold land	160	10.8.16	0	Diurnal survey
76	Freehold land	90	6.8.00	1 calling not seen	Diurnal survey G. Chapman
76	Freehold land	90	25.1.00	0	19.40-20.16 hrs
76	Freehold land	90	23.2.00	0	19.07-19.25 hrs
76	Freehold land	90	24.2.00	0	19.42-20.20 hrs
76	Freehold land	90	3.12.00	0	20.00-20.55 hrs
77	Jerrawangala NP	370	6.9.01	0	18.56-19.26 hrs
77	Jerrawangala NP	370	5.9.02	16 tadpoles	20.25-20.55 hrs
77	Jerrawangala NP	370	10.9.03	0	18.24-18.54 hrs
77	Jerrawangala NP	370	23.9.05	0	19.48-20.18 hrs
77	Jerrawangala NP	370	21.9.06	0	18.31-19.01 hrs
77	Jerrawangala NP	370	21.9.08	0	18.44-19.14 hrs
77	Jerrawangala NP	370	12.10.15	0	19.47-20.17 hrs
78	Jerrawangala NP	90	3.9.01	0	22.00-22.30 hrs
78	Jerrawangala NP	90	5.9.02	0	22.45-23.15 hrs
78	Jerrawangala NP	90	18.9.03	0	21.10-21.40 hrs
78	Jerrawangala NP	90	22.9.05	0	20.10-20.40 hrs
78	Jerrawangala NP	90	18.9.06	0	19.27-19.57 hrs
78	Jerrawangala NP	90	9.9.08	0	19.15-19.45 hrs
78	Jerrawangala NP	90	17.2.09	0	20.51-21.21 hrs
78	Jerrawangala NP	90	5.10.15	0	20.00-20.30 hrs
79	Jerrawangala NP	130	3.9.01	0	23.15-23.45 hrs
79	Jerrawangala NP	130	5.9.02	2 tadpoles	21.50-22.20 hrs
79	Jerrawangala NP	130	18.9.03	0	21.10-21.40 hrs
79	Jerrawangala NP	130	22.9.05	0	21.10-21.40 hrs
79	Jerrawangala NP	130	18.9.06	0	18.23-18.53 hrs
79	Jerrawangala NP	130	9.9.08	0	20.07-20.37 hrs
79	Jerrawangala NP	130	17.2.09	0	20.51-21.21 hrs
79	Jerrawangala NP	130	14.9.15	0	21.43-21.58 hrs
80	Jervis Bay NP	60	15.2.94	3 adults, 2 males.	Nocturnal survey
80	Jervis Bay NP	60	22.2.94	Spawn located under Sawsedge	Diurnal survey
80	Jervis Bay NP	60	12.2.94	0	Diurnal survey

Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
80	Jervis Bay NP	60	15.3.94	1 calling during overcast day	Diurnal survey
80	Jervis Bay NP	60	2.4.94	2 calling during the day	9.00-9.15
80	Jervis Bay NP	60	20.4.94	Spawn located under Coral Fern	Diurnal survey
80	Jervis Bay NP	60	29.5.94	1 calling during day post burn	14.00-14.15
80	Jervis Bay NP	60	9.6.94	1 calling	Nocturnal survey
80	Jervis Bay NP	60	5.1.96	8 tadpoles, one metamorphling	Diurnal search
80	Jervis Bay NP	60	21.2.96	1 calling	21.00-21.30 hrs
80	Jervis Bay NP	60	28.2.96	0	Nocturnal survey
80	Jervis Bay NP	60	3.4.96	2 tadpoles	Diurnal search
80	Jervis Bay NP	60	7.5.96	1 calling – 100m from creek	17.30-18.00 hrs
80	Jervis Bay NP	60	15.1.97	2 metamorphlings	Diurnal search
80	Jervis Bay NP	60	29.5.97	c.100 tadpoles	Diurnal search
80	Jervis Bay NP	60	1.5.98	c.4000 tadpoles	Diurnal search
80	Jervis Bay NP	60	25.2.03	1 adult	19.20-19.30 hrs
80	Jervis Bay NP	60	25.2.03	No tadpoles	19.30-20.00 hrs
80	Jervis Bay NP	60	13.3.03	5 calling	19.00-19.30 hrs
80	Jervis Bay NP	60	25.3.08	> 4 tadpoles	19.55-20.25 hrs
80	Jervis Bay NP	60	27.3.08	Tadpoles plus one spawn	Diurnal search
80	Jervis Bay NP	60	21.4.09	2 calling	21.02-21.16 hrs
80	Jervis Bay NP	60	21.4.09	4 calling	21.25-21.55 hrs
80	Jervis Bay NP	60	9.2.10	Observed 2 males and 1 female	20.45-21.07 hrs
80	Jervis Bay NP	60	9.2.10	5 calling	21.13-21.43 hrs
80	Jervis Bay NP	60	11.2.12	8 tadpoles	20.39-21.09 hrs
80	Jervis Bay NP	60	23.7.16	More than 9 tadpoles	Diurnal search
80	Jervis Bay NP	60	5.3.17	4 males, 1 female all seen	Nocturnal search
80	Jervis Bay NP	60	6.3.17	9 adults 8 males 1 female, 6 sighted 2 heard calling	20.15 - 20.45 hrs
80	Jervis Bay NP	60	8.3.17	No tadpoles, 2 spawns 12 adult males 7 head, 6 sighted plus 2 sighted after survey	19.40 - 20.10 hrs
81	Jervis Bay NP	50	4.3.98	0	20.15-20.45 hrs
81	Jervis Bay NP	50	11.2.10	0	19.43-20.13 hrs
82	Jervis Bay NP	30	11.4.98	0	18.30-19.00 hrs
83	Jervis Bay NP	80	11.2.10	0	21.15-21.45 hrs
84	Jervis Bay NP	50	23.7.16	0	Diurnal survey
85	Jervis Bay NP	50	23.7.16	0	Diurnal survey
86	Jervis Bay NP	50	23.7.16	0	Diurnal survey
87	McDonald SF	150	18.9.13	25 tadpoles	Diurnal search

Surveys of the Giant Burrowing Frogs in the Shoalhaven

Site number	Tenure	Alt.	Date of survey	Number of Giant Burrowing Frogs detected	Survey Period (hours EST)
87	McDonald SF	150	26.7.17	68 tadpoles	Diurnal search
87	McDonald SF	150	26.7.17	0	Diurnal search
88	McDonald SF	20	19.8.16	0	Diurnal search
89	Morton NP	380	16.3.02	5 tadpoles	Diurnal survey
90	Morton NP	630	4.9.02	3 tadpoles	19.20-19.50 hrs
91	Morton NP	700	30.10.07	10 tadpoles	Diurnal survey
92	Morton NP	560	3.5.08	tadpoles	Diurnal survey
93	Morton NP	700	1992	tadpoles	Diurnal survey
94	Morton NP	640	4.9.01	0	19.15-19.45 hrs
94	Morton NP	640	4.9.02	0	18.35-19.05 hrs
94	Morton NP	640	15.10.03	0	18.51-19.21 hrs
94	Morton NP	640	30.9.05	0	18.45-19.15 hrs
94	Morton NP	640	20.9.06	0	20.29-20.59 hrs
94	Morton NP	640	9.10.08	0	18.38-19.08 hrs
94	Morton NP	640	15.10.15	0	19.05-19.35 hrs
95	Morton NP	500	5.9.01	0	19.40-20.10 hrs
95	Morton NP	500	5.9.02	0	19.15-19.45 hrs
95	Morton NP	500	28.8.03	0	19.38-20.08 hrs
95	Morton NP	500	23.9.05	0	18.20-18.50 hrs
95	Morton NP	500	19.9.06	0	20.03-20.33 hrs
95	Morton NP	500	25.9.08	0	19.30-20.00 hrs
95	Morton NP	500	10.9.09	0	21.02-21.32 hrs
95	Morton NP	500	6.10.15	0	21.05-21.35 hrs
96	Morton NP	630	4.9.01	0	20.31-21.01 hrs
96	Morton NP	630	4.9.02	3 tadpoles	19.20-19.50 hrs
96	Morton NP	630	15.10.03	0	19.37-20.07 hrs
96	Morton NP	630	30.9.05	0	19.37-20.07 hrs
96	Morton NP	630	20.9.06	0	19.37-20.07 hrs
96	Morton NP	630	9.10.08	0	19.30-20.00 hrs
96	Morton NP	630	6.10.15	0	19.00-19.30 hrs
97	Morton NP	540	2.9.06	0	Diurnal survey
98	Morton NP	690	20.10.03	0	20.16-20.46 hrs
99	Parma Ck NR	310	19.9.03	0	21.00-21.30 hrs
100	Parma Ck NR	125	17.2.09	0	20.51-21.21 hrs
101	Parma Ck NR	125	17.2.09	0	20.51-21.21 hrs
102	Kangaroo River NR	110	5.3.03	0	20.18-20.48 hrs

