Western Norway University of Applied Sciences

BACHELOR'S ASSIGNMENT

River Deltas of the Inner Sognefjord (Inner Sogn Region): Consequences of Anthropogenic Change

Elvedeltaer i Indre Sognefjorden (Sogn): konsekvenser av menneskelig endring

BSc. Geology

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I confirm that the work is self-prepared and that references/source references to all sources used in the work are provided, *cf. Regulation relating to academic studies and examinations at the Western Norway University of Applied Sciences (HVL), § **10***

Abstract

This study investigates ten river deltas for anthropogenic environmental change in the Inner Sogn Region, Western Norway, using aerial photographs of the 1960s and the 2010s. In addition, it presents qualitative interviews made with two experts, focusing on the development of bird and fish populations in the observed river deltas. These river deltas are the Årøy Delta near Sogndal, the Lærdal Delta at Lærdal, the Sogndalsfjøra Delta at Sogndal, the Gaupne Delta at Gaupne, the Gudvangen Delta at Gudvangen, the Skjolden Delta at Skjolden the Årdalstangen Delta at Årdalstangen, the Bøyaøyra Delta near Fjærland, the Vetlefjordøyra Delta at Vetlefjorden and the Flåm Delta at Flåm.

The observed river deltas are habitats for fish and bird populations. The deltas are used as resting places, feeding grounds, nesting areas and for nursery.

All the observed river deltas are influenced by human activity. Two of these river deltas have changed from >50% natural to <25% cultivated over the past 50 years. One river delta has changed from >50% natural to >25% cultivated. Four out of the ten observed river deltas have changed from >50% natural to >>50% urban. Three river deltas changed from >50% urban to >>50% urban. The natural delta area of six out of ten river deltas decreased by more than 50% between the 1960s and the 2010s due to land fillings, road buildings and harbor constructions.

These results suggest that the progressing destruction of the natural river delta environment had a declining effect on the fish and bird population of the region.

To reduce the potential for future conflicts, it is suggested that river delta management uses the historic development of the river deltas as an additional tool when deciding on future delta change.

Acknowledgements

I am thankful to Johannes Anonby and Torbjørn Dale for sharing their time and knowledge and being helpful interview partners. I also thank all students from the Western Norway University of Applied Science in Sogndal who have shared their research and have supported me. Special thanks go to Dr. Matthias Paetzel for being a cooperative adviser in general and for providing useful contacts in particular.

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1. Introduction

The Inner Sogn Region is a region in central Norway and part of the Sogn og Fjordane county (Figure 1b). It includes the end branches of the 204km long Sognefjord (http 1). The Inner Sogn Region is divided into seven municipalities: Leikanger, Sogndal, Balestrand, Aurland, Lærdal, Årdal and Luster (Figure 1c) with a total population of 16.745 people on a populated area of 12.64 km² (http 2). Because of the mountainous terrain in most of the region, villages and towns are often located in the flat transitional areas between rivers and fjords.

With their flat morphology, river deltas are preferable places for human settlements. Fillings and build-ups of deltas are a relatively easy way for villages to create habitable space. Building of harbors, roads and industry on the newly won areas is effecting the local economy and supra-regional connectivity. Through the increased mobility due to bigger harbors, villages like Flåm or Gudvangen managed to become hotspots for tourism (http 3 & 4). In Gaupne, delta build-ups made it possible for industry to settle. Companies like “Avery Dennison NTP” opened factories in the small town and created over 100 jobs for locals (http 5). Processes like these strengthen the economic value of the whole Inner Sogn Region.

Environmentalists see these changes in the deltaic environment critically. They point out the effects that delta built-ups have on local ecology (Solhaug, 2009). River deltas are preferable spots for fish spawning and nursery as well as for birds to rest during migration (Dybwad, 2014). Because of this, environmentalists plead for saving the river deltas still left, by preventing them from further human cultivation (Dybwad, 2014).

This conflict of interest will be addressed in a geographical review: The thesis at hand will thus have a closer look on how the deltaic environment has been shaped in the Inner Sogn Region since the early 1960s. It will further discuss what consequences human activities on the river deltas might have in the entire Inner Sogn Region.

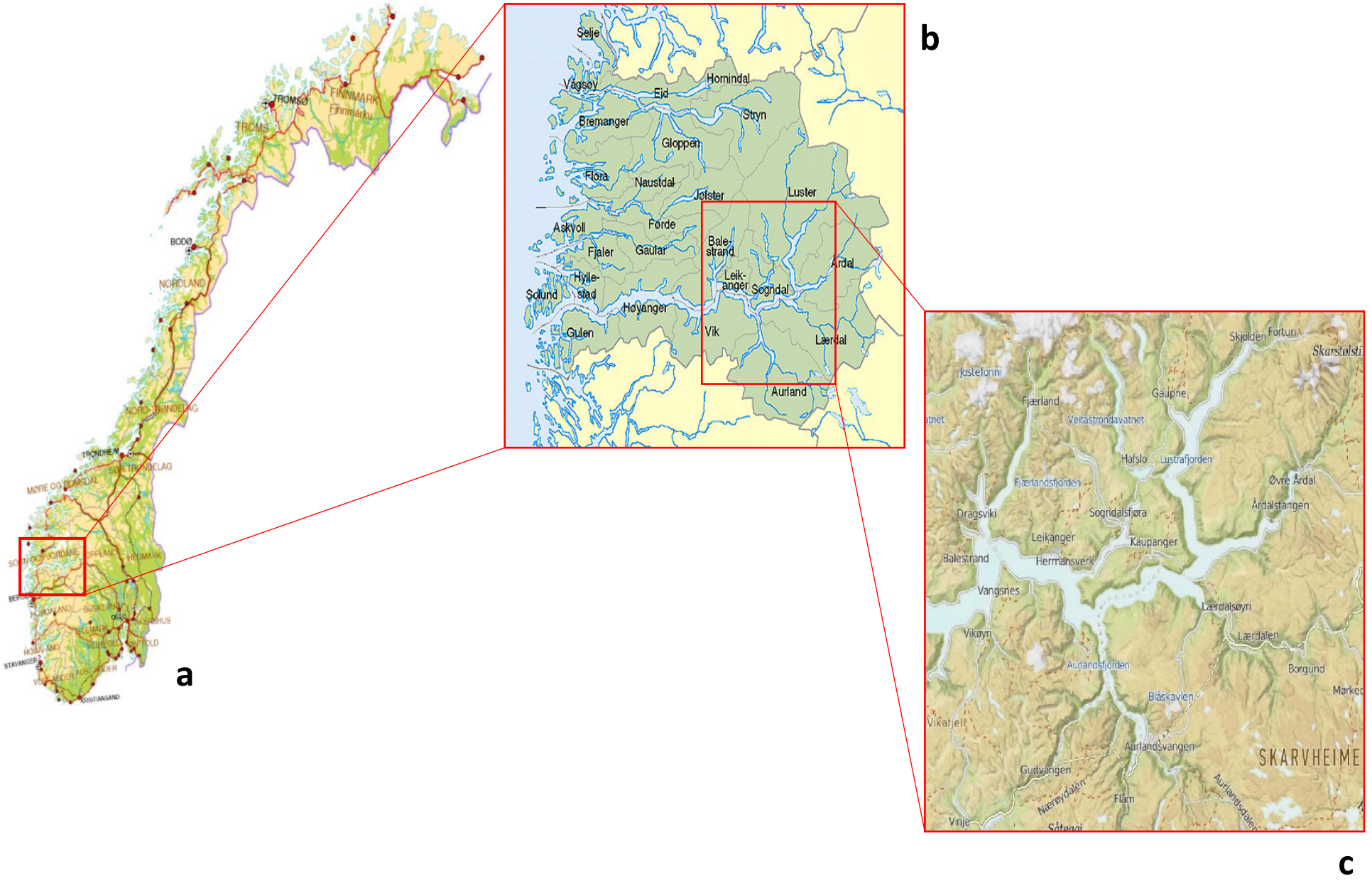


Figure 1: a) Map of Norway (http 6) b) Sogn og Fjordane County (http 7) c) Inner Sogn Region (http 6)

2. Objectives

1. Have fjord river deltas changed in the Inner Sogn Region over the last 50 years?

2. How and at which degree have these fjord river deltas changed?

3. What are the causes of the observed changes?

4. What are the possible consequences of these changes for river, delta, and fjord management?

Explanation of objective 1

A first step in discovering deltaic changes is the comparison of prior and modern aerial photographs from the fjord river deltas of the Inner Sogn Region. The aerial photographs give the opportunity to detect changes in size of the deltas and an expansion or retreat of cultivated and urbanized land areas in and around these deltas. The 1960s are chosen as a comparing timeframe because the first aerial photographs have been made in this time, providing the oldest comparable time series.

Explanation of objective 2 and 3

This work will try to classify the examined deltas according to the size and usage of the changed delta areas. It will investigate the type of interferences and the motives for the changes. The Norwegian Environmental Agency has created a database (in the following referred to as Elvedelta database), where deltas all over Norway are listed (http 8). While the Elvedelta database gives an overview of the current situation of river deltas, this study will try to show the historical development of river deltas of the Inner Sogn Region. One aim of this work will be to add data to the Elvedelta database and to expand it with new categories to give an historical and thus more complete overview of the changes.

Explanation of objective 4

This work will point out possible consequences based on the examined changes. Here, the deltaic ecology, especially fish and birds are of interest. Due to a lack of quantitative data in these fields, qualitative data is of increased importance. Using qualitative interviews with experts, this work attempts to give a first overall image of ecological consequences and the historical development of river deltas under human influence. Offering this information will help landscape managers and environmentalists to find solutions for delta changing programs and to avoid further conflicts in the future.

3. Setting

3.1. Environmental setting

3.1.1. Deltas

Deltas are shoreline formations, formed when rivers enter oceans, fjords, lakes or lagoons and supply sediment more rapidly than it can be redistributed (Elliot, 1986).

They can be divided into alluvial and non-alluvial deltas (Nemec, 1990). While alluvial deltas are formed by rivers, non-alluvial deltas form by lava flows and pyroclastic flows extending into water (Boggs, 1995). This work will focus on alluvial deltas.

Alluvial or river deltas can further be distinguished by Galloways classification (Galloway, 1975) into fluvial-dominated, tide-dominated and wave-dominated deltas (Figure 2).

Deltas in general consist of a delta plain and a delta front. The delta plain includes the sub-aerial part of the delta with its distributary channels, lakes and marshes and is situated behind the delta front. The delta front is situated seawards and includes the distributary mouth areas and interdistributary bays (Leeder 1982) (Figure 3).

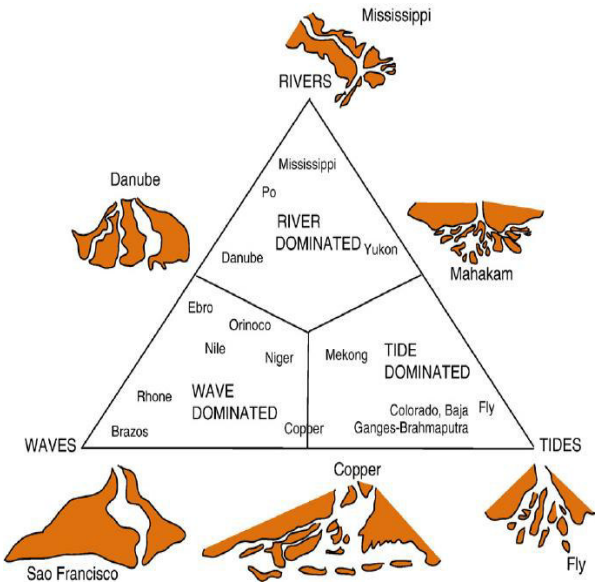


Figure 3: Galloway´s delta classification and examples (http 9)

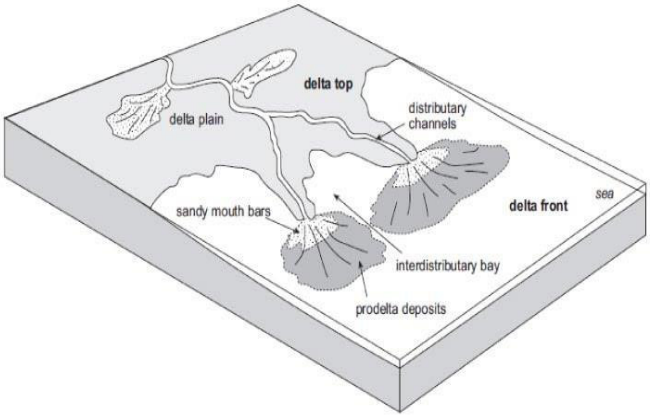


Figure 2: Basic morphology of a typical river delta (Nichols, 1999)

In tide-dominated deltas, tidal currents are stronger than the river outflow. This leads to a redistribution of river mouth sediments. By redistributing, sand-filled and funnel shaped distributaries are being produced. In addition, the river mouth bar can be formed into linear ridges. These ridges can extend from the channel mouth out to the delta-front (Boggs, 1995). This process stretches the deltas seawards.

In wave-dominated deltas, the river outflow is being slowed down by waves. The waves produce narrow or redirected river mouths. In addition, shore currents redistribute river mouth deposits along the delta front and form beaches. (Boggs, 1995).

The most common deltas are river-dominated deltas. Bates (1953) makes a division into three types of fluvial-dominated deltas, depending on the density difference of the inflowing river water and the basin water coming in from the seaside of the delta.

When river water enters a water body with the same density, the inflowing water velocity decelerates rapidly. This causes an abrupt deposition of sediments and forms the so-called Gilbert-type Deltas (Boggs, 1995) (Figure 4a).

Inflowing river water entering a water body with lower density flows beneath the water body as a density current. This flow can be erosive in the beginning, but deposits its sedimentary loads at the gentler slopes of the delta (Boggs, 1995) (Figure 4b).

When river water is entering a water body with higher density, the inflowing water is flowing above the water body. This happens typically when freshwater flows into more dense saltwater. Due to the lower density of the freshwater, fine sediments can be carried in suspension far away from the river mouth before being deposited (Boggs, 1995) (Figure 4c).

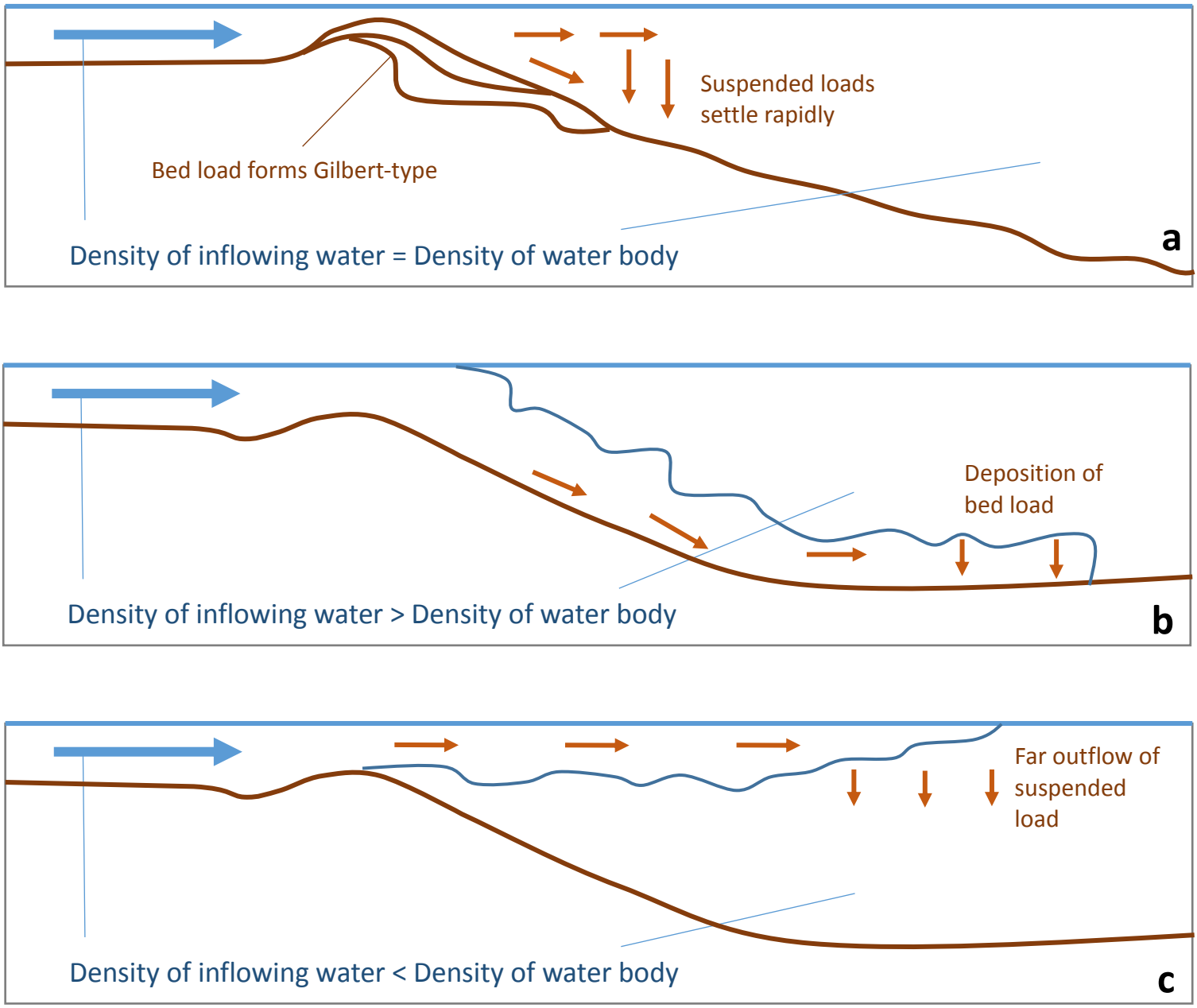


Figure 4: Different river delta types (after Bates, 1953)

3.1.2. River deltas of the Inner Sogn Region

The river deltas investigated in this work are all located in the Inner Sogn Region. They can be divided into two groups: Deltas of the Inner Sogn Region described by Elvedelta database (blue numbers in Figure 5) and Deltas of the Inner Sogn Region not described by Elvedeltadata (red numbers in Figure 5).

