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Targeted surveys of a poorly conserved threatened orchid (*Pterostylis chaetophora*) in Columbey National Park (Hunter Valley, NSW) reveal substantial populations and elucidate occupied habitat

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Abstract: Systematic targeted surveys for the vulnerable and poorly conserved *Pterostylis chaetophora* (family Orchidaceae) were undertaken during peak flowering over ten days in 2018 and 2019 across 720 ha of Columbey National Park (Columbey). The assumed population size of this species in Columbey prior to this study (c. 20 individuals) was found to be unrepresentative of the number of sub-populations (175) and individuals (544) subsequently located along 141 km of search transects. Extrapolation of this result across the full Columbey study area suggests an upper population size of nearly 3000 plants, increasing the total documented New South Wales population 15-fold.

The most commonly occupied communities for *Pterostylis chaetophora* were found to be Floodplain Redgum-Box Forest (57% of individuals and 54% of sub-populations), Lower Hunter Spotted Gum-Ironbark Forest (28% of individuals, 25% of sub-populations), and Seaham Spotted Gum-Ironbark Forest (14% of individuals, 18% of sub-populations). The largest sub-populations (>10 individuals) were in Floodplain Redgum-Box Forest where *Eucalyptus moluccana* dominated the canopy, followed by Lower Hunter Spotted Gum-Ironbark Forest and Seaham Spotted Gum-Ironbark Forest. All three occupied communities are relatively widespread in the lower Hunter Valley and lower North Coast regions, suggesting that such habitat elsewhere may harbour undetected populations of *Pterostylis chaetophora*.

These results suggest that systematic targeted surveys for other threatened orchids are necessary to fully understand both the magnitude of a species' population and its occupied habitat. Such surveys may ultimately lead to re-assessment of the conservation status of some of these species where, like *Pterostylis chaetophora*, considerably more populations and individuals are uncovered within secure land tenure.

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Introduction

Terrestrial orchids are a diverse group of plants globally (c. 28000 species: Fay 2018) and within Australia (c. 1960 species: Backhouse et al. 2019), and possess high rates of both species extinction and speciation (Chase et al. 2015; Brundrett 2016). In a review of Australian threatened orchid taxa, New South Wales (NSW) ranked fifth behind Queensland, South Australia, Victoria, and Tasmania for the number of significant (extinct, threatened and rare) species (Backhouse 2007), with 78 (37%) of the then 210 endemic NSW species listed as threatened. Increased listings over the last thirteen years in line with ongoing threats suggest, however, that State rankings may have changed largely through additions of State endemic taxa. Relative to their earlier work in 2016, Backhouse et al. (2019), for example, now show 588 orchid species for NSW and 232 endemic taxa (including 64 undescribed). Of these, 77 (33%) are currently listed as threatened under the NSW *Biodiversity Conservation Act 2016* (NSW BC Act). Apart from South Australia (36 taxa), NSW has shown the largest increase (22 taxa) in State endemic taxa over the past three years, over Queensland (10 taxa), Western Australia (8 taxa), and Tasmania (3 taxa) (Backhouse et al. 2019), and it may be expected that increased listings have emanated from this pool of endemic species. The Northern Territory has shown no change in the number of endemics since 2016, while Victoria has seen a decrease of 7 taxa, presumably through the discovery of new populations of formerly Victorian endemics in other States. Clearly, orchid taxonomy, discovery and listing status remains dynamic, and there is still much to learn about the distribution and ecology of this iconic group of plants.

The discovery of new populations of orchid species can be fortuitous but certain aspects of their morphology lend considerable assistance. Many orchid genera produce vivid and colourful flowers during a short flowering season which aid detection, but the flowers of numerous others are often small, less colourful and relatively insignificant. Knowledge informing the conservation status of all such orchids is heavily reliant on the ability of surveyors to detect individuals and populations within often floristically and structurally diverse habitats. This is not always an easy task, with variations in seasonal emergence dramatically influencing measures of population abundance (Gillman & Dodd 1998; Kindlmann & Balounova 2001; Kindlmann 2003), coupled with numerous environmental stressors operating on plants that limit their effective detection (flowering) period (Kery & Gregg 2003; McCormick & Jacquemyn 2014; Brundrett 2016). Essentially, measures of abundance in terrestrial orchids are a factor of detectability during surveys rather than a finite census of a population (Kery & Gregg 2003; Bell 2019). Because of the feeble nature of orchid detection, any population count will be an underestimate of the true number of individuals (Sanger & Waite 1998; Weston et al. 2005).

