

## DECLINE IN NATIVE ANNUALS AND INCREASE IN NONNATIVE ANNUALS IN THE CALIFORNIA DESERTS

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### ABSTRACT

Empirical observations in collecting plants for antitumor screening indicate that the occurrence of native annuals in the California deserts appears to be in decline, while nonnative annuals are spreading. Previous studies by others indicate a close relationship between off-road vehicle tracks and the presence of nonnative annuals. In this study, the Consortium of California Herbaria was consulted to determine whether there is evidence for a decline in the number of collections for selected native annuals (*Anisocoma acaulis*, *Atrichoseris platyphylla*, *Caulanthus inflatus*, *Mohavea breviflora*, *M. confertiflora*, *Mimulus bigelovii*, *Mentzelia involucrata*, *Orobancha cooperi*, *Stillingia spinulosa*), compared to native shrubs (*Atriplex hymenelytra*, *Bebbia juncea*, *Hymenoclea salsola*, *Isomeris arborea*, *Krameria grayi*), and one native annual (*Monoptilon bellioides*) thought to be less impacted by off-road vehicles, and whether such a decline corresponds to an increase in collections for nonnative annuals (*Brassica tournefortii*, *Erodium cicutarium*, *Schismus arabicus*, *S. barbatus*). The number of collections for each species was tabulated for decade periods from 1880 to 2000 and from 2001 to 2005. Most native species had the highest number of collections for 1931–1940 when collections for herbaria in general were also greater; however, since 2000 most native annuals either showed a decline in collections, or were less frequently collected than shrub species and the annual *Monoptilon bellioides* (selected as a basis for comparison). This is in sharp contrast to an increase in collections of nonnative species. The decline in native annuals and increase in nonnative annuals is suggested to be a result of increasing off-road vehicle activity.

Key words: annuals, California deserts, herbarium specimens, invasive species, off-road vehicle (ORV).

### INTRODUCTION

The number of plant species yielding samples of 0.5–1.0 kg dry weight for antitumor screening of novel compounds by the National Cancer Institute (NCI) appears to be in decline. The major environmental changes in the southern California deserts observed over the years (Fig. 1–2), aside from urban expansion (Pavlik 2008), are due to off-road vehicle recreation (OVR) as seen by the ATV (all-terrain vehicle) or ORV (off-road vehicle) tracks and the spread of nonnative species, both of which have been observed to be spreading rapidly across the California deserts, especially since the year 2000. These vehicular designations and others such as OHV (off-highway vehicles) are herein collectively referred to as ORV for off-road vehicle(s), defined as those that are driven off designated roads.

The ORV reduces plant diversity and density (Adams et al. 1982; Lathrop 1983; Luckenbach and Bury 1983; Webb 1983; Ouren et al. 2007), while also introducing nonnative species (Bury 1980; Lonsdale and Lane 1994; Brooks and Berry 2006). The relationship between ORV and the spread of exotic annual species has long been recognized to be a serious problem (Lovich and Bainbridge 1999;

Ouren et al. 2007). The estimated number of ORVs in California during 1999–2004 was more than 4.3 million, nearly doubling every four years (Cordell et al. 2005). This problem is not just limited to California; a graphic illustration of this trend, as seen in Idaho, is presented in Fig. 3.

I sought to determine whether there is evidence for a decline in the number of collections of native herbaceous species, compared to native shrub species and one native annual, and whether this decline corresponds to an increase in nonnative species and ORV activity as measured by vehicle registrations, which in turn would help explain a greater-than-expected decline in herbaceous species available for antitumor screening. Changes occurring in the California desert flora—due to the spread of invasive species in which the ORV is a contributing factor—are assessed from data on herbarium specimens of selected native and nonnative species for decade periods from 1880 to 2005.

### MATERIALS AND METHODS

I have been collecting a broad diversity of plants in California and elsewhere for the NCI antitumor screening program since 1970; initially under a



Fig. 1–2. A dramatic change in desert vegetation.—1 (left). An abundance of native flowering annuals. Looking from Indian Avenue toward the San Bernardino Mountains ca. 4–5 mi N of Palm Springs, CA, 6 Apr 1973.—2 (right). The same area 35 years later with an abundance of nonnative Sahara mustard (*Brassica tournefortii*) in flower. Photos: Richard Spjut.

cooperative agreement with the US Department of Agriculture (USDA) Agricultural Research Service (until Oct 1982), and then under an agreement with the World Botanical Associates (WBA). Collections from southern California deserts have been part of a worldwide effort by the NCI and other drug-discovery groups at various universities to identify novel compounds from natural products for use in chemotherapy. The collecting methodology is a systematic sampling of the botanical diversity (Spjut 1985; Spjut et al. 1992). “General samples” of the whole plant, or parts of the plant (e.g., root), are collected as encountered in the field, in quantities that will yield 0.5–1 kg dry weight. Duplication of species is generally avoided.

Initially I focused on southern California, collecting ca. 325 spp. from late Dec 1971 to early Apr 1972, and ca. 150 spp. from Apr to May 1973. Subsequent collections from California were part of a broader geographic area; 413 spp. were collected from the semi-arid regions in the United States and Mexico (Baja California) in 1978–1980 (Spjut 1981), followed by 1–6-wk trips for most years from 1985 until 2000. Included were lichen samples (25 g) and specimens for a lichen flora of Baja California (Spjut 1996). During 2001–2004 and 2007–2008, I collected ca. 3200 samples of vascular plants for the NCI, spending on average of 100 days each year in the field (WBA 2004). Vouchers for California species may be found at BRIT (2001–2008), HSC (1972–1973, 2007–2008), NA (1970–1982), OSH (1983–2000), RSA (2007–2008), UC (2001–2004), US (1986–2008), and other institutions.

