

<b>Taxon:</b> <i>Sphagnum palustre</i> L.	<b>Family:</b> Sphagnaceae
<b>Common Name(s):</b> boat-leaved sphagnum peat moss praire sphagnum spoon-leaved sphagnum	<b>Synonym(s):</b> <i>Sphagnum cymbifolium</i> (Ehrhart) R. .....

<b>Assessor:</b> Chuck Chimera	<b>Status:</b> Assessor Approved	<b>End Date:</b> 17 Sep 2019
<b>WRA Score:</b> 11.0	<b>Designation:</b> H(Hawai'i)	<b>Rating:</b> High Risk

**Keywords:** Dioecious Moss, Environmental Weed, Shade-Tolerant, Dense Mats, Spreads Vegetatively

Qsn #	Question	Answer Option	Answer
101	Is the species highly domesticated?	y=-3, n=0	n
102	Has the species become naturalized where grown?		
103	Does the species have weedy races?		
201	Species suited to tropical or subtropical climate(s) - If island is primarily wet habitat, then substitute "wet tropical" for "tropical or subtropical"	(0-low; 1-intermediate; 2-high) (See Appendix 2)	Intermediate
202	Quality of climate match data	(0-low; 1-intermediate; 2-high) (See Appendix 2)	High
203	Broad climate suitability (environmental versatility)	y=1, n=0	n
204	Native or naturalized in regions with tropical or subtropical climates	y=1, n=0	y
205	Does the species have a history of repeated introductions outside its natural range?	y=-2, ?=-1, n=0	y
301	Naturalized beyond native range	y = 1*multiplier (see Appendix 2), n= question 205	y
302	Garden/amenity/disturbance weed	n=0, y = 1*multiplier (see Appendix 2)	n
303	Agricultural/forestry/horticultural weed	n=0, y = 2*multiplier (see Appendix 2)	n
304	Environmental weed	n=0, y = 2*multiplier (see Appendix 2)	y
305	Congeneric weed	n=0, y = 1*multiplier (see Appendix 2)	n
401	Produces spines, thorns or burrs	y=1, n=0	n
402	Allelopathic	y=1, n=0	y
403	Parasitic	y=1, n=0	n
404	Unpalatable to grazing animals	y=1, n=-1	y
405	Toxic to animals	y=1, n=0	n
406	Host for recognized pests and pathogens		
407	Causes allergies or is otherwise toxic to humans	y=1, n=0	n
408	Creates a fire hazard in natural ecosystems	y=1, n=0	n

Qsn #	Question	Answer Option	Answer
409	Is a shade tolerant plant at some stage of its life cycle	y=1, n=0	y
410	Tolerates a wide range of soil conditions (or limestone conditions if not a volcanic island)	y=1, n=0	n
411	Climbing or smothering growth habit	y=1, n=0	n
412	Forms dense thickets	y=1, n=0	y
501	Aquatic	y=5, n=0	n
502	Grass	y=1, n=0	n
503	Nitrogen fixing woody plant	y=1, n=0	n
504	Geophyte (herbaceous with underground storage organs -- bulbs, corms, or tubers)	y=1, n=0	n
601	Evidence of substantial reproductive failure in native habitat	y=1, n=0	n
602	Produces viable seed	y=1, n=-1	y
603	Hybridizes naturally		
604	Self-compatible or apomictic	y=1, n=-1	n
605	Requires specialist pollinators	y=-1, n=0	n
606	Reproduction by vegetative fragmentation	y=1, n=-1	y
607	Minimum generative time (years)	1 year = 1, 2 or 3 years = 0, 4+ years = -1	1
701	Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas)	y=1, n=-1	y
702	Propagules dispersed intentionally by people	y=1, n=-1	y
703	Propagules likely to disperse as a produce contaminant	y=1, n=-1	y
704	Propagules adapted to wind dispersal	y=1, n=-1	y
705	Propagules water dispersed		
706	Propagules bird dispersed	y=1, n=-1	n
707	Propagules dispersed by other animals (externally)	y=1, n=-1	n
708	Propagules survive passage through the gut	y=1, n=-1	n
801	Prolific seed production (>1000/m <sup>2</sup> )		
802	Evidence that a persistent propagule bank is formed (>1 yr)		
803	Well controlled by herbicides	y=-1, n=1	y
804	Tolerates, or benefits from, mutilation, cultivation, or fire	y=1, n=-1	y
805	Effective natural enemies present locally (e.g. introduced biocontrol agents)		

**Supporting Data:**

Qsn #	Question	Answer
101	Is the species highly domesticated?	n
	Source(s)	Notes
	Karlin, E. (2001). Taxonomy of Hawaiian Sphagna. The Bryologist, 104(2), 290-296	[No evidence of domestication] "Sphagnum palustre has a suboceanic, amphiatlantic and amphipacific distribution in the northern hemisphere."

102	Has the species become naturalized where grown?	
	Source(s)	Notes
	WRA Specialist. (2019). Personal Communication	NA

103	Does the species have weedy races?	
	Source(s)	Notes
	WRA Specialist. (2019). Personal Communication	NA

201	Species suited to tropical or subtropical climate(s) - If island is primarily wet habitat, then substitute "wet tropical" for "tropical or subtropical"	Intermediate
	Source(s)	Notes
	Karlin, E. (2001). Taxonomy of Hawaiian Sphagna. The Bryologist, 104(2), 290-296	"In the Hawaiian Islands, Sphagnum palustre occurs naturally only on the Island of Hawaii. The population on the Island of Oahu (in the Mt. Kaala Natural Area Reserve) resulted from a transplantation from the Island of Hawaii in the 1960's (Hoe 1971; Karlin & Andrus 1995)." ... "Hawaiian S. palustre is probably the result of a single dispersal event, with one diaspore serving as the founding agent. Since there is evidence that S. palustre has existed on the island of Hawaii for over 23,000 yr (Karlin & Hotchkiss, pers. comm.), we know that S. palustre has a long history there."
	Flora of North America. (2019). Sphagnum palustre. <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	"Widespread in forested fens and poor to rich sedge fens; low to moderate elevations; B.C., N.B., Nfld. and Labr. (Nfld.), N.S., Ont., P.E.I., Que.; Ala., Ark., Calif., Conn., Del., Fla., Ga., Ill., Ind., Iowa, Ky., La., Maine, Md., Mass., Mich., Minn., Miss., Mo., N.H., N.J., N.Y., N.C., Ohio, Okla., Oreg., Pa., S.C., Tenn., Tex., Vt., Va., Wash., W.Va., Wis.; Europe; Pacific Islands." [Temperate to subtropical]

