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The risk of individual fish being captured multiple times in a catch and release fishery

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Abstract

The proportion of angled Atlantic salmon *Salmo salar* L. being caught and released has increased. If individuals are repeatedly captured, this may have fish welfare consequences. Of 995 Atlantic salmon tagged during catch and release in eight Norwegian rivers, 10% were captured twice, while 3% were captured three times within the same fishing season. The probability that released salmon were captured again decreased with decreasing time left of the fishing season, decreased for larger-sized fish and varied among rivers/years. Increased exploitation rates within the river, indicating an increased fishing pressure, strongly increased the probability that fish would be recaptured. However, the proportion of salmon caught a second time was much lower than the total exploitation rates in the same rivers (which was on average 46%). For fish tagged in the sea, the likelihood of being angled decreased with time since entering the river, which may explain why the recapture rates of caught and released fish were lower than the total exploitation rates.

KEYWORDS

angling, Atlantic salmon, catch and release, exploitation, management, *Salmo salar*

1 | INTRODUCTION

Exploitation of fishery resources has become a major conservation issue, not only in commercial fisheries, but also in recreational fisheries (Cooke & Cowx, 2004). Cooke and Cowx (2004) estimated that global angling catches could be as high as 47 billion fish annually. Many fishes targeted by anglers face various threats, resulting in reduced populations (e.g. Forseth et al., 2017; Kerr et al., 2009; Lucas & Baras, 2001; Paukert et al., 2017), and thereby a reduced harvestable surplus available for fisheries. Catch and release (C&R), which refers to live fish being released to the waters where they were captured after being angled, is a conservation practice that has been adopted by fishers and managers to reduce the potential effects of angling on fish populations while still maintaining recreational fisheries (Arlinghaus et al., 2007).

Atlantic salmon, *Salmo salar* L., is a popular fish species for recreational fisheries, but catches have fallen due to declining populations over large parts of its distribution area (Anon., 2018; ICES, 2019). Consequently, the proportion of captured fish being released has increased, both voluntarily by anglers and due to harvest restrictions in terms of quotas, size restrictions and/or female harvest restrictions (ICES, 2019; Lennox, Falkegård, Vøllestad, Cooke, & Thorstad, 2016).

The effects of recreational angling on individual Atlantic salmon behaviour, wounding or survival have been investigated (summarised by Lennox et al., 2017). Survival after release can be high (>90%), provided the fish are carefully handled, and the water temperature is not too high (Lennox et al., 2017). However, fish that are released may still be vulnerable to exploitation.

Catch and release can be an effective management tool to enhance declining Atlantic salmon populations (Lennox et al., 2017; Thorstad, Næsje, Fiske, & Finstad, 2003). However, if substantial portions of a population are repeatedly subjected to multiple C&R events, this may not be true. For example, individual white-spotted charr, *Salvelinus leucomaenis* (Pallas), were captured by angling up to seven times (Tsuboi & Morita, 2004). Multiple recaptures may increase the risk of mortality and injury to individual fish, and the vulnerability of fish to multiple recapture is therefore an important aspect of catch and release fisheries. For welfare reasons, the Norwegian Food Safety Authority has required that the Atlantic salmon recreational fisheries should be organised so there is minimum risk that the same individuals will be caught and released multiple times (letter to the Ministry of Fisheries and Coastal Affairs dated 24 June 2010, ref. 2007/79076). However, recapture rates have previously only been studied in one Norwegian river (Thorstad et al., 2003). Recapture rates may vary with several factors and among rivers, and it is therefore important to examine the recapture rates of Atlantic salmon released in C&R fisheries in several rivers. Further, catch statistics are used to assess the status of Atlantic salmon populations and the attainment of spawning targets (Anon., 2018; Forseth et al., 2013). For precise assessments, it is important to know whether the same individuals are recorded as captured more than one time in the catch statistics.

The aim of this study was to ascertain the extent to which released salmon remain vulnerable to exploitation by recreational anglers by examining the proportion of released fish being captured again in the catch and release fisheries of eight Norwegian rivers. Specific aims were to determine: (a) the proportion of caught and released Atlantic salmon recaptured later in the same fishing season; (b) how many times each individual was recaptured; (c) variation in recapture rates among rivers and years; (d) whether risk of being recaptured was dependent on fish size, sex, time of the season, capture gear and the exploitation pressure in each river in terms of overall catch rates; (e) time between catch events for individuals captured more than once; and (f) whether the catchability of individual fish changed with time after they had entered the river. The study was performed by tagging 995 Atlantic salmon with external tags during catch and release angling and based on reports of recaptures by anglers incentivised by a high reward for reporting.