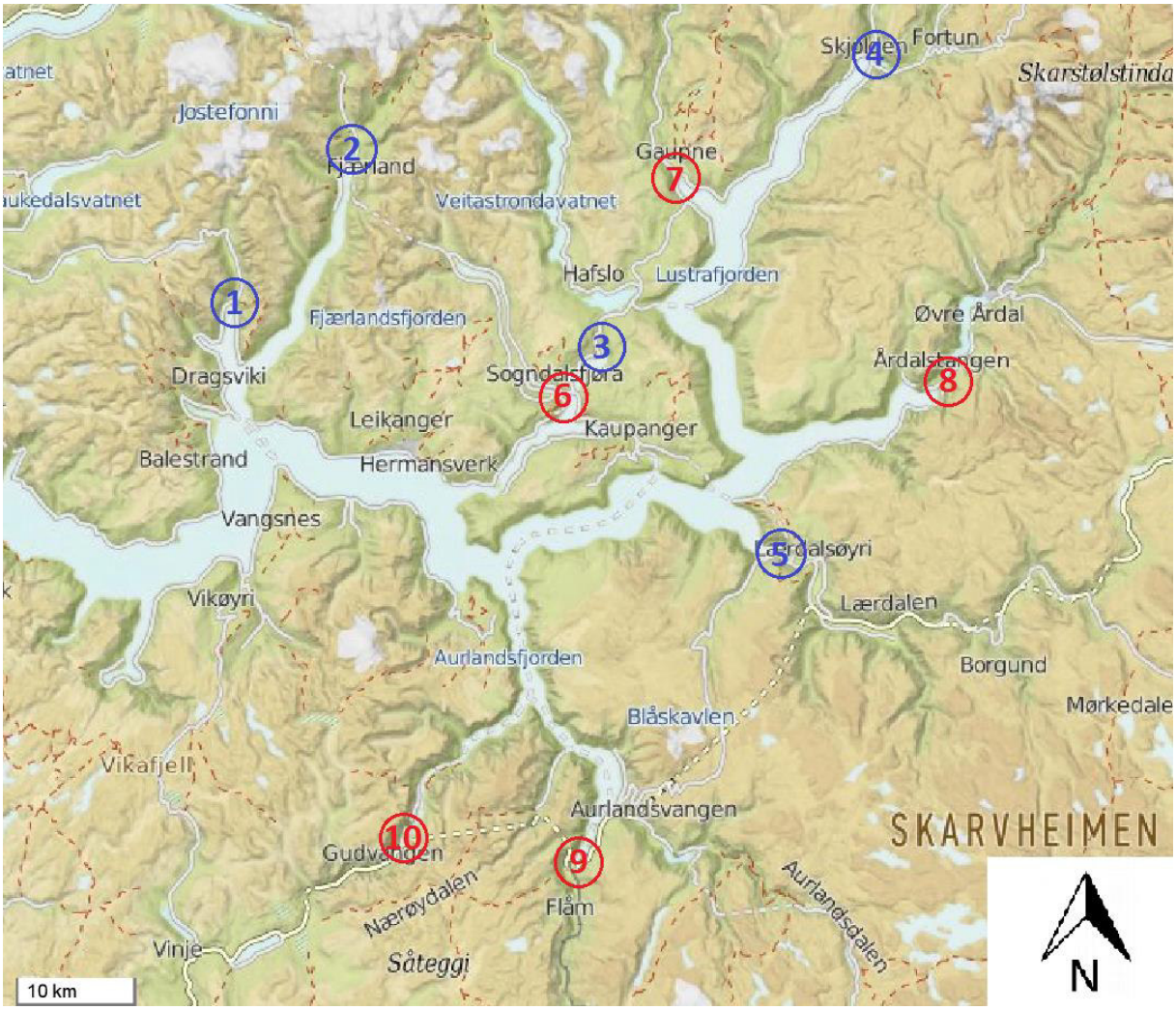


Figure 5: Map of the Inner Sogn Region: Blue encircled numbers show the deltas described by the Elvedelta database, red encircled numbers show the deltas not described by the Elvedelta database (Figure modified from http 6).

3.1.2.1. Deltas of the Inner Sogn Region described by the Elvedelta datavase (http 8); numbering follows that of Figure 5

1) The Vetlefjordøyra Delta in Vetlefjorden (Figure 5 and Figure 6)

The Vetlefjordsøyra Delta is located at the end of the Vetlefjord and belongs to the Balestrand municipality. The natural delta area today is 0.12 km² (Table 3a). There are only few houses situated near the delta area. The main river is called Vetleelvi. It has been regulated and is not protected in the upper parts of the delta. The lower seaward part of the delta, the "Vetlefjordsøyra naturreservat" is a protected nature reserve and home to 35 different bird species (Dybwad, 2014). It is one of the five deltas that are listed in the Elvedelta dataset by the Norwegian Environment Agency (NEA). The NEA categorizes the human influence on this delta as "weak" (http 10).

2) The Bøyaøyra Delta at Fjærland (Figure 5 and Figure 7)

The Bøyaøyra Delta is situated at the end of the Fjærlandsfjord and belongs to the municipality of Sogndal. The natural delta area today is 0.04 km² (Table 3b). Around 300 people live close by the delta. The main river called Storelvi is not protected and has been regulated. The delta is part of the "Bøyaøyra naturreservat" a protected nature reserve. It is a popular spot for birds, both migratory and non-migratory. Around 100 different species have been observed in the nature reserve and 40-50 of them are using the delta for breeding, nursing and foraging (Dybwad, 2015). This delta is also registered in the Elvedelta dataset by the NEA and is categorized as heavily influenced by humans (http 11).

3) The Årøy Delta (Figure 5 and Figure 8)

The Årøy Delta is located at the northern end of the Barsnesfjord. It belongs to the municipality of Sogndal. The natural delta area today is 0.12 km² (Table 3a). The river forming the delta is called Årøyelvi and is regulated. A few farm houses are located around the delta area. Some parts of the delta are used for agriculture. It is also used by migratory wetland birds as a resting place (http 12). The NEA classifies the human influence on the Årøy-delta as "medium" (http 12).

4) The Lærdal Delta (Figure 5 and Figure 9)

The Lærdal Delta is located at the Lærdalsfjord and is part of the Lærdal municipality. The natural delta area today is 0.21 km² (Table 3c). The river called Lærdalsøyri is regulated and not protected. About 1100 people live near the delta in the village Lærdal. Parts of the delta are cultivated and used as an industrial site. According to the NEA, human influence on the delta is "heavy" (http 13).

5) The Skjolden Delta (Figure 5 and Figure 10)

The Skjolden Delta is located at the Lustrafjord and belongs to the municipality of Luster. The natural delta area today is 0.04 km² (Table 3d). It is build up by two rivers flowing into the fjord from different angles. The regulated Mørkridselvi river flows into the Lustrafjord from the north, while the Fortunelva comes in from the east. They enter the fjord close to each other and form the delta together. The delta is a preferable overwintering spot for birds like the Common Goldeneye and the Common Goosander (http 14). The NEA categorizes the influence of humans on this delta as "medium" (http 14).

3.1.2.2. Deltas of the Inner Sogn Region not described by the Elvedelta database

6) The Sogndalsfjøra Delta (Figure 5 and Figure 11)

The Sogndalsfjøra Delta is located at the Sogndalsfjord and belongs to the municipality of Sogndal. The natural delta area today is below 0.01 km² (Table 3d). The regulated river forming the delta is called Sogndalselvi. The town of Sogndal is one of the biggest towns in the Inner Sogn Region and has around 4000 inhabitants. It stretches along the river, the delta and the fjord.

7) The Gaupne Delta (Figure 5 and Figure 12)

The Gaupne-delta is located at the Gaupnefjord, which is a side arm of the Lustrafjord. Gaupne is part of the Luster municipality. The natural delta area today is 0.12 km² (Table 3c). On and around the delta is the small town of Gaupne with around 1100 inhabitants. The regulated Jostedøla river flows through Gaupne and forms the delta.

8) The Årdalstangen Delta (Figure 5 and Figure 13)

The Årdalstangen-delta is formed by the Hæreidselvi river. It is located at the north-eastern end of the Årdalsfjord in the Årdal municipality. The natural delta area today is 0.02 km² (Table 3d). The regulated Hæreidselvi flows through the town Årdalstangen. With around 1500 inhabitants, Årdalstangen is one of the bigger townships in the Inner Sogn Region. It stretches along the river, on the delta and around the fjord.

9) The Flåm Delta (Figure 5 and Figure 14)

The delta in Flåm is located in the Aurland municipality. The natural delta area today is 0.09 km² (Table 3c). It is formed by the Flåmselvi river which is regulated. The village Flåm nearby the delta is one of the touristic hot spots of western Norway and has around 450 inhabitants. The famous Flåmsbanen railroad attracts thousands of tourists every year (http 9). To cope with the high number of tourists, the entire delta was filled in and built-up (Venneman, 2017). The built-up area is used as a harbor for cruise ships, a location for tourist shops and a local recreation area. The frequent cruise ship traffic leads to high tourist numbers especially in the summer season (http 3).

10) The Gudvangen Delta (Figure 5 and Figure 15)

The Gudvangen-delta is located at the southern end of the Nærøyfjord, which became a UNESCO World Heritage Site in 2005 (http 15). The natural delta area today is 0.09 km² (Table 3c). The river Nærøydalselvi forming the delta is regulated. The small village of Gudvangen and the surrounding nature is a popular tourist site (http 4). It is located in the Aurland municipality. Parts of the delta were filled and built-up to create space for a harbor and tourist shops (Dybo et al., 2016).

3.2. Scientific setting

Previous research has been made focusing and specializing on different aspects of this work. However, the influence of human made deltaic change on the environment in Norwegian fjords has not been investigated earlier.

- Paetzel, M.; Schrader, H. (1992): Recent environmental changes recorded in anoxic Barsnesfjord sediments: Western Norway.

This paper looks at the signals of historical environmental changes in Barsnesfjord sediments. It mentiones the sedimentation rate and sediment composition of the Årøyriver delta. The paper identifies deltaic processes that might have influenced the amount of dissolved nutrients in the delta. The work mostly focuses on sediments and sediment history in the Barsnesfjord. The authors identify the delta of the Årøyriver as a pathway of sediment transport into the fjord.

- Dybo, M.H., Sundheim, M.L. and A.M. Søgnesand (2016): Analysis of recent sediment cores in the anoxic Nærøyfjord, Western Norway.

This work gives an overview of deltaic changes at the Gudvangen delta of the Nærøyfjord. It compares aerial photographs from 1971 and 2013. Sediment cores document the history and impact of the deltaic changes on the Nærøyfjord. Sediment interpretation concludes that the deltaic changes have lowered the overall oxygen conditions below the critical amount of 2 mlO_2/l (Aure et al., 1989) in the Nærøyfjord bottom water layers and sediment. Dybo et al. (2016) are the first to document the impact of deltaic changes on the water column and sediments of the Nærøyfjord.

- Bortheim Mulelid, O.S., Olaisen, V. & Strømme, K. (2017): Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The geochemical record.
- Midttømme, M., Næss Haga, O. & Refsdal Thiem, E. (2017): Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The sediment record.
- Venneman M (2017): Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The pollution record.

Midttømme et al. (2017), Mulelid et al. (2017), and Venneman (2017) recognized historical changes of the village of Flåm and their environmental effects from Aurlandsfjord sediment signals. They focus among others on the sediment record from the building of a cruise ship harbor onto the Flåm River delta. This building activity had a major influence on the river flow, and thus on the fjord and harbor sedimentological and hydrographic environment.

- Global Biodiversity Information Facility (GBIF) Norway & Norwegian Biodiversity Information Center (NBIC): http://artskart.artsdatabanken.no/default.aspx (http 16)

The GBIF and the NBIC have produced a catalogue and a map of species in Norway. It offers an overview of local bird, fish and other animal populations in the investigated deltas. The catalogue provides a first *status quo* on the total species distribution of recent years. It also provides the basis for development and trend analyses of the species distribution for future registrations.

- Norwegian Environment Agency: http://elvedelta.miljodirektoratet.no/ (http 8)

The Norwegian Environment Agency has created a database, where deltas all over Norway are listed. Five of the deltas investigated in this thesis are listed as well. The database broadly describes the delta types, the flora and fauna in and around the deltas and classifies human influence on the deltas it occurs today.

In addition to these investigations, the work at hand will provide information on historic changes in delta size, cultivated area, and animal species where appropriate. This work will thus be a first step into the research of anthropogenic change of river deltas and its consequences. It has the task to give a first description of the phenomenon and is meant to be a basis for further investigations.

4. Methods

4.1. Literature research

To find out what dissertations were already published on this topic, a literature research was made. The academic library of the Western Norway University of Applied Science at the campus Sogndal and literature recommendations from Dr. Matthias Paetzel, Torbjørn Dale and Johannes Anonby were used as a basis for literature research. Further research was made online with the search engine "Google Scholar" (http 17).

4.2. Aerial photographs

4.2.1. Collecting aerial photographs

4.2.1.1. Photographs from the 2010s

The collection of aerial photographs from the 2010s was made with the website "Norge i bilder" (http 18). There, the mapping tools were used to zoom in the requested areas. If aerial photographs from different years were available, the newest possible photograph was chosen to be worked with. If the visibility of the deltas was weakened due to shades or clouds in the photographs, the newest possible photograph without these sources of irritation was chosen. The dates of the newer photographs range from 2010 to 2014. The photographs were copied from the website and saved as pdf-files. They then were converted into tiff-files.

4.2.1.2. Photographs from the 1960s

The collection of aerial photographs from the 1960s was made through the website of the National Mapping Authority of Norway (Kartverket) (http 19). The order of photographs was made via e-mail. The choosing of photographs was made with a map given by Kartverket. The map showed the areas covered by single aerial photographs. One photograph of each delta was picked. For choosing a photograph, two parameters were considered: 1) The photo should cover the whole delta area, and 2) the date of the photo should be as old as possible. The photographs were received from Kartverket as tiff-files. The dates of the old photographs range from 1961 till 1971.

