

Field report for snorkeling surveys and removal of escaped farmed salmon in 13 rivers in Iceland 2023



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Summary

In August 2023, the aquaculture company Arctic Fish (Arctic Sea Farm) reported two small holes in one of its net-pens in Patreksfjörður in the Westfjords, Iceland. The Icelandic Food and Veterinary Authority estimated that about 3500 farmed salmon escaped from the net-pen. On assignment from the Directorate of fisheries in Iceland, NORCE LFI surveyed 13 rivers on the north and west coast of Iceland by snorkeling in September-October. The objective was to screen key segments of the rivers for farmed fish and remove as many as possible using spearguns, to limit negative impacts of farmed salmon spawning with wild salmon. Likely hotspots for occurrence of farmed salmon were chosen based on experience from Norway and guidance from local river owners and fishing guides. Escaped farmed salmon was found in 9 of the 13 rivers. A total of 79 farmed fish were observed, whereof 59 were caught, while 7 more were shot and wounded but managed to escape. The highest number of farmed salmon were found in Hrútafjarðará (34 observed, 32 caught). The farmed salmon were in general found in the upper reaches of the rivers, often in pools below rapids and waterfalls, or in association with holding pools/spawning areas together with aggregations of wild salmon. In some instances, farmed salmon were located more than 20 km upriver from the sea, demonstrating the possibility and motivation of the farmed salmon to migrate extensive distances up the rivers. All the surveyed rivers were considered suitable for performing snorkeling surveys, but varying visibility affected the possibilities to effectively observe and hunt farmed fish in the different rivers. The results suggest that snorkeling surveys and speargun fishing may be a useful approach to monitor and reduce the impacts of escaped farmed salmon in Icelandic rivers in case of future incidences.

Background

In August 2023, the company Arctic Fish, owned by the Norwegian aquaculture company MOWI, had an escape incident of farmed Atlantic salmon from a net pen in Patreksfjörður in Iceland. The fish had an average size of about 5,5 kg, and after harvesting, the Icelandic Food and Veterinary Authority estimated that about 3500 fish was found to be missing from the net pen. Escaped farmed salmon were in the following weeks recaptured in many rivers up to 400 km from the escape location, and there was considerable concern that the farmed salmon would spawn in the important salmon rivers on the north and west coast of Iceland.

Domesticated strains of Atlantic salmon have been bred for life in the net pens but are frequently found to escape and spawn with wild salmon (Glover *et al.* 2019). Considerable concern is related to the genetic impacts of introgression of farmed salmon strains into wild Atlantic salmon populations (Glover *et al.* 2017). In Norway the impacts of escaped farmed salmon have been studied extensively, and genetic introgression of farmed fish is considered one of the greatest threats to wild salmon on a national level in Norway (Forseth *et al.* 2017). The aquaculture production in Iceland is considerably smaller than in Norway, but the production has increased in recent years, and hybrid juveniles of wild x farmed fish have been recorded in several Icelandic salmon rivers (Guðmundsson *et al.* 2023). The aquaculture production is based on Norwegian-origin salmon (StofnFiskur strain), which raises extra concern with regards to effects of genetic introgression into wild populations (Wacker *et al.* 2023).

The occurrence of farmed salmon in Norwegian rivers is monitored yearly through a national monitoring program (Glover *et al.* 2019), and several measures are taken to reduce the impacts of farmed fish. Snorkeling (also called drift diving) is a method that is commonly used to survey the rivers for farmed salmon in Norway (Mahlum *et al.* 2019). Furthermore, farmed fish are in many instances hunted using harpoons/spearguns. The snorkeling method for surveying and removing farmed salmon has several advantages as it is a versatile, non-invasive and relatively cost-efficient method, and therefore allows surveying of extensive river lengths in relatively short time (Skoglund *et al.* 2021). The method requires skilled personnel in order to identify farmed fish, but experienced drift divers are able to identify farmed fish with high precision given sufficient visibility (Mahlum *et al.* 2019). The biggest limitation is that the method requires good underwater visibility and is therefore best suited in small to medium sized rivers with clear water.

The Directorate of Fisheries on Iceland, together with the Federation of Icelandic River Owners, requested the assistance of NORCE LFI to propose activities to handle the situation with regards to farmed salmon in the rivers. This field report describes the approach and result from snorkeling surveys and active removal efforts in 13 rivers in Iceland in the autumn of 2023.

Methods and approach

The snorkeling surveys were performed during the period 28 September – 3 October 2023 with four persons using dry suits and snorkeling gear. The four persons operated as two teams, with two snorkelers surveying different parts of the river systems. The teams were supervised by personnel on land from the Directorate of Fisheries and Marine (John Bek) and Freshwater Research Institute (MFRI) (Leó Alexander Guðmundsson), as well as local river managers/guides. Snorkeling was performed in selected river stretches that were considered potential hotspot areas for likely occurrence of farmed salmon, and included important spawning reaches, holding pools, pools below waterfalls, and areas where locals had spotted farmed salmon from land. The snorkeling stretches were selected by local river managers and fishing guides with detailed local knowledge of the rivers and the fish populations. Escaped farmed salmon were distinguished based on various morphological characters (Mahlum *et al.* 2019), such as deviating pigmentation patterns (Jørgensen *et al.* 2018) and fin erosion (Noble *et al.* 2007). These morphological differences are sufficient for experienced snorkelers to differentiate escaped farmed salmon from wild salmon with high accuracy. In addition

to encounters with escaped farmed salmon, observations of wild salmon, sea trout and arctic char in the different river stretches were also noted. However, counting of wild fish was not a primary objective in this study and the approach did not fulfill the requirements (see Skoglund *et al.* 2021) for obtaining good population estimates of the wild fish populations. Thus, the numbers of wild fish reported do by no means represent the total population sizes in the investigated rivers. For each river, the visual conditions are given as the approximate effective distance (in meters) of which the snorkeler can distinguish between farmed and wild salmon.

Upon encounters, farmed fish was hunted using rubber thrusted spearguns (75 or 90 cm). On one location in Hrótafjarðará, a gill net was also applied. All captured fish were handled and processed for further sampling by MFRI.

In most of the rivers investigated here there were also captured farmed salmon during local fishing both before and after the field period for the present project. Several of the rivers were also covered by a separate team of snorkelers from Skandinavisk Naturovervåking AS. Here we only report the farmed fish observed and captured during the field period for the present project.

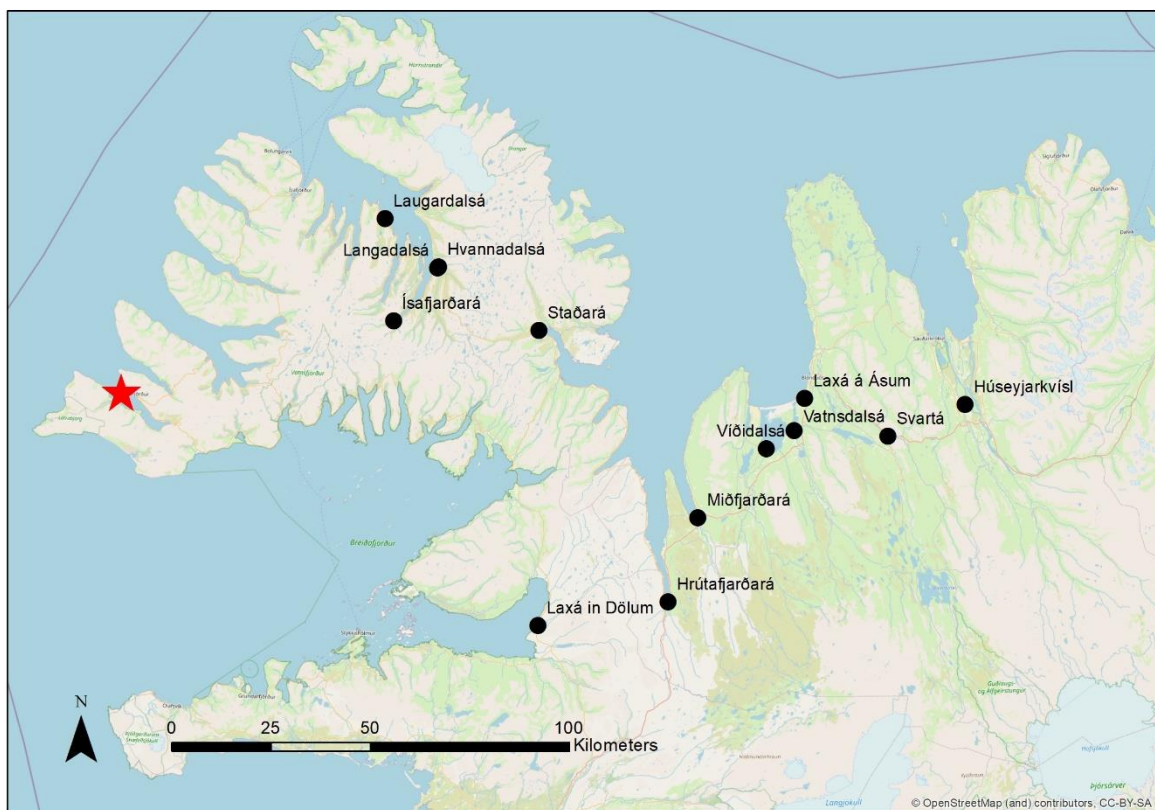


Figure 1. Overview of rivers included in the snorkeling surveys during the period 28 September-3 October 2023. The star indicates the escape location.