2 | MATERIALS AND METHODS

2.1 | Tagging of fish during catch and release angling and reports of recaptures

During catch and release events, a total of 995 Atlantic salmon were tagged with individually numbered external T-bar anchor tags (n = 848, Hallprint Fish Tags, South Australia) or radio tags (n = 147, model F2120, outline dimensions 21 × 52 × 11 mm, Advanced Telemetry Systems, Isanti, Minnesota) in eight Norwegian rivers (Tables 1 and 2, Figure 1). Tags were attached beneath the dorsal fin after the fish had been landed. The T-bar tags were inserted in the dorsal muscle with a cartridge-fed applicator by fishing guides or anglers. Guides and anglers participating in the study were trained in how to perform tagging, and they were instructed to handle the fish according to best practices recommended by the Norwegian Association of Hunters and Anglers, such as using knotless landing nets and limiting air exposure. Radio tagging was performed by scientists who accompanied the anglers. Radio-tagged salmon were kept in a water-filled tube during tagging, and the tags were attached by steel wires through the musculature beneath the dorsal fin, as described by Økland et al. (2001). Radio tags were used for other purposes than studying recapture rates, but because these tags are external and easily visible to anglers, they were included in the data set. Behavioural data from these studies are available in Havn et al. (2015), Lennox et al. (2015), Lennox, Cooke, et al. (2016), and Lennox, Diserud, et al. (2016).

Data on the capture location, date, total length of the fish and individual tag number were recorded. The fish were released back into the river immediately after capture and tagging. A high reward (500 NOK) was offered to people reporting recaptures to incentivise reporting of recaptures. A cell phone number and email address, where scientists were available to receive information on recaptures, were printed on the tags. The study was performed in close collaboration with the local angling and river owner organisations, and they also provided local opportunities for reporting recaptures. The study was well-known locally through this collaboration, and information was also spread via notices on boards along the rivers, in local newspapers and other media, in local meetings and by distribution of about 6,000 brochures describing the project. Scientists were also present at the rivers to spread information about the study. The study was conducted according to the Norwegian regulations for treatment and welfare of animals and approved by the Norwegian Animal Research Authority.

To estimate and limit the effects of tag loss, 544 fish had T-bar tags inserted into the dorsal musculature in pairs, with one tag on each side of the dorsal fin. With a few exceptions, salmon tagged in rivers Gaula, Verdalselva and Lakselva were all double-tagged in 2012, as were salmon in all rivers in the years after, except Lærdalselva in 2016. Of the 54 originally double-tagged salmon that were recaptured, 12 salmon had only one tag left. Since a double-tagged salmon has two tags it can lose, the probability p of losing one tag is 0.127 ($2 \times p(1 - p) = 12/54$) assuming that tags are lost independently. The probability of a fish tagged with two tags losing both tags is 0.016. Hence, the recapture rates are 12.7% underestimated in rivers/years when the fish were tagged with only one tag and 1.6% underestimated in rivers/years when the fish were tagged with two tags. This estimate was used to determine to which extent the potential tag loss could have impacted any of the reported values in this study, but due to insignificant effect in most rivers and years (see results), results were not generally corrected according to this estimate. The study rivers were distributed from the southern to the northern part of Norway

TABLE 1 Overview of study rivers and total body length of the salmon tagged in each river

River	Position of river mouth	Mean annual water discharge (m^3/s)	Average length (cm) of tagged salmon (range, *SD*)	Angling season	Average total salmon catch in the river (number of fish)	Average proportion (%) of total catch caught and released	Fishing regulations influencing the extent of catch and release
Lakselva	70°04'38.0"N 24°55'39.1"E	27	88.3 (53–121, 15.8)	2012:1 June – 31 August 2013:1 June – 31 August 2014:1 June – 31 August	1562	35	2012: Salmon larger than 80 cm caught after 21th July must be released. 2013: Only one female >80 cm could be killed per person before 15 July. Salmon larger than 80 cm must be released after 15th July. 2014: Same as in 2013
Ranaelva	66°20'10.4"N 14°09'21.4"E	78	79.9 (46–121, 16.0)	2013:1 July–14 August 2014:1 July–3 September	569	74	Both years: Personal quota of 1 salmon per 24 hr, 2 per week and 4 per season. Of seasonal quota, only 2 salmon >65 cm could be killed. Obligatory release of all females >65 cm
Verdalselva	63°47'42.2"N 11°28'23.6"E	52	80.1 (50–101, 13.8)	2012:20 June–20 July 2013:10 June–31 July 2014:10 June–31 July	234	41	2012: Personal quota of 2 salmon per season. 2013 and 2014: Personal quota of 2 salmon per season. River quota of 300 salmon. Obligatory release of females after 1 July
Gaula	63°20'19.7"N 10°15'18.9"E	93	86.0 (50–113, 13.7)	2012, 2013 and 2014: 1 June–31 August	3,835	38	2012: Personal quota of 1 salmon per 24 hr and 8 per season of which only 4 >80 cm. 2013: Personal quota of 1 salmon per 24 hr and 8 per season of which only 3 >80 cm. Obligatory release of females in July–August. 2014: Personal quota of 1 salmon per 24 hr and 5 per season of which only 2 >80 cm. Obligatory release of females after 17 June and of salmon >65 cm in August
Orkla	63°18'39.2"N 9°49'50.5"E	70	76.0 (50–117, 13.6)	2012, 2013 and 2014: 1 Jun–31 Aug	3,304	45	2012: Personal quota of 1 salmon per 24 hr and 8 per season of which only 4 >80 cm. Obligatory release of females in August. 2013: Personal quota of 1 salmon per 24h and 8 per season of which only 2 >80 cm. Obligatory release of females in July–August. 2014: Personal quota of 1 salmon per 24 hr and 5 per season of which only 2 >80 cm. Obligatory release of females after 17 July and of salmon >65 cm in August
Osen-Vestre Hyen	61°33'04.7"N 5°24'00.3"E	20	76.3 (39–100, 10.5)	2013 and 2014: 1 June–15 August	267	73	Both years: Personal quota of 2 or 3 salmon per week
Lærdalselva	61°06'07.7"N 7°28'34.0"E	36	87.8 (47–119, 11.1)	2015:10 June–15 August 2016:5 June–20 August	1,121	77	Both years: Obligatory release of all females

