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A pilot study of occurrence, characteristics and restoration potential in watercourses with anadromous and resident fish stocks

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COVER PICTURE
An old obsolete dam in Aunåa watercourse probably built in early 1900s for the first hydropower plant in Hitra island, central Norway. © Morten Andre Bergan

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Abstract

Eloranta, A., Thomassen, G., Bergan, M.A., Andersen, O. & Gregersen, F. 2019. Restoration potential of old dams in Norway. A pilot study of occurrence, characteristics and restoration potential in watercourses with anadromous and resident fish stocks. NINA Report 1628. Norwegian Institute for Nature Research.

Man-made migration obstacles and barriers, such as dams and culverts, are among the main reasons why numerous migratory fish stocks (e.g. Atlantic salmon *Salmo salar*, sea trout *Salmo trutta*, and European eel *Anguilla anguilla*) in Norway and elsewhere have become locally endangered or extinct. This is particularly the case in small streams which are often neglected by management authorities, despite of their high importance for fish recruitment and water quality in downstream river, lake and coastal areas. To reach good ecological status in Norwegian freshwaters, river restorations and mapping of migration barriers are urgently needed to improve connectivity and ecological status of these valuable ecosystems.

The main objectives of this pilot project were (1) to evaluate the number, location, characteristics and restoration potential of old dams that are no longer in use, and (2) to give an overview of relevant literature and projects related to barrier removals. Data on dams were collected with a publicly available, electronic questionnaire and by conducting field surveys in two types of watercourses: (1) inner and outer coastal areas of Trondheimsfjorden with anadromous fish (sea trout, salmon and/or eel) and (2) tributaries of Drammenselva with resident fish stocks (mainly brown trout, but also lamprey *Lampetra* sp., eel and freshwater pearl mussel *Margaritifera margaritifera*).

Based on our results from 102 dams, only 21% of the reported dams are currently among the 3887 registered dams in the national DamPunkt-database (www.nve.no). Hence, the total number of dams in Norway can be roughly estimated to exceed 18 000. Most dams studied were made of concrete and/or stone and were typically 1–10 m high, 2–20 m wide, and partial or total migration barriers for aquatic biota. Most dams were currently used for hydropower operations, but some were originally built for other purposes.

Our field surveys demonstrate that large areas of suitable fish spawning habitats are lost due to dams. In Trondheimsfjorden, numerous (mainly unregistered) dams are built for fish hatcheries that are no longer in operation and thus cause unnecessary fragmentation of anadromous river systems. Our two examples of potential restoration targets in Trondheimsfjorden (i.e., Kaldvella in Gaula river system and Dragvatnet in Hitra) demonstrate how barrier removal or restoration would substantially increase the accessible spawning and nursing habitats for anadromous fish.

In Drammenselva area with long history of mining, forestry and hydropower activities, a great proportion of suitable spawning and nursing habitats for brown trout and freshwater pearl mussel is lost due to damming of small streams. Some dams have naturally collapsed and thus create only partial migration barriers for aquatic biota. However, the major and most difficult restoration targets are in the downstream river sections where even some very new dams block migratory fish.

Various public institutions have collected information of man-made barriers in Norwegian watercourses. To support efficient and holistic planning and implementation of river restoration projects, these data should be gathered into a single, open-access database. Moreover, a user-friendly registration system (e.g. a mobile application) should be developed for mapping and reporting of old dams and other migration barriers (cf. “citizen-science project”). From an international perspective, Norway should become a more active member in present and future European river restoration projects (e.g. AMBER and Dam Removal Europe). This would help to

increase public awareness and involvement, improve ecological status of riverine ecosystems and their valuable biota, and support fundamental applied science with wide international outreach.

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Sammendrag

Eloranta, A., Thomassen, G., Bergan, M.A., Andersen, O. & Gregersen, F. 2019. Restaureringspotensial av gamle demninger i Norge. En pilotundersøkelse av forekomst, egenskaper og gjenopprettingspotensial i vassdrag med diadrome og stedegne fiskebestander. NINA Rapport 1628. Norsk institutt for naturforskning.

Menneskeskapte vandringshindre er blant hovedårsakene til at vandrende fiskebestander (f.eks. laks *Salmo salar*, sjøørret *Salmo trutta*, og ål *Anguilla anguilla*) har blitt negativt påvirket eller utryddet i Norge. Dette gjelder spesielt i mindre elver, som er viktige for fiskeproduksjon, men ofte oversett av forvaltningsmyndighetene. I Norske vassdrag er restaurering og kartlegging av vandringshindre et viktig virkemiddel for å gjenopprette konnektivet og god økologisk status i disse mindre, men verdifulle økosystemene.

Hovedformålet med dette pilotprosjektet er: (1) å kartlegge antall, plassering, karakteristika og restaureringspotensial for demninger som ikke lenger er i bruk, (2) å gi en oversikt over relevant litteratur og damprosjekter med tanke på å fjerne vandringshindre. Vi samlet data om demninger ved bruk av et åpent spørreskjema hvor folk kunne registrere demninger som ikke lenger var i bruk. Vi valgte også ut to områder for nærmere feltundersøkelser: (1) indre og ytre deler av Trondheimsfjorden med diadrome arter (f.eks. sjøørret, laks og/eller ål) og (2) Drammensvassdraget med sideelver med stedegne fiskebestander (i hovedsak ørret, men også elvemusling *Margaritifera margaritifera*, niøye *Lampetra* sp. og ål).

Basert på spørreundersøkelsen og feltstudiene (n = 102 demninger), var bare 21% av de demningene vi har registrert blant de 3887 demningene som er registrert i DamPunkt-databasen til NVE. Dette betyr at det kan være totalt mer enn 18 000 demninger i Norge. Den gjennomsnittlige demningen i denne studien var bygd av betong eller stein og var typisk 1–10 m høy, 2–20 m bred og fungerte helt eller delvis som vandringsbarriere for fisk eller andre vannlevende organismer. De fleste av demningene er utnyttet for vannkraftformål, men flere hadde blitt bygd i forbindelse med annen aktivitet.

Resultatene fra de to studieområdene viser tydelig at store bekke- og elvearealer egnet som gyteområder er utilgjengelige som følge av demninger i vassdragene. I Trondheimsfjordområdet er flere demninger som ikke lenger er i bruk (og som ikke finnes i NVE sin DamPunkt-database) bygget på grunn av fiskeoppdrett. Disse fører til en fragmentering av anadrom strekning og reduserer gyte- og oppvekstområder. To eksempler (Kaldvella i Gaula og Dragvatnet på Hitra) viser hvordan fjerning av demninger som ikke lenger er i bruk kan øke arealet av de tilgjengelige gyte- og oppvekstområder.

I Drammenselvas nedbørsfelt er en stor andel av egnede gyte- og oppvekstområder for ørret og elveperlemusling gjort utilgjengelige på grunn av gruvedrift, tømmerfløting og vannkraft. Noen av demningene har i dag kollapset og utgjør et delvis vandringshinder for vannlevende organismer. De største vandringshindrene ligger i de nedre deler av tilløpselvene (f.eks. Dørja, Bingselva og Hoenselva), der demninger (noen nokså nye), hindrer vandring.

Ulike institusjoner i Norge (f.eks. NVE, Statens vegvesen, Fylkesmannen, kommuner og forskningsinstitusjoner) har samlet informasjon om menneskeskapte vandringshindre i vassdrag over hele Norge. For å sikre effektiv og helhetlig planlegging og gjennomføring av elverestaureringsprosjekter, bør slike data samles i en felles, åpen database. Videre bør det utvikles et brukervennlig registreringssystem (f.eks. en norsk mobilapp) for å tilrettelegge for en storskala kartlegging av vandringshindre i Norge (som “folkeforskningsprosjekt”). Norge burde bli mer aktiv i pågående og fremtidige europeiske elverestaureringsprosjekter (som AMBER eller Dam Removal Europe). En slik strategi vil bidra til å øke folks bevissthet og involvering i restaureringsprosjekter,

forbedre økologisk status i mange vassdrag med tanke på fisk og andre akvatiske organismer, og støtte grunnleggende anvendt forskning med bred, internasjonal rekkevidde.

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Contents

Foreword

Rivers and streams are biodiversity hot-spots providing valuable ecosystem services for people. Despite their importance for human-kind and well-being of connected lake, marine and terrestrial ecosystems, a huge proportion of river networks are currently highly fragmented and deteriorated due to damming, infrastructure development, land use activities etc. Luckily there is an increasing awareness of these issues and people are generally willing to make an effort to protect these valuable ecosystems. This trend is also evident in national and international environmental agreements and legislation (e.g., EU's Water Framework Directive) demanding more holistic and sustainable management and conservation of riverine ecosystems.

This pilot project aims to collect data of dams in Norway, indicate potential targets for river restoration and increase common awareness of environmental issues associated with man-made barriers. We hope that this project will stimulate development of local and international restoration projects which would improve the ecological status and connectivity of riverine ecosystems in Norway and elsewhere.

We thank the Norwegian Environment Agency (Miljødirektoratet) for financial support and all people who have reported dam locations for their valuable contribution to data collection. The project was conducted in close collaboration between the Norwegian Institute for Nature Research (NINA) and Multiconsult Norge AS. Both institutions contributed to project planning, implementation and reporting. Multiconsult were responsible for data collection in Drammenselva watercourse, whereas NINA collected data from Trondheimsfjorden area and via the electronic questionnaire.

Open discussion and a common will to make compromises and an effort for the benefit of nature are crucial for protecting Norwegian rivers and their ecosystem services for future generations.

Trondheim 22nd February 2019

Antti Eloranta
Project leader

1 Introduction

Habitat fragmentation is one of the major global threats to biodiversity and natural functioning of aquatic (Nilsson et al. 2005) and terrestrial (Haddad et al. 2015) ecosystems. Human disturbance, such as land use activities and infrastructure development, are the main causes for habitat fragmentation, typically leading to multiple, cumulative negative impacts that can influence various connected ecosystems. This is particularly the case with infrastructure development and land use activities in river networks and the surrounding catchment areas. A huge proportion of European rivers are fragmented due to damming and building of roads that prevent natural hydrological processes and movement of biota (Trombulak & Frissell 2000, Bednarek 2001). Humans have dammed rivers for decades to produce hydropower and for flood control, irrigation, domestic water supply, recreation (e.g. fishing and other outdoor activities), navigation and various other reasons. Today, there are over 45 000 dams exceeding 15 m height globally (WCD 2000). Damming and control of water flow has had remarkable economic benefits locally, nationally and globally. At the same time, these human activities have had detrimental environmental and societal impacts e.g. due to reduced stocks of migratory fish and decreased biodiversity and habitat quality in the affected freshwater and terrestrial ecosystems.

Besides decreasing connectivity within river networks, dams and other barriers alter natural hydrological processes, including downstream transport of vital food resources and bottom substrate for aquatic biota (Foley et al. 2017). Indeed, reduced food and habitat quality and quantity are among the main factors limiting survival of salmonid (e.g. sea trout, *Salmo trutta*) populations in dammed streams and rivers (Brink et al. 2018). Dams and other barriers may also increase flooding risk and reduce water quality due to river bank erosion and increased runoff of nutrients, pollutants, silt, humus and other inorganic and organic material from the catchment. Potential damming-induced changes in water flow and quality typically have cascading impacts on downstream river, lake and coastal ecosystems. Dams and other man-made barriers are most abundant in small streams that are often neglected in local management and planning actions even though they have a central role in determining habitat quantity and quality and biodiversity in the connected aquatic and terrestrial ecosystems.

Dams and other barriers are typically in conflict with national and international environmental agreements. The goal for the EU Water Framework Directive (WFD) and the national Water Management Regulation (“vannforskriften”) in Norway is that all waterbodies should reach “good” or “very good” ecological and chemical status by the year 2021. In general, highly fragmented river systems with modified hydro-morphological characteristics and reduced diversity and productivity of biota cannot reach this goal. Correspondingly, the Norwegian Nature Diversity Act (“naturmangfoldloven”) demands that “nature with its biological, landscape and geological diversity and ecological processes is taken care of by sustainable use and protection so that it provides the basis for human activity, culture, health and well-being now and in the future”. Numerous dams were built at a time when environmental issues were poorly known and considered. Therefore, these structures often do not meet the requirements of today’s legislation. To reach national and international environmental goals, freshwater ecosystems need to be managed in a sustainable and holistic way and protected against further deterioration. Hence, river restoration, including removal of migration barriers, is one of the most important measures to maintain biodiversity and natural processes in freshwaters, as well as the valuable ecosystem services they provide today and for future generations.

During the last decades, there has been a global trend to map and mitigate environmental problems associated with man-made migration barriers. Removal of old dams has become a common mitigation measure especially in cases where maintenance or re-licencing would be non-profitable. In some cases, dam removal would result in significant ecological and socio-economic benefits e.g. due to improved fisheries and recreational activities. Over a thousand old dams have been removed in the United States (www.americanrivers.org) and large projects and organizations have been established to improve connectivity and ecological status of European rivers (https://amber.international/). Still, the number of remaining, often profitless and poorly maintained dams, is estimated to be very high (as listed in e.g. Lejon et al. 2009). The recent ReMiBar project (Remediation of migratory barriers in Nordic/Fennoscandian watercourse) demonstrates the huge number of migration barriers (particularly culvers and dams) in the rivers of northern Sweden (Schönfeldt 2017). These barriers prevent socio-economically important fish species, such as sea trout, Atlantic salmon (*Salmo salar*) and European eel (*Anguilla anguilla*), from migrating up to their suitable spawning and nursery habitats. Moreover, by altering water quality and quantity, dams and other barriers have negative impacts on natural ecosystem processes and other aquatic biota than fish, such as the endangered freshwater pearl mussel (*Margaritifera margaritifera*) and otter (*Lutra lutra*).

Dams can also have positive environmental and socio-economic impacts. They may create suitable habitats (e.g. small ponds, wetlands, mudflats and swamps) for a wide variety of aquatic and terrestrial biota, including red-listed species. For example, in Hoenselva watercourse in Øvre Eiker, southern Norway, one dam has accumulated sediments and created an ecologically important large wetland area providing habitats for e.g. amphibians (Gregersen 2013). Another dam further upstream creates a reservoir which is a very popular place for sport fishing and cabin owners. Dams and other barriers may also prevent spreading of black-listed species and fish to naturally uncolonized areas, with a potential positive effect on aquatic insects and insectivorous waterfowl (Jensen et al. 2014). Some dams are also valuable cultural heritages, as is the case for several dams built in the 17th and 18th centuries in the Kongsberg, Fled and Øvre Eiker mining areas (Nynäs 2013). These examples demonstrate that dam removal is not always the most feasible or desirable mitigation measure for improving river connectivity and status of riverine biota. In many cases, alternative solutions, such as nature-like bypass channels, should be considered to balance the costs and benefits of dam restoration projects.

While numerous dams have been removed in Finland and Sweden (www.damremoval.eu), such barrier restoration projects seem scarce in Norway. This is surprising considering the high number of known and unknown dams, as well as high number of small streams whose fish populations have declined or become locally extinct since barrier constructions and/or other human activities (e.g. Bergan 2012a, 2013). At present, 3887 dams are registered in the national Dam-Punkt-database managed by the Norwegian Water and Energy Directorate (hereafter NVE; www.nve.no). Based on the registered data, most of these dams are currently working for hydropower production, domestic water supply and/or recreation (**Figure 1 and 2**). However, the number of unregistered, old dams is expected to be much higher. Many of these old dams no longer serve their original purpose and thus have unnecessary negative environmental and socio-economic impacts. Therefore, there is an urgent need to improve the knowledge base and management practices in small Norwegian streams whose fish populations and ecosystems are threatened due to damming and other human impacts.

The main objectives of this pilot project were to get an overview (1) of the number, location, characteristics and restoration potential of dams, with a focus on old structures that are no longer in use, and (2) of relevant literature and projects related to dam and other barrier removals. The project also aimed to improve the general awareness of environmental issues associated with old dams. This report does not provide detailed descriptions of each dam location or describe how to conduct a dam removal or river restoration project. The literature listed in section 3.4. gives relevant background details and practical guidelines for planning, implementation and monitoring of barrier removal and river restoration projects. For more details of the present study areas, see Appendices and/or contact the authors.

