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The use of catch statistics to monitor the abundance of escaped farmed Atlantic salmon and rainbow trout in the sea

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Catch statistics and scale samples were collected from a gillnet fishery targeting escaped farmed salmonids between 1 October and 28 February each year from 2001 to 2004 in Hordaland County, western Norway. Fish were classified into different groups, or escape incidents, using catch per unit effort (cpue) and size distribution of the catch from different geographical subregions. Reported escape incidents of both rainbow trout and salmon appeared to be followed by peaks in the cpue lasting four to six weeks, but a large proportion of the catch of escaped salmon appeared to stem from unreported, small-scale escape events. The wide size-range of fish caught suggests that the escapees originated from different escape incidents, and the variability between regions suggests that most catches were of local origin. Genetic comparisons among three groups of escapees indicated that DNA profiling may facilitate identification in monitoring programmes of escapees originating in different genetic groups. A low incidence of wild fish was found in the catches. Provided the conservation status of local wild salmonid stocks is taken into account, a fishery targeting escaped farmed salmonids may reduce the numbers of escapees, thus lowering the risk of introgression with wild salmon populations and removing potential sources of sea lice. Information on the relative abundance of escapees in the sea would also be provided by a fishery targeting escapees.

Keywords: escapees, gillnet fishery, rainbow trout, salmon.

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Introduction

Concerns about the negative impacts of fish farming on wild salmonid populations are growing (Youngson *et al.*, 2001; Naylor *et al.*, 2005). In Norway, production of farmed Atlantic salmon, *Salmo salar* L., has increased from approximately 4100 t in 1980 to more than 507 000 t in 2004 (ICES, 2005), and both large-scale (e.g. owing to gear failure or storm damage) and small-scale (e.g. owing to handling errors) escapes occur (Statistics Norway, www.ssb.no). In many Norwegian rivers, escaped farmed salmon outnumber the wild fish (Fiske *et al.*, 2001). Official data on the numbers of escapees are derived mainly from large-scale events reported by fish farmers, and little is known about the contribution of unreported escapes to the total escapement (Baarøy *et al.*, 2004).

Efforts have been made to recapture farmed salmon following large-scale escape events, but data from these fisheries have not been systematically collected, and the source of the escapees has sometimes been disputed. Most fish escape from fish farms when they are immature, but there is little information on the size of escapees. Release experiments with offspring of wild salmon indicate that size at escape and the time of year of their escape may influence both the survival of the escaped fish and their distribution (Hansen and Jonsson, 1989).

Data on the distribution of escaped farmed salmon in the sea in Norway have been collected from the summer bag net fishery for wild salmon (Lund *et al.*, 1991). However, more information is needed on the presence and geographical distribution of escaped farmed salmon in the sea. In a study in Northern Ireland, temporal variations in the catches of escapees were observed and related to escape events (Crozier, 1998). Efforts to recapture escaped farmed Atlantic salmon in British Columbia, Canada, indicated that gillnets were the most successful gear irrespective of the length of time the escapees had been at large (Morton and Volpe, 2002).

The present study was conducted in Hordaland County (Figure 1), where several of Norway's earliest Atlantic salmon and rainbow trout, *Oncorhynchus mykiss*, farms were established in the early 1970s. More than 100 fish farms, with permits for approximately 300 net pen sites, are located in this region, and production in 2003 was approximately 110 000 t of salmon and rainbow trout (Table 1), about 20% of Norwegian production. In comparison, the total catch of wild salmon in the rivers in Hordaland County was between 8.8 and 10.9 t annually in 2001–2003, about 0.01% of the farmed salmonid production in the region. Many of the wild salmon populations in the area have declined to historically low levels, particularly since 1990 (Skurdal *et al.*, 2001).

In 1997, the County Governor of Hordaland, Department of Environmental Affairs, opened a public fishery for salmonids in the sea during late autumn (from 1 October) and winter, after most wild salmon have entered fresh water, in an effort to reduce the number of escaped farmed fish in the sea. Annual catches in this fishery ranged from 5 to 15 t for farmed salmon and from 1 to 13 t for rainbow trout (Figure 2). Fishers reported the number and total weight of salmon and rainbow trout caught in this fishery. The aim of the present study was to gather more specific information from this fishery about the distribution of escaped farmed fish and to address the following questions:

(i) Can catch per unit effort (cpue) be used to assess the relative abundance of escaped farmed fish in different regions and different years?
(ii) Will local escape incidents be apparent in the cpue?
(iii) Can a fishery be used to reduce the abundance of escapees without damaging wild salmon populations?

Material and methods

Data collection

Participants in the fishery provided information on fishing gear and effort, including the number of nets set, net mesh size, and dates fished. For each fish caught, they

