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Short communication

Wild flower harvesting on the Agulhas Plain, South Africa: Impact of harvesting intensity under a simulated commercial harvesting regime for two re-seeding and two re-sprouting fynbos species

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ABSTRACT

We present a simple method for assessing the medium-term sustainability of different flower harvesting intensities (i.e. percentage of number of stems harvested per individual) for two re-seeders and re-sprouters of fynbos plants on the Agulhas Plain in the Cape Floristic Region, South Africa. We interpret our results from an ecological point of view, looking at impacts of harvesting on vegetative re-growth and survival of frequently harvested fynbos species, and an economic point of view, determining the cumulative number of stems harvested per year.

We analysed the impact of different harvesting intensities on two obligate re-seeding (*Erica corifolia* (L.) and *Erica imbricata* (L.)) and two strongly re-sprouting species (*Brunia laevis* (Thunb.) and *Staavia radiata* (L. Dahl)) on different flower farms. Seventy-five randomly selected plants of each species were experimentally harvested in the same way as is done by flower harvesters. Fifteen plants of each species were left as controls (un-harvested) and 15 each were harvested (cut 15–20 cm below the inflorescence) such that 25%, 50%, 75%, and 100% of the inflorescences were removed. Harvested stems were labelled and the number of new shoots counted. Additionally we recorded plant height and mortality.

100% harvesting resulted in high mortality rates for both re-seeders (for both species 100% of the individuals were dead at the end of the experiment) and resprouters (for one species all 15 individuals were dead at the end of the experiment and for the other species 4 of 15). Re-seeders in particular were highly susceptible to harvesting below the first branching node, which generally also resulted in plant death. Both guilds can survive up to 75% harvesting (resprouters experienced no mortality for one species, while in the other 4 out of 15 died; of the re-seeders, 9 out of 15 died in the one species, while only 1 out of 15 in the other) and are still able to grow in height. For both seeders and resprouters we recommend that flower harvesters do not harvest in young veld. To ensure sufficient seed set and to avoid seed bank depletion we recommend to preferably only harvest between 25 and 50% of stems per individual.

1. Introduction

Harvesting of wild flowers is an important economic activity in the Cape Floristic Region of the Western Cape, South Africa (Cabral et al. 2010, Turpie et al. 2003, Bek et al. 2013) with about 60% of the total fynbos flower retail sales in the Western Cape harvested from natural populations (Jones, 2004). The Agulhas Plain is thought to have higher flower harvesting levels and generate more income than any other fynbos area in the Cape Floristic Region (Heydenrych, 1999). Much of the Limestone fynbos and Overberg Sandstone Fynbos of the Agulhas Plain are not suitable for productive agriculture, here flower harvesting and tourism are the main economic activities that support habitat conservation and livelihoods of landowners. Fynbos flower farming, including wild flower harvesting and cultivation of fynbos, is hence the second highest land-use by area in the Agulhas Plain (Heydenrych, 1999) and wild flower harvesting brings in an estimated 28% of landowner income, higher than any other source of income, with some farms in the area relying entirely on the income derived from wild fynbos harvesting (Heydenrych, 1999).

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The Agulhas Plain is a lowland region within the Cape Floristic Region (CFR), one of the 'hottest' biodiversity hotspots in the world (Myers et al., 2000). It is one of the largest extant storehouses of lowland fynbos and is recognised as a 'centre of endemism'. However, this biodiversity is currently being severely impacted by alien plant infestation, inappropriate fire regimes, agricultural and urban expansion and unsustainable flower harvesting practices. Approximately 39% of the Plain has already been transformed by these processes (Cole et al. 2000).

Understanding the impacts of flower harvesting and making appropriate recommendations is important as the export market for fresh wildflowers has become highly competitive in recent years. The demand for fynbos flower products has increased significantly in both local and foreign markets, escalating the pressure on natural populations. This pressure has caused over-harvesting of fynbos species which can have severe economic and ecological consequences. Over-harvesting can result in a decline in available fynbos resources over time, which will ultimately impact on the sustainability of fynbos products and the ability to deliver to local and international markets. A major ecological concern is that over-harvesting could drive certain species towards extinction (Heydenrych, 1999).