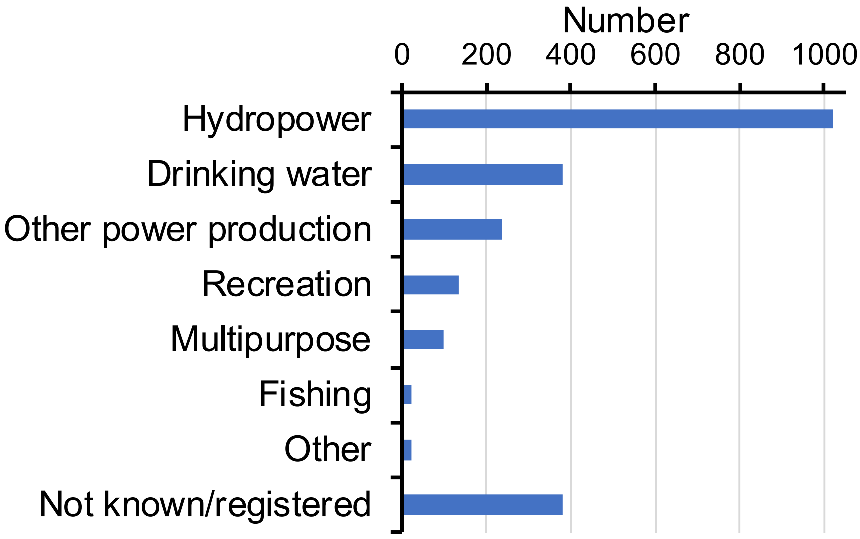

Figure 1. *Today's main purpose of 2291 dams in Norway as registered in the DamPunkt-database managed by the NVE (www.nve.no).*

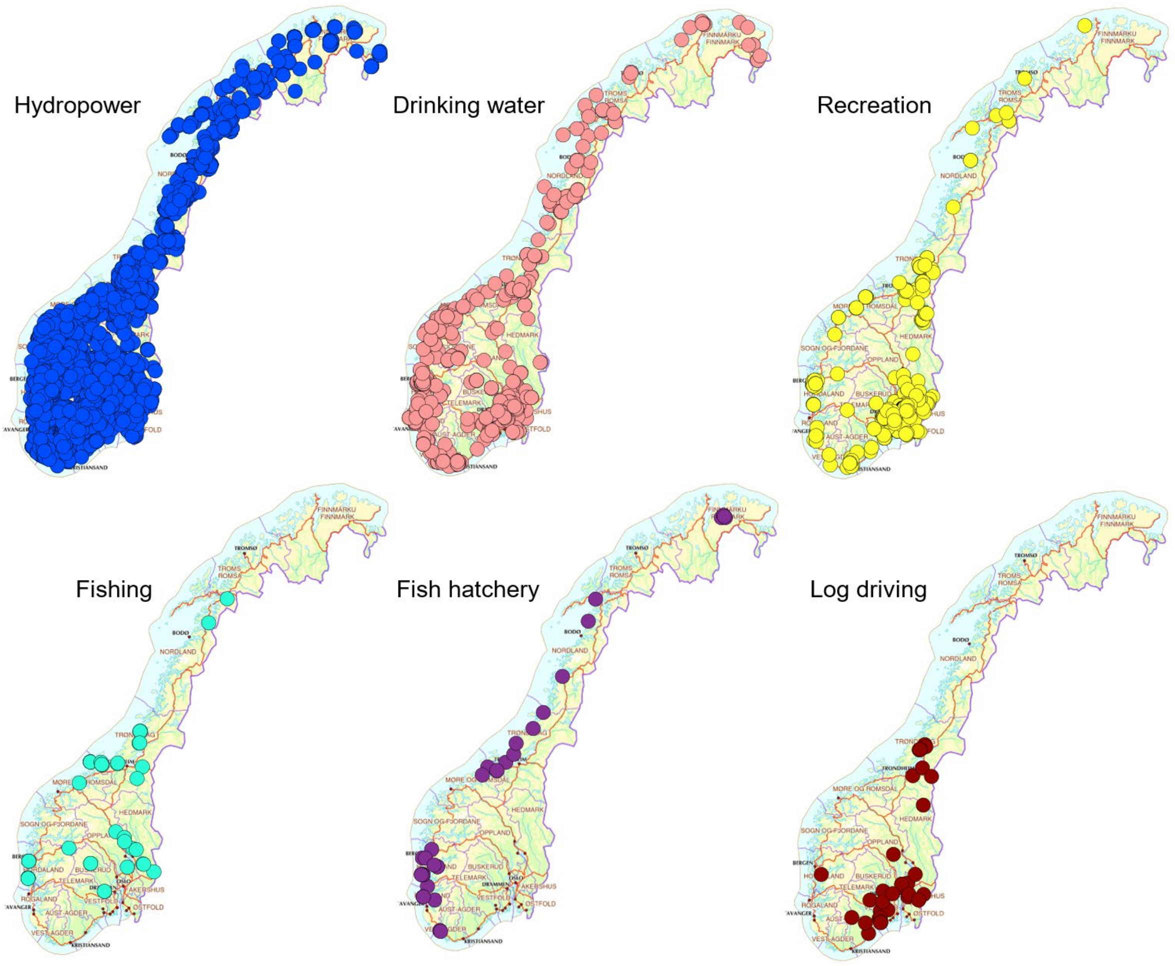

Figure 2. *Location and present purpose of dams as registered in the DamPunkt-database managed by the NVE (www.nve.no). Some of the registered dams have multiple purposes.*

2 Material and methods

2.1 Questionnaire survey

We developed a questionnaire (**Appendix 1**) and distributed it to relevant stakeholders (e.g. county governors, as well as municipal and other environmental actors) and local people to collect information about the location and characteristics of old dams in Norway. Besides contacting people by email and phone, we advertised our project and questionnaire by publishing articles in NINA news (www.nina.no/Aktuelt/Nyhetsartikkel/ArticleId/4575/) and pH-status (Eloranta et al. 2018), both having a broad readership. The questionnaire was published on 27th August 2018 and the data was downloaded on 16th November 2018, i.e. 81 days after publishing.

The project and questionnaire received quite some public attention: the project members were contacted by local people and journalists, radio interviews were given to NRK P1+ and NRK Finnmark, and news articles were published e.g. in Nationen (published 11.9.2019, pages 10–11) and Aftenposten (published 13.9.2018, page 30). This clearly indicates the wide public interest on migration barriers and status of riverine fish populations in Norway.

2.2 Dams and restoration potential in two watercourses

We selected two watercourses/areas as case studies for in-depth surveys of old dams and potential for restoration actions: (2) inner and outer coastal areas of Trondheimsfjorden (central Norway) with anadromous fish and (2) tributaries of Drammenselva (southern Norway) with resident fish populations. In these case-study areas, we estimated the number, location and characteristics of dams and evaluated the potential for future restoration actions. The surveys included some field work and contacts with people who might know more about the study sites and dams in the area.

The data from Trondheimsfjorden area were mainly collected in previous projects. In tributaries of Drammenselva, no previous knowledge or data were available and thus we had to conduct in-depth field surveys of dams. Indeed, most dams in this area are largely unknown to the public, county governor and NVE. Some information could be found in historical documents, but such a literature survey seemed less cost-effective than conducting a field survey by an expert. Some of the field-collected data were supplemented by interviewing local people.

2.3 Overview of national and international literature and projects

Besides data collection and evaluation of restoration potential, we searched for relevant national and international literature and projects to get an overview of current status and key aspects related to dam and other barrier removal projects, particularly in Fennoscandia. This brief summary is aimed to help different stakeholders (e.g. management authorities) to plan, implement and monitor barrier restoration projects and to contact relevant people in Norway and elsewhere.

3 Results

3.1 Questionnaire survey

In total, 40 dams that were properly localized with coordinates or a map source were reported via the questionnaire. Most registrations came from eastern (Østlandet) and western (Vestlandet) Norway (**Figure 3**). Of the 40 localized dams, only 6 (15 %) were registered in the NVE DamPunkt-database. Most dams reported via the questionnaire were relatively small, i.e. 2–5 m high and 5–10 m wide, spanned across the entire waterbody, were in poor or moderate status and/or were no longer in use (**Table 1**, **Appendix 2**). In most cases, the dams were originally built for a mill, log driving or hydropower production, but some were built for drinking water, fish hatcheries, recreation and/or to provide water for a fire station (**Table 1**, **Appendix 2**). Most dams were built of concrete, stone or a combination of these materials (**Table 1**).

Most dams were considered either total or periodic migration barriers and/or to have multiple impacts, including severe drying of the downstream river section (**Table 1**, **Appendix 2**). In respect of societal importance, many dams were considered not to have any known function today. However, a marked proportion had multiple purposes (e.g. hydropower, recreational use and habitat for aquatic biota) and/or were considered valuable for cultural heritage (e.g. old power plant or mill; **Table 1**, **Appendix 2**). For more detailed description of each dam location, see **Appendix 2** and/or contact the authors.

Table 1. *Characteristics of the 40 properly localized dams reported via electronic questionnaire.*

Characteristic	n	%	Characteristic	n	%
Height (m)			***Purpose of the dam***		
0-1	5	17	Hydropower plant	8	26
1-2	7	23	Mill (saw, flour etc.)	6	19
2-5	14	47	Log driving	5	16
5-10	4	13	Drinking water	2	6
>10	0	0	Fish hatchery	1	3
Not known	10		Other	3	10
Width (m)			Multiple	6	19
<1	1	3	Not known	9	
1-2	2	6	***Expected environmental impact***		
2-5	3	9	Total migration barrier	15	39
5-10	14	44	Periodic migration barrier	8	21
10-20	8	25	Drying of downstream river section	1	3
>20	4	13	Multiple impacts	13	34
Not known	8		Other	1	3
Material			Not known	2	
Concrete	17	44	***Expected societal importance***		
Stone	9	23	Cultural heritage (power plant, mill etc.)	8	21
Multiple	13	33	Recreation (swimming, fishing etc.)	2	5
Not known	1		Multiple interests	10	26
Technical condition			Other	2	5
Good	5	19	No known function today	17	44
Moderate	13	50	Not known	1	
Poor	14	54			
Not known	8				

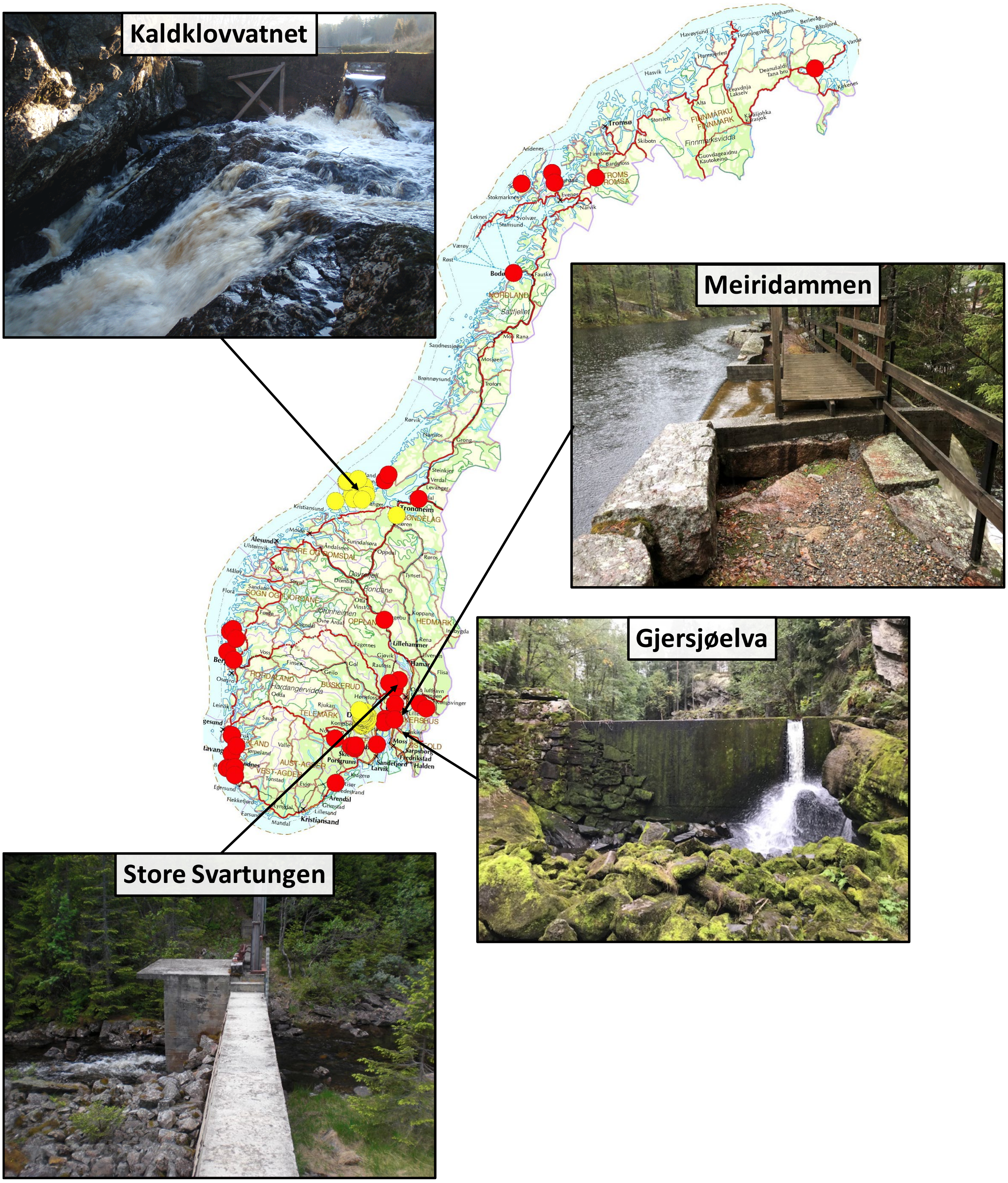

Figure 3. *Location and some photos of dams reported via the electronic questionnaire (red dots) and included in the field surveys (yellow dots). Photos: © Morten Andre Bergan (Kaldklovvatnet), Roy Winge (Meiridammen), Sander Engeland (Gjersjøelva) and Erik Olstad (Store Svartungen).*

3.2 Case I: Anadromous watercourses in Trondheimsfjorden

3.2.1 Background and description of the study area

Norway has a very long coastline where numerous small streams and large rivers with anadromous/catadromous fish populations (sea trout, salmon and eel) flow into the sea. While the negative impacts of fish farming, salmon fluke (*Gyrodactylus salaris*), salmon louse (*Lepeophtheirus salmonis*) and hydropower operations on wild salmon populations in large rivers are studied intensively, there has been little research on how man-made barriers in small streams affect migratory fish populations along the Norwegian coast. However, if accessible and having a good water quality, these small streams can be very important spawning and nursing habitats for anadromous fish, thereby also supporting fish stocks in nearby rivers with high recreational and socio-economic value. Recent studies from numerous small and medium-sized sea trout streams in central Norway indicate a total of 80–90 % loss in fish production capacity resulting from various human impacts, such as migration barriers, reduced water quality and hydro-morphological alterations (Bergan & Nøst 2017, Bergan & Solem 2018, Hol 2018).

Coastal areas in Trondheimsfjorden, central Norway (**Figure 4**) are good targets for case studies of old dams that restrict or prevent fish migrations in small streams with anadromous fish (Bergan 2012a, 2013, 2014b, Bergan & Nøst 2017, Bergan et al. 2011). As mentioned above, in the Trondheim region and lower parts of the Gaula river, an estimated up to 90 % of sea trout production has been lost in small streams due to migration barriers, agriculture and urbanization (Bergan & Nøst 2017, Bergan & Solem 2018). The past 10 years of research in these areas (Bergan 2012a, 2014a-b, 2016, Bergan & Steen 2013) indicates that old dams and other barriers likely have extensive impacts on fish migrations (**Figure 4 and 5**). This is the case in small streams that flow directly into the sea, as well as in tributaries of larger salmon rivers. Besides sea trout and salmon, migration barriers in these streams can also have varying local impacts on catadromous eel populations.

To consider two types of small watercourses with anadromous fish, we selected to study old dams in: (1) **Kaldvella**, a tributary of Gaula river, and (2) **Dragvatnet** in Hitra island where numerous small streams flow to the sea (**Figure 4**). These two case study areas are expected to give valuable insights into the common problems associated with old dams and other barriers in small coastal streams with anadromous fish.

More information about the numerous tributaries in some of the large salmon rivers in central Norway is provided in the following reports (and references therein): **Orkla** (Bergan 2012c, Bergan & Steen 2013, Solem et al. 2018), **Gaula** (Bergan & Solem 2019, Solem et al. 2014, 2018), **Nidelva** (Nøst 2018), **Stjørdalselva** (Bergan 2012b) and **Verdalselva** (Bergan et al. 2007, Hol 2018). For more information about small streams and migration barriers along the outer and inner coastal areas of Trondheimsfjorden, see the reports by Bergan (2012a, 2013, 2014a-b, 2016), Bergan & Steen (2013) and Bergan & Solem (2018).

