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COMMENT PIECE

The complex nature of headland shrub encroachment: The case of Headland Zieria (*Zieria prostrata*)

By John Thomas Hunter and Vanessa Hewlett Hunter

Summary Headland Zieria (*Zieria prostrata*) is an endangered species restricted to four headlands with a potential population of 1000 individuals. The species also occurs within the endangered ecological community *Themeda* grassland on sea cliffs and coastal headlands in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions. Shrub encroachment of native species is perceived as a threatening process within these grasslands, and also to the unique species within them, such as Headland Zieria. Suggested management actions for the community and Headland Zieria include the removal of other shrubs by frequent fire or mechanical means. We conducted a survey and correlative analyses to test the validity of these proposed actions. We provide evidence that Headland Zieria is facilitated by a higher density of nearby shrubs which may provide protection from the elements and decrease competition from other understorey species but is eventually out competed by them when the grassland fully transitions to a *Banksia* shrubland. We suggest that Headland Zieria is an ecotonal specialist that may require an invasion front of shrubs and/or isolated patches. The implementation of fire and/or overstorey shrub removal may be detrimental where populations of Headland Zieria occur. Our study highlights the need to look more closely at interactions before management actions changing vegetation structure and composition are implemented.

Key words: *coast, fire management, Generalised Additive Modelling, monitoring, rutaceae, threatened species.*

John Hunter is an adjunct Associate Professor with the School of Environmental and Rural Science, University of New England (Armidale, NSW 2351, Australia. Tel+61 2 6775 2452; Email: jhunter8@bigpond.com. Vanessa Hunter is a senior ecologist within Hewlett-Hunter Pty Ltd, Armidale, NSW 2350, Email: vhhunter@bigppond.com.

Introduction

Headland Zieria (*Zieria prostrata* J.A.Armstrong) is described as a component of the endangered ecological community, *Themeda* grassland on sea cliffs and coastal headlands in the New South Wales North Coast, Sydney Basic and South East Corner Bioregions, under the NSW *TSC* Act. It is suggested these communities are in decline due to the absence of fire encouraging shrub encroachment, particularly by Coastal Wattle (*Acacia longifolia* var. *sophorae* (Labill.)) Court and Coast Banksia (*Banksia integrifolia* L.f. subsp. *integrifolia*; Morris *et al.* 1990; Griffith 1992b; Dexter 2015; Dexter *et al.* 2015). Very little has been published on the dynamics of these endangered *Themeda* grasslands with only limited correlative research conducted very recently (Dexter 2015; Hunter & Hunter 2017). The prevailing concerns about shrub encroachment occur within the void of limited information; however, current management prescriptions include the removal of overstorey shrubs mechanically or by the introduction of frequent fire (every 3–6 years) to protect and enhance both the *Themeda* grassland and Headland Zieria populations. The endangered community as it occurs in northern New South Wales is a mosaic of small grassland areas within a matrix dominated by prostrate shrubs such as Headland Zieria (Hunter & Hunter 2017).

Headland Zieria (*Zieria prostrata*) was first discovered in 1981 and formally described by Armstrong (2002). While additional prostrate forms of the closely related Sandfly Zieria (*Zieria smithii* Jacks) were found soon after its description, Hogbin and Crisp (2003) provided evidence to confirm the erection of the taxon to specific status using morphometric analysis and genetic data. Headland Zieria was originally known from three headlands (Look At Me Now, Damerells and Bare Bluff) along a three kilometre stretch of coastline north of Coffs Harbour (Hogbin & Peakall 2000). Griffith (1992a) estimated the total population to be in the order of 400 individuals and found a fourth population on Diggers Point. The species was also presumed to have occurred further south on Bonville Headland. Genetic investigations and interviews conducted by Hogbin and Peakall (1999) suggested that the Bonville Headland population was a misnomer and the collections were probably a mislabelling of material from Diggers Point. Research into the reproductive biology of Headland Zieria revealed sufficient pollen production, good seed set and germination with shallow seed burial and soil disturbance enhancing recruitment (Hogbin & Peakall 2000). Further surveying increased the population estimate to over 1000 individuals (Hogbin & Peakall 2000). Currently, Headland Zieria is listed on the Federal *Environmental Protection and Biodiversity Conservation* (EPBC) Act and the State *Threatened Species Conservation* (TSC) Act as endangered.