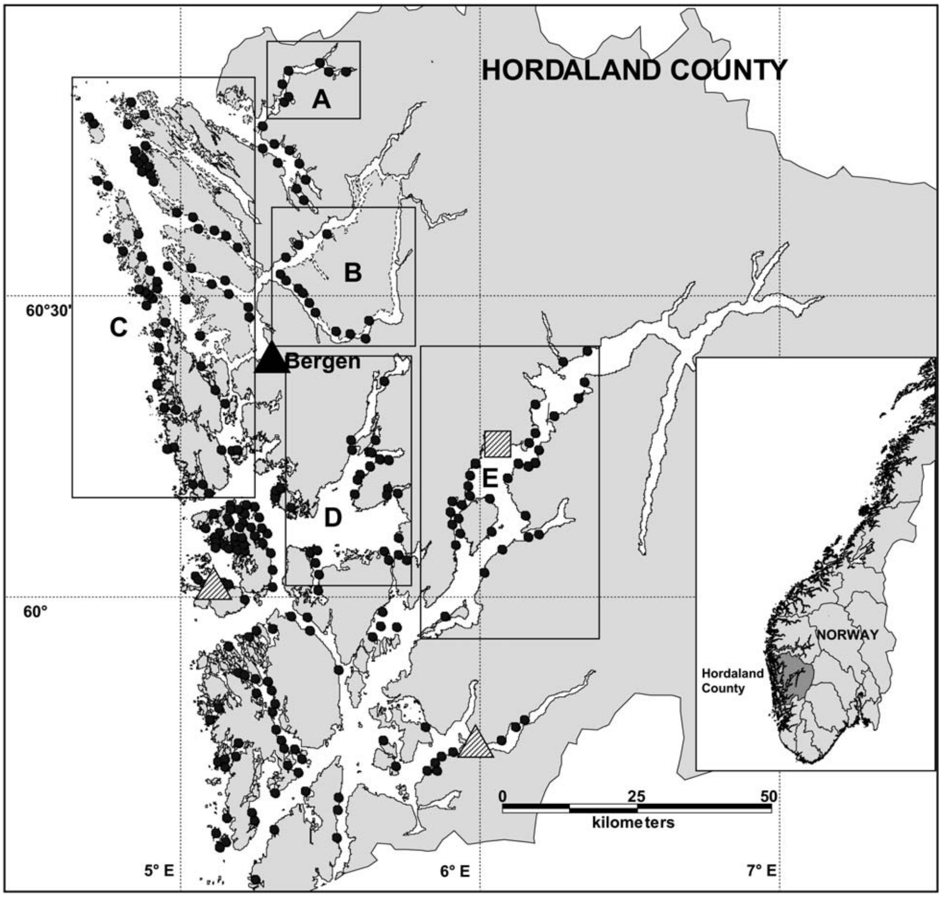

Figure 1. Map showing the location of Hordaland County in western Norway, the location of salmon and rainbow trout farms in 2002–2003 (source: Directorate of Fisheries), and Subregions A–E. The locations of reported escape incidents are indicated with black (2001/2002 fishing season) and hatched triangles (2002/2003 fishing season) for rainbow trout and a hatched square (2002/2003 fishing season) for salmon.

Table 1. Annual production of farmed salmon and rainbow trout and the weight of farmed salmon and rainbow trout reported to have escaped in Hordaland County in 2001, 2002, and 2003. Production is also given for Regions A, B, and E (figures for Region E include the entire Hardanger Fjord basin), but no data were available for Regions C and D (see Figure 1; source: Directorate of Fisheries, Bergen, Norway, unpublished data).

	2001		2002		2003	
	Salmon	Rainbow trout	Salmon	Rainbow trout	Salmon	Rainbow trout
Production (t)						
Hordaland	70 351	14 615	72 509	23 909	94 348	15 713
Region A	390	663	1 106	1 001	369	1 081
Region B	491	7 554	0	14 047	0	9 712
Region E	28 027	4 671	32 552	5 688	39 251	2 320
Reported weight of escapees (t)						
	32	43	94	37	89	0.2

provided data on length, weight, sex, species, and origin, i.e. farmed or wild, based on external appearance. The fishers were paid NOK 50 per fish (about £4) to collect a sample of scales from each fish. Thirty-four fishers returned catch data for the 2001/2002 fishery, 39 for 2002/2003, and 19 for 2003/2004 (Table 2).

Supporting information on fish farm escape incidents, in the form of the estimated mean weight and number of escapees and the location and date of escape events, was provided by the Directorate of Fisheries, based on reports submitted by fish farmers. Escape events involving more than 500 fish that occurred during the fishing seasons were compared with data from the fishery. One event involving a smaller reported number of escapees was also included in the analysis.

Gillnets

Most fish were caught in gillnets with bar-measure mesh sizes ranging from 52 to 70 mm (Table 3). Fewer than 40 fish were reported from gear and mesh sizes different from those shown in Table 3, and these fish were not included in this study. Nets with bar-mesh of 66 and 70 mm were treated as one size category (Table 3).

Except for a small number of nets set on the bottom in shallow water, floating nets were used and were usually mounted with a lead rope and a float line. The nets ranged in length from 25 to 30 m and varied in depth from 1.9 to 3.0 m, but the most commonly used net was approximately 2 m deep and approximately 25 m long. Both mono- and multifilament thread nets were used.

Geographical subdivisions

Catch statistics were collected for Hordaland County and for several geographical subregions. Based on topographical features and the availability of catch reports, the following five regions were designated (Figure 1):

A: The Masfjord. The production of farmed salmon and rainbow trout in this fjord is relatively low compared with the rest of the county (Table 1).

B: The Osterøy Fjord system. This system is made up of several narrow fjords. Several large rivers drain into them, which can cause the formation of a surface fresh

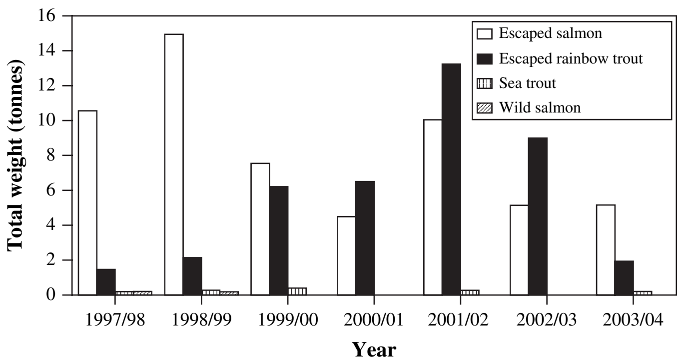

Figure 2. The total weight (t) of the reported catch during the autumn/winter fishery for escapees in Hordaland County, 1997−2004 (source: Department of Environmental Affairs, Hordaland County).