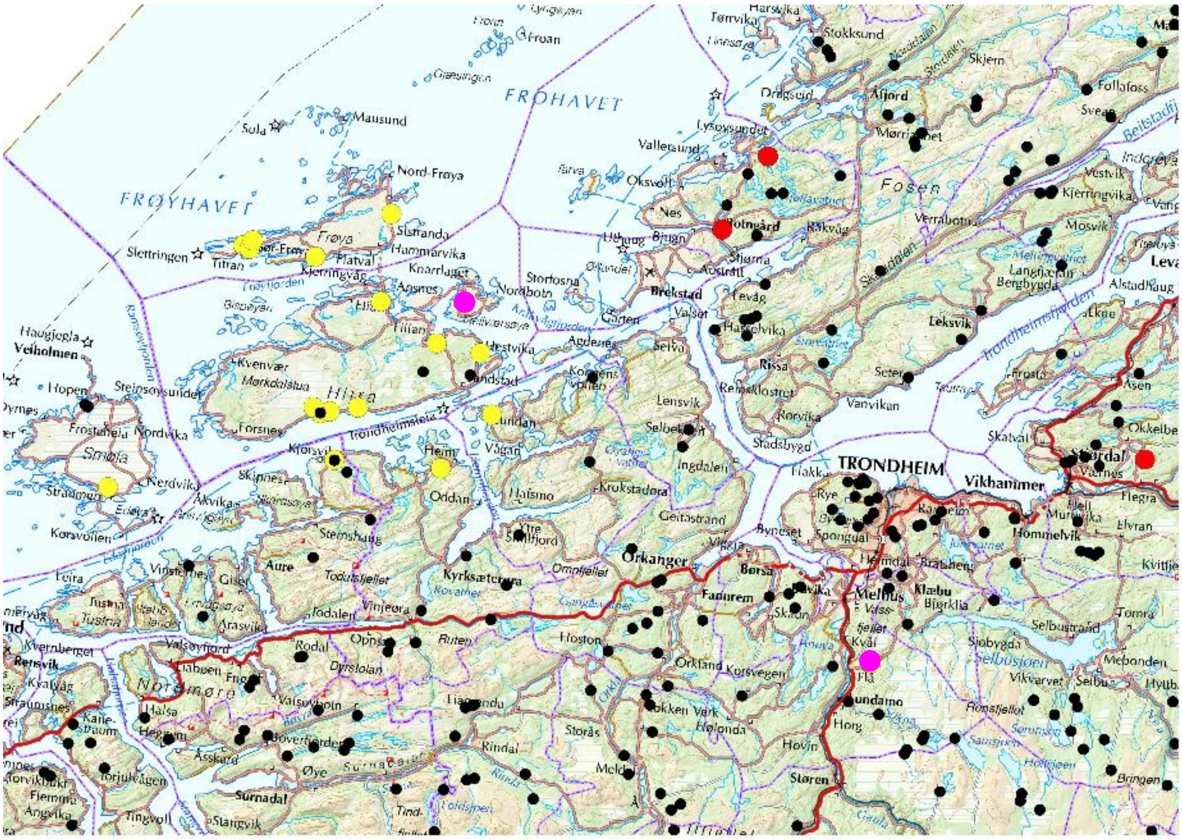

Figure 4. *Dams in inner and outer coastal areas of Trondheimsfjorden reported via the electronic questionnaire (red dots), in the present field surveys (yellow dots) and in the NVE DamPunkt-database (black dots). Pink dots show the location of dams in Kaldvella, a tributary to Gaula river located south of Trondheim, and at the outlet of Dragvatnet in Hitra island.*

Figure 5. *Remains of old dams in Fosen area (top row), in a tributary to Orkla (middle), and Hofstadelva, a tributary of Gråelva in Stjørdalsvassdraget (bottom row). See Bergan (2014b), Bergan & Steen (2013) and Bergan et al. (2017) for more details of these streams with anadromous fish populations, respectively. Photo: © Morten Andre Bergan.*

3.2.2 Kaldvella – a tributary to Gaula

Based on field data from 19 dams in the Hitra area, most dams (73 %) in the outer coastal areas of Trondheimsfjorden are built for fish hatcheries (**Appendix 2**). Only two of the 19 dams (11 %) are currently registered in the NVE DamPunkt-database (**Figure 4**). Hence, dams built for fish hatcheries likely represent a significant, yet unevaluated, problem for migratory fish along the coast of Norway (see **Figure 2**).

Dams built for fish hatcheries also affect anadromous fish populations in Kaldvella, a tributary to Gaula river in the municipality of Melhus (**Figure 4 and 6**). Kaldvella used to be an important spawning habitat for salmon and sea trout. Today, three dams prevent access of migratory fish to upstream spawning habitats (**Figure 6 and 7**). Adult and juvenile salmon and sea trout have been observed all the way up to a 1.5–2 m high and approx. 8 m wide dam made of large rocks and gravel (**Figure 7**; Solem et al. 2014). The purpose of this relatively old dam (#1) is unknown, but it may have been built for agriculture or to obtain water for the A/S Lundamo Settefisk fish hatchery. Later, a 1–1.5 m high and ca. 5 m wide concrete dam (#2) and a reservoir with an approx. 8 m wide dam (#3) were built in separate branches of the Kaldvella stream (**Figure 7**). It is unknown whether these dams are or will be used, depending on the plans of Lundamo Settefisk hatchery.

Based on estimates by Bergan & Solem (2018), over 50 % of the total length and area of potential spawning and nursing habitats for anadromous fish are lost due to the three mentioned dams in Kaldvella. Removing these barriers or building fish ways would allow migratory fish to utilize upstream areas offering better water and habitat quality than found downstream of the fish hatchery (**Figure 6**; Bergan & Solem 2018).

Figure 6. *Adult sea trout and juvenile salmon caught downstream of the dams in Kaldvella on 23rd September 2013 (top row). Upstream stretches of Kaldvella with little human activity and good but inaccessible habitat for anadromous fish. Photo: © Morten Andre Bergan.*

Figure 7. *Location and photos of three dams in Kaldvella. The dams prevent access of anadromous fish to upstream spawning and nursing areas (inaccessible stretch shown with a red line) and cause partial drying of a side branch of Kaldvella (see photo in lower right corner). Photo: © Morten Andre Bergan. Aerial photo obtained from https://kart.finn.no.*

3.2.3 Small coastal streams: case Dragvatnet in Hitra

As demonstrated by previous reports by Bergan (2012a, 2014a-b), many small streams in the outer coastal areas of Trondheimsfjorden are no longer accessible for anadromous fish due to old dam constructions. Although our pilot project focuses on only one of these watercourses, Dragvatnet in the island of Hitra, we expect numerous similar riverine systems to be affected along the entire Norwegian coast due to old dams and other migration barriers (see **Figure 2**). Information about other dams and migration barriers in the outer coastal areas of Trondheimsfjorden can be found in **Appendix 2** and in previous reports by Bergan (2012a, 2014a-b, 2016).

Dragvatnet (14 m a.s.l.) is the largest lake at Fjellværsøya island connected with a bridge to the larger Hitra island (**Figure 4 and 8**). Besides the lake outlet, Dragvatnet has four inlet streams including the streams from Sandtjørna (14 m a.s.l.), Hauklivatnet (15 m a.s.l.) and Gjertrudvatnet (37 m a.s.l.). All these small streams were likely suitable spawning and nursing habitats for resident trout, sea trout and/or salmon before a concrete dam was built at the Dragvatnet outlet (**Figure 8 and 9**). It is unknown exactly when the dam was built for the fish hatchery, which has been closed down since many years. It is not known how the fish populations were affected by the damming, but based on local knowledge and historical aerial photos, the streams connected to Dragvatnet have had viable sea trout stocks, probably because an old stone dam visible in photos from 1967 did not create a migratory barrier for fish, unlike the newer 1 m high concrete dam. This dam still exists although the fish hatchery is closed (**Figure 8 and 9**).

Based on electrofishing surveys, a scarce sea trout population still exists at the lowest stretch of the Dragvatnet outlet, whereas the upper, temporarily dry stream section is nearly fishless (Størset 2011; Bergan 2012a). Bergan (2012a) estimated that 79.5% (i.e. 862 m of a total 1085 m) of the potential stream stretch for anadromous fish in the Dragvatnet watercourse is currently lost due to the concrete dam at the lake outlet. Bergan (2012) also estimated that the dam may have caused an annual loss of over 9000 smolts and up to 1000 spawning (1SW) sea trout. Hence, dam removal or a nature-like bypass channel seem to be promising mitigation measures to improve recruitment potential of anadromous and resident fish populations, as well as the ecological status of Dragvatnet and its connected streams. Overall, a comprehensive survey of migration barriers and restorations in small streams along the Norwegian coast is urgently needed to preserve genetically unique anadromous fish stocks utilizing these widely ignored but potentially very productive river networks.

Figure 8. *A concrete dam with a downstream chute at the outlet of Dragvatnet. Photo: © Morten Andre Bergan.*

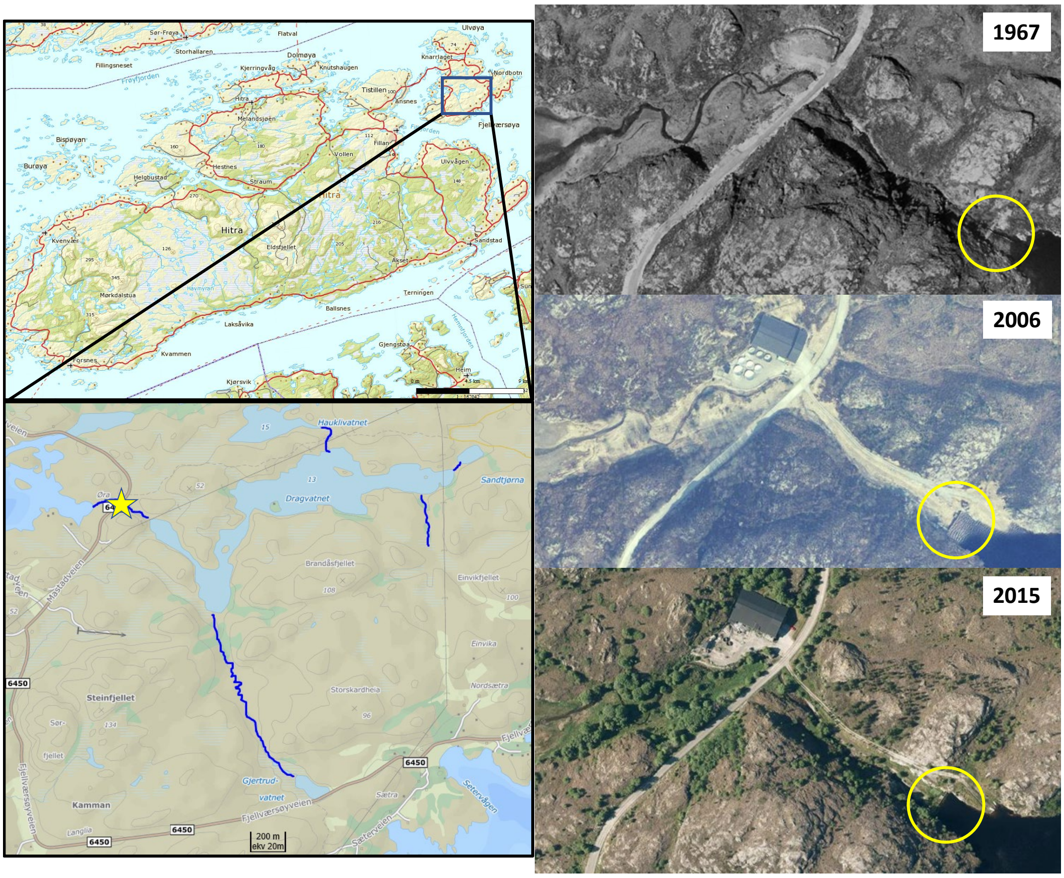

Figure 9. *The location of Dragvatnet and its outlet dam (yellow star) at Fjellværsøya island connected to Hitra island. Blue lines indicate inlet and outlet streams around Dragvatnet. These streams were accessible for migratory fish before a small stone dam (see yellow circle in aerial photo from 1967) was replaced by a 1 m high concrete dam built for the fish hatchery (see photos from 2006). Today, the hatchery is closed but the concrete dam remains (see photo from 2015). Map and aerial photos obtained from https://kart.finn.no.*

3.3 Case II: Tributaries of Drammenselva with resident fish

3.3.1 Background and description of the study area

We selected four tributaries to Drammenselva in Øvre Eiker, southern Norway, as the second case to study the number, characteristics and restoration potential of old dams in a river network hosting resident fish populations. Brown trout is the most common fish species in these watercourses, but there are also other valuable species that are affected by dams, including lamprey, eel and the endangered freshwater pearl mussel. Since the 17^{th} century, the rivers in this area have been subjected to substantial human activities, mainly wood processing (saw mills and log driving), mining and hydropower production. These activities have caused various conflicts related to e.g. cultural heritage, recreational use, safety, private property and nature in the area, but also left behind numerous dams that are no longer in use and thus potential targets for river restoration projects (**Figure 10**).

Our survey focused on four tributaries to the large Drammenselva river: **Bingselva**, **Dørja**, **Hoenselva** and **Darbuelva** (also called Fiskumelva). All these streams originate from different parts of the Holtefjell highland area with large coniferous forest tracts. Most streams host populations of brown trout, freshwater pearl mussel, lamprey and eel. **Bingselva** is the largest of the four tributaries (catchment area: ca.187 km^2), consisting of 10 waterbodies with good or very good ecological status. **Dørja** is the second largest tributary (ca. 70 km^2), consisting of 10 waterbodies with ecological status varying between moderate and very good. **Hoenselva** is the third largest tributary (ca. 44 km^2), consisting of 12 waterbodies with ecological status ranging from moderate to very good. **Darbuelva** is the smallest study tributary with waterbodies having ecological status ranging from poor to very good. In general, waterbodies in the uppermost parts of the river systems have better ecological status than those downstream where e.g. agriculture, mining and residential activities have reduced water and habitat quality for aquatic biota.

Here, we summarize the main findings of our field survey. For more detailed description of the watercourse and dam properties, see **Appendix 2 and 4** and/or contact the authors.

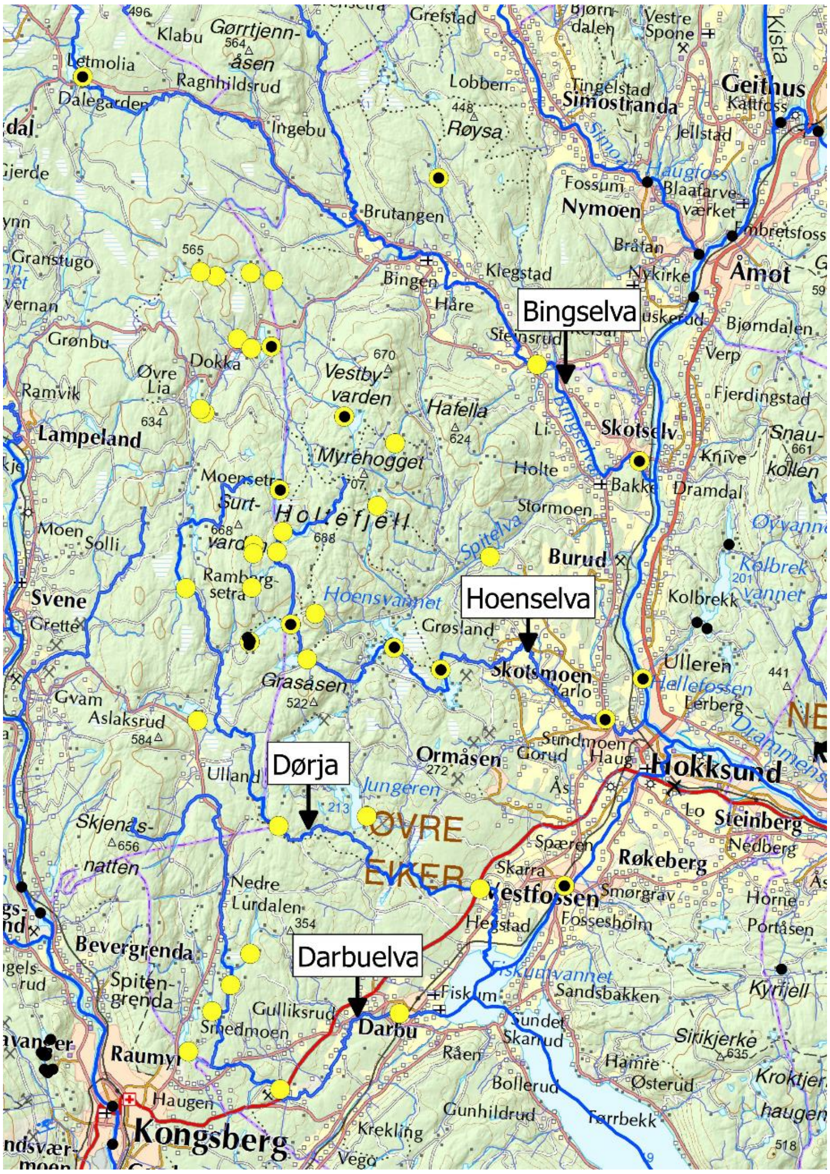

Figure 10. *Location of dams in the Drammenselva study area in Øvre Eiker, southern Norway, including structures recorded in the field survey (yellow dots) and in the NVE DamPunkt-database (black dots).*

3.3.2 Dam and stream characteristics

Our survey included data from a total of 43 dams: 18 dams in Bingselva, 5 dams in Dørja, 12 dams in Hoenselva, 6 dams in Darbuelva and two dams in the lower parts of the river systems, i.e. Hellefossen in Drammenselva and Vestfossen between Drammenselva and the large lake Eikeren (**Figure 10**). Of the 43 surveyed dams, only 13 (30 %) are currently registered in the NVE DamPunkt-database. Eight of the study dams were already removed and one was under construction (i.e. "Stensrud kraftverk"). Most dams were 2–5 m high and >20 m wide and built of stone and/or concrete (**Table 2**, **Figure 11**). Many dams were multipurpose structures; they were often originally built for log driving and later used to store water for hydropower production. Today, the reservoirs created by the dams are often used for recreational activities (fishing, swimming etc.) and they provide habitat for other biota than migratory fish, including waterfowl and amphibians. Most dams were considered total barriers for fish, but some were passable because they were either partially or completely removed or had naturally collapsed.

Most investigated dams in Drammenselva river system have small or moderate potential for barrier removal or other mitigation measures. Many dams are located in small "first-order" creeks and streams in Holtefjell highland area, where barrier removals or fish-passages would open up only relatively small river sections for migratory fish. Moreover, many dams have important ecological (e.g. habitats for amphibians and waterfowl), cultural and recreational values making them less feasible targets for dam removal projects. However, as indicated below, some of the dams are potential candidates for restoration projects.

