Circumpolar Arctic Vegetation Classification

Donald A. Walker, University of Alaska Fairbanks, Alaska Geobotany Center, Institute of Arctic Biology and Department of Biology & Wildlife, Fairbanks, AK, USA; **Amy L. Breen**, University of Alaska Fairbanks, International Arctic Research Center, and Alaska Geobotany Center, Institute of Arctic Biology, Fairbanks, AK, USA; **Lisa A. Druckenmiller**, University of Alaska Fairbanks, Alaska Geobotany Center, Institute of Arctic Biology, Fairbanks, AK, USA; **Jozef Šibík**, Institute of Botany, Department of Geobotany, Slovak Academy of Sciences, Bratislava, Slovak Republic; **Stephan Hennekens,** Alterra, Wageningen, The Netherlands; **Fred J.A. Daniëls,** Institute of Biology and Biotechnology of Plants, Münster, Germany; **Nadezhda V. Matveeva,** Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg, Russia; **Marilyn D. Walker,** HOMER Energy, Boulder, CO, USA; **Martha K. Raynolds,** University of Alaska Fairbanks, Alaska Geobotany Center, Institute of Arctic Biology, Fairbanks, AK, USA; **William H. MacKenzie,** B.C. Ministry of Forests, Lands and Natural Resources, Smithers, B.C., Canada

Purpose

- A hierarchy of vegetation maps at plot to circumpolar scales with consistent legend approaches is needed for understanding the Arctic as a single global geo-ecosystem with common geographical, climatic, ecological, cultural, political and economic issues that unite it (**Fig. 1**).

Scope

- The Arctic Tundra Biome as portrayed by the Circumpolar Arctic Vegetation Map (**CAVM Team 2003, Walker et al. 2005**; **Fig. 2**).
- These regions are dominated by treeless tundra vegetation consisting of various combinations of herbaceous plants, dwarf shrubs (<40 cm tall), low shrubs (40-200 cm tall), bryophytes and lichens.

A hierarchy of maps and legends at circumpolar to plot scales

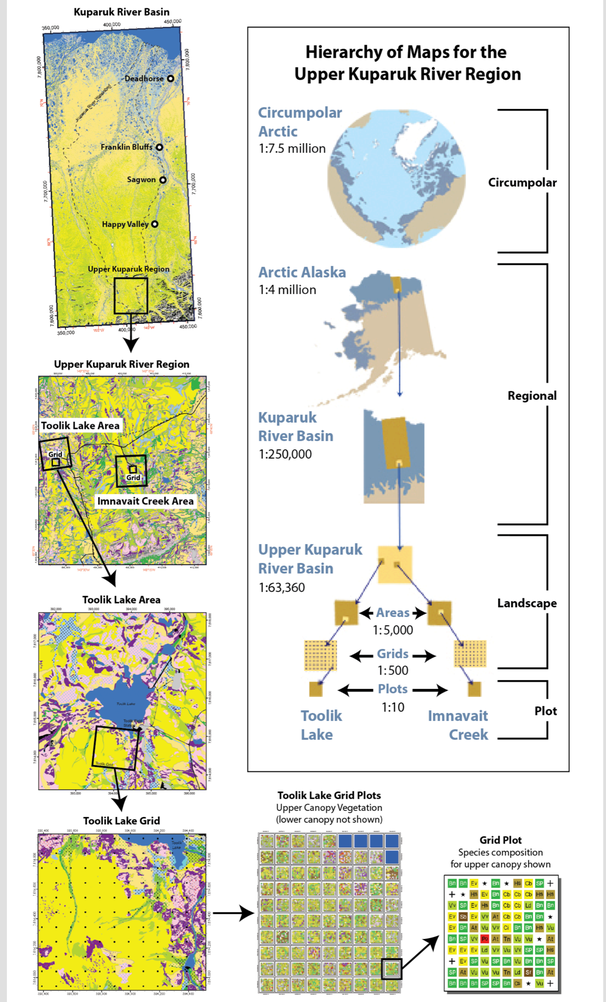

***Figure 1**. Hierarchy of vegetation maps at the Toolik Research Station, and the Kuparuk River region, Alaska* (**Walker et al. 2017 submitted**).