Table 2. The number of fishers reporting catch data for this study, the number of net-nights fished, catches of salmon and rainbow trout, and the cpue for the 2001/2002, 2002/2003, and 2003/2004 fishing seasons. The information is presented for Hordaland County (HC) and for each Subregion A−E.

	Number of salmon caught	Number of rainbow trout caught	Number of net-nights	Number of fishers	Cpue salmon	Cpue rainbow trout
2001/2002 HC	329	784	1 756	34	0.19	0.45
Region A	8	1	5	1		
Region B	2	587	186	6	0.01	3.16
Region C	123	188	1 271	19	0.10	0.15
Region D	43	4	88	4	0.49	0.05
Region E	153	4	206	4	0.74	0.02
2002/2003 HC	1 453	1 028	2 443	39	0.60	0.42
Region A	116	16	29	1	4.00	0.55
Region B	31	243	230	9	0.13	1.06
Region C	148	688	1 679	16	0.09	0.41
Region D	275	46	234	4	1.18	0.20
Region E	883	35	260	7	3.40	0.13
2003/2004 HC	383	82	949	19	0.40	0.09
Region A	79	0	16	1	4.94	0.00
Region B	2	39	56	2	0.04	0.70
Region C	128	31	497	9	0.26	0.06
Region D	33	8	123	2	0.27	0.07
Region E	141	4	257	5	0.55	0.02

or brackish water layer several metres in depth. Except for limited production of farmed salmon in 2001 only rainbow trout were farmed in this region (Table 1).

Table 3. Total catch (numbers of fish) and percentages of the catch of salmon, rainbow trout, and sea trout in each of the different net mesh sizes used during the 2001/2002, 2002/2003, and 2003/2004 fishing seasons.

	Mesh size (mm)				
	48	52	57	63	66−70
2001/2002 Fishery					
Salmon (%)	35.0	94.7	93.2	32.1	7.9
Rainbow trout (%)	10.0	2.6	6.1	66.4	90.2
Sea trout (%)	55.0	2.6	0.7	1.5	1.8
Catch	20	38	148	378	541
2002/2003 Fishery					
Salmon (%)	56.7	65.3	93.9	49.1	54.7
Rainbow trout (%)	40.4	30.3	5.5	50.0	44.4
Sea trout (%)	1.9	4.4	0.6	0.9	0.9
Catch	104	271	328	1 371	347
2003/2004 Fishery					
Salmon (%)		84.9	67.8	81.5	78.1
Rainbow trout (%)		7.5	23.3	17.2	20.3
Sea trout (%)		7.5	8.8	1.3	1.6
Catch		106	90	233	64
All years					
Total catch	124	415	566	1 982	952

C: A coastal region in a marine environment with a high density of fish farms.

D: A small, relatively open fjord system with approximately 20 net-pen sites.

E: The middle part of the Hardangerfjord, one of Norway's largest fjords. Approximately 30−40% of the production of farmed salmonids in Hordaland County is produced in net pens in this fjord (Table 1).

Catch per unit effort

The cpue for salmon and rainbow trout in each fishery was calculated daily, using the daily catch per net-night for each species. One net-night was defined as one net used during a 24-h period. The mean weekly cpue was the mean daily cpue in each week, and the mean cpue for a fishing season was the mean daily cpue in each season.

Scale reading

The scales were read using a microfiche print-reader by an environmental consultancy (Rådgivende Biologer As) experienced in using scale characteristics to distinguish escaped farmed salmon from wild salmon based on estimated smolt length and the presence of juvenile winter zones and accelerated early marine growth. The growth was calculated on a magnified printout, and the fish were categorized as being wild or escaped farmed fish according to the method described by Lund and Hansen (1991).

Analysis and visualization of genetic data

Scale samples from the following three groups of escaped farmed salmon caught during the 2002/2003 fishery were used for DNA profiling: 24 grilse-sized salmon from Region A, and 27 grilse-sized salmon and 29 large salmon from Region E.

DNA was extracted from four to six dried scales from each fish using a Qiagen DNeasy kit, following the procedure recommended by the manufacturer. Seven microsatellite loci were amplified: *Ssa13.37*, *SsaF43*, *Ssa20.19* (Sanchez *et al.*, 1996, 2000), *Ssa85*, *Ssa197*, *Ssa202* (O'Reilly *et al.*, 1996), and *SsOSL85* (Slettan *et al.*, 1995). Polymerase Chain Reactions (PCR) were performed, and three to four different PCR products were combined and run on an Applied Biosystems ABI 3100 Genetic Analyser. Alleles were scored using the Genotyper Analysis Software version 3.7, with manual control of the automatically scored peaks.

The possible multiple origin of the samples of escaped farmed salmon was visualized by applying factorial correspondence analysis on microsatellite data as described by She *et al.* (1987) and Berrebi *et al.* (2000), using the program Genetix 4.0 (Belkhir *et al.*, 2000).