4.2.2. Comparing aerial photographs

For comparing the new and old aerial photographs Microsoft PowerPoint tools were used. The cutting tool was used on all the photographs to cut them into same sizes. For a better overview of the photographs, a PowerPoint presentation was created. The pictures of the same river deltas in different years were put next to each other on a 4:3 sheet. They were arranged with the same angle and zoomed

in to have the same size. A grid was inserted to help positioning the photographs more precisely and to make comparisons easier. The new and old river delta borders were marked with colored lines to illustrate the changes in areal size.

4.3. Qualitative interviews

For the qualitative interviews, two experts were chosen based on recommendations of Dr. Matthias Paetzel.

4.3.1. Torbjørn Dale

Torbjørn Dale was chosen as an expert for fish populations. He is an associate professor for Biology and Ecology at the Western Norway University of Applied Science in Sogndal. After contacting him, questions were formulated and a questionnaire was created (Annex 1). The interview with Torbjørn Dale took place at the Western Norway University of Applied Science Campus in Sogndal. The interview was recorded and later analyzed.

4.3.2. Johannes Anonby

Johannes Anonby was chosen as an expert for bird populations. He works at the County Government of Sogn og Fjordane in the Climate and Environment sector. He has made a variety of ornithological observations for the county's river delta database Elvedelta (see chapter 4.4). After contacting him, questions were formulated and a questionnaire was created (Annex 2). The interview with Johannes Anonby took place in Leikanger at the headquarter of the County Government of Sogn og Fjordane. The interview was recorded and later analyzed.

4.4. Complementation of the Elvedelta database

Information from the Elvedelta database was taken from the website of the Norwegian Environmental Agency (http 8). It was used as a basis for creating a table that summarizes the results of this work. For creating this table, the Excel 2013 spreadsheet software of Microsoft Office was used. The original Elvedelta database parameters to describe a river delta were complemented with three parameters: 1) River delta areal sizes in the past and present, 2) nearby population of humans, and 3) fish populations living in on the delta.

The river delta areal sizes were calculated with the calculation tool of the "Norge i bilder" website (http 18). The number of nearby living humans was taken from the website of "Statistics Norway" (http 20). The information about fish populations was added after analyzing the interview with Torbjørn Dale.

The classification of human influence on the river deltas was made with the method of categorization from the Elvedelta dataset (http 21), after translating it into English (Annex 3). Researched information about the five river deltas not observed by Elvedeltadata were added to the table. Missing information about the five existing river deltas in the Elvedeltadata base was also added.

5. Results

Aerial photograph comparisons

Aerial photographs from the 1960s and 2010s were compared to each other. In Figures 6 to 15, the blue lines mark the ends of the river delta fronts. The green areas show natural reserves. The orange colored spots mark the delta areas that are influenced and changed by humans in the time between the old and the new photograph. The yellow dotted line marks the estimated natural delta before the 1960s.

= End of river delta fronts = Natural reserve

= Influenced delta areas = Estimated delta area before 1960s

5.1. The Vetlefjordøyra Delta in Vetlefjorden

Figure 6 shows the aerial photographs of the Vetlefjordøyra Delta**.** Figure 6a shows the picture taken in 1963. Figure 6b shows the picture taken in 2010. The delta front has not changed since 1963. The green area shows the natural reserve that was installed in 1991.

Only few changes happened at this river delta in the time between the two photographs. For example, the parts D4 and E4 in the old picture were used for agriculture. Due to the installation of the natural reserve, those areas are used today only for grazing. Only 20 - 40 sheep and two horses can graze there per year (*Dybwad, 2014*).

The total size of the natural delta area stayed almost the same (0.12 km²) between 1963 and 2010 (Table 3a).

The river delta is home to 35 different bird species. According to Johannes Anonby (2017, *personal communication*), the most common bird species are the Black-headed Gull, the Taiga Bean Goose, the Common Snipe, the Common Red Bunting and the Common Tern (Figures 16 a,c,h,g,d). They use the area as a resting place during migration, as a nesting ground and for foraging.

According to the Elvedelta database, the human influence on the Vetlefjordøyra Delta is weak (http 10).

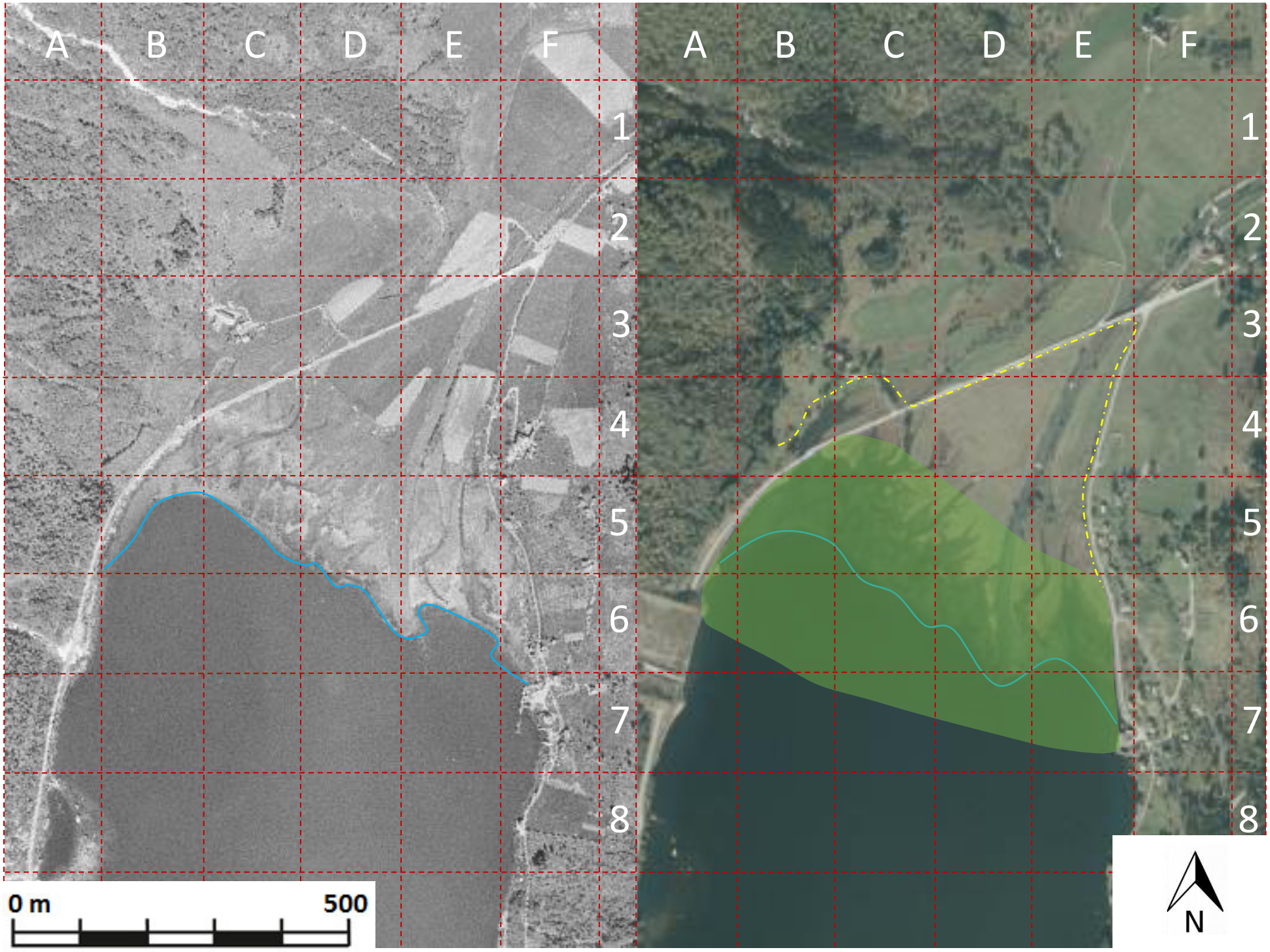


Figure 6: a) Bottom: Aerial photograph Vetlefjordøyra Delta in 1963 (Statens Kartverk 1963) b) Top: Aerial photograph Vetlefjordøyra Delta in 2010 (http 18)

5.2. The Bøyaøyra Delta at Fjærland

Figure 7 shows the aerial photographs of the Bøyaøyra Delta. Figure 7a shows the picture taken in 1964. Figure 7b shows the picture taken in 2010. The green area shows the area of the Bøyaøyra nature reserve that was installed in 1991.

The channeling of the Storelvi was completed in the 1980s. Instead of flowing in many dividing arms over the whole delta area, the river is now forced to flow in a straight channel (seen in parts D6, E5, F4). Thus, sediments are prevented from accumulating in the old delta. This leads on one hand to an increased erosion of the former delta, due to the lack of new incoming sediments by the river (orange area). On the other hand, a new river delta starts being formed at the new Storelvi river mouth (blue line, D6).

The Road Rv5 alongside the delta in the east and the Road Fv152 in the north and west of the delta were built and opened in 1994. The noise and constant traffic from the road might disturb local bird populations.

The total size of the natural delta area has decreased from 0.25 to 0.04 km² (Table 3b) between 1964 and 2010.

The Bøyaøyra nature reserve is home to 40 – 50 different bird species (Dybward, 2015). According to Johannes Anonby (2017, *personal communication*), the most common bird species are Gulls, the Common Snipe, the Common Scooter, the Velvet Scooter, the Common Reed Bunting, the Common tern and Dabbling- and Diving duck species (Figures 16 a,b,d,e,f,g,h,i,j). Torbjørn Dale (2017, *personal communication*) points out that the Fjærlandsfjord is known to inhabit Salmon and Sea Trout (Figures 17 d,e,).

According to the Elvedelta database, the human influence on the Bøyaøyra Delta is high (http 11).

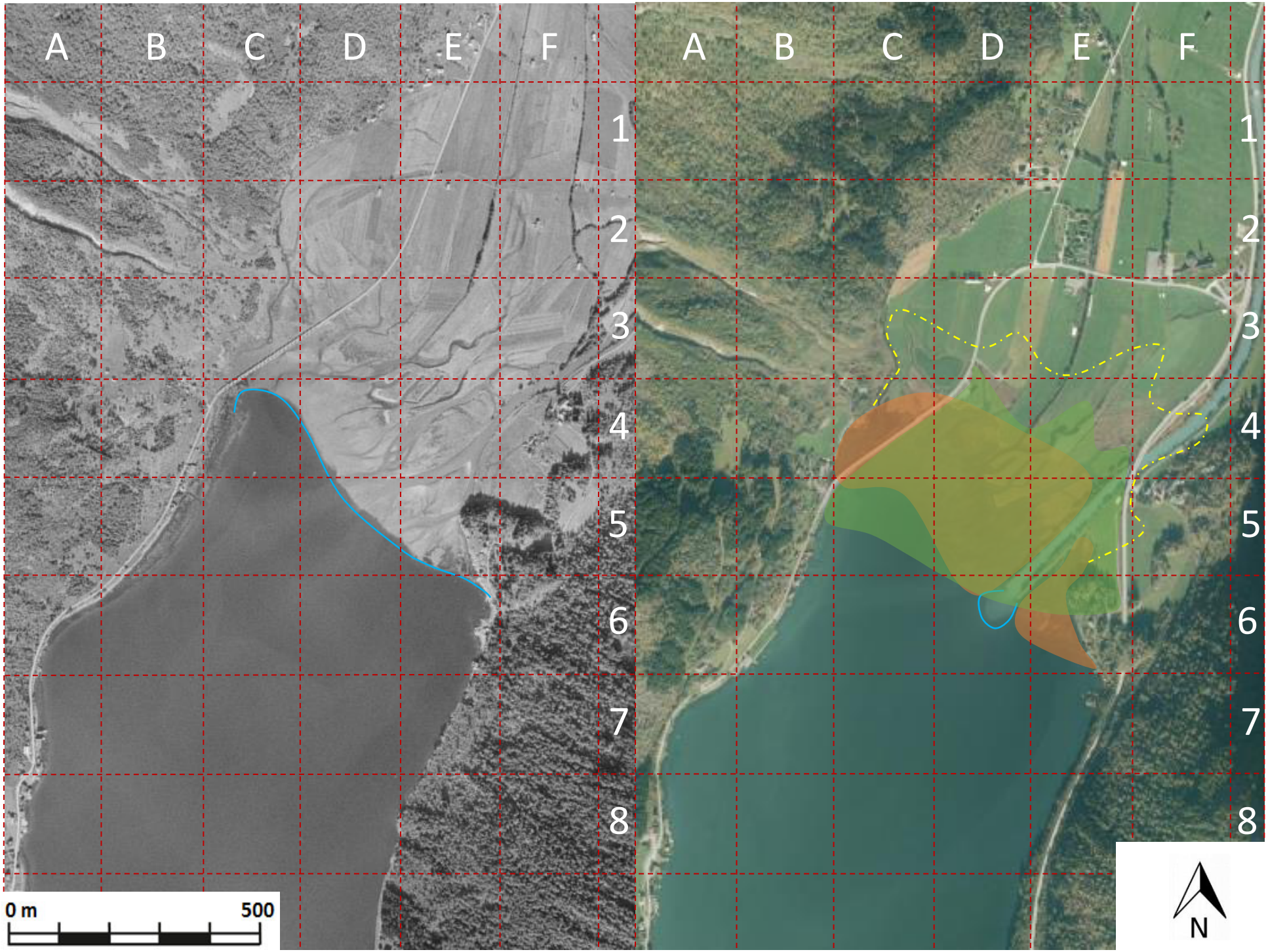


Figure 7: a) Bottom: Aerial photograph Bøyaøyara Delta in 1964 (Statens Kartverk 1964) b) Top: Aerial photograph Bæyaæyra Delta in 2010 (http 18)

5.3. The Årøy Delta

Figure 8 shows the aerial photographs of the Årøy Delta. Figure 8a shows the picture taken in 1961. Figure 8b shows the picture taken in 2014.

The picture from 2014 differs from the picture in 1961 in three ways. In the west of the delta (B4,5), parts of it were filled up. In the north (D3 and E3), a second fill up took place. The newly won area is used for agriculture. In the south east of the delta, diggings were made (D6,7 and E6,7). The material from this excavation was used to fill up areas of the delta in the east (E5).

The total size of the natural river delta has decreased from 0.14 to 0.12 km² (Table 3a) between 1961 and 2014.

According to Johannes Anonby (2017, *personal communication*), the Årøy Delta is home to different Gull species and the Common Goldeneye (Figure 16 a,b,m). Torbjørn Dale (2017, *personal communication*) points out that especially the southeastern bank of the river delta is a preferred spot for Flatfish (Figure 17 a) to breed.

According to the Elvedelta database, the human influence on the Årøy Delta is medium (http 12).