spent conducting nocturnal searches (systematic and spot searches) over 53 of these sites.

The survey included sites at altitude from as low as 5 m and others to 700 m AHD (Tables 1 and 2). This variation in altitude meant that a range of vegetation communities were sampled. A description of the tree and shrub species, disturbance history and stream characteristics were undertaken for some sites. Nocturnal drive transects formed a component of the survey, but the distance travelled through potential habitat was not quantified.

Habitat

The soil landscape series sheet indicates that the study area has soils derived from Hawkesbury, Nowra and Snapper Point sandstone (Hazelton 1993) and undifferentiated sediments (Rose 1966). The environment within the immediate area of the creeks was relatively flat. The creeks had several well defined physical transitions ranging from non-perennial water on exposed sandstone rocks and rock pools that typically had a depth that ranged between 0.1-0.4 m. The vegetation communities at sites where frogs and tadpoles were detected have been classified by OEH (2013) and are described below. However, the sites were ecotonal, with two or more communities in close proximity to the creeks. This was especially the case where breeding sites were adjacent to escarpments.

Floristic communities where Giant Burrowing Frogs were detected

Red Bloodwood - Grey Gum shrubby forest (SR593)

The dominant species in this community are Red Bloodwood *Corymbia gummifera*, Grey Gum *Eucalyptus punctata* and Turpentine *Syncarpia glomulifera*. It has a diverse dry shrub understorey, including Narrow-leaved Geebung *Persoonia linearis*, Hair-pin Banksia *Banksia spinulosa*, Blunt-leaved Wattle *Acacia obtusifolia*, Black-eyed Susan *Tetratheca thymifolia*, Lace-beard Heath *Leucopogon lanceolatus*, Holly Lomatia *Lomatia ilicifolia*, Sunshine Wattle *Acacia terminalis*, Shrubby Platysace *Platysace lanceolata*, Spiny Bossiaea *Bossiaea obcordata*, Burrawang *Macrozamia communis* and Golden Glory Pea *Gompholobium latifolium*. This community occurred at altitudes between 100-600m AHD in Bugong NP, Jerrawangala NP and Parma Creek NR and adjoining crown lands along the escarpment edge.

Red Bloodwood - Blackbutt - Spotted Gum shrubby open forest on coastal foothills, southern Sydney Basin (SR592)

This association was recorded at one site in Jervis Bay NP (Vincentia) at 60 m AHD and a portion of the habitat at Ulladulla (Kevin Mills 1997). It had a canopy of Red Bloodwood and Blackbutt *Eucalyptus pilularis* but Spotted Gum *Corymbia maculata* was absent.

The shrublayer and understorey consisted of Coastal Banksia *B. integrifolia*, Saw-toothed Banksia *B. serrata*, Black She-oak *Allocasuarina littoralis*, Slender Rice Flower *Pimelea linifolia*, Hair-pin Banksia, *Persoonia linearis* and Holly Lomatia. This community occurs at altitudes below 100 m AHD.