Understanding this potential conflict between commercial harvest demand and conservation of a species requires information about the ecological and economic effects of harvesting on that species (Cabral et al. 2010, Mace and Reynolds, 2001). Information on the effects of sustainable flower harvesting is restricted to a few ecological studies which mainly focus on serotinous species in the CFR and the South West Australian Floristic Region. These studies investigate the seed bank ecology in relation to flower harvesting (Mustart and Cowling, 1992), the effects of harvesting on population regeneration (Lamont et al., 2001, Maze and Bond, 1996), and modelling of the persistence and abundance of harvested shrubs (Cabral et al. 2010). Two studies focused on non-serotious species looking at the effects of harvesting on seed and seedling ecology of two co-occurring ericoid fynbos species (Kilian, 1991) and on the effects of harvesting on mortality and seed production of a re-sprouting fynbos species (Rebelo and Holmes, 1988). To our knowledge no study has investigated long-term impacts of actual simulated commercial wild flower harvesting on various fynbos species. In this study we combine an ecological perspective looking at possible negative population impacts of flower harvesting and an economic perspective looking at what harvesting regimes are economically sustainable.

The aim is to present a simple method for assessing the medium-term sustainability of different flower harvesting rates. As an example of how the method can be applied we present a study from the Agulhas Plain, South Africa.

We examine the influence of harvesting on the vegetative regrowth of regularly harvested re-sprouting and re-seeding fynbos species on the Agulhas Plain. We provide ecological and economic thresholds for sustainable flower harvesting based on mortality rate, height growth, change of absolute number of stems and the cumulative number of stems harvested per year.

The study was initiated in 2006 as a long-term monitoring project on two farms on the Agulhas Plain and is the first to provide a measure for species-specific tolerance of different harvesting rates. These different tolerances can be used to define thresholds for sustainable harvesting within the different plant guilds.

2. Methods

The study area is situated on the Agulhas Plain in the Western Cape Province South Africa (2160 km^2) (Fig. 1). The climate of the region is typical Mediterranean with approximately 70% rainfall during the winter months (May–October) with mean annual rainfall of approximately 450 mm and average annual temperatures between 15 and 16 °C. The Agulhas Plain is characterised by a mosaic of vegetation types, with Overberg Sandstone Fynbos, the vegetation type that is most widely used for wildflower farming, as the predominant vegetation unit covering some 54% of the Plain (Heydenrych, 1999, Mucina and Rutherford, 2006).

We chose species of two different guilds (two re-seeders and two re-sprouters) on different flower farms (Table 1). Obligate seeders (re-seeders) consist of plants which are either killed out-right by fire and recruit thereafter from banks of seed buried in soil or protected in woody fruits (serotinous) in the above-ground canopy. Re-sprouters employ a sharply contrasting strategy whereby rootstocks, thick trunks and branches survive fire and replace entire shoot canopies by sprouting from heat-resistant buds.