The Consortium of California Herbaria (CCH 2008–2009) was consulted to compile data on the

number of specimens collected since 1880 for selected:

(1) native annuals—*Anisocoma acaulis* Torr. & A.Gray (scalebud; Asteraceae), *Atrichoseris platyphylla* A.Gray (parachute flower; Asteraceae), *Caulanthus inflatus* S. Watson (desert candle; Brassicaceae), *Mohavea breviflora* Cov. (golden desert snapdragon; Plantaginaceae), *M. confertiflora* (A.Gray) A.Heller (ghost flower), *Mimulus bigelovii* (A.Gray) A.Gray (Bigelow’s monkey flower, both varieties; Phrymaceae), *Mentzelia involucrata* S.Watson (sand blazing star; Loasaceae), *Monoptilon bellioides* (A.Gray) H.M.Hall (Mojave desert star; Asteraceae), *Orobancha cooperi* (A.Gray) A.Heller (desert broomrape; Orobanchaceae), and *Stillingia spinulosa* Torr. (annual toothleaf; Euphorbiaceae).

(2) native shrubs—*Atriplex hymenelytra* (Torr.) S.Watson (desert holly; Chenopodiaceae), *Bebbia juncea* (Benth.) E.Greene var. *aspera* E.Greene (sweetbush; Asteraceae), *Hymenoclea salsola* A.Gray (cheesebush, all varieties; Asteraceae), *Isomeris arborea* Nutt. (bladderpod, all varieties; Capparaceae, syn. *Cleome isomeris* Greene), and *Krameria grayi* Rose & Painter (white ratany; Krameriaceae).

(3) nonnative annuals—*Brassica tournefortii* Gouan (Sahara mustard; Brassicaceae), *Erodium cicutarium* (L.) L’Hér. ex Aiton (red stem stork’s bill, Geraniaceae), *Schismus arabicus* Nees (Arabian schismus; Poaceae), and *S. barbatus* (Loefl. ex L.) Thell. (Mediterranean grass).

The term “collection” is used instead of specimen because collectors often obtain duplicates under one number, or collect more than one specimen of a species from nearby sites and assign them different numbers.

The number of collections for each species was tabulated according to the following decadal periods: 1881–1920 (four decades), 1921–1930, 1941–1960 (two decades), 1961–1970, 1971–1980, 1981–1990, 1991–2000, and 2001–2005 (half-decade). Data for several decades were combined because fewer collections would be expected in the earlier history of botanical exploration of California (1881–1920) and during years of wartime activities and drought (1941–1960). Collections for the remaining decades are the focus of this investigation, especially since 2000 (2001–2005). Data for *Erodium cicutarium* were limited to the California deserts, and those from *Schismus arabicus* and *S. barbatus* were combined. Aside from *E. cicutarium*, data for all other species, which are primarily found in the deserts, included all California locations.

Duplicates and near duplicates were excluded. Near duplicates are collections by the same collector(s) on consecutive dates from the same general area, or from nearby locations during the same period of time. The disregarded “near duplicates” were often species repeatedly collected for vegetation and floristic studies of a local area; however, additional collections were scored if

obtained from different sites in different months. The “near duplicates” were most common for the years 2001–2005. For example, of 22 specimens of *Atrichoseris platyphylla* collected by S. J. De Groot et al.—all from the Whipple Mountains under different collection numbers—only seven were counted (collected Jan, Mar, Apr, May 2003; Mar, May 2004), whereas in previous decades the most collected was five, H. M. Hall in 1905 and C. B. Wolf in the 1930s (1932, 1935, 1937), all from different locations.

## RESULTS AND DISCUSSION

Collection data are summarized for native species (Fig. 4, 5, Table 1), followed by a history of winter precipitation data for the Mojave Desert (Fig. 6), and collection data for nonnative species (Fig. 7).

Collections for all native species (Fig. 4, 5) were highest for the decade 1931–1940, except for the annual *Stillingia spinulosa* that peaked earlier (1921–1930); this also applies to 42 collections of *Atrichoseris platyphylla*, not the 44 collections for 1941–1960 that were subsequently determined to include 14 collections from 1941 to 1950 and 30