Results

The catch reports included in this study corresponded to approximately 14%, 40%, and 20% of the total reported catches in the fishery for escapees (Figure 2) in Hordaland County in the 2001/2002, 2002/2003, and 2003/2004 fishing seasons, respectively.

Most fish were caught in nets of >63 mm mesh, but the percentage of salmon and rainbow trout caught in nets of different mesh sizes varied between years (Table 3), probably reflecting mesh sizes used and availability of the two species to the fishery. This was most clearly seen during the 2001/2002 fishery, when fishers in Region B used nets of 63–70 mm mesh to catch almost exclusively rainbow trout, while fishers in Region E used nets of 52 and 57 mm mesh and caught almost exclusively salmon (Table 2). It was possible to compare mesh sizes used and weights of salmon and rainbow trout caught in Region C during the 2002/2003 fishery season because of the high fishing effort (Table 2) and the use of a wider range of mesh sizes in this region. Mean weight of both salmon and rainbow trout tended to increase with mesh size, and for a given mesh size, the salmon caught were approximately 1 kg heavier than the rainbow trout (Figure 3). However, fish with a wide range of weights were caught in all mesh sizes. The morphology of the two species probably influenced their catchability in nets of different mesh size. The mean condition factor of the fish shown in Figure 3 was 1.05 (s.d. = 0.20) and 1.51 (s.d. = 0.21) for salmon and rainbow trout, respectively. Comparable increases in weight with mesh size were seen for catches of salmon in Region E

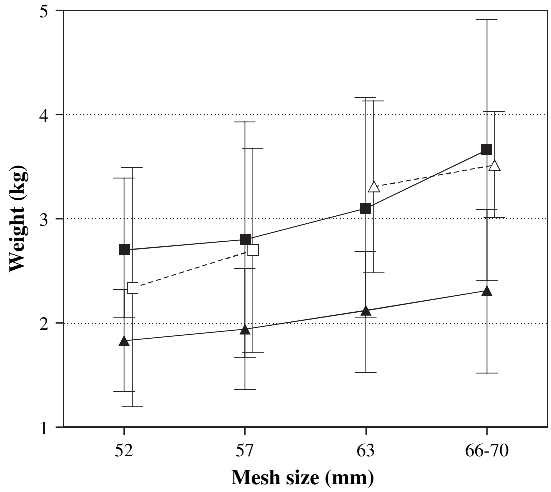

Figure 3. Mean weights and standard deviations (vertical bars) of salmon (filled squares) and rainbow trout (filled triangles) caught in nets of different mesh size during the 2002/2003 fishery in Region C, and of salmon caught in Region E (open squares) and rainbow trout from Region B (open triangles) during the 2001/2002 fishery.

and of rainbow trout in Region B during the 2001/2002 fishing season (Figure 3). Most of the escaped farmed salmon caught from 2001 to 2004 were sexually immature fish (Table 4).

Catches in Region A

The production of farmed salmon in Region A was low, between 0.4% and 1.5% of the total production in Hordaland County (Table 2). The catches, however, were dominated by salmon (Table 2), and the catch per unit effort of salmon was higher than for the other regions in the 2002/2003 and 2003/2004 fisheries. However, data from this region comprises catches of one fisher for the first three weeks of each fishing season, so detailed figures for cpue are not presented.

Catches in Region B

More than 50% of the farmed rainbow trout produced in Hordaland County was from Region B (Table 1). Catches in the region were dominated by rainbow trout, and the cpue of rainbow trout was higher in Region B than in the

Table 4. Percentages of the catches of escaped farmed salmon that were mature in the fisheries in 2001/2002–2003/2004.

Year	Mature salmon (%)	Sample size (*n*)
2001/2002	28.0	93
2002/2003	12.5	509
2003/2004	22.7	141

other regions during all three fishing seasons (Table 2). The cpue of rainbow trout was very high from the opening of the fishery on 1 October 2001, approximately eight fish per net-night, but it declined rapidly to less than two fish per net-night during the following four weeks (Figure 4). Escape events had not been reported in the region in 2001, but the cpue of rainbow trout in Region B during the 2001/2002 fishery was markedly higher than the cpue in the other regions (3.16 vs. 0.02−0.15; Table 2). The mean weight of fish caught was 3.0 kg (s.d. = 0.84), significantly less than the mean weight (3.3 kg; s.d. = 0.74) of the fish caught in Region C ($p < 0.05$, *t*-test).

The fishing effort in Region B increased slightly from the 2001/2002 to the 2002/2003 fishing season (Table 2), but