Red Bloodwood - Hard-leaved Scribbly Gum - Silvertop Ash heathy open forest on sandstone plateau of the lower Shoalhaven Valley, Sydney Basin (SR 594)

The canopy consists of Red Bloodwood, Hard-leaved Scribbly Gum *Eucalyptus sclerophylla*, and Silvertop Ash *Eucalyptus sieberi*. There is a dense shrublayer consisting of Mountain Devil *Lambertia formosa*, Broad-leaved Geebung *Persoonia levis*, Hair-pin Banksia, Conesticks *Petrophile pedunculata*, Flaky-barked Tea-tree *Leptospermum trinervium*, Holly Lomatia, Variable Bossiaea *Bossiaea heterophylla*, *Hakea laevipes*, Carrot Tops *Platysace linearifolia*, Slender Rice Flower and Black-eyed Susan. This community occurs on sandstone plateaus from 150-700m AHD in the lower Shoalhaven area.

Red Bloodwood - Scribbly gum heathy woodland on sandstone plateau, Sydney Basin (SR 595)

The main canopy species included Red Bloodwood and Scribbly Gum. There is a dense layer of shrubs including Flaky-barked Tea-tree, Mountain Devil, Broad-leaved Geebung, Old Man Banksia *Banksia serrata*, Carrot Tops, Sweet Wattle *Acacia suaveolens*, Broad-leaved Drumsticks *Isopogon anemonifolius*, Eggs and Bacon *Dillwynia retorta*, Conesticks *Petrophile pulchella*, Hair-pin Banksia, *Bossiaea heterophylla*, Heath-leaved Banksia *Banksia ericifolia*, Prickly Moses *Acacia ulicifolia*, Prickly Broom Heath *Monotoca scoparia*, Finger Hakea *Hakea dactyloides*, Common Phyllota *Phyllota phyllicoides* and Dwarf Apple *Angophora hispida*. This community occurs on coastal sandstone plateaus such as those that exist in Jervis Bay NP, Booderee NP and Beecroft peninsula.

Silvertop Ash - Hard-leaved Scribbly Gum - Blue-leaved Stringybark heathy woodland on sandstone plateau, southern Sydney Basin SR625

The main canopy species are depauperate Silvertop Ash, Hard-leaved Scribbly Gum, Blue-leaved Stringybark *E. agglomerata* with associated species including Brittle Gum *E. mannifera*, and Narrow-leaved Peppermint *E. radiata* subsp. *radiata*. The shrublayer is dense consisting of Finger Hakea, Flaky-barked Tea-tree, Hair-pin Banksia, Sunshine Wattle, Broom Spurge *Amperea xiphoclada*, Tanton *Leptospermum polygalifolium* and Black She-oak. This community occurs on elevated sandstone country in Morton NP usually between 400-700 m ADH.

***Banksia - Red Bloodwood - Hard-leaved Scribbly Gum*
heathy open woodland on sandstone plateau, southern
Sydney Basin SR513**

This association has a dense shrub stratum dominated by Heath-leaved Banksia, Dagger Hakea *Hakea teretifolia* and Prickly Conesticks *Petrophile sessilis*. There are scattered Hard-leaved Scribbly Gum, Red Bloodwood and Yertchuk *E. consideriana* to 5 m. The ground cover consisted of Wiry Panic *Entolasia stricta*, Sheath Rush *Cyathochaeta diandra*, *Ptilothrix deusta*, Daisy-leaved Goodenia *Goodenia bellidifolia*, Blue Dampiera *Dampiera stricta*, *Leptocarpus tenax* and Scale Rush *Lepyrodia scariosa*. Morton Mallee-Heath may grade into Hanging Swamp (SR591). This association occurs on the Morton NP plateau (700 m ADH) and on the coast in Booderee (80 m ADH) (OEH 2013).

***Prickly Tea-tree - sedge wet heath on sandstone plateau,*
central and southern Sydney Basin, also known as
hanging swamp (SR591).**

This community has no canopy but a thick shrublayer of Prickly Tea-tree *Leptospermum juniperinum*, Weeping Baeckea *Baeckea linifolia*, Pink Swamp Heath *Sprengelia incarnata*, Blunt-leaf Heath *Epacris obtusifolia*, Dagger Hakea and Heath-leaved Banksia. It occurs in headwater valleys in the Morton NP on sandstone plateaus from 450-1100 m (OEH 2013).