(Continues)

TABLE 1 (Continued)

River	Position of river mouth	Mean annual water discharge (m^3/s)	Average length (cm) of tagged salmon (range, *SD*)	Angling season	Average total salmon catch in the river (number of fish)	Average proportion (%) of total catch caught and released	Fishing regulations influencing the extent of catch and release
Otra	58°08'58.1"N 8°00'21.3"E	149	66.4 (43–114, 11.6)	2012 and 2013: 1 June–15 September	1566	12	2012: Personal quota of 2 salmon per 24 hr and 20 per season. Obligatory release of salmon >90 cm. 2013: Personal quota of 2 salmon per 24h and 20 per season of which only 2 >80 cm. Obligatory release of salmon >90 cm

Note: Duration of the angling season, average number of salmon captured during the angling season and average proportion of the angled salmon that was released in each river during the study years are also given.

(58–70°N, Figure 1, Table 1). Mean annual water discharge in these rivers varied between 20 and 149 m^3/s (Table 1). The length of the fishing season varied between 1.0 and 3.5 months. The proportion of total river catches being released varied between 12% and 77%. The variation in the percentages of fish caught and released in the different rivers stemmed from variation in personal quotas, obligatory release of females, obligatory release of large females or large fish of both sexes (Table 1), and that some anglers voluntary released their catch.

2.2 | Tagging of fish to examine catchability during the season

Another data set was used to examine whether the catchability of individual fish changed with time after they had entered the river. Data were obtained from 1,667 adult Atlantic salmon that were captured when returning from the ocean migration in bag nets in the sea (Namsen Fjord), 6–25 km from the mouth of the River Namsen, and tagged with Lea tags in the years 1994 (n = 303), 1995 (n = 487), 2007 (n = 422), 2008 (n = 455). Lea tags, which are small individually numbered plastic tags with printed information on where to report recaptures, were attached with steel wires beneath the dorsal fin. After subtracting salmon that were caught in other bag nets or rivers, 1,402 Atlantic salmon were assumed to be able to enter the River Namsen, and 212 (15.7%) were reported recaptured by anglers in the river. Studies of radio-tagged salmon captured in the same bag nets showed that they spent on average <2.5 days from tagging to being recorded 9 or 11 km upstream in the river (Thorstad, Heggberget, & Økland, 1998; E.B. Thorstad & P. Fiske, unpublished data). It was assumed that Atlantic salmon being captured in bag nets in the sea behaved as uncaptured fish when entering the river, since they were captured by passive gear and not played before being tagged.