Results and discussion

Escaped farmed salmon was observed in 9 of the 13 rivers surveyed by snorkeling in the period 28-3 October 2023 (Table 1). A total of 79 farmed fish were observed, whereof 59 were captured, and 7 more were shot and wounded but managed to escape after impact with the harpoons. The remaining 13 fish managed to escape. Failed removal attempts were mainly attributed to poor visibility (e.g. Laxá in Dölum and Víðidalsá) or difficulties to hunt fish due to large water bodies (e.g. Húseyjarkvísl and Hvannadalsá). Furthermore, some farmed salmon also reacts with panic during approach and flee (usually downstream). The highest number of farmed salmon were found in Hrótafjarðará (34 observed, 32 caught) and Miðfjarðará (14 observed, 10 caught).

Table 1. Overview of the observations and captures of escaped farmed salmon in each of the rivers that were surveyed during the period 28. September – 3. October 2023. The observations are restricted to surveyed stretches and do not reflect the total numbers in each of the rivers. *See comment in field notes.

River	Date	Farmed salmon		Wild salmon	Sea trout	Arctic char	Visibility
		Obs.	Caught				
Víðidalsá	28.09	4*	1	189	127	882	Moderate 3-5 m
Miðfjarðará	29.09	14	10	275	4	2	Moderate- good 3-7 m
Laxá á Ásum	30.09	0	-	279	0	0	Moderate 4 m
Húseyjarkvísl	30.09	2	1	136	324	0	Good 6-7 m
Svartá	30.09	0	-	18	15	0	Good 5-7 m
Vatnsdalsá	01.10	0	-	159	170	259	Moderate 3-6 m
Hrótafjarðará/ Síka	01-02.10	34	32	109	1	94	Very good 6-8 m
Laxá í Dölum	02.10	6	3	363	5	2	Poor 2-6 m
Laugardalsá	03.10	0	-	0	1	0	Poor, 3-4 m
Ísafjarðará	03.10	7	6	4	0	0	Good 7-10 m
Langadalsá	03.10	1	1	55	10	0	Good 7-10 m
Hvannadalsá	03.10	5	0	35	0	0	Good 7-9 m
Staðará	03.10	6	5	24	0	5	Good 7-8 m
Sum		79	59	1646	657	1244	

The escaped farmed salmon were spread on a variety of locations within the rivers, and the sites of the observations are described for each of the rivers further below. In most cases the farmed salmon were found either in pools and/or below waterfalls in the upper parts of the rivers, or in important

holding pools/spawning grounds together with aggregations of wild salmon. On some occasions farmed salmon were found more than 20 km upstream from the sea (e.g. Miðfjarðará and Laxá in Dölum). As the snorkeling surveys only covered a selection of likely hotspot locations and stretches in the different rivers, our results do not necessarily display the entire distribution within the rivers. Nor do the numbers observed/caught given in Table 1 reflect the total number of farmed salmon (or wild fish) present in each of the rivers. The distribution pattern observed, with most farmed fish being found in larger pools and below waterfalls, nevertheless suggest that the approach was reasonably effective for tracking the majority of farmed fish present in the rivers at the time of the surveys.

Although not a primary objective of the survey, the number of wild salmon present at the surveyed stretches were also noted. While the numbers are not necessarily representative for the entire river, they suggest that the proportion of farmed salmon relative to wild salmon was high in some of the rivers, particularly in Ísafjarðará (63 %), Hrótafjarðará (23 %) and Staðará (20 %). The salmon catches in the Icelandic rivers in 2023 was among the lowest ever recorded, and although no comparable surveys of wild fish from these rivers/stretches from previous years exists, the number of wild salmon on many of the key spawning grounds appeared to be low. Thus, the escape event appears to have occurred in a year when the spawning population of wild salmon was particularly low, and thus more vulnerable to genetic introgression from farmed salmon.

In most rivers the water discharge was relatively low, and the river size and reach types were in general well suited for performing snorkeling surveys. The visual conditions varied however both within and among the rivers. In some of the rivers, the visibility was limited due to a hue of fine sediments/algae (e.g. Víðidalsá, Austurá in Miðfjarðará, Vatndalsá, Laxá á Ásum), but visibility often improved somewhat downstream with influx of smaller and clearer tributaries. One exception is Laxá í Dölum where visibility became progressively poorer downstream, likely due to strong winds stirring up algae and fine sediments on shallow river reaches, which greatly restricted the possibility to survey and hunt farmed salmon in this river. The visibility was best in Hrótafjarðará and in some of the tributaries in the other rivers (i.e. Vesturá in Miðfjarðará, Fitjá in Víðidalsá), but also several of the other rivers were found to be well suited for snorkeling surveys. In total, the experience and results suggest that snorkeling surveys, in combination with speargun hunting, is a suitable and relatively efficient method for monitoring and removing escaped farmed salmon in many Icelandic rivers.

Field notes for each of the rivers

In the following we provide a description of the work in the different rivers, in the order that they were investigated.

Víðidalsá

Snorkeling was performed in various pools/stretches both in upper and lower parts of the river system, including two locations in the tributary Fitjá (Figure 2). Visibility was moderate (3-5 m in Víðidalsá, better in Fitjá), which was sufficient to likely identify farmed salmon in the observation reaches, but limiting for effective hunting with spearguns.

Three (possibly four, as it was uncertain whether one of the fish was observed twice) farmed salmon were observed in lower half of the river (pools Silungabakki and Faxabakki), which is an important spawning reach for salmon in this river. One was captured with a speargun, whereas the remaining were difficult to hunt due to limiting visibility. One farmed salmon was caught by rod fishing on the same location later the same day. No farmed salmon were observed on the locations in the canyon and the upper reaches of Víðidalsá, or in the surveyed locations of Fitjá (Laxapollur & Ker).