The genus *Pterostylis* ('Greenhoods') contains at least 262 species across Australia, Indonesia, Papua New Guinea, New Caledonia and New Zealand, and within New South Wales there are currently 111 accepted taxa and 29 unpublished entities (Janes & Duretto 2010; Backhouse et al. 2019). Two subgenera have been constructed around this diverse group (but see Clements et al. 2011 for a differing view), largely based on the alignment of the lateral sepals (reflexed or recurved) and labellum morphology. *Pterostylis chaetophora* M.A.Clem. & D.L.Jones (Rusty Greenhood; the subject of this paper) is the type species for section *Oligochaetochilus* within subgenus *Oligochaetochilus*, a collection of species characterised by multiple flowers comprising the inflorescence, lateral sepals fully recurved, labella with distinctive white setae, and column wings with barrier trichomes (Janes & Duretto 2010). There are 47 species of *Pterostylis* described for section *Oligochaetochilus*, 19 of which occur in New South Wales. Five species are currently listed as threatened in New South Wales (1 critically endangered, 2 endangered, 2 vulnerable), while 12 are listed nationally (3 critically endangered, 5 endangered, 4 vulnerable).

This paper presents the results of systematic targeted surveys undertaken across Columbey National Park over the course of two flowering seasons (2018 and 2019), where only small populations of *Pterostylis chaetophora* were previously known. It uses *Pterostylis chaetophora* as a model species to illustrate the value of systematic searches (rather than *ad hoc* occasional searches) in potential habitat to improve understanding of distribution and population size. It also examines habitat for the species and outlines vegetation communities currently known to support it, both in Columbey and elsewhere.

Study Species

Pterostylis chaetophora (Figure 1) is a small terrestrial orchid bearing ornate yet nectar-less flowers, and principally occurs between Taree and Cessnock in central eastern New South Wales. Pollination in this genus is thought to be enacted by male flies in the families Culicidae and Mycetophilidae, attracted to flowers through sexual mimicry and the prospect of copulation by pseudo-pheromones (Weston et al. 2005). The type specimen for the species was grown from material collected at Neath, near Cessnock in the mid-Hunter Valley in the early 1980s. Apart from a line drawing and the required Latin diagnosis in Clements (1989), no other detailed information has been published on this species.

Databased populations of *Pterostylis chaetophora* are not representative of the true geographical distribution of this species. Records from the upper Hunter Valley in the Wingen (1998) and Denman (2001) localities are in error and represent different taxa (indeterminate but not *Pterostylis chaetophora* for Wingen, *Pterostylis* aff. *praetermissa* for Denman; L. Copeland, pers. com.), while Queensland populations now form a separate and distinct un-named species with close affinities to *Pterostylis chaetophora* (Backhouse et al. 2019). Additionally, two early collections in the Australian Virtual Herbarium (AVH) from Sydney (PERTH 8885168, R. Brown, 1804, Willoughby area; CBG

8704841.1, G. D'Aubert, October 1987, Georges River), and an observation record from Glenhaven (1949), are also thought to be in error or are now locally extinct. Hosking and James (1998) and Hunter (2008) report populations of *Pterostylis chaetophora* from Warrabah National Park (c. 100 km north of Tamworth), but these are considered misidentifications and likely represent *Pterostylis* aff. *praetermissa* (L. Copeland, pers. com.).

Figure 1: *Pterostylis chaetophora* at Columbey National Park, side view (left) and front view (right).

Pterostylis chaetophora is currently listed as a Vulnerable species on the NSW BC Act, on the basis of low population numbers (NSW Scientific Committee 2014). Under the NSW Government's *Saving our Species* program (SoS) the species has been allocated to the site-managed stream. One key action within this stream is to increase the number of known populations through the completion of targeted surveys. Records of *Pterostylis chaetophora* within Columbey National Park represent the only recently confirmed population within the secure and gazetted conservation estate. Little is known on the ecology of *Pterostylis chaetophora*, although impacts from macropod grazing and observations on potential pollinators were documented by Smart (2018). Phenology data has been collected over four seasons (unpub. data), and will be presented in a separate paper.

