REPTILES & AMPHIBIANS

Citizen-Science Records of Dainty Treefrogs (*Chlorohyla gracilenta*) in Sydney, Australia

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Abstract.—The Dainty Treefrog (*Chlorohyla gracilenta*[1]) is endemic to coastal eastern Australia, with the Central Coast Region of New South Wales just north of Sydney recognized as its southern limit. We investigated records of *C. gracilenta* in the Sydney metropolitan area using two citizen-science databases, iNaturalist and the FrogID project. We found 42 unique records, 60% of which occurred in the Northern Beaches Local Government Area, with concentrations of detections in two particular suburbs. Similarly, approximately 19% of unique records were traced to one particular site in the Randwick Local Government Area. These concentrations potentially represent established populations, although sample-size limitations warrant targeted surveys for verification. In another six local government areas, records were broadly distributed. This preliminary study revealed some degree of persistence of *C. gracilenta* in Sydney, and demonstrated the value of citizen science for gathering such evidence.

[1] The assignment of this species to the genus *Chlorohyla* was recent (Donnellan et al. 2025). At the time of writing, the species was still referred to as *Litoria gracilenta* by the FrogID project (Australian Museum 2025) and *Ranoidea gracilenta* in iNaturalist (2025).

Seeking shelter in concealed spaces is characteristic for several anurans around the world. Several species are well adapted to anthropogenic habitats, such as urban areas, rural lands used for agricultural or horticultural production, and disturbed bushland remnants (Luscier et al. 2023; Bi et al. 2024; Manuel Serrano et al. 2024). In these landscapes, anurans frequently exploit anthropogenic structures as artificial refugia (White 2007; Mo 2017a). While these habits are being leveraged by scientists and wildlife managers for various research and management initiatives (Liberman et al. 2024; Van Helden et al. 2024; Waddle et al. 2024), they also provide possibilities for sheltering anurans to be inadvertently transported between locations, including areas outside the species' natural distribution (White and Shine 2009; Mo 2017b).

The Dainty Treefrog (*Chlorohyla gracilenta*) (Pelodryadidae) is a medium-sized hylid reaching 45 mm in body length (Fig. 1). It is endemic to the coastal zone of eastern Queensland and northeastern New South Wales (NSW), Australia (Cogger 2018), although members of the *C. gracilenta* species-group extend into neighboring landmasses (Menzies and Tyler 2004; Kraus 2013). The area around Gosford, commonly referred to as the Central Coast Region of New South Wales, is typically recognized as the southern limit of the species' distribution (Anstis 2007; Tyler and Knight 2011), which is just north of Sydney (Cogger 2018). However, hylid frogs are commonly transported accidentally in shipments of fruit and vegetables, earning them the colloquial name "banana box frog" (O'Dwyer et al. 2000; Hartigan et al. 2012), including *C. gracilenta* (Griffiths 2012; Mo and Oliver 2020).

In this study, we used occurrence data from two citizen-science databases to examine the extent of reported observations of *C. gracilenta* in the Sydney metropolitan area.

Methods

The first data source we used in this study was iNaturalist (2025), a joint initiative of the California Academy of Sciences and the National Geographic Society that commenced in 2008 and which already has proven useful to an array of scientific studies (e.g., Mesaglio and Callaghan 2021; Cull 2022; Daniels et al. 2022; Mo and Mo 2022, 2023; Rosa et al. 2022; López-Guillén et al. 2024). iNaturalist operates through registered application users uploading photographs and/or sound recordings of organisms or evidence of organisms' presence (e.g., tracks, nests, or sloughed skin), which are reviewed by fellow users who contribute suggestions for identification to the most specific taxonomic rank possible (Di Cecco et al. 2021). iNaturalist applies a data-quality assessment in which observations are classified as verifiable if the observation is dated, georeferenced, has one or more photographs or sound recordings, and is a free-living organism (not a captive animal or cultivated plant or fungus). Verified observations attain "research grade" status when a majority of at least two application users agree on the species identity

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Figure 1. A Dainty Treefrog (*Chlorohyla gracilenta*). Photograph by Matthew Mo.

