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Weed Risk Assessment for *Asphodelus fistulosus* L. (Asphodelaceae) – Onion weed

Top left and right: Flower and whole plant of *A. fistulosus* growing in flood control channel in California [source: Ron Vanderhoff (2019), Calflora]. Bottom left: seeds of *A fistulosus* [source: CDFA and USDA-APHIS (2015)].

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Executive Summary

The result of the weed risk assessment for *Asphodelus fistulosus* is High Risk of becoming weedy or invasive in the United States. This taxon is an annual or perennial herb that can form dense populations in arid and disturbed environments and has been most invasive in pastures and rangelands in Australia. It has become naturalized in the southwestern United States and has been reported in twelve counties in four states (California, Arizona, New Mexico, and Texas). *Asphodelus fistulosus* is regulated as a Federal Noxious Weed in the United States, although we found no evidence that Federal or state official control efforts are currently being undertaken. This taxon is a prolific seed-producer with seeds that can remain viable in the seed bank for several years and are easily transported in trade, on vehicles, and by animals. *Asphodelus fistulosus* is unpalatable to livestock and can reduce the carrying capacity of rangelands and pastures. Twenty-four percent of the area of the United States is climatically suitable for *A. fistulosus* to establish.

1. Plant Information and Background

SPECIES: *Asphodelus fistulosus* L. (NPGS, 2018).

FAMILY: Asphodelaceae (NPGS, 2018) but formerly listed under Liliaceae (Bailey and Bailey, 1976)

SYNONYM: *Asphodelus tenuifolius* is sometimes listed as a synonym of *A. fistulosus* (CABI, 2018; Holm et al., 1997). However, we are treating these as two distinct species based on their karyotypes and morphological differences (Díaz Lifante and Aguinagalde, 1996; Rejon et al., 1990). It is hypothesized that *A. fistulosus* is an amphidiploid (2n = 56) (i.e., allotetraploid[1]) hybrid of *A. tenuifolius* (2n = 28) and *A. ayardii* (2n = 28) because it appears to be intermediate between these two species in terms of reproductive biology (Díaz Lifante and Valdés, 1995).

COMMON NAMES: Onionweed or onion weed (Auld and Medd, 1987; DiTomaso and Healy, 2007), onion asphodel (NPGS, 2018), hollow-stem asphodel (NPGS, 2018), and wild onion (North East Pastoral Conservation Board, 1997; NPGS, 2018).

BOTANICAL DESCRIPTION: *Asphodelus fistulosus* is an herb that can grow up to 0.8 m in height (Boatwright, 2012). It is primarily biennial or perennial but can occasionally behave as an annual (López, 2010). The leaves are hollow and originate from the base of the plant (CABI, 2018; Parsons and Cuthbertson, 2001). This species is commonly found in dense populations in semi-arid or arid disturbed environments of Australia (Cullen, 2012; Parsons and Cuthbertson, 2001). Seeds of *A. fistulosus* are angular, 3-4 mm long, and marked by deep, irregular pits (Boatwright, 2012; Scher et al., 2015). For a full botanical description, see Boatwright (2012).

INITIATION: *Asphodelus fistulosus* is regulated as a Federal Noxious Weed in the United States (7 CFR § 360, 2019). In this document, we evaluate its current distribution and risk potential.

WRA AREA[2]: Entire United States, including territories.

FOREIGN DISTRIBUTION: *Asphodelus fistulosus* is native to the Mediterranean region, including Spain (including the Canary Islands), Portugal, Italy, Malta, France, Greece, Turkey, Morocco, and Tunisia (Campos et al., 2004; Díaz Lifante and Aguinagalde, 1996; GBIF, 2019; López, 2010; Mifsud, 2019; Taleb et al., 1998). It is considered invasive in Australia (Brandle, 2001; Parsons and Cuthbertson, 2001; Roark, 1955) and is naturalized in New Zealand, South Africa, Argentina, Bolivia, Chile, and Mexico (Boatwright, 2012; Delgado Balbuena et al., 2013; Matthei, 1995; New Zealand Plant Conservation Network, 2010; NPGS, 2018). It is also reported as a casual alien in Ireland (Reynolds, 2002). It was likely introduced to Australia as an ornamental plant in a botanical garden in the 19th

[1] These types of hybrids have a complete diploid set of chromosomes from each parent.

[2] The "WRA area" is the area in relation to which the weed risk assessment is conducted (definition modified from that for "PRA area") (IPPC, 2017).

century (Parsons and Cuthbertson, 2001). *Asphodelus fistulosus* is not specifically listed as a harmful organism by other countries (PExD, 2019), although it is considered to be of quarantine significance in Honduras (Puerto, n.d.) and is recommended for eradication in South Africa (Jubase et al., 2019). Its congener *A. tenuifolius* is considered a harmful organism by Australia, Brazil, Chile, Honduras, Nauru, Paraguay, Taiwan, and Thailand (PExD, 2019). *Asphodelus tenuifolius* is classified as non-reportable/non-actionable at ports of entry in the United States (APHIS, 2019).

U.S. DISTRIBUTION AND STATUS: *Asphodelus fistulosus* is naturalized in California, Arizona, New Mexico, and Texas (California Invasive Plant Council, 2019; DiTomaso and Healy, 2007; EDDMapS, 2019; Kartesz, 2018; NPGS, 2018; NRCS, 2018; Russell, 2008; Saguaro National Park, 2015; West et al., 2019). It was likely introduced as an ornamental plant for cultivation (Bailey and Bailey, 1976; Russell, 2008), and it was reported in California as early as 1978 and in New Mexico as early as 1984 (SEINet, 2019). A limited infestation was reported in Arizona in 2004 (Dubrul et al., 2010; Escarciga et al., 2009) and has since spread to drainage basins, roadsides, and natural areas, among other sites (Russell, 2008; Saguaro National Park, 2015; West et al., 2019). It is regulated as a state noxious weed by Florida, New Mexico, and South Carolina (National Plant Board, 2019). The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) and cooperating organizations attempted to eradicate *A. fistulosus* from Arizona with hand-pulling and herbicide treatments (Dubrul et al., 2010; Escarciga et al., 2009; Russell, 2008). *Asphodelus fistulosus* is listed as a priority noxious and invasive plant by the Arizona Department of Transportation and the Bureau of Land Management (ADOT, 2019).

