Relation between stock size and catch data of Atlantic salmon (*Salmo salar*) and Arctic charr (*Salvelinus alpinus*)

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ABSTRACT

Reliable catch statistics are one of the most important factors in fisheries research and in managing exploitation of fish stocks. For more than 30 years catches in Icelandic rivers have been reported in logbooks. In these logbooks, fish species, fish size, fishing pool, date, etc. were registered. It has been suggested that the total number of salmonids caught annually reflects the total population in each river. Fishing effort, i.e. the number of rods per day, has been regulated by authorities, as well as the length of the fishing season. However some minor changes have developed gradually over time. In the '90s new fish counters were introduced, making possible to evaluate the relation between run and catch. The counter gives the number of migrating fish and their size. The run was divided into one-sea-winter salmon (1SW), two-sea-winter salmon (2SW) and charr, by size. The relationship between the total stock size and the number of fish caught for 1SW salmon, 2SW salmon and charr in the Vesturdalsá and Blanda rivers was then examined. This relationship was highly significant in all cases, except for charr in the River Blanda. The results showed that the salmon catch statistics in the Vesturdalsá and Blanda rivers are good indicators of the size of the salmon run. This relationship was not as strong for the charr. Furthermore, the size of the population of salmon and charr showed similar fluctuations.

Keywords: catch statistics, fish counters, fishing effort, stock size

YFIRLIT

Stofnstærð lax (Salmo salar L.) og bleikju (Salvelinus alpinus L.) í samhengi við veiði

Áreiðanleg skráning á veiði er ein undirstaða rannsókna á fiskstofnum og nýtingu þeirra. Oft eru þetta einu gögnin um fiskistofn, en stærð veiðistofnsins er óþekkt. Laxveiði hefur verið skráð í þar til gerðar veiðibækur í flestum ám landsins um 30 ára skeið og sumum ám töluvert lengur. Þar koma fram upplýsingar um lengd, þyngd, kyn, dagsetningu veiðinnar og veiðistaður. Silungsveiði hefur einnig verið skráð en ekki eins vel og laxveiðin. Talið hefur verið að skráð veiði hvert ár endurspegli gönguna bæði í fjölda og samsetningu (t.d. smálax/stórlax). Erfitt hefur verið að sannreyna þetta. Sóknin, þ.e. fjöldi stanga og fjöldi daga sem veitt

er, hefur verið tiltölulega stöðug í mörgum ám síðustu áratugi. Ef veiðihlutfallið er misjafnt frá ári til árs, endurspeglar veiðin stofnstærðina verr heldur en ef veiðihlutfallið væri stöðugt. Rannsókn þessi tekst á við að svara þessum spurningum út frá gögnum frá Vesturdalsá í Vopnafirði og Blöndu (þ.m.t. Svartá) í Húnaþingi. Byggt var á niðurstöðum rafeindateljara sem veita upplýsingar um heildarfjölda fiska sem upp í árnar gengu. Jafnframt fékkst stærðarmat á fiskinn sem notað var til að greina á milli stórlax, smálax og silungs. Helstu niðurstöður voru þær að hámarktækt samhengi var í fjölda stórlaxa, smálaxa og bleikju sem um teljara gekk við veiði í Vesturdalsá. Svipaðar niðurstöður voru í Blöndu, nema þar var samhengið ekki marktækt fyrir bleikju. Einnig var kannað samhengi stofnsveiflna milli tegundanna.

INTRODUCTION

Reliable catch statistics are one of the most important factors in fisheries research and in managing exploitation of fish stocks. The quality of the catch statistics varies within and between countries and even between species, but frequently these are the only available data regarding the stocks. Since 1970 the catches have been accurately recorded in those Icelandic rivers where recreational fisheries are operated (Guðbergsson 2007). For each fish weight, length and sex is registered, along with the date of catch and its location (pool number). The fishing effort has generally remained constant for the last three decades. On this basis it has been suggested that the number of fish caught each year reflects the stock size (Scarnecchia 1983, Gudjonsson et al. 1995).

