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1 ***Deliverable Type:***
R: Document, report (excluding the periodic and final reports)
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Executive Summary

The ArcticHubs project has applied the Driver–Pressure–State–Impact-Response (DPSIR) framework to 17 unique locations in the Arctic that are characterised by rising industries such as forestry, aquaculture, mining, tourism, and indigenous activities. In these Arctic “hubs” we have assessed the changes in the Arctic environment and its ecosystem services that are caused by signature economic activities and means of livelihood.

Since the mid-nineties, the Driver–Pressure–State–Impact-Response (DPSIR) framework is widely adopted for integrated environmental reporting and assessment. We have applied the DPSIR to the context of Arctic hubs which are defined as geographic nodes that host either one or a combination of industrial activities or means of livelihood, where challenges and impacts (environmental, social) facing the Arctic are tangible and acute. In close collaboration with experienced DPSIR practitioners as well as numerous local hub experts and their networks from all 17 locations, the ArcticHubs project identified main driving forces causing pressures that affect the state of the local and regional environment and communities, in turn having impacts on habitat, species, economic and cultural losses. The identification of these indicators was followed up by developing “glocal” responses, i.e., methods and procedures involving local communities and global actors to circumvent or cushion impacts on local environment and society.

The data collection and DPSIR model application happened in an interactive and collaborative way including intensive workshops, webinars, group meetings, data-collection guides, and different dissemination events. As an overall conclusion, the DPSIR analysis has been able to bring all hub actors together to provide added value element to the entire ArcticHubs research process. Moreover, the individual hubs have received an additional analysis framework for their own future work. Also, the DPSIR has shown to be a flexible illustrative tool that allows for very complex, but also compact options for model visualization and mapping.

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1. Introduction

The overall objective of WP2 - Assessment of environmental impact of the ArcticHubs project is to assess the changes in the Arctic environment and its ecosystem services that are caused by the different economic activities, and to distinguish these from changes due to climate change.

The analysis of the Driver-Pressure-State-Impact-Response (DPSIR) framework factors and establishing the DPSIR framework for the different activities in hubs is one of the major tasks of the WP2 implementation.

According to the ArcticHubs Description of Actions, the identification of DPSIR factors is based on the results of the previous WP2 work and deliverables, namely Plan for data acquisition and analysis of selected hubs (deliverable D 2.1), Compilation of existing data on environmental impact of economic activities in the Arctic (deliverable D2.2), and Assessment of environmental impacts (deliverable D 2.3).

This report presents the ArcticHubs analysis of the factors in the DPSIR framework for the different activities in relation to environmental impact. A major part of the analysis was implemented in 2023, with an update and finalisation in 2024. For each of the selected hubs, DPSIR framework has been developed describing the different drivers and pressures that cause changes in the state of the environment, and the impacts on the ecosystem services. Special attention has been given to the fact that drivers and pressures can operate at multiple scales. The results will feed into WP5 of the ArcticHubs: Creating sustainable future pathways.

The DPSIR analysis has been coordinated by ArcticHubs partner NORCE in Norway. The ArcticHubs Steering Committee, as well as the monthly meetings of the entire ArcticHubs research team, have acted as important information channels, as well as contact forum between NORCE and the representatives of the hubs. Frequent bilateral contacts between NORCE and hubs have been an important element of the process, too.

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2. Theoretical background

The Driver–Pressure–State–Impact-Response (DPSIR) framework for integrated environmental reporting and assessment has been widely adopted in the study of environmental problems (Charr, 2007). In the mid-nineties, the European Environment Agency (EEA) developed the DPSIR framework as a conceptual approach to structure high numbers of complex information and indicators from a variety of disciplines in a simple and effective communication model (Tscherning et al., 2011; Gari et al. 2014; Lewison et al., 2015; Rounsevell et al., 2010; Wolfslehner et al., 2008). In this way, the DPSIR framework was intended to organize and present analysis results with a holistic system perspective where communication between scientific disciplines, experts, but also policymakers, and the public could be linked and facilitated. This has made DPSIR a tool that supports decision makers in designing and implementing science-based policies, and to identify essential strategies to achieve sustainable development within socio-ecological systems (Tscherning et al (2011); Gari et al. (2014); Lewison et al. (2015); EEA report, (1999)). Accordingly, the DPSIR model has often been interpreted as a Problem Structuring Method that offers different actors an opportunity to facilitate the creation of shared knowledge (Gomez Junior et al, 2021). In the context of this report, the DPSIR framework serves first and foremost as a conceptual framework that is used to tackle environmental problems and impacts.

The DPSIR model describes a causal framework that shows cause and effect relationships between five categories that represent the effect or impact of anthropogenic activities on ecosystems as well as social systems (Gari et al, 2015). Over the last 20 years the DPSIR framework has been revised, modified, and integrated in a variety of ways to deal with its analytical and conceptual limits. Within the ArcticHubs project, the five DPSIR categories are understood and inspired[3] by the category descriptions as they are defined by e.g., the EEA (1999), Kristensen (2004) and Carr et al (2007). Accordingly, the five categories are defined below:

(1) Drivers represent fundamental social processes which are associated with demographic and economic developments in societies as well as corresponding changes in lifestyles, levels of consumption and production patterns. These processes shape human activities and have a direct impact on the environment.

[3] See more information about the process of defining and using DPSIR in the ArcticHubs project in the following chapter: Methodological background.

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(2) **Pressures** describe developments associated with human activities such as e.g., the use of land, resource extraction, food production, transportation, and the corresponding emissions in form of substance release and biological or chemical agents. More concretely, Kristensen (2004) distinguishes between three main themes: (1) The excessive use of environmental resources, (2) changes in land use, and (3) emissions (of chemicals, waste, radiation, noise) to air, water, and soil. These pressures exerted by society are transported and transformed in a variety of natural processes that determine changes in environmental State (S). Eventually, a significant part within scientific literature also considers natural hazards and similar phenomena as a directing pressure. This might include e.g., extreme weather conditions, solar radiation, volcanos etcetera (see for instance Kristensen (2004) and Charr et al (2007)).

(3) **State** clusters information about the state of the environment that is affected by respective pressures. This includes the quality of various environmental compartments (air, water, soil etcetera) in relation to the functions that these compartments fulfil. The state can thus be considered as the combination of the biological, physical, and chemical conditions. Linked to a "changing" state, these conditions are under current conceptualizations not static, but are meant to reflect current environmental trends. Examples are e.g., air quality, water quality (rivers, lakes, groundwater etcetera), soil quality, ecosystems (biodiversity, vegetation, soil- and water organisms' etcetera) and similar.

(4) **Impacts** summarize the ways in which the changing environmental state influences human well-being and welfare. In other words, changes in the state may have environmental or economic "impacts" on the functioning of ecosystems, their life-supporting abilities, and ultimately on human health and on the economic and social performance of society. Here, we can also think of the impacts on, more broadly, the term ecosystem services.

(5) **Reponses** are eventually triggered by the impacts on the environment and society. They bundle information that describe actions taken by groups, individuals, governments, or other institutional efforts to prevent, compensate, ameliorate, or adapt to changes in the environment. These actions can be directly related to the previous elements and can provide a reaction towards any part of the chain between driving forces and impacts.

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The DPSIR model was carefully built upon several previous frameworks for environmental reporting. While it is applied in the context of integrated environmental assessments in diverse social-ecological contexts (Carr et al, 2007), it has also been criticised by several authors considering some aspects. These critiques are relevant also from the perspective of the ArcticHubs project considering its multidisciplinary and holistic approach. When it comes to the application of the DPSIR model as an analysis tool, the following shortcomings are commonly discussed.

First, one of the main critiques is the simplification of causal relationships and the impossibility to consider feedbacks and complex interactions (Tscherning et al., 2011; Gari et al., 2014; Lewison et al., 2015; Wolfslehner et al., 2008). Here, Paillet et al. (2021) also highlight the strong anthropocentric perspective that structures the DPSIR framework which ignores aspects such as ecological resilience as part of the Responses, focusing mostly on a political dimension. Therefore, by ignoring ecosystem feedbacks and complex dynamics, the framework promotes rather an instrumental view of nature.

Second, there are no specifically defined rules in attributing information or indicators to categories. The same counts also for the five categories themselves. This specific point is hard to adjust to, since there cannot be, as a matter of fact, univocal rules and definitions, and much information input could be included in one or another category (Vacik et al., 2007; Paillet et al., 2021). Accordingly, the definition of which variables should be included in each category is contextual and depends on the specific identification of system boundaries (see next paragraph), policy objectives, actors' interests etcetera (Vacik et al., 2007; Paillet et al., 2021).

Third, the DPSIR framework does not include a definition of scale and system boundaries. According to Svarstad et al (2008), the DPSIR framework represents a systems perspective, implying a demarcation of a particular system of interest, with explicit or implicit boundaries. The system is demarcated in two ways: On the one hand, it is bounded in terms of the scale in which the Impacts are defined (e.g., local to global) and on the other hand, it is bounded in terms of the Responses and Driving forces affecting the system (e.g., local economic changes to global environmental agreements). These boundaries will not necessarily coincide and Impacts at one scale will often be determined by Responses and Driving forces that act at a different scale. Eventually, the drawing of these boundaries depends on the issue of interest

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and its conceptualization, which are strongly influenced by the perspective of those using the framework. (Svarstad et al., 2007)

The next chapter introduces the methodological framework of this report and explains how the DPSIR framework has been integrated into the ArcticHubs project and specifically how it was used for the analysis of environmental impacts caused by hub-specific industrial activities. In addition, the methodological framework addresses how the commonly discussed shortcomings, as described above, were addressed when integrating the DPSIR model into the project.

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3. Methodological framework

Within the working package (WP) 2 of ArcticHubs, the DPSIR framework was chosen as a central framework for assessing environmental impacts caused by industrial activities in all project hubs.

The application of the DPSIR model to structure and assess environmental impacts from hub-specific industry activities (WP2 in ArcticHubs) is the main topic of this report. Figure 1 presents the methodological steps taken from defining a common understanding of the DPSIR indicators (drivers, pressures, states, impacts and responses) through data collection to the final application and completion of the DPSIR framework. First (1), an expert group for DPSIR methodology was established to discuss how the DPSIR model should be used for the tasks of WP2 and how gathered impact data should correspond with the five categories of DPSIR. The "DPSIR technical expert forum" involved next to the WP2 team members researchers with special working experience in applying the DPSIR model in publications, field works and case studies. During the impact data collection and application of the DPSIR model in the ArcticHubs work, the expert group was consulted in cases of potential obstacles or methodological questions. In this way, a common understanding about indicator definitions and boundaries was established and data management within the DPSIR model could be structured, negotiated, and safeguarded.

The second step (2) was the collection of environmental impact data. Here a lot of data was gathered from the WP2 delivery D2.3 about the "Changes in the Arctic Environment as a result of hub activities "(2022). This report developed a catalogue of detailed environmental impacts and resulting environmental changes for each Arctic hub with a special focus on forestry, aquaculture, tourism, mining, and indigenous industries. The report data was collected in collaboration with all hubs by using data collection guides, arranging selected interviews as well as extensive feedback rounds[4]. At the same time, data for the DPSIR was included from WP1 delivery D2.1 about "global economic drivers in the development of different industries". Here, essential global drivers[5] were detected which were taken as first basis for the first DPSIR indicator "global drivers". Meanwhile, interviews and bilateral contact to different hubs contributed to impact data collection.

[4] Delivery D2.3 was specifically designed to provide the DPSIR with environmental impact data. Accordingly, the DPSIR indicators were included in the data-collection guides, interviews, and feedback rounds.
[5] Global drivers were determined according to (1) policy papers, (2) industry-specific strategies, (3) interviews with political representatives, authorities, and industry specialists, and (4) statistical analyses of foreign investment.

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Third (3), all gathered environmental impact data was structured with the DPSIR framework. As a first draft, the DPSIR framework was developed and visualized by applying the *Banxia Decision Explorer* software[6]. The decision to use the software in ArcticHubs was experimental. While in research most DPSIR models have been applied for specific locations or ecosystems, some hubs in the ArcticHubs address up to three industries at the same time. This makes the DPSIR models multidimensional and more complex. In correspondence with the "technical DPSIR forum", the Decision Explorer® was integrated into the work as it was perceived as the most flexible and integrative software for structuring much and complex data. This allowed for a holistic perspective when exploring causal relationships between impact data.

The fourth step (4) included the arrangement of extensive feedback rounds: All the constructed DPSIR frameworks were sent to their individual hubs for feedback and validation. A written guide for providing feedback was attached for every hub and suggestions for data revision or adjustment were expressed by mail or in Teams meetings. At this point, the majority of DPSIR models was highly detailed and branched.

The fifth step (5) included intensive DPSIR workshop sessions. In total, 17 workshops were organized and every DPSIR model was collaboratively simplified by agreeing on most important indicators, takeaways, and key responses. Here, shapes and arrows were untangled and made more comprehensible. For the simplified DPSIR version, the Banxia software was not further included. Except three, all workshops took several hours and included every hub coordinator, very many hub experts, but also external participants with relevant industry experience and local knowledge such as the local mining and aquaculture sector.
While most workshops were held online via Teams, several workshops were also held physically. Physical workshops were organized in Torino, Italy with the learning hubs Germanasca Valley and Alagna Valsesia; in Umeå, Sweden with the multi-industrial hubs Gaellivare, Malå, Jokkmokk and Gran Sameby; in Alta with the mining hubs Kautokeino-Kvalsund, Varangerfjord and Egersund; as well as in Tromsø with the aquaculture hub Varangerfjord. During the physical workshops also external contacts participated, most of them being researchers.

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[6] Developed by academics from Bath and Strathclyde, Decision Explorer® is a tool for managing "soft" issues, the qualitative information that surrounds complex or uncertain situations. It captures in detail thoughts and ideas, to explore them, and gain new understanding and insight. (Banxia, 2023).

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In all workshop meetings a particular session was held to address the addition of specific local drivers. After some hubs raised concerns that not all global drivers in the DPSIRs reflect local perspectives, the WP2 team decided to collaboratively add new local drivers for every hub. This improved the focus on exclusively local community perspectives in the hubs.
In early 2024, also a special webinar was organized with hub representatives from the Faroe Islands, Nuuk in Greenland, and alpine learning cases in Italy to share insights, discussions, and experiences of applying the DPSIR to their unique locations. The webinar had around 50 participants. Besides, the observations of applying the DPSIR to all hubs were presented at the Arctic Frontiers conference in January 2024 in Tromsø in a session entitled “Empowering Arctic Citizens for involvement and decision-making”. Here, panel debates and discussions contributed to the data input into the final DPSIR outcomes.

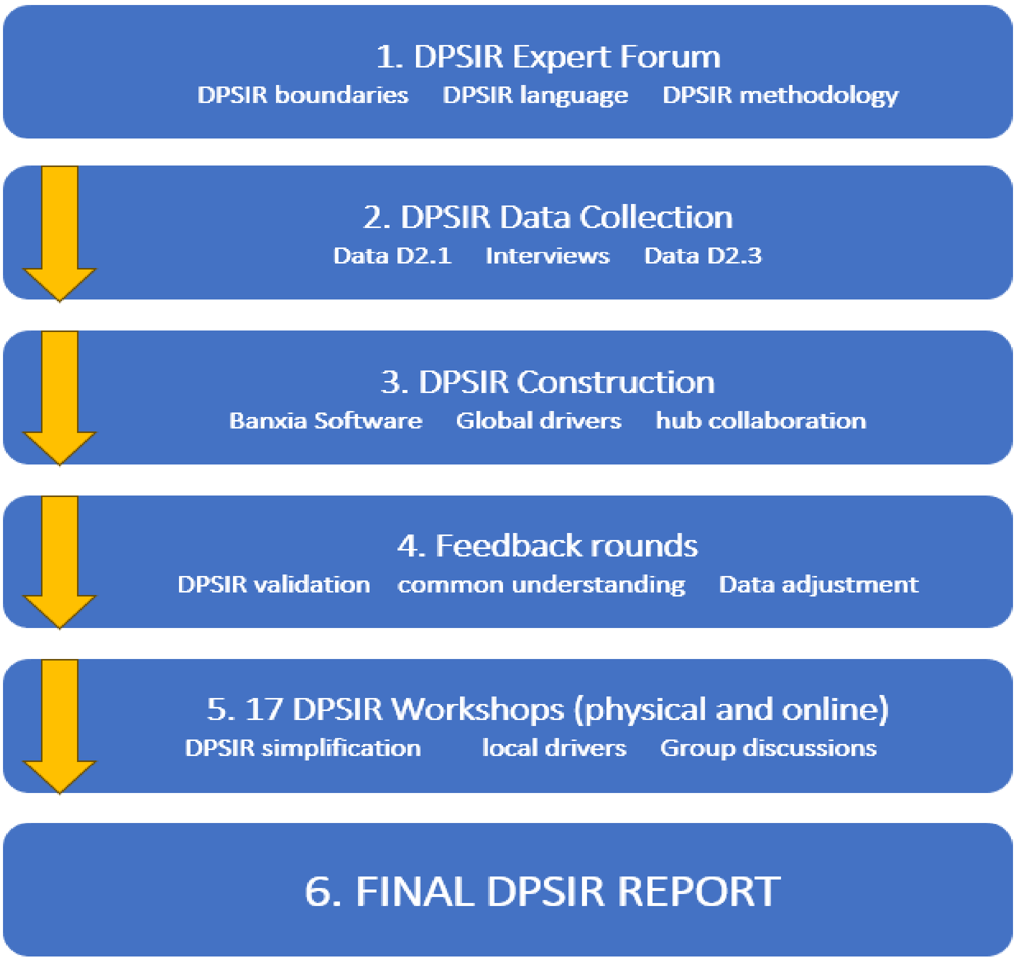

Figure 1. Methodological steps for delivery D2.5: The DPSIR framework

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3.1. Identification of DPSIR components

In practise, the DPSIR framework is an assessment tool that structures the complex interplay between environmental dynamics and human activities. It categorically maps out the sequence from drivers to impacts, capturing the progression from initial environmental or human-induced changes to their ultimate consequences. This structured approach enables a clear visualization of the pathways through which different drivers exert pressures on the environment, how these pressures alter the state of the system, and the subsequent impacts that emerge from these changes. When engaging in the DPSIR, such an organized representation aids in discerning the multifaceted nature of environmental challenges, but it also underpins the need for a nuanced understanding when formulating important response strategies. Over the last years, the DPSIR framework has been revised, modified, and integrated in a variety of ways to explore its analytical and conceptual limits. By applying the DPSIR model to the 18 case hubs in the Arctic, the ArcticHubs project has extended its limits to a new dimension. Here, the DPSIR framework also proved itself helpful not only as a structuring tool for environmental impact data, but also as a communication tool. The collaborative use of indicators uncovered deep discussions and new insights into the hubs and made it possible to also collect and draft data on an interpersonal basis.

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4. Results

This chapter presents the DPSIR frameworks related to Arctic hubs analysed in WP2, in terms of an environmental assessment in response to industrial activities and associated environmental impacts for each individual Arctic hub. The DPSIR models are presented according to the countries in which the hubs are located. Within the frameworks, the indicators of each DPSIR category are displayed in text squares. Moreover, arrows show the causal relationships between indicators.

With every simplified DPSIR presented here, there is also a more detailed DPSIR prepared by the WP2 team showing the DPSIR frameworks prepared using the Banxia DecisionExplorer software. These more detailed DPSIR frameworks can be found in the Appendix.

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4.1. Kemi

The figure below shows the DPSIR framework for the **forestry hub Kemi**, Finland.

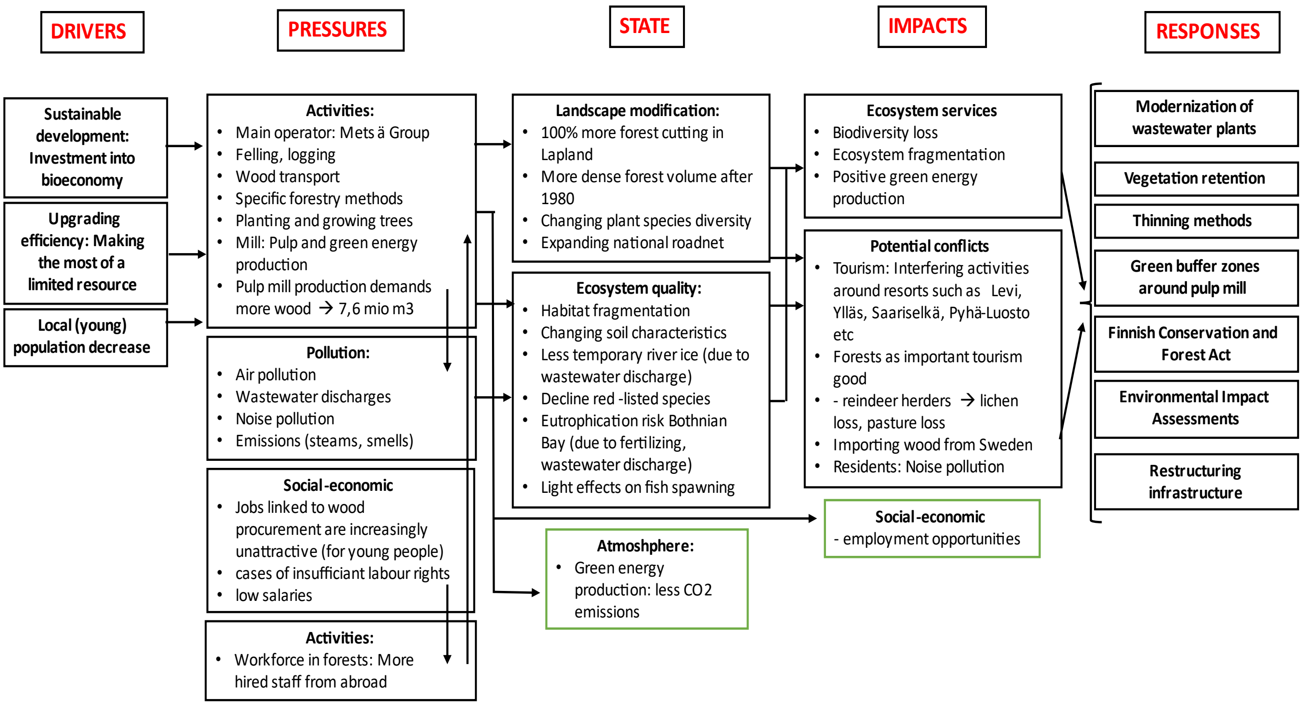

Figure 2. DPSIR framework for Kemi: Forestry

The call for sustainable development has become an important global driver for the Finnish forestry sector: After closing the Veitsiluoto pulp and paper mill in 2021, the Metsä Group's investment into a new bioproduct mill in Kemi can be seen as a milestone investment (1,6 billion EUR) that corresponds with increasing efforts to develop the green transition in Finland. New technologies provide the new mill with a stronger circular economy design, which enables, next to pulp production, also bioenergy, biomaterial, biochemical or renewable energy production. But the need for resources is increasing with 7.6 mil m3 wood demand and environmental pressures can be associated with increasing forestry activities in terms of felling and logging, but also with the bioproduct mill itself. At the same time, Kemi is characterised by a population decrease, also in terms of younger generations. Since recent years, wood procurement jobs have lost attractiveness for young people, salaries are low, and

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there are reported cases about insufficient labour right conditions. As a result, a lot of workforces are increasingly hired from abroad to keep production processes ongoing.

Associated pressures of the bioproduct mill on a local to regional scale include slight air pollution (but less compared to old mill), transport, noise pollution, the creation of waste material as well as wastewater discharges such as effluent wastewater and cooling water. The Metsä factory is constructed on already existing industrial estate, however, wastewater discharges containing e.g., organic halogens, phosphor or nitrogen find their way into nearby rivers. This is associated with decreasing ice conditions of -1 month or more, algae expansion at wastewater discharge points, consequent eutrophication risks nearby the Bothnian Bay National Park[7] as well as slightly negative effects on fish spawning. Regarding the latter, the EIA summarized effects on most-farmed fishes as minor[8].
Impacts of Eutrophication risks in rivers and decreasing ice duration were associated with potential tourism conflicts, especially in terms of (ice-) fishing activities. Moreover, noise production during construction is associated with stress for nearby residents.
Positive impacts of the project are its contribution to regional development and employment, renewable energy production, and circular approach,

Associated pressures of increasing wood procurement include expanding traffic and wood transportation, different applied forestry methods, but also fertilization processes, tree planting and growing.
Increasing wood transportation is associated with expanding road networks causing continuous habitat fragmentation. Due to noise pollution and environmental fragmentation, animal species might flee from preferred areas and local vegetation characteristics will change. Moreover, different forestry activities affect ecosystems. E.g., clear-cutting increases sunlight radiation which is favoured by special indicator vegetation such as lichens[9] or healthy mosses[10][11]. Many forestry methods are associated with risks for noteworthy flora including red-listed species as well.

[7] Also, tree fertilization contributes to the discharge of phosphor and nitrogen into river systems.
[8] While e.g., gonodal changes were observed in burbot roach and perch, bioaccumulations of chemical elements could not be identified.
[9] important for e.g., reindeer survival
[10] Healthy mosses e.g., counteract erosion and remove toxins in soils.
[11] Besides, while controlled burning and spruce-forest logging decrease mosses and lichens and contribute to animal hindrances, soil preparation methods are associated with surface erosion and changes in soil temperature, radiation, moisture as well as nutrient conditions. Also, the logging of wood residuals after cutting declines soil nutrients and ultimately new biomass production

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Over time, forestry also increased the forest volume in Finland for wood extraction since 1980. The intensification of forestry will increase continuously and forest cuttings in Lapland and Kainuu and Ostrobothnia are expected to double until 2050.
The expected environmental changes cause environmental impacts which influence human well-being economically and socially. The decrease of lichen abundance threatens the natural environment of reindeer and has historically led to conflicts with indigenous industries. Besides, the potential loss of biodiversity in terms of e.g., ecological indicators remove an important ecosystem service as it supports the ecological functioning of forests. Losses in this regard can be linked to economic risks.

Finally, several responses were identified as a reaction to pressures, states, and impacts:

- The modernization of wastewater plants is associated with reducing chemical components that might harm the environment in their overproduction and discharge of e.g., phosphor or nitrogen.
- Retention areas improve the natural development of forests. After the application of different forestry methods, retention areas give the ecosystems space to recover vegetation structure, and thus more sustainability.
- Thinning methods are linked to more radiation which is favoured by several vegetation tyoes and can increase biodiversity.
- The establishment of green zones around the industrial estate of factories increases the balance between industry and nature.
- Since several decades the Finnish Forest Act and Conservation Act are guidelines for sustainable development also in the forestry sector and promote e.g., natural forest regeneration and the diversity of nature in Finland.
- It is compulsory to carry out Environmental Impact Assessments (EIAs) throughout construction processes and industry development. In this way potential harm to the environment is assessed and monitored. Here, the focus on e.g., tolerance values is prominent.
- A restructuring and upgrading of infrastructure are a response to noise pollution causing stress for residents and habitat fragmentation. This includes e.g. the establishment of noise banks or the electrification of vehicles.

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4.2. Kemijärvi

The figure below shows the DPSIR framework for the **forestry hub Kemijärvi**, Finland.

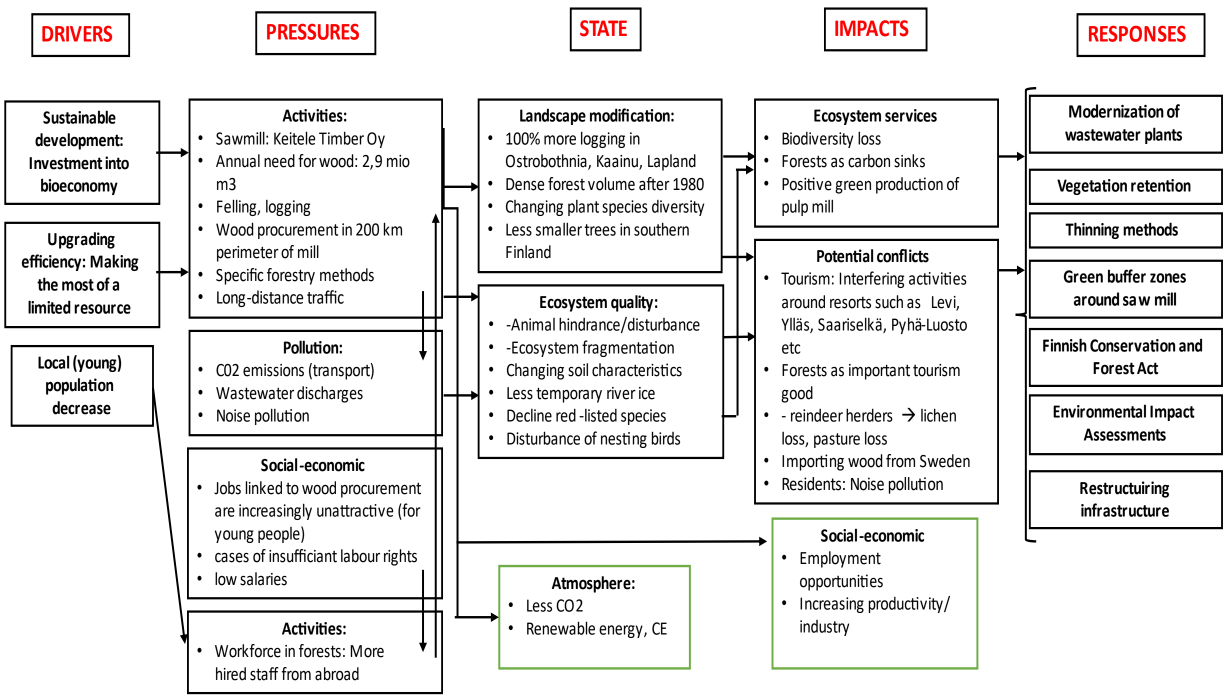

Figure 3. DPSIR framework for Kemijärvi: Forestry

In Kemijärvi (located circa 250 km northeast of Kemi), increasing investments into the bioeconomy shape the industrial development in the hub. The wood pulp industry has been one of the most essential economic activities in Kemijärvi since the 1960s. After the closure of the Stora Enso wood pulp mill in 2008, the saw mill by Keitele Timber Oy is to date the main activity in Kemijaervi. The estimated annual need for wood corresponds with a resource need of 2.9 mil m3.

The dynamics of the DPSIR framework of the Kemijärvi hub are comparable with those of the Kemi hub. Also here, it can be distinguished between local to regional environmental pressures associated with the sawmill itself, and the necessary wood procurement for bioproduction on national scale. In this context, when it comes to identified pressures, states, impacts and responses associated with the bioeconomy in Kemijärvi we refer to **chapter 4.1** (DPSIR framework of Kemi).

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4.3. Inari

The figure below shows the DPSIR framework for the **tourism hub Inari**, Finland.

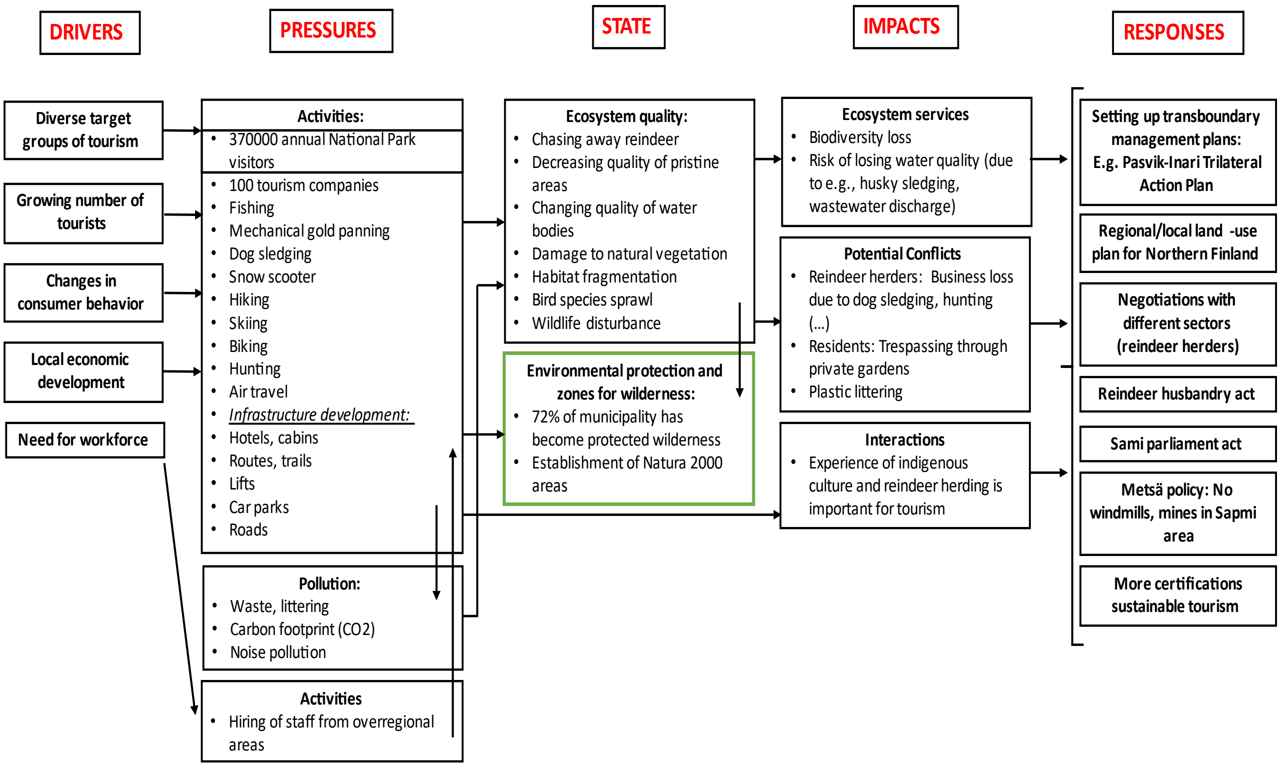

Figure 4. DPSIR framework for Inari: Tourism

Diverse tourist target groups and new investments into the industry, have made Inari grow as a tourism destination. Also, locally, the city is an essential driver for economy and development. Currently, over a hundred tourism companies (some of them biggest national operators) are registered in Inari and around 370000 people visit the nearby 2nd largest National Park of Finland annually. This came with increasing infrastructure development, expanding road nets, new hotels, car parks, lifts, cabins, and lodges, also across the shorelines of lake Inari. Most important tourism activities include hiking, dog sledging, skiing, snow scooter driving, fishing, but also shipping and boat rentals at lake Inari. During recent years, air travel from abroad increased fast as well. The activities underline common environmental pressures that come with different kinds of pollution such as waste littering and water discharges, CO2 emissions, as well as noise pollution from e.g., shipping, scootering, traffic,

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or constructing. Another local driver affecting the tourism sector in Inari is the decrease of workforce. Consequently, a lot of staff is hired from over-regional places to ensure continuous tourism activities.

Tourism activities and consequent pollution are continuously impacting the regional environmental state: Over time the industry has exerted more pressure on nearby pristine areas, including protected areas and National Parks. High numbers of hikers have over time damaged natural vegetation by trampling, and waste streams as well as wastewater discharges (also at lake Inari), have caused loss of water quality. The latter has worsened, and waste treatment plants have exceeded prescribed capacities. Moreover, the establishment of big ski resorts have contributed to habitat fragmentations of several animals including urban sprawls of several native bird species. Similarly, habitat fragmentation of reindeer caused by dog sledging, skiing, and increasing infrastructure have negatively impacted the animals, moving them away from natural feeding grounds.

Pressures and changing environmental states are associated with impacts on human activities and well-being. While locals have reported more cases of trespassing, the local community is concerned about increasing waste disposals and the impact of waste and wastewater discharges on the water quality of lake Inari: The lake as a popular location for recreational fishing. Furthermore, the disturbance of reindeer herding comes with business losses for indigenous industries. But also, the loss and disturbance of biodiversity and pressures on ecosystems are conversely a risk for the tourism sector itself because Tourists visit Inari to experience Arctic wilderness and untouched nature. Besides, also the experience and learning about indigenous cultures is an important driver of the regional tourism sector and underlines an important interaction between tourism and indigenous industries.