Study Area

Columbey National Park (32° 35'S 151° 44'E) is located immediately west of Clarence Town, on the lower Williams River in the Hunter Valley, within the local government areas of Dungog and Port Stephens (Figure 2). Formerly part of Uffington State Forest, the area has been heavily logged over a prolonged period leaving few 'old growth' trees, and has a network of current and former four-wheel drive and recreational motor bike trails. The portion of this reserve comprising this study, the Columbey SoS management site (720 ha), lies on Carboniferous sediments, with the sandstone-dominated Wallaringa Formation of the Tamworth fold belt the most widespread lithology (Department of Mineral Resources 1999). Soil landscapes have been mapped and described by Matthei (1995), and are dominated (87%) by moderately deep, well-to-imperfectly drained Yellow Soloths, and shallow moderately-drained Lithosols of the Clarence Town soil landscape. Other less common soil types include deep well-drained Yellow and Brown Soloths and rapidly-drained Lithosols and Bleached Loams (5%); and well-drained and moderately deep alluvium on alluvial plains, and deep well-drained siliceous sands in stream channels (8%). The vegetation of Columbey has been previously documented (Bell 2009), where eleven naturally occurring vegetation communities were delineated and mapped. The most widespread community was Lower Hunter Spotted Gum – Ironbark Forest, a recognised threatened ecological community within New South Wales (NSW Scientific Committee 2019).

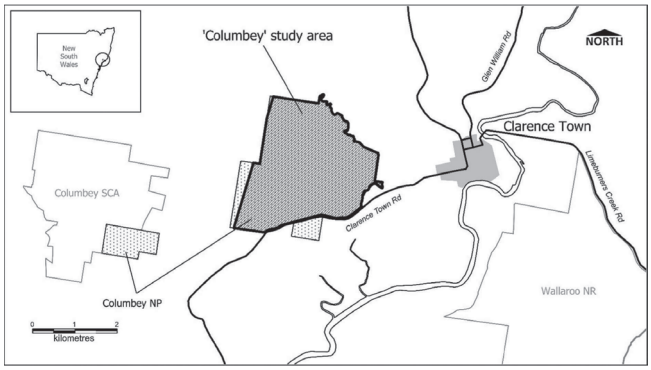

Figure 2: Location of the Columbey SoS management site (the study area), within the context of Columbey National Park (NP) and surrounding reserves.

Pterostylis chaetophora was first recorded within Columbey in 2008, and subsequent to that new observations have since been reported although no evaluation of the full extent of the population has yet been made. The initial finding of approximately five plants was made in old regrowth grassy forest of *Eucalyptus amplifolia* subsp. *amplifolia* (Bell 2009), and other collections were made shortly after in "box/spotted gum woodland" (e.g. NSW 866878, B. Abbott & E. Burton, October 2008). The most recent finds in Columbey were in open forest of *Eucalyptus moluccana, Eucalyptus fibrosa, Eucalyptus umbra*, *Corymbia maculata* and dense *Melaleuca nodosa* thickets (Environmental Property Services 2018).

Methods

Field survey

Systematic targeted surveys to fulfil the SoS action were undertaken during the 2018 and 2019 flowering seasons. Plot-based phenology monitoring being undertaken concurrently within Columbey allowed the timing of targeted surveys to match the peak (September-October) in observed flowering across a three week flowering window. In 2018, 430 ha was searched by two observers over five days, and in 2019 290 ha was searched by one observer over an additional five days. There was no overlap in search effort across the two seasons, and in both years searches incorporated surveys along the edges of existing trails (areas commonly inhabited by terrestrial orchids) as well as within undisturbed bushland.

All targeted searches involved systematic traversing of potential habitat with walked tracks recorded in GPS units. Based on available knowledge at the commencement of surveys, potential habitat was deemed to be all vegetation communities previously mapped for Columbey, with the exception of riparian zones supporting rainforest or *Melaleuca* thickets on alluvial soils (Bell 2009). Separation distances of walked transects were generally 60-100 m, but wider where areas of inappropriate habitat occurred (e.g. dense riparian forest). Previous trial searches showed that the majority of *Pterostylis* were detected only within 5 m either side of walked transects, suggesting that more than 50 m of unsearched habitat lay between adjacent transects. Where orchids were detected, care was taken to ensure that all *Pterostylis* were distinguished from other locally occurring species, such as *P. erecta, P. longifolia, P. mutica,* and *P. rufa*. Of these, only *Pterostylis rufa* lies within subgenus *Oligochaetochilus* and could be potentially confused with *Pterostylis chaetophora*. However, the long, filamentous dorsal and lateral sepals of *Pterostylis chaetophora* clearly distinguish this species from *Pterostylis rufa*, even when in bud (Figure 3). Photographs of all newly discovered individuals were used to verify identification, and only orchids in late bud or flowering were recorded: leafy rosettes, although rarely recorded during the search periods, were not considered positive location records.