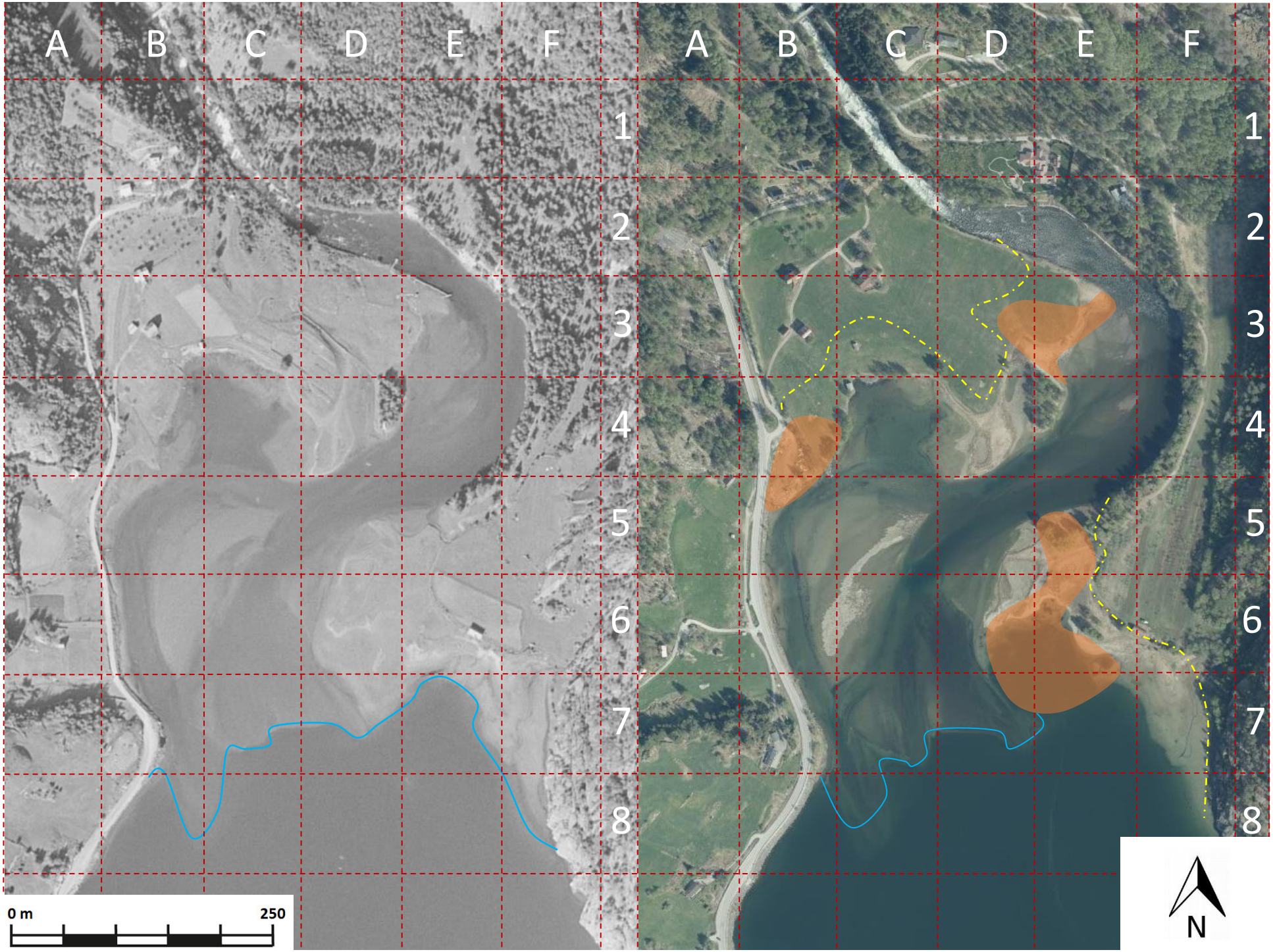


Figure 8: Bottom: Aerial photograph Årøy Delta in 1961 (Statens Kartverk 1961) b) Top: Aerial photograph Årøy Delta in 2014 (http 18)

5.4. The Lærdal Delta

Figure 9 shows the aerial photographs of the Lærdal Delta. Figure 9a shows the picture taken in 1961. Figure 9b shows the picture taken in 2014.

The Lærdalsøyri river was regulated and now flows in a channel. Around half of the delta was filled up with gravel and covered with buildings in the south (orange area). The newly won area is used mainly as an industrial location. The Road Rv5 was built across the delta, connecting the northern and southern sides of the Lærdalsfjord. In the south (parts B2 and C2) a harbor was built. There are no protected areas on the Lærdal Delta.

The total size of the natural delta area has decreased from 0.54 to 0.21 km² (Table 3c) between 1961 and 2014.

According to Johannes Anonby (2017, *personal communication*), several duck and wader species have been observed on the delta. It is also home to the European Herring Gull (Figure 16b). Torbjørn Dale (2017, *personal communication*) points out that Salmon and Sea Trout (Figure 17 d,e) are known to live in the Lærdalsfjord.

The Elvedelta database categorizes the human influence on the Lærdal Delta as heavy (http 13).

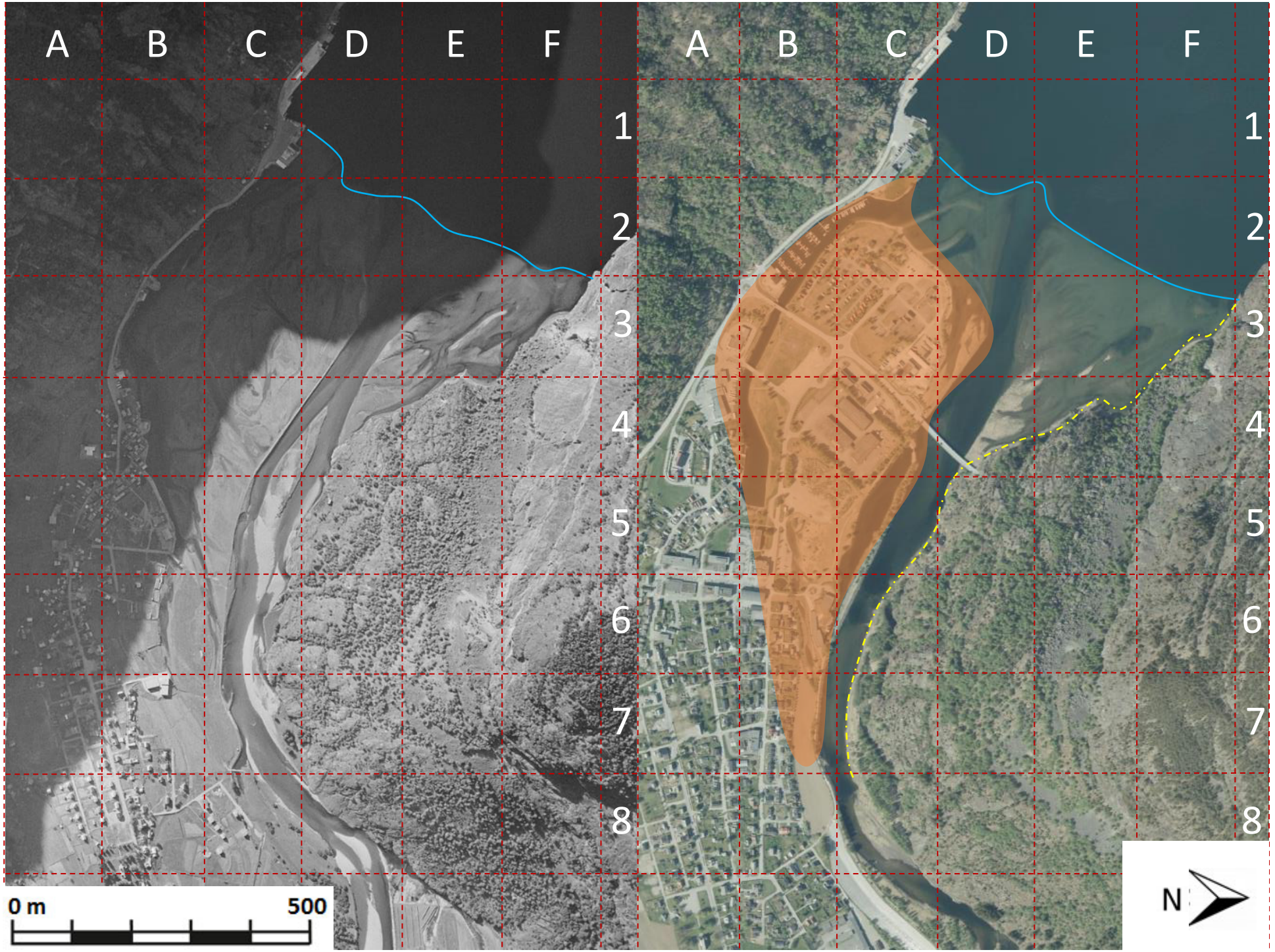


Figure 9: Bottom: Aerial photograph Lærdal Delta in 1961 (Statens Kartverk 1961) b) Top: Aerial photograph Lærdal Delta in 2014 (http 18)

5.5. The Skjolden Delta

Figure 10 shows the aerial photographs of the Skjolden Delta. Figure 10a shows the picture taken in 1963. Figure 10b shows the picture taken in 2012.

Some delta fillings happened in the northern and southern river mouth of the regulated Mørkridselvi river (C2,3 and C4, D3). The newly won space in the north (C2,3) is used as a recreation area. The end of the delta front stayed almost the same over the years. The new space on the southern part of the Mørkridselvi river mouth (C4 and D3) is used as an industrial location today. There are no protected areas in the Skjolden Delta.

The total size of the natural river delta has decreased from 0.05 to 0.04 km² (Table 3d) between 1963 and 2012.

According to the Elvedelta database, the human influence on the Skjolden Delta is medium (http 14).

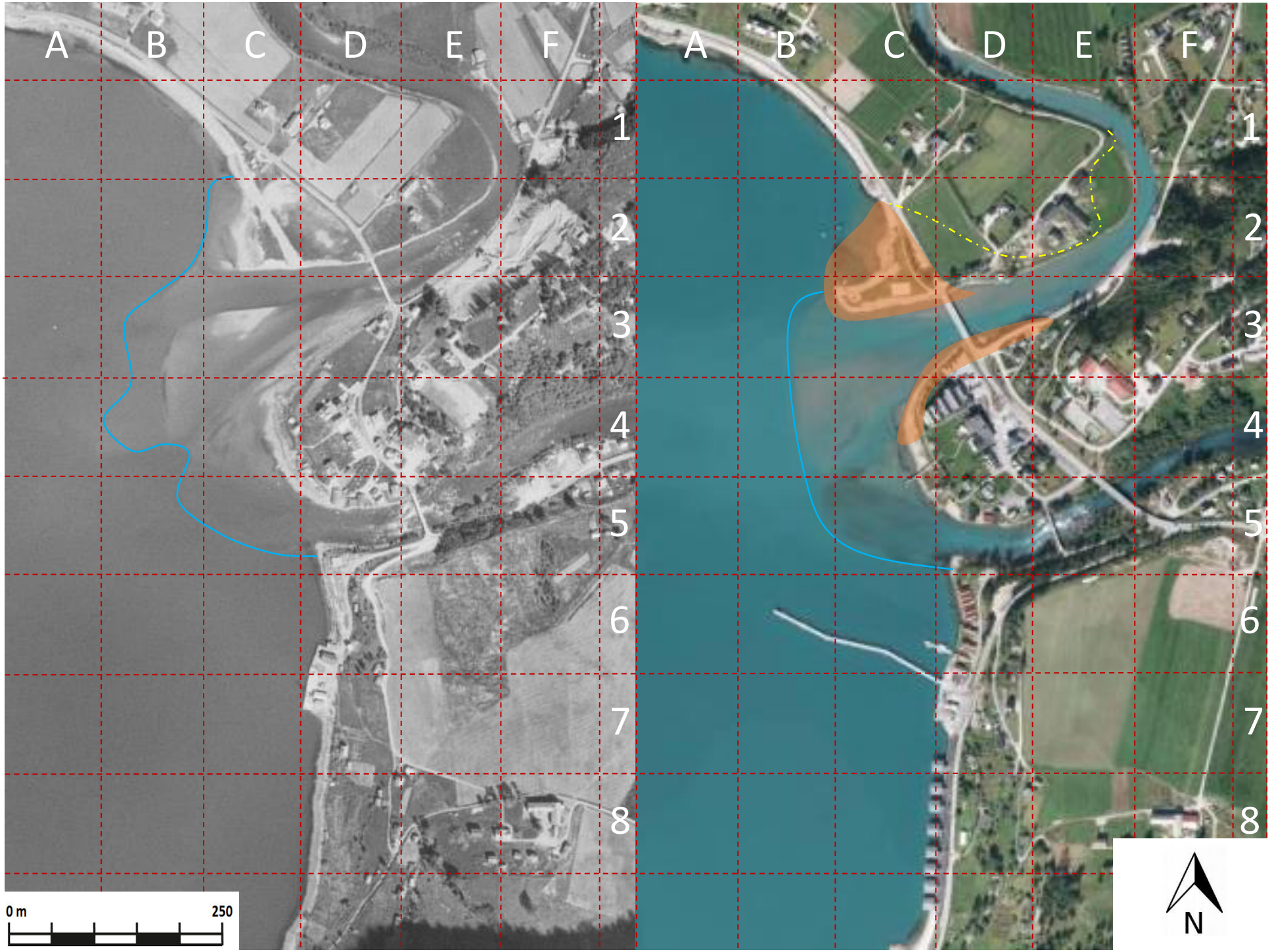


Figure 10: a) Bottom: Aerial photograph Skjolden Delta in 1963 (Statens Kartverk 1963) b) Top: Aerial photograph Skjolden Delta in 2012 (http 18)

5.6. The Sogndalsfjøra Delta

Figure 11 shows the aerial photographs of the Sogndalsfjøra Delta. Figure 11a shows the picture taken in 1961. Figure 11b shows the picture taken in 2014.

In 1961, humans had already cultivated the natural Sogndalsfjøra Delta (yellow dotted line marks the original natural delta). After 1961, the northern and southern river mouth of the Sogndalselvi were filled up (parts B6 and C6). The new area is used today as an industrial location. The delta front end has not changed significantly since 1961. There are no protected areas in the Sogndalsfjøra Delta.

The total size of the natural river delta has decreased from 0.01 km² to almost not existent (<0,01 km²) (Table 3d) between 1961 and 2014.

According to Johannes Anonby (2017, *personal communication*), the Sogndalsfjøra Delta is home to several Gull species and the Common Goldeneye (Figure 16 a,b,m). Torbjørn Dale (2017, *personal communication*) points out that the Sogndalsfjord is known to be home to Salmon and Sea Trout (Figure 17 d,e).

Using the Elvedelta classification system (Annex 3), the Sogndalsfjøra Delta can be categorized as heavily influenced by humans.

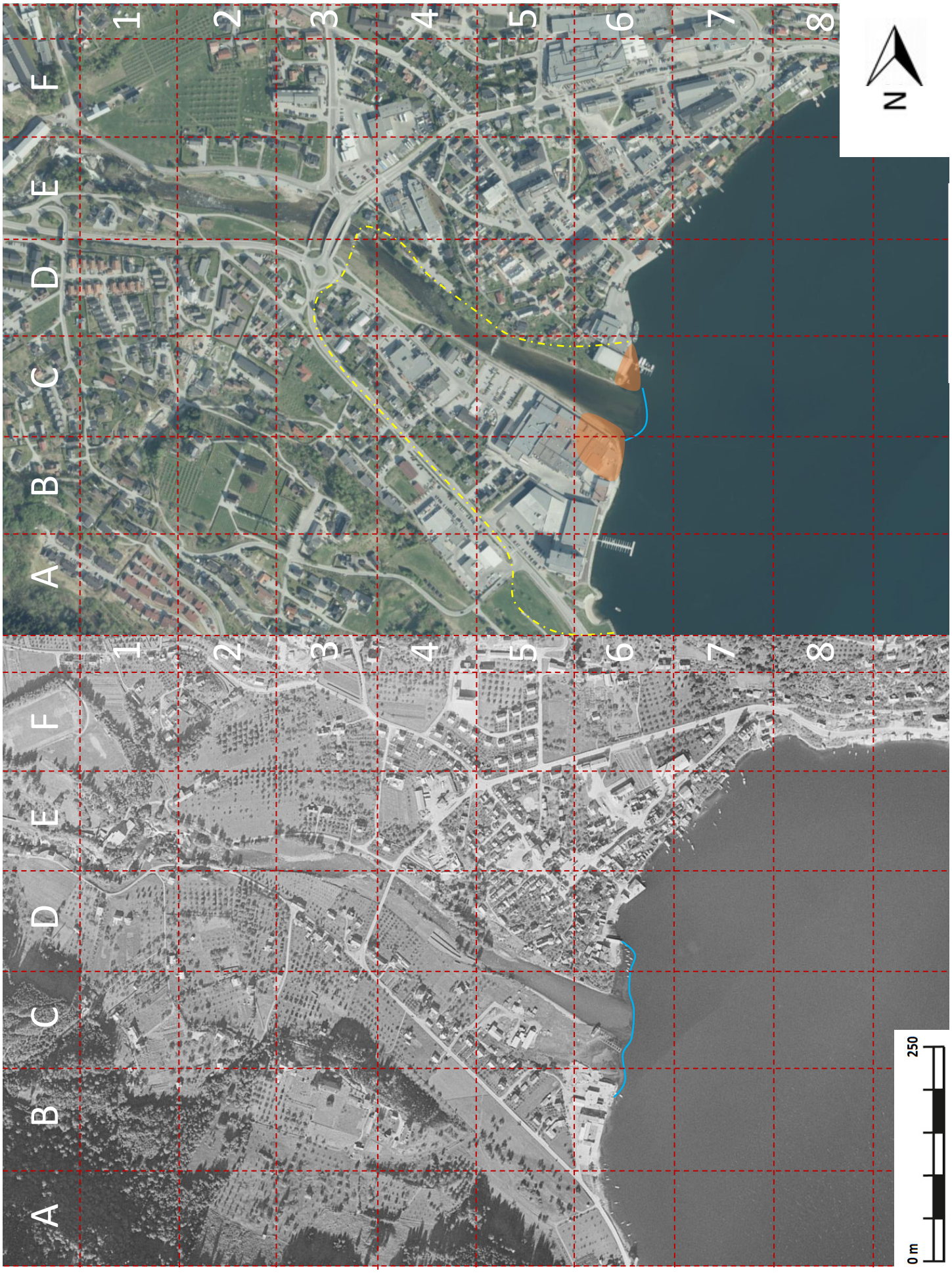


Figure 11: a) Bottom: Aerial photograph Sogndalsfjøra Delta in 1961 (Statens Kartverk 1961) b) Top: Aerial photograph Sogndal Delta in 2014 (http 18)

5.7. The Gaupne Delta

Figure 12 shows the aerial photographs of the Gaupne Delta. Figure 12a shows the picture taken in 1962. Figure 12b shows the picture taken in 2012.