2.3 | Data analyses

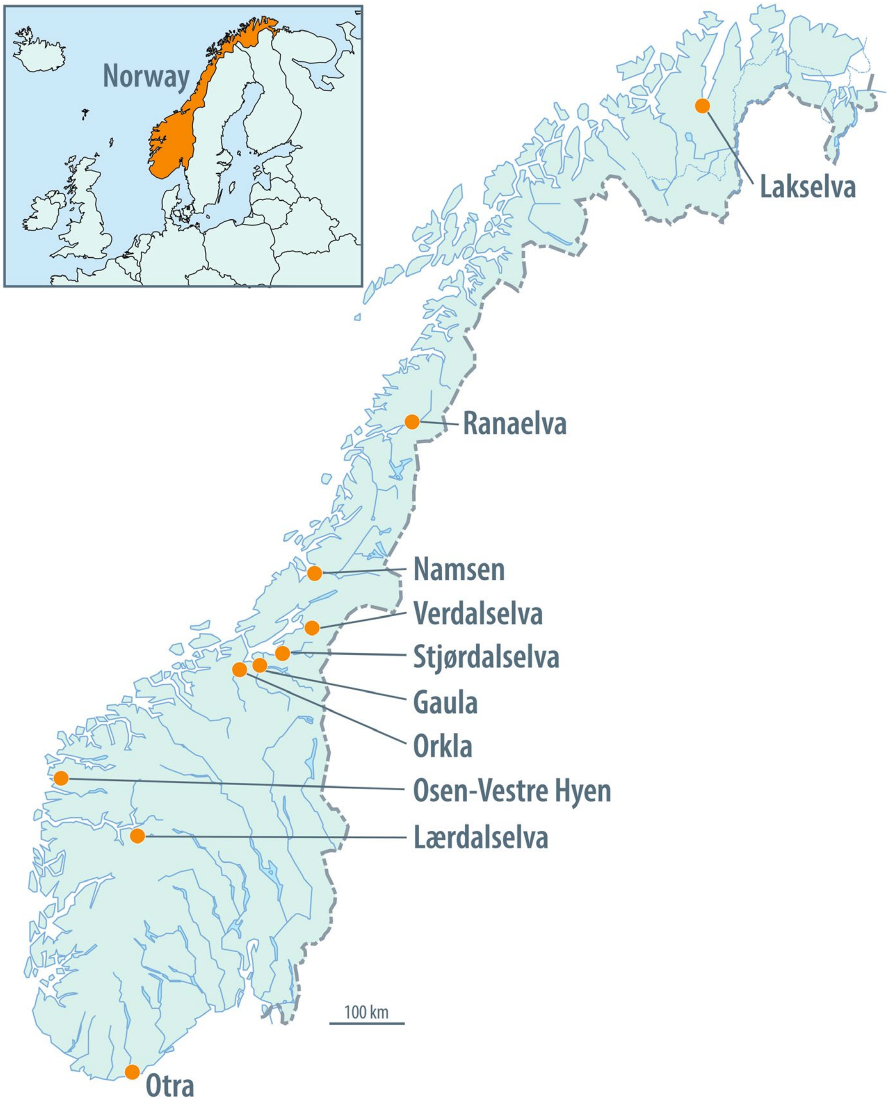
The statistical analyses and modelling were carried out using the statistical software R (R Core Team, 2018, v. 3.4.4). Recapture probabilities of caught and released fish were modelled by a generalised linear model with a binomially distributed response (Dalgaard, 2008). Because the data set includes two years (2015, 2016) of data from the River Lærdalselva and three years of data (2012, 2013 and 2014) from other rivers, the model cannot effectively account for year as a random factor in a mixed model, so year was considered as a fixed effect. Explanatory variables considered to influence the recapture probability were body length, sex, tag type, river, year, days left of fishing season when released, capture gear and river/year-specific total capture rates. Fish length was standardised around river-specific mean lengths to emphasise how variation in body length within the river affects recapture rate. How recapture probability was affected by differences in mean length among rivers was accounted for by the river factor coefficients. The river/year-specific estimates of total

TABLE 2 Overview of tagged salmon and recaptures per river per year

River	Year	Tagged total (# fish)	Tagged with T-bar tags (# fish)	Tagged with radio tags (# fish)	Recaptured with T-bar tags (# fish)	Recaptured with radio tags (# fish)	Recapture rate total	Model-based predictions of recapture rate	Total capture rate estimated for total river population	Recaptured in the sea T-bar/radio (# fish)	Recaptured in another river T-bar/radio (# fish)	Found dead T-bar/radio (# fish)
Gaula	All	150	123	27	24	5	19.3%	14.0		1/0	0/0	5/0
	2012	54	54	0	20	0	37.0%	33.7	52%	1/0	0/0	2/0
	2013	45	18	27	2	5	15.6%	18.7	41%	0/0	0/0	3/0
	2014	51	51	0	2	0	3.9%	3.3	32%	0/0	0/0	0/0
Lakselva	All	119	80	39	7	9	13.4%	12.4		0/0	1/0	0/0
	2012	59	59	0	6	0	10.2%	14.5	73%	0/0	0/0	0/0
	2013	21	21	0	1	0	4.8%	5.6	57%	0/0	1/0	0/0
	2014	39	0	39	0	9	23.1%	12.4	56%	0/0	0/0	0/0
Orkla	All	88	82	6	9	0	10.2%	8.9		2/0	1/0	1/0
	2012	39	39	0	7	0	17.9%	8.2	50%	1/0	0/0	1/0
	2013	28	22	6	1	0	3.6%	10.6	50%	1/0	1/0	0/0
	2014	21	21	0	1	0	4.8%	7.8	44%	0/0	0/0	0/0
Osen-Vestre Hyen	All	103	103	0	16	0	15.5%	11.2		2/0	0/0	0/0
	2013	79	79	0	16	0	20.3%	17.8	61%	2/0	0/0	0/0
	2014	24	24	0	0	0	0%	2.2	16%	0/0	0/0	0/0
Otra	All	95	20	75	1	7	8.4%	8.1		0/0	0/0	1/5
	2012	61	9	52	0	6	9.8%	9.3	45%	0/0	0/0	1/3
	2013	34	11	23	1	1	5.9%	6.3	47%	0/0	0/0	0/2
Ranaelva	All	62	62	0	5	0	8.1%	6.4		0/0	0/0	0/0
	2013	39	39	0	3	0	7.7%	6.5	82%	0/0	0/0	0/0
	2014	23	23	0	2	0	8.7%	6.4	-	0/0	0/0	0/0
Verdalselva	All	30	30	0	1	0	3.3%	0		0/0	1/0	0/0
	2012	23	23	0	1	0	4.3%	0	18%	0/0	1/0	0/0
	2013	5	5	0	0	0	0%	0	31%	0/0	0/0	0/0
	2014	2	2	0	0	0	0%	0	9%	0/0	0/0	0/0
Lærdalselva	All	348	348	0	14	0	4.0%	3.3		0/0	0/0	1/0
	2015	189	189	0	10	0	5.3%	2.6	56%	0/0	0/0	1/0
	2016	159	159	0	4	0	2.5%	4.4	57%	0/0	0/0	0/0