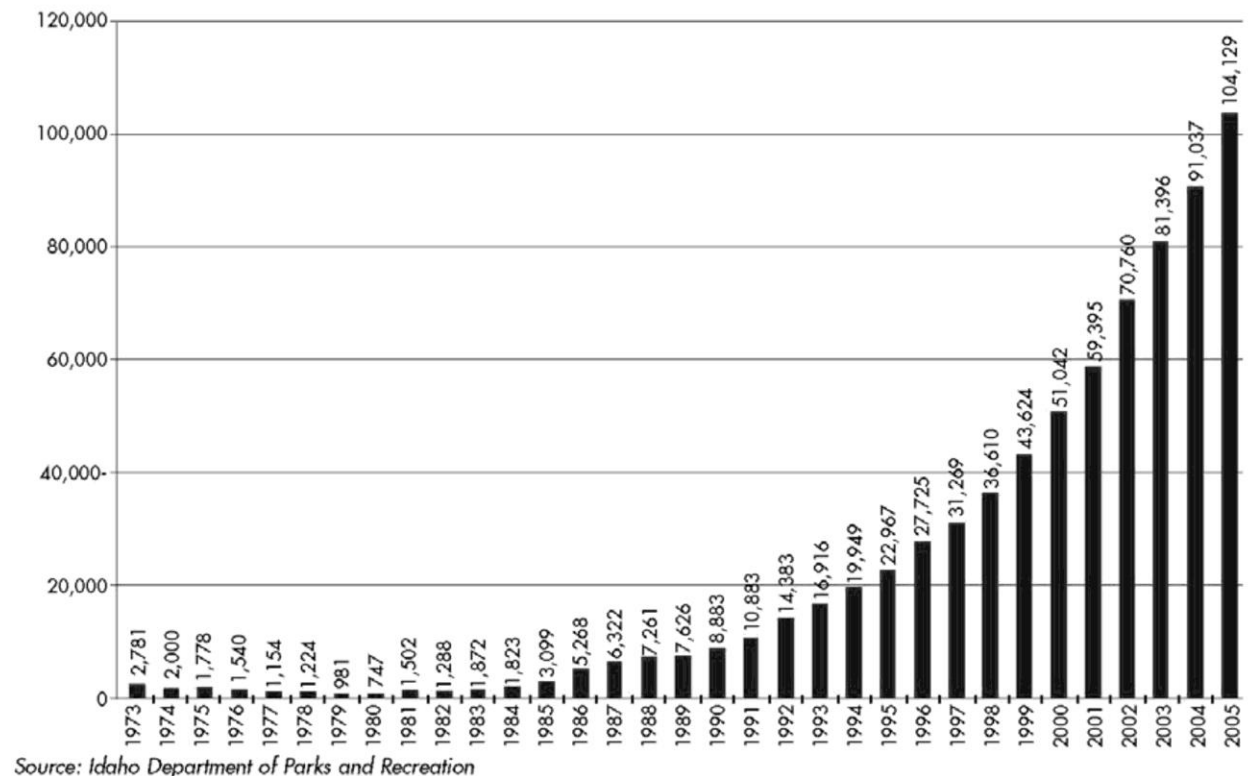


Fig. 3. Number by year of dirt bikes and ATV registrations in Idaho. Reproduced with permission from The Wilderness Society (2006).

collections from 1951 to 1960 (data not shown). This is in stark contrast to the nonnative species that showed exponential increases in numbers of collections since 1940, while either appearing absent or represented by relatively few collections in the earlier decades (Fig. 7).

The general decline in the number of collections for native species since the 1930s is largely due to a decline in botanical collecting (Prather et al. 2004), not necessarily due to the relative absence of nonnative species. Indeed, this is supported by subsequent determination on the number of different collectors for all native annuals combined for each period, reported here as follows: 35 (1881–1920), 58 (1921–1930), 100 (1931–1940), 107 (1941–1960), 91 (1961–1970), 84 (1971–1980), 62 (1981–1990), 56 (1991–2000), and 48 (2001–2005). However, the number of collectors for many of the individual species increased for the years 2001–2005, compared to the preceding decade (1991–2000); for instance, those for *Monoptilon bellioides* increased from 13 (23%) to 20 (56%). During the present half-decade, the average number of collections per collector for each species increased for native shrubs but not for native annuals (Table 1): in all previous decade

periods there is little difference between the two groups in numbers of collections per collector. Thus, it would appear that native annuals are declining in their occurrences since the year 2000 (see also Fig. 5).

#### Native Shrubs

*Atriplex hymenelytra*, *Bebbia juncea*, *Hymenoclea salsola*, *Isomeris arborea*, and *Krameria grayi*—shrubs selected as the basis for comparison (Fig. 4) to native annuals (Fig. 5)—were collected on average 1.3× more often in the present half-decade (2001–2005), than in the preceding decade (1991–2000), ranging from 0.99× (almost no change) for *Isomeris arborea* to 2.3× for *Krameria grayi*. This average increase in collections for native shrubs (1.3×) is undoubtedly due to more collectors in the field, or to collectors spending more time in the field, or both. For example, the number of collectors for shrub species was found to have increased on average by 26% with exception to *Atriplex hymenelytra* that declined slightly, from 15 (1991–2000)