***Turpentine - Red Bloodwood - Sydney Peppermint*
shrubby open forest on the foothills, southern Sydney
Basin and northern South East Corner (SR658)**

This community was represented at the one site in McDonald State Forest. The canopy suggested higher nutrient soils as it attained a height of 25 m. The main species present were Turpentine, Red Bloodwood, White Stringybark *E. globoidea* and Sydney Peppermint *E. piperita*. There was a xeric understorey consisting of Narrow-leaved Geebung, Lace-beard Heath, Stiff-leaved Wattle *Acacia obtusifolia*, Black-eyed Susan, Blueberry Ash *Elaeocarpus reticulatus* and Hair-pin Banksia. This community occurs in sheltered slopes with below 600 m. This site was located in McDonald SF.

Results

Survey results

Giant Burrowing Frogs were more easily detected by the presence of tadpoles than adults, with tadpoles being observed at 27 of the 102 sites. Fifteen of these 27 sites were resurveyed at night (spot and/or systematic searches) during weather conditions/season considered favourable to detect frogs. Adult frogs were detected at eight of these sites. The number of tadpoles at a site ranged from one to about 4000. Although not

measured, the depth of pools was between 0.1 - 0.4 m, with one outlier (Jervis Bay NP) being about 1.1 m.

Adult Giant Burrowing Frogs were detected during nine of the 94 nocturnal systematic searches. Some of these searches were conducted when the adults are known to be inactive and in these periods tadpoles indicated presence. The main method of detection was hearing calling males.

The number of frogs detected during the systematic searches ranged between 0 and 12 adults. The maximum number of adult frogs detected was within one 30 m section of the headwaters of a creek in Jervis Bay NP. This site was surveyed 28 times over the 23 years and was the most consistent location where frogs and tadpoles were detected. Assuming a balanced sex ratio it is estimated that the site supports about 24 adult frogs. This was the only site where the species was detected in Red Bloodwood – Blackbutt forest.

One frog was detected on a road during drive transects. The animal was active on a warm (circa 20°C), dry, still night. Other people (M. Norton and A Parsons pers. comm.) found frogs on or crossing tarred roads. Except for metamorphs found in drying pools, only one subadult was found, the animal being secreted in a crevice under a waterfall. Calling was recorded from February to May mainly on the night after intense rain. Calling was recorded primarily at night, but was also heard on four occasions during the day. Three adults were observed active on an overcast wet day (K. Mills pers. comm.).

Five spawns were located, over four breeding events in February, March and April, within 50 m of a creekline at one site in Jervis Bay NP. The eggs were slightly pigmented (Figure 2, also see Anstis 2013). One spawn was located under a creek bank and another in a seepage hole near a creek, but most were laid within the dead leaves of Sawsedge *Gahnia sieberiana* that grew over the creek. An observation of breeding at the same location was made. In this situation, spawns were located under a Sawsedge in the same location (see Daly 1996) with a 14 year separation between observations. Breeding was not recorded at sites annually. At one site, tadpoles were only detected twice over a period of 19 years, but this site was only surveyed for six of these years.

Distribution of populations

Giant Burrowing Frogs were detected at altitudes that ranged from 20-700 m AHD. With the exceptions of Conjola NP and Beecroft Peninsula the species was detected in all reserves that contained suitable habitat. Based on distribution, published habitat preference, clearing and the avoidance of steep slopes i.e. large streams rivers (Penman *et al.* 2007 - southern sibling species) the study area has five populations of Giant Burrowing Frog. Based on distance between occurrence records, lithology and vegetation the populations



Figure 2. Giant Burrowing Frog spawn located under Sawsedge showing slightly pigmented eggs.

were within the broader areas of the Budgong - Morton, Cambewarra Range NR (historically known as Red Rocks NR), southern peninsula of Jervis Bay, Jerrawangala - Morton, McDonald SF and Ulladulla (Fig 1). Genetic comparisons are recommended to elucidate generation time between populations.