(Campbell et al. 2023). This results in a database of georeferenced species records.

The second data source used in this study was the FrogID project, an initiative of the Australian Museum (2025) that commenced in 2017. This project operates principally through a smartphone application in which registered application users can submit 20–60-sec sound recordings of anuran vocalizations from the field that are identified by scientists working on the project, resulting in a database of georeferenced anuran species records (Rowley and Callaghan 2020). Comprehensive explanations of project procedures and technical details are provided in Rowley et al. (2019). As with iNaturalist, the FrogID project has proven useful for scientific studies, including mapping distributions of species (Cutajar et al. 2022; Rowley and Callaghan 2022) and post-event impact assessments (Rowley et al. 2020; Mitchell et al. 2024).

We searched for verified observations of *C. gracilenta* from the Sydney metropolitan area (33.53–34.28°S, 150.55–151.37°E) on iNaturalist on 1 November 2024, and the equivalent dataset on FrogID was extracted from its most recent data release (FrogID dataset 5.0, containing data from 10 November 2017 to 9 November 2022; Australian Museum 2022). For iNaturalist records, species identifications were confirmed by manually examining all photographs uploaded to records for characteristic external body features that distinguish *C. gracilenta* from similar species, such as the Red-eyed Treefrog (*C. chloris*) and Orange-thighed Treefrog (*C. xanthomera*). These characteristics were finely granular skin covering the tympana (smoother in *C. chloris* and *C. xanthomera*), green color of the forearms stopping abruptly at the elbows (transitional in *C. chloris* and *C. xanthomera*), and narrow white edging along the rims of the lower jaws (Tyler and Knight 2011; Cogger 2018).

We than mapped records to examine the distribution of reported sightings within the study area and searched for concentrations of sightings that could suggest potentially established populations. For iNaturalist records, the accuracy of location information was highly variable, with application users having options to report sighting locations within a selected margin of accuracy or obscure georeferencing. In the latter case, displayed locations are anywhere within a 30-km radius of the actual location. Despite these limitations, record metadata generally showed details of at least the suburb or the local government area in which the sighting was made.

Location information also provided a general overview of the types of localities where sightings were occurring (e.g., *C. gracilenta* reported in residential areas, garden retail stores, or remnant bushland). For iNaturalist records, photographs uploaded to each record provided visual interpretations of environmental settings surrounding the observations (e.g., *C. gracilenta* perched in vegetation, on substrates, or on anthropogenic structures).

Results

We found 53 records of *C. gracilenta* across eight local government areas in the study area (Fig. 2). iNaturalist (2025) provided 17 records, all of which were research grade, and the FrogID dataset 5.0 provided 36 records (Table 1). iNaturalist records were contributed by 13 unique application users, with two individuals each contributing three separate records (Table 2). For 10 of these records, application users had provided location information within a 300-m margin of accuracy (ranging from 5–240 m), whereas for the remaining iNaturalist records, application users either did not record a margin of accuracy (4 records) or had selected for georeferencing to be obscured (3 records). Record meta-