In the 1990s a new technology was introduced for counting migrating fish in rivers (Gudjonsson & Gudmundsson 1994). These new counters made it possible to verify whether catches were representative of the total run. Research on changes in fishing effort on the total catch indicates minor effects of increasing the number of rod-days (no. of rods x no. of days) from 200 up to 400 in the River Elliðaár (Guðbergsson & Antonsson 2008). Significant relationships between catch and the size of the run would suggest that it is possible to evaluate long term stock size fluctuations, based on catch statistics, also in those rivers where stock size has not been estimated.

The objectives of the present study were to analyse the relationship between the population size and angling catch statistics for Atlantic salmon and Arctic charr. Our hypotheses were: (1) that the number of salmon and charr caught in recreational fisheries reflects the total run of these species; furthermore, (2) that the proportion of the population caught by anglers has remained fairly stable from year to year. We also examined (3) the relationship between the population abundance of Atlantic salmon and Arctic charr.

MATERIALS AND METHODS

Study area

The two main study rivers were the River Vesturdalsá in northeast Iceland and the River Blanda in north Iceland (Figure 1). In addition catch data from the River Selá and the River Hofsá were used, as these rivers are located in Vopnafjörður close to the River Vesturdalsá (Figure 1).

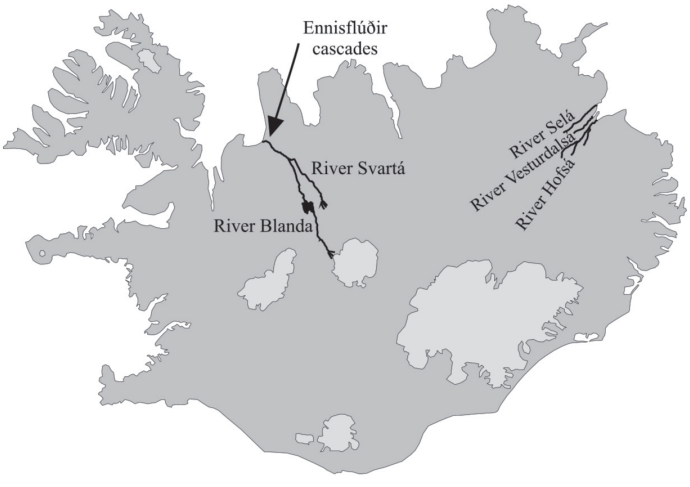

Figure 1. Location of the study rivers, in north and northeast Iceland.

The River Vesturdalsá has been classified as a wetland heath stream and is characterized by flat moraine heaths with lake and wetland systems (Gudjonsson 1991). The river has a catchment area of 190 km^2 (Rist 1990) and is about 35 km long, of which 28 km are passable for migrating fish (Antonsson 1998). The anadromous Arctic charr (*Salvelinus alpinus* L.) and Atlantic salmon (*Salmo salar* L.), are the main freshwater fish species in the Vesturdalsá, with a mean annual angling catch (from 1984 – 2002) of 688 and 207 fish, respectively.

The River Blanda is a partly glacier-fed river with a catchment area of 2,370 km^2 (Rist 1990). The flow has been regulated since 1991 due to hydroelectric power production. The reservoir (57 km^2) is located about 70 km upstream, above the most valuable nursery areas for charr and salmon. It has changed the character of the river, making the flow more stable and decreased the turbidity of the water, which has improved the angling conditions. When the reservoir becomes full, typically in July to October each year, it results in increased flow and turbidity. Salmon and sea migrating charr are the main species in the river, along with a local population of brown trout (*Salmo trutta* L.) (Jónsson & Guðjónsson 2007).

The River Hofsá and River Selá have similar characteristics, originating on flat heaths with extensive lakes and wetland systems between moraine ridges. The catchment area of the rivers Hofsá and Selá is 1,100 km^2 and 750 km^2 respectively (Rist 1990). The main freshwater fish species is Atlantic salmon, but immigrating fish can migrate approximately 30 km upstream the rivers before reaching impassable waterfalls.

