

Dalrymple, R. L., Buswell, J. M. and Moles, A. T. 2014. Asexual species change just as often and just as fast as do sexual species when introduced to a new range. – Oikos doi: 10.1111/oik.01582

Appendix 1

Study species information

Table A1. Six introduced species in New South Wales, Australia included in the study, and information on reproduction, growth form and introduction.

Species, family	Mode of reproduction	Introduction	Growth form	Notes and references
<i>Ageratina adenophora</i> Asteraceae	Apomictic triploid with seeds formed by agamospermy/parthenogenesis. Vegetative reproduction for local propagation.	First found near Sydney 1920 (recorded under name <i>Eupatorium glandulosum</i>).	Herbaceous shrub	Auld 1970, Baker 1965
<i>Anredera cordifolia</i> Basellaceae	Vegetative propagation by tubers from roots or stems. Seed production very uncommon, only a single documented account since introduction – Toowoomba, QLD. Samples from this area excluded as only sampled NSW specimens. Australia's other populations are effectively sterile, it is unknown why this population set seed.	Introduced before 1906 for ornamental purposes. Herbarium specimens from 1931. Naturalised at least since 1960s	Herbaceous creeper or shrub	AVH 2010, Swarbrick 1999, Vivian-Smith et al. 2009 Even species identified as obligate apomicts will often have a sexual-asexual polymorphism in some populations (Stebbins 1971).
<i>Chondrilla juncea</i> Asteraceae	Triploid, obligate apomict, seeds produced without meiosis. Vegetative propagation of satellite rosettes from adventitious buds.	Accidental introduction, first identification from specimen collected in 1917 but probably arrived before 1910 as seed in animal fodder.	Rosette forming herb	Cuthbertson 1974, McVean 1966, Panetta and Dodd 1995
<i>Ipomoea indica</i> Convolvulaceae	Reproduces vegetatively from stem fragments that produce new roots at nodes. Does not produce viable seed in Australia. Fruits rarely setting.	Recorded 1915 in NSW (NSW647127).	Herbaceous climber	Muyt 2001
<i>Oxalis pes-caprae</i> Oxalidaceae	Vegetative propagation by bulbils and rhizomes. Viable seed produced by tetraploid population restricted to WA. Pentaploid east coast populations (aggressive invader of much of Australia) are accounted to produce zero seed set or sterile uncommon seed.	Probably introduced before 1845, declared weed of cereals by 1860, herbarium records date from 1884. Pentaploid variety possibly introduced as a soil contaminant in vine and fruit stocks in 1880's. tetraploid is not aggressive, possibly escaped ornamental.	Bulbous herb	Baker 1965, Peirce 1998, Rottenberg and Parker 2004
<i>Tradescantia fluminensis</i> Commelinaceae	Vegetative propagation by stolons and fragmentation. Seed is uncommon in Australia and is unviable.	Herbarium records date from at least 1921. May have been introduced as a garden plant as is popular ground cover.	Succulent, stoloniferous herb	AVH 2010, Muyt 2001

Table A2. Six introduced species in New Zealand included in the study, and information on reproduction, growth form and introduction.