Table 2. *Characteristics of the 43 dams surveyed in Drammenselva river system in Øvre Eiker, southern Norway.*

Characteristic	n	%	Characteristic	n	%
Purpose of the dam			***Height (m)***		
Log driving	7	18	<0.5	0	0
Mill (saw, flour etc.)	5	13	0.5-1	3	9
Hydropower plant	2	5	1-2	10	29
Fish farming	1	3	2-5	21	60
Multipurpose	25	63	5-10	1	3
Not known	3		>10	0	0
Material			Not known	8	
Concrete	16	42	***Width (m)***		
Stone	20	53	<1	0	0
Multi-material	2	5	1-2	1	3
Not known	5		2-5	4	11
Migration barrier effect			5-10	9	26
Total barrier	24	63	10-20	4	11
Partial barrier	3	8	>20	17	49
Not a barrier	11	29	Not known	8	
Not known	5				

***Figure 11**. Photos of dam locations in different tributaries of Drammenselva. The old dam at the Dørsjø outlet in Dørja river is already removed. Photos: © Finn Gregersen.*

3.3.3 Restoration potential

The reported and unknown dams in Drammenselva watercourse apparently decrease connectivity of the river network and reduce the access of migratory fish to suitable spawning, nursing and overwintering habitats (**Figure 10 and 12**). Many of the small streams in this area have good water quality and host populations of endangered freshwater pearl mussel which, in turn, are strongly dependant on salmonid fish (in this case brown trout) as hosts for their larval stages. Therefore, improving migration potential and living conditions for salmonid fish in tributaries of Drammenselva would support recruitment of the freshwater pearl mussel and the well-being of other invertebrate, plant and vertebrate species living in these unique ecosystems. However, in many cases, such mitigation measures are not straightforward and feasible due to e.g. relatively high costs and minor socio-economic benefits, as well as other ecological and societal values associated with the existing dam structures.

At least 10 dams have already been removed or restored in tributaries to Drammenselva, including both relatively small (e.g. Arnfinnsplassen, Muggerudtjernet, Bråtatjern and Svartbekkdammen) and large (Smedsvatnet, Hoensvatnet, Himsjø and Krokvatnet) dams. These restoration projects are poorly documented, but they are likely undertaken with support from the county governor and/or county authorities. Moreover, many remaining old dams will naturally collapse and thereby restore connectivity. Below we indicate some of the potential targets for future restoration projects based on our field surveys in three of the studied tributaries of Drammenselva.

Dørja: Dørja is a picturesque stream flowing through forested areas on the southern slope of Holtefjell. Large brown trout are found in lower parts of the stream downstream of a waterfall, and freshwater pearl mussel are found in upstream areas. Even if large brown trout might have been able to pass the downstream waterfall, their migrations are nowadays blocked because of a 1–2 m high dam at Lundteigen (see Lundteigendammen in **Figure 12**). Building a nature-like bypass channel at the dam and possibly altering some difficult slopes at the downstream waterfall would enable large brown trout from Drammenselva to migrate to high-quality spawning and nursing habitats down- and upstream of Jungeren and Dørsjø where old dams have already been removed at the lake outlets. However, before such mitigation measures are implemented, genetic analyses of brown trout and freshwater pearl mussel should likely be conducted to avoid potential unwanted mixing of genetically unique populations in up- and downstream sections of the river.

Bingselva: Bingselva is a relatively large river system with numerous beautiful tributaries. However, fish from Drammenselva need to pass 1–2 relatively large hydropower dams at the lower parts of Bingselva, i.e. Skotselv dam (damNr 3326) and the planned Stensrud dam. Building fish ways (e.g. nature-like bypasses) or removing these dams would allow fish from Drammenselva to migrate up to valuable spawning and nursing areas in e.g. Spitelva, Smedselva, Letmolielva and Løken. As far as we know, most tributaries of Bingselva host resident populations of brown trout and freshwater pearl mussel. Removal of migration barriers would improve recruitment and colonization potential for both species. The most feasible targets for restoration projects include (1) an old, obsolete dam in the middle-part of Spitelva and (2) a dam at the outlet of Grølla (**Figure 12**). The dam at Grølla is in poor condition but it may need to be retained as a cultural heritage. Other candidates for mitigation measures include establishing simple fish passages at the Letmolivatnet and Smedsvatnet dams.

Hoenselva: Hoenselva is a long picturesque stream originating from the relatively large lakes Himsjø and Hoensvannet, which are surrounded by many holiday cabins. Both lakes are dammed at the outlet. Hoenselva also has a hydropower dam (damNr 4836, not in use) at Hoen before it drains to Drammenselva. Fish from Drammenselva cannot migrate upstream to potential spawning and nursing habitats in Hoenselva, Kåsabakken and Gorudbekken due to Hoensfossen, an approx. 10 m high natural waterfall. Moreover, several road crossings and runoff from surrounding fields and settlements probably reduce fish access and habitat quality in the downstream stretches of Hoenselva. Upstream Hoensfossen, better river connectivity would be vital for the fish populations (Ruud 2019, in prep.). Even at the very large hydropower dam at Hoensvannet (damNr 3331, not in use), one has been able to build a nature-like bypass channel and hence this should be possible also at the Himsjø outlet. Improving possibilities for up- and downstream migration between Himsjø and Hoenselva would support natural recruitment and the well-being of brown trout and freshwater pearl mussel populations in this river system and thereby also increase recreational value of this popular area. Although the mentioned dams would likely be the most fruitful restoration targets in terms of increased availability of valuable river stretches, the easiest and cheapest first target in Hoenselva is probably the dam at Krokvannsløken outlet (**Figure 12**). Opening of the dam's bottom drain channel would already improve fish passage. One should also consider creating nature-like bypass channels at the dams in Krokvannsløken and Krokvatnet outlets because such restorations would allow fish to migrate to extensive spawning and nursing habitats in the uppermost areas of the river system.

Figure 12. *Potential targets for dam restorations in the study tributaries of Drammenselva in Øvre Eiker, southern Norway. Photos: © Finn Gregersen. See* ***Appendix 4*** *for more detailed description.*

3.4 Overview of national and international literature and projects

This section gives an overview of previous and ongoing national and international restoration projects aiming to increase connectivity and ecological status of rivers. This overview indicates relevant literature and findings from previous projects which can help future planning and implementation of river restoration projects at local and larger national and international scales.

There are several practical handbooks that are highly relevant for planning, implementation and monitoring outcomes of river restorations and barrier removals. Two recent and freely available books are: (1) "From Sea to Source 2.0. Protection and restoration of fish migration in rivers worldwide" (Brink et al. 2018) and (2) "River Restoration: A Strategic Approach to Planning and Management" (Speed et al. 2016). For instance, the book "From Sea to Source 2.0" provides step-by-step guidelines and best practice solutions for mitigation measures in rivers, including dam removal. The web pages of some international projects and foundations, such as AMBER (https://amber.international/), Dam Removal Europe (www.damremoval.eu) and NSLC Adopt A Stream (www.adoptastream.ca), are also very useful sources of information providing a wider perspective of dam removal and river restoration projects around the world. Another easy way to get more knowledge of dam restoration projects is to watch the two episodes of the "Dam removal step by step" webinar series (https://www.youtube.com/watch?v=Jkrksvr1nv4, https://www.youtube.com/watch?v=5bFqHSqPcWU).

There is a huge number of scientific publications describing findings from various barrier removal and river restoration projects around the world. The special section of BioScience journal (volume 52, issue 8; Hart & Poff 2002) includes several interesting articles related to the environmental, societal and economic aspects of dam removals. Other relevant and more recent scientific publications related to dam removals include: Foley et al. (2017), Tonitto & Riha (2016), King et al. (2017), McCartney 2009, Katopodis & Aadland (2006), Stanley & Doyle (2003) and Bednarek (2001). From a Nordic perspective, the insights of Lejon et al. (2009) to conflicts associated with dam removal in Sweden are highly relevant for successful planning and implementation of such restoration actions. The study by Fjeldstad et al. (2012) demonstrates how removal of weirs in a Norwegian river can increase spawning habitat area and recruitment success of salmon and lead to disappearance of unwanted, non-riverine fish species (pike and cyprinids).

The results and experiences from Swedish dam removal projects provide relevant information about ecological, economic and societal aspects (i.e., benefits and challenges) of dam removals in the Nordic countries. The recent Swedish reports and projects include: (1) "Restaurering av vattendrag med dammar – med exempel på dammutrivningar" (Sjöstrand et al. 2018), (2) Remediation of migratory barriers in Nordic/Fennoscandian watercourses – ReMiBar" (Schönfeldt 2017), and (3) the ongoing "ReBorN LIFE – Restoration of Boreal Nordic Rivers project" (https://www.rebornlife.org/). In Finland, the pilot project by Eloranta & Eloranta (2016) gives an overview of environmental problems associated with road–river crossing structures (particularly culverts and bridges). The recent "Esteet pois!" project lead by Metsähallitus (Moilanen & Luhta 2018) and the "K Fishways" project lead by WWF Finland and K-market company (https://kesko.fi/kalapolut; see the project promotion video: https://www.youtube.com/watch?v=dKb2JEI11I0&feature=youtu.be) demonstrates how national citizen science projects can increase public awareness and involvement in river restoration and barrier removal projects.

In Norway, different institutions and authorities have mapped and removed migration barriers in rivers and streams. In addition to the mentioned literature, the most relevant national reports related to stream restorations and barrier removal include: (1) "Tiltakshåndbok for bedre fysisk vannmiljø: God praksis ved miljøforbedrende tiltak i elver og bekker" (Pulg et al. 2018) and (2) "Håndbok for miljødesign i regulerte laksevassdrag" (Forseth & Harby (2013). There are also two

Norwegian handbooks demonstrating how migration barriers in road–river crossing structures (particularly culverts) can be restored to improve migration potential of fish and other biota: (1) “Slipp fisken fram!” (Direktoratet for naturforvaltning 2002) and (2) “Frie fiskeveger – Utbedring av vandringshinder for fisk” (Haugland & Vågnes Hjelle 2015). The comprehensive survey of man-made barriers in Hurdalsvassdraget watercourses (Pedersen et al. 2017) is a great example of a local collaborative project with various stakeholders (e.g. municipality, county governor and local people) contributing for a common good and developing a database needed for planning future restoration projects in these watercourses. The NVE report by Nynäs (2013) describes the various societal aspects related to dams in Norway, with a particular focus on cultural heritage value.

To the best of our knowledge, the most recent dam removal projects in Norway include: (1) Ovenstaddemningen (UTM32N: 574185E, 6633266N) in Rotuelva in Lierskogen, southern Norway, which is planned to be removed in summer 2019; (2) Viuldammen in Randselva located between Jevnaker and Tyrifjorden in southern Norway (Foldvik et al. 2019); and (3) a dam at Foldsjøen outlet in Malvik municipality in central Norway (https://www.nve.no/konsesjonssaker/konsesjonssak?id=7942&type=V-2). If documented well, these planned dam removal projects will provide interesting insights into how such river restorations can be realized in Norway, e.g. in respect to various challenges, conflicts and opportunities.

4 Discussion

4.1 Dams and small streams in Norway

This pilot project gives a glimpse into how numerous, variable and challenging restoration targets dams and small streams in Norway can be. At the same time, our project indicates a great potential to improve connectivity, biodiversity and fish population status in river systems affected by damming and various other human impacts. The collected data (**Appendix 2**) is a useful starting point for planning and implementation of dam removal projects. However, more data on old dams and other man-made barriers are urgently needed from all over Norway. Our survey demonstrates the huge number of dams in Norwegian watercourses. Given the fact that only 21 % of the 102 reported dams are among the 3887 dams registered in the NVE DamPunkt-database, the total number of dams in Norway can be roughly estimated to exceed 18 000. When other man-made migration barriers such as road/railway crossings (culverts) are added to the total count, it can be concluded that Norwegian stream and river networks are highly fragmented, particularly due to the massive hydropower industry, different land-use activities and infrastructure development.

Many dams in Norway are old, obsolete and/or they no longer fulfil their original purpose. However, even such dams are often challenging targets for barrier removal or other mitigation measures due to e.g. high costs, low benefits and/or various other ecological and societal aspects. Holistic and meticulous planning and cooperation between e.g. engineers, ecologists, environmental authorities and local people is essential for successful mitigation projects (see **Appendix 3**). Moreover, several legal documents, such as the Water Resources Act and the Dam Safety Regulations, must be considered during the planning, implementation and monitoring phases of barrier restoration projects.

4.2 Restoration potential

Removal of dams and other migration barriers has become a widely applied measure in river restoration aiming to improve the ecological status of rivers, their fish stocks, and the connected ecosystems (Schönfeldt 2017, Brink et al. 2018, Sjöstrand et al. 2018). Rivers and their surroundings are often biodiversity hot-spots and human impacts on rivers can cascade across various connected habitats, including terrestrial, freshwater and marine ecosystems. Climate change is predicted to induce extreme weather conditions (e.g. flooding and drought) whose associated environmental problems can be both dampened and strengthened by dams and other man-made constructions. However, dams typically prevent natural hydrological and ecological processes in rivers and they are also in violation of national and international environmental agreements and targets. There is a huge potential for improving the ecological status and connectivity of rivers in Europe and elsewhere by removing barriers such as obsolete dams. However, removal of dams and other man-made barriers is not at all a simple task due to e.g. conflicts between various stakeholders.

The results from our questionnaire and field surveys indicate a great potential for stream restorations and dam removals around Norway. Many of the reported dams are relatively small-sized and in poor condition and thus feasible targets for restorations. In some cases, dam removal would open substantial new spawning and nursing habitats for migratory fish, as is the case e.g. in Kaldvella, Dragvatnet and some tributaries of Drammenselva, including Dørja and Bingselva. The most beneficial, but often also most challenging, targets for dam removals are found in the lower-most parts of the river systems. In these areas, a single dam or other barrier can cause several kilometres or hectares of lost spawning and nursing habitats for migratory fish. Hence, the highest priority should be given to removal of dams that no longer have a known function (Schönfeldt 2017, Sjøstrand et al. 2018). If the technical condition of the dam is good enough and the dam has societal value (e.g. cultural heritage; Nynäs 2013), then creating a nature-like bypass channel could be the most feasible option for increasing river connectivity and movement of biota up- and downstream of the dam (Dodd et al. 2017). This was the case in Hoendammen in Drammenselva watercourse where cabin owners, anglers and environmental actors joined forces to finance a new dam and a fish passage after the old dam started leaking and the lake water level decreased.

Some old dams have already started to collapse and with time natural forces may finalize removal of these man-made barriers. Many old dams and especially numerous road-river crossing structures (e.g. culverts) are relatively easy and inexpensive targets for restoration. With some financial support and guidance, even local groups can implement such barrier removal projects, as indicated by the recent ReMiBar project in Sweden (Schönfeldt 2017). Based on a recent Swedish report (Sjöstrand et al. 2018), the total costs of dam removal vary a lot, but are typically between 100 000 and 180 000 SEK per dam height meter. In ReMiBar project, the cost of removal of 30–97 barriers in each of five Swedish river networks amounted to a total of 1.2–3.0 mill. euros (Schönfeldt 2017). In the “Frie fiskeveger” project conducted by The Norwegian Public Roads Administration, building of fishways, weirs and new bridges to allow migratory fish to pass road crossings amounted to between 20 000 and 6 000 000 NOK, depending on the size and implementation of the project (Haugland & Vågnes Hjelle 2015). Hence, given the potential far-reaching environmental and socio-economic benefits, as well as the high costs associated with maintenance or renewal of old constructions, removal of old dams may be an attractive mitigation measure in many river systems (Brink et al. 2018).

Today, the purpose of most dams in Norway is to generate hydropower or to create reservoirs for drinking and irrigation water, recreational use and/or fish hatcheries (**Figure 1**). Many small dams were built a long time ago for other purposes, such as log driving, mining and household use, but in the recent years or decades they have been utilized for more modern purposes. Based on data in the NVE DamPunkt-database and from our survey, the purpose of dams seems to vary depending on their geographical location (**Figure 2**). Dams for hydropower plants are most abundant close to highly-populated areas in the western and southern Norway as well as in the mountain areas. In contrast, reservoirs for drinking water, recreational use and fish hatcheries are typically found in the low-land and coastal areas. The oldest dams seem to be built in areas with substantial mining and forestry activity, as is the case in the tributaries to Drammenselva. Overall, the largest densities of old, obsolete and abandoned dams, and thus also the largest potential for dam removal, is probably found near highly populated areas, i.e. in Oslo, Stavanger, Bergen and Trondheim regions (**Figure 13**). Although dam removal in these regions could result in significant environmental and socio-economic benefits via improved biodiversity, ecosystem status and recreational value, they may also turn out to be particularly challenging restoration targets due to the potential importance of dams for cultural heritage, flood control and recreational activities (e.g. Nynäs 2013).

Indeed, there are many important political, social, economic and environmental factors that need to be considered in the dam removal decision-making process (Brink et al. 2018). As described in the section “7.3 Basic steps to dam removal” in Brink et al. (2018), there are four basic steps that should be taken when considering a dam removal (**Appendix 3**): (1) the feasibility and planning phase, (2) a design and permitting phase, (3) the construction or deconstruction phase, and (4) a monitoring and adaptive management phase. Several criteria need to be evaluated and considered within each step, and these steps may differ significantly between regions. In addition, the presented generalized conceptual model should be adapted for Norwegian dam removals. Nevertheless, early involvement of diverse stakeholders (dam and land owners, municipal offices, county administration boards, research groups etc.) is key to avoid conflicts and to conduct successful dam removal projects because it increases people's willingness to find compromises and to contribute to the actual restoration work (Lejon et al. 2009; Brink et al. 2018). In Norway, one of the greatest challenges for dam restoration projects is that the owners of old dams are often unknown; thus, it can be difficult to obtain permits and financial support for dam removal projects.

There are many ways to optimize the outcome of a dam removal process. Some of the important questions during the planning and implementation phase are:

1) Would dam removal be a feasible option in terms of costs and benefits?

2) Would dam removal cause conflicts between different interest groups and activities, such as recreational use, water supply for households, agriculture and/or fish hatchery, flood control, cultural heritage, other biota than fish etc.?

3) Is the current technical condition and environmental and/or socio-economic impacts of the dam acceptable? Could compromises and/or simple mitigation measures (e.g. a natural bypass channel or other technical solutions) be sufficient and the dam be retained?