Note: The number of recaptures and recapture rates is based on recaptures in the same river and same fishing season as they were tagged. Model-based predictions for recapture rates using the best model for recapture probability for each river and year are also presented. Total capture rates for the entire river population each year are based on estimates from the Norwegian Scientific Advisory Committee for Atlantic Salmon (not calculated for the River Ranaelva in 2014). Few salmon were recaptured either in the sea, in rivers other than they were originally tagged or were found dead.

FIGURE 1 Map of Norway showing the location of the eight rivers where salmon were tagged during catch and release angling. In addition, the location of the River Namsen is shown, from which an additional data set was obtained [Colour figure can be viewed at wileyonlinelibrary.com]



exploitation rates (the proportion of the salmon in the river being captured during the angling season, including caught and released salmon) were collected from the Norwegian Scientific Advisory Committee for Atlantic Salmon (published at www.vitenskapsradet.no). The estimates were done as described by Forseth et al. (2013), using a model developed from 214 local estimates describing the exploitation rates for different fish sizes and differently sized rivers, in addition to using local, annual fish counts, which existed for most rivers included in this study, together with catch statistics. The annual estimates of exploitation rates for each river were adjusted according to information on fishing pressure (e.g., number of anglers, organisation of the fishery, quotas, length of the season, permitted gear) and fishing conditions (favourable/unfavourable discharge or temperature). There was no estimate of the exploitation rate from the committee for the River Ranaelva in 2014, so the 2013 estimate was used for 2014. A maximum model including all relevant explanatory variables as fixed effects was simplified by stepwise reduction based on the Akaike information criteria (AIC). A change in AIC of more than two was considered as enough support for keeping a variable in the model. The models gave no indication of overdispersion, that is that the error distribution has a variance larger than expected (Crawley, 2007).

A null model was used to test whether the catchability of individual fish changed with time after entering the river based on data from the River Namsen, where it was assumed that each salmon had a constant capture probability each day during the period when it was expected to be in river and the river was open for fishing. Each salmon was present in the river for 65.2 days during the fishing season, and 15.7% of them were reported to have been caught in the river. Under the assumption of equal capture probability each day, this gives a capture probability of 0.0024 per salmon per day. Using this assumption, an expected distribution of captures as a function of number of days after river entry was made, and this distribution was compared with the observed distribution.

3 | RESULTS

In total, 10% of the caught and released salmon (98 of 995 tagged salmon) were caught a second time during the same fishing season in the same river as they were first caught and released (Table 2). Recapture rates varied among rivers, from averages of 3% and 4% in Verdalselva and Lærdalselva, to an average of 19% in Gaula. In some rivers, recapture rates varied considerably among years, particularly in Gaula (from 4% in 2014 to 37% in 2012), Lakselva (from 5% in 2013 to 23% in 2014) and Osen-Vestre Hyen (from 0% in 2014 to 20% in 2013). The time between release and second capture within the same river and year was on average 24 days (*SD* = 17.4, range 1–78). Only one salmon (0.1%, in Lakselva) was captured a third time. No salmon was captured more than three times. Fifty-nine salmon (of 91 salmon for which information was provided on their destiny, i.e. 65%) were killed by the anglers when they were recaptured, reducing the probability that individuals would be captured more than two times. Considering this, there were 32 salmon that were released the second time they were captured and hence could potentially be captured a third time, and with one of these salmon being recaptured, this constituted 3.1% of the fish. Tag loss impacted estimated recapture rates to a minor extent, because data from most rivers and years were based on fish with two T-bar tags or radio transmitters. Only in the River Orkla in 2012 and River Lærdalselva in 2016 could tagging with only one tag significantly impact the estimates of recapture rates. Adjusting for likely tag loss, the expected recapture rate for Orkla in 2012 was 20.6% instead of 17.9%, and in Lærdal in 2016, 2.9% instead of 2.5%. In other rivers and years, the effect of tag loss was considered inconsequential on the estimates.