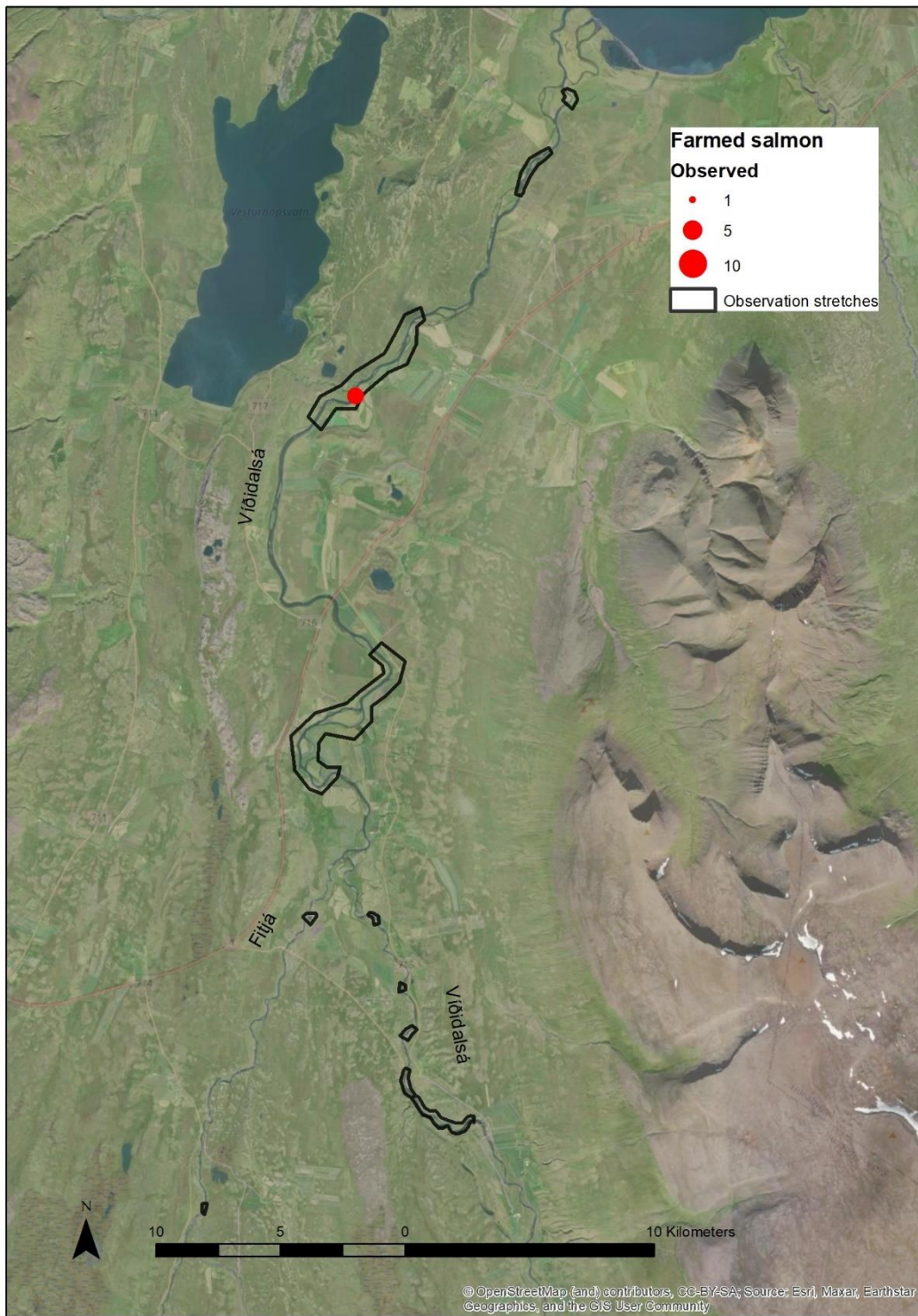


Figure 2. Hybrid map/aerial photo of Víðidalsá with overview of the approximate stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

Miðfjarðará

Snorkeling was performed in various pools/stretches in Vesturá, Austurá, Núpsá and in the main river of Miðfjarðará (Figure 3). Visibility was moderate (3-4 m) in Austurá, good (6-7 m) in Vesturá and Núpsá, and moderate in the main river of Miðfjarðará (5 m). A total of 14 farmed salmon was observed, whereof 10 caught with speargun and further three was shot and wounded but managed to escape. Five farmed salmon (whereof three caught and to wounded) in Austurá, six (whereof five caught) in Vesturá, and three (2 caught) in Miðfjarðará. In both Austurá and Vesturá the farmed salmon were found in pools below water falls that may have limited further upstream migration. Wild salmon were observed upstream of these waterfalls in both rivers.



Many of the farmed salmon were found downstream waterfalls that may partly or completely obstruct further migration upstream the river. The farmed salmon in the lower picture were caught in the pool below the waterfall (upper picture) in Vesturá.

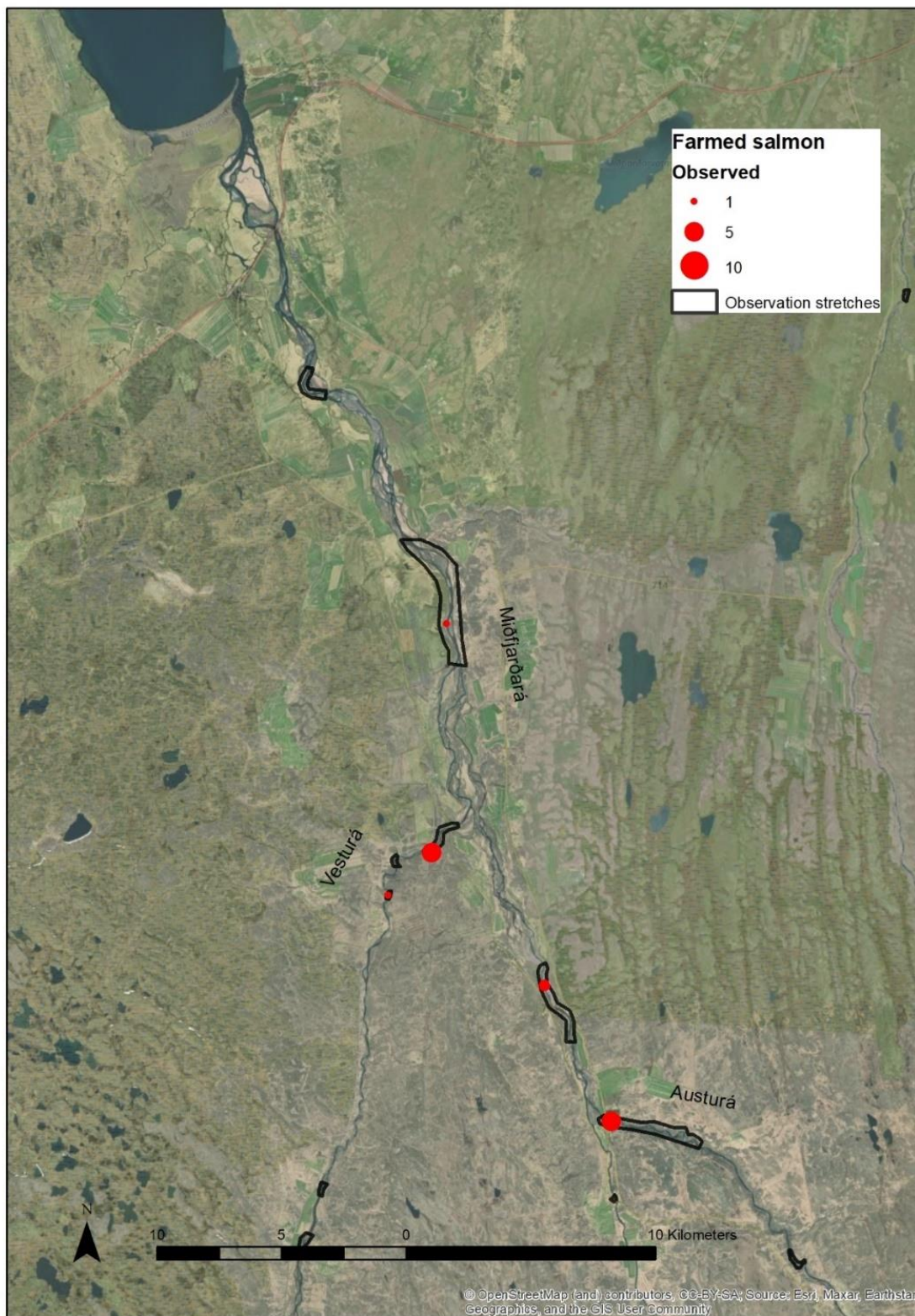


Figure 3. Hybrid map/aerial photo of Miðfjarðará with (approximate) stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

Laxá á Ásum

Snorkeling was performed in various locations in both upper and lower parts of the river system. Approximately 280 wild salmon were observed, with highest concentration of fish in the uppermost locations (Langhylur). No escaped farmed salmon were observed.