202	Quality of climate match data	High
	Source(s)	Notes
	Flora of North America. (2019). Sphagnum palustre. <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	

203	Broad climate suitability (environmental versatility)	n
	Source(s)	Notes

Qsn #	Question	Answer
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	"Sphagnum has a very limited presence in the Hawaiian Islands, occurring naturally on Hawaii and Maui. It occurs at elevations ranging from 900 to 1,900 m, which closely correspond to the wettest zone in the Hawaiian Islands (on summits and northeast-facing slopes at elevations ranging from 600 to 1,500 m). Because of the presence of a temperature inversion layer between 1,500 and 2,100 m, elevations much above 1,800 m tend to be quite dry (Carlquist 1980; Cuddihy 1989) and do not support Sphagnum."
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	"Widespread in forested fens and poor to rich sedge fens; low to moderate elevations"

<b>204</b>	<b>Native or naturalized in regions with tropical or subtropical climates</b>	<b>y</b>
	<b>Source(s)</b>	<b>Notes</b>
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	"Sphagnum has a very limited presence in the Hawaiian Islands, occurring naturally on Hawaii and Maui. It occurs at elevations ranging from 900 to 1,900 m, which closely correspond to the wettest zone in the Hawaiian Islands (on summits and northeast-facing slopes at elevations ranging from 600 to 1,500 m)." [Occurs in mid-elevation, wet areas of the Hawaiian Islands]

<b>205</b>	<b>Does the species have a history of repeated introductions outside its natural range?</b>	<b>y</b>
	<b>Source(s)</b>	<b>Notes</b>
	Crum H.A. & Anderson, L.E. (1981). <i>Mosses of Eastern North America. Volume 1.</i> Columbia University Press, New York, NY	"Reported from many parts of South America, Korea, and southeastern Asia and southward to Australia and New Zealand."

<b>301</b>	<b>Naturalized beyond native range</b>	<b>y</b>
	<b>Source(s)</b>	<b>Notes</b>
	Waite, M. (2007). <i>Mosses of Hawaii Volcanoes National Park. Technical Report 153.</i> Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI	"A <i>Sphagnum</i> sp., probably <i>S. palustre</i> that is indigenous to Kohala Mountain, is found in two locations near Kilauea Visitor Center in HAVO. The nearest known location is on the side of the Old Volcano Road across and upslope from the Volcano post office along the fence of a residence. It was also found (HAVO Herbarium, coll. Will Haines) at a house lot in the Hawaii Orchid Island Estates subdivision below Volcano Village under the shade of uluhe ( <i>Dicranopteris linearis</i> ) fern. It has recently been found in the new Kahuku unit (Belfield, pers. comm.) of HAVO. Although it is indigenous to Hawaii it was limited to the Kohala Mountains until its use with forestry seedlings spread it more widely on the island of Hawaii (Karlin & Andrus 1995)." ... " <i>S. palustre</i> was also spread to Kaala Bog on Oahu where it displaces ground bryophytes. In the longer term it may also prevent regeneration of ohia ( <i>Metrosideros polymorpha</i> ) and other trees by increasing waterlogging and acidification of the ground (Vanbreenen 1995)."

Qsn #	Question	Answer
	Karlin, E. (2001). Taxonomy of Hawaiian Sphagna. <i>The Bryologist</i> , 104(2), 290-296	"In the Hawaiian Islands, <i>Sphagnum palustre</i> occurs naturally only on the Island of Hawaii. The population on the Island of Oahu (in the Mt. Kaala Natural Area Reserve) resulted from a transplantation from the Island of Hawaii in the 1960's (Hoe 1971; Karlin & Andrus 1995)."
	Degener, O., Degener, I., & Hormann, H. (1969). <i>Cyanea carlsonii</i> Rock and the unnatural distribution of <i>Sphagnum palustre</i> L. <i>Phytologia</i> . 19(1): 1-4	"The moss we found on May 30, 1969, evidently grew from material used in packing seedlings of various species of <i>Pinus</i> , <i>Toona</i> , of <i>Fraxinus uhdei</i> , etc., to this general area between 1962 and 196U. Whether the sphagnum became naturalized in this new station from spores or from desiccated, dormant gametophyte fragments, or both, we do not know." [ <i>Sphagnum palustre</i> was used for embalming earth-free seedlings of exotic seeds before carrying them into the jungle for planting. Known only from the District of Kohala, Hawaii, populations have naturalized along the rainforest road, 42 miles (as the crow flies) from the Waipio Valley.]

302	Garden/amenity/disturbance weed	n
	Source(s)	Notes
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	[Negative environmental impacts. See 3.04] "Some insight on distribution can be gained from the results of transplanting <i>S. palustre</i> from the Kohala Mountains of Hawaii to what is now the Mt. Kaala Natural Area Reserve on Oahu (Hoe 1971). The species has thrived in the cloud forest it was introduced to, so much so that it endangers the ecological balance of the native ecosystem (Betsy Harrison Gagne, pers. comm.; Randy Kennedy, pers. comm.; Clifford Smith, pers. comm.). It forms an extensive carpet and this evidently retards regeneration by the native cloud forest overstory species."

