CLINF

Climate change effects on the epidemiology of infectious diseases and the impacts on Northern societies

Nordic Centre of Excellence

Funded by NordForsk programme "*Responsible Development in the Arctic: Opportunities and Challenges – Pathways to Action*".

63 MNOK, of which 36 MNOK from NordForsk

> 40 senior scientists

8 Cooperating partners + 15 affiliated parties in 8 countries

Photo: Carl-Johan Utsi

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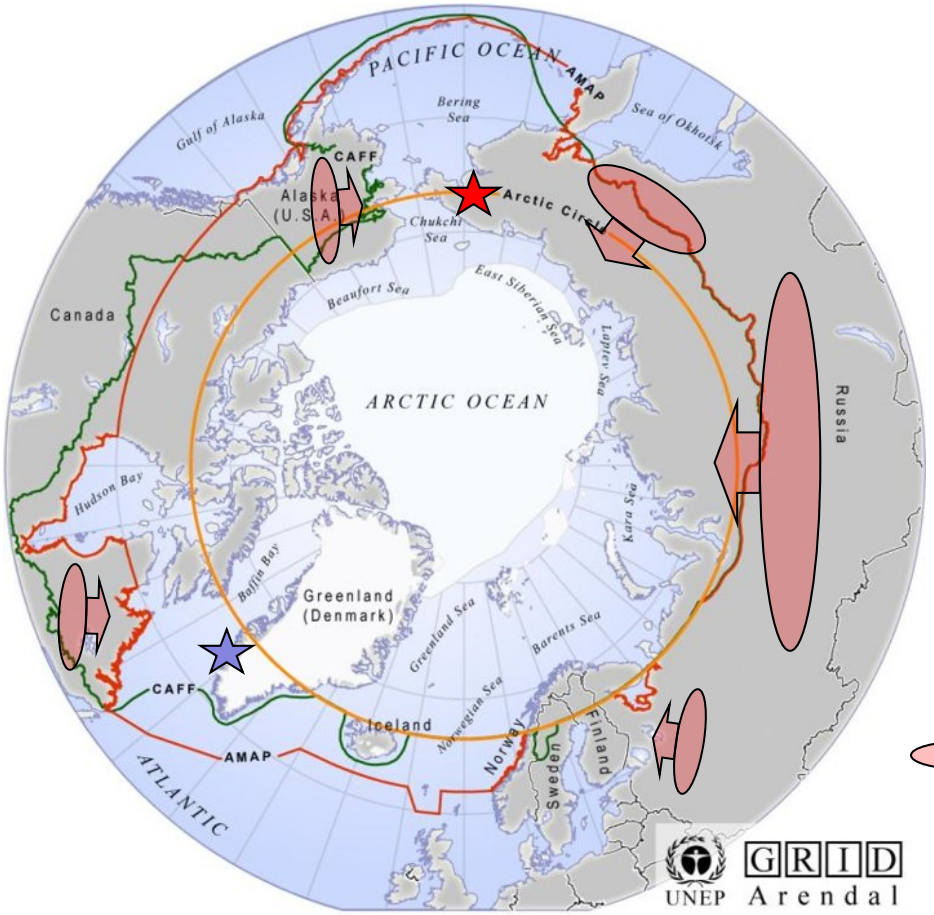
The CLINF NCoE

Basic hypothesis: The habitats of CSI carrier organisms are expanding towards the North!



- ✓ Bluetongue
- ✓ West Nile fever
- ✓ Tularaemia
- ✓ TBE
- ✓ etc.

★ Yakutsk

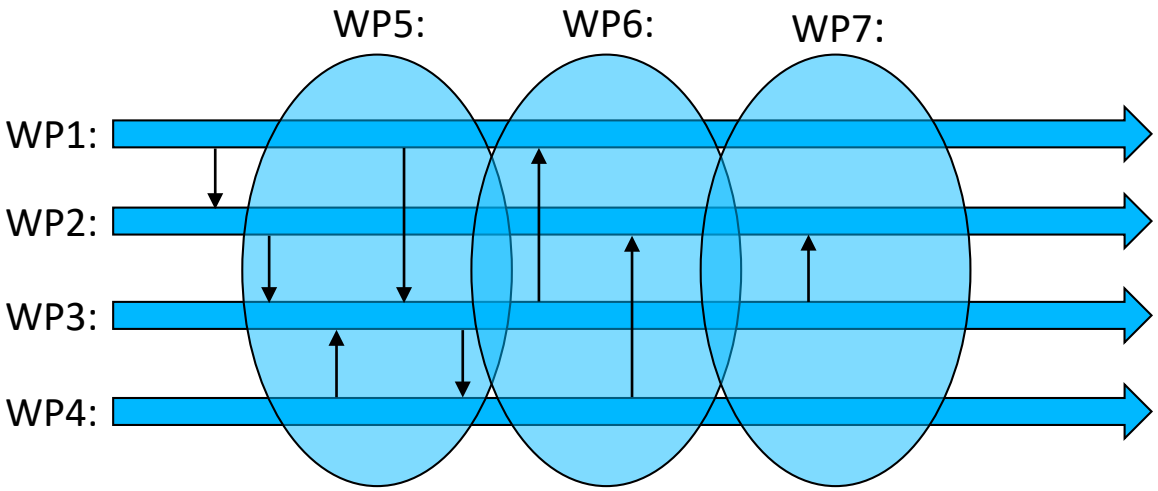
★ Nuuk

Geographic CSI extension (hypothetic)

CSI: “Climate Sensitive Infections”