The sparsely populated village of Gaupne from 1962, with 618 inhabitants in 1960 (*Central Bureau of Statistics of Norway, 1963*), has developed to a town with 1183 inhabitants in 2016 (http 22), using areas from the natural river delta.

The Road Rv55 was built connecting the western and eastern part of the Lustrafjord, going over the delta. Almost 84% of the river delta was filled up and covered with buildings (Table 1c). On the western bank (C5,6,7) most of the new ground is used as an industrial location. The channeling of the Jostedøla river lead to a different sedimentation. Parts of the western bank (B7,8) are cut off the sedimentary environment. Increasing water speed velocity through the river channeling lead to a further outwash of sediments into the Lustrafjord. The delta front has decreased by half (blue lines). East of the Jostedøla river, more fillings were made and again areas were cut off the sedimentary environment (D5,6,7 and E5,6,7). The newly won area is mainly used today as an industrial location. Smaller parts (E7) are used as recreation areas. There are no protected areas in the Gaupne Delta.

The total size of the natural river delta has decreased from 0.50 to 0.12 km² (Table 3c) between 1962 and 2012.

According to Johannes Anonby (2017, *personal communication*), several bird species live in the remained natural delta. The most common species are the European Herring Gull, the Mallard, the Tufted Duck and the Common Goldeneye (Figure 16 b,i,j,m). Torbjørn Dale (2017, *personal communication*) points out that the Lustrafjord is home to the SeaTrout (Figure 17e).

Using the Elvedelta classification system (Annex 3), the Gaupne Delta can be categorized as heavily influenced by humans.

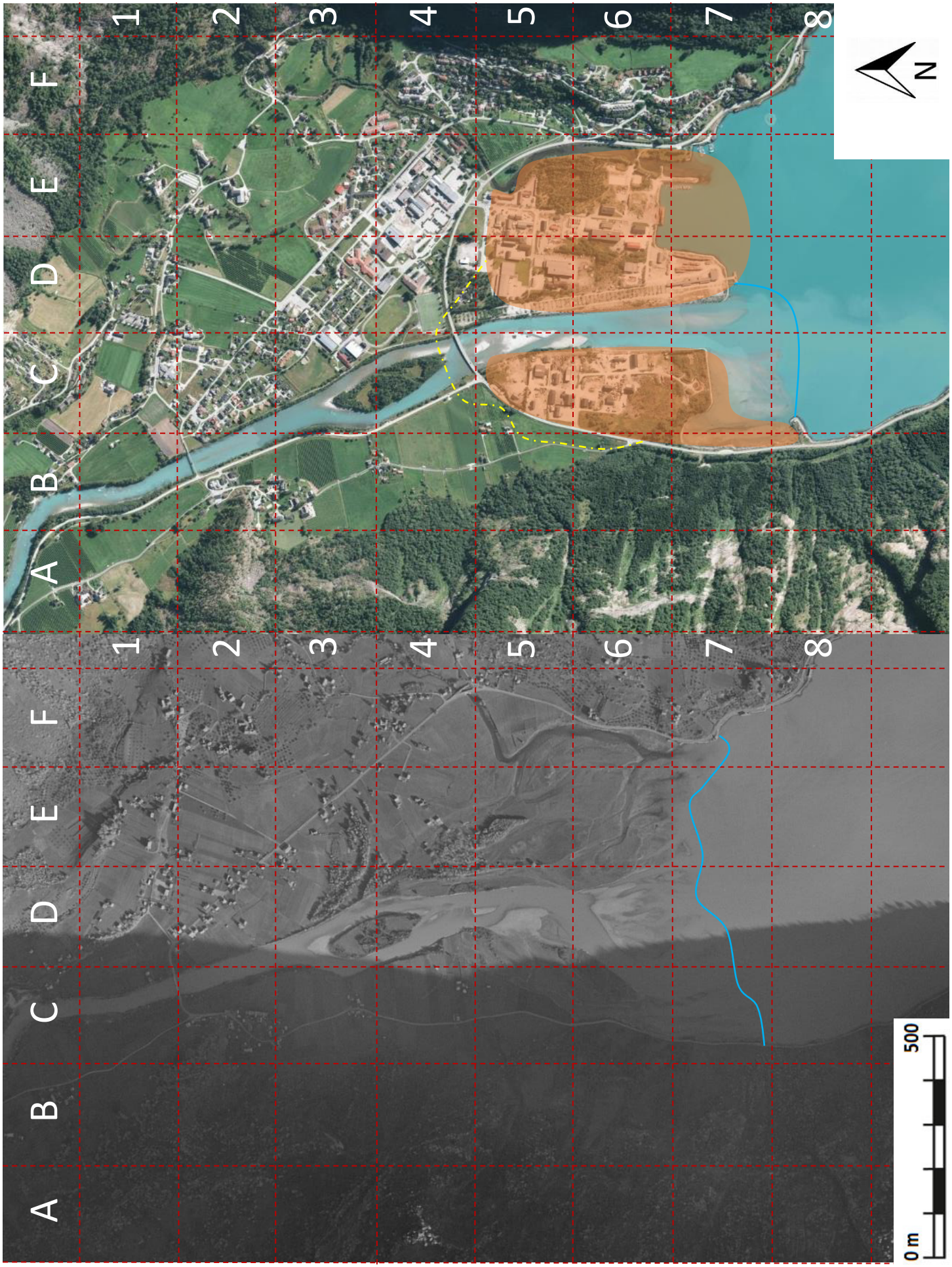


Figure 12: a) Bottom: Aerial photograph Gaupne Delta in 1962 (Statens Kartverk 1962) b) Top: Aerial photograph Gaupne Delta in 2012 (http 18)

5.8. The Årdalstangen Delta

Figure 13 shows the aerial photographs of the Årdalstangen Delta. Figure 13a shows the picture taken in 1964. Figure 13b shows the picture taken in 2010.

Like in Sogndal, the Årdalstangen Delta was changed before the first taken aerial photograph (yellow dotted line marks the original delta). The Hæreidselvi river was channeled and parts of the delta were filled. The newly won area was used as an industrial location.

Between 1964 and 2010 no human made changes happened to the delta. Also, the delta front stayed the same (blue line). There are no protected areas in the Årdalstangen Delta.

The total size of the natural river delta stayed at 0.02 km² (Table 3d) between 1964 and 2010.

According to Johannes Anonby (2017, *personal communication*), the Årdalstangen Delta is home to different Gull species and the Common goldeneye (Figure 16 a,b,m).

Using the Elvedelta classification system (Annex 3), the Årdalstangen Delta can be categorized as heavily influenced by humans.

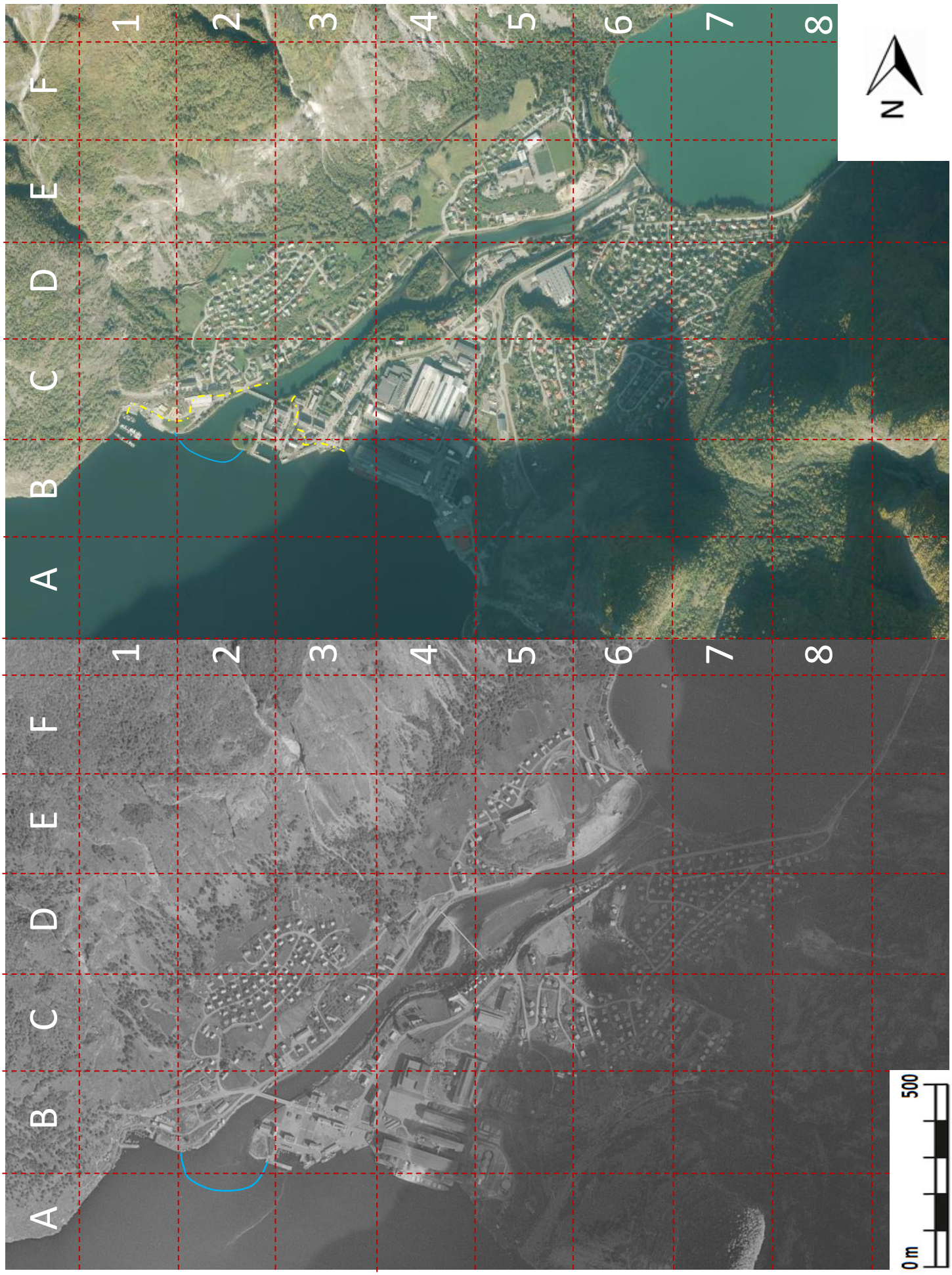


Figure 13: a) Bottom: Aerial photograph Årdalstangen Delta in 1964 (Statens Kartverk 1964) b) Top: Aerial photograph Årdalstangen Delta in 2010 (http 18)

5.9. The Flåm Delta

Figure 14 shows the aerial photographs of the Flåm Delta. Figure 14a shows the picture taken in 1969. Figure 14b shows the picture taken in 2014.

Over the last 100 years, Flåm developed to a touristic hot spot in the Inner Sogn Region. Several delta fillings took place during this time, beginning with a railway construction in 1924. The railway station was enlarged in 1940 after another part of the delta was filled up (*Venneman, 2017*). The old photograph shows the situation after the enlargement of the railway station (D4,5). The biggest difference between the two pictures is the large filling up of the southern delta bank (B1, C1,2,3,4 and D2,3,4). This new ground led to the construction of a cruise ship harbor in 1985 that was completed in 1999. It is also used as a location for tourist shops. Together with the harbor construction, the Flåmselvi river was channeled and deepened. The former delta was cut off from sedimentary input. The water is flowing today with higher speed velocity through a narrow river mouth and is capable of transporting sediments far out into the Aurlandsfjord (*Venneman, 2017*). Another change took place in the north east of the Flåm Delta (A2 and B2,3). Here another land filling was made and a recreation area was created in 1982. There are no protected areas in the Flåm Delta.

The total size of the natural river delta has decreased from 0.09 km² to below 0,01km² (Table 3c) between 1969 and 2014.

Johannes Anonby (2017, *personal communication*) knows of several Gull species living at the delta (Figure 16 a,b). According to Torbjørn Dale (2017, *personal communication*), the Flåm Delta is used as a spawning and hunting ground by Flatfish, Lesser sand eel and Herring (Figure 17 a,b,c).

Using the Elvedelta classification system (Annex 3), the Flåm Delta can be categorized as heavily influenced by humans.

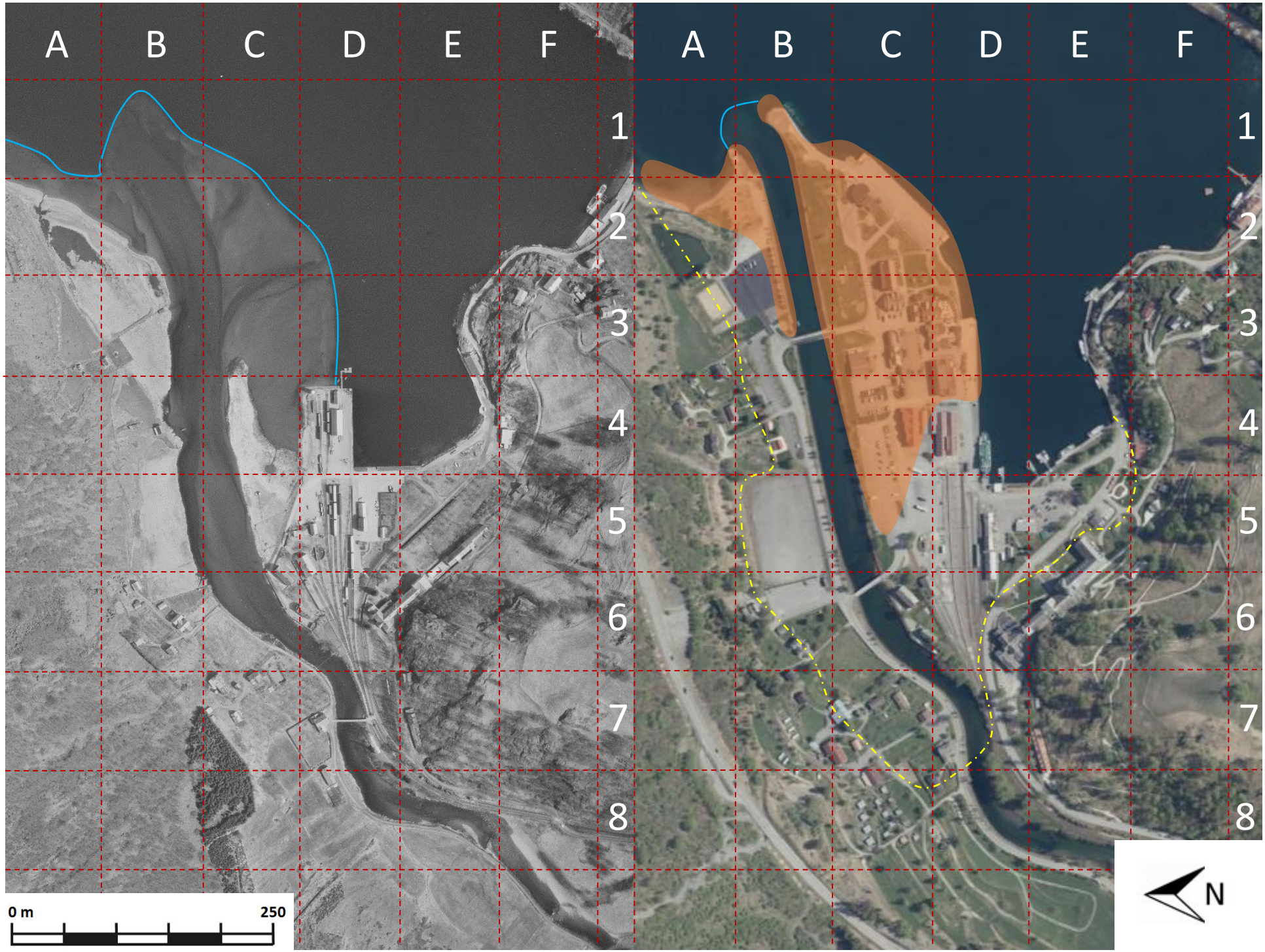


Figure 14: a) Bottom: Aerial photograph Flåm Delta in 1969 (Statens Kartverk 1969) b) Top: Aerial photograph Flåm Delta in 2014 (http 18)

5.10. The Gudvangen Delta

Figure 15 shows the aerial photographs of the Gudvangen Delta. Figure 15a shows the picture taken in 1971. Figure 15b shows the picture taken in 2013.