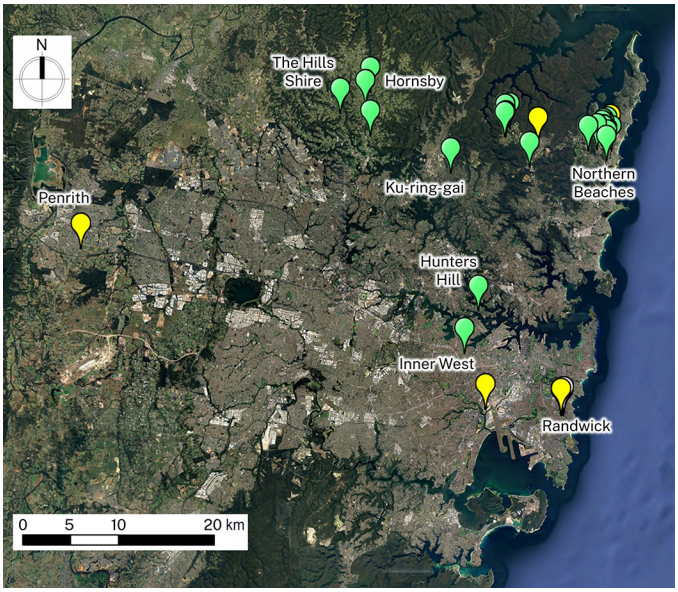

Figure 2. Locations of unique records of Dainty Treefrogs (*Chlorohyla gracilenta*) in the Sydney metropolitan area, Australia, reported in iNaturalist (yellow; only records within an accuracy margin < 300 m are shown) and the FrogID dataset 5.0 (green). Local government areas are labelled.

data for those four records indicated the suburb, whereas for the three obscured records, location was only identifiable to the local government area. Three pairs of iNaturalist records were potentially duplicates between different application users based on having the same observation dates, the same relative location, and the photographs showing similar-looking individuals (see footnotes 2–4 in Table 1). Similarly, seven pairs or groups of FrogID records were considered records of the same *C. gracilenta* vocalizing based on those records pertaining to a common observation date and general vicinity. Thus, of the 53 records, only 42 were probably unique.

The sample size from FrogID records stretched across a four-year period from January 2018 to March 2022, whereas the iNaturalist were all within a more recent three-year period from March 2020 to February 2024. More occurrences evidently were detected in the warmer months than the cooler months, with the highest numbers of records occurring in January and February and to a lesser extent in March and November (Fig. 3). Records from January and February comprised approximately half of the sample size of unique records.

All unique iNaturalist records, except one, had photographs that provided some indication of how *C. gracilenta* were positioned in the environment (Fig. 4). In half of these, photographs showed *C. gracilenta* perched in vegetation (7 records). Only one other unique record featured a photograph of *C. gracilenta* on a natural substrate, which was leaf litter on the ground. The remaining five unique records featured photographs of *C. gracilenta* on anthropogenic structures, one on a vertical sheet of glass, one in a door cavity, one on a concrete slab, and two on wooden platform structures.

Northern Beaches Local Government Area.— Approximately 60% of the unique records were 25 sightings that occurred in the Northern Beaches Local Government Area (Table 1). Almost half of these 25 unique records were from the suburb of Warriewood, with an additional four unique records originating from directly adjacent suburbs, Ingleside, Mona Vale, and North Narrabeen (Fig. 5). These records occurred within a period of just over two years, from January 2018 to February 2022. Within Warriewood, four instances involved pairs of unique records in the same relative

Table 1. Unique records of the Dainty Treefrog (*Chlorohyla gracilenta*) in Sydney. Where multiple records are suspected to be duplicates (likely same *C. gracilenta* recorded by more than one iNaturalist application user) or records pertaining to the same occurrence of *C. gracilenta* calling (FrogID), records are merged to represent a single unique record. Numbers of decimal points displayed for geographical coordinates are as available in the respective data sources. Accuracy margins are applicable only to iNaturalist records. Note that iNaturalist records are recorded as "Dainty Tree Frog, *Ranoidea gracilenta*" and those in FrogID as "Graceful Tree Frog, *Litoria gracilenta*."