Figure 3: *Pterostylis chaetophora* in bud (left) and flowering *Pterostylis rufa* (right), Columbey National Park. Note clearly visible upward protruding filamentous ends to dorsal and lateral sepals in *Pterostylis chaetophora* (combined in bud; see also Figure 1), absent in *Pterostylis rufa*.

Population size and habitat

Using newly collected detection data, the abundance of *Pterostylis* was calculated for the search area, and extrapolated across Columbey to determine an estimated population size for the species. New and existing locations of *Pterostylis* were also overlain onto vegetation mapping of Columbey to determine the most prevalent vegetation community supporting the species in this reserve. A pre-disturbance modification of the mapping of Bell (2009), built on over 500 ground data points, was used to tally both sub-populations and individuals. As part of this modification, all roads, tracks, plantations, low condition and cleared areas within existing mapping were reviewed and allocated to the most appropriate vegetation community based on ground data points and topography.

Results

New individuals and sub-populations

Over 140 km of walked transects were completed over ten days in September and October 2018 and 2019 (Figure 4). Using the assumption that confident ground searches for *Pterostylis* within the grassy open forests of Columbey can be made only within 5 m either side of walked tracks, then the effective search area over the 2018 and 2019 flowering seasons was a belt transect 10 m wide and 141 km long (91 km in 2018, 50 km in 2019). This equated to an effective search area of 141 ha, or 20% of the total area of Columbey.

During targeted surveys in 2018 114 new locations (sub-populations) of *Pterostylis chaetophora* were recorded, while 61 new locations were recorded in 2019 (Figure 4). In total, 544 individual *Pterostylis chaetophora* were detected (n=251 in 2018; n=293 in 2019). The observed population size ranged from single plants (21 sub-populations in 2018, 16 in 2019) to 58 plants (1 sub-population in 2019). The bulk of sub-populations (91%) comprised fewer than 10 individuals (Figure 5). There were two main clusters of orchids across the study area, separated loosely by the slightly higher elevation of Tower Hill (100m ASL), and all records occurred in a distinctly SW-NE alignment. There seemed no clear reason for this pattern in distribution, certainly when assessed against vegetation community distribution (Figure 6).

Estimated population size

Given the assumptions that all search areas supported potential habitat and that search transects effectively surveyed the ground only within 10 m wide belt transects, the 544 individual *Pterostylis* recorded within this 141 ha effective search area are indicative of an orchid density of 3.9 orchids/ha. Extrapolating this density across the remaining 579 ha of Columbey (i.e. the area remaining outside of the 141 ha search area), an additional 2258 orchids may be expected. In the absence of any other more reliable data across multiple seasons, this figure can be used as an upper bound to estimate the total population size of *Pterostylis chaetophora* at Columbey within the survey period, suggesting somewhere in the order of over 2800 plants. Persistence of this population above-ground in any one season will be tempered by seasonal weather conditions affecting emergence and flowering, invertebrate and vertebrate grazing impacts and asynchronous flowering. Better seasons with good rainfall and lower grazing impacts may well yield a larger estimate of total population size.

Habitat

Pterostylis chaetophora was found to occur in four of the eleven vegetation communities described for Columbey (Figure 7). Of the 114 new sub-populations recorded, 54% of these were within Floodplain Redgum-Box Forest (50% within the *Eucalyptus moluccana* variant of this community, 4% within the *Eucalyptus amplifolia* variant), 25% were

within Lower Hunter Spotted Gum-Ironbark Forest, 18% within Seaham Spotted Gum-Ironbark Forest, and 2% in Seaham Ironbark Forest. A similar pattern was evident for the distribution of individual orchids, with 57% in Floodplain Redgum-Box Forest, 28% in Lower Hunter Spotted Gum-Ironbark Forest, 14% in Seaham Spotted Gum-Ironbark Forest, and 1% in Seaham Ironbark Forest. Within these landscapes, favoured micro-habitat was in areas where previous ground disturbances were evident, such as old disused management trails or along the edges of current trails, in ground scrapes or culverts associated with drainage works, and in seemingly undisturbed forest habitats (Figure 8).