Species, family	Mode of reproduction	Introduction	Growth form	Notes and references
<i>Anredera cordifolia</i> Basellaceae	Spreads by fragments of rhizome and stem tubers. Fruits are not formed in New Zealand.	Naturalised between 1900 and 1940; herbarium collection date back to 1935 (WELT62363)	Perennial vine	Esler 1987, Roy et al. 1998, Webb et al. 1988
<i>Delairea odorata</i> Asteraceae	Reproduction is seedless, with dispersal from fragmentation. Asexuality is accounted to the presence of sporophytic self incompatibility in the New Zealand populations which could have been derived from the introduction of a single genotype or a few genets that contain the same s-allele.	Naturalised and collected by Kirk 1871	Scrambling perennial	Esler 1987, Scott 200)
<i>Glechoma hederaceae</i> Lamiaceae	Fruit not found in NZ. Spreads by stolon growth and fragmentation.	Herbarium collections date back to 1935 (CHR17794)	Scrambling perennial	Roy et al. 1998
<i>Ipomoea indica</i> Convolvulaceae	Reproduces vegetatively from stem fragments that produce new roots at nodes. Seed and fruit production is reported as very rare in New Zealand or fruits not forming. Plants have been found on the Omokoroa Peninsula and in the Tauranga area of the Bay of Plenty producing viable seed and growing from seedlings between 1996 and 2008*. The population is believed to have derived from a single individual which was the first reported to set seed: CHR507184 - Loc South Auckland district, Bay of plenty, Omokoroa Peninsula, Prole road, Lat 37 39S Long 176 01E, Plant identification register 96/76 (PID Bk 18, 18,20) collected by Stahel, W., 01 May 1996.	Naturalised by 1950; herbarium collections date back to 1942 (CHR36208)	Herbaceous perennial climber	Esler 1987, NZVH 2010, Roy et al. 1998 Even species identified as obligate apomicts will often have a sexual-asexual polymorphism in some populations (Stebbins 1971). * The event has been well documented by herbaria. The following specimens were excluded from sampling as are records of the population in this area: AK253972, AK253973, AK283487, AK302903, AK280101, CHR507184 CHR522972
<i>Oxalis pes-caprae</i> Oxalidaceae	Vegetative propagation by bulbils and rhizomes. Capsules, seed and fruit are not seen in NZ.	Naturalised and collected by Cheeseman in 1883	Perennial herb	Esler 1987, Roy et al. 1998, Webb et al. 1988
<i>Tradescantia fluminensis</i> Commelinaceae	Vegetative propagation by stolons and fragmentation. Fruits not recorded.	Naturalised by 1916, 1 st recorded by Carse, Dec 1916 (AK95206)	Stoloniferous herb	Edgar and Healy 1980, Roy et al. 1998

Appendix 2

Results Tables

ANCOVAs were used to determine whether asexual species showed a change in a trait through time while controlling for region. Year was used as a covariate, region as a fixed factor, and the trait as the dependent variable ($\alpha = 0.05$). If a significant interaction between year and region was found, then linear regressions were fitted to each region separately. When any of these region specific linear regressions returned a significant effect for Year, the details are reported. If the interaction was not significant then the interaction term was dropped from the model and the analysis rerun.

If the term for Year was significant, then the details of the model for the Year term are listed, indicating the change through time. Significance of the term for Region indicates that plants are growing differently along the environmental gradients on which our regions are based, but does not indicate anything about change through time. Therefore details of any models demonstrating significant differences between regions are not provided in the tables.

Magnitudes of changes were calculated as percent per 100 years, derived from the slopes of linear regressions:

$$\text{Change per century} = (((10^{\text{SLOPE}})^{100}) - 1) \times 100$$

Table A3. Leaf shape.

* “variant” was included as a term in the analysis for this species as 3 style races are known. ANCOVA analysis showed a significant difference in leaf shape between variants (variant × year p=0.978, year p=0.474, variant p=0.003; n=38). It is important to note that the analysis did not show an interaction between variant and time; the results reflect a small difference in mean leaf shapes between the variants (mid style length variant mean = 0.07, short style length variant mean = 0.095) that remains static through time.

Species	Interaction Region × Year	Region	Year	Slope	Slope std error	Intercept	R ²	Magnitude of change - % per 100 years	n1 - sheets, sum of weights	n2 - individuals
Introduced										
<i>Ageratina adenophora</i>	p=0.646	p=0.880	p=0.060	0.00099	0.0020	-2.099	0.06	25.6%	54	59
<i>Anredera cordifolia</i> NSW	p=0.704	p=0.640	p=0.149						51	53
<i>Anredera cordifolia</i> NZ	p=0.758	p=0.186	p=0.183						49	51
<i>Delairea odorata</i>	p=0.775	p=0.149	p=0.475						79	83
<i>Glechoma hederacea</i>	p=0.120	p=0.045	p=0.243						41	110
<i>Ipomoea indica</i> NSW	p=0.239	p=0.720	p=0.813						42	46
<i>Ipomoea indica</i> NZ	p=0.679	p=0.048	p=0.036	-0.001	0.00046	1.989	0.16	- 20.5%	44	45
<i>Oxalis pes-caprae</i> NSW	p=0.948	p=0.001	p=0.213						68	83
<i>Oxalis pes-caprae</i> NZ*	p=0.216	p<0.0001	p=0.247						80	99
<i>Tradescantia fluminensis</i> NSW	p=0.408	p=0.697	p=0.872						54	87
<i>Tradescantia fluminensis</i> NZ	p=0.942	p=0.161	p=0.0005	-0.0013	0.00036	2.165	0.12	- 25.9%	82	126

Table A4. Leaf area.

