Culverts as migration barriers: evaluation and mitigation of environmental impacts

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Outline

1) Relevance of the problem
2) Examples of typical problems
3) What to do? Evaluation, mitigation & management

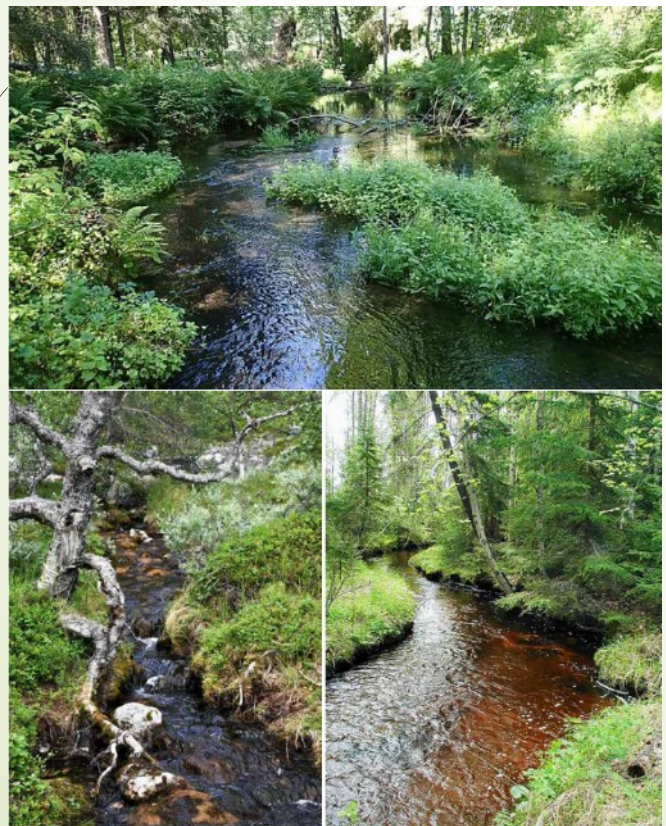
Who am I?

- MSc (2002-2007) and PhD (2008-2013) studies at University of Jyväskylä
  - Research: Arctic charr and food webs in subarctic lakes
- Post-doc in HydroBalance project (03/2014-06/2017)
- Now researcher at NINA Trondheim
- Participated some in Finland and

  planning new culvert projects

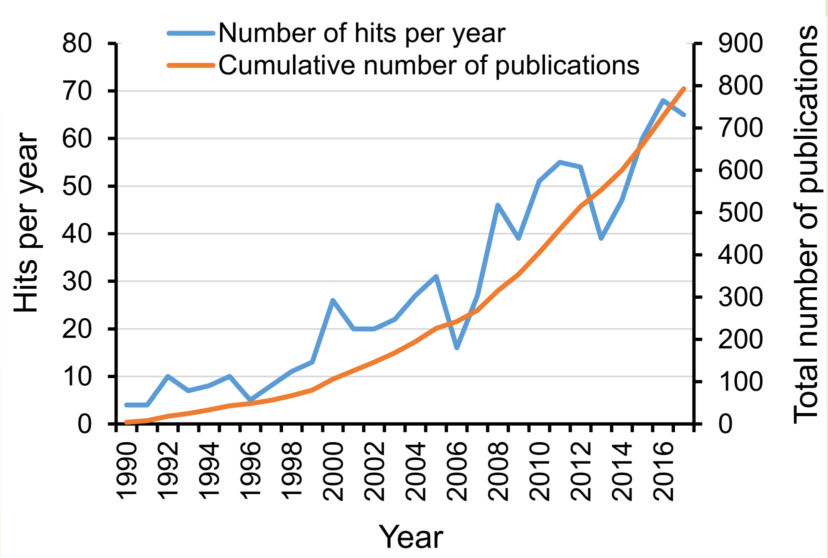
Culverts and small streams: numerous but neglected

- Small streams vital for fish population and ecosystem health
  - spawning and nursing habitats for various species
  - influence water and habitat quality in connected ecosystems



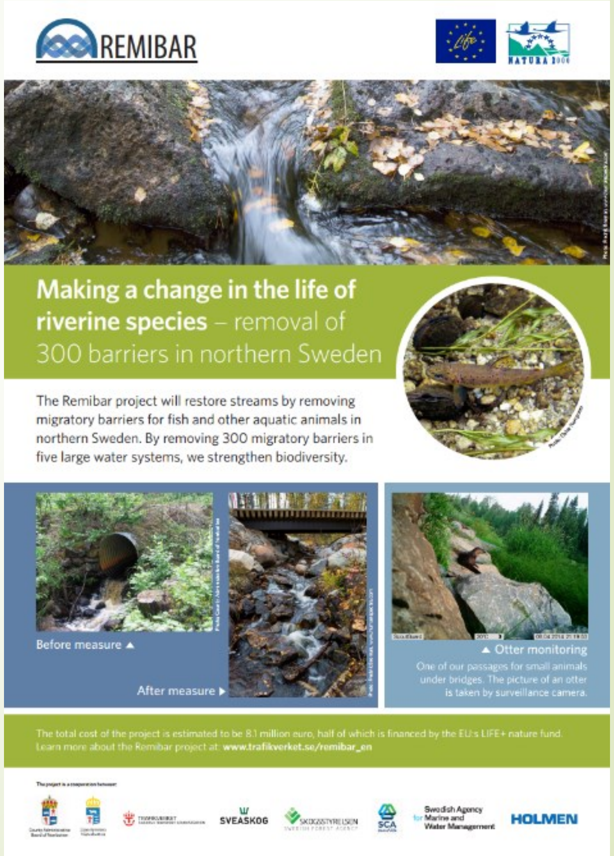
Culverts and small streams: numerous but neglected

- Small streams vital for fish population and ecosystem health
  - spawning and nursing habitats for various species
  - influence water and habitat quality in connected ecosystems
- Culverts have become a very hot topic
  - international and national environmental agreements
  - public concern



Extent of the problem

- ReMiBar project in Norrbotten and Västerbotten (Schönfeldt 2017)
  - 5000-8000 (30-50%) culverts are barriers → 2-5M m^2 negatively impacted



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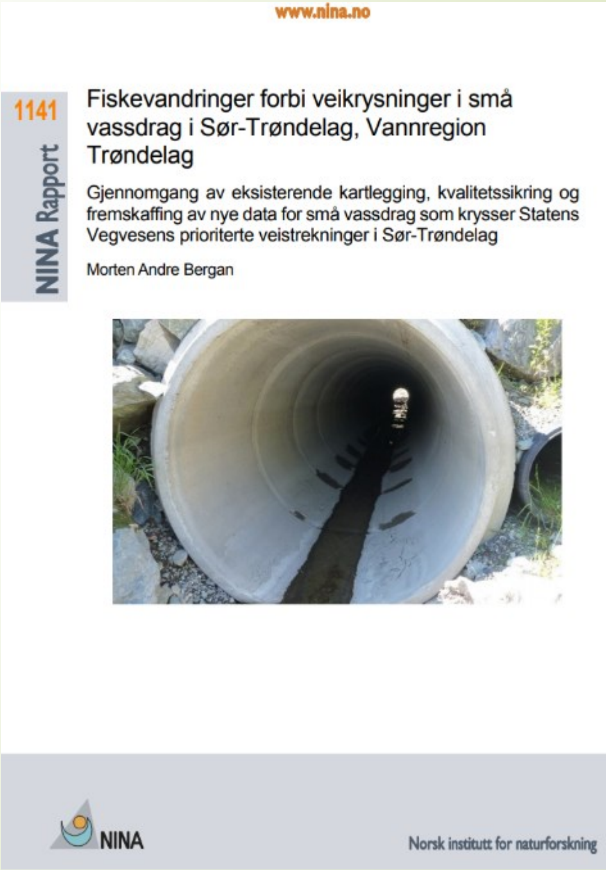
  - 34% of culverts block sea trout migrations