The removal of overstorey shrubs by cutting or regular burning can significantly alter the structure and composition of assemblages. Such actions may cause long-term affects and should be considered with caution, and if implemented, must involve rigorous statistically relevant monitoring and with a before and after design. Here we use the initial results collected from permanent monitoring plots placed within *Themeda* grassland and *Banksia* shrubland on headlands in the North Coast of NSW. We test assumptions about the dynamics of these *Themeda* grasslands within northern NSW as they relate to Headland Zieria management by correlative analysis of the preliminary survey results. We test the assumption that the presence of shrubs is detrimental to Headland Zieria and thus whether management actions that include fire and/or mechanical removal of shrubs are appropriate for the survival of this species or if a more nuanced approach may be necessary.

Methods

The study area involved all four headlands known to contain Headland Zieria populations. These headlands include Bare Bluff, Diggers Point, Damerells Headland and Look At Me Now Headland, all of which occur within the Moonee Beach Nature Reserve between Moonee and Sandy Beach north of Coffs Harbour in the North Coast Bioregion of New South Wales. Plots measuring 2 × 2 m were placed randomly with a minimum distance of 10 m between sites across two strata; zones with known Headland Zieria populations and those without. Survey plots included 35 surveyed by Hunter and Hunter (2017) and monitored between November 2015 and February 2016 and an additional 36 in October 2016 placed within *Themeda* grassland and additional plots within adjoining *Banksia* shrubland.

Plots were permanently marked in diagonal corners. Information on GPS location, slope (degree), aspect (degree) and distance to vegetation edge (margin of headland in metres) were recorded. Vascular plant species were identified to species or subspecies and scored using overlapping percentage cover (total cover of all species can be >100%). Per cent cover was chosen as a scoring system for analysis due to the dense interlocking nature of the vegetation. Attempting to find rooted Headland Zieria would likely cause damage or death to individuals. Additionally, the three-taxa considered to have the greatest contribution to overall biomass within the plot (rooted or not) were scored from 1 (highest) to 3 (lowest). A 10 cm-diameter drop plate attached to a metal ruler was used to measure height of understorey standing biomass (Hunter & Hunter 2017). Five randomly placed measurements of biomass height were taken within each plot and averaged for analysis. The general health and condition of individual plants of Headland Zieria was also assessed within each plot and in surrounding occurrences.

To assess the impact of shrub encroachment, shrub biomass within the vicinity of each plot was assessed using circular point method transects. This involved recording the height and identity of shrub taxa at 1 m intervals around the circumference of a circle surrounding the centre of each 2 × 2 m plot. Three circles were assessed; 2, 4 and 8 m radius from plot centre. Heights were summed for each circle and a total for all circles was also derived for analysis purposes. The circular method, unlike a straight line transect allowed for an assessment of shrub biomass in all directions equally. Linear point transects only allow assessments in a single direction as two perpendicular transects become increasingly confounded as they approach the centre of the plot. This statistical error is removed using a circular point method.

Generalised Additive Modelling (GAM) was used to model the single attribute of Headland Zieria cover against significant environmental variables in constrained ordination space. The fitted GAM is a graphical representation of the relationship between the values of the predictor and its effect on the modelled response variable (Šmilauer & Leps 2014). Within CANOCO5 a stepwise model selection occurs, both in terms of predictors used and model complexity. The GAM models of varying complexity are tested within CANOCO5 and the model with highest parsimony is tested via Akaike Information Criterion (Šmilauer & Leps 2014). Environmental variables chosen to test included: combined shrub height (biomass) at 2 m, 4 m and 8 m radius; combined shrub biomass from all circles; average ground layer depth within plot (biomass); altitude; proximity to headland margin; slope; and calibrated aspect (northness to southness). Significant environmental variables were chosen by the manual forward selection procedure in CANOCO5, followed by Monte Carlo permutation tests (1000 iterations). Forward selection allows for the removal of collinear/redundant variables from the Canonical Correspondence Analysis (CCA) regression model and subsequent reanalysis of the contribution of the remaining unselected variables as each new variable is added to the model. Holm's correction was used to adjust the significance values for potential inflated family-wise Type I errors, thus reducing the chances of colinearity and false significance (ter Braak & Šmilauer 2012). Only variables which achieved a *P*-value of <0.05 after Holm's correction were included within the model.