* Due to the morphology of this species, this result is based upon stem leaf length, not leaf width to length ratio (shape). Due to lack of regional spread in the data this species is analysed by linear regression against year.

** a significant interaction effect was returned on the full model for Region × Year. When the regressions were plotted for each region separately a significant result was returned for north region, however, statistical quality rules removing temporal outliers and assuring a 30 year sampling period nullified this significant result, and hence no significant interaction is plotted on graph.

*** “variant” was included as a term in the analysis for this species as three style races are known – Short, Mid and Long Style forms. ANCOVA analysis showed no significant effect of variant on this trait (variant × year $p=0.111$, year $p=0.120$, variant $p=0.330$; $n=38$).

Species	Interaction Region × Year	Region	Year	Slope	Slope std error	Intercept	R ²	Magnitude of change - % per 100 years	n1 - sheets, sum of weights	n2 - individuals
Introduced										
<i>Ageratina adenophora</i>	p=0.204	p=0.127	p=0.801						54	59
<i>Anredera cordifolia</i> NSW	p=0.190	p=0.074	p=0.658						51	53
<i>Anredera cordifolia</i> NZ	p=0.309	p=0.974	p=0.193						49	51
<i>Chondilla juncea</i> *			p=0.033	- 0.0041	0.0018	9.733	0.15	- 61.1%	29	31
<i>Delairea odorata</i>	p=0.981	p=0.097	p=0.850						79	83
<i>Glechoma hederacea</i>	p=0.006**	p=0.012	p=0.014						41	110
	South		p=0.741						22	64
<i>Ipomoea indica</i> NSW	p=0.801	p=0.784	p=0.110						42	46
<i>Ipomoea indica</i> NZ	p=0.937	p=0.656	p=0.566						44	45
<i>Oxalis pes-caprae</i> NSW	p=0.724	p=0.029	p=0.120						68	83
<i>Oxalis pes-caprae</i> NZ ***	p=0.024	p=0.385	p=0.029						80	99
	North		p=0.757						56	64
	Mid		p<0.0001	0.0074	0.0015	-12.371	0.43	449.5%	22	33
<i>Tradescantia fluminensis</i> NSW	p=0.422	p=0.381	p=0.235						54	87
<i>Tradescantia fluminensis</i> NZ	p=0.748	p=0.249	p<0.0001	0.0082	0.0017	-13.449	0.17	560.7%	82	126

Table A5. Internode length.

*a significant interaction effect was returned on the full model for Region × Year. When the regressions were plotted for each region separately, statistical quality rules removing temporal outliers, assuring a 30 year sampling period and a minimum within-region sample size of 10 nullified this significant result, and hence no significant interaction is plotted on graph.

** Due to lack of regional spread in the data this species is analysed with linear regression against year

Species	Interaction Region × Year	Region	Year	Slope	Slope std error	Intercept	R ²	Magnitude of change - % per 100 years	n1 - sheets, sum of weights	n2 - individuals
Introduced										
<i>Ageratina adenophora</i>	p=0.688	p=0.711	p=0.541						53	58
<i>Anredera cordifolia</i> NSW	p=0.535	p=0.034	p=0.803						40	42
<i>Anredera cordifolia</i> NZ	p=0.004*	p=0.550	p=0.484						49	51
North			p=0.564						42	44
<i>Chondrilla juncea</i> **			p=0.213						31	33
<i>Delairea odorata</i>	p=0.327	p=0.832	p=0.271						78	82
<i>Glechoma hederacea</i>	p=0.0004	p=0.005	p=0.130						41	110
North			p=0.861						12	28
South			p=0.041	-0.0043	0.0021	9.944	0.07	-62.8%	22	64
<i>Ipomoea indica</i> NSW	p=0.131	p=0.281	p=0.842						38	42
<i>Ipomoea indica</i> NZ	p=0.459	p=0.329	p=0.428						35	36
<i>Tradescantia fluminensis</i> NSW	p=0.302	p=0.100	p=0.136						54	86
<i>Tradescantia fluminensis</i> NZ	p=0.497	p=0.100	p=0.144						81	125

Table A6. Plant height.

* Due to lack of regional spread in the data this species is analysed with linear regression against year

** “variant” was included as a term in the analysis for this species as 3 style races are known. ANVOCA analysis returned a non-significant effect of variant (variant × year p=0.277, year p=0.181, variant p=0.832; n=38).