Identified responses to pressures, states and impacts are much associated with national and trans-boundary management plans that address environmental problems caused by the tourism. This includes an expansion of officially protected wilderness (72% of Inari municipality is under protection), the collaboration of the Inari region in transboundary management plans[12], the integration of Natura 2000 areas to protect endangered species, and the regional land-use plan for northern Finland. Besides, more environmental certification for sustainable tourism is considered a requirement. Lastly, to improve co-existence between sectors, there is a need for additional negotiation platforms and discussion fora.

[12] E.g., the Pasvik-Inari-Trilateral Action Plan

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The figure below shows the DPSIR framework for the **indigenous industry hub Inari**, Finland.

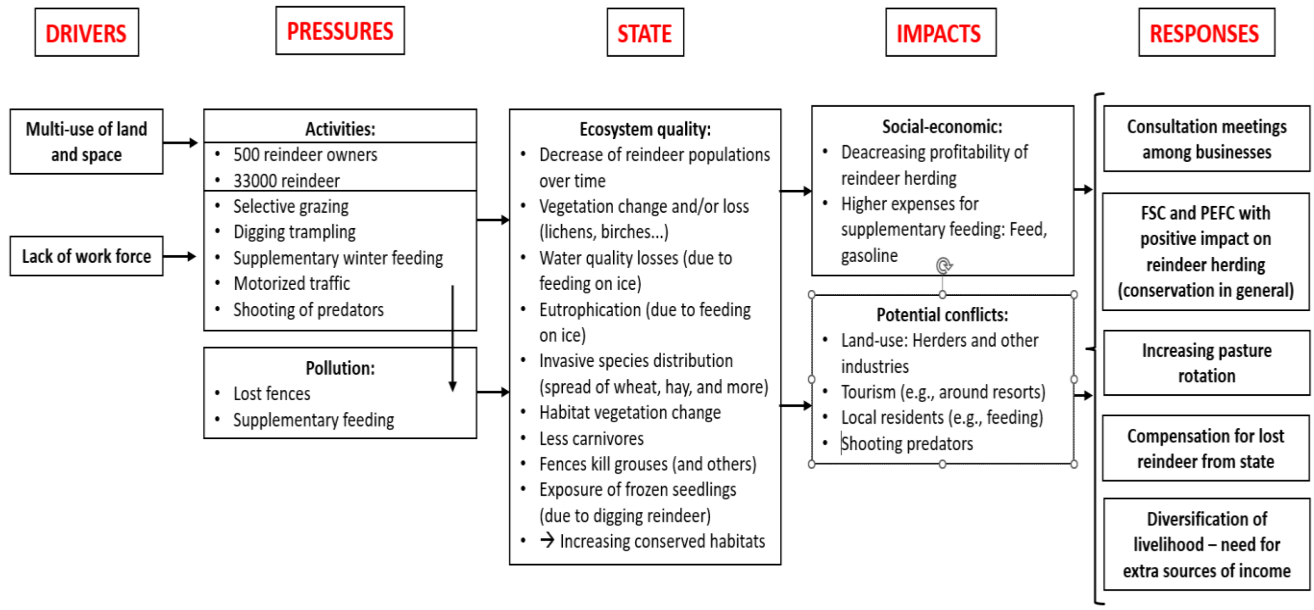

Figure 5. DPSIR framework for Inari: Indigenous industries

Reindeer herding is an essential part of the region's identity: There are over 500 reindeer owners in Inari with over 33000 reindeer in total. However, competition for land and habitat fragmentation caused by other industries such as tourism, forestry, mining, or energy production contribute to a slow decrease of reindeer populations as well as a continuous need to find alternative feeding grounds. At the same time, a lack of workforce affects the reindeer industry and its future maintenance.

Reindeer herding is associated with environmental pressures that affect the state of the environment. Reindeer feed on lichens and when the herd is dense, trampling can pose erosion risks along migration routes. Moreover, overgrazing by reindeer can be linked to changing vegetation structures: While e.g., lichens[13], birches or underground vegetation can strongly decrease, other vegetation types such as pines usually increase. In winter, reindeer are specialists in localizing lichens under the snow and dig deep into the layers to get through to them. This exposes seedlings of several vegetation types to frost.

[13] Lichens are considered an ecological indicator for intact ecosystems.

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If necessary (e.g., due to high snow or habitat fragmentation caused by other industries), reindeer herders gather their reindeer for supplementary winter feeding. This comes with environmental changes: On the one hand, feed leftovers in the snow move into the soil over time and act as fertilizer for invasive plants[14]. On the other hand, supplementary feeding can decrease water qualities when reindeer are fed on ice covers of lakes, ponds, or rivers. Finally, supplementary feeding has been linked to pollution in terms of rubbish and left fences. Consequently, grouses and other animals have reportedly got stuck and killed in these fences.

The environmental pressures and changing states are associated with economic impacts and conflicts with other industry activities. First, supplementary feeding comes namely with high additional costs for reindeer herding businesses. Second, selected grazing has caused conflicts between reindeer herders and forestry due to the deterioration of forest grounds. Third, habitat fragmentation caused by different forestry methods increase the need for supplementary winter feeding, but also the need to find new reindeer feeding grounds. This is additionally caused by tourism activities such as skiing, hiking or dog sledging. Fourth, conflicts between reindeer herding and the tourism sector are visible: Increased traffic and expanding road nets have continuously caused reindeer deaths.

Several responses have been identified to react to pressures, states and impacts:

- Consultation meetings among businesses: Reindeer herding businesses and forestry businesses have increased their cooperation to avoid conflicts between the sectors in the future. For example, the Stora Enso company introduced more participatory approaches when it comes to their project management.
- The certification system of the NGOs FSC and PEFC have shown positive impacts on reindeer herding. When FSC certification is applied, the perspectives of the herding businesses are better considered due to required consultation procedures.
- Increasing reindeer pasture rotation causes less grazing pressure on vegetation and provides opportunities for retention. Moreover, cooperation with other stakeholders regarding the selection of land areas used for supplementary feeding can lower conflict potential.
- The state compensates reindeer herders for losses of reindeer
- Decreasing reindeer populations, workforce and profitability highlight a need for alternative sources of income and new diversifications of livelihood within the indigenous industry.

[14] This has led e.g. to an overabundance of weed plants, dried hay, or silage. This can especially be a critical problem in protected environments.

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4.4. Kittilä

The figure below shows the DPSIR framework for the **tourism hub Kittilä**, Finland

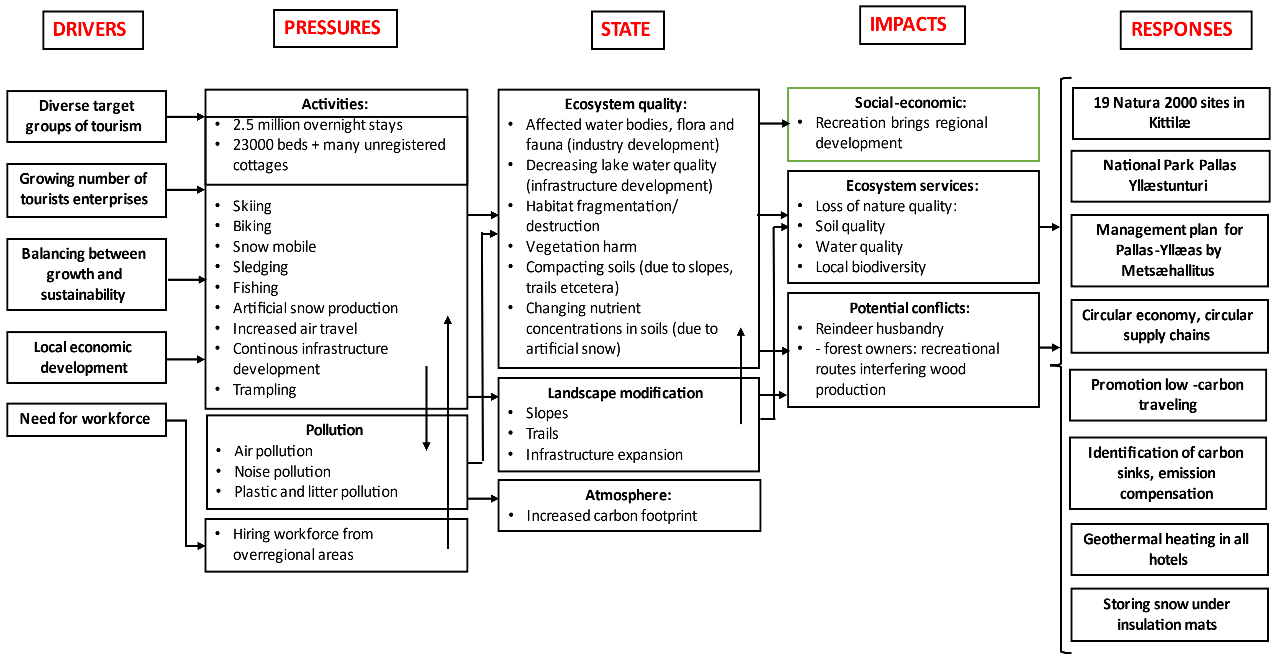

Figure 6. DPSIR framework for Kittilä: Tourism

Increasing investment and ownership as well as diversifications of tourist interests and target groups have developed Kittilä to the biggest ski and tourist resort in Finland. Here, especially the Levi ski resort has become popular for all kinds of tourism activities including skiing, snow mobile excursions, husky safaris, hiking and mountain biking. Levi as a tourism destination grew rapidly in recent years and fosters the local economy and vice versa: There are around 2,5 million overnights per year, 23000 beds in hotels and unregistered cottages, and 58 restaurants in immediate proximity. Around Levi there are a few villages with additional tourism activities. The continuous industry growth increases the demands for workforce and a lot of staff is hired from over-regional places. Most tourists arrive to Levi/Kittilä by air. Tourism activities are mostly associated with air, noise, and plastic litter pollution.

The pressures on the environment are linked to changes of the environmental state: As the landscape of Kittilä is characterised by many lakes and the dissecting river Ounasjoki,

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continuous infrastructure development for tourism services and high tourist numbers is associated with risks of higher nutrient levels and waste pollution in water bodies. Also flora and fauna in and around Levi are affected: Especially the establishment and use of trails and ski slopes has led to compacting soils and degradation as well as habitat fragmentation. Moreover, it has been shown that artificial snow production is linked to changes in soil nutrient concentrations. Because of more warming weather conditions, artificial snow is increasingly used. Lastly, due to the intensification of air travel and millions of annual visitors, the carbon footprint in Kittilä has been steadily decreasing as well.

Continuous regional development and employment opportunities are a positive economic trend in Kittilä. However, the intensification of infrastructure development and expansion of tourism activities comes with risks of losing natural quality which is at the same time one of the most important tourism attractions. Furthermore, the tourism sector development has led to conflicts with reindeer husbandry: Natural forage grounds have become more fragmented by industrial activities, especially during the last two decades. This means economic loss for the reindeer herding businesses. Eventually, there are potential conflicts with forest owners: The expansion of recreational routes might interfere forestry activities and production.

Responses to pressures, changing states, and impacts are the maintenance of protected environment and its expansion: There are currently 19 Natura 2000 sites in Kittilä and the established Pallas Yllästunturi National Park. Moreover, also in response to National Climate Action Plans, there are continuous efforts to identify carbon sinks and to strengthen emission compensation systems, this also addresses growing air travel. There are additional plans to integrate geothermal energy in all hotels and accommodations towards the future. Lastly, to further decrease the tourism destination's carbon footprint, the application of insulation mats to cool snow has become prominent.

To address continuous waste production, more approaches for circular economy including circular supply-chains and waste management have been introduced to municipal planning and local tourism action plans.

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The figure below shows the DPSIR framework for the **mining hub Kittilä,** Finland

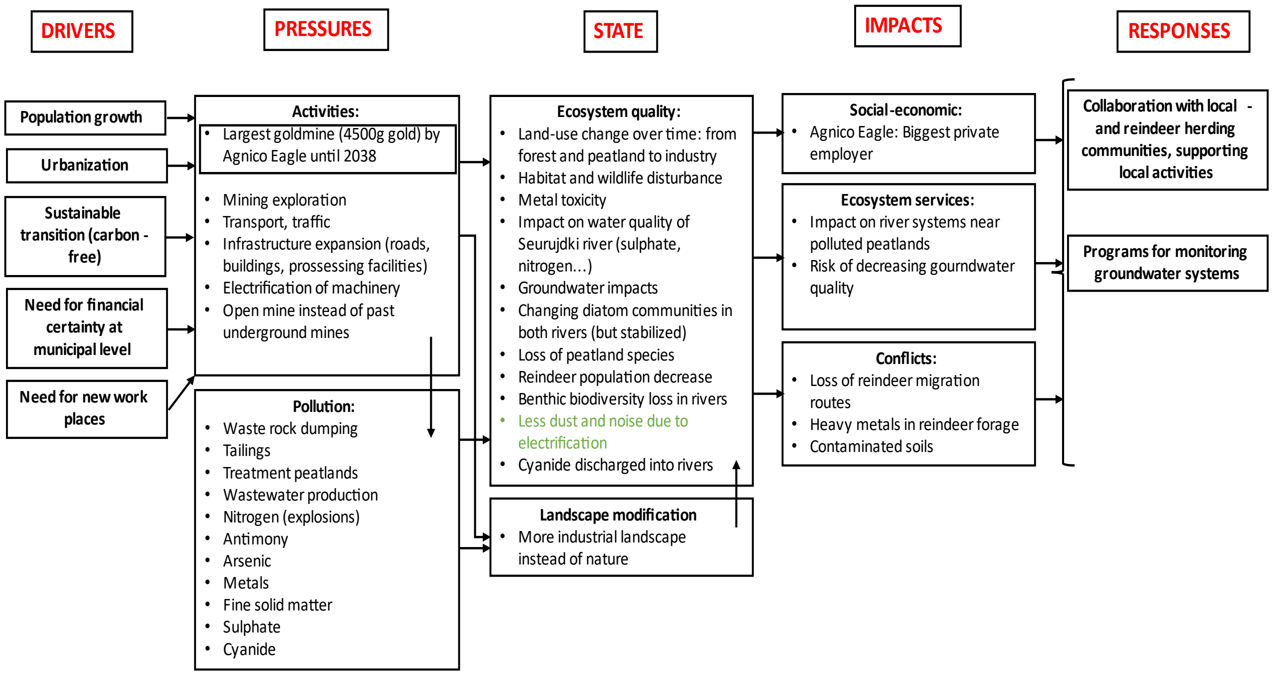

Figure 7. DPSIR framework for Kittilä: Mining

The Suurikuusikko deposit is one of the largest known gold deposits in Finland and the Kittilä mine is currently the largest operating gold mine in Europe with a production of about 4500 kg gold per year. The Canadian mining company, Agnico Eagle Finland Oy, started the constructions in 2006, the gold extraction commenced in 2008 with open pit mining. The underground mining started in 2010 and fully replaced open pit mining with a lifetime until 2037. Global drivers such as population growth[15], urbanization, and the sustainable transition towards carbon-free technologies highlights the need for high quality gold and meanwhile, Agnico Eagle has permits for exploration to find new deposits. But also the strive for financial certainty and profitable economy on a local level as well as employment opportunities drive gold mining in Kittilä.

However, environmental pressures of gold mining were identified in form of pollution. This includes the dumping of waste rock material, wastewater production, nitrogen release from

[15] Population growth is expected to double in 2050.

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explosives as well as contaminations of different elements such as antimony, arsenic, sulphates, and different metals.

Such pressures alter the environmental state. The landscape is strongly affected by the construction of the mine infrastructure: The mine covers about 15 km2 where the original landscape is replaced by infrastructure (buildings, processing facilities, roads, two open pit mines, waste rock dumps, tailings ponds and treatment peatlands). The change of land use from natural forests and peatlands to industrial use impacts habitat and wildlife behaviour. The Kittilä mine is in the Reindeer Herding Area in northern Finland and the land use change has impacted the natural migration routes and grazing areas of reindeer. Besides, the mine has caused losses of threatened peatland habitats for e.g., Carex heleonastes. When it comes to wastewater discharges, the ability of peatlands to retain toxic heavy metals from polluted waters is used to purify wastewater before discharging it into river systems. This leads to accumulations of heavy metals in the peatlands over time affecting habitat quality and ecosystem services such as food supply for reindeer[16].

Wastewater and mine drainage contain nitrogen compounds from explosives, antimony, arsenic, metals, as well as fine solid matter and sulphate. Studies have also shown a clear increase in the concentrations of nitrogen, sulphate, and Sb downstream from the mining area[17]. Although the ecological state of the Seurujoki and Loukinen rivers are considered good, changes in benthos diversity and abundance have been identified. Sulphate, Sb and Ni are potentially most harmful and could pose a risk for aquatic ecosystems. Another potential risk for the environment, especially water bodies, is the discharge of toxic cyanide which is used to leach precious metals from ore.

Lastly, monitoring has shown that groundwater in the mining area has increased concentrations of contaminants indicating clear impacts on groundwater quality, however, measured concentrations are still below the maximum permissible concentrations of drinking water.

Socio-economic impacts are associated with chemical- and metal contamination risks for water bodies, soils, and potentially groundwater. This can have economic impacts on other

[16] Besides, the use of natural peatlands to treat mine wastewaters leads to an accumulation of toxic heavy metals in the peatland, which will decrease the effectiveness of the treatment peatlands over time. The lifetime of treatment peatlands is therefore limited, and accumulation can lead to concentrations exceeding guideline values for contaminated soils. Over time there is a risk that the peatlands will become a source of contamination for the adjacent river systems.

[17] The higher sulphate content in the mine drainage water increased the electric conductivity about tenfold compared to natural waters. After the change from open pit to underground operations, the amount of solid matter in the drainage waters increased. There is a clear impact on the river water quality of the Seurujoki river as a result of discharge of mine wastewater and drainage waters. This is characterised by elevated metal and metalloid concentrations, especially As and Sb, as well as distinct ion composition in comparison with natural waters.

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sectors and health risks, should tolerance values be exceeded. Moreover, losses of reindeer migration routes, traffic collisions and metal contaminations of forage plants can come with economic losses for reindeer businesses. The reduction of ecosystem quality around the mine is also in general an external effect for residents and tourism, stakeholders that are dependent on a healthy landscape. Eventually, a positive aspect is associated with employment opportunities: The mining sector is locally the biggest private employer with a capacity of 480 positions.

Prominent responses to pressures, states and impacts are continuous and expanding monitoring programs for groundwater quality and increasing efforts of the mining industry to collaborate, establish dialogue and to negotiate with local communities and other industries and stakeholders to reduce potential conflicts because of mining activity.

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4.5. Kautokeino-Kvalsund

The figure below shows the DPSIR framework for the **indigenous hub Kautokeino-Kvalsund**, Norway.

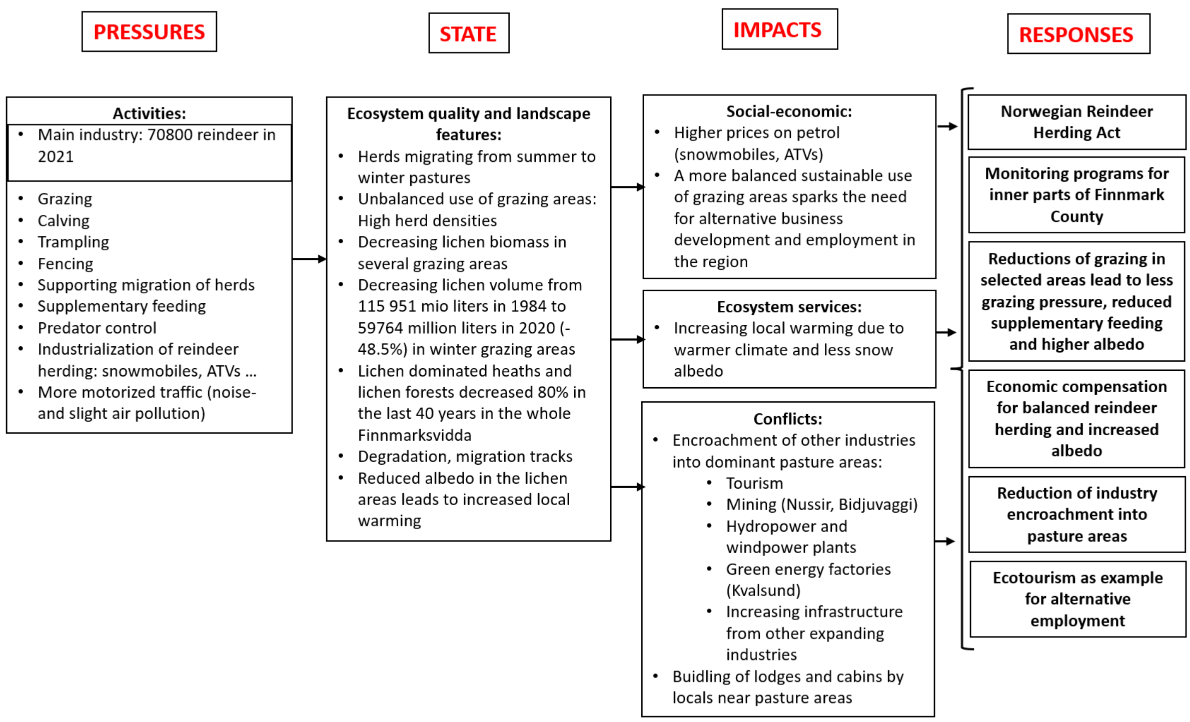

Figure 8. DPSIR framework for Kautokeino-Kvalsund: Indigenous industries

Kautokeino is the Sámi "capital" of Norway. 95% of its population are indigenous Sámi, being one of only two municipalities where the Sámi people are the majority. Reindeer herding is the main industry and is embedded in the public sector and several Sámi institutions. In East-Finnmark, which includes reindeer areas of East, Middle and West Kautokeino, there were in total 70 800 reindeer in spring 2021. Since 2016, the number is considered stable, with fluctuations between 68900 and 71300. Also, Kvalsund is a traditional sea Sámi community. While the Kvalsund area includes important spring, summer, and autumn pastures for reindeer husbandry, some essential winter pastures are found in Kautokeino.

Grazing and migration of reindeer can alter the environment in different ways. On the one hand, the intensity of grazing and speed of migration are tied to environmental circumstances such as fluctuating weather conditions causing changing snow depths. This leads to changing

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grazing intensities in different areas during winter. If snow depths are too high, reindeer herders may provide reindeer with supplementary feeding at central feeding places.

On the other hand, grazing pressures and migration routes have been impaired by the encroachment of other industries such as mining, tourism, and different energy sectors. The competition for space and resulting serious reductions of essential pasture grounds have consequently increased grazing pressures on pastures and significantly higher herd densities making use of them. This caused a much more unbalanced use of many grazing areas over decades. Also the continuous establishment of cabins and lodges of locals nearby pastures has contributed to this development. The increased grazing pressure has affected the abundance of certain vegetation over time:

Monitoring programs using remote sensing and ground surveys reported that vegetation types dominated by bilberry (Vaccinium myrtillus), wavy hairgrass (Deschampsia fleuxuosa), the dwarf cornel (Cornus suecica), mosses, but also birch forests have tripled in abundance compared to 40 years ago in inner parts Finnmark County. In contrast, lichen-dominated heaths and woodlands (forests), much preferred by the reindeer stocks, have decreased by approximately 80 % in abundance during the same period[18]. Especially the decline in lichen-dominated areas can be explained by intensive grazing by reindeer, already since the 1970s[19]. The overgrazing of lichens is often associated with environmental concerns due to the environmental indicator status of lichens in northern regions. Furthermore, the accumulated grazing in lichen-abundant areas has decreased the strength of albedo effects in several areas[20]. Through digging, and removing snow from the soil surface by reindeer, some pasture areas have shown reductions in sunlight reflection. This leads to a stronger warming effect.

Besides, supplementary feeding is criticized by several stakeholders, including the reindeer herders themselves. Supplementary feeding accumulates reindeer in selected areas which has negative effects on surrounding vegetation abundance and soil quality due to grazing and trampling. Supplementary feeding is also associated with inductions of invasive plant species in the environment as well as eutrophication of lakes. The latter is an issue when reindeer are fed on ice surfaces that melt in spring[21].

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[18] More specifically, decreasing lichen volume has decreased from 115 951 million liters in 1984 to 59764 million liters in 2020 in winter grazing areas. This equals a reduction of 48.5%.
[19] In addition, other factors such as climate change (increased precipitation), caterpillar attacks, and long-transported air pollution (e.g., nitrogen) may also have contributed to the increase of forests and other vegetation types.
[20] Albedo is an expression of the ability of surfaces to reflect sunlight (heat from the sun). Light-coloured surfaces return a large part of the sunrays back to the atmosphere (high albedo). Dark surfaces absorb the rays from the sun (low albedo).(see: Albedoeffekten – Norsk Polarinstitutt (npolar.no))
[21] However, the state of biodiversity measured by the Norwegian Nature Index (2020), is considered as good (quantitatively evaluated on a scale from 0 to 1) for the Kvalsund-Kautokeino area.

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Considering industry encroachment and fluctuating snow conditions, the reductions of grazing pastures make reindeer herding often more cost intense which is an increasing impact. Longer reindeer migration routes to new pastures increase the need for motorized transport and thus, costs for petrol supply. Also supplementary feeding comes with additional costs. Moreover, a more balanced and less dense grazing pressure on pastures would come with potential financial losses because less reindeer would be able to make use of pastures. All in all, the profitability of reindeer herding is thus decreasing, suggesting the need for alternative business development and employment in the region on a long-term perspective.

When it comes to responses, the Norwegian Reindeer Herding Act (2007) underlines that an unlimited access to seasonal pastures is an important material basis for Sámi reindeer herders' culture and livelihoods and must be preserved. However, with competing land uses and encroachments like tourism and mining, severe winter conditions seem to be an ongoing threat to reindeer husbandry which needs to be addressed. To reduce negative effects on albedo by grazing and to decrease reindeer population densities, economic compensations could be a way to make a balanced pasture use more attractive for herders. At the same time, ways must be found to reduce encroachment of other industries into grazing grounds to reduce overall grazing pressures of reindeer. New business ideas and collaboration between the industries could be a way forward. An example could be ecotourism.

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The figure below shows the DPSIR framework for the **mining hub Kautokeino-Kvalsund**, Norway.

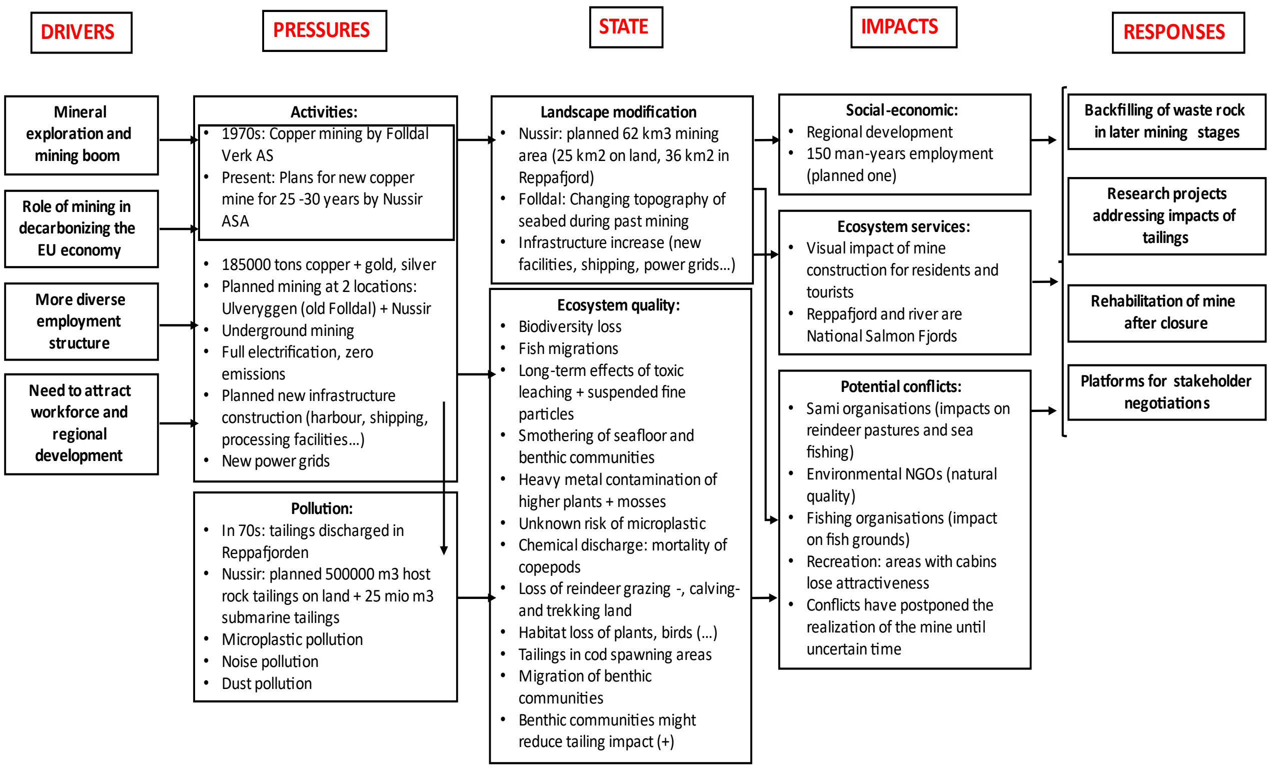

Figure 9. DPSIR framework for Kautokeino-Kvalsund: Mining

The mountains around Repparfjorden hold some of the largest known copper deposits in Norway, including the Ulveryggen and Nussir deposits. The Ulveryggen copper deposit was mined by the company Folldal Verk AS in several open pits between 1972 and 1978. During the operation of the mine, mine tailings were deposited as a series of cone-shaped mounds in the inner part of Repparfjorden. Meanwhile, global drivers such as decarbonizing industries stress the need for different minerals, but also local drivers such as attracting a multi-skilled workforce and local regional development emphasise an interest in new projects.

Together with international investors, the Norwegian company Nussir ASA has been planning to open a new copper mine since 2005 at Ulveryggen and Nussir deposits. The expected lifetime of the new mine is 25-30 years with an expected employment of 150 man-years. The total amount of copper ore reserves in the Ulveryggen and Nussir deposits is estimated to be 25 million tonnes, which can produce ca 185000 tonnes copper and additional gold and silver.

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Nussir has tailing permits to deposit 2 million tonnes of tailings per year, up to 25 million m3 tailings in total in a submarine deposit in Repparfjorden. The permit allows up to 500000 m3 of host rock to be deposited on land. The total mining area in the zoning plan covers 63 km2, of which 25 km2 are on land and 36 km2 in Repparfjorden. The mine is planned as an underground mine utilising existing infrastructure, but some new infrastructure, including new harbour facilities will be constructed. The mine is also planned to be a fully electric, zero emissions mine. Nussir received an operating license from the Government in 2019, supported by the local council, but conflicts with Sámi organisations, environmental NGOs, and other user groups about the impact on reindeer husbandry and the use of submarine mine tailings have so far blocked the start of the mining operations.

Accordingly, most pressures, changes of environmental states and impacts addressed in this section are potential and include observations from the past Foldal Verk AS operations. The main pressures from the Nussir ASA mining activities on habitat and landscape will derive from the submarine mine tailings in Repparfjorden, infrastructure development (harbour, facilities at Markoppneset), depositions of waste rock on land as well as noise pollution. In addition, plastic and microplastic pollution is associated with processing activities.

The potential pressures exerted by mining activities are expected to cause changes to the environmental: The construction of new facilities at Markoppneset include the removal of all vegetation, habitat loss for a variety of plants, birds, and other animals, but also loss of reindeer grazing land. It will also have a visual impact for the residents and recreational users. Although the new Nussir mine will be underground, mine construction, planned waste rock deposits and traffic will alter the landscape and impact migration routes for reindeer.

Moreover, submarine tailings will have an impact on the marine habitat and landscape due to the physical smothering of the seabed and benthic organisms. This changes seafloor topography and sediment characteristics, and species diversity will most likely decrease significantly in the deposition area[22]. Tailings with suspended fine particles can also influence fish populations: Some fish avoid turbid waters, change their migration routes, and may ingest and bioaccumulate dissolved chemicals and metals. The spawning area for cod partially overlaps with the tailing area and, according to local fishermen, cod left the spawning area

[22] However, studies in Bøkfjorden have shown that benthic species will likely return after tailing discharges have ended, despite potential toxic effects from the leaching of copper or chemicals that could affect species on a longer term.

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when mine tailings were deposited in the 1970's. The volume of planned mine tailings is much larger than in the 1970's and similar impacts are expected[23].

Regarding their components, the mine tailings that were deposited between 1972 and 1978 in the inner part of Repparfjord remained in place for 40 years. The tailings are presently a 9 cm thick layer enriched in Cu, Fe, Ni, Cr and Ba, 3-9 cm below the current seafloor surface[24]. It is shown that less than 5% of the Cu in the original mine tailings has dispersed to the outer fjord. However, most of the Cu in the tailings is bound to potential bioavailable fractions and may get released in the water column or taken up in benthic organisms. Besides, an ecotoxicology study investigating the effect of process chemicals discharged with mine tailings found that the chemicals have no toxic effect on algae, but that high concentrations caused mortality of copepods Tisbe battagliai and polychaetes A. Marina. This indicates that there may be some impact on the environment when mine tailings are discharged at maximum concentration. In addition, the mine tailings could also contain and release microplastics, however, the direct effects on the environment are rather unknown[25]. Eventually, noise and air pollution (dust) are a minor issue as most of the mining activities are underground and all vehicles will be electric. Possible pollution from land deposits, such as acid mine drainage, is also considered to be low.

In the context of potential pressures and environmental states, several impacts might be detected. A positive aspect that new mining operations would bring is regional development, especially in terms of employment with capacities of 150 man-years. On the other hand, the negative environmental consequences associated with new mining operations has increased heated discussions between the industry and stakeholders such as Sami organisations, environmental NGO's, fishing organizations, locals, and other user groups. Here, tailing impacts on the environment and reindeer populations is very contested and stakeholders are concerned about the external effects of mining on other sectors. Also the visual impact of new mining grounds is a contested issue for local habitants as well as recreational users.

In the end, some responses have been detected:

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[23] Another concern is the effect of suspended particles on fish eggs: A laboratory study found that a significant number of particles was attached to fish eggs that were exposed to suspended mine tailings. However, they found no or very limited effect on embryo and larval mortality and no differences on the timing of hatching or abnormalities. Investigations have also shown that young salmon migrate relatively quickly through Repparfjorden and will briefly be exposed to potential contamination from the mine tailings. There is, however, no data on the behaviour of older returning salmon, which are expected to spend a longer time in the fjord

[24] High concentrations of Ni and Cr are also typical for natural sediments in the area.

[25] An ecotoxicological study investigating the effect of both Cu and microplastics from the mine tailings on blue mussels Mytilus edulis found no significant effect on Cu accumulation and no significant combined effect of Cu and microplastics. It is noted, however, that the exposure time in the study was short and that longer exposure times may give a different result.

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- There are increasing efforts to integrate stakeholder negotiations and discussions between the mining industry and reindeer herding businesses to reduce impacts on the reindeer sector.
- In later stages of the mining project, it is considered to backfill waste rock material in tunnels or elsewhere underground. This is an alternative for dumping tailings in fjords or on land where weathering processes and leaching increase pollution risks.
- There are high ambitions to re-integrate the mining grounds into nature after closure and a mine rehabilitation after the project is finished is planned. Since more recently, according to the new National mining law, clean-ups are now also legally binding and extra-funds have to be presented for this matter.

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4.6. Varangerfjord

The figure below shows the DPSIR framework for the **aquaculture hub Varangerfjord**, Norway.