The CLINF NCoE

Disposition in a nutshell



Parallel themes

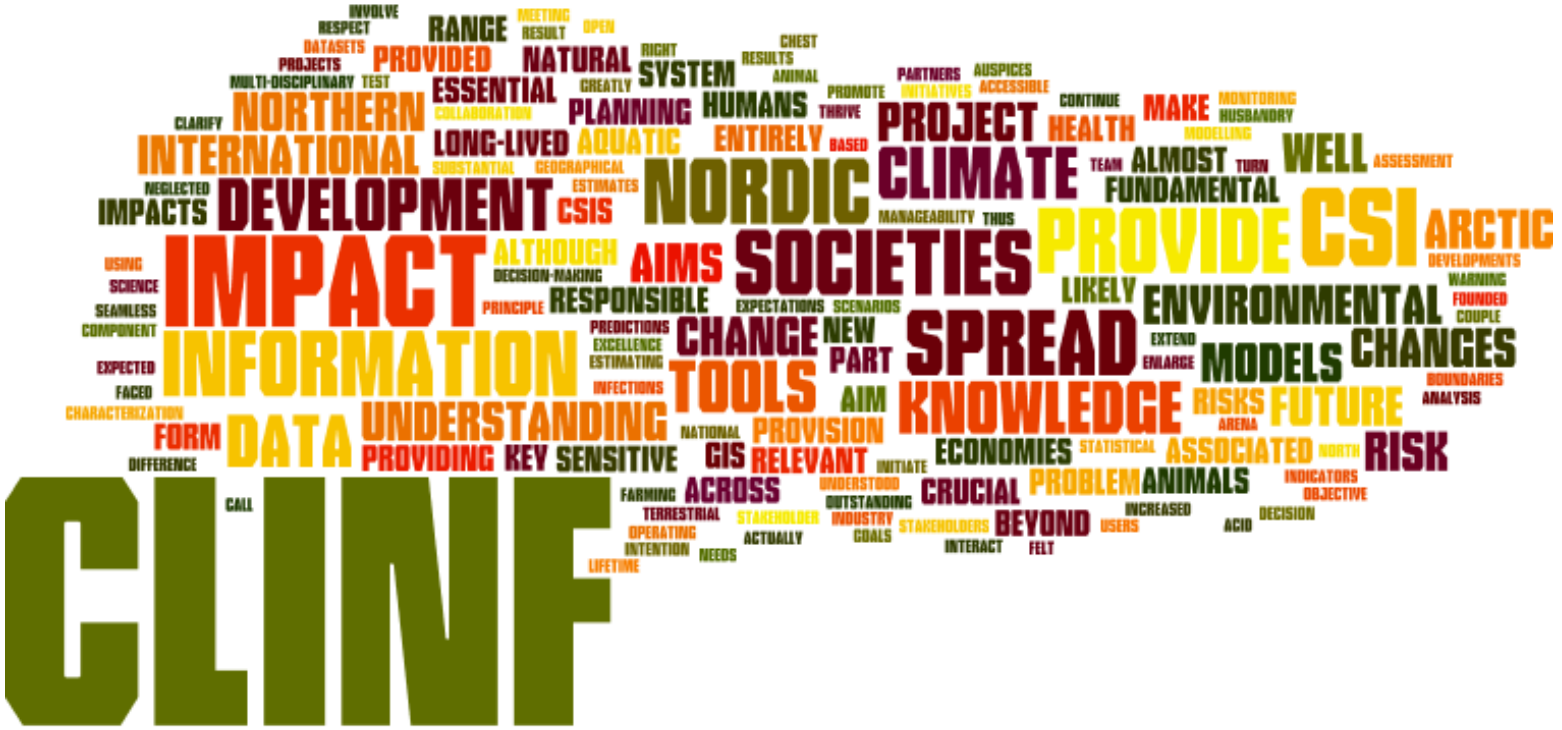
- WP1. *Birgitta Evengård*: Human and animal diseases in the Nordic region: Retrospective data processing and modelling of future scenarios for locally applicable alert systems for CSI (Climate Sensitive Infections).
- WP2. *Shaun Quegan*: Climate change in the Nordic region: procuring data and modelling future scenarios.
- WP3. *Tomas Thierfelder*: Depicting the geographic spread of climate sensitive infections in the Nordic region.
- WP4. *Grete Hovelsrud*: Climate sensitive infections. Societal impacts and adaptation needs.

Crosscutting issues

- WP5. *Jan Åge Riseth*: Traditional knowledge, gender, and local agency.
- WP6. *Tomas Thierfelder*: The CLINF geographic information system.
- WP7. *Birgitta Evengård*: Project management.

The CLINF NCoE

Welcome to CLINF!



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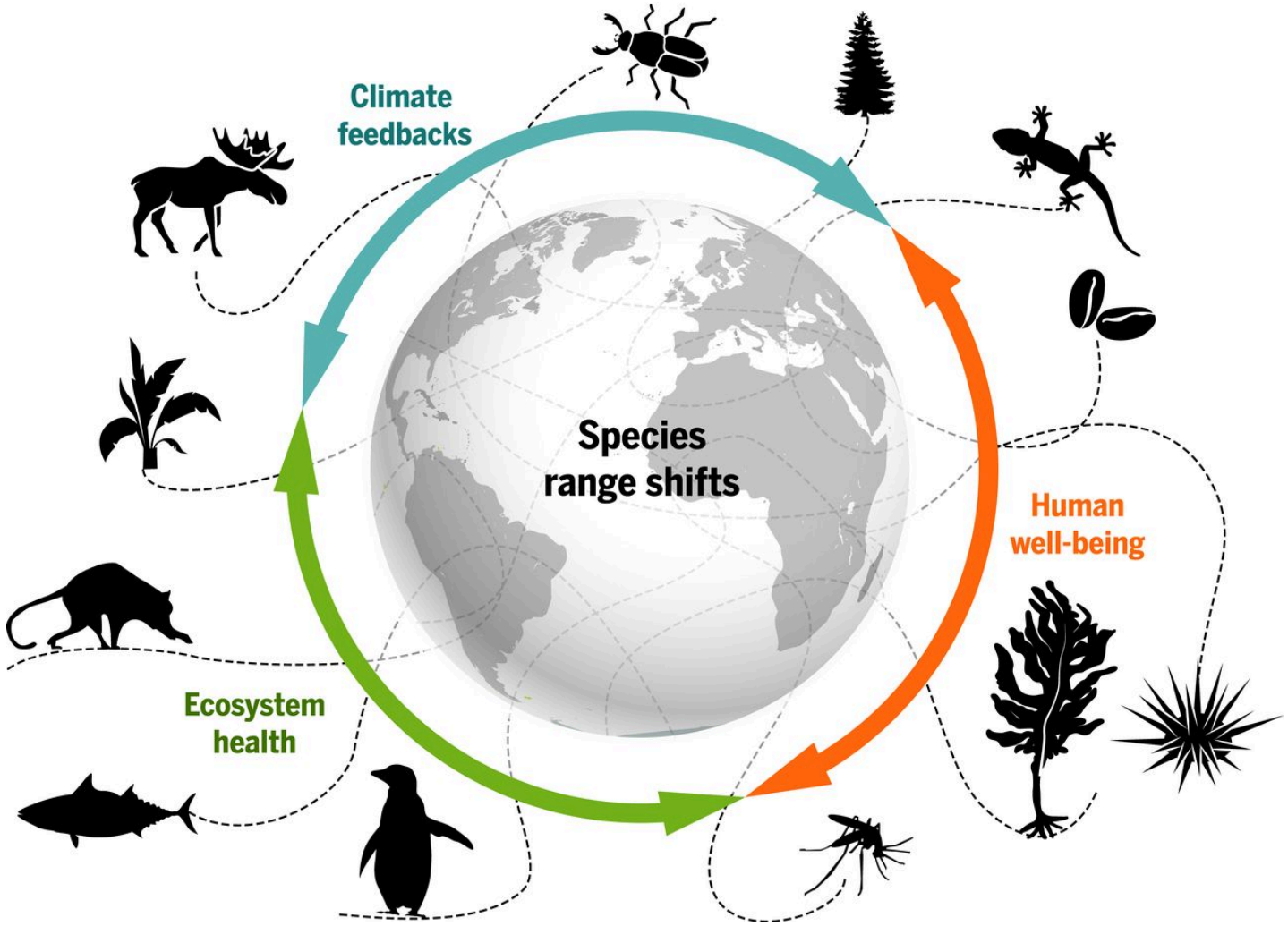
One Health