4) Does the dam prevent fish migrations, and if yes, what kind of migrations? Does the fish community include anadromous/catadromous or resident fish species or both, and how might they be affected by the presence/absence of the dam?

5) Is it possible to improve living conditions (e.g. habitat quality and food availability) for fish in other ways than by increasing migration potential within the river system?

Barrier removal and river restoration projects must always follow national legislation. Chapter 7 in the Norwegian Water Resources Act ("vannressursloven"; §§ 41 - 43) deals with the removal/shutdown of man-made constructions in river systems. §41 states that upon removal/shutdown, "the watercourse must be returned as far as possible to the conditions as they were before the construction was built". If removal/shutdown of a construction can lead to substantial damage or disadvantage to public interests, a license is required pursuant to §8 of the Act. Therefore, one must communicate with management authorities (e.g. NVE) ahead of a planned construction removal/shutdown to find out what kind of process is required and to get a license requirement assessment. In such a process, relevant instances are heard, and it is decided whether one needs a license or not. Whatever happens with the licensing, relevant stakeholders (environmental authorities, dam and landowners, municipalities, NGOs etc.) must be informed and heard in good time before starting the actual work. According to the Dam Safety Regulations managed by NVE, all dams need to be assigned to one of four safety classes prior to work on the constructions. These classes are related to the potential for harm to people, infrastructure and the environment in the case of a dam failure. Such classification must therefore take place in the preparation of a dam removal/river restoration project if it has not been done earlier.

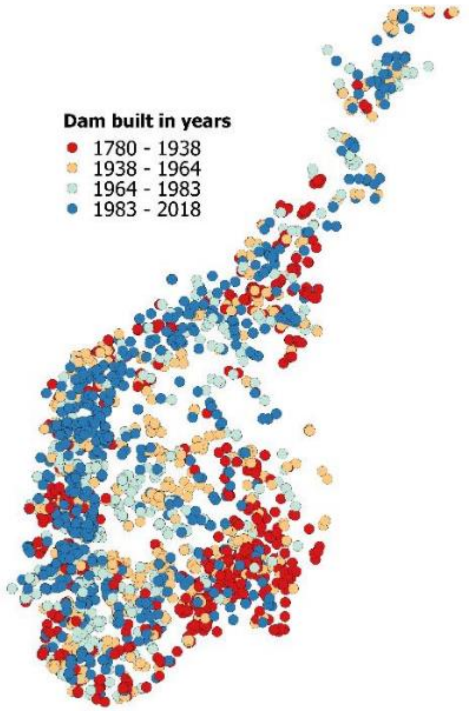

Figure 13. *A map showing the location of dams built in different time periods in southern Norway. Data obtained from the NVE DamPunkt-database.*

4.3 Dams, ecological connectivity, and the EU Water Framework Directive

During the last decade, the implementation of the EU Water Framework Directive (WFD) has required Norwegian water management authorities to adapt their evaluation, monitoring and mitigation activities in freshwater ecosystems, including e.g. measurement and assessment of hydro-morphological (HYMO) parameters (Anonymous 2018b). In Norway, the implementation of WFD is done by passing of the Water Management Regulation (vannforskriften) which ensures formal anchoring of the WFD in Norwegian law and management as Norway is not an EU member. § 4 in the regulation states that the status of surface water shall be protected, improved and recovered with the aim of reaching at least good ecological and chemical status. Restoration projects related to dams and barriers in Norwegian streams and rivers is certainly in line with this aim. § 5 deals with heavily altered water bodies which should reach good ecological potential, instead of good ecological status. This altered wording relates to the fact that waterbodies are defined as heavily modified if they have been subjected to hydro-morphological (HYMO) alteration of a nature that is of societal benefit. If this is the case, the goal is defined in terms of ecological potential being the ecological status in the waterbody, with the HYMO alteration present, but after all possible mitigation measures have been implemented. In respect to our pilot project, most potential restoration targets should not be considered as heavily modified waterbodies because the dams are mainly obsolete and thus not of high societal value. Hence, most watercourses studied here should reach a good ecological status in the coming years. Even if the waterbodies are considered as heavily modified and/or dam removal is an infeasible solution, other mitigation measures such as nature-like fish passages could have a significant positive effect on the ecological status of and migratory fish living in these river systems.

Hydro-morphological parameters are commonly evaluated and used in ecological classification of Norwegian waterbodies (Anonymous 2018b). These human-impacted HYMO parameters, such as alterations of river connectivity and habitat quality, are fundamental factors that need to be assessed and mitigated to achieve the national and international environmental goals. In the WFD concept, fish populations are important quality elements for classifying the ecological status of waterbodies, being supported by other parameters related to e.g. fish migrations and life-history-specific habitat and water quality requirements. Barrier-induced changes or reductions in availability and quality of suitable spawning and nursing habitats for fish (e.g. migratory salmonids, eel and grayling) are therefore important measurement criteria in the ecological classification system (Anonymous 2018b). Sustainable populations of these valuable fish stocks generally indicate good ecological status of a waterbody, but this status can rarely be achieved if the waterbody is highly fragmented due to damming.

4.4 "Veien videre?" – Recommendations for future barrier removal work

Improved mapping of numerous unregistered dams and subsequent mitigation of environmental problems associated with such barriers are urgently needed to increase the ecological status and connectivity of Norwegian river systems. Better communication between stakeholders and guidance of land-owners are among the most important steps towards sustainable management of rivers and streams. A "citizen science" approach would be an efficient and self-feeding way to increase public attention and involvement in registration and restoration of migration barriers. The "Barrier tracker" application developed in AMBER project (https://portal.amber.international/) is a good example of a user-friendly solution for barrier registration. We were surprised how much immediate public attention and positive feedback our pilot project received. However, we quite soon realized that a web-based questionnaire is probably not the most efficient and reliable tool to collect data of old dams: a significant proportion of registrations were incomplete, thus lacking important information, and most people did not send photos of the constructions. In addition, some people or institutions (e.g. Sjøørretklubben and Vannområdet Hurdalsvassdraget/Vorma) would have preferred simultaneous registration of multiple dams or other migration barriers. Therefore, different kinds of registration methods should be developed for future mapping. For instance, without our own field surveys, we would have gotten hardly any information about dams located in the coastal areas of Trondheim or in the tributaries of Drammenselva.

Besides collecting new data, the existing information about dams and other man-made barriers should be gathered into a comprehensive, well-functioning database. Such a database and data registration system would facilitate cost-efficient planning and implementation of barrier removals and stream restorations at local and national scales in Norway. Norway should also allocate funding from the state budget to develop a national action plan for restoration of migration barriers and conservation of small streams and rivers. This is also highly relevant considering that old, poorly maintained dams have high risk for collapse and predicted extreme weather conditions may further increase dam collapse and flooding risk, with significant negative socio-economic and environmental consequences in affected areas. Finally, Norway should become a more active member in the existing European river restoration projects (e.g. AMBER and Dam Removal Europe) and provide barrier data to international databases (see e.g. AMBER Barrier Atlas with very few barrier registrations and no official partners from Norway). More active sharing of knowledge, ideas, experiences and data, both nationally and internationally, would be an essential step towards a more sustainable management and protection of valuable river systems in Norway and to develop large-scale international research projects of high societal relevance and scientific quality.

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6 Appendices

6.1 Appendix 1: Electronic questionnaire

Velkommen til spørreundersøkelse om demninger i elver og bekker

Små bekker og elver spiller en svært viktig økologisk rolle, særlig som gyte- og oppvekstområder for fisk, men også for ulike akvatiske og terrestriske virvelløse arter, fugler og pattedyr (f.eks. elvemusling, fossekall, oter og bever). Det er også viktig at små bekker og deres tilhørende økosystemer langs elvebredden opprettholder sin økologiske funksjon, vann- og miljøkvalitet, slik at nedstrøms vannforekomster oppnår en god økologisk tilstand. Til tross for deres viktighet blir små bekker og elver ofte oversett i forvaltning og planlegging.

Demninger gir habitatfragmentering, og danner vandringshindre eller -barrierer, som gjør at mange fiskearter mister tilgang til viktige gyte- og oppvekstområder. Dette ser ut til å være en avgjørende grunn til at mange (sjø-)ørret-, harr- og ålebestander i vassdrag i Norge har redusert bestandsstørrelse.

Derfor er det et nødvendig behov for å få oversikt over omfanget, kartlegge plasseringen av demninger, og planlegge sanering/fjerning av gamle eller utrangerte demninger som ikke lenger er i bruk. Demninger som er etablert i de nederste elvestrekninger eller nedstrøms innsjøer/vann er de viktigste objektene, fordi fjerning av disse barrierene vil forbedre konnektivet betydelig, og gi størst økning i tilgjengelig areal for fisk til nye (men opprinnelige) gyte- og oppvekstområder.

Formålet med denne undersøkelsen er å samle inn kunnskap om plassering og egenskaper hos demninger som kan stoppe eller hindre fiskevandringer, og få oversikt over gamle demninger som ikke lenger er i bruk og kan fjernes, eller trenger oppgradering, slik at fisk igjen kan vandre lett forbi. Det er Norsk institutt for naturforskning (NINA) og Multiconsult Norge AS som gjennomfører undersøkelsen på oppdrag for Miljødirektoratet. All informasjon vil bli behandlet i henhold til personvernloven og anonymiteten til den enkelte vil bli ivaretatt i henhold til gjeldende lovverk. Du kan lese mer om NINA s personvernerklæring her: https://nina.no/Om-NINA/Personvernerkl%C3%A6ring

Har du spørsmål om undersøkelsen kan disse stilles til prosjektleder Antti Eloranta, e-post: antti.eloranta@nina.no, eller Morten Kraabøl, e-post: morten.kraabol@multiconsult.no

Her ber deg oppgi kontaktinformasjon, i tilfelle vi trenger å kontakte degfor ytterligere opplysninger eller avklaringer rundt demningen du rapporterer inn. Siden vi samler inn og lagrer personopplysninger om deg som svarer på undersøkelsen, kommer vi inn under de nye EU-reglene, og vi trenger derfor ditt samtykke til at prosjektet kan lagre disse opplysningene om deg til prosjektet er slutt. Skriv derfor "**Ja**" i første tekstrubrikk, dersom du samtykker i at vi kan lagre ditt navn, telefonnummer og epostadresse til prosjektslutt.

Kontaktopplysninger

Her ber vi deg oppgi kontaktopplysninger, dersom vi har behov for ytterligere informasjon om demningen

Jeg samtykker i at NINA kan lagre personopplysningene jeg oppgir nedenfor _____

Fornavn og etternavn _____

Telefon nr _____

Epost adresse _____

Oppgi navn og posisjonen på dammen

Bruk koordinatsystem WGS 84

Hva er navnet på dammen? _____

Nord-koordinater _____

Øst-koordinater _____

Kopier inn kartlink her _____

Hva er/var formålet til demningen? (flere kryss mulig)

(1) ❑ Vannkraftproduksjon

(2) ❑ Tømmerfløting

(3) ❑ Mølle/kvern/sagbruk

(4) ❑ Vannreservoar til brannberedskap

(5) ❑ Landbruksformål (vannmagasin/vann til beitedyr)

(6) ❑ Drikkevannskilde for mennesker

(7) ❑ Fiskeoppdrett/settefiskanlegg

(8) ❑ Rekreasjonsformål/badekulp

(9) ❑ Annet formål

(10) ❑ Kjenner ikke til/vet ikke

Du svarte "annet formål", vennligst oppgi det her

____

Hva er dammen bygget av?

(1) ❑ Betong
(2) ❑ Stein
(3) ❑ Tre
(4) ❑ Stål
(5) ❑ Annet materiale
(6) ❑ Kjenner ikke til/vet ikke

Du svarte "annet materiale", oppgi type materiale her

____

Oppgi høyde på dammen

(1) ❑ mindre enn 0,5 meter
(2) ❑ 0,5<1 meter
(3) ❑ 1-2 meter
(4) ❑ 2-5 meter
(5) ❑ 5-10 meter
(6) ❑ > 10 meter
(7) ❑ Kjenner ikke til/vet ikke

Oppgi bredde på dammen

(1) ❑ < 1 meter
(2) ❑ 1-2 meter
(3) ❑ 2-5 meter
(4) ❑ 5-10 meter
(5) ❑ 10-20 meter

(6) ❑ > 20 meter

(7) ❑ Kjenner ikke til/vet ikke

Strekker damkonstruksjonen seg over hele elva?

(1) ❑ Ja

(2) ❑ Nei

(3) ❑ Vet ikke

Om damkonstruksjonens tilstand, miljøpåvirkning og samfunnsmessige betydning

Er demningen fortsatt i bruk?

(1) ❑ Ja

(2) ❑ Nei

(3) ❑ Vet ikke

Hva er din vurdering av demningens tekniske tilstand?

(1) ❑ God

(2) ❑ Moderat

(3) ❑ Dårlig

(4) ❑ Vet ikke

Hva er din vurdering av damkonstruksjonen miljøpåvirkning? (flere kryss mulig)

(1) ❑ Total vandringsbarriere (for fisk eller andre viktige arter)

(2) ❑ Periodisk vandringsbarriere (for fisk eller andre viktige arter)

(3) ❑ Høy flomrisiko

(4) ❑ Tørrlegging av nedstrøms elvestrekning

(5) ❑ Annet

(6) ❑ Kjenner ikke til/vet ikke

Du svarte at damkonstruksjonen er en vandringsbarriere, angi om dette gjelder opp-strøms vandring, nedstrøms vandring eller begge deler

(1) ❑ Gjelder kun oppstrøms vandring

(2) ❑ Gjelder kun nedstrøms vandring

(3) ❑ Gjelder begge deler

(4) ❑ Kjenner ikke til/vet ikke

Du svarte "annen miljøpåvirkning", vennligst oppgi det her

____

Hva er demningens samfunnsmessige betydning (flere kryss mulig)

(1) ❑ Kulturminne (kraftverk, mølle, sagbruk)

(2) ❑ Rekreasjon, bading, fiske oppstrøms demningen

(3) ❑ Amfibiedam (frosk, salamander)

(4) ❑ Habitat for vannfugl

(5) ❑ Annet

(6) ❑ Har i dag ingen kjent funksjon

(7) ❑ Vet ikke/kjenner ikke til

Du svarte "annen samfunnsmessig betydning", vennligst oppgi det her

____

Har du noen utfyllende kommentarer, kan du gi dem her (f.eks beskrivelse av elve- og landområder oppstrøms og nedstrøms)

____

____

Vi ønsker oss også bilder av damkonstruksjonen, dersom du har dette. Bilder kan sendes på epost til: antti.eloranta@nina.no, skriv da navn på demningen og forklaring om hvor ved demningen bildet er tatt.

Undersøkelsen er nå ferdig, tusen takk for din besvarelse!

6.2 Appendix 2: Raw data

Raw data of dams reported via the questionnaire (coordinates in WGS-84 format).

Latitude	Longitude	Purpose	Material	Height (m)	Width (m)	In-use	Condition	Environmental-impact	Societal-importance
61.45771	10.19878	Hydropower	Concrete	5-10	5-10	No	Poor	Total-barrier	No-known-function
59.81897	10.46437	Mill	Concrete	2-5	5-10	NA	NA	Total-barrier	No-known-function
60.32271	10.70313	Multi-purpose	Concrete	1-2	1-2	No	Poor	Multiple-impacts	Multiple-interests
60.07206	10.75162	NA	Multiple	1-2	NA	NA	NA	NA	NA
60.47607	10.83211	NA	Concrete	1-2	2-5	No	Moderate	Periodic-barrier	No-known-function
67.3007	14.61136	Hydropower	Multiple	NA	<1	No	Moderate	Periodic-barrier	Multiple-interests
68.95502	16.35756	Hydropower	Stone	2-5	10-20	No	Poor	Total-barrier	No-known-function
68.84998	18.35888	NA	Concrete	2-5	5-10	No	NA	Multiple-impacts	No-known-function
60.97677	4.97005	NA	Stone	1-2	5-10	No	Moderate	Total-barrier	No-known-function
60.63965	4.98237	Mill	Stone	0.5-1	1-3	No	Poor	Drying-downstreams	No-known-function
61.02212	5.05701	Mill	Stone	5-10	10-20	No	Poor	Total-barrier	No-known-function
60.52073	5.23514	Other-purpose	Concrete	NA	NA	NA	Moderate	NA	Multiple-interests
59.27624	5.53757	Hydropower	Concrete	0.5-1	5-10	No	Poor	Periodic-barrier	No-known-function
59.28283	5.5386	NA	Stone	0.5-1	2-5	No	Poor	Other	No-known-function
58.97761	5.61446	Hydropower	Stone	1-2	2-5	No	Poor	Total-barrier	Cultural-heritage
59.4265	8.87706	Log-driving	Concrete	0.5-1	5-10	No	Moderate	Multiple-impacts	No-known-function
58.6932	9.02541	Log-driving	Multiple	2-5	10-20	No	Poor	Multiple-impacts	Cultural-heritage
59.32593	9.4096	Log-driving	Multiple	NA	NA	No	Poor	Multiple-impacts	Cultural-heritage
59.29051	9.55011	Hydropower	Multiple	NA	NA	NA	NA	Total-barrier	Multiple-interests
59.3163	9.55311	NA	Multiple	2-5	NA	NA	NA	Multiple-impacts	Cultural-heritage
59.34382	9.56458	Log-driving	Multiple	NA	NA	NA	NA	Multiple-impacts	Cultural-heritage
63.76377	9.82334	Mill	NA	NA	NA	No	NA	Periodic-barrier	Cultural-heritage
63.86566	9.9433	Multi-purpose	Concrete	NA	NA	No	Poor	Periodic-barrier	Multiple-interests
59.75772	10.44172	NA	Multiple	5-10	5-10	No	Poor	Total-barrier	No-known-function
60.41761	10.51407	Multi-purpose	Multiple	5-10	10-20	No	NA	Total-barrier	Cultural-heritage
68.79256	16.46419	Multi-purpose	Multiple	2-5	10-20	No	Good	Multiple-impacts	Recreation
59.38534	10.25296	Mill	Concrete	2-5	5-10	Yes	Good	Periodic-barrier	Multiple-interests
60.87183	5.209811	Multi-purpose	Concrete	2-5	5-10	No	Moderate	Total-barrier	No-known-function
58.730709	5.526029	Water-for-farm	Concrete	NA	5-10	No	Moderate	Periodic-barrier	No-known-function
58.736488	5.643288	Mill	Multiple	2-5	5-10	No	Good	Total-barrier	Multiple-interests
59.117193	5.729898	Drinking-water	Stone	NA	10-20	Yes	Good	Total-barrier	Multiple-interests
58.761794	5.781509	Other-purpose	Multiple	0.5-1	>20	Yes	Moderate	Multiple-impacts	Other
58.634326	5.810146	Hydropower	Stone	2-5	>20	No	Moderate	Multiple-impacts	No-known-function
60.102265	11.578127	NA	Concrete	2-5	10-20	NA	Good	Total-barrier	Recreation
60.031896	11.793499	Log-driving	Concrete	2-5	5-10	No	Moderate	Total-barrier	No-known-function
63.49798	11.13551	NA	Concrete	NA	>20	No	Poor	Multiple-impacts	Multiple-interests
68.78246	14.94966	Fish-farm	Stone	1-2	>20	Yes	Moderate	Total-barrier	Amphibians
68.79257	16.46416	Multi-purpose	Concrete	2-5	5-10	NA	Moderate	Multiple-impacts	No-known-function
70.11985	29.36327	Drinking-water	Concrete	1-2	10-20	No	Poor	Multiple-impacts	Multiple-interests
59.81767	10.77109	Hydropower	Multiple	2-5	5-10	No	Moderate	Periodic-barrier	Cultural-heritage