Species	Interaction Region × Year	Region	Year	Slope	Slope std error	Intercept	R ²	Magnitude of change - % per 100 years	n1 - sheets, sum of weights	n2 - individuals
Introduced										
<i>Chondrilla juncea</i> *			p=0.092	-0.0032	0.0018	9.065	0.14	- 52.1%	20	21
<i>Glechoma hederacea</i>	p=0.0001	p=0.013	p=0.777						27	76
South			p=0.002	-0.0060	0.0019	14.095	0.18	- 74.9%	16	48
<i>Oxalis pes-caprae</i> NSW	p=0.406	p=0.194	p=0.768						61	74
<i>Oxalis pes-caprae</i> NZ**	p=0.174	p=0.018	p=0.209						79	98

Table A7. Leaf mass per area (LMA).

*All leaf mass measurements were taken from coast region *Tradescantia* specimens. LMA data was linearly regressed against time.

Species	Interaction Region × Year	Region	Year	Slope	Slope std error	Intercept	R ²	Magnitude of change - % per 100 years	n1 - sheets, sum of weights	n2 - individuals
Introduced										
<i>Anredera cordifolia</i> NSW	p=0.693	p=0.103	p=0.017	-0.0036	0.0014	2.827	0.23	- 56.3%	28	28
<i>Tradescantia fluminensis</i> NSW*			p=0.198						17	17

Appendix 3

Observer bias control

Observer bias was investigated to examine the effect of observer in detecting the rates of change in sexual and asexual species, to validate the direct comparisons of our measurements (by Dalrymple) on asexual species with Buswell et al's. (2011) measurements (by Buswell and others, including Dalrymple) on sexually reproducing species.

Firstly, a measurement comparison was performed to test for observer bias in measurement methodology. One species was randomly selected (*Tragus australianus*) from those that showed no change in height through time. Height was chosen as the measure for this part of the control as there is only a single measurement per individual and thus the measurements of the two observers can be paired and compared, while other traits that involve leaves involve a degree of choice which shall be teased out further on. Linear regression on \log_{10} transformed data showed a very strong level of agreement of the two observers' measurements, with a slope of 1.03, an intercept of -0.07 and an R^2 of 0.93 ($n = 21$) (Table A1, Fig. A1).

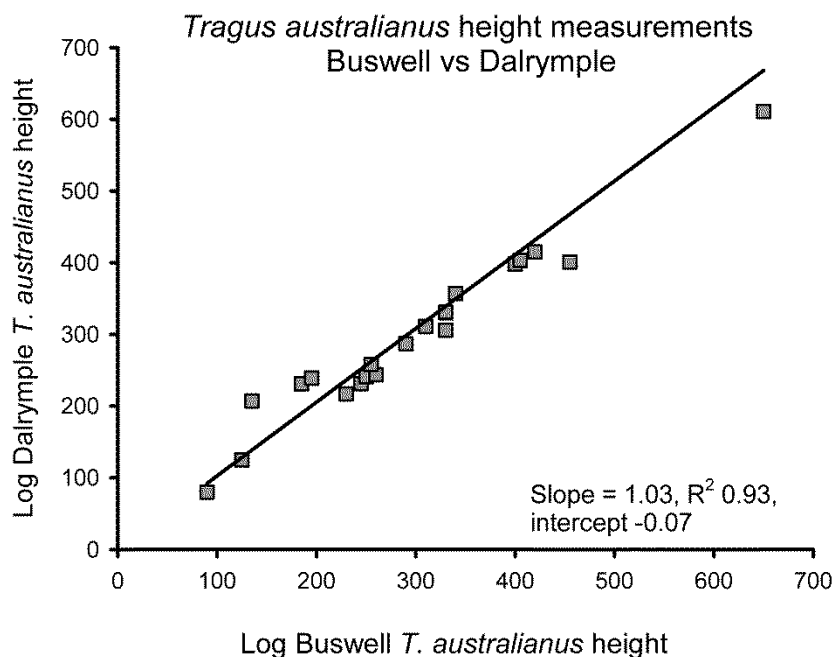


Figure A1. Relationship of measurements of height of *Tragus australianus* by Buswell and Dalrymple.

In order to examine the observer effect of the choice of specific individuals and leaves measured for data, one species (*Gamochaeta americana* (which had the largest number of accessible specimens)) was measured for leaf shape. The aim of this study was to resample the specimens of the species, and see if the same rate of change (slope of regression) could be detected by a different observer. The data were analysed using ANCOVA, as described in the methods. Buswell’s raw data was reanalysed in order to get a higher resolution than the rounded published figures for a more accurate comparison.