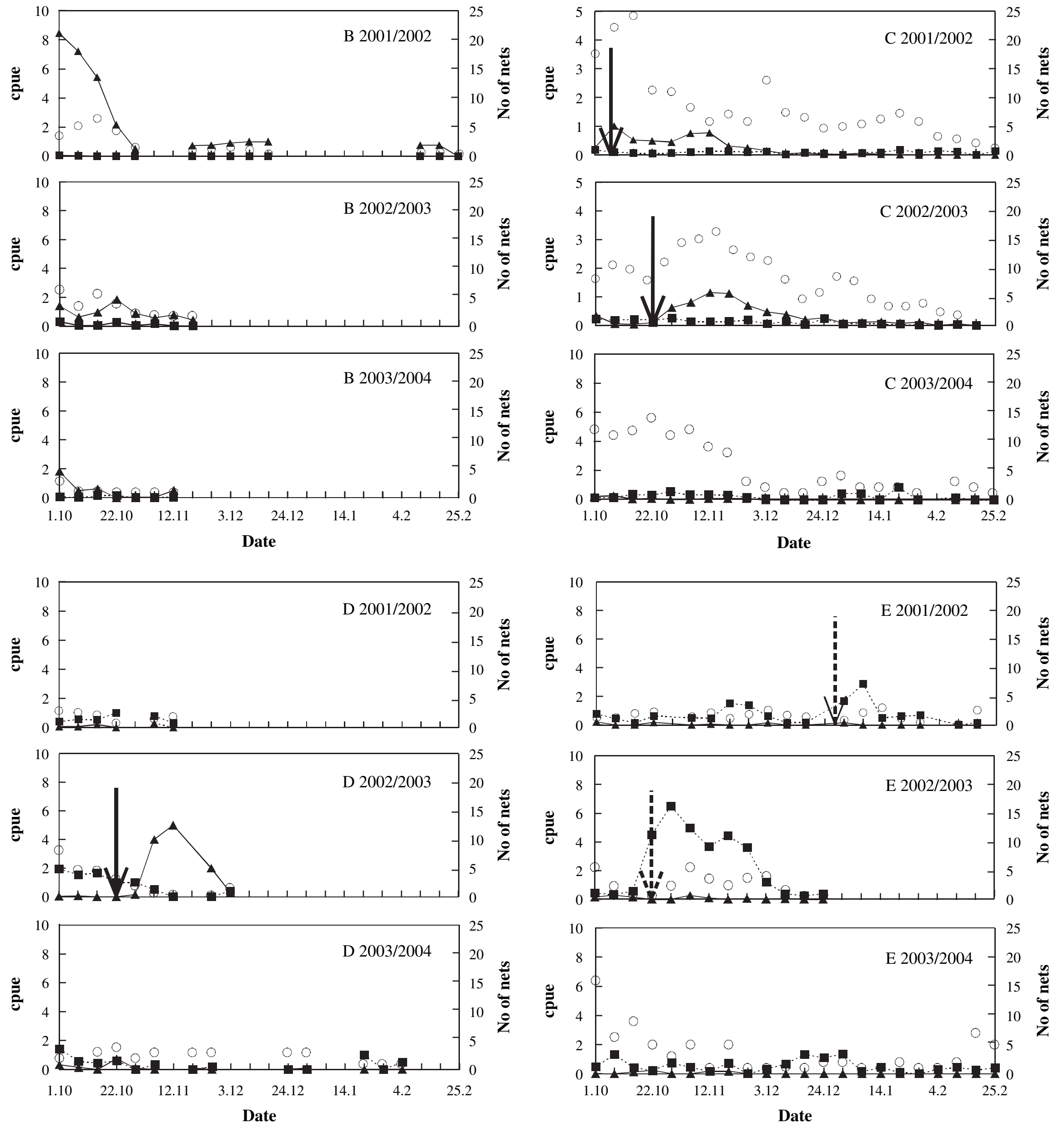

Figure 4. Mean weekly catch per unit effort (cpue), i.e. the number of fish per net-night, for salmon (filled squares) and rainbow trout (filled triangles) and the weekly mean number of net-nights (open circles) during the autumn/winter fishery in 2001/2002, 2002/2003, and 2003/2004 for Regions B, C, D, and E. The dates of reported escape incidents are indicated for rainbow trout (solid arrow) and for salmon (dashed arrow). The escape event in Region C in 2001/2002 is based on reports from fishers to the Directorate of Fisheries. Note that the scale of the *y*-axis for Region C during the 2001/2002 and 2002/2003 fisheries is smaller than the *y*-axis of the other panels.

the cpue of rainbow trout declined by two-thirds to approximately 1.0 during the same period (Figure 4, Table 1). This was further reduced to 0.7 in the 2003/2004 fishing season. This gradual decline in both reported catches (Table 2) and cpue from the 2001/2002 to the 2003/2004 fishing season (Figure 4) follows the general trend in the total reported catches for Hordaland County during this period (Figure 2). However, the cpue of 0.7 during the 2003/2004 fishing season was markedly higher than the cpue (0.0−0.07; Table 2) in the other regions. The wide size range of rainbow trout, especially during the 2002/2003 season (Figure 5), suggests that the fish originated from different escape events. Compared with the other regions, the catch of salmon was very low in Region B during each of three fishing seasons (Table 2).

Catches in Region C

The trend in cpue in Region C was characterized by low, stable catches of salmon during all three fishing seasons (Table 2). Two events of increased catches of rainbow trout in 2001/2002 and 2002/2003 appeared to coincide with two reported escape events (Table 2, Figure 4). In 2001, there were two known escapes of large rainbow trout in Bergen harbour close to Region C (Figure 1), following the transfer of fish for harvesting. In all, 3000 trout, with a reported mean weight of 3.5 kg, escaped seven days before the opening of the fishery on 1 October, and 9930 trout (3.3 kg mean weight) escaped from the same location on 10 October. In comparison, the catch in Region C was dominated by fish weighing between 2 and 5 kg (Figure 5) with a mean weight of 3.3 kg (s.d. = 0.84).

The increase in catches during the 2002/2003 fishery in Region C coincided with a reported escape event of rainbow trout close to the southern border of this region on 24 October (Figures 1 and 4). In all, 5569 trout with a mean size of 3 kg were reported to have escaped. However, the mean size of the catch was 2.1 kg (s.d. = 0.64), lower than the reported weight of the escapees.