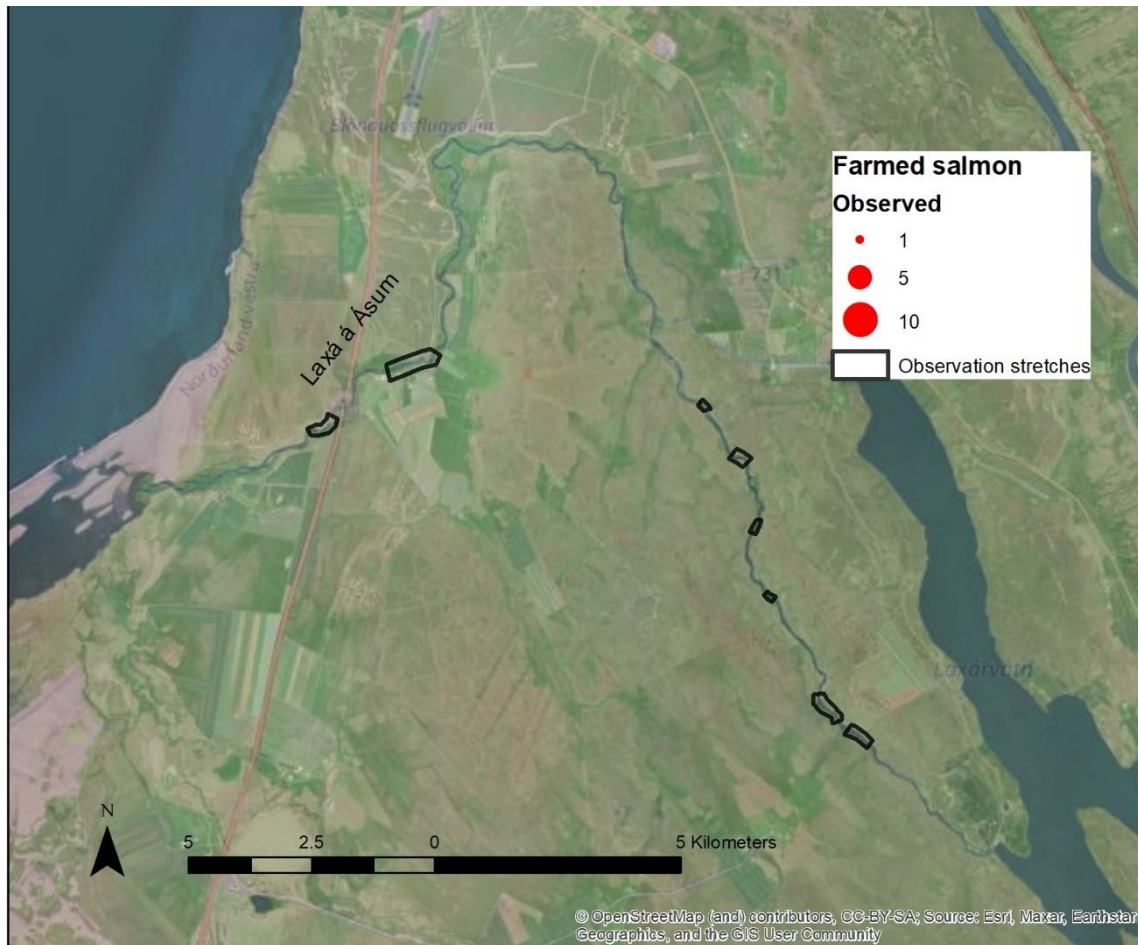


Figure 4. Hybrid map/aerial photo of Laxá á Ásum with stretches for snorkeling. There were no observations of farmed salmon in this river.

Húseyjarkvísl

Húseyjarkvísl is a tributary in the Héraðsvötn river system in Skagafjörður. Snorkeling was performed in various stretches from the migration barrier to the middle/lower part of the river (Figure 5). Visibility was moderate to good (6-7 m), and most of the rivers is well suited for snorkeling surveys. Two farmed salmon were observed, whereof one caught with speargun and one was wounded but managed to escape.

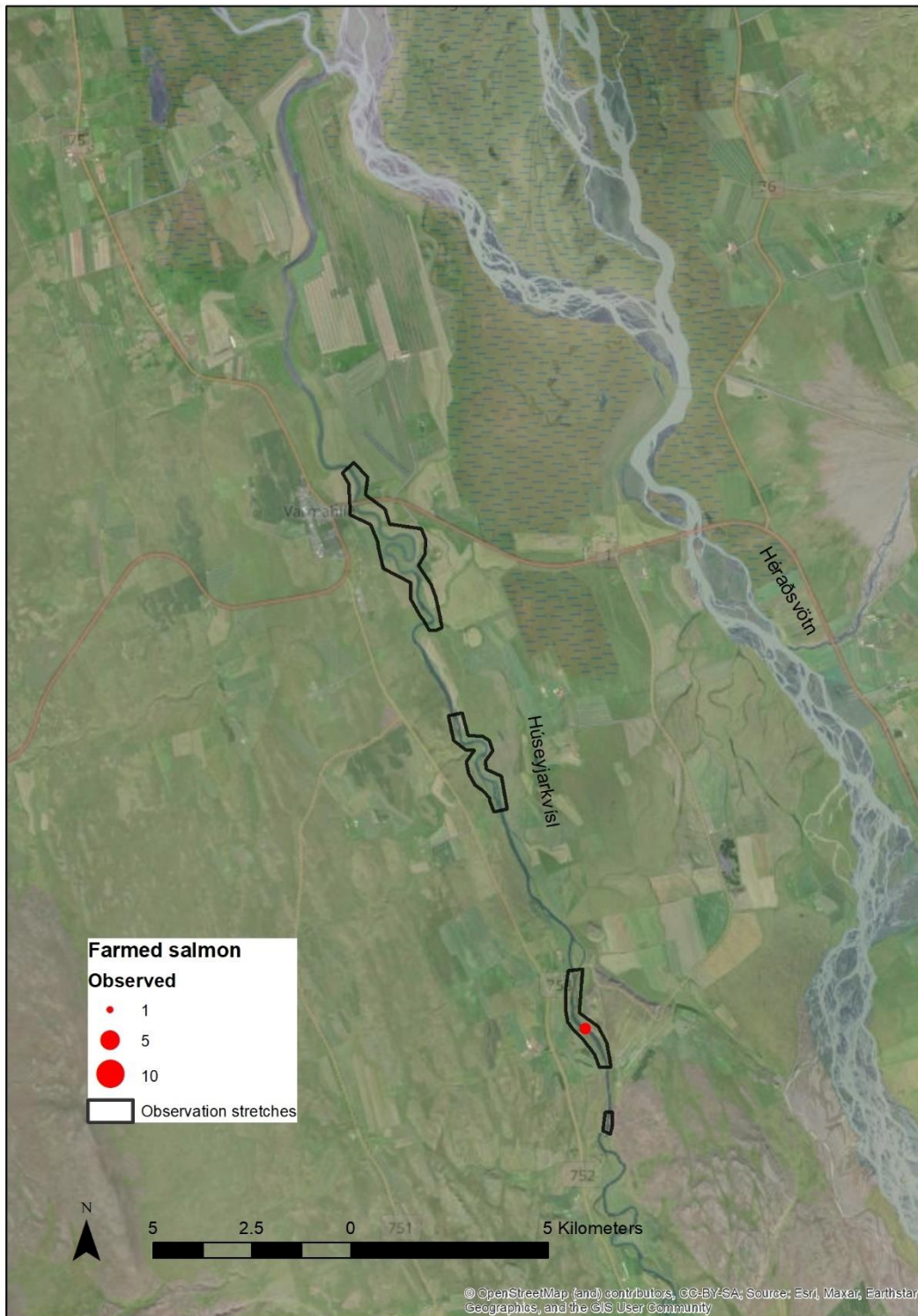


Figure 5. Hybrid map/aerial photo of Húseyjarkvísl with stretches for snorkeling and locations of escaped farmed salmon observations. Two farmed salmon were observed in the upper part of the river, whereof one caught.

Svartá

Svartá is a tributary in the Blanda river system. A few selected pools/stretches in various parts of the river were surveyed by snorkeling (Figure 6). The visibility was moderate to good (4-5 m). A total of 18 wild salmon and 15 sea trout were observed in the surveyed reaches, but no farmed salmon. The visibility in the main river of Blanda was too poor for snorkeling due to glacial sediments.