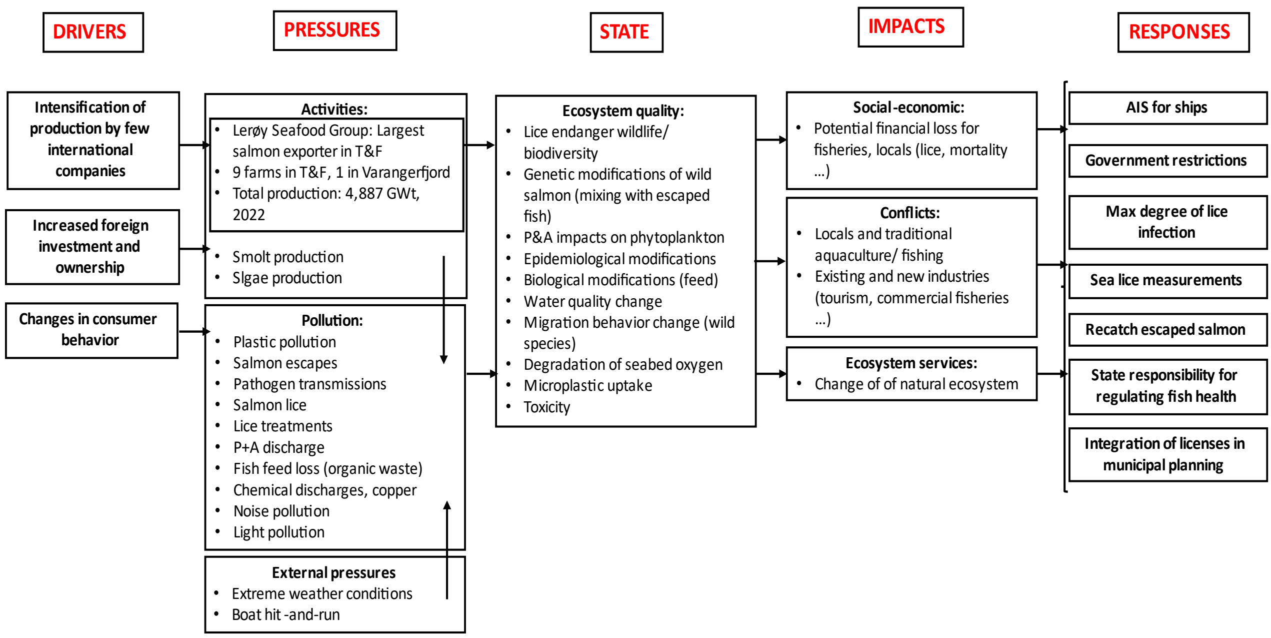

Figure 10. DPSIR framework for Varangerfjord: Aquaculture

The aquaculture and fishery sector in Norway is the 2nd largest national economy. Increased investment into the aquaculture and fisheries industry and an intensification of production of few operating companies have driven sector development at Varangerfjord. Meanwhile, salmon has become one of the 10 most valuable farmed fish. However, social, and environmental concerns linked to production processes have been steadily increasing.

Atlantic salmon and rainbow trout aquaculture are the most prominent in Norway. The company Leroy Seafood Group is the largest Norwegian exporter of Atlantic salmon. The farming of mostly salmon, but also rainbow trout in Northern Norway makes up 25% of the whole aquaculture production of the company in Norway. While there are 9 farms in the region of Troms and Finnmark, one of 4 farms in Finnmark is in Varangerfjord. The production in Troms and Finnmark was 4,887 GWT in the first quarter of 2022. Next to aquaculture, smolt production, algae production and fishing tourism are important activities. Next to these activities, harsh weather conditions were identified as a pressure.

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The aquaculture activities are associated with environmental pressures in terms of parasite contamination and different kinds of pollution which ultimately affect the state of the environment. Sea lice that feed on fish tissue can kill the fish and the accumulation of fish in farms can become an attractive target for sea lice. This also bears risks for wild fish species that are moving near the fish cages. Therefore, farmed salmon is often ascribed the status of an epidemiological modifier of wild fish, also in terms of other potential pathogens. A common way to reduce sea lice are treatments in form of antibiotics, but also freshwater has shown success in this context. Antibiotics were furthermore associated with risks for water quality changes. In terms of pollution, another pressure is plastic pollution: Aquaculture makes use of plastic-based lines, cages or nets suspended from buoyant or submergible structures as well as nanotech plastic-based anti-biofouling agents and paints. Tanks, pens, nets, floats, pontoons, and the pipes of the fish feed suppling systems are made of plastic material. Risks of releasing plastic into the environment where it dissolves further into microplastic are associated with toxicity and ingestion of sea organisms. Another pressure is biological pollution in terms of lost fish feed and fish faeces that are discharged into the marine environment. Fish feed loss is associated with decreasing water quality due its release of nutrients. Feed loss can attract wild fish and deteriorate natural migration behaviours. Fish faeces also release phosphor and nitrogen which can cause eutrophication. Consequent production of algae on the seafloor comes with negative effects on fauna and flora due to decreasing seabed oxygen. Another pressure are fish escapes which are a controversial side effect of fish farms: The mixing of farmed fish and wild fish is linked to biological modifications of wild fish including changes in fish tissue. E.g., research has shown that new fish generations were less adaptable to the natural environment. Finally, hit-and run accidents caused by other boats are a pressure on cage farming as it can break material and increase the risks of fish escape. Similar consequences were ascribed to negative effects of harsh weather conditions.

Pressures and changing states as they have been described were associated with the following impacts: As there is much fishery activity in the Varangerfjord, potential conflicts might rise between fisheries and aquaculture in the future. Reasons can be linked to sea lice contaminations of wild fish, influence of algae production on the seafloor, potentially changing migration behaviours of wild fish due to fish feed attraction, fish escapes, or high numbers of economically feasible fish where aquaculture cages are located. Potentially resulting negative effects on ecosystem functioning and fish death is associated with financial losses.

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Ultimately, several responses were identified:

- The Norwegian government is highly involved in the regulation and monitoring of aquaculture production processes. Here the government predefines maximum allowed farmed biomass, stock numbers, fish densities, but also fish health. The latter is associated with strict reporting procedures of production processes.
- There are predefined maximum allowed degrees of sea lice contamination
- There is continuous research about most effective treatments against sea lice.
- Escaped salmon is recaught, if possible.
- The allocation of licenses for fish farming is considered and integrated in the planning programs of municipalities where the fish farms are located. In this regard, aquaculture is integrated into the local and regional planning as well as regional development.

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The figure below shows the DPSIR framework for the **mining hub Varangerfjord**, Norway.

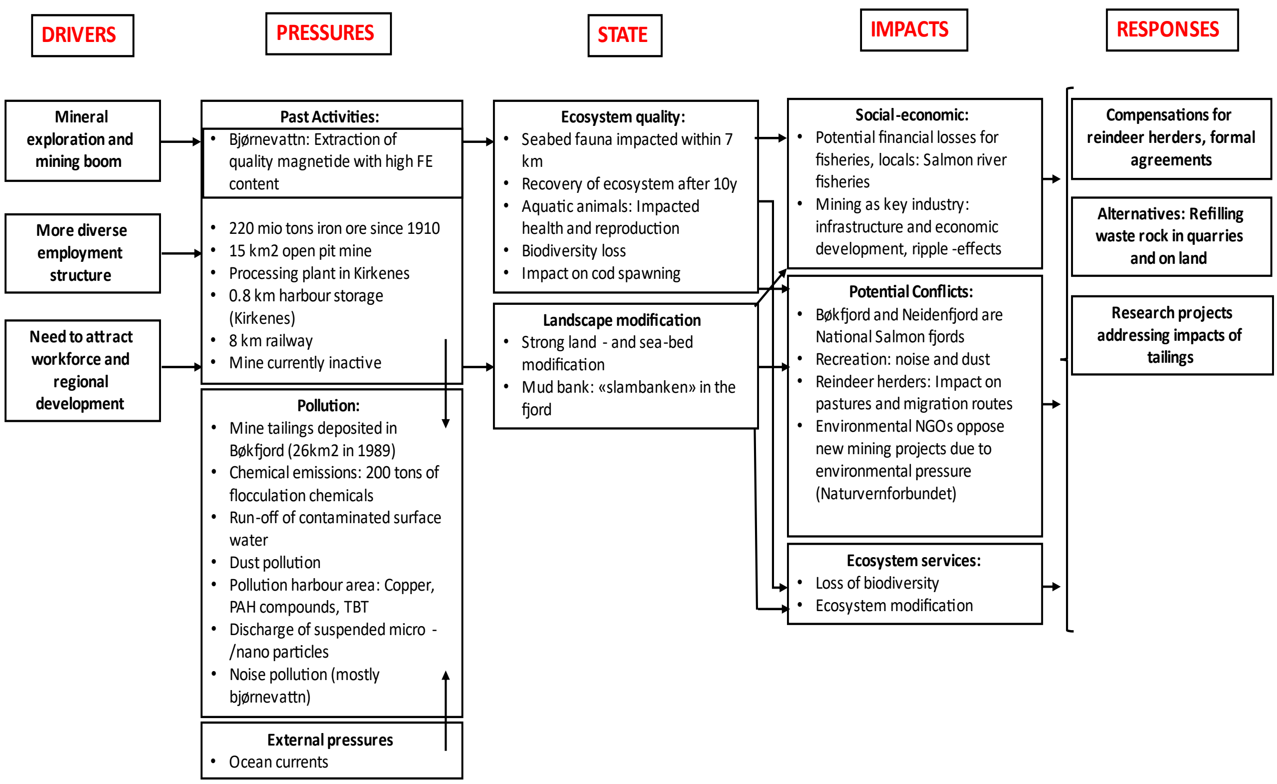

Figure 11. DPSIR framework for Varangerfjord: Mining

Varangerfjord is also a mining hub, however, current mining activities are on hold since 2015. The mining history of the Sør-Varanger municipality dates back to the earlier 20th century. After a longer period of state ownership, the Sydvaranger mine was operated by the Australian company Northern Iron between 2008 and 2015. In 2016, the mine was bought by the Norwegian Tschudi group, who updated geological knowledge of the resources, mining plans for sustainable use, environmental permits, and operational licensing. In 2019 the mine was bought by the American company Tacora Resources which has plans to re-open the mine. This corresponds with global drivers such as increasing demands for minerals and metals and increasing foreign investments in the sector. But also local drivers such as attracting a multi-skilled workforce and local regional development emphasise an interest in new projects. The Sydvaranger mine covers an area of 15 km^2, which includes a main open pit mine of ca 2 km^2, multiple waste rock piles, production facilities, and mining infrastructure. There is a railway

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line from the main mine site to production and storage facilities in Kirkenes including a harbour.

In Kirkenes, substantial submarine tailings were deposited in Langfjorden and Bøkfjorden. Since 1910, circa 220 mil tons of iron ore were extracted with a production of circa 4 mil tons of iron per year.

The past mining activities are associated with further environmental pressures in terms of pollution. First, in 1989, 26km^2 of mine tailings were deposited into the Bokfjord. This also included 200 tons of toxic flocculation chemicals. Second, there has been a continuous run-off of contaminated water from the mine which leached into the environment and the fjord. Third, there has been a significant harbour pollution with copper PAH compounds and TBT from shipyards. Fourth, suspended plastic particles from machinery, other production equipment, and facilities were induced into the environment. Fifth, noise and dust pollution have been prominent over the decades of mining operation.

The environmental pressures have come with impacts on the environmental state of the Varangerfjord hub over time. Hence, the bottom fauna was destroyed due to mine tailings into the fjord and by emissions of flocculation chemicals. The bottom fauna recovered after approximately 10 years. Moreover, harbour pollution and contaminated water run-off was linked to negative effects on health and reproduction of aquatic animals. More broadly, iron ore extraction and open pits have deteriorated the surrounding landscape with irreparable damage of nature. Lastly, cases of conflicts with recreation in the area were associated with dust and noise pollution. Moreover, there have been continuous conflicts with reindeer herders because the mining activity was impacting reindeer migration routes and pastures. During recent years, new mining projects in the municipality were much criticized by environmental NGOs because of the negative effects on reindeer herding and the potentially increasing pressure on the environment. Here, especially the submarine tailing disposal is highly contested. A driving force behind these public discussions was the Norwegian Naturvernforbundet (English: Friends of the Earth Norway). Recently, the Bøkfjord and Neidenfjord received the status of National Salmon Fjords which foster the protection and health of specific ecosystems that are essential habitats of salmon.

In the end, the following responses were identified as a reaction to mining activities and their long-term pressures on environmental states as well as social-economic impacts:

- There have been local conflicts between mining activity and reindeer herding. Reindeer herding was strongly impacted by mining activities in terms of habitat fragmentation and pollution. In this regard, formal agreements have been made with reindeer herders including compensations.

- There are suggestions to make use of quarries and to use parts of the mining area for storage of tailings. Refilling tailings into the ground would impact the environment less than tailings on land or submarine tailings.
- Laborious research projects were funded by the mining sector and the state to further explore and analyse the impacts of mining tailings as well as opportunities for alternative storage. An important contractor in this context is the research institute SINTEF.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869580.

4.7. Svalbard

The figure below shows the DPSIR framework for the **tourism hub Svalbard**, Norway

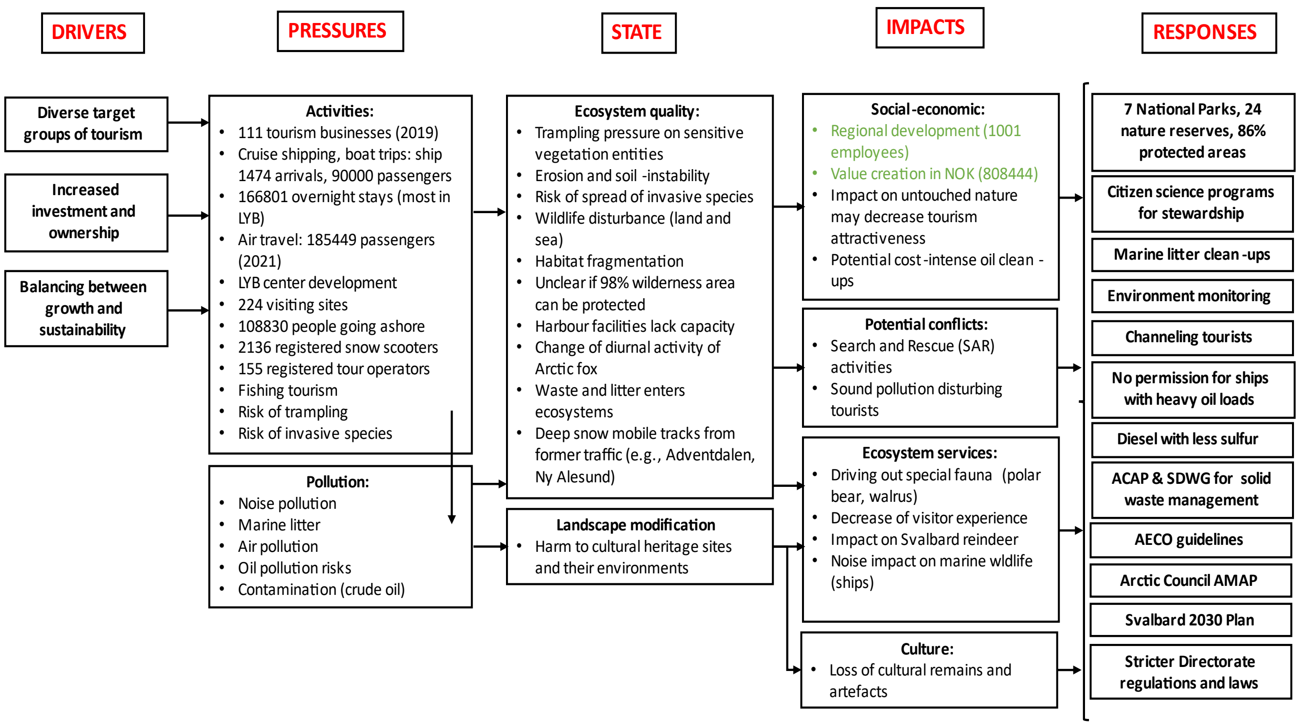

Figure 12. DPSIR framework for Svalbard: Tourism

Svalbard is an archipelago in the high-Arctic and despite its remote location, it has attracted tourists for more than a century. Through new tourism markets (e.g. eco-, cruise-, business-, adventure-, or nature-based tourism), new investments, and ownership, the sector has increased substantially since 2000. Meanwhile, increasing tourism and Svalbard's reputation of untouched Arctic wilderness have led to national demands for a more sustainable tourism destination on the archipelago. Longyearbyen is the largest settlement on the archipelago and is the major hub for tourism in Svalbard.

Most environmental pressures associated with the tourism sector in Svalbard can be linked to different tourism activities and associated pollution that impact the pristine environment:

Growth and a continuously diversifying tourism industry have led to 166800 annual overnight stays. Furthermore, 1474 ship arrivals including mostly cruise ships have been registered in 2019 with 90000 passengers. In 2021 almost 185500 passengers travelled via air. In 2019,

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111 tourism businesses were registered including accommodation and agencies, meanwhile there are 155 businesses with licenses for tour operation including large companies and smaller few-man enterprises. These developments have altered the centre of Longyearbyen. Regional development has come with new roads, tracks, new buildings, a mall, and more harbour facilities. The tourists are increasingly distributed over the archipelago by excursions: There are 224 visiting sites all over Svalbard with in total 18830 people going ashore. Also the number of registered snow scooters is rising with currently 2136. Cruise shipping, excursions and accommodations have come with pollution risks such as noise- and air pollution, but also marine litter. Plastic pollution and contaminated beaches have become a problem at the coasts of Svalbard[26]. Moreover, there is a critical risk of crude oil pollution from marine traffic. This is of concern due to Svalbard's sensitive environment and difficult conditions for clean-up operations because of ice-, weather-, and bad light conditions. Another strong concern are the impacts of trampling by tourists. Risks of inducing invasive species on the archipelago, erosion, and the destruction of slow-growing and sensitive vegetation is a major concern.

The pressures are associated with changes of the environmental state of the archipelago. Increasing excursions and little developed destinations increase risks of overstressing the environmental, but also historical assets of Svalbard. The movement of larger tourism groups increases trampling which endangers sensitive flora, soil stability, but also disturbs terrestrial wildlife. E.g., research has underlined changes in diurnal activities of the Arctic fox and reindeer including changing migration routes. This represents an increasing problem of habitat fragmentation. In addition, waste that enters the environment, especially organic and plastic, have become a major concern. Trampling and waste do not only concern the 98% wilderness area, but also cause risks to historical remains which are also excursion destinations and need to be protected as cultural heritage. Eventually, the continuous rise of cruise shipping and boat registrations in Svalbard as led to an overuse of the Longyearbyen harbour. Harbour facilities lack behind in terms of capacity to regulate all marine traffic, and in the future this problem might increase. Also, the marine traffic is associated with habitat fragmentation for marine and terrestrial animals because of noise-, light-, and diesel pollution.

Pressures and changing environmental states cause socio-economic impacts in Svalbard: On the one hand, the increasing regional development, especially in Longyearbyen comes with positive income opportunities and positive value creation. On the other hand, the negative

[26] Much plastic also arrives at the archipelago via currents from abroad which cannot exclusively be linked to the tourism sector around Svalbard.

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impacts of the tourism sector on the environment and cultural remains are concerning for nature conservationists and other stakeholders and come with economic risks for tourism itself as the pristine nature is also the most important attraction and experience for tourists. Here re-migration of popular Arctic animals (e.g., polar bear, fox and walrus) can intensify this problem because tourism excursions will likely adjust to new destinations on Svalbard. The increasing marine tourism traffic is also associated with potential conflicts with other registered vessels that are essential for public services such as Search and Rescue (SAR) activities, ocean clean-ups, or military activities such as training operations.

Lastly, the following responses were detected in the DPSIR data:

- There is a continuous effort to expand the nationally protected area of the Svalbard archipelago. Meanwhile, there are 68% protected area including 7 National Parks and 24 nature reserves. In the future, this development might increase to preserve the pristine nature and ecosystems.
- There are efforts to involve the tourism consumer himself: Citizen-science projects have been established not only at the tourism destinations of Svalbard per se, but also on ships to increase knowledge and stewardship. This corresponds with the idea to involve the tourist in protective measures and to raise awareness of how important own actions are for nature conservation.
- As in northern Norway, marine litter clean-up activities are arranged also at the coasts of Svalbard to reduce plastic contamination.
- There are many monitoring and research programs that target the protection of sensitive nature on Svalbard.
- There are efforts to reduce seasonal tourism to avoid peaking accumulations of tourists that distribute over the archipelago.
- To reduce oil and diesel pollution, there are measures to include more marine diesel as fuel for ships. The low-sulphur fuel is seen as an alternative to heavy oil that contaminates more severely.
- To upscale the solid waste management system, especially in Longyearbyen, the working groups of the Arctic Council for sustainable development (SDWG) and the Arctic Contaminants Action Program (ACAP) established a collaboration to make the waste management system more efficient. Here, a close collaboration with the local community is an essential feature of the project.
- Lastly, the Association of Arctic Expedition Cruise Operators (AECO) which is an international association for expedition cruise operators in the Arctic and others with

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interest in the industry, have introduced specific guidelines for operation in Arctic environments. Here, the AECO members are obligated to operate in accordance with national and international laws and regulations and have, in addition, agreed to follow an extensive set of guidelines to ensure operations are in accordance with the association's objectives, including several site-specific guidelines and guidelines for visitors to the Arctic.

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The figure below shows the DPSIR framework for the **mining hub Svalbard**, Norway

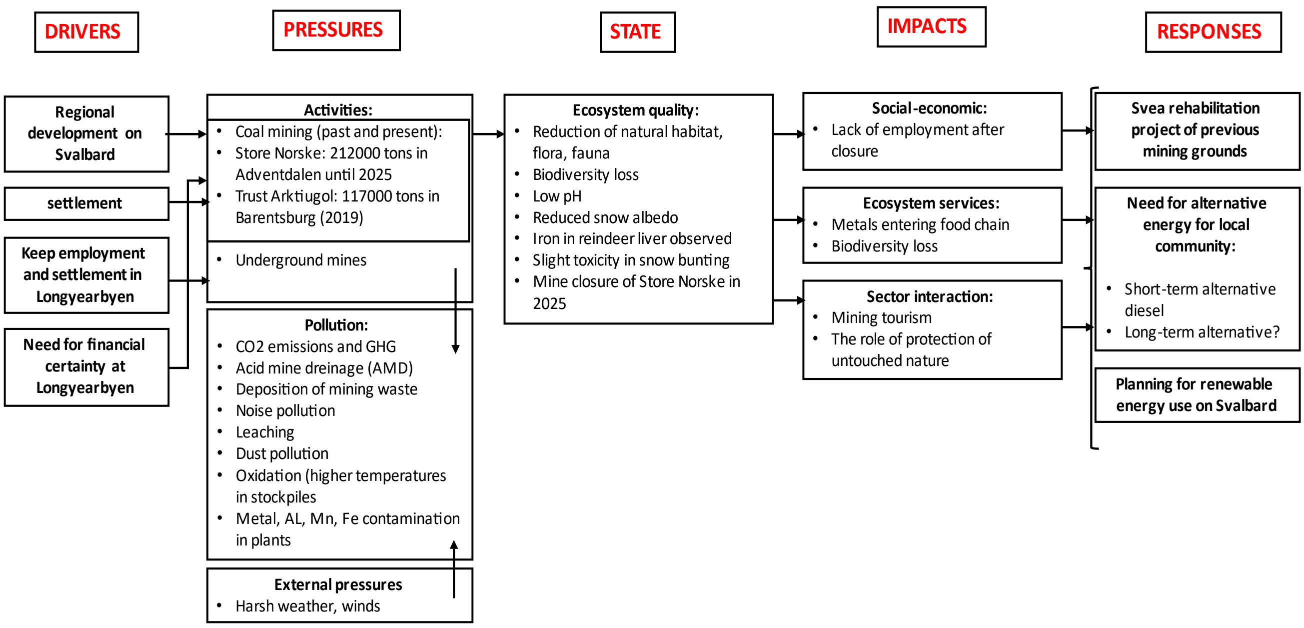

Figure 13. DPSIR framework for Svalbard: Mining

First coal mining activities on Svalbard can be dated back to 1899[27]. The main areas where coal mining has taken place are: 1. Adventdalen near Longyearbyen, 2. Barentsburg and Grumantbyen in Isfjorden, 3. Pyramiden in Billedfjorden, 4. Svea in van Mijenfjorden and 5. Ny Ålesund in Kongsfjorden. Only 2 coal mines are currently still in operation on Svalbard: Gruve 7 in Adventdalen near Longyearbyen which is operated by Store Norske (closure: 2025) and a coal mine in the Russian Barentsburg operated by the Russian company Trust Arktikugol. The former is Norway's only coal power plant and is driven by the need to produce heat and electricity for the town Longyearbyen ensuring its regional development. The mine also brings employment to the town and ensures some financial stability for the settlement.

[27] Svalbard's coal mining history started when the first coal was excavated in Svalbard in 1899 and a 'coal rush' with more than a hundred groups from different nations exploring and mining for coal occurred between 1900-1920. In 1916 and 1917, several Norwegian coal mining companies started up, including Store Norske Spitsbergen Kulkompani (Store Norske) and Norway became the dominant nation with commercial activities in Svalbard. This contributed to the Svalbard Treaty which came into force in 1925, when Norway was formally granted sovereignty over Svalbard.

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The main environmental pressures of the mining industry are linked to the mining activities and resulting different kinds of pollution. While Store Norske has accumulated 212000 tons of coal in Adventdalen in 2021, Trust Arktiugol has extracted 117000 tons of coal in Barentsburg in 2019.

The main pressures on habitat and landscape are linked to the construction of infrastructure and the deposition of mining waste. The construction of waste dumps, roads, buildings, coal transport lines, mining entrances, harbours, and airfields, have occupied several square kilometres at each mine location. The change in land use from natural to industrial has reduced the original habitat and population sizes of numerous species. A few species are considered threatened by mining activities including rare plants such as Carex bigelowii ssp. arctisibirica[28], Arctodupontia scleroclada[29], Juncus leucochlamys[30] as well as groups of Luzula wahlenbergii[31] and Coptidium pallasii[32].

The main pollution related to coal mining in Svalbard is leaching and the spreading of dust from mine tailings. Oxidizing, sulfidic coal tailings generate heat within the piles, maintaining non-freezing temperatures year-round within the piles. Consequently, weathering processes cause heavy metals leaching from the tailings. Contaminants are generally flush released in spring at the outer layer of the pile thaws, causing acid mine drainage (AMD). As a result of the draining acidic waters which is rich in heavy metals, the soil pH is often below 4. This affects the vegetation in the seepage tracks where plant abundance is low and plant health poor. The weathering products Al, Mn and Fe induce the largest negative impact on vegetation[33]. Also lakes close to coal mining hubs are contaminated. Coal dust (elemental carbon) from open coal stockpiles is dispersed by wind and accumulates on snow causing lower snow albedo. However, the local contribution to the total pollution is only 2-10 % and remaining amounts are caused by long-range transport by winds[34].

In addition, plants take up heavy metals from soil and birds such as snow bunting have shown elevated tissue concentrations of toxic in Adventdalen. This is assumed to be caused by the

[28] Can be found in only few localities at Svalbard (IUCN category: CR). Most have been seen near Hotellneset close to Longyearbyen Airport, the airfield construction is made responsible for the population decrease
[29] IUCN category EN with large abundance in Ny-Ålesund. It is destroyed by buildings and road constructions
[30] (IUCN: EN) and no longer present in Longyeardalen due to destruction of natural tundra.
[31] (IUCN: NT) from Longyeardalen and has been destroyed by human infrastructure.

[32] (IUCN: NT) from the Longyearbyen area, also destroyed.
[33] In regions far from active coal mines (e.g., Hornsund in southern Spitsbergen), accumulation of heavy metals in plants is primarily caused by long-distance transport from industrialized regions in Europe and Asia, or from marine metal ions brought to land as sea aerosols by strong winds.
[34] Besides, high Ni concentrations in a moss, a lichen and two vascular plants from a gradient near Longyearbyen are assumed to be a function of wind-blown coal particles from the mining industry. Soils around Longyearbyen contain high concentrations of Cd, Co, Cu, Ni, Pb and Zn, which is also considered to be a result of coal dust accumulation.

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dispersal of coal from the mining industry which is taken up by plants and insects and later ingested by the birds[35]. Besides, spontaneous iron overload caused by high uptake of dietary iron from iron-rich forage plants has repeatedly been reported regarding liver tissues of Svalbard reindeer. It is not yet concluded that this is related to coal dust[36]. Lastly, the burning of coal on Svalbard and all activities related to the extraction, including shipping, heavy vehicles and air-borne transport of employees, lead to substantial emissions of CO2 and other greenhouse gases.

Pressures and changing states have been linked to few socio-economic impacts. On the one hand, employment is seen as a positive aspect. On the other hand, pollution effects on landscape, ecosystems and wildlife are associated with critical effects for the well-being of other industries such as tourism, which is dependent on the nature experience of tourists. Besides, the contamination of metals and chemical elements is associated with risks for food chains and that contaminations circulate to other organisms. Lastly, as the Store Norske mine will close in 2025, there is a need for alternative employment. At the same time, there is a need for alternative energy to electrify and heat the settlements on Svalbard.

Generally, two responses were detected in the DPSIR data:

- The energy supply system in Longyearbyen is based primarily on the extracted coal. Emissions from this source are neither subject to the carbon tax nor included in the European Emissions Trading System (ETS). In connection with its consideration of the white paper Svalbard (Meld. St. 32 (2015–2016)), the Storting asked the Government to initiate a broad-based review of the options for the future energy supply system in Svalbard based on sustainable, renewable solutions, as set out in the recommendations from the Standing Committee on Foreign Affairs and Defence (Innst. 88 S (2016–2017)). The Ministry of Petroleum and Energy is conducting more thorough cost-benefit analyses for a short list of energy solutions and combinations of solutions. The Government’s position is that the future energy supply system must be reliable, sustainable, and cost-effective. Currently, a more short-term solution is the integration of diesel use.
- The Svea coal mines in Svalbard have been closed, and the area is under restoration. The goal of the landscape restoration was to strengthen dynamic ecological and

[35] Al, Co, Se, and Zn showed higher concentrations in snow bunting from Adventdalen. It is not yet known whether these levels are detrimental for the birds.
[36] It is more likely that it is caused by naturally high Fe concentrations in Svalbard bedrocks and soil. However, a comparison of reindeer from Adventdalen (coal industry-affected) with reindeer from Kapp Linné (not near any coal mining) has clearly shown contrasting element levels between the locations. Most of these differences have natural causes (e.g. sea aerosols and precipitation rates). However, the concentration of Cd was closely linked to distance from coal power plant.

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geomorphological processes by removing roads, houses, industry facilities, airports, landfills, and quarries that once dominated the area. Cultural heritage features, such as pre-1946 buildings, structures, and mining traces, have been preserved, while the rest of the landscape has been restored to a near-natural state.

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4.8. Egersund

The figure below shows the DPSIR framework for the **aquaculture hub Egersund**, Norway.

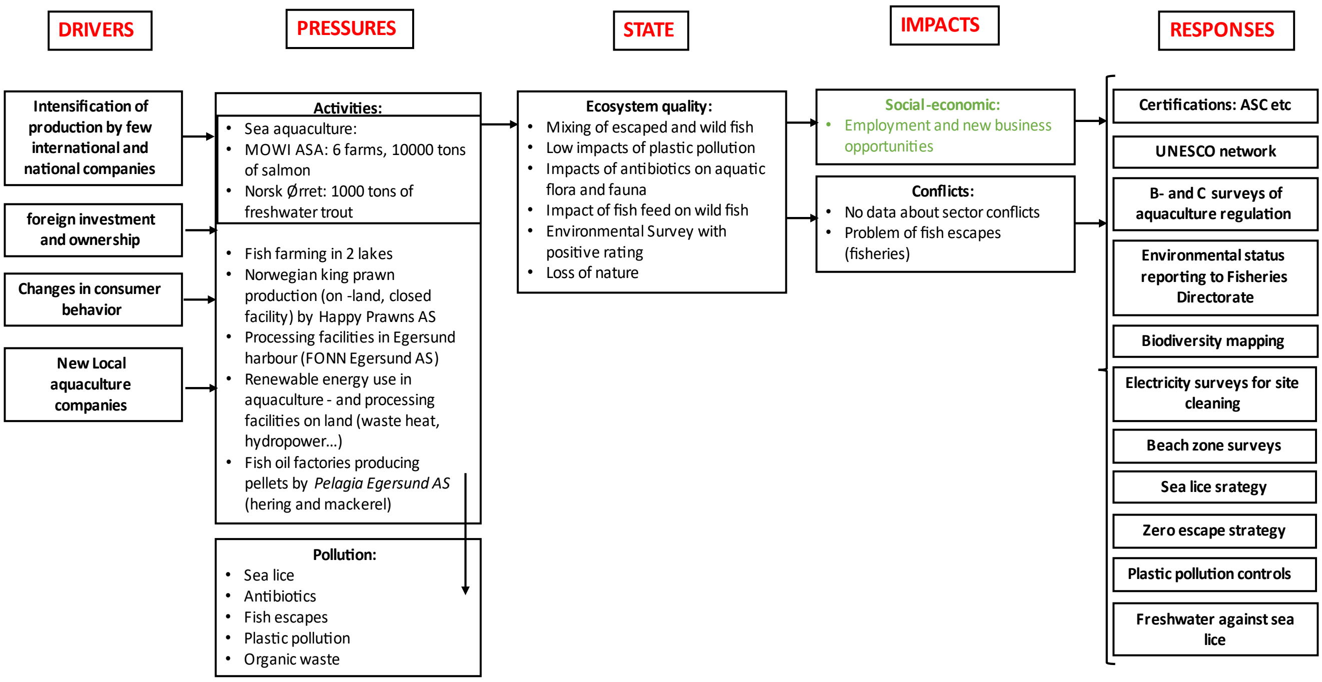

Figure 14. DPSIR framework for Egersund: Aquaculture

The global consumption for fish protein increases the need for more aquaculture production which is expected to double volumes of farmed seafood until 2050. The intensification of production by few international and national companies is a driver for aquaculture in Egersund. In the Egersund area there are 6 sea-based fish farms close to Magma Geopark[37] with an annual salmon production of 10000 tons, owned by the globally operating company MOWI ASA. Moreover, the local seafood producer Norsk Ørret, owned by the Egersund Group[38], has constructions for freshwater aquaculture on the terrain of Magma Geopark. Norsk Ørret produces 1000 tons of freshwater trout annually. Moreover, there is a fish oil factory in Egersund owned by Pelagia AS, a fish product producer that also manufactures fish feed pellets from mostly herring and mackerel. In addition, the company Happy Prawns has started Norwegian King Prawn aquaculture in a closed on-land facility. Here, energy is used from waste heat.

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[37] Please see the next chapter for more information about Magma Geopark.
[38] Egersund Group is a total supplier of trawling equipment, aquaculture nets and merchandice to the fishing fleet and aquaculture industry

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Environmental pressures caused by aquaculture are mostly associated with sea-based aquaculture which is linked to common risks of sea lice contamination, the application of sea lice antibiotics, fish escapes, the discharge of biological waste as well as minor plastic pollution.

In terms of changing environmental states, pressures from aquaculture activity in Egersund were mostly linked to potential negative effects on the surrounding marine ecosystem and species populations. Hence, accumulating sea lice in fish cages were associated with contamination risks for wild fish populations while the application of antibiotics against sea lice was associated with potential negative effects for wild marine species nearby cages in general. In addition, fish feed losses were linked to potential negative effects on other wild species nearby cages as well. This included e.g. changes in feeding behaviour. Lastly, fish escapes, which are considered low, are associated with risks of mixing between wild and farmed salmon. This comes with risks of gene manipulation and resulting changes of the natural fish physique. However, all these changes in environmental states are considered very minor. Accordingly, recent central aquaculture monitoring surveys addressing bottom impacts in the construction zone including hydrography, chemical analysis, and monitoring benthic communities (and more) rated aquaculture practises near MAGMA Geopark as almost entirely "very good".

Environmental pressures and changing states were linked to the following impacts: A positive impact was associated with regional development and employment that aquaculture brings in the Flekkefjord municipality where MOWI ASA is operating. This includes more than 100 employees. Aquaculture production also has business ripple-effects for other companies and service providers in Egersund in terms of e.g., equipment, fish feed, food production, or local energy providers. Another positive impact is linked to the fact that environmental assessments in the aquaculture area were continuously associated with positive results and low external effects. This suggests a positive ecological performance of the aquaculture sector in Egersund. There has been no information about current conflicts between the aquaculture sector and other industries. The only negative impact found are potential fish escapes and the risks of farmed fish mixing with wild fish. This was associated with potential conflicts with fishery activities.