The cpue of rainbow trout increased somewhat following these escape incidents, from close to zero to 0.5−1.0 fish per net-night. The effort in Region C was consistently higher than in other regions and corresponded to more than 50% of the total reported effort for each of the three fishing seasons (Table 2). The cpue of rainbow trout remained higher for approximately six weeks after the two escape incidents (Figure 4).

The cpue of salmon was relatively low during the 2001/2002 and 2002/2003 fishing seasons. It was higher, zero to one fish per net-night, during the 2003/2004 season, but no distinct escape events were evident in the cpue data (Figure 4, Table 2).

Catches in Region D

The cpue of salmon in Region D was low during the 2001/2002 and 2003/2004 fishing seasons, but was higher than that in neighbouring Region C (Table 2). The highest

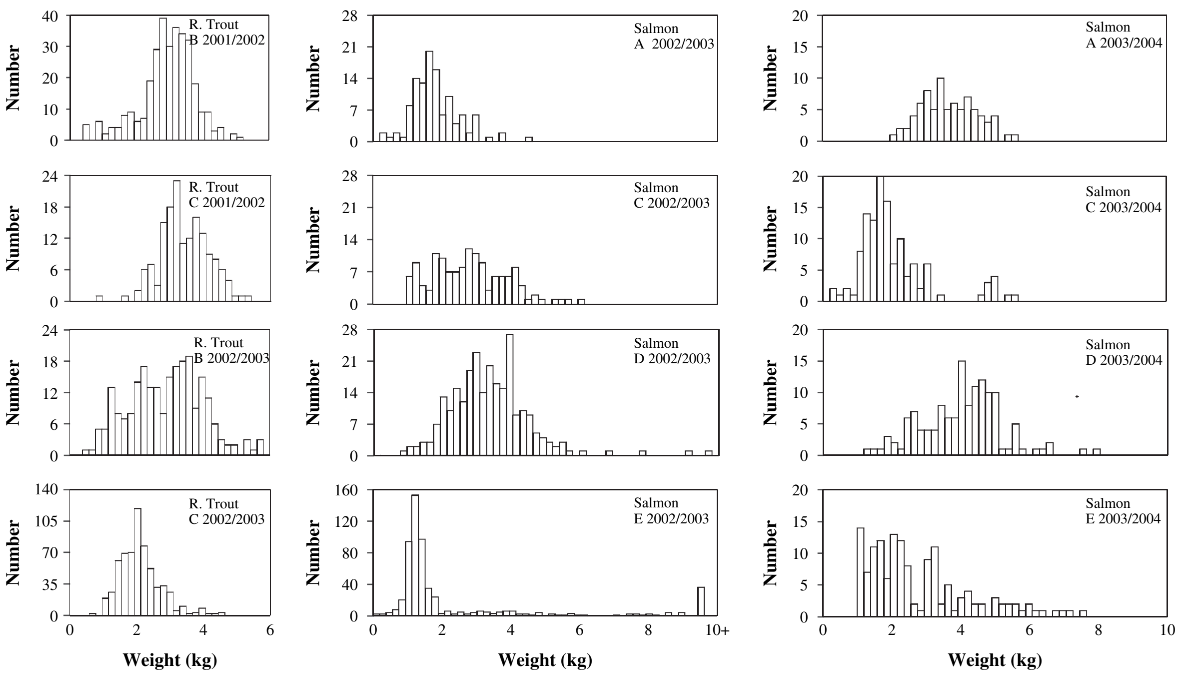

Figure 5. Weight-frequency distributions of rainbow trout caught in Regions B and C during the 2001/2002 and 2002/2003 autumn/winter fisheries (left panels), and of salmon caught in Regions A, C, D, and E during the 2002/2003 (middle panels) and 2003/2004 (right panels) fishing seasons.

cpue, between one and two fish per net-night, occurred during the first four weeks of the fishery in 2002/2003 (Figure 4). The wide range in weight of the fish caught, from 1 to >6 kg (Figure 5), suggests that the fish were from different escape events.

The cpue of rainbow trout was close to zero in the 2001/2002 and 2003/2004 fishing seasons, but increased rapidly from zero to four trout per net-night in early November 2002, approximately one week after the reported escape of 5569 rainbow trout west of Region B on 24 October (Figure 1). The mean weight of the fish caught was 2.1 kg (s.d. = 0.76), the same as the mean weight of the rainbow trout caught in Region C during the same period. If the fish were part of the reported escape incident west of Region D, then the one-week time-lag between the escape event and the increase in cpue reflects the time taken by the fish to travel the 25–40 km in a straight line from the escape site to the location of the fishery (Figure 1).

Catches in Region E

Despite production in the Hardangerfjord basin accounting for 15–32% of the total production of rainbow trout in the county (Table 1), the cpue of escaped farmed rainbow trout was very low in Region E compared with the other regions (Table 2, Figure 4). There was one reported escape incident south of Region E (Figure 1) that may have caused rainbow trout numbers to be higher than salmon numbers in the catches of two local fishers (54 rainbow trout vs. 17 salmon). These were the only catch reports received from the southern part of the Hardangerfjord basin.