- Zoonotic infectious diseases in the era of climate change

"As the global climate changes, human well-being, ecosystem function, and even climate itself are increasingly affected by the shifting geography of life."



Gretta T. Pecl et al. Science 2017;355:eaai9214

Zoonotic infectious diseases

- Infectious diseases that are spread from animals to humans and vice versa, sometimes via a vector (eg. mosquitos, ticks).
- The interlinkages between animal and human infectious diseases and their spread is strong.
- Many of the same microbes infect animals and humans, as they share the eco-systems they live in.
- The WHO estimates that approximately 70% of all current emerging human infections are zoonotic.

The One Health concept

- Recognizing that efforts by just one sector cannot prevent or eliminate the problem of emerging zoonotic diseases.
  - For instance, rabies in humans is effectively prevented only by targeting the animal source of the virus (for example, by vaccinating dogs).
- Working across multiple sectors from different academic disciplines as well as institutions to collaborate on policies, programmes for better public health outcomes.
- Other important areas besides the control of zoonoses, include food and water safety, and
- combatting antibiotic resistance.

UMEÅ UNIVERSITY

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FROM NUUK TO YAKUTSK

SVA NATIONAL VETERINARY INSTITUTE

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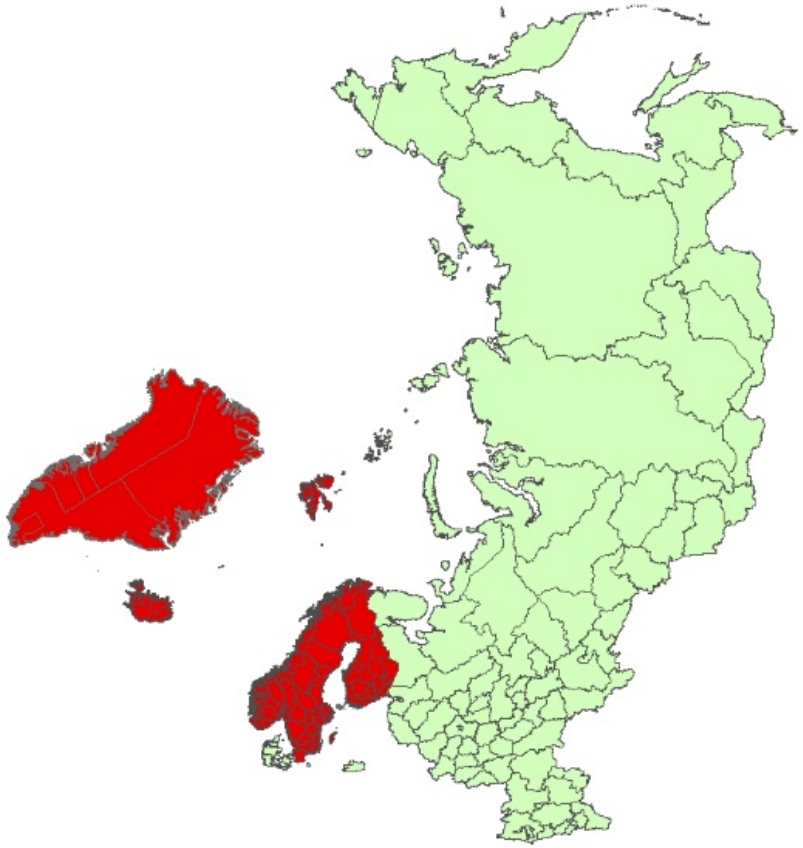
Disease data reporting in the Nordic countries



Registered disease data across Sweden, Finland, Norway, Iceland and Greenland

- Data were obtained from the Public Health Agency of Sweden, the Norwegian Institute of Public Health, the National Institute for Health and Welfare in Finland, the Directorate of Health in Iceland and the Greenlandic Board of Health in Greenland.