2. Analysis

ESTABLISHMENT/SPREAD POTENTIAL

Asphodelus fistulosus received a high score for its establishment and spread potential. The most significant factor for this rating was that this species is invasive elsewhere (Parsons and Cuthbertson, 2001). Also contributing to this high risk score was its ability to form dense populations (Cullen, 2012; Parsons and Cuthbertson, 2001) that can expand over the course of a year (Ramsey, 2010) and potentially reproduce within one year (Díaz Lifante and Aguinagalde, 1996; López, 2010). This taxon is a prolific seed producer with a high germination rate (Bell, 1993; Fox, 2004; Roark, 1955); the seeds can also remain viable for multiple years in the seed bank (DiTomaso and Healy, 2007; Parsons and Cuthbertson, 2001) and can easily travel in international trade (APHIS, 2019; Smither-Kopperl, 2007). We had low overall uncertainty for this risk element due to the large amount of information about the basic biology of the species.

Risk score = 15 Uncertainty index = 0.08

IMPACT POTENTIAL

Asphodelus fistulosus received a high score for its impact potential. This taxon is considered an important weed in Australia because it is unpalatable to livestock and can compete with pasture species (Grice, 2002). It is reported to reduce the carrying capacity of rangeland by up to 75 percent (Parsons

and Cuthbertson, 2001), although the perception of its weediness may exceed its impact (Pitt et al., 2006). We also found evidence of research and control efforts for this taxon (Hasan, 1991; Smith and Smith, 2014). *Asphodelus fistulosus* is managed as a weed in natural and anthropogenic systems (Grow Plants, 2019; Hewson, 2017; National Gardening Association, 2017; PBS, 2019; Saguaro National Park, 2015; Smith and Smith, 2014). We had low overall uncertainty for this risk element, but we did have some uncertainty about the effects of *A. fistulosus* in natural systems because we found little evidence about its ecological impacts.

Risk score = 3.7 Uncertainty index = 0.23

GEOGRAPHIC POTENTIAL

Based on three climatic variables, we estimate that about 24 percent of the United States is suitable for the establishment of *A. fistulosus* (Fig. 1). This predicted distribution is based on its known distribution elsewhere in the world, using evidence from both point-referenced localities and general areas of occurrence. The potential distribution map for *A. fistulosus* represents the concurrence of Plant Hardiness Zones 7-12, areas with 0-50 inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, and marine west coast. The area that appears to be most at risk is the arid region of the southwestern United States, where *A. fistulosus* populations have already established. It is likely that its range could extend into Nevada, Oklahoma, parts of Oregon and Utah, and additional regions of California, Arizona, New Mexico, and Texas. *Asphodelus fistulosus* is already established in globally outstanding ecoregions that include the Pacific coast of California and areas of Arizona, New Mexico, and Texas that border Mexico (Ricketts et al., 1999).

The area of the United States shown to be climatically suitable (Fig. 1) for species establishment considered only three climatic variables. Other variables, such as soil and habitat type, novel climatic conditions, or plant genotypes, may alter the areas in which this species is likely to establish. A controlled environment study that looked at photoperiod and average day and night temperatures found that *A. fistulosus* was most likely to occur in areas with an average monthly temperature of 7-26 °C and average monthly rainfall between 0.5 and 5.3 inches (1.3 and 13.5 cm) (Patterson, 1996). Patterson (1996) pointed out that some climates in the southwestern United States are similar to areas in Australia where *A. fistulosus* is an important weed, although the southwestern United States has greater seasonal fluctuations of both temperature and precipitation. Patterson's study used climate information from Australia, whereas we based our geographic model on climate data from Mexico, the Mediterranean, and South Africa. Furthermore, Patterson (1996) only tested plants from one population in Mexico. In Arizona, Russell (2008) observed that altitudes between 2,000 and 4,500 ft above sea level were most conducive to the growth of *A. fistulosus*. These altitudes were associated with areas above the desert floor that received moderate rainfall. We did not consider altitude as a parameter in our model, but no other study connected the growth of *A. fistulosus* with altitudinal gradients, so we are confident in our geographic potential estimate.