303	Agricultural/forestry/horticultural weed	n
	Source(s)	Notes
	Randall, R.P. (2017). <i>A Global Compendium of Weeds</i> . 3rd Edition. Perth, Western Australia. R.P. Randall	No evidence

304	Environmental weed	y
	Source(s)	Notes
	Waite, M. (2007). Mosses of Hawaii Volcanoes National Park. Technical Report 153. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI	" <i>S. palustre</i> was also spread to Kaala Bog on Oahu where it displaces ground bryophytes. In the longer term it may also prevent regeneration of ohia ( <i>Metrosideros polymorpha</i> ) and other trees by increasing waterlogging and acidification of the ground (Vanbreemen 1995). The Army Environmental Team is conducting smallscale experiments at the Kaala Bog to control <i>Sphagnum</i> using calcium hydroxide, which very effectively kills the <i>Sphagnum</i> . An interesting side effect is a high number of ohia seedlings germinating in the dead <i>Sphagnum</i> ; although it is too early to know if the seedling growth is supported much beyond germination. Very few ohia seedlings are found in live <i>Sphagnum</i> except in a few spots where the <i>Sphagnum</i> is stressed as indicated by stunted growth and dark coloration probably from sun exposure and good drainage."

Qsn #	Question	Answer
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	"Some insight on distribution can be gained from the results of transplanting <i>S. palustre</i> from the Kohala Mountains of Hawaii to what is now the Mt. Kaala Natural Area Reserve on Oahu (Hoe 1971). The species has thrived in the cloud forest it was introduced to, so much so that it endangers the ecological balance of the native ecosystem (Betsy Harrison Gagne, pers. comm.; Randy Kennedy, pers. comm.; Clifford Smith, pers. comm.). It forms an extensive carpet and this evidently retards regeneration by the native cloud forest overstory species. Natural Area Reserve staff have attempted to clear the moss out of portions of the forest by wholesale bagging and removal, but have not been very successful in controlling it. One volunteer botanist (John Obata) even sprays the <i>Sphagnum</i> repeatedly with bleach! Obviously, habitats suitable for the robust growth of <i>Sphagnum</i> do exist on some of the islands where it does not occur naturally."
	DOFAW Oahu Native Ecosystems Protection and Management. (2015). Report to the Hawaii Invasive Species Council. <a href="https://dlnr.hawaii.gov/hisc">https://dlnr.hawaii.gov/hisc</a> . [Accessed 16 Sep 2019]	" <i>Sphagnum palustre</i> ( <i>Sphagnum</i> ): Contributes to the formation of saturated nutrient-poor acidic soils and grows in a dense blanket over native vegetation. Easily spreads vegetatively via hikers and staff. Negatively impacts rare native snail species. In 2013, results of a UH snail lab study found that native snails become entrapped and die in moss hummocks."
	Joe, S.M. (2015). Controlling the invasive moss <i>Sphagnum palustre</i> at Ka'ala, Island of O'ahu. Technical Report 191. Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Department of Botany, Honolulu, HI	" <i>Sphagnum palustre</i> , a bog moss, was purposely introduced to what is now the Ka'ala Natural Area Reserve on O'ahu in the 1960's from the Kohala area of the Big Island of Hawai'i, where it is indigenous. Though <i>S. palustre</i> cannot produce spores, over a 43 fold increase in the size of the core infestation has been observed between 1997 and 2013. Through vegetative reproduction, <i>S. palustre</i> now occupies an area estimated at 17.3 acres." ... " <i>Sphagnum palustre</i> impacts in Hawai'i are not well documented; nonetheless, bryologists consider it a threat to endemic bryophytes (Waite 2007)."

305	Congeneric weed	n
	Source(s)	Notes
	Randall, R.P. (2017). <i>A Global Compendium of Weeds</i> . 3rd Edition. Perth, Western Australia. R.P. Randall	No evidence

401	Produces spines, thorns or burrs	n
	Source(s)	Notes

Qsn #	Question	Answer
	<p>Flora of North America. (2019). <i>Sphagnum palustre</i>. <a href="http://www.efloras.org">http://www.efloras.org</a>. [Accessed 16 Sep 2019]</p>	<p>[No evidence] "Plants moderate-sized to robust, strong-stemmed, lax to somewhat compact, capitulum somewhat flattened to more typically compact and rounded; green to golden brown to pale brown with often a pinkish tinge; carpets to more or less compact, low to moderate sized hummocks. Stems brown, superficial cortical cells with spiral reinforcing fibrils visible, usually 2-4 pores per cell, comb-fibrils lacking on interior wall. Stem leaves to 1.7 × 1 mm, occasionally longer; rarely hemiisophyllous; hyaline cells non-ornamented, nonseptate. Branches long and tapering, leaves ± imbricate to spreading in shade forms. Branch fascicles with 2 spreading and 2 pendent branches. Branch stems with hyaline cells non-ornamented; no or weak funnel-like projections on the interior end walls, often with 1 large pore per cell on superficial cell walls. Branch leaves broadly ovate, 2.2 × 1.3 mm, hyaline cells non-ornamented, convex surface with elliptic pores along the commissures, chlorophyllous cells isosceles-triangular to ovate triangular in transverse section and just enclosed to just exposed on the convex surface; end wall not thickened."</p>