Classification at the circumpolar scale

The CAVM displays the dominant zonal vegetation within five Arctic bioclimate subzones (A –E, from north to south, **Fig. 2**), as well as the dominant azonal vegetation within mountain and wetland complexes. The CAVM classification includes 15 physiognomic vegetation units (**Table 1**), the names of which are based on the dominant plant growth forms (**Table 1)**. A full description of an example CAVM map unit is in **Table 2** from the backside of the map.

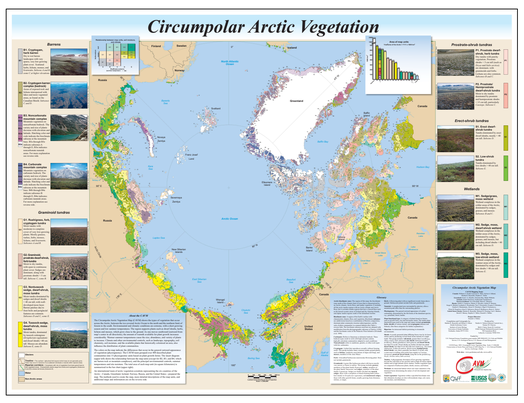

***Figure 1**. Circumpolar Arctic Vegetation Map (**CAVM Team 2003**).*

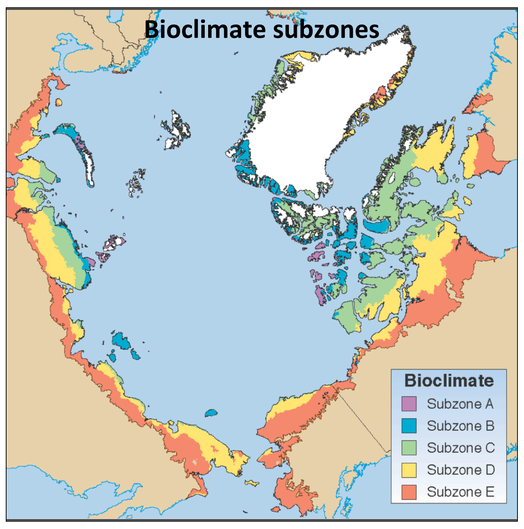

***Figure 2**. Bioclimate subzones of the CAVM.*

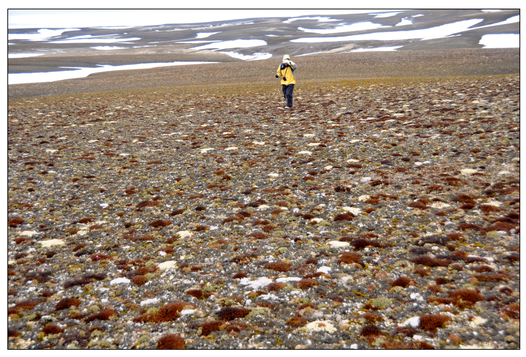

***Figure 3**. Map Unit B1 of the CAVM. Cryptogam, cushion-forb barren, Hayes Island, Franz Jozef Land, Russia.*

***Table 1**. Abbreviated legend for the CAVM.*

Unit no.	Vegetation Unit Name	Description
Barrens (B):		
B1	Cryptogam, herb barren	Mainly zonal vegetation of the coldest areas, bioclimate subzones A and B
B2	Cryptogam barren complex	Low-elevation bedrock, often mixed with many lakes and well vegetated glacial deposits, mainly in Shield areas
B3	Non-carbonate mountain barren complex	Alpine areas on limestone and dolomite with mix of communities within several elevation belts too fine to differentiate at 1: 7.5-million scale
B4	Carbonate mountain barren complex	Alpine areas on siliceous bedrock, with mix of communities with several elevation belts too fine to differentiate at 1: 7.5-million scale
Graminoid-dominated tundras (G):		
G1	Rush/grass, forb, cryptogam tundra	Mainly mesic and relatively well vegetated zonal areas of bioclimate subzones A and B
G2	Graminoid, prostrate-dwarf-shrub, forb tundra	Mesic to xeric zonal vegetation of bioclimate subzone C
G3	Nontussock-sedge, prostrate-dwarf-shrub, moss tundra	Mesic mossy zonal vegetation of bioclimate subzone D and C
G4	Tussock-sedge, prostrate dwarf-shrub, moss tundra	Mesic zonal tussock-tundra (*Eriophorum vaginatum*) vegetation of unglaciated ice-rich permafrost areas of bioclimate subzone E, mainly in Beringia
Prostrate-dwarf-shrub-dominated tundras (P):		
P1	Prostrate-dwarf-shrub, herb tundra	Dry vegetation in bioclimate subzones B and C, mainly on nonacidic substrates
P2	Prostrate- and hemiprostrate-dwarf-shrub, tundra	Dry tundra on acidic substrates dominated by *Cassiope tetragona* and *Dryas integrifolia* in bioclimate subzone C
Erect-shrub-dominated tundras (S):		
S1	Erect-dwarf-shrub tundra	Including zonal tundra dominated by erect dwarf shrubs (<40 cm tall) in well-drained, often acidic areas of bioclimate subzone E and D
S2	Low-shrub tundra	Includes zonal vegetation dominated by low shrubs (40-200 cm tall) near treeline and warmer areas in subzone E
Wetland tundra complexes (W):		
W1	Sedge/grass, moss tundra	Wetland complexes in the High Arctic, Subzones B and C, with few erect shrubs
W2	Sedge, moss, dwarf-shrub tundra	Wetland complexes in subzone D with erect dwarf-shrubs (<40 cm tall)
W3	Sedge, moss, low-shrub tundra	Wetland complexes in warmer areas of the Arctic, mainly subzone E, with low shrubs (40-200 cm tall)

***Table 2**. Detailed vegetation description of map Unit B1 (**Fig. 3**). Updated from the back side of the CAVM, based on **Daniëls et al. 2016**.*

Barrens: B
B1. Cryptogam, cushion-forb barren
General description: Dry to wet barren desert-like landscapes mainly in Arctic Bioclimate Subzone A, with very cold summer climates (mean July temperature <3 ˚C). Plant canopies consist of sparse (2-40%) horizontal plant cover, and very low vertical structure (generally <2 cm tall) with a single layer of plants where they occur. Dry herb barrens composed of few scattered vascular plants are present over much of the landscape. Snow-flush communities are often a conspicuous component, forming dark streaks on the otherwise barren lands, composed largely of bryophytes and cryptogamic crusts. In upland areas, vascular plant cover is generally very sparse (<2%), mainly scattered individual plants often in crevices between stones or small (< 50 cm diameter) cryoturbated polygons. Sedges (Cyperaceae), dwarf shrubs, and peaty mires with *Sphagnum* are normally lacking.