Results

Recorded cover scores of Headland Zieria within the 2 × 2 m monitoring plots ranged from 2% to 60% with an average of 22%. Headland Zieria was the dominating species in terms of ground layer biomass in nine (21%) and second or third in seven (20%) of the monitoring sites containing Headland Zieria.

Forward selection of all environmental variables indicated that Shrub biomass at 2 m, combined total shrub biomass, average understorey biomass depth and distance from headland edge were of significance after Holm's adjustment ($P < 0.05$; Fig. 1). The final CCA model accounted for 15.8% of all variation with Axis 1 and 2 of the constrained ordination explaining 65.45% of variance. GAMs were found to be significant ($P < 0.00001$). All significant environmental vectors were found to increase on the same side of ordination (Fig. 1). The proximity of vectors to each other is an

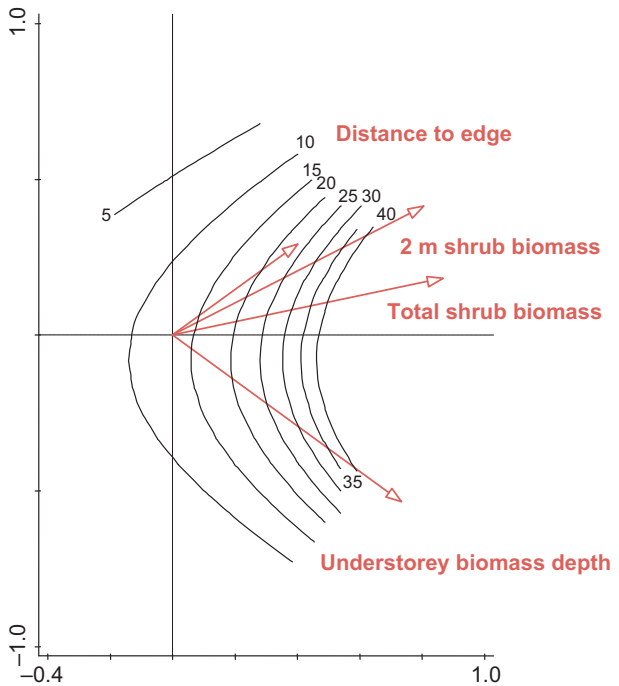

Figure 1. Generalised Additive Model of the effect of significant variables on *Zieria prostrata* cover ($P < 0.00001$). Isolines indicate increasing per cent cover of *Zieria prostrata*. [Colour figure can be viewed at wileyonlinelibrary.com]

indication of interrelationships or reactions to similar gradients. Shrub biomass at 2 m and the total shrub biomass were both found to be of significance indicating independent influence. Plots that were located further from the headland margin also had an increase in Headland Zieria cover. Understorey biomass depth correlated with an increase in Headland Zieria cover and was also associated with an increase in total shrub biomass. Closer analysis indicates an uncoupling of the relationship between total shrub biomass surrounding plots (Fig. 2) at low Headland Zieria cover. The relationship strengthens as both shrub biomass and Headland Zieria cover increases. The polynomial regression of the combined shrub biomass score effect on Headland Zieria explains approximately 46% of the variance (Fig. 3). Additional plots and personal observations within the core of *Banskia* Shrubland indicated that Headland Zieria did not occur within the core of the *Banksia* shrubland community. Health of Headland Zieria plants were recorded within and nearby plots during the survey and the only observations of dead individuals found during the survey were associated with areas that had manual removal of overstorey exotic and native shrubs.