Eventually, several responses were identified as a reaction to so far discussed pressures, states and impacts, but also to maintain sustainability in the sector. These include specific environmental assessments in terms of surveys (addressing impacts on benthic flora and fauna, electricity use, the cleaning of cage sides, beach surveys…), national Strategies (such

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as the Sea Lice Strategy, Zero Escape Strategy), plastic pollution controls, certification systems such as ASC or the Geo Food Brand[39], and environmental reporting to the Fisheries Directorate. Lastly, a more practical response to the risks of sea lice contamination was using freshwater against the parasites, a more sustainable way to address the problem.

[39] **The brand** supports the sustainable development of local communities by increasing actions towards the achievement of the SDGs in UNESCO global geoparks

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The figure below shows the DPSIR framework for the **tourism hub Egersund**, Norway.

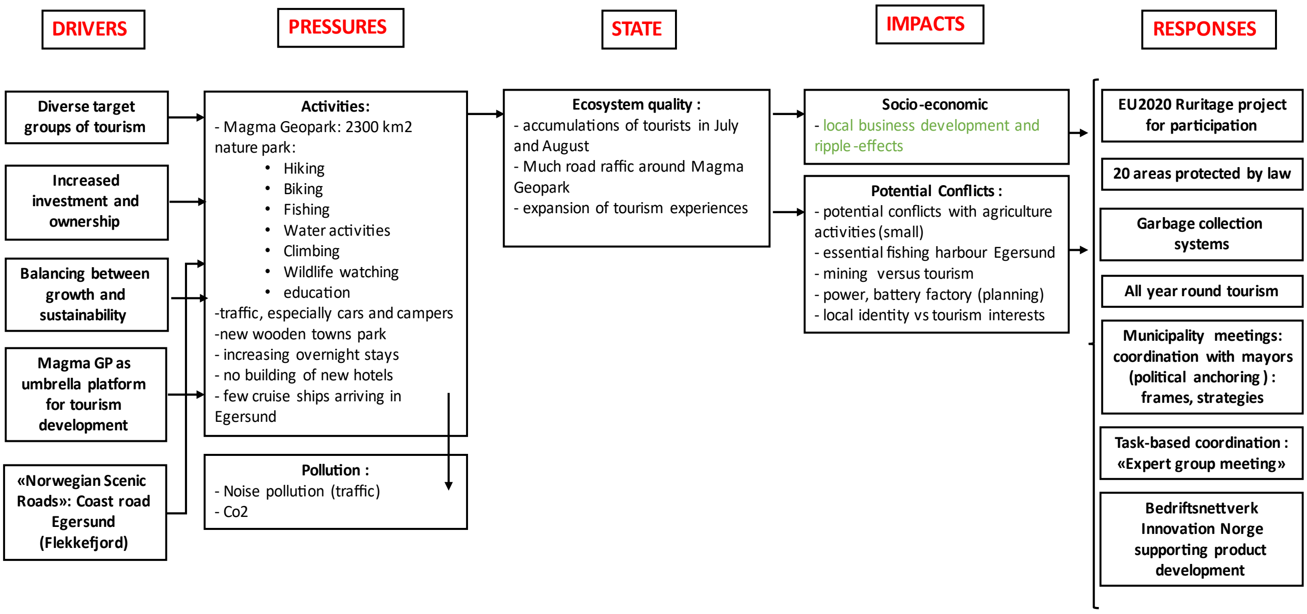

Figure 15. DPSIR framework for Egersund: Tourism

The demand for diversified tourism experiences and new investments into tourism activities have brought a slow, but steady tourism development to Egersund. At the same time, local acceptance and a compromise between sector growth and sustainable development have also become more relevant in the area. The most important tourism attraction in Egersund is the 2300 km2 MAGMA Geopark, a geographic area with a geology of major international recognition and which is included in the global UNESCO network. Magma Geopark is an essential driver for tourism, not only from a destination perspective, but also administratively: The brand Magma Geopark has become an umbrella platform for collaboration, exchange and planning for the 5 closest municipalities (Egersund, Bjerkreim, Sokndal, Lund and Flekkefjord), 2 counties (Rogalnd, Vest Agder), essential tourism businesses, museums, local institutions, and others. Another driver that attracts more tourists to the Egersund hub is its recent inclusion to the Norwegian Scenic Routes (Nasjonale Turistveger) portfolio. The Scenic Routes contain 18 selected roads that run through landscapes with unique natural

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qualities, along coasts and fjords, mountains, and waterfalls. The routes are intended as alternatives to the main roads, and the drive itself should be an enjoyable experience.

Tourism activities in the Magma Geopark are diverse and include hiking, biking, climbing, fishing, boat rentals, wildlife watching, but also exhibitions, local food and local products development and educational activities. Due to scenic roads and the many attractions in Magma Geopark, increased traffic is expected on a longer time frame in the Egersund hub, especially cars, campers and motorcycles. This is associated with noise pollution and elevated Co2 emissions, especially in summer. During the last years, overnight stays in Egersund peaked with 53300 guests, however, there are no plans for building more hotels and accommodations. Egersund is also a destination for cruise ships with up to 25 cruise ship arrivals in the town's harbour in the first half of 2023.

Few changes of the environmental state were detected in the hub. During the summer season, there is an accumulation of tourists especially in July and August which leads to more crowded areas in and around Magma Geopark. Moreover, there are continuous pans to add new tourism attractions to the park. E.g., currently a new project is the construction of a wooden town. In general, there were no noteworthy changes of ecosystems or habitats detected. Due to the extensive park area, tourism flows are balanced, and consequences of trampling or noise are considered as minor.

Several impacts were perceived in the Egersund hub, especially in terms of potential future conflicts tied to the Magma Geopark. First, some parts of the park are close to private agricultural landscape. There are few reported cases of trespassing tourists on private land close to the park trails, however, such conflicts are rather small. Second, potential long-term conflicts were associated with the multi-use of the Egersund harbour. Seasonal accumulations of tourists, cruise-shipping and other boat use could interfere with other sectors such as fisheries and processing industries. A potential conflict could also be that the capacities of the harbour to manage shipping traffic are getting exceeded. Third, prominent concepts such as nature-based tourism in Magma Geopark might get into conflicts with the mining industry. While dominating mining operators such as Titania AS want to increase exploration activities to find new mineral ilmenite deposits, also Norge Mining is planning a new mine in the hub area. This might come with land-use conflicts on the longer term. Also additional plans to build a new battery factory close to the hub might fuel such conflicts. Fourth, there is usually a finer line between tourist interests and expectations of local communities how to develop industries in the Egersund hub. On the longer term, too much interference of many tourists with local life could similarly lead to conflicts over time.

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Responses to pressures, states and impacts are the EU2020 participation program Ruritage which fosters local communities at the Geopark site, strict garbage collection systems for tourists and tourism facilities as well as continuous and expanding nature protection. Regarding the latter, there are currently 20 areas within the Geopark that are protected by National law. Moreover, a special taskforce within the Magma Geopark umbrella has been established. Here, important representatives from municipalities and other stakeholders come together to strategize on future activities relevant for the park. Lastly, to ensure an efficient product development and its marketing, the Magma Geopark umbrella is collaborating with the business network Innovation Norge.

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The figure below shows the DPSIR framework for the **mining hub Egersund**, Norway.

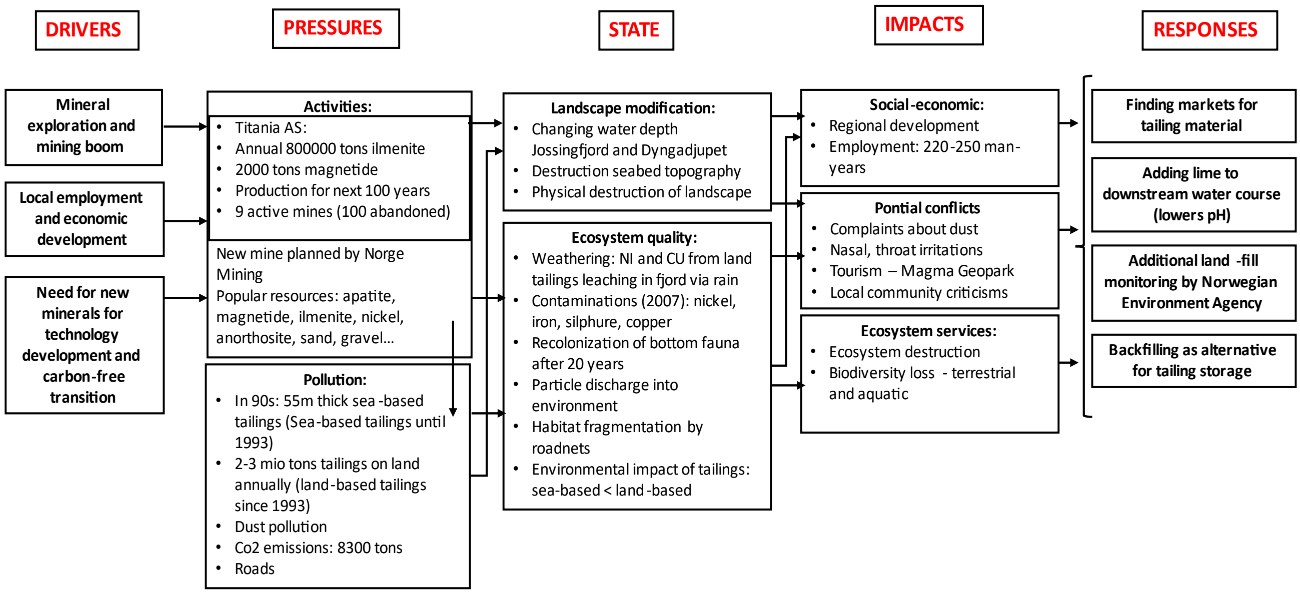

Figure 16. DPSIR framework for Egersund: Mining

The area nearby the Magma Geopark in Sokndal municipality has a long mining industry. The increasing demand for certain minerals and metals has led to continuous exploration in the area and various openings and closures of many mining grounds. At the same time a customers and financers call for sustainability has become more relevant as well. The mining industry is driven by the company Titania AS, owned by Kronos Worldwide INC which operates since the 1960s. Over the last years different kinds of minerals and rocks have been extracted out in the hub and there over 100 abandoned mining grounds. Today there are 8 active smaller-larger mines in the area. Here, Titania AS extracts 800000 tons of ilmenite and 2000 tons of magnetite in an open pit mine with production capacity for up to 100 years. Meanwhile, there are new plans to open new mining grounds to extract amounts of the high-quality rare metal vanadium. Also additional actors such as Norge Mining plan to expand the local mining business. Past and present mining activities have led to more infrastructure development which is expanding due to potential new mine openings and continuous exploration. This includes especially increasing road nets. Pressures exserted by the mining

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activities are linked to further environmental pressures in terms of pollution. Current mining activities are associated with an annual amount of 2-3 mil tons of mine tailings on land (with deposit license until 2026). In the 1990s, sea-based mine tailings were discharged into the Jossingfjord. This included 55m thick deposits in the bottom of the fjord. In addition, the mining activities are associated with CO2 emissions and dust pollution that can be locally intense at times.

The environmental pressures have changed of the environmental state over time: First of all, changing water depths of the fjord bottom are a result of past sea-based tailings. This includes the destruction of the bottom habitat and biodiversity such as benthic communities over time. However, assessments have shown that a recolonization of the fjord ground by bottom fauna happened within a time of 20 years. Second, land-based tailings are mostly positioned like a dam which is permeable for water. Through weathering processes amounts of nickel (Ni) and copper (Cu) are accumulated in draining rainwater which further transports these elements into the surrounding landscape and the fjord. Accordingly, contaminations of Ni, iron, sulphur, and Cu were detected in sediments across draining water flows in 2007 and such processes are ongoing. Moreover, the continuous destruction of landscape through mine openings has altered the natural environment and will continue with new mining exploration. Eventually, the DPSIR data included the suggestion that, on the long-term, sea-based tailings are associated with less environmental damage via pollution than land-based tailings, especially when it comes to contaminations with chemical elements. Assessments of the fjord bottom by e.g., NINA and DNV-GL (2017-2019) have shown positive results regarding the state of seafloor fauna biodiversity, but still measured toxic effects of metal content on organisms. The conclusion was therefore a “moderate” ecological state. Finally, increasing road networks and infrastructure are linked to habitat fragmentation of animals.

Impacts as understood and defined in the theoretical background of this report, were associated with the pressures of mining activity and pollution as well as the resulting changes of the environmental state. Positive impacts are linked to increasing regional development and more employment, with circa 220-225 man-years at Titania AS. Negative impacts are generally perceived when it comes to the irreversible ecological destruction of landscape that mining grounds cause. This includes losses of biodiversity. This is associated with ecosystem losses and the landscape is only hardly usable for alternative land-use options after mining closure. Further, complaints about dust circulation from the mines have become louder by nearby residents. Complaints and measurements were associated with nasal- and throat irritations. Potential bigger conflicts on the long-term can be associated with the mining industry and tourism. Current mining locations are close to the popular Magma Geopark. Future plans to expand tourism attractions in the park and new plans to open new mines and foster exploration in the tourism hub area can lead to land-use conflicts. Especially the tourism sector in Magma Geopark which uses concepts like nature-based tourism, is concerned about the future mining activities. Besides, also local communities have raised concerns about the changing environmental state of the natural landscape.

Finally, the following responses were detected as a reaction to pressures, states and resulting impacts:

- Searching for markets that can re-use tailings material is an option for including more circular approaches in the mining sector. However, this has not shown much progress during the last years.
- Adding lime to draining downstream water is a response to the contamination of metals and chemicals that is carried further into the environment by leaching processes. This significantly lowers the pH value of the water and makes it less toxic.
- When it comes to evaluations of tailings, the Norwegian Environment Agency is more involved in ongoing monitoring processes and assessments.
- In the future, finding opportunities for backfilling mining waste underground is an alternative for sea-based and on-land tailing depositions.
- There are recent and continuous funding efforts for research regarding the impact of mine-tailings. This includes sea-based and land-based tailings and contributors to associated research projects are e.g., SINTEF or DNV-GL.

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4.9. Westfjords

The figure below shows the DPSIR framework for the **aquaculture hub Westfjords**, Iceland.

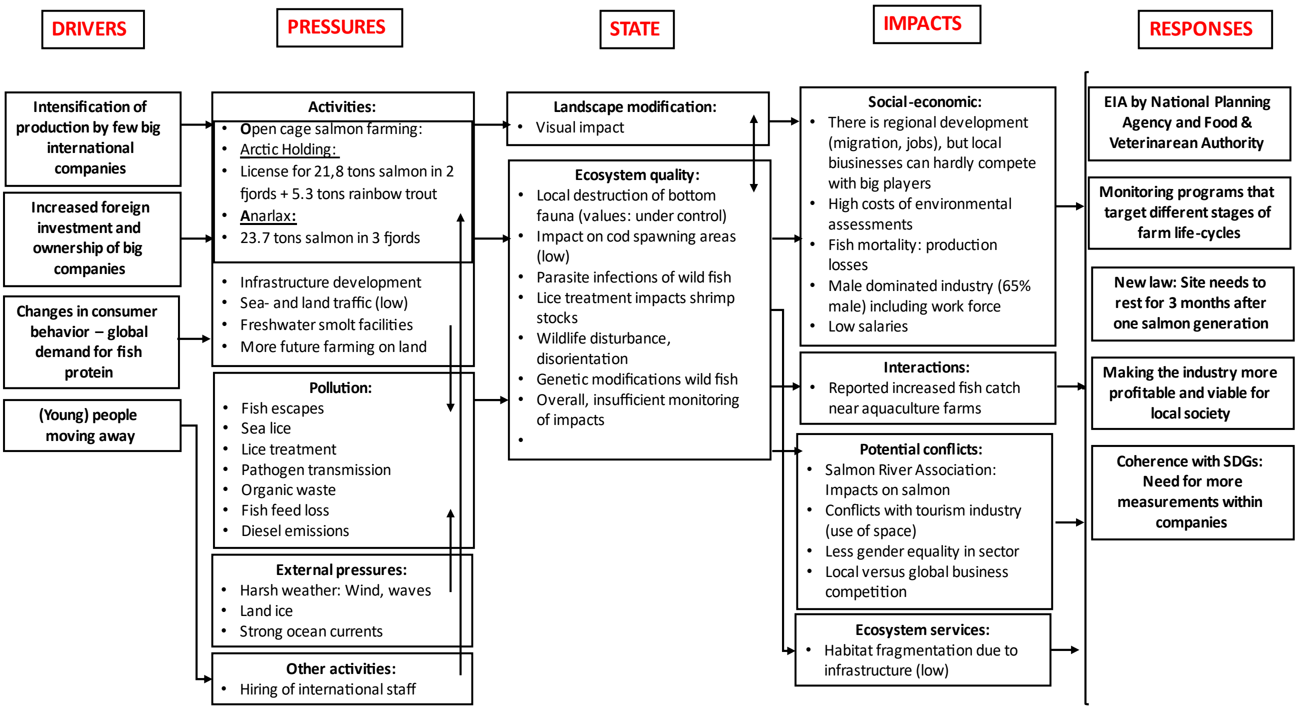

Figure 17. DPSIR framework for Westfjords: Aquaculture

The intensification of seafood production by only a few international operating companies, increasing investments because of rising consumer demands for marine protein, have caused a rapid development of cultivating Norwegian salmon in open sea cages in Westfjords since recent years. There are two operating aquaculture companies at the southern Westfjords: Arnarlax and Artic Fish Holding which are now in majority owned by Norwegian aquaculture companies. These companies want to expand their production in the area, rationalising the expansion by positive economic impact for the communities, such as population migration and job creation. Anarlax is owned by the (Norwegian) Icelandic Salmon Group, by 100%. Here, SalMar ASA (Norwegian) is the biggest shareholder of 51% of shares. Anarlax has licenses for 23.7 thousand metric tons of maximum allowed salmon biomass in three fjords: Patreksfjörður, Tálknafjörður and Arnarfjörður. Meanwhile, the company has applied for additional 4.5 thousand metric tons in the fjord Arnarfjörður. Another harvesting plant is in Bíldudalur with an annual capacity of 30000 metric tons. Anarlax also operates four freshwater smolt facilities with a combined capacity of 7-8 million smolts. In general, there is an interest of the sector to increase aquaculture on land.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869580.

Arctic Fish Holding ASA is owned by various shareholders with Norway Royal Salmon ASA in majority of shares by 51,28%. Smaller shareholders are mostly Norwegian. Arctic Fish Holding operates in the two fjords Patreksfjörður and Tálknafjörður with a license for 21.8 thousand tons of maximum allowed biomass of salmon and 5.3 thousand tons of rainbow trout (currently being converted to salmon licences). The company applied for additional 4.8 thousand metric tons. This year, the harvesting volume in 2022 was circa 9.4 thousand tons (18% lower than in 2021). The company owns licenses for freshwater land-based smolt production in Tálknafjörður and has, so far, produced 13 million smolts (dating back to 2022).

An additional local driver in Westfjords is population decrease and young people moving away to bigger cities is a trend. In response, the sector has become more dependent on hiring staff from over-regional places and international employees. The working environment of the local aquaculture sector is with 65% male dominated.

The aquaculture activities have in recent years increased infrastructure development in terms of roads, buildings, and facilities. There is also more land- and sea-based traffic which is associated with wildlife disturbance. Another pressure is also associated with weather conditions which can be harsh at times in terms of floating sea ice, strong ocean currents through winds, and high waves. Infrastructure development and aquaculture cultivation is linked to pollution pressures. This includes fish tailings in terms of biological waste from feces and fish feed leftovers, but also diesel emissions from ships and vehicles, but this is considered rather low. Regarding the former, biological waste has shown negative effects on cod spawning areas, however the degree of impact is rather small due to fjord currents. Similar pressures are exerted on bottom faunas as biological waste increases algal productions which reduce oxygen (however, also here the measured values are defined as low). Next to pollution, aquaculture exerts additional pressures by the common problem of sea lice contamination. The density of fish biomass in cages attracts sea lice and increases the risk that farmed fish contaminate wild fish that surround the cages. On the other hand, treatments that have been used to lower sea lice contaminations have shown negative effects on the health of shrimp stocks. Also, next to sea lice, potential pathogen transmissions from farmed fish to wild fish are perceived as a common pressure in the aquaculture sector. Moreover, there is a common problem of fish escapes which has negative impacts on wild fish in terms of genetic modifications. Such modifications reduce the natural adaptability of fish to the natural environment.

Pressures and states come with socio-ecological impacts. First, the increasing aquaculture production comes with positive effects on local regional development and employment.

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Second, local fishermen have reported an increased catch of fish near aquaculture farms. This may be caused by fish feed, however, detailed reasons in this context are unknown. Third, pressures such as fish feed loss, sea lice contamination or fish escapes require strict monitoring and reporting systems. Costs of environmental assessments are high and comes with economic pressures. Fourth, fish mortality caused by pressures exerted by aquaculture activities are associated with economic losses in terms of production and harvesting. Here, we it can be also thought of reduced health of wild fish due to e.g., fish escapes. This might also come with potential conflicts with fishery activities and interests of actors such as the Salmon River Association. Fifth, there are potential conflicts with the tourism industry when it comes to land-use in the future. Sixth, it is challenging for local businesses and communities to participate in the expanding aquaculture sector which is dominated by international companies with global businesses. This is fueled by decreasing salaries and an increased hiring of over-regional staff. Besides, gender inequality in the work environment is mentioned as a problem which comes with a potential risk of unequal opportunities when entering the work market.

Several responses were identified to pressures, states and impacts:

- Increasing EIAs are carried out by the National Planning Agency, and Food & Veterinerian Authority. Besides, public voices have raised the need to sharpen monitoring systems by addressing different stages of life-cycles of aquaculture sites more particularly. This includes also site removal and including time for local ecosystem recovery.
- A recent new law enfoced that aquaculture sites have to rest for three onths after each salmon generation that has been raised and farmed.
- Public local voices have raised the need for economic incentives that make a participation in the aquaculture market more easy and accessable for local businesses in Westfjords. More research and collaboration with external actors are necessary to move forward in such contexts.

The figure below shows the DPSIR framework for the **tourism hub Westfjords**, Iceland.

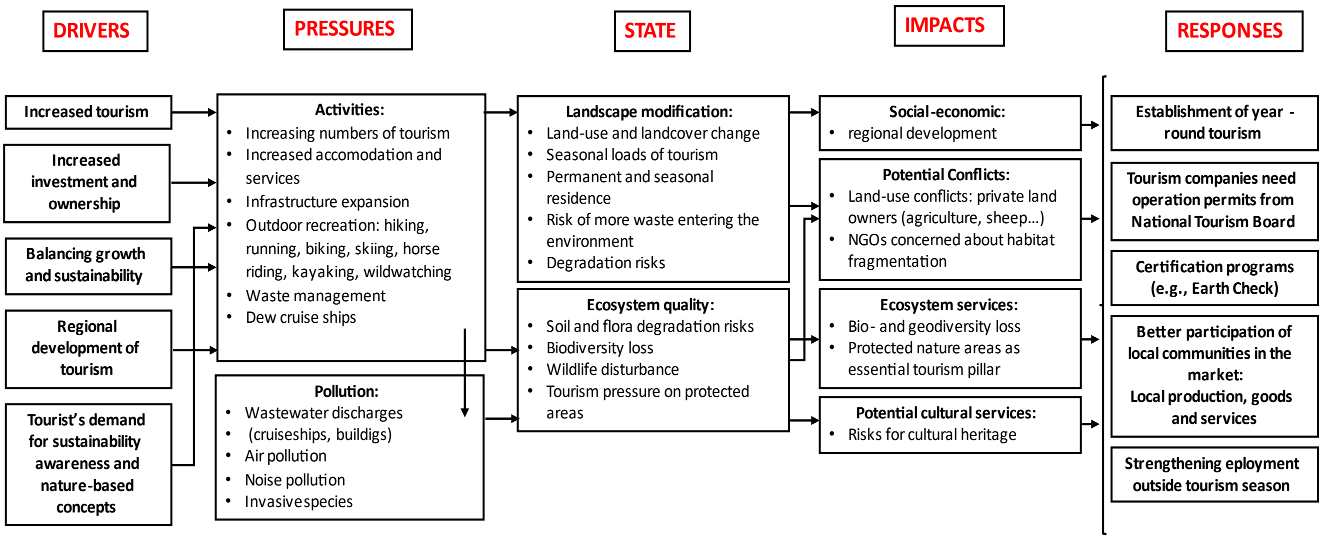

Figure 18. DPSIR framework for Westfjords: Tourism

The tourism sector in the Westfjords area is increasing because of more investments into destination activities, more tourists that want to enjoy unique nature, but also due to local aims to develop an attractive economy in Westfjords including workforce and regional development. At the same time a sustainable management of tourism becomes more publicly important. This is not only advocated by local communities, but also by tourists themselves as Westfjord is an attractive destination for especially nature-based tourism.

During recent years, overnight stays were increasing. Moreover, few cruise ships visit the Westfjord area every year. Tourism activities are mostly characterized by nature-based and adventure tourism: Visiting natural and historical sites, hiking, running, biking, horse riding, backpacking, racing, skiing, kayaking, fishing, bird watching, (other wildlife: seals and arctic foxes), boat trips, scooter touring in winter, cruise tourism, but also smaller event tourism such as film festivals. Expanding tourism activities and more infrastructure development are associated with pollution in terms of air pollution, waste discharges (especially from cruise

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ships) and noise pollution. Besides, the introduction of invasive species is a concern linked to the natural ecosystems on land, especially because of hiking and adventure tourism.

Pressures and activities are associated with negative effects on the environmental state. Hence, some tourism activities are linked to soil degradation which comes with risks for sensitive vegetation and eventually, risks of biodiversity loss. Noise production, and a continuous distribution of tourists in the Westfjords area is associated with wildlife disturbance on land and in marine environments. Eventually, the tourism activities are often seen as a pressure for protected nature areas that might become more accessible in the future. Over time, the industry has altered the land-use approaches in the area and changed the surrounding towns from self-subsistence economies such as small fishery activities and farmland to a continuously growing tourism sector with more opportunity to expand.

While the growing sector can be linked to positive economic feedbacks such as employment and regional development, there is on the long-term a demand for sustainable development of the sector that shapes management structures in line with nature conservation. On the long-term this philosophy is also perceived as essential for the further success of the tourism industry as untouched nature and scenic environments are a main attraction for all visitors. Lastly, expanding tourism is considered problematic when it comes to conflicts between different sectors. Unlocking surrounding areas for nature tourism might e.g., come with conflicts between tourism and local farmers. Besides, environmental NGOs have raised concerns for protected natural habitats and stress the need to set clear boundaries for tourism outdoor activities. All in all, the most central potential impact of tourism is associated with the the loss of bio- and geodiversity. Besides, also risks to cultural heritage are mentioned.

Responses have been identified addressing a need to maintain and expand nature protection areas. More recently, a milestone has been reached in this context when Iceland’s 2nd biggest National Park was initiated in the Westfjords area. Furthermore, all companies must collaborate more effectively with the Icelandic Tourism Board and need to fulfil more specific environmental criteria of operational permits. Also, certification programs gain more relevance such as EarthCheck which has sustainability certifications and programs for tourism businesses, hotels, destinations, governments, developers, building designers and more. As currently the tourism sector is rather seasonal with many tourists traveling to Westfjords in summer, the tourism industry could avoid potential pressures and accumulations of tourists by promoting and developing incentives for more year-round tourism activities. Eventually, to strengthen local community development, responses have been suggested in the hub to enhance opportunities for branding local products more locally when it comes to local products, services, and goods. At the same time, due to the seasonal character of tourism in Westfjords, a need for strengthening employment outside the tourism season is proposed to keep workforce and permanent residence in Westfjords constant and, at best, growing.

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4.10. Suðuroy

The figure below shows the DPSIR framework for the **aquaculture hub Suðuroy**, Faroe Islands.

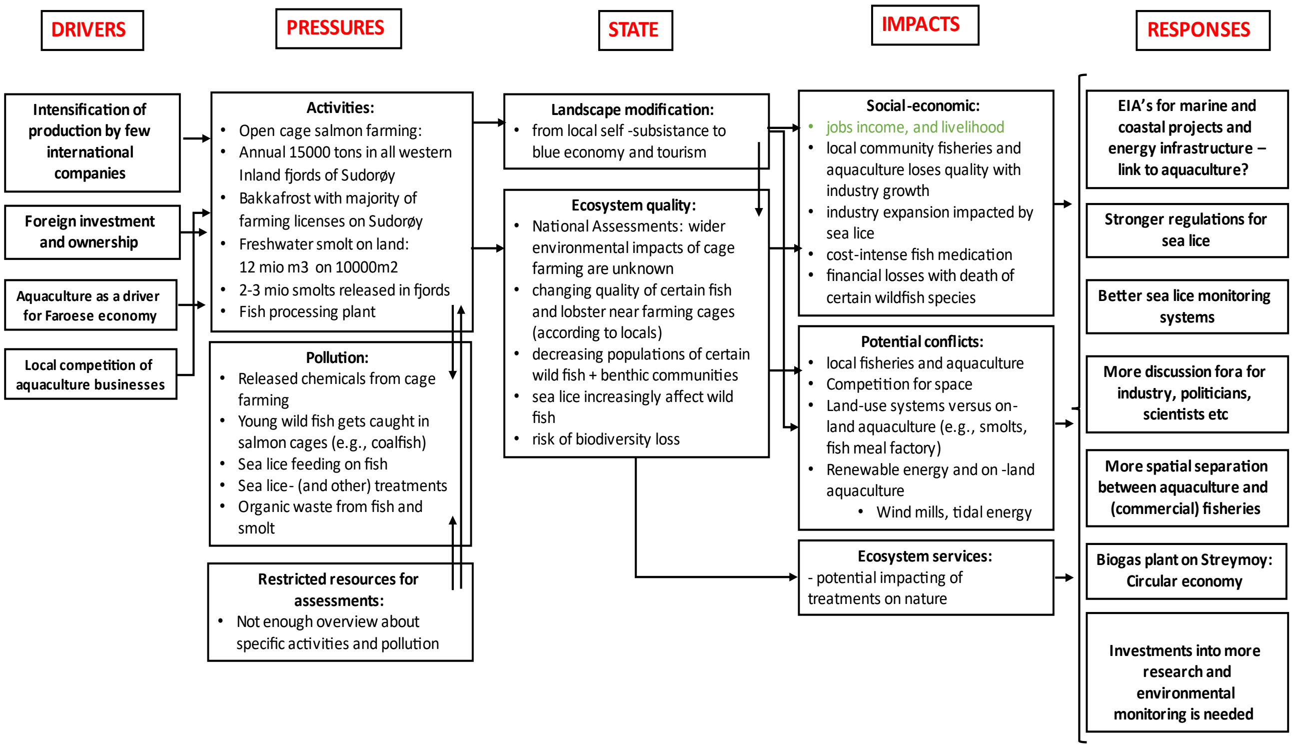

Figure 19. DPSIR framework for Suðuroy: Aquaculture

As a result of increased investment, Suðuroy experienced a relatively fast development towards a flourishing aquaculture industry. Globally increasing demands of marine protein and the intensification of aquaculture production by only a few operating companies have transformed Suðuroy from a location which was formally characterised by mostly smaller land-use businesses, to a large hub for open salmon cage farming. In general, the Faroe Islands are reported to have the largest production per capita of farmed fish in the world. All fjords and sounds in the Faroe Islands are exploited to full extent when it comes to open cage salmon farming. Since 2016, the production of salmon in the Faroes has ranged between 1.3 and 1.5 tons per capita. But also local competition between aquaculture companies is driving the industry. There are 7 municipalities on Suðuroy and aquaculture is an essential economic driver for all of them.

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In Suðuroy open cage-farming is applied in all western inland fjords of the island. The most active aquaculture company holding permits in the Suðuroy area is Bakkafrost which is characterised by open cage fish farming, fish processing and smolt development. The company's goal is to produce 15.000 tons of salmon within a few years, this equals more than 3 tons per Suðuroy inhabitant on an annual basis. Currently, Bakkafrost is constructing a new smolt plant which is expected to produce 3 million smolt annually with a size of 500g when released to the fjords. The plant will start operating in 2023. The smolt production facility is expected to require 12.000 cubic meters of production space, covering 10.000 square meters. The company also operates a fish processing facility on Suðuroy. Another global fish farm producer is Norwegian Mowi ASA. Examples for local aquaculture companies are Hiddenfjord Salmon and Luna.

Aquaculture farming activities are associated with several further environmental pressures. First, a continuous problem in aquaculture is fish contamination with sea lice, a parasite that feeds on fish and ultimately can lead to death. Sea lice treatments such as antibiotics are used to decrease contaminations, but have potential risks for the local water quality. Moreover, aquaculture is associated with biological waste production. This can be linked to not eaten fish feed, fish faeces that are discharged into the surrounding marine environment, but also biological waste from fish processing facilities. This might bare risks for algae production due to an overabundance of unnatural nutrients. Lastly, there are cases in which young wild fish or smaller fish species got caught in salmon cages (e.g., coalfish).

The pressures presented so far are associated with negative effects on the environmental state. Hence, local fishermen have complained about decreasing quality of certain fish and lobsters nearby fish cages. If this is related to biological waste, sea lice or chemical releases is not highlighted in the DPSIR data. However, in this regard there might be risks for decreasing wild fish populations due to e.g., sea lice contamination or the entangling in cage nets. However, with focus on environmental pressures of fish farming, more detailed knowledge about the wider environmental impacts of the industry is unknown. While national assessments have been carried out, there are still restricted resources available to expand such efforts. As a result, there is a lack of knowledge about what the effect of aquaculture on the Suðuroy ecosystems is and there is no baseline for comparison.

Changing states of the environment are linked to several socio-economic impacts. First, the intensification of the aquaculture production and abundance comes with impacts on local community fisheries and aquaculture because of e.g., reported decreasing quality of fish nearby fish cages. It is not specified why locals reported this issue. Second, industry

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expansion might increase at the same time the sea lice problem which can come with additional costs for treatment as well as economic losses due to dying fish. Third, fish medication is expensive and comes with additional costs. Furthermore, several potential conflicts can be associated with the expanding aquaculture sector. Here, the competition for space can make co-existence between different land-use systems more difficult in the future. This concerns not only interferences with local and commercial sea-based fisheries, but also interferences between sectors on land. It is forecasted that the future of Suðuroy aquaculture will also rise on land including smolt production, fish meal production and other. Another sector that is expanding land-use nearby the coastlines is the energy industry. Here, new wind mill- and tidal energy projects could potentially foster competition for in the future.

The following responses were identified in the data:

- Every aquaculture project must go through an Environmental Impact Assessment (EIA) that addresses new coastal projects or the development of energy infrastructure.
- There are fewer and more updated regulation systems and monitoring systems that target and monitor the problem of sea lice.
- The aquaculture industry and the government arrange discussion fora in which new projects can be negotiated and planned by including several stakeholders such as institutions, politicians, scientists, and others.
- There is a call for a stronger separation between aquaculture- and commercial fishery activities to avoid further developing conflicts.
- A biogas plant has been introduced on the island Streymoy. It has been newly constructed by a subsidiary of a constructing company operating on Su∂uroy. The facility makes use of biological waste discharged by aquaculture.
- Eventually, there is an urgent need to establish science-driven monitoring of environmental changes caused by extensive salmon cage farming. Here, more financial resources and staff are needed to establish databases and to interpret measurements over time.