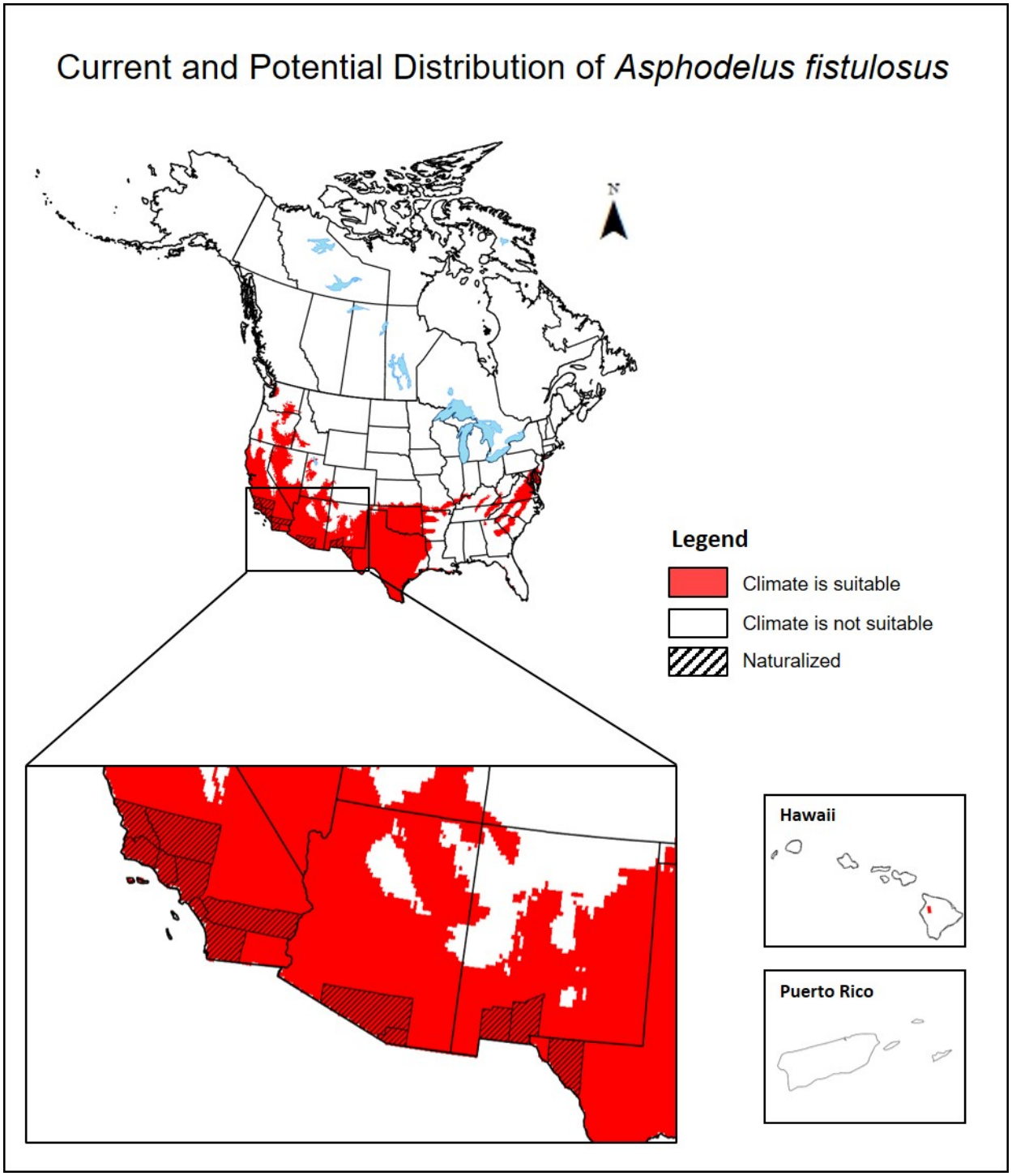

Figure 1. Current and potential geographic distribution of *Asphodelus fistulosus* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale. For additional on information on the PPQ climate-matching process see Magarey et al. (2018).

ENTRY POTENTIAL

We did not assess the entry potential of *A. fistulosus* because it is already present in the United States (California Invasive Plant Council, 2019; DiTomaso and Healy, 2007; NPGS, 2018; NRCS, 2018; Russell, 2008; Saguaro National Park, 2015; West et al., 2019) (Fig. 1).

3. Predictive Risk Model Results

Model Probabilities: P(Major Invader) = 83.6%
P(Minor Invader) = 15.8%
P(Non-Invader) = 0.6%
Risk Result = High Risk
Risk Result after Secondary Screening = Not Applicable