*NA = no data available

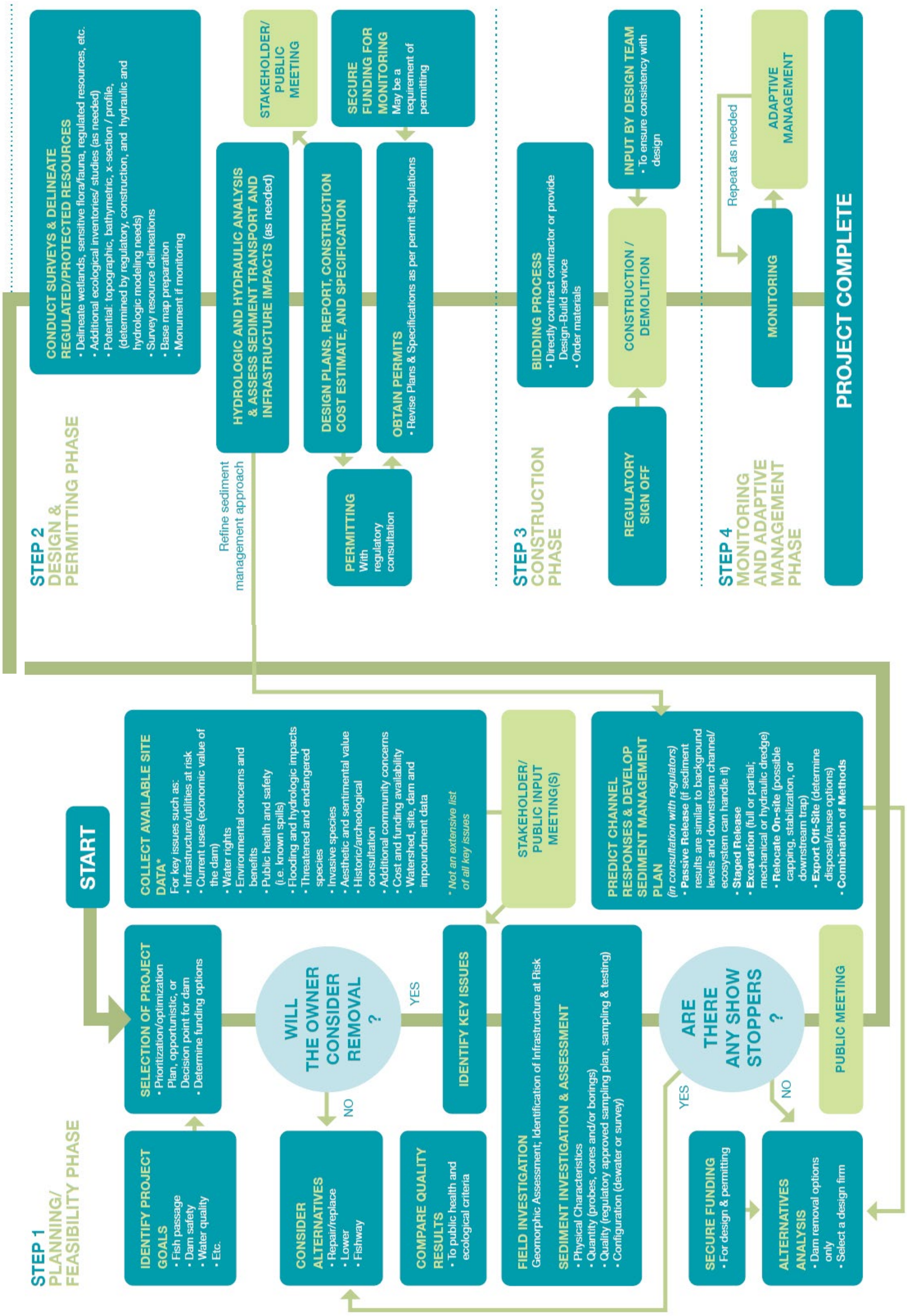
Raw data of dams included in field surveys (coordinates in WGS-84 format).

Watercourse	Latitude	Longitude	Dam-name	Purpose	Material	Height (m)	Width (m)	In-use	Condition	Environmental	Societal-importance
Drammenselva	59.78719	9.899609	Hellefossen	Hydropower	Concrete	5-10	>20	Yes	NA	NA	NA
Vestfosselva	59.733008	9.868344	Vestfossen	Hydropower	Concrete	2-5	5-10	Yes	NA	NA	NA
Darbuelva	59.697275	9.790238	Darbu-sentrum	Mill	NA	1-2	5-10	removed	removed	NA	NA
Darbuelva	59.675542	9.733263	Jørandruddammen	Multi-purpose	Multiple	2-5	>20	Yes	NA	NA	Cultural-heritage
Darbuelva	59.683297	9.685606	Kjennerudvatnet	Log-driving	NA	NA	NA	No	NA	NA	NA
Darbuelva	59.694001	9.695916	Muggerudtjern	Log-driving	Stone	1-2	2-5	Yes	NA	NA	NA
Darbuelva	59.709428	9.712819	Grønntjern	Log-driving	Stone	2-5	5-10	Yes	NA	Total-barrier	NA
Darbuelva	59.701096	9.704183	Stilla	NA	NA	NA	NA	removed	removed	NA	NA
Dørja	59.730569	9.825899	Lundteigendammen	Mill	Concrete	1-2	5-10	Yes	NA	NA	NA
Dørja	59.74247	9.721919	Dørsjødammen	Log-driving	Stone	1-2	>20	removed	removed	NA	NA
Dørja	59.746746	9.766032	Junger	NA	Stone	NA	NA	removed	removed	NA	NA
Dørja	59.767638	9.67683	Bråtatjern	Log-driving	Concrete	1-2	>20	Yes	NA	NA	NA
Dørja	59.801073	9.665585	Langevatn	Log-driving	Stone	1-2	>20	removed	removed	NA	NA
Hoensvassdraget	59.776179	9.882537	Hoensdammen	Mill	Concrete	2-5	>20	Yes	NA	Total-barrier	Multiple-interests
Hoensvassdraget	59.785541	9.797419	Himsjø	Multi-purpose	Concrete	2-5	>20	Yes	NA	Total-barrier	Multiple-interests
Hoensvassdraget	59.790124	9.772941	Hoensvatnet	Multi-purpose	Concrete	2-5	>20	Yes	NA	NA	Multiple-interests
Hoensvassdraget	59.797219	9.731923	Engtjern	Multi-purpose	NA	NA	NA	removed	removed	NA	NA
Hoensvassdraget	59.785468	9.729599	Prestvatnet	Multi-purpose	Multiple	1-2	>20	Yes	NA	NA	Recreation
Hoensvassdraget	59.794025	9.719986	Bjørvatnet-ny	Multi-purpose	Concrete	2-5	1-2	Yes	NA	NA	Recreation
Hoensvassdraget	59.788727	9.699936	Bjørvatnet-gammel	Multi-purpose	Stone	2-5	5-10	Yes	NA	Total-barrier	Recreation
Hoensvassdraget	59.802571	9.698818	Søre-Øyvatnet	Multi-purpose	Stone	1-2	2-5	Yes	NA	Total-barrier	NA
Hoensvassdraget	59.81345	9.698012	N-Øyvatnet-overløp	Multi-purpose	NA	NA	NA	removed	removed	NA	NA
Hoensvassdraget	59.811285	9.698181	Nordre-Øyvatnet	Multi-purpose	Stone	2-5	>20	Yes	NA	Total-barrier	Recreation
Hoensvassdraget	59.812128	9.710072	Krokvannsløken	Multi-purpose	Stone	2-5	>20	Yes	NA	Total-barrier	Recreation
Hoensvassdraget	59.817397	9.712199	Krokvatnet	Multi-purpose	Stone	2-5	>20	Yes	NA	Total-barrier	Recreation
Bingselva	59.842486	9.889537	Skotselv	Mill	Concrete	2-5	5-10	Yes	NA	Total-barrier	NA
Bingselva	59.865012	9.83398	Stensrud-kraftverk	Hydropower	Concrete	1-2	>20	constr.	constr.	Total-barrier	NA
Bingselva	59.815194	9.817757	Spitelva	Log-driving	Concrete	1-2	5-10	Yes	NA	Total-barrier	NA
Bingselva	59.825874	9.758877	Hoggtjerndammen	Multi-purpose	Stone	1-2	5-10	Yes	NA	Total-barrier	NA
Bingselva	59.910503	9.776757	Mortenstjern	Multi-purpose	Stone	2-5	5-10	Yes	NA	Total-barrier	Recreation
Bingselva	59.84217	9.765368	Langtjern	NA	Stone	1-2	5-10	Yes	NA	Total-barrier	NA
Bingselva	59.847936	9.738551	Abbortjern	Multi-purpose	Stone	2-5	>20	Yes	NA	Total-barrier	Cultural-heritage
Bingselva	59.827975	9.708857	Grølla	Multi-purpose	Stone	2-5	>20	Yes	NA	Total-barrier	Multiple-interests
Bingselva	59.865538	9.68155	Skulkeroa	Fish-farm	Stone	1-2	10-20	Yes	NA	NA	NA
Bingselva	59.86428	9.698916	Smedsvatnet	Multi-purpose	Concrete	2-5	>20	Yes	NA	Total-barrier	NA
Bingselva	59.863372	9.688898	Sagtjern	Multi-purpose	Concrete	1-2	5-10	Yes	NA	NA	Cultural-heritage
Bingselva	59.846005	9.667927	Tjern	Multi-purpose	Concrete	0.5-1	2-5	Yes	NA	Total-barrier	NA
Bingselva	59.846933	9.665518	Dokkvatnet	Multi-purpose	Concrete	NA	NA	removed	removed	NA	Cultural-heritage
Bingselva	59.88258	9.685472	Høltjern	Multi-purpose	Concrete	2-5	>20	Yes	NA	Total-barrier	Multiple-interests
Bingselva	59.881034	9.668111	Stjerntjern	Multi-purpose	Stone	1-2	>20	Yes	NA	Total-barrier	NA
Bingselva	59.881099	9.697161	Svartebekkdammen	Multi-purpose	Stone	2-5	5-10	Yes	NA	Total-barrier	NA
Bingselva	59.881776	9.660033	Trytetjern	Multi-purpose	Stone	1-2	>20	Yes	NA	Total-barrier	NA
Bingselva	59.928943	9.592467	Letmolivatnet	Multi-purpose	Concrete	2-5	>20	Yes	NA	Total-barrier	Multiple-interests
Kaldvella	63.203844	10.362846	NA	Fish-farm	Stone	1-2	5-10	NA	NA	NA	NA
Kaldvella	63.203754	10.363836	NA	Fish-farm	Concrete	1-2	2-5	NA	NA	NA	NA
Kaldvella	63.203696	10.363296	NA	Fish-farm	Concrete	NA	NA	NA	NA	NA	NA
Dragvatnet	63.63631	9.07162	NA	Fish-farm	Concrete	NA	>20	NA	NA	NA	NA
Aunåa	63.484475	8.784306	NA	Hydropower	Wood	2-5	NA	No	Moderate	NA	NA
Laksåelva	63.472502	8.674506	NA	Fish-farm	Concrete	>10	NA	NA	Good	NA	NA
Sloelva	63.475631	8.702067	NA	Fish-farm	NA	NA	NA	NA	NA	NA	NA
Tverrelva	63.479082	8.652292	NA	Fish-farm	Stone	NA	NA	NA	NA	NA	NA
Barmvatnet-utløpsbekk	63.627977	8.821777	NA	NA	Stone	NA	NA	No	NA	NA	NA
Kaldklovvassdraget	63.579616	8.999819	NA	Fish-farm	Concrete	NA	NA	No	NA	NA	NA
Undåsvatnet	63.620972	8.731752	NA	Mill	Multiple	NA	NA	No	Poor	NA	NA
Tjæravassdraget	63.572303	9.133573	NA	NA	Concrete	NA	NA	No	Poor	NA	NA
Dragvatnet-utløpselv	63.636245	9.071589	NA	Fish-farm	Concrete	NA	NA	No	Good	NA	NA
Sundevassdraget	63.491817	9.183379	NA	NA	Multiple	NA	NA	No	Good	NA	NA
Hallarvatnet	63.67867	8.613647	NA	Fish-farm	Multiple	NA	NA	No	Good	NA	NA
Kvernhusvatnet	63.684154	8.39486	NA	Fish-farm	Stone	NA	NA	NA	NA	NA	NA
Skagevatnet	63.680278	8.414754	NA	Fish-farm	NA	NA	NA	NA	NA	NA	NA
Kystadvatnet	63.691877	8.4223	NA	Fish-farm	NA	NA	NA	NA	NA	NA	NA
Ervikelva	63.745289	8.827927	NA	Fish-farm	Concrete	5-10	NA	no	Good	NA	NA
Leirvikvatnet	63.344921	8.06978	NA	NA	Stone	NA	NA	NA	NA	NA	NA
Ledalsvatnet	63.411903	8.729802	NA	Fish-farm	Concrete	NA	NA	NA	Good	NA	NA
Heimsvatnet	63.414475	9.046442	NA	Fish-farm	NA	NA	NA	NA	NA	NA	NA

*NA = no data available

6.3 Appendix 3: Dam removal project step-by-step

A flow chart showing the planning, design, construction and monitoring steps in the dam removal process. The chart is obtained from the book "From Sea to Source 2.0" (Brink et al. 2018) and originally derived by Laura Wildman (2017).



6.4 Appendix 4: Survey of obsolete dam and water regulation structures – field notes from Øvre Eiker study area

Befaringer av utrangerte dam- og reguleringsanlegg – feltnotat studieområde Øvre Eiker

Utarbeidet av Gaute Thomassen og Finn Gregersen, Multiconsult

Innledning

Bakgrunn

Drammenselva med sidevassdrag har en rekke interessante installasjoner i form av demninger og andre menneskeskapte strukturer som kommer til fysisk inngripen med vassdrag og påvirker økologiske prosesser. De eldste kartlagte dammene i Norge er fra 1600-tallet og ble bygd ved sølvgruvene på Kongsberg (Nynäs, 2013). Dammene ved Sølvverket skulle fange opp, magasinere og fordele driftsvann til vannhjul som drev lensepumper og heiste opp malm fra gruvene. Sølvgruvedriften hadde stort behov for trevirke og vassdrag ble bygd ut for fløting av tømmer og ved. Mange rester etter dammer til fløtingsformål vitner om også denne aktiviteten. I dagens Norge benyttes dammer hovedsakelig for å magasinere vann til produksjon av elektrisitet, men også for vannforsyning. I utlandet er ofte flomdemping, vannforsyning eller vanning dominerende formål.

Som så mange andre steder i landet er det her et omfattende forfall å se, når det gjelder disse vassdragstekniske installasjonenes tilstand. De har svært variabel nytteverdi i dag, eierforholdene er ofte uklare og vedlikeholdet avhenger i stor grad av funksjon og nytte. Mange steder utføres vedlikehold på dugnad der dammene har en praktisk funksjon eller historisk interesse knyttet til seg. Det er for øvrig slik at det påhviler dameier en plikt til å vedlikeholde vassdragstiltak som kan volde skade. Denne plikten er hjemlet i vannressurslovens § 37.