The catchment of the Shoalhaven River from the Princes Highway bridge at the downstream end to Kangaroo Valley bridge upstream has suitable habitat for this species (woodlands on sandstone escarpments), however the size of the river between these two locations (and now the Tallowa dam) would potentially act as a barrier for a species that does not occur beside major drainage lines and has a morphology not suited to swimming. The Ulladulla population is an anomaly being found on clay based soils with a sandy surface layer.

Habitat used by the frog

Giant Burrowing Frogs were detected on plateaus and ridges in the sedimentary sandstones of the Hawkesbury (Figure 3), Nowra and Snapper Point sedimentary rock formations. The Cambewarra Range population occurs

on Hawkesbury sandstone that is the most southern occurrence of this lithology as surface rock in the Sydney Basin. The Jervis Bay (Vincentia plus Booderee NP populations) plus the McDonald SF population occur on Snapper Point sandstone and the remaining populations (north and south of the Shoalhaven River) occur on Nowra sandstone. Kevin Mills (1997) found three adults south of Ulladulla. This population occurs on undifferentiated sediments (Rose 1966) but searches at that site indicate that in some locations Snapper Point sandstone occurs at the surface.

Giant Burrowing Frogs were detected in a range of vegetation communities that had an open canopy and dense shrublayer of xeric species. The breeding sites were generally in areas that had low topographic relief, but 46% were within 100 m of cliff edges/waterfalls - cascades, indicating the species preference for breeding in the upper laterals of creeks.

In general the pools where tadpoles were detected were small (a few square metres) and shallow (less than 0.2 m). With the exception of the one site in Jervis Bay NP all others had relatively few tadpoles in one of two adjoining pools suggesting small populations. Within Booderee NP, a one kilometre section of trail crossed nine small drainage lines within a catchment. All sites had fringing vegetation and plunge pools at the distal end of culverts, yet only one supported Giant Burrowing Frog tadpoles. In this study tadpoles were found in three creeklines in association with road culverts and one creek that was dammed by a small (1.2 m) concrete wall.

Native crayfish (*Euastacus* spp) were detected within several of the creeks, but were absent from the Jervis Bay NP site. The exotic yabbie *Cherax destructor* was located in several catchments (Clyde River catchment and Parma Ck) in Morton NP. Apart from crayfish (Fisheries Act 1994), the sites were fish free.

Discussion

Status

Apart from one creek in Jervis Bay NP, Giant Burrowing Frogs occurred in small, scattered populations. This may be a reflection of the limited habitat available for a species that has specialised requirements for breeding and/or a low population density. With the exception of Jervis Bay NP only a small number of tadpoles were observed (Table 2), supporting the proposal that the species does not call and breed annually, but does show breeding site fidelity (Stauber 2006). The location of spawns under the same Sawsedge 14 years apart, suggests a high specificity of spawning sites. Although rigorous monitoring data are lacking, this study suggests at present the Giant Burrowing Frog occurs in widely spaced, small, disjunct populations within the study area.



Figure 3. Male Giant Burrowing Frog found in Cambewarra Range NR on Hawkesbury sandstone

The status of the Ulladulla population is unknown. Since the original detection a sports field has been constructed in the area and no frogs or tadpoles have been detected in subsequent surveys. No Giant Burrowing Frogs were found on Beecroft Peninsula or Conjola NP, even though suitable habitat exists in these areas. Given the difficulty in detecting this species, further surveys are required to ascertain if these are real absences.

Habitat at Giant Burrowing Frog sites

Previous accounts of the vegetation communities that Giant Burrowing Frogs occupy vary widely according to descriptions of the habitat of the northern and southern species. A considerable amount of work has been undertaken on BIOCLIM modelling for both taxa (Penman *et al.* 2005; Penman *et al.* 2007). BIOCLIM analysis indicated significant differences in the climatic profile for the northern and southern taxa underlying the importance of the current study to better inform the biophysical conditions that they use.