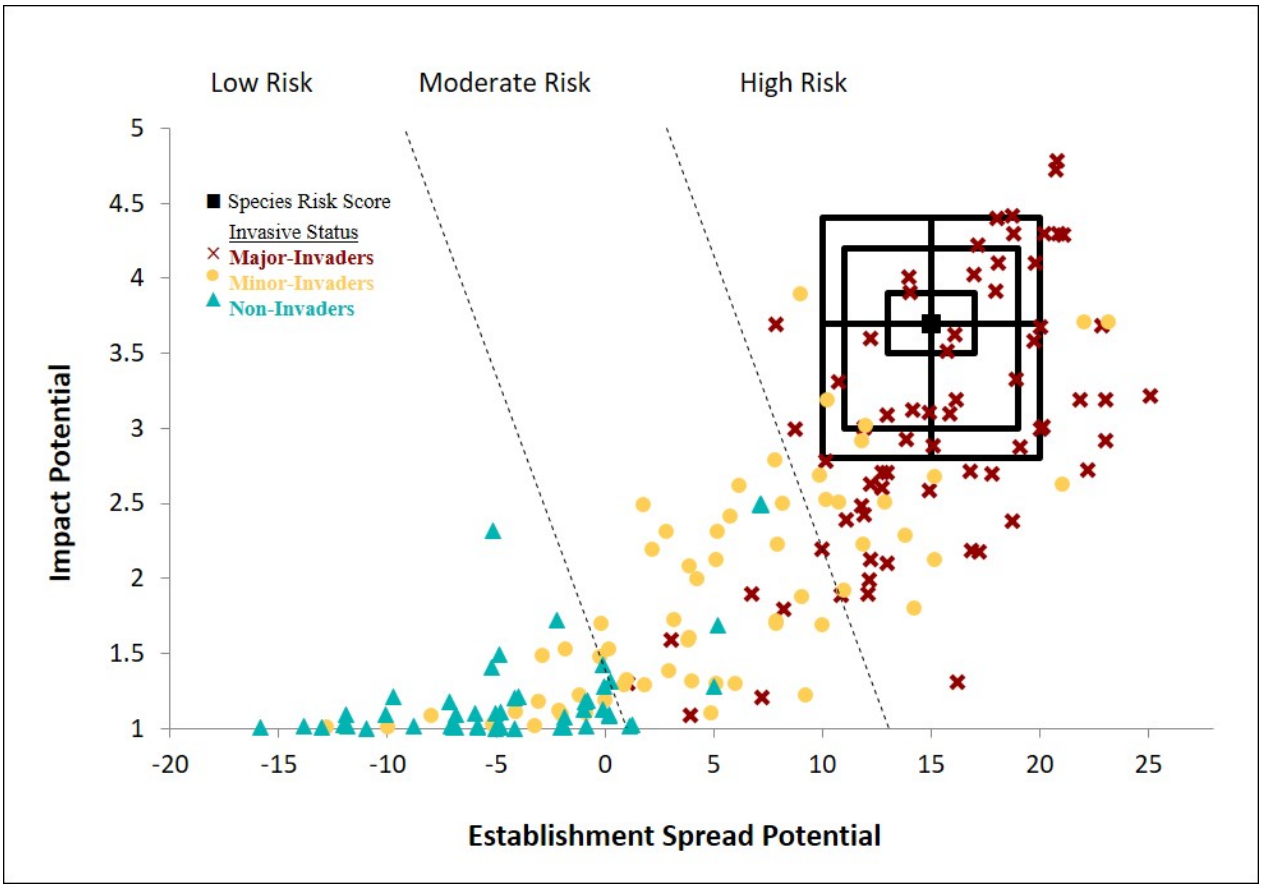

Figure 2. Risk and uncertainty results for *Asphodelus fistulosus*. The risk score for the species (solid black symbol) is plotted relative to the risk scores of the species used to develop and validate the PPQ WRA model (Koop et al., 2012). The results from the uncertainty analysis are plotted around the risk score for *A. fistulosus.* The smallest, black box contains 50 percent of the simulated risk scores, the second 95 percent, and the largest 99 percent. The black vertical and horizontal lines in the middle of the boxes represent the medians of the simulated risk scores (N=5000). For additional information on the uncertainty analysis used, see Caton et al., (2018).

4. Discussion

The result of the weed risk assessment for *Asphodelus fistulosus* is High Risk of becoming weedy or invasive in the United States. *Asphodelus fistulosus* is invasive in other regions where it has been introduced (Jubase et al., 2019; Parsons and Cuthbertson, 2001; Ramsey, 2010). Additionally, it is a prolific seed producer (Roark, 1955), and seeds can survive for multiple years in the seed bank (DiTomaso and Healy, 2007; Parsons and Cuthbertson, 2001). This taxon can form dense populations (Cullen, 2012; Parsons and Cuthbertson, 2001), and it is generally unpalatable, which has reduced the carrying capacity of pastureland in Australia (Grice, 2002; Parsons and Cuthbertson, 2001). Because we had low overall uncertainty values for this taxon, we can be confident in the overall result of high risk.

Asphodelus fistulosus is already present in southwestern areas of the United States. Based on the geographic potential model, *A. fistulosus* could potentially expand its range to approximately 24 percent of the United States. Mowing has been shown to be effective for control in some areas of Australia (Smith and Smith, 2014). Past eradication efforts in the United States by USDA-APHIS and cooperating organizations used manual removal (Russell, 2008) and herbicide applications (Ramsey, 2010). Several herbicides are labeled for the control of *A. fistulosus* (DiTomaso et al., 2013), although chemical management of this plant is rarely economically feasible in Australia unless the population is small (Grice, 2002; Parsons and Cuthbertson, 2001).

5. Acknowledgements

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SUGGESTED CITATION

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DOCUMENT HISTORY

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Appendix A. Weed risk assessment for *Asphodelus fistulosus* L. (Asphodelaceae)

The following table includes the evidence and associated references used to evaluate the risk potential of this taxon. We also include the answer, uncertainty rating, and score for each question. The Excel file in which this assessment was conducted is available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 [What is the taxon's establishment and spread status outside its native range? (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown]	f - low	5	*Asphodelus fistulosus* is native to the Mediterranean region, western Asia, and Macaronesia (Díaz Lifante and Aguinagalde, 1996). It is naturalized in South Africa (Boatwright, 2012) and Australia (Bell, 1993). It was first reported as a weed in Australia in 1974, and by 2001 it had spread to every territory (Parsons and Cuthbertson, 2001). Alternate answers chosen for the simulation were both "e".
ES-2 (Is the species highly domesticated)	n - negl	0	We found no evidence that *A. fistulosus* has been highly domesticated. It was likely introduced to Australia as an ornamental in a botanical garden (Roark, 1955).
ES-3 (Significant weedy congeners)	y - low	1	The genus *Asphodelus* includes seven species (NPGS, 2018). Most *Asphodelus* spp. are not very weedy, but *A. tenuifolius* has been cited as a weed numerous times (Randall, 2017). *Asphodelus tenuifolius* is estimated to reduce mustard yields by 56 percent (Yadav and Poonia, 2005) and chickpea yields by up to 80 percent (Mishra et al., 2006). Weber (2003) does not list any other *Asphodelus* taxa as invasive species. Confusion over the distinction between *A. tenuifolius* and *A. fistulosus*, however, may confound the number of weedy references for these species (CABI, 2018).
ES-4 (Shade tolerant at some stage of its life cycle)	n - mod	0	*Asphodelus fistulosus* is primarily a weed of open pasture land or roadsides after disturbance (Boatwright, 2012), suggesting it is not shade tolerant. One study showed that it has high germination rates over a range of light wavelengths, as well as in the dark (Bell, 1993). The congener *A. tenuifolius* demonstrates reduced growth under competitive cropping scenarios, in which the field is more shaded (Mishra et al., 2006).
ES-5 (Plant a vine or scrambling plant, or forms tightly appressed basal rosettes)	n - low	0	*Asphodelus fistulosus* does not form tightly appressed basal rosettes. Its leaves all