The cpue of salmon in Region E generally remained higher than in the other regions, with catches of between 0.5 and 2 fish per net-night for long periods in both the 2001/2002 and 2003/2004 fishing seasons (Table 2, Figure 4). Two escape events were reported in the region during the fishing seasons. The first incident in January 2002 (Figure 4) was not reported to the Directorate of Fisheries by a fish farmer, but was reported by fishers. There was a slight increase in the cpue after the report of the alleged escape, but it was of shorter duration than the other cpue peaks linked to escape events (Figure 4). A second escape incident (Figure 1) that occurred on 25 October 2002 appeared to overlap temporally with a rapid and prolonged increase in the cpue of salmon near the escape incident (Figure 4). The cpue increased from close to zero to approximately four to five fish per net-night for the next six weeks. The total reported catch of more than 800 fish greatly exceeded the number of fish reported to have escaped (100 fish), but the size distribution of the catch (Figure 5) corresponded well with the reported mean weight of 1 kg of the escapees. Within this catch, a group of large salmon weighing 9.0–19.5 kg was also caught, suggesting that they originated from more than one escape event. Fish from these two size categories were chosen for DNA profiling.

Comparison of DNA profiles

The sample of escaped farmed salmon used for DNA profiling from Region A in autumn 2002 consisted of 24 fish with a mean weight of 1.49 kg (s.d. = 0.27). These fish were selected from a catch consisting of 96 grilse-sized salmon with a mean weight of 1.62 kg (s.d. = 0.46), and were significantly heavier ($p < 0.05$, t-test) than the sample from Region E of 27 grilse-sized fish (mean weight = 1.21 kg, s.d. = 0.14) that were chosen from the small size group caught in 2002 and shown in Figure 5. The third group was 29 of the 40 salmon weighing more than 9 kg caught in Region E in autumn 2002 (mean weight = 12.0 kg, s.d. = 2.38).

The factorial analysis applied to the microsatellite data of the three samples (Figure 6) strongly indicated that the two size groups caught in Region E originated in different genetic groups or farm strains. There was a high degree of genetic overlap between the grilse-sized salmon caught in Regions A and E, indicating that they belonged to the same farm strain.

Comparisons between regions

The mean weights of rainbow trout caught in Regions B and C were significantly different in 2001/2002 and 2002/2003. The mean weights of the escaped farmed salmon caught in Regions A, C, D, and E were significantly different in 2002/2003 and 2003/2004 ($p < 0.05$, t-tests, weight distributions in Figure 5).

Incidence of wild salmon and trout in the catches

Based on external appearance, fishers reported that 17 of the 395 salmon caught during the 2001/2002 fishery were of wild or possibly wild origin. Scale readings indicated that wild salmon made up 2.3% of the total catch, that only four of the 17 fish identified as wild by the fishers

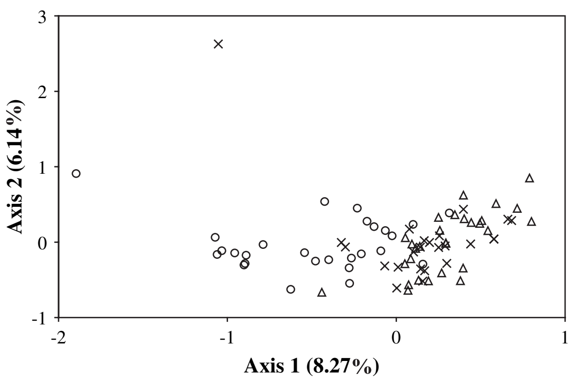

Figure 6. Factorial correspondence analysis based on seven microsatellites between individuals of the following three samples from autumn 2002: grilse-sized salmon from Region A (crosses), and grilse-sized (triangles) and large (circles) salmon from Region E.

were wild, and that five of the other 378 salmon were wild. In all, 62 of 1460 fish (4.24%) were categorized by fishers as either wild or possibly wild in 2002/2003. The scale readings of these 62 fish indicated that there were 4 wild sea trout, 44 escaped farmed salmon, and 14 wild salmon. During the 2003/2004 fishery, 27 fish were classified by fishers as wild or possibly wild. Scale readings indicated that 15 of these were escaped farmed salmon, 10 were wild salmon, and 2 were wild sea trout.

The catch of wild sea trout was low, with only 38, 33, and 25 fish caught in 2001/2002, 2002/2003, and 2003/2004, respectively. However, there was a clear tendency for the incidence of sea trout to be higher in the catch of nets with the two smallest mesh sizes used by the fishers (48- and 52-mm mesh size; Table 3). A higher percentage of sea trout was caught in nets with 57-mm mesh size in the 2003/2004 fishing season as a result of the catch of 12 large sea trout in Region C (mean weight = 2.5 kg).

Discussion

This study reports the first attempt in Norway to monitor the occurrence and estimate the relative abundance of escaped farmed salmon and rainbow trout using catch statistics from a gillnet fishery. It was not possible to derive estimates of total escapee abundance. The catch per net-night of both salmon and rainbow trout varied widely between years, geographical regions, and within regions between fishing seasons. Increases in cpue appeared to be synchronized with reported escape incidents, and changes in cpue probably reflect changes in the relative abundance of escapees. The large variability within and between regions in the sizes of escapees caught, and differences between the size of escapees caught and those reported from escape events suggest that escapees from small-scale unreported escape events make up a large proportion of the escaped farmed fish.

Although the production of farmed salmon in Hordaland County was approximately three to six times that of rainbow trout in 2001−2003, the catch of rainbow trout was greater than that of salmon (Figure 2). The catches corresponded to 0.04% (24 t compared with 54 273 t) and 0.01% (20.5 t compared with 237 208 t) of the total production of rainbow trout and salmon, respectively, in Hordaland County during the same period. There appeared to be a general tendency for the cpue of both salmon and rainbow trout to be higher in sheltered fjord regions than in more exposed areas closer to the open sea, but we do not know the extent to which this pattern and the ratio of rainbow trout to salmon in the catches are influenced by the technical standards and operational procedures at the farms or the selectivity of the nets or fish behaviour in the cages and after they escape.