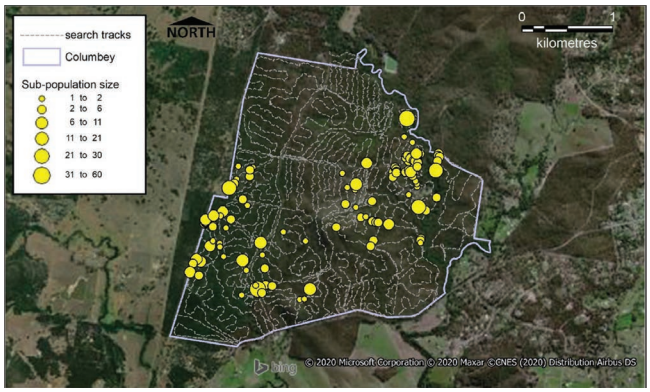

Figure 4: Survey effort within Columbey, showing new sub-populations of *Pterostylis chaetophora* and their magnitude, located over the 2018 and 2019 flowering season.

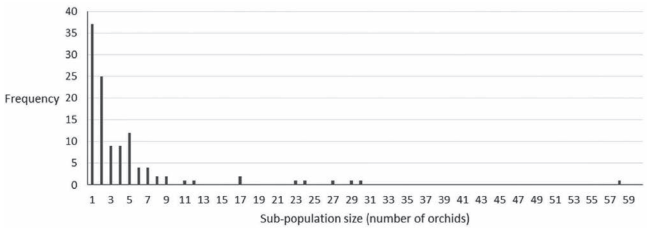

Figure 5: Frequency and size of new *Pterostylis chaetophora* sub-populations recorded over 10 days of targeted survey at Columbey, September-October 2018 (n=53) and 2019 (n=61).

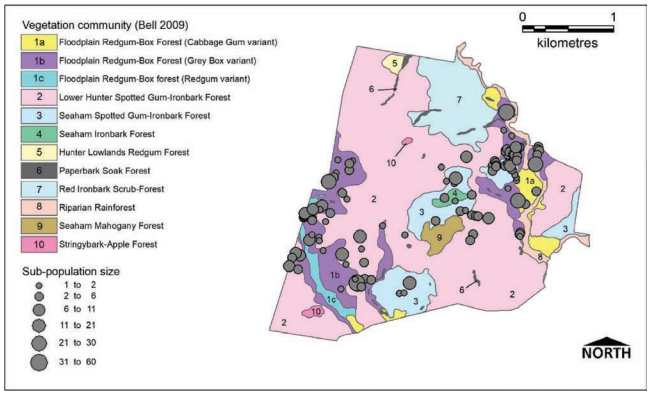

Figure 6: New sub-populations of *Pterostylis chaetophora* shown over Columbey vegetation communities (after Bell 2009).

Of all sub-populations comprising more than 10 individuals (n=10), the highest number of detected orchids occurred within Floodplain Redgum-Box Forest (58, 29, 27 and 23 individuals, all within the *Eucalyptus moluccana* variant), followed by Lower Hunter Spotted Gum-Ironbark Forest (30, 24, 17 and 12 individuals), and Seaham Spotted Gum-Ironbark Forest (17 and 11 individuals). Based on Bell (2009), key floristic attributes of these four communities are:

1. Floodplain Redgum-Box Forest (54% of sub-populations, 57% of individuals) - restricted to low-lying areas along major creeklines and their associated flood-outs. This community can be dominated by any of *Eucalyptus amplifolia* subsp. *amplifolia*, *Eucalyptus siderophloia*, *Eucalyptus tereticornis* or *Eucalyptus moluccana*, with local dominance often reflecting the pattern of regrowth following past clearing practices. Understorey typically includes the shrubs *Leucopogon juniperinus, Acacia irrorata* subsp. *irrorata, Bursaria spinosa* and *Breynia oblongifolia*, over a well-developed ground layer of grasses (e.g. *Microlaena stipoides* var. *stipoides, Aristida vagans, Cymbopogon refractus, Panicum simile, Echinopogon caespitosus* var. *caespitosus*), forbs (e.g. *Dichondra repens, Brunoniella australis, Cyanthillium cinereum* var. *cinereum, Lobelia purpurascens, Plantago debilis*) and other species (e.g. *Cheilanthes sieberi* subsp. *sieberi, Dianella revoluta* var. *revoluta, Gahnia aspera, Fimbristylis dichotoma, Glycine tabacina*).