Question ID	Answer - Uncertainty	Score	Notes (and references)
			originate from the base (CABI, 2018; Parsons and Cuthbertson, 2001) but are not likely to physically crowd out other competitors.
ES-6 (Forms dense thickets, patches, or populations)	y - low	2	*Asphodelus fistulosus* forms dense populations (Cullen, 2012; Parsons and Cuthbertson, 2001).
ES-7 (Aquatic)	n - negl	0	This taxon is not an aquatic plant. *Asphodelus fistulosus* thrives in arid and disturbed environments (Parsons and Cuthbertson, 2001). One source reports that it is found in alluvial environments in Western Australia (Keighery, 2010).
ES-8 (Grass)	n - negl	0	*Asphodelus fistulosus* is not a grass, although it is a monocot. It is an annual or perennial herb in the family Asphodelaceae (Boatwright, 2012).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	*Asphodelus fistulosus* is an herbaceous monocot species (Boatwright, 2012; CABI, 2018), and we found no evidence that it can fix nitrogen. This taxon does not belong to a family known to fix nitrogen (Martin and Dowd, 1990; Santi et al., 2013).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	This species produces viable seeds (Boatwright, 2012; Díaz Lifante and Aguinagalde, 1996; Parsons and Cuthbertson, 2001).
ES-11 (Self-compatible or apomictic)	y - negl	1	*Asphodelus fistulosus* can self-pollinate (Díaz Lifante and Aguinagalde, 1996; Díaz Lifante and Valdés, 1995; Roark, 1955). It is not known how much this occurs in natural settings, but it is suspected that it does occur in nature (Díaz Lifante and Valdés, 1995).
ES-12 (Requires specialist pollinators)	n - low	0	It is unlikely that *A. fistulosus* requires specialist pollinators not present in the WRA area. *Asphodelus fistulosus* is pollinated by bees, although the literature does not specify which bees (Roark, 1955). Pollination by wind is "unlikely" (Roark, 1955).
ES-13 [What is the taxon's minimum generation time? (a) less than a year with multiple generations per year; (b) 1 year, usually annuals; (c) 2 or 3 years; (d) more than 3 years; or (?) unknown]	b – low	1	*Asphodelus fistulosus* is reported to be an annual or short-lived perennial in South Africa (Boatwright, 2012), and it is described as an "annual-biennial" in its native range in Spain (Díaz Lifante and Aguinagalde, 1996). This taxon is reported to be typically a perennial but able to behave as an annual if it is smaller in size (López, 2010). Parsons and Cuthbertson (Parsons and Cuthbertson, 2001) report that plants generally flower at around 18 months of age in Australia. Because multiple publications report that it can behave

Question ID	Answer - Uncertainty	Score	Notes (and references)
			as an annual, we chose to answer "b" with moderate uncertainty. Alternate answers for the uncertainty simulation were both "c."
ES-14 (Prolific seed producer)	y - mod	1	*Asphodelus fistulosus* is reported to produce 2,325 seeds/plant/year on average but can produce up to 13,200 seeds (Fox, 2004). From counts of a 1/400-acre plot, it was calculated that 26,035,200 seeds could be produced per acre, which is equivalent to approximately 6,400 seeds per square meter (Roark, 1955). According to Roark (Roark, 1955), 95-100 percent of seeds are germinable. Jubase et al. (Jubase et al., 2019) showed that, from two groups of seeds, 63 and 86 percent of seeds germinated, respectively. This difference in germinability between these two groups in the Jubase et al. experiment attributed to seed age; seed germination rates may vary with the amount of time in the seed bank. They also conducted seed bank surveys of a recently established population of *A. fistulosus* in South Africa and found that after only a few years, a "substantial" seed bank had on average 646 seeds per m^2 and 111 per m^2 in two survey years. They found a maximum seed bank of 3309 seeds per m^2 (Jubase et al., 2019).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - mod	1	Seeds can be spread through tilling or on vehicles if caught in equipment (Parsons and Cuthbertson, 2001).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	Seeds of *A. fistulosus* are frequently intercepted in trade of commodities (APHIS, 2019; Smither-Kopperl, 2007).
ES-17 (Number of natural dispersal vectors)	1	-2	Propagule traits for questions ES-17a through ES-17e: Seeds are "angular, 3-4 mm long, with deep irregular pits, brown to black, surface papillate" and produced in a capsule (Boatwright, 2012; Scher et al., 2015).
ES-17a (Wind dispersal)	n - mod		Parsons et al. (2001) report that dead plants can act as tumbleweeds, allowing strong winds to spread seeds that are still attached to the plants. We found little other evidence, however, to indicate that wind dispersal is important for this plant, and we found no evidence that seeds possess adaptations to facilitate wind dispersal.
ES-17b (Water dispersal)	n - low		Seeds of *A. fistulosus* are not adapted for water dispersal. Propagules can be dispersed by water in dry areas through run-off (Pitt et al., 2006) and transported long distances in