402	Allelopathic	y
	Source(s)	Notes
	<p>Tsubota, H., Kuroda, A., Masuzaki, H., Nakahara, M., &amp; Deguchi, H. (2006). A preliminary study on allelopathic activity of bryophytes under laboratory conditions using the sandwich method. <i>The Journal of the Hattori Botanical Laboratory</i>, 100, 517-525</p>	<p>"Allelopathy is a common phenomenon in plants, with environmental impacts in ecosystems through interference of allelochemicals that inhibit or promote growth and activity of other life. In this study, allelopathic activities of bryophytes, represented by <i>Sphagnum palustre</i>, <i>Racomitrium japonicum</i>, <i>Dicranum japonicum</i>, and <i>Hypnum plumaeforme</i>, were detected using the sandwich method for bioassay of allelopathic effect for lettuce under laboratory conditions. Most of the representatives more or less showed inhibition or promotion of radicle elongations of lettuce seedlings. These results suggested that bryophytes also have allelopathic activities, and the influence would provide the ecosystems one of the factors for decelerating progressive succession in an early stage of succession of vegetation." ...                      "Sphagnum palustre exhibited differences between the drying conditions, suggesting that some parts of the allelopathic effects in <i>S. palustre</i> are caused by low-molecular substances and other parts of the effects are caused by high-molecular substances."</p>
	<p>Rozema, J., Aerts, R. &amp; Cornelissen, H. (2007). <i>Plants and Climate Change</i>. Springer, Dordrecht, The Netherlands</p>	<p>"Sphagnum is very resistant to decomposition, while it also generates acidic, anoxic, heat insulating and nutrient-poor conditions, and exudes secondary metabolites reducing microbial decay of plant litter."</p>
	<p>Waite, M. (2007). <i>Mosses of Hawaii Volcanoes National Park</i>. Technical Report 153. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI</p>	<p>"Sphagnum species strongly modify their habitats in ways that limit the growth of other plants."</p>

Qsn #	Question	Answer
403	Parasitic	n
	Source(s)	Notes
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	Sphagnaceae. No evidence

404	Unpalatable to grazing animals	y
	Source(s)	Notes
	Meinders, M., & Van Breemen, N. (2005). Formation of soil-vegetation patterns. In <i>Ecosystem function in heterogeneous landscapes</i> (pp. 207-227). Springer, New York, NY	"“Almost nothing eats <i>Sphagnum</i> ” (Clymo and Hayward 1982), in spite of its high content of polysaccharides and its lack of lignin. Its low palatability to herbivores and decomposers alike may be caused mainly by its high content of polyphenols, which partly form a polymeric network that is probably covalently linked to the cell wall polysaccharides (Van der Heijden 1994)."
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	"In <i>Sphagnum</i> peatlands, grazing animals have little to feed on, as the vegetation is dominated by bryophytes, dwarf shrubs, and sedges of low palatability."

405	Toxic to animals	n
	Source(s)	Notes
	Quattrocchi, U. 2012. <i>CRC World Dictionary of Medicinal and Poisonous Plants: Common Names, Scientific Names, Eponyms, Synonyms, and Etymology</i> . CRC Press, Boca Raton, FL	No evidence
	NIH U.S. National Library of Medicine. (2019). TOXNET Toxicology Data Network. <a href="https://toxnet.nlm.nih.gov/">https://toxnet.nlm.nih.gov/</a> . [Accessed 16 Sep 2019]	No evidence

406	Host for recognized pests and pathogens	
	Source(s)	Notes
	WRA Specialist. (2019). Personal Communication	Unknown

407	Causes allergies or is otherwise toxic to humans	n
	Source(s)	Notes
	Quattrocchi, U. 2012. <i>CRC World Dictionary of Medicinal and Poisonous Plants: Common Names, Scientific Names, Eponyms, Synonyms, and Etymology</i> . CRC Press, Boca Raton, FL	No evidence
	NIH U.S. National Library of Medicine. (2019). TOXNET Toxicology Data Network. <a href="https://toxnet.nlm.nih.gov/">https://toxnet.nlm.nih.gov/</a> . [Accessed 16 Sep 2019]	No evidence

408	Creates a fire hazard in natural ecosystems	n
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Qsn #	Question	Answer
	<b>Source(s)</b>	<b>Notes</b>
	Crum H.A. & Anderson, L.E. (1981). Mosses of Eastern North America. Volume 1. Columbia University Press, New York, NY	"Forming wide carpets or cushions of varying size in more or less mineral-rich swampy habitats, usually in the shade." [No evidence. In wet, shaded habitats]
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. Bryologist, 98(2): 235-238	[No evidence. Occurs in perpetually wet habitat] "Sphagnum has a very limited presence in the Hawaiian Islands, occurring naturally on Hawaii and Maui. It occurs at elevations ranging from 900 to 1,900 m, which closely correspond to the wettest zone in the Hawaiian Islands (on summits and northeast-facing slopes at elevations ranging from 600 to 1,500 m)."

409	Is a shade tolerant plant at some stage of its life cycle	y
	<b>Source(s)</b>	<b>Notes</b>
	Atherton, I., Bosanquet, S. D., & Lawley, M. (Eds.). (2010). Mosses and Liverworts of Britain and Ireland a field guide.	[The most shade tolerant of the species ] "S. palustre is rather variable in colour, forming large, untidy mats or loose hummocks that are green to yellow-brown, with or without a contrasting capitulum centre." ... "The most shade tolerant of the species in this Section, found in sites that are moderately enriched with nutrients, for example wet woodland, ditches, stream margins and flushes."
	Crum H.A. & Anderson, L.E. (1981). Mosses of Eastern North America. Volume 1. Columbia University Press, New York, NY	[Usually in the shade] "Forming wide carpets or cushions of varying size in more or less mineral-rich, swampy habitats, usually in the shade"

410	Tolerates a wide range of soil conditions (or limestone conditions if not a volcanic island)	n
	<b>Source(s)</b>	<b>Notes</b>
	Martin, A. (2015). The Magical World of Moss Gardening. Timber Press, Portland, OR	"acidic, low-nitrogen soil"
	Atherton, I., Bosanquet, S. D., & Lawley, M. (Eds.). (2010). Mosses and Liverworts of Britain and Ireland a field guide.	"found in sites that are moderately enriched with nutrients, for example wet woodland, ditches, stream margins and flushes."