Despite differences in choice of which herbarium sheets to include, which has led to a difference in the result for effect of region, the observers were able to detect the same rate of change in the species (Table A2). The slope results are remarkably close with Buswell’s $m = -0.000958$ and Dalrymple’s $m = -0.000964$ (Fig. A2a–b). The intercepts of these regressions are also very close, and the R^2 of the data is quite low for both data sets indicating that there is a large proportion of variance measured by both observers that remains unexplained by the model.

In conclusion, there was no evidence for observer bias in measurement methodology or in the rate of change results produced by different observers. Thus, comparisons of data for sexual species gathered by Buswell and data for asexual species gathered by Dalrymple are valid.

Table A9. ANCOVA results of Buswell and Dalrymple’s data for *G. americana* showed different observers were able to detect the same rate of change.

Raw data	Observer	
	Buswell	Dalrymple
Year × region	p=0.23	p=0.99
Year	p=0.02	p=0.02
Region	p=0.34	p=0.006
Slope	-0.000958	-0.000964
Intercept	1.21	1.25
Rsquare	0.04	0.08
n	90	84

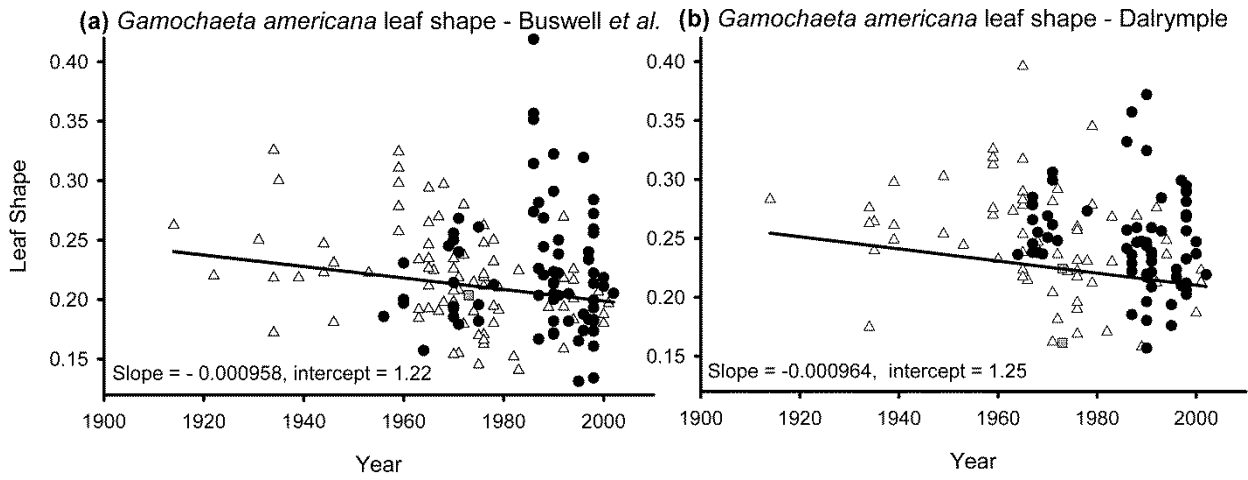


Figure A2a–b. Choice of sheets to include in the study means that a slightly different subset of individuals were sampled by the two observers when measuring leaf shape of *G. americana*. Despite this, the slope of the regressions and the intercepts detected were the same.

Appendix 4

Binomial tests for type 1 error

As a lot of individual analyses were run, we have explored the possibility of type I error by applying binomial tests. The binomial test involves one bi-level categorical dependent variable (in our case: trials, and successes in those trials) and no independent variable. These analyses explored whether the number of significant results was greater than expected by chance, using an alpha of 0.05. We have applied the binomial test separately to the asexual and sexual data as different numbers of tests were performed on the two datasets (the datasets differ in number of species). These tests were performed using `binom.test` in R.

We performed 41 tests for our asexual introduced species, of which nine returned significant results. There is a very low probability of observing this many or more significant changes due to chance alone ($p = 0.0001$). In Buswell et al. (2011) 121 tests were performed on sexual species, 26 of which returned significant results. There is a very low probability of observing this many or more significant changes due to chance alone ($p = 0.0001$).