Data source: record no(s).	Observation date	Reported location (latitude, longitude, accuracy margin)	Local Government Area
FrogID: 13665	9 Jan 2018	Warriewood (33.68905853°S, 151.29299°E)	Northern Beaches
FrogID: 15159, 15174	26 Jan 2018	Warriewood (33.69197948°S, 151.2971976°E)	Northern Beaches
FrogID: 17387	25 Feb 2018	Warriewood (33.68879417°S, 151.2932196°E)	Northern Beaches
FrogID: 18979	13 Mar 2018	Warriewood (33.69188797°S, 151.2973088°E)	Northern Beaches
FrogID: 53647	20 Dec 2018	Duffys Forest (33.67602149°S, 151.1846938°E)	Northern Beaches
FrogID: 60658	20 Feb 2019	North Narrabeen (33.69861675°S, 151.2963712°E)	Northern Beaches
FrogID: 62451, 62449	17 Mar 2019	Duffys Forest (33.67673701°S, 151.1834989°E)	Northern Beaches
FrogID: 101483, 101486	25 Jan 2020	Warriewood (33.68585205°S, 151.2942444°E)	Northern Beaches
FrogID: 104893	8 Feb 2020	Belrose (33.7045°S, 151.211°E)	Northern Beaches
FrogID: 104852	8 Feb 2020	Warriewood (33.68780518°S, 151.285695°E)	Northern Beaches
FrogID: 104757, 104872, 104862	8 Feb 2020	Duffys Forest (33.6698°S, 151.184°E)	Northern Beaches

(Table 1 continued)

(Table 1 continued)

FrogID: 105787, 105811	10 Feb 2020	Middle Dural (33.64724731°S, 151.0288501°E)	Hornsby
FrogID: 107551	14 Feb 2020	Warriewood (33.6895°S, 151.302°E)	Northern Beaches
iNaturalist: 41024472	30 Mar 2020	Randwick (33.93345833°S, 151.2468139°E, accuracy not recorded)	Randwick
iNaturalist: 192713953	14 Aug 2020	Orchard Hills (33.77887833°S, 150.7127083°E, within 7 m)	Penrith
FrogID: 164832, 164831	26 Oct 2020	Ingleside (33.68931887°S, 151.2761569°E)	Northern Beaches
FrogID: 200694, 200700	2 Jan 2021	Warriewood (33.68475727°S, 151.2914719°E)	Northern Beaches
iNaturalist: 197875513	29 Jan 2021	Mona Vale (33.67934264°S, 151.3009563°E, within 240 m)	Northern Beaches
FrogID: 210137	29 Jan 2021	Hunters Hill (33.83693544°S, 151.1541407°E)	Hunters Hill
FrogID: 210198	30 Jan 2021	Warriewood (33.68775276°S, 151.2857597°E)	Northern Beaches
FrogID: 226483	18 Mar 2021	Galston (33.63545593°S, 151.0344965°E)	Hornsby
FrogID: 326648	22 Nov 2021	Warriewood (33.68310818°S, 151.2929457°E)	Northern Beaches
FrogID: 327720	23 Nov 2021	Duffys Forest (33.6698°S, 151.184°E)	Northern Beaches
FrogID: 327592	23 Nov 2021	Duffys Forest (33.6687°S, 151.189°E)	Northern Beaches
FrogID: 331883	25 Nov 2021	Warriewood (33.6687°S, 151.189°E)	Northern Beaches
iNaturalist: 104443790	6 Jan 2022	Undisclosed location in Northern Beaches Local Government Area [1]	Northern Beaches
FrogID: 363554	8 Jan 2022	Dural (33.6753133°S, 151.0343529°E)	Hornsby
iNaturalist: 105013493	9 Jan 2022	Undisclosed location in Northern Beaches Local Government Area [1]	Northern Beaches
FrogID: 366176	13 Jan 2022	Wahroonga (33.71015962°S, 151.1235177°E)	Ku-ring-gai
FrogID: 383434	23 Feb 2022	Haberfield (33.87614093°S, 151.1388112°E)	Inner West
FrogID: 384286	24 Feb 2022	Warriewood (33.68301347°S, 151.2927877°E)	Northern Beaches
FrogID: 385230	25 Feb 2022	Kenthurst (33.6549°S, 151.001°E)	The Hills
FrogID: 390379	5 Mar 2022	Mona Vale (33.68156929°S, 151.2972742°E)	Northern Beaches
iNaturalist: 110565662, 110567067[2]	6 Apr 2022	110565662: Randwick (33.93349167°S, 151.2481083°E, within 47 m) 110567067: Randwick (33.93211001°S, 151.2484169°E, within 179 m)	Randwick
iNaturalist: 113249072	29 Apr 2022	Randwick (33.930852°S, 151.249239°E, accuracy not recorded)	Randwick
iNaturalist: 125086727	7 Jul 2022	Randwick (33.9305404°S, 151.2492593°E, accuracy not recorded)	Randwick
iNaturalist: 132722346	29 Aug 2022	Terrey Hills (33.68178669°S, 151.2204691°E, within 6 m)	Northern Beaches
iNaturalist: 137742639	6 Oct 2022	Randwick (33.93204986°S, 151.2462928°E, within 138 m)	Randwick
iNaturalist: 138245135	10 Oct 2022	Tempe (33.9278641°S, 151.1621637°E, within 151 m)	Inner West
iNaturalist: 142322151	18 Nov 2022	Randwick (33.9327°S, 151.2462467°E, within 5 m)	Randwick
iNaturalist: 145574329, 145624018[3]	1 Jan 2023	145574329: Randwick (33.93342167°S, 151.2467333°E, within 5 m) 145624018: Randwick (33.93232209°S, 151.2463219°E, within 62 m)	Randwick
iNaturalist: 202908090, 224168177[4]	22 Feb 2024	202908090: Undisclosed location in Randwick Local Government Area[1] 224168177: Randwick (33.9335433°S, 151.2482768°E, accuracy not recorded)	Randwick