Stock size and catch statistics

For the more valuable recreational angling rivers in Iceland, rod catches are registered in logbooks (species, fish size, fishing pool, etc.) (Guðbergsson 2007). All fish were caught by angling in the study rivers. According to the size of the salmon it is possible to determine if the fish are returning to the river after one (1SW) or two (2SW) winters in the sea. The catch in the River Vesturdalsá has been registered since 1956. The fishing effort has been reasonably stable during most of this period, but in 2004 the fishing effort was decreased in order to increase the number of spawning salmon. These changes make the catch statistics after 2003 not comparable to the previous years. Consequently, for the River Vesturdalsá only the catch statistics for 1956 to 2003 were analysed in this study. For the River Blanda (including its tributary the River Svartá) catch data for 1982 to 2006 were analysed.

The number of immigrating fish to the River Vesturdalsá has been recorded since 1994 and since 1982 for the River Blanda. In the Blanda migrating fish were trapped in a fishway in the Ennisflúðir cascade (about 3 km upstream) from 1982 to 1993, where they were measured, tagged with Floy tags and then released above the fishway (Viðarsson & Guðjónsson 1994). As a part of the upstream migrating fish are able to pass the cascade beside the fishway, an estimate was made of the proportion of the run passing the cascade during this period, or 20% of the run (Jónsson & Guðjónsson 2007). Since 1994 an automatic fish counter (www.vaki.is) has been operated in the fishway instead of the trap, as well as in the River Vesturdalsá (about 10 km upstream) where fish are not able to bypass the counter when migrating to areas above it. The counter measures the size of each fish, which is used to divided the run into 1SW salmon, 2SW salmon and Arctic charr (Jónsson & Guðjónsson 2007).

Very limited nursery areas for salmon juveniles are found in these rivers below the counters and therefore it is assumed that all salmon which are not caught will eventually migrate to areas upstream of the counters. Consequently, to calculate the total run of salmon from the sea into the rivers, the catch below the counters was added to the number of salmon recorded by the counter. Salmon reported without fishing location (a minor part of the run) were divided between fishing pools according to the distribution of salmon with known fishing locations.

The registration of the charr catch in the River Vesturdalsá was not as good as for the salmon catch and the fishing location was frequently missing. Therefore the total catch of charr was used in the analyses regardless of whether the fish were caught above or below the counter. In the Blanda only the charr catch above the counter was used in the analysis.

Table 1. Relationships analysed by linear regression between the stock size and catch for Atlantic salmon and Artic charr in rivers in Vopnafjörður and the River Blanda. N is the number of years covered.

Independent variables	Dependent variables	Years	N
River Vesturdals			
Stock size of salmon above counter	Salmon catch above counter	1994-2003	10
Stock size of 1SW salmon above counter	1SW salmon catch above counter	1994-2003	10
Stock size of 2SW salmon above counter	2SW salmon catch above counter	1994-2003	10
Stock size of charr above counter	Total charr catch	1994-2003	10
Total charr catch	Salmon catch (smolt year)	1956-2003	44
Rivers in Vopnafj			
Total charr catch in River Vesturdal	Total salmon catch (smolt year)	1956-2003	46
Total charr catch	Total salmon catch (smolt year)	1977-2003	27
River Blanda			
Stock size of 1SW salmon above counter	1SW salmon catch above counter	1982-2006	25
Stock size of 2SW salmon above counter	2SW salmon catch above counter	1982-2006	25
Stock size of charr above counter	Charr catch above counter	1982-2006	25
Stock size of charr above counter	Total salmon run	1982-2006	25
Stock size of charr above counter	Total salmon run (smolt year)	1982-2004	23

Data analysis

The data were analysed using a linear regression model. The relationship between the number of salmon recorded in the counters and the number of salmon caught by anglers above the counters was analysed. This was done for 1SW and 2SW salmon separately, as well as for the Vesturdalsá for these two groups combined. The relationship between the size of the Arctic charr run and the number of charr caught by anglers was also analysed (Table 1).

The relationship between the charr catch in the River Vesturdalsá and the salmon catch in the same river were analysed, where the salmon catch was recorded for the year of smoltification (smolt year), i.e. total catch year n = (number of 1SW caught year n+1) + (the number of 2SW caught year n+2).

The relationship between the total salmon catch (smolt year) and the total charr catch in three rivers in Vopnafjörður, the rivers Selá, Hofsá and Vesturdalsá, was analysed, as well as the total salmon catch in these rivers and the charr catch in the Vesturdalsá.