2. Lower Hunter Spotted Gum-Ironbark Forest (25% of sub-populations, 28% of individuals) - widespread across Columbey on gentle slopes and rises, dominated by *Eucalyptus fibrosa, Corymbia maculata* and *Eucalyptus umbra*, while in places *Eucalyptus moluccana* can also be present. Typical understorey species include the shrubs *Bursaria spinosa, Pultenaea villosa, Leucopogon juniperinus, Acacia falcata* and *Daviesia ulicifolia* subsp. *ulicifolia*, with the grasses *Entolasia stricta, Aristida vagans, Microlaena stipoides* var. *stipoides* and *Panicum simile*, forbs *Phyllanthus hirtellus, Pomax umbellata, Brachyscome multifida* and *Goodenia heterophylla* subsp. *heterophylla,* graminoids *Lomandra multiflora* subsp. *multiflora, Lomandra filiformis* subsp. *coriacea* and *Dianella revoluta* var. *revoluta,* the fern *Cheilanthes sieberi* subsp. *sieberi* and the cycad *Macrozamia flexuosa*. In some areas, *Melaleuca nodosa* also occurs sporadically, and where this species dominates the tall shrub layer they form the Red Ironbark Scrub-Forest (no *Pterostylis chaetophora* yet recorded in that community).

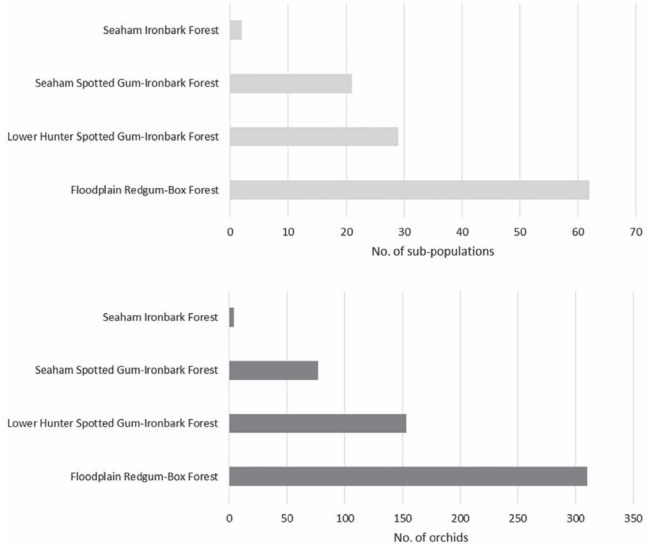

Figure 7: Distribution of *Pterostylis chaetophora* sub-populations (upper; n=114) and individuals (lower; n=544) across vegetation communities defined in Bell (2009).

Figure 8: Examples of micro-habitat supporting *Pterostylis chaetophora* at Columbey National Park. Clockwise from top left; former 4WD trail now rehabilitated, road drainage culvert, undisturbed forest, edge of motor bike trail. Orchid locations shown by pink flagging tape (circled).

3. Seaham Spotted Gum-Ironbark Forest (18% of sub-populations, 14% of individuals) - occurs on higher slopes and ridges and is typically dominated by *Eucalyptus siderophloia, Eucalyptus crebra, Corymbia maculata* and *Eucalyptus moluccana*, often with *Eucalyptus tereticornis*. Understorey species include the shrubs *Bursaria spinosa, Acacia falcata, Acacia implexa, Pultenaea villosa* and *Acacia ulicifolia*, the grasses *Aristida vagans, Cymbopogon refractus, Microlaena stipoides* var. *stipoides, Dichelachne micrantha* and *Entolasia stricta*, the graminoids *Lomandra multiflora* subsp. *multiflora* and *Lomandra confertifolia* subsp. *pallida*, the fern *Cheilanthes sieberi* subsp. *sieberi*, the sedge *Lepidosperma laterale*, and a high diversity of forbs and herbs including *Lobelia purpurascens, Brunoniella australis, Lagenophora stipitata, Phyllanthus hirtellus,* and *Desmodium gunnii*.

4. Seaham Ironbark Forest (2% of sub-populations, 1% of individuals) - restricted within Columbey to two small areas, both of which comprise even-aged stands of *Eucalyptus crebra* and/ or *Eucalyptus siderophloia* following previous clearing events. Shrubs are generally sparse or absent, but include *Acacia implexa, Acacia irrorata* subsp. *irrorata* and *Breynia oblongifolia*, over a diverse ground layer of grasses (*Cymbopogon refractus, Echinopogon ovatus, Microlaena stipoides* var. *stipoides, Panicum effusum, Paspalidium distans*), forbs (*Brunoniella australis, Dichondra repens, Hypericum gramineum, Hypoxis hygrometrica* var. *villosisepala, Lagenophora stipitata, Oxalis perennans, Glycine clandestina*) and other species (e.g. *Cheilanthes sieberi* subsp. *sieberi, Fimbristylis dichotoma, Dianella caerulea*).