[1] iNaturalist application users selected option to obscure geographical coordinates, such that actual location is anywhere within 30 km of displayed location.

[2] Records 110565662 and 110567067 were potentially the same *C. gracilenta* based on the records having the same observation date (6 April 2022), the same relative location in Randwick and the animal/s photographed being visually similar.

[3] Records 145574329 and 145624018 were potentially the same *C. gracilenta* based on the records having the same observation date (1 January 2023), the same relative location in Randwick and the animal(s) photographed being visually similar.

[4] Records 202908090 and 224168177 were potentially the same *C. gracilenta* based on the records having the same observation date (22 February 2024), both observed within the Randwick local government area and the animal(s) photographed being visually similar.

location, which were FrogID records detecting *C. gracilenta* vocalizations on separate dates one to 11 months apart.

Approximately 8 km west of Warriewood, a cluster of five unique records of *C. gracilenta* vocalizations in the suburb of Duffys Forest were within a 500-m radius. Two of these were vocalizations recorded at the same exact location on separate dates almost two years apart (Fig. 6). Duffys Forest records occurred within a period of almost three years, from December 2018 to November 2021.

The remaining unique records from the Northern Beaches Local Government Area identifiable to specific suburbs were sightings that occurred in Belrose and Terrey Hills (Table 1).

Randwick Local Government Area.—Eight unique records were in the Randwick Local Government Area, rep-

Table 2. Contributions of iNaturalist application users to records of the Dainty Treefrog (*Chlorohyla gracilenta*) in Sydney. Note that iNaturalist records are recorded as "Dainty Tree Frog, *Ranoidea gracilenta*."