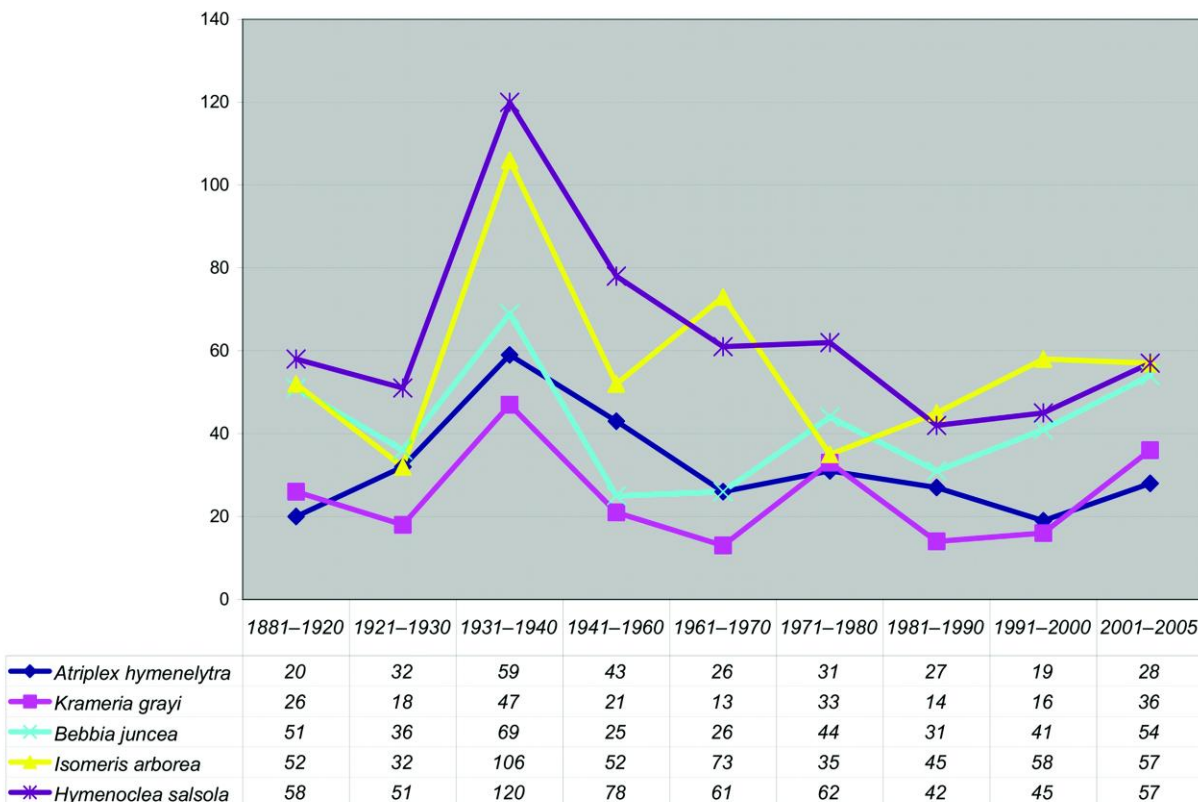


Fig. 4. Number of collections for native California shrubs by decade: 1880–2005.



to 13 (2001–2005). This decline is offset by more collections obtained from many sites, thus, more time was probably spent in the field as also evident for *Monoptilon bellioides* and other species.

Collections of *Isomeris arborea* by decade do not follow the pattern seen for the other shrub species; for example, *I. arborea* collections increased in the 1960s and 1980s when those of other shrub species decreased, and declined in the 1970s, or remained unchanged in the present half-decade when collections for other shrub species increased. It may be that during the relatively drier years that collectors find *I. arborea* in flower/fruit when most other shrubs are dormant. *Isomeris arborea* will flower within a week after rain (pers. obs.), which may be anytime of the year (Munz 1959). Also, its geographical range

extends to the southern Coast Ranges and Channel Islands where it likely was collected when the deserts received little precipitation.

#### Native Annuals

*Monoptilon bellioides* was selected to contrast its collections from that of other annuals (Fig. 5) because of its preference for rocky substrates where ORV travel has been less evident (pers. obs.). Collections of *M. bellioides* increased 1.6x during the present half-decade (2001–2005), compared to the previous decade, which also had more collections than the 1980s. This pattern is similar to data for shrub species (Fig. 4).

For the remaining native annuals (Fig. 5), which often occur in desert washes where ORV tracks are

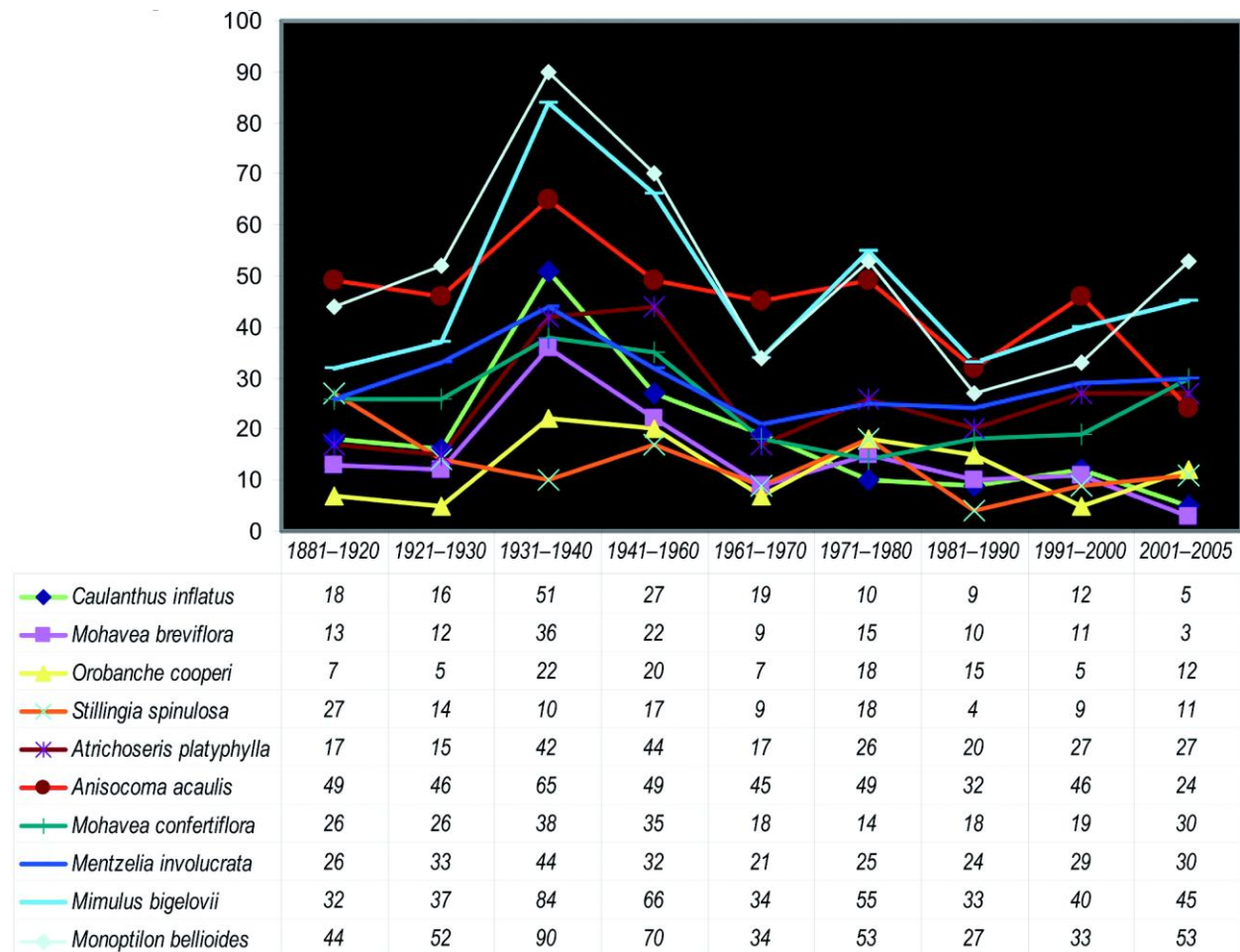


Fig. 5. Number of collections of native California annuals by decade: 1880–2005.