The relationship between the number of charr and salmon migrating up the Ennisflúðir cascades in the River Blanda and the catches of these species in the river system above the cascades was analysed, as well as the relationship between the total salmon run (both fishing year and smolt year) and charr run up the cascades (Table 1).

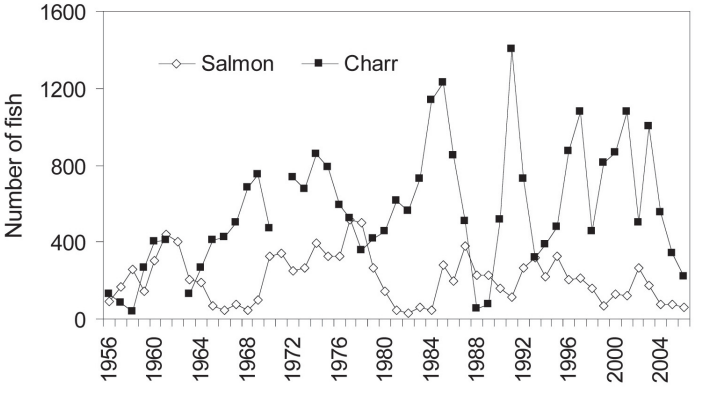

Figure 2. The annual rod catches of Atlantic salmon (total for 1SW and 2SW salmon) and Arctic charr in the River Vesturdalsá in Vopnafjörður in 1956 to 2006.

RESULTS

There have been great fluctuations in the salmon catch in River Vesturdalsá during the last few decades (Figure 2). Before 2004 there was no significant change in the fishing effort, but since then the effort has been reduced substantially in order to conserve the salmon spawning stock in the river. The charr catch has also fluctuated considerably

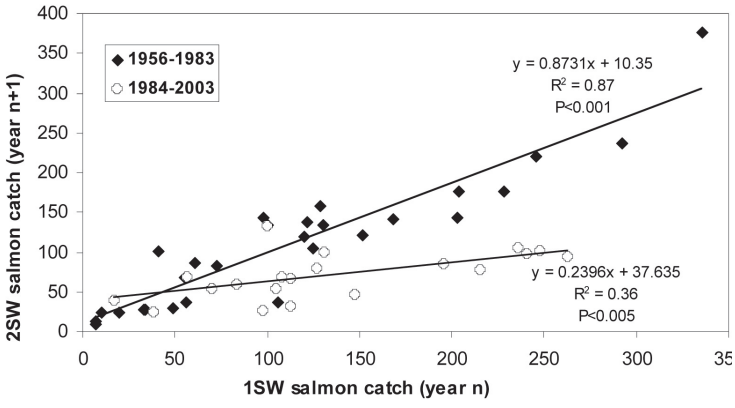

Figure 3. Regression between the annual rod catch (number) of one-sea-winter (1SW) and two-sea-winter (2SW) Atlantic salmon, originating from the same cohort, in the River Vesturdalsá for 1956-1983 and 1984-2003.

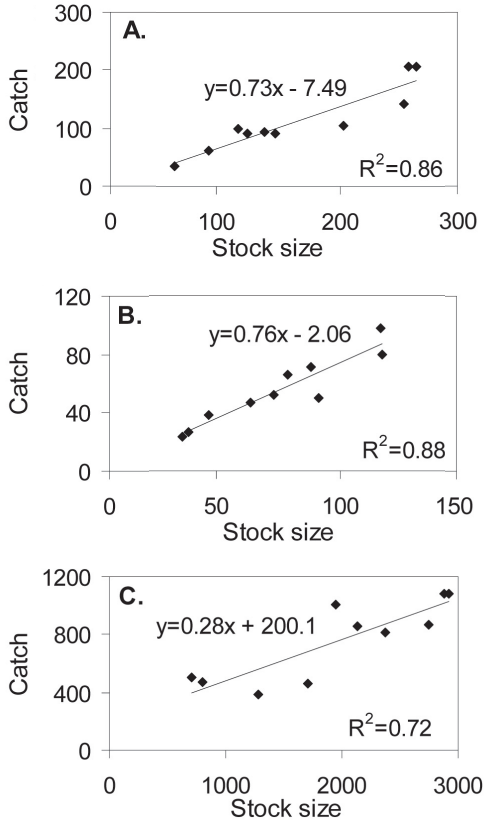

Figure 4. Relationship between the stock size and catch by anglers of (A) one-sea-winter (1SW) and (B) two-sea-winter (2SW) Atlantic salmon and (C) Arctic charr in the River Vesturdalsá from 1994 to 2003. The stock size is the number of fish migrating through the counter. The catch for salmon is the number of fish caught upstream of the counter, but for the Arctic charr the total catch in the river is used.