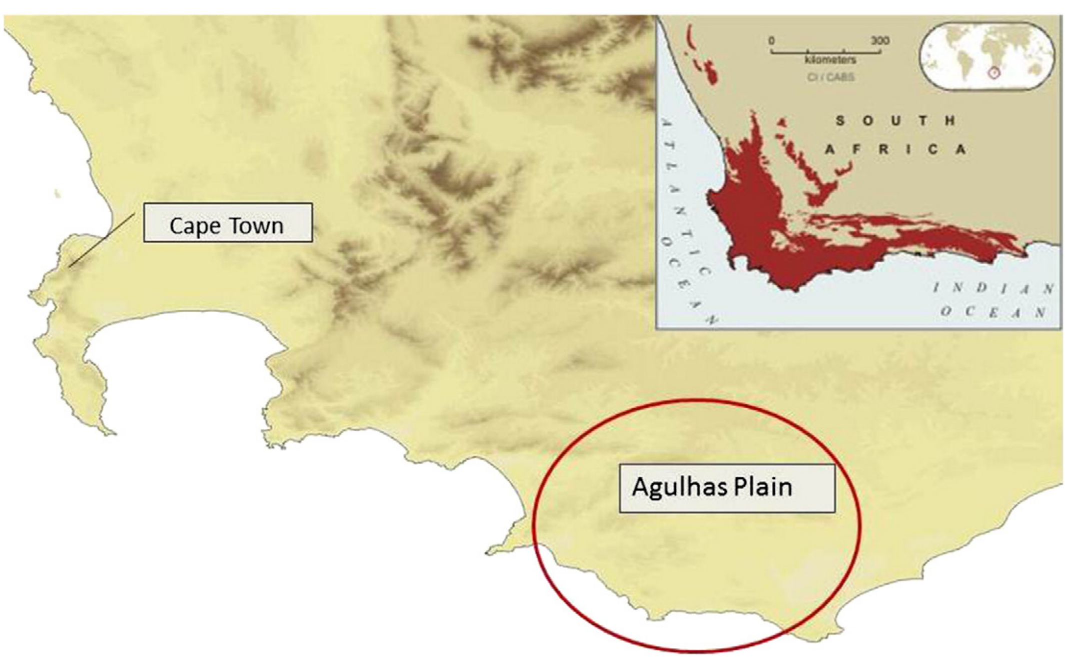

Fig. 1. Map of the study area, Agulhas Plain, in the Cape Floristic Region, Western Cape, South Africa.

Table 1
Species of different guilds investigated for impacts of harvesting between 2006 and 2011 on different flower farms on the Agulhas Plain, Western Cape, South Africa.

Species name	Species guild	Study site	Month harvested	Study period
Brunia laevis	Re-sprouter	Sandberg	Oct–Nov	2006–2011
Staavia radiata	Re-sprouter	Witvoetskloof	May–July	2007–2011
Erica corifolia	Re-seeder	Witvoetskloof	May–July	2007–2011
Erica imbricata	Re-seeder	Witvoetskloof	May–July	2007–2011

Plant populations chosen for this study had not been harvested since the last fire 12 years ago. Seventy-five plants of each population were randomly chosen, labelled and experimentally harvested in the same way as is done by flower harvesters. Fifteen plants of each population were left as controls (un-harvested) and 15 plants of each treatment were stem harvested (cut 15–20 cm below the inflorescence) such that 25%, 50%, 75%, and 100% of the inflorescences were removed. Harvesting was consistently done during the peak flowering time of each plant (see table 1). Prior to experimental harvesting, stems were labelled and the number of new shoots was recorded. Additionally we recorded the height and if the plant had died. In order to gain insight into the effect of repeated harvesting on these species, the harvesting experiments were repeated for a maximum of five subsequent years (harvesting period for each species is specified in Table 1).

3. Statistical analysis

The measure used to determine ecological thresholds of sustainable flower harvesting were mortality rate, height growth, and change of absolute number of stems. The measure used to determine economic thresholds of sustainable flower harvesting was the cumulative number of stems harvested per year. In contrast to e.g. mean number of stems per plant, the cumulative number of harvested stems is the number which can be most directly linked to economic measures as it represents the total economic return from a species over a defined period.

We used linear mixed-effects models (lme(), package nlme, Pinheiro et al., 2012) in R 2.15.2 (R Core Team, 2012) to determine the effects of different harvesting regimes on the above listed variables. The script used to do the analysis and the graphs can be found in the electronic appendix. To compare different models and to identify the best model, the Akaike Information Criterion (AIC) was used.

To display and assess individual differences between individual harvesting rates and years, notched box-and-whisker plots were generated with the function boxplot() in R (R Core Team, 2012). Non-overlapping notches are "strong evidence" that the two medians differ (Chambers et al. 1983, p. 62).

4. Results

4.1. Ecological sustainability

4.1.1. Re-sprouter

For *Brunia laevis* time, harvesting rate and their interactions contribute significantly to the identified best fitting model (Fig. 2a). The box whisker plot shows that there is no significant difference in height between treatments except for 100% harvesting. In addition the only mortality recorded was in the 100% treatment (Fig. 2a).

For *Stavia radiata* the only harvesting regime that differs consistently from the others is 100% harvesting. In general, plant height increases with decreasing harvesting rate. Control and 100% harvesting show higher mortality than other treatments (Fig. 2b).

4.1.2. Re-seeder

In contrast to the re-sprouters, the re-seeding species, *Erica corifolia* and *Erica imbricata* showed no observable or significant difference in height between any of the treatments. 100% harvesting kills both *Erica* species and the second highest mortality was observed for the control treatment. Mortality declines with decreasing harvesting rates (75% to 25%) (Fig. 2c,d).

4.2. Economic sustainability (cumulative number of stems harvested)

4.2.1. Re-sprouter

For *B. laevis* the highest cumulative harvest was obtained in 100% harvesting rates in the first year of harvesting and over the duration of the experiment. In the short term, increased harvesting rates lead to increased returns (Fig. 3a).