Some salmon left the river after they were caught and released and were recaptured in other rivers; five salmon were recaptured in nearby sea fisheries, and three salmon were recaptured in neighbouring rivers (i.e. at least 0.8% of the salmon left the river after catch and release; Table 2). There was also some mortality after release, as 13 salmon (1.3% of the caught and released salmon) were found dead after release, mainly in the Gaula and Otra rivers (Table 2).

The best model for recapture probability included days left of the fishing season, tag type, river mean adjusted body length, total capture rate and river as factors (Table 3). Note that the coefficients are for the logit-linear model. The number of days left of the fishing season when caught and released had a positive effect on recapture rate, fish with T-bar tags had a lower recapture rate than those tagged with radio tags, larger salmon had a lower recapture rate, and a higher total exploitation rate in the river had a positive effect on recapture rate. All rivers had a lower average recapture rate than the River Gaula, although the rivers Orkla and Verdalselva were not significantly different. However, only one fish was recaptured in the River Verdalselva, so this estimate had a large standard error. Model-based predictions for recapture rates for each river and year using the best model for recapture probability were fairly well correlated with the observed recapture rates, except for some deviation for the River Orkla in 2012 and 2013 (Table 2).

The total exploitation rate in each river and year was in all cases higher than the recapture rates after catch and release. The total exploitation rate in the study rivers was on average 46% (±19SD, range 9%–82%), whereas the comparable recapture rate (River Ranaelva 2014 not included) was 9.3% (±9.6SD, range 0%–37%). The deviation between the total exploitation rate was an average 37 percentage points (±17SD, range 9–74 percentage points).

The length of the salmon reported by fishers recapturing the salmon was sometimes different from the length at tagging (Figure 2). However, there was no systematic difference between length reported at recapture and length measured at tagging (mean pairwise difference = 0.10 cm, 95% confidence interval [−0.90, 1.10]); the measurements deviated both ways, and there was no sign of anglers reporting the fish as larger than they were.

Data from salmon tagged in the sea near the River Namsen indicated that the salmon were easier to catch during their first days in the river and that they became more difficult to catch when they had been in the river for some time. The observed recaptures were higher than expected from the null model in the first 25 days after marking and lower thereafter (Figure 3). Most of the salmon were caught during the first 15 days after they were tagged in the sea (52% of the fish), whereas only 26% of the recaptures were expected during the same period based on expectations from the null model ($X^2 = 32.8$, $df = 1$, $p < 0.001$).

4 | DISCUSSION

This study showed that there is a risk that some individual Atlantic salmon will be captured two times within the angling season in Norwegian rivers (10% in the present study), but that the risk that individuals will be captured more than two times is very low (0.1%). The results are similar to other studies. Between 5% and 20% of Atlantic

TABLE 3 Generalised linear model of recapture probability of caught and released Atlantic salmon

Parameter	Estimate ± 95% CI	*z* value	*p* value
(Intercept)	−5.80 ± 1.91	−5.94	<0.001
Days left of season	0.0381 ± 0.0148	5.03	<0.001
T-bar tag	−0.841 ± 0.763	−2.16	0.031
Length	−0.0277 ± 0.0188	−2.89	0.004
Capture rate	6.29 ± 4.08	3.02	0.003
River Lakselv	−1.24 ± 1.20	−2.03	0.042
River Lærdal	−2.10 ± 0.830	−4.95	<0.001
River Orkla	−0.540 ± 0.882	−1.20	0.231
River Osen-Vestre Hyen	−1.26 ± 0.866	−2.84	0.005
River Otra	−1.24 ± 1.00	−2.42	0.016
River Ranaelva	−3.00 ± 1.76	−3.35	<0.001
River Verdalselva	−13.3 ± 1,445	−0.02	0.986

Note: The intercept gives the expected recapture rate for salmon with radio tags from River Gaula. Parameter estimates are given with the 95% confidence intervals (CI).