411	Climbing or smothering growth habit	n
	<b>Source(s)</b>	<b>Notes</b>
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	"Plants moderate-sized to robust, strong-stemmed, lax to somewhat compact, capitulum somewhat flattened to more typically compact and rounded; green to golden brown to pale brown with often a pinkish tinge; carpets to more or less compact, low to moderate sized hummocks."

Qsn #	Question	Answer
412	Forms dense thickets	y
	Source(s)	Notes
	DOFAW Oahu Native Ecosystems Protection and Management. (2015). Report to the Hawaii Invasive Species Council. <a href="https://dlnr.hawaii.gov/hisc">https://dlnr.hawaii.gov/hisc</a> . [Accessed 16 Sep 2019]	"Contributes to the formation of saturated nutrient-poor acidic soils and grows in a dense blanket over native vegetation."
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	"It forms an extensive carpet and this evidently retards regeneration by the native cloud forest overstory species."

501	Aquatic	n
	Source(s)	Notes
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	[Terrestrial] "Widespread in forested fens and poor to rich sedge fens; low to moderate elevations"

502	Grass	n
	Source(s)	Notes
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	Sphagnaceae

503	Nitrogen fixing woody plant	n
	Source(s)	Notes
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	Sphagnaceae

504	Geophyte (herbaceous with underground storage organs -- bulbs, corms, or tubers)	n
	Source(s)	Notes
	Goffinet, B. & Shaw, A.J. (2009). <i>Bryophyte Biology</i> . Second Edition. Cambridge University Press, Cambridge, UK	"In <i>Sphagnum</i> rhizoids occur only at the base of the thalloid protonemata and are lacking on mature leafy plants, except for a single species from New Caledonia (Iwatsuki 1986)."
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	[Sphagnaceae] "Plants moderate-sized to robust, strong-stemmed, lax to somewhat compact, capitulum somewhat flattened to more typically compact and rounded; green to golden brown to pale brown with often a pinkish tinge; carpets to more or less compact, low to moderate sized hummocks."

Qsn #	Question	Answer
601	Evidence of substantial reproductive failure in native habitat	n
	Source(s)	Notes
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	[No evidence] "Widespread in forested fens and poor to rich sedge fens; low to moderate elevations; B.C., N.B., Nfld. and Labr. (Nfld.), N.S., Ont., P.E.I., Que.; Ala., Ark., Calif., Conn., Del., Fla., Ga., Ill., Ind., Iowa, Ky., La., Maine, Md., Mass., Mich., Minn., Miss., Mo., N.H., N.J., N.Y., N.C., Ohio, Okla., Oreg., Pa., S.C., Tenn., Tex., Vt., Va., Wash., W.Va., Wis.; Europe; Pacific Islands."

602	Produces viable seed	y
	Source(s)	Notes
	Bold, H. (1948). The Prothallium of <i>Sphagnum palustre</i> L. <i>The Bryologist</i> , 51(2), 55-63	"Air-dried spores of <i>Sphagnum palustre</i> L. stored for as long as six months germinate within 3 to 5 days when planted on agar."
	Sobotka, D. (1976). Regeneration and vegetative propagation of <i>Sphagnum palustre</i> as factor of population stability. <i>Acta Societatis Botanicorum Poloniae</i> , 45(4), 357-368	"Protonema only developed after spore germination. The germination ability of <i>Sphagnum</i> spores is variable. In series of experiments some spores germinated by way of a short cellular filament after 7-8 days, in series II germination occurred as late as after 15 days. This different spore germination period does not, however affect the rapidity with which the gametophore develops from the pro-tonema. In both cultures after 50-55 days buds of young foliated <i>Sphagnum</i> plants appear on the protonema"
	Flora of North America. (2019). <i>Sphagnum palustre</i> . <a href="http://www.efloras.org">http://www.efloras.org</a> . [Accessed 16 Sep 2019]	"Spores 24-33 µm, surface finely papillose to smooth, distal surface with distinct bifurcated Y-mark sculpture; proximal laesura more than 0.6 spore radius."

603	Hybridizes naturally	
	Source(s)	Notes
	Cronberg, N., & Natcheva, R. (2002). Hybridization between the peat mosses, <i>Sphagnum capillifolium</i> and <i>S. quinquefarium</i> (Sphagnaceae, Bryophyta) as inferred by morphological characters and isozyme markers. <i>Plant Systematics and Evolution</i> , 234(1-4), 53-70	[Unknown. Evidence of hybridization in genus exists] "Abstract. Isozyme markers and morphological characters were studied in four populations of <i>Sphagnum capillifolium</i> and <i>S. quinquefarium</i> . Recombinant plants were found in three populations, where the two species occur sympatrically. All recombinants possessed different haplotypes and combinations of morphological characters, which show that they are results of independent hybridization events. Strongly male-biased sex ratios were found for <i>Sphagnum capillifolium</i> in all populations where it grew sympatrically with <i>S. quinquefarium</i> . Most of the recombinants were also male fertile. These observations suggest that <i>S. quinquefarium</i> is the female parent in the primary crosses and in subsequent backcrosses."

Qsn #	Question	Answer
604	Self-compatible or apomictic	n
	Source(s)	Notes
	Terracciano, S., Giordano, S., Bonini, I., Miserere, L., & Spagnuolo, V. (2012). Genetic variation and structure in endangered populations of <i>Sphagnum palustre</i> L. in Italy: a molecular approach to evaluate threats and survival ability. <i>Botany</i> , 90(10), 966-975	"It is a dioecious species, reproducing primarily by fragmentation, with occasional sporophyte and spore production." ... " <i>Sphagnum palustre</i> is dioecious, therefore an obligated outbreeding species. But, given the gregarious nature of moss populations, inbreeding between related plants is unavoidable."