commonly seen; seven of the nine species were collected less often than shrub species in the recent half-decade (2001–2005); i.e.,  $<1.3\times$  when compared to their number of collections from the preceding decade (1991–2000). *Anisocoma acaulis* ( $0.5\times$ ), *Caulanthus inflatus* ( $0.4\times$ ), and *Mohavea breviflora* ( $0.3\times$ ) declined notably in their collections; *Atrichoseris platyphylla* ( $1.0\times$ ), *Mentzelia involucrata* ( $1.0\times$ ), *Mimulus bigelovii* ( $1.1\times$ ) and *Stillingia spinulosa* ( $1.2\times$ ) had almost no increase to marginal increases in collections, and *Mohavea confertiflora* ( $1.6\times$ ) and *Orobanch cooperi* ( $2.4\times$ ) had increases in collections similar to or greater than that of the average for shrubs ( $1.3\times$ ). However, collections for *O. cooperi* also appear in decline when compared to its collections from earlier decades as discussed later.

Cyclic patterns in winter precipitation that may account for variation in the collection of native annuals is shown in Fig. 6—in which a decline in the collections during the 1960s, followed by a rise in the 1970s, and a decline in the 1980s—is undoubtedly related to drier and wetter decades. However, *Anisocoma acaulis* does not follow this pattern, probably because its range extends to California chaparral and Great Basin Desert where more winter precipitation likely occurred. Additionally, the abundance of native annuals can vary considerably according to seasonal precipitation as related to diurnal and nocturnal temperatures and day length, the intensity, frequency and distribution of rainfall across the deserts, and whether precipitation is preceded by long periods of drought (Talbot et al. 1939; Shreve 1942; Went 1949; McCleary 1968; M. A. Bowers 1987; Rundel and Gibson 1996; Tielbörger and Kadmon 1997; J. E. Bowers 2005; Minnich 2008). The selected species, which are more spotty in their occurrences compared to more

ubiquitous native annuals (e.g., *Malacothrix glabrata*) are thought to require downpours of sufficient force to transport seeds in which abrasive action against rock or soil breaks dormancy.

Further, the selected annuals are not restricted to washes where ORV activity has been most evident; for example, *Mimulus bigelovii* is also common on steep rocky slopes where travel by ORV appears nearly impossible (Spjut 15890, Mar 2005; <http://www.worldbotanical.com/mimulus.htm>). Nonetheless, its slight rise in collections in the recent half-decade (2001–2005), compared to sharper rises for *Monoptilon bellioides* and most shrub species, indicates that its occurrence in washes may be in decline (pers. obs.).

Of curiosity is the listing of the parasitic desert broomrape (*Orobanch cooperi*) as a noxious weed (USDA 2007). It reportedly parasitizes roots of tomato plants in agricultural areas of the Coachella and Imperial valleys (Munz 1959; Heckard 2002), however, all collections of desert broomrape in the CCH database (5 Apr 2009) appear to have been from areas of natural vegetation, with *Ambrosia dumosa* (A.Gray) Payne (burro-bush) and *Hymenoclea salsola* (cheese-bush) frequently reported as host plants. Like most native species in this study, the majority of specimens were collected during 1931–1940; it also ranked lowest in overall number of collections, 111 total compared to an average of 232 for the nine selected annuals (excludes *Monoptilon*). Excluded were 28 collections in the 1970s by L. R. Heckard because his sequential collection numbers of this species indicated an effort to collect it, but the remaining 18 collections for that decade were still more than three times that of the five collections recorded for the 1990s. Thus, the increase to 12 collections in the present half-decade (2001–2005)—from just five collections in the

Table 1. Average number of collections per collector for 5 species of native shrubs (Fig. 4) and 10 species of native annuals (Fig. 5) for decadal periods 1881–2005. For the years 2001–2005, the range in variation for shrubs was 1.68 (*Isomeris arborea*) to 2.77 (*Krameria grayi*). For annuals, this was 1.00 (*Caulanthus inflatus*, *Mohavea breviflora*) to 2.08 (*Atrichoseris platyphylla*). Annual species with values between 1.00 and 1.68 were *Anisocoma acaulis* (1.60), *Mohavea confertiflora* (1.43), and *Stillingia spinulosa* (1.10). *Monoptilon bellioides*, an annual thought to be less impacted by ORV, was 1.96.

Years	1881–1920	1921–1930	1931–1940	1941–1960
Shrubs	1.85	1.49	1.78	1.35
Annuals	1.93	1.63	1.68	1.44

Years	1961–1970	1971–1980	1981–1990	1991–2000	2001–2005
Shrubs	1.30	1.44	1.44	1.82	2.05
Annuals	1.28	1.43	1.40	1.83	1.57

preceding decade (1990s)—should not be viewed as an increase, since there were more collections in prior decades—that included 15 collections in the 1980s, none of which were obtained by Heckard. While *O. cooperi* may not be rare, I have encountered it and related species less often since 1980; a 1.5 kg sample, which showed antitumor activity in the NCI astrocytoma assay, was obtained from Baja California Sur in Mar 1980 (Spjut 6039, NA; <http://www.worldbotanical.com/orobanche.htm>), and a similar collection was made in Mar 2008 from San Bernardino County (Spjut 16229, BRIT).