Question ID	Answer - Uncertainty	Score	Notes (and references)
			open channels (Boatwright, 2012). Although water is occasionally referenced as a dispersal mechanism for this taxon, it is not typically referred to as the primary dispersal mechanism (Parsons and Cuthbertson, 2001). We found no evidence that seeds are buoyant.
ES-17c (Bird dispersal)	n - mod		We found no evidence that seeds are dispersed by birds. One study demonstrated that seeds of this species were toxic to house sparrows (*Passer domesticus*) at a dose of 1-1.5 g (Sharma, 1977).
ES-17d (Animal external dispersal)	n - high		It is thought that seeds can be transported long distances by animals (Boatwright, 2012), but we found no evidence to support this, so we answered no with high uncertainty.
ES-17e (Animal internal dispersal)	y - high		Seeds of *A. fistulosus* can be dispersed by animals internally. They can be transmitted through horse dung (Ansong and Pickering, 2013), but only 0.9 percent are viable (St John-Sweeting and Morris, 1990). *Asphodelus fistulosus* is unpalatable though non-toxic (Pitt et al., 2006). It has been found in the stomach contents of tammar wallabies, although it was not specified if the materials were seeds or other plant tissues (Coulson, 2010). In eucalyptus forests in Australia, seven percent of *A. fistulosus* seeds were observed to be taken by invertebrates and one percent by vertebrates in a 48 hour period, suggesting that these are not dispersed internally in animals often, although the experimental design is unclear (Arianoutsou and Groves, 1994).
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - low	1	Seeds are reported to remain viable in the seed bank for "many years" (DiTomaso and Healy, 2007; Parsons and Cuthbertson, 2001). We found some anecdotal evidence that *A. fistulosus* can reproduce by stolons or runners (Ramsey, 2019), although we found no other information to support this conclusion; see Appendix B for a photo.
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	n - low	-1	We found no evidence that *A. fistulosus* plants are tolerant or resilient to disturbance. Cultivation can be used as a control mechanism for this taxon (DiTomaso and Healy, 2007; Parsons and Cuthbertson, 2001). Mowed plants do not regenerate (Smith and Smith, 2014), and “no vegetative regrowth was observed at the populations where plants were hand-pulled or dug out” (Jubase et al., 2019).

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence that *A. fistulosus* has developed herbicide resistance (Heap, 2019). Herbicides were tested and found to be potentially useful in control of this taxon in the United States (Russell, 2008), but their use in Australia is "only appropriate on small colonizing sites" (Grice, 2002). The congener *A tenuifolius* has demonstrated some tolerance to fluchloralin but not to 2,4-D (Yadav and Poonia, 2005). *Asphodelus tenuifolius* can also be "tolerant" to other herbicides, but this depends on the growth stage when herbicide is applied and the biotype that is being targeted (Khan et al., 2008).
ES-21 (Number of cold hardiness zones suitable for its survival)	6	0	
ES-22 (Number of climate types suitable for its survival)	5	2	
ES-23 (Number of precipitation bands suitable for its survival)	5	0	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	We found no evidence that *A. fistulosus* is allelopathic, though we did find some evidence that the congener *A. tenuifolius* can produce allelopathic toxins (Porwal and Gupta, 1986; Qasem and Foy, 2001).
Imp-G2 (Parasitic)	n - negl	0	We found no evidence that *A. fistulosus* is a parasitic plant. It is not a member of a family known to contain parasitic plants (Heide-Jorgensen, 2008; Nickrent, 2019).
Impacts to Natural Systems			
Imp-N1 (Changes ecosystem processes and parameters that affect other species)	y - high	0.4	*Asphodelus fistulosus* can reduce drift of sand in dune landscapes (North East Pastoral Conservation Board, 1997). It is associated with a decrease in population dominance of native grasses in Mexico, which can decrease plant productivity in terms of carbon uptake (Delgado Balbuena et al., 2013). *Asphodelus fistulosus* was one of the two dominant species in an overgrazed ecosystem in Mexico, and this site was found to have lower soil water content, although a causal relationship was not established (Delgado Balbuena et al., 2013). This taxon can also decrease soil nitrogen levels, which may prevent the colonization of other plants (Fox, 2004; Parsons and Cuthbertson, 2001). We answered yes with high uncertainty here because the changed