- Anthrax, Borreliosis, Brucellosis, Cryptosporidiosis, Nephropatia epidemica (puumulavirus), Leptosporidiosis, Q-fever, Tickborne encephalitis, Tularemia,

Registered disease data across Sweden, Finland, Norway, Iceland and Greenland

		Disease							
		Borreliosis	Brucellosis	Cryptosporidiosis	Leptospirosis	Nephropathia epidemica	Q-fever	Tick-borne encephalitis	Tularaemia
Data obtained from year	Sweden	n/a[a]	2010	2004	2008	1997	2007	2004	1997
	Finland	1995	1995	1995	1995	1995	1995	1995	1995
	Norway	1990[e]	2004	2012	n/a[a]	1991	n/a[d]	1998	1985
	Iceland	n/a[a]	2005	2013	2014	1997	2005	n/a[a]	2005
	Greenland	n/a[f]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]
Disease notifiable from year	Sweden	n/a[a]	2004	2004	2004	1985	2004	2004	1969
	Finland	1995	1995	1995	1995	1995	1995	1995	1995
	Norway	1991	1977	2012	n/a[a]	1991	2012	1975	1977
	Iceland	n/a[a]	2005	2013	2014	1997	2005	n/a[a]	2005
	Greenland	n/a[f]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]
Information regarding sex and age/age group from year	Sweden	n/a[a]	n/a[c]	2004	n/a[c]	1997	n/a[c]	2004	1997
	Finland	1995	1995	1995	1995	1995	1995	1995	1995
	Norway	1990[e]	2004	2012	n/a[a]	1991	n/a[d]	1998	1985
	Iceland	n/a[a]	n/a[b]	n/a[c]	n/a[b]	n/a[b]	n/a[b]	n/a[a]	n/a[b]
	Greenland	n/a[f]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]

[a] Not notifiable, sometimes voluntarily reported.

[b] No cases reported.

[c] Information was not given due patient integrity.

[d] No data obtained.

[e] Between 1983-1990, borreliosis was sporadically reported in Norway.

[f] In Greenland, only neuroborreliosis is notifiable.

Registered disease data across Sweden, Finland, Norway, Iceland and Greenland

The table shows some discrepancies across the Nordics concerning data reporting:

- diseases became notifiable and reported at different years, going back in time
- information regarding sex and/or age has been unsystematically registered
- data from Finland, were not categorised with respect to place of transmission (abroad or domestically)
- borreliosis and leptospirosis are not notifiable in all Nordic countries
- in Greenland and Iceland only a few diseases are yet notifiable

Reported disease incidences across Finland, Sweden and Norway

- Data was received from the Public Health Agency of Sweden, Norwegian Institute of Public Health and the National Institute for Health and Welfare in Finland.
- Statistics on populations were collected from Statistiska centralbyrån, Sweden, Statistisk sentralbyrå, Norway and Statistikcentralen, Finland.
- Greenland and Iceland are not represented in the table due to of lack of data.

Reported disease incidences across Finland, Sweden and Norway

	Finland						Sweden						Norway					
Disease	1995	2000	2005	2010	2015	2016	1995	2000	2005	2010	2015	2016	1995	2000	2005	2010	2015	2016
Borreliosis	6,8	17,1	23,6	26,9	34,9	35,0	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	n/a[a]	1,9	2,5	5,0	5,1	6,5	3,8
Brucellosis	0,0	0,0	0,0	0,0	0,0	0,0	n/a[b]	n/a[b]	0,0	0,0	0,0	0,0	n/a[d]	n/a[d]	0,0	0,0	0,0	0,0
Cryptosporidiosis	0,3	0,1	0,3	0,4	0,6	1,3	n/a[b]	n/a[b]	0,2	2,9	3,2	3,4	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0,5	1,7
Leptospirosis	0,0	0,0	0,1	0,0	0,0	0,0	n/a[b]	n/a[b]	0,0	0,0	0,0	0,0	n/a[f]	n/a[f]	n/a[f]	n/a[f]	n/a[f]	n/a[f]
Nephropathia epidemica	17,4	15,0	48,1	27,0	26,7	30,1	n/a[c]	1,3	3,1	3,9	2,6	0,9	1,2	0,7	1,1	0,4	0,1	0,1
Q-fever	0,0	0,0	0,1	0,1	0,1	0,0	n/a[b]	n/a[b]	0,0	0,1	0,0	0,0	n/a[g]	n/a[g]	n/a[g]	n/a[g]	n/a[g]	n/a[g]
Tick-borne encephalitis	0,1	0,8	0,3	0,7	1,2	1,1	n/a[b]	n/a[b]	1,4	1,8	2,6	2,3	n/a[h]	0,0	0,1	0,2	0,2	0,1
Tularaemia	9,1	17,9	1,2	1,7	1,9	12,7	n/a[c]	4,8	2,5	5,1	7,7	1,3	0,1	0,0	0,3	0,6	0,6	0,6

[a] Borreliosis is not notifiable in Sweden.
[b] Brucellosis is notifiable since 2004.
[c] No data obtained prior to 1997.
[d] No data obtained prior to 2004.
[e] Crypotosporidiosis is notifiable since 2012 in Norway.
[f] Leptospirosis in not notifiable in Norway.
[g] No data obtained. Q-fever is notifiable since 2012 in Norway.
[h] No data obtained prior to 1998.

Reported disease incidences across Finland, Sweden and Norway

Incidence rates from 1995 to 2015 and 2016, show:

- increasing trends of borreliosis and TBE in Norway, Sweden and Finland
- highest incidence rates of borreliois, tularaemia and nephropathia epidemica in Finland
- still few, however increasing incidences of cryptosporidiosis (outbreaks)

Conclusions and recommendations

- There are discrepancies in the systematic data reporting across the Nordic health authorities which complicates proper comparison of incidence rates between countries.
- Although no data was accessed before 1995 from Finland, the dataset is highly organized.
- An international standardisation in reporting of zoonotic diseases is needed to better monitor and understand the epidemiological changes in disease patterns due to climate change.
- An extended collaboration and harmonisation including the rest of the Arctic nations would also be desirable.

CLINF

Climate change effects on the epidemiology of infectious diseases and the impacts on Northern societies

Photos: Carl-Johan Utsi

Identification of possible climate sensitive infections

ZOONOTIC INFECTIONS

- >70% of all human infectionsn (WHO)
- 14 milj. humans die – every year!
- More difficult to control than ”human only diseases”

Factors considered when Climate Sensitive Infections are selected and characterised

Clinical Relevance
high, moderate, low, none

Temporal Relevance
present, emerging, future

Spatial Relevance
entire area, several countries/ regions, spot-wise in a country/region, in few locations/local/regional, not present/presence not known

Drivers of Epidemiology
species movement/extinction, invasion of new species, changed habits/behaviour opportunistic infections

Transmission

Climate Sensitive Infections
in animals and humans

Zoonotic Infections
transmission between animals and human

Intermediate host/ Reservoirs Animals

Arthropod Vectors

Climate Sensitive Infections (CSI) – here defined as:

Infections that in some way react on climate induced dynamics in the environment, and thereby change their spread or persistence.