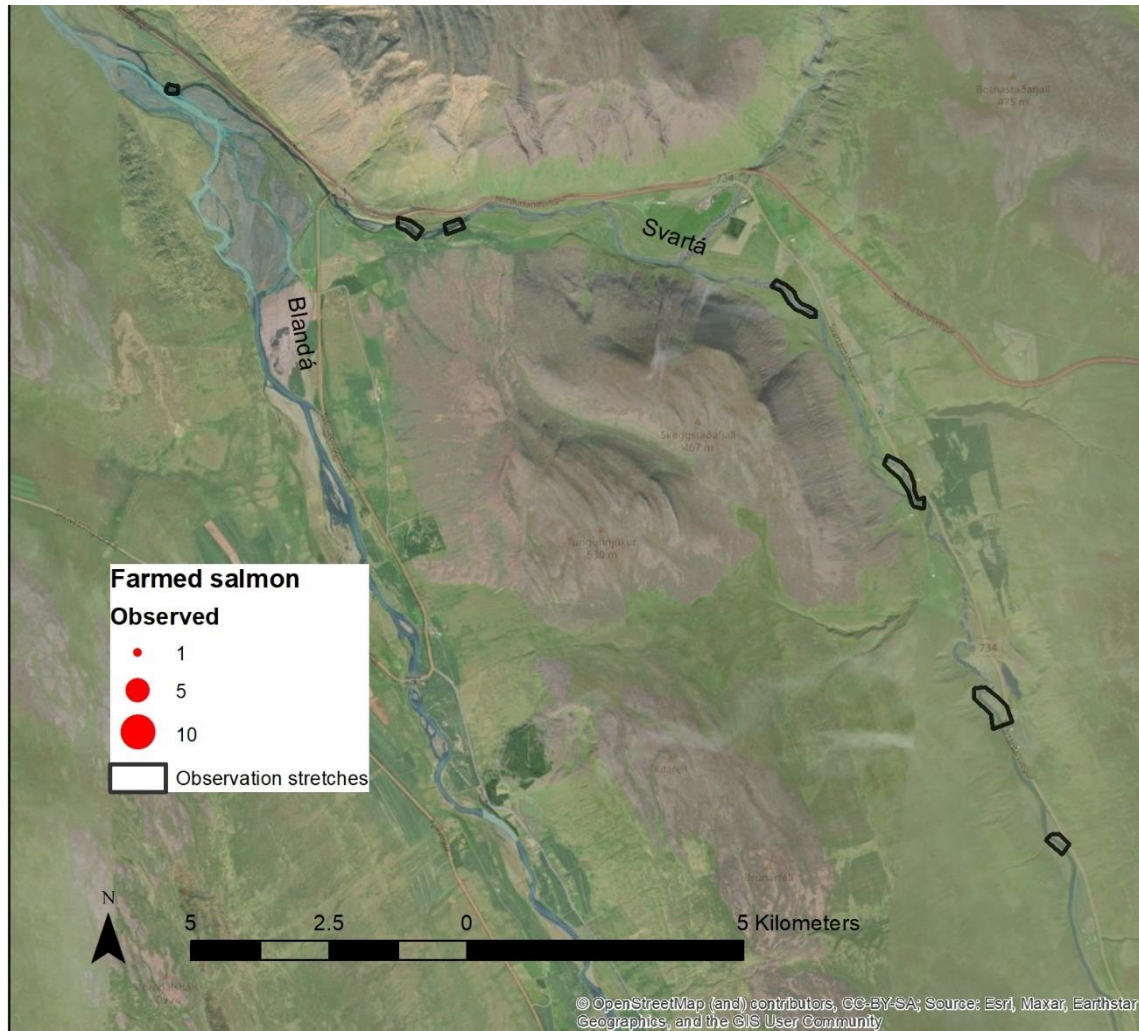


Figure 6. Hybrid map/aerial photo of Svartá with stretches for snorkeling. No farmed salmon were observed in Svartá.

Vatnsdalsá

In Vatnsdalsá, snorkeling was performed in one location downstream the small lake Vatnsdalsflóð (Flóðið), in several locations/stretches in the upper part of Vatnsdalsá and in the tributary Álká (Figure 7). The visibility was poor in the lower and upper part (2-3 m), and moderate in the remaining parts of the river (4-5 m). Approximately 159 wild salmon, 170 trout and 259 Arctic char were observed in the surveyed river stretches. No farmed salmon were observed. However, farmed salmon were caught during fishing in Vatnsdalsá in the autumn prior to snorkeling, and it is possible that farmed salmon may have been present in parts of the river not covered by snorkeling.

The visibility is somewhat limiting for effective snorkeling surveys in parts of Vatnsdalsá, particularly in the deep pool (Stekkjafoss) in the upper part and downstream Vatnsdalsflóð. Large parts of the upper river areas had sufficient visibility for snorkeling.

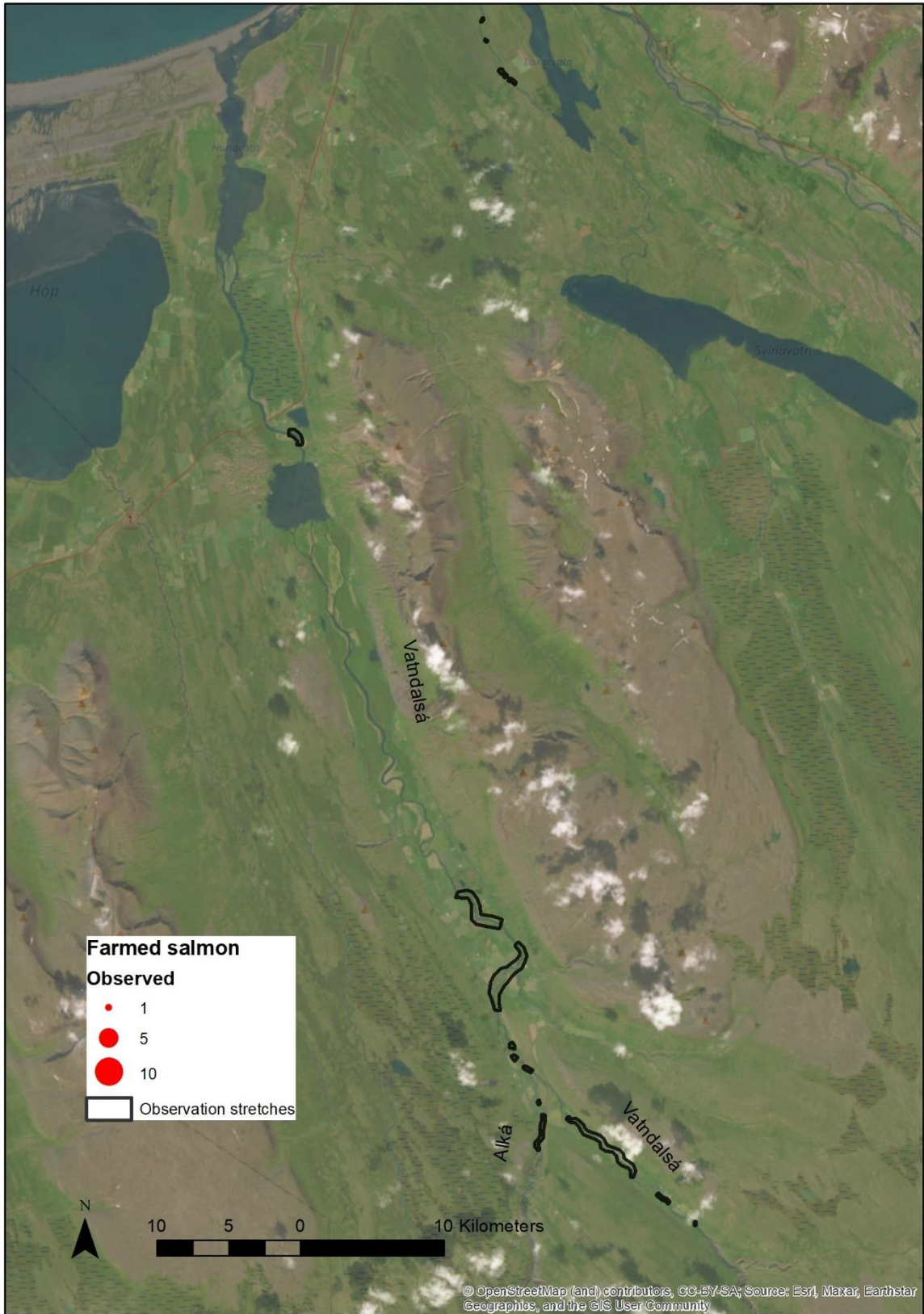


Figure 7. Hybrid map/aerial photo of Vatnsdalsá with stretches for snorkeling. No farmed salmon were observed in Vatnsdalsá during the survey.