Det er først og fremst hver enkelt eier som har ansvar for alle forhold hva gjelder en dam. Dammer er definert som vassdragsanlegg og faller inn under Forskrift om sikkerhet ved vassdragsanlegg (2010). Et vassdragsanlegg er definert som «dammer og vannveier med tilhørende konstruksjoner». NVE har ansvaret for å forvalte forskriften, som skal fremme sikkerhet og forebygge skade. Den stiller organisatoriske og faglige krav til de ansvarlige og tekniske krav til vassdragsanleggene. Den gjelder også dersom vassdragsanlegget ikke er i bruk. NVE påser at den ansvarlige følger kravene. Dersom ikke dette skjer kan det gis pålegg for at en dam skal komme i forskriftsmessig stand. Hovedansvaret for å ta vare på kulturminner og kulturmiljøer ligger hos eierne og det overordnede faglige ansvaret ligger hos kulturminnemyndighetene. Ansvaret for naturmiljø tilligger ofte Fylkesmannen, men gjerne også fylkeskommunen og kommunen. Dette avhenger av hvilke naturverdier som er å finne.

Prosess rundt nedleggelse

Kapittel 7 i vannressursloven (§§ 41 – 43) omhandler nedlegging av vassdragsanlegg. § 41 fastslår at man ved nedleggelse skal sørge for at «vassdraget så langt som mulig tilbakeføres til forholdene slik de var før anlegget ble bygd». Dersom en nedleggelse kan medføre «påtakelig» skade eller ulempe for allmenne interesser, kreves det konsesjon etter lovens § 8.

Dette medfører at man bør kommunisere med vassdragsmyndighetene i forkant av en planlagt nedleggelse for å finne ut av hva slags prosess som kreves. Ofte vil det være nyttig å be NVE om en konsesjonspliktvurdering. I en slik prosess høres de relevante instanser og det avklares om man trenger konsesjon eller ikke. Dersom konsesjon kreves vil konsesjonsprosessen sikre at de nødvendige parter underrettes og får spille inn sine synspunkter. Uavhengig av om konsesjon kreves eller ikke, krever bestemmelsene i loven at tiltakseier i god tid før anlegget planlegges nedlagt underretter alle interesserte. I de tilfellene en nedleggelse skjer uten krav om konsesjonsbehandling er det viktig at det tas hensyn til de merknadene som er kommet inn i forbindelse med nevnte underretning.

Muligheter

Det er mange muligheter for å optimalisere utkommet av en prosess rundt et eldre vassdragsanlegg. Det er faktisk mulig å utforme dammen slik at den blir et bedre miljø for både vannfugl, vilt, amfibier og fisk, samtidig som allmenne interesser i form av friluftsliv, rekreasjon og hyttefolket tjener på dette, samtidig som også kulturminneforvaltning ser seg tjent med dette. Dette må sies å kunne by på en vinn-vinn mulighet, men det forutsetter kompetent prosjektering og saksbehandling. I den sammenheng er det nødvendig å stille en del spørsmål. Noen viktige følger her, men denne opplistingen er ikke uttømmende:

- Stoppes fiskevandringer? Og eventuelt hva slags vandringer? Er det snakk om anadrom fisk, innlandsfisk eller begge deler? Hvilke arter fins, og hvordan påvirkes de ulike?
- Er det potensial for forbedrede fiskeforhold utover vandring? Habitatforbedrende tiltak? Styrket næringsgrunnlag?
- Er det konflikter ved å rive dam mot andre interesser og hvilke interesser er det snakk om? Rekreasjon og friluftsliv? Vanning/vannforsyning? Kulturminner? Annen biologi enn fisk? Flomdemping? Brannvann?
- Er forholdene egentlig tilfredsstillende i dag, eller kan utfordringene løses med kompromisser og/eller enklere tiltak enn fullstendig avvikling av anlegget?
- Er et slikt tiltak fornuftig ut fra et kost/nytteperspektiv?
- Hvilken teknisk tilstand har den/de aktuelle dammen(e)?

Undersøkelsesområdet

Vi valgte ut fire sidevassdrag til Drammenselva i Øvre Eiker hvor vi var kjent med at det var en del dammer med ulike problemstillinger blant annet knyttet til kulturminner, friluftsliv, eiendom, naturmiljø, sikkerhet osv. På lik linje med Sølvverksdriften på Kongsberg så ble liknende bergverksdrifter forsøkt i omliggende kommuner som Flesberg og Øvre Eiker.

De utvalgte vassdragene er Bingselva, Dørja, Fiskumelva og Hoenselva, vi inkluderte også Vestfosselva og Hellefossen i Drammenselva siden disse ligger på strekninger som fisk må passere om de skal nå opp til sidevassdragene vi undersøkte. Alle vassdragene drenerer hver sin del av Holtefjell: Dørja og Darbuelva den sørlige foten av Holtefjell (og Lurdalen), Hoensvassdraget sørøstsiden og Bingeselva nordvestsiden. Området har vært preget av menneskers utnyttelse av naturressursene i nær 400 år. Særlig viktige aktiviteter i dette området har vært bergverksdrift og treforedlingsindustri. De fleste av dammene ble bygd for lang tid siden, hovedsakelig med fløtnings- og gruvedriftsformål, formål som ikke lenger er relevante her i dag. I dammene ble vannet lagret til det skulle brukes og det finnes et innfløkt nettverk av overføringer av vann i området. Senere er mange av de brukt som vannreservoarer for kraftverk nedstrøms i vassdragene, men uten reguleringsmuligheter. Mange av dammene er i dag restaurert og tatt vare på av hensyn til friluftsliv, fisk og miljø, men i få tilfeller er det gjort noe med fiskens vandringsmuligheter forbi dammene.

Hele Holtefjell ble i første fase av barskogsvernet utredet, og vurdert som et av de største potensielle verneområdene for barskog i Norge. Mesteparten av arealet har fått stå urørt inntil nå selv om det ikke ble vernet i nevnte prosess. Det er i dette området de fleste av dammene i vår undersøkelse ligger og disse vitner om at bruken av disse områdene har vært omfattende i gamle dager. De mange hyttene i området vitner også om at dette er svært populære frilufts- og naturområder.

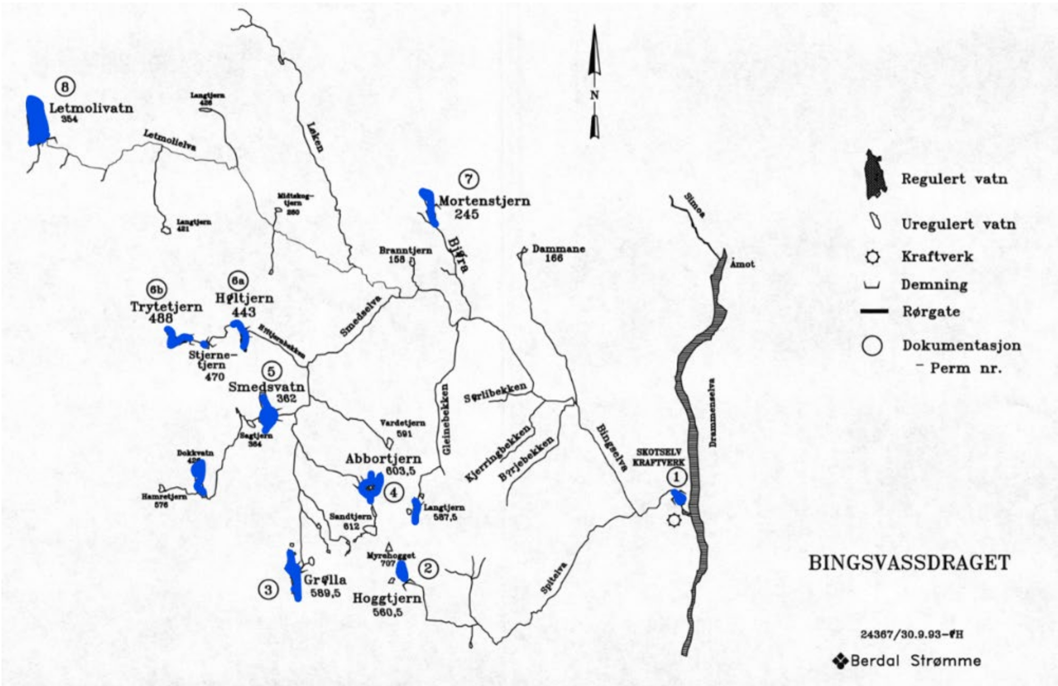
Lokalitetsbeskrivelse

Bingselva

Figur 1: Dam ved Mortenstjern i Bingselvavassdraget.

Bingselvavassdraget er det største av hovedvassdragene i dette studieområdet (Figur 2), og det drenerer et nedbørfelt med et areal på 186,7 km^2. Øverst i feltet utgjøres vassdraget av tre hovedgrener: Smedselva, Letmolielva og Løken. Vassdraget med sidegrener utgjør 10 vannforekomster som alle har oppgitt god eller svært god økologisk tilstand (Vann-Nett). Omtrent fra samløp med Smedselva og ned er hovedvassdraget definert som naturtype viktig bekkedrag særlig begrunnet med vesentlige forekomster av elvemusling (Naturbase). Med tanke på hensynet til denne arten er det behov for å unngå utsetting av laks og at laks kommer opp forbi dammen ved Skotselv kraftverk.

Vi er kjent med 18 installasjoner i vassdraget som i større eller mindre grad utgjør potensielle økologiske barrierer som gjør de interessante i denne sammenheng. Alle disse ble befart ved denne undersøkelsen. I tillegg til de 18 installasjonene vi selv har befart har vi fått opplysninger fra Bingselvas Historielag om ytterligere 18 installasjoner som det finnes mer eller mindre synlige spor av i vassdraget i dag (Pers medd. T. A. Ingebo). Vassdraget har med andre ord blitt betydelig utnyttet av mennesker opp gjennom historien.



Figur 2: Kart over eksisterende fysiske installasjoner i Bingsvassdraget datert 1993.

Dørja

Figur 3: Tidligere damsted ved Dørsjø i Dørja.

Dørja har en lang elvestreng som strekker seg fra Langevatnets kilder og ned til Fiskumvannet. Den eneste større sidegrenen til denne er Jungerbekken som løper sammen med Langevannselva om lag 5 kilometer oppstrøms utløpet i Fiskumvannet. Hele nedbørfeltet som dreneres måler ca 70 km^2. Vassdraget består av 10 vannforekomster som varierer fra moderat til svært god økologisk status (Vann-Nett). Hele hovedvassdraget, og sidebekkene øverst i feltet har minst god økologisk status, mens to sidebekker som løper inn i hovedelva fra øst i de nedre delene har moderat tilstand. Det er registrert tre naturtypelokaliteter knyttet til hovedvassdraget og sidebekken Jungerbekken, som er avgrenset som viktig bekkedrag basert på elvemuslingforekomst (Naturbase). Det er også en del registrerte myrtilknyttede naturtypelokaliteter som har direkte samband med vassdraget.

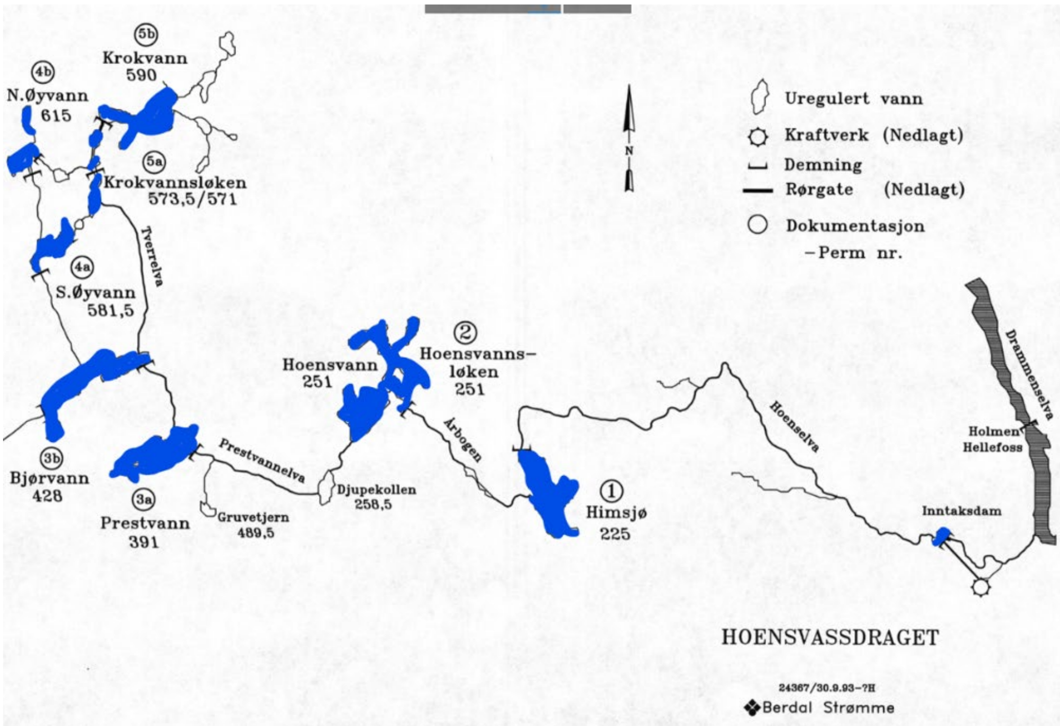
I vassdraget finner vi fem dammer som er interessante i denne konteksten. En av disse, dammen ved Junger eksisterer ikke lenger. I tillegg til disse fem er det gjort oppdemminger av Bjørvatnet som har ført til at dette vannets nedbørfelt nå er overført til Hoensvassdraget. Alle disse dammene ble befart ved denne undersøkelsen.

Hoenselva

Figur 4: Himsjødammen i Hoensvassdraget.

De øverste delene av nedbørsfeltet som i dag dreneres av Hoenselva er overført fra Dørja sitt felt ved installasjoner i Bjørvatnet (Figur 5). I denne øvre delen av feltet kalles hovedelva Tverrelva og Prestvannselva før den skifter navn til Hoenselva fra utløpet av Hoensvannet. Hoenselva drenerer et nedbørfelt på ca 44 km^2, og vassdraget består av 12 vannforekomster med økologisk status som varierer fra moderat til svært god (Vann-Nett). Hele vassdraget har økologisk status satt til god eller bedre helt ned til et stykke nedstrøms Himsjø, der elva kommer mer i kontakt med landbrukspåvirkede arealer og bosetning. Herfra og ned har både hovedelva og sidevassdragene moderat økologisk status. De påvirkningene som er registrert som størst i de nedre delene av vassdraget er landbruksavrenning og utsetting av lakseunger. Det er registrert en rekke naturtypelokaliteter med tilknytning til dette vassdraget. Det er flere forekomster av viktig bekkedrag-lokaliteter, blant annet med begrunnelse i elvemuslingforekomst (Naturbase). Det er også registrert flere naturtypelokaliteter av ulike skogformer, myrlokaliteter og en bekkekløftlokalitet. Det er et naturlig vandringshinder i nedre deler av vassdraget, Hoensfossen, med over 10 meter fall fordelt på en serie trinn trinnvise fall, som gjør at det ikke er anadrom laksefisk oppstrøms dette. Ål og niøye passerer imidlertid denne fossen. Fallet over denne fossen ble tidligere utnyttet til vannkraft, men ikke i dag.

I vassdraget finnes det et stort antall interessante installasjoner som ble befart i forbindelse med dette prosjektet. Vi har registrert disse som 12 objekter, men det er flere enn 12 dammer. Særlig Bjørvatnet som er overført fra Dørjavassdraget har mange daminstallasjoner.



Figur 5: Kart over eksisterende fysiske installasjoner i Hoensvassdraget datert 1993.

Darbuelva/Fiskumelva

Figur 6: Jørandruddammen i Darbuelva/Fiskumelva.

Darbuelva er et vassdrag som drenerer skogsområdene innover Lurdalen. Vassdraget går også under navnet Fiskumelva. De øvre delene av vassdraget er klassifisert til god eller svært god økologisk tilstand. Fra Kjennerudvannet og ned har vassdraget dårligere økologisk tilstand (Vann-Nett). Hovedvassdraget og Kjennerudbekken har moderat økologiske tilstand, mens vannforekomsten som utgjøres av bekkefeltet til nedre deler av hovedvassdraget har fått dårlig økologisk tilstand. De mest betydelige påvirkningene som medfører redusert tilstand her er landbruksavrenning, avrenning fra spredt avløp og avrenning fra gruver/deponering. Ved byggingen av ny E134 ligger hoveddeponiet rett inntil Darbuelva på Damåsen. Vassdraget har færre naturtypelokaliteter knyttet til seg enn de tre foregående, men det er en registrering av en viktig bekkedraglokalitet som er begrunnet i funn av elvemusling (Naturbase).

Det er ikke kjent så mange dammer i vassdraget, men det er en del fløtningskanaler/-forbygninger fra gammelt av. Det er dam i Darbu sentrum som var et gammel inntaksanlegg til fabrikk nede ved Skytterhallen. I alt har vi registrert seks installasjoner som er av interesse i denne sammenheng der alle er befart.

Drammenselva

En av installasjonene som er med i materialet ligger i Drammenselva. Dette gjelder Hellefossen (Figur 7) som er inkludert her siden fisk som kommer nedstrøms fra og skal opp til Bingselva må forbi denne via fisketrappa som er installert der. Her finnes et av landets store elvekraftverk.

Figur 7 Dammen på Hellefossen, Drammenselva.

Vestfosselva

Før eventuell vandrende fisk kan komme opp i Darbuelva og Dørja må den gjennom Vestfossen og dammen som finnes der (Figur 8). Det byr på utfordringer. Her ligger det et kraftverk. Det er ingen fisketrapp ved kraftverket, men det er installert en ålerenne her.

Figur 8 Dammen i Vestfosselva.

Resultater

Dammenes fysiske karakteristika

Det er et stort spenn i de fysiske attributtene til dammene som er registrert i dette området. De fleste er moderat høye, men lange dammer (se tabell 1).