The decline in collections of *Caulanthus inflatus* (desert candle) may in part be due to urban expansion (in areas outside the Mojave Desert) than to ORV activity; its range extends to the southern part of the Central Valley and southern Coast Ranges with one record from the Channel Islands.

Although periodic decline in native annuals may be attributed in part to collecting effort, and/or to geographical variation in precipitation, the recent decline (2001–2005) may be explained by increasing ORV travel that facilitates the spread of nonnative annuals.

#### Nonnative Annuals

*Erodium cicutarium* (red-stem stork's bill), *Brassica tournefortii* (Sahara mustard), *Schismus arabicus*, and *S. barbatus* (Mediterranean grass) represent only four of 23 nonnative species that are common in the California deserts (Kemp and Brooks 1998). The selected nonnative species for this study exhibited exponential increases in their collections since 1940 (Fig. 7). *Brassica tournefortii* more than doubled its number of collections in the 1970s (from the preceding decade), and again in the 1990s; *Schismus barbatus* had 5X more collections from 1941–1960 than in the 1930s, with collections subsequently nearly doubling every two decades. *Erodium cicutarium* showed substantial increases in the 1960s, 1980s, and in the present decade. The increases for *E. cicutarium* and *B. tournefortii* correspond to the time frame for the exponential increase in the number of ORV registrations in California (Cordell et al. 2005). The increased collections of *S. barbatus* from 1980–2005 are evidently related, while the earlier rise in collections may be attributed in part to other human disturbances such as military activities, construction projects, and grazing (see Table 1 in Lovich and Bainbridge 1999).

The frequency and biomass of the nonnative species can fluctuate at specific locations between

periods of drought and wet years to the extent that another invasive species, *Bromus madritensis* L. subsp. *rubens* (L.) Husn. (red brome, data not tabulated) may be extirpated where drought is severe (Minnich 2008). The decline in collections of *Brassica tournefortii* and *Schismus* spp. for the 1980s and *Erodium cicutarium* for the 1990s may relate to cyclic precipitation patterns in which the relatively drier years favor dominance of nonnative annuals (Brooks and Berry 2006; Minnich 2008); however, the nonnative species will not decline in the present decade; their collections already exceed those of previous decades.

Data for *Erodium cicutarium* were restricted to the deserts because I had not recalled it being common there before 1980. Native to the Mediterranean region, *E. cicutarium* was established in California before 1800 and had become abundant in the Central Valley by the mid-1800s (Minnich 2008). Prior to 1960, the majority of the 953 records in the CCH database (4 Apr 2009) were from the Coast Ranges and Central Valley. Rundel and Gibson (1996) reported that the occurrences of *E. cicutarium* in their Mojave Desert plots at Rock Valley, NV, had increased sharply during the 1980s where earlier it had been noted to be relatively uncommon. This is also evident from data in this study (Fig. 7). However, Brooks and Berry (2006) refer to studies in the 1970s that indicate *E. cicutarium*, along with *Schismus* spp., were well established in the western Mojave Desert, a region where ORV damage to the environment was estimated to require more time for recovery than for other disturbances (Table 1 in Lovich and Bainbridge 1999). *Erodium cicutarium* has become one of the most abundant nonnative forbs along paved roads (Gelbard and Belnap 2003). Its spread into the desert interior away from the highways is clearly linked to the spread of “dirt roads” (Brooks and Berry 2006), which are often created by ORVs (Brooks and Lair 2005).

*Brassica tournefortii* and *Schismus* spp. are relatively recent introductions compared to *E. cicutarium*; *Schismus* reportedly spread across the California deserts in the 1940s followed by *B. tournefortii* in the 1970s (Minnich 2008). A voucher specimen for a 227 g sample of *B. tournefortii* accessioned by the USDA Agricultural Research Service (PR 24338, “0.5 lbs.”), was collected near Desert Center on 1 Feb 1972; it was reported that *B. tournefortii* was “common along most highways” of the Colorado Desert” (Spjut 2157, HSC, NA). Thus, the results shown for *B. tournefortii* (Fig. 7) are certainly no surprise to those who frequent the

deserts of southern California since its appearance was first documented from the Coachella Valley (Feudge 1660, POM147846) 25 Feb 1927.

Paved highways provide the initial pathways for spread of nonnative species by vehicles of all types that utilize road margins—where disturbance is thus common and where precipitation runoff collects (Johnson et al. 1975; Gelbard and Belnap 2003). In years of relatively low rainfall, such as in the winter of 1971–1972, *Brassica tournefortii* may germinate and grow to maturity while seeds of native annual remain dormant, or perhaps are inhibited from germinating by the mustard's allelopathic chemicals as reported for the related black mustard, *Brassica nigra* (L.) W.D.J.Koch (Turk and Tawaha 2003). The mucilaginous seeds of *B. tournefortii* adhere easily to the tires of vehicles (Minnich 2008) and as many as 16,554 seeds may be produced by one plant (Trader et al. 2006). Thus, the spread of *B. tournefortii* beyond the margins of paved roads into the desert interior (Fig. 8) is not surprising in view of the increasing ORV registrations in California (Cordell et al. 2005); however, it can also spread by other means as evidenced by its relatively recent introduction to San Nicolas Island (*Junak SN-1626*, SBBG117709), 22 Mar 2001, a remote island in the Channel Islands.