Username	No. records	Records
celineeop	1	197875513
cmacgregor	1	105013493
deanboyd04	1	192713953
freedomfish	1	125086727
guanocrazy	3	110565662, 142322151, 145574329
hannah_deau	1	138245135
Haikai	1	202908090
lewisloncar	3	110567067, 137742639, 145624018
liz_ryan	1	132722346
ravencon	1	104443790
taxidermiedbaphomet	1	41024472
trebouxia	1	224168177
twan3253	1	113249072

resenting 19% of unique records (Table 1). Reported geographic coordinates for these records all fell within a single site along the perimeter of a permanent body of water in the Randwick Environment Park (Fig. 7). However, iNaturalist application users did not record a margin of accuracy for four of the records; consequently, these *C. gracilenta* might not actually have been in this wetland area. Similarly, two other records had margins of accuracy recorded as 47 m and 138 m, respectively, which likewise could suggest that these *C. gracilenta* were actually farther from the wetland area. Records of *C. gracilenta* in the Randwick Local Government Area occurred across a period of almost four years, from March 2020 to February 2024.

Hornsby Local Government Area.—Three unique records were in the Hornsby Local Government Area (Table 1), all FrogID records on large-lot residential properties based on the submitted geographic coordinates and each located more than 1 km from one another (Fig. 2). The earliest record, dated 10 February 2020, was a *C. gracilenta* in the semi-rural suburb of Middle Dural. The second record, dated 18 March 2021, was an individual in the semi-rural suburb of Galston. The third record, dated 8 January 2022, was a *C. gracilenta* in the semi-rural suburb of Dural. Thus, the unique records in the Hornsby Local Government Area occurred over a period of just under two years.

Inner West Local Government Area.—Two unique records were located 6 km apart in the Inner West Local Government Area (Table 1) (Fig. 2). The earliest record was a FrogID record of a *C. gracilenta* in the suburb of Haberfield. This *C. gracilenta*, recorded on 23 February 2022, was in a residential area based on the geographic coordinates submitted. The second record, dated 10 October 2022, was an iNaturalist record of a *C. gracilenta* in the suburb of Tempe. The geographic coordinates lodged for this record indicate the location of the *C. gracilenta* within a wetland in remnant bushland; however, a margin of accuracy of 151 m was recorded by this application user and the only photographs submitted with the record show a *C. gracilenta* in the hand, so the actual location of this animal might have also been in the adjacent residential area, sporting fields, or industrial area.

Hunters Hill Local Government Area.—Only a single record came from the Hunters Hill Local Government Area, which was a FrogID record from the suburb of Hunters Hill (Table 1). This *C. gracilenta*, recorded on 29 January 2021, was in a residential area based on the geographic coordinates submitted.

Ku-ring-gai Local Government Area.—Only a single record came from the Ku-ring-gai Local Government Area, which was a FrogID record from the suburb of Wahroonga

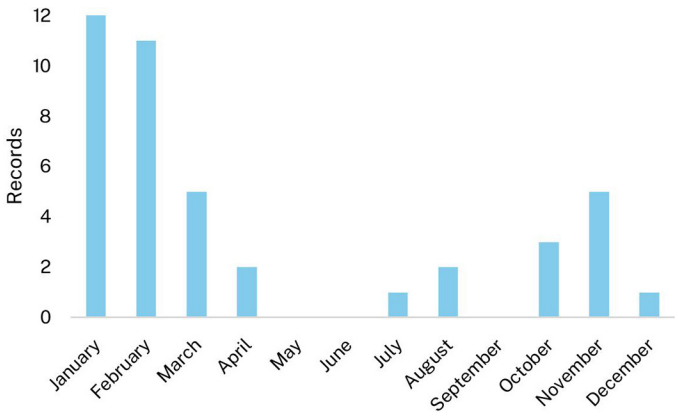

Figure 3. Monthly frequency across the sample size of unique Dainty Treefrog (*Chlorohyla gracilenta*) records in the Sydney metropolitan area, Australia.