In contrast, *S. radiata* shows the highest return in intermediate harvesting rates (50 and 75%). In addition, *S. radiata* shows an increase in return over time whereas *B. laevis* shows no significant increase in return after the second year (Fig. 3b).

4.2.2. Re-seeder

The highest return was achieved in maximum harvesting rates for *Erica corifolia* (75%) and in the first year for *E. imbricata* (100%). *E. imbricata* shows linear increase in number of stems harvested in intermediate harvesting levels (25%) (Fig. 3 c,d).

5. Discussion

Our results provide insights into ecological and economic effects of harvesting on selected re-seeding and re-sprouting fynbos species on the Agulhas Plain, South Africa. Natural fynbos vegetation on the Agulhas Plain provides a valuable, yet dynamic and limited natural resource for farmers to exploit. Flower farmers are often required to provide a steady volume of produce throughout the year with pressure on certain economically valuable species such as the very popular *Brunia laevis*.

According to our findings 100% harvesting of individual plants results in near 100% mortality for three of the four species studied. The re-sprouting *B. laevis* appears to be able to withstand even 100% harvesting with a higher, but still relatively low overall mortality (4 of the 15 individuals versus 0 for the other treatments). The 100% harvesting treatment of *B. laevis* produced the highest cumulative harvest over the five year study period. However, the increasing mortality with time as well as the lack of cumulative increase in harvest over time relative to the lower harvesting rates suggests that harvesting at 100% over the longer term (>5 years) is not sustainable. Furthermore the very high mortality in three of the four species at 100% harvesting rates (100% mortality over five years) indicates that 100% harvesting is not sustainable and should not be permitted.

Fire plays a crucial role in the availability of flower resources and there is often pressure on farmers to harvest in young vegetation for economic reasons. Re-seeders are particularly susceptible to harvesting below the first branching node, which generally results in plant death. However, re-sprouters, which are capable of re-establishing from storage organs, can better tolerate harvesting below the first branch. Both guilds can survive up to 75% harvesting and are still able to grow in height.

While 50% of our species showed the highest cumulative returns at moderate harvesting rates, even over the short term of this study, two of the species (*B. laevis* and *Erica imbricata*) produced the highest cumulative harvest at 100% harvesting over the five year period. However, our results show the cumulative harvest from these species does not