The high cpue of escaped farmed rainbow trout in Region B after the opening of the fishery in autumn 2001 may indicate that there had been one or more unreported escape incidents in this region. The marked reduction in cpue during the next two to four weeks may indicate that the abundance of rainbow trout was greatly reduced by the fishery, was a consequence of rainbow trout moving away from the area, or a combination of the two. Tagging experiments in Norwegian fjords have shown that rainbow trout are usually recaptured close to the release site (Jonsson *et al.*, 1993), although escaped farmed salmon have been recaptured as far away as the feeding grounds around the Faroe Islands (Hansen *et al.*, 1999) and may be widely distributed geographically when they return as mature adults (Skilbrei and Holm, 1998). Differences in behaviour between the two species may result in an increased catchability of escaped rainbow trout and may influence the effectiveness of the fishery in reducing the abundance of the two species.

Sea lice may have harmful impacts on wild sea trout and Atlantic salmon smolts migrating to sea (Finstad *et al.*, 2000; Bjørn *et al.*, 2001), and harvesting escaped salmonids may reduce the potential number of sea lice hosts. During a research fishery conducted in Region B in April 2000, 141 escaped rainbow trout were caught with a mean infestation of 3.6 adult female lice per fish (J. C. Holst, pers. comm.). Reducing the stock of escaped farmed rainbow trout and salmon during autumn and winter, therefore, may reduce the infestation rate of lice on sea trout and migrating salmon smolts during spring and summer and improve the control of sea lice in fish farms (Heuch and Mo, 2000).

Reducing the number of farmed salmon spawning in rivers, a cause of concern because of their genetic impacts on wild populations (Fleming *et al.*, 2000; Naylor *et al.*, 2005), is another possible benefit of a fishery targeting escapees. The direct effect of the fishery on the numbers of escaped farmed salmon entering rivers is unknown, but the catch of 4−13 t of escaped farmed salmon in the autumn/winter fishery was comparable with the total catch of wild salmon, 6−11 t, in the rivers of Hordaland County in recent years. In addition, the unreported catch in the fishery for escapees has been estimated at approximately 40% of the reported catch (A. Kambestad, pers. comm.). A large proportion of the catch of escaped farmed salmon consisted of immature fish known to have a low survival to maturity, probably depending on their size and the time of year they escape (Hansen and Jonsson, 1989). However, their numbers in rivers may still be larger than wild salmon because of the extent of the salmon farming industry.

This study has demonstrated that, for several weeks following an escape incident, gillnet fishing could target escaped salmon and rainbow trout and reduce the numbers of escapees, thus lowering the risk of introgression with wild populations and removing potential sources of sea lice.

Several observations suggest that most of the salmon reported in this study were part of local small-scale escape incidents, or trickle losses, that are not reported to the authorities. Only one distinct escape event was evident in the cpue in the fishery, but there were clear differences between all geographical regions with respect to the size distribution of the salmon caught. Such differences, which were observed in all years, strongly suggest that a large proportion of the escapees originated in the same region as the fisheries, although escapees from other regions may have contributed as well. Furthermore, the size variability of the catches implies that the escapees originated from several different escape events.

The fishery for escaped farmed salmon in the autumn is possible because escaped farmed salmon enter rivers later in the year than wild salmon (Jonsson *et al.*, 1990; Crozier, 1998). However, fisheries for salmonids in seawater tend to exploit wild fish from a number of rivers (mixed stock fisheries), and such exploitation may conflict with conservation objectives for small stocks, especially if they support late-running wild salmon. There is no evidence that large numbers of wild salmon and sea trout were caught in the fishery for escapees. The catch of wild sea trout was lower than expected, possibly because, first, many sea trout enter fresh water earlier in autumn; second, the populations of sea trout are at historically low levels of abundance in the Hardangerfjord basin; third, large net mesh sizes were used in this study. As most of the sea trout were caught in nets with the smallest mesh size, it may be appropriate to regulate the mesh size allowed in a fishery targeting escaped farmed fish to protect wild sea trout.

Currently, there is no systematic monitoring of escaped farmed salmon and rainbow trout in Norwegian coastal waters throughout the year. It is recognized that some of the large-scale escape events and most of the more frequent, smaller-scale escape events are not reported by fish farmers (Baarøy *et al.*, 2004). An expert group, established to review methods to counteract the continued predominance of escaped farmed fish in Norway, particularly those that were part of unreported escape events, concluded that one possible approach would be to develop contingency plans to be activated when large-scale escape events occur (Baarøy *et al.*, 2004). The plan will use chemical analysis, genetic profiling, and other methods, individually or in combination, to trace the source and spread of escaped salmon. Recently, it was demonstrated that there is sufficient genetic differentiation between cultured strains of Atlantic salmon to separate them using microsatellite analysis (Skaala *et al.*, 2004). This study reports the first attempt to categorize groups of escaped farmed salmon by DNA profiling. Apparently, two of the samples originated in a common farmed strain, probably in use at two different fish farms. The clear differences in the DNA profiles between the two groups of escaped farmed salmon caught simultaneously in Region E indicate that the combination of genetic profiles with catch data, such as fish size, date of harvest, etc., can potentially improve the information derived from monitoring programmes for these fish.

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