Question ID	Answer - Uncertainty	Score	Notes (and references)
			ecosystem processes could be caused by several factors and not just *A. fistulosus*.
Imp-N2 (Changes habitat structure)	n - mod	0	We found no definitive evidence that *A. fistulosus* changes habitat structure.
Imp-N3 (Changes species diversity)	y - low	0	In the Mexican grassland biome system, overgrazing leads to the replacement of the native grass, *Bouteloua gracilis*, with perennial shrubs such as *Isocoma veneta* and non-native herbs such as *A. fistulosus* (Delgado Balbuena et al., 2013)
Imp-N4 (Is it likely to affect federal Threatened and Endangered species?)	n - high	0	We found no direct evidence that *A. fistulosus* has affected Federally listed Threatened or Endangered species in the United States. This taxon produces toxic seeds that can be fatal to small passerine birds if ingested, although these seeds may be avoided in nature (Sharma, 1977). Given this possibility, we answered no with high uncertainty.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions?)	n - high	0	*Asphodelus fistulosus* is already present in globally outstanding ecoregions in the United States (Ricketts et al., 1999), including the central and southern California coasts (DiTomaso, 2012; DiTomaso and Healy, 2007), as well as near the Mexico border in Texas, New Mexico, and Arizona (EDDMapS, 2019; Kartesz, 2018). EDDMapS (2019) does not list *A. fistulosus* as present in Texas. This taxon, however, seems mainly to affect disturbed areas (Parsons and Cuthbertson, 2001).
Imp-N6 [What is the taxon's weed status in natural systems? (a) Taxon not a weed; (b) taxon a weed but no evidence of control; (c) taxon a weed and evidence of control efforts]	c - low	0.6	*Asphodelus fistulosus* is common in Australia, and is an "important indicator" of acacia-dominated shrubland ecosystems (Brandle, 2001).This taxon has been reported to thrive in deserts with moderate rainfall in a specific elevation range (2,000-4,500 ft above sea level) in Arizona, although its "potential threat to natural areas [is] unclear" (Russell, 2008). It is considered a noxious weed in the United States, and past eradication efforts by USDA-APHIS and cooperating organizations involved hand-pulling in natural systems of Arizona (Russell, 2008) and efforts in U.S. national parks until 2015 (Saguaro National Park, 2015). Efforts are underway to eradicate this plant from areas in Australia (Smith and Smith, 2014).
Impact to Anthropogenic Systems (e.g., cities, suburbs, roadways)			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-A1 (Negatively impacts personal property, human safety, or public infrastructure)	n - high	0	*Asphodelus fistulosus* grows prolifically on roadsides (Dubrul et al., 2010; Escarciga et al., 2009; Jubase et al., 2019), but we found no evidence of direct impacts to public infrastructure.
Imp-A2 (Changes or limits recreational use of an area)	n - mod	0	We found no evidence of these impacts.
Imp-A3 (Affects desirable and ornamental plants, and vegetation)	y - mod	0	*Asphodelus fistulosus* can survive in suburban gardens in southern Arizona, where it may outcompete other ornamentals (ASDM, 2019; Ask Mr. Smarty Plants, 2009). It has also been reported to invade lawns (Ramsey, 2019). Thus, we answered yes with moderate uncertainty.
Imp-A4 [What is the taxon's weed status in anthropogenic systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c – high	0.4	*Asphodelus fistulosus* is considered a weed in anthropogenic systems, and we found evidence that it is controlled. Comments on the site "Dave's Garden" are generally pleased with the plant but recommend against it because it is Federally regulated (Dave's Garden, 2019). It is considered invasive in several gardening websites and forums (Grow Plants, 2019; Hewson, 2017; National Gardening Association, 2017; PBS, 2019). Private and public entities recommend eradication where possible if found on personal property in the United States (ASDM, 2019; Saguaro National Park, 2015). We found some online guides for controlling this plant in home gardens (Kurtz, 2019). A USDA-APHIS plan was put forth for official control of this weed in Arizona, where the majority of sites with *A. fistulosus* were characterized as residential, roadside, commercial, and municipal (Russell, 2008).
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - low	0.4	*Asphodelus fistulosus* is unpalatable to livestock and can compete with pasture species in Australia (Grice, 2002). The carrying capacity of grazing land is reported to be reduced by up to 75 percent in parts of Australia (Parsons and Cuthbertson, 2001). This species is considered to be a weed of corn in Morocco (Taleb et al., 1998). The congener *A. tenuifolius* was found to be the least competitive weed in an experimental wheat agricultural system in India and was found to reduce grain yield by approximately 11 percent (Mishra, 2002).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P2 (Lowers commodity value)	n - mod	0	We found no evidence of this impact for *A. fistulosus*, and the weed is fairly well characterized.
Imp-P3 (Is it likely to impact trade?)	? - max	0	We are unsure whether *A. fistulosus* will impact trade. This plant is not listed as a harmful organism (PExD, 2019), although Honduras recognizes it as a pest of quarantine significance (Puerto, n.d.), and it is recommended that it be listed as a target for eradication in South Africa (Jubase et al., 2019). The congener *A. tenuifolius* is reported to be a harmful organism in Australia, Brazil, Chile, Honduras, Nauru, Paraguay, Taiwan, and Thailand (PExD, 2019). This taxon is often intercepted in shipments of cumin and red rice (APHIS, 2019), although these shipments often come from India, where *A. fistulosus* is not present. The seeds of *A. fistulosus* and *A. tenuifolius* overlap in size (Rejon et al., 1990) and appear similar (Scher, 2018). Therefore, countries that list *A. tenuifolius* as a quarantine pest may mistake *A. fistulosus* for *A. tenuifolius*.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	We found no evidence of this type of impact in agricultural systems (e.g., Parsons and Cuthbertson, 2001).
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	This taxon produces toxic seeds that can be fatal to small passerine birds if ingested, although the seeds may be avoided in nature (Sharma, 1977). *Asphodelus fistulosus* is unpalatable to livestock in Australia (Grice, 2002) but low in toxicity to herbivores (Pitt et al., 2006). This taxon is not listed in a list of toxic plants in North America (Burrows and Tyrl, 2001). We found some evidence that *A. fistulosus* pollen contains high levels of potassium, which may have a negative effect on bee health, although no direct evidence of this phenomenon was reported (Somerville and Nicol, 2002).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Imp-P6 [What is the taxon's weed status in production systems? (a) Taxon not a weed; (b) Taxon a weed but no evidence of control; (c) Taxon a weed and evidence of control efforts]	c - low	0.6	*Asphodelus fistulosus* is considered a weed of cereals in Morocco (Taleb et al., 1998) and pastureland in Australia (Parsons and Cuthbertson, 2001). We found recommendations for control of this weed in Australia, but it is mentioned that this is only economically feasible for small populations (Grice, 2002; Parsons and Cuthbertson, 2001). Herbicides are labeled for control of *A. fistulosus* in the United States (DiTomaso et al., 2013) and have been tested and applied (Dubrul et al., 2010; Escarciga et al., 2009; Ramsey, 2010; Russell, 2009). We found no reports that this species interferes with production systems in the United States.
GEOGRAPHIC POTENTIAL			Unless otherwise indicated, the following evidence represents geographically referenced points obtained from the Global Biodiversity Information Facility (GBIF).
Plant Hardiness Zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that it is present in this hardiness zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence.
Geo-Z3 (Zone 3)	n - negl	N/A	We found no evidence.
Geo-Z4 (Zone 4)	n - negl	N/A	We found no evidence.
Geo-Z5 (Zone 5)	n - negl	N/A	We found no evidence.
Geo-Z6 (Zone 6)	n - high	N/A	Two points, both on the border with Zone 7.
Geo-Z7 (Zone 7)	y - high	N/A	Two points in Australia, 3 points in Spain (on border with Zone 8), 8 points in France.
Geo-Z8 (Zone 8)	y - negl	N/A	Many points in Spain and France, 3 points in Australia, 1 point in New Zealand on border with Zone 9, 1 point in the United States (TX).
Geo-Z9 (Zone 9)	y - negl	N/A	Many points in Spain, France, and Mexico and on the southern Australian coast; 6 points in Italy; 2 points in New Zealand; and 2 points in the United States (AZ).
Geo-Z10 (Zone 10)	y - negl	N/A	Many points in southern Spain and southern France and on the southern Australian coast. Scattered points in Israel and Mexico and on the western Italian coast; 2 points in Tunisia.
Geo-Z11 (Zone 11)	y - negl	N/A	Many points in Portugal, Mallorca, and Israel, on the southern Australian coast, and in the United States (southern California coast); 2 points in South Africa.
Geo-Z12 (Zone 12)	y - low	N/A	Many points in the Canary Islands, 1 point in South Africa on border with PHZ 11, 5 points in Western Australia (close to PHZ 11). Likely some points on the Israeli coast (resolution