Hrútafjarðará/Siká

In Hrútafjarðará, several long stretches were snorkeled, in total covering a large part of the anadromous river reach, including important areas of the tributary Siká (Figure 8). The visibility for underwater observation was very good (8-10 m). In total we observed 34 farmed salmon, whereof 32 were captured, while the remaining two were wounded with the speargun but managed to escape. Most farmed salmon were located in the upper part of Hrútafjarðará, with 17 of the fish in the pool “Stokkur”, while five were located in the tributary river Siká. 31 of the farmed salmon were caught with spearguns and one was caught using a gill net.

The visibility and river size of Hrútafjarðará makes this river well suited for snorkeling surveys and effective hunting of farmed fish with spearguns.



Catch of 17 farmed salmon from the pool “Stokkur” in Hrútafjarðará (photo: Leó Alexander Guðmundsson).

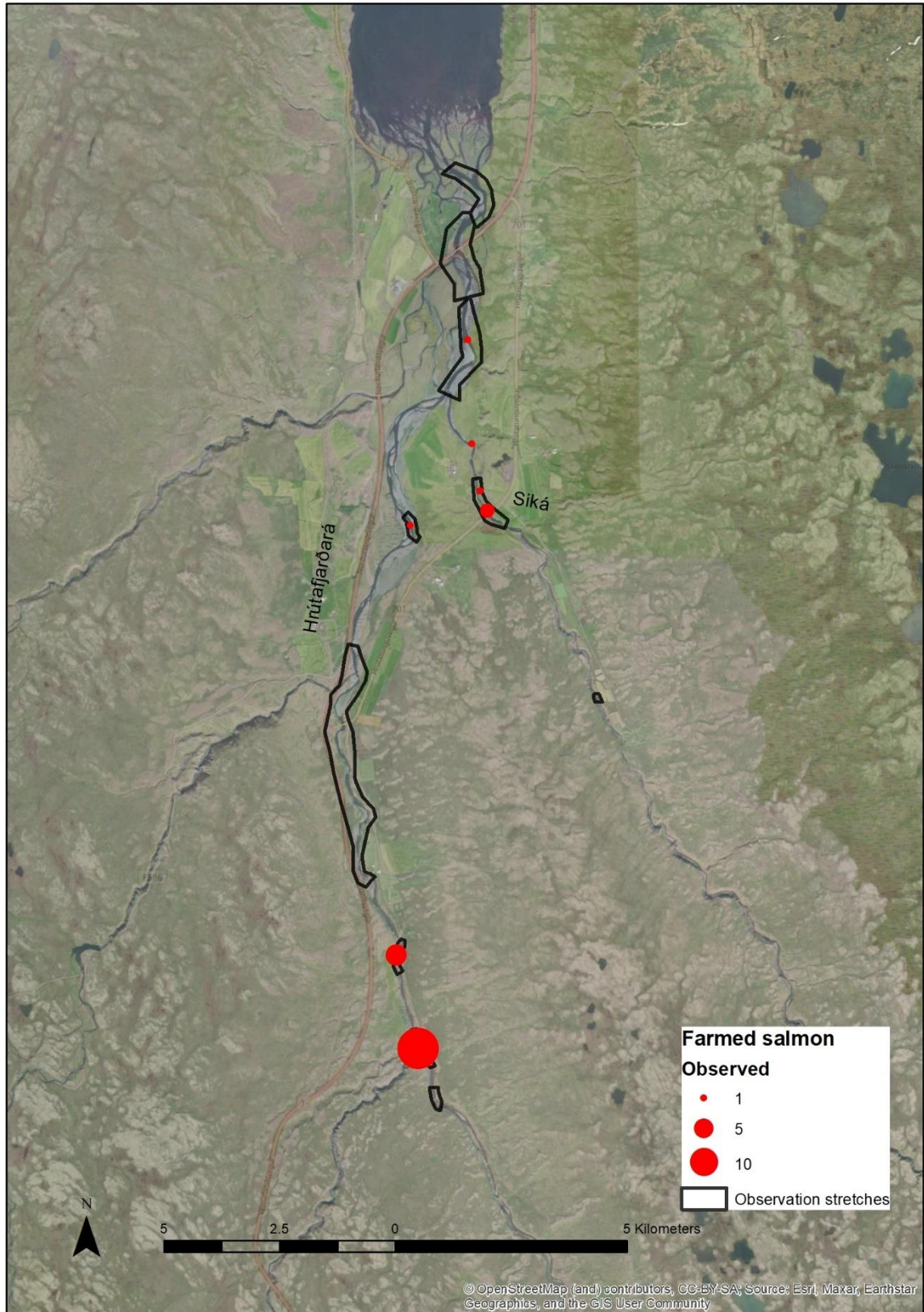


Figure 8. Hybrid map/aerial photo of Hrótafjarðará and Síká, with stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

Laxá í Döllum

Snorkeling was performed in various pools/stretchers covering the range of the anadromous reach of Laxá í Döllum (Figure 9). Visibility was good in the upper part (> 6 m), immediately below the natural migration barrier, but poor further down in the river (2-3 m). The visibility was likely affected by strong winds stirring up algae and fine sediments in shallow areas. Six farmed salmon were observed, whereof three were captured with spearguns. Further hunting was obstructed due to poor visibility. The farmed salmon observed were spread along the entire river reach, with the uppermost salmon having ascended almost 25 km upriver.

The snorkeling surveys were hampered due to poor visibility, but under better circumstances (less wind) snorkeling surveys are likely to be a well-suited method for surveying salmon and hunting farmed salmon in Laxá.

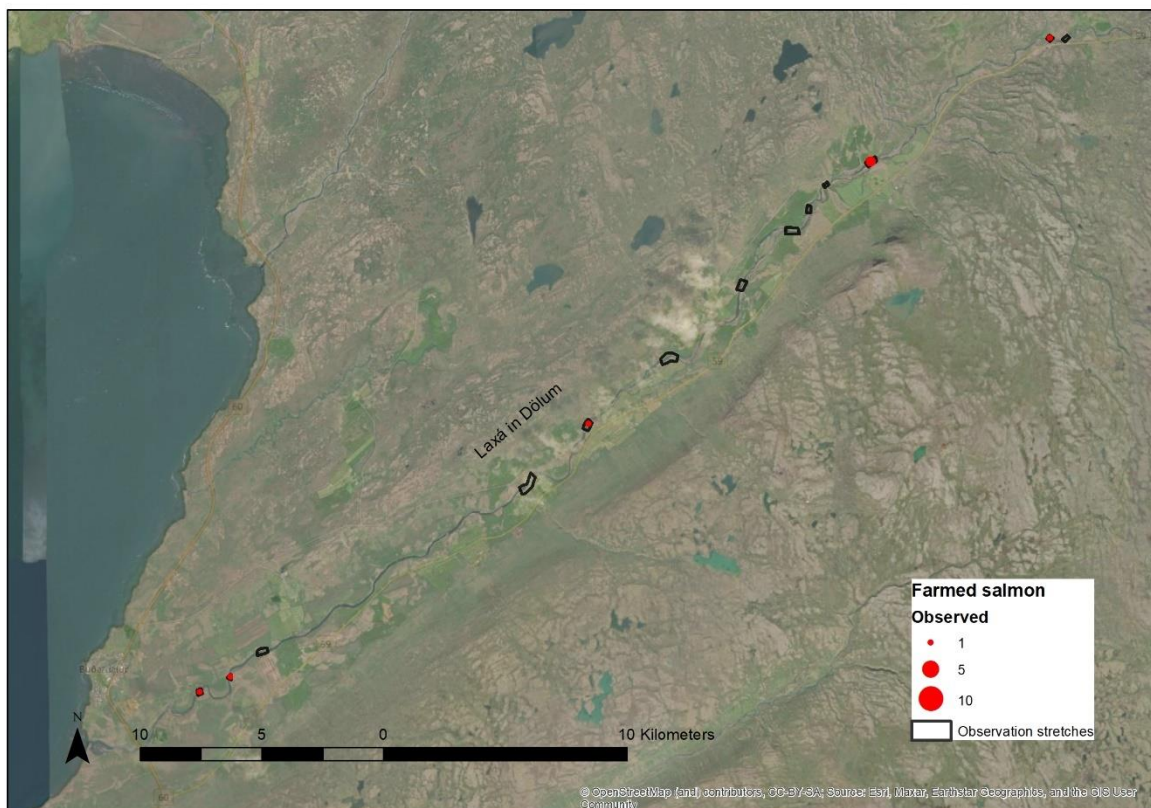


Figure 9. Hybrid map/aerial photo of Laxá í Döllum with stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

Langadalsá

Snorkeling was performed in selected locations in the upper, middle and lower parts of Langadalsá (Figure 10). The visibility was very good (7-10 m). One farmed salmon was caught in the pool below the bridge in the lower part. A weir with a fish counter in the lower part of the river was closed to hinder further up-migrating of farmed salmon during the autumn. Some farmed fish had however migrated up prior to closing the passage, and three were caught later in the autumn in this river. Large parts of the Langadalsá are quite shallow during low flow conditions, but the deeper parts are well suited for snorkeling surveys.