Representative syntaxa: Zonal communities within Bioclimate Subzone A of the class *Drabo corymbosae-Papaveretea dahliani* Daniëls, Elvebakk et Matveyeva 2016 (e.g. Canada: *Puccinellia angustata-Papaver radicatum* community (Vonlanthen et al. 2008); Greenland: *Saxifraga oppositifolia-Papaver* community (Bay 1997); Svalbard: *Papaveretum dahliani typicum* (Möller 2000); Russia, Severnaya Zemlya Archipelago: *Stellario edwardsii-Hylocomietum alaskani* (Matveyeva 2006), *Saxifraga oppositifolia-Stereocaulon rivulorum* community type (Matveyeva 2006). **Common plants:** Diagnostic (character, differential and constant companion) taxa of the class *Drabo corymbosae-Papaveretea dahliani* include: **Vascular plants**: *Alopecurus borealis, Braya glabella* subsp. *purpurascens, Cerastium arcticum, C. regelii* subsp. *caespitosum, Deschampsia sukatschewii* subsp. *borealis, Draba arctica* s.l., *D. corymbosa, D. micropetala, D. pauciflora, D. simmonsii, D. subcapitata, Festuca baffinensis, Luzula confusa, L. nivalis, Micranthes nivalis, Minuartia rossii, Papaver cornwallisense, P. dahlianum, Parrya arctica, Phippsia algida, Poa abbreviata, Potentilla hyparctica, Puccinellia angustata, Ranunculus sabinei, R. sulphureus, Saxifraga cernua, S. cespitosa, S. oppositifolia, S. platysepala, Stellaria longipes* s.l. Mosses: *Aulacomnium turgidum, Polytrichum piliferum, P. strictum, Racomitrium ericoides, R. lanuginosum, R. panschii, Schistidium frigidum.* **Liverwort:** *Gymnomitrion corallioides.* **Lichens**: *Alectoria ochroleuca, A. nigricans, Catapyrenium cinereum, Dactylina ramulosa, Flavocetraria cucullata, F. nivalis, Parmelia skultii, Sphaerophorus globosus, Sticta arctica, Thamnolia vermicularis.*
The character taxa of the alliance, order and class are mainly cushion forbs, and a few grasses and graminoids, such as *Draba pauciflora*, *D. subcapitata*, *Papaver cornwallisense*, *P. dahlianum*, *Ranunculus sabinei*, *R. sulphureus*, *Saxifraga oppositifolia*, *S. platysepala*, *Puccinellia angustata* and the lichen *Parmelia skultii.*
Constant taxa in most communities comprise: *Cerastium arcticum*, *C. regelii* ssp. *caespitosum*, *Micranthes nivalis*, *Saxifraga cernua*, *S. cespitosa, Stellaria longipes* s.l., *Alopecurus borealis* and *Phippsia algida*. Also highly diagnostic is the absence of *Carex* species, dwarf shrubs and other woody species (*Betula, Cassiope, Dryas, Empetrum, Harrimanella, Salix* and *Vaccinium*) and this feature differentiates the polar desert syntaxa against the *Thlaspietea rotundifoliae, Salicetea herbaceae, Scheuchzerio-Caricetea fuscae, Carici-Kobresietea* and *Loiseleurio-Vaccinietea*. Additionally, numerous lichens (*Alectoria ochroleuca, A. nigricans, Dactylina ramulosa, Flavocetraria cucullata, F. nivalis, Sphaerophorus globosus, Thamnolia vermicularis* and other chionophobous lichens) and bryophytes (*Aulacomnium turgidum, Polytrichum piliferum, P. strictum, Racomitrium ericoides, R. lanuginosum, R. panschii,* and *Schistidium frigidum*) serve as differential species against scree vegetation of the *Thlaspietea rotundifoliae* and that of snow-bed vegetation of the *Salicetea herbaceae.*

Classification at the plot scale

The Arctic Vegeation Archive (AVA)

- The goal is to standardize the species-cover and environmental so that they can be analyzed jointly using cluster-analysis and table-sorting approaches to group plots into recognizable vegetation units that have similar species composition.
- A publically accessible archive of standardized available plot data from the circumpolar Arctic (**Raynolds & Walker 2013)** (**Fig. 4)** is under development**.**

The Alaska AVA (AVA-AK)

- The first prototype regional archive has been completed for Arctic Alaska (**Walker et al. 2016**). Two others are under development for Greenland and the Yamal-Gydan region of Russia.
- The AVA-AK currently contains 24 mainly Arctic Alaska datasets (3026 plots) (**Fig. 5**) in a common format with common environmental header data and panarctic taxonomical reference for all species.
- The Alaska Arctic Geoecological Atlas (http://alaskaaga.gina.alaska.edu) is a web-based publically accessible portal for the AVA-AK. It includes access to the Turboveg database and a wide variety of ancillary data for each plot dataset, including publications, photos, plot location maps, soils and environmental data

Toward an Arctic-wide classification using the Braun-Blanquet approach

- The first panarctic classification will use Braun-Blanquet (Br.Bl.) vegetation classification approach (**Braun-Blanquet 1932**), which is the most widely used approach in the Arctic.
- The approach for the AVA will follow as close as possible a recent revision of the European Vegetation Classification (**Mucina et al. 2016**), which aligns higher-level Br.-Bl. syntaxa (classes, orders and alliances) with the European Nature Information System (EUNIS) habitat types (**Rodwell et al. 2002**).
- The organizing framework for the AVA-AK is based on Braun-Blanquet units found in common Arctic habitats as defined for Greenland and expanded for Alaska **(Table 3**) (**Bültmann & Daniëls 2013; Walker et al. 2016**).
- Units at all levels in the classification are defined floristically according to characteristic and diagnostic species and named according to rules by the International Code of Phytosociological Nomenclature (ICPN) (**Weber et al. 2000**).
- Recent advances in vegetation databases and analysis (e.g**. Schaminee et al. 2011, De Cáceres et al. 2015, Chytrý et al. 2015)** make a circumpolar vegetation archive and classification based on many thousands of plots feasible.