The channeling of the Nærøydalselvi cut off the sediment supply of large parts of the delta in the west and east (F4 and D6,7). The narrow river mouth led to higher water speed velocities and the beginning of a new delta formation (Figure 15b**,** blue line). In the period between 1986 and 1991, the western and eastern parts of the Gudvangen Delta were filled up and covered with buildings. The western delta bank is now used as a ferry harbor and a location for tourist shops. The eastern side of the delta is used mainly for tourism. The local tourist attraction "The Viking Valley" stretches over 1500m² of the delta (http 23). Another change to the Gudvangen Delta was the building of the E16 road. It goes from the southern end of the delta to the north east over the Nærøydalselvi river (A1,2,3 and B4,5,6). There are no protected areas in the Gudvangen Delta.

The total size of the natural river delta has decreased from 0.09 km² to less than 0.01 km² (Table 3c) between 1971 and 2013.

According to Johannes Anonby (2017, *personal communication*), the Gudvangen Delta is home to the Red-breasted Merganser and the Common Goldeneye (Figure 16 k,m). Torbjørn Dale (2017, *personal communication*) points out that Salmon and Sea Trout are known to live in the Nærøyfjord (Figures 17 d,e**)**.

Using the Elvedelta classification system (Annex 3) the Gudvangen Delta can be categorized as heavily influenced.

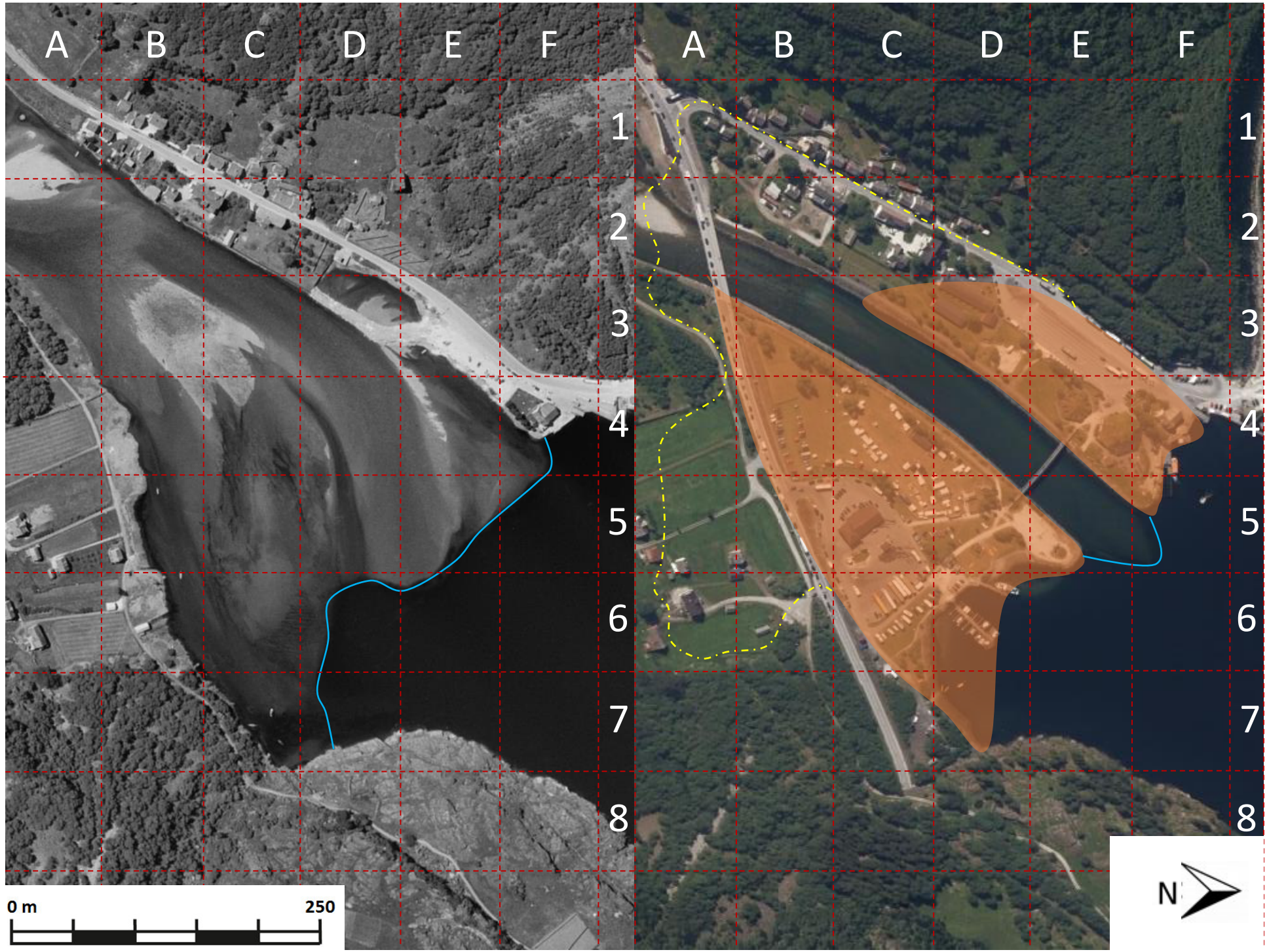


Figure 15: a) Bottom: Aerial photograph Gudvangen Delta in 1971 (Statens Kartverk 1971) b) Top: Aerial photograph Gudvangen Delta in 2013 (http 18)

a) Black-headed Gull
(Chroicocephalus ridibudus)

b) European Herring Gull
(Larus argentatus)

c) Taiga Bean-goose
(Anser fabalis)

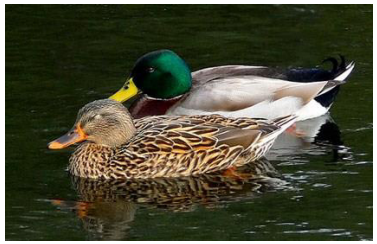
d) Common Snipe
(Gallinago gallinago)

e) Common Scooter
(Melanitta nigra)

f) Velvet Scooter
(Melanitta fusca)

g) Common Reed Bunting
(Emberiza schoeniculus)

h) Common Tern
(Sterna hirundo)



i) Mallard
(Anas platyrhinchos)

j) Tufted Duck
(Aythya fuligula)

k) Red-breasted Merganser
(Mergus serrator)

l) Common Merganser
(Mergus merganser)

m) Common Goldeneye
(Bucephala clangula)

Figure 16: Common birds in river deltas in the Inner Sogn Region a) (http 24), b) (http 25), c) (http 26), d) (http 27), e) (http 28), f) (http 29), g) (http 30), h) (http 31), i) (http 32), j) (http 33), k) (http 34), l) (http 35), m) (http 36)

a) Flatfish
(Pleuronectiformes)

b) Lesser Sand Eel
(Ammodytes tobianus)

c) Herring
(Clupea harengus)

d) Salmon
(Salmo salar)

e) Sea Trout
(Salmo trutta)

Figure 17: Common fish in river deltas in the Inner Sogn Region a) (http 37), b) (http 38), c) (http 39) Common fish in fjords in the Inner Sogn Region d) (http 40), e) (http 41)

6. Discussion

This discussion is structured according to the four objectives.

6.1. Have fjord river deltas changed in the Inner Sogn Region over the last 50 years?

After looking at the aerial photographs of the 1960s and of today it can be stated that eight out of the ten river deltas in the Inner Sogn Region have changed over the last 50 years. Only the size of the Vetlefjordsøyra Delta and the Årdalstangen Delta stayed mostly the same during this period. In Flåm and Gudvangen, the natural deltas have disappeared almost completely from a size of 0.09 km^2 in the 1960s to a size below 0.01 km^2 today (Table 3c). The combined size of the delta areas in the Inner Sogn Regions in the 1960s was around 1.71 km^2 (Annex 4). Until 2010, this number had been reduced to around 0.67 km^2 (Annex 4). In 50 years, the size of the natural river delta areas decreased by around 63%. Thus, 37% of the natural river delta areas in the Inner Sogn Region from the 1960s still exist (Annex 4).

These numbers do not consider that changes in some of the observed river deltas took place before the first aerial photographs. In the Årdalstangen Delta and the Sogndalsfjøra Delta most land fillings and river regulations happened before the 1960s. In Flåm, railway constructions on former delta areas took place in 1924 and 1940 (Venemann, 2017*)*. Considering these older changes, the estimated percentage of river delta areas in the Inner Sogn Region changed by humans is around 78% (Annex 4).

6.2. How and at which degree have these fjord river deltas changed?

With the observed results the ten river deltas can be categorized into four different groups (Figure 18):

a) Changes from >50% natural to <25% cultivated river deltas in the past 50 years.

b) Changes from >50% natural to >25% cultivated river deltas in the past 50 years.

c) Changes from >50% natural to >>50% urban river deltas in the past 50 years.

d) Changes from >50% urban to >>50% urban river deltas in the past 50 years.

6.2.1. Changes from >50% natural to <25% cultivated river deltas in the past 50 years

Two out of ten observed deltas fit into this category: the Vetlefjordøyra Delta in Vetlefjorden (Figure 6) and the Årøy Delta near Sogndal (Figure 8).

In the Vetlefjordøyra Delta (Figure 6), the natural delta area size in the 1960s was 0.12 km² (Table 3a). This was around 57% of the estimated original natural delta area (Table 3a). From the 1960s on, the natural delta area in the Vetlefjordøyra Delta remained the same over the past 50 years (Table 3a). The human influence on the river delta was changed only by using a different method of cultivation. After installing the Vetlefjordøyra nature reserve in 1991, the former agricultural areas of the delta were replaced by grazing land. The grazing intensity is controlled by nature reserve regulations (Dybward, 2014). Today, around 24% of the estimated original natural delta area is cultivated in the Vetlefjordøyra Delta (Table 3a).

The natural delta area size of the Årøy Delta (Figure 8) in the 1960s was 0.14 km² (Table 3a). Around 88% of the original natural delta area remained until the 1960s (Table 3a). In the past 50 years, the natural delta area decreased by 14.29% to a size of 0.12 km² (Table 3a). Parts in the east and west of the river delta were dug up or filled in. Influenced areas at the eastern bank are known to be breeding grounds for Flatfish (Torbjørn Dale 2017, *personal communication*) (Figure 17a). The newly won ground is used mainly for agriculture. Today, around 12.5% of the original natural delta area is cultivated (Table 3a).

The average decrease of natural river delta areas in the past 50 years in the Inner Sogn Region is around 51% (Annex 4). The decrease in the Vetlefjordøyra Delta (0.00%) and the Årøy Delta (14.29%) is both below this average (Table 3a).

6.2.2. Changes from >50% natural to >25% cultivated river deltas in the past 50 years

The Bøyaøyra Delta at Fjærland (Figure 7) fits into this category. The natural delta area size of the Bøyaøyra Delta in the 1960s was 0.25 km² (Table 3b). This was around 76% of the estimated original natural delta area (Table 3b). Today, the Bøyaøyra Delta at Fjærland seems to be influenced only weakly by building activity. Installing the Bøyaøyra nature reserve in 1991 prevented the delta from becoming covered by buildings. On the other hand, the original river delta was already influenced before 1991. Channeling the Storelvi river caused the sedimentation inflow to be cut off in most parts of the former delta. With a decreased sediment supply from the river, coastal erosion in those parts gets prevalence. The uninfluenced natural delta size decreased by 84% from 0.25 km² to 0.04 km² between 1964 and 2010 (Table 3b). The river channeling drained the water, creating new agricultural areas on the delta. In 2010, around 39% of the original natural delta area was cultivated (Table 3b).

6.2.3. Changes from mainly >50% natural to >>50% urban river deltas in the past 50 years

Four out of ten observed river deltas in the Inner Sogn Region fit into this category: the Lærdal Delta (Figure 9), the Gaupne Delta (Figure 12), the Flåm Delta (Figure 14), and the Gudvangen Delta (Figure 15).

The natural delta area size of the Lærdal Delta (Figure 9) in the 1960s was 0.54 km² (Table 3c). This was around 86% of the estimated original delta area of the Lærdal Delta (Table 3c). Between the 1960s and 2010s the natural river delta area decreased by 61.11% to a size of 0.21km² (Table 3c). This decrease happened due to land fillings and the regulation of the Lærdalsøyri river. The new area is used as an industrial location. Today, around 67% of the estimated original delta area is covered with buildings (Table 3c).

In the Gaupne Delta (Figure 12), the natural delta area size in the 1960s was 0.50km² (Table 3c). This was around 75% of the estimated original delta area of the Gaupne Delta (Table 3c). Land fillings on both riversides of the Jostedøla river led to a natural delta area decrease of 77.00% between the 1960s and the 2010s (Table 3c). The new area is used as an industrial location. Today, around 84% of the estimated original delta area is covered with buildings (Table 3c).

In the 1960s, the natural delta area size of the Flåm Delta (Figure 14) was 0.09km² (Table 3c). This was around 60% of the estimated original delta area of the Flåm Delta (Table 3c). Between the 1960s and the 2010s, the natural delta area was reduced by 96.67% to below 0.01km² (Table 3c). The decrease was made by land fillings on both sides of the Flåmselvi river and the river channeling. Today, around 93% of the estimated original delta area are changed to an urban delta (Table 3c).

In the Gudvangen Delta (Figure 15), the natural delta area size in the 1960s was 0.09km² (Table 3c). This was around 82% of the estimated original delta area of the Gudvangen Delta (Table 3c). Land fillings and the channeling of the Nærøydalselvi led to a natural delta area decrease of 96.67% (Table 3c). Today, around 91% of the estimated original delta area is covered with buildings (Table 3c).

The average decrease of natural river delta areas in the past 50 years in the Inner Sogn Region is around 51% (Annex 4). The decreases in the Lærdal Delta (61.11%), the Gaupne Delta (77.00%), the Flåm Delta (96.67%) and the Gudvangen Delta (96.67%) are all above this average (Table 3c**)**.

6.2.4. Changes from mainly >50% urban to >>50% urban river deltas in the past 50 years

Three out of ten observed river deltas fit into this category: the Skjolden Delta (Figure 10), the Sogndalsfjøra Delta (Figure 11) and the Årdalstangen Delta (Figure 13).

In the Skjolden Delta (Figure 10), the natural delta area size in the 1960s was 0.05km² (Table 3d). This was around 50% of the estimated original delta area of the Skjolden Delta (Annex 4). The other 50% of the estimated original delta area were covered with buildings (Table 3d). Between the 1960s and the 2010s, the natural delta area decreased by 20.00% to 0.04km² due to land fillings (Table 3d). The new area is used today as an industrial location. Thus, the urban delta area increased in this period by 20% to 0.06km² (Table 3d).