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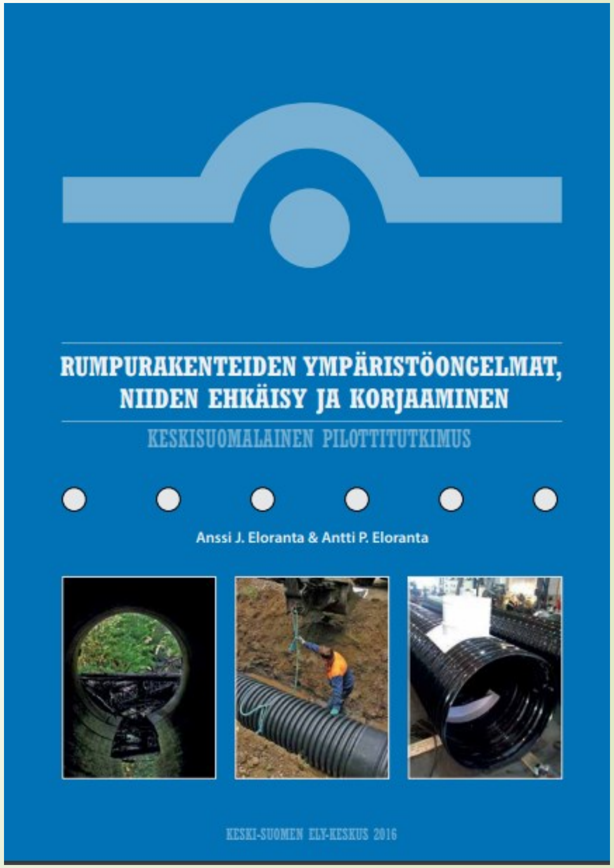
  - **~90 000** water crossing culverts in Finland



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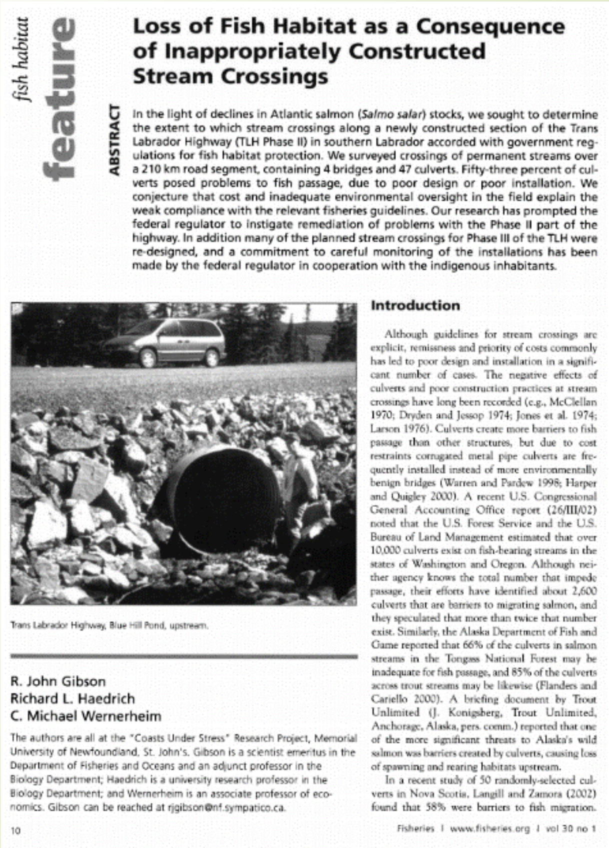
- Corresponding results around the world



fish habitat

feature

Loss of Fish Habitat as a Consequence of Inappropriately Constructed Stream Crossings

ABSTRACT

In the light of declines in Atlantic salmon (*Salmo salar*) stocks, we sought to determine the extent to which stream crossings along a newly constructed section of the Trans Labrador Highway (TLH Phase II) in southern Labrador accorded with government regulations for fish habitat protection. We surveyed crossings of permanent streams over a 210 km road segment, containing 4 bridges and 47 culverts. Fifty-three percent of culverts posed problems to fish passage, due to poor design or poor installation. We conjecture that cost and inadequate environmental oversight in the field explain the weak compliance with the relevant fisheries guidelines. Our research has prompted the federal regulator to instigate remediation of problems with the Phase II part of the highway. In addition many of the planned stream crossings for Phase III of the TLH were re-designed, and a commitment to careful monitoring of the installations has been made by the federal regulator in cooperation with the indigenous inhabitants.

Trans Labrador Highway, Blue Hill Pond, upstream.

R. John Gibson
Richard L. Haedrich
C. Michael Wernerheim

The authors are all at the "Coasts Under Stress" Research Project, Memorial University of Newfoundland, St. John's. Gibson is a scientist emeritus in the Department of Fisheries and Oceans and an adjunct professor in the Biology Department; Haedrich is a university research professor in the Biology Department; and Wernerheim is an associate professor of economics. Gibson can be reached at rjgibson@nf.sympatico.ca.

Introduction

Although guidelines for stream crossings are explicit, remissness and priority of costs commonly has led to poor design and installation in a significant number of cases. The negative effects of culverts and poor construction practices at stream crossings have long been recorded (e.g., McClellan 1970; Dryden and Jessop 1974; Jones et al. 1974; Larson 1976). Culverts create more barriers to fish passage than other structures, but due to cost restraints corrugated metal pipe culverts are frequently installed instead of more environmentally benign bridges (Warren and Pardew 1998; Harper and Quigley 2000). A recent U.S. Congressional General Accounting Office report (26/III/02) noted that the U.S. Forest Service and the U.S. Bureau of Land Management estimated that over 10,000 culverts exist on fish-bearing streams in the states of Washington and Oregon. Although neither agency knows the total number that impede passage, their efforts have identified about 2,600 culverts that are barriers to migrating salmon, and they speculated that more than twice that number exist. Similarly, the Alaska Department of Fish and Game reported that 66% of the culverts in salmon streams in the Tongass National Forest may be inadequate for fish passage, and 85% of the culverts across trout streams may be likewise (Flanders and Cariello 2000). A briefing document by Trout Unlimited (J. Konigsberg, Trout Unlimited, Anchorage, Alaska, pers. comm.) reported that one of the more significant threats to Alaska's wild salmon was barriers created by culverts, causing loss of spawning and rearing habitats upstream.

In a recent study of 50 randomly-selected culverts in Nova Scotia, Langill and Zamora (2002) found that 58% were barriers to fish migration.

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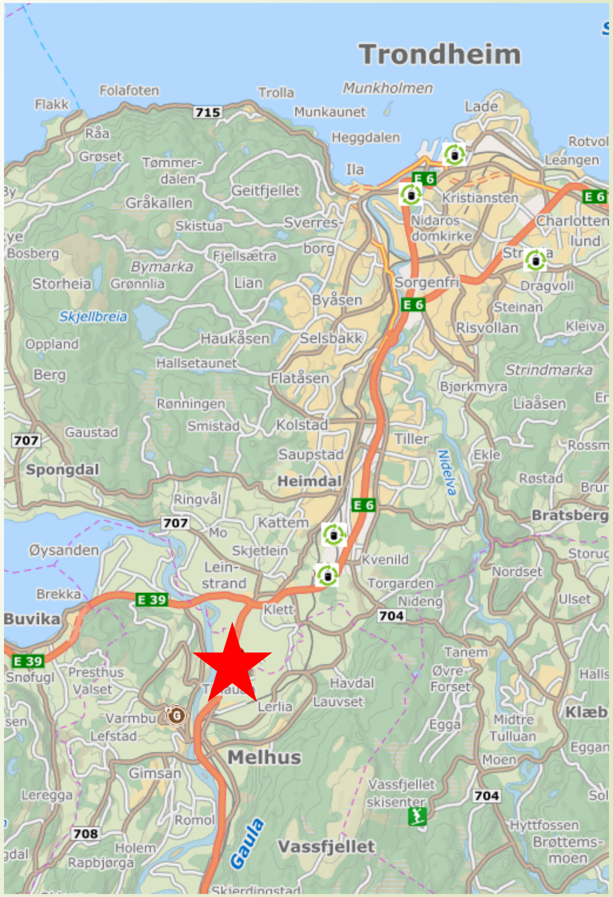
  - **~90 000** water crossing culverts in Finland
- Corresponding results around the world
- **Despite increased awareness, poor culverts are still installed!**