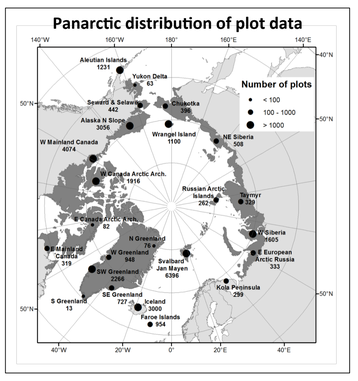

***Figure 4.** Distribution of the currently know and available plot data data* -- approximately **31,972 total plots**.

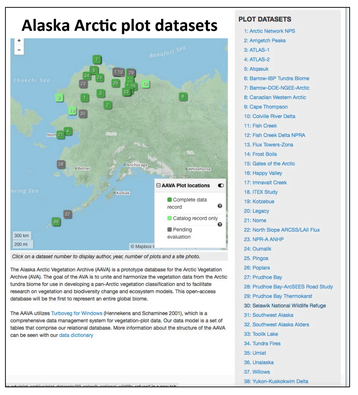

***Figure 5.** Distribution of vegetation-plot datasets in Arctic Alaska.*

***Table 1.** Partial list of habitat types for the AVA-AK, with roughly equivalent syntaxa from Greenland (**Bültmann & Daniëls 2013**) and reorganized to more closely follow organization of Br.-Bl. classes and habitat types of Europe (**Mucina et al. 2016 in press**). A few habitat types are added that are currently missing in the Alaska samples but occur in Greenland and could be expected elsewhere in North America.*