In the Sogndalsfjøra Delta (Figure 11), the natural delta area in the 1960s was 0.01km², while the urban delta area was 0.10km² (Table 3d). Around 91% of the estimated original delta area was covered with buildings already in the 1960s (Table 3d). In the past 50 years, the natural delta area decreased further by 70% to below 0.01km² due to land fillings (Table 3d). Today, around 97% of the estimated original delta is covered with buildings (Table 3d).

The natural delta area size of the Årdalstangen Delta (Figure 13) in the 1960s was 0.02km², while the urban delta area was 0.05km² (Table 3d). The estimated original delta was covered with buildings by around 71% already in the 1960s (Table 3d). From the 1960s on, the urban- and natural delta areas stayed the same over the past 50 years (Table 3d).

6.3. What are the causes of the observed changes?

In most of the river deltas that have changed in the past 50 years, a wish to increase industry and tourism was the initiative to change them (Lærdal: (http 13); Skjolden: (http 14); Gudvangen: (Dybø et al. 2016); Flåm: (Venneman, 2017)). With land fillings and river channelings, new areas were created for tourist shops or industrial buildings. For example, in the Gaupne Delta, the "Avery Dennison NTP" factory managed to increase employee numbers from four (in 1988) to 130 people today (http 5). The total number of cruise tourists visiting Norway increased from 110.000 in 1995 to 355.000 in 2006 (Dybedal et al. 2015). Due to the new cruise ship harbor, Flåm became one of the eight most important cruise ports in Norway with 148 ship calls in 2014 (Dybedal et al. 2015). In the Sogn og Fjordane county over 8% of all people employed worked in the tourism industries in 2013 (http 42). New roads like the Rv5 were built in Fjærland, Sogndal and Lærdal to increase the mobility and connectivity of the locals (Norwegian Public Roads Administration, 2015). In the Bøyaøyra Delta (http 11) and the Årøy Delta (http 12), gaining new agricultural areas was the reason for the observed changes.

6.4. What are the possible consequences of these changes for river, delta, and fjord management?

Deltas are important habitats for both, fish and birds. Johannes Anonby (2017, *personal* communication) and Torbjørn Dale (2017, *personal* communication) gave an idea of what the possible consequences of human made deltaic changes could have been or still could be for bird and fish populations. The incoming nutrient rich water makes river deltas a feeding ground for them. The brackish water, created by mixing fresh water from the incoming river and salt water from the fjord, causes a special environment. Only specialized species can cope with the changing salinity values. This leads to a poor diversity of species in river deltas, despite of a high productivity (Torbjørn Dale 2017, *personal communication*).

According to Johannes Anonby (2017, *personal communication)*, the observed river deltas are feeding grounds and resting places during migration for birds. Areas around deltas are also used as nesting places by some species, as the Mallard (Figure 16i), the Common Red Bunting (Figure 16g), the Common Snipe (Figure 16d) or the Common Tern (Figure 16h). Deltas at fjords are preferred over lakes, because the area around the fjord river delta is warmer than around a lake and the water is free of ice earlier in spring. Because of this, food is available much longer in fjord river deltas. The incoming nutrients of the rivers create a food rich environment in deltas. Land fillings and river channelings

create a cut off from nutrient rich freshwater inflow into former deltas. With decreasing river delta areas, the feeding, breeding and resting possibilities for birds have also decreased (Johannes Anonby 2017, *personal communication*).

Johannes Anonby (*personal communication, 2017)* further mentioned that Dabbling ducks like the Mallard use deltas as feeding grounds, while they breed further inland. Land fillings have increased the way from their breeding grounds to the deltas and made it more difficult for them to feed. In river deltas that were covered with buildings heavily, birds seem to be influenced even more. In the Gaupne Delta, nesting in the backland has diminished completely due to road buildings and industry. In the Flåm Delta birds are disturbed and stressed by the increased number of incoming cruise ships and tourists (Johannes Anonby 2017, *personal communication*).

These factors could lead to a decrease in bird populations in the Inner Sogn Region. According to Johannes Anonby (2017, *personal communication*), the above-mentioned factors might have led to a decrease in number of the Common Tern in the observed deltas. The Arctic Tern that was known to breed in the Bøyaøyra Delta stopped its activity in the river delta completely. Other birds like the Eurasian Curlew and the Northern Lapwing have decreased globally in numbers lately. They are both on the red list and classified as “near threatened” (http 43 & 44). Because of their migration it is however unlikely, that decreasing natural delta areal sizes in the Inner Sogn Region are the main reason for their decline in numbers. Nevertheless, the loss of resting and feeding grounds could still play a role in their decreasing numbers.

Johannes Anonby (2017, *personal communication*) points out, that other birds are partly profiting from the land fillings and increased human activity. Waders use dry parts of the deltas that have been filled and that are not covered with buildings as feeding grounds. New areas used as acres became also a good feeding ground for birds. Seagulls are common in most of the observed river deltas. They profit from the increased waste production by humans and use it as an additional food source.

According to Torbjørn Dale (2017, *personal communication*), river deltas in the Inner Sogn Region are preferred habitats for fish. Because of the brackish water and the low diversity, the fish populations in river deltas are dominated by three species: The Lesser Sand Eel (Figure 17b), Flatfish (Figure 17a) and Herring (Figure 17c). They use the deltas for spawning, nursery, hunting and protection. The river outflow areas are rich in nutrients and therefore good feeding grounds. The loose ground at the delta bottoms makes it easy for the Lesser Sand Eel and Flatfish to dig into the sediment and find protection against predators. Decreases of natural delta areal sizes might thus have led to a decrease in numbers of these fish species, due to a reduced hunting ground, fewer nursery areas and weaker protection. There are no quantitative measurements of fish species living in river deltas in the Inner Sogn Region. There is very little information about fish in the observed deltas in general, therefore, it can be only

speculated how strong the effects of changing river deltas might be on the fish species living there. Brigitte Ødven (2012) discovered a general retreat of fish populations in the Sognefjord over the last 65 years. Her results based on qualitative interviews she made with locals (Ødven, 2012). Her research indicates that a decline of fish species in the delta areas of fjords could be possible, too.

6.5. Complementation of the Elvedelta database

One aim of this study is to offer complementary information to the Elvedelta database and expand it with new, quantitative categories. Tables 1 and 2 show original data from the Elvedelta database (written in blue color), amplified with data from this study (written in green color). While the Elvedelta database gives an overview of the current situation of river deltas, this study shows the historical development of river deltas. It offers a first basis of information for future delta managements and shows how river deltas might be influenced by human induced change. Table 3 a, b, c, d and Figure 18 show the summarized development of river deltas in the Inner Sogn Region over time.

The extension of the Elvedelta database is meant to create an awareness of the current situation and development of natural river deltas. It helps to provide as much as possible information for future landscape managers to decide over future delta changes.

Blue = Data from Elvedelta; Green = Data from this study

Delta Names	Human influence	River protected	River regulated	Nature reserve
Vetlefjordøyra	Weak	No	Yes	Vetlefjordsøyra naturreservat
Bøyaøyra	Heavy	No	Yes	Bøyaøyra naturreservat
Årøy	Medium	No	Yes	No
Skjolden	Medium	No	Yes	No
Lærdal	Heavy	No	Yes	No
Sogndalsfjøra	Heavy	No	Yes	No
Gaupne	Heavy	No	Yes	No
Årdalstangen	Heavy	No	Yes	No
Flåm	Heavy	No	Yes	No
Gudvangen	Heavy	No	Yes	No

Table 1: Complementation of the Elvedelta database regulation status

Blue = Data from Elvedelta; Green = Data from this study

Delta Names	Birds	Fish on Delta	Fish in Fjord	Human population nearby (2016)
Vetlefjordøyra	Black-headed gull, Taiga bean goose, Common tern, Common reed bunting, Common snipe	Unknown	Unknown	No data (<50)
Bøyaøyra	Dabbling ducks, Diving ducks, Gulls, Common scooter, Velvet scooter, Common tern, Common reed bunting, Common snipe	Unknown	Salmon, seatrout	300
Årøy	Gulls, Common goldeneye, Common goosander	Flatfish	Salmon, trout	No data (<20)
Skjolden	Unknown	Unknown	Salmon	300
Lærdal	Ducks, Vaders, European herring gull	Unknown	Salmon, seatrout	1120
Sogndalsfjøra	Gulls, Common goldeneye	Unknown	Salmon, seatrout	3852
Gaupne	European herring gull, Mallard, Common goldeneye, Tufted duck	Unknown	Seatrout	1183
Årdalstangen	Gulls, Common goldeneye	Unknown	Unknown	1421
Flåm	Gulls	Tobis, flatfish, herring	Salmon	450
Gudvangen	Common goldeneye, Red-breasted merganser	Unknown	Salmon, seatrout	120

Table 2: Complementation of the Elvedelta database ecological status

>50% natural delta area <50% natural delta, >25% cultivated delta area >50% urban delta area

a) Changes from >50% natural to <25% cultivated								
Delta Names	**Estimated original natural delta area in km²**	**Natural delta areas 1960s in km²**	**Estimated natural delta areas 1960s in %**	**Natural delta areas 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in %**	**Cultivated delta areas 2010s in km²**	**Estimated cultivated delta areas 2010s in %**
Vetlefjordøyra	0,21	0,12	57,14	0,12	0,00	0,00	0,05	23,81
Årøy	0,16	0,14	87,50	0,12	0,02	14,29	0,02	12,50

b) Changes from >50% natural to >25% cultivated								
Delta Names	**Estimated original natural delta area in km²**	**Natural delta areas 1960s in km²**	**Estimated natural delta areas 1960s in %**	**Natural delta areas 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in %**	**Cultivated delta areas 2010s in km²**	**Estimated cultivated delta areas 2010s in %**
Bøyaøyra	0,33	0,25	75,76	0,04	0,21	84,00	0,13	39,39

c) Changes from >50% natural to >>50% urban								
Delta Names	**Estimated original natural delta area in km²**	**Natural delta areas 1960s in km²**	**Estimated natural delta areas 1960s in %**	**Natural delta areas 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in %**	**Urban delta areas 2010s in km²**	**Estimated urban delta areas 2010s in %**
Lærdal	0,63	0,54	85,71	0,21	0,33	61,11	0,42	66,67
Gaupne	0,67	0,50	74,63	0,12	0,39	77,00	0,56	83,58
Flåm	0,15	0,09	60,00	0,003	0,09	96,67	0,14	93,33
Gudvangen	0,11	0,09	81,82	0,003	0,09	96,67	0,10	90,91

d) Changes from >50% urban to >>50% urban									
Delta Names	**Estimated original natural delta area in km²**	**Natural delta areas 1960s in km²**	**Urban delta areas 1960s in km²**	**Estimated Urban delta areas 1960s in %**	**Natural delta areas 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in km²**	**Natural delta area decrease between 1960s and 2010s in %**	**Urban delta areas 2010s in km²**	**Estimated urban delta areas 2010s in %**
Skjolden	0,10	0,05	0,05	50,00	0,04	0,01	20,00	0,06	60,00
Sogndalsfjøra	0,11	0,01	0,10	90,91	0,003	0,01	70,00	0,107	97,27
Årdalstangen	0,07	0,02	0,05	71,43	0,02	0,00	0,00	0,05	71,43

Table 3 a-d: Categorization of river deltas in the Inner Sogn Region

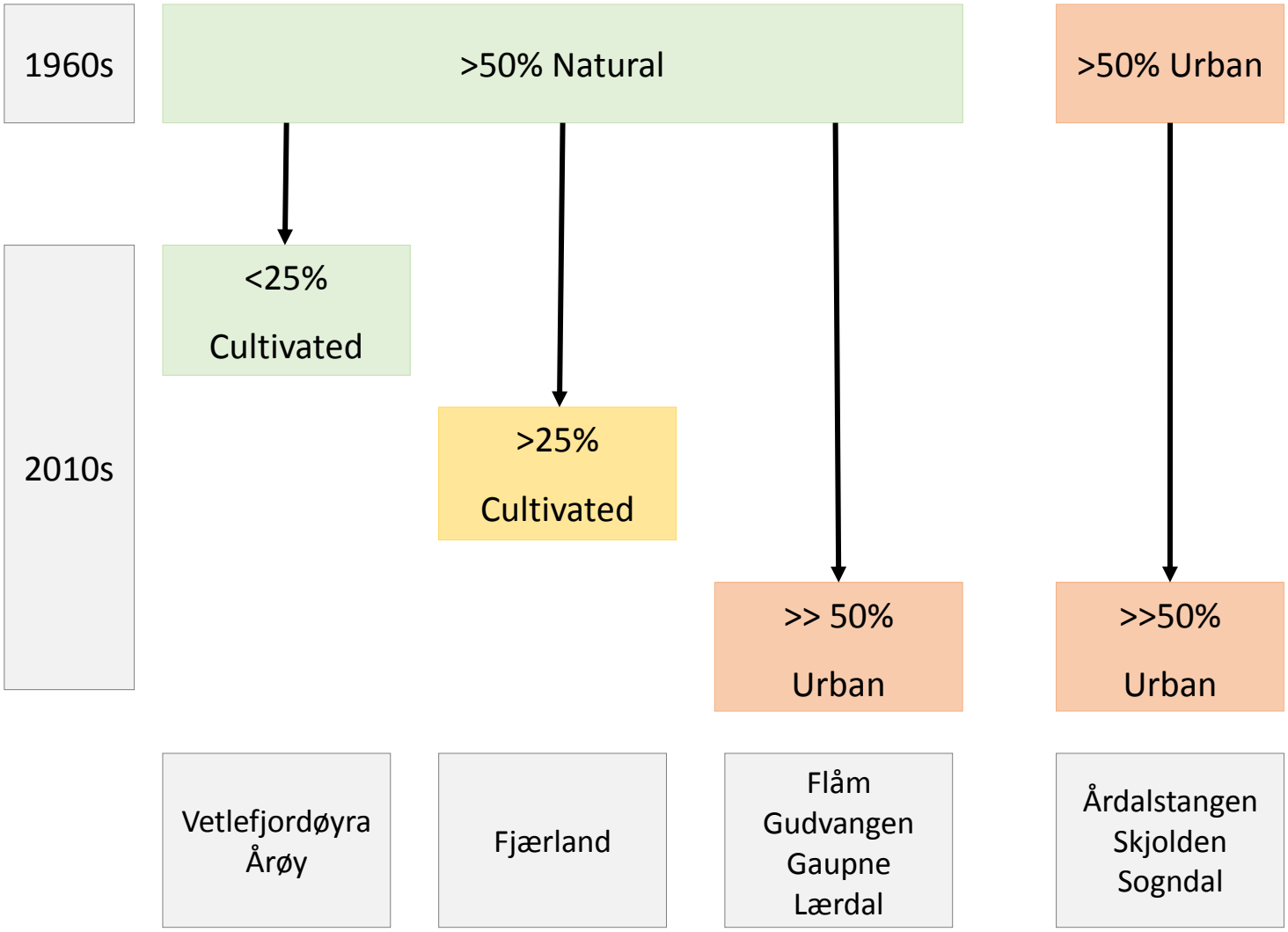


Figure 18: Summary categorization of the observed river deltas in the Inner Sogn Region

>50% natural delta area <50% natural delta, >25% cultivated delta area >50% urban delta area

Natural river deltas in the Inner Sogn Region have decreased in total by 62.76% between the 1960s and the 2010s (Annex 4). They were reduced from 1.81 km² to 0.67 km² (Annex 4). The total estimated decrease of uninfluenced original river delta areas until the 2010s is around 73% (Annex 4). A trend to deltas dominated by buildings (>>50% urban) is detectable (Figure 18, Table 3 c,d).

According to Johannes Anonby and Torbjørn Dale (both 2017, *personal communication*), natural river deltas are preferred by and often the only spots for birds and fish to feed, rest and breed. The sparse existing data on this topic indicates that so far, no investigations were made on the consequences of decreasing natural river deltas when planning deltaic changes. The aim of this study is to create an awareness of the possible ecological effects of deltaic changes. It is also meant to provide a basis of information for future landscape managers, to help them prevent damages on local ecology when planning to change river deltas. Due to the sparse existing data on this topic, the ecological value of river deltas in the Inner Sogn Region can only be estimated. Further investigations should focus on gathering more information about the consequences of deltaic changes on local flora and fauna. To understand the possible damage of river delta changes on ecology, the current situation of local ecology should be investigated and described more precisely.