New road crossing Ratbekken in 2017

https://www.youtube.com/watch?v=dtuIXfAjOhI

Migratory sea trout in October 2017

https://www.youtube.com/watch?v=KUHGEuWL3Y4

Tana/Teno probably not the most problematic watercourse…

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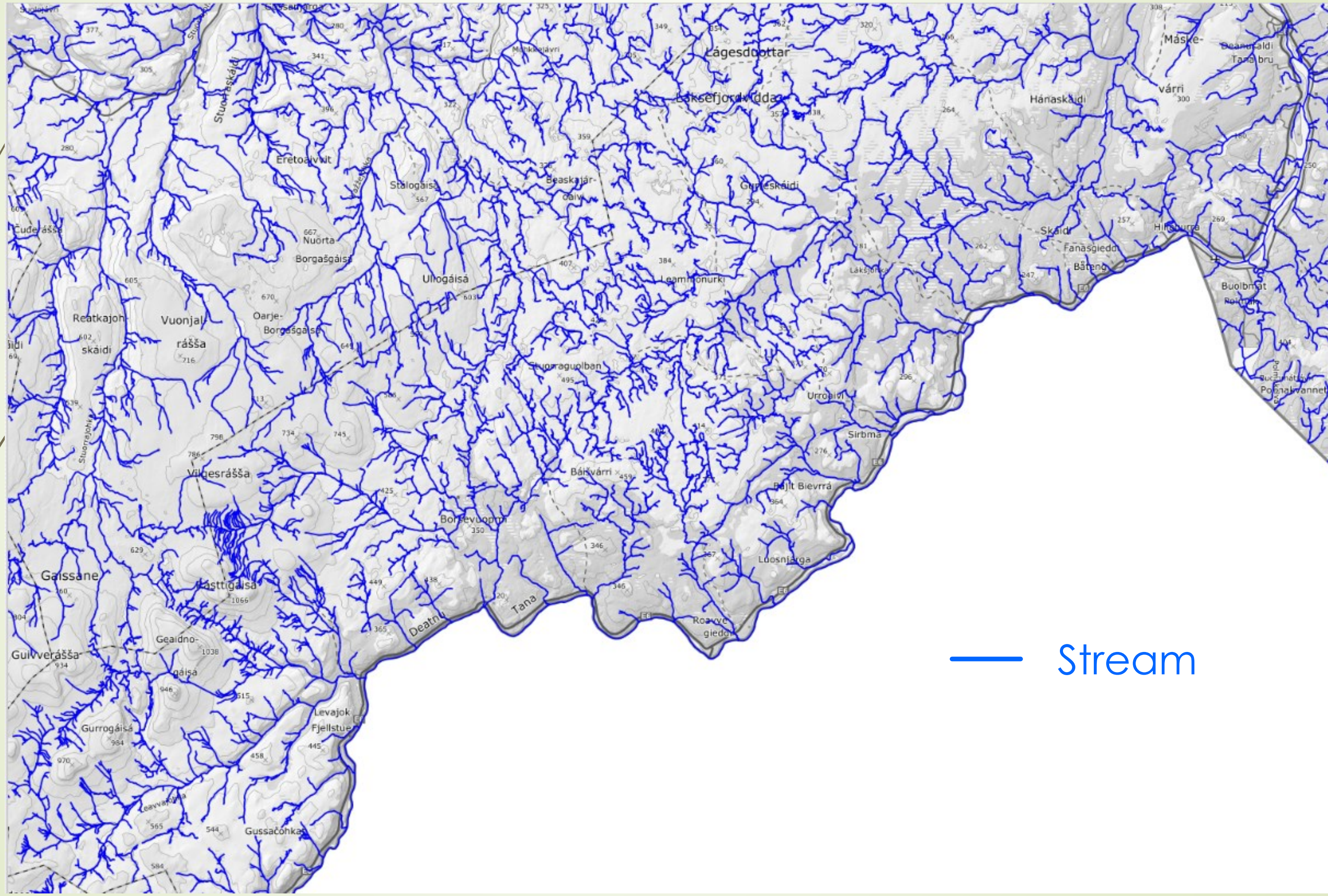

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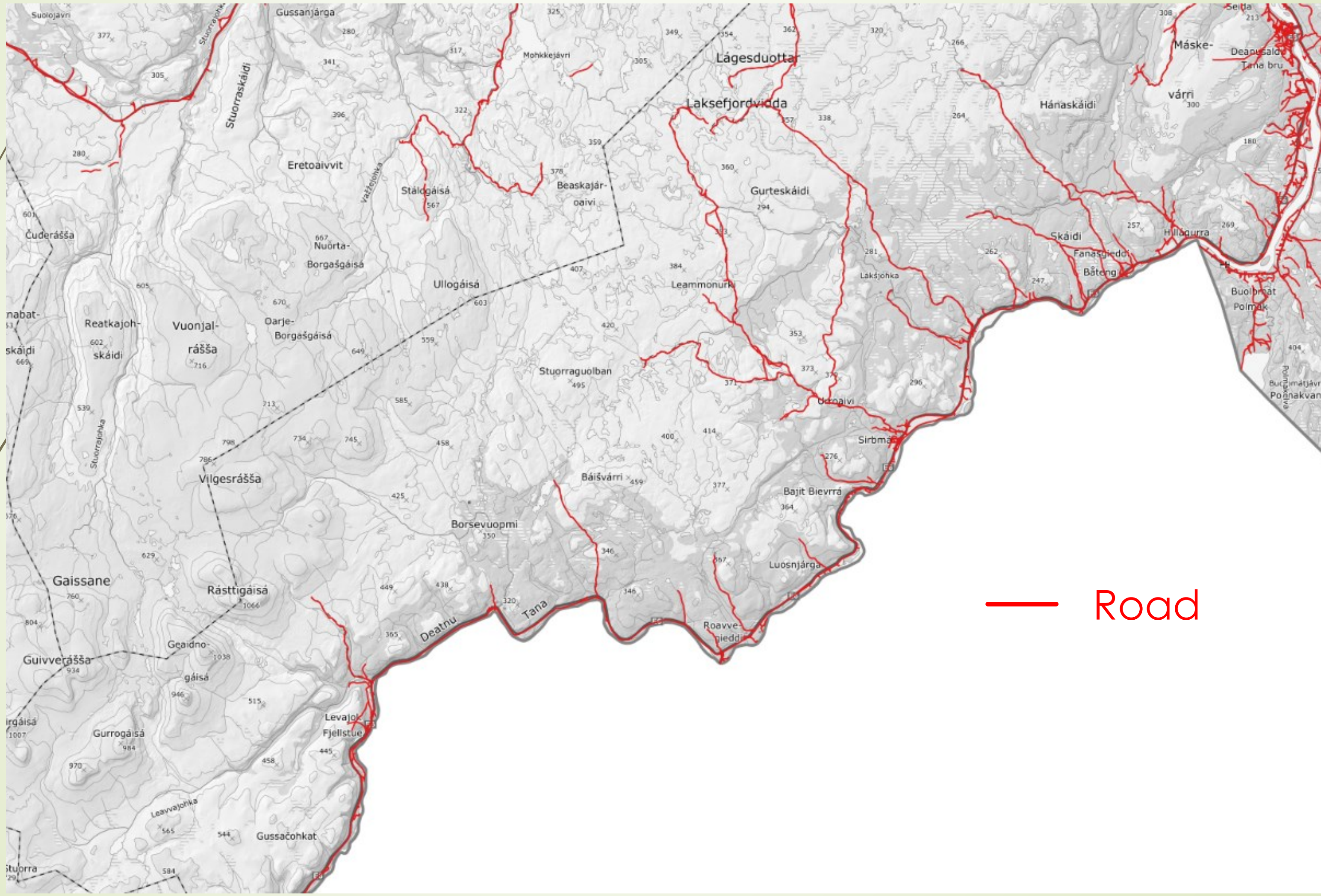