605	Requires specialist pollinators	n
	Source(s)	Notes
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	"For sexual reproduction, the male gametes must be transported in water to an archegonium, and a zygote is formed by fertilization. The zygote then grows to become a sporophyte which is the minute, ephemeral diploid stage of a moss resting on a short stalk (pseudopodium)."
	Goffinet, B. & Shaw, A.J. (2009). <i>Bryophyte Biology</i> . Second Edition. Cambridge University Press, Cambridge, UK	"Water is required for fertilization, as bryophyte sperm are flagellated and must swim to reach an egg."

606	Reproduction by vegetative fragmentation	y
	Source(s)	Notes
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	" <i>Sphagnum</i> can also disperse and expand over the mire surface by vegetative reproduction. A large capitulum can split its meristem into two, and side shoots can also emerge from lower parts of the stem. A method of vegetative reproduction that is probably common in some species is that fragments (capitulum or branches) can form new independent shoots. If the capitulum is detached the original shoot can still survive, as a side shoot emerges from the lower part to form a new main stem."
	DOFAW Oahu Native Ecosystems Protection and Management. (2015). Report to the Hawaii Invasive Species Council. <a href="https://dlnr.hawaii.gov/hisc">https://dlnr.hawaii.gov/hisc</a> . [Accessed 16 Sep 2019]	" <i>Sphagnum palustre</i> ( <i>Sphagnum</i> ): Contributes to the formation of saturated nutrient-poor acidic soils and grows in a dense blanket over native vegetation. Easily spreads vegetatively via hikers and staff."
	Studlar, S. (1983). Recovery of Trampled Bryophyte Communities Near Mountian Lake, Virginia. <i>Bulletin of the Torrey Botanical Club</i> , 110(1), 1-11	" <i>Sphagnum palustre/henryense</i> produced adventitious buds on shoot fragments after one week. New shoots and bright green buds on detached capitula were seen in the field after three weeks."

607	Minimum generative time (years)	1
	Source(s)	Notes
	Studlar, S. (1983). Recovery of Trampled Bryophyte Communities Near Mountian Lake, Virginia. <i>Bulletin of the Torrey Botanical Club</i> , 110(1), 1-11	" <i>Sphagnum palustre</i> produced adventitious buds on shoot fragments after one week. New shoots and bright green buds on detached capitula were seen in the field after three weeks."

701	Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas)	y
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Qsn #	Question	Answer
	<b>Source(s)</b>	<b>Notes</b>
	DOFAW Oahu Native Ecosystems Protection and Management. (2015). Report to the Hawaii Invasive Species Council. <a href="https://dlnr.hawaii.gov/hisc">https://dlnr.hawaii.gov/hisc</a> . [Accessed 17 Sep 2019]	"Sphagnum palustre (Sphagnum): Contributes to the formation of saturated nutrient-poor acidic soils and grows in a dense blanket over native vegetation. Easily spreads vegetatively via hikers and staff."
	Karlin, E. F., & Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i> , 98(2): 235-238	"The Kohala Mountains appear to be the original natural location of Sphagnum on the island of Hawaii. Sphagnum is found elsewhere on the island (Hilo Forest Reserve, Kau Forest Reserve, Honaunau Forest Re-serve, Kilauea) but it appears that these other populations most probably resulted from recent transplantation or accidental introduction by humans. Information on the herbarium label of the one specimen from the Honaunau population indicates that this population was established by a transplant from the Kohala area."

702	Propagules dispersed intentionally by people	y
	<b>Source(s)</b>	<b>Notes</b>
	Karlin, E. (2001). Taxonomy of Hawaiian Sphagna. <i>The Bryologist</i> , 104(2), 290-296	"In the Hawaiian Islands, Sphagnum palustre occurs naturally only on the Island of Hawaii. The population on the Island of Oahu (in the Mt. Kaala Natural Area Reserve) resulted from a transplantation from the Island of Hawaii in the 1960's (Hoe 1971; Karlin & Andrus 1995)."
	Martin, A. (2015). <i>The Magical World of Moss Gardening</i> . Timber Press, Portland, OR	[Cultivated] "Sphagnum planted in open areas away from a direct water source will benefit from extra watering. A quick glance will tell you whether these plants are getting thirsty. Since this moss thrives in low-nitrogen conditions, it is important that you do not apply any fertilizers. In particular, calcium fertilizer can be lethal to the plants."

703	Propagules likely to disperse as a produce contaminant	y
	<b>Source(s)</b>	<b>Notes</b>
	Waite, M. (2007). Mosses of Hawaii Volcanoes National Park. Technical Report 153. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI	"Although it is indigenous to Hawaii it was limited to the Kohala Mountains until its use with forestry seedlings spread it more widely on the island of Hawaii (Karlin & Andrus 1995)."
	McQueen, C.R. & Andrus R.E. (2007). Sphagnaceae. In: <i>Flora of North America</i> Editorial Committee, eds. 1993+. <i>Flora of North America North of Mexico</i> . 12+ vols. Oxford University Press, New York and Oxford	Nurserymen typically use wet Sphagnum for shipping live plants.

704	Propagules adapted to wind dispersal	y
	<b>Source(s)</b>	<b>Notes</b>
	Terracciano, S., Giordano, S., Bonini, I., Miserere, L., & Spagnuolo, V. (2012). Genetic variation and structure in endangered populations of <i>Sphagnum palustre</i> L. in Italy: a molecular approach to evaluate threats and survival ability. <i>Botany</i> , 90(10), 966-975	"It is a dioecious species, reproducing primarily by fragmentation, with occasional sporophyte and spore production. Capsules mature in summer and spores are released for wind dispersal."