during the same period, but the catch statistics for charr are not as reliable as for salmon, especially during the first years of the period in question. In the earlier part of this period (before 1984) there was a good correlation between the 1SW salmon caught each summer with the number of 2SW salmon caught the year after in the River Vesturdalsá (Antonsson 1996). This relationship has been different since 1984 and the correlation not as high as it was before (Figure 3).

The number of salmon (total of 1SW and 2SW salmon) caught upstream of the fish counter in the River Vesturdalsá showed a general increase with the number of salmon migrating through the counter in 1994 to 2003 ($P<0.001$, $R^2=0.94$). This was also the case for 1SW (Figure 4A, $P<0.001$) and 2SW (Figure 4B, $P<0.001$) salmon separately. There was also a significant relationship ($P=0.002$) between the charr run and charr catch in the river during the period (Figure 4C). No significant correlation ($P=0.220$) was found between the charr and salmon catches in the River Vesturdalsá in 1956 to 2003, but a significant correlation ($P<0.001$, $R^2=0.45$) was found between the charr catch in the River Vesturdalsá and the total catch of salmon in the rivers Selá, Vesturdalsá and Hofsá. There was also a significant relationship ($P<0.001$, $R^2=0.49$) between the total charr catch and the total salmon catch in these rivers.

The relationship between the number of salmon migrating upstream via the Ennisflúðir

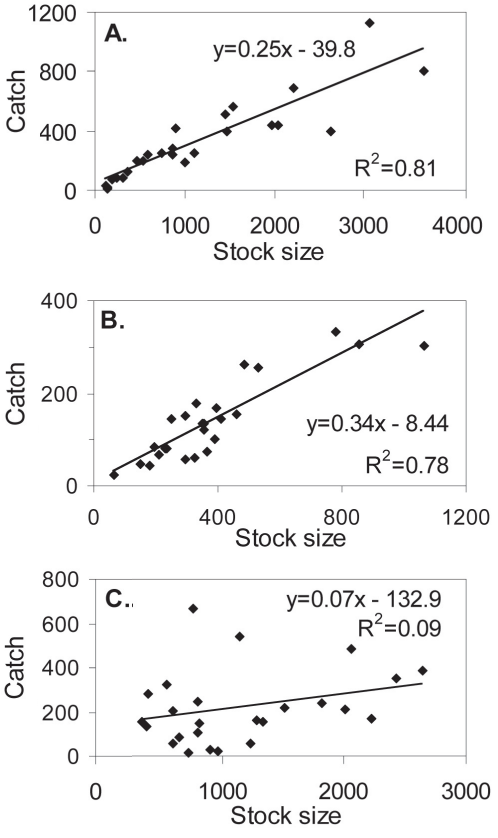

Figure 5. Relationship between the stock size and catch by anglers of (A) one-sea-winter (1SW) and (B) two-sea-winter (2SW) Atlantic salmon and (C) Arctic charr, above the counter in the River Blanda from 1982 to 2006. The stock size is the number of fish migrating up the Ennisflúðir cascades.

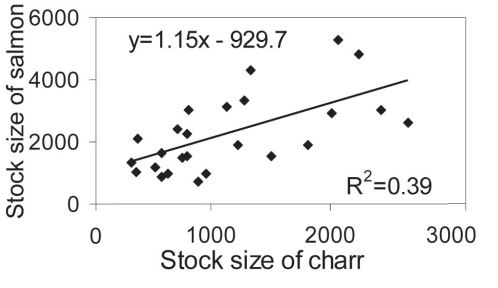

Figure 6. Relationship between the stock size of Arctic charr and Atlantic salmon in the River Blanda from 1982 to 2006. The stock size of charr is the number of fish migrating up the Ennisflúðir cascades and the stock size of salmon the total run in the river.

cascades in the River Blanda and the salmon catch upstream was significant (P<0.001), both for one and two year old salmon (Figure 5A and B). The relationship was not significant (P=0.152) for charr (Figure 5C).