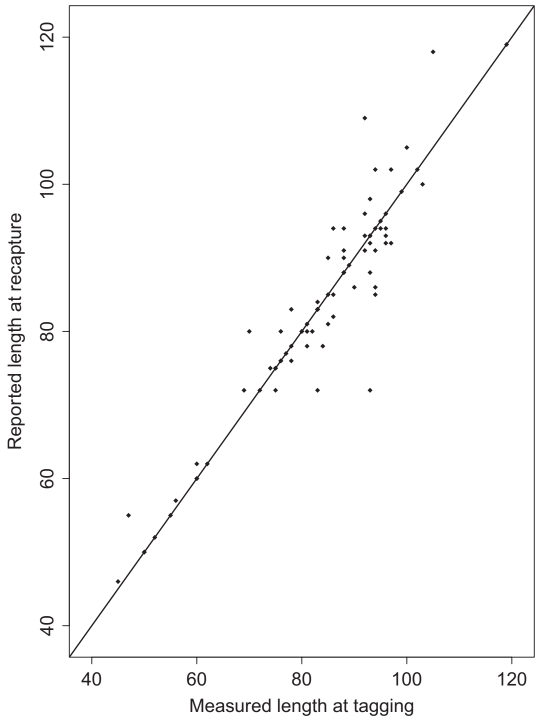


FIGURE 2 Relationship between the measured body length at tagging and the body length of the same fish reported by anglers who recaptured them

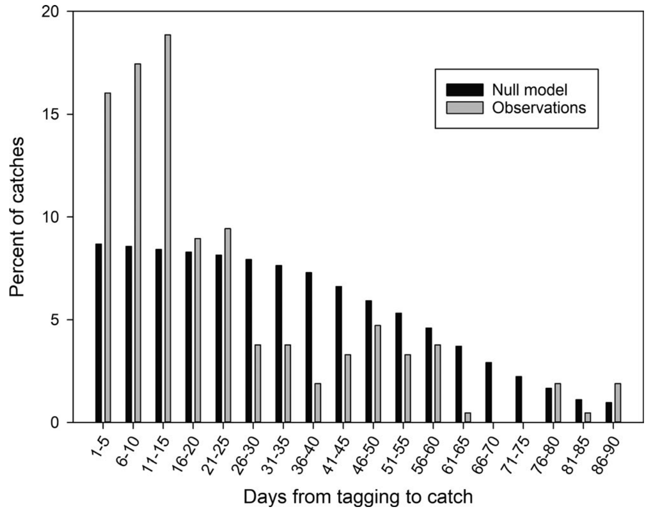


FIGURE 3 Distribution of number of days from tagging of individual Atlantic salmon captured in bag nets in the sea near the River Namsen to recapture by anglers in the River Namsen (n = 212 salmon reported recaptured out of 1,402 available for recapture). The null model is also shown, based on the assumption that each salmon had a constant capture probability each day during the period when it was assumed to be in river and the river was open for fishing

salmon caught and released in the Aberdeenshire Dee in Scotland were recaptured within the same angling season, 10%–11% in the Ponoi in Russia, 4% in the Alta in Norway and 5% in the River Spey in Scotland (Thorley, Youngson, & Laughton, 2007; Thorstad et al., 2003; Webb, 1998; Whoriskey, Prusov, & Crabbe, 2000). One reason for few fish being captured more than two times in the present study was that two-thirds of the fish were killed by the angler the second time they were caught, which reduced the probability that some fish would be caught a third time. However, when adjusting for this and considering only the fish that were released when they were caught the second time, the proportion being captured three times was still low (3%). Another reason for a low percentage of repeated recaptures was that the mean time between catch and recapture was 24 days (19 days in an earlier study in the River Alta, Thorstad et al., 2003), which does not allow for fish being captured many times within the angling season, because the season usually lasts about three months in Norway (but with some variation among rivers). A similarly low risk of being captured more than two times within the same season was found in the Ponoi, the Alta and the Spey (0%–0.5%, Thorley et al., 2007; Thorstad et al., 2003; Whoriskey et al., 2000). No individuals were captured more than three times in either the present study or in any of the other studies. Hence, it seems uncommon that Atlantic salmon are repeatedly captured within the same fishing season.

The proportion of caught and released Atlantic salmon recaptured later in the same fishing season varied considerably among rivers, the lowest river average being 3.3% and the highest being 19%. The probability that caught and released salmon would be captured again later during the same fishing season decreased with decreasing time left of the fishing season, decreased with increasing fish size, but varied among rivers/years. Further, increased total exploitation rates during angling had a strong positive effect on recapture rate, which means that with increasing fishing pressure, the recapture rate increased. However, the proportion of salmon being caught twice in the catch and release fishery was much lower than the estimated exploitation rates in the rivers, which has been found previously in the River Alta (Thorstad et al., 2003).