Species of *Schismus* may contribute to one-third or more of the biomass of desert annuals (Brooks and Berry 2006). The distinction between *Schismus arabicus* and *S. barbatus* is subtle, based on length of lemma and acuteness of the palea (Allred 1993), and

by differences in the hairiness of the lemma (Van Devender 1997). The most widespread *Schismus* reported for the Sonoran Desert is *S. arabicus* (Van Devender et al. 1997); however, collections in the Consortium of California Herbaria (4–6 Apr 2009) were approximately three times greater for *S. barbatus* than *S. arabicus* in which some collectors appear to recognize only *S. barbatus*, while others recognize both species. Data for these species were thus combined. In a recent winter of above normal precipitation in the California deserts, 2004–05, *S. barbatus* was so profuse in the creosote desert that its reddish color could be discerned at distances of five miles or more (Fig. 9).

Approximately 50% of the California native species have been “collectable” for antitumor screening (Spjut 1985); however, many “common species” appear in decline, not only in California (Fig. 5), but also over much of the western United States. This decline is seen mainly in the herbaceous element of the flora due largely to the spread of invasive species as a result of native vegetation becoming over-grazed by domesticated animals and trampled by the ORV (Ornduff et al. 2003; Minnich 2008; Pavlik 2008; Spjut (pers. obs.). During 2001–2004, field expeditions—that ranged from California to Texas—yielded at least six samples per day, whereas during FY 2008 (Fiscal Year, Oct 2007–Sep 2008), only three samples on average were collected each day from a similar geographical range that

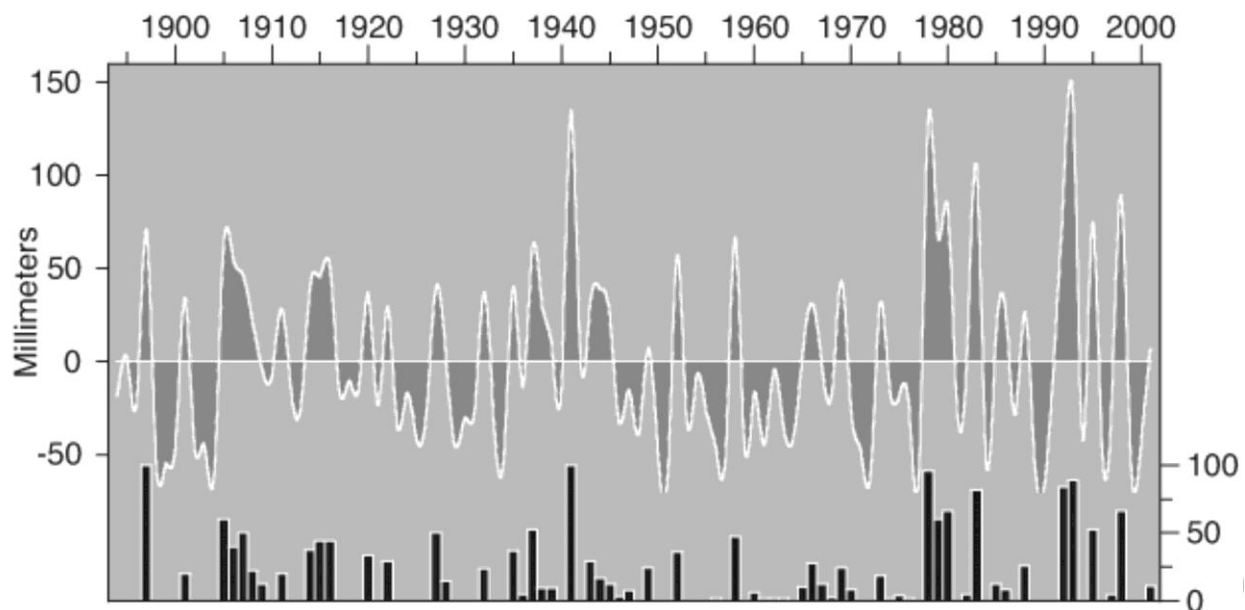


Fig. 6. Precipitation history in the Mojave Desert: 1893–2001. Reproduced (in part) with permission from Hereford et al. (2004). Only winter precipitation is shown here; original figure also included summer precipitation.