The more information can be offered to landscape managers, the better future delta management projects can calculate the consequences of deltaic changes and help preserve local ecology.

6.6. Sources of Error

During collecting information and working on the results possible errors might have occurred:

The manual use of the (linear) calculation tools at the “Norge i bilder” website (http 18) might have led to a slight underestimation of the river delta areas. The tidal elevation could not be finally determined for the time when the aerial photographs were taken. It was thus difficult to spot the ultimate extension of the river deltas especially in the photographs from the 1960s. Misinterpretation might have occurred of river delta extensions and features due to shades, clouds, or poor contrast of the photographs.

7. Conclusion

The aim of this study was to offer a first description of river delta changes in the Inner Sogn Region between the 1960s and 2010s.

It can be concluded, that:

1) Eight out of ten river deltas in the Inner Sogn Region have changed between the 1960s and the 2010s.
2) The natural river delta area of six out of ten observed river deltas in the Inner Sogn region has decreased more than 50% in the past 50 years. In seven out of ten observed river deltas, over 50% of the delta is urbanized today. All of the observed river deltas are influenced by human activity. The river deltas were mainly changed by land fillings and river channelings.
3) Deltaic changes were made to create new areas for industry, tourism, mobility and agriculture.
4) River deltas in the Inner Sogn Region are habitats for bird and fish species. Changes in natural delta area sizes could have led to declining numbers in bird and fish populations.
5) A basis is provided for future landscape management to conclude on the long-term effects of human deltaic change.

8. References

8.1. Literature

Aure, J., Stigebrandt, A. (1989): *On the influence of topographic factors upon oxygen consumption rate in sill basins of fjords*. Esturaine, Coastal and Shelf Science, v. 28, Issue 1, p. 59-69.

Bates, C.C. (1953): *Rational theory of delta formation*. Am. Assoc. Petroleum Geologists Bull., v. 37, p. 2119-2161.

Boggs, S. Jr. (1995): *Principles of sedimentology and stratigraphy*. 2nd ed.: Prentice Hall, New Jersey, p. 355-377.

Bortheim Mulelid, O.S., Olaisen, V. and Strømme, K. (2017): *Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The geochemical record.* BSc thesis, Western Norway University of Applied Sciences, Sogndal, Norway, *in progress.*

Dybedal, P., Farstad, E., Winter, P. and I. Landa-Mata (2015): *Cruise passenger traffic to Norway – history and forecast until 2060*. Institute of Transport Economics, Norwegian Centre for Transport Research, Oslo.

Dybo, M.H., Sundheim, M.L. and A.M. Søgnesand (2016): Analysis of recent sediment cores in the anoxic Nærøyfjord, Western Norway. BSc thesis, Sogn og Fjordane University College, Sogndal, Norway. 59 pp.

Dybwad, T. (2014): *Forvaltningsplan for Vetlefjordøyra naturreservat.* County Governor of Sogn og Fjordane, Leikanger.

Dybwad, T. (2015): *Forvaltningsplan for Bøyaøyra naturreservat.* County Governor of Sogn og Fjordane, Leikanger.

Eliott, T. (1986): *Deltas*, in H.G. Reading (ed.), Sedimentary environments and facies. 2nd ed.: Blackwell, Oxford, p. 113-154.

Midttømme, M., Næss Haga, O. and Refsdal Thiem, E. (2017): *Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The sediment record.* BSc thesis, Western Norway University of Applied Sciences, Sogndal, Norway *in progress.*

Nemec, W. (1990): *Deltas – Remarks on terminology and classification*, in A. Colella and D.B. Prior (eds.), Coarse grained deltas. Internat. Assoc. Sedimentologists Spec. Pub. 10, Blackwell, Scientific Publications, Oxford, p. 3-12.

Nichols, G. (1999): *Sedimentology and Stratigraphy*. Wiley-Blackwell, Oxford, p. 419.

Norwegian Public Roads Administration (2015): *Utrending om forbindelser mellom Østlandet og Vestlandet*.

Ødven, B. (2012): *Mulige endringer I forekomst av ulike arter I og langs Sognefjorden de siste 65 år. Resultater frå en spørreundersøkelse.* BSc thesis, Sogn og Fjordane University College, Sogndal, Norway. 154 pp.

Paetzel, M., Schrader, H. (1992): *Recent environmental changes recorded in anoxic Barsnesfjord sediments: Western Norway.* Marine Geology, 105 (1992), pp. 23-36. Amsterdam.

Solhaug, T. (2009): *Norway´s Report on Implementation of the Convention on Biological Diversity*. The Royal Ministry of Environment, Oslo.

Statens Kartverk (1961): Flybilde WF-2223_L-19, serie S61

Statens Kartverk (1961): Flybilde WF-2223_P-05, serie S61

Statens Kartverk (1961): Flybilde WF-2223_Q-05, serie S61

Statens Kartverk (1962): Flybilde WF-1354_A-2, serie S62

Statens Kartverk (1963): Flybilde NF-0184_3-5, serie S63

Statens Kartverk (1963): Flybilde NF-0209_1, serie S63

Statens Kartverk (1964): Flybilde NF-0184_8-2, serie S64

Statens Kartverk (1964): Flybilde NF-0265_2-29, serie S64

Statens Kartverk (1969): Flybilde WF-2502_A-13, serie S69

Statens Kartverk (1971): Flybilde NF-949-Æ6, serie S71

Venneman, M. (2017): *Deposits from historic events in the Aurlandsfjord, Western Norway, over the last 40 years – The pollution record*. MSc thesis, Western Norway University of Applied Sciences, Sogndal, Norway. 131 pp.

8.2. Websites

Http 1: http://en.sognefjord.no/

Visited: 04.05.2017

Http 2: http://www.ssb.no/248688/tettsteder.folkemengde-og-areal-etter-kommune.1.januar-2015

Visited: 20.05.2017

Http 3: https://www.visitflam.com/en/informasjon/om-flam/flam-havn/

Visited: 07.04.2017

Http 4: http://gudvangen.com/

Visited: 07.04.2017

Http 5: http://www.averydennisonntp.com/about/

Visited: 19.04.2017

Http 6: https://www.ut.no/kart/

Visited: 22.05.2017

Http 7: https://media.snl.no/system/images/10333/standard_sognfjor.gif

Visited: 22.05.2017

Http 8: http://elvedelta.miljodirektoratet.no/

Visited: 02.04.2017

Http 9: https://www.researchgate.net/figure/223832280_fig1_Fig-1-Typical-cartoon-used-in-textbooks-to-explain-the-morphodynamics-of-the-earth's

Visited 20.05.2017

Http 10: http://elvedelta.miljodirektoratet.no/delta-85.htm

Visited: 25.05.2017

Http 11: http://elvedelta.miljodirektoratet.no/delta-86.htm

Visited: 25.05.2017

Http 12: http://elvedelta.miljodirektoratet.no/delta-93.htm

Visited: 25.05.2017

Http 13: http://elvedelta.miljodirektoratet.no/delta-96.htm

Visited: 25.05.2017

Http 14: http://elvedelta.miljodirektoratet.no/delta-97.htm

Visited: 25.05.2017

Http 15: http://www.unesco.de/kultur/welterbe/welterbestaetten/welterbeliste.html#c62213

Visited: 07.04.2017

Http 16: http://artskart.artsdatabanken.no/default.aspx

Visited: 04.05.2017

Http 17: https://scholar.google.no/

Visited: 26.04.2017

Http 18: https://www.norgeibilder.no/

Visited: 22.05.2017

Http 19: http://www.kartverket.no/en/

Visited: 03.04.2017

Http 20: http://www.ssb.no/

Visited: 23.05.2017

Http 21: http://elvedelta.miljodirektoratet.no/inngrep.htm

Visited: 25.05.2017

Http 22: https://www.ssb.no/statistikkbanken/selectvarval/define.asp?SubjectCode=al&ProductId=al&MainTable=ArealBefTett&contents=Areal&PLanguage=1&Qid=0&nvl=True&mt=1&pm=&SessID=13879626&FokusertBoks=1&gruppe1=TtStedGjeldende&gruppe2=Hele&aggreg1=&VS1=TtSted2003&VS2=&CMSSubjectArea=befolkning&KortNavnWeb=beftett&StatVariant=&Tabstrip=SELECT&aggresetnr=1&checked=true

Visited: 22.05.2017

Http 23: https://www.uk.vikingvalley.no/about-us/

Visited: 13.04.2017

Http 24: http://www.audubon.org/field-guide/bird/black-headed-gull

22.05.2017

Http 25: https://gullstothehorizon.wordpress.com/2013/02/03/you-look-different-today/

Visited: 22.05.2017

Http 26: http://www.aabirdpix.com/gallery/DUCKS/ducks.htm

Visited: 22.05.2017

Http 27: http://www.geometer.org/Birds/charadriiformes/index.html

Visited: 22.05.2017

Http 28: http://www.kerrygems.com/kerry-gems-app/a-birdwatching-guide-to-kerry/the-birds-you-can-see/

Visited: 22.05.2017

Http 29: http://www.simplybirdsandmoths.co.uk/sbam/index.php/2013/12/15/a-bird-worth-twitching-velvet-scoter/

Visited: 22.05.2017

Http 30: http://www.vogelwarte.ch/en/birds/birds-of-switzerland/common-reed-bunting

Visited: 22.05.2017

Http 31: https://www.allaboutbirds.org/guide/Common_Tern/id

Visited: 22.05.2017

Http 32: https://www.allaboutbirds.org/guide/Mallard/id

Visited: 22.05.2017

Http 33: http://www.animalspot.net/tufted-duck-aythya-fuligula.html

Visited: 22.05.2017

Http 34: https://www.allaboutbirds.org/guide/Red-breasted_Merganser/id

Visited: 22.05.2017

Http 35: http://www.audubon.org/field-guide/bird/common-merganser

Visited: 22.05.2017

Http 36: http://www.audubon.org/field-guide/bird/common-goldeneye

Visited: 22.05.2017

Http 37: http://seaiceland.is/what/fish/flatfishes

Visited: 22.05.2017

Http 38: http://peeterke.blogspot.no/2013_01_01_archive.html

Visited: 22.05.2017

Http 39: http://www.liegruppen.no/english/fishing/species-fishing-zones/herring

Visited: 22.05.2017

Http 40: https://news.mongabay.com/2016/08/fish-farm-escapees-are-weakening-norwegian-wild-salmon-genetics/

Visited: 22.05.2017

Http 41: http://www.wildtrout.org/content/sea-trout

Visited: 22.05.2017

Http 42: https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/statistikker/turismesat/aar/2016-02-24

Visited: 23.05.2017

Http 43: http://www.iucnredlist.org/details/22693190/0

Visited: 11.04.2017

Http 44: http://www.iucnredlist.org/details/22693949/0

Visited: 11.04.2017

9. Annex

Annex 1: Questions to Torbjørn Dale

1. Are the influenced places of the deltas a preferable spot for fish spawning?
2. Are the influenced places of the deltas a preferable spot for fish nursery?
3. Are the influenced places of the deltas a preferable spot for fish overwintering?

4. Which are the concrete spots in the delta areas?
5. Why and in what way are these spots preferable for fish?

6. What are the most common species in the areas?

7. Has there been a decrease of the total number of fish populations observed in the affected deltas?
   7.1. Did this decrease happen gradually or sudden?
   7.2. Since when is a decrease going on?
8. Has there been a decrease of the total number of fish populations observed in the fjords?
9. Did this decrease happen gradually or sudden?
10. Since when is a decrease going on?

11. Has there been a change in fish variations and populations in the affected deltas?
    11.1. Has there been a change in dominant species of fish in the affected deltas?
    11.2. How do these changes influence other parts of the ecosystem?
12. Has there been a change in fish variations and populations in the fjords?
    12.1. Has there been a change in dominant species of fish in the fjords?
    12.2. How do these changes influence other parts of the ecosystem?

13. Which species is the most affected by the influences?
14. What are the effects for humans, if certain species of fish decrease?

Annex 2: Questions to Johannes Anonby

1. Are the influenced places of the deltas a preferable spot for birds?
2. Which are the concrete spots in the delta areas?
3. Why and in what way are these spots preferable for birds?

4. What are the most common species in the areas?

5. Has there been a decrease of the total number of bird populations observed at the affected deltas?
   5.1. Did this decrease happen gradually or sudden?
   5.2. Since when is a decrease going on?

6. Has there been a change in bird variations and populations at the affected deltas?
   6.1. Has there been a change in dominant species of birds in the affected deltas?
   6.2. How do these changes influence other parts of the ecosystem?

7. Which species is the most affected by the influences?
8. What are the effects for humans, if certain species of birds decrease?

Annex 3: Elvedelta dataset classification of human influence on river deltas (http 21), (translated from Norwegian)

Intervention type (IT)	Intervention range	Intervention score	Details of the intervention	Score adjustment
IT 1 River regulation	River not regulated	0		
	River regulated	-10		
IT 2 Buildings and fillings (In the water string, and into the tidal zone)	20% or less of the length of the water contour at low tide is affected by such intervention	0		
	Between 20% and 35% affected	-20		
	Between 35% and 50% affected	-30		
	50% or more affected	-50		
Land changes at weaker intervention on land (intensively farmed area, parchment, etc.) or heavier intervention (building, plant, transport etc)	20% or less of the delta area (on land) is affected by such interventions	0		
	Between 20% and 50% affected	-30	A) 40 - 80% of the area concerned is affected by heavier intervention	10
			B) 40% or less of the area concerned is affected by heavier intervention	20
	50% or more affected	-50	A) 40 - 80% of the area concerned is affected by heavier intervention	10
			B) 40% or less of the area concerned is affected by heavier intervention	20

Human influence	
Weak	100-80 points
Medium	70-30 points
Heavy	< 30 points

Annex 4: Complete calculated and estimated data of river delta areas in the Inner Sogn Region

Delta Names	Estimated original natural delta area in km²	Natural delta areas 1960s in km²	Estimated % of natural delta areas in 1960s	Natural delta areas 2010s in km²	Natural delta area decrease between 1960s and 2010s in km²	Natural delta area decrease between 1960s and 2010s in %	Estimated natural delta area decrease between original delta and 2010s in km²	Estimated natural delta area decrease between original delta and 2010s in %	Cultivated delta areas 2010s in km²	Estimated cultivated delta areas 2010s in %	Urban delta areas 1960s in km²	Estimated urban delta areas 1960s in %	Urban delta areas 2010s in km²	Estimated urban delta areas 2010s in %
Vetlefjordøyra	0,21	0,12	57,14	0,12	0,00	0,00	0,09	42,86	0,05	23,81				
Bøyaøyra	0,33	0,25	75,76	0,04	0,21	84,00	0,29	87,88	0,13	39,39				
Årøy	0,16	0,14	87,50	0,12	0,02	14,29	0,04	25,00	0,02	12,50				
Skjolden	0,10	0,05	50,00	0,04	0,01	20,00	0,06	60,00			0,05	50	0,060	60,000
Lærdal	0,63	0,54	85,71	0,21	0,33	61,11	0,42	66,67					0,420	66,667
Sogndalsfjøra	0,11	0,01	9,09	0,003	0,01	70,00	0,11	97,27			0,10	90,91	0,11	97,273
Gaupne	0,67	0,50	74,63	0,12	0,39	77,00	0,56	82,84					0,560	83,582
Årdalstangen	0,07	0,02	28,57	0,02	0,00	0,00	0,05	71,43			0,05	71,43	0,050	71,429
Flåm	0,15	0,09	60,00	0,003	0,09	96,67	0,15	98,00					0,140	93,333
Gudvangen	0,11	0,09	81,82	0,003	0,09	96,67	0,11	97,27					0,100	90,909
Sum	2,54	1,81		0,67	1,14	62,76	1,87	73,46						
Average decrease						51,97		72,92						

Sworn declaration

Hereby I affirm that I wrote the present thesis

"River Deltas of the Inner Sognefjord (Inner Sogn Region): Consequences of Anthropogenic Change"

without any inadmissible help by a third party and without using any other means than indicated. Thoughts that were taken directly or indirectly from other sources are indicated as such. This thesis has not been presented to any other examination board in this or a similar form and it has not been published.

Sogndal, 30.05.2017

(place, date)

Thomas Klamer

(signature)