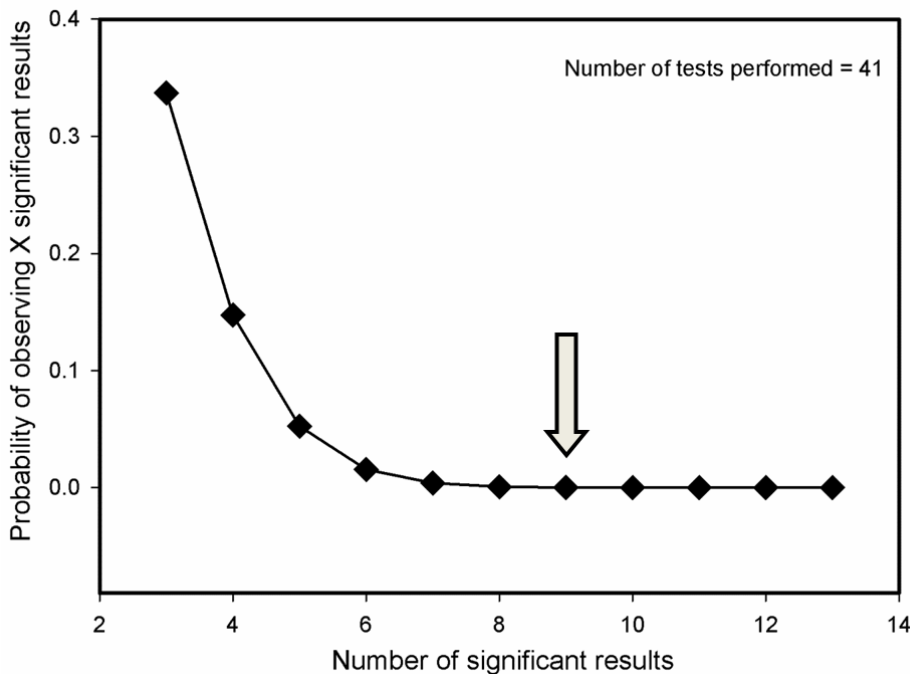


Figure A3. Probability of type I error for the asexual data, given that 41 tests were performed. Nine of our tests were significant, indicated with the arrow.

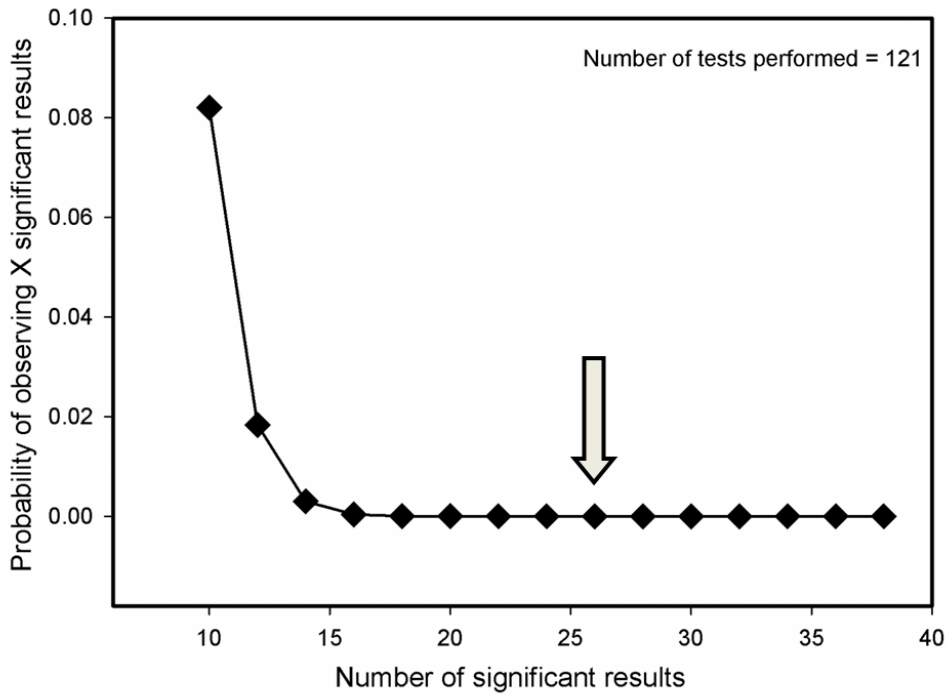


Figure A4. The probability of type I error for Buswell et al.'s sexual data, given that 121 tests were performed. 26 of their tests were significant, indicated with the arrow.

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