In addition, some opportunistic infections were suggested which may emerge and cause diseases in individuals that are physically stressed, e.g. heat-stressed, due to a changing climate and thereby become immune suppressed.

Diseases/Infections	Pathogens	Zoonotic
Alphaherpesvirus infection	Alphaherpesvirus (CvHVB)	No
Anaplasmosis	*Anaplasma phagocytophilum*	Yes
Anthrax	*Bacillus anthracis*	Yes
Babesiosis	*B. divergens*	Yes
Bluetongue disease	Bluetongue virus (BTV)	No
Borreliosis	*Borrelia burgdorferi* sensu lato	Yes
Botulism	Clostridium botulinum	Yes
Brucellosis	*Brucella abortus, B. melitensis*	Yes
Campylobacter infection	Campylobacter	Yes
Clostridiosis	Clostridium spp. unknown	Yes
Cryptosporidiosis	*Cryptosporidium parvum*	Yes
Echinococcosis	*Echinococcus multilocularis/granularis*	Yes
Elaphostrongylus rangiferi	Elaphostrongylus rangiferi	No
Erysopelotrix	Erysipelothrix rhusiopathiae	Yes
Fascioliosis	*Fasciola hepatica*	Yes
Gammaherpesvirus	Gammaherpesvirus (spp. unknown)	No
Giardiasis	Giardia spp.	Yes
Leptospirosis	*Leptospira interrogans*	Yes
Listeriosis	*Listeria monocytogenes*	Yes
Necrobacilloseis	Necrobacillose spp. unknown	Yes
Nephropathia epidemica	Puumalavirus	Yes
Parapoxvirus (Orf)	Parapoxvirus (Orf)	Yes
Pasteurellosis	Pasteurella spp.	No
Pestivirus	Pestivirus (spp. unknown)	No
Q-fever	*Coxiella burnetii*	Yes
Rabies	Rhabdovirus	Yes
Salmonellosis	*Salmonella spp.*	Yes
Schmallenberg virus (SBV)	Schmallenberg virus (SBV)	No
Setaria tundrae	Setaria tundrae (nematode)	No
Sindbis fever/Pogosta/Ockelbo	Sindbisvirus	Yes
Tick Borne Encephalitis (TBE)	Flavivirus	Yes
Toxoplasmosis	*Toxoplasma gondii/ spp*	Yes
Trichinellosis	*Trichuris trichiura*	Yes
Tularemia	*Francisella tularensis*	Yes
West Nile Fever	Flavivirus	Yes
Vtec/EHEC	Eshericia coli O A57	Yes

Possible Climate Sensitive Infections (CSI) in the Clinf-project area

Expert discussions on e.g.

- Clinical relevance
- Way of transmission
- Possible climate sensitive due to abiotic or ecosystem changes
- Opportunistic/stress induced CSI
- Drivers of epidemiology

CLINF SVA NordForsk

Terms used to form search strings to screen literature for CSIs

A to B	C to K	L to R	S to W
alphaherpes* [a] or "alpha herpes"	**campylobacter***	**leptospir*** or "weils disease"	**salmonell***
anaplasm* or ehrlichi* anthrax or anthracis	**clostridi*** **cryptosporidi***	**listeri*** **necrobacillos*** or "fusobacterium necrophorum"	**schmallenberg** or SBV **setaria** or "filaria* nematode"
babesios*	**echinococc*** or hydatid*	"**nephropathia epidemica**" or puumalavirus or "puumala virus" or hantavirus	"**sindbis fever**" or pogosta or ockelbo or sindbisvirus or "sindbis virus"
(**bluetongue** or BTV) or "blue tongue"	**elaphostrongylus** or "cerebral nematodiasis" or "brain worm"	**parapoxvirus** or orf or "contagious ecthyma"	"**tick borne encephalitis**" or TBE*
borreli* or "lyme disease"	**erysipelothrix** or erysipeloid	**pasteurell***	**toxoplasm***
botuli*	**fasciol*** or distomatosis or "liver rot"	**pestivirus**	**trichinellos*** or trichuris
brucellos* or brucella or "bangs disease"	**gammaherpes*** or "gamma herpes" **giardia*** or "beaver fever"	**q-fever** or "q fever" or coxiell* **rabies** or rhabdovirus	**tularemi*** or francisella or tularens* vtec or ehec or enterohemorr$ag* and (“e coli” or “Escherichia coli”) "**west nile fever**" or wnf or "west nile virus" or wnv

Search strings

Terms used for each CSI formed one search string, in total 37 CSIs.