Qsn #	Question	Answer
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	"Sphagnum has a unique mechanism for spore dispersal: as the capsule ripens and dries out, air pressure is built up. In the end the force is high enough to throw the lid off, and the spores are dispersed in an audible explosion. The mechanism ensures that the spores are lifted several centimetres in the air and thereby reach a moving airstream. It also ensures that the spores are dispersed in dry conditions – in damp air or during rain they would be immediately forced to the ground."

705	Propagules water dispersed	
	Source(s)	Notes
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	[Possible that spores or fragments could be moved by water] "Sphagnum has a unique mechanism for spore dispersal: as the capsule ripens and dries out, air pressure is built up. In the end the force is high enough to throw the lid off, and the spores are dispersed in an audible explosion. The mechanism ensures that the spores are lifted several centimetres in the air and thereby reach a moving airstream. It also ensures that the spores are dispersed in dry conditions – in damp air or during rain they would be immediately forced to the ground." ... "A method of vegetative reproduction that is probably common in some species is that fragments (capitulum or branches) can form new independent shoots."

706	Propagules bird dispersed	n
	Source(s)	Notes
	Karlin, E. F., & Andrus, R. E. (1995). <i>The sphagna of Hawaii</i> . <i>Bryologist</i> , 98(2): 235-238	"Apparently the dispersal of native <i>Sphagnum</i> to adjacent islands by adhering to birds has also not been successful."

707	Propagules dispersed by other animals (externally)	n
	Source(s)	Notes
	Karlin, E. F., & Andrus, R. E. (1995). <i>The sphagna of Hawaii</i> . <i>Bryologist</i> , 98(2): 235-238	"Apparently the dispersal of native <i>Sphagnum</i> to adjacent islands by adhering to birds has also not been successful."
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	[No means of external attachment, although small size might aid in attachment when spores are produced] "Sphagnum has a unique mechanism for spore dispersal: as the capsule ripens and dries out, air pressure is built up. In the end the force is high enough to throw the lid off, and the spores are dispersed in an audible explosion. The mechanism ensures that the spores are lifted several centimetres in the air and thereby reach a moving airstream. It also ensures that the spores are dispersed in dry conditions – in damp air or during rain they would be immediately forced to the ground."

Qsn #	Question	Answer
708	Propagules survive passage through the gut	n
	Source(s)	Notes
	Rydin, H. & Jeglum, J. K. (2006). <i>The Biology of Peatlands</i> . Oxford University Press, Oxford, UK	"In Sphagnum peatlands, grazing animals have little to feed on, as the vegetation is dominated by bryophytes, dwarf shrubs, and sedges of low palatability." [Unlikely. No evidence of consumption]

801	Prolific seed production (>1000/m2)	
	Source(s)	Notes
	Terracciano, S., Giordano, S., Bonini, I., Miserere, L., & Spagnuolo, V. (2012). Genetic variation and structure in endangered populations of <i>Sphagnum palustre</i> L. in Italy: a molecular approach to evaluate threats and survival ability. <i>Botany</i> , 90(10), 966-975	"Different from most mosses, which have a dominant haploid gametophyte, <i>S. palustre</i> is only functionally haploid because its gametophytes develop from diploid spores (Shaw et al. 2008). It is a dioecious species, reproducing primarily by fragmentation, with occasional sporophyte and spore production."
	Joe, S.M. (2015). Controlling the invasive moss <i>Sphagnum palustre</i> at Ka'ala, Island of O'ahu. Technical Report 191. Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Department of Botany, Honolulu, HI	[ <i>S. palustre</i> is dioecious. Spores may not be produced at site because only one sex may be present] "Though <i>S. palustre</i> cannot produce spores, over a 43 fold increase in the size of the core infestation has been observed between 1997 and 2013. Through vegetative reproduction, <i>S. palustre</i> now occupies an area estimated at 17.3 acres."

802	Evidence that a persistent propagule bank is formed (>1 yr)	
	Source(s)	Notes
	Bold, H. (1948). The Prothallium of <i>Sphagnum palustre</i> L. <i>The Bryologist</i> , 51(2), 55-63	"Air-dried spores of <i>Sphagnum palustre</i> L. stored for as long as six months germinate within 3 to 5 days when planted on agar."

Qsn #	Question	Answer
	<p>Sundberg, S., &amp; Rydin, H. (2000). Experimental evidence for a persistent spore bank in Sphagnum. <i>The New Phytologist</i>, 148(1), 105-116</p>	<p>[Possibly. Other species may form a persistent spore bank] "Spore capsules of four Sphagnum species were buried at different depths in peat on a bog. Spore viability was determined after 0, 1, 2 and 3 yr. Viability generally declined with time, but viable spores were still found at all depths after 3 yr. The light-coloured spores of <i>S. balticum</i> and <i>S. tenellum</i> retained their viability better than the darker spores of <i>S. fuscum</i> and <i>S. lindbergii</i>. Survival was highest under wet but aerobic conditions, but was also high under humid or periodically desiccated conditions. By contrast, most spores stored under wet, anaerobic conditions died within 2–3 yr. These results, and predictions from them, are not consistent with earlier results for spores of long-lived and dominant bryophytes, or for seeds of phanerogams of undisturbed wetlands and forests. There was no correlation between spore size and longevity across species, but the small spores from small capsules of <i>S. balticum</i> and <i>S. tenellum</i> generally showed higher viability than those from the medium-sized and large capsules of the same species. This suggests a positive intraspecific relationship between longevity and dispersal distance. There was an indication of conditional dormancy, controlled by weather, in Sphagnum spores. The experiments indicate that Sphagnum spores can form a long-term persistent spore bank under suitable conditions, with a half-life of between 1 and 20 yr (mean across species of 2.6 and 5.0 yr at two depths studied), and with potential values in individual spore capsules of several decades, or even of centuries. Sphagnum spores kept refrigerated showed 15–35% viable spores after 13 yr. The capacity to form a persistent spore bank that can be activated whenever favourable conditions occur might help explain the wide geographical distribution of many Sphagnum species in the boreal and temperate zones, where they have managed to colonize almost every suitable patch of acidic, nutrient-poor wetland."</p>