Habitat-type code	Arctic habitat types (modified from Walker et al. 2016a and Bültmann & Daniëls 2013)	Br.-Bl. syntaxa from the European Vegetation Classification (class, order, and alliance) (Mucina et al. 2016 in press)
1	ZONAL ARCTIC TUNDRA *(vegetation developed on well-drained sites with nonextreme soil properties, reflecting the full expression of the prevailing climate)*	
1.01	Zonal sites in Arctic bioclimate subzone A (= polar deserts with mean July temperature <3 ˚C)	PAP: *Drabo corymbosae-Papaveretea* dahliani Daniëls et al. 2016
	Zonal habitats of Arctic bioclimate subzone A	PAP-01 *Saxifrago oppositifoliae-Papaveretalia dahliani* Daniëls et al. 2016
1.01.1	Zonal habitats of Arctic bioclimate subzone A	PAP-01A: *Papaverion dahliani* Hoffmann 1968
1.02	Zonal, dry to mesic wind-swept habitats on base-rich soils mainly of Arctic bioclimate subzones B, C (= High Arctic Tundra with mean July temperatures ≈ 3-7 ˚C)	KOB: *Carici rupestris-Kobresietea bellardii* Ohba 1974
	Dry to mesic prostrate dwarf-shrub and graminoid vegetation on base-rich soils of the Arctic	KOB-01: *Thymo arcticae-Kobresietalia bellardii* Ohba 1974
1.02.1	Zonal, dry habitats on base-rich soils mostly in Arctic bioclimate subzones B and C (mean July temperatures = 3-7 ˚C), also occurs extensively on dry exposed sites with base-rich soils in subzones D and E	KOB-01A: *Kobresio-Dryadion* Nordhagen 1943
1.02.2	Zonal, mesic habitats on base-rich soils mostly in Arctic bioclimate subzones C, D, and E (mean July temperatures =5-9 ˚C) of Arctic Western Russia and Siberia	KOB-01B: *Dryado octopetalae-Caricion arctisibiricae* Koroleva et Kulyugina in Chytrý et al. 2015
1.02.3	Zonal, mesic habitats on base-rich soils mainly in Arctic bioclimate subzones C, D (mean July temperatures ≈ 5-9 ˚C) in Greenland, Canada, and Alaska	KOB-01C: *Dryadion integrifoliae* Ohba ex Daniëls 1982
1.03	Zonal, dry to mesic habitats on nutrient-poor acidic substrates and siliceous fellfields mostly in Arctic bioclimate subzones D and E (mean July temperatures ≈ 7-12 ˚C)	LOI: *Loiseleurio procumbentis-Vaccinietea* Eggler ex Schubert 1960
	Zonal tundras in Arctic bioclimate subzone D and E on acidic substrates	LOI-03: *Deschampsio flexuosae-Vaccinietalia myrtilli* Dahl 1957
1.03.1	Wind-swept habitats on acidic soils	LOI-03A: *Loiseleurio-Arctostaphylion* Kalliola ex Nordhagen 1943
1.03.2	Moist to dry zonal habitats on acidic soils mostly in Arctic bioclimate subzones D and E (mean July temperatures = 7-12 ˚C) with erect dwarf-shrub, moss, and lichen heaths	LOI-03B: *Phyllodoco-Vaccinion myrtilli* Nordhagen 1943
1.03.3	Moist low-shrub tundra on acidic soils in the warmest parts of the Arctic bioclimate subzones D and E	
2	ZONAL BOREAL MARITIME TUNDRA	
2.01	Tall-herb vegetation on mesic-moist soil of boreal maritime tundra	*Mulgedio-Aconitetea* Hadač et Klika in Klika et Hadač 1944
	Tall-herb vegetation on nutrient-rich soils	MUL-05: *Epilobio lactiflori-Geranietalia sylvatici* Michl et al. 2010
2.01.1	Tall-herb vegetation on nutrient-rich soils in maritime-boreal tundra (Aleutian Islands)	Compare MUL-05A: *Mulgedion alpini* Nordhagen 1943