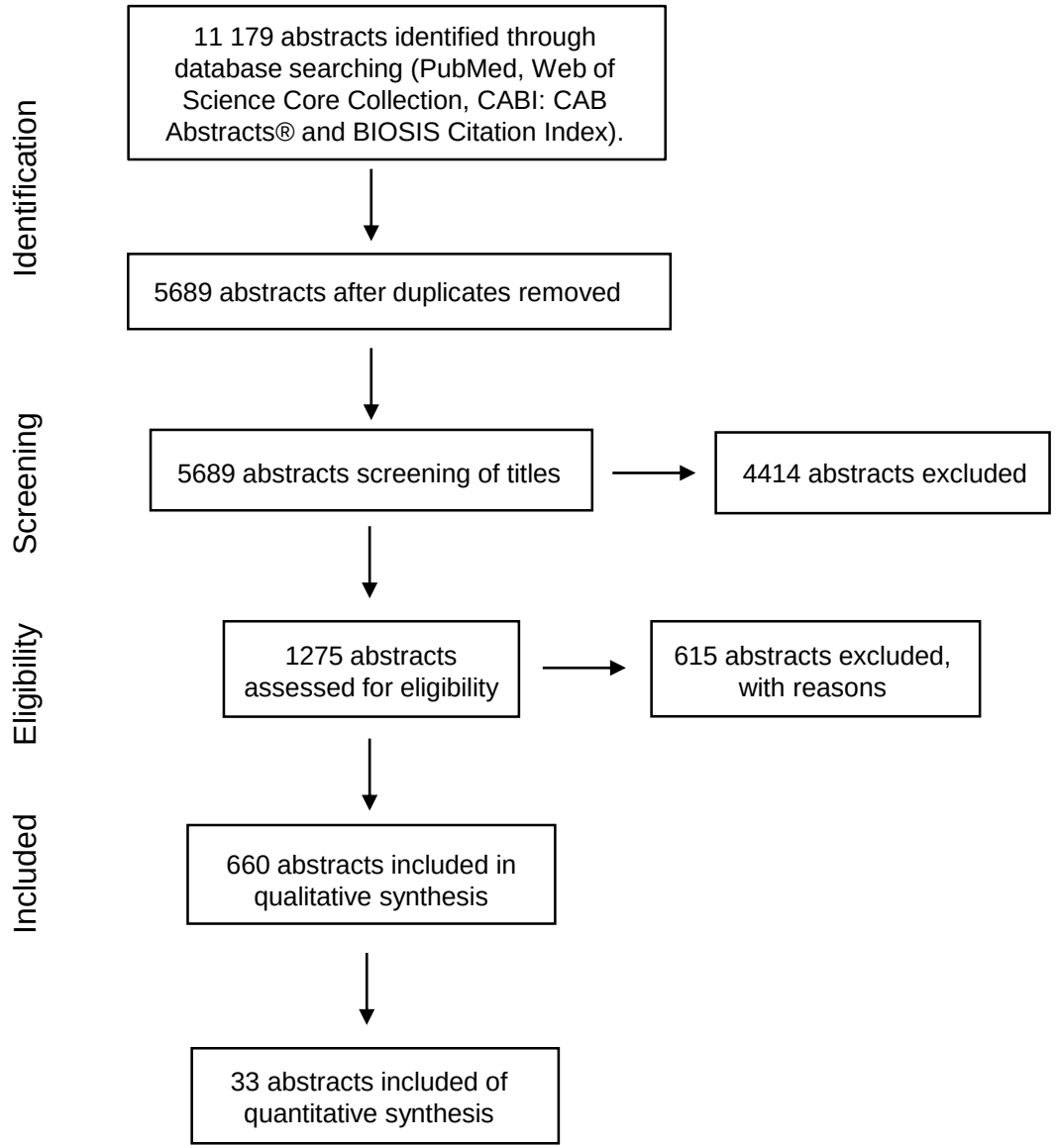
((chang* NEAR[b]/2 climat) or “global warming” or “extreme weather” or (chang* AND precipitation) or flood or drought or snow or ((increase* or rising or chang*) AND global AND temperature))

All CSI combined with "OR"

All CSI combined with "AND" ((chang* NEAR/2 climat) or “global warming” or “extreme weather” or (chang* AND precipitation) or flood or drought or snow or ((increase* or rising or chang*) AND global AND temperature))

Flowchart of the abstract review process

(slightly modified from Moher et al., 2009)



Transmission route - CSIs distributed into five categories

Arthropod vector borne
- Ticks
- Midges
- Mosquitos

Food-, feed- and water borne

Soil and natural water borne

Contact transmission/stress induced

CSIs in wildlife
- Rodents
- Mammals
- Other

Based on
- how they are transmitted to new individuals, within or between species.

- most has several transmission routes, here organised according to the most relevant route as we expect to be affected by climate change.

Potential CSIs literature search summary

- Is there an increased awareness of the influence of CC from 2008?“The gap” between all abstracts and those as mention CC aspects narrows then.
- Only few abstract said that the influence of CC on an specific disease was “proven”
- For the characterisation of CSIs most abstracts claimed that CSIs is mainly influenced by abiotic factors
- The vector-borne transmission way is most often mentioned especially tick-borne CSIs

Animal Data Collection

Healthy animals

- Zoonotic diseases
- Animal welfare aspects

Central for a sustainable production since they;

- Produce more egg, milk, meat…
- Live longer
- Reproduce better
- Produce less manure and GHG

ANIMAL HEALTH AND THE SUSTAINABLE DEVELOPMENT GOALS

Animal Data Collection

- Data has been received from **Swedish Board of Agricultural**, **Norwegian Veterinary Institute** and **EVIRA, the Finnish Food Safety Authority**.

- No data from Iceland, **Icelandic Food and Veterinary Authority (MAST)** – the diseases does not exist or are not registered.

- Only few data from Greenland, **Naalakkersuisut, Government of Greenland** – Rabies (mainly fox and dog) and Trichinellosis (mainly polar bear).

- Data from Russia, **Institute of Veterinary Virology and Microbiology in Russian Academy of Agricultural Sciences** – fragments, but hard to organize in Russia, more data and help with this during CLINF RII.

- At present, we are working on transferring data to the CLINF-data base, delayed due to several reasons.

Animal Data Collection

- We aimed to collect data for all diseases based on the list on our potential CSIs
- Only domestic incidences is reported

Diseases/Infections	Pathogens	NO	FIN	SWE
Alphaherpesvirus infection	Alphaherpesvirus (CvHVB)	No	No	Yes
Anaplasmos	*Anaplasma phagocytophilum*	No	No	Yes
Anthrax	*Bacillus anthracis*	Yes	Yes	Yes
Babesios	*B. divergens*	No	Yes	Yes
Bluetongue disease	Bluetongue virus (BTV)	Yes	No	Yes
Borrelios	*Borrelia burgdorferi* sensu lato	No	No	Yes
Botulism	Clostridium botulinum	No	Yes	Yes
Brucellos	*Brucella abortus, B. melitensis*	No	No	Yes
Campylobacter infection	Campylobacter	No	No	Yes
Clostridios	Clostridium spp. unknown	No	Yes	Yes
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Gammaherpesvirus	Gammaherpesvirus (spp. unknown)	No	No	Yes
Giardiasis	Giardia spp.	No	No	Yes
Leptospiros	*Leptospira interrogans*	Yes	Yes	Yes
Listerios	*Listeria monocytogenes*	No	Yes	Yes
Necrobacillose	Necrobacillose spp. unknown	No	No	Yes
Nephropathia epidemica	Puumalavirus	No	No	Yes
Parapoxvirus (Orf)	Parapoxvirus (Orf)	No	Yes	Yes
Pasteurella	Pasteurella spp.	No	No	Yes
Pestivirus	Pestivirus (spp. unknown)	No	No	Yes
Q-fever	*Coxiella burnetii*	No	Yes	Yes
Rabies	Rhabdovirus	No	Yes	Yes
Salmonellos	*Salmonella spp.*	No	No	Yes
Schmallenberg virus (SBV)	Schmallenberg virus (SBV)	No	No	Yes
Setaria tundrae	Setaria tundrae (nematode)	No	No	Yes
Sindbis fever/Pogosta/Ockelbo	Sindbisvirus	No	No	Yes
Tick Borne Encephalitis (TBE)	Flavivirus	No	No	Yes
Toxoplasmosis	*Toxoplasma gondii/ spp*	No	No	Yes
Trichinellosis	*Trichuris trichiura*	Yes	Yes	Yes
Tularemia	*Francisella tularensis*	Yes	Yes	Yes
West Nile Fever	Flavivirus	No	No	Yes
Vtec/EHEC	Eshericia coli O A57	No	No	Yes