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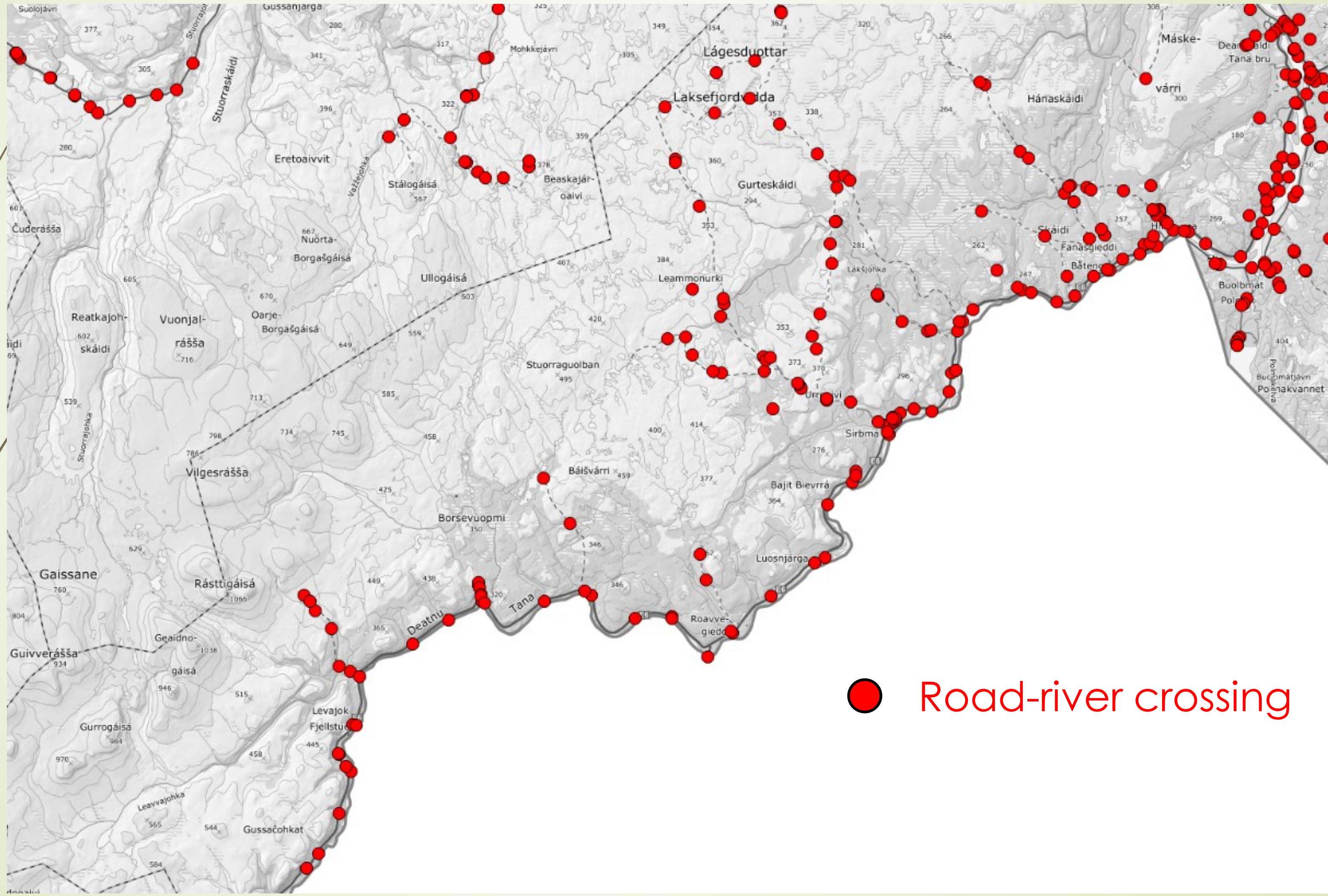
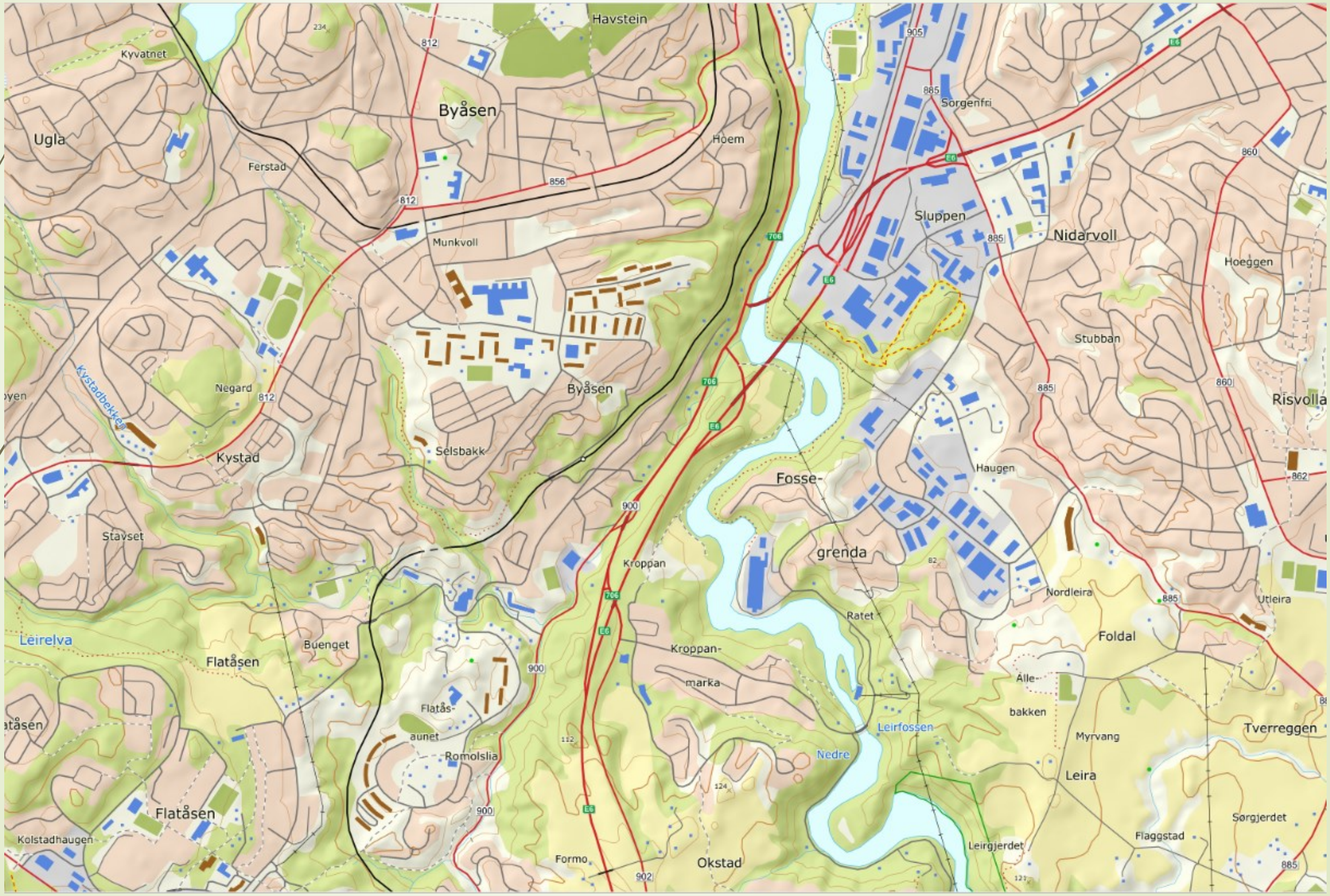


An example from my "backyard"