The low proportion of salmon being caught a second time compared with total exploitation rates in the rivers could be due to the following: (1) tags from recaptured fish not being reported; (2) mortality of caught and released fish; (3) salmon caught once avoid being captured again; or (4) fish being more prone to being captured shortly after entering the rivers than later in the season. Low reporting rates and mortality of released fish (1 and 2) were likely not the reasons for the proportion of salmon being caught a second time in the catch and release fishery being much lower than the total exploitation rates in the rivers. The proportion of recaptures being reported was probably high, because angling was well organised in the study rivers, the project was well-known and well-received among stakeholders and anglers, the rewards for reporting recaptures were high, and results from radio-tagged salmon did not indicate that recaptures to a large extent were not reported. There may be some mortality after catch and release, as the present results also indicated, but the survival is generally high for caught and released Atlantic salmon (93%, Lennox et al., 2017). Salmon avoiding being recaptured again (3) could be the case, as discussed by Lennox, Diserud, et al. (2016). Explanation (4), that is fish being more prone to being captured shortly after entering the rivers than later in the season, is perhaps the most plausible explanation for the recapture rates of caught and released salmon being lower than the exploitation rates in the different rivers. A common assumption among salmon anglers is that salmon are easier to catch during their first days in the river and that they become more difficult to catch as they have been in the river for an extended period. Recaptures in the River Namsen of salmon tagged in the bag nets in the sea before they entered the river seem to confirm this assumption, as most of the salmon were caught during the first 15 days after tagging in the sea. Hence, if catchability decreases as time in the river progresses, this may partly explain why recapture rate of released salmon was lower than the estimated exploitation rate in the rivers.

The rivers differed in the proportion of caught and released salmon being captured two times for reasons beyond the varying impacts of fishing pressure, fish sizes and time of season. The rivers Verdalselva and Lærdalselva had particularly low recapture rates (3%–4%). For Verdalsleva, the result could have been influenced by few fish being tagged. A similarly low recapture rate was found in a previous study in the River Alta, where only 4% of 353 tagged salmon were recaptured later in the same fishing season (Thorstad et al., 2003). One reason for the low recapture rates in the rivers Lærdalselva and Alta could be that only fly fishing is allowed in these rivers, whereas in most other Norwegian rivers a variety of gears could be used, such as spoons, spinners, wobblers and worms. Lennox, Diserud, et al. (2016) showed that individual Atlantic salmon tended to be recaptured by a different gear the second time, suggesting that salmon avoided familiar gear types. The explanations for this could be learned hook avoidance or could alternatively be due to individual fish altering their behaviour after release with time spent in the river, or by time of the season, which could change the catchability of different gears. Independent of the reason for this phenomenon, it supports the hypothesis that the recapture rates could be lower in rivers where only one gear type is allowed. Different recapture rates among gear types per se could not explain a lower recapture rate in rivers with only fly fishing, because no difference was found among salmon captured by different gear types in the risk of being captured again.

The risk of being recaptured decreased with increasing body length. Exploitation rates during angling are generally lower for large than for small salmon, independent of river size (Forseth et al., 2013). Generally, lower exploitation of larger fish could explain why they are less likely than smaller fish to be captured a second time in a catch and release fishery. There were no differences between males and females in the probability of being captured again.

The model predicted a lower recapture probability for salmon tagged with T-bar tags than for those tagged with radio transmitters. This can, in part, be caused by T-bar tag loss, but it did not explain the whole difference. It might also be that anglers to a larger extent report recaptures of a large radio transmitters than T-bar tags or that the radio-tagged salmon had a lower mortality, but there are no indications that any of these explanations are true. However, salmon that were in a poor shape and judged to not be able to survive were killed and not released, and it might be that the likelihood of not releasing a fish was larger during the radio tagging than the T-bar tagging. In general, it may be argued that the fish in the present study might have had larger stress responses and increased mortality because of the extra handling and impacts by being tagged. On the other hand, the tagged fish were angled and handled by experienced anglers who likely had better knowledge on how to handle fish and greater attention towards careful handling of the fish than the average angler performing catch and release.

Catch statistics include the size of fish as reported by anglers. The fish in this study were tagged by experienced anglers, guides or scientists prepared and equipped to measure the fish, whereas they were recaptured by ordinary anglers, who might report the fish length based on an estimate. To test how reliable length measures by ordinary anglers were, the length measured during tagging was compared with the length reported by anglers for recaptured fish. For some fish, there was a relatively large difference, but no systematic differences, and no sign of anglers reporting the fish as larger than they were. Hence, using fish lengths reported by anglers in catch statistics in different analyses seems not to cause any biases in the results.

This is the largest study to date investigating the recapture of Atlantic salmon in recreational fisheries, incorporating data across years and throughout Norway. The results showed that there was not a large risk that Atlantic salmon were caught and released multiple times in these fisheries. Many rivers with angling for Atlantic salmon also have sea trout, *Salmo trutta* L., populations, which, to a varying extent among rivers, are released again. There are many studies of the effects of catch and release on Atlantic salmon, but studies on sea trout are largely missing and should be a focus of future studies.

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