Question ID	Answer - Uncertainty	Score	Notes (and references)
			poor) and some points in the United States (CA).
Geo-Z13 (Zone 13)	n - negl	N/A	We found no evidence that it is in this Zone.
Köppen -Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - high	N/A	We found two points in Mexico, but answered no because we found no evidence in the literature to conclude that *A. fistulosus* can establish in a tropical rainforest out of a cultivation setting.
Geo-C2 (Tropical savanna)	n - negl	N/A	We found no evidence it is present in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Many points Spain and Australia, some points in Israel, 1 point in South Africa (touching Mediterranean), 6 points in the United States (2 points AZ, 4 points CA).
Geo-C4 (Desert)	y - negl	N/A	Many points in Spain (including Canary Islands) Australia, and Mexico, some points in Israel.
Geo-C5 (Mediterranean)	y - negl	N/A	Many points in Israel, Turkey, Italy, France, Spain, Portugal, Australia, and the United States (CA), few points in Canary Islands, Tunisia, Morocco, and South Africa.
Geo-C6 (Humid subtropical)	y - negl	N/A	Many points in Spain, Australia, and Mexico, some points in Italy, 1 point in the United States (TX).
Geo-C7 (Marine west coast)	y - negl	N/A	Many points in Australia and Mexico, some points in France and New Zealand, 1 point in Bolivia.
Geo-C8 (Humid cont. warm sum.)	n - negl	N/A	We found no evidence.
Geo-C9 (Humid cont. cool sum.)	n - negl	N/A	We found no evidence.
Geo-C10 (Subarctic)	n - negl	N/A	We found no evidence.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - negl	N/A	Many points in Spain (including Canary Islands) Israel, Australia, and the United States (CA).
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Many points in Spain, Israel, Australia, and the United States (CA); some points in Italy, Monaco, and Mexico; 3 points in Canary Islands, 2 points in Tunisia, 2 points in South Africa. Two points in the United States (AZ).
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Many points in Portugal, Spain, France, Israel, and Australia, some points in Italy and Mexico, 1 point in South Africa, 3 points in New Zealand.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Many points in Australia, some points in Spain and Portugal, 1 point in Italy, 1 point in New Zealand, 2 points in Mexico, 1 point in the United States (TX).
Geo-R5 (40-50 inches; 102-127 cm)	y - mod	N/A	Eight points in Spain and Portugal together, 3 points in Australia, 1 point in New Zealand, 4 points in Mexico.
Geo-R6 (50-60 inches; 127-152 cm)	n - high	N/A	Four points in Spain, Portugal, and France together, about 7 points in Mexico. We answered no because the points in this precipitation band were located very close to the 40-50 cm precipitation band.
Geo-R7 (60-70 inches; 152-178 cm)	n - high	N/A	Three points were recorded in Mexico, but we selected "no" here because the resolution of the rain bands was poor (each rain band was about a pixel wide), and because the geolocation suggested that these points were likely located in an urban environment and were therefore probably cultivated as ornamentals.
Geo-R8 (70-80 inches; 178-203 cm)	n - negl	N/A	0
Geo-R9 (80-90 inches; 203-229 cm)	n - negl	N/A	0
Geo-R10 (90-100 inches; 229-254 cm)	n - negl	N/A	0
Geo-R11 (100+ inches; 254+ cm)	n - negl	N/A	1 in point Mexico (in Mexico City; we assume this is was most likely an ornamental plant)

ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	*Asphodelus fistulosus* is present in California, Arizona, New Mexico, and Texas (ASDM, 2019; DiTomaso and Healy, 2007; EDDMapS, 2019; Fox, 2004; Kartesz, 2018; NRCS, 2018; Patterson, 1996).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 [Human value & cultivation/trade status: (a) Neither cultivated or positively valued; (b) Not cultivated, but positively valued or potentially beneficial; (c) Cultivated, but no evidence of trade or resale; (d) Commercially cultivated or other evidence of trade or resale]	-	N/A	
Ent-4 (Entry as a contaminant)			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	

Appendix B. Additional photograph.

Photo labeled as an *Asphodelus fistulosus* stolon or runner, although we have some uncertainty because it may be an older inflorescence that had fallen (source: Ramsey, 2019).