Hvannadalsá

Snorkeling was performed in a reach with several pools and waterfalls (Figure 10). The visibility was very good (>10 m). Five farmed salmon were observed. All fish were hiding in deeper parts under

waterfalls, out of reach from hunting with spearguns. At least two farmed fish were reported caught in this river later in the autumn.

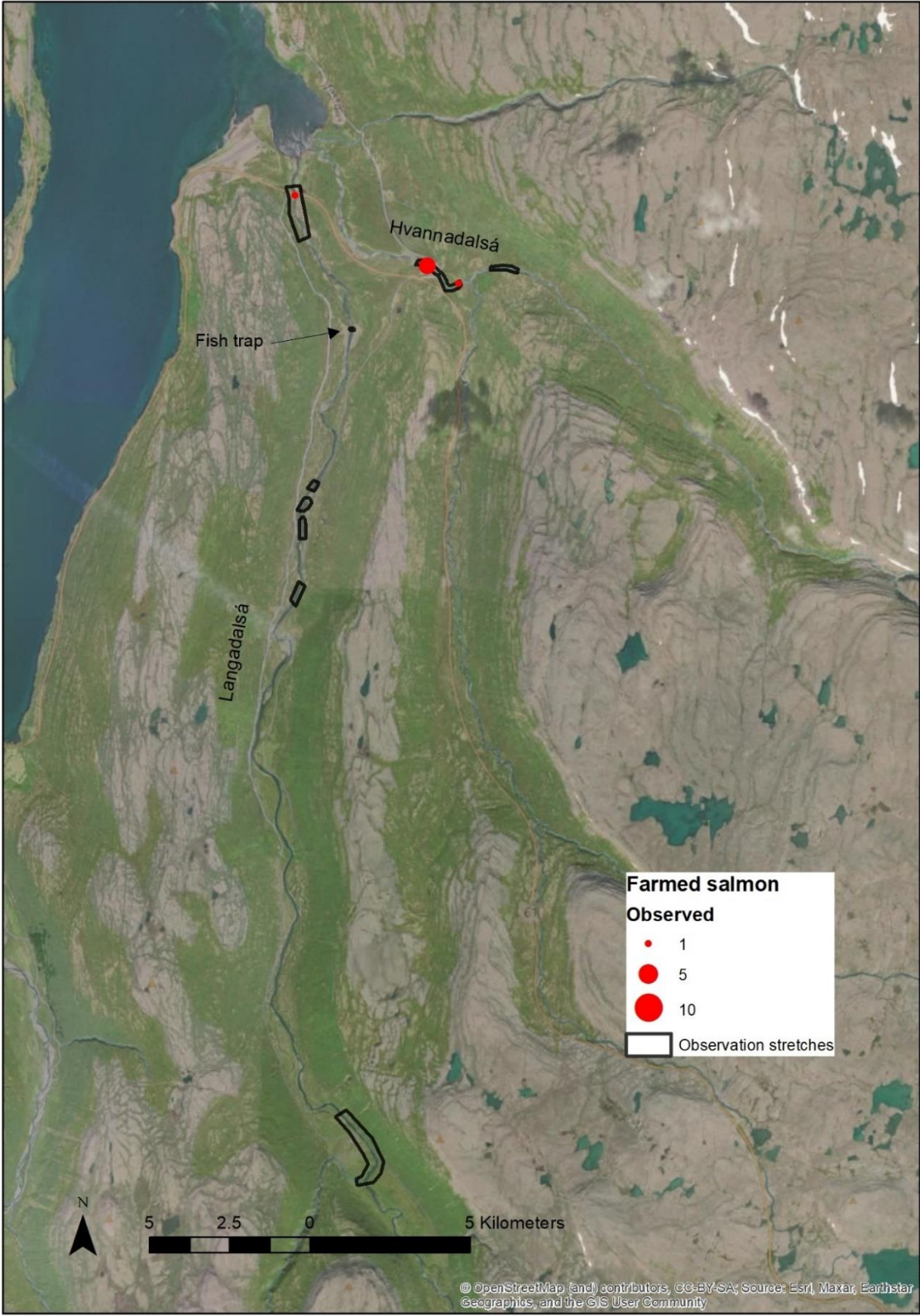


Figure 10. Hybrid map/aerial photo of Langadalsá and Hvannadalsá, with stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

Ísafjarðará

Snorkeling was performed in large parts of the upper parts of Ísafjarðará (Figure 11). The visual conditions were good (6 m). Six escaped salmon were observed, whereof five were captured with spearguns. Most of the farmed salmon were aggregated in bigger pools in the upper part of the river. The lower reaches were in general shallow with few pools and considered less likely to hold farmed salmon.

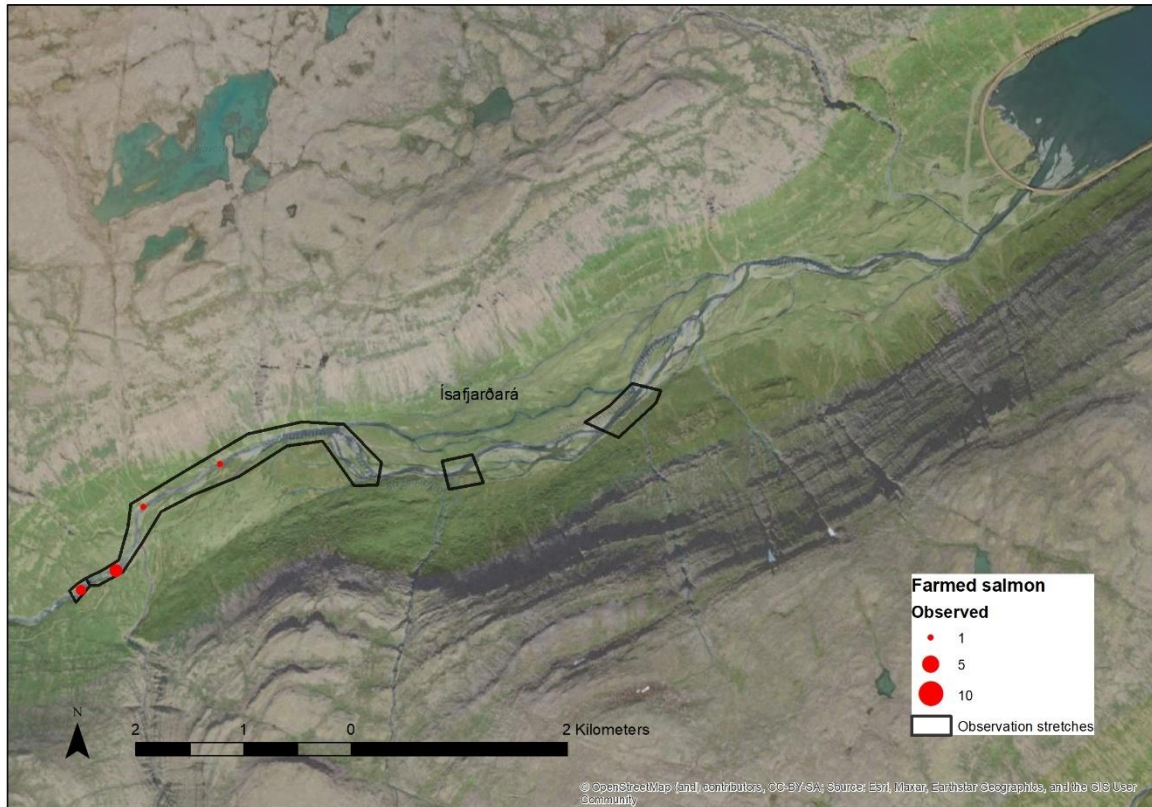


Figure 11. Hybrid map/aerial photo of Ísafjarðará, with stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.