3	INTRAZONAL VEGETATION OF THE ARCTIC ZONE *(fully developed vegetation on less common substrates or microclimates within zones)*	
3.01	Cryo-xerophytic steppe tundra on base-rich soils	SAX: *Saxifrago tricupidatae-Calamagrostietea purpurascentis* Drees & Daniëls 2009
	Base-rich, subsaline substrates in continental northeast Asia, North America, and Greenland, with cryo-xerophytic steppes (steppe tundra)	SAX-01: *Saxifrago tricuspidatae-Calamagrostietalia purpurascentis* Drees et Daniëls 2009
3.01.1	Cryo-and thermoxerophytic steppe and associated scrub on base-rich soils in continental northeast Asia, North America, and Greenland. Includes dry steppe-tundra communities on south-facing slopes of pingos.	SAX-01A: *Saxifrago tricuspidatae-Calamagrostion purpurascentis* Cooper ex Drees et Daniëls 2009
3.01.2	Low arctic steppe vegetation on nonacidic, calcium-saturated, loess or sandy sediments, generally on dry south-facing exposures along streams, sand dunes, on pingos and in the alpine. Includes turfy forb-rich meadows rich in amphi-Beringian steppe grasses and sedges	Compare SAX-01B: *Puccinellion nuttallianae* Daniëls 2015 in Chytry et al. 2015
4	EXTRAZONAL BOREAL VEGETATION OCCURRING IN THE ARCTIC ZONE *(vegetation occurring in the Arctic that is more typical of the boreal zone)*	
4.01	Boreal coniferous forest enclaves occurring within the tundra zone	PIC: *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 (in North America: *Linnaeo americanae-Piceatea marianae* Rivas-Martínez. Sánchez-Mata & Costa 1999)
4.02	Subalpine and subarctic herb-rich alder and willow scrub and krummholz	VIR: *Betulo carpaticae-Alnetea viridis* Rejmánek ex Boeuf, Theurillat, Willner, Mucina et Simler in Boeuf et al. 2014
	Thermophilous herb-rich alder, willow scrub and krummholz	VIR-01 *Alnetalia viridis* Rübel ex Karner et Willner in Willner et Grabherr 2007 Still to be described for North America
4.02.2	Moist alder communities (*Alnus viridis*). Includes riparian alder communities and moist alder savannas with tussock-tundra understories, in warm portions of Arctic bioclimate subzone E, also includes for now, habitats with thermophilous communities on south facing slopes in Arctic bioclimate subzone E with lush stands low shrubs including *Alnus viridis, Juniperus communis, Betula glandulosa,* and *Salix* spp.	Still needs to be classified
5	AZONAL ARCTIC HABITATS *(young habitats with poorly developed soils)*	
	SALT MARSHES, SAND DUNES, SEA CLIFFS	
5.01	Wet saline coastal marshes	JUN: *Juncetea maritimi* Br.-Bl. in Br.-Bl. et al. 1952
	Coastal salt-marsh swards	JUN-04: *Puccinelletalia phryganodis* Hadač 1946
5.01.1	Coastal salt-marsh swards (*Puccinellia phryganodes, Carex subspathacea*)	JUN-04A: *Puccinellion phryganodis* Hadač 1946
5.02	Tall-grass perennial swards on mobile coastal dunes	AMM: *Ammophiletea* Br.-Bl. et Tx. ex Westhoff et al. 1946
	Tall grassy swards on rocky beaches, cliffs and embryonic dunes of the cold temperate and arctic shores of Europe, the European Arctic islands and Greenland	AMM-02: *Honckenyo-Elymetalia arenarii* Tx. 1966