Animal Data Collection summary

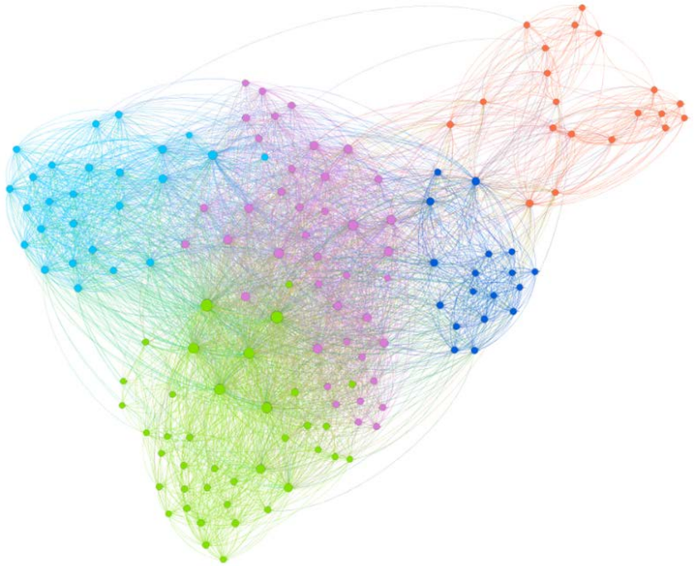
Across countries and over the time we have noticed varied

- availability and quality of data.
- reporting routines for a specific disease, especially for wildlife.
- registration routines and data bases changes
- for certain diseases if they are notifiable and if control and eradication programs exist

- We have had some difficulties to receive animal data and it has been very time consuming.
- An international standardisation in reporting of animal infectious diseases is needed to better monitor and understand the epidemiological changes influenced by climate change.
- An extended collaboration and harmonisation including the rest of the Arctic nations would also be desirable.

Assessing the infrastructure of CLINF stakeholder organisations from Nuuk to Yakutsk

Sepp Böhme



Purpose

- Identification/depiction → network of CSI stakeholder organisations - Nuuk to Yakutsk
- Identification: administrative inter-organisational network linkages

Stakeholders and extent of the CLINF-“study area”

- Wide range different organisations: CSI vulnerability
- Thematic categories:
    1. Indigenous reindeer herders
    2. Municipal
    3. Advocacy groups
    4. Cultural advocacy groups
    5. Economic advocacy groups
    6. Environmental advocacy groups
    7. Health advocacy group
    8. Governmental
    9. Scientific institutions