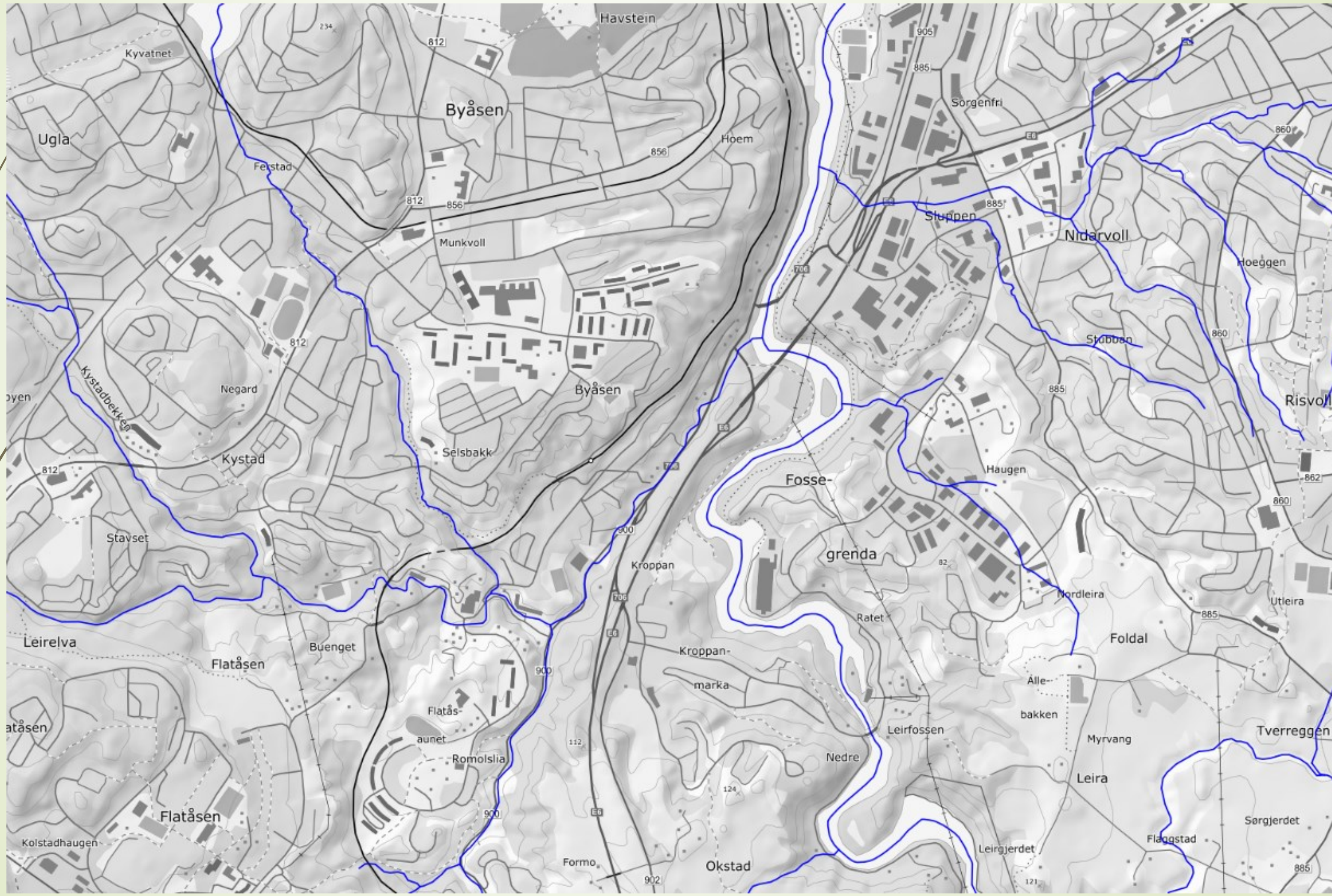


An example from my "backyard"

— Road

An example from my "backyard"

Stream



An example from my "backyard"

● Road-river crossing

Typical problems:

Vertical drop at the outlet

Typical problems:

Barriers at culvert end(s)

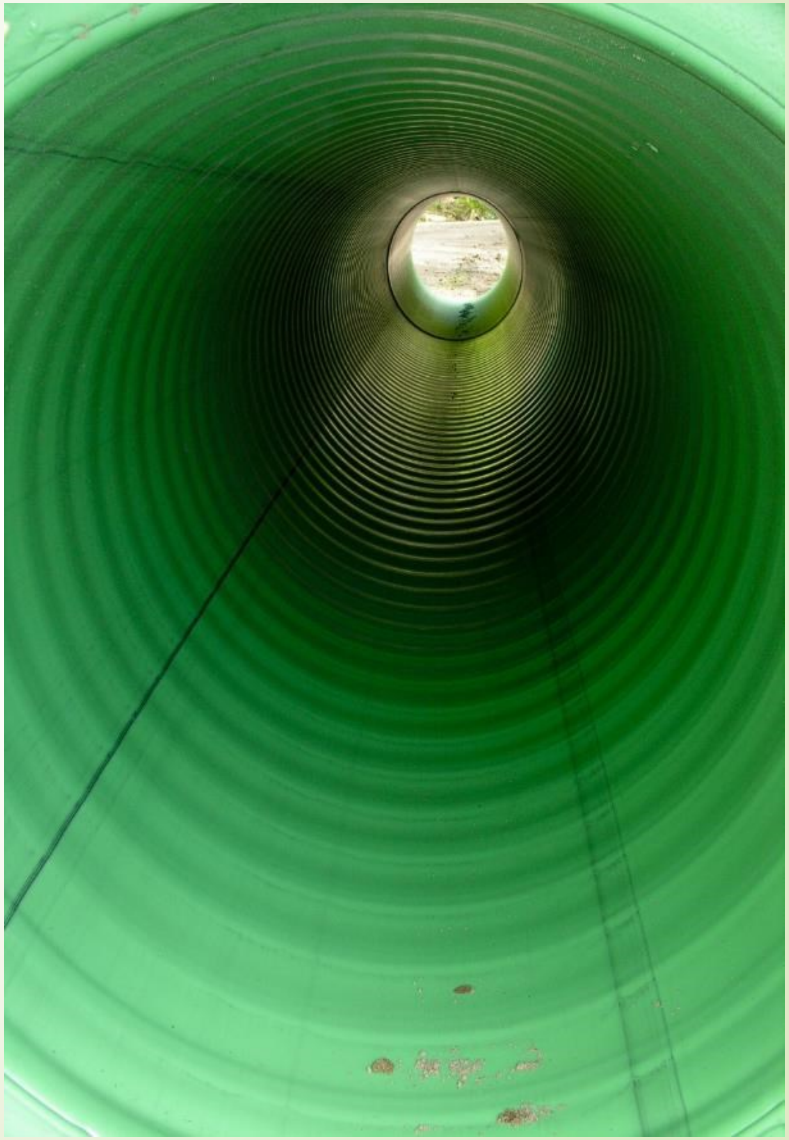
Typical problems:

Trash at culvert end(s)

Typical problems:

High water velocity

Typical problems:
Lack of bottom substrate



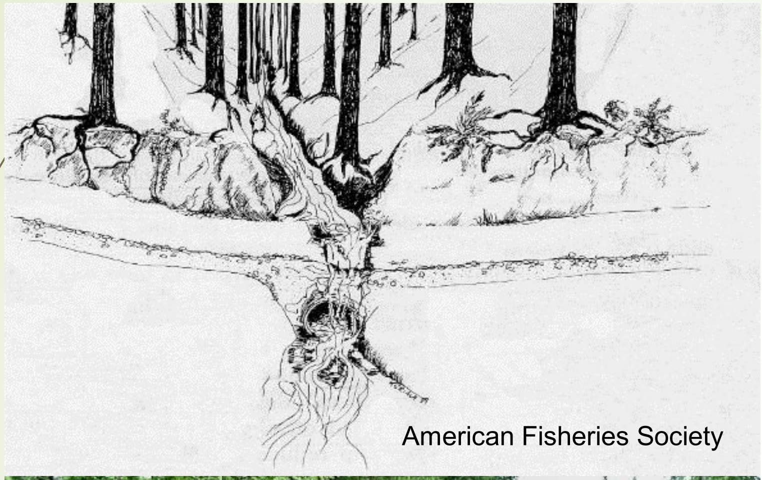
Typical problems:

Low water depth

Typical problems:
Ice formation

Typical problems:

Erosion and hydrological problems

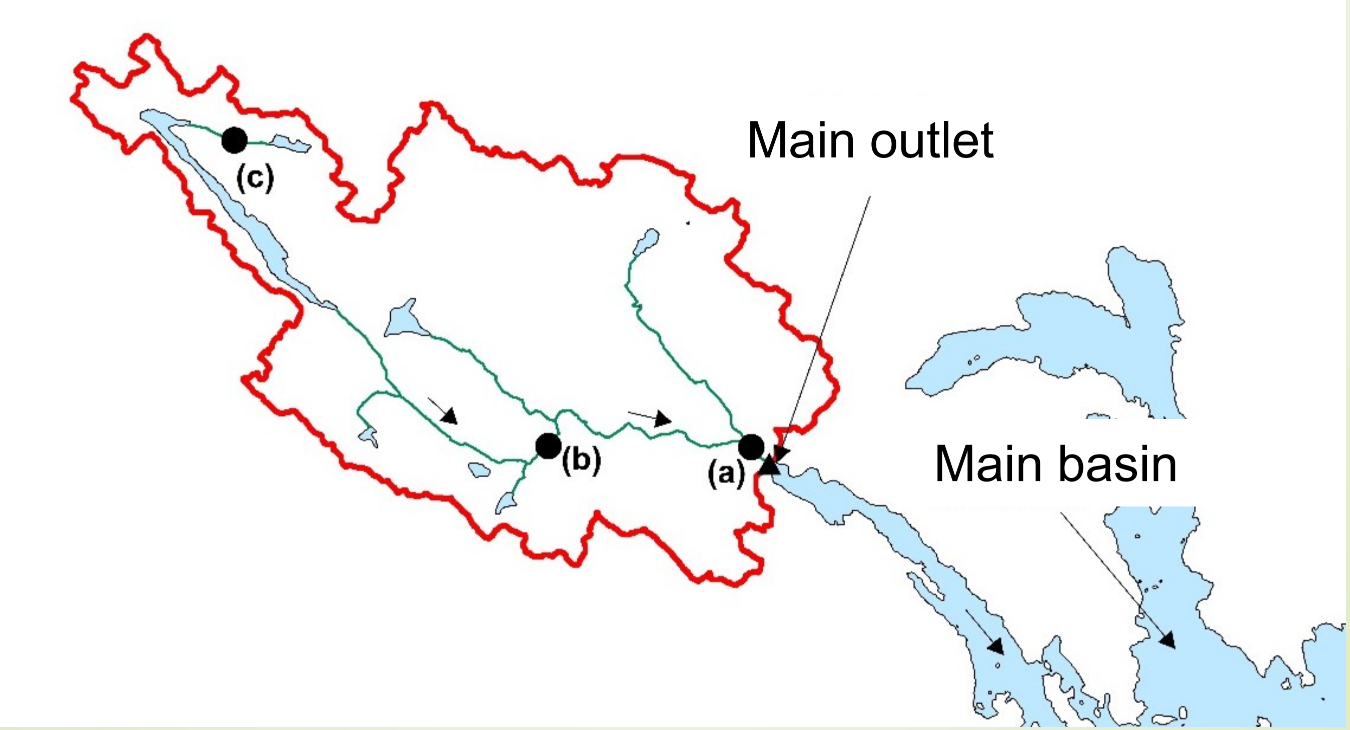


Typical problems:

Estethic problems

What to do?
Crucial things to consider

- Prioritize important watercourses and road crossings
  - Ecological and socio-economic values
    - Suitable habitat for migratory fish, pearl mussel, otter etc.?
  - Importance for river continuum
    - Highest priority at downstream sites



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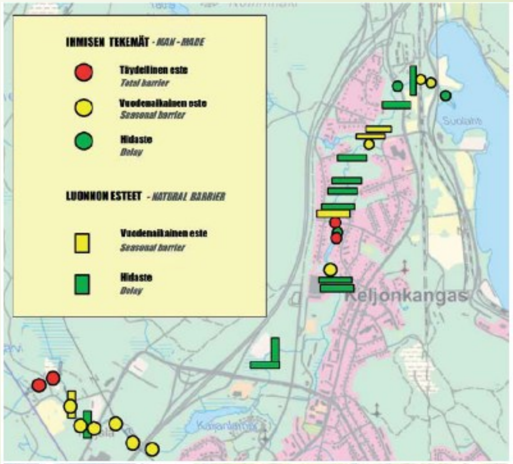
- Prioritize important watercourses and road crossings
  - Ecological and socio-economic values
    - Suitable habitat for migratory fish, pearl mussel, otter etc.?
  - Importance for river continuum
    - Highest priority at downstream sites
- Consider other migration barriers
  - Dams, weirs, trash racks etc.
  - Natural waterfalls, boulder fields, dense vegetation beds etc.


What to do?
Evaluation

1) Evaluate connectivity of the watercourse
2) Indicate potential man-made and natural barriers
3) Use GIS tools together with field surveys

Some electronic maps & aerial photos

- http://www.norgeskart.no
- https://www.norgeibilder.no
- https://kart.finn.no
- https://www.retkikartta.fi
- https://asiointi.maanmittauslaitos.fi/karttapaikka



What to do?
Evaluation: GIS tools

- Map potential barriers and/or prioritize mitigation actions
  - Stream and road networks, elevation models, catchment properties, fish community, field-survey data etc.
  - GIS approach used in ongoing INVAFISH project at NINA

Diversity and Distributions, (Diversity Distrib.) (2014) 20, 1414–1424

BIODIVERSITY RESEARCH

Predicting road culvert passability for migratory fishes

Stephanie R. Januchowski-Hartley[1]*, Matthew Diebel[2], Patrick J. Doran[3] and Peter B. McIntyre[1]

[1]*Center for Limnology, University of Wisconsin, Madison, WI 53706, USA,* [2]*Wisconsin Department of Natural Resources, Bureau of Science Services, Madison, WI 53706, USA,* [3]*The Nature Conservancy, Michigan Chapter and Great Lakes Project, Lansing, MI 48906, USA*

ABSTRACT

Aim Our goal was to predict road culvert passability, as defined by culvert outlet drop and outlet water velocity, for three fish swimming groups using remotely collected environmental variables that have been shown to influence the passability of road culverts.

Locatio Laurentian Great Lakes Basin, north-eastern North America, on the Canada–USA border.

Methods We generated four boosted regression tree models, one for road culvert outlet drop and one each for the three culvert outlet water velocities, and predicted the probability of impassable road culverts on low-order streams (Strahler 1-4) based on the models. Independent variables in the models included the upstream area draining to the culvert, slope at the culvert, stream segment gradient and stream reach gradient.

Results Gradient of the stream segment was the most important predictor in the outlet drop model, while upstream drainage area was the most important predictor in the three water velocity models. A majority of road culverts on low-order streams are estimated to be passable even for weaker swimming fishes. Moderate to highly impassable road culverts are distributed across many low-order streams throughout the basin, but particular regions are predicted to have higher densities than others due to topography.

Main conclusions Predicted passability of road culverts by migratory fish is related to natural gradients in topography and stream size. While the probability of any particular culvert being impassable is low, the vast number of culverts in the basin means that, together, they could pose a greater challenge to migratory fish than dams. Our modelling framework could be used in any region where culverts are prevalent in the riverscape. The resulting estimates of passability to fishes can guide surveys towards the most problematic hydrological regions and structures and contribute to broad-scale prioritization of barrier removals to restore ecological connectivity.

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E-mail: stephieronee@gmail.com

Keywords
Distribution maps, ecological connectivity, fish passage, Laurentian Great Lakes Basin, remediation.

Fisheries Management and Ecology

Fisheries Management and Ecology, 2016

Prioritising culvert removals to restore habitat for at-risk salmonids in the boreal forest

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Department of Renewable Resources, University of Alberta, Edmonton, AB, Canada

A. E. ANDERSON
Department of Renewable Resources, University of Alberta, Edmonton, AB, Canada
Water Program, FRI Research, Hinton, AB, Canada

Abstract In the boreal forests of Canada, industrial development has resulted in the installation of thousands of culverted road crossings that act as barriers to fish movement and degrade habitat for native freshwater fishes. In view of culvert removals being expensive, prioritisation methods have been developed, but the efficacy of such methods has not been thoroughly investigated nor have they been tested on low-gradient boreal forest watersheds containing at-risk salmonids. The management utility of a novel GIS-based optimisation-planning tool to prioritise fish barrier remediation was tested in two highly developed watersheds. Region-specific parameter estimates of monetary variables (e.g. budget, individual barrier remediation costs), barrier passability and biologically relevant information for species on conservation concern (e.g. habitat suitability, dispersal ability) were incorporated. Results indicate that for Arctic grayling, *Thymallus arcticus* Pallas, and bull trout, *Salvelinus confluentus* Suckley, a large proportion (~61–83%) of currently isolated habitat can be reconnected with low investment (~$200–$500 K). This study demonstrates the management utility of barrier optimisation methods for use in boreal watersheds, particularly as it significantly reduces the technical expertise needed to perform relatively complex optimisation analyses.