803	Well controlled by herbicides	y
	Source(s)	Notes
	<p>Waite, M. (2007). Mosses of Hawaii Volcanoes National Park. Technical Report 153. Pacific Cooperative Studies Unit, University of Hawaii at Manoa, Department of Botany, Honolulu, HI</p>	<p>"The Army Environmental Team is conducting small-scale experiments at the Kaala Bog to control Sphagnum using calcium hydroxide, which very effectively kills the Sphagnum."</p>



Qsn #	Question	Answer
	<p>Joe, S.M. (2015). Controlling the invasive moss <i>Sphagnum palustre</i> at Ka'ala, Island of O'ahu. Technical Report 191. Pacific Cooperative Studies Unit , University of Hawai'i at Mānoa, Department of Botany, Honolulu, HI</p>	<p>"When exposed to three herbicides SAFER Moss &amp; Algae Killer, Lilly Miller Worry Free Moss &amp; Algae Control and St. Gabriel's Moss Killer (SGMK) in a greenhouse setting, <i>S. palustre</i> only responded to SGMK. It contains the active ingredients clove oil and sodium lauryl sulfate. In a growth chamber, we tested extremely low doses of SGMK (the recommended label rate is 25-33% SGMK diluted in water), between 0.3 - 5.0% concentration SGMK solution in water, on healthy <i>S. palustre</i>. Within 48 hours 100% mortality was achieved at concentrations greater than or equal to 1.2% SGMK solution. In the field, we treated <i>S. palustre</i> with a 2.5, 5 and 7.5% SGMK solution. The solution was applied at a rate of one liter solution per meter square of moss. Results nine months post-treatment showed only the highest concentration SGMK tested (7.5%) significantly reduced <i>S. palustre</i> cover over the control group. Even this dose left close to half of the target pest alive (mean survival = 49% + 11% SEM). From this work, we concluded that higher field doses were needed to achieve adequate moss control."</p>

804	Tolerates, or benefits from, mutilation, cultivation, or fire	y
	Source(s)	Notes
	<p>Studlar, S. (1983). Recovery of Trampled Bryophyte Communities Near Mountain Lake, Virginia. <i>Bulletin of the Torrey Botanical Club</i>, 110(1), 1-11</p>	<p>"Controlled levels of human trampling fragmented and, after one year, rejuvenated six species of mosses. <i>Polytrichum commune</i>, <i>Ditrichum pallidum</i>, <i>Thuidium delicatulum</i>, <i>Hypnum imponens</i> and <i>Sphagnum palustre/henryense</i> showed c. 80% or more recovery from 4200 walks." ... "<i>Sphagnum palustre/henryense</i> showed a c. 60% recovery in height after one year versus a c. 25% increase in controls"</p>
	<p>Karlin, E. F., &amp; Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i>, 98(2): 235-238</p>	<p>[Mechanical control ineffective] "The species has thrived in the cloud forest it was introduced to, so much so that it endangers the ecological balance of the native ecosystem (Betsy Harrison Gagne, pers. comm.; Randy Kennedy, pers. comm.; Clifford Smith, pers. comm.). It forms an extensive carpet and this evidently retards regeneration by the native cloud forest overstory species. Natural Area Reserve staff have attempted to clear the moss out of portions of the forest by wholesale bagging and removal, but have not been very successful in controlling it."</p>

Qsn #	Question	Answer
805	Effective natural enemies present locally (e.g. introduced biocontrol agents)	
	<p style="text-align: center;"><b>Source(s)</b></p> <p>Karlin, E. F., &amp; Andrus, R. E. (1995). The sphagna of Hawaii. <i>Bryologist</i>, 98(2): 235-238</p>	<p style="text-align: center;"><b>Notes</b></p> <p>[Climate appears to be the major limiting factor in the Hawaiian Islands] "Sphagnum has a very limited presence in the Hawaiian Islands, occurring naturally on Hawaii and Maui. It occurs at elevations ranging from 900 to 1,900 m, which closely correspond to the wettest zone in the Hawaiian Islands (on summits and northeast-facing slopes at elevations ranging from 600 to 1,500 m). Because of the presence of a temperature inversion layer between 1,500 and 2,100 m, elevations much above 1,800 m tend to be quite dry (Carlquist 1980; Cuddihy 1989) and do not support Sphagnum. Often a prominent component of peatlands elsewhere, Sphagnum is lacking from most Hawaiian peatlands and is evidently not a major peat former when it does occur."</p>

**Summary of Risk Traits:**

## High Risk / Undesirable Traits

- A predominantly temperate species, but able to grow in higher elevation tropical islands
- Naturalized on Oahu and outside natural range on Hawaii island
- An environmental weed on Oahu (Hawaiian Islands), smothering the ground and threatening native plant regeneration
- Allelopathic
- Unpalatable to browsing and grazing animals
- Shade-tolerant
- Forms dense mats that exclude native vegetation
- Reproduces by spores and vegetatively
- Able to reproduce rapidly
- Dispersed along trails by human activity
- Spores dispersed by wind and possibly water
- Intentionally spread by people, and unintentionally spread in planting materials
- Able to recover from trampling and mechanical control

## Low Risk Traits

- May be limited to cooler, higher elevation areas with sufficient moisture
- Unarmed (no spines, thorns, or burrs)
- Non-toxic
- Dioecious (may limit sexual reproduction)
- Chemical control methods have proven effective