Results

- CLINF stakeholder network analysis with Gephi

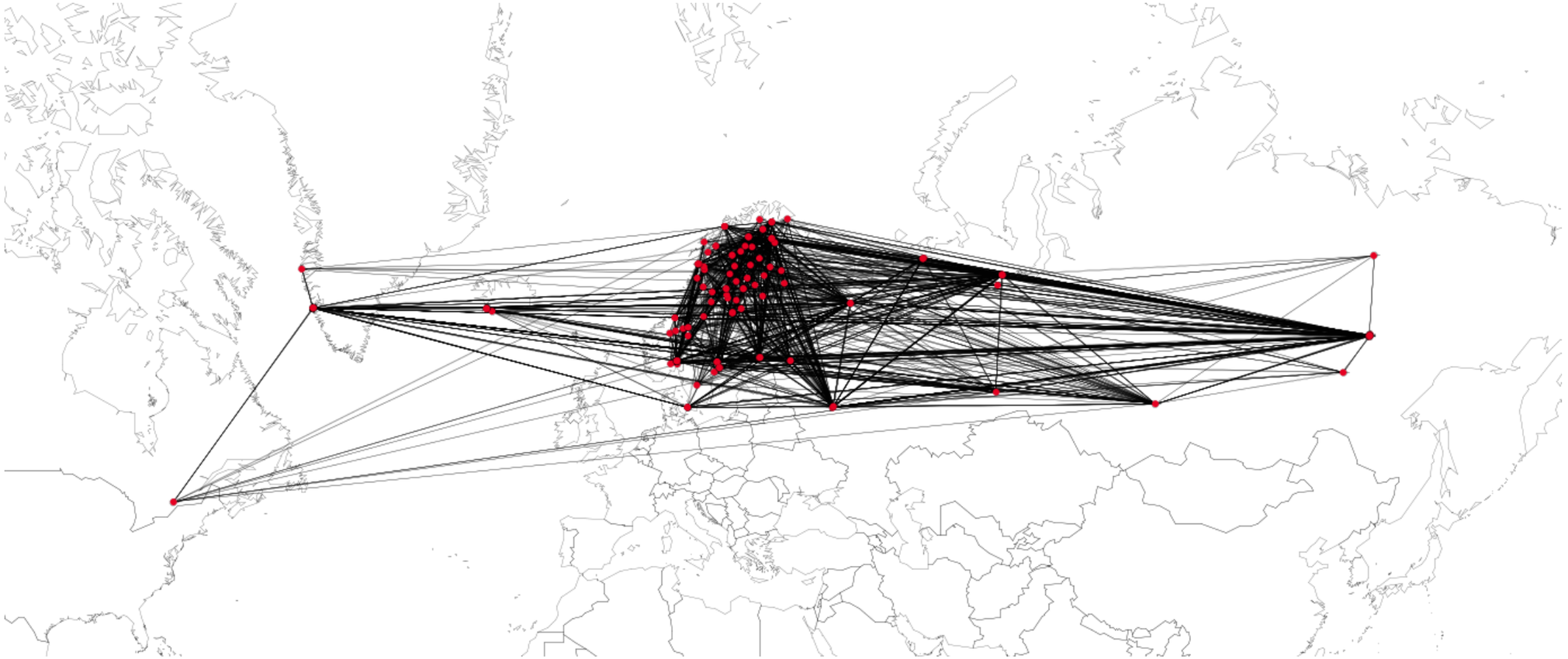


Figure 1. Northern distribution of CLINF stakeholders. Geographic coordinates

CLINF stakeholder network analysis

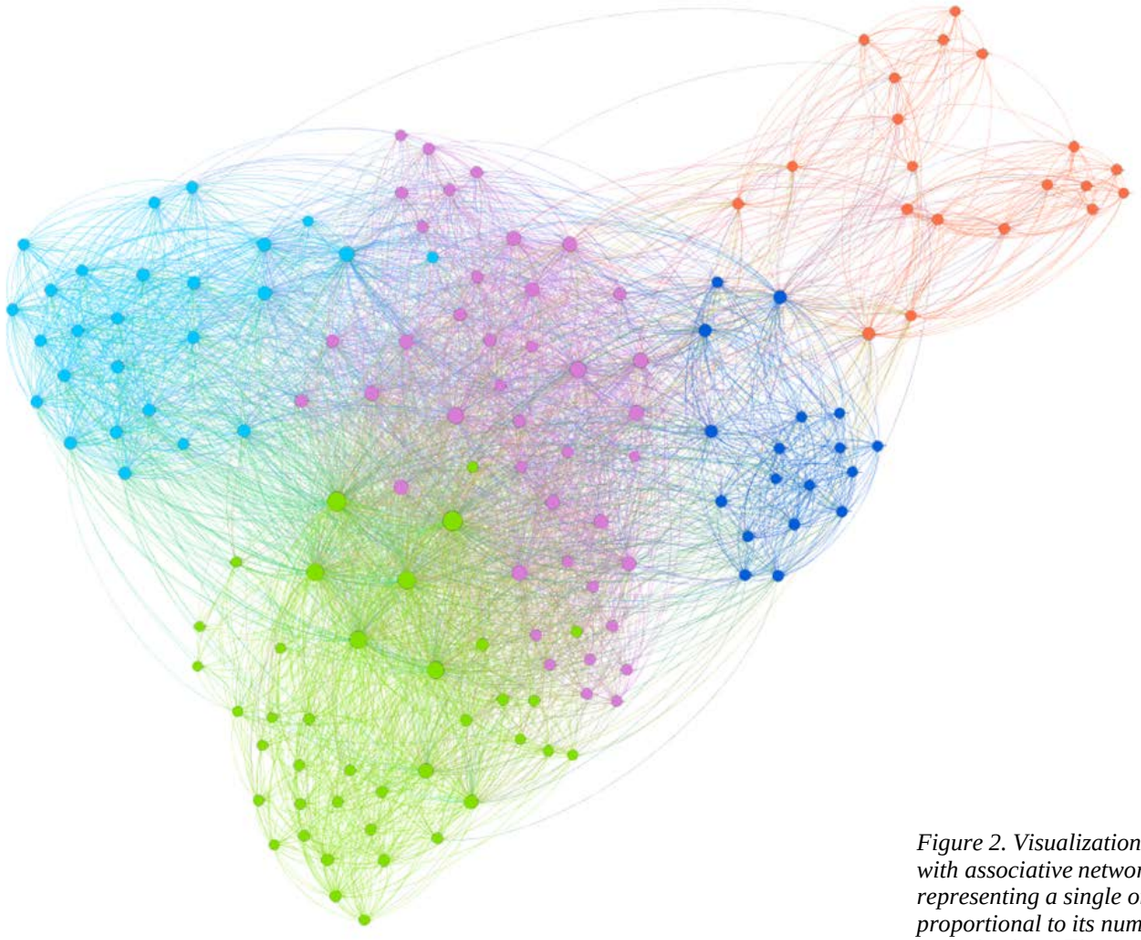


Figure 2. Visualization of CLINF stakeholder organisations with associative network and clustering. Each node is representing a single organisation, and the size of nodes is proportional to its number of associations to other organisations. Five main clusters, associative coordinates

CLINF stakeholder analysis with PCA

Table 1. Selection of typical Stakeholder organisations assigned to the five clusters by a factor-analysis with STATISTICA

Cluster	Typical organisations
1	Scientific Research Center of the Arctic (Salekhard); State Scientific Center of "Arctic and Antarctic Research Institute" (St. Petersburg); Research Institute of Medical Problems of the North; Ministry of Healthcare of the Russian Federation
2	County Governor of Nordland; Norwegian Food Safety Authority; Norwegian Agricultural Authority; Norwegian reindeer pasture districts
3	Sami Education Institute Inari, Finland; Finnish Reindeer Herders' Association; Sámi Cultural Center Sajos, Food Safety Authority, Finland (EVIRA); International Centre for Reindeer Husbandry (ICR)/ Association of World Reindeer Herders
4	Swedish Lapland; Heart of Lapland; Pajala tourism and events (Pajala Turism och Evenemang); HaparandaTornio tourist office
5	Greenland Center for Health Research (GCHR); Board of Agency for Health and Prevention (Greenland); Queen Ingrid's Hospital, Nuuk; Danish Medical Association

Structure of CLINF stakeholder organisations

- Well connected:
  - Governmental health authorities/research institutions with a focus on medical sciences, disease prevention, veterinary medicine, Arctic Sciences
  - Local/international reindeer herding/meat production, Sami - other indigenous people/scientific institutions → indigenous people and reindeer herding

- Country dependent:
  - Organisations → land use-, agriculture-/meat production
  - Superordinate health-surveillance authorities and Sami associations

- Pan northern CSI organisation →missing link – Arctic

  → Representation aggregated interests/connection – Policy makers