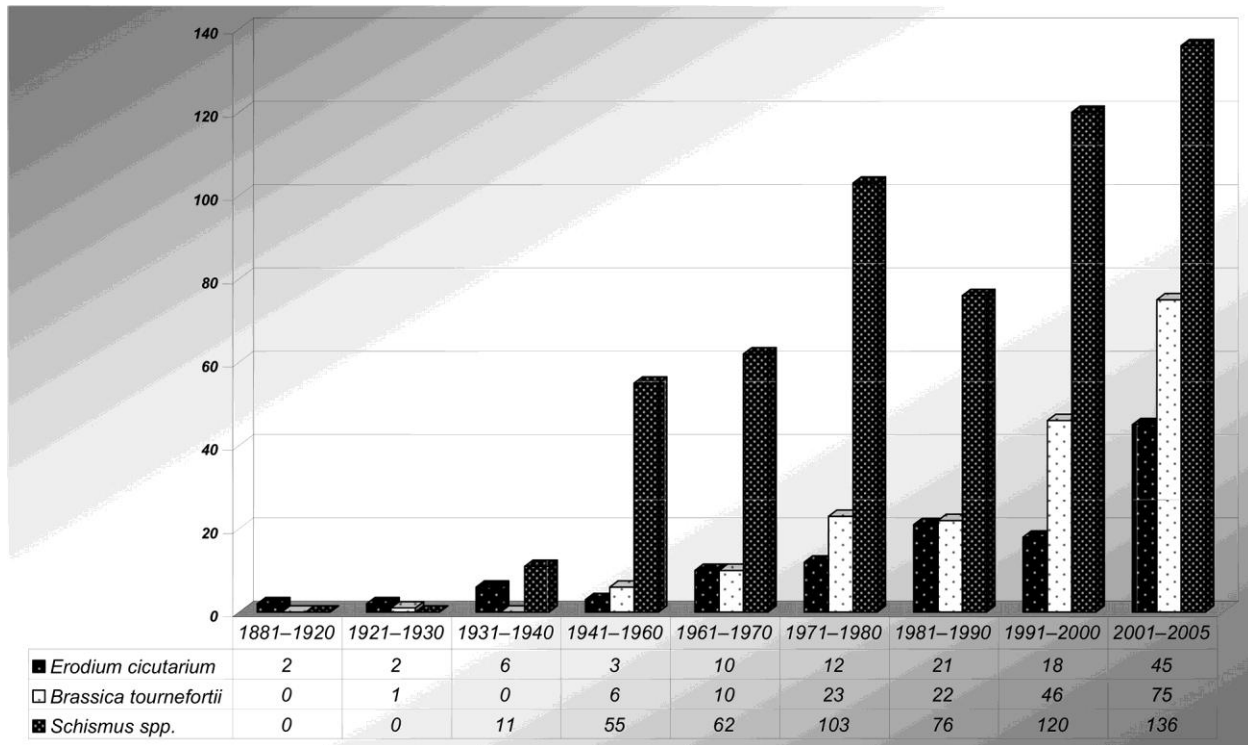


Fig. 7. Number of collections for invasive species by decade: 1880–2005.

extended to Colorado. Occasional sites yielding 10 or more samples per day were found (FY 2008) on public lands near boundaries of Indian reservations and national parks/monuments where grazing and OVR are generally restricted.

The California deserts were once thought to be an unlikely place for establishment of nonnative species due to the extreme climatic conditions; however, 9% of the desert flora has nonnative taxa in which two-thirds are annuals (Bossard and Randall 2007). The long history of farming and grazing (by domesticated animals) in the Central Valley of California has certainly contributed to >98% of its flora being dominated by nonnative species (Bossard and Randall 2007; Minnich 2008). *Brassica tournefortii*, *Erodium cicutarium*, and *Schismus barbatus* are spreading to the extent that they and others (e.g., *Bromus* spp.) “will potentially compete with the approximately 50% of our native ephemerals” in the California deserts (Bossard and Randall 2007).

## CONCLUSIONS AND RECOMMENDATIONS

Many annual species found in California desert washes are declining in their occurrences while

nonnative annuals continue to expand their geographical range. A major factor is ORV travel as evident by their increased registrations and tracks in nearly all washes that cross state highways. This activity has accelerated the spread of nonnative species into the interior of the deserts. The increasing dominance of invasive species seems like the most plausible explanation as to why I have found it difficult to collect native herbs in quantities sufficient for the NCI antitumor screening program.

Off-road vehicle recreation should be allowed only in designated areas where clearly posted. Areas not posted should then be regarded as non-designated, thus, not permitted for ORV. Currently, the Bureau of Land Management (BLM) and U.S. Forest Service promulgate where ORV travel is allowed and disallowed; however, ORV use also needs to be a state law so that violations can be addressed by all authorities. Executive Orders 11644 and 11989, signed by Presidents Nixon in 1972 and Carter in 1977 (37 FR 2877, 3 CFR, 1971–1975 Comp., p. 666; 42 FR 26959, 3 CFR, 1977 Comp., p. 120), were issued to “ensure that the use of off-road vehicles on public lands will be controlled and directed so as to

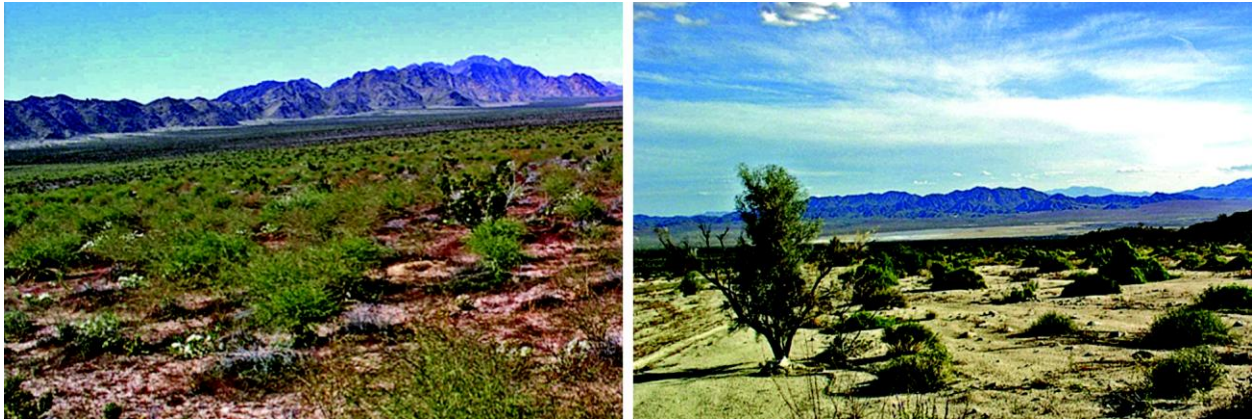


Fig. 8–9. Invasion of nonnative species in California deserts.—8 (left). Spread of *Brassica tournefortii* beyond the margins of paved roads into the desert interior, as seen from Highway 62, looking N toward the Iron Mountains, Mar 2005. Note equal spacing of *B. tournefortii* (which are in fruit), possibly due to allelopathy or water availability. The darker green vegetation in the distance is creosote scrub.—9 (right). Looking S from near Sheephole Pass toward the Pinto Mountains, Mar 2005. *Schismus barbatus* was so profuse in the creosote desert that its reddish color could be discerned at distances of five miles or more.

protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands.”

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