Discussion

The paradigm that the presence and increased density of shrubs, such as Coastal Wattle and Coast Banksia is detrimental to the survival of Headland Zieria is at odds with the results of our model, at least at the encroachment front. The results indicate a more complex relationship between encroaching *Banksia* shrubland and Headland Zieria cover. The encroaching shrubland appears to be initially facilitative but eventually competitive based on this survey of all known populations. Field observations backed by the correlative analysis provided here indicate Headland Zieria may have a unimodal response to shrub occurrence. The species increases in dominance at the encroachment front or around isolated taller shrub patches (facilitative) and decreases in dominance in more open grass dominated areas (possible competition with *Themeda,* Hunter & Hunter 2017) but also is absent from deep within the Coastal Wattle and Coast Banksia shrub zone (potential competition with taller shrubs). Headland Zieria on the *Banksia* shrubland margins or underneath isolated patches of taller shrubs increased in height significantly (pers. obs.). In such locations Headland Zieria was found to dominate the understorey biomass of the plot with a procumbent habit reaching up to 80 cm tall (Hunter 2016). There is potential that Headland Zieria is an ecotonal specialist thriving at the interchange between grass and shrub dominated structural assemblages on these headlands. The encroaching shrub layer may reduce the competitive abilities of Kangaroo Grass (*Themeda triandra* Forsk.) and other grassland specialists, advantaging Headland Zieria.

Our results suggest that removal of overstorey shrubs and/or their control by fire may not be appropriate for the management of Headland Zieria, at least in locations that have a current understorey containing Headland Zieria. If Headland Zieria is an ecotonal specialist, this presents a more complicated scenario that will require a multifarious set of management actions which may include the continued presence of sufficient shrub encroachment zones and isolated patches but not to the extent where *Banksia* shrubland is the dominant habitat on these headlands. Hunter (2016) found the species co-occurring with highest fidelity and abundance with Headland Zieria included other prostrate shrub taxa: Coastal Bush Pea (*Pultenaea maritima* de Kok) and Guinea Flower (*Hibbertia vestita* var. *thymifolia* Benth). Hunter and Hunter (2017) discussed the mosaic of assemblages within the broadly described endangered community (*Themeda* grasslands on coastal headlands) in the Coffs Harbour Region and proposed several vegetation associations, some of which were codominated by prostrate shrubs. These prostrate shrub codominated assemblages would have entirely different recovery from burning compared to the grass and forb dominant types. The use of frequent fire at 3–6 years intervals or yearly as suggested by the Dexter (2015) and Dexter *et al.* (2015) and included as potential management actions for these headland communities, based on evidence presented here, would be

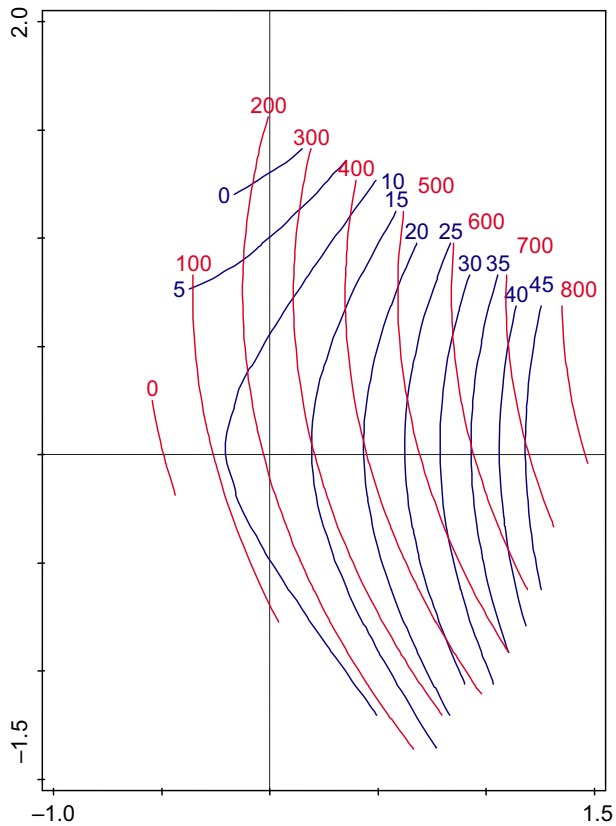

Figure 2. Generalised Additive Model overlapping response isolines of total shrub biomass from each plot (0–800) and *Zieria prostrata* cover (0–45; $P < 0.00001$). [Colour figure can be viewed at wileyonlinelibrary.com]