KEYWORDS: Arctic grayling, bull trout, connectivity, habitat restoration, OptiPass.

What to do?
Evaluation: field surveys

- Report from each site:
  - **Location**: connection to up- and downstream ecosystems
  - **Ecological & socio-economic value**: aquatic & terrestrial animals, nature reserves, recreational areas, etc.
  - Detailed information about
    - **Structure**: type, number, shape, material, dimensions, condition, water velocity, slope, drop, passability & restoration, etc.
    - **Nearby stream**: water depth, velocity and quality, channel width, bottom substrate, riparian habitat, presence of fish, etc.
  - **Take photos!**
  - **Revisit** important sites to evaluate passability at different times
  - **Electro-fishing** in up- and downstream sites
- Pirkko-Liisa Luhta and Markku Seppänen from Metsähallitus will present detailed templates for culvert inspection

An evaluation chart by WDFW

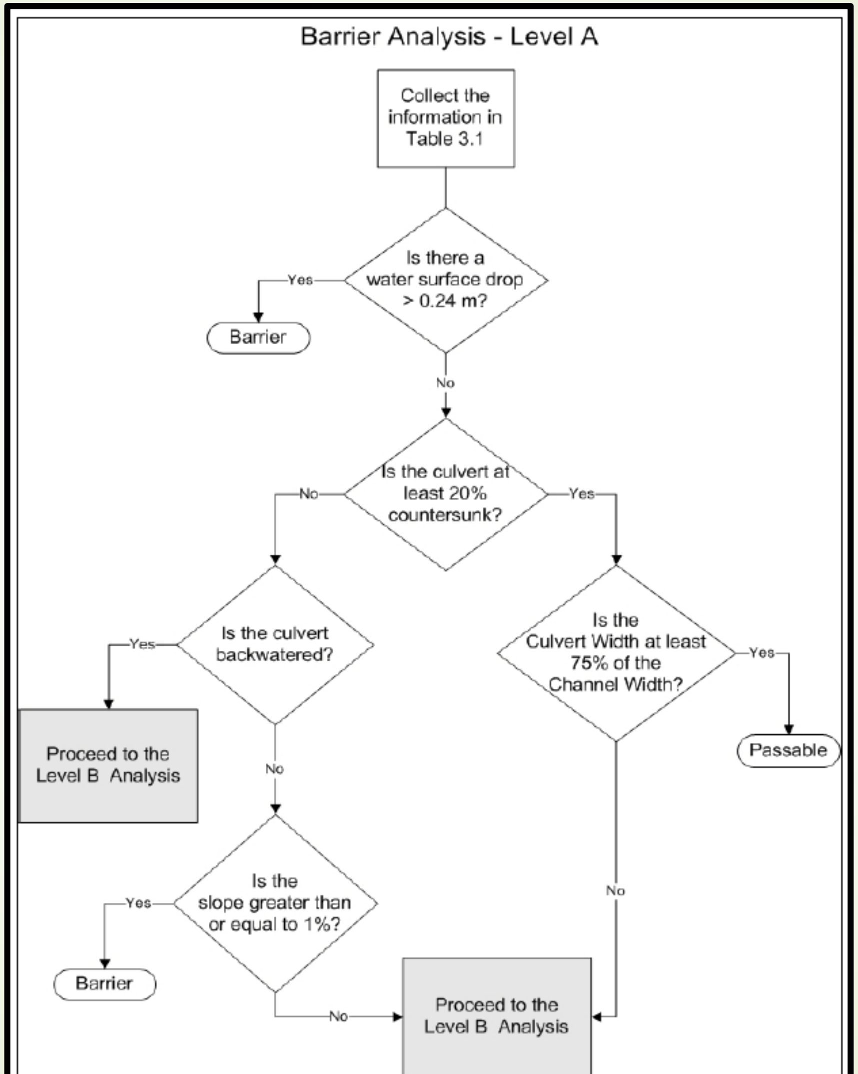
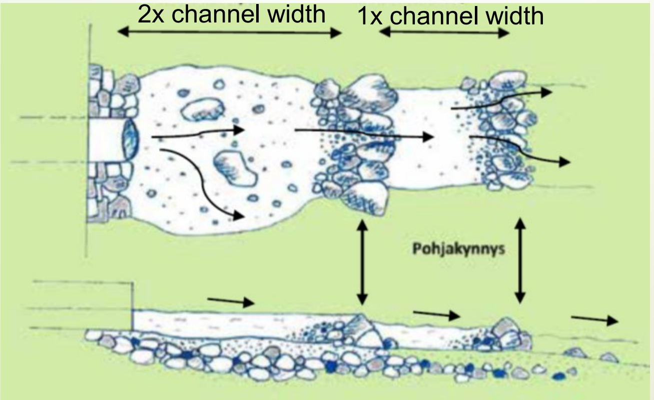


Figure 3.4. Flow chart of the Level A culvert analysis.

Chapter 3: Road Crossing Structures – Fish Passage Inventory 3-12
Fish Passage Barrier and Surface Water Diversion Screening and Prioritization Manual

What to do? Mitigation

- Remove or replace damaged culverts with bridges or large culverts
- Remove barriers in culvert mouths
- Create dry paths for terrestrial animals
- Increase water depth and decrease water velocity
  - lowering/alignment of the culvert
  - down- and upstream pools
  - baffles and/or natural bottom substrate



ReMiBar: examples of mitigation

Picture 2a. Object 44 before, culvert with a fall at the outlet.

Picture 1a. Object 191 before, culverts with falls in the outlet.

Picture 2b. Object 44 after, arch with natural riverbed.

Picture 1b. Object 191 after, bridge with a natural riverbed.

ReMiBar: examples of mitigation

Picture 5a. Object 173, before, a dam that is a migratory barrier for fish

Picture 5b. Object 173, after, the dam is removed.