Discussion

Assessments of conservation status for plant species rely heavily on knowledge of geographical distribution, occupied and potential habitat, and population size. When combined with observed or inferred threat, there is strong support for listings of critically endangered, endangered or vulnerable status under IUCN criteria (IUCN Standards and Petitions Committee 2019), and this process has been previously applied to orchids (e.g. Backhouse & Cameron 2005). Terrestrial orchids, like other deciduous geophytes, comprise a difficult group in this regard because detection of individuals is reliant on suitable conditions for emergence and flowering (Pfeifer et al. 2006; McCormick & Jacquemyn 2014), and on the adequacy of survey within potential habitat across their known geographical extent. Individual orchids may remain dormant in the ground for several years awaiting appropriate conditions for emergence (Weston et al. 2005; Brundrett 2016), but when they do emerge knowledge on the most suitable time to conduct surveys ('peak flowering') can be critical for correctly timed surveys (Yare et al. 2020). Added to this are the sizeable number of naturally occurring processes that impact on detection in any one season, including grazing and/or trampling by vertebrates (e.g. mammals, birds) and invertebrates (e.g. grasshoppers, slugs), dry pre-flowering periods, extreme wind, heat or drought at flowering, and asynchronous flowering (Duncan et al. 2005; Backhouse 2007; Dilley 2007; Faast & Facelli 2009; Swarts & Dixon 2009; Bell 2019). While these processes may hamper an ability to detect orchids during surveys, individual orchids remain viable and will in most cases persist underground and flower in following seasons.

For *Pterostylis chaetophora*, listing as a vulnerable species was driven primarily by the low numbers of mature individuals known at that time, which while not specified can be deducted from information contained in the final determination to be in the order of 200-400 plants (NSW Scientific Committee 2014). Prior to the present study, approximately 20 individuals were known from Columbey National Park. Surveys up until 2018 in this reserve had been *ad hoc* and incidental, and although noted as being present there was no information available on how extensive the species was. Following 10 days of dedicated survey

over two successive seasons, 544 *Pterostylis chaetophora* individuals were detected within Columbey. Additionally, surveys conducted concurrently for proposed road upgrading within the reserve during the 2018 flowering season (Narla Environmental 2019 a,b) revealed a further 10 sub-populations comprising 119 individuals, elevating the total number of individuals within Columbey to 663 (duplicate sub-populations with the present study removed). This magnitude of observed plants increases by 30-fold the formerly known extent of *Pterostylis chaetophora* within Columbey, and by 15-fold the previously estimated total population size for the species in New South Wales.

The systematic nature of searches undertaken in Columbey also enabled extrapolation of the total number of individuals expected to occur there in any one season, allowing for those orchids that may have remained undetected in unsearched areas between survey transects. Based on a density of 3.9 orchids/ha, nearly 3000 *Pterostylis chaetophora* are predicted to be present within Columbey. This significant and large population therefore represents the most important population of *Pterostylis chaetophora* currently known, occurring as it does in well vegetation lands comprising a national park with little active threats. Most other populations known comprise less than 100 individuals, with the exception of one site near Raymond Terrace where several hundred plants occur within an area of approximately 5 ha, with most plants closely packed within approximately 200 m^2 (NSW Scientific Committee 2014; pers. obs.).