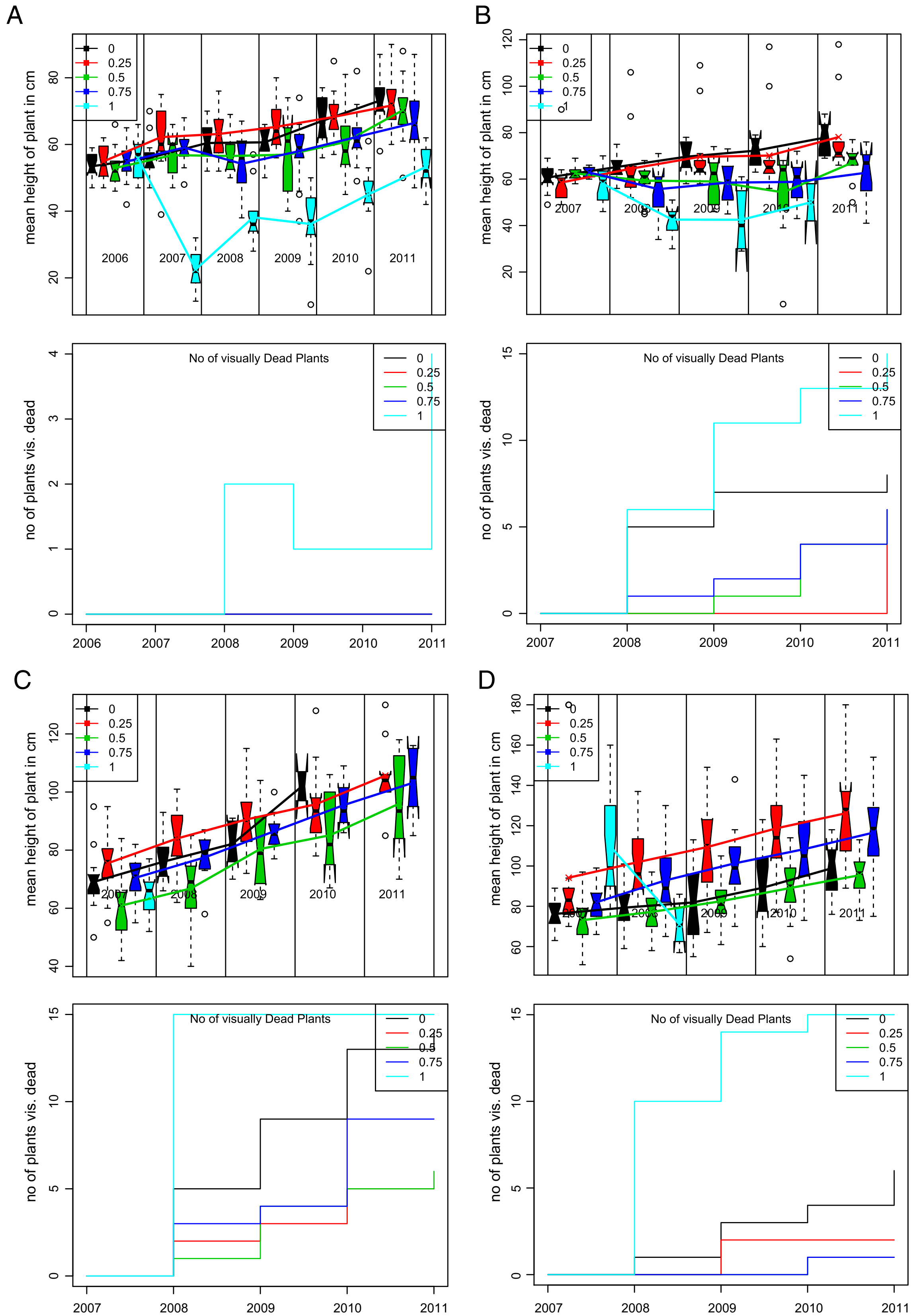

Fig. 2. Mean height and mortality for the two reprouters (A *Brunia laevis* and B *Staavia radiata*) and two re-seeders (C *Erica corifolia* and D *Erica imbricata*) for different harvesting rates (0%, 25%, 50%, 75% and 100%) over a period of maximum 5 years. Linear mixed-effects models were used to determine the effects of different harvesting regimes.

increase after the second year, while there is a steady annual increase in cumulative harvest for the lower harvesting rates. We suggest that, as shown by 50% of our species over the short term, cumulative harvesting is highest at moderate harvesting rates and that a wise farmer who does not know the exact response of a species should be conservative and harvest at between 25 and 50%. This is line with the 50% harvesting