Farmed salmon caught in Ísafjarðará (photo: Leó Alexander Guðmundsson).

Laugardalsá

In Laugardalsá, only a ca 300 m long stretch from the fish ladder and down to the sea was snorkeled (Figure 12). The visibility was poor, but sufficient to cover the total river width during the prevailing low-flow conditions. Only one seatrout and neither farmed nor wild salmon were observed. There have been observations of at least five farmed salmon on the camera counter in the fish ladder, suggesting that farmed fish have migrated further up in the river system. Due to limited time available and poor visibility, however, it was not considered feasible to locate these farmed fish in the upstream stretches in Laugardalsá.

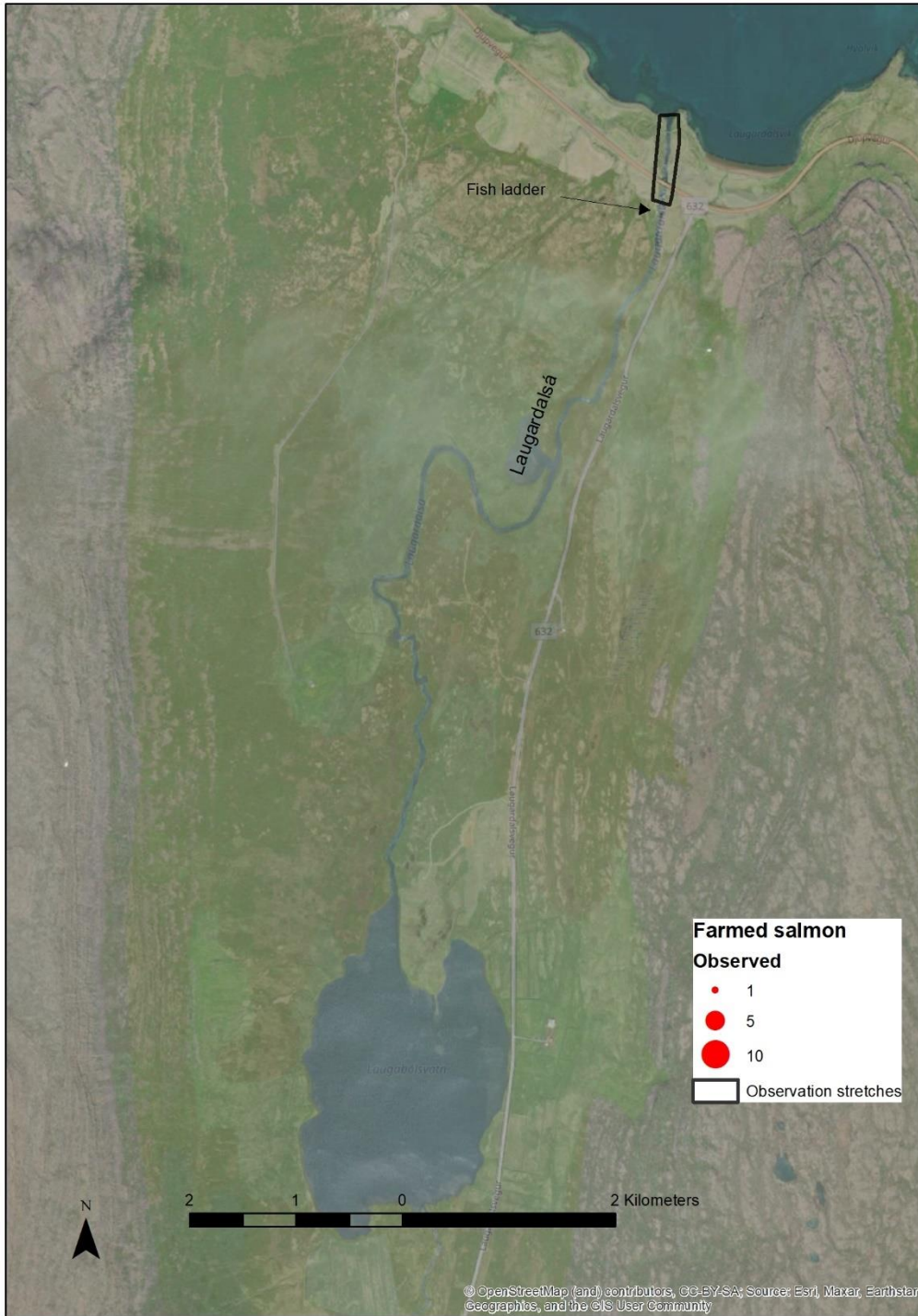


Figure 12. Hybrid map/aerial photo of Laugardalsá, with stretches for snorkeling. No farmed salmon were observed.

Staðará

Snorkeling was performed in several locations/stretches in the upper part of Staðará, as well as some selected larger pools in the middle and lower part of the river (Figure 13). Six farmed salmon were observed, whereof five were captured with spearguns. Four of the farmed salmon were located in pools below rapids in the upper part of the river, whereas the remaining two were located in the middle section of the river.

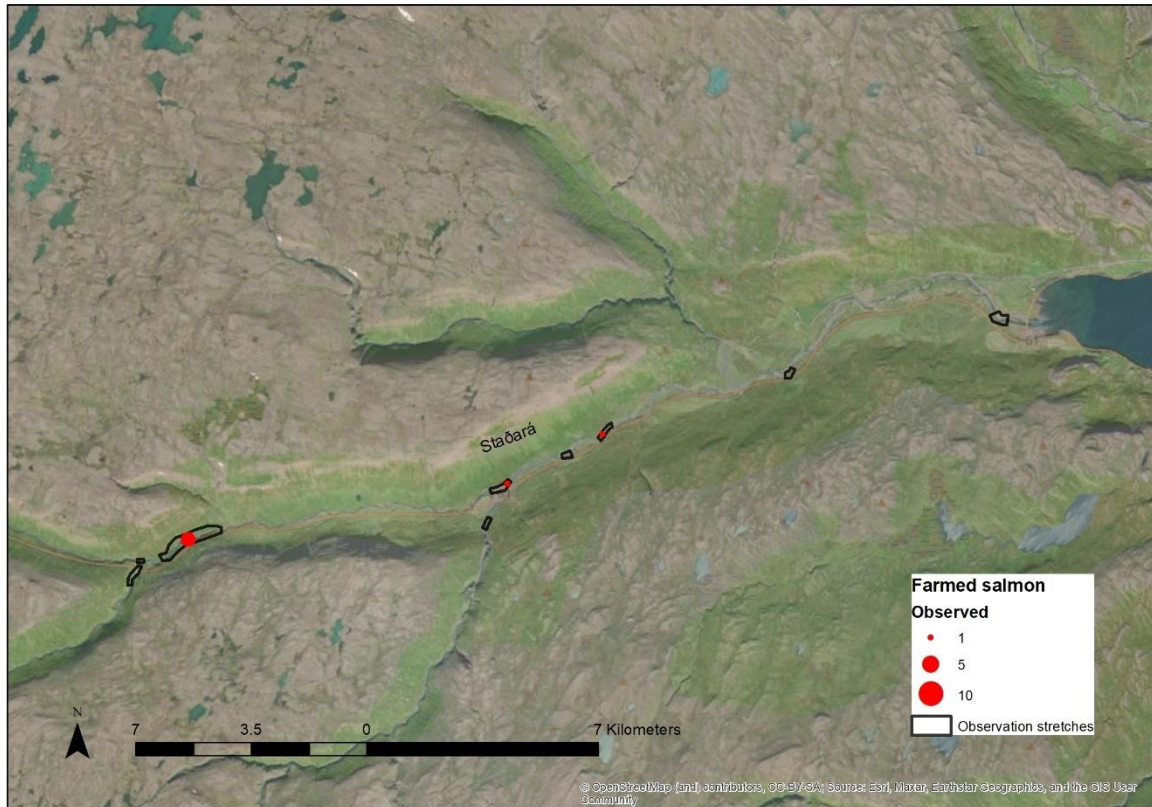


Figure 13. Hybrid map/aerial photo of Staðará, with stretches for snorkeling and locations of escaped farmed salmon observations. The size of the points indicates number of farmed salmon observed on the different locations.

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