North of Ulladulla the species occurs in a range of vegetation associations in areas where sandstone occurs close to the surface and often within a few hundred metres of hanging swamps (Daly 1996, Stauber 2006, DECC 2007). The general associations are woodlands/

heaths with a dense understorey of xeric species (Webb 1983, Daly *et al.* 2009), a reflection of shallow infertile soils. The Ulladulla population is of special significance as it currently represents the southern limit of the northern taxa and occurs on an irregular substrate.

In NSW, habitat used by Giant Burrowing Frogs (woodlands and heath) experience fire with ecological sustainable intervals ranging between 7-30 years (OEH 2016). In all locations where the frog occurs wildfire, arson (OEH 2013), climate change (Hennessy *et al.*, 2005, DECCW 2010) and short fire intervals such as those applied in National Parks (target is 3-5% of total management area within a 5 year rolling average) occur. A fire regime applied to fit a management target may not directly kill frogs (Penman *et al.* 2006), but may alter vegetation structure and the habitat (Bradstock and Kenny 2003; Whelan *et al.* 2006) used by this long lived species. The impact of fire regimes on this species warrants further investigation.

Stauber (2006) analysed sites used by the Giant Burrowing Frog in the northern portion of the Sydney basin and found that the mean elevation was 242 m (range 20-1000 m); a similar result to that found here (248 m, range 20-700 m). He also found the geology at

occupied sites was mainly Hawkesbury sandstone with few populations occurring on Narrabeen sandstone. In the current study the species occurred on Hawkesbury sandstone, Nowra sandstone, Snapper Point sandstone and undifferentiated sediments, indicating a geologic preference for sandy substrates.

My survey results generally concur with previous studies that the breeding habitat is associated with first order creeks and hanging swamps on sandstone plateaus, on sandy soils that have a low fertility and in woodland and open forest with a xeromorphic understorey. Breeding sites were generally characterised by the presence of crayfish borrows, a result also found by other researchers (Stauber 2006). The exception was the site in Jervis Bay NP that supports the largest population of frogs. This site is located within tall open Blackbutt Forest and crayfish were absent.

Habitat corridors for the frog

Previous considerations of habitat corridors for the Shoalhaven herpetofauna considered geology as a driver for some species distributions (Daly 2000 and 2006). The Giant Burrowing Frog was found to be highly associated with sandy soils derived from several formations of sedimentary sandstones. In the north-west of Morton NP Hawkesbury sandstone overlays Nowra sandstone facilitating the dispersal of frogs associated with sandy substrates across geological boundaries (Daly 2006).

However, there are several anomalies in regard to the distribution of this species in the region. For example, Giant Burrowing Frogs at Cambewarra Range NR occur on an isolated block of Hawkesbury sandstone, surrounded by steep escarpments and different geologies. The Jervis Bay population is separated from similar habitat (Parma Ck NR) by a distance of about 10 km (Daly 2000) and

the Ulladulla population occurs on sandy clay soils with the closest sandstone shelves also being some 10 km away.

The northern Giant Burrowing Frog is relatively sedentary making an average movement of 45 m and up to 637 m (Stauber 2006), especially after rain (Lemckert and Brassil 2003). The low displacement distances reflects the species low dispersal ability (Stauber 2006). Frogs have been found to move through logged forest (Lemckert and Brassil 2003), but there are no records of the species being found in agricultural or urban landscapes. The species appears to be restricted to areas of native vegetation, but can cross small gaps such as roads. Populations can become isolated from the clearing of bushland. Clearing associated with urban developments has resulted in the Jervis Bay, Ulladulla and Bomaderry Creek populations being isolated, albeit the Jervis Bay (Daly 2000) and Ulladulla populations appeared to have been fragmented prior to recent human actions.

Although systematic monitoring over a range of sites has not been undertaken, within large conservation reserves such as Booderee - Jervis Bay NP and Morton NP and environs, the persistence of the species at present appears secure. This may not be the case for smaller reserves such as Bomaderry Creek and the Ulladulla population.

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