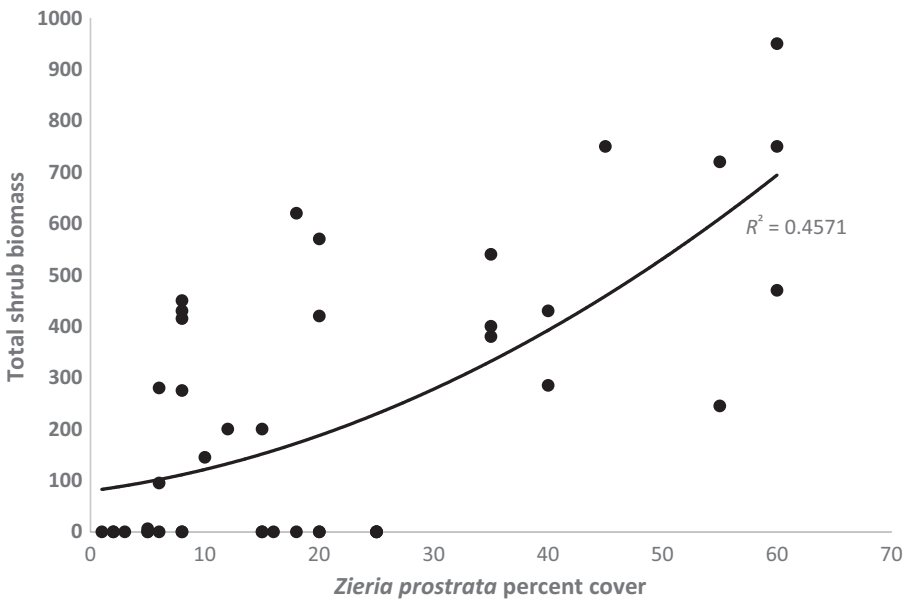

Figure 3. Relationship between total shrub biomass surrounding *Zieria prostrata* sites and the per cent cover of *Zieria prostrata* found within 2 × 2 m plots.

inappropriate for word not required Headland Zieria. We suggest that longer fire intervals may be necessary for the maintenance of Headland Zieria and other prostrate shrub species on headlands in the Coffs Harbour region. Mechanical removal of shrubs around Headland Zieria populations will cause greater exposure to the elements which may advantage other understorey species at the expense of Headland Zieria. The only Headland Zieria plants found dead during this survey were found in *Banksia* shrubland recently opened up by mechanical removal of overstorey native and introduced shrubs. For many threatened species and communities, there is insufficient knowledge available and care should be taken in recommending actions that are likely to significantly change the dynamics of entire assemblages, such as the introduction of regular burning without further investigation.

Conclusion

The results presented are based on an intensive correlative study have provided evidence to suggest that Headland Zieria has a preference for areas with some taller shrub presence, such as around *Banksia* encroachment zones and also may not persist if frequent fires were introduced into these locations. This hypothesis will require testing through following the fate of Headland Zieria growth, fecundity and survival within permanent plots with sufficient replication to provide necessary proof in relation to *Banksia* shrubland encroachment and/or its removal. There is often a perceived need to take action to assist threatened species but this should only ever be done when sufficient evidence is available or if a statistically relevant experimental design concurrently occurs. Simplistic monitoring programmes are often instigated and provide little more than anecdotal information which can too easily lead to confirmation bias.

Shrub encroachment like all environmental phenomenon, particularly those involving native species, will rarely if ever be all bad or all good and consequently there will be benefits to some species within the system but also a detriment to others. Ecology has few simple problems and even fewer simple solutions. This complexity needs to be embraced and the use of black and white solutions, even if expedient and agreed by a majority, need greater evidence before they are implemented. Headland Zieria provides a cautionary tale in this regard.

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