5.02.1	Tall-grass swards on mobile sand dunes (*Leymus arenarius*), includes for now other saline coastal embryonic communities that are presently undescribed. For example, various communities dominated by *Puccinellia andersoni, Mertensia maritima, Honkenya peploides, Salix arctica, Braya glabella* spp. *purpurascens,* and/or *Cochlearia officinalis*	Compare AMM-02B Mertensio maritimae-Honckenyion diffusae Tx. et Géhu in Géhu 1998
	TALUS, SCREES, AND BOULDER FIELDS (also see habitat codes 15.13 to 15.16 for epilithic moss- and lichen-dominated communities)	
5.03	Chasmophytic vegetation of crevices, rocky ledges and faces of rocky cliffs and walls (includes for now acidic and base-rich rocks)	ASP: Asplenietea trichomanis (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977
	Chasmophytic vegetation of crevices of siliceous rocks in the mountains in the nemoral, boreal and Arctic zones of Europe	ASP-11: *Androsacetalia vandellii* Br.-Bl. in Meier et Br.-Bl. 1934 nom. corr
5.03.1	Chasmophytic vegetation of crevices and on ledges of siliceous rocks	ASP-11A Saxifragion cotyledonis Nordhagen ex Mucina et Chytrý in Mucina et al. 2016
5.04	Vegetation of scree habitats and coarse alluvium	THL: Thlaspietea rotundifolii Br.-Bl. 1948
	Alpine and subalpine calcareous scree vegetation	THL-01: *Thlaspietalia rotundifolii* Br.-Bl. in Br.-Bl. et Jenny 1926
5.04.1	Base-rich and neutral screes and moraines	THL-01M: *Arenarion norvegicae* Nordhagen 1935
	Snow-beds on stabilized calcareous screes	THL-02: *Arabidetalia caeruleae* Rübel ex Nordhagen 1937
5.04.2	Herb-rich snow-beds on stabilised calcareous soils	THL-02A: *Saxifrago oppositifoliae-Oxyrion digynae* Gjaerevoll 1950
	Arctic-alpine vegetation of siliceous screes and moraines of Europe, the Arctic Ocean islands and Greenland	THL-06 *Androsacetalia alpinae* Br.-Bl. in Br.-Bl. et Jenny 1926
5.04.3	Herb-rich vegetation on damp coarse gravels and deep humus-rich soils over siliceous substrates of Iceland	THL-06A *Arntitrichio-Rhodiolion roseae* Hadač 1971
	Riverine gravel terraces	THL-08: *Epilobietalia fleischeri* Moor 1958
5.04.4	Ruderal riparian floodplain and terrace vegetation (*Chamerion latifolium*)	THL-08C: *Calamagrostion neglectae* Nordhagen ex de Molenaar 1976

Summary

Vegetation classification of the circumpolar Arctic Tundra Biome is a priority project of Conservation of Arctic Flora and Fauna. Recent rapid advancements in large international vegetation databases and information systems now make the creation of a circumpolar vegetation archive and classification possible, along with their application to nature conservation and policy making. A recently published prototype for Arctic Alaska uses the Braun-Blanquet (Br.-Bl.) classification approach, with zonal and habitat-type based grouping of syntaxa, similar to the approach used in the European Vegetation Classification. Vegetation scientists from around the circumpolar Arctic are meeting at ASSW 2017 to take the next step toward a circumpolar Arctic Vegetation Classification.

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