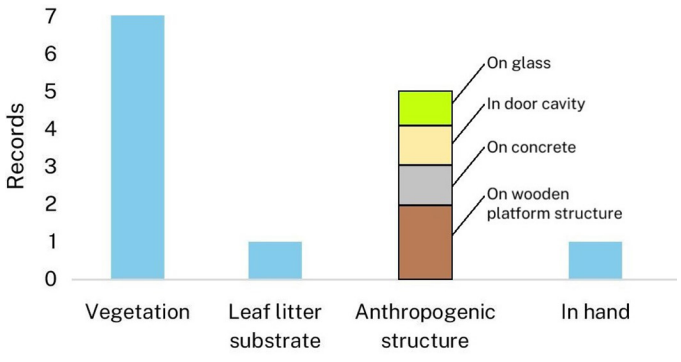

Figure 4. Breakdown of unique iNaturalist records of Dainty Treefrogs (*Chlorohyla gracilenta*) in the Sydney metropolitan area, Australia, by environmental settings based on photographs uploaded by application users.

Figure 5. Locations of unique records in Warriewood and surrounding suburbs (labelled) in the Sydney metropolitan area, Australia, reported in the iNaturalist application (yellow) and the FrogID dataset 5.0 (green). The iNaturalist record in Mona Vale was recorded within an accuracy margin of 240 m.

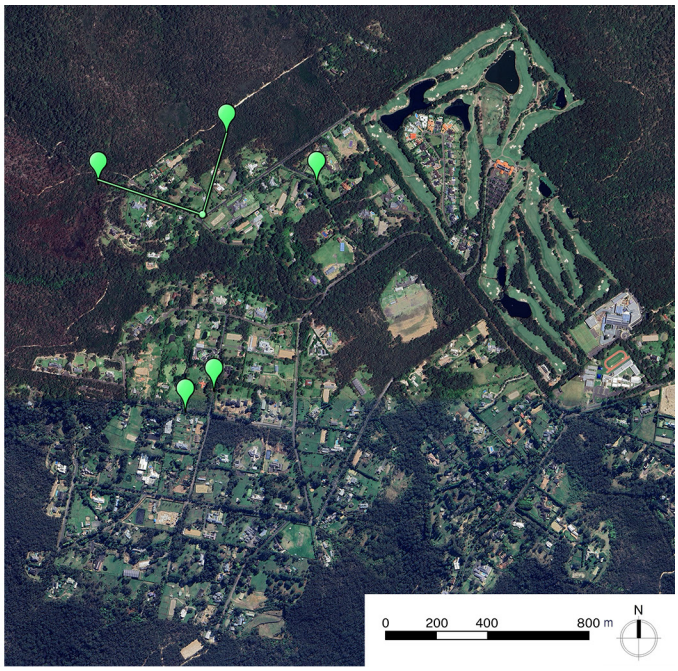

Figure 6. Locations of unique records reported in Duffys Forest, Sydney metropolitan area, Australia. All records in this suburb were from the FrogID dataset 5.0.