Occupied habitat for *Pterostylis chaetophora* within Columbey, in terms of both the spatial pattern of sub-populations and the number of individuals, was Floodplain Redgum-Box Forest (c. 55%) or one of three communities where Spotted Gum (*Corymbia maculata)* and/or Ironbarks *(Eucalyptus crebra, Eucalyptus fibrosa, Eucalyptus siderophloia*) are characteristic (c. 45%). All of these communities are typified by a sparse-to-dense shrub layer over a well-developed ground flora of grasses and forbs. Two of the defined communities are included within NSW-listed threatened ecological communities: Floodplain Redgum-Box Forest falls within River-Flat Eucalypt Forest on Coastal Floodplains, and Lower Hunter Spotted Gum-Ironbark Forest within the listed community of the same name (Bell 2009; NSW Scientific Committee 2019). Populations of *Pterostylis chaetophora* outside of Columbey occur in similar vegetation: at Pindimar, Raymond Terrace and Beresfield plants occur in Lower Hunter Spotted Gum-Ironbark Forest; at Twelve Mile Creek (north of Raymond Terrace) in forests dominated by Ironbarks (*Eucalyptus placita, Eucalyptus siderophloia, Eucalyptus paniculata*) and *Corymbia maculata,* or on lower slopes of *Eucalyptus amplifolia* or *Eucalyptus moluccana* (Paget 2008); at Purfleet (near Taree) in *Eucalyptus propinqua-Eucalyptus microcorys* shrubby forest (Paget 2008); at Burrell Creek (west of Taree) in grasslands derived from cleared *Eucalyptus propinqua*, *Eucalyptus acmenoides*, *Eucalyptus microcorys*, *Eucalyptus placita* and *Eucalyptus siderophloia* forest (A. Paget, pers. com.); at Kurri in shrubby forest of *Corymbia maculata* and *Eucalyptus fibrosa*, or *Eucalyptus tereticornis, Eucalyptus punctata* and *Angophora floribunda* in dry drainage lines; and at North Rothbury in regrowth forest of *Eucalyptus tereticornis, Angophora floribunda* and *Eucalyptus crebra*. Regionally, it is evident that potential habitat for *Pterostylis chaetophora* includes any or all of vegetation described in NSW National Parks and Wildlife Service (2000) as Lower Hunter Spotted Gum-Ironbark Forest (Unit 17), Seaham Spotted Gum-Ironbark Forest (Unit 16) or Hunter Lowlands Redgum Forest (Unit 19), and likely parts of several other more broadly defined communities. Based on current knowledge, surveys required for development assessment work should pay particular attention to any vegetation characterised by grassy open forests of *Eucalyptus amplifolia* and *Eucalyptus moluccana* on gentle flats, or that are dominated by *Corymbia maculata* with any of *Eucalyptus fibrosa, Eucalyptus sideroploia* or *Eucalyptus crebra*.

Many threatened orchids are known from few populations despite apparently suitable habitat being widespread in the landscape. Documentation of occupied habitat is critical to further understanding and management of all terrestrial orchids, and can focus future search effort in environments where the greatest return can be achieved. Few detailed assessments of habitat have been completed for Australian threatened orchids (but see Bell et al. 2005; Bougoure et al. 2008; de Lacey et al. 2012), yet these should be a first step in the management of habitat and maintaining pollinator networks. Janes et al. (2010) found that altitude, aspect, drainage, precipitation, radiation, temperature and moisture were important factors influencing distribution in *Pterostylis*, but examined only broad vegetation types and correlations with specific communities could not be found. Some authors (e.g. Phillips et al. 2015; Reiter et al. 2019) suggest that orchids may be more limited by rarity of specific pollinators than the availability of habitat, and others have tied distribution to the presence or absence of mycorrhizal fungi (e.g. McCormick & Jacquemyn 2014), which may vary across different habitats (Reiter et al. 2018). Both are equally important, and Brundrett (2006) combines the need for fungi and pollinators with orchids in his three key dimensions of orchid presence: differing levels of interactions between the three dimensions determine the specificity and availability of habitat. Potentially suitable habitat may be plentiful in an area, but without fungi and pollinators (or fungi only for self-pollinating species), orchids may not germinate and prosper. Descriptions of occupied vegetation types presented in the current paper, while not comprehensive, now allow a more focused approach to management and searching for further populations of *Pterostylis chaetophora*. Ecologists targeting this species, such as in surveys relating to the development industry, should at least initially consider all habitat as outlined above to potentially support populations of *Pterostylis chaetophora*, surveyed only during known flowering periods but recognising constraints imposed during times of drought. Grasslands derived from these habitats, including those subject to livestock grazing, should also be considered.

Perceptions of population size in any terrestrial orchid species is dependent on the level of effort expended on targeted surveys. A range of factors can influence the extent of a particular species in an area, including experience of

the observer, intensity and regularity of survey, and various environmental conditions (Kery & Gregg 2003; McCormick & Jacquemyn 2014; Brundrett 2016). The experience at Columbey during the 2018 and 2019 flowering seasons has shown how the small number of plants known from past occasional undocumented surveys was unrepresentative of abundance evident following a systematic and targeted search. The implications of this are critical to long-term management of this species, and the positive outcome achieved here can (and should) be replicated with similar systematic surveys for many other threatened terrestrial orchid species. Ultimately, revisions to conservation status may be required for some species where targeted surveys reveal substantial populations on secure land tenure with few active threats, irrespective of perceived fluctuations in numbers apparent over wet and dry seasons.

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