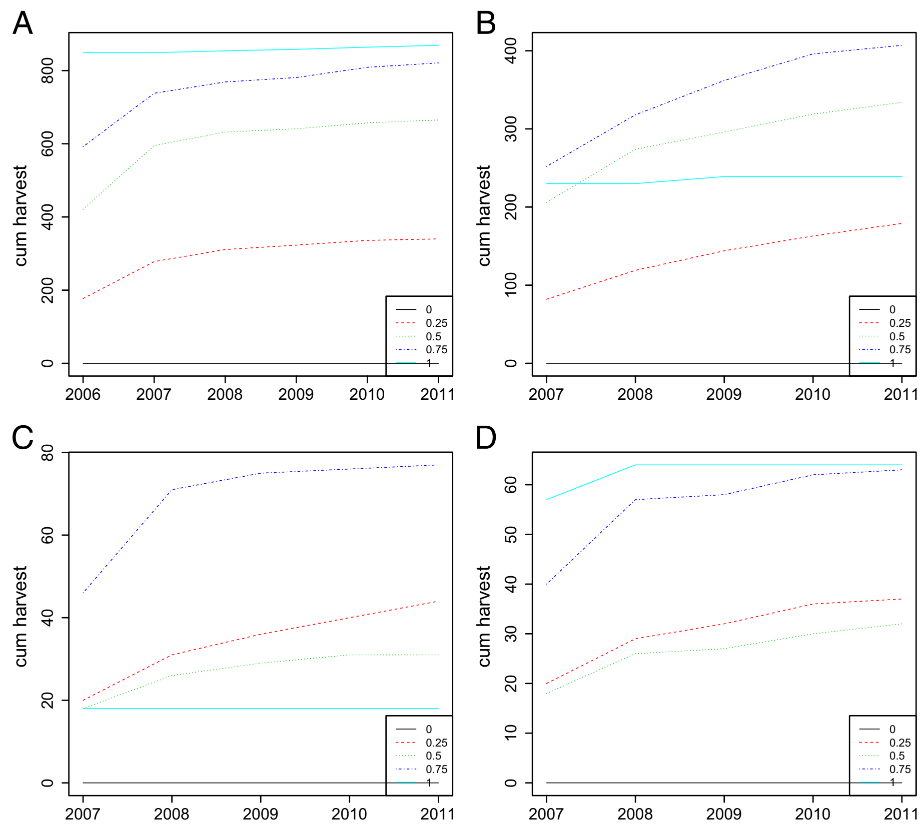

Fig. 3. Cumulative number of harvested stems for the two resprouters (A *Brunia laevis* and B *Staavia radiata*) and two re-seeders (C *Erica corifolia* and D *Erica imbricata*) for different harvesting rates (0%, 25%, 50%, 75% and 100%) over a period of maximum 5 years. Linear mixed-effects models were used to determine the effects of different harvesting regimes.

limits proposed from seed bank ecology studies which will ensure sufficient seed set to avoid seed bank depletion (Mustart and Cowling, 1992).

The combined use of economic and ecological sustainability measures provides an exciting opportunity to strengthen ecological arguments with economic reasoning. While high harvesting levels (75–100%) produce the highest harvesting returns in the short term, they result in higher mortality levels and are therefore not sustainable in the medium to longer term. Whereas low to medium harvesting rates produce lower short-term returns but can sustain higher long-term productivity (economic sustainability) while ensuring the survival of the plant (ecological sustainability).

Further research should include experiments that allow for a recovery period (i.e. one to two years of no harvesting at all). Although not shown here, preliminary results on this suggest that at least for re-sprouters a recovery period is not needed in regards to number of stems and height growth.

It is important to note that abundant species, particularly those that are resilient to the impact of harvesting through high growth rates and/or re-sprouting/coppicing response, are more easily able to withstand the impact of intensive harvesting (Botha et al. 2004). A vulnerability index (Privett et al. in prep) has been developed for 150 potentially harvestable species on the Agulhas Plain that ranks the vulnerability of species to harvesting on the basis of their abundance, distribution and biological features. This index has proven a valuable first step in being able to distinguish those species that are more vulnerable to harvesting from those that are more resilient. However, species-specific research such as undertaken for this study is essential to better understand harvesting impacts on commonly harvested commercial species.

In the face of increasing financial constraints, it may be tempting to reduce research and monitoring of plants. However, determining appropriate harvesting quotas combined with adequate monitoring of populations has proven crucial in the long-term management of commercially important species (Lamont et al. 2001, Witkowski et al. 1994). Our results have shown that it is imperative that monitoring and research continues over a longer time period and with more species. Ideally this study should have been carried out over a longer time frame than five years to fully understand how the cumulative harvest is affected by repeated harvesting at different rates. Follow-up studies could also gain by adding more study sites for the same species to incorporate environmental variation. Furthermore, it would be beneficial to include other biological attributes such as reproduction and plant–plant interactions (i.e. competition) as well as post fire population recovery following these medium-term harvesting treatments.

It has been shown that the persistence of fynbos species to harvesting is often unaffected up to a threshold level of harvest (Cabral et al. 2010). Our study is the first to categorically show that heavy harvesting on both re-seeders and re-sprouters results in high mortality, with higher mortality in all cases, and near 100% mortality for three of the four species studied. This is especially important with regards to harvesting in young veld (i.e. anywhere where cutting is required below the first node in re-seeders) but also with regards to repeated heavy harvesting of re-sprouters. Further, our results support the notion that light to moderate harvesting can result in increased re-growth (stem length) at least in re-sprouting species. The results also indicate, at least for three of the four species, that light harvesting might reduce mortality relative to no harvesting, however this needs to be explored further. We conclude that flower farmers should not harvest in young veld (i.e. 4–5 years post fire), and should not harvest 75–100% but preferably stick to the 25–50% rule (Mustart and Cowling, 1992) to maintain ecological but also economical sustainability.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.sajb.2014.06.015.

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