Picture 4a. Object 59, before, a culvert with a fall at the outlet

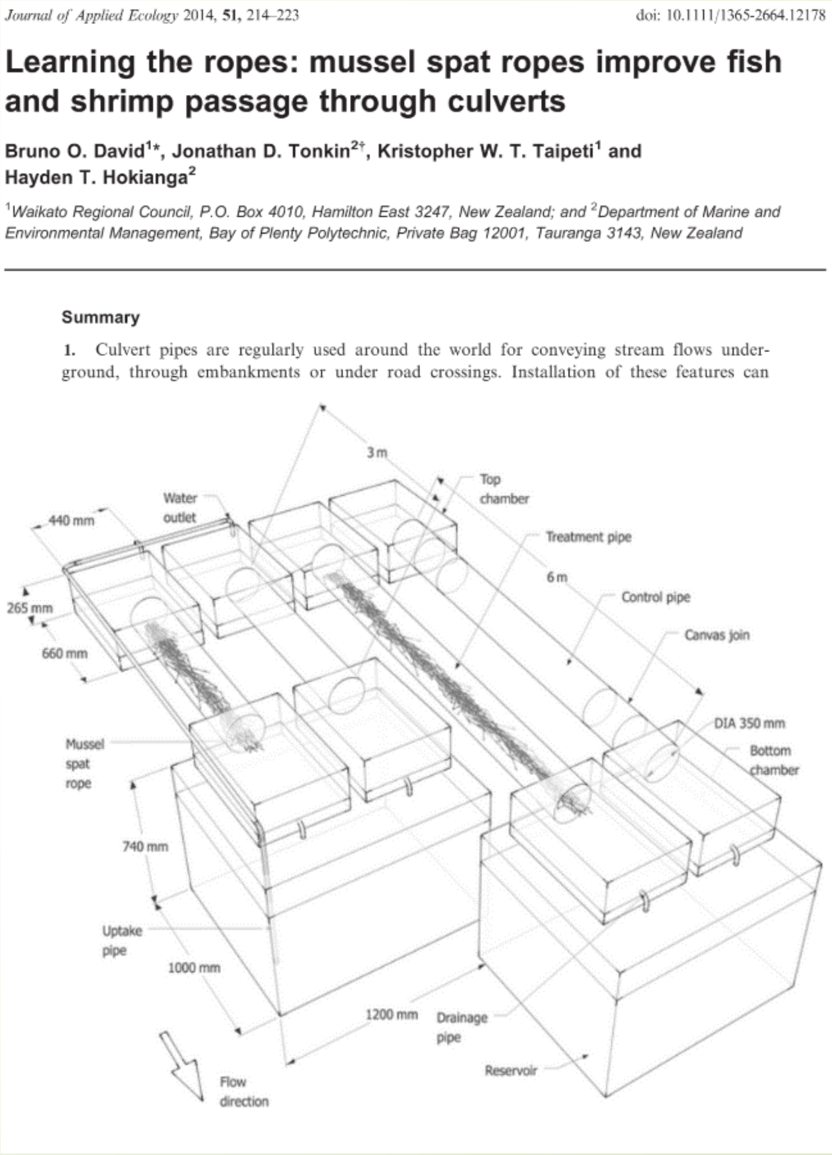
Picture 4b. Object 59, after, a culvert which is lowered and increased culvert to let the riverbed continue under the road

Don’t forget other species!

Dry paths and "hanging ropes"

Picture 3a. Otter mitigation, object 24.

Picture 3b. Otter mitigation, a dry culvert for otters to go through, object 197.



Journal of Applied Ecology 2014, **51,** 214–223 doi: 10.1111/1365-2664.12178

Learning the ropes: mussel spat ropes improve fish and shrimp passage through culverts

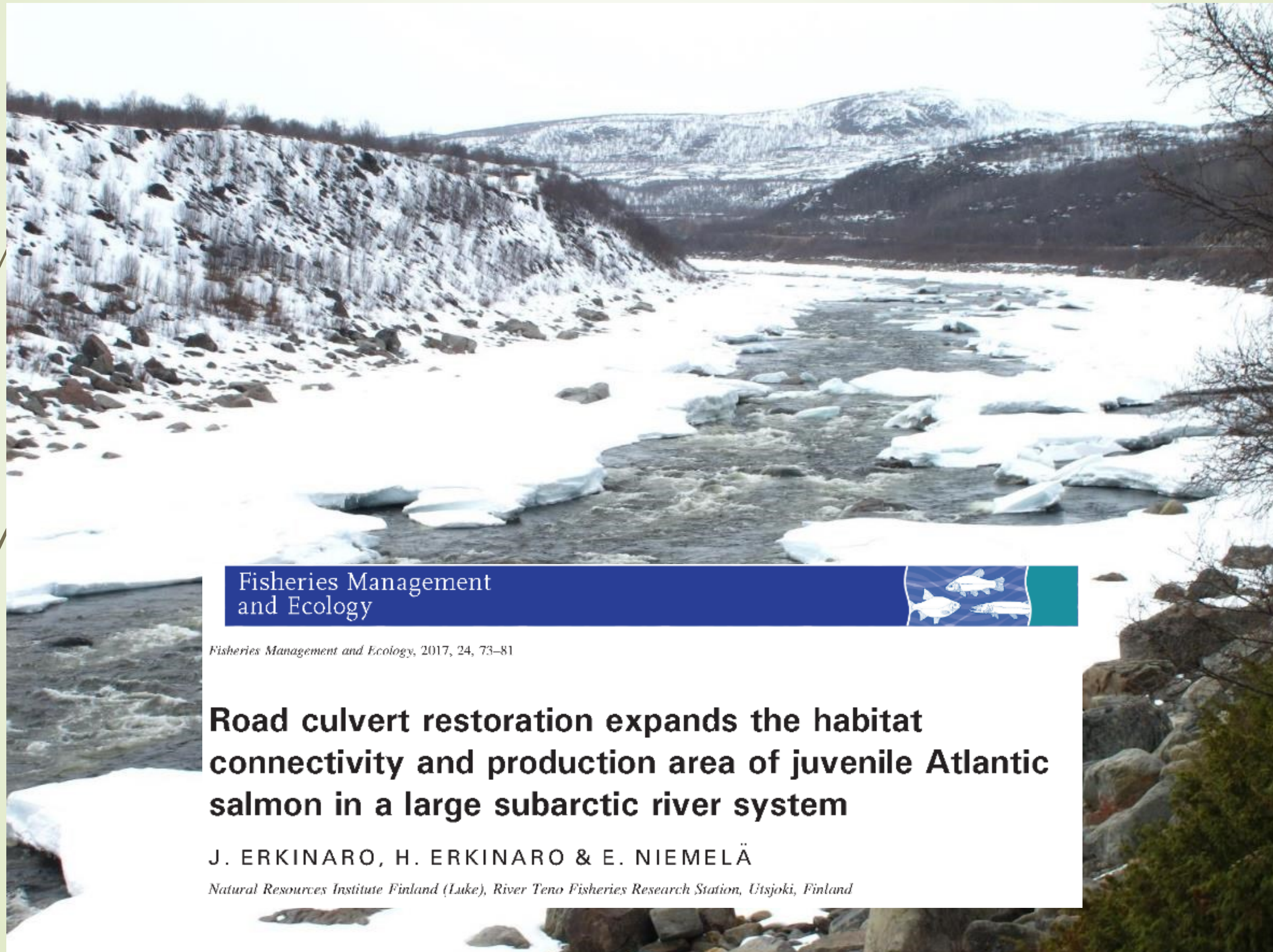
Bruno O. David[1]*, Jonathan D. Tonkin[2†], Kristopher W. T. Taipeti[1] and Hayden T. Hokianga[2]

[1]*Waikato Regional Council, P.O. Box 4010, Hamilton East 3247, New Zealand; and* [2]*Department of Marine and Environmental Management, Bay of Plenty Polytechnic, Private Bag 12001, Tauranga 3143, New Zealand*

Summary

1. Culvert pipes are regularly used around the world for conveying stream flows underground, through embankments or under road crossings. Installation of these features can

Jaakko will tell us success stories from Teno! ☺



Fisheries Management and Ecology

Fisheries Management and Ecology, 2017, 24, 73–81

Road culvert restoration expands the habitat connectivity and production area of juvenile Atlantic salmon in a large subarctic river system

J. ERKINARO, H. ERKINARO & E. NIEMELÄ

Natural Resources Institute Finland (Luke), River Teno Fisheries Research Station, Utsjoki, Finland

What to do?
Future management

- Fish migration barriers are **in violation of national and international environmental agreements**
- **Improved advisory, control and communication** would reduce environmental damage
- **Improved public awareness and involvement** would be fruitful
- **New local and large-scale projects** would be welcome ☺

Some reading

- Eloranta & Eloranta (2016) (**in Finnish** + English summary and legends)
  - https://www.doria.fi/bitstream/handle/10024/120869/Rumpurakenteiden_ymparistoongelmat.pdf?sequence=2
- Haugland & Hjelle (2015) Frie fiskeveger (**in Norwegian**)
  - https://www.vegvesen.no/_attachment/1117935/binary/1078427?fast_title=Frie+fiskeveger+-+Utbedring+av+vandringshinder+for+fisk.pdf
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  - https://www.slu.se/globalassets/ew/org/inst/aqua/externwebb/sidan-publikationer/ekologisk-restaurering-av-vattendrag/ekologisk-restaurering-av-vattendrag_web.pdf
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  - http://wdfw.wa.gov/publications/00049/wdfw00049.pdf
- Barber et al. (2009) Fish Passage and Surface Water Diversion Screening Assessment and Prioritization Manual
  - http://wdfw.wa.gov/publications/00061/wdfw00061.pdf

Kíítos! Tusen takk!