There was a significant relationship (P<0.001) between the number of the charr above the counter and total run of salmon in the River Blanda (Figure 6), but the correlation was not significant (P=0.145, R^2=0.10) if the smolt year of the salmon was used.

DISCUSSION

The results of this study show that the salmon catches in the rivers Vesturdalsá and Blanda are highly significantly correlated to the total upstream run of salmon, both for 1SW and 2SW salmon. A similar relationship has been found for fish stocks in other countries (Crozier & Kennedy 2001, O'Connell 2003, Thorley et al. 2005) and has been suggested for Icelandic rivers (Scarnecchia 1983, Gudjonsson et al. 1995). For Arctic charr this association is not as clear, for a number of reasons. The catch statistics for charr are not as accurate as for salmon and the catch effort for charr varies more. In the River Vesturdalsá some pools are better charr fishing pools than others and the effort at these pools probably varies between anglers and their interest in salmon in the river. The Blanda river system is large and the life history of the local charr population is complicated (Gudjonsson 1989). Resident charr are also found in the River Blanda and its tributary the River Svartá. The flow of the Blanda and the turbidity of the water can be very variable, which in turn influence the fish migration patterns and the conditions for fishing. A previous study has shown a correlation between the turbidity of the water in the river and the migration pattern of the salmon, where increased turbidity reduced the proportion of salmon migrating upstream (Antonsson 1984) and therefore affect the catchability. In 1996 the charr catch upstream from the Ennisflúðir cascades in the Blanda was relatively high compared to the size of the run according to the fish counter. The reason for this is not known,

but low flow in the river that year may have had some impact, as with the increased catch of both resident and anadromous charr.

According to these results the salmon catch statistics in the Vesturdalsá and Blanda rivers are good indicators of the size of the salmon run. Similar findings have been seen for the salmon stock in the River Elliðaár (Guðbergsson & Antonsson 2008). It is reasonable to conclude that this is also the case in other rivers in Iceland where catch statistics are accurate and where there have been little changes in effort between years. The catch data in these rivers are therefore assumed to reflect the size of the salmon run. A positive correlation has been found between the annual number of salmon caught by angling in different rivers in different regions of Iceland (Scarnecchia 1983, Antonsson et. al. 1996). According to our results there is a positive correlation in the size of the salmon run between these rivers.

The present study showed a highly significant relationship between the total number of charr caught and the number of salmon caught from the smolt run of the same year for the three main rivers (Selá, Hofsá and Vesturdalsá) in Vopnafjörður. This indicates some environmental factors affecting both the charr and the salmon smolts during their migration to the sea or their first months at sea. This correlation is found despite the fact that there are three to four year classes of charr migrating to the sea each year (Jonsson 1994). Scarnecchia (1984) found a relationship between the spring sea temperature and the total catch of salmon from the smolt cohort. A highly significant correlation has before been observed between the number of 1SW and 2SW salmon caught by anglers in these three rivers in Vopnafjörður (Antonsson et al. 1996).

In the River Blanda the correlation between the charr and salmon runs is different, with a higher correlation between the charr run and the salmon run the same year. This different correlation in these two river systems can possible be explained by the different life history of the charr stocks in these two river systems (Gudjonsson 1989, Jonsson 1994). It seems that environmental factors in the rivers and during the sea migration strongly affect the stock size and consequent run of both salmon and charr, as they show same trends in stock size.

Reliable catch statistics have been available for numerous rivers in Iceland for decades. The present study is important to examine the change in stock sizes of charr and salmon in these rivers. Catch statistics for these species in these rivers reflect the stock size fluctuations fairly well. The results are consistent with what has been found in other studies (Crozier & Kennedy 2001, O'Connell 2003). The results of the present study are an important basis for further research in stock size variability.

ACKNOWLEDGEMENTS

We want to thank our colleagues at the Institute of Freshwater Fisheries for their assistance. We also want to thank the members of the fisheries associations of the rivers mentioned in the study. The Salmonid Enhancement Fund partly funded this research.

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Manuscript received 21 May 2008
Accepted 16 October 2008