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The figure below shows the DPSIR framework for the **tourism hub Suðuroy**, Faroe Islands

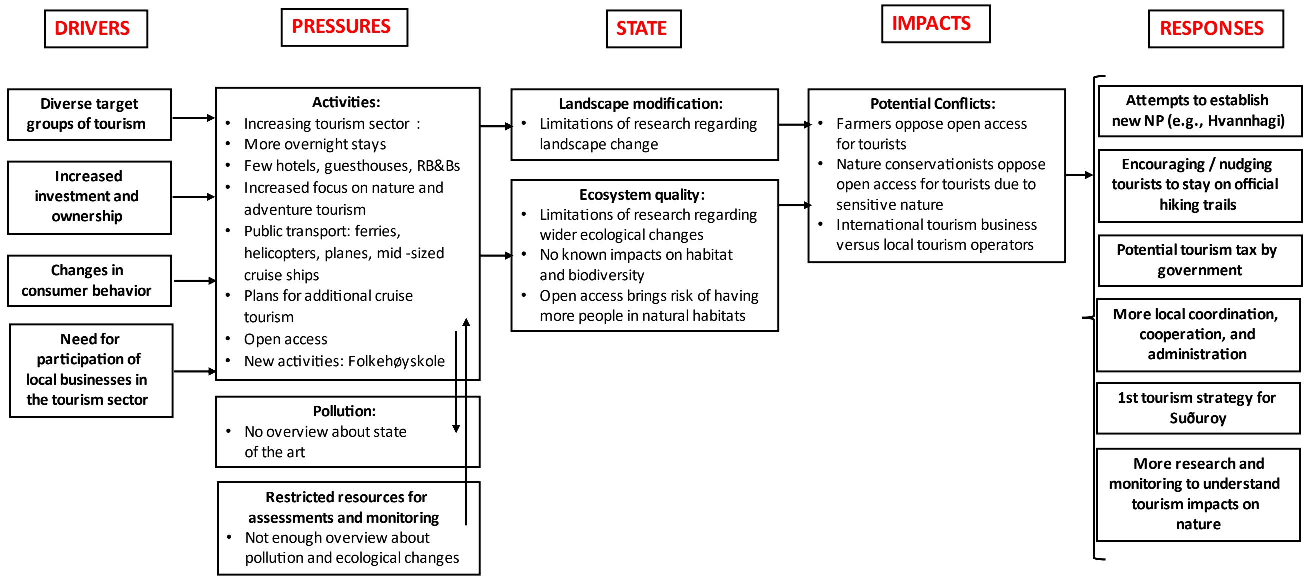

Figure 20. DPSIR framework for Suðuroy: Tourism

More local and national sectoral investments as well as a diversification of tourism target groups have developed Suðuroy towards a tourism destination. There are increasing overnight stays and new hotels, guesthouses and RB&Bs. The most popular tourism activities on the island include nature- and adventure tourism. Accordingly, public transport opportunities have further developed, and tourists can move over longer distances via ferries, helicopters, planes or mid-sized cruise ships. An important driver of the tourism development in Suðuroy is the demand of local tourism operators and local communities to participate in ongoing destination development and to strengthen their local position when it comes to accessing emerging tourism markets. This shall prevent an overtaking of the tourism sector by dominant international operators. Meanwhile, there are additional plans to strengthen opportunities for cruise ship tourism on Suðuroy.

Tourism activities are associated with changes of the environmental state to a low degree. Currently, there are no reports about ecological impacts by tourism on habitats or biodiversity. In addition, research addressing wider ecological impacts of tourism is very

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limited and there is a lack of monitoring programs or projects to overview potential consequences of tourism activities on environment and wilderness. A risks that is associated with tourism activities, especially nature-based tourism, is the open access for visitors to agricultural land and sensitive natural habitats. The latter has also been linked to socio-economic impacts where farmers are increasingly opposing open access for tourism to all parts of the island to protect land-use activity. Moreover, also nature conservationists oppose an open access for tourists when it comes to sensitive natural habitats.

Finally some responses were identified. First, there are attempts to establish more National Parks on the island, such as Hvannhagi National Park which is known for its unique geology and unique wilderness. This shall increase protection of Suðuroy's unique wilderness and ecosystems. Second, there are more measures developed that encourage tourists to stay on prescribed hiking paths. This responds to potential issues of trespassing tourists on agricultural land, but also to dampen an open tourist access to untouched and protected nature. Third, Suðuroy also developed a destination-specific tourism strategy as a point of departure for future tourism development. Fourth, incentives must be developed to make local tourism businesses more competitive with international operators and to grant them easier access to the sector market. This includes an integration of local operators in coordination, cooperation, and administration when it comes to destination development of Suðuroy. Fifth, there might be more potential to apply governmental regulations on tourism activities to safeguard the well-being of untouched nature on Suðuroy. Possible solutions are tourism taxes on products and tourism experiences.

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4.11. Nuup Kangerlua – Nuuk

The figure below shows the DPSIR framework for the **tourism hub Nuuk**, Greenland.

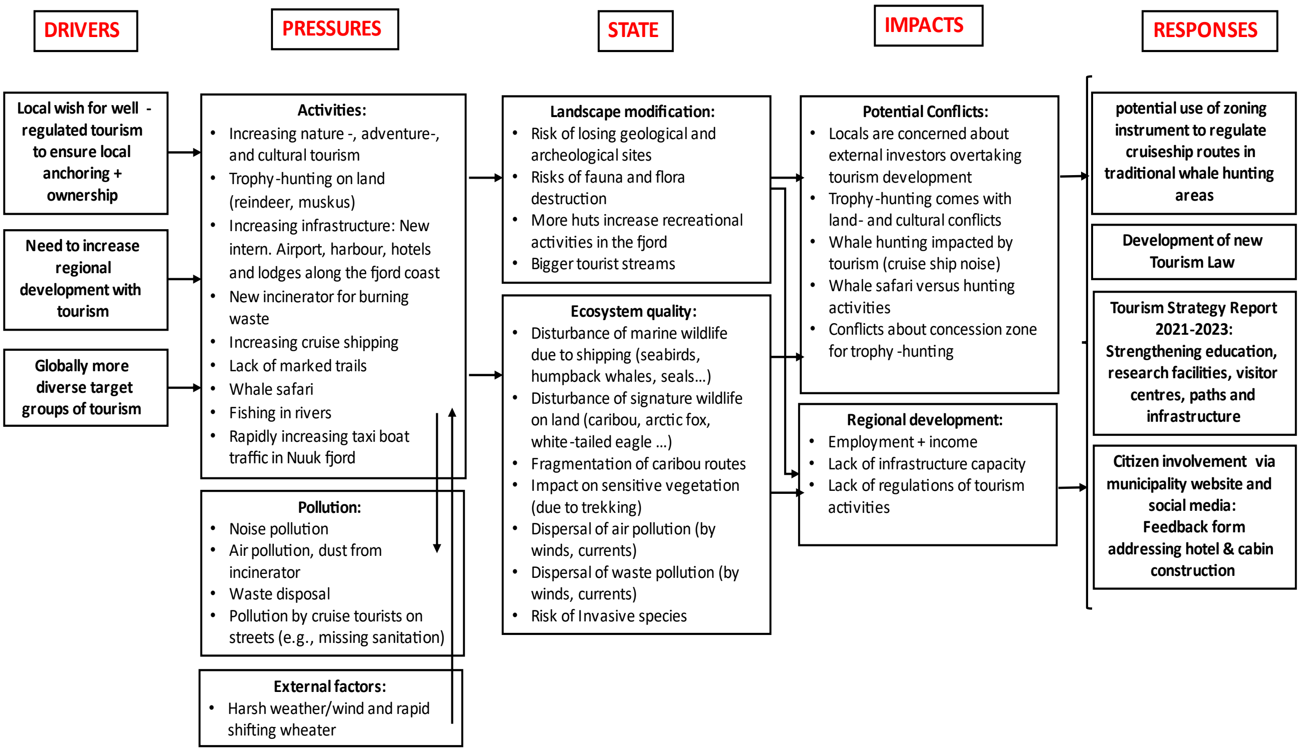

Figure 21. DPSIR framework for Nuup Kangerlua: Tourism

The tourism industry in Greenland is slowly increasing. Many of the tourism activities focus on the coastal and fjord environment, the main activities are nature-, adventure-, and cultural tourism. This includes whale watching, northern lights, photography, cruise shipping, boat sightseeing, fishing, hiking, kayaking, mountaineering, biking, trophy-hunting on reindeer and muskus and skiing. Furthermore, increasing numbers of cruise ships arrive in the harbour of Nuuk. As a result, significant infrastructural development has taken place: The airport and harbour in Nuuk have been upgraded, and new projects such as remote luxury wilderness camps and several new hotels opening in the city centre have been realized. In addition, a new incineration facility was built which burns waste from Nuuk and surrounding cities. The local municipal and national government wish to further develop the tourism industry in a sustainable way to increase employment and income from tourism in Nuuk. An important driver of the tourism industry in Nuuk is also a growing scepticism by the local community

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towards the expanding tourism industry. There is a local demand for a well-regulated tourism to ensure local anchoring in the regional market, to increase local ownership, and to foster local regional development.

The tourism activities and infrastructure development are associated with additional pollution pressures in terms of noise pollution from shipping, vehicles and helicopters, air pollution from traffic, shipping and dust from the incineration as well as increasing waste disposal that might get discharged in sensitive nature.

The pressures are associated with changes of the environmental state: Increasing shipping activities are associated with disturbances of marine wildlife including large mammals. In addition, increasing trekking activities and increasing densities of tourism groups are associated with concerns for the sensitive local vegetation as well as essential archaeological remains because of trampling. Regarding archaeological remains, insufficient signs and markings of respective sights are considered as additionally pressuring such remains. Expanding nature tourism is furthermore linked to increasing disturbances of terrestrial wildlife including protected mammals and birds. Eventually, wind transport and transfer of ocean currents negatively contribute to emission dispersal of air pollution as well as movements of waste litter to other pristine areas.

Pressures and changing environmental states come with several impacts. While regional development is associated positively with rising employment and income for the local population, a critical condition is the local acceptance and concerns for expanding tourism. The surrounding nature has a strong recreational and cultural value for people in Nuuk, and locals use the environment for traditional hunting, fishing, as well as for cabins and huts. Besides, locals have expressed skepticism if the current infrastructure can endure rising tourist numbers in Nuuk, especially when it comes to harbor space and facilities. Furthermore, several potential conflicts are associated with expanding tourism: First, trophy-hunting might interfere with traditional hunting grounds and other nature-based tourism activities in the future. More recently, such concerns led to heated public discussions. The municipal institution for Planning and Land Management proposed the creation of a concession area for trophy hunting at the bottom of Nuup fjord. It was met with massive opposition by fishermen, traditional hunters and locals and was therefore rejected by the municipal council[40]. Second, traditional whale hunting is impacted by noise pollution from tourist boats for whale

[40] ArcticHubs carried out a PPGIS study during the decision-making process. Please see more information in the continuing working packages.

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watching, but also from rising numbers of cruise ships arriving in the Nuuk fjords. Third, there have been conflicts about a new tourism regulation that reintroduced a passenger tax with effect from 1 January 2024. The passenger tax is DKK 50 per passenger and there are additional port charges when cruise ships dock in the harbor. However, the passenger tax is considered too low because there is a lack of money for infrastructure around the Nuuk harbor including walkways from ship to shore, sanitations, and routes. Fourth, locals are concerned about international external investors and tourism actors that acquire to much ownership on the market. Here, local communities stress the importance of local development and market access.

In response to mentioned pressures, changing states and impacts, the latest tourism strategy report (2021-2023) targets supporting measurements such as strengthening tourism education programs, research facilities that support sustainable tourism development, but also the establishment of more guiding visitor centers, more clear and structured paths, and in general an improvement of infrastructure capacities. Moreover, in response to local concerns about tourism, more opportunities for citizen involvements and citizen science approaches in local planning are fostered. Hence, the *Kommuneqarfiga* website from the Kommuneqarfik Sermersooq municipality enables citizens to start and share new ideas and receive support from fellow citizens. If an idea or wish has enough support, the political level has to address these aspects at *Kommuneqarfiga* to receive feedback from the citizens and stakeholders. Furthermore, there are plans to more effectively establish zoning measures to regulate cruises shipping in traditional whale hunting areas.

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The figure below shows the DPSIR framework for the **indigenous hub Nuuk**, Greenland.

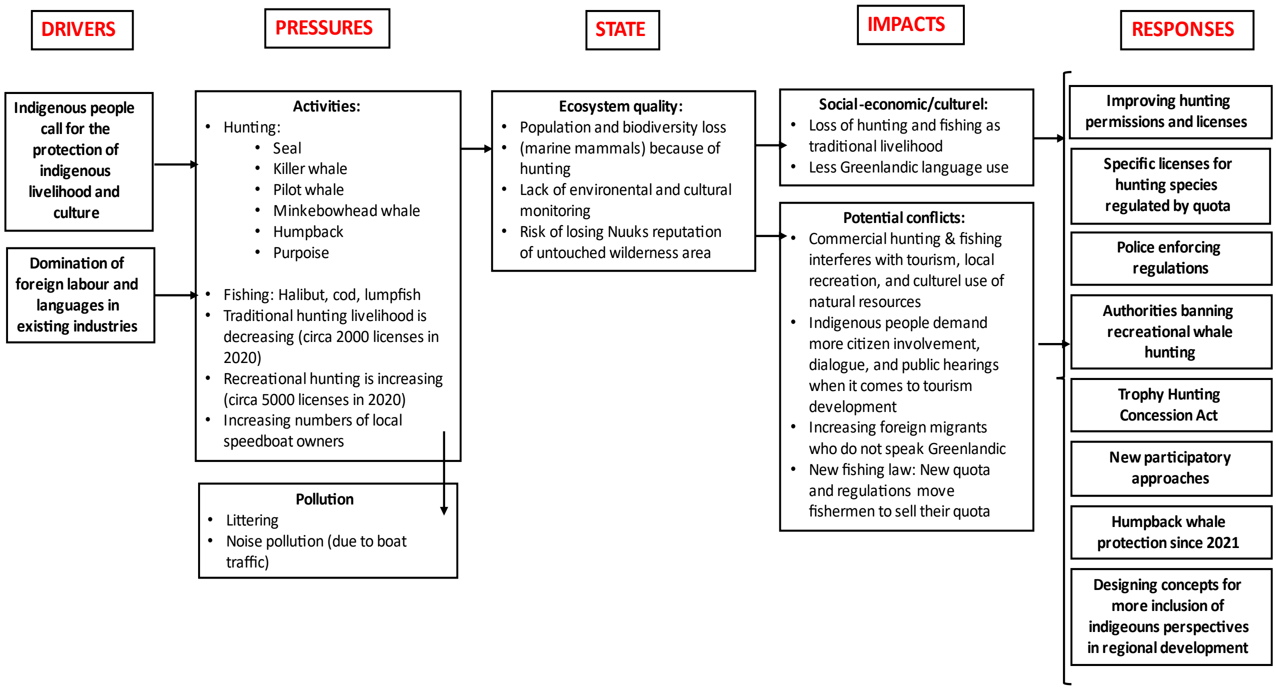

Figure 22.DPSIR framework for Nuup Kangerlua: Indigenous industries

When it comes to indigenous activities in and around Nuuk, hunting and fishing have been the livelihood for generations. Hunting is regulated by means of seasons and permissions. A general hunting license is mandatory for anyone, who wants to hunt. The general license comes in two categories: professional and recreational. In addition, a specific license is needed when hunting species are limited by quota. The quota system regulates the number of animals available for hunting. Professional hunting license holders usually do not make a full living from hunting. In addition, they will often do dinghy fishing in summer and ice fishing in winter. Nowadays, seal, and whale still play an important role. Whale species have hunting quota and meat and skin is consumed in Greenland only. On the other hand, reindeer and musk ox are the most important hunted land species. Besides, seabird hunting is regulated by means of quotas well, only a few species are not quota-regulated. In general, the police enforce the hunting regulations. Latest trends have shown that traditional hunting activities have been decreasing with circa 2000 licenses in 2020 while recreational hunting increased

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with over 5000 licenses in 2020. With traditional and recreational hunting and fishing also local speed boat owners are becoming more dominant in the fjords.

Concerning changing environmental states, consequences of traditional indigenous hunting and fishing are associated with population decreases of marine mammals and thus loss of local biodiversity. This emphasises potential concerns about Nuup's reputation as a natural wilderness area. However, the severity of hunting impacts is hard to estimate. There is an overall lack of environmental monitoring and overview about the degree of cultural hunting activities in the fjords of Nuuk.

Socio-economic impacts are linked to the protection of traditional activities and cultural identity which underline that hunting and fishing have been livelihoods for generations. Interferences with commercial fishing and tourism activities (trophy hunting, cruise ships) are associated with losses of cultural identity as well as commercial losses for indigenous peoples. Moreover, migrants that come to Nuuk to settle there or temporarily work in the municipality are dominantly speaking English and Danish, but not Greenlandic. This undermines closer interactions with local people and the understanding of cultural values and traditional activities.

Like other local communities, indigenous people have shared the views that increased citizen involvement is necessary to negotiate and solve potential conflicts between different kinds of land-use systems.

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4.12. Jokkmokk

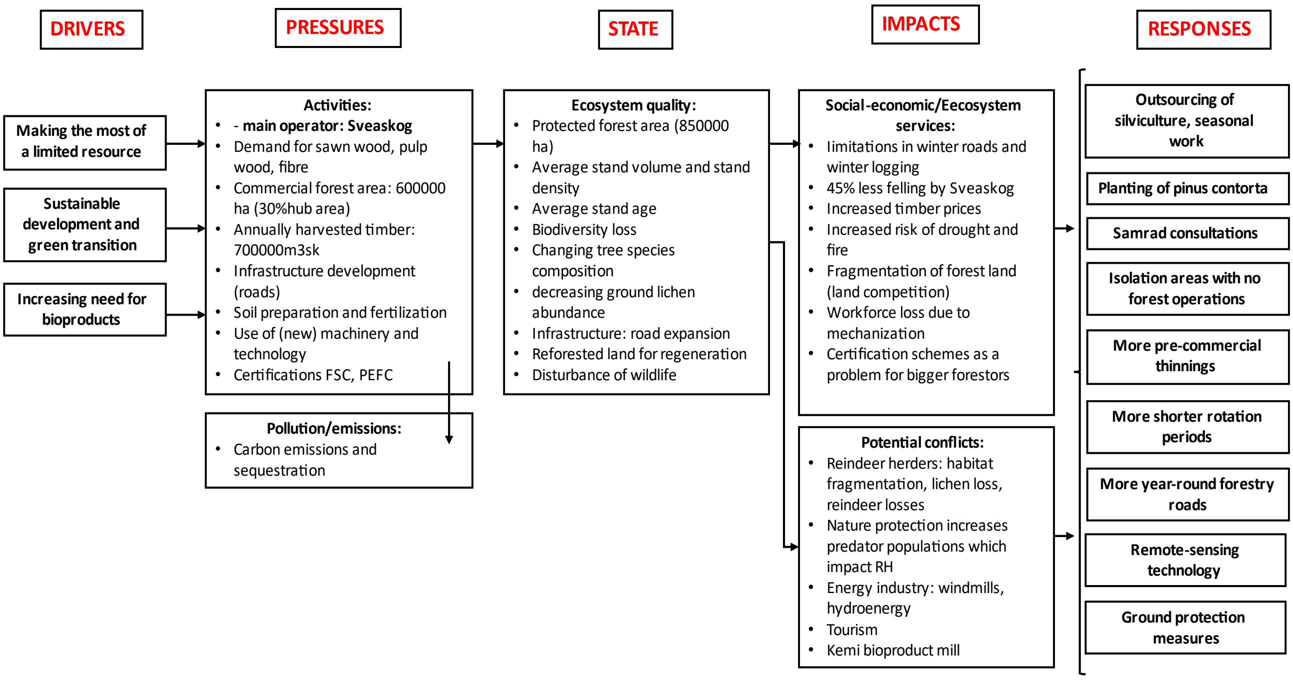

Figure 23. DPSIR framework for Jokkmokk: Forestry

Jokkmokk has almost as much forest resources as Gällivare. However, the annually harvested amount is much higher with 700 000 m³ of wood, forming the base of a strong position of forestry. However, there are discussions about how the forests should be used: In June 2002, a Government Commission was established to find new opportunities for wood procurement and search for “virgin” forests that were barely influenced by harvesting and therefore valuable for nature conservation. This sparked controversies in some parts of Norrbotten, where the biggest proportion of those forests was located, and Jokkmokk emerged as one of the places where the debate was particularly strong. Environmental goals can thus be a pressure to local forest owners. As of 2015, almost half of the total area of Jokkmokk municipality was under some kind of protection, which amounts to more than 850 000 hectares – placing Jokkmokk as number one in terms of absolute area protection, and number 4 in relative numbers among all the Swedish municipalities.

Forestry as a Driving force leads to several pressures on the environment and reindeer husbandry, mainly in form of decreasing biodiversity, especially lichen abundance, by forestry practices like clearcuts, soil scarification and fertilization, and the introduction of

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foreign tree species like fast-growing Pinus contorta. Meanwhile, forestry itself is under Pressure as well by the need to make the most of a limited resource and an expected increase in competition by the new Kemi bioproduct mill. Those factors lead to Responses like increased measures of rationalization, e.g. outsourcing of silvicultural work, shortening of rotation periods, or the aforementioned planting of Pinus contorta. As forestry is forced to make the most of a limited resource to meet rising demands of the bioeconomy and green transition, the use of new technologies and machines is rising, and remote sensing technologies become more important. This is a Response from forestry and other industries like RH as well, however, the pressure to keep up with this mechanization has also been described negatively, contributing to a shrinking workforce in forestry.

The green transition also leads to other pressures: for example, most bigger forest owners face troubles selling wood that is not FSC or PEFC certified. To fulfill environmental goals, some areas are set aside and excluded from forestry operations. This has positive Impacts on biodiversity as stand age and deadwood increase. For FSC certification, forest owners have to offer Samrad consultations with other Stakeholders like reindeer herders, and if those fail, harvests cannot proceed as planned. This was the case for Sveaskog, who have announced to reduce their final fellings in Norrbotten drastically because of failed Samrad consultations. As environmental protection became more important, predator populations in Sweden have risen drastically in the past decades, and while that has positive effects on biodiversity in many areas, it does pose another challenge for reindeer herding. Compensation payments are available for herders, but those are often criticized for being not sufficient.

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The figure below shows the DPSIR framework for the **mining hub Jokkmokk**, Sweden

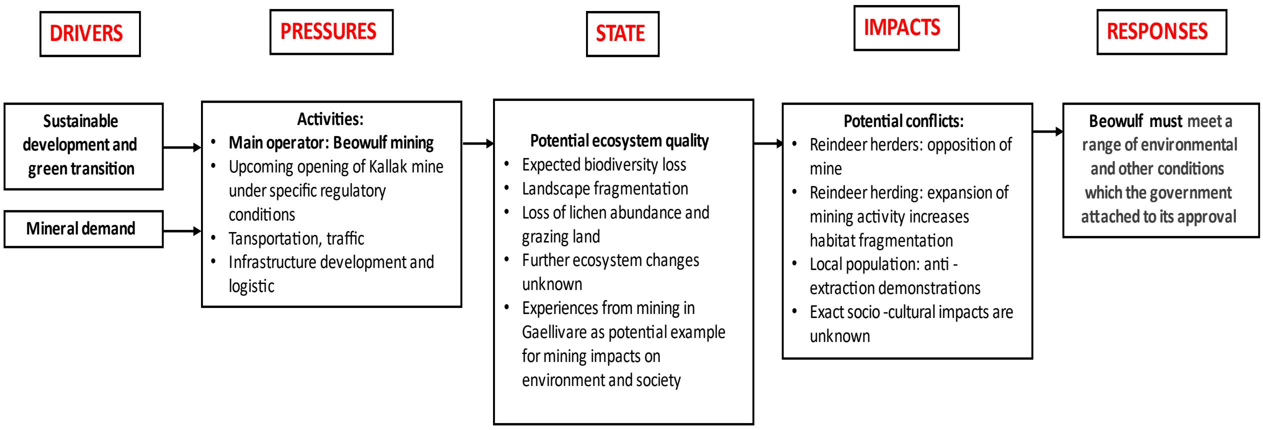

Figure 24. DPSIR framework for Jokkmokk: Mining

In all of Sweden, the call for sustainable development manifests itself in the green transition, a driving force affecting politics and market strategies of many businesses. For Jokkmokk, this means that on the one hand the increased need for minerals driven by this green transition led to the Kallak mine being finally granted an exploitation concession by the government. But on the other hand, the local opposition against the mining project demands another definition of sustainability, pointing out that the Kallak mine would put added pressures on Reindeer Husbandry, which is of great importance for Sami culture, as well as the environment, and tourism. Anti-extraction movements can be seen as a Response from society, but from a mining perspective, they are an essential pressure.

Exact potential activities and their impacts associated with the Kallak mine cannot be foreseen, but other nearby mining hubs such as Gaellivare might give hints on what environmental changes could be expected if a mine in Jokkmokk would be opened. However, exploration activities can be associated with potential noise pollution and infrastructure development around the exploration area. Plans to open the Kallak mine trigger mostly socio-economic impacts in terms of conflicts. Especially due expected biodiversity loss, especially lichen abundance, and resulting habitat fragmentation of reindeer, the indigenous industry and local community is strongly opposing an opening of the mine. A potential opening of the Kallak mine is tied to special environmental and social conditions that the mining company must fulfil. A future fulfilment of these conditions can be seen as possible a reaction to the demonstrative position of other industries and stakeholders towards future mining activities.

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The figure below shows the DPSIR framework for the **indigenous hub Jokkmokk**, Sweden

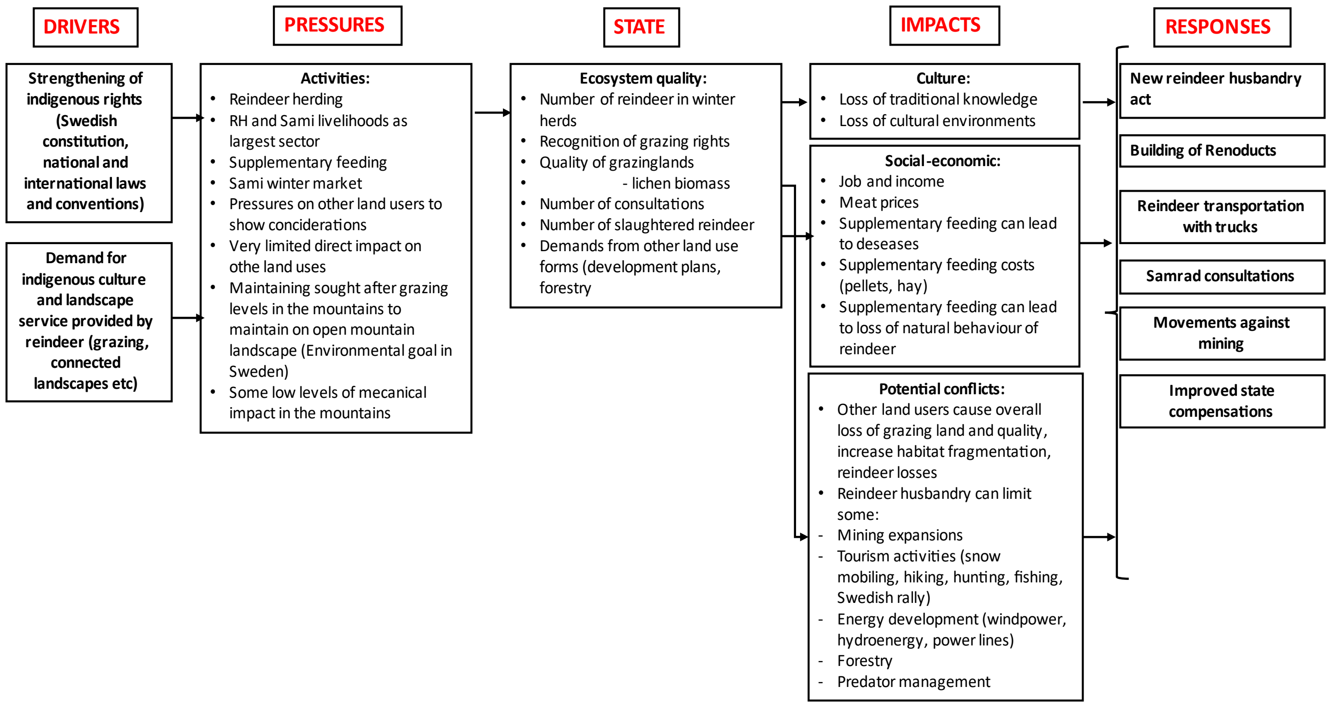

Figure 25. DPSIR framework for Jokkmokk: Indigenous industries

Jokkmokk is a well-known Sami culture center in Northern Sweden, attracting tourists especially during the annual winter market. Historically, Jokkmokk had always been a center for trade and meetings for the Sami population, and nowadays, it is often called the cultural capital of Lapland. The Swedish Mountain and Sami museum Ajtte is situated there, and the Sami Education centre Sámij åhpadusguovdásj, offering courses in Sami crafts, reindeer herding, and Sami language. An especially famous tradition is the Jokkmokk winter market, having taken place annually for more than 400 years, and attracting Sami visitors and foreign tourists alike. Sami culture is a main driving force in Jokkmokk. Indigenous rights are strengthened by the Swedish constitution and implemented in several laws and conventions. The most central indigenous industry is reindeer herding. Its direct impact on the environment is considered low in Northern Sweden and there is no essential impact on other forms of land-use. Pressures of reindeer herding on other industries are rather indirect: There is a pressure on other sectors to avoid interference with reindeer habitats. Reindeer herding has effects on the environmental state mostly by migration to seasonal pastures and by grazing selected

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vegetation such as lichens. Migration behavior (and slaughter) changes densities of reindeer herds over time and grazing changes the abundance of lichen biomass. Reindeer herding comes with several socio-economic- and cultural impacts. On the one hand, it provides important income for the indigenous community in terms of meat prices and goods like fur. On the other hand, especially because of land-use competition, reindeer herding often comes with extra costs for supplementary feeding or economic losses due to reindeer deaths. Most impacts are associated with conflicts with other sectors. Here habitat fragmentation and reindeer deaths caused by other industrial activities are major disputes. Prominent land-use conflicts occur with tourism activities (snowmobiling, hiking etcetera), mining (infrastructure development, traffic, tailing depositions etcetera), energy development (hydropower, wind power, power lines) and forestry (harvesting and planting trees, traffic, predator increase etcetera).

Several responses can be identified when it comes to pressures, states, and impacts. Migration of reindeer is often supported by herders by transporting reindeer to their seasonal pastures. Also, renoducts are implemented to overcome potential habitat fragmentation. Moreover, governmental measurements can improve the well-being of reindeer herding by offering financial compensations for reindeer losses, or establishing regulations, laws as well as policy papers such as the Reindeer Herding Act. Another important response is the fostering of collaboration and communication platforms where indigenous industries can come together with other industries for negotiation and to find ways for reconciliation when it comes to land-use conflicts.

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4.13. Malå

The figure below shows the DPSIR framework for the **forestry hub Malå**, Sweden.

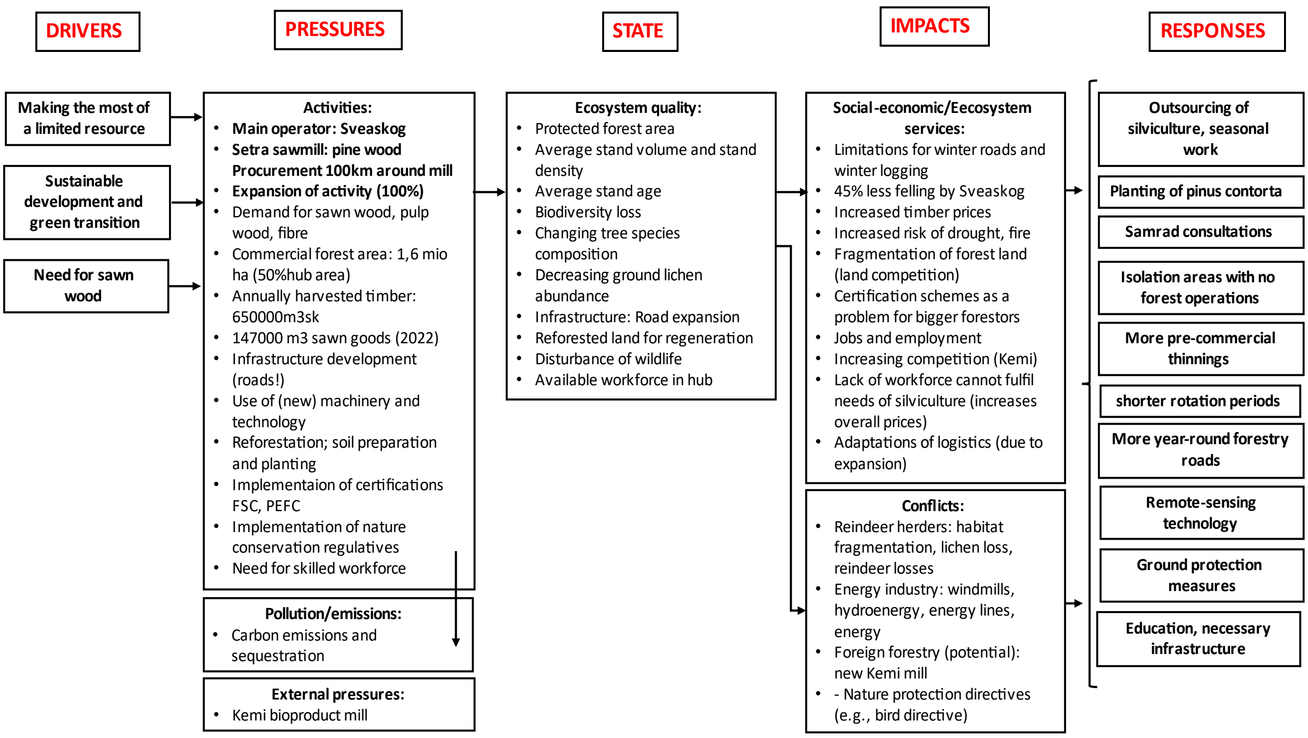

Figure 26. DPSIR framework for Malå: Forestry

With commercial forestry affecting about half of the hub area and harvests of almost 2 million m³, Malå hub is defined strongly by commercial forestry. In fact, the hub boundaries are defined as a wood procurement circle around the local Setra sawmill, which produces pine saw wood. As for 2022, the production of the Setra sawmill was 147 000 m³ of sawn goods, but this amount is expected to double in the next years. By-products like sawdust and bark are combusted in the adjacent power plant to supply heating to the municipality.

As the opening of the Kemi bioproduct mill is nearing, a new pressure on local sawmills will appear because of increasing competition. A pressure from forestry itself is the scarification of forest soil for planting, as well as fertilization in some areas – both affect ground lichen abundance negatively, thus impacting Reindeer Husbandry. There are also several impacts that are not originating from, but instead affecting forestry: Timber prices are expected to rise

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in response to the opening of the Kemi bioproduct mill and the expansions of Setra and other mills, which is a positive impact for forest owners, but negative for timber industry. Moreover A general lack of workforce impacts the forest sector negatively. Forestry activities alter the state of the environment by establishing commercial forest area and protected forest areas. Annually harvested timber changes the tree species composition, stand density and consequently also biodiversity. Biodiversity is also described by the Swedish indicators for "living forests". The green transition also leads to other pressures: For example, most bigger forest owners face troubles selling wood that is not FSC or PEFC certified. To fulfill environmental goals, some areas are set aside and excluded from forestry operations. This has positive Impacts on biodiversity as stand age and deadwood increase.

Like all Swedish forestry hubs, Malå faces impacts in terms of land-use conflicts. This includes reindeer herding which is negatively influenced by forestry activities because of lichen loss, habitat fragmentation and reindeer losses. Moreover, the energy industry may increase competition for land when establishing hydro energy, windmills or energy lines in forest areas. Responses to pressures, states and impacts of the forestry industry can be mostly separated into forestry methods that increase productivity and environmental conditions (e.g., thinning, the planting of fast-growing species such as Pinus contorta, rotations periods or reforestation efforts) and making use of communication and collaboration platforms such as Samrad consultations to avoid land-use conflicts. More linked to the former response, seasonal silvicultural activities like planting is more and more often outsourced by forestry companies as a special response to the growing lack of workforce.

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The figure below shows the DPSIR framework for the **mining hub Malå**, Sweden.

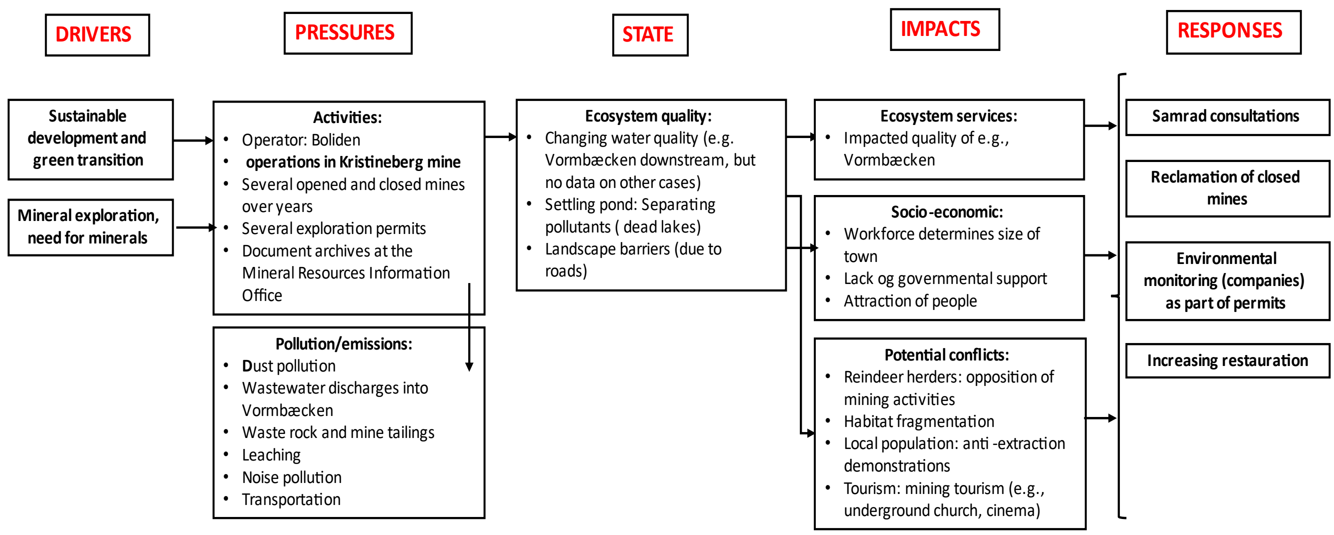

Figure 27. DPSIR framework for Malå: Mining

Another important industry in the hub is mining. Over the years, several mines have been operating and closed down again in this area. The oldest one that is still in operation is the Kristineberg mine, and several other explorations permits in the area indicate that mining will continue to play an important role in the future. Mining leads to several Pressures on the environment and environment-based land uses (forestry and reindeer herding) by dust pollution, mine dewatering, waste rock and tailings as well as noise pollution. Mine dewatering is impacting water quality negatively, which was measured in the Vormbäcken stream. Negative impacts to mining seem to be not overly strong in Malå: While there is the Pressure of an increasing societal opposition against mining in Sweden, this barely affects long-standing mines like Kristineberg in Malå.

Malå is also the location of the Mineral Resources Information Office. The office administers the Document Archives which comprise a large number of maps, exploration reports, field notes, drill core documentation, work material, and more. The hundreds of thousands of

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documents were collected over a period of more than hundred years and new material continuously added.

Mining in Malå comes with impacts on regional development in terms of local population increase through workforce. Moreover, there is future conflict potential when it comes to land-use competition with other sectors such as reindeer herding and tourism.

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The figure below shows the DPSIR framework for the **indigenous hub Malå**, Sweden.

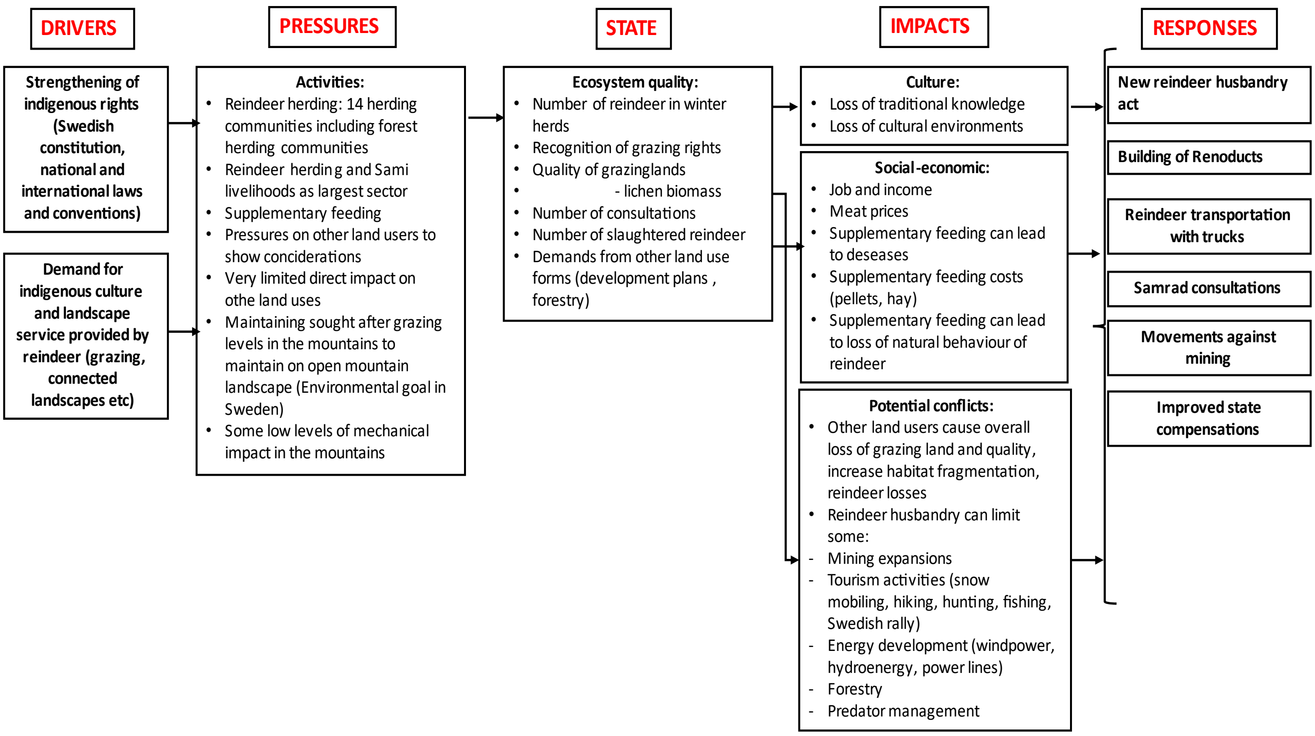

Figure 28. DPSIR framework for Malå: Indigenous industries

The Malå hub encompasses grazing lands of 14 samebyar (reindeer herding communities), thus reindeer husbandry also must be considered as a significant activity in the hub. Of those 14 samebyar, 9 have large areas in the circle that defines the Malå hub, amongst them the Malå skogssameby, Sweden's southernmost skogssameby. For forest reindeer herding communities, reindeer are not migrating from coast to mountains and back, but instead are dependent on suitable grazing grounds in smaller areas, containing summer as well as winter pastures. With some of those areas lost to mining, others to the windparks, and some more degraded by forestry, reindeer husbandry in the area finds itself again pressure from many sides. Reindeer herding itself does not exert many pressures on other land uses, however, there is a growing societal opposition against mining, which is supported by many reindeer herders. Reindeer Husbandry is impacted negatively by the loss of grazing grounds and migration routes, caused not only by forestry, but also by energy industry and mining. Another negative Impact affecting Reindeer Husbandry is the loss of traditional knowledge, caused by Responses to other negative Impacts and Pressures on this livelihood: As reindeer herders have to use trucks to mitigate the lack of migration routes, knowledge about those

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routes and their natural characteristics gets lost. As supplemental feeding becomes necessary to offset the lack of lichen in winter, the knowledge about remaining good grazing grounds may disappear.

One of the few indicators available for reindeer husbandry is the number of reindeer allowed in the winter herd. This number may not be accurate and the actual number of reindeer changes over the year, but it gives an idea of the profitability of Reindeer Husbandry in the area as well as the carrying capacity of the environment.

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4.14. Gran Sameby

The figure below shows the DPSIR framework for the **forestry hub Gran Sameby**, Sweden.

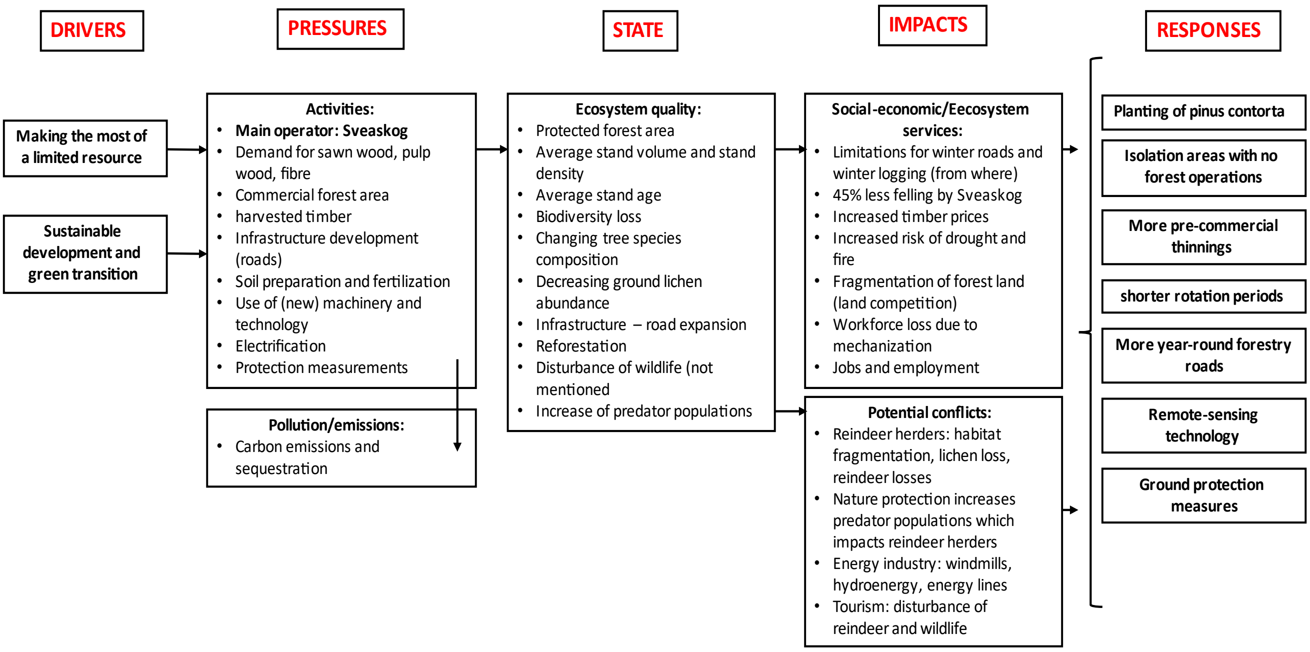

Figure 29. DPSIR framework for Gran Sameby: Forestry

Forestry is a Driving force shaping the landscape in the grazing grounds. Pressured by a rising demand for wood as a renewable resource, forestry often presents itself as a source for many Pressures and issues for reindeer gerding, like soil scarification and fertilization or a lack of pre-commercial thinning. The current State of the forest – which is the reindeers' winter grazing ground – can be represented by State indicators like commercial and protected forest area, harvested volume, average stand volume and density, average stand age, tree species composition, and hectares clear cut and reforested. These indicators all affect lichen abundance and thus determine the availability of winter forage for reindeer. Stand density also affects accessibility of grazing grounds, and clear cut and reforested areas affect local snow conditions. Possible responses by forestry include increasing their pre-commercial thinnings,

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which for example Sveaskog state as a goal, or setting aside areas without conducting the final felling there. On the other hand, many responses from forestry to the increasing demand of wood supply are on the other hand pressures and negative Impacts to reindeer herding: For example the planting of Pinus contorta, which is more productive than native species, leads to very dense forest structures, affecting lichen availability negatively, and shorter rotation periods and earlier final fellings take away the possibility of forests getting old enough to develop a rich lichen cover. One response sought out by both foresters and reindeer herders to deal with this issue are Samrad consultations, and often, solutions that are favorable for both parties can be found. However, a sameby also often gets a great lot of requests for Samrad consultations, which can be another pressure during times of high workload.

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The figure below shows the DPSIR framework for the **mining hub Gran Sameby**, Sweden.

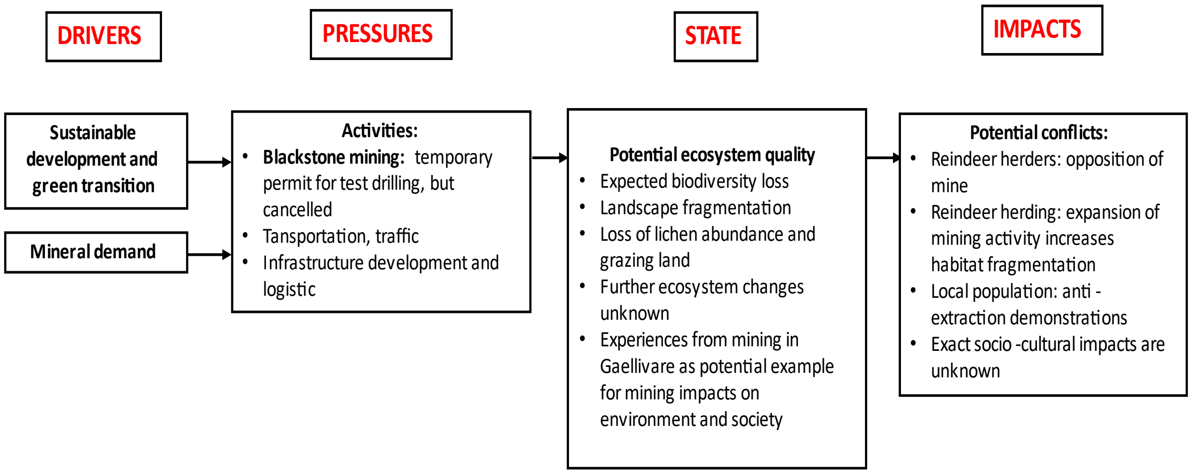

Figure 30. DPSIR framework for Gran Sameby: Mining

Around 15 years ago the exploration company Blackstone Nickel carried out investigations for opening a new mine in the Gran Sameby area. The area is a natural grazing area for reindeer which meant major problems for the local reindeer herders. The area is furthermore a nature reserve. Eventually, Blackstone had to pay the community of Gran Sameby a high compensation and went bankrupt at the same time. Meanwhile there are plans to grant new exploration permits to other companies, however, local opposition is high.

It is hard to foresee with what kind of activities and pollution a realization of a mine in the Gran Sameby area would come. In this regard, the mining hubs Malå and Gaellivare can be an indicator for what pressures, states and impacts can be expected if a mine was opened in the Gran Sameby community. The DPSIR framework in figure 29 is hence potential and is inspired by basic DPSIR outcomes from Gaellivare and Malå.

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The figure below shows the DPSIR framework for the **indigenous hub Gran Sameby**, Sweden.

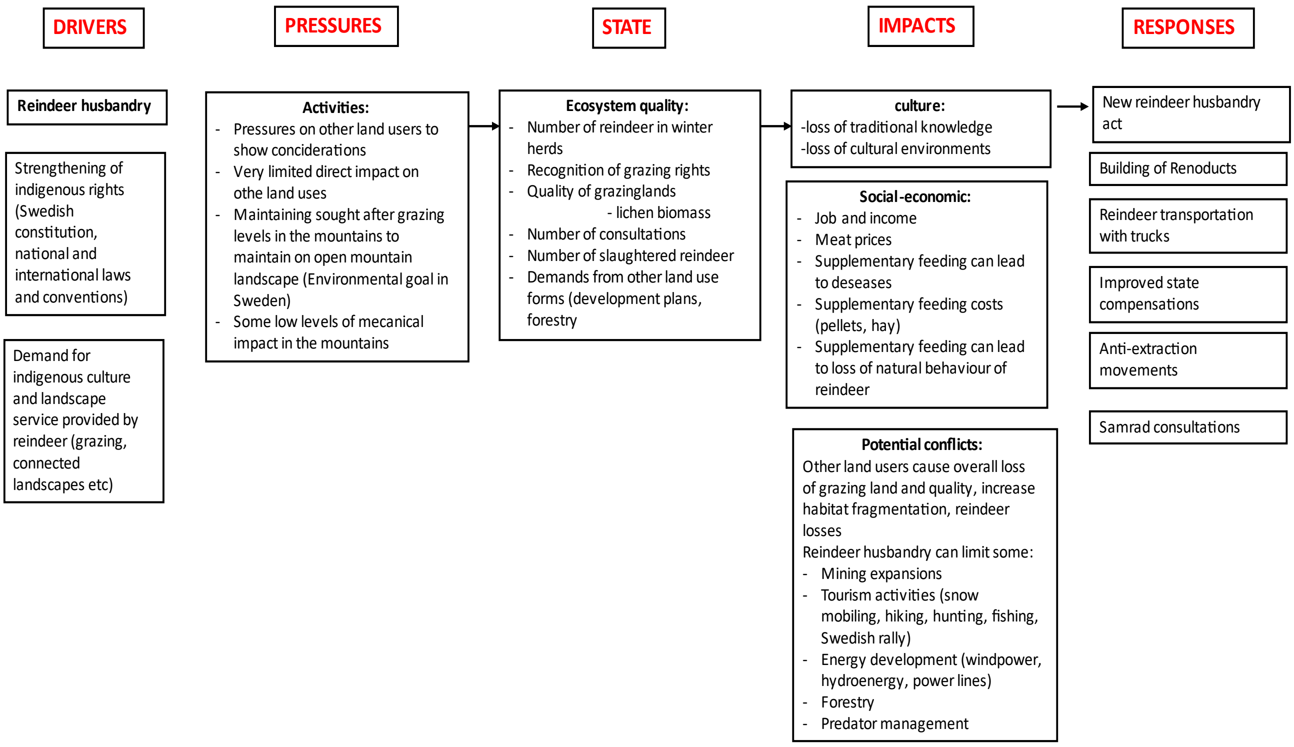

Figure 31. DPSIR framework for Gran Sameby: Indigenous industries

The Gran hub consists of the reindeer grazing grounds of Gran Sameby. Reindeer herding itself exerts barely any Pressures on existing industries and land uses, but can be a barrier to the establishment of new land uses, for example mining. In other cases, new land use projects got approved, e.g., the Högaliden wind park, which does provide about 300-400 GWh of renewable energy, but on the other hand is a barrier for migrating reindeer. Another often overlooked Pressure to reindeer herding is the use of new technology and machines: while dirtbikes and truck transporting of reindeer allow for an easier migration, they also lead to a loss of traditional knowledge. Other new technology, like remote sensing and drone use, can however lead to the generation of new knowledge. To describe the current state of RH, State indicators like herd size, meat prices, and number of slaughtered animals can be assessed; another important indicator is the availability and use of emergency funds. Negative Impacts to reindeer herding are the loss of grazing grounds and migration routes, and direct reindeer losses to predators, traffic, and diseases. Reindeer herding responds to the many Pressures and

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Impacts by transporting reindeer with trucks, but this can contribute to the aforementioned loss of knowledge, or by feeding reindeer to offset a lack of winter forage, which can, however, cause the reindeer to behave less naturally or even affect reindeer health negatively if done wrong or if leading to the spread of diseases. Feeding with hay instead of pellets is said to be healthier, and the way of feeding is important: Which areas are chosen for feeding and how the hay is spread out affects the reindeers' behaviour. One noteworthy Response of reindeer herders from Gran to the more and more complicated migration was to secure a project for building a Renoduct, a safe passageway over the E4 road.

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4.15. Gällivare

The figure below shows the DPSIR framework for the **forestry hub Gällivare**, Sweden.

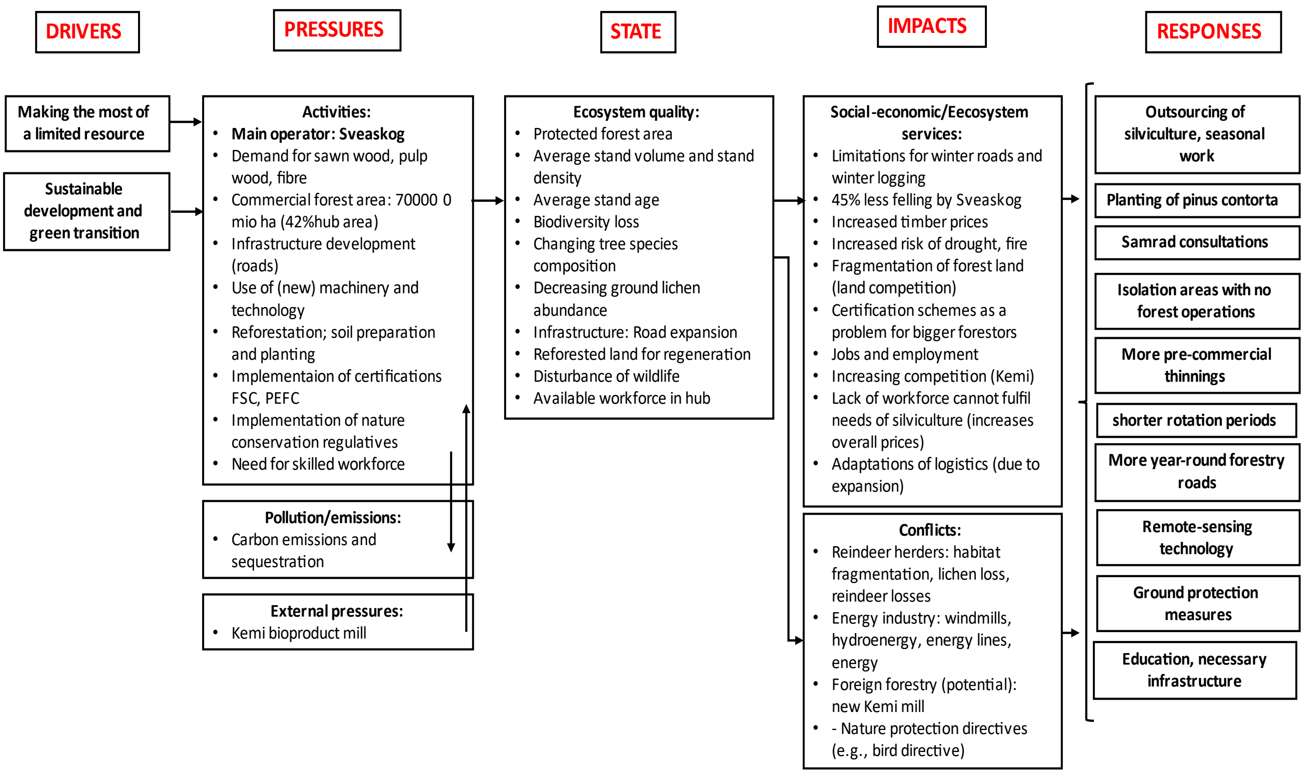

Figure 32. DPSIR framework for Gällivare: Forestry

An important land use in the area is forestry, and while a large share of the forests is available for commercial forestry – 700 000 hectares, making up 42% of the hub area – the competitive mining salaries lead to a lack of workforce, which is usually compensated by outsourcing silvicultural work and relying on seasonal workers. As demand is rising and the opening of a new bioproduct mill in Kemi is pending, forestry must look for ways to increase production – shorter rotation periods and the introduction of Pinus contorta are the response of many forest owners, but those measures add to the pressures on Reindeer Husbandry. The largest forestry actor in the area is Sveaskog. As the Samrad consultations with reindeer herders have failed, Sveaskog has announced a reduction of the final felling area in Norrbotten by 45% - a huge number, concerning to wood processing industries.

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Pressures from forestry affect environment and Reindeer Husbandry as well. Most forestry ressures could be classified as responses as well, as rationalization and the need to make the most of a limited resource force forestry companies to shorten rotation times, plant fast-growing species, and fertilize weaker soils. Those measures usually decrease lichen abundance, a defining factor for the state of reindeer grazing grounds, and often those measures affect biodiversity as well, for example by decreasing stand age as forests cannot grow so old anymore. Responses from forestry include set-aside areas with no forest operations in order to conserve the natural environment; increased pre-commercial thinning in areas important for Reindeer Husbandry in order to avoid the stands becoming too dense; and remote sensing technologies for rationalization as well as the detection of damages that might stem from climate change events like storms or insect pests.

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The figure below shows the DPSIR framework for the **mining hub Gällivare**, Sweden.

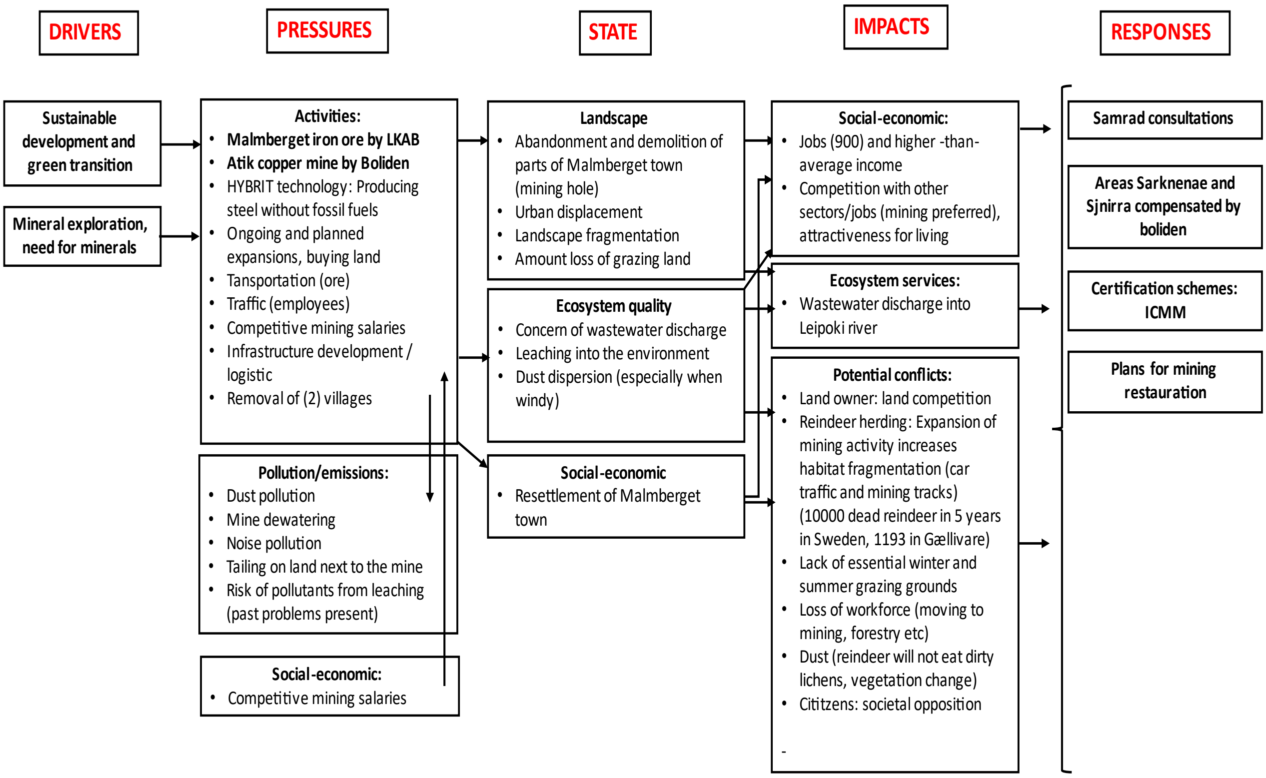

Figure 33. DPSIR framework for Gällivare: Mining

Mining in Gällivare hub is prospering thanks to the „green transition ", which calls for a higher degree of decarbonization and reduction of fossil fuel use. The mineral demand increases, and the two mines in Gällivare – the Malmberget iron ore mine owned by LKAB and the Aitik copper mine owned by Boliden – help Sweden gain a forerunner position in mineral extraction in Euorpe. As the interest „greener «solutions is growing, new techlogies are being developed – noteworthy, the innovative HYBRIT technology, developed by LKAB, SSAB and Vattenfall, a new way of producing steel without fossil fuels. A demonstration plant is being planned in Gällivare for 2026.

The town of Gällivare it is often called a „mining town «and mining is a rather highly valued activity in the municipality, providing jobs and a higher-than average income. The Aitik mine alone provides 900 jobs. However, there are several Pressures and negative Impacts originating from the mining companies: the large land demand for mining operations and

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mining waste is concerning landowners and has already led to the abandonment and demolition of large parts of the Malmberget town. Environmental impacts of wastewater are also a concern.

Mining exerts several Pressures on the environment, like dust pollution, mine dewatering leading to discharge of polluted water, waste rock and tailings, and noise pollution. In addition, it exerts Pressures on the human environment, in the form of providing very high, competitive salaries on the one hand, leading to positive impacts, but on the other hand, the resettlement of the Malmberget town, leading to increased societal opposition against mining. These Pressures and Impacts on the human environment in turn affect the natural environment. Additionally, the Pressures from mining affect Reindeer Husbandry, a livelihood strongly dependent on natural environments. Mining responses include compensation areas for increasing biodiversity and participating in Samråd consultations with reindeer herders to find solutions together.

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The figure below shows the DPSIR framework for the **indigenous hub Gällivare**, Sweden.

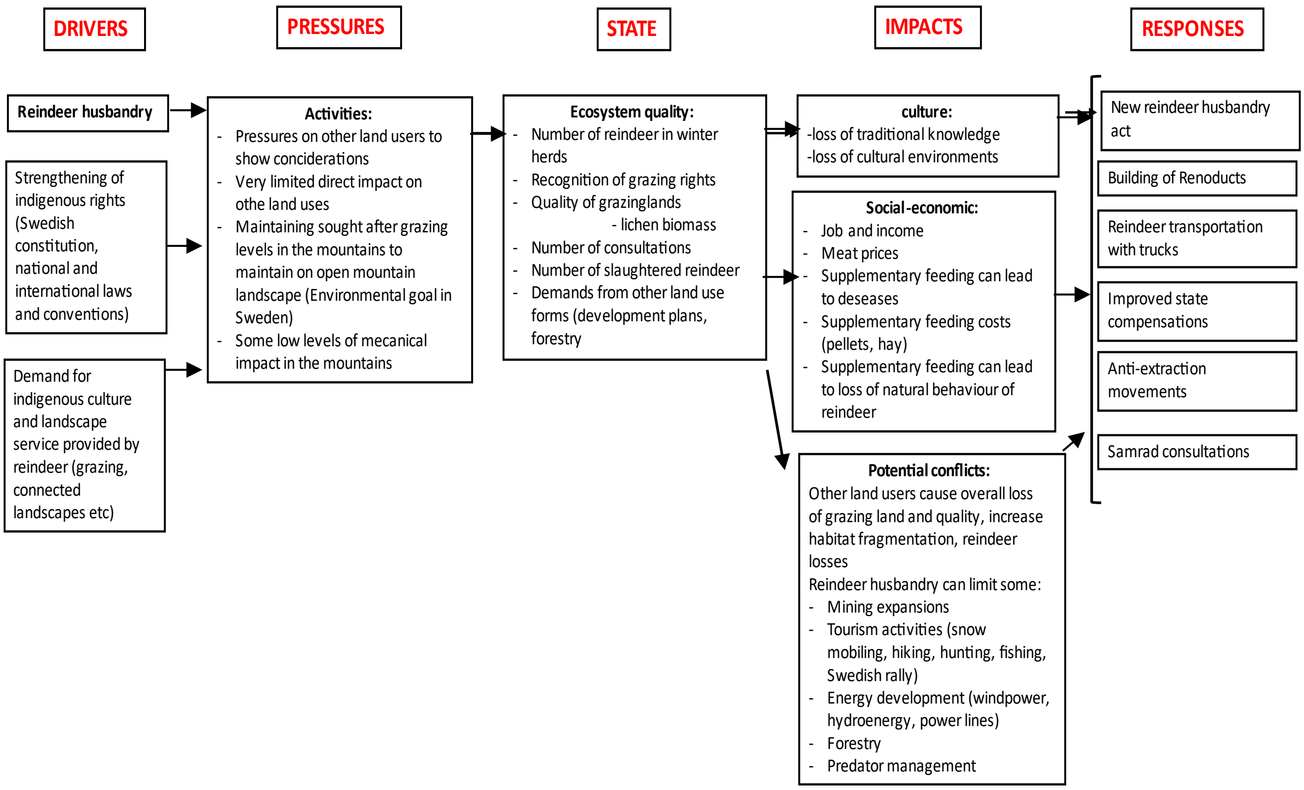

Figure 34. DPSIR framework for Gällivare: Indigenous industries

Reindeer Husbandry in the area is wary of a further expansion of the mining sector: a lack of grazing grounds, especially in winter, and a fragmentation of reindeer migration routes are impacting Reindeer Husbandry in the area very heavily. Common forestry practices like soil scarification or fertilization before planting are harmful to lichen, and the standard clearcut methods do mostly not allow for forest stands to get old enough to form a good lichen habitat. The energy industry is another land user that reduces available land for Reindeer Herding as well: hydropower and a planned increase in wind power plants add disturbances and barriers for reindeer migration. For some herders, the only solution is supplementary feeding and the transportation of their reindeer with trucks – practices that are then often criticized as “non-traditional «others. Increasing predator populations and intense traffic for transportation of workforce and resources add to the reindeer losses.

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There are only few Pressures from Reindeer Husbandry, for example an opposition of mining. Gällivare is an established mining town where mining is viewed as an important pillar of economy; opposition affects rather the granting of new permits for exploration and exploitation than significant opposition against the existing mines. Other land uses require operation permits as well, if there are environmental concerns, and the reduction of the final felling area by 45% in all of Norrbotten by Sveaskog after failed Samråd (=consultation) is one example of how Reindeer Husbandry has effectively influenced other land uses. Responses from Reindeer Herding to the many Pressures are supplementary feeding in winter, the transport of reindeer with trucks during migration, and the use of remote sensing technology; however, it is sometimes criticized that those Responses in turn lead to the loss of traditional knowledge, a negative impact.

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4.16. Germanasca Valley

The figure below shows the DPSIR framework for the **mining hub Germanasca Valley**, Italy.

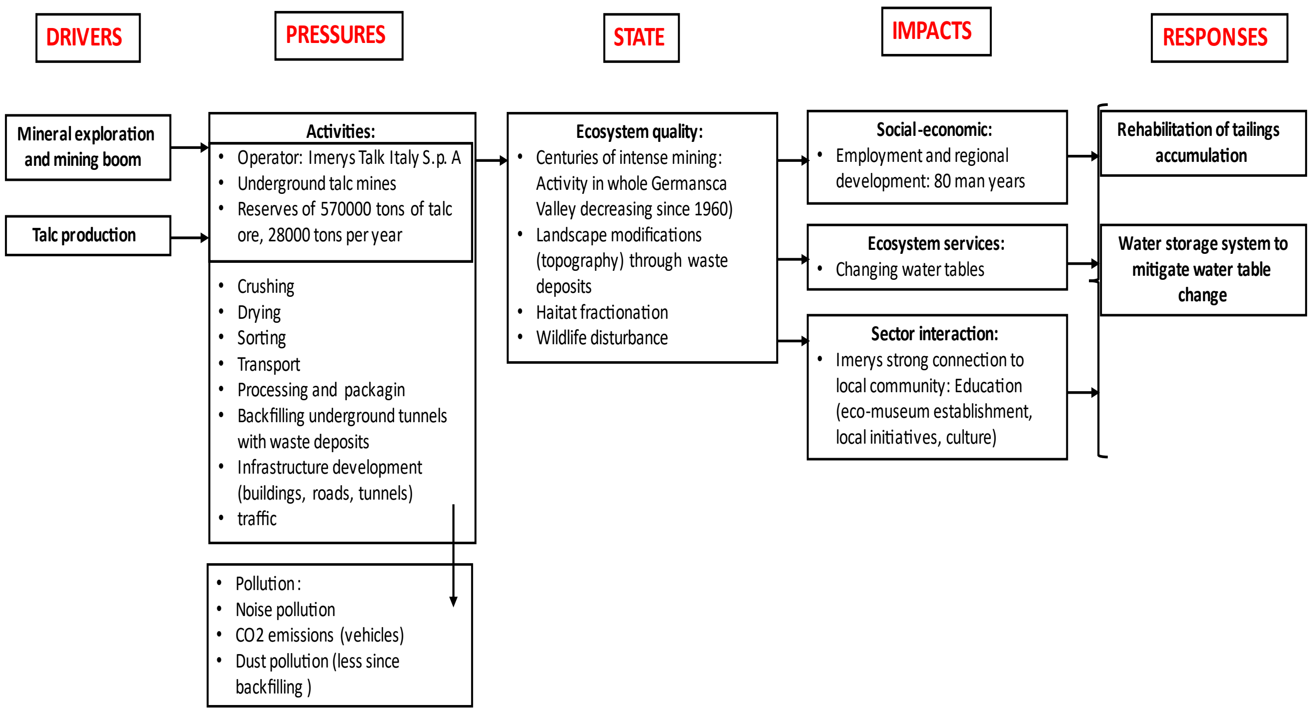

Figure 35. DPSIR for Germanasca Valley: Mining

Germanasca Valley is a mining hub which is characterised by a long history of talc extraction. In the past, the talc deposits of the Piedmontese Germanasca and Chisone valleys have had great importance, both for the purity of the extracted material and for the economic role it played in the last century. Since the mid-1700s, talc, under the name of "craie de Briancon" was known throughout Europe as a tailor stone. However, industrial exploitation can only be dated back to the second half of the nineteenth century.

The continuous global need for mineral resources and related exploration for new resources have had a steady influence on the talc production in Germanasca over time. After a period of changing ownership, an underground talc mine is operated by the Italian mining company Imerys Talk Italy S.p. A. Here, Reserves are estimated to provide 570.000 tons of talc ore to be excavated in 8 years. This equals circa 28.000 tons average talc annually. Meanwhile, ecological exploration is in progress for securing additional resources. Extraction and

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production processes include crushing, drying, sorting, transporting, and packaging of talc material. The mining operations come with mine tailings which are currently backfilled into underground tunnels. Further resource exploration processes and expansions of mining activities over time have come with increased infrastructure development (buildings, roads, tunnels etcetera). This and the irreparable unwrapping of land areas caused by the underground mine is linked to destruction of signature landscape and vegetation.

The environmentally pressuring mining activities are associated with pollution related to noise, CO2 emissions through increased traffic and the spreading of dust. However, less dust has been discharged since mining waste is backfilled underground.

Mining activity and associated pollution alter the environmental state:

Although a proportion of the produced tailings are now used to backfill underground tunnels, older waste deposits exist on the mountain slopes and in streams. This has modified the original topography and landscape. Parts of the older waste deposits have meanwhile been rehabilitated. Furthermore, mining infrastructure, including buildings and roads, have changed land use dynamics, and contributed to habitat fractionation. In addition, mining activities have also changed the water table which bares risks for the local vegetation. This has been mitigated by the creation of water storage systems. While wildlife disturbance by traffic along the roads is seasonally high, habitat fractionation due to mining infrastructure and mining activities is likely to have an effect on wildlife behaviour.

As most of the mining activity is underground, air and surface pollution from dust is not a major issue around the talc mine. Much of the mine tailings are used for backfilling of the underground tunnels and pollution from waste deposits is therefore limited. The main air pollution related to the mine activities is due to CO2 emissions from vehicles.

A major response as a reaction to still existing old tailings and mine remains is the establishment of rehabilitation projects. Here a re-integration of old tailing grounds and mine-remains into the landscape is targeted with opportunities to again shape new ecosystems.

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4.17. Alagna Valsesia

The figure below shows the DPSIR framework for the hub Alagna Valsesia, Italy.

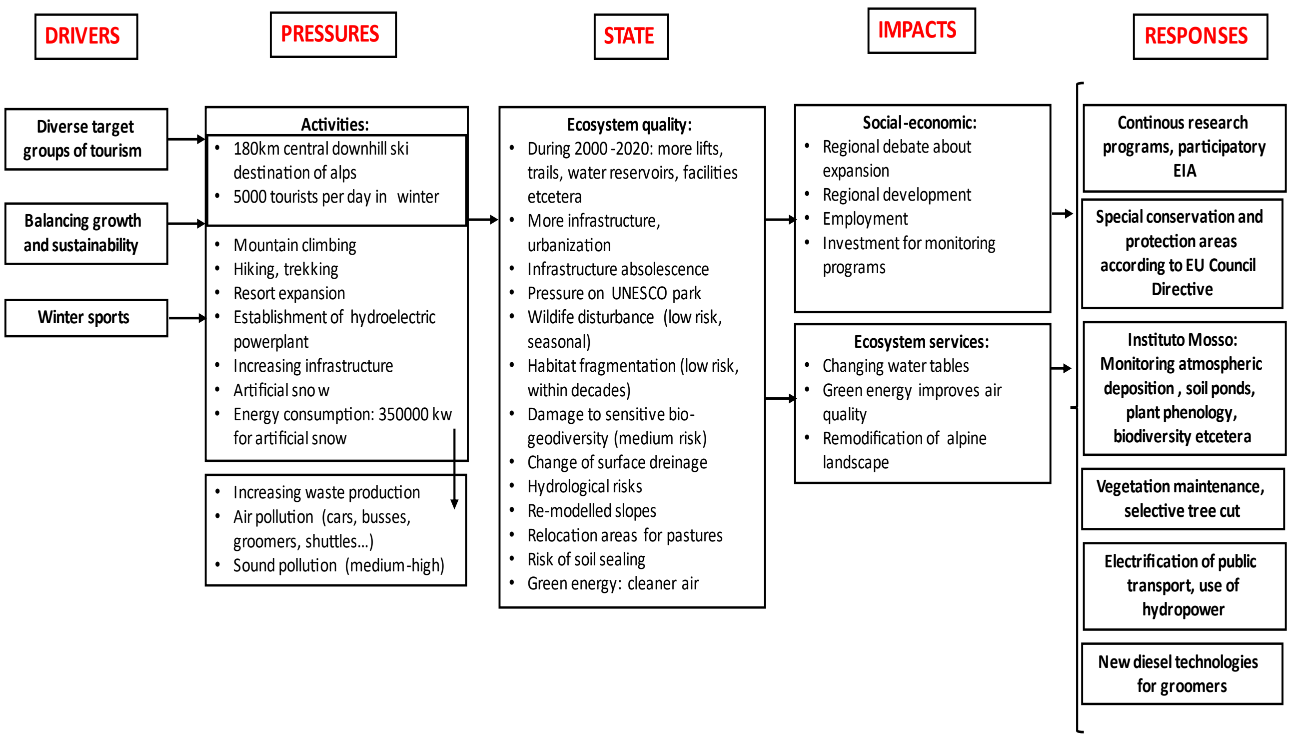

Figure 36. DPSIR for Alagna Valsesia: Tourism

Global drivers such as growing investments into the tourism sector and the increase of different tourist target groups developed Alagna Valsesia to a strong tourism sector. Especially the winter tourism is highly popular, around 5000 tourists visit the 180km downhill ski destination in the Alps per day. In addition, there is a regional debate to expand the ski resort and increasing its capacity. Next to skiing, the area promotes activities such as mountain climbing, trekking, and hiking or guided tours. The growing tourism sector came with an expanding infrastructure development between 2000 and 2020. This includes more ski lifts, trails, hotels, houses, road nets, artificial water reservoirs to support snow-making systems and more. In Alagna, a hydroelectric power plant is located that supports existing infrastructure with green energy.

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The many tourism activities and developments come with environmental pressures in terms of pollution including air pollution through increasing traffic, snow groomers, or flights; sound pollution (seasonally medium to high) due to groomers and ropeways, but also increasing waste production. Another pressure of the sector is its high energy demand. Hence, e.g., to produce artificial snow an energy demand of 350000kw is required while the energy demand for ropeways is more than 1.5 mil kw. Lastly identified in the data is the development of obsolescent infrastructure (low impact).

The environmental pressures have influences on the environmental state. Tourism activities such as winter activities, hiking, biking, especially when tourism is dense, are associated with negative effects on the UNESCO Geopark Sesia Val Grande which protects the geodiversity and geo-heritage of the area. Here, also waste disposal is linked to this. Moreover, waste disposal, fragmented ski tracks of the ski resort, noise pollution and infrastructure development are linked to habitat fragmentation of native animal species which usually happens slowly over decades. In this context wildlife disturbance is seasonal but considered as rather low. The expansion of infrastructure, especially when it comes to winter sport infrastructure, is associated with changes of surface drainage processes with medium risks that happen over decades (the character of the changes was not further highlighted in the data). On top of that, infrastructure expansion and abundant tracks and trails bare the risk of soil sealing. Furthermore, the growing obsolescence of winter sport infrastructure comes with needs to re-model the slopes and (ski-) tracks which has medium risks for the environment in terms of e.g., increasing habitat fragmentation. A positive aspect in this context is connected to new opportunities to include pastures within the area. Lastly, a positive aspect can be related to the hydropower plant. Here, green energy production is used for the high energy demand of tourism facilities and infrastructure which lowers the need for fossil fuel energy production. This ultimately contributes to an improved CO2 balance.

The following socio-economic impacts were linked to existing environmental pressures and changing states. Infrastructure construction and maintenance as well as third sector development have a positive impact on regional development and employment in the area. In addition, more generally, the impact on- and modification of alpine landscape is associated with economic losses in terms of less ecological quality of pristine milieus as a shrinking ecosystem service. For better considering the impacts of tourism activities and urban mobilization, increasing investments and funding were provided for monitoring systems and related research.

The so far described pressures, states and impacts have led to the following responses (see figure: "responses"-category)

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5. Concluding remarks

The DPSIR analysis by the ArcticHubs project has been able to present and analyse the Driver-Pressure-State-Impact-Response (DPSIR) framework factors and establish the DPSIR framework for the different activities in selected hubs in the Arctic. The DPSIR causal framework has been applied to firstly identify the main global driving forces causing pressures that affect the state of the local and regional environment and communities, in turn having impacts on habitat, species, economic and cultural losses. The identification of global driving forces was followed up by developing "glocal" responses, i.e., methods and procedures involving local communities and global actors to circumvent or cushion impacts on local environment and society.

The following concluding remarks could be made, based on the DPSIR analysis by the ArcticHubs.

Firstly, the DPSIR analysis has turned out to be an illustrative tool of presenting framework factors relevant to the ArcticHubs project work. The abundance of data available in each hub, as well as the complexity of causal relations between the framework factors of the hubs, made it challenging to present the research results in a way that enables comparability between the hubs, too. The execution of the mapping of global drivers and local impacts in different hubs has been done in a standardized and comparable illustrative way.

Secondly, the individual hub specific DPSIR illustration and analyses build a bridge between the data acquisition and analysis implemented at the earlier phases of the ArcticHubs, and with the forthcoming work of the ArcticHubs project. The DPSIR analysis is an integrative part of the entire ArcticHubs project. The individual hubs are playing a central role when the ArcticHubs maps global drivers that are causing local environmental, socio-economic, and cultural impacts. The work contributes to develop 'glocal' solutions in WPs 4 and 5.

Thirdly, the practical DPSIR work brings together individual hubs to discuss and compare the results. This fosters an important joint learning process, too, among and between the hubs. In this regard, the experiences and extensive data input in this delivery is also

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implemented in an individual synthesis report that exclusively compares the DPSIR findings of numerous hubs and analyses key dynamics and interactions.

Regarding the possible limitations of using the DPSIR framework in the context of ArcticHubs, it needs to be stated that the ArcticHubs project represents a pilot project in applying the DPSIR framework to Arctic regional and local conditions. Although DPSIR as a concept is not entirely new, a great deal of the WP2 work has included dissemination process around the ArcticHubs research community on DPSIR methodology: How should the individual hubs provide the data for the DPSIR analysis, interpret the results of the DPSIR, and validate the results of the DPSIR? It is also obvious that some hubs are more acquainted with the analysis tools such as DPSIR compared to some other hubs, which challenges the DPSIR coordinators in their work to systematize the DPSIR work.

As an overall conclusion, the DPSIR analysis has been able to bring the ArcticHubs actors together to provide added value element to the entire ArcticHubs research process. Moreover, as a bonus, the individual hubs have received an additional analysis framework for their own future work.

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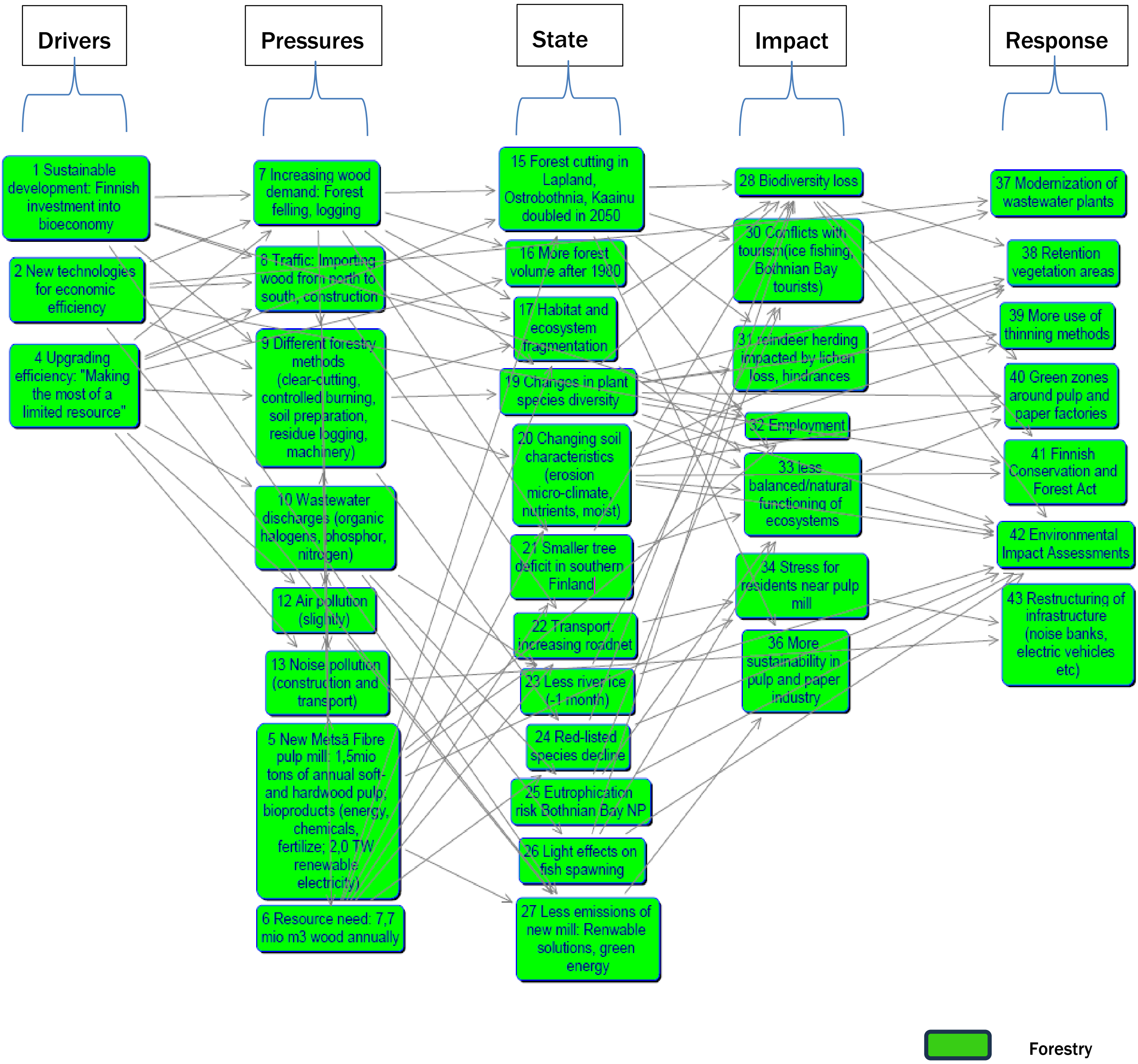
Appendix: More detailed DPSIR frameworks for the selected hubs (utilizing the Banxia Decision Explorer® software)

DPSIR KEMI



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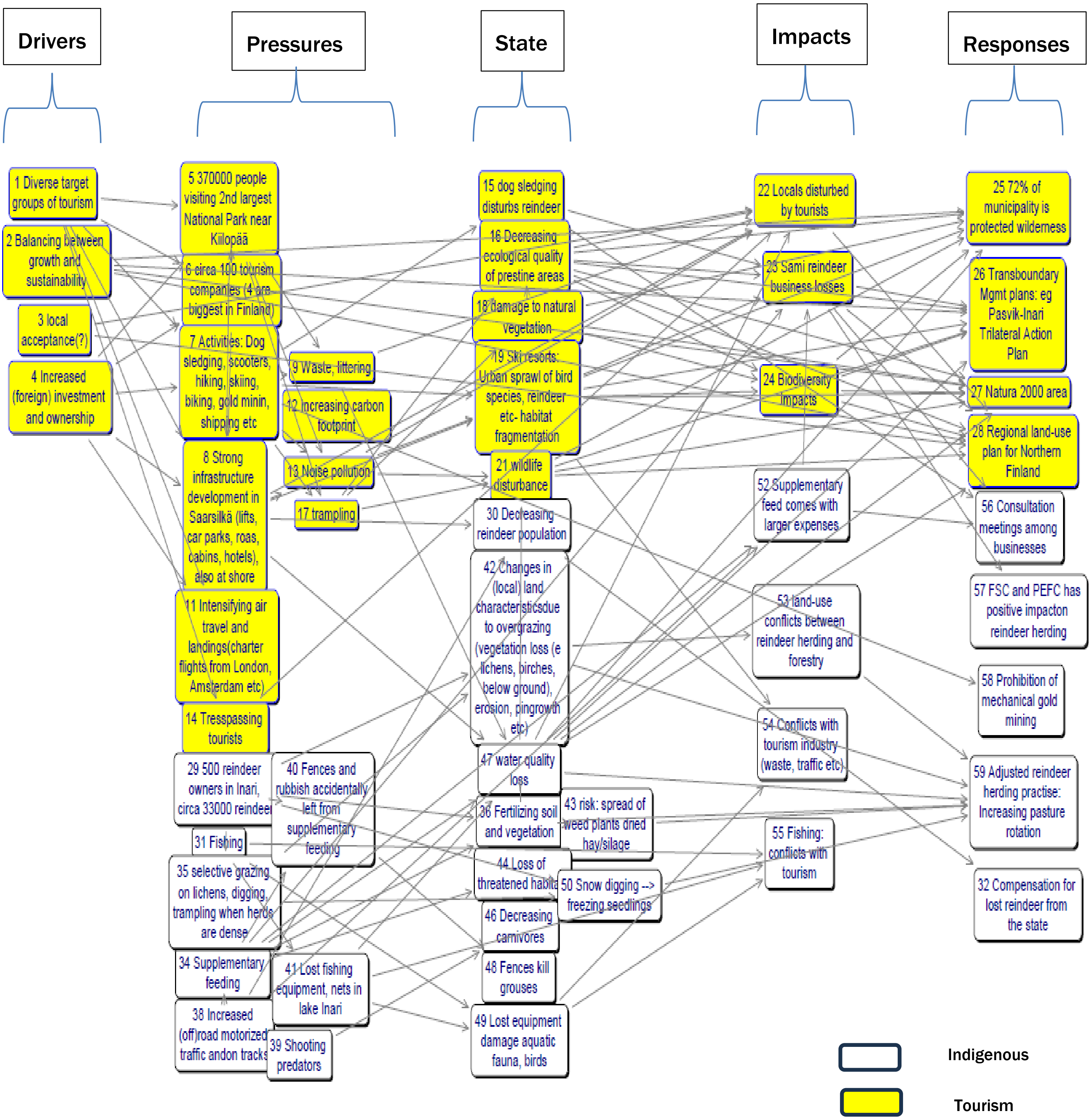
DPSIR INARI



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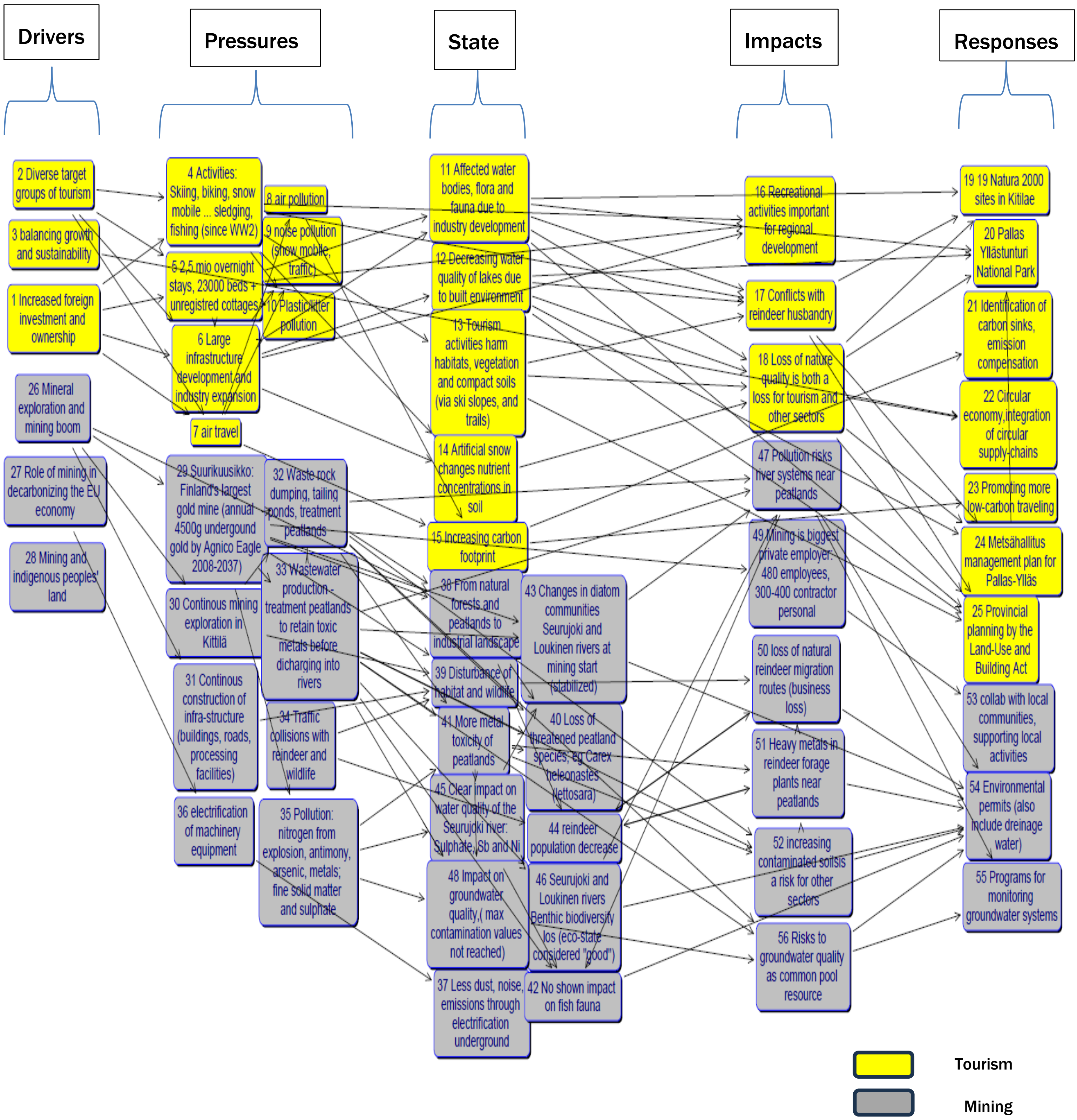

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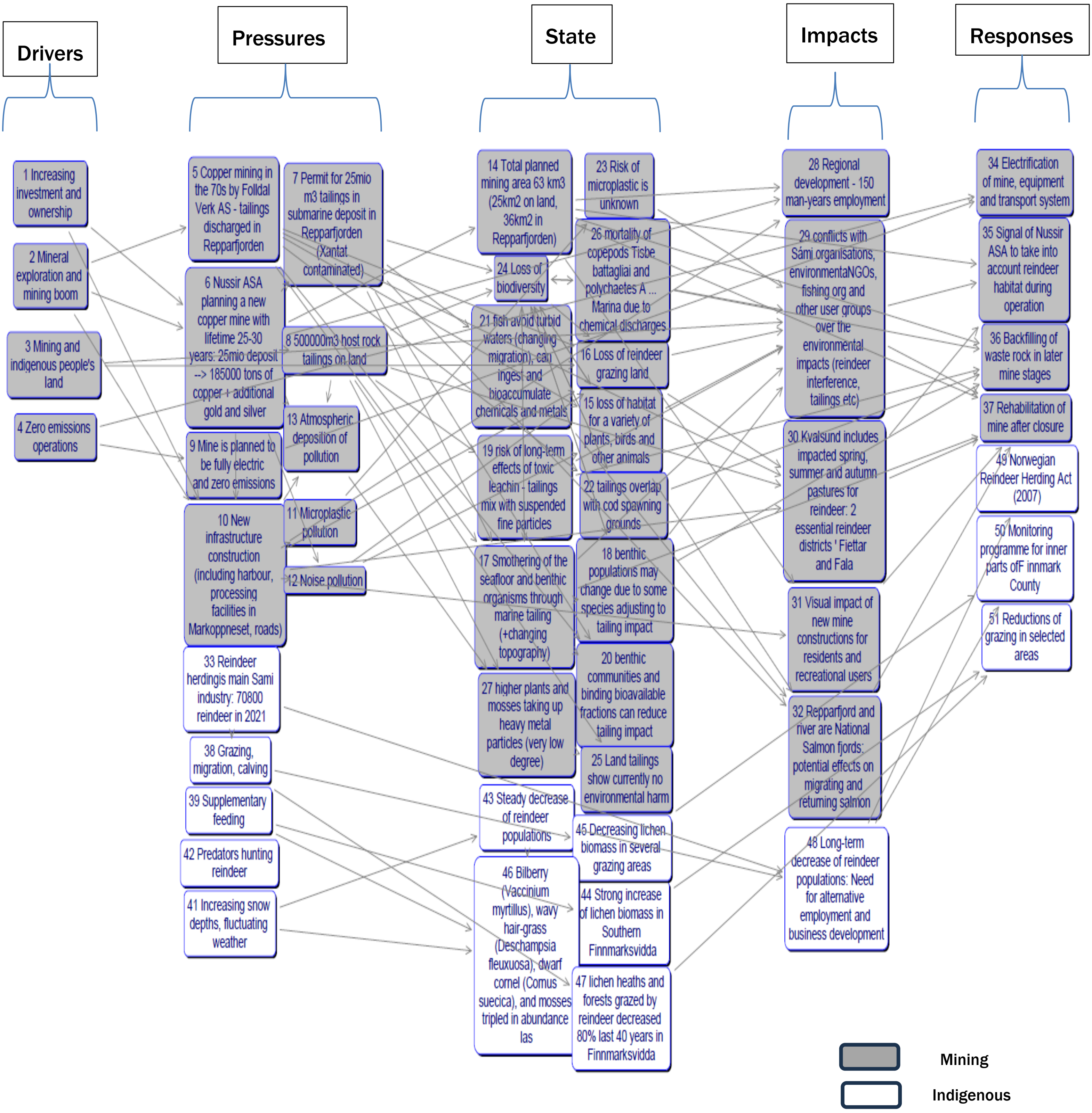
DPSIR Kautokeino-Kvalsund



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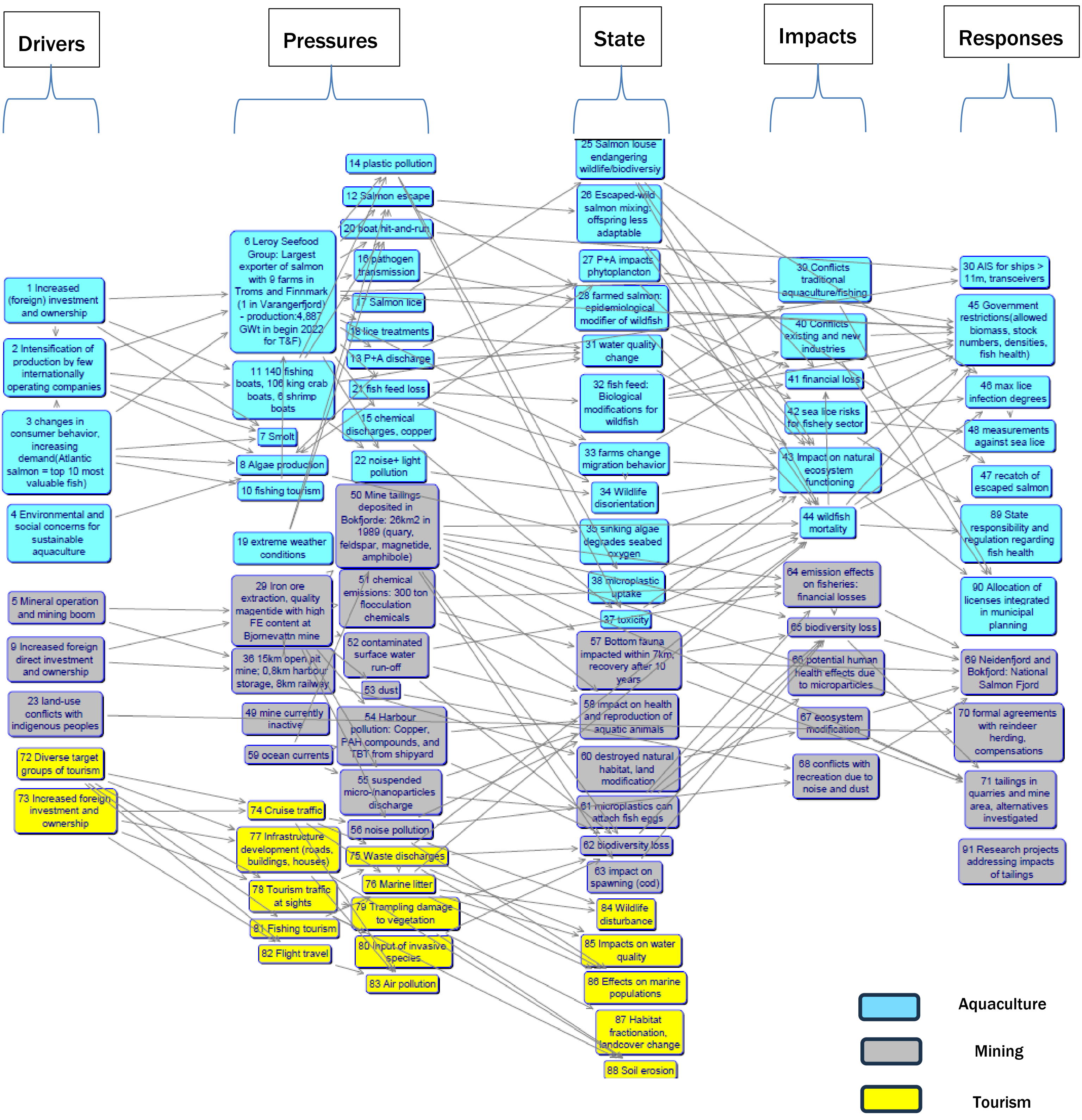
DPSIR Varangerfjord



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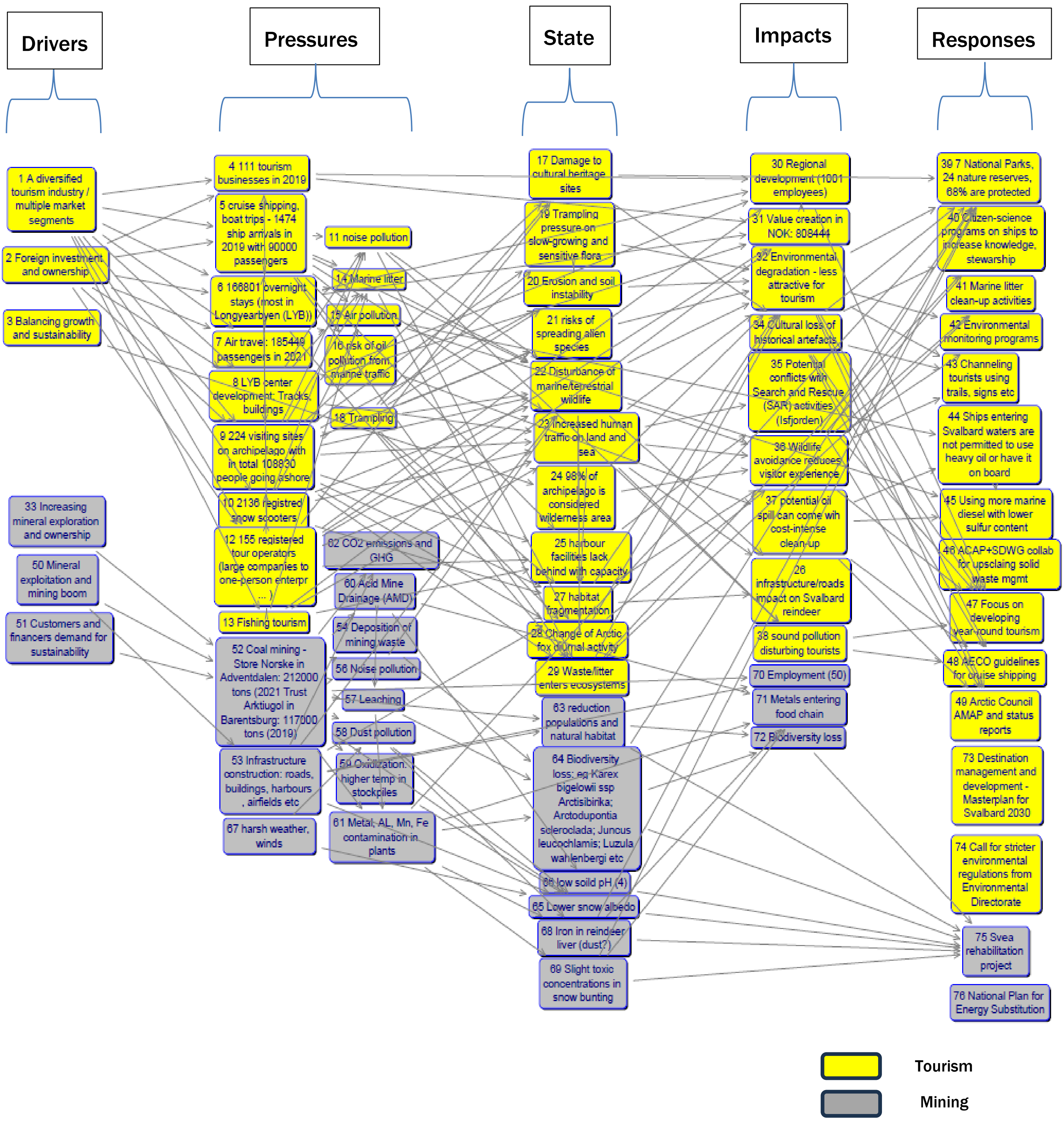
DPSIR Svalbard



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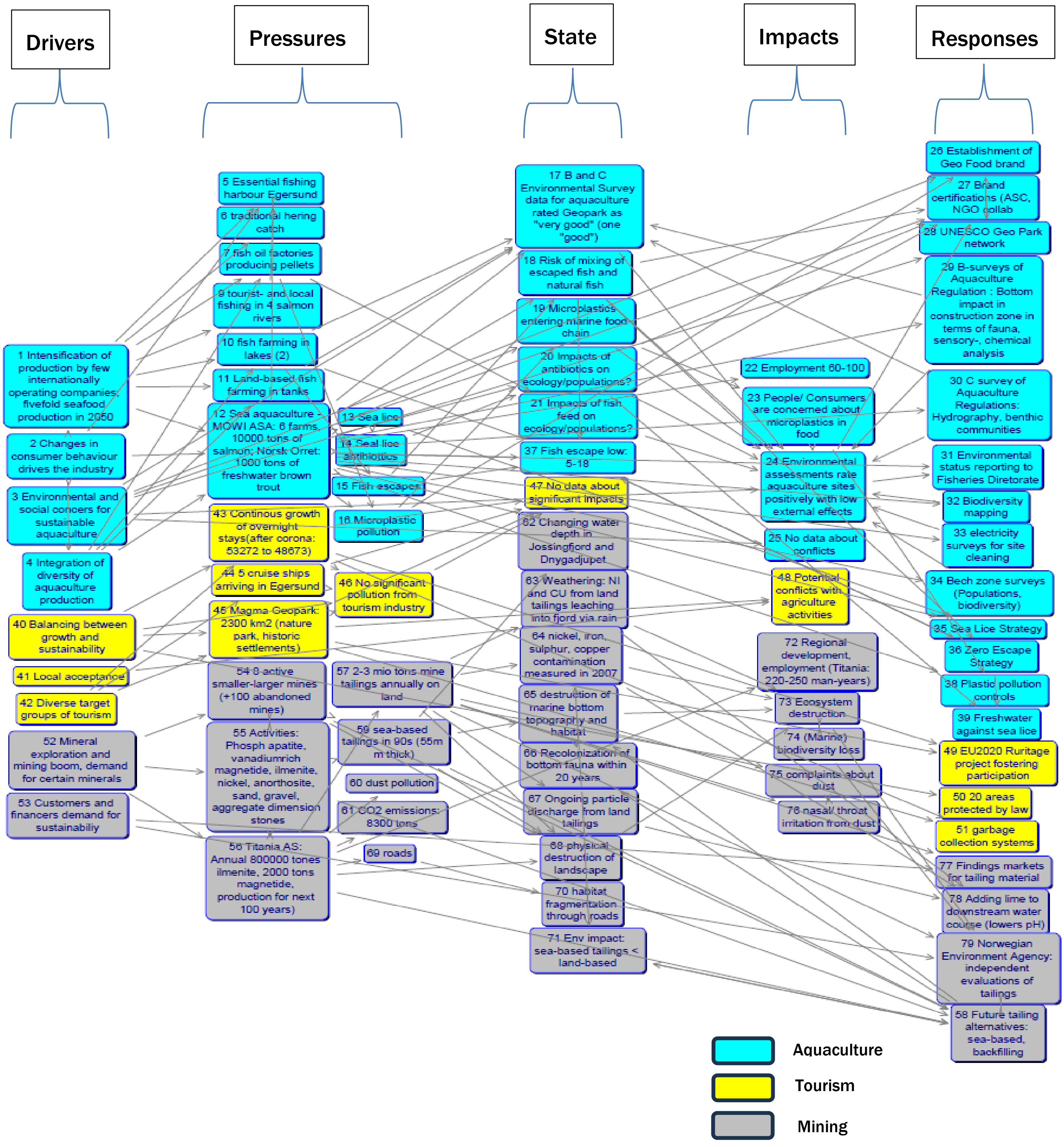
DPSIR Egersund



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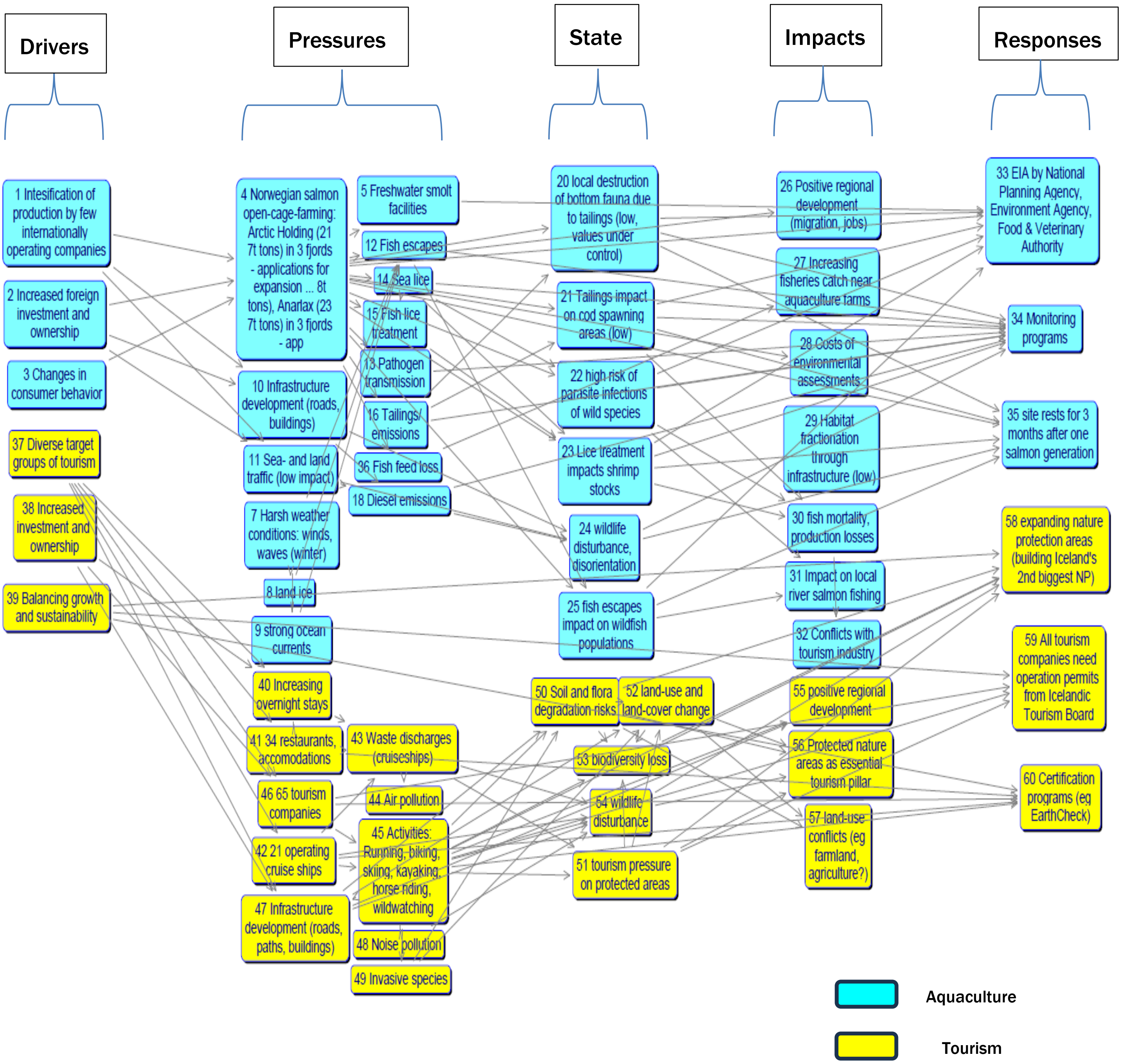
DPSIR Westfjords



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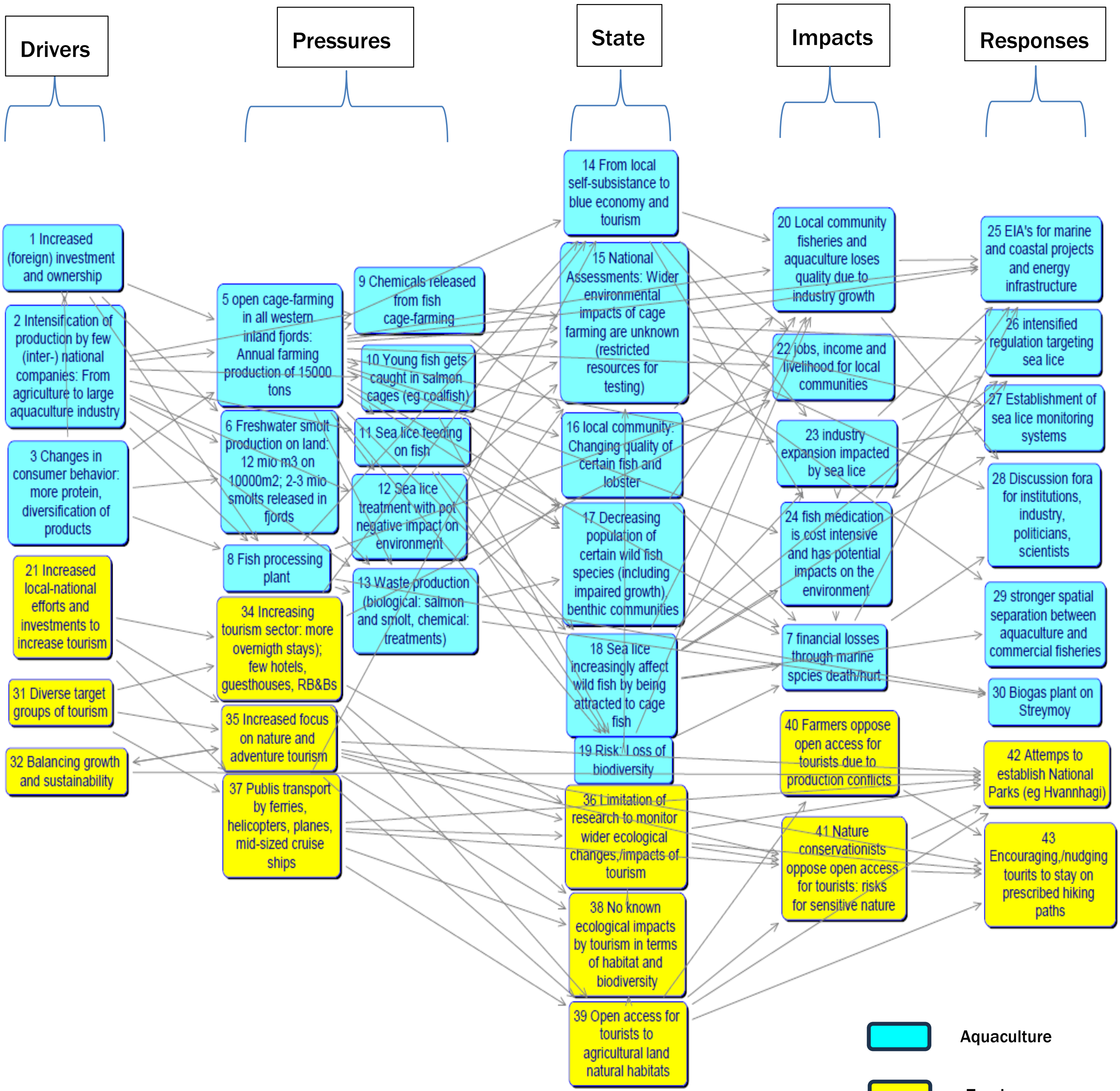
DPSIR Sudorøy



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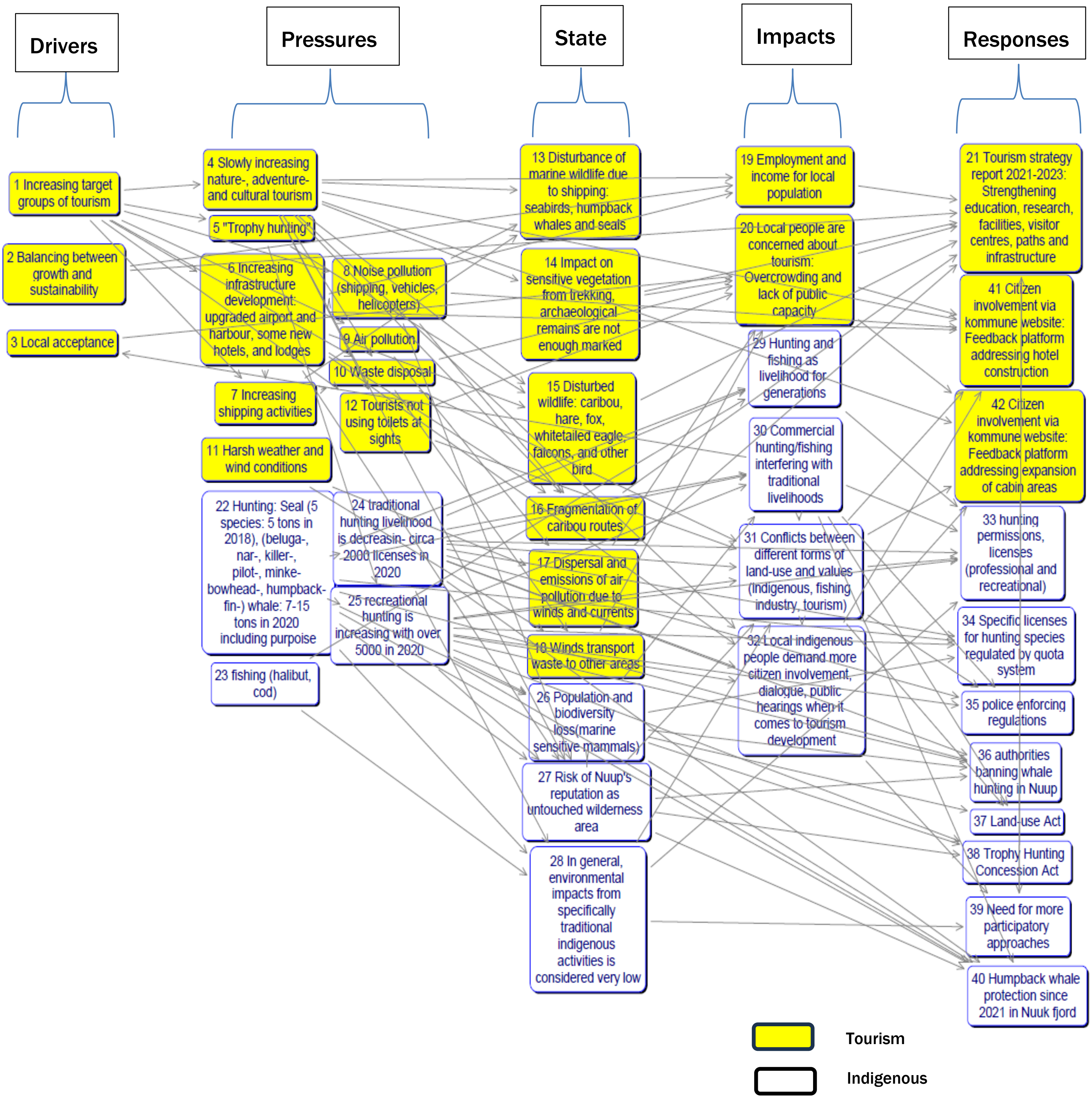
DPSIR NUUK



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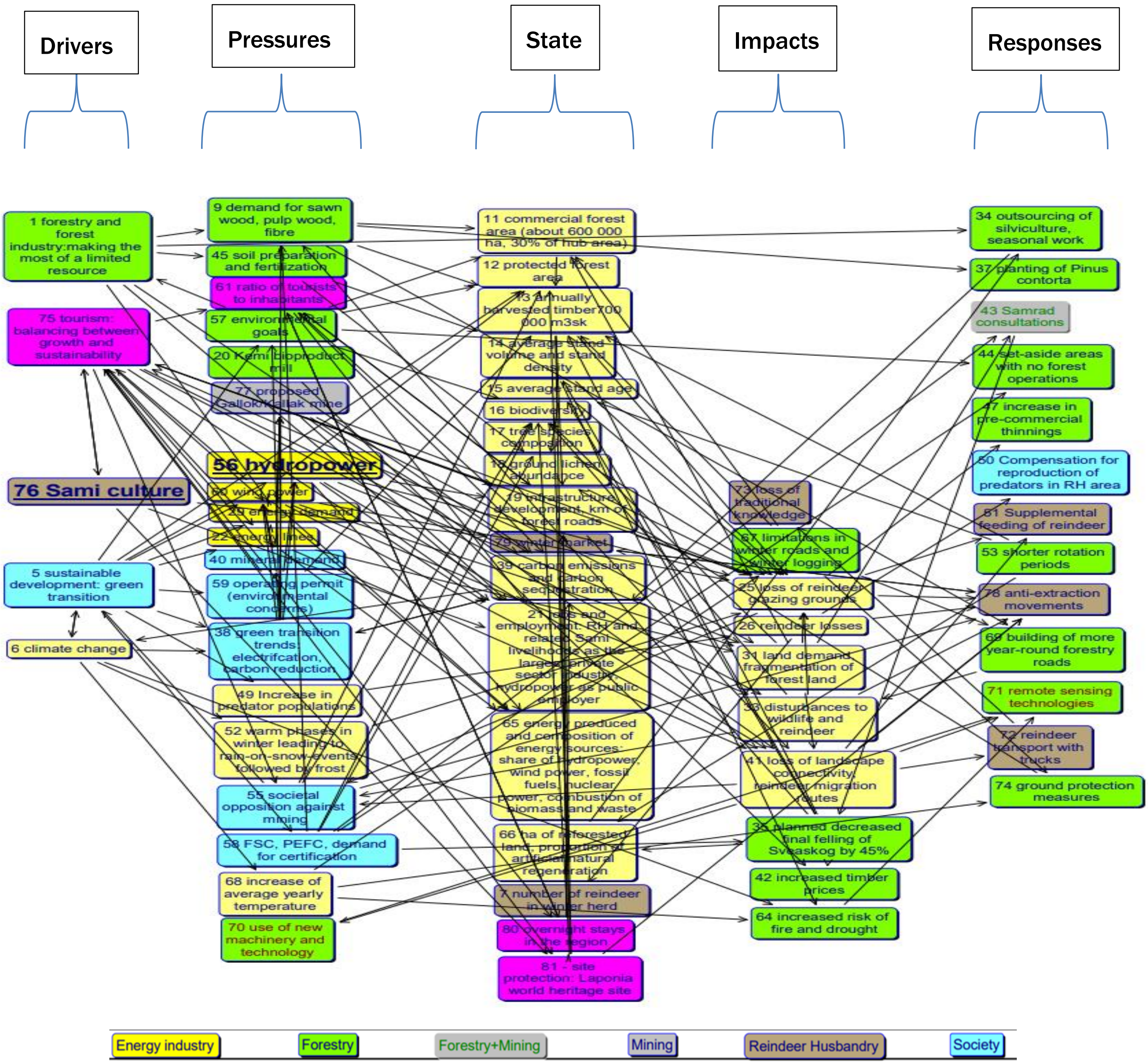
DPSIR JOKKMOKK



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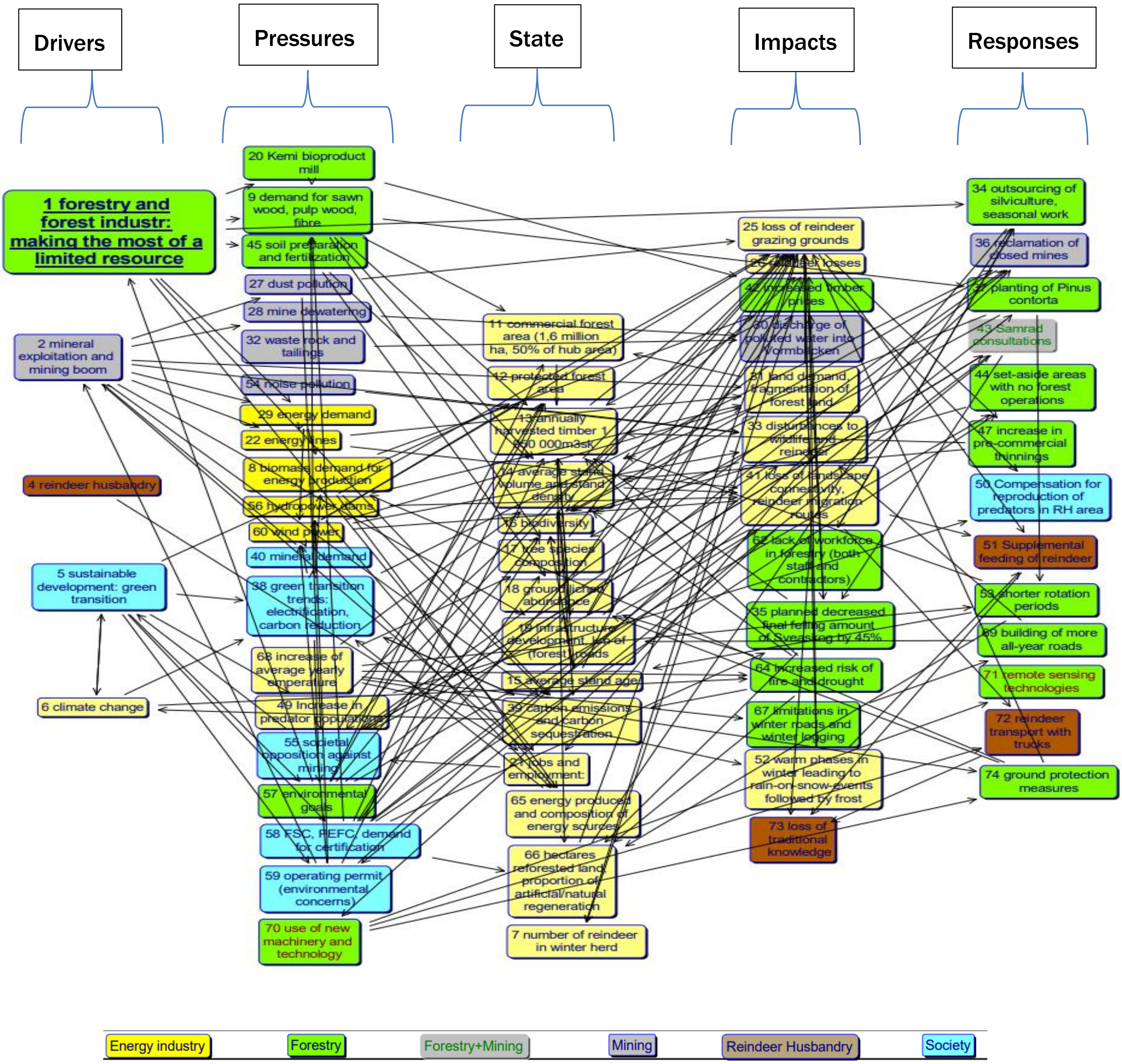
DPSIR MALÅ



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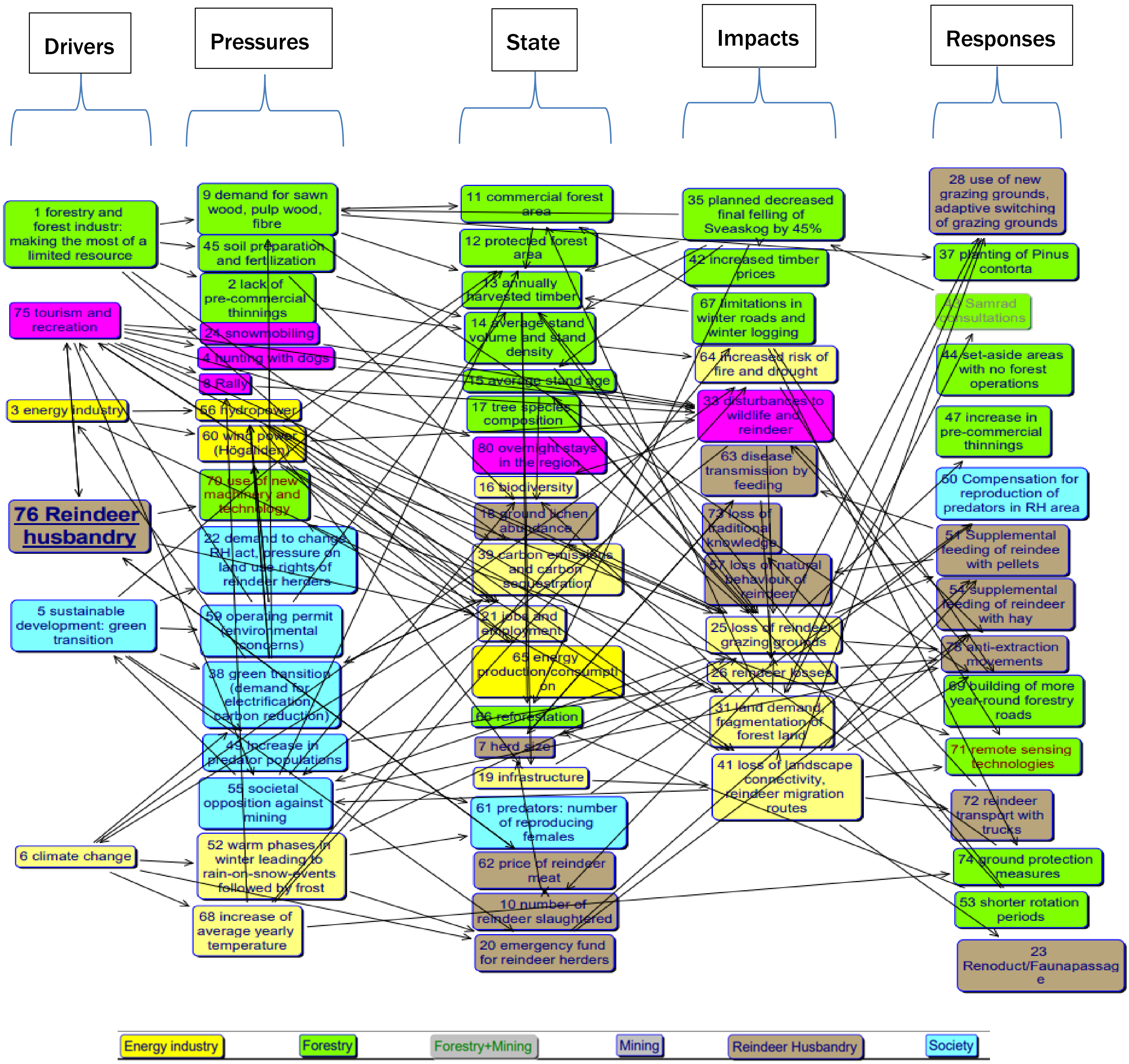
DPSIR GRAN SAMEBY



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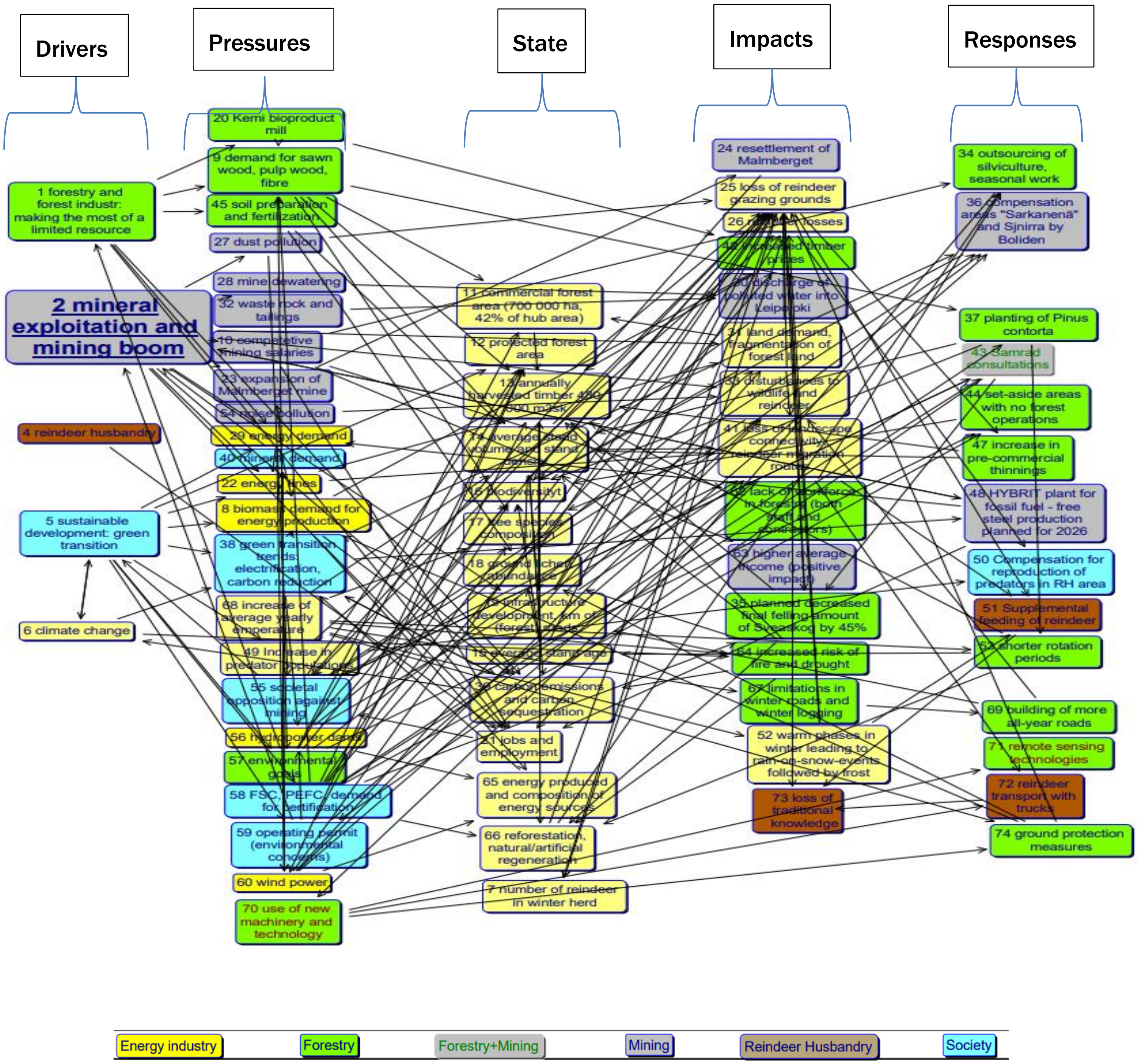

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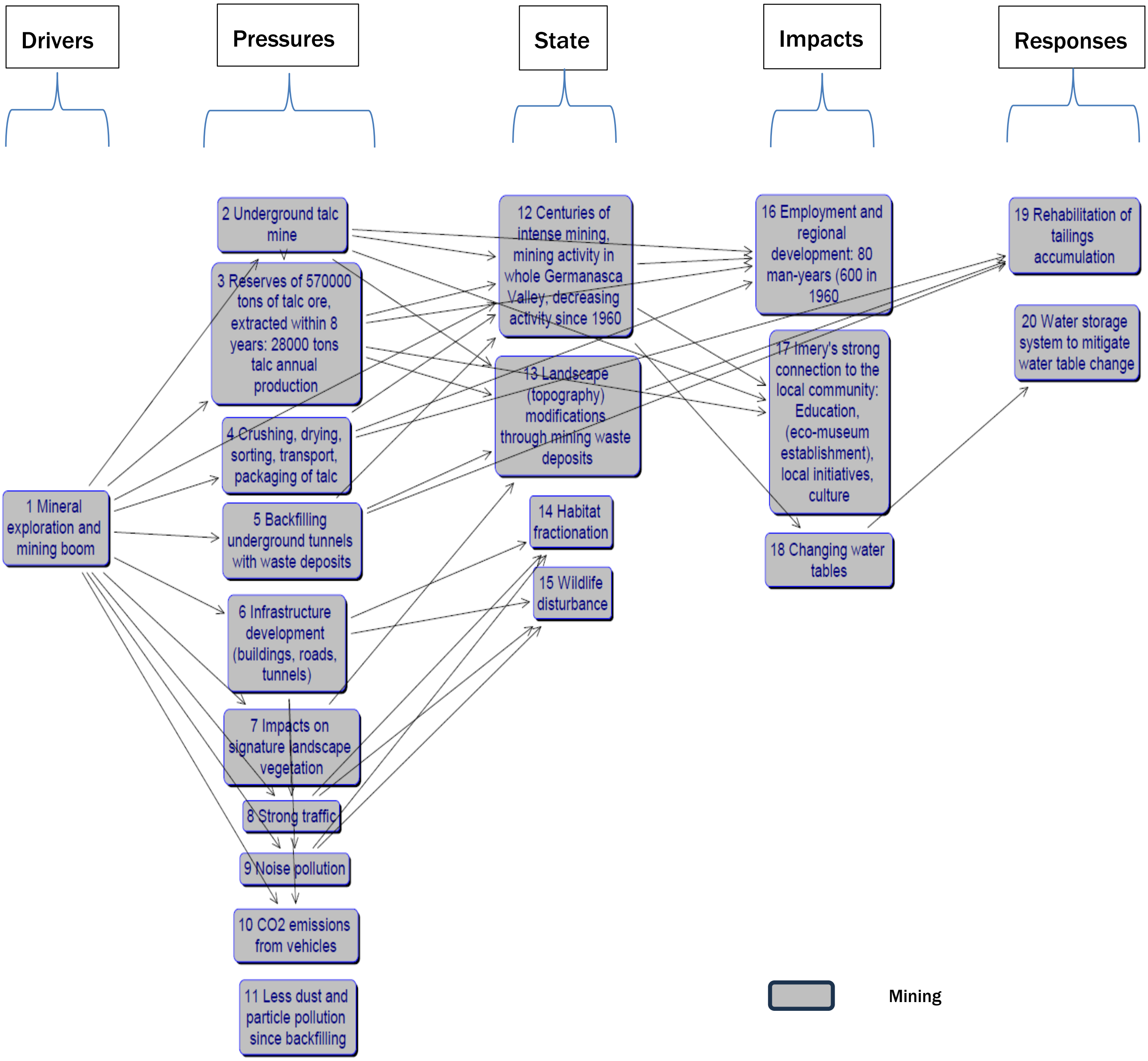
DPSIR Germansca Valley



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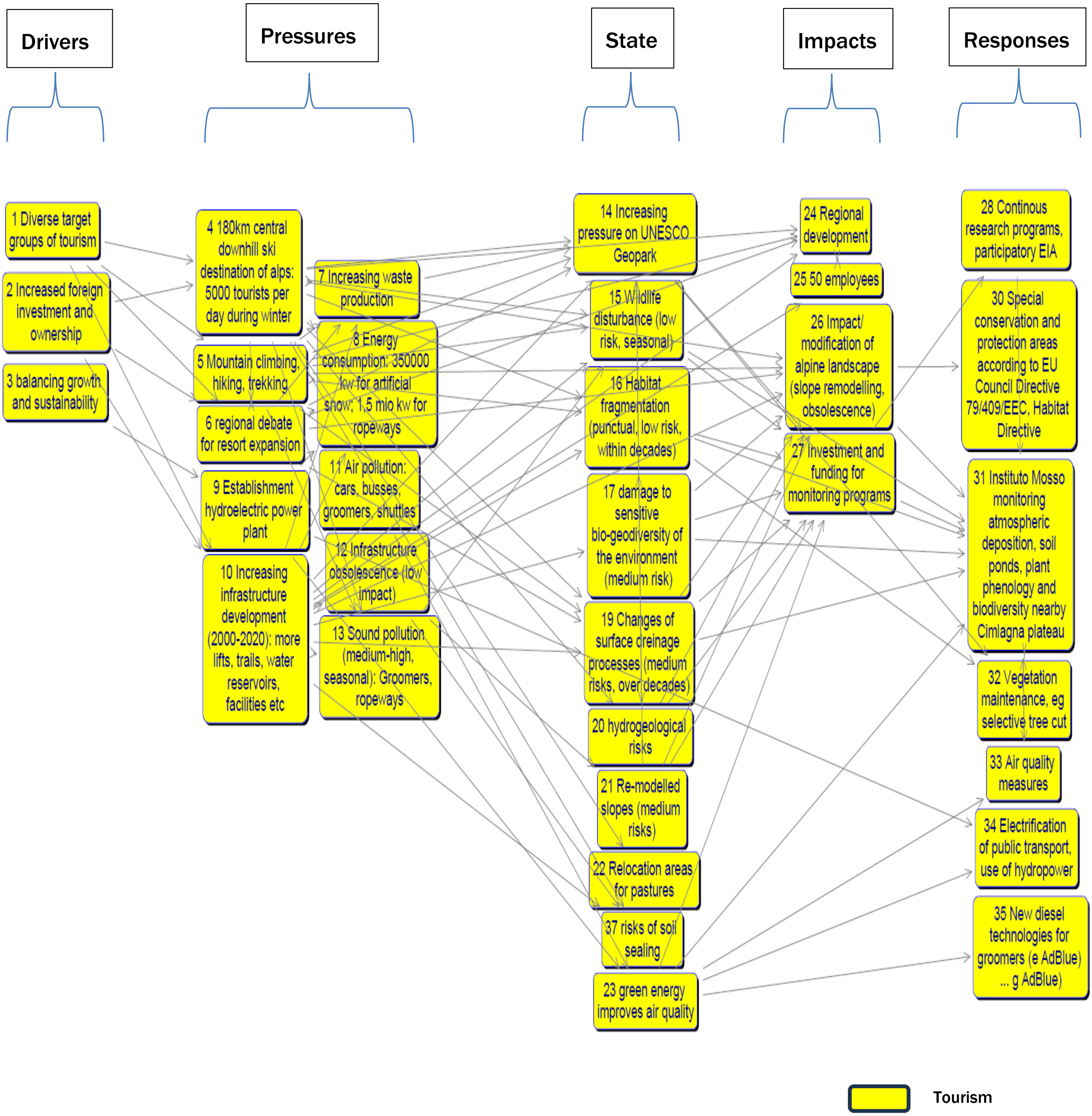
DPSIR Alagna Valselsia



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