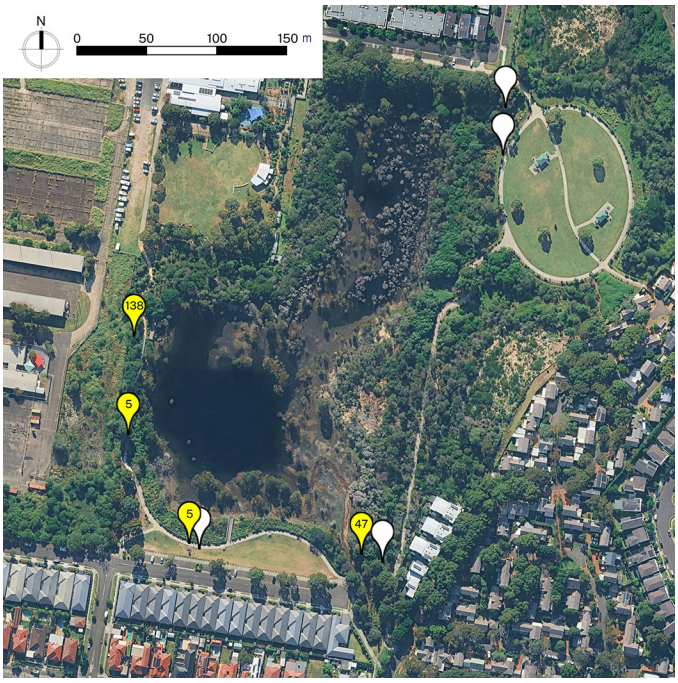

Figure 7. Locations of unique records reported in Randwick, Sydney metropolitan area, Australia (excluding the record that had obscured georeferencing). All records in this suburb were from the iNaturalist application. Records with a recorded location accuracy margin are shown in yellow, with numerals showing each record's accuracy margin (units in m), and records in which application users did not record an accuracy margin are shown in white.

(Table 1). This *C. gracilenta*, recorded on 13 January 2022, was in a residential area based on the geographic coordinates submitted.

Penrith Local Government Area.—Only a single record came from the Penrith Local Government Area, which was an iNaturalist record from the suburb of Orchard Hills (Table 1). This sighting was the most geographically isolated of any in the sample, occurring 30 km from the nearest other sighting. This *C. gracilenta* was sighted on 14 August 2020 and recorded by the application user within a 7-m margin of accuracy. Based on this, its location was identifiable to the site of a garden retail store.

The Hills Local Government Area.—Only a single record came from The Hills Local Government Area, which was a FrogID record from the semi-rural suburb of Kenthurst (Table 1). This *C. gracilenta*, recorded on 25 February 2022, was in a large-lot residential property based on the geographic coordinates submitted. This sighting occurred 2.7 km from the location of the 18 March 2021 record in Galston.

Discussion

Citizen-science records examined in this study show that *C. gracilenta* has been detected visually and acoustically at varied sites across Sydney, ranging from developed residential areas in the inner suburbs to semi-rural areas in the northern districts. The records around the Randwick Environment Park

were probably the most suggestive indication of an established population of *C. gracilenta*, especially with unique records with reasonable margins of accuracy situated close together and spread across a four-year period. These records also occurred across all four meteorological seasons. Based on these lines of evidence, further investigation of this site is warranted. As the species is known to peak in activity after spring and summer rains (Robinson 2002), these times would be the most ideal for targeted visual and acoustic surveys. This aligns with the results of our seasonal frequency analysis, with the majority of the existing sample comprising January and February detections.

Unique records of *C. gracilenta* from Warriewood comprised approximately one third of the total sample size. Although this was a higher number of detections than for the Randwick site, locations of *C. gracilenta* detections within Warriewood were less proximate. Nevertheless, in both Warriewood and Duffys Forest, several *C. gracilenta* were detected at the same location on different dates separated by periods of months. These repeated detections indicate a level of persistence, and further presence data at these sites could reveal establishing populations.

In other parts of Sydney, records of *C. gracilenta* identifiable to suburb level were more segregated, with substantial distances between reported locations. While the evidence for these locations show only isolated individuals, the species readily occurs in urban landscapes within its traditional distribution (M. Mo, pers. obs.), so it would be reasonable to suggest that lone individuals could persist at these sites.

Given that the literature has traditionally considered *C. gracilenta* occurring only as far south as the Central Coast Region (Anstis 2007; Tyler and Knight 2011), the Hawkesbury River separating the Central Coast from the Sydney metropolitan area likely provided a natural physical barrier in the past. With frequent and ongoing human transportation of materials, animals can now readily overcome these natural barriers (White and Shine 2009), demonstrated by non-indigenous herpetofauna like *C. gracilenta* (this study) and other anurans being observed in Sydney (Mo 2017b; Greenlees et al. 2018). This study, along with others (Gaier and Resasco 2023; Serniak et al. 2023; Goldberg 2024; Zocca et al. 2024), demonstrate the value of citizen science for amassing georeferenced data that can be applied to examining the distributional patterns and especially extralimital occurrences of species.

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