Stein er det dominerende materialet som er brukt i dammene som er anlagt i studieområdet, men også betong forekommer i et visst omfang. Flere av dammene er anlagt ved bruk av flere enn en type materiale, og særlig vanlig forekommende blant disse er eldre steindammer som i dag har et visst innslag av betong som har tilkommet ved reparasjoner i nyere tid. De eldste steindammene stammer trolig fra 1600-1700-tallet.

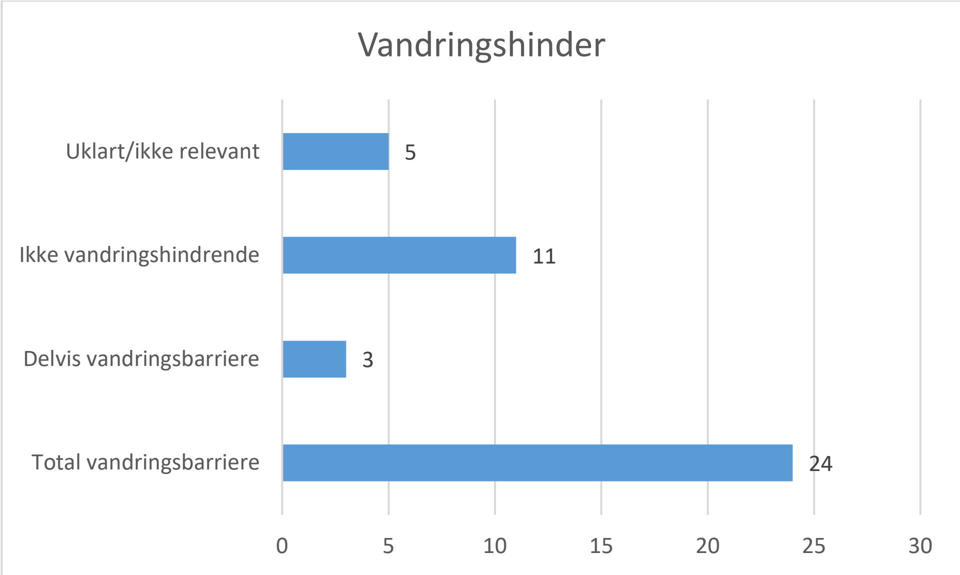
Tabell 1: Oppsummering av fysiske mål på daminstallasjonene i området.

		Bredde på dammen							
		1 meter	1-2 meter	2-5 meter	5-10 meter	10-20 meter	> 20 meter	Ikke målt / revet dam	Totalt
Høyde på dammen	< 0,5 meter								0
	0,5 - 1 meter			2		1			3
	1 - 2 meter			2	3	1	4		10
	2 - 5 meter		1		6	2	12		21
	5 - 10 meter						1		1
	> 10 meter								0
	Ikke målt / revet dam							8	8
Totalt		0	1	4	9	4	17	8	43

Om forholdene for fisk knyttet til demningene

Det er relativt betydelig spredning i forekomsten av naturlig vandrende bestander knyttet til disse dammene. Ørret er stort sett forekommende i en viss grad av utstrekning i tilknytning til de aller fleste av dammene, og dette er som kjent en art som gjerne vandrer i ulike deler av sin livssyklus. Imidlertid er det mange av dammene som ligger plassert i tilknytning til naturlige vandringshindre slik at dammen i seg selv ikke er utløsende som vandringsbarriere for fisken i systemet. Enkelte steder kan det også være at dammer er reelle vandringsbarrierer for fisk, men at dette er en utilsiktet velsignelse da de dermed utgjør en fysisk begrensende faktor for spredning av uønskede organismer og/eller sykdom. Slik sett er spredningen av lakseparasitten *Gyrodactylus salaris* begrenset til hovedvassdraget da laksen og sjøørreten stanser i nedre del av vassdragene. Ål og niøye kan passere mange av disse barrierene og bringer ikke med seg kjente parasitter. Disse artene er som oftest utbredt i nedre til midtre deler av alle vassdragene, men bestandene er svekkede grunnet globale forhold. Undersøkelser viser at det fortsatt går ålelarver over dammene i Vestfossen og Hellefossen (Gregersen m.fl. 2011).

For dammene i dette systemet vurderer vi at ca 56 % av dammene utgjør totale vandringshindre for laksefisk. 7 % vurderes som delvis vandringshindrende, mens ca 26 % anses for å ikke være vandringshindrende (Figur 9). For de resterende dammene vurderes fiskevandringsproblematikk som ikke relevant av ulike årsaker. Den vanligste årsaken til dette er at det er andre naturlige vandringshindre som medfører minst like stor vandringsbarriere som den aktuelle installasjonen.

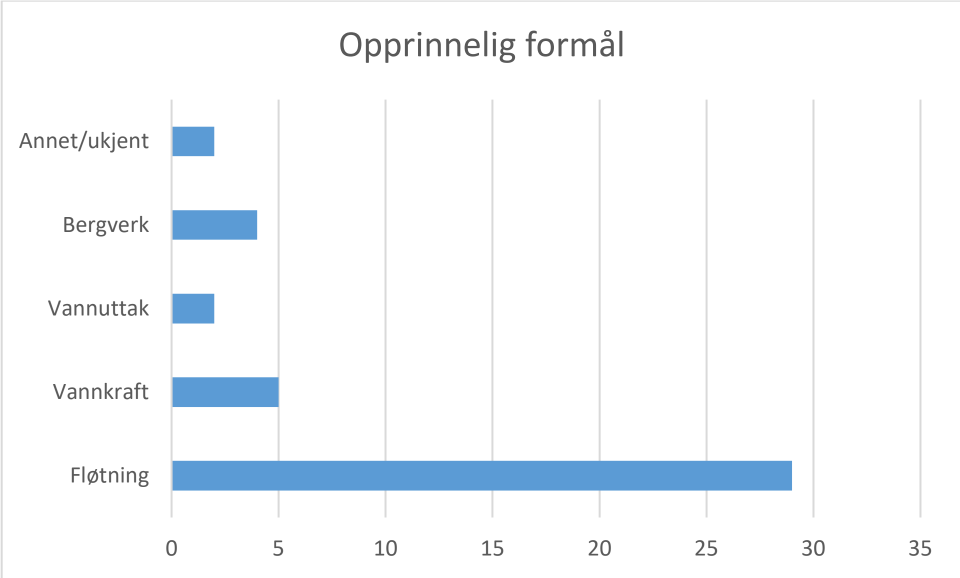


Figur 9: Vurdering av de vurderte installasjonenes effekt som vandringsbarrierer.

Skulle man fordele disse resultatene på de fire vassdragene finner vi at 1 av 6 dammer i Darbuelva-vassdraget er total vandringsbarriere. I Dørja er ingen av de fem registrerte installasjonene vurdert som relevante absolutte vandringshindre. I Hoensvassdraget utgjør 6 av de 12 installasjonene absolutte vandringshindre mens bare en av de seks resterende frikjennes fullstendig som vandringsbarriere. I Bingselva-vassdraget har vi registrert flest installasjoner, og der er det også størst andel som vi vurderer som absolutte vandringshindre. 15 av de 18 registrerte dammene i Bingselva har vi vurdert som totale vandringsbarrierer.

Dammenes formål og andre potensielle interesser knyttet til dammene

Det overveiende vanligste formålet for daminstallasjoner i disse vassdragene har antagelig vært fløtning (Figur 10). Det ligger i sakens natur at de fleste av dammene her derfor ikke lenger fyller det samfunnsnyttige formålet de ble anlagt for å fylle siden, tømmerfløtning i disse vassdragene opphørte på 1960- og 70-tallet, eller enda tidligere. Det er imidlertid slik at mange av dammene i dag fyller andre, mer eller mindre samfunnsnyttige formål enn hva de ble bygget for. Flere av disse gamle fløtningsdammene fungerer i dag som magasiner for vannkraftanlegg lenger ned i vassdraget. De langt fleste har imidlertid meget begrenset evne til å regulere vannstand og vannføring, så deres nytte i slik sammenheng er derfor å anse som begrenset. De vanligst forekommende samfunnsnyttige formålene disse dammene fyller i dag er knyttet til rekreasjon og som habitat for annet naturmiljø enn vandrende laksefisk.



Figur 10: Det opprinnelige formålet bak anleggelsen av dammene i studieområdet. Basert på ulike kilder og intervjuer, eventuelt vurdering av anleggenes utforming.

Noen særlig interessante dammer for restaureringsprosjekter

Vi har vurdert at det er enkelte av installasjonene som det er større restaureringspotensiale for enn andre. Vi vil her enkelt legge frem noen illustrerende eksempler på mulige restaureringsprosjekter i disse vassdragene. For eksempel er det ingen vits i å restaurere de vandringshindrende dammene i bekker og elver der det hverken er, eller kan bli, vandrende fiskebestander. Dette gjelder mange dammer øverst i nedbørfeltene.

Grønntjern i Darbuelva/Fiskumelva

Grønntjern er det øverste vatnet i vassdraget. Vannet er meget fint, men ligger i karrig gammel furuskog. Det er elvemusling et stykke nedstrøms og storørreten fra Eikeren kan, eller kunne nok historisk gå helt opp hit.

Her finnes en svært gammel steindam fra 1800-tallet (Figur 11). Magasinet har sunket et par meter grunnet lekkasje i dam. Fisk greier ikke å passere dam eller gå igjennom bunnluken fordi masser har kollapset sammen og tettet denne. Det tidligere så store Grønntjern er nå i søndre deler en stor myr/våtmark med bekk igjennom og den nordre delen utgjør et mindre tjern (Figur 12). Den naturlige restaureringen av systemet som følge av lekkasjen i dammen har gått meget fint.

Det er ikke lange fiskeføringer oppstrøms men det hadde vært gunstig om fisken i Grønntjern hadde kunnet passere damsted for å bruke de fine bekkestrekningene nedstrøms. Man bør åpne/renske bunnventil for å fremme fiskevandringer. Dammen er trolig uansett for dyr å restaurere og tette. Å renske bunnventilen i dammen er en billig operasjon som vil øke potensialet for fiskevandringer kraftig. Det at dammen uansett har gått lekk og vatnet sunket har gitt mye våtmark som er å regne for en miljøbonus.

Figur 11 Den gamle steindammen på Grønntjern.

Figur 12 "Ny" våtmark i Grønntjern.

Lundteigendammen i Dørja

Dørja er et flott vassdrag som drenerer skogsområdene på sørsiden av Holtefjell. Det er flere vann og lange elvestrekninger oppstrøms damstedet ved Lundteigen (Figur 13). Det er storørret som kan gå til foten av stryk/fall nedstrøms dammen. Hvor mye storørret som går hit eller om den historisk har gått videre vites ikke. Det er registrert elvemusling oppstrøms. Bergnakkene nedstrøms dam er muligens absolutt vandringshinder (Figur 14).

Om fisk historisk sett har kunnet nå dammen stopper den i dag uansett her. Imidlertid hadde det vært enkelt å bygge fisketrapp her. Oppstrøms er det store produksjonsområder for ørret og for vandring opp til Junger og Dørsjø, og videre. Det er elvemusling her som har ørreten som vertsfisk. Dammen er antageligvis ikke den primære vandringsbarrieren, det er trolig fallene i forkant. Dersom storørreten får passasje vil dette drastisk øke produksjonen av storørret til Eikernstammen.

Her vil det være en stor gevinst for musling og ørret dersom dette er et forsvarlig tiltak. Genetikk vil kunne avklare om det har vært historisk genflyt av storørret over disse barrierene. Dersom det er tilfelle vil en tilrettelegging for fiskevandring forbi denne dammen være et svært godt tiltak.

Figur 13 Lundteigendammen i nedre deler av Dørja.

Figur 14 Fallene nedstrøms Lundteigendammen som kan være absolutte vandringshinder.

Hoensvassdraget

Himsjø

Vassdraget er flott over lange strekninger opp og nedstrøms for damsted. Det er et næringsfattig vassdrag, men likevel rikt dyreliv, vannfugl og amfibier i de mange vatnene, myrlonene og myrområdene. Det er solide ørretbestander i vannene og på elv/bekk. Like nedstrøms er det mye elvemusling.

Dammen demmer opp Himsjø som er et meget fint skogsvann med mange hytter rundt (Figur 4). Dette området bærer preg av å være et svært populært turområde og sikkert fiskevatn også. Dammen (Figur 4, Figur 15), som er nyrenovert i betong er stor og høy og ligger på kanten av et fall der Hoenselva renner over lange strykstrekninger nedstrøms. Skogsområdene rundt vatnet og nedover Hoenselva er fine gammelskoger, om enn karrige. Dammen er viktig for å opprettholde vannspeil og størrelsen på vatnet, noe som er viktig for hyttefolket. Allikevel ville det vært svært positivt å få gjenopprettet vandringer over dette damstedet, men dette kan koste litt. Det er her en betydelig stigning, men med en fisketrappløsning vil det være mulig. Det hadde vært svært gunstig for fiskebestanden og også elvemusling om vandring mellom bestandene ble gjenopprettet.

Det er etablert en omløpsbekk forbi dammen på det overliggende Hoensvatnet. Dette gjør, at man ved et fungerende tiltak for fiskevandring her, ville gjenopprette konnektiviteten over en lang strekning i dette vassdraget.

Figur 15 Nyrestaurert Himsjødam. Her er det ingen fiskepassasje.

Krokvatnet og Krokvannsløken

Disse to vannene ligger i de øvre deler av Hoensvassdraget. Krokvatnet er et av de store vannene i Holtefjell. Begge dammer er nylig flikket på og har antagelig en viss bevaringsverdi. I Krokvannsløken er dammen nylig sprunget lekk (Figur 16). Her har dammen en bunntappesluse som er helt lekk, men som allikevel hindrer fiskevandring. Ved Krokvatnet er det en omløpsbekk som bør tilrettelegges for å sikre fiskevandringer.

Når det gjelder dammen på Krokvannsløken vil det være nesten gratis å åpne/rense bunntappekanalen, noe som forventes å være tilstrekkelig for å sikre fiskevandringspotensialet her. Dersom dam skal restaureres kan en omløpsbekk forbi damstedet vurderes. Ved dammen på Krokvatnet (Figur 17) vil det antageligvis være mest fornuftig å bevare dammen og heller gjøre tiltak for å tilrettelegge den allerede eksisterende omløpsbekken for fiskevandring.

Realiserer man tiltak som gjenoppretter fiskevandringer ved begge disse dammene vil man sørge for å tilgjengeliggjøre store oppvekst-, leve- og gyteområder for fisken i den øvre delen av dette vassdraget.

Figur 16 Dammen på Krokvassløken.

Figur 17 Dammen på Krokvann med overløpet nærmest fotograf.

Bingselvvassdraget

Spitelva

Denne dammen (Figur 18) ligger på en lang elvestrekning i Spitelva der det er langt opp til nærmeste vatn, som er Hoggtjern. Her finner man et fint elvemiljø der det finnes elvemusling nedstrøms dammen. Vi antar at det nok var naturlige vandringer over bergnabben dammen er plassert på før den ble anlagt.

Det bør være enkelt å eliminere dette vandringshinderet. Dammen har, så vidt vi kan forstå, ingen funksjon og brua over elva kan beholdes. Utbedres dette hinderet vil resultatet bli en god sammenbinding av bekkeørretbestander.

Figur 18 Dammen i Spitelva.

Grølla

Grølla ligger høyt oppe i et fint vassdrag med fine gammelskogsomgivelser. Vannet er et næringsfattig vann som ligger sentralt på Holtefjell. Dammen (Figur 19) hindrer fisk fra å vandre både opp og ned. Dammen er antagelig bevaringsverdig som kulturminne, men den er ingen enkel sak å restaurere. Dammen lekker og deler av dammen, over lukehuset er sammenrast og som et resultat har vannet sunket betydelig. Det sees en markant reguleringssone på 0,5 meter som tyder på at lekkasjen har kommet nylig. Det er mulig at årets tørkesommer har bidratt til redusert magasinfylling.

Dam bør vurderes bevart som kulturminne og for å bevare naturmiljø, dermed er det ikke lett å fikse enkel fiskepassasje gjennom tappeluke i dammen. Det er fine gyte- og oppvekstområder nedstrøms og innløpsbekkene til vannet er små. Det kan derfor vurderes en litt bratt omløpsrenne som vandringsløsning forbi dammen for å tilgjengeliggjøre mer areal for fisken her. Om dammen ikke restaureres vil den ramle sammen og det kan da opprettes fiskepassasje ved enkle midler.

Figur 19 Dammen på Grølla. Legg merke til tappehuset oppå dammen.

Høltjern

Denne delen av vassdraget er fint, men det er antagelig vandringshindre flere steder ovenfor og nedstrøms. Det er mye myr rundt vatnet og i vassdraget generelt. Området vurderes å være viktig for amfibier og vannfugl. Ved vår befaring ble det observert ørret på bekken. Trolig er det gode oppvekstsvilkår her.

Dammen (Figur 20) er vandringshinder, og fjerning av dam eller å åpne tappesluse vil gi fisk tilgang til større gyte og oppvekstområder, men slike tiltak vil også få andre konsekvenser. Vannets størrelse vil synke dramatisk og mye myr og våtmark vil tørke inn. Dette er å anse som negativt for både hyttefolk og vannfugl i området. Det er imidlertid potensiale for å beholde dam og bygge en omløpsbekk på nordsiden av dam her. I dette tilfellet vil det kunne gi en løsning som ivaretar de fleste hensyn på en god måte.

Figur 20 Dammen på Høltjern